Particle Physics Division
Fachverband Teilchenphysik (T)

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Overview of Invited Talks and Sessions

(Lecture halls T-H15 to T-H39)

Invited Talks

T 1.1	Mon	9:30–10:00	T-H15	**From scattering amplitudes to precision predictions for the LHC** — •Claude Duhr
T 1.2	Mon	10:00–10:30	T-H15	**Tackling new physics at the fringe of precision: Standard Model physics at the LHC** — •Simone Amoroso
T 1.3	Mon	10:30–11:00	T-H15	**Hunt for New Physics at the LHC** — •Swagata Mukherjee
T 27.1	Tue	11:00–11:30	T-H15	**First Results From the Next Generation B-Factory Experiment Belle II** — •Thomas Kuhr
T 27.2	Tue	11:30–12:00	T-H15	**Flavour Anomalies** — •Christoph Langenbruch
T 27.3	Tue	12:00–12:30	T-H15	**The top quark is still going strong (and electroweak)** — •Andrea Knue
T 80.1	Thu	11:00–11:30	T-H15	**Borexino looks in the direction of solar neutrinos** — •Livia Ludhova
T 80.2	Thu	11:30–12:00	T-H15	**Gravitational waves - a new probe of the early Universe** — •Valerie Domcke
T 80.3	Thu	12:00–12:30	T-H15	**Gravitational wave detectors - current and future challenges** — •Michèle Heurs
T 109.1	Fri	11:00–11:30	T-H15	**Ten years of Higgs boson measurements: what we know and what we don't know** — •Christian Grefe
T 109.2	Fri	11:30–12:00	T-H15	**Future of Silicon Tracking Detectors: LHC Upgrades and Beyond** — •Georg Steinbrück
T 109.3	Fri	12:00–12:30	T-H15	**The dawn of high energy neutrino astronomy** — •Elisa Resconi

Invited Topical Talks

T 28.1	Tue	14:00–14:25	T-H15	**Hadronic Jets: Accuracy and Precision of their Reconstruction and Calibration in ATLAS** — •Christopher Young
T 28.2	Tue	14:25–14:50	T-H15	**Direct searches testing BSM explanations of the flavor anomalies** — •Arne Christoph Reimers
T 28.3	Tue	14:50–15:15	T-H15	**ATLAS probes QCD measuring photons** — •Heberth Torres
T 28.4	Tue	15:15–15:40	T-H15	**The upgrade of the ATLAS trigger to augment the physics reach of Run-3** — •Daniele Zanzi
T 29.1	Tue	14:00–14:25	T-H16	**Testing the Standard Model through Gauge-boson Self-interactions** — •Philip Sommer
T 29.2	Tue	14:25–14:50	T-H16	**Axions and similar particles - how to cover 10^{17} orders of magnitude in mass** — •Kristof Schmieden
T 29.3	Tue	14:50–15:15	T-H16	**From GERDA to LEGEND - Hunting no neutrinos** — •Christoph Wiesinger
T 29.4	Tue	15:15–15:40	T-H16	**Mapping Highly-Energetic Messengers throughout the Universe** — •Sara Buson
T 54.1	Wed	11:00–11:25	T-H15	**Hunting XYZ Beasts at Belle and Belle II** — •Elisabetta Prencipe
T 54.2	Wed	11:25–11:50	T-H15	**Precision tests of the Standard Model using CP violation in B meson decays** — •Thibaud Humair
T 54.3	Wed	11:50–12:15	T-H15	**Back to the top: charting the bounds of the standard model** — •Afiq Anuar

T 54.4	Wed	12:15–12:40	T-H15	**Dark matter from spin-2 mediators** — •Stefan Vogl
T 55.1	Wed	11:00–11:25	T-H16	**Machine Learning for LHC Theory** — •Anja Butter
T 55.2	Wed	11:25–11:50	T-H16	**Towards high-precision deep learning for astroparticle physics** — •Christoph Weniger
T 55.3	Wed	11:50–12:15	T-H16	**The quest for the mechanism behind the matter-antimatter asymmetry** — •Julia Harz
T 55.4	Wed	12:15–12:40	T-H16	**Towards the lightest dark matter in direct searches** — •Belina von Krosigk
T 81.1	Thu	14:00–14:25	T-H15	**LND - A ("Made in Germany") Radiation Monitor Operating at the far Side of the Moon** — •Sönke Burmeister, Shenyi Zhang, Jia Yu, Zigong Xu, Stephan Böttcher, Robert Wimmer-Schweingruber
T 81.2	Thu	14:25–14:50	T-H15	**Energetic Pulsar Environments and the Origins of Galactic Cosmic Rays** — •Alison Mitchell
T 81.3	Thu	14:50–15:15	T-H15	**Looking forward to exciting physics with FASER** — •Felix Kling
T 81.4	Thu	15:15–15:40	T-H15	**Astroparticle physics at the LHC: Exploring the forward region with cross-section measurements** — •Hans Dembinski
T 82.1	Thu	14:00–14:25	T-H16	**Searches for new scalar particles at the LHC** — •Dominik Duda
T 82.2	Thu	14:25–14:50	T-H16	**Novel approaches to search for new physics in rare charm decays** — •Dominik Stefan Mitzel
T 82.3	Thu	14:50–15:15	T-H16	**Constraining the Higgs-charm Yukawa coupling with the CMS experiment** — •Luca Mastrolorenzo
T 82.4	Thu	15:15–15:40	T-H16	**Characterization of H boson events in the $\tau\tau$ decay channel with the full CMS Run-2 data set** — •Sebastian Wozniewski

Invited Talks of the joint symposium SMuK Dissertation Prize 2022 2022 (SYMD)

See SYMD for the full program of the symposium.

SYMD 1.1	Mon	14:00–14:25	Audimax	**Timeless Quantum Mechanics and the Early Universe** — •Leonardo Chataigner
SYMD 1.2	Mon	14:25–14:50	Audimax	**First tritium β-decay spectrum recorded with Cyclotron Radiation Emission Spectroscopy (CRES)** — •Christine Claessens
SYMD 1.3	Mon	14:50–15:15	Audimax	**Watching the top quark mass run - for the first time!** — •Matteo M. Defranchis, Katerina Lipka, Sven-Olaf Moch
SYMD 1.4	Mon	15:15–15:40	Audimax	**Towards beam-quality-preserving plasma accelerators: On the precision tuning of the wakefield** — •Sarah Schröder

Prize Talks of the joint Awards Symposium (SYAW)

See SYAW for the full program of the symposium.

SYAW 1.1	Wed	14:10–14:40	Audimax	**Wie überprüft man die Ziele der Lehramtsausbildung Physik?** — •Horst Schecker
SYAW 1.2	Wed	14:40–15:10	Audimax	**Astronomy at Highest Angular Resolution - Adaptive Optics, Interferometry and Black Holes** — •Frank Eisenhauer
SYAW 1.3	Wed	15:10–15:40	Audimax	**Turbulence in one dimension** — •Alexander M. Polyakov

Sessions

T 1.1–1.3	Mon	9:30–11:00	T-H15	**Invited Talks 1**
T 2.1–2.9	Mon	16:15–18:30	T-H15	**QCD (Theorie) 1**
T 3.1–3.9	Mon	16:15–18:35	T-H16	**Flavour Physics 1**
T 4.1–4.7	Mon	16:15–18:00	T-H17	**Flavour Physics 2**
T 5.1–5.8	Mon	16:15–18:20	T-H18	**Electroweak Interactions (Exp.) 1**
T 6.1–6.9	Mon	16:15–18:30	T-H19	**Top Quarks: Production (Exp.) 1**
T 7.1–7.8	Mon	16:15–18:15	T-H20	**Top Quarks: Properties 1**
T 8.1–8.9	Mon	16:15–18:30	T-H21	**Higgs Boson: Decay in Fermions 1**
T 9.1–9.9	Mon	16:15–18:30	T-H22	**Search for Supersymmetry**
T 10.1–10.9	Mon	16:15–18:30	T-H23	**Search for New Particles -1**
T 11.1–11.8	Mon	16:15–18:15	T-H24	**Gaseous Detectors**

T 12.1–12.9	Mon	16:15–18:30	T-H25	**Pixel Detectors**
T 13.1–13.8	Mon	16:15–18:15	T-H26	**Semiconductor Detectors:Radiation Hardness, new Materials and Concepts**
T 14.1–14.9	Mon	16:15–18:30	T-H27	**DAQ and Trigger 1**
T 15.1–15.7	Mon	16:15–18:00	T-H28	**GRID Computing**
T 16.1–16.9	Mon	16:15–18:30	T-H29	**Experimental Methods (general) 1**
T 17.1–17.8	Mon	16:15–18:20	T-H30	**Gamma Astronomy 1**
T 18.1–18.9	Mon	16:15–18:30	T-H31	**Neutrino Astronomy 1**
T 19.1–19.8	Mon	16:15–18:20	T-H32	**Cosmic Ray 1**
T 20.1–20.9	Mon	16:15–18:40	T-H33	**Neutrino Physics without Accelerators 1**
T 21.1–21.9	Mon	16:15–18:35	T-H34	**Neutrino Physics without Accelerators 2**
T 22.1–22.8	Mon	16:15–18:20	T-H35	**Search for Dark Matter 1**
T 23.1–23.6	Mon	16:15–17:45	T-H36	**Experimental Techniques in Astroparticle Physics 1**
T 24.1–24.5	Mon	16:15–17:35	T-H37	**Outreach Methods**
T 25.1–25.8	Mon	16:15–18:25	T-H38	**Data Analysis, Information Technology and Artificial Intelligence**
T 26.1–26.9	Mon	16:15–18:30	T-H39	**Data Analysis, Information Technology and Artificial Intelligence**
T 27.1–27.3	Tue	11:00–12:30	T-H15	**Invited Talks 2**
T 28.1–28.4	Tue	14:00–15:40	T-H15	**Invited Topical Talks 1**
T 29.1–29.4	Tue	14:00–15:40	T-H16	**Invited Topical Talks 2**
T 30.1–30.9	Tue	16:15–18:30	T-H15	**Flavour Physics 3**
T 31.1–31.8	Tue	16:15–18:15	T-H16	**Beyond the Standard Model (Theory) 1**
T 32.1–32.8	Tue	16:15–18:15	T-H17	**QCD (Exp.) 1**
T 33.1–33.9	Tue	16:15–18:30	T-H18	**Top Quarks: Production (Exp.) 2**
T 34.1–34.7	Tue	16:15–18:00	T-H19	**Top Quarks: Properties -2**
T 35.1–35.8	Tue	16:15–18:15	T-H20	**Higgs Boson: Associated Production 1**
T 36.1–36.9	Tue	16:15–18:30	T-H21	**Higgs Boson: Extended Models 1**
T 37.1–37.9	Tue	16:15–18:30	T-H22	**Search for New Particles 2**
T 38.1–38.7	Tue	16:15–18:00	T-H23	**Search for New Particles 3**
T 39.1–39.8	Tue	16:15–18:15	T-H24	**Gaseous Detectors 2**
T 40.1–40.9	Tue	16:15–18:30	T-H25	**Pixel Detectors 2**
T 41.1–41.9	Tue	16:15–18:30	T-H26	**Calorimeters 1**
T 42.1–42.7	Tue	16:15–18:00	T-H27	**Detector Systems 1**
T 43.1–43.8	Tue	16:15–18:15	T-H28	**DAQ and Trigger 2**
T 44.1–44.6	Tue	16:15–17:45	T-H29	**Experimental Methods (general) 2**
T 45.1–45.8	Tue	16:15–18:15	T-H30	**Gamma Astronomy 2**
T 46.1–46.9	Tue	16:15–18:30	T-H31	**Neutrino Astronomy 2**
T 47.1–47.8	Tue	16:15–18:15	T-H32	**Cosmic Ray 2**
T 48.1–48.10	Tue	16:15–18:45	T-H33	**Neutrino Physics without Accelerators 3**
T 49.1–49.9	Tue	16:15–18:40	T-H34	**Neutrino Physics without Accelerators 4**
T 50.1–50.7	Tue	16:15–18:00	T-H35	**Search for Dark Matter 2**
T 51.1–51.8	Tue	16:15–18:20	T-H36	**Experimental Techniques in Astroparticle Physics 2**
T 52.1–52.6	Tue	16:15–17:45	T-H37	**Outreach Methods 2**
T 53.1–53.9	Tue	16:15–18:30	T-H38	**Data Analysis, Information Technology and Artificial Intelligence 3**
T 54.1–54.4	Wed	11:00–12:40	T-H15	**Invited Topical Talks 3**
T 55.1–55.4	Wed	11:00–12:40	T-H16	**Invited Topical Talks 4**
T 56.1–56.9	Wed	16:15–18:30	T-H15	**Flavour Physics 4**
T 57.1–57.8	Wed	16:15–18:15	T-H16	**Flavour Physics 5**
T 58.1–58.7	Wed	16:15–18:00	T-H17	**QCD (Exp.) 2**
T 59.1–59.6	Wed	16:15–17:50	T-H18	**Neutrino Physics with Accelerators 1**
T 60.1–60.9	Wed	16:15–18:30	T-H19	**Top Quarks: Decay and CP Violation and Mixing Angles**
T 61.1–61.8	Wed	16:15–18:15	T-H20	**Higgs Boson: Decay in Bosons**
T 62.1–62.9	Wed	16:15–18:30	T-H21	**Higgs Boson: Extended Models 2**
T 63.1–63.9	Wed	16:15–18:30	T-H22	**Search for New Particles 4**
T 64.1–64.9	Wed	16:15–18:30	T-H23	**Search for New Particles 5**
T 65.1–65.8	Wed	16:15–18:15	T-H24	**Silicon Strip Detectors**
T 66.1–66.9	Wed	16:15–18:30	T-H25	**Semiconductor Detectors: Radiation Hardness, new Materials and Concepts 2**
T 67.1–67.9	Wed	16:15–18:40	T-H26	**Myon Detectors**

T 68.1–68.8	Wed	16:15–18:15	T-H27	**Detector Systems 2**
T 69.1–69.9	Wed	16:15–18:30	T-H28	**DAQ and Trigger 3**
T 70.1–70.9	Wed	16:15–18:30	T-H29	**Experimental Methods (general) 3**
T 71.1–71.9	Wed	16:15–18:30	T-H30	**Neutrino Astronomy 3**
T 72.1–72.9	Wed	16:15–18:30	T-H31	**Cosmic Ray 3**
T 73.1–73.8	Wed	16:15–18:15	T-H32	**Cosmic Ray 4**
T 74.1–74.8	Wed	16:15–18:20	T-H33	**Neutrino Physics without Accelerators 5**
T 75.1–75.9	Wed	16:15–18:35	T-H34	**Neutrino Physics without Accelerators 6**
T 76.1–76.9	Wed	16:15–18:30	T-H35	**Search for Dark Matter 3**
T 77.1–77.8	Wed	16:15–18:15	T-H36	**Search for Dark Matter 4**
T 78.1–78.7	Wed	16:15–18:00	T-H37	**Experimental Techniques in Astroparticle Physics 3**
T 79.1–79.9	Wed	16:15–18:30	T-H38	**Data Analysis, Information Technology and Artificial Intelligence 4**
T 80.1–80.3	Thu	11:00–12:30	T-H15	**Invited Talks 3 (joint session T/EP)**
T 81.1–81.4	Thu	14:00–15:40	T-H15	**Invited Topical Talks 5 (joint session T/EP)**
T 82.1–82.4	Thu	14:00–15:40	T-H16	**Invited Topical Talks 6**
T 83.1–83.9	Thu	16:15–18:30	EP-H1	**Astroteilchen: Von der Quelle zum Detektor (contributed talks) (joint session EP/T)**
T 84.1–84.9	Thu	16:15–18:30	T-H15	**Flavour Physics**
T 85.1–85.9	Thu	16:15–18:30	T-H16	**Beyond the Standard Model (Theory) 2 and QFT and Lattice Gauge Theory 1**
T 86.1–86.7	Thu	16:15–18:00	T-H17	**Neutrino Physics (Theory) 1 and Theoretical Astroparticle Physics and Cosmology 1**
T 87.1–87.8	Thu	16:15–18:20	T-H18	**Electroweak Interactions (Exp.) 2**
T 88.1–88.9	Thu	16:15–18:30	T-H19	**Top Quarks: Production (Exp.) 3**
T 89.1–89.7	Thu	16:15–18:00	T-H20	**Higgs Boson: Decay in Fermions 2**
T 90.1–90.8	Thu	16:15–18:15	T-H21	**Higgs Boson: Associated Production 2**
T 91.1–91.6	Thu	16:15–17:45	T-H22	**Higgs Boson: Rare Decays**
T 92.1–92.7	Thu	16:15–18:00	T-H23	**Higgs Boson: Extended Models 3**
T 93.1–93.10	Thu	16:15–18:45	T-H24	**Search for New Particles 6**
T 94.1–94.7	Thu	16:15–18:00	T-H25	**Silicon Strip Detectors 2**
T 95.1–95.8	Thu	16:15–18:15	T-H26	**Pixel Detectors 3**
T 96.1–96.8	Thu	16:15–18:15	T-H27	**Detector Systems 3**
T 97.1–97.7	Thu	16:15–18:00	T-H28	**Electronics 1**
T 98.1–98.7	Thu	16:15–18:05	T-H29	**Experimental Methods (general) 4**
T 99.1–99.9	Thu	16:15–18:35	T-H30	**Neutrino Astronomy 4**
T 100.1–100.9	Thu	16:15–18:30	T-H32	**Cosmic Ray 5**
T 101.1–101.9	Thu	16:15–18:30	T-H33	**Cosmic Ray 6**
T 102.1–102.9	Thu	16:15–18:35	T-H34	**Neutrino Physics without Accelerators 7**
T 103.1–103.9	Thu	16:15–18:30	T-H35	**Neutrino Physics without Accelerators 8**
T 104.1–104.7	Thu	16:15–18:05	T-H36	**Search for Dark Matter 5**
T 105.1–105.10	Thu	16:15–18:45	T-H37	**Search for Dark Matter 6**
T 106.1–106.9	Thu	16:15–18:30	T-H38	**Experimental Techniques in Astroparticle Physics 4**
T 107.1–107.8	Thu	16:15–18:15	T-H39	**Data Analysis, Information Technology and Artificial Intelligence 5**
T 108	Thu	19:30–21:00	T-MV	**General assembly - Particle Physics Division (for DPG members)**
T 109.1–109.3	Fri	11:00–12:30	T-H15	**Invited Talks 4**

Annual General Meeting of the Particle Physics Division

Thursday 19:30–21:00 T-MV

T 1: Invited Talks 1

Time: Monday 9:30–11:00 Location: T-H15

Invited Talk T 1.1 Mon 9:30 T-H15
From scattering amplitudes to precision predictions for the LHC — •Claude Duhr — Bethe Center for Theoretical Physics, Bonn University

Scattering amplitudes are the main theory tool to compute precise predictions for collider experiments like the Large Hadron Collider (LHC) at CERN. Over the last decade, we have reached a new level of understanding of the mathematics describing scattering amplitudes. This has resulted in the development of novel powerful computational techniques that are often inspired by cutting-edge results in pure mathematics. We give a review of these recent developments and techniques, and we illustrate their use for precision predictions on several recent milestone computations for LHC observables.

Invited Talk T 1.2 Mon 10:00 T-H15
Tackling new physics at the fringe of precision: Standard Model physics at the LHC — •Simone Amoroso — DESY, Hamburg

Despite the lack for direct evidence for physics beyond the Standard Model, the potential of the Large Hadron Collider is far from exhausted. The large datasets accumulated, combined with advancements in detector calibrations, data analysis, and theory calculations, allows for measurements of Standard Model parameters with precision which were unthinkable even a decade ago, and for the observation of new and rarer processes. These high energy and high precision measurements can be used to probe the behavior of the Standard Model at scales well beyond the direct reach of the Large Hadron Collider, providing a promising avenue for the investigation of New Physics. In this talk recent Standard Model results from the LHC Collaborations will be reviewed, and their impact in constraining the Standard Model and its extensions will be illustrated.

Invited Talk T 1.3 Mon 10:30 T-H15
Hunt for New Physics at the LHC — •Swagata Mukherjee — RWTH Aachen University

The search for new physics is a major goal of the LHC physics program. The excellent quality of the Run-2 data set collected by the LHC experiments provides a promising avenue to search for signatures of physics beyond the Standard Model. In this talk I will review some of the searches from Run-2. These searches have covered a wide range of new physics scenarios including supersymmetry, new hidden sectors, dark matter, and long-lived particles. In addition to reviewing some of the innovative techniques that made the analyses possible, I will summarise what we have learned from the results and briefly discuss prospects for Run-3 which is starting this year.

T 2: QCD (Theorie) 1

Time: Monday 16:15–18:30 Location: T-H15

T 2.1 Mon 16:15 T-H15
Soft photon bremsstrahlung at Next-to-Leading Power — •Domenico Bonocore and Anna Kulesza — Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster

A long-standing discrepancy in the soft photon bremsstrahlung has attracted a renewed attention in view of the proposed measurements with a future upgrade of the ALICE detector in the upcoming runs of the LHC. In this talk I will discuss the possibility to implement techniques that have been recently developed for soft gluon resummation at Next-to-Leading-Power (NLP) to the soft photon spectrum.

T 2.2 Mon 16:30 T-H15
Leading-Color Two-Loop Amplitudes for Four Partons and a W-Boson in QCD — Samuel Abreu[1,2,3], Fernando Febres Cordero[4], Harald Ita[5], •Maximilian Klinkert[5], Benjamin Page[1], and Vasily Sotnikov[6] — [1]Theoretical Physics Department, CERN, Geneva — [2]Higgs Centre for Theoretical Physics, School of Physics and Astronomy,The University of Edinburgh — [3]Mani L. Bhaumik Institute for Theoretical Physics, Department of Physics and Astronomy, UCLA, Los Angeles — [4]Physics Department, Florida State University, Tallahassee — [5]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg — [6]Max Planck Institute for Physics (Werner Heisenberg Institute), München

Leading-Color Two-Loop Amplitudes for Four Partons and a W-Boson in QCD

I will present the leading-color two-loop QCD corrections for the scattering of four partons and a W boson, including its leptonic decay. The amplitudes are assembled from the planar two-loop helicity amplitudes for four partons and a vector boson decaying to a lepton pair. The analytic expressions are obtained by setting up a dedicated Ansatz and constraining the free parameters from numerical samples obtained within the framework of numerical unitarity. Our results are expressed in a basis of one-mass pentagon functions, which opens the possibility of their efficient numerical evaluation.

T 2.3 Mon 16:45 T-H15
Fast simulations with NNLO QCD accuracy — •Lucas Kunz — Karlsruhe Institute of Technology, Karlsruhe, Germany

The calculation of theoretical predictions for hadron colliders at higher orders in perturbation theory involves computing time expensive iterative procedures. The same is true for the extraction of parton distribution functions (PDFs) from measured data. Hence, to produce results in reasonable time, a very efficient and flexible setup is needed. The APPLfast project fulfills these requirements by linking the parton-level Monte Carlo program NNLOjet with both the APPLgrid and fastNLO grid libraries, thereby allowing for an a posteriori choice of a set of PDFs or value of the strong coupling constant. This talk will give an overview of the project, focusing on an explanation of the general logic and on possible applications rather than technical details.

T 2.4 Mon 17:00 T-H15
MiNNLO$_{PS}$ for dibosons: matching NNLO QCD with parton showers — •Daniele Lombardi[1], Marius Wiesemann[1], Giulia Zanderighi[1], Gabriël Koole[1], Luca Buonocore[2], and Luca Rottoli[2] — [1]Max-Planck-Institut für Physik, Munich, Germany — [2]University of Zurich, Zurich, Switzerland

The comparison of theory calculations against experimental measurements for many particle collider processes is nowadays one of the main roads towards the discovery of new physics. The tremendous amount of data collected and the great effort of the experimental collaborations have allowed us to reach an unprecedented accuracy in the measurements of many processes. To avoid that the theory uncertainties become the limiting factor of this comparison, a similar effort from the theory community is demanded. In this talk, I will first motivate why matching our best available fixed-order results with parton showers is a necessary step in this direction. Then I will focus on MiNNLO$_{PS}$, which is one of the latest methods that have been proposed to embed a next-to-next-to-leading order QCD calculation into a full-fledged Monte Carlo event generator. Originally formulated for single boson production, this method has been recently extended to general color-singlet final states and successfully applied to different diboson processes, such as $Z\gamma$, W^+W^- and ZZ. After a brief review of the underlying idea of MiNNLO$_{PS}$ and a presentation of the main results, I will conclude by highlighting the potential of the method for future applications.

T 2.5 Mon 17:15 T-H15
Automating the calculation of jet functions and beam functions in SCET — Guido Bell, •Kevin Brune, Goutam Das, and Marcel Wald — Center for Particle Physics Siegen, Theoretische Physik 1, Universität Siegen

In perturbative QCD large logarithms can arise in the computation of collider observables. These logarithms can be resummed via factorization theorems within Soft-Collinear Effective Theory(SCET).

These factorization theorems include beam functions accounting for the initial-state collinear interactions and jet functions for the final-state collinear interactions. While these functions have been calculated case by case for different observables until now, we are investigating an automated approach for a general class of observables. For this, we study a general phase-space parameterization that factorizes the universal singularities of the functions. We have implemented this framework for different observables, by using the public code "pySecDec" to compute the next-to-next-to-leading order beam and jet function.

T 2.6 Mon 17:30 T-H15

Invertible Networks for the Matrix Element Method — Anja Butter[1], •Theo Heimel[1], Till Martini[2], Sascha Peitzsch[2], and Tilman Plehn[1] — [1]Institut für Theoretische Physik, Universität Heidelberg, Germany — [2]Institut für Physik, Humboldt-Universität zu Berlin, Germany

For many years, the matrix element method has been considered the perfect approach to LHC inference. We show how conditional neural networks can be used to unfold detector effects and initial-state QCD radiation, to provide the hard-scattering information for this method. We illustrate our approach for the CP-violating phase of the top Yukawa coupling in associated Higgs and single-top production.

T 2.7 Mon 17:45 T-H15

Targeting Multi-Loop Integrals with Neural Networks — •Ramon Winterhalder[1,2,3], Vitaly Magerya[4], Emilio Villa[4], Stephen P. Jones[5], Matthias Kerner[4,6,7], Anja Butter[1,2], Gudrun Heinrich[2,4], and Tilman Plehn[1,2] — [1]Institut für Theoretische Physik, Universität Heidelberg, Germany — [2]HEiKA - Heidelberg Karlsruhe Strategic Partnership, Heidelberg University, Karlsruhe Institute of Technology (KIT), Germany — [3]Centre for Cosmology, Particle Physics and Phenomenology (CP3), Université catholique de Louvain, Belgium — [4]Institut für Theoretische Physik, Karlsruher Institut für Technologie, Germany — [5]Institute for Particle Physics Phenomenology, Durham University, UK — [6]Institut für Astroteilchenphysik, Karlsruher Institut für Technologie, Germany — [7]Physik-Institut, Universität Zürich, Switzerland

Numerical evaluations of Feynman integrals often proceed via a deformation of the integration contour into the complex plane. While valid contours are easy to construct, the numerical precision reached for a multi-loop integral can depend critically on the chosen contour. We present methods to optimize this contour using a combination of machine-learned complex shifts and a normalizing flow. This can, potentially, lead to a very significant gain in precision.

T 2.8 Mon 18:00 T-H15

Generative Networks for Precision Enthusiasts — •Anja Butter, Theo Heimel, Sander Hummerich, Tobias Krebs, Tilman Plehn, Armand Rousselot, and Sophia Vent — U. Heidelberg, ITP

Generative networks are opening new avenues in fast event generation for the LHC. We show how generative flow networks can reach percent-level precision for kinematic distributions, how they can be trained jointly with a discriminator, and how this discriminator improves the generation. Our joint training relies on a novel coupling of the two networks which does not require a Nash equilibrium. We then estimate the generation uncertainties through a Bayesian network setup and through conditional data augmentation, while the discriminator ensures that there are no systematic inconsistencies compared to the training data.

T 2.9 Mon 18:15 T-H15

Development of transverse flow for small and large systems in conformal kinetic theory — •Clemens Werthmann[1], Sören Schlichting[1], and Victor Eugen Ambrus[2,3] — [1]Universität Bielefeld, Germany — [2]Goethe-Universität Frankfurt, Germany — [3]West University of Timisoara, Romania

We employ an effective kinetic description to study the space-time dynamics and development of transverse flow of small and large collision systems. By combining analytical insights in the few interactions limit with numerical simulations at higher opacity, we are able to describe the development of transverse flow from very small to very large opacities, realised in small and large collision systems. Surpisingly, we find that deviations between kinetic theory and hydrodynamics persist even in the limit of very large interaction rates, which can be attributed to the presence of the early pre-equilibrium phase. We discuss implications for the phenomenological description of heavy-ion collisions and the applicability of viscous hydrodynamics to describe small and large collision systems.

[1] V.Ambrus, S.Schlichting, C.Werthmann arXiv:2109.03290

T 3: Flavour Physics 1

Time: Monday 16:15–18:35 Location: T-H16

T 3.1 Mon 16:15 T-H16

Measurement of the ratios $\mathcal{R}(\mathrm{D}^{(*)})$ with leptonic τ and hadronic tag at Belle — •Felix Metzner[1], Florian Bernlochner[2], Michael Feindt[1], and Pablo Goldenzweig[1] for the Belle-Collaboration — [1]Karlsruhe Institute of Technology — [2]University of Bonn

The discrepancy observed for the ratios $\mathcal{R}(\mathrm{D}^{(*)})$ of the decays $\mathrm{B} \to \mathrm{D}^{(*)}\tau\nu_\tau$ relative to the normalisation modes $\mathrm{B} \to \mathrm{D}^{(*)}\ell\nu_\ell$ ($\ell = \mathrm{e}, \mu$) between the experimental results and the Standard Model (SM) prediction is one of few longstanding tensions of the SM. The new Belle II software framework and the therein included conversion tool B2BII allows to reevaluate the Belle data set of 772 million $\mathrm{B\bar{B}}$-pairs recorded from 1999 until 2010 using the improved algorithms of the modern framework. With this approach a new measurement of the ratios $\mathcal{R}(\mathrm{D}^{(*)})$ with an improved hadronic tagging algorithm — the Full Event Interpretation (FEI) — is carried out. Profiting from a higher reconstruction efficiency, due to the new tagging algorithm, this analysis aims to provide new insights into these semileptonic B-decays. In this talk, the procedure and the current status of the analysis will be presented.

T 3.2 Mon 16:30 T-H16

Inclusive B-meson tagging for an $R(D^{(*)})$ measurement at Belle II — Thomas Kuhr, Thomas Lück, and •Sofia Palacios Schweitzer — Ludwig-Maximilians-Universität, München

The world average of previous measurements of $R(D^{(*)})$, defined as $R(D^{(*)}) = \frac{\mathcal{B}\left(B\to D^{(*)}\tau\nu_\tau\right)}{\mathcal{B}\left(B\to D^{(*)}l\nu_l\right)}$, shows a 3.4σ deviation from Standard Model predictions, which could indicate some new physics phenomena, such as the existence of Leptoquarks. This analysis uses data and simulations from the Belle II experiment at the SuperKEKB electron-positron collider to measure $R(D^{(*)})$. To account for the challenge of multiple neutrinos as final state particles, an approach is considered, where besides the signal B-meson decay kinematical and topological properties of the other B-meson are reconstructed fully inclusively. In contrast to exclusive tagging used for previous measurements of $R(D^{(*)})$ by the B-factories, this inclusive tagging approach suffers from a larger background, but also offers a higher reconstruction efficiency. The current status of the analysis will be presented.

T 3.3 Mon 16:45 T-H16

Probing the $R(D^{(*)})$ discrepancy with inclusive $B \to X\tau\nu$ decays at Belle II — Jochen Dingfelder, Florian Bernlochner, •Henrik Junkerkalefeld, and Peter Lewis — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

Excesses in the $R(D)$ and $R(D^*)$ ratios measured by multiple experiments have caused large interest in recent years and align with other measurements in the flavor sector that may hint at non-universality of lepton flavor. Exclusive decays of B mesons into τ leptons ($B \to D^{(*)}\tau\nu$) seem to appear more frequently compared to the respective decays into light leptons than expected by theory.

The Belle II experiment in Japan enables a complementary test of these measurements. Due to the precise knowledge of the initial state of the collision and the controlled production of $B\bar{B}$ pairs, an inclusive measurement of $B \to X\tau\nu$ becomes possible. Here, the hadronic system X is not explicitly reconstructed, i.e. all possible hadrons contribute. This approach offers a better statistical precision than exclusive measurements at the expense of larger backgrounds.

In this talk, the current status of the inclusive $R(X)$ measurement is presented. The event selection, the signal extraction strategy and the most important systematic uncertainties are discussed.

T 3.4 Mon 17:00 T-H16

Measuring $R(D^*)$ in hadronic one-prong τ decays at Belle II — Florian Bernlochner, William Sutcliffe, and •Ilias Tsaklidis for the Belle II-Collaboration — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

In this work we are measuring the $R(D^*)$ ratio with hadronically decaying τ leptons. The Belle II experiment is producing exact $B\bar{B}$ pairs and it greatly benefits from the clean experimental environment of e^+e^- collisions. In this study we tag one of the two B mesons using the Full Event Interpretation algorithm in fully hadronic modes, in order to kinematically constrain the second B meson. We reconstruct $B \to D^*\tau\nu$ decays with a single charged track originating from the τ decay and two missing neutrinos. This gives us a unique access to quantities, sensitive to New Physics, such as the τ lepton polarization besides the $R(D^*)$ ratio. In this talk the reconstruction strategy, the current status and future targets of the analysis will be presented.

T 3.5 Mon 17:15 T-H16

Measurement of R(D*) with semileptonic tagging at Belle II — Florian Bernlochner, Jochen Dingfelder, Peter Lewis, and •Alina Manthei for the Belle II-Collaboration — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

The Belle II experiment at the SuperKEKB asymmetric-energy electron-positron collider is able to collect a large number of events with $B\overline{B}$ pairs. The analysis of semitauonic decays of these B mesons allows for tests of lepton flavour universality. Existing experimental results on the ratios of the branching fractions $\mathcal{R}(D^{(*)} = \mathcal{B}(\overline{B} \to D^{(*)}\tau^-\overline{\nu})/\mathcal{B}(\overline{B} \to D^{(*)}l^-\overline{\nu})$, where l denotes an electron or muon, are in tension with the Standard Model (SM) predictions, which might hint at physics beyond the SM, such as the presence of charged Higgs bosons or leptoquarks. A combined analysis of $\mathcal{R}(D)$ and $\mathcal{R}(D^*)$ with measurements from Belle, BaBar and LHCb yields a divergence from the SM prediction by approximately 3.8σ, where σ indicates the standard deviation. Thus, further investigations of these decays with the recently collected data by Belle II are necessary. This talk will present the current status and plans for a measurement of $\mathcal{R}(D^{(*)})$ using this data, while reconstructing the respective other B meson in the event in semileptonic modes.

T 3.6 Mon 17:30 T-H16

$m_b(m_Z)$ revisited with Zedometry — •Stefan Kluth — MPI für Physik, Föhringer Ring 6, 80805 München

Precision measurements of Z^0 boson properties can allow a determination of the mass of the b quark at the scale of the Z^0 boson mass $m_b(m_Z)$. The dependence of Standard Model predictions by the programs zfitter and Gfitter on the b quark mass are studied. The precision of the currently available measurements by the LEP experiments and SLD, together with measurements from the LHC experiments for the mass of the top quark and the Higgs boson, is not sufficient for a relevant measurement. The predicted precision of Z^0 boson resonance measurements at future e^+e^- colliders will allow a competetive determination of $m_b(m_Z)$.

T 3.7 Mon 17:45 T-H16

From sWeights to COWs: News about the sWeight method — •Hans Dembinski[1], Matt Kenzie[2], Christoph Langenbruch[3], and Michael Schmelling[4] — [1]TU Dortmund, Germany — [2]University of Warwick, United Kingdom — [3]RWTH Aachen, Germany — [4]MPIK Heidelberg

A common problem in experimental flavour physics is the separation of signal and background, when the background is difficult to parameterise. We revisit the foundation of the popular method known as sWeights (or sPlot), which allows one to calculate estimates from the signal density in a control variable (for example, the decay time of a particle) using a fit of a mixed signal and background model to a discriminating variable (typically the invariant mass of decay candidates). sWeights are a special case of a larger class of Custom Orthogonal Weight functions (COWs), which can be applied to a more general class of problems in which the discriminating and control variables are not necessarily independent and still achieve close to optimal performance. We present new insights into the properties of parameters estimated from fits to sWeighted data, and provide closed formulas for the asymptotic covariance matrix of these parameters. To illustrate our findings, we show practical applications of these techniques.

T 3.8 Mon 18:00 T-H16

Normalization of the rare $K^+ \to \pi^+\nu\bar{\nu}$ decay by a $K^+ \to \pi^+\pi^0/K^+ \to \mu\nu$ measurement with NA62 — •ATAKAN TUĞBERK AKMETE — JOHANNES GUTENBERG UNIVERSITÄT, MAINZ

The ultra-rare $K^+ \to \pi^+\nu\bar{\nu}$ decay has a precisely predicted Standard Model branching ratio of $8.4 \pm 1.0 \times 10^{-11}$ which is almost free from theoretical uncertainties. Therefore, this SM limit can be tested by a precision measurement. Further, the very high sensitivity of this decay also makes it one of the most suitable candidates to investigate indirect effects of new physics in the flavour sector.

The NA62 experiment at the CERN SPS was proposed and designed to measure this branching ratio by using a decay-in-flight technique. NA62 took data of the $K^+ \to \pi^+\nu\bar{\nu}$ decay in 2016, 2017, 2018 and 2021. The previous analyses yielded the most precise branching-ratio measurement of the decay. In those analyses, the $K^+ \to \pi^+\pi^0$ was used as normalization in order to extract the number of kaon decays for the $K^+ \to \pi^+\nu\bar{\nu}$ branching ratio measurement.

However, it is also possible to use another normalization mode, $K^+ \to \mu\nu$, which can be useful for eliminating undesirable effects that were considered in the previous analyses such as photon and multiplicity rejections. In this talk, I will be discussing the results of this $K^+ \to \mu\nu$ normalization mode and representing a new measurement on $K^+ \to \pi^+\pi^0/K^+ \to \mu\nu$.

Group Report T 3.9 Mon 18:15 T-H16

Towards a Super Charm-Tau Factory in Russia — •Mustafa Schmidt, Simon Bodenschatz, Lisa Brück, Michael Düren, Jan Niclas Hofmann, Sophie Kegel, Jhonatan Pereira de Lira, Marc Strickert, Chris Takatsch, Leonard Welde, and Vincent Wettig — II. Physikalisches Institut, Justus-Liebig-Universität Gießen

The Super Charm-Tau Factory (SCTF) is a future electron-positron collider that is planned to be built in Sarov, Russia. Its center-of-mass energy can be tuned between 2 and 6 GeV for studying a large variety of physics programs. The crab-waste method, a novel collision scheme for particle beams, makes it possible to reach an exceptionally high luminosity up to a value of $\mathcal{L} = 10^{35}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ which is 3–4 orders larger than in previous accelerators. In combination with longitudinally polarized lepton beams in the interaction point and an excellent Particle Identification (PID), SCTF will offer the unique possibility to study open questions in the field of particle physics and to find new physics beyond the standard model (SM). Prominent examples are the investigation of CP-violation in the open-charm sector or Charged Lepton Flavor Violation (CLFV) in decays of τ-leptons. This talk will present some highlights of the physics program and the detector design. Our working group in Giessen focuses on the PID design using RICH and DIRC detectors.

T 4: Flavour Physics 2

Time: Monday 16:15–18:00 Location: T-H17

T 4.1 Mon 16:15 T-H17

Testing Lepton Flavour Universality with $B_s^0 \to \phi\ell^+\ell^-$ decays using LHCb data — Christoph Langenbruch[1], Stefan Schael[1], •Sebastian Schmitt[1], and Eluned Smith[2] — [1]I. Phys. Inst. B - RWTH Aachen — [2]University of Zürich

In the Standard Model of Particle Physics (SM), $b \to s\ell^+\ell^-$ transitions are forbidden at tree-level and may only occur at the loop-level. The branching fractions of these so-called Flavour Changing Neutral Currents (FCNCs) can thus be significantly affected by New Physics (NP) beyond the SM. While in the SM, the coupling of the electroweak gauge-bosons is Lepton Flavour Universal (LFU), this universality can be broken in NP scenarios. Ratios of branching fractions of semileptonic rare decays with muons and electrons in the final state constitute clean SM tests. Recent measurements of LFU ratios have shown tensions of up to $3.1\,\sigma$.

The LHCb detector is located at the Large Hadron Collider (LHC) at CERN and is optimised to study rare b-hadron decays. For this purpose LHCb features high trigger efficiencies, excellent track reconstruction, and particle identification.

This talk gives an overview of the measurement of R_ϕ, which benefits from the experimentally clean $B_s^0 \to \phi\ell^+\ell^-$ environment. The analysis uses the full Run 1 and Run 2 dataset collected by LHCb which corresponds to $9\,\mathrm{fb}^{-1}$ of integrated luminosity.

T 4.2 Mon 16:30 T-H17

Search for the lepton flavour violating decays $B^0 \to K^*(892)^0\mu^\pm e^\mp$ and $B_s^0 \to \phi(1020)\mu^\pm e^\mp$ with the LHCb experiment — •Jan-Marc Basels, Andreas Güth, and Christoph Langenbruch — I. Physikalisches Institut B, RWTH Aachen University

The conservation of lepton flavour in interactions involving charged leptons is a central property of the Standard Model (SM). Thus, every discovery of lepton flavour violation (LFV) would simultaneously be a discovery of new physics.

Designed to study the decays of heavy flavour hadrons, the LHCb detector at the Large Hadron Collider (LHC) at CERN allows for the search for LFV in $b \to s\ell^+\ell'^-$ transitions of B-mesons with unprecedented sensitivity. An additional motivation for such searches arises by recent tests of lepton flavour universality in rare $b \to s\ell^+\ell^-$ decays, which have shown tensions with the SM prediction. Any discovery of lepton flavour non-universality would generally imply the existence of LFV decays.

This talk presents the status of a search for the LFV decays $B^0 \to K^*(892)^0\mu^\pm e^\mp$ and $B_s^0 \to \phi(1020)\mu^\pm e^\mp$, based on a dataset taken with the LHCb detector during Run 1 and Run 2 of the LHC that corresponds to an integrated luminosity of $9\,\mathrm{fb}^{-1}$. Particular focus is placed on the study and control of backgrounds and the determination of expected upper limits on the signal branching fraction.

T 4.3 Mon 16:45 T-H17

Search for the lepton flavour violating decays $B^+ \to K^+e^\pm\mu^\mp$ with the full dataset of the LHCb experiment — Johannes Albrecht, •Alexander Battig, and Elena Dall'Occo — Technische Universität Dortmund

The conservation of lepton flavour in interactions of charged leptons is an important prediction of the Standard Model of particle physics, making searches for lepton flavour violating decays of B mesons an interesting probe for New Physics. In addition, hints of lepton non-universality in $b \to sll$ transitions (measurements of R_{K^+}, $R_{K^{*0}}$) imply the violation of lepton flavour conservation. Due to the abundance of produced B-mesons and ability to precisely study them, the LHCb experiment provides an ideal environment for searches for lepton flavour violating decays of B-mesons.

In this talk, the search for the lepton flavour violating decays $B^+ \to K^+e^\pm\mu^\mp$ with the LHCb experiment is presented. The analysed data has been recorded during Run 1 and Run 2 of the LHC and corresponds to an integrated luminosity of $9.1\,\mathrm{fb}^{-1}$.

T 4.4 Mon 17:00 T-H17

Test of Lepton Flavour Universality (LFU) in $\Lambda_b \to \Lambda\ell\ell$ with the LHCb experiment — Flavio Archilli[1], Simone Bifani[2], Vlad Dedu[3], Lex Greeven[3], Sietske Keijzer[3], Mick Mulder[4], Niladri Sahoo[2], Marco Santimaria[5], Silvia Sole[3], Paul Swallow[2], Niels Tuning[3], Maarten Veghel[3], •Chishuai Wang[1], and Nigel Watson[2] — [1]Physikalisches Institut, Heidelberg, Germany — [2]University of Birmingham, UK — [3]Nikhef, Netherlands — [4]University of Groningen, Netherlands — [5]INFN, Frascati, Italy

The Flavour Changing Neutral Current (FCNC) transition $b \to s\ell\ell$ is highly suppressed in the Standard Model (SM), which makes it susceptible to the impact of possible New Physics (NP).

In the SM, the electroweak interaction does not distinguish between the three generations of leptons. However, several recent studies of LFU using $b \to s\ell\ell$ processes, e.g. $R_K = \frac{\mathcal{B}(B^+\to K^+\mu\mu)}{\mathcal{B}(B^+\to K^+ee)}$ and $R_{K^{*0}} = \frac{\mathcal{B}(B^0\to K^{*0}\mu\mu)}{\mathcal{B}(B^0\to K^{*0}ee)}$ measurements, have shown deviations from the SM expectations.These ratios have the advantage that theoretical uncertainties from the hadronization cancel, which makes them relatively clean observables. For the $\Lambda_b \to \Lambda\ell\ell$ system, a similar observable $R_\Lambda = \frac{\mathcal{B}(\Lambda_b\to\Lambda\mu\mu)}{\mathcal{B}(\Lambda_b\to\Lambda ee)}$ can be defined. The measurement of R_Λ will provide an independent test with respect to the tests of LFU performed with the B-mesons.

This talk will present the ongoing study of the R_Λ measurement at LHCb, using the data collected by the LHCb experiment during the years 2011-2012 and 2015-2018.

T 4.5 Mon 17:15 T-H17

Search for lepton flavour violation in four-body charm decays at LHCb — •Daniel Unverzagt — Physikalisches Institut, Heidelberg, Germany

LHCb is playing a leading role in the study of rare and forbidden decays of charm hadrons, which might reveal effects beyond the Standard Model. This talk aims in particular to motivate the search for lepton flavour violation in four-body charm decays. In addition an overview about the current status of an analysis studying neutral charm hadrons decaying to two hadrons and an electron and muon, $D^0 \to hh\mu e$ with $h = \pi^\pm, K^\pm$, is provided.

T 4.6 Mon 17:30 T-H17

Angular analysis of $B^0 \to K^*e^+e^-$ decays — Martino Borsato, Fabian Glaser, and •Jiangqiao Hu — Physikalisches Institut - Universität Heidelberg

Over the last decade, the LHCb detector at the Large Hadron Collider (LHC) collected the world largest sample of beauty hadron decays. This dataset allowed to study rare transitions of a b quark into an s quark and a pair of charged leptons ($b \to s\ell\ell$) with unprecedented precision and unearthed a series of anomalies that could be a sign of dynamics beyond the Standard Model. Namely, the angular distributions of $b \to s\mu\mu$ decays do not agree with theoretical predictions and their rate is lower than that observed in $b \to see$ decays, in contrast to the expectation dictated by the SM symmetry of lepton universality. A key measurement to solve this puzzle is the angular analysis of $B^0 \to K^*e^+e^-$ decays. In this talk I will present my contribution to this analysis, focusing on the difficult kinematic region of high dielectron invariant mass. Advanced analysis techniques are used to classify signal candidates, characterise background contributions and measure the angular properties of the decay.

T 4.7 Mon 17:45 T-H17

Angular analysis of the decay $B^0 \to K^{*0}\mu^+\mu^-$ — Leon Carus[1], Christoph Langenbruch[1], •Thomas Oeser[1], and Eluned Smith[2] — [1]I. Physikalisches Institut B, RWTH Aachen University — [2]Physik-Institut, University of Zurich

Recently, several tensions between measurements and Standard Model predictions emerged in the area of $b \to s\ell\ell$ decays in measurements of branching fractions, angular observables, and tests of lepton universality. Additional experimental information, such as angular observables determined from the angular distribution of $b \to s\ell\ell$ decays, can provide deeper insight into the nature of potential New Physics contributions.

A previous measurement of the angular distribution of $B^0 \to K^{*0}(\to K^+\pi^-)\mu^+\mu^-$ decays, performed by the LHCb collaboration using data collected during Run 1 and 2016, found tensions with Standard Model predictions at the level of 3 standard deviations.

This talk will present an overview of the update of this analysis, including LHCb data collected in 2017 and 2018.

T 5: Electroweak Interactions (Exp.) 1

Time: Monday 16:15–18:20 Location: T-H18

Group Report T 5.1 Mon 16:15 T-H18

Measuring mass and width of the W-boson with the ATLAS detector — Philip Bechtle[1], Klaus Desch[1], Philip Kennedy[2], Oleh Kivernyik[1], Jakub Kremer[2], •Philipp König[1], and Matthias Schott[2] — [1]Rheinische-Friedrich-Wilhelms-Universität Bonn — [2]Johannes Gutenberg-Universität Mainz

In 2017, the ATLAS collaboration measured the W-boson mass using pp-collision data taken at $\sqrt{s}$ = 7 TeV in 2011, resulting in the most precise single measurement with a precision of 19 MeV. We present a revised analysis of the same dataset, improving the fit methods and including a measurement of the width of the W-boson. A precise measurement of these quantities in the decay of the W-boson represent an excellent precision test of the Standard Model (SM).

A detailed comparison of the analysis design between the reanalysis and the 2017 analysis is carried out. Improvements are made in the estimation of the multijet background and the description of some systematic uncertainties. The new fitting method of a profile likelihood fit is studied carefully and cross-checked against the results of the revised analysis.

T 5.2 Mon 16:35 T-H18

Measurement of the mass and width of the W-boson at the ATLAS experiment — •Philip David Kennedy[1], Jakub Kremer[1], Philipp König[2], and Matthias Schott[1] — [1]Institute of Physics, Johannes Gutenberg Universität, D-55099 Mainz, Germany — [2]Institute of Physics, Rheinische Friedrich-Wilhelms-Universität Bonn, D-53115 Bonn, Germany

We discuss the status of the W-boson mass and width measurements using data from the ATLAS experiment at the LHC. This work utilises a profile-likelihood fit to re-analyse the Run-1 dataset. This method provides an advantage over a χ^2 approach used in the original analysis as the likelihood is minimised over the whole parameter space, including all systematic uncertainties. It is then used to perform the first fit of Γ_W at the LHC. These results are of crucial importance for the EW-fit which bounds possible new physics scenarios. Comparison is then made between these results and those from other experiments. Particular emphasis will be placed on the performance of the profile-likelihood fit and its impact on the uncertainties of parton density functions.

T 5.3 Mon 16:50 T-H18

Measurement of the differential $W \to e + \nu$ cross-section at high transverse masses at $\sqrt{s} = 13$ TeV with the ATLAS detector — Frank Ellinghaus and •Frederic Schröder — Bergische Universität Wuppertal

The charged-current Drell-Yan (DY) cross-section is measured for the leptonic decay of the W boson $W \to e\nu$. While the cross-section at the peak of the W boson mass is known very well, the measurement of the differential cross-section for transverse masses up to $\mathcal{O}(1\,\text{TeV})$ is measured for the first time. In addition, the double-differential cross-section will be measured as a function of the transverse mass of the W boson and the pseudorapidity of the lepton.
The charged-current DY can be used to constrain the density function that describes the partonic content of the proton and to measure fundamental parameters of the Standard Model. In particular, the high m_T^W region of the charged-current DY allows probing new physics by constraining effective field theory parameters, because these parameters are sensitive to small deviations in the cross-section with respect to the theory prediction.
An overview of the cross-section measurement focused on issues related to the reconstruction of the missing transverse momentum in the fake lepton background estimation will be presented. The data has been taken at the ATLAS experiment during Run-2 based on pp-collisions at a center-of-mass energy of $\sqrt{s} = 13\,\text{TeV}$ at the LHC.

T 5.4 Mon 17:05 T-H18

Measurement of the differential $W \to \mu + \nu$ cross section at high transverse masses at $\sqrt{s} = 13$ TeV with the ATLAS detector. — Frank Ellinghaus, Frederic Schröder, and •Johanna Wanda Kraus — Bergische Universität Wuppertal

The cross section of the charged-current Drell-Yan process in the decay $W \to \mu + \nu$ is measured with data taken with the ATLAS detector from pp-collisions at a center-of-mass energy of $\sqrt{s} = 13\,\text{TeV}$. The full run 2 dataset of $\mathcal{L} = 139\,\text{fb}^{-1}$ is analyzed.
While the inclusive cross-section is well-known, a differential measurement at very high transverse masses is done for the first time. The cross-section will also be measured double-differentially in the transverse mass of the W-boson m_T^W and the pseudorapidity of the lepton. This measurement is important since it can be used to constrain the parton distribution function of the proton as well as electroweak parameters.
A quick overview of the complete analysis will be given while the main focus is on the unfolding strategy via Iterative Bayesian Unfolding.

T 5.5 Mon 17:20 T-H18

A data-driven multijet background estimation method for the measurement of the electroweak Wjj production with the ATLAS experiment — •Lisa Marie Baltes — Kirchhoff-Institute for Physics, University Heidelberg, Germany

The observation and measurement of self-interactions of weak gauge bosons provide an indirect search for physics beyond the Standard Model. The electroweak production of a W boson in association with two jets includes the triple gauge boson vertices WWγ and WWZ and is thus sensitive to the vector-boson-fusion (VBF) production of a W boson. In proton-proton collisions, the characteristic signature of a VBF includes two high-momentum jets at small angles with respect to the incoming beams and a centrally produced lepton-neutrino pair originating from the W boson decay. A significant background for this analysis is the multijet production via the strong interaction where a jet is misidentified as a lepton. It is difficult to model this background since it strongly depends on detector-related quantities such as lepton identification and isolation criteria. Therefore, data-driven techniques are used to estimate this background. In this talk, the results of the multijet background estimation using the matrix method are presented.

T 5.6 Mon 17:35 T-H18

Measurement of angular coefficients of the Z boson production at ATLAS — •Julian Blumenthal and Stefan Tapprogge — Institut für Physik, Johannes Gutenberg-Universität, Mainz

A better understanding of QCD production processes at hadron colliders is a key aspect for theoretical predictions of perturbative QCD at higher accuracy. It allows for more precise measurements of Standard Model parameters and background estimations for searches. This contribution focusses on the measurement of angular coefficients that are used to describe the differential cross section of the Z boson production and subsequent decay into leptons in the Collins-Soper-frame. These angular coefficients can be used to probe QCD contributions in Z production processes in detail. Two of the coefficients in particular can also be used to make inferences about the effective weak mixing angle. For the measurement the full Run 2 ATLAS dataset with an integrated luminosity of L $\approx$ 139 fb^{-1} at $\sqrt{s}$ =13 TeV is used, which increases the statistical accuracy significantly at a higher centre-of-mass energy than previous analyses. Major challenges of the measurement using centrally produced charged lepton pairs will be described and expected uncertainties discussed.

T 5.7 Mon 17:50 T-H18

Measurement of the anomalous magnetic moment of the tau lepton in heavy ion collisions with the ATLAS experiment — •Leonie Hermann, Valerie Lang, and Markus Schumacher — Albert-Ludwigs-Universität Freiburg

The anomalous magnetic moment of leptons is an important property in the Standard Model of particle physics and is highly sensitive to new physics beyond the Standard Model. At the LHC the anomalous magnetic moment of the tau lepton (a_τ) can be measured in ultra-peripheral PbPb collisions exploiting the large photon flux via the partonic process $\gamma\gamma \to \tau\tau$. Anomalous values of a_τ change the total cross-section and differential cross-sections in various kinematic observables. The analysis is based on PbPb collision data with a center-of-mass energy of 5.02 TeV collected with the ATLAS experiment in 2018 with an integrated luminosity of 1.33 nb^{-1}. Events with one leptonically decaying tau lepton, i.e. an electron or muon in the final state, and the other decaying hadronically or leptonically are exploited in the analysis. The sensitivity of the measurement is determined by a maximum likelihood fit to the number of selected events, the shape of kinematic distributions and a combination of both in several signal regions corresponding to different final states. Studies of the expected sensitivity quantified by the length of the confidence interval for a_τ will be presented.

T 5.8 Mon 18:05 T-H18

Measurement of $Z\gamma\gamma$ and $ZZ\gamma$ final states with the ATLAS detector at the LHC — •Anke Ackermann and Philipp Ott — Kirchhoff-Institute for Physics, Heidelberg University

The Standard Model of Particle Physics (SM) predicts the rare production of triboson states, in which three gauge bosons are produced simultaneously. Although suffering from small cross sections and hence a limited amount of signal events, such triboson states can be studied with the vast amount of data that is collected by the ATLAS detector in Run 2. In addition to validating the predictions of the SM for rare processes, sensitivity to New Physics is given via anomalous quartic couplings of e.g. four neutral gauge bosons. This talk will focus on the analysis of the simultaneous production of $ZZ\gamma$ as well as $Z\gamma\gamma$. In order to determine the cross sections of those processes, it is crucial to separate signal events from events arising through background processes mimicking the signal topology. The most dominant background process contains fake photons, which are non-prompt photons within jets. Different data-driven methods are used to estimate the amount of fake photons in the signal region. After giving a general introduction about the triboson production of the processes $Z\gamma\gamma$ and $ZZ\gamma$, a short summary of the two analyses, including the event selection, the background estimation and a study for effects of New Physics, is presented.

T 6: Top Quarks: Production (Exp.) 1

Time: Monday 16:15–18:30 Location: T-H19

T 6.1 Mon 16:15 T-H19

Measurement of the Single-Top production cross section in the s-channel at $\sqrt{s}$=13 TeV with the ATLAS detector — •Kreul Ken — Humboldt-Universität zu Berlin

The production of single top-quarks in electroweak processes (Single-Top) is an important part for the study of the Standard Model and possible extensions. Single-Top production is possible in three channels: t-channel, s-channel and via associated production of a W-boson. In proton-proton collisions at the Large Hadron Collider (LHC), the s-channel has the lowest production cross section and is dominated by many background processes. During the LHC run at 8 TeV, the s-channel was already observed with a significance of 3.2σ using the Matrix Element Method. In this method, the matrix elements for the most important signal and background processes are integrated over the available phase space to compute process likelihoods, which can then be combined to a discriminant. The method is now applied to current ATLAS data at $\sqrt{s}$=13 TeV to improve the previous result using the higher luminosity of up to 139 fb^{-1}.

T 6.2 Mon 16:30 T-H19

Measurement of the t-channel single top-quark production cross-section in proton-proton collisions at a centre-of-mass energy of 13 TeV with the ATLAS detector — Olga Bessidskaia Bylund[1], Dominic Hirschbühl[1], •Joshua Reidelstürz[1], Mohsen Rezaei Estabragh[1], Wolfgang Wagner[1], Johannes Erdmann[2], and Benedikt Gocke[2] — [1]Bergische Universität Wuppertal, Wuppertal, Deutschland — [2]Technische Universität Dortmund, Dortmund, Deutschland

The measurement of the single top-quark t-channel production cross sections σ_{tq} and $\sigma_{\bar{t}q}$ and their fraction R_t as well as the total cross section $\sigma_{tq,\bar{t}q}$ is presented. These measurements provide a precise test of the standard model and are sensitive to new-physics phenomena by probing the properties of the Wtb vertex and placing limits on the CKM matrix element $|V_{tb}|$. Data taken with the ATLAS detector from 2015 to 2018 corresponding to an integrated luminosity of $\mathcal{L} = 139\,\text{fb}^{-1}$ at a center-of-mass energy of 13 TeV is analyzed using corresponding samples of simulated events. Requirements are applied to the data selecting events with the signature expected for the signal process. To further enhance the separation between signal and background events a neural network is trained using the Monte Carlo simulated data combining several kinematic variables. The neural network output distribution is then used in a binned profile maximum likelihood fit including all systematic uncertainties to determine the cross sections.

T 6.3 Mon 16:45 T-H19

Measurement of W-boson-associated single-top-quark production in boosted lepton-plus-jets final states with CMS — •Christopher Matthies[1], Johannes Haller[1], Roman Kogler[2], and Matthias Schröder[1] — [1]Institut für Experimentalphysik, Universität Hamburg — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg

We present a differential cross section measurement of the associated production of a single top quark and a W boson (tW) in boosted lepton-plus-jets final states in pp collisions at $\sqrt{s} = 13$ TeV with the CMS experiment. Boosted hadronic decays of both the W boson or the top quark are reconstructed as large-radius jets, using the Heavy Object Tagger with Variable R (HOTVR). Deep learning techniques are employed to discriminate tW from top quark pair production and other background processes. It is shown that a measurement up to a transverse momentum of several hundred GeV of the top quark or associated W boson is feasible, extending the phase space covered by previous measurements considerably.

T 6.4 Mon 17:00 T-H19

Measurements of differential cross sections and spin asymmetry in tZq — •David Walter and Abideh Jafari — DESY, Hamburg, Germany

The associated production of a single top quark and a Z boson in pp collisions at the LHC includes the tZ coupling as well as the coupling of three vector bosons (WWZ) and is therefore a unique process to study the couplings of heavy particles in the SM. The top quark in this process is polarized due to its production through the weak interaction. Since the top quark decays before it hadronizes, the spin information is conserved in the leptonic decay products and can be measured. In this talk the first differential measurement of the tZq cross section is presented where the full Run-2 data of 138 /fb is used. The tZq cross section is measured at parton and particle level as a function of various kinematic observables including leptons and jets. A maximum likelihood unfolding procedure is exploited to correct for detector and hadronization effects. Also presented is the first measurement of the spin asymmetry in tZq, which is proportional to the top quark polarization.

T 6.5 Mon 17:15 T-H19

Differential cross-section measurement of the tZq process with the ATLAS detector — •Nilima Akolkar and Ian Brock — Physikalisches Institut, Universität Bonn

The production of a single top quark in association with a Z boson (tZq) is a rare process that has been discovered by the CMS and ATLAS Collaborations. This process is of special interest, as it allows one to probe the couplings of the Z boson to the quark sector and to W boson simultaneously.

This talk will focus on the differential cross-section measurement of the tZq process, analyzed in the trilepton decay channel. The data used was collected with the ATLAS detector during Run 2 of the LHC, corresponding to an integrated luminosity of 139 fb^{-1}. The tZq differential cross-section is measured using different methods of unfolding and the preliminary results will be presented in the talk.

T 6.6 Mon 17:30 T-H19

Towards a WbWb differential cross-section measurement — •Thomas Mclachlan — DESY

Top quark pair production is a widely studied process at the Large Hadron Collider (LHC) and is a significant background in many searches beyond the Standard Model (BSM). The WWbb final states of this process interfere with the production of a single top quark in association with a W boson and a b-quark (tWb). Using data from

Run-2, I will measure the WbWb production cross-section in a phase space that is maximally sensitive to the interference effects with the goal of improving the modelling of SM processes for BSM searches. An event selection using single lepton events is being developed. In this context, I will present a range of quantities and theoretical parameters that will be used in the differential cross-section measurement.

T 6.7 Mon 17:45 T-H19

Search for single production of top quarks in association with a photon with the ATLAS detector at $\sqrt{s} = 13$ TeV — •Björn Wendland, Johannes Erdmann, and Kevin Kröninger — Technische Universität Dortmund, Fakultät Physik

Analyses of top quark production in association with a photon are important tests of the Standard Model. They probe top quark properties with respect to the electroweak interaction, such as the top quark charge or the structure of the top quark and photon vertex. Top quark pair production with a photon in leptonic final states was observed and investigated extensively by the ATLAS and CMS collaborations. No significant deviations from the Standard Model expectations were found by now.

With the rich datasets collected by the ATLAS and CMS experiments during Run 2 of the LHC programme, it is feasible to observe single production of top quarks in association with a photon. The CMS collaboration reported evidence corresponding to $4.4\,\sigma$ for this process using a partial Run 2 dataset.

In this talk, studies of t-channel single production of top quarks with a photon using the full Run 2 dataset collected by the ATLAS detector are presented. As the leptonic decay channel of the top quark is used in this analysis, the final state consists of either an electron or a muon, a jet containing B hadrons, missing transverse energy, a photon and an additional jet produced in the forward direction.

T 6.8 Mon 18:00 T-H19

First studies on the Monte Carlo simulation of single-top quark production in association with a photon using effective field theory samples — •Nils Julius Abicht, Johannes Erdmann, and Björn Wendland — Technische Universität Dortmund, Fakultät Physik

The observation of Standard Model (SM) single-top quark production in association with a photon with the ATLAS detector is expected to be possible with the full Run-2 dataset. A differential measurement of the process can be used to further test the SM. In particular, the interaction between the photon and the top quark is sensitive to modifications of the electroweak couplings of the top quark. An effective field theory (EFT) approach, with variations of the relevant parameters c_{tW} and c_{tB} is employed in order to further constrain current limits on the respective EFT operators. For a better understanding of the influence of these parameters on the simulation of the process in MadGraph, preliminary studies for future EFT interpretations are presented.

T 6.9 Mon 18:15 T-H19

Search for flavour-changing neutral-current interactions of a top quark and a gluon in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector — •Wolfgang Wagner, Gunnar Jäkel, and Dominic Hirschbühl — Bergische Universität Wuppertal

In the standard model, flavour-changing neutral currents (FCNCs) are strongly suppressed, in particular in the top-quark sector. Any observation of top-quark-related FCNCs will thus be a clear sign of physics beyond the standard model. A search is presented for the production of a single top quark via left-handed flavour-changing neutral-current (FCNC) interactions of a top quark, a gluon and an up or charm quark. Two production processes are considered: $u+g \to t$ and $c+g \to t$. The analysis is based on proton–proton collision data taken at a centre-of-mass energy of 13 TeV with the ATLAS detector at the LHC. The data set corresponds to an integrated luminosity of 139 fb^{-1}. Events with exactly one electron or one muon, exactly one b-tagged jet and missing transverse momentum are selected, resembling the decay products of a singly produced top quark. Neural networks based on kinematic variables differentiate between events from the two signal processes and events from background processes. The measured data are consistent with the background-only hypothesis, and limits are set on the production cross-sections of the signal processes. Based on the framework of an effective field theory, the cross-section limits are translated into limits on the strengths of the tug and tcg couplings occurring in the theory.

T 7: Top Quarks: Properties 1

Time: Monday 16:15–18:15 Location: T-H20

T 7.1 Mon 16:15 T-H20

Measurement of the top quark pole mass using $\mathrm{t\bar{t}}+1$ jet events with the CMS experiment — •Sebastian Wuchterl[1], Katerina Lipka[1], and Matteo Defranchis[2] — [1]Deutsches Elektronen Synchrotron (DESY) — [2]CERN

The top quark is the most massive elementary particle known. Its mass, m_{t}, is a fundamental parameter of the Standard Model (SM), and its value needs to be determined experimentally. A precise measurement of m_{t} and the masses of the W and Higgs bosons play a crucial role in precision tests of the SM. Additionally, the value and the uncertainty of m_{t} are driving predictions for the energy dependence of the Higgs quartic coupling, which determines the stability of the electroweak vacuum. In proton-proton collisions at the LHC, top quark-antiquark ($\mathrm{t\bar{t}}$) production can be used to extract m_{t} in different renormalization schemes.

In this work, the pole mass of the top quark is measured using events in which the $\mathrm{t\bar{t}}$ system is produced in association with one additional jet. This analysis is performed using proton-proton collision data collected by the CMS experiment in 2016-2018 with $\sqrt{s} = 13$ TeV, corresponding to a total integrated luminosity of 138 fb^{-1}. Events with two opposite-sign leptons in the final state are analyzed to measure the normalized differential cross section as a function of the inverse of the invariant mass of the $\mathrm{t\bar{t}}+1$ jet system. This observable has been chosen due to strongest sensitivity to m_{t} at the threshold of the $\mathrm{t\bar{t}}$ pair production.

T 7.2 Mon 16:30 T-H20

Measurement of the jet mass distribution in hadronic decays of boosted top quarks and determination of the top quark mass with CMS — •Alexander Paasch[1], Johannes Haller[1], Roman Kogler[2], and Dennis Schwarz[3] — [1]Institut für Experimentalphysik, Universität Hamburg — [2]DESY, Hamburg — [3]Austrian Academy of Sciences, Vienna

The top quark is the heaviest known elementary particle. Due to its high mass it plays an important role in the electroweak sector of the Standard Model and the measurement of its properties is of special interest. In contrast to conventional top quark mass measurements, we provide an analysis in the boosted regime. At these high energies, the top quark decay products are collimated and are clustered into a single large-radius jet with a mass sensitive to the top quark mass.

In this talk, we present the measurement of the jet mass distribution and top quark mass in hadronic decays of boosted top quarks, using 137 fb^{-1} of data collected by the CMS experiment during the LHC Run-2. New techniques such as a refined calibration of the jet mass scale and improving the description of the final state radiation through a measurement of jet substructure variables substantially increase the precision compared to earlier analyses. The result represents a large step towards the precision observed in measurements at threshold production.

T 7.3 Mon 16:45 T-H20

Measurement of the top-quark mass in $t\bar{t}$ events using the template method in the lepton+jets channel with the ATLAS detector — •Dimbiniaina Rafanoharana and Andrea Knue — Albert-Ludwigs-Universität Freiburg

The top-quark mass is a fundamental parameter of the Standard Model (SM). Its precise determination is therefore crucial to test the consistency of the SM. A multitude of measurements was performed at the Tevatron and the LHC using different methods and final states.

The combination of the ATLAS measurements at $\sqrt{s} = 7$ TeV and at $\sqrt{s} = 8$ TeV has a relative overall uncertainty of 0.28% and a relative statistical uncertainty of 0.14%. The measurement precision is therefore limited by the understanding of systematic effects.

In this presentation, an investigation of the systematic effects in the top-quark mass measurement using the template method in $t\bar{t} \rightarrow$ lepton+jets channel at $\sqrt{s} = 13$ TeV is shown. The studies are performed using different observables sensitive to the top-quark mass as well as different event selections, aiming at reducing the overall uncertainty.

T 7.4 Mon 17:00 T-H20

Neural network based estimators to measure the top quark mass — Christoph Garbers, Johannes Lange, •Nathan Prouvost, Peter Schleper, and Hartmut Stadie — Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

The top quark is the heaviest known particle in the Standard Model. As such, the top quark mass is an important parameter for constraining and checking the validity of Standard Model predictions. In the semi-leptonic decay channel, a value of the top quark mass of 172.25 ± 0.63 GeV has been measured with 35 fb^{-1} of the 2016 data at the CMS experiment. The mass of the top quark from a kinematic fit and the reconstructed mass of the W boson are used as variables. It is expected that adding more variables will improve the measurement. This presentation focuses on the development of neural network based estimators of the top quark mass using nuisance parameters for the systematics and multiple observables.

T 7.5 Mon 17:15 T-H20

Measurement of the top quark width from Wb scattering — Thorsten Chwalek[1], Matteo Defranchis[2], Nils Faltermann[1], Jan Kieseler[2], Matthias Komm[2], •Marco Link[1], Martijn Mulders[2], Thomas Müller[1], Michael Pitt[2], and Pedro Silva[2] — [1]Institut für Experimentelle Teilchenphysik (ETP), Karlsruher Institut für Technologie (KIT) — [2]CERN

The top quark is the heaviest elementary particle in the standard model (SM). As such it is especially interesting to search for hints of physics beyond the standard model (BSM). Current measurements of the top quark decay width make strong assumptions on the branching ratio of the top quark into a W boson and a bottom quark (Wb).

This talk explores the possibility of the model independent measurement of the top quark decay width in Wb→Wb scattering via a top quark propagator at the CMS experiment. Generator level studies are used to develop reconstruction methods for the Wb system. In combination with a measurement of the single top cross section this measurement could be sensitive to effects from BSM physics. Given the limited size of the current data set and the small cross section of the signal process, the measurement will be interesting with the increase of data expected during HL-LHC data taking.

T 7.6 Mon 17:30 T-H20

Measurement of top-quark pair spin correlation in the ℓ + jets channel using the ATLAS experiment — •Oleksandr Burlayenko, Andrea Knue, and Zuzana Rurikova — Albert-Ludwigs Universität Freiburg, Experimentelle Teilchenphysik AG Herten

The top quark is the heaviest known fundamental particle and has a lifetime on the order of 10^{-25} s. This lifetime is shorter than the quantum chromodynamic (QCD) hadronization time scale $1/\Lambda_{QCD} \approx 10^{-24}$ s, and much shorter than the spin decorrelation time scale $m_t/\Lambda_{QCD}^2 \approx 10^{-21}$ s. This gives an opportunity to study the spin properties of a bare quark, as top-quark spin information is preserved in the angular distribution of its decay products.

The Standard Model predicts the $t\bar{t}$ pairs to have correlated spins. The degree of the this correlation is sensitive to the production mechanism of the top quark. The ATLAS collaboration measured it at 13 TeV in the dilepton channel. In this measurement, a discrepancy between the predicted and observed results was found.

This work presents ongoing studies of the $t\bar{t}$ spin correlation in the lepton + jet channel at $\sqrt{s} = 13$ TeV. While this channel provides a larger dataset to study, the analyzing power is reduced compared to the dilepton channel. In this talk, first studies will be presented including different event selections and different observables for this final state.

T 7.7 Mon 17:45 T-H20

Extracting top-Yukawa coupling from $t\bar{t}$ cross-section using ATLAS data — •Supriya Sinha — DESY, Hamburg and Zeuthen, Germany

This work aims to extract the top-Yukawa coupling (Y_t) from $t\bar{t}$ cross section close to the threshold. In order to achieve this, one can use the kinematic distributions in $t\bar{t}$ production along with the virtual Higgs boson loop correction. This boson exchange modifies the differential distributions near $t\bar{t}$ production threshold energy. It becomes highly sensitive to Y_t, and hence, is used to extract its value.

This talk introduces the involved physics processes and gives an insight to the analysis strategy. The decay channel considered for the analysis is the lepton+jets final state. Full Run-II data with the integral luminosity of 139 fb^{-1} taken from the ATLAS experiment at 13 TeV, is used.

T 7.8 Mon 18:00 T-H20

Sensitivity studies for the measurement of the top-Yukawa coupling using four-top final states — Arnulf Quadt, Elizaveta Shabalina, and •Sreelakshmi Sindhu — II. Physikalisches Institut, Georg-August-Universität Göttingen

The top quark is the heaviest particle in the Standard Model and hence a precise measurement of its properties is key to identifying evidence for physics beyond the Standard Model. One such property is the top-Yukawa coupling, which describes the strength of the interaction between the top quark and the Higgs boson. The production of four top quarks can be mediated by the Higgs boson, making this process highly sensitive to the top-Yukawa coupling. Various kinematic variables from the decay of the four top process in the trilepton and same-sign dilepton channels are studied to identify the observables that are most sensitive to the top-Yukawa coupling. To get better sensitivity, the top quarks are reconstructed to directly probe the properties of the top quark. The neural network is studied to further improve the sensitivity of the four top quark production to the top-Yukawa coupling. In this talk, a summary of these sensitivity studies will be presented.

T 8: Higgs Boson: Decay in Fermions 1

Time: Monday 16:15–18:30 Location: T-H21

T 8.1 Mon 16:15 T-H21

Measurement of Higgs boson production cross sections in the di-τ decay channel with the ATLAS detector and the combination with other decay channels — •Frank Sauerburger, Karsten Köneke, Christopher Young, and Karl Jakobs — Albert-Ludwigs-Universität Freiburg, Deutschland

The coupling of the Higgs boson to τ-leptons is one of the most precisely measured couplings of the Higgs boson to fermions. A measurement of the production cross sections of the Higgs boson decaying into two τ-leptons is presented. The cross section is measured in the gluon-fusion, vector-boson-fusion, W/Z boson associated, and top-quark pair associated production channels. The study illustrates the application of machine-learning techniques. The analysis uses proton-proton collision data at a center-of-mass energy $\sqrt{s} = 13$ TeV corresponding to an integrated luminosity of 139 fb^{-1} recorded during Run 2 with the ATLAS detector at the LHC.

In addition, the combination of this measurement with other Higgs boson production and decay channels is presented. The presentation focuses on the measurement of coupling modifiers in the κ framework.

T 8.2 Mon 16:30 T-H21

Optimization of di-tau mass reconstruction in the ATLAS experiment using a deep neural network — Klaus Desch, Philip Bechtle, Christian Grefe, Lena Herrmann, and •Ramy Hmaid — Rheinische-Friedrich-Wilhelms-Universität Bonn

A major challenge of identifying Higgs decays to tau leptons is the similarity of Higgs- and Z-Boson decays, due to their similar mass and at least least two unobservable neutrinos in the final state.

We will present a regression neural network that determines the invariant mass of the reconstructed di-tau system and compare its performance with existing solutions for this problem. In addition, the stability of the neural network response under different training conditions will be discussed.

T 8.3 Mon 16:45 T-H21

Improving the sensitivity of CP tests in VBF Higgs-boson production exploiting the $H \to \tau_e\tau_\mu$ decay with neural networks for the reconstruction of the Higgs-boson four-momentum at the ATLAS experiment — •Alexandra Spitzer, Michael Böhler, and Markus Schumacher — Albert-Ludwigs-Universität Freiburg

Violation of CP invariance is one of the three Sakharov conditions needed to explain the observed baryon asymmetry in our universe. In the Standard Model CP violation is already introduced via the CKM matrix. However, its size is not sufficient to explain the amount of observed baryon asymmetry. The vector-boson fusion production of the Higgs particle allows to study its CP structure of the couplings to electroweak gauge bosons HVV.

CP invariance of HVV couplings is probed by investigating the mean value of the CP-odd Optimal Observable. Since the Higgs bosons's four-momentum is required for calculating the Optimal Observable the resolution of the Optimal Observable is limited by the reconstruction quality of the Higgs boson's four-momentum. It is investigated how neural networks improve the reconstruction quality of the four-momentum in comparison to the Missing Mass Calculator. The hyperparameters of four different neural networks were optimized by using a hyperparameter optimization software framework OPTUNA. The impact on determing the strength of CP violation in the $H \to \tau_e\tau_\mu$ decay channel assuming $\mathcal{L} = 139$ fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV is presented.

T 8.4 Mon 17:00 T-H21

Signal selection and background estimation for testing CP invariance in vector boson fusion production of the Higgs boson in the $H \to \tau_e\tau_\mu$ decay channel using the ATLAS detector — •Ye Joon Kim, Valerie Lang, Ö. Oğul Öncel, and Markus Schumacher — Albert-Ludwigs-Universität Freiburg

The combination of charge conjugation symmetry (C) and parity symmetry (P), together denoted as CP invariance, is violated in the Standard Model (SM) of particle physics in the weak interaction. The amount of CP violation in the SM is not enough to explain the observed baryon asymmetry in the universe. Further sources of CP violation may exist in the Higgs sector. The CP nature of the Higgs boson coupling to vector bosons is investigated in vector-boson fusion production (VBF) of the Higgs boson exploiting the $H \to \tau_e\tau_\mu$ decay channel.

In this talk, contributions to the search for CP violation in VBF production in the $H \to \tau_e\tau_\mu$ channel based on *pp* collision data collected with the ATLAS detector at $\sqrt{s} = 13$ TeV corresponding to an integrated luminosity of 139 fb^{-1} are discussed.

The estimation of background processes, in particular from events where jets are falsely identified as electrons or muons, with the data-driven matrix method is presented. Studies of the signal selection will also be shown.

T 8.5 Mon 17:15 T-H21

Signal selection and background estimation for testing CP invariance in vector boson production of the Higgs boson in the $H \to \tau_{lep}\tau_{had}$ decay channel using the ATLAS detector — •Helena Moyano, Valerie Lang, Ö. Oğul Öncel, and Markus Schumacher — Albert-Ludwigs-Universität Freiburg

The existence of charge conjugation and parity symmetry (CP) violating processes represents one of the three Sakharov conditions for baryogenesis, the mechanism that explains the different abundances of matter and antimatter in the universe. The Standard Model of particle physics includes a description of CP violating processes, however, their contribution is not sufficient to explain the observed baryon asymmetry in the universe. The discovery of the Higgs boson in 2012 opened the window to search for new sources of CP violation in the production or decay of the Higgs boson.

The analysis exploits Higgs-boson production via vector-boson fusion (VBF) and the decay $H \to \tau_{lep}\tau_{had}$ to search for CP-violating contributions to the HVV vertex based on data collected by the ATLAS detector at $\sqrt{s} = 13$ TeV corresponding to an integrated luminosity of $\mathcal{L}$ =139 fb^{-1}.

This presentation discusses the selection of $\tau_{lep}\tau_{had}$ events with neural networks as well as the estimations of the background contributions. Particularly, first studies will be shown regarding the estimation of the background contribution due to jets misidentified as hadronically decaying τ leptons using the Fake Factor method.

T 8.6 Mon 17:30 T-H21

Event reconstruction techniques in the context of a Higgs boson CP analysis in the di-tau lepton final state with the CMS experiment — Wolfgang Lohmann, Achim Stahl, and •Alexander Zotz — RWTH Aachen University - Physics Institute III B, Aachen, Germany

In 2020 the first measurement of the effective CP mixing angle in Higgs boson decays into two tau leptons has been performed by the CMS experiment. It was determined to be $(4 \pm 17)^\circ$ using the Run 2 data set of pp collision of $137 fb^{-1}$ integrated luminosity. The mixing angle was extracted from a distribution of angles between the decay planes of the tau lepton decay products in the $H \to \tau\tau$ decay. In the case of hadronic tau lepton decays via the intermediate a_1 resonance the full tau lepton kinematics including its neutrino and furthermore its polarimetric vector can be reconstructed. Requiring both tau leptons to decay via a_1 mesons allows for the reconstruction of a CP sensitive observable with higher sensitivity. However the a_1a_1 final state suffers from a small branching fraction and therefore these improvements have a neglible effect on the overall sensitivity once all final states are included.

In this talk, an extension of the polarimetric vector method via the inclusion of final states with an a_1 decay on one side and a single charged lepton or hadron on the other side of the $H \to \tau\tau$ decay is presented. To reconstruct the event a kinematic fit with external constraints is used and the potential improvement on the measurement of the CP mixing angle is discussed.

T 8.7 Mon 17:45 T-H21

Tau reconstruction exploiting machine learning techniques at CMS — •Ze Chen — DESY, Hamburg, Germany

Reconstruction of hadronically decaying tau leptons (denoted as τ_h) in the CMS experiment at the Large Hadron Collider has been historically performed with the Hadron-plus-strip (HPS) algorithm. In the HPS algorithm, the τ_h final state signature is identified by combining information from charged hadrons, reconstructed by their associated tracks, and π_0 candidates, obtained by clustering photon and electron candidates in rectangular regions, called "strips". As of the LHC Run 2, deep-learning techniques have been implemented to improve the identification of genuine τ_h leptons and reduce contributions from backgrounds. This talk covers a study to improve the tau decay mode reconstruction using machine learning techniques. Its efficiency is shown and compared to the one of the HPS algorithm.

T 8.8 Mon 18:00 T-H21

Search for lepton-flavour violating decays of the Higgs boson using the symmetry method for background estimation with the ATLAS experiment at $\sqrt{s} = 13$ TeV — •Katharina Schleicher, Valerie Lang, and Markus Schumacher — Albert-Ludwigs-Universität Freiburg

The discovery of the Higgs boson opened the window to a variety of interesting probes to physics beyond the standard model (SM), including searches for lepton-flavour violating (LFV) Higgs-boson decays. Such decays are predicted in several extension of the SM e.g. in models with two Higgs doublets. In nature, LFV was already observed in form of neutrino oscillations. In this analysis the decays of $H \to e\tau$ and $H \to \mu\tau$ with leptonic τ-decays leading to $e\mu + 2\nu$ final states are considered. A central part of the analysis is the precise estimation of the SM backgrounds. Therefore, a data-driven method is used - the so-called symmetry method. It exploits two principles: First, SM backgrounds with prompt leptons are symmetric w.r.t. the interchange of electrons and muons. And second, this symmetry is broken if the branching ratios of the two LFV decays are of different magnitude. The first principle implicates the challenge of restoring this symmetry since electrons and muons are experimentally different. The second principle is motivated by the upper limit on the $BR(\mu \to e\gamma)$. To obtain the best possible sensitivity, a dedicated statistical model was developed and neural networks for classification are deployed. In this talk, an overview of the analysis using the LHC Run-2 dataset recorded with the ATLAS detector in pp collisions at $\sqrt{s} = 13$ TeV is given.

T 8.9 Mon 18:15 T-H21

Sensitivity to lepton flavour violating Higgs boson decays at the HL-Lhc using data-driven background estimation — •Naman Kumar Bhalla, Katharina Schleicher, Valerie Lang, and Markus Schumacher — Albert-Ludwigs-Universität Freiburg

One of the primary goals of the Large Hadron Collider (LHC) program is to look for processes beyond the Standard Model (SM) of particle physics. One such process predicted by many beyond-SM theories is lepton flavour violation (LFV) in the decays of the Higgs Boson. A search for LFV decays of the Higgs boson with $H \to e\tau_\mu$ and $H \to \mu\tau_e$ final states was performed using the full Run 2 data collected at $\sqrt{s} = 13\,\text{TeV}$, corresponding to an integrated luminosity of $138\,\text{fb}^{-1}$. A part of this analysis used a data-driven background estimation, which takes advantage of the idempotency of SM backgrounds under the exchange of an electron and a muon. This symmetry is then broken only by the difference in the two LFV signals considered. Due to its data-driven nature, the sensitivity of this approach is limited by statistical uncertainties, which are expected to reduce with more data.

This talk describes the extrapolation of the Run 2 analysis' sensitivity to conditions at the high-luminosity LHC (HL-LHC), where a data set, collected in *pp* collisions at $\sqrt{s} = 14\,\text{TeV}$ corresponding to an integrated luminosity of $3000\,\text{fb}^{-1}$, is expected. The extrapolation also accounts for the expected improvements in systematic uncertainties from detector upgrades planned for the HL-LHC. The first expected sensitivities for LFV decays of the Higgs boson at the HL-LHC, based on the data-driven background estimation, are presented.

T 9: Search for Supersymmetry

Time: Monday 16:15–18:30 Location: T-H22

T 9.1 Mon 16:15 T-H22

Search for Higgsino production in SUSY scenarios with a compressed mass spectrum — •Yuval Nissan, Sam Bein, Peter Schleper, and Gudrid Moortgat-Pick — Universität Hamburg

A search for leptonic decays of Higgsino-like neutralinos in the case of a compressed mass spectrum using two soft lepton tracks and missing transverse momentum is presented. We consider the case of a second-lightest neutralino decaying into a dark matter candidate - lightest neutralino - and two leptons via an off-shell Z boson. In the case of a small mass differences between the neutralinos, the leptons produced are very soft, making them difficult to reconstruct at CMS. Signals of different mass splitting are probed and interpreted within a set of simplified models. Multivariate discriminants are employed in the event and object-level selection, and their performance is studied.

T 9.2 Mon 16:30 T-H22

Search for Higgsinos in final states with a low-momentum, displaced track at the CMS experiment — Samuel Bein, Yuval Nissan, Peter Schleper, Alexandra Tews, and •Moritz Wolf — Universität Hamburg

Many supersymmetric extensions to the Standard Model predict the three lightest electroweakinos, χ_2^0, $\chi_1^\pm$, χ_1^0, to be Higgsino-like with similar masses around the electroweak scale. The lightest chargino and the second-lightest neutralino can be pair-produced and decay to the lightest neutralino. To search for these particles, the best strategy depends on the differences between their masses. For $\Delta m(\chi_2^0, \chi_1^0) > \mathcal{O}(1\,\text{GeV})$ lepton pairs from the decay of the second-lightest neutralino leave an experimentally distinct signature, whereas $\Delta m(\chi_1^\pm, \chi_1^0) \lesssim 0.3\,\text{GeV}$ can lead to the chargino giving rise to a disappearing track. However, mass splittings in the range of $\Delta m(\chi_1^\pm, \chi_1^0) = 0.3 - 1.0\,\text{GeV}$ are still unexplored at the LHC.

In this analysis, a slightly displaced track with low momentum, corresponding to a pion originating from the chargino decay, is used to gain sensitivity to this intermediate range of mass splittings.

T 9.3 Mon 16:45 T-H22

Search for disappearing tracks with the CMS experiment at $\sqrt{s}$ = 13 TeV — •Viktor Kutzner[1], Samuel Bein[1], Seh Wok Lee[2], Sang-Il Pak[2], Peter Schleper[1], and Sezen Sekmen[2] — [1]Institute for Experimental Physics, Hamburg University, Luruper Chaussee 149, D-22761 Hamburg, Germany — [2]Kyungpook National University, Daegu, South Korea

Long-lived heavy particles are often predicted in BSM theories with a small mass splitting between the two lightest new particles, for example a chargino and a neutralino in supersymmetry. Given a sufficiently small mass splitting in the range of $m_\pi \lesssim \Delta m \lesssim 200$ MeV, the chargino is expected to decay in the CMS tracker volume into soft non-reconstructed leptons or hadrons and a lightest supersymmetric particle, leaving a short track that then seems to disappear. This signature is characterized by missing hits in the outer layers of the tracker with little or no energy deposited in the calorimeter. In addition to events with one or more disappearing tracks, events with an additional lepton are considered as well to account for a second very long-lived chargino, which decays outside the tracker volume. For both topologies events with additional b-quark jets are investigated to account for gluino-/squark-associated chargino production. Data-driven methods are used to determine the dominant backgrounds arising from prompt leptons and fake tracks. Results are presented using proton-proton collision data with $\sqrt{s}$ = 13 TeV collected with the CMS experiment during Run-2.

T 9.4 Mon 17:00 T-H22

Search for Elektroweak Production of Sleptons in Di-Lepton Final States with the ATLAS Detector — •Marian Rendel, Michael Holzbock, Hubert Kroha, and Sandra Kortner — Max-Planck-Institut für Physik (Werner-Heisenberg-Institut)

Supersymmetry (SUSY) is one of the best studied extensions of the Standard Model (SM) and as such a major part of the ATLAS physics program. SUSY scenarios with light scalar partners of the SM leptons (sleptons) and the neutralino as lightest SUSY particle (LSP) may address the observed muon g-2 anomaly, as well as provide a viable candidate for Dark Matter, and are thus of particular interest. The kinematic properties of final states in events with pair-produced sleptons primarily depend on the mass splitting (Δm) between the sleptons and the LSP. Two complementary ATLAS searches targeting large and small mass splittings, respectively, have been published. However, there remains a sensitivity gap in the intermediate region of moderate mass splittings between 20 GeV and 60 GeV.

In this talk, a new search for sleptons in events with an electron or muon pair produced with an initial–state radiation jet, is presented which particularly aims at closing the sensitivity gap.

The design of the signal region and the background estimation strategies are introduced and the expected sensitivity using 139 fb^{-1} LHC proton–proton collision data collected by the ATLAS experiment during the years of 2015 and 2018 is presented.

T 9.5 Mon 17:15 T-H22

Search for supersymmetry in single lepton events with the full Run 2 data — •Frederic Engelke[4,5], Kerstin Borras[4,5], Kimmo Kallonen[3], Henning Kirschenmann[3], Pantelis Kontaxis[1], Dirk Krücker[4], Isabell Melzer-Pellmann[4], Ashraf Mohammed[4,5], Paris Sphicas[1,2], Costas Vellidis[1], and Lucas Wiens[4] — [1]University of Athens — [2]CERN — [3]Helsinki Institute of Physics — [4]DESY — [5]RWTH Aachen IIIA

Results are presented from a search for supersymmetry in events with a single electron or muon, and multiple hadronic jets. The data corresponds to a sample of proton-proton collisions at $\sqrt{s}$ = 13 TeV with an integrated luminosity of 138 fb^{-1}, recorded by the CMS experiment at the LHC.

We use the angular correlation between the lepton and the W boson's transverse momenta for a strong separation between the signal and the background region. The investigation of the two different signal models benefits from improved top and W tagging methods.

The search targets gluino pair production, where the gluinos decay into the lightest supersymmetric particle (LSP) and either a top quark-antiquark pair or a pair of light quarks in the final state.

T 9.6 Mon 17:30 T-H22

Reconstruction of the displaced τ for the long-lived τ slepton searches at CMS — •Mykyta Shchedrolosiev[1], Konstantin Androsov[2,3], Andrea Cardini[1], Dirk Krücker[1], and Isabell Melzer-Pellmann[1] — [1]DESY, Hamburg, Germany — [2]École polytechnique fédérale de Lausanne — [3]ETH Zurich

Supersymmetric scenarios with long-lived tau sleptons are well motivated, e.g. within gauge mediated symmetry breaking scenarios. Direct searches of $\widetilde{\tau} \to \tau\widetilde{\chi}_0^1$ are limited by the reconstruction efficiency of displaced tau leptons at CMS that are produced up to 50 cm away from the IP. In our study, we explore the optimization of the displaced τ lepton reconstruction using deep neural networks for the corresponding stau searches.

T 9.7 Mon 17:45 T-H22

Constraints on Supersymmetry from Collider Searches and Other Experiments — Samuel Bein, •Malte Mrowietz, and Peter Schleper — Universität Hamburg, Institut für Experimentalphysik

Constraints from 13 TeV LHC searches for supersymmetry and other experiments on the minimal supersymmetric standard model (MSSM) are evaluated in the context of the 19-parameter phenomenological MSSM (pMSSM). Complementarity and possible tension between the LHC data, the recent g-2 result, and direct detection experiments are examined.

T 9.8 Mon 18:00 T-H22

Study of the chargino discovery at FCC-hh and inner tracker proposition — •Cédrine Hügli — DESY, Zeuthen, Germany

The Standard Model has been shown to be an incomplete theory. The most popular theory beyond the SM is Supersymmetry (SUSY). Up to now, no evidence for any of the SUSY particles was found, it was only possible to set exclusion regions and limits on their properties. The post LHC era Future Circular Collider (FCC) with a center of mass energy of 100 TeV could be a new possibility to find SUSY particles. In this work the discovery potential of the pure wino (higgsino) with mass 3 TeV (1 TeV) and average lifetime 0.2 ns (0.023 ns) at FCC-hh is studied in the context of the Minimal Supersymmetric Standard Model with Anomaly Mediated Supersymmetry breaking ($\tan(\beta) = 5$, $m_0 = 20$ TeV and $sign(\mu) > 0$). Using simulations of minimum bias events and single chargino interactions in the reference design of the tracker, the fake rate is estimated. Additionally, the influence of the tracker performance on the discovery potential is studied. The fake rate is then used to predict the final discovery potential of the wino (higgsino) at FCC-hh. The possible mass reach for charginos at FCC-hh is found and the mass prediction possibility is studied.

T 9.9 Mon 18:15 T-H22

SUSY at future colliders - an overview — •Mikael Berggren — Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607Hamburg

A study of the prospects for discovering or excluding SUSY at various proposed future colliders is presented. The study is based on scanning the relevant parameter space of (weak-scale) SUSY parameters. In particular, I concentrate on the properties most relevant to evaluate the experimental prospects: mass differences, lifetimes and decay-modes. The observations are then confronted with estimated experimental capabilities, including - importantly - the detail of simulation these estimates are based upon. Conclusions on realistic prospects are presented.

T 10: Search for New Particles -1

Time: Monday 16:15–18:30 Location: T-H23

T 10.1 Mon 16:15 T-H23

Combination of diboson resonance searches with CMS Run2 data — •Enrico Wendrich[1], Anna Albrecht[1], Irene Zoi[2], Ankita Mehta[1], and Andreas Hinzmann[1] — [1]Universität Hamburg, Institut für Experimentalphysik, Luruper Chaussee 149, Hamburg, Germany — [2]Fermilab, Batavia IL, USA

In many extensions of the standard model, we have new physics resonances decaying to boson pairs. This talk focuses on new resonances decaying into a pair of W, Z and H bosons. Searches in two channels (fully hadronic VV and semi-leptonic VW) are statistically combined to receive a higher sensitivity for the upper cross section limits and the expected sensitivity is presented. The searches are based on CMS proton-proton collision data at 13 TeV, corresponding to an integrated luminosity of 138/fb.

T 10.2 Mon 16:30 T-H23

Search for high-mass dilepton resonances in association with b-jets with the ATLAS detector at $\sqrt{s}$=13TeV — Volker Austrup, Frank Ellinghaus, Jens Roggel, and •Maren Stratmann — Bergische Universität Wuppertal

Potential deviations from the Standard Model predictions observed in decay processes involving a $b \to s$ quark transition hint at Beyond Standard Model physics. One possible explanation for the deviations is the existence of a new heavy vector boson, the Z', which couples only to quarks of the second and third generation.
In this talk, the status of a search for a lefthanded Z' produced in association with jets originating from b or s quarks is presented. The search is carried out in the dileptonic Z' decay channel. An overview of the analysis strategy, including two different approaches for defining a signal region, is given and a preliminary limit on the Z' production cross section is set.

T 10.3 Mon 16:45 T-H23

Search for heavy resonances in ATLAS experiment in events with four top final state — •Elizaveta Sitnikova, Krisztian Peters, Alicia Wongel, and Philipp Gadow — DESY, Hamburg, Germany

A search for heavy resonances in the four-top-quark final state is presented. This search provides a unique way to probe new physics, such as top-philic resonances (Z') produced in association with top quarks ($t\bar{t}Z'$) resulting in events containing four top-quarks. The study was performed using data of proton-proton collisions with center-of-mass energy of 13 TeV collected by the ATLAS experiment at the LHC in 2015-2018 with total luminosity of 139 fb^{-1}. Selected events contain a single lepton in association with multiple jets and are categorized into signal regions according to the multiplicity of jets and how likely these contain b-hadrons. In this presentation we will outline the analysis strategy and discuss the results which are interpreted in a model independent way, as well as in terms of a simplified model for top-philic resonances.

T 10.4 Mon 17:00 T-H23

Search for heavy resonances decaying to top quark pairs at CMS — •Ksenia de Leo[1], Johannes Haller[1], Roman Kogler[2], Artur Lobanov[1], and Matthias Schröder[1] — [1]Institut für Experimentalphysik, Universität Hamburg — [2]DESY, Hamburg

A search for new heavy resonances decaying to top quark pairs is presented. The analysis uses pp-collision data with a center-of-mass energy of 13 TeV, collected with the CMS experiment during Run-2 of the LHC. The data correspond to an integrated luminosity of 137 fb^{-1}.

The search is performed in final states with one lepton, missing transverse energy and jets, and exploits top-tagging techniques to identify the hadronic decay of top quarks. A multi-class neural network has been developed to categorise the events into the main backgrounds from known standard model processes. Exclusion limits on the production cross section of new particles are set for different benchmark models. While the main target of the analysis is the highest possible mass region, improvements have been implemented to increase the sensitivity for masses below 1 TeV, important for models where a scalar or pseudo-scalar particle decays to top quark pairs.

T 10.5 Mon 17:15 T-H23

A search for pair production of excited top quarks t* at CMS — •Finn Labe[1], Johannes Haller[1], Roman Kogler[2], Artur Lobanov[1], and Matthias Schröder[1] — [1]Institut für Experimentalphysik, Universität Hamburg — [2]DESY

A search for pair production of excited top quarks t^* in the decay channel $t^*t^* \to tgtg$ is presented. The search uses proton-proton collision data at a center-of-mass energy of 13 TeV, collected with the CMS experiment during Run 2 of the LHC, corresponding to a total integrated luminosity of 137 fb^{-1}. The analysis is performed in the lepton+jets final state, where the fully hadronic decay of the highly boosted top quark is identified with top tagging techniques. For discrimination of signal from background, a deep neural network is used, which is decorrelated from the sum of all object momenta S_T using a "designing decorrelated taggers" (DDT) approach. Distributions of signal and background events of S_T are used to evaluate the expected sensitivity of the search, which yields promising results over the full mass range analyzed.

T 10.6 Mon 17:30 T-H23

Categorizing final states and deriving limits on ALPs coupling to the SM Higgs boson in multiphoton events with ATLAS — Peter Krämer, Kristof Scmieden, Matthias Schott, and •Olivera Vujinović — Johannes Gutenberg University, Mainz, Germany

Some puzzling questions in particle physics, such as the strong CP problem or the discrepancy of the muon magnetic moment could be solved by introducing light scalar or pseudo-scalar axion-like particles (ALPs). Theoretical models allow a wide range of ALP-masses and couplings to SM particles such as photons and the Higgs boson. Therefore, parts of the ALP parameter space could be investigated with collider experiments like the ATLAS experiment at the LHC.

In the ongoing analysis, we search for the SM Higgs boson decaying into a pair of ALPs further decaying into two photons each. Depending on ALP properties such as mass and their coupling to photons, the signal is expected to form different final states, ranging from 2 to 4 photons. Each final state requires a dedicated approach to deriving the desired limits. In this talk it will be discussed which final states are expected, how they can be accessed and categorized.

T 10.7 Mon 17:45 T-H23

Multivariate photon classification for an analysis aiming to derive limits on ALPs coupling to the SM Higgs boson in multiphoton events — •Peter Krämer, Kristof Schmieden, Matthias Schott, and Olivera Vujinovic — Johannes Gutenberg Universität Mainz

Some puzzling questions in particle physics, such as the strong CP problem or the discrepancy of the muons magnetic moment could be solved by introducing light scalar or pseudo-scalar axion like particles (ALPs). Theoretic models allow a wide range of ALP-masses and couplings to SM particles such as the photon and the Higgs boson. Therefore, parts of the ALPs parameter space could be investigated with collider experiments like the ATLAS experiment at the LHC.

In the present analysis we search for SM Higgs bosons decaying to a pair of ALPs further decaying to two photons each. Depending on the mass of the ALP, the kinematic of the decay photons differ a lot. Especially for low ALP masses, the photons experience a Lorentz-boost which results in highly collinear photons. These collinear photons are not recognized by standart ATLAS photon reconstruction algorithms.

In this talk I want to discuss how events with highly collimated photons can be distinguished from $H \to \gamma\gamma$ events using multivariate techniques.

T 10.8 Mon 18:00 T-H23

Search for Axion-Like Particles in Non-Resonant $t\bar{t}$ Production Using Lepton+Jets Final States with the CMS Detector — •Henrik Jabusch[1], Ksenia de Leo[1], Johannes Haller[1], Roman Kogler[2], Artur Lobanov[1], and Matthias Schröder[1] — [1]Institut für Experimentalphysik, Universität Hamburg — [2]DESY, Hamburg

We search for signs of axion-like particles (ALPs) in top quark pair production at the LHC. In high-energy proton-proton collisions, ALPs could arise as off-shell mediators. Employing a model-independent effective field theory approach with ALP couplings to gluons and top quarks, ALPs lead to non-resonant signatures modifying the shape of the invariant mass distribution of the $t\bar{t}$ system.

Our search targets these signatures using 137 fb^{-1} of pp collision data at $\sqrt{s} = 13$ TeV recorded with the CMS detector. Focusing on lepton+jets final states, we utilize a deep neural network for event classification and constrain the ALP-top quark coupling for the first time.

T 10.9 Mon 18:15 T-H23

Searching for ALPs in Light-by-light Scattering in pp Collisions Using AFP Proton Tagging with the ATLAS Detector — Peter Bussey[1], Tomas Chobola[2], Petr Dostal[2], •Hussain Kitagawa[3], Patrick Odagiu[4], Rafal Staszewski[5], André Sopczak[2], Gen Tateno[6], Junichi Tanaka[6], Marek Tasevsky[7], and Koji Terashi[6] — [1]University of Glasgow — [2]CTU in Prague — [3]Okayama University — [4]EPFL Lausanne — [5]IFJ PAN Krakow — [6]ICEPP Tokyo — [7]CAS Prague

The search for an Axion-Like-Particle (ALP) is being performed using about 20 fb^{-1} data recorded with the ATLAS experiment and the ATLAS Forward Proton (AFP) detector in 2017. The two components of the AFP detector are positioned symmetrically at approximately 220 m on either side of the interaction point near the beam pipe and are used to measure the kinematics of surviving protons. The high-mass diphoton spectrum is studied for the search for an ALP mediated by light-by-light scattering. The investigated mass range is between 0.1 TeV and 2 TeV ALP with a typical coupling $g = 1\,\mathrm{TeV}^{-1}$. A blinding strategy is established, and an optimization of the acoplanarity angle is performed. A Functional Decomposition study for the background modeling is applied.

T 11: Gaseous Detectors

Time: Monday 16:15–18:15 Location: T-H24

T 11.1 Mon 16:15 T-H24

Photon Detection by Structured Converter Layers in Micro-Pattern Gaseous Detectors — •Katrin Penski, Otmar Biebel, Stefanie Götz, Vitaliy Havrylenko, Ralf Hertenberger, Christoph Jagfeld, Maximilian Rinnagel, Chrysostomos Valderanis, and Fabian Vogel — LMU München

Micro-Pattern Gaseous Detectors are high-rate capable with excellent spatial and temporal resolution. Developed for the detection of charged particles, the low density in the active gas volume of these detectors exhibit only a poor detection efficiency for electrically neutral particles. For photons the detection via the photoelectric effect can be increased using a solid converter cathode, which is made of high-Z materials. With our novel approach the detection efficiency can be optimized by incorporating several converter plates, which are mounted parallel to the electric drift field in the detector. With an optimized electric field, the created electrons are guided out of the conversion volume. First measurement results are presented and compared to corresponding simulations. This technique allows for higher photon detection efficiencies and more sensitive equipment, which might be applied to modern astrophysics, material research or medical physics.

T 11.2 Mon 16:30 T-H24

Characterisation of a neutron source using MICROMEGAS detectors — •Stefanie Götz, Otmar Biebel, Vitalii Havrylenko, Ralf Hertenberger, Christoph Jagfeld, Katrin Penski, Maximilian Rinnagel, Chrysostomos Valderanis, and Fabian Vogel — LMU München

MICRO MEsh GAseous Structure detectors (Micromegas) are high-rate capable micro-structured gaseous detectors with high spatial resolution due to small-scale readout strip pitch. This study uses the Micromegas detector technology to characterise the intensity profile and the interaction probability of the radiation composition of a 10 GBq Am-Be neutron source. The detector response from the neutron source is evaluated for different source positions relatively to the detector. Pieces of plastic and lead for radiation shielding allow differentiating between neutrons and gamma radiation when placed on the detector, thus disentangling the detector response of photons and neutrons. The interaction rate of the MeV neutrons and gammas is determined using random triggers. From the source characteristics, an interaction rate of 12 MHz is expected in a $40 \times 150\,\mathrm{cm}^2$ Micromegas detector with 1000 strips which corresponds to 6 accidental hits per trigger. The goal is to resolve the beam profile of the neutron source in both horizontal and lateral direction.

T 11.3 Mon 16:45 T-H24

Particle position reconstruction using a segmented GEM foil in a micro-structured gaseous detector — •Christoph Jagfeld, Otmar Biebel, Stefanie Götz, Vitalii Havrylenko, Ralf Hertenberger, Katrin Penski, Maximilian Rinnagel, Chrysostomos Valderanis, and Fabian Vogel — LMU, München

In Micromegas (Micro-MEsh GAseous Structures) detectors, a modern form of micro-pattern gaseous detectors, the signal is usually read out via readout strips on the anode. The signal created at the mesh is usually neglected for the particle position reconstruction. By replacing the mesh with a GEM (Gas Electron Multiplier) foil, which is segmented into 0.5 mm wide readout strips on one side, the particle position can be determined from the GEM foil signal as well. If the strips on the GEM foil are orientated perpendicular to the anode readout strips, a particle position can be reconstructed in two spatial coordinates without adding a second layer of readout strips on the anode. CERN test beam measurement results are presented. These show a good good particle reconstruction efficiency, spatial and angular resolution of this GEM-Micromegas concept.

T 11.4 Mon 17:00 T-H24

Research and Development of an Electret based Gaseous Detector — •Vitalii Havrylenko, Otmar Biebel, Stefanie Götz, Ralf Hertenberger, Christoph Jagfeld, Katrin Penski, Maximilian Rinnagel, Chrysostomos Valderanis, and Fabian Vogel — LMU, München

Gaseous Electron Multiplier (GEM) detectors require a high electric field for the signal amplification. In order to simplify the operation of such a detector system, e.g. for use on X-ray astronomy satellites the GEM foil will be replaced by an electret GEM foil. An electret is a material that conserves an internal polarisation, thus creating an electrostatic potential on a long time scale. This detector does not need an external HV supply. Results of different techniques of electret production are presented. Different bipolar epoxies were hardened in strong electric fields yielding a static polarization which can be observed by the induced voltage. Furthermore, Teflon is charged via corona-discharges. The voltage dependence on time is measured for all electret samples and compared. Potential up to 1000 V stable over multiple days are reported.

T 11.5 Mon 17:15 T-H24

Prototype of a Cherenkov position sensitive Micromegas — •Maximilian Rinnagel, Otmar Biebel, Stefanie Goetz, Christoph Jagfeld, Katrin Penski, Chrysostomos Valderanis, Fabian Vogel, and Ralf Hertenberger — LMU München

etectors utilizing the Cherenkov effect are well established for particle identification of charged particles in detector systems such as LHCb or HADES. In reverse it is possible to determine the momentum of a known particle by measuring the opening angle of the Cherenkov cone in Cherenkov media. Our goal with this 10x10 cm^2 prototype is a proof of principle using cosmic muons. A traversing muon creates around 1500 Cherenkov photons in our 19 mm thick ultra-violet transparent Lithium Fluoride (LiF) crystal (diameter 50 mm; UV optical refractive index 1.5). The conversion to electrons happens in transmission in a photosensitive CsI layer evaporated onto a 5 nm Cr layer, both applied to the bottom of the radiator. High voltage of -300 V, at the Cr layer, guides the ionization and photoelectrons into the drift region of a Micromegas gaseous micro pattern detector. First results utilizing muon tracks reconstructed from reference detectors will be shown. The typical signal shape of this detector as well as the spatial position reconstruction are compared to the Micromegas detector without the LiF Cherenkov radiator.

T 11.6 Mon 17:30 T-H24

Test of ATLAS Micromegas detectors with a ternary gas mixture at the CERN GIF++ facility — •Fabian Vogel, Otmar Biebel, Stefanie Götz, Vitaliy Havrylenko, Ralf Hertenberger, Christoph Jagfeld, Katrin Penski, Maximilian Rinnagel, and Chrysostomos Valderanis — LMU München

The ATLAS collaboration at LHC has chosen the resistive Micromegas technology, along with the small-strip Thin Gap Chambers (sTGC), for the high luminosity upgrade of the first muon station in the high-rapidity region, the New Small Wheel (NSW) project. Four different sizes of Micromegas quadruplets have been constructed at four construction sites in Italy (SM1), Germany (SM2), France (LM1) and CERN/Greece/Russia (LM2). Achieving the requirements for these detectors revealed to be even more challenging than expected. One of the main features being studied is the HV stability of the detectors. Several approaches have been tested in order to enhance the stability, among them the use of different gas mixtures. A ternary Argon-CO_2-iC_4H_{10} mixture has shown to be effective in dumping discharges and dark currents. It allows the operation of the Micromegas detectors at safe working points with high cosmic muon detection efficiency. The presence of Isobutane in the mixture required a set of aging studies, ongoing at the GIF++ radiation facility at CERN, where the expected HL LHC background rate is created by a ^{137}Cs 14 TBq source of 662 keV photons. Preliminary aging results and effectiveness of the ternary mixture will be shown.

T 11.7 Mon 17:45 T-H24

The Influence of Oxygen Defects at Measurements with a MicroMegas Detector Filled with an Ar-CO_2 Gas Mixture — •Burkhard Böhm[1], Deb Sankar Bhattacharya[1,2], Thorben Swirski[1], and Raimund Ströhmer[1] — [1]Universität Würzburg — [2]INFN Trieste

In particle physics, Micro-Pattern Gaseous Detectors (MPGD) find high usage in different experiments like ATLAS, CMS or ALICE. In this study MicroMegas (MM) - a special type of MPGDs - are researched in terms of O_2 contamination. They are well known for their simple single-stage amplification, high and stable gain and excellent spatial and temporal resolutions. These detectors can be contaminated by O_2 from the air and due to the electronegativity of O_2, electrons in the gaseous detector can be captured. Hence, even a low concentration of O_2 has an impact on the detector performance. By precisely controlled inflowing of O_2 inside a resistive MicroMegas chamber, the effect on the gas-gain,mainly due to attachment in the drift region, and the amplification of the number of primary electrons are studied. In parallel to the experimental study numerical investigations were done to estimate the amplification gap from the comparison of the simulated to the measured signal.

T 11.8 Mon 18:00 T-H24

A GridPix detector for IAXO — •Tobias Schiffer, Klaus Desch, Jochen Kaminski, Sebastian Schmidt, and Markus Gruber — Physikalisches Institut der Universität Bonn

In the scope of the search for axions with helioscopes, like the International Axion Observatory (IAXO) and its precursor BabyIAXO, detectors capable of measuring low energy X-rays down to the 200 eV range are necessary. For this purpose the GridPix detector, which was already successfully used at CAST, is an appropriate and constantly evolving solution.

The GridPix is a MicroMegas like readout consisting of a pixelized readout ASIC (Timepix/Timepix3) with a perfectly aligned gas amplification stage on top. Due to the very high granularity this detector is capable of detecting single electrons allowing the measurement of low energy X-rays. To convert these X-rays into electrons a gas volume is built above the readout sealed with a vacuum tight X-ray entrance window.

For the goals of IAXO and BabyIAXO a very low detector background needs to be achieved, therefore only a few radiopure materials are contemplable. Also a good offline separation of signal and background events is to be achieved, here the insights from the CAST detector are used. Further, to get more signal the X-ray entrance window needs to be as transparent as possible for the low energy X-rays. This is achieved with an ultra thin (<200 nm) silicon nitride membrane.

The challenges of the design process and some first results of the detector will be presented.

T 12: Pixel Detectors

Time: Monday 16:15–18:30 Location: T-H25

T 12.1 Mon 16:15 T-H25

ATLAS ITk Pixel Detector Quad Module Building and Testing for the HL-LHC Upgrade — Jörn Grosse-Knetter, Arnulf Quadt, •Yusong Tian, and Hua Ye — II. Physikalisches Institut, Georg-August-Universität Göttingen

In the ATLAS detector upgrade for the High-Luminosity LHC (HL-LHC), the current Inner Detector will be upgraded to an all-silicon Inner Tracker (ITk), to operate under higher occupancy and radiation damage resulting from the higher luminosity. The pixel detector is the inner-most layer of the ITk, shaped like a cylinder with about 0.4m radius and 6m long. It is assembled with barrels and end-cap rings made of single and quad-chip modules. Each module is assembled with a bare module and a printed circuit board (PCB). A quad bare module consists of one sensor bump-bonded to 4 front-end readout chips. RD53A is the name for the front-end readout chip prototype, the name for the final version is ITkPix. The modules are referred to with the name of the front-ends. This talk shows the module assembly and testing results.

T 12.2 Mon 16:30 T-H25

ITk-pixel outer barrel demonstrator — Jörn Grosse-Knetter[1], Susanne Kühn[2], •Silke Möbius[1], Arnulf Quadt[1], Benedikt Vormwald[2], and Hua Ye[1] — [1]II. Physikalisches Institut, Georg-August-Universität Göttingen — [2]CERN

For the upgrade of the LHC to the High-Luminosity-LHC, the ATLAS tracking detector will be replaced with a pure silicon detector, the Inner Tracker (ITk), as the higher luminosity requires radiation hard components that can deal with higher occupancies and radiation. Given the close proximity to the interaction point, the environment is especially challenging for the pixel detector which will comprise quad chip modules for outer barrel layers.

In order to characterize and test ITk-pixel prototype quad modules, up to 40 modules are built and tested for the outer barrel demonstrator. This so-called demonstrator is a larger structure which features some of the final mechanics to test the system functionalities. Systems like an interlock need to be implemented and tested and the modules behaviour before and after being powered in serial needs to be examined to allow for thorough tests.

After having done initial tests with a preliminary version of the demonstrator with older modules, the preparation of the set-up and commissioning of the new demonstrator is currently ongoing.

This talk will give an overview over the current state of the demonstrator, explain the set-up and summarize the potential tests to be performed on the demonstrator.

T 12.3 Mon 16:45 T-H25

Testing of loaded local supports of the ATLAS Inner Tracker — •Wael Alkakhi, Joern Grosse-knetter, and Arnulf Quadt — II. Physikalisches Institut, Georg-August-Universität Göttingen

During the third long shut down (LS3) of the Large Hadron Collider (LHC), a high luminosity upgrade takes place in which the instantaneous luminosity reaches $7.5 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ in Run 4. The current inner detector of the ATLAS experiment is going to be replaced by inner tracker (ITk). ITk is composed of a pixel detector surrounded by a strip detector. The pixel detector consists of 5 layers where the first 2 layers represent the inner pixel detector and the last 3 layers represent the outer barrel and the endcap. The outer barrel consists of 4474 modules. These modules are mounted on loaded local supports of which there are two types : loaded longeron and loaded inclined half ring. Due to the large number of elements used during the assembly and production of the ITk, the ITk production database is used to store and track the information of the ITk components. Moreover a graphical user interface (GUI) is used to ease working with the ITk production database during the production of the ITk outer barrel.

This talk introduces the integration procedure of modules to local supports. Moreover it demonstrates my contribution to the implementation of the loaded local supports in the ITk production database and the GUI developments.

T 12.4 Mon 17:00 T-H25

ATLAS ITKPix Waferprobing — •Mark Standke, Yannick Dieter, Tomasz Hemperek, Florian Hinterkeuser, Fabian Hügging, Hans Krüger, David-Leon Pohl, Marco Vogt, and Jochen Dingfelder — Forschungs- und Technologie-Zentrum Detektorphysik - Kreuzbergweg 26, 53115 Bonn

Wafer-probing is a process, in which each individual chip is tested for its key function parameters on wafer level. For this purpose, Bonn has developed a fast and versatile testing and analysis environment, making large-scale testing for ATLAS-ITkPix possible. ITkPix is the first full-scale 65 nm ATLAS - hybrid pixel-detector readout chip, developed by the RD53 collaboration. ITkPix consists of more than one billion transistors with high triplication ratio in order to cope with high particle and therefore radiation densities at the heart of ATLAS. The chips will be located as close as possible to the interaction point to optimize impact parameter resolution. ITkPix features a single low power, low noise analog front-end to ensure high readout speeds and low detection thresholds. A failure of such chips at the heart of ATLAS is assumed to be hard to correct. Therefore, thorough testing is necessary. This talk will give an overview over the testing environment, while summarizing the latest results and performance of ATLAS's future inner tracker performance driver, ITkPix.

T 12.5 Mon 17:15 T-H25

Bump bond stress tests with ITk-Pixel-style daisy-chain modules through thermal cycling — Jörn Grosse-Knetter, •Steffen Korn, and Arnulf Quadt — II. Physikalisches Institut, Georg-August-Universität Göttingen

For the upgrade of the LHC to the HL-LHC, the Inner Detector will be replaced by the fully silicon-based Inner Tracker Detector (ITk). The pixel detector of the ITk uses hybrid modules where sensor and readout chips are connected by bump bonds. Early ITk module prototypes highlighted these bump bond connections as a possible point of failure in future ITk Pixel modules when exposed to thermally induced stress. In order to investigate this issue, daisy chain modules with realistic bump bond pitch were tested before and during exposure to thermal stress through cycling in a thermal shock chamber using a dedicated in-situ method in Goettingen. The results of these tests using different modules with different assembly options are presented in this talk.

T 12.6 Mon 17:30 T-H25

Pixel front-end masking and DQ monitoring — Marcello Bindi, Jörn Grosse-Knetter, •Andreas Kirchhoff, and Arnulf Quadt — II. Physikalisches Institut, Georg-August-Universität Göttingen, Göttingen, Germany

During Run 2 of the LHC, the ATLAS tracking software masked non-working pixel modules for offline reconstruction. The masking itself is applied if a module does not receive hits. To improve track reconstruction the number of holes should be reduced. Holes are defined as intersections of reconstructed tracks with sensitive detector elements that did not result in a hit. They are estimated by comparing the hits-on-track with the intersected modules. Inactive modules are excluded from the hole definition. As a consequence, a masked module is treated in the track reconstruction as if it received always a hit.

The ATLAS tracking group for Run 3 will increase the granularity of the masking (moving from module to single front-ends) in order to reduce the number of pixel holes and increase the tracking efficiency. Hit maps collected at the end of each run are chosen as input for the front-end masking. Due to the detector geometry the masking for the different front ends needs to be optimised individually. This talk will present the corresponding studies.

The second topic of the talk will be data quality monitoring. While taking data it is extremely crucial to check whether the detector performs as expected to avoid loss in data. Therefore different monitoring software exists. This talk will present the updated software GNAM2 and its current status.

T 12.7 Mon 17:45 T-H25

Data quality monitoring for the ATLAS pixel detector using large radius tracks — Carmen Diez Pardos, Ivor Fleck, •Jan Joachim Hahn, and Iskander Ibragimov — Center for Particle Physics Siegen, Experimentelle Teilchenphysik, Universität Siegen

The ATLAS detector is a general-purpose detector at the Large Hadron Collider (LHC) at CERN. Its Inner Detector (ID), used for reconstruction of tracks of charged particles, consists of four barrel layers and two end-caps of three discs each of the silicon pixel detector, surrounded by the silicon strip detector and the transition radiation tracker. During operation of ATLAS, a small fraction of recorded collision events is reconstructed in real time, providing prompt information on the quality of data being taken. For the upcoming LHC Run 3, the reconstruction of tracks in the ID will include the reconstruction of large radius tracks (LRT). These tracks are of interest for the search of long-lived particles beyond the Standard Model. With respect to the standard tracks, they are reconstructed with relaxed constraints on their starting position. The information from LRTs can be used to create additional histograms for monitoring detector performance during operation of ATLAS. This talk will discuss how this can improve data quality monitoring of the pixel detector.

