Particle Physics Division
Fachverband Teilchenphysik (T)

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Overview of Invited Talks and Sessions

(Lecture halls AudiMax, KH 00.011, KH 00.014, KH 00.015, KH 00.016, KH 00.020, KH 00.023, KH 00.024, KH 01.011, KH 01.012, KH 01.013, KH 01.014, KH 01.019, KH 01.020, KH 01.022, KH 02.013, KH 02.014, KH 02.016, KH 02.018, KH 02.019, AM 00.014, KS H C, KS 00.004, KS 00.005, KS 00.006, and MED 00.915)

Plenary Talk of the Particle Physics Division

PV X	Wed	9:45–10:30	AudiMax	**Precision at the Energy Frontier: What the LHC is revealing about Fundamental Particle Physics** — •Ludovica Aperio Bella

Invited Overview Talks

T 1.1	Mon	14:45–15:15	AudiMax	**Top-quark physics in a new regime: precision, effective field theory, and the top-quark pair production threshold** — •Knut Zoch
T 1.2	Mon	15:15–15:45	AudiMax	**Monte Carlo event generators for the HL-LHC** — •Steffen Schumann
T 21.1	Tue	11:00–11:30	AudiMax	**Three Decades of Dark Matter Annual Modulation Searches: Overview and Current Status** — •Karoline Schaeffner
T 21.2	Tue	11:30–12:00	AudiMax	**Status and meaning of current tensions in cosmology** — •Julien Lesgourgues
T 21.3	Tue	12:00–12:30	AudiMax	**In search of the unknown: Pushing the boundaries in searches for new physics at the LHC** — •Danyer Perez Adan
T 41.1	Wed	11:00–11:30	AudiMax	**One of a kind: the Higgs boson** — •Matteo Bonanomi
T 41.2	Wed	11:30–12:00	AudiMax	**Higgs Physics at the LHC and Beyond: Connecting Colliders and the Early Universe** — •Thomas Biekötter
T 41.3	Wed	12:00–12:30	AudiMax	**Gravitational waves from cosmological phase transitions.** — •Thomas Konstandin
T 63.1	Thu	11:00–11:30	AudiMax	**Binary Black Hole Populations: Scientific Perspectives for the Einstein Telescope** — •Michela Mapelli
T 63.2	Thu	11:30–12:00	AudiMax	**JUNO's First Light: High-Precision Reactor Neutrino Oscillations** — •Michael Wurm
T 63.3	Thu	12:00–12:30	AudiMax	**Flavour physics at the precision frontier: recent highlights from the LHCb and Belle II experiments** — •Evelina Gersabeck
T 107.1	Fri	11:00–11:30	AudiMax	**Beyond the Main Detectors: An Overview of Smaller Experiments at the LHC** — •Felix Kling
T 107.2	Fri	11:30–12:00	AudiMax	**Pimp my ride: Overhauling the ATLAS and CMS experiments to ride the High Luminosity Highway at the LHC** — •Stefan Maier
T 107.3	Fri	12:00–12:30	AudiMax	**Overview of the solar model and LUNANOVA** — •Daniel Bemmerer

Invited Topical Talks

T 43.1	Wed	13:45–14:15	AudiMax	**Upgrade of the ATLAS tracker for HL-LHC: production status and challenges** — •Roland Koppenhoefer
T 43.2	Wed	14:15–14:45	AudiMax	**Entering the high-granularity calorimetry era: the CMS HGCAL upgrade** — •Antoine Laudrain
T 43.3	Wed	14:45–15:15	AudiMax	**Searching for New Physics in Otherwise Lost LHC Data** — •Falk Bartels
T 43.4	Wed	15:15–15:45	AudiMax	**Federated Computing Infrastructures** — •Inga Lakomiec
T 44.1	Wed	13:45–14:15	MED 00.915	**Probing Heavy New Physics at the Precision Frontier with Effective Field Theory** — •Peter Stangl
T 44.2	Wed	14:15–14:45	MED 00.915	**Hadron Spectroscopy at Belle (II)** — •Stefan Wallner
T 44.3	Wed	14:45–15:15	MED 00.915	**Rare B meson decays at Belle II: indirect searches for new physics at the luminosity frontier** — •Ana Luisa Moreira de Carvalho
T 44.4	Wed	15:15–15:45	MED 00.915	**Search for CP violation in $D^0 \to K^0_S K^0_S$ decays at the LHCb experiment** — •Giulia Tuci
T 64.1	Thu	13:45–14:15	AudiMax	**Charting the Higgs Sector with Effective Field Theories** — •Ilaria Brivio
T 64.2	Thu	14:15–14:45	AudiMax	**Probing CP invariance of Higgs boson production and decay and its interpretation in effective field theories with the ATLAS detector** — •Lorenzo Rossini
T 64.3	Thu	14:45–15:15	AudiMax	**b-tagging unlocks the Higgs potential** — •Nicole Hartman
T 64.4	Thu	15:15–15:45	AudiMax	**Modern Machine Learning for LHC Event Generation** — •Ramon Winterhalder
T 65.1	Thu	13:45–14:15	MED 00.915	**Atmospheric neutrino oscillations with IceCube and the IceCube Upgrade** — •Jan Weldert
T 65.2	Thu	14:15–14:45	MED 00.915	**Exploring the Gravitational Wave Universe with Pulsar Timing Arrays** — •Andrea Mitridate
T 65.3	Thu	14:45–15:15	MED 00.915	**Supernova Remnants as Accelerators of Galactic Cosmic Rays** — •Robert Brose
T 65.4	Thu	15:15–15:45	MED 00.915	**Supermassive black holes and their relativistic jets: a beacon into the early universe** — •Lea Marcotulli

Sessions

T 1.1–1.2	Mon	14:45–15:45	AudiMax	**Invited Overview Talks I**
T 2.1–2.8	Mon	16:15–18:15	AudiMax	**Neutrino Physics I**
T 3.1–3.7	Mon	16:15–18:00	KH 00.014	**Standard Model Physics I**
T 4.1–4.8	Mon	16:15–18:15	KH 00.016	**Higgs Physics I**
T 5.1–5.8	Mon	16:15–18:15	KH 00.020	**Methods in Particle Physics I**
T 6.1–6.8	Mon	16:15–18:15	KH 00.023	**Electronics, Trigger, DAQ I**
T 7.1–7.8	Mon	16:15–18:15	KH 00.024	**Data, AI, Computing, Electronics I**
T 8.1–8.8	Mon	16:15–18:15	KH 01.011	**Flavour Physics I**
T 9.1–9.6	Mon	16:15–17:45	KH 01.012	**Silicon Detectors I**
T 10.1–10.7	Mon	16:15–18:00	KH 01.013	**Axions/ALPS I**
T 11.1–11.8	Mon	16:15–18:15	KH 01.014	**Gaseous Detectors I**
T 12.1–12.8	Mon	16:15–18:15	KH 01.022	**Silicon Detectors II**
T 13.1–13.8	Mon	16:15–18:15	KH 02.013	**Higgs Physics II**
T 14.1–14.8	Mon	16:15–18:15	KH 02.014	**Data, AI, Computing, Electronics II**
T 15.1–15.8	Mon	16:15–18:15	KH 02.018	**Searches/BSM I**
T 16.1–16.8	Mon	16:15–18:15	AM 00.014	**Search for Dark Matter I**
T 17.1–17.8	Mon	16:15–18:15	KS H C	**Neutrino Astronomy I**
T 18.1–18.8	Mon	16:15–18:15	KS 00.004	**Methods in Astroparticle Physics I**
T 19.1–19.8	Mon	16:15–18:15	KS 00.005	**Gravitational Waves I**
T 20.1–20.6	Mon	16:15–17:45	KS 00.006	**Cosmic Rays I**
T 21.1–21.3	Tue	11:00–12:30	AudiMax	**Invited Overview Talks II**
T 22.1–22.9	Tue	16:15–18:30	AudiMax	**Neutrino Physics II**
T 23.1–23.8	Tue	16:15–18:15	KH 00.011	**Top Physics I**
T 24.1–24.8	Tue	16:15–18:15	KH 00.014	**Standard Model Physics II**
T 25.1–25.8	Tue	16:15–18:15	KH 00.016	**Higgs Physics III**
T 26.1–26.5	Tue	16:15–17:30	KH 00.020	**Methods in Particle Physics II**

T 27.1–27.8	Tue	16:15–18:15	KH 00.023	**Muon Detectors**
T 28.1–28.10	Tue	16:15–18:45	KH 00.024	**Data, AI, Computing, Electronics III**
T 29.1–29.8	Tue	16:15–18:15	KH 01.011	**Flavour Physics II**
T 30.1–30.9	Tue	16:15–18:30	KH 01.012	**Silicon Detectors III**
T 31.1–31.8	Tue	16:15–18:15	KH 01.014	**Scintillator Detectors I**
T 32.1–32.9	Tue	16:15–18:30	KH 01.019	**Higgs Physics IV**
T 33.1–33.8	Tue	16:15–18:15	KH 01.022	**Silicon Detectors IV**
T 34.1–34.10	Tue	16:15–18:45	KH 02.014	**Data, AI, Computing, Electronics IV**
T 35.1–35.9	Tue	16:15–18:30	KH 02.018	**Searches/BSM II**
T 36.1–36.9	Tue	16:15–18:30	AM 00.014	**Search for Dark Matter II**
T 37.1–37.9	Tue	16:15–18:30	KS H C	**Neutrino Astronomy II**
T 38.1–38.9	Tue	16:15–18:30	KS 00.004	**Methods in Astroparticle Physics II**
T 39.1–39.6	Tue	16:15–17:45	KS 00.005	**Gravitational Waves II**
T 40.1–40.9	Tue	16:15–18:30	KS 00.006	**Cosmic Rays II**
T 41.1–41.3	Wed	11:00–12:30	AudiMax	**Invited Overview Talks III**
T 42.1–42.1	Wed	12:40–13:40	KS H C	**Annual Meeting of Young Scientists in High Energy Physics (yHEP)**
T 43.1–43.4	Wed	13:45–15:45	AudiMax	**Invited Topical Talks I**
T 44.1–44.4	Wed	13:45–15:45	MED 00.915	**Invited Topical Talks II**
T 45.1–45.9	Wed	16:15–18:30	AudiMax	**Neutrino Physics III**
T 46.1–46.7	Wed	16:15–18:00	KH 00.011	**Top Physics II**
T 47.1–47.8	Wed	16:15–18:15	KH 00.014	**Higgs Physics V**
T 48.1–48.8	Wed	16:15–18:15	KH 00.020	**Methods in Particle Physics III**
T 49.1–49.8	Wed	16:15–18:15	KH 00.023	**Electronics, Trigger, DAQ II**
T 50.1–50.7	Wed	16:15–18:00	KH 00.024	**Data, AI, Computing, Electronics V**
T 51.1–51.10	Wed	16:15–18:45	KH 01.011	**Flavour Physics III**
T 52.1–52.8	Wed	16:15–18:15	KH 01.012	**Silicon Detectors V**
T 53.1–53.9	Wed	16:15–18:30	KH 01.014	**Scintillator Detectors II**
T 54.1–54.8	Wed	16:15–18:15	KH 01.019	**Higgs Physics VI**
T 55.1–55.10	Wed	16:15–18:45	KH 01.022	**Silicon Detectors VI**
T 56.1–56.6	Wed	16:15–17:45	KH 02.014	**Data, AI, Computing, Electronics VI**
T 57.1–57.9	Wed	16:15–18:30	KH 02.016	**Outreach I**
T 58.1–58.7	Wed	16:15–18:00	KH 02.018	**Searches/BSM III**
T 59.1–59.9	Wed	16:15–18:30	KS H C	**Neutrino Astronomy III**
T 60.1–60.9	Wed	16:15–18:30	KS 00.004	**Methods in Astroparticle Physics III**
T 61.1–61.6	Wed	16:15–17:45	KS 00.005	**Gamma Astronomy I**
T 62.1–62.8	Wed	16:15–18:15	KS 00.006	**Cosmic Rays III**
T 63.1–63.3	Thu	11:00–12:30	AudiMax	**Invited Overview Talks IV**
T 64.1–64.4	Thu	13:45–15:45	AudiMax	**Invited Topical Talks III**
T 65.1–65.4	Thu	13:45–15:45	MED 00.915	**Invited Topical Talks IV**
T 66.1–66.7	Thu	16:15–18:00	AudiMax	**Neutrino Physics IV**
T 67.1–67.7	Thu	16:15–18:00	KH 00.011	**Top Physics III**
T 68.1–68.6	Thu	16:15–17:45	KH 00.014	**Standard Model Physics III**
T 69.1–69.6	Thu	16:15–17:45	KH 00.020	**Methods in Particle Physics IV**
T 70.1–70.7	Thu	16:15–18:00	KH 00.023	**Electronics, Trigger, DAQ III**
T 71.1–71.7	Thu	16:15–18:00	KH 00.024	**Data, AI, Computing, Electronics VII**
T 72.1–72.8	Thu	16:15–18:15	KH 01.011	**Flavour Physics IV**
T 73.1–73.6	Thu	16:15–17:45	KH 01.012	**Calorimeters I**
T 74.1–74.7	Thu	16:15–18:00	KH 01.014	**Gaseous Detectors II**
T 75.1–75.8	Thu	16:15–18:15	KH 01.019	**Higgs Physics VII**
T 76.1–76.8	Thu	16:15–18:15	KH 01.022	**Silicon Detectors VII**
T 77.1–77.8	Thu	16:15–18:15	KH 02.013	**Higgs Physics VIII**
T 78.1–78.8	Thu	16:15–18:15	KH 02.014	**Flavour Physics V**
T 79.1–79.6	Thu	16:15–17:45	KH 02.018	**Searches/BSM IV**
T 80.1–80.6	Thu	16:15–17:45	KH 02.019	**Axions/ALPs II**
T 81.1–81.6	Thu	16:15–17:45	AM 00.014	**Search for Dark Matter III**
T 82.1–82.7	Thu	16:15–18:00	KS H C	**Neutrino Astronomy IV**
T 83.1–83.7	Thu	16:15–18:00	KS 00.004	**Methods in Astroparticle Physics IV**
T 84.1–84.6	Thu	16:15–17:45	KS 00.005	**Gamma Astronomy II**
T 85.1–85.6	Thu	16:15–17:45	KS 00.006	**Cosmic Rays IV**
T 86	Thu	18:30–19:30	AM 00.014	**Members' Assembly**

T 87.1–87.6	Fri	9:00–10:30	AudiMax	**Neutrino Physics V**
T 88.1–88.6	Fri	9:00–10:30	KH 00.011	**Top Physics IV**
T 89.1–89.6	Fri	9:00–10:30	KH 00.014	**Higgs Physics IX**
T 90.1–90.5	Fri	9:00–10:15	KH 00.015	**Calorimeters II**
T 91.1–91.5	Fri	9:00–10:15	KH 00.020	**Methods in Particle Physics V**
T 92.1–92.5	Fri	9:00–10:15	KH 00.023	**Electronics, Trigger, DAQ IV**
T 93.1–93.5	Fri	9:00–10:15	KH 00.024	**Data, AI, Computing, Electronics VIII**
T 94.1–94.6	Fri	9:00–10:30	KH 01.011	**Flavour Physics VI**
T 95.1–95.6	Fri	9:00–10:30	KH 01.014	**Gaseous Detectors III**
T 96.1–96.6	Fri	9:00–10:30	KH 01.020	**Outreach II**
T 97.1–97.5	Fri	9:00–10:15	KH 01.022	**Silicon Detectors VIII**
T 98.1–98.6	Fri	9:00–10:30	KH 02.013	**Higgs Physics X**
T 99.1–99.6	Fri	9:00–10:30	KH 02.014	**Searches/BSM V**
T 100.1–100.3	Fri	9:00– 9:45	KH 02.016	**Miscellaneous**
T 101.1–101.6	Fri	9:00–10:30	KH 02.018	**Searches/BSM VI**
T 102.1–102.6	Fri	9:00–10:30	KH 02.019	**Axions/ALPs III**
T 103.1–103.5	Fri	9:00–10:15	AM 00.014	**Search for Dark Matter IV**
T 104.1–104.6	Fri	9:00–10:30	KS H C	**Neutrino Astronomy V**
T 105.1–105.6	Fri	9:00–10:30	KS 00.004	**Methods in Astroparticle Physics V**
T 106.1–106.5	Fri	9:00–10:15	KS 00.005	**Gamma Astronomy III**
T 107.1–107.3	Fri	11:00–12:30	AudiMax	**Invited Overview Talks V**

Members' Assembly of the Particle Physics Division

Thursday 18:30–19:30 AM 00.014

T 1: Invited Overview Talks I

Time: Monday 14:45–15:45 Location: AudiMax

Invited Overview Talk T 1.1 Mon 14:45 AudiMax
Top-quark physics in a new regime: precision, effective field theory, and the top-quark pair production threshold — •Knut Zoch — CERN, Geneva, Switzerland

The top quark, the heaviest known elementary particle, plays a central role in testing the Standard Model and probing physics at the highest energy scales. Building on the legacy of the Run 2 data set and motivated by the growing Run 3 program, the LHC experiments continue to deliver a broad range of results that advance our understanding of top-quark production and interactions.

This talk will review recent experimental highlights from the ATLAS and CMS collaborations, including measurements of top-quark production in association with the Higgs boson, effective field theory interpretations of top-quark observables, improved determinations of the top-quark mass, and first results exploiting Run 3 data. Particular emphasis will be placed on measurements of top-quark pair production near threshold, where bound-state-like effects (“toponium”) become accessible and open a new window on strong-interaction dynamics in the top-quark sector.

Together, these results illustrate how precision measurements and novel kinematic regimes in top-quark physics continue to sharpen our picture of the Standard Model and constrain possible extensions.

Invited Overview Talk T 1.2 Mon 15:15 AudiMax
Monte Carlo event generators for the HL-LHC — •Steffen Schumann — Institut für Theoretische Physik, Georg-August Universität Göttingen

Monte Carlo event generators are indispensable tools for the analysis and interpretation of high-energy collider experiments. They provide detailed simulations of scattering events at the level of observable particles that reflect our current understanding of the dynamics and interactions of the fundamental constituents of nature. In this talk an overview of the status of Monte Carlo event generators will be given. Guided by the experimental needs and requirements of the High-Luminosity LHC, areas of active developments will be highlighted. This includes, among others, the enhancement of the perturbative accuracy of the predictions and means to improve the computational efficiency of the simulations. A strategic approach of event generator development will allow these tools to be further improved and systematic uncertainties to be reduced, facilitating future experimental success.

T 2: Neutrino Physics I

Time: Monday 16:15–18:15 Location: AudiMax

T 2.1 Mon 16:15 AudiMax
Status Report on the ECHo Experiment — •Raghav Pandey for the ECHo-Collaboration — Kirchhof Institute for Physics, INF 227, Heidelberg 69120

The analysis of the endpoint region of β-decay or electron capture decay spectra is a model independent method for the determination of the effective electron (anti-)neutrino mass. The ECHo collaboration aims to achieve this goal by preparing a high energy resolution and high statistics measurement of the electron capture spectrum in ^{163}Ho. This experiment uses Metallic Magnetic Calorimeters enclosing samples of the ^{163}Ho source. The first phase of the experiment — called ECHo-1k — has been completed with the publication of the best limit on the effective electron neutrino mass obtained from ^{163}Ho, $m_{\nu_e} < 15$ eV(90%C.L.).

We present the results obtained in the ECHo-1k experiment and discuss the development of the next phase of ECHo, the ECHo-LE (Large Experiment). In ECHo-LE, 20000 MMC detectors will be read out using a microwave SQUID multiplexing scheme with the goal of acquiring 10^{13} events at a high energy resolution. The achievement of such a spectra allows for a sub-eV sensitivity on the effective electron neutrino mass.

T 2.2 Mon 16:30 AudiMax
Fitting of the endpoint region of the Ho-163 spectrum in the ECHo–1k experiment — •Lorenzo Calza — Kirchhoff Institute for Physics, Heidelberg University

The effective electron neutrino mass can be derived from the analysis of the endpoint region of electron capture spectra, since the finite mass distorts the spectral shape near the Q value. In ECHo the shape of the Ho-163 EC spectrum is studied. During the first phase of the ECHo experiment, more than 200 million Ho-163 events were acquired using 2 arrays of metallic magnetic calorimeters enclosing Ho-163. For a reliable analysis of the endpoint region, a precise calibration of the spectrum was obtained by applying a tailored procedure determined in a dedicated calibration measurement. Since theoretical models fail to provide an accurate analytical description of the spectral shape, we have tested two different approaches for the determination of a phenomenological function. The obtained functions were tested for stability of fit in the endpoint region of the acquired Ho-163 spectrum. We present the analysis of the ECHo-1k data leading to the present best limit of $m(\nu_e) < 15$ eV 90% confidence interval ($m(\nu_e) < 18$ eV 95% C.I.) and discuss the study of the systematic uncertainties.

T 2.3 Mon 16:45 AudiMax
Studies on general neutrino interactions with the KATRIN experiment — •Hanna Henke for the KATRIN-Collaboration — Institute for Astroparticle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

The Karlsruhe Tritium Neutrino (KATRIN) Experiment aims to determine the neutrino mass using precision spectroscopy of electrons from tritium β-decay. Recently, KATRIN published an improved upper bound of 0.45 eV at 90% C.L. [1] on the effective electron-neutrino mass. Beyond the neutrino mass measurement, KATRIN's high-precision spectroscopy enables searches for physics beyond the Standard Model, such as general neutrino interactions (GNI). These interactions can manifest as subtle shape deformations in the measured energy spectrum. The GNI framework provides a model-agnostic approach by combining all theoretically allowed interaction terms into an effective field theory, describing energy-dependent spectral contributions as indicators of novel weak processes. Recently, first constraints on GNI based on KATRIN data were released [2]. This talk will give an overview of the GNI framework and analysis, and present further studies using KATRIN data.
This work is supported by the Helmholtz Association and by the Ministry for Education and research BMFTR (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6)
[1] DOI: 10.1126/science.adq9592,
[2] DOI: 10.1103/PhysRevLett.134.251801

T 2.4 Mon 17:00 AudiMax
Insight into the Analysis of the KATRIN Neutrino Mass Data — Chloé Goupy[1], Christoph Köhler[1], Susanne Mertens[1], •Jan Plössner[1], Richard Salomon[2], Alessandro Schwemmer[1], Jaroslav Štorek[3], Xaver Stribl[1,4], and Christoph Wiesinger[1] for the KATRIN-Collaboration — [1]Max-Planck-Institut für Kernphysik — [2]Universität Münster — [3]Karlsruher Institut für Technologie — [4]Technische Universität München

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 0.45 eV c^{-2} (90 % C.L.) has been set, including the data of the first five measurement campaigns. With data collection now complete after a total of 19 measurement campaigns, the available statistics have increased by more than a factor of six compared to the initial dataset. In this presentation, I will provide an update on the current status of the KATRIN neutrino mass analysis, including the data from the first 17 measurement campaigns, and discuss the neural network approach utilized for this analysis.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMFTR (grant numbers 05A23PMA, 05A23PX2, 05A23VK2, and 05A23WO6).

T 2.5 Mon 17:15 AudiMax

Magnetic-field compatibility of TRISTAN detectors for the KATRIN keV sterile neutrino search — •Simon Gentner — Karlsruhe Institute for Technology (KIT)

At the Karlsruhe Institute of Technology (KIT), a full-scale replica of the KATRIN experiment's detector system was developed to pretest the innovative TRISTAN detectors. This replica enables comprehensive testing and calibration of up to nine TRISTAN detector modules under controlled conditions, ensuring optimal performance before their integration into the KATRIN beamline in 2026. This upgrade will enhance KATRIN's sensitivity in the search for keV-scale sterile neutrinos. Preliminary results demonstrate that the TRISTAN modules deliver exceptional high-resolution for beta spectroscopy, which is essential for precise neutrino mass measurements and the exploration of potential new physics.

During operation in the KATRIN beamline, the detector modules will be exposed to a strong magnetic field. To investigate its influence on critical detector parameters, including energy resolution and signal rise time, dedicated measurements were performed using the replica system. This presentation will discuss these results and highlight the excellent properties of the TRISTAN detector modules.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMFTR (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6).

T 2.6 Mon 17:30 AudiMax

Current status of the next-generation neutrino mass experiment Project 8 — •Rene Reimann for the Project 8-Collaboration — Johannes Gutenberg Universität Mainz

The Project 8 experiment aims to probe the absolute neutrino mass through direct kinematic measurements of the tritium beta decay spectrum using cyclotron radiation emission spectroscopy (CRES). Future tritium beta decay experiments that aim for neutrino mass sensitivities below ∼200meV, must be operated with atomic tritium to avoid effects from rotational and vibrational final states of the daughter nucleus. The CRES technique has been demonstrated successfully with molecular tritium in a small cylindrical wave guide. For a competitive experiment, the CRES technique must be scaled up and be operated in combination with atomic tritium. Currently the CRES cavity apparatus is under commissioning, which will demonstrate the CRES technique with improved energy resolution within a cavity using an event-by-event reconstruction. The low-frequency apparatus is currently in its design phase and should demonstrate the coexistence of CRES electron detection and an atomic trap while increasing the effective volume and lowering the background magnetic field compared to previous CRES experiments. In addition, atomic tritium sources at unprecedent fluxes are under development. In this contribution, I give a short overview of the current demonstrators, which pave the way to a full-scale neutrino mass experiment.

T 2.7 Mon 17:45 AudiMax

Offline data validation framework for JUNO — •Nurbakyt Amanbek[1,2] and Livia Ludhova[1,2] — [1]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstr. 1, D-64291 Darmstadt, Germany — [2]Institute of Physics and EC PRISMA+, Johannes Gutenberg Universität Mainz, Mainz, Germany

The Jiangmen Underground Neutrino Observatory (JUNO) is a multipurpose liquid-scintillator detector in China that aims to determine the neutrino mass ordering by measuring reactor antineutrinos at a 52.5 km baseline. The central detector contains 20 kton of liquid scintillator and is instrumented with 17,612 large (20") PMTs and 25,600 small (3") PMTs, providing high light yield and excellent energy resolution. After physics data taking began on August 26, 2025, JUNO reported the most precise measurements of Δm^2_{12} and $\sin^2\theta_{12}$ from 59.1 days of data - a level of precision that requires stable detector performance and consistently low-background, high-quality data. To monitor data quality, JUNO operates a semi-automated data-validation framework that performs prompt (online) and offline monitoring. About 10% of the data are validated promptly online to allow us to quickly react in case of major problems, while more detailed offline validation is performed once the full dataset of each run becomes available. We monitor various properties at the level of single channels, events, and the whole run. We also monitor longer-term stability of the detector to identify potential slower changes. This contribution presents the offline validation workflow and highlights its essential role in securing the data quality required for JUNO's precision oscillation program.

T 2.8 Mon 18:00 AudiMax

Measurement of Solar Neutrino Oscillation Parameters with the First JUNO Data — •Cristobal Morales Reveco[1,2,3], Nurba Amanbek[1,3], Tim Charisse[1,3], Ze Chen[1,3], Livia Ludhova[1,3], Marco Malabarba[1,3], Mariam Rifai[1,2,3], Sahar Safari[1,3], Ujwal Santhosh[1,3], and Rosmarie Wirth[1,3] — [1]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — [2]III. Physikalisches Institut B, RWTH Aachen University, 52062 Aachen, Germany — [3]Institute of Physics and EC PRISMA+, Johannes Gutenberg Universität Mainz, Mainz, Germany

The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kt liquid scintillator detector experiment located in the Jiangmen region, China. It is situated at an optimal distance of 52.5 km from multiple nuclear reactor cores and is designed for precision measurements of neutrino oscillation parameters and the determination of the neutrino mass ordering (NMO). In December 2024, construction was completed, and commissioning began by fully filling the detector with water. In February 2025, the water in the inner detector started to be replaced with liquid scintillator, a process that continued until the end of August of the same year. This talk presents results from 59.1 days of data, achieving a world-leading measurement of the solar oscillation parameters. It will focus on the analysis strategy: signal event and data-driven background selections, the estimation of residual backgrounds, uncertainties, and the fit strategy used to extract the solar oscillation parameters.

T 3: Standard Model Physics I

Time: Monday 16:15–18:00 Location: KH 00.014

T 3.1 Mon 16:15 KH 00.014

Strategy for constraining multi-parton interactions at the LHC using Z boson events — •Ek-ong Atthaphan and Ynyr Harris — University of Bonn, Bonn, Germany

Multi-Parton Interactions (MPI) occur in every proton-proton collision at the CERN Large Hadron Collider and play a crucial role in the modelling of soft QCD processes and observables at low momentum transfer. In particular, an accurate description of Z-boson production at low transverse momentum requires a detailed understanding of MPI effects. In this talk, a novel method for directly measuring the number of MPI scatters in individual pp events is presented. The MPI multiplicity is extracted from a fit to the azimuthal two-particle correlation function. A comparison of this method applied to ATLAS data and Pythia Monte Carlo simulations demonstrates sensitivity to the MPI model parameters $p_{T,0}$ and $p_{T,min}$, providing new constraints on their values for LHC collisions.

T 3.2 Mon 16:30 KH 00.014

Phenomenology of heavy flavour jet angularities at hadron colliders — Andrea Ghira[1], Lorenzo Mai[2], Simone Marzani[2], Daniel Reichelt[3], Steffen Schumann[4], and •Leon Stöcker[4] — [1]Technical University of Munich, TUM School of Natural Sciences, Physics Department, Garching, Germany — [2]Dipartimento di Fisica, Universita di Genova and INFN, Sezione di Genova, Italy — [3]CERN, Theoretical Physics Department, Geneva, Switzerland — [4]Institut für Theoretische Physik, Georg-August-Universität Göttingen, Germany

We compute resummed and matched predictions for jet angularities in hadronic Z+jet events, where the jet is initiated by a b quark. The analysis is performed both with and without grooming the candidate jets using the SoftDrop algorithm. Mass effects are consistently included at both fixed-order and resummed levels. Our theoretical predictions also incorporate non-perturbative corrections from the underlying event and hadronisation, implemented through parton-to-hadron transfer matrices extracted from dedicated Sherpa Monte Carlo simulations. Finally, we compare our results with previous implementations in order to quantify the impact of mass effects.

T 3.3 Mon 16:45 KH 00.014

Triple differential Z+Jet cross section measurement — •Cedric Verstege and Klaus Rabbertz — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Germany

We present a measurement of the triple-differential production cross section of Z($\rightarrow \mu\mu$)+jet events in proton-proton collisions at $\sqrt{s}$ = 13 TeV recorded with the CMS detector during Run 2, corresponding to 138 fb^{-1}. The cross section is measured simultaneously in three dimensions defined by the transverse momentum of the muon pair, half of the absolute rapidity separation between the muon pair and the leading jet, and the rapidity boost of their center-of-mass system. This choice of observables provides sensitivity to the scattering angle and to the fractional momenta of the initial-state partons. After unfolding for detector effects, the results at particle level are compared to NNLO QCD predictions supplemented with electroweak and non-perturbative corrections, as well as to predictions from state-of-the-art Monte Carlo event generators.

T 3.4 Mon 17:00 KH 00.014

Estimation of α_s from dijet/Z+jet CMS data — •Johannes Gässler — Schlossgartenstraße 52, 76327 Pfinztal, Germany

In a recent CMS analysis (Eur. Phys. J. C 85, 72 (2025)) the 2016 multidifferential dijet cross sections were published. This also included fits of the strong coupling constant and the proton structure to the data with results of $\alpha_s = 0.1179 \pm 0.0019$ for the double-differential binning and $\alpha_s = 0.1181 \pm 0.0022$ for the triple-differential binning respectively. I will present the results of a re-analysis of the data using complete NNLO predictions (taken from Phys.Rev.Lett. 135 (2025) 3, 031903) in comparison to the leading-color approximation employed previously. Moreover, I upgraded the xFitter package to the latest version, providing access to improved theory settings. I am extending the analysis to also include CMS Z+jet data with the ultimate goal of a combined fit using both datasets.

T 3.5 Mon 17:15 KH 00.014

Data-driven background estimation in EW VBF-Zjj ATLAS Analysis — •Simone Ruscelli — Technische Universität Dortmund (Germany)

Measurements exploiting weak vector-boson fusion (VBF) processes have become increasingly prominent at the Large Hadron Collider (LHC). Among these are studies of electroweak production of two jets in association with a weak boson (EW Vjj), a process highly sensitive to the VBF mechanism and to the gauge structure of the Standard Model, and potential anomalous weak-boson self-interactions. These measurements rely on precise theoretical predictions and Monte Carlo event generators, which are used to model electroweak processes, optimise event selections, and isolate the electroweak signal from dominant backgrounds. The results presented here employ the ABCD statistical method to estimate the strong-Zjj (QCD Zjj) background in signal-enriched regions, using fits to relevant kinematic distributions. The studies are based on $\sqrt{s}$ = 13 TeV pp collision data collected by the ATLAS detector between 2015 and 2018.

T 3.6 Mon 17:30 KH 00.014

Improvement of Parton Distribution Functions through the ATLAS W-boson Measurement at High Transverse Masses — •Luca Nicastro, Tim Frederik Beumker, Frank Ellinghaus, and Johanna Wanda Kraus — Bergische Universität Wuppertal

High-precision measurements of W bosons at large transverse masses offer sensitivity to the proton*s parton distribution functions (PDFs), particularly in the high Bjorken-x region. In this work, the impact of the recently published ATLAS Run-2 measurement of double-differential charged-current Drell-Yan cross sections at $\sqrt{s}$ = 13 TeV is investigated. Using the `xFitter` framework, the study assesses how this dataset can refine existing PDF sets through profiling. Different analysis strategies, including the treatment of lepton channels, the choice between additive and multiplicative electroweak corrections, and the use of charge asymmetries, are systematically compared. The results demonstrate which configurations yield the strongest quantitative constraints on specific PDF components and illustrate these constraints.

T 3.7 Mon 17:45 KH 00.014

Production of hadronically-decaying boosted vector bosons reconstructed as large-radius jets at the ATLAS experiment — •Donna Maria Mattern and Chris Malena Delitzsch — TU Dortmund, Fakultät Physik

At the Large Hadron Collider (LHC), W and Z bosons are often produced with large Lorentz boosts due to the high energies of the proton-proton collisions. When such boosted vector bosons (BVBs) decay hadronically, they are reconstructed as large-radius jets ($R = 1.0$) at the ATLAS experiment. These large-radius jets pass through a chain of different calibration steps, including an in-situ jet energy scale correction to account for differences between data and Monte Carlo simulation, before they can be used in analyses. To separate BVB jets from the much more abundantly produced background jets from quantum-chromodynamic (QCD) processes at the LHC, their substructure is considered, which describes the energy flow within the large-radius jet. Using a neutral-network based tagger that relies on substructure information and is decorrelated with the input large-radius jet's mass, the background events can be suppressed. This talk discusses important aspects of the cross-section measurement of hadronically-decaying BVBs in association with jets.

T 4: Higgs Physics I

Time: Monday 16:15–18:15 Location: KH 00.016

T 4.1 Mon 16:15 KH 00.016

Search for non-resonant Higgs boson pair production in dilepton final states of the bbWW decay mode at CMS — •Lara Markus, Matteo Bonanomi, Mathis Frahm, Johannes Haller, Balduin Letzer, and Matthias Schröder — Institut für Experimentalphysik, Universität Hamburg

The trilinear coupling of the Higgs boson is related to the shape of the Higgs potential, which makes it a crucial parameter of the Standard Model. The trilinear coupling can be directly probed by measuring the cross section of Higgs boson pair production in proton-proton collisions at the LHC.
A search for non-resonant Higgs boson pair production is presented, targeting final states where one Higgs boson decays to a pair of bottom quarks and the other Higgs boson decays to two W bosons, with subsequent decays of the W bosons into leptons and neutrinos. The analysis is performed on data collected at a center-of-mass energy of 13.6 TeV by the CMS detector in 2022 and 2023, with a corresponding integrated luminosity of 62.4 fb^{-1}. Events are selected based on the b-tagged jets multiplicity, and state-of-the-art neural network classifiers are used to enhance the sensitivity to the rare signal topology. Upper limits are set on the Higgs boson pair production cross section and as a function of the trilinear coupling strength.

T 4.2 Mon 16:30 KH 00.016

Search for Semiboosted Higgs Pair Production From Vector Boson Fusion in the Single Lepton $b\bar{b}W^+W^-$ Final State Using the ATLAS Detector — •Stefan Brückner, Lars Linden, Valerio d'Amico, Celine Stauch, Patrick Rudolph Schumacher, and Otmar Biebel — LMU Munich

The discovery of the Higgs boson solved one of the biggest problems in the standard model, the generation of particle masses. However, one property that is still not well known is the quartic coupling of a Higgs boson pair to a pair of electroweak gauge bosons. A process involving this coupling is the Di-Higgs production via vector boson fusion(VBF), which is the second most common production mode at LHC. The analysis in this talk focuses on events in the $b\bar{b}W^+W^-$ final state with a single lepton, using a semiboosted approach. In this semiboosted scenario, one of the two objects, either the $H \rightarrow b\bar{b}$ or the W boson, which decays hadronically, is represented by a large radius jet. Some results of the general kinematics of the process and the event selection strategy for the semiboosted approach will be presented in the talk.

T 4.3 Mon 16:45 KH 00.016

Search for Boosted Higgs Pair Production From Vector Boson Fusion in the Single Lepton $b\bar{b}W^+W^-$ Final State Using the ATLAS Detector — •Celine Stauch, Stefan Brückner, Lars Linden, Valerio d'Amico, Patrick Schumacher, and Otmar Biebel — LMU Munich

While the discovery of the Higgs boson solved one of the biggest problems in the standard model, even more than 10 years after its discovery, not all of its properties are well know. One of these is the quartic coupling of a Higgs boson pair to a pair of electroweak gauge bosons. A process suited to constrain this coupling is given by Di-Higgs production via vector boson fusion (VBF), the second most common production mode at LHC.
The presented search for VBF Di-Higgs production investigates the $b\bar{b}W^+W^-$ final state with a single lepton. For this study a boosted approach is investigated, where Large Radius jets represent the hadronically decaying W and the $H \to b\bar{b}$. This talk presents the Event Selection strategy using ATLAS run 2 datasets and first results for analysis optimizations to increase sensitivity.

T 4.4 Mon 17:00 KH 00.016

Search for Higgs Boson Pair Production in Three-Lepton Final States with the ATLAS Detector — Anamika Aggarwal, Volker Büscher, Christian Schmitt, •Niklas Schmitt, and Duc Bao Ta — Johannes Gutenberg-University, Mainz

After the discovery of the Higgs boson in 2012 at the LHC, many of its properties have already been determined precisely using 139 fb^{-1} of proton-proton collisions at $\sqrt{s}$ = 13 TeV. 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 the physics of the universe. 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.

This talk will give an overview about the three-lepton analysis, which relies on neural networks to distinguish the signal processes from all SM backgrounds. In addition, a dedicated treatment of leptons overlapping with jets is described, improving the sensitivity due to spin correlations in semi-leptonic $H \to WW$ decays. Finally, the status of the Run 2 plus partial Run 3 analysis, based on a combined dataset of about 300 fb^{-1}, will be shown.

T 4.5 Mon 17:15 KH 00.016

HH Analysis with Multileptons Using Run-2 ATLAS Data — •Ondrej Kulhanek and André Sopczak — CTU in Prague

The latest results with Run-2 ATLAS data are presented for the search HH in the multilepton channel.

T 4.6 Mon 17:30 KH 00.016

Studies towards a search for HHH production in the 4b2W channel in dilepton final states with CMS — •Parth Patil, Johannes Haller, Lara Markus, Mathias Frahm, Matteo Bonanomi, and Matthias Schröder — Institut für Experimentalphyisk, Universität Hamburg

The quartic coupling of the Higgs boson is an important parameter of the Standard Model (SM) Higgs sector and is related to the shape of the Higgs potential. Triple Higgs boson (HHH) production offers a direct probe of the quartic coupling. In the SM, HHH production is an extremely rare process evading current experimental sensitivity; however, the HHH production cross section can become large for non-SM scenarios, motivating a search for this process.

In this talk, studies towards a search for HHH production are presented, targeting events in which two Higgs bosons decay into bottom quark-antiquark pairs and one Higgs boson decays into a pair of W bosons, both of which decay leptonically. The analysis uses simulated data of the CMS experiment, corresponding to data-taking conditions at a center-of-mass energy of 13.6 TeV. Events are categorised based on the dilepton mass and b-tagged jet multiplicities, and deep neural networks are employed to discriminate the small signal from SM background processes.

Finally, a maximum likelihood fit is performed to establish expected exclusion limits on the HHH production cross section and constrain the quartic Higgs coupling.

T 4.7 Mon 17:45 KH 00.016

gg→HH NLO EW corrections in the forward limit — •Dominik Grau[1], Daniel Stremmer[1], Matthias Steinhauser[1], Joshua Davies[2], and Kay Schönwald[3] — [1]Karlsruher Institut für Technologie, Karlsruhe, Deutschland — [2]University of Liverpool, Liverpool, United Kingdom — [3]Cern, Genève, Switzerland

In this talk, we present the calculation of the NLO EW corrections to di-Higgs production via gluon fusion. We compute the electroweak amplitude using analytical approximations around the forward limit, which cover large parts of the phase space with sufficient accuracy. Our results are given in symbolic form, offering flexibility with respect to parameter value and renormalization scheme choices.

T 4.8 Mon 18:00 KH 00.016

Electroweak corrections to Higgs boson pair production: The light quark case — Marco Bonetti[1], Gudrun Heinrich[2], •Philipp Rendler[2], and William J. Torres Bobadilla[3] — [1]Institute for Theoretical Physics, University of Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany — [2]Institute for Theoretical Physics, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany — [3]Department of Mathematical Sciences, University of Liverpool, Liverpool L69 3BX, U.K.

We present a fully analytic computation of the electroweak corrections to Higgs-boson pair production mediated by light quarks in both the gluon and quark-antiquark channels. The calculation is performed using the method of differential equations, employing a large mass expansion to generate boundary functions. We implement the results in the POWHEG BOX framework for phenomenological studies. The corrections to the differential cross section are found to be sizable, reaching up to -30% in the gluon channel and +10% in the quark channel near the production threshold. The quark channel has not been considered before in calculations of the NLO electroweak corrections to Higgs-boson pair production.

T 5: Methods in Particle Physics I

Time: Monday 16:15–18:15 Location: KH 00.020

T 5.1 Mon 16:15 KH 00.020

Machine Learning Methods for Charged-Particle Identification at Belle II — •Robert Mundzeck[1,2], Martin Bartl[1], Hans-Günther Moser[1], and Stefan Wallner[1] — [1]Max Planck Institute for Physics, Garching, Germany — [2]Technical University of Munich

We present recent advances in charged-particle identification at the Belle II experiment at KEK, Japan. So far, particle identification at Belle II has relied on a likelihood-based method that combines information from six subdetectors to distinguish between different particle species. Recently, a neural-network-based classifier has been developed that complements and improves upon this conventional approach. We report on a study comparing the neural network performance to an alternative classifier based on boosted decision trees. We also present the approaches of further optimization of the neural network, aimed at optimizing particle identification performance at Belle II.

T 5.2 Mon 16:30 KH 00.020

Validation of the Graph Neural Network tracking at Belle II — •Jonas Lotz and Slavomira Stefkova — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn, Bonn, Germany

A novel end-to-end multi-track reconstruction algorithm based on a graph neural network (GNN) architecture was developed for the Belle II collaboration (Comput Softw Big Sci 9, 6 (2025)). These studies demonstrate substantial improvements in key performance metrics such as tracking efficiency, with particularly strong gains for tracks originating from displaced vertices. In addition, different hit-to-track association provides an opportunity for improved event clean-up, which may be particularly useful for missing energy decays. In this presentation, building on this development, the applicability of this GNN-based tracking algorithm in the context of searches for $B^0 \to K^0_s \nu\bar{\nu}$ decays will be studied. We will focus on validating the algorithm against established tracking methods and assessing potential benefits for rare decay searches. The talk will present the status of integrating the new GNN tracking framework into the $B^0 \to K^0_s \nu\bar{\nu}$ analysis.

T 5.3 Mon 16:45 KH 00.020

Towards a Complete Tracking Concept for ILD@FCC-ee — Frank Gaede[1], Daniel Jeans[3], Jenny List[1], Thomas Madlener[1], and •Victor Schwan[1,2] — [1]Deutsches Elektronen-Synchrotron DESY — [2]Universität Hamburg — [3]Institute of Particle and Nuclear Studies, KEK, Tsukuba, Japan

The International Large Detector (ILD) concept was originally conceived for the International Linear Collider (ILC). In-depth simulations benchmarked against the performance of prototype components have shown that ILD in its ILC incarnation is exceptionally well suited to pursuing the physics program of a linear e^+e^- collider at energies from the Z pole to the TeV regime. Recently, the ILD collaboration has begun investigating how the detector concept would need to be modified to operate successfully in the experimental environment of a circular e^+e^- collider, and ILD is now being evaluated as a candidate detector concept for FCC-ee. In particular, the interaction region and the machine-detector interface (MDI) require substantial changes to accommodate accelerator elements and to withstand background levels. This contribution presents recent progress on beam-induced background (BIB) estimates in ILD's tracking systems, along with ongoing developments in adapting ILD tracking and reconstruction to FCC-ee operating conditions. Together, these efforts lay the groundwork for enabling full-simulation physics studies with ILD@FCC-ee and for further optimizing the detector concept for the FCC-ee environment.

T 5.4 Mon 17:00 KH 00.020

Tracking Performance Studies for the Mu3e Experiment — •Elija Engelhardt, Tamasi Kar, and André Schöning for the Mu3e-Collaboration — Physikalisches Institut, Universität Heidelberg, Germany

The Mu3e experiment aims to find the charged lepton flavour violating decay $\mu^+ \to e^+e^-e^+$ at the Paul Scherrer Institute (PSI). Phase 1 of the experiment will reach a single event sensitivity of 2×10^{-15} on the branching ratio, and Phase 2 aims for a sensitivity down to 10^{-16}[1]. In order to reach this level of sensitivity, a high muon stopping rate (2 GHz) and a large track reconstruction efficiency are required. The tracking detector comprises of four pixel detector layers based on the HV-MAPS technology for precise position measurements, scintillating fibres, and scintillating tiles for precise timing. The tracking algorithm used is based on the General Triplet Track Fit (GTTF) [2].

The tracking efficiency, purity, and various parameter resolutions are studied and improved using Monte Carlo simulations and data taken during the June 2025 commissioning run. The track reconstruction efficiency and purity are defined with simulation truth as reference. Various track parameter cuts are investigated to balance fake rate and efficiency. Results from the tracking performance optimisation studies will be presented.

[1] The Mu3e Collaboration. Technical design of the phase I Mu3e experiment. doi: 10.1016/j.nima.2021.165679
[2] A. Schöning. A general track fit based on triplets. doi: 0.1016/j.nima.2025.170391

T 5.5 Mon 17:15 KH 00.020

Vertex Reconstruction Using the General Triplet Track Fit for the Mu3e Experiment — •Thomas Schwartze, André Schöning, Tamasi Kar, and David Fritz for the Mu3e-Collaboration — Physikalisches Institut, Heidelberg University, Germany

The Mu3e Experiment at the Paul Scherrer Institut (PSI) searches for the charged-lepton-flavour-violating decay $\mu^+ \to e^+e^-e^+$. Mu3e aims to improve the sensitivity to the exclusion-limit of this process by four orders of magnitude. It uses a high-intensity muon beam to deliver up to 2 GHz of muons to a stationary target. To efficiently distinguish signal from background, a fast and accurate reconstruction of the common vertex is essential.

In this talk, an extension to the General Triplet Track Fit (GTTF) [1] is presented that is able to reconstruct the vertex of three-track combinations. The GTTF is a track fitting algorithm based on triplets. It is highly parallelizable and therefore, for example, well suited for GPU implementation. It has been extended to reconstruct the position of the decay vertex by treating it as an additional pseudo-hit. The performance of this vertex reconstruction is evaluated using both Monte Carlo simulations and data from the June 2025 commissioning run at PSI.

[1] A.Schöning, A general track fit based on triplets, doi: 10.1016/j.nima.2025.170391.

T 5.6 Mon 17:30 KH 00.020

Improving secondary vertexing for HL-LHC: Algorithm research using ACTS and ODD — •Diptaparna Biswas[1], Markus Cristinziani[1], Margret Keuper[2], Adrian Szymon Kosmala[3], Vadim Kostyukhin[1], and Paweł Swoboda[3] — [1]Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen, Germany — [2]Data and Web Science Group, Universität Mannheim, Germany — [3]Heinrich-Heine-Universität Düsseldorf, Germany

The High-Luminosity Large Hadron Collider (HL-LHC) offers unprecedented discovery potential but introduces extreme pileup conditions that challenge standard reconstruction techniques. Accurate Secondary Vertex (SV) reconstruction is critical for precision flavour physics and BSM searches. This contribution presents research utilizing A Common Tracking Software (ACTS) to develop and benchmark robust SV algorithms tailored for this environment. While ACTS is established for tracking R&D, this work expands its scope to address the distinct complexities of vertexing. Using the Open Data Detector (ODD) for realistic HL-LHC simulations, we evaluate the performance of various algorithmic strategies, ranging from established techniques to novel approaches based on machine learning. We report on the current status in terms of the key metrics including vertex reconstruction efficiency, resolution and fake rates, demonstrating the viability of ACTS as a powerful platform for developing cross-experiment vertexing solutions for the HL-LHC era.

T 5.7 Mon 17:45 KH 00.020

Towards an implementation of ACTS for the Belle II experiment — •Marc-Philipp Thomas, Giacomo De Pietro, and Torben Ferber — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

Track reconstruction is a fundamental component of particle physics experiments, relying critically on robust and precise track fitting algorithms that must perform reliably across a wide range of particle momenta. The Belle II experiment at the asymmetric electron-positron SuperKEKB collider presents particular challenges for track fitting. These include particles with momenta ranging from a few tens of MeV to several GeV, and an asymmetric detector geometry.

In this talk, we discuss the integration of the experiment-independent ACTS (A Common Tracking Software) toolkit into the Belle II reconstruction chain. In the proposed workflow, track finding is performed within the Belle II Analysis Software Framework, while ACTS is used solely for track fitting. We will present the current status of this integration effort, including the first results on ACTS track fitting for the Silicon Vertex Detector, and a comparison with the current Belle II track-fitting approach in terms of reconstruction efficiency, parameter resolution, and robustness for low-momentum tracks.

T 5.8 Mon 18:00 KH 00.020

Track Reconstruction with the Pixel Detector for the Phase-2 Upgrade of the CMS High-Level Trigger — •Jan Gerrit Schulz[1,2], Alexander Schmidt[1], Marco Rovere[2], Elena Vernazza[2], Bruno Alves[2], Emanuele Coradin[2,3], Luca Ferragina[2,4], Marco Musich[2], and Felice Pantaleo[2] — [1]III. Physikalisches Institut A, RWTH Aachen University, Germany — [2]CERN, Switzerland — [3]Università di Padova & INFN, Italy — [4]Università di Bologna, Italy

The CMS detector will undergo an extensive upgrade for the upcoming High-Luminosity LHC, which will include the complete replacement of the inner tracking system. Event reconstruction algorithms must be adapted to the new geometry and the planned denser environment of up to 200 simultaneous proton-proton interactions. An important component of this event reconstruction in the High-Level Trigger (HLT) is pixel tracking, which forms the first step in the track reconstruction chain as well as a fast alternative for full tracking entirely. To exploit the full potential of the improved pixel detector, the CMS pixel tracking algorithm has been improved in various respects. This includes an extension of the coverage to parts of the outer tracker, an optimization of the parameters, and a new DNN-based track selection. This contribution provides an overview of these new developments.

T 6: Electronics, Trigger, DAQ I

Time: Monday 16:15–18:15 Location: KH 00.023

T 6.1 Mon 16:15 KH 00.023

Next-Generation Readout ASIC for DEPFET Pixel Detectors in 65-nm CMOS — •Vasiliki Gogolou, Hans Krüger, and Jochen Dingfelder — University of Bonn, Germany

The continued evolution of particle-physics experiments places increasing demands on the performance, efficiency, and integration density of readout electronics. As detector systems grow in channel count and as data rates accelerate, high-quality, low-noise readout chains become essential to preserve the precision of the underlying sensor technology. DEPFET (Depleted p-channel field effect transistor) pixel sensors play a key role in this landscape with successful applications ranging from high-energy physics vertex detectors such as those for the ILC and Belle II to advanced medical imaging systems. This work presents a next-generation readout integrated circuit for DEPFET matrices, implemented in a state-of-the-art 65-nm CMOS process node. The transition to a smaller feature size enables improved power-area efficiency while maintaining low noise. Each channel integrates a cascode transimpedance amplifier and a compact single-ended-to-differential stage, optimized to fully drive the input range of a high-speed, low-power SAR ADC (successive-approximation register analog-to-digital converter). The readout architecture is specifically designed to interface seamlessly with such ADCs, enabling a system that meets stringent constraints on power density and pixel pitch while delivering the precision required for future high-rate, high-resolution experiments.

T 6.2 Mon 16:30 KH 00.023

Firmware developments and hardware tests for the HL-LHC ATLAS Liquid Argon Signal Processor system — Peter Fischer, •Markus Helbig, Rainer Hentges, Arno Straessner, Johann C. Voigt, and Philipp Welle — Institut für Kern- und Teilchenphysik, TU Dresden

In the HL-LHC era, the ATLAS Liquid Argon Calorimeters will be equipped with the new LAr Signal Processors (LASP). This off-detector processing system based on Altera Agilex 7 FPGAs will perform energy reconstruction for all 182 468 detector cells at every bunch crossing in real time and provide them to the new trigger systems Global Event Processor (GEP) and the Forward Feature Extractor (fFEX) as well as the main readout.

To cope with the higher pile-up, the use of 1-dimensional Convolutional Neural Networks (CNNs) with up to 400 parameters for energy reconstruction has been studied as an alternative to the current Optimal Filter approach. Using efficient FPGA resource allocations, a sufficient number of CNN instances to process up to 384 cells are fit on a single FPGA, leaving enough resources for other components. Their implementation has been verified in standalone hardware setups based on FPGA development kits and LASP testboards.

Furthermore, the first Agilex-based prototype board has recently become available. On this board, the interfaces from the front-end and towards the trigger systems are implemented as optical transceivers using Samtec FireFly modules. Their performance is studied to guarantee reliable data transmission.

T 6.3 Mon 16:45 KH 00.023

The ATLAS Tile Calorimeter Trigger and Data Acquisition Interface: Final Design Overview and Validation Results — •Maximilian Köper and Thomas Junkermann — Kirchhoff-Institut für Physik, Heidelberg University

The ATLAS experiment is undergoing the Phase-II Upgrade to accommodate the High Luminosity LHC (HL-LHC), necessitating a complete redesign of the trigger and readout architectures to handle increased pile-up. This contribution focuses on the Tile Calorimeter's Trigger and Data Acquisition interface (TDAQi), an ATCA Rear Transition Module designed to bridge the off-detector electronics with the ATLAS Level-0 trigger systems.

Equipped with an AMD Kintex UltraScale+ FPGA, the TDAQi receives calibrated cell energies and computes trigger primitives at 40 MHz. Key processing tasks include forming coarse-granularity objects for electron/jet triggers, identifying muon hits, and sorting high-energy cells for the Global Trigger Processor. These operations must be executed within a strict 250 ns latency budget while managing high-speed links up to 11.2 Gbps.

We present the TDAQi design and its role in the real-time data path. The discussion focuses on the final hardware validation and integration tests required before the start of the in-house production phase. We report on the performance of the latest pre-production modules, which serve as the final verification step for the upcoming series assembly.

T 6.4 Mon 17:00 KH 00.023

Electron algorithm studies for the ATLAS forward Feature Extractor — •Florian Harz, Hannes Mildner, and Stefan Tapprogge — Institut für Physik, JGU, Mainz, Germany

The High-Luminosity LHC upgrade presents unprecedented challenges for real-time event selection in the ATLAS experiment, driven by significantly increased rates, pile-up conditions, and the need for fast, high-precision triggering. The forward Feature Extractor (fFEX) board, based on high-performance FPGAs, will play a central role in the Level-0 calorimeter trigger, enabling low-latency identification of electromagnetic signatures in the forward area. This presentation summarizes recent algorithmic studies performed for the fFEX electron identification pipeline, highlighting strategies that balance physics performance with the stringent timing and resource constraints inherent to FPGA-based processing. A sliding-window algorithm has been implemented in firmware to act as a baseline comparison as it has been used previously used in ATLAS calorimeter triggering. Building on this, the use of machine-learning approaches is explored with the goal to have a full implementation in firmware that surpasses the legacy sliding-window method.

T 6.5 Mon 17:15 KH 00.023

Development of the clustering algorithm for the LHCb Up-

grade II SciFi tracker — •Jan Sorokovski, Michael Lupberger, and Marco Gersabeck — Albert-Ludwigs-Universität Freiburg, Freiburg im Breisgau, Germany

The LHCb Upgrade II aims to increase the instantaneous luminosity by a factor of 5. To achieve that, many detector systems have to be upgraded to address the increased detector occupancy and pileup. This includes the new downstream tracker, the Mighty Tracker, which will combine silicon pixel sensors in the high-occupancy region and improved Scintillating Fibres (SciFi) in the remaining region.

One of the key challenges of the SciFi Tracker is the handling of the output of the advanced front-end chip. For that, the development of an efficient, real-time clustering algorithm capable of processing the increased data volume, while maintaining a high spatial resolution and track hit efficiency, is crucial. A major consideration are noise sources, which have to be identified, understood and characterised to provide robustness against noise and to improve overall performance.

In this presentation, an early algorithm design and noise considerations and studies are

T 6.6 Mon 17:30 KH 00.023

Full Path Data Injection for an FPGA-Based Data Acquisition System — •Bent Buttwill for the Mu3e-Collaboration — Institut für Kernphysik, Johannes Gutenberg-Universität Mainz

The Mu3e experiment, located at the Paul Scherer Institute in Switzerland, aims to study the charged-lepton-flavour violating decay $\mu^+ \to e^+e^+e^-$. To achieve the goal of probing the branching fraction beyond 10^{-15} in Phase I, the experiment is designed to detect 10^8 muon decays per second.

The FPGA-based data acquisition system for Mu3e is designed to handle a data production rate of approximately 100 Gbit/s. Its hardware is optimized for efficient resource utilization and sustained high-throughput operation. Continuous verification of the data pipeline during development is essential to ensure reliable and performant operation.

Previously, test data was injected into internal memory locations within the FPGA, limiting the scope of the test procedure to a subset of the full pipeline. This work investigates a new data injection approach that enables testing of the complete pipeline. In this approach, data is injected digitally at the optical input interface of the FPGA, allowing the test data to propagate through the entire design, therefore testing every component of the firmware.

T 6.7 Mon 17:45 KH 00.023

Investigation of Electronic Crosstalk in the Optical Modules of the Pacific Ocean Neutrino Experiment — •Lars von der Werth for the P-ONE-Collaboration — Technische Universität München

The Pacific Ocean Neutrino Experiment (P-ONE) is a proposed cubic-kilometer*scale neutrino detector to be deployed in the Pacific Ocean. Its fundamental detection units are the P-ONE optical modules (P-OMs), each housing 16 photomultiplier tubes (PMTs) to record Cherenkov light emitted by secondary particles produced in high-energy neutrino interactions. Each P-OM includes a trigger system that performs an initial selection of relevant signals. A detailed understanding of the internal electronic crosstalk is essential for reliable triggering. To characterize these effects, electromagnetic interference (EMI) measurements help identify the dominant noise sources and investigate the pathways through which these couple into the PMT signal. Further, we present how different grounding schemes, cabling configurations, and shielding strategies affect the crosstalk level observed in the different PMT positions within the P-OM.

T 6.8 Mon 18:00 KH 00.023

Emulator-Based Evaluation of FPGA Algorithms for the ATLAS MDT Trigger Processor — •Marcel Marques Boonen, Davide Cieri, Oliver Kortner, and Sandra Kortner — Max Planck Institute for Physics , Garching, Germany

The Monitored Drift Tube Trigger Processor (MDTTP), a new FPGA-based component of the High- Luminosity LHC upgrade of the ATLAS muon trigger, is being developed to reconstruct muon tracks at the first-level trigger using the information from the MDT detectors. Two proposals for the determination of the muon transverse momenta are currently under investigation: an algorithm that translates the sagitta of the muon trajectory into transverse momentum using pre-defined conversion functions, and a machine-learning approach that exploits the directions and positions of the muon trajectory in the muon chambers.

Both approaches rely on a data processing chain capable of buffering and handling large data streams. To simulate such data processing under realistic conditions, dedicated Monte Carlo data are stored in DDR memories of one MDTTP board and then sequentially injected via optical fibers into the MDTTP board under test. This presentation will describe the implementation of this approach and its application in evaluating the performance of the aforementioned transverse-momentum calculation procedures.

T 7: Data, AI, Computing, Electronics I

Time: Monday 16:15–18:15 Location: KH 00.024

T 7.1 Mon 16:15 KH 00.024

Understanding and Expanding the Transformer-Based Neural Network to Analyze Extensive Air Showers at the Pierre Auger Observatory — •Ronja Westphalen, Maximilian Straub, Alex Reuzki, Niklas Langner, Josina Schulte, and Martin Erdmann — RWTH Aachen University, Aachen, Germany

Determining the mass of ultra-high-energy cosmic rays is crucial to understanding their origin. Ground-based detectors, such as the Pierre Auger Observatory, measure extensive air showers and collect multidimensional, time- and location-dependent signals that contain information on the primary particle. Analyzing these complex signals with a Transformer-based neural network to reconstruct mass-dependent observables, such as the depth of the shower maximum $X_{\max}$ and the muon content R_μ, from surface detector (SD) measurements at the Pierre Auger Observatory has been shown to be successful.

This study investigates the working principle of the Transformer in detail. We examine the attention mechanism in the time trace and in spatial analysis to understand how effectively features are reconstructed from these complex measurements. Additionally, we assess the agreement between the data and simulations in the latent network space to determine whether known discrepancies of hadronic interaction models are inherently apparent in the network response. Finally, we want to extend the network by the radio detector, enabling the evaluation of SD measurements in combination with the radio signal for the AugerPrime setup.

T 7.2 Mon 16:30 KH 00.024

Reconstruction and Identification of Atmospheric Neutrino Events at JUNO Using Machine-Learning Methods — •Milo Charavet, Caren Hagner, Daniel Bick, and Mikhail Smirnov — University of Hamburg, Hamburg, Germany

The Jiangmen Underground Neutrino Observatory (JUNO) is a next-generation multipurpose liquid scintillator detector with a 20-kiloton target mass, located in southern China. One of its primary goals is to determine the neutrino mass ordering (NMO) with a significance of at least 3σ by precisely measuring the oscillation pattern of reactor antineutrinos over a 53 km baseline. While JUNO's NMO sensitivity primarily comes from reactor neutrinos, atmospheric neutrino oscillations provide complementary sensitivity via matter effects and can enhance the overall performance in a joint analysis. The construction of the detector has been completed, and JUNO has already started physics data taking since August 2025. Detecting atmospheric neutrinos in a liquid scintillator detector poses several challenges, such as the reconstruction of complex event topologies and the separation of interaction channels. Advanced machine learning methods, in particular deep-learning based reconstruction techniques, offer promising solutions to address these difficulties. This talk will present recent progress in using such methods to reconstruct the energy, direction, and vertex of atmospheric neutrino events, as well as their performance in particle identification from Monte Carlo studies, highlighting both the challenges and the advantages of these innovative approaches.

T 7.3 Mon 16:45 KH 00.024

Particle Identification in OSIRIS using Deep Learning —

•Martin Kandlen, Elisabeth Neuerburg, Achim Stahl und Christopher Wiebusch — RWTH Aachen

In August 2025, the filling of the 20-kton liquid scintillator based Jiangmen Underground Neutrino Observatory (JUNO) was finished. The radiopurity of the liquid scintillator (LS) was monitored by the Online Scintillator Internal Radioactivity Investigation System (OSIRIS). OSIRIS has a cylindrical acrylic vessel for 20-ton batches of LS observed by 64 20" PMTs. The Uranium and Thorium impurities are measured via Bismuth-Polonium coincidence decay signals. I use attention-based deep learning methods for particle identification, where the input consists of the scintillation time profile. Simulation-data-mismatches are overcome by domain adaptation; the model is trained using both simulated and real detector data. In this talk, I present the methodology and performance of the classification.

T 7.4 Mon 17:00 KH 00.024

Self-Supervised Pretraining of HPGe Waveforms for Pulse-Shape Discrimination for LEGEND — •Niko Lay[1], Christoph Vogl[1], Tommaso Comellato[1], Konstantin Gusev[1], Brennan Hackett[2], Baran Hashemi[1], Lukas Heinrich[1], Patrick Krause[1], Andreas Leonhardt[1], Béla Majorovits[2], Moritz Neuberger[1], Nadezda Rumyantseva[1], Mario Schwarz[1], Michael Willers[1], and Stefan Schönert[1] — [1]Technical University of Munich, Garching, Germany — [2]Max Planck Institute for Physics, Garching, Germany

LEGEND searches for ($0\nu\beta\beta$)-decay using HPGe detectors enriched in ^{76}Ge and operated in instrumented LAr. For LEGEND-1000, underground-sourced Ar, depleted in ^{42}Ar, constitutes the baseline choice. In the event that such argon is unavailable, a well-established and experimentally validated mitigation strategy is under preparation. Using HPGe detectors operated in ^{42}Ar-enriched LAr at the SCARF test facility at TUM, we compare three self-supervised pretraining objectives: a transformer-based autoencoder, an autoregressive objective, and masked contrastive modeling. We finetune the pretrained models to classify signal-proxy vs. background, and bulk vs. surface interaction. The resulting pretrained backbones provide a basis for future likelihood-amortization and simulation-based inference workflows, while this talk focuses on their impact on these two PSD tasks. We acknowledge support from the DFG under Germany's Excellence Strategy – EXC 2094 (ORIGINS), through the Sonderforschungsbereich SFB 1258, and by TUM MDSI Seed Funds.