T 12.8 Mon 18:00 T-H25

Measurement of position resolution of small pixel sensors — •Amala Augusthy[1], Daniel Pitzl[2], Erika Garutti[1], and Jörn Schwandt[1] — [1]Institute für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Deutschland —

[2]Deutsches Elektronen-Synchrotron, Notkestraße 85, 22607 Hamburg, Deutschland

In order to cope with the high radiation environment in the phase 3 upgrade of CMS and ATLAS, pixel detectors with spatial resolution below $1\mu m$ will become necessary. The resolution of pixel sensors can be improved by reducing their pitch. However, the pitch of pixel sensors is limited by the read-out electronics.

To study the intrinsic resolution capabilities, non-irradiated pixels sensors with sizes of $17 \times 150\mu m^2$, $25 \times 100\mu m^2$ and $50 \times 50\mu m^2$ were tested with $5.2GeV$ electron beam at the DESY test beam facility. The $25 \times 100\mu m^2$ and $50 \times 50\mu m^2$ sensors have already been characterized and are being considered for the phase 2 upgrade of the CMS experiment. The aim of this study is to reduce the pitch even further to $17\mu m$ and investigate its performance.

These sensors have a thickness of $285\mu m$ and are bump bonded to a low noise read-out chip ROC4SENS. The spatial resolution as a function of angle of incidence of the particle is extracted from these measurements. In this talk, the results of these measurements will be presented.

T 12.9 Mon 18:15 T-H25

Characterisation of planar pixel sensor for the CMS phase-2 upgrade — •Mohammadtaghi Hajheidari[1], Massimiliano Antonello[1], Finn Feindt[2], Erika Garutti[1], Daniel Pitzl[2], Jörn Schwandt[1], Georg Steinbrück[1], Annika Vauth[1], and Irene Zoi[3] — [1]Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Deutschland — [2]Deutsches Elektronen-Synchrotron, Notkestraße 85, 22607 Hamburg, Deutschland — [3]Fermilab, Batavia, IL, 60510, USA

For the High Luminosity phase of the Large Hadron Collider (HL-LHC), the CMS pixel detector is expected to collect up to 1-MeV neutron equivalent fluence, Φ_{eq}, of $2.3 \times 10^{16}\text{cm}^{-2}$ for integrated luminosity of $3000\,\text{fb}^{-1}$. The pixel detector will be upgraded to withstand this range of fluence.

Planar n-in-p pixel sensors with an active thickness of $150\,\mu$m and a pixel size of $25 \times 100\,\mu m^2$ have been produced by Hamamatsu Photonics (HPK) and FBK. The sensors were bumped bonded to the RD53A readout chip prototype. The sensor-chip modules were irradiated with 23 MeV protons to the equivalent fluence of up to $2.4 \times 10^{16}\,\text{cm}^{-2}$.

The modules were investigated in the DESY II beam test facility after irradiation. The hit efficiency and spatial resolution as a function of the incidence angle of pixel sensors were determined from these measurements. For non-irradiated modules, a single hit resolution of $2\,\mu$m was achieved at the optimal angle. For irradiated modules with highest fluence, the single hit efficiency still reached 98% at bias voltages below 800 V.

T 13: Semiconductor Detectors:Radiation Hardness, new Materials and Concepts

Time: Monday 16:15–18:15 Location: T-H26

T 13.1 Mon 16:15 T-H26

Voltage scans on germanium detectors — •Felix Hagemann for the GeDet-Collaboration — Max-Planck-Institut für Physik, München

Germanium detectors are used in fundamental research to search for neutrinoless double-beta decay or dark matter. In many of these experiments, a perfect understanding of the working principle and characteristics of these detectors is essential.

The electric field inside a germanium detector consists of two main components: one resulting from the potentials applied to the contacts to bias the detector, and one from the ionized impurities in the germanium crystal. While the overall number of ionized impurities can be estimated from Hall measurements on the surface of the detector, the spatial distribution of the impurities inside the germanium crystal is not well known. This results in large uncertainties on the resulting electric field.

One way to probe the impurity density profile is through voltage scans. In voltage scans, the pulses resulting from the same volumes of the detectors are recorded with different bias voltages applied to the detector. This way, the contribution from the bias voltage is varied and the constant contribution from the impurities can be separated and determined. This also requires reliable pulse shape simulation.

In my talk, I will present first data from voltage scans on a p-type segmented point-contact germanium detector and compare them to simulation results obtained from the open-source Julia software package *SolidStateDetectors.jl* to give an estimate of the impurity density profile.

T 13.2 Mon 16:30 T-H26

Eine neue Software zur 3D Simulation von Halbleiterdetektoren - SolidStateDetectors.jl — •Martin Schuster für die GeDet-Kollaboration — Max-Planck Insitut für Physik, München, Deutschland

Halbleiterdetektoren, insbesondere aus Silizium und Germanium, haben schon lange einen festen Platz in zahlreichen Experimenten und Industriefeldern. In der GeDet (Germanium Detektor Entwicklung) Gruppe am Max-Planck Institut für Physik werden Germaniumdetektoren genau untersucht. Eine entscheidende Rolle spielt dabei der Vergleich von in Testständen aufgenommenen und simulierten Daten. In der Gruppe wurde eine neue "Open Source" Software in der jungen Programmiersprache Julia geschrieben, mit der das Verhalten aller auf Dioden basierenden Halbleiterdetektoren simuliert werden kann. Das Paket ermöglicht die schnelle Berechnung der elektrischen Potentiale und Felder und bietet die Möglichkeit der Pulsformsimulation basierend auf der Drift der Ladungsträger. Das Einlesen von GEANT4-generierten Ereignissen ist möglich. In diesem Vortrag werden die Funktionsweise und Möglichkeiten der Software erläutert. Als Beispiel dient ein vierfach segmentierter n-Typ Punktkontakt - Germaniumdetektor.

T 13.3 Mon 16:45 T-H26

Influence of radiation damage on the absorption of near-infrared light in silicon — •Annika Vauth, Robert Klanner, and Jörn Schwandt — Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Deutschland

Radiation damage of silicon sensors is an important area of investitation in high energy physics today. Frequently, red and near-infrared light is used to generate electron-hole pairs to study the charge collection efficiency of radiation-damaged silicon sensors. In order to determine the absolute number of produced charge carriers, the light absorption coefficient, α, has to be known.

To study the change of α due to radiation-induced defects, we have measured the transmission of light with wavelengths between 1-2 μm through silicon samples irradiated to 1 MeV-neutron-equivalent fluences between 0 and 1×10^{17} cm^{-2}.

In this contribution, the results of these measurements will be presented: the contribution of the irradiation to α was found to scale with fluence for the entire fluence range investigated. In the wavelength region around $1.8\,\mu$m, evidence for the production of the radiation-induced divacancy defect V_{2i}^0 with a density approximately proportional to the fluence was found. A decrease of the effective band gap of silicon with irradiation fluence will be shown, up to a reduction of about 60 meV for a fluence of 1×10^{17} cm^{-2}.

T 13.4 Mon 17:00 T-H26

Studies of irradiated ATLASpix3.1 sensors for the LHCb MightyTracker — •Jan Hammerich for the LHCb MightyTracker group-Collaboration — University of Liverpool, Liverpool, United Kingdom

The Mighty Tracker is a proposed upgrade to the downstream tracking system of LHCb for operations at luminosities of up to $1.5 \times 10^{34}\,\text{cm}^{-2}\,\text{s}^{-1}$ starting with the LHC Run 5 data taking period. It foresees the replacement of the most central area of the current scintillating fibre tracker with High Voltage CMOS (HV-CMOS) pixel sensors. HV-CMOS sensors have demonstrated a significant radiation tolerance and good performance making them an ideal choice of technology for the LHCb experiment.

Monolithic Active Pixel Sensors (MAPS) fabricated in HV-CMOS processes provide fast charge collection via drift and allow the implementation of the readout on the same die as the sensitive volume. Due to the use of commercial processes, these sensors can be fabricated at low cost as no hybridisation with bump bonds is required. Since they are not fully depleted, the inactive volume can be thinned away.

A dedicated sensor called the MightyPix is developed for this programme. It is based on the HV-MAPS families MuPix and ATLASpix and tailored to the requirements of LHCb. To demonstrate the feasibility of this technology for the LHCb environment, ATLASpix3.1 sensors have been irradiated. These sensors are studied in terms of time resolution and power dissipation in a temperature controlled environment.

T 13.5 Mon 17:15 T-H26

Full-size passive CMOS sensors for radiation tolerant hybrid pixel detectors — •Yannick Dieter[1], Michael Daas[1], Tomasz Hemperek[1], Fabian Hügging[1], Hans Krüger[1], David-Leon Pohl[1], Tianyang Wang[2], Norbert Wermes[1], Pascal Wolf[1], and Jochen Dingfelder[1] — [1]Physikalisches Institut der Universität Bonn — [2]Zhangjiang Laboratory, China

CMOS process lines are an attractive option for the fabrication of hybrid pixel sensors for large-scale detectors like ATLAS and CMS. Besides the cost-effectiveness and high throughput of commercial CMOS lines, multiple features like poly-silicon layers, metal-insulator-metal capacitors and several metal layers are available to enhance the sensor design.

After an extensive R&D programme with several prototype sensors in 150 nm LFoundry technology, passive CMOS pixel sensors have been manufactured for the first time as full-size sensors compatible with the RD53 readout chips designed for the ATLAS and CMS tracker upgrades.

This presentation will focus on IV-curve and hit-detection efficiency measurements and the characterization of the full-size sensors, before and after irradiation to fluences of $2 \times 10^{15}\,n_{eq}/cm^2$ and $5 \times 10^{15}\,n_{eq}/cm^2$, using a minimum ionising electron beam.

T 13.6 Mon 17:30 T-H26

Electrical characterisation of passive CMOS strip sensors — •Hannah Jansen[1], Jan-Hendrik Arling[3], Marta Baselga[1], Leena Diehl[2], Ingrid Maria Gregor[3,4], Tomasz Hemperek[4], Kevin Kröninger[1], Sven Mägdefessel[2], Ulrich Parzefall[2], Arturo Rodriguez[2], Surabhi Sharma[3], Dennis Sperlich[2], and Jens Weingarten[1] — [1]TU Dortmund University — [2]University of Freiburg — [3]DESY Hamburg — [4]University of Bonn

One of the major limitations of experiments in high energy physics are the production costs of the sensors used. Silicon sensors made with CMOS technology can solve this problem because they are very cost efficient and allow big production possibilities. Therefore, passive CMOS strip sensors with different implant layout types are investigated in this project to determine their suitability for high energy physics experiments as well as in medical applications. In particular, large passive strip sensors produced with CMOS technology are considered. In this talk, the current results of the electrical characterisation of the passive CMOS strip sensors will be presented.

T 13.7 Mon 17:45 T-H26

Total Ionizing Dose effects on CMOS Image Sensor of the ULTRASAT space mission — •Vlad Dumitru Berlea for the ULTRASAT-Collaboration — DESY Zeuthen Platanenallee 6, 15738

ULTRASAT (ULtraviolet TRansient Astronomy SATellite) is a wide-angle space telescope that will perform deep time-resolved surveys in the near ultraviolet spectrum. ULTRASAT is led by the Weizmann Institute of Science (WIS) in Israel and the Israel Space Agency (ISA) and is planned for launch in 2024. The telescope implements a backside-illuminated, stitched pixel detector. The pixel has 4T architecture with a pitch of 9.5 μm and is produced in 180 nm process by Tower Semiconductor.

As part of the space qualification for the sensors, radiation tests are to be performed on both test sensors provided by Tower and the final flight design of the sensor. One of the main contributions to sensor degradation due to radiation for the ULTRASAT mission is Total Ionizing Dose (TID). TID measurements on the test sensors have been performed with Co-60 gamma source at Helmholz Zentrum Berlin (HZB) and CC-60 facilities at CERN, and preliminary results are presented in this talk.

T 13.8 Mon 18:00 T-H26

CVD diamonds for the use in radiation hard particle detectors — Holger Stevens, •Patrick Hölken, and Robert Konradi — Experimentelle Physik 5, TU Dortmund

Chemical-vapor deposition (CVD) diamond sensors have gained more influence in the area of particle detection in recent years. For example, they are used in the beam conditions monitor (BCM) of the LHCb experiment at CERN. The BCM monitors the quality of the particle beam and can abort the beam in flawed conditions, such as insufficient beam focus, to protect the experiment setup from possible radiation damage. The big advantages of CVD diamonds include their radiation hardness and fast response time. Furthermore, the CVD diamonds have a high tissue equivalence, which is why they are theoretically well suited for clinical dosimetry in hospitals.
In order to further investigate the radiation characteristics of the diamonds, measurements of the time behavior are carried out. In addition, a possible spatial resolution of the diamond sensors is of interest. This talk will give an overview about the results of these studies.

T 14: DAQ and Trigger 1

Time: Monday 16:15–18:30 Location: T-H27

T 14.1 Mon 16:15 T-H27

A readout system for the LHCb Beam Condition Monitor based on off-the-shelf FPGA hardware — •Martin Bieker, Holger Stevens, and Dirk Wiedner — Experimentelle Physik 5, TU Dortmund

The LHCb experiment is a single-arm forward spectrometer at the LHC and focuses on measurements in the *b* and *c* quark sector. Due to its unique geometry, featuring a sensitive tracking system located as close as 3.5 mm to the LHC beams, the detector is at risk of damage from adverse beam conditions. For this reason, the particle flux is monitored near the beam pipe by 8 diamond sensors in a circular arrangement at either side of and close to the interaction point.

This so-called Beam Condition Monitor (BCM) successfully protected the LHCb detector during Run I and Run II of the LHC. In preparation for the following Run III, the BCM is overhauled as part of a comprehensive upgrade of the LHCb detector. The development of a new readout system is an important part of the BCM related improvements. This system is responsible for monitoring the BCM data and initiating a beam abort in case adverse beam conditions are detected.

This talk will give an overview of the new readout system and the accompanying firmware developments: A flexible architecture based on commercially sourced FPGA boards is presented and the integration into the existing LHCb DAQ framework is outlined.

T 14.2 Mon 16:30 T-H27

Modular and scalable Timepix3 readout system — Klaus Desch, •Markus Gruber, Tomasz Hemperek, Jochen Kaminski, and Tobias Schiffer — Physikalisches Institut, Universität Bonn, Nußallee 12, 53115 Bonn

With the highly granular pixel ASIC Timepix3 several different detectors can be built by combining it either with a bump bonded sensor, with a photolithographically postprocessed MicroMegas gas amplification stage (InGrid) or with a micro-channel plate (MCP). With these combinations quite different applications like beam telescopes, X-ray detectors for axion search and polarimetry and neutron detectors can be realised.

Based on the basil framework we are developing a Timepix3 readout system which can efficiently adapt these applications that range from single chip to multi-chip designs and from low- to high-rate applications. Furthermore we are implementing a flexible monitoring system that is needed to support a range of data sources depending on the detector. The hardware consists of our own PCB designs and a support of multiple FPGA boards including the Scalable Readout System (SRS) which offers scalability in low to medium rate multi-chip applications.

In this talk I will present the readout and control system and how it scales for the applications. Furthermore, I will show how the modular approach enables several different detector designs and offers the needed functionality like calibration, equalisation, readout and monitoring.

T 14.3 Mon 16:45 T-H27

Upgrade of a cosmic muon teststand for the CMS DT-Project — •Dmitry Eliseev, Thomas Hebbeker, Markus Merschmeyer, and Matej Repik — Physics Institute III A, RWTH Aachen University

The Drift Tube (DT) system is one of the muon detectors of the Compact Muon Solenoid (CMS). The DT system is now upgraded to provide the increased luminosity for CMS Phase II. The upgrade pertains mainly the on-chamber digital readout and the subsequent data chain, which are completely replaced to enable higher acquisition rates and better trigger flexibility. The especially important component of the data chain is the electronics for digital readout of the muon hit data. This is the newly designed On-Board Drift Tube (OBDT) electronics, located directly at the DT chambers. This electronics enables higher data acquisition rates and is radiation tolerant. After production, the OBDT electronics will require numerous verification tests. One of the verification sites will be RWTH Aachen University with its cosmic muon teststand, originally developed during CMS construction. The core part of the muon teststand is a fully functional DT chamber, which is similar to the DT chambers at CMS. For the upcoming verification tests the teststand has undergone a comprehensive upgrade. The upgrade included the complete replacement of the data system as well as the redesign and upgrade of other systems: high- and low- voltage power-supply, gas mixing system. The teststand enables in-situ tests of the newly produced OBDT electronics as well as the verification of the data integrity of the muon-data along the readout chain.

T 14.4 Mon 17:00 T-H27

Calibration of the analogue signal path of the Level-1 Calorimeter Trigger after the ATLAS Phase-I upgrade — •Thomas Junkermann — Kirchhoff-Institut für Physik, Heidelberg

The Phase-I Upgrade of the ATLAS Level-1 Calorimeter Trigger targets a finer granularity of the spatial information of energy depositions when selecting events. To process the higher amounts of data a new digital trigger is installed. Therefore new electronic components get introduced in the on-detector electronics leading up to the trigger. These components effect the old analog trigger system and re-calibration of it is needed as it will be run in Run 3 parallel to the new system. Examples for the effects of the new components on the legacy system are the introduction of time delays to certain signal parts and amplitude losses. The effects are measured and corrected for by re-adjusting the calibration of various components.

T 14.5 Mon 17:15 T-H27

Test beam studies of the new ATLAS MDT front-end electronics in the GIF++ facility at CERN — •Davide Cieri[1], Gregor Eberwein[1], Markus Fras[1], Oliver Kortner[1], Hubert Kroha[1], Chrysostomos Valderanis[2], Elena Voevodina[1], and Bastian Wesely[1] — [1]Max-Planck-Institut für Physik, Munich, Germany — [2]Ludwig-Maximilians-Universität, Munich, Germany

The front-end readout electronics of the ATLAS Monitored Drift Tube (MDT) detector will be replaced for High-Luminosity LHC operations in order to provide a triggerless read-out required by the upgraded first-level muon trigger. The read-out chain of an MDT chamber is composed of several Amplifier/Shaper/Discriminator (ASD) ASICs, capturing the arrival signal at the wires; Time-to-Digital Converter (TDC) ASICs, performing the required time measurements on 24 channels coming from three ASD ASICs, and a Chamber Service Module (CSM), which multiplexes data from up to 18 TDCs and sends the data via two optical fibres to the MDT trigger processor for the further trigger processing and transmission to the data acquisition (DAQ) system. The front-end electronics were designed to cope with a hit rate of 600 kHz/tube, which is twice the maximum expected rate.

Prototypes of the entire MDT front-end electronics were operated on MDT chambers in a muon beam at the GIF++ facility at CERN in 2021 using two small MDT chambers. The electronics were shown to work perfectly under different levels of the photon background irradiation, covering twice the range of the expected background fluxes at the HL-LHC.

T 14.6 Mon 17:30 T-H27

Scan Automated Testing for the ATLAS Pixel Detector — Marcello Bindi, Arnulf Quadt, and •Chris Scheulen — II. Physikalisches Institut, Georg-August Universität Göttingen

The ATLAS Pixel detector data acquisition system (DAQ) is distributed over several different physical components, such as front-end detector modules, read-out drivers, and PCs for operating and calibrating the detector. As a result, time-consuming manual tests are currently required to ensure the correct operation of the entire system after software or firmware changes in any component.

To simplify software validation and free up manpower, a suite of automated tests of the is being developed for deployment in the DAQ software's continuous integration system on GitLab. Fully automated testing is only possible without involvement of the detector modules, whose operation requires some degree of manual supervision. Therefore, emulated detector responses are used for tests of readout-chain components under exclusion of the detector modules themselves.

This talk will give an overview over the first version of the automated calibration testing and validation framework currently deployed for code developments on GitLab. An outlook to further developments of the testing infrastructure will be presented as well.

T 14.7 Mon 17:45 T-H27

GUI framework and configuration database for ATLAS ITk Pixel system tests — Gerhard Brandt, Marvin Geyik, •Jonas Schmeing, and Wolfgang Wagner — Bergische Universität Wuppertal

For the LHC Phase-2 upgrade, a new ITk Pixel detector will be installed in the ATLAS experiment. It will allow for even higher data rates and will be thoroughly tested in the ATLAS ITk Pixel system tests. To operate these tests, a GUI and configuration system is needed. A flexible and scalable GUI framework based on distributed microservices is introduced. Each microservice consists of a frontend GUI, a Python app served by a WSGI server, and a system-level backend. The frontend GUI is a single-page application built with the React JavaScript library. It uses PatternFly, which provides many UI elements as React components. The API for RESTful HTTP communication between the frontend and the Python app is defined via an OpenAPI specification. The Python app is the central part of each microservice. It connects to the microservices backend, such as a database or various DAQ applications that provide a Python binding. With this microservice framework, it is possible to serve specialized applications for different purposes: e.g., an API to access the data acquisition software, a service for configuration of hardware components, and a database to store these configurations. To enable users to access all services from a single web page, all frontend GUIs are compiled into one chassis. The REST and Python interfaces facilitate the maintainability and long-term upgradability of the system.

T 14.8 Mon 18:00 T-H27

The First Layer of the Mu3e Data Acquisition System — •Martin Müller for the Mu3e-Collaboration — Institute for Nuclear Physics, JGU Mainz

The Mu3e experiment will search for the charged lepton flavor violating decay of a positive Muon into two positrons and one electron. The branching ratio of this decay in the Standard Model is predicted to be in the order of 10^{-54} and therefore any observation of such a decay would be a clear sign for new physics. Observing up to 10^8 muon decays per second, the phase I Mu3e detector will produce 100 GB/s of data from monolithic pixel chips, scintillating fibres and scintillating tiles.

The trigger-less data acquisition for the detector consists of multiple layers. Layer 1 is located inside of the Mu3e magnet and is directly connected to the detector readout ASICs with 1.25 Gbit data links. It is built from 112 Frontend-Boards which include two field programmable gate arrays (FPGAs). These FPGAs are responsible for all communication with the different detector ASICs, including data readout, decoding, sorting, synchronisation and also the configuration of the detectors. The talk will discuss the firmware developed for the FPGAs in Layer 1 of the Mu3e DAQ and the interfaces to the other DAQ layers.

T 14.9 Mon 18:15 T-H27

Data Flow in the Mu3e Filter Farm — •Marius Köppel for the Mu3e-Collaboration — Institute for Nuclear Physics, Johannes Gutenberg University, Mainz Germany

The Mu3e experiment at the Paul Scherrer Institute searches for the decay $\mu^+ \rightarrow e^+e^+e^-$. This decay violates charged lepton flavour conservation - any observation would be a clear indication for Physics Beyond the Standard Model. The Mu3e experiment aims for an ultimate sensitivity of one in 10^{16} μ decays. The first phase of the experiment, currently under construction, will reach a branching ratio sensitivity of $2 \cdot 10^{-15}$ by observing 10^8 μ decays per second over a year of data taking. The highly granular detector based on thin high-voltage monolithic active pixel sensors (HV-MAPS) and scintillating timing detectors will produce about 100 GB/s of data at these particle rates.

Since the corresponding data cannot be saved to disk, a trigger-less online readout system is required which is able to sort, align and analyze the data while running. A farm with PCs equipped with powerful graphics processing units (GPUs) will perform the data reduction. The talk presents the ongoing integration of the sub detectors into the Field Programmable Gate Array (FPGA) based readout system, in particular focusing on the data flow inside the FPGAs of the filter farm. It will also show insides of the DAQ system used in the Mu3e Integration Run performed in Spring 2021.

T 15: GRID Computing

Time: Monday 16:15–18:00 Location: T-H28

T 15.1 Mon 16:15 T-H28

Rucio Datamanagement: Expanding the capabilities for dealing with potentially problematic files — •Christoph Ames[1], Günter Duckeck[1], Rodney Walker[1], and Cédric Serfon[2] — [1]Ludwig-Maximillians-Universität, Munich — [2]Brookhaven National Laboratory

Rucio is a software framework that enables the management of large collections of data. Originally developed for the ATLAS experiment at the Large Hadron Collider (LHC), it has been expanded to encompass other scientific experiments, such as CMS and Belle II, whereby data is stored on and transferred between over 100 data centres across the world. Accessing files on these data centres doesn't always function without problems occurring, therefore dedicated services are used to track files that are being accessed or transferred. Files that cause problems are marked as suspicious by the tracking services and have to be handled by another service, the suspicious replica recoverer. The goal of this work is to expand the suspicious replica recoverer by adding more flexibility and nuance when deciding what should be done with a suspicious file. This is achieved by introducing a policy system based on file metadata, which allows each virtual organisation to individually set their own policies.

T 15.2 Mon 16:30 T-H28

Probing a tiered storage for a WLCG Tier-3 center — Michael Böhler, •Dirk Sammel, and Markus Schumacher — Albert-Ludwigs-Universität Freiburg

The storage of large amounts of data is an important topic in the HEP community, especially with the start of the High-Luminosity LHC in the near future. This data has to be available to local users at the institutes, which represent the Tier-3 level of the WLCG infrastucture. An interesting scenario would be a "tiered" Tier-3 system consisting of a combination of cold and warm storage. In such a setup, a parallel file system might serve as the warm storage and in addition, an object storage would be used as cold storage to avoid a too large occupancy of the parallel file system. In this talk, performance tests of a local S3 object store using a typical HEP use case are presented. The results are compared to read access to the local parallel storage and to other ATLAS grid sites within the WLCG.

T 15.3 Mon 16:45 T-H28

Modelling Large Scale Distributed Computing Systems for Identification of Efficient Architectures — •Maximilian Horzela, Manuel Giffels, Artur Gottmann, Günter Quast, and Achim Streit — Karlsruhe Institute of Technology

One approach to overcome the expected gap between available and required resources at future colliders like the High Luminosity Large Hadron Collider (HL-LHC) is to increase the efficiency of existing workflows, for example via caching of frequently used data. However, in complex environments with distributed computing systems and many users like the Worldwide LHC Computing Grid (WLCG), finding a solution is not trivial. Due to the complexity and size of such systems, it is not feasible to deploy several experimental test-beds at large scales.

Simulation of such systems has proved a scalable and versatile approach to identify efficient and practical computing architectures for High Energy Physics (HEP). A prominent example is the Monarc Simulation Framework, which lead to the present structure of the WLCG. However, the discontinuation of the old software and the demand for the ability to simulate recent scenarios including caching solutions requires a revision of suitable software.

In the context of this talk, a modern example for such applications based on the WRENCH and SimGrid simulation packages will be presented. Furthermore, first results obtained by the simulation will be shown.

T 15.4 Mon 17:00 T-H28

Dynamic and transparent provisioning of opportunistic compute resources for HEP — •Ralf Florian von Cube, René Caspart, Max Fischer, Manuel Giffels, Eileen Kühn, Günter Quast, and Matthias Schnepf — Karlsruhe Institute of Technology

The utilization of only temporarily available compute resources (opportunistic resources) not dedicated to HEP becomes more and more important for future HEP experiments. On the one hand, due to the unprecedented need and resulting scarcity of HEP compute resources. On the other hand, due to the desired integration of HPC, Cloud and locally available resources.

To meet the challenges posed by the resulting heterogeneous compute environment, the Karlsruhe Institute of Technology (KIT) developed the COBalD/TARDIS resource manager and an entire ecosystem around an HTCondor overlay batch system to allow for a dynamic, transparent and hassle-free integration of those resources into the World-wide LHC Computing Grid (WLCG) via a single point of entry.

In this contribution we will present the current status of COBalD/TARDIS developments as well as our experience with the integration of various opportunistic resources into the WLCG.

T 15.5 Mon 17:15 T-H28

AUDITOR: An accounting system for opportunistically used resources — Michael Böhler, •Stefan Kroboth, and Markus Schumacher — Albert-Ludwigs-Universität Freiburg

Computing clusters often experience varying workload over time, which may lead to suboptimal utilization of available hardware. Sharing resources between multiple clusters can mitigate this inefficiency. The software COBalD/TARDIS enables the integration of resources in an opportunistic, dynamic, and transparent manner and is successfully operated on various sites for a wide range of scenarios. In such a setup, the question of how to account for computations conducted on shared resources arises.

In this work the prototype of AUDITOR, the *AccoUnting Data handlIng Toolbox for Opportunistic Resources* is presented. At its core it consists of a database and a server which can be interacted with using a REST API. This allows *collectors* to store data relevant for accounting in the database and *plugins* to publish the data on an external platform or perform other actions. The extensible nature of AUDITOR enables handling of various use cases by combining the appropriate *collectors* and *plugins*. An example use case is described, where the fairshare of one batchsystem is transfered to priorities of another based on data collected from COBalD/TARDIS.

T 15.6 Mon 17:30 T-H28

Optimization of performance for HEP ML applications on GPU Clusters — •Tim Voigtländer, René Caspart, Manuel Giffels, Günter Quast, Matthias Schnepf, and Roger Wolf — Karlsruhe Institute of Technology, Karlsruhe, Germany

GPU clusters are gaining increased importance also in particle physics. To use GPUs most efficiently, concepts like multi-processing on a single GPU, multi-GPU usage for suitable applications or the balance between CPU and GPU resources must be considered. In particular, GPU support for applications in Machine Learning has become quite common, and they provide a wide variety of usage scenarios. The GPU performance in relation to CPUs depends on the complexity of the network topology, on the training strategy and other hyperparameters of the problem at hand. To illustrate the possible performance gains, a number of scenarios in neural network training on a shared GPU cluster attached to the TOpAS Tier3 at KIT are discussed.

T 15.7 Mon 17:45 T-H28

Belle II Grid Computing Developments at KIT — •Moritz Bauer, R. Florian von Cube, Torben Ferber, Manuel Giffels, Maximilian Horzela, Günter Quast, and Matthias Schnepf — Karlsruhe Institute of Technology

The Belle II experiment studies B-meson decays with high precision. Therefore, Belle II plans to record 50ab^{-1}. This will result in 50PB of raw data, which has to be reconstructed and analyzed. Furthermore, corresponding simulations have to be produced. To achieve this goal the Belle II collaboration uses several data centers around the world as a Grid, similar to the worldwide LHC Computing Grid.

While LHC experiments usually only analyze data from one data-taking period, Belle II analyses typically use the complete dataset over all periods. The high energy physics computing group at KIT works on several development projects to handle these challenges. In this presentation, we describe the challenges as well as the current development projects. These projects include the transparent integration of opportunistic resources to provide more computing resources and caching to provide additional copies of datasets to improve their accessibility automatically.

T 16: Experimental Methods (general) 1

Time: Monday 16:15–18:30 Location: T-H29

T 16.1 Mon 16:15 T-H29

Measurement of the CMS offline tracking efficiency from the ratio of reconstructed D^* and D^0 mesons — •Yewon Yang and Achim Geiser — DESY, Hamburg, Germany

The efficiency for offline track reconstruction in CMS is measured directly from the data using a novel method. This method is based on taking the ratio of charm mesons reconstructed in the decay chains $D^{*\pm} \to K^{\mp}\pi^{\pm}\pi_s^{\pm}$ and $D^0 \to K^{\mp}\pi^{\pm}$, using the special kinematics of the so-called 'slow pion' π_s from D^* decay. It also requires the treatment of the a priori unknown mixture of prompt (from charm) and non-prompt (from beauty) contributions to the final states. Details of the method are explained and first results for the actual tracking efficiencies are presented.

T 16.2 Mon 16:30 T-H29

Clustering and tracking in dense environments with the ITk — •Nicola de Biase — DESY Hamburg

Dense hadronic environments, encountered in particular in the core of high-p_T jets or hadronic τ decays, present specific challenges for the reconstruction of charged-particle trajectories (tracks) in the ATLAS silicon-pixel tracking detector, as the charge clusters left by different ionising particles in the silicon sensors can merge with a sizeable rate. Tracks competing for the same cluster are penalised for sharing it, leading to a loss in tracking efficiency.

In the current ATLAS Inner Detector, a machine learning algorithm is used for classifying and splitting merged clusters with minimal efficiency losses, leading to better performances of Clustering and Tracking in Dense Environments (CTIDE). The new Inner Tracker (ITk), which will replace the current Inner Detector as part of the ATLAS phase-2 upgrade, will benefit from an improved granularity thanks to its smaller pixel sensor size, which might render such a procedure unnecessary.

In this talk, the expected performance of the ITk in dense environments will be discussed, addressing the question of whether a cluster splitting procedure is necessary.

T 16.3 Mon 16:45 T-H29

Clustering and Tracking in Dense Environment studies of the ATLAS ITk Strip Detector for the HL - LHC Upgrade — Katharina Behr, Nicholas Styles, and •Akhilesh Tayade — DESY, Hamburg, Germany

The new **I**nner **Track**er (ITk) in the ATLAS detector is being built as a part of the HL-LHC upgrade. The High Luminosity upgrade will see an increase in track density, pile up and collisions per bunch crossing. Correspondingly, the current offline tracking reconstruction is being upgraded to handle this. Strongly boosted objects give highly collimated tracks. Reconstructing these tracks can be crucial in discovering new physics. Highly collinear and dense tracks are likely to share pixel or strip clusters for which they are penalized in the track reconstruction. Machine learning techniques are employed for the current ATLAS Pixel Detector to resolve the ambiguities due to cluster merging. In this talk, we discuss whether similar techniques are needed for clusters in the ITk strip detector.

T 16.4 Mon 17:00 T-H29

Jet Vertex Tagger in release 22 — •Abdullah Nayaz[1], Teng Jian Khoo[2], and Cigdem Issever[3] — [1]Humboldt University, Berlin, Germany — [2]Humboldt University, Berlin, Germany — [3]Humboldt University, Berlin, Germany

Pile-up mitigation is a crucial part of many important Particle Physics analysis e.g. HH->4b. The Jet Vertex Tagger (JVT) is a multivariate pile-up suppression variable developed for the ATLAS experiment that combines information from other track based pile-up variables and plays a major role in ATLAS analysis. In this study, as part of the preparation for Run 3 data-taking and analysis, the performance of JVT has been checked for the new release 22 Track to Vertex Association (TTVA) working points using Monte-Carlo simulated dijet data samples. First, the TTVAs that result in a good performance of the JVT have been identified. Furthermore, to increase the JVT performance, a Multilayer Perceptron Neural Network (NN) has been used to retrain the JVT for release 22. The training was done separately for offline and trigger level jets, varying the inputs to the NN to optimise the separation of hard scatter and pile-up jets. Some improvement on the JVT performance was observed after the training process which will be beneficial for Run 3 ATLAS analyses.

T 16.5 Mon 17:15 T-H29

Global χ^2 fitter for Acts — Florian Bernlochner, Jochen Dingfelder, and •Ralf Farkas — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

The reconstruction of trajectories of charged particles is a crucial task for most HEP experiments. The Acts (A Common Tracking Software) aims to be a generic, framework and experiment-independent toolkit for track reconstruction, initially started from the ATLAS tracking software. My talk summarizes the recent development of a global χ^2 fitter for Acts, which complements and validates the existing (Combinatorial) Kálmán Filter.

T 16.6 Mon 17:30 T-H29

Track Reconstruction of the FASER Experiment — Florian Bernlochner, •Tobias Böckh, Jochen Dingfelder, and Markus Prim — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

FASER (ForwArd Search ExpeRiment) is a new, small and inexpensive experiment designed to search for light, weakly interacting particles during Run 3 of the LHC. Such particles may be produced in large quantities in proton-proton collisions, travel for hundreds of meters along the beam axis, and can decay in two charged Standard Model particles. To reach its physics goals, a good hit resolution, and track reconstruction to separate the two closely-spaced, oppositely charged tracks is essential. In this talk, I review the track reconstruction, which is based on the ACTS toolkit. ACTS aims to provide an experiment-independent toolkit for track reconstruction.

T 16.7 Mon 17:45 T-H29

detray - a GPU-friendly tracking geometry description — Andreas Salzburger[1], •Joana Niermann[1,2], Beomki Yeo[3,4], Attila Krasznahorkay[1], and Stan Lai[2] — [1]CERN — [2]II. Physikalisches Institut, Georg-August-Universität Göttingen — [3]Department of Physics, University of California — [4]Lawrence Berkeley National Laboratory

With the next generation high luminosity experiments, the computational demand of particle track reconstruction will increase strongly. A potential way to tackle this is by offloading highly parallelizable tasks to an accelerator device. Existing codebases need to be adapted to e.g. specific host and device memory management and the calling of dedicated compute kernels, while avoiding code duplication as much as possible. Designed to be integrated into ACTS (A Common Tracking Software), which provides efficient algorithms for common tracking tasks, detray is an ongoing R&D effort to formulate the tracking geometry description for heterogeneous hardware. In order to propagate track states through the geometry model, detray follows the navigation design established in ACTS, but presents the geometry in a GPU-friendly way. It makes use of flat container structures without runtime polymorphism, a dedicated memory management scheme provided by the vecmem library, as well as direct indexing to link the geometry data, which together allows to instantiate the geometry model in host and device code. This talk gives an overview of the detray tracking geometry description and highlights the advantages and challenges of this GPU-friendly approach.

T 16.8 Mon 18:00 T-H29

ATLAS Primary Vertexing with ACTS — •Bastian Schlag[1,2], Andreas Salzburger[1], Markus Elsing[1], Christian Schmitt[2], and Volker Büscher[2] — [1]CERN — [2]Johannes Gutenberg-Universität Mainz

The reconstruction of particle trajectories and their associated vertices is a crucial task in the event reconstruction of most high energy physics experiments. In order to maintain or even improve upon the current performance of tracking and vertexing algorithms under the upcoming challenges of increasing energies and ever increasing luminosities in the future, major software upgrades are required.

Based on the well-tested ATLAS tracking and vertexing software, the ACTS (*A Common Tracking Software*) project aims to provide a standalone, modern and experiment-independent toolkit of track- and vertex reconstruction software, specifically designed for parallel code execution. The newly developed ACTS vertexing software suite provides thread-safe, highly performant and state-of-the-art vertex reconstruction tools that have been fully integrated and validated in the ATLAS software framework AthenaMT. Due to its superb physics and CPU performance, the ACTS vertexing software will be used as the default primary vertex reconstruction tool in ATLAS for LHC Run 3. Additionally, an entirely new vertex seed finding algorithm with great physics performance and CPU speed-ups of up to a factor of 100 in high pile-up environments has been developed and implemented in ACTS. This talk presents an overview of the ACTS vertexing software suite, its performance in ATLAS as well as latest developments.

T 16.9 Mon 18:15 T-H29

Electron reconstruction and identification with the ATLAS detector — •Asma Hadef and Lucia Masetti — Johannes Gutenberg Universität, Mainz, Germany

Electrons are important objects both for the search for new physics and for precision measurements. In the ATLAS detector, electrons in the central detector region are triggered by and reconstructed from energy deposits in the electromagnetic (EM) calorimeter that are matched to a track in the inner detector. Electrons are distinguished from other particles using identification (ID) criteria with different levels of background rejection and signal efficiency. The electron ID used in ATLAS for Run 2 is based on a likelihood discrimination to separate isolated electron candidates from candidates originating from photon conversions, hadron misidentification and heavy flavor decays. The performance of the electron reconstruction and ID algorithms is evaluated by measuring efficiencies using tag-and-probe techniques with large statistics samples of isolated electrons from $Z \to ee$ and $J/\psi \to ee$ resonance decays. These measurements were performed with pp collisions data at $\sqrt{s}$ =13 TeV in 2015-2018 corresponding to an integrated luminosity of 139 fb^{-1} and studied as a function of the electron's transverse momentum, pseudorapidity and number of primary vertices. Furthermore, in order to achieve reliable physics results, the simulated samples need to be corrected to reproduce the measured data efficiencies as closely as possible. For this reason, the efficiencies are estimated both in data and in simulation. The scale factors (data to MC efficiency ratios) are then estimated and provided to all physics analyses involving electrons.

T 17: Gamma Astronomy 1

Time: Monday 16:15–18:20 Location: T-H30

Group Report T 17.1 Mon 16:15 T-H30

Status and First Results of the CTA Large-Sized Telescope — •Martin Will for the CTA-Collaboration — Max-Planck-Institut für Physik, München

The prototype of the Large-Sized Telescope (LST), intended to become part of the Northern site of the Cherenkov Telescope Array (CTA) in the Canarian island of La Palma, is currently finishing its commissioning phase and started taking engineering data runs. With its reflective surface of 23 meter diameter, the LSTs are optimized to detect gamma-rays in the energy range between 20 and 200 GeV. In this presentation, some preliminary physics results, the performance of the prototype, and the plans to construct more LSTs as part of CTA will be shown.

T 17.2 Mon 16:35 T-H30

Muons as a tool for background rejection in Imaging Atmospheric Cherenkov Telescope arrays — •Laura Olivera-Nieto[1], Alison Mitchell[2,3], Konrad Bernlöhr[1], and Jim Hinton[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Department of Physics, ETH Zurich, Zurich, Switzerland — [3]Erlangen Centre for Astroparticle Physics, Erlangen, Germany

The presence of muons in air-showers initiated by cosmic ray protons and nuclei is well established as a powerful tool to separate such showers from those initiated by gamma rays. However, so far this approach has been fully exploited only for ground level particle detecting arrays. We explore the feasibility of using Cherenkov light from muons as a background rejection tool for imaging atmospheric Cherenkov telescope arrays at the highest energies. We adopt an analytical model of the Cherenkov light from individual muons to allow rapid simulation of a large number of showers in a hybrid mode. This allows us to explore the very high background rejection power regime at acceptable cost in terms of computing time. We show that for very large ($\gtrsim$20 m mirror diameter) telescopes, efficient identification of muon light can potentially lead to background rejection levels up to 10^{-5} whilst retaining high efficiency for gamma rays. While many challenges remain in the effective exploitation of the muon Cherenkov light in the data analysis for imaging Cherenkov telescope arrays, our study indicates that for arrays containing at least one large telescope, this is a very worthwhile endeavor.

T 17.3 Mon 16:50 T-H30

Adjusting Monte Carlo Simulations for the Cherenkov Telescope Array's Large-Sized Telescope Prototype — •Lukas Nickel and Maximilian Nöthe for the CTA LST Project — Astroparticle Physics, WG Elsässer, TU Dortmund University, Germany

The lowest energy range of the Cherenkov Telescope Array, which is going to be the next-generation very-high energy ($\geq 20\,\mathrm{GeV}$) gamma-ray observatory, will be covered by the Large-Sized Telescopes (LSTs). The prototype of the LST was inaugurated in October 2018 on the Canary Island of La Palma and has since performed observations of bright gamma-ray sources as part of the commissioning process.

One area that needs special care for any analysis regards potential differences between Monte Carlo simulations and observed data. In this talk current approaches to adjust existing simulations for different observational conditions will be presented.

T 17.4 Mon 17:05 T-H30

Data Volume Reduction for the Cherenkov Telescope Array's Large-Sized Telescope Prototype — •Jonas Hackfeld for the CTA-Collaboration — Institute for theoretical physics IV, Ruhr-University Bochum, Germany

The prototype of the Large-Sized Telescope (LST) of the Cherenkov Telescope Array (CTA), which is going to be the next-generation very-high energy ($> 20\,\mathrm{GeV}$) gamma-ray observatory, was inaugurated in October 2018 and has already observed several bright gamma-ray sources during its commissioning phase. For the next years, in addition to 3 more LSTs, several Medium-Sized Telescopes (MST) are planned, which together will equip the northern site of the CTA Observatory. Due to the locally limited data transfer rates and the technical and economic effort to store data quantities of ~ 100 PByte/year permanently over a planned duration of ~ 30 years, a volume reduction for low level data is inevitable. In addition to lossless compression methods for volume reduction, there are lossy methods such as pixel selection. In this process, the pixels with signal are isolated from the night-sky background ones, so that the physics results are impacted as minimally as possible during subsequent event reconstruction. In this talk, pixel selection algorithms and their impact on higher level data analysis will be presented.

This project is funded via BMBF Verbundforschung, Project 05A20PC1

T 17.5 Mon 17:20 T-H30

Background Estimation: Towards an Analysis of MAGIC Data Using Gammapy — •Simone Mender and Lena Linhoff for the MAGIC-Collaboration — Astroparticle Physics WG Elsässer, TU Dortmund University, Germany

The Python package Gammapy is mainly developed for the high-level analysis of gamma-ray data of the future Cherenkov Telescope Array. As it can also be used to analyze data from existing imaging air Cherenkov telescopes, it is reasonable to perform the high-level analysis of MAGIC data with Gammapy and compare the results with existing analyses. Gammapy requires event-based data combined with the corresponding instrument response functions. In order to process these so-called DL3 data for MAGIC, the new database-based framework AutoMAGIC is developed. With AutoMAGIC it is possible to create DL3 data in an automated and reproducible way.

So far, the MAGIC DL3 data does not include background models, which are needed for the creation of skymaps. In this talk, the dependence of the background on parameters like the azimuth and zenith angle of the pointing position will be presented. Using the exclusion region method, background models are built from DL3 data. Using these background models, the first preliminary skymaps of MAGIC data created with Gammapy will be shown.

T 17.6 Mon 17:35 T-H30

Automatized Analysis of MAGIC Sum-Trigger-II Data — •Jan Lukas Schubert and Lena Linhoff for the MAGIC-Collaboration — Astroparticle Physics WG Elsässer, TU Dortmund University, Germany

The MAGIC telescopes are a stereoscopic system of Imaging Air Cherenkov Telescopes. They are used for the detection of gamma rays in the GeV to TeV range. With the Sum-Trigger-II, low-energy data with a threshold as low as 25 GeV can be recorded. This data requires a dedicated analysis adapted to the low energies. Since the analysis structure is complex, it is reasonable to automatize the analysis in order to save time for an analyzer and to deliver entirely reproducible results. The automatization of the analysis of Sum-Trigger-II data was implemented in the autoMAGIC project which aims to automatize the entire MAGIC analysis chain.

For testing the performance, currently an analysis of the Crab pulsar is performed based on the autoMAGIC output and compared to previous analyses.

In the future, the automatization of the analysis of Sum-Trigger-II data could be used for further optimizations of the low-energy analysis as well as for comparisons of low-energy data from MAGIC and the CTA-LST1.

T 17.7 Mon 17:50 T-H30

Characterization of the performance of the MAGIC LIDAR — •Felix Schmuckermaier for the MAGIC-Collaboration — Max-Planck-Institut für Physik — TU München

The Major Atmospheric Gamma-ray Imaging Cherenkov (MAGIC) telescopes are a system of two Imaging Atmospheric Cherenkov Telescopes (IACTs). IACTs make calorimetric use of the Earth's atmosphere, which allows them to reach large effective areas, but also makes them strongly dependent on the quality of the atmosphere at the time of the observations. Suboptimal conditions can then lead to a wrong reconstruction of the gamma-ray data. In order to mitigate this problem, the MPP group built and has been operating a single wavelength elastic LIDAR (LIght Detection And Ranging) system to perform real time ranged-resolved measurements of the atmospheric transmission. This information is then used to quantify the quality of the telescope data, as well as to correct the data taken under suboptimal atmospheric conditions. In this talk, I will present the first detailed characterization of the correction capabilities of the LIDAR system. The results describe the impact of the LIDAR corrections for a variety of atmospheric and observational conditions, and therefore contribute to a better understanding of the telescope's performance and related systematic uncertainties.

T 17.8 Mon 18:05 T-H30

Combined analysis pipeline for joint observations with MAGIC and CTA LST-1 — •Giorgio Pirola[1], Yoshiki Ohtani[2], Alessio Berti[1], Davide Depaoli[3], Federico Di Pierro[3], David Green[1], Lea Heckmann[1], Moritz Hütten[1], Ruben López-Coto[4], Abelardo Moralejo[5], Daniel Morcuende[6], Marcel Strzys[2], Yusuke Suda[7], Ievgen Vovk[2], and Martin Will[1] for the CTA-Collaboration — [1]Max Planck Institute for Physics, München, Germany — [2]ICRR, the University of Tokyo, Japan — [3]INFN Sezione di Torino, Italy — [4]INFN Sezione di Padova, Italy — [5]IFAE, Barcelona, Spain — [6]Universidad Complutense de Madrid, Spain — [7]Hiroshima University, Japan

The performance achievable with Imaging Atmospheric Cherenkov Technique is remarkably improved by using multiple telescopes. Currently, in La Palma (Canary Islands), there are three operative Cherenkov telescopes: the two MAGIC telescopes and the prototype Large-Sized Telescope (LST-1), intended for the future northern site of the Cherenkov Telescope Array (CTA), the next generation Very-High Energy gamma-ray observatory. The data acquired during nights of simultaneous observation of the same target have been used to develop and test an algorithm for the offline search of coincident events. Recently, this algorithm was implemented for the development of the combined analysis pipeline: an analysis chain meant to perform the 3-telescope event reconstruction. The talk aims to present the current status of the pipeline and to give an insight into the possible results achievable with the 3-telescope system.

T 18: Neutrino Astronomy 1

Time: Monday 16:15–18:30 Location: T-H31

T 18.1 Mon 16:15 T-H31

Follow-up of high-energy neutrino events in IceCube — •Martina Karl for the IceCube-Collaboration — Max Planck Institute for Physics, Munich, Germany — Technical University of Munich, Department of Physics, Garching, Germany

We investigate the arrival direction of the most energetic track-like neutrino events in IceCube. These high-energy events allow for a good pointing back to their origin direction and have a high probability to be of astrophysical origin. Roughly 10 of these track-like high-energy neutrino events are detected per year. With these events acting as a source catalog, we present a search for cosmic neutrino emission on 11 years of IceCube neutrino-induced muon data. We explore the hypotheses of steady and transient neutrino emission, and present methods to find neutrino flares.

T 18.2 Mon 16:30 T-H31

High-Energy Neutrinos From Accretion Flares — •Jannis Necker for the IceCube-Collaboration — DESY, Zeuthen, Deutschland

The past two decades have seen a revolution in astronomy as for the first time it became possible to gain information about astrophysical processes not only from (low energy) photons but also from other messengers such as gravitational waves and neutrinos. The IceCube observatory is a cubic kilometre neutrino detector array in the antarctic ice, looking for astrophysical, high-energy neutrinos. The collected data reveal a diffuse flux of these neutrinos over the whole sky, indicating an extragalactic origin. Recent observations suggest a contribution to this diffuse flux from accretion flares, radiation outbursts from Super-Massive Black Holes that accrete at an enhanced rate. In this contribution I will present results from a stacking analysis looking for IceCube neutrinos from these accretion flares.

T 18.3 Mon 16:45 T-H31

A study to detect neutrino signals from AGN using machine-learning methods for source classification — •Sebastian

Schindler for the IceCube-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), University Erlangen-Nürnberg, Germany

The IceCube Neutrino Observatory is currently the world's largest high-energy neutrino detector. After the initial detection of a diffuse astrophysical neutrino flux in 2013, one of the main goals has been to associate parts of this flux with specific source classes. A few tentative "hot spots" at the three-sigma level have been found and associated with certain classes of Active Galactic Nuclei (AGN), among them blazars and Seyfert galaxies. The underlying physical mechanisms of neutrino production, however, remain poorly understood. One problem for neutrino source searches comes from the use of historically-driven class definitions of AGN, which are based on specific spectral properties that are not necessarily optimal for the selection of potential neutrino sources.

This talk will motivate a study that aims to address this problem in two stages. The first stage will use multi-wavelength data to define a source selection using modern machine-learning approaches in a way that emphasizes intrinsic physical properties and mostly disregards the general AGN classification. This will allow us to identify potential neutrino sources similar in physical properties to those associated with the currently detected "hot spots". The second part will perform a statistical analysis in the form of a correlation analysis, for example a stacking search, using these previously defined source selections.

T 18.4 Mon 17:00 T-H31

Blazar stacking using new and improved neutrino point-source analysis method — •Tomas Kontrimas, Martina Karl, and Chiara Bellenghi for the IceCube-Collaboration — Physik-department, Technische Universität München, D-85748 Garching, Germany

The IceCube Neutrino Observatory has experienced remarkable success in the field of neutrino astronomy since its completion. One of the main goals is to identify sources of the diffuse astrophysical high-energy neutrino flux. In 2018, IceCube found evidence for a correlation between high-energy neutrinos and the blazar TXS 0506+056. Blazars, one of the most powerful objects in the universe, are among the most promising source candidates of high-energy neutrinos. We present a new method improving the accuracy of the likelihood function, including enhanced neutrino reconstruction and data calibration. Furthermore, we discuss a correlation study between IceCube high-energy neutrinos and different classes of blazars.

T 18.5 Mon 17:15 T-H31

Neutrino source searches with DNN based Cascade Dataset in IceCube — •Mirco Hünnefeld for the IceCube-Collaboration — Astroparticle Physics WG Rhode, TU Dortmund University, Germany

IceCube has discovered a flux of astrophysical neutrinos and presented evidence for one neutrino source, a flaring blazar known as TXS 0506+056. However, the sources responsible for the majority of the astrophysical neutrino flux remain elusive. While charged-current muon-neutrino datasets (track events) are predominantly used for source searches due to their superior pointing resolution, cascade events (neutral-current interactions of all neutrino flavors and charged-current interactions of electron- and tau-neutrinos) allow to lower the energy threshold in the southern sky for IceCube. In this contribution, searches for neutrino sources are presented utilizing an improved cascade dataset that builds upon recent advances in deep learning based reconstruction methods. The resulting dataset improves IceCube's sensitivity in the southern neutrino sky and is thus particularly promising for the identification of neutrino production from the galactic plane.

T 18.6 Mon 17:30 T-H31

Constraining populations of astrophysical neutrino sources with IceCube — •Chiara Bellenghi and Kristian Tchiorniy for the IceCube-Collaboration — Technische Universität München, Physik-Department, James-Franck-Str. 1, 85748 Garching

The discovery of a diffuse flux of high-energy astrophysical neutrinos in 2013 by the IceCube neutrino observatory has triggered a vast effort to identify the mostly unknown sources of this signal. We present an analysis optimized for identifying an excess of astrophysical neutrino clusterings produced by a population of sub-threshold point sources. We aim at testing the hypothesis of time-integrated emission in the Northern Hemisphere using 9 years of IceCube data. We present here the methods and the potential of the analysis on constraining the neutrino flux contribution from populations of neutrino point sources.

T 18.7 Mon 17:45 T-H31

Targeting luminous optical transients in the search for high-energy neutrinos — •Massimiliano Lincetto for the IceCube-Collaboration — Astronomisches Institut, Ruhr-Universität Bochum, Bochum, Germany

Years after the discovery of astrophysical neutrinos by the IceCube Neutrino Observatory, the dominant sources of the measured flux are still to be determined. Despite existing evidence in favour of blazars, multi-messenger considerations suggest the need of sources that do not produce high-energy gamma rays. Recent observations, following the detection of a high-energy neutrino in coincidence with a tidal disruption event, point to accreting black holes as promising candidate sources. With the rise of wide-field optical surveys such as the Zwicky Transient Facility, an unprecedented amount of optical transients is being observed on a regular basis. Among these, superluminous supernovae (SLSNe) stand out as the most luminous class. The power source behind such extreme phenomena is still unclear: magnetars, black hole accretion or CSM interaction have been proposed to explain their increased luminosity. In this contribution, the prospects for targeting SLSNe in a search for high energy neutrinos with IceCube data are presented, giving an overview of the candidate event catalogue and the proposed analysis methods.

T 18.8 Mon 18:00 T-H31

A Combined Analysis of IceCube's High Energy Muon Tracks and Cascades Neutrino Data — •Erik Ganster[1], Markus Ackermann[2], Jakob Böttcher[1], Philipp Fürst[1], Jonas Hellrung[1], Richard Naab[2], Georg Schwefer[1], Roman Suveyzdis[1], and Christopher Wiebusch[1] for the IceCube-Collaboration — [1]Physics Institute III B, RWTH Aachen University, Germany — [2]DESY, Zeuthen, Germany

The IceCube Neutrino Observatory is observing a diffuse flux of high-energy astrophysical neutrinos in multiple detection channels. We combine two of these channels, through-going muon tracks and contained cascades, in a single analysis that employs a consistent treatment of signal and background as well as systematic uncertainties in a global fit. Then, the complementary information from the two channels reduces the overall uncertainties in signal and background. This improves our understanding of the astrophysical neutrino flux properties: measuring the energy spectrum and testing the flux composition. We will describe the method of this global fit and present first results from 10 years of IceCube neutrino data.

T 18.9 Mon 18:15 T-H31

Sensitivity of IceCube-Gen2 for the identification of high-energy tau neutrinos and for the measurement of the flavour composition — •Neha Lad[1], Maximillian Meier[2], and Markus Ackermann[1] for the IceCube-Collaboration — [1]DESY, Zeuthen, Germany — [2]Dept. of Physics and Institute for Global Prominent Research, Chiba University, Japan

The IceCube neutrino observatory at the South Pole has disfavoured the absence of an astrophysical tau-neutrino flux at the 2.8σ level. IceCube-Gen2 is the planned extension of current IceCube detector, which will be about 8 times bigger than the current instrumented volume. In this work, we study the sensitivity of IceCube-Gen2 to the astrophysical flavour composition and investigate it's tau neutrino identification capabilities. We apply the IceCube analysis on a Gen2 dataset that mimics the High Energy Starting Event classification. Reconstructions are performed using sensors that have 3 times higher quantum efficiency and isotropic angular acceptance compared to the current IceCube optical modules. We present results of this sensitivity study.

T 19: Cosmic Ray 1

Time: Monday 16:15–18:20 Location: T-H32

Group Report T 19.1 Mon 16:15 T-H32

The Pierre Auger Observatory – Status, Results, Prospects — •Philip Ruehl for the Pierre Auger-Collaboration — Center for Particle Physics Siegen, Experimental Astroparticle Physics, University of Siegen

With an instrumented area of about 3000 km^2, the Pierre Auger Observatory is the world's largest experiment for measuring cosmic particles. Its surface detector (SD) array is comprised of 1660 water Cherenkov detectors with a next-neighbor spacing of 1.5 km. The atmosphere above the SD is monitored by 27 fluorescence telescopes.

Precision measurements of the cosmic-ray energy spectrum have recently been extended down to 10^{17} eV using the SD-750 low-energy enhancement of the SD array, showing a gradual transition of the spectral index just above the "knee". A first measurement of the fluctuations in the muon content of air showers at ultra-high energies can be used to constrain hadronic interaction models trying to explain the observed muon deficit in air shower simulations. Recent advancements in the application of deep neural networks to Auger data enabled the successful reconstruction of $X_{\max}$ from SD data and an extraction of the muon component of simulated SD signal traces. The construction of the AugerPrime upgrade together with the AMIGA enhancement is in progress and will further enhance the mass discrimination power of the Observatory with additional scintillation and radio detector units in the SD array.

The Pierre Auger project is supported by BMBF Verbundforschung Astroteilchenphysik.

T 19.2 Mon 16:35 T-H32

Analysis of laser shots of the Aeolus satellite in the Pierre Auger Observatory — •Felix Knapp for the Pierre Auger-Collaboration — Karlsruher Institut für Technologie

The Pierre Auger Observatory is a large-scale facility for the investigation of ultra-high-energy cosmic rays. It uses a combination of surface detectors and fluorescence telescopes to measure extensive air showers initiated by cosmic-ray particles. Aeolus is an ESA-operated satellite with the mission of conducting global wind profile measurements. To this end, a UV-lidar is employed which emits laser beams towards Earth. When passing over the Pierre Auger Observatory, light that scatters off the laser beam in the atmosphere is detected by the Fluorescence Detector of the Observatory. This allows for a reconstruction of the laser tracks from the Fluorescence Detector data for several overpasses each year. These laser tracks provide a unique opportunity for analyses of the atmosphere above the Observatory.

In this presentation, we will explain the process of reconstructing laser tracks from data taken by the fluorescence telescopes and give an overview of the possible application for aerosol measurements. Furthermore, some results of the laser reconstruction are shown, including the most recent overpasses under a special orbital configuration of the satellite.

T 19.3 Mon 16:50 T-H32

A method to determine baselines of time traces at the Pierre Auger Observatory — •Tobias Schulz, David Schmidt, Darko Veberič, and Markus Roth for the Pierre Auger-Collaboration — Karlsruhe Institute of Technology, Institute for Astroparticle Physics, Karlsruhe, Germany

The calibration and identification of detector signals is crucial for minimizing systematic uncertainties in measurements. A constant offset, called the baseline, which is generated by the electronics, has to be determined to properly estimate the size of the signals. At the Pierre Auger Observatory, two detector types, namely Water Cherenkov and Surface Scintillation Detectors, are used to measure the lateral distribution of extensive air showers at the ground. To determine the signal produced by the particles that enter the detectors, photomultiplier tubes (PMTs) are used to collect the emitted Cherenkov or scintillation light. The PMTs have one low gain channel and one amplified high gain channel. The analog pulses are read out and sampled with a flash analog to digital converter in a FADC time trace.

After a signal, the output of the PMTs is reduced by an undershoot, resulting in a lowered baseline, that recovers after a certain time period. Accidental muons or late air shower components can result in additional signal in the traces, which complicate the estimation of the baseline. Here, we present a method to estimate the baseline, that is robust to signal contributions in the trace and accounts for undershoot of the PMT.

T 19.4 Mon 17:05 T-H32

Combined analysis of the ultrahigh-energy cosmic-ray mass composition and hadronic interaction cross-sections — •Olena Tkachenko for the Pierre Auger-Collaboration — Karlsruhe Institute of Technology, Karlsruhe, Germany

Studies of the cosmic-ray mass composition and hadronic interaction properties can improve our understanding of the origin and nature of the ultrahigh-energy cosmic rays. However, neither the mass composition nor the interaction cross sections are well measured at ultrahigh energies and normally the standard analyses require certain assumptions on either of these quantities to estimate the other one.

In this talk, we present a method for the independent and simultaneous estimation of the cosmic-ray composition fractions and proton-proton interaction cross-sections. We perform a standard mass composition fit using the measured distributions of the shower maximum of air showers ($X_{\max}$) while varying at the same time the interaction cross-sections and thus getting the best-fit combination of the estimated quantities without making any underlying assumptions on either of them. For this purpose, we modify the proton-proton interactions and the corresponding nucleus-nucleus cross-sections are then rescaled via the Glauber theory. We test the performance of this method and its sensitivity for the different composition and cross-section scenarios and compare the outcomes to the standard approach. We also study the effects of the $X_{\max}$ range selection and $X_{\max}$ scale uncertainty on the fit. Finally, we apply the method to data collected at the Pierre Auger Observatory and discuss the results.

T 19.5 Mon 17:20 T-H32

Measurement of the Energy Spectrum of UHECRs with the Fluorescence Detector of the Pierre Auger Observatory — •Kathrin Bismark for the Pierre Auger-Collaboration — Karlsruher Institut für Technologie, Karlsruhe, Germany

The origin of ultrahigh-energy cosmic-rays (UHECRs) is one of the unsolved mysteries of modern-day astrophysics. The flux of UHECRs at Earth provides an important constraint on the luminosity density of their sources and the features in the UHECR energy spectrum shed light on the properties of astrophysical accelerators and on the propagation of cosmic rays through extragalactic photon fields.

Combining the measurements of the surface (SD) and fluorescence detector (FD) of the Pierre Auger Observatory allows us to determine a high resolution hybrid energy spectrum. Due to the partially redundant measurement of air showers with FD and SD, most event selection criteria and environmental influences on detection capabilities and reconstruction parameters can be investigated using measured data instead of simulations.

This presentation will focus in particular on the condition-independent visibility range of the FD, the so-called fiducial distance, given by the trigger efficiency of the FD. This trigger efficiency can be measured by determining the conditional probability to trigger a fluorescence telescope given an air shower detected by SD. The results of this study are compared to predictions from detector simulations and their impact on improvement of the precision of the measured spectrum will be discussed.

T 19.6 Mon 17:35 T-H32

Effects of magnetic fields on anisotropies in the arrival direction of ultra-high-energy cosmic rays — •Luca Deval, Ralph Engel, Thomas Fitoussi, and Michael Unger — Karlsruhe Institute of Technology, Institut für Kernphysik, Karlsruhe, Germany

The source of ultra-high-energy cosmic rays (UHECRs) is still an open question in astrophysics. The latest analysis of the dataset from the Pierre Auger Observatory revealed presence of anisotropy in the arrival direction of UHECRs which is an indication of the signal contribution of nearby sources. A maximum likelihood analysis found a statistical significance of 4σ for the correlation of the measured arrival directions with a sample of nearby starburst galaxies (SBG). Although, the dependence of the galactic magnetic field (GMF), which is expected to have a key role in the arrival direction of charged particles, has not been considered.

In this work we present a study of the effects of the GMF on the arrival directions of particles related to different source populations, namely SBG and active galactic nuclei. We assume an injected cosmic ray spectrum with a mixed composition and a maximum rigidity. The extragalactic propagation is simulated with CRPropa3 while the deflections of cosmic rays in the Galaxy are calculated assuming the GMF model of Jansson&Farrar (2012). The obtained results show that it is possible to recover scenarios which are compatible with the results obtained by the Pierre Auger Collaboration although the signal fraction related to the source contribution has to be increased. Moreover no contribution of the extragalactic magnetic field is necessary.

T 19.7 Mon 17:50 T-H32

Measuring the muon content of inclined air showers using the radio and particle detector of the Pierre Auger Observatory* — •Marvin Gottowik for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstraße 20, 42119 Wuppertal

A first measurement of the muon content of an air shower using hybrid radio and particle detection is presented. For inclined air showers with zenith angles above 60 °, the water Cherenkov detector (WCD) of the Pierre Auger Observatory performs an almost pure measurement of the muonic component, whereas the Auger Engineering Radio Array (AERA) reconstructs the electromagnetic energy independently using the radio emission of the air shower. The analysis of more than 6 years of AERA data shows a deficit of muons predicted by all current-generation hadronic interaction models for energies between 4 EeV and 20 EeV. This deficit, already observed with the Auger Fluorescence Detector, is now confirmed using for the first time radio data. The analysis is limited by low statistics due to the small area of AERA and the high energy threshold originating from the WCD reconstruction. With the AugerPrime Radio Detector currently being deployed, this analysis can be extended to the highest energies to allow for in-depth tests of hadronic interaction models with large statistics.

** Gefördert durch die BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A20PX1).*

T 19.8 Mon 18:05 T-H32

Optimization of Radio Reconstruction for Inclined Air Showers with AERA at the Pierre Auger Observatory* — •Jelena Petereit for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstraße 20, Wuppertal, Germany

The Pierre Auger Observatory is the world's largest cosmic ray observatory. Its Auger Engineering Radio Array (AERA) consists of more than 150 antenna stations that cover an area of about 17 km^2 and is used to detect radio signals emitted by extensive air showers. These measurements are used to reconstruct properties of the primary cosmic rays inducing the air showers.

This talk describes the improvements that have been made on the AERA analysis with the Auger reconstruction framework. Using CoREAS simulations for measured event geometries, noise extracted from data can be added to a simulated pure signal. Various parameters for identifying noise dominated stations for the rejection in the geometry reconstruction, such as the time difference between the pure signal and the signal with noise, are examined and modified in order to improve the event reconstruction.

**Gefördert durch die BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A20PX1)*

T 20: Neutrino Physics without Accelerators 1

Time: Monday 16:15–18:40 Location: T-H33

Group Report T 20.1 Mon 16:15 T-H33

JUNO physics potential and status — •Alexandre Göttel for the JUNO-Collaboration — Forschungszentrum Jülich GmbH, Nuclear Physics Institute IKP-2, Jülich, Germany — III. Physikalisches Institut B, RWTH Aachen University, Germany

The Jiangmen Underground Neutrino Observatory (JUNO) is a next-generation liquid scintillator experiment being built in the Guangdong province in China. JUNO's target mass of 20 kton will be contained in a 35.4 m acrylic vessel, itself submerged in a water pool, under about 700 m of granite overburden. Surrounding the acrylic vessel are 17612 20" PMTs and 25600 3" PMTs. The main goal of JUNO, whose construction is scheduled for completion in 2022, is a 3-4σ determination of the neutrino mass ordering (MO) using reactor neutrinos within six years, as well as a sub-percent measurement of the oscillation parameters θ_{12}, Δm^2_{21}, and Δm^2_{31}. JUNO's large target mass, low background, and dual calorimetry, leading to an excellent energy resolution and low threshold, allows for a rich physics program with many applications - including solar-, geo-, and atmospheric neutrino measurements. JUNO will also be able to measure neutrinos from galactic core-collapse supernovae, detecting about 10,000 events for a supernova at 10 kpc within 10 s, and achieve a 3σ discovery of the diffuse supernova neutrino background in ten years. JUNO is also suited for exotic searches and can be expected to give a lower limit of 8.34e33 years (90% C.L.) on the proton lifetime. This group talk covers the rich neutrino and astrophysics potential of the JUNO experiments and gives an update on the current experimental status.

T 20.2 Mon 16:35 T-H33

Studies on the sensitivity for the Neutrino Mass Ordering Measurement of JUNO — •Nikhil Mohan[1,3], Alexandre Goettel[2,3], Philipp Kampmann[1], Runxuan Liu[2,3], Livia Ludhova[2,3], Luca Pelicci[2,3], Mariam Rifai[2,3], Apeksha Singhal[2,3], and Cornelius Vollbrecht[2,3] — [1]GSI Helmholtz Centre for Heavy Ion Research, Darmstadt — [2]Forschungszentrum Jülich GmbH, Nuclear Physics Institute IKP-2, Jülich — [3]III. Physikalisches Institut B, RWTH Aachen University, Aachen

JUNO is a multipurpose 20 kton liquid scintillator detector under construction in a 700 m underground laboratory in China, positioned 53 km from Yangjiang and Taishan nuclear power plants. The central detector is being built with high photocathode coverage of 78%, provided by 17,612 20-inch PMTs (LPMTs) and 25,600 3-inch PMTs (SPMTs). The unprecedented expected energy resolution at $3\%/\sqrt{E[\mathrm{MeV}]}$ and the large fiducial volume anticipated for the JUNO detector offers exciting opportunities for addressing many important topics in neutrino and astroparticle physics.

This talk will focus on the primary physics goal of JUNO, which is the determination of Neutrino Mass Ordering (NMO) via the measurement of the vacuum oscillation pattern of the reactor antineutrinos. JUNO will detect the antineutrinos of electron flavor via the Inverse Beta Decay (IBD) interaction with a 1.8 MeV energy threshold. The estimated sensitivity to the NMO is a 3-4 σ significance with at least six years of data taking.

T 20.3 Mon 16:50 T-H33

Analysis of possible implications by the finestructure in the reactor neutrino spectrum on the JUNO NMO sensitivity — •Tobias Heinz, Lukas Bieger, David Blum, Marc Breisch, Srijan Delampady, Jessica Eck, Gina Grünauer, Benedict Kaiser, Frieder Kohler, Tobias Lachenmaier, Axel Müller, Tobias Sterr, Alexander Tietzsch, and Jan Züfle — Eberhard Karls Universität Tübingen, Physikalisches Institut

The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kt liquid scintillator detector currently constructed in southern China with the main goal to determine the neutrino mass ordering (NMO). Therefore, JUNO measures the reactor neutrino spectrum from two nuclear power plants located in a distance of around 53 km. The precise knowledge of the emitted reactor neutrino spectrum is one of the major aspects for the NMO determination. In recent years, new calculations of the spectrum predicted the existence of a spectral finestructure which could impede the measurement with the unprecedented energy resolution of the JUNO detector.

This talk will discuss possibilities to study the implications of the still unknown finestructure in the reactor neutrino spectrum for the sensitivity of the mass hierarchy determination with JUNO. Further, some preliminary results of these sensitivity studies will be presented.

This work is supported by the Deutsche Forschungsgemeinschaft.

Group Report T 20.4 Mon 17:05 T-H33

The Taishan Antineutrino Observatory — •Hans Theodor Josef Steiger — Cluster of Excellence PRISMA+, Staudingweg 9, 55128 Mainz — Johannes Gutenberg Universität Mainz, Staudingerweg 7, 55128 Mainz — Physik-Department, Technische Universität München, James-Franck-Str. 1, 85748 Garching, Germany

The TAO (Taishan Antineutrino Observatory) detector is aiming for a measurement of the reactor neutrino spectrum at very low distances (<30m) to the core with a groundbreaking resolution better than 2 % at 1 MeV. The TAO experiment will realize the unprecedented neutrino detection rate of about 2000 per day, which is approximately 30 times the rate in the JUNO main detector. In order to achieve its goals, TAO is relying on yet to be developed, cutting-edge technology, both in photosensor and liquid scintillator (LS) development which is expected to have an impact on future neutrino and Dark Matter detectors. In this talk TAO's design, physics prospects as well as the status of its construction will be presented, together with a short excursion into its rich R&D program with a special focus on the German contribution to the development of the novel gadolinium-loaded liquid scintillator. This work is supported by the Cluster of Excellence PRISMA+ at the Johannes Gutenberg University in Mainz and the DFG research unit JUNO.

T 20.5 Mon 17:25 T-H33

Event reconstruction for the neutrino mass ordering measurement of JUNO — •Mariam Rifai[1,2], Livia Ludhova[1,2], Philipp Kampmann[3], Luca Pelicci[1,2], Apeksha Singhal[1,2], Alexandre Goettel[1,2], Cornilius Vollbrecht[1,2], Runxuan Liu[1,2], and Nikhil Mohan[2,3] — [1]Forschungszentrum Jülich GmbH, Nuclear Physics Institute IKP-2, Jülich, Germany — [2]III. Physikalisches Institut B, RWTH Aachen University, Aachen, Germany — [3]GSI Helmholtz Centre for Heavy Ion Research, Darmstadt, Germany

The Jiangmen Underground Neutrino Observatory (JUNO) is a multipurpose liquid scintillator-based neutrino experiment with a target mass of 20 kt. The detector is currently under construction and plans to start the data-taking in 2023. Its main goal is the determination of the neutrino mass ordering (MO), through a measurement of the oscillation pattern of reactor neutrinos over 53 km baseline. For a successful measurement of MO with at least 3σ in 6 years, the energy resolution of JUNO must reach an unprecedented 3% at 1 MeV, which is challenging in terms of event reconstruction. Moreover, future JUNO results about neutrino MO could be further improved via a combined analysis with atmospheric neutrinos, which can be observed and reconstructed in JUNO. To achieve this target performance, a precise knowledge of the detector's energy scale has been studied and event reconstruction methods based on charge and time information of the PMTs will be presented in this talk.

T 20.6 Mon 17:40 T-H33

Machine learning based reconstruction of atmospheric neutrino events in JUNO — •Rosmarie Wirth — Hamburg University, Hamburg, Germany

The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kt liquid scintillation detector. By observing reactor anti-neutrinos with a 53 km baseline, JUNO aims to determine the mass hierarchy with $3\,\sigma$ significance.
Due to JUNOs large volume, it could be suitable to measure atmospheric neutrino events with high precision. In that case, this channel could deliver further measurements on the mass ordering and the atmospheric oscillation parameters. To obtain this goal sufficient reconstruction methods are needed. This talk presents machine learning based reconstruction methods to analyze these atmospheric neutrino events at JUNO.

T 20.7 Mon 17:55 T-H33

Event Reconstruction in JUNO-TAO using Deep Learing — •Vidhya Thara Hariharan — University of Hamburg

The primary goal of JUNO is to resolve the neutrino mass hierarchy using precision spectral measurements of reactor antineutrino oscillations. To achieve this goal a precise knowledge of the unoscillated reactor spectrum is required in order to constrain its fine structure. To account for this, Taishan Antineutrino Observatory (TAO), a ton-level, high energy resolution liquid scintillator detector with a baseline of about 30 m, is set up as a reference detector to JUNO. The 20% increase in the coverage of photosensors, the replacement of Photomultiplier Tubes (PMTs) with Silicon Photomultiplier (SiPM) tiles, the smaller dimension and the low temperature at -51°C, would enable TAO to achieve an yield of 4,500 p.e./MeV. Consequently TAO will achieve an energy resolution of 1.5%/E(MeV). The measurement of the reactor antineutrino spectrum with this energy resolution will provide a model-independent reference spectrum for JUNO.

The reconstruction can be performed using several approaches. However previous studies have proved Deep Learning yields competitive reconstruction results. Hence this work aims at demonstrating the general applicability of Graph neural networks (GNNs) to reconstruct vertex and energy and later at studying the directionality of TAO events.

T 20.8 Mon 18:10 T-H33

Search for the DSNB in JUNO: Development of new Methods for Background Event Identification — •Matthias Mayer[1], Lothar Oberauer[1], Raphael Stock[1], Hans Steiger[2], Konstantin Schweizer[1], Ulrike Fahrendholz[1], David Dörflinger[1], Sebastian Zwickel[1], Simon Appel[1], Carsten Dittrich[1], Vincent Rompel[1], Luca Schweizer[1], Korbinian Stangler[1], and Simon Csakli[1] for the JUNO-Collaboration — [1]Technische Universität München, München, Germany — [2]Institute of Physics and EC PRISMA+, Johannes Gutenberg Universität Mainz, Mainz, Germany

The diffuse supernova neutrino background (DSNB) is a constant, diffuse flux of relic neutrinos from past core-collapse supernovae over the entire visible universe. The upcoming Jiangmen Underground Neutrino Observatory (JUNO), a 20 kton liquid scintillator detector, expects to observe the DSNB through the inverse beta decay (IBD) detection channel. Besides IBD background from other electron antineutrino sources, there are also neutron-induced background events and NC interactions of atmospheric neutrinos of all flavours. This non-IBD background can be discriminated using pulse shape discrimination (PSD) methods. In this talk, I investigate the possibility to increase the fiducial volume available for the DSNB search using machine learning methods. Further, this talk discusses the effects of an electronics simulation and the flourescence parameter choice on the achievable PSD performance. This work is supported by the DFG research unit "JUNO", the DFG collaborative research centre 1258 "NDM", and the DFG Cluster of Excellence "Origins".

T 20.9 Mon 18:25 T-H33

Indirect dark matter search with neutrinos in JUNO and THEIA — Lukas Bieger, •David Blum, Marc Breisch, Srijan Delampady, Jessica Eck, Gina Grünauer, Tobias Heinz, Benedict Kaiser, Frieder Kohler, Tobias Lachenmaier, Axel Müller, Tobias Sterr, Alexander Tietzsch, and Jan Züfle — Eberhard Karls Universität, Physikalisches Institut, Tübingen, Germany

Neutrino detectors like the Jiangmen Underground Neutrino Observatory (JUNO) and the prospective neutrino detector THEIA are sensitive to a potential neutrino flux produced by dark matter self-annihilation in the Milky Way. The expected neutrino signals from dark matter self-annihilation and the relevant backgrounds in the energy range from 10 MeV to 100 MeV are investigated for both neutrino detectors. Further background suppression is realized by pulse shape discrimination analysis in JUNO and by studying the ratio between Cherenkov and scintillation light in THEIA. Results of a sensitivity study of JUNO and THEIA on the dark matter self-annihilation cross section are presented in this talk. This work is supported by the Deutsche Forschungsgemeinschaft.

T 21: Neutrino Physics without Accelerators 2

Time: Monday 16:15–18:35 Location: T-H34

Group Report T 21.1 Mon 16:15 T-H34

Sterile neutrino search at the keV mass scale with KATRIN — •Frank Edzards for the KATRIN collaboration[1], Marco Carminati[2,3], David Fink[1], Carlo Fiorini[2,3], Matteo Gugiatti[2,3], Pietro King[2,3], and Peter Lechner[4] — [1]Max Planck Institute for Physics, Munich, Germany — [2]DEIB, Politecnico di Milano, Milano, Italy — [3]INFN, Sezione di Milano, Milano, Italy — [4]Halbleiterlabor der Max Planck Gesellschaft, Munich, Germany

Sterile neutrinos are a natural extension of the Standard Model of particle physics. If their mass is in the keV range, they are a viable dark matter candidate. One way to search for sterile neutrinos in a laboratory-based experiment is via tritium beta decay. A sterile neutrino with a mass up to 18.6\,keV would manifest itself in the decay spectrum as a kink-like distortion. The objective of the TRISTAN project is to extend the KATRIN experiment with a novel multi-pixel silicon drift detector and readout system to search for a keV-scale sterile neutrino signal. This talk will give an overview on the current status of the project. First characterization measurement results obtained with a 166 pixel system will be shown. This work is supported by BMBF (05A17PM3, 05A17PX3, 05A17VK2, 05A17WO3), KSETA, the Max Planck society, and the Helmholtz Association.

T 21.2 Mon 16:35 T-H34

Shifted Analyzing Plane: Optimizing spectrometer potentials and fields to reduce background in KATRIN — •Benedikt Bieringer for the KATRIN-Collaboration — Institut für Kernphysik, Uni Münster, Germany

The KArlsruhe TRItium Neutrino (KATRIN) experiment aims at measuring the electron antineutrino mass to an estimated sensitivity of $0.2\,\mathrm{eV/c^2}$ at 90 % CL through spectroscopy of Tritium beta decay electrons using an electrostatic spectrometer of MAC-E filter type. For this level of precision, a low spectrometer background is required. The novel Shifted Analyzing Plane method achieves a significant reduction of this background through optimization of MAC-E filter electric potentials and magnetic fields. In this talk, computational and physical methods are presented that enabled the reduction of background of the KATRIN experiment by over a factor of two and fully eliminated measurable correlated background events from trapped high-energetic electrons. This includes a brief introduction to the inner workings of a MAC-E filter, a novel software collection to enable realtime field calculations based on Zonal Harmonic Field Expansion and background modelling for the largest ultra-high vacuum component in the KATRIN experiment.

This talk presents work funded via BMBF contract numbers 05A20VK3, 05A20PX3, 05A20PMA and 05A17WO3.

T 21.3 Mon 16:50 T-H34

Determination of Electromagnetic Fields in the Shifted Analyzing Plane of the KATRIN Main Spectrometer — •Fabian Block[1] and Alexey Lokhov[2] for the KATRIN-Collaboration — [1]Karlsruhe Institute of Technology — [2]WWU Münster

The KATRIN experiment aims to determine the effective electron antineutrino mass with a sensitivity of 0.2 eV (90 % C.L.) by high-resolution spectroscopy of the endpoint region of the tritium β decay spectrum. To reach the sensitivity goal, the experimental setup of KATRIN combines a windowless gaseous tritium source with a high-resolution MAC-E filter, called main spectrometer. The energy analysis of the β-decay electrons in the main spectrometer takes place via a complex interplay of electric and magnetic fields.

To improve the signal-to-background ratio during neutrino mass measurements, the electromagnetic field configuration in the main spectrometer is adapted to the so-called Shifted Analyzing Plane (SAP). The SAP electromagnetic fields need to be known with high precision in order for them to be taken accurately into account in the β-spectrum model applied in the fit of the data. We present in this talk the results of SAP characterization measurements employing conversion electrons of krypton-83m as sensitive probes for the electromagnetic fields.

This work is supported by the Helmholtz Association (HGF), the Ministry for Education and Research BMBF (05A17PM3, 05A17PX3, 05A17VK2, 05A20PMA, and 05A17WO3), the Helmholtz Alliance for Astroparticle Physics (HAP), and the Helmholtz Young Investigator Group (VH-NG-1055).

T 21.4 Mon 17:05 T-H34

aTEF: Background reduction at KATRIN via an active transverse energy filter — •Sonja Schneidewind[1], Kevin Gauda[1], Volker Hannen[1], Alexey Lokhov[1], Hans-Werner Ortjohann[1], Wolfram Pernice[2], Richard Salomon[1], Maik Stappers[2], and Christian Weinheimer[1] for the KATRIN-Collaboration — [1]Institut für Kernphysik, Universität Münster, Wilhelm-Klemm-Str. 9, 48149 Münster, Germany — [2]Physikalisches Institut, Universität Münster, Heisenbergstr. 11, 48149 Münster, Germany

The Karlsruhe Tritium Neutrino Experiment (KATRIN) aims at the direct measurement of the electron antineutrino mass with $0.2\,\mathrm{eV/c^2}$ sensitivity from precision spectroscopy of the tritium beta decay. The analysis of its first two science runs yields a new upper limit of $m_\nu < 0.8\,\mathrm{eV}$ (90% C.L.). Even in the shifted-analysis-plane (SAP) mode it is required to further lower the background rate to reach the target sensitivity. The background rate is dominated by electrons originating from ionisation of highly-excited (Rydberg) atoms produced by α-decays in the spectrometer walls. Thus, they cannot be distinguished from the signal electrons by energy but they possess much smaller angles w.r.t. the beam axis and, thus, much smaller cyclotron radii in the magnetic fields of KATRIN. The aTEF idea is to construct a detector by microstructuring that is mainly sensitive to the signal electrons because of their larger cyclotron radii. Investigations of first prototypes based on microstructured silicon PIN detectors are presented in this talk. The work of the authors for KATRIN is supported by BMBF under contract number 05A20PMA.

T 21.5 Mon 17:20 T-H34

Electron tracking simulations for the active transverse energy filter at KATRIN — •Richard Salomon, Kevin Gauda, Sonja Schneidewind, Volker Hannen, Alexey Lokhov, Hans-Werner Ortjohann, and Christian Weinheimer for the KATRIN-Collaboration — Institut für Kernphysik, Wilhelm-Klemm-Straße 9, 48149 Münster, Germany

The Karlsruhe Tritium Neutrino Experiment (KATRIN) aims at determining the electron neutrino mass with a sensitivity of $0.2\ \mathrm{eV/c^2}$ from a precision measurement of the tritium β-decay spectrum. To reach the desired sensitivity it is crucial to minimize experimental background events especially in the endpoint region of the electron spectrum.

One of the dominant backgrounds identified is the ionization of highly-excited (Rydberg) atoms inside the main spectrometer. To mitigate this background source, the concept of an active transverse energy filter (aTEF) is being investigated. As the electrons emitted by ionized Rydberg atoms, in contrast to most signal electrons from tritium beta decay, possess only a small amount of energy perpendicular to the guiding magnetic field, an angular-selective detector might be able to distinguish between the two. In order to test this novel detection technique, prototypes consisting of microstructured Si-PIN diodes are currently investigated in a test setup in Münster. This talk focuses on the accompanying particle tracking simulations which are essential for the analysis and interpretation of measurement data.

This project is supported by BMBF under contract number 05A20PMA.

T 21.6 Mon 17:35 T-H34

Combined analysis of the first five KATRIN measurement campaigns with KaFit — •Stephanie Hickford and Leonard Köllenberger for the KATRIN-Collaboration — Institute for Astroparticle Physics, Karlsruhe Institute of Technology

The KATRIN collaboration aims to determine the neutrino mass with a sensitivity of $0.2\,\mathrm{eV/c^2}$ (90 % CL). This will be achieved by measuring the endpoint region of the tritium β-electron spectrum. Combined analysis of the first two KATRIN measurement campaigns yielded a neutrino mass limit of $m_\nu \leq 0.8\,\mathrm{eV}$ (90 % CL).

Analyses of data from the first five measurements campaigns are currently underway. One of the combined analyses is performed using the `KaFit/SSC` model within the `KASPER` software framework. In this analysis systematic uncertainties are propagated as additional fit parameters with constraints (the “pull term” method). An overview of the collected data and the expected combined sensitivity on the neutrino mass from these five measurement campaigns will be presented in this talk.

This work is supported by the Helmholtz Association (HGF), the Ministry for Education and Research BMBF (05A17PM3, 05A17PX3, 05A17VK2, and 05A17WO3), the Helmholtz Alliance for Astroparticle Physics (HAP), and the Helmholtz Young Investigator Group (VH-NG-1055).

T 21.7 Mon 17:50 T-H34

Status of the KATRIN neutrino mass analysis using Monte Carlo propagation and a novel neural network approach — Christian Karl[1,2], Susanne Mertens[1,2], •Alessandro Schwemmer[1,2], and Christoph Wiesinger[1,2] for the KATRIN-Collaboration — [1]Max-Planck-Institut für Physik, München — [2]Physik Department, Technische Universität München, Garching

The Karlsruhe Tritium Neutrino (KATRIN) experiment probes the effective electron anti-neutrino mass by a precision measurement of the tritium beta-decay spectrum near the endpoint. A world-leading upper limit of $0.8\,\mathrm{eV\,c^{-2}}$ (90 % CL) has been set with the first two measurement campaigns. New operational conditions for an improved signal-to-background ratio, the reduction of systematic uncertainties and a substantial increase in statistics allow to expand this reach.

The performance figures of three additional datasets, analysed with the Monte Carlo propagation method, and an outlook on their combination using a novel neural network technique will be presented in this talk.

T 21.8 Mon 18:05 T-H34

Measurement of the drift time in a silicon drift detector for the KATRIN experiment by laser pulsing — •Korbinian Urban[1], Marco Carminati[2,3], David Fink[1], Carlo Fiorini[2,3], Matteo Gugiatti[2,3], Pietro King[2,3], and Peter Lechner[4] for the KATRIN-Collaboration — [1]Max Planck Institute for Physics, Munich, Germany — [2]DEIB, Politecnico di Milano, Milano, Italy — [3]INFN, Sezione di Milano, Milano, Italy — [4]Halbleiterlabor der Max Planck Gesellschaft, Munich, Germany

The KATRIN experiment investigates the endpoint of the tritium beta-decay spectrum to search for the effective mass of the electron neutrino. Furthermore, the KATRIN experiment has the potential to also search for the signature of a sterile neutrino in the keV-mass regime by measuring the entire tritium beta-decay spectrum with an upgraded detector system. The new detector system, named TRISTAN, will be a multi-pixel silicon drift detector. This technology provides an improved energy resolution at high rates compared to PIN detector diodes. The radial drift of a charge cloud to the small anode of each pixel with 3 mm radius can be a significant contribution to the time resolution of the detector. This talk presents a measurement where a pulsed red laser is used to characterize the drift time in a 7-pixel TRISTAN detector device.

This work is supported by BMBF (05A17PM3, 05A17PX3, 05A17VK2, and 05A17WO3), KSETA, the Max Planck society, and the Helmholtz Association.

T 21.9 Mon 18:20 T-H34

SQL database caching for calculating the response function of the KATRIN experiment in HPC environments — •Jan Behrens and Fabian Block for the KATRIN-Collaboration — Institut für Astroteilchen-/Experimentelle Teilchenphysik, KIT Karlsruhe, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen

The **Ka**rlsruhe **Tri**tium **N**eutrino experiment aims to determine the mass of the electron antineutrino with a sensitivity of 0.2 eV/c^2 (90% C.L.). The measurement of the shape of the tritium beta-spectrum enables a model-independent investigation of the absolute neutrino mass scale. The setup consists of a 70 m long beam line that magnetically guides electrons from a gaseous, windowless tritium source through an electrostatic spectrometer of the MAC-E filter type. The neutrino mass analysis involves a time-consuming calculation of the response function that depends on various experimental parameters, such as the magnetic fields along the beam line or the source column density. In order to facilitate a fit over hundreds of data runs with varying conditions, a caching mechanism is implemented which operates on a SQL database that can be shared between multiple users. Using a central database allows to distribute the calculations in a HPC cluster environment in order to improve the efficiency of existing parallelization techniques. *This work is supported by the Helmholtz Association (HGF), the Ministry for Education and Research BMBF (05A17PM3, 05A17PX3, 05A17VK2, and 05A17WO3), the Helmholtz Alliance for Astroparticle Physics (HAP), and the Helmholtz Young Investigator Group (VH-NG-1055).*

T 22: Search for Dark Matter 1

Time: Monday 16:15–18:20 Location: T-H35

Group Report T 22.1 Mon 16:15 T-H35

Current status of the XENONnT Dark Matter Search Experiment — •Luisa Hötzsch — Max-Planck-Institut für Kernphysik, Heidelberg — on behalf of the XENON Collaboration

The XENON experiments are among the most sensitive dark matter (DM) detectors, utilizing the concept of dual-phase xenon time projection chambers (TPCs) for the direct detection of weakly interacting massive particles (WIMPs). The XENON1T detector, which utilized a total of 3.2 tonnes of xenon target, was able to set the most stringent limits on the WIMP-nucleon spin-independent cross section for WIMP masses above $6\,\mathrm{GeV/c^2}$, with a minimum of $4.1\times10^{-47}\,\mathrm{cm^2}$ at $30\,\mathrm{GeV/c^2}$.

The latest iteration in the XENON experiment series is the XENONnT detector, which is currently running at the INFN Gran Sasso National Laboratory in Italy. With a total of 8.4 tonnes of xenon, it is projected to improve the sensitivity to WIMP dark matter by another order of magnitude. In addition, due to its further background reduction by a factor of approximately 6, XENONnT is expected to be able to clarify the nature of an electronic recoil event excess observed in XENON1T.

In this talk, I will give an overview of the XENONnT detector and its subsystems, and present the current status of the experiment.

T 22.2 Mon 16:35 T-H35

Light signal correction for the XENONnT experiment — •Johanna Jakob for the XENON-Collaboration — Institut für Kernphysik - WWU, Münster, Germany

XENONnT, the latest stage of the XENON dark matter project, is currently taking science data with the science goals to detect WIMP-nucleus scattering and to search for other rare events. The detector is a dual-phase time projection chamber (TPC) filled with 8.5 tonnes of liquid xenon. The detector side walls reflect scintillation light caused by energy deposition in the detector, which is registered at the top and bottom by photomultiplier arrays. Free electrons, additionally created by the energy deposition in the detector, are drifted to the gaseous phase at the top of the detector where they create a second scintillation light pulse by electroluminescence. Both the light as well as the charge signal allow to perform a 3-dimensional position reconstruction of the recorded events.

This talk focuses on the light signal reconstruction, which requires a correction of the position dependent light collection efficiency and the understanding of the effects of the non-uniform electric drift field. Based on calibration data with several internal sources, light collection efficiency maps are derived and applied to the light signals.

This work is supported by BMBF under contract 05A20PM1 and by DFG within the Research Training Group GRK-2149.

T 22.3 Mon 16:50 T-H35

Energy calibration of the XENONnT Experiment — •Henning Schulze Eissing for the XENON-Collaboration — Institut für Kernphysik - WWU, Münster, Deutschland

The XENON Dark Matter Project uses a dual phase time projection chamber filled with liquid xenon to search for Dark Matter in the form of weakly interacting massive particles (WIMPs). The current iteration, the XENONnT experiment with 8.5 t of xenon, is taking science data and will also allow the investigation of other science topics due to its extremely low background especially for low energies.

The energy deposition as well as the three-dimensional location of an event in the detector is reconstructed using fast scintillation light signal and a delayed charge signal. The latter is converted into a light signal by electroluminescence in the gaseous xenon phase above the liquid. The size of the primary scintillation light and of the charge signal are anticorrelated. This talk will outline the energy calibration of the XENONnT experiment using several mono-energetic gamma sources that can be found in the background data as well as in dedicated calibration data using external and internal sources.

This work is supported by BMBF under contract 05A20PM1 und by DFG within the Research Training Group GRK-2149.

T 22.4 Mon 17:05 T-H35

Calibration of XENONnT with tagged neutrons in its TPC and water Cherenkov neutron veto — •Daniel Wenz — Institut für Physik & Exzellenzcluster PRISMA+, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany

For more than a decade, liquid xenon (LXe) time projection chambers (TPC) have been playing a key role in the direct search for WIMP dark matter and other rare events. In 2018, XENON1T set the most stringent limits for WIMP-nucleon couplings for masses above 6 GeV/c2. Building on this success, an even larger LXe TPC called XENONnT was built, which features a ~3-times larger target mass of 5.9 t. The experiment reuses much of the existing infrastructure of XENON1T, which has been augmented by additional sub-systems. One of these new systems is a water Cherenkov neutron veto encapsulating the TPC cryostat. Neutrons are capable of mimicking WIMP signals by undergoing a single-scatter nuclear recoil inside the TPC and escaping the TPC cryostat. The neutron veto system has the goal to reduce the intrinsic nuclear-recoil background by serving as an active veto for those neutrons.

In 2021, XENONnT successfully finished commissioning and started science data taking. In this talk, we will present the first results of XENONnT*s nuclear recoil calibration as well as the calibration of the neutron-veto tagging efficiency, using coincident gammas and neutrons from an Americium-Beryllium source.

T 22.5 Mon 17:20 T-H35

Towards an automated krypton assay in xenon at the ppq level — •Robert Hammann, Hardy Simgen, and Steffen Form — Max-Planck Institut für Kernphysik, Heidelberg, Germany

The beta-decaying isotope ^{85}Kr is one of the main internal background sources of liquid xenon (LXe) detectors. With purification techniques, it is possible to reduce the concentration of krypton in xenon below 100 ppq (parts per quadrillion). To model the background contribution of the remaining ^{85}Kr, it is crucial for low-background experiments such as XENONnT to precisely quantify the concentration of krypton in the detector material. The rare gas mass spectrometer (RGMS) at MPIK Heidelberg can meet this requirement by measuring the krypton concentration of an extracted xenon sample in two steps: First, krypton is separated from the bulk of xenon using a cryogenic gas chromatographic system. Then, the amount of krypton is analyzed using a mass spectrometer. A fully automatic rare gas mass spectrometer (AutoRGMS) is envisaged for the krypton assay of future low-background LXe detectors. This instrument will considerably facilitate the time-consuming measurement procedure, thus enabling a more frequent krypton monitoring. In addition, larger adsorption traps with a novel adsorbent will be employed, which makes the system sensitive to lower krypton concentrations. A proof of concept was demonstrated with a test setup of an automated gas chromatographic system in which stable conditions were maintained for more than 10 hours during the separation process. Moreover, the setup was used to test individual components and to find a working point for AutoRGMS.

T 22.6 Mon 17:35 T-H35

Radon removal system of the XENONnT experiment — •Denny Schulte, Henning Schulze Eissing, Philipp Schulte, Christian Huhmann, and Christian Weinheimer — WWU Münster

A novel high flux radon removal system has been built for the dark matter experiment XENONnT reducing the dominant electron recoil background produced by Rn-222 and its progenies. Continuous emanation from detector components and its half-life of 3.8 days leads to a homogenous distribution of the Rn-222 within the detector system before it decays. Our radon removal method is based on the vapor pressure difference of xenon and radon. We built a cryogenic distillation column with a throughput of 200 slpm to exchange the liquid xenon mass of 8.5 tonnes within one mean lifetime of Rn-222 in order to decrease the radon concentration by a factor 2. An additional extraction flow of 25 slpm from the xenon gas phase at the top of the XENONnT detector, where some specific radon sources were identified, demonstrated to provide an additonal radon reduction factor of nearly 2. Both reduction methods aim for reaching for the first time a radon activity concentration of 1 μBq/kg in a xenon-based dark matter experiment. To provide the enormous cooling power of more than 3 kW at about -100°C we use a heat-pump concept with custom-built, radon-free xenon compressors and heat exchangers.

This talk will focus on the principle, construction and commissioning measurements of the radon removal system.

The project is funded by BMBF under contract 05A20PM1.

T 22.7 Mon 17:50 T-H35

Coating techniques for radon mitigation in liquid xenon detectors — •Mona Piotter, Hardy Simgen, and Florian Jörg — Max-Planck-Institut für Kernphysik, Heidelberg

Searching for rare events like dark matter interaction or neutrinoless double beta decay using liquid xenon detectors, requires a low radon background. Radon, which is part of the uranium and thorium decay chain, can continuously emanate from the detector materials. Current attempts to lower the radon induced background include the selection of radio-pure materials, techniques allowing to actively remove radon from xenon, as well as data selection criteria. However, next generation experiments will require even lower radon levels which likely can not be achieved by employing those methods alone. A new technique to stop radon emanation based on surface coatings has been investigated. This requires a tight and radium-free layer. We have developed a electro-deposited copper coating and present here the promising results. During the development, we systematically investigated the coating parameters with the short-lived ^{220}Rn emanating from tungsten rods or stainless steel plates. After this preliminary tests we applied the coating to a suitable ^{222}Rn emanating stainless steel source, which has a longer half-life. It was produced at the CERN facility ISOLDE by implanting ^{226}Ra in stainless steel plates. In the talk we present the results of the first coating of that sample.

T 22.8 Mon 18:05 T-H35

S1-based position reconstruction in dual phase time projection chambers — •Jaron Grigat — Albert-Ludwigs-Universität, Freiburg, Deutschland

Most particle interactions inside liquid xenon dual phase time projection chambers (LXe-TPCs) create two light signals. Besides the prompt scintillation light (S1), electrons from the interaction site are drifted in an electric field to the gas phase of the TPC. There, they create a delayed proportional scintillation signal (S2). Normally, the position in the x-y-plane is reconstructed from the hit pattern of the S2 signal on the top photosensor array. The depth of the interaction can be calculated from the time delay between S1 and S2. In this talk, we explore the possibility to reconstruct the 3D position by only looking at the S1 signal using machine learning techniques. We discuss possible applications of this additional information and show how this method can help us to characterize the electric field inside the XENONnT TPC.

T 23: Experimental Techniques in Astroparticle Physics 1

Time: Monday 16:15–17:45 Location: T-H36

T 23.1 Mon 16:15 T-H36

Monte Carlo simulation of background components in low level Germanium spectrometry — •Nicola Ackermann[1], Hannes Bonet[1], Christian Buck[1], Janina Hakenmüller[1], Gerd Heusser[1], Matthias Laubenstein[2], Manfred Lindner[1], Werner Maneschg[1], Jochen Schreiner[1], and Herbert Strecker[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Laboratori Nazionali del Gran Sasso, Via G.

Acitelli 22, 67100 Assergi L'Aquila, Italy

This talk presents Monte Carlo simulations of the background spectra of the 4 screening detectors GeMPI 1 - 4 at the Gran Sasso Underground Laboratory (LNGS) using the Geant4 based framework MaGe. The GeMPI detectors are low background Ge spectrometers located at a depth of 3500 m.w.e. and achieve extremely high sensitivites in material screening at a level of μBq/kg. They are used to test material samples on their suitability to use in rare event experiments. In the simulations, muons, neutrons and tiny radioactive contaminations of the detector and shielding materials are investigated as possible sources of background radiation and it was found that the ^{210}Pb contaminations in the detector shield and the neutrons coming from radioactive decays in the surrounding rock are the biggest contributors. A detailed understanding of the composition of the background spectra was achieved, allowing for the suggestion of two new possible shield designs for future GeMPI-like detectors

T 23.2 Mon 16:30 T-H36

Biases in the ^{76}Ge $0\nu\beta\beta$ tagging from calibrations — •Tommaso Comellato[1], Matteo Agostini[1,2], and Stefan Schönert[1] — [1]Technical University of Munich, Garching bei München, Germany — [2]University College London, London, United Kingdom

The analysis of the time profile of electrical signals in germanium detectors provides a powerful tool for a high efficiency selection of neutrinoless double beta decay ($0\nu\beta\beta$) of ^{76}Ge. The standard discrimination techniques are calibrated using samples of $0\nu\beta\beta$-like events, which either occur at a different energy or contain a significant background contamination. With the help of a ^{56}Co source (which was custom produced by the Jagiellonian University in Krakow), we present a precision measurement of the biases of the standard event selection techniques in $0\nu\beta\beta$ experiments with ^{76}Ge, and propose an additional calibration method. This work has been supported in part by the ERC (Grant agr. No. 786430 - GemX) and by the SFB1258 funded by the DFG.

T 23.3 Mon 16:45 T-H36

Towards a low background SDD for IAXO — David Casado Moran[1,2], Frank Edzards[1,2], Thibaut Houdy[3], Susanne Mertens[1,2], Juan Pablo Ulloa Beteta[1,2], •Christoph Wiesinger[1,2], and Michael Willers[1,2] — [1]Max-Planck-Institut für Physik, München — [2]Physik-Department, Technische Universität München, Garching — [3]IJCLab, Université Paris-Saclay, Paris

The International Axion Observatory (IAXO) is aiming to detect solar axions, as they are converted into X-rays in a strong magnet pointing towards the sun. Excellent spectroscopic performance, high X-ray absorption efficiency at and below 10 keV and potential for ultra-low background operations are features of Silicon Drift Detectors (SSDs) that could facilitate this search. First measurements in the Munich shallow underground laboratory have shown promising background performance. Dedicated low-background designs, following a conventional passive shielding strategy and a novel all-semiconductor active shield approach, are under development. In this talk, we will report on the latest achievement towards a low background SDD for IAXO.

T 23.4 Mon 17:00 T-H36

The Pacific Ocean Neutrino Experiment: Results from three years of pathfinder data — Christopher Fink, Kilian Holzapfel, Stephan Meighen-Berger, Imma Rea, Li Ruohan, •Lisa Schumacher, Maria Sharshunova, and Laura Winter for the P-ONE-Collaboration — Experimental Physics with Cosmic Particles, TU Munich

The Pacific Ocean Neutrino Experiment (P-ONE) is a planned, cubic-kilometer-scale neutrino telescope at 2660 m depth in Cascadia Basin located off the coast of Vancouver, Canada. The telescope is planned by a growing collaboration of Ocean Networks Canada (ONC), and Universities from Germany, Canada and the USA. Two pathfinder experiments have been deployed in Cascadia Basin using the already available infrastructure of ONC: STRAW (STRings for Absorption length in Water) in 2018 and STRAW-b in 2020. Both pathfinder experiments - and P-ONE in the future - are based on vertical, deep-sea cable lines equipped with multiple photosensors and calibration light sources. The main goal of the pathfinder lines is to characterize the optical properties of the site, which proved suitable to host P-ONE. Another purpose of the pathfinder lines is the monitoring of background light caused by K40 decay and bioluminescence, by now over more than three years. We will present an overview over recent results obtained with the STRAW and STRAW-b lines.

T 23.5 Mon 17:15 T-H36

Performance evaluation of the Wavelength-shifting Optical Module for the IceCube Upgrade — •Yuriy Popovych[1], Sebastian Böser[1], Anna Pollmann[2], John Rack-Helleis[1], and Martin Rongen[1] for the IceCube-Collaboration — [1]JGU Mainz — [2]Bergische Universität Wuppertal

In the upcoming IceCube Upgrade several new types of sensors will be deployed so to increase the sensitivity and explore possibilities for the envisioned IceCube Gen2 detector.

One of the modules to be deployed in the Upgrade is the Wavelength-shifting Optical Module (WOM). It consists of a quartz tube coated with Wavelength-Shifting (WLS-) paint with two Photomultiplier Tubes (PMTs) attached to its ends located inside a quartz pressure vessel filled with PFPE. The paint absorbs UV-photons and reemits them as visible light which is then captured through total internal reflection and propagate to a PMT on each side. This design results in a large photosensitive area, UV-sensitivity and a high signal-to-noise ratio. Through various improvements, like the choice of the filling material or coating techniques the efficiency of the modules can be optimized.

This talk will present the optical design of the WOM and explain the contributions of the single WOM components to efficiency of the module. Further, several simulation tools will be presented used to study and optimize the overall performance.

T 23.6 Mon 17:30 T-H36

Timing characteristics of the Wavelength-shifting Optical Module — •John Rack-Helleis[1], Sebastian Böser[1], Martin Rongen[1], Klaus Helbing[2], Anna Pollmann[2], Nick Schmeisser[2], Yuriy Popovych[1], and Kyra Mossel[1] for the IceCube-Collaboration — [1]Johannes Gutenberg Universität Mainz — [2]Bergische Universität Wuppertal

The Wavelength-shifting Optical Module (WOM) uses the techniques of wavelength shifting and light guiding to achieve a large photosensitive area, UV-sensitivity and improved signal-to-noise ratio. The centerpiece of the sen- sor is a hollow quartz cylinder coated with wavelength-shifting paint with a PMT (Photomultiplier Tube) optically coupled to each of its ends. Incident photons are absorbed, wavelength shifted and re-emitted into the tube walls. From there, they are guided towards one of the read out PMTs via total inter- nal reflection. While effective area and signal-to-noise ratio scale approximately linearly with the cylinder length, the average time it takes photons to reach one of the readout PMTs also increases. The timing of the WOM can be described by a convolution of three main components: The time response of the attached read out PMT, the photoluminescence characteristics of the WLS paint, and the path length distribution of photons inside the WLS tube. In this presentation we elaborate on the understanding of the timing of the WOM from a theoretical and experimental stand point. We present the intricacies of a device where everything seemingly runs in circles.

T 24: Outreach Methods

Time: Monday 16:15–17:35 Location: T-H37

Group Report T 24.1 Mon 16:15 T-H37

Netzwerk Teilchenwelt als Plattform für Outreach in der Teilchenphysik, Astroteilchenphysik sowie Hadronen- und Kernphysik — •Uta Bilow und Michael Kobel für die Netzwerk Teilchenwelt-Kollaboration — Technische Universität Dresden und 28 weitere Standorte

Forschende sind heute verstärkt gefordert, Einblick in ihre Arbeit zu geben und den Dialog mit der fachfremden Öffentlichkeit zu führen. Für die Physik der kleinsten Teilchen existiert mit dem Netzwerk Teilchenwelt eine einzigartige Struktur, in der sich bundesweit Forschungsgruppen aus 29 Instituten zusammengeschlossen haben, um ihre wissenschaftliche Arbeit einem breiten Publikum zugänglich zu machen. Netzwerk Teilchenwelt stellt etablierte Programme und Strukturen bereit, mit denen Jugendliche bei Projekttagen die faszinierende Forschung an Beschleunigern kennenlernen oder eigene Messungen mit Detektoren durchführen. Gleichzeitig werden junge Forscherinnen und Forscher zur Wissenschaftskommunikation motiviert und befähigt. Ein mobiles Modul, das durch Deutschland tourt, spricht weniger wissenschaftsaffine Zielgruppen an. Die Aktivitäten werden durch das BMBF-Projekt KONTAKT2 gefördert und ausgebaut. Für Lehrkräfte als wichtige Multiplikator:innen führt Netzwerk Teilchenwelt regelmäßig Fortbildungen im Programm Forschung trifft Schule durch und bietet ein breites Spektrum an Unterrichtsmaterial an. Der Vortrag stellt die Angebote im Netzwerk Teilchenwelt sowie Beteiligungsmöglichkeiten für interessierte Forscherinnen und Forscher vor.

T 24.2 Mon 16:35 T-H37

Urknall unterwegs: eine mobile Ausstellung zur Teilchenphysik — Uta Bilow[1], •Christian Klein-Bösing[2], Michael Kobel[1], Philipp Lindenau[1] und Joseph Piergrossi[1] für die Netzwerk Teilchenwelt-Kollaboration — [1]TU Dresden, Institut für Kern- und Teilchenphysik — [2]WWU Münster, Institut für Kernphysik

Seit Juli 2021 tourt die mobile Ausstellung Urknall unterwegs durch Deutschland und macht Station in Fußgängerzonen und auf öffentlichen Plätzen. Die Ausstellung besteht aus einem sechs Meter langen begehbaren Tunnel, in dem Besucherinnen und Besucher eine Reise durch die Geschichte des Universums erleben. Zwei Infosäulen präsentieren auf unterhaltsame Art Wissenswertes zu Elementarteilchen und Wechselwirkungen, erläutern Forschungsmethoden in der Teilchenphysik und stellen anhand von Spin-Offs dar, wie die Teilchenphysik und ihre Technologien unser tägliches Leben beeinflussen. Ein Pavillon mit Spielen komplettiert die Schau. Mithilfe des eigenen Smartphones können Besucherinnen und Besucher die Ausstellung interaktiv erkunden. Urknall unterwegs kann in kurzer Zeit aufgebaut werden, da Tunnel und Säulen aufblasbar sind.

Die Ausstellung hat zum Ziel, Menschen aller Altersgruppen zu erreichen, die eher weniger Berührung mit Wissenschaft haben. Sie entstand im BMBF-geförderten Vorhaben KONTAKT in einer Zusammenarbeit von Weltmaschine und Netzwerk Teilchenwelt. Der Vortrag stellt vor, welche Erfahrungen mit der Ausstellung gesammelt wurden und welche Möglichkeiten zur Nutzung bestehen.

T 24.3 Mon 16:50 T-H37

I am a Scientist als niedrigschwelliger Beitrag zur Wissenschaftskommunikation — Uta Bilow und •Lydia Döring für die Netzwerk Teilchenwelt-Kollaboration — Technische Universität Dresden

Wissenschaft im Dialog gGmbH hat in Kooperation mit Netzwerk Teilchenwelt den Austausch zwischen Jugendlichen und Forschenden auf niedrigschwellige Art ermöglicht: Innerhalb von 30-minütigen Chats konnten Schulklassen ihre Fragen rund um die Welt der kleinsten Teilchen beantwortet bekommen. 59 Schulklassen und 25 Forschende hatten sich für die zweiwöchige Aktion im November 2021 registriert. Auch auf der Website I am a Scientist konnten die Schülerinnen und Schüler Fragen stellen. Diese und die entsprechenden Antworten, die neben physikalischen Fachfragen auch den beruflichen Alltag und den Werdegang der Wissenschaftlerinnen und Wissenschaftler betreffen, sind für die Öffentlichkeit auf der Website nachlesbar. Zum Abschluss der Aktion wurde als Lieblingswissenschaftler Dominik Koll gekürt. Er ist als Kernphysiker am Helmholtz-Zentrum Dresden-Rossendorf tätig und promoviert an der TU Dresden und in Australien. Er hat besonders engagiert die Fragen beantwortet und den Wert von Grundlagenforschung herausgestellt. Um fake news zu entgegnen, ist es wichtig zu wissen, wie wissenschaftliches Arbeiten funktioniert. Mit dem verliehenen Preisgeld möchte Koll Schulen besuchen, über wissenschaftliches Arbeiten aufklären und für die Forschung begeistern. Der Vortrag stellt die Aktion vor und begeistert für Wissenschaftskommunikation.

T 24.4 Mon 17:05 T-H37

Implementation of a Portal Dedicated to Higgs Bosons for Experts and the General Public — Ivan Demchenko, Martin Kupka, André Sopczak, Antoine Vauterin, and •Peter Zacik — CTU in Prague

The implementation of a web portal dedicated to Higgs boson research is presented. A database is created with more than 1000 relevant articles using CERN Document Server API and web scraping methods. The database is automatically updated when new results on the Higgs boson become available. Using natural language processing, the articles are categorised according to properties of the Higgs boson and other criteria. The process of designing and implementing the Higgs Boson Portal (HBP) is described in detail. The components of the HBP are deployed to CERN Web Services using the OpenShift cloud platform. The web portal is operational and freely accessible on http://cern.ch/higgs.

T 24.5 Mon 17:20 T-H37

Management of conference presentations in CMS — •Arnd Meyer — III. Physikalisches Institut A, RWTH Aachen, Germany

While presentations of the scientific output to the community in conferences and workshops constitute a major duty of any collaboration, large collaborations face the issue of ensuring the highest quality, a proper recognition of the work done by members, and an adequate representation of all the contributing bodies and institutions. In this talk, the management of conference presentations by the CMS collaboration as well as a statistical analysis over the past 14 years are summarized.

T 25: Data Analysis, Information Technology and Artificial Intelligence

Time: Monday 16:15–18:25 Location: T-H38

Group Report T 25.1 Mon 16:15 T-H38

CROWN - A Software framework for fast analysis ntuple production — •Sebastian Brommer[1], Markus Klute[1], Nikita Shadskiy[1], Guenter Quast[1], Roger Wolf[1], and Sebastian Wozniewski[2] — [1]Karlsruhe Institute of Technology — [2]Universität Göttingen

With the ever-increasing data recorded by the LHC experiments, new software solutions are required to handle the rising demand in computational power and to ensure fast and efficient processing of the data. The CROWN framework is designed to provide such a fast and robust solution for the conversion of stuctured event data into flat ntuples for histogramming and further analysis. Within the framework, code generation is used to create compiled C++ executables based on ROOT data frames, ensuring fast data processing with minimal dependencies.

In this talk, the core concepts of the framework as well as performance comparisons to existing solutions are presented.

Group Report T 25.2 Mon 16:35 T-H38

Verringerung systematischer Unsicherheiten durch systematics-aware training — Markus Klute, Günter Quast, •Lars Sowa, Roger Wolf und Stefan Wunsch — Karlsruhe Institute of Technology (KIT)

Eine Aufgabe für Analysen in der Hochenergiephysik besteht in der Trennung von Signal und Untergrundereignissen. Durch statistische Anpassung an Daten werden mit Hilfe dieser Trennung Fitparameter und deren Unsicherheiten, die die Genauigkeit der Fitparameter quantifizieren, bestimmt. Um statistische Unsicherheiten dieser Fitparameter zu minimieren, nehmen moderne Teilchenbeschleuniger enorme Datenmengen auf. Infolgedessen treten systematische Unsicherheiten verstärkt in den Vordergrund und Methoden zu deren Unterdrückung gewinnen für Analysen zunehmend an Wichtigkeit.

Dieser Vortrag präsentiert Studien zur Verringerung systematischer Unsicherheiten. Dabei wird eine diagnostische, auf Taylorkoeffizienten basierende Methode verwendet, um den Einfluss systematischer Variationen der Eingangsparameter auf die Ausgabefunktion eines Neuronalen Netzes zu untersuchen. Darauf aufbauend werden erprobte Methoden für systematics-aware training erläutert und vielversprechende, zur Umsetzung geplante Methoden vorgestellt.

T 25.3 Mon 16:55 T-H38

Understanding Event-Generation Networks via Uncertainties — Marco Bellagente[1], Manuel Haussmann[2], •Michel Luchmann[3], and Michel Luchmann[4] — [1]Institut für Theoretische Physik, Universität Heidelberg, Germany — [2]Heidelberg Collaboratory for Image Processing, Universität Heidelberg, Germany —

[3]Institut für Theoretische Physik, Universität Heidelberg, Germany — [4]Institut für Theoretische Physik, Universität Heidelberg, Germany

Following the growing success of generative neural networks in LHC simulations, the crucial question is how to control the networks and assign uncertainties to their event output. We show how Bayesian normalizing flows or invertible networks capture uncertainties from the training and turn them into an uncertainty on the event weight. Fundamentally, the interplay between density and uncertainty estimates indicates that these networks learn functions in analogy to parameter fits rather than binned event counts.

T 25.4 Mon 17:10 T-H38

Evaluating Uncertainties in Measurements of the Production of a Single Top-Quark in Association with a Photon with Bayesian Neural Networks — Johannes Erdmann[1], Burim Ramosaj[2], and •Daniel Wall[1] — [1]TU Dortmund University, Department of Physics — [2]TU Dortmund University, Department of Statistics

Multivariate approaches including neural networks constitute powerful and established methods in experimental particle physics. However, using these methods, it is difficult to account for uncertainties from statistical and systematic sources in a consistent and efficient way. By employing weight distributions instead of fixed weights and by utilising the process of Bayesian inference, Bayesian Neural Networks not only suffer significantly less from overfitting, but also allow to obtain an uncertainty estimate on the output.

These characteristics are of particular interest in measurements of processes suffering from limited statistics and challenging signal-to-background ratios. The analysis of top-quark production in association with a photon ($tq\gamma$), probing the structure of the electroweak couplings of the top quark, is one of such processes, as the corresponding cross section is considerably lower than those of relevant background processes, most importantly top-quark pair production ($t\bar{t}\gamma$).

In this talk, studies of Bayesian Neural Networks for their application in the classification of top-quark processes in association with a photon are presented.

T 25.5 Mon 17:25 T-H38

Non-parametric background models for axion haloscopes — •Johannes Diehl[1], Jakob Knollmüller[2], and Oliver Schulz[1] — [1]Max Planck Institute for Physics, Munich, Germany — [2]Max Planck Institute for Astrophysics, Munich, Germany

Axions have been introduced to solve the strong CP problem of the standard model of particle physics and turned out to be an excellent candidate to explain cold dark matter. "Haloscopes" are searching world wide for axions from the galactic dark matter halo, mostly by axion conversion to photons at radio frequencies in a strong B-field. Finding an axion signal in haloscope data means finding a small peak in a vast non-uniform RF background. One crucial challenge is therefore to selectively suppress larger frequency scales while inducing as little attenuation and correlation as possible at smaller frequency scales. This has so far been tackled using filter theory, e.g. through Savitzky-Golay filters for the HAYSTAC experiment, but proof that this is the optimal filter to use is still lacking. Using simulated data from the MADMAX haloscope, I present a novel machine-learning based approach to separate scales and subtract the background without attenuating the signal which lends itself well to being incorporated into a final Bayesian analysis.

T 25.6 Mon 17:40 T-H38

Open Science in KM3NeT — •Jutta Schnabel for the ANTARES-KM3NET-ERLANGEN-Collaboration — Erlangen Centre for Astroparticle Physics, FAU Erlangen-Nürnberg

The KM3NeT neutrino detectors are currently under construction at two locations in the Mediterranean Sea, with a first taking of data from high-energy neutrino interactions already under way. This scientific data is valuable both for the astrophysics and neutrino physics communities as well as for marine biologists. In order to facilitate FAIR data sharing of the research results, the KM3NeT collaboration is actively working towards an open science infrastructure to provide high-level scientific data, software, and analysis pipelines in an interoperable research environment suited both for research and education. This contribution introduces the open science program of KM3NeT and gives an overview of its current architecture and implementation.

T 25.7 Mon 17:55 T-H38

Columnar data analysis with ATLAS analysis formats — •Nikolai Hartmann — Ludwig-Maximilians-Universität München

Future analysis of ATLAS data will involve new small-sized analysis formats to cope with the increased storage needs. The smallest of these, named DAOD_PHYSLITE, has calibrations already applied to allow fast downstream analysis and avoid the need for further analysis-specific intermediate formats. This allows for application of the "columnar analysis" paradigm where operations are applied on a per-array instead of a per-event basis. This presentation shows the latest developments of tools within the scientific python ecosystem and discusses a prototype analysis for testing both on single Machines as well as Analysis Facilities or similar scale-out systems.

T 25.8 Mon 18:10 T-H38

Information visualization platform for data quality monitoring of CMS tracker — •Abhit Patil — Ruprecht-Karls-Universität Heidelberg, Germany

The tracker of the CMS detector consists of silicon sensors arranged in concentric cylinders and endcap disks to track muons, which requires continuous monitoring during operation and certification of the recorded data for physics analysis. The process relies on shifters who assess the data quality by comparing data distributions with references. This challenging task requires examining possible types of failures with expert-based rule systems and manual profiling of a large number of histograms. To assess the quality of data volumes with finer granularity and to improve the quality of the data certification, this work proposes to augment the monitoring process with information visualization based methods, which aims to pre-process large amount of multidimensional data during the data taking period and provide a visual abstraction of the data quality and provide hints for potential anomalies. The visualisation methods are deployed on a platform built using Python-Django framework and Postgres database.

T 26: Data Analysis, Information Technology and Artificial Intelligence

Time: Monday 16:15–18:30 Location: T-H39

T 26.1 Mon 16:15 T-H39

Investigation of robustness of b-Tagging algorithms for the CMS Experiment — Xavier Coubez[1,2], Nikolas Frediani[1], Spandan Mondal[1], Andrzej Novak[1], Alexander Schmidt[1], and •Annika Stein[1] — [1]RWTH Aachen University, Germany — [2]Brown University, USA

Deep learning as one form of machine learning is utilized for various applications and shows its benefits also in the field of high-energy physics, or more specifically, for jet flavour tagging. However, subtle mismodelings in the simulation could be invisible to typical validation methods. Investigating the response to mismodeled input data is motivated by the later usage of the outputs in physics analyses, as the values for simulation and data are deviating. The vulnerability of b-tagging algorithms used at the CMS experiment is probed through application of adversarial attacks. In this talk, a corresponding defense strategy that improves the robustness, namely adversarial training, will be presented. Comparisons of the model performance and the susceptibility show that this method constitutes a promising candidate to reduce the vulnerability and that this could improve the capability to generalize to data.

T 26.2 Mon 16:30 T-H39

Performance Studies of the Conditional Attention Deep Sets *b*-Tagger for the ATLAS Experiment — •Alexander Froch[1], Manuel Guth[2], and Andrea Knue[1] — [1]Albert-Ludwigs-Universität Freiburg — [2]Université de Genève

The identification of jets containing *b*-hadrons, called *b*-tagging, is crucial for most analyses performed at the ATLAS experiment. Several new multivariate techniques have been developed for this purpose. One of these is the Deep-Impact-Parameter-Sets (DIPS) tagger.

The DIPS tagger is a deep neural network based on the Deep-Sets architecture. It uses track information of the particles inside the clustered jets for classification. It is part of a new generation of tagging algorithms currently developed in ATLAS. DIPS itself can distinguish between different jet origins, like light, charm or bottom jets.
Although DIPS already outperforms the currently recommended RNNIP tagger, its high-p_T performance can still be improved further. While the number of fragmentation tracks increases rapidly with p_T, less heavy-flavour tracks are being reconstructed at high p_T. Therefore, it is more difficult for this kind of network to filter the most important tracks.
To further enhance the tagging capabilities of DIPS and fix the issues arising in the higher p_T region, DIPS will be extended with an attention mechanism conditioned on jet kinematics. This new version is the Conditional Attention Deep Sets (CADS) tagger.
The new CADS tagger will be discussed and its performance will be compared to the current best DIPS model.

T 26.3 Mon 16:45 T-H39

Charm tagger shape calibration for BDT-based signal-background discrimination — •Spandan Mondal[1], Xavier Coubez[1,2], Alena Dodonova[1], Ming-Yan Lee[1], Luca Mastrolorenzo[1], Andrzej Novak[1], Andrey Pozdnyakov[1], Alexander Schmidt[1], and Annika Stein[1] — [1]RWTH Aachen University — [2]Brown University, USA

Identification of charm-quark-initiated jets at the LHC is especially challenging. Usage of deep learning based algorithms have enabled several CMS analyses to efficiently discriminate charm jets simultaneously from bottom and light jets. The charm probability scores yielded by such charm tagging algorithms can play a powerful role when used as inputs to a machine learning based algorithm for discrimination between signal and background. However, as jet identification algorithms are trained strictly on simulated jets, a direct usage of charm tagger output values requires calibrating the entire output probability distributions using real jets reconstructed from CMS data. This talk focuses on the calibration of the output discriminator values of charm-tagging algorithms using flavour-enriched selections of jets in data. Additionally, the improvement resulting from a shape calibration approach, over the traditional approach of calibrating efficiencies at fixed c-tagger working points, is exemplified in the context of the resolved VHcc analysis.

T 26.4 Mon 17:00 T-H39

Reduction of the Irreducible Background in the $t\bar{t}H(b\bar{b})$ Analysis at ATLAS, Using a Deep-Sets-Based $b\bar{b}$-Tagger — •Joschka Birk, Alexander Froch, and Andrea Knue — Albert-Ludwigs-Universität Freiburg

The search for the $t\bar{t}H(b\bar{b})$ signal suffers from the large irreducible $t\bar{t}+b\bar{b}$ background. This irreducible background contains the same final-state particles as the signal, including four b quarks. In the background process, a radiated gluon can split into a b-quark pair, which often leads to two b-jets that are very close together. With the currently used b-tagging algorithm, these $b\bar{b}$-jets are often misidentified as a single b-jet.
In order to improve the rejection of these background events, the existing Deep-Impact-Parameter-Sets (DIPS) Tagger is extended with an additional output class dedicated to jets which contain two b-hadrons ($b\bar{b}$-jets). DIPS is part of a new ATLAS b-tagging algorithm, based on the Deep Sets architecture, and has already shown promising performance compared to the RNNIP tagger, which is part of the DL1r tagger that is currently used in ATLAS analyses. Studies of this extended version of the DIPS tagger, including first results of a hyperparameter optimisation, are presented.

T 26.5 Mon 17:15 T-H39

High-p_T b-tagging using track classification in the ATLAS experiment — Beatrice Cervato, Markus Cristinziani, Gabriel Gomes, Vadim Kostyukhin, •Katharina Voss, and Wolfgang Walkowiak — Center for Particle Physics Siegen, Experimentelle Teilchenphysik, Universität Siegen

In the ATLAS experiment the search for new physics beyond the Standard Model is of particular interest. In many theories, new physics processes result in the production of energetic b-quarks, fragmenting to high-p_T jets in the detector. Many successful b-jet identification algorithms suffer from the jet energy increase due to higher multiplicity of fragmentation tracks, reduced track reconstruction efficiency and, looking ahead to the High-Luminosity LHC, increased pile-up. As b-tagging algorithms typically use properties of the track-in-jet ensemble, the increased multiplicity of fragmentation tracks in energetic jets inevitably decreases the b-tagging efficiency at high p_T. A b-tagging algorithm, based on a multivariate technique, particularly suited for very energetic events, is presented. The multiplicity problem is solved by considering only those tracks, which are most likely to stem from a B-hadron decay. These are identified through a multi-class multivariate track classification algorithm, considering heavy flavour, fragmentation and other tracks from material interactions, as well as pile-up tracks.

T 26.6 Mon 17:30 T-H39

Exploration of neural network architectures for Flavour Tagging algorithms at the LHCb experiment — •Vukan Jevtic[1], Quentin Führing[1], Christoph Hasse[3], Niklas Nolte[2], and Claire Prouvé[1] — [1]Experimentelle Physik 5, TU Dortmund — [2]MIT — [3]CERN

The LHCb detector at the LHC is specialised for measurements of B meson decays, which open a window into the nature of weak interactions through measurements of rare decays and charge parity (CP) violation. In the Standard Model, CP violation is enabled through a complex phase of the Cabibbo-Kobayashi-Maskawa quark-mixing matrix. B meson mixing refers to the property of neutral B mesons to oscillate between two states of matter, B^0_q and $\overline{B^0}_q$, with different quark contents (i.e. different flavours).

The reconstruction of the flavour at the time of the B meson production is a difficult but indispensable component of measurements of time-dependent CP violation at LHCb. In this talk new approaches to Flavour Tagging via full-event-interpretation techniques will be presented by the example of recurrent neural networks and deep sets.

T 26.7 Mon 17:45 T-H39

Regression of Missing Transverse Momentum (MET) with Graph Neural Networks — •Nikita Shadskiy[1], Matteo Cremonesi[2], Jost von den Driesch[1], Lindsey Gray[3], Ulrich Husemann[1], Yihui Lai[4], and Michael Wassmer[1] — [1]Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT) — [2]University of Notre Dame — [3]Fermilab — [4]University of Maryland

Neutral particles that are only interacting weakly, like neutrinos, which are known from the standard model, or other, still unknown, particles in theories beyond the standard model, can be measured indirectly using the missing transverse momentum (MET). Analyses which search for specific invisible particles or expect such particles in their final state need well reconstructed MET. The reconstruction of MET is sensitive to e.g. experimental resolutions, mismeasurements of reconstructed particles or pileup interactions and is therefore a challenging task.

This talk will give an overview about a new approach to reconstruct MET with graph neural networks using information from particle flow (PF) candidates. Particle flow is an algorithm used by the CMS collaboration to reconstruct particles by combining information from different detector parts. Using graphs is a more intuitive way to describe the topology of an event because it has the advantage to be permutation invariant. Thus, the order of the PF candidates is irrelevant. The graph neural network is optimized to predict a weight for each PF candidate. These predictions are then used to weight the contribution of each PF candidate in the calculation of MET.

T 26.8 Mon 18:00 T-H39

Studies of machine learning inspired clustering algorithms for jets — Amrita Bhattacherjee[1], Debarghya Ghoshdastidar[1], •Siddha Hill[2], and Stefan Kluth[2] — [1]TUM Informatik — [2]MPI für Physik

We study several machine learning inspired hierarchical clustering algorithms algorithms to cluster the particles of hadronic final states in high energy e+e- collisions into jets. We compare their performance against well known algorithms such as JADE or Durham. Performance indicators are physically motivated such as angular distance or energy difference of matching jets at parton, hadron or detector level. We also study new performance indicators derived from computer science clustering theory.

T 26.9 Mon 18:15 T-H39

Improvement of the Jet-Parton Assignment in $t\bar{t}H(b\bar{b})$ Events using Symmetry-Preserving Attention Networks — •Daniel Bahner, Andrea Knue, and Gregor Herten — Albert-Ludwigs-University, Freiburg, Germany

The associated production of a Higgs boson and a top-quark pair allows for a direct measurement of the top-Higgs Yukawa coupling, which can be sensitive to Beyond Standard Model physics. In the studies presented, the process of interest is the semileptonic decay of the $t\bar{t}$-pair accompanied by a $b\bar{b}$-pair resulting from the most prominent Higgs decay. In this topology, at least four b-jets and two light jets are expected. This Higgs decay channel suffers from irreducible background due to $t\bar{t} + b\bar{b}$ production. Furthermore, the full reconstruction of this final state proves difficult because of the ambiguities in assigning the jets to their original parton, which is called combinatorial background.

In the latest publication, a Boosted Decision Tree was used for the jet-parton assignment. In the studies presented in this talk, a novel Symmetry-Preserving Attention Network is exploited (suggested in arXiv:2106.03898). The training was performed and evaluated on two different samples: In the first sample the full detector simulation with Geant4 and the new ATLAS b-tagging algorithm *DL1r* was used and in the second sample the Delphes framework was used. The performances of the networks and possible future improvements will be presented.

T 27: Invited Talks 2

Time: Tuesday 11:00–12:30 Location: T-H15

Invited Talk T 27.1 Tue 11:00 T-H15
First Results From the Next Generation B-Factory Experiment Belle II — •Thomas Kuhr — Ludwig-Maximilians-Universität München

The first generation B-factory experiments BaBar and Belle had successfully confirmed the theory of CP violation in the Standard Model, but it is known to be insufficient to explain the observed matter antimatter asymmetry in the universe. To address this and further open questions more precise measurements are needed to find evidence for a more general theory.

The Belle II experiment at the SuperKEKB accelerator in Tsukuba, Japan is designed to collect 50 times more data than its predecessor. The increase in luminosity and backgrounds is a challenge for the detector and the data processing and analysis. The physics data run started in 2019.

The status of the experiment, with focus on the Pixel Vertex Detector, and first physics results, highlighting the complementarity to the flavor physics program at the LHC, will be presented.

Invited Talk T 27.2 Tue 11:30 T-H15
Flavour Anomalies — •Christoph Langenbruch — RWTH Aachen, Germany

Precision measurements of observables in heavy flavour decays constitute powerful tests of the Standard Model of particle physics. New heavy particles beyond the Standard Model can significantly affect flavour observables through (virtual) quantum corrections. Precision measurements of these observables can reveal potential deviations from the Standard Model predictions and probe energy scales far beyond the beam energies presently available at colliders.

The talk will present recent precision measurements of flavour observables by the B-factories BaBar and Belle (II), and the LHC experiments ATLAS, CMS, and LHCb. Particular focus will be on the *flavour anomalies*, recent tensions between measurements and SM predictions in the flavour sector, and prospects for their clarification in the near future.

Invited Talk T 27.3 Tue 12:00 T-H15
The top quark is still going strong (and electroweak) — •Andrea Knue — Albert-Ludwigs-University Freiburg

The unique properties of the top quark have fascinated particle physicists since several decades. With its large mass, the top quark is expected to be connected to the mechanism of electroweak symmetry breaking. Moreover, the top quark is key to most research areas at the LHC: it can be measured very precisely, it is involved in rare processes that are finally accessible and it plays a special role in beyond-standard-model theories that are constantly being tested.

In this talk, the latest top-quark results will be discussed, revealing a rich research landscape that is thriving on the abundance of collision data available at the LHC.

T 28: Invited Topical Talks 1

Time: Tuesday 14:00–15:40 Location: T-H15

Invited Topical Talk T 28.1 Tue 14:00 T-H15
Hadronic Jets: Accuracy and Precision of their Reconstruction and Calibration in ATLAS — •Christopher Young — University of Freiburg, Freiburg im Breisgau, Germany

Hadronic jets are prolifically produced in LHC collisions such that their reconstruction is essential for understanding many different physics processes. This talk will detail how such jets are precisely reconstructed in the ATLAS detector using a particle flow algorithm developed for the high pile-up environment of Run 2 of the LHC and beyond. Additionally the accuracy of the calibration of the energy scale of hadronic jets is a leading source of experimental systematic uncertainty in many searches and measurements. The derivation of the latest calibration using data, and the accuracy and understanding achieved will also be covered.

Invited Topical Talk T 28.2 Tue 14:25 T-H15
Direct searches testing BSM explanations of the flavor anomalies — •Arne Christoph Reimers — Universität Zürich, Switzerland

Anomalies measured in the decay of B mesons have revealed first indications for the possible existence of lepton flavor universality violation. If confirmed by future measurements, the presence of such processes in nature would imply physics beyond the standard model.

In this presentation, LHC results of direct searches for new particles that are commonly proposed as an explanation for the flavor anomalies are reviewed. Particular emphasis is given to final states with large transverse momenta.

Invited Topical Talk T 28.3 Tue 14:50 T-H15
ATLAS probes QCD measuring photons — •Heberth Torres — TU Dresden, Germany

The production of prompt isolated photons in proton-proton collisions is an important test of perturbative QCD prediction. Despite its electromagnetic nature, photon production at the LHC is affected by surprisingly large strong-interaction effects. Thanks to the precise ATLAS measurements of photon processes, the collaboration is able to probe these effects and scrutinise state-of-the-art theoretical calculations. In this talk, we present the latest measurements of prompt photon production using proton-proton collision data collected by the ATLAS experiment at $\sqrt{s} = 13$ TeV.

Invited Topical Talk T 28.4 Tue 15:15 T-H15
The upgrade of the ATLAS trigger to augment the physics reach of Run-3 — •Daniele Zanzi — Albert-Ludwigs-Universität Freiburg, Freiburg, Germany

The ATLAS experiment uses a two-level trigger system to record about 1 kHz out of the 40 MHz of collisions delivered by the LHC. After a very successful operation in Run-2, the ATLAS trigger system has gone through a radical upgrade both in hardware and in software in preparation for Run-3. This upgrade is critical for maintaining the high data-taking efficiency achieved in Run-2, while opening up new trigger opportunities to augment the ATLAS physics programme. This talk will present an overview of the ATLAS trigger system in Run-3 together with studies on its expected performance.

T 29: Invited Topical Talks 2

Time: Tuesday 14:00–15:40 Location: T-H16

Invited Topical Talk T 29.1 Tue 14:00 T-H16
Testing the Standard Model through Gauge-boson Self-interactions — •Philip Sommer — The University of Sheffield, Sheffield, United Kingdom; CERN, Geneva, Switzerland

In the Standard Model, electroweak interactions of fermions proceed through the exchange of gauge bosons, the W and Z bosons, and the photon. In addition, self-interactions of the gauge bosons through trilinear and quartic couplings are predicted. At the LHC, these lead to the production of single- and multiboson final states. Measurements of such processes, thus, provide a sensitive probe of the gauge structure of the electroweak theory. The pp collision data from the second experimental phase of the LHC has allowed for precise measurements of processes proceeding through trilinear couplings and facilitated, for the first time, the observation of a number of processes that proceed through quartic electroweak couplings. Recent measurements of single- and multi-boson production by the ATLAS collaboration are presented. The agreement of the measurements with the theoretical predictions is quantified by constraining Effective Field Theory operators that modify the trilinear and quartic gauge-boson self-interactions in a general extension of the Standard Model.

Invited Topical Talk T 29.2 Tue 14:25 T-H16
Axions and similar particles - how to cover 10^{17} orders of magnitude in mass — •Kristof Schmieden — Johannes Gutenberg-Universität Mainz

Axions, the famous hypothetical particle that explains the absence of CP violation in QCD, was already though of in the 70ies. Yet only in the past decade the hunt for this and similar particles took up pace, which huge advancements in the recent years. The reason behind the growing interest is the understanding that axions and axion-like particles can contribute to the dark matter content of the universe. In fact, pseudo-scalar particles are a natural prediction of many extensions of the Standard model and even possibly explain the muon (g-2) anomaly. Considering the general case of pseudo-scalar particles a huge parameter space in mass and coupling to SM particles opens up, requiring a variety of experimental approaches to hunt for these particles. This talk will briefly introduce the phenomenology of axions and axion-like particles and discuss a selection of experiments and their latest results in more detail.

Invited Topical Talk T 29.3 Tue 14:50 T-H16
From GERDA to LEGEND - Hunting no neutrinos — •Christoph Wiesinger — Max-Planck-Institut für Physik, München — Physik-Department, Technische Universität München, Garching

Hidden by their tiny mass, neutrinos may carry a profound secret with far-reaching consequences for both particle physics and cosmology. Given zero electric charge and no color, they may be Majorana particles - fermions that are their own anti-particles. Double beta decay offers a unique probe for this hypothesis. Finding no neutrinos, but solely two electrons sharing the full available decay energy, would prove lepton number non-conservation and reveal the Majorana character of neutrinos. The superb spectroscopic performance of high-purity germanium detectors provides exceptional discovery potential for this mono-energetic peak. The Germanium Detector Array (GERDA) experiment has operated 40 kg of enriched germanium in an instrumented low-background liquid argon environment. In a total exposure of more than 100 kg yr, taken under record-low background conditions, no signal was found. The corresponding half-life limit for neutrinoless double beta decay of ^{76}Ge is $>1.8\cdot10^{26}$ yr at 90% C.L., and coincides with the median sensitivity for the null hypothesis. The Large Enriched Germanium Experiment for Neutrinoless double beta Decay (LEGEND) is about to expand this search towards 10^{28} yr and beyond. Following LEGEND-200, the initial 200-kg phase currently under construction, LEGEND-1000 will probe the full parameter space spanned by the inverted ordering scenario.

Invited Topical Talk T 29.4 Tue 15:15 T-H16
Mapping Highly-Energetic Messengers throughout the Universe — •Sara Buson — Institut für Theoretische Physik und Astrophysik, Universität Würzburg

Cosmic rays prove that our Universe hosts elusive astrophysical "monsters" capable of continuously and efficiently accelerating particles at extreme energies. High-energy photons and neutrinos may be the key to ultimately decipher the mystery of cosmic rays. In 2017, the candidate detection of neutrino emission from the direction of the gamma-ray flaring blazar TXS 0506+056 has put forward gamma-ray blazars as promising neutrino point-sources, hence cosmic-ray accelerators. However, to date there is neither a consistent picture for the physical mechanism nor a theoretical framework capable of convincingly explain the full set of multi-messenger observations. I will present initial encouraging steps in this multimessenger (electromagnetic and neutrino) quest and finally discuss the latest status of the field.

T 30: Flavour Physics 3

Time: Tuesday 16:15–18:30 Location: T-H15

T 30.1 Tue 16:15 T-H15
Time-Dependent Charge-Parity Violation at Belle II — •Caspar Schmitt — Max-Planck Institute for Physics, Munich, Germany

Overconstraining the unitarity triangle of the Cabibbo-Kobayashi-Maskawa mixing matrix by precision measurements is an essential test for the description of weak currents in the standard model (SM) of particle physics. We thereby test our present understanding of charge-parity (CP) violation in the quark sector and search for CP violation beyond the SM, necessary to explain the observed baryon-asymmetry in the universe.

We present time-dependent measurements of CP violation and flavor mixing in the B meson system using data from the Belle II Experiment. We introduce the measurement principles of time-dependent analyses at B factories and put emphasis on our latest analysis of flavor mixing in the neutral B meson system. In particular, we focus on the treatment and estimation of uncertainties resulting from residual background processes.

T 30.2 Tue 16:30 T-H15
Inclusive analysis of untagged $B \to Xl^+l^-$ decays at Belle II — •Sviatoslav Bilokin and Thomas Kuhr — Geschwister-Scholl-Platz 1, Munchen, Germany

The $b \to s(d)l^+l^-$ processes are sensitive to New Physics phenomena since these decays may only occur through loops in the Standard Model.

This contribution describes a study of $b \to s(d)l^+l^-$ decays at the Belle II experiment using a fully-inclusive approach, where we have no explicit restrictions on the quark hadron final states. So far, no results of fully inclusive $b \to s(d)l^+l^-$ studies have been published because of the small signal branching ratio in the Standard Model, limited efficiency of the established tagging methods, and high rate of background processes.

This analysis intends to use machine learning techniques to reject background processes and an unrestricted tag side to measure $R(X) = \mathcal{B}(B \to X\mu^+\mu^-)/\mathcal{B}(B \to Xe^+e^-)$ as a lepton universality test, similarly to $R(K)$ and $R(K^*)$ measurements, which are known for their deviations from the Standard Model predictions.

T 30.3 Tue 16:45 T-H15
Belle II results on charmless hadronic B-decays and prospects — •Justin Skorupa, Thibaud Humair, Hans-Günther Moser, Markus Reif, and Benedikt Wach — Max Planck Institute for Physics

The Belle II experiment at the SuperKEKB e+ e- accelerator in Tsukuba, Japan, aims to constrain the parameters of the Cabibbo-Kobayashi-Maskawa matrix by measuring the size of the sides and angles of the unitary triangle associated to B-meson decays. Possible non-closure of the triangle would provide a hint for physics beyond the Standard Model. Belle II will significantly improve the accuracy of the determination of the angle ϕ_2 of the unitary triangle due to the large yield of expected charmless hadronic B-meson decays. Measurements of branching ratios of several charmless hadronic B-meson decays using 190 fb^{-1} of Belle II data are presented.

T 30.4 Tue 17:00 T-H15

Search for the lepton flavour violating decay $B^0 \to \tau^\pm \ell^\mp$ — •Nathalie Eberlein, Thomas Lück, and Thomas Kuhr — Ludwig-Maximilians-Universität, München

Lepton flavour is conserved in the Standard Model, but violated in many new physics models. An observation of the $B^0 \to \tau^\pm \ell^\mp$ decay, where $\ell = e/\mu$, would be a clear sign for new physics.

At B factories one can determine the kinematics of the signal B meson by fully reconstructing the accompanying B meson in $e^+e^- \to \Upsilon(4S) \to$ BB events. In the rest frame of the signal B meson the mono-energetic lepton provides a clean signature to identify the signal decays. This talk presents the current status of the search for $B^0 \to \tau^\pm \ell^\mp$ decays with Belle data using the Full Event Interpretation algorithm for the reconstruction of the accompanying B meson.

T 30.5 Tue 17:15 T-H15

Search for the LFV Decay $\tau \to \mu\pi^0$ — •Marton Nemeth-Csoka, Felix Meggendorfter, and Christian Kiesling — Max-Planck-Institute for Physics Munich

During its runtime from 1999 to 2010 the Belle experiment was able to confirm the Kobayashi-Maskawa theory about the occurrence of $\mathcal{CP}$ violation and by this played a decisive role in firmly establishing the Standard Model (SM). However, there is also convincing evidence for physics beyond the SM.

Belle's upgraded successor Belle II aims for a higher precision with a goal to collect 50 times more data than Belle, a total integrated luminosity of $L_{\text{int}} = 50ab^{-1}$.

This work focuses is on the lepton flavor violating decay $\tau \to \mu\pi^0$ with the goal to explore the prospects of finding New Physics in this particular channel.

In the analysis, the decay simulated by a Monte Carlo software including detectors and full reconstruction to get an understanding of the overall kinematics. When studying the background, the largest background is that of the pair production of muons, together with light quarks and τ that decay according to the predictions of the SM.

After applying kinematic cuts and requiring a moderate confidence threshold for the identification of the muon, only 5.3% of the signal is left, but the background is fully suppressed in a sample equaling $100fb^{-1}$.

T 30.6 Tue 17:30 T-H15

Analysis of $B \to \mu\nu$ with inclusive tagging at Belle II — Florian Bernlochner, Jochen Dingfelder, •Daniel Jacobi, Peter Lewis, and Markus Prim for the Belle II-Collaboration — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

$B\overline{B}$ meson pairs are the dominant decay products of the $\Upsilon(4S)$ resonance, which is produced in large amounts in e^+e^- collisions at the SuperKEKB collider in Japan, and their decays are measured by the Belle II experiment. Leptonic B meson decays such as $B \to \mu\nu$ are highly CKM- and helicity-suppressed. In a two-body decay like $B \to \mu\nu$, the muon momentum is exactly known in the rest frame of the signal-side B meson. By boosting the signal-side muon into that frame, a better signal resolution and improved sensitivity can thus be achieved compared to the center-of-mass frame. This requires a high-precision for the boost vector, which can be determined from the rest of the event that contains the decay products of the second B meson. At the same time, this information can be used to reconstruct the kinematics of the signal-side B meson. Boosted decision trees are trained to suppress background and increase signal purity. This talk will discuss the current status of the analysis and present approaches to maximize the sensitivity of the measurement of $B \to \mu\nu$ at Belle II, and will additionally provide an outlook on the search for sterile neutrinos.

T 30.7 Tue 17:45 T-H15

First Results and Prospects for $\tau \to \ell + \alpha$(invisible) at Belle II — •Thomas Kraetzschmar for the Belle II-Collaboration — Max-Planck-Insitut für Physik (Werner-Heisenberg-Insitut), München, Deutschland

The Belle II experiment at SuperKEKB, an asymmetric e^+e^- collider, aims at a total integrated luminosity of 50 ab^{-1}, to pursue a rich program of Standard Model and Beyond the Standard Model physics. Until the end of 2020 and the beginning of 2021, 62.8 fb^{-1} were collected at the $\Upsilon(4S)$ resonance. This data set results in a sizeable sample of τ pairs, enabling detailed studies of Standard and Beyond the Standard Model measurements, including searches for Lepton Flavor Violating (LFV) decays. One of the first channels where competitive limits are expected is the $\tau \to \ell + \alpha$(invisible) process, where α is a Goldstone boson. Here, the currently best limit has been obtained by ARGUS with an integrated luminosity of 475 pb^{-1}. Belle II will improve on this result with the recorded data. This contribution will discuss the first results of this search.

T 30.8 Tue 18:00 T-H15

Tau lifetime measurement at Belle II — •Anselm Baur and Daniel Pitzl — Deutsches Elektronen Synchrotron (DESY), Hamburg, Germany

The tau-lepton lifetime represents a fundamental parameter within the Standard Model framework, contributing to the test of lepton flavor universality. Exploiting the vertex detector resolution and the tiny beam spot size at the interaction point, Belle II is expected to improve the present tau-lifetime value. The event topology where one tau decays to three charged hadrons (3-prong) and the other tau goes to a charged pion or lepton, allows to have an higher event yield respect to 3-prong vs 3-prong topology studied by Belle. Therefore, a measurement with a statistical uncertainty competitive with the world average could already be performed using Zech's Monte Carlo re-weighting method with an early Belle II dataset.

T 30.9 Tue 18:15 T-H15

Optimization of the K_L^0 detection and rejection at Belle II — Florian Bernlochner, Jochen Dingfelder, Peter Lewis, and •Lucas Stötzer for the Belle II-Collaboration — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

We investigate an optimization of the reconstruction of K_L^0 mesons in the Belle II experiment. K_L^0 mesons are challenging to detect and identify because they are chargeless, and due to their long lifetime they typically do not decay within the Belle II detector. The main way to detect them is via hadronic showers in the K-Long-Muon detector (KLM). However, the detection efficiency is low and background clusters are common, which limits the usability of the KLM clusters in physics analyses. Thus, we seek to improve the discrimination between KLM clusters produced by K_L^0 showers and background sources using a clean sample of K_L^0 mesons from the process $e^+e^- \to \gamma_{\text{ISR}}\,[\phi \to K_L^0 K_S^0]$. The K_S^0 will mainly decay to two charged pions. Thus, by finding the high energy photon (γ_{ISR}) and reconstructing the K_S^0 from the pions, the four-momentum of the K_L^0 can be inferred. This allows for a direct comparison between KLM clusters from K_L^0 and background sources. Further, we investigate whether K_L^0 showers deposited in the electromagnetic calorimeter can be used to improve the K_L^0 detection efficiency while maintaining high purity.

T 31: Beyond the Standard Model (Theory) 1

Time: Tuesday 16:15–18:15 Location: T-H16

T 31.1 Tue 16:15 T-H16

Constructing Effective Field Theories to Higher Mass Dimensions — Robert V. Harlander, Tim Kempkens, Jakob W. Linder, and •Magnus C. Schaaf — Institute for Theoretical Particle Physics and Cosmology, RWTH Aachen University

The Standard Model Effective Field Theory (SMEFT) provides a framework to parametrise the effects of yet unseen heavy degrees of freedom in a model independent way. While in recent years the interest in higher-dimensional operators has increased, the construction of a complete and minimal set of operators is remarkably challenging. In this talk, I will report on the implementation of a recently proposed group-theoretical algorithm for the construction of an operator basis. It systematically takes into account the redundancies which arise due to equations of motion and integration-by-parts identities among the operators. The resulting program can be applied to phenomenologically relevant theories like the Standard Model or extensions of it, including new light particles and additional symmetry groups.

T 31.2 Tue 16:30 T-H16

Catching Heavy Vector Triplets with the SMEFT: from one-loop matching to phenomenology — •Emma Geoffray[1], Ilaria Brivio[1], Sebastian Bruggisser[1], Wolfgang Kilian[2], Michael Krämer[3], Michel Luchmann[1], Tilman Plehn[1], and Benjamin Summ[3,4] — [1]Institute for Theoretical Physics, Heidelberg University, Germany — [2]Department of Physics, University of Siegen, Germany — [3]Institut für Theoretische Teilchenphysik und Kosmologie, RWTH Aachen University, Germany — [4]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Germany

An important question for both phenomenologists and experimentalists is whether one can put limits on UV model parameters by matching the full theory onto the SMEFT. I will show that this is possible and explore the complementarity between SMEFT and model-specific approaches.

In particular, I will focus on an additional theory uncertainty arising from the matching at one-loop and discuss how this affects the limits set for the Heavy Vector Triplet extension of the Standard Model. I use the SFitter framework to derive limits, taking into account Higgs measurements and electroweak precision data previously implemented, as well as two new resonance searches for VH and VV. I will discuss the impact of those measurements on the fit and the complementarity of our results with direct searches.

T 31.3 Tue 16:45 T-H16

Precision predictions for scalar leptoquark pair production at the LHC — •Christoph Borschensky[1], Benjamin Fuks[2], Adil Jueid[3], Anna Kulesza[4], and Daniel Schwartländer[4] — [1]KIT, Karlsruhe, Germany — [2]LPTHE/Sorbonne Université, Paris, France — [3]KIAS, Seoul, South Korea — [4]WWU Münster, Germany

Leptoquarks are particles that simultaneously carry lepton and baryon number, and appear in many extensions of the Standard Model. The appearance of so-called flavour anomalies has led to increased interest in leptoquark models which are known to mitigate the tensions between theoretical expectations and experimental measurements.

In my talk, I will present precision predictions for the production of scalar leptoquarks at the LHC, evaluated at next-to-leading order in QCD and improved by threshold resummation corrections at next-to-next-to-leading-logarithmic accuracy. Apart from QCD contributions, included are the lepton t-channel exchange diagrams relevant in the light of the recent B-flavour anomalies. The results exhibit an interesting interplay between the different contributions, affected considerably by the choice of parton distribution functions. Additionally, I discuss the impact of NLO-QCD corrections on the so-called off-diagonal production channels, i.e. the production of a pair of different components of a given leptoquark multiplet. These predictions consist of the most precise leptoquark cross section calculations available to date and are necessary for the best exploitation of leptoquark LHC searches.

T 31.4 Tue 17:00 T-H16

Constraining BSM models using high precision observables — •Marten Berger[1], Gudrid Moortgat-Pick[1,2], Georg Weiglein[1,2], and Sven Heinemeyer[3] — [1]II. Institute of Theoretical Physics, University of Hamburg, Germany — [2]DESY, Hamburg, Germany — [3]Instituto de Fisica Teorica UAM-CSIC, Madrid, Spain

The high experimental accuracy of the W boson mass, M_W, measurement provides a powerful tool to test the theory and differentiate between models. One of the best motivated extensions of the Standard Model (SM) is the Minimal Supersymmetric Standard Model (MSSM). The electroweak precision observables such as M_W are highly sensitive to loop contributions determined by the model parameters respectively. Therefore the precise experimental accuracy can be used to narrow down possible scenarios. In this talk a stand-alone mathematica code for predicting M_W in the MSSM is presented. It includes full one-loop as well as leading higher-order corrections of SUSY-type, which are combined with state-of-the-art SM-type contributions. The prediction for M_W is discussed in comparison with the current experimental result.

T 31.5 Tue 17:15 T-H16

Bachelor thesis: Vacuum stability constraints in the NMSSM — •Fabio Campello[1], Georg Weiglein[2], and Thomas Biekötter[2] — [1]Universität Hamburg, Hamburg, Deutschland — [2]DESY, Hamburg, Germany

In supersymmetric extensions of the Standard Model the electroweak (EW) vacuum is not generally the global minimum of the scalar potential, and tunneling to deeper minima is possible. Since the lifetime of the EW vacuum must be at least of the order of the age of the universe, constraints on the parameter space can be obtained from an analysis of vacuum stability. In this talk the vacuum structure of the next-to-minimal supersymmetric extension of the SM (NMSSM) is investigated, where the scalar potential receives contributions from an extended Higgs sector and from superpartners of the SM fermions. The results are discussed in comparison to the case of the minimal supersymmetric extension (MSSM).

T 31.6 Tue 17:30 T-H16

SU(6) Gauge Higgs Unification — •Andreas Bally[1], Andrei Angelescu[1], Florian Goertz[1], and Simone Blasi[2] — [1]Max Planck Institute for Nuclear Physics, Heidelberg — [2]Vrije Universiteit, Brussel, Belgium

We present a minimal viable Gauge-Higgs Grand Unification scenario in warped space based on a SU(6) bulk symmetry - unifying the gauge symmetries of the SM and their breaking sector. We show how the issue of light exotic new states is eliminated by appropriately breaking the gauge symmetry on the UV and IR boundaries by either brane scalars or gauge boundary conditions. The SM fermion spectrum is naturally reproduced including Dirac neutrinos and we compute the Higgs potential at one-loop, finding easily solutions with a realistic Higgs mass. The problem of proton decay is addressed by showing that baryon number is a hidden symmetry of the model. Among the phenomenological consequences, we highlight the presence of a scalar leptoquark and a scalar singlet. The usual X,Y gauge bosons from SU(5) GUTs are found at collider accessible masses.

T 31.7 Tue 17:45 T-H16

Baryogenesis and Dark Matter in Extended Inert Doublet Model — •Sven Fabian, Florian Goertz, and María Isabel Dias Astros — Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland

Despite the great success of the Standard Model (SM) of Particle Physics in explaining many experimental observations to an astonishing degree of accuracy, it cannot account for the long-standing conundrums of the nature of dark matter (DM) and of the obvious dominant abundance of matter compared to antimatter in our Universe. In this talk, we will discuss the Inert Doublet Model, augmented with a higher-dimensional operator tied to the SM gauge sector and – vital for baryogenesis – inducing CP violation. In addition to identifying the parameter space for the observed DM relic abundance, we investigate the potential of this operator for giving rise to the measured baryon asymmetry during the electroweak phase transition. We will find that the discussed extension of the IDM can, in principle, serve as an effective theory in which both DM and baryogenesis are accounted for.

T 31.8 Tue 18:00 T-H16

Higher-Dimensional Operators in the Inert Doublet Model: Dark Matter and CP Violation — •María Isabel Dias Astros, Florian Goertz, and Sven Fabian — Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland

Facing the puzzles of dark matter (DM) with its properties yet to be deciphered, the Inert Doublet Model (IDM) has been widely studied as a possible theory explaining DM and in the context of the Electroweak Phase Transition, as a first step towards accommodating the three Sakharov conditions allowing for baryogenesis. Following this motivation, we will discuss in this talk the IDM as an effective field theory (EFT) with a higher-dimensional CP-violating operator added to the scalar potential. Working with the EFT approach, a comprehensive discussion of DM phenomenology with promising parameter space is given, while taking theoretical and the latest experimental constraints into account. In particular, for particles heavier than 500 GeV higher-dimensional derivative operators lead to an extended viable parameter space even for non-(quasi)degenerate scalar masses. We conclude that the discussed sources of CP violation do not spoil the predicted DM relic abundance.

T 32: QCD (Exp.) 1

Time: Tuesday 16:15–18:15 Location: T-H17

T 32.1 Tue 16:15 T-H17

Measurement and QCD analysis of inclusive jet production in deep inelastic scattering at ZEUS — •Florian Lorkowski — DESY, Hamburg, Germany

The cross sections of deep inelastic scattering processes at the electron-proton collider HERA are a well established tool to test perturbative QCD predictions. Additionally, they can be used to determine the non-perturbative parton distribution functions of the proton. Measurements of jet production cross sections are particularly well suited to also constrain the strong coupling constant.

In this talk, a measurement of inclusive jet cross sections in neutral current deep inelastic scattering using the ZEUS detector at the HERA collider is presented. The data was taken in the years 2003 to 2007 at a center of mass energy of 318 GeV and corresponds to an integrated luminosity of 344 pb^{-1}. Massless jets, reconstructed using the $k_{\perp}$-algorithm in the Breit reference frame, are measured as a function of the squared momentum transfer Q^2 and the transverse momentum of the jets in the Breit frame $p_{\perp,\mathrm{Breit}}$.

The measured cross sections are compared to previous measurements as well as NNLO theory predictions. The consistency of the measurement is demonstrated by a simultaneous determination of parton distribution functions and the strong coupling constant.

T 32.2 Tue 16:30 T-H17

QCD and SMEFT analysis of CMS 13 TeV inclusive jet cross section data — •Toni Mäkelä and Katerina Lipka — DESY, Hamburg, Germany

The parton distributions of the proton, the strong coupling constant and the top quark mass are extracted simultaneously, using the cross sections of inclusive jet production and top quark-antiquark pair production at the LHC at a center of mass energy of 13 TeV. The standard model analysis is performed at NLO and NNLO. In an alternative analysis, the standard model cross section is extended with effective couplings for 4-quark contact interactions at NLO. In particular, left-handed vector-like or axial vector-like colour-singlet exchanges are considered. For the first time, the Wilson coefficients of contact interactions are extracted simultaneously with the standard model parameters using the LHC data.

T 32.3 Tue 16:45 T-H17

Triple-differential measurement of dijet production at $\sqrt{s} = 13$ TeV with the CMS detector — Günter Quast, Klaus Rabbertz, and •Daniel Savoiu — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

Jet measurements at high precision are an essential probe of quantum chromodynamics (QCD) and constitute valuable experimental inputs to determinations of fundamental QCD parameters and of the parton distribution functions (PDFs) describing the structure of protons.

In this talk, we present a recent measurement of the dijet production cross section using proton-proton collision data collected at a center-of-mass energy of 13 TeV by the CMS detector at the CERN LHC, amounting to an integrated luminosity of 36.3 fb^{-1}. Jets are reconstructed using the anti-k_T algorithm for radius parameters of $R = 0.4$ and 0.8 and cross sections are measured triple-differentially as a function of the kinematic properties of the two jets with largest transverse momenta. After accounting for detector- and reconstruction-specific effects in a three-dimensional unfolding procedure, the data are compared to theoretical predictions derived at next-to-next-to-leading order in perturbative QCD and the impact of the data for determinations of the proton PDFs and the strong coupling constant α_s is studied.

T 32.4 Tue 17:00 T-H17

Electroweak corrections to high pT jets — •Mikel Mendizabal and Hannes Jung — DESY, Hamburg, Germany

The production of electroweak (EW) bosons in association with jets has been extensively studied at particle colliders. The EW boson is considered the outcome of the hard process and the jets a product of parton evolution. These events are a great test of quantum chromodynamics and allow to study parton density functions and parton evolution equations. So far, light quarks and gluons are considered in the parton evolution. However, with increasing centre-of-mass energies the probability of radiating heavier particles increases.

In this analysis, the production of EW bosons in association with jets is studied specifically with the aim to investigate EW boson emitted in the parton shower. To this end, events with high transverse momentum jets are studied. Then, the contribution of EW boson emissions is measured.

Preliminary results are presented with data collected in 2016, corresponding to an integrated luminosituy of 36.3 fb^{-1}. The contribution of the Z boson is studied in the leptonic decay channel.

T 32.5 Tue 17:15 T-H17

Triple differential measurement of the inclusive Z+jet production — •Cedric Verstege, Klaus Rabbertz, and Günter Quast — Institut für Experimentelle Teilchenphysik, Karlsruher Institut für Technologie (KIT)

The triple differential inclusive cross section for Z ($\rightarrow \mu\mu$) + jet production is measured combining CMS Run II data from 2016-2018. The measurement uses the observables p_T^Z, the difference in rapidity between the Z-Boson and the jet y^* as well as the boost of the center of mass system y_b. Those variables allow for a suitable division of the phase space in order to obtain a better sensitivity to the partonic subprocesses.

Detector effects are corrected via a three-dimensional unfolding procedure. The resulting cross section is then compared to QCD theory predictions at next-to-next-to-leading order. The results can be used as constraints for fitting the PDFs.

T 32.6 Tue 17:30 T-H17

Measurement of jet mass distribution of hadronic W and Z bosons — •Steffen Albrecht[1], Andreas Hinzmann[1], Dennis Schwarz[2], and Roman Kogler[3] — [1]Universität Hamburg — [2]Austrian Academy of Sciences — [3]DESY Hamburg

In this talk we introduce a new effort towards measuring the jet mass distribution of hadronically decaying W and Z bosons.

We study events in which the bosons have a large transverse momentum and thus produce strongly collimated decay products reconstructed as single fat jets. The substructure of such jets proves to be a useful handle in various procedures (e.g. jet calibration, jet tagging), but has room for improvement in its modelling. We aim to gain an in-depth understanding of the substructure by studying the unfolded jet mass distribution in dependence of the jet p_T and substructure tagger discriminants. While previous measurements of jet mass have been carried out for gluon, quark and top jets in dijet, Z(ll)+jet and $t\bar{t}$ samples, this is the first study of W and Z jet masses in the processes with $W(qq)$+jets, $Z(qq)$+jets as well as hadronic $t\bar{t}$ systems in the final states.

In addition the measurement of the difference $m_Z - m_W$ will be pursued, setting a first step towards a potential measurement of the W mass with jet substructure.

T 32.7 Tue 17:45 T-H17

Jet Energy Calibration for Ultra Legacy Data with Z+Jet Events at CMS — •Robin Hofsaess, Daniel Savoiu, Florian von Cube, and Maximilian Horzela — KIT (ETP), Karlsruhe, Germany

High precision analyses in modern particle physics experiments rely on the measurement of jets coming from the particle interactions. Since jets comprise many different particles and the observation of such complex physics objects is affected by detector- and reconstruction-specific effects, sophisticated methods are necessary to get a reliable and accurate calibration of the jet energy.

At CMS, a factorized approach – collectively known as the jet energy calibration – is employed for correcting shifts in the jet energy. An important step in this process exploits events where a jet is balanced against a well-measured reference object such as the Z boson. By comparing the transverse momenta of the two objects, it is possible to determine the absolute jet energy scale, accounting for any residual differences between simulation and data.

In this talk, the methods for the determination of the jet energy scale will be described and the latest results for the legacy calibration of Run II will be presented.

T 32.8 Tue 18:00 T-H17

Differential cross section for $Z\gamma$+jets using the ATLAS detector — •Vincent Goumarre — Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

Differential measurements of the production of Zγ bosons in association with jet activity in pp collisions at $\sqrt{s} = 13$ TeV are presented in this work, using the full Run2 dataset of 139fb^{-1} collected by the ATLAS detector at the LHC.

Jet activity is a crucial point to study since differential distributions can help constrain important Standard Model (SM) parameters and calibrate models used in inputs in other observables, such as PDFs functions. Moreover, due to the possibility to fully reconstruct the final state, and a large cross section with a small background, $Z\gamma$ is a good candle to test beyond the SM physic, with models such as ALPs or anomalous gauge couplings.

Distributions are measured in a fiducial space with transverse momentum of the photon greater than 30 GeV and considering only events where the Z-boson decays leptonically. The sum of the dilepton invariant mass and the dilepton plus photons invariant mass has to be greater than 182 GeV to suppress final state radiation.

T 33: Top Quarks: Production (Exp.) 2

Time: Tuesday 16:15–18:30 Location: T-H18

T 33.1 Tue 16:15 T-H18

An effective field theory approach using top quark polarisation and spin correlations in $t\bar{t}$ production at the LHC — •Andre Zimermmane-Santos, Afiq Anuar, Alexander Grohsjean, and Christian Schwanenberger — Deutsches Elektronen-Synchrotron, Hamburg, Germany

The Effective Field Theory (EFT) approach provides a systematic and model-independent way to search for new physics. It assumes new heavier particles exist outside the energy reach of the LHC. Nonetheless, their effects can be parametrized by new effective interactions constructed with Standard Model (SM) fields. Hence, new couplings can be identified and measured via small deviations from SM predictions.

In this study, we aim to use particular sets of observables related to the top quark polarisation and spin correlation in top quark pair events with two leptons in the final state. Each of those sets are sensitive exclusively to a subset of EFT couplings. This provides a natural way of uncorrelating EFT effects, allowing limits on their strength to be drawn with unprecedented precision. We investigate various EFT scenarios using the *dim6top* and *SMEFTatNLO* models. Subsequently, we also verify necessary translations between different EFT formalism. Our findings pave the way for the EFT interpretation using full CMS Run 2 data.

T 33.2 Tue 16:30 T-H18

Measurement of the dileptonic t$\bar{\text{t}}$ differential cross section in a BSM phase space at CMS — Valeria Botta, Lutz Feld, •Danilo Meuser, Philipp Nattland, and Marius Teroerde — I. Physikalisches Insitut B, RWTH Aachen University

Measurements of the t$\bar{\text{t}}$ production cross section yield important precision tests of the Standard Model (SM), while also probing scenarios for physics beyond the SM (BSM).

This analysis aims to measure the t$\bar{\text{t}}$ cross section in a phase space where additional contributions from BSM scenarios could be present. It is based on the data set recorded by CMS in the years 2016 to 2018 at a center-of-mass energy of 13 TeV, corresponding to an integrated luminosity of 138 fb^{-1}. The BSM scenarios considered include supersymmetric and dark matter models, where, similarly to the dileptonic t$\bar{\text{t}}$ channel, two leptons, b jets and undetected particles are produced.

Unlike previous measurements, where the differential cross sections were mainly measured as a function of kinematic variables of the leptons or top quarks, this analysis focuses on observables related to the neutrinos, like the missing transverse momentum and the angular distance between the missing transverse momentum and the nearest lepton, to separate BSM from SM t$\bar{\text{t}}$ events. In order to increase the sensitivity of the analysis multivariant techniques are used which improve the resolution of the missing transverse momentum in SM t$\bar{\text{t}}$ events. In this talk the analysis strategy will be presented and preliminary results on the improved missing transverse momentum resolution and on systematic uncertainties will be shown.

T 33.3 Tue 16:45 T-H18

Studying prospects of a measurement of the cross section of top-quark pair production with additional charm quarks in the lepton+jets channel at ATLAS at $\sqrt{s} = 13$ TeV — •Lukas Ehrke, Tobias Golling, Manuel Guth, Johnny Raine, and Knut Zoch — Université de Genève, Geneva, Switzerland

The goal of this analysis is to measure the inclusive cross section of $t\bar{t}$ production with additional charm quarks in the ATLAS collaboration. This talk focuses on the semileptonic $t\bar{t}$ decay channel for which it would be the first measurement of this cross section. The measurement will benefit several analyses where this process is a non negligible background, most notably in the search for a $t\bar{t}$ pair in association with a Higgs boson where the Higgs boson decays into two b-quarks.

To reduce background processes not containing a $t\bar{t}$ pair b-tagging is needed, whereas to identify the events with additional c-quarks c-tagging is needed. A further complication in the lepton+jets channel are c-quarks originating from the hadronically decaying W boson. Therefore, the existing flavour tagging methods are extended to allow for simultaneous b- and c-tagging. New working points are derived on a 2D plane, and based on the b- and c-multiplicity, multiple regions are defined with different contributions of the different $t\bar{t}$+jets components. Initial studies show promising sensitivity to the cross section. The measurement in the lepton+jets channel benefits from larger statistics compared to the dilepton channel. However, the charm quarks from the hadronic W decays pose a greater modelling challenge.

T 33.4 Tue 17:00 T-H18

Measurement of the inclusive production cross sections of a top-quark pair in association with a Z boson at $\sqrt{s} = 13$ TeV in final states with three leptons using deep neural nets with the ATLAS detector — •Steffen Korn, Arnulf Quadt, and Elizaveta Shabalina — II. Physikalisches Institut, Georg-August-Universität Göttingen

Through the associated production of a top quark pair and a Z boson, the strength and structure of the neutral current weak coupling of the top quark and the Z boson can be measured. It provides sensitivity to the top quark's weak isospin in the framework of the Standard Model (SM). The measurement of this fundamental parameter of the SM also serves as a probe to new physics beyond the SM. The process was measured by ATLAS and CMS at $\sqrt{s} = 13$ TeV with the full run 2 data set. In a new, refined analysis multivariate techniques are used to improve the sensitivity of the measurement. The impact of the usage of multi-class deep neural network for event classification on the systematic uncertainties for a measurement of the inclusive cross section of $t\bar{t}Z$ final states with three charged leptons is presented.

T 33.5 Tue 17:15 T-H18

First simultaneous differential measurement of tZq and t$\bar{\text{t}}$Z processes at the CMS Experiment — •Federica Colombina, Andreas Meyer, and Abideh Jafari — Notkestraße 85, 22607 Hamburg, Germany

At the Large Hadron Collider (LHC) at CERN, about millions of top quark events have been produced. The data recorded during LHC Run-2, in the years 2016-2018, gave access to first differential measurements of top quark production in association with Z-bosons, and precisely probes the coupling between top quarks and Z bosons for the first time. The cross sections of top quark pair producton, t$\bar{\text{t}}$Z, and single-top quark production, tZq, are similar, and both processes are mutual backgrounds to one another. Measurements of top-Z coupling and EFT analyses require measurements of both these processes and their correlation. In this analysis, tZq and t$\bar{\text{t}}$Z are measured simultaneously for the first time, aiming to better understand the correlation between these two processes. Furthermore, the evaluation of their differential cross section can bring evidence of possible deviations from the standard model, providing information for EFT analyses and new physics scenarios.

T 33.6 Tue 17:30 T-H18

Background model in a $t\bar{t}W$ cross-section measurement — •Marcel Niemeyer, Arnulf Quadt, and Elizaveta Shabalina — Georg-August University Goettingen

The top-quark pair production in association with a W boson is an interesting process by itself and exhibit an important background to processes like $t\bar{t}H$ or 4-tops production. Due to higher order electroweak corrections, the process is difficult to model. In consequence, a mismodelling of $t\bar{t}W$ has been observed in previous analyses. Thus, it is of high importance to measure this process to improve our understanding of it. The analysis is performed in the multi-lepton channel requiring 2ℓ (same-sign) or 3ℓ. The resulting event sample has a significant contribution from fake backgrounds.

To estimate this background, an extended template fit is performed that uses a discriminant based on isolation and b-tagging variables, referred to as a prompt lepton veto. The fit, the calibration of the prompt lepton veto, and the related systematic uncertainties will be discussed in this talk.

T 33.7 Tue 17:45 T-H18

Measurement of differential cross-sections of the $t\bar{t}\gamma$ production in the dilepton channel in proton-proton collisions at $\sqrt{s}$ = 13 TeV with ATLAS detector — •Buddhadeb Mondal, Ivor Fleck, and Carmen Diez Pardos — Center for Particle Physics Siegen, Experimentelle Teilchenphysik, Universität Siegen

The top quark being the heaviest fundamental particle in the Standard Model (SM) plays a very important role in the study of fundamental interactions. It has a very short lifetime and it decays before it hadronizes, passing its properties to its decay products. Top quark pair production in association with a photon ($t\bar{t}\gamma$) is a very important process for measuring the coupling between top quark and photon. A precise measurement of this coupling is necessary for testing the SM and also for probing any new physics effect at very high energy scale. Deviations from the SM coupling can be a limit of new physics phenomena that can be interpreted in the context of effective field theory approaches. In this talk, measurement of differential cross-section using 139 fb^{-1} of data collected by the ATLAS detector in proton-proton collisions at $\sqrt{s}$ = 13 TeV will be presented. This measurement is done in the dileptonic decay channel of the $t\bar{t}$ pair.

T 33.8 Tue 18:00 T-H18

Measurement of $t\bar{t}+\gamma$ production with the full Run 2 ATLAS data set — •Andreas Kirchhoff, Arnulf Quadt, and Elizaveta Shabalina — II. Physikalisches Institut, Georg-August-Universität Göttingen

The optimal way to measure the top-photon coupling and later interpret it within an EFT-framework would be an e^+e^- collider with sufficient energy. As such a collider does not exist, another possibility to measure it is the production of $t\bar{t}$ pairs in association with a photon. Unfortunately, most of such photons will originate from the decay products of the top quarks and hence do not convey any information about the top-photon coupling. In contrast, photons produced in the production of the $t\bar{t}$ pair mostly originate from the top quark (beside a small contribution from ISR). The separation of photons originating from production and decay is tried for the first time in this ATLAS analysis. In this talk, the status of the currently ongoing full Run 2 analysis of the $t\bar{t}+\gamma$ process in the l+jets channel will be presented. The talk will focus on showing how deep neural networks are used to measure the $t\bar{t}+\gamma$ cross section, where the photon is emitted during production. First fit results will also be shown.

T 33.9 Tue 18:15 T-H18

Search for $t\bar{t}\gamma\gamma$ production in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector — •Arpan Ghosal, Ivor Fleck, Carmen Diez Pardos, and Amartya Rej — Center for Particle Physics Siegen, Experimentelle Teilchenphysik, Universität Siegen

The production of top quarks with photons gives access to measure the strength of the electroweak coupling of the top quark and the photon. While the production of top quark pairs ($t\bar{t}$) with one photon is being extensively studied, the $t\bar{t}$ production in association with two photons ($t\bar{t}\gamma\gamma$) has not been observed yet. The $t\bar{t}\gamma\gamma$ is a rare process and not only is it a good candidate for probing the top EW coupling but is also relevant as an irreducible background process to $t\bar{t}$ production in association with a Higgs boson decaying to two photons ($H \to \gamma\gamma$). Besides, new sources of CP-violation are expected from physics phenomena beyond the SM. These sources can appear as electric dipole moment terms in top-quark interactions, and their precise measurement is essential to determine the effects of new physics. Understanding the $t\bar{t}\gamma\gamma$ process can help put better bounds on top-quark dipole moments.

The cross-section of the process is expected to be of the order of 10 fb at $\sqrt{s}$ = 13 TeV, much lower than the $t\bar{t}\gamma$ process. The presentation will discuss the ongoing efforts in the search for the process in semileptonic $t\bar{t}$ decay channel using the full Run 2 dataset collected by ATLAS detector at 13 TeV.

T 34: Top Quarks: Properties -2

Time: Tuesday 16:15–18:00 Location: T-H19

T 34.1 Tue 16:15 T-H19

Measurement and EFT interpretation of differential $t\bar{t}$ cross-sections in the boosted lepton+jets channel with the ATLAS detector at $\sqrt{s}$ = 13 TeV — Kevin Kröninger, Johannes Erdmann, and •Kevin Sedlaczek — TU Dortmund University, Department of Physics

Physics beyond the Standard Model (SM) can, in absence of resonances, be investigated in a model-independent way by using effective field theory (EFT) approaches. Without assumption of the underlying theory, effects of potential new high-mass particles at a low energy scale can be quantified by higher dimension expansions of the SM Lagrangian.

At the LHC, physics in the top sector is entering a phase of precision measurements combined with very accurate predictions. Meanwhile, many theories beyond the SM predict deviations in the top-quark couplings or new interactions of the top quark. These aspects make model-independent measurements in the top sector a very attractive way to test the SM for deviations arising from new physics at higher energy scales.

In this talk, a differential $t\bar{t}$ cross-section measurement is shown. The measurement is performed in the boosted lepton + jets channel on the full Run 2 dataset taken with the ATLAS detector at $\sqrt{s}$ = 13 TeV. The differential measurements in different kinematic variables are unfolded to the particle level. One of the unfolded distributions is then used to derive bounds on the contributions of new physics within the EFT framework via two dimension-6 operators.

T 34.2 Tue 16:30 T-H19

Top-antitop energy asymmetry in jet-associated top-quark pair production at ATLAS — •Alexander Basan[1], Asma Hadef[1], Jessica Höfner[1], Lucia Masetti[1], Eftychia Tzovara[1], and Susanne Westhoff[2] — [1]Universität Mainz — [2]Universität Heidelberg

The top quark is particularly well suited to probe the standard model (SM) and many extensions thereof at the electroweak symmetry-breaking scale and beyond.

At hadron colliders, the $t\bar{t}$ production is symmetric at leading order perturbation theory under the exchange of the top- and anti-top-quark, while interferences at higher orders create an asymmetry. This charge asymmetry can provide sensitive probes for many models beyond the standard model. Within the framework of standard model effective field theories (SMEFT), the charge asymmetry is especially sensitive to four-quark operators and one operator that modifies the top-gluon interaction.

In inclusive jet-associated top-quark pair production the asymmetry arises already at leading order in quark-gluon interactions. Furthermore, the $t\bar{t}j$ final states allow the definition of a new observable, the energy asymmetry, expressed in terms of the distribution of the energy difference $E_t - E_{\bar{t}}$.

This talk presents the measurement in lepton+jets events with a high p_T hadronically decaying top quark at ATLAS with a centre of mass energy of $\sqrt{s} = 13\,$TeV as well as limits on the Wilson coefficients of four-quark operators within the SMEFT framework.

T 34.3 Tue 16:45 T-H19

Untersuchung neuer Physik über die Energieasymmetrie in der Top-Antitop-Jet Produktion am ATLAS — •Jessica Höfner[1], Alexander Basan[1], Asma Hadef[1], Lucia Masetti[1], Eftychia Tzovara[1] und Susanne Westhoff[2] — [1]Universität Mainz — [2]Universität Heidelberg

Das Top-Quark ist das schwerste Teilchen im Standardmodell der Elementarteilchen und das einzige Quark das nicht direkt hadronisiert sondern zerfällt. Es eignet sich sehr gut dafür Physik außerhalb des Standardmodells zu suchen, denn es könnten noch unentdeckte schwerere Teilchen oder auch neue Wechselwirkungen mit dem Top-Quark interagieren.

Bei der Produktion eines Top-Antitop-Paares mit zusätzlichem Jet kann die Energieasymmetrie, eine neue Observable der Ladungsasymmetrie, bestimmt werden, die besonders sensitiv auf Physik jenseits des Standardmodells sein kann. Nach einer ersten veröffentlichten Messung der Energieasymmetrie mit dem ATLAS Experiment, werden Möglichkeiten untersucht sowohl den Phasenraum der Messung zu erweitern als auch die Ergebnisse mit denen aus Wirkungsquerschnittmessungen zu kombinieren. In diesem Vortrag wird die erwartete Sensitivität dieser Erweiterungen vorgestellt.

T 34.4 Tue 17:00 T-H19

Measurements of observables sensitive to colour reconnection in $t\bar{t}$ events — Dominic Hirschbühl, Wolfgang Wagner, and •Shayma Wahdan — Bergische Universität Wuppertal, Wuppertal, Germany

Colour reconnection (CR) is a mechanism that describes the interactions that can occur between colour fields during the hadronisation transition. In the context of precise top-quark mass measurements, it plays a crucial role. The modelling of CR has become one of the dominant sources of systematic uncertainty in these measurements. Ongoing top-quark mass analyses use PYTHIA 8 MC event generator for parton showering and hadronisation. PYTHIA 8 comes with several alternative CR models which should be explored to estimate the CR modelling uncertainty. At the same time, the models should be confronted with LHC data to test their validity. Only models which are in agreement with data, in general, are suitable to define the corresponding modelling uncertainty. This analysis presents a measurement of charged-particle distributions sensitive to the different CR models in PYTHIA 8 in top-quark pair production. The measurement is based on data collected using the ATLAS detector at the LHC in proton-proton collisions at a centre-of-mass energy of 13 TeV with an integrated luminosity of 139 fb-1.

T 34.5 Tue 17:15 T-H19

Search for flavour-changing photon interactions in top-quark production and decay at the ATLAS experiment — Tomas Dado, Johannes Erdmann, Benedikt Gocke, •Florian Mausolf, Olaf Nackenhorst, and Björn Wendland — TU Dortmund University, Department of Physics

In the Standard Model (SM) of particle physics, flavour-changing neutral currents (FCNC) are strongly suppressed, but several theories beyond the SM predict FCNC with much higher rates. In this talk, a search for flavour-changing photon interactions in top-quark production and decay is presented. Proton-proton-collision data corresponding to an integrated luminosity of 139 fb^{-1} are analysed which were taken with the ATLAS detector at a centre-of-mass energy of 13 TeV. It is separately searched for interactions involving the top quark, the up quark and the photon as well as for interactions of the top quark, the charm quark and the photon. Events with one photon, one b-tagged jet, one electron or one muon, and a minimum amount of missing transverse momentum are selected. Contributions from events with objects mis-reconstructed as photons are estimated using data-driven methods. Multiclass deep neural networks are used to separate the signal from the background. The analysis strategy is presented and upper limits on the strength of the FCNC couplings are set.

T 34.6 Tue 17:30 T-H19

Studies for the measurement of the production of top-quark pairs in association with a Z boson decaying to a pair of tau leptons with the ATLAS detector — •Simon Neuhaus and Thomas Dado — TU Dortmund University, Department of Physics

A Study of the associated production of a top-quark pair and a Z boson decaying into a tau-lepton pair is presented. This process allows to test the lepton-universality prediction of the Standard Model of particle physics in the top-quark-sector. Additionally, this process is sensitive to various BSM couplings between the top quarks and tau-leptons. Because only the visible mass of the di-tau system is reconstructable, a significant contribution from the off-shell events is expected in the signal region.

The measurement targets decays with one or two light leptons, at least three jets and two hadronically decaying tau leptons. Some of the important background processes include the diboson (ZZ, WZ, WW) processes and processes with misreconstructed tau leptons. Initial studies on the optimization of the event selection using the Monte Carlo simulations for the ATLAS data of the complete LHC Run 2 will be shown. Observables that are interesting for the optimisation of the selection include: the transverse momentum of all three or four leptons, the number of jets and the number of b-tagged jets.

T 34.7 Tue 17:45 T-H19

Simulation of selected top-quark processes at the FCC-ee and their interpretation in terms of effective field theories — Cornelius Grunwald[1], Kevin Kröninger[1], Romain Madar[2], Stéphane Monteil[2], and •Lars Röhrig[1] — [1]Department of Physics, Dortmund, Germany — [2]Laboratoire de Physique de Clermont, Clermont-Ferrand, France

While in the flavor-physics sector future upgrades of the LHCb detector at CERN and Belle II at KEK are aimed at precision measurements, experiments at future colliders such as the FCC-ee are expected to improve electroweak and top-quark physics in an unrivaled way. Since it is interesting to set the measurements by the FCC-ee into a global context, the estimation of the precision of selected top-quark processes is important for estimating the impact on the constraints of dimension-six operators.

In this talk, relevant observables and the impact of dimension-six operators on these observables are presented. The parameterizations as function of the dimension-six operator strength are given. This will allow to set constraints on the strength of dimension-six operators assuming uncertainties for the measurements at the FCC-ee.

T 35: Higgs Boson: Associated Production 1

Time: Tuesday 16:15–18:15 Location: T-H20

T 35.1 Tue 16:15 T-H20

Higgs Boson Mass Reconstruction in the ttH Multi-lepton Channel Using ATLAS data — Igor Boyko[1], •Adam Herold[2], Nazim Huseynov[1], Jan Kybic[2], André Sopczak[2], Petr Urban[2], and Cyrus Walther[3] — [1]JINR Dubna — [2]CTU in Prague — [3]TU Dortmund

This study deals with the reconstruction of the Higgs boson mass in the 2lSS + $1\tau_{\mathrm{had}}$ channel in ttH production. Based on the reconstructed mass, the goal is to separate the signal from background productions such as the ttZ production. The data created by the full ATLAS detector simulation are used to develop two neural networks. First, a classification neural network that organizes the data by assigning detected particles to corresponding positions in the channel. Second, a regression neural network that reconstructs the mass of the Higgs boson. The developed neural network is tested and is shown to outperform the Missing Mass Calculator technique.

T 35.2 Tue 16:30 T-H20

Investigation of ttH(bb) Events with Very High Higgs Boson Momentum at ATLAS Detector — •Doga Elitez, Lucia Masetti, Eftychia Tzovara, Asma Hadef, and Alexander Basan — Johannes Gutenberg-Universität Mainz, Mainz, Deutschland

The coupling of the Higgs boson to the top quark is very sensitive to effects of the physics beyond the Standard Model (BSM) and the most favorable production mode for direct measurement of the top

Yukawa coupling is the Higgs production in association with a pair of top quarks ($t\bar{t}H$). The decay to two bottom quarks ($H \rightarrow b\bar{b}$) has the largest branching fraction of about 58%. This analysis aims at events in which one of the top quarks decays semi-leptonically and produces an electron or a muon plus several jets. The so-called ultra boosted topology targets events containing a Higgs boson produced at very high transverse momentum, which is contained in a single small-R jet. This topology is not included in the current high p_T (boosted) Higgs boson selection and requires a dedicated analysis. In this talk, methods to improve background rejection and event reconstruction to increase the sensitivity above the current p_T range are presented, along with the challenges of combining the different channels.

T 35.3 Tue 16:45 T-H20

Measurement of the $t\bar{t}H$ production cross-section with $H \rightarrow b\bar{b}$ in the boosted topology with the ATLAS detector — •Eftychia Tzovara, Lucia Masetti, Doga Elitez, Asma Hadef, and Alexander Basan — JGU Mainz, Germany

Studying the coupling of the Higgs boson to the top quark is of particular interest, since it could be sensitive to effects of physics beyond the SM. The Higgs production in association with a top-quark pair is the most favourable process for a direct measurement of the top Yukawa coupling. The decay to two b-quarks has the largest branching ratio, while it allows for the reconstruction of the Higgs boson kinematics. The analysis presented here aims at events in which one of the top quarks decays semi-leptonically, producing an electron or a muon, and the other one hadronically. In the single-lepton channel, there is a specific boosted region, targeting events with a Higgs boson produced at high transverse momentum p_T.

Due to the highly complex final state and the large SM backgrounds, the reconstruction of the Higgs boson becomes a complicated task. The ultimate goal is to constrain the background events of the boosted channel in order to maximise the statistical significance of the measurement. For this purpose, multivariate techniques are used to discriminate between signal and background events, in particular from $t\bar{t}$+jets production. For the first time, the signal strength is also measured differentially in bins of the Higgs boson p_T. Finally, the measurement of the $t\bar{t}H(b\bar{b})$ cross-section, using the full LHC run-2 data, as well as further improvements on the boosted channel, will be presented.

T 35.4 Tue 17:00 T-H20

Improvements of the MVA classifiers for the $t\bar{t}H(b\bar{b})$ analysis in the dilepton channel with full Run2 data in the CMS experiment — •Angela Giraldi and Maria Aldaya — DESY, Hamburg, Germany

In the Standard Model (SM), the Higgs boson couples to fermions with a Yukawa-type interaction and a strength proportional to the fermion mass. The associated production of a Higgs boson with a top-quark pair ($t\bar{t}H$) is therefore the best direct probe of the top-Higgs Yukawa coupling, a vital element to verify the SM nature of the Higgs boson. In the SM, the Higgs boson decays into b-quark-antiquark pair with the largest branching fraction, and is thus experimentally attractive as a final state. The dominant background contributions arise from $t\bar{t}$+jets production, and in particular the $t\bar{t}b\bar{b}$ background is irreducible with respect to $t\bar{t}H$,$H \rightarrow b\bar{b}$. To better enhance the sensitivity, the signal is extracted exploiting multivariate analysis (MVA) techniques.

This talk focuses on the analysis of the $t\bar{t}H$,$H \rightarrow b\bar{b}$ process in final states with two leptons using proton-proton data collected by the CMS experiment at the LHC during 2016-2018 at $\sqrt{s} = 13$ TeV. The possibility to critically increase the sensitivity to the $t\bar{t}H$ signal is investigated using machine learning approaches. Detailed studies on the optimization and performance of MVA discriminants trained using Artificial Neural Networks are presented in this final state.

T 35.5 Tue 17:15 T-H20

Adversarial Machine Learning Methods for Modelling Uncertainty Reduction in the Bottom Anti-Bottom Higgs Decay Channel of Higgs-associated Top Quark Pair Production with ATLAS at 13 TeV — Arnulf Quadt, •Chris Scheulen, and Elizaveta Shabalina — II. Physikalisches Institut, Georg-August Universität Göttingen

The bottom anti-bottom Higgs decay channel of Higgs-associated top quark pair production offers direct access to measurements of the top Yukawa coupling and Higgs-p_{T} differential cross section, which are sensitive to potential new physics. To incorporate improvements such as developments in b-tagging and event simulation, a legacy analysis of the $t\bar{t}H(H \rightarrow b\bar{b})$ process in the full ATLAS Run 2 Dataset of $\mathcal{L} = 139\,\mathrm{fb}^{-1}$ is currently ongoing.

Modelling differences between Monte Carlo samples of the dominant $t\bar{t}$ + jets background process were found to be one of the most significant sources of uncertainty in previous analysis rounds. Along with investigating and mitigating the source of these modelling differences via generator studies of new $t\bar{t}$ + jets background simulation setups or improving event classification performance to decrease background contamination in signal regions, the usage of adversarial machine learning techniques to select robust features could decrease the impact of background modelling systematics on the fit performance. This talk will present ongoing efforts concerned with developing such adversarial machine learning approaches.

T 35.6 Tue 17:30 T-H20

Performance Tests of tH(bb) Signal and Background Separation Using a Binary Classifier Neural Network with ATLAS Data — Igor Boyko[1], Nazim Huseynov[1], Oksana Koval[1], •Marcel Patzwahl[2], and André Sopczak[2] — [1]JINR Dubna — [2]CTU in Prague

The production of a Higgs boson in association with a single top quark is a strongly suppressed process in the Standard Model (SM). In the current ATLAS data set of $140\,\mathrm{fb}^{-1}$, the SM expected production rate is below the experimental sensitivity. Thus, observing such a tH production would indicate new physics. The absolute ttH coupling strength was already measured and the tH process can in addition measure the relative sign of the ttH coupling. Therefore, observing the tH process gives an important additional insight into the physics of the Higgs mechanism. Owing to the low production rate, it is particularly important to enhance the signal sensitivity, and a Neural Network (NN) is used. The resulting significance is studied by varying the NN structure. Based on simulated data, the performances of these different NN structures were tested and results are expressed as area under the ROC curve to quantify the signal and background separation.

T 35.7 Tue 17:45 T-H20

Higgs Boson Mass Reconstruction in the tH Multi-lepton Channel Using ATLAS Data — Igor Boyko[1], Adam Herold[2], Nazim Huseynov[1], Lars Kolk[3], Jan Kybic[2], André Sopczak[2], Petr Urban[2], and •Cyrus Walther[3] — [1]JINR Dubna — [2]CTU in Prague — [3]TU Dortmund

The Higgs boson mass is reconstructed in single top production in association with a Higgs boson, tH, using a regression neural network approach. The reconstruction of the Higgs boson mass is expected to show discrimination to background processes. A focus lies on the lepton association. For the lepton association, a classification neural network is used. Hyperparameter optimization, as well as feature importance studies, are applied in order to increase the neural network performance. For the Higgs boson mass reconstruction, a hyperparameter optimization is also performed. The performance of the network is tested on tH signal and tZ background simulations.

T 35.8 Tue 18:00 T-H20

Associated production of a Higgs boson and a single top quark from t-channel production (tHq) in channels with hadronically decaying tau leptons at ATLAS — •Tanja Holm and Ian C. Brock — Physikalisches Institut Universität Bonn

Associated Higgs boson production gives us the opportunity to study its couplings to fermions and bosons. An especially interesting but challenging channel is the associated production with a single top quark, as it allows one to probe the relative coupling to both kind of objects. The downside to this is a small predicted cross-section and a complicated final state including jets from light quarks or gluons, jets containing b-hadrons, missing E_T and leptons. The decay into tau leptons which subsequently decay hadronically was chosen as it has a relatively high Higgs decay branching ratio, while having a lower background than hadronic processes with higher branching ratios. This talk will discuss the search for this channel in the Run 2 LHC dataset by ATLAS.

T 36: Higgs Boson: Extended Models 1

Time: Tuesday 16:15–18:30 Location: T-H21

T 36.1 Tue 16:15 T-H21

Search for heavy Higgs bosons decaying to top quark pairs using the CMS experiment — Afiq Anuar, Alexander Grohsjean, •Jonas Rübenach, Dominic Stafford, and Christian Schwanenberger — DESY, Hamburg, Germany

The discovery of the Higgs boson at the Large Hadron Collider in 2012 marked a major breakthrough for particle physics, as it permits the verification of the Higgs mechanism, a central building block of the Standard Model. However, the Standard Model still lacks explanation for many phenomena we observe throughout the universe, including dark matter. For a great number of proposed extensions, such as the minimal supersymmetric standard model, a key ingredient is the existence of additional Higgs bosons. Using data collected by CMS at the LHC at $\sqrt{s} = 13$ TeV, corresponding to a luminosity of 138 fb^{-1}, a search is performed for scalar and pseudoscalar, electrically neutral bosons decaying predominantly to top quark pairs, which are assumed to further decay dileptonically. The challenges connected to this particular search, such as interference with the standard model background and unknown quantities resulting from neutrino momenta, are tackled by a full reconstruction of the top quark system and the utilization of multi-dimensional distributions arising from mass and spin information.

T 36.2 Tue 16:30 T-H21

Exotic Higgs Decays: ATLAS Search for Higgs Decays to Two Light Scalars — •Judith Höfer, Claudia Seitz, Rickard Ström, and Beate Heinemann — DESY, Hamburg, Germany

Extensions of the SM Higgs sector featuring one or several singlet scalar fields are realised in many BMS models. While several searches have been performed targeting decays of the SM Higgs boson to two light spin-zero particles of the same mass, the decay to two new scalars of different mass is largely unexplored. The successive decays of these particles can give rise to spectacular high-multiplicity collider signatures, including so-called cascade decays, where the heavier of the scalars decays into the lighter one. The talk discusses an analysis searching for scalar decays to multi-b final states with the ATLAS experiment at the Large Hadron Collider, CERN. The analysis focuses on the ZH production mode and the channel where the scalars decay to b-quarks, resulting in a challenging low-pT jet final state. These signatures motivate the use of many novel reconstruction techniques, such as the reconstruction of soft secondary vertices, a newly developed low-pT X->bb tagger, and an event hypothesis neural network to accurately identify the Higgs decay to the light scalars among the reconstructed objects.

T 36.3 Tue 16:45 T-H21

Search for DiHiggs production $\mathrm{H} \rightarrow \mathrm{hh_S}$ in an extended NMSSM Higgs sector with CMS — •Martin Marz, Felix Heyen, Ulrich Husemann, Nikita Shadskiy, Michael Wassmer, and Roger Wolf — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

The search for new physics is essential to validate or exclude theoretical models. For this purpose, models including additional non-standard-model-like Higgs bosons are of great interest. The Next-to-Minimal Supersymmetric Standard Model (NMSSM) for example predicts such additional Higgs bosons. Especially the decay of a heavy Higgs boson H into two lighter Higgs bosons $(\mathrm{h_S}, \mathrm{h})$, allows for a rich experimental program. Here h is the observed Higgs boson with properties as expected by the SM.

The analysis presented in this talk is intended to use a general re-reconstruction of the LHC run 2 dataset from 2018 to profit from the best understanding of physics objects measured and reconstructed with the CMS detector in the search of new physics. The decay channel $\mathrm{h} \rightarrow \mathrm{bb}$, $\mathrm{h_S} \rightarrow \tau\tau$ and the subsequent decay of the tau pair into a muon and hadrons is studied to add to a recently published analysis (JHEP 11 (2021) 057) by the CMS collaboration.

T 36.4 Tue 17:00 T-H21

Verwendung parametrischer neuronaler Netzwerke bei der Suche nach neuer Physik im Rahmen von NMSSM inspirierten Modellen — •Ralf Schmieder, Markus Klute, Günter Quast, Roger Wolf, Sebastian Brommer, Maximilian Burkart, Felix Heyen und Tim Voigtländer — KIT, Karlsruhe, Deutschland

Ein parametrisches neuronales Netzwerk (pNN) ist äquivalent zu einer Folge einzelner, verwandter NNs, von denen jedes eine eigene Aufgabe erfüllt. Diese Äquivalenz wird erreicht, indem der Raum der Eingangsparameter des pNNs, im Vergleich zu den einzelnen NNs, um zusätzliche Modellparameter erweitert wird. Das pNN erfüllt dann, abhängig von diesen Modellparametern, die Aufgaben der einzelnen NNs. Ein typisches Beispiel für den Einsatz eines pNN in der Teilchenphysik ist die Suche nach einem neuartigen Teilchen mit unbekannter Masse. In diesem Fall wird der aus physikalischen Observablen bestehende Raum der Eingangsparameter der einzelnen NNs um den Modellparameter der Masse des neuen Teilchens für die jeweils zu testende Signalhypothese erweitert.

Dieser Vortrag behandelt Studien zu pNNs im Kontext einer durch das NMSSM inspirierten Analyse der Daten des CMS Experiments. Gesucht wird nach dem Zerfall eines schweren Higgs-Bosons H in zwei leichtere Higgs-Bosonen h und $\mathrm{h_S}$ im Endzustand mit zwei τ-Leptonen und zwei b-Quarks, $\mathrm{H} \rightarrow \mathrm{h}(\tau\tau)\mathrm{h_S}(\mathrm{bb})$, unter der Annahme von $m(\mathrm{h}) = 125\,\mathrm{GeV}$. Dieses Problem besitzt zwei unbekannte Massen $m(\mathrm{H})$ und $m(\mathrm{h_S})$, die von der zu testenden Signalhypothese abhängen und beide als Modellparameter in das pNN Training eingehen sollen.

T 36.5 Tue 17:15 T-H21

Search for NMSSM inspired di-Higgs events in bb+$\tau\tau$ final states — •Felix Heyen, Ralf Schmieder, Sebastian Brommer, Günter Quast, Roger Wolf, Nikita Shadskiy, Martin Marz, and Maximilian Burkhart — KIT, Karlsruhe

In the next-to-minimal supersymmetric extension of the Standard Model (NMSSM), modifications to the Standard Model Electroweak sector lead to an extended Higgs sector with a total of seven Higgs bosons. The decay of a heavy scalar Higgs boson to a light scalar Higgs boson and a Higgs boson with the properties of the discovered Higgs boson is a promising target of this extension. This talk discusses the physics motivations of the NMSSM and introduces the search for such a decay in $\tau\tau$ + bb final states. Of the possible tau lepton final states that can be considered, this search focusses on $\tau_\mathrm{h}\tau_\mathrm{h}$ final state. A simulation of the 2018 CMS data taking period is considered.

T 36.6 Tue 17:30 T-H21

Search for additional MSSM/2HDM H→bb with Run 2 CMS data — •Daina Leyva Pernia — DESY, Hamburg, Germany

Some Beyond Standard Model (BSM) theories, like the Minimal Supersymmetric extension of the Standard Model (MSSM) or the Two-Higgs Doublet Model (2HDM), predict the existence of additional Higgs bosons with an enhanced coupling to bottom quarks. This talk focuses on the search for new neutral Higgs bosons decaying into b-quarks and produced in association with at least one b-quark. The analyzed data were collected by the CMS experiment at a centre-of-mass energy of 13 TeV, with the latest data reprocessing. First limits on the MSSM H→bb process using these data are shown.

T 36.7 Tue 17:45 T-H21

A 96 GeV Higgs Boson in the 2HDM plus Singlet — •Cheng Li[1], Steven Paasch[1], Gudrid Moortgat-pick[1,2], Sven Heinemeyer[3], and Florian Lika[2] — [1]DESY, Notkestraße 85, Hamburg, Germany — [2]II. Institut für Theoretische Physik, Universität Hamburg,
Luruper Chaussee 149, Hamburg, Germany — [3]Instituto de Física Teórica (UAM/CSIC), Universidad Autónoma de Madrid, Cantoblanco, Madrid, Spain

We discuss a $\sim 3\,\sigma$ signal (local) in the light Higgs-boson search in the diphoton decay mode at ~ 96 GeV as reported by CMS, together with a $\sim 2\,\sigma$ excess (local) in the $b\bar{b}$ final state at LEP in the same mass range. We interpret this possible signal as a Higgs boson in the 2 Higgs Doublet Model type II with an additional Higgs singlet, which can be either complex (2HDMS) or real (N2HDM). We find that the lightest $\mathcal{CP}$-even Higgs boson of the two models can equally yield a perfect fit to both excesses simultaneously, while the second lightest state is in full agreement with the Higgs-boson measurements at 125 GeV, and the full Higgs-boson sector is in agreement with all Higgs exclusion bounds theoretical and experimental constraints. We derive bounds on the 2HDMS and N2HDM Higgs sectors from a fit to both excesses and describe how this signal can be further analyzed at future e^+e^- colliders. We analyze in detail the anticipated precision of the coupling measurements of the 96 GeV Higgs boson at the ILC. We find that these Higgs-boson measurements at the LHC and the ILC cannot distinguish between the two Higgs-sector realizations.

T 36.8 Tue 18:00 T-H21

Dark Matter Phenomenology in Two Higgs Doublet Model with a Complex Singlet — Gudrid Moortgat-Pick, Juhi Dutta, and •Julia Ziegler — II. Institut für Theoretische Physik Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Although the Standard Model is very successful, there are still open problems which it cannot explain. (e.g. dark matter, baryon asymmetry etc.) This has led to various Beyond Standard Model theories, of which Two Higgs Doublet models are very popular, as they are one of the simplest extensions and lead to a rich phenomenology. We consider a Two Higgs Doublet model extended by a complex singlet scalar, where both, the doublets, as well as the singlet obtain a vacuum expectation value (vev). The singlet serves as a dark matter candidate. This model can solve the above mentioned problems and can also provide gravitational wave signals under specific circumstances, respectively. Furthermore one could obtain additional mixing of the dark matter and Higgs sector through the singlet vev. In this work we examine the influence of the parameters of the singlet potential on the dark matter relic density and nuclear scattering cross sections. The results are then compared with constraints from experiments.

T 36.9 Tue 18:15 T-H21

Impact of the different discrete symmetries in the 2HDM and N2HDM on Domain Wall formation and its phenomenological implications — •Luis Hellmich[1] and Gudrid Moortgat-Pick[1,2] — [1]Universität Hamburg, Hamburg, Deutschland — [2]DESY, Hamburg

Domain wall formation is a consequence of spontaneously broken discrete symmetries. Stable domain walls are cosmological bad news as they are expected to dominate the energy density of the universe. One way to overcome this domain wall problem are energetically biased vacua, which can render domain walls unstable.

In the 2HDM and N2HDM a discrete $\mathbb{Z}_2$ symmetry is usually present in order to avoid FCNCs, which is softly broken and hence can produce collapsing domain walls. We find that in the Type I 2HDM and N2HDM there is an additional inherent and not explicitly broken $\mathbb{Z}_2$ symmetry. Furthermore the N2HDM also exhibits the well-known only spontaneously broken $\mathbb{Z}_2'$ symmetry. We want to discuss the impact of those different discrete symmetries on domain wall formation. In particular we want to show how stable domain walls for the unbroken discrete symmetries may be suppressed and analyze the phenomenological consequences when applying the resulting constraints on the 2HDM and N2HDM.

T 37: Search for New Particles 2

Time: Tuesday 16:15–18:30 Location: T-H22

T 37.1 Tue 16:15 T-H22

Search for heavy neutral leptons in decays of W bosons using a dilepton displaced vertex in $\sqrt{s} = 13$ TeV pp collisions with the ATLAS detector. — •Christian Appelt and Heiko Lacker — Humboldt University, Berlin, Germany

We present the ATLAS search for displaced heavy neutral leptons ($\mathcal{N}$) using the full integrated LHC-Run 2 luminosity of 139/fb. Adding right-handed Majorana neutrinos, so-called heavy neutral leptons, to the SM Lagrangian can help explain observed phenomena such as neutrino oscillations, matter-antimatter asymmetry, and dark matter. For the first time, we test not only the single-flavor mixing scenario but also multi-flavor mixing scenarios motivated by neutrino flavor oscillation results for normal and inverted neutrino mass hierarchies. The signature involves $\mathcal{N}$ production in W-boson decays, $W \to \mathcal{N}\mu$ or $W \to \mathcal{N}e$, and its decay into two charged leptons and a neutrino forming a displaced vertex. We interpret the search results in the $\mathcal{N}$ coupling versus mass plane.

T 37.2 Tue 16:30 T-H22

Search for excited leptons in the contact interaction and Z decay channels with CMS — •Fabian Nowotny, Thomas Hebbeker, and Kerstin Hoepfner — III. Physikalisches Institut A, RWTH Aachen

The Standard Model of particle physics does not provide a comprehensive explanation for the observed hierarchy of three generations of fermions, for both leptons and quarks. A possible explanation is delivered by models postulating that quarks and leptons themselves are composite objects. Their constituents are bound by an asymptotically free gauge interaction below a characteristic scale Λ. Such models of compositeness predict the existence of excited lepton ($l^\star$) and excited quark ($q^\star$) states at the characteristic scale Λ of the new binding interaction. The theory allows the production of excited leptons via contact interactions in conjunction with a Standard Model lepton. Furthermore, the leptons can decay into several final states.

This talk focuses on the contact interaction and Z-boson decay channels, both resulting in $l^\star \to lq\bar{q}$ transitions where l represents e and μ. Preliminary results are presented on the 2018 proton-proton dataset corresponding to a luminosity of 59.8 fb^{-1} at a center of mass energy of $\sqrt{s} = 13$ TeV.

T 37.3 Tue 16:45 T-H22

Search for pair-produced leptoquarks decaying into quarks of the third and leptons of the first or second generation with the ATLAS experiment at $\sqrt{\text{s}} = \mathbf{13}$TeV — •Volker Austrup and Frank Ellinghaus — Bergische Universität Wuppertal

Motivated by similarities between the quark and lepton sectors, leptoquarks (LQs) are hypothetical bosons assumed to couple to quarks and leptons at the same time. First proposed in the 1980s, the initial models included couplings only within one generation. However, hints at lepton flavor universality violation observed in several B meson decay experiments such as LHCb, BaBar, and Belle have sparked a renewed interest in LQ models, particularly extensions allowing couplings to quarks and leptons of different generations. These models introduce lepton flavor violating processes - strongly suppressed in the Standard Model - at tree level, thus modifying rare B meson decays. In this talk, a search for pair-produced scalar and vector LQs decaying into quarks of the third and leptons (neutral and charged) of the first or second generation is presented. The focus of the analysis is on final states with exactly one charged lepton and large amounts of missing transverse momentum. Neural networks are utilized to ensure good separation between signal and background processes across a wide range of the parameter space. Exclusion limits are presented, based on pp-collision data corresponding to 139fb^{-1} at a centre-of-mass energy of $\sqrt{s} = 13$ TeV collected by the ATLAS experiment at the LHC between 2015 and 2018.

T 37.4 Tue 17:00 T-H22

Leptoquark production in a single τ, charm/bottom and met final state at the ATLAS detector — •Patrick Bauer, Philip Bechtle, and Klaus Desch — Physikalisches Institut Bonn

At B-factories, anomalies were observed in decays of the B-hadrons into $\text{D}^{(*)}$ and $\text{K}^{(*)}$, which are consistent with the hypothesis of contributions from Leptoquarks in the high GeV to low TeV range.

Therefore, the direct search for leptoquarks (LQ) got once again in focus at high energy collider experiments. So far most searches aimed at the pair-production via strong interaction, as it is enables a almost model independent approach and is for LQ-masses below 1 TeV expected to be dominating.
However for LQ masses well above 1 TeV the single production mode becomes more relevant. The analysis presented this talk, offers the most direct approach for a search of LQ signature related to the $\text{B} \to \text{D}^{(*)}\tau\nu$ anomaly, as it incorporates essentially the same couplings. Furthermore the process to be investigated could be mediated by a U_1-vector LQ, which is presently widely discussed among theorists, as preferred solution to B-anomalies.It could explain the two observed anomalies within one model. The talk will motivate the analysis and present the ongoing search for vector LQ in single and pair production in final states with one τ, bottom or charm jet and large met.

T 37.5 Tue 17:15 T-H22

The LHC as Lepton–Proton Collider: Searches for Resonant Production of Leptoquarks — •Daniel Buchin, Michael Holzbock, and Hubert Kroha — Max-Planck-Institut für Physik, München

Searches for leptoquarks constitute an essential part of the physics programme at the ATLAS detector. These hypothetical particles couple to both leptons and quarks and are predicted by many extensions of the Standard Model such as Grand Unified Theories. In particular leptoquarks with couplings to third generation fermions are of general interest since they represent a possible solution to the tensions observed in tests of the lepton flavour universality in $b \to s$ and $b \to c$ transitions. By considering the small but non-zero lepton content of the proton due to quantum fluctuations it becomes possible to target the resonant production of leptoquarks at the LHC. Phenomenological studies indicate that this production mode yields competitive sensitivity to existing leptoquark searches.

Resonantly produced leptoquarks give rise to a lepton + jet signature. Interestingly, such a final state is currently not well covered by ATLAS and CMS. Therefore, the analysis of the resonant production is an exciting complementary approach to the current leptoquark searches that consider e.g. pair production. The talk will introduce the leptoquark models of interest for this analysis and outline its general strategy.

T 37.6 Tue 17:30 T-H22

Search for Vector Like Quarks in the decay channel to top and Higgs boson with the CMS experiment — •guillaume greau — Deutsches Elektronen-Synchrotron DESY, Hamburg, Allemagne

A search for vector like quarks (VLQ) using the Run 2 data collected by the CMS experiment is presented. The VLQs are searched in the decay channel into a top quarks and a Higgs boson, in which the Higgs boson further decays into WW. The channel with two leptons of same sign is studied, as it suppresses considerably the standard model background. First results on distributions to discriminate the signal from the background will be shown.

T 37.7 Tue 17:45 T-H22

Suche nach vektorartigen Quarks in Endzuständen mit einem Lepton, Jets und fehlendem transversalem Impuls am ATLAS Experiment — Frank Ellinghaus und •Jens Roggel — Bergische Universität Wuppertal

Verschiedene Modelle für Physik jenseits des Standardmodells sagen vektorartige Quarks voraus, deren rechts- und links-händige Komponenten gleichartig unter der schwachen Wechselwirkung transformieren.

Die Analyse fokussiert sich auf die Suche nach vektorartigen Top-Quarks aus Paarproduktion mit einem Zerfall in Top-Quark und Z-Boson, wobei das Z-Boson in Neutrinos zerfällt. Die betrachteten Ereignisse werden durch ein Lepton, Jets und einen hohen fehlenden transversalen Impuls im Endzustand gekennzeichnet. Weiter führen die hohen Massen der vektorartigen Quarks zu einem starken Boost der Zerfallsprodukte, was zu einer kollimierten Zerfallstopologie führt. Der Status der Analyse der ATLAS pp Daten bei $\sqrt{s} = 13$ TeV wird präsentiert, wobei Ausschlussgrenzen auf die Paarproduktion von vektorartigen Top- und auch Bottom-Quarks in allen Zerfallskanälen des vektorartigen Quarks in ein Boson und ein Quark gesetzt werden.

T 37.8 Tue 18:00 T-H22

Search for long-lived particles within the CMS tracker — •Karim El Morabit, Lisa Benato, Melanie Eich, Gregor Kasieczka, and Karla Pena — Institut für Experimentalphysik, Universität Hamburg

Several theories for physics beyond the standard model (BSM) predict the existence of long-lived particles (LLPs) that have comparably long lifetimes leading to macroscopic flight distances. Higgs-portal models, for example, propose the existence of a dark sector with particles that are neutral under the standard model (SM) gauge groups. In such theories, the SM Higgs boson mixes with a dark partner and acts as a mediator between the SM and the dark sector. The SM Higgs boson could then decay to a pair of dark sector LLPs which subsequently decay to SM particles – predominantly into bottom quark-antiquark ($b\bar{b}$) pairs.

This talk discusses searches for LLPs using data recorded with the CMS experiment at a center-of-mass energy of 13 TeV. The searches target events in which the LLPs decay into $b\bar{b}$ pairs within the CMS tracking system after flight distances ranging from micrometers up to 1 m. The signature of the signal events consists of $b\bar{b}$ originating from displaced vertices. The searches face different challenges depending on the lifetime of the LLPs. For short lifetimes, the decay products of LLPs need to be distinguished from those of SM particles, while the search for longer lifetimes requires dedicated tracking and vertex reconstruction methods. In both cases the challenges are tackled using machine learning approaches.

T 37.9 Tue 18:15 T-H22

Search for long-lived particles in the CMS calorimeters and muon chambers — •Lisa Benato, Jörg Schindler, and Gregor Kasieczka — Institut für Experimentalphysik, Universtät Hamburg

Many beyond the standard model (BSM) theories predict the existence of long-lived particles (LLPs) that have long lifetimes and decay in the outermost parts of a hadron collider experiment, such as the calorimeters and muon chambers of the CMS detector. Very displaced signatures (decay length beyond 1 m) can only be reconstructed with non-standard approaches by using low-level detector information (hits in the muon chambers and scintillation time of the calorimeter crystals). LLP decays in calorimeters are identified as jets, delayed with regards to the proton-proton collision and with a small number of associated tracks. Muon chambers act as sampling calorimeters and LLP decays originate showers of hits in the gas detectors, identified as clusters, with no concurrent activity in the inner layers. No SM process produces this kind of signatures at a relevant rate. The expected background is nearly zero and due to detector noise and non-collision backgrounds. Such a clean environment allows to probe light LLPs with unprecedented sensitivity.

T 38: Search for New Particles 3

Time: Tuesday 16:15–18:00 Location: T-H23

T 38.1 Tue 16:15 T-H23

Searching for Axion-Photon Couplings — •Robin Löwenberg, Tom Krokotsch, Daniel Klein, Gudrid Moortgat-Pick, and Krisztian Peters — Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

The nature of dark matter is not yet known. Extensive studies have been done searching for a weakly interactive massive particle (WIMP) but are still waiting for a positive signal.

Another popular approach is assuming that dark matter consists of light particles rather than WIMPs. These particles are called weakly interactive slender particles (WISPs). One of the most promising candidates is the axion which was proposed in the seventies to solve the so-called strong-CP-problem. It later turned out to be a good dark matter candidate in a certain mass range.

Experiments searching for axions and axion-like particles like ALPS 1 (2007-2010) and ALPS 2 (since 2021) are provided by Deutsches Elektronen-Synchrotron (DESY) in Hamburg with further experiments on the way. Most of them are based on the assumption that axions show photon-like couplings and therefore would interact with electromagnetic fields.

This talk aims to explain the concept of axions and in which mass ranges and coupling strengths they might be a good dark matter candidate. Furthermore, a quick overview will be given of current and possible future experiments promising to detect the particle if it exists.

T 38.2 Tue 16:30 T-H23

The ALPS II experiment at DESY - Status and prospects — •Kanioar Karan for the ALPS-Collaboration — DESY / Cardiff University, Hamburg, Germany

The Any Light Particle Search II (ALPS II) is a laboratory-based light shining through a wall experiment (LSW) to probe the existence of

Axion-Like-Particles (ALPs) with a coupling to electromagnetic fields as low as $g_{a\gamma\gamma} \approx 2 \times 10^{-11}\text{GeV}^{-1}$ that is hinted at some astrophysical anomalies such as stellar evolutions and the TeV transparency of the universe. This LSW experiment is based on the simple idea that a high power laser field that propagates through a static magnetic field can partly oscillate into an ALP field. The ALP field then crosses an opaque wall to a second static magnetic field and can partly reoscillates into an electromagnetic field which can be detected with a detector. In order to achieve the anticipated sensitivity, two 125m long optical cavities, operated in a vacuum system, are used: one with an expected circulating power of 150kW for the ALPs production and one with an expected power build-up of 40,000 to enhance the regeneration of the electromagnetic field. The circulating field in each cavity is directed through a string of 12 superconducting HERA dipole magnets providing a magnetic field of 5.3T. The ALPS II experiment is located at DESY in Hamburg and is currently in the commissioning phase. In this talk, we will present the current status, challenges and perspectives of the ALPS II experiment with the focus on the optical setup.

T 38.3 Tue 16:45 T-H23

Analysis and simulation of TES data in the ALPS II experiment — •José Alejandro Rubiera Gimeno for the ALPS-Collaboration — Deutsches Elektronen-Synchrotron, Hamburg, Germany

The Any Light Particle Search II (ALPS II) is a Light-Shining-through-a-Wall experiment under construction at DESY, Hamburg. Its goal is to probe the existence of Axion Like Particles (ALPs), a possible candidate for dark matter. In the ALPS II region of study, a rate of photons reconverting from ALPs on the order of 10^{-5} cps is expected. This requires a sensor capable of measuring low-energy photons (1.165 eV) with high efficiency and a low dark count rate. We investigate a tungsten Transition Edge Sensor (TES) system as a photon-counting detector that promises to meet these requirements. This detector exploits the drastic change in its resistance caused by the absorption of a single photon when operated in its superconducting transition region at millikelvin temperatures. In this work, the analysis procedure applied to measured TES pulses, in time and frequency domain, is presented. This analysis allows extracting characteristic parameters used for signal discrimination against backgrounds. The energy resolution computed from data is compared to simulations of electronic noise superimposed with ideal photon pulses.

T 38.4 Tue 17:00 T-H23

Status and Prospects of a TES-based Detector System for ALPS II — •Gulden Othman for the ALPS-Collaboration — University of Hamburg, Hamburg, Germany

The Any Light Particle Search II (ALPS II) experiment will search for QCD axions and axion-like particles (ALPs) in an important parameter space that is relevant in understanding anomalous astrophysical phenomena, including stellar evolution and dark matter. ALPS II takes advantage of the axion coupling to photons using a Light-Shining-through-a-Wall technique. Photons created using a strong laser may convert into ALPs in the presence of a strong magnetic field. The ALPs can traverse a light-tight barrier, reconvert into photons within a second magnet string, and be subsequently detected. The rate of re-converted photons is extremely low, on the order of 10^{-5} counts/second, and their observation requires the use of sensitive photon detectors with high efficiency and low backgrounds. The first stage of ALPS II, currently under construction at DESY, Hamburg, will use a heterodyne detection method. In the subsequent phase, ALPS II can utilize advances in cryogenic quantum sensing by employing Transition Edge Sensors (TESs). We are currently developing a TES-based detector system that can meet the requirements for ALPS II, offering single-photon detection with high efficiency and low-backgrounds at the 1064 nm (1.165 eV) energy of interest. In this talk, we present the feasibility, challenges, and current status of the TES-based detector system for ALPS II at DESY, Hamburg.

T 38.5 Tue 17:15 T-H23

Monte Carlo based ray tracing for BabyIAXO — •Johanna von Oy, Klaus Desch, Jochen Kaminski, Tobias Schiffer, and Sebastian Schmidt — Physikalisches Institut der Universität Bonn

The premise of the International AXion Observatory (IAXO) and its intermediate experimental stage BabyIAXO is to detect the undiscovered particle axion, which can be a good candidate for dark matter. This will be done by utilizing the inverse Primakoff effect to reconvert them into X-rays in the magnetic field of a movable magnet. Following this, they would get focused by an X-ray optic and detected in, for example, a window sealed gaseous detector.

To simulate this whole process, ray tracing based on the Monte Carlo method is a useful tool, as a certain number of axions would be generated and get assigned different probabilities and changes of direction depending on the setup. This talk will focus on the individual steps, starting with the production in the sun and following the axion's path to the detector.

T 38.6 Tue 17:30 T-H23

Anisotropy effects in a dielectric haloscope for dark matter searches — •bernardo ary dos santos for the MADMAX-Collaboration — RWTH III. Physikalisches Institut A, Aachen, Germany

The MADMAX collaboration intends to build a dielectric haloscope targeted to detect galactic axion dark matter, in the mass range $40-400\mu$eV . This experiment consists of a series of dielectric discs and a mirror placed inside a strong homogeneous magnetic field that would produce the emission of coherent electromagnetic radiation with a frequency related to the mass of the axion. One of the current challenges is to simulate this experiment taking into account realistic settings. We present an improved simulation that is able to include the effects of anisotropic dielectric discs in the experiment.

T 38.7 Tue 17:45 T-H23

Axion dark matter searches using superconducting radio frequency cavities — •Tom Krokotsch[1], Robin Löwenberg[1], Daniel Klein[1], Gudrid Moortgat-Pick[1,2], and Krisztian Peters[2] — [1]Universität Hamburg, Hamburg, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

Recent proposals of employing superconducting radio frequency (SRF) cavities to detect axions suggest promising sensitivities in previously unexplored parameter space. This includes QCD axions and axion-like dark matter with masses in a range of about eight orders of magnitude.

The setup aims to detect photons generated through the predicted interaction of axions with electromagnetic fields. An advantage of this design is that it allows scanning over a range of axion masses by slightly altering the cavity. Such a detector benefits from the high quality factors achieved in modern SRF technology.

In the talk we discuss the general idea behind the detector, it's most significant parameters to achieve a high signal power and evaluate which cavity geometries and transitions are the most promising. Particular attention must be paid to minimise various noise sources which limit the sensitivity of the setup.

T 39: Gaseous Detectors 2

Time: Tuesday 16:15–18:15 Location: T-H24

T 39.1 Tue 16:15 T-H24

Development of gas and high voltage systems for a small-strip Thin Gap Chamber quadruplet — •José Antonio Fernández Pretel, Ksenia Solovieva, Bernhard Pfeifer, Jürgen Tobias, Patrick Scholer, Ulrich Landgraf, and Vladislavs Plesanovs — Albert-Ludwigs Universität Freiburg

In the ATLAS detector, a good performance of the trigger and tracking systems is needed to ensure its physics program. For this purpose, the end-cap muon system has been upgraded by installing the so-called New Small Wheel. The small-strip Thin Gap Chambers (or sTGCs for short, one of its main technologies) are multi-wire proportional counters running with a working mixture of CO_2:n-pentane (55:45) and a high voltage about 3kV for signal amplification. For the test setup being designed in Freiburg, a gas and high voltage systems are needed to run sTGCs, whose optimal operation needs to be guaranteed in real time via monitoring. In this presentation, the mixing, delivery and storage components of the gas system, the high-voltage and monitoring systems to run sTGCs in Freiburg are discussed.

T 39.2 Tue 16:30 T-H24

Cosmic Test Stand Studies with a small-strip Thin Gap Chamber quadruplet — •Ksenia Solovieva, Jose Antonio Fernandez Pretel, Patrick Scholer, Vladislavs Plesanovs, and Ulrich Landgraf — Albert-Ludwigs University, Freiburg

The small-strip Thin Gap Chamber (sTGC) technology is being implemented in the New Small Wheel upgrade of ATLAS for improved triggering and tracking in a higher particle rate environment. The sTGC detector readout includes a pad segmentation, which plays a key role in the trigger chain. For the purpose of investigating readout and trigger parameters, a quadruplet was set up in a cosmic muon test stand in Freiburg and read out with the final ATLAS NSW readout system and the final gas mixture. Another quadruplet was also tested in the gamma irradiation facility (GIF++) at CERN with a muon beam. The results of this study will be used for comparison with the results from the local setup. This presentation discusses the goals and challenges of the dedicated setup, as well as presenting the prospective results.

T 39.3 Tue 16:45 T-H24

Study of the Position Resolution of Large Scale Micromegas Detectors — •Vladislavs Plesanovs, Patrick Scholer, Ulrich Landgraf, and Gregor Herten — University of Freiburg

During the current Long Shutdown 2 (LS2), the ATLAS muon spectrometer will receive an upgrade with the New Small Wheels (NSW), which consist of two new technologies, the sTGC detector (trigger) and the Micromegas detector (tracking).

The performance parameters of the Micromegas detectors, such as efficiency, gain, and position resolution, have been studied in the past with cosmic muons and test beams. In a recent study using cosmic muons, which forms the basis for this presentation, an attempt was made to improve the position resolution using a charge-weighted mean time correction.

T 39.4 Tue 17:00 T-H24

Clock phase calibration of the readout controller of the NSW — •Jonas Roemer[1], Anne Fortman[2], Michelle Solis[3], and Jared Sturdy[1] — [1]Department of Physics and Astronomy, University of California, Irvine — [2]Harvard University — [3]University of Arizona

ATLAS introduces a new muon detector system for the upcoming Run 3 of the LHC: The New Small Wheel (NSW). The NSW features two detector technologies, the Micromegas and the small Thin Gap Chambers. The front-end boards of both technologies use the same readout controller ASIC (ROC). The purpose of the ROC is, among other things, to receive and route trigger, timing and control (TTC) signals, and to collect the channel hit data and transmit it to the readout system.

The ROC samples the TTC stream with a configurable 40 MHz clock. The phase of this clock must be calibrated to interpret the TTC words correctly. Furthermore, the ROC has two 160 MHz clocks for internal functionality and for sampling the hit data from the VMMs. Both must be calibrated relative to each other.

This talk outlines the electronics architecture and calibration procedure and presents the results.

T 39.5 Tue 17:15 T-H24

Gas Monitoring Chambers for the T2K Near Detector Upgrade — Philip Hamacher-Baumann, Ines Hannen, Leon Mans, Thomas Radermacher, Stefan Roth, David Smyczek, and •Nick Thamm — RWTH Aachen University - Physics Institute III B, Aachen, Germany

Measurements from the Tokai to Kamioka (T2K) long baseline neutrino oscillation experiment have shown first indications for CP violation in the leptonic sector. To improve these results, a part of the near detector (ND280) of T2K will be replaced by a 3D fine-grained scintillator tracker acting as target (SFGD), two high-angle time projection chambers (HA-TPCs) and a time-of-flight system (TOF). The Aachen group is developing and constructing new gas monitoring chambers for the existing and new TPC systems to be installed in 2023. These chambers are dedicated to the continuous calibration and monitoring of the TPC drift gas properties. This talk gives an overview of the design, simulation, comissioning and series production of the new gas monitoring system.

T 39.6 Tue 17:30 T-H24

Electronics of the New T2K Gas Monitoring Chambers — Philip Hamacher-Baumann, Thomas Radermacher, Stefan Roth, •David Smyczek, and Nick Thamm — RWTH Aachen University - Physics Institute III B, Aachen, Germany

A pair of High Angle Time Projection Chambers (HATs) will be installed during the upgrade of the T2K near detector ND280. For the calibration of the new HATs the gas parameters will be continuously monitored. For this task, new Gas Monitoring Chambers (GMCs) are developed by the Aachen group and currently under construction. The electronics of the GMC consist of a preamplifier for the anode signals, a triggering system using SiPMs, a data acquisition system using VME waveform digitizers and a slow control logging parameters like pressure and temperature. The design and the commissioning of the electronics system will be presented.

T 39.7 Tue 17:45 T-H24

Hydrogen-rich Gases for High Pressure Time Projection Chambers at Neutrino Beamlines — •Philip Hamacher-Baumann, Thomas Radermacher, Stefan Roth, and Nick Thamm — Physics Institute III B, Aachen, Germany

DUNE's near detector complex foresees a magnetized high-pressure gaseous time projection chamber (HPgTPC) as part of its detector suite. The gaseous active volume boasts a very low detection threshold with high particle-identification power and large acceptance for tracking. Especially interactions on the gas itself in the high intensity neutrino beam will be collected with an unmatched rate. For design and development of a pressurized TPC, it is essential to quantify and validate electron drift parameters, to predict performance of the final detector, e.g. HPgTPC. This presentation investigates how electron drift parameters of drift gas mixtures perform at higher than atmospheric pressures. Additionally, a study of hydrogen-rich Argon:Methane gas mixtures for consideration in HPgTPC is presented using measurements from a test chamber.

T 39.8 Tue 18:00 T-H24

Boron-based neutron Time Projection Chamber — •Divya Pal[1], Jochen Kaminski[1], Micheal Lupberger[1], Markus Köhli[1,2], Klaus Desch[1], Markus Gruber[1], Saime Gürbuz[1], and Laura Rodriguez Gómez[1] — [1]Physikalisches Institut, Universität Bonn — [2]Physikalisches Institut, Universität Heidelberg

Thermal neutron detection is crucial in various areas ranging from fundamental physics research to national security, crystallography and medicine. Tradionally, thermal neutron detectors use Helium-3 filled proportional counters. However, due to the supply shortage of Helium-3, leading to a rapid increase in its price, alternative detectors are sought.

In Bonn, the BOron DEtector with Light and Ionization Reconstruction (BODELAIRE) is being developed to provide high spatial and time resolution in thermal neutron detection. The BODELAIRE is based on the principle of a Time Projection Chamber (TPC) with thin layers of Boron-10 neutron converters placed perpendicular to a GridPix readout which will have Timepix3 as ASIC. The trigger is placed along the field cage, consisting of multiple layers: Boron, scintillator and light readout. Thus, the working principle is that the conversion of the neutron with Boron-10 gives two tracks, one giving a trigger signal in the scintillator while the other leaves a track in the gas volume.

The concept and current development status of the BODELAIRE will be presented.

T 40: Pixel Detectors 2

Time: Tuesday 16:15–18:30 Location: T-H25

T 40.1 Tue 16:15 T-H25

Tangerine: Monte Carlo simulations of MAPS in a 65 nm imaging process — •Manuel Alejandro Del Rio Viera, Håkan Wennlöf, and Adriana Simancas for the Tangerine-Collaboration — Deutsches Elektronen-Synchrotron (DESY)

The Tangerine project's goal is to develop the next generation of small collection electrode monolithic silicon pixel detectors using the 65 nm CMOS imaging process. This offers a higher logic density and overall lower power consumption compared to previously used processes. In monolithic sensors the sensitive volume and readout are in a single chip, which enables a lower material budget, and reduced cost and production effort compared to hybrid sensors.

In order to understand the processes and parameters that are involved in the developments in the new 65 nm technology, a combination of TCAD and Monte Carlo (MC) simulations are used. Allpix Squared utilizes the realistic electric fields and doping profiles provided by the TCAD simulations and by the use of MC methods, obtains results that can later be compared to experimental data from test beam experiments.

This presentation will cover the design and setup of the Monte Carlo simulations and present the results obtained so far.

T 40.2 Tue 16:30 T-H25

Tangerine project - Studies of MAPS prototypes in CMOS 65 nm technology — •Gianpiero Vignola for the Tangerine-Collaboration — Deutsches Elektronen-Synchrotron, Hamburg, Germany

CMOS Monolithic Active Pixel Sensors, widely used as imaging devices, represent an attractive alternative to hybrid pixel detectors in High Energy Physics. The Tangerine project at DESY aims to develop a fully integrated 65 *nm* CMOS pixel sensor for future application, from beam-test facilities to Higgs factories. The goal is to achieve time resolutions of the order of 1 ns and spatial resolution below 3 μm. First 65 *nm* CMOS test chips with 4 pixels of 16 μm pitch and analog readout have been investigated in beam-test studies and with an Iron-55 source. Results of detailed waveform analysis, characterizing the charge sensitive amplifier, will be reported. The outcome of these studies will be used to improve the sensor layout and its signal-processing circuitry in the next Tangerine prototype.

T 40.3 Tue 16:45 T-H25

Device simulations of a MAPS developed in 65nm CMOS Imaging Technology — •Adriana Simancas for the Tangerine-Collaboration — Deutsches Elektronen-Synchrotron, Hamburg, Deutschland

Monolithic CMOS sensors have found their way through imaging technologies into High Energy Physics thanks to multiple advantages in particle detection. Their main characteristic is the integration of an active sensor and readout in the same silicon wafer, which provides a reduction in production effort, costs and material. The Tangerine project aims to develop the next generation of silicon pixel sensors for lepton colliders using a 65 nm CMOS imaging technology with a small collection electrode. It offers a significant improvement in the logic density of the pixels, the power consumption, the material budget and the S/N in comparison to previously studied technologies. Since the electric fields in monolithic sensors are quite complex, device simulations are needed to develop an understanding of this technology and provide important insight into performance parameters of the sensor. TCAD is a very powerful tool that allows to simulate the electrical properties of semiconductors. Herewith, it is possible to optimize the sensor layout and other features to achieve excellent time and spatial resolution. This contribution will present the latest developments in device simulation of a 65 nm CMOS sensor with a small collection electrode using TCAD.

T 40.4 Tue 17:00 T-H25

Simulating Hexagonal Monolithic Pixel Sensors in CMOS Imaging Technology — •Larissa Mendes for the Tangerine-Collaboration — Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

In this research, monolithic pixel sensors in CMOS imaging technologies with small collection electrodes are investigated for fast signal collection and precise timing to be used at future lepton colliders. Integrated monolithic CMOS offers a cost-effective monolithic integration of sensor and electronics. It allows significant reductions in the material budget compared to hybrid pixel detectors, providing an excellent signal-to-noise ratio and position resolution.

When compared to a square grid, the distance between the pixel border and the collection electrode can be reduced by placing the collection electrodes on a hexagonal grid for a given area defined by the circuit functionality. The hexagonal grid reduces charge sharing, increasing the signal in the seed pixel. The studies are being carried out with 3D Synopsys' Technology Computer-Aided Design (TCAD) to create a sensor structure that can optimize the depletion region size and increase the lateral electric field for fast charge collection by drift. The electrode size, electrode size, as well as other parameters of the sensor design, are optimized using 3D TCAD simulations.

T 40.5 Tue 17:15 T-H25

Guard-ring optimisation for sensors in LFoundry 150nm CMOS technology — •Sinuo Zhang, Tomasz Hemperek, and Jochen Dingfelder — Physikalishes Institut, Rheinishe Friedrich-Welhem Universität Bonn, Nussallee 12, 53115 Bonn, Germany

In high energy physics, the silicon pixel sensors manufactured in commercial CMOS chip fabrication lines have been proven to have a good radiation hardness and spatial resolution. Along with the mature manufacturing techniques and the potential of large throughput provided by the foundries, the so-called "passive CMOS" sensor has become an interesting alternative to standard planar sensors, in particular for large-area applications. High and predictable breakdown behaviour for pre- and post-irradiation is a major design goal for sensors and the guard-ring structure is one factor to optimise. This is especially important for applications that require higher voltages.

We present several concepts of the guard-ring design that can be realised in LFoundry 150nm CMOS technology. As was studied with TCAD simulations, such designs can lead to a higher breakdown voltage by modifying the potential and electric field distribution in the guard-ring area. A number of test structures have been designed for the RD50 MPW-3 and the CMS CROC submission for verifications and further studies.

T 40.6 Tue 17:30 T-H25

Monte Carlo simulations of a beam telescope setup based on the 65nm CMOS Imaging Technology — •Sara Ruiz Daza for the Tangerine-Collaboration — Deutsches Elektronen-Synchrotron, Hamburg, Germany

Monolithic CMOS sensors enable the development of detectors with a low material budget and a low fabrication cost. Moreover, using a small collection electrode results in a small sensor capacitance, a low analogue power consumption, and a large signal-to-noise ratio. These characteristics have become very attractive in the development of new silicon sensors for charged particle tracking at future experiments. A beam telescope setup consisting of detector prototypes designed in a novel 65 nm CMOS imaging process is being simulated. This contribution describes the first steps and verifications in the design of such a telescope using the Allpix Squared and Corryvreckan frameworks for simulation and analysis.

T 40.7 Tue 17:45 T-H25

The Allpix Squared pixel detector simulation framework — •Håkan Wennlöf, Simon Spannagel, and Paul Schütze — DESY, Notkestrasse 85, 22607 Hamburg, Germany

The Allpix Squared sensor simulation framework is a modular and flexible open-source tool for simulating pixel detectors. The framework has the capability of simulating the full detector chain, from energy deposited by incident particles to signal formation and digitisation. Both single detectors and more complex setups, such as testbeam telescope experiments, can be investigated in great detail. Through its interface to GEANT4, Allpix Squared has access to advanced physics models and particle sources. The framework can also import fields and doping maps from technology computer-aided design (TCAD) simulations, creating a detailed simulation of individual charge carrier behaviour in the investigated sensor models. This yields a powerful combination of TCAD and Monte Carlo simulations, which provides accurate high-statistics results while also accounting for stochastic fluctuations in the involved processes. This method has been used in comparing simulations with testbeam data, and finding a good match between results. Through the detailed electric field inclusion, time-dependent charge pulse formation can also be simulated in the framework.

Allpix Squared is currently used as part of developments of several state-of-the art sensors, for example in the Tangerine project at DESY. This contribution will present the current status of the Allpix Squared framework, and give examples of use cases.

T 40.8 Tue 18:00 T-H25

Development and characterization of a DMAPS chip in TowerJazz 180 nm technology for high radiation environments — Ivan Berdalovic[2], •Christian Bespin[1], Jochen Dingfelder[1], Tomasz Hemperek[1], Toko Hirono[1,3], Fabian Hügging[1], Hans Krüger[1], Thanushan Kugathasan[2], Cesar Augusto Marin Tobon[2], Konstantinos Moustakas[1], Heinz Pernegger[2], Walter Snoeys[2], Tianyang Wang[1], and Norbert Wermes[1] — [1]Universität Bonn, Bonn, Deutschland — [2]CERN, Genf, Schweiz — [3]DESY, Hamburg, Deutschland

The increasing availability of commercial CMOS processes with high-resistivity wafers has fueled the R&D of depleted monolithic active pixel sensors (DMAPS) for usage in high energy physics experiments. One of these developments is a series of monolithic pixel detectors with column-drain readout architecture and small collection electrode facilitating low-power designs: the TJ-Monopix series.

TJ-Monopix is designed in a 180 nm TowerJazz CMOS process and features a pixel size of 33 um * 33 um. Due to improvements on the front-end electronics and sensor design of the current iteration TJ-Monopix2 the radiation hardness and efficiency could be increased while lowering the threshold and noise. Results from laboratory measurements and test beam campaigns will be presented to discuss the suitability of TJ-Monopix2 for use in high-radiation environments.

T 40.9 Tue 18:15 T-H25

Characterization of depleted monolithic active pixel sensors (DMAPS) designed in 150nm CMOS technology — •Lars Schall[1], Jochen Dingfelder[1], Christian Bespin[1], Ivan Caicedo[1], Tomasz Hemperek[1], Toko Hirono[1,2], Fabian Hügging[1], Hans Krüger[1], Piotr Rymaszewski[1], Tianyang Wang[1,3], and Norbert Wermes[1] — [1]Physikalisches Insitut, University of Bonn — [2]DESY, Hamburg — [3]Zhangjiang Laboratory, China

Monolithic active pixel sensors with depleted substrates are a promising option for pixel tracker detectors in high radiation environments. The use of a highly resistive silicon substrate and short drift paths enhance the radiation tolerance, while a careful guard ring design facilitates high biasing voltages to deplete the sensor.