T 7.5 Mon 17:15 KH 00.024

ML-based LAr classification in LEGEND-200 — •Jonas Schlegel and Christoph Wiesinger for the LEGEND-Collaboration — Max-Planck-Institut für Kernphysik, Germany

LEGEND-200 uses the scintillation properties of liquid argon (LAr) to suppress backgrounds in the search for neutrinoless double beta decay of ^{76}Ge. The LAr is instrumented with wavelength-shifting fibers coupled to arrays of silicon photomultipliers. The current veto implementation relies on a global threshold and is limited by random coincidences, as it does not exploit spatial information. We implement a machine-learning (ML) based topology-aware LAr veto that combines the photoelectron pattern with the relative angular position of the triggering high-purity germanium detector. The network is trained on samples of true and random coincidences and outputs an event-by-event veto probability. This implementation achieves improved background discrimination and serves as a proof-of-concept for further improvements, including timing information and alternative neural network architectures.

T 7.6 Mon 17:30 KH 00.024

Application of FiLM Neural Networks for π/K Separation in the PANDA Barrel DIRC — •Daniel Markhoff[1,2], Roman Dzhygadlo[2], Jochen Schwiening[2], and Yannic Wolf[2,3] — [1]University of Edinburgh, Edinburgh, United Kingdom — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — [3]Goethe-Universität Frankfurt, Frankfurt, Germany

Machine learning techniques were investigated as an alternative approach to PID in the PANDA Barrel DIRC at FAIR. FiLM neural-network models were trained on simulated Geant4 photon-hit patterns and achieved $>2\sigma$ π/K separation at 3.5 GeV/c. The models provide a significant reduction in computation time compared to the conventional time-based imaging reconstruction, while retaining competitive classification performance. These results indicate that ML-based PID has strong potential to complement or accelerate traditional DIRC reconstruction methods.

T 7.7 Mon 17:45 KH 00.024

LSTM Networks for Enhanced Signal Efficiency in the CRESST Experiment — •Praveen Murali for the CRESST-Collaboration — Kirchhoff-Institut für Physik, Heidelberg, Germany

Cryogenic experiments, such as CRESST (Cryogenic Rare Event Search with Superconducting Thermometers), frequently encounter time-series pulses from recoil events that are corrupted by distorting artefacts. These artefacts mandate data quality cuts, resulting in a drop in desired signal efficiency. This talk will introduce an application of Long Short-Term Memory (LSTM) networks to solve this problem. More specifically, it will illustrate how LSTM networks can be used to accurately "resurrect" these previously discarded pulses. This method represents a significant opportunity to enhance both the overall signal efficiency and the data yield in these highly sensitive, low-background experiments. Moreover, this method's applicability extends beyond CRESST to encompass other experiments exhibiting similar pulse and noise characteristics.

T 7.8 Mon 18:00 KH 00.024

Machine learning based Particle Identification in a Diffusion Cloud Chamber. — •Benjamin Rosendahl, Jasper von Lepel, Mario Schwarz, and Stefan Schönert — Department of Physics, TUM School of Natural Sciences, Technical University of Munich, 85748 Garching b. München, Germany

We present a work on a diffusion cloud chamber, which establishes quasi-stationary alcohol vapor diffusion through air by a temperature gradient, generating a supersaturated layer (S) in which ions seed droplet formation. By measuring the vertical temperature profile $T(y)$ and applying heat and diffusion equations as well as nucleation theory, we characterize local supersaturation and growth kinetics during vapor condensation on ions. Together with a camera setup, a U-Net based machine learning pipeline performs segmentation of particle tracks, followed by skeletonization and vectorisation. The live time setup enables joint thermodynamic and particle physics analyses: Mapping $T(y)$ and $S(y)$, quantifying fluxes of charged particles by both cosmic and ambient radiation (e.g., muons, betas and alphas) calibrated by comparison to radioactive sources and identifying phenomena such as radon decay. Beyond measurement, the instrument functions as an exhibit with high educational value, translating otherwise abstract concepts into observable events. We acknowledge support from the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy - EXC 2094 - 390783311 and through the Sonderforschungsbereich (Collaborative Research Center) SFB 1258 'Neutrinos and Dark Matter in Astro- and Particle Physics'.

T 8: Flavour Physics I

Time: Monday 16:15–18:15 Location: KH 01.011

T 8.1 Mon 16:15 KH 01.011

Sensitivity study on combined analysis of beyond the Standard Model contributions in $B^0 \to D^{*-}\tau^+\nu_\tau$ decay. — •Marco Colonna — TU Dortmund University

Semileptonic $b \to c\ell\nu$ decays are excellent probe for testing Lepton Flavour Universality and New Physics effects. New Physics contributions are measured via their corresponding Wilson coefficients and in several fit configurations including different New Physics operators. A study of sensitivity of a combined measurement of Wilson coefficients using of $B \to D^*\tau\nu$ decays in proton-proton collision data collected by LHCb and electron-positron collision data from Belle II has been done, showing enhanced sensitivity from shared parameters between different datasets. We discuss the most recent progress in developing data reinterpretation techniques, as well as the prospects and challenges for direct measurements of New Physics in semileptonic decays at the collider experiments.

T 8.2 Mon 16:30 KH 01.011

Search for $B^- \to \Lambda_c^+\bar{p}\ell^-\bar{\nu}_\ell$ at the Belle II experiment — •Verena Mendel, Torben Ferber, Pablo Goldenzweig, and Raynette Van Tonder — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

About 90% of the inclusive semileptonic $B \to X_c\ell\nu$ branching fraction can be accounted for by summing the branching fractions of known exclusive $B \to D^{(*)}(\pi)\ell\nu$ decays. Semileptonic B decays to charmed baryons may account for some of the remaining difference. These decays are poorly understood theoretically and may provide additional insight into the longstanding inclusive/exclusive puzzle in determinations of the CKM matrix element $|V_{cb}|$.
In this talk, we present the status of the first search for $B^- \to \Lambda_c^+\ \bar{p}\ \ell^-\ \bar{\nu}_\ell$, which is the lightest final state containing charmed baryons and is expected to be the dominant individual baryonic mode. The analysis is conducted at the Belle II experiment, located at the SuperKEKB asymmetric e^+e^- collider. We employ a hadronic tagging approach, where the accompanying B meson in $e^+e^- \to \Upsilon(4S) \to B^+B^-$ events is fully reconstructed via hadronic decay chains. The signal side is reconstructed in the electron and muon modes, with the Λ_c^+ reconstructed in the decay channels $\Lambda_c^+ \to pK^-\pi^+$ and $\Lambda_c^+ \to pK_S^0$.

T 8.3 Mon 16:45 KH 01.011

Two-loop corrections to the penguin amplitude a_6 in QCD factorization — Guido Bell[1], Kevin Brune[2], Tobias Huber[1], and •Sandra Kvedaraite[1] — [1]Universität Siegen, Siegen, Germany — [2]Johannes Gutenberg-Universität Mainz, Mainz, Germany

The QCD penguin amplitude plays a central role in understanding CP violation in non-leptonic B-meson decays. It arises from the loop-induced weak-interaction process $b \to D\sum_{q=u,d,s} q\bar{q}$, where $D = d, s$, and can be expressed in terms of the leading-power amplitude a_4 and the higher-twist amplitude a_6. Even though a_6 is power-suppressed in the heavy-quark limit, chiral enhancement makes it numerically comparable to a_4, making it relevant for branching ratios and CP-violating observables. While a_4 is known to next-to-next-to-leading order, a_6 is currently available only at next-to-leading order. In this talk, I will present recent progress towards the two-loop calculation of a_6 in the QCD factorization approach to non-leptonic B-meson decays.

T 8.4 Mon 17:00 KH 01.011

One-loop improved modelling of hadronic light-cone distributions amplitudes in HQET — Riccardo Bartocci[1], Philipp Böer[2], Max Ferré[3], Thorsten Feldmann[4], Nico Gubernari[5], and •Daniel Vladimirov[4] — [1]Institut für Theoretische Teilchenphysik, Karlsruhe Institute of Technology (KIT), 76128 Karlsruhe, Germany — [2]CERN, Theoretical Physics Department, CH-1211 Geneva 23, Switzerland — [3]PRISMA+ Cluster of Excellence & Mainz Institute for Theoretical Physics, Johannes Gutenberg University, D-55099 Mainz, Germany — [4]Center for Particle Physics Siegen, Universität Siegen, 57068 Siegen, Germany — [5]Helmholtz-Institut für Strahlen- und Kernphysik (Theorie) and Bethe Center for Theoretical Physics, Universität Bonn, 53115 Bonn, Germany

Light-cone distribution amplitudes (LCDAs) parametrize the relevant hadronic information in factorization-based predictions for exclusive reactions with large energy/momentum transfer. In this talk we focus on the LCDAs of heavy hadrons containing one heavy b-quark in the framework of heavy-quark effective theory (HQET). We explain how theoretical information about the so-called "radiative tail" in fixed-order perturbation theory can be consistently implemented in the construction of models or generic parametrizations of the LCDAs. As a specific example, we apply our approach to a generalized 3-particle LCDA of the B-meson, where the light quark and gluon field are separated along *opposite* light-cone directions, and briefly discuss the phenomenological relevance for rare exclusive B-meson decays.

T 8.5 Mon 17:15 KH 01.011

Measurement of the Differential Branching Ratio, Lepton Angular Distribution and Determination of the CKM Matrix Element $|V_{cb}|$ in Inclusive $B \to X_c\ell\nu$ Semileptonic Decays using Belle II Data — •Rajeshwari Roy, Florian Bernlochner, Markus Prim, and Munira Khan — Physikalische Institut der Rheinische Friedrich-Wilhelms- Universität Bonn

We present a measurement of the differential branching ratio and lepton angular distribution in inclusive semileptonic $B \to X_c\ell\nu$ decays using data collected with the Belle II detector corresponding to an integrated luminosity of 365 fb^{-1}, recorded at the $\Upsilon(4S)$ resonance. Signal candidates ($b \to c\ell\bar{\nu}_\ell$) are selected using a tag-side full-event interpretation, enabling precise reconstruction of the kinematics in the inclusive decay. The differential branching ratios as functions of the lepton momentum, momentum transfer q^2, and lepton helicity angle $\cos\theta_\ell$ are calculated incorporating efficiency corrections and including a comprehensive evaluation of systematic uncertainties using the Sysvar framework, which provides a consistent treatment of arbitrary correlations arising from systematic effects affecting shapes in simultaneous template fits. A global fit to the measured spectra within the HQE formalism yields an updated determination of the Cabibbo-Kobayashi-Maskawa matrix element $|V_{cb}|$, contributing to resolving the difference between inclusive and exclusive determinations of $|V_{cb}|$.

T 8.6 Mon 17:30 KH 01.011

Search for $B \to \Lambda_c p\ell\nu$ decays at Belle II — •Tim Müller, Markus Prim, Valerio Bertacchi, and Florian Bernlochner — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn

The branching fraction of the inclusive semileptonic decays $B \to X_c\ell\nu$ is around 10 % and is experimentally and theoretically well understood. On the other hand, the exclusive semileptonic decays of the B-meson add up to only 9 % of the branching ratio. This gap might originate from baryonic semileptonic decays such as $B \to \Lambda_c p\ell\nu$, which have not been directly measured yet. We aim to solve this gap by further investigating this decay and determining its absolute branching ratio.

To achieve this, a tag-side full-event interpretation is performed by reconstructing the tag B meson in both hadronic and semileptonic decay channels to maximize the available statistics. The SysVar framework is then being used to evaluate systematic uncertainties for template fitting via pyhf. In this talk we present the motivation, analysis strategy and preliminary results of this ongoing analysis.

T 8.7 Mon 17:45 KH 01.011

An effective hadronic field theory for B-meson decays at high recoil — •Jaime del Palacio Lirola, Thorsten Feldmann, and Jack Jenkins — University of Siegen

We construct an effective hadronic Lagrangian for heavy-meson decays into energetic pseudo-Goldstone bosons of chiral symmetry breaking, by exploring the interplay between two already existing Effective Field Theory frameworks: Heavy Hadron Chiral Perturbation Theory, and Soft-Collinear Effective Theory (SCET). In the new theory, the dynamical degrees of freedom are given by quasi-static heavy meson fields coupled to soft and collinear pions, kaons and η mesons. In this talk we focus on the matching of external heavy-to-light currents in SCET onto effective operators in the hadronic Lagrangian. From our result, we calculate the 1-loop corrections for the external current, which determines the non-analytic dependence on the light meson mass, known as "chiral logarithms". This information is needed to perform the chiral extrapolation in lattice-QCD data, and to estimate $SU(3)$ breaking effects in heavy-to-light form factors, both at large recoil (low q^2).

T 8.8 Mon 18:00 KH 01.011

QCDF amplitude estimates for $B \to V_L V_L$ decays using a data-driven approach — •Anshika Bansal[1], Aritra Biswas[1], Tobias Huber[1], Joaquim Matias[2], and Gilberto Tetlalmatzi-Xolocotzi[1] — [1]Theoretical Particle Physics, Center for Particle Physics Siegen, University of Siegen — [2]Institut de Física d*Altes Energies (IFAE), The Barcelona Institute of Science and Technology, Campus UAB, 08193 Bellaterra (Barcelona)

QCD factorisation (QCDF) is one of the main theoretical frameworks to compute the amplitudes of non-leptonic decays of B-mesons. However, these calculations are polluted by infrared divergences arising, for example, from the weak annihilation topologies. These effects cannot be computed using first-principle calculations and can only be parametrised, which leads to sizable theoretical uncertainties. In this talk, I will discuss a data-driven approach to estimate QCDF amplitudes for B-meson decaying to two charmless vector mesons. This is done by exploiting the relations between QCDF amplitudes and the SU(3) invariant amplitudes. One key aspect of this analysis is the introduction of SU(3) breaking effects.

T 9: Silicon Detectors I

Time: Monday 16:15–17:45 Location: KH 01.012

T 9.1 Mon 16:15 KH 01.012

Particle Identification Based on the Time-over-Threshold with MuPix11 Sensors — •Effrosyni Zachou for the HVMAPS HD-Collaboration — Physikalisches Institut, Universität Heidelberg, Germany

The High-Voltage Monolithic Active Pixel Sensors (HV-MAPS) extend the monolithic design concept by embedding the readout electronics in a deep n-well, enabling high voltage operation and fast charge collection via drift. The MuPix11 is a HV-MAPS chip with a pixel size of $80 \times 80\,\mu\text{m}^2$ that can be thinned to $50\,\mu$m, offering low material budget and precise spatial and time resolution.

The analogue pixel signal is digitised in the periphery, producing leading- and trailing-edge timing information from which the Time-over-Threshold (ToT) is computed. Since charged particles deposit different amounts of energy depending on their type and momentum, the ToT provides a useful proxy for measuring energy deposition and distinguishing different particles.

This work presents preliminary results from testbeam campaigns conducted at the Paul Scherrer Institute with the goal of systematically investigating the dependence of the ToT response on particle type and momentum. The measurements were performed with a setup consisting of four layers, each composed of four MuPix11 sensors mounted on a single printed circuit board. By reconstructing particle trajectories across the sensor planes, hits are associated with individual particles, enabling a track-based analysis of the ToT response.

T 9.2 Mon 16:30 KH 01.012

Noise Analysis in the MuPix11 Sensor for the Mu3e Experiment — •Antonios Kontopoulos, Heiko Augustin, and Andre Schöning for the Mu3e-Collaboration — Physikalisches Institut Heidelberg

The Mu3e experiment searches for the charged-lepton-flavour-violating decay $\mu^+ \to e^+e^-e^+$ with an ultimate single-event sensitivity on the BR of 10^{-16}, imposing stringent requirements on the noise performance of its ultra-low-mass vertex detector. The MuPix11, a high-voltage monolithic active pixel sensor (HV-MAPS), has been observed to exhibit spatially fixed noise features, necessitating a detailed characterisation of its noise behaviour.

In this contribution, a systematic noise study of MuPix11 is presented, based on cosmic data from the Mu3e vertex detector and quad-module measurements conducted at the Physics Institute in Heidelberg and the Paul Scherrer Institute. Noise characterisation is performed using a frequency-domain analysis to identify spectral features and coherent noise sources. A dedicated reconstruction framework is used to extract per-pixel noise rates, temporal correlations, and spatial noise maps.

First results reveal the dominant noise contributions under varying operating conditions and demonstrate the suitability of the developed methods for supporting sensor optimisation and the qualification of MuPix11 for integration into the Mu3e detector.

T 9.3 Mon 16:45 KH 01.012

An overview of the European XFEL's bespoke DSSC DEPFET single module detector characteristics and integration — •Mina Mohebbi[1,2], Erika Garutti[2], and Monica Turcato[1] — [1]European XFEL, Schenefeld, Germany — [2]University of Hamburg, Hamburg, Germany

The unique beam properties of the European XFEL, including its high brilliance and pulse structure, impose stringent requirements on X-ray imaging detectors in terms of dynamic range, signal-to-noise ratio, and readout speed. The DEPFET Sensor with Signal Compression (DSSC) detector, developed by an international consortium together with the European XFEL, addresses these challenges for soft X-ray detection in the 0.5-6 keV range. With a sensitive area of 241×251 mm^2, the DSSC enables single-photon sensitivity while providing a dynamic range of several thousand photons at frame rates up to 4.5 MHz. Although the full 1-megapixel DSSC system demonstrates excellent performance, its extensive and complex infrastructure limits portability and broader applicability. To overcome these constraints, a compact single-ladder system, the DSSCsm, has been developed. It features a 128×512 pixel sensitive area and incorporates a thermoelectric cooling design that removes the need for bulky cryogenic components. The DSSCsm preserves the dynamic range and fast readout capabilities of the full system while significantly reducing size, weight, and support requirements. This makes it well suited for experiments requiring an active area of 125×30 mm^2. This talk will present the DSSCsm design, operating infrastructure, and characterization and calibration techniques.

T 9.4 Mon 17:00 KH 01.012

Assembly and Characterization of the TRISTAN Detector for the KATRIN Experiment — •Christian Forstner for the KATRIN-Collaboration — TUM School of Natural Sciences - Physics Department, Garching, Germany

Sterile neutrinos, a minimal extension to the Standard Model of particle physics, are a promising dark matter candidate if their mass is in the keV-range. Following the completion of its neutrino mass measurement campaign, the Karlsruhe Tritium Neutrino (KATRIN) experiment will be equipped with a novel silicon drift detector array, the TRISTAN detector, to search for a keV-scale sterile neutrino signature in the tritium β-decay spectrum.
In this work, we report on the assembly of the TRISTAN detector, which consists of nine TRISTAN detector modules. The talk covers the module testing procedure as well as the characterization using photon and electron sources.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMBF (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6).

T 9.5 Mon 17:15 KH 01.012

The mechanical rotation system of the P2 tracking detector — •Dhanushka Bandara for the P2-Collaboration — Institute of Nuclear Physics, Johannes Gutenberg University of Mainz, Johann-Joachim-Becher-Weg 45, 55128 Mainz, Germany.

The P2 experiment will measure the weak mixing angle at low-momentum with unprecedented precision, using the parity violating asymmetry in electron-proton scattering. The experiment will take place at the Mainz Energy-Recovering Superconducting Accelerator (MESA), currently in the advanced stage of construction at Johannes Gutenberg University of Mainz.

A key component in the P2 experiment is the tracking detector, which measures the momentum transfer Q^2 of the scattered electrons. To allow for full azimuthal coverage with a limited size detector, a mechanical system is designed to rotate the tracker modules around the beam axis. The system should be operable in vacuum, withstand the intense radiation and provide precise movement. A scaled model is being built to study and understand the mechanics and the limitations of the rotational system.

This talk gives an overview of the P2 experiment and tracking detector, with the focus on the requirements and challenges of designing the tracker rotation system and how they are addressed.

T 9.6 Mon 17:30 KH 01.012

Mechanical, Thermal, and Electrical Design of the P2 Tracking Detector Modules — •Lucas Sebastian Binn for the P2-Collaboration — Institute of Nuclear Physics, Johannes Gutenberg-University Mainz, Germany

The P2 Experiment at the new Mainz Energy-Recovering Superconducting Accelerator (MESA), which is currently under construction in Mainz, will measure the weak mixing angle $\sin^2\theta_W$ in elastic electron-proton scattering at low momentum transfer with unprecedented precision.

A key parameter for the analysis, the momentum transfer Q^2, and systematic effects, are measured by a low-mass tracking detector consisting of 4 identical modules arranged in two layers. Each module consists of two sensor planes, with silicon pixel sensors glued and wire-bonded on rigid-flex ladders, which are tensioned individually using a spring-loaded mechanism. A laminar flow of cool helium gas across the ladders provides the needed cooling of around 650 W per module. The sensors are read out using a radiation-hard ASIC (lpGBT) developed by CERN.

The mechanical, thermal, and electrical designs have been developed and are currently undergoing testing. For this purpose, dedicated prototypes and test stands for each area have been constructed.

This talk gives an overview of the P2 experiment tracking detector module design, covering the mechanical, thermal, and electrical aspects.

T 10: Axions/ALPS I

Time: Monday 16:15–18:00 Location: KH 01.013

T 10.1 Mon 16:15 KH 01.013

Search for the $K^+ \to \pi^+\pi^0 X$ decay — •Marco Ceoletta — JGU Mainz (DE) + CERN (CH)

This analysis aims to search for the hypothetical decay channel $K^+ \to \pi^+\pi^0 X$, where X is invisible and can be interpreted as an Axion-like particle (ALP, indicated as A) or as a massless Dark Photon (a), at the NA62 experiment (CERN). Obtaining a stringent upper limit on BR($K^+ \to \pi^+\pi^0 X$) is important for constraints on several BSM theories. In particular, for $X = A$ the decay is sensitive to an axial-vector coupling of pseudo-scalar particles to quarks. A search on $K^+ \to \pi^+\pi^0 A$ therefore complements the extensive work already performed on the associated two-body decay $K^+ \to \pi^+ A$, that is sensitive only to the polar-vector coupling current. A preliminary upper limit of the branching ratio to ALPs, as part of a feasibility study done in 2022, already outperformed the best previous limit using less than 20% of the available data. The presentation describes the analysis, the selection, and the background estimation and and gives an outlook on the expected upper limits.

T 10.2 Mon 16:30 KH 01.013

Search for axion-like particles with gluon couplings in $B \to Ka, a \to \pi^+\pi^-\pi^0$ at the Belle II experiment — •Karlina Kröhnert, Priyanka Cheema, and Torben Ferber — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

Axion-like particles (ALPs) appear in different theoretical extensions to the Standard Model. This analysis targets ALPs within a mass range of 400 MeV to 1 GeV and with gluon couplings produced in hadronic B decays. A particularly interesting decay mode is $a \to \pi^+\pi^-\pi^0$ since, for ALP-gluon couplings within the reach of the Belle II sensitivity, it produces a long-lived ALP a.

Although large parts of the parameter space have been explored by beam dump experiments and former prompt searches by BaBar and Belle, the displaced signature of the ALP offers a promising possibility to significantly extend existing ALP-gluon coupling limits.

In this analysis we search for an ALP in $a \to \pi^+\pi^-\pi^0$ using $B \to Ka$ decays at Belle II. We highlight how the displaced signature offers the possibility of significantly suppressing the background, but leads to unique challenges regarding the π^0 reconstruction from displaced vertices.

This talk will show the status of this search and present sensitivity estimates based on the current Belle II data set.

T 10.3 Mon 16:45 KH 01.013

Search for Higgs decays into long-lived Axion-Like Particles with the ATLAS Experiment — •Janek Both, Volker Büscher, Christian Schmitt, and Emanuel Meuser — Johannes Gutenberg-Universität

Axion-Like Particles (ALPs) or more generally, pseudoscalars that are gauge singlets under the Standard Model gauge group, appear in many well-motivated extensions of the Standard Model. In scenarios where the ALP couples to the Higgs boson, collider searches can provide sensitivity to ALPs in the GeV range and thus offer a complementary approach to other experiments that mainly focus on lighter ALPs. Depending on the ALP lifetime, it might decay displaced from the primary vertex inside the calorimeters of the ATLAS detector. Such a decay leads to an exotic signature that clearly differs from promptly produced backgrounds, but also challenges conventional reconstruction and analysis methods.

In this talk, a search for Higgs boson decays into long-lived ALPs is presented. The analysis makes use of a graph neural network classifier that identifies ALP decays into photons within the ATLAS calorimeters. The analysis uses Run-3 data and a data driven background estimation. The search improves on the existing Run-2 analysis that focuses on promptly decaying ALPs.

T 10.4 Mon 17:00 KH 01.013

Search for top quark decays to long-lived axion-like particles (ALPs) with ATLAS: ALP candidate reconstruction — •Frederic Fischer, Martin Christiansen, Lucia Masetti, Hendrik Smitmanns, Jessica Höfner, and Annika Stein — Johannes Gutenberg-Universität Mainz, Institut für Physik

The Standard Model (SM), although it agrees with great precision with experimental measurements, is still insufficient to give answers to many fundamental questions. One prime example is the strong CP problem which axions could solve. Axions as well as the broader axion-like particles (ALPs) are introduced as electrically neutral scalar fields extending the SM to accomodate new physics. One way to approach ALPs is to parameterise ALP couplings to SM particles like top quarks. ALPs appear in flavour-changing exotic top decays where the top quark decays into an ALP and an up- or charm-quark. Within this decay mode, parts of the parameter space dictates ALPs to have lifetimes long enough to travel macroscopic distances before decaying. This search is dedicated to look for $t\bar{t}$ events with one SM leptonically decaying top quark and one exotically decaying top quark. In this topology the focus is on ALP decays in the hadronic calorimeter at ATLAS with a centre-of-mass energy of $\sqrt{s} = 13.6$ TeV. Being electrically neutral, they leave no signals in the ATLAS tracking system. Moreover, the ratio of signals in the electromagnetic calorimeter and hadronic calorimeter are used to suppress SM backgrounds. This talk presents the reconstruction strategy of the ALP candidate to be used in a search for long-lived ALPs from exotic top decays at ATLAS.

T 10.5 Mon 17:15 KH 01.013

Search for Axion-Like Particles via Top Quark Decays with ATLAS: Statistical Methods — •Martin Christiansen, Frederic Fischer, Annika Stein, Jessica Höfner, Hendrik Smitmanns, and Lucia Masetti — Johannes Gutenberg-Universität Mainz, Institut für Physik

A search for long-lived Axion-like particles (ALPs) originating from exotic top quark decays is performed using the ATLAS detector at a center-of-mass energy of $\sqrt{s} = 13.6$ TeV. ALPs can be investigated by parameterizing their couplings to Standard Model (SM) particles. This analysis targets top-antitop events characterized by one top quark decaying leptonically and one decaying via a flavour-changing neutral current $t \to a + u/c$, where a denotes the ALP. Portions of the viable parameter space predict ALP lifetimes sufficiently long for macroscopic displacement prior to decay. Focusing on ALPs decaying within the ATLAS hadronic calorimeter, the ratio of energy deposits in the electromagnetic and hadronic calorimeters is utilized to mitigate SM backgrounds. Statistical methods play an important role in this context. The event topology is reconstructed based on χ^2 minimization combined with b-tagging information, and the resulting loglikelihood score becomes relevant also for cutflow optimization. In addition, a Boosted Decision Tree is trained on the background and signal model. With the help of this multivariate analysis technique, variables are identified that are highly discriminative yet statistically independent and that can be used for data-driven methods, further improving the sensitivity of the analysis.

T 10.6 Mon 17:30 KH 01.013

Sensitivity of the FCC-ee to axion-like particles — Juliette Alimena[1], Freya Blekman[1,2], Jeremi Niedziela[1], Giacomo Polesello[3], •Anna Przybyl[1,2], and Lovisa Rygaard[1,2] — [1]Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg — [2]Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]INFN Sezione di Pavia, Via Bassi 6, 27100 Pavia, Italy

The electron-positron stage of the Future Circular Collider (FCC-ee) has incredible potential for particle physics. Not only does the clean collision environment at this stage allow for high-precision measurements, but it also allows for direct searches for new particles. The FCC-ee is preferred by the German particle physics community as the next flagship collider at CERN, and it is scheduled to operate with center-of-mass energies at the Z pole, the WW threshold, the ZH production maximum, and the tt threshold.

Axion-like particles (ALPs) are pseudoscalars that appear in many extensions of the Standard Model of particle physics, and they could potentially explain the nature of dark matter. We study ALPs at the FCC-ee. This talk will present the sensitivity of the FCC-ee to ALPs at all planned center-of-mass energies.

T 10.7 Mon 17:45 KH 01.013

Searching for ALPs in $H \rightarrow 4K$ at FCC-ee — Juliette Alimena[1], •Sarah Alshamaily[2], Sofia Giappichini[2], Johannes Hornung[2], Markus Klute[2], and Matteo Presilla[2] — [1]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany — [2]Institute for Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

This study investigates a rare Higgs decay at the Future Circular Collider (FCC-ee). The e^+e^- stage is investigated at a center-of-mass energy of 240 GeV, with an integrated luminosity of 10.8 ab^{-1}. Following the axion-like particle (ALP) effective theory framework of Bauer et al., which provides a model-independent description of light pseudoscalar particles that commonly arise in theories beyond the Standard Model, the processes explored are $e^+e^- \rightarrow ZH$, where the Higgs boson decays into a pair of ALPs that subsequently decay into pairs of charged kaons. FCC-ee is an excellent experimental environment for such a study due to the improved momentum resolution and clean environment compared to hadronic colliders. We explored the parameter space where ALPs are long-lived particles, where background can be almost fully eliminated by exploiting their displaced decay vertices, obtaining sensitivity contours and limits on the Higgs-ALP coupling.

T 11: Gaseous Detectors I

Time: Monday 16:15–18:15 Location: KH 01.014

T 11.1 Mon 16:15 KH 01.014

A Straw Tube Chamber Prototype — •Julia Okfen, Oliver Kortner, Sandra Kortner, Hubert Kroha, Max Lohrmann, Nick Meier, Giorgia Proto, and Jörg Zimmermann — Max Planck Institute for Physics, Munich, Germany

The future e^+e^- collider provides a unique opportunity for precision measurements of the Higgs boson. The Higgs-strahlungs process enables the detection of Higgs bosons through the recoil momentum and thereby allows the determination of its total width in a model independent way. To achieve this, the precise momentum measurement of the Z-boson decay particles is crucial, requiring an accuracy at the level of 0.1% for $p_T \approx 50$ GeV/c, commensurate with the narrow spread of the center-of-mass energy. As GEANT-4-based studies performed by the Straw Tracker community reveal, a tracking system consisting of a combination of silicon and gaseous detectors achieves the best momentum resolution. The gaseous detector can be realized using a drift chamber, however, a straw tube tracker also achieves a comparable performance, offering additional advantages, such as functioning as independent detector units. This contribution presents the development and production of a 1.5m-long Straw Tube chamber prototype. It also reports test beam results obtained at CERN's GIF++ facility, including key performance criteria such as efficiency and single tube resolution, which highlight the suitability of the Straw Tube tracker for an inner detector concept of a future e^+e^- collider experiment. In addition, important lessons learned are discussed that will be essential for designing and building the next 4m-long prototype.

T 11.2 Mon 16:30 KH 01.014

Spatial Resolution of the SHiP Decay Spectrometer Straw Tracker with SAMPIC Read-Out — •Wei-Chieh Lee, Caren Hagner, Daniel Bick, and Walter Schmidt-Parzefall — Institute of Experimental Physics, University of Hamburg, Hamburg, Germany

SHiP (Search for Hidden Particles) is a general-purpose beam-dump experiment currently in preparation at CERN SPS. The experiment is designed to look for feebly interacting particles (FIPs) predicted by several theoretical models of the hidden sector. From dumping the high-intensity proton beam from the SPS onto a target, hidden particles would be potentially produced and fly towards a 50 m long decay volume, where they decay into SM particles to be detected. The Decay Spectrometer Straw Tracker (DSST) downstream, consisting of about 10,000 straw tubes of 4 m length and 2 cm diameter, plays the role of tracking the charged decay products and measuring their momentum for the reconstruction of the decay vertex and mass of the hidden particles. A high spatial resolution of the DSST is essential and requires a precise drift time measurement. To achieve this, the use of a waveform time-to-digital converter (WTDC) for read-out, such as SAMPIC with its high timing precision and capability to sample the leading edge of a signal, is currently under investigation.

For testing, a small DSST prototype was taken to DESY and CERN PS for test beams. The results will be presented in this talk. Furthermore, a plan to test a full-scale prototype of 4 m long straw tubes will be discussed.

T 11.3 Mon 16:45 KH 01.014

Triplet assembly and certification of the new generation of RPC for the ATLAS phase-2 upgrade — Giorgia Proto, •Viktor Griniushin, David Schulteiss, Oliver Kortner, Pavel Maly, and Daniel Soyk — Max Planck Institute for Physics

A new generation of Resistive Plate Chambers have been developed for the ATLAS phase-2 upgrade in sight of the High-Luminosity phase of the Large Hadron Collider. These RPCs consist in three independent 1 mm gas gaps(singlets) equipped with a newly low-threshold Front-End electronics(1 fC), assembled in the same mechanical structure(triplet). The production of the phase-2 RPCs started and the detectors will undergo a certification test before the installation in the ATLAS cavern. The triplet assembly and the certification with cosmic rays of the BIS-type detectors is performed at the Max-Planck-Institute for Physics(MPI) in Munich. The architecture of the cosmic rays test stand has been built at MPI and has been studied in order to provide an efficient and robust structure to ensure an excellent quality control and study precisely the whole RPC performance needed to certify the detectors for the ATLAS experiment. In this presentation the assembly procedure, the architecture of the test stand and the first results on the performance of the Module 0 will be presented.

T 11.4 Mon 17:00 KH 01.014

Influence of gap parameters in a triple-GEM detector — Erik Ehlert, Kerstin Hoepfner, •Stella Israel, Daniel Klee, Markus Merschmeyer, Alexander Schmidt, and Shawn Zaleski — III. Physikalisches Institut A, RWTH Aachen University

Triple Gas Electron Multiplier (GEM) detectors are used in various experiments with different gap configurations, most notably 3/2/2/2 mm and 3/1/2/1 mm. While previous studies have shown that shorter drift gaps can improve the time resolution in different gas mixtures, a systematic comparison for the commonly used Ar/CO_2 (70/30) mixture is still missing. To investigate the influence on the signal, the gap spacings are varied in a dedicated 10×10 cm^2 test chamber.

This talk offers a first look into the comparison of the different gap configurations operated with the same electric fields. The aim is to clarify the role of the gap parameters in the signal formation of triple-GEM detectors.

T 11.5 Mon 17:15 KH 01.014

Impact of environmental pressure and temperature variations on triple-GEM detector gas gain — •Erik Ehlert, Kerstin Hoepfner, Francesco Ivone, Giovanni Mocellin, Alexander Schmidt, and Shawn Zaleski — III. Physikalisches Institut A, RWTH Aachen University

The gas electron amplification factor of Gas Electron Multiplier (GEM) detectors depends on the mixture, the temperature and the pressure. While the gas mixture can be adjusted precisely, the gas temperature and pressure are influenced by the fluctuations of the environmental parameters. Correcting for such variations is therefore crucial to maintain stable operating conditions or to compare performance measured in different conditions. The talk presents the experimental setup which was used to study the dependence of triple-GEM gas gain on temperature and pressure. The results of the experimental study are shown alongside a results from simulation studies.

T 11.6 Mon 17:30 KH 01.014

Characterisation of a multi-anode ACHINOS sensor for Spherical Proportional Counters — •Itxaso Beatriz Antolín, Konstantinos Nikolopoulos, Ioannis Manthos, Isabella Oceano, and Theodoros Avgitas — University of Hamburg, Hamburg, Germany

The Spherical Proportional Counter (SPC) is a gaseous detector that combines intrinsic low capacitance with high gain, enabling energy detection thresholds down to the single ionization electron level. These features make the SPC a promising technology for searches for low-mass dark matter. In this talk the characterisation of a multi-anode ACHINOS sensor, consisting of 11 individually readout anodes, is presented. Moreover, the latest developments in SPC readout are discussed.

T 11.7 Mon 17:45 KH 01.014

Research and Development of a micro-pixel capacitive sharing Micromegas detector — •Eshita Kumar, Otmar Biebel, Valerio D'Amico, Ralf Hertenberger, Nick Schneider, Lilla Schneider, Chrysostomos Valderanis, and Fabian Vogel — Ludwig Maximilians University, Munich

MICRO MEsh GAseous Structure (Micromegas) detectors are micro patterned gaseous detectors that have high rate capability due to the fast evacuation of positive ions and excellent spatial resolution due to a small scale readout strip pitch. However, large scale detectors need thousands of channels which leads to increased power consumption and significant heat generation, often requiring dedicated cooling systems. This talk explores a way to reduce the number of readout channels without compromising position measurement accuracy by encoding the precise position information of the particle's passage through the detector via capacitive sharing using multiple stacked layers of signal electrodes. A prototype of this detector was tested at CERN's SPS beam of 120 GeV muons and the results of the performance and efficiency of this detector will be presented. Comparison with the simulation results using ANSYS and Garfield++ will also be discussed.

T 11.8 Mon 18:00 KH 01.014

Amplification properties of gaseous tetramethylsilane (TMS) for antineutrino-based nuclear safeguards — •Adhitya Sekhar[1], Nick Thamm[2], Sarah Friedrich[1], Robin Mentel[1], Stefan Roth[2], and Yan-Jie Schnellbach[1] — [1]Technische Universität Darmstadt — [2]RWTH Aachen University

In recent years there has been growing interest in antineutrino-based nuclear safeguards for monitoring reactor operation and spent fuel containment through the low-MeV antineutrinos emitted in beta-decay of fission fragments. Following previous promising simulations, a prototype for a novel antineutrino detection concept utilising a liquid organic time projection chamber (LOr-TPC) is now being developed. This study presents the initial phase of this project, showcasing investigations into the amplification properties of gaseous tetramethylsilane (TMS).

NMR-grade liquid TMS was boiled and flushed through an experimental chamber using a simple gas circulation system, with the exhaust gas condensed and recollected for future repurification efforts. A first test was conducted using a single-wire proportional counter in a ∼5mL cylindrical chamber and a ^{55}Fe source, with current amplification of up to three orders of magnitude observed at just under 4kV. Subsequently, a second test is being planned using a Thick Gaseous Electron Multiplier (THGEM). The results of these tests will be shown, along with comparisons made to previous measurements of amplification in other standard gases using the same setup.

T 12: Silicon Detectors II

Time: Monday 16:15–18:15 Location: KH 01.022

T 12.1 Mon 16:15 KH 01.022

Testing infrastructure for the quality control of ITk Pixelmodules — •Ruben Förster, Jörn Grosse-Knetter, and Arnulf Quadt — II. Physikalisches Institut, Georg-August-Universität Göttingen

With the long shutdown of the Large Hadron Collider (LHC) and the subsequent upgrade to the High-Luminosity LHC (HL-LHC) starting soon, the ATLAS experiment will be undergoing extensive upgrades. A central element of this is the new Inner Tracker (ITk), an all-Silicon detector designed to cope with the increased particle flux, radiation levels, and data rates expected at the HL-LHC.

One of the subdetectors is the ITk pixel detector, composed of roughly 8 000 pixel modules that are now in the critical phase of production. As part of the German production cluster, the University of Göttingen is responsible for many of the later production and quality control testing steps for several hundred of these modules.

The testing infrastructure in Göttingen, including setups, procedures, and software for electrical and thermal testing, gluing, and metrology, has been improved and upgraded. The experience gained during production has led to more streamlined workflows and an overall increase in achievable throughput.

A central aspect of this is a newly constructed radiation-compliant electrical test stand, designed for routine operation in a production environment. Together with clear procedures, training of laboratory staff and simplified operator interfaces, this infrastructure places Göttingen in a strong position for the remaining ITk pixel module production.

T 12.2 Mon 16:30 KH 01.022

Electrical tests for the quality control of ITk Pixel modules — Ruben Förster, Jörn Grosse-Knetter, •Niklas Grün, and Arnulf Quadt — II. Physikalisches Institut, Georg-August-Universität Göttingen

The Phase-II upgrade of the ATLAS experiment at the LHC includes a complete replacement of the current Inner Detector with the new all-Silicon Inner Tracker (ITk). The ITk is designed to operate at significantly higher luminosities, providing improved granularity, radiation hardness, and tracking performance for the HL-LHC environment. Its construction requires large-scale production, qualification, and integration of highly complex Silicon Strip and Pixel modules across several international sites.

The Pixel Detector modules feature a hybrid module design, meaning that the sensor is read out via frontend readout chips that are bump-bonded to the sensor. To secure high production standards and quality of the ITk Pixel modules, each of the Pixel modules faces multiple electrical QC check-ups between every major production step on top of non-electrical tests and metrology of the components.

In this contribution, work within the ITk Pixel module production chain is presented as carried out in Göttingen, which is one of the sites of the German production cluster. A focus will be placed on ensuring production quality, improving data-driven validation procedures, and contributing to the smooth operation of the module production workflow. In particular the electrical tests for the quality control of ITk Pixel modules are spotlighted.

T 12.3 Mon 16:45 KH 01.022

Production and Quality Control of CMS Phase-2 Inner Tracker Pixel Modules — •Chin-Chia Kuo, Massimiliano Antonello, Erika Garutti — Bianca Raciti, Jörn Schwandt, and Georg Steinbrück — University of Hamburg, 22761, Luruper Chaussee 149, Hamburg, Germany

A quad module for the Phase-2 upgrade of the CMS Inner Tracker is a hybrid detector consisting of four (2×2) CMS readout chips manufactured in 65 nm CMOS technology (RD53B_CMS) and a silicon pixel sensor. The sensor with 100×25 μm^2 pixel size and 150 μm thickness is coupled to the chips via fine-pitch flip-chip bump bonding. At the University of Hamburg, 500 quad modules for the CMS Tracker Endcap Pixel Detector will be assembled and qualified. Module production and quality control procedures are presented in this talk, including serial powering, threshold tuning, and data transmission tests of the readout chip, IV measurements for sensors, open bump bond identification, and thermal stress tests. The presentation will focus on grading criteria and the performance of pre-production modules.

T 12.4 Mon 17:00 KH 01.022

Core column issue investigation on ATLAS ITk pixel detector modules in Siegen — Markus Cristinziani[1], Qader Dorosti[1], Olivier Fox[1], Daniel Groth[1], •Luke Hammer[1], Stefan Heidbrink[2], Lasse Jäderberg[1], Nils Krengel[1], Leonie Krippendorf[1], Denise Müller[1], Jason Müller[1], Lina Reifenberg[1], Noah Siegemund[1], Waldemar Stroh[2], Darshil Vagadiya[1], Wolfgang Walkowiak[1], Jens Winter[2], Michael Ziolkowski[2], and Alessia Zuev[1] — [1]Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen — [2]Elektronikentwicklungslabor Physik, Universität Siegen

The High-Luminosity Large Hadron Collider (HL-LHC) upgrade will substantially increase the LHC's instantaneous luminosity, requiring a complete replacement of the ATLAS Inner Detector with the new all-silicon Inner Tracker (ITk). For the ITk pixel quad modules, a silicon sensor is connected to four front-end readout chips based on the ITkPix application-specific integrated circuit. During module production, characteristic inefficiencies in multiple columns of pixels, referred to as core column issues, were observed in ITkPix v1.1 and v2 quad modules. In this talk, results from dedicated investigations of these inefficiencies are presented. These studies in Siegen use and extend electrical testing tools developed by the collaboration. The observed response patterns are categorized and their impact on module performance is assessed. These investigations provide insight into the core column behavior observed during production and support quality assurance for reliable module operation in the future ATLAS ITk.

T 12.5 Mon 17:15 KH 01.022

2S module assembly in Aachen for the CMS Phase-2 Outer Tracker upgrade — Max Beckers[2], Clara Ebisch[1], Lutz Feld[1], •Nina Höflich[2], Katja Klein[1], Martin Lipinski[1], Daniel Louis[1], Oliver Pooth[2], Vanessa Oppenländer[1], Joëlle Savelberg[1], Michael Wlochal[1], and Wioletta Wyszkowska[2] — [1]I. Physikalisches Institut B, RWTH Aachen University, D-52056 Aachen — [2]III. Physikalisches Institut B, RWTH Aachen University, D-52056 Aachen

In the context of the CMS Phase-2 upgrade, the complete Outer Tracker of the CMS detector will be replaced. The new Outer Tracker will contain two types of modules, 2S modules consisting of two silicon strip sensors and PS modules made from a silicon macro-pixel and a silicon strip sensor. In total, around 7600 2S and 6000 PS modules will be built and installed in the new outer tracker. These modules are currently under assembly in multiple assembly centers worldwide.

At the Physics Institutes IB and IIIB at RWTH Aachen University, approximately 1000 2S modules will be assembled, with over 100 already completed. The module assembly consists of multiple gluing and wirebonding steps, which have to be performed with high precision. The assembly is accompanied by various QC measurements, especially module readout and sensor-sensor alignment tests, to ensure consistent module quality.

In this talk, the 2S module assembly at RWTH Aachen will be presented, including the current status and details on the different assembly steps.

T 12.6 Mon 17:30 KH 01.022

2S module assembly progress and module test results for the CMS Phase-2 Tracker Upgrade — •Max Beckers[2], Lutz Feld[1], Nina Höflich[2], Katja Klein[1], Martin Lipinski[1], Vanessa Oppenländer[1], Oliver Pooth[2], and Joëlle Savelberg[1] — [1]I. Physikalisches Institut B, RWTH Aachen University, D-52056 Aachen — [2]III. Physikalisches Institut B, RWTH Aachen University

For the CMS Phase-2 Outer Tracker upgrade, new silicon strip detector modules consisting of two silicon strip sensors, so-called 2S modules, are developed and produced. This process is distributed along multiple assembly centers worldwide.

RWTH Aachen University will build around 1000 2S modules. After each assembly step different QC measurements and tests are performed. Different kinds of specifications needs to be respected. The assembled modules are then shipped to DESY, where they are thermally cycled in the "Burn-in" setup. In addition, a multi module cold box is available in Aachen to perform thermal cycles for up to 4 modules.

With over 100 modules built in Aachen and shipped to DESY the assembly process is currently ongoing. As more and more modules become available, the QC and test results are continuously monitored and can be evaluated in relation to the overall statistical. These results can be used to implement a module grading concept.

This talk presents the current assembly progress of 2S modules at Aachen together with results from QC measurements, module tests and thermal cycling.

T 12.7 Mon 17:45 KH 01.022

Petal Loading for the ITk Strip Endcap — •Mariana Vivas Albornoz — Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

The ATLAS detector will be upgraded for operation at the High Luminosity LHC. The upgrade of the detector includes the construction of a new all-silicon inner tracker (ITk) to effectively take data in an environment with increased pile-up and corresponding high occupancies. The ITk detector is composed of an outer silicon microstrip-based (strip) detector and an inner pixel detector. Both trackers are divided into a barrel region, around the interaction point, and two endcaps, extending into the forward regions. One strip endcap is being constructed at DESY. A strip endcap is composed of 192 petals holding 12 silicon module detectors in place. The assembly work for 96 petals is taking place at DESY. The silicon modules are loaded onto the petal cores via a multi-step procedure that requires careful handling and micrometer level precision. This contribution summarizes the steps and techniques involved in the loading task, and explains how precision during each step of the process is necessary for the overall functioning of the new ITk detector.

T 12.8 Mon 18:00 KH 01.022

Segement Test on ATLAS ITk Strips End Cap — •Konstantin Mauer — Deutsches Elektronen-Synchrotron DESY, Hamburg

The upcoming High-Luminosity upgrade of the Large Hadron Collider (HL-LHC) will significantly increase its instantaneous luminosity. This will lead to a higher track density, a higher hit rate and an increased amount of radiation damage in the experiments. For this reason, the ATLAS experiment will be upgraded, and a new all-silicon inner tracking (ITk) detector has been designed, consisting of strip and pixel detector modules.

In the outer layers silicon strips modules are used and loaded onto local support structures. In the forward directions these are called petals. They are integrated into an End Cap (EC) mechanical structure at one of the two EC integration sites. After welding 16 petals to a cooling manifold, this segment will be fully powered and characterized using the final detector powering chain and readout devices.

With the production ramping up, petals are accumulating for fully populating the first segment. Thus, in summer 2026 the first segment test is scheduled. This talk presents ongoing preparations towards this milestone.

T 13: Higgs Physics II

Time: Monday 16:15–18:15 Location: KH 02.013

T 13.1 Mon 16:15 KH 02.013

Search for light pseudoscalar Higgs boson decays in the flavour-asymmetric $\mu^+\mu^-$ $c\bar{c}$ final state with the CMS detector — Kai Fabian Adamowicz, Danyer Perez Adan, Lutz Feld, Philipp Nattland, and •Keitlin Sejdarasi — 1. Physikalisches Institut B, RWTH Aachen

A search for exotic decays of the Standard Model (SM) Higgs boson into pairs of light pseudoscalar Higgs bosons a decaying in the flavour-asymmetric final state $a \to \mu^+\mu^-$ and $a \to c\bar{c}$ is presented. This channel exploits both the clean experimental signature provided by the excellent detector resolution for muons and the large branching fraction of the pseudoscalar decay into charm quarks, as predicted by the two-Higgs-doublet model extended by a singlet (2HDM+S). Pseudoscalar masses in the range 4-11 GeV are probed, corresponding to a kinematic regime where they exhibit a significant Lorentz boost. The resulting, highly collimated decay products lead to a distinctive topology: the dimuon invariant mass is used as the primary discriminating observable to extract any potential signal, while in the hadronic channel, the decay to charm quarks can be reconstructed using existing charm-jet identification techniques. In this talk, results obtained using the newly acquired Run 3 CMS data from 2024, at a center-of-mass energy of 13.6 TeV, are presented, aiming at improving the sensitivity through increased statistics. In addition, the performance and suitability of newly developed charm jet identification algorithms for Run 3 are investigated in the context of this search.

T 13.2 Mon 16:30 KH 02.013

Search for light pseudoscalar bosons from Higgs boson decays in the four-kaon final state with the CMS detector — Nils Faltermann[1], Jonas Flossmann[1], •Johannes Hornung[1], Benedikt Maier[2], and Markus Klute[1] — [1]Karlsruher Institut für Technologie, Karlsruhe, Germany — [2]Imperial College, London, United Kingdom

Since the discovery of the Higgs boson, extensive measurements of its properties have set upper limits on the branching ratio of its yet undetected decay modes. The branching ratio encompasses immediate decays into SM particles that are not detectable, as well as decays into BSM particles. This talk focuses on a search for Higgs boson decays into pairs of hypothetical pseudoscalar bosons a. These bosons can either be identified as pseudoscalar Axion-Like Particles (ALPs) or, more specifically, as additional Higgs Bosons, as suggested for example by the NMSSM. Specifically, the search strategy, focussing on the background estimation, and expected limits of an analysis targeting prompt decays H -> aa -> KKKK using data collected by the CMS detector during Run 2 of the LHC will be discussed.

T 13.3 Mon 16:45 KH 02.013

Searches for rare Higgs boson decays to light hadronic resonances with CMS data — Konstantinos Nikolopoulos, •Mahtab Jalal Vandi, and Robert James Ward — University of Hamburg, Hamburg, Germany

The current experimental constraints still allow for light, weakly coupled states in the *Higgs* sector. This motivates searches for rare *Higgs* boson decays such as $H \to Za$, where a is a hadronically decaying resonance with a mass between 0.5 and 3.5 GeV. While this mass range has been explored in previous searches, it remains experimentally challenging, and further investigation can benefit from improved experimental techniques. Studies on the development of such techniques and on the estimation of the expected sensitivity will be presented.

T 13.4 Mon 17:00 KH 02.013

Interference effects of Beyond Standard Model Higgs to ditau production on Z pole — •Frank Nowak, Luka Vomberg, Philip Bechtle, Christian Grefe, and Klaus Desch — Universität Bonn

The Higgs sector is still one of the most interesting areas of the Standard Model (SM), even more than 13 years after the discovery of the Higgs boson. There is a wide variety of motivation for expanded Higgs sectors in beyond-the-SM theories (BSM), both from theoretical considerations and from experimental hints. A particularily attractive addition would involve an additional light Higgs-boson below the mass of the SM-like Higgs boson at 125 GeV. It would be even more theoretically attractive to consider CP even H, CP odd A and mixed CP states ϕ for this particle.

For this study the search for these BSM Higgs bosons in the decay of $H/A \to \tau\tau$ covers the particularly challenging mass range around the Z peak. In this case, interference of the BSM Higgs boson production with Z boson production cannot be excluded for some contributions to the production. The possible interference effects of new particles are explored in truth level Monte Carlo samples in the $pp \to \tau\tau + X$ channel. A special emphasis of this study is the influence of the CP-state of the new bosons on the interference between the BSM Higgs and Z.

T 13.5 Mon 17:15 KH 02.013

The Importance of Being Kite — •Karim Elyaouti[1], Rafael Boto[1], Duarte Fontes[1], Maria Gonçalves[1], Milada Margarete Mühlleitner[1], Jorge C. Romão[3], Rui Santos[2], and João P. Silva[3] — [1]Karlsruher Institut für Technologie — [2]Universidade de Lisboa, Campo Grande — [3]Departamento de Física and CFTP, Instituto Superior Técnico, Universidade de Lisboa

The Complex Two-Higgs-Doublet Model (C2HDM) features an explicitly CP-violating scalar sector, making the electron electric dipole moment (eEDM) one of the most stringent probes of the model. The current limit of 4.1×10^{-30} e.cm already places strong constraints on CP-violating Higgs interactions, and future sensitivities are expected to improve by several orders of magnitude. This talk presents an updated analysis of the C2HDM parameter space under all current theoretical and experimental constraints. The calculation of the eEDM includes the contribution from the charm quark, which can be relevant in certain regions of the parameter space. Machine-learning techniques are employed to explore parameter regions that are difficult to access with traditional search strategies.

T 13.6 Mon 17:30 KH 02.013

The cS2HDM as a unified framework for dark matter and electroweak baryogenesis — Thomas Biekötter[1], •Pedro Gabriel[2,3], Milada Margarete Mühlleitner[2], and Rui Santos[3,4] — [1]Instituto de Física Teórica UAM/CSIC, Madrid, Spain — [2]Institute for Theoretical Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany — [3]Centro de Física Teórica e Computacional, Faculdade de Ciências da Universidade de Lisboa, Lisboa, Portugal — [4]ISEL - Instituto Superior de Engenharia de Lisboa, Instituto Politécnico de Lisboa, Lisboa, Portugal

The discovery of the Higgs boson at the LHC confirms the Standard Model's (SM) mechanism for electroweak symmetry breaking, yet the SM fails to address key cosmological phenomena such as dark matter (DM) and the matter-antimatter asymmetry. Higgs-portal models with extended scalar sectors offer promising frameworks to bridge this gap. Among them, models incorporating a complex singlet scalar field can host pseudo-Nambu-Goldstone (pNG) DM, naturally suppressing direct-detection signals and making them ideal candidates for collider-based DM searches. However, minimal pNG DM models lack ingredients for electroweak baryogenesis. To overcome this, we look at the CP-violating singlet-extended two Higgs doublet model (cS2HDM) which contains both a pNG DM candidate and several sources of CP-violation and could serve as a benchmark for upcoming LHC searches

T 13.7 Mon 17:45 KH 02.013

Machine learning in the 2HDM2S model for dark matter — •Rafael Boto[1], Tiago Rebelo[2], Jorge Romão[2], and João Silva[2] — [1]Institute for Theoretical Physics, Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany — [2]CFTP, Instituto Superior Técnico, Universidade de Lisboa, Av Rovisco Pais, 1, P-1049-001 Lisboa, Portugal

In this work, we build a two real scalar singlet extension of the two Higgs doublet model to answer the dark matter problem. We study the vacuum structure, the bounded from below conditions, the restrictions from the oblique parameters S,T and U, as well as the unitarity constraints. We submit the model to collider and Dark Matter experimental constraints and explore its allowed parameter space. We compare randomly populated simulations, simulations starting near the alignment limit, and a Machine Learning based exploration to find viable solutions.

T 13.8 Mon 18:00 KH 02.013

Dark Matter Aspects of the Composite Higgs Models — •Yu Chen — Universität Würzburg

The nature of Dark Matter (DM) and the origin of small neutrino masses remain open questions in particle physics, motivating extensions of the Standard Model. In this talk, I explore Composite Higgs (CH) models that can simultaneously address both issues. As a concrete example, I will present a CH model based on the coset SU(6)/Sp(6), which naturally provides potential DM candidates as a composite pseudo-Nambu Goldstone boson. I will discuss the phenomenological implications, focusing on explaining the DM relic density within this framework.

T 14: Data, AI, Computing, Electronics II

Time: Monday 16:15–18:15 Location: KH 02.014

T 14.1 Mon 16:15 KH 02.014

Towards a sustainable ET Computing Center — •Stefan Krischer and Achim Stahl — RWTH Aachen University, III. Physikalisches Institut B

For the Einstein Telescope, a dedicated computing center will be required to support detector control, low-latency data processing, and parts of the offline analysis. In preparation, the infrastructure is being explored with a strong focus on sustainability. To assess feasibility, a prototype computing facility is being developed with its own renewable energy system capable of supplying 100% locally generated power. In this setup, computing workloads and hardware adapt their power consumption to the instantaneous energy availability, reducing the required energy-storage capacity. We present the concept and initial insights from the prototype development as a basis for a more sustainable computing center for the Einstein Telescope.

T 14.2 Mon 16:30 KH 02.014

Recent Developments in HEP Computing in Karlsruhe — Giacomo De Pietro, Patrick Ecker, Nils Faltermann, Emelie Fuchs, Johannes Gaessler, Manuel Giffels, Artur Gottmann, Jan Kieseler, Max Kühn, Yannis Kluegl, Günter Quast, Raquel Quishpe, Matthias Schnepf, Nikita Shadskiy, Lars Sowa, •Tim Voigtlaender, and Ralf Florian Von Cube — Karlsruhe Institute of Technology (KIT)

The computing contribution of the Karlsruhe Institute of Technology (KIT) to the WLCG pledge is provided through the Tier-1 center GridKa, together with opportunistic resources from the HoreKa HPC and the local Tier-3 cluster. These resources, together with the development activities of the Karlsruhe computing group, form a tightly integrated component that addresses a broad spectrum of high-energy physics (HEP) workloads and operational needs.

This talk outlines the current status and ongoing developments in HEP computing activities at KIT. This includes the status of the GPU integration into the WLCG from HoreKa and the Karlsruhe Tier-3 cluster, highlighting the first official workflows by LHC experiments on these systems. These early tests provide a baseline for future large-scale GPU-accelerated workflows. In addition, the ongoing effort to sustainably use legacy hardware during periods of renewable-energy surplus is presented as part of a broader move towards an energy-adaptive computing strategy. Finally, planned storage and compute extensions at GridKa Tier-1 center are presented, aimed at meeting future requirements and ensuring compliance with pledged resources.

T 14.3 Mon 16:45 KH 02.014

Integration of NHR resources into the ATLAS computing workflow in Freiburg — •Dirk Sammel, Michael Böhler, and Markus Schumacher — Albert-Ludwigs-Universität Freiburg

At many sites of the Worldwide LHC Computing Grid (WLCG), high-performance computing (HPC) resources are already integrated (or soon will be) into the computing workflows of various experiments. The WLCG Tier-2 cluster ATLAS-BFG in Freiburg has been extended by incorporating resources from the NHR cluster HoreKa at KIT.

To integrate these computing resources into the Freiburg Tier-2 cluster in a transparent and efficient manner, a container-based approach was adopted using the meta-scheduler COBalD/TARDIS. TARDIS launches so-called drones on the HPC system, providing additional compute capacity to the Tier-2 cluster. To differentiate between these augmented resources and the WLCG resources in Freiburg, the AUDITOR accounting ecosystem is used.

This presentation provides an overview of the current status and initial experiences with integrating HPC resources into the Freiburg Tier-2 cluster ATLAS-BFG.

T 14.4 Mon 17:00 KH 02.014

AUDITOR: Tackling HL-LHC accounting challenges and estimating environmental impact of jobs — •Raghuvar Vijayakumar, Michael Böhler, Dirk Sammel, and Markus Schumacher — Universität Freiburg

Distributed computing infrastructures are shared by multiple research communities, particularly within High Energy Physics (HEP), where precise and transparent resource accounting is critical. To meet these demands, we developed AUDITOR (AccoUnting DatahandlIng Toolbox for Opportunistic Resources), a flexible, modular, and extensible accounting ecosystem designed for heterogeneous computing clusters.

AUDITOR captures, processes, and analyzes usage metrics through specialized collectors from HTCondor, Kubernetes, and Slurm batch systems, storing all data in a PostgreSQL database. Its plugin-based architecture allows integration with external tools with Rust and Python clients. Existing plugins include the APEL plugin, which publishes accounting data to the European Grid Initiative (EGI).

Recent developments include a Role-Based Access Control system and an archival subsystem that now periodically exports historical data to Parquet files. The new utilization report plugin provides summaries of job counts, HEPScore performance, power consumption, and estimated CO_2 footprint. Looking ahead, our accounting system is being designed to integrate environmental attributes directly into job-level analytics to measure the carbon impact of computing workloads. In this talk, we will present our new features and highlight how to meet the present and future challenges of HL-LHC accounting.

T 14.5 Mon 17:15 KH 02.014

Theia - A General Photon Propagation Framework for GPUs — •Tobias Kerscher — Technical University of Munich

In neutrino telescopes, understanding how light produced by neutrino interactions via Cherenkov radiation propagates through the detector volume is essential. Due to its complexity this is usually done using Monte Carlo simulations. Using popular tools like GEANT4, however, this often turns out to be the most time consuming step in the overall simulation pipeline and thus becomes a bottleneck. Theia aims to solve this by not only running on GPUs, but also utilizing hardware accelerated ray tracing for fast and accurate intersections with the detector geometry. Since it uses an open standard GPU API, it is not limited to CUDA and NVIDIA hardware. Besides the classical photon tracking simulation, it can also solve for the radiance field producing the underlying expected signal distribution the tracking implicitly samples from. Theia was designed with expendability in mind, making minimal assumptions about the simulated environment. This allows it to be used in various scenarios not limited to neutrino telescopes.

T 14.6 Mon 17:30 KH 02.014

Background Jobs for Efficient Resource Utilisation on HPC Systems — Inga Lakomiec[1], •Ughur Mammadzada[1], Saidev Polisetty[1], Arnulf Quadt[1], Rodney Walker[2], and Sebastian Wozniewski[1] — [1]Georg August University of Göttingen — [2]Ludwig Maximilian University of Munich

The upcoming High Luminosity Large Hadron Collider (HL-LHC) era will greatly increase the computational and storage demands of high energy physics beyond what the current Worldwide LHC Computing Grid (WLCG) can provide. In Germany, university based Tier-2 sites are therefore transitioning their workloads to national HPC facilities at Nationales Hochleistungsrechnen (NHR). In this context, the GoeGrid Tier-2 site at the University of Göttingen is migrating its computing activities to the local NHR cluster EMMY.

To integrate HPC resources into the WLCG, virtual worker nodes are created. They must stop accepting WLCG jobs well before the time limit set by the HPC system, which prevents premature termination but leaves a significant fraction of the allocated CPU time unused near the end of the lifecycle. As the HL-LHC will increase the data volume by a factor of ten, such resource loss becomes increasingly inefficient. The heterogeneous WLCG-HPC environment also requires robust monitoring.

This work investigates opportunistic background jobs at GoeGrid and EMMY to recover this otherwise wasted capacity, and reviews the monitoring infrastructure and the concept of virtual worker nodes.

T 14.7 Mon 17:45 KH 02.014

Assessing Power-Saving Potential Through ACPI Sleep States in Data Center Rack Servers at DESY — •Sandro Grizzo[1], Dwayne Spiteri[2], Kilian Schwarz[3], Martin Gasthuber[4], Konrad Kockler[5], and Jan Hartmann[6] — [1]sandro.grizzo@desy.de — [2]dwayne.spiteri@desy.de — [3]kilian.schwarz@desy.de — [4]martin.gasthuber@desy.de — [5]konrad.kockler@desy.de — [6]jan.hartmann@desy.de

This report evaluates the feasibility of using ACPI sleep states to reduce power consumption in rack servers at the DESY data center. It outlines the ACPI power-state model, with emphasis on the S5 *soft*off* state and the Linux-specific suspend-to-idle mechanism, as these are the only sleep states typically supported on server-grade hardware. Measurements obtained via IPMI interfaces on several server models show potential power savings above 80% in S5 relative to idle mode. Suspend-to-idle provides a substantially lower reduction, but also lower wake-latencies in return. The findings indicate that using S5 for idle servers could offer considerable power-saving potential in data centers where low wake-latency is not a primary requirement.

T 14.8 Mon 18:00 KH 02.014

Optimisation of GPU Accelerated Algorithms for Track Finding in Particle Physics — •Petr Fiedler, André Sopczak, and Pavel Tvrdik — CTU in Prague

Track finding in particle physics has been an increasing challenge over the past decades because the intensities of collisions in state-of-the-art particle colliders have increased enormously. One of the track reconstruction steps is the track finding. For this, track seeds are determined and the tracks are successively reconstructed by adding more measurements. We explain the main ideas of the state-of-the-art GPU-accelerated implementation of the track finding algorithm and describe several optimisations focusing on an early elimination of fake tracks.

T 15: Searches/BSM I

Time: Monday 16:15–18:15 Location: KH 02.018

T 15.1 Mon 16:15 KH 02.018

Search for Di-lepton+X and Di-Photon Signatures with Forward Proton Scattering — •Viktoriia Lysenko and André Sopczak — CTU in Prague

The latest results are presented using combined data recorded with the central ATLAS detector and the ATLAS Forward Proton spectrometer. The focus is on two analyses, the search for a missing mass resonance in the channel $pp \to p'p'\ell\ell X$, and the search for an axion-like particle (ALP) in light-by-light scattering with the detection of a scattered forward proton.

T 15.2 Mon 16:30 KH 02.018

Search for new phenomena in dilepton final states with associated b-jets at the ATLAS experiment — •Anna Bingham and Frank Ellinghaus — Bergische Universität Wuppertal

An overview of a search for new phenomena in high-mass dilepton (ee,$\mu\mu$) final states with associated b-jets is presented. The main analysis considers a Z' model as a candidate explanation for potential anomalies in B hadron decays, where the Z' boson couples to b and s quarks in the production. Non-resonant contact interactions and t-channel leptoquark production are taken in account as additional interpretations. The search is carried out using the dataset collected by the ATLAS detector in Run-2 of the LHC corresponding to an integrated luminosity of $140\,\mathrm{fb}^{-1}$. Backgrounds are estimated from MC and also by data-driven methods. Control, signal and validation regions are defined, and these regions are fitted in a profile-likelihood fit. Exclusion limits are obtained based on the results of the fit.