LF-Monopix2 is the latest prototype of a DMAPS development in 150 nm CMOS technology. It features a fully functional column-drain readout architecture in a 2x1 cm^2 matrix. A reduced pixel pitch of 50x150 μm^2 compared to its predecessor results in a smaller detector capacitance and an improved spatial resolution. Each pixel's digital electronics are integrated within the large collection electrode. Optimization of the pixel layout minimizes potential cross talk from the digital transients into the sensor node.

LF-Monopix2 chips have successfully been thinned to a thickness of 100 μm while their breakdown voltage remained above 350 V. In this talk, the ongoing characterization and preliminary results of the first test-beam campaign of these sensors are discussed.

T 41: Calorimeters 1

Time: Tuesday 16:15–18:30 Location: T-H26

T 41.1 Tue 16:15 T-H26

Scintillator studies for the CALICE Analogue Hadronic Calorimeter and the DUNE ND-GAr Electromagnetic Calorimeter — Andrea Brogna[2], Peter Bernhard[2], Volker Büscher[1], Karl-Heinz Geib[1], Asma Hadef[1], •Antoine Laudrain[1], Lucia Masetti[1], Marisol Robles Manzano[1], Anna Rosmanitz[1], Christian Schmitt[1], Alfons Weber[1], and Quirin Weitzel[2] for the CALICE-D-Collaboration — [1]Institut für Physik, Johannes Gutenberg Universität, Mainz — [2]PRISMA Detector Lab, Johannes Gutenberg Universität, Mainz

The CALICE Analogue Hadronic Calorimeter (AHCal) is designed as an imaging calorimeter optimised for particle flow algorithms. It features a high granularity and timing resolution, with plastic scintillator active layers and SiPM readout. The concept of Megatile is developed to ease the assembly of a large scale detector, separating a large piece of scintillator with a glue + TiO_2 mixture and gluing a reflective sheet on both sides instead of individually wrapping smaller tiles in a reflective foil for each channel.

In the DUNE ND-GAr, neutron energy is reconstructed using the time-of-flight information provided by the Electromagnetic Calorimeter (ECal). The ECal must therefore provide neutron identification with high granularity and timing, making the AHCal with Megatiles a potential design candidate. Pulse shape discrimination is envisaged as a means to discriminate photon from neutron interaction in the ECal. A setup to study the PSD performance of various plastic scintillators with SiPM readout has been set up and first results will be presented.

T 41.2 Tue 16:30 T-H26

Exploring the intrinsic Time Resolution of the SiPM-on-Tile Technology — •Fabian Hummer, Lorenz Emberger, and Frank Simon for the CALICE-D-Collaboration — Max-Planck-Institut für Physik

The SiPM-on-Tile technology, where small plastic scintillator tiles are directly read out with SiPMs, has been developed for the CALICE Analog Hadron Calorimeter (AHCAL), and has been adopted for parts of the hadronic section of the CMS HGCAL. For future electron-positron colliders, a single cell time stamping on the sub-nanosecond level for energy deposits corresponding to single minimum-ionizing particles is desired to provide background rejection and to support pattern recognition and energy reconstruction with particle flow algorithms. To better understand the intrinsic time resolution achievable with the SiPM-on-Tile technology, detailed measurements have been performed in test beams at DESY, probing different scintillator tile sizes and materials. The study is complemented by laser measurements that provide insights into processes within the scintillator tile relevant for timing. Geant4 simulations allow us to verify our results and to find the correlations between scintillator tile size, light yield and time resolution. In this contribution, we will discuss our measurement methods, the results of our SiPM-on-Tile timing study and the implementation and performance in simulations.

T 41.3 Tue 16:45 T-H26

Latest Tests of CMS HGCAL Tilemodule Prototypes — •Malinda de Silva, Mathias Reinecke, Katja Krüger, Ole Bach, and Felix Sefkow — Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

For the HL-LHC phase, the calorimeter endcap of the CMS detector will be upgraded with a High Granularity Calorimeter (HGCAL), a sampling calorimeter that will use silicon sensors as well as scintillator tiles read out by silicon photomultipliers (SiPMs) as active material (SiPM-on-tile). The complete HGCAL will be operated at −30 °C. The SiPMs will be used in areas where the expected radiation dose during the lifetime of the detector is up to 5×10^{13} n_{eq}/cm^2. The design of the SiPM-on-tile part is inspired by the CALICE AHCAL.

The basic detector unit in the SiPM-on-tile part is the tile module, consisting of a PCB with one or two HGCROC ASICs, reading out up to 96 tiles with SiPMs. To acquire the data as well as to send the fast and slow control commands, monitor temperature and voltages from the tile modules a dedicated DAQ system has been designed and implemented. This DAQ system was tested alongside the latest generation of tile modules at the October 2021 test beam at DESY as well as tests at −30 °C were conducted using a climate chamber. Results from these tests will be reported.

T 41.4 Tue 17:00 T-H26

Test beam results of the Megatile prototype for the CALICE AHCAL — •Anna Rosmanitz for the CALICE-D-Collaboration — Johannes Gutenberg-Universität Mainz

The CALICE collaboration is developing a highly granular Analog

Hadronic Calorimeter (AHCAL) for a future e^+e^- linear collider.
The current design for the AHCAL consists of small, separately produced scintillator tiles with a size of 3x3 cm^2 read out by silicon photomultipliers (SiPM). They are separately wrapped in reflective foil and glued to the boards. In total, the AHCAL is going to consist of around 8 million tiles.
To facilitate the assembly process, a new mechanical design is currently under development. The new concept, called Megatile, is based on a larger scintillator plate, in which the optical separation is obtained via trenches filled with a glue and TiO_2 mixture for reflectivity and optical insulation. The Megatile is enclosed with reflective foil, the edges are covered with varnish.
This talk presents the performance in terms of light yield and cross talk of the latest megatile prototype, based on test beam data from recent campaigns at DESY.

T 41.5 Tue 17:15 T-H26

Timing analysis of testbeam data with the KLauS6 ASIC for a Silicon Photomultiplier on Scintillator Tile Setup — •Erik Warttmann for the CALICE-D-Collaboration — Kirchhoff-Institute for Physics, Heidelberg

The CALICE collaboration is developing highly-granular scintillator-based calorimeters with the need of sophisticated readout solutions. For this purpose, the KLauS ASIC has been developed. It is designed to dissipate very little power and features precise charge measurement optimized for low-gain SiPMs, covering their full dynamic range. Additionally, the sixth iteration of the chip provides timing information via a Phase-Locked-Loop (PLL) driven TDC with a bin size of 200 ps. The chip has been evaluated in a SiPM-on-Tile setup at the DESY testbeam facility, using an arrangement of four layers of scintillating tiles air-coupled to SiPMs. Various calibration measurements have been carried out to ensure precise charge and time measurements. The influence of multiple chip parameters on timing at the single MIP level has been investigated. To study the dependence of timing on the deposited energy, measurements with absorbers have been carried out. For the analysis of single MIP and absorber data, a stable and versatile timewalk correction has been implemented. We present the time measurement capabilities of KLauS6 using the SiPM-on-Tile arrangement, discuss the calibration routines and critical ASIC parameters. The results from single MIP runs and the absorber data regarding the time measurement are presented, which are comparable to the intrinsic resolution of the setup.

T 41.6 Tue 17:30 T-H26

Apply Computer Vision Algorithm to High Granularity Calorimetry — •Julian Utehs and Stan Lai for the CALICE-D-Collaboration — II. Institute of Physics, Georg-August-University Göttingen, Germany

In the course of the development of the new ILC detector, there is extensive research towards high granularity calorimeters. The CALICE collaboration has developed a prototype, the Analog Hadron Calorimeter, which uses SiPM technology to read out highly granular scintillator tiles. Test beam data provides unprecedented opportunities to investigate particle shower reconstruction with highly granular calorimetry.

This talk will concentrate on the opportunities of shower shapes analysis, that are given by the usage of well-known computer vision algorithms. These algorithms, coming from object detection and industry robotics and automation, will be applied on AHCAL calorimetry data. Their application allows for opportunities to reconstruct and resolve sub-shower activity and possibly estimate the electromagnetic fraction of hadronic showers. This can be input into energy reconstruction and particle identification techniques, and possible improvements for these are investigated.

T 41.7 Tue 17:45 T-H26

New shower direction reconstructing calorimeter — •Matei Climescu and Rainer Wanke — Johannes Gutenberg Universität Mainz

The so-called SplitCAL detector is a new design of a mixed electromagnetic-hadronic calorimeter which provides both energy reconstruction through layers of scintillating strips, read-out with wavelength shifting fibres and SiPMs, and shower direction information through high-precision layers. This can be used for fixed target experiments which require high geometrical precision and directional reconstruction of photon showers. The development needs to account for low rates but large dynamic range. The whole concept is presented with specific focus on the link of the scintillating fibres to the SiPMs and the readout.

T 41.8 Tue 18:00 T-H26

Convolutional Neural Networks for the Energy Reconstruction of ATLAS Liquid-Argon Calorimeter Signals — Anne-Sophie Berthold, Nick Fritzsche, •Christian Gutsche, Max Märker, Johann Christoph Voigt, and Arno Straessner — Institut für Kern- und Teilchenphysik, TU Dresden, Germany

In 2027, it is planned to start the High-Luminosity LHC, which will push the possibilities of research in particle physics with ATLAS to a new level. But since a higher trigger rate and more simultaneous collisions imply more pile-up the readout electronics of the detector will face a new challenge. The signal processing of the LAr Calorimeter is currently using an optimal filter algorithm which will reach its limits in performance with increasing overlapping signals. New approaches for energy-reconstruction are needed, and neural networks are promising candidates for such a task. While it is not hard to build a neural network which reconstructs energies reliably with a lot of trainable parameters, the problem is the limited availability of resources on the FPGAs which are foreseen for the digital signal processing.

In this talk, a possible solution for this task using convolutional neural networks (CNNs) will be presented. It will be shown how CNNs can be structured and trained in such a way that they will fit to the above-mentioned requirements. Special attention will be paid to the energy resolution for signals with a small temporal distance, having the pile-up at the HL-LHC in mind.

T 41.9 Tue 18:15 T-H26

ATLAS Liquid Argon Calorimeter Readiness for LHC Run 3 — •Tom Kresse, Arno Straessner, and Rainer Hentges — Institut für Kern- und Teilchenphysik, Dresden, Deutschland

Liquid argon (LAr) sampling calorimeters are employed by ATLAS for all electromagnetic calorimetry in the pseudo-rapidity region $|\eta| < 3.2$, and for hadronic and forward calorimetry in the region from $|\eta| = 1.5$ to $|\eta| = 4.9$. After detector consolidation during a long shutdown, LHC Run 2 started in 2015 and about 150fb-1 of data at a center-of-mass energy of 13 TeV was recorded. Phase-I detector upgrades began after the end of Run 2. New trigger readout electronics of the ATLAS LAr Calorimeter have been developed. Installation began at the start of the LHC shutdown in 2019 and is expected to be completed in 2021. A commissioning campaign is underway in order to realise the capabilities of the new, higher granularity and higher precision level-1 trigger hardware in Run 3 data taking. This contribution will give an overview of the new trigger readout commissioning, including the first data taken of the recommissioned LAr system in the October 2021 Pilot run, as well as its preparations for Run 3 detector operation.

T 42: Detector Systems 1

Time: Tuesday 16:15–18:00 Location: T-H27

T 42.1 Tue 16:15 T-H27

R&D of Multidimensional Calorimetry for the SHiP SBT — •Fairhurst Lyons for the SBT-Collaboration — ALU Freiburg

We present R&D towards a large-area detector for energy reconstruction and limited resolution tracking, which consists of many individual cells filled with liquid scintillator. Each cell is equipped with two wavelength-shifting optical modules (WOMs) that capture scintillation light and transfer it to silicon photomultipliers. This design could serve as the surrounding background tagger (SBT) of the proposed Search for Hidden Particles (SHiP) experiment, a general-purpose detector housed at the CERN SPS accelerator to search for light, feebly interacting particles. SHiP allows probing dark photons, dark (pseudo-)scalars, and heavy neutrinos, as well as the investigation of light dark matter, neutrinos, and flavour physics. The SBT studied here surrounds the vacuum decay vessel of SHiP to detect charged particles either entering the vacuum vessel from outside, or produced in inelastic interactions of muons and neutrinos in the vacuum vessel walls. We present studies of readout electronics and simulated individual detector cells investigating scintillator response.

T 42.2 Tue 16:30 T-H27

Studies to improve the light absorption of wavelength-shifting optical modules in the SHiP experiment — •Jakob Schmidt for the SBT-Collaboration — Humboldt-Universität zu Berlin, Berlin, Germany

The usage of wavelength-shifting optical modules (WOMs) as photon detectors was first proposed for the IceCube large-volume extension and then also for large-area liquid scintillator detectors as the SHiP surrounding background tagger (SBT). A WOM is a light-guiding tube coated with a UV light-absorbing paint that emits secondary photons in the visible spectrum. By total internal reflection inside the tube walls, these photons are guided to the actual photon detector, which in this case is made of a ring array of silicon photomultipliers that is coupled to one end of the tube. The light detection efficiency depends significantly on the light absorption in the wavelength shifter. This talk will present studies of coating methods to improve the light absorption in WOMs. This work is funded by the DFG.

T 42.3 Tue 16:45 T-H27

Measurements of photon exit angles of Wavelength-Shifting Optical Modules used in a large-area liquid-scintillator detector — •Florian Rehbein for the SBT-Collaboration — RWTH Aachen University, Aachen, Germany

This contribution presents first laboratory measurements of the optical characteristics and the quality of a Wavelength-Sifting Optical Module (WOM) as foreseen for a liquid-scintillator-based large-area detector. Measurements of the photon exit angle distribution have been taken with a DSLR camera on a test stand that was built specifically for this purpose. Further, it will be discussed how systematic measurements and comparisons to simulations will help to examine the properties of the module. WOMS combine a well-designed light guide with a wavelength-shifting coating, presenting a novel optical sensor for numerous applications, first proposed for the large-volume extension of the IceCube detector. WOMs are also foreseen as photon detectors in the Surround Background Tagger (SBT) in SHiP (Search for Hidden Particles), a proposed general-purpose fixed target experiment at the SPS accelerator of the CERN Facility. The SBT acts as a discriminator against external particle interactions and is composed of many cells utilizing liquid scintillator and tube-shaped WOMs made of PMMA to detect traversing particles. The coating of the WOMs absorbs the scintillation photons and re-emits wavelength-shifted photons, which are then detected by an array of SiPMs coupled to one end of the WOM. Supported by the DFG.

T 42.4 Tue 17:00 T-H27

Position-dependent detector response of a liquid scintillation detector instrumented with wavelength-shifting optical modules and SiPMs using cosmic muons — •Andrea Ernst for the SBT-Collaboration — Humboldt-Universität zu Berlin

The usage of wavelength-shifting optical modules (WOMs) as photon detectors was first proposed for the IceCube large-volume extension and then also for large-area liquid scintillator detectors as the SHiP surrounding background tagger (SBT). A WOM is a light-guiding tube coated with a UV light-absorbing paint that emits secondary photons in the visible spectrum. By total internal reflection inside the tube walls, these photons are guided to the actual photon detector, which in this case is made of a ring array of silicon photomultipliers that is coupled to one end of the tube. This contribution shows results of studies on the particle-position-dependent response of a prototype SBT-unit located at HU Berlin using cosmic muons. This work is funded by the DFG.

T 42.5 Tue 17:15 T-H27

Impact of a reflector on the light yield of WOMs — •Alexander Vagts for the SBT-Collaboration — Humboldt-Universität zu Berlin, Berlin, Deutschland

The usage of wavelength-shifting optical modules (WOMs) as photon detectors was first proposed for the IceCube large-volume extension and then also for large-area liquid scintillator detectors as the SHiP surrounding background tagger (SBT). A WOM is a light-guiding tube coated with a UV light-absorbing paint that emits secondary photons in the visible spectrum. By total internal reflection inside the tube walls, these photons are guided to the actual photon detector, which in this case is made of a ring array of silicon photomultipliers that is coupled to one end of the tube. This contribution shows results on whether a reflector at the other end of a WOM tube improves the light yield using cosmic muons traversing a liquid-scintillator detector prototype. This work is funded by the DFG.

T 42.6 Tue 17:30 T-H27

Tracking of charged particles using an FE-I4B pixel telescope and moving emulsion films — •Nikolaus Owtscharenko[1], Vadim Kostyukhin[1], Christopher Betancourt[2], Fabian Hügging[3], David-Leon Pohl[3], Antonia Di Crescenzo[4], Antonio Iuliano[4], and Markus Cristinziani[1] — [1]Center for Particle Physics Siegen, Experimentelle Teilchenphysik, Universität Siegen — [2]Universität Zürich — [3]Physikalisches Institut, Universität Bonn — [4]Sezione INFN di Napoli

The SHiP collaboration proposes a general purpose fixed-target experiment to search for hidden particles at the new beam-dump facility at CERN SPS. To estimate the charm production cross section in the experiment, which includes hadronic cascade production, several dedicated measurements have been proposed. A first run was performed in summer 2018. Protons from SPS interacted with a thick multilayer target, interleaved with tracking emulsion films. While the emulsion detector offered high spatial resolution, it did not provide timing information. For full event reconstruction a 6-plane telescope made of ATLAS IBL double-chip modules was assembled and placed downstream of the target to provide a high timing resolution. An occupancy limit on the emulsion films made a movement of the target during and in between spills necessary. Reconstruction of tracks and vertices in the pixel detector as well as matching of track and vertex candidates reconstructed in the moving emulsion detectors are presented.

T 42.7 Tue 17:45 T-H27

The SHiP Surrounding Background Tagger — •Annika Hollnagel for the SBT-Collaboration — JGU Mainz

Within the CERN Physics Beyond Colliders (PBC) initiative, the SHiP fixed-target experiment is a frontrunner proposal for the SPS Beam-Dump Facility (BDF). Making use of the high-intensity SPS beam with 4×10^{19} protons on target per year, the experiment will combine the Search for Hidden Particles (SHiP) of masses up to $200\,\mathrm{MeV/c^2}$ - such as Heavy Neutral Leptons (HNL) and Light Dark Matter (LDM) - with studies of tau neutrino physics.

The Hidden Sector Decay Spectrometer (HSDS) of the SHiP detector consists of a large evacuated volume followed by a magnetic spectrometer and particle identification system. To enable a background-free study of the decays of feebly-interacting particles, the reduction of beam-induced background heavily relies on the Surrounding Background Tagger (SBT) that envelops the 50 m-long decay vessel. The current baseline for the SBT is a segmented Liquid Scintillator (LS) detector of LAB and PPO that is instrumented with Wavelength-shifting Optical Modules (WOM) and read out via SiPMs. Since 2017, several test beam exposures of prototype detector cells have been conducted, supported by laboratory measurements and simulations. This talk will give a general overview on the SBT, summarise the state of the ongoing R&D, and present our plans for the next period of test beam measurements.

T 43: DAQ and Trigger 2

Time: Tuesday 16:15–18:15 Location: T-H28

T 43.1 Tue 16:15 T-H28

Calibration and Trigger Studies for the OSIRIS pre-detector of JUNO — •Runxuan Liu[1,2], Philipp Kampmann[3], Kai Loo[4], Livia Ludhova[1,2,3], Alexandre Göttel[1,2], Nikhil Mohan[3,2], Luca Pelicci[1,2], Mariam Rifai[1,2], Apeksha Singhal[1,2], and Cornelius Vollbrecht[1,2] — [1]Forschungszentrum Jülich GmbH, Nuclear Physics Institute IKP-2, Jülich, Germany — [2]III. Physikalisches Institut B, RWTH Aachen University, Aachen — [3]GSI Helmholtz Centre for Heavy Ion Research, Darmstadt, Germany — [4]Institute of Physics and EC PRISMA$^+$, Johannes Gutenberg Universität Mainz, Mainz

JUNO is a 20 kt liquid scintillator detector under construction in Jiangmen, China, which is expected to start data-taking in 2023. Its main goal is to determine the neutrino mass hierarchy with the measurement of reactor neutrinos from two adjacent nuclear power plants. This requires stringent limits on the radiopurity of the detector. The OSIRIS pre-detector is designed to monitor the liquid scintillator during the several months of filling the large volume of JUNO. OSIRIS will contain 18 ton of scintillator and will be equipped with 76 20-inch PMTs. OSIRIS will utilize two calibration systems: a laser fiber system and an insertion system for an LED or radioactive sources. The data acquisition system will have no global hardware trigger: instead, each PMT will provide a data-stream composed of the digitized PMT pulses, each containing a time stamp. Based on the latter, dedicated event builder software will organize these data streams into events. This talk will discuss the several trigger modes that are realized in the event builder software, a coincidence trigger and the calibration trigger.

T 43.2 Tue 16:30 T-H28

The MDT Trigger Processor for the ATLAS HL-LHC Upgrade — •Davide Cieri, Markus Fras, Oliver Kortner, and Sandra Kortner — Max-Planck-Institut für Physik, Munich, Germany

The novel MDT Trigger Processor (MDTTP) system is a fundamental part of the upgrade of the first-level (L0) muon trigger of the ATLAS experiment at the HL-LHC. The new system will be responsible for improving the muon momentum resolution and thus refining the muon selectivity, using for the first time at L0 the precision tracking information from Monitored Drift Tube (MDT) chambers in addition to the trigger chamber information. The system will also transmit the MDT hit data to the data acquisition (DAQ) system in the event of a trigger accept. A total of 64 MDTTP boards will be installed in ATLAS, one for each MDT trigger sector. The design of the MDTTP is highly challenging, requiring a high number of optical links and high-performance processing units.

We present here the recently designed prototype of the MDTTP. The prototype adopts a ATCA design, composed by two modules: the Service Module responsible for the powering and the infrastructure; and the Command Module, performing the trigger and DAQ processing and communicating with the other components of the ATLAS muon trigger. The Command Module mounts a state-of-the-art Xilinx Virtex Ultrascale+ FPGA, and employs ten 12-channel bidirectional optical transceiver modules with a link speed of up to 14 Gbps.

T 43.3 Tue 16:45 T-H28

The ATLAS Global Event Processor and the jet energy determination perspectives at level-0 trigger in Run-4 — •Fernado Del Rio — Kirchhoff Institut für Physik, Universität Heidelberg

Run 4 of the LHC, scheduled to take place between 2028 and 2032, is planned to deliver never-before-seen conditions for high energy physics measurements, including a center of mass energy of 14 TeV and an average number of interactions per crossing of 200. Under these challenging conditions the triggering algorithms and their performance becomes more important than ever.

Amongst the changes that will be implemented in ATLAS for this Run we highlight the construction and installation of the Global Event Processor (GEP), a single board with the whole detector information made for triggering at 40 MHz with offline-like algorithms for the reconstruction of all objects, such as electrons, photons, muons and jets. In the particular case of jet reconstruction, access to layer information allows for state-of-the-art calibration techniques to be applied at the trigger level. This talk will discuss the potential of having a level 1 version of the Global Sequential Calibration, a part of the jet calibration sequence tailored for improving the resolution in the measurement of jet energy. This improvement in resolution naturally yields a better trigger efficiency and a higher sensitivity to dijet mass resonances, allowing ATLAS to fully exploit the large statistics given by Run4.

T 43.4 Tue 17:00 T-H28

Trigger optimization studies in the search for displaced heavy neutral leptons with the ATLAS detector. — •Julius Ehrsam, Heiko Lacker, and Christian Appelt — Humboldt University, Berlin, Germany

Adding heavy neutral leptons (HNLs) with masses below the electroweak scale to the SM Lagrangian can help explain observed Beyond-Standard-Model phenomena such as neutrino oscillations, matter-antimatter asymmetry, and dark matter. We study a new trigger option for the ATLAS experiment designed explicitly for the search for HNLs produced in events $pp \to W + X$, $W \to \ell + \mathrm{HNL}$, with $\mathrm{HNL} \to \mu^+\mu^-\nu$, resulting in a prompt lepton and a displaced vertex due to the expected long HNL lifetime. The proposed trigger uses a muon as the prompt lepton and the angular separation between the two muons from the HNL decay.

T 43.5 Tue 17:15 T-H28

Optimizing the ATLAS b-jet Trigger for the LHC Run 3 — •Victor H. Ruelas Rivera — Humboldt-Universität zu Berlin, Berlin, Germany

The Higgs potential provides a way to experimentally probe and understand the underlying principles of mass generation and electroweak symmetry breaking. The shape of the Higgs potential is proportional to the Higgs self-coupling, λ_{HHH}, which can be probed at the LHC via proton-proton collisions ($pp \to HH$). Di-Higgs to 2 pairs of quarks ($HH \to b\bar{b}b\bar{b}$) is one of the most sensitive decay channels and it relies heavily on b-jet triggers. Triggers select information in real-time from the collisions and help mitigate ATLAS data acquisition getting overwhelmed by QCD jets. However, $HH \to b\bar{b}b\bar{b}$ is difficult to trigger due to the soft signal kinematics and high thresholds of hadronic triggers. Hence, more signal can be gained in Run 3 with better b-jet triggers. One of the goals of Run 3 is to improve the $HH \to b\bar{b}b\bar{b}$ triggers to enhance signal acceptance of SM and Beyond Standard Model (BSM) scenarios. The taggers that will be used for the b-jet trigger in Run 3 exploit multivariate analysis techniques, mainly Deep Neural Networks. This talk presents the optimization of the neural-network based flavour tagging discriminant used by the b-jet trigger. The algorithm is optimized on tracks, jets and vertices reconstructed by the High Level Trigger (HLT) software. The training software, network architecture and simulated events are being shared with the ATLAS offline b-tagging group to address redundancies and combine efforts towards a unified training framework for quick model re-optimization.

T 43.6 Tue 17:30 T-H28

Development of the Topological Trigger for LHCb Run 3 — Johannes Albrecht[1], Gregory Max Ciezarek[2], Niklas Nolte[3], Miroslav Saur[1], and •Nicole Schulte[1] — [1]TU Dortmund University, Department of Physics — [2]CERN — [3]MIT

In Run 3, the LHCb experiment will undergo a significant upgrade including the conversion to a software-only trigger system. This means the trigger software will have to efficiently process a substantially higher amount of data compared to previous years. The largest trigger algorithm for beauty physics in LHCb software is the Topological Trigger, which produces output used for most analyses. It is an inclusive trigger, aiming to select beauty decays based on topological and kinematic properties. Due to its inclusive nature, it can select candidates and trajectories from decays that might not have been discovered yet.

Two contributions to the Topological Trigger are shown. The first contribution will serve as a baseline for the collaboration and is based on a boosted decision tree algorithm. This approach has proven to be efficient in former years of data taking but has been optimized and remodeled for simulation of LHCb's upgrade. One of the major changes for the upgrade is the rise in the number of primary vertices during the interaction. Since primary vertex information is crucial for the Topological Trigger, the algorithm needs to be optimized to the conditions in the upgrade. The second contribution will explore a more experimental technique using a newly developed neural network architecture providing a robust model for the selection. Finally, both performances are compared.

T 43.7 Tue 17:45 T-H28

Study of potential lifetime bias in the LHCb reconstruction software for Run 3 — •Paula Herrero Gascón and Peilian Li — University of Heidelberg, Physikalisches Institut Heidelberg, Germany

The upgraded LHCb experiment will restart data taking in spring 2022 at an instantaneous luminosity of up to 2×10^{33} cm^{-2} s^{-1}. To effectively select the interesting b and charm hadron events at these high rates a full software trigger system is required. The entire reconstruction framework and its algorithms have been reimplemented and optimized. To be well-prepared for the coming data taken, it is essential to validate the physics performance for this completely new system. The precise reconstruction of the decay-time of b hadrons is vital for many time-dependent physics measurements at LHCb. This talk will focus on a performance study of the decay-time reconstruction for Run 3 and investigate potential reconstruction-induced biases.

T 43.8 Tue 18:00 T-H28

Performance of Belle II's Level 1 Single Track Trigger — •Felix Meggendorfer[1,3], Christian Kiesling[1,4], Elia Schmidt[1,4], Kai Lukas Unger[2], Steffen Bähr[2], Alois Knoll[3], Alexander Lenz[3], Sebastian Skambraks[2], and Jürgen Becker[2] for the Belle II-Collaboration — [1]MPI for Physics, Munich, Germany — [2]KIT, Karlsruhe, Germany — [3]TUM, Munich, Germany — [4]LMU, Munich, Germany

Belle II is the world record holder for the highest instantaneous luminosity, and the machine is still more than a factor 20 away of what it is capable of. These high collision rates make it mandatory to have an efficient trigger system. The Neurotrigger is a level 1 track trigger using the central drift chamber in the Belle II experiment. It estimates the z vertex and the polar angle θ of the tracks. To suppress the dominating background of events coming from outside of the interaction point, a cut on the track vertices along the beam axis is combined wit a momentum cut. This trigger, the 'STT', operates without a prescale and outperforms all other track triggers in Belle II. It is the first of its kind in high energy physics and most important for events with low charged multiplicity, such as tau pair production and candidates for dark matter searches.

T 44: Experimental Methods (general) 2

Time: Tuesday 16:15–17:45 Location: T-H29

T 44.1 Tue 16:15 T-H29

Particle identification with fast timing detectors at future Higgs factories — •Bohdan Dudar[1,2], Jenny List[1], and Ulrich Einhaus[1] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [2]Universität Hamburg, Hamburg, Germany

Future e^+e^- Higgs factory collider projects are designed for precision measurements of the Higgs boson and of electroweak observables, thereby utilizing every event to their full potential. The identification of the pions, kaons and protons plays a key role for precision measurements and event reconstruction, especially for the flavour tagging. To improve the identification of charged hadrons at low momentum we can use the time-of-flight method. It relies on current silicon sensor technologies with extremely good time resolution of 10 - 30 ps. This allows to measure the time-of-flight of particles and reconstruct their mass providing additional tool for identification of $\pi^\pm$, $K^\pm$ and p.

We study possible realistic implementation scenarios and potential physics applications of the fast timing silicon sensors into the future Higgs factory detectors using as an example the International Large Detector (ILD) at the International Linear Collider (ILC).

T 44.2 Tue 16:30 T-H29

Charged Kaon Mass Measurement via Time-of-Flight at a Future Higgs Factory — •Ulrich Einhaus[1], Bohdan Dudar[1,2], and Jenny List[1] — [1]Deutsches Elektronen-Sychrotron DESY, Notkestraße 85, 22607 Hamburg — [2]Universität Hamburg, Germany

The proposed future e^+e^- Higgs factories will allow to study not only the Higgs boson but the entire electroweak sector to an unprecendented precision. In order to utilise each event as well as possible, particle identification (PID) can be a powerful tool, which has been studied with increasing interest in recent years. The development of picosecond-timing detectors has been driven by the demand of background suppression at the LHC, but they can also be used for an effective time-of-flight (TOF) measurement to distinguish different charged hadrons. In addition to flavour physics applications, TOF can also be used to perform a competitive measurement of the charged kaon mass. This value is among the less precisely known ones and the two leading contributions from the early 1990s are at tension by more than 5σ with each other. The kaon mass value, however, is input to precision tracking and decay chain reconstruction, and can also be used to test theory predictions, e.g. from lattice QCD. This presentation discusses the prospects of a measurement of the charged kaon mass at future Higgs factories based on the full detector simulation of the International Large Detector (ILD) concept. This is the first analysis to make use of the recent implementation of TOF in a full-detector simulation for a future Higgs factory. It shows that such a measurement is feasible, but also highlights requirements and open questions.

T 44.3 Tue 16:45 T-H29

Identification of leptons inside jets at future Higgs factories — •Leonhard Reichenbach[1,2], Yasser Radkhorrami[1,2], and Jenny List[1] — [1]DESY Hamburg — [2]Universität Hamburg

One goal of a future Higgs factory is the precise measurement of the 125 GeV Higgs boson properties. As the Higgs boson predominantly decays to $b\bar{b}$, the precise reconstruction of heavy flavor jets is crucial. A source of uncertainty for these jets is missing momentum from semi-leptonic decays $b \to \ell\nu X$. Recent work has shown the possibility of correcting this missing neutrino momentum. For this, the charged lepton from the decay needs to be successfully detected and reconstructed. While particle flow detector concepts with their high granularity offer ideal conditions to identify leptons inside jets, the excellent hardware needs to be matched with corresponding reconstruction algorithms. In this work, we use the detailed simulation of the ILD detector concept to investigate how to exploit the information provided by a particle flow detector to identify single electrons and muons in a dense environment and how this improves the reconstruction of $H \to b\bar{b}$ decays.

T 44.4 Tue 17:00 T-H29

Detection of Spectra in the Strong-Field QED Regime with LUXE — •John Hallford[1,2] and Matthew Wing[1,2] — [1]University College London — [2]Deutsches Elektronen Synchrotron

Conventional QED's validity breaks down in the presence of an external strong electric field. LUXE (LASER Und XFEL Experiment), in Hamburg, intends to collide a high-intensity LASER pulse with highly boosted electrons and photons, up to 17.5 GeV from the EuXFEL, creating assisted electric fields up to and greater than the Schwinger limit.

This enables a non-negligible probability of non-linear Compton Scattering and Breit-Wheeler interactions - which represents a spontaneous boiling of the vacuum. The rates and kinematics of these interactions will be measured. Detection challenges include low-flux positron detection and tracking in a high-radiation environment, GeV-photon spectrometry, and high-flux, high-energy electron energy distribution reconstructions for a variety of spectrum shapes and dynamic ranges.

One of two detection solutions employed for the electron detection is a thin screen of a scintillating material, imaged remotely by optical cameras, and using magnetic deflection to reconstruct with respect to energy. The reconstruction methods and expected results for this detector and its consequences for LUXE are discussed.

T 44.5 Tue 17:15 T-H29

Simulation Studies for the Polarimetry of a LPA Electron Beam — •Jennifer Popp[1,2], Simon Bohlen[1], Felix Stehr[1,2], Jenny List[1,2], Gudrid Moortgat-Pick[2,1], Jens Osterhoff[1], and Kristjan Põder[1] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg — [2]University of Hamburg

Polarized particle beams are a key instrument for the investigation of spin-dependent processes and Laser Plasma Acceleration (LPA) has become a promising alternative to conventional RF accelerators. However, so far, it has only been theoretically shown that polarized LPA beams are possible.

The LEAP (Laser Electron Acceleration with Polarization) project at DESY aims to demonstrate this experimentally for the first time, using a prepolarized plasma target.

Because it is best suited for the expected energy range, the electron polarization will be measured with photon transmission polarimetry. It makes use of the production of circularly polarized Bremsstrahlung during the passage of the electrons through a suitable target. The photon polarization is then measured with the aid of the transmission asymmetry related to the magnetization direction of an iron absorber.

In this contribution an overview of the LEAP project will be given and a design for the polarimeter, simulation studies, and requirements on beam and polarimeter parameters for reliable polarization measurements will be presented.

T 44.6 Tue 17:30 T-H29

Calorimeter R&D for LPA Polarimetry — •Felix Stehr[1,2], Simon Bohlen[1], Oleksandr Borysov[1], Maryna Borysova[3,1], Jennifer Popp[1,2], Jenny List[1], Gudrid Moortgat-Pick[2,1], Jens Osterhoff[1], and Kristjan Põder[1] — [1]Deutsches Electronen-Synchrotron DESY, Hamburg — [2]University of Hamburg — [3]Institute for Nuclear Research NASU, Kyiv

The LEAP (Laser Electron Acceleration with Polarization) project at DESY aims to demonstrate the generation of polarized electron beams with a Laser-Plasma-Accelerator (LPA). Due to the expected beam energy of about 50 MeV, photon transmission polarimetry will be used to determine the achieved degree of polarization.

The key observable is an energy asymmetry of photons passing through a magnetized iron absorber. The total transmitted photon energy will be in the order of tens of TeV, which needs to be measured with percent-level accuracy in order to reliably detect asymmetries of a few ten percent. This contribution will discuss the detector requirements derived from detailed Geant4-simulations of the polarimeter and compare them to a first test of a calorimeter prototype operated in the LPA beam.

T 45: Gamma Astronomy 2

Time: Tuesday 16:15–18:15 Location: T-H30

T 45.1 Tue 16:15 T-H30

The Crab pulsar wind nebula in high-energy gamma-rays and its flaring emission — •Michelle Tsirou[1], Brian Reville[1], Emma de Oña-Wilhelmi[2], Gwenaël Giacinti[1], and John Kirk[1] — [1]MPIK, Heidelberg, Germany — [2]DESY, Berlin-Zeuthen, Germany

The Crab nebula system is one of the brightest gamma-ray sources in the Milky Way, extensively observed across the electromagnetic spectrum. Recent studies purport intermittent flaring events deviating from the continuous flux associated with its synchrotron spectrum below a few hundreds of MeV, straining the theoretical synchrotron burn-off limit in these energy ranges. By analysing available Fermi-LAT data across a thirteen-year-long monitoring, we study the energy-dependence of its flaring behaviour in a few hundred MeV up to a few GeV energy ranges. We explore acceleration mechanisms prone to explain the variability of the observed emission and discuss its implication on our current understanding of this extreme system.

T 45.2 Tue 16:30 T-H30

Machine learning methods for constructing probabilistic Fermi-LAT catalogs — •Aakash Bhat[1] and Dmitry Malyshev[2] — [1]Dr. Karl-Remeis Strernwarte, Bamberg — [2]ECAP Erlangen

Classification of sources is one of the most important tasks in astronomy. Sources detected in one wavelength band, for example using gamma rays, may have several possible associations in other wavebands or there may be no plausible association candidates. In this work, we aim to determine probabilistic classification of unassociated sources in the third and the fourth data release 2 Fermi Large Area Telescope (LAT) point source catalogs (3FGL and 4FGL-DR2) into two classes (pulsars and active galactic nuclei (AGNs)) or three classes (pulsars, AGNs, and other sources). We use several machine learning (ML) methods to determine probabilistic classification of Fermi-LAT sources. We evaluate the dependence of results on meta-parameters of the ML methods, such as the maximal depth of the trees in tree-based classification methods and the number of neurons in neural networks. We determine probabilistic classification of both associated and unassociated sources in 3FGL and 4FGL-DR2 catalogs. We cross-check the accuracy by comparing the predicted classes of unassociated sources in 3FGL that have associations in 4FGL-DR2. We find that in the 2-class case it is important to correct for the presence of other sources among the unassociated ones in order to realistically estimate the number of pulsars and AGNs.

T 45.3 Tue 16:45 T-H30

Classification of Fermi-LAT blazars with Bayesian neural networks — Anja Butter[1], •Thorben Finke[2], Felicitas Keil[2], Michael Krämer[2], and Silvia Manconi[2] — [1]Institut für Theoretische Physik, Universität Heidelberg, Germany — [2]Institute for Theoretical Particle Physics and Cosmology, RWTH Aachen University, Germany

We apply Bayesian neural networks on the classification of γ-ray sources within the Fermi-LAT catalog. We focus on blazar candidates and their sub-classification into BL Lacertae and Flat Spectrum Radio Quasars. We explore the correspondence between conventional dense and Bayesian neural networks and the effect of data augmentation. We find that Bayesian neural networks provide a robust classifier with reliable uncertainty estimates and are particularly well suited for classification problems that are based on comparatively small and imbalanced data sets. The results of our blazar candidate classification are valuable input for population studies aimed at constraining the blazar luminosity function and to guide future observational campaigns.

T 45.4 Tue 17:00 T-H30

Analysis of the high energy γ-ray emission from HESS J1813-178 with H.E.S.S and Fermi-LAT data — •Tina Wach, Vikas Joshi, Alison Mitchell, and Stefan Funk — Erlangen Center for Astroparticle Physics

HESS J1813-178 is one of the brightest and most compact objects detected by the HESS Galactic Plane Survey. Within the extent of the TeV emission lies a young Supernova Remnant G12.8-0.02 and a pulsar wind nebula driven by a pulsar with the second highest spin-down luminosity of known pulsars in the Galaxy PSR J1813-1749. The origin of the TeV emission is still not clear. Because of the young age of the system, the pulsar wind nebula and the Supernova Remnant overlap and present a good opportunity to examine how the interactions between these two components influence the acceleration of particles in the system. In previous analyses, a discrepancy in extension has been observed between a point-like component seen in TeV γ-rays measured by H.E.S.S and a extended component in GeV γ-ray observations from the Fermi-LAT satellite. We used 3 dimensional map-based analysis with gammapy to do a morphological and spectral analysis of this region in GeV and TeV energy ranges, as well as a joint-analysis of both datasets. We find a new significant extended emission component in the TeV energy range, with a morphology close to the GeV energy range. While the question of the origin of the very high γ-ray emission from HESS J1813-178 could not be answered yet, our analysis allows a consistent description and a smooth energy spectrum of the region across five decades of energy.

T 45.5 Tue 17:15 T-H30

Science verification and highlights of the new FlashCam-based camera in the 28m telescope of H.E.S.S. — •Simon Steinmassl for the H.E.S.S.-Collaboration — Max Planck Institut für Kernphysik, Heidelberg, Germany

In October 2019, the 28m telescope in the centre of the H.E.S.S. array was upgraded with a new camera. The camera itself is a prototype based on the FlashCam design, which was originally developed for the Cherenkov Telescope Array (CTA). We report here the results of the validation and science verification programme that has been performed after the commissioning period. From that, we conclude that the camera, analysis and simulation pipelines are working up to expectations. Finally, we discuss some highlights of the scientific results obtained during the first two years of science operation with the new camera, as well as possible future science cases.

T 45.6 Tue 17:30 T-H30

Lake Deployment of Southern Wide-field Gamma-ray Observatory Detector Units — •Hazal Goksu for the SWGO-Collaboration — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

This contribution is about the lake concept, one of the possible detector designs for Southern Wide-field Gamma-ray Observatory (SWGO). SWGO will be a next-generation high altitude gamma-ray survey observatory in the southern hemisphere consisting of an array of water cherenkov detectors. With its energy range, wide field of view, large duty cycle, and location it will complement the other existing and planned gamma-ray observatories. The lake concept is an alternative to the HAWC-like separate detector unit design, and the LHAASO-style artificial ponds. Instead of having tanks filled with water, bladders filled with clean water are deployed near the surface of a natural lake, where each bladder is a light-tight stand-alone unit containing one or more photosensors. We will give an overview of the advantages and challenges of this design concept and describe the first results obtained from prototyping.

T 45.7 Tue 17:45 T-H30

Status and first results from TAIGA — •Michael Blank and Martin Tluczykont — Institut für Experimentalphysik, Universität Hamburg

TAIGA has implemented a new, unique observation technique, based on a combination of the imaging air Cherenkov telescope (IACT) technique, and the HiSCORE timing array concept. TAIGA aims to further explore the celestial gamma-ray sources at energies of a few 10s of TeV to several 100 TeV. This energy range is particularly important to spectrally resolve the cutoff regime of the galactic Pevatrons, the cosmic-ray accelerators to PeV energies. TAIGA currently consists of an array of 121 wide angle (0.6 sr) air Cherenkov timing stations distributed over an area of about 1 km^2 and two IACTs with a diameter of 4.75 m and a field of view of 9.7°. A third IACT will be completed during this year.

In this presentation, the current status of the experiment and the analysis is discussed and the detection of the Crab Nebula with data of previous seasons, with a smaller size array and only with the first IACT in operation, is shown.

T 45.8 Tue 18:00 T-H30

COMCUBE: Exploring the violent Universe with CubeSat Technology — •Jan Lommler for the COMCUBE-Collaboration — Johannes Gutenberg-Universität Mainz

Gamma Ray Bursts are a window into some of the most energetic processes in the Universe. Due to the energy range of the emitted electro-magnetic radiation, measurements have to be performed in space by a network of either dedicated observatories like SWIFT and POLAR or secondary detectors mounted on larger observatories like Fermi GBM. Most detectors only allow the measurement of the burst's energy-spectrum and time evolution, missing out on polarization of the incident photons. Using Compton scattering as main detection channel, Cubesats offer the opportunity to setup a network of small-scale dedicated detectors at relatively low cost that are able to pinpoint GRBs, measure their spectra and temporal evolution while obtaining polarization information. In this talk, we want to present the detector concept of COMCUBE, performance estimates and the status of the balloon prototype.

T 46: Neutrino Astronomy 2

Time: Tuesday 16:15–18:30 Location: T-H31

T 46.1 Tue 16:15 T-H31

Search for the Galactic Diffuse Neutrino Flux with IceCube — •Jonas Hellrung[1], Jakob Böttcher[1], Philipp Fürst[1], Erik Ganster[1], Philipp Mertsch[2], Georg Schwefer[1], Roman Suveyzdis[1], and Christopher Wiebusch[1] for the IceCube-Collaboration — [1]III. Physikalisches Institut B, RWTH Aachen University — [2]Institut für Theoretische Teilchenphysik und Kosmologie, RWTH Aachen University

A diffuse flux of high-energy astrophysical neutrinos has been detected with the IceCube Neutrino Observatory. This flux is dominated by neutrinos of extragalactic origin. However, a fraction of these neutrinos is expected to originate from cosmic rays interacting with the interstellar medium in our Galaxy. This flux has not been measured yet, but a detection could be within reach of IceCube's sensitivity. The signature of this flux with respect to the isotropic extragalactic flux is its close correlation with the galactic plane. The detection would contribute to the understanding of propagation and sources of galactic cosmic rays of typically PeV energies. In this talk the principle of an analysis using neutrino-induced through-going muons is presented and its sensitivity is discussed.

T 46.2 Tue 16:30 T-H31

The energy spectrum of the diffuse neutrino flux in a combined fit using 10 years of IceCube data — •Richard Naab[1], Erik Ganster[2], Markus Ackermann[1], and Christopher Wiebusch[2] for the IceCube-Collaboration — [1]DESY, Zeuthen, Germany — [2]Physics Institute III B, RWTH Aachen University, Germany

The IceCube Neutrino Observatory has discovered a diffuse astrophysical neutrino flux and measures the energy spectrum and flavor composition in different detection channels. With almost 10 years of data, we aim to combine different detection channels to constrain this energy spectrum and flavor composition with unprecedented precision. The increased statistics require rigorous treatment of systematic uncertainties, which we aim to achieve with the so-called SnowStorm method, recently developed within the IceCube collaboration. This technique involves a continuous variation of systematics parameters during the detector simulation and requires a dedicated analysis approach.

In this work, we present the validation of this method for the purpose of measuring the energy spectrum, using two distinct analysis approaches. Furthermore, we discuss the sensitivity of an upcoming analysis combining the detection channels of tracks and cascades.

T 46.3 Tue 16:45 T-H31

Impact of the Binning in the Likelihood-Analysis of the Diffuse Neutrino Flux in IceCube — •Roman Suveyzdis, Jakob Böttcher, Philipp Fürst, Erik Ganster, Jonas Hellrung, and Christopher Wiebusch for the IceCube-Collaboration — RWTH Aachen University, Aachen, Germany

The IceCube Neutrino Observatory is measuring a diffuse flux of astrophysical high-energy muon-neutrinos. For this measurement, events are binned in energy and zenith direction, and a flux model can be fitted to the resulting distributions with a likelihood. The current analysis is based on a binning scheme with equidistant bins in logarithmic energy and cosine zenith. Such a binning is suboptimal, because particularly for high energies, the event statistics in the experimental data as well as in the Monte-Carle prediction is low, leading to inherent uncertainties. Here, we explore the effects of non-equidistant and generalized binnings, and investigate how these binnings can improve the analysis.

T 46.4 Tue 17:00 T-H31

Studying the Energy Dependent Cosmic Ray Moon and Sun Shadow with IceCube Data. — •Johan Wulff and Julia Becker Tjus for the IceCube-Collaboration — Institute for theoretical physics IV, Ruhr-University Bochum, Germany

While the Cosmic Ray Moon shadow can be utilised to verify the pointing of detectors such as IceCube, the Sun shadow has proven to be a successful tool for the assessment of solar magnetic field models.

In a previous publication (Aartsen et al, Phys. Rev. D), the relationship between the solar activity and the strength of the Cosmic Ray Sun shadow was investigated by comparing seven years of IceCube data with the solar cycle and solar magnetic field models. By modelling the propagation of Cosmic Rays through the solar magnetic field, two models of the coronal magnetic field were tested by comparing the observed shadow to the predicted one.

For this analysis, an energy reconstruction of Cosmic Ray induced muon events was introduced, allowing for an investigation of the energy dependence of both shadows. Furthermore, magnetic field effects of the Sun shadow can be investigated at different energies and an energy- dependent pointing can be studied with the Cosmic Ray Moon shadow. In this talk, the performance of the machine-learning based energy reconstruction with respect to the IceCube Cosmic Ray Sun and Moon shadow dataset, as well as the extension of the Cosmic Ray Sun shadow analysis up to the minimum of the 24th Solar cycle will be discussed. This project is funded via BMBF Verbundforschung, Project 05A20PC2.

T 46.5 Tue 17:15 T-H31

Seasonal Variations of the Atmospheric Neutrino Flux determined from 10 years of IceCube Data with DSEA+ — •Karolin Hymon and Tim Ruhe for the IceCube-Collaboration — Astroparticle Physics WG Rhode, TU Dortmund University, Germany

The IceCube Neutrino Observatory is a cubic-kilometer detector array at the South Pole. Beyond the detection of astrophysical neutrinos, the detector measures atmospheric neutrinos at a high rate. These atmospheric neutrinos originate from cosmic ray interactions in the upper atmosphere, mainly from the decay of pions and kaons. The rate of the measured neutrinos, however, is affected by seasonal temperature variations in the Stratosphere, and the variations are expected to increase with the particle's energy. The Dortmund Spectrum Estimation Algorithm (DSEA+) is a novel approach to spectrum unfolding. The ill-posed problem is transferred to a multinomial classification task, in which the energy distribution is estimated from measured quantities by machine learning algorithms. In this talk, the analysis approach to measure the spectral dependence of the seasonal neutrino flux will be presented. Seasonal neutrino energy spectra are determined by DSEA+, utilizing 10 years of IceCube's atmospheric muon neutrino data. The differences of the unfolded seasonal spectra will be compared to the unfolded annual mean flux.

T 46.6 Tue 17:30 T-H31

NN-based parametrization of muon deflections simulated by PROPOSAL — •Pascal Gutjahr and Mirco Hünnefeld — Astroparticle Physics WG Rhode, TU Dortmund University, Germany

Neutrinos are fundamental particles that are nearly massless and not charged. This allows them to traverse the universe along a straight line without deflection. It makes them an excellent candidate for the search of astrophysical neutrino sources. This is achieved using detectors such as the IceCube Neutrino Observatory, which is located at the geographic South Pole. In the ice at a depth of 1450 m, Cherenkov radiation from the secondary particles of neutrino interactions is measured. Reconstruction of the daughter particles can then be used to infer the direction of the original neutrino. Due to the high energies in the GeV to PeV range, the deflection of the particles due to stochastic energy losses and multiple scattering is assumed to be negligible compared to the directional resolution of IceCube. This assumption may begins to be inaccurate as resolution increases and low energy muons are studied especially with respect to the IceCube upgrade. A study with the lepton propagator PROPOSAL is done to present expected deflections of muons for different energy ranges. The result is parametrized by a neural network.

T 46.7 Tue 17:45 T-H31

Improving Astrophysical Muon-Neutrino Measurements with New Energy Estimators in IceCube — •Philipp Fürst, Jakob Böttcher, Erik Ganster, Jonas Hellrung, Georg Schwefer, Roman Suveyzdis, and Christopher Wiebusch for the IceCube-Collaboration — RWTH Aachen University - Physics Institute III B, Aachen, Germany

The IceCube Neutrino Observatory is measuring a diffuse astrophysical neutrino flux with a spectral shape compatible with a single power law at Tev to PeV energies. With neutrinos conveying information directly from their source, their spectral shape is closely connected to open questions about the acceleration and propagation of the hadronic component of cosmic rays. While hints for spectral features beyond a single power law exist, spectral resolution in the muon-neutrino detection channel is strongly tied to the achievable energy resolution. We present new methods of energy estimation based on machine learning methods and estimate the expected sensitivity gain for model hypotheses beyond the single power law, exploring the possibility to distinguish different spectral shapes in the future.

T 46.8 Tue 18:00 T-H31

The Pacific Ocean Neutrino Experiment: prototype line development — •Martin Dinkel, Elisa Resconi, and Christian Spannfellner for the P-ONE-Collaboration — Technische Universität München

The Pacific Ocean Neutrino Experiment (P-ONE) is a planned large-scale neutrino telescope in the Northeast Pacific Ocean, near the coast of Vancouver Island, British Columbia. The P-ONE collaboration, founded by an initiative of Canadian and German institutes, successfully deployed two pathfinder experiments to probe the site for P-ONE. The next milestone is the construction and deployment of the first line of the Pacific Ocean Neutrino Experiment. This so-called prototype line will comprise optical and calibration modules and follow a novel design approach to minimize interface gaps and allow a scalable deployment approach. We will present the optical and calibration module development status and introduce the overall line design and deployment approach.

T 46.9 Tue 18:15 T-H31

Machine-learning aided experimental design for P-ONE — •Janik Prottung, Christian Haack, and Arturo Llorente Anaya — Technical University Munich, Germany

The Pacific Ocean Neutrino Experiment (P-ONE) is a collaboration of Ocean Networks Canada (ONC) and Universities from Germany, Canada, and the USA to build a large volume neutrino telescope in the Pacific Ocean. Similar to other neutrino telescopes, P-ONE wants to instrument the ocean with photosensors deployed on vertical cables (lines) to detect high-energy neutrino interactions by the Cherenkov light emitted from secondary particles. The design of such telescopes has a variety of free parameters, such as the sensor spacing and sensor density, trigger algorithms and thresholds, or hardware used for signal digitization. These parameters directly impact the physics potential of the telescope and need to be optimized under external constraints (cost, bandwidth, site limitations). These optimization studies typically require expensive Monte-Carlo simulations that limit the explorable parameter phase space. This talk presents a framework that uses graph-neural networks and multi-parameter optimization to comprehensively explore the parameter phase space while reducing the simulation time. The framework facilitates data-driven decisions for the P-ONE design, maximizing the physics potential while minimizing the expenses.

T 47: Cosmic Ray 2

Time: Tuesday 16:15–18:15 Location: T-H32

T 47.1 Tue 16:15 T-H32

The Underground Muon Detector in The Pierre Auger Observatory: calibration and characterization — •Marina Scornavacche[1,2], Federico Sánchez[1], Juan Manuel Figueira[1], and Markus Roth[2] for the Pierre Auger-Collaboration — [1]Instituto de Tecnologías en Detección y Astropartículas, Comisión Nacional de Energía Atómica, Buenos Aires, Argentina — [2]Institut für Astroteilchenphysik, Karlsruher Institut für Technologie, Karlsruhe, Deutschland

The Pierre Auger Observatory was designed to answer the key questions about the origin and composition of ultra-high energy cosmic rays. The Underground Muon Detector (UMD) is optimized to perform a direct measurement of the muon component of the air showers in the ankle-region of the energy spectrum. To estimate the number of muons, one of the most sensitive observables to the mass composition of primary cosmic rays, the UMD works in two complementary ways dubbed as binary (or counting) and ADC (or integrator) modes. The first relies on the amplitude of the signals, the latter on its charge. In this work, we will focus on the integrator mode, where the number of muons can be estimated once the average charge left by a single muon is known. In previous analysis, we showed how to calibrate the integrator based on simulations. Now we study evolution of the calibration data, including monitoring variables involved in the calibration process. We also perform comparisons between data and simulation results and report on most recent developments and interpretations.

T 47.2 Tue 16:30 T-H32

Compatibility of trigger and timing between the non-upgraded and the upgraded electronics of the Pierre Auger Observatory. — •Fabio Convenga for the Pierre Auger-Collaboration — Karlsruher Institut für Technologie (IAP), Karlsruhe, Germany

The surface detectors of the Pierre Auger Observatory are being upgraded by adding new detectors and replacing electronics.

The upgraded electronics, dubbed Upgraded Unified Board (UUB), is able to acquire data from the new detectors. It includes an improved GPS receiver, a higher sampling rate, and a more powerful logic capacity.

The new features of UUB made it possible to introduce new types of triggers. Despite this, to ensure backward compatibility, pre-upgrade triggers are implemented using digitally filtered and downsampled waveforms to simulate the triggering behavior in the non-upgraded stations.

The logic functionality of the UUB also includes a module for event timing. The fundamental architecture of this module is parallel to that used in non-upgraded electronics. The on-board software that manages the module is similar to that of the non-upgraded electronics, with minor modifications required for the new UUB hardware.

In this talk, we will present the first analysis on the compatibility of the triggering efficiency and timing focusing on two neighboring stations one with the non-upgraded electronics and the other with the UUB.

T 47.3 Tue 16:45 T-H32

Performance and Calibration of the Upgraded Surface Detector of the Pierre Auger Observatory — •Alexander Streich, David Schmidt, Darko Veberic, Markus Roth, and Ralph Engel for the Pierre Auger-Collaboration — Karlsruher Institut für Technologie (KIT), Karlsruhe, Deutschland

The AugerPrime upgrade defines the transition to the next measurement stage of the Pierre Auger Observatory and is rolled out among other things with the addition of new scintillation detectors on top of the water-Cherenkov detectors of the Surface Detector. These Surface Scintillator Detectors provide a complementary measurement of the secondary particles enabling the discrimination of the individual air shower components on an event-to-event basis. This leads to an significantly improved determination of the properties of the ultra-high energy cosmic rays, for example their mass composition. Besides the scintillation detectors, the electronics boards of each station will be replaced with an enhanced version with an increased signal resolution, a higher sampling frequency, as well as faster data processing. This presentation focuses on the analyses of the performance of these hardware components under the measurement conditions in the Observatory. Thereby, the general operation stability and hardware requirements are investigated. Additionally, the performance of the air shower reconstruction applied to the first array of AugerPrime stations is analyzed, including the necessary adaptations to the detector calibration procedure and the signal discrimination capability of the hybrid event detection utilizing the scintillation and Cherenkov detectors.

T 47.4 Tue 17:00 T-H32

Test of the front-end electronics of the AugerPrime Radio Detector* — Stephan Keller and •Julian Rautenberg for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstr. 20, 42119 Wuppertal

As part of the AugerPrime extension of the Pierre Auger Observatory each of the 1660 Surface Detector stations will be upgraded for the radio detection of air showers. The corresponding specialized front-end electronics has been developed within the collaboration for optimal performance in the cosmic ray detection. To ensure the quality of the electronics before deployment over the 3000 km^2 of the Observatory they are temperature cycled between -25 and 75 degree for 48 hours. At four temperatures their performance is repeatedly measured with a defined set of test-signal inputs. The setup to test the 2000 electronic boards will be presented together with the results of the first pre-production boards.

**Gefördert durch die BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A20PX1).*

T 47.5 Tue 17:15 T-H32

CRPropa 3.2 — an advanced framework for high-energy particle propagation in extragalactic and galactic spaces — •Julien Dörner for the CRPropa-Collaboration — Theoretische Physik IV, Ruhr University Bochum, Bochum, Germany — RAPP-Center at Ruhr University Bochum, Bochum, Germany

The landscape of high- and ultra-high-energy astrophysics has changed in the last decade, largely due to the inflow of data collected by large-scale cosmic-ray, gamma-ray, and neutrino observatories. At the dawn of the multimessenger era, the interpretation of these observations within a consistent framework is important to elucidate the open questions in this field. CRPropa 3.2 is a Monte Carlo code for multimessenger simulations of high-energy particles and their secondaries. With this new version, the framework is now extended to more than extragalactic propagation opening up the possibility to more astrophysical applications, like Galactic cosmic-ray and local source modeling.

In this talk, we will show some of these new aspects that can be applied with CRPropa 3.2. It will include simulations of high-energy particles in diffusion dominated domains and self-consistent, fast modelling of electromagnetic cascades and interactions with customized photon fields. With the new CRPropa 3.2 version several technical updates and improvements were implemented, which will be presented in the talk.

T 47.6 Tue 17:30 T-H32

Testing the Starburst Galaxy and Active Galactic Nuclei correlation result for Pierre Auger Observatory with CRPropa simulations* — •wilson namasaka — Bergische Universität Wuppertal, Gaußstr. 20, 42119 Wuppertal, Germany.

Intermediate scale anisotropies in the distribution of Ultra-High Energy Cosmic Rays (UHECRs) arrival directions can be associated with two prominent classes of extragalactic gamma-ray sources detected by Fermi-LAT. In most recent study, a correlation between the arrival direction of cosmic rays at energies above 38 EeV for starburst galaxies (SBG) and 39 EeV for active galactic nuclei (AGN) was reported by the Pierre Auger Collaboration with a significance of 4.5σ and 3.1σ, respectively. The cosmic ray excess models for these sources used an angular smearing parameter to fit the observed arrival direction distribution in an optimization scan.

The viability of this angular smearing using CRPropa is investigated in this research, to test whether the results of the Pierre Auger Observatory can be reproduced by the deflections expected due to magnetic fields. The five strongest gamma-ray sources in both the Fermi-LAT AGN and SBG catalogs based on flux weight have been selected. In this talk, results from the simulations and expected angular deflections shall be presented.

*Funded by DAAD under reference No.91653888.

T 47.7 Tue 17:45 T-H32

Extending CRPropa with hadronic interactions for in-source propagation of UHECRs* — •Leonel Morejon — Bergische Universität Wuppertal, Gaußstr. 20, 42119 Wuppertal

CRPropa is a versatile Monte Carlo code for the propagation of Ultra-High Energy Cosmic Rays (UHECRs). Part of its strength is the possibility to combine it with user code to provide additional functionality. For example, it has been employed with post-simulation computations to study sources where hadronic interactions are of interest. However, when such interactions are too important, like may be the case in certain bursting sources, this type of approach is inconsistent.

This contribution reports on the ongoing effort to extend CRPropa with the inclusion of hadronic interactions. The approach involves exposing hadronic modelling softwares (*e.g.* EPOS-LHC, SYBILL, QGSJet) to the main code, and thus, make them available to all users natively (*i.e.* no need for additional coding). The result is a new module within CRPropa that computes hadronic interactions in runtime, along with the other interactions in the code. The performance of this new module is profiled and simple case studies are selected to illustrate its use.

** Funded by the Deutsche Forschungsgemeinschaft through project number 445990517.*

T 47.8 Tue 18:00 T-H32

Advances in parallelization of cosmic rays simulations in CORSIKA 8 — •Antonio Augusto Alves Junior, Pranav Sampathkumar, and Ralf Ulrich for the CORSIKA 8-Collaboration — Institute for Astroparticle Physics (IAP) - KIT

Advances in the parallelization of CORSIKA 8, which is being developed in modern C++17 and is designed to run on multi-thread modern processors and accelerators, are discussed.

Aspects such as out-of-the-order calculations, generation of high quality random numbers and fast task scheduling and submission on massively parallel platforms are highlighted, followed by presentation of preliminary performance measurements.

Finally, the design choices and integration into CORSIKA 8 are presented, together with some basic examples.

T 48: Neutrino Physics without Accelerators 3

Time: Tuesday 16:15–18:45 Location: T-H33

T 48.1 Tue 16:15 T-H33

Improved measurement of the neutrino mixing angle θ_{13} with Double Chooz — •Philipp Soldin, Lars Heuermann, Achim Stahl, and Christopher Wiebusch — III. Physics Institute B, RWTH Aachen University

Double Chooz is a reactor neutrino disappearance experiment that was operating between 2011 until 2018. Its primary purpose was the precise measurement of the neutrino mixing angle θ_{13}. The experimental setup consisted of two identical liquid scintillator detectors at average baselines of about 400 m and 1 km to two nuclear reactor cores in Chooz, France. The neutrinos were detected by measuring the inverse beta decay (IBD) signature, which consists of a prompt positron annihilation and a delayed neutron capture signal. The simultaneous measurement of the neutrino energy spectra with two detectors is used in a Poisson-based likelihood fit to obtain the neutrino mixing angle θ_{13}. This fit takes into account the respective neutrino fluxes, their energy spectra, all relevant backgrounds, and correlated uncertainties. The final data set, latest results, and novel ideas are presented in this talk.

T 48.2 Tue 16:30 T-H33

Likelihood based Sterile Neutrino Search with Double Chooz — •Lars Heuermann, Philipp Soldin, Achim Stahl, and Christopher Wiebusch — RWTH Aachen University - Physics Institute III B, Aachen, Germany

The Double Chooz experiment was a reactor electron anti-neutrino disappearance experiment with the purpose of measuring the neutrino oscillation angle θ_{13}. It used two nearly identical detectors at the respective distances of 400m and 1050m to the reactors of the nuclear power plant in Chooz, France, for this purpose.

Sterile neutrinos are hypothetical neutrino mass states, which do not participate in weak interactions, but still could participate in neutrino oscillations and thus would be measurable with Double Chooz. We present a search which focusses on a profile likelihood approach to test the data with respect to the parameters of a model with a single additional sterile neutrino state (3+1 model). A particular challenge thereby is that Wilks' theorem is not fulfilled and computationally intensive parameter scans have to be used to estimate the test statistics. The talk explains the analysis method and presents the median sensitivity for the sterile mixing parameter θ_{14} in dependence of Δm^2_{41}, as well as an analysis of the available experimental dataset.

T 48.3 Tue 16:45 T-H33

OSIRIS – a radiopurity detector for JUNO — •Christian Wysotzki for the JUNO-Collaboration — RWTH Aachen University - Physics Institute III B, Aachen, Germany

The Jiangmen Underground Neutrino Laboratory (JUNO) is a 20 kt liquid scintillator based neutrino observatory, which is currently under construction in southern China.

OSIRIS (Online Scintillator Internal Radioactivity Investigation System), as one of JUNOs subsystems, monitors the radiopurity of the liquid scintillator. Stringent limits regarding the contamination of radioactive isotopes, especially uranium and thorium have been defined to ensure the success of JUNOs physics program.

The assembly and commissioning of OSIRIS is foreseen for 2022. This talk will give an overview of the design philosophy, the detector systems, and the current status.

T 48.4 Tue 17:00 T-H33

Calibration of the JUNO pre-detector OSIRIS — •Moritz Cornelius Vollbrecht[1,2], Alexandre Göttel[1,2], Philipp Kampmann[3], Runxuan Liu[1,2], Livia Ludhova[1,2], Nikhil Mohan[1,2], Luca Pelicci[1,2], and Mariam Rifai[1,2] — [1]Forschungszentrum Jülich GmbH, Nuclear Physics Institute IKP-2, Jülich — [2]III. Physikalisches Institut B, RWTH Aachen University, Aachen — [3]GSI Helmholtzcentre for Heavy Ion Research, Darmstadt

The multi-kton liquid scintillator (LS) detector of the Jiangmen Underground Neutrino Observatory (JUNO) experiment, currently under construction in Southern China, has a vast potential for insights in several fields of (astro-) particle physics. To achieve its goals of determining the neutrino mass ordering, stringent radiopurity levels are required. To ensure these limits, the Online Scintillator Internal Radioactivity Investigation System (OSIRIS) was designed as a predetector for JUNO. In OSIRIS, 76 self-triggering intelligent PMTs (iPMTs) instrument a watershielded 20 ton liquid scintillator target. During the months-long filling of JUNO, a fraction of each purified scintillator batch passes through OSIRIS and its radiopurity is closely monitored. This enables fast countermeasures on possible contaminations. Multiple calibration systems are employed in OSIRIS. An Automatic Calibration Unit (ACU) of the Daya Bay experiment is used to calibrate energy and vertex event reconstructions as well as iPMT timing and charge responses. A separate laser system is used for the timing calibration of the iPMTs. This presentation will summarize the current status of the work concerning the calibration strategy of OSIRIS.

T 48.5 Tue 17:15 T-H33

Liquid Handling System of the OSIRIS detector — Michael Wurm, Hans Steiger, Kai Loo, Eric Theisen, and •Oliver Pilarczyk — Johannes Gutenberg-Universität Mainz

The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kt liquid scintillator experiment currently under construction in Jiangmen (China). Its main scientific goal is to determine the neutrino mass ordering by measuring antielectron neutrinos from two nearby nuclear power plants at a distance of 53 km. To achieve this goal the liquid scintillator has to go through several purification plants on site to make sure it meets the optical and radiopurity requirements.

The $20m^3$ OSIRIS pre-detector is the last device behind these purification plants and will be constructed in a underground hall close to the main JUNO detector. Its task is to monitor the radiopurity of the purified scintillator before it is filled in the JUNO detector and it will reach sensitivity levels of $10^{-16}g/g$ on Uranium and Thorium. OSIRIS is expected to be operated in a continuous mode, which means that parts of the scintillator from the main filling line will be redirected into a bypass in which the OSIRIS detector is placed and then being send on back into the main filling line. To make sure every batch of the scintillator stays about 24 h inside the OSIRIS detector a temperature gradient will be established in the detection volume. This talk covers the operation of the Liquid Handling System (LHS) and the included Level Measurement (LM) which control and oversee the operation of OSIRIS. The development is funded by the DFG Research Unit *JUNO* (FOR2319) and the Cluster of Excellence $PRISMA^+$.

T 48.6 Tue 17:30 T-H33

The Laser calibration system of the JUNO pre-detector OSIRIS — •Tobias Sterr, Lukas Bieger, David Blum, Marc Breisch, Srijan Delampady, Jessica Eck, Gina Grünauer, Tobias Heinz, Benedict Kaiser, Frieder Kohler, Tobias Lachenmaier, Axel Müller, Alexander Tietzsch, and Jan Züfle — Eberhard Karls Universität Tübingen, Physikalisches Institut

The Jiangmen Underground Neutrino Observatory is a multi-kton, multi-purpose Neutrino observatory currently under construction in Kaiping, Southern China. It has a vast potential for progress in several field of (astro-) particle physics (e.g., the neutrino mass ordering, supernova neutrinos, geoneutrinos, etc.). To achieve the goals, a thorough control of the radiopurity levels of the liquid scintillator is required. Therefor the Online Scintillator internal Radioactivity Investigation System (OSIRIS) was introduced as a pre-detector to JUNO. OSIRIS features 76 self-triggering intelligent PMTs (iPMTs) as well as a water-shielded, 20-ton liquid scintillator target. During the filling phase of the main detector, OSIRIS will measure the radiopurity of a fraction of each batch of liquid scintillator passed to JUNO. To enable OSIRIS to reach the necessary sensitivity to perform this task, two calibration systems will be available: An automated calibration unit and a laser calibration system. This talk will focus on the laser calibration system which will be used for both, timing and charge calibration of the iPMTs. Additionally, the preliminary calibration strategy of the laser system of OSIRIS will be presented. This work is supported by the Deutsche Forschungsgemeinschft (DFG)

T 48.7 Tue 17:45 T-H33

Final Results of the PoLiDe Experiment — •Ulrike Fahrendholz[1], Lothar Oberauer[1], Hans Steiger[1,2], Raphael Stock[1], David Dörflinger[1], Mario Schwarz[1], and Konstantin Schweizer[1] — [1]Technische Universität München (TUM), Physik-Department, James-Franck-Str. 1, 85748 Garching bei München — [2]Institute of Physics and Excellence Cluster PRISMA+, Johannes Gutenberg-Universität (JGU) Mainz, Staudingerweg 9, 55099 Mainz

The Jiangmen Underground Neutrino Observatory (JUNO) aims to determine the neutrino mass ordering by detecting reactor electron-antineutrinos. In the main detection channel, the inverse beta decay (IBD), a positron is produced, which is used to reconstruct the neutrino*s initial energy. If the positron forms a bound state with spin 1, called ortho-Positronium (o-Ps), with an electron prior to its annihilation, the time structure of the event is distorted due to the longer lifetime of o-Ps. The Positron Lifetime Determination (PoLiDe) experiment was built to determine the lifetime and formation probability of o-Ps in liquid scintillators (LSs). In this talk, the final results of the lifetime measurements for different organic LSs, including the JUNO mixture, and a water-based LS sample are presented.This work is supported by the DFG research unit "JUNO", the DFG collaborative research centre 1258 "NDM", and the DFG Cluster of Excellence "Origins.

T 48.8 Tue 18:00 T-H33

Measurements of the attenuation length and the group velocity of liquid scintillators with the CELLPALS method — •Jessica Eck, Lukas Bieger, David Blum, Marc Breisch, Srijan Delampady, Gina Grünauer, Tobias Heinz, Benedict Kaiser, Frieder Kohler, Tobias Lachenmaier, Axel Müller, Tobias Sterr, Alexander Tietzsch, and Jan Züfle — Eberhard Karls Universität Tübingen, Physikalisches Institut

The Jiangmen Underground Neutrino Observatory (JUNO) is currently constructed in southern China with the main goal to determine the neutrino mass hierarchy by detecting reactor antineutrinos. The JUNO detector consists of a large spherical vessel filled with 20ktons of highly transparent liquid scintillator. To quantify the transparency, a measurement of the attenuation length is crucial, however, this poses a challenge for attenuation lengths of several tens of meters due to the necessity of a sufficient long light path through the sample.

This talk will present the CELLPALS method to measure the attenuation length of liquid scintillators using an optical cavity to extend the effective light path. In addition, the CELLPALS method also provides the determination of the group velocity of the sample. The experimental setup and the results for different samples will be presented.

This work is supported by the Deutsche Forschungsgemeinschaft.

T 48.9 Tue 18:15 T-H33

Fluorescence Time Profiles of the JUNO and TAO Liquid Scintillators using a Pulsed Neutron Beam in the Energy Range from 3.5 to 5.5 MeV — •Matthias Raphael Stock[1], Hans Th. J. Steiger[1,2], David Dörflinger[1], Stefan Schoppmann[3], Ulrike Fahrendholz[1], Lothar Oberauer[1], Luca Schweizer[1], Korbinian Stangler[1], and Dorina Zundel[2] — [1]Physik-Department, TU München, James-Franck-Str. 1, 85748 Garching — [2]JGU Mainz, Cluster of Excellence PRISMA+, Staudingerweg 9, 55128 Mainz — [3]University of California, Department of Physics, Berkeley, CA 94720-7300, USA

We simultaneously performed two liquid scintillator (LS) characterization experiments using a pulsed neutron beam at the CN accelerator of INFN Laboratori Nazionali di Legnaro. At energies ranging from 3.5 MeV to 5.5 MeV, one experiment measures the quenching factor of recoil protons while the one other measures the scintillation time profile of recoil protons. This talk is about the time profile experiment, where we show results of LS mixtures for the upcoming neutrino experiments JUNO and TAO in China as well as for future projects e.g., Theia, which will use a water-based LS. Differences in the time profiles after gamma and neutron excitation allows to perform pulse shape discrimination and therefore advances the ability to distinguish the neutrino signal from background. This work is supported by the BMBF Verbundforschung 05H2018 "R&D Detektoren (Szintillatoren)", the DFG research unit "JUNO", the DFG CRC 1258 "NDM" and the DFG Clusters of Excellence "PRISMA+" and "Origins".

T 48.10 Tue 18:30 T-H33

Quenching Factor Studies for Organic Liquid Scintillators with a Pulsed Neutron Beam — •Hans Th. J. Steiger[1,2], M. Raphael Stock[2], David Dörflinger[2], Stefan Schoppmann[3], Manuel Böhles[1], Ulrike Fahrendholz[2], Lothar Oberauer[2], Luca Schweizer[2], Korbinian Stangler[2], and Dorina Zundel[1] — [1]JGU Mainz, Cluster of Excellence PRISMA+, Staudingerweg 9, 55128 Mainz, Germany — [2]Physik-Department, TU München, James-Franck-Str. 1, 85748 Garching, Germany — [3]UC Berkeley, Department of Physics, CA 94720-7300, USA

Leading current multi-ton-scale neutrino experiments rely on the successful application of liquid scintillators (LS). Therefore, detailed understanding of the detectors and their detection media are crucial to construct realistic simulations and predictions of phenomena. With our measurements at the CN accelerator of the INFN Laboratori Nazionali di Legnaro, we conduct precision characterizations of LSs in terms of proton quenching and fluorescence spectra. In these experiments neutron interactions are distinguished from beam correlated gammas by time-of-flight measurements. During several beamtimes in the past two years we studied samples of scintillators from the experiments JUNO, TAO, Borexino, Theia and SNO+. Precise data about the quenching factors of proton and 12C-recoils for all measured liquid scintillators were gained for the first time. This work is supported by the Cluster of Excellence PRISMA+, the Bundesministerium für Bildung und Forschung (Verbundprojekt 05H2018: R&D Detectors and Scintillators) and the DFG Research Unit JUNO.

T 49: Neutrino Physics without Accelerators 4

Time: Tuesday 16:15–18:40 Location: T-H34

Group Report T 49.1 Tue 16:15 T-H34

Direct neutrino mass measurement with the Project 8 experiment: status and outlook — •Larisa Thorne and Martin Fertl for the Project 8-Collaboration — Institute of Physics and Excellence Cluster PRISMA+, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

There have been significant gains in characterizing neutrino properties in recent decades, however the absolute neutrino mass scale continues to be elusive. The Project 8 experiment seeks to probe this quantity directly via kinematic analysis of atomic tritium single beta decay, using the novel CRES (cyclotron radiation emission spectroscopy) technique. CRES employs a frequency-based approach to measure the differential tritium beta decay spectrum in the endpoint region, where the spectral shape is most sensitive to distortions from a non-zero neutrino mass. Here we present a roadmap of Project 8's milestones towards a neutrino mass measurement with a final design sensitivity of 40 meV. This includes recent results from a successful first-time demonstration of the CRES technique with molecular tritium, as well as status updates on the components comprising the experiment's future full-scale version.

T 49.2 Tue 16:35 T-H34

Atomic hydrogen beam monitor for Project 8 — •Christian Matthe and Sebastian Böser for the Project 8-Collaboration — Institute of Physics and Excellence Cluster PRISMA+, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

The Project 8 collaboration aims to determine the absolute neutrino mass with a sensitivity of 40 meV by measuring the tritium decay spectrum around the endpoint energy. For this level of precision it is necessary to use atomic tritium, since molecular tritium sensitivity is limited by the molecular final state distribution to about 100 meV. We anticipate using an atomic tritium flux of $\approx 10^{19}$atoms/s from a source to inject a beam with $\approx 10^{15}$atoms/s of the proper state and temperature into the detection volume.

For monitoring this beam, we are developing a detector that uses a wire with a micrometer-scale diameter intersecting the beam on which a small fraction of the beam's hydrogen atoms recombine into molecules. The energy released heats the wire and produces a measurable change in its resistance. Using either a grid of wires or a sweep with a single wire the beam profile will be determined. Such a detector is suitable for both development work and for minimally disruptive online monitoring in the final experiment. In this talk I will present first results using such a detector in the beam of the Mainz atomic hydrogen setup.

T 49.3 Tue 16:50 T-H34

Atom-source development for Project 8 — •Alec Lindman and Sebastian Böser for the Project 8-Collaboration — Institute of Physics and Excellence Cluster PRISMA+, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

The Project 8 experiment aims to make a direct measurement sensitive to much of the unexplored range of neutrino masses. Past experiments used molecular tritium, which has a large energy smearing from its final states. Project 8 will use atomic tritium to reach $m_\beta \leq 40$ meV. This requires $\mathcal{O}(10^{20})$ T atoms held at tens of mK in a several-cubic-meter magnetic trap. The efficiencies of cooling the atoms and their trapped lifetime require $> 10^{19}$ atoms/s at the source. Phase III of Project 8 will include an Atomic Tritium Demonstrator to confirm we can produce, cool, and trap sufficient atomic T for the final Phase IV experiment.

I will discuss work at the University of Mainz to develop a high-flux tritium-compatible atom source. Our tests extend to a hydrogen flow of 20 sccm, 20 times the previously-published values for this type of source. Recent progress includes a redesign that boosted the atomic signal 100-fold and separation of the atom signal from background via low-energy ionization. Upgrades are underway to definitively determine if the present atom source provides sufficient atomic flux for Project 8's neutrino mass sensitivity. Designs for a higher-output source, if needed, and subsequent cooling and trapping stages are in progress and will be tested in due course.

T 49.4 Tue 17:05 T-H34

Project 8 Free Space CRES Demonstrator: Signal characteristics and matched-filter detection — •René Reimann, Florian Thomas, and Martin Fertl for the Project 8-Collaboration — Institute of Physics and Excellence Cluster PRISMA+, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

The Project 8 collaboration aims to measure the neutrino mass with a sensitivity of 40 meV by measuring the endpoint region of the atomic tritium beta decay spectrum using the new technology of Cyclotron Radiation Emission Spectroscopy (CRES). While the measurement principle of CRES has been successfully demonstrated using the enclosed volume of a microwave guide filled with molecular tritium or krypton, one major challenge is to scale up the source volume in order to increase the overall statistics. One promising approach is to leave the confined space of the microwave guide and detect the cyclotron radiation emitted by the electron in free space using an array of antennas. To investigate the CRES technique in free space the so called Free Space CRES Demonstrator (FSCD) is under development. Because the signal is diluted into 4π an antenna array with a high number of readout channels is required, which drastically increases the data rate. Therefore real-time processing, triggering and reconstruction are required in the FSCD. The signal characteristics are mainly dominated by the magnetic field and the antenna response. In this talk we present the influence of the magnetic field on the signal spectrum and present how matched filtering can be used to detect and reconstruct CRES signals.

Group Report T 49.5 Tue 17:20 T-H34

The SNO+ experiment: current status and future prospects — •Johann Dittmer and Kai Zuber — IKTP, TU Dresden, Deutschland

SNO+ is a large liquid scintillator based experiment reusing the infrastructure of the successful Sudbury Neutrino Observatory (SNO). Located 2 km underground in a mine near Sudbury, Ontario, Canada, the detector consists of 12 m diameter acrylic vessel which is filled with 780 tonnes of a liquid scintillator. For the main goal, the search for the neutrinoless double beta decay ($0\nu\beta\beta$) of ^{130}Te, the scintillator will be doped by 0.5% natural Tellurium. Since SNO+ was designed as a general purpose neutrino detector, it is also possible to measure neutrinos from different sources (reactor, geo, solar, Supernova, etc.). After a commissioning water phase which was ended in 2018, the scintillator fill was completed in April 2021.

In this talk the recent results and broad physics program will be presented.

SNO+ is supported by the German Research Foundation (DFG).

T 49.6 Tue 17:40 T-H34

Column Density Determination for the KATRIN Neutrino Mass Measurement — •Christoph Köhler[1], Fabian Block[2], and Alexander Marsteller[2] for the KATRIN-Collaboration — [1]Technical University of Munich/Max Planck Institute for Physics — [2]Karlsruhe Institute of Technology

The KATRIN experiment aims to model-independently probe the effective electron anti-neutrino mass with a sensitivity of 0.2 eV (90 % CL) by investigating the endpoint region of the tritium beta decay spectrum. To achieve this goal the gas quantity of the windowless gaseous tritium source, characterized by the column density, has to be known with great accuracy.

We present in this talk the principle of measuring the column density with an angular resolved photoelectron source and report on the monitoring accuracy of the column density achieved with dedicated activity monitoring devices in the first five measurement campaigns of KATRIN. The influence of the column density uncertainty on the neutrino mass determination is then discussed in light of KATRIN's world-leading direct upper limit on the neutrino mass and the ongoing further data-taking.

This work is supported by the Technical University of Munich, the Max Planck Society, the Helmholtz Association (HGF), the Ministry for Education and Research BMBF (05A17PM3, 05A17PX3, 05A17VK2, and 05A17WO3), the Helmholtz Alliance for Astroparticle Physics (HAP), the GRK 1694, and the Helmholtz Young Investigator Group (VH-NG-1055).

T 49.7 Tue 17:55 T-H34

^{83m}Kr N-line spectrum measurement at KATRIN — Matthias Böttcher[1], Moritz Machatschek[2], Magnus Schlösser[2], and •Jaroslav Storek[2] for the KATRIN-Collaboration — [1]Institute of Nuclear Physics, University of Münster — [2]Institute for Astroparticle Physics, Karlsruhe Institute of Technology

The KArlsruhe TRItium Neutrino experiment currently provides the best neutrino mass upper limit of 0.8 eV/c^2 (90% C. L.) in the field of direct neutrino-mass measurements. This result has been obtained with only 5% of the anticipated total measurement time. However, reaching the target sensitivity of 0.2 eV/c^2 at 90% C. L. not only requires the full measurement time, but also the detailed study of systematic measurement uncertainties. Several of them can be studied by measuring a shape distortion of the ^{83m}Kr intrinsic electron conversion N-lines which creates high demands on precise knowledge of the undistorted spectrum. Results of a dedicated measurement of the intrinsic ^{83m}Kr N-spectrum conducted at unprecedented precision at KATRIN will be presented in this talk.

This work is supported by the Ministry for Education and Research BMBF (05A17PM3, 05A17PX3, 05A17VK2, and 05A17WO3) and the Doctoral School "Karlsruhe School of Elementary and Astroparticle Physics: Science and Technology (KSETA)" through the GSSP program of the German Academic Exchange Service (DAAD).

T 49.8 Tue 18:10 T-H34

Unmodeled features in the KATRIN spectrum as a hint for unaccounted systematic effects * — •Karol Debowski for the KATRIN-Collaboration — Bergische Universität Wuppertal, Wuppertal, Deutschland

The Karlsruhe Tritium Neutrino (KATRIN) Experiment is designed and operated to determine the mass of the electron-antineutrino with a final sensitivity of 200meV (90% C.L.) using the radioactive beta decay spectrum of tritium. In order to achieve the design sensitivity, a precise knowledge of all systematic effects is needed.

Simulations of the energy spectrum take all known systematic effects into account which are also used in the neutrino mass analysis. Using the measured slow control variables as inputs to the simulation, the measured and simulated spectra should agree with each other except for statistical fluctuations in the measured data. Any significant features exceeding those statistical fluctuations can be potential hints towards systematic effects which are not considered (correctly) in the simulation and hence also in the analysis. By intentionally introducing unprecisely modeled systematics into simulations, the nature and origin of potential unknown effects can be estimated for better understanding and modeling of the measured spectrum in the final analysis. This work aims on a simulation based proof of concept for upcoming analyses to find unaccounted systematic effects in the experiment.

* *This work is supported by the Ministry for Education and Research BMBF (05A20PMA, 05A20PX3, 05A20VK3)*

T 49.9 Tue 18:25 T-H34

Increasing KATRIN's luminosity by an enlarged acceptance angle — •Emanuel Weiss, Jan Behrens, Ferenc Glück, and Stephanie Hickford for the KATRIN-Collaboration — Institute for Astroparticle Physics and Institute of Experimental Particle Physics, Karlsruhe Institute of Technology

The KATRIN collaboration aims to determine the neutrino mass with a sensitivity of $0.2\,\mathrm{eV/c^2}$ (90% CL). This will be achieved by measuring and fitting the endpoint region of the tritium β-electron spectrum. The integral spectrum is measured by a MAC-E filter, which features a high acceptance angle for electrons emitted by a high-luminosity, isotropically emitting tritium source, $\Delta\Omega/2\pi = 1 - \cos\theta_{\max}$.

One approach to improve the statistical uncertainty of the experiment is to further the acceptance angle $\theta_{\max}$, which depends on the ratio of source and maximum magnetic field. This can be achieved by keeping the source magnetic field at standard setting and scaling down the magnetic fields in the rest of the beam line. The changed electromagnetic conditions lead to increased β-electron statistics and influence several systematic effects. These effects, as well as the gain in statistics compared to the standard magnetic field settings, are evaluated by simulations and measurements that are presented in this talk.

This work is supported by the Helmholtz Association (HGF), the Ministry for Education and Research BMBF (05A17PM3, 05A17PX3, 05A17VK2, and 05A17WO3), the Helmholtz Alliance for Astroparticle Physics (HAP), and the Helmholtz Young Investigator Group (VH-NG-1055).

T 50: Search for Dark Matter 2

Time: Tuesday 16:15–18:00 Location: T-H35

T 50.1 Tue 16:15 T-H35

Optimisation of the TPC aspect ratio for the DARWIN observatory — •Sebastian Vetter — Institute for Astroparticle Physics (IAP), Karlsruhe Institute of Technology (KIT)

DARWIN is a proposed next-generation astroparticle physics observatory focused on the direct detection of WIMP Dark Matter. It will use 40 tonnes of natural xenon inside a dual-phase Time Projection Chamber (TPC) following the technology of the successful detectors that use noble elements as active material. Due to the elusive nature of Dark Matter and the envisaged unprecedented discovery potential, DARWIN requires an ultra-low background level.

The final design of many components of the detector is not decided yet. One of the central parameters for optimization is the aspect ratio (AR) of the TPC. A higher AR leads to better light collection and shorter electron drift lengths, but also comes with different fractions of sensor and cryostat materials, being a source of external background.

In this talk we present results based on detailed 3-dim Monte Carlo simulations on the influence of the AR on the S1 signal detection efficiency for WIMPs as well as on background components such as dark count rates and neutrons from the TPC materials.

T 50.2 Tue 16:30 T-H35

The Freiburg DARWIN Demonstrator — •Julia Müller — University of Freiburg

Liquid xenon (LXe) time projection chambers (TPCs) are the leading detector technology for searches for dark matter in form of WIMPs. DARWIN will be the ultimate LXe-based dark matter detector covering the entire accessible parameter space for WIMP masses above a few $\mathrm{GeV/c^2}$, superseding current detectors in size and sensitivity. The technical realization of its central low-background TPC with a diameter of about 2.6m will be very challenging due to the size of the detector, the low-temperature operation, and the required radiopurity levels. The DARWIN detector test platform PANCAKE at the University of Freiburg will be used to develop and test flat detector components with diameters up to the DARWIN-scale. We will present an overview of the platform that can accomodate up to 400 kg of xenon gas and present first results from the commissioning phase.

T 50.3 Tue 16:45 T-H35

Full MonteCarlo simulations of the cosmogenic background for the DARWIN observatory at different underground locations — •Jose Cuenca-García for the DARWIN-Collaboration — Institute for Astroparticle Physics (IAP), Karlsruhe Institute of Technology (KIT)

The DARWIN observatory is a proposed next-generation experiment focused on the direct detection of Dark Matter. It will use 40 tonnes of natural xenon inside a dual-phase Time Projection Chamber (TPC) being the evolution of the detectors that use noble elements as active material. The final design of the detector and its location are not decided yet. Besides the direct detection of Dark Matter a large variety of science channels can be studied, as for example $0\nu bb$, Axion Like Particles or solar neutrinos, among others. To fully exploit these physics goals an ultra-low background level is required. Although this type of experiments is located in underground laboratories to shield them against the cosmic radiation, muons and their induced secondary particles can still contribute significantly to the background. This *in situ* production cannot be suppressed and further veto systems are needed. We present here the simulations of the cosmogenic background for several underground laboratories. In particular, we focus on the production of some nuclei that can potentially affect the science channels of interest.

T 50.4 Tue 17:00 T-H35

DARWIN background estimations through multi-scatter separation — •Maike Doerenkamp, Antoine Chauvin, Andrii Terliuk, and Stephanie Hansmann-Menzemer — Physikalisches Institut, Universität Heidelberg

The DARWIN experiment is a future multi-ton dual-phase xenon TPC, whose primary goal will be the search for WIMPs through nuclear recoil. One of the major backgrounds in WIMP-nucleus interactions are radiogenic neutrons. A single nuclear recoil caused by a neutron is indistinguishable from one caused by a WIMP. However, due to their much shorter mean-free path, more than 90% of neutrons scatter multiple times within the detector. This can be exploited for background rejection. This talk will describe a method to separate single- and multi-scatter events in a dual-phase xenon TPC and how this translates to the expected neutron background rates in DARWIN.

T 50.5 Tue 17:15 T-H35

Estimation of electronic recoil leakage into nuclear recoil signal for DARWIN — •Antoine Chauvin, Maike Doerenkamp, Andrii Terliuk, and Stephanie Hansmann-Menzemer — Physikalisches Institut, Universität Heidelberg

The DARWIN experiment is a proposed future Direct Dark Matter detector which aims to detect WIMPs through WIMP-nucleus interactions, in a multi-ton liquid xenon target. Is goal is to become the most sensitive experiment to WIMP-nucleus interaction. To estimate this sensitivity, good models for signal and background generation, and of the detection processes, are fundamental. Electronic Recoil (ER) processes are the dominant background. Thus a good rejection of ER background, and an estimation of the ER leakage in Nuclear Recoil (NR) signal, is fundamental to achieve a high sensitivity. In this talk, I will report on the setup of a simulation of the DARWIN detection process, and its use to estimate the ER leakage fraction.

T 50.6 Tue 17:30 T-H35

Charge detection via proportional scintillation in a single-phase liquid xenon TPC — •Florian Tönnies for the DARWIN-Collaboration — Albert-Ludwigs-Universität Freiburg, Deutschland

Dual-phase liquid/gas xenon TPCs are a well-established detector technology to search for WIMP Dark Matter. Nevertheless, the homogenious detection of the charge signal via proportional scintillation will be challenging at the scale of the next-generation detectors due to the size of the TPCs. The detection of the charge signal in the liquid phase of a single-phase TPC might be an option to circumvent this issue. In Freiburg we successfully operate a single-phase TPC demonstrator which exploits proportional scintillation in the strong electric field around thin wires. Some of the most recent results will be presented in this talk.

T 50.7 Tue 17:45 T-H35

The MonXe Radon Emanation Chamber — •Daniel Baur for the DARWIN-Collaboration — Albert-Ludwigs-Universität Freiburg

Liquid xenon-based experiments are currently leading the search for WIMP dark matter. Their electronic recoil background in the energy region of interest is dominated by the naked (i.e., not accompanied by the coincident emission of a gamma-ray) beta decays of ^{214}Pb, a progeny of ^{222}Rn which is emanated from all material surfaces. Consequently, the reduction of ^{222}Rn emanation is mandatory for the success of next-generation dark matter experiments with multi-ton xenon targets such as DARWIN.

The ^{222}Rn surface emanation can be measured directly with a radon emanation chamber. In such a detector the daughters of ^{222}Rn are collected electrostatically on a silicon PIN diode and the subsequent alpha decays are measured spectrometrically. We report on the MonXe radon emanation chamber, which was recently commissioned in Freiburg for the radiopurity assay of DARWIN.

T 51: Experimental Techniques in Astroparticle Physics 2

Time: Tuesday 16:15–18:20 Location: T-H36

T 51.1 Tue 16:15 T-H36

Comparison of Sky Models of the Galactic Radio Background for the Calibration of Radio Arrays — •Max Büsken for the Pierre Auger-Collaboration — Institut für ExperimentelleTeilchenphysik, Karlsruher Institut für Technologie, Karlsruhe, Deutschland

The Pierre Auger Observatory is the largest ground-based experiment for the detection of ultra-high energy cosmic rays. New radio antennas will be installed on each of the surface detector stations as part of the AugerPrime upgrade. This will allow to study the mass composition of cosmic rays arriving with large inclination angles.

Performing an accurate calibration and having a good understanding of its uncertainties is crucial for any physics analysis. Conducting a calibration campaign in the field with a reference antenna is not feasible on this large scale. Therefore the absolute calibration of the radio antennas will be performed using the diffuse galactic radio emission as an absolute reference, as it is the most dominant source of background. I will present a comparison of sky models that predict the galactic emission received from the whole sky. I will show how large the uncertanties on these predictions are and illustrate, what this means for radio experiments relying on this calibration method.

T 51.2 Tue 16:30 T-H36

Verbesserung des externen Triggers von AERA für ausgedehnte Luftschauer am Pierre-Auger-Observatorium — •Rukije Uzeiroska für die Pierre Auger-Kollaboration — Bergische Universität Wuppertal

Das Pierre-Auger-Observatorium ist das größte Observatorium für kosmische Strahlung der Welt. Sein Auger Engineering Radio Array (AERA) besteht aus mehr als 150 Antennenstationen, die eine Fläche von etwa 17 km^2 abdecken, und dient der Erfassung von Radiosignalen, die von ausgedehnten Luftschauern emittiert werden. Diese Messungen werden verwendet, um die Eigenschaften der primären kosmischen Strahlung zu rekonstruieren, die die Luftschauer verursacht. Die Datennahme von AERA wird insbesondere extern durch die zentrale Datennahme des Observatoriums getriggert. Seine Funktionsweise führt dazu, dass viele Ereignisse getriggert werden, die für AERA nicht relevant sind. Zudem werden nicht alle interessanten Ereignisse als solche erkannt. Um den externen Trigger zu verbessern wird eine neue, vereinfachte Rekonstruktionsmethode für die Bestimmung der Richtung eines ausgedehnten Luftschauers vorgestellt. Die Zuverlässigkeit dieser Methode wird anhand von rekonstruierten Luftschauern getestet. Auf Basis der entwickelten Rekonstruktionsmethode werden verschiedene Trigger-Bedingungen definiert und getestet. Die optimale Trigger-Bedingung erreicht eine Effizienz von 99,87 % für relevante AERA-Ereignisse, während sie die Gesamt-Datenrate um 49,98 % reduziert. Dies stellt eine substantielle Verbesserung gegenüber dem aktuellen AERA-Trigger dar.

T 51.3 Tue 16:45 T-H36

Depth of Maximum of Air-Shower Profiles at the Pierre Auger Observatory — •Thomas Fitoussi for the Pierre Auger-Collaboration — Karlsruhe Institute of Technology, Institute for Astroparticle Physics, Karlsruhe, Germany

The Pierre Auger Observatory is the largest ultra-high energy cosmic rays observatory in the world. Using a hybrid technique (fluorescence telescopes and surface detectors) it is possible to estimate the mass composition of cosmic rays. The main mass-sensitive observable measured with fluorescence telescopes is the depth of maximum of air-shower profiles called $X_{\max}$.

In this presentation, we will present the analysis of the most recent dataset with a special focus on results at low energies down to $\sim 10^{17}$ eV. These low energy measurements are preformed with the High Elevation Auger Telescope (HEAT) and they allow to study the energy region where the transition between Galactic and extragalactic cosmic rays is expected.

T 51.4 Tue 17:00 T-H36

Separation of muonic and electromagnetic signals using the upgraded detectors of the Pierre Auger Observatory — •Allan Machado Payeras[1,2], Anderson Campos Fauth[2], Darko Veberic[1], and David Schmidt[1] — [1]Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]University of Campinas, Campinas, Brazil

The Pierre Auger Observatory detects extensive air showers (EAS), produced by high-energy cosmic rays. Its surface detector (SD) is composed of 1660 water-Cherenkov detectors (WCD) disposed in a triangular grid with a spacing of 1500 m between nearest neighbours. At the moment, the Observatory is being upgraded with the main addition of a surface scintillation detector (SSD), which will be installed on top of each WCD. The main goal of the upgrade is to obtain data sensitive to the composition of the primary cosmic rays, which is necessary to understand the astrophysical origin of these particles. In this work, we have studied a method to obtain a separation of signals due to the electromagnetic and muonic components of EAS, using the responses of the WCD and SSD. Such separation is the key to obtain composition-sensitive information from the new dataset. The signals of each of the components were modelled for the detectors and, using Monte Carlo simulation of both EASs and of the detector responses, we studied the reconstruction of the components for different distances to the shower axis, energies and zenith angles of the primaries. We assessed the reconstruction precision of the different components not only for the total signal, but also for its time structure.

T 51.5 Tue 17:15 T-H36

Pointing accuracy of the roving laser system for the energy calibration of the Pierre Auger Observatory* — •Alina Nasr Esfahani — Bergische Universität Wuppertal, Gaußstr. 20, Wuppertal, Germany

The Fluorescence Detector (FD) of the Pierre Auger Observatory provides a nearly model independent measurement of the energy of primary cosmic rays. This FD energy measurement sets the energy scale of the Surface Detector, its precision thereby factors into the systematic uncertainties of practically all scientific results from the Observatory. By firing a laser with known energy output in front of the FD telescopes the energy calibration obtained from other methods can be cross-checked independently. The camera response to the laser closely resembles its response to a real cosmic ray shower providing a valuable end-to-end calibration. The laser system includes components to expand and depolarize the laser beam to optimize the scattering in the atmosphere and detection by the FD camera. We built the roving laser system by utilizing a telescope mount as a carrier for the laser. Angular precision measurements show that this greatly improves the pointing accuracy, which has been a significant source of uncertainty

in previous campaigns. The precision requirements for a sufficient reduction of systematic uncertainties compared to previous systems are based on the analysis of laser simulations.
**Supported by the BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A20PX1).*

T 51.6 Tue 17:30 T-H36

Applications of the high-energy lepton and photon propagator PROPOSAL — •Jean-Marco Alameddine[1], Jan Soedingrekso[1], and Alexander Sandrock[2] — [1]Astroparticle Physics WG Rhode, TU Dortmund University, Germany — [2]University of Wuppertal, Germany

PROPOSAL is a simulation library, usable in both C++ and Python, which provides 3D Monte Carlo simulations of charged leptons and high-energy photons. One key concept of PROPOSAL is to offer a trade-off between simulation precision and performance for each individual use case. Due to its customizable and modular structure, PROPOSAL is used for a wide range of applications, for example in the simulation chain of the IceCube Neutrino Observatory or as an electromagnetic interaction model in the shower simulation framework CORSIKA 8.

In this contribution, an introduction to the simulation framework as well as an overview of its current and possible future applications, including muography, are presented.

T 51.7 Tue 17:45 T-H36

Effects of unresolved particles in the counts estimated by a segmented detector — •Flavia Gesualdi[1,2] and Daniel Supanitsky[1] — [1]Instituto de Tecnologías en Detección y Astropartículas (CNEA, CONICET, UNSAM), Centro Atómico Constituyentes, B1650KNA San Martín, Buenos Aires, Argentina — [2]Karlsruhe Institute of Technology, Institute for Astroparticle Physics (IAP), 76021 Karlsruhe, Germany

Segmented particle counters are part of many astroparticle physics detectors and are used to estimate particle densities. For instance, measuring the density of muons in air showers is key for composition analyses, which in turn help to elucidate the origin of cosmic rays. Technically, the goal of a segmented particle counter is to provide an accurate estimate of the impinging number of particles from the measured number of hit segments. If two particles hit a same segment within a time interval smaller than the time resolution, the two particles are counted as one. This undercounting effect, referred to as pile-up, is larger when the number of segments is small with respect to the number of impinging particles, and when the time resolution is poor compared to the characteristic duration of a single-particle signal. In this work, we develop a new pile-up-correction method that makes use of the whole temporal structure of the signal. We compare its performance against methods in literature. We show that the method of this work performs well when considering typical air-shower signals, and that it is also the only one that extends well to long or double-bump-like signals.

Group Report T 51.8 Tue 18:00 T-H36

Intensity interferometry campaign at the H.E.S.S. telescopes — •Naomi Vogel, Andreas Zmija, Gisela Anton, Stefan Funk, Dmitry Malyshev, Thilo Michel, Frederik Wohlleben, and Adrian Zink — Friedrich-Alexander-Universität Erlangen-Nürnberg, ECAP

Intensity interferometry (II) enables high angular resolution (~milliarcsecond) astronomical observations in the optical band by measuring the photon fluxes of at least two telescopes with varying baselines and correlating them. It has already been applied by VERITAS and MAGIC with excellent results. Imaging Atmospheric Cherenkov Telescopes are suitable for performing intensity correlations because of their very large collecting areas. We are planning an upcoming II campaign at the H.E.S.S. telescopes in Namibia. Our developed II setup, which includes a 2nm interference filter, is designed to fit on the lid of the telescopes and to handle the high photon count rates expected from the stars. This is achieved by photomultipliers whose photo currents are measured and then correlated. As preparation for our campaign lab measurements were carried out to achieve low background and good signal-to-noise ratios. In this contribution we will present our technical setup and results from our lab measurements as precursor for II at the H.E.S.S. telescopes.

T 52: Outreach Methods 2

Time: Tuesday 16:15–17:45 Location: T-H37

T 52.1 Tue 16:15 T-H37

Wie viele Farben hat ein Quark? Eine Messung mit Daten des Belle II Experimentes für die Teilchenphysik-Masterclasses — Florian Bernlochner, Jochen Dingfelder, •Svenja Granderath, Henrik Junkerkalefeld, Sebastian Lülsdorf, Florin Martius, Barbara Valeriani-Kaminski und Christian Wessel für die Netzwerk Teilchenwelt-Kollaboration — Universität Bonn

Bei den Teilchenphysik-Masterclasses des bundesweiten Projektes "Netzwerk Teilchenwelt" bekommen Jugendliche einen Einblick in die Grundlagen und Forschungsmethoden der Teilchenphysik sowie in die Arbeitswelt von Wissenschaftler:innen. 2021 wurde an der Universität Bonn von der Belle II-Arbeitsgruppe und von Lehramtsstudierenden eine neue Masterclass entwickelt, die auf einer Messung mit Daten des Experimentes in Japan basiert. Schüler:innen untersuchen dabei Bilder von Teilchenkollisionen, bei denen ein Teilchen-Antiteilchen-Paar entstanden ist, und lernen, die Quark-Antiquark- und Lepton-Antilepton-Paare anhand geeigneter Selektionskriterien zu klassifizieren. Anschließend bestimmen sie den experimentellen Wert des R-Wertes sowie die daraus resultierende Anzahl der Farbladungen und vergleichen dann diesen Wert mit der theoretischen Erwartung, die sie während der Masterclass selber berechnet haben. In dem Vortrag werden das didaktische Konzept und die Materialien der Masterclass sowie die Erfahrungen präsentiert, die bei Durchführung der Messungen sowohl online als auch in Präsenz gemacht wurden.

T 52.2 Tue 16:30 T-H37

Outreach Modules for a New Particle Search Using the ATLAS Forward Proton Detector and Higgs Boson Physics — Ivan Demchenko, Martin Kupka, André Sopczak, •Antoine Vauterin, and Peter Zacik — CTU in Prague

We present two modules as part of the Czech Particle Physics Project (CPPP). These are intended as learning tools in masterclasses aimed at high-school students (aged 15 to 18). The first module is dedicated to the detection of an Axion-Like-Particle (ALP) using the ATLAS Forward Proton (AFP) detector. The second module focuses on the reconstruction of the Higgs boson mass using the Higgs boson golden channel with four leptons in the final state. The modules can be accessed at the following link: http://cern.ch/cppp

T 52.3 Tue 16:45 T-H37

Ten years of the Outreach Project "International Cosmic Day" — •Nora Feigl, Carolin Schwerdt, and Heike Prokoph for the Netzwerk Teilchenwelt-Collaboration — DESY Zeuthen

Since 2012 students become researchers in astroparticle physics for one day of the year in November: the International Cosmic Day (ICD). Participants from more than 60 institutions such as schools, universities and research institutes in 17 countries performed experiments, discussed results and learned from scientists about the latest research in their field on ICD 2021.

There are many ways to participate, such as carrying out cosmic particle experiments, analyzing publicly available cosmic ray data and much more. Communication between the groups is arranged via up to 10 video meetings that take place throughout the day.

The ICD allows the students to have a first-hand experience of working in science, shows the students how international collaborations work and how science functions as a connecting element across national borders, language barriers and cultural differences.

In this talk we will give insights into the organization of the day and present the different possibilities of participating in the International Cosmic Day - from small projects in high school physics classes to more time-intensive elaborate experiments.

T 52.4 Tue 17:00 T-H37

IceCube Masterclass - ein Onlinekonzept — •Jannes Brostean-Kaiser, Maren Voitz-Wiedau, Carolin Schwerdt, Leander Fischer und Nora Feigl für die Netzwerk Teilchenwelt-Kollaboration — DESY Zeuthen

Im Rahmen einer Bachelorarbeit an der HU Berlin und bei DESY, Standort Zeuthen, wurde die IceCube Masterclass des Netzwerk Teilchenwelt von einer Präsenz- zu einer digitalen Veranstaltung umstrukturiert. Dabei wurden die einzelnen Veranstaltungsbereiche auf Kompatibilität mit dem Rahmenlehrplan Berlins geprüft, modular und mit Fokus auf den Kompetenzbereich Kommunizieren gestaltet. Diese Masterclass konzentriert sich inhaltlich auf drei Schwerpunkte. Zunächst wird das Standardmodell der Teilchenphysik vorgestellt, um das theoretische Fundament und die Relevanz des Detektors selbst zu geben. Anschließend werden die Funktionsweise des IceCube Detektors, sowie einfache Analysen und Identifikationsmöglichkeiten von Teilchen präsentiert. Und zuletzt werden noch am Beispiel der Punktquellensuche statistische Methoden in der Physik erklärt. Alle Bereiche werden von einem/einer Vermittler:in mit einem klassischen Vortrag gestartet, sowie mit Hands-On Übungen für die Schüler:innen begleitet. Der Ablauf der Einheiten orientiert sich am Basismodell 4 Begriffs- und Konzeptbildung nach Oser. Den Abschluss der Masterclass bildet ein Vortrag eines wissenschaftlichen Mitarbeitenden, welche:r den Detektor am Südpol besucht hat, sowie eine allgemeine Fragerunde zum wissenschaftlichen Arbeiten und dem Werdegang eines Forschenden.

T 52.5 Tue 17:15 T-H37

A Michelson interferometer as a demonstrator for gravitational wave detection in outreach activities — •David Koke and Alexander Kappes — WWU Münster, Münster, Deutschland

Gravitational waves are one of the most exciting phenomena in astrophysics and have given us new insights into our universe since their first direct detection in 2015. In order to easily demonstrate the basic principles of gravitational wave detection in outreach activities, a demonstration experiment based on a Michelson interferometer was created in the framework of a master thesis. The subject of this talk is the presentation of the current status of the project, with a special focus on the technical realization and the challenges involved.

T 52.6 Tue 17:30 T-H37

Escape Radon: Entwicklung eines digitalen Escape Rooms für den Physikunterricht — •Hannes Nitsche — Technische Universität Dresden

Digitale Spiele werden über die letzten Jahre vermehrt zu Lehrzwecken genutzt und sollen Lernkonzepte auf spielerische Art und Weise erweitern. Eine der außergewöhnlicheren Spielformen, die ihren Weg in die Bildung findet, ist die des digitalen Escape Rooms. Grundlage dieses Vortrags ist eine wissenschaftliche Arbeit, in der der didaktische Mehrwert dieses Spielformats für den Physikunterricht untersucht wurde. Dazu wurde eine digitale Escape Story entwickelt, welche sich inhaltlich mit der Radonbelastung in Deutschland auseinandersetzt und dabei kernphysikalische Grundlagen vermittelt. Im Vortrag wird die Escape Story 'Escape Radon' sowie die Ergebnisse ihrer Erprobung und Evaluation vorgestellt. Des Weiteren wird erörtert, welche Gestaltungselemente von digitalen Escape Rooms das Interesse der Lernenden am Lehrinhalt fördern können und wieweit sich die Methode für Lehrzwecke adaptieren lässt.

T 53: Data Analysis, Information Technology and Artificial Intelligence 3

Time: Tuesday 16:15–18:30 Location: T-H38

T 53.1 Tue 16:15 T-H38

Improved selective background Monte Carlo simulation at Belle II with graph attention networks and weighted events — •Boyang Yu, Nikolai Hartmann, and Thomas Kuhr — Ludwig-Maximilians-Universität München

When measuring rare processes at Belle II, a huge luminosity is required, which means a large number of simulations are necessary to determine signal efficiencies and background contributions. However, this process demands high computation costs while most of the simulated data, in particular in case of background, are discarded by the event selection. Thus filters using graph neural networks with attention mechanisms are introduced after the Monte Carlo event generation to save the resources for the detector simulation and reconstruction of events discarded at analysis level. Merely filtering out events will however inevitably introduce biases. Therefore statistical methods including sampling and reweighting are invested to deal with this side effect.

T 53.2 Tue 16:30 T-H38

Analysis Specific Filters for Selective Background Monte Carlo Simulations at Belle II — •Luca Schinnerl, Boyang Yu, Nikolai Hartmann, and Thomas Kuhr — Ludwig Maximilians University Munich, Munich, Germany

The Belle II experiment is expected to accumulate a data sample of 50 ab-1 in its lifetime. For rare processes, strong background suppression is needed to precisely measure these types of events. Because of this, an extremely large number of simulated background events is necessary for an effective analysis. However, a significant portion of the simulated data is discarded trivially in the first stage of analysis, demanding a better method of simulation to keep up with the amount of data. For this purpose a neural network is implemented to select the relevant data after the Monte Carlo event generation and then only run the costly detector simulation and reconstruction for selected events. Existing methods have shown good success with graph neural networks. However, the total speedup of simulations is limited when considering generic selections with a retention rate of 4.25%. Here a maximum speedup of 2.1 was reached. In this work we iteratively introduce analysis specific filters to the training of the neural networks, which can greatly increase efficiencies. For the rare process B -> K*vv this methodology has been successful in significantly improving simulation speed.

T 53.3 Tue 16:45 T-H38

Preparing transformer-based dose predictions: Performance of encoder/decoder structures for CT- and dose-sequence encoding — •Piet Hoffmann, Kevin Kröninger, Armin Lühr, Florian Mentzel, and Jens Weingarten — TU Dortmund

In radiotherapy, fast dose predictions based on CT images are useful as they reduce the need for computing-intensive Monte Carlo simulations and thus can speed up treatment planning. A new approach to these fast dose predictions consists of interpreting the CT to dose conversion as a sequence translation task and making use of a transformer machine learning model.

For this, the CT data is disected perpendicularly to the beam into a sequence of 2D slices, if not already aquired in this direction. Before these slices are fed into the translation architecture it is useful to first encode them to reduce their dimensionaltiy and concentrate the contained information. After translation the data then has to be decoded into a dose prediction slice.

For the whole model to work properly, the structure of such encoder and decoder is important and thus in this talk different approaches are compared with respect to their performance. Properties of the resulting encoded data space, like smooth transitioning between data points and the density distribution of data points, and their potential benefits are discussed.

T 53.4 Tue 17:00 T-H38

Progressive Generative Adversarial Networks for High Energy Physics Calorimeter Simulations — •Simon Schnake[1,2], Kerstin Borras[1,2], Dirk Krücker[1], Florian Rehm[2,3], and Sofia Vallecorsa[3] — [1]DESY, Hamburg, Germany — [2]RWTH Aachen, Germany — [3]CERN openlab, Geneva, Swiss

The simulation of particle showers in calorimeters is a computational demanding process. Deep generative models have been suggested to replace these computations. One of the complexities of this approach is the dimensionality of the data produced by high granularity calorimeters. One possible solution could be progressively growing the GAN to handle this dimensionality. In this study, electromagnetic showers of a (25x25x25) calorimeter in the energy range of 10 - 510 GeV are used to train generative adversarial networks. The resolution of the calorimeter data is increased while training. First results of this approach are shown.

T 53.5 Tue 17:15 T-H38

Generative Models For Hadron Shower Simulation — •Engin Eren — Deutsches Elektronen-Synchrotron, Notkestrasse 85, 22607

Hamburg, Germany

Simulations provide the crucial link between theoretical descriptions and experimental observations in particle physics. It describes fundamental processes or the interactions of particles with detectors. The high computational cost associated with producing precise simulations in sufficient quantities, e.g. for the upcoming data-taking phase of the Large Hadron Collider (LHC) or future colliders, motivates research into more computationally efficient solutions. However, the simulation of realistic showers in a highly granular detector remains a hard problem due to a large number of cells, values spanning many orders of magnitude, and the overall sparsity of data.

This contribution advances the state of the art in two key directions: Firstly, we present a precise generative model for the fast simulation of hadronic showers in a highly granular hadronic calorimeter. Secondly, we compare the achieved simulation quality before and after interfacing with a so-called particle-flow-based reconstruction algorithm. Together, these bring generative models one step closer to practical applications.

T 53.6 Tue 17:30 T-H38

Deep Set Generation of Collider Events — •Erik Buhmann — Institut für Experimentalphysik, Universität Hamburg

With current and future high-energy collider experiments' vast data collecting capabilities comes an increasing demand for computationally efficient simulations. Generative machine learning models allow fast event generation, yet are largely constrained to fixed data and detector geometries.

We introduce a novel autoencoder setup for generation of permutation invariant point clouds with variable cardinality - a flexible data structure optimal for collider events. Our model is simple, lightweight and purely set based without exploiting additional graph structures. We show that our model scales well to large particle multiplicities and achieves good performance on various data sets.

T 53.7 Tue 17:45 T-H38

Angular Conditioning of Generative Models for Fast Calorimeter Shower Simulation — •Peter McKeown — Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

Modern high energy physics experiments fundamentally rely on accurate simulation- both to characterise detectors and to bridge observed signals and underlying theory. Traditional simulation tools are reliant upon Monte Carlo methods which, while powerful, require significant computational resources, and are projected to become a major bottleneck at the high luminosity stage of the LHC and for future colliders. Calorimeter showers are particularly computationally intensive to simulate, due to a large number of particle interactions with the detector material.

A potential solution based on deep generative models promises to provide drastic reductions in compute times. Previous work in our group has demonstrated the ability of various generative models to accurately reproduce key physical properties of showers in highly granular calorimeters. While this work has focused on the specific case of a particle incident perpendicular to the face of the calorimeter, a practical simulator must be able to correctly simulate arbitrary angles of incidence. In this talk, efforts to add conditioning on the incident angle of the particle will be addressed.

T 53.8 Tue 18:00 T-H38

Refinement of jet simulation with generative adversarial networks — •Shruthi Janardhan[1,2], Sven Harder[1], Patrick Connor[1], Peter Schleper[1], Daniel Ruprecht[2], and Sebastian Götschel[2] — [1]Universität Hamburg — [2]Technische Universität Hamburg

In High Energy Physics, the interaction of particles with matter at the detectors are best simulated with the GEANT4 software. Alternatively, less precise but faster simulations are sometimes preferred to reach higher statistical precision. We present recent progress of refinement of fast simulations with ML techniques to enhance the quality of such fast simulations. We demonstrate the use of generative adversarial networks in the context of jet simulation using a Wasserstein loss function. The architecture consists of two opposing networks, Refiner and Critic. The Refiner, refines the distribution of the energy of the jets obtained with the fast simulation. The Critic is used to effectively differentiate between the distributions of refined energy and the distribution obtained by the GEANT4 simulation. The Refiner can be used solely to obtain a fast but refined jet simulation.

T 53.9 Tue 18:15 T-H38

Using ML to analytically model the CMS detector response to jets — •Nils Gerber, Samuel Bein, and Peter Schleper — Universität Hamburg

Many applications in particle physics require an accurate modelling of the energy response of detectors to individual particles as well as jets. For example, unfolding, fast detector simulation, as well as certain background estimation techniques, all require some input related to the jet response. While typical models are constructed from established functional forms such as Crystal Ball functions fit to data distributions of the response, an alternative approach is explored where a DNN classifier is employed in order to arrive at a model which takes into account correlated dependencies in the response on the true jet energy, pseudorapidity, jet flavour, and other factors.

T 54: Invited Topical Talks 3

Time: Wednesday 11:00–12:40 Location: T-H15

Invited Topical Talk T 54.1 Wed 11:00 T-H15

Hunting XYZ Beasts at Belle and Belle II — •Elisabetta Prencipe for the Belle II-Collaboration — Justus-Liebig-University of Giessen, Giessen, Germany

The search for conventional and non-conventional charmonium states has gained a lot of attention over the past twenty years. It has undoubtedly been shown since 2003 that there are more complex structures than mesons and baryons, and for several of those a non-unique interpretation has been provided, mainly due to the lack of statistics. We refer to these resonant states as X, Y, Z, depending on their properties. Recently the PDG has renamed those that are well established, trying to provide a better understanding. Undoubtedly B factories such as Belle and BaBar have in the past made a notable contribution in filling in the missing blocks of the charmonioum spectrum; however, the limited statistics did not allow to search further for these exotic XYZ states.

LHCb collected huge data sets, which allowed to conduct interesting analyses in the *i.e.* search for pentaquarks and the properties of the X(3872). An important contribution to the field will come from the Belle II data, once the planned integrated luminosity is reached, in particular in the search for exotic states in radiative decays, ISR and $\Upsilon(nS)$ transitions, which represent unique physics cases.

Recent spectroscopy results with the complete Belle data sets are discussed, and a summary of results in charmonium and bottomonium spectroscopy is provided with current Belle II data. Future plans with Belle + Belle II combined data sets are then presented.

Invited Topical Talk T 54.2 Wed 11:25 T-H15

Precision tests of the Standard Model using CP violation in B meson decays — •Thibaud Humair for the Belle II-Collaboration — Max Planck Institute for Physics, Föhringer Ring 6, 80805 Munich

One of the main goals of the Belle II physics program is to test the flavour sector of the Standard Model to very high precision by measuring the parameters of the CKM triangle, which governs quark mixing. This talk focuses on the measurements of two of these parameters: the angles alpha and beta.

The angle alpha requires to measure direct CP violation in various charmless, rare, modes. These modes require excellent performances in background reduction and in the reconstruction of neutrals. The angle beta is accessed through time-dependent measurements of CP violation. These measurements require a very good B vertex resolution, excellent flavour tagging capabilities and a perfect understanding of the detector response. I will present recent Belle II results in both types of measurements, and discuss the future prospects for analyses of highest possible precision.