T 15.3 Mon 16:45 KH 02.018

Reconstruction of Heavy Neutral Leptons decaying into $l+\rho$ with ATLAS using mass-constraint techniques — •Maximilian Ruhl — Institut für Physik, Humboldt-Universität zu Berlin

Heavy Neutral Leptons (HNLs) are well-motivated candidates for new physics in the GeV mass range and are investigated at the LHC, in particular with the ATLAS experiment, through displaced semileptonic decays. The channel $N \to \ell\rho \to \ell\pi^{\pm}\pi^{0}$ might increase the search sensitivity at low HNL masses because its branching fraction is comparatively large and the visible decay products form a clean displaced-vertex signature. If the π^0 is not explicitly reconstructed, essential kinematic information is missing. In this study, the three-momentum vector of the neutral pion is estimated using mass-constraint techniques. The photons from the π^0 decay have a direction very close to the π^0 momentum, hence $\Delta\mathrm{R}(\gamma, \pi^0_{reco})$ is small. This characteristic pattern can help to reduce the background without requiring full reconstruction of the π^0. The analysis investigates these photon-based observables and evaluates their potential relevance for future searches for semileptonic HNL decays with ATLAS.

T 15.4 Mon 17:00 KH 02.018

Anomaly detection for long-lived particles using CATHODE with CMS — •Jovin Drews, Louis Moureaux, Gregor Kasieczka, Karim El Morabit, Chitrakshee Yede, and Tore von Schwartz — University of Hamburg, Hamburg, Germany

In high-energy physics, numerous analyses search for phenomena beyond the Standard Model (BSM). Anomaly detection methods offer a model-independent way to probe such potential BSM signatures. We discuss CATHODE, an anomaly detection method combining density estimation and weak supervision, applied to signals from long-lived particles (LLP) embedded in multijet background from the CMS experiment. The work studies LLP scenarios with varying properties and different approaches to classification.

T 15.5 Mon 17:15 KH 02.018

Search for Delayed Long-Lived Particles in Consecutive Bunch Crossings using the ATLAS Detector — •Tobias Heintz — Kirchhoff Institute for Physics, Heidelberg, Germany

This contribution presents a novel strategy to detect long-lived particles (LLPs) that decay across two consecutive bunch crossings, combining missing transverse momentum from a slowly propagating LLP in one bunch crossing with a displaced jet that appears more than 25 ns later and is azimuthally correlated. Unconventional BSM scenarios would give rise to such a signature over multiple bunch crossings, but are not efficiently captured by conventional trigger and reconstruction approaches. The concept of a dedicated trigger and its implementation within the ATLAS detector are discussed, along with projected sensitivities for a benchmark scenario motivated by inelastic dipole dark matter.

T 15.6 Mon 17:30 KH 02.018

Search for long-lived dark scalars at the LHCb experiment — •Penelope Hoffmann and Christoph Langenbruch — Physikalisches Institut, Universität Heidelberg, Germany

In the minimal dark scalar portal model, a potential dark scalar sector is expected to couple to the Standard Model Higgs boson, with a dark scalar particle acting as a mediator for dark matter. At LHC energies, flavour-changing neutral current decays of K and B mesons are excellent probes for dark scalar particles in the MeV/c^2 to GeV/c^2 mass region.

This talk presents a search for a dark sector scalar particle χ, produced via the decay $B^0 \to K^{*0}\chi(\to \mu\mu)$, in data recorded in late 2025 with the LHCb detector. Tracks from final state particles originating from long-lived scalar particles that decay outside the LHCb vertex detector (VELO) are reconstructed using only information from the LHCb upstream tracker (UT) and the downstream tracking system (SciFi). These tracks are referred to as downstream tracks.

Employing an improved downstream track reconstruction and a new dedicated trigger line, the preliminary expected limit presented in this talk showcases the promising potential of using downstream tracks in the search for a dark scalar particle at LHCb.

T 15.7 Mon 17:45 KH 02.018

Search for Semivisible Jets with CMS Run 2 Scouting Data — •Marcel Gaisdörfer[1], Jonas Janik[1], Brendan Regnery[1], Markus Klute[1], Benedikt Maier[2], Cesare Tiziano Cazzaniga[3], Roberto Seidita[3], Annapaola de Cosa[3], Aimar Aguado Berasaluce[3], Rebecca Natalia Hamp[3], Celeste Holm[3], and Kevin Pedro[4] — [1]Karlsruher Institut für Technologie (KIT) — [2]Imperial College London — [3]ETH Zürich — [4]Fermi National Accelerator Laboratory

Cosmological observations point towards the existence of Dark Matter (DM), a type of matter not described by the Standard Model (SM) that only interacts gravitationally and at most weakly with SM particles. This search looks for a signature called semivisible jets, which are jets containing invisible DM candidates. Semivisible jets could be caused by a QCD-like dark sector, coupled to the SM via a Z' mediator. To expand previous search efforts towards lower mediator masses, this search utilizes data scouting. Data scouting records the coarser HLT reconstruction instead of the full detector information to save on bandwidth, which allows lowering trigger thresholds, giving access to events that would typically have been discarded. This talk will give an overview of the search strategy, current status and expected limits of the search for semivisible jets with CMS Run 2 HLT scouting data.

T 15.8 Mon 18:00 KH 02.018

Search for X17 particle at the BESIII — •Hang Zhou[1,2] and Achim Denig[1,2] — [1]Johannes Gutenberg University Mainz, Germany — [2]Helmholtz Institute Mainz, Germany

The anomalous internal pair creation signals reported by the ATOMKI group suggest the emission of a new boson with an invariant mass of approximately 17 MeV, often referred to as X17. This hypothetical particle has been proposed as a mediator of a fifth force or as a portal between the Standard Model (SM) and a dark sector. Besides the ATOMKI measurements, several dedicated experiments, such as NA64, MEG II and PADME, have searched for X17-like signatures. So far, however, no independent experiment has conclusively confirmed the existence of X17. If X17 is a real boson, it should also be produced in processes beyond nuclear transitions. One suggested possibility is heavy meson decay, e.g. charmonium decay. Charmonium Dalitz decays, which are analogous to nuclear de-excitation with internal pair creation, offer an independent test of the X17 hypothesis and a unique environment to probe its couplings to second-generation quarks. Moreover, the available phase space in these decays is well suited for searches for MeV-scale dark photons that couple weakly to SM particles.

The BESIII experiment operating at the BEPCII e^+e^- accelerator, has collected world's largest data sample in the τ-charm region. Using these data, a dedicated search for X17 in charmonium Dalitz decays is performed. This talk will present the analysis strategy and recent results from BESIII, providing a complementary and collider-based probe of the X17 scenario.

T 16: Search for Dark Matter I

Time: Monday 16:15–18:15 Location: AM 00.014

T 16.1 Mon 16:15 AM 00.014

XLZD: a next-generation multi-purpose liquid xenon observatory. — •Daniel Wenz for the XLZD-Collaboration — University of Münster

Owing to their excellent detection efficiency, scalability, and ultra-low background levels, dual-phase time projection chambers (TPCs) employing multi-tonne liquid xenon (LXe) targets provide a powerful tool for the discovery and study of a broad range of rare, low-energy phenomena. Key science channels include the search for dark matter, measurements of solar neutrinos and their properties, and searches for rare processes such as the neutrinoless double beta decay of Xe-136. In addition, LXe TPCs enable flavor-independent measurements of low-energy neutrino fluxes from supernovae, contributing to multi-messenger astronomy.

The proposed XLZD experiment is a next-generation, multi-purpose liquid xenon observatory that builds upon the technologies developed by the currently world-leading experiments XENONnT and LZ, as well as the R&D program of DARWIN. The nominal detector design foresees a 60-tonne LXe target mass, with a potential upgrade path to approximately 80 tonnes. In this talk, we present an overview of the XLZD concept and its projected sensitivities across the different science channels.

The author of this talk is supported by BMBF through the project numbers 05A23PM1 and the EU through the ERC AdG LowRad (101055063).

T 16.2 Mon 16:30 AM 00.014

Design, Development and Characterization of Electrodes for XENONnT and towards XLZD — •Alexey Elykov — Karlsruhe Institute of Technology, Institute for Astroparticle Physics

Dual-phase noble gas time projection chambers (TPCs) lie at the heart of detectors that perform a wide range of rare event searches, spanning from attempts to detect particle dark matter to studies of neutrino physics. High-voltage electrodes are instrumental for the generation and interpretation of signals produced in the TPC.

The XENON collaboration currently operates a state of the art, ∼1.5 m-wide TPC, immersed in 8.9 t of liquid xenon. The XLZD (XENON, LZ, DARWIN) collaboration aims to construct and operate the ultimate xenon-based TPC, which will span ∼3 m in diameter and will host 60 t of liquid xenon. With a keV-range threshold and an ultra-low radioactive background, XLZD will aim to probe the entire parameter space for WIMP dark matter down to the so-called neutrino fog, and will conduct searches for solar axions, axion-like particles, as well as measurements of the solar neutrino flux, and a probe of the Majorana nature of neutrinos.

In this talk, we will present the successful design, development and characterization of ∼1.5 m-scale electrodes for the upgrade of the XENONnT detector and the R&D work towards electrodes for the XLZD detector [1]. This work has been supported in part by the Federal Ministry of Research, Technology and Space (BMFTR) through the grant 05A23VK3 within the ErUM-Pro funding line.

[1] arXiv:2511.16408

T 16.3 Mon 16:45 AM 00.014

Modeling of signatures from charged leptonic products of dark matter annihilation — •Milena Brütting[1,2], Athithya Aravinthan[1,2], Julia Becker Tjus[1,2,3], Julien Dörner[1,2], and Jannis Wagner[1,2] — [1]Theoretical Physics IV, Ruhr-University Bochum, Germany — [2]Ruhr Astroparticle and Plasma Physics Center (RAPP Center), Bochum, Germany — [3]Department of Space, Earth and Environment, Chalmers University of Technology, Gothenburg, Sweden

The indirect search for Dark Matter (DM) has been challenging for decades due to the need for low-background environments and the ambiguity between potential DM signals and conventional astrophysical emission. A promising strategy is to model and compare signatures from different DM annihilation channels with astrophysical emission in a synthetic dwarf galaxy assuming the same total energy from both DM and astrophysical sources.

The prompt emission of DM annihilation and the secondary emission from interactions of charged products (such as electrons and positrons) with the ambient fields are modeled to help differentiate the DM and the astrophysical signal. Simulations are performed with the open-source code CRPropa 3.2, which provides a flexible and self-consistent modeling framework for particle propagation. Results reveal morphological differences between both sources. We test different DM annihilation channels, such as bottom quarks, top quarks and W gauge bosons, as well as DM density profiles, such as Einasto, Burkert and Navarro-Frenk-White.

T 16.4 Mon 17:00 AM 00.014

Direct Detection of sub-GeV Dark Matter with the CRESST experiment — •Federico Casadei for the CRESST-Collaboration — Max Planck Institut für Physik, Garching bei München, Deutschland

The Cryogenic Rare Event Search with Superconducting Thermome-

ters (CRESST) experiment is operating at the Laboratori Nazionali del Gran Sasso (LNGS) in Italy, where it has been pursuing the direct detection of dark matter for almost three decades. Employing scintillating crystals instrumented with Transition Edge Sensors (TESs) and operated as cryogenic calorimeters at millikelvin temperatures, CRESST has achieved energy thresholds as low as 6.7 eV. Combined with the use of targets with light nuclei, this enables CRESST to be particularly sensitive to sub-GeV dark matter particles through nuclear-recoil interactions. In this talk, an overview of the CRESST experiment is presented, highlighting detector operation and recent dark-matter results. Ongoing work to improve sensitivity and advance detector design will also be discussed, together with prospects for future explorations of low-mass dark matter.

T 16.5 Mon 17:15 AM 00.014

Illuminating the Invisible: Deep underground dark matter search with COSINUS — •Mukund Bharadwaj for the COSINUS-Collaboration — Max Planck Institute for Physics, 85748 Garching - Germany

The COSINUS experiment (Cryogenic Observatory for SIgnatures seen in Next generation Underground Searches) is a cryogenic, low-background experiment being set up at Laboratori Nazionali del Gran Sasso, Italy. It aims to provide a model independent cross-check of the DAMA/LIBRA findings of a potential dark matter-like modulation signal. COSINUS utilizes a two-channel readout system based on transition edge sensors (TESs) that allows for particle discrimination. It consists of ultrapure scintillating sodium iodide (NaI) crystals, read out using a novel remoTES scheme to measure the phonon signal of a particle interaction. A silicon beaker surrounding the crystal is used to measure the light signal from the same particle interaction. Results from the latest measurements and updates on the setup will be presented in this contribution.

T 16.6 Mon 17:30 AM 00.014

Towards DELight: First Results from a Prototype R&D Cell — •Anna Bertolini for the DELight-Collaboration — Kirchhoff-Institut für Physik, Universität Heidelberg

As direct detection experiments continue to push down the limits on heavy WIMPs, the low-mass dark matter (DM) regime remains comparatively unexplored. Probing this region requires detectors that combine sub-keV energy thresholds with large exposures. The Direct search Experiment for Light dark matter (DELight) aims to meet this challenge by using superfluid helium-4 as a target material and magnetic micromalorimeters (MMCs), enabling excellent energy resolution and detection thresholds of only a few eV. As a first step toward the full experiment, we have developed a dedicated R&D cell to study the MMC response to particle interactions in superfluid helium. In this setup, a 300-ml copper cell is cooled to ~10 mK, where an MMC fabricated on a silicon substrate and a resistive heater are fully submerged in the superfluid. This configuration allows us to characterize the detector response to both particle induced signals in helium and controlled heater pulses. In this contribution, we present the R&D setup, its operational performance, and the first experimental results that form the foundation for the DELight experiment. This work is supported through the Heidelberg Karlsruhe Strategic Partnership (HEiKA STAR).

T 16.7 Mon 17:45 AM 00.014

Simulating DELight: the simulation framework of the DELight experiment — •Francesco Toschi for the DELight-Collaboration — Kirchhoff-Institut für Physik, Heidelberg University

The strong experimental constraints on well-motivated dark matter candidates for masses above 1 GeV/c^2 motivates the exploration of lighter alternative candidates. Probing the low-mass regime requires ultra-low energy thresholds: these are already achieved by solid-state cryogenic detectors thanks to their phonon signal and ultra-sensitive sensors. Combining this approach of ultra-low energy phonon detection with much lighter target nuclei will further enhance the low mass reach. The Direct search Experiment for Light dark matter (DELight) will use a superfluid helium-4 target instrumented with large area microcalorimeters (LAMCALs), combining the low threshold of phonon-based detection with the scalability of noble liquids. This allows DELight to explore masses below 100 MeV/c^2 with just 1 kg·d of exposure.

DELight is in its design phase, and detailed simulations play a central role in informing the design and construction of the final detector. This talk will present the DELight simulation framework, including the signal formation and propagation within the superfluid volume, as well as models of the relevant background sources.

T 16.8 Mon 18:00 AM 00.014

ImpCresst - A versatile simulation tool focusing on cryogenic solid-state detectors at sub-MeV energies — •Holger Kluck for the CRESST-Collaboration — Marietta-Blau-Institut für Teilchenphysik der Österreichischen Akademie der Wissenschaften, 1010 Wien, Österreich

We present ImpCresst, a Geant4 based Monte Carlo tool to simulate radioactive and cosmogenic backgrounds in cryogenic solid-state detectors. It is tuned for a fast-evolving and heterogeneous detector environment with a focus on physics at the sub-MeV level. ImpCresst was developed for the CRESST experiment and proved its suitability there. However, its flexibility and configurability makes it adaptable to any other experiment with a similar profile of requirements: dynamical creation of detector geometries, optionally directly from CAD files; ROOT based data persistency of the whole simulated event topology; automatic metadata annotation for data provenance; and interfacing various particle generators specialized for radioactive and cosmogenic background sources. Especially for radioactive bulk and surface contaminations, we developed a new and convenient particle generator. Detector-specific energy and time resolutions are flexibly applied based on a user-provided data set of empirical parameterization.

T 17: Neutrino Astronomy I

Time: Monday 16:15–18:15 Location: KS H C

T 17.1 Mon 16:15 KS H C

Search for coincidences between IceCube sub-TeV neutrinos and sub-threshold Gravitational Wave events in the LIGO-Virgo-KAGRA third observing run — •Tista Mukherjee for the IceCube-Collaboration — Institute for Astroparticle Physics (IAP), Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

Since the first direct detection of gravitational waves (GW) by the LIGO-Virgo-KAGRA detectors, the IceCube Neutrino Observatory has actively participated in identifying their neutrino counterparts. The sub-threshold GW alerts from the third observation run of LIGOVirgo-KAGRA, identified by both template-based searches and minimally modelled pipelines, have also been examined in follow-up analyses with TeV-PeV neutrinos, but no correlations were found. This work presents a systematic search for lower-energy neutrino emission from the sub-threshold GWs, utilising the archival all-flavour, sub-TeV neutrino sample from the IceCube Neutrino Observatory. From the public GW catalogues, we identify 103 promising candidates, comprising a mixture of compact binary mergers and GW burst triggers. After conducting a catalogue search to identify correlated sub-TeV neutrinos within a 1000 s time window, employing an unbinned maximum likelihood method, no significant coincidences are found. Hence, we report neutrino flux upper limits from the sub-threshold GW sources followed up in this analysis within sub-TeV neutrino energy.

T 17.2 Mon 16:30 KS H C

Improving Measurement of Astrophysical Neutrino Flux with Advanced Northern Tracks Selection in IceCube — •Shuyang Deng, Lasse Düser, Sönke Schwirn, Philipp Soldin, Christopher Wiebusch, and Marco Zimmermann — III. Physikalisches Institut B RWTH Aachen University, Aachen, Germany

The IceCube Neutrino Observatory is a large neutrino detector at the South Pole. One of its main detection channels is via neutrino-induced muon tracks, which provide a large effective area and high angular resolution. The Advanced Northern Track Selection (ANTS) framework uses a graph convolutional neural network to improve the selection of these events, as well as to perform reconstructions of their physical parameters. Furthermore, these events show different topologies and signatures within the detector, which can be classified with ANTS, enabling dedicated handling of these topologies in analyses. In this talk, we will show the performance of ANTS and the improvement in sensitivity it provides for the measurement of the astrophysical neutrino flux.

T 17.3 Mon 16:45 KS H C

Understanding Wind Related Background Radio Pulses at the Radio Neutrino Observatory in Greenland — •Pascal Schriefer for the RNO-G-Collaboration — ECAP, Friedrich-Alexander-Universität Erlangen-Nürnberg

The Radio Neutrino Observatory in Greenland (RNO-G) aims to detect ultra-high energy (> 10 PeV) neutrinos through pulsed radio signals generated by in-ice particle showers on the basis of the Askaryan effect. 35 independent detector stations are to be built on a grid with a spacing of $\sim$ 1.2 km, eight of which are already operational and equipped with antennas at shallow depths in the ice. Even though the detector is being constructed at the very remote summit of Greenland, approximately 3200 m above sea level, background radio signals of different origins are detectable. Especially during periods with high wind speeds ($> 8 - 10$ m/s), an overwhelming number of radio pulses with signatures comparable to those of neutrino events are detected. This poses a significant issue for the identification of cosmic particles as high wind speeds are not only very common in Greenland, but during the polar winter, wind is the only power source available to keep the stations operational. In this contribution, RNO-G is being introduced and the current state of knowledge about wind-related backgrounds is discussed, including the theorized mechanism and origin of these signals as well as unexplained features and plans of how to further investigate them.

T 17.4 Mon 17:00 KS H C

Downward ultra-high-energy neutrino detection in the atmosphere with radio antenna at the ground-based observatories — •Yue Baobiao for the Pierre Auger-Collaboration — Bergische Universität Wuppertal

Ultra-high-energy (UHE) neutrinos are unique cosmic messengers offering direct insight into the most energetic processes in the universe. Radio detection promises significant advantages for detecting highly inclined air showers induced by UHE neutrinos, including a larger exposure range compared to particle detectors, which is due to minimal atmospheric attenuation of radio signals combined with good reconstruction precision. Furthermore, this technique improves the air shower longitudinal reconstruction, which can be used to identify neutrinos with their first interaction far below the top of the atmosphere. In this work, we present a method to reconstruct the radio emission maximum ($X_{\max}^{\text{radio}}$) and demonstrate its power in distinguishing deeply developing neutrino-induced showers from background cosmic rays. Using the Pierre Auger Observatory as a case study, we evaluate the detection efficiency of the ν_e-CC, and the resulting effective area. Our results show that radio detection significantly enhances the sensitivity to very inclined showers above 1 EeV, complementing traditional particle detectors. This technique is highly scalable and applicable to future radio observatories such as GRAND. The proposed reconstruction and identification strategy provides a pathway toward achieving the sensitivity needed to detect UHE neutrinos. **Supported by BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A23PX1)*

T 17.5 Mon 17:15 KS H C

Modeling Gamma-Ray Bursts Using CRISP — •Therese Paulsen, Leonel Morejón, and Karl-Heinz Kampert — Bergische Universität Wuppertal, Gaußstraße 20, 42119 Wuppertal, Germany

Astrophysical neutrinos are a clear identifier of photohadronic interactions in sources of Ultra-High-Energy Cosmic Rays (UHECRs). As the Pierre Auger Observatory has shown that UHECRs exhibit a composition heavier than protons at Earth, we expect that these heavy primaries undergo nuclear cascades due to photodisintegration in the dense source environments from which they originate.

In this talk, we will derive the neutrino spectra produced by these heavier primaries undergoing photohadronic interactions. This will be explored in the context of modeling the emission region of a gamma-ray burst. Photohadronic interactions will be modeled using the new framework for "Cosmic Ray Stochastic Interactions for Propagation" (CRISP), which employs an analytic approach to compute the underlying probabilistic description of UHECR interactions.

T 17.6 Mon 17:30 KS H C

Prospects for Combined Hadronic Emission Analyses with KM3NeT and CTA — •Shivani Padma Mohan for the KM3NET-ERLANGEN-Collaboration — ECAP, FAU Erlangen-Nürnberg, Erlangen, Germany

Multi-messenger analysis is becoming essential to probe the fundamental astrophysical processes in distant astrophysical sources. In particular, hadronic processes, where both neutrinos and high-energy gamma rays can be simultaneously produced, motivate the combined analysis of these two messengers. KM3NeT (cubic kilometre neutrino telescope) and CTA (Cherenkov Telescope Array) are next-generation instruments with increased sensitivities in neutrino and gamma-ray astronomy, respectively, making them ideal for such joint studies. A previous study demonstrated the feasibility of a combined CTA-KM3NeT analysis using GAMMAPY, an open source Python package widely used in gamma-ray astronomy. Due to its flexible framework, it can also incorporate neutrino data and was used in the study to determine the contribution of hadronic processes in well-known galactic gamma-ray sources. To facilitate future studies involving different messengers, source classes and detector configurations, the analysis pipeline has now been updated to the latest GAMMAPY 2.0 framework. Based on the current Monte-Carlo simulations, the updated Instrument Response Functions (IRFs) for KM3NeT will be presented in comparison with earlier results.

T 17.7 Mon 17:45 KS H C

Framework for Gravitational-Wave and Neutrino stacking Analysis — •Chloe Fisher[1,2] and Tista Mukherjee[1,2] for the IceCube-Collaboration — [1]Karlsruhe institute of Technology — [2]Institute of Experimental Particle Physics (ETP)

Cosmic rays are charged particles whose trajectories are scrambled by magnetic fields, obscuring direct associations with their astrophysical origins. Identifying the engines capable of accelerating them therefore relies on neutral messengers such as neutrinos and gravitational waves. Compact binary coalescences, with or without neutron stars, are promising source candidates in this regard, as they may produce both gravitational-wave emission and hadronic outflows capable of generating high-energy neutrinos under suitable conditions. The joint interpretation of these signals within a multi-messenger framework enhances our ability to probe the physical conditions of their potential common source environments. However, no individual common source of gravitational waves and neutrinos has been identified with a global significance exceeding 3σ after trial correction. This motivates a population-level analysis to search for correlated neutrino emission from the ensemble of observed compact binary coalescences.

T 17.8 Mon 18:00 KS H C

Multi-Messenger Synergies at the Pierre Auger Observatory: Archive Expansion and Real-Time Neutrino Follow-Ups[*,†] — •Srijan Sehgal for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Germany

The Pierre Auger Observatory, the world's largest cosmic-ray detector, is designed to study the highest-energy particles in the universe and also has a remarkable capability to detect ultra-high-energy neutrinos. Operating continuously since 2004, it has made major contributions to cosmic-ray physics and to the growing field of multi-messenger astronomy. The Observatory is part of the Astrophysical Center for Multi-messenger in Europe (ACME), an infrastructure initiative aimed at facilitating data sharing among major observatories and improving the coordination of multi-messenger observations.

Within ACME, the Pierre Auger Observatory is expanding access to its extensive archive of data and preparing to provide real-time follow-ups by utilizing its sensitivity to neutrino-induced air showers. These efforts are intended to support the rapid identification and characterization of astrophysical sources. This talk will summarize the efforts undertaken within ACME, with particular emphasis on the planned expansion of the public data archive and the current status and development of Auger's real-time alert system.

**Supported by BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A23PX1)*

†This work is supported by the EU Horizon Europe Research and Innovation Programme, Grant No. 101131928.

T 18: Methods in Astroparticle Physics I

Time: Monday 16:15–18:15 Location: KS 00.004

T 18.1 Mon 16:15 KS 00.004

Large-scale TPB Vacuum Evaporation for the LEGEND-1000 Liquid Argon Veto — •Lorenzo Pietropaoli[1], Konstantin Gusev[1,2], Laszlo Papp[1], Nadezda Rumyantseva[1,2], and Stefan Schönert[1] — [1]Department of Physics, TUM School of Natural Sciences, Technical University of Munich, 85748 Garching b. München, Germany — [2]Dubna, Russia

LEGEND-1000 searches for $0\nu\beta\beta$-decay using HPGe detectors in instrumented LAr. A critical background suppression component is the LAr instrumentation, utilizing scintillating fibers coated with Tetraphenyl Butadiene (TPB) and read out by SiPMs. TPB acts as a wavelength shifter, converting 128 nm VUV scintillation light from LAr to ∼430 nm blue light, which is absorbed by green wavelength-shifting (and scintillating) fibers and guided to SiPMs for detection.

We present the design and status of the new LEGEND-1000 TPB evaporator. Building on the LEGEND-200 experience, the system features a 2.3 m tall vacuum chamber designed for the simultaneous, uniform coating of 9 fiber modules with lengths up to 1.6 m. The setup is under construction and assembly in a dedicated new clean room facility at TUM. This talk covers the technical design, the scaling of the evaporation process, and the current status of the commissioning.

We acknowledge support from the DFG under Germany's Excellence Strategy – EXC 2094 (ORIGINS), through the Sonderforschungsbereich SFB 1258. We acknowledge support by the BMFTR Verbundprojekt 05A2023 (LEGEND).

T 18.2 Mon 16:30 KS 00.004

The detection principle and implementation of the Cryogenic Outer Veto for the NUCLEUS experiment — •Alexandra Schröder for the NUCLEUS-Collaboration — Technische Universität München

Coherent Elastic Neutrino-Nucleus Scattering (CEvNS) is predicted in the Standart model to be a neutral current process with low recoil energies in the order of keV. Its experimental observation requires extremely sensitive detectors, enabling the study of neutrino properties and offering the potential to probe physics beyond the Standard Model. The NUCLEUS experiment is designed to observe CEvNS using cryogenic calorimeters with ultra-low energy thresholds oi the order of a few 10 eV. The final experimental site will be at the Chooz nuclear power plant in France, featuring a relatively low overburden of 3 m water equivalent. As a result, a robust background mitigation strategy is required to achieve the desired sensitivity. The Cryogenic Outer Veto (COV), consisting of kilogram-scale high-purity germanium crystals, constitutes a key component of the NUCLEUS background suppression system. The realization of the COV was a collaboration-wide effort. Prior to the integration of the full COV configuration consisting of six crystals, a single COV crystal was tested and operated within the experiment. The complete six-crystal COV system was integrated in December 2024. In this talk, I will present the design and operating principle of the COV, along with an overview of the upscaling process from a single crystal to the final six-crystal configuration.

T 18.3 Mon 16:45 KS 00.004

Overview of the Cryogenic Detector and Development of the Cryogenic Inner Veto for the Observation of Coherent Elastic Neutrino Nucleus Scattering (CEνNS) with NUCLEUS10g — •Michael Hock — Technische Universität München

The study of Coherent Elastic Neutrino Nucleus Scattering (CEνNS) offers new opportunities to investigate fundamental neutrino properties and to probe physics beyond the Standard Model. The NUCLEUS experiment aims to precisely measure the CEνNS cross-section from electron antineutrinos produced at the reactors of the Chooz nuclear power plant in France.

NUCLEUS targets ultra-low recoil energies by employing gram-scale cryogenic calorimeters with energy thresholds on the order of $\mathcal{O}(10\,\mathrm{eV})$. In its first science phase, NUCLEUS 10g will deploy two detector modules, each comprising nine cryogenic target detectors embedded in a Cryogenic Inner Veto.

This contribution presents the current status of the NUCLEUS 10g detector components and reports on the ongoing development of the Cryogenic Inner Veto, which is expected to mitigate the Low Energy Excess (LEE) and therefore may be essential for achieving the required low-background conditions.

T 18.4 Mon 17:00 KS 00.004

Digital broadband interferometry for mapping lightning at the Pierre Auger Observatory — Markus Cristinziani[1], •Eric-Teunis de Boone[1], Qader Dorosti[1], Stefan Heidbrink[2], Waldemar Stroh[2], Jens Winter[2], and Michael Ziolkowski[2] — [1]Experimentelle Astroteilchenphysik, Center for Particle Physics Siegen, Universität Siegen — [2]Elektronikentwicklungslabor der Physik, Universität Siegen

Lightning-related phenomena are known to interact with and influence all detector systems of the Pierre Auger Observatory in Argentina. Notably, the Surface Detector has recorded unique signals linked to Terrestrial Gamma Flashes (TGFs) which are rare phenomena related to the initial processes of lightning. Interpreting these signals remains challenging due to the absence of a system capable of providing detailed 3D imaging of lightning propagation.

To address this gap, we are developing BOLT: Broadband Observatory for Lightning and TGFs, a state-of-the-art interferometric lightning mapping array that enhances the Observatory's unique capabilities for precision research including TGFs. It consists of radio detectors that have been previously developed for the Auger Engineering Radio Array (AERA), located at strategic positions within the Auger field.

This contribution highlights the recent hardware developments, progress towards selective triggering and precision timing, and first field data, illustrating the growing capability of the system for TGF and lightning studies.

T 18.5 Mon 17:15 KS 00.004

Performance of a cryogenic heat pump demonstrator for future liquid xenon observatories — •Philipp Schulte, Lutz Althüser, Robert Braun, Volker Hannen, Christian Huhmann, David Koke, Ying-Ting Lin, Patrick Unkhoff, Daniel Wenz, and Christian Weinheimer — Institut für Kernphysik, Universität Münster

Future liquid xenon (LXe) dark-matter detectors require detector backgrounds about ten times below the solar neutrino-induced background level. Achieving this demands 222Rn concentrations in LXe <0.1 *Bq/kg (less than one 222Rn atom in 160 mol xenon). The ERC project *LowRad* develops high-throughput cryogenic distillation for radon removal, where xenon flow rates of ~1600 kg/h imply heating and cooling powers of O(60) kW at the column reboiler and condenser. To reduce the external cooling demand, a xenon-based cryogenic heat-pump demonstrator has been built and operated. This contribution will present its design and performance, achieving up to ~130 W cooling/heating power at 3.3 bar and 4.3 bar with an electrical input of ~390 W (COP *0.32). Implications for the design and integration of full-scale systems in future LXe observatories such as XLZD will be discussed. Acknowledging support of the ERC AdG *LowRad* (101055063).

T 18.6 Mon 17:30 KS 00.004

Construction and Deployment of the Wavelength-Shifting Optical Module for the IceCube Upgrade — •Lea Schlickmann[1], Sebastian Böser[1], Enrico Ellinger[2], Klaus Helbing[2], Kyra Mossel[1], Adam Rifaie[2], and Nick Schmeisser[2] — [1]JGU Mainz University — [2]University of Wuppertal

The Wavelength-shifting Optical Module (WOM) is a novel optical sensor developed to enhance the sensitivity of neutrino detectors to ultraviolet (UV) Cherenkov light. It employs wavelength-shifting and light-guiding technology to efficiently detect UV photons that are otherwise difficult to capture with conventional sensors. Each WOM consists of a quartz tube coated with a wavelength-shifting paint, with a photomultiplier tube (PMT) coupled to each end. UV photons absorbed in the coating are re-emitted at longer wavelengths, captured by total internal reflection inside the tube, and guided to the PMTs for detection.

As part of the IceCube Upgrade, ten WOMs were produced, tested, and deployed in the Antarctic ice during the 2025/26 season. The IceCube Upgrade provides a unique opportunity to evaluate the performance of WOMs under real detector conditions, contributing to the development of future optical sensor technologies. This talk will present an overview of the WOM for the IceCube Upgrade.

T 18.7 Mon 17:45 KS 00.004

Evaluating Dry Nitrogen Purging to Reduce Water Adsorption in Ultra-High-Vacuum Beam Tubes — Charlotte Benning, •Hsiang-Chieh Hsu, Tim Kuhlbusch, Achim Stahl, and Jochen Steinmann — III. Physikalisches Institut B, RWTH Aachen

The Einstein Telescope (ET) requires 120 km beam pipes with a diameter of one meter. Additionally, to achieve the design sensitivity of the ET, a residual pressure below 10^{-10} mbar is required. Meeting both requirements will make the vacuum cost to about one-third of the total anticipated budget using current production and vacuum technologies. Continuous on-site manufacturing of the beam pipes in the tunnels can lower the cost while requiring novel cleaning method. Laser cleaning is proposed to be used to clean ferritic stainless steel surfaces and remove adsorbed water, eliminating the need for high-temperature and time-consuming bakeout. Therefore, controlling moisture re-adsorption is crucial. This work investigates how the dryness of the purging gas (nitrogen) influences the re-adsorption of water vapor on surfaces after cleaning, to identify the dryness level that keeps water contamination acceptably low.

T 18.8 Mon 18:00 KS 00.004

Development of a High-Temperature Superconducting magnet — •Christian von Byern for the AMS-100 at RWTH Aachen-Collaboration — I. Physics Institute B, RWTH Aachen

While AMS-02 is currently operated on board of the International Space Station, the next generation of cosmic particle detector is already planned. AMS-100 is designed for operation at Lagrange Point 2 and will feature a geometric acceptance of $100m^2sr$. With this large acceptance and improved momentum resolution a measurement of cosmic rays up to the PeV scale will be possible and an improvement of a factor 1000 regarding the sensitivity of anti-matter measurements is expected. The magnetic field of the spectrometer will be generated by a High Temperature Superconducting (HTS) solenoid. This coil will include several layers of individual HTS tapes. During operation at 55K it will produce a field of 0.5T at 4.5kA current. To reduce the material budget in terms of mass and interaction length the HTS tapes will be stabilized using few millimetres of aluminium. As an intermediate step a small demonstrator coil is in preparation. In this R&D phase multiple samples, including straight cable samples, bent cable samples as well as coil samples with few windings are prepared and tested. In this talk the development of a soldering process for cable production and measurement results of the different samples will be presented and interpreted.

T 19: Gravitational Waves I

Time: Monday 16:15–18:15 Location: KS 00.005

T 19.1 Mon 16:15 KS 00.005

Integrating a Sagnac Interferometer into the Einstein Telescope — •Niklas Nippe and Achim Stahl — III. Physikalisches Institut B, RWTH Aachen

The Einstein Telescope (ET) aims to detect gravitational waves with unprecedented low-frequency sensitivity, where gravity gradients, so-called Newtonian Noise (NN), from seismic density fluctuations become a dominant limitation. While NN mitigation will most likely rely on arrays of seismometers measuring translational seismic motion to predict the resulting gravity perturbations, rotational motion carries complementary information that could improve NN prediction.

This talk explores the implementation of a Sagnac interferometer, a ring-laser system that would naturally provide high-precision rotational data in the low frequency regime, into one corner of the ET infrastructure. The area enclosed by the ring-laser setup would substantially increase compared to current state-of-the-art interferometers, hence an improvement in sensitivity by up to two orders of magnitude could be achieved. Finally, the potential contribution of such an integrated Sagnac interferometer to NN mitigation in the ET infrastructure is investigated.

T 19.2 Mon 16:30 KS 00.005

Parameter Estimation for long duration Gravitational Wave signals at the Einstein Telescope using Deep Learning — •Tobias Reike[1], Johannes Erdmann[1], and Achim Stahl[2] — [1]III. Physikalisches Institut A, RWTH Aachen University — [2]III. Physikalisches Institut B, RWTH Aachen University

The proposed Einstein Telescope will be a third-generation gravitational-wave detector, succeeding the current detectors LIGO, Virgo, and KAGRA. It aims to extend the sensitive frequency band toward both lower and higher frequencies and to improve the sensitivity of the current detectors by an order of magnitude. As a result, detected signals can be observed for much longer durations, ranging from minutes to hours, and the detection rate is expected to increase dramatically, reaching hundreds per day.

The analysis methods currently used to estimate source parameters from detected signals are extremely demanding in terms of computational resources, making them unsuitable for the substantially larger data volume anticipated for the Einstein Telescope. Consequently, new and more efficient methods are under development. We present a deep-learning-based approach to parameter estimation that relies on conditional normalizing flows, along with our ongoing work on the analysis of long-duration signals, which pose a particular challenge.

T 19.3 Mon 16:45 KS 00.005

Prospects for Coincident Detection of Short Gamma-Ray Bursts with IceCube-Gen2 and the Einstein Telescope — •Rajanvir Singh[1], Anna Franckowiak[2], Philipp Fürst[1], Christopher Wiebusch[1], and Angela Zegarelli[2] — [1]III. Physikalisches Institut B, RWTH Aachen — [2]Astronomisches Institut, Ruhr-Universität Bochum

With the coincident observation of a short gamma-ray burst (sGRB) and gravitational waves from a neutron star binary merger (NSM) in 2017, these objects have become a primary target for multi-messenger astronomy. In this context, measuring also coincident neutrinos from these NSMs is decisive for probing hadronic processes in these violent environments. With enhanced sensitivity of next-generation neutrino and gravitational wave observatories, such as IceCube-Gen2 and the Einstein Telescope, the chances of observing coincidences improve. Based on previous work we will discuss simulated neutron star mergers with the goal of estimating detection rates of IceCube-Gen2 and the Einstein Telescope and a joint detection rate.

T 19.4 Mon 17:00 KS 00.005

Probing binary black hole merger populations in AGN disks through future IceCube-Gen2 and Einstein Telescope observations — •Tista Mukherjee[1], Mainak Mukhopadhyay[2], Foteini Oikonomou[3], Andreas Haungs[1], and Ralph Engel[1] — [1]Institute for Astroparticle Physics (IAP), Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz Platz 1, 76344 Eggenstein-Leopoldshafen, Germany — [2]Astrophysics Theory Department, Theory Division, Fermi National Accelerator Laboratory, Batavia, Illinois 60510, USA — [3]Institutt for fysikk, NTNU, Trondheim, Norway

The detection of astrophysical neutrinos and gravitational waves (GWs) has ushered in a new era of multi-messenger astroparticle physics. While coincident detections of GW and neutrinos alongside electromagnetic signals have already been achieved in separate instances, no common source of GW and neutrinos has yet been identified. To address the implications of non-detection, this work investigates the prospects for identifying binary black hole mergers embedded in AGN disks as common GW-neutrino sources with next-generation facilities, e.g., the Einstein Telescope and IceCube-Gen2. For sources located in the Northern Hemisphere, the detection significance is quantified for both individual mergers and their populations, to be seen by the Einstein Telescope. It is found that, even with improved sensitivity of next-generation detectors, catalogue searches have limited potential. In contrast, stacking offers a viable path to uncover a population of common GW-neutrino sources in the future.

T 19.5 Mon 17:15 KS 00.005

Investigating the Visibility of Newtonian Noise in the Einstein Telescope Null Stream — •Josie Altenhövel, Johannes Erdmann, and Patrick Schillings — III. Physikalisches Institut A, RWTH Aachen University

The Einstein Telescope (ET) is a planned third-generation gravitational-wave observatory designed to surpass the sensitivity of current detectors. Its triangular layout provides three interferometer signals with fixed geometric relations, enabling the construction of a null stream in which any gravitational-wave contribution is expected to cancel, while all non-gravitational disturbances are expected to remain with finite amplitude. Any event that appears in the null stream can therefore be identified as noise and is excluded from astrophysical interpretation. Among the relevant disturbances is Newtonian noise (NN), which originates from gravitational field fluctuations caused by seismic density variations in the surrounding rock and at surfaces. NN is expected to dominate the low-frequency regime that is critical for ET. To investigate its behavior, simulations are used to generate three-dimensional seismic fields and the corresponding NN forces acting on the ET test masses. A broad range of NN configurations is examined to determine under which conditions NN could produce signatures that disappear in the null-stream construction. The study thereby evaluates the diagnostic role of the ET null stream for an estimate of NN at future low-frequency gravitational-wave observatories.

T 19.6 Mon 17:30 KS 00.005

Reducing Wind Turbine Vibrations for the Einstein Telescope in the EMR Region — •Tom Niggemann and Achim Stahl — III. Physikalisches Institut B RWTH Aachen University

The planned realization of the Einstein Telescope in the EMR region (Euregio Meuse-Rhine) requires a significant reduction of environmental disturbances, particularly those caused by seismic waves and the resulting Newtonian Noise. A significant contribution to these disturbances originates from the vibration modes of wind turbines, whose foundation and tower motions propagate through the ground and may compromise the sensitivity of the gravitational-wave detector. To mitigate these effects, several engineering measures are being investigated: the enlargement of foundations to lower eigenfrequencies and improve ground coupling, as well as the implementation of tuned mass dampers to suppress critical vibration modes. Complementary numerical simulations and studies are conducted to validate the effectiveness of these approaches. The overarching goal is to develop a robust vibration-reduction concept that reconciles the integration of renewable energy with the extreme requirements of gravitational-wave research.

T 19.7 Mon 17:45 KS 00.005

Towards a more realistic Seismometer Position Optimization for Newtonian Noise Mitigation at the Einstein Telescope — •Patrick Schillings and Johannes Erdmann — III. Physikalisches Institut A, RWTH Aachen University

The Einstein Telescope is a third-generation, underground gravitational wave detector that will allow us to measure gravitational waves with significantly improved precision. Its 'xylophone' arrangement is designed to extend the frequency range down to a few Hertz. To improve the sensitivity of the low-frequency interferometer, one needs to mitigate the gravitational effect of density fluctuations in the surrounding rock caused by seismic activity, which result in so-called Newtonian noise. To predict the Newtonian noise, an array of seismometers will be installed around the interferometer mirrors. Expensive boreholes will have to be drilled in order to place these seismometers, which will limit the total number of seismometers that can be placed for a given budget. Therefore, the available resources should be used optimally in terms of predicting the Newtonian noise from the seismometer data. Until now, optimizations were based on a simplifed, analytical model of the seismic wave field. In this talk, I introduce a simulation of seismic waves that allows to lift several assumptions of this model. It provides a stepstone towards more complex site-specific geological models to be used for seismometer position optimization.

T 19.8 Mon 18:00 KS 00.005

Stimulated Emission or Absorption of Gravitons by Light — •Ralf Schützhold — Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

We study the exchange of energy between gravitational and electromagnetic waves in an extended Mach-Zehnder or Sagnac type geometry that is analogous to an optical Weber bar. In the presence of a gravitational wave (such as the ones measured by the Laser Interferometer Gravitational Wave Observatory), we find that it should be possible to observe (via interference or beating effects after a delay line) signatures of stimulated emission or absorption of gravitons with present-day technology. Apart from marking the transition from passively observing to actively manipulating such a natural phenomenon, this could also be used as a complementary detection scheme. Nonclassical photon states may improve the sensitivity and might even allow us to test certain quantum aspects of the gravitational field.

[1] R. Schützhold, *Stimulated Emission or Absorption of Gravitons by Light*, Phys. Rev. Lett. **135**, 171501 (2025)

T 20: Cosmic Rays I

Time: Monday 16:15–17:45 Location: KS 00.006

T 20.1 Mon 16:15 KS 00.006

The Roving Laser System for Absolute Energy Calibration of the Fluorescence Telescopes at the Pierre Auger Observatory* — •Rukije Uzeiroska-Geyik for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstraße 20, 42119 Wuppertal

The Fluorescence Detector (FD) of the Pierre Auger Observatory provides energy measurements of primary cosmic rays that are largely independent of specific interaction models. The FD energy measurement is crucial for calibrating the energy reconstruction of the Surface Detector. Consequently, the accuracy of the FD energy calibration plays a significant role in the systematic uncertainties associated with nearly all scientific results of the Observatory. To this end, a laser with a well-defined energy output will be fired in the field of view of the FD telescopes. Unlike other calibration methods, the response of the telescopes to the laser closely simulates its reaction to an actual cosmic-ray air shower. The system was designed with special attention to the depolarization of the laser beam to ensure a consistent relationship between energy output and directional light yield.

This contribution presents the results of the laboratory test measurements of the laser system, which were performed to validate and optimize its performance before field deployment. In addition, we report on the preparations for the first in-field calibration campaign of the FD telescopes in Argentina.

T 20.2 Mon 16:30 KS 00.006

Estimating the GZK Photon Flux from Extragalactic Cosmic Rays — •Chiara Jane Papior, Marcus Niechciol, and Markus Risse — Experimentelle Astroteilchenphysik, Center for Particle Physics Siegen, Universität Siegen

Extragalactic cosmic-ray sources emit particles with energies beyond 100 EeV. At ultra-high energies, charged particles interact with the cosmic microwave background via photo-pion production, also referred to as the Greisen-Zatsepin-Kuzmin (GZK) effect, generating so-called GZK photons. The photon flux at Earth originating from this effect and other interactions depends on parameters of the cosmic-ray spectrum like the spectral index or potential cutoffs. Other variables like the distance distribution of sources and the cosmic-ray mass composition have an impact on the expected photon flux as well. Simulations based on different input parameters have been performed with the CRPropa code and the expected GZK photon yields will be presented. The goal is to update the allowed range of the expected GZK photon flux based on current measurements of cosmic-ray observatories at ultra-high energies.

This work is supported by the German Research Foundation (DFG, Project No. 508269468).

T 20.3 Mon 16:45 KS 00.006

Cosmic-Ray energy spectrum measurements with IceTop — •Fahim Varsi for the IceCube-Collaboration — Karlsruhe Institute of Technology, Karlsruhe, Germany

IceTop, the surface ice-Cherenkov array of the IceCube Neutrino Observatory, detects extensive air showers generated from the interaction of the cosmic rays with the atmosphere. It measures cosmic rays in the

PeV-EeV energy range, targeting the transition region between galactic and extragalactic cosmic-ray origins, including spectral features such as the knee and the second knee. A novel two-component LDF method is used for event reconstruction, providing an energy estimator along with mass-dependent parameters. An unfolding procedure is then employed to derive the all-particle energy spectrum from the energy estimator parameter. The details of the analysis will be presented in the conference.

T 20.4 Mon 17:00 KS 00.006

Neural Network-Based Estimation of Muon Content from Data Recorded by the SD-1500 of the Pierre Auger Observatory — •Steffen Hahn for the Pierre Auger-Collaboration — Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen, Germany

Ultra-high-energy cosmic rays (UHECRs) offer insights into the physics beyond the energies of human-made accelerators. However, to fully understand processes such as their acceleration, precise knowledge of their mass composition is crucial. Since the direct detection of UHECRs is infeasible, determining the mass of the primary particles is challenging. One method of accessing this information is to estimate the number of muons produced in extensive air showers (EASs). The direct measurement of high-energy muons in an EAS can be achieved by using arrays of buried detectors, such as the Underground Muon Detector (UMD) at the Pierre Auger Observatory. However, the instrumentation area of the UMD is limited in size. One of the central components of the Pierre Auger Observatory is the Surface Detector (SD), which consists of multiple triangular grids of hybrid detector stations. These stations record the time signals of the secondary particles that are produced in EASs that reach the ground. In this contribution, we present a neural network (NN) that utilizes SD-1500 data, the main surface detector array of the Pierre Auger Observatory, to predict the muon content of EASs. This NN is calibrated indirectly to the UMD measurements using a calibrated NN designed for the SD-750, the second-largest surface detector array located near the UMD.

T 20.5 Mon 17:15 KS 00.006

Observation of EarthCARE Laser Emissions with the Pierre Auger Observatory — •Thara Caba Pineda for the Pierre Auger-Collaboration — Institute for Astroparticle Physics, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany — Observatorio Pierre Auger, Av. San Martín Norte 304, 5613 Malargüe, Argentina

The Atmospheric Lidar (ATLID) onboard the Earth Clouds, Aerosols and Radiation Explorer (EarthCARE) satellite has been repeatedly observed by the Fluorescence Detector of the Pierre Auger Observatory. Side-scattered ultraviolet light from ATLID laser pulses is recorded by the Auger fluorescence telescopes, which are primarily designed to measure the longitudinal development of extensive air showers initiated by ultra-high-energy cosmic rays. These measurements enable a precise reconstruction of the atmospheric trajectory of the laser beam over the Observatory and provide a unique opportunity for systematic studies of the local atmospheric aerosol content. Furthermore, EarthCARE laser tracks can be observed at the Telescope Array Experiment in the USA within a few days during the same moon cycle, opening the possibility for a direct cross-calibration of the energy scales of the two cosmic-ray observatories. We present first reconstruction results from ATLID observations following EarthCARE*s launch in 2024. These results highlight the potential of satellite-based lidar observations to support calibration and atmospheric characterization efforts at the Pierre Auger Observatory.

T 20.6 Mon 17:30 KS 00.006

First results of the Auger Radio Infill SKALA Extension (ARISE) — •Carmen Merx[1], Stef Verpoest[2], Ben Flaggs[2], and Frank Schröder[1,2] for the Pierre Auger-Collaboration — [1]Karlsruhe Institute of Technology — [2]University of Delaware

Radio detection of extensive air showers has become a powerful technique for studying high-energy cosmic rays. To further enhance these measurements, the Pierre Auger Observatory in Argentina, one of the world‘s largest cosmic-ray experiments, has been upgraded with radio antenna stations. This upgrade aims to improve the precision of air-shower energy measurements in the energy range of several tens of PeV and above.

Within this framework, a new experiment, ARISE (“Auger Radio Infill SKALA Extension”), has been deployed at the Pierre Auger Observatory. ARISE consists of six stations, each comprising three SKALA antennas installed around a surface detector in the denser infill region.

This presentation will present first air-shower measurements from ARISE recorded in coincidence with the Auger surface detector array.

T 21: Invited Overview Talks II

Time: Tuesday 11:00–12:30 Location: AudiMax

Invited Overview Talk T 21.1 Tue 11:00 AudiMax

Three Decades of Dark Matter Annual Modulation Searches: Overview and Current Status — •Karoline Schaeffner — Max-Planck-Institut für Physik, München, Germany — Technische Universität München, München, Germany

A powerful method to discriminate potential dark matter signals from detector backgrounds is to search for an annual modulation in the event rate, induced by the seasonal variation of the Earth’s velocity with respect to the Sun and, consequently, to the galactic dark matter halo.

The DAMA/LIBRA experiment pioneered this approach using sodium iodide (NaI(Tl)) detectors and has reported the observation of an annual modulation signal with very high statistical significance, exhibiting a period and phase consistent with expectations for dark matter interactions. The DAMA/LIBRA results remain in strong tension with the null results reported by most other direct dark matter detection experiments. Despite extensive experimental and theoretical efforts, a model-independent verification capable of resolving this long-standing discrepancy is still lacking.

In this talk, I will present an overview of the worldwide experimental program based on NaI detectors, summarize the current status of these experiments, discuss the key experimental challenges, and outline the open questions that continue to keep this enduring puzzle unresolved.

Invited Overview Talk T 21.2 Tue 11:30 AudiMax

Status and meaning of current tensions in cosmology — •Julien Lesgourgues — RWTH Aachen University

After a decade of consensus around the standard cosmological model, LambdaCDM, more precise data have triggered the emergence of multiple tensions in cosmology. Tensions can hint either at misunderstood systematics or new physics. I will review the current status of the main ones: the Hubble tension, the lack of evidence for massive neutrinos, and recent indications for dynamical dark energy. I will also comment on the difficulty to find a working and plausible theoretical solution to these problems, at least according to our current understanding.

Invited Overview Talk T 21.3 Tue 12:00 AudiMax

In search of the unknown: Pushing the boundaries in searches for new physics at the LHC — •Danyer Perez Adan — RWTH Aachen University, Sommerfeldstrasse 16, 52074 Aachen, Germany

Several fundamental aspects of particle physics lie beyond the predictive power of the Standard Model (SM), providing strong motivation for the search for new physics at the Large Hadron Collider (LHC). This presentation reviews the current landscape and prospects of searches for physics beyond the Standard Model (BSM) at the LHC experiments. Covered topics include investigations focused on well-motivated scenarios, such as supersymmetric and exotic particles, dark matter, heavy resonances, and extended Higgs sectors, as well as signature-driven strategies that transcend model specificity. Emphasis is placed on the relevance of balancing innovative exploration paradigms and the continued refinement of established methodologies. The growing effort of the experimental collaborations to expand the reach of BSM probes across multiple dimensions—including kinematic coverage, object topologies, and analysis approaches—is also highlighted.

T 22: Neutrino Physics II

Time: Tuesday 16:15–18:30 Location: AudiMax

T 22.1 Tue 16:15 AudiMax

Particle Identification in the Hybrid Opaque Scintillator Experiment NuDoubt++ — •Kyra Mossel for the NuDoubt-Collaboration — Johannes Gutenberg-Universität Mainz

Neutrinoless double beta decay is a hypothetical lepton-number-violating process whose observation would establish the Majorana nature of the neutrino. Detecting this extremely rare decay demands exceptionally low background levels and highly effective particle identification techniques.

The NuDoubt++ experiment investigates double beta plus decay modes using a novel hybrid opaque scintillator instrumented with a dense grid of optical fibers coupled to SiPMs. This detector concept enables the reconstruction of energy-deposit topology while simultaneously exploiting the ratio of Cerenkov to scintillation light to enhance background rejection and particle identification.

In this presentation, event reconstruction and particle identification methods developed for NuDoubt++ are presented. Performance studies based on Monte-Carlo simulations are shown, demonstrating the potential of this approach for rare event searches.

T 22.2 Tue 16:30 AudiMax

NuDoubt^{++}: Search for Double Beta Plus Decays — •Veronika Palusova for the NuDoubt-Collaboration — Johannes Gutenberg-Universität Mainz

Double beta plus decay modes ($\beta^+\beta^+$, β^+EC, and 2EC) are rare second-order weak processes converting two protons into two neutrons. Their observation is difficult due to extremely low probabilities, complex signatures, and the low natural abundance of suitable isotopes. Studying these decays offers insights into nuclear structure and fundamental symmetries. Decay rates depend on nuclear matrix elements (NMEs) and phase space factors (PSFs), crucial for interpreting data and refining theoretical models. We introduce NuDoubt^{++}, a novel detector concept for double beta plus decay searches with unprecedented sensitivity. It integrates hybrid and opaque scintillation technologies with advanced light readout to enhance positron detection. Preliminary estimates show that a 1-tonne-week exposure could reach sensitivity to $2\nu\beta^+\beta^+$ and $2\nu\beta^+$EC decays in ^{78}Kr. The design also improves background rejection and resolution, enabling exploration of $0\nu\beta^+\beta^+$ decay beyond current limits.

T 22.3 Tue 16:45 AudiMax

LEGEND-1000: Quasi Background-Free Search for Neutrinoless Double Beta Decay in ^{76}Ge at the Ton-Scale — •Lorenz Gessler for the LEGEND-Collaboration — Eberhard Karls Universität, Tübingen, Germany

In pursuit of the observation of the first lepton-number violating process, the LEGEND collaboration is progressing towards a next-generation detector – LEGEND1000. The search for the neutrinoless double beta decay of ^{76}Ge probes the Majorana nature of neutrinos as well as the absolute neutrino mass scale, directly accessing physics beyond the Standard Model. Lessons learned from GERDA, MAJORANA Demonstrator and LEGEND200 allow us to further improve background mitigation strategies and to bring state-of-the-art high-purity germanium detector technology to the ton-scale, enabling a quasi background-free regime at the design exposure. This will allow LEGEND1000 to probe the entire effective Majorana mass range of the inverted ordering, corresponding to a half-life sensitivity exceeding 10^{28} yr. This overview talk summarizes the current status of LEGEND1000 and highlights recent progress in the experimental design, background rejection strategy, and overall detector concept.

We acknowledge support from the DFG under Germany's Excellence Strategy – EXC 2094 (ORIGINS) and through the Sonderforschungsbereich SFB 1258. We acknowledge support by the BMFTR Verbundprojekt 05A2023 (LEGEND).

T 22.4 Tue 17:00 AudiMax

LEGEND-200: Recent results and experimental status — •Nadezda Rumyantseva for the LEGEND-Collaboration — Department of Physics, TUM School of Natural Sciences, Technical University of Munich, 85748 Garching b. München, Germany

LEGEND is a staged program progressing from LEGEND–200 to the ton-scale LEGEND–1000, searching for neutrinoless double-beta decay ($0\nu\beta\beta$) in ^{76}Ge. Using enriched high-purity germanium detectors, LEGEND targets discovery sensitivity to half-lives beyond 10^{28} years.

LEGEND builds on the GERDA and MAJORANA Demonstrator experiments and employs novel inverted-coaxial HPGe detectors operated in instrumented liquid argon, providing powerful signal identification and background rejection capabilities. The first LEGEND–200 physics results are based on an exposure of 61.0 kg yr and, in combination with GERDA and the MAJORANA Demonstrator, achieve a world-leading 90% confidence-level exclusion sensitivity of 2.8×10^{26} yr and set a lower limit of $T^{0\nu}_{1/2} > 1.9\times10^{26}$ yr.

This talk summarizes the LEGEND–200 experimental concept, background-reduction strategy, and latest results.

We acknowledge support from the DFG under Germany's Excellence Strategy – EXC 2094 (ORIGINS) and through the Sonderforschungsbereich SFB 1258. We also acknowledge support from the BMFTR Verbundprojekt 05A2023 (LEGEND).

T 22.5 Tue 17:15 AudiMax

First observation of reactor antineutrinos by coherent scattering with CONUS+ — •Nicola Ackermann for the CONUS-Collaboration — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

The CONUS+ experiment measures coherent elastic reactor antineutrino nucleus scattering (CEvNS) on germanium nuclei. The detector is located at the KKL nuclear power plant in Leibstadt, Switzerland at a distance of 20.7 m from the reactor core. It uses four High Purity Germanium detectors with energy thresholds of ~ 160 eV. In Run 1 of the experiment, which lasted from November 2023 to August 2024, the first observation of a CEvNS signal from a nuclear reactor was achieved. In 119 days of data taking (395+-106) anti-neutrinos were measured, compared to a predicted number of (347+-59) events. For improved sensitivity, the experiment is currently taking data in Run 2 using three new 2.4 kg germanium detectors.

T 22.6 Tue 17:30 AudiMax

Beyond the Standard Model investigations at CONUS+ — •Dario Piani for the CONUS-Collaboration — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

The detection of coherent elastic neutrino-nucleus scattering (CEνNS) opens up new opportunities for neutrino physics within and beyond the standard model (BSM) of elementary particles. The first detection of CEνNS at nuclear reactors by the CONUS+ experiment allows very valuable tests of BSM scenarios in a low momentum transfer regime. Among them, Non Standard Interactions (NSIs), light mediators (scalar and vector couplings) and electromagnetic properties were tested, setting very competitive limits in both the nuclear scattering interaction channel as well as the electron scattering channel. In particular, for vector NSIs a sensitivity to new physics of up to 145 GeV was achieved. Whereas, for the light mediators, couplings down to 10^{-6} were probed.

T 22.7 Tue 17:45 AudiMax

Exploring coherent elastic neutrino-nucleus scattering with NUCLEUS: Overview of the experiment — •Alexander Wallach for the NUCLEUS-Collaboration — Technical University Munich, Munich, Germany

Coherent Elastic Neutrino-Nucleus Scattering (CEνNS) is a pure weak-neutral current interaction predicted within the Standard Model. The CEνNS cross section is several orders of magnitude larger than that of other low-energy neutrino interactions, enabling its study with small, highly sensitive detectors. Investigating CEνNS provides a pathway to probe neutrino properties, explore physics beyond the Standard Model, and address the CEνNS background in dark matter searches.

The NUCLEUS experiments aim to perform precision measurements of CEνNS properties using reactor antineutrinos at the Chooz nuclear power plant. In order to measure nuclear recoils below 100eV, NUCLEUS employs a multi-stage detection system, consisting of $CaWO_4$ and Al_2O_3 cryogenic calorimeters with an $\mathcal{O}(10\,\mathrm{eV})$ energy threshold, surrounded by a twofold system of instrumented cryogenic vetoes, an external passive shielding and a muon veto to improve the identification and discrimination of backgrounds.

In this talk I will give an overview of the NUCLEUS experiment, focusing on the underlying physics motivation and the detection concept.

T 22.8 Tue 18:00 AudiMax

Exploring coherent elastic neutrino-nucleus scattering: status of the NUCLEUS experiment — •Lars Wienke for the NUCLEUS-Collaboration — Technische Universität München, München, Deutschland

Coherent Elastic Neutrino-Nucleus Scattering (CEνNS) is a Standard Model process in which a neutrino scatters coherently off an entire nucleus via weak neutral current interactions. The CEνNS cross section is several orders of magnitude larger than that of other low-energy neutrino interactions, which makes this process a powerful tool to probe various physics scenarios, motivating a worldwide effort to detect the tiny nuclear recoils it produces.

The NUCLEUS experiment aims to perform precision measurements of CEνNS properties using reactor antineutrinos at the Chooz nuclear power plant. In order to measure nuclear recoils below 100eV, NUCLEUS employs a multi-target detection system, consisting of $CaWO_4$ and Al_2O_3 cryogenic calorimeters with an O(10eV) energy threshold, surrounded by a twofold system of instrumented cryogenic vetoes, an external passive shielding and a muon veto to improve the identification and discrimination of backgrounds.

At present, the experiment is in the last steps of commissioning in the shallow underground laboratory at the Technical University of Munich (TUM), and the relocation to the Chooz-B nuclear power plant in the French Ardennes is underway. In this talk, I will provide an overview of the experiment's current status, focusing on the latest developments, milestones achieved and future plans.

T 22.9 Tue 18:15 AudiMax

Development of a Novel Te-doped Liquid Scintillator with Slow Light Emission for $0\nu\beta\beta$-Decay Searches in a Hybrid Neutrino Detector — •Hans Th. J. Steiger[1], M. Beretta[2], M. Böhles[3], A. Garfagnini[4], A. Gavrikov[4], P. Lombardi[2], K. Loo[5], E. Pasini[4], B. Rasera[4], A. Serafini[4], K. Walter[1], and M. Wurm[3] — [1]Technical University of Munich, TUM School of Natural Sciences, Garching, Germany — [2]INFN, Sezione di Milano e Università degli Studi di Milano, Dipartimento di Fisica, Italy — [3]Institute for Physics, Johannes Gutenberg University Mainz, Mainz, Germany Mainz, Germany — [4]Dipartimento di Fisica e Astronomia dell' Universita di Padova and INFN Sezione di Padova, Padova, Italy — [5]University of Jyväskylä, Department of Physics, Jyväskylä, Finland

It is a long-standing paradigm that organic scintillators allow excellent energy resolution but no directional reconstruction. Here we show the foundation for overcoming this by scintillators with slow light emission, paving the way for hybrid detectors that combine the advantages of Cherenkov and scintillation detectors. In such slow liquid scintillators, it is possible to reconstruct directional and topological information from Cherenkov light, while the high light yield of an organic scintillator ensures excellent energy resolution and low thresholds necessary for many applications in neutrino and particle physics such as the search for the $0\nu\beta\beta$ decay. We also developed a novel loading technique for these scintillators with 130Te and show studies of fundamental properties of these scintillators and the novel dopant. This work is supported by the Clusters of Excellence PRISMA+ and ORIGINS.

T 23: Top Physics I

Time: Tuesday 16:15–18:15 Location: KH 00.011

T 23.1 Tue 16:15 KH 00.011

Measurement of differential cross sections in the process $pp \to WWbb$ with the ATLAS experiment — •Johannes Hessler — Max-Planck-Institut für Physik, Boltzmannstr. 8, 85748 Garching

Precise measurements of differential cross sections in the process $pp \to WWbb$ offer an outstandingly rich physics potential at highest precision. Although the process is theoretically and experimentally well defined, dedicated measurements of $WWbb$ production cross sections were not (extensively) performed in the past at the LHC.

I will report on recently published measurements in the single-lepton channel with Run-II data taken by the ATLAS experiment. The analysis comprises three signal regions, focusing on the interference between $t\bar{t}$ and tW processes, the explicit reconstruction of the kinematics of the $WWbb$ system and on phase spaces motivated by BSM searches.

T 23.2 Tue 16:30 KH 00.011

Extracting the Top Yukawa coupling from the $t\bar{t}$ differential cross section in dilepton channel using ATLAS data — •Sadia Marium — DESY, Zeuthen

Top quark, being the heaviest Standard Model fermion, has the highest value of Yukawa coupling with the Higgs field. This contribution presents an extraction of the top-quark Yukawa coupling, (Y_t), from the $t\bar{t}$ differential cross-section in the dilepton final state. Near the $t\bar{t}$ production threshold, electroweak virtual corrections, including Higgs-boson exchange, modify the kinematic distributions of the invariant mass of the $t\bar{t}$ system $M_{t\bar{t}}$ and the top quark production angle $\cos\theta_t^*$ in the $t\bar{t}$ rest frame. These kinematic variables are therefore sensitive to Y_t, and hence, their distributions are used to extract its value. In the dilepton channel, the presence of two neutrinos prevents full event reconstruction, motivating the use of proxy observables that retain sensitivity to these effects. The analysis uses proton*proton collision data at $\sqrt{s} = 13$ TeV corresponding to an integrated luminosity of 140 fb^{-1}, collected with the ATLAS detector at the Large Hadron Collider.

T 23.3 Tue 16:45 KH 00.011

NNLO soft function for 0-jettiness in (associated) $t\bar{t}$ production — Guido Bell[1], Alessandro Broggio[2], •Sebastian Edelmann[1], Matthew A. Lim[3], and Rudi Rahn[2] — [1]Theoretische Physik 1, Center for Particle Physics Siegen, Universität Siegen, Germany — [2]Faculty of Physics, University of Vienna, Austria — [3]Leonardo UK, Luton LU1 3PG, United Kingdom

Given the exceptional precision of LHC data, a detailed theoretical understanding of $t\bar{t}$ and $t\bar{t}X$ cross sections, where $X = \gamma$, W, Z, H, is required to better probe the top and the Higgs sectors of the Standard Model and search for new physics.

One promising method to achieve precise QCD calculations is N-jettiness slicing. It was shown that the $t\bar{t}$ production cross section factorizes into hard, beam and soft functions at small values of the 0-jettiness variable. At NNLO only the relevant soft functions are currently missing for processes with two heavy quarks in the final state. By extending the SoftSERVE program to incorporate massive final-state partons, we were able to automate the numerical computation of the renormalized $t\bar{t}$ soft function for various observables and verify its pole structure using the renormalization group equation.

The produced grids can be used to implement associated $t\bar{t}$ production processes in the Monte-Carlo event generator GENEVA.

T 23.4 Tue 17:00 KH 00.011

Studies of the $t\bar{t}$+heavy flavour jets using the ATLAS data — •Abderahmane Maiza, Mahsana Haleem, and Raimund Ströhmer — Universität Würzburg, Germany

The top-quark pair production in association with heavy-flavour jets provides an essential test of quantum chromodynamics (QCD) predictions. These processes are challenging to model and constitute large irreducible background to rare SM processes such as $t\bar{t}H$ and tH productions as well as to the processes predicted by several extensions of the Standard Model.

The fiducial and differential cross-sections of $t\bar{t}$+b-jets have been measured using the ATLAS Run-2 data with precision ranging from 8.5% − 20%. Inclusive cross-section of $t\bar{t}$+c-jets has been measured with the precision of 15%−20% in given phase space. Further improvements in these measurements are expected through exploitation of the full ATLAS Run-2 and Run-3 datasets, improved MC simulations, advanced background estimation techniques and enhanced b-/c-jet origin classification leading to better event construction.

This talk will present the ongoing developments on the b-jets classifications in $t\bar{t}bb$ events using a transformer network. Furthermore, the method for the simultaneous estimation of flavour composition of additional jets in $t\bar{t}$+jets events will be presented.

T 23.5 Tue 17:15 KH 00.011

First measurement of the CKM matrix element $|V_{cb}|$ in $t\bar{t}$ decays with the ATLAS detector — Diptaparna Biswas, Carolina Costa, Markus Cristinziani, Carmen Diez Pardos, Ivor Fleck, Gabriel Gomes, Jan Joachim Hahn, Nikolaos Kamaras, Vadim Kostyukhin, Nils Benedikt Krengel, Austin Olson, Inês Pinto, Sebastian Rentschler, Elisabeth Schopf, Katharina Voss, Wolfgang Walkowiak, and •Adam Warnerbring — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

The CKM matrix element $|V_{cb}|$ is one of the free parameters of the Standard Model. Until now, all determinations of $|V_{cb}|$ have relied on B-hadron decays, using either inclusive measurements, which include all possible final states, or exclusive measurements that focus on specific decay channels. Between these methods, a tension of about 3σ is observed. However, $|V_{cb}|$ can also be determined from on-shell W boson decays, as the branching ratio of $W \to cb$ is proportional to $|V_{cb}|^2$. This talk presents the first ATLAS measurement to determine $|V_{cb}|$ from hadronic W boson decays in $t\bar{t}$ production, targeting events in which one W boson decays leptonically and the other hadronically. The talk will cover the data analysis strategy, including the multivariate classifier used to separate signal from background and the use of flavour tagging, along with the dominant systematic uncertainties. The measurement is the first determination of this CKM matrix element at the electroweak scale and provides an orthogonal determination of $|V_{cb}|$ compared to previous measurements.

T 23.6 Tue 17:30 KH 00.011

Flavour Changing Neutral Current decays of the top quark to a Higgs boson and a charm or up quark with the ATLAS experiment — Diptaparna Biswas, Carolina Costa, Markus Cristinziani, Carmen Diez Pardos, Ivor Fleck, Gabriel Gomes, Jan Joachim Hahn, Nikolaos Kamaras, Vadim Kostyukhin, Nils Benedikt Krengel, Austin Olson, •Inês Pinto, Sebastian Rentschler, Elisabeth Schopf, Katharina Voss, Wolfgang Walkowiak, and Adam Warnerbring — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

Top-quarks can decay to lighter quarks with the same charge by emitting a neutral boson in processes called Flavour Changing Neutral Current (FCNC). These are forbidden at the lowest order, and highly suppressed at higher orders, by the Glashow–Iliopoulos–Maiani mechanism.

We aim to search for FCNC decays of a top quark to a Higgs boson, and either a charm or an up quark, with data collected by the ATLAS detector during Run 2 and the ongoing Run 3 of the LHC. These decay modes are extremely rare, with expected branching ratios of about 10^{-15} for $t \to Hc$ and 10^{-17} for $t \to Hu$, far beyond the sensitivity of current detectors. As such, observing these decays at a significant rate would be a clear indication of New Physics. The search will aim to exploit the highest branching ratio decay mode of the Higgs boson, $H \to b\bar{b}$, taking advantage of the latest machine learning developments in jet flavour tagging in the ATLAS experiment.

T 23.7 Tue 17:45 KH 00.011

FCNC in the Top Sector — •Maurice Schüssler[1], Pedro Miguel Ferreira[2], and Milada Margarete Mühlleitner[1] — [1]Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]Universidade de Lisboa, Lisboa, Portugal

Several observations give access to physics beyond the Standard Model. Among these are flavor-changing neutral currents, which are suppressed within the Standard Model. While flavor-changing neutral current processes in the bottom sector are strongly constrained experimentally even in beyond Standard Model theories, those involving the top quark remain less explored due to its short lifetime. In our work, we extend the Standard Model by an additional Higgs doublet and study the flavor-changing neutral currents of these Higgs bosons, focusing on the top sector. Within this framework a scan of the possible parameter space is done after taking into account experimental constraints. Then the cross section of flavor violating final states originating from gluon fusion is calculated and discussed.

T 23.8 Tue 18:00 KH 00.011

Measurement prospects for the top-antitop energy asymmetry in the production with an additional jet in the resolved topology with ATLAS — •Jessica Höfner, Annika Stein, Frederic Fischer, and Lucia Masetti — University Mainz, Insitute for physics

The top quark is the heaviest particle in the Standard Model (SM) of particle physics and the only quark which decays before hadronization can happen. The top quark is suitable for the search of physics beyond the SM of particle physics (BSM). There could be even heavier particles and they might become observable at higher center-of-mass energies, and the top quark could potentially interact with them. At the currently reachable center-of-mass energies, however, the impact of BSM physics might only be indirectly observable via the variation of properties of the production or decay of SM particles. In the production of a top-antitop pair with an additional jet at the LHC the energy asymmetry, complementary to the rapidity asymmetry, can be measured. The energy asymmetry is expected in the SM, but also sensitive to physics beyond the SM and therefore it is of high interest to measure this observable. The measurement is performed in the single lepton and jets resolved topology, in which the quarks are reconstructed separately in small-R jets. The challenge in the event reconstruction is to assign the jets to the correct mother particle, which is done using a neural network. This presentation will show the performance of the neural network and the impact of the event reconstruction on the energy asymmetry measurement.

T 24: Standard Model Physics II

Time: Tuesday 16:15–18:15 Location: KH 00.014

T 24.1 Tue 16:15 KH 00.014

Hadronic Recoil in future high μ measurements — Fabrice Balli[1], •Tim Frederik Beumker[2], and Frank Ellinghaus[2] — [1]Université Paris-Saclay — [2]Bergische Universität Wuppertal

A precise calculation of the missing transverse momentum (E_T^{miss}) is crucial for many Standard Model measurements. In addition, the recently published measurement of charged-current Drell-Yan cross-sections at high transverse masses showed that uncertainties arising from the E_T^{miss} calculation dominate, in particular when determining fake lepton contributions.

The Hadronic Recoil provides an alternative method of calculating the E_T^{miss} by using the recoil of the vector boson. It has been successfully used in low-μ precision W measurements so far and an implementation of the Hadronic Recoil was moved to the central ATLAS reconstruction software, to make it accessible for future high-μ ($\hat{=}$ #interactions per bunch crossing) analyses. This talk presents the general procedure for calculating the Hadronic Recoil and its validation at high μ.

T 24.2 Tue 16:30 KH 00.014

Measuring the W Mass with the ATLAS low-$\langle\mu\rangle$ Dataset — •Mathias Backes — Heidelberg University

The measurement of the mass of the W-boson is one of the fundamental tests of the Standard Model. ATLAS (2024) and CMS (2024) published measurements presenting results for the W-mass which are in agreement with the Standard Model. These measurements are in more than 5σ tension with the value obtained by the CDF collaboration (2022). In order to investigate this tension ATLAS is currently performing an additional measurement.

The W mass is most accurately measured using the leptonic decay channel $W \to l\nu_l$ with $l \in (e, \mu)$. The low-pileup dataset of ATLAS (taken in Run-2) is especially useful because a central aspect of this analysis is the precise estimation of the hadronic recoil to infer the energy and direction of the neutrino. Since the W mass cannot be measured directly it has to be inferred through comparisons with Monte Carlo simulations in a Profile Likelihood Fit.

In this talk the current status of the analysis including the details of the Profile Likelihood Fit is presented.

T 24.3 Tue 16:45 KH 00.014

Impact of measuring the W boson mass in a combined analysis at several collision energies with the ATLAS experiment

— Philip Bechtle[1], •Oliver But[1], Matthias Schott[1], and Chen Wang[2] — [1]Physikalisches Institut, Universität Bonn — [2]Deutsches Elektronen Synchrotron, Hamburg

The precision measurement of the W boson mass is an important consistency test of the standard model. To match the standard model fit uncertainty of the W boson mass of less than 10 MeV all sources of uncertainties have to be carefully controlled. One strategy is to include data taken at multiple proton proton collision energies and fit them simultaneously. As a consequence, systematic effects which act differently for different collision energies decorrelate from the parameter of interest and reduce their impact on the uncertainty.

In this talk, I introduce the concept of correlated parameters and demonstrate how combining a 5 TeV and 13 TeV dataset in the W mass measurement at the ATLAS experiment can help reduce the uncertainty coming from systematics.

T 24.4 Tue 17:00 KH 00.014

Study of electroweak production of $W(\ell\nu)\gamma\gamma$ events in the Run-2 and Run-3 proton-proton collision data of the ATLAS detector. — •Sina Aktas, Gia Khoriauli, Raimund Ströhmer, and Thomas Trefzger — Julius-Maximilians-Universität Würzburg, Würzburg, Germany

Production of electroweak vector bosons provides a sensitive probe of the gauge interactions of the Standard Model, especially through the study of heavy gauge boson polarisation. The longitudinal polarisation of the W and Z bosons is of particular interest. The electroweak production of the $W\gamma\gamma$ events in proton-proton collisions at the LHC is sensitive to triple and quartic electroweak gauge couplings and its study provides an opportunity to test the predictions of the electroweak theory.

We work on the development of analysis methods to measure differential cross sections and polarisation fractions of the W boson in the electroweak production of $W(\ell\nu)\gamma\gamma$ in the ATLAS detector. The analysis will use the full datasets of proton-proton collisions at the LHC at $\sqrt{s} = 13$TeV (Run-2) and $\sqrt{s} = 13.6$TeV (Run-3).

In this work, we discuss the current status of the study. The methods and preliminary results of the analysis based on Monte Carlo simulations are presented.

T 24.5 Tue 17:15 KH 00.014

Machine Learning Based Tagging of Vector Boson Polarization — •Lena Alshut, Erik Bachmann, Mareen Hoppe, and Frank Siegert — Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Germany

The longitudinal polarization of massive vector bosons (MVBs) is a direct consequence of electroweak symmetry breaking and serves as a sensitive probe of the Higgs mechanism and potential new physics. Because longitudinally polarized MVBs are rare, previous studies at the LHC have relied on neural-network classifiers trained to distinguish polarization states. However, this formulation depends on an nonphysical quantities with unknown distribution and assumes classes of purely longitudinal or transverse polarized MVBs.

In this work, the alternative strategy of polarization fraction regression is explored. These fractions at phase-space point level are physical observables with well-defined distributions. This enables a direct comparisons of model predictions and MC truth values, providing the opportunity for systematic improvement of polarization tagging.

We develop a Machine Learning-based tagger that predicts event level polarization fractions using the four-momenta of final-state particles. A MLP and a Transformer are trained on Standard Model expectations. In this talk, we present results for Z+jets in the leptonic decay channel at LO, LO+PS, and higher perturbative orders as a exemplary test case. The approach can directly be translated to the analysis of LHC pp colission data, where it allows for a more physical interpretation of polarization measurements.

T 24.6 Tue 17:30 KH 00.014

Probing vacuum dispersion with electron-laser interactions — •Anthony Hartin — LMU, Munich, Germany

Partice physics processes occurring in the strong field of an intense laser can only be fully described by a quantum field theory that is non-perturbative with respect to the strong field. Such a theory is provided by the Furry interaction picture where the strong field is included in exact solutions of the Dirac equation. These solutions describe a new particle, the bound fermion, which sees a structured space-time depending on where it is in relation to the kinematics and phase of the strong field. This theory predicts novel phenomenology, including a shift in rest mass of the bound fermion, a dispersive vacuum and consequently, novel resonances in the bound fermion propagator. We review the theory and phenomenology and propose an experiment which can detect these novel non-perturbative resonances.

T 24.7 Tue 17:45 KH 00.014

The gradient flow coupling of three- and four-dimensional QED — •Lars Georg, Robert Harlander, and Robert Mason — RWTH Aachen University

Connecting low-energy lattice results to high-energy continuum calculations is highly nontrivial, as they rely on fundamentally different regularizations. The gradient flow offers an elegant way to bridge this gap, since it can be implemented both on the lattice and in the continuum and naturally defines renormalized couplings and observables.

While the GF up to now has found most of its applications in QCD, I consider its implementations in other theories such as scalar QCD, or theories with U(1) gauge factor. I present explicit results for the perturbative gradient-flow coupling for QED in (3+1) and (2+1) dimensions. QED_4 serves as a clean Abelian testing ground and limiting case of QCD, while QED_3 shares important qualitative features with QCD such as chiral symmetry breaking and the presence of an infrared fixed point in the large-N_f expansion.

T 24.8 Tue 18:00 KH 00.014

Nonrelativistic reduction of relativistic effective field theories — •Tobias Asano[1], Fabio Di Pumpo[2], Enno Giese[3], and Motoaki Bamba[1,4] — [1]Department of Physics, Graduate School of Engineering Science, Yokohama National University, Japan — [2]Institut für Quantenphysik, Universität Ulm, Germany — [3]Technische Universität Darmstadt, Institut für Angewandte Physik, Germany — [4]Institute for Multidisciplinary Sciences, Yokohama National University, Japan

The applications of effective field theories (EFTs) range from Standard Model EFT to nonrelativistic (NR) EFTs like NR quantum chromodynamics. A symmetry-based construction of relativistic EFTs, like Standard Model EFT is straightforward. In contrast, Lorentz invariance is not trivial in NR EFTs, making a construction more complicated. While construction rules are well understood for, e.g., NR quantum chromodynamics, there is no simple extension when one includes more fields, such as gravity.

In this work, we present an approach starting from the construction of a relativistic EFT, conceptually close to Standard Model EFT, and perform an NR reduction, centered on an extended Foldy-Wouthuysen transformation, leading to NR quantum chromodynamics, for instance. Such a treatment is highly suited for theories where NR construction rules are not straightforward, such as an EFT on curved spacetime.

This work is supported by the Japan Society for the Promotion of Science (JSPS) (Grant Nos. JP25KJ1313, JP24K21526, JP25K00012, JP25K01691, JP25K01694, JPJSJRP20221202) and the Research Foundation for Opto-Science and Technology.

T 25: Higgs Physics III

Time: Tuesday 16:15–18:15 Location: KH 00.016

T 25.1 Tue 16:15 KH 00.016

Measurement of differential cross-sections in the $H \rightarrow ZZ^* \rightarrow 4\ell$ decay channel with the ATLAS Run 3 data — •Elena Cuppini[1], Sandra Kortner[1], Oliver Kortner[1], Luca Spitzauer[1], Alice Reed[2], and Tae Hyoun Park[1] — [1]Max Planck Institute for Physics — [2]University of Glasgow

The decay of the Higgs boson into a pair of Z bosons, which subsequently decay to four leptons ($H \rightarrow ZZ^* \rightarrow 4\ell$), provides a clean signature and high signal-to-background ratio for studying the properties of the Higgs boson. This allows for precise differential fiducial cross-section measurements of this decay channel.

The measurement is performed using 165 fb^{-1} of proton-proton collision data at $\sqrt{s} = 13.6$ TeV recorded with the ATLAS detector between 2022 and 2024. This data set, for the first time, surpasses the size of the full Run 2 sample, enabling further improvement in measurement precision. The analysis minimises model dependence by employing fiducial phase-space selections that closely match the experimental acceptance, together with corrections for detector effects. The results will be compared to Standard Model predictions, with emphasis on key differential observables.

T 25.2 Tue 16:30 KH 00.016

Higgs boson production cross-section measurements in the $H \rightarrow ZZ^* \rightarrow 4l$ decay channel with the ATLAS Run 3 data — •Luca Matthias Spitzauer[1], Elena Cuppini[1], Sandra Kortner[1], Oliver Kortner[1], Tae Hyoun Park[1], and Alice Reed[2] — [1]Max-Planck-Institut for Physics, Garching — [2]University of Glasgow, Glasgow

Cross-section measurements of various Higgs boson production processes are crucial for exploring Higgs boson properties and are highly sensitive to potential physics beyond the Standard Model. The decay of the Higgs boson into a pair of Z bosons, each subsequently decaying into two leptons ($H \rightarrow ZZ^* \rightarrow 4l$), is particularly important for these measurements due to its exceptionally clean signature.

Within the framework of Simplified Template Cross Sections (STXS), exclusive regions of phase space are defined for the different Higgs boson production modes. Accurate classification of reconstructed events into the appropriate STXS Higgs production regions is essential to enhance signal sensitivity and reduce uncertainties. The latest cross-section measurements in each STXS production region are based on 165 fb^{-1} of Run 3 ATLAS data. The analysis results are presented together with improvements achieved through an optimized classification employing a new Set Transformer machine learning model, replacing the baseline Recurrent Neural Network method.

T 25.3 Tue 16:45 KH 00.016

Measurement of $H \rightarrow \gamma\gamma$ fiducial cross sections with 13.6 TeV CMS data — •Caio Daumann, Johannes Erdmann, Linus Erdmann, Jan Lukas Späh, and Maximilian Wrabetz — RWTH Aachen, Physikalisches Institut III A

The Higgs boson is of fundamental importance for the understanding of particle physics. Since its discovery in 2012, it has been studied extensively by the ATLAS and CMS collaborations. The measurement of Higgs boson production cross sections is crucial for studying deviations from the Standard Model (SM) in the scalar sector.

In this presentation, the developments and current status of the Run 3 $H \rightarrow \gamma\gamma$ fiducial cross-section measurement are presented. With the increasing amount of data collected by the CMS experiment, these measurements are able to precisely test the SM and set constraints on scenarios beyond the SM. Effective Field Theory (EFT) and light-quark Yukawa coupling interpretations of these measurements are presented.

Special emphasis is placed on the statistical analysis, interpretations, and the new methods employed. In particular, the implementation and impact of the main systematic uncertainties are discussed, which become increasingly relevant with the unprecedented amount of data provided by the LHC during Run 3.

T 25.4 Tue 17:00 KH 00.016

STXS Measurements of H $\rightarrow \gamma\gamma$ Cross Sections with 13.6 TeV CMS Data — Johannes Erdmann and •Maximilian Wrabetz — III. Physikalisches Institut A, RWTH Aachen University

The discovery of the Higgs boson opened the way to test the standard model through precise measurements of its production and decay properties. As the experimental precision increases with the large Run 3 datasets, a key challenge is to design measurements that remain interpretable in the presence of potential physics beyond the standard model (BSM), while maintaining minimal dependence on theoretical assumptions.

This contribution discusses the ongoing efforts within the CMS experiment to perform Higgs boson cross-section measurements in the simplified template cross section (STXS) framework, using events in which the Higgs boson decays into a pair of photons. The analysis makes use of proton-proton collision data recorded at a centre-of-mass energy of $\sqrt{s} = 13.6$ TeV.

The STXS framework partitions Higgs production into a set of well-defined particle-level bins, characterised by the production mode and key kinematic variables. This granular binning reduces the dependence on detailed SM modelling and isolates specific regions of phase space that are particularly sensitive to potential BSM contributions. The talk will outline the analysis strategy and highlight selected methodological components, with a focus on ongoing developments.

T 25.5 Tue 17:15 KH 00.016

Combined analysis of H $\rightarrow \gamma\gamma$ and H $\rightarrow$ ZZ* $\rightarrow 4\ell$ cross sections using partial Run-3 CMS data — •Linus Erdmann, Johannes Erdmann, Jan Lukas Späh, and Maximilian Wrabetz — III. Physikalisches Institut A, RWTH Aachen University

Measurements of the Higgs boson production cross sections and decay channels are extensively studied and essential to probe possible deviations from the standard model in the scalar sector.

This presentation outlines studies towards a combined measurement of the Higgs boson production cross section in the diphoton and four-lepton decay channels with the CMS experiment. The dataset used comprises proton-proton collisions at $\sqrt{s} = 13.6$ TeV recorded during Run-3, corresponding to an integrated luminosity of 171.4 fb^{-1}. Both decay channels provide clean signatures and well-understood event topologies, which contribute to a precise determination of Higgs boson properties. Their combination increases the overall statistical precision and enables the simultaneous constraint of several Higgs boson properties. For each channel, the cross sections are measured in a fiducial phase space at particle level, which enhances model independence and minimises extrapolation uncertainties, before being extrapolated to the total phase space for the combined measurement.

These studies highlight the potential of combining different Higgs boson decay channels for a more precise determination of its production cross sections and discuss prospects for simultaneously constraining Higgs boson couplings through the joint analysis of the two channels.

T 25.6 Tue 17:30 KH 00.016

Quantum tomography using machine learning to infer incomplete information in $H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$ — Carsten Burgard[1], Vince Croft[2], André Sopczak[3], •Andrii Vak[3], and Lennart Völz[1] — [1]TU Dortmund University — [2]2Leiden University — [3]CTU in Prague

We present a novel experimental strategy for testing quantum entanglement in Higgs boson decays to W boson pairs at the Large Hadron Collider. Unlike theoretical approaches that rely on expectation values of Bell operators, which are highly sensitive to outliers and detector effects, we introduce a continuous formulation of the CGLMP inequality that enables standard hypothesis testing between entangled and separable states. To overcome the fundamental challenge of reconstructing invisible neutrino momenta in the $H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$ channel, we employ conditional denoising diffusion probabilistic models (cDDPM), which provide unbiased, multidimensional unfolding applicable to the full measured dataset including backgrounds. We compare the performance of diffusion-based reconstruction against neural network regression and analytical methods, evaluating each through profile likelihood hypothesis tests implemented in RooFit. Our results demonstrate that the diffusion-based approach enables robust hypothesis testing of quantum entanglement in a realistic collider environment, achieving sensitivity to Bell inequality violation with existing LHC datasets.

T 25.7 Tue 17:45 KH 00.016

Constraining Effective Field Theory operators in the HZZ4l

channel with CMS — •Christian-Max Sammoray, Matteo Bonanomi, Johannes Haller, and Matthias Schröder — Institut für Experimentalphyisk, Universität Hamburg

The discovery of the Higgs boson in 2012 by the CMS and ATLAS collaborations at the CERN Large Hadron Collider (LHC) set a major milestone in confirming the predictive power of the Standard Model (SM) of particle physics. However, despite its remarkable success, it leaves several unanswered questions, and direct searches for new physics have fallen short in observing new particles that could answer them, thus hinting at the existence of new physics beyond the energy scale reachable at the LHC.

The Standard Model Effective Field Theory (SMEFT) provides a powerful framework to probe such effects indirectly by expanding the SM Lagrangian with higher order operators. In this work, we use simulated CMS data corresponding to data-taking conditions at 13.6 TeV center-of-mass energy to study SMEFT effects in the Higgs to four-lepton channel. Differential cross section measurements are used to constrain new physics within the SMEFT framework.

This talk details the derivation of the parameterization of EFT effects on both the production and decay of the Higgs boson in the four-lepton final state, and how these measurements can be used to obtain constraints on new physics through a maximum likelihood fit.

T 25.8 Tue 18:00 KH 00.016

Combined measurements of the Higgs boson at ATLAS — •Ahmed Markhoos, Benedict Winter, and Karl Jakobs — University of Freiburg, Freiburg im Breisgau, Germany

Statistical combinations provide the cutting edge results for processes that can be studied through different signatures. Notable examples at the LHC have been measurements of Higgs boson production and decays. In this talk, I present the status of the latest combination of the Higgs boson measurements, performed by the ATLAS experiment with the Run 2 dataset spanning two main subjects. The first are measurements of the overall products of the Higgs-boson cross-sections and branching ratios, as well as a measurement performed in the Simplified Template Cross-section scheme, showcasing sensitivity gains in challenging parts of the phase space that may feature first hints of physics beyond the Standard Model. The second are interpretations of these measurements with the Kappa framework, which compares the measured coupling properties with those predicted by the Standard Model, and via Effective Field theory exploring possible couplings beyond the Standard Model.

T 26: Methods in Particle Physics II

Time: Tuesday 16:15–17:30 Location: KH 00.020

T 26.1 Tue 16:15 KH 00.020

Luminosity Calibration in the 2025 Oxygen Runs for the ATLAS Experiment using van der Meer Scans — •Jon Hoxha, Cigdem Issever, and Clara Elisabeth Leitgeb — Humboldt-Universität zu Berlin

The ATLAS experiment is a general-purpose detector at the Large Hadron Collider (LHC) at CERN, which conducts precise measurements for a wide range of physics phenomena. To obtain precise cross-section measurements, it is crucial to properly calibrate the luminosity detectors. ATLAS employs dedicated van der Meer (vdM) scan sessions to calibrate them, during which interaction rates are measured in certain beam conditions. Most importantly, during these scans, the beams are transversely separated in a controlled manner to understand changes in the interaction rate with separation, which is ultimately used for the luminosity calibration.

This presentation will outline the methodology, the analysis workflow, and the specific challenges for the luminosity calibration of the oxygen collision runs, which were conducted in July 2025. These runs represent the first time such collisions happened at the LHC, providing unique information into the dynamics of light-ion collisions, as well as the potential for improving of the modeling of the high energy cosmic ray air showers. Particular attention will be given to the data analysis procedure.

T 26.2 Tue 16:30 KH 00.020

Precision Luminosity Measurement with Standard Candles using HLT Scouting Data — •Tatiana Selezneva — Karlsruher Institut für Technologie, Karlsruhe, Deutschland

Precise determination of instantaneous and integrated luminosity at the LHC becomes increasingly challenging as collision rates rise and radiation damage accumulates in the CMS detector. Alongside the baseline luminosity determination, Standard Candle processes offer valuable complementary constraints. Although an absolute calibration below the 1% level is limited by theoretical cross-section uncertainties, such measurements are essential for validating long-term stability and linearity.

CMS has extensive experience with Z counting, benefiting from the clean $Z \to \mu\mu$ signature and efficient high-p_T muon reconstruction. A complementary approach is based on J/ψ production, which features a much larger cross section and thus higher event rates, including during van der Meer scans. By recording most reconstructed muons in a reduced data format, the HLT Scouting stream enables rates up to 30 kHz without degrading reconstruction performance, compensating for the suppression of low-p_T muons by standard triggers.

While the statistical gain for Z counting is moderate, the rapid availability of Scouting data enables near real-time luminosity monitoring using both Z and J/ψ. In addition, first results on W counting are presented, providing an orthogonal observable that can further constrain Z-based luminosity through its dependence on the electroweak mixing angle.

T 26.3 Tue 16:45 KH 00.020

Position monitoring system for the LHCb Upgrade II downstream tracker — •Todor Todorov[1], Marco Gersabeck[1], Flo Reiss[1], and Pascal Sainvitu[2] — [1]Albert-Ludwigs-Universität Freiburg — [2]CERN

The LHCb Upgrade 2 has the ambitious goal of increasing the instantaneous luminosity in the detector by a factor of 5. Due to the increase in detector occupancy and pileup, upgrades of many detector systems will be required, including the tracker. A new hybrid tracker will be installed downstream from the magnet, the Mighty Tracker, that will consist of silicon pixel sensors in the most occupied regions near the beam pipe and improved scintillating fibres in the remaining areas. The detector alignment and physics results will benefit from a real-time position monitoring system, but any such system will have to adhere to the strict material budget and space constraints. Frequency sweeping interferometry is chosen as a technique capable of fulfilling all requirements. A study on its use for effective position monitoring in the Mighty Tracker is presented.

T 26.4 Tue 17:00 KH 00.020

Proof of Concept for a Brute-Force Alignment Approach for the CBM STS Detector — •Nora Bluhme[1], Sergey Gorbunov[2], and Volker Lindenstruth[1,2] for the CBM-Collaboration — [1]Goethe-University Frankfurt, Frankfurt am Main, Germany — [2]GSI, Darmstadt, Germany

The Compressed Baryonic Matter experiment (CBM) at FAIR will study heavy-ion collisions at interaction rates of up to 10^7 events per second. For this purpose, accurate alignment of the detector systems is essential to exploit the high resolution of the sensors. This is typically achieved through track-based software alignment, which minimises a global χ^2 over a set of high-quality tracks.

To complement existing alignment tools, we investigate a brute-force χ^2 minimisation approach that can be applied with minimal analytical prerequisites. The method allows individual alignment parameters to be treated independently and enables the straightforward inclusion of various constraint types.

In this contribution, we present a proof-of-concept study demonstrating that this brute-force optimisation strategy is viable for the CBM Silicon Tracking System (STS) under idealised conditions. Using MC events with randomized sensor shifts and rotations, we evaluate the method's ability to recover the imposed misalignments. We show that the approach converges stably across a range of test configurations and discuss its potential and limitations as a part of the alignment strategy within CBM.

This work is supported by BMFTR (05P24RF3).

T 26.5 Tue 17:15 KH 00.020

Track Based Software Alignment Using the General Triplet Track Fit — •David Fritz, Tamasi Kar, and André Schöning for the Mu3e-Collaboration — Physikalisches Institut, Universität Heidelberg, Germany

The Mu3e experiment aims to observe the charged-lepton-flavour-violating decay $\mu^+ \to e^+e^-e^+$ at the Paul Scherrer Institut with a signal sensitivity of 1 in 10^{16} muon decays. To reach the physics goals and tracking performance of Mu3e, precise alignment of the tracking detector is crucial. Whereas optical surveillance systems provide an initial reference, track-based software alignment is required to achieve the resolution required.

A new alignment procedure based on the General Triplet Track Fit (GTTF) [1] enables the simultaneous determination of track and alignment parameters. The GTTF is a non-iterative triplet-based track fit that incorporates hit uncertainties and multiple scattering. It is highly parallelizable and suitable for implementation on, for example, GPUs or FPGAs.

This talk introduces the Mu3e experiment and places the GTTF-based alignment in the context of standard track based alignment approaches. Results from simulation studies and first applications to Mu3e commissioning data collected in June 2025 are presented, thereby demonstrating the potential of the GTTF-based alignment for the experiment.

[1] A. Schöning, 2025, A General Track Fit based on Triplets, https://doi.org/10.1016/j.nima.2025.170391

T 27: Muon Detectors

Time: Tuesday 16:15–18:15 Location: KH 00.023

T 27.1 Tue 16:15 KH 00.023

Development of a test bench for the MDT front-end electronics and L0 MDT Trigger Processor full-slice tests at the expected HL-LHC rates — •Georgios Lamprinoudis, Gia Khoriauli, Raimund Ströhmer, and Thomas Trefzger — Julius-Maximilians-Universität Würzburg

The new electronic readout of the Muon Drift Tube (MDT) chambers is a key component of the ATLAS Phase 2 upgrade for HL-LHC. The system will incorporate new mezzanine boards and chamber service modules of the MDT front-end electronics in conjunction with the new L0 MDT Trigger Processor. The development of this electronic chain requires continuous quality control and assessment. The test bench is being designed to fulfil both of these tasks by using simulated muon samples to emulate the operation and performance of the full-slice MDT readout and to optimize the muon L0 trigger.

T 27.2 Tue 16:30 KH 00.023

Small-Diameter Muon Drift Tube Detector Chambers for the ATLAS Phase-II Upgrade: Performance and Certification with Final Readout Electronics — •Elena Voevodina, Oliver Kortner, Hubert Kroha, Nick Meier, and David Weber — Max Planck Institut für Physik - Werner Heisenberg Institute Boltzmannstr. 8 - 85748 Garching, Germany

To meet the High-Luminosity LHC (HL-LHC) requirements, the Muon Drift Tube (MDT) chambers in the ATLAS Muon Spectrometer's inner barrel layer (BIS) are being replaced by small-diameter MDT (sMDT) chambers. The new sMDT stations will be integrated with triplets of thin-gap Resistive Plate Chambers (RPCs) to increase geometric acceptance and strengthen the barrel muon trigger. Between January 2021 and September 2023, 102 sMDT chambers were produced at two sites; 50% with some spares were built at the Max Planck Institute for Physics (MPI), Munich. All detectors from both production sites have been shipped to CERN for final validation. Following the production of ~3,600 stacked readout mezzanine cards and their QC/QA testing at the University of Würzburg, the cards were installed on the BIS1-6 sMDT chambers at CERN in 2025. In this contribution, we present the certification methodology and performance results for detectors equipped with the final electronics at the CERN BB5 facility*covering gas tightness, electronic noise, muon detection efficiency, and spatial resolution*and compare them with the outcomes of the initial quality-assurance campaign conducted at MPI.

T 27.3 Tue 16:45 KH 00.023

Integration of an SiPM-Based Scintillation Detector into the Readout Chain of a Cosmic Muon Test Stand with a CMS Drift Tube Chamber — Erik Ehlert, Dmitry Eliseev, •Nils Jonathan Esper, Thomas Hebbeker, Kerstin Hoepfner, Markus Merschmeyer, Carsten Presser, and Alexander Schmidt — III. Physikalisches Institut A, RWTH Aachen University

The III. Physics Institute A at RWTH Aachen University operates a cosmic test stand with a fully functional Drift Tube (DT) chamber and all necessary peripherals, which is similar to the chambers used in the Compact Muon Solenoid (CMS) experiment. Recently, the chamber was equipped and recommissioned with the readout electronics that will be used in the Phase-2 upgrade of CMS. In addition, a scintillation detector with Silicon Photomultiplier (SiPM) readout has been constructed at our institute. With the goal of integrating the readout of the scintillator into the chamber backend system, new electronics and corresponding firmware have been developed. These electronics feature the Low Power Gigabit Transceiver (lpGBT) chip, a serializer-deserializer device developed at CERN. It allows to inject the detector data into the backend system, and maintains synchronization with the global clock. This talk presents the newly developed scintillator readout chain and first recorded data. The data is compared to the independently reconstructed tracks from the DT chamber.

T 27.4 Tue 17:00 KH 00.023

Integration of Upgraded MDT Readout Electronics in the LMU Cosmic Ray Facility — •Lilla Schneider, Otmar Biebel, Valerio D'Amico, Ralf Hertenberger, Eshita Kumar, Nick Schneider, Chrysostomos Valderanis, and Fabian Vogel — LMU München

The Phase-II upgrade of the ATLAS Muon Spectrometer for the High Luminosity LHC (HL-LHC) involves the implementation of a more advanced trigger and readout system for the Monitored Drift Tube (MDT) chambers. The Cosmic Ray Facility (CRF) at Ludwig-Maximilians University Munich, equipped with two fully operational ATLAS series production, 8 m^2 sized MDT chambers enclosed by a scintillator hodoscope for triggering, is an optimal location for the testing and evaluation of these systems. Integrating the new readout electronics into the existing reconstruction chain in the CRF is a crucial step in this evaluation process. It allows for detailed studies of any differences between the legacy electronics and the upgraded system. This talk will present the current status of this project and show a comparison between the performance of the old system and the new Phase-II electronics.

T 27.5 Tue 17:15 KH 00.023

Simulation of a calorimetric muon detector using liquid organic media for imaging of nuclear materials — •Nicolas Andreas Schwarz, Yan-Jie Schnellbach, and Sarah Friedrich — Technische Universität Darmstadt, Darmstadt, Germany

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) aims to ensure the exclusively peaceful civilian use of nuclear technology in energy generation and disarmament. Nuclear safeguards are technical measures to support non-proliferation. This contribution presents a conceptual muon detector that could prove itself useful as a safeguard for the purpose of (re-)verification. The energy loss of cosmic muons as charged particles is described by the Bethe-Bloch formula. They belong to minimally ionizing particles (MIPs) and thus the mean energy loss is a function of the momentum alone for given material charge densities in the Bethe region. The proposed detector concept studied in this work is a two-sided hybrid muon detector, that uses a PVT scintillator hodoscope for muon track reconstruction, and a liquid organic TPC for calorimetric energy loss measurement since the muon ionizes the medium, producing drift electrons proportional to the deposited energy. Multiple Coulomb Scattering implies a near Gaussian distribution of scattering angles. Combining both information, simulation-based feasibility studies have been conducted to yield density images and show that a differentiation of heterogeneous materials is possible. The insights gained from this analysis will be further developed to apply them to the context of Spent Nuclear Fuels.

T 27.6 Tue 17:30 KH 00.023

Simulations regarding the water tank instrumentation for LEGEND-1000 — •Eric Esch — University Tübingen

In order to reach the challenging background goal of less than 10^{-5} cts/(keV*kg*yr) targeted by the next phase of the Large Enriched Germanium Experiment for Neutrinoless $\beta\beta$ Decay (LEGEND), new detector systems have to be planned and optimized. Previous Monte Carlo studies have revealed that the in-situ production and delayed decays of ^{77}Ge and its metastable state ^{77m}Ge constitute a significant cosmogenic background. This talk will present recent simulations exploring the instrumentation of the water tank, aimed at mitigating these contributions. Specifically, the instrumentation seeks to identify and veto events produced by neutron-showering muons, the key source of $^{77(m)}$Ge background.

T 27.7 Tue 17:45 KH 00.023

Development of new measurement methods of particle track dE/dx and time slew corrections to drift times for the ATLAS MDT detectors — •Jens Ledermann, Thomas Trefzger, Raimund Ströhmer, Gia Khoriauli, and Georgios Lamprinoudis — Julius-Maximilians-Universität Würzburg

The Monitored Drift Tube detectors (MDT) of the ATLAS Muon Spectrometer will be equipped with a new front-end electronics system after the ATLAS Phase-2 upgrade for an operation at the HL-LHC. The new 24-channel front-end mezzanine cards are designed for a precise time measurement of MDT hits at the expected HL-LHC particle rates. Comprehensive quality assessment and control tests of the mezzanine cards are performed using the tester hardware tool developed at the University of Würzburg. The test data of the mezzanine cards can be used for a calibration of a measurement of MDT ionisation charge and hence, dE/dx of charged tracks for a particle identification. Besides that, the time slew corrections for measurements of MDT hit drift times can be derived using the test data. Corresponding new methods are currently being developed. The development progress and the application of the new methods using cosmic data collected at the MDT Cosmic Ray Facility at the LMU Munich are presented in this work.

T 27.8 Tue 18:00 KH 00.023

Activities towards Phase-II upgrade of the CMS Drift Tube detector — •Dmitry Eliseev, Nils Esper, Carsten Presser, Markus Merschmeyer, Alexander Schmidt, and Thomas Hebbeker — III. Physikalisches Institut A, RWTH Aachen University

The Compact Muon Solenoid (CMS) experiment is currently preparing for its Phase-2 Upgrade, which includes major improvements to the electronics of the Drift Tube (DT) muon detectors. A central part of this upgrade is the replacement of the legacy on-chamber minicrates with newly developed and recently produced units.

Large-scale production of the new components has been completed, and the project has now entered the assembly and quality-assurance phase. Our group has played a significant role not only in the development and production of the new electronics but also in establishing of the quality assurance of the new DT electronics. Together with the CMS DT collaboration, the group has developed and deployed a software framework designed for testing and validating the new electronics, enabling consistent operation at multiple collaboration sites.

This talk reviews the ongoing CMS DT upgrade activities, and also summarizes the latest results from the current validation program. The upcoming steps on the path toward the CMS DT Upgrade are discussed as well.

T 28: Data, AI, Computing, Electronics III

Time: Tuesday 16:15–18:45 Location: KH 00.024

T 28.1 Tue 16:15 KH 00.024

Multi-Modal track reconstruction using Graph Neural Networks at Belle II — •Tristan Brandes[1], Torben Ferber[1], Giacomo De Pietro[1,2], and Lea Reuter[1] — [1]Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]Scientific Computing Center, Karlsruhe Institute of Technology, Karlsruhe, Germany

Large backgrounds and detector aging impact the track finding in the Belle II central drift chamber, reducing both purity and efficiency in events. This necessitates the development of new track algorithms to mitigate detector performance degradation. Building on our previous success with an end-to-end multi-track reconstruction algorithm for the Belle II experiment at the SuperKEKB collider (arXiv:2411.13596), we have extended the algorithm to incorporate inputs from both the drift chamber and the silicon vertex tracking detector, creating a multi-modal network. We employ graph neural networks to handle the irregular detector structure and object condensation to address the unknown, varying number of particles in each event. This approach simultaneously identifies all tracks in an event and determines their respective parameters.

We have fully integrated this algorithm into the Belle II analysis software framework. Utilizing a realistic full detector simulation, which includes beam-induced backgrounds and detector noise derived from actual collision data, we report the performance of our track-finding algorithm across various event topologies compared to the existing baseline algorithm used in Belle II.

T 28.2 Tue 16:30 KH 00.024

Graph Neural Networks for multi-hypothesis clustering in the Belle II Electromagnetic Calorimeter to improve hadron clustering — •Jonas Eppelt and Torben Ferber — Karlsruhe Institute for Technology

The Belle II experiment at the SuperKEKB collider in Tsukuba, Japan, studies the products of e^+e^- collisions to probe the Standard Model and search for new physics. Many of these processes involve π^0, which almost always decay into two γ, and reconstructing these correctly is Important for many analyses. The currently used clustering algorithm is optimized towards the reconstruction of photon clusters, which form regular, mostly round clusters. However, the e^+e^- collisions also produce hadronic particles, which also interact in the calorimeter. As their energy depositions are more irregularly shaped and can produce split-off particles, which create disconnected, additional clusters, they pose a significant challenge for any clustering optimized for electromagnetic clusters. Improving upon their reconstruction would not only improve their identification, but also help constrain the energy in the calorimeter to the collision energy. I will show an implementation of a graph neural network, optimized for both photon and hadron reconstruction. Not only does it improve the photon energy resolution, but it also improves the hadron position reconstruction. Further, I will demonstrate the improved constraints on the energy in the calorimeter on the collision energy.

T 28.3 Tue 16:45 KH 00.024

Point Cloud Segmentation for the Belle II GNN-Based Tracking — •Daniel Grossmann, Tristan Brandes, Giacomo De Pietro, Torben Ferber, and Lea Reuter — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

Our implementation of an end-to-end multi-track based reconstruction algorithm for the Belle II experiment at the SuperKEKB collider improves the tracking performance compared to the baseline algorithm (arXiv:2411.13596). It combines the Object Condensation algorithm with a Graph Neural Network that simultaneously identifies all tracks in an event and determines their respective parameters. However, our current algorithm is based on a segmentation step during the model post-processing, which fails to capture specific signatures for more complex track topologies.

This work improves the segmentation by employing a pointcloud-based model in the post-processing step for the track and hit assignment. We report the performance of our improved track-segmentation algorithm across various event topologies compared to the existing segmentation method and to the baseline tracking algorithm used in Belle II.

T 28.4 Tue 17:00 KH 00.024

Graph Neural Network based inclusive flavour tagger at the LHCb experiment — •Yukai Zhao[1], Sara Celani[2], Stephanie Hansmann-Menzemer[1], and Pelian Li[3] — [1]Physikalisches Institut,

Ruprecht-Karls-Universität Heidelberg, Germany — [2]CERN, Switzerland — [3]University of Chinese Academy of Sciences, China

The study of CP violation at the LHCb experiment is essential for understanding the observed matter*antimatter asymmetry in the universe. A key component of many such measurements is the decay-time-dependent analysis of oscillating neutral B mesons, which requires knowledge of the b-hadron flavour at production. This initial flavour information can not be determined directly from the decay products of the signal candidate. Instead, it is inferred using flavour tagging algorithms which exploit correlations with other particles produced in the same proton*proton collision. This talk presents a novel flavour-tagging method based on Graph Neural Networks (GNNs). The approach leverages the Deep Full Event Interpretation framework, which performs inclusive reconstruction of heavy hadrons in the event. By modelling the relationships between particles identified through inclusive reconstruction, the GNN-based tagger is expected to enhance the usage of kinematic and topological information, leading to a significant improvement in the estimated flavour-tagging performance. The results represent a promising advancement for time-dependent CP violation measurements at LHCb.

T 28.5 Tue 17:15 KH 00.024

Machine-Learning based Energy Regression of Muon Detector Showers in CMS — •Mascha Hackmann, Ayse Asu Guvenli, Karim El Morabit, and Gregor Kasieczka — University of Hamburg, Hamburg, Germany

Exotic Long-Lived Particles (LLPs), predicted by many extensions of the Standard Model, can travel macroscopic distances before decaying. Decays inside the muon system of the CMS detector produce hadronic showers instead of isolated muon tracks, leading to unconventional signatures beyond the scope of standard muon reconstruction.

This talk presents a machine learning approach to analyze Muon Detector Showers (MDS) originating from LLP decays in the CMS experiment. For the analysis of the MDS, the Cathode Strip Chambers are interpreted as a sampling calorimeter. Low-level hit information is used as input to train a ParticleNet based Dynamic Graph Convolutional Neural Network (DGCNN) to regress the energy of the LLP. These studies provide insight to improve future searches for LLPs that decay in the muon system of the CMS.

T 28.6 Tue 17:30 KH 00.024

Machine-Learning Based Reconstruction of Muon Detector Showers in CMS — •Ayse Asu Guvenli, Karim El Morabit, Gregor Kasieczka, and Mascha Hackmann — University of Hamburg, Hamburg, Germany

Long-lived particles (LLPs) appear in many extensions of the Standard Model and can travel measurable distances before decaying. When such decays occur in or near the CMS muon system, they can produce atypical showers of hits rather than standard muon signatures. These muon detector showers (MDS) offer a promising handle for LLP searches but remain difficult to reconstruct with algorithms optimized for muons.

This work explores machine-learning based reconstruction of shower-like hit patterns in the CMS Cathode Strip Chambers, aiming to improve the identification and characterization of MDS from LLP decays. We present ongoing developments toward low-level hit reconstruction with ML methods and discuss their potential to enhance the sensitivity of Run-3 LLP searches.

T 28.7 Tue 17:45 KH 00.024

Reconstructing missing transverse momentum for electroweak precision measurements at the ATLAS experiment — •Gabriel Sanchez Shestakova, Matthias Schott, Timo Saala, and Philip Bechtle — Physikalisches Institut, Bonn, Germany

We present first studies of a supervised Machine Learning (ML) approach for reconstructing missing transverse energy (MET) using Particle Flow (PF) information acquired from open Large Hadron Collider (LHC) data. Using simulated $W^+ \to \mu^+\nu$ events at $\sqrt{s} = 8$ TeV, we compute an event-level MET observable directly from PF objects by explicitly reconstructing transverse momentum components and forming an analytically calculated MET, which serves as a controlled regression target for the ML approach.

A fully connected multilayer perceptron (MLP) is trained on per-event PF momentum components, with variable-length PF collections handled via zero-padding to a fixed input dimension. We also develop a graph neural network (GNN) approach that operates on variable-size PF representation. Quantile-based selections on the number of PF objects and on the calculated MET are applied prior to training in order to mitigate outliers and reduce input distribution mismatches.

T 28.8 Tue 18:00 KH 00.024

Secondary Particle Tracking with Graph Neural Networks for the ATLAS Experiment — •Hannah Schlenker, Sebastian Dittmeier, and André Schöning — Physikalisches Institut, Universität Heidelberg, Germany

The increased number of simultaneous proton-proton collisions in the upcoming High Luminosity LHC will increase the computational demands for charged particle track reconstruction in the new Inner Tracker (ITk) of the ATLAS Experiment. To reduce computing resources, the usage of parallel architectures like GPUs are investigated, and new track reconstruction algorithms based on machine learning are in development. Track finding on the basis of Graph Neural Networks (GNNs) has been shown to be promising [1]. This method constructs a graph based on all hits of an event using a module map, assigns a score to each edge and finds track candidates based on these scores.

Previous work focused on particle tracks originating near the interaction region [1]. Secondary particle tracks, which are produced all over the detector, have not been targeted. A good track finding efficiency for these particles is important for enhanced energy measurements, characterisations of material interactions and potential searches of long-lived particle decays.

This talk discusses the secondary tracking performance of current models and of new models developed specifically for this task.

[1] ATLAS Collaboration, Optimizations of the ATLAS ITk GNN reconstruction pipeline, tech. rep., CERN, 2025, URL: https://cds.cern.ch/record/2948192

T 28.9 Tue 18:15 KH 00.024

Keeping Track of Graphs: 4D Tracking with Graph Neural Networks at Muon Colliders — •Lukas Bauckhage — Deutsches Elektronen-Synchrotron DESY — Physikalisches Institut, Universität Bonn

This talk explores the application of Graph Neural Networks (GNNs) to track reconstruction at a future muon collider experiment utilising precise timing information. We highlight the challenges posed by high beam-induced backgrounds, making robust and efficient tracking exceptionally difficult. We demonstrate how GNNs can effectively model the 4D relationships among detector hits to identify and group related hits by leveraging spatial and timing information to distinguish true particle trajectories from background activity. Our results on the performance of reconstruction algorithms aided by GNNs compared to established algorithms purely based on Kalman-Filters are presented.

T 28.10 Tue 18:30 KH 00.024

Machine Learning Models for Separating Signal and Background Events in LHC pp Collisions — Oleksandr Shekhovtsov, André Sopczak, and •Lukas Vicenik — CTU in Prague

We investigate machine-learning-based signal-background discrimination for measuring Higgs boson production in association with top quarks (ttH) in multilepton final states at $\sqrt{s} = 14$ TeV. We simulated a dataset for a generic detector that mimics a realistic analysis. Low low-level features are used. A range of methods from standard Machine Learning models to advanced approaches inspired by geometric deep learning are benchmarked. The study evaluates these approaches, highlighting their performance and identifying directions for improving symmetry-aware machine learning in collider measurements.

T 29: Flavour Physics II

Time: Tuesday 16:15–18:15 Location: KH 01.011

T 29.1 Tue 16:15 KH 01.011

Branching fraction measurement of the $\Lambda_b^0 \to p\pi\mu^+\mu^-$ decay with Run 1 + Run 2 data at LHCb — •Piera Battista[1,2] and Marie-Helene Schune[1] — [1]IJCLab, Orsay — [2]TU Dortmund

Rare decay transitions are powerful tools to search for New Physics. Flavour physics experiments have extensively studied $b \to s\ell^+\ell^-$ transitions in a multitude of various modes and have found tensions with the Standard Model. To further the study of Flavour Changing Neutral Currents, $b \to d\ell^+\ell^-$ transitions are the next object of study, as they are additionally Cabibbo suppressed. The baryonic $\Lambda_b^0 \to p\pi\mu^+\mu^-$ transition is part of this family of decays. This mode was first observed in LHCb using pp-collision Run 1 data with 3 fb^{-1} luminosity, and its branching fraction was measured to be $(6.9 \pm 1.9 \pm 1.1^{+1.3}_{-1.0}) \times 10^{-8}$. This talk will present the ongoing efforts to update the branching fraction measurement, incorporating Run 2 data and achieving a 9 fb^{-1} luminosity, in order to reduce the uncertainties. In addition, a study of the differential branching fraction in bins of di-muon momentum q^2 is presented, representing the first measurement of this type in this mode.

T 29.2 Tue 16:30 KH 01.011

Electromagnetic corrections to leptonic charm decays — •Aritra Biswas[1], Max Ferre[2], Jack Jenkins[1], and Ipsita Ray[3] — [1]University of Siegen, Siegen, Germany — [2]Johannes Gutenberg University, Mainz, Germany — [3]University of Montreal, Montreal, Canada

We investigate the soft photon energy spectrum of leptonic charm decays $D_{(s)} \to l\nu(\gamma)$, $l = \mu, \tau$ at fixed order in the electromagnetic coupling, including hadronic substructure effects that are the dominant sources of theoretical uncertainty. We address the different scales involved in the problem with respect to the heavy and light leptonic final states. We find that the leading electromagnetic corrections are comparable to the experimental precision at BESIII in general. We also incorporate the effect of these corrections on model dependent/independent constraints in BSM scenarios and comment on the shift in the corresponding parameter space resulting from the inclusion of these corrections in the Standard Model estimate.

T 29.3 Tue 16:45 KH 01.011

Measurement of the $\pi^0 \to e^+e^-\gamma$ decay at NA62 — •Celia Polivka — Mainz Universitaet

The current value for the $\pi_D^0 \to e^+e^-\gamma$ Dalitz decay is $\mathcal{B}r(\pi_D^0) = (1.174 \pm 0.035) \cdot 10^{-2}$ and has a large uncertainty. This is a limiting factor for other measurements that use the Dalitz decay as normalisation channel. This analysis aims to improve the precision on this measurement using data from the NA62 experiment at CERN. The π^0 mesons are tagged by $K^+ \to \pi^+\pi^0$ decays. The π_D^0 is then identified by reconstruction of the three track vertex of e^+, e^- and π^+. Presented are the status of the analysis and an outlook on the precision of the measurement.

T 29.4 Tue 17:00 KH 01.011

Search for $B^+ \to K^{*+}\tau^+\tau^-$ with Hadronic Tagging at the Belle II Experiment — •Lennard Damer, Torben Ferber, and Pablo Goldenzweig — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

In recent years, hints for violation of lepton flavor universality have been observed in semileptonic B decays by various experiments. The flavor-changing neutral current process $b \to s\tau^+\tau^-$ is particularly sensitive to models which feature large couplings to third generation leptons or couplings proportional to the particle mass. Some theoretical models allow for an increase in the branching fraction of up to three orders of magnitude compared to the Standard Model prediction, which is within the observable range of the Belle II experiment. In this analysis, hadronic tagging is employed where the corresponding B meson partner in $\Upsilon(4S)$ decays is reconstructed in a variety of hadronic decay chains to increase the selection purity. This talk presents the status of the first search for $B^+ \to K^{*+}\tau^+\tau^-$ decays along with an estimate on the signal sensitivity.

T 29.5 Tue 17:15 KH 01.011

Early measurement of $r_{J/\psi}^{K,K^*}$ with 2024 data — Johannes Albrecht[1], Michele Atzeni[2], Lukas Calefice[3], Angel Fernando Campoverde Quezada[4], James Gooding[1], Carla Marin Benito[5,3], •Lorenzo Nisi[1], Renato Quagliani[5], Alessandro Scarabotto[1], Eluned Smith[2], and Pol Vidrier Villalba[3] — [1]TU Dortmund University, Dortmund, Germany — [2]Massachusetts Institute of Technology, Cambridge, United States — [3]Universitat de Barcelona, Barcelona, Spain — [4]University of Chinese Academy of Sciences, Beijing, China — [5]CERN, Geneva, Switzerland

During 2024, the LHCb experiment collected more than 9 fb^{-1} of integrated luminosity for pp collisions, recording approximately as many collisions as between 2011 and 2018. The performance of the upgraded LHCb detector in Run 3 of the LHC must be fully understood to perform precise measurements with this new dataset.

Measurements of ratios between B meson decays to final states containing different lepton pairs can be used to study lepton flavour universality, e.g., R_{K,K^*} between $B^{+(0)} \to K^{+(0*)}\mu^+\mu^-$ and $B^{+(0)} \to K^{+(0*)}e^+e^-$ decays. The $J/\psi \to \ell\ell$ resonant modes are commonly used as control channels and their ratio $r_{J/\psi}^{K,K^*}$ is well-understood to be consistent with unity. As such $r_{J/\psi}^{K,K^*}$ can be used to validate detector performance and data-MC corrections.

This contribution presents the progress towards a measurement of $r_{J/\psi}^{K,K^*}$ using 2024 data.

T 29.6 Tue 17:30 KH 01.011

Search for $B_c^+ \to B_s^0\mu^+\nu_\mu$ decays at LHCb — •Mikhail Chekal and Marco Gersabeck — Albert-Ludwigs-Universität Freiburg, Freiburg im Breisgau, Germany

Semileptonic decays are useful for probing new physics as they can be used to test lepton flavour universality. To date, $B_c^+ \to J/\psi\ell^+\nu_\ell$ remains the only semileptonic B_c^+ decay channel to be observed. A search for the semileptonic decay $B_c^+ \to B_s^0\mu^+\nu$ using the LHCb Run 3 data collected in 2024–2025 is presented. The strategy is to extract the $B_c^+ \to B_s^0\pi^+$ yield, which serves as the normalization channel, as well as the combined $B_c^+ \to B_s^0\mu^+\nu$ and $B_c^+ \to B_s^{*0}\mu^+\nu$, and compute their ratio of branching fractions. The B_s^0 candidates are reconstructed as $B_s^0 \to D_s^-(K^+K^-\pi^-)\pi^+$ and the results will later be combined with those of the second group working on the $B_s^0 \to J/\psi\phi$ channel. Methods, used for B_s^0 and B_c^+ candidates selection for the normalization and signal channels are presented.

T 29.7 Tue 17:45 KH 01.011

Update of the SM prediction for $\bar{B} \to X_s\gamma$ — •Tobias Huber[1], Mikolaj Misiak[2], Matthias Steinhauser[3], Mateusz Czaja[3], Michal Czakon[4], Kay Schönwald[5], Abdur Rehman[6], and Marco Niggetiedt[7] — [1]Theoretische Physik 1, Center for particle physics Siegen, University of Siegen, Germany — [2]Institute of Theoretical Physics, University of Warsaw, Poland. — [3]Institute for theoretical particle physics, KIT, Karlsruhe, Germany — [4]Institut f. Theoretische Teilchenphysik und Kosmologie, RWTH Aachen University, Germany — [5]CERN theory group, CERN, Geneva, Switzerland — [6]Department of Physics, University of Alberta, Edmonton, Canada — [7]Max Planck Institute for Physics, Munich, Germany

We will provide an update of the SM theory prediction for $\mathcal{B}(\bar{B} \to X_s\gamma)$, including, in particular, NNLO $Q_{1,2} - Q_7$ interferences with exact charm-quark mass dependence. Also phenomenologial implications such as constraints on the charged-Higgs mass in two-Higgs-doublet models will be given.

T 29.8 Tue 18:00 KH 01.011

B-meson decay width up to $1/m_b^3$ corrections within and beyond the Standard Model — •Ali Mohamed[1], Alexander Lenz[1], Martin Lang[1], Maria Laura Piscopo[2,3], and Alexey Rusov[4] — [1]Siegen University, Siegen, Germany — [2]Nikhef, Amsterdam, Netherlands — [3]Vrije Universiteit Amsterdam, Amsterdam, Netherlands — [4]Technische Universität München, München, Germany

We determine subleading power corrections to heavy-hadron decay rates within and beyond the Standard Model. In the SM, we compute previously unknown penguin-induced contributions to the chromomagnetic $(1/m_Q^2)$ and Darwin $(1/m_Q^3)$ operators in the Heavy Quark Expansion, improving predictions for B-hadron lifetimes.

Motivated by tensions in colour-allowed non-leptonic decays, we extend the analysis to a general BSM framework and provide complete contributions to the Wilson coefficients of the chromomagnetic and Darwin operators, including the calculation of BSM Weak Annihilation contributions. This completes the dimension-six BSM operator basis for non-leptonic decays.

Our results enable precise global SM analyses and model-independent new physics searches using lifetime observables such as $\tau(B_s)/\tau(B_d)$, closing a critical gap in the theoretical description of these quantities.

T 30: Silicon Detectors III

Time: Tuesday 16:15–18:30 Location: KH 01.012

T 30.1 Tue 16:15 KH 01.012

Current and low-field carrier mobility in silicon sensors irradiated to extreme fluences — Christian Scharf[1], Peilin Li[1], •Heiko Markus Lacker[1], Ingo Bloch[2], and Ben Bruers[2] — [1]Humboldt-Universität zu Berlin — [2]Deutsches Elektronen-Synchrotron (DESY)

We present a study of the forward and reverse currents in silicon pad diodes irradiated to extreme neutron fluences up to $1 \times 10^{18}\, n_{eq}/\text{cm}^2$, similar to the expected fluences of tracking detectors at a future circular hadron collider.

At such fluences, the silicon bulk and the implant no longer behave like a typical pn diode. Excess free carriers are trapped at radiation-induced deep defects, compensating ionized shallow defects in the bulk. Consequently, carrier concentrations in the bulk decrease and become similar to those in intrinsic silicon, increasing the resistivity of the bulk. The interaction between ionized defects and free carriers leads to increased Coulomb scattering, causing a decrease in the low-field carrier mobilities with fluence.

To quantify the mobility degradation as a function of fluence and to obtain a qualitative understanding of the diode's electrical performance, current-voltage characteristics were measured at various temperatures. These measurements are compared to TCAD simulations using different radiation-damage models.

T 30.2 Tue 16:30 KH 01.012

The Production Database of the High-Granularity Timing Detector for the ATLAS Phase-II Upgrade — •Annika Stein[1], Luca Cadamuro[2], Martin Christiansen[1], Frederic Fischer[1], Jessica Höfner[1], Yun-Ju Lu[3], Lucia Masetti[1], Yuan-Yen Peng[4], Hendrik Smitmanns[1], and Song-Ming Wang[3] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz — [2]IJCLab, Frankreich — [3]Academia Sinica, Taiwan — [4]NTHU, Taiwan

The High-Granularity Timing Detector is being built as part of the Phase-II upgrade of ATLAS. It is based on Low-Gain-Avalanche-Detector sensors and provides the time of tracks in the forward region. Assembly and testing sites use the Production Database (ProdDB) to track components and their properties like measurements and part-to-part relations. To leverage dynamic updates of the ProdDB and local data, a python API client has been developed that ensures proper data structure and minimizes backend server load by running consistency checks on the client side before uploading. With the new user interface, we model the module assembly, module loading onto support units, and detector assembly processes. The tools integrate seamlessly into existing frameworks for quality control of modules (consisting of module PCB and two hybrids) as well as flexible PCB cables (flex tails). Applying module hybrid clustering algorithms on current-voltage curves to find matching components is possible. Furthermore, by running automated continuous integration pipelines, we also perform nightly reporting of part yields. In this presentation, the DB infrastructure, focusing on novel interface methods, will be explained.

T 30.3 Tue 16:45 KH 01.012

Radiation damage studies of the ATLAS ID Pixel detector at LHC — Arnulf Quadt, Steffen Korn, and •Marcello Bindi — II. Physikalisches Institut, Georg-August-Universität, Göttingen

By the end of 2025, the ATLAS ID Pixel detector, including its inner Insertable B-Layer (IBL), have integrated up to 2×10^{15} n-eq cm^{-2} substantially increasing sensor leakage currents. Since leakage current is a key indicator of detector health and a proxy for particle fluence, its accurate monitoring is essential. Because it is strongly temperature-dependent, simultaneous current and temperature measurements are needed to disentangle thermal effects from true radiation-induced bulk damage. I-V scans provide this information and allow early identification of abnormal currents or breakdown behaviour, which is critical for detector safety. Rising leakage currents affect operations through higher power dissipation, increased noise, and potential power-supply limitations.

This work presents leakage current data for the ATLAS Pixel detector, including results from IBL planar and 3D sensor technologies, before and after normalization to sensor volume and temperature correction. Temperature measurements from NTC thermistors on the hybrid flex are also discussed. All scans were recorded over multiple years in stable detector conditions, either without beam (e.g., winter shutdowns and technical stops) or during collisions alongside charge-collection measurements. A summary of the full Run-3 dataset will be shown, emphasizing the effects of radiation fluence and temperature inhomogeneities across detector layers, staves, and modules.

T 30.4 Tue 17:00 KH 01.012

Analysis of de-tuning behaviour of the ATLAS Insertable B-Layer during LHC Run 2 and Run 3 — •Johannes Klas[1], Kerstin Lantzsch[1], and Sergi Rodriguez Bosca[2] — [1]Universität Bonn — [2]CERN

Over time the ATLAS pixel detector has been re-tuned many times. Either due to a change of the tuning set-points, routine retuning after a shutdown, or, in the case of the 2014 installed Insertable B-Layer (IBL), due to de-tuning because of irradiation. Effects like the TID had a severe impact on the tuning of IBL at the start of LHC Run 2. While this concrete behaviour of the de-tuning was studied systematically during the start of Run 2 for IBL, it has not been done in such detail thereafter. Tuning data for the full Run 2 and partial Run 3 was collected and analysed to gain a better understanding of the de-tuning behaviour on a larger timeline and document the overall evolution of the relevant parameters.