Invited Topical Talk T 54.3 Wed 11:50 T-H15

Back to the top: charting the bounds of the standard model — •Afiq Anuar — Deutsches Elektronen Synchrotron (DESY), Notkestraße 85, D-22607 Hamburg

The top quark, the most massive member of the standard model, is unique in that it is the only known fermion with a Yukawa coupling of order one. In addition, its short lifetime provides us with the only opportunity to study a quark prior to hadronization. These advantages make it among our best probes in searches for physics beyond the standard model. At the same time, the stream of negative results in searches of specific extensions of the standard model from the LHC makes the use of effective approaches increasingly attractive. In this talk, experimental analyses where such approaches are employed will be discussed, ranging from interpretations of precise standard model measurements to direct constraints on effective operators through the use of advanced statistical methods.

Invited Topical Talk T 54.4 Wed 12:15 T-H15

Dark matter from spin-2 mediators — •Stefan Vogl — University of Freiburg

Dark matter interacting with massive spin-2 mediators is an intriguing possibility. However, due to the high energy behavior of longitudinal modes of spin-2 particles, the rate of DM annihilation into the mediators exhibits a tremendous growth as soon the channel is kinematically open. To have a consistent effective theory for the spin-2 particle, we analyze an extra-dimensional model such that the mediator(s) are the Kaluza-Klein (KK) modes of the 5D graviton. We find that including the full KK-tower in the computation reduces the annihilation rate by an order of magnitude or more. This casts some doubt on the universal applicability of previous studies with spin-2 mediators within an EFT framework and indicates that a careful consideration of UV physics is required to accurately capture the phenomenology.

T 55: Invited Topical Talks 4

Time: Wednesday 11:00–12:40 Location: T-H16

Invited Topical Talk T 55.1 Wed 11:00 T-H16

Machine Learning for LHC Theory — •Anja Butter — Institut für Theoretische Physik, Heidelberg, Germany

Over the next years, measurements at the LHC and the HL-LHC will provide us with a wealth of data. The best hope of answering fundamental questions like the nature of dark matter, is to adopt machine learning techniques for particle experiment and theory. LHC physics relies at a fundamental level on our ability to simulate events efficiently from first principles. In the coming LHC runs, these simulations will face unprecedented precision requirements to match the experimental accuracy. Neural networks can overcome limitations from the calculation of amplitudes and event generation. Generative networks can achieve high-precision in simulations while maintaining control over training stability and associated uncertainties. Since networks in the form of normalizing flows can be inverted, they also open new avenues in LHC analyses. The access to the density of the generated distribution enables new methods for anomaly detection, while their interpretation in terms of probability densities leads to new methods for multi-dimensional unfolding.

Invited Topical Talk T 55.2 Wed 11:25 T-H16

Towards high-precision deep learning for astroparticle physics — •Christoph Weniger — University of Amsterdam, Netherlands

Observational data relevant for astroparticle physics and astrophysical searches for dark matter becomes increasingly complex and detailed. We are in a situation where often what we can learn from new observations is limited not by the amount of data, but by the sophistication of our analysis tools and the quality and detail of our physical models. Classical statistical techniques, like Markov Chain Monte Carlo, severely limit model realism and complexity, due to their high simulation requirements and limitation on the number of free parameters. Neural simulation-based inference algorithms have the capability to break through these barriers in surprising ways. However, using these new classes of algorithms without compromising the precision and accuracy of statistical inference results remains challenging. I will present both successful examples and discuss typical pitfalls related to the application of neural simulation-based inference algorithms to dark matter searches with astrophysical data.

Invited Topical Talk T 55.3 Wed 11:50 T-H16

The quest for the mechanism behind the matter-antimatter asymmetry — •Julia Harz — Technische Universität München, München, Germany

Our own existence is still a mystery, as some yet unknown mechanism had to generate an excess of matter over antimatter during the evolution of the Universe. After an introduction on why physics beyond the Standard Model is needed in order to explain the observed matter-antimatter asymmetry, I will give an overview of different theoretical mechanisms that are potentially able to explain such an asymmetry. Hereby, I will highlight interesting possible connections to neutrino physics and dark matter. Moreover, I will discuss the challenges of probing baryogenesis models and review promising experimental strategies.

Invited Topical Talk T 55.4 Wed 12:15 T-H16

Towards the lightest dark matter in direct searches — •Belina von Krosigk — Karlsruhe Institute of Technology, Institute for Astroparticle Physics, Eggenstein-Leopoldshafen, Germany

In the last decades, astronomical observations have consistently indicated that most of the matter in the Universe remains hidden to even the most sensitive telescopes because it is nonluminous - because it is dark. Observing the respective dark matter particles became one of the most tantalizing endeavors of modern physics. A new generation of large exposure direct search experiments is at the ready to observe weak-scale dark matter particles, with their successors already in the planning. At the same time a new era has begun towards a direct detection of ever lighter dark matter candidates. Novel detector designs are reaching ultra-low detection thresholds with which new detection channels can be exploited and unprecedentedly low dark matter masses can be probed. State-of-the-art direct detection searches most sensitive to light dark matter will be reviewed together with an outlook on where the near future is expected to take us in this quest towards dark matter discovery in the laboratory.

T 56: Flavour Physics 4

Time: Wednesday 16:15–18:30 Location: T-H15

T 56.1 Wed 16:15 T-H15

Bs mixing in scalar Leptoquark models — •Jordi Folch Eguren[1], Javier Virto[2], and Andreas Crivellin[3] — [1]University of Barcelona/TU Dortmund — [2]University of Barcelona — [3]PSI

Leptoquarks provide viable solutions to the flavour anomalies, i.e. they can explain the tensions between the measurements and the Standard Model predictions of the anomalous magnetic moment of the muon as well as b-s and b-c$\tau\nu$ processes.

However, LQs also contribute to other flavour observables, such as F = 2 processes, at the loop-level. In particular, Bs mixing provides a crucial bound in setups addressing b-c$\tau\nu$ data, often excluding a big portion of the parameter space that could otherwise account for it.

In this work, we first derive the complete leading order matching, including all five scalar LQ representations, for D0, K0 and Bs mixing (at the dimension-six level). We then calculate the next-to-leading order αs matching corrections to these F = 2 processes in generic scalar leptoquark models.

We find that the two-loop corrections increase the effects in F = 2 processes by 5-10% and significantly reduce the matching scale uncertainty.

T 56.2 Wed 16:30 T-H15

Testing the Standard Model with CP-asymmetries in flavour-specific non-leptonic decays — Tim Gershon[1], Alexander Lenz[2], •Aleksey Rusov[2], and Nicola Skidmore[3] — [1]Department of Physics, University of Warwick, Coventry, CV4 7AL, UK — [2]Center for Particle Physics Siegen, Theoretische Teilchenphysik, Universität Siegen, Walter-Flex-Str. 3, 57068 Siegen, Germany — [3]University of Manchester, Schuster Building, Manchester, M13 9PL, UK

Motivated by recent indications that the rates of colour-allowed non-leptonic channels are not in agreement with their Standard Model expectations based on QCD factorisation, we investigate the potential to study CP asymmetries with these decays. In the Standard Model, these flavour-specific decays are sensitive to CP violation in $B^0_{(s)}$–$\bar{B}^0_{(s)}$ mixing, which is predicted with low uncertainties and can be measured precisely with semileptonic decays. If there are beyond Standard Model contributions to the non-leptonic decay amplitudes, there could be significant enhancements to the CP asymmetries. Measurements of these quantities therefore have potential to identify BSM effects without relying on Standard Model predictions that might be affected by hadronic effects. We discuss the experimental prospects, and note the excellent potential for a precise determination of the CP asymmetry in $\bar{B}_s \to D_s^+\pi^-$ decays by the LHCb experiment.

T 56.3 Wed 16:45 T-H15

Endpoint divergences in QED corrections to $B_s \to \mu^+\mu^-$ — •Nicolas Seitz, Thorsten Feldmann, Tobias Huber, and Nico Gubernari — Center for Particle Physics Siegen, Theoretische Teilchenphysik, Universität Siegen

We consider leptonic B-meson decays of the form $B_s \to \mu^+\mu^-$. These are mediated in the standard model by operators of the effective weak Hamiltonian for $|\Delta B| = |\Delta S| = 1$ transitions. At leading order, only the semi-leptonic operator O_{10} contributes. If one calculates the QED corrections mediated by the operator O_7, the suppression by the fine-structure constant α is amplified by a factor $1/\lambda^2 = m_b/\Lambda_{\rm QCD} \gg 1$ Here, one additionally obtains a quadratic logarithmic amplification $\propto \ln^2\lambda^2$, which comes from endpoint divergences in regions of small momenta. The aim of our project is to investigate the interaction of QCD corrections on the hadronic side and the endpoint divergences of the muon propagator. An important technical tool here is the method of regions in the calculation of the loop integrals that occur.

T 56.4 Wed 17:00 T-H15

BSM effects in lifetimes of B mesons — •Jakob Müller, Alexander Lenz, Maria Laura Piscopo, and Aleksey Rusov — Center for Particle Physics Siegen, Theoretische Teilchenphysik, Universität Siegen

We study the impact of potential BSM contributions to non-leptonic b quark decays on observables like $\tau(B^+)/\tau(B_d)$ and $\tau(B_s)/\tau(B_d)$. These observables are measured with a precision of the order of several per mille. The corresponding theory predictions are obtained within the framework of the Heavy Quark Expansion.

T 56.5 Wed 17:15 T-H15

NLO QCD corrections to inclusive $b \to c\ell\bar{\nu}$ decay spectra up to $1/m_b^3$ — Thomas Mannel, •Daniel Moreno, and Alexei A. Pivovarov — Center for Particle Physics Siegen, Theoretische Physik 1, Universität Siegen, 57068 Siegen, Germany

We present analytical results for higher order corrections to the decay spectra of inclusive semileptonic heavy hadron weak decays, using the heavy quark expansion (HQE). We describe the analytical computation of the spectrum of the leptonic invariant mass for $B \to X_c\ell\bar{\nu}$ up to terms of order $1/m_b^3$ within the HQE at next-to-leading order (NLO) in α_s. The full dependence of the differential rate on the mass of the final-state quark is taken into account. We discuss the implications of our results for the precision determination of the CKM matrix element $|V_{cb}|$.

T 56.6 Wed 17:30 T-H15

Towards completion of the four-body contributions to $\bar{B} \to X_s\gamma$ at NLO — Tobias Huber and •Lars-Thorben Moos — Center for Particle Physics Siegen, Theoretische Teilchenphysik, Universität Siegen

The inlusive radiative $\bar{B} \to X_s\gamma$ decay constitutes an important pillar in the indirect search for new physics and allows to constrain the parameter space of many models.

In this talk we present the ongoing efforts in the computation of four-body contributions to the process $\bar{B} \to X_s\gamma$, namely those of $b \to sgg\gamma$ at NLO in the strong coupling and the necessary complementing 5-particle cuts of the gluon-bremsstrahlung $b \to sgg\gamma + g$.

Although these corrections are expected to be small, this computation formally completes the NLO contributions to $\bar{B} \to X_s\gamma$.

Since the anomalous dimensions are already computed to a sufficient order, the main tasks are the systematic generation of the 1-loop amplitude, the automation of the phase space integration, the infrared-regularization and finally the renormalization of the diagrams including the operator mixing.

The results obtained so far are shown and the further structure of the calculation is outlined.

T 56.7 Wed 17:45 T-H15

Improved theory determination of $|V_{ub}|$ from inclusive B-decays — •Kevin Olschewsky — Center for Particle Physics (CPPS), Siegen University

Inclusive B-meson decays into light final state particles like the semileptonic $\bar{B} \to X_u\ell\bar{\nu}$ are of great importance for the precise determination of the Cabbibo-Kobayashi-Maskawa (CKM) matrix element $|V_{ub}|$. With the unprecedented amount of experimental data, it becomes more and more important to have sound theoretical predictions with small and controllable uncertainties.

In order to obtain the $\bar{B} \to X_u\ell\bar{\nu}$ decay rate, the much larger $b \to c$ background has to be removed by appropriate kinematical cuts. Theoretically the calculation of partial decay rates in this region of phase space where $\bar{B} \to X_c\ell\bar{\nu}$ decays are suppressed requires the introduction of a non-perturbative distribution function; the "shape function" (SF).

In this talk I will present an update for the BLNP framework, which is based on the soft-collinear effective field theory framework. This includes updates for all known perturbative quantities as well as new parameterizations for the SF. Our systematic approach in modelling the SF allows us to provide a sound error analysis based on even higher orders in the Heavy Quark Expansion than before.

T 56.8 Wed 18:00 T-H15

Dispersive bounds for local form factors of $\Lambda_b \to \Lambda$ — Thomas Blake[1], Stefan Meinel[2], •Muslem Rahimi[3], and Danny van Dyk[4] — [1]Department of Physics, University of Warwick, UK — [2]Department of Physics, University of Arizona, USA — [3]Center for Particle Physics Siegen, Theoretische Physik 1, Universität Siegen, Germany — [4]Physik Department T31, Technische Universität München, Germany

We investigate the 10 form factors relevant to the b-baryon decay $\Lambda_b \to \Lambda\ell^+\ell^-$ by combining information of Lattice QCD and dispersive bounds. To this end, we use a parametrization of the local form factors in terms of orthonormal polynomials with respect to the dispersive integral kernel. Our approach provides control over the form factor uncertainties due to truncation of the series expansion and extrapolation to the region of low momentum transfer, which is of great phenomenological interest.

T 56.9 Wed 18:15 T-H15

B-meson decay into a proton and dark antibaryon from QCD light-cone sum rules — Alexander Khodjamirian and •Marcel Wald — Center for Particle Physics Siegen, Theoretische Teilchenphysik, Universität Siegen

Recently, a B-Mesogenesis scenario was suggested to simultaneously solve the baryon asymmetry and relic dark matter abundance problems. In this scenario, decays of B-mesons into a baryon and dark antibaryon in the final state are expected with an appreciable branching fraction within the reach of modern B factories. We suggest to apply QCD light-cone sum rules to the decay mode $B^+ \to p\Psi$, where Ψ is a dark antibaryon. With this method we obtain the $B \to p$ hadronic matrix element of the three-quark effective operator in terms of the nucleon light-cone distribution amplitudes and estimate the partial width.

T 57: Flavour Physics 5

Time: Wednesday 16:15–18:15 Location: T-H16

T 57.1 Wed 16:15 T-H16

Search for $B^0_{(s)} \to p\bar{p}\mu^+\mu^-$ decays with the LHCb experiment — Johannes Albrecht, •Maik Becker, Lukas Calefice, and Vitalii Lisovskyi — Experimentelle Physik 5, TU Dortmund

In 2019 the LHCb collaboration reported the first observation of the decays $B^0_{(s)} \to J/\psi p\bar{p}$. The branching fraction of the B^0_s mode was measured to be $(3.6 \pm 0.4) \times 10^{-6}$, which was much larger than the theoretically expected value of $\mathcal{O}(10^{-9})$ at that time. For the B^0 mode, however, the branching fraction was in agreement with theoretical predictions.

The question arises whether the corresponding non-resonant decays are also observable with the full data set of 9 fb^{-1} collected by the LHCb experiment. For the B^0_s mode the leading-order Feynman diagram is similar to the one for the $B^0_s \to \mu^+\mu^-$ decay, but includes an additional $p\bar{p}$ pair from gluon radiation, lifting the helicity suppression. For the B^0 mode Cabibbo-suppressed $b \to d\mu^+\mu^-$ transitions dominate.

In this talk an ongoing analysis of $B^0_{(s)} \to p\bar{p}\mu^+\mu^-$ decays using data from the LHCb experiment will be presented. In particular, the selection and studies on the resonant control channels are shown. The search aims at intensifying the efforts of the LHCb collaboration to study rare decays with leptons and baryons in the final state.

T 57.2 Wed 16:30 T-H16

Test of lepton universality with $\Lambda_b \to pKl^+l^-$ decays at LHCb — Johannes Albrecht, Vitalii Lisovskyi, and •Jannis Speer — Experimentelle Physik 5, TU Dortmund

In recent measurements of b-hadron decays a pattern of consistent tensions with the SM predictions is observed. This includes decays with $b \to sl^+l^-$ transitions, which play an important role in lepton flavor universality tests such as R_K and $R_{K^{*0}}$. Complementary to b-meson decays, lepton flavor universality can also be tested in b-baryon decays which come with partly orthogonal experimental uncertainties. The first measurement of the ratio of branching fractions of the decays $\Lambda_b \to pKe^+e^-$ and $\Lambda_b \to pK\mu^+\mu^-$, R^{-1}_{pK}, was published by the LHCb Collaboration using proton-proton collision data corresponding to $4.7\,\mathrm{fb}^{-1}$. In the dilepton mass-squared range $0.1 < q^2 < 6.0\,\mathrm{GeV}^2/\mathrm{c}^4$ and the pK mass range $m(pK) < 2600\,\mathrm{MeV}/\mathrm{c}^2$ the ratio of branching fractions was measured to be $R^{-1}_{pK} = 1.17^{+0.18}_{-0.16} \pm 0.077$. The legacy measurement of R^{-1}_{pK} tries to reduce the uncertainties by analysing the full $9\,\mathrm{fb}^{-1}$ dataset of LHCb experiment and improving the selection.

In this talk the first study of the data recorded in the years 2017 and 2018 is presented. Furthermore the ongoing improvements in the signal selection requirements are discussed.

T 57.3 Wed 16:45 T-H16

Isospin asymmetries in rare B decays — Johannes Albrecht, •Fabio De Vellis, and Vitalii Lisovskyi — Experimentelle Physik 5, TU Dortmund

Isospin symmetry is a fundamental property of the Standard Model. It predicts a branching fraction that is almost the same for decays which differ only by one spectator quark, like $B^0 \to K^0\mu^+\mu^-$ and $B^+ \to K^+\mu^+\mu^-$. The same is true for the decays $B^0 \to K^{*0}\mu^+\mu^-$ and $B^+ \to K^{*+}\mu^+\mu^-$. For these decays a quantity which describes differences in branching fraction, namely the asymmetry, can be defined. This is particularly convenient since it is theoretically clean and it allows to cancel some experimental systematics. Previous measurements on these decays from LHCb and Belle, despite being compatible with expectations, suggested coherent deviations that could be interpreted as statistical fluctuations, or unaccounted theoretical uncertainties, or as a sign of New Physics. In this talk an update of the asymmetry measurement with the full LHCb dataset is presented. This means that data corresponding to an integrated luminosity of 6 fb^{-1} are added to the dataset used in previous Run 1 analysis. This analysis also aims to give an update to the differential branching fraction measurement of the above-mentioned decays.

T 57.4 Wed 17:00 T-H16

Measurement of the ratio $R_{K\pi\pi}$ with the LHCb experiment — Christoph Langenbruch, •Johannes Heuel, and Stefan Schael — I. Physikalisches Institut B, RWTH Aachen University

In the Standard Model (SM) of particle physics, the coupling of electroweak gauge bosons to all leptons is universal. Stringent tests of this Lepton Flavour Universality (LFU) are possible by measuring ratios of rare $b \to s\ell\ell$ decays with different leptons in the final state. These decays are loop-suppressed in the SM and therefore sensitive to new heavy particles beyond the SM.

The LHCb experiment is ideally suited for the study of rare b hadron decays due to its large acceptance, the high trigger efficiencies and the excellent tracking and particle identification. Recent measurements of $b \to s\ell\ell$ ratios published by the LHCb Collaboration show tensions with the SM predictions of up to 3.1 standard deviations. Therefore, further studies of LFU tests using other rare B decay channels are crucial.

The current status of the ongoing measurement of the ratio $R_{K\pi\pi}$ of the branching fractions of the decays $B^+ \to K^+\pi^+\pi^-\mu^+\mu^-$ and $B^+ \to K^+\pi^+\pi^-e^+e^-$ is presented. The measurement is experimentally challenging as the hadronic system is measured inclusively.

T 57.5 Wed 17:15 T-H16

Probing multilepton decays with the LHCb experiment — Johannes Albrecht and •Vitalii Lisovskyi — Experimentelle Physik 5, TU Dortmund

In the recent years, a number of tensions has been observed in rare decays of B hadrons to a lighter hadron and two leptons. With the large dataset collected by the LHCb experiment, it becomes possible to study even higher-order processes. For instance, in the Standard Model, radiation of a virtual photon from the initial state or the final state can create an additional dilepton pair, leading to a final state with four leptons. In theories beyond the Standard Model, there are alternative mechanisms to reach such final state, which makes such decays excellent probes in searches for New Physics. In this talk, decays of beauty hadrons and quarkonia to final states with four leptons will be discussed. In particular, a search for the decay $B^+ \to K^+\mu^+\mu^-\mu^+\mu^-$ with the dataset collected by the LHCb experiment will be presented. I will discuss the experimental challenges and sources of background, as well as estimate the expected sensitivity.

T 57.6 Wed 17:30 T-H16

Search for the $B^0 \to D^0\bar{D}^0$ decay with the LHCb experiment. — •Jonah Blank and Sophie Hollit — TU Dortmund

With precise measurements of B meson decays the LHCb experiment can test the integrity of the Standard Model of particle physics. Especially $B \to D\,D$ decays are interesting to examine CP violation and further constrain the unitarity triangle. While decays to charged $D^{\pm}$ mesons have already been well measured, the $B^0 \to D^0\bar{D}^0$ decay channel has not yet been observed by any experiment.
In this analysis, data collected by the LHCb experiment at $\sqrt{s} = 7, 8\,\mathrm{TeV}$ and $13\,\mathrm{TeV}$ corresponding to an integrated luminosity of $9\,\mathrm{fb}^{-1}$ is used to search for the $B^0 \to D^0\bar{D}^0$ decay channel. The $B^0 \to \bar{D}^0\pi^+\pi^-$ decay channel is utilized as a normalisation mode to cancel most uncertainties. An update of the current status of the analysis will be presented.

T 57.7 Wed 17:45 T-H16

Measurements of strangeness production with the upgraded LHCb detector — •Lukas Calefice[1,2], Vitalii Lisovskyi[1], Johannes Albrecht[1], and Vladimir Gligorov[2] — [1]Experimentelle Physik 5, TU Dortmund — [2]CNRS/LPNHE, Sorbonne Université, Paris

The LHCb experiment is currently undergoing a major upgrade of its detector to enable running at a five times higher instantaneous luminosity with respect to the previous data taking. Among other things the upgrade comprises the removal of the hardware trigger stage, a complete re-design of the software trigger, replacing the front-end readout electronics of all sub-detectors and an entire new set of tracking detectors. Validating the performance and data quality of the newly configured detector is a crucial task for the beginning of the next data taking period.

Due to their very large production cross-sections at the LHC strange hadrons such as Λ^0 and K^0_S can be studied with only few days of data taking. Therefore, these are used to investigate the alignment of tracking detectors, to check the PID performace and validate the simulation of the upgraded detector. Finally, a measurement of the strangeness production cross-sections at 13 and 13.5 TeV will be performed with the early data after restarting the LHC.

This talk focuses on the preparations of the detector validation with data from the previous data takings.

T 57.8 Wed 18:00 T-H16

Search for ^{3}He ions at LHCb — •Hendrik Jage, Gediminas Sarpis, Valery Zhukov, and Stefan Schael — I. Physikalisches Institut B, RWTH Aachen University

In recent presentations, AMS-02 has reported the observation of several anti-helium candidates in cosmic rays. In 2020, it has been suggested by M. Winkler and T. Linden that dark matter annihilation into b-quarks could produce a detectable $^3\overline{\mathrm{He}}$ flux in cosmic rays via $\overline{\Lambda}_b^0$ decays.

The LHCb detector at CERN is an experiment dedicated to the study of b-hadrons, which are abundantly produced in the proton-proton collisions at the Large Hadron Collider (LHC). Therefore, the large sample of Λ_b^0 decays, collected by LHCb until 2018, provides a unique opportunity to study the potential displaced production of ^{3}He via Λ_b^0 decays.

While prompt ^{3}He from proton-proton collisions has already been observed at the LHC by the ALICE Collaboration in the central region ($|y| < 0.5$), prompt and displaced ^{3}He has not yet been searched for at LHCb ($2 < \eta < 5$). In this talk, the possibility of identifying ^{3}He at LHCb is discussed and the status of the on-going analysis is presented.

T 58: QCD (Exp.) 2

Time: Wednesday 16:15–18:00 Location: T-H17

T 58.1 Wed 16:15 T-H17

Measurements of the total charm and beauty cross sections with the CMS detector — •Josry Metwally, Achim Geiser, Nur Zulaiha Jomhari, and Yewon Yang — DESY, Hamburg, Germany

The aim of this project is the determination of the total cross section for inclusive charm and beauty production at the LHC with different center-of-mass energies down to very low transverse momentum, and the comparison with QCD predictions in next-to-next-leading order of perturbation theory. The measurement of the cross sections for the production of heavy quarks at the LHC is one important test of QCD, and can, as has already happened in the case of top quark production, be used for a measurement of the quark masses.

Other experiments as ATLAS and ALICE covered only small fractions of the available phase space while the LHCb experiment fully covered the forward region, $2.0 < y < 4.5$. For this project, we measure cross sections in the full phase space complementary to LHCb of prompt D mesons, and D mesons from b hadron decays through the decays $B \to D^* X \to D^0 \pi_s X \to K\pi\pi_s X$ and $B \to D^0 X \to K\pi X$. One of the challenges is the separation of prompt D mesons and D mesons from b hadron decays near the production threshold. In this talk, the details of this separation and resulting cross sections including a comparison with theory are presented in the accessible phase space of CMS for different center-of-mass energies and, where it can be performed, a comparison with other experiments is shown.

T 58.2 Wed 16:30 T-H17

Low mass Drell-Yan measurement in p-p collision at $\sqrt{s}$ = 13 TeV using the ATLAS detector at the LHC — •Alessandro Guida — DESY (Hamburg)

High energy physics experiments are performed at the Large Hadron Collider at CERN colliding bunches of protons at energies up to 13 TeV. The ATLAS experiment, with its multipurpose detector, studies the products of these collisions and compares the experimental measurements with the predictions of the Standard Model. This talk presents the study of the process $Z/\gamma^* \to \mu\mu$ at low invariant mass of the di-muon pair, in the region between 7 GeV and 60 GeV, below the the Z boson resonance mass peak ($m_Z = 91.2$ GeV). The single and double differential cross sections $d\sigma/dm_{\mu\mu}$, $d^2\sigma/dm_{\mu\mu}\,d|y_{\mu\mu}|$ and $d^2\sigma/dm_{\mu\mu}\,dp_T^{Z/\gamma^*}$ of the process are measured in 13 TeV proton-proton collisions at the LHC, using the ATLAS detector. The measurement explores an extreme region of the phase space and is sensitive to resummation results in the theoretical prediction. The analysis exploits the good resolution of the ATLAS detector in reconstructing low momentum muons. The main difficulties come instead from the high background component that enters in the event selection, the triggering of events and the modelling of some key physical quantities.

The main features of the analysis, the studies done to overcome the main challenges, as well as the first results and comparison to theory predictions are presented in the talk.

T 58.3 Wed 16:45 T-H17

Studies on Monte Carlo tuning using Bayesian Analysis — •Salvatore La Cagnina[1], Andrii Verbytski[2], Johannes Erdmann[1], Kevin Kröninger[1], and Stefan Kluth[2] — [1]TU Dortmund, Fakultät Physik — [2]Max-Plank-Institut für Physik, München

Monte Carlo (MC) simulations are an essential aspect of data analysis at the LHC. One aspect of MC event generation involves hadronisation and parton shower models. Since these models are based on approximations, they introduce a number of parameters. These parameters cannot be inferred from first principles. Therefore, their values have to be optimized using numerical tools and experimental data (MC tuning). Generally, MC tuning is performed by choosing observables that are sensitive to the parameters. Afterwards, a fit of the parameters to data using a simplified MC response function derived from fits to MC events is performed. Though state-of-the-art methods for MC tuning exist, uncertainties are usually treated as uncorrelated. In this talk, MC tuning using a Bayesian approach will be discussed. The EFTfitter tool is used for fitting, which enables the implementation of correlations for different sources of uncertainties. First results using this method on a MC tune with LEP data will be presented.

T 58.4 Wed 17:00 T-H17

LHCb for astroparticle physics: Prompt production of charged particles — Johannes Albrecht[1], •Julian Boelhauve[1], Hans Dembinski[1], and Michael Schmelling[2] — [1]TU Dortmund University, Dortmund, Germany — [2]Max Planck Institute for Nuclear Physics, Heidelberg, Germany

A long-standing issue in the field of cosmic-ray research is the discrepancy in the number of muons produced in high-energy air showers between observations and simulation, which is referred to as the Muon Puzzle. Precision measurements of hadron production in the forward region are required in order to validate and improve the hadronic-interaction models used in the simulation of air showers, aiming at solving the Muon Puzzle. For this, measuring the differential cross-section of prompt production of long-lived charged particles as a function of transverse momentum and pseudorapidity is of great importance.

An analysis in which this differential cross-section has recently been determined in proton-proton collisions recorded with the LHCb experiment at a centre-of-mass energy of 13 TeV is presented in this talk. Moreover, extensions of the analysis towards a measurement of prompt production of identified hadrons are described.

T 58.5 Wed 17:15 T-H17

Potential of Common Data-Taking of the ATLAS, AFP, ZDC and LHCf Detectors in Run 3 of the LHC — •Yusuf Can Çekmecelioğlu, Clara Elisabeth Leitgeb, and Çiğdem Işsever — DESY, Zeuthen, Germany

Studies of air showers induced by highly energetic cosmic particles depend heavily on models for the soft hadronic interactions. Perturbative QCD cannot be applied to these interactions due to the low momentum exchange between particles. Instead, phenomenological models that take inputs from the (ultra-)forward regions of collider experiments are used to better understand these processes. The LHC with a collision energy of $\sqrt{s} = 13.6$ TeV in run 3 can generate such events and provide data to reduce the large uncertainties for hadronic models.

This talk will target the potential of a common data-taking of several forward detectors (so far used independently) that are located at both sides of the ATLAS detector, namely: The ATLAS Forward Proton detector (AFP), the ATLAS Zero Degree Calorimeters (ZDC), and the LHC forward (LHCf) calorimeters. The analysis focuses on the determination and optimisation of the common acceptance between detectors for simulated single diffractive (SD) events at (preliminary) run 3 beam conditions. SD events allow AFP to tag the intact proton and the LHCf and ZDC calorimeters to detect the neutral particles from the dissociated proton. Together with pseudorapidity gap measurements in the central region provided by the ATLAS detector, a joint data-taking between these detectors could improve the identification and kinematic reconstruction of such events.

T 58.6 Wed 17:30 T-H17

Study of the $X(3915)$ at Belle — •Yaroslav Kulii[1], Thomas Kuhr[1], and Boris Grube[2] — [1]Ludwig-Maximilians-Universität München — [2]Technische Universität München

Charmonium states consist of a charm and anti-charm quark. Detailed theoretical predictions of the charmonium excitation spectrum agree well with the experimental data.

However, in recent years experiments discovered a growing number of charmonium-like states that do not fit into the predicted charm-anticharm excitation spectrum. One such state is the $X(3915)$. It has been discovered by the BaBaR and Belle collaborations in the reaction $e^+e^- \to e^+e^-X(3915) \to e^+e^-J/\psi\omega$, where the final-state electron and positron are not detected. The analysis of projections of the decay angular distribution preferred the $J^{PC} = 0^{++}$ hypothesis, but other quantum numbers, in particular $J^{PC} = 2^{++}$, could not be excluded.

Because of this the $X(3915)$ was initially identified as the $\chi_{c0}(2P)$ charmonium state, although its mass and decay width were not in good agreement with the theory predictions. Following the Belle discovery of the $X^*(3860)$, which agrees much better with the $\chi_{c0}(2P)$ hypothesis, opinions shifted towards interpreting the $X(3915)$ as an exotic state. It could be, for example, a meson molecule or a so-called hybrid meson.

We will present the current state of measuring of the spin and parity of the $X(3915)$ at Belle and discuss the prospects of studying the $X(3915)$ using the Belle II data.

T 58.7 Wed 17:45 T-H17

Partial wave analysis of the $\tau \to 3\pi\nu_\tau$ decay at Belle — •Andrei Rabusov, Daniel Greenwald, and Stephan Paul — TUM, Munich, Germany

The COMPASS collaboration observed a potential new particle, the $a_1(1420)$, that doesn't fit the quark model. An independent study of the existence of this particle, as well as the studies of the light axial and pseudoscalar resonances, can be done in the tauon decay to three pions and a tau neutrino. The latest such study was published by the CLEO II collaboration in 1999 by analyzing 51000 data events. That study can be significantly improved at B-factories, which collected tens of millions events of this decay. We present data selection criteria, acceptance studies, and partial wave analysis of the $\tau \to 3\pi\nu_\tau$ decay with the Belle detector.

T 59: Neutrino Physics with Accelerators 1

Time: Wednesday 16:15–17:50 Location: T-H18

T 59.1 Wed 16:15 T-H18

Particle Identification and Reconstruction with the DUNE ND-GAr Near Detector — •Lorenz Emberger and Frank Simon — Max-Planck-Institut für Physik

The Near Detector (ND) of the Deep Underground Neutrino Experiment (DUNE) will play an important role in the search of CP violation in the neutrino sector. Additionally, as a standalone complex, it will be an excellent laboratory to study a wide range of neutrino interactions and BSM models. The ND design consists of three independent sub-detectors, placed downstream of the neutrino production target. One of these detectors, called ND-GAr, consists of a magnetized high pressure gaseous Argon Time Projection Chamber (TPC), surrounded by an electromagnetic calorimeter (ECAL) and a magnet yoke. One key aspect of the ECAL is the reconstruction of neutral particles such as neutral pions and potentially neutrons. The ECAL also extends the detector's separation capability of muons and pions, which is further enhanced by a muon tagger in the magnet yoke. We present a simulation study of the detector system featuring a highly granular electromagnetic calorimeter inspired by the SiPM-on-Tile technology developed by the CALICE collaboration. We will introduce the detector design considerations, as well as the potential physics program. Furthermore, we will discuss the separation of muons and pions using the ECAL and study the impact of different possible muon tagger layouts. A simulation study on time-of-flight reconstruction of the kinetic energy of neutrons will also be presented.

T 59.2 Wed 16:30 T-H18

Studies on the DUNE ND-GAr ECAL Design — •Sebastian Ritter[1], Peter Bernhard[2], Andrea Brogna[2], Volker Büscher[1], Karl-Heinz Geib[1], Asma Hadef[1], Antoine Laudrain[1], Lucia Masetti[1], Marisol Robles Manzano[1], Anna Rosmanitz[1], Christian Schmitt[1], Alfons Weber[1], and Quirin Weitzel[2] — [1]Johannes-Gutenberg Universität Mainz — [2]PRISMA+ Detector Lab

The Deep Underground Neutrino Experiment (DUNE) aims to unlock the mystery of neutrinos. One of the major goals is to measure the CP-violating phase of the neutrino mixing matrix for which the DUNE near detector (ND) is crucial. A leading role in measuring neutrino interactions in the ND will be filled by the high-pressure gaseous argon TPC. A sampling ECAL based on plastic scintillators with SiPM readout is surrounding the TPC (ND-GAr). In this talk, optimized geometries are considered for the ND ECAL motivated by external boundary conditions and the beam-on-target nature of DUNE. A second focus will be on the readout of the ECAL's scintillator strips trying to efficiently use the available space and optimizing the light output.

T 59.3 Wed 16:45 T-H18

Plastic Scintillator and Light Guide Research and Development — •Patrick Deucher — Johannes Gutenberg Universität Mainz

Plastic scintillators are broadly used in physics experiments for the detection of particles and electromagnetic radiation. With tunable emissive properties and a fluorescent decay time of a few ns, plastic scintillators are a solid option that can be tailored to individual applications. First steps for the production and optimization of polystyrene based plastic scintillators have been taken at the Johannes Gutenberg University in Mainz. This includes the purification of styrene, the addition of different fluorophores and thermal polymerization. In cooperation with Tübingen, we develop dedicated active light guides for use with large SiPM arrays. Moreover, plastic scintillators with optimized capability for pulse-shape discrimination are investigated for use in the ECAL of the DUNE Near Detector. This talk will present the progress on plastic scintillator production and characterization including absorption, emission and lifetime measurements of first samples. This work is supported by funds of the Excellence Cluster PRISMA+.

Group Report T 59.4 Wed 17:00 T-H18

ANNIE: The Accelerator Neutrino Neutron Interaction Experiment — •Marc Breisch for the ANNIE-Collaboration — Physikalisches Institut, Eberhard Karls Universität Tübingen

The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is a 26-ton gadolinium doped water Cherenkov detector situated on-axis of the Booster Neutrino Beam (BNB) at FermiLab. Its main goal is to measure the final state neutron multiplicity of neutrino-nucleus interactions to improve the systematic uncertainties of next-generation long baseline neutrino experiments. An additional milestone will be the deployment of the first Large Area Picosecond Photodetectors (LAPPD). These novel detectors will feature a time resolution less than 100 picoseconds and a spatial accuracy of a few millimetres, thus improving the track reconstruction capabilities of the detector. This talk will give a general overview of ANNIE including an update on the currently running Phase Two as well as an upcoming expansion using Water based Liquid Scintillator (WbLS).

T 59.5 Wed 17:20 T-H18

Water-based Liquid Scintillators in ANNIE — Daniele Guffanti[2], David Maksimovic[1], •Michael Nieslony[1], and Michael Wurm[1] for the ANNIE-Collaboration — [1]Johannes Gutenberg-Universität Mainz, Germany — [2]Università degli Studi di Milano Bicocca, Italy

The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is a Gadolinium doped water Cherenkov detector located in the Booster Neutrino Beam at Fermilab with the primary goal of measuring the final state neutron multiplicity of neutrino-nucleus interactions. A future phase of the experiment will explore the benefits of using the novel detection medium of Gadolinium-doped Water-based Liquid Scintillators (GdWbLS) in a neutrino beam environment by placing a small vessel within the current detector. GdWbLS aims to combine the advantages of liquid scintillator and water Cherenkov detectors by accessing directional information from the Cherenkov light and simultaneously using the scintillation signal to infer additional calorimetric event properties, especially with respect to lower-energy hadronic recoil signals. The following talk will highlight the expected improvements for the neutrino energy reconstruction in beam events for GdWbLS as a target material in comparison to a more conventional water detection volume based on simulation studies.

T 59.6 Wed 17:35 T-H18

Overview of the ESSνSB Conceptual Design — •Tamer Tolba — Institut für Experimentalphysik, Universität Hamburg, Hamburg - Germany

In the search for the CP-violation in the leptonic sector, crucial information has been obtained from neutrino experiments. The measurement of the third neutrino mixing angle, θ_{13}, opened the possibility of discovering the Dirac leptonic CP violating angle, δ_{CP}, with intense "super" neutrino beam experiments. In the light of these new findings, an urgent need has arisen to improve the detection sensitivity of the current long-baseline detectors, considering proton driver at MW scale with MegaTon scale detector, with a key modification to place the far detectors at the second, rather than the first, oscillation maximum.

The European Spallation Source neutrino Super Beam (ESSνSB) aims to benefit from the high power of the ESS, LINAC in Lund-Sweden, to produce the world's most intense second-generation neutrino beam, enabling measurement to be made at the second oscillation maximum. Assuming a ten-year exposure with five-years running in neutrino- and five-years in antineutrino-mode, CP-violation could be established with a significance of 5σ over more than 70% of all values of δ_{CP}. With the current design-study program of the experiment is coming to its successful end, with the production of the CDR, an overall status of the project will be presented. The technical aspects on the current design study programs running within the collaboration and the physics potential of the experiment will be presented, as well.

T 60: Top Quarks: Decay and CP Violation and Mixing Angles

Time: Wednesday 16:15–18:30 Location: T-H19

T 60.1 Wed 16:15 T-H19

Tagging of Boosted Leptonically Decaying Top Quarks Using Convolutional Neural Networks — •Hala Elhag, Soham Bhattacharya, and Isabell Melzer-Pellmann — DESY, Hamburg, Germany

The study of boosted top quarks is very important for probing a wide variety of new physics models. The use of machine learning techniques for tagging leptonically decaying boosted top quarks has not yet been explored as extensive as the hadronic decay channel. In this study, we utilize an image based machine learning technique for tagging highly boosted leptonically decaying top quarks. Jet images – representing the energies of jet constituents displayed in the form of a grid of pixels – are used as inputs to our convolutional neural network (CNN) based tagger. This talk will discuss the details of the jet formation, jet preprocessing and the CNNs, and a few promising preliminary results will be shown.

T 60.2 Wed 16:30 T-H19

Studies for the search for $t \to Zc$ transitions via interference effects — •Lucas Cremer, Johannes Erdmann, Roni Harnik, Jan Lukas Späh, and Emmanuel Stamou — TU Dortmund University, Department of Physics

Exclusion limits for anomalous flavour-changing neutral currents (FCNC) are typically set by searching for two-body decays of the top quark, which are quadratic in the new physics (NP) coupling. The limits are constantly improved by new data, but the sensitivity to small couplings could be enhanced by an alternative approach. This approach takes advantage of the interference between the FCNC and the Standard Model (SM) contributions. The focus of this work is to access the experimental feasibility of this idea.

Concretely we investigate the three-body decay $t \to b\bar{b}c$ in the presence of an anomalous $t-Z-c$ coupling. In the SM, this process proceeds through the emission of a W boson, while the FCNC diagram contains an intermediate Z boson. The two contributions interfere. The dominant contribution of the interference is in the restricted kinematic region in which both intermediate bosons are onshell. In this region, both the SM and the pure FCNC contribution are suppressed by the small width of the gauge bosons, which enhances the impact of the interference contribution. Because the interference scales linearly with the NP coupling constant, while the pure FCNC contribution scales with the coupling constant squared, an analysis of events in this region can potentially improve the sensitivity to small coupling constants.

T 60.3 Wed 16:45 T-H19

Search for FCNC-couplings between the top-quark and the Higgs-boson in dilepton final states — •Marvin Geyik[1], Wolfgang Wagner[1], Oliver Thielmann[1], Abhishek Sharma[2], Frederic Deliot[3], Charles Grant[4], Paul Jackson[4], Peter Onyisi[5], Kyungeon Choi[5], and Marc Tost[5] — [1]Bergische Universität Wuppertal — [2]Columbia University — [3]Universite Paris-Saclay — [4]University of Adelaide — [5]University of Texas at Austin

Flavor-changing neutral current interactions are strongly suppressed in the Standard Model. Still, some extensions of the Standard Model predict tree-level FCNC-couplings between the top quark, other up-type quarks and neutral bosons, including the Higgs boson. These anomalous couplings can be parameterised in the framework of effective field theories (EFT). The presented analysis searches for the production of a single top-quark in association with a Higgs boson and for top-quark-antiquark production with one of the top quarks decaying to an up quark or a charm quark and a Higgs boson. Higgs decays to WW*, ZZ* and two taus leading to leptonic final states are considered in the event selection. Two analysis channels are defined: one with two leptons (electrons or muons) of the same electric charge and a second channel with three leptons. This talk focuses on advancements in the dilepton final state. The sensitivity of the analysis in setting limits to relevant coefficients of EFT operators will be presented.

T 60.4 Wed 17:00 T-H19

Search for flavour-changing neutral current couplings between the top-quark and the Higgs boson in the $H \to b\bar{b}$ decay channel and the tri-lepton final state with the ATLAS detector at the LHC — •Oliver Thielmann[1], Geoffrey Gilles[4], Wolfgang Wagner[1], Marvin Emin Geyik[1], Dominic Hirschbühl[1], Kyungeon Choi[2], Frederic Deliot[3], Charles Michael Grant[5], Paul Jackson[5], Peter Onyisi[2], Abhishek Sharma[6], and Marc Tost[2] — [1]Bergische Universität Wuppertal — [2]Austin — [3]Saclay CEA — [4]Nikhef — [5]Adelaide — [6]Columbia

A search for flavour-changing neutral current (FCNC) couplings between the top-quark and the Higgs boson in the $H \to b\bar{b}$ decay channel and the tri-lepton final state is presented. The search for FCNC couplings in the top-quark-Higgs-boson sector is a promising search for a theory beyond the SM. Proton-proton collision data produced by the LHC at a centre-of-mass energy of $\sqrt{s} = 13$ TeV and collected by the ATLAS experiment during 2015, 2016, 2017 and 2018, and corresponding to an integrated luminosity of 139 fb^{-1}, are used. Data is analysed in different final states, characterised by the number of isolated electrons or muons, missing transverse energy and the number of jets where either three (for $H \to b\bar{b}$) or one (for tri-lepton final state) of them are identified as b-jets. A machine learning analysis based on neural networks is conducted to improve the discrimination between the signal and the backgrounds. Preliminary results, interpreted in the context of an effective field theory for FCNC, are presented, where additional exclusion limits on the qtH effective coupling are derived.

T 60.5 Wed 17:15 T-H19

Search for charged lepton flavour violation in top-quark pro-

duction and decay with the ATLAS experiment at 13 TeV — Markus Cristinziani[1], William George[2], •Gabriel Gomes[1], Carlo Gottardo[3], Chris Hawkes[2], Jacob Kempster[2], Alexios Stampekis[2], and Miriam Watson[2] — [1]Center for Particle Physics Siegen, Experimentelle Teilchenphysik, Universität Siegen — [2]University of Birmingham — [3]NIKHEF

In the Standard Model (SM) with massless neutrinos, the flavour of charged leptons cannot be altered in weak interactions. However, the observed neutrino oscillations allow for charged lepton flavour violating (cLFV) processes, even though highly suppressed. Hence, experimental evidence of such rare processes would provide signs of new physics beyond the SM.

Investigations targeting a direct search for cLFV will be presented using proton–proton collision data collected by the ATLAS detector between 2015 and 2018 at $\sqrt{s} = 13$ TeV. Decays of a top quark into a pair of opposite-sign different-flavour (OSDF) leptons and an up-type quark, as well as single top-quark production in association with an OSDF dilepton pair, are examined. Thus, besides the top-quark decay channel, the single top-quark production channel is included, providing additional sensitivity. For signal-discrimination purposes, a multivariate discriminant, namely a boosted decision tree, is implemented and optimised.

T 60.6 Wed 17:30 T-H19

Measurement of *CP* violation in $B_s^0 \to D_s^+ D_s^-$ and $B^0 \to D^+ D^-$ decays with the LHCb experiment — •Louis Gerken, Philipp Ibis, and Antje Mödden — Experimentelle Physik 5, TU Dortmund

At the LHCb experiment, time-dependent measurements of *CP* violation are performed to test the Standard Model of particle physics. The decays $B_s^0 \to D_s^+ D_s^-$ and $B^0 \to D^+ D^-$ give access to the *CP* violation parameters ϕ_s and $\sin(2\beta)$. In these decays of neutral mesons, *CP* violation arises in the interference of the direct decay and the decay after mixing. Due to the similarities of the decays, a time-dependent *CP* violation measurement is performed in parallel for both decays.

In this talk, the current status of these measurements will be presented. The analysis uses data collected by the LHCb detector during 2015 to 2018 at a centre-of-mass energy of 13 TeV corresponding to an integrated luminosity of $6\,\mathrm{fb}^{-1}$.

T 60.7 Wed 17:45 T-H19

Search for $B_s^0 \to D^{*+} D^{*-}$ and *CP* violation studies in $B_d^0 \to D^{*+} D^{*-}$ with the LHCb experiment — Sophie Hollitt, Philipp Ibis, •Jan Langer, and Antje Mödden — Experimentelle Physik 5, TU Dortmund

At the LHCb experiment, precision measurements are performed to search for physics beyond the Standard Model. For this purpose, e.g. searches for unobserved decays and measurements of their branching fractions or measurements of *CP* violation in decays of neutral B mesons are carried out.

The primary aim of this analysis is to observe the decay $B_s^0 \to D^{*+} D^{*-}$. Besides, the branching fraction is measured relative to the decay $B_d^0 \to D^{*+} D^{*-}$. By measuring the relative branching ratio, dominant systematic uncertainties cancel out. Further, an angular and decay-time dependent *CP* violation measurement is performed in the $B_d^0 \to D^{*+} D^{*-}$ decay, which allows the measurement of the parameter $\sin(2\beta)$.

In this talk, the current status of both analyses is presented using the full data set of the LHCb experiment corresponding to an integrated luminosity of $9\,\mathrm{fb}^{-1}$.

T 60.8 Wed 18:00 T-H19

Measurement of the CKM mixing angle γ with $B_s^0 \to D_s^{\mp} K^{\pm}$ decays at the LHCb experiment — •Quentin Führing and Kevin Heinicke — Experimentelle Physik 5, TU Dortmund

In the Standard Model of particle physics the quark mixing matrix is expected to be unitary. To test this unitarity, the properties of the unitarity triangles are constrained. The mixing angle γ is such a property of interest.

To constrain the mixing angle γ, precise decay-time-dependent measurements of *CP* violation in $B_s^0 \to D_s^{\mp} K^{\pm}$ decays can be used. With an excellent decay-time resolution and a large number of B_s^0 decays, the LHCb experiment provides the necessary data for this measurement.

In this talk a decay-time-dependent analysis aiming to measure γ is presented. Data corresponding to an integrated luminosity of $6\,\mathrm{fb}^{-1}$ recorded by the LHCb experiment from 2015 to 2018 at a centre-of-mass energy of 13 TeV are used for this analysis.

T 60.9 Wed 18:15 T-H19

Measurement of *CP* violation in $B^0 \to \psi K_S^0$ decays with the LHCb experiment — Vukan Jevtic, Patrick Mackowiak, and •Gerwin Meier — Experimentelle Physik 5, TU Dortmund

Precision measurements of parameters of the Standard Model are important methods for tests of the Standard Model. One excellent parameter to measure is the CKM angle β, where the golden mode is $B^0 \to J/\psi K_S^0$ due to the dominant contributions of tree-level amplitudes. With new reconstruction types of the K_S^0 and the combination of different decay channels it is possible to increase the statistical sensitivity in the most precise measurement of this quantity to date.

In this talk the current status of the time-dependent $\sin(2\beta)$ measurement in the decays $B^0 \to J/\psi(\to \ell\ell) K_S^0(\to \pi^{\pm}\pi^{\mp})$ with $\ell = e, \mu$ and $B^0 \to \psi(2S)(\to \mu\mu) K_S^0(\to \pi^{\pm}\pi^{\mp})$ will be presented, where the full LHCb Run II dataset from 2015 to 2018 corresponding to $6\,\mathrm{fb}^{-1}$ is used.

T 61: Higgs Boson: Decay in Bosons

Time: Wednesday 16:15–18:15 Location: T-H20

T 61.1 Wed 16:15 T-H20

Effective Field Theory interpretation of the $pp \to H \to 4\ell$ Higgs boson decay measurements with the ATLAS detector — •Alice Reed, Sandra Kortner, and Hubert Kroha — Max Planck Institut für Physik (Werner-Heisenberg-Institut), München

An important process for the measurement of the Higgs boson properties is the Higgs boson decay into two Z bosons, which subsequently decay into a $\mu^+\mu^-$ or an e^+e^- pair, $pp \to H \to 4\ell$. In the Standard Model (SM), the Higgs boson is predicted to be a spin-0 particle with a positive CP quantum number. This hypothesis is also favoured by the Run-1 data at the LHC. Still, small admixtures of anomalous and possibly also CP-violating couplings with non-SM tensor structure are not yet excluded.

Such deviations from the SM can be described within the effective field theory (EFT) framework in which the SM is extended by the addition of higher-dimensional operators. In this talk, the EFT interpretation of the measured Higgs boson properties in the 4-lepton decay channel is presented, allowing constraints on several EFT parameters to be determined. Particular emphasis is given to the impact of the these EFT parameters on the acceptance of the four-lepton event selection criteria, which needs to be taken into account in addition to the EFT effects on the production cross section and branching ratio.

T 61.2 Wed 16:30 T-H20

Measurement of $H \to WW^*$ Decays in the $\ell\nu qq$ Final State with a Large-R Jet — •Johannes Hinze, Karsten Köneke, and Benedict Winter — Universität Freiburg

The talk presents a study of $H \to WW^*$ decays at large transverse momenta ($pT(H) > 200$ GeV) with one leptonic ($W \to \mu\nu$ or $W \to e\nu$) and one hadronic W boson decay, where the experimental signature of the hadronic W boson decay is a large-R jet. The lepton provides means to efficiently trigger event candidates and to eliminate background events in particular from multijet events. Further background events, primarily from W+jets events, can be suppressed via W-boson taggers for large-R jets. The measurement benefits from the larger branching fraction in comparison with $\ell\nu\ell\nu$ final states, and from the reduced background levels for large transverse momenta. The measurement will contribute significantly in an area of the phase space that is considered particularly sensitive to possible BSM effects.

T 61.3 Wed 16:45 T-H20

Multivariate Techniques for Measurement of Higgs Bosons in $H \to WW^* \to e\nu\mu\nu$ Decays at ATLAS — •Ahmed Markhoos, Benedict Winter, and Karsten Köneke — University of Freiburg

Since its discovery, the Higgs Boson has been studied in detail at the LHC. The $H \to WW^* \to e\nu\mu\nu$ channel offers sizeable signal and moderate background yields enabling accurate measurements of the total cross-section and of differential cross-sections. The measurements for gluon-fusion production are generally dominated by systematic uncertainties except in the sparsely populated regions of the phase space such as at large transverse momenta.

The talk showcases deep neural networks (DNN) that can enhance the signal purity with respect to the current cut-based selection reducing systematic uncertainties from backgrounds and statistical uncertainties. Additionally, a regression DNN is presented that determines the Higgs Boson transverse momentum, which is elusive due to the presence of neutrinos, and required to measure simplified template cross-sections (STXS).

T 61.4 Wed 17:00 T-H20

Search for Di-Higgs production in the $bb\gamma\gamma$ final state with the ATLAS detector — •Florian Beisiegel, Jochen Dingfelder, and Tatjana Lenz — Physikalisches Institut, Uni Bonn

The discovery of the Higgs boson in 2012 was a great success of modern particle physics since it served as a proof of the Higgs mechanism introduced in 1964. One focus of the current particle physics experiments at the LHC is the measurement of the Higgs properties, such as its coupling strengths to fundamental particles. In addition to the coupling of the Higgs boson to fermions and gauge bosons, the Higgs mechanism predicts Higgs self-coupling. The triple-Higgs self-coupling can be measured in di-Higgs (non-resonant) production. Di-Higgs analyses also facilitate the search for new heavy particles that decay to two Higgs bosons (resonant production).

This talk presents a search for di-Higgs production in the $bb\gamma\gamma$ final state using 139 fb^{-1} of proton-proton collisions at 13 TeV recorded with the ATLAS detector. The analysis aims to measure the non-resonant SM di-Higgs production cross section and the Higgs self-coupling as well as search for resonant di-Higgs production. The focus is put on studies to improve the limits on the non-resonant production cross-section using a 2D fit in $m_{\gamma\gamma}$ and m_{bb}.

T 61.5 Wed 17:15 T-H20

Search for non-resonant Higgs boson pair production in the bbWW final state with leptonic W boson decays at the CMS experiment — Martin Erdmann, •Peter Fackeldey, Benjamin Fischer, and Dennis Noll — III. Physikalisches Institut A, RWTH Aachen University

The measurement of the Higgs boson pair production is a direct test of the electroweak symmetry breaking in the standard model of particle physics (SM) with direct access to the shape of the Higgs potential.

The cross section of the Higgs boson pair production is about a factor of a thousand smaller than that of a single SM Higgs boson, making it a highly challenging search. Physics-inspired deep learning techniques are leveraged for the signal extraction and the control over overwhelming backgrounds, mainly from the top pair production and Drell-Yan processes.

The expected sensitivity of the search for HH $\to \mathrm{bbW_{lep}W_{lep}}$ is presented for the data-taking periods 2016, 2017, and 2018 of the CMS experiment.

T 61.6 Wed 17:30 T-H20

Search for non-resonant di-Higgs production in the semi-leptonic bbWW decay channel at the CMS experiment — Martin Erdmann, Peter Fackeldey, Benjamin Fischer, and •Dennis Noll — III. Physikalisches Institut A - RWTH Aachen University

A measurement of the di-Higgs boson production can directly determine the trilinear Higgs coupling and probe the structure of the Higgs potential.

We present a search for Higgs boson pair production with one Higgs boson decaying into b quarks and the other Higgs boson decaying into W bosons, with one W boson decaying leptonically.

The central challenge of this analysis is a tiny signal among a large amount of background. We approach this task with a Deep Neural Network driven Physics Process Multi-Classification. It utilises a physics motivated architecture, the Lorentz-Boost Network, in conjunction with a Residual Neural Network.

We present expected limits corresponding to the data recorded at the CMS experiment in Run 2.

T 61.7 Wed 17:45 T-H20

Search for non-resonant Higgs boson pair production in the $b\bar{b}b\bar{b}$ final state with the CMS Experiment — Martin Erdmann, Peter Fackeldey, •Benjamin Fischer, and Dennis Noll — III. Physikalisches Institut A, RWTH Aachen University

The non-resonant Higgs boson pair production enables probing the shape of the Higgs potential, in particular the triple Higgs self coupling λ_{hhh}. The decay channel with the highest branching ratio of $\sim 1/3$ has a four-b-quark final state.

This phase space is dominated by QCD-processes, which are challenging to model using Monte Carlo samples. A data-driven modeling is implemented through a Neural Network based reweigthing from a sideband region into the signal region. Through a Neural Network based multi-classification both Di-Higgs production modes, gluon- and vector-boson-fusion, are separated from background processes for the statistical inference.

T 61.8 Wed 18:00 T-H20

Search for non-resonant Higgs boson pair production in lepton+jets final states of the bbWW decay mode at CMS — •Mathis Frahm, Johannes Haller, Matthias Schröder, and Artur Lobanov — Institut für Experimentalphysik, Universität Hamburg

The Higgs boson self-coupling is an important parameter of the Standard Model, since it is related to the shape of the Higgs potential. At the LHC, this parameter can be probed by measuring the Higgs boson pair production (HH) cross section. In the Standard Model, HH production occurs in processes via Higgs-boson self-coupling and in processes with a fermion loop. Due to destructive interference of these two contributions, the resulting production cross section is small, amounting to only 33 fb at 13 TeV.

In this talk, a search for HH production in lepton+jets finals states of the bbWW decay mode is presented. The analysis is performed on data recorded by the CMS experiment during LHC Run 2 at a center-of-mass energy of 13 TeV, which corresponds to an integrated luminosity of 137.2 fb^{-1}. The analysis utilizes a deep neural network to classify between signal and different background categories. Exclusion limits on the production cross section are derived as a function of the Higgs boson self-coupling strength to set constraints on this parameter.

T 62: Higgs Boson: Extended Models 2

Time: Wednesday 16:15–18:30 Location: T-H21

T 62.1 Wed 16:15 T-H21

Combined measurements of Higgs boson production and interpretation in the context of two Higgs doublet models at the ATLAS experiment — •Birgit Stapf — Universität Hamburg/DESY, Hamburg, Germany

The discovery of the Higgs boson in 2012 is the latest big success story of the Standard Model of particle physics (SM). Although this discovery formally completes the SM, it is not an end to all questions on the matter. There are many observations and phenomena that the SM is unable to explain, and it is clear that there must be Beyond the Standard Model (BSM) physics. However, the lack of discoveries of (BSM) particles since 2012 puts particle physics at a cross-roads: there are many ways forward, posed by many different BSM theories, but it is unclear which one is likely to be successful as a description of reality. High precision measurements of the Higgs bosons' properties and its couplings help to guide the way: any measured deviation from the SM predictions indicate the existence of BSM physics and may even point at specific theories. To unlock the full potential of such measurements, the results from analyses of several different Higgs production processes and decays are combined. This talk covers the latest Higgs combination results from ATLAS using up to 139 fb^{-1} of pp-collision data with $\sqrt{s}$=13 TeV, focussing in particular on the measurement of inclusive production cross-sections and the interpretation in terms of specific BSM models, such as two Higgs doublet models.

T 62.2 Wed 16:30 T-H21

Search for charged Higgs bosons in the $H^+ \to Wh \to qqbb$ decay channel — •Shubham Bansal, Jochen Dingfelder, and Tatjana Lenz — Physikalisches Institut, Universität Bonn

After the discovery of the Higgs boson at a mass of 125 GeV, the last missing piece of the Standard Model (SM) might be found. On the other hand, various theories beyond the SM predict additional Higgs bosons, one of which could be the found Higgs boson at 125 GeV. One such example is the two-Higgs-Doublet Model (2HDM) that features an extended scalar sector including the existence of charged Higgs bosons (H^+). The observation of such a charged scalar particle would clearly indicate physics beyond the SM. The H^+ production mechanism depends on its mass (m_{H^+}) and for $m_{H^+} > m_t + m_b$, the leading H^+ production mode is the associated production with a top and a bottom quark via $gg \to tbH^+$. In the alignment limit for 2HDM, the dominant decay mode is $H^+ \to tb$. However, in models like N2HDM and the Georgi-Machacek (GM) model, it is possible to obtain a sizable branching ratio for $H^+ \to Wh$.

This talk presents a search for charged Higgs bosons in $H^+ \to Wh \to qqbb$ decays. The recent developments of the analysis strategy will be discussed, which include the use of boosted decision trees to reconstruct the H^+, data-driven corrections to improve the modeling of the main background, $t\bar{t}$, the definition of signal-enriched and -depleted regions, and a first estimate of the expected sensitivity using the full Run-2 ATLAS dataset.

T 62.3 Wed 16:45 T-H21

Search for a charged Higgs Boson decaying to cs in the low mass region with the ATLAS detector at $\sqrt{s}$ = 13 TeV — Jochen Dingfelder, Tatjana Lenz, and •Christian Nass — Physikalisches Institut, Universität Bonn, Deutschland

In the Standard Model (SM) electroweak symmetry breaking (EWSB) is introduced by a single complex scalar field. The consequence is the prediction of a scalar, neutrally charged particle, the Higgs Boson, which was discovered at the LHC in 2012 at the LHC. A simple extension of the SM is to introduce EWSB through two complex scalar fields. Such two-Higgs doublet models (2HDM) are attractive because they offer the opportunity to include additional CP violation in the SM, which is needed for explaining baryogenesis. 2HDMs feature 3 neutral and 2 charged Higgs bosons. Observation of such a charged scalar would be a striking signal for physics beyond the SM.

In the low mass region, i.e. $m_H^{\pm} < m_t$, the dominant production mode is by a $t\bar{t}$ pair with one t-quark decaying to $H^{\pm}b$. At low masses, the search for $H^{\pm} \to cs$ decays is promising, as suggested in several theory papers. This talk will present background estimates, data-driven MC corrections and usage of c-tagging to define signal enriched and depleted regions as well as the first estimate of the expected sensitivity for the $H^{\pm} \to cs$ search with the full Run-2 ATLAS dataset recorded at a center-of-mass energy of 13 TeV.

T 62.4 Wed 17:00 T-H21

Search for $A \to ZH \to \nu\bar{\nu}b\bar{b}$ at $\sqrt{s}$ = 13 TeV with the ATLAS detector — •Ilia Kalaitzidou, Tetiana Moskalets, and Spyridon Argyropoulos — University of Freiburg

The extension of the scalar SM Higgs sector, as described in the Two Higgs Doublet Models (2HDMs), could lead to a cosmological first order electroweak phase transition, which is necessary to explain the origin of the matter-antimatter asymmetry in the early Universe. The existence of a second Higgs doublet results in five physical scalar fields, two charged ($H^{\pm}$), a CP-odd (A) and two CP-even (h and H) neutral fields. A strong electroweak phase transition favours a heavy CP-odd scalar state A, together with a large mass splitting between the CP-odd A and CP-even H scalars. In this scenario, the $A \to ZH$ decay becomes dominant. In the present work, the $A \to ZH$ decay is investigated, with the H boson decaying to a pair of b-quarks and the Z boson decaying to neutrinos. The $Z \to \nu\bar{\nu}$ decay is examined, because of the expected increased sensitivity for large A masses. The optimisation studies for the $A \to ZH \to \nu\bar{\nu}b\bar{b}$ analysis are presented, along with the expected exclusion in the $m_H - m_A$ plane, covering a previously unexplored region.

T 62.5 Wed 17:15 T-H21

Search for $A \to ZH \to \ell\ell t\bar{t}$ at $\sqrt{s}$ = 13 TeV with the ATLAS detector — •Roman Kuesters, Tetiana Moskalets, and Spyros Argyropoulos — University of Freiburg, Freiburg im Breisgau, Germany

The generation of the matter-antimatter asymmetry in the universe is one of the biggest open questions that require physics beyond the Standard Model. An attractive explanation is provided by the electroweak baryogenesis models, which require the addition of a second Higgs doublet, giving rise to five Higgs bosons: a light (heavy) CP-even Higgs $h(H)$, a CP-odd one (A) and two charged ones ($H^{\pm}$). A necessary requirement for baryogenesis is a large mass splitting between the heavy CP-odd and CP-even Higgs bosons, which makes the $A \to ZH$ decay dominant.

This talk presents a search for the $A \to ZH \to \ell\ell t\bar{t}$ process, targeting the phase space with $m_H > 350$ GeV, which has not been explored so far. The talk will discuss the optimisation of the event selection and the sensitivity expected to be achieved with the full Run 2 ATLAS data.

T 62.6 Wed 17:30 T-H21

Search for heavy Higgs bosons in the $Zt\bar{t}$ final state with CMS — •Daniel Christian Hundhausen, Ksenia de Leo, Yannick Fischer, Johannes Haller, and Matthias Schröder — Institut für Experimentalphysik, Universität Hamburg

Since its discovery in 2012 the properties of the Higgs boson at 125 GeV have been studied extensively, confirming a standard model like behavior. However, the observed resonance might well be part of an extended Higgs sector, which is predicted in various scenarios of new physics beyond the standard model. Two Higgs Doublet Models (2HDM) provide a generic description of the phenomenology arising in models with a second Higgs doublet. In this talk we will investigate the hypothetical decay of a CP odd heavy Higgs boson A decaying into a CP even heavy Higgs boson H and a Z boson, with the H decaying further into a pair of top quarks. This decay channel is particularly relevant in the high mass and low tan(β) regime. We will present the strategy and status of our analysis, targeting the fully hadronic $t\bar{t}$ decay with the Z boson decaying to $\mu^+\mu^-$.

T 62.7 Wed 17:45 T-H21

Search for heavy Higgs bosons in the $Z + t\bar{t}$ final states with CMS — •Yannick Fischer, Ksenia de Leo, Johannes Haller, Daniel Hundhausen, and Matthias Schröder — Institut für Experimentalphysik, Universität Hamburg

Since its discovery in 2012, the properties of the Higgs boson at 125 GeV have been studied in numerous measurements. Within the uncertainties all results suggest a Standard Model like behaviour. However, the observed boson might well be part of an extended Higgs sector, which is predicted in various scenarios of new physics beyond the standard model. Two Higgs Doublet Models (2HDM) provide a generic description of the phenomenology arising in models with a second Higgs doublet. In this talk we will investigate the hypothetical decay of a CP odd heavy Higgs boson A decaying into a CP even heavy Higgs boson H and a Z boson, with the H decaying further into a pair of top quarks. This decay channel is particularly relevant in the high mass and low tan(β) .We will give an overview about the parameter space with detailed phenomenological studies, the results of the investigations of the kinematic properties of the decay products and present first expected exclusion limits in the decay channel $Z \to \mu^+\mu^-$ and $t\bar{t} \to$ jets.

T 62.8 Wed 18:00 T-H21

Search for light pseudoscalar boson pairs produced from decays of the 125 GeV Higgs boson in final states with tau leptons — •Lakshmi Pramod — DESY

An extended Higgs sector is well-motivated in several Beyond the Standard Model theories. A vast set of models containing two Higgs doublets plus one additional Higgs singlet complex field (2HD+1S) are consistent with SM measurements, constraints from searches for additional Higgs bosons and supersymmetry, as well as with the measured properties of the H(125) boson. The Higgs sector of the 2HD+1S models contains seven physical states: three CP-even, two CP-odd and two charged bosons. In the context of these models, the H(125) boson can decay into a pair of light pseudoscalar bosons (a_1), which can subsequently decay to pairs of Standard Model particles. There exist scenarios where a_1 can have an enhanced decay rate to a pair of τ leptons. A search for a pair of light bosons, a_1, produced from decays of 125 GeV Higgs boson, each decaying to a pair of τ leptons will be presented. The search is based on proton-proton collision data collected by the CMS experiment during Run 2 at a centre of mass energy of 13 TeV, corresponding to an integrated luminosity of 138 fb^{-1} . Model-independent upper limits at 95% confidence level on the 125 GeV Higgs boson production cross-section times the branching fraction into the studied final state, relative to the SM H(125) production cross-section, are set. Model-specific upper bounds obtained as constraints on the parameter space of the different benchmark scenarios within the 2HDM+S will also be presented.

T 62.9 Wed 18:15 T-H21

Search for a light CP-odd Higgs boson decaying into a pair of taus with ATLAS — •Jannik Friese, Tom Kresse, Max Märker, Wolfgang Mader, and Arno Straessner — IKTP, Dresden, Germany

Even though theoretical predictions of the SM are corresponding to experimental results to an incredible degree, there are still some phenomena unexplained, for example the deviation of the measured anomalous magnetic moment, $g-2$, of the muon from SM calculations. This deviation could be explained by the flavor-aligned two-Higgs-doublet model (2HDM). The introduction of a second Higgs doublet leads to four additional Higgs bosons, one of which being CP-odd and electrically neutral. The muon $g-2$ deviation is best explained with a light CP-odd Higgs boson which couples nearly exclusively to top quarks and tau leptons. This talk presents the search of such a light CP-odd Higgs boson produced via gluon fusion. The decay into two tau leptons is analyzed by looking at one electron and one muon in the final state. The mass of the light Higgs boson is assumed to be in the range between 40 GeV and 90 GeV. The search is based on 139 fb^{-1} of data collected by the ATLAS experiment at 13 TeV center of mass energy. Before unblinding the signal region, background control regions are analyzed to verify a good description of the data distributions. In particular, the transverse momentum spectrum of the electrons and muons receives contributions from QCD background which is not modeled well by Monte Carlo simulations. This talk focuses on the estimation of this source of background using a data driven fake-factor method.

T 63: Search for New Particles 4

Time: Wednesday 16:15–18:30 Location: T-H22

T 63.1 Wed 16:15 T-H22

Search for a long-lived particle in $b \to s$ transitions at Belle II — •Sascha Dreyer[1] and Torben Ferber[2] for the Belle II-Collaboration — [1]DESY, Hamburg, Germany — [2]ETP, KIT, Karlsruhe, Germany

The Belle II experiment at the asymmetric e^+e^- SuperKEKB collider in Tsukuba, Japan provides an ideal test bench for searches for light dark sectors, due to a clean collision environment leading to low backgrounds.

A hypothetical new long-lived particle could serve as a portal to dark sectors. This particle could be produced in B-meson decays via $b \to s$ quark transitions and decay to pairs of charged Standard Model particles. The displaced vertex signature can be reconstructed in case the particle decays within the tracking detectors.

This talk gives an overview of the search for such a new long-lived particle at Belle II. The sensitivity for different lifetime and mass scenarios will be shown together with work towards validating long-lived particle performance in data using control samples.

T 63.2 Wed 16:30 T-H22

Study of $e^+e^- \to D_s^\pm D_{s0}^*(2317)^\mp A$ process at Belle+BaBar — •Dmytro Meleshko[1], Elisabetta Prencipe[1,2], Jens Soeren Lange[1], and Ashish Thampi[2] — [1]Justus-Liebig Univ. Giessen — [2]IKP-1, Forschungszentrum Juelich

The present analysis is focused on the study of the $e^+e^- \to D_s^\pm D_{s0}^*(2317)^\mp A$ process in the continuum (A = anything else) combining the BaBar and Belle data sets to cure problems of insufficient statistics. The main goal of this work is the analysis of the $D_s^+ D_{s0}^*(2317)^-$ invariant mass system to look for possible resonant states with $c\bar{c}s\bar{s}$ quark content, and cross-section measurement. At the current stage of the analysis, a preliminary study over MC samples and Belle data has already been performed. The acquired results contain intriguing sign of a possible state seen in the invariant mass distribution of the $D_s^\pm D_{s0}^*(2317)^\mp$ system. In addition, the analysis is opened to a potential perspective of measuring the $D_{s0}^*(2317)^\pm$ width upper limit, which plays an important role in understanding the nature of the $D_{s0}^*(2317)^\pm$ itself.

T 63.3 Wed 16:45 T-H22

Search for inelastic Dark Matter with a Dark Higgs at Belle II — •Patrick Ecker, Torben Ferber, Pablo Goldenzweig, and Jonas Eppelt for the Belle II-Collaboration — Karlsruhe Institute of Technology, Karlsruhe, Germany

Although the Standard Model (SM) of particle physics describes most of the phenomena observed in our universe very well, there are still some observations where the SM lacks to provide an explanation. One of these observations is the presence of Dark Matter which is very well motivated. Nevertheless, it is still not clear which particles make up this Dark Matter.

This talk will present a sensitivity study based on Monte Carlo simulations for a search for an inelastic Dark Matter model which involves the presence of a Dark Higgs boson. This model has a signature of up to two displaced vertices, one from the resonant decay of the Dark Higgs and another non-resonant one emerging from the decay of the involved Dark Matter particles.

T 63.4 Wed 17:00 T-H22

Search for $B^\pm \to K^\pm a(a \to \gamma\gamma)$ with promptly decaying ALPs - A Monte Carlo study — •Lucas Weidemann, Pablo Goldenzweig, and Torben Ferber — Institute of Experimental Particle Physics, Karlsruhe, Germany

Axion-Like-Particles (ALPs) are a well motivated extension to the Standard Model. They are light, pseudoscalar particles which are dominantly interacting with Standard Model gauge bosons. As a result ALPs can be produced in a flavor-changing neutral current transition by its coupling g_{aWW} to W bosons. Subsequently, the ALP dominantly decays into two photons, which makes $B^\pm \to K^\pm a(a \to \gamma\gamma)$ a promising process for measuring g_{aWW}.

We use Monte Carlo simulation for analyzing this process by reconstructing the B meson and examining the invariant di-photon mass distribution. The study is performed with ALPs in mass range 0.1-4.6 GeV/c^2 and zero lifetime.

An outline of our analysis as well as our current status are going to be presented in this talk.

T 63.5 Wed 17:15 T-H22

Sensitivity study in the Search for $B^\pm \to K^\pm a$ (displaced $a \to \gamma\gamma$) Decays at Belle II — •Alexander Heidelbach, Pablo Goldenzweig, and Torben Ferber — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

In a set of extensions of the Standard Model, Axion Like Particles (ALPs) arise as (pseudo) Nambu-Goldstone bosons of an additional spontaneously broken U(1) symmetry. Due to constraints in flavour-changing processes, involving the coupling of ALPs directly to Standard Model fermions and gluons, direct couplings of ALPs to the electroweak gauge bosons are particularly interesting. As a result of coupling to W bosons, ALPs can emerge in flavour-changing-neutral-current $b \to s$ transitions. Depending on the ALP model, mass and the coupling to photons possible signatures become probeable in $B \to Ka$ transitions which can be studied at e^+e^- colliders like the Belle II experiment. I present a search for $B^\pm \to K^\pm a, a \to \gamma\gamma$ with long-lived ALPs. We investigate the mentioned decay based on a full Belle II Monte Carlo study. In this talk, I will show sensitivity estimates established by the reconstruction of the B meson, an optimised candidate selection and a scan of the invariant di-photon mass spectrum for different ALP lifetimes.

T 63.6 Wed 17:30 T-H22

Dark Photon Searches at Future e^+e^- Colliders — •Sepideh Hosseini[1,2], Jenny List[2], Mikael Berggren[2], and Gudrid Moortgat-Pick[1,2] — [1]Universität Hamburg, Hamburg, Germany — [2]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

The dark photon (A_D) is a hypothetical particle that can be possibly produced through its kinetic mixing with the ordinary, visible photon. The existence of kinetic mixing means that the two gauge bosons can transform into each other as they propagate and this provides a link between the dark and visible sectors. The decay modes of the dark photon to the standard model charged fermions motivate to look at $A_D \to \mu^+\mu^-$ as signal. The dark photon will have a specific mass and hence, the invariant mass of the muon pair is the main observable to look for the dark photon in the presence of standard model background. For this, we evaluate the prospects to detect the dark photon and to determine the mixing parameter for the example of the International Large Detector (ILD) concept at the International Linear Collider (ILC).

T 63.7 Wed 17:45 T-H22

Investigation of Collider Effects of Flavour Anomalies Using EFTs and Simplified Models — Philip Bechtle, Klaus Desch, Christian Grefe, and •Murillo Vellasco — Rheinische Friedrich-Wilhelms-Universität Bonn

The Standard Model of particle physics (SM) is undoubtedly one of the most successful scientific theories in history. Despite its overwhelming success, several tensions with its predictions have been discovered in recent years, including the measurements of the muon g-2 at Fermilab and rare B-decays at the LHC. The natural next step is to build even more powerful future colliders, but exactly which combination of future experiments is best to investigate further these hints is non-trivial.

The most challenging possibility is a scenario where the energy scale of New Physics is out of reach of direct discovery at future colliders. Therefore, our approach is to use the formalism of the Standard Model Effective Field Theory (SMEFT), performing scans over several operators which could perhaps explain the hints of experimental deviations from the SM. Kinematic observables of collider signatures can be directly affected by the presence of these operators, and the optimal combination of future experiments would be the one that optimizes the observation of these kinematic deviations. In this talk, we will discuss a possible strategy to choose the best combination of experiments given all current measurements in the electroweak and the flavour sectors. Ideally, any strategy for future colliders should aim for a "no-lose" scenario, analogous to the situation for the approval of the LHC.

T 63.8 Wed 18:00 T-H22

Heavy neutrino search at LHCb — Martino Borsato, Rebecca Gartner, and •Maurice Morgenthaler — Physikalisches Institut - Universität Heidelberg

Neutrino masses could be explained by the existence of heavy neutrinos. These elusive particles might have escaped detection at previous experiments due to their long lifetimes and low production rate. If their mass is in the range of a few GeV, heavy neutrinos are produced copiously from the weak decays of beauty hadrons and can be searched effectively at the world-brightest source of these hadrons: the Large Hadron Collider (LHC). In this talk I will present an ongoing search for heavy neutrinos produced in (semi)leptonic beauty-hadron decays using the dataset collected by the LHCb experiment at the LHC. The search strategy relies on the heavy-neutrino macroscopic lifetime and its decay to a pion and a muon. The sensitivity is maximised by targeting all beauty hadron species (including strange and charmed B mesons) and using a partial reconstruction of the decay. The sensitivity of the search in comparison to other experiments will be discussed.

T 63.9 Wed 18:15 T-H22

Search for Heavy Majorana Neutrinos in same-sign W Boson Scattering — •Jonas Neundorf — Deutsches Elektronen-Synchrotron, Notkestraße 85, 22607 Hamburg

Among the open question of particle physics is the origin of neutrino masses. While they are predicted to be zero by the Standard Model, oscillation measurements have shown that at least two of the three neutrino flavours observed in nature are massive. These masses can be explained by the "Seesaw Mechanism", which introduces Majorana neutrinos with a mass on the TeV scale. For the first time at the LHC, a search for Heavy Majorana Neutrinos produced via same-sign W boson scattering is performed. This talk will discuss the discovery potential and outline the analysis design.

T 64: Search for New Particles 5

Time: Wednesday 16:15–18:30 Location: T-H23

T 64.1 Wed 16:15 T-H23

Model Unspecific Search in CMS (MUSiC) — •Lorenzo Vigilante[1], Arnd Meyer[1], Thomas Hebbeker[1], and Saranya Samik Ghosh[2] — [1]III. Physikalisches Institut A, RWTH Aachen, 52074 Aachen, Germany — [2]CERN, Experimental Physics Department, Geneva, Switzerland

The Model Unspecific Search in CMS (MUSiC) is a search for new physics beyond the standard model (BSM). The analysis looks for significant deviations from the standard model (SM) expectation in LHC data. The method of the analysis is to compare kinematic distributions of the data with the SM expectation in hundreds of different final states, using an automated procedure. This strategy allows MUSiC to search for new phenomena in final states that are not all covered by dedicated analyses in CMS. In this talk the general method and its implementation will be discussed and results of the MUSiC analysis using 35.9 $\mathrm{fb}^{-1}$of data collected by the CMS experiment during proton-proton collisions at a center of mass energy of 13 TeV will be presented. The current status of the analysis and a possible new search method, based on machine learning technique, will be described.

T 64.2 Wed 16:30 T-H23

Search for high mass lepton flavour violating processes with CMS — •Sebastian Wiedenbeck, Thomas Hebbeker, Arnd Meyer, and Swagata Mukherjee — III. Physikalisches Institut A, RWTH Aachen University

Lepton flavour is a conserved quantity in the standard model of particle physics, but it does not follow from an underlying symmetry. Neutrino oscillations imply that lepton flavour is not conserved in the neutral sector. Lepton flavour violating processes are common in several models of physics beyond the standard model (e.g. supersymmetry with R-parity violation, black hole production, and leptoquarks). Some models predict objects at the TeV mass scale that can decay into two standard model leptons of different flavours: electron + muon, muon + tau, or electron + tau. The challenges in a search for such phenomena are to achieve a high mass resolution, good rejection of standard model backgrounds, and efficient lepton identification at the same time. The status of the analysis is presented, based on the latest CMS data taken in Run 2.

T 64.3 Wed 16:45 T-H23

Search for new physics in the τ+MET final state with CMS — •Christoph Schuler, Kerstin Hoepfner, Thomas Hebbeker, and Swagata Mukherjee — III. Physikalisches Institut A, RWTH Aachen University

A search for new physics in the τ+missing transverse momentum (MET) channel is presented based on proton-proton collisions measured with the CMS detector at the LHC, using the full Run-2 CMS data set recorded at a center of mass energy of 13 TeV. The analysis strategy is discussed and the results are interpreted in the context of various models predicting enhancements to the Standard Model in the high mass region.

T 64.4 Wed 17:00 T-H23

Interpreting the ATLAS missing-energy-plus-jets measurement for New Physics — •Martin Habedank and Priscilla Pani — Deutsches Elektronen-Synchrotron (DESY)

The large dataset of $139\,\mathrm{fb}^{-1}$ of proton–proton collisions at $13\,\mathrm{TeV}$ recorded with the ATLAS detector allows for a precise measurement of events with large missing transverse momentum and at least one jet. In the Standard Model, this final state can mostly be attributed to Z bosons being produced in association with jets, with subsequent decay of the Z boson into neutrinos. By correcting for detector effects, the measurement can thus make an important contribution to our Standard Model understanding and modelling.

However, various questions that cannot be answered within the framework of the Standard Model give rise to models predicting New Physics. Many of those – in particular when incorporating a Dark Matter candidate – also give rise to events with missing transverse momentum and one or more jets, rendering the mentioned measurement a powerful handle in constraining these models.

This talk gives insight into the approach taken by the mentioned measurement and progress on interpreting it with regard to New Physics models.

T 64.5 Wed 17:15 T-H23

Identification of highly boosted $Z \to e^+e^-$ decays with the ATLAS detector — Dominik Duda, •Florian Kiwit, Sandra Kortner, and Hubert Kroha — Max-Planck-Institut für Physik

The identification of W, Z and Higgs bosons with large transverse momenta is crucial in many searches for new heavy resonances. Thus far, the development of algorithms for the tagging of boosted bosons focuses on the reconstruction and identification of hadronic boson decays, while no dedicated algorithm to identify boosted $Z \to e^+e^-$ decays exists. The performance of the standard electron reconstruction and identification algorithms degrades with decreasing angular separation between the e^+e^- pairs and will eventually vanish once the angular separation between the e^+e^- pairs is too small to construct individual clusters in the calorimeter. To improve the reconstruction and identification of such highly boosted $Z \to e^+e^-$ decays, a dedicated algorithm for $Z \to e^+e^-$ tagging is being developed using a deep neural network. This talk presents first results of this development.

T 64.6 Wed 17:30 T-H23

Search for charged Higgs bosons in $H^+ \to Wh \to l\nu bb$ decays with the ATLAS detector — Dominik Duda, •Simon Grewe, Sandra Kortner, and Hubert Kroha — Max-Planck-Institut für Physik, München

Various theories predicting an extended Higgs sector predict also the existence of at least one set of charged Higgs bosons. The main production mode of these new particles depends on their mass. For charged Higgs boson masses larger than the sum of the top and the bottom quark mass, the dominant production mode is expected to be in association with a top quark and a bottom quark (tbH^+).

In the alignment limit of the two-Higgs-Doublet Model (2HDM), heavy charged Higgs bosons with m(H^+)>m(t)+m(b) decay almost exclusively via $H^+ \to tb$. However, in other models such as the Next-to-two-Higgs-Doublet Model (N2HDM), the three-Higgs-Doublet model (3HDM) or in Higgs triplet models (e.g. Georgi-Machacek model), significant branching ratios for $H^+ \to W^+h$ are possible. The latter decay mode has so far been covered neither by ATLAS nor CMS.

We present first studies on the search for $H^+ \to W^+h \to \ell\nu bb$ decays in final states with the resolved topology containing five or more jets, one charged lepton and missing transverse momentum. A multiclass classifier is used to separate the semileptonic $H^+ \to l\nu bb$ and fully hadronic $H^+ \to qqbb$ decay modes from the dominant background processes. The reconstruction of the charged Higgs boson decay is performed using boosted decision trees (BDTs).

T 64.7 Wed 17:45 T-H23

Status of the FASER Experiment — •Markus Prim and Florian Bernlochner — Rheinische Friedrich-Wilhelms-Universität Bonn

FASER, or the Forward Search Experiment, is a new experiment at CERN designed to complement the LHC's ongoing physics programme, extending its discovery potential to light and weakly-interacting particles that may be produced copiously at the LHC in the far-forward region. New particles targeted by FASER, such as long-lived dark photons or dark scalars, are characterised by a signature with two oppositely-charged tracks or two photons in the multi-TeV range that emanate from a common vertex inside the detector. The experiment is composed of a silicon-strip tracking-based spectrometer using three dipole magnets with a 20-cm aperture, supplemented by four scintillator stations and an electromagnetic calorimeter to allow for energy measurements. The full detector was successfully installed in March 2021 in an LHC side-tunnel 480 meters downstream from the interaction point in the ATLAS detector. FASER is planned to be operational for the upcoming LHC Run 3. We will discuss the physics reach of FASER, present the current status of the experiment and results from the ongoing in situ commissioning.

T 64.8 Wed 18:00 T-H23

Results from First Simulation Studies for a Dark Photon Search Experiment at the ELSA Electron Accelerator — Philip Bechtle, Klaus Desch, Oliver Freyermuth, Matthias Hamer, •Jan-Eric Heinrichs, and Martin Schürmann — Rheinische Friedrich-Wilhelms-Universität Bonn

The true nature of Dark Matter (DM) has long been of interest for scientists worldwide. Previous searches have so far been unsuccessful in finding proposed DM particles. A promising and not well explored parameter space of light DM particles up to 1 GeV remains to be subjected to intense experimental testing. Mainly two approaches are investigated by the community, namely beam dump and fixed targets experiments.

This talk highlights the future prospects of a fixed target experiment aimed at finding evidence for a dark sector, which couples to the standard model through a dark photon. The underlying theory and the resulting experimental challenges and strategy will be explained. The possibility of building a corresponding experiment at the ELSA electron accelerator in Bonn is highlighted. This talk covers first steps towards a Geant 4 simulation. Special emphasis will be put on some first simulation results concerning the layout and technology for an electromagnetic calorimeter based on requirements on radiation hardness and response times.

T 64.9 Wed 18:15 T-H23

Neutrino and Muon induced background studies - SHiP experiment — •Anupama Reghunath, Heiko Lacker, Andrew Conaboy, and Jakob Schmidt for the SBT-Collaboration — Institut für Physik, Humboldt-Universität zu Berlin, Berlin, Germany

The Search for Hidden Particles (SHIP) experiment is proposed to be constructed at a dedicated beam-dump facility at the CERN Super Proton Synchrotron (SPS) aiming to search for new feebly interacting particles generated in the decay of heavy flavour hadrons or through interactions of photons inside the beam-dump target. During a period of five years, SHIP aims to collect data from $2 \cdot 10^{20}$ 400 GeV/c protons on target. The experimental design is optimised to maximise the production of charm and beauty mesons with zero background events to have the best sensitivity to hidden-sector particles. Simulation studies with emphasis on the neutrino and muon induced background arising from inelastic interactions and its rejection using kinematical and topological requirements as well as information dedicated veto detectors, such as the Surround Background Tagger, will be discussed.

T 65: Silicon Strip Detectors

Time: Wednesday 16:15–18:15 Location: T-H24

T 65.1 Wed 16:15 T-H24

Optical inspection of silicon strip sensors for the Phase-2 Upgrade of the CMS Tracker — Anna Becker[1], Christian Dziwok[2], Lutz Feld[1], Patrick Juraschitz[1], Katja Klein[1], Martin Lipinski[1], Alexander Pauls[1], Oliver Pooth[2], •Nicolas Röwert[1], and Tim Ziemons[2] — [1]I. Physikalisches Institut B, RWTH Aachen University, Germany — [2]RWTH Aachen University - Physics Institute III B, Aachen, Germany

During the Long Shutdown 3 the LHC will be upgraded to the High Luminosity LHC with a planned instantaneous luminosity of at least $5 \cdot 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$. For this purpose the current strip tracker of the CMS experiment will be entirely replaced by a new system consisting of innovative silicon detector modules. RWTH Aachen University as one of the assembly centers is responsible for manufacturing around 1000 so-called 2S modules, which are equipped with two vertically stacked strip sensors having an active area of $10 \cdot 10\,\mathrm{cm}^2$.

During module production the inspection of the silicon sensors is crucial in order to detect damage or contamination caused by the assembly process which could seriously affect the successful operation of the module. For this purpose an automated optical inspection setup has been developed. It consists of a 24 mega pixel camera equipped with

a macro lens and an xy-stage.
This talk presents the setup, the approach to detect damages, and results obtained from images taken in the course of the assembly of a 2S module prototype featuring preproduction sensors.

T 65.2 Wed 16:30 T-H24

Testing results of the latest Service Hybrid prototypes for CMS silicon strip modules — Christian Dziwok[2], Lutz Feld[1], Katja Klein[1], Martin Lipinski[1], Daniel Louis[1], •Alexander Pauls[1], Oliver Pooth[2], Matej Repik[1], Nicolas Röwert[1], Michael Wlochal[1], and Tim Ziemons[2] — [1]1. Physikalisches Institut B, RWTH Aachen — [2]3. Physikalisches Institut B, RWTH Aachen

The CMS Collaboration is developing silicon strip modules for the second phase of the CMS tracker upgrade. This upgrade will enable the CMS experiment to utilize the high luminosity provided by the future HL-LHC. The modules' Service Hybrids are responsible for the sensor bias voltage and low voltage distribution on the module and the data transmission via optical links to the back-end electronics. Multiple batches of Service Hybrid prototypes have been produced. The latest use the final ASIC set with its most recent available versions and materials and geometries as foreseen in the detector. The prototyping campaign and present measurements of the hybrid performance are summarized. The measurements were performed with setups similar to the foreseen production test system, which is also presented.

T 65.3 Wed 16:45 T-H24

Vermessung von Streifenmodulen für das CMS Phase-2 Tracker Upgrade bei Betriebstemperatur — Christian Dziwok[2], Lutz Feld[1], •Patrick Juraschitz[1], Katja Klein[1], Martin Lipinski[1], Alexander Pauls[1], Oliver Pooth[2], Nicolas Röwert[1], Michael Wlochal[1] und Tim Ziemons[2] — [1]1. Physikalisches Institut B, RWTH Aachen — [2]RWTH Aachen University - Physics Institute III B, Aachen, Germany

Im Zuge des HL-LHC Upgrades im Long-Shutdown 3 (2025-2027) muss der Silizium-Spurdetektor des CMS Experiments ausgetauscht werden. Das Phase-2 Outer Tracker Upgrade umfasst neue Module, welche aus zwei übereinander parallel ausgerichteten Sensoren bestehen. Diese ermöglichen es durch die Analyse der Teilchendurchgänge bereits im Auslesechip eine Abschätzung des transversalen Impulses zu erhalten. Die relative Ausrichtung der Sensoren zueinander beeinflusst dabei maßgeblich die Qualität dieser Abschätzung. Die Alignierung wird mittels doppelseitiger Metrology gemessen, wobei das Modul von zwei Kameras betrachtet wird.
Der Phase-2 Spurdetektor soll bei einer Temperatur von -35°C betrieben werden. Daher ist das Verhalten der Module im Hinblick auf die Ausrichtung bei Betriebstemperatur von besonderem Interesse.
Es wird ein Verfahren präsentiert, welches es ermöglicht, Module mit einer Kühlmaschine zu kühlen und im Anschluss zu vermessen. Die Ergebnisse werden mit Messungen bei Raumtemperatur verglichen, um mögliche Auswirkungen der Temperatur auf die Ausrichtung der Sensoren zueinander nachzuvollziehen.

T 65.4 Wed 17:00 T-H24

Stress testing optical readout components for CMS 2S modules — •Christian Dziwok[2], Lutz Feld[1], Katja Klein[1], Martin Lipinski[1], Alexander Pauls[1], Oliver Pooth[2], Nicolas Röwert[1], and Tim Ziemons[2] — [1]I. Physikalisches Institut B, RWTH Aachen University, Aachen, Germany — [2]RWTH Aachen University - Physics Institute III B, Aachen, Germany

For the upcoming CMS Phase-2 Outer Tracker upgrade, new detector modules will be installed. There are two general types of modules, one consisting of two co-planar silicon strip sensors (2S) and one of a macro pixel and a strip sensor (PS). The communication and the auxiliary support are supplied by a so called SErvice Hybrid (SEH) in case of a 2S module. At the RWTH Aachen University the SEHs are qualified regarding power and communication stability in a so called test board setup, where the SEHs will undergo additional thermal cycling while being tested. This talk will focus on the data tests of this setup.

T 65.5 Wed 17:15 T-H24

Functional Testing of Silicon Sensor Modules for the CMS Experiment using Infrared LED Arrays — •Roland Koppenhöfer[1], Tobias Barvich[1], Bernd Berger[1], Justus Braach[2], Alexander Dierlamm[1], Ulrich Husemann[1], Markus Klute[1], Gani Kösker[1], Stefan Maier[1], Thomas Müller[1], Marius Neufeld[1], Hans Jürgen Simonis[1], Pia Steck[1], and Florian Wittig[1] — [1]Institute of Experimental Particle Physics (ETP), Karlsruhe Institute for Technology (KIT) — [2]CERN

In the context of the Phase-2 Upgrade of the CMS experiment, the complete CMS tracker will be replaced. The new CMS Outer Tracker will consist of two types of silicon sensor modules (PS and 2S modules). These modules are built and tested for their full functionality at different assembly centers. The ETP is one of the assembly centers for 2S modules. A dedicated test station for the electrical characterization of 2S modules has been designed and built at ETP. Using infrared LEDs it is possible to generate charge in the silicon sensors and test every module channel. This talk will present the test station developed at ETP and summarize the functional test results of the newest 2S module prototypes.

T 65.6 Wed 17:30 T-H24

Assembly and Test Procedures of 2S modules for the future Outer Tracker of the Phase-2 Upgrade of the CMS Experiment — •Stefan Maier, Tobias Barvich, Bernd Berger, Alexander Dierlamm, Alexander Droll, Umut Elicabuk, Jan-Ole Müller-Gosewisch, Ulrich Husemann, Roland Koppenhöfer, Markus Klute, Gani Kösker, Thomas Müller, Marius Neufeld, Hans Jürgen Simonis, Pia Steck, Lea Stockmeier und Florian Wittig — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology

In preparation for the High Luminosity LHC, the entire tracker of the CMS experiment will be exchanged within the Phase-2 Upgrade until 2027. The new outer tracker will be made of approximately 13000 silicon sensor modules called 2S modules (consisting of two parallel silicon strip sensors) and PS modules (one pixel and one strip sensor combined in a module). These modules provide tracking information to the Level-1 trigger by correlating the hit information of both sensor layers and, thus, allowing to discriminate charged particles by their transverse momentum. To guarantee successful operation of the CMS detector at the HL-LHC, the production of the outer tracker modules has to fulfil strict requirements. The talk will summarize the various assembly and test concepts for the large scale production of 2S modules and will present the latest module prototypes.

T 65.7 Wed 17:45 T-H24

Integration Tests with 2S Module Prototypes for the Phase-2 Upgrade of the CMS Outer Tracker — •Lea Stockmeier, Tobias Barvich, Bernd Berger, Alexander Dierlamm, Alexander Droll, Umut Elicabuk, Ulrich Husemann, Markus Klute, Roland Koppenhöfer, Stefan Maier, Thomas Müller, Jan-Ole Müller-Gosewisch, Marius Neufeld, Hans Jürgen Simonis, Gani Kösker, Pia Steck, and Florian Wittig — Institut für Experimentelle Teilchenphysik (ETP), Karlsruher Institut für Technologie (KIT)

To deal with the increased luminosity of the HL-LHC, the CMS experiment will be upgraded until 2027. During this Phase-2 Upgrade the CMS Outer Tracker will be equipped with modules each consisting of two silicon sensors. Depending on the position in the tracker, these silicon sensors are pixel or strip sensors. The modules with two strip sensors are called 2S modules. In the barrel region, they are placed on mechanical structures called ladders. A fully equipped ladder contains twelve modules.

Within the prototyping phase of the 2S modules, laboratory and integration tests are performed. This talk summarizes the first integration test on a ladder performed with four modules at Institut Pluridisciplinaire Hubert CURIEN (IPHC) in cooperation with KIT and laboratory tests performed at KIT.

T 65.8 Wed 18:00 T-H24

Commissioning of a Burn-In Setup for PS and 2S Detector Modules for the Upgrade of the CMS Outer Tracker — •Ana Ventura Barroso, Katerina Lipka, and Paul Schütze — DESY, Hamburg, Germany

The high luminosity LHC Upgrade will increase the instantaneous luminosity by a factor of five. The CMS detector will be upgraded in the so called Phase-2 Upgrade in order to meet the new requirements, among others the level of radiation tolerance and coping with larger pileup and thus higher data rates, as well as to add triggering capabilities. The entire silicon tracker will be replaced. The Outer Tracker (OT), consisting of macro-pixel and strip detectors, will be based on silicon modules that must operate at low temperatures ($-33°$ C) due to the exposition at high radiation levels. The probability for defective electronic components to fail is higher after few hours of operation. Moreover, temperature cycles can induce mechanical stress. Therefore a burn-in procedure as well as thorough quality control is needed to ensure the correct operation of each of the OT modules before installation.

For this, a burn-in system is being commissioned at DESY. This setup will perform thermal cycles from room to operation temperature and key measurements to ensure the good performance of the modules. In this talk, the status of the DESY burn-in setup as well as first tests will be presented.

T 66: Semiconductor Detectors: Radiation Hardness, new Materials and Concepts 2

Time: Wednesday 16:15–18:30 Location: T-H25

T 66.1 Wed 16:15 T-H25

Study of the self-heating in SiPMs — •Carmen Victoria Villalba Petro, Erika Garutti, Robert Klanner, Stephan Martens, and Jörn Schwandt — Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Deutschland.

A dramatic increase of the dark current is the main effect of radiation damage in SiPMs. The power dissipated, if not properly cooled, heats the SiPM, whose performance parameters depend on temperature. Therefore, the knowledge of the SiPM temperature is necessary to understand the changes of its parameters with irradiation.

The self-heating studies were performed with a KETEK SiPM, 15x15 mm^2 pixel size, mounted on an Al_2O_3 substrate 0.6 mm thick, which was either directly connected to the temperature controlled chuck of a probe station, or through layers of material with well-known thermal resistance. The SiPM was illuminated by a LED operated in DC-mode. SiPM current was measured at different voltages, LED currents, chuck temperatures, and thermal resistivities for a number of measurement cycles. The data are used to determine the steady-state temperature as a function of dissipated power and thermal resistance, as well as the time dependencies for heating and cooling. This information could be used to correct the parameters determined for radiation-damaged SiPM for the effects of self-heating.

The presentation describes the experimental layout, the data taking, the analysis methods, the results obtained and a comparison to thermal simulations. The application of the method for the study of radiation damaged SiPMs and its use in actual experiments is discussed.

T 66.2 Wed 16:30 T-H25

PeakOTron: A Python Module for Fitting Charge Spectra of Silicon Photomultipliers — •Jack Rolph, Erika Garutti, and Joern Schwandt — Institute for Experimental Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

An automated software method is developed to characterise the pulse-height spectra of SiPM obtained in the dark or response to low-intensity light illumination. The method is based on a fit utilising a published SiPM response model. It aims to provide SiPM performance parameters for single measurements, mass production characterisation, or high granular detector calibration. The fit considers dark count rate, the average number of detected photons, crosstalk and after-pulsing, electronics noise and gain fluctuations. Due to the sensitivity of the fit to the initial values assigned to these parameters, the software must perform careful estimation before fitting the model to data, which has been designed to be fast, accurate and robust to fluctuations. First, the model*s accuracy is validated against simulation and then tested to experimental data from various SiPMs.

T 66.3 Wed 16:45 T-H25

Silicon Photomultiplier characterization for a space-borne optical instrument in Low Earth Orbit — •Lucas Finazzi[1,2,4], Federico Golmar[2,4], Andreas Haungs[1], Thomas Huber[1], and Federico Izraelevitch[2,3,4] — [1]Institut für Astroteilchenphysik (IAP), Karlsruher Institut für Technologie (KIT), Germany — [2]Universidad de San Martín (UNSAM), Argentina — [3]Comisión Nacional de Energía Atómica (CNEA), Argentina — [4]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina

The S4 (Space-borne SiPM-based Single-photon Sensor) is an instrument designed for single-photon detection in Low Earth Orbit (LEO) using Silicon Photomultiplier (SiPM) technology. The instrument, currently under developed by the LabOSat group (UNSAM), is expected to launch on Q2 2023 as a secondary payload of a commercial Earth-observation satellite. Beside the increase of the Technology Readiness Level (TRL) of SiPM sensors for space applications, the S4 instrument will be a pathfinder for Ground-LEO single-photon communications and fundamental Physics experiments that require single-photon detection.

In this talk we will describe the S4 instrument, focusing on the Analog-Front End (AFE) and SiPMs subsystem. Particularly, we will present the characterization performed at the SPOCK (Single PhOton Calibration stand at KIT) laboratory at the Institute of Astroparticle Physics (KIT), including studies on the performance of the AFE board and sensors at different temperatures, SiPM overvoltages and illumination conditions.

T 66.4 Wed 17:00 T-H25

Timing measurements of a tip avalanche photodiode (TAPD) - A near-infrared enhanced silicon photomultiplier based on spherical depletion — •Wolfgang Schmailzl[1,3], Jonathan Preitnacher[1], Erika Garutti[2], and Walter Hansch[1] — [1]Bundeswehr University Munich, Neubiberg, Germany — [2]University of Hamburg, Hamburg, Germany — [3]Broadcom Inc., Regensburg, Germany

The gain of attention in LiDAR technology also pushed the development of sensors for time of flight measurements. Such a measurement requires a fast and very sensitive receiver. Often a wavelength in the near-infrared (NIR) region is chosen if the emitter is part of the system while a high sensitivity over a broad range is an advantage for deviating applications. Silicon photomultiplier (SiPM) with enhanced sensitivity in the NIR region provide a good combination of performance and cost-efficiency. In our investigations we simulated and fabricated spherical junctions for the single-photon avalanche diodes and a photo-detection efficiency of 22% at 905nm was achieved. We present timing measurements of this new NIR SiPM to provide an overview and to put the performance into the context of possible applications with very low and high light intensities. Compared to their blue enhanced counterparts, the single photon time resolution of these devices is lower where some of this performance loss is related to the required depletion depth for longer wavelengths while the current design is still not at its limit. We want to outline some of these intrinsic limits and show where improvements can be made.

T 66.5 Wed 17:15 T-H25

Characterisation and Radiation Hardness of Tip-Avalanche PhotoDiodes — •Julius Römer[1], Erika Garutti[1], Wolfgang Schmailzl[2,3], Jörn Schwandt[1], and Stephan Martens[1] — [1]Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Deutschland — [2]Bundeswehr Universität München, Neubiberg, Deutschland — [3]Broadcom Inc., Regensburg, Deutschland

Silicon Photomultipliers (SiPM) are the photon detectors of choice for many applications. Development of SiPMs with conventional single photon avalanche diode (SPAD) built around a planar pn-junction reaches a trade-off between photon detection efficiency (PDE) and dynamic range. A challenge in designing efficient red-sensitive SiPMs lies in the requirement for large depletion depths.

A novel design design featuring a quasi-spherical pn-junction called Tip Avalanche Photodiode (TAPD) tackles both problems. For a pixel pitch of 15 μm, the SiPM prototype reaches a PDE of 73 % at 600 nm and 22 % at 900 nm, a high dynamic range, as well as a recovery time below 4 ns. The aim of this study is to characterize this novel type of SiPM. In particular the question of radiation hardness of TAPD is addressed.

After irradiation with reactor neutrons with fluences up to $1 \cdot 10^{12}\,\mathrm{cm}^{-2}$ 1 MeV neutron equivalent, characterisation with $I-V$ and $C-V-f$ measurements show that despite the increased bulk volume, TAPD-SiPMs show similar loss of response and increase in dark count rate (DCR) with irradiation compared to planar SiPM devices, enhancing the usability in high energy particle experiments.

T 66.6 Wed 17:30 T-H25

Investigation of the Time Resolution of LGADs and 3D Sen-

sors — •Leena Diehl, Monty King, Dennis Sperlich, Ulrich Parzefall, Marc Hauser, and Christina Schwemmbauer — Universität Freiburg

Future collider experiments as the high-luminosity LHC or the FCC will increase the demands of the detectors used for tracking. Sensors will not only face fluences of up to $1 \cdot 10^{17}$ n_{eq}/cm^2, but also high pile-up scenarios. Thus sensors are needed which have a high radiation tolerance, but also an excellent time resolution while still providing a good spatial resolution. Currently Low Gain Avalanche Diodes (LGADs) are the prime candidate when it comes to timing, reaching a resolution of below 30 ps. However, 3D sensors are promising candidates as well, as they have not only a good time resolution but also a superior radiation hardness. In order to investigate the time resolution of both LGADs and 3D sensors thoroughly, timing measurements were performed using either a beta-source or a laser with infrared wavelength. The timing-TCT measurements allow to measure the position-dependence of the time resolution, which is interesting especially for the 3D-sensors, where the time walk is an important component of the resolution. This talk will present some initial results of the measurements, including the calibration of the timing-TCT setup and first measurements with were 3D-sensors as well as LGADs.

T 66.7 Wed 17:45 T-H25

Time resolution comparison between LGADs and 3D silicon detectors — •Montague King, Christina Schwemmbauer, Leena Diehl, Dennis Sperlich, Marc Hauser, and Ulrich Parzefall — Albert-Ludwigs Universität, Freiburg, Germany

For the planned high luminosity upgrade of the LHC it is vital to develop detector systems with both excellent spatial and timing resolution in the inner tracking layers to be able to distinguish separate collisions in the same bunch crossing. This has to be achieved even after severe irradiation with expected fluences of up to 2.6 x 10^{16} n_{eq}/cm^2.

It has been shown that a timing resolution of 30 ps can be achieved with Low Gain Avalanche Diodes (LGADs). However, these devices have drawbacks, especially regarding spatial resolution, effective fill factor and radiation hardness. A second detector type, 3D-detectors with electrodes extending deeply into the silicon bulk, are expected to be able to achieve such a high timing resolution while having a superior spatial resolution and radiation hardness.

In this talk, the calibration of a setup developed specifically for fast timing measurements at the University of Freiburg will be presented. This setup utilises a ^{90}Sr electron source along with a reference sensor and scintillator to measure fluctuations in the time between signals from reference and tested sensor. Furthermore, first results measured for LGADs before and after irradiation as well as unirradiated 3D sensors will be discussed.

T 66.8 Wed 18:00 T-H25

Boron removal effect in silicon sensors induced by 6 MeV electrons — •Chuan Liao, Eckhart Fretwurst, Erika Garutti, and Joern schwandt — Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Deutschland

In the frame of the CERN_RD50 collaboration, the acceptor removal effect is investigated in p-type material, used for example in pixel sensors or Low Gain Avalanche Detectors (LGADs). The suspected cause is the displacement of substitutional Boron (Bs), being negatively charged, by incident particles or other recoil atoms into an interstitial position (Bi). This is followed by Bi migration and being captured by Oxygen atoms and forming complex defects of interstitial Boron and interstitial Oxygen (BiOi) with a positive charge. This is the boron removal effect. For lower radiation fluence, this has one main consequence: The maximum electric field at a given reverse bias will decrease, causing e.g. a decrease of the LGAD gain. In this presentation, the Thermally Stimulated Techniques including TS-Current (TSC) and TS-Capacitance (TS-Cap) have been used to study the properties of the radiation-induced BiOi defect complex by 6 MeV electrons. Two different types of diodes manufactured on p-types epitaxial-(EPI) and Czochralski(CZ) silicon with a resistivity of about 10 Wcm were irradiated with fluence values in the range between 1 x 1015 cm-2 and 6 x 1015 cm-2. The results will be presented and compared with those gained from sensors exposed to 23 GeV protons.

T 66.9 Wed 18:15 T-H25

Physics case for a forward timing disc covering 3<η<4 of the CMS detector at HL-LHC — •Anna Albrecht[1], Anna Benecke[2], Andreas Hinzmann[1], Ben Kilminster[3], and Stefanos Leontsinis[3] — [1]Universität Hamburg — [2]UC Louvain — [3]University of Zurich

The LHC will be upgraded to a collider with 10 times higher luminosity, the high luminosity (HL)-LHC. One main challenge arising from the upcoming high luminosity, is the large amount of interactions that occur in one proton-proton bunch crossing, and therefore the separation of the interaction of interest from the additional ones (pileup). The insertion of a new timing layer in the upgraded CMS experiment is planned, to use timing as an additional discrimination variable between signal and pileup.

One interesting channel to probe at the HL-LHC is vector boson fusion (VBF) Higgs pair production that has two characteristic jets in the forward region of the detector. The separation of this signal from pileup is extremely challenging. In this physics case study, the performance of an extension of the timing layer from $\eta < 3$ to $\eta < 4$ is estimated by using the Delphes simulation software.

T 67: Myon Detectors

Time: Wednesday 16:15–18:40 Location: T-H26

Group Report T 67.1 Wed 16:15 T-H26

DT upgrade activities during LHC long shutdown II and readiness status for Run 3 — •Archana Sharma, Thomas Hebbeker, Kerstin Hoepfner, Hans Reithler, Markus Merschmeyer, and Dmitry Eliseev — III. Physikalisches Institut A, RWTH Aachen University

After delivering an integrated luminosity of more than 160/fb until the end of Run 2, at the beginning of 2019, LHC was shut down until the end of 2021 (LS2) in order to get its accelerator-chain and detectors upgraded for the HL-LHC phase, expected to deliver an instantaneous luminosity 5 times higher with respect to the present value. During this LS2, the Compact Muon Solenoid (CMS) experiment worked to upgrade its electronics and detector performance to improve the data taking and a precise reconstruction of all the particles in high pile-up conditions of HL-LHC. Drift Tubes (DT) detectors equip the CMS muon system barrel region, serving both as offline tracking and triggering devices. An upgrade of the current readout and trigger electronics is also planned in order to withstand event rates and integrated doses far beyond the initial design specification expected in HL-LHC. During LS2, prototypes of the new electronics were installed in four DT chambers with the same azimuthal acceptance, instrumenting a demonstrator of the HL-LHC DT upgrade (DT slice-test). This report briefly summarises the commissioning activities performed during LS2, along with the status of the slice-test and its performance with cosmic -ray events.

T 67.2 Wed 16:35 T-H26

A tester tool for the new read-out electronics of the MDT detectors of the ATLAS muon spectrometer in the Phase-II upgrade — •Thorben Swirski, Gia Khoriauli, and Raimund Ströhmer — Universität Würzburg

To make the ATLAS monitored drift tube detectors (MDT) ready for the new high rate environment in the High-Luminosity LHC, new read-out electronics, including new mezzanine cards, are being developed. These mezzanine cards feature a triggerless read-out mode to allow the MDT stations to be used in the trigger decisions. A tester-tool has been designed for mass quality testing of the new mezzanine cards. The tester-hardware is ready since summer 2021 and is now being programmed to allow for the testing of all functionalities of the mezzanine cards. The work allows the use of the tester tool not only for the mass testing of already produced cards, but also adds valuable insights during the ongoing prototyping effort. This talk will present the tester-tool, give an overview over the test-regime, show how the gathered data will be archived in a dedicated database and present examples of how the use of the tester tool has helped the development of the mezzanine cards.

Group Report T 67.3 Wed 16:50 T-H26

The small-diameter Drift Tube (sMDT) Chambers for ATLAS at High-Luminosity LHC and for Future Colliders — Davide Cieri, Gregor Eberwein, Oliver Kortner, Hubert Kroha, Patrick Rieck, Marian Rendel, and •Elena Voevodina — Max-Planck-Institut für Physik, München, Deutschland

The small-diameter Drift Tube (sMDT) detector technology with 15 mm tube diameter has proven to be an excellent candidate for precision muon tracking detectors in experiments at future hadron colliders like HL-LHC and FCC-hh where unprecedentedly high background rate capabilities are required. The upgrades of the inner barrel layer of the ATLAS Muon Spectrometer in the LS2 (2019-2021) and LS3 (2026-2028) shutdowns of the LHC machine use combinations of the sMDT detectors and RPC trigger chambers. We present the test results of the performance of the sMDT chambers under construction for the operation at HL-LHC and the measurements of the behavior of the detectors and their new readout electronics under very high background irradiation rates like at FCC-hh performed at the CERN Gamma Irradiation Facility (GIF++).

T 67.4 Wed 17:10 T-H26

Quality Control in the Construction of new small-diameter Muon Drift Tube (sMDT) Chambers for the ATLAS Muon Spectrometer at the HL-LHC — •Daniel Buchin, Marian Rendel, Alice Reed, Patrick Rieck, Oliver Kortner, and Hubert Kroha — Max-Planck-Institut für Physik, München

In order to improve the muon trigger efficiency and the rate capability of the ATLAS muon detectors for operation at the high luminosity upgrade of the Large Hadron Collider (HL-LHC), the Monitored Drift Tube (MDT) tracking chambers in the inner barrel layer of the ATLAS Muon Spectrometer will be replaced by small-diameter Muon Drift Tube (sMDT) chambers integrated with new thin-gap RPC trigger chambers. The sMDT chambers fit, together with the RPCs, into the very tight available space and provide an order of magnitude higher background rate capability compared to the current detectors.

The sMDT chambers are in serial production since January 2021. In the talk, the measures implemented to assure the quality of the chambers will be explained, starting from the results of the tests and inspections each individual assembled drift tube is undergoing. The dedicated quality control database and monitoring web interface will also be discussed.

T 67.5 Wed 17:25 T-H26

Construction of small-diameter Monitored Drift Tube (sMDT) chambers for the ATLAS Muonspectrometer at the HL-LHC — •Marian Rendel, Daniel Buchin, Alice Reed, Oliver Kortner, Hubert Kroha, Patrick Rieck, and Elena Voevodina — Max-Planck-Institut für Physik (Werner-Heisenberg-Institut)

For the high luminosity upgrade of the Large Hadron Collider, the Monitored Drift Tube (MDT) tracking chambers in the inner barrel layer of the ATLAS muon spectrometer will be replaced by small-diameter Monitored Drift Tube (sMDT) chambers integrated with new thin-gap RPC trigger chambers. The sMDT chambers fit, together with the RPCs, into the very tight available space and provide an order of magnitude higher background rate capability compared to the current MDT chambers.

Since January 2021 the sMDT chamber serial production is proceeding at a steady pace of one chamber every two weeks as planned. In this talk, the sMDT chamber design and the construction procedures will be explained as well as the technology transfer to the second production site at the University of Michigan.

T 67.6 Wed 17:40 T-H26

Measuring the geometry of the new small-diameter Monitored Drift Tube (sMDT) chambers constructed for the HL-LHC upgrade of the ATLAS Muonspectrometer — •Alice Reed, Daniel Buchin, Marian Rendel, Patrick Rieck, Elena Voevodina, Oliver Kortner, and Hubert Kroha — Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München

In order to improve the muon trigger efficiency and the rate capability of the ATLAS muon detectors for operation at the high-luminosity upgrade of the Large Hadron Collider (HL-LHC), the Monitored Drift Tube (MDT) chambers in the inner barrel layer of the ATLAS Muon Spectrometer will be replaced by small-diameter Muon Drift Tube (sMDT) chambers integrated with new thin-gap RPC trigger chambers. The sMDT chambers fit, together with the RPCs, into the very tight available space and provide provide an order of magnitude higher background rate capability compared to the current detectors.

The sMDT chambers have to provide a sense wire positioning accuracy of better than 20 μm and this requires the geometry of the chambers to be measured with a high precision. The measurement procedure and results are discussed for the chambers in serial production.

T 67.7 Wed 17:55 T-H26

Fabrication of Resitive Plate Chambers — Oliver Kortner, Hubert Kroha, Daniel Soyk, and •Timur Turkovic — Max-Planck-Institut für Physik, Föhringer Ring 6, 80805 München, Germany

Resistive plate chambers (RPCs) with electrodes of high-pressure phenolic laminate (HPL) and small gas gap widths down to 1 mm provide large area tracking at relatively low cost in combination with high rate capability and fast response with excellent time resolution of better than 500 ps. They can be operated up to γ background count rates of up to 10 kHz/cm2 which is five times the maximum rate these RPCs will encounter in the innermost layer of the barrel muon spectrometer of the ATLAS detector where they will be installed in the phase-II upgrade for the HL-LHC operation. A cost-effective production procedure which is compliant with industrial techniques was worked out and tested by a production of prototype thin-gap RPCs in the laboratory. Cosmic ray muons were used to check the proper functioning of these prototypes. The new production procedure has been transfered to several companies for the production of test samples. We will report about the RPC production in the laboratory and the technology transfer to industry.

T 67.8 Wed 18:10 T-H26

The CMS Muon upgrade and the commissioning of the first GEM station — •Francesco Ivone, Thomas Hebbeker, Kerstin Hoepfner, Giovanni Mocellin, and Shawn Zaleski — III. Physikalisches Institut A, RWTH Aachen University

The LHC will undergo a major upgrade to deliver ~10 times more proton-proton collisions in the next two decades, which has been named High-Luminosity LHC (HL-LHC). To cope with the higher event rates and to improve the trigger capabilities in the forward region, the Compact Muon Solenoid (CMS) experiment will undergo several upgrades. These include the installation of an additional set of muon detectors based on the Gas Electron Multipliers (GEM) technology. The triple-GEM detectors named GE1/1 have already been installed during 2020. Two more stations, GE2/1 and GE0, will adopt the same technology during subsequent shutdowns. The GE1/1 system consists of 72 chambers made by two layers of Triple-GEM detectors, this will improve the muon triggering and tracking capabilities of CMS.

We report on the commissioning of the GE1/1 detectors, focusing on the performance measured during the first CMS commissioning runs which include cosmic-ray muons and collision events. We discuss on the strategy implemented to identify the optimum working point and the system performance stability.

T 67.9 Wed 18:25 T-H26

A first look at CMS gas electron multiplier data and certification — Thomas Hebbeker, Kerstin Hoepfner, Francesco Ivone, and •Shawn Zaleski — III Physikalisches Institut A, RWTH Aachen University

To accommodate the increased radiation doses expected during the upcoming Run 3 at the CERN LHC, one of the primary experiments there, the Compact Muon Solenoid (CMS) will be upgraded. The first part of this upgrade, the installation of the gas electron multiplier (GEM) GE1/1 detector has been completed recently to help CMS cope with the radiation levels. The GEM chambers that comprise the GE1/1 detector have passed a rigorous battery of quality checks and are currently being commissioned in the end caps of the CMS muon system.

Initial data has been recorded by the GE1/1 detector using cosmic ray muon as well as proton-proton collision data. Dedicated data collection runs with and without the CMS 3.8 T magnetic field were performed. Certification procedures for this new GEM system have been developed and are being integrated with the existing procedures from the other CMS muon subsystems.

T 68: Detector Systems 2

Time: Wednesday 16:15–18:15 Location: T-H27

T 68.1 Wed 16:15 T-H27

Design and construction of a neutron imaging detector based on a neutron sensitive MCP on Timepix3 ASICs — •Saime Gürbüz[1], Markus Gruber[1], Jochen Kaminski[1], Markus Köhli[2], Michael Lupberger[1], Divya Pal[1], Laura Rodríguez Gómez[1], and Klaus Desch[1] — [1]Physikalisches Institut, Rheinsiche Friedrich-Wilhlems-Universität Bonn, Bonn — [2]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg

The non-invasive method of neutron imaging has applications from medicine to engineering. With its unique capabilities, we can image elements that can not be distinguished via X-rays.