T 30.5 Tue 17:15 KH 01.012

Luminosity measurements using the ATLAS Forward Proton (AFP) detector — Jan Broulim, Petr Fiedler, •Daniil Khmelnytskyi, and André Sopczak — CTU in Prague

The latest results of luminosity measurements using the ATLAS Forward Proton (AFP) detector are presented.

T 30.6 Tue 17:30 KH 01.012

ATLAS Forward Proton (AFP) detector operation challenges and ToF Run-3 performance — •Viktoriia Lysenko and André Sopczak — CTU in Prague

Operational and data quality challenges for the ATLAS Forward Proton (AFP) detector in 2025 are presented together with performance studies of the Time-of-Flight (ToF) detector during LHC Run-3 datataking.

T 30.7 Tue 17:45 KH 01.012

Towards ultra-thin hybrid pixel detectors via wafer-to-wafer bonding — Fabian Hügging[1], Janna Vischer[2], Jens Weingarten[2], Matthias Schüssler[1], •Maximilian Mucha[1], Thomas Fritzsch[3], Yannick Dieter[1], and Jochen Dingfelder[1] — [1]Physikalisches Institut, Universität Bonn, Deutschland — [2]Technische Universität Dortmund, Deutschland — [3]Fraunhofer Institute IZM, Berlin, Deutschland

Hybrid pixel detectors are a key technology for precise particle tracking in high energy physics in high rate and high radiation environments. Conventional hybrid detector assemblies rely on die-level bump bonding techniques, which impose limitations on the achievable detector area and the overall material budget. Wafer-to-wafer bonding provides an alternative by interconnecting sensor and readout wafers prior to dicing, enabling large-area devices and aggressive thinning of the bonded stack, while keeping the advantage of a separate development and optimization of both the sensor and readout wafer. This contribution presents ongoing work towards the realization of ultra-thin hybrid pixel detectors based on wafer-to-wafer bonding. An overview of the project and current progress is given. Particular emphasis is placed on the electrical characterization of silicon sensor wafers prior to bonding. Current-voltage (IV) measurements at wafer level are discussed to evaluate leakage current behavior and breakdown performance. The talk concludes with an outlook on the transition to bonded wafer stacks, including the preparations for wafer-level studies.

T 30.8 Tue 18:00 KH 01.012

Investigation of bond qualities in daisy chain wafers for Wafer-to-wafer bonded hybrid pixel detectors — •Janna Vischer[1], Yannick Dieter[2], Fabian Hügging[1], Kevin Kröninger[2], Maximilian Mucha[2], Matthias Schüssler[2], and Jens Weingarten[1] — [1]Technische Universität Dortmund, Dortmund, Germany — [2]Universität Bonn, Bonn, Germany

Semiconductor pixel detectors allow for precisely tracking ionizing particles in high-energy physics experiments and medical applications. Previously, during the manufacturing of hybrid pixel detectors, a common practice to combine the separately manufactured sensor and its readout chip is to bump-bond two single dies together. Wafer-to-wafer bonding is a new method in development for manufacturing hybrid pixel detectors, where whole detector wafers and chip wafers are bonded before being diced to their definite size. This promises detectors to have larger sensitive areas and a reduced thickness through thinning of the wafers after bonding.

To refine the Wafer-to-wafer bonding procedure low-cost non-detector daisy chain wafer stacks have been produced for proof of principle. This talk discusses recent results of measurements on one of those bonded wafer stacks. The resistivity of single bonds as well as bonds connected in daisy chains have been measured on wafer level to investigate spatial dependent deviances in preparation for the first Wafer-to-wafer bonded detectors.

T 30.9 Tue 18:15 KH 01.012

All-Silicon Modules - RDL development in FTD Cleanroom — •Andreas Ulm, Marco Vogt, Hans Krüger, and Jochen Dingfelder — Physikalisches Institut der Universität Bonn, Bonn, Germany

Silicon Pixel Detectors are an essential part of most modern tracking systems for high energy physics as they can fulfill requirements of high spatial and time resolution, feasible power consumption and relatively low material budget. To cover large areas in the detector volume individual chips are glued together to create modules. These modules are easier to assemble to full tracking systems than what would be possible if all chips had to be installed individually, however gluing, additional flex PCBs, cooling and support structures and also structural silicon can introduce significant amounts of material.

To reduce the material budget of tracking detectors as far as possible, a new concept of module-building is investigated. By post-processing monolithic chip wafers, redistribution layers (RDL) can be built on top of the chips for electrical connections to several chips in a row. By using low power monolithic chips air cooling is feasible and mechanical support is not necessary for thin ladder structures of up to 15 cm in length with thicknesses around 200 micron .

This talk will discuss concepts, look into prototype production, and discuss early measurements and simulations of high speed differential lines for module-sized RDL.

T 31: Scintillator Detectors I

Time: Tuesday 16:15–18:15 Location: KH 01.014

T 31.1 Tue 16:15 KH 01.014

Commissioning of the Mu3e Tile Detector — •Erik Steinkamp for the Mu3e-Collaboration — Kirchhoff-Institut für Physik, Heidelberg, Germany

The Mu3e experiment has been designed with the objective of detecting the charged lepton flavour violating decay $\mu \to eee$ with an ultimate branching ratio of 10^{-16}. To achieve this sensitivity, the Mu3e experiment needs precise vertexing and tracking as well as very precise timing.

The Mu3e tile detector is a scintillator-based timing detector with SiPM readout that aims at a timing resolution of less than 100 ps. The final detector modules are currently being assembled and installed in the Mu3e experiment. A first commissioning beamtime of the Mu3e detector with three out of a total of 14 tile modules took place in mid-2025. In preparation for the first physics beamtime in late 2026, this data is being used to improve the performance of the tile detector through a comprehensive offline calibration procedure, as well as a robust clustering algorithm to combine individual channel hits into clusters for track matching. This talk will present the current status of the commissioning of the Mu3e tile detector, focusing on results from the 2025 beamtime, the qualification of existing modules and further developments.

T 31.2 Tue 16:30 KH 01.014

Timing performance of multiple prototypes of the Surrounding Background Tagger of the SHiP experiment — •Alessia Brignoli for the SHiP-SBT-Collaboration — Humboldt Universität zu Berlin

SHiP (Searching for Hidden Particles) is a beam-dump experiment that will be built at CERN, to search for new feebly interacting particles. A crucial component of the SHiP experiment is the Surrounding Background Tagger (SBT), a liquid scintillator based detector designed to suppress background arising from muons entering the helium-filled decay volume, as well as from muon/neutrino inelastic interactions occurring within the decay volume and its surroundings. The SBT consists of about 900 cells filled with liquid scintillator (LAB+PPO). Light collection is achieved through two PMMA wavelength-shifting optical modules (WOMs) per cell, each optically coupled to an array of 40 SiPMs. This work presents a collection of results from timing performance studies of SBT prototypes developed and tested between 2022 and 2025 at the CERN PS and at DESY Hamburg. The prototypes differ in the cell construction material as well as in the materials used to enhance the reflectivity of the inner walls, which is a crucial factor for light collection. In addition to the timing performance, the detector's capability of reconstruct particle crossing point and direction was studied. Finally, the experimental results were compared with Geant4-based photon transport simulations, providing further insight into the detector response and the overall quality of the constructed prototypes.

T 31.3 Tue 16:45 KH 01.014

Results from the November 2025 Test Beam measurements of SHiP's Surrounding Background Tagger prototypes — •Hannes Braune for the SHiP-SBT-Collaboration — Humboldt-Universität zu Berlin

The SHiP (Search for Hidden Particles) experiment, scheduled to start operation in 2032 at the CERN SPS Beam Dump Facility, aims to search for as-yet undiscovered feebly interacting long-lived particles. A large $\mathcal{O}(50\,\mathrm{m})$ long decay volume filled with helium together with a spectrometer allows the reconstruction of their decay products. The decay volume is surrounded by the Surrounding Background Tagger (SBT) to tag muons entering from outside and muon or neutrino inelastic interactions in helium. The SBT consists of $\mathcal{O}(900)$ cells forming a continuous 20 cm thick layer of LAB+PPO liquid scintillator around the entire volume, and is read out with wavelength-shifting optical modules (WOMs) coupled to SiPM arrays. In November 2025, the long-term performance as well as different cell sizes and WOM configurations were tested in dedicated test beam measurements at the CERN PS.

T 31.4 Tue 17:00 KH 01.014

Large liquid scintillator detectors in SHiP - Hardware and electronics — •Tilman Rock for the SHiP-SBT-Collaboration — Albert-Ludwigs-Universität, Freiburg, Germany

In the search for particles in the hidden sector, the SHiP (Search for Hidden Particles) experiment, a high-intensity, general-purpose beam-dump experiment, is in preparation. The primary objective is to search for weakly interacting particles within the GeV mass range, which requires a zero-background level. To this end, SHiP's large, helium-filled decay volume is encircled by the Surrounding Background Tagger (SBT), which is essentially a large array of about 900 individual mirror-polished aluminum cells filled with liquid organic scintillator. The SBT is designed to identify particles entering the decay volume and neutrino-induced reactions within it. To efficiently collect light, the cells have UV-reflective walls and wavelength-shifting optical modules (WOMs) for light collection. The collected light is detected by 40 silicon photomultipliers arranged in a circle, which are optically coupled to each of the WOMs. In this presentation, different types of optical coupling will be compared. Additionally, temperature-dependent gain variations will be compensated by changing the operating voltages. To measure the temperature-dependent breakdown voltages of the SiPMs, a dedicated test setup has been developed that measures the dark currents of entire arrays of 40 SiPMs for varying bias voltages and temperatures. The setup will be explained and first results will be presented.

T 31.5 Tue 17:15 KH 01.014

Data-based studies on the single hit efficiencies of the LHCb Scintillating Fibre Tracker — Blake Leverington, Ulrich Uwer, •Tom Wolf, Chishuai Wang, Miguel Ruiz Diaz, Giulia Tuci, Sebastian Bachmann, Xiaoxue Han, and Ya Zhao — Physikalisches Institut Universität Heidelberg

During 2019-2022 the LHCb detector was upgraded to allow operation at higher luminosity and full-detector read-out at 40 MHz. As core part of this upgrade, the Scintillating Fibre Tracker (SciFi) has been installed as the new main tracker. To detect charged tracks it makes use of 12 layers, constructed from 250 μm diameter scintillating fibres that are readout by silicon photomultipliers.

A principle performance parameter for the SciFi is the single hit efficiency, its ability to detect a hit when a particle track passes through one of its layers. To measure this value from data, charged particle tracks are reconstructed while excluding the layer under study, in which matching hits are then searched for. The efficiency is studied over the entire detector area, as well as over time and as a function of occupancy, to gauge the impact of the ionising radiation and luminosity delivered during Run 3 of the LHC.

T 31.6 Tue 17:30 KH 01.014

Optical simulations of plastic and $CeBr_3$ scintillator modules read out by SiPMs for the scintLaCharm Compton camera — •Kaveh Kooshkjalali, Alexander Deisting, Theresa Hahn, and Uwe Oberlack — Institute of Physics and Excellence Cluster PRISMA++

Within the framework of the ScintLaCHARM (Localization and CHAracterization of Radioactive Material) Compton Camera Project, which aims at the development of scintillation-based Compton cameras for applications such as nuclear power plant decommissioning, we present a Geant4-based optical simulation developed to study scintillation and Cherenkov light production and transport in plastic and $CeBr_3$ scintillators with silicon photomultiplier (SiPM) readout.

The detector geometry models two types of scintillation medium, reflective boundaries, and segmented top and bottom SiPM planes. Wavelength-dependent optical material properties and surface models are implemented to describe refraction, absorption, and reflection at all interfaces. Optical photon transport is tracked in detail, including absorption in the crystal, escape into the surrounding volume, and multiple reflections prior to detection. A SiPM sensitive detector records photon boundary crossings and classifies hits by detector plane, timing, and reflection history.

We study the impact of geometry and optical properties on detector performance, simulating light-collection efficiency, timing response, and detector position and energy resolution.

T 31.7 Tue 17:45 KH 01.014

Opaque Scintillators for Neutrino Physics — Christian Buck[1], Benjamin Gramlich[1], and •Stefan Schoppmann[2] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Johannes Gutenberg-Universität Mainz, Exzellenzcluster PRISMA+, Detektorlabor, Staudingerweg 9, 55128 Mainz, Germany

A new scintillator system was developed based on admixtures of wax in organic scintillators. The opacity and viscosity of this gel-like material can be tuned by temperature adjustment, wax concentration, and wax type. Whereas it is a colourless transparent liquid at high temperatures, it has a milky wax structure below.

Due to its light confinement, the scintillator system is expected to exhibit unprecedented particle ID via the morphology of energy depositions. Moreover, a high degree of isotope loading is feasible, e.g. in the context of searches for double beta decays or neutron capture.

In this presentation, the production and properties of various opaque scintillators as well as their advantages compared to transparent scintillators are described.

T 31.8 Tue 18:00 KH 01.014

Opaque liquid scintillator prototype for Light Dark MatterSearches — •Jonas Pätschke for the MAGIX-Collaboration — Institute for Nuclear Physics, Johannes Gutenberg-University Mainz, Germany

In the ongoing search for light dark matter, the DarkMESA and $NuDoubt^{++}$ collaborations have joined forces to explore a new region of parameter space. DarkMESA is an upcoming electron beam dump experiment at the new MESA accelerator facility in Mainz, designed to search for light dark matter particles mediated by a hypothetical dark photon γ', using a crystal calorimeter for detection. The $NuDoubt^{++}$ experiment will employ an opaque liquid scintillator detector to investigate double beta decay ($2\beta\beta$) and the beyond Standard Model neutrinoless double beta decay ($0\nu\beta\beta$), two processes that have yet to be discovered.
This contribution will focus on the ongoing investigation into the use of opaque liquid scintillators as an additional or alternative detector medium to the DarkMESA crystal calorimeter. Such a detector would be able to reject events based on the topological signature. For this purpose, a prototype detector was designed, simulated and tested at the MAMI accelerator at energies around 10 MeV. This detector uses a 22-litre cubic volume of linear alkylbenzene (LAB) scintillator and 255 wavelength-shifting fibres attached to SiPMs arranged in a triangular grid with 10 mm pitch near a beam entrance window. A comparative analysis will be presented, evaluating the simulation and expected performance against the results of this first prototype.

T 32: Higgs Physics IV

Time: Tuesday 16:15–18:30 Location: KH 01.019

T 32.1 Tue 16:15 KH 01.019

Preparation of Higgs boson STXS measurements in the $H \to \tau\tau$ decay, based on LHC Run-3 data taken with the CMS Experiment — •Sofia Giappichini, Roger Wolf, Markus Klute, and Günter Quast — Karlsruher Institut für Technologie, Institut für Experimentelle Teilchenphysik, Karlsruhe, Deutschland

This analysis presents measurements of Higgs boson production in the $\tau\tau$ decay channel. The study uses proton-proton collision events collected by the CMS experiment at the CERN LHC between 2022 and 2025, at a center-of-mass energy of 13.6 TeV, with a total integrated luminosity of 287 fb^{-1}. Focusing on both gluon fusion and vector boson fusion production modes, measurements of the signal strengths and cross-sections times branching fraction within the simplified template cross-section scheme are presented. These results provide precise sensitivity to Higgs boson production at high transverse momentum and to event topologies featuring jets.

T 32.2 Tue 16:30 KH 01.019

Newest developments and validation of the τ-embedding method for the estimation of genuine $\tau\tau$ backgrounds for H $\to \tau\tau$ analyses of CMS — •Sebastian Kaiser, Christian Winter, Roger Wolf, Günter Quast, and Markus Klute — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

The τ-embedding method, used to estimates all backgrounds with genuine τ lepton pairs in an event, is one of the main pillars for a number of precision measurements in the H $\to \tau\tau$ decay channel, of CMS. For this method events with two muons are selected, in data. All energy deposits associated to these muons during reconstruction, are removed from the event record and replaced by the energy deposits of simulated τ lepton decays with the same kinematic properties. The presentation will summarize the method itself and report on the steps undertaken to validate it for the upcoming LHC Run-3 analyses.

T 32.3 Tue 16:45 KH 01.019

Re-analysis of the LHC Run-2 data taken with the CMS Experiment in view of a combined LHC Run-2 + Run-3 measurement of Higgs boson STXS measurements in the $H \to \tau\tau$ decay channel — •Tamara App, Artur Monsch, Markus Klute, Günter Quast, and Roger Wolf — KIT, Karlsruhe, Germany

A re-analysis of LHC Run-2 data of the year 2018, after a complete re-reconstruction performed by the CMS Collaboration, in view of an anticipated combined Run-2 + Run-3 measurement of Higgs boson STXS measurements in the $H \to \tau\tau$ decay channel is presented. The level of data understanding is demonstrated indicating the transition towards high precision measurements and the perspective of a future measurement based on a systematic uncertainty aware neural network training is given.

T 32.4 Tue 17:00 KH 01.019

ML-driven Di-Tau Mass and Momentum Reconstruction at the ATLAS Detector — •Jonathan Pampel, Tatjana Lenz, and Jochen Dingfelder — University of Bonn

A common process in particle physics analyses is the decay of a neutral particle into two tau leptons. Each tau lepton decay contains at least one neutrino, making the reconstruction of the 4-momentum – and in particular, the mass – of the neutral particle an underdetermined problem.

In this work, a neural network has been trained on ATLAS γ^* Monte Carlo samples at $\sqrt{s}$ = 13.6 TeV to estimate the di-tau system's 4-momentum, using the reconstructed visible tau 4-momenta and the missing transverse momentum as input features.

This talk presents the development of the neural network and its performance in comparison to the Missing Mass Calculator (MMC), the previously established tool for di-tau 4-momentum reconstruction.

T 32.5 Tue 17:15 KH 01.019

Higgs Boson Mass Reconstruction in the Analysis of $tH(\tau\tau)$ Production with ATLAS Run-2 Data — Jiri Javora[1], •Christian B. Hughes[1], Chalaka Fernando[2], and André Sopczak[1] — [1]CTU in Prague — [2]CERN

The latest results on the mass reconstruction in the analysis $tH(\tau\tau)$ are presented with focus on machine learning using ATLAS Run-2 data.

T 32.6 Tue 17:30 KH 01.019

Estimate of the contribution from jets misidentified as hadronic tau decays using normalizing flows — •Matthias Moser, Tamara App, Nikita Shadskiy, Artur Monsch, Markus Klute, Günter Quast, and Roger Wolf — KIT, Karlsruhe, Germany

For H $\to \tau\tau$ analyses, the most accurate estimation of the background originating from falsely identified hadronic τ decays remains a major challenge. To estimate this background from data, we employ the fake-factor method, in which the rate of misidentified τ candidates is obtained from a Determination Region, which is maximally pure in a given background process, and then applied in an Application Region to determine the rate of misidentified tau candidates in the desired Signal Region.

The resulting F_{F} transfer function exhibits non-trivial dependencies on several variables, which are difficult to model using conventional techniques. It can be shown that these dependencies are determined by the probability density functions (p.d.f.) of events in the Application and Signal Regions. These p.d.f.'s can be learned with neural-networks, like e.g., normalizing flows. While the training procedure may be computationally intensive, the evaluation of the p.d.f.'s after training is fast. This approach provides an efficient and scalable description of the multi-variable dependence of the F_{F} transfer function.

T 32.7 Tue 17:45 KH 01.019

Construction and investigation of optimal observables for testing CP invariance in the decay $H \to \tau^+\tau^-$ at the LHC — •Yann Stoll, Heidi Rzehak, and Markus Schumacher — Albert-Ludwigs-Universität, Freiburg

Since the Higgs boson's discovery, a central objective in particle physics has been the precise determination of its properties. Beyond its key role in electroweak symmetry breaking, the Higgs sector may also provide clues to physics beyond the Standard Model.

In particular, extended models that aim to support electroweak baryogenesis require additional sources of CP violation, which could arise if the Higgs boson is not a CP eigenstate but a CP-mixed state. In the Higgs-tau-tau vertex the strength of CP violation can be parameterized by a single parameter ϕ_{CP}. This talk examines whether the CP-sensitivity in the decay $h \to \tau^+\tau^-$ at the LHC can be enhanced through the use of optimal observables. The tau-lepton decay modes $\tau^\pm \to (\pi^\pm\nu), (\pi^\pm\pi^0\nu)$ and $(l^\pm\nu\nu)$ are considered. We will outline the construction of these observables and present a sensitivity study based on simulated signal samples. This study is based on the past analysis by the ATLAS collaboration using the Run-2 data set collected at a centre-of-mass energy of 13 TeV, in the sense that we use a comparable event selection and categorization.

T 32.8 Tue 18:00 KH 01.019

Test of CP invariance of the Higgs-strahlungs process $pp \to V \to VH$ exploiting the $H \to \tau\tau$ and $V \to jj$ decay mode with the ATLAS detector — •Frederik Schulz, Lorenzo Rossini, and Markus Schumacher — Albert-Ludwigs-Universität, Freiburg, Deutschland

One open question in cosmology is the origin of the observed baryon asymmetry in our universe. This asymmetry can be explained if the three Sakharov conditions are fulfilled. One of these conditions includes the violation of the invariance under combined charge (C) and parity (P) conjugation. However, the magnitude of CP effects predicted in the Standard Model (SM) is not large enough to explain the size of the observations. The Higgs boson is a promising candidate for investigating possible CP-violating interactions, particularly in the coupling vertex with vector bosons (HVV).

In this talk, the focus will be on the Higgs-strahlung production mode (VH), with a subsequent decay of the Higgs boson into two hadronically decaying tau-leptons, and the V boson also decaying hadronically. Preliminary studies for an analysis based on the proton-proton data collected by the ATLAS experiments at a center of mass energy of $\sqrt{s}$ = 13.6 TeV during Run 3 will be presented. The analysis is based on the measurement of the CP-odd optimal observable. A profile-likelihood fit is performed to extract the expected sensitivity to CP-sensitive EFT models, such as SMEFT.

T 32.9 Tue 18:15 KH 01.019

Machine Learning to search for the CP violation of the Higgs boson in $H \to \tau\tau$ decays at ATLAS — •Laney Klipphahn, Philip Bechtle, Klaus Desch, Christian Grefe, and Timo Saala — University of Bonn

Reconstruction at ATLAS has been evolving throughout the past decades. Especially machine learning (ML) techniques have been implemented to support and replace individual steps in the reconstruction chain. With these powerful methods, the question arises, to what extend Machine learning models can learn and reproduce the complex calculations that map detector signals to high-level physics observables?

A particularly interesting challenge for ML is the study of CP violation of the Higgs boson in $H \to \tau\tau$ decays. The CP property of the Higgs is closely linked to one of the unsolved questions in physics, namely the matter and anti-matter asymmetry observed in the universe today. While the pure CP-odd state has been excluded by measurements, the CP-even or CP-mixed property of the Higgs has yet to be confirmed experimentally. In the Higgs-Yukawa coupling the CP-violation is accessible from the angular correlations of the decay products, which depend on the decay mode of the τ leptons in the $H \to \tau\tau$ decay. The CP-property is then obtained by a non-trivial combination of multiple observables in the final state. In this talk I will present the studies on ML for the CP violation of the Higgs boson to assess whether ML models can reach similar or better accuray than traditional reconstruction algorithms.

T 33: Silicon Detectors IV

Time: Tuesday 16:15–18:15 Location: KH 01.022

T 33.1 Tue 16:15 KH 01.022

Production of Outer Barrel pixel detector modules for the ATLAS ITk pixel detector at the FTD in Bonn — •Matthias Schüssler, Yannick Dieter, Jochen Dingfelder, Florian Hinterkeuser, Fabian Hügging, Hans Krüger, Matthias Hamer, and Maximilian Mucha — Physikalisches Institut der Universität Bonn, Bonn, Germany

With the upgrade of the Large Hadron Collider (LHC) to the High-Luminosity LHC (HL-LHC), the instantaneous luminosity will increase by a factor of 5 with respect to its design value from 2030 onward. This results in unprecedented hit rates and radiation levels which require major upgrades of the detectors at the HL-LHC.

For the upgrade of the ATLAS detector, a new all-silicon inner tracking detector (ITk detector) consisting of silicon strip and pixel modules will be installed to replace the currently operated Inner Detector. In total, approximately 10.000 new pixel detector modules have to be built and carefully tested to ensure that only functional detector modules are installed. During the currently ongoing 2-year production of the ATLAS ITk pixel detector, at least 1600 pixel detector modules are being built and tested at the Forschungs- und Technologiezentrum Detektorphysik (FTD) in Bonn.

This large-scale production requires a dedicated quality control (QC) effort to assure the functionality of the final detector. This talk provides an overview of the assembly and testing procedures that are ongoing at the FTD in Bonn, including an overview of the production so far.

T 33.2 Tue 16:30 KH 01.022

Experience with the production of ATLAS ITk pixel detector modules for the HL-LHC upgrade in Siegen — Markus Cristinziani[1], Qader Dorosti[1], Olivier Fox[1], Daniel Groth[1], Luke Hammer[1], Stefan Heidbrink[2], Lasse Jäderberg[1], Nils Krengel[1], Leonie Krippendorf[1], Denise Müller[1], Jason Müller[1], Lina Reifenberg[1], •Noah Siegemund[1], Waldemar Stroh[2], Darshil Vagadiya[1], Wolfgang Walkowiak[1], Jens Winter[2], Michael Ziolkowski[2], and Alessia Zuev[1] — [1]Center for Particle Physics Siegen, Experimentelle Teilchenphysik, Universität Siegen — [2]Elektronikentwicklungslabor Physik, Universität Siegen

With the High-Luminosity upgrade of the Large Hadron Collider (HL-LHC), the innermost layer of the ATLAS detector will be replaced by a new Inner Tracker (ITk) pixel detector. The University of Siegen contributes to this upgrade by producing quad modules for the outer barrel region of the pixel detector. A quad module is designed as a hybrid structure consisting of a flexible printed circuit board (PCB) glued onto a bare module in a cleanroom environment. That bare module is composed of a silicon-based sensor and four front-end readout chips (FEs). Electrical connection between the FEs and the PCB is provided by about 700 wirebonds. Extensive quality control (QC) procedures are performed before and after assembly, including metrology, visual inspections, and electrical characterization. In this contribution, the production chain of quad modules at the University of Siegen will be presented, with focus on the non-electrical aspects of the QC workflow.

T 33.3 Tue 16:45 KH 01.022

The ATLAS ITk cell integration site in Bonn — •Alexandra Wald, Klaus Desch, Matthias Hamer, Florian Hinterkeuser, Jochen Dingfelder, Nico Klein, and Dominik Hauner — Physikalisches Institut, Universität Bonn, Deutschland

In conjunction with the high luminosity upgrade of the Large Hadron Collider at CERN, the current tracking system of the ATLAS experiment will be replaced by the Inner Tracker (ITk), an all-silicon detector consisting of 5 layers of pixel detectors and 4 layers of strip detectors. More than 8000 modules will be installed in the pixel layers, which together have an active area of approximately 13m2 and cover a pseudorapidity of up to 4. In order to build such a large detector in time, the integration of the ITk Pixel modules on their local support structures (longerons or incliend halfrings(IHR)), as well as the quality control of individual loaded local supports will be distributed over many institutes. One of the assembly lines will be setup at the University of Bonn, with technicians from other German locations also helping with cell integration. Due to the serial powering scheme of the ITk Pixel Detector, the quality control of a loaded local support is challenging in several aspects, as the simultaneous operation of multiple modules is necessary for any tests. A large number of different components must hence be integrated into the quality control setup, such as an optical readout system, an interlocks system, industrial power supplies and a scalable DCS. In this presentation, the loaded local support assembly line and the QC setup in Bonn are presented, with particular attention to recent operational developments and the latest tests.

T 33.4 Tue 17:00 KH 01.022

Integration Test with 2S Modules for the CMS Phase-2 Outer Tracker Upgrade — Max Beckers[2], Lutz Feld[1], Nina Höflich[2], Katja Klein[1], Martin Lipinski[1], •Vanessa Oppenländer[1], and Oliver Pooth[2] — [1]1. Physikalisches Institut B, RWTH Aachen — [2]3. Physikalisches Institut B, RWTH Aachen

The new operating conditions of the future HL-LHC require a replacement of the complete silicon tracking system of the CMS experiment as part of the CMS Phase-2 Upgrade. For the Phase-2 Outer Tracker new silicon strip modules, so-called 2S modules, have been developed that consist of two silicon sensors stacked on top of each other. By correlating the measured hits of both sensors, this module design enables the inclusion of tracking information in the Level-1 trigger at CMS for the first time. For the new Phase-2 tracker the endcap region is known as the Tracker Endcap Double-Disks (TEDD) and is composed of five double-disks on each detector side that feature PS modules at smaller radii as well as 2S modules at larger radii. Each disk will be composed of two half disks that are called dee. After the careful assembly of the modules they are integrated onto the dees, which serve as the cooling and support structure for the modules. In this talk measurements and results from a dee integration test at DESY with 8 of the first pre-production 2S Modules built at RWTH Aachen will be shown.

T 33.5 Tue 17:15 KH 01.022

CMS Outer Tracker Beam Test at CHARM — Alexander Dierlamm[1], Andromachi Tsirou[2], Ashling Clare Quinn[3], Guido Magazzu[4], •Ivan Shvetsov[1], John Steven Lawless[5], Piero Giorgio Verdini[4], Prafulla Saha[6], Yuri Gershtein[6], and Garvita Agarwal[7] — [1]Institute of Experimental Particle Physics (ETP),Karlsruhe Institute of Technology (KIT) — [2]National and Kapodistrian University of Athens — [3]Princeton University — [4]University of Pisa — [5]University of Tennessee — [6]Rutgers State University of New Jersey — [7]University of Notre Dame

In the scope of the HL-LHC upgrade the new CMS Tracker will be built. The future tracker will consist of two module types: strip-strip (2S) and pixel-strip (PS) modules. In order to stress the operation of these modules a test beam at the CERN Highly-Accelerated Mixed Field Facility (CHARM) was performed. The facility provides a mixed particle spectrum, which allows to operate the modules in an environment close to realistic conditions of the future detector. The modules were irradiated with a flux of up to $\sim 10^7/cm^2 \cdot s$. The data was successfully collected with a prototype of the final data acquisition chain. Technical details of the test beam operation as well as results of the studies performed during the test beam are presented.

T 33.6 Tue 17:30 KH 01.022

Characterization of the bPOL48V DC-DC converter and Integration Tests with a CMS Phase-2 Strip Module — Lutz Feld, Katja Klein, Martin Lipinski, and •Joëlle Savelberg — 1. Physikalisches Institut B, RWTH Aachen

The bPOL48V is a newly developed DC-DC Point-of-Load (POL) buck converter designed at CERN and characterized at RWTH Aachen University within the DRD7 program, which supports R&D for future electronic systems and technologies for particle-physics experiments. It converts a 48 V input to an adjustable low-voltage output (5-24 V), enabling power delivery at higher distribution voltages and lower cable currents, thereby improving overall system efficiency by reducing Ohmic losses.

The converter features a radiation-hard controller designed at CERN, capable of continuous operation up to 50 Mrad and in magnetic fields above 4 T. It is paired with a EPC2152 GaN power stage. This combination provides performance in harsh radiation and magnetic-field environments, making the bPOL48V a strong candidate for power distribution in future high-energy physics experiments.

At RWTH Aachen, the bPOL48V has been characterized in multiple setups, evaluating its efficiency, stability, temperature dependence, and radiated and conducted noise. This presentation focuses on reducing conducted noise using a pi filter, demonstrating clear improvements consistent with simulation. Additionally, we present results in which the bPOL48V powers a CMS Phase-2 silicon strip module as a proof of principle, confirming its suitability for detector integration.

T 33.7 Tue 17:45 KH 01.022

Verification of a cell isolation test for loaded cells of the ATLAS ITk Pixel detector — •Nico Klein, Klaus Desch, Matthias Hamer, Florian Hinterkeuser, Alexandra Wald, and Dominik Hauner — Physikalisches Institut, Universität Bonn, Deutschland

The high luminosity upgrade for the Large Hadron Collider at CERN requires a complete redesign of the current tracking detector of the ATLAS experiment. The new Inner Tracker, the ITk Detector, will consist of a silicon pixel detector and a silicon strip detector. The ITk Pixel Detector is divided into three subsystems, the Outer Barrel (OB), Outer Endcaps and Inner System. In the OB, modules are loaded on thermally conductive bare module cells (now called loaded cells) before they are mounted on the local supports (so-called longerons and half-rings). The serial powering scheme of the ITk Pixel Detector requires a good electrical isolation of the readout ASICs from the (grounded) local support structures. For the loaded cells a test was developed to verify this isolation and the results obtained, using pre-production cells, are shown in this presentation.

T 33.8 Tue 18:00 KH 01.022

Development of an automated ATLAS pixel detector monitoring website — Marcello Bindi, Arnulf Quadt, and •Tim Schlömer — II. Physikalisches Institut, Georg-August-Universität Göttingen

The ATLAS Pixel Detector records charged particles through the ionisation charge they deposit as they traverse the sensor. A hit is recorded when the collected charge exceeds a programmable threshold, and the corresponding time-over-threshold (TOT) provides an estimate of the deposited charge. The threshold and TOT response are periodically re-tuned to maintain their target values, which drift with accumulated luminosity due to radiation-induced degradation. It is therefore essential to continuously monitor the key operational parameters like charge threshold, TOT, digital-to-analogue converter settings, the number of masked pixels, and the number of disabled columns. Tracking their evolution as a function of time and integrated luminosity is crucial both for ensuring optimal detector performance and contributing to radiation-damage studies.

A dedicated web-based framework presents these operational parameters through a set of automatically updated plots and summary metrics. Following each detector tuning, an automated pipeline refreshes the displayed results while preserving previous versions for reference. The framework also enables users to visualise long-term trends in critical parameters and to compare tunings from different periods of the detector*s operational lifetime.

T 34: Data, AI, Computing, Electronics IV

Time: Tuesday 16:15–18:45 Location: KH 02.014

T 34.1 Tue 16:15 KH 02.014

SysVar: A new tool for enhancing consistency in the treatment of systematic — •Agrim Aggarwal[1], Georgios Alexandris[1], Florian Bernlochner[1], Stefanie Meinert[1], Felix Metzner[1], Giacomo De Pietro[2], Markus Prim[1], Slavomira Stefkova[1], and Ilias Tsaklidis[1] — [1]Universität Bonn — [2]Karlsruhe Institute of Technology

SysVar provides an end-to-end, consistent machinery to build template histograms and their systematic variations with correlations preserved. To account for effects such as detector acceptance and calibration, physics reweighting, event-by-event correction weights are applied to the Monte-Carlo templates which have systematic uncertainties. For a typical template fit spanning multiple channels, multiple templates and multiple observables keeping book of all correlations becomes non-trivial.

In this talk, we present SysVar - A python package that streamlines the treatment of systematic uncertainties for collider-physics analyses that rely on Monte-Carlo template fits. SysVar produces outputs compatible with popular HEP template-fitting libraries such as cabinetry and pyhf. It was originally developed within the Belle II context, but its design and interfaces are experiment-agnostic.

By having consistency across systematics and preserving correlations, this also enables the combination of a measurement from different analysis based on orthogonal selections

T 34.2 Tue 16:30 KH 02.014

MC-Run: Monte Carlo Workflows for Precision Phenomenology — Maximilian Horzela[1] and •Cedric Verstege[2] — [1]Georg-August-Universität Göttingen, Germany — [2]Karlsruhe Institute of Technology, Germany

Reliable Monte Carlo (MC) predictions are a key ingredient for precision phenomenology in high-energy physics, in particular for the derivation of non-perturbative and electroweak correction factors. We present MC-Run, a lightweight framework that enables reproducible end-to-end MC studies, from event generation to Rivet-based analyses and further processing.

Originally developed for the determination of non-perturbative corrections, MC-Run has been successfully applied in phenomenological analyses and HEP publications, supporting large-scale production campaigns at the level of O(100k) CPU hours. More recently, the framework has been extended to studies of electroweak corrections and can be readily adapted to different physics processes and observables.

This talk will give an overview of MC-Run, its modular workflow design, built-in support for grid computing, how to extend it to other MC generators and adapt it for further physics analyses.

T 34.3 Tue 16:45 KH 02.014

FeynGraph - A Modern High-Performance Feynman Diagram Generator — •Jens Braun — Institute for Theoretical Physics, Karlsruhe Institute of Technology

We present FeynGraph, a modern high-performance Feynman diagram generator designed to integrate seamlessly with modern computational workflows to calculate scattering amplitudes. FeynGraph is designed as a high-performance Rust library with easy-to-use Python bindings, allowing it to be readily used in other tools. With additional features like arbitrary custom diagram selection filters and automatic diagram drawing, FeynGraph strives to be a fully-featured Feynman diagram toolkit at any loop order.

T 34.4 Tue 17:00 KH 02.014

Differentiable Setup for a Top-Higgs Analysis — •Felix Zinn[1], Peter Fackeldey[2], Benjamin Fischer[1], Nina Herfort[1], and Martin Erdmann[1] — [1]RWTH Aachen University — [2]Princeton University

In high energy physics (HEP), the measurement of physical quantities often involves intricate data analysis workflows that include the application of kinematic cuts, event categorization, machine learning techniques, and data binning, followed by the setup of a statistical model. Each step in this process requires careful selection of parameters to optimize the outcome for statistical interpretation.

This presentation introduces a differentiable approach to the data analysis workflow utilizing the python package evermore for statistical model building. Built on top of JAX, the models created in evermore benefit from automatic differentiation. By leveraging this feature alongside neural networks, we can apply optimization across all stages of the analysis. This method allows for a more systematic selection of parameter values while also ensuring that the optimization process accounts for systematic uncertainties included in the analysis.

We apply this approach to a CMS analysis targeting the production of a Higgs boson in association with one or two top quarks and demonstrate how each individual step can be implemented in a differentiable manner. A setup for a differentiable analysis workflow is presented.

T 34.5 Tue 17:15 KH 02.014

Exploring future Monte-Carlo generators: MC Validation in

ATLAS with PAVER — •Dominic Hirschbühl, Johanna Kraus, Anna Bingham, Frank Ellinghaus, and Tim Beumker — Bergische Universität Wuppertal, Wuppertal, Germany

Monte-Carlo (MC) simulations play a key role in high energy physics, for example at the ATLAS experiment. MC generators evolve continuously, so a periodic validation is indispensable for obtaining reliable and reproducible physics simulations. For that purpose, an automated and central validation system was developed: PMG Architecture for Validating Evgen with Rivet (PAVER). It provides an MC event generator validation procedure that allows a regular evaluation of new revisions and updates for commonly used MC generators in ATLAS as well as comparisons to measured data. The result is a robust, fast, and easily accessible MC validation setup that is constantly developed further. This way, issues in simulated samples can be detected before generating large samples for the collaboration, which is crucial for a sustainable and low-cost MC production procedure in ATLAS.

T 34.6 Tue 17:30 KH 02.014

Implementation of a reliable ML model life cycle for the CMS Phase-2 L1 Trigger Upgrade — •Leon Joel Kerner[1,2] and Alexander Schmidt[1] — [1]Physics Institute IIIA, RWTH Aachen University, (DE) — [2]CERN, (CH)

To achieve the ambitious goals of the High-Luminosity LHC upgrade, a new Level-1 trigger must be developed for the CMS experiment. Machine Learning based models will be deployed in the trigger system, which introduces a range of new challenges. The development of such models involves many individual steps. Any change in the configuration or the data can require repeating the entire workflow, and these steps are currently carried out manually by the model developers. In addition, the deployment of trained models in the trigger requires robust procedures that ensure long-term quality and stability. To address these issues, methods from machine learning operations (MLOps) must be integrated into the workflow.

To address this problem, a GitLab CI/CD pipeline and a training infrastructure consisting of a MLflow server and a WebEOS instance was created to log and manage model training sessions.

T 34.7 Tue 17:45 KH 02.014

A Common Language for Complex Particle Decays: demonstrated on $B^+ \to D^{*\pm} D^{\mp} K^+$ — •Alexander Kazatsky, Mikhail Mikhasenko, and Marian Stahl — Experimental Physics I, Ruhr-University Bochum, Germany

The Amplitude Model Serialization (AMS) project of the DEMOS (DEMocratizing MOdelS) consortium aims to provide a standardized format for the description of particle decay processes of varying complexity. This enables more straightforward reproduction of existing analyses, offers a framework for performing new amplitude studies, and facilitates the integration of complex decay chains into external systems such as Monte Carlo generators. In this work, the translation of a partial-wave analysis from the TensorFlow Partial Wave Analysis (TF-PWA) framework, which is widely used in experiments like LHCb and BESIII, is demonstrated. While the AMS format has so far been applied to singular three-body decays, the present analysis of $B^+ \to D^{*\pm} D^{\mp} K^+$ features a more complex topology. Namely, the decay of $D^{*\pm} \to D^0 \pi^\pm$ needs to be accounted for. The branching structure of two-body decays inherent to TF-PWA is translated into a system of three- and two-body decays in the AMS format. This coupled-channel analysis, which previously revealed new tetraquark candidates (PRL 133 (2024) 13, 131902), was reproduced using TF-PWA, translated, and repeated in the AMS framework. A standardized workflow for translating models from TF-PWA into the AMS system is presented.

T 34.8 Tue 18:00 KH 02.014

Python framework for the topological track reconstruction in JUNO — •Mikhail Smirnov, Daniel Bick, Milo Charavet, and Caren Hagner — Institute of Experimental Physics, University of Hamburg, Hamburg, Germany

The Jiangmen Underground Neutrino Observatory (JUNO) is a new-generation kiloton-scale neutrino detector based on liquid scintillator (LSc). With a target mass of 20 kilotons, it is the largest LSc detector in the world. Utilizing the antineutrino flux from two nuclear power plants at a baseline of approximately 53 km, JUNO aims to determine the neutrino mass ordering with high statistical significance and to perform precision measurements of neutrino oscillation parameters. JUNO has successfully started to operate in August 2025. Topological Track Reconstruction (TTR) was originally developed to reconstruct energetic muon events in large unsegmented LSc detectors. The algorithm exploits the time and spatial distributions of PMT first-hit times to reconstruct a three-dimensional photon-emission density inside the detector. In the original C++ implementation, this density is obtained via deterministic kernel summation, which provides a heuristic estimate but lacks a well-defined statistical interpretation. This talk presents pyTTR, a Python-based reimplementation and conceptual extension of the TTR. The new framework reformulates TTR as a likelihood-based inverse problem, naturally separating detector geometry, photon propagation, PMT response, and statistical inference, and provides increased flexibility for future physics analyses

T 34.9 Tue 18:15 KH 02.014

LEGEND Analysis with the JuLeAna Software Stack — •Andreas Gieb[1], Florian Henkes[2], Susanne Mertens[1], Jonas Schlegel[1], Oliver Schulz[3], and Christoph Wiesinger[1] for the LEGEND-Collaboration — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Technische Universität München, Munich, Germany — [3]Max-Planck-Institut für Physik, Munich, Germany

The Large Enriched Germanium Experiment for Neutrinoless $\beta\beta$ Decay (LEGEND) is a staged experimental program searching for the neutrinoless double-beta ($0\nu\beta\beta$) decay of ^{76}Ge. The first stage of the experiment LEGEND-200 is currently taking data at the Gran Sasso Underground Laboratory. Data analysis within LEGEND-200 is carried out using two dedicated software stacks. This talk will focus on the structure and analysis workflows of the JuLeAna software stack.

T 34.10 Tue 18:30 KH 02.014

Data- and Metadata Management at HZDR — •Stefan E. Müller, Thomas Gruber, Oliver Knodel, David Pape, and Martin Voigt — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

The integrity and utility of research output critically depends on both data and metadata. While data comprise the primary outputs of experiments, simulations or analyses, metadata describe the origin, structure, semantics, and context of the data, enabling the interpretation, discovery, and reuse. Metadata are essential for ensuring compliance with the FAIR principles (Findable, Accessible, Interoperable, and Reusable), and failure to adequately define or manage metadata leads to poor reproducibility and limited interoperability.

At HZDR, the Helmholtz-Zentrum Dresden-Rossendorf, researchers profit from the "Rossendorf Data Repository" RODARE, which allows them to publish their research data. Especially for large data sets, which can contain up to several Terabyte of data, a good description of the metadata is required to allow a practical reuse of the data sets. The SciCat metadata catalog is used at HZDR to provide the corresponding metadata together with a RODARE data publication.

The presentation will describe how SciCat and RODARE are used together to make a large data set FAIR.

T 35: Searches/BSM II

Time: Tuesday 16:15–18:30 Location: KH 02.018

T 35.1 Tue 16:15 KH 02.018

The current status of the Mu2e experiment at Fermilab — •Stefan E. Müller, Anna Ferrari, 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 direct conversion of a muon to an electron in the field of an aluminum nucleus, aiming at a sensitivity four orders of magnitude better than previous experiments. The observation would imply the violation of charged lepton flavor, and hint at physics beyond the Standard Model.

With the arrival of the large superconducting solenoid magnets at Fermilab, and the installation of the main detector subsystems at their final locations inside the Mu2e hall, the experiment has entered an exciting phase of its construction towards data taking.

The design and status of the Mu2e experiment and its detector subsystems will be presented, highlighting the large progress made over the last year.

T 35.2 Tue 16:30 KH 02.018

Probing hidden sectors with the SHiP experiment at CERN — •James Webb for the SHiP-D-Collaboration — Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, 79104 Freiburg, Germany

SHiP (Search for Hidden Particles) is a general purpose fixed target experiment. Approved in 2024 by the CERN research board, SHiP will be CERNs flagship experiment in the search for GeV-scale Feebly Interacting Particles (FIPs) and accelerator neutrino physics.

A 400 GeV/c proton beam extracted from the Super Proton Synchrotron (SPS) will be dumped on a heavy target, producing an expected 6×10^{20} proton-target collisions over 15 years of operation. A dedicated detector, based on a long helium decay volume, surrounded by veto detectors, and then followed by a spectrometer and particle identification detectors, will allow for a variety of new physics models with light long-lived exotic particles to be probed in a near-zero background environment. This detector will increase the discovery sensitivity for many new physics models by orders of magnitude. A second detector dedicated to the study of neutrino cross-sections of all three flavours, will incorporate tracking and calorimetry detectors interwoven between five tonnes of tungsten and iron plates. The large neutrino flux produced during the beam dump coupled with the mass of the detector will yield a significant number of neutrino interactions that will become available for measurement.

In this talk a brief discussion on the physics potential and an overview of the detector layout, with an emphasis on the contributions from the German community, will be presented.

T 35.3 Tue 16:45 KH 02.018

Search for exotic particles at NA62 — •Daniel Grewe[1], Babette Döbrich[1], Otmar Biebel[3], Tommaso Spadaro[2], Jan Jerhot[1], Lo Chiatto Prisco[1], Jonathan Schubert[1], and Marczika András[1] — [1]Max-Planck-Institut für Physik, Munich, Germany — [2]INFN e Laboratori Nazionali di Frascati,Frascati,Italy — [3]LMU, Munich, Germany

The NA62 experiment at the CERN SPS primarily aims to measure rare kaon decays. In addition, the experiment has the capability to collect data in a beam dump mode, where the 400 GeV protons are dumped on an absorber. In this configuration, exotic particles might be produced and reach the fiducial volume. Previous searches have focused on exotic particles with charged particle final states. In this talk, the first steps toward an analysis of a $\gamma\ \gamma$ final state decay are presented, including the development of new methods for vertex reconstruction for such decays.

T 35.4 Tue 17:00 KH 02.018

Event Selection for the Search of Sub-Relativistic Magnetic Monopoles with the IceCube Neutrino Observatory — •Jonas Häussler[1], Bryndis Kern[1], Nick Schmeisser[2], and Christopher Wiebusch[1] — [1]RWTH Aachen, Aachen, Deutschland — [2]Bergische Universität Wuppertal, Wuppertal, Deutschland

Grand-Unified-Theories predict the existence of magnetic monopoles to be created during transitions from one gauge group to a smaller sub-group. For most GUTs, magnetic monopoles can reach masses above 10^{14} GeV resulting in sub-relativistic speeds. These magnetic monopoles can catalyze nucleon decays via the Rubakov-Callan effect, resulting in a unique signature of small particle cascades along the trajectory of a slow moving particle. To search for this signature, a dedicated slow particle trigger has been implemented in the IceCube Neutrino Observatory since 2012. The low, if existent, flux of magnetic monopoles requires an exceptional classification, with high background rejection and signal efficiency. In this talk, a multi-level boosted decision tree for the event selection and the sensitivity of IceCube for the detection of sub-relativistic magnetic monopoles, is shown. This talk presents an event selection using a multi-level boosted decision tree, the sensitivity for the detection of sub-relativistic magnetic monopoles, and potential applications to other slow exotic particle searches in IceCube.

T 35.5 Tue 17:15 KH 02.018

Luminescence Simulation for the Search of Sub-Relativistic Magnetic Monopoles in IceCube — •Bryndis Kern, Jonas Häussler, and Christopher Wiebusch — III. Physikalisches Institut B, RWTH Aachen University

Magnetic monopoles are hypothetical particles predicted by various Grand Unified Theories, typically expected to have masses exceeding 10^{14} GeV. Such monopoles, as relics from the Big Bang, would propagate with sub-relativistic velocities, characterized by $\beta < 10^{-2}$. In ice they can emit light through two mechanisms: the catalyzation of nucleon decays via the Rubakov-Callan effect and luminescence. This results in a distinct signature of a slow light-emitting track in the IceCube Neutrino Observatory. Dedicated simulations of sub-relativistic monopole propagation and detector response are employed to model these signatures and to provide training data for Boosted Decision Trees (BDTs) used in event selection. This talk shows results from the inclusion of a new luminescence model into the monopole simulation framework.

T 35.6 Tue 17:30 KH 02.018

Search for Nuclearites with IceCube — •Nick Jannis Schmeisser[1] and Jonas Häussler[2] for the IceCube-Collaboration — [1]Bergische Universität Wuppertal — [2]RWTH Aachen

Nuclearites are lumps of strange quark matter that were first proposed in the 1980s. Strange quark matter consists of roughly equal amounts of up-, down-, and strange-quarks and could appear in the Standard model at high densities as well as in BSM theories. They are candidates for the cold dark matter observed in the Universe. We are presenting the first search for nuclearites with IceCube. The IceCube Neutrino Observatory is expected to have the best sensitivity to nuclearites due to its size and lower noise rate in comparison to other neutrino telescopes.

This presentation gives a short motivation for nuclearites and discusses their properties and the signature they are expected to produce in the IceCube detector, which are thermal shocks produced by atomic collisions in the Antarctic ice. The analysis chain used to search for nuclearites is discussed, leading to the first sensitivities of the IceCube detector for different nuclearite masses.

T 35.7 Tue 17:45 KH 02.018

Design Studies and Detector Simulation for the proposed Dark Photon Search Experiment Lohengrin — •Cedric Breuning for the Lohengrin-Collaboration — Physikalisches Institut, University of Bonn, Bonn, Germany

The proposed Lohengrin experiment will search for light dark matter at the Electron Stretcher Accelerator (ELSA) in Bonn. It employs the fixed-target missing momentum based technique for searching for dark-sector particles. A beam of electrons is extracted from ELSA and is shot onto a thin target to produce mainly Standard Model bremsstrahlung and – in rare occasions – possibly new particles, like the dark photon, coupling feebly to the electron. In the current phase, detector layouts and designs are studied and optimized to reach the highest sensitivity. This requires an accurate simulation of the interactions in the target and the detector response. In this talk, we present one of the ongoing design studies for the target and electromagnetic calorimeter of the experiment, including a full detector simulation in the DD4hep framework.

T 35.8 Tue 18:00 KH 02.018

Light Dark Matter simulation studies with GEANT4 for the DarkMESA experiment — •Saskia Plura for the MAGIX-Collaboration — Institute for Nuclear Physics, Johannes Gutenberg University Mainz, Germany

Dark Matter searches are an integral part of physics beyond the Standard Model. However, Dark Matter has yet to be observed directly. Theoretical models provide a large parameter space for Dark Matter and allow for different particle properties. Models incorporating so-called portal interactions, which allow Dark Matter to interact with Standard Model matter, are of special interest. Examples for these are Dark Photons and Axion-like particles (ALPs), which can be studied at low energy accelerator facilities.

The DarkMESA experiment is a beam dump experiment located at the upcoming accelerator MESA at the JGU Mainz, set to start operation in 2026. The accelerator provides an electron beam of 155 MeV and 150 μA in extracted beam mode, which, alongside the beam dump of the P2 experiment, provides an ideal environment for Light Dark Matter (LDM) searches.

To predict the potential signal yield of the separate phases of the DarkMESA experiment in relation to different Dark Matter models, a GEANT4 simulation is used. The simulation incorporates different production channels for Dark Matter through Dark Photons, ALPs, pseudoscalar or scalar mediators and offers both invisible (e.g. DM decays) or visible (e.g. SM decays) decay options. Here, the current status of the simulations is discussed.

T 35.9 Tue 18:15 KH 02.018

Search for Dark Matter with metastable nuclear isomer ^{180m}Ta — •Jannis Ender, Björn Lehnert, and Kai Zuber — IKTP TU Dresden

Due to extremely suppressed transitions, the nuclear isomer ^{180m}Ta is stable on cosmological time scales. It is the longest lived isomer and its decay has not yet been observed with half-live limits at $T_{1/2} > 0.29 \times 10^{18} y$ over all decay channels. Recently it has been proposed to use such isomers as detectors for Dark Matter particles, in which the DM particles would deexcite the isomer by scattering with the nucleus. A measurable signal could then be obtained through the decay chain of the isomer or the exited DM particle rescattering in a conventional DM detector setup. In this talk, different methods of implementing these possibilities into DM detectors are discussed to further probe the parameter space of various DM models currently unavailable.

T 36: Search for Dark Matter II

Time: Tuesday 16:15–18:30 Location: AM 00.014

T 36.1 Tue 16:15 AM 00.014

A large-diameter, dual-phase liquid xenon TPC in the unshielded PANCAKE facility — •Sebastian Lindemann — University of Freiburg, Germany

Future liquid xenon (LXe) based observatories searching for rare processes, such as XLZD, require testing of large components and subassemblies in cryogenic liquid or gaseous xenon environments. In this talk, I will present results from operating a 1.5 m diameter, 3 cm deep, dual-phase LXe time projection chamber (TPC) in the unshielded PANCAKE platform without underground suppression of cosmic ray backgrounds.

Measurements of various detector- and LXe-specific quantities, such as the electron lifetime dependent on purity and the electron drift velocity dependent on electric field, demonstrate that operating a large-diameter TPC is feasible in a high-background environment.

T 36.2 Tue 16:30 AM 00.014

Radon removal by cryogenic distillation for future liquid xenon detectors — •Robert Braun, Lutz Althueser, David Koke, Volker Hannen, Christian Huhmann, Ying-Ting Lin, Philipp Schulte, Patrick Unkhoff, Daniel Wenz, and Christian Weinheimer — Universität Münster

Radon emanation from detector materials is a dominant background source in liquid xenon (LXe) detectors used for rare event searches including dark matter and neutrinoless double beta decay. Because of the continuous emanation of radon it is necessary to remove radon faster than its half-life of 3.8 days in order to effectively reduce the radon concentration of the detector itself. For the large detector masses of next generation LXe experiments (e.g. XLZD) this requirement corresponds to a total xenon flow of up to 1600 kg/h, which is more than an order of magnitude higher than those achieved by current systems of about 80 kg/h.

In the LowRAD project a cryogenic distillation setup is developed for reducing the concentration of radon to unprecedented levels. To investigate the scalability of the system, the required heating and cooling power is provided by an hermetically separated heat pump cycle, for which a first demonstrator with about 10 slpm is now scaled to a "XENONnT-sized" heat pump with 300 slpm. This talk will present the design and commissioning of the radon distillation column and its subsystems, with a particular emphasis on the integrated radon-decay detector enabling continuous online monitoring of radon concentrations. Supported by the ERC Advanced Grant "LowRad" (101055063).

T 36.3 Tue 16:45 AM 00.014

Beyond standard model physics with electronic recoil data of XENONnT — •Sebastian Vetter — Karlsruhe Institute of Technology, Institute for Astroparticle Physics

The XENONnT detector is among the world leading experiments in the direct search for Weakly Interacting Massive Particles (WIMPs), one of the prime candidates to form particle Dark Matter (DM). XENONnT uses liquid Xe in a dual-phase time projection chamber (TPC) as a detector target. One of the great advantages of a TPC is the ability to discriminate between energy deposits from incoming particles on the target nuclei, nuclear recoils (NRs), or on the electron clouds of the atoms, electron recoils (ERs). While WIMPs are expected to interact via NRs, many signals of scientific interest can occur as ERs. The ER data allows us to explore the flux of solar neutrinos from the pp chain, and look beyond the standard model for other than WIMP DM candidates like Dark Photons or Axion Like Particles.

In this talk, I will highlight challenges and opportunities, as well as the latest status, in the analysis of XENONnT ER data in a wide energy range from keV to MeV scale.

This work is supported in part through the Helmholtz Initiative and Networking Fund (grant agreement no.~W2/W3-118) and through the grant 05A23VK3 within the ErUM-Pro funding line by the German Federal Ministry of Research, Technology and Space. In addition, support by the KIT graduate school KSETA is gratefully acknowledged.

T 36.4 Tue 17:00 AM 00.014

Characterization of anomalous electron backgrounds in XENONnT — •Alexis Michel for the XENON-Collaboration — Karlsruhe Institute of Technology, Institute for Astroparticle Physics

Dual-phase xenon time projection chambers like XENONnT are widely used in searches for rare events. These detectors have a layer of gaseous xenon (GXe) above a target of liquid xenon (LXe). Interactions in the LXe produce scintillation light and ionization electrons. With electric fields generated by electrodes, clouds of such ionization electrons are drifted upwards in the liquid and then extracted into the gas, where they produce a secondary proportional scintillation light signal.

Such xenon-based TPCs commonly see various forms of spurious emission that are associated with electrical fields and electrode operation. One such emission type are so-called e^--bursts that were observed in XENONnT and other detectors. These e^--bursts are large and clustered delayed electron signals observed where the extraction of the initial electron cloud at the LXe-GXe interface was incomplete and electrons got trapped at the LXe surface. Another such spurious emission type is from so-called hot-spots, which are spatially localized sources of continuous and intermittent single electron emission.

In this talk I will present the recent results on the studies of spurious electron emission phenomena in XENONnT and their implications for the next generation of xenon-based detectors such as XLZD.

This work has been supported in part by the Federal Ministry of Research, Technology and Space (BMFTR) through the grant 05A23VK3 within the ErUM-Pro funding line.

T 36.5 Tue 17:15 AM 00.014

Development of Cryogenic Single-Photon Detectors to Study the Light Output of Sodium Iodide Crystals for Rare Event Searches — •Lutz Ziegele for the COSINUS-Collaboration — Max-Planck-Institut für Physik, 85748 Garching, Germany

The Cryogenic Observatory for Signatures seen in Next-generation Underground Searches (COSINUS) is a dark matter direct detection experiment located at the Laboratori Nazionali del Gran Sasso (LNGS) in Italy. It employs sodium iodide (NaI) crystals operated as cryogenic calorimeters. Particle interactions in the crystal produce phonons, which are detected by a remote Transition Edge Sensor (remoTES), while the accompanying scintillation light is absorbed by silicon absorbers equipped with Transition Edge Sensors. This dual-readout scheme enables particle discrimination and allows for an in-situ determination of energy-dependent quenching factors.

This contribution presents the development of a detector module with enhanced scintillation light sensitivity, enabling photon-number-resolved measurements. Rather than using a single large light detector, multiple smaller light absorbers are arranged around the NaI crystal. Their reduced heat capacity improves the overall sensitivity. The main goal is a precise characterization of the scintillation light yield of ultrapure NaI crystals, which is crucial for the analysis of upcoming COSINUS data. In addition, this development establishes the basis for future studies of dark matter-electron interactions within the OνDES project, funded by the Klaus Tschira Foundation.

T 36.6 Tue 17:30 AM 00.014

Tracking down the Low-Energy Excess: First results from CRESST Double-TES Modules — •Marco Zanirato for the CRESST-Collaboration — Max Planck Institut für Physik, München, Deutschland

The Cryogenic Rare Event Search with Superconducting Thermometers (CRESST) is a forefront experiment in the direct detection of dark matter, located at the Laboratori Nazionali del Gran Sasso (LNGS) in Italy. By employing cryogenic calorimeters based primarily on scintillating crystals equipped with Transition Edge Sensors (TESs), CRESST achieves energy thresholds of the order of 30 eV with a 24 g detector. However, the development of such a cutting-edge experiment presents several challenges. One of the most pressing is the unexplained rise in the number of events observed below 200 eV, commonly referred to as the Low-Energy Excess (LEE).

To investigate the origin of this excess, the current data-taking campaign utilises detector modules with two sensors per crystal, allowing the collaboration to disentangle whether the LEE is linked to the crystal or to the sensors themselves. This talk will provide an overview of the concept behind these new modules, the results obtained in aboveground tests, and the first preliminary findings from the ongoing underground run.

T 36.7 Tue 17:45 AM 00.014

The Projected Sensitivity of the DELight Experiment — •Eleanor Fascione for the DELight-Collaboration — Kirchhoff-Institut für Physik

In the search for dark matter, there is vast unexplored parameter space for masses below a few GeV, and the field of direct dark matter detection is constantly expanding to new frontiers. Low mass dark matter candidates necessitate novel detector designs with lower thresholds and alternative target materials compared to experiments currently providing the strongest overall constraints on many thermal dark matter models. The Direct search Experiment for Light dark matter (DELight) will deploy a target of superfluid ^{4}He instrumented with large area microcalorimeters (LAMCALs) based on magnetic microcalorimeter (MMC) technology in a setup optimized for light dark matter searches. In this talk an overview of this upcoming experiment will be presented along with the expected dark matter sensitivity.

T 36.8 Tue 18:00 AM 00.014

Aboveground Studies of the Low-Energy Excess in CRESST — •Eleonora Rebecca Cipelli for the CRESST-Collaboration — Max Planck Institut für Physik, Garching bei München, Deutschland

The CRESST experiment, located at the Laboratori Nazionali del Gran Sasso (LNGS), is a leading direct dark matter detection experiment. It employs cryogenic calorimeters operated at millikelvin temperatures and instrumented with Transition Edge Sensors (TESs), achieving extremely low energy thresholds (~10 eV) and high sensitivity to sub-GeV dark matter particles. However, the experiment's sensitivity is currently limited by an unexplained increase in background events below ~200 eV, known as the Low-Energy Excess (LEE).

This talk will present new investigations into possible origins of the LEE based on dedicated above-ground R&D studies. In particular, it will focus on the impact of thermal cycles on the LEE decay, as well as the influence of aluminium phonon collectors. These studies provide new insights into the nature and mechanisms of the LEE.

T 36.9 Tue 18:15 AM 00.014

Status of the MainzTPC Upgrade for Precision Low-Energy Recoil Measurements in Liquid Xenon — •Constantin Szyszka, Alexander Deisting, Christopher Hils, Peter György, Johannes Merz, and Uwe Oberlack — Institut für Physik & Exzellenzcluster PRISMA$^+$, Johannes Gutenberg-Universität Mainz

The MainzTPC is an experimental dual-phase xenon time projection chamber (TPC) dedicated to the study of scintillation and ionization processes in liquid xenon (LXe) for low-energy electronic and nuclear recoils. Its design has been optimized for use as the primary target in Compton and neutron scattering experiments to measure recoil energies in LXe down to 1 keV.

To improve position resolution in x and y the MainzTPC was redesigned to accommodate an array of silicon photomultipliers (SiPMs) in place of its monolithic top photomultiplier tube (PMT) and eight avalanche photodiodes. The goal of this upgrade is to enable the MainzTPC to perform a measurement of the Migdal effect in LXe. For this purpose, a cryogenic amplifier board housing the SiPM array was developed. To address known instabilities in the liquid level of the MainzTPC, we rebuilt the level meters and level control based on camera observations of the liquid-gas interface. We report on the status of this work.

T 37: Neutrino Astronomy II

Time: Tuesday 16:15–18:30 Location: KS H C

T 37.1 Tue 16:15 KS H C

Title: Characterization and calibration of photomultiplier tubes for the Pacific Ocean Neutrino Experiment — •Josef Pflanz for the P-ONE-Collaboration — Technische Universität München, Germany

The Pacific Ocean Neutrino Experiment (P-ONE) is a planned cubic-kilometer scale neutrino telescope, designed for high-precision neutrino source searches and long-baseline astrophysical observations. The first detector line is currently under development and will consist of 20 modules, equipped with photomultiplier tubes (PMTs). The Hamamatsu R14374 PMT was selected for this first deployment due to its low transit-time spread, high stability, and overall performance quality. In this talk, I will present the characterization and validation procedures carried out on these PMTs. In particular, I will focus on measurements of quantum efficiency, photon detection efficiency, and the linearity of the PMT response when coupled to P-ONE's dedicated front-end electronics. These results provide essential input for the detector's Monte Carlo simulations and establish a robust framework for future large-scale PMT characterization for the full P-ONE array. The talk will highlight the measurement techniques, calibration methods, and results obtained from a subset of the PMTs.

T 37.2 Tue 16:30 KS H C

Construction and testing of the first string for the Pacific Ocean Neutrino Experiment — •Laura Winter for the P-ONE-Collaboration — Technical University of Munich, TUM School of Natural Sciences, Department of Physics, James-Franck-Straße 1, D-85748 Garching bei München, Germany

The Pacific Ocean Neutrino Experiment (P-ONE) is a next-generation multi-cubic-kilometer neutrino telescope under construction in the Northeast Pacific Ocean off the coast of Vancouver Island, Canada. The first construction phase comprises the initial detector string, which is currently under construction and testing, with deployment planned for summer 2026. The line consists of 20 optical and calibration modules designed for the detection of Cherenkov light. Each module features a modular multi-photomultiplier tube (PMT) design with 16 PMTs per module, optically and mechanically coupled to the glass using individual silicone gel pads. The first line will also be used to test biofouling mitigation strategies using both polished glass hemispheres and hemispheres treated with a special anti-biofouling coating. Module integration onto the detector line is currently being performed at TRIUMF (Tri-University Meson Facility) in Vancouver. This contribution presents the optical module production process, the line integration process, and first results from system-level testing of the full string.

T 37.3 Tue 16:45 KS H C

Development of a High-Resolution Muon Calibration Sample for the IceCube Upgrade — •Simon Pick — DESY, Zeuthen

The IceCube Upgrade will deploy nearly 800 new optical sensors in a closely spaced region within the IceCube DeepCore volume, enabling an unprecedented view of atmospheric muons and neutrinos. This dense instrumentation may offer the opportunity to identify muon tracks with exceptionally high angular precision through direct detection. Such events could serve as powerful calibration sources for detector response and angular reconstruction algorithms.

In this contribution, I will present ongoing work toward the development of a high-resolution muon calibration sample. This includes progress on characterizing muon-induced sensor responses through laboratory measurements and simulation, with a particular focus on the development of a new dedicated calibration stand. More broadly, I will provide an overview of the current status and outline the next steps toward the sample development and studies of potential improvements in reconstruction performance.

T 37.4 Tue 17:00 KS H C

Wavelength Division Multiplexing for the Pacific Ocean Neutrino Experiment — •Lea Ginzkey for the P-ONE-Collaboration — Technical University of Munich

The Pacific Ocean Neutrino Experiment (P-ONE) aims to detect high-energy astrophysical neutrinos by instrumenting more than one cubic kilometer of deep ocean water in the Northeast Pacific, off the coast of Vancouver Island (Canada). With the first detector line nearing deployment, planning for the next stages of P-ONE is already underway.

To decrease both cable production complexity and overall cost, we aim to reduce the number of fibers per module while maintaining DAQ redundancy. Wavelength Division Multiplexing (WDM) enables the simultaneous transmission of multiple independent optical channels through a single fiber, offering a promising path towards more efficient deep-sea readout architectures.

The current status of WDM tests for P-ONE will be presented, providing an outlook on how WDM could support the next generation of large-volume oceanic neutrino detectors.

T 37.5 Tue 17:15 KS H C

Production, Installation & Detector Operations of a Calibration Device for the IceCube Upgrade — •Leonhard Eidenschink, Andrii Terliuk, and Patrick Schaile for the IceCube-Collaboration — Technical University of Munich

The Precision Optical Calibration Module (POCAM) is an isotropic, multi-wavelength, self-monitoring optical calibration device. The IceCube Upgrade, an extension of the IceCube detector located at the geographic South Pole, includes seven new strings equipped with more than 700 modules, 22 of which are POCAM devices. All produced POCAMs underwent extensive calibration of their optical properties at our testing facility at Technical University of Munich (TUM). The purpose of POCAM is to emit a well-characterized isotropic light pulse that allows for calibration of both the optical medium and the detector modules. In addition to the routine calibration operations planned after full deployment, a series of special operations were carried out during the installation. This talk provides an overview of the device production, installation in the IceCube Upgrade, and the special calibration operations performed, along with their first data.

T 37.6 Tue 17:30 KS H C

Calculation of the neutrino flavour ratios for astrophysical dense environments — •Tilman Eckstein[1,2], Vladimir Kiselev[1,2], Jonas Hellrung[1,2], and Julia Becker Tjus[1,2,3] — [1]Theoretical Physics IV, Plasma Astroparticle Physics, Faculty for Physics and Astronomy, Ruhr University Bochum, 44780 Bochum, Germany — [2]Ruhr Astroparticle and Plasma Physics Center (RAPP Center), Germany — [3]Department of Space, Earth and Environment, Chalmers University of Technology, 412 96 Gothenburg, Sweden

Neutrinos are elementary particles that are characterised in particular by their weak interaction. This allows them to travel enormous distances almost unhindered and still be detected on Earth. Dense astrophysical environments, such as compact obscured nuclei (CONs), are potential sites where high-energy neutrinos may be produced.

In this work, the event generator SIBYLL 2.3d was used to simulate pp collisions under extreme astrophysical conditions, as they might occur in such dense environments. A special feature of the resulting particle showers is that different decay channels lead to characteristically different neutrino flavour compositions. These flavour ratios were calculated using the numerical tool MCEq.

After their creation, neutrinos are subject to the quantum mechanical phenomenon of neutrino oscillation, which causes their flavour composition to change as they propagate over distance. Finally, the numerical tool NuSQuIDS was used to determine the theoretical flavour ratios after propagation from these potential astrophysical source regions to Earth.

T 37.7 Tue 17:45 KS H C

Tau neutrino appearance with KM3NeT/ORCA — •Sebastian Weissbrod for the KM3NET-ERLANGEN-Collaboration — Friedrich-Alexander-Universität Erlangen-Nürnberg, ECAP, Erlangen, Germany

KM3NeT/ORCA is a water-Cherenkov neutrino telescope currently under construction in the Mediterranean Sea. Due to its modular design, based on strings of Digital Optical Modules (DOMs), data taking is possible already during the construction phase. In the last year, the KM3NeT collaboration has presented a multitude of physics results obtained with a 433 kt-yr data-set recorded with the six-string ORCA6 sub-array. Among these results is the analysis of tau neutrino appearance in the atmospheric neutrino flux through neutrino oscillations, providing insight into the tau neutrino cross section, as well as probing non-unitary neutrino mixing.

The analysis is based on the minimization of a binned log-likelihood ratio comparing model predictions with observed event counts. The detector response is estimated using detailed Monte Carlo simulations that are specific to the present detector geometry.

A new analysis is currently in preparation, harnessing the further deployment of more strings, providing an expanded detector sub-array and increasing the exposure to up to 1.7 Mt-yr. This update introduces new challenges, such as the characterization of the larger dataset and the transition to a new software framework for the statistical calculations. In my talk I will be presenting preliminary insights on atmospheric tau neutrino appearance using the expanded data-set.

T 37.8 Tue 18:00 KS H C

Integration of the NEUT Neutrino Interaction Model into the KM3NeT/ORCA Simulation Framework and Evaluation of Its Impact on Oscillation Analyses — •Frederik Andersen, Thomas Eberl, and Rodrigo Gracia-Ruiz for the KM3NET-ERLANGEN-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

The KM3NeT/ORCA neutrino telescope is currently under construction in the Mediterranean Sea. It is optimised to detect atmospheric neutrinos with energies up to 100 GeV. To this end a three dimensional grid of photomultiplier tubes detects Cherenkov radiation induced by particles that result from neutrino interactions with seawater. The data recorded by the experiment is analysed by comparing to detailed Monte-Carlo simulations which implement state-of-the-art knowledge on secondary particle production and detection processes. As a first step, so-called neutrino event generator codes employ different approximations to simulate the distribution of final-state particles produced in neutrino interactions. Differences in neutrino generators can introduce biases in the interpretation of the experimental data, and lead to tensions in measurements performed by different experiments. In this talk we will present our results how using different neutrino event generators impacts KM3NeT/ORCA's scientific results by implementing an alternative simulation pipeline using NEUT, the neutrino event generator developed by Super-Kamiokande, and compare its results to the default KM3NeT pipeline employing GENIE as event generator.

T 37.9 Tue 18:15 KS H C

KM3NeT/ARCA All-Sky Diffuse Analysis using PyForward-Folding — •Anke Mosbrugger and Oliver Janik — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

KM3NeT/ARCA is a cubic-kilometer water-Cherenkov neutrino detector under construction in the Mediterranean Sea. Its primary goal is to detect high-energy neutrinos from both galactic and extragalactic sources. This talk presents methods to improve the search for the astrophysical neutrino flux using ARCA21, the construction phase with 21 detection lines in operation.

Studies of the astrophysical neutrino flux commonly use a binned, forward-folding likelihood method. Our analysis is carried out with the new open-source tool PyForwardFolding (PyFF). PyFF supports the full analysis chain following event selection, including flux weighting, binning, and handling of systematics. PyFF also enables combined analyses across different detector configurations and between experiments, such as KM3NeT and IceCube. This is especially relevant for searches along the Galactic Plane and for identifying potential Galactic neutrino sources.

T 38: Methods in Astroparticle Physics II

Time: Tuesday 16:15–18:30 Location: KS 00.004

T 38.1 Tue 16:15 KS 00.004

The Super-SANDI nylon vessel: Compatibility with Water-based Liquid Scintillator — •Noah Goehlke, Amala Augusthy, Johann Martyn, Philipp Kern, Michael Wurm, David Maksimovic, and Oliver Pilarczyk — Johannes Gutenberg-Universität Mainz

The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is a neutrino detector at the Booster Neutrino Beam at Fermilab, designed for measuring the neutron multiplicity in neutrino-nucleus interactions. ANNIE has a strong focus on testing new detector technologies, among which is Water-based Liquid Scintillator (WbLS). WbLS is a novel detection medium, consisting of liquid scintillator dissolved in water with the help of a surfactant. It allows for the simultaneous observation of Cherenkov and scintillation light. To test the reconstruction of extended event topologies in WbLS, ANNIE is going to deploy a nylon vessel containing 8 m^3 of WbLS (dubbed Super-SANDI) this summer. In preparation for Super-SANDI, the chemical compatibility between WbLS and different types of Nylon was investigated. UVvis spectroscopy was used to study the effects on the transparency and on the organic components of the WbLS after exposure to Nylon for an extended period of time. While the transparency is unaffected, an adsorption of PPO into nylon was found, creating slightly scintillating nylon.

T 38.2 Tue 16:30 KS 00.004

Developing a Cryogenic SiPM Characterization Setup — •Nicolas Krieger, Andreas Leonhardt, Stefan Schönert, and Mario Schwarz — Department of Physics, TUM School of Natural Sciences, Technical University of Munich, 85748 Garching b. München, Germany

Silicon photomultipliers (SiPMs) are promising photodetectors for liquid noble gas detectors, which impose challenging cryogenic and vacuum-ultraviolet conditions. Understanding SiPM behavior in this environment is crucial, given the strong temperature dependence of key performance parameters, such as the dark count rate (DCR), breakdown voltage (V_{bd}), gain, photon detection efficiency (PDE), crosstalk, and afterpulsing. We developed a dedicated SiPM characterization setup inside a temperature-controlled vacuum chamber (300-40K) and present the main challenges in achieving stable SiPM operation and readout. The vacuum environment enables systematic measurements over a wide temperature range and rapid sample turnaround, both of which are not accessible in liquid noble gas setups. Finally, we present temperature-dependent SiPM performance measurements, which will support ongoing studies of SiPM behavior for the LEGEND experiment. We acknowledge support from the Deutsche Forschungsgemeinschaft and through the Sonderforschungsbereich SFB 1258.

T 38.3 Tue 16:45 KS 00.004

Innovative Production Approach to Vacuum Beam Pipes of the Einstein Telescope — •Charlotte Benning, Robert Joppe, Oliver Pooth, and Achim Stahl — RWTH Aachen University, Physics Institute 3B

The Einstein Telescope (ET), Europe's next-generation gravitational-wave detector, requires 120 km of underground vacuum tubes with a diameter of 1 m to achieve the design sensitivity. The current design foresees the production of the beam pipes in sections of 15 m, which results in high efforts for transportation, welding, and cleaning. BeamPipes4ET proposes an innovative production approach in which the vacuum pipes are manufactured directly on-site inside the tunnels through a continuous forming process using sheet-metal coils. It offers potential reductions in time, cost, installation effort, and environmental impact. In this talk, the current project status, key technological developments, and a comparison between the current ET design and the BeamPipes4ET approach are discussed.

T 38.4 Tue 17:00 KS 00.004

Commissioning of a vacuum-insulated liquid argon purifier for removing trace amounts N2 featuring a novel Li-FAU molecular sieve for LEGEND — •Georgia Pavlidaki[1], Christoph Vogl[1], Laszlo Papp[1], Mario Schwarz[1], Grzegorz Zuzel[2], and Stefan Schönert[1] — [1]Department of Physics, TUM School of Natural Sciences, Technical University of Munich, 85748 Garching b. München, Germany — [2]M. Smoluchowski Institute of Physics, Jagiellonian University, Cracow, 30-348, Poland

LEGEND-1000 will search for neutrinoless double-beta decay of ^{76}Ge with up to 1000 kg of enriched high-purity germanium detectors. The detectors are operated bare in liquid argon (LAr) which acts as a coolant, shield, and particle detector. To effectively detect background radiation, LAr has to be kept clean. Impurities such as oxygen, nitrogen or water deteriorate its scintillation properties. A recently identified Li-FAU molecular sieve effectively removes nitrogen from LAr. We construct a LAr purification system featuring Li-FAU and a copper catalyst and report on the current status. The system is able to purify in batch and loop mode, and is vacuum insulated, minimizing LAr losses. The purifier will provide high-purity LAr for a future investigation of the scintillation properties of xenon-doped liquid argon, and offers excellent windows of opportunity to gain operational experience with Li-FAU for LEGEND-1000. We acknowledge support from the DFG under Germany's Excellence Strategy – EXC 2094 (ORIGINS) and through the Sonderforschungsbereich SFB 1258. We acknowledge support by the BMFTR Verbundprojekt 05A2023 (LEGEND).

T 38.5 Tue 17:15 KS 00.004

Low-Background Gamma Spectrometry for LEGEND — Hannes Bonet[1], •Patrick Bongratz[1], Benjamin Gramlich[1], Manuel Huber[2], Matthias Laubenstein[3], Susanne Mertens[1], Hardy Simgen[1], Herbert Strecker[1], and Edgar Sanchez Garcia[1] for the LEGEND-Collaboration — [1]Max Planck Institut für Kernphysik, Heidelberg — [2]Technische Universität München, Garching — [3]Laboratori Nazionali del Gran Sasso (LNGS)

Low-background experiments depend on minimizing radioactive contamination in detector materials. For example, in the Large Enriched Germanium Experiment for Neutrinoless $\beta\beta$ Decay (LEGEND), all materials are screened for radioisotopes to achieve this high radiopurity. This is commonly done by gamma spectroscopy using low-background, high-purity Germanium (HPGe) spectrometers. Operating these spectrometers in an underground laboratory reduces the cosmic background for the measurement. In this talk, I present on HPGe-spectrometers operated at 15 m.w.e. in Heidelberg (Germany) and at 3800 m.w.e. at LNGS (Italy). I describe how measurements from these detectors are used to derive the total background budget for the LEGEND-1000 experiment and to fix radiopurity requirements for its components. Sample-specific detection efficiencies are determined using the Geant4-based simulation framework remage.

T 38.6 Tue 17:30 KS 00.004

Characterizing infrared scintillation light in xenon — •Robert Hammann, Kai Böse, Steffen Form, Luisa Hötzsch, and Teresa Marrodán Undagoitia — Max- Planck-Institut für Kernphysik

Xenon in gaseous and liquid form is a widely used target material for rare-event searches, including the direct detection of dark matter. Its scintillation properties in the ultraviolet (UV) spectrum are well-known and extensively used. However, the potential of infrared (IR) scintillation light remains largely unexplored. Characterizing this IR component is important for evaluating possible improvements in the physics output of future astroparticle detectors.

This contribution presents studies of xenon gas scintillation at room temperature using a dedicated setup equipped with an alpha particle source, as well as one IR- and two UV-sensitive photomultiplier tubes. This allowed the first time-resolved measurement of the IR scintillation response, revealing both a fast nanosecond-scale and a slow microsecond-scale decay component. Remarkably, our measurements showed that the IR light yield is comparable to the UV yield. We also investigated the effects of gas pressure and impurity levels on the IR signal.

Initial results with a dual-phase detector possessing broadband wavelength sensitivity are consistent with IR emission from the liquid xenon target and electroluminescence in the gas phase, indicating the potential of xenon-based detectors with multi-wavelength readout.

T 38.7 Tue 17:45 KS 00.004

Methods to measure the ice stratigraphy in the IceCube Upgrade — •Anna Eimer for the IceCube-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

A precise understanding of the optical properties of the instrumented Antarctic ice sheet is crucial to the performance of the IceCube Neutrino Observatory and its planned successors.

The ice optical properties are driven by impurities deposited with the snow that formed the ice and thus layers of constant optical properties form a stratigraphy. Due to the underlying bedrock, these layers undulate over the large lateral footprints of these detectors.

Within IceCube, the layer undulations have originally been mapped using stratigraphy measurements by a stand-alone laser dust logger. It required a dedicated deployment setup, as it was not located on the main sensor cables. This resulted in significantly increased costs.

New methods to replace the stand-alone dust logger as have been employed during the deployment of the IceCube Upgrade will be shown in this talk. One approach consists of a light source that was co-deployed with the photosensor modules and operated during the deployment of the detector. Another approach uses a camera to record the stratigraphy. Initial data from both approaches, in particular sampling 150m below the depth instrumented by IceCube, will be shown and discussed.

T 38.8 Tue 18:00 KS 00.004

Deployment of the Acoustic Module for the IceCube Upgrade — •Andreas Nöll, Jan Audehm, Jürgen Borowka, Mia Giang Do, Christoph Günther, Dirk Heinen, Christopher Wiebusch, and Simon Zierke — III. Physikalisches Institut B, RWTH Aachen University

The IceCube Neutrino Observatory is a cubic kilometer-sized detector located at the geographic South Pole, consisting of 5160 Digital Optical Modules (DOMs). In the Antarctic summer 2025/26 more than 700 new modules will be installed as part of the IceCube Upgrade. These include ten Acoustic Modules (AMs), capable of transmitting and receiving acoustic signals between 5 and 30kHz. Additionally, up to 30 acoustic receivers will be located in new DOMs. The goal of these devices is to improve the geometry calibration based on multilateration of the measured acoustic propagation times, as well as enhance our understanding of the acoustic properties of the ice. This talk presents the current state of the project after the deployment of the IceCube Upgrade.

T 38.9 Tue 18:15 KS 00.004

Experimental progress of the Munich Electrostatic Storage Ring (ESR) — •Adil W. Muggo, Chiara Brandenstein, Nils Doll, Peter Fierlinger, Dario Rückwarth, Wolfgang Schott, Vitus Schuster, Hans Th. J. Steiger, Konstantin Walter, and Florian Zötl — School of Natural Sciences, Physics-Department, Technical University of Munich, 85748 Garching, Germany

Stored ions or ionic molecules in a non-relativistic electrostatic storage ring can serve as a versatile platform for various fundamental experiments. Through precise control of beam dynamics and polarization, searches for electric dipole moments (EDMs) or axion-like particles (ALPs) become feasible in a rather unique and novel setting. Recent progress on the implementation of such a device is being discussed. Our experimental demonstrator comprises three subsystems: a laser ablation source for ion generation and acceleration, an injection beamline for beam focusing and transport, and the storage ring itself, where electrostatic elements confine the ions on stable trajectories. The current commissioning status of the setup is presented, as well as experimental challenges and first performance benchmarks.

T 39: Gravitational Waves II

Time: Tuesday 16:15–17:45 Location: KS 00.005

T 39.1 Tue 16:15 KS 00.005

Cavity-Based High-Frequency Gravitational-Wave Detection at GravNet — •Stefan Horodenski, Kristof Schmieden, Matthias Schott, and Swarangee Saraf — University of Bonn, Physikalisches Institut, Bonn, Germany

The GravNet collaboration aims to perform the first detection of high-frequency gravitational waves (HFGWs) in the GHz range (1-10 GHz), which could provide sensitivity to primordial black holes, one candidate for dark matter.

GravNet is a network of high-frequency gravitational-wave detectors currently under construction. One detector concept exploits the inverse Gertsenshtein effect, in which gravitational waves induce electromagnetic signals in small, strongly magnetized radio-frequency (RF) cavities.

The experimental setup comprises a cryogenic cylindrical RF cavity mounted inside a 12 T superconducting magnet and coupled to an ultra-low-noise readout chain, whose first amplification stage is a traveling-wave parametric amplifier (TWPA), enabling near-quantum-limited noise performance. We discuss the prospects of RF-based gravitational-wave searches and present the development of a new experimental setup at Bonn, including optimization of the prototype cavity and characterization of the TWPA.

T 39.2 Tue 16:30 KS 00.005

Challenge of High-Frequency Gravitational Waves Detection — •Gudrid Moortgat-Pick z. Hd. Lipps[1,2], Gudrid Moortgat-Pick z. Hd. Lipps[1], Gudrid Moortgat-Pick z. Hd. Lipps[1], Gudrid Moortgat-Pick z. Hd. Lipps[1], Gudrid Moortgat-Pick z. Hd. Lipps[2], and Gudrid Moortgat-Pick z. Hd. Lipps[2] — [1]University of Hamburg — [2]Am alten Tor 11

High frequency gravitational waves (GWs) remain unexplored messengers of new physics. Proposed sources in the MHz - GHz band include primordial black hole mergers, black hole superradiance and several stochastic backgrounds.Our collaboration is working on tapping into this source by employing superconducting microwave cavities for high precision measurements of harmonic displacements.

The talk give an actual status report on the experimental as well as the theoretical new developments including the measurements as well as background considerations.

T 39.3 Tue 16:45 KS 00.005

ML based detection strategies for high frequency GWs. — •Swarangee Saraf[1], Matthias Schott[2], Kristof Schmieden[2], Stefan Horodenski[2], and Christian Gottschlich[2] — [1]University of Bonn, Germany — [2]Physikalisches Institute, University of Bonn, Germany

The Gravitational Wave Network (GravNet) is a network of high frequency gravitational wave detectors currently under construction. The detector concept relies on the resonant conversion of gravitational wave energy into electromagnetic energy, using the inverse Gertsenshtein effect. In this talk we will discuss challenges in detecting high frequency GWs and explore solutions by using machine learning techniques.

T 39.4 Tue 17:00 KS 00.005

Newtonian Noise in non-spherical caverns for the Einstein Telescope — •Valentin Tempel, Jörg Pretz, and Achim Stahl — III. Physikalisches Institut, RWTH Aachen

The Einstein Telescope (ET), a proposed third-generation gravitational-wave detector, aims to exceed the sensitivity of current interferometers, enabling the observation of significantly fainter signals. Achieving the desired performance requires a precise understanding and likely also mitigation of Newtonian Noise (NN), which is expected to be a significant contribution to the ET noise budget in the 1-10 Hz region. One important NN component originates from seismic-induced density fluctuations in the surrounding rock, as well as from the motion of cavern walls, producing fluctuating gravitational forces on the interferometer test masses. In the past, simplified models with spherical caverns have often been used as a theoretical order-of-magnitude estimation for NN, but those models are not generally representative of realistic underground environments. We present how cavern geometry affects the coupling of NN from seismic waves to the ET mirrors. Using analytical and numerical methods, we quantify how deviations from spherical symmetry and variations in cavern size modify the NN coupling transfer functions. The results highlight the limitations of simplified models and emphasize the importance of accurate models for reliable NN predictions in the Einstein Telescope.

T 39.5 Tue 17:15 KS 00.005

Newtonian Noise mitigation for the Einstein Telescope using Deep Learning — •Jonathan Kuckert, Jan Kelleter, Patrick Schillings, and Johannes Erdmann — III. Physikalisches Institut A, RWTH Aachen University

In the past, gravitational wave interferometers were not able to measure low frequency gravitational waves. The Einstein-Telescope (ET) is a proposed third-generation underground gravitational wave interferometer. For the first time, ET will enable measurements in the 1-10 Hz region. In this region, Newtonian Noise (NN), perturbations in the gravitational field due to density fluctuations in the underground, is the predicted dominant noise source. As a gravitational phenomenon NN, cannot be shielded. Therefore, the most promising mitigation strategy is based on seismometer arrays. The seismometers surround the interferometer mirrors and the gravitational noise on the mirrors is predicted using the seismometer data. For this kind of prediction, Wiener Filters (WFs) were deployed as a standard solution in the past. Based on simulations of simplified seismic events, it has been shown that Deep Learning methods, specifically Graph Neural Networks (GNNs) can match and outperform WFs. In this talk we present further improvements in mitigation and first steps towards optimising seismometer positions using Machine Learning.

T 39.6 Tue 17:30 KS 00.005

Testing Noise Mitigation Techniques for Future Gravitational Wave Detectors — Markus Bachlechner, Johannes Erdmann, •Tim J. Kuhlbusch, Achim Stahl, and Jochen Steinmann — III. Physikalisches Institut, RWTH Aachen

Future gravitational wave (GW) detectors like the Einstein Telescope aim to decrease the detector noise to increase the precision of measurements and to detect weaker signals. To measure the minuscule length changes induced by GWs, extremely low vibration levels for the test masses are required. New noise sources become relevant in reducing the residual vibrations of the test masses. Gravitational couplings from density fluctuations of the surrounding material, called gravity gradient noise, can not be shielded. Therefore, predicting the coupled noise from inertial sensors is essential to reduce the impact in the 1 to 10 Hz range.

Wiener filters are a simple and robust approach to predicting coupled noise. However, the classic Wiener filter can not adapt to variations in the amplitude of the coupled noise. As variations in the amplitude over time are expected for the ambient noise sources in GW detectors, an adaptive filter is required for optimal performance. This talk discusses adaptive filtering options and presents the evaluation in a small-scale interferometer.

T 40: Cosmic Rays II

Time: Tuesday 16:15–18:30 Location: KS 00.006

T 40.1 Tue 16:15 KS 00.006

The triboelectric effect at the Pierre Auger Observatory — •Julian Rautenberg for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstr. 20, 42119 Wuppertal, Germany

With the AugerPrime extension of the Pierre Auger Observatory all surface detector stations have been equipped with radio antennas to measure extensive air showers in the 30-80 MHz region. For the data acquisition using a trigger based on radio pulses, the triboelectric effect has been reported to be responsible for an increased background rate at high wind-speeds for ice-based radio experiments. With the self-triggered data of the Auger Engineering Radio Array (AERA) we estimate the correlation between trigger rate and wind speed.

T 40.2 Tue 16:30 KS 00.006

Transferability of 3D-Wave Reconstruction with ML Models* — •Sven Querchfeld for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstr. 20, 42119 Wuppertal, Germany

Within the ErUM-Wave project, a Machine Learning (ML) model is developed to reconstruct three-dimensional wave fields. The goal is to predict the propagation of seismic waves on the basis of only a few measurements. To test the transferability of this method to other fields, it will be applied to the propagation of radio waves in the atmosphere. These waves are produced by cosmic-ray-induced extensive air showers and are measured by the Pierre Auger Observatory. First events have already been recorded by its radio detector, which finished deployment on the full array in November 2024. Training and validation are based on CORSIKA 7 simulations using the CoREAS extension. To obtain more realistic traces, a noise library was created using in-field measurements, utilising the small radio footprint of vertical showers to supplement the simulated events. Due to the CPU-intensive simulations, a preliminary test of the developed ML models for reconstructing 3D wave propagation is presented, using a limited set of showers.

**Supported by BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A23PX1) and ErUM-Wave*

T 40.3 Tue 16:45 KS 00.006

Measurement of air-showers by the radio antennas of the IceCube Surface Array Enhancement — •Megha Venugopal for the IceCube-Collaboration — Institute of Astroparticle Physics (IAP), Karlsruhe Institute of Technology, Germany

In a cubic km of ice at the South Pole, strings of Digital Optical Modules of the IceCube observatory measure neutrinos from astrophysical phenomena. IceTop, located on the surface of this detector, comprising 81 pairs of ice Cherenkov detectors measure the electromagnetic and muonic parts of air showers induced by cosmic rays. Challenges arising from the accumulation of snow over these detectors over time led to a planned enhancement of these detectors. Since early 2025, the Surface Array Enhancement has three stations each equipped with 3 antennas and 8 scintillators deployed on the IceTop footprint. The data from the new stations were checked and the first radio data triggered by scintillators measured in all three stations have been reconstructed and verified. Estimation of Xmax with the previous dataset with a single station is also discussed.

T 40.4 Tue 17:00 KS 00.006

Absolute Energy Calibration of the Auger Engineering Radio Array — •Asil Meidow for the Pierre Auger-Collaboration — Karlsruhe Institute of Technology

The Pierre Auger Observatory detects ultra-high-energy cosmic rays over a surface area of more than 3000 km^2, requiring a precise and stable energy-scale calibration. Traditionally, this calibration relied solely on fluorescence detectors (FD). In recent years, radio detection has become an increasingly valuable technique, offering complementary insights through an independent reconstruction. Previous comparisons revealed that the energy scales determined with the FD and the Auger Engineering Array (AERA) are consistent within systematic uncertainties, with energies reconstructed with AERA being 12% higher. We present how the AERA standard event reconstruction has been adapted to provide electromagnetic and cosmic-ray energies consistent with the energy scale determined with AERA. We also outline how this approach will be extended to inclined air showers in future work.

T 40.5 Tue 17:15 KS 00.006

A bayesian method for radio-based air shower reconstruction — •Karen Terveer[1] and Anna Nelles[1,2] — [1]ECAP, FAU Erlangen-Nürnberg, Germany — [2]Deutsches Elektronen-Synchroton (DESY) Zeuthen, Germany

Over the past decade, radio detection of cosmic-ray air showers has established itself as a standalone technique. Observatories such as the Low-Frequency Array (LOFAR) have successfully constrained the mass composition in the $10^{16.5}$ - 10^{18} eV range, capturing the transition region from galactic to extragalactic sources. Although standard reconstruction methods based on CoREAS simulations achieve a state-of-the-art $X_{\max}$ precision of 19 g/cm^2, they are computationally expensive and do not use all available signal information. We present a new reconstruction method based on Information Field Theory (IFT) that simultaneously uses particle and radio data. The Bayesian framework of IFT ensures rigorous uncertainty quantification and reconstruction of the full posterior distribution. Using JAX for automatic differentiation, the method enables efficient gradient-based inference in high-dimensional parameter spaces. We present the first results of this technique applied to LOFAR data, representing the first approach to exploit a more complete information content of these datasets.

T 40.6 Tue 17:30 KS 00.006

Bayesian Inference to Reconstruct Current Densities from Radio Emission of Extensive Air Showers — •Stefanie Girod, Maximilian Straub, and Martin Erdmann — RWTH Aachen University, Physics Institute 3A, Otto-Blumenthal-Str., 52074 Aachen, Germany

We are developing an approach to image extensive air showers based on Bayesian Inference. This approach aims to reconstruct the atmospheric current densities that induce radio emissions. The reconstruction requires a forward model with a generator capable of producing current densities in extensive air showers. To ensure differentiability and computational efficiency, we employ Gaussian processes to generate the current densities. We extract the current densities from air showers simulated by the Monte Carlo code CORSIKA to tune the generator's hyperparameters. With a tuned generator capable of sampling the parameter space of realistic air showers, we can apply the reconstruction on realistic scenarios.

T 40.7 Tue 17:45 KS 00.006

The Auger Radio Infill SKALA Extension (ARISE) — •Carmen Merx[1], Ben Flaggs[2], Alexander Novikov[2], Frederik Schmitt[1], Megha Venugopal[1], Stef Verpoest[2], Andreas Weindl[1], and Frank Schröder[1,2] — [1]Institute for Astroparticle Physics, Karlsruhe Institute of Technology — [2]Bartol Research Institute, Department of Physics and Astronomy, University of Delaware

Radio detection of extensive air showers has become a powerful technique for studying high-energy cosmic rays. To further enhance the measurement of ultra-high-energy cosmic rays, the Pierre Auger Observatory in Argentina, the world‘s largest cosmic-ray experiment, has been upgraded with radio antennas for inclined air showers. In 2025, we have installed an additional pathfinder radio array, ARISE ("Auger Radio Infill SKALA Extension"), aiming at the demonstration of full detection efficiency for vertical air showers in the energy range of 100 PeV and above.

The ARISE setup is based on the radio component of the IceCube Surface Array Enhancement. It consists of six stations, each comprising three SKALA antennas installed around a surface detector in the denser infill region of the Pierre Auger Observatory.

This talk will give an overview of ARISE and present first radio measurements triggered by the Auger surface detector.

T 40.8 Tue 18:00 KS 00.006

A Near-Field Interferometry of Cosmic Ray Air Showers with the Square Kilometre Array — •Keito Watanabe[1], Tim Huege[1,2], Torsten Ensslin[3,4,5], and Vincent Eberle[3,4] for the SKA HECP SWG-Collaboration — [1]Institute for Astroparticle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]Inter-University Institute For High Energies, Vrije Universiteit Brussel, Brussels, Belgium — [3]Max-Planck Institut für Astrophysik, Garching, Germany — [4]Ludwig-Maximilians-Universität München,

München, Germany — [5]Deutsches Zentrum für Astrophysik, Görlitz, Germany

With the advent of the low-frequency component of the Square Kilometre Array (SKA-Low), its high antenna density and large frequency bandwidth will allow radio measurements of cosmic ray air showers to be performed with unprecedented accuracy. Current analysis techniques can already reconstruct shower properties with high precision, but are limited by their high computational cost and limited use of the information within the signal. In this work, we showcase that SKA-Low has the potential to perform near-field interferometry by reconstructing the spatial and temporal evolution of the shower with Information Field Theory, a novel Bayesian reconstruction framework that retrieves distributions of field-like quantities from observed signals. We validate our approach with realistic simulated datasets, showing that, through the reconstruction of the shower evolution, we can not only improve our understanding of the mass composition of cosmic rays but also probe the underlying hadronic physics within the shower.

T 40.9 Tue 18:15 KS 00.006

Development of Radio-Interferometric Lightning Reconstruction for BOLT Using AERA Measurements* — •Melanie Joan Weitz for the Pierre Auger-Collaboration — Bergische Universität Wuppertal, Gaußstraße 20, 42119 Wuppertal

The Pierre Auger Observatory has detected downward terrestrial gamma-ray flashes (TGFs) with its water-Cherenkov detectors. A key to understanding this high-energy radiation in thunderstorms is to combine such measurements with those of lightning processes in their earliest stages. The Broadband Observatory of Lightning and TGFs (BOLT) is a detector currently under construction for imaging lightning propagation in three dimensions using radio interferometry. With eleven modified Auger Engineering Radio Array (AERA) stations and their bandwidth range from 30-80 MHz, the necessary spatial and temporal resolution can be provided.

To prepare for BOLT measurements, we characterize lightning signals in existing AERA data to validate the instrument design, particularly concerning the signal amplitude and dynamic range. We will present the reconstructed location and emission time of lightning candidates observed with AERA stations using external lightning information. Furthermore, we present the development of a radio-interferometric analysis suitable for application to the first BOLT signal traces.

**Supported by BMBF Verbundforschung Astroteilchenphysik (Vorhaben 05A23PX1)*

T 41: Invited Overview Talks III

Time: Wednesday 11:00–12:30 Location: AudiMax

Invited Overview Talk T 41.1 Wed 11:00 AudiMax

One of a kind: the Higgs boson — •Matteo Bonanomi — Universität Hamburg

Discovered by the ATLAS and CMS experiments nearly 60 years after its prediction, the Higgs boson is a cornerstone of the Standard Model of particle physics.

What began as the challenge of discovering a rare particle has now become a vast program of precision measurements which have enabled a deep understanding of the origin of particle masses, the observation of rare Higgs couplings, and a highly granular characterization of the Higgs boson properties with unprecedented precision. This has only been possible thanks to sophisticated detector technologies and great advances in analyses techniques.

Today, experimental efforts are increasingly focused on the simultaneous production of multiple Higgs bosons. The observation of this process would provide direct insight into the Higgs self-interaction and could shed light on fundamental open questions about the origin and evolution of the Universe.

In this talk, I will provide an experimental overview of the field and highlight recent progress of the ATLAS and CMS Collaborations to understand and characterize this one-of-a-kind particle. In the final part of the talk, I will also discuss the experimental prospects for the ongoing Run III and the upcoming High-Luminosity phases of the LHC.

Invited Overview Talk T 41.2 Wed 11:30 AudiMax

Higgs Physics at the LHC and Beyond: Connecting Colliders and the Early Universe — •Thomas Biekötter — Instituto de Física Teórica UAM/CSIC, Madrid, Spain

The discovery of the Higgs boson was a landmark achievement, confirming the mechanism of electroweak symmetry breaking that gives mass to elementary particles. At the same time, it marked the beginning of a deeper quest: to understand the underlying dynamics responsible for this mechanism, and to determine whether the Higgs sector is truly minimal, as predicted by the Standard Model (SM), or part of a richer structure predicting additional Higgs bosons.

I will present a theory overview of Higgs physics at the LHC and how precision measurements of the Higgs boson, together with searches for additional scalar particles, provide powerful probes of physics beyond the SM. Many well-motivated extensions of the Higgs sector link collider phenomenology directly to the early Universe. Extended Higgs sectors can accommodate viable Higgs-portal dark matter scenarios that can be probed at the LHC. Moreover, by altering the nature of the electroweak phase transition, a non-minimal Higgs sector can provide the conditions to dynamically generate the matter-antimatter asymmetry of the universe and leave observable imprints in the form of primordial gravitational waves. I will discuss how incorporating the full wealth of current and future LHC data is essential to obtain realistic, data-driven predictions for complementary observations at space-based gravitational-wave observatories like LISA.

Invited Overview Talk T 41.3 Wed 12:00 AudiMax

Gravitational waves from cosmological phase transitions. — •Thomas Konstandin — Notkestraße 85, 22607 Hamburg, Germany

First-order cosmological phase transitions are an intriguing source of gravitational waves. Depending on the temperature of the phase transition, the gravitational wave spectrum can be observed by pulsar timing arrays, space-based interferometers or ground-based experiments. Quantifying the produced power spectrum is however quite challenging, and non-linear hydrodynamics and turbulence are essential for robust predictions. The aim of the presentation is to summarize the history of the field and also discuss some recent developments.

T 42: Annual Meeting of Young Scientists in High Energy Physics (yHEP)

Time: Wednesday 12:40–13:40 Location: KS H C

T 42.1 Wed 12:40 KS H C

10th Annual Meeting of Young Scientists in High Energy Physics (yHEP) — •Simran Gurdasani[1], Michael Lupberger[2], Srijan Seghal[3], Leonel Morejon[3], Farah Afzal[4], Judita Beinortaite[1], and Julian Gethmann[5] — [1]DESY — [2]Albert-Ludwigs-Universität Freiburg — [3]Bergische Universität Wuppertal — [4]Ruhr-Universität Bochum — [5]Karlsruher Institut für Technologie

In this year's yHEP meeting, we will give a brief overview of our activities from the past year and present a retrospective on the development of yHEP since its founding in 2015.

This talk will be structured as a snapshot of current and old activities — including the European Strategy process, ECR representation in national and European committees, sustainability initiatives, the WissZeitVG and residence permit issues, and our efforts to strengthen ECR visibility and connectivity across Germany. Finally, we would like to hear from you: What should yHEP focus on in the coming year?

Food and light refreshments will be provided. All students, doctoral candidates, post-docs and scientists on temporary contracts are warmly invited. Please register to our mailing list (via yhep.desy.de) to receive details on the meeting.

T 43: Invited Topical Talks I

Time: Wednesday 13:45–15:45 Location: AudiMax

Invited Topical Talk T 43.1 Wed 13:45 AudiMax

Upgrade of the ATLAS tracker for HL-LHC: production status and challenges — •Roland Koppenhoefer — Albert-Ludwigs-Universität, Freiburg, Germany

In 2030, the High-Luminosity Large Hadron Collider (HL-LHC) at CERN is planned to start its operation. An integrated luminosity of up to 4000 fb^{-1} is expected over a runtime of up to twelve years. This results in significantly increased particle densities and radiation levels in all HL-LHC experiments compared to the LHC phase. The ATLAS experiment replaces its inner detector by a completely new all-silicon tracking detector within the Phase-II Upgrade.

The new ATLAS Inner Tracker (ITk) consists of pixel modules in the innermost layers and strip modules in the outer layers. To assemble the required number of detector modules with highest quality and install them in larger detector structures ready for installation in the ATLAS detector in time, a production scheme has been developed with shared responsibilities between ITk institutes all over the world. After an overview of the scope of the ATLAS ITk Upgrade, this contribution will mainly focus on the production plan of the ITk strip detector. Besides discussing the current production status, a selection of technical challenges that needed to be overcome on the way is presented.

Invited Topical Talk T 43.2 Wed 14:15 AudiMax

Entering the high-granularity calorimetry era: the CMS HGCAL upgrade — •Antoine Laudrain — Deutches Elektronen-Synchrotron, Hamburg, Germany

The LHC has seen a successful data taking over the last 15 years. However, 90% of the planned dataset will be recorded in the upcoming High-Luminosity phase of the LHC (HL-LHC). While this enormous dataset will enable the high-precision measurements on a range of topics, the LHC experiments will come under a high stress: radiation damage, detector occupancy, data rate, etc. To cope with these challenging conditions, the CMS experiment is upgrading most of its subsystems, including its end-cap calorimeters: they will be completely removed and replaced by the High-Granularity Calorimeter. The HGCAL uses a mixture of silicon sensors in the high-radiation areas, and plastic scintillator tiles readout by SiPMs in the lower radiation areas. It totals more than 6 million channels, 2 orders of magnitude more than the current calorimeter system. The scintillator section alone is composed of 4000 modules hosting more than 270'000 individual channels which poses challenges for the production scalability, especially automating the assembly and quality control. This contribution will present the HGCAL upgrade and the German contributions to its construction: DESY, one of the two assembly centres worldwide for the scintillator section, will build and test half of these modules, while KIT is involved in the readout electronics in.

Invited Topical Talk T 43.3 Wed 14:45 AudiMax

Searching for New Physics in Otherwise Lost LHC Data — •Falk Bartels — CERN

The search for physics beyond the Standard Model at the LHC is often limited by trigger requirements that prioritise high-energy signatures. As a consequence, potential signals at lower energies may evade conventional analyses altogether. Extending the experimental sensitivity into this previously inaccessible phase space is therefore a key challenge for current and future searches at both ATLAS and CMS.

This talk will discuss several innovative ideas that aim to overcome these limitations and open up new regions of parameter space for LHC searches. A central example is trigger-level analysis, which makes use of event information reconstructed online during data taking. By recording reduced event content at high rates, this strategy relaxes bandwidth constraints and allows searches to probe significantly lower mass scales. Beyond this, further developments are addressing the hardware-based Level-1 trigger, including the use of anomaly detection techniques to increase sensitivity to unconventional or unexpected signatures. Together, these approaches demonstrate how novel trigger concepts can substantially expand the discovery potential of the LHC.

Invited Topical Talk T 43.4 Wed 15:15 AudiMax

Federated Computing Infrastructures — •Inga Lakomiec — II. Institute of Physics, Georg-August-University, Göttingen, Germany

Federated computing infrastructures are established to address the rapidly growing data volumes and computational demands of high energy physics (HEP) research. The transition from self-sufficient data and computing centres towards federated resources requires a dedicated approach to ensure interoperability across heterogeneous architectures, research organisations, and geographically distributed sites. Such changes cannot be introduced without significant financial support. The ErUM-Data, ErUM-Pro and NFDI projects are an essential part of this transformation in Germany.

An important step in this process is a transition of storage and computing contributions of the German university-based WLCG Tier-2 centres to the Helmholtz Centres and National High Performance Computing (NHR) sites, respectively. The technologies developed within the dedicated projects are crucial to meeting the computing and storage needs of the WLCG and HEP research in general. The solutions offered by the involved communities are designed in a sustainable way, taking into account scalability as well as efficient resource provisioning and utilisation.

This talk presents recent strategies for federated computing infrastructures and technologies being developed within the R&D projects in Germany. It focuses on the WLCG and the challenges posed by the High-Luminosity LHC.

T 44: Invited Topical Talks II

Time: Wednesday 13:45–15:45 Location: MED 00.915

Invited Topical Talk T 44.1 Wed 13:45 MED 00.915
Probing Heavy New Physics at the Precision Frontier with Effective Field Theory — •Peter Stangl — Johannes Gutenberg-Universität Mainz

The Standard Model of particle physics successfully describes all known elementary particles, yet it leaves fundamental questions unanswered, from the origin of neutrino masses and the Higgs hierarchy problem to the puzzling patterns in particle masses and mixings. With direct searches at the LHC having reached their energy limit without discovering particles beyond the Standard Model, precision measurements offer a powerful complementary approach: heavy new particles, even if beyond direct reach, modify the interactions of known particles in measurable ways. I will discuss how Effective Field Theory methods combined with precision data from flavour physics, electroweak measurements, and collider observables can be used to systematically search for these subtle signatures of physics beyond the Standard Model.

Invited Topical Talk T 44.2 Wed 14:15 MED 00.915
Hadron Spectroscopy at Belle (II) — •Stefan Wallner — Max Planck Institute for Physics, Garching, Germany

The Belle and Belle II experiments recorded the world's largest dataset of e^+e^- collisions at center-of-mass energies at and around the $\Upsilon(nS)$ resonances. This dataset provides diverse opportunities to study the excitation spectrum of mesons and baryons with unparalleled precision. We present measurements of hadrons composed of heavy quarks, searches for exotic states beyond the quark model, and studies of the light-meson spectrum.

Invited Topical Talk T 44.3 Wed 14:45 MED 00.915
Rare B meson decays at Belle II: indirect searches for new physics at the luminosity frontier — •Ana Luisa Moreira de Carvalho — DESY, Hamburg, Germany

There is a lot we still do not understand about the Universe and its evolution. A striking example is the observed asymmetry in the quantity of matter and antimatter, which, together with other experimental evidence, points to physical processes and/or particles not contemplated in our current theoretical framework (the Standard Model).

Despite extensive searches at the LHC, the highest energy particle collider available, no evidence of physics beyond the Standard Model has been observed, indicating that new physical phenomena may lie beyond the energy reach of current experiments.

In this context, indirect searches - based on precision measurements and the study of rare Standard Model processes - provide a powerful and complementary approach. These studies require very large data samples, such as those produced in high-luminosity electron-positron collisions at the SuperKEKB accelerator, where the Belle II detector operates. At Belle II, rare electroweak transitions of a b-quark into an s-quark can be studied as sensitive probes of physics beyond the Standard Model. Additionally, precise measurement of the differences in the transition properties of a b-quark and an anti-b-quark may shed light on the mechanisms responsible for the matter-antimatter asymmetry in the present Universe.

Invited Topical Talk T 44.4 Wed 15:15 MED 00.915
Search for CP violation in $D^0 \to K^0_S K^0_S$ decays at the LHCb experiment — •Giulia Tuci — Heidelberg University

The study of CP violation in charm mesons provides a complementary probe of possible physics beyond the Standard Model with respect to beauty mesons, and allows the exploration of very high energy scales. The LHCb experiment has collected the largest sample of charm hadrons ever and in 2019 reported the first observation of CP violation analysing $D^0 \to K^+K^-$ and $D^0 \to \pi^+\pi^-$ decays, marking a milestone in flavour physics. However, the interpretation of this observation within the Standard Model is still under debate, making complementary experimental results essential to clarify the picture. In this presentation, a new measurement of the time-integrated CP asymmetry in the $D^0 \to K^0_S K^0_S$ decay will be presented. The analysis uses data collected by LHCb in 2024, inaugurating a new era enabled by the upgraded detector, which provides improved tracking, vertex resolution, and a fully software-based trigger, allowing unprecedented precision in charm physics.

T 45: Neutrino Physics III

Time: Wednesday 16:15–18:30 Location: AudiMax

T 45.1 Wed 16:15 AudiMax
Upgrading the ECHo-1k experimental setup — •Margareta Chill for the ECHo-Collaboration — Kirchhoff-Institute for Physics

With the ECHo experiment, the effective electron neutrino mass can be determined via the high energy resolution measurement of the ^{163}Ho electron capture spectrum. In ECHo, large arrays of metallic magnetic calorimeters hosting ^{163}Ho are operated at millikelvin. For the ECHo-1k phase, two MMC arrays have been used for acquiring 200 million ^{163}Ho events with an energy resolution of about 7 eV FWHM at 1800 eV. For that experiment, only about one half of the channels could be read out due to failures in several SQUID channels. We present the upgrade of the ECHo-1k set-ups by the exchange of the SQUID read-out. We discuss the performance achieved with one of those setups and the implication for a coming small scale experiment aiming to reach a sensitivity on the effective neutrino mass below 5 eV/e^2.

T 45.2 Wed 16:30 AudiMax
Principal Component Analysis for Pile-up Event Detection in the ECHo Experiment — •Domenic Klumpp for the ECHo-Collaboration — Kirchhof Institut of Physics, Heidelberg, Germany

The ECHo (Electron Capture in Holmium-163) experiment uses metallic magnetic calorimeter (MMC) detectors to calorimetrically measure the electron capture spectrum of Ho-163 with the goal of determining the effective electron neutrino mass via the analysis of the endpoint region. In the data analysis, a significant challenge is the identification and rejection of pile-up events for which the time interval is of the order or smaller than the rise time of the pulse signal. Those events represent an intrinsic background distorting the spectrum and therefore affecting the accuracy of neutrino mass determination. We present an approach using Principal Component Analysis (PCA) to identify pile-up events. Simulated events preserving the shape and noise of real events have been generated according to the shape of the Ho-163 spectrum, including pile-up events to test the developed algorithms. For the ECHo-LE experiment the unresolved pile up fraction, given as product of the pixel activity times the time resolution, should be kept below 10^{-6}, which for an activity of 10 Bq per pixel, implies a time resolution of 100 ns. We present the preliminary results obtained with the simulated data and discuss the implication of then in respect to the requirements for ECHo-LE.

T 45.3 Wed 16:45 AudiMax
Sterile-neutrino search based on 259 days of KATRIN data — •Xaver Stribl and Susanne Mertens for the KATRIN-Collaboration — Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland

Light sterile neutrinos with a mass on the eV-scale could explain several anomalies observed in short-baseline oscillation experiments. The Karlsruhe Tritium Neutrino (KATRIN) experiment is designed to directly determine the effective electron anti-neutrino mass by measuring the tritium beta decay spectrum. The measured spectrum can also be investigated for the signature of light sterile neutrinos.

In this talk we present the result of the light sterile neutrino analysis of the first five KATRIN measurement campaigns. To handle the computational challenge, a neural network is used. The obtained result is compared to results from other experiments and anomalies in the field of light sterile neutrinos.

T 45.4 Wed 17:00 AudiMax

Qualification Measurements Toward a New KATRIN Rear Wall — •Kerstin Trost[1], Dominic Batzler[1], Marco Röllig[1], Marius Schaufelberger[1], Marie Schäfer[1], Michael Sturm[1], and Mart van den Bosch[2] for the KATRIN-Collaboration — [1]Karlsruhe Institute of Technology, Germany — [2]Eindhoven University of Technology, Netherlands

Starting this year, the KATRIN experiment is undergoing a major upgrade to enable the search for sterile neutrinos in the keV mass range. This upgrade introduces a significant systematic uncertainty arising from electron backscattering at the upstream end of the tritium source, the Rear Wall (RW). To mitigate this effect, two new RW candidates, beryllium and microstructured silicon, are currently under investigation as they are expected to reduce the backscattering probability significantly.

This presentation discusses the ongoing qualification program for these Rear Wall candidates, including systematic studies of tritium accumulation as well as an ozone-based decontamination procedure. The stability of both materials under ozone exposure is assessed to ensure long-term compatibility with routine decontamination cycles. Furthermore, charge-up effects and potential surface modifications induced by ozone treatments are analyzed using Auger Electron Spectroscopy (AES). These characterization measurements form a crucial step toward implementing an optimized Rear Wall for the upcoming KATRIN keV sterile neutrino measurement phase.

T 45.5 Wed 17:15 AudiMax

Electron Backscattering at the Focal Plane Detector of KATRIN — •Philipp Lingnau for the KATRIN-Collaboration — Tritium Laboratory Karlsruhe (TLK), Institute for Astroparticle Physics (IAP), Karlsruhe Institute of Technology (KIT), 76344 Eggenstein-Leopoldshafen, Germany

The KATRIN experiment has put the most stringent model-independent upper limit on the electron antineutrino mass. The goal is to limit it to < 0.3 eV. To achieve this, a large amount of tritium beta-electrons need to be spectroscopied using a MAC-E-filter type spectrometer.

One systematic effect on the neutrino mass measurement is the detector backscattering. In the past we performed an in-situ measurement using time-of-flight spectroscopy. With it, the structure in electron energy loss due to plasmon excitations inside the detector can be resolved.

I will present the analysis of the measurement, featuring various improvements, including a rigorous investigation of the impact of fluctuations of the electrical potentials, improved electric and magnetic field simulations using Kassiopeia, as well as more in-depth ToF simulations.

In the future, this measurement principle and the analysis framework can be adapted for the TRISTAN phase of KATRIN, where understanding the escape spectrum from backscattered electrons is of greater importance than for KATRIN.

T 45.6 Wed 17:30 AudiMax

Detection of neutrons produced in neutrino-nucleus interactions with T2K — •Asit Srivastava — Johannes Gutenberg - Universität Mainz

T2K is a long-baseline experiment which measures parameters of neutrino oscillations. This can be done by analysing the interaction of neutrinos closer to the point of beam production and 295 km downstream. The detector located near the source of beam production, called ND280, primarily includes the interactions of neutrinos with carbon nuclei. The particles produced as a result of the interactions deposit energy in ND280 which is used to characterise the incoming neutrino flux and neutrino cross sections before oscillation occurs.

Out of all the particles produced in typical neutrino interactions, neutrons are by far the most challenging to detect since they are electrically neutral and do not leave a visible track in the detector. As a result, they provide uncertainties in identifying the interactions happening in the detector and measuring cross sections. ND280 has a newly installed Super Fine-Grained Detector (SFGD) made of plastic scintillator cubes. The upgraded detector capable of better position resolution and 3D reconstruction opens up the possibilities of improving the efficiency of neutron detection. Presence of a neutron is established using cuts on energy deposits and hence, possible neutron candidates, such as based on time of flight, kinetic energy of the candidate and the separation of energy deposit from the interaction vertex. This talk will go through neutron selection and how neutrons can help in understanding nuclear effects better.

T 45.7 Wed 17:45 AudiMax

Reconstruction of neutrino interactions with silicon strip detectors at the SHiP experiment — •James Webb, Christian Weiser, Yannika Matt, and Elias Bauknecht — Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, 79104 Freiburg, Germany

SHiP (Search for Hidden Particles) is a general purpose fixed target facility, currently in the design phase, and to be installed at CERN at the beginning of the next decade. A 400 GeV/c proton beam will be dumped on a heavy target, yielding an expected 6×10^{20} proton-target collisions over 15 years of operation. The beam dump will produce a huge neutrino flux of all three flavours, making this environment ideally suited for performing neutrino physics studies: a key component of the SHiP physics programme.

A proposed detector design for the measurement of neutrino interactions consists of a passive tungsten plane, followed by a pair of silicon strip detectors, oriented such that the pair of strips are directed perpendicularly. Many such layers are envisioned to be stacked-up along the beam axis to maximise the detector mass.

This talk will discuss the potential of such a detector in terms of a tracking detector (track and vertex reconstruction) and a high-granularity calorimeter, with an emphasis on the study of tau neutrino interactions.

T 45.8 Wed 18:00 AudiMax

Data-driven pile-up systematic estimation for neutrons in T2k ND280Upgrade detector — •Gioele Reina — JGU Mainz

The T2K experiment is a long baseline neutrino experiment, located in Japan. It studies neutrino oscillations by detecting accelerator neutrinos with a complex of near detectors and a far detector. ND280, one of the near detectors, provides a reduction of the neutrino flux and cross section uncertainties and performs cross section measurement. The new features of the upgraded ND280 detector allow to improve reduction these capabilities. In particular, the newly installed target, the Super Fine-Grained Detector, which consists of small plastic scintillator cubes read out by three WLS fibers in the three orthogonal directions, offers high granularity and 3D reconstruction. This new detector design unlocks the sensitivity to neutrons produced in charge-current interactions by measuring their time of flight in the detector.

In order to develop a selection of neutron events it is crucial to estimate the relevant systematic uncertainties. An important systematic uncertainty is related to the background contribution of the pile-up, which consists of simultaneous interactions that mimic the presence of a neutron in the signal sample. By creating a hybrid sample composed of signal events and enhanced background estimated in data, it is possible to evaluate the pile-up contribution using a data-driven approach. Here, this approach is described, along with the effects of this systematic on the signal sample selection.

T 45.9 Wed 18:15 AudiMax

Towards a High-Rate Active Neutrino Detector at FASER: Performance Studies with Deep Learning — Florian Bernlochner, Tobias Boeckh, Dhruv Chouhan, Jörn Mahlstedt, •Felix Antonio Junjiro Obando Molina, Matthias Schott, and Konstantinos Spyrou — Universität Bonn, Regina-Pacis-Weg 3, D-53113 Bonn, Germany

The FASER experiment at the LHC is a forward detector designed to study light, weakly interacting particles and has successfully established a dedicated neutrino program to measure high-energy collider neutrinos. During LHC Run-4, however, the expected increase in muon background rates will exceed the tolerable limits of the current emulsion-based neutrino detector, motivating the exploration of alternative technologies. We investigate the feasibility of an active neutrino detector concept based on multilayer active pixel sensors capable of operating at high rates. In this talk, we present a detailed study of neutrino reconstruction performance in such a detector using modern deep learning approaches, including deep neural networks (DNNs) and convolutional neural networks (CNNs), with a focus on efficient neutrino event classification in a challenging high-background environment.

T 46: Top Physics II

Time: Wednesday 16:15–18:00 Location: KH 00.011

T 46.1 Wed 16:15 KH 00.011

Measurement of the differential t-channel production cross-section of single top quarks and top antiquarks in proton-proton collisions at 13 TeV using the full Run 2 dataset recorded with the ATLAS detector — Dominic Hirschbühl, Lukas Kretschmann, •Maren Stratmann, and Wolfgang Wagner — Bergische Universität Wuppertal

The t-channel production is the dominant process for single top quark and single top antiquark production at the LHC. The measurement of the differential cross section can contribute to constraining proton PDFs and has not been measured with the full Run 2 dataset up to date. This measurement uses the full Run 2 dataset recorded with the ATLAS detector in the years 2015-2018. The differential production cross-sections of the top-quark and top-antiquark as well as their ratio are measured as a function of their transverse momentum p_{T} and rapidity $|y|$.

T 46.2 Wed 16:30 KH 00.011

Investigating systematic uncertainties in the search for single-top s-channel production — •Alfredo Manente and Andrea Knue — TU Dortmund, Otto-Hahn Str. 4a, 44227 Dortmund

An analysis of single top-quark production in the s-channel at a centre-of-mass energy of 13 TeV will be presented, using simulated proton–proton collision data corresponding to the Run 2 dataset recorded by the ATLAS detector at the Large Hadron Collider. The single top quark s-channel production mode is characterised by a relatively small production cross section and large backgrounds. To enhance the separation between signal and background processes, a Deep Neural Network (DNN) classifier is employed and used as the discriminant in a binned profile likelihood fit. The analysis focuses on the leptonic decay mode of the top quark, resulting in a final state consisting of one charged lepton, missing transverse momentum and two b-tagged jets. The signal strength of the single top-quark s-channel process is measured using an Asimov dataset and a detailed investigation of the statistical and systematic uncertainties will be shown.

T 46.3 Wed 16:45 KH 00.011

Using Machine Learning Techniques for a Search for Single Top Quark Production — •Niklas Düser and Andrea Knue — TU Dortmund

The search for single-top-quark production in the s-channel is experimentally challenging due to its small cross-section and similarity to dominant background processes. This analysis investigates two machine-learning approaches to enhance signal discrimination: a deep neural network (DNN) using high-level kinematic variables, and a graph neural network (GNN) encoding event topology through particle-object correlations. Both models were trained and evaluated on simulated proton-proton collisions at a center-of-mass energy of 13 TeV, corresponding to the Run 2 dataset at ATLAS with an integrated luminosity of 140 fb-1. The performance of the DNN and GNN is compared with a focus on signal and background modelling uncertainties.

T 46.4 Wed 17:00 KH 00.011

Measurement of differential cross-sections of single-top-quark production in association with a photon at the ATLAS experiment with $\sqrt{s}$ = 13 TeV — •Lucas Cremer[1], Nils Julius Abicht[1], Andrea Helen Knue[1], Tomas Dado[2], and Marina Andress[3] — [1]TU Dortmund — [2]CERN — [3]Bergische Universität Wuppertal

The inclusive measurement of single-top-quark production in association with a photon at the ATLAS experiment yielded an increased cross-section compared to the Standard Model prediction. As the analysis was not statistically limited, a measurement of differential cross-sections is performed to further investigate the excess.

A signal region enriched with $tq\gamma$ events is defined using machine learning techniques to separate signal and background events. Corresponding distributions sensitive to physics beyond the Standard Model are unfolded to particle level utilising a profile likelihood unfolding approach. An approach for the optimisation of the binning as well as the stability of the unfolding is investigated. The results estimated on the complete ATLAS Run-2 dataset, corresponding to an integrated luminosity of 140 fb^{-1}, are presented.

T 46.5 Wed 17:15 KH 00.011

Using Neural Networks to Identify Pure Signal Regions for $tq\gamma$ Production at the ATLAS Experiment — •Marina Andress[1], Andrea Knue[2], and Lucas Cremer[2] — [1]Bergische Universität Wuppertal — [2]TU Dortmund

Following the observation of single-top production in association with a photon at the ATLAS experiment, a differential cross-section measurement is performed. An event classification strategy for $tq\gamma$ events is developed, with the goal of defining a pure signal region suitable for a subsequent unfolding measurement. Such a region is essential to enable differential studies of this rare process, which directly probe the electroweak coupling of the top quark. Therefore, two machine learning approaches are investigated: a deep neural network with a conventional feed-forward structure and a graph neural network that incorporates event topology. The results are estimated using the full ATLAS Run-2 dataset, corresponding to an integrated luminosity of 140 fb^{-1}.

T 46.6 Wed 17:30 KH 00.011

Search for tWZ in proton-proton colisions at $\sqrt{s}$ = 13 and = 13.6 TeV with the ATLAS Experiment — Diptaparna Biswas, •Carolina Costa, Markus Cristinziani, Carmen Diez Pardos, Ivor Fleck, Gabriel Gomes, Jan Joachim Hahn, Nikolaos Kamaras, Vadim Kostyukhin, Nils Benedikt Krengel, Austin Olson, Inês Pinto, Sebastian Rentschler, Elisabeth Schopf, Katharina Voss, Wolfgang Walkowiak, and Adam Warnerbring — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

The production of top quarks in association with bosons are important Standard Model processes that allow tests of the electroweak couplings of the top quark to bosons. Any deviations of these couplings from Standard Model expectations could indicate the presence of new physics, which could be probed in the context of, e.g. Effective Field Theory interpretations. The associated production of a single top quark together with a W and a Z boson (tWZ) is one of the rarest processes accessible at the LHC, benefiting from the large proton-proton collision datasets collected at centre-of-mass energies of 13 TeV and 13.6 TeV. In this contribution, the ongoing effort to measure tWZ with the ATLAS detector using Run 2 and Run 3 data is presented. The measurement focuses on multilepton final states, where the Z boson and at least one of the two W bosons decay to leptons, yielding a final state with three or four leptons.

T 46.7 Wed 17:45 KH 00.011

Measurement of tWZ production with full Run 2 and 3 data at CMS — •Florent Préau, Roman Kogler, Alberto Belvedere, and Dennis Schwarz — Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, D-22607 Hamburg

The production of a single top quark in association with a W boson and a Z boson, also referred to as tWZ production, is a very rare process of high energy proton-proton collisions. It presents unique and important features when it comes to probing the Standard Model of particle physics and looking for physics beyond this model. This process offers the possibility to probe the electroweak couplings of the top quark, as well as its coupling to the Higgs field.

In this talk I will present the current state-of-the-art of the CMS tWZ analysis and will discuss some of the important extensions that I will explore during my PhD project. These extensions include performing an analysis with the full Run 2 and Run 3 datasets of CMS, performing a differential measurement of the process, and extracting top quark couplings using the Standard Model Effective Field Theory (SMEFT) framework.

T 47: Higgs Physics V

Time: Wednesday 16:15–18:15 Location: KH 00.014

T 47.1 Wed 16:15 KH 00.014

Top-Yukawa- and Light-Quark-Induced Electroweak Corrections in Higgs Pair Production — Arunima Bhattacharya[1], Francisco Campanario[1], •Sauro Carlotti[2], Jamie Chang[3], Javier Mazzitelli[3], Milada Margarete Mühlleitner[2], Jonathan Ronca[4], and Michael Spira[3] — [1]University of Valencia-CSIC, Spain — [2]Karlsruher Institut für Technologie, Germany — [3]Paul Scherrer Institut, Switzerland — [4]University of Padua, Italy

Since the discovery of the Higgs boson in 2012, the measurements of the Higgs self coupling remains a major challenge for current and future experiments in particle physics. Current projections for the trilinear coupling measurements at HL-LHC, and next generation of colliders, require the experimental precision to be matched by theory predictions. This necessitates besides the QCD corrections, which are found to be large, also the electroweak corrections (EW). The NLO corrections involve evaluation of two-loop Feynman diagrams. The EW corrections are a true challenge for the numerical solution of the two-loop integrals due to the presence of many different mass scales, such as the gauge boson, bottom, top quark, and Higgs boson masses. Additional challenges arise from numerical instabilities near virtual thresholds, which require a careful treatment. In my talk, I will present results for the EW corrections induced by the top Yukawa coupling, including contributions from light-quark loops, without using any reduction techniques to master integrals. All calculations are performed with fully symbolic masses while maintaining a manageable code size, enabling future studies of parametric and mass-scheme/scale uncertainties.

T 47.2 Wed 16:30 KH 00.014

Search for non-resonant Higgs boson pair production in $\mathrm{bb}\tau\tau$ **final states with the CMS experiment** — •Simon Daigler, Jan Voss, Nikita Shadskyi, Artur Gottmann, Roger Wolf, and Markus Klute — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technol-ogy (KIT)

Our preparation of a search for non-resonant Higgs boson pair production in $\mathrm{bb}\tau\tau$ final states is presented. A first setup of the analysis is based on the well-understood data of the LHC Run-2, of the year 2018, which have been completely re-reconstructed by the CMS Collaboration. The $\mathrm{e}\tau_\mathrm{h}$, $\mu\tau_\mathrm{h}$, and $\tau_\mathrm{h}\tau_\mathrm{h}$ final states are analysed. Event classification is based on neural network multi-class classification. The sensitivity is compared to a previous publication of CMS.

T 47.3 Wed 16:45 KH 00.014

Status of the $HH \to \bar{b}b\tau^-\tau^+$ **anaylsis with the CMS experiment with Run 3 data** — •Ana Andrade, Bogdan Wiederspan, Nathan Prouvost, Marcel Rieger, Moritz Wolf, Tobias Kramer, Quintus Diepholz, Benjamin Le, Jonah Fischer, and Peter Schleper — University of Hamburg

The shape of the Higgs potential plays a crucial role in our understanding of vacuum stability. The potential is directly dependent on the Higgs boson self-coupling which, despite continuous efforts, has yet to be experimentally determined. One way to probe its existence is through double Higgs boson production, where one Higgs boson can directly decay into two Higgs bosons. The predicted cross-section of such a decay depends on the self-coupling strength and can therefore be probed with experimental data. The $\bar{b}b\tau^-\tau^+$ final state is a promising candidate to perform such a search, as it offers a good compromise between sufficient statistics and reasonably low background contamination.