At the University of Bonn, we have been developing neutron detectors with different configurations and specifications. One of the neutron imaging detectors that has been studied is based on neutron sensitive Microchannel plate (nMCP) in combination with a Timepix3 ASIC. Previous studies show that neutron sensitive ^{10}B and Gd enriched MCPs have up to 10 μm spatial resolution and neutron detection efficiency of up to 70%. The readout will be achieved using four Timepix3 ASICs with 55 μm pixels covering (28 x 28) mm^2 active area. The readout has a timing resolution of up to 1.5 ns.

By combining the efficiency of the MCP with the good time and spatial resolution of Timepix3, we aim to achieve excellent instrument performance in both domains. Such a detector can be used for many neutron imaging applications such as neutron tomography or time-of-flight imaging. In this talk, the current status as well as the principles of the detector will be presented.

T 68.2 Wed 16:30 T-H27

Wavelength-shifter coated polystyrene as a low-cost plastic scintillator detector — Alessia Brignoli[1], Andrew Conaboy[1], •Doramas Jimeno[1,2], Heiko Lacker[1], Christian Scharf[1], and Jakob Schmidt[1] — [1]Humboldt-Universität zu Berlin, Berlin, Germany — [2]Universitat de Barcelona, Barcelona, Spain

Plastic scintillator detectors are widely used in particle physics for detecting charged particles crossing the scintillating material, converting the excitation energy into fluorescence radiation. We studied the light yield of pure polystyrene plates uncoated, and coated with a wavelength-shifting dye, coupled to a photomultiplier, using beta particles from a Sr-90 source. The results with the coated polystyrene plate show around four times higher photoelectron yield compared to the uncoated plate. To estimate the fraction of Cherenkov radiation, we compared it to the light yield of an uncoated and a coated plate of a non-scintillating material (PMMA). These results motivate future studies for the development of easy-to-build, low-cost, polystyrene-based plastic scintillator detectors.

T 68.3 Wed 16:45 T-H27

Simulation of the Beam Conditions Monitor for the upgrade of the LHCb experiment — Johannes Albrecht, Elena Dall'Occo, and •David Rolf — Experimentelle Physik 5, TU Dortmund

The LHCb experiment is currently undergoing a major upgrade, preparing for the next period of data taking (Run 3) starting in 2022. The instantaneous luminosity in Run 3 will increase by a factor of five with respect to the previous runs. To ensure a safe operation of the experiment, simulation studies are performed for the Beam Conditions Monitor (BCM), responsible of protecting the LHCb detector against possible damage from the beam. Should an adverse beam scenario occur, the BCM will request a beam dump, thus preventing the beam from damaging the detector.

In this talk the impact of the changed beam conditions and configurations of the LHCb subdetectors on the BCM settings is evaluated, by studying the BCM response under both nominal and failing beam scenarios. Under nominal conditions the currents of the diamond sensors of the BCM detector are simulated and new settings for the beam dump logic are determined.

The effectiveness of the new proposed BCM settings are then investigated in critical beam scenarios. Simulations are performed under a beam scraping scenario to ensure the BCM will dump the beam before the beam drifts too far from its nominal position and starts to damage the sensitive detector parts.

T 68.4 Wed 17:00 T-H27

Development of a real-time track reconstruction for the proposed LumiTracker detector — Johannes Albrecht, Lukas Calefice, Elena Dall'Occo, •Lukas Rolf, and Holger Stevens — Experimentelle Physik 5, TU Dortmund

Measuring the luminosity is a vital task performed at the LHCb experiment. The luminosity is used as feedback for the LHC and as input for many analyses. The main goal of the proposed LumiTracker detector is to provide a measurement of luminosity by operating independently from the rest of the LHCb experiment. The LumiTracker measures luminosity by reconstructing and counting tracks and to provide an online measurement of luminosity per bunch every few seconds, the reconstruction needs to be performed in real-time. This contribution will present the current status of the pattern recognition and track fitting algorithms developed. The overall performance of the track reconstruction will be compared between a CPU and a GPU implementation, with the latter bringing the advantage of greater parallelism.

T 68.5 Wed 17:15 T-H27

Commissioning of the SND@LHC detector — •Andrew Picot Conaboy — Humboldt-Universität zu Berlin, Berlin, Deutschland

The Scattering and Neutrino Detector at the LHC (SND@LHC) is a compact experiment installed 480 m from the ATLAS interaction point. SND@LHC allows for a novel investigation of all three neutrino flavours in the pseudo-rapidity range $7.2 < \eta < 8.6$, with energies from 100 GeV to the TeV scale. Crucial for the reconstruction of neutrino charged current events, is the identification of the outgoing lepton: SND@LHC will reconstruct muons using iron blocks interleaved with planes of plastic scintillators coupled to silicon-photomultipliers. This technology will also be used to perform hadronic calorimetry. In the CERN north area, the muon system was installed for pion and muon test beams of energies in the 100 GeV to 300 GeV range. Presented in this contribution is the current status of muon system analyses from CERN test beams.

T 68.6 Wed 17:30 T-H27

Commissioning and Results of a Scintillator Based Beam Abort and Machine Protection System at SuperKEKB — •Ivan Popov, Hendrik Windel, and Frank Simon for the Belle II-Collaboration — Max-Planck-Institut für Physik, München, Deutschland

The asymmetric-energy collider SuperKEKB started its physics operation in March 2019. The usage of the nano-beam scheme enables collisions of electrons and positrons at record-breaking luminosities, but requires continuous particle injections at a rate of 50 Hz. These injections result in periods of high backgrounds, which can negatively affect the operation of Belle II subdetectors. In order to monitor and mitigate such backgrounds, the CLAWS detector system, consisting of scintillator tiles read out by silicon photomultipliers, has been in operation in various forms since 2016. Beginning with the first physics run in 2019, 32 sensors have been distributed along the final focusing magnets. Over the course of SuperKEKB's run time in 2020 they have proven to reliably observe disturbances in the particle beam which can result in catastrophically high backgrounds and quenches of the final focusing magnets. An electronics upgrade together with the implementation of a smart trigger logic enables the generation of a beam abort trigger within 200 ns after the occurrence of excessive background, thus ensuring the safe operation of the experiment. The CLAWS have been operating as a beam abort system since May 2021. In this report, the commissioning of the system and results achieved are discussed, and an outlook on plans for its further expansion is given.

T 68.7 Wed 17:45 T-H27

Detector system and simulation of the 155 MeV Hydro-Møller polarimeter at MESA — •Michail Kravchenko for the P2-Collaboration — PRISMA+ Cluster of Excellence and Institute of Nuclear Physics, Johannes Gutenberg University Mainz

The Mainz Energy-recovering Superconducting Accelerator (MESA) is an electron accelerator, which is currently under construction at the Johannes Gutenberg University Mainz. One aim for the MESA is the precise measurement of the weak mixing angle $sin^2\theta_w$, an important parameter of the Standard Model, with a relative uncertainty of 0.14%. The measurement will be performed by the P2 experiment by measuring the parity-violating asymmetry in elastic electron-proton scattering at low momentum transfer Q^2. MESA will provide a 150 μA beam of alternatingly polarized 150 MeV electrons with excellent beam stability. In order to achieve the goal of the P2 experiment, the beam polarization must be measured online with a very low systematic error ($< 0.5\%$ relative). The 155 MeV Møller polarimeter using a polarized atomic hydrogen target, known as the Hydro-Møller polarimeter, as proposed by V. Luppov and E. Chudakov opens the opportunity for achieving these requirements. The current design of the detector system for the Hydro-Møller polarimeter and the results of the simulation with Geant4 are presented.

T 68.8 Wed 18:00 T-H27

Fast neutron and gamma tomography with a stilbene-based multi-pixel detector — •Nina Höflich and Oliver Pooth — RWTH Aachen University - Physics Institute III B, Aachen, Germany

The neutron detectors group at the Physics Institute III B, RWTH Aachen University, develops a multi-pixel detector for a compact fast neutron imaging setup. Since the interactions of fast neutrons in matter differ from those of X-rays and gamma rays, imaging with fast neutrons in addition to X- or gamma ray imaging can provide complementary information about the object of interest.
Our current detector prototype uses cuboids of the organic scintillator stilbene as active material, coupled to a SiPM array. The pixel size is 6×6 mm^2. The usage of stilbene allows to distinguish neutron- and gamma-induced signals in the detector.
An Americium-Beryllium neutron source delivers fast neutrons of up to 11 MeV as well as gamma rays of 4.44 MeV for our measurements.
The talk will focus on recent results from tomographic test measurements of simple objects. Strategies for image reconstruction and image processing will be presented. Additionally, possible improvements will be discussed, based on Geant4 simulation results.

T 69: DAQ and Trigger 3

Time: Wednesday 16:15–18:30 Location: T-H28

T 69.1 Wed 16:15 T-H28

Development of an FPGA Implementation of Convolutional Neural Networks for Signal Processing for the Liquid-Argon Calorimeter at ATLAS — Anne-Sophie Berthold, •Nick Fritzsche, Markus Helbig, Rainer Hentges, Arno Straessner, and Johann Christoph Voigt — Institut für Kern- und Teilchenphysik (IKTP), TU Dresden, Germany

The Phase-II upgrade of the ATLAS detector will prepare for the high-luminosity phase of the LHC, where the number of proton-proton collisions occurring at the same time will increase significantly. This leads to higher requirements for the data processing, since the rate of detected particles in one detector cell will increase. New machine learning solutions are under development to better reconstruct the energy deposited in the calorimeter and its timing information than the current optimal filter approach.

This talk introduces the implementation of convolutional neural networks for FPGA hardware. The application of time division multiplexing is discussed, which is necessary to cover the high number of detector readout channels and to reuse the network for multiple input streams. The latest performance results in terms of FPGA resource usage, achievable operation frequency and latency are presented. To verify the hardware implementation, a software reference model was created and the precision of the calculation results was analyzed. At last, first preparations for tests on hardware are shown.

T 69.2 Wed 16:30 T-H28

Towards the next generation Level-1 Trigger of SuperCDMS — •Hanno Meyer zu Theenhausen — Karlsruher Institut für Technologie

The SuperCDMS SNOLAB dark matter search experiment targets sensitivity towards nuclear and electron recoils down to energies of a few eV. At the lowest energies, the detector sensitivity is limited by thermal and electronic noise. To extract signals from the noise with high efficiency and resolution, SuperCDMS employs a Level-1 trigger system implemented on an FPGA on custom-hardware detector readout cards. Therein, digitized input traces are analyzed in a complex trigger architecture with a finite-impulse-response (FIR) filter at its heart. The FIR is configured as an optimal filter (OF) which can cause pathological "echo triggers" in the presence of large pulses. This presentation reports on the Level-1 trigger architecture, the OF FIR design and how echo triggers are circumvented making use of the complex trigger logic. Furthermore, an outlook on the performance of a neural network trigger as a potential trigger upgrade is given.

T 69.3 Wed 16:45 T-H28

The ATLAS Forward Feature Extractor for the Phase-II trigger upgrade — •Adrian Alvarez Fernandez, Julian Blumenthal, Stefan Tapprogge, Ulrich Schaefer, and Bruno Bauss — Institut für Physik, Johannes Gutenberg Universität

The ATLAS detector will undergo many upgrades to account for the more challenging running conditions of the High Luminosity LHC. Some of these Phase-II upgrades will be focused on improving the trigger system, a crucial part to deal with the higher data rates and pile-up. Phase-I upgrades for Run 3 introduced the Feature EXtractors for a more refined processing of the calorimeter information and to better discriminate between jets, photons, electrons and taus. A Forward Feature EXtractor (fFEX) will be developed for the HL-LHC that will provide more flexible algorithms for the objects in the forward region ($|\eta|>2.5$ for electrons and photons and $|\eta|>3.2$ for jets). In contrast to the first level calorimeter trigger before HL-LHC, this new system will have access to the full detailed calorimeter granularity. The status of the preliminary design work on the fFEX will be presented and possible technology options will be discussed.

T 69.4 Wed 17:00 T-H28

Neural network based primary vertex reconstruction with FPGAs for the upgrade of the CMS level-1 trigger system — •Matthias Komm — Desy, Hamburg

A major challenge of the high-luminosity upgrade of the CERN LHC is to single out the primary interaction vertex of the hard scattering process from the expected 200 pileup interactions that will occur each bunch crossing. To meet this challenge, the upgrade of the CMS experiment comprises a complete replacement of the silicon tracker that will allow for the first time to perform the reconstruction of charged particle tracks and the primary interaction vertex at the hardware-based first level of the event trigger system (L1). Knowledge of the primary interaction vertex is a central component for distinguishing tracks and calorimeter clusters belonging to the hard scattering process from pileup interactions, which subsequently improves the energy estimate and resolution of physics objects such as jets and the missing transverse momentum. This talk will focus on the reconstruction of the primary vertex from tracks at L1 within the stringent time requirements of O(100ns) while being additionally restricted by the FPGA resource usage and latency. To optimally exploit and pass-on the available information at each stage of the vertex reconstruction, an algorithm based on an neural network model has been developed that possesses simultaneous knowledge about all stages and hence enables end-to-end optimization. Future plans for operating and tuning the algorithm on real data during data-taking will also be outlined.

T 69.5 Wed 17:15 T-H28

Development of machine-learning based topological selection algorithms for the upgraded L1 trigger system of the CMS detector — •Ihor Komarov, Johannes Haller, Finn Labe, Artur Lobanov, and Matthias Schröder — Institut für Experimentalphysik, Universität Hamburg

Future data-taking periods at the LHC bring a major increase of the instantaneous luminosity. To cope with the large detector occupancy within the bandwidth constraints, significant improvements of the trigger systems of the experiments are needed. The upgraded Level-1 trigger system of the CMS experiment will allow the execution of complex algorithms, such as neural networks, on field-programmable gate arrays (FPGAs).

In this talk, a first proof-of-concept study on fast neural-network-based selection algorithms for the L1 trigger system of CMS will be presented. The algorithms were benchmarked with top-quark and Higgs pair production signals. Preliminary results show significant performance improvements compared to existing algorithms.

T 69.6 Wed 17:30 T-H28

Anomaly detection as a new strategy for the CMS Trigger — •Sven Bollweg, Karim El Morabit, Gregor Kasieczka, and Artur Lobanov — University of Hamburg, Germany

There exist strong hints for the existence of physics beyond the standard model (BSM). To search for such BSM processes at the LHC, potential candidate events first need to be selected. At CMS, the first selection step is the Level 1 (L1) trigger, which decides whether an event is stored for further analysis. The trigger decision is usually based on criteria motivated by specific models. Another strategy uses the idea that BSM events differ from events originating from standard model (SM) processes. A trigger decision could then utilize this difference to detect anomalous event properties.

This talk discusses such an anomaly detection trigger based on neural networks. An autoencoder (AE) network is trained to reproduce SM events. Using the AE to reproduce BSM events with anomalous properties leads to a reduced quality which can be used for the trigger decision. Since the L1 trigger has a very limited time for the decision, the AE needs to be deployed on dedicated hardware in the form of field programmable gate arrays which presents additional challenges.

T 69.7 Wed 17:45 T-H28

Implementation of tracking algorithms for live reconstruction using AI processors — •Patrick Schwäbig[1], Jochen Kaminski[1], Michael Lupberger[1], Klaus Desch[1], and Stephen Neuendorffer[2] — [1]Physikalisches Institut, Universität Bonn, Deutschland — [2]Xilinx Research Labs, San Jose, USA

For years, data rates generated by modern detectors and the corresponding readout electronics exceeded by far the limits of bandwidth and data storage space available in many experiments. Using fast triggers to discard uninteresting and irrelevant events is a solution used to this day. FPGAs, ASICs or even directly the readout chip are programmed or designed to apply a fixed set of rules based on low level parameters for an event pre-selection.

Up until the last few years, live track reconstruction for triggering was rarely possible due to a conflict between processing time and the required trigger latency. With the emergence of novel fast and highly parallelized processors, targeted mainly at AI inference, attempts to sufficiently accelerate tracking algorithms become viable. The Xilinx Versal AI Series Adaptive Compute Acceleration Platform (ACAP) is one such technology and combines traditional FPGA and CPU resources with dedicated AI cores and a network on chip for fast memory access.

In this talk AI and non-AI algorithms for track reconstruction and especially their implementation on the Xilinx VCK190/Versal VC1902 Evaluation Kit for a dark photon experiment at the ELSA accelerator in Bonn will be shown and the expected performance will be discussed.

T 69.8 Wed 18:00 T-H28

A Hardware-Based Track Trigger — •Joachim Zinsser, Sebastian Dittmeier, and André Schöning — Physikalisches Institut, Universität Heidelberg

A hardware-based solution to filter interesting events more efficiently was explored for the planned increase in luminosity during the ATLAS Phase-II Upgrade. The plan is to install a filter based on the particles' tracks, which have to be evaluated in real-time. This task is well suited for implementation in hardware since, on the one hand, it requires only basic arithmetics and comparisons, and, on the other hand, it can be implemented in highly parallel hardware architecture, e.g., by exploiting FPGAs. This approach utilizes linear approximations to the helix parameters of trajectories and a database of simulated possible trajectories. A Track Fitter is implemented on the Stratix X FPGA from Intel with an integrated High Bandwidth Memory (HBM) for storing the simulated constants. In this talk, the final state of the firmware will be discussed and the implementation in hardware will be compared to simulation results and expectancies.

T 69.9 Wed 18:15 T-H28

Jet Tagging in the Level-1 Trigger of CMS for the HL-LHC — •Philipp Rincke, Karim El Morabit, Gregor Kasieczka, and Artur Lobanov — Institut für Experimentalphysik, Universität Hamburg

With the upcoming upgrade of the High-Luminosity LHC, triggering in the CMS experiment will become more challenging as more particles will be present in each event. A possible solution to the increased complexity could be to employ trigger algorithms that use inputs from all sub-detectors that will become available in future upgrades and the increased computing power of the FPGAs on which the algorithms of the Level-1 Trigger (L1T), the first trigger level in CMS, are implemented.

At the L1T track parameters and particle identification of some of the jet constituents will be available, making it possible to evaluate the jet substructure. Many high-energy physics analyses require jet flavour identification, for which the substructure information can be exploited. By attempting this in the L1T a higher fraction of interesting events could be recorded or thresholds could be lowered. One big challenge is that neural networks, often used in jet tagging, are not straightforward to deploy on FPGAs.

Besides the tagging performance, strict timing and resource limitations need to be considered, which results in a compromise between network architecture and size. In this talk we present studies on how jet tagging can be used in the L1T. We consider a simple multilayer perceptron architecture as well as graph-inspired network architectures.

T 70: Experimental Methods (general) 3

Time: Wednesday 16:15–18:30 Location: T-H29

T 70.1 Wed 16:15 T-H29

Calibration of the b-tagging mis-tag rate for charm jets based on W+c events at $\sqrt{s} = 13$ TeV with the ATLAS experiment — Johannes Erdmann and •Benedikt Gocke — TU Dortmund University, Department of Physics

Identifying jets containing heavy-flavour hadrons is needed for many analyses in the ATLAS experiment. This is done using flavour tagging algorithms. Since these algorithms need to be calibrated, it is important to also calibrate the mis-tag rate for non-heavy flavour jets. These calibrations are done by matching their performance in simulation to data.

The mis-tag rate calibration for c-jets using W+c events is presented, which allows for a relatively pure sample of c-jets. For this process, a prompt muon and a muon inside a jet (soft muon) are expected in the final state. Therefore, the usage of an event selection which selects events in regions defined by the electric charge of the expected muon pair in the final state is shown. Furthermore, the construction of a signal region to reduce the background contributions, which is based on the expected opposite-sign-charged lepton pair for the signal process is illustrated. The calculation of the efficiencies for the used heavy flavour tagger is shown. Finally, the resulting data-to-simulation scale factors are discussed.

T 70.2 Wed 16:30 T-H29

Convolutional Networks and Deep Learning at the Belle II Experiment — •Johannes Bilk, Sören Lange, Katharina Dort, Stephanie Käs, and Timo Schellhaas — Justus-Liebig-Universität, Gießen,Germany

The Belle II pixeldetector (PXD) has a trigger rate of up to 30 kHz for 8 M pixels. Its proximity to the interaction point allows it to detect exotic highly ionizing particles such as antideuterons, magnetic monopoles, stable tetraquarks or pions with small transverse momenta < 100 MeV. Those particles leave no tracks in the outer parts of the Belle II detector, and thus their pixel data may be deleted online as part of background suppression. In this contribution, we evaluate the performance of a machine learning algorithm to identify slow pions only on the basis of pattern recognition of pixel cluster structures. We employ convolutional neural networks with different kernel configurations and use images of 9x9 pixel matrices as input. On the long term such image recognition techniques could provide a rescue mechanism for the pixel data before they are erased. Results on accuracy and sensitivity are presented.

T 70.3 Wed 16:45 T-H29

b-Tagging studies for the ATLAS experiment — •Eleonora Loiacono — Deutsches Elektronen-Synchrotron DESY, Hamburg and Zeuthen, Germany

At the LHC, among the different Higgs boson production mechanisms, the associated production with a vector boson $VH \to \bar{b}b$ is considered as the golden channel for the measurement of the Higgs coupling to b-quarks, due to its high sensitivity. In the VH(bb) analysis, the available statistics of the simulated Monte Carlo (MC) samples is largely reduced by the b-tagging algorithms, especially for background processes, resulting in large statistical fluctuations in the MC templates. The first study that will be presented, is related to the reduction of this statistical uncertainty. In order to avoid being dominated by this uncertainty a technique based on Truth Tagging is performed, exploiting a Graph Neural Network to make an optimal use of multidimensional information associated to jets. The second study relies on improving of the connection between Flavour Tagging scale factors measured on data and those corresponding to MC to MC variations. b- tagging is very important for VH(bb) and the calibration procedures provide the use of the Scale Factors (SF). The so-called smoothing procedure is currently applied to these SF, which allows to have SF that are not dependent on the binning of the histograms used to do the calibration. In particular, there will be a focus on reviewing the currently smoothing procedure and also on including more statistical tests on procedure currently adopted for data SF.

T 70.4 Wed 17:00 T-H29

Extrapolation of flavour tagging calibrations to high transverse momenta — Arnulf Quadt, Elizaveta Shabalina, and •Sreelakshmi Sindhu — II. Physikalisches Institut, Georg-August-Universität Göttingen

Identifying jets containing heavy flavoured hadrons can be very beneficial for a variety of analyses and this can be done using flavour tagging algorithms. Currently, these algorithms are calibrated by matching their performance on data to simulation. However, for jets with transverse momentum greater than a few hundred GeV these calibrations do not exist due to statistical limitations. Flavour-tagging information for jets with high transverse momenta can be quite useful for analysis such as search for heavy resonances. Hence, a Monte Carlo based extrapolation of the data based flavour tagging calibrations is done to extend these up to 3 TeV. The extrapolation uncertainties are calculated by propagating the relevant modelling, tracking and jet uncertainties through the tagging algorithm. In this talk, the extrapolation procedure will be explained and the results from my work on the extrapolation uncertainties for charm and light jets will be presented for the b-tagging algorithms (DL1, DL1r) that are used for the analysis of the Run 2 data by the ATLAS Collaboration.

T 70.5 Wed 17:15 T-H29

Utilizing muons to tag b-jets in ATLAS — •Frederic Renner, Clara Elisabeth Leitgeb, and Cigdem Issever — DESY, Zeuthen, Germany

Several Beyond Standard Model theories predict Higgs boson pair production with much larger cross sections compared to the Standard Model. While Higgs boson pair production has not yet been observed at the LHC due to the rarity of the process, it may come within reach with more data in upcoming runs with improved statistics and improved particle reconstruction. A Higgs boson pair decays predominantly into four b-quarks, which makes the identification of jets originating from b-quarks particularly important. B-quarks have a longer lifetime than lighter quarks, leading to a second displaced vertex separated from the primary vertex which is mainly exploited in b-tagging algorithms. However, when using the results in a neural network to distinguish the flavor origin of jets, the network still misidentifies a lot of jets originating from lighter quarks as b-quark jets. About 20% of b-quarks decay semileptonically with a so-called soft muon in the final state. They are soft because they are generally less energetic than particles originating from the primary vertex. Utilizing the muon information, the rejection of fake b-jets can be improved substantially at a given selection efficiency.

T 70.6 Wed 17:30 T-H29

Signal efficiency corrections for boosted $X \to b\bar{b}$ tagger using $Z \to b\bar{b}$ events with the ATLAS experiment — •Daariimaa Battulga, Arely Cortes Gonzalez, and Cigdem Issever — Institut für Physik, Humboldt-Universität zu Berlin

It is of utmost interest to efficiently identify a new heavy resonant particle or to study boosted Higgs boson decaying into a pair of b-quarks in the ATLAS experiment. Particles produced with high transverse momentum (p_T) will have very collimated decay products in the final state. This boosted topology makes it particularly challenging to distinguish two b-jets in the calorimeter. To overcome this, these b-jet fragmentations are clustered within a large radius R=1.0 jet, and its associated track jets are b-tagged. However, even with this approach, the double b-tagging efficiency decreases at the large p_T. The boosted $X \to b\bar{b}$ tagger improves the efficiency of the b-tagging at the higher p_T region. This double b-tagger is based on the neural network that uses the kinematic distributions of the large-R jet and flavour information of variable radius track jets. In order to apply this $X \to b\bar{b}$ tagger to the physics analysis, it needs a dedicated calibration.

Hence, this talk presents the in situ signal efficiency calibrations of a new $X \to b\bar{b}$ tagger using $Z \to b\bar{b}$ events. We have derived the data-to-simulation scale factors using full Run 2 pp collision data collected by the ATLAS experiment at the center of mass energy of $\sqrt{s} = 13$ TeV with an integrated luminosity of $\mathcal{L} = 139\,\text{fb}^{-1}$. The signal efficiency corrections covering the soft (hard) p_T region are derived using $Z \to b\bar{b}$ events with a recoiling photon (jets).

T 70.7 Wed 17:45 T-H29

A machine-learning based method to improve isolation variables for photon identification with the ATLAS detector — Johannes Erdmann, Olaf Nackenhorst, and •Michael Windau — TU Dortmund University, Department of Physics

The study of photons is crucial for finding and measuring many processes at colliders. Predominantly, prompt photons, which are created during the collisions, play an important role and have to be distinguished from hadrons decaying into photons. Different methods are used to distinguish this signal from the background. One of these is the use of isolation variables. These are based on track measurements and information from the calorimeters, where they are defined by the activity in a cone around the candidate object. They are currently built in ATLAS by discrete cuts.

In this talk, studies on improving isolation variables using deep neural networks will be presented.

T 70.8 Wed 18:00 T-H29

Data-driven corrections to shower shape variables for photon identification at the ATLAS experiment with 13 TeV *pp* collision data — •Jan Lukas Späh, Björn Wendland, and Johannes Erdmann — Technische Universität Dortmund, Fakultät Physik

Measurements of Standard Model processes, searches for new particles or processes forbidden in the Standard Model with photons in the final state play an important role in the physics programme of the ATLAS experiment. At hadron colliders, studies of photons are particularly challenging, as large background contributions arise from jets that can be misidentified as photons. This requires an identification algorithm that provides high efficiency for genuine photons while ensuring an excellent background rejection for misreconstructed objects.

Currently, this method relies on rectangular cuts on so-called shower shape variables, which capture relevant information about the shape and evolution of the electromagnetic shower and the possible leakage into the hadronic calorimeter. While the longitudal shower development through the calorimeter layers is modelled well, residual mismodelling is observed for lateral shower shape distributions. Therefore, the simulated distributions are corrected with a data-driven approach.

In this talk, studies of univariate first- and second-order corrections obtained from the full Run 2 dataset are discussed and recent improvements are highlighted.

T 70.9 Wed 18:15 T-H29

Towards tuning electromagnetic shower properties to data with AtlFast3 — •Joshua Beirer[1,2], Michael Duehrssen[1], and Stan Lai[2] — [1]CERN — [2]Georg-August-Universität Göttingen

AtlFast3 is the next generation of high precision fast simulation in ATLAS and encompasses a parametrised and a machine-learning approach based on Generative Adversarial Networks (GANs). With respect to its predecessor, AtlFast3 significantly improves in physics performance while retaining the benefit of a considerably faster simulation in comparison to Geant4.

A precise simulation of electromagnetic (EM) shower properties in the ATLAS calorimeter is crucial for the identification of particle showers originating from electrons and photons. While AtlFast3 precisely simulates the properties of EM showers, it inevitably inherits any mismodelling of the full Geant4 simulation, upon which its parametrization is based. Differences between the Geant4 simulation and data collected by the ATLAS detector are well known but insufficiently understood. Traditionally, these discrepancies are corrected using ad hoc methods such as the applications of shifts to the central values of the corresponding distributions, a procedure known as fudging.

In this talk, a brief overview of fast simulation in ATLAS is given. Furthermore, the development of different models directly embedded within the simulation framework used to tune EM shower properties directly to data are described and it is shown that AtlFast3 can be modified in a way that the shower shapes observed in data are accurately reproduced by the simulation.

T 71: Neutrino Astronomy 3

Time: Wednesday 16:15–18:30 Location: T-H30

T 71.1 Wed 16:15 T-H30

Up-going high energy showers with the fluorescence detector of the Pierre Auger Observatory — Ioana Alexandra Caracas and •Karl-Heinz Kampert for the Pierre Auger-Collaboration — Bergische University Wuppertal, Gaußstr. 20, Wuppertal, Germany

The ANITA observations of two steeply up-going cosmic ray like showers with energies above 10^{17} eV remain unexplained. The Fluorescence Detector (FD) of the Pierre Auger Observatory is also sensitive to such phenomena, given its wide field of view and substantial operation time. Using 14 years of available FD data, the post-selection exposure to up-going induced showers exceeds the one of ANITA by a factor of at least 10, as indicated from dedicated studies. Therefore a search for up-going induced air showers with the FD can be used to either refute or confirm the occurrence of such intriguing events.

We have conducted a generic search for upward cosmic ray like induced air showers using the FD of the Pierre Auger Observatory. Dedicated Monte Carlo simulations of both signal and expected background, together with the usage of a 10% burn data sample, have been used in order to apply selection criteria and calculate the resulting FD exposure. The unblinding of the data indicates no excess found above background expectations. As a result, preliminary upper limits are set on the flux of up-going cosmic ray like induced air showers.

**Gefördert durch die BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A20PX1)*

T 71.2 Wed 16:30 T-H30

Constraining BSM scenarios producing up-going τ induced air showers with the Pierre Auger Observatory* — •Ioana Alexandra Caracas for the Pierre Auger-Collaboration — Bergische University Wuppertal, Gaußstr. 20, Wuppertal, Germany

High energy steeply up-going air showers as observed by ANITA can't be explained by Standard Model (SM) physics and require Beyond Standard Model (BSM) scenarios. τ-leptons decaying in the atmosphere represent the main primary candidates for such showers.

The Pierre Auger Observatory has set strict upper limits on the flux of up-going cosmic ray like air showers. The generic search is recast here in terms of BSM particles producing up-going τ-leptons. In any such BSM scenario a significantly reduced cross section of the hypothetical particle with matter is required, allowing them to propagate through the Earth with sufficiently low interaction probability. Interactions close to the surface could result in the creation of τ-leptons that escape into the atmosphere to induce up-going showers. The optimum BSM cross section for this to happen is found to be $\sigma_{\rm BSM} \approx 10^{-2}\sigma_\nu$.

Using both the Surface Detector and the Fluorescence Detector data, combined upper limits are set on particles creating up-going τ-leptons for different BSM scenarios.

**Gefördert durch die BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A20PX1)*

T 71.3 Wed 16:45 T-H30

Search for a high energy neutrino flux from Gamma Ray Bursts using the Pierre Auger Observatory* — •Tobias Heibges for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstraße 20 42119 Wuppertal, Germany

Gamma Ray Bursts (GRBs) are among the most violent explosions known in the Universe. A characteristic feature is a very high flux of gamma rays produced in these explosions which can be observed and located by satellites, such as the Swift and Fermi satellites.

A high energy gamma ray flux can be interpreted as an indication for the acceleration of charged particles up to the highest energies. Therefore, Gamma Ray Bursts are among the prime candidates to be sources of ultra high energy cosmic rays (UHECRs). High energy neutrinos are commonly regarded as a smoking gun indicator of UHECR acceleration and as they are not deflected by magnetic fields they can be easily traced back to their source and thereby contribute to unraveling the mystery about the origin of UHECRs.

The Pierre Auger Observatory is sensitive to high energy neutrinos with energies beyond $\sim 10^{17}$ eV. In this talk the non-observation of any high energy neutrino events is used to set an upper limit on the high energy neutrino flux seen on earth, produced by GRBs.

* Supported by BMBF Verbundforschung, grant 05A20PX1

T 71.4 Wed 17:00 T-H30

Event selection for new triggers used for neutrino detection at the Pierre Auger Observatory* — •Srijan Sehgal for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Wuppertal, Germany

The Pierre Auger Observatory with its large array of Surface Detector (SD) stations can be used to detect highly inclined neutrino-induced extensive air showers. Two new SD triggers, time-over-threshold-deconvolved (ToTd) and multiplicity of positive steps (MoPS), installed in 2014 were shown to vastly increase the detection capability for the neutrino-induced air showers in the lower energy ($\mathrm{E} < 10^{19}$eV) regime with a little to no change in background events.

This talk analyzes the event selection procedure on data and neutrino-induced showers simulated with CORSIKA both reconstructed using the Auger software framework. Events in the zenith angle range of $60^o < \theta < 75^o$ and energies below 10^{19}eV are selected to investigate the low-energy performance of the new triggers. The main point of focus is the effect of the new triggers on efficiency and purity of an improved neutrino selection.

**Gefördert durch die BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A20PX1)*

T 71.5 Wed 17:15 T-H30

Reconstruction performance using RNO-G — •Sjoerd Bouma for the RNO-G Collaboration-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Erwin-Rommel-Str. 1, D-91058 Erlangen

RNO-G is an in-ice radio detector in Greenland which aims to detect Extremely High Energy (EHE) neutrinos through the Askaryan effect. Deployment started in Summer 2021, with the first 3 out of a planned 35 detector stations now built and taking data. As the first production-scale in-ice radio neutrino detector, RNO-G both complements as well as helps to inform the design of the planned radio extension of IceCube-Gen2.

One important aspect of RNO-G and potential future radio neutrino detectors, aside from their effective volume, is the ability to reconstruct the properties of detected (neutrino-induced) radio shower signals. An accurate reconstruction of the neutrino direction is crucial in order to identify potential sources of EHE neutrinos. We will present a brief overview of the current state of reconstruction performance using algorithms developed for the open-source NuRadioMC software package by the RNO-G collaboration, and provide an outlook for future improvements.

T 71.6 Wed 17:30 T-H30

Data reduction for the Radio Neutrino Observatory Greenland — •Zachary Meyers for the RNO-G Collaboration-Collaboration — DESY, Platanenallee 6, 15738 Zeuthen, Germany — Erlangen Center for Astroparticle Physics (ECAP), Friedrich-Alexander-University Erlangen-Nuremberg, 91058 Erlangen, Germany

Continuing the search for utra-high energy neutrinos (> 10 PeV) beyond the range of optical detection methods, the Radio Neutrino Observatory Greenland (RNO-G) is now online after a successful first season of deployment. Total data taken during the shortened 2021 campaign from the three operational stations amounts to nearly ten million recorded events, requiring more than 330GB of storage. While this could be considered a manageable sum, next year another 7 stations are planned to come online, while the complete array will consist of 35 total. And for future experiments, requiring hundreds of similar stations, the data volumes rapidly increase to a level where it is no longer feasible to run direction and energy reconstruction algorithms on the entire dataset. Low level cuts must be made early in the data processing stages (or even onboard the detector itself in real time) in order to be computationally efficient. In an attempt to discriminate between thermal noise fluctuations, anthropogenic noise and neutrino-like signal, we show the potential effectiveness of deep learning approaches, specifically convolutional neural networks (CNNs), in both the time and frequency domains. When compared and combined with more traditional methods such as matched filtering, a comprehensive strategy for post trigger filtering can be established.

T 71.7 Wed 17:45 T-H30

Cosmic ray detection efficiency and implications for in-ice radio detectors for high-energy neutrinos — •Lilly Pyras for the RNO-G Collaboration-Collaboration — DESY, Platanenallee 6, 15738 Zeuthen, Germany — Erlangen Center for Astroparticle Physics (ECAP), Friedrich-Alexander-University Erlangen-Nuremberg, 91058 Erlangen, Germany

A promising technique to measure neutrinos above 10 PeV is the detection of radio signals generated by the Askaryan effect. The emission is caused by neutrino-induced particle cascades in dense media e.g. ice. Since 2021 the Radio Neutrino Observatory Greenland (RNO-G) is being deployed, consisting of in-ice strings of antennas down to 100 m and antennas closer at the surface. One of the main challenges of the data analysis is distinguishing between background stemming from cosmic rays e.g. high energy muons and a real neutrino event. By building the detector with surface antennas we can use the established method of radio detection of air showers to identify incoming muons and use these signals as veto mechanism in the neutrino detection. An efficient veto trigger will lend higher confidence in identifying neutrinos and prevent the false positive neutrino detections caused by muons. This report presents the development of tagging incoming air showers as veto and analyses its performance.

T 71.8 Wed 18:00 T-H30

Search for periodic low energy neutrino sources — •Maximilian Eff for the ANTARES-KM3NET-ERLANGEN-Collaboration — ECAP, Friedrich-Alexander Universität Erlangen-Nürnberg (FAU), Erlangen, Germany

Pulsars are rotating neutron stars that emit beams of electromagnetic radiation. Neutrino emission from pulsars has been the subject of phenomenological models during the last decades. So far, experimental data has not shown any significant neutrino emission at high energies. This contribution reports about the development of a novel approach that aims at identifying low-energy neutrinos from periodic sources with a neutrino telescope. This is done by applying a Fast Fourier Transformation to the PMT counting rate time series.

T 71.9 Wed 18:15 T-H30

PLEnuM: A world-wide monitoring system of high-energy astrophysical neutrinos — •Lisa Schumacher[1], Matteo Agostini[2], Mauricio Bustamante[3], Foteini Oikonomou[4], and Elisa Resconi[1] — [1]ECP, TU Munich, GER — [2]UCL, London, UK — [3]NBI, Copenhagen, DEN — [4]NTNU, Trondheim, NOR

The discovery of high-energy astrophysical neutrinos by IceCube has shaped neutrino astronomy in the recent years. However, the observation rate of astrophysical neutrinos in the TeV-PeV energy range remains small, such that various questions about high-energy neutrinos and their astrophysical origin remain open. This situation will improve when new neutrino telescopes will come online in the next years: KM3NeT, Baikal-GVD and P-ONE in the Northern Hemisphere, as well as IceCube-Gen2 as extension of IceCube in the Southern Hemisphere. In order to answer our open questions, we propose the Planetary Neutrino Monitoring System (PLEnuM), a concept for a combined repository of world-wide high-energy neutrino observations. PLEnuM can reach more than four times the exposure available today by combining the exposures of the current and future neutrino telescopes distributed around the world. Depending on the declination, spectral index, and flavor, PLEnuM will improve the sensitivity to astrophysical neutrinos by up to two orders of magnitude. We present first estimates on the capability of PLEnuM to discover Galactic and extragalactic sources of astrophysical neutrinos and to characterize the diffuse flux of high-energy neutrinos in unprecedented detail.

T 72: Cosmic Ray 3

Time: Wednesday 16:15–18:30 Location: T-H31

T 72.1 Wed 16:15 T-H31

Using in-ice muons for Cosmic-Ray composition analysis at IceCube Observatory — •Paras Koundal for the IceCube-Collaboration — Institute for Astroparticle Physics, KIT Karlsruhe, Germany

Understanding the dynamics of astrophysical sources is a pursuit that is very dear to many astrophysicists. Cosmic-Rays (CRs), charged particles from these astrophysical accelerators, provide us with a unique opportunity to discern the fundamental properties and behavior of such sources. IceCube Neutrino Observatory, concealed deep under the South-Pole Antarctic ice, detects the particles from these astrophysical sources. The integrated operation of the in-ice array of IceCube (primarily a neutrino detector), with its surface array, IceTop, affords us unique three-dimensional detection capabilities for CR-induced air showers.

The talk will discuss the work done to use the in-ice shower-footprint primarily caused by high-energetic muons in cosmic-ray air-showers, for improving cosmic-ray composition estimation at IceCube Observatory. The work will introduce new composition-sensitive parameters with minimal dependence on hadronic-interaction models. Hence, the work provides a suitable solution for detailed composition analysis while reducing systematic effects of choosing a hadronic-interaction model for interpretation of observed real data.

T 72.2 Wed 16:30 T-H31

Unfolding the Atmospheric Muon Spectrum Using Stopping Muons in IceCube — •Lucas Witthaus, Karolin Hymon, Johannes Werthebach, Janina Bolles, and Jan Soedingrekso for the IceCube-Collaboration — Astroparticle Physics WG Rhode, TU Dortmund University, Germany

The IceCube Neutrino Observatory is a cubic-kilometer neutrino detector located in the ice sheet close to the geographical South Pole. However, the majority of detected events is caused by atmospheric muons created in cosmic ray induced air showers in the upper layers of the atmosphere. Upon entering the antarctic ice, they lose energy in interactions with the surrounding matter, resulting in a limitation of their propagation length.

This talk presents the unfolding of the stopping muon depth intensity by means of a maximum likelihood approach. It is conducted on a subset of events, comprising single muons, which stop inside the IceCube detector. Deep neural networks are used to perform the event classification and reconstruction tasks.

T 72.3 Wed 16:45 T-H31

Towards the Energy Spectrum of Cosmic Rays using Atmospheric Stopping Muons in IceCube — •Janina Bolles, Karolin Hymon, Johannes Werthebach, Lucas Witthaus, and Jan Soedingrekso for the IceCube-Collaboration — Astroparticle Physics WG Rhode, TU Dortmund University, Germany

In the IceCube Neutrino Observatory the main type of detected events are muons being produced by cosmic ray particles interacting with the Earth's atmosphere. In the context of neutrino analyses, these muons are the dominant background. In case of cosmic ray physics the energy losses of the muons within the detector can be used as an indicator to reconstruct the cosmic ray energy spectrum.

In this work, muon events stopping inside the detector are selected to use the range to the stopping point as a proxy for the muon energy. This approach takes advantage of the high statistics of atmospheric muons. Strict cuts on the reconstruction can be applied to obtain an event sample of single muons with high resolution. The reconstructed range of the muons can be used to estimate the cosmic ray energy spectrum. First results of the unfolded cosmic ray flux are presented.

T 72.4 Wed 17:00 T-H31

An updated model of galactic diffuse neutrinos for future IceCube searches — •Georg Schwefer[1,2], Philipp Fürst[2], Erik Ganster[2], Philipp Mertsch[1], and Christopher Wiebusch[2] — [1]RWTH Aachen University - Institute for Theoretical Particle Physics and Cosmology, Aachen, Germany — [2]RWTH Aachen University - Physics Institute III B, Aachen, Germany

Diffuse galactic neutrinos are produced in interactions of hadronic cosmic rays with the interstellar medium in the Milky Way. This flux is a practically guaranteed signal for high-energy neutrino observatories. It has not been identified yet, but recent searches indicate that a discovery might be in reach within the next few years.

Because of the large background from atmospheric neutrinos, these searches require detailed modelling of the signal. These models also relate the (non-)observations to the propagation and injection properties of galactic cosmic rays at PeV energies.

In this talk, we present an updated model for the galactic diffuse neutrino flux tuned to the latest direct cosmic ray and diffuse gamma ray measurements, and discuss its systematic dependencies. We also show sensitivity estimates for future IceCube galactic plane searches with this model.

T 72.5 Wed 17:15 T-H31

Neural networks for cosmic ray simulations — •Pranav Sampathkumar, Antonio Augusto Alves Junior, Tanguy Pierog, and Ralf Ulrich for the CORSIKA 8-Collaboration — Institute for Astroparticle Physics (IAP) - KIT

Simulating cosmic ray showers at high energies is very memory and time intensive. Current model-dependent hybrid techniques are constrained by our ability to model from known physics. This contribution discusses novel machine learning techniques in order to bypass explicit simulations, and extract features which can't be modeled easily from first principles. The potential of Generative Adversarial Neural Networks (GANs) in learning and emulating cosmic ray simulations is discussed, along with a presentation of preliminary attempts in using a GAN in generating universal electron-positron distributions associated to showers with varying primaries and energies. The applicability and potential pitfalls in using a neural network based approach for cosmic ray simulations is also discussed. Finally, a CONEX (hybrid simulations using cascade equations) inspired Recurrent Neural network (RNN) model is presented. Preliminary results obtained from training an RNN using a cosmic ray simulation dataset for electromagnetic cascades generated using CORSIKA8 are summarized.

T 72.6 Wed 17:30 T-H31

Extrapolation uncertainty of meson-air cross-sections in UHECR air shower simulations — •Maximilian Reininghaus[1,2], Ralf Ulrich[1], Ralph Engel[1], and Tanguy Pierog[1] — [1]Karlsruher Institut für Technologie, Karlsruhe, Deutschland — [2]Instituto de Tecnologías en Detección y Astropartículas, Buenos Aires, Argentina

The interaction cross-sections of long-lived hadrons with air nuclei are an important ingredient in the simulation of air showers initiated by high energy cosmic rays. For protons they are tightly constrained by LHC measurements. For other species, in particular pions, which are the most abundant hadrons in air showers, however, precise measurements are available only at low energies. Since there exists significant leeway in a large energy range up to the highest energies, hadronic interation models differ in their extrapolations by up to 30 %.

In this contribution, we study the impact of this extrapolation uncertainty on air shower phenomenology by introducing ad hoc, energy-dependent factors to scale the cross-sections for each species independently. Using a hybrid setup with CORSIKA 8 and CONEX, we simulate UHECR air showers with these modified cross-sections and study the effect on muon content, shower maximum and muon production depth. We find that the longitudinal development is sizeably affected, while the particle content changes only to a minor degree.

T 72.7 Wed 17:45 T-H31

Simulating radio emission from air showers with CORSIKA8 — •Nikolaos Karastathis[1], Remy Prechelt[2], Tim Huege[1,3], and Juan Ammerman-Yebra[4] for the CORSIKA 8-Collaboration — [1]Institute for Astroparticle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]Department of Physics and Astronomy, University of Hawaii Manoa, Hawaii, USA — [3]Astrophysical Institute, Vrije Universiteit Brussel, Brussels, Belgium — [4]Instituto Galego de Física de Altas Enerxías, Universidade de Santiago de Compostela, Santiago de Compostela, Spain

CORSIKA 8 (C8) is a new framework for air shower simulations implemented in modern C++17, based on past experience with existing codes like CORSIKA 7. It is a project structured in a modular and flexible way that allows the inclusion and development of independent modules that can produce a fully customizable air shower simulation. The calculation of radio emission from the simulated particle showers is incorporated as an integral module of C8, including signal propagation and electric field calculation at each antenna location using the "Endpoints" and ZHS formalisms simultaneously. Due to C8's flexibility, the radio functionality can be used both to validate other physics modules and to investigate specific physical scenarios. In this talk, we are going to present air shower simulations generated with C8 and compare their predicted radio emission with corresponding air showers simulated with CORSIKA 7 and ZHAireS. Radio calculation validation, a comparison of the "Endpoints" and ZHS formalisms along with the future steps of radio in C8 are also going to be shown.

T 72.8 Wed 18:00 T-H31

Energy Reconstruction using a Template Method for Radio Signal of Air Showers recorded by the Prototype Station of the IceCube Surface Enhancement — •Roxanne Turcotte for the IceCube-Collaboration — Institut für Astroteilchenphysik, Karlsruher Institut für Technologie (KIT)

The IceTop array, located at the surface of the IceCube Neutrino Observatory, is currently used as a veto for the in-ice neutrino detection as well as a cosmic-ray detector. Over the years, snow accumulated on the IceTop detector leading to a reduction of its sensitivity and resolution. In order to improve the detector, an enhancement of IceTop is planned in the coming years which consists of an array of scintillation panels and radio antennas. The radio antennas will lead to a better resolution of the energy and the depth of shower maximum (X_{max}) around the second knee region of the cosmic-ray energy spectrum. Eventually, hybrid detection will enable a better estimation for the mass of the primary cosmic ray.

In January 2020, a prototype station comprising three antennas and eight scintillation panels was deployed at the South Pole. We developed the tools necessary to use a template-matching method for energy reconstruction and applied it to some of the radio events recorded. This template method uses Monte-Carlo simulations and compares it to recorded data. For this, a set of simulations is created using the reconstruction by IceTop as input to CORSIKA/CoREAS. In this talk, we will present the method and the preliminary results.

T 72.9 Wed 18:15 T-H31

IceAct Upgrade Status - SiPM Based Compact Imaging Air-Cherenkov Telescopes for IceCube — •Hannah Erpenbeck, Thomas Bretz, Lars Heuermann, Cengiz Kuruoglu, Frank Malowski, Mark Meyers, Florian Rehbein, Merlin Schaufel, and Christopher Wiebusch for the IceCube-Collaboration — RWTH Aachen University - Physics Institute III B, Aachen, Germany

IceAct is an array of compact imaging air Cherenkov telescopes that are optimized for the harsh conditions of the South Pole. Since January 2019 two IceAct telescopes, featuring 61 SiPM pixels and a Fresnel lens based optics, operate at the surface above IceCube in the center of IceTop. By hybrid measurements of cosmic rays together with the IceTop and the IceCube detectors, they enable improved cosmic ray studies and cross calibrations. Six new telescopes are currently being assembled as an upgrade for IceAct. To ensure high instrument reliability, each of the telescopes is tested individually including field tests and strict quality assurance of all components. This talk will report on the project status as well as on the construction and the testing results of the new telescopes.

T 73: Cosmic Ray 4

Time: Wednesday 16:15–18:15 Location: T-H32

T 73.1 Wed 16:15 T-H32

Probing magnetic fields in the Galactic halo and studing their effects on arrival direction of cosmic rays — •Vasundhara Shaw, Andrew Taylor, and Arjen Van Vliet — Deutsches Elektronen-Synchrotron (DESY), Zeuthen, Germany

The Galactic halo in the past was less explored than other regions of the Galaxy. However, in the last decade, this has started to change with the observation of the Fermi bubbles and the latest eROSITA bubbles, we know that there is much to unravel in this region.

These large extended Galactic halo bubbles can play a key role in the magnetic field structure of the Galaxy. The magnetic fields for the bubble region have so far been largely masked out in the models however, the strength and geometry of magnetic fields in this region can be fundamental not only in understanding the Galactic magnetic fields but also the deflection of extra-Galactic cosmic rays.

In this talk, I will try to motivate the reason behind our toy model magnetic field for the Galactic halo and highlight how it compares with radio observation data. The second part of this talk will focus on the effect arrival directions of cosmic rays from our toy model and compare it with other existing magnetic field models.

T 73.2 Wed 16:30 T-H32

Incorporating the Galactic magnetic field into the propagation effects of cosmic rays in the transition region* — •Alex Kääpä — Bergische Universität Wuppertal, Gaußstr. 20, 42119 Wuppertal

In the energy range signifying the transition from Galactic to extragalactic cosmic rays (GCRs and EGCRs), propagation in the Galactic magnetic field (GMF) changes from diffusive to ballistic. This leads to a range of observable effects vital to understanding the respective contributions of GCRs and EGCRs to the total flux. GCRs more readily leak out of the Galaxy with increasing energy and, hence, the flux arriving at Earth is suppressed. EGCRs experience two competing effects, shielding from as well as confinement in the Galactic plane, both of which weaken with energy. These effects have been re-confirmed to cancel exactly in the case of isotropic injection. Flux modifications can occur in the case of an anisotropic EGCR flux into the Galaxy. Their nature depends both on the type and direction of the anisotropy.

In this talk, we present the propagation effects that the GMF imposes on the flux of GCRs and EGCRs. We incorporate these into minimal, experimentally and theoretically motivated injection spectra of GCRs and EGCRs. With this incorporation, we seek to retrieve a more realistic picture of the expected flux arriving at Earth, and to better estimate the nature and degree of possible additional contributions to the injected flux.

* Gefördert durch die BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A20PX1).

T 73.3 Wed 16:45 T-H32

Influence of diffusive cosmic-ray transport on multi-messenger observables — •Patrick Reichherzer[1,2,3], Julia Becker Tjus[1,2], Lukas Merten[1,2], Leander Schlegel[1,2], Julien Dörner[1,2], M.J. Pueschel[4,5], and Ellen Zweibel[6] — [1]Theoretical Physics IV: Plasma-Astroparticle Physics, Faculty for Physics & Astronomy, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [2]Ruhr Astroparticle And Plasma Physics Center (RAPP Center), Bochum, Germany — [3]University Paris-Saclay, France — [4]Dutch Institute for Fundamental Energy Research, 5612 AJ Eindhoven, The Netherlands — [5]Eindhoven University of Technology, 5600 MB Eindhoven, The Netherlands — [6]Department of Astronomy, University of Wisconsin-Madison, Madison, WI 53706, U.S.A.

Cosmic-ray transport in astrophysical environments is often dominated by diffusion in a magnetic field with a turbulent component. The diffusion properties of charged particles directly influence observable properties, such as the spectrum of cosmic rays and their secondaries produced in interactions. In many diffusion scenarios, the simplified assumption of fully resonant Kolmogorov diffusion in the quasi-linear limit results in a parallel diffusion coefficient $D \propto E^{1/3}$. A quantitative investigation of the scattering regimes, however, shows that the diffusion coefficient tensor can deviate significantly from this behaviour. In this talk, the complex dependencies of charged particle diffusion on the turbulence level of the magnetic field are presented. Examples of how this affects observational signatures will be shown in the context of galaxies or the transient sky, i.e., flaring Blazars.

T 73.4 Wed 17:00 T-H32

Perception of arrival direction maps of cosmic rays — •Edyvania Emily Pereira Martins[1], Markus Roth[2], and Darko Veberič[2] — [1]Institut für Experimentelle Teilchenphysik - Karlsruher Instituts für Technologie, Karlsruhe, Germany — [2]Institut für Astroteilchenphysik - Karlsruher Instituts für Technologie, Karlsruhe, Germany

The processing of visual information in the human brain is guided by identifying colors and patterns formed by same-color areas. In cosmic-ray research, two main interests are to relate detected events to their sources and to identify excess regions in the sky. In this pursuit, maps of arrival directions are a commonly used tool. Depending on the choice of the smoothing applied to the maps, the plotting can render different locations of the perceived flux-excess regions on the map, represented in a different color to the flux-deficit regions. In addition, the most commonly used smoothing fabricates structures that are not real nor significant, and can lead to misinterpretation. An alternative to the standard, top-hat smoothing is presented, which facilitates the interpretation of data.

T 73.5 Wed 17:15 T-H32

Self-confinement of low-energy cosmic rays around supernova remnants — •Hanno Jacobs, Philipp Mertsch, and Vo-Hong Minh Phan — TTK RWTH Aachen

Supernova Remnants have long been considered as promising candidate sources for cosmic rays. However, modelling the transport around these sources is difficult due to its nonlinear nature. The strong overdensity in the near source region leads to the production of plasma turbulence, upon which the particles scatter. To calculate this mechanism, called self-confinement, requires the numerical solution of two coupled differential equations describing the transport of particles and waves. Here, this formalism is extended to energies below 10 GeV, where energy losses become relevant. Particles around 100 MeV are found to be confined for in between 300 kyr and 1 Myr, depending on the interstellar medium. The diffusion coefficient is initially suppressed by up to two orders of magnitude. Interestingly, the spectrum outside the supernova flattens below 1 GeV at later times, similar to the spectral behaviour observed by Voyager. Furthermore, the grammage accumulated in the near source region is found to be non-negligible, which could be important for precision fitting cosmic ray spectra.

T 73.6 Wed 17:30 T-H32

No longer ballistic, not yet diffusive–the formation of cosmic ray small-scale anisotropies — •Marco Kuhlen, Vo Hong Minh Phan, and Philipp Mertsch — TTK Institut, RWTH Aachen

In the standard picture of cosmic ray transport the propagation of charged cosmic rays through turbulent magnetic fields is described as a random walk with cosmic rays scattering on magnetic field turbulence. This is in good agreement with the highly isotropic arrival directions as this diffusion process effectively isotropizes the cosmic ray distribution. However, high-statistics observatories like IceCube and HAWC have observed significant deviations from isotropy down to very small angular scales. This is in strong tension with this standard picture of cosmic ray propagation. By relaxing one of the assumptions of quasi-linear theory and explicitly considering the correlations between the fluxes of cosmic rays from different directions, we show that power on small angular scales is a generic feature of particle propagation through turbulent magnetic fields. We present a first analytical calculation of the angular power spectrum assuming a physically motivated model of the magnetic field turbulence and find good agreement with numerical simulations. We argue that in the future, the measurement of small-scale anisotropies will provide a new window to testing magnetic turbulence in the interstellar medium.

T 73.7 Wed 17:45 T-H32

Non-thermal ion acceleration at highly oblique non-relativistic shocks — •Naveen Kumar and Brian Reville — Max-Planck Institute for Nuclear Physics Heidelberg, Germany

Non-thermal acceleration of particles (both electrons and ions) at an oblique, non-relativistic shock is demonstrated by using one-dimensional large-scale particle-in-cell simulations. Our results show the generation of non-thermal ions at highly oblique shocks with acceleration efficiencies of $\sim 5\%$ measured at the end of simulation runs. These results have important implications for understanding the non-thermal radiation generation at astrophysical sites such as supernova remnants.

T 73.8 Wed 18:00 T-H32

Can superbubbles accelerate PeV protons? — •Thibault Vieu and Brian Reville — Max-Planck-Institut für Kernphysik, Postfach 10 39 80, 69029 Heidelberg, Germany

The local cosmic-ray spectrum and recent gamma-ray observations suggest the existence of Galactic sources able to accelerate protons up to at least several PeV. These sources are still to be identified. Standard scenarios of particle acceleration at isolated supernova remnants struggle to reach PeV bands. However, most massive stars are not isolated but clustered. Clustered stars heat their surrounding medium, which inflates a cavity called a superbubble. In the superbubble, the stellar feedback creates multiple shocks, a turbulent environment, and amplifies the magnetic fields. These are ideal conditions for particle acceleration and superbubbles have long been thought to accelerate PeV protons. While it is indeed expected that an extended and strongly turbulent source could accelerate protons up to tens of PeV, it is yet unclear how the different acceleration processes can act collectively in superbubbles.

In this work we estimate the maximum energy of protons accelerated in superbubbles, considering various detailed scenarios. We derive under which circumstances PeV protons are expected. The forward shock of the superbubble barely accelerates particles up to 100 TeV. Supernova remnants expanding in the interior, or the collective wind termination shock which forms around a compact cluster, barely accelerate PeV protons. We show that protons of several PeV are only expected within loose and extended stellar clusters.

T 74: Neutrino Physics without Accelerators 5

Time: Wednesday 16:15–18:20 Location: T-H33

Group Report T 74.1 Wed 16:15 T-H33

CEνNS and new neutrino physics searches with the CONUS experiment — •Edgar Sanchez Garcia for the CONUS-Collaboration — Max-Planck-Institut für Kernphysik (MPIK), Heidelberg

The CONUS experiment (COherent elastic NeUtrino nucleus Scattering) aims to detect coherent elastic neutrino-nucleus scattering (CEνNS) of reactor antineutrinos on germanium nuclei in the fully coherent regime. The CONUS experiment - operational since April 2018 - is located at a distance of 17m from the 3.9 GWth core of the Brokdorf nuclear power plant (Germany). The possible CEvNS signature is measured by four 1 kg point-contact high-purity germanium (HPGe) detectors, which provide a sub keV energy threshold with background rates in the order of 10 events per kg, day and keV. The analysis of the first CONUS data set allows to establish the current best limit on CEνNS from a nuclear reactor with a germanium target. Moreover, competitive limits on neutrino physics beyond the standard model can be set such as on non-standard neutrino interactions or on the neutrino electromagnetic properties. These results will be presented in this talk together with the CONUS long-term operation.

T 74.2 Wed 16:35 T-H33

Novel constraints on neutrino physics beyond the standard model from the Conus experiment — •Thomas Rink for the CONUS-Collaboration — Max-Planck-Institut für Kernphysik (MPIK)

The detection of coherent elastic neutrino-nucleus scattering (CEνNS) opens up new opportunities for neutrino physics within and beyond the standard model. As a leading reactor experiment, Conus aims for an observation in the fully coherent regime with antineutrinos emitted from the powerful $3.9\,\mathrm{GW_{th}}$ reactor of the nuclear power plant in Brokdorf (Germany). In particular, the application of ultra-low threshold, high-purity germanium detectors within a compact shield design in close vicinity to a nuclear reactor core describes the next milestone towards high-statistics neutrino physics. The acquired and future Conus data sets allow investigations of yet undetected neutrino channels and electromagnetic properties. Moreover, measurements of the Weinberg angle with neutrinos at the MeV-scale and analyses of the high energy part of a reactor's antineutrino emission spectrum become possible with CEνNS. This talk deals with constraints on beyond the standard model neutrino phenomenology that are obtained from data collected between April 2018 and June 2019. Bounds on non-standard neutrino-quark interactions of vector and tensor type from CEνNS are presented. Further, the parameter space of simplified scalar and vector mediators that is probed by CEνNS and elastic neutrino-electron scattering is discussed. Finally, limits on an effective neutrino magnetic moments and an effective neutrino millicharge are given.

T 74.3 Wed 16:50 T-H33

Pulse Shape Discrimination for the CONUS experiment — •Josef Stauber for the CONUS-Collaboration — Max-Planck-Institut für Kernphysik (MPIK), Heidelberg, Germany

The CONUS experiment, located at the nuclear power plant in Brokdorf, Germany, aims at the detection of coherent elastic neutrino nucleus scattering (CEνNS) in the fully coherent regime. Four 1kg-sized point-contact germanium detectors are used for this purpose. The suppression of the background and a very low energy threshold are crucial for the successful detection of CEνNS. The pulse shape discrimination PSD offers a tool to reduce the background by analysing the shapes of the individual events. The data acquisition module (DAQ) can alter the pulse shape (electric feedback) and add electrical noise to the signal. In this talk the concept of the PSD will be presented with special focus on the DAQ feedback and the impact of electrical noise in the low energy regime.

T 74.4 Wed 17:05 T-H33

Shield and detector optimization for the CONUS experiment — •Janina Hakenmüller for the CONUS-Collaboration — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69115 Heidelberg, Germany

The CONUS experiment is looking for coherent elastic neutrino nucleus scattering (CEνNS) with four low energy threshold point contact high-purity Ge spectrometers. The CONUS Collaboration is exploring options for a new reactor site outside Germany to continue and extend its scientific program. In the talk, the possibilities of improvement regarding the shield and detector design will be explored. The strong neutrino flux required for a detection is provided by a nuclear power plant, where only a small overburden to shield against cosmic rays is available. The current CONUS shield employs 25 cm of lead to shield against environmental gamma rays. Cosmic ray muons create secondaries inside the lead especially neutrons, that can induce CEνNS like recoils in the detector. Even though the background is suppressed by an active muon veto, it still contributes significantly to the measured background. With the help of MC simulations improvements and alternatives of the shield design are examined. Additionally, also the impact of a larger crystal size on the background as well as potentially enhancements of detector-specific background will be discussed.

T 74.5 Wed 17:20 T-H33

Simulation of Pulse Shapes for Low Background Germanium Spectrometers in CONUS — •Janine Hempfling for the CONUS-Collaboration — Max-Planck Institut für Kernphysik (MPIK), Heidelberg

The CONUS experiment aims to detect coherent elastic neutrino nucleus scattering (CEνNS). For this goal four 1 kg point-contact high-purity germanium detectors are operated near the $3.9\,\mathrm{GW_{th}}$ core of the Brokdorf nuclear power plant. A very good background suppression is crucial for the success of the experiment, achieved by an elaborate shield. A new opportunity for additional background reduction is offered by pulse shape analysis of the detector signals. To verify this analysis a pulse shape simulation (PSS) for the CONUS experiment is developed based on the software package SigGen. Additionally, investigations of the correlation between the signal shape and the interaction position as well as the fraction of single-site events and multi-site events are possible with the PSS. This talk presents the requirements needed to set up a PSS, starting from the input signal generation with the GEANT4 framework MaGe to the modeling of the response of the electronics up to the final output pulses. Furthermore, a comparison between the obtained simulation results and the measured signals will be discussed.

T 74.6 Wed 17:35 T-H33

The CRAB Experiment: a New Calibration Technique for CEvNS Detectors in the 100 eV Regime — •Victoria Wagner for the CRAB-Collaboration — Physik-Department, Technische Universität München, D-85748 Garching, Deutschland

Searches for light dark matter (DM) and studies of coherent elastic neutrino-nucleus scattering (CEvNS) imply the detection of nuclear recoils in the 100 eV range. However, an absolute energy calibration in this regime is yet missing. The CRAB project proposes a method based on nuclear recoils induced by the emission of an MeV-gamma following thermal neutron capture. Detailed feasibility studies show that this method yields distinct nuclear recoil calibration peaks at 112 eV and 160 eV for tungsten. In the first phase, the CRAB project foresees to perform a nuclear recoil calibration of cryogenic $CaWO_4$ detectors read-out by TES. The low power TRIGA reactor in Vienna provides a clean beam of thermal neutrons well suited for such a measurement. In the second phase, additional tagging of the photons produced in the de-excitation process will allow to extend the calibration method to even lower energies and to a wider range of detector materials, such as Ge. Combined with an electron recoil calibration, CRAB will allow to measure energy quenching in the sub-keV regime. With its novel idea, CRAB provides a direct and accurate calibration of nuclear recoils in the ROI of light DM and future CEvNS experiments, which is essential for studying new physics.
This work is supported by the DFG through the Excellence Cluster ORIGINS and the SFB1258.

T 74.7 Wed 17:50 T-H33

Development oft the cryogenic detector for observing coherent elastic neutrino nucleus scattering with NUCLEUS 10g — •Nicole Schermer[1], Andreas Erhart[1], Dieter Hauff[1,2,3], Margarita Kaznacheeva[1], Tobias Ortmann[1], Luca Pattavina[1], Johannes Rothe[1], Raimund Strauss[1], Victoria Wagner[1], and Alexander Wex[1] — [1]Technische Universität München, Physik Department Lehrstuhl E15, James-Franck-Straße 1, D-85748 Garching — [2]Max-Planck-Institut für Physik, Föhringer Ring 6, D-80805 München — [3]Universität Tübingen, Physikalisches Institut, Auf der Morgenstelle 14, D-72076 Tübingen

The study of coherent elastic neutrino nucleus scattering (CEνNS) offers the opportunity to explore fundamental neutrino properties and to search for physics beyond the Standard Model. The NUCLEUS experiment aims to precisely measure the CEνNS cross-section of reactor-antineutrinos produced by the Chooz nuclear power plant in France at low energies with gram-scale cryogenic detectors with ultra-low energy thresholds of O(10eV). The first science phase, NUCLEUS 10g, will deploy two detector modules, each containing nine cryogenic target detectors embedded in an inner veto. I will present the development of the first versions of the NUCLEUS 10g detector components as well as further strategies towards the full cryogenic detector, which will consist of the two detector modules, a LED calibration system and a cryogenic outer veto. The research was supported by the DFG through the Excellence Cluster ORIGINS and the SFB1258, and the ERC Starting Grant 2018 "NU-CLEUS".

T 74.8 Wed 18:05 T-H33

Exploring Coherent Elastic Neutrino-Nucleus Scattering at a nuclear reactor with the NUCLEUS experiment — •Johannes Rothe for the NUCLEUS-Collaboration — Physik-Department, Technische Universität München, D-85748 Garching, Germany

The NUCLEUS collaboration is working towards the first detection of reactor antineutrinos via Coherent Elastic Neutrino-Nucleus Scattering (CEvNS) using cryogenic detectors operating at 15mK temperature. This observation will open a new window to study fundamental neutrino properties at low energy with a high-flux source.

The first physics phase will employ a 10g target made of Al_2O_3 and $CaWO_4$ crystals read out with superconducting transition edge sensors, surrounded by cryogenic infrastructure, passive shielding and active anti-coincidence veto systems. Assembly and commissioning of all components of the experimental setup is planned at TUM in 2022. Afterwards, the experiment will be moved to the Chooz Nuclear Power Plant in France. I will present updates on the design and simulation of the setup, experimental work towards the 10g target detector and the physics goals of NUCLEUS-10g. This research was supported by the DFG through the Excellence Cluster ORIGINS and the SFB1258, and the ERC Starting Grant 2018 "NU-CLEUS".

T 75: Neutrino Physics without Accelerators 6

Time: Wednesday 16:15–18:35 Location: T-H34

Group Report T 75.1 Wed 16:15 T-H34

Overview of LEGEND and the Commissioning Status of LEGEND-200 — •Patrick Krause for the LEGEND-Collaboration — Physik-Department, Technische Universität München, Garching

The discovery that neutrinos are Majorana fermions would have profound implications for particle physics and cosmology. The Majorana character of neutrinos would make neutrinoless double-beta ($0\nu\beta\beta$) decay, a matter-creating process without the balancing emission of antimatter, possible. The LEGEND Collaboration pursues a phased, ^{76}Ge-based double-beta decay experimental program with discovery potential covering the inverted hierarchy. The first phase, LEGEND-200, will have a discovery potential of 10^{27} years and a background index of 0.6 cts/(ROI t yr). The second phase, LEGEND-1000, will deploy 1000 kg of enriched germanium and will have a discovery sensitivity beyond 10^{28} years. This talk will give an overview of LEGEND and will report on the currently ongoing commissioning work in LEGEND-200. This research is supported in part by the BMBF through the Verbundforschung 05A2020, the MPG, the DFG through the Excellence Cluster ORIGINS and the SFB1258, and the through the ERC Advanced Grant 786430 - GemX

T 75.2 Wed 16:35 T-H34

ASIC based readout electronics for high-purity Germanium detectors in LEGEND-1000 — •Florian Henkes, Frank Edzards, Susanne Mertens, and Michael Willers for the LEGEND-Collaboration — Technische Universität München, München, Deutschland

The **L**arge **E**nriched **G**ermanium **E**xperiment for **N**eutrinoless $\beta\beta$ **D**ecay (LEGEND) is a ton-scale, ^{76}Ge-based, neutrinoless double-beta ($0\nu\beta\beta$) decay experimental program with discovery potential at half-lifes greater than 10^{28} years.

Signal readout electronics are essential in order to achieve the experiment's sensitivity on $0\nu\beta\beta$-decay. The close proximity to the detectors poses unique challenges to balance electronic performance with radiopurity requirements. In LEGEND-200, the readout system consists of a charge sensitive amplifier realised from discrete components with an ultra radiopure first stage close to the detectors and a second stage from less radiopure commercial components. In LEGEND-1000, the use of **A**pplication-**S**pecific **I**ntegrated **C**ircuit (ASIC) technology would allow to implement the entire charge sensitive amplifier into a single low-mass chip with ultimate electronic noise performance and signal fidelity while ideally further reducing backgrounds.

In this contribution, the current status of the LEGEND-1000 ASIC based readout development at the Technical University of Munich will be presented and prospects for future developments of ASIC based charge sensitive amplifiers for high-purity germanium detectors will be discussed.

T 75.3 Wed 16:50 T-H34

Constraining the $^{77(m)}$Ge Production with GERDA Data and Implications for LEGEND-1000 — •Moritz Neuberger[1], Luigi Pertoldi[1], Stefan Schönert[1], and Christph Wiesinger[1,2] for the GERDA-Collaboration — [1]Physik-Department E15, Technische Universität München — [2]Max-Planck-Institut für Physik (Werner-Heisenberg-Institut) Föhringer Ring 6 80805 München

The delayed decay of $^{77(m)}$Ge, produced by neutron capture on ^{76}Ge, is a potential background for the next-generation neutrino-less double-beta decay experiment LEGEND-1000, especially when considering the alternative LNGS site. Based on Monte Carlo simulations, various mitigation strategies and suppression techniques have been proposed to tackle this background [1,2]. In this talk we will present first results on $^{77(m)}$Ge searches in the full GERDA data. Given the very similar configuration - bare germanium detectors in liquid argon - it serves as a benchmark for our LEGEND-1000 predictions. This research was supported by the BMBF through the Verbundforschung 05A20WO2 and by the DFG through the SFB1258 and Excellence Cluster ORIGINS.

[1] C. Wiesinger et al., Eur. Phys. J. C (2018) 78: 597

[2] LEGEND-1000 pCDR, arXiv 2107.11462

T 75.4 Wed 17:05 T-H34

First light in LEGEND-200 — •Rosanna Deckert, Patrick Krause, Laszlo Papp, and Stefan Schönert — Technische Universität München

LEGEND (Large Enriched Germanium Experiment for Neutrinoless $\beta\beta$ Decay) is a ton-scale experiment to search for neutrinoless double beta ($0\nu\beta\beta$) decay using high-purity germanium detectors enriched in ^{76}Ge. An observation of $0\nu\beta\beta$ decay would prove the existence of lepton number violation and provide insight into the nature of neutrino masses. The first phase of the experiment LEGEND-200 will deploy 200 kg of enriched material and aims for a sensitivity of 10^{27} years on the $0\nu\beta\beta$ half-life. To achieve this, the germanium detectors will be operated in liquid argon (LAr), instrumented as an active detector to detect the scintillation light produced by backgrounds from trace radioactive contaminants.

Commissioning of the LAr instrumentation, consisting of wavelength-shifting fibers, a wavelength-shifting reflector and silicon photomultiplier arrays, started in August 2021 at the Laboratori Nazionali del Gran Sasso. In this talk, the analysis of the first LAr commissioning data for LEGEND-200 will be presented.

This research is supported by the BMBF through the Verbundforschung 05A20WO2 and by the DFG through the Excellence Cluster ORIGINS and the SFB1258.

T 75.5 Wed 17:20 T-H34

New Limit on the radiative 0νECEC of ^{36}Ar from GERDA Phase II Data — •Michele Korosec[1], Elisabetta Bossio[1], and Christoph Wiesinger[2] for the GERDA-Collaboration — [1]Physik-Department, Technische Universität München — [2]Max-Planck-Institut für Physik, München

Neutrinoless double electron capture (0νECEC) is a theoretically possible decay that would prove lepton number violation, which is forbidden by the Standard Model of Physics, and therefore provide evidence for the Majorana nature of neutrinos. The GERmanium Detector Array (GERDA) experiment offers the possibility to search for 0νECEC of ^{36}Ar which is one of the isotopes that theoretically allows this rare decay.

A search for neutrinoless double electron capture of ^{36}Ar was conducted based on Phase II data from the GERDA experiment, located at the Gran Sasso Laboratory of INFN, Italy. A simultaneous fit to multiple datasets has been performed in which no signal for the decay has been observed. However, a new, preliminary experimental lower limit on the half-life of 0νECEC in ^{36}Ar has been established with the CLs method at $T_{1/2} > 1.22 \cdot 10^{22}$ yr (90% C.L.) which will take over from the previous best limit of $T_{1/2} > 3.6 \cdot 10^{21}$ years (90% C.I.) [1] which was found in GERDA Phase I.

This research is supported by the BMBF through the Verbundforschung 05A20WO2 and by the DFG through the Excellence Cluster ORIGINS and the SFB1258. [1] GERDA Collaboration, Eur.Phys.J.C 76 (2016) 12, 652

T 75.6 Wed 17:35 T-H34

***In-situ* characterization of germanium detectors from ^{39}Ar decays for low-energy data modeling in GERDA and LEGEND** — •Luigi Pertoldi for the GERDA-Collaboration — TU München, Germany

A reliable estimate of the active volume of high-purity germanium (HPGe) detectors, defined as the internal volume in which charge collection efficiency (CCE) reaches its maximum, is a fundamental piece of a detector's response model. Typical HPGe detectors feature a null or incomplete CCE in correspondence with the lithium-doped, high-voltage bias contact. In this contribution, a new method for determining the active volume of HPGe detectors immersed in liquid argon (LAr), will be presented. The method exploits the shape of the low-energy distribution of ^{39}Ar β^- decays, naturally occurring in atmospheric LAr and recorded by the detectors, which strongly depends on the CCE profile. The technique is applied to physics data by the GERDA experiment and used to characterize the deployed detectors *in-situ*. As a consequence, a first model of the low-energy data spectrum recorded by the experiment will also be shown. The developed technique will be useful for the LEGEND experiment, which aims to perform searches of new-physics phenomena at low energies. Moreover, by using these novel ^{39}Ar-based active volume estimates, we aim to obtain a precise and unbiased estimate of the two-neutrino double-beta decay rate of ^{76}Ge. This research is supported by the BMBF through the Verbundforschung 05A20WO2 and by the DFG through the Excellence Cluster ORIGINS and the SFB1258.

T 75.7 Wed 17:50 T-H34

New results on the ^{76}Ge double-beta decay with neutrinos and exotic decay modes from GERDA Phase II — •Elisabetta Bossio for the GERDA-Collaboration — Physik Department, Technische Universität München, Garching, Germany

Two-neutrino double beta ($2\nu\beta\beta$) decays are amongst the rarest nuclear processes ever observed. Precision studies of the electron sum energies require ultra-low background and an excellent understanding of the experiment's response. Both are key features of the Germanium Detector Array (GERDA) experiment, which searched for neutrino-less double beta ($0\nu\beta\beta$) decay with enriched high purity germanium detectors in Liquid Argon at Laboratori Nazionali del Gran Sasso (LNGS) in Italy. The measurement of the Standard Model $2\nu\beta\beta$ decay half-life of ^{76}Ge was performed with unprecedented precision, profiting from the high signal-to-background ratio and the small systematic uncertainties. It provides essential inputs for nuclear structure calculations, that benefit the interpretation of $0\nu\beta\beta$ decay results. Furthermore, the search for distortions of the $2\nu\beta\beta$ decay spectrum allows exploring new physics, like $0\nu\beta\beta$ decay with Majorons emission, Lorentz invariance, or search for sterile neutrinos. The new results of the ^{76}Ge $2\nu\beta\beta$ decay half-life and improved limits on exotic decay modes will be presented in this talk.

This research is supported by the BMBF through the Verbundforschung 05A20WO2 and by the DFG through the Excellence Cluster ORIGINS and the SFB1258.

T 75.8 Wed 18:05 T-H34

Double weak decays of ^{124}Xe and ^{136}Xe in XENON1T and XENONnT — •Christian Wittweg for the XENON-Collaboration — Physik-Institut, Universität Zürich

In recent years xenon-based dark matter direct detection experiments have reached large enough target masses and low enough background levels to also probe rare double weak decays. Among these decays are the two-neutrino double electron capture (2νECEC) of ^{124}Xe as well as the neutrinoless double beta decay ($0\nu\beta\beta$) of ^{136}Xe. Observation of the hypothetical neutrinoless decay would provide definite proof of the neutrino's Majorana nature and indicate lepton number violation. The measurement of the Standard Model 2νECEC – first detected by XENON1T in 2018 – provides nuclear structure information that is a crucial input for the nuclear models used to interpret $0\nu\beta\beta$ experiments. This contribution will present the ^{124}Xe 2νECEC results and search for $0\nu\beta\beta$ of ^{136}Xe in XENON1T. Moreover, the sensitivity projection for a ^{136}Xe $0\nu\beta\beta$ search in XENONnT will be outlined.

T 75.9 Wed 18:20 T-H34

Latest results from XENON1T and prospects for XENONnT for $0\nu\beta\beta$ — •Tim Michael Heinz Wolf for the XENON-Collaboration — MPIK, Heidelberg, Deutschland

XENON1T was a dual-phase xenon time projection chamber (TPC) looking mainly for the direct detection of WIMP dark matter at energy depositions of up to tens of keV. This talk will focus on the high energy part of the spectrum (above hundreds of keV) where we can search for neutrinoless double beta decay ($0\nu\beta\beta$). This is a hypothetical process implying two beta decays without emitting any neutrinos. The natural isotope ^{136}Xe (abundance approximately 8.9%) is a candidate isotope to look for $0\nu\beta\beta$ which allows to carry out a search in LXe TPCs. This process tests lepton flavour conservation and it is potentially able to shed light on the nature of neutrinos (Dirac or Majorana particles) or give hints on the mass ordering of neutrinos. We present for the first time, a search for $0\nu\beta\beta$ where a limit on the $0\nu\beta\beta$ half-life of ^{136}Xe with XENON1T data is derived, and give prospects on the performance of XENONnT data.

T 76: Search for Dark Matter 3

Time: Wednesday 16:15–18:30 Location: T-H35

T 76.1 Wed 16:15 T-H35

Search for dark matter production in association with a single-top and w-boson with the ATLAS experiment — •Alvaro Lopez Solis — DESY-Zeuthen, Zeuthen, Germany

Measurements at large scales suggest that Dark Matter (DM) constitutes around 27% of all the energy available in the Universe and around 85% of all the available mass. However, its nature remains a mystery. Several theories try to address this problem by suggesting the existence of new weakly interacting particles that would constitute most of this new type of energy. This talk will present a search using the ATLAS experiment at LHC for these weakly interacting particles. It is motivated by the hypothesis that DM particles would couple to the Standard Model (SM) particles via a pseudo-scalar mediator within an extended two-Higgs-doublet model (2HDM+a). Among all the possible signatures predicted by this model, this talk will present the search for DM production in association to a single-top quark and a W-boson in channels where both, top and W-boson, are assumed to decay hadronically (0L channel) or either one of them decay leptonically (1L channel).

T 76.2 Wed 16:30 T-H35

Search for Dark Matter at the ATLAS detector with a W-boson and a top-quark in the final state — •Paul Moder[1], Alvaro Lopez Solis[2], Ben Brüers[2], and Claudia Seitz[1] — [1]DESY Hamburg — [2]DESY Zeuthen

The Standard Model (SM) is one of the most robust models in particle physics containing all observed elementary particles and their interactions. Over the years, its predictions were tested and proven in a number of experiments. However, there are still observations that can not be explained by the SM with one of the most prominent ones being the existence of Dark Matter (DM). While the existence of DM was first theorised through astronomical observations, extensions of the SM allow for a search of DM at the Large Hadron Collider (LHC) as well. Since DM can not be detected directly, final states analysing its existence at the LHC are always designed around high missing transverse energy. This talk will present such a search at the ATLAS detector based on an extended two-Higgs-doublet model (2HDM+a) where the pseudo-scalar mediator allows the production of DM in the final state. In addition to the DM, a top-quark and a W-boson are produced in the final state, where the W-boson of this signal process can be expected to have high momentum. This allows for a unique technique by tagging these W-bosons through large-radius jets increasing the sensitivity of the signal process. This talk presents the cut-based definitions for an analysis with zero leptons in the final state as well as the most recent results.

T 76.3 Wed 16:45 T-H35

Search for Dark Matter in a tW+MET signature with the ATLAS experiment — •Ben Brüers — Deutsches Elektronen Synchrotron DESY, Zeuthen, Germany

Dark Matter (DM) remains one of the unrevealed mysteries of the universe. Even though it constitutes $\sim$ 80% of the matter, considerably little is known about DM, despite it significantly influences the dynamics of galaxies and the expansion of the universe. The search for DM at colliders, probing mainly a particle nature of the unknown matter, marks an important pillar in exploring all possible realisations of DM. This talk will present a search for DM with the ATLAS experiment, where the DM is coupled to the Standard Model (SM) via a pseudo-scalar mediator within an extended two-Higgs-doublet model (2HDM+a). The associated production of DM with a W-boson and a top-quark is considered. As the DM deposits no energy in the detector, the experimental signature includes high missing transverse energy ($E_{\mathrm{T}}^{\mathrm{miss}}$). To reconstruct highly energetic W-bosons, expected for signals with a heavy H^{+}, large-radius jets are employed. The talk will give an introduction to the analysis and present the most recent results.

T 76.4 Wed 17:00 T-H35

Search for dark matter produced in association with two top quarks and missing energy in the final state using ATLAS 13 TeV pp collision data — •Marco Rimoldi — DESY, Hamburg, Germany

The hypothesis of the existence of non-baryonic dark matter (DM) comes from gravitational evidence across a wide range of astrophysical and cosmological systems. Of the many types of DM candidate proposed, weakly interacting massive particles (WIMP) are believed to be a theoretically convincing candidate. WIMPs must interact weakly with electromagnetic radiation and be consistent with the expected DM density. If WIMPs are the manifestation in nature of DM, then it may be possible to produce it directly at the LHC.

Results of the combination of four analyses are presented, selecting final state events with two top quarks and invisible particles. Proton proton collisions data collected by the ATLAS experiment at a centre-of-mass energy of 13 TeV during the Run-2 data-taking are used. Results are interpreted in terms of dark matter simplified models considering a spin-0 mediator to dark sector.

Upper limits on the Higgs boson invisible branching ratio, where the Higgs is produced according to the Standard Model in association with a pair of top quarks are also reported.

T 76.5 Wed 17:15 T-H35

Search for new physics in $t\bar{t}$+$\mathbf{E}_T^{miss}$ final states in pp collisions at 13 TeV with the ATLAS experiment. — •Simran Gurdasani — Albert-Ludwigs-Universität, Freiburg, Germany

This talk will present the developments of an ongoing search for Beyond Standard Model (BSM) signatures that can be probed using the $t\bar{t}$+E_T^{miss} final state at the Large Hadron Collider (LHC). Neural Networks are used for the search which is performed on data collected with the ATLAS detector between 2015 and 2018, corresponding to 139 fb^{-1} of pp data at 13 TeV. Models specifically targeted include DM production via scalar or pseudo-scalar mediators, SUSY stop pair production and Higgs decays to new invisible particles. A two-fold implementation of neural nets is designed, where the first step aims to efficiently reconstruct the hadronically decaying top quarks in a given event. This is designed to specifically target mid-pt range tops decaying to resolved jets. The second step aims to exploit full kinematic correlations of the $t\bar{t}$+E_T^{miss} system and tag a given event to one of the targeted BSM processes while providing background rejection against both major (ttbar and Wjets) and non-major SM processes. The talk will give an overview of the strategy developed and the status of ongoing optimization studies.

T 76.6 Wed 17:30 T-H35

Combining Dark Matter searches with top quarks with the ATLAS detector — •Marianna Liberatore — Deutsches Elektronen-Synchrotron DESY, Hamburg and Zeuthen, Germany

A motivation to WIMP dark matter (DM) searches at the LHC, and in particular in ATLAS, is the especially promising possibility that interactions between ordinary matter and DM are mediated by new spin-0 particles. Such particles would extend the SM with a potential dark sector, to which DM particles belong. Similarly to the Higgs boson, these new mediators interact strongest with the heaviest particles via Yukawa-type couplings, making them more prone to associated production with heavy-flavour quarks.

To test those models, two recently released search channels are considered within ATLAS: DM with top quark pairs[1] or a single top quark[2], with a focus on the two charged leptons final states. This talk will motivate how the statistical combination of these two results in simplified models could significantly enhance the sensitivity to DM signals, and the first results of these combined studies will be presented.

[1] JHEP04(2021)165
[2] Eur.Phys.J.C(2021)81:860

T 76.7 Wed 17:45 T-H35

Searching for Dark Matter in top quark production with the CMS experiment — Danyer Perez Adan, Afiq Anuar, Alexander Grohsjean, Laurids Jeppe, Jonas Rübenach, Christian Schwanenberger, •Dominic Stafford, and Nicole Stefanov — Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

Astronomical observations provide strong evidence that a large proportion of the matter in the universe is "Dark Matter" (DM), which is currently not included in the Standard Model (SM) of particle physics. Furthermore, many cosmological models suggest Dark Matter should couple to the SM around the 100 GeV scale, and hence may be produced at the LHC, appearing as missing transverse momentum. We present a search for Dark Matter produced in association with top quarks, via a spin-0 mediator, with a focus on the dileptonic channel. This analysis will be part of the upcoming CMS result with the full Run-2 dataset, and will be the first to combine the top quark pair + DM and single top + DM processes for dileptonic, semileptonic and full hadronic final states, which greatly aids sensitivity to the highest mediator masses in the search.

The dileptonic channel poses an interesting challenge due to a large amount of missing transverse momentum in the SM $t\bar{t}$ background, and an irreducible $t\bar{t}Z(Z \to \nu\nu)$ background. This analysis therefore uses novel variables and machine learning techniques in the signal extraction, and new control regions to constrain the irreducible backgrounds.

T 76.8 Wed 18:00 T-H35

Performance of different MET reconstruction methods in a monotop DM analysis — •Jost von den Driesch[1], Sebastian Wieland[1], Michael Wassmer[1], Nikita Shadskiy[1], Ulrich Husemann[1], Matteo Cremonesi[2], Lindsey Gray[3], and Yihui Lai[4] — [1]Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT) — [2]University of Notre Dame (ND) — [3]Fermilab — [4]University of Maryland (UMD)

Missing transverse momentum (MET) is an important quantity in many analyses at hadron colliders. Especially Dark Matter (DM) analyses often make use of this quantity as DM particles leave the detector without interactions and therefore create large amounts of MET. However, due to its origin from non-detectable particles, MET cannot be measured directly, but must be estimated from the transverse momentum of all reconstructable particles.

Over the years, various MET reconstruction methods have been developed and applied at CMS. The latest approaches use machine learning methods, e.g. Convolutional Neural Networks (DeepMET) or Graph Neural Networks (GraphMET). Monte Carlo studies show an improvement of MET reconstruction performance by these novel reconstruction methods compared to the older ones. Yet, it remains unclear how large this effect will be in a full analysis.

This talk will introduce the aforementioned MET reconstruction methods and compare their expected impact on a monotop analysis, aimed at the search for Dark Matter in events with a single top quark and large MET.

T 76.9 Wed 18:15 T-H35

Search for axion-like particles (ALPs) at Belle II experiment. — •Awais Bin Zahid, Pablo Goldenzweig, and Torben Ferber — Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

One possible extension of the Standard Model (SM), which may contribute in solving the mystery of Dark Matter (DM) and/or explain some astrophysical anomalies, are Axion-Like Particles (ALPs). The model taken into consideration in this search is of an ALP interacting with SM photons with a coupling strength $g_{a\gamma\gamma}$ and having mass m_a. The search for the direct production of such an ALP via the process (ALP-Strahlung) $e^+e^- \to \gamma a(a \to \gamma\gamma)$, is performed in the mass range $0.2 < m_a < 9.8$ GeV/c^2. Given that the final state of the $e^+e^- \to \gamma a(a \to \gamma\gamma)$ process is fully neutral, being made up of three photons, a proper kinematic fit with neutral particles is a powerful tool to improve signal resolution. In this talk, I will present the status of sensitivity evaluation based on Monte Carlo simulation which corresponds to the data of almost 500 fb^{-1} that will be collected by Belle II at the end of summer 2022.

T 77: Search for Dark Matter 4

Time: Wednesday 16:15–18:15 Location: T-H36

T 77.1 Wed 16:15 T-H36

Light dark matter search using SuperCDMS single-charge-sensitive devices and anticoincident tagging — •Alexander Zaytsev for the SuperCDMS-Collaboration — Karlsruher Institut für Technologie, Karlsruhe, Germany

As a part of its R&D program, the SuperCDMS collaboration has been developing cryogenic gram-scale eV-resolution (HVeV) detectors that utilize Neganov-Trofimov-Luke amplification by applying a voltage bias across the Si crystals. During the two previous above-ground dark matter (DM) searches, each collecting data with only one HVeV detector, competitive constraints were obtained for DM-electron scattering, as well as for dark photon and axion-like particle absorption. However during the second HVeV run, a background characterized by bursts of single electron-hole pair events was observed, which may originate from luminescence in SiO2 - the primary component of the detector holder material. Single-pulse events from the tails of such bursts degrade the sensitivity of the HVeV DM searches in the entire mass range of interest. In the latest underground HVeV DM search (Run 3), we have collected O(10) gram-days of exposure using three HVeV detectors, operated simultaneously within a shared housing. We present the current progress of the respective DM search analysis, which is expected to surpass the previous HVeV DM limits by utilizing an inter-detector anticoincidence event selection that considerably suppresses the rate of background events caused by bursts.

T 77.2 Wed 16:30 T-H36

Characterizing bursts of single-electron-hole-pair events using a SuperCDMS R&D device and a sodium-22 source — •Matthew Wilson for the SuperCDMS-Collaboration — Karlsruher Institut für Technologie

Recently, R&D facilities within the SuperCDMS collaboration have developed and employed cryogenic, high-voltage, eV-scale (HVeV) detectors that have single-charge sensitivity. When a bias voltage is applied across these gram-sized, silicon detectors, the charge signals are amplified in the form of phonons, making the detectors sensitive to low-energy electron interactions. HVeV detectors have been previously utilized for two separate above-ground dark matter (DM) searches to set competitive constraints on low-mass DM candidates. However, these constraints are limited by the presence of an unknown, low-energy background, a large component of which appears to be bursts of single-electron-hole-pair events. One hypothesis is that these events originate from the photoluminescence of SiO_2, a primary component of the detector holder material. A sodium-22 source has been placed near an HVeV detector to determine whether such burst events are induced by the high-energy gammas emitted by a radioactive source, which would support this hypothesis. This presentation shows the latest results of the investigation and characterization of this low-energy background.

T 77.3 Wed 16:45 T-H36

SuperCDMS detector testing at the Cryogenic Underground TEst (CUTE) facility — •Sukeerthi Dharani for the SuperCDMS-Collaboration — Universität Hamburg

SuperCDMS SNOLAB is an upcoming direct dark matter search experiment using silicon and germanium detectors operated at cryogenic temperatures. The experiment is planned to start data taking in 2023 at SNOLAB which is located 2 kilometers underground in the Creighton mine in Canada. With a low background from cosmic sources, SNOLAB is ideal for rare event searches. The Cryogenic Underground TEst (CUTE) is a well-shielded test facility operating at SNOLAB with a measured background rate of ~ 7 events/keV/kg/day. It acts as a testbed for the SuperCDMS detectors and facilitates performing early science runs. In this talk, an overview of the CUTE facility's features, ongoing activities, and applications for the SuperCDMS experiment will be presented.

T 77.4 Wed 17:00 T-H36

Current Status of the BRASS-P Experiment — •Fayez Bajjali[1], Le Hoang Nguyen[1], Dieter Horns[1], Andrei Lobanov[1,2], Artak Mkrtchyan[1], Sven Dornbusch[2], Christoph Kasemann[2], Martin Tluczykont[1], and Marko Ekmedžić[1] — [1]Institute of Experimental Physics - University of Hamburg — [2]Max-Planck-Institute for Radio Astronomy - Bonn

Axions and Hidden Photons (HPs) are among the best motivated candidates for explaining the enigmatic nature of the dark matter. These weakly interacting slim particles (WISPs) have a small mass and can be detected via electromagentic (EM) radiation arising from their interaction with normal matter, photons, and magnetic field. The concept for Broadband Radiometric Axion/ALP Searches (BRASS) provides a pioneering experimental setup for WISP searches in the range of 10-10000μeV. The prototype setup BRASS-P is currently being constructed at the University of Hamburg. It combines permanently magnetized conversion panels producing the EM signal from passages of WISPs, a parabolic mirror focusing the EM signal, a cryogenic 12-18 GHz heterodyne receiver, and a broadband digitizing backend DBBC3 for detecting and processing the signal.

The structure of the conversion panels and the measurement of the static magnetic field will be presented. The setup and calibration procedures employed for the 12-18 GHz receiver and the DBBC3 digitizer will be discussed. Finally, preliminary results from the first science run carried out for searching for HPs in the frequency range of 12-16 GHz will be presented.

T 77.5 Wed 17:15 T-H36

Axion simulation in various geometry — •Johannes Ulrichs[1], Le Hoang Nguyen[1], Dieter Horns[1], and Andrei Lobanov[1,2] — [1]Institut für Experimentalphysik, Universität Hamburg, Hamburg, Deutschland — [2]Max-Planck-Institut für Radioastronomie, Bonn, Deutschland

Using commercial FEM software (COMSOL TM), we solve the Axion-Maxwell equation in the geometrical context of experiments that search for axion and axion-like-particles (ALPs) dark matter. Firstly, the BRASS-p is the pilot experiment that search for axion/alps in the frequency range of 12 - 18 GHz (49.63 - 74.4 μeV). The multiphysics simulation (AC/DC and RF modules) is used to explore the realistic magnetic field of the magnet panels and the axion-induced radiation. Accompanied with further studies concerning the efficiency and coherence effect of the overall setup. Secondly, we consider the possibility of detecting the skin current induced by the low mass axion dark matter (few kHz to 3MHz, 4.14 peV - 12.4 neV) using a novel solenoid magnet. The theoretical foundation, simulation result is discussed. Followed by the proposed approaches to pickup the signal using High Impedance Amplifier (HIA) and SQUIDS receiver.

T 77.6 Wed 17:30 T-H36

Low Temperature MMC-based X-ray Detectors for IAXO — •Daniel Unger, Andreas Abeln, Daniel Behrend-Uriarte, Daniel Hengstler, Andreas Fleischmann, Christian Enss, and Loredana Gastaldo — Kirchhoff Institute for Physics, Heidelberg University

Axion helioscopes search for evidence of axion-like particles (ALPs) produced in the Sun. Via the generic ALP-photon coupling, a strong magnetic field would convert ALPs into photons which could then be detected by low background and high efficiency X-ray detectors. Having also detectors with good energy resolution and low energy threshold would in addition in case of discovery allow to investigate ALP properties and generation mechanisms in the Sun. We propose to use low temperature metallic magnetic calorimeters (MMCs) for the International Axion Observatory (IAXO). We present the current state of our detector system developed for IAXO containing a two-dimensional 64-pixel MMC array covering an active area of 16 mm^2 with a fill factor of 93 %. We achieve an average energy resolution of 6 eV FWHM allowing for energy thresholds well below 100 eV. The results obtained during experiments with different experimental configurations show a background reduction in the case of low-Z material directly surrounding the active part of the detector. In the future, active and passive shields will be used to reduce the background further. The obtained results highlight that MMC-based arrays are a suitable technology for helioscopes to discover and study ALPs.

T 77.7 Wed 17:45 T-H36

Indirect dark matter search with IceCube — •Li Ruohan, Stephan Meighen-Berger, and Anja Brenner — Technische Universität München, James-Franck-Straße 1, 85748, Garching, Germany

Dark Matter annihilation can generate standard particle pairs in primary and decay into neutrinos at the final state. Its spectrum can have a line shape in case of direct annihilation into neutrinos pair. IceCube neutrino observatory is a powerful instrument for indirect dark matter search because of its sensitivity to neutrinos energy of TeV to PeV. Its planned Upgrade can improve the dark matter nucleons interaction cross-section limits of one magnitude at lower energy. This talk will show a potential approach to test IceCube's line-spectrum detection ability and estimate the conservative cross-section using both spin-independent and -dependent effective fields theory.

T 77.8 Wed 18:00 T-H36

EXCESS workshop: a collaborative investigation of the sub-keV backgrounds observed in various rare event search experiments — •Margarita Kaznacheeva[1], Alexander Fuss[2,3], Florian Reindl[2,3], and Felix Wagner[2] — [1]Physik-Department E15, Technische Universität München, D-85748 Garching, Germany — [2]Institut für Hochenergiephysik der Österreichischen Akademie der Wissenschaften, 1050 Wien, Austria — [3]Atominstitut, Technische Universität Wien, 1020 Wien, Austria

After having lowered the energy thresholds down to O(10eV), various dark matter and coherent elastic neutrino-nucleus scattering experiments observe an unexpected exponential rise of the event rate towards low energies. This excess signal caused by an as yet unknown origin currently provides the main limitation for further sensitivity improvement. A collective initiative to share experimental observations and compare the measured excess signals was started. I will report the outcomes of the dedicated EXCESS workshop that took place in June 2021 as a joint effort of 10 collaborations and lead to an in-depth discussion within the community. Presented measurements were taken by cryogenic, CCD, and gaseous ionization detectors, under and above ground, with different levels of shielding and a wide range of operating temperatures. In the scope of the workshop, a publicly accessible data repository was created that allows studying the sub-keV excess signals measured by the participating collaborations. A summary paper of the workshop is expected to be published in early 2022 and further meetings are already planned.

T 78: Experimental Techniques in Astroparticle Physics 3

Time: Wednesday 16:15–18:00 Location: T-H37

T 78.1 Wed 16:15 T-H37

Monoenergetic electronic recoil calibration of LXe TPCs with 37Ar (XENON1T/nT) — •Christopher Hils for the XENON-Collaboration — Institut für Physik & Exzellenzcluster PRISMA+, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany

Large multi-ton LXe time projection chambers like XENON1T/nT set the most stringent constraints on the interaction cross-section between nucleons and Dark Matter in form of Weakly Interacting Massive Particles. The large active volume and the excellent self shielding properties of liquid xenon make the use of internal calibration sources a necessity to understand detector responses. In the past these calibrations were mainly based on gaseous 83mKr and 220Rn isotopes diluted into the liquid xenon and distributed equally into the active volume. In the last science run of XENON1T we introduced a new low-energy calibration source, the Argon isotope 37Ar, with calibration lines at energies of 2.8 keV and 270 eV. In this talk we will present the results of the XENON1T calibration in form of a study of the detector response at these ultra low energies. We also show that the isotope can be efficiently removed by cryo distillation in the XENON1T distillation column originally designed for krypton removal, which made this isotope suitable as a regular calibration source despite ist long halflife time of 35 d. In this regard, a first calibration was already performed In XENONnT at the end of 2021 with first results about to come.

T 78.2 Wed 16:30 T-H37

Measuring the liquid xenon scintillation pulse shape and its electric field dependence — •Dominick Cichon[1], Guillaume Eurin[1,2], Florian Jörg[1], Teresa Marrodán Undagoitia[1], and Natascha Rupp[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]IRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette, France

In the search for new physics, such as particle dark matter and the neutrinoless double-beta decay, liquid xenon (LXe) detectors play an important role and have provided highly competitive results over the past years. As an example, XENON1T, which utilized a LXe time projection chamber (TPC), constrained the cross-section for interactions between weakly interacting massive particles (WIMPs) and nucleons to values below $4.1 \cdot 10^{-47}$ cm^2 at a WIMP mass of 30 GeV/c^2. To push LXe detector technology to its limits and achieve even better sensitivities, a detailed understanding of the microphysics processes responsible for signal generation in LXe is necessary. One avenue to investigate such processes is the pulse shape of the prompt scintillation signal caused by excitation of LXe via particle interactions.

This talk presents measurements of the LXe scintillation pulse shape after excitation by either electrons from the isomeric transition of ^{83m}Kr or alpha particles from ^{222}Rn chain decays. For both sources, the pulse shape has been characterized at more than 25 different electric field configurations between $\sim$ 0 V/cm and $\sim$ 1200 V/cm. The results are compared to previoulsy published data and interpreted in the context of the involved microphysics processes.

T 78.3 Wed 16:45 T-H37

Gaseous xenon measurements with APIMS and gas chromatography — •Veronica Pizzella and Hardy Simgen — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117, Heidelberg

The latest generation of dual phase gas-liquid xenon TPC detectors for rare event searches employ several tonnes of xenon. It is crucial for the success of these experiments that the chemical impurities in LXe are below ppb level. Some chemical impurities of concern are: electronegative molecules such as oxygen, since they trap the electrons; radioactive impurities such as H-3, since they increase the background in the ROI.

In this presentation, a method to measure chemical impurities below ppb level is presented. The measurement is performed using Atmospheric Pressure Ionization Mass Spectrometry (APIMS), with a commercial instrument from Thermo Scientific. This instrument uses a corona discharge to ionize helium gas at atmospheric pressure, which in turn ionizes mixed trace impurities very efficiently. The setup uses a custom chromatography setup to separate the impurities from the xenon and mix them with helium. Some of the challenges of oxygen and hydrogen quantification are illustrated and some adapted solutions are outlined. A first measurement of the xenon from the gas phase of the XENONnT experiment is reported.

T 78.4 Wed 17:00 T-H37

Scintillation and optical properties of xenon-doped liquid argon — •Christoph Vogl, Mario Schwarz, Xaver Stribl, Johanna Griessing, Patrick Krause, and Stefan Schönert — Chair for Astroparticle Physics, Department of Physics, Technical University Munich, Garching, Germany

Liquid argon (LAr) is widely employed as a scintillator in rare-event searches. Its optical and scintillation properties, as well as the impact of impurities, are being studied extensively by many groups worldwide. LAr scintillation light exhibits a main emission wavelength of 128 nm, which makes propagation and detection challenging because of short attenuation lengths and low quantum efficiencies of photo sensors in the VUV spectral range. The addition of small amounts of xenon to LAr shifts the emission wavelength towards 175 nm and reduces the overall scintillation time. Here, we present our latest study of xenon-doped LAr with focus on the primary photon yield, the effective triplet lifetime and attenuation length, with xenon concentrations ranging from 3 ppm to 300 ppm. The scintillation and optical properties were measured simultaneously with the LLAMA instrument operated inside SCARF, a 1 ton LAr test stand, and the xenon concentrations using IDEFIX, a dedicated mass spectrometer setup. This research is supported by the DFG through the Excellence Cluster ORIGINS and the SFB1258.

T 78.5 Wed 17:15 T-H37

Characterization of Wavelength Shifters for LAr Instrumentation Using VUV Spectrofluorometry — •Andreas Leonhardt[1], Gabriela R. Araujo[2], Patrick Krause[1], Laszlo Papp[1], Tina R. Pollmann[3], and Stefan Schönert[1] — [1]Physik Department, Technische Universität München, Garching, Germany — [2]Physik-Institut, Universität Zürich, Zurich, Switzerland — [3]Nikhef National Institute for Subatomic Physic, Amsterdam, Netherlands

Experiments searching for dark matter or neutrinoless double-beta decay commonly use liquid argon (LAr) as a target or instrumented shielding medium. Particle interactions in the LAr produce vacuum-ultraviolet (VUV) light flashes peaking at 128 nm, which are converted to longer wavelengths by wavelength shifters (WLSs). Due to the short LAr scintillation wavelength and low LAr temperature, the characterization of WLSs requires VUV optics and a cooling system in vacuum. We present the developed custom spectrofluorometer, which enables us to characterize WLSs at VUV excitation and low temperatures. The setup consists of a high-intensity deuterium light source coupled to a VUV monochromator and a vacuum-tight sample chamber. The wavelength shifting material can be mounted on a cryocooler coldhead to measure the wavelength-resolved and wavelength-integrated photoluminescence light yield at the relevant LAr temperature. We describe the characterization campaign of the wavelength-shifting reflector of the LEGEND-200 experiment with the VUV spectrofluorometer and summarize the results. This research is supported by the DFG through the Excellence Cluster ORIGINS and the SFB1258.

T 78.6 Wed 17:30 T-H37

Development of an Organic Plastic Scintillator based Muon Veto Operating at Sub-Kelvin Temperatures for the NUCLEUS Experiment — •Andreas Erhart[1,2], Victoria Wagner[1], Ludwig Klinkenberg[1], Thierry Lasserre[2], David Lhuillier[2], Claudia Nones[2], Tobias Ortmann[1], Luca Pattavina[1], Rudolph Rogly[2], Johannes Rothe[1], Vladimir Savu[2], Nicole Schermer[1], Raimund Strauss[1], and Matthieu Vivier[2] — [1]Physik-Department, Technische Universität München, D-85748 Garching — [2]IRFU, CEA, Université Paris Saclay, F-91191 Gif-sur-Yvette

The NUCLEUS experiment aims to measure coherent elastic neutrino nucleus scattering of reactor anti-neutrinos using cryogenic calorimeters. Operating at an overburden of 3m.w.e., muon-induced backgrounds are expected to be dominant. It is therefore essential to develop an efficient muon veto, with a detection efficiency of more than 99%. A novel concept has been investigated, featuring a plastic scintillator based muon veto operating inside the NUCLEUS cryostat at sub-Kelvin temperatures. The required investigation of the detector's low temperature behavior led to the first reported measurements of organic plastic scintillators at sub-Kelvin temperatures. The functionality of the principal scintillation process has thereby been confirmed. A disc-shape muon veto equipped with wavelength shifting fibers and a silicon photomultiplier has been developed. The research was supported by the DFG through the Excellence Cluster ORIGINS and the SFB1258, and the ERC Starting Grant 2018 "NU-CLEUS".

T 78.7 Wed 17:45 T-H37

Vibration Decoupling System for the NUCLEUS Experiment — •Alexander Wex, Raimund Strauss, Johannes Rothe, Luca Pattavina, Nicole Schermer, Andreas Erhart, Tobias Ortmann, Victoria Wagner, and Margarita Kaznacheeva — Technische Universität München, Physik Department Lehrstuhl E15, James-Franck-Straße 1, D-85748 Garching

The coherent neutrino nucleus scattering experiment NUCLEUS deploys a new-generation dry dilution refrigerator. Vibrations induced by the cryostat's pulse tube cooler are a challenge for stable detector operation. To achieve detector performance undisturbed by pulse tube operation, a dedicated spring-decoupling system is being developed for NUCLEUS. Recent results and benchmark measurements for the design of this cryogenic vibration decoupling system are presented. The research was supported by the DFG through the Excellence Cluster ORIGINS and the SFB1258, and the ERC Starting Grant 2018 "NU-CLEUS".

T 79: Data Analysis, Information Technology and Artificial Intelligence 4

Time: Wednesday 16:15–18:30 Location: T-H38

T 79.1 Wed 16:15 T-H38

K^0_S tracking efficiency studies at Belle II — •Elisabetta Prencipe[1], Oleksandr Skorenok[2], and Jens Soeren Lange[1] — [1]JLU-Giessen, Giessen, Germany — [2]TSNU-Kyiv, Kyiv, Ukraine

Reconstruction efficiency of low momentum tracks in particle physics is a very important issue. Here we report about a study conducted at Belle II, with MC samples and Phase-3 data, and present a dedicated study of the efficiency to correctly reconstruct $K^0_S \to \pi^+\pi^-$, whose daughter tracks can have a different efficiency due to their displacement from the primary event origin.

A significant number of analyses in Belle II involve the reconstruction of $K^0_S \to \pi^+\pi^-$. The reconstruction efficiency of the K^0_S daughters depends on the K^0_S transverse momentum, p_T, polar angle, θ_{LAB} and transverse (XY) flight distance, d_{XY}, which is computed as the distance between the primary vertex of the event and the refitted K^0_S decay vertex.

The general strategy is to subdivide the data and MC events into a large number of samples by choosing an appropriate binning in these variables, determine the number of K^0_S in each bin, in data and MC samples, and for each of the momentum and polar angle ranges, normalize the ratio of its value in the first bin in d_{XY}, where all tracking effects are well understood. The results here presented are acquired by studying the $B \to K^+K^-K^0_S$ and $B \to \pi^+\pi^-K^0_S$ decay channels at Belle II. They will help in understanding systematic effects of analysis where K^0_S are involved.

T 79.2 Wed 16:30 T-H38

Clustering Energy Depositions in the Electromagnetic Calorimeter at Belle II using Graph Neural Networks — •Florian Wemmer, Pablo Goldenzweig, and Torben Ferber for the Belle II-Collaboration — Karlsruher Institut fuer Technologie

Electromagnetic calorimeters in particle detectors like at the Belle II Experiment consist of almost ten thousand sensitive crystals providing detailed energy deposition information in space. The correct assignment of energy depositions in those crystals to clusters originating from a distinct particle imposes a huge challenge especially in the presence of beam induced backgrounds, electronic noise and overlapping clusters. Graph Neural Networks (GNNs) allow for a machine learning algorithm to unrestrictedly and elegantly learn a feature space best suited to solve a problem. Using readily available Monte Carlo data we apply a GNN to try and cluster crystalwise energy information as well as distinguishing physics signals from beam background in the Belle II electromagnetic calorimeter. As a starting point to the development of more capable algorithms the - in actuality complex - detector data is simplified to two possibly overlapping clusters and beam background. We give insight to possible loss functions and metrics of the GNN as well as presenting first results of the clustering process.

T 79.3 Wed 16:45 T-H38

Fast Particle Reconstruction in the Belle II Experiment with Graph Neural Networks — •Isabel Haide, Pablo Goldenzweig, and Torben Ferber for the Belle II-Collaboration — Karlsruhe Institute of Technology

The correct clustering and reconstruction of particles in electromagnetic calorimeters are vital to many analyses to ensure a correct reconstruction of the actual event. This clustering poses difficulties such as an unknown number of particles in the calorimeter and the existence of background events and promotes the use of machine learning (ML) algorithms. Due to the irregular geometry of such detectors, graph neural networks (GNNs) are most suitable to provide an improvement over standard algorithms. GNNs do not depend on regular geometries to learn detector-hit representations and have already been successfully applied to simulated data of a simplified calorimeter model. Extending this application to the geometry of real detectors, such as the Belle II electromagnetic calorimeter (ECL), while reconstructing an unknown number of clusters with possible overlap and additional background events, is the goal of this study. In this talk, the concept of using object condensation with GNNs to reconstruct particles in the ECL and the current status of this development is shown. The evaluation method, which is the separation of the signature of the hypothetical dark photon process $e^+e^- \to A'\gamma, A' \to e^+e^-$ to the signature of radiative Bhabha scattering $e^+e^- \to e^+e^-\gamma$, is also explained.

T 79.4 Wed 17:00 T-H38

Identification of pions and muons with the Belle II calorimeter using convolutional neural network — •Abtin Narimani Charan[1] and Torben Ferber[2] for the Belle II-Collaboration — [1]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany — [2]Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

The Belle II experiment is located at the asymmetric SuperKEKB e^+e^- collider in Tsukuba, Japan. The electromagnetic calorimeter (ECL) in Belle II is designed to reconstruct neutral particles. Additionally, the ECL can identify charged particles e.g. electrons, muons and pions. Identification of low-momenta muons and pions in the ECL is crucial if they do not reach the outer muon detector.

This talk presents an application of a convolutional neural network (CNN) to separate muons and pions in the ECL using energy deposition patterns of 7x7 crystal images. Due to the high level of beam background, the performance of the CNN in samples with different beam background levels is studied. Moreover, the impact of adding pulse-shape and timing information in addition to the energy information is investigated and compared with the previous results in different momentum ranges. Finally, the performance of the network is investigated with data control samples of muons and pions.

T 79.5 Wed 17:15 T-H38

Anomaly detection in the searches for inelastic dark matter at Belle II — •Jonas Eppelt, Patrick Ecker, Pablo Goldenzweig, and Torben Ferber for the Belle II-Collaboration — Karlsruhe Institut for Technology, Karlsruhe, Germany

Inelastic Dark Matter (IDM) is a rather complex model containing two Dark Particles and two Mediators. Its expected signatures include one resonant and one non-resonant decay.

In this talk current efforts are presented to approach searches for IDM at Belle II with anomaly detection via machine learning. This approach aims to train algorithms on (simulated) background events in order to recognize previous unknown signals. It seeks to reduce limitations due to the chosen model and parameter space in searches for physics beyond the Standard Model.

The current status on employing anomaly detection in an IDM search at Belle II will be given.

T 79.6 Wed 17:30 T-H38

Implementing a graph-based approach for semi-inclusive tagging in Belle II — Florian Bernlochner, •Axel Heimeroth, William Sutcliffe, and Ilias Tsaklidis — Physikalisches Institut, University of Bonn, Germany

In the Belle II experiment pairs of B-mesons are produced from electron-positron collisions. The clean experimental environment allows for constraining kinematically the second B-meson if the other one is correctly reconstructed. The current tagging algorithm used in Belle II, called Full Event Interpretation, has relatively low tagging efficiency since all the intermediate decays of the second B-meson must be explicitly reconstructed. This can be critical for searches of extremely rare decays. A semi-inclusive approach, where one reconstructs only partially the tag-side, instead of an exclusive one, can be used in order to increase the overall efficiency. In this work we explore how graph neural networks can improve the purity and efficiency of a semi-inclusive approach, where only a charmed hadron, instead of a B-meson, is reconstructed. In this talk I present a proof of concept on a generic phasespace dataset and a realistic application on $B- > D^* l\nu$ decays from the official Belle II Monte Carlo.

T 79.7 Wed 17:45 T-H38

Performance portability for the Physics Object Reconstruction Software of the CMS Experiment — •Wahid Redjeb — RWTH University, III. Physikalisches Institut A, Aachen, Germany

The High Luminosity upgrade of the LHC will pose unprecedented challenges for the offline and online computing. The higher luminosity and pileup will require larger processing power, not achievable with the current CPUs. Heterogeneous computing will play a fundamental role in the physics object reconstruction software to fully exploit the reach of the HL-LHC. Several computing architectures are available for the CMS software, but specialized implementations for each of them is not sustainable in terms of development, maintenance and validation. Performance Portability libraries allow performance portability across different hardware architectures with a single code basis. In this talk, we present the last results of the first usage of the Alpaka performance portability library on a standalone version of the reconstruction of tracks and vertices in the CMS silicon pixel detector. Porting the pixel tracks and vertices reconstruction to Alpaka demonstrates the possibility of writing a single source code that can be executed on different devices with different parallelization strategies, achieving similar performance with respect to the native implementations.

T 79.8 Wed 18:00 T-H38

Designing VQE ansatz circuits for track reconstruction with Quantum Computers at LUXE — Arianna Crippa[1], Lena Funcke[3], Tobias Hartung[4], Beate Heinemann[1,2], Karl Jansen[1], Annabel Kropf[1], Stefan Kühn[5], Federico Meloni[1], •David Spataro[1], Cenk Tüysüz[1], and Yee Chinn Yap[1] — [1]Deutsches Elektronen Synchrotron DESY — [2]Albert-Ludwigs-Universität Freiburg — [3]Massachusetts Institute of Technology — [4]University of Bath — [5]CaSToRC, The Cyprus Institute

The recently proposed Laser Und XFEL Experiment (LUXE) enables the study of Quantum Electrodynamics (QED) in the strong-field regime, where QED becomes non-perturbative. In this regime, the production of electron-positron pairs by field-induced tunneling out of the vacuum is realised in the interaction of a high energy electron beam from the European XFEL and a high power laser.

Positron track reconstruction on a silicon pixel tracking detector becomes a demanding combinatorial problem at high laser intensity. It is expected to measure up to 10^6 positrons on the four consecutive detector layers. A Quadratic Unconstrained Binary Optimization (QUBO) formulation enables the use of quantum computers and a Variational Quantum Eigensolver (VQE) to reconstruct tracks. For this, designing a suitable ansatz circuit which maps the track candidates to qubits is an important part of the VQE heuristic. Results are compared to common hardware efficient ansatzes. In addition, the final track reconstruction efficiency is compared to a classical approach.

T 79.9 Wed 18:15 T-H38

Benchmarking Variational Quantum Algorithms for track reconstruction at LUXE — Arianna Crippa[1], Lena Funcke[3], Tobias Hartung[4], Beate Heinemann[1,2], Karl Jansen[1], •Annabel Kropf[1], Stefan Kühn[5], Federico Meloni[1], David Spataro[1], Cenk Tüysüz[1], and Yee Chinn Yap[1] — [1]Deutsches Elektronen-Synchrotron DESY — [2]Albert-Ludwigs-Universität Freiburg — [3]Massachusetts Institute of Technology — [4]University of Bath — [5]CaSToRC, The Cyprus Institute

The primary aim of the recently proposed LUXE experiment is to investigate the transition into the non-perturbative regime of Quantum Electrodynamics. For this, the interaction of photons with electrons, or photons with photons is measured at field strengths where couplings to charges become non-perturbative. In these interactions, up to 10^6 positrons are produced that then impinge on a four-layered silicon pixel tracking detector. The accurate reconstruction of the positrons' trajectories from a set of hits is a combinatorial problem challenging for a classical computer to solve. For LUXE, a novel approach is explored that expresses pattern recognition as a quadratic unconstrained binary optimisation, allowing the algorithm to be mapped onto a quantum computer. Variational quantum algorithms provide a promising approach to solve combinatorial optimisation problems on noisy quantum devices. Here, we benchmark the accuracy of two such algorithms, the Variational Quantum Eigensolver and the Quantum Approximate Optimisation Algorithm, against classical tracking using data from an idealised LUXE detector set-up.

T 80: Invited Talks 3 (joint session T/EP)

Time: Thursday 11:00–12:30 Location: T-H15

Invited Talk T 80.1 Thu 11:00 T-H15

Borexino looks in the direction of solar neutrinos — •Livia Ludhova for the Borexino-Collaboration — Forschungszentrum Jülich, Jülich, Germany — RWTH Aachen University, Aachen, Germany

Borexino is a 280-ton liquid scintillator detector located at the LNGS in Italy. Characterized by an unprecedented radio-purity, it has succeeded in providing several milestone measurements of MeV-scale neutrinos, with the main focus on solar neutrinos. The latter are the only direct probe of the Hydrogen-to-Helium fusion powering our Sun. The European Physical Society awarded the 2021 Giuseppe and Vanna Cocconi Prize to the Borexino Collaboration for the ground-breaking observation of solar neutrinos from the pp chain and CNO cycle that provided unique and comprehensive tests of the Sun as a nuclear fusion engine. Borexino has developed a new method, Correlated and Integrated Directionality (CID), to exploit the sub-dominant directional Cherenkov light in a liquid scintillator detector. This technique can disentangle the solar neutrino signal, correlated with the known position of the Sun, from the isotropic background. In the region of interest dominated by the signal from 0.862 MeV Be-7 solar neutrinos, the no-solar neutrino hypothesis has been excluded with $>5\sigma$ C.L. This novel method is readily applicable to next generation experiments. The talk will focus on the recent Borexino solar neutrino results, including the motivation, analysis details, as well as their interpretation.

Invited Talk T 80.2 Thu 11:30 T-H15

Gravitational waves - a new probe of the early Universe — •Valerie Domcke — CERN, Geneva, Switzerland

Due to their extremely weak interactions with the matter content of the Universe, gravitational waves generated right after the Big Bang can traverse the Universe basically unperturbed, carrying information about their production processes and the expansion history of our Universe. This makes them a unique probe of BSM physcis at very high energies. I will talk about possible next steps in this field, including the search for the stochastic gravitational wave background and new ideas for searching for gravitational waves at ultra-high frequencies.

Invited Talk T 80.3 Thu 12:00 T-H15

Gravitational wave detectors - current and future challenges — •Michèle Heurs — Leibniz Universität Hannover

Since the first direct detection in 2015, gravitational wave signals have been enriching the field of multi-messenger astronomy with insights into formerly "invisible" regimes of the universe. Despite their mind-boggling sensitivities, the current (second) generation of ground-based gravitational wave detectors are limited by various noise sources in their detection band, in particular quantum noise, thermal noise, and seismic noise. Next-generation detectors (e.g. Einstein Telescope, Cosmic Explorer) aim for sensitivities one or two orders of magnitude better even, making innovative techniques for noise reduction or mitigation a requirement. This talk will present challenges and technical developments on the road to ever-higher gravitational wave event detection rates.

T 81: Invited Topical Talks 5 (joint session T/EP)

Time: Thursday 14:00–15:40 Location: T-H15

Invited Topical Talk T 81.1 Thu 14:00 T-H15

LND - A ("Made in Germany") Radiation Monitor Operating at the far Side of the Moon — •Sönke Burmeister[1], Shenyi Zhang[2], Jia Yu[1], Zigong Xu[1], Stephan Böttcher[1], and Robert Wimmer-Schweingruber[1] — [1]Institut für Experimentelle und Angewandte Physik, Uni Kiel — [2]NSSC, Chinese Academy of Science

Space Radiation is one of the major concerns in human space flight. Of course, this also applies to human exploration of the Moon. On the lunar surface, this consists of chronic exposure to galactic cosmic rays and sporadic solar particle events. The interaction of this radiation field with the lunar soil leads to a third component that consists of neutral particles, i.e., neutrons and gamma radiation. Chang'E 4 is the Chinese mission that landed on the far side of the Moon on January 3rd, 2019. It consists of a lander, a rover, and a relay spacecraft. The LND (Lunar Lander Neutrons and Dosimetry) instrument that was built by CAU is located inside the lander under an opening lid. It consists of a stack of ten segmented Si solid-state detectors (SSDs), which form a particle telescope to measure charged particles (electrons from 0.5 MeV to several MeV, protons 8-35 MeV, and heavier nuclei 17-75 MeV/nuc). A special geometrical arrangement allows observations of fast neutrons (and gamma-rays) that are also important for dosimetry purposes. Thermal neutrons are measured by using a very thin Gd conversion foil sandwiched between two SSDs. The Lunar Lander Neutrons and Dosimetry experiment aboard China's Chang'E 4 lander has made the first ever measurements of the radiation exposure to both charged and neutral particles on the lunar surface.

Invited Topical Talk T 81.2 Thu 14:25 T-H15
Energetic Pulsar Environments and the Origins of Galactic Cosmic Rays — •Alison Mitchell — Erlangen Centre for Astroparticle Physics, FAU, Erlangen, Germany

Cosmic Rays - and their origins - have fascinated Physicists for over a hundred years. Within our Milky Way Galaxy, particles are known to reach energies beyond the so-called Cosmic Ray *knee*, a spectral break at ~3 PeV in the all particle cosmic ray spectrum. However, evidence for the particle accelerators reach PeV energies - PeVatrons - has proven elusive. Only within the last five years have astrophysical sources of gamma-rays above 100 TeV been identified; gamma-rays produced through interactions of particles with PeV energies. Many of these sources are associated with known energetic pulsars.

In this talk, I will review the current census of PeVatrons and discuss implications for our understanding of pulsar environments. There are several open questions to grapple with: Which particle species are being accelerated - leptonic or hadronic? How are the particles transported through the surrounding medium? What is the maximum energy limit for particle acceleration in pulsar environments? In the near future, data from current and forthcoming facilities will help us to address these questions.

Invited Topical Talk T 81.3 Thu 14:50 T-H15
Looking forward to exciting physics with FASER — •Felix Kling — DESY

Physics searches and measurements at high-energy collider experiments traditionally focus on the high-pT region. However, if particles are light and weakly-coupled, this focus may be completely misguided: light particles are typically highly collimated around the beam line, allowing sensitive searches with small detectors, and even extremely weakly-coupled particles may be produced in large numbers there. The FASER experiment will use the opportunity and extend the LHC's physic potential by searching for long-lived particles and studying neutrino interactions at TeV energies. In this talk, I will present the physics potential of FASER for new physics searches, neutrino physics and QCD and astro-particle physics.

Invited Topical Talk T 81.4 Thu 15:15 T-H15
Astroparticle physics at the LHC: Exploring the forward region with cross-section measurements — •Hans Dembinski — Fakultät Physik, Technische Universität Dortmund, Dortmund, Germany

Astroparticle physics is the study of the non-thermal universe with gamma rays, neutrinos, and cosmic rays. Cosmic rays are abundantly produced in cosmic accelerators, like supernova remnants. Some gamma rays and neutrinos are produced indirectly in interactions of cosmic rays with matter in the source, and cosmic rays interact with Earth's atmosphere to produce air showers, which are observed by ground-based cosmic ray observatories and contribute the main background to gamma ray and neutrino observatories. QCD cross-sections for the forward production of hadrons with light and heavy flavor are therefore needed to interpret astroparticle measurements. The experiments at the Large Hadron Collider (LHC) have powerful instruments to measure forward production, but data are more sparse compared to central production. I will summarize the state-of-the-art of forward cross-section measurements at the LHC from the point of view of astroparticle physics and give an outlook into the opportunities in near future with the upcoming run of the LHC and the planned pilot run with oxygen beams.

T 82: Invited Topical Talks 6

Time: Thursday 14:00–15:40 Location: T-H16

Invited Topical Talk T 82.1 Thu 14:00 T-H16
Searches for new scalar particles at the LHC — •Dominik Duda — Max-Planck-Institut für Physik

The Higgs boson discovery by the ATLAS and CMS experiments at the Large Hadron Collider was a great success. Ever since, numerous studies have been performed to establish whether it is a Standard Model particle or rather the first observed physical state of an extended scalar sector beyond the Standard Model.

Extended scalar sectors are well motivated as they can modify the electroweak phase transition and facilitate baryogenesis, enhance vacuum stability, provide a dark matter candidate or provide a solution to the strong CP problem (i.e. predict axions). In short, extending the scalar sector provides solutions to some of the questions the Standard Model fails to answer.

Various theories beyond the Standard Model predict the existence of new Higgs bosons in addition to the already discovered one. E.g., the introduction of a second Higgs doublet field in the minimal supersymmetric extension of the Standard Model leads to the prediction of three neutral and two charged Higgs bosons, while an additional Higgs triplet field e.g. in models with a type-II seesaw mechanism would result in seven scalars in total. The discovery of such new scalar particles would be a direct evidence of new physics.

In this presentation, the latest searches for additional neutral and charged scalars performed with the ATLAS and CMS experiments will be reviewed.

Invited Topical Talk T 82.2 Thu 14:25 T-H16
Novel approaches to search for new physics in rare charm decays — •Dominik Stefan Mitzel — TU Dortmund University, Germany

Recent studies of rare b-hadron decays have revealed a coherent pattern of deviations from Standard Model predictions in $b \to s\ell^+\ell^-$ transitions, known as *flavour anomalies*. Rare charm decays are sensitive to $c \to u\ell^+\ell^-$ flavour-changing neutral-current processes and offer the unique and complementary opportunity to search for anomalies in the up-type quark sector that has hardly been explored in the past. For long, rare charm decays have been considered as less promising due to difficulties in the description of its low energy dynamics. During this talk, I will discuss how exact or approximate symmetries in the charm system allow to construct clean null-test observables, yielding an excellent road to the discovery of New Physics.

Invited Topical Talk T 82.3 Thu 14:50 T-H16
Constraining the Higgs-charm Yukawa coupling with the CMS experiment — •Luca Mastrolorenzo — RWTH, Aachen, Germany

In this talk, an overview of the most recent results of the direct search for the VH, H→cc process with the CMS experiment is presented. The search targets Higgs bosons produced in association with a vector boson (W, Z) exploiting the full Run-2 data set. The analysis is carried out in mutually exclusive channels selecting specific leptonic decays of the vector bosons: Z→ $\ell\ell$, Z→ $\nu\nu$, W→ $\ell\nu$, with ℓ=electron or muon. To fully exploit the topology of the Higgs boson decay in the different regimes of the Higgs boson transverse momentum, two strategies have been adopted aiming to reconstruct the Higgs boson candidate through two distinct Ak4 jets or via a unique Ak15 "fat-jet". Remarkable improvements have been brought to the analysis techniques with respect to the previous public results: from new and more efficient algorithms to tag charm-initiated jets to dedicated jet energy and mass regression techniques, conceived exploiting advanced machine learning methods. The analysis strategy has been extensively validated by observing the VZ, Z→cc process for the first time at a hadron collider experiment. The results represent the world's most stringent limit on the VH, H→cc process and on the Higgs-charm Yukawa coupling.

Invited Topical Talk T 82.4 Thu 15:15 T-H16
Characterization of H boson events in the $\tau\tau$ decay channel with the full CMS Run-2 data set — •Sebastian Wozniewski — Georg-August-Universität, Göttingen, Germany

The LHC Run-2 data set of proton-proton collisions provides first deeper insights into the properties and production of Higgs bosons. Besides the verification of the assumed coupling structure, which remains a challenge, also differential investigations of Higgs boson events are important tests of the Standard Model (SM) Higgs sector. Moreover, models based on supersymmetry allow for modifications of the couplings of the SM-like Higgs boson to (down-type) fermions, which puts particular interest on the decay channel into tau leptons. The analysis of di-tau events of the full LHC Run-2 data set, taken by the CMS experiment, in the STXS framework for differential cross sections measurements is presented. It is based on modern technologies in terms of object identification, data-driven background modeling, and neural-network based multiclass event-classification. The full granularity of the differential STXS measurement, with twelve signal components, is reflected by the neural networks, in addition to the major background contributions.

T 83: Astroteilchen: Von der Quelle zum Detektor (contributed talks) (joint session EP/T)

Time: Thursday 16:15–18:30 Location: EP-H1

T 83.1 Thu 16:15 EP-H1
Multi-messenger studies with gravitational waves and neutrinos — •Tista Mukherjee for the IceCube-Collaboration — Institute for Astroparticle Physics (IAP), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

IceCube is a neutrino observatory located in Antarctica. Since its discovery of a high-energy neutrino (IC170922A) from the blazar TXS0506+056 in 2017, neutrino astronomy has been established as a viable option to probe the high-energy Universe. Neutrinos can carry undistorted information about their respective astrophysical sources, thus can serve as a cosmic 'messenger' to us. There are other potential messengers as well, e.g. gravitational waves (GW) and cosmic rays other than the traditional photons of various wavelengths. Combining interesting signals of such messengers available from different observatories leads us towards multi-messenger searches, allowing us to address many of the so far unanswered questions about the fundamentals of this Universe, such as the origin of ultra-high-energy cosmic ray sources. So far, we have the knowledge of detecting electromagnetic signal in multiple wavelengths, spatially and temporally correlated with GW and high-energy neutrinos, as two separate events. However, there is still a missing link as we have not been able to correlate GW with neutrino signals. The aim of my work is to contribute in this aspect, searching for Virgo detected GW counterparts of neutrino events detected by IceCube, including low-energy neutrinos as well as sub-threshold GW events in our analysis. The work plan and initial results will be discussed in this talk.

T 83.2 Thu 16:30 EP-H1
Multi-messenger characterization of Mrk501 during historically low X-ray and gamma-ray activity — •Lea Heckmann[1], David Paneque[1], Sargis Gasparyan[2], Matteo Cerruti[3], Narek Sahakyan[2], and Axel Arbet-Engels[1] for the Multi-wavelength collaborators and the MAGIC and Fermi-LAT-Collaboration — [1]Max-Planck-Institut für Physik, D-80805 München, Germany — [2]ICRANet-Armenia, Marshall Baghramian Avenue 24a, Yerevan 0019, Armenia — [3]Institut de Ciències del Cosmos (ICCUB), Universitat de Barcelona (IEEC-UB), Martí i Franquès 1, 8 E08028 Barcelona, Spain

Blazars are the most numerous very-high-energy (>0.2 TeV, VHE) gamma-ray emitters, due to their continuous and very luminous emission; but they are far from being understood.

In this contribution we describe the multi-wavelength behavior of Mrk501, one of our closest and therefore brightest blazars, from 2017 to 2020. Alongside the dense monitoring campaign over this four years, three long observations with NuSTAR were conducted displaying various low-activity flux levels for the hard X-ray emission. This very comprehensive data set reveals a historically low X-ray and VHE gamma-ray emission period lasting two years. Using the low-activity broadband spectral energy distribution (SED) and data published by IceCube, we investigate the nature of the low state. Additionally, we try to explain the evolution of the broadband SED data during the low state to evaluate its potential of being the baseline emission of Mrk501 that is usually outshone by more dominant and variable components.

T 83.3 Thu 16:45 EP-H1
Hadronic models of active galaxies to constrain cosmic-ray acceleration — •Xavier Rodrigues — DESY Zeuthen

In a new era of multi-messenger observatories, numerical models can help shed light on what are the sources of the astrophysical neutrinos and the ultra-high-energy cosmic rays. In this talk I discuss recent results on active galactic nuclei (AGN) as multi-messenger sources, based on numerical simulations of photonuclear cosmic-ray interactions. Assuming AGN jets can reaccelerate cosmic rays up to the EeV regime, I will show that an AGN population may in fact dominate the observed flux and chemical composition of ultra-high-energy cosmic rays. Under certain conditions, the accompanying neutrino flux may be observable by future EeV neutrino telescopes, while respecting the current IceCube limits at PeV energies.

T 83.4 Thu 17:00 EP-H1
Neutrino Emission during Supermassive and stellar mass Binary Black Hole Mergers — •Ilja Jaroschewski[1], Julia Becker Tjus[1], and Peter L. Biermann[2,3] — [1]Theoretische Physik IV, Ruhr-Universität Bochum — [2]MPI for Radioastr., Bonn — [3]Dept. of Phys. & Astron., Univ. Alabama, Tuscaloosa, AL, USA

Ever since the discovery of a diffuse astrophysical neutrino flux by IceCube, the question arose which sources contribute most. With several neutrino-blazar associations since the first high-probability association of such a neutrino to the blazar TXS 0506+056 in 2017, there is an indication that at least a non-negligible part of this diffuse neutrino flux emerges from blazars.

As over ninety stellar mass binary black hole mergers were already detected via gravitational waves (GWs), with more to come, there are strong indications that supermassive black holes (SMBHs) in galaxy centers, and thus blazars, also merge and have had at least one merger in their lifetime. Such a merger is almost always accompanied by a change of observable jet direction, leading to interactions of a preceding jet with surrounding molecular clouds and neutrino productions.

By creating a connection between neutrinos and GWs, we set limits on how much energy can be emitted in form of neutrinos in each merger of binary SMBHs and stellar mass black holes and estimate their contributions to the diffuse neutrino flux that is measured by IceCube. As neutrino production is directly connected to high energy cosmic ray interactions, the contribution of these sources to the cosmic ray injection rate is established.

T 83.5 Thu 17:15 EP-H1
Search for high-energy neutrinos from blazars with IceCube — •Cristina Lagunas Gualda for the IceCube-Collaboration — DESY Zeuthen

The IceCube Neutrino Observatory is the world's largest neutrino telescope, instrumenting one cubic kilometre of Antarctic ice. IceCube started its operation with full configuration in 2011 and a diffuse flux of neutrinos was discovered in 2013. To this day the sources of those neutrinos are still largely unknown. One of the most promising neutrino source candidates is blazars, Active Galactic Nuclei with jets aligned towards Earth.

In 2018 IceCube reported the first clearly identified observation of an astrophysical high-energy neutrino, IC170922A, in spatial and temporal coincidence with blazar TXS 0506+056. Other examples of coincidences that have been observed with lower significance are, but not limited to, IC190730A with blazar PKS 1506+012 and IC141209A with blazar GB6 J1040+0617. What these have in common is that they involve a blazar and a high-energy neutrino with a high probability of being astrophysical in origin (neutrino alert). These coincidences can be combined to calculate a global p-value by performing a stacking analysis. Here we present the results obtained with the Fourth Catalog of Active Galactic Nuclei detected by Fermi-LAT (4LAC-DR2, for

Data Release 2) and neutrinos detected by IceCube between 2011 and 2020 that would have passed the neutrino alert criteria.

T 83.6 Thu 17:30 EP-H1

Comparison of Models for Predicting Periodic Gamma-Ray & Neutrino Emissions From Blazars — •Armin Ghorbanietemad, Ilja Jaroschewski, and Julia Becker Tjus — Theoretische Physik IV, Ruhr-Unviersität Bochum

There are several indications that electromagnetic emissions from blazars have quasi-periodic variability, ranging from minutes to years. The long-term periodicity in the span of years is particularly evident in gamma-ray observations with the Fermi LAT instrument. Two separate high probability associations of neutrinos, detected by IceCube in 2014/15 and 2017, to the blazar TXS0506+056 further indicate that blazars are neutrino emitters. These two flares can be interpreted as a possible periodicity. It is the aim of this work to develop a general set of models that can explain the periodic gamma-ray and neutrino emissions from blazars.

In this talk, we present models with single supermassive black holes as well as supermassive binary black hole mergers at the centers of blazers. Our focus lies on supermassive binary black hole mergers, due to them radiating gravitational waves which could be detectable by the Laser-interferometer Space Antenna (LISA). The binary systems are characterized by the change of jet direction accompanied by jet precession close to an imminent merger. This allows predictions of possible neutrino and gravitational wave emissions from blazars with quasi-periodic behavior.

T 83.7 Thu 17:45 EP-H1

First science results from the X-ray telescope STIX on Solar Orbiter — •Alexander Warmuth, Frederic Schuller, and Gottfried Mann — Leibniz -Institut für Astrophysik Potsdam (AIP)

The ESA mission Solar Orbiter was successfully launched in 2020, with the main goal of improving our understanding of how the Sun creates and controls the heliosphere. The Spectrometer/Telescope for Imaging X-rays (STIX) is one of six remote-sensing instruments on board and provides imaging spectroscopy of solar flares in the energy range of 4 to 150 keV. Thus, STIX is able to measure quantitatively both the parameters of the hot flare plasma and the characteristics of the accelerated electrons. Together with the other instruments on Solar Orbiter as well as with other space-borne and ground based observational assets, STIX studies energy release and particle acceleration in solar flares. This talk will be focused on the first science results obtained during the cruise phase of Solar Orbiter (2020 and 2021). This includes observations of microflares, constraints on flare energetics, collaborative studies of gamma-ray flares together with Fermi, and the investigation of flare-associated solar energetic particle events.

T 83.8 Thu 18:00 EP-H1

Unfolding the muon neutrino energy spectrum from 10 years of IceCube data with DSEA+ — •Leonora Kardum, Karolin Hymon, Johannes Werthebach, Pascal Gutjahr, Tim Ruhe, and Jean-Marco Alameddine for the IceCube-Collaboration — Astroparticle Physics WG Rhode, TU Dortmund University, Germany

Neutrinos, the most elusive particles in the Standard Model, can travel tremendous distances unaffected by magnetic fields or encountered particles from distant sources in the Universe. As this makes them perfect information carriers, many attempts at uncovering their properties are made. The IceCube Neutrino Observatory, a cubic kilometer detector embedded in the South Pole ice, is capable of detecting neutrinos from several GeV up to PeV energies enabling precise reconstruction of the neutrino spectrum. Determining the accurate spectrum is of great importance to neutrino physics, especially in differentiating the three predicted components - prompt, conventional, and astrophysical, of which only the latter two have been detected so far. The Dortmund Spectrum Estimation Algorithm (DSEA+) is a novel approach to unfolding the energy spectrum from measured experimental quantities that effectively translates ill-posed problems to multinomial classification solvable using readily available machine learning tools. The current status of applying DSEA+ on 10 years of IceCube data will be presented.

T 83.9 Thu 18:15 EP-H1

Recent solar and geoneutrino results from Borexino — •Sindhujha Kumaran for the Borexino-Collaboration — Forschungszentrum Jülich - Institute for Nuclear Physics, IKP-2, Jülich, Germany — III. Physikalisches Institut B, RWTH Aachen University, Aachen, Germany

Borexino is a 280-ton liquid scintillator experiment which ran from May 2007 until October 2021 at the Laboratori Nazionali del Gran Sasso (LNGS), Italy. The main goals of Borexino include the measurement of solar neutrinos and geoneutrinos. The extreme radiopurity and thermal stability of the detector have proven to be valuable assets in achieving these goals. Borexino has not only performed a complete spectroscopy of the dominant pp-chain solar neutrinos but has also provided the first direct experimental evidence of the rare CNO-cycle neutrinos. These measurements have several implications for solar and stellar Physics and further improvements are envisioned using the full dataset. In addition, it has recently presented the first directional measurement of sub-MeV solar neutrinos using the subdominant Cherenkov light, through a novel technique called Correlated and Integrated Directionality (CID). This method can be further combined with a typical spectral fit and can also prove valuable for next-generation liquid scintillator detectors. The latest geoneutrino measurement from Borexino included a substantial improvement in the precision as well as the rejection of the no-mantle signal with a high significance. This group report will summarize all these recent solar and geoneutrino results of Borexino.

T 84: Flavour Physics

Time: Thursday 16:15–18:30 Location: T-H15

T 84.1 Thu 16:15 T-H15

Tagged analysis of $B \to X_u \ell \nu$ at Belle — •Armindokht Afsharipour, Florian Bernlochner, Jochen Dingfelder, Svenja Granderath, Peter Lewis, and Rieka Rittsteiger — Physikalisches Institut, Universität Bonn

We present a study of the exclusive charmless semileptonic decays, $B \to X_u \ell \nu$, where $X_u = \pi^0, \eta, \eta'$ and ℓ is an electron or a muon, with the Belle experiment at the SuperKEKB collider in Japan. In the Belle experiment, electrons and positrons are collided at the center-of-mass energy equal to the mass of the $\Upsilon(4S)$ resonance, which decays to pairs of B mesons. One of the two B mesons can be fully reconstructed in a hadronic decay mode (hadronic B tagging) using the Full Event Interpretation algorithm. The signal B meson is then reconstructed from the remaining particles (hadrons and leptons) formed from the unassigned tracks and neutral clusters in the event. In this talk, the general analysis strategy and status of the $B \to X_u \ell \nu$ analysis using hadronic B-tagging in Belle is presented.

T 84.2 Thu 16:30 T-H15

Untagged Analysis of $B \to \pi \ell \bar{\nu}_\ell$ and extraction of $|V_{ub}|$ at Belle II — Florian Bernlochner, Jochen Dingfelder, •Svenja Granderath, and Peter Lewis for the Belle II-Collaboration — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

One of the puzzles of current research in flavor physics is the persisting discrepancy between the results of exclusive and inclusive measurements of the CKM matrix element $|V_{ub}|$. The charmless semileptonic decay $B \to \pi \ell \bar{\nu}_\ell$ is one of the most accessible and powerful channels for determining $|V_{ub}|$ in exclusive modes. Using data from the Belle II experiment, a new precision measurement of $|V_{ub}|$ can be performed. In preparation for this, an untagged measurement method for extracting $B \to \pi \ell \bar{\nu}_\ell$ events is developed using Belle II data. An untagged measurement allows for sufficiently large samples of this rare decay already with the current Belle II dataset. In order to increase the signal purity, boosted decision trees are employed to suppress continuum and $B\overline{B}$ backgrounds. This talk will discuss the current status of the analysis and $|V_{ub}|$ extraction.

T 84.3 Thu 16:45 T-H15

Exclusive $B \to X_u \ell \nu_\ell$ Decays with Hadronic Tagging in

Belle II Data — •Moritz Bauer, Pablo Goldenzweig, and Torben Ferber for the Belle II-Collaboration — KIT, Karlsruhe, Germany

There has been a longstanding 3σ tension between inclusive and exclusive measurements of the magnitude of the CKM matrix element $|V_{ub}|$. Semileptonic decays involving $b \to u$ transitions present a unique opportunity to measure $|V_{ub}|$ with the current Belle II dataset due to their comparatively high branching fraction.

We present analyses of the semileptonic processes $B \to \pi \ell \nu_\ell$ and $B \to \rho \ell \nu_\ell$ in Belle II data as steps towards the extraction of this matrix element from exclusive decays. These analyses are conducted with hadronic tagging, utilizing a new tagging algorithm, the Full Event Interpretation.

T 84.4 Thu 17:00 T-H15

Tagged analysis of $B \to \rho^0 \ell \nu$, $B \to \rho^+ \ell \nu$ and $B \to \omega \ell \nu$ — Armindokht Afsharipour, Florian Bernlochner, Jochen Dingfelder, Svenja Granderath, Peter Lewis, and •Rieka Rittsteiger for the Belle-Collaboration — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

We present a study of the charmless semileptonic decays $B \to \rho^0 \ell \nu$, $B \to \rho^+ \ell \nu$ and $B \to \omega \ell \nu$, where ℓ is an electron or a muon, with the Belle experiment at KEK in Tsukuba, Japan. Belle took data from 1999 until 2010 at a center-of-mass energy corresponding to the mass of the $\Upsilon(4S)$, which predominantly decays into a pair of B mesons. The Full Event Interpretation is used to fully reconstruct one B meson in a hadronic decay mode. The signal B meson is reconstructed from a lepton and the respective hadron (ρ, ω) using the remaining tracks and neutral clusters in the event. The precise knowledge of the tag-side B decay leads to a good signal-to-background ratio but also a very small efficiency.

In this talk the analysis strategy and status of the $B \to \rho^0 \ell \nu$, $B \to \rho^+ \ell \nu$ and $B \to \omega \ell \nu$ analysis using hadronic B-tagging at Belle are presented.

T 84.5 Thu 17:15 T-H15

Measurement of the photon energy spectrum in the fully-inclusive hadronic-tagged $B \to X_s \gamma$ decays at the Belle II experiment — •Henrikas Svidras — DESY, Hamburg

Belle II is an experiment at the next-generation B factory SuperKEKB located at KEK in Tsukuba, Japan. It aims to probe heavy flavour physics at a higher precision than its predecessors, namely BaBar and Belle. The goal is to collect 50 ab^{-1} of data during its run: more than 50 times that of Belle. One of the particularly promising decay channels to study is the inclusive radiative $B \to X_s \gamma$ decay, where X_s denotes any possible decay products containing an s quark and γ is a high-energetic photon. This decay can provide constraints for beyond-SM theories, for example by measuring CP asymmetries, and be used to extract important parameters such as the b quark mass. The analysis presented in this talk focuses on the hadronic-tagged fully-inclusive approach, where one of the daughter B mesons of the $\Upsilon(4S) \to B\bar{B}$ decays into hadrons. The extraction of the photon energy spectrum of the $B \to X_s \gamma$ is one of the goals of the analysis. The talk presents the analysis setup and main challenges of this measurement at Belle II.

T 84.6 Thu 17:30 T-H15

Measurement of the q^2 moments in semi-leptonic B meson decays at Belle II — •Maximilian Welsch, Florian Bernlochner, and Jochen Dingfelder — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

The determination of inclusive $|V_{\mathrm{cb}}|$ from $b \to c \ell \nu$ decays relies on the Heavy Quark Expansion (HQE) involving coefficients and associated non-perturbative matrix elements, which can be expressed in terms of a number of expansion parameters. The moments of the kinematic distribution of the decay can be computed in a similar manner and are dependent on the same HQE parameters. Consequently, measurements of such moments can be used to better constrain the expansion parameters and, thereby, more precisely determine $|V_{\mathrm{cb}}|$. In this talk, we present the first measurement of the q2 moments of $B \to X_c \ell \nu$ decays with 62.8 fb^{-1} of Belle II data. The q2 moments of the $b \to c \ell \nu$ transition are particularly powerful for constraining the HQE expansion as they can be expressed in terms of a reduced set of non-perturbative parameters due to reparametrization invariance. In addition, we present an preliminary determination of $|V_{\mathrm{cb}}|$.

T 84.7 Thu 17:45 T-H15

Untagged $\overline{B}^0 \to D^{*+} \ell^- \overline{\nu}_\ell$ studies with Belle II — Florian Bernlochner[1], Lu Cao[1,2], Jochen Dingfelder[1], and •Chaoyi Lyu[1] — [1]Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn — [2]Deutsches Elektronen-Synchrotron DESY

The precise determination of the CKM matrix element $|V_{cb}|$ and semileptonic form factors in B meson decays are important for carrying out precision tests of the flavour sector of the Standard Model and to search for new physics. The decay of $\overline{B}^0 \to D^{*+} \ell^- \overline{\nu}_\ell$ is particularly well suited to determine $|V_{cb}|$ due to its large branching fraction, small backgrounds and the availability of lattice data to describe the form factors. In this talk, we will present the current status of establishing an untagged measurement of the $\overline{B}^0 \to D^{*+} \ell^- \overline{\nu}_\ell$ branching fraction and form factors using early Belle II data.

T 84.8 Thu 18:00 T-H15

Measuring kinematic distributions of $B \to D^* \ell \nu_\ell$ with hadronic tagging at Belle II — Florian Bernlochner, Jochen Dingfelder, •Michael Eliachevitch, Michael Hedges, Peter Lewis, Markus Prim, and William Sutcliffe — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

The analysis of semileptonic B meson decays is one of the main pillars of the physics program of the Belle II experiment, since their theoretical cleanliness enables precise theoretical predictions which can be compared with measurements for tests of the Standard Model of particle physics (SM).

This talk presents early results and analysis plans for the $B \to D^* \ell \nu_\ell$ decay with ℓ denoting the light leptons e and μ. Its high branching fraction and ease of reconstruction allow to use available Belle II data for differential measurements of the shapes describing the decay kinematics. These are sensitive to the $|V_{\mathrm{cb}}|$ CKM matrix-element and to the form-factors describing the interactions of the hadronic current. Based on these shapes we can further measure angular observables such as the forward-backward asymmetry A_{FB} to probe the SM. In the presented analysis the other B meson originating from the $\Upsilon(4S)$ is fully reconstructed in hadronic decay modes via the *Full Event Interpretation* tagging algorithm, providing the full four-momentum of the signal B meson. Due to the resulting high purity and good resolution this serves as an important cross-check of similar measurements using an inclusive tagging approach.

T 84.9 Thu 18:15 T-H15

Studies of $B \to D^{**} \ell \nu$ at Belle II — Ariane Frey, •Noreen Rauls, and Benjamin Schwenker — II. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Deutschland

The semileptonic decay $B \to D^{**} \ell \nu$ is one of the main background modes for the determination of the ratio $R(D^{(*)})$, which is used to probe the Standard Model. One of the aims of this analysis is to understand the decay $B \to D^{**} \ell \nu$ as background contribution to the $R(D^{(*)})$ measurement. For the reconstruction of the daughters of the D^{**} various different hadronic D and D^* modes are used. The B meson is reconstructed using these D^{**} decay modes as well as light and charged leptons.

B mesons are always produced in pairs on the $\Upsilon(4S)$ resonance at the Belle II experiment in Japan. One of these B mesons is reconstructed using the decay mode stated above. The other B meson uses the hadronic Full Event Interpretation (FEI) for its reconstruction. The FEI is an algorithm, which is based on the hierarchical reconstruction of final-state, intermediate particles and B mesons using multivariate classifiers.

This talk will give a first insight on the reconstruction of the B meson in these channels using Belle II Monte Carlo samples. Furthermore, a brief outlook will be shown.

T 85: Beyond the Standard Model (Theory) 2 and QFT and Lattice Gauge Theory 1

Time: Thursday 16:15–18:30 Location: T-H16

T 85.1 Thu 16:15 T-H16

Four-top final states as a probe of Two-Higgs-Doublet models — •Steven Paasch and Henning Bahl — Deutsches Elektronen-Synchrotron DESY

Using a CMS measurement of four top ($t\bar{t}t\bar{t}$) production in proton-proton collisions we constrain the parameter space of BSM scalar models. We study these effects for models with a generic scalar X with couplings to W-bosons and to top-quarks. We use Monte-Carlo simulators and fast detector simulations to recast the CMS analysis in order to obtain upper limits on the cross section times branching fraction for the production modes $pp \to (t\bar{t}, tW, t) + X$ with $X \to t\bar{t}$, where X is a new heavy Higgs H, a pseudoscalar A or mixed CP-state. Furthermore we study the impact on Two-Higgs-Doublet models where four top production places constraints on the low tanβ region which is of special interest for Baryogenesis.

T 85.2 Thu 16:30 T-H16

Flavour and LHC constraints in the 2HDM — Oliver Atkinson[1], •Matthew Black[2], Christoph Englert[1], Alexander Lenz[2], Aleksey Rusov[2], and James Wynne[3] — [1]SUPA, School of Physics and Astronomy, University of Glasgow, Glasgow, UK — [2]Physik Department, Universität Siegen, Walter-Flex-Str. 3, Siegen, Germany — [3]IPPP, Department of Physics, University of Durham, UK

We present comprehensive studies of the Two Higgs Doublet Model with Type I and Type II Yukawa couplings. To find bounds on the mass spectrum of these models, contributions to flavour, Higgs, and electroweak observables from the new scalars and couplings are considered, using theoretical constraints to inform these fits. We compare the results of these fits to those from direct searches at the LHC, finding regions of parameter space allowed by both flavour and collider. In addition, we test the consequences of our results on electroweak baryogenesis and the possibility of generating a strong first order phase transition in the 2HDM.

T 85.3 Thu 16:45 T-H16

Benchmarking Di-Higgs Production in Various Extended Higgs Sector Models — •Duarte Azevedo[5,6], Hamza Abouabid[1], Abdesslam Arhrir[1], Jaouad El Falaki[3], Pedro M. Ferreira[2,4], Margarete Mühlleitner[5], and Rui Santos[2,4] — [1]AbdelMalek Essaadi University, Faculty of Sciences and Techniques B.P 416, Tangier, Morocco — [2]ISEL - Instituto Superior de Engenharia de Lisboa, Instituto Politécnico de Lisboa 1959-007 Lisboa, Portugal — [3]EPTHE, Physics Department, Faculty of Science, Ibn Zohr University, Faculty of Sciences Agadir, Morocco — [4]Centro de Física Teórica e Computacional, Faculdade de Ciências, Universidade de Lisboa, Campo Grande, Edifício C8 1749-016 Lisboa, Portugal — [5]Institute for Theoretical Physics, Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany — [6]Institute for Astroparticle Physics, Karlsruhe Institute of Technology, 76344 Karlsruhe, Germany

We study di-Higgs production in various extended Higgs sector models such as the real and complex 2HDM, the 2HDM with a real singlet and the next-to-Minimal Sypersymmetric Standard Model. We study the process $pp\to h_ih_j$ with $h_i=h_j$ the 125 GeV scalar and the case where h_i and/or h_j are new scalars predicted by the models. When performing the parameter scan, we consider all relevant constraints. The di-Higgs production cross section in these models can exceed the Standard Model rate by more than one order of magnitude. Furthermore we presenting our results for extended Higgs sector considered and list benchmark scenarios which exhibit important di-Higgs production rates at the LHC.

T 85.4 Thu 17:00 T-H16

Phenomenology of unusual top partners in composite Higgs models — Giacomo Cacciapaglia[1], Thomas Flacke[2], •Manuel Kunkel[3], and Werner Porod[3] — [1]Université Lyon 1, Villeurbanne, France — [2]Center for AI and Natural Sciences (KIAS), Seoul, Korea — [3]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Germany

We consider a particular composite Higgs model which contains SU(3) color octet top partners besides the usually considered triplet representations. Moreover, color singlet top partners are present as well which can in principle serve as dark matter candidates. We investigate the LHC phenomenology of these unusual top partners. Some of these states could be confused with gluinos predicted in supersymmetric models at first glance.

T 85.5 Thu 17:15 T-H16

HiggsTools: a toolbox for BSM scalar phenomenology — •Steven Paasch[1], Cheng Li[1], Jonas Wittbrodt[1], Thomas Biekoetter[1], Henning Bahl[1], Georg Weiglein[1], and Sven Heinemeyer[2] — [1]Deutsches Elektronen-Synchrotron DESY — [2]Instituto de Fisica Teorica (UAM/CSIC), Universidad Autonoma de Madrid

The codes HiggsBounds and HiggsSignals compare model predictions of BSM models with extended scalar sectors to searches for additional scalars and measurements to the 125GeV Higgs boson. We present a unification and extension of the functionalities provided by both codes into the new HiggsTools framework. The codes have been re-written in modern C++ with a native python interface for easy interactive use. We discuss the user interface for providing model predictions, now part of the new sub-library HiggsPredictions, which also provides access to many tabulated cross sections and BRs in reference models such as the SM. HiggsBounds now implements experimental limits purely through json data files and can better handle clusters of BSM particles of similar mass, even for complicated search topologies. In HiggsSignals, the treatment of different types of measurements has been unified, both in the $\chi 2$ computation and in the data file format used to implement experimental results.

T 85.6 Thu 17:30 T-H16

First-order strong-field QED processes including the damping of particle states — •Tobias Podszus and Antonino Di Piazza — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

Strong field QED considers electrodynamic processes in the presence of an electromagnetic background field. Here 'strong' refers to the intensity of the background field, which is so high that the interactions of electrons and positrons with the background field have to be taken into account exactly in the calculations. This is done by implementing the background field in the quantization procedure of the fermion field. Exact solutions of the corresponding Dirac equation in the presence of an arbitrary plane wave field are the so called Volkov states. However, Volkov states, as well as free photon states, are not stable in the presence of the background plane-wave field but 'decay' as electrons/positrons can emit photons and photons can transform into electron-positron pairs. By using the solutions of the corresponding Schwinger-Dyson equations within the locally constant field approximation, we compute the probabilities of nonlinear single Compton scattering and nonlinear Breit-Wheeler pair production by including the effects of the decay of electron, positron, and photon states. As a result, we find that the probabilities of these processes can be expressed as the integral over the light-cone time of the known probabilities valid for stable states per unit of light-cone time times a light-cone time-dependent exponential damping function for each interacting particle.

T 85.7 Thu 17:45 T-H16

QCD equation of state via the complex Langevin method — •Felipe Attanasio[1], Benjamin Jäger[2], and Felix Ziegler[2,3] — [1]Institute for Theoretical Physics, Universität Heidelberg, Philosophenweg 16, D-69120, Germany — [2]CP3-Origins & Danish IAS, Department of Mathematics and Computer Science, University of Southern Denmark, Campusvej 55, 5230 Odense M, Denmark — [3]School of Physics and Astronomy, The University of Edinburgh, EH9 3FD Edinburgh, United Kingdom

The equation of state of hadronic matter is of high importance for many fields, ranging from heavy-ion collisions to neutron stars. Non-perturbative methods to simulate QCD encounter difficulties at finite chemical potential μ due to the so-called sign problem. We employ the complex Langevin method to circumvent this problem and carry out simulations at a variety of values for temperature and μ. We present results on the pressure, energy and entropy equations of state, as well as a numerical observation of the Silver Blaze phenomenon.

T 85.8 Thu 18:00 T-H16

High-energy diffractive processes without and with soft photon radiation and Low's theorem — •Piotr Lebiedowicz[1], Otto Nachtmann[2], and Antoni Szczurek[1] — [1]Institute of Nuclear Physics Polish Academy of Sciences, Krakow, Poland — [2]Institut für Theoretische Physik, Universität Heidelberg, Heidelberg, Germany

Exclusive high-energy reactions at small momentum transfer without and with soft photon radiation are discussed. The tensor-pomeron model describing such reactions involving hadrons is introduced. The tensor-pomeron model is for hadronic high-energy reactions and has its origin in general investigations of the soft, nonperturbative, pomeron in QCD. The emission of soft radiation provides a fundamental probe of the consistency of the underlying Quantum Field Theory. As an example pion-pion scattering without and with soft photon emission is considered. The "exact" model results are compared to soft photon approximations based on Low's theorem. The term of order (photon energy)^0 in the expansion of the photon emission amplitude needs to be changed compared to Low's result.

T 85.9 Thu 18:15 T-H16

Decay constants of B, B_s, and B_c mesons — •Matthew Black and Oliver Witzel — Physik Department, Universität Siegen, Walter-Flex-Str. 3, Siegen, Germany

We present the status of our ongoing work extracting B-meson decay constants f_B with $B = B_0, B^+, B_s, B_c$. Our calculation is based on $N_f = 2 + 1$ dynamical flavour gauge field ensembles generated by the RBC/UKQCD collaborations using domain wall fermions and the Iwasaki gauge action. Using domain wall light, strange, and charm quarks and relativistic b-quarks we obtain results at three different lattice spacings $a \approx 0.11, 0.08, 0.07$ fm and multiple valence quark masses. We perform a global fit to obtain phenomenologically relevant results in the continuum and at physical quark masses.

T 86: Neutrino Physics (Theory) 1 and Theoretical Astroparticle Physics and Cosmology 1

Time: Thursday 16:15–18:00 Location: T-H17

T 86.1 Thu 16:15 T-H17

Majoron Models without Domain Walls — •Tim Brune — TU Dortmund

In the singlet Majoron model, neutrino masses arise due to the spontaneous violation of lepton number. Apart from providing a viable dark matter candidate, the model can also explain the generation of a baryon asymmetry via Leptogenesis. However, the Majoron model suffers from the existence of cosmological domain walls, contradicting observations. I present extensions of the Majoron model by additional right-handed doublets and triplets that render it domain wall free. Besides avoiding the existence of domain walls, the additional particles have a non-trivial effect on the Sphaleron process that converts the lepton asymmetry to a baryon asymmetry in Leptogenesis models.

T 86.2 Thu 16:30 T-H17

Search for Fermionic Dark Matter using Astrophysical Neutrinos and Quantum Gravitational Decoherence — Heinrich Päs, •Dominik Hellmann, and Erika Rani — TU Dortmund, Dortmund, Deutschland

A model involving quantum gravitationally induced decoherence is proposed to investigate on the properties of fermionic dark matter using astrophysical neutrinos.

The main assumption of the model is that interactions of particles with the spacetime foam violate global quantum numbers such as lepton number and only conserve unbroken gauge quantum numbers. Hence, if N hypothetical fermionic dark matter species exist transforming as a singlet under $SU(3)_c \times U(1)_{EM}$, quantum gravity interactions cannot distinguish between neutrinos and these unknown degrees of freedom.

Applying this phenomenological $3 + N$ flavor model to systems of high energy neutrinos shows that these effects lead to a uniform flavor distribution over all neutral fermionic species in an initially pure neutrino beam after sufficiently long distances. Therefore, fluxes of neutrinos from astrophysical origin are expected to differ drastically from the standard expectation depending on the number of additional dark matter fermions present.

Consequently, future neutrino experiments could provide new clues about the fermionic dark sector.

T 86.3 Thu 16:45 T-H17

CPT Violation in Neutrino Oscillations with Quantum-Gravitational Decoherence — •Erika Rani[1,2], Heinrich Päs[1], and Dominik Hellmann[1] — [1]TU Dortmund, Lehrstuhl für Theoretische Physik III — [2]UIN Maulana Malik Ibrahim Malang, Indonesia

Quantum gravity effects can lead to the violation of fundamental symmetries, including global symmetries such as flavor, baryon and lepton number and discrete symmetries such as CPT. In this talk, we investigate CPT violation in neutrino oscillations in the context of quantum-gravitational decoherence. By employing the Ellis, Hagelin, Nanopoulos, and Srednicki (EHNS) formalism we study a two-flavor scenario and discuss the size of the effect in different parametrizations.

T 86.4 Thu 17:00 T-H17

"Magnetic" Mass of the Neutron — •Manfred Geilhaupt — HSN, Mönchengladbach, Germany

In Quantum Physics, the Spin of an elementary particle is defined to be an intrinsic, inherent property. The same to the magnetic moment (μ) due to the spin of charged particles - like Electron (me) and Proton (mp). So the intrinsic spin (S=1/2h-bar) of the electron entails a magnetic moment because of charge (e). However, a magnetic moment of a charged particle can also be generated by a circular motion (due to spin) of an electric charge (e), forming a current. Hence the orbital motion (of charge around a mass-nucleus) generates a magnetic moment by Ampère's law. This concept must lead to an alternative way calculating the neutrino mass (mν) while looking at the beta decay of a neutron into fragments: proton, electron, neutrino and corresponding kinetic energies. The change of neutrons magnetic moment (μn) during the decay process is a fact based on energy and spin and charge conservation, so should allow to calculate the restmass of the charge-less neutrino due to a significant change of: μe= -9.2847647043(28)E-24J/T down to μev= -9.2847592533(28)E-24J/T (while assuming mv=0.30eV to be absorbed and if (g-2)/2 from QED is independent of mass). As always the last word has the experiment

T 86.5 Thu 17:15 T-H17

Impact of bound states on non-thermal dark matter production — •Julian Bollig — Albert-Ludwigs-Universität, Freiburg

In this talk I will discuss the influence of non-perturbative effects, namely Sommerfeld enhancement and bound state formation, on the cosmological production of non-thermal dark matter (DM). For this purpose, I will focus on a class of simplified models with t-channel mediators. These naturally combine the requirements for large corrections in the early Universe, i.e. beyond the Standard Model states with long range interactions, with a sizable new physics production cross section at the LHC.

I will show that the dark matter yield of the superWIMP mechanism is suppressed considerably due to the non-perturbative effects under consideration, which leads to a significant shift in the cosmologically preferred parameter space of non-thermal dark matter in these models. By revisiting the implications of LHC bounds on long-lived particles associated with non-thermal dark matter, I will conclude that testing this broad class of DM models at the LHC and its successors is a bigger challenge than previously anticipated.

T 86.6 Thu 17:30 T-H17

Constraining dark matter annihilation with cosmic ray antiprotons using neural networks — Felix Kahlhoefer[1], Michael Korsmeier[2], Michael Krämer[1], Silvia Manconi[1], and •Kathrin Nippel[1] — [1]Institute for Theoretical Particle Physics and Cosmology (TTK), RWTH Aachen University, D-52056 Aachen, Germany — [2]The Oskar Klein Centre for Cosmoparticle Physics, Department of Physics, Stockholm University, Alba Nova, 10691 Stockholm, Sweden

The interpretation of data from indirect detection experiments searching for dark matter annihilations requires computationally expensive simulations of cosmic-ray propagation. We present new methods based on Recurrent and Bayesian Neural Networks that significantly accelerate simulations of secondary and dark matter Galactic cosmic ray antiprotons by at least two orders of magnitude compared to conventional approaches while achieving excellent accuracy. This approach allows for an efficient profiling or marginalisation over the nuisance parameters of a cosmic ray propagation model in order to perform parameter scans for a wide range of dark matter models. We present resulting constraints using the most recent AMS-02 antiproton data on several models of Weakly Interacting Massive Particles.

T 86.7 Thu 17:45 T-H17

Constraining Inflationary Dynamics with the SKA — Tanmoy Modak[1], Tilman Plehn[1], •Lennart Röver[1], and Björn Malte Schäfer[2] — [1]Institut für Theoretische Physik, Universität Heidelberg, Germany — [2]Astronomisches Recheninstitut, Universität Heidelberg, Germany

The SKA allows to map the distribution of neutral hydrogen in the Universe over a vast redshift range. The three-dimensional 21cm power spectrum found through this map can be used to perform precision tests not only for several astrophysical phenomena but also for early Universe cosmology. Even considering only a small redshift range it allows to significantly improve current constraints on the Hubble slow-roll parameters when combined with the CMB anisotropies measurement of Planck.

T 87: Electroweak Interactions (Exp.) 2

Time: Thursday 16:15–18:20 Location: T-H18

Group Report T 87.1 Thu 16:15 T-H18

Latest results on vector boson scattering studies from CMS — •Ankita Mehta, Andreas Hinzmann, and Steffen Albrecht — UHH, Hamburg, Germany

Vector boson scattering (VBS) is a key production process to probe the electroweak symmetry breaking sector of the standard model and to look for new physics phenomena beyond the standard model indirectly. VBS measurements have entered into a precision era with availability of larger dataset from LHC runII and recent developments in the field of machine learning. A summary of the latest VBS cross section measurements in different channels from the CMS experiment will be presented. A future outlook for the measurement of longitudinally polarized scattering of the W and Z bosons in the HL-LHC scenario and a combination of ATLAS and CMS measurements will also be presented.

T 87.2 Thu 16:35 T-H18

Measurement of same-sign WW Production at 13 TeV with the ATLAS Experiment — •Shalu Solomon — Albert-Ludwigs University of Freiburg, Germany

The electroweak production of same-sign W boson pairs is one of the pivotal processes to experimentally probe the electroweak symmetry breaking mechanism. With the Standard Model Higgs boson playing a key role in regularising the scattering amplitude of longitudinally polarised W bosons, and thanks to the large electroweak to strong production mode ratio, measuring same-sign WW production is an important tool to understand the electroweak sector.

The analysis of 2015-2016 LHC data at $\sqrt{s} = 13$ TeV by the ATLAS experiment resulted in the observation of electroweak WW production with a signal significance of 6.5 σ. With the entire Run 2 dataset, corresponding to an integrated luminosity of 139 fb^{-1}, the signal event yield has increased approximately by a factor of four, which gives the potential for the first differential cross-section measurement of this process.

The talk aims to present a summary of the analysis. The estimations of all the major backgrounds along with their uncertainties and behaviour in different validation regions are discussed. Fitting and unfolding methods including closure tests are presented. The expected event yields and the largest uncertainties on the cross-section are also shown.

T 87.3 Thu 16:50 T-H18

Study of polarization fractions in same-sign W boson scattering — •Prasham Jain, Beate Heinemann, and Oleg Kuprash — Albert-Ludwigs-Universität Freiburg, Freiburg, Germany

Polarized same-sign W boson pair production is a crucial process to examine the electroweak symmetry breaking mechanism. A measurement of the fraction of longitudinally polarized W bosons, $W_L^{\pm}W_L^{\pm}$, directly probes the unitarization mechanism of the vector boson scattering amplitude through Higgs boson contributions, and is sensitive to potential new physics effects. This talk presents the validation of Monte Carlo samples for polarized WW production at the LHC and shows first results of applying machine learning methods for extracting the longitudinal polarization fraction.

T 87.4 Thu 17:05 T-H18

Polarized same-sign W boson scattering at the CMS experiment — Thorsten Chwalek[1], Nils Faltermann[1], Abideh Jafari[2], Thomas Müller[1], and •Komal Tauqeer[1] — [1]Institut für Experimentelle Teilchenphysik (ETP), Karlsruher Institut für Technologie (KIT) — [2]Deutsches Elektronen-Synchrotron (DESY), Hamburg

Polarized vector boson scattering (VBS) provides an opportunity for testing the Higgs mechanism in the electroweak sector of the standard model. At the LHC, the scattering of the weak gauge bosons can reveal the actual process by which they get their masses. In particular, the longitudinal polarized state of these bosons can reveal new information about the goldstone bosons of the electroweak symmetry breaking sector.

The most promising VBS channel for this type of study is same-sign WW scattering, which has a good balance between signal and backgrounds. In particular, the semi-leptonic decay channel provides a larger cross section than the fully leptonic decay channel; however, this channel faces large background contributions from V + jets process.

To increase the signal extraction, our study aims for advancements in the boosted W-jet tagging techniques to identify the W jet decaying into hadrons along with its charge and polarization. In this talk, I will discuss about the ongoing work to identify the W jet charge via ParticleNet algorithm.

T 87.5 Thu 17:20 T-H18

A Search for anomalous couplings in the hadronic decay channel of Vector Boson Scattering at the CMS experiment — Steffen Albrecht[2], Thorsten Chwalek[1], Nils Faltermann[1], Thomas Müller[1], and •Max Neukum[1] — [1]Institut für Experimentelle Teilchenphysik (ETP), Karlsruher Institut für Technologie (KIT) — [2]Institut für Experimentalphysik, Universität Hamburg

Vector boson scattering (VBS) is the dominating process to investigate the quartic vertex of electroweak theory at the LHC. Additionally, cancellations with contributions from the Higgs boson are required to ensure unitarity. New physics in the Higgs sector may thus alter the cross section noticeably even if it is currently out of reach of direct measurements.

Deviations of couplings at high energies are formulated in an effective field theory, a bottom-up approach, which parametrizes a multitude of explicit theories. Limits on introduced parameters allow to draw conclusions regarding the strength and energy scale of new physics.

A search for anomalous couplings in the hadronic decay channel of VBS based on proton-proton collisions at a center-of-mass energy of 13 TeV is presented. Jet substructure techniques are used to distinguish between signal and background events and a three-dimensional fit supresses contributions from QCD events.

T 87.6 Thu 17:35 T-H18

Search for $\gamma\gamma \to WW(jjl\nu)$ coupling in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector — •Varsiha Sothilingam — Kirchhoff-Institut für Physik, Heidelberg

Due to the non-abelian nature of the electroweak sector of the Standard Model of Particle Physics (SM), direct interactions between gauge couplings is possible. Measurements of its cross section allow for validation of the SM and potential deviations opens possibilities for physics beyond the SM. This talk is focused on the coupling between W bosons and photons where the W bosons decay semileptonically. They interact via the triple (γW^+W^-) and quartic ($\gamma\gamma W^+W^-$) gauge couplings of the SM. This process can be produced via centrally exclusive production at the LHC, which provides the signal while keeping the protons intact.

These protons can be detected using the ATLAS Forward Proton (AFP) spectrometers, which are located around 200m away from the ATLAS detector, on both sides. Using the central detector to measure the WW decay and protons measured using AFP, the four momenta of the final state is known. This talk gives a deeper overview of this rare process and the methods used to define a mass signal region of interest to perform the searches for this process. Additionally it will provide an overview of the pile up and background challenges which have to be managed in this analysis.

T 87.7 Thu 17:50 T-H18

Automated Resummation of Electroweak Sudakov logarithms using SCET$_{\mathbf{EW}}$ — •Stefan Rode — Julius-Maximilians-Universität Würzburg

The search for new physics at the LHC necessitates the precise comparison between theoretical predictions in the Standard Model and experimental data. The calculation of electroweak radiative corrections, required to reach a sub-percent accuracy on the theory side, yields potentially large logarithmic corrections of the form $\alpha\log(s/M_W^2)$ to each order in perturbation theory. While at the LHC these corrections can already reach several tens of percent, this problem will be even more relevant at future colliders, where a resummation of these corrections will be inevitable to maintain the predictive power of the calculation.

We present a framework for the automated calulation of observables including the resummation of large logarithmic corrections using a generalisation of Soft-Collinear Effective Theory (SCET) to spontaneously broken gauge theories. We present results for W-boson pair production at the LHC and compare with the well-known results obtained using fixed-order methods.

T 87.8 Thu 18:05 T-H18

Upper limits on tri nucleon decays from GERDA — •Sean Sullivan for the GERDA-Collaboration — MPIK, Heidelberg, Germany

Tri-nucleon decay is a hypothetical process violating baryon number conservation allowed for in the standard model with an extension for light neutrino masses [1,2]. The GERDA search for neutrinoless double-beta decay employs HPGe detectors enriched in ^{76}Ge which could undergo tri-nucleon decay to unstable daughter nuclei. This work investigates the tri-nucleon decay chain of ^{76}Ge to ^{73}Ga and the subsequent beta decay and gamma cascade to the stable daughter ^{73}Ge. This allows setting limits on the tri-nucleon decay channels without the need to consider the exotic physics of the initial decay.

[1]S.I. Alvis et al. (Majorana Collaboration), 2019. Search for Tri-Nucleon Decay in the Majorana Demonstrator Phys. Rev. D 99, 072004

[2] Babu, K.S., Gogoladze, I. and Wang, K., 2003. Gauged baryon parity and nucleon stability. Physics Letters B, 570(1-2), pp.32-38.

T 88: Top Quarks: Production (Exp.) 3

Time: Thursday 16:15–18:30 Location: T-H19

T 88.1 Thu 16:15 T-H19

Studies of modern generators for top-quark pair-production — •Dominic Hirschbühl, Jens Roggel, and Wolfgang Wagner — Bergische Universität Wuppertal, Deutschland

The precise simulation of $t\bar{t}$ processes is crucial for precision tests of the Standard Model and in the search for new physics at the Large Hadron Collider. Several important new event generators for the simulation of $t\bar{t}$ production have been released in the last years. The "$bb4\ell$" generator is a NLO matrix-element generator for $pp \to b\bar{b}\ell^+\ell^{-\prime}\nu\bar{\nu}'$ final states implemented in the POWHEG-BOX. It includes theoretical improvements in the simulation of $t\bar{t}$ processes, which allows the production of $t\bar{t}$ and tW events including interference, off-shell effects, and top-quark decays at NLO. In this talk comparisons of these predictions with unfolded ATLAS data as well as with predictions for different DR and DS models implemented in MG5_aMC@NLO are shown. A second major improvement is the MINNLOPS implementation of the $t\bar{t}$ process in the POWHEG-BOX, which can be used to generate the $t\bar{t}$ production at NNLO. Studies of several parameter variations and an optimised setup for the NNLO generator matched with Pythia8 are presented.

T 88.2 Thu 16:30 T-H19

Machine learning approaches for parameter reweighting in MC samples of top quark production — •Valentina Guglielmi, Katerina Lipka, and Simone Amoroso — DESY, Hamburg, Germany

In high-energy particle physics, complex Monte Carlo simulations are needed to connect the theory to measurable quantities. Often, the significant computational cost of these programs becomes a bottleneck in physics analyses.

In this contribution, we evaluate an approach based on a Deep Neural Network to reweight simulations to different models or model parameters, using the full kinematic information in the event. This methodology avoids the need for simulating the detector response multiple times by incorporating the relevant variations in a single sample.

We test the method on Monte Carlo simulations of top quark pair production, that we reweight to different SM parameter values and to different QCD models.

T 88.3 Thu 16:45 T-H19

Modelling $t\bar{t}$ + jets with the Sherpa fusing approach — •Lars Ferencz[1], Judith Katzy[1], Frank Siegert[2], Stefan Höche[3], Chris Pollard[4], and Johannes Krause[2] — [1]DESY, Hamburg, Germany — [2]IKTP, Dresden, Germany — [3]Fermilab, Chicago, United States — [4]University of Oxford, Oxford, United Kingdom

Analyses interested in measuring the production of a top quark pair in association with a Higgs boson decaying into a $b\bar{b}$ final state rely on the MC modelling or irreducible backgrounds like $t\bar{t}+b\bar{b}$, $t\bar{t}+c\bar{c}$ and $t\bar{t}$+light jets. Recently MCs with massive b-quarks in the $t\bar{t}b\bar{b}$ ME@NLO (so called 4FS) predictions became available and are used for the $t\bar{t}b\bar{b}$ related backgrounds. However, in order to predict the background for the analysis, they need to be combined with calculations of $t\bar{t}+c\bar{c}$ and $t\bar{t}$ + light jets taken from a different calculation based on massless quarks (5FS). This talk will present a method for embedding a $t\bar{t}b\bar{b}$ 4 FS prediction into a multi-leg tt+jets 5 FS prediction using the Sherpa MC generator. This method is called "Sherpa Fusing". This approach would make it possible to predict the various $t\bar{t}$ + jets components like $t\bar{t}$ + light jets, $t\bar{t}$ + c-jets and $t\bar{t}$ + b-jets in a single sample, while ensuring the coverage of the full phase space. This talk will introduce the fusing method and present results comparing the fused predictions to standalone $t\bar{t}$+ jets and $t\bar{t}b\bar{b}$ predictions.

T 88.4 Thu 17:00 T-H19

Studies of $t\bar{t}$ production with additional heavy flavour jets in p-p collision with the ATLAS detector — •Lucas Klein, Mahsana Haleem, and Raimund Ströhmer — Julius-Maximilians-Universität Würzburg

The production of $t\bar{t}$-pairs with additional jets provides a strong test of quantum chromodynamics (QCD) predictions at high orders. Furthermore, this production represents as a significant background to rare SM processes (e.g. $t\bar{t}H$, $t\bar{t}t\bar{t}$), as well as to processes beyond the standard model. The additional jets consisting of b-quarks originating from gluon splitting are particularly interesting in constraining uncertainties in the prediction of the process.

In this talk, we will show studies of $t\bar{t}$-pair production with additional b-jets in the dileptonic top decay channel using full Run 2 ATLAS data from proton-proton collision at $\sqrt{s} = 13$ TeV. Events are chosen by requiring an oppositely-charged $e\mu$-pair and at least two b-jets in the final state as a baseline selection. The backgrounds originating from $t\bar{t}$ events with additional light- or c-flavour jets ($t\bar{t}l$, $t\bar{t}c$) misidentified as b-jets in exclusive 3 b-tagged jet and ≥ 4 b-tagged jet regions are estimated using a data-driven method.

The fiducial cross-sections for a phase space with at least one and at least two additional b-jets at particle-level will be shown and compared. Differential cross-section distributions for several variables in ≥ 3 b-jet and ≥ 4 b-jet regions will also be shown and compared to several theoretical predicions.

T 88.5 Thu 17:15 T-H19

Measurement of the associated production of top-antitop pair with charm jets using the DL1r b-tagging algorithm in the dileptonic final state — •Moritz Habbaba, Arnulf Quadt, and Elizaveta Shabalina — II. Physikalisches Institut, Georg-August-Universität Göttingen

Top-antitop pair production production accompanied by a quark-antiquark pair is an important background for many measurements and searches. Top- antitop pair production in association with a bottom-antibottom pair has been measured with relatively good precision inclusively and differentially using powerful b-tagging tools. The b-tagging algorithms have a long and stable history within the analysis tools of particle physics. Dedicated tagging algorithms for charm quarks on the other hand have not been widely used. This work investigates the possibilities of using existing b-tagging tools for c-tagging. The expected signal purity that can be achieved by using DL1r b-tagging algorithm for the purpose of c-jet tagging is investigated. The optimal signal regions in the dilepton ttbar final state are defined and expected uncertainty on the $\mathrm{t\bar{t}} + \mathrm{c\bar{c}}$ cross section is evaluated.

T 88.6 Thu 17:30 T-H19

Results of differential $\mathrm{t\bar{t}}$+$\mathrm{b\bar{b}}$ measurement in the lepton+jets channel at the CMS experiment — •Jan van der Linden, Ulrich Husemann, and Emanuel Pfeffer — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

Due to the large mass difference between the light bottom quarks and the heavy top quarks, the modeling of the associated production of bottom quarks with a pair of top quarks ($\mathrm{t\bar{t}}$+$\mathrm{b\bar{b}}$) is very challenging and is still associated with large uncertainties today. Past measurements of the inclusive cross section of that process also showed discrepancies between the predicted and measured cross sections, which can be attributed to the challenging modeling. Furthermore, different Monte Carlo event generation methods show significant differences in the modeling of this process, for example in the different treatment of heavy flavors in the parton density functions or the simulation of the additional QCD radiation via parton showering or matrix element simulation.

Hence a measurement of the inclusive cross section, as well as the absolute and normalized differential cross section of $\mathrm{t\bar{t}}$+$\mathrm{b\bar{b}}$ production is performed at the CMS experiment in the lepton+jets decay channel of the $\mathrm{t\bar{t}}$ system. The measurement will provide important input for the development and tuning of future Monte Carlo event generators, to describe the physics of the $\mathrm{t\bar{t}}$+$\mathrm{b\bar{b}}$ process more accurately.

In this talk results of this analysis, using data from the full Run-2 period of the LHC, are discussed.

T 88.7 Thu 17:45 T-H19

Simultaneous measurement of tt+X(bb) processes in the semileptonic channel at the CMS experiment — •Rufa Rafeek, Emanuel Pfeffer, Jan van der Linden, Michael Wassmer, and Ulrich Husemann — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

Top quark anti-quark pairs ($t\bar{t}$) are produced in association with other particles (X) where X can be the Higgs boson, Z/W boson or QCD-initiated heavy flavour jets ($b\bar{b}/c\bar{c}$). The measurement of $t\bar{t} + X$ is a direct probe of the coupling of standard model particles like the Higgs and Z boson to the top quark and may reveal new physics effects in modifications of these couplings.

The analysis is challenging as these processes, particularly when the bosons decay into heavy flavour quarks, like for example, $t\bar{t} + H(H \rightarrow bb)$ and $t\bar{t} + bb$ or $t\bar{t} + Z(Z \rightarrow bb)$, share the same signature and kinematic features. These high jet multiplicity final states create ambiguities in the reconstruction and identification of these processes and thus, it is hard to differentiate them from each other. Due to this challenge, an attempt to simultaneously measure these $t\bar{t} + X$ processes is made by exploring multivariate analysis strategies.

In this talk, an overview of the ongoing analysis, designed with the full Run-2 data of the LHC using the single lepton channel, is given.

T 88.8 Thu 18:00 T-H19

Graph neural network applications in $\mathrm{t\bar{t}}$+heavy flavor studies at the CMS experiment — •Emanuel Pfeffer, Max Erhart, Ulrich Husemann, Rufa Rafeek, Jan van der Linden, and Michael Wassmer — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

Graph neural networks are a promising and novel method of artificial intelligence. In contrast to other classes of machine learning, graphs may be better at mapping relationships and dependencies among objects such as jets and at learning interconnections. The application of these networks is particularly interesting in processes consisting a pair of top quarks produced in association with bottom quarks ($\mathrm{t\bar{t}}$+$\mathrm{b\bar{b}}$) and other indistinguishable processes such as $\mathrm{t\bar{t}}$+H with H → $\mathrm{b\bar{b}}$ or $\mathrm{t\bar{t}}$+Z with Z → $\mathrm{b\bar{b}}$. Initial studies show promising results in identifying the b jets not originating from the decay of the top quarks in such processes. The graph neural network studies show better results than previous ones based on conventional deep neural networks.

This talk gives an overview of the applications and results of jet assignments in $\mathrm{t\bar{t}}$+heavy flavor processes at the CMS experiment using graph neural networks.

T 88.9 Thu 18:15 T-H19

Studies on $t\bar{t}$+$c\bar{c}$/$t\bar{t}$+$b\bar{b}$ separation — •Max Erhart, Ulrich Husemann, Jan van der Linden, Emanuel Pfeffer, and Rufa Rafeek — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

Bottom jets and charm jets have very similar signatures and their identification techniques (b-tagging, c-tagging) use similar approaches, thus misidentification between these jets is common. Therefore the production of a top quark pair ($t\bar{t}$) in association with heavy flavor jets, i.e. charm and bottom ($t\bar{t}$+$c\bar{c}$, $t\bar{t}$+$b\bar{b}$), is an important, irreducible background to analyses targeting top quark pairs with additional bottom quark jets such as associated Higgs boson production with a subsequent Higgs boson decay into bottom quarks ($t\bar{t}$+H($b\bar{b}$)). The modeling of the additional bottom or charm jets also suffers from large uncertainties in theroetical calculations due to the difference in mass scale for the large top quark mass and the relatively light bottom or charm quarks.

Due to the similarities of these processes a simultaneous measurement of the production cross section for heavy flavor jets in association with top quarks in the dileptonic final state of the top quarks is being conducted at the CMS experiment.

In this talk an overview of the ongoing analysis and the analysis strategies to separate the $t\bar{t}$+$b\bar{b}$, $t\bar{t}$+H($b\bar{b}$), $t\bar{t}$+Z($b\bar{b}$) and $t\bar{t}$+$c\bar{c}$ processes from one another is given.

T 89: Higgs Boson: Decay in Fermions 2

Time: Thursday 16:15–18:00 Location: T-H20

T 89.1 Thu 16:15 T-H20

Search for decays of boosted Higgs bosons to pairs of charm quarks with the CMS Experiment — •Andrzej Novak, Luca Mastrolorenzo, Xavier Coubez, Spadan Mondal, Andrey Pozdnyakov, and Andrzej Novak — Physics Institute III A, RWTH Aachen

The Higgs boson decay into charm quarks has the highest branching fraction of the yet unobserved decays. Moreover, it is predicted to be the strongest coupling to the second generation of fermions which as of now remains unconfirmed. This talk presents a search for the Higgs boson in the gluon fusion production mode with high Lorentz boosts, decaying to a pair of charm quarks. The analysis is modelled on a previous analysis of decays to pairs of bottom quarks and is enabled by recent developments in deep learning based tools for jet identification in such topologies. Probing this channel is not only important for completeness, but it could also be sensitive to potential beyond Standard Model corrections.

T 89.2 Thu 16:30 T-H20

Search for Higgs boson decay to a pair of charm quarks in a two-jets topology at CMS with full Run-2 data. — •Andrey Pozdnyakov[1], Bjorn Burkle[2], Xavier Coubez[1,2], Alena Dodonova[1], Luca Mastrolorenzo[1], Spandan Mondal[1], Andrzej Novak[1], and Alexander Schmidt[1] — [1]RWTH Univer-

sity, Germany — [2]Brown University, USA

Full Run-2 data of the CMS experiment has been analyzed in order to obtain the most sensitive result to date on the measurement of the Higgs boson coupling to charm quarks. The coupling of the Higgs boson to charm is probed in a direct search for the H → cc decay, when the Higgs boson is produced in association with a W or Z boson. The full analysis is carried out in two topologies : boosted, where the two jets from a Higgs boson candidate are merged into one large-cone jet, and resolved, where two small-radius jets are reconstructed. In this talk we present a detailed overview of the resolved part of the full analysis. Major developments are introduced compared to the previously published CMS result, based on a partial data set. Those include an improved jet flavor tagging for charm jets based on DNNs, a dedicated jet-energy regression, a "kinematic fit" that constrains momenta of the jets using leptons from an associated Z boson decay. All these improvements lead to a stringent constraint on $|\kappa_c|$, which pose a limit for BSM models with large κ_c variations.

T 89.3 Thu 16:45 T-H20

Deep Sets for the ttH(H->bb) cross section measurement — •José Manuel Clavijo Columbié and Judith Katzy — Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, D-22607 Hamburg

We present our analysis strategy for the measurement of the cross-section of the ttH(H->bb) process differential in Higgs pT. We use a newly developed Deep Set neural network to split the events into separate regions which are enriched in signal or any of the main background processes. This allows the signal measurement together with good control of the background normalization factors and their associated uncertainties. In addition, we split the signal-like events into different Higgs pT ranges for the differential cross-section measurement. We perform an Asimov fit which gives the expected uncertainties of the measurement, and a fit of the background regions to real collision data to measure our ability to control the background processes.

T 89.4 Thu 17:00 T-H20

Effective Field Theory interpretations in Higgs boson pair production studies and constraints on the Higgs boson self-coupling — •Christina Dimitriadi[1,2], Jochen Dingfelder[1], Arnaud Ferrari[2], Tatjana Lenz[1], and Serhat Ördek[2] — [1]Physikalisches Institut Universität Bonn, Germany — [2]Uppsala University, Sweden

After the discovery of the Higgs boson in 2012, an important test of electroweak symmetry breaking would be to establish evidence of the Higgs boson self-coupling (λ_{HHH}), which can be achieved through a measurement of Higgs boson pair production. In the Standard Model (SM), di-Higgs events are dominantly produced in gluon-gluon fusion processes, e.g. involving the Yukawa coupling to top quarks (top quark loops) or via the Higgs boson self-coupling. These two production mechanisms interfere destructively, which leads to a very small di-Higgs production cross-section. However, deviations in couplings of the Higgs boson from the SM expectation could lead to a significant enhancement of the di-Higgs production rate.

A re-interpretation of the search for non-resonant Higgs boson pair production in the $bb\tau\tau$ channel, which is one of the most sensitive for probing the Higgs self-coupling, is presented. A scan of the self-coupling modifier, $\kappa_\lambda = \lambda_{HHH}/\lambda_{HHH}^{SM}$, is performed and limits on κ_λ are set. Projected sensitivity results at the High-Luminosity LHC are also discussed. Finally, preliminary studies for Higgs Effective Field Theory interpretations of the existing analysis are shown.

T 89.5 Thu 17:15 T-H20

Search for Higgs Boson Pair Production in Multi-Lepton Final States with the ATLAS Detector — Volker Büscher, Antoine Laudrain, Christian Schmitt, •Niklas Schmitt, and Duc Bao Ta — Johannes Gutenberg-Universität, Mainz

After the discovery of the Higgs boson in 2012 at the LHC, many of its properties have already been determined precisely using data of an integrated luminosity of 139 fb^{-1}. However, one of the biggest challenges in this field remains the measurement of the coupling of the Higgs boson to itself. It allows for a deep insight into the real shape of the Higgs potential and hence has a big impact on the understanding of fundamental interactions not only at the electroweak scale. In order to constrain the trilinear self-coupling, the Di-Higgs production cross section is measured. While decay modes including b-quarks typically have larger branching fractions, leptonic final states are generally much cleaner and have less SM background. Accordingly, probing this channel as a complement to $b\bar{b}$ analyses will be very promising.

Because of the small branching ratio and the large number of different SM backgrounds, it is difficult to investigate every leptonic HH decay mode individually. For this reason, dedicated neural networks in the 2,3 and 4 lepton final states have been trained to distinguish all relevant signal processes against the sum of all backgrounds. This talk will introduce the analysis strategy and give an overview on the performance of the multi-lepton channel compared to other decay modes.

T 89.6 Thu 17:30 T-H20

Search for Higgs-boson pair production in the $bb\ell\ell$+$\mathbf{E_T^{miss}}$ final state with the ATLAS detector — •Benjamin Rottler, Benoit Roland, and Markus Schumacher — Albert-Ludwigs-Universität Freiburg

The determination of the triple Higgs-boson self-coupling λ is one of the key goals of the physics program at current and future colliders. It will allow to reconstruct the Higgs potential. The self-coupling can be accessed via non-resonant Higgs-boson pair production, which can happen at the LHC via the destructively interfering top-loop and Higgs self-interaction diagrams.

The goal of this analysis is to measure the cross-section of the non-resonant Higgs-boson pair production σ_{HH} and the Higgs-boson self-coupling λ using the full Run-2 dataset collected by the ATLAS experiment, corresponding to an integrated luminosity of $\sim$139 fb^{-1} at $\sqrt{s} = 13$ TeV. This is done by considering the $bb\ell\ell + E_T^{miss}$ final state, which combines the high branching ratio of the $H \to bb$ decay and the good efficiency of lepton triggers. Our focus is on a combined search for the $HH \to bb(WW \to 2\ell 2\nu)$, $HH \to bb(\tau\tau \to 2\ell 4\nu)$ and $HH \to bb(ZZ \to 2\ell 2\nu/2\ell 2q)$ processes.

A multi-class deep neural network (NN) is used to separate signal and background processes on top of a loose preselection. The shape of the NN output distribution will be used in the statistical analysis. I will present the results of the σ_{HH} and λ measurements. I will also discuss the application of parametrized NNs (pNN) for the λ measurement, which allows to train a combined NN for multiple λ values.

T 89.7 Thu 17:45 T-H20

HH→bb$\tau\tau$ Run 3 Trigger Studies — •Andrés Melo, Jason Veatch, and Stan Lai — II. Physikalisches Institut, Georg-August-Universität Göttingen

The HH→bb$\tau\tau$ search is performed using data taken from the ATLAS experiment at the LHC, and allows us to probe the Higgs self-coupling (for non-resonant decays) and the existence of heavier particles from which both Higgs would have been produced (for resonant decays). Since the Higgs boson is identified by its decay products, tau triggering is an important and crucial part of the search.

In order to ensure optimal trigger efficiency for this final state signature in Run-3, the efficiency at the high level trigger (HLT) with respect to the Level-1 trigger (L1) is studied. A characterization of various kinematic variables and quantities of the events that do not pass the HLT triggers is performed. This study allows for an improvement of the trigger efficiency, minimizing event loss.

T 90: Higgs Boson: Associated Production 2

Time: Thursday 16:15–18:15 Location: T-H21

T 90.1 Thu 16:15 T-H21

Search for the standard model Higgs boson in association-with a bottom-quark pair (bbH) — •Maryam Bayat Makou — CMS-DESY, Hamburg, Germany

One of the main goals of the LHC experiment is the precise measurement of the Higgs boson production mechanisms to clarify its coupling structure. In the Standard Model of particle physics, the coupling of the Higgs boson to fermions is introduced via the Yukawa interaction. Up to now the Yukawa coupling to b-quarks (y_b) was measured only in the decay process, and not yet in the production mechanism due to the low cross-section and the overwhelming background processes.

This measurement aims at measuring the b-associated Higgs production (bbH) using data collected by the CMS experiment during Run 2. The study covers events where the Higgs boson is produced through the bbH channel and further decays into two tau leptons, subsequently fully leptonically ($\tau_e\tau_\mu$) or fully hadronically ($\tau_h\tau_h$). A machine learning approach has been used to classify the events into two Higgs signal classes and several background classes. First results on the sensitivity on the bbH production channel will be shown.

T 90.2 Thu 16:30 T-H21

Higgsstrahlung with H→bb decay at NNLO+PS — •Silvia Zanoli[1], Mauro Chiesa[2], Emanuele Re[3,4], Marius Wiesemann[1], and Giulia Zanderighi[1,5] — [1]Max-Planck-Institut für Physik, Föhringer Ring 6, 80805 München, Germany — [2]Dipartimento di Fisica, Università di Pavia, and INFN, Sezione di Pavia, Via A. Bassi 6, 27100 Pavia, Italy — [3]INFN, Sezione di Milano - Bicocca, and Università di Milano - Bicocca, Piazza della Scienza 3, 20126 Milano, Italy — [4]LAPTh, Université Grenoble Alpes, Université Savoie Mont Blanc, CNRS, 74940 Annecy, France — [5]Physik-Department, Technische Universität München, James-Franck-Strasse 1, 85748 Garching, Germany

I present the computation of HZ and HW production followed by the Higgs boson decay into a pair of bottom quarks within the MiNNLO$_{\mathrm{PS}}$ framework. Both the production and the decay of the Higgs boson are evaluated at NNLO+PS accuracy, consistently combined and then matched to the parton shower by means of a vetoed shower. This MiNNLO$_{\mathrm{PS}}$ calculation supersedes the previous NNLOPS results, obtained through MiNLO'+reweighting. I will show and discuss phenomenological results for LHC collisions at 13 TeV.

T 90.3 Thu 16:45 T-H21

Back to the Formula - LHC Edition — Anja Butter[1], Tilman Plehn[1], •Nathalie Soybelman[2], and Johann Brehmer[3] — [1]Institut für Theoretische Physik, Heidelberg, Deutschland — [2]Weizmann Institute of Science, Rehovot, Israel — [3]New York University, New York, USA

While neural networks offer an attractive way to numerically encode functions, actual formulas remain the language of theoretical particle physics. We use symbolic regression trained on matrix-element information to extract, for instance, optimal LHC observables. This way we invert the usual simulation paradigm and extract easily interpretable formulas from complex simulated data. We introduce the method using the effect of a dimension-6 coefficient on associated ZH production. We then validate it for the known case of CP-violation in weak-boson-fusion Higgs production, including detector effects.

T 90.4 Thu 17:00 T-H21

Deep-Learning driven Signal Extraction in the Associated VH-Production with the CMS Experiment — •Niclas Eich, Svenja Diekmann, and Martin Erdmann — RWTH Aachen

The Higgs Boson production in association with a Vector Boson known as "Higgs-Strahlung" (VH) is one of the four main production modes of the Higgs at the LHC. The VH-production can be divided into two modes, being produced by quark-annihilation and gluon-fusion for a Z boson respectively. In our analysis, we aim to measure the gluon-fusion process in the final states with the Higgs decaying to a b-quark pair and the W/Z decaying leptonically. We make use of the symmetries between the quark and gluon induced processes and deploy Deep Learning techniques to maximize the sensitivity of the measurement. Finally, we present first results towards the signal extraction using the data-taking period 2017 of the CMS experiment.

T 90.5 Thu 17:15 T-H21

Extracting the Gluon Fusion Component of the Associated ZH Production with the CMS Experiment — •Svenja Diekmann, Niclas Eich, and Martin Erdmann — III. Physikalisches Institut A, RWTH Aachen University

The gluon fusion production mechanism of the associated ZH production ($gg \to ZH$) is a yet unmeasured Standard Model process sensitive to various new physics scenarios. The considered final state of two leptons and two b-jets is not only populated by large backgrounds arising from other processes, but also by the dominant quark initiated ZH production ($q\bar{q} \to ZH$). In order to separate these two production mechanisms, the total ZH production can be utilised in combination with the WH production to extract the gluon fusion component by analysing the ratio of their cross sections. The strategy of this analysis to extract the gluon fusion component of the ZH production is demonstrated using the data-taking period 2017 of the CMS experiment.

T 90.6 Thu 17:30 T-H21

Extraction of the gluon-initiated component of the associated production of the Higgs boson and a vector boson with the CMS experiment — •Alena Dodonova[1], Alexander Schmidt[1], Xavier Coubez[1,2], Luca Mastrolorenzo[1], Andrey Pozdnyakov[1], Andrzej Novak[1], Spandan Mondal[1], and Ming-Yan Lee[1] — [1]III. Physikalisches Institut A, RWTH Aachen University, Aachen, Germany — [2]Brown University, Providence, USA

Associated Higgs boson production with a Z boson (ZH) contains quark- and gluon-initiated components. The gluon-initiated component ($gg \to ZH$) could be a good probe for the physics beyond the Standard Model (SM) since the effects of the new physics for the loop-induced processes would be of the same order as the SM process. Due to destructive interference between box and triangle contributions at the leading order, this component is suppressed with respect to the dominant quark-initiated contribution to ZH production.

In this talk, I will present the prospects to measure the upper limit on the $gg \to ZH$ component in the $H \to b\bar{b}$ decay channel using multivariate analysis. The study is performed with the full Run 2 dataset collected with the CMS detector at the LHC at $\sqrt{s} = 13\ TeV$.

T 90.7 Thu 17:45 T-H21

Simplified Template Cross Section Measurement of $pp \to WH \to WWW \to l\nu l\nu l\nu$ — •Moritz Hesping, Volker Büscher, Ralf Gugel, and Christian Schmitt — Johannes Gutenberg Universität Mainz

The measurement of the couplings of the Higgs boson is of great scientific interest, since it has the potential of testing possible extensions to the Standard Model. The decay of a Higgs boson into a pair of W bosons after production in association with a W boson is especially useful, since in this process the Higgs boson exclusively couples to W bosons.

In addition to the inclusive analysis of the full run 2 dataset of the ATLAS experiment, the $pp \to WH \to WWW \to l\nu l\nu l\nu$ process was measured in the scheme of Simplified Template Cross Sections (STXS). The STXS mesurement of this process requires access to the transverse momentum of the associated W boson, which due to the presence of three neutrinos in the final state cannot be fully reconstructed. In this talk the analysis strategy will be presented, with a focus on the regression neural network for the W momentum reconstruction and the multiclassifier network for signal-background separation.

T 90.8 Thu 18:00 T-H21

Prospects of measuring the Higgs self-coupling at the ILC — •Julie Torndal[1,2], Jenny List[1], and Yasser Radkhorrami[1,2] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg — [2]Universität Hamburg, Hamburg, Germany

The Higgs-self coupling is a key feature in understanding the Higgs potential and hence the underlying mechanism that provides mass to the elementary particles. Any deviations from the Standard Model (SM) could indicate new physics beyond the SM.

Experimentally, the measurement of the Higgs self-coupling poses many challenges due to the very small production cross sections and multi-jet final states. The International Linear Collider offers a clean experimental environment at energies above the threshold of double Higgs-strahlung. Since the Higgs self-coupling was last studied (5-8 years ago) there have been tremendous progress for high-level reconstruction tools which could lead to a large improvements in the sensitivity.

In this contribution, we revisit the projections made for the Higgs self-coupling measurement at the ILC at a center-of-mass energy of 500 GeV and study the effects of improvements made in the high-level reconstruction tools.

T 91: Higgs Boson: Rare Decays

Time: Thursday 16:15–17:45 Location: T-H22

T 91.1 Thu 16:15 T-H22

Search for the Higgs Boson decay to a Z boson and a photon — •Ming-Yan Lee — RWTH III. Physikalisches Institut A, Aachen, Germany

The results of the search for the Higgs boson decays to $Z\gamma$ will be presented. In the search for this rare Higgs boson decay, the leptonic channel is most promising as it has relatively low background and can be fully reconstructed in the CMS detector. A few analysis techniques such as multivariate analysis methods, kinematic fit and final state radiation recovery are introduced to improve the sensitivity. The combination of the Run 2 data results in an observed (expected) upper limit on the signal strength of 4.1 (1.8) at 95% confidence level.

T 91.2 Thu 16:30 T-H22

Higher order QCD corrections and effective operators in Higgs boson pair production — Gudrun Heinrich[1], •Jannis Lang[1], and Ludovic Scyboz[2] — [1]Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]University of Oxford, Oxford, United Kingdom

We present results for Higgs boson pair production in gluon fusion including both, NLO (2-loop) QCD corrections with full top quark mass dependence as well as anomalous couplings related to operators describing effects of physics beyond the Standard Model. The latter can be realized in non-linear (HEFT) or linear (SMEFT) Effective Field Theory frameworks. We show results for both and discuss the impact of different approximations within the SMEFT description.

T 91.3 Thu 16:45 T-H22

Employing Matrix Elements with Neural Networks to Search for Higgs Self-coupling — •Christoph Ames, Otmar Biebel, and Lars Linden — Ludwigs-Maximillians-Universität, Munich

The Higgs boson was discovered in 2012 as predicted by the Standard Model, however, not all of its predicted couplings have been measured yet. One such coupling is the Higgs self-coupling, in which a Higgs boson decays into two further Higgs bosons. By integrating over all possible initial states and by using the details of the end state, the matrix element method evaluates the weight of an event for the specific production cross section. In this work, machine learning is combined with the matrix element method to search for $HH \to b\bar{b}W^+W^-$ using simulated data. A neural network is trained to calculate the matrix element weight of an event and to use this to determine whether the event contains a signal or a background decay.

T 91.4 Thu 17:00 T-H22

Investigating Sensitive Observables as Input Variables for Neural Networks in the Search for Higgs Self-Interaction — •Lars Linden, Christoph Ames, and Otmar Biebel — Ludwig-Maximilians-Universit\"at, M\"unchen

A precise measurement of Higgs boson self-interaction is important to determine the properties and the shape of the Higgs potential. Deviations of the expected shape may possibly hint to new physics phenomena. However, the cross-section of the Higgs self-interaction process is very small. So, neural networks are employed to enhance the experimental sensitivity for this process. These networks require a training using specific input observables sensitive to the Higgs self-interaction final states. This talk presents such observables for Higgs boson pair production via the process \$gg \to HH\$ with a special focus on \$HH\to b\bar{b}W^+W^-\$ final states.

T 91.5 Thu 17:15 T-H22

Search for Higgs boson pairs decaying to multilepton final states with the CMS experiment — •Tobias Kramer, Torben Lange, Marcel Rieger, and Peter Schleper — Institut für Experimentalphysik, Universität Hamburg

In this presentation, the first CMS analysis searching for Higgs boson pairs decaying into multilepton final states is presented. It uses the full Run 2 dataset corresponding to 138 fb^{-1} recorded by the CMS experiment at a center of mass energy $\sqrt{s} = 13\,\mathrm{TeV}$. Several scenarios for producing events with SM Higgs boson pairs are considered, such as the decay of heavy resonances as well as non-resonant production via the SM as well as EFT modified couplings. The talk focuses on Higgs decays to pairs of W bosons and tau leptons. The analysis provides limits on the yet to be discovered trilinear Higgs self-coupling λ as well as cross section limits for different BSM scenarios, especially at high values for the coupling strength modifier κ_λ and low resonance masses.

T 91.6 Thu 17:30 T-H22

Search for di-Higgs Production with the CMS Experiment using the full Run 2 Dataset — •Marcel Rieger, Peter Schleper, and Tobias Kramer — Institut für Experimentalphysik, Universität Hamburg

After the discovery of the Higgs boson and measurements of its couplings to vector bosons as well as third generation fermions, the search for processes involving more than one Higgs boson will constitute one of the main goals of the global particle physics program in the coming years. The study of trilinear self-coupling will eventually give rise to the structure of the Higgs potential and can lead to profound theoretical consequences. Thereby, di-Higgs searches can gauge our understanding of electroweak symmetry breaking and probe a variety of scenarios that reach beyond the Standard Model.

The full Run 2 collision dataset recorded by the CMS experiment is analyzed in a wide range of potential di-Higgs final states to maximize the coverage of the available phase space. This talk highlights aspects of these searches with focus on final states involving two bottom quarks and two tau leptons. Prospects of the combination of channels, as far as available, are presented and constraints on the trilinear self-coupling as well as the coupling of two Higgs and two vector bosons are reported.

T 92: Higgs Boson: Extended Models 3

Time: Thursday 16:15–18:00 Location: T-H23

T 92.1 Thu 16:15 T-H23

Suche nach unsichtbaren Zerfällen des Higgs-Bosons in Ereignissen mit einem hadronisch zerfallenden Vektorboson mit dem ATLAS-Detektor — •Johannes Balz, Volker Büscher, Duc Bao Ta und Kira Köhler — Institut für Physik, Johannes Gutenberg-Universität Mainz

Eines der gegenwärtig größten Ziele für das ATLAS Experiment ist neben der präzisen Vermessung des Standardmodells (SM) die Suche nach Physik jenseits des SM.

In diesem Vortrag geht es um die Suche nach unsichtbaren Zerfällen des Higgs-Bosons jenseits des Standardmodells. Beim untersuchten Kanal wird das Higgs-Boson über die assoziierte Produktion mit einem Vektorboson erzeugt, wobei das beteiligte Vektorboson im weiteren Verlauf hadronisch zerfällt und das Higgs-Boson in für den Detektor unsichtbare Teilchen, zum Beispiel Dunkle Materie, zerfällt. Daher umfasst die Selektion Ereignisse mit hohem fehlendem Transversalimpuls und Jets, die kompatibel mit einem hadronisch zerfallenden Vektorboson sind. Dadurch kann der Hauptuntergrund $Z \to \nu\nu$ bereits stark unterdrückt werden. Die höchste Sensitivität liegt bei hohen Transversalimpulsen des Vektorbosons, das dann als ein großflächiger Jet rekonstruiert wird. Dessen Jetsubstrukturvariablen ermöglichen eine weitere Untergrundunterdrückung.

Im Vortrag wird der aktuelle Stand der Analyse bei einer Schwerpunktsenergie von $\sqrt{s}$=13 TeV vorgestellt.

T 92.2 Thu 16:30 T-H23

Higgs Decay into Dark Matter in the CxSM at Next-to-Leading Order — •Felix Egle[1], Margarete Mühlleitner[1], Rui Santos[2,3], and João Viana[2] — [1]Institute for Theoretical Physics, Karlsruhe Institute of Technology, Wolfgang-Gaede-Str. 1, 76131 Karlsruhe, Germany — [2]Centro de Física Teórica e Computacional, Fac-

uldade de Ciências, Universidade de Lisboa, Campo Grande, Edifício C8 1749-016 Lisboa, Portugal — [3]ISEL - Instituto Superior de Engenharia de Lisboa, Instituto Politécnico de Lisboa 1959-007 Lisboa, Portugal

The Complex Singlet extension of the Standard Model (CxSM) is one of the simplest models to extend the scalar sector of the Standard Model (SM) and is also able to provide a suitable Dark Matter (DM) candidate. A possibility to probe the DM candidate at the LHC is given by the decay of the 125 GeV SM-like Higgs boson into a pair of DM particles. In order to match the experimental accuracy, higher-order corrections to this process have to be considered. We will present the computation of the complete next-to-leading order electroweak corrections to this decay process. In particular, we will describe the renormalization procedure for the CxSM, compare different renormalization schemes, discuss theoretical and experimental constraints on the input parameters and compare the results with current exclusion bounds.

T 92.3 Thu 16:45 T-H23

Dark Matter Phase Transitions in 'CP in the Dark' — •Lisa Biermann, Margarete Mühlleitner, and Jonas Müller — Institute for Theoretical Physics, Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany

We study the possibility of a strong first-order electroweak phase transition (SFOEWPT) in the extended scalar sector model 'CP in the Dark'. 'CP in the Dark' provides a Dark Matter (DM) candidate as well as explicit CP violation in the dark sector. A global minimization of the one-loop daisy-resummed effective potential at finite temperature is performed with the C++ code BSMPT. We find a broad viable parameter space for an SFOEWPT within the reach of XENON1T and future invisible decay searches. 'CP in the Dark' also offers SFOEWPT points that display spontaneous CP violation at finite temperature. Having not only an SFOEWPT that provides the necessary departure from thermal equilibrium, but also a source of additional non-standard CP violation, opens a promising gate towards enabling the creation of the BAU in an electroweak baryogenesis scenario.

T 92.4 Thu 17:00 T-H23

Combination of Higgs boson measurements using Simplified Template Cross Sections with interpretations in the κ-framework at the ATLAS experiment — •Joshua Clercx — Universität Hamburg/DESY, Hamburg, Germany

In the past, the standard model (SM) has been very successful in explaining and predicting a wide range of phenomena, but currently there are clear indications that not everything is described by the SM. Experimental measurements of certain high energy physics parameters could show deviations from the theoretical predictions, which would indicate the existence of physics beyond the standard model (BSM). Depending on where these deviations are found, it also gives some insight into which BSM physics theories are interesting to further investigate. Measurements in the Higgs sector are especially interesting, as there are many opportunities to detect BSM effects here. The most precise measurements in the Higgs sector are obtained by combining measurements of cross sections of different Higgs boson production processes and decay channels. This is typically done in the Simplified Template Cross Sections (STXS) framework: measurements of cross sections of mutually exclusive regions of phase space, defined per production process, are combined. The measurements can be interpreted in the κ-framework as a test of the SM coupling values of the Higgs boson to other SM particles. What will be presented are results from the most recent combination from the autumn of 2021, which is based on analyses of 13 TeV data with an integrated luminosity of up to 139 fb^{-1}.

T 92.5 Thu 17:15 T-H23

Z_2 Non-Restoration and Composite Higgs: Singlet-Assisted Baryogenesis w/o Topological Defects — Andrei Angelescu, Florian Goertz, and •Aika Tada — Max-Planck-Institut für Kernphysik, Heidelberg

Simple scalar extensions of the Standard Model with a spontaneously broken Z_2 symmetry allow for a strongly first order electroweak phase transition, as sought in order to realize electroweak baryogenesis. To circumvent the emergence of phenomenologically problematic domain walls often encountered in this context, in 2112.12087 (A. Angelescu, F. Goertz, AT), a scalar singlet framework featuring a thermal history which does not restore Z_2 in the early universe is proposed. This can be realized in a low energy effective theory with D>4 operators. A possible UV completion is provided by a $SO(6)/SO(5)$ Composite Higgs model with fermions in a symmetric $20'$ of $SO(6)$, where the potential and the Yukawa terms are obtained by spurion analysis and a CP violating term arises. Matching the two models and exploring them numerically shows that this scenario can fulfil all Sakharov criteria needed for electroweak baryogenesis.

T 92.6 Thu 17:30 T-H23

Constraining possible $\mathcal{CP}$-admixtures in modified Higgs sectors — •Marco Menen, Henning Bahl, Philip Bechtle, Elina Fuchs, Sven Heinemeyer, Judith Katzy, Krisztian Peters, Matthias Saimpert, and Georg Weiglein — Physikalisch-Technische Bundesanstalt Braunschweig

The question why an excess of matter over antimatter was produced shortly after the Big Bang is one of the greatest unsolved problems of modern physics. The Standard Model of particle physics cannot explain the amount of $\mathcal{CP}$ violation needed for the observed baryon asymmetry of the universe. Additional $\mathcal{CP}$ violation may be found in the Higgs sector where a mixed $\mathcal{CP}$ state of the 125 GeV Higgs boson is not ruled out experimentally by current search limits.

In this talk, the Higgs Characterization model is presented. It is parameterized by factors c_i and $\tilde{c}_i$ which modify the scalar and pseudoscalar part of Higgs couplings to other SM particles, respectively. The program HiggsSignals (HS) is used to calculate the resulting Higgs signal rates and compare them to available Run 1 and Run 2 data from the Large Hadron Collider (LHC) at CERN.

The signal rate measurements in HS are complemented by a dedicated $\mathcal{CP}$ analysis in the $H \to \tau\tau$ decay from CMS. Furthermore, constraints from the current best limit on the electron electric dipole moment are examined to complement the constraints from the LHC. The amount of baryogenesis reachable within the allowed parameter space regions is computed in the vev insertion approximation with optimal parameters.

T 92.7 Thu 17:45 T-H23

Studies of di-Higgs production at the FCC-hh in the bbZZ(ll$\nu\nu$) final state — •Kevin Laudamus — DESY, Hamburg, Germany

The FCC-hh is a proposed circular hadron collider at an energy of 100 TeV. The total integrated luminosity is expected to be around 30 ab^{-1}. With such a large dataset, 400 times more double-Higgs events are expected than with the full HL-LHC dataset, allowing to measure the Higgs self-coupling with high precision. As a consequence, also rarer final states, which are not within reach of the (HL)-LHC, have good prospects at the FCC-hh. One such final state is the bbZZ(ll$\nu\nu$) channel, which is studied in this work. A multivariate analysis of bbll$\nu\nu$ events is implemented and upper limits on the di-Higgs production cross-section are derived in order to assess the potential of this channel. Moreover, it is investigated in how far specific kinematic regions, such as at high Higgs transverse momentum, can be exploited. In these studies, particular attention needs to be paid to the reconstruction of the missing transverse momentum, which will be extremely challenging at the FCC-hh due to the very high pile-up environment.

T 93: Search for New Particles 6

Time: Thursday 16:15–18:45 Location: T-H24

T 93.1 Thu 16:15 T-H24

Symmetries, Safety, and Self-Supervision — Barry M. Dillon[1], Gregor Kasieczka[2], Hans Olischläger[1], Tilman Plehn[1], Peter Sorrenson[1,3], and •Lorenz Vogel[1] — [1]Institut für Theoretische Physik, Universität Heidelberg, Germany — [2]Institut für Experimentalphysik, Universität Hamburg, Germany — [3]Heidelberg Collaboratory for Image Processing, Universität Heidelberg, Germany

Collider searches face the challenge of defining a representation of high-dimensional data such that physical symmetries are manifest, the discriminating features are retained, and the choice of representation is data-driven and new-physics agnostic. We introduce JetCLR (Contrastive Learning of Jet Representations) to solve the mapping from low-level jet constituent data to optimized observables through self-supervised contrastive learning. Using a permutation-invariant transformer-encoder network, physical symmetries such as rotations and translations are encoded as augmentations in a contrastive learning framework. As an example, we construct a data representation for top and QCD jets and visualize its symmetry properties. We benchmark the JetCLR representation against other widely-used jet representations, such as jet images and energy flow polynomials.

T 93.2 Thu 16:30 T-H24

Searching for Jet Pairs with Anomalous Substructure in CMS — Gregor Kasieczka, Louis Moureaux, Tobias Quadfasel, and •Manuel Sommerhalder — Institut für Experimentalphysik, Universität Hamburg

Despite compelling experimental and theoretical motivation as well as extensive new physics searches at the Large Hadron Collider, there have been no discoveries of physics beyond the standard model (BSM) so far. One potential reason for this is that the common search strategy relies on selecting BSM signal candidate events based on specific signal and background models. Such a dedicated search cannot be performed for every possible BSM theory and phase space region. Thus, model-independent anomaly detection methods are an important addition to existing search methods. These algorithms aim to select signal candidates in a data-driven manner based on anomalous phase space signatures.

One such anomaly detection method is CATHODE. It detects resonant signal peaks by combining neural density estimation in a sideband region with a weakly supervised classification task of disinguishing real data from synthetic background-like samples. We present the first application of CATHODE in a search for BSM physics in the CMS experiment targeting a dijet final state.

T 93.3 Thu 16:45 T-H24

Autoencoders and k-Means for unsupervised anomaly detection in high energy physics — Thorben Finke, Michael Krämer, Alessandro Morandini, Alexander Mück, and •Ivan Oleksiyuk — Institute for Theoretical Particle Physics and Cosmology (TTK), RWTH Aachen University, D-52056 Aachen, Germany

Unsupervised anomalous jet tagging based on low-level observables has recently gained popularity in the high energy physics community. The main goal here is to be as efficient and model-independent as possible. We scrutinize a widely used anomaly detection method based on the reconstruction loss of a deep autoencoder to show its capabilities, but also its limitations. Although we reproduce the positive results from the literature, we show that the standard autoencoder setup cannot be considered as a model-independent anomaly tagger by inverting the task: the autoencoder fails to tag QCD jets if it is trained on top jets. We improve the capability of the autoencoder to learn non-trivial features of jet images, such that it is able to achieve both top jet tagging and QCD jet tagging with the same setup. We propose an alternative machine learning approach using k-Means and Gaussian Mixture Model to construct anomaly scores. We show that these methods, albeit simple, have several benefits and may also be regarded as promising anomaly detection tools.

T 93.4 Thu 17:00 T-H24

How to Identify Anomalies at the LHC — •Thorsten Buss[1], Barry Dillon[1], Thorben Finke[2], Michael Krämer[2], Alessandro Morandini[2], Alexander Mück[2], Ivan Oleksiuk[2], and Tilman Plehn[1] — [1]Institut für Theoretische Physik, Universität Heidelberg, Germany — [2]Institute for Theoretical Particle Physics and Cosmology (TTK), RWTH Aachen, Germany

Searches for anomalous events are the main motivation for the LHC and define key analysis steps, including triggers. We discuss how LHC anomalies are defined through probability density estimates evaluated through an appropriate latent space. Different approaches, like invertible networks, and Dirichlet latent spaces are illustrated for the especially challenging scenario of dark matter jets. Finally, we present benchmark results for unsupervised top vs QCD jet tagging.

T 93.5 Thu 17:15 T-H24

Better latent spaces for better autoencoders — Barry Dillon[1], Tilman Plehn[1], Christof Sauer[2], and •Peter Sorrenson[1,3] — [1]Institut für Theoretische Physik, Universität Heidelberg, Germany — [2]Physikalisches Institut, Universität Heidelberg, Germany — [3]Heidelberg Collaboratory for Image Processing, Universität Heidelberg, Germany

Autoencoders as tools behind anomaly searches at the LHC have the structural problem that they only work in one direction, extracting jets with higher complexity but not the other way around. To address this, we derive classifiers from the latent space of (variational) autoencoders, specifically in Gaussian mixture and Dirichlet latent spaces. In particular, the Dirichlet setup solves the problem and improves both the performance and the interpretability of the networks.

T 93.6 Thu 17:30 T-H24

Development of a new trigger for exotic particle searches with IceCube — •Timo Stürwald for the IceCube-Collaboration — Bergische Universität, Wuppertal, Deutschland

The IceCube Neutrino Observatory is a cubic kilometer scale Cherenkov light detector that also searches for signatures of particles beyond the standard model. The upcoming IceCube Upgrade and IceCube-Gen2 extension will improve the sensitivity for these searches due to an increased and partly denser instrumented sensitive volume. The better sensitivity allows for the detection of signatures of exotic particles including fractionally charged particles, which directly and indirectly produce light.

In this talk results of adjusted IceCube standard triggers applied on simulated fractionally charged particles are presented. Furthermore, the development of a new trigger is presented. This new trigger includes the analysis of isolated single hits that so far are not included in any IceCube trigger, because a large fraction of them originates from well understood noise sources. For simulated faint exotic signatures these isolated single hits become the dominant hit type.

**Funded by BMBF-Verbundforschung Astroteilchenphysik*

T 93.7 Thu 17:45 T-H24

Simulation of the WOM in IceCube Gen2 for the detection of exotic particles — •Nick Jannis Schmeisser[1], Anna Pollmann[1], and John Rack-Helleis[2] for the IceCube-Collaboration — [1]Bergische Universität Wuppertal — [2]JGU Mainz

The IceCube Neutrino Observatory is a cubic kilometer scale Cherenkov light detector located at the geographic South Pole. Besides the detection of neutrinos, it is used for searches for particles beyond the Standard Model. One kind of these exotic particles are fractionally charged particles which carry a fraction of the electron charge. The IceCube detector will be enhanced first by the IceCube Upgrade and then by IceCube Gen2 in the next years. The Wavelength-shifting Optical Module (WOM) is a newly developed sensor that is going to be deployed in the IceCube Upgrade amongst other sensors. The WOM achieves an improved signal to noise ratio and UV-sensitivity in comparison to the sensors deployed in the original IceCube detector via wavelength shifting and light guiding. In this presentation the results of simulations with the WOM in IceCube Gen2 investigating the efficiency of the WOM in detecting fractionally charged particles in comparison to the optical modules used in the original IceCube detector is shown. These simulations show that the WOM has a higher efficiency than the original sensors.

T 93.8 Thu 18:00 T-H24

Search for heavy neutral lepton production and decay with the IceCube Neutrino Observatory — •Leander Fischer for the IceCube-Collaboration — DESY Zeuthen

We investigate the ability of IceCube DeepCore to reconstruct low-energy (GeV) double-cascade topologies, which can be produced through Beyond Standard Model interactions. In particular, we consider Heavy Neutral Leptons (HNLs) in the mass range of 0.1-3 GeV that are produced from up-scattering of atmospheric tau-neutrinos. The sensitivity to HNL interactions, where the production and subsequent decay happen inside the detector volume, is investigated using 8 years of atmospheric data from IceCube DeepCore.

T 93.9 Thu 18:15 T-H24

Search for Sub-Relativistic Magnetic Monopoles in IceCube — •Christian Dappen[1], Jakob Böttcher[1], Sukeerthi Dharani[2], and Christopher Wiebusch[1] for the IceCube-Collaboration — [1]RWTH Aachen University - Physics Institute III B, Aachen, Germany — [2]Universität Hamburg

The IceCube Neutrino Observatory detects high energy neutrinos through their interaction in the Antarctic ice while also searching for more exotic particles such as magnetic monopoles. These hypothetical particles are predicted by Grand Unified Theories as relics from the very early Universe. For masses on the GUT-scale (10^{14} GeV - 10^{17} GeV) those monopoles would move at sub-relativistic speeds ($\beta < 10^{-2}$) through IceCube. A subrelativistic monopole in matter may catalyze nucleon decays via the Rubakov-Callan effect. This results in Cherenkov light from small particle showers along the trajectory of the monopole with separations of centimeters up to tens of meters. This pattern is recorded by a dedicated slow particle trigger at a rate of ≈ 10 Hz. For the separation of signal from background events, we have developed a chain of boosted decision trees (BDTs) which are trained with simulated monopole signal and data-driven background events. In each level of the BDT, a background rejection of about 99% is achieved which allows a more efficient training of the subsequent BDT for rare backgrounds. Based on the final selection, the sensitivity is estimated and the analysis is evaluated with an experimental dataset of five months.

T 93.10 Thu 18:30 T-H24

Searching for axion-like particles via ultra-high-energy photons — •Chiara Papior, Markus Risse, and Philip Ruehl — Center for Particle Physics Siegen, Experimentelle Astroteilchenphysik, Universität Siegen

As axion-like particles (ALPs) provide solutions for several questions that current models leave unanswered, it is of great interest to study them experimentally. A potential coupling of ALPs to photons can be probed by large scale cosmic ray detectors like the Pierre Auger Observatory which are sensitive to ultra-high-energy (UHE) photons. After the hypothetical production of high energy ALPs in the environment of e.g. a flaring blazar or a binary neutron star merger, ALPs may propagate over cosmological distances through the intergalactic medium without attenuation. Back-conversion into UHE photons may happen via the Primakoff effect in the magnetic field of the local cluster or the Galaxy itself. A high-confidence detection of an UHE photon from a transient source well beyond the megaparsec scale would be a strong indicator for the presence of ALPs due to the opaqueness of the cosmic microwave background towards photons at these energies. The probability of the ALP-photon conversion depends on several parameters such as the magnetic field in the intergalactic medium, the distance of propagation and the mass and coupling of the ALPs themselves. The work presented in this contribution aims to evaluate the possibility to probe the phase space of UHE ALPs by using the functionality of the gammaALPs python package.

T 94: Silicon Strip Detectors 2

Time: Thursday 16:15–18:00 Location: T-H25

T 94.1 Thu 16:15 T-H25

Status of the CMOS Strip Detector Project in Freiburg — •Niels Sorgenfrei, Leena Diehl, Marc Hauser, Cedric Hönig, Karl Jakobs, Sven Mägdefessel, Ulrich Parzefall, Arturo Rodriguez, and Dennis Sperlich — Albert-Ludwigs Universität, Freiburg, Germany

Due to the increased use of large area silicon detectors in current and future particle detectors and only very few vendors available, which are capable of silicon production and processing fulfilling quality and size requirements, the need for reliable, fast and cost efficient production processes arises. As part of a CERN market survey, CMOS sensors in pixel and strip geometries were developed.

The idea is to utilise the already existing industry infrastructure of the CMOS process. However, typical CMOS foundries are usually only equipped to process smaller sensors compared to what is required in e.g. the strip region of the ATLAS Inner Tracker. Therefore, the process of stitching has to be used. By employing wafer masks where the sensor structure is divided up into different parts, the individual parts can be imprinted multiple times side by side on the wafer resulting in coherent areas larger than the reticles themselves. The effect of stitching on charge collection, electric field strength and configuration, detection efficiency and radiation hardness has to be investigated.

In this talk measurements on passive CMOS strip sensors, produced by LFoundry in a 150 nm process, will be discussed. Three different strip designs are investigated and the results of IV, ^{90}Sr-source and edge-TCT measurements will be presented.

T 94.2 Thu 16:30 T-H25

Humidity Studies on ATLAS ITk sensors — Naim Bora Atlay[2], Ingo Bloch[1], Heiko Lacker[2], •Ilona Stefana Ninca[1], and Christian Scharf[2] — [1]Deutsches Elektronen-Synchrotron (DESY), Zeuthen, Germany — [2]Humboldt-Universität zu Berlin, Berlin, Germany

This study aims to investigate electrical breakdown in the periphery of silicon sensors, with a focus on humid conditions. The study will take advantage of the large number of silicon strip sensors produced for the ATLAS Upgrade in order to probe their behavior. The sensors are investigated using the transient current technique (TCT). The TCT setup available at Deutsches Elektronen-Synchrotron in Zeuthen employs both red and infrared laser light. This setup can be used to study the transport of free charge carriers in the sensors at the surface and inside the bulk. Additionally, to better understand the electric properties of the sensors, simulations using Technology Computer Aided Design were produced. ATLAS ITk silicon miniature diodes were investigated in a humid environment. We are planning to use a dedicated camera to localize the critical spots where breakdown occurs on the surface of the diodes through luminescence of hot carriers. Using the information provided by the TCT measurements, the humidity dependence of the electric field at the breakdown point is planned to be studied. Understanding these dependencies will help us propose better geometries for future sensors and potentially allow us to develop improved operation scenarios for the future ATLAS ITk strips detector.

T 94.3 Thu 16:45 T-H25

Recent results from the End-of-Substructure card for the ATLAS Strip Tracker Upgrade — •Rickard Stroem[1], Artur Boebel[1], Harald Ceslik[1], Mogens Dam[2], Sergio Diez Cornell[1], Peter Goettlicher[1], Ingrid Gregor[1], James Keaveney[3], Max Nikoi Van Der Merwe[3], Jan Oechsle[2], Stefan Schmitt[1], Marcel Stanitzki[1], and Jane Wyngaard[3] — [1]DESY, Germany — [2]Niels Bohr Institute, Denmark — [3]University of Cape Town, South Africa

The silicon tracker of the ATLAS experiment will be upgraded for the High-Luminosity Upgrade of the LHC. The main building blocks of the new strip tracker are modules of silicon sensors and hybrid PCBs hosting the read-out ASICs. The modules are mounted on rigid carbon-fibre substructures, known as staves in the central barrel region and petals in the end-cap regions, that provide services to all the modules. At the end of each stave/petal, a so-called End-of-Substructure (EoS) card facilitates the transfer of data, power, and control signal between the modules and the off-detector systems. The module front-end ASICs transfer data to the EoS card on 640 Mbit/s differential lines. The EoS connects up to 28 data lines to one or two lpGBT chips that provide data serialisation and uses a 10 GBit/s versatile optical link (VL+) to transmit signals to the off-detector systems. We will here present the EoS card's design, results from various stress tests, and the design and status of the dedicated production quality control test-stands in the Detector Assembly Facility at DESY.

T 94.4 Thu 17:00 T-H25

Beam Test Studies with Silicon Sensor Modules for the CMS Experiment — •Florian Wittig[1], Tobias Barvich[1], Bernd Berger[1], Alexander Dierlamm[1], Alexander Droll[1], Umut Elicabuk[1], Ulrich Husemann[1], Markus Klute[1], Gani Kösker[1], Roland Koppenhöfer[1], Stefan Maier[1], Thomas Müller[1], Jan-Ole Müller-Gosewisch[1], Andreas Nürnberg[2], Marius Neufeld[1], Hans Jürgen Simonis[1], Pia Steck[1], and Lea Stock[1] — [1]Institute of Experimental Particle Physics (ETP), Karlsruher Institute of Technology (KIT) — [2]Deutsches Elektronen-Synchrotron (DESY)

In the context of the Phase-2 Upgrade of the CMS Experiment, the whole tracker will be replaced. The new CMS Outer Tracker will be equipped with two different types of silicon sensor modules called PS and 2S modules. During the LHC runtime, the modules and especially the silicon sensors will accumulate radiation damage, which lowers the signal measured by the module. In order to ensure the full functionality of the 2S modules during the entire operation time of CMS, modules in the advanced prototyping phase have been built. One of the prototypes features sensors that have been irradiated to fluences that are expected at the end of the CMS runtime. These unirradiated and irradiated prototypes have been tested at the DESY beam test facility. This talk summarizes the results gathered at the beam tests.

T 94.5 Thu 17:15 T-H25

test beam analysis of a silicon-strip module for the CMS phase-II tracker upgrade — •Chun Cheng — DESY, Hamburg, Germany

The foreseen Large Hadron Collider upgrade is expected to deliver an integrated luminosity that is one order of magnitude larger after 2027. Rare processes and new phenomena may be observed in this high luminosity era. The Phase-II Outer Tracker upgrade of the CMS experiment is required to surmount higher radiation and increased event rate. Transverse momentum (PT) discrimination is introduced in the design and will contribute to the Level-1 Trigger. A CMS 2S silicon strip module with PT discrimination concept was built by the DESY Outer Tracker group and has undergone a test beam experiment at the DESY test beam facility.

The talk will briefly summarize the assembly of the DESY 2S module, sensor studies and the data acquisition scheme during the beam test. The main focus will be on the results from recent test beam measurements. The analysis will be done based on corryvreckan framework, a modular concept of test beam reconstruction chain. Hit efficiency of the sensors under a bias scan, the performance over the large module area, and on-module PT discrimination functionality will be presented.

T 94.6 Thu 17:30 T-H25

Beam test of 2S module prototypes for the Phase-2 CMS Outer Tracker — Christian Dziwok[2], Lutz Feld[1], Katja Klein[1], Martin Lipinski[1], Alexander Pauls[1], Oliver Pooth[2], Nicolas Röwert[1], and •Tim Ziemons[2] — [1]I. Physikalisches Institut B, RWTH Aachen University, Germany — [2]RWTH Aachen University - Physics Institute III B, Aachen, Germany

The CMS detector will be upgraded in the Phase-2 Upgrade for the operation at the HL-LHC. Among others, the silicon tracking system will be completely replaced by a new system providing an extended acceptance, an improved granularity and the feature to include tracking information into the level-1 trigger. The new Outer Tracker will consist of 2S modules with two strip sensors and PS modules with a macro-pixel sensor and a strip sensor, specialized detector modules with onboard p_T discrimination.

The functionality of current generation prototype 2S modules has been tested at the test beam facility at DESY Hamburg in November 2019. With a 4 GeV electron beam, various studies are performed like efficiency scans at different positions of the module or at varying inclination angles to mimic different p_T particles. In this talk, efficiency studies are presented.

T 94.7 Thu 17:45 T-H25

A new high rate electron beam line at DESY II — •Dohun Kim — DESY, Notkestraße 85, 22607 Hamburg

The R-Weg is a former transfer beam line from the DESY II synchrotron to DORIS. Recently, it has been refurbished to serve as a high-rate electron beam line. The full DESY II beam with up to several $10^{10}e^-$ can be dumped at a rate of 12.5 Hz. The available rates allow many detector tests that require high particle rates, but this also allows to use the beam line has a facility for electron irradiation.
Before the R-Weg is put into full operation, it is necessary to understand the beam parameters and the radiation field in detail. Therefore, the R-Weg has been simulated and studied using FLUKA, which is a MC simulation framework for the interaction and transport of particles in materials.
The beam divergence, stability, beam profile etc. have been simulated.To verify the results, a suite of measurements has been prepared and compared. In addition, the neutron and gamma background from the beam dump are studied to ensure safe operation and to enable the use as a electron irradiation facility.
This presentation is going to explain details of the R-Weg and present the simulation result. Finally, an outlook into future measurements at the R-Weg is given.

T 95: Pixel Detectors 3

Time: Thursday 16:15–18:15 Location: T-H26

T 95.1 Thu 16:15 T-H26

Effects of gamma radiation on DEPFET pixel sensors for the Belle II experiment — •Georgios Giakoustidis[1], Jochen Dingfelder[1], Ariane Frey[2], Botho Paschen[1], Benjamin Schwenker[2], and Marike Schwickardi[2] for the Belle II-Collaboration — [1]University of Bonn, Germany — [2]University of Göttingen, Germany

For the Belle II experiment at KEK (Tsukuba, Japan) the KEKB accelerator was upgraded to deliver e^+e^- collisions at a center of mass energy of $E_{CM} = 10.58\ GeV$ with an instantaneous luminosity of $8 \cdot 10^{35}\ cm^{-2}s^{-1}$. As the innermost part of the Belle II detector, the PiXel Detector (PXD), based on DEpleted P-channel Field Effect Transistor (DEPFET) technology, is most exposed to radiation from the accelerator. Prototypes as well as a module from the final Belle II production batch were irradiated with X-rays to doses up to 20 $Mrad$, corresponding to the expected lifetime exposure. The performance of the DEPFET sensors and front-end electronics will be presented and the results of two recent campaigns will be compared to previous results.

T 95.2 Thu 16:30 T-H26

CMOS Upgrade of the Belle II Vertex Detector — •Marco Vogt, Christian Bespin, Ivan Dario Caicedo Sierra, Jochen Dingfelder, Tomasz Hemperek, Fabian Hügging, Hans Krüger, and Norbert Wermes — Physikalisches Institut der Universität Bonn

The Belle II experiment at KEK in Japan will have an opportunity for upgrades of its detector components during a long shutdown in 2027, when several upgrades of the SuperKEKB $e^+ e^-$ collider are planned. At the expected high instantaneous luminosity of $6x10^{35}\,cm^{-2}$, SuperKEKB will generate a high rate of background particles, especially in the inner detector layers, the vertex detector. Here, hit rates will exceed 100 $MHz\,cm^{-2}$, inducing radiation levels of 100 $Mrad$ TID and fluences reaching $5x10^{14}\,neq\,cm^{-2}$. Such a high level of beam background will create new challenges and requirements that can be met by a new vertex detector.

A performant and robust vertex detector upgrade (VTX) is currently being defined by the Belle II collaboration. The baseline design foresees an all-layer pixel detector system based on the TJ-Monopix2 fully depleted monolithic CMOS sensor. For the inner layers of the VTX, a new ultra-thin all-silicon ladder concept is being developed and tested.

In this talk, the proposed monolithic CMOS upgrade will be presented. Technological aspects, system integration and performance estimations will be discussed.

T 95.3 Thu 16:45 T-H26

Irradiation burst study of Belle II PXD module components — Florian Bernlochner[1], Jochen Dingfelder[1], Georgios Giakoustidis[1], Matthias Hoek[2], Botho Paschen[1], and •Jannes Schmitz[1] for the Belle II-Collaboration — [1]University of Bonn, Germany — [2]University of Mainz, Germany

The Belle II detector started recording collision data in spring 2019. During physics runs, unexpected irradiation burst events occurred, which exposed the inner detectors and especially the PXD (PiXel Detector) to unwanted levels of prompt irradiation. Dedicated measurement campaigns were carried out at the Mainz Microtron (MAMI), which aimed to reproduce the observed effects of irradiation bursts on the PXD in Belle II. To this end, a focused high intensity (up to 10uA) pencil beam of 855 MeV electrons was used to irradiate full system demonstrators in several spatially confined fiducial regions. During first campaigns in 2020 the observed failure mode could be reproduced and restricted to vulnerable regions in one specific module component.

In this talk, the results of the latest measurement campaign in December 2021 will be presented, focussing on possible protective measures against the impact of irradiation bursts on the PXD modules installed inside Belle II.