This talk summarizes the current status of the $HH \to \bar{b}b\tau^-\tau^+$ analysis with Run 3 data recorded by the CMS experiment at a center-of-mass energy of $\sqrt{s}$ = 13.6 TeV. The techniques employed in background estimation, signal extraction, and statistical inference will be discussed, amongst other developments. Particularly, we will present recent work in the discriminator network which enhances the search sensitivity.

T 47.4 Wed 17:00 KH 00.014

Statistical analysis for the $HH \to b\bar{b}\tau^+\tau^-$ **analysis with the ATLAS detector** — •Pim Bijl, Karl Jakobs, Brian Moser, Benedict Winter, and Yingjie Wei — University of Freiburg, Freiburg im Breisgau, Germany

Di-Higgs production at the Large Hadron Collider (LHC) allows to directly measure the Higgs boson self-coupling and, in turn, the shape of the Higgs potential. This talk will present studies performed for the statistical analysis used to measure or establish limits on the di-Higgs signal strength in the $HH \to b\bar{b}\tau^+\tau^-$ decay channel, using the combined LHC Run 2 and partial Run 3 datasets of up to 191 fb^{-1} collected by the ATLAS experiment. This decay channel has one of the largest branching ratios of di-Higgs decays and provides a clean decay signature. Because di-Higgs production is expected to be a very small signal, the statistical analysis makes use of pseudo-experiments which serve to validate results of the analysis.

T 47.5 Wed 17:15 KH 00.014

Neural network classifier strategy for optimal Higgs boson self-coupling sensitivity in the CMS $HH \to bb\tau\tau$ **analysis** — Ana Andrade, •Benjamin Le, Bogdan Wiederspan, Marcel Rieger, Moritz Jonas Wolf, Nathan Prouvost, Peter Scleper, and Tobias Kramer — University of Hamburg

The Standard Model (SM) of particle physics remains one of the most accurate theories describing the universes matter and its fundamental interactions at the smallest scales. One prediction that is yet to be fully tested is the self-interaction of the Higgs boson, characterized by the trilinear coupling strength λ, which gives rise to the shape of the Higgs potential. Typical analysis strategies involve neural networks for signal-background classification, often trained with simulated signal events following the SM prediction for λ. However, in case the actual value of λ deviates from the SM expectation, kinematic properties are subject to change and therefore, rendering the choice of λ used during training suboptimal. This talk summarizes a study that addresses this challenge by exploring different neural network strategies, enhancing the sensitivity to a wide range of hypothetical self-coupling values.

T 47.6 Wed 17:30 KH 00.014

Searching for Higgs boson pair production in the $HH \to bb\tau\tau$ **channel with the ATLAS experiment** — •Katharina Häussler, Karl Jakobs, Brian Moser, Yingjie Wei, Christian Weiser, and Benedict Winter — University of Freiburg

The Standard Model (SM) predicts final states with multiple Higgs bosons, which have yet to be observed experimentally, to occur in proton-proton collisions at the LHC. The production of Higgs boson pairs is interesting especially because it provides a direct test of triple Higgs boson self-interactions. The $bb\tau\tau$ final state presents a good compromise between expected signal yields and background contamination, making it one of the golden channels to explore this phenomenon.

This talk presents the current ATLAS $HH \to bb\tau\tau$ analysis with a focus on the estimation of the background stemming from Z bosons produced in association with heavy flavour jets, which is a major background for the analysis.

T 47.7 Wed 17:45 KH 00.014

Estimation of the Background from $t\bar{t}$ **Events with Misidentified Tau Leptons in the Search for Di-Higgs Production in the** $bb\tau_\mathrm{had}\tau_\mathrm{had}$ **Channel with the ATLAS Detector** — •Baktash Amini, Brian Moser, Yingjie Wei, Christian Weiser, Benedict Tobias Winter, and Karl Jakobs — Albert-Ludwigs-Universität Freiburg

Interactions involving multiple Higgs bosons in the final state are yet to be observed. Higgs boson pair production via gluon-gluon fusion or vector-boson fusion involves tri-linear couplings of Higgs bosons providing a unique opportunity to observe the self-coupling at the LHC and to test the Standard Model. Thanks to a good balance of signal yields and signal purity, di-Higgs boson production with one Higgs boson decaying into two b-quarks and the other into two tau leptons is one of the best channels to observe this process. The second-largest background in the $HH \to bb\tau\tau$ analysis is top pair production, where at least one quark- or gluon-initiated jet is misidentified as a hadronic tau decay. This background is estimated via a data-driven scale-factor method. The talk presents this method for the analysis of the ATLAS Run 2 and partial Run 3 datasets.

T 47.8 Wed 18:00 KH 00.014

Studies for validating the CMS Run-3 HH $\to b\bar{b}\gamma\gamma$ analysis with ZZ $\to b\bar{b}e^+e^-$ events — Johannes Erdmann, •Lea Jakubowski, and Nitish Kumar — III. Physikalisches Institut A, RWTH Aachen University

Since its discovery, the properties of the Higgs boson have been the subject of extensive study. Of particular interest is the structure of the Higgs potential, which can be constrained by measuring the trilinear Higgs self-coupling. This coupling can be accessed via Higgs boson pair production. However, owing to the small predicted production cross-section relative to the background processes, it has yet to be observed experimentally.

A particularly promising channel for probing this interaction is the HH$\to b\bar{b}\gamma\gamma$ decay. Its sensitivity arises from the large branching fraction of H$\to b\bar{b}$, combined with the low background rates and excellent mass resolution achievable in the H$\to\gamma\gamma$ final state.

This talk presents studies for validating the CMS Run-3 nonresonant HH $\to b\bar{b}\gamma\gamma$ analysis via a well-understood Standard Model process with a similar final-state topology. The validation channel, ZZ $\to b\bar{b}e^+e^-$, is chosen due to its significantly higher cross-section compared to di-Higgs production and the similar detector signatures of electrons and photons, which yield a final-state signature closely mirroring HH $\to b\bar{b}\gamma\gamma$. By employing an analysis strategy analogous to that of the HH$\to b\bar{b}\gamma\gamma$ search, we perform studies toward a cross-section measurement of ZZ$\to b\bar{b}e^+e^-$ that aims to provide a robust validation and benchmark for the di-Higgs analysis.

T 48: Methods in Particle Physics III

Time: Wednesday 16:15–18:15 Location: KH 00.020

T 48.1 Wed 16:15 KH 00.020

Muon flux measurements at SND@LHC for the LHC p+O run — •Jannis Thienel, Heiko Lacker, and Eduard Ursov — Humboldt-Universität zu Berlin

The Scattering and Neutrino Detector at LHC (SND@LHC) has collected data from various runs of proton-proton (pp) collisions at the ATLAS interaction point (IP1) of the LHC in a previously unexplored pseudo-rapidity range of $7.2 < \eta < 8.4$. The analyses of these runs have successfully demonstrated the detection of (high-energy) neutrinos, including the first detection of muon-neutrino charged-current interactions. Muon flux measurements are essential to quantify one of the backgrounds to neutrino measurements and to verify Monte Carlo simulations. A dedicated investigation of the muon flux in the very forward direction from the p+O collisions at SND@LHC might be of interest for testing hadronic interaction models relevant for cosmic airshower physics. First preliminary results of these muon flux measurements will be presented.

T 48.2 Wed 16:30 KH 00.020

Supressing muon-induced background in SHiP with the Surrounding Background Tagger — •Jasmin Weiss — Humboldt-Universität zu Berlin

SHiP (Search for Hidden Particles) will be a fixed-target experiment at CERN's SPS designed to search for feebly interacting particles (FIPs) in the GeV range. Installed in a dedicated beam-dump facility in the ECN3 cavern, SHiP will use 400 GeV/c SPS protons to reach $6 \cdot 10^{20}$ on-target collisions over 15 years of data taking, while suppressing backgrounds from the intense muon and neutrino flux emerging from the beam dump. A key element is the Surrounding Background Tagger (SBT), which encloses the 50 m helium-filled decay volume and tags charged particles entering from the sides as well as inelastic interactions occurring inside the decay volume.

The contribution focuses on simulation studies evaluating muon-induced backgrounds and the performance of the SBT in rejecting these events, highlighting their impact on the overall background-suppression strategy.

T 48.3 Wed 16:45 KH 00.020

Muon Momentum Scale and Resolution Calibration for CMS in Run 3 — •Dorian Guthmann[1], Markus Klute[1], Filippo Errico[2], and Jost von den Driesch[1] — [1]Karlsruhe Institute of Technology — [2]INFN

Precise muon momentum calibration is essential for many analyses at the LHC, as detector misalignment and magnetic field uncertainties lead to systematic differences between data and simulation. Within the CMS experiment, updated scale and resolution corrections for Run 3 data were derived over the past year using the ScaReKIT framework, which was also optimized with a focus on performance and stability. These improvements streamline the calibration workflow and reduce the computational cost of producing accurate calibration factors. This presentation highlights the motivation, methodology, and recent progress in refining the CMS muon momentum calibration, as well as the outlook for further improvements in upcoming datasets.

T 48.4 Wed 17:00 KH 00.020

Calibrating Charm Jet Tagging in ATLAS — Diptaparna Biswas, Carolina Costa, Markus Cristinziani, Carmen Diez Pardos, Ivor Fleck, Gabriel Gomes, Jan Joachim Hahn, Nikolaos Kamaras, Vadim Kostyukhin, Nils Benedikt Krengel, Austin Olson, •Inês Pinto, Sebastian Rentschler, Elisabeth Schopf, Katharina Voss, Wolfgang Walkowiak, and Adam Warnerbring — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

Classifying jets according to the flavour of the initiating parton is essential for many ATLAS analyses involving b- and c-quarks. Recent developments employ end-to-end transformer architectures to improve jet flavour identification. In this talk, we present an alternative data-driven calibration of the c-jet tagging efficiency using the W+c method, which selects $W + c$ events through a soft muon from the semi-leptonic decay of a charmed hadron. The charge correlation between the W boson and the charm quark strongly suppresses backgrounds, allowing a clean determination of the c-jet content. Unlike the standard $t\bar{t}$-based calibration, which is not suitable for Beyond the Standard Model top-quark studies, this method provides an independent and complementary handle on c-jet performance. We present current measurements of the c-jet efficiency, and the c-jet mis-identification efficiency in the case of b-jet identification, in data and simulation, and derive the corresponding scale factors.

T 48.5 Wed 17:15 KH 00.020

Finding Photon Fusion processes with a track veto — •Daniel Werner — DESY, Hamburg

Photon Fusion processes offer the possibility of studying QED production modes in the otherwise QCD dominated environment of the LHC. A key difference between the production of leptons via photo fusion or the Drell-Yan process is the presence of underlying events. To exploit this difference, a veto on any tracks near the primary vertex can be used.

This talk aims to introduce both photon fusion processes and the reconstruction of tracks in the ATLAS detector. A focus is put on tracks with a low transverse momentum that can boost the discrimination power of the veto. Reconstruction efficiencies are shown for low momentum tracks in Run 4.

T 48.6 Wed 17:30 KH 00.020

Calibration of the Photon Identification Efficiency in ATLAS — •Leonor Santos Pereira Trigo — Deutsches Elektronen-Synchrotron (DESY), Zeuthen, Germany

The accurate measurement of photon efficiency remains an essential ingredient of many physics analyses at the LHC and with the ATLAS detector. Considering the reliance of said analyses on simulation samples, the calculation of scale factors quantifying the differences in how accurately the ATLAS detector identifies real photons and fake photons between simulation and real data is an important task. One of the methods used to obtain these scale factors is the matrix method, which provides a data-driven estimate for the efficiency of the ATLAS detector in distinguishing photons of interest from other particles misidentified as photons. With the use of data regions enriched in either true or misidentified photons, it is possible to estimate the photon identification efficiency within ATLAS with minimal reliance on background simulation.

T 48.7 Wed 17:45 KH 00.020

Determining the τ-Lepton Efficiency in a Global Approach at the ATLAS Experiment — •Harilal Bhattarai, Philip Betchler, and Christian Grefe — Physikalisches Institut, Universität Bonn

The measurement of the hadronic τ-lepton identification efficiency at ATLAS is important for the proper modeling of signal and background processes, which directly impacts the sensitivity to Standard Model (SM) and BSM phenomena. In this approach, we will measure tau ID at a centre of mass energy $\sqrt{s} = 13$ TeV, across multiple channels such as $Z \to \tau\tau$ and $W \to \tau\nu$.

In this analysis, we use Run 2 data corresponding to an integrated luminosity of 139 fb^{-1} and applying optimized selections on lepton isolation, tau p_T, η, and charge requirements to suppress backgrounds. We perform a global measurement of tau ID efficiencies and the corresponding Data-to-MC scale factors at ATLAS for 1-prong and 3-prong τ candidates using the HAPPy and ROOT frameworks. In this talk, we will present the efficiencies and scale factors.

T 48.8 Wed 18:00 KH 00.020

Determination of Universal Tau Fake Factors for the Run 3 Data Taking Period of ATLAS — •Christian Schmidt, Arno Straessner, and Asma Hadef — Institut für Kern- und Teilchenphysik, Technische Universität Dresden

Tau leptons are an important product in collision events at the LHC; they primarily decay into a hadronic final state. Hadronic jets can easily produce similar signatures inside the ATLAS detector, leading to misidentified or "fake" taus, so it becomes necessary to estimate the fake tau background. The Fake Factor (FF) method estimates this background from data events with non-isolated tau candidates using a correction factor which depends on the transverse momentum of the tau candidate. In addition, the FF depends on the origin of the fake-producing jets, such as quark or gluon jets. Instead of measuring the FFs in a separate control region for each physics analysis, the Universal Fake Factor (UFF) method uses an estimate of the jet composition to linearly interpolate the FFs.

This talk will present the general principles of the UFF method, the process and data preparation being used to determine the UFF parameters in ATLAS Run 3 data, and current results.

T 49: Electronics, Trigger, DAQ II

Time: Wednesday 16:15–18:15 Location: KH 00.023

T 49.1 Wed 16:15 KH 00.023

Readout Electronics for the ECHo-LE Experiment — •Timo Muscheid, Robert Gartmann, Daniel Crovo, Matthias Balzer, and Luis Ardila-Perez for the ECHo-Collaboration — Karlsruhe Institute of Technology, Karlsruhe, Germany

Precise knowledge of the neutrino mass is crucial for solving fundamental questions in the Standard Model of Particle Physics. The ECHo collaboration aims to further limit the electron neutrino mass by analyzing the electron-capture spectrum of Holmium-163. ECHo-100k employs 10,000 detectors with a total activity of 100 kBq to improve energy resolution through increased measurement statistics. For operation of these microwave-SQUID-multiplexed pixels a custom Software-defined radio (SDR) system has been developed. This system is responsible for stimulating the resonators in the 4-8 GHz band, frequency demultiplexing and flux-ramp demodulation of the carrier tones as well as online data rate reduction. The next phase, ECHo-LE, will further increase the pixel count to 20,000 across 25 cryogenic readout lines. The room-temperature readout system will be based on the existing SDR electronics from ECHo-100k, completed by 10 additional modules. Firmware development will continue, focusing on enhanced capabilities such as tone-tracking, which promises to reduce distortion and intermodulation. In this contribution, we will present the proposed hardware architecture and firmware concept of the ECHo-LE room-temperature readout electronics. We discuss potential hardware upgrades and new firmware features of the SDR, highlighting their importance for meeting the high demands of the experiment.

T 49.2 Wed 16:30 KH 00.023

Compact and fast ADCs for pixel detectors — •Kennedy Caisley, Hans Krüger, and Jochen Dingfelder — University of Bonn, Germany

This work investigates improving analog to digital converters (ADCs) in the context of CMOS pixel detectors; a discipline with perhaps the most stringent silicon area constraints. We assembled a custom flow built on open source chip design tools, which enabled comparisons between circuit topologies and process nodes including 180, 65, and 28 nm. We then fabricated a prototype ASIC in 65 nm using this methodology, aiming for a state-of-the-art 2500 μm^2 area and 100 μW power budget, while sustaining a performance of 12-bit resolution at 10 Ms/s. Initial validation of this prototype and our on-going developments will be presented.

T 49.3 Wed 16:45 KH 00.023

Readout Electronics for the IceCube Surface Array Enhancement — •Frederik Schmitt[1], Megha Venugopal[1], Andreas Weindl[1], Alexander Novikov[2], Frank Schröder[1,2], Andreas Haungs[1], and Matthias Kleifges[3] for the IceCube-Collaboration — [1]Institute of Astroparticle Physics (IAP), Karlsruhe Institute of Technology, Germany — [2]University of Delaware, Newark, USA — [3]Institute for Data Processing and Electronics (IPE), Karlsruhe Institute of Technology, Germany

The IceCube Neutrino Observatory consists of a cubic-kilometer in-ice neutrino detector and the IceTop surface detector. IceTop comprises 81 pairs of ice-Cherenkov tanks for air-shower detection. As part of the upgrades, IceTop will be equipped with new surface stations, each consisting of eight scintillator panels and three radio antennas. Three of these stations are already in operation at the South Pole, and more are to be installed in the coming years in the area of the current IceCube experiment. The design is also the baseline for the surface instrumentation of IceCube-Gen2.

In this contribution, we focus on improvements to the current readout electronics deployed in prototype stations at IceCube, Pierre Auger, and the Telescope Array. Additionally, we present the development status of a new generation of the electronics capable of being implemented in the future IceCube and IceCube-Gen2 readout system. This design is based on a multi-FPGA board and provides GSa/s radio readout capabilities along with extensive onboard memory for signal buffering.

T 49.4 Wed 17:00 KH 00.023

Upgrade of the KlauS6 ASIC — •Yung-Wei Chang — Im Neuenheimer Feld 227, 69120 Heidelberg

In this talk, we share recent work on the KLauS ASIC, which was designed for the prototype of CALICE collaboration's Analog Hadron CALorimeter (AHCAL) and now is undergoing significant enhancements to its digital blocks and IOs to better meet the needs of future experimental applications in particle physics. The next generation of the KlauS6 ASIC will emphasize improvements in its digital interface robustness, aim at achieving higher measurement data rate and increased adaptability in experimental settings. As in previous versions, the new design incorporates strategies for low power consumption with the requirements of high-density channel applications, ensuring that the KLauS ASIC remains a cutting-edge solution for scintillator-based calorimetry in future collider experiments.

Key features of the upgraded KlauS6c include dual-configurable interfaces via both I2C and SPI, which will facilitate integration with various systems and enhance operational flexibility. Furthermore, the ASIC will support numerous speed options of LVDS readout exceeding 160 Mbps, ensuring rapid data transmission to accommodate the demands of future circular collider (FCC) experiments. Improved packaging options, compatible with QFN84 and QFN100, will provide greater reliability and ease of integration. The upgraded KlauS6c will maintain its core functionalities still on high precision charge measurement and a wide dynamic range, allowing for comprehensive and precise silicon photomultiplier (SiPM) readout behavior.

T 49.5 Wed 17:15 KH 00.023

Validation of the SiPM-on-Tile Readout Chain for the CMS High Granularity Calorimeter — •Fabian Hummer — Institute for Data Processing and Electronics, Karlsruhe Institute of Technology, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

For the upcoming high-luminosity LHC, the endcap calorimeters of the CMS experiment will be replaced by the high-granularity calorimeter (HGCAL), a sampling calorimeter using silicon sensors in the front and plastic scintillators read out by SiPMs in the back. We have built and tested a complete horizontal slice of scintillator tile modules and readout electronics under realistic installation, grounding and powering conditions. Using this system, we validated the powering scheme, assessed the system stability and demonstrated data readout with the Serenity back-end hardware. The successful validation of the SiPM-on-Tile front-end as a complete system is an important milestone towards the construction and operation of HGCAL. In this contribution, we will describe our system validation setup and showcase results from bench-top tests.

T 49.6 Wed 17:30 KH 00.023

Enabling lpGBT Interface Prototyping with a New FPGA Mezzanine Card — •Dmitry Eliseev, Nils Esper, Carsten Presser, Markus Merschmeyer, Alexander Schmidt, and Thomas Hebbeker — III. Physikalisches Institut A, RWTH Aachen University

The lpGBT (Low Power GigaBit Transceiver) is a radiation-tolerant ASIC developed to provide robust, high-speed, bidirectional optical links for the next generation of high-energy physics experiments. It is dedicated to communicate via optical links and supports transfer rates up to 10 Gb/s. The chip integrates Timing and Trigger Control (TTC), Data Acquisition (DAQ), and Slow Control (SC) data streams into a single constant-latency link. This unified architecture enables reliable transmission of timing, trigger, control, and monitoring information between the counting room and on-detector electronics, even in the harsh radiation environment of the LHC.

This talk introduces a newly developed FMC mezzanine board that provides an accessible and flexible platform for working with the lpGBT ASIC. It gives engineers and researchers a practical way to explore, test, and integrate the lpGBT into their detector readout and control systems. With the ready to use electrical and firmware interfaces, the board supports early development without requiring a full custom electronic and firmware design.

The talk gives an overview of the board's design features, from the optical SFP link to the on-board switches for selecting lpGBT working modes. It also presents a brief overview of the IP cores for interfacing.

T 49.7 Wed 17:45 KH 00.023

ITkPix Read-out Chip Software Emulator for the ITk Pixel Online DAQ Software — Matthias Drescher, Jörn Grosse-Knetter, •Timo Pospiech, Arnulf Quadt, and Ali Skaf — II. Physikalisches Institut, Georg-August-Universität Göttingen

During the approaching ATLAS HL-LHC phase 2 upgrade, the current Inner Detector will be replaced by the all-silicon Inner Tracker (ITk). In particular, the ITk pixel part will be composed of around 9k detector modules built with about 30k ITkPix read-out chips. The data acquisition (DAQ) read-out system needs to deal with the tremendous challenges it faces and, of course, be validated before the commissioning of the new ITk. With the read-out software as the head of the chain, it needs to be running reliably to acquire data and test other components of the DAQ chain, ideally at a large-scale system level.

To help with the development and debugging of the read-out software, a software model of the on-detector hardware is needed. As such, this project focuses on developing a standalone C++ software emulator of the ITkPix front-end, which can be used for that purpose. The software emulator faithfully replicates the behaviour of the ITkPix-V2 chip, which is the final production read-out chip. With that, the behaviour of the emulator is as close to the real conditions as possible. The emulator is validated against already existing read-out chain tools and will be integrated in the online DAQ software, allowing system-level development and debugging, but could also be used during actual data taking for validation purposes.

T 49.8 Wed 18:00 KH 00.023

Front-End Readout for the LHCb Migthy SciFi Tracker — Carlos Garcia Argos, Marco Gersabeck, •Michael Lupberger, Santiago Ochoa, Ksenia Solovieva, and Jan Sorokovski — Albert-Ludwigs-Universität Freiburg, Freiburg im Breisgau, Germany

During CERN's Long Shutdown 4, several sub-detectors of the LHCb experiment will be replaced. This upgrade is required to cope with the further increase in instantaneous luminosity and with the radiation that will accumulate until the end of the experiment's lifetime.

One of these is the tracker located downstream of the spectrometer magnet. The current tracking detector is based on Scintillating Fibres (SciFi). It will be replaced by a hybrid detector, called Mighty Tracker, that combines HV-CMOS MAPS in the central region near the beam pipe and new SciFi modules in the outer part. The latter will be read out using Silicon Photomultipliers operated at cryogenic temperatures. Their signals will be processed by a front-end chip, which is controlled and read out by lpGBT chips. The readout board is housed in a metal box that serves cooling and shielding.

This contribution presents the current status of the front-end readout. It focuses on the key requirements and on how the design aims to satisfy them.

T 50: Data, AI, Computing, Electronics V

Time: Wednesday 16:15–18:00 Location: KH 00.024

T 50.1 Wed 16:15 KH 00.024

NEEDLE - A modern orchestration framework for Neural Simulation Based Inference tools — •Kylian Schmidt[1], Ulrich Husemann[2], Nicoló Trevisani[1], Stephen Jiggins[2], Levi Evans[2], Judith Katzy[2], Stefan Katsarov[2], Felix Kahlhöfer[3], Nino Kovačić[4], Lena Rathmann[3], and Niklas Reus[3] — [1]ETP, KIT, Karlsruhe — [2]DESY, Hamburg — [3]IAP, KIT, Karlsruhe — [4]Department of Physics, U. of Zagreb

Neural Simulation Based Inference (NSBI) is a new machine learning (ML) paradigm for statistical data analysis in high energy physics (HEP). These tools learn the underlying statistical distribution of the data using surrogate neural networks and show clear improvements over classical likelihood estimation methods. However, these methods require the training of a large number of networks in order to achieve this increase in performance while retaining robustness towards biases. It is therefore crucial to address the challenges of orchestrating many neural network trainings, alongside efficient utilization of computational resources.

The NEEDLE project aims to provide a flexible framework for distributed training together with a library of NSBI tools for deployment on High Performance Computing clusters. NEEDLE combines modern ML libraries together with commonly-used HEP data analysis tools and formats. In this talk, we present the design of the NEEDLE framework, how it handles large data streams and our integration with pytorch lightning.

T 50.2 Wed 16:30 KH 00.024

Search for keV-Scale Sterile Neutrinos with TRISTAN at KATRIN Using Neural Simulation-Based Inference — •Luca Fallböhmer for the KATRIN-Collaboration — Max-Planck-Institute for Nuclear Physics

Following the completion of its neutrino mass measurement program at the end of 2025, the KATRIN experiment aims to probe keV-scale sterile neutrinos by analyzing the full tritium beta decay spectrum with a novel detector system, TRISTAN. Leveraging KATRINs high source activity, this search is sensitive to mixing amplitudes at the parts-per-million level. However, extracting a potential sterile neutrino signature is challenging, as it relies on detailed modeling of the the observed tritium spectrum and requires computationally intensive Monte Carlo simulations. To address this challenge, we implement neural simulation-based inference using normalizing flows to approximate the underlying probability density of the physics simulation. We demonstrate that continuous normalizing flows trained via conditional flow-matching enable highly efficient modeling of experimental spectra. This approach opens up the possibility of a fast surrogate model for rapid sampling and generates a continuous, unbinned representation of the KATRIN beamline response, accelerating and enabling the analysis pipeline.

T 50.3 Wed 16:45 KH 00.024

Unbinned, High-dimensional Precision Measurements through the Lens of Deep Learning — •Jingjing Pan — Karlsruhe Institute of Technology, Karlsruhe, Germany

Unbinned, high-dimensional machine learning-based unfolding has rapidly progressed from a conceptual method to a practical analysis tool now deployed across multiple experiments, including but not limited to ATLAS, CMS, H1, LHCb, STAR and T2K. Building on the classifier-based framework of OmniFold, recent work has consolidated best practices for validation, calibration, uncertainty quantification, and data-release format, enabling robust unbinned measurements in the natural high-dimensional phase space of experimental data. Two recent analyses that highlight this progress are presented in this talk.

The recent H1 measurement performs the first OmniFold unfolding of all final-state particles in high-Q^2 events using a point-edge transformer to process variable-length event topologies. This full-phase-space result enables both re-measurements of classic DIS observables and new projections, such as simultaneous jet measurements in the laboratory and Breit frames from a single unfolded dataset. Meanwhile at the LHC, ATLAS has applied ML-assisted unfolding to extract jet track-function moments while circumventing binning artifacts that affect non-linear QCD evolution studies. These results demonstrate that modern ML-based unfolding delivers systematically controlled, fully differential data products that are broadly reusable for downstream physics.

T 50.4 Wed 17:00 KH 00.024

Unbinned Unfolding of the WWbb Analysis with OmniFold — •Josef Murnauer, Daniel Britzger, and Stefan Kluth — Max-Planck-Institute for Physics

We revisit the recently published ATLAS measurement of WWbb production and explore an alternative unfolding strategy based on OmniFold. The newly published single- and di-lepton WWbb cross-section measurements have demonstrated that this process constitutes a major new avenue for precision studies in top-quark physics at the LHC. New paradigms in data analysis for Run-III and beyond are emerging rapidly, with traditional techniques (such as cut-and-count or matrix-based unfolding) increasingly being superseded by more flexible and powerful machine-learning algorithms. We present initial results from applying an unbinned unfolding technique to the WWbb analysis in the lepton+jets channel, highlight its potential advantages over standard unfolding methods, and discuss its implications for Run-III data analyses.

T 50.5 Wed 17:15 KH 00.024

Binary Black Hole Parameter Estimation using a Conditioned Normalizing Flow — •Markus Bachlechner and Achim Stahl — III. Physikalisches Institut B, RWTH Aachen

The proposed Einstein Telescope is the first of the third-generation gravitational wave detectors. It is expected to reach a noise level at least one order of magnitude lower than current interferometers like LIGO and Virgo. Thus, the improved sensitivity increases the observable volume and extends the time window in which the inspiral phase of binary systems is measurable. To analyze the resulting vast amounts of data efficiently, Neural Networks (NNs) can be utilized. This talk presents a fast Binary Black Hole parameter reconstruction using a conventional convolutional NN, which conditions a subsequent Normalizing Flow (NF). Using the NF, an approximate posterior parameter distribution is obtained on an event-by-event basis, allowing for the estimation of uncertainties.

T 50.6 Wed 17:30 KH 00.024

Normalizing-Flow-Based Reweighting of Detector Systematics in Neutrino Telescopes — •Oliver Janik — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

Accurate measurements of the astrophysical neutrino flux require reliable predictions of the detector response in neutrino telescopes. Because this response is highly non-analytical, such predictions rely on Monte Carlo (MC) simulations and a forward-folding approach. A key limitation is that MC simulations must assume specific detector properties. Evaluating detector systematic uncertainties therefore requires either simulating multiple MC sets with fixed detector parameters or using approaches such as SnowStorm, which sample detector parameters continuously on an event-by-event basis. In both cases, reweighting typically relies on interpolation between MC expectations, introducing an implicit dependence on an assumed flux model.We present a normalizing-flow*based approach that factorizes detector systematics into shape and yield components. A conditional normalizing flow is used to model changes in the distribution of reconstructed observables, while the overall event yield is modeled separately as a function of the relevant detector parameters. This separation enables consistent reweighting for both discrete MC sets and SnowStorm simulations, without relying on flux-dependent interpolation.In this talk, we demonstrate the application of this method to detector-systematics modeling in astrophysical neutrino flux measurements.

T 50.7 Wed 17:45 KH 00.024

Covering Unknown Correlations in Bayesian Priors by Inflating Uncertainties — •Lukas Koch — JGU Mainz

Bayesian analyses require that all variable model parameters are given a prior probability distribution. This can pose a challenge for analyses where multiple experiments are combined if these experiments use different parametrisations for their nuisance parameters. If the parameters in the two models describe exactly the same physics, they should be 100% correlated in the prior. If the parameters describe independent physics, they should be uncorrelated. But if they describe related or overlapping physics, it is not trivial to determine what the joint prior distribution should look like. Even if the priors for each experiment are well motivated, the unknown correlations between them can have unintended consequences for the posterior probability of the parameters of interest, potentially leading to underestimated uncertainties. In this presentation I will show that it is possible to choose a prior parametrisation that ensures conservative posterior uncertainties for the parameters of interest under some very general assumptions.

T 51: Flavour Physics III

Time: Wednesday 16:15–18:45 Location: KH 01.011

T 51.1 Wed 16:15 KH 01.011

Angular analysis technique for systems of two identical vector mesons and its applications in the LHCb experiment — •Ilya Segal, Mikhail Mikhasenko, and Marian Stahl — Ruhr-University Bochum, Bochum, Germany

The angular analysis of systems composed of two identical vector mesons offers a powerful framework for probing a wide range of physical phenomena. Notable examples include searches for all-charm tetraquarks $T_{cc\bar{c}\bar{c}}$ in the $J/\psi\,J/\psi$ system, investigations of glueball candidate in the central exclusive production of $\phi\,\phi$, and studies of the internal structure of charmonia through their decays to $\phi\,\phi$. A dedicated technique for constructing reaction amplitudes for the production of resonances decaying into pairs of identical vector particles is presented. The method accounts for the full symmetry properties of the system and provides a consistent framework for amplitude modeling and angular analysis. Applications of this technique to LHCb data are presented.

T 51.2 Wed 16:30 KH 01.011

Dalitz analysis of B to D pi pi decays — •Melisa-Melek Akdag — University of Bonn, Bonn, Germany

Recent studies have provided strong evidence that the D_0^* meson is better described by an amplitude modeled using unitarized chiral perturbation theory rather than a traditional Breit-Wigner distribution. This finding underscores the importance of a more nuanced approach to modeling these states. The $D^+\pi^-\pi^-$ decay is dominated by a loop diagram that includes the ρ meson, resulting in significant theoretical uncertainties. To mitigate these uncertainties, we directly access the ρ meson in the analysis by incorporating the isospin conjugated modes which include the π^0 via the decay chain $\overline{B}^0 \to D^+\rho^-$ into our considerations.

To achieve these goals, it is crucial to analyze not only the $B^- \to D^+\pi^-\pi^-$ final state, which the LHCb experiment can measure with high precision, but also decays involving neutral pions, emerging from $\overline{B}^0 \to D^+\pi^-\pi^0$, where the Belle II experiment can uniquely contribute. This allows us to study the orbitally excited charmed mesons, the D_0^* and the D_2^* in the $D\pi\pi$ final state, and the D_1, D_1' and D_2^* in the $D^*\pi\pi$ final state. By studying both processes we can test heavy quark spin symmetry in these final states.

T 51.3 Wed 16:45 KH 01.011

Pole Search for $\Xi^*(1620)$ and $\Xi^*(1690)$ Resonances in the $\Xi_c^+ \to \Xi^-\pi^+\pi^+$ Decay at LHCb — •Anna Lena Zimmer, Mikhail Mikhasenko, and Marian Stahl — Ruhr-Universität Bochum, Germany

Understanding the excitation spectrum of strange baryon resonances remains a challenge. In particular, many excited Ξ baryon states are poorly established and their properties vary widely between models. Pole positions characterize hadronic states in a reaction-independent manner, but are rarely determined with rigor. This project aims to extract the pole positions of $\Xi^*(1620)^0$ and $\Xi^*(1690)^0$ using parameters from an amplitude model of the decay $\Xi_c^+ \to \Xi^-\pi^+\pi^+$. The model is based on an analysis of the proton*proton collision data obtained by the LHCb detector at $\sqrt{s} = 13\,\text{TeV}$. The resonance poles are determined directly from the parameterized K-matrix model, coupling the $\Xi\pi$, $\Lambda\bar{K}$, $\Sigma\bar{K}$ and $\Xi\eta$ scattering channels. The extracted pole parameters aid in accurate reaction-independent quantification of the excitation spectrum and evaluation of coupled channel effects.

T 51.4 Wed 17:00 KH 01.011

Angular analysis of $\Omega_b^- \to \Xi_c^+ K^-\pi^-$ using LHCb Run3 data — •Dhruvanshu Parmar, Mikhail Mikhasenko, and Marian Stahl — Ruhr-Universität Bochum, Bochum, Germany

Using Run2 data, five excited states of Ω_c^0 were observed decaying into $\Xi_c^+K^-$ in prompt inclusive production. From exclusive Ω_b^- decays, reconstructed with LHCb Run2 data, spin and parity of four out of the five previously observed states were studied. However, the results were inconclusive due to the limited statistics of Run2 dataset. To address this, the study of process $\Omega_b^- \to \Xi_c^+K^-\pi^-$ is motivated using Run3 data of LHCb experiment, enabling precise measurement of these quantum numbers of excited Ω_c^0 states. Additional sensitivity in helicity amplitude of Ω_c^0 is achieved by accounting for the spin and parity dependencies arising from Ξ_c^+ decay. Selection techniques implemented to filter Ω_b^- events from Run3 data will be highlighted in the presentation, which are crucial to get necessary statistical precision for the angular analysis.

T 51.5 Wed 17:15 KH 01.011

Lineshape study of the $\chi_{c1}(3872)$ state with LHCb — •Robert Hentges[1], Mikhail Mikhasenko[1], Vanya Belyaev[2], and Matthew Needham[3] — [1]Ruhr-University Bochum — [2]Sapienza Universita e INFN, Roma — [3]University of Edinburgh

After its dicovery in 2003, the $\chi_{c1}(3872)$ state, also known as $X(3872)$, has been established as an exotic hadron. However, its exact nature as meson-anti-meson molecule, compact tetraquark, conventional charmonium or a mixture thereof is still being investigated. Using the full LHCb Run 1&2 data set of the inclusive $b \to (X(3872) \to J/\psi\,\pi^+\pi^-) + Any$ and exclusive $B^+ \to (X(3872) \to J/\psi\,\pi^+\pi^-)\,K^+$ decays, this analysis probes different lineshapes in their ability to describe the recorded data. The probed lineshapes arise from diverse theoretical models, taking into account the proximity of the $\chi_{c1}(3872)$ state to the $D^0\overline{D}^{*0}$ threshold. From these lineshapes, this analysis aims at precise determination of the physical parameters mass m and width Γ, as well as the scattering parameters. Especially knowledge of its position relative to the $D^0\overline{D}^{*0}$ threshold is required to advance our understanding of the state. Thus, a special focus is set on the systematic uncertainty stemming from background interference.

T 51.6 Wed 17:30 KH 01.011

Implementation of a generic three-body decay model in EvtGen for a Ξ_c^+ polarimetry analysis — •Henry van der Smagt, Ilya Segal, Mikhail Mikhasenko, and Marian Stahl — Ruhr-University Bochum, Bochum, Germany

The amplitude-serialization project of the LHCb Bochum group as part of the BMFTR-funded Democratizing-Models (DEMOS) consortium provides a generic and well-structured format that facilitates reproducibility and exchange within the high-energy physics community. This work presents a C++ implementation of the helicity formalism using the Dalitz-plot decomposition method. The framework is integrated into a new decay model EvtThreeBodyDecays for EvtGen, the main b-physics event generator, which constructs amplitude models from JSON descriptions. The model enables the inclusion of the recently published $\Xi_c^+ \to pK^-\pi^+$ decay variables in hadronic amplitude analyses involving the Ξ_c^+ baryon. Furthermore, it provides access to the polarimetry vector field of this decay, allowing studies of Ξ_c^+ polarization and improved handling of model-dependent uncertainties by describing all 31 alternative models.

T 51.7 Wed 17:45 KH 01.011

Event Selection for $\Upsilon(5S)$ Entanglement Studies — •Kilian Brückner, Hans-Günther Moser, Vanessa Geier, Louise Beriet, and Celia Álvarez — Max Planck Institut für Physik, Boltzmannstraße 8, 85748 Garching

The entanglement of $B^0\bar{B}^0$ meson pairs from $\Upsilon(4S)$ decays is an important resource for many analyses, especially for time dependent CP violation analyses. At the $\Upsilon(5S)$, however, more features of the entanglement itself can be studied.

Due to the higher energy of the $\Upsilon(5S)$, excited B^{0*} mesons can be produced from its decay. These spin 1 excited B^{0*} states decay via the emission of a photon, so that $C = +1$ and $C = -1$ entangled $B^0\bar{B}^0$ states are produced. In comparison, The $\Upsilon(4S)$ only provides a state entangled with a $C = -1$ wave function.

The challenge for an analysis at the $\Upsilon(5S)$ arises from the low amount of 121 fb^{-1} of data, so far taken only by Belle. This requires an efficient event selection with many decay channels to keep statistics high enough.

In this talk, the full event selection for the analysis is described. This includes choosing the decay channels of the B mesons, as well as handling all occurring backgrounds. For the main background source of $q\bar{q}$ continuum, a gradient boosted decision tree is utilized.

T 51.8 Wed 18:00 KH 01.011

Entanglement studies with Belle $\Upsilon(5S)$ data — •Louise Beriet, Vanessa Geier, and Hans-Günther Moser — Max Planck Institute for Physics, Garching, Germany

Compared to the $\Upsilon(4S)$, the $\Upsilon(5S)$ can decay into excited B^{0*}, giving rise to $B^0/\bar{B}^0$ pairs in different quantum states. Directly after the $\Upsilon(5S)$ decay, the produced $B^{0(*)}\bar{B}^{0(*)}$ pairs are expected to be in a $J^{PC} = 1^{--}$ state. Following the radiative transition $B^{0*} \rightarrow B^0\gamma$, the system evolves into states with $J^{PC} = 1^{-+}$. Depending on the C-parity, the $B^0/\bar{B}^0$ can be in a symmetric (triplet) or antisymmetric (singlet) wave function, leading to different time evolutions of the entangled states. By mixing the two C-parity states $C = -1$ and $C = +1$, one can create a mixed state that is physically indistinguishable from a disentangled system.

We aim to study these effects using the $\Upsilon(5S)$ data available from Belle. The analysis includes the reconstruction of the signal $B^{0(*)}$ meson pairs through the decay chain $B^0 \rightarrow D^-(\rightarrow K^+\pi^-\pi^-)\pi^+$, as well as obtaining the vertex and flavor information of the other B-meson inclusively. In addition, the $B^0/\bar{B}^0$ quantum states are separated using the variables M_{bc} and ΔE.

We analyze the quantum coherence using the Partial Spontaneous Disentanglement model, which quantifies the entanglement via a number $\zeta \in [0, 1]$. This parameter can be extracted by performing a likelihood fit on time-dependent parameters, which themselves can be computed from the spatial separation of the B^0 pair. First results using Monte Carlo data are presented.

T 51.9 Wed 18:15 KH 01.011

Separation of different quantum states of B^0 $\bar{B}^0$ meson pairs at the Upsilon $5S$ — •Celia Álvarez Álvarez, Kilian Brückner, Vanessa Geier, and Hans-Günther Moser — Max Planck Institut für Physik, Boltzmannstr. 8 85748 Garching.

At the Upsilon $5S$ the energy is high enough that B^0 can be produced in excited states such as $\Upsilon(5S) \rightarrow B^0\bar{B}^0$, $\Upsilon(5S) \rightarrow B^{0*}\bar{B}^0 + c.c.$ and $\Upsilon(5S) \rightarrow B^{0*}\bar{B}^{0*}$. The B^{0*} decays via the emission of a photon and $B^0/\bar{B}^0$ pairs can be observed in different quantum states. Those pairs which stem from $B^0\bar{B}^0$ and $B^{0*}\bar{B}^{0*}$ have a $C = -1$ antisymmetric wave function, while the ones that decay from $B^{0*}\bar{B}^0 + c.c.$ have a $C = +1$ symmetric wave function. The different states show different forms of entanglement.

Using data of the Belle experiment, these three decay modes are reconstructed through the three hadronic decay chains: $B^0 \rightarrow D^-\pi^+$ with $D^- \rightarrow K^+\pi^-\pi^-$, $B^0 \rightarrow D^{*-}\pi^+$ with $D^{*-} \rightarrow \bar{D}^0\pi_s^-$ and $\bar{D}^0 \rightarrow K^+\pi^-$ or $\bar{D}^0 \rightarrow K^+\pi^-\pi^+\pi^-$. Using M_{bc}, the three decay modes are separated and signal and background is fitted using ΔE. Using the S-weight technique the Δt signal is extracted and a signal fit is performed with the weighted data.

T 51.10 Wed 18:30 KH 01.011

Study of Quantum Disentanglement in the $B^0\bar{B}^0$ System at Belle II — •Abhijith Rajagopalan, Maximilian Kei Hattenbach, Sagar Hazra, and Hans-Günther Moser — Max-Planck-Institute for Physics, Munich, Germany

Quantum entanglement has been extensively tested in systems of photons and atoms. Its investigation in the context of heavy, unstable particles such as B mesons remains an active and compelling area of research. Quantum entanglement is a crucial assumption for time dependent CP violation studies at Belle II. However, a fraction of these $B^0\bar{B}^0$ pairs that are disentangled would introduce systematic uncertainties in these studies, which are currently not accounted for. We present simulation-based studies of quantum entanglement in the $B^0\bar{B}^0$ system using the hadronic $B^0 \rightarrow D^{(*)-}\pi^+$ and $D^-\pi^+$ decay channels. We test the model of partial spontaneous disentanglement, in which a fraction of the $B^0\overline{B}^0$ pairs lose their entanglement and subsequently evolve independently.

T 52: Silicon Detectors V

Time: Wednesday 16:15–18:15 Location: KH 01.012

T 52.1 Wed 16:15 KH 01.012

Performance of FBK Trench-Isolated LGAD coupled to Timpix3 Chip — •Chin-Chia Kuo, Erika Garutti, Jörn Schwandt, Annika Vauth, and Constanze Wais — University of Hamburg, 22761, Luruper Chaussee 149, Hamburg, Germany

The widely used instrumentation telescope operated at the DESY-II beam lines consists of six sensor planes using MIMOSA 26 monolithic active pixel devices for track reconstruction. However, the readout time of the current telescope is around 115 μs. As a result, a time reference layer is necessary to properly associate telescope tracks with the hits in the device under test. Additionally, a layer with high time resolution would provide a reference for the characterization of timing detectors. The low-gain avalanche diode (LGAD) with a good time resolution at the picosecond level is a good candidate for this purpose. LGAD with an isolated trench design is chosen for the study. With the trench design, the multiplication layer is extended, resulting in a better fill factor. In this presentation, the performance of FBK TI-LGAD bump-bonded to the Timepix3 chip is presented, including the gain factor, efficiency, and time resolution. Modules are tested at the DESY testbeam facility, using electrons with an energy of 3 GeV.

T 52.2 Wed 16:30 KH 01.012

Characterization of CASSIA 1, an LGAD design in a commercial CMOS imaging process — •Silas Müller, Christian Bespin, Hans Krüger, Lars Schall, Sinou Zhang, Alexander Walsemann, Rasmus Partzsch, Fabian Hügging, and Jochen Dingfelder — Physikalisches Institut der Universität Bonn, Nußallee 12, 53115 Bonn

Next-generation detector technologies have to cope with high rate environments, where precise time-tagging is needed. Sensors with internal gain may offer several advantages for these applications. They can achieve higher signal amplitudes, which can simplify the design of in-pixel electronics, and their superior timing performance may be beneficial for future 4D tracking or time-tagging applications. The CASSIA project (CMOS Active SenSor with Internal Amplification) seeks to develop monolithic active pixel sensors (MAPS) with internal signal gain and low noise, implemented within the Tower Semiconductor 180 nm process. This talk presents first characterization results from CASSIA 1, a prototype designed to test the feasibility of integrating a gain layer in a 180 nm commercial CMOS imaging Tower Semiconductor process. Different gain layer configurations are examined and results from electrical tests as well as measurements with radioactive sources are shown. Gain measurements obtained with pulsed lasers of different wavelength and initial test beam results are presented.

T 52.3 Wed 16:45 KH 01.012

Test beam studies of Resistive Silicon Detectors — •Niyathikrishna Meenamthuruthil Radhakrishnan[3], Roberta Arcidiacono[1], Nicolo Cartiglia[2], Alexander Dierlamm[3], Ling Leander Grimm[3], Lorena Hahn[3], Markus Klute[3], Aurora Losana[4], Brendan Regnery[3], and Luca Menzio[5] — [1]Univesita di Piemonte Orientale — [2]Istituto Nazionale di Fisica Nucleare — [3]Karlsruhe Institute of Technology, Karlsruhe, Germany — [4]University of Turin — [5]CERN

Resistive Silicon Detectors (RSDs) are among the most promising candidates for 4D tracking for future colliders where precise position and timing information will be quintessential for tracking. RSDs are based on the Low Gain Avalanche Diode technology with an additional resistive layer which enables spread of signal so that a single particle hit induces signal on multiple readout pads, and the reconstruction results in a higher resolution compared to traditional pixelated or strip detectors. The talk will give a summary of the results obtained from the data collected during the test beam measurements at the H6B beam line of the CERN SPS North Area with 120 GeV pions in October 2025. The setup consisted of two DC coupled RSD sensors and one AC coupled RSD sensor. This talk will emphasize the efforts to improve track reconstruction and analysis of test beam data with the software framework, Corryvreckan.

T 52.4 Wed 17:00 KH 01.012

A novel Low Gain Avalanche Diode design: MARTHA — •E. C. Wais[1], A. Baehr[2], J. Damore[2], E. Garutti[1], C. Koffmane[2], J. Ninkovic[2], E. Prinker[2], R. H. Richter[2], G. Schaller[2], F. Schopper[2], J. Schwandt[1], and J. Tries[2] — [1]University of Hamburg — [2]Semiconductor Laboratory of the MPG

To cope with the high interaction rates of new colliders, detectors with time resolution in the range of 10 ps are required to disentangle pile-ups. LGADs are a promising candidate for this task. LGADs feature a low amplification gain, which enables good timing resolution in thin sensors. However, due to the strong electrical field in the gain region, LGADs tend to break down at the pixel edges. In order to overcome this, the sensors have to be equipped with complex separation structures, which usually result in dead areas without gain between pixels. The Monolithic Array of Reach THrough Avalanche diodes design aims to tackle this problem, by combining a deeply implanted gain layer followed by an additional n-doped Field Drop Layer. This reduces the electric field at the n+-edges, thereby preventing them from breaking down. Since the gain region is not segmented, there are no dead spaces in the inter-pixel regions. A first prototype batch with test structures is being investigated. The sensors are optimized for photon detection without any specific timing requirements and are expected to have a fill factor of 100%. Future R&D aims to optimize this design for fast timing applications. In this talk, the MARTHA concept, characterization measurements and first test beam data from the DESY 2 test beam facility, are presented.

T 52.5 Wed 17:15 KH 01.012

Probing the Acceptor Removal Effect in Silicon Test Diodes Mimicking LGAD Gain Layers — •P. Erberk, E. Garutti, J. Schwandt, and E. Fretwurst — Universität Hamburg

P-type low gain avalanche diodes are silicon sensors with an intrinsic charge multiplication gain layer. They offer high temporal resolution and are foreseen to be used in HL-LHC timing detectors but are susceptible to radiation damage. Especially in the highly boron doped gain layer the acceptor removal effect occurs, leading to boron defect formation. This process not only deactivates the boron atoms as dopants but also leads to the formation of BiOi defects. These defects are detrimental to the gain layer as they counteract the local electric field by providing positive space charge, eventually removing the gain layer. Carbon co-doping has shown promising results in mitigating gain loss, as the implantation of carbon atoms is believed to influence the boron defect formation kinetically. The study of radiation-induced defects in the gain layer using microscopic defect spectroscopy techniques is challenging as it is difficult to distinguish between bulk and gain layer. To enable more precise investigation of defect kinetics, silicon diodes on highly doped p-type substrates mimicking the gain layer were produced, a total of 25 wafers with test structures covering various doses of carbon implantation, phosphorous co-doping, and oxygenation. This extensive set of samples allows to systematically investigate and thereby parametrize the acceptor removal effect. In this talk the analysis of the samples before and after irradiation including DLTS, TSC and IV/CV measurements is presented.

T 52.6 Wed 17:30 KH 01.012

Characterisation of an Enhanced Lateral Drift (ELAD) Sensor Prototype — •Judith Schlaadt, Naomi Davis, Doris Eckstein, Moritz Guthoff, Simon Spannagel, Anastasiia Velyka, and Gianpiero Vignola — DESY, Hamburg, Germany

The development of vertex and tracking detectors for future lepton colliders faces various challenges regarding time and position resolution while maintaining a low material budget and the capability to process high particle rates. In this context, one approach to improve the spatial resolution is to utilise the effect of charge sharing Here, the ratio of the signal amplitudes measured by neighbouring readout electrodes gives information about the hit position of the traversing particle. By applying a magnetic field and exploiting the Lorentz drift of the generated charge carriers in the sensor volume, charge sharing can be observed. Also, tilting the sensor results in the same effect. However, neither approach is suitable for vertex detectors, since the effect is not sufficient in the case of thin sensors.

The enhanced lateral drift (ELAD) sensor prototype addresses these requirements by featuring a multiple-layer design including buried doping implants. The deep implants generate an additional lateral electric field inside the sensor bulk, resulting in increased charge sharing. Through simulations, the sensor design was optimised to allow for position-dependent charge sharing close to the theoretical optimum, which results in an improved impact position interpolation. This talk presents first results of the characterisation of an ELAD sensor prototype.

T 52.7 Wed 17:45 KH 01.012

The ATLAS High Granularity Timing Detector: Quality Control Results on Low Gain Avalanche Diodes — •Theodoros Manoussos[1,2], Simon Koch[1], Guilherme Saito[3], Marco Leite[3], Dominik Dannheim[1], Stefan Guindon[1], and Lucia Masetti[2] — [1]CERN — [2]Johannes Gutenberg-Universität Mainz, Germany — [3]Universitade de São Paulo, Brasil

The increase in instantaneous luminosity at the High Luminosity-LHC will be a challenge for the ATLAS detector, as the pile-up is expected to increase to an average of 200 interactions per bunch crossing. To sustain current physics performance and mitigate pile-up effects, a High Granularity Timing Detector (HGTD) will be integrated into the ATLAS end-cap regions, covering a pseudorapidity range of $2.4 \le |\eta| \le 4.0$. HGTD aims to achieve 30 ps per-track time resolution for MIPs in the beginning of the lifetime, up to 50 ps after a maximum fluence of $2.5 \cdot 10^{15}$ n_{eq}/cm^2. High-precision timing information improves the correct assignment of tracks to vertices. HGTD sensors are based on the Low Gain Avalanche Diode (LGAD) technology. They provide moderate internal gain, resulting in fast rise time and large signal-to-noise ratio, required for excellent time resolution. Each sensor is a 15×15 array of 1.3×1.3 mm^2 LGAD pads. Along with the sensors, an equal amount of Quality Control-Test Structures (QC-TS) is produced to monitor the quality and uniformity of wafers and extract various technology and fabrication parameters during production. This contribution presents process quality control measurements on QC-TS of the initial phase of the HGTD sensor production.

T 52.8 Wed 18:00 KH 01.012

Module assembly for the ATLAS High Granularity timing detector — •Hendrik Smitmanns[1], Jessica Höfner[1], Frederic Maximilian Matthias Silvan Fischer[1], Annika Stein[1], Lucia Masetti[1], Andrea Brogna[2], Atila Kurt[2], Fabian Piermaier[2], Steffen Schönfelder[2], Quirin Weitzel[2], and Florian Lika[2] — [1]Institut für Physik, Johannes-Gutenberg Universität Mainz — [2]PRISMA+ Detector Lab, Johannes-Gutenberg Universität Mainz

To meet the challenges of the High Luminosity Large Hadron Collider (HL-LHC), especially the increase of pile-up interactions, the ATLAS detector will need to be upgraded. One of the foreseen upgrades will be the installation of the High-Granularity Timing Detector (HGTD). The HGTD will mitigate the effects of pile-up in the ATLAS forward region, providing a time resolution of about $30 - 50$ ps per track. The active detector area consists of 2-double-sided disks per end-cap. A disc side contains about 1000 modules, each consisting of two $2x2$ cm^2 Low Gain Avalanche Detectors which are bump-bonded to two ASICs and glued to a PCB. Multiple modules are then glued onto a support unit to form a detector unit, which will then be built into the final detector at CERN. The current phase of pre-production is used to test and finalize all procedures towards production, for while around 1000 modules, roughly 10 % of the final detector, will be assembled at Johannes Gutenberg University Mainz, one of the six assembly sites. The complete assembly procedure of the final version of the detector module is presented, with focus on assembly, metrology, wire bonding, initial testing and the assembly process for the detector units.

T 53: Scintillator Detectors II

Time: Wednesday 16:15–18:30 Location: KH 01.014

T 53.1 Wed 16:15 KH 01.014

3d-Printing of Structured Plastic Scintillators — •Philipp Karl Kollar, Fabian Piermaier, Sebastian Ritter, Steffen Schönfelder, and Quirin Weitzel — JGU Mainz

Future experiments at high energy colliders call for calorimeters with high granularity. For scintillator-based sampling calorimeters, scintillator tiles, combined with a SiPM-based readout system, have established as a scalable solution to achieve such high granularity. To simplify production and assembly, structured scintillators-large scintillator plates, divided into optically isolated sections-offer a promising approach. Such structured scintillators can be produced in one single step by 3d-printing, while keeping the design customizable. In this presentation, the quality of 3d-printed scintillators will be discussed based on measurements utilizing cosmic muons. Additionally a comparison to injection-molded scintillators will be presented together with approaches for optimizing printing and polishing methods.

T 53.2 Wed 16:30 KH 01.014

Increasing Photon Capture Rate of Wavelength-Shifting Fibers for Opaque Scintillator Experiments — •Bastian Kessler and Sebastian Böser for the NuDoubt-Collaboration — Johannes Gutenberg-Universität Mainz

Wavelength-shifting optical fibers are widely used to collect and guide scintillation light from large detector volumes to photosensors, making them ideal for water Cherenkov and scintillator-based detectors. A key limitation, however, is their low photon capture efficiency, which degrades energy resolution of fiber-based detectors.

Building on prior work, we show that capture efficiency can be enhanced by optimizing the fibers absorption profile and adding a low-refractive-index outer cladding to boost total internal reflection. Although this reduces the fibers effective active area - rendering it less suitable for transparent detectors - it is advantageous in opaque scintillators, where photons remain localized and may hit the fiber multiple times before they get absorbed in the scintillator.

In this work, we study the impact on photon capture rate, cluster size, and timing performance in the hybrid opaque scintillator experiment NuDoubt++. Also, results of the first prototypes of optimized wavelength-shifting fibers (OWLs) are shown.

T 53.3 Wed 16:45 KH 01.014

Update on the Constuction of SuperSANDI for ANNIE — •Philipp Kern, Michael Wurm, Noah Goehlke, Amala Augusthy, and Johann Martyn — JGU Mainz

The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is a CHerenkov neutrino detector at the Booster Neutrino Beam (BNB) at Fermilab. To also allow measurements with scintillation light, a water based scintillator (WbLS) is installed inside the detector. The advantage of WbLS in the detector is that it is possible to extreact the energy of the neutrinos with the scintillation light as well as the trajectory of it with the Cherenkov cone. To allow us to observe the full potential of the water based scintillator by a full reconstruction of extended neutrino event vertices, a vessel made of nylon holding 8000 litres will be deployed in 2026. To be able to deploy this vessel into ANNIE it must be inflatable to be able to fill out the whole volume of the detector. We will present you with the current status of the development of this vessel, SuperSANDI, which has unique challenges because of its size and the properties of the WbLS.

T 53.4 Wed 17:00 KH 01.014

Characterisation of internal backgrounds in JUNO using BiPo-214 decays — •Ujwal Santhosh[1,2] and Livia Ludhova[1,2] — [1]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — [2]Institute of Physics and EC PRISMA+, Johannes Gutenberg Universität Mainz, Mainz, Germany

The Jiangmen Underground Neutrino Observatory (JUNO) operates at a depth of 700 m underground in South China. The detector has multiple ambitious physics goals, but to achieve them, JUNO must maintain the radiopurity of the scintillator at very high levels. This work focuses on the ^{238}U decay chain, which is assumed to be in secular equilibrium because of its long lifetime and can therefore be determined by measuring ^{214}BiPo coincidences. ^{214}Bi decays into ^{214}Po with a characteristic prompt-delayed signature that can be isolated using spatial and temporal coincidence. However, the secular equilibrium of isotopes below ^{222}Rn in the ^{238}U chain can be disturbed by radon influx from the surrounding air. This is characterised by an increase in the BiPo-214 rate, as they are the decay products of radon. Such contamination can typically occur during detector filling in the presence of small leaks. In a closed system, the broken equilibrium is then restored in weeks due to the relatively short lifetime of radon. This study follows the ^{214}BiPo rate during filling to search for radon leaks and later in a stable data-taking period to extract the ^{238}U level.

T 53.5 Wed 17:15 KH 01.014

First light in the MANGO target cell — •Elena Winiker[1], Daniela Fetzer[1], Michael Wurm[1], Manuel Böhles[1], Hans Steiger[2], and Kai Loo[3] — [1]Johannes Gutenberg-Universität Mainz — [2]Technische Universität München — [3]University of Jyväskylä

The Mainz Advanced Neutron Gamma Observatory (MANGO), currently in the final stages of construction in Mainz, is designed as a testing facility for scintillating detector materials used in neutrino experiments, such as JUNO.

High energy photons up to 9 MeV are generated by neutron capture on a converter and subsequently Compton scattered on the detector material. Varying the selected scattering angle enables the measurement of characteristics such as the linearity of the scintillation response across a wide range of energy depositions in the target, which is an important systematic for measuring the neutrino mass ordering in JUNO.

Additionally, the neutron converter can be removed to investigate the detector response to a neutron signal. The energy deposition of the scattered neutrons can be ascertained from the time of flight to the secondary detector.

This talk will outline the current status of construction of MANGO, focusing in particular on test measurements of coincidence events in the target cell.

T 53.6 Wed 17:30 KH 01.014

Development and Performance of a High-Pressure Scintillator Test Cell for NuDoubt^{++} — •Magdalena Eisenhuth for the NuDoubt-Collaboration — JGU Mainz, Institute of Physics

The investigation of two-neutrino and neutrino-less double beta decay is crucial for understanding the Dirac or Majorana nature of neutrinos. In this context, the krypton isotope Kr-78 (Q=2.88 MeV) stands out as a promising candidate for a first detection of two-neutrino producing decays, electron-capture beta-plus decay (2nuECb+) and double-beta decay (2nubb+). Detectors like the NuDoubt^{++} experiment featuring hybrid opaque scintillator can profit from solving krypton gas in the scintillator at high pressure to increase the number of target nuclei, thereby enhancing the probability of observing the extremely rare double beta decay modes. This presentation explores the ongoing development of a small-scale scintillator test cell for high-pressure loading, designed to examine the loading factor of krypton in scintillator as well as the influence on scintillator properties. We discuss the calibration required for a quantitative determination of the krypton concentration. Finally, we elaborate on the light yield and overpressure performances of the test cell and possible improvements.

T 53.7 Wed 17:45 KH 01.014

status of the cosmogenic analisis in the Jiangmen underground neutrino observatory — •Marcel Büchner, Tim Charisse, Arshak Jafar, Michael Wurm, Daniela Fetzer, Oliver Pilarczyk, and Manuel Böhles — Johannes-Gutenberg-Universität Mainz

The Jiangmen underground neutrino observatory (JUNO) is a 20 Kton liquid scintillator experiment located approx. 700m underground in the Guangdong province in China. Its main physics goal is the determination of neutrino mass ordering. To achieve that goal, it measures reactor neutrinos produced by two nuclear power plants that are located approx. 53 km away from the experimental site. Even at this depth, cosmic muons pass through the detector regularly. These muons are not only a significant background source but also produce various radioactive isotopes. This presentation focuses on the selection of these cosmogenic isotopes, which while producing an additional background can also be used to calibrate the detector for higher energies.

T 53.8 Wed 18:00 KH 01.014

Quality control of wavelength-shifting optical modules for the SHiP Surrounding Background Tagger — •Ida Wöstheinrich for the SHiP-SBT-Collaboration — Humboldt-Universität zu Berlin

SHiP (Search for Hidden Particles) is a general-purpose beam dump experiment in preparation at CERN. Its goal is to search for new Feebly Interacting Particles at the GeV-scale in an environment of effectively zero background. The Surrounding Background Tagger (SBT) is a key part of SHiP's background-suppression system. It detects muons entering SHiP's helium-filled decay volume from the sides, as well as muon and neutrino inelastic interactions within the volume. The SBT is based on liquid scintillator as the active detector material, read out by Wavelength-shifting Optical Modules (WOMs). An SBT WOM consists of a PMMA tube dip-coated with a dye that absorbs scintillation photons in the range of 280 nm to 400 nm and re-emits photons in the visible spectrum. The re-emitted photons are guided to a circular Silicon photomultiplier array at the end of the WOM tube via total internal reflection inside the tube walls. Approximately 1800 WOMs are required for the SBT, and their performance must be consistent and verifiable. This talk will discuss the development of a dedicated setup for standardised quality control of the SBT WOMs, along with first results. The setup measures the amplitude and homogeneity of the response at different positions on the WOM surface using a pulsed UV LED and photomultipliers in an automated system.

T 53.9 Wed 18:15 KH 01.014

Probing hybrid scintillators for NuDoubt++ — •Dorina Zundel for the NuDoubt-Collaboration — Johannes Gutenberg Universität Mainz

Neutrinoless double beta-plus decays ($0\nu\beta^+\beta^+, 0\nu\beta^+$EC, 0νECEC) have yet to be observed, posing a significant experimental challenge in the search for rare lepton-number-violating processes. The NuDoubt++ project (Neutrino Double Beta Plus Plus) addresses this challenge by developing novel detection techniques that combine hybrid slow opaque scintillators with advanced light readout systems. The first prototype will employ enriched Krypton-78 gas at high pressure within an opaque scintillator vessel, enabling containment and detection of positrons and their annihilation photons. This configuration allows detailed reconstruction of event topology and particle identification, enhancing sensitivity to rare decay modes.
The characterization of slow scintillators is performed using the SCHLYP (**S**cintillation **CH**erenkov **L**ight **Y**ield **P**rism) laboratory setup. A hollow prism filled with scintillator samples is instrumented with three ultra-fast photomultipliers. A nearby ^{137}Cs source generates signals via Compton scattering, and a secondary detector selects recoil photons aligned with the prism geometry. Two PMTs detect Cherenkov and scintillation light, while the third detects only scintillation, allowing measurement of the relative contribution of Cherenkov and scintillation components. The talk will present improvements to the setup including a Cherenkov radiator, enabling precise determination of scintillator decay timing characteristics.