T 95.4 Thu 17:00 T-H26

KEK Total Ionizing Dose Measurement of PXD Modules and sensor effects at Belle II — Ariane Frey, Benjamin Schwenker, Yannik Buch, and •Marike Schwickardi — II. Physikalisches Institut, Georg-August-Universität Göttingen

The Belle II experiment at the Japanese B-factory SuperKEKB has started data taking in early 2019 and the peak luminosity will be ramped up to $8{\cdot}10^{35}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, which is 40 times higher than the previous luminosity delivered to the Belle experiment. It was therefore equipped with a new DEpleted P-channel Field Effect Transistor (DEPFET) based silicon PiXel Detector (PXD) for vertex detection to cope with higher beam backgrounds.

The monitoring of radiation effects on the new PXD is important throughout operation, since sensor settings have to be adjusted to ensure efficient operation. To compare observed effects to preliminary studies an accurate measurement of the total ionizing dose (TID) is needed. One way of dose monitoring is the diamond control units, that measure the radiation conditions for the Belle II detector. The diamonds are placed at different angles and positions close to the beam pipe and continuously take data. However, the diamonds do not measure the dose that the PXD received during beam times correctly, therefore the approach was chosen to estimate the TID of the PXD, using its occupancy. The drawback of this is that the PXD only sends out data while it is powered. To compensate that, the dose rate deposited when PXD DAQ is disconnect is estimated by scaling the dose rate of nearby diamonds with the ratio of pxd dose to diamond dose.

T 95.5 Thu 17:15 T-H26

Analog to Digital Converter ASICs scan on irradiated modules of the Pixel Vertex Detector at the Belle II experiment — •Tommy Martinov and Arthur Bolz — DESY, Hamburg, Germany

The Belle II detector placed at the SuperKEKB collider in Japan aims at studying heavy flavour physics through electron-positron collisions at a center of mass energy of approximately 10.6 GeV. The innermost element of the detector is the Pixel Vertex Detector (PXD). The pixels are based on the DEPFET technology (depleted p-channel field effect transistor). The PXD is composed of 10 ladders representing a total of approximately 3.6 * 10^6 pixels. The PXD detects charged particles with a transverse momentum higher than 40 MeV. On each module, four Drain Current Digitizers (DCDs) measure the drain currents of all DEPFET pixels. In each DCD, 256 ADCs convert the analog currents to digital signals. The characteristics of the ADCs are influenced by several components and reference voltages in the DCD. An ADC scan needs to be performed in order to calibrate the ADCs and optimize the number of channels considered as "good". The Belle II detector has been taking data for three years and it has become vital to evaluate the ageing of the different components of the detector. This presentation focuses on the ADC calibration as a way to assess the operation quality of the PXD DCDs in 2022 after three years of data taking.

T 95.6 Thu 17:30 T-H26

Challenges of offset calibration in irradiated modules of the Pixel Vertex Detector at the Belle II experiment — •Maria Konstantinova and Arthur Bolz — DESY Hamburg

The Pixel Vertex Detector (PXD) is situated as the innermost subdetector of the Belle II experiment at the SuperKEKB collider in Japan. Each PXD module includes a matrix of 192'000 pixels based on the Depleted P-channel Field-Effect Transistor (DEPFET) technology. The matrices are read out in rolling shutter mode such that 1000 channels are digitized in parallel by four custom Drain Current Digitizer (DCD) ASICs. For a consistent response to transversing charged particles during operation, homogeneous pedestal currents must be subtracted for each pixel to obtain as much room as possible for analogue-to-digital conversion of the signal current. Therefore, a narrow pedestal spread is achieved by adding a 2-bit DAC offset current to every pixel. The offset currents show non-linear behaviour which is dependent on the hardware architecture and may change during module operation in a harsh radiation environment in the interaction region. In this talk those effects are analyzed and the challenges they pose to a good offset calibration of PXD are discussed.

T 95.7 Thu 17:45 T-H26

Characterizatoin of DEPFET Pixel Modules for PXD2 — •Larissa von Jasienicki, Jannes Schmitz, Patrick Ahlburg, Georgios Giakoustidis, Botho Paschen, Florian Bernlochner, and Jochen Dingfelder for the Belle II-Collaboration — University of Bonn, Germany

The SuperKEKB electron-positron collider in Japan has reached unprecedented luminosities. The Belle II experiment operating at the SuperKEKB collider is equipped with a PiXel Detector (PXD) based on the Depleted P-channel Field Effect Transistor (DEPFET) technology, which serves as the innermost two layers of the VerteX Detector (VXD) of Belle II and was designed to cope with the large particle rates. The current PXD is, however, incomplete, since (mostly) only the innermost of the two layers is installed. A new full-scale PXD (*PXD2*) is currently being built and is expected to be installed in 2023(?).

This talk highlights improvements in the lab characterization of individual PXD2 modules. In particular, the biasing requirements of the sensors and investigations of the intrinsic properties like transconductance and gain of the DEPFET sensor will be discussed.

T 95.8 Thu 18:00 T-H26

Assembly and tests of the first TRISTAN detector modules — •Daniel Siegmann for the KATRIN-Collaboration — Max-Planck Institute for Physics, Munich, Germany

The TRISTAN (TRitium Invetigations of STerile to Active Neutrino mixing) project aims to search for the signature of a keV sterile neutrino in the tritium beta decay spectra by upgrading the detector system of the KATRIN experiment. This extension of the experiment will be performed after its neutrino mass survey.

To reach a high sensitivity to the sterile neutrino mixing angle the strong activity of the KATRIN tritium source is required. The resulting high electron rate is one of the greatest challenges for the TRISTAN project. It will be approached by distributing the rate among 3500 pixels, resulting in count rates of 100 kcps per pixel. To resolve the kink-like signature of the keV sterile neutrino signal the detector needs to maintain an excellent energy resolution of 300 eV (FWHM) at 20 keV and a low energy threshold.

The TRISTAN detector is segmented into 21 identical modules, each hosting 166 independent pixel. The development and tests of the first detector modules will be presented in this talk.

This work is supported by the Max Planck society and the TU Munich ("Chair for Dark Matter, Susanne Mertens").

T 96: Detector Systems 3

Time: Thursday 16:15–18:15 Location: T-H27

T 96.1 Thu 16:15 T-H27

Status of the Mu3e tile detector — •Hannah Klingenmeyer for the Mu3e-Collaboration — Kirchhoff-Institut für Physik, Universität Heidelberg

The aim of the Mu3e experiment is the search of the lepton-flavour violating decay $\mu \to eee$ down to a sensitivity of 10^{-16}. It will be operated at the Paul Scherrer Institute (PSI) in Switzerland and consists of dedicated tracking and timing detectors, which will provide precise spatial and time measurements in order to suppress any background mimicking the signal decay.

One of the timing systems is the Mu3e tile detector, which allows precise timing of individual electrons with a resolution below 100 ps. It uses plastic scintillator tiles and silicon photomultipliers that are read out by a custom-designed ASIC, and is currently in the pre-production phase. This talk will give an overview of the current status and development of the tile detector, as well as of the performance of individual detector components. The tile matrix production and quality assurance measurements will be discussed along with advancements in the readout electronics, the cooling system, and the integration into the full experiment. Furthermore, an outlook on the full detector production will be given.

T 96.2 Thu 16:30 T-H27

Simulation studies on the Mu3e tile detector - Time alignment & clustering — •Erik Steinkamp and Maximilian Köper for the Mu3e-Collaboration — Kirchhoff Institute for Physics, Heidelberg University

The Mu3e experiment aims to detect the charged lepton flavor violating decay $\mu \rightarrow eee$ with a target sensitivity of 10^{-16}, improving the existing limit by four orders of magnitude. A successful observation would be a strong indicator for physics beyond the Standard Model. Precise timing information is needed to correctly identify the vertices of the three decay electrons and to suppress background from internal conversion decays and combinatorics. The tile detector, which utilizes scintillator tiles and SiPMs, aims to provide this precise time measurement of better than 100ps. To achieve this precision on the detector system level, a time calibration scheme using different event topologies to determine time offsets for every tile, is required. The obtained single-tile timestamps are clustered and matched to tracks from the tracking detectors. We present simulation studies of the time calibration routine, as well as clustering and track-tile matching.

T 96.3 Thu 16:45 T-H27

Irradiation studies for the Mu3e tile detector — •Tiancheng Zhong for the Mu3e-Collaboration — Kirchhoff-Institut für Physik, Universität Heidelberg, Heidelberg, Germany

The Mu3e experiment is designed to search for the decay $\mu^+ \rightarrow e^+e^+e^-$ with a sensitivity of 10^{-16}, which would be a clear signal for new physics beyond the Standard Model. To reduce the combinatorial background from muon decays while efficiently identifying 3-electron final states, a scintillating-tile detector with a required timing resolution < 100 ps and efficiency close to 100% is under development.

Irradiation damage and effects on Silicon Photomultiplier (SiPM) used in the tile detector were investigated by exposing the sensors to the decay electrons from stopped muons at the PiE5 beamline at PSI. For the SiPMs irradiated with a dose up to 1.57×10^{11} 1 MeV n_{eq}/cm^2, corresponding to 70% of the maximum dose of the Mu3e Phase I run, the dark current increased by a factor up to 1000. We will report on the irradiation campaign performed, measurements of dark current and impact on annealing at different temperatures. The timing performance after irradiation was investigated in testbeam campaigns at DESY and will also be discussed.

T 96.4 Thu 17:00 T-H27

The detector system for the Stopping Target Monitor of the Mu2e experiment at Fermilab — •Anna Ferrari, Stefan E. Mueller, Oliver Knodel, and Reuven Rachamin for the Mu2e-Collaboration — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

The Mu2e experiment, which is currently under construction at the Fermi National Accelerator Laboratory near Chicago, will search for the neutrinoless conversion of muons to electrons in the field of an aluminum nucleus, with the aim to reach a sensitivity four orders of magnitude better than previous experiments . Observations of a signal would be an example of Charged Lepton Flavor Violation, which would require physics beyond the Standard Model.

In order to normalize the result, a stopping target monitor will measure the number of stopped and captured muons in the aluminum target. The detector system includes a HPGe and a Lanthanum Bromide detector, which with different capabilities will measure x- and gamma-ray lines up to 1809 keV, in presence of high rate Bremsstrahlung and other backgrounds. At the Helmholtz-Zentrum Dresden-Rossendorf, we use the Bremsstrahlung photon beamline at the ELBE radiation facility to study the detector system performance in the pulsed conditions similar to that expected in Mu2e.

In the presentation, after an overview of the design and status of the Mu2e experiment, the main results of the ELBE campaign will be presented and discussed.

T 96.5 Thu 17:15 T-H27

Track reconstruction for the Mu3e experiment — •Alexandr Kozlinskiy for the Mu3e-Collaboration — Institut für Kernphysik, Johannes Gutenberg-Universität Mainz

The *Mu3e* experiment is designed to search for the lepton flavor violating decay $\mu^+ \rightarrow e^+e^-e^+$. The ultimate aim of the experiment is to reach a branching ratio sensitivity of 10^{-16}. The experiment is located at the Paul Scherrer Institute (Switzerland) and an existing beam line providing 10^8 muons per second will allow to reach a sensitivity of a few 10^{-15} in the first phase of the experiment. The muons with a momentum of about 28 MeV/c are stopped and decay at rest on a target. The decay products (positrons and electrons) with energies below 53 MeV are measured by a tracking detector consisting of two double layers of 50 μm thin high-voltage monolithic active pixel sensors. The high granularity of pixel detector with a pixel size of 80×80 μm together with the small material budget allows for a precise track reconstruction. The track reconstruction is based on 3-dimensional multiple scattering fit and uses special methods to remove incorrectly reconstructed tracks, which is made possible by high efficiency and low noise rate of the pixel detector. This talk will present the details of the track reconstruction including the methods that are used to reduce the number of fake tracks.

T 96.6 Thu 17:30 T-H27

Commissioning of the LHCb Scintillating Fibre Tracker — Sebastian Bachmann, Daniel Berninghoff, Xiaoxue Han, Blake Leverington, Ulrich Uwer, and •Lukas Witola — Universität Heidelberg, Heidelberg, Deutschland

The LHCb detector underwent a major upgrade in the past years. The modifications enable the detector to operate at an increased instantaneous luminosity and to read out data at the LHC bunch crossing rate of 40MHz. The new operating conditions required the replacement of the complete tracking system. The main tracking stations are replaced by the SciFi Tracker, a large high granular scintillating fibre tracker readout by arrays of silicon photomultipliers (SiPMs). A custom ASIC is used to digitise the SiPM signals at 40MHz. Further digital electronics perform clustering and data-compression before the data is sent via optical links to the DAQ system.
The detector modules together with the readout electronics and all services are mounted on so-called C-Frames. The serial assembly and commissioning of frames is in its last stages before the start of the LHC in early 2022. The talk will give an overview of the detector and present experiences from the serial production and the latest commissioning results.

T 96.7 Thu 17:45 T-H27

Alignment studies of the LHCb SciFi Tracker — •Nils Breer[1] and Sophie Hollitt[2] — [1]TU Dortmund, experimentelle Physik 5 — [2]TU Dortmund, experimentelle Physik 5

As part of the LHCb upgrade, the Scintillating Fibre Tracker (SciFi) will replace the previous Outer and Inner Tracker detectors. It is crucial to understand which constraints and which parts of the SciFi have the most impact on the alignment quality.

In order to align the SciFi, several configurations of degrees of freedom and alignment constraints are studied. Further analysis is used to search for possible weak modes and confirm that the alignment configuration produces stable results. In this talk, we will present results from misalignment tests using the current best configuration.

T 96.8 Thu 18:00 T-H27

Monitoring alignment performance for LHCb's Scintillating Fibre Tracker — Nils Breer and •Sophie Hollitt — Experimentelle Physik 5, TU Dortmund

During the LHC upgrade period, the LHCb experiment has replaced the majority of its subdetectors and extensively upgraded its trigger system. Before the physics data collection period late in 2022, careful commissioning of the full system is required. The Scintillating Fibre Tracker (SciFi) is the first detector after the LHCb magnet, and its alignment will be crucial for the final mass and momentum resolution of the upgraded experiment.

In this talk, we discuss how misalignment effects in the SciFi detector can be monitored via tracking and physics performance, and give an overview of the alignment and calibration procedures for the commissioning period of the detector.

T 97: Electronics 1

Time: Thursday 16:15–18:00 Location: T-H28

T 97.1 Thu 16:15 T-H28

Instrumentation of a GEM-Based Neutron Detector — •Laura Rodríguez Gómez[1], Saime Gürbüz[1], Jochen Kaminski[1], Markus Köhli[2], Michael Lupberger[1], Divya Pal[1], and Klaus Desch[1] — [1]Universität Bonn — [2]Universität Heidelberg

The VMM chip, originally developed for the ATLAS New Small Wheel Upgrade, was implemented in the multi-purpose readout system of the RD51 collaboration over the last years. Within this so-called Scalable Readout System (SRS) the frontend board is called VMM hybrid as it holds two frontend chips as well as an FPGA and other electronic components to handle data and powering. This system provides a complete readout chain for a large variety of particle detectors.

For the developement of a multilayer Gas Electron Multiplier (GEM) - based neutron detector, a larger system of hybrids is planned, set up and tested. This includes not only the high voltage protection of the readout electronics and the power stability of all hybrids, but also the design of a cooling system and a mechanical suspension.

The detector concept, VMM hybrid test results and measurements with a test layer are presented. The application of VMM hybrids and GEMs in multilayer neutron detectors as a technology transfer is discussed.

T 97.2 Thu 16:30 T-H28

Development of a DC-DC converter for powering the Mu3e detector — •Sophie Gagneur for the Mu3e-Collaboration — Institut für Kernphysik, JGU Mainz

The Mu3e experiment under construction at the Paul Scherrer Institute, Switzerland, aims to search for the lepton flavour violating decay of a muon into one electron and two positrons with an ultimate sensitivity of one in 10^{16} muon decays. The Mu3e detector consists of a tracker based on High-Voltage Monolithic Active Pixel Sensors (HV-MAPS) combined with scintillating tile and fibre timing detectors. The detector ASICs need a supply voltage of around 2V. This voltage is generated from the 20V external supply voltage via switching DC-DC converters. These buck converters must be able to operate within a magnetic field and provide a constant output voltage with a ripple of less than 10mV to guarantee a proper operation of the pixel sensors and timing detectors. The second version of the Mu3e DC-DC converter has been designed, produced and already tested successfully in the laboratory, implementing features such as a secondary output filter and a temperature interlock for the pixel sensors. The final version is currently being designed and integrated into the experiment to be used during the upcoming commissioning runs.

T 97.3 Thu 16:45 T-H28

Powering Scheme of the Tracking Detector of the P2 Experiment at MESA — •Lars Steffen Weinstock — PRISMA+ Cluster of Excellence and Institute of Nuclear Physics, Johannes Gutenberg University Mainz

P2 is a precision experiment planned for the Mainz Energy recovering Superconducting Accelerator (MESA) currently under construction. The goal of P2 is to determine the electroweak mixing angle at low energy scales with unprecedented precision by measuring the parity violating asymmetry in proton-electron scattering at low momentum transfer. A key parameter for the analysis, the electron momentum transfer during scattering, is measured by the P2 tracker, which is placed inside the 0.6 T solenoid spectrometer. The tracker consists of eight identical modules utilising a total of 4320 novel High Voltage Monolithic Active Pixel Sensors (HV-MAPS) for precise track reconstruction. With each HV-MAPS drawing about 1W the tracker frontend requires more than 5kW of power, which is supplied to the tracker using a remote-sense technique. This talk presents the current state of the powering scheme of the P2 tracking detector, key design parameters, and technical details of the implementation including first test measurements.

T 97.4 Thu 17:00 T-H28

A Simulation Framework to Optimize Signal Processing for Particle Detectors — •Florian Rössing[1], André Zambanini[1], Christian Grewing[1], and Stefan van Waasen[1,2] — [1]ZEA-2, Forschungszentrum Jülich GmbH — [2]NTS, University of Duisburg-Essen

Particle Detectors evolve to ever higher performance, both in terms of sensitivity and channel density. This increases the amount of data to be handled. As transmitting this raw data is often not a viable option, data reduction has to be employed. To achieve this, the individual channel signals are converted, and the data is processed close to the sensor, extracting observable parameters of the signal. Recent developments often rely on low-level, analog blocks and simple digitizers as signal converters, which are tailored to the specific sensor used in the detector. This limits reusability, making a repeated design effort necessary. The design of generic readout electronics based on digital data processing could overcome this issue. In a pursuit to build such a generic detector readout, part of the necessary work is the design of a single channel signal conversion and data handling, both to be used for a wide range of detectors with different sensors. For this, MatLab and Simulink are used to study and evaluate signal and data processing chains. This includes shaping, different digitization approaches (e.g. TDC, ADC) and data processing algorithms. This contribution will describe the models used as input signals for simulations, the architecture of the simulation software, and introduce first algorithm implementations.

T 97.5 Thu 17:15 T-H28

FPC design and prototype for the ATLAS High Granularity Timing Detector Demonstrator — •Maria de la Soledad Robles Manzano[1], Peter Bernhard[2], Andrea Brogna[2], Atila Kurt[2], Karl-Heinz Geib[1], Lucia Masetti[1], Binh Pham[2], Steffen Schoenfelder[2], and Quirin Weitzel[2] — [1]Institut für Physik, Johannes-Gütenberg Universität Mainz — [2]PRISMA$^+$ Detector Lab, Johannes-Gütenberg Universität Mainz

The ATLAS detector requires upgrades to face the challenges of the new HL-LHC, mainly the increase of pile-up interactions. The High-Granularity Timing Detector (HGTD) will be built in order to mitigate the effects of pile-up in the ATLAS forward region, providing a time resolution of about 30 ps per track. The active area consists of 2-double-sided disks per end-cap. The HGTD basic unit, so-called module, is made up of two 2x2 cm^2 Low Gain Avalanche Detectors bump-bonded to two ASICs and glued to a flexible PCB. The modules are connected to the Peripheral Electronics Boards, surrounding the active area, via a Flexible Printed Circuit (Flex tail) that serves as interconnection for power, communication signals and HV bias. As part of the HGTD R&D phase, a demonstrator is proposed to test the functionality and assembly of a subset of components of the full detector. The design and tests of a Flex tail prototype in the context of an overall description of the demonstrator activities are presented.

T 97.6 Thu 17:30 T-H28

Prototyping Serial Powering with RD53A — Klaus Desch, Matthias Hamer, •Florian Hinterkeuser, Fabian Hügging, Hans Krüger, Charlotte Perry, and Lars Schall — Physikalisches Institut, Universität Bonn

The high luminosity upgrade for the Large Hadron Collider at CERN requires a complete redesign of the current inner detectors of ATLAS and CMS. These new inner detectors will consist of all-silicon tracking detectors. A serial powering scheme has been chosen as baseline for the pixel detector to cope with the higher number of modules and the higher power consumption of the new front-end chip, spatial constraints and the need to minimize the tracker's material budget. This new powering scheme provides challenges for the electrical and mechanical design. In order to verify this new powering scheme and its implications on the detector integration, efforts have been ongoing to set up a prototype for serial powering using modules based on the RD53A chip, a half-size prototype for the new Pixel front-end chip, developed by the RD53 collaboration. In particular, a serial powering stave consisting of up to 8 RD53A quad chip modules has been set up in Bonn. The results from the activities with RD53A chips are presented. Emphasis is put on the electrical characterization of an RD53A serial powering chain, using representative services and power supplies. The setup, measurement goals and characterization of the serial powering chain will be discussed.

T 97.7 Thu 17:45 T-H28

Test Results of the New ASD Chips for Phase-II Upgrade of the ATLAS MDT Chambers at HL-LHC — •Katrin

Penski, Otmar Biebel, Stefanie Götz, Vitaliy Havrylenko, Ralf Hertenberger, Christoph Jagfeld, Maximilian Rinnagel, Chrysostomos Valderanis, and Fabian Vogel — LMU München

The Phase-II Upgrade of the ATLAS Muon Spectrometer to the High Luminosity LHC (HL-LHC) requires an efficient trigger and readout system for the Monitored Drift Tube (MDT) chambers. For this purpose, new front-end electronics have been developed including an 8-channel amplifier shaper discriminator (ASD) chip built in 130 nm GF CMOS technology. Using pre-production chips, this presentation discusses the overall performance of these chips as well as the dependence on programmable parameters. Moreover, the uniformity between pre-production chips and the first batch of production chips is shown. These test results are used to define the acceptance criteria for the series testing which is planned for winter 2021. For this series testing a new tester is necessary. Its behavior is studied by retesting all chips with this tester and comparing the corresponding results with those of the previous tester.

T 98: Experimental Methods (general) 4

Time: Thursday 16:15–18:05 Location: T-H29

Group Report T 98.1 Thu 16:15 T-H29

High-D: F&E für hochsegmentierte mehrdimensionale Detektoren für zukünftige Experimente — •Erika Garutti für die High-D-Kollaboration — U Hamburg

Zukünftige Experimente für Higgs-Präzisionsmessungen, die Suche nach Physik über das Standardmodell hinaus, sowie für die Untersuchung des Quark-Gluon-Plasmas und die Erforschung des QCD-Phasendiagramms, verlangen eine neue Generation von Hochpräzisionsdetektoren mit beispielloser räumlicher, zeitlicher und energetischer Auflösung. Die Anforderungen an solche 5-dimensionale (5D) Messungen können nur durch die Kombination von Detektoren mit extremer Granularität und neuartigen Rekonstruktionsmethoden erreicht werden. Eine höhere Segmentierung wird durch neu zu entwickelnde mikroelektronische Technologien, Halbleiterdesigns, Segmentierungskonzepte und Ausleseelektronik möglich werden. Diese Forschung auf der Detektorseite muß von neuartigen Algorithmen begleitet werden, die die bereitgestellte 5D-Information effektiv nutzt. Sie geht darin weit über einen einzelnen Detektor hinaus, indem sich alle Komponenten von einem Detektorsystem ergänzen, um eine optimale Rekonstruktionspräzision zu gewährleisten. High-D ist ein neuer vom BMBF geförderter Verbund, in dem die Gemeinschaften der Elementarteilchen-, Kern- und Hadronenphysik erstmalig miteinander gemeinsam an der Entwicklung verschiedener grundlegender Technologien zu solchen 5D-Detektoren zusammenarbeiten. Der Vortrag gibt einen Überblick über die geplanten Arbeiten und Projekte.

T 98.2 Thu 16:35 T-H29

The characterisation of non collisions background events in the ATLAS detector during Run-2 data taking. — •Sergio Grancagnolo — Humboldt-Universität, Berlin, Germany

Understanding events from proton interactions with residual gas in the beam pipe, with collimators, or from cosmic rays is of primary importance to identify potential risk of damage to the accelerator and experiments. In addition, these events represent one of the main background on non-conventional physics signatures based on tracks not pointing to the interaction point, out-of-time energy deposits, or displaced decay vertices might come from signals released by long-living heavy particles. The characteristics of these non-collision backgrounds are illustrated in detail in order to identify, estimate and reject them by using all the ATLAS detector.

T 98.3 Thu 16:50 T-H29

BGNet: A neural network for beam background prediction for SuperKEKB — •Yannik Buch, Ariane Frey, and Benjamin Schwenker — II. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Deutschland

In pursuit to understanding the observed CP-violation in our universe, the Belle II detector investigates the b-sector by measuring the decays of the $\Upsilon(4S)$ resonance. These resonances are produced by the SuperKEKB accelerator at KEK in Tsukuba, Japan. The goal of SuperKEKB is to achieve an instantaneous luminosity of $6.5 \times 10^{35}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$. Currently, a luminosity of $5 \times 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ is reached, showing that considerable improvements to the beam focusing and increases of the ring currents are still necessary. A key component to achieve the design luminosity is the nano beam scheme. At the same time, however, the Belle II detector must not be damaged or its performance compromised by extensive radiation and hit rates.

The beam backgrounds at Belle II are mostly composed of storage backgrounds, luminosity-based backgrounds and injection backgrounds of both rings due to the top-up injection scheme. BGNet is trained to predict the overall hit rates and their composition in terms of background source for various Belle II sub-detectors. The input data for BGNet are 1 Hz time series of variables describing the state of the SuperKEKB accelerator. This helps to monitor and mitigate the beam backgrounds during future operation.

T 98.4 Thu 17:05 T-H29

Low-background poly(ethylene naphthalate) as active structural material for the LEGEND-200 $0\nu\beta\beta$ experiment — •Felix Fischer for the PEN-Collaboration — Max-Planck-Institut für Physik, München, Deutschland

Poly(ethylene naphthalate), PEN, is a widely used industrial polyester which intrinsically scintillates blue light and has very good mechanical properties, also at cryogenic temperatures. This makes PEN an ideal candidate for self-vetoing structural materials in the close surrounding of ultra low background detectors for the search of extremely rare events like $0\nu\beta\beta$ decay. The process from procurement of commercially available PEN pellets to an optically active low background support-structure to be used in the next generation $0\nu\beta\beta$-decay search experiment Legend-200 will be presented.

T 98.5 Thu 17:20 T-H29

Setup for a ground parameter measurement for the radio detection at the Pierre Auger Observatory* — •Jannis Pawlowsky for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstraße 20, 42119 Wuppertal, Deutschland

The Pierre Auger Observatory is the largest observatory in the world measuring ultra high energy cosmic rays (UHECR). With the on-going AugerPrime upgrade, the hybrid detection of the 27 Fluorescence Telescopes and 1660 Water Cherenkov Detectors (WCD) is complemented by the Radio Detector (RD) on top of each WCD. The mounted antenna detects the radio emission of the air shower.

The reconstruction of the UHECR properties with radio signals is dependent on environmental parameters like atmospheric (weather) conditions and soil composition. The ground conditions are especially important for inclined air showers, where a non-negligible fraction of the radio signal is reflected off ground prior to being measured by the antenna. Knowledge of the ground parameters, namely permittivity, ε, and conductivity, σ, is therefore essential for a precise reconstruction.

The usage of constant reference values for ε and σ is not applicable for the extended RD grid. With an area of approximately $3000\,\mathrm{km}^2$ it consists of many different soil types and has distinct weather conditions. In this talk we present a campaign for a measurement of the different soil types and a permanent stable and cost efficient setup in order to detect relative changes due to varying weather conditions.

**Gefördert durch die BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A20PX1)*

T 98.6 Thu 17:35 T-H29

Rydberg Background reduction in KATRIN experiment using THz Radiation* — •Shivani Ramachandran and Enrico Ellinger for the KATRIN-Collaboration — Bergische Universitaet Wuppertal, Germany

One of the key requirement for the KATRIN experiment to reach its goal sensitivity in measuring the neutrino mass is minimal background. In order to achieve this and eliminate some known contributors, several background suppression methods have already been implemented. Presently the most prominent contribution to the background in the measured signal are electrons produced by thermal ionization of Rydberg atoms which originate from the walls of the main spectrometer.

A plausible method is using THz and microwave radiation which can lead to a reduced lifetime of Rydberg atoms and allow for dedicated stimulated de-excitation. The influence of THz light source in the main spectrometer along with the state and spatial evolution of the Rydberg atoms is studied via simulations. The transition and ionization rates due a light source depend mainly on its frequency, intensity and spectral width. A range of frequencies in the THz regime with different intensities are tested for background reduction. Influence of currently available broadband and narrowband THz sources are also studied. The results show important parameters namely the radiative power, frequency range and number of sources required for effective background reduction with this method. *Gefördert durch die BMBF-Verbundforschung Astroteilchenphysik

T 98.7 Thu 17:50 T-H29

Geometry Calibration of IceCube - A new Likelihood-based Multilateration Approach — •Saskia Philippen, Christoph Günther, and Christopher Wiebusch for the IceCube-Collaboration — RWTH Aachen University - Physics Institute III B, Aachen, Germany

The IceCube Neutrino Observatory consists of 5160 Digital Optical Modules (DOMs), attached to 86 cable strings, which are embedded in the Antarctic ice in a depth between 1.5 to 2.5 kilometers. The reconstruction of neutrino events is based on the arrival times of Cherenkov light at the position of these DOMs. Currently, these positions are only known with a precision of about one meter, because of the uncertainty during the hole drilling process. For several calibration purposes IceCube has produced data-sets in which flashes from LEDs installed inside the DOMs are detected by the surrounding DOMs. The transit times of these signals can be converted into distances between each pair of DOMs. We have developed a multilateration algorithm which fits the positions of all DOMs to these distances in a global maximum-likelihood analysis. The here presented algorithm can be applied beyond IceCube also to the acoustic calibration systems that are foreseen in the IceCube Upgrade and IceCube-Gen2.

T 99: Neutrino Astronomy 4

Time: Thursday 16:15–18:35 Location: T-H30

Group Report T 99.1 Thu 16:15 T-H30

Status of the KM3NeT experiment and contributions from ECAP — •Rodrigo Gracia-Ruiz for the ANTARES-KM3NET-ERLANGEN-Collaboration — Erlangen Centre for Astroparticle Physics, Erlangen, Germany

There are exciting times ahead for neutrino physics and neutrino astronomy! Despite the pandemic the KM3NeT detectors keep growing at two locations in the depth of the Mediterranean Sea. They currently host a total of 18 detection units, 10 for the ORCA detector in France and 8 for the ARCA detector off the coast of Sicily, with a total of more than 10000 photomultiplier tubes in 324 optical modules. Further significant extensions of the detector arrays are under way. This already enables sensitive investigations of GeV-scale atmospheric and TeV-to-PeV-scale cosmic neutrinos during the ongoing commissioning phase. We will report on the status of the KM3NeT detectors, first results on flavour oscillations, and the contributions from the ECAP team to these scientific endeavours.

T 99.2 Thu 16:35 T-H30

Studying optical water properties with atmospheric muon events in KM3NeT/ORCA — •Martin Schneider for the ANTARES-KM3NET-ERLANGEN-Collaboration — ECAP, Friedrich-Alexander-Universität Erlangen-Nürnberg

KM3NeT-ORCA is an underwater neutrino detector featuring a dense configuration of optical modules, designed for the detection of atmospheric neutrinos down to the low-GeV energy regime. Located in a deep-sea environment, the detector performance depends on the optical water properties. In this talk, a study of the optical properties of the sea water surrounding the ORCA detector is presented. For this, a sample of atmospheric muons is compared to sets of Monte Carlo simulations obtained by varying the light attenuation length.

T 99.3 Thu 16:50 T-H30

Energy spectrum unfolding for Supernova burst neutrinos in JUNO — •Thilo Birkenfeld for the JUNO-Collaboration — RWTH Aachen University

Since the detection of neutrinos emitted by the supernova SN 1987A, no neutrinos from other supernovae have been observed to date. The Jiangmen Underground Neutrino Observatory (JUNO) will measure the neutrino burst from a galactic supernova explosion. High statistics, a low detection threshold, and an excellent energy resolution will strongly constrain the details of the neutrino-driven supernova mechanism. JUNO will be sensitive to signals from all neutrino flavours via different detection channels. The reconstruction of their respective energy spectra requires an effective event classification, whose preliminary results will be presented in this talk. A subsequent bayesian-based energy spectrum unfolding method for reconstructing the initial neutrino energy distribution will also be presented.

T 99.4 Thu 17:05 T-H30

Constraining neutrino mass using black hole formation during supernova neutrino emission — •George Parker and Michael Wurm — Johannes Gutenberg Universität Mainz, Mainz, Germany

In this work, we study how neutrino emission from supernovae collapsing to black holes could be used constrain the absolute neutrino mass. In the case where a black hole forms during a core-collapse supernova, it would lead to a sharp cut-off in the neutrino flux. An abrupt drop-off in the neutrino emission offers a clear-cut stage to look for neutrino time-of-flight effects, allowing stricter constraints to be set on the neutrino mass compared to previous estimates. We focus on the possibility that supernova neutrinos are detected with the Jiangmen Underground Neutrino Experiment (JUNO), a next-generation neutrino experiment with enhanced flavour sensitivity, exceptional energy resolution and high statistics. Using three-dimensional core-collapse supernova simulations, the sensitivity of JUNO to the absolute neutrino mass is evaluated.

T 99.5 Thu 17:20 T-H30

Studies on Solar Be7 Neutrino Measurements and Applications in JUNO — •Sebastian Zwickel[1,2], Lothar Oberauer[1], Simon Csakli[1], Carsten Dittrich[1], David Dörflinger[1], Ulrike Fahrendholz[1], Florian Kübelbäck[1], Matthias Mayer[1], Vincent Rompel[1], Luca Schweizer[1], Konstantin Schweizer[1], Korbinian Stangler[1], and Raphael Stock[1] for the JUNO-Collaboration — [1]Technische Universität München — [2]Helmholtz Zentrum Dresden Rossendorf

Besides its major physics goal, the determination of the neutrino mass ordering, the upcoming Jiangmen Underground Neutrino Observatory (JUNO) will have a rich physics program. One part of this are solar neutrinos, where JUNO benefits the most from its large target mass of 20 kt liquid scintillator. In this talk the results of studies on searching for periodic flux variation, e.g. caused by solar g-modes, in the solar (Be7) neutrino flux, as well as the possible use of solar Be7 neutrinos for detector monitoring will be presented.

This work is supported by the DFG research unit "JUNO", the DFG collaborative research center 1258 "NDM", and the DFG Cluster of Excellence "Origins.

T 99.6 Thu 17:35 T-H30

First Comparison of Ballistic and Diffusive Propagation in Flares of Blazar Jets - Implications for Neutrino Emission Models — •Marcel Schroller[1], Julia Becker Tjus[1], Patrick Reichherzer[1,2], and Mario Hörbe[1,3] — [1]Ruhr-Universität Bochum, Theoretische Physik IV — [2]IRFU, CEA, Université Paris-Saclay — [3]Oxford Astrophysics, University of Oxford

Active galactic nuclei (AGN), and the accompanied jets, are some of the most luminous objects in the observable Universe. Both the active cores and their jets are candidates for the engine of cosmic rays, gamma rays, and neutrinos with the highest energies measured at Earth. In 2017, IceCube recorded an extragalactic high energy neutrino event with a strong hint of a directional coincidence with the position of a known jetted AGN TXS0506+056. A deep understanding of the processes related to jets will fuel the field of high energy cosmic rays, fundamental plasma, astro, and particle physics. The physical and mathematical modelling of an AGN jet is challenging, with ambiguous signatures that need to be understood by numerical simulations of cosmic ray transport and interactions. Based on the work of Hoerbe et al. (MNRAS 2020), a simulation framework for hadronic constituents and their interactions inside of a plasmoid, propagating along the AGN jet axis, was made. For this talk, we tested several state-of-the-art simulation setups from the literature in this field with our framework to analyse the assumptions about propagation behaviour both ballistically and diffusively. We present the results and point out, where those assumptions cannot hold in a realistic setup.

T 99.7 Thu 17:50 T-H30

A new code for the modeling of multimessenger flares from blazars — •Leander Schlegel[1,2], Marcel Schroller[1,2], Mario Hörbe[1,2,3], and Julia Becker Tjus[1,2] — [1]Theoretische Physik IV, Ruhr Universität Bochum, Bochum, Germany — [2]RAPP-Center at Ruhr Universität Bochum, Bochum, Germany — [3]University of Oxford, Oxford Astrophysics, Denys Wilkinson Building, Keble Road, Oxford, OX1 3RH, United Kingdom

Since their discovery over a century ago, the origin of cosmic rays of the highest energies is still widely uncertain. While in the past much attention was paid to analyzing steady state source models, bursting sources that appear in quiescent and flaring states, like the class of Active Galactic Nuclei (AGN) seem to be a promising candidate for possible sources of ultra-high-energy cosmic rays (UHECR). The goal of this work is trying to understand the detailed behaviour of bursting sources by simulating the time resolved propagation of a plasma blob inside the jet of an AGN. For this purpose, a tool for cosmic-ray propagation in relativistic plasmoids of AGN jets has been developed and implemented into the open-source code CRPropa 3.1. With this framework, we will predict the multimessenger signatures of flaring sources, aiming to contribute to a more complete picture of the UHECR sky including the bursting sources and therefore also to a deeper understanding of the origin of the highest energetic charged particles. First results of the flaring behaviour from relativistic plasmoids are being presented.

T 99.8 Thu 18:05 T-H30

Investigation of the effect of elliptical orbits in supermassive binary black holes at the example of the neutrino lightcurve of the blazar TXS0506+056 — •Johannes Just, Julia Becker Tjus, and Ilja Jaroschewski — Theoretische Physik IV, Ruhr-Universität Bochum

IceCube detections from 2014/15 and 2017 show two possible high-energy neutrino correlations with the blazar TXS0506+056, making blazars promising candidates for high-energy neutrino emission. Those neutrinos can be produced in pp or $p\gamma$ interactions of cosmic rays, making bazars possible sources of high energy cosmic rays. Two separate detections might imply a periodicity of the neutrino flux from TXS0506+056 at Earth.

Such a periodicity can be explained by a precession of the heavier super massive black hole jet in a merger of a super massive binary black hole (SMBBH), caused by a Spin-Flip of the Jet. Considering the post newtonian mechanics up to the 2.5 order, the Spin-Flip-Phenomenon is described with the Spin (and therefore the Jet) slowly aligning with the total angular momentum.

Assuming that TXS0506+056 is a SMBBH merger, this work predicts the upcoming neutrino flux as well as the observability of the emitted gravitational waves with LISA, taking different eccentricities of the SMBBH orbit into account. Several eccentricities, leading to differing periodicities and shrinking timescales, are discussed.

T 99.9 Thu 18:20 T-H30

A novel Machine Learning-approach for the detection of the DSNB — •David Maksimović[1], Michael Nieslony[2], and Michael Wurm[3] — [1]Johannes Gutenberg-Universität Mainz — [2]Johannes Gutenberg-Universität Mainz — [3]Johannes Gutenberg-Universität Mainz

The Diffuse Supernova Neutrino Background (DSNB) is the faint signal of all core-collapse supernovae explosions on cosmic scales. A prime method for detecting the DSNB is finding its IBD signatures in Gadolinium-loaded large water Cherenkov detectors like Super-Kamiokande(SK-GD). While the enhanced neutron tagging capability of Gadolinium greatly reduces single-event backgrounds, correlated events mimicking the IBD coincidence signature remain a potentially harmful background. Especially in the low-energy range of the observation window, Neutral-Current (NC) interactions of atmospheric neutrinos dominate the DSNB signal, which leads to an initial signal-to-background (S:B) ratio inside the observation window of about 1:10.

Here, we report on a novel machine learning method based on Convolutional Neural Networks (CNNs) that offer the possibility for a direct classification of the PMT hit patterns of the prompt events. Based on the events generated in a simplified SK-GD-like detector setup, we find that a trained CNN can maintain a signal efficiency of 96 % while reducing the residual NC background to 2 % of the original rate, corresponding to a final signal-to-background ratio of about 4:1. This provides excellent conditions for a DSNB discovery.

This work has been funded by the Excellence Cluster PRISMA+.

T 100: Cosmic Ray 5

Time: Thursday 16:15–18:30 Location: T-H32

T 100.1 Thu 16:15 T-H32

Low-Energy Cosmic Ray Composition with IceCube and IceTop — •Julian Saffer for the IceCube-Collaboration — Institut für Experimentelle Teilchenphysik, Karlsruher Institut für Technologie (KIT)

IceTop is the surface component of the IceCube Neutrino Observatory at the geographic South Pole and dedicated to the indirect detection of cosmic rays (CRs). Studying the primary CR spectrum and mass composition around the knee requires a dedicated IceTop trigger for smaller air showers initiated by lower-energy primaries as well as the combination of surface (predominantly electromagnetic) and corresponding in-ice (muonic) signals. Monte-Carlo simulation data of air showers at IceCube ranging down to $E_0 = 10^5$ GeV have been used to train boosted decision trees for the reconstruction of shower core position, zenith angle, primary energy and mass of the incoming CR particles.

This talk presents the input features fed into the different machine learning models, the chosen model architectures and reconstruction results for four primary mass types. Additionally, plans towards an enhancement of the reconstruction utilizing a set of convolutional neural networks are discussed.

T 100.2 Thu 16:30 T-H32

Simulation Study of Atmospheric Muons with IceCube-Gen2 — •Jonathan Messner, Agnieszka Leszczynska, and Andreas Haungs for the IceCube-Collaboration — Institute for Astroparticle Physics, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

The next generation of the IceCube Neutrino Observatory called IceCube-Gen2 will extend the detector's capabilities in both, neutrino and cosmic-ray measurements. In particular, the combination of the in-ice optical modules and the large array of surface detectors will enhance the understanding of extensive air showers and the studies of cosmic rays. Muons produced in air showers can deliver relevant information not only about incoming cosmic rays but also about properties of the air showers. Conventional atmospheric muons are produced by decays of pions and kaons, while prompt muons originate mainly from decay of charmed and unflavoured mesons. This prompt component is expected to dominate the muon flux at higher energies. Due to larger aperture for coincident measurements, with surface and in-ice arrays, IceCube-Gen2 has the potential to measure this prompt component in relation to the properties of parent cosmic rays. In this contribution high energy muons, especially prompt muons, will be studied based on air shower simulations in order to better understand the capabilities of IceCube-Gen2.

T 100.3 Thu 16:45 T-H32

Improving gamma-hadron separation for air showers at the IceCube Neutrino Observatory — •Federico Bontempo for the IceCube-Collaboration — Institute for Astroparticle Physics, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

The IceCube Neutrino Observatory is an experiment located at the geographic South Pole. It is composed of two detectors: an optical array deep in the ice and an array of ice-Cherenkov tanks at the surface called IceTop. The combination of the two detectors can be exploited for the study of cosmic rays. The in-ice detector measures the high-energy muonic component of air showers, whereas the signal strength on IceTop is dominated by the electromagnetic component. The aim of this work is to discriminate between photon and hadron initiated air showers. This discrimination was already attempted using a machine learning technique named Random Forest. Here, a different approach is presented which uses both Random Forests and deep learning techniques, in particular, supervised learning techniques that predicts unknown data after studying labeled data. The physics quantities used for this study are the charges measured by the in-ice detector, the reconstructed zenith angle, the in-ice containment of the shower, the reconstructed energy and a likelihood estimator that captures both the presence of individual muons and charge fluctuations in the surface array.

Furthermore, the planned enhancement of IceTop, comprised of surface radio antennas and scintillator panels, will contribute to the improvement of the gamma-hadron separation.

T 100.4 Thu 17:00 T-H32

Mass-sensitive parameter with the IceTop surface array — •Donghwa Kang for the IceCube-Collaboration — Karlsruher Institut für Technologie (KIT)

IceTop, the surface component of the IceCube Neutrino Observatory at the South Pole, measures the air showers of cosmic ray with energies from PeV up to EeV. By means of the charge signal measurements only with the IceTop surface array, a parameter sensitive to the muon content was defined and estimated event by event. In this contribution, the estimated mass-sensitive parameter and its dependencies on the hadronic interaction models will be presented. In addition, the applicability of energy and mass composition reconstruction of cosmic rays will be discussed.

T 100.5 Thu 17:15 T-H32

Sensitivity of IceCube-Gen2 for High-Energy Cosmic Ray Anisotropy Studies — •Wenjie Hou and Donghwa Kang for the IceCube-Collaboration — Institute for Astroparticle Physics, Karlsruhe Institute of Technology (KIT), Karlsruhe

At which energy the transition from galactic to extra-galactic cosmic rays (CRs) takes place is one of the major unresolved issues of cosmic ray physics. Although the sources of high-energy cosmic rays remain unknown, one expects to identify them by studying the anisotropy in their arrival directions. Recently, the cosmic ray anisotropy measurements in TeV to PeV energy range were updated from IceCube using its nine years of data. IceCube-Gen2 is designed to have a detector volume about 8 times larger than IceCube and will achieve an increased exposure to cosmic rays by a factor of 30. This improvement could allow us to obtain high-quality measurements of cosmic ray air showers and investigate the cosmic ray anisotropy with higher sensitivity.

The sensitivity of IceCube-Gen2 to anisotropy is purely a matter of statistics. Hence, based on the simulation of IceCube-Gen2, the first attempt is to make an exposure map taking into account detection efficiency and resolution. We will build a Monte Carlo toy simulation model of IceCube-Gen2. In this case, the expected maps will be generated with random events, resulting in the angular power spectrum. Eventually, we can determine under what conditions IceCube-Gen2 could achieve the highest sensitivity to observe cosmic ray anisotropy. In this contribution, the current studies on the anisotropy with the simulation will be discussed.

T 100.6 Thu 17:30 T-H32

First results of the IceCube Surface Array Enhancement Prototype — •Marie Oehler for the IceCube-Collaboration — KIT, Karlsruhe, Germany

The IceCube Observatory is a cubic-kilometer neutrino detector installed in the ice at the geographic South Pole. To increase the efficiency of detecting astrophysical neutrinos the upgrade IceCube-Gen2 is under development. To also boost the sensitivity of the surface array, IceTop, an enhancement consisting of a hybrid scintillation-detector and radio-antenna array is planned.

An optimized prototype station, consisting of eight scintillation detectors and three radio antennas, was deployed in January 2020. Both, scintillation detectors and radio antennas, are read out by a central hybrid data acquisition system (DAQ). The scintillation detectors transfer digitized integrated signals to the DAQ to minimize the amount of transmitted data and trigger the radio antennas. The radio waveforms are transferred as analog signals to the central DAQ and are digitized and read out, when triggered by the scintillation detectors. In this contribution the first measurement results will be shown.

T 100.7 Thu 17:45 T-H32

Measurements with the IceCube Surface Array Enhancement prototype — •Hrvoje Dujmovic for the IceCube-Collaboration — Institut für Astroteilchenphysik, Karlsruher Institut für Technologie (KIT)

IceTop, the surface array of the IceCube Neutrino Observatory, currently consists of 162 ice Cherenkov tanks distributed over an area of 1 km. IceTop is used for cosmic-ray air shower detection and as a veto for the in-ice neutrino detector. The science case of IceTop will be greatly improved by complementing the existing detectors with an array of radio antennas and scintillator panels. The enhancement array will cover the same footprint as IceTop and will consist of 32 stations. One such station, consisting of 3 radio antennas and 8 scintillator panels, was deployed at the South Pole in January 2020. In this talk, we will present the measurements with the prototype station. The results obtained from the prototype station will help us better understand the full capabilities and physics potential of the IceCube*s surface enhancement.

T 100.8 Thu 18:00 T-H32

Status of the R&D and production of the scintillation detectors for the Surface Array Enhancement — •Shefali Shefali for the IceCube-Collaboration — Institut für Astroteilchenphysik, Karlsruher Institut für Technologie (KIT), Karlsruhe, Germany

The IceCube Neutrino Observatory is a cubic kilometer scale detector deployed in the Antarctic ice and is involved in cosmic ray physics. The surface array of IceCube, IceTop, operates as a veto for the astrophysical neutrino searches and calibration detector for the IceCube in-ice instrumentation. Despite its contribution, the snow accumulation on top of these detectors results in an increased energy uncertainty in the detected particles and consequently, the shower reconstruction. Moreover, the enhancement of IceTop will lead to a better measurement of the extensive air showers and improve the astrophysics of the high-energy cosmic-ray sky.

Enhancing IceTop with a hybrid array of scintillation detectors and radio antennas will lower the energy threshold for air-shower measurements, provide more efficient veto capabilities, enable the separation of the electromagnetic and muonic shower components and improve the detector calibration by compensating for snow accumulation. Following the success of the first complete prototype station consisting of three radio antennas and eight scintillation detectors deployed at the South Pole in 2020, the R&D and production of detectors for a total of 32 stations is ongoing. The production challenges, deployment status, and calibration methods of the scintillation detectors will be discussed in this contribution.

T 100.9 Thu 18:15 T-H32

An IceCube Surface Array Enhancement station for deployment at Telescope Array — •Noah Goehlke for the IceCube-Collaboration — Institut für Astroteilchenphysik, Karlsruher Institut für Technologie (KIT), Karlsruhe

The IceTop array, located on the surface of the IceCube Neutrino Observatory, will be enhanced with hybrid radio and scintillator stations. The DAQ of each station is housed in a FieldHub. In January 2020 a full prototype station was deployed and is successfully operating and taking data. For the planned IceCube-Gen2 facility, the DAQ of the surface array and the in-ice array will be combined, using a modified FieldHub. The development of this FieldHub will be performed by the University of Utah, which is also contributing to the Telescope Array (TA), an air-shower detector array located in Utah.

By deploying a prototype station at TA, the Univerity of Utah is provided with the preliminary hardware of the future surface array, which is needed to design the new FieldHub. In addition, it can serve as a testing platform for IceCube-Gen2 and it enables cross calibration with TA. Since the environment and infrastructure in Utah and the South Pole differ significantly, adjustments of the prototype station are in development. As example, the detectors have to be able to measure air-shower particles at much higher ambient temperature and humidity levels as found at the South Pole.

In this contribution the adapted design of the prototype station as well as experiments done to investigate the detectors behavior at higher temperatures will be presented.

T 101: Cosmic Ray 6

Time: Thursday 16:15–18:30 Location: T-H33

T 101.1 Thu 16:15 T-H33

Implications of turbulence dependent diffusion on Galactic cosmic ray — •Julien Dörner[1,2], Patrick Reichherzer[1,2,3], Julia Becker Tjus[1,2], and Horst Fichtner[1,2] — [1]Theoretische Physik IV, Ruhr University Bochum, Bochum, Germany — [2]RAPP-Center at Ruhr University Bochum, Bochum, Germany — [3]IRFU, CEA, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France

The motion of Galactic cosmic rays is dominated by spatial diffusion. Therefore, in order to describe their transport, a detailed knowledge of the diffusion tensor $\hat{\kappa}$ is necessary. This tensor depends on the particle energy, the structure of the local background field $\vec{B}$, and its turbulent component $\vec{b}$. Recent numerical analyses of diffusion coefficients in three-dimensional, isotropic turbulence show a discrepancy between its energy scaling for intermediate turbulence levels b/B and the corresponding quasi-linear prediction.

In this talk we report about probing different models for the diffusion tensor and its dependence on energy and turbulence level. We compare the results with observations of the gradient in the cosmic-ray density and of the spectral energy behavior in the Milky Way by Fermi-LAT.

T 101.2 Thu 16:30 T-H33

Optimization of the Numerical Calculation of the Field Line Random Walk Diffusion Tensor — •Jan-Niklas Bohnensack[1], Patrick Reichherzer[1,2], Julia Becker Tjus[1,2], Leander Schlegel[1,2], and Julien Dörner[1,2] — [1]Theoretical Physics IV: Plasma-Astroparticle Physics, Faculty for Physics & Astronomy, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [2]Ruhr Astroparticle And Plasma Physics Center (RAPP Center), Bochum, Germany

The goal of this talk is to calculate the Field Line Random Walk (FLRW) diffusion coefficient. FLRW is the random movement of the magnetic fieldlines in a turbulent field, particles with low rigidities follow those lines and diffuse accordingly. The FLRW diffusion coefficient only depends on the turbulence of the magnetic fields and is particle-energy independent. That makes their calculation more universal and computationally more efficient. Therefore, the coefficient is of high relevance for providing astrophysical simulations for cosmic-ray transport with a fundamental description of the diffusion tensor. These can be applied in environments such as the Milky Way, but also relativistic plasmoids in jets of active galaxies. To check the agreement of the fieldlines to the corresponding particle trajectories, a GPU based visualization software based on the software Vispy was developed in this bachelor thesis. With the optimized FLRW software, we will present first results and interpretations of the FLRW diffusion tensor for different turbulence levels. Furthermore, we will show examples of 3D plotted fieldlines and particle trajectories with our visualization tool.

T 101.3 Thu 16:45 T-H33

Proton event reconstruction with the MAGIC experiment — •Alicia Fattorini and Maximilian Noethe for the MAGIC-Collaboration — Astroparticle Physics WG Elsässer, TU Dortmund University, Germany

Air showers induced by cosmic protons and heavier nuclei form the dominant background for very high energy gamma-ray observations with Imaging Air Cherenkov Telescopes. Even for strong very high energy gamma-ray sources the signal-to-background ratio in the raw data is typically less than 1:5000, so a very large statistic of cosmic proton and heavier nuclei induced events are available as a byproduct of gamma-ray source observations. In this contribution, we present the reconstruction of the particle type of primary events and the energy reconstruction of the events classified as protons. For this purpose, we used a random forest method trained and tested by using Monte Carlo simulations from the MAGIC telescopes, for energies above 70 GeV. We use the aict-tools framework, which includes machine learning methods for the particle type classification and energy reconstruction. The open-source Python project aict-tools was developed at TU Dortmund University and its reconstruction tools are based on scikit-learn predictors. Finally, an unfolding taking into account the background is performed to compensate for the typical bias of the random forest results. Here we report on the performance of the proton event reconstruction using the well-tested and robust random forest approach.

T 101.4 Thu 17:00 T-H33

Search for heavy antimatter with AMS — •Robin Sonnabend — 1. Physikalisches Institut B, RWTH Aachen

The Alpha Magnetic Spectrometer (AMS-02) on the International Space Station has been performing precision measurements of cosmic rays in the GeV to TeV energy range since 2011. The search for heavy antimatter (Z>=2) requires advanced methods for the suppression of instrumental background which arises from the mis-reconstruction of the charge sign. I will present a set of dedicated multivariate estimators for different event topologies designed to achieve this goal.

T 101.5 Thu 17:15 T-H33

Galactic gamma-ray and neutrino emission from interacting cosmic-ray nuclei — •Mischa Breuhaus[1], James Anthony Hinton[1], Vikas Joshi[2], Brian Reville[1], and Harm Schoorlemmer[1,3] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Friedrich-Alexander-Universität Erlangen-Nürnberg, ECAP, Erwin-Rommel-Str. 1, D 91058 Erlangen, Germany — [3]IMAPP, Radboud University Nijmegen, Nijmegen, The Netherlands

We present a study of the expectations for very/ultra high energy (VHE/UHE) gamma-ray and neutrino emission from interacting cosmic rays in our Galaxy and a comparison to the latest results for the Galactic UHE diffuse emission. We demonstrate the importance of properly accounting for the mixed cosmic-ray composition as well as gamma-ray absorption. We adopt the wounded-nucleon model of nuclei interaction and provide parameterisations of the resulting gamma-ray and neutrino production. Nucleon shielding due to clustering inside nuclei is shown to have a measurable effect on the production of gamma-rays and is particularly evident close to breaks and cut-offs in mixed composition particle spectra. The change in composition around the 'knee' in the cosmic ray spectrum has a noticeable impact on the diffuse neutrino and gamma-ray emission spectra. We show that current and near-future detectors can probe these differences in the key energy range from 10 TeV to 1 PeV, testing the paradigm of the universality of the cosmic ray spectrum and composition throughout the Galaxy.

T 101.6 Thu 17:30 T-H33

Vacuum-Cherenkov radiation in UHE air showers: a way of probing Lorentz violation — •Fabian Duenkel, Marcus Niechciol, and Markus Risse — Center for Particle Physics Siegen, Experimentelle Astroteilchenphysik, Universität Siegen

In extensive air showers induced by ultra-high energy (UHE) cosmic rays, secondary electrons are expected to be produced at energies far above those accessible by other means. Those high energies can be used to search for new physics, in particular we study the effects of isotropic, nonbirefringent Lorentz violation in the photon sector. In the case of a photon velocity which is larger than the maximum attainable velocity of standard Dirac fermions, vacuum-Cherenkov radiation becomes possible, which can lead to significant changes of the shower development. Implementing this Lorentz-violating effect in air shower simulations, we present first results on the impact on the shower development, specifically on the average atmospheric depth of the shower maximum $\langle X_{\max}\rangle$ and its shower-to-shower fluctuations $\sigma(X_{\max})$.

This work is supported by the Deutsche Forschungsgemeinschaft (DFG).

T 101.7 Thu 17:45 T-H33

CoREAS simulation for the GRAND project — •Chao Zhang, Tim Huege, Tanguy Pierog, Markus Roth, Andreas Haungs, Frank Schroeder, and Ralph Engel — Institut fuer Astroteilchenphysik, Karlsruher Institut fuer Technologie-Campus Nord, Post-fach 3640, 76021 Karlsruhe, Germany

The GRAND project starts deploying antennas this year, which will give birth to its first stage, GP300 with 300 antennas in the near future. A new version of CORSIKA7 has been adapted and validated to simulate upward-going air showers for radio detection which will be the main detection channel in this project. A library of air showers is made with CoREAS by applying the best knowledge of GRAND including the atmospheric model and magnetic field of the site. A detailed analysis of the new patterns induced by inclined air showers leads to a better understanding of the scenario of their radio emission from higher to lower air density.

T 101.8 Thu 18:00 T-H33

Diffractive and radiative corrections to muon energy loss cross-sections — •Alexander Sandrock — Bergische Universität Wuppertal

High-energy muons can travel large distances before reaching underground detectors, for example cosmic-ray detectors and neutrino telescopes. The accurate simulation of muon transport through matter is therefore especially important for underground experiments. The dominant energy loss processes are ionization and at higher energies pair production, bremsstrahlung and inelastic interaction with nuclei. To reduce uncertainties in the simulation of muon transport, the calculation of higher-order corrections to these cross-sections is necessary. In this contribution, diffractive and radiative corrections to the cross-sections of bremsstrahlung and pair production are discussed.

T 101.9 Thu 18:15 T-H33

Results from a Pilot Study on Measurement of Fragmentation of Intermediate Mass Nuclei with NA61/SHINE at CERN — •Neeraj Amin for the NA61/SHINE-Collaboration — Institute for Astroparticle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

Cosmic-ray propagation in the Galaxy can be constrained by modeling the secondary-to-primary cosmic-ray flux ratios, like the Boron-to-Carbon flux ratio that reaches Earth. While these fluxes are currently measured with high precision (<5%) by space-based detectors like AMS-02 and CALET, insufficient knowledge of nuclear fragmentation cross sections hinders the precision with which we can constrain cosmic-ray propagation. Therefore, new laboratory measurements of fragmentation cross-sections above 10 A GeV/c are needed.

In this talk, we report on the analysis of pilot data on fragmentation taken in 2018 with the NA61/SHINE experimental facility at CERN with ^{12}C projectiles at a $p_{\mathrm{beam}} = 13.5$ A GeV/c. The main aim of this pilot run was to demonstrate the ability of NA61/SHINE to measure nuclear fragmentation cross sections in C+p interactions. Two fixed targets, polyethylene (C_2H_4) and graphite were used to achieve this. We present a preliminary measurement of Boron production in C+p interactions including the contribution from the short-lived 'ghost nucleus' ^{11}C.

T 102: Neutrino Physics without Accelerators 7

Time: Thursday 16:15–18:35 Location: T-H34

T 102.1 Thu 16:15 T-H34

Sensitivity Study with Theia Detector — •Wei-Chieh Lee, Caren Hagner, and Björn Wonsak — Institut für Experimentalphysik, Universität Hamburg, 22761 Hamburg, Germany

With new technologies exploiting the advantages of both the Cherenkov and scintillation lights, a new type of neutrino detector, Theia, is able to determine the direction and species of incoming particles while still having a good energy resolution and low threshold. In consequence, Its ability to reach high levels of background rejection would allow us to improve the precision in the measurement of oscillation parameters when employed at a long baseline neutrino experiment. For this, the realization of Theia is planned at the far site of DUNE, whose near detector also provides information to further improve the measurement of neutrino oscillation. In this experiment, Theia can have enough sensitivity to the determination of mass hierarchy and CP phase of neutrino oscillation, the two missing pieces of our knowledge in the topic. In order to simulate such experiments, a software tool called GLoBES is developed for describing the detector properties and doing analysis easily, and is used in this sensitivity study.

T 102.2 Thu 16:30 T-H34

On the road to Theia: current status of the Mainz WbLS test cell DISCO — •Manuel Böhles[1], Daniele Guffanti[1], Hans Steiger[1,2], and Michael Wurm[1] — [1]Johannes Gutenberg-Universität Mainz, Staudinger Weg 7, 55124 Mainz, Germany — [2]Technische Universität München, James-Franck-Str. 1, 85748 Garching b. München, Germany

The detection of neutrinos using water-based liquid scintillators (WbLS) is a promising method in the field of detector development. Its strength lies in combining high-resolution energy determination with a low energy threshold through the use of scintillation light and in the directional reconstruction with the help of Cherenkov radiation. The spectrum of potential applications is broad, ranging from long-baseline oscillation experiments to the measurement of low-energy solar neutrinos. The key point of this new technique is the discrimination between scintillation and Cherenkov photons, which can be achieved by exploiting the different chromatic features, time behaviour and angular emission. In order to characterise this innovative medium and to prove whether scintillation and Cherenkov radiation can be distinguished, we have built a test cell equipped with 16 ultrafast photomultipliers that will provide useful insights towards a new generation of detectors. In addition, complementary ultrafast photodetection systems (SiPM array, LAPPD) can be investigated in future studies. This work is supported by the BMBF Verbundprojekt 05H2018: R&D Detectors and Scintillators.

T 102.3 Thu 16:45 T-H34

Characterisation measurement of LAPPDs for ν-detectors — •Benedict Kaiser, Lukas Bieger, David Blum, Marc Breisch, Srijan Delampady, Jessica Eck, Gina Grünauer, Tobias Heinz, Frieder Kohler, Tobias Lachenmaier, Axel Müller, Tobias Sterr, Alexander Tietzsch und Jan Züfle — Universität Tübingen, Physikalisches Institut, Auf der Morgenstelle 14, 72076 Tübingen

Large Area Picosecond Photodetectors (LAPPDs) are novel photodetectors suitable for use in upcoming neutrino detection experiments. LAPPDs incorporate a square multi-alkali photocathode, a chevron pair of microchannel plates (MCPs) for photoelectron multiplication and multiple anode strips for readout, all in a hermitically sealed package.

The design of the LAPPDs results in an unprecedented time resolution better than 70 ps and a spatial resolution of 2.5 mm and 0.8 mm in x- and y-direction respectively at uniform gains of 10^6 to 10^7 over a large active detector area of more than 370 cm^2.

Currently, we are commissioning a setup to test LAPPDs for their performance and key characteristics. This talk will outline the working principle as well as characteristics of an LAPPD and measurement results of the first LAPPD received from the manufacturer will be discussed.

Group Report T 102.4 Thu 17:00 T-H34

Neutrino mass determination with ^{163}Ho-loaded MMCs – the ECHo experiment — •Arnulf Barth for the ECHo-Collaboration — Kirchhoff-Institute for Physics, Heidelberg University

The Electron Capture in ^{163}Ho experiment, ECHo, is a running experiment for the determination of the neutrino mass scale via the analysis of the end point region of the ^{163}Ho electron capture spectrum. In the first phase, ECHo-1k, about 60 MMC pixels enclosing ^{163}Ho ions for an activity of about 1 Bq per pixel have been operated for several months. The goal of this first phase is to reach a sensitivity on the effective electron neutrino mass below 20 eV/c^2 by the analysis of a ^{163}Ho spectrum with more than 10^8 events. We discuss the characterization of the single pixel performance and the stability over the measuring period. Results from the analysis of the acquired data will be presented with focus on data reduction efficiency and on the procedures to obtain the final high statistics spectrum. A preliminary analysis of the ^{163}Ho spectral shape will be described and the expected sensitivity on the effective electron neutrino mass on the basis of the properties of the presented spectrum will be discussed. In conclusion, we will present how the performance obtained by the MMC arrays used during the first phase of the ECHo experiment have led to the design of the MMC arrays for the second phase, ECHo-100k. In this phase, about 12000 MMC pixels each hosting ^{163}Ho for an activity of 10 Bq will be simultaneously operated thanks to the microwave SQUID multiplexing readout. Operating these arrays for three years will allow for reaching a sensitivity on the electron neutrino mass at the 1 eV/c^2 level.

T 102.5 Thu 17:20 T-H34

From Temperature pulses to high statistic Ho-163 spectrum: Analysis Algorithms for the ECHo Experiment — •Markus Griedel, Arnulf Barth, Robert Hammann, Daniel Hengstler, Neven Kovac, Federica Mantegazzini, Andreas Fleischmann, and Loredana Gastaldo — Kirchhoff-Institute for Physics, Heidelberg University

The goal of the Electron Capture in Ho-163 (ECHo) experiment is the determination of the effective electron neutrino mass by analysing the electron capture (EC) spectrum of Ho-163. The ECHo experiment uses Metallic magnetic calorimeters (MMCs) operating at millikelvin temperatures, in which the Ho-163 has been implanted. In order to reliably infer the energy of Ho-163 events and discard triggered noise or pile-up events, fast and robust analysis algorithms are required. For this, algorithms based on filters acting on the trigger time of the events and on filters using pulse shape information were developed. To convert the measured temperature pulses into an energy spectrum, further steps are takes, as corrections for temperature shifts and energy calibration.

We describe the steps we took for the reduction of the data acquired during the first phase of the ECHo experiment, ECHo-1k; as well as the process to build a high statistic Ho-163 spectrum from data acquired with several single Ho-163 implanted MMCs.

T 102.6 Thu 17:35 T-H34

From ECHo-1k to ECHo-100k: Optimisation of the high-resolution metallic magnetic calorimeters with embedded ^{163}Ho for the determination of the electron neutrino mass — •Neven Kovac[1], Federica Mantegazzini[1], Loredana Gastaldo[1], Arnulf Barth[1], Markus Griedel[1], Andreas Fleischmann[1], Matthew Herbst[1], Daniel Hengstler[1], Andreas Reifenberger[1], Christian Enss[1], Christoph Düllmann[2], Holger Dorrer[2], Tom Kieck[3], Nina Kneip[3], and Klaus Wendt[3] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg — [2]Department of Chemistry - TRIGA Site, Johannes Gutenberg-Universität Mainz — [3]Institute of Physics, Johannes Gutenberg-Universität Mainz

Large arrays of metallic magnetic calorimeters have been selected for the ECHo experiment due to the excellent energy resolution, the fast response time and the almost linear detector response which allows for a reliable energy calibration. Based on the performance achieved with the detector array developed for the first phase of the ECHo experiment, ECHo-1k, the design of the ECHo-100k arrays has been conceived. This new design features an optimized single pixel geometry, upgrade of the on-chip thermalisation layout and a high operational flexibility. First wafers with ECHo-100k arrays have been fabricated and several arrays have been fully characterized. We summarise the performance achieved with the ECHo-1k and the newly developed ECHo-100k arrays in comparison with the design performance. We discuss how these results are important for achieving the goals defined for the ECHo-100k experiment.

T 102.7 Thu 17:50 T-H34

The MONUMENT Experiment; ordinary muon capture as a benchmark for $0\nu\beta\beta$ decay nuclear structure calculations — Elisabetta Bossio[1], Elizabeth Mondragon[1], Stefan Schönert[1], •Mario Schwarz[1], and Christoph Wiesinger[1,2] for the MONUMENT-Collaboration — [1]Physik-Department, Technische Universität München, Garching — [2]Max-Planck-Institut für Physik, München

Extracting particle physics properties from neutrinoless double-beta ($0\nu\beta\beta$) decay requires a detailed understanding of the involved nuclear structures. Still, modern calculations of the corresponding nuclear matrix elements (NMEs) differ by factors 2-3. The high momentum transfer of Ordinary Muon Capture (OMC) provides insight into highly excited states similar to those that contribute virtually to $0\nu\beta\beta$ transitions. The precise study of the γ's following the OMC process makes this a promising tool to validate NME calculations. The MONUMENT collaboration is performing a series of explorative OMC measurements involving typical $\beta\beta$ decay daughter isotopes such as ^{76}Se and ^{136}Ba, as well as other benchmark isotopes. In this talk the experiment carried out at the Paul Scherrer Institute and first results from the beamtime in 2021 will be presented. This research is supported by the DFG Grant 448829699.

T 102.8 Thu 18:05 T-H34

Antineutrino Monitoring with Liquid Organic Time Projection Chambers — Johannes Bosse, Sarah Friedrich, Malte Göttsche, Helge Haveresch, •Thomas Radermacher, Stefan Roth, Georg Schwefer, and Hagen Weigel — RWTH Aachen University - Physics Institute III B, Aachen, Germany

For the first few hundreds of years the dominant radioactivity of nuclear waste comes from long-lived beta-decaying elements that are emitting antineutrinos in the low-energy region below 5 MeV. In a newly envisioned application for nuclear monitoring purposes, we want to use these antineutrinos to monitor the content of nuclear waste repositories. We are investigating a time projection chamber filled with an organic liquid aiming at full reconstruction of inverse beta decay events. In the low energy region, the direction of the neutron in IBD is strongly correlated to the direction of the incoming antineutrino. For this we study to which extend the neutron direction can be reconstructed by its first few elastic scatterings with the nuclei of the detector medium. This talk gives an overview on our project and the progress of our simulation studies.

T 102.9 Thu 18:20 T-H34

Development of the comprehensive analysis tools for the Supernova neutrino detectors — •Vsevolod Orekhov and Michael Wurm — Institute of Physics and Cluster of Excellence PRISMA+, JGU Mainz, Germany

A galactic Supernova explosion is a unique neutrino source: detecting the neutrinos from deep inside the star will help us understand both the physics of the core collapse and properties of the neutrino themselves. If a SN neutrino burst arrived at Earth today or in the near future, it would be detected by a variety of ton to kiloton scale neutrino detectors based on different technologies and target media. By combining the analysis of the possible explosion in multiple next generation neutrino experiments, one could significantly improve the precision of determining the neutrino spectra parameters such as the mean energy and spectral index. In this contribution it is shown what one could achieve by doing a simultaneous fit of the energy spectra of JUNO, DUNE and IceCube-like detectors assuming a common flavour-dependent neutrino signal. This work was supported by funds of the DFG.

T 103: Neutrino Physics without Accelerators 8

Time: Thursday 16:15–18:30 Location: T-H35

T 103.1 Thu 16:15 T-H35

Status of tau appearance sensitivities and measurements with KM3NeT/ORCA — •Nicole Geisselbrecht for the ANTARES-KM3NET-ERLANGEN-Collaboration — Friedrich-Alexander-Universität Erlangen-Nürnberg, ECAP

KM3NeT/ORCA is a water Cherenkov detector currently under construction in the Mediterranean Sea. The primary goals are the study of neutrino oscillations and the determination of the neutrino mass ordering. One of the main physics objectives in the early phase of ORCA is a measurement of the appearance of tau neutrinos.

Tau neutrinos detected by ORCA are a pure product of neutrino oscillations since ORCA is optimized for atmospheric neutrinos that are almost exclusively produced as electron and muon neutrinos. Even though they can only be measured indirectly as an excess of shower-like events compared to the non-oscillation scenario, their detection will offer valuable information.

One of the first requirements for this study is a reliable particle identification (PID). Therefore, existing PID algorithms need to be optimized with regard to charged current tau neutrino interactions. This talk will report about the first efforts and results using classical machine learning techniques based on boosted decision trees

T 103.2 Thu 16:30 T-H35

Neutrino decoherence effects with KM3NeT — •Nadja Lessing for the ANTARES-KM3NET-ERLANGEN-Collaboration —

Friedrich-Alexander-Universität Erlangen-Nürnberg

Quantum decoherence of neutrino states is an effect that is proposed in different theories of quantum gravity. It is envisaged to emerge from interactions of the neutrino as a quantum system with the environment and could modify the probabilities of neutrino flavour oscillations in various ways. Therefore, neutrino telescopes such as KM3NeT, that are sensitive to different flavours and to oscillations in a wide range of neutrino energies, can ideally probe this effect. ORCA and ARCA are water Cherenkov detectors that are currently under construction by the KM3NeT Collaboration in the Mediterranean Sea. While ARCA is primarily designed to detect high energy cosmic neutrinos, ORCA aims at the precise measurement of atmospheric neutrino oscillations. This contribution reports on the decoherence sensitivity for both detectors using a phenomenological model in a three-family framework including matter effects. It is shown that, considering different energy dependencies of the phenomenon, either ORCA or ARCA might be capable of improving current bounds on the strength of decoherence effects.

T 103.3 Thu 16:45 T-H35

GiBUU based neutrino interaction simulations in KM3NeT — •Johannes Schumann for the ANTARES-KM3NET-ERLANGEN-Collaboration — Friedrich-Alexander-Universität, Erlangen, Germany

The characteristics of the primary neutrino interaction and the subsequent secondaries determine the reconstruction of the primary neutrino properties in neutrino detection experiments. As part of the evaluation of the detector performances, neutrino interactions are simulated via so-called neutrino generators. In order to reduce the computational complexity, these use different approximations which in turn lead to systematic uncertainties on the science output of the experiments. The use of different neutrino generators can therefore help to understand and reduce the systematic uncertainties associated with the simulation of neutrino interactions. GiBUU is a generator that utilises the Boltzmann-Uehling-Uhlenbeck equation in order to propagate the secondary particles through the nucleus. The KM3BUU software package has been developed to adapt GiBUU simulations to the geometry and data format of the KM3NeT neutrino telescope, which is under construction in the Mediterranean Sea. The current status of KM3BUU and first results obtained with this new software package will be presented.

T 103.4 Thu 17:00 T-H35

Modelling Seasonal Variations of Atmospheric Muon Neutrinos using MCEq — •Jakob Böttcher, Hannah Erpenbeck, Philipp Fürst, and Christopher Wiebusch for the IceCube-Collaboration — RWTH Aachen, III. Physikalisches Institut b

The IceCube Neutrino Observatory measures the flux of atmospheric muon neutrinos with unprecedented statistics. These muon neutrinos are produced in cosmic-ray air-showers in the atmosphere, and their flux depends on meteorological quantities such as air temperature and density. The analysis of the resulting seasonal variations improves the understanding of the production of atmospheric neutrinos and provides a novel method for testing hadronic interaction models for air-showers. This talk compares the results of analysing four years of IceCube neutrino data to predictions using the numeric cascade equation solver MCEq. The predictions are based on detailed daily calculations of the atmospheric neutrino flux. These use latitude and longitude dependent vertical temperature profiles of the atmosphere as provided by the AIRS instrument on NASA's Aqua satellite.

T 103.5 Thu 17:15 T-H35

Neutrino oscillation sensitivity studies with IceCube Upgrade — •Martin Ha Minh for the IceCube-Collaboration — Technische Universität München

IceCube is a kiloton-scale neutrino telescope embedded in the Antarctic ice of the South-Pole and it's equipped with over 5000 optical modules. IceCube has delivered world-leading measurements on the neutrino oscillation parameters and plans to further constrain the parameter space with the IceCube Upgrade. The IceCube Upgrade is an augmentation of the detector consisting of 7 detector additional detector strings with new optional modules to improve the directional resolution and lower the energy threshold of particle detection. The construction of this extension will be started in the coming years. In the past, sensitivity curves on the oscillation parameters were based on assumptions of how we expect future event reconstruction resolutions, as we did not have a fully operational algorithms at that time. Now however we developed a Graph Neural Network-based reconstruction algorithm, which allows us to make more realistic predictions about the oscillation analysis performance. In this work we present projections on the sensitivity of the IceCube Upgrade on neutrino oscillation parameters, such as the mixing angle θ_{23}, the squared mass difference m^2_{23}, and the ratio of expected and recorded ν_τ flux.

T 103.6 Thu 17:30 T-H35

Precision self-monitoring calibration module for the IceCube Upgrade — •Tobias Andreas Pertl and Felix Henningsen — Technische Universität München

The IceCube observatory is a large-volume neutrino observatory at the geographic South Pole. The IceCube Upgrade aims to improve the low-energy and oscillation physics sensitivities as well as re-calibrate the existing detector. This upgrade consists of seven new densely instrumented strings with various different optical and calibration modules. A novel type of precision optical calibration module – or POCAM – for large-volume detectors has been developed and will be deployed as part of the IceCube Upgrade. We report on the design, calibration and production status.

T 103.7 Thu 17:45 T-H35

Optimization of selection cuts for the directional analysis of sub-MeV solar neutrinos in Borexino — •Antonia Wessel[1,3], Alexandre Göttel[2,3], Sindhujha Kumaran[2,3], Livia Ludhova[2,3], Luca Pelicci[2,3], Ömer Penek[2,3], and Apeksha Singhal[2,3] — [1]GSI Helmholtzcentre for Heavy Ion Research, Darmstadt, Germany — [2]Forschungszentrum Jülich GmbH, Nuclear Physics Institute IKP-2, Jülich, Germany — [3]III. Physikalisches Institut B, RWTH Aachen University, Aachen, Germany

Borexino, a liquid scintillator (LS) detector at the Gran Sasso National Laboratory in Italy, has measured all solar neutrinos thanks to its low energy threshold, high energy resolution, and unprecedented radio-purity. Although LS detectors generally cannot obtain any directional information as opposed to Water Cherenkov detectors, Borexino now achieved the first directional measurement of sub-MeV solar neutrinos. The method is based on the early Cherenkov photons which are emitted before the dominant scintillation light. The first photons of the events are then correlated to the Sun's direction. The resulting angles are summed up to form an angular distribution, which is used to measure the total number of solar neutrinos in the selected energy region of interest. For this analysis, high statistics and an excellent signal-to-background ratio are necessary. These criteria can only be met by optimizing the data selection cuts to find the best combination of the fiducial volume and the definition of the energy interval. This talk will describe the strategy for the selection cut optimization and present the resulting fiducial volume and energy region.

T 103.8 Thu 18:00 T-H35

First directional detection of sub-MeV solar neutrinos in Borexino — •Johann Martyn for the Borexino-Collaboration — Johannes Gutenberg-Universität Mainz

Borexino is a 280 t liquid scintillator detector at the Laboratori Nazionali del Gran Sasso (LNGS), Italy. Its main goal is the precision spectroscopy of solar neutrinos down to energies of 0.19 MeV and for this task it features an unprecedented high radio-purity and a high light yield of ~10000 scintillation photons per 1 MeV deposited energy.
In this talk we present the first measurement of sub-MeV solar neutrinos around the ^{7}Be edge, using their associated Cherenkov photons in a liquid scintillation detector. In Borexino electrons with E>0.16 MeV produce Cherenkov photons but the ratio of Cherenkov photons from the neutrino scattered electrons is estimated to be $< 0.5\%$ for all PMT hits, so a typical reconstruction of the event direction is not possible. Therefore we look instead at the so called "Correlated and Integrated Directionality" (CID), where the known position of the Sun is correlated with the photon hit direction, given by the reconstructed event vertex, and integrated over all selected events. In this way it is possible to measure an angular distribution that shows the statistical contribution of Cherenkov photons from the neutrino recoil electrons. The number of solar neutrinos is then inferred from the measured angle distribution with probability density functions produced by the Geant4-based Borexino Monte Carlo simulation. This work is supported by the Cluster of Excellence No. 2118 PRISMA+, funded by the German Research Foundation (DFG).

T 103.9 Thu 18:15 T-H35

Analysis strategies used in directional analysis of sub-MeV solar neutrinos in liquid scintillator detector — •Apeksha Singhal[1,3], Alexandre Göttel[1,3], Sindhujha Kumaran[1,3], Livia Ludhova[1,3], Luca Pelicci[1,3], Ömer Penek[1,3], and Antonia Wessel[2,3] — [1]Forschungszentrum Jülich GmbH, Nuclear Physics Institute IKP-2, Jülich, Germany — [2]GSI Helmholtzcentre for Heavy Ion Reseach, Darmstadt, Germany — [3]III. Physikalisches Institut B, RWTH Aachen University, Aachen, Germany

The sub-MeV solar neutrinos are measured in a liquid scintillator detector via their elastic scattering off electrons, which induce isotropically emitted scintillation photons that are detected by PMTs. Borexino, located at the LNGS in Italy, is liquid scintillator detector that performed real time spectroscopy of solar neutrinos from pp chain and CNO fusion cycle of the Sun. For first time, it is possible with Borexino to disentangle sub-MeV solar neutrinos detected in liquid scintillator using few Cherenkov photons emitted at early times, and in direction of scattered electrons with given energy threshold. The directional solar neutrino signal is statistically discriminated from isotropic background events by correlating well known position of the Sun and the direction of the first two time-of-flight subtracted hits of each event, with respect to the reconstructed vertex. This results in angular distribution of data, fitted with signal and background distributions from Monte Carlo simulations. This talk will describe analysis strategy used to disentangle sub-MeV solar neutrino signal in data in a liquid scintillator detector. The future scope of this method will also be discussed.

T 104: Search for Dark Matter 5

Time: Thursday 16:15–18:05 Location: T-H36

Group Report T 104.1 Thu 16:15 T-H36
Status of the COSINUS Experiment at Gran Sasso — •Martin Stahlberg for the COSINUS-Collaboration — Max-Planck-Institut für Physik, 80805 München

The upcoming COSINUS experiment aims at clarifying the origin of the modulation signal reported by the DAMA-LIBRA collaboration since many years, which is in strong contrast to null-results from other direct dark matter search experiments. Construction of the COSINUS facility has started at Laboratori Nazionali del Gran Sasso (LNGS) in 2021, and first results are expected in 2024. COSINUS cryogenic NaI calorimeters will feature two-channel readout of heat and scintillation signal, and recoil energy thresholds of only few keV. We will give an overview on the status of the experimental setup, as well as outlook on the physics reach, and present first results from remoTES prototype detector measurements.

T 104.2 Thu 16:35 T-H36
remoTES sensors: Development of a novel detector design for NaI cryogenic calorimeters for the COSINUS dark matter experiment — •Mukund Bharadwaj for the COSINUS-Collaboration — Max Planck Institute for Physics, Fohringer Ring 6, Munich, Germany - 80805

The COSINUS experiment is an upcoming low-threshold, cryogenic experiment being setup at the Laboratori Nazionali Del Gran Sasso, Italy. It aims to provide a model independent cross-check of the DAMA/LIBRA claim of a potential dark-matter like modulating signal, the result of which is contrary to data reported by other direct dark matter experiments over the past few decades.

COSINUS utilizes a dual-channel readout system based on transition edge sensors(TESs) that allows for particle discrimination. It consists of ultra-pure scintillating sodium iodide (NaI) crystals enclosed by a silicon detector which function as the phonon and light channels respectively. The physical and chemical properties of NaI prevent the direct deposition of a TES on it's surface. In order to overcome this, a new prototype detector design dubbed **remoTES** has been developed. It utilizes a gold pad coupled to the absorber crystal as the primary interface to transmit the phonon signal to the TES, which is fabricated on a separate wafer substrate. The first preliminary results from above ground R&D measurements are reported in this talk.

T 104.3 Thu 16:50 T-H36
Operation of low threshold cryogenic calorimeters in a dry dilution refrigerator in the COSINUS experiment — •Moritz Kellermann, Karl-Heinz Ackermann, Henrik Ansorge, Mukund Bharadwaj, Torsten Frank, Karoline Schäffner, Robert Stadler, Martin Stahlberg, and Vanessa Zema — Max-Planck-Institut für Physik, Föhringer Ring 6, 80805 München

For 25 years the DAMA/LIBRA dark matter search measures an annually modulated signal, using sodium iodide (NaI)-scintillators at room temperature. The COSINUS experiment aims to give a model-independent cross-check of the DAMA/LIBRA results by operating pure NaI absorber crystals as cryogenic scintillating calorimeters at mK-temperatures.

COSINUS will be among the first experiments to operate low-threshold calorimeters in a dry dilution refrigerator, being sensitive to temperature changes on a micro-Kelvin level. A pulse tube cooler will be used to arrive at 3K, trading simplified handling for an increased mechanical vibration noise level in the acoustic frequency range. In order to maintain the thermal stability to operate low-threshold calorimeters, it will be necessary to decouple the detectors from possible noise sources. For COSINUS, a spring-based passive decoupling system is planned and tested using piezo-based accelerometers at room temperature. This talk will focus on the design and test results of the in-house developed decoupling system.

T 104.4 Thu 17:05 T-H36
Direct dark matter search with CRESST-III experiment — •Lucia Canonica for the CRESST-Collaboration — Max-Planck-Institut für Physik, D-80805 München, Germany

CRESST (Cryogenic Rare Event Search with Superconducting Thermometers) is a direct dark matter search experiment located at the Gran Sasso Underground Laboratory (Italy) that uses scintillating cryogenic calorimeters as a target material for elastic DM-nucleus scattering.

The current phase of the experiment, CRESST-III, is optimized for low-energy nuclear recoil detection. It has reached an unprecedented value of 30 eV for nuclear recoil energy thresholds on a $CaWO_4$ target, allowing the exploration of low-mass dark matter candidates down to 0.16 GeV/c^2. At higher masses the sensitivity is currently limited by a rising event rate (from threshold up to few hundreds of eV) from a so-far unknown origin.

Currently dedicated measurements with upgraded detectors (including different target materials) are being performed at the Gran Sasso Underground Laboratory, with the goal of investigating and identifying the origin of the event excess.

In this contribution, the current stage of the CRESST-III experiment, together with the most recent dark matter results, will be presented.

T 104.5 Thu 17:20 T-H36
Development of a Cryogenic Alpha Screening Facility at TUM — •Angelina Kinast[1], Andreas Erb[1,2], Andreas Erhart[1], Fiona Hamilton[1], Margarita Kaznacheeva[1], Alexander Langenkämper[1], Tobias Ortmann[1], Luca Pattavina[1,3], Walter Potzel[1], Johannes Rothe[1], Nicole Schermer[1], Stefan Schönert[1], Raimund Strauss[1], Victoria Wagner[1], and Alexander Wex[1] — [1]Physik-Department E15, Technische Universität München, D-85748 Garching, Germany — [2]Walther-Meißner-Institut für Tieftemperaturforschung, D-85748 Garching, Germany — [3]INFN, Laboratori Nazionali del Gran Sasso, I-67100 Assergi, Italy

A precise measurement of the radio-purity levels of the $CaWO_4$ crystals used for Dark Matter search with the CRESST experiment and CEvNS measurements with the NUCLEUS experiment is fundamental for a better background understanding. The sensitivity of HPGe detectors is not sufficient to measure the excellent radio-purity levels of the $CaWO_4$ crystals produced in-house at the Technische Universität München (TUM). I report on a cryogenic alpha-screening facility developed at TUM, which is currently being commissioned, and will provide a method to determine the radiopurity of our $CaWO_4$ crystals by measuring the alpha-decays with high precision in the unique experimental environment of the shallow underground laboratory (UGL) at TUM. The research was supported by the DFG through the Excel-

lence Cluster ORIGINS, the SFB1258 and the BMBF: 05A17WO4 and 05A17VTA.

T 104.6 Thu 17:35 T-H36

Development of a new generation of beaker modules for CRESST — •Fiona Hamilton[1], Gode Angloher[2], Antonio Bento[2], Anna Bertolini[2], Lucia Canonica[2], Nahuel Ferreiro[2], Dominik Fuchs[2], Abhijit Garai[2], Dieter Hauff[1,2,3], Margarita Kaznacheeva[1], Angelina Kinast[1], Alexander Langenkämper[1], Michele Mancuso[2], Athoy Nilima[2], Tobias Ortmann[1], Luca Pattavina[1], Federica Petricca[2], Walter Potzel[1], Franz Pröbst[2], Francesca Pucci[2], Johannes Rothe[1], Karoline Schaeffner[2], Stefan Schönert[1], Martin Stahlberg[2], Leo Stodolsky[2], Raimund Strauss[1], and Vanessa Zema[2] — [1]Technische Universität München, Physik Department Lehrstuhl E15, James-Franck-Straße 1, D-85748 Garching — [2]Max-Planck-Institut für Physik, Föhringer Ring 6, D-80805 München — [3]Universität Tübingen, Physikalisches Institut, Auf der Morgen- stelle 14, D-72076 Tübingen

The CRESST experiment is leading the direct search for nuclear recoils induced by light dark matter. The CRESST "beaker modules", using a silicon beaker as a light detector, provide a complete surface anticoincidence veto. For the next generation of beaker modules, the target and beaker sizes were scaled down in order to further improve energy resolution, allowing background suppression down to energy thresholds below 100 eV. A status update on the research and development of the new generation of beaker modules at TUM is presented. The research was supported by the DFG through the Excellence Cluster ORIGINS and the SFB1258, and the BMBF: 05A17WO4 and 05A17VTA.

T 104.7 Thu 17:50 T-H36

Investigation of Production Techniques for Sputtered Tungsten Thin Films — •Tobias Ortmann[1], Andreas Erhart[1], Margarita Kaznacheeva[1], Angelina Kinast[1], Alexander Langenkämper[1], Luca Pattavina[1], Walter Potzel[1], Johann Riesch[2], Johannes Rothe[1], Nicole Schermer[1], Stefan Schönert[1], Raimund Strauss[1], Victoria Wagner[1], and Alexander Wex[1] — [1]Technische Universität München, Physik Department Lehrstuhl E15, James-Franck-Straße 1, D-85748 Garching — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstraße 2, D-85748 Garching bei München

Cryogenic rare event searches like the CRESST and the NUCLEUS experiments use TES (Transition Edge Sensors) as phonon sensors to read out their target crystals. This type of sensors utilizes the superconducting phase transition of tungsten to measure the energy deposited in the absorbers. The most established method of production for these films is electron beam physical vapor deposition. For future large scale production the application of argon DC-magnetron sputtering is investigated in terms of film quality and reproducibility. The most recent results of these investigations are presented. The research was supported by the DFG through the Excellence Cluster ORIGINS and the SFB1258, and the BMBF: 05A17WO4 and 05A17VTA.

T 105: Search for Dark Matter 6

Time: Thursday 16:15–18:45 Location: T-H37

T 105.1 Thu 16:15 T-H37

The MAgnetized Disk and Mirror Axion eXperiment — •Christoph Krieger for the MADMAX-Collaboration — Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

The axion is a viable and natural candidate for (cold) dark matter. The mass range for the discovery of axions, favored by some models, 40 to 400 μeV, can be investigated using a dielectric haloscope. The **MA**gentized **D**isc and **M**irror **A**xion e**X**periment is the first axion haloscope based on this approach, utilizing the axion photon conversion at dielectric surfaces in a strong magnetic field. By combining many surfaces, the conversion can be boosted significantly using constructive interference and resonances.

MADMAX will feature a booster system consisting of up to 80 dielectric discs with more than a meter diameter which can be precisely positioned at cryogenic conditions and inside a 9 T magnetic field created by a superconducting dipole magnet with a large warm bore. To prototype this challenging apparatus, a scaled down version (reduced number of discs with 300 mm diameter) is in development. It will be commissioned first at the Universität Hamburg in a dedicated cryostat. It is planned to conduct a first axion-like particle search utilizing the MORPURGO magnet at CERN.

In this presentation, the concept of MADMAX will be presented and an overview will be given on the status and development of MADMAX and its prototype.

T 105.2 Thu 16:30 T-H37

Measurements of dielectric properties of single crystals of Lanthanum Aluminate (LaAlO3) and Sapphire (Al2O3) for the axion dark matter search experiment, MADMAX — •Erdem Oez for the MADMAX-Collaboration — RWTH, Aachen

The magnetized disk and mirror axion (MADMAX) experiment will search for axions as cold dark matter candidate in the range of microwave frequencies from 10 to 100 GHz. Multiple parallel dielectric discs are planned to be used to boost the axion generated RF signal by 3 orders of magnitude compared to a single metal surface of the same area. Precise knowledge of the dielectric loss and the dielectric constant of the disc materials is crucial for understanding the predicted axion signal. At these RF frequencies the measurement of low loss materials are especially challenging. Here we present cryostatic measurements of LaAlO3 and Al2O3 which are the best candidate materials for MADMAX. The measurements were done in the 10 to 40 GHz range using a microwave resonator.

T 105.3 Thu 16:45 T-H37

Dielectric Disk Production for the MADMAX — •Dominik Breitmoser — Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

The MAgentized Disk and Mirror Axion eXperiment (MADMAX) is an upcoming experiment to search for dark matter axions in the unexplored mass range of 40-400 μeV. The QCD axion is a solution to the strong CP problem and simultaneously an excellent cold dark matter candidate. In a strong magnetic field, axion-induced photons would be emitted at dielectric interfaces. MADMAX uses the dielectric haloscope approach to boost such a signal by combining up to 80 dielectric disks with 1.25 m diameter and precisely adjustment of the disk distances. The axion to photon conversion is enhanced through interference and resonance effects.

To reach the required sensitivity the disks need a large dielectric constant whilst having low dielectric losses. Experimental constraints demand a planarity below 10 μm, surface roughness below 10 μm and a thickness of 1 mm. A favorable material could be lanthanum aluminate. However the material is only available in the size of 3" wafers. Thus, the disks need to be produced from small tiles which are glued together. This talk presents the method of manufacturing a prototype disk (∅ 300 mm), the studies for optimizing production parameters, and explains the measurement system used for quality control.

T 105.4 Thu 17:00 T-H37

Calibrating a Dielectric Haloscope — •Jacob Egge for the MADMAX-Collaboration — Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee149, 22761 Hamburg

Dielectric haloscopes like the **MA**gnetized **D**isk and **M**irror **A**xion e**X**periment aim to detect axions, a dark matter candidate, from the galactic halo by resonant conversion to photons in a strong magnetic field. A movable stack of parallel dielectric disks can amplify the axion-photon conversion probability by several orders of magnitude. This amplification depends on the spatial variation of the axion, photon, and magnetic field. While the axion and magnetic fields are largely static and homogeneous, the frequency-dependent photon field inside the dielectric stack and thus the overall amplification is difficult to characterize.

In this talk, a new calibration method based on non-resonant perturbation theory is presented. It provides a promising way to experimentally constrain the photon field inside the dielectric stack. By perturbing the position of each dielectric disk and measuring the resulting change in reflectivity, one can infer the photon field configuration at each dielectric interface. This then allows computing the amplified axion-photon conversion probability independent of many parameters like dielectric loss and disk geometry. The validity and feasibility of this method are demonstrated with FEM simulations and first measurements on a 5 disks setup.

T 105.5 Thu 17:15 T-H37

Investigating a symmetric booster setup for MADMAX's dielectric haloscope — •Lolian Shtembari for the MADMAX-Collaboration — Max Planck Institute for Physics, Munich, Germany

The MADMAX experiment aims to directly detect galactic dark matter axions using the axion-induced emission of electromagnetic waves from boundaries between materials of different dielectric constants placed in a strong magnetic field. Carefully spacing many dielectric disks, their combined emission can be significantly enhanced (boosted) using constructive interference and resonances. In an attempt to reduce the complexity of the system and to gain an understanding of the flexibility and frequency response of the booster, we investigate the performance of a configuration made up of repeating symmetric sections of dielectric disks.

T 105.6 Thu 17:30 T-H37

Loss mechanisms of the MADMAX minimal booster setup — •Antonios Gardikiotis for the MADMAX-Collaboration — Institut für Experimentalphysik,Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

The axion is a promising candidate to solve the strong CP problem in the SM of particle physics. Its existence could also explain the observations in dark matter (DM) problem. To date, no axions have been detected. An envisioned technique for axion detection in the mass range of 40-400 μeV is the dielectric haloscope. The MADMAX (MAgentized Disc and Mirror Axion eXperiment) haloscope employs axion conversion into photons on surfaces within a strong magnetic field.

MADMAX uses a booster system consisting of multiple dielectric discs in front of a metal mirror to enhance the tiny axion converted power. Different booster setups have been built to examine the mechanical feasibility and electromagnetic behaviour. Project200 is a proof of principle setup with only one disc in front of a mirror. This simplified version of the MADMAX booster setup can compare basic radio frequency measurements with corresponding simulations.

In this presentation, the study of disc flatness, tilts of the disks and the antenna properties on a minimal setup that can help to better understand the loss mechanisms of the MADMAX booster setup will be discussed.

T 105.7 Thu 17:45 T-H37

Piezoelectric driven dielectric discs for the MADMAX haloscope — •Dagmar Kreikemeyer-Lorenzo for the MADMAX-Collaboration — Max Planck Institute for Physics, Munich, Germany

Axions are hypothetical particles conceived to explain the strong CP problem of the Standard Model. Simultaneously, axions are an excellent candidate for cold dark matter. MADMAX (MAgnetized Disk and Mirror Axion eXperiment) aims to detect axions in the mass range between 40 and 400 μeV. For that, it exploits axion to photon conversion at surfaces with different dielectric constants in the presence of a strong magnetic field. The MADMAX haloscope or booster setup will consist of several parallel and adjustable dielectric discs. The separation between discs will be optimised for the axion mass using very precise piezoelectric motors. Here we present the first investigation of the performance of such piezo motors, developed by the company JPE, under realistic conditions relevant for MADMAX. First results at room temperature and at 4.2 K will be shown.

T 105.8 Thu 18:00 T-H37

MADMAX: Dealing with Motor Failures — •David Leppla-Weber for the MADMAX-Collaboration — Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

The **MA**gnetized **D**isk and **M**irror **A**xion e**X**periment is a dielectric haloscope aiming to detect axions from the galactic halo by resonant conversion to photons in a strong magnetic field. It uses a stack of dielectric disks, called booster, that amplifies the axion-photon conversion probability over a significant mass range dependent on the position of the adjustable disks. In the planned prototype, depending on the axion mass, amplifications of a factor of $\sim 10^4$ can be achieved. The booster is positioned in a cryostat to achieve the low noise levels necessary for the detection of the tiny power stemming from the axion-photon conversion. In case a repair is needed, the cryostat has to be warmed up and cooled down again resulting in significant shutdown time of the experiment. To explore the case where one disk motor of the MADMAX prototype fails, an investigation for the maximum possible scan range with one disk stuck is presented. It is found that one stuck disk reduces the amplification by no more than 25 % over a range of 1.5 GHz. This enables the experiment to continue operating for a significant amount of time without having to interrupt the axion search and warm up the booster for repairs.

T 105.9 Thu 18:15 T-H37

A closed booster prototype for MADMAX: CB100 — •Chang Lee for the MADMAX-Collaboration — Max Planck Institute for Physics, Munich, Germany

CB-100 is a closed dielectric haloscope that aims to verify the dielectric haloscope concept. We use the setup to understand the reflectivity and thermal noise of a dielectric haloscope, which is a prerequisite for a good calibration. The MADMAX collaboration plans to use the system for its axion-like particle dark matter search using the MORPURGO magnet at CERN. We present the concept, design, and construction of CB-100. We also present the reflectivity measurement at room temperature and 4K.

T 105.10 Thu 18:30 T-H37

A novel approach to simulate axion-induced electrodynamics utilizing deep learning techniques in the MADMAX experiment — Dominik Bergermann, Tim Graulich, •Alexander Jung, Andrzej Novak, Ali Riahinia, and Alexander Schmidt — III. Physikalisches Institut A RWTH Aachen, Aachen, Deutschland

Promising concepts for the search for axion dark matter are dielectric haloscopes, such as the MAgnetized Disk and Mirror Axion eXperiment (MADMAX). The realisation of the experiment strongly depends on an accurate and reliable simulation leading to ever-increasing demands on computing resources, due to the complexity of simulations. A proof of principle is presented that modern deep learning techniques can be used in the simulation of the axion haloscope, and thereby assist in its optimisation.

T 106: Experimental Techniques in Astroparticle Physics 4

Time: Thursday 16:15–18:30 Location: T-H38

T 106.1 Thu 16:15 T-H38

Automation of the PMT Acceptance Tests for the IceCube Upgrade mDOMs — •Lasse Halve[1], Hannah Erpenbeck[1], Maja Freienhofer[2], Konstantin Mrozik[2], Joëlle Savelberg[1], Johannes Werthebach[2], and Christopher Wiebusch[1] for the IceCube-Collaboration — [1]RWTH Aachen University - Physics Institute III B, Aachen, Germany — [2]Astroparticle Physics WG Rhode, TU Dortmund University, Germany

The IceCube Upgrade will extend the IceCube Neutrino observatory with seven additional cable-strings of instrumentation. More than 400 multiple-PMT Digital Optical Modules (mDOMs), with 24 3" Photomultiplier Tubes (PMTs) each, will be deployed. We are testing more than 10.000 PMTs for compliance with manufacturer specifications before the integration into the final modules. A dedicated software for steering the test facilities at RWTH Aachen University and TU Dortmund University for a fully automated operation and online analysis has been developed. We present the design principles and specific solutions for full automization of the test procedures and analyses of PMT data.

T 106.2 Thu 16:30 T-H38

First Results of the PMT Acceptance Tests for the IceCube Upgrade mDOMs — •Johannes Werthebach[1], Hannah Erpenbeck[2], Maja Freienhofer[1], Lasse Halve[2], Konstantin Mrozik[1], and Christopher Wiebusch[2] for the IceCube-

Collaboration — [1]Astroparticle Physics WG Rhode, TU Dortmund University, Germany — [2]III. Physikalisches Institut B, RWTH Aachen University

For the IceCube Upgrade seven new strings will be deployed in the centre of the IceCube Neutrino Observatory. Each string contains several types of modules and in total more than 400 multiple-PMT Digital Optical Modules (mDOMs), with 24 3" Photomultiplier Tubes (PMTs) each, will be frozen into the glacial ice at the South Pole. Testing these PMTs for compliance with manufacturer specifications is crucial before integration into the final mDOM. Utilizing two test facilities at RWTH Aachen University and TU Dortmund University with fully automated operation allows for mass testing of all PMTs. Here, we present the results of the characterization tests for the first batch of PMTs.

T 106.3 Thu 16:45 T-H38

Acceptance Tests for 10,700 PMTs of the mDOMs of the IceCube Upgrade — •Joëlle Savelberg[1], Hannah Erpenbeck[1], Maja Freienhofer[2], Lasse Halve[1], Konstantin Mrozik[2], Johannes Werthebach[2], and Christopher Wiebusch[1] for the IceCube-Collaboration — [1]RWTH Aachen University - Physics Institute III B, Aachen, Germany — [2]Experimentelle Physik 5, TU Dortmund University

The currently prepared IceCube Upgrade will add seven new detector-strings to the central region of the IceCube detector, with the goal of improving the photon-detection and lowering the energy threshold. Part of the new instrumentation are more than 400 multi-PMT Digital Optical Modules (mDOMs), each containing 24 3" Photomultiplier Tubes (PMTs) of type Hamamatsu R15458-20. Prior to the assembly of the mDOMs, the 10,700 required PMTs need to be tested for compliance with set specifications. These tests are carried out at dedicated testing facilities at RWTH Aachen University and TU Dortmund University, with setups that have been optimized for large throughput during the production phase. This talk will focus on the design of these setups and development of optimized testing procedures of PMTs in these large quantities.

T 106.4 Thu 17:00 T-H38

Testing the multi-PMT digital optical modules for IceCube Upgrade — •Nora Feigl for the IceCube-Collaboration — DESY Zeuthen

The IceCube Upgrade will enhance IceCube's capabilities at low and high energies. An important part of the Upgrade is the multi PMT approach: the new optical detector module, the multi-PMT digital optical module (mDOM), promises a large sensitive area, homogeneous solid angle coverage and the possibility of multiplicity triggering within a single module.

In the past year the mDOM was tested and characterized to verify the design is up to requirements. During the mDOM Design Verification Test (DVT) phase, all the most basic features of the mDOM mainboard, the PMT bases and the calibration systems for the first DVT modules were tested.

The next step will be the large-scale integrated mDOM Final Acceptance Testing (FAT) to verify the previous measurements and the functionality of all subsystems while undergoing temperature cycles.

In this talk the structure and the current state of the mDOM Testing will be presented. Some results of the Design Verification Tests will be shown as well as a short outlook for the upcoming Final Acceptance Testing.

T 106.5 Thu 17:15 T-H38

LOM - A multi-PMT optical sensor for IceCube-Gen2. — Markus Dittmer, •Berit Schlüter, Alexander Kappes, and Lew Classen for the IceCube-Collaboration — WWU Münster

With a smaller diameter and 4-inch PMTs, the eLongated Optical Module (LOM) combines lessons learned from the development of mDOM and DEgg for IceCube Upgrade with gel pads as a new element for optical coupling. The gel pads are a key component here and offer several advantages over previously used approaches. However, they also pose a challenge for the design of the internal mechanical components and subsequent volume production.

This presentation will provide an overview of the proposed LOM design, gel pad studies, and highlight measures taken to ensure consistent quality of the modules under the harsh conditions in the deep ice at the South Pole.

T 106.6 Thu 17:30 T-H38

Reconstruction of simulated muons in a water basin with a multi-PMT optical module — •Francisco Javier Vara Carbonell, Martin Antonio Unland Elorrieta, Markus Dittmer, Lew Classen, and Alexander Kappes for the IceCube-Collaboration — Institut für Kernphysik, Westfälische Wilhelms-Universität Münster, Münster, Germany

The IceCube detector, currently the largest neutrino detector in the world, is scheduled to undergo two upgrades that will be accompanied by new and improved optical modules. These new modules include the LOM and the mDOM, which feature a larger number of PMTs in a pressure vessel. Compared to the old modules, they have a larger effective photosensitive area and nearly uniform angular coverage. In addition, the sensitive area is now fragmented, resulting in intrinsic directional sensitivity of each module. The zenith angle resolution of both types of modules for atmospheric muons in water was studied with Geant4 simulations, using machine learning for reconstruction.

T 106.7 Thu 17:45 T-H38

Studien zum Zeitverhalten eines Photomultipliers mit COMSOL Multiphysics — •Janis Averbeck, Markus Dittmer, Martin Antonio Unland Elorrieta, Lew Classen und Alexander Kappes für die IceCube-Kollaboration — WWU Münster, Münster, Deutschland

Zur Detektion der charakteristischen Tscherenkow-Strahlung werden beim IceCube-Neutrinoteleskop Photomultiplier eingesetzt. Die Photonen lösen an der Photomultiplier-Kathode durch den photoelektrischen Effekt Photonen aus, die anschließend in einem elektrischen Feld beschleunigt werden und ein Dynodensystem mit steigendem Potential durchlaufen. Dabei werden bei jeder Dynodenkollision mehrere Sekundärelektronen ausgelöst, die letztlich zu einem messbaren Signal führen. Für den Einsatz in IceCube ist u.a. eine sehr genaue Kenntnis der zeitlichen Verzögerung zwischen Auslösung an der Photokathode und Ankunft des Elektronensignals an der Anode (Transit-Time) erforderlich. Die Transit-Time hängt dabei nicht nur von der Größe der Beschleunigungsspannung, sondern auch vom Entstehungsort der Elektronen auf der kugelförmigen Kathode, der Anfangsenergie der Elektronen sowie deren Geschwindigkeitsvektor ab. Um den Einfluss dieser drei Parameter auf die Transit-Time zu untersuchen wurde damit begonnen, einen Photomultiplier in COMSOL Multiphysics nachzubauen. Der Vortrag präsentiert erste Ergebnisse der Studien.

T 106.8 Thu 18:00 T-H38

Studies of the LED emission profile in the mDOM with a Geant4 simulation — •Anna-Sophia Tenbruck, Alexander Kappes, Martin Antonio Unland Elorrieta, Lew Classen, and Cristian Jesús Lozano Mariscal for the IceCube-Collaboration — Institut für Kernphysik, Westfälische Wilhelms-Universität Münster, Münster

The multi-PMT digital optical modules (mDOMs) used in IceCube Upgrade are not only designed to detect neutrinos at low energies, but are also expected to greatly improve the understanding of the detector by installing calibration devices such as LED flashers. LED flashers are versatile devices successfully used in IceCube to measure the ice properties, sensitivity, and timing of optical modules and their positioning. For this purpose, the emission profile of the LEDs must be accurately characterized after they are installed in an mDOM. To study this, the LEDs were simulated in detail in a Geant4 simulation, and the influence of the other module components on the emission profile as well as systematics resulting from the uncertainties in position and inclination of the LED in the module were investigated.

T 106.9 Thu 18:15 T-H38

The Acoustic Module for the IceCube Upgrade — Jürgen Borowka, •Christoph Günther, Dirk Heinen, Maverick Schönell, Christopher Wiebusch, and Simon Zierke for the IceCube-Collaboration — RWTH Aachen University - Physics Institute III B, Aachen, Germany

One major goal of the IceCube Upgrade is improved calibration by deploying additional calibration devices in the center of IceCube. Amongst these devices are ten stand-alone Acoustic Modules, capable of receiving and sending acoustic signals. Additionally, these signals are detected by compact acoustic sensors inside some of the optical sensor modules. The positions of emitters and receivers are determined by means of trilateration of the acoustic propagation times. With this system we aim for the calibration of the detector's geometry with a precision better than a few 10 cm. In view of the future IceCube-Gen2 detector, this system will provide an important proof of principle for the reliable geometry calibration on distance scales of a few hundred meters. The design of the acoustic modules and the status of the development are presented in this talk.

T 107: Data Analysis, Information Technology and Artificial Intelligence 5

Time: Thursday 16:15–18:15 Location: T-H39

T 107.1 Thu 16:15 T-H39

Introducing novel order statistic tests based on spacings and their applications — •Lolian Shtembari — Max Planck Institute for Physics, Munich, Germany

The use of spacings between ordered real-valued numbers is very useful in many areas of science. In particular, either unnaturally small or large spacings can be a signal of an interesting effect. We introduce new statistical tests based on the observed spacings of ordered data. These statistics are sensitive to detect non-uniformity in random samples, or short-lived features in event time series. Under some conditions, these new test can outperform existing ones, such as the well known Kolmogorov-Smirnov or Anderson-Darling tests, in particular when the number of samples is small and differences occur over a small quantile of the null hypothesis distribution. A detailed description of the test statistics is provided including examples and proposed applications for the analysis of neutrino experiments.

T 107.2 Thu 16:30 T-H39

Cosmic ray composition measurement with Graph Neural Networks in KM3NeT/ORCA — •Stefan Reck for the ANTARES-KM3NET-ERLANGEN-Collaboration — Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), ECAP

KM3NeT/ORCA is a water-Cherenkov neutrino detector, currently under construction in the Mediterranean Sea at a depth of 2450 meters. The project's main goal is the determination of the neutrino mass hierarchy by measuring the energy- and zenith-angle-resolved oscillation probabilities of atmospheric neutrinos traversing the Earth. Additionally, the detector observes atmospheric muons, which can be used to study the properties of extensive air showers and cosmic ray particles.

This contribution will present a deep-learning based approach to analyse the signatures of muon bundles traversing the detector using graph convolutional networks. Even though the detector is still in an early stage of construction, this reconstruction can already be used to measure the composition of cosmic ray primary particles.

T 107.3 Thu 16:45 T-H39

Tau neutrino selection with Graph Neural Networks for KM3NeT/ORCA — •Lukas Hennig for the ANTARES-KM3NET-ERLANGEN-Collaboration — Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen Centre for Astroparticle Physics, Erwin-Rommel-Straße 1, 91058 Erlangen, Germany

One of the goals of the KM3NeT collaboration is to constrain the PMNS matrix elements associated with the tau neutrino flavor. The data needed to perform this task is taken by KM3NeT's ORCA detector, a water Cherenkov neutrino detector currently under construction in the deep Mediterranean Sea. To constrain the matrix elements, one needs to measure the tau neutrino flux produced by atmospheric muon and electron neutrinos oscillating into tau neutrinos. Selecting the tau neutrino events from the full neutrino event dataset is a notoriously difficult task because the final states of a tau neutrino interaction on a nucleon or nucleus look very similar to those produced in other CC and NC neutrino interactions. This classification problem is addressed by using Graph Neural Networks, a type of neural network architecture that has shown promising results, e.g., in the related task of jet tagging. This presentation will explain how GNNs are applied to neutrino telescope data and report the first results concerning the classification performance.

T 107.4 Thu 17:00 T-H39

Conditional Invertible Neural Network for the inference of properties of ultra-high-energy cosmic ray sources — Teresa Bister, Martin Erdmann, Natalie Nast, Johanna Schafmeister, and •Josina Schulte — III. Physikalisches Institut A, RWTH Aachen

A core challenge in physics data analyses is to estimate model parameters from corresponding measurements, often without the possibility to formulate an explicit inverse function. In a Bayesian framework, parameters are usually estimated using posterior distributions providing not only point estimates but also enabling the determination of uncertainties and correlations. To assess the posterior distributions, we use a so-called conditional Invertible Neural Network (cINN) which is based on the concept of normalizing flows. We apply this new method to a simulated scenario from astroparticle physics to gain information on the parameters of a source model of ultra-high-energy cosmic rays. The corresponding simulated measurements are the energy spectrum, depth of shower maximum distributions and the arrival directions as measured on Earth with similar statistics as data from the Pierre Auger Observatory. We present and evaluate the performance of the cINN on this scenario.

T 107.5 Thu 17:15 T-H39

Deep-Learning-Based Reconstruction of Cosmic-Ray Masses from Extensive Air Shower Measurements with AugerPrime — Martin Erdmann, Jonas Glombitza, Berenika Idaszek, •Niklas Langner, and Dominik Steinberg — III. Physikalisches Institut A, RWTH Aachen University

Ultra-high-energy cosmic rays (UHECRs) that penetrate the Earth's atmosphere induce extensive air showers. At the Pierre Auger Observatory, showers are measured from the ground using the fluorescence detector (FD) and the surface detector (SD) consisting of water Cherenkov detectors (WCDs). Currently, the SD is extended with scintillators (SSDs) as part of the AugerPrime upgrade.

Actual measurements of the UHECR mass composition are based on FD observations of the depth of shower maximum $X_{\max}$. Using deep learning, $X_{\max}$ was successfully extracted using only the SD, exploiting the full statistics of the observatory. However, the precision of $X_{\max}$ as a mass estimator at the event level is limited. The new SD upgrade offers the possibility to measure individual components of the shower, potentially improving the reconstruction of the mass composition.

We introduce our network to extract the properties of air showers by analyzing the signals of water Cherenkov detectors as well as the SSDs. We show that the mass-separation power when using only the observable $X_{\max}$ is already fully exploited using only WCDs. Thus, we investigate additional observables, novel network architectures and new reconstruction strategies to increase the mass sensitivity with the combination of WCDs and SSD measurements.

T 107.6 Thu 17:30 T-H39

PID with Recurrent Neural Networks in the ATLAS Transition Radiation Tracker for Run 3 — •Lena Herrmann, Christian Grefe, Philip Bechtle, and Klaus Desch — Physikalisches Institut, University of Bonn

The measurement of transition radiation effects by the ATLAS transition radiation tracker (TRT) is a key ingredient to the electron identification, especially at low momenta. A recurrent neural network (NN) was developed to combine hit- and track-level information into a single classifier, which significantly improves the particle identification capabilities provided by the TRT.

Since the gas configuration in the TRT will change for the upcoming Run 3 data taking period, separate RNNs have to be trained. The optimisation and training of the RNN will be presented and differences between the Run 2 and Run 3 networks will be discussed. Furthermore, the RNN response on real data taken during Run 2 will be compared to its performance in simulation.

T 107.7 Thu 17:45 T-H39

Usage of neural networks in photon identification in ATLAS — •Florian Kirfel — Physikalisches Institut der Universität Bonn

Precise photon identification is crucial for many ATLAS analyses. Currently, photons are selected using a set of cuts on calorimeter variables which characterise the shape of electromagnetic showers. These cuts were optimized using Monte Carlo simulations of photons and jets. Due to the simulations not being ideal, the selection efficiency must be corrected to match data. However, the measurement technique used to determine the identification efficiency in the data requires the hadronic activity around the photon candidate and the photon identification efficiency to be independent. In this work, neural networks are employed to improve over cut-based photon identification. In addition, they are constrained to keep the classification independent of the isolation using the distance correlation. This allows a simplified setup comparing to alternatives such as the adversarial neural network.

T 107.8 Thu 18:00 T-H39

A super-resolution GAN for photon identification at collider experiments — Johannes Erdmann, Florian Mentzel, Olaf Nackenhorst, and •Aaron van der Graaf — TU Dortmund University, Department of Physics

Many processes in proton-proton collisions contain prompt photons in the final state, ranging from Standard Model (SM) measurements, such as $H \to \gamma\gamma$, to searches for physics beyond the SM. In order to measure these processes with a high precision, a good photon identification efficiency while retaining a high background rejection rate is important. Most misidentified photons arise from hadron decays, such as $\pi^0 \to \gamma\gamma$, which could possibly be rejected better with a higher calorimeter granularity. This motivates the idea of artificially increasing the calorimeter granularity by training a super-resolution Generative Adversarial Network (SRGAN) with simulated low and high resolution calorimeter images. As a proof of concept, mono-energetic photons and neutral pions are simulated in an electromagnetic calorimeter and only the second calorimeter layer is used for the SRGAN training. In this presentation, the used SRGAN model, the results of the SRGAN training and the predicted super-resolution images are presented. It is shown that the predicted super-resolution images contain additional information that increases the pion rejection rate compared to the low resolution images.

T 108: General assembly - Particle Physics Division (for DPG members)

Time: Thursday 19:30–21:00 Location: T-MV

General Assembly - Mitgliederversammlung

T 109: Invited Talks 4

Time: Friday 11:00–12:30 Location: T-H15

Invited Talk T 109.1 Fri 11:00 T-H15

Ten years of Higgs boson measurements: what we know and what we don't know — •Christian Grefe — Physikalisches Institut, Universität Bonn

One decade after the discovery of the Higgs boson, the ATLAS and CMS experiments continue to publish more and more precise measurements of the Higgs sector, so far confirming the expectations of the Standard Model. With the start of LHC Run 3 ahead – which will double the existing *pp*-collision dataset – we will review the current knowledge of the fundamental properties of the Higgs boson.

In addition to the Higgs boson couplings, understanding the width and the CP properties of the Higgs boson is crucial to shed light on the open questions in particle physics: Is there CP violation in the Higgs sector? And are there invisible Higgs boson decays which would allow it to couple to a dark sector beyond the Standard Model? We will review the currently available measurements, their limitations and what to expect from Run 3 and beyond.

Invited Talk T 109.2 Fri 11:30 T-H15

Future of Silicon Tracking Detectors: LHC Upgrades and Beyond — •Georg Steinbrück — Institut für Experimentalphysik, Universität Hamburg

In this presentation I will review silicon detector technologies for particle tracking in current and future hadron collider experiments.

Significant improvements were needed to reach the requirements for the Phase 2 upgrades of the LHC experiments. I will report on these challenges and the technological solutions with a focus on the upgrades of the CMS and ATLAS tracking detectors. While the collaborations are moving towards production, they are already looking into the future. An overview of further upgrade ideas for the LHC tracking detectors will be given.

The demands on silicon detectors for planned future hadron colliders are even more extreme with 1 MeV neutron equivalent fluences up to 10^17 cm^-2 and huge particle rates. The limiting factors for the use of silicon will be discussed, as well as what is relevant in extrapolating current technologies to the future.

Invited Talk T 109.3 Fri 12:00 T-H15

The dawn of high energy neutrino astronomy — •Elisa Resconi — Technical University of Munich, Department of Physics, James-Franck-Straße 1, 85748 Garching bei München

Current knowledge of the Universe is based on information carried by electromagnetic radiation, gravitational waves, neutrinos, and cosmic rays. For over a century, scientists have observed cosmic rays, but the understanding of their place of production is limited. As a product of cosmic ray interaction, neutrinos can shed light on the extreme part of the Universe. IceCube Neutrino Observatory has been leading neutrino astronomy research over the last ten years and is the only observatory with the exposure to detect high-energy neutrinos beyond Earth*s atmosphere. This presentation will highlight the IceCube observations, including new recent results. Despite the exiting times, with IceCube operating alone and limited by the South Pole location and cubic-km scale, the neutrino astronomy efforts have yet to advance the field past infancy. It is clear that more observatories and larger telescopes, ultimately linked via a global network, are needed to advance fundamental discoveries in astro and particle physics. In this direction, a new opportunity has emerged over the last years to construct a new large volume neutrino telescope, the Pacific Ocean Neutrino Experiment (P-ONE), which will be based on the first time, within an existing oceanographic infrastructure. I will summarize how we have established a scientific relationship with Ocean Networks Canada to pioneer their global network as a testbed infrastructure and identified the optimal location and prepared the ground for first case deployment.