T 54: Higgs Physics VI

Time: Wednesday 16:15–18:15 Location: KH 01.019

T 54.1 Wed 16:15 KH 01.019

Search for heavy neutral Higgs bosons A and H in the $t\bar{t}Z$ channel at CMS — •Yannick Fischer, Matteo Bonanomi, Lukas Ebeling, Johannes Haller, and Matthias Schröder — Institut für Experimentalphysik, Universität Hamburg

While the measurements of the Higgs boson at 125 GeV are so far consistent with the standard model (SM) prediction, the observed particle might well be part of an extended Higgs sector. Such an extended Higgs sector is predicted by many theories of physics beyond the SM. Two Higgs Doublet Models (2HDM) assume the existence of a second Higgs doublet, giving rise to a total of five physical Higgs bosons. This talk presents a search for a hypothetical heavy CP-odd Higgs boson A decaying into a hypothetical CP-even heavy Higgs boson H and a Z boson, with the H decaying into a top quark-antiquark pair. This channel has been dubbed the "smoking gun" channel for electroweak baryogenesis in 2HDMs. We will present the status of $A \to ZH$ with $H \to t\bar{t}$ searches at CMS at 13 and 13.6 TeV centre-of-mass energy, focusing on the fully-hadronic decay channel of the $t\bar{t}$ system. The results exclude masses of the A boson up to several TeV and constrain the 2HDM parameter space relevant for electroweak baryogenesis.

T 54.2 Wed 16:30 KH 01.019

Strong First-Order Phase Transitions and Exotic Phases in the CP-Conserving 2HDM — Lisa Biermann[1], •Christoph Borschensky[2], Rafael Boto[2], Margarete Mühlleitner[2], Rui Santos[3,4], and João Viana[3] — [1]PSI Center for Neutron and Muon Sciences, Villigen, Switzerland — [2]Karlsruher Institut für Technologie, Germany — [3]Centro de Física Teórica e Computacional, Faculdade de Ciências, Universidade de Lisboa, Portugal — [4]Instituto Superior de Engenharia de Lisboa, Instituto Politécnico de Lisboa, Portugal

Extended scalar sectors can significantly influence the cosmological evolution of the early universe. The additional scalar degrees of freedom allow for strong first-order phase transitions (SFOPT) into the electroweak-broken vacuum, which induce gravitational waves that, for sufficiently strong signals, might be detectable in the near future. Additionally, the universe might have undergone exotic intermediate phases such as charge-breaking or CP-violating phases via a multi-step phase transition.

In this talk, the parameter space of the CP-conserving 2-Higgs-Doublet Model is investigated with the recent version 3 of the public code BSMPT. Within this model, we study the viability of SFOPTs in light of the recent experimental data from Higgs measurements and exotic Higgs searches. We present points involving different one- and multi-step phase histories, and study their features such as the size of the trilinear Higgs couplings as well as the strength of their gravitational wave signals.

T 54.3 Wed 16:45 KH 01.019

Precision predictions of partial decay widths in the general Two-Higgs-Doublet Model — •Jose Angel Hernandez Cuevas, Heidi Rzehak, Martin Gabelmann, and Robin Feser — Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, 79104 Freiburg, Germany

The Standard Model (SM) of particle physics has achieved remarkable success in describing a broad spectrum of experimentally observed phenomena in particle physics with high precision. However, there are still some phenomena that lie beyond its description, such as the existence of dark matter, the matter-antimatter asymmetry of the universe, and the origin of neutrino masses. Several extensions to the SM have been proposed to account for these phenomena. Among them, the general Two-Higgs-Doublet Model (THDM) provides a framework with a rich phenomenology. It comprises the symmetry-constrained THDM scenarios as special limits, and enables the study of new sources of CP violation, Higgs-mediated flavor violation, generalized Yukawa structures, and the impact of complex parameters in both the potential and the Yukawa sector. In this talk, I will present next-to-leading-order (NLO) predictions of partial decay widths of the Higgs boson within the general THDM. I will focus on Higgs-boson decays into fermions and on exploring renormalization conditions, including on-shell and $\overline{\text{MS}}$ renormalization conditions, together with different tadpole treatments, in order to establish criteria that can point to a good choice of renormalization schemes for some extensions of the SM.

T 54.4 Wed 17:00 KH 01.019

tbH$^+$ Analysis with Multileptons Using Run-2 ATLAS Data — •Azad Afandizada and André Sopczak — CTU in Prague

The latest results with Run-2 ATLAS data are presented for the search tbH$^+$ in the multilepton channel. The charged Higgs boson decay into WH is studied.

T 54.5 Wed 17:15 KH 01.019

Search for a charged Higgs ($H^\pm$) boson in $Wh(h \to bb)$ boosted channel using multivariate methods in ATLAS — •Satyajit Chakraborty and Tatjana Lenz — Physikalisches Institut, Universität Bonn, Germany

To address the shortcomings of the Standard Model, many models describing physics beyond the Standard Model (BSM) have been proposed. One such extension is the Two-Higgs-Doublet Model (2HDM), which predicts the existence of five Higgs Bosons: three neutral and two charged Higgs($H^{\pm}$).

This talk presents the search for a charged Higgs boson produced in association with a top quark and a bottom quark. The decay channel studied is $H^{\pm} \to W^{\pm}h$, where h is the Standard Model Higgs boson (125 GeV) and $h \to b\bar{b}$, while the $W^{\pm}$ boson decays either hadronically ($W^{\pm} \to qq'$) or leptonically ($W^{\pm} \to \ell\nu$). The analysis is performed in the high-p_T (Boosted) region using the full ATLAS Run-2 dataset. In this work, $H^{\pm}$ masses ranging from 1.2 TeV to 3 TeV have been studied. Multivariate methods based on a Deep neural network (DNN) architecture have been used to separate signal from background following the strategy used in the previous analysis. The use of a mass parameterized neural network (PNN) has also been investigated. The resulting limits on the charged Higgs boson production cross-section times branching ratio are compared between the two approaches to assess their relative performances.

T 54.6 Wed 17:30 KH 01.019

Jet Matching Performance with SPANet and GN3 in the Search for Charged Higgs Bosons Decaying to a cs Final State with the ATLAS Experiment — •Johannes Klas, Tatjana Lenz, and Jochen Dingfelder — Universität Bonn

The discovery of the Higgs boson solved the mystery of particle masses. Although the Standard Model requires the existence of only one Higgs boson, an extension of the Higgs sector with at least four Higgs bosons is possible and required by many theories beyond the Standard Model, e.g. SUSY. This leads to the existence of a pair of charged Higgs bosons with the same mass and opposite electric charges. The main production mechanism is $pp \to Wb\bar{b}H^{\pm}$ and the $H^{\pm} \to cs$ decay is one of the favoured decay modes. Below the top quark mass this is realized via $pp \to t\bar{t} \to Wb\bar{b}H^{\pm}$. The search targets leptonic decays of the W, resulting in a final state with at least four expected jets and one lepton. Matching these jets to the appropriate particles is a difficult task. New developments like SPANet offer improved performance in jet matching and signal/background separation. The possibility of further improvements using the GN3 flavour tagger, which is currently in development, is being investigated. This is especially relevant when considering improvements in the correct matching of the s-jet and the rejection of gluon-initiated jets.

T 54.7 Wed 17:45 KH 01.019

Search for resonances decaying to Higgs boson pairs at $\sqrt{s} = 13.6$ TeV with the CMS experiment — •Haoyu Wang[1,2], Suman Chatterjee[1], Elisabetta Gallo[1,2], Rainer Mankel[1], and Roberval Walsh[1] — [1]Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607, Hamburg, Germany — [2]University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

The Higgs boson, since its discovery, has been a powerful probe of physics beyond the standard model of particle physics. The CMS experiment at the Large Hadron Collider is analysing the data from the ongoing proton-proton collisions at $\sqrt{s} = 13.6$ TeV, which provides an unprecedented opportunity to search for the production of Higgs boson pairs through the decays of heavy resonances. The analysis to be presented here targets such new physics signatures in the final state with four bottom quarks. Cutting-edge machine-learning techniques are employed for the reconstruction of Higgs boson pairs and the estimation of standard model background. We present the expected sensitivity for a large range of resonance masses, using data corresponding to an integrated luminosity of 170 fb^{-1}.

T 54.8 Wed 18:00 KH 01.019

The CMS Run2 resonant HH $\to$ bb$\tau\tau$ analysis — •Tobias Kramer, Marcel Rieger, Peter Schleper, Ana Andrade, Nathan Prouvost, and Bogdan Wiederspan — Hamburg University, Hamburg, Germany

This contribution presents an analysis in the search for the decays of heavy spin 0/2 resonances to a pair of Higgs bosons in the bb$\tau\tau$ final state. A wide mass range of the hypothetical resonance from 250 GeV up to 3 TeV is covered. The analysed data correspond to 138 fb^{-1} recorded by the CMS experiment at the LHC from 2016 to 2018. The talk highlights key aspects, such as the momentum regression of the neutrinos from the tau decays and the neural network for signal-background classification, and will present the results of the analysis.

T 55: Silicon Detectors VI

Time: Wednesday 16:15–18:45 Location: KH 01.022

T 55.1 Wed 16:15 KH 01.022

Simulation and development of the Mighty-Tracker for LHCb Upgrade II — Johannes Albrecht, Dominik Mitzel, •Donata Osthues, Dirk Wiedner, and Lukas Witola — TU Dortmund University, Dortmund, Germany

During the High-Luminosity LHC period, the LHCb detector will be operated at a significantly higher instantaneous luminosity compared to Run 3.

To adapt to higher radiation levels and hit occupancies, the LHCb detector will undergo a second upgrade. The SciFi tracker will be replaced by the Mighty-Tracker, comprised of scintillating fibres in the outer region and silicon pixel sensors in the region closest to the beam pipe. The MightyPix modules are currently under development; the module design, serial powering and cooling solutions must be determined.

Simulation studies are a crucial input to these developments. This talk presents material budget scans, tracking efficiency calculations and momentum resolution results using a detailed detector geometry simulation based on the latest Mighty-Tracker design.

T 55.2 Wed 16:30 KH 01.022

Low-Mass Mechanics: Support structure investigations for the LHCb Mighty Tracker — •Ksenia Solovieva, Todor Todorov, and Marco Gersabeck — Albert-Ludwigs University Freiburg

In preparation for the challenging environment of the High Luminosity LHC, the LHCb detector will undergo major improvements. The Upgrade II is scheduled to be installed during Long Shutdown 4 and includes a replacement of the downstream tracker. The current scintillating fibre tracker detector will be replaced with a hybrid system, the Mighty Tracker, comprising layers of improved scintillating fibres and 6 layers of silicon pixel detectors. The latter requires optimisation in the detector design, service routing and support structures to adhere to a strict material budget of below 1% X/X0 per layer. In this presentation, a potential support structure solution and progress towards its prototyping is discussed.

T 55.3 Wed 16:45 KH 01.022

Performance Characterisation of LF-MightyPix for the LHCb Mighty Tracker — •Celina Welschoff, Sebastian Bachmann, Lucas Dittmann, Ruben Kolb, David Kuhn, and Ulrich Uwer — Physikalisches Institut, Universität Heidelberg

For Run 5 of the LHC, LHCb will reach an instantaneous luminosity of up to $1.0 \cdot 10^{34}\ cm^{-2}s^{-1}$. To cope with this challenging environment the current detector needs to be upgraded. One crucial part is the new main tracker, the Mighty Tracker. It will utilise scintillating fibres in the outer regions and silicon pixel sensors in the innermost region. For that inner region, prototype chips based on the High-Voltage Monolithic Active Pixel Sensor (HV-MAPS) technology have been developed. To fulfil the detector's requirements and support LHCb's physics performance, the sensors have to achieve a detection efficiency of > 99 % within the 25 ns bunch crossing period. LF-MightyPix is the first prototype sensor for the Mighty Tracker using the LFoundry process. The previous first and upcoming third prototype are produced with different foundries. Evaluating the performance of LF-MightyPix allows to qualify the LFoundry 150nm HV-CMOS process as possible technology for the Mighty Tracker pixel sensor. LF-MightyPix is a small scale prototype and has a size of $3.5\ mm \times 4\ mm$ and a pixel size of $100\ \mu m \times 100\ \mu m$. In addition, it features a LHCb compatible readout. In this presentation the key features of LF-MightyPix are outlined and the performance of LF-MightyPix is presented utilising both lab and testbeam results. These results show a detection efficiency of > 99 % within 25 ns, fulfilling the Mighty Tracker requirements.

T 55.4 Wed 17:00 KH 01.022

Investigation of X-ray-induced effects and resulting high backside currents in DePFET pixel sensors for the Belle II experiment — Florian Bernlochner, Jochen Dingfelder, and •Georgios Giakoustidis — University of Bonn, Bonn, 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 $E_{CM} = 10.58\ GeV$ and it has reached a record-breaking instantaneous luminosity of $5.1 \cdot 10^{34}\ cm^{-2}s^{-1}$ in December 2024. During the so-called Long Shutdown 1 (LS1) the innermost part of the Belle II detector, the initially descoped PiXel Detector (PXD1) with 20 modules, based on Depleted P-channel Field Effect Transistor (DePFET) technology, was replaced by a fully-populated, two-layer PXD with 40 modules. As the detector closest to the experiment's interaction region, the PXD is most exposed to radiation from the accelerator. Throughout the operation of the PXD1 a steady increase of backside current with irradiation was observed in several modules. Doping-profile measurements and electric field simulations show that this is a consequence of (partially) shorted guard rings at the backside leading to high electric fields and avalanche current multiplication. In this contribution, irradiation studies investigating both the X-ray-induced effects in DePFET sensors and the resulting high backside currents will be presented.

T 55.5 Wed 17:15 KH 01.022

Fast Shutdown for the Belle II Pixel Detector — •Paula Scholz[1], Jannes Schmitz[1], Florian Bernlochner[1], Jochen Dingfelder[1], and Michael Ritzert[2] — [1]Universität Bonn — [2]Universität Heidelberg

During beam loss events at the SuperKEKB accelerator in Japan, large amounts of radiation can severely damage the innermost layers of the Belle II Pixel Detector (PXD). Due to these events, the PXD has remained shut down since May 2024. The PXD consists of silicon pixel matrices based on DEPFET technology. Application-Specific Integrated Circuits (ASICs), known as "switchers", control these matrices by changing voltage levels of 20 V within a few nanoseconds during each 50 kHz readout cycle. Since the detector is safe when the switchers are unpowered, a secure method for rapidly powering down modules during beam loss events is required.

To address this, a modification of the custom-made power supply enabling an immediate pull-down of the switcher channels has been developed. Tests in the laboratory were conducted to verify its reliability and to observe the voltage evolution during the shutdown. The effectiveness of the fast shutdown was further evaluated during a test beam campaign at the MAMI electron facility, where it was triggered before an electron beam reached the sensitive switchers to determine limits for minimum shutdown response times and tolerable beam currents. This upgrade is a key prerequisite for the safe reactivation of the PXD and therefore essential for restoring full vertexing capabilities in the next SuperKEKB run.

T 55.6 Wed 17:30 KH 01.022

Investigation of neutron-induced single-event effects in the Belle II PXD overvoltage protection logic — •Jannes Schmitz, Florian Bernlochner, Jochen Dingfelder, and Hans Krüger — University of Bonn

The Belle II experiment at the SuperKEKB collider in Tsukuba, Japan, collects e^+e^- collision data reaching a record-breaking instantaneous luminosity of $5.1 \cdot 10^{34}\ cm^{-2}s^{-1}$ in December 2024. The innermost Belle II sub-detector is the PiXel Detector (PXD), which is based on modules with Depleted P-channel Field Effect Transistor (DePFET) sensors. Each PXD module is powered by a custom-made power supply, providing 23 channels for the DePFETs operational voltages, linear post regulation and overvoltage protection circuitry. Although located on top of the Belle II detector and far away from the interaction region, the PXD power supplies triggered false overvoltage events induced by increased beam backgrounds during operation. Expecting a proportional increase up to the target instantaneous luminosity of $6 \cdot 10^{35}\ cm^{-2}s^{-1}$, investigations started to find the cause of these effects and minimize the resulting downtime of the detector.

This talk will discuss the observed neutron-induced single-event effects, covering improvements of the firmware as well as dedicated studies of its effectiveness in neutron-rich accelerator environments.

T 55.7 Wed 17:45 KH 01.022

Wafer-level quality control procedure of silicon pixel sensors for the LHCb U2 Mighty-Tracker — Johannes Albrecht, •Jonas Rönsch, Dirk Wiedner, and Lukas Witola — TU Dortmund University, Dortmund, Germany

To exploit the full flavour physics potential of the HL-LHC after long shutdown 4 (2034-2036), the LHCb detector will be operated at an instantaneous luminosity of $1.0 \times 10^{34}\text{cm}^{-2}\text{s}^{-1}$. Due to the higher particle density, an upgrade is necessary to increase the granularity of the tracking system. The main tracking stations will be replaced by the Mighty-Tracker. It combines roughly 285 m^2 of scintillating fibres in the outer region and 8 m^2 of high voltage monolithic active pixel sensors (HVMAPS) called MightyPix in the inner region.
The pixel detector will be instrumented with approximately 46000 sensors, which all need to be thoroughly tested before being assembled into modules. Due to the large quantity the tests will be performed on a semi-automatic probe station.
The wafer-level quality control procedure of the MightyPix will be presented in this talk.

T 55.8 Wed 18:00 KH 01.022

Cluster Size Simulations in Allpix Squared for the LHCb Mighty Pixel Tracker — •Ruben Kolb, Sebastian Bachmann, Lucas Dittmann, David Kuhn, Ulrich Uwer, and Celina Welschoff — Physikalisches Institut Universität Heidelberg

During LHC's Run 5, the instantaneous luminosity of the LHCb experiment is expected to increase by at least a factor of five, imposing significantly more stringent requirements on the tracking detectors in terms of occupancy and radiation tolerance. To meet these challenges, the Upgrade II program foresees the replacement of the current scintillating fiber (SciFi) tracker with the so-called Mighty Tracker. This new tracking system combines scintillating fiber detectors in the outer regions with monolithic silicon pixel sensors (Mighty Pixel) in the innermost region.

One of the critical specifications to design the pixel detector is the expected hit rate. Here, the cluster size has a substantial impact, as the particles traverse the detector under an angle. This has implications on the expected data rate and the overall detector performance. Besides the incident angle, the cluster size depends on pixel geometry, depletion depth, sensor thickness and detection threshold. A data-validated simulation in Allpix Squared utilizing the angle distribution expected in the pixel region of the Mighty Tracker is presented in this talk. The results aid in the decision for critical sensor design choices and detector layout.

T 55.9 Wed 18:15 KH 01.022

Particle-Weighted Material Budget Studies for the Mighty Pixel Layer and Enclosure Box in LHCb Upgrade II — •Rehan Waheed Haroon Rashid Sayyed, Ksenia Solovieva, and Marco Gersabeck — Physikalisches Institut, Albert-Ludwigs-Universitat Freiburg, Freiburg, Germany

The LHCb Upgrade II requires a complete redesign of the downstream tracking system to withstand extreme particle flux at increased luminosity. The Mighty Tracker design, featuring interleaved Mighty Pixel and Mighty SciFi layers, must minimise both active and passive material to preserve tracking performance. The work centers on optimising the layout of material in Mighty Pixel layers, focusing on the thermal enclosure box and the strategic placement of associated electronics (HDI and DCDC converters). Particle-weighted material budget estimations are performed using simplified simulations of particle trajectories through these system components, including staves (comprising carbon foam, Nomex, titanium cooling tubes, and other materials), the readout-flex, the enclosure, and the electronics. The study specifically targets the geometric and material optimisation of these elements. A primary objective is to determine the optimal placement for high-density electronics, evaluating whether to integrate them within the enclosure volume, mount them on its exterior, or position them further away, based on their exposure to the particle flux. This work aims to design a Mighty Pixel layer system that minimises the degradation of track quality from material-particle interactions, thereby supporting the overall physics performance goals of the LHCb Upgrade II tracker.

T 55.10 Wed 18:30 KH 01.022

Development and Validation of a TID irradiation setup based on a strong ^{90}Sr β-source — •David Kuhn, Sebastian Bachmann, Lucas Dittmann, Ruben Kolb, Ulrich Uwer, and Celina Welschoff — Physikalisches Institut, Universität Heidelberg

During Long Shutdown 4 of LHC, the LHCb detector is planned to receive its Upgrade II to be able to cope with the significant increase in instantaneous luminosity to up to $1.0 \times 10^{34}\,\mathrm{cm^{-2}s^{-1}}$. As part of the upgrade the current scintillating fiber tracker will be replaced by the Mighty Tracker. This new main tracker will continue to use scintillating fibers in the outer region. In the inner region, however, the required granularity and radiation tolerance exceed the capabilities of this technology. There, a silicon-based pixel detector will be employed instead. The proposed technology for this is High Voltage Monolithic Active Pixel Sensor (HV-MAPS).

As the MightyTracker pixel detector will be subject to ionizing radiation damage up to dose of 40 Mrad during its lifetime, the associated influence on the operation of the pixel sensors needs to be studied precisely. For this, a setup utilizing a 3.7 GBq Strontium-90 β-source is developed and simulated using FLUKA. The simulated dose rate of up to 10 krad/h for silicon pixel detectors in the irradiation setup can be validated by using dose rate and hit rate measurements. In this talk the development and validation process of the irradiation setup will be presented.

T 56: Data, AI, Computing, Electronics VI

Time: Wednesday 16:15–17:45 Location: KH 02.014

T 56.1 Wed 16:15 KH 02.014

How to make artificial intelligence more sustainable and precise? - Introducing the project PEARLS — •Simran Gurdasani[1], Valerie Lang[2], Pardis Niknejadi[1], and Naman Kumar Bhalla[2] — [1]DESY — [2]Albert-Ludwigs-Universitaet Freiburg

Artificial intelligence (AI) is increasingly applied in scientific research, but its growing computational demands raise concerns regarding reliability, transparency, and environmental impact. The PEARLS project: Precision in Energy-aware AI Research for Low-carbon Solutions, is an ErUM-Data consortium between DESY and the University of Freiburg and aims to address these challenges. Within PEARLS, we are developing tools to measure the Carbon footprint of Machine Learning applications, evaluate algorithm efficiency and precision, and improve the processing of data in ML workflows. In this talk, I will introduce the PEARLS project, report on the current progress from DESY and Freiburg, and outline plans for the future.

T 56.2 Wed 16:30 KH 02.014

b-hive: a CMS wide Machine Learning Framework — Niclas Eich, Alexander Jung, Alexander Schmidt, and •Ulrich Willemsen — III. Physikalisches Institut A, RWTH Aachen

b-hive is a state of the art machine learning framework with wide adaptation in various working groups in CMS. It is a pipeline for training and testing of machine learning algorithms allowing for a modular approach to developing and deploying ML models in high-energy physics applications. The framework provides standardized interfaces for data preprocessing, model training, validation, and inference, enabling researchers to efficiently prototype and compare different algorithms for jet identification and analysis tasks. This presentation will demonstrate the current capabilities of b-hive, showcase recent applications in b-tagging and discuss future development plans.

T 56.3 Wed 16:45 KH 02.014

Foundation Model Based Approaches to Jet Tagging Using JEPA — Mirac Noyan Özdemir, Alexander Schmidt, •Sergio Schöneberg, and Ulrich Willemsen — III. Physikalisches Institut A, RWTH Aachen University

Foundation Models have gained significant traction in Natural Language Processing and Computer Vision and have recently become the focus of intensive research in the field of high-energy physics as they provide highly adaptable models that require less task-specific training and data. Moreover, their ability to leverage unlabelled data and their capacity to derive meaningful representations are promising opportunities for improving model robustness.

This talk presents the application of the Joint-Embedding Predictive Architecture (JEPA) to jet physics, capabilities of few-shot learning are demonstrated and the viability for jet flavor tagging is discussed. Finally, the broader implications for AI safety within high-energy physics are addressed.

T 56.4 Wed 17:00 KH 02.014

Cross-Geometry Transfer Learning in Fast Electromagnetic Shower Simulation — •Lorenzo Valente[1], Gregor Kasieczka[1], and Frank Gaede[2] — [1]Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, 22607 Hamburg, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany

Fast and accurate particle shower simulation is essential for high-energy physics, but traditional Monte Carlo methods like Geant4 are computationally expensive, while machine learning alternatives typically require complete retraining for each detector geometry. We present a transfer learning approach for generative calorimeter simulation using point cloud representations and diffusion/flow models. By pretraining on detector configurations and fine-tuning with limited target data, our method enables efficient adaptation across diverse geometries without geometry-specific preprocessing. We demonstrate significant performance improvements with minimal training samples through both full fine-tuning and parameter-efficient adaptation strategies. This work establishes transfer learning as a practical technique for geometry-flexible fast simulation, reducing computational requirements for detector design studies and physics analyses.

T 56.5 Wed 17:15 KH 02.014

Agents of Discovery — Sascha Diefenbacher[1], Anna Hallin[2], Gregor Kasieczka[1], Michael Krämer[1], Anne Lauscher[3], and •Tim Lukas[1] — [1]University of Hamburg, Hamburg, Germany — [2]Lawrence Berkeley National Laboratory, Berkley, USA — [3]RWTH Aachen University, Aachen, Germany

Particle physics is becoming more and more data intensive, requiring increasingly complex analysis methods. Large parts of these methods belong to standard procedures which have to be implemented by hand, taking time away from more innovative work. With the rise of agentic AI systems other approaches become feasible: Tasking AI agents with implementing those known parts, making workflows more efficient.

In this work we present a framework allowing a team of AI Agents to work autonomously on a given task, including capabilities for writing code, code execution, error correction and logic checks. The setup uses state-of-the art OpenAI LLMs and has been tested in the realm of anomaly detection. The performance was monitored throughout many different technical and physical metrics, allowing us to draw detailed conclusions on the capabilities of the different LLMs: Most are capable of solving the given task, while the best were able to match human level performance.

T 56.6 Wed 17:30 KH 02.014

Development of Exclusive Tagging Algorithms for b-hadrons at FCC-ee — •Elgi Orozi[1], Florian Bernlochner[2], Valerio Bertacchi[2], Thomas Kuhr[1], Markus Prim[2], and Slavomira Stefkova[2] — [1]Ludwig-Maximilians-Universität München (LMU), München, Germany — [2]Rheinische Friedrich-Wilhelms-Universität Bonn, Bonn, Germany

The FCC-ee physics programme will feature operations at energies ranging from $\sqrt{s} = m_Z$ up to the $t\bar{t}$ production threshold. The enormous statistics of Z-boson decays will allow the study of beauty-quark electroweak precision observables with exceptional statistical precision. Identifying b-hadrons in high-statistics $Z \to b\bar{b}$ events is therefore crucial for probing small deviations from the Standard Model. While existing exclusive tagging approaches, such as the Belle II FEI, provide a conceptual framework, they must be adapted to the high-multiplicity environment at FCC-ee, where hadronisation, initial- and final-state radiation, and track densities are significantly more complex.

In this work, we develop and assess the performance of an exclusive B-tagging algorithm for FCC-ee, based on hierarchical decay reconstruction combined with gradient-boosted decision tree classifiers. This configurable framework performs track combination, vertex fitting, feature extraction, and multivariate classification. As a benchmark, we reconstruct the decay channel $B^+ \to \bar{D}^0[\to K^+\pi^-]\pi^+$ from simulated $Z \to b\bar{b}$ events, using the IDEA detector concept. This talk will provide insight into the feasibility of exclusive B-tagging at FCC-ee and outline future developments of advanced tagging strategies.

T 57: Outreach I

Time: Wednesday 16:15–18:30 Location: KH 02.016

T 57.1 Wed 16:15 KH 02.016

Vorstellung einer Teilchenphysik Masterclass über einen Stratosphären Ballonflug — •Lara Dippel, Kai-Thomas Brinkmann, Simon Glennemeier-Marke und Hans-Georg Zaunick für die Netzwerk Teilchenwelt-Kollaboration — II. Physikalisches Institut, Justus-Liebig-Universität Gießen

Die vorgestellte Masterclass führt Schüler:innen in die Welt der Teilchen- und Detektorphysik ein. Zu Beginn erhalten sie anhand der vom Netzwerk Teilchenwelt bereitgestellten Materialien eine grundlegende Einführung in das Standardmodell der Teilchenphysik. Ergänzend wird das Thema Umweltradioaktivität behandelt und durch den praktischen Bau von Nebelkammern anschaulich vertieft.

Darauf folgt eine Einführung in die Detektorphysik mit besonderem Fokus auf Szintillatoren, bevor die kosmische Strahlung und ihre Eigenschaften erläutert werden. Anschließend wird der Stratosphärenballon-Flug thematisiert, dessen Messdaten im weiteren Verlauf analysiert werden.

Nach einer kurzen theoretischen Einführung in Python und Jupyter Notebooks werten die Schüler:innen selbstständig die Daten des während des Ballonflugs eingesetzten Teilchendetektors aus. Dabei erwerben sie grundlegende Kenntnisse der Programmierung und erleben unmittelbar, wie physikalische Fragestellungen mithilfe realer Daten beantwortet werden können.

T 57.2 Wed 16:30 KH 02.016

Activities of the Belle II-ErUM-FSP Office in Outreach, Transfer, Networking and Young Talents Support — •Veronika Kratzer[1], Florian Bernlochner[2], Amanda Cloth[1], Torben Ferber[3], Isabel Haide[3], Johanna Häusler[1], and Thomas Kuhr[1] — [1]Ludwig-Maximilians-Universität München — [2]Rheinische Friedrich-Wilhelms-Universität Bonn — [3]Karlsruher Institut für Technologie (KIT)

The Belle II-ErUM-FSP Office is the central unit for outreach, transfer, networking, and young talents support withing the German research groups affiliated with the Belle II experiment that are organised in the Belle II Forschungsschwerpunkt (FSP). The office coordinates these activities across all groups, utilizing funding from the Federal Ministry for Research, Technology and Space (BMFTR) in the ErUM (Erforschung von Universum und Materie) framework. Several online and offline activities are conducted, such as maintaining and updating the website belle2.de and social media channels, organizing outreach and community events, networking with outreach professionals within and beyond the ErUM community and facilitating knowledge transfer. This talk gives an overview of ongoing and planned activities.

T 57.3 Wed 16:45 KH 02.016

Adaption of the Particle Therapy Masterclass for Use in Netzwerk Teilchenwelt — •Rebecca Seip and Michael Kobel for the Netzwerk Teilchenwelt-Collaboration — TU Dresden, Dresden

The Particle Therapy Masterclass is a one-day program for students (mainly targeted for high school students). It aims to enhance participants* understanding of medical applications of particle physics, using radiation therapy as a representative example, and highlights the relevance of fundamental research in particle physics for everyday life. The Masterclass focuses on hadron therapy and the physics behind it. It was originally developed by Yiota Foka (GSI), Niklas Wahl (matRad, DKFZ) and collaborators, and the corresponding material is currently available in English and Greek. In order to make this Masterclass more accessible in Germany and to facilitate its integration into the activities of Netzwerk Teilchenwelt, it was translated to German and adapted to the German research landscape as well as the educational curricula. The Masterclass consists mainly of two parts: In the first part, students are introduced to the theoretical background. The second part is a hands-on session where the students apply their new knowledge to create a treatment plan for a tumor using matRad, an open-source treatment planning software employed for educational purposes and teaching. The talk will present the newly adapted materials for this Masterclass as well as experiences gained in the first implementation of the Particle Therapy Masterclass within Netzwerk Teilchenwelt.

T 57.4 Wed 17:00 KH 02.016

Creativity as pathway into Physics for Primary Schools — •Michael Hoch and Markus Klute — KIT, Karlsruhe, Germany

Science and art at school at CERN is a pilot program exploring how artistic creativity can make science more engaging for primary school pupils. Building on Art@CMS and the ORIGINS initiative, it combines simple physics explorations with creative activities that help children aged 8*10 intuitively grasp scientific ideas.

Tested in Karlsruhe and developed with two local schools in the Geneva region, the program provides practical tools for teachers and introduces pupils to broader STEM topics. The strong response from schools, families, and local communities - highlighted by exhibitions and CERN visits - shows the program's motivational impact. The pilot also demonstrates clear scalability and adaptability, offering a promising model for inspiring young learners through science and art.

T 57.5 Wed 17:15 KH 02.016

Schüler:innen für Physik begeistern — •Heike Vormstein — Johannes Gutenberg-Universität, Mainz, Deutschland

Schüler:innen nehmen Physik häufig als trocken und langweilig wahr. Die Erfahrung zeigt aber, dass durchaus Interesse an Physik und Forschung vorhanden ist, wenn der richtige Zugang gefunden wird.

Oft wird versucht, dieses Interesse durch möglichst viel Show und Effekte zu wecken. Gerade bei älteren Schüler:innen ist das jedoch nicht notwendig und nicht immer hilfreich. Meistens reicht es schon, wenn Begeisterung vermittelt und direkter Bezug zu aktueller Forschung hergestellt wird.

Eine besonders wirkungsvolle (und einfache) Möglichkeit ist es, Wissenschaftler:innen über die spannenden Aspekte ihrer eigenen Forschung sprechen zu lassen. Dabei bringen die Forschenden ihre intrinsische Motivation und Begeisterung mit, die von den Schüler:innen positiv wahrgenommen wird. Vor allem die Möglichkeit, offen Fragen zu stellen, sowohl zu fachlichen Themen als auch zum Alltag in der Forschung, hilft Schüler:innen, ein besseres Verhältnis zur Physik zu entwickeln. So wird Physik nicht als trockenes, altmodisches Fach erlebt, sondern als lebendiges, modernes Forschungsgebiet. Dies ermöglicht es uns, nachhaltiges Interesse zu wecken.

T 57.6 Wed 17:30 KH 02.016

DIY Detector Workshop Concepts for Schools and Universities — •Sebastian Laudage, Florian Bernlochner, and Maike Hansen for the Netzwerk Teilchenwelt-Collaboration — Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn

In the last two years, we developed and tested interactive workshops at the University of Bonn under the motto "Build Your Own Particle Detector." These hands-on workshops enable participants, regardless of prior experience, to construct their own functional particle detector in just a few hours. Participants can then use these detectors to measure cosmic rays or natural background radiation, gaining direct insights into the invisible world of particle physics. Building on the lessons learned from numerous workshops, we have developed next-generation detector concepts designed to be versatile, user-friendly, and accessible to a broad audience, from school students to university-level participants. To ensure sustainability of the project, we are currently creating comprehensive educational materials that will empower other institutions to host similar workshops independently. This contribution introduces our developed hardware and outlines our plans for the upcoming year.

T 57.7 Wed 17:45 KH 02.016

Workshops zu Halbleiterdetektoren bei Science Camps Teilchen- und Astroteilchenphysik am KIT — •Günter Quast und Carolin Quast — Karlsruher Institut für Technologie

Im Rahmen von Science Camps zur Teilchen- und Astroteilchenphysik am KIT wurden mehrfach Workshops mit Jugendlichen zum Thema "Halbleiterdetektoren" durchgeführt. Thematische Schwerpunkte, Geräte und Materialien sowie Erfahrungen werden in diesem Vortrag beschrieben.

Den teilnehmenden Jugendlichen sollte die Möglichkeit gegeben werden, Grundlagen, Funktionsweise und Anwendungsgebiete von modernen, auf Halbleitern beruhenden Teilchendetektoren zu ergründen. Nach einer Klärung der physikalischen Grundlagen wurde zunächst eine einfache Schaltung mit einer PIN-Fotodiode zum Nachweis der Infrarotstrahlung von Fernbedienungen aufgebaut. Als Hauptprojekt bauten die Jugendlichen dann einen eigenen Halbleiter-Detektor auf, basierend auf dem am CERN entwickelten "DIY Particle Detector", und analysierten die Daten mit Hilfe eines Computers mit Soundkarte.

Als letzter Schritt wurde Umgebungsstrahlung mit kommerziell erhältlichen Detektoren aufgenommen und ausgewertet: einem kostengünstigen Gamma-Spektrometer (RadiaCode) mit einem CsJ(Tl)-Kristall mit SiPM-Auslese und einem Si-Pixeldetektor mit 256x256 Pixeln (Advacam MiniPIX EDU) mit einem Timepix-Chip. Letzterer erlaubt die anschaulichen Darstellung und Klassifizierung von Teilchenspuren.

T 57.8 Wed 18:00 KH 02.016

Outreach Module for Detection of Cosmic Rays at Earth — •Nikolai Chaunin[1], Jerzy Pryga[2], André Sopczak[1], and Vladyslav Tabaciniuc[1] — [1]CTU in Prague — [2]Jagiellonian University in Kraków

We present a new model as a part of the Czech Particle Physics Project (CPPP). This module is intended as a leaning tool in masterclasses aimed at high-school students (ages 15 to 18). The module is dedicated to the detection of cosmic rays at earth. The user will read a theoretical introduction, separate real shower events from background noise and try to determine the direction of the showers. Afterwards the user can leave a feedback message on the same page. The module can be accessed at the following link: http://cern.ch/cppp

T 57.9 Wed 18:15 KH 02.016

Bilderkennung für einfache Signal-Hintergrund-Trennung — •Andreas Zeh-Marschke für die Netzwerk Teilchenwelt-Kollaboration — Karlsruher Institut für Technologie: Karlsruhe, DE

Im Rahmen eines Science Camp Teilchen- und Astroteilchenphysik am KIT für Schülerinnen und Schüler wurde eine typische Anwendung aus der Physik bearbeitet: eine Mustererkennung. Diese einfache, leicht verständliche, physikalische Anwendung wurde mit Werkzeugen des maschinellen Lernens durchgeführt. Dies zeigt einen möglichen Einsatz von Künstlicher Intelligenz in Rahmen der physikalischen Grundausbildung.

Anhand der Kontur, also des Verlaufs, einer Welle eines radioaktiven Zerfalls wird eine Trennung zwischen Signal (radioaktiver Zerfall) und Hintergrundrauschen durchgeführt. Dabei werden etwa 25 Pixel rund um den maximalen negativen Ausschlag analysiert. Diese Kontur ist ein eindimensionales Bild mit 25 Pixeln mit Graustufen. Somit ist die Signalerkennung ein Bilderkennungsproblem. Mittels maschinellen Lernens wird eine Trennung von Signal und Hintergrund vorgenommen. Dabei erfolgt eine Trennung auch dann mit großer Güte, wenn die Stärke des maximalen negativen Impulses vom Signal im Bereich des Hintergrundrauschens ist.

Die Wellen werden mit Hilfe des CERN-DIY-Detektor erfasst und mit einer Soundkarte aufgenommen und gespeichert. Für das maschinelle Lernen wurde als Werkzeug die Python-Bibliothek scikit-learn verwendet.

T 58: Searches/BSM III

Time: Wednesday 16:15–18:00 Location: KH 02.018

T 58.1 Wed 16:15 KH 02.018

Search for new physics in the final state with a tau lepton and missing transverse momentum using Run-3 CMS data — Thomas Hebbeker, Kerstin Hoepfner, Mirac Noyan Özdemir, Valentina Sarkisovi, Alexander Schmidt, and •Joseph Karl Schumacher — III. Physikalisches Institut A, RWTH Aachen University

Various extensions to the Standard Model predict new particles, which can decay into final states characterized by high-energy lepton-neutrino pairs. The CMS detector at the CERN LHC is used to investigate deviations from predictions of the Standard Model in the high transverse mass region of the $\tau + p_T^{miss}$ spectrum. Efficient identification of TeV-scale τ leptons, precise modeling of the high transverse mass region and sensitivity to a wide range of models are essential in the search for Beyond the Standard Model (BSM) physics in this channel. CMS data recorded in Run-3 pp-collisions with a center-of-mass energy of 13.6 TeV have been analyzed to this end. This talk presents the key concepts of the analysis techniques used in the search for BSM physics in the $\tau + p_T^{miss}$ channel, including statistical interpretations in terms of various BSM models, with a special interest in models with preferred coupling to third generation leptons.

T 58.2 Wed 16:30 KH 02.018

Search for New Physics in Events with an Energetic Jet and Missing Transverse Momentum with the ATLAS Experiment — •Moritz Hesping, Volker Büscher, Christian Schmitt, and Duc Bao Ta — Johannes Gutenberg Universität Mainz

A wide range of theories beyond the Standard Model predict particles which only weakly interact with SM particles. If such particles are produced in collisions at the Large Hadron Collider, they are invisible to the detector. However, their presence can be inferred from a large missing transverse momentum when they recoil off a highly energetic jet. This requires a precise estimation of the SM processes resulting in a similar signature, such as the production of Z bosons decaying to neutrinos.

Searches for new physics in such events have been previously carried out at the ATLAS experiment using the full 140 fb^{-1} dataset of the LHC Run 2 (2015-2018). This talk shows the progress of an updated analysis using data from the ongoing LHC Run 3, which at 160 fb^{-1} for the years 2022-2024 has already exceeded Run 2 in luminosity, including an overview of the analysis strategy and data-simulation comparisons in the control regions, as well as systematic uncertainties.

T 58.3 Wed 16:45 KH 02.018

Search for new physics in the electron plus missing transverse momentum channel using Run-3 CMS data — Thomas Hebbeker, Kerstin Hoepfner, •Mirac Noyan Özdemir, Valentina Sarkisovi, Alexander Schmidt, and Karl Joseph Schumacher — III. Physikalisches Institut A, RWTH Aachen University

There are many Beyond the Standard Model (BSM) theories that predict new particles in the final state with a high-energy lepton and missing transverse momentum as their experimental signature. Now, using the newly acquired data of the CMS detector from the ongoing Run-3 at an unprecedented center-of-mass energy of 13.6 TeV, a new window is opened for searches in the high-energy regions.

This talk presents the main ideas behind the search for high-mass resonances and the analysis strategy in the electron plus missing transverse momentum channel. Among other results, the comparison of the observed data to the expected background, including a data-driven background estimation method, and several theoretical interpretations, will be shown.

T 58.4 Wed 17:00 KH 02.018

Search for Asymmetric Leptoquark Production in the Multilepton Channel with ATLAS Data — Ondrej Matousek, André Sopczak, and •Ishaan Utkarsh — CTU in Prague

The latest results in the search for asymmetric leptoquark production in the multilepton channel are presented using ATLAS data.

T 58.5 Wed 17:15 KH 02.018

Improved strategy for searches for Heavy Neutral Leptons decaying into $\ell + \pi$ with ATLAS — •Andrej Prescher — Humboldt Universität zu Berlin

Heavy Neutral Leptons (HNLs) appear in beyond Standard Model scenarios and can address open problems such as neutrino masses and the matter-antimatter asymmetry. At the LHC, long-lived HNLs might be produced in leptonic W decays, $W \to \ell N$ ($\ell = e, \mu$), and lead to displaced decay signatures inside the detector.

The most stringent limits set in ATLAS searches so far have been achieved in the purely leptonic decay channels $N \to \ell\ell'\nu$. For small HNL masses, in the mass range of 2-3 GeV the two body decay $N \to \ell + \pi$ might help to increase the search sensitivity.

In a recently published ATLAS analysis this decay channel however could not significantly improve the sensitivity beyond the one from $N \to \ell\ell'\nu$, due to higher background level in the $N \to \ell + \pi$ search.

In this presentation we show studies how this background can be significantly reduced while keeping or even increasing the signal efficiency.

T 58.6 Wed 17:30 KH 02.018

Exploring OmniJet-α for Model-Agnostic Anomaly Detection with CATHODE — •Salome Fresenbet[1], Gregor Kasieczka[1], Louis Moureaux[1], Anna Hallin[1], Joschka Birk[1], Humberto Reyes Gonzalez[2], and Soumya Shaw[3] — [1]University of Hamburg — [2]RWTH Aachen University — [3]Saarland University

Model-agnostic anomaly detection has become an important complement to traditional, signal-driven searches for new physics at the LHC. One such method is CATHODE, which combines conditional density estimation in invariant-mass sidebands with a weakly supervised classifier in the signal region. In this talk, we present the integration of the jet foundation model OmniJet-α into CATHODE by training it to distinguish signal events from background events modeled by the generative component of CATHODE. We evaluate this approach on a dijet dataset with beyond-the-Standard-Model (BSM) benchmark resonance signals, which we use as a realistic anomaly-detection scenario. The aim of this ongoing study is to quantify the impact of jet foundation models on CATHODE's performance and how they may enhance the sensitivity of future model-agnostic searches.

T 58.7 Wed 17:45 KH 02.018

Significance metrics for anomaly detection with the CATHODE method — •Tore von Schwartz, Louis Moureaux, Gregor Kasieczka, Chitrakshee Yede, and Kristian Warnholz — University of Hamburg, Hamburg, Germany

Despite an extensive search program at the LHC, no evidence for new physics has been found so far. Anomaly detection has emerged as a promising approach bridging generic searches and analyses targeting specific signals. CATHODE, a model-agnostic anomaly detection method, is designed to enhance resonant signals in the smoothly falling dijet invariant mass spectrum. We present an investigation of different strategies for extracting the signal significance after applying this method, with the aim of improving sensitivity to potential new physics signals while maintaining calibration.

T 59: Neutrino Astronomy III

Time: Wednesday 16:15–18:30 Location: KS H C

T 59.1 Wed 16:15 KS H C

Extending the Advanced Northern Tracks Selection with Energy Uncertainty Estimation — •Lasse Düser, Shuyang Deng, Sönke Schwirn, Philipp Soldin, Christopher Wiebusch, and Marco Zimmermann for the IceCube-Collaboration — RWTH Aachen University

The IceCube Neutrino Observatory is a cubic kilometer-sized detector located at the South Pole. It uses more than 5000 photomultipliers (PMTs) to detect particles via their Cherenkov radiation including muons induced by atmospheric and astrophysical neutrinos. Using a graph convolutional neural network that encodes the spatial geometry of the PMTs, the Advanced Northern Tracks Selection (ANTS) identifies these events and reconstructs important event features like the neutrino energy. Extending the existing ANTS framework allows for the simultaneous, event-based estimation of the uncertainty on the reconstructed energy. In this talk, we discuss the network's performance in terms of resolution and calibration. The reconstruction is compared to established methods and evaluated across different event topologies.

T 59.2 Wed 16:30 KS H C

Event reconstruction for different detector geometries in a toy simulation of water-Cherenkov neutrino telescopes — •Franziska Kirchner for the IceCube-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

Water-Cherenkov neutrino detectors are typically built with instrumentation strings placed on a triangular grid. Next-generation detectors such as P-ONE or IceCube-Gen2 are planned as less ordered structures so that no charged particle can pass through the detector without approaching any detector string. However, it is not fully understood which detector geometries result in an optimal resolution of event energies and event positions. The talk will present a toy simulation of various detector geometries and corresponding cascade and muon track event reconstructions, which is used to investigate the corresponding resolutions.

T 59.3 Wed 16:45 KS H C

Approximating Photon Propagation in Ice Using Generative Neural Networks — •Amith Ashwath Narayan for the IceCube-Collaboration — Technical University of Munich

The Precision Optical Calibration Module (POCAM) is an isotropic, self-monitored calibration device. As part of the IceCube upgrade an extension of the IceCube detector located at the geographical South Pole, POCAMs are being installed to tackle existing optical detector systematics with higher precision. Estimating these detector systematic uncertainties requires parsing a multidimensional parameter space, which is computationally intensive, therefore it is infeasible. Since an analytical approximation with sufficient precision does not exist, we employ machine learning: by sparsely sampling the parameter space and using a neural network to interpolate between simulated points. In this project, the focus is specifically on scattering coefficient, training the network to generate the corresponding detection optical module (DOM)-response histograms and total photon counts. The talk will focus on the neural-network architecture and its performance in generating DOM-response histograms and photon counts for the scattering coefficient, with the method being in principle extendable to the remaining detector systematics.

T 59.4 Wed 17:00 KS H C

Advanced Northern Tracks Selection using a Graph Convolutional Neural Network for the IceCube Neutrino Observatory — •Philipp Soldin, Shuyang Deng, Lasse Düser, Sönke Schwirn, Christopher Wiebusch, and Marco Zimmermann — RWTH Aachen University

The IceCube Neutrino Observatory is a large neutrino detector located in the ice at the geographic South Pole. It detects atmospheric and astrophysical neutrinos via Cherenkov radiation emitted by secondary charged particles, recorded by more than 5,000 digital optical modules equipped with photomultiplier tubes (PMTs). A central challenge for IceCube analyses is the efficient separation of muons produced in neutrino interactions from the dominant background of muons from cosmic-ray air showers. To address this challenge, the Advanced Northern Tracks Selection (ANTS) employs a two-stage, machine-learning-based event selection. A transformer-based autoencoder first performs dimensionality reduction of the time-resolved sensor data, followed by a deep graph convolutional neural network (GCNN) that explicitly exploits the irregular, node-like geometry of the IceCube detector. Compared to established selection methods, ANTS achieves a significant improvement in classification performance. This presentation examines the ANTS network architecture, training strategy, background-rejection capability, and computational efficiency.

T 59.5 Wed 17:15 KS H C

Adapting the Advanced Northern Tracks Selections Neural Network for the IceCube Upgrade — •Sönke Schwirn, Shuyang Deng, Lasse Düser, Hasti Maghsoudipour, Philipp Soldin, Christopher Wiebusch, and Marco Zimmermann for the IceCube-Collaboration — III. Physikalisches Institut B, RWTH Aachen

The IceCube Neutrino Observatory is a neutrino detector located at the South Pole, consisting of over 5000 Digital Optical Modules (DOMs), each containing a single photomultiplier tube (PMT). In winter 2025/26, the IceCube Upgrade was deployed, including around 400 newly developed multi-PMT modules (mDOMs). Each mDOM contains 24 PMTs, providing in-module directionality information and increased effective area. A denser spacing of the modules also enables the detection threshold to be lowered to a few GeV. These new modules require modifications to existing event reconstruction methods. The Advanced Northern Tracks Selection (ANTS), developed for the original single-PMT DOMs, uses a multi-stage neural network approach that utilizes the full event information as measured by the DOMs for event selection and reconstruction of event parameters such as the particle direction and energy. This talk presents modifications of the

ANTS network architecture to include the mDOMs of the IceCube Upgrade and discusses reconstruction performance at low energies.

T 59.6 Wed 17:30 KS H C

The Pacific-Ocean Neutrino Experiment Design Optimization with Machine-Learning — •Kristian Tchiorniy and Lukas Heinrich for the P-ONE-Collaboration — Technische Universität München, Physik-Department, James-Frank-Str. 1, Garching bei München, D-85748, Germany

The geometrical layout of any experiment or detector can have a large impact on its ability to produce meaningful outcomes for physics. Oftentimes we see that optimal geometries can be unintuitive. Studying and optimizing this is therefore essential. This has become a relevant topic for the optimization of cubic-kilometer-scale neutrino telescopes, in particular, the Pacific Ocean Neutrino Experiment (P-ONE), which is planned to be constructed in the coming years. With more than 70 lines across multiple kilometers of seafloor, the P-ONE geometry is yet to be finalized and studies on how to place these lines can inform crucial design decisions. In this presentation, the possible geometric optimization of such an experiment will be discussed, in particular, how it will employ machine-learning techniques to apply end-to-end optimization.

T 59.7 Wed 17:45 KS H C

Neural Network-based DAQ System for in-ice Radio Detection of Neutrinos for RNO-G and IceCube-Gen2 — •Adam Rifaie for the RNO-G-Collaboration — Bergische Universität Wuppertal, Wuppertal, Deutschland

Detecting astrophysical neutrinos at energies above 10 PeV is challenging due to their extremely low flux. The state-of-the-art detectors, such as RNO-G, and the planned IceCube-Gen2 Radio Array, exploit radio emissions via the Askaryan effect. The km-scale attenuation length of radio signals in ice enables large-scale detectors spanning several tens or hundreds of kilometres.

High trigger rates of such large-scale detectors demand efficient trigger systems and high data purity, such as Neural Network (NN)-based triggers. Previous simulation studies estimate an increase in the detection rates of astrophysical neutrinos by up to a factor of 2 at energies of 10 PeV, doubling the effective detection volume of the detector for no additional costs.

This presentation briefly describes the NNs we will be testing. Followed by the first lab measurements using the new DAQ system, NuRadioDAQ, and compares them to projected estimates based on simulated data.

T 59.8 Wed 18:00 KS H C

Neural Network Tools for the IceCube-Gen2 Optical Array — •Francisco Javier Vara Carbonell and Alexander Kappes for the IceCube-Collaboration — Universität Münster, Institut für Kernphysik

IceCube-Gen2 is a planned extension of the current IceCube neutrino observatory that will increase the in-ice instrumented volume by roughly a factor of eight and introduce 9600 new optical sensors with multiple photomultiplier tubes (PMTs) designed to provide nearly full solid-angle coverage. In this new configuration, neural networks are particularly strong candidates to replace or complement traditional algorithms in key tasks such as event reconstruction, topology classification, noise cleaning, and simulation, as they naturally exploit the additional information provided by the new sensors and can process large data volumes efficiently, especially when run on graphics processing units (GPUs). This talk will provide an overview of these methods, summarize their current performance in the IceCube-Gen2 context, and discuss their possible physics implications.

T 59.9 Wed 18:15 KS H C

Combined Likelihood Analysis for Supernova Hunting — •Thilo Birkenfeld, Achim Stahl, and Christopher Wiebusch — III. Physikalisches Institut B, RWTH Aachen, Germany

The Combined Likelihood Analysis for Supernova Hunting (CLASH) is a software framework for the search for faint Supernova (SN) signals in various kinds of experimental data streams. Supernovae are frequently observed via optical telescopes. Observations via neutrinos and/or gravitational waves are highly anticipated, as they will provide valuable insights into the nature of the explosion onset. However, the observation of neutrinos from an SN has succeeded only once so far, for SN 1987A. The chance of such an observation is given by the SN rate in Earth's vicinity and the limited detection range of individual experiments. We developed a likelihood-ratio test comparing the persistent signal hypothesis with a background-only model as a function of time. It can be applied to individual experiments of various kinds or multiple detectors in combination, increasing the observable range. In this talk, I present CLASH, its underlying methodology, and discuss its use for pertinent detectors such as JUNO and Hyper-K.

T 60: Methods in Astroparticle Physics III

Time: Wednesday 16:15–18:30 Location: KS 00.004

T 60.1 Wed 16:15 KS 00.004

Test setup for a potential electron tagger at KATRIN — •Patrick Unkhoff, Volker Hannen, Christian Huhmann, and Christian Weinheimer for the KATRIN-Collaboration — Universität Münster

The neutrino mass experiment KATRIN has effectively collected 1000 days of tritium beta decay data, allowing to achive a sensitivity for an upper limit on the electron neutrino mass of m < 300 meV at 90% C.L.. After searching for sterile keV neutrinos with the TRISTAN detector at KATRIN a potential next generation experiment labeled KATRIN++ aims to go beyond this limit and probe the inverted mass ordering range down to neutrino masses m < 50 meV. Besides the necessary development of an atomic tritium source, achieving the required sensitivity requires a new differential method with a sub-eV energy resolution. This may be possible through direct time-of-flight spectroscopy of beta-decay electrons. This approach requires detecting the electron start time when entering the KATRIN spectrometer with minimal change of its energy. In this talk, the concept of electron tagging using the image current technique is discussed. Here, the electrons are detected by measuring tiny currents induced by the motion of passing electrons on a nearby electrode structure. A cryogenic test setup has recently been developed at the University Münster to investigate the feasibility of this method and will be presented in this talk. This work is supported by BMFTR under contract number 05A23PMA.

T 60.2 Wed 16:30 KS 00.004

Atomic tritium source development for future neutrino mass experiments — •Caroline Rodenbeck — Karlsruher Institut für Technologie, IAP-TLK

The Karlsruhe Tritium Neutrino experiment (KATRIN), which measures the tritium beta-decay spectrum, recently reached its goal of 1000 measurement days. It is now well on its way to achieving its targeted final neutrino mass sensitivity of $0.3\,\mathrm{eV/c^2}$. Already, efforts are ongoing for future experiments aiming at sensitivities below $0.05\,\mathrm{eV/c^2}$.

Beyond improved detector technologies, switching from a molecular to an atomic tritium source will likely be necessary: The molecular ro-vibrational excitations result in an effective broadening of the endpoint spectrum and thus in a reduced neutrino mass sensitivity, an issue avoided by the use of an atomic source.

Within the Karlsruhe Mainz Atomic Tritium Experiment (KAMATE), groups at the Johannes Gutenberg University (JGU) in Mainz and at the KIT's Tritium Laboratory Karlsruhe (TLK) benchmark different types of hydrogen dissociators (thermal dissociation versus RF-discharge plasma) as possible high-flux and high-efficiency sources. For the characterization of the dissociators, various analysis tools such as mass spectroscopy are under development.

After identifying suitable dissociators, key challenges such as multistage cooling and the magnetic trapping of atoms have to be addressed.

The talk gives an overview of the experimental achievements and an outlook for the cooling and trapping of atoms beyond the KAMATE efforts.

T 60.3 Wed 16:45 KS 00.004

Development of the LUIGI ASIC for LEGEND-1000 — •Juan Pablo Ulloa Beteta[1], Andreas Gieb[1], Susanne Mertens[1],

Michael Willers[2], Edgar Sanchez Garcia[1], Hannes Bonet[1], and Florian Henkes[2] for the LEGEND-Collaboration — [1]Max-Planck-Institut für Kernphysik, Heidelberg DE — [2]Technische Universität München, München DE

The **L**arge **E**nriched **G**ermanium **E**xperiment for **N**eutrinoless $\beta\beta$ **D**ecay (LEGEND) is a ^{76}Ge-based experiment searching for the neutrinoless double-beta ($0\nu\beta\beta$) decay. The second stage of the experiment, LEGEND-1000, aims to reach discovery sensitivity at half-lives beyond 10^{28} years, covering the inverted-ordering neutrino mass region. Achieving this goal requires about 1000 kg of enriched germanium detectors, a substantial reduction of background in the region of interest, together with further improvements in noise performance and signal fidelity. An important contribution to the overall background budget arises from the readout electronics due to their proximity to the detectors. At the same time, the front-end electronics play a critical role for the energy resolution and pulse shape discrimination. In this context, we explore a novel approach to ASIC-based charge-sensitive front-end electronics designed for operation close to high-purity germanium detectors in liquid argon under low-background restrictions.

T 60.4 Wed 17:00 KS 00.004

Sputtered Transition Edge Sensors for the NUCLEUS Experiment — •Philipp Wasser for the NUCLEUS-Collaboration — Technical University of Munich

Coherent elastic neutrino-nucleus scattering (CEνNS) enables sensitive studies of neutrino properties and physics beyond the Standard Model at low momentum transfer. The NUCLEUS experiment aims to measure CEνNS using MeV reactor antineutrinos from the Chooz nuclear power plant with gram-scale cryogenic calorimeters at 7 mK. Detecting the resulting sub-keV nuclear recoils requires transition edge sensors (TES) with ultra-low energy thresholds, realized using thin superconducting tungsten films.

Good detector performance requires a sharp superconducting transition near the bulk tungsten value (15 mK), motivating magnetron sputtering as a scalable alternative to electron-beam evaporation. I present the successful development of a dedicated sputter facility allowing to produce detector-grade tungsten films for TES applications.

On differently coated silicon substrates, reproducible transition temperatures around 15 mK and narrow transition widths below 0.5 mK were achieved, allowing the fabrication of highly sensitive TES. A systematic variation of the sputter power revealed a linear dependence of the critical temperature on the applied power, with values varying from 15 mK to 36 mK, enabling controlled tuning of the TES properties via deposition parameters. These results establish sputtered tungsten films as a viable TES technology for NUCLEUS.

T 60.5 Wed 17:15 KS 00.004

Fabrication and characterization of MMC arrays for the ECHo-LE — •Krittika Sarkar for the ECHo-Collaboration — Kirchhoff Institute für Physik

The Electron Capture in Holmium-163 (ECHo) experiment is designed for the determination of the electron neutrino mass using the analysis of the 163-Holmium electron capture spectrum. It uses low temperature detectors called metallic magnetic calorimeters (MMCs) to measure the electron capture decay in samples of Holmium-163 that are implanted inside the MMCs. Each MMC pixel contains Ho-163 upto an activity of 10Bq. ECHo-LE aims to simultaneously operate ~20,000 such MMC detectors. Ten wafers hosting 40 arrays each will be fabricated. A quality check produce will be defined in order to confine the suitability of the arrays for the Holmium 163 implantation and therefore to be used in the experiment. Two such wafers have been fabricated and characterised. We present the quality control results obtained for the first two fabricated wafers and discuss the fabrication yield and its implications for the preparation of the ECHo-LE experiment.

T 60.6 Wed 17:30 KS 00.004

Development of an Integrated Photon Phonon Detector to be used for $0\nu\beta\beta$ Search — •Ashish Jadhav, Christian Enss, Andreas Fleischmann, Clara Günther, Daniel Hengstler, Sebastian Hilscher, Cagla Mahanoglu, Ioana-Alexandra Nitu, Andreas Reifenberger, Christian Ritter, Daniel Unger, and Loredana Gastaldo — Kirchhoff Institute for Physics, Heidelberg, Germany

The AMoRE project uses scintillating crystals, enriched with ^{100}Mo, which are operated at millikelvin temperatures to search for $0\nu\beta\beta$ decay in this isotope of molybdenum. An advantage of using scintillating crystals is that they allow for particle discrimination based on the ratio of light to heat energy released by an event. We present an integrated photon-phonon (P2) detector based on metallic magnetic calorimeters (MMC) operated at 20 mK. The P2 detector design utilizes a 3" Si wafer, with a central area that serves as a photon absorber with a stripline geometry MMC sensor. This central area is connected to the rest of the wafer via seven bridges, which are fabricated using silicon etching techniques. In the outer region of the wafer, three MMC sensors with a double meander geometry are fabricated, on top of which the crystal is resting, to act as phonon detectors. The three independent signals from these phonon detector units would allow a fiducial volume to be defined, while improving particle discrimination based on single- and multi-site events. We discuss the various fabrication challenges and the results of detector characterisation in a dilution refrigerator.

T 60.7 Wed 17:45 KS 00.004

Development of an Experimental Platform for MMC Operation in the Next-Generation Neutrino Mass Experiment KATRIN++ — •Abdullah Özkara[1], Sebastian Kempf[2,3], and Michael Müller[2] for the KATRIN-Collaboration — [1]Institute for Astroparticle Physics (IAP), Karlsruhe Institute of Technology (KIT) — [2]Institute of Micro- and Nanoelectronic Systems (IMS), Karlsruhe Institute of Technology (KIT) — [3]Institute for Data Processing and Electronics (IPE), Karlsruhe Institute of Technology (KIT)

The Karlsruhe Tritium Neutrino (KATRIN) experiment measures the electron antineutrino mass via high-precision electron spectroscopy of tritium β-decay. Currently, KATRIN has established an upper limit of 0.45 eV for the absolute neutrino mass and aims to reach a final sensitivity of 0.3 eV (90% C.L.). With the future upgrade to KATRIN++, the goal is to push the sensitivity down to 0.05 eV to probe the inverted mass ordering. To achieve this, a new experimental platform will be implemented, incorporating metallic magnetic calorimeters (MMCs). MMCs are low-temperature single-particle detectors based on quantum technology, offering excellent energy resolution. We present the scheme of a novel platform featuring a magnetic cold chicane, enabling a barrierless transition from the room-temperature vacuum of the KATRIN main spectrometer to the cryogenic environment of the MMC detector.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMFTR (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6).

T 60.8 Wed 18:00 KS 00.004

Microwave Multiplexing readout for the ECHo Experiment — •Dominik Zawierucha for the ECHo-Collaboration — KIP im Neuenheimerfeld 227 Heidelberg 69120

The Electron Capture in Holmium-163 (ECHo) experiment uses metallic magnetic calorimeters (MMCs) to measure the energy spectrum of the electron-capture decay of ^{163}Ho implanted inside the detector. The analysis of the end-point region of this spectrum can be used to determine the effective electron neutrino mass. To achieve sub-eV sensitivity to the neutrino mass, a high-statistics energy spectrum with more than 10^{13} events is required. This necessitates a multiplexed readout scheme that enables consistent, high-energy-resolution, simultaneous readout of approximately 20,000 ^{163}Ho-implanted MMC detectors over a long acquisition period.

In ECHo-LE (Large Experiment), this is achieved through the application of microfabricated microwave resonators coupled to radio-frequency superconducting quantum interference devices (rf-SQUIDs) used to acquire signals from the MMC detectors. In this scheme, each detector (400 in total) is coupled to an individual resonator with a resonance frequency in the 4–8 GHz range, allowing the simultaneous readout of multiple detectors by monitoring the transmission through a common feedline.

We discuss the preparation of the 25 high-frequency readout lines and present the status of the multiplexer development for ECHo-LE.

T 60.9 Wed 18:15 KS 00.004

KATRIN++ - New Detector Technologies for a Future Neutrino Mass Experiment with Tritium — •Neven Kovac for the KATRIN-Collaboration — Institute for Astroparticle Physics - Karlsruhe Institute of Technology

Currently, the tightest constraints on the absolute scale of neutrino mass from a direct, model-independent approach, are obtained by the KATRIN experiment, giving an upper limit on the mass of the electron anti-neutrino of 0.45 eV (DOI: 10.1126/science.adq959), with final projected sensitivity below 0.3 eV. Going beyond this limit, and probing the inverted mass ordering (and beyond), will be the task for future neutrino mass experiments. In this regard, development of new detector technologies is of utmost importance, with quantum sensor arrays currently being the front runners due to their exceptional performance and excellent energy resolution.

In this talk we present our recent results where we demonstrate the feasibility for measurements of external electrons using metallic microcalorimeters, and report on our plans for first ever measurements of tritium β-spectrum using quantum sensors.

T 61: Gamma Astronomy I

Time: Wednesday 16:15–17:45 Location: KS 00.005

T 61.1 Wed 16:15 KS 00.005

MSH 15-52 in the high-energy regime: Exploring 3D eROSITA and H.E.S.S. data in a joint analysis with Gammapy — •Katharina Egg and Alison Mitchell for the H.E.S.S.-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen Nürnberg

The pulsar wind nebula (PWN) MSH 15-52 is a fascinating system. It is not only a bright and prominent source in TeV gamma-rays, as seen by the H.E.S.S. telescope array, but is also visible in GeV gamma-rays with Fermi-LAT, as well as in X-ray data at keV energies. By characterizing the multiwavelength spectral energy distribution of MSH 15-52 we can draw conclusions about this PWN and its underlying physics.

In this vein, we present a multiwavelength analysis of MSH 15-52, using X-ray data from the eROSITA telescope, as well as H.E.S.S. data. Using 3D eROSITA data – comprising one spectral and two spatial dimensions – which we import into the open source analysis software Gammapy, enables us to conduct a joint analysis at photon event level over 12 orders of magnitude in energy, painting a comprehensive picture of this PWN in three dimensional data. We investigate different spectral and spatial models, test for energy-dependent morphology, and draw conclusions on the underlying particle spectrum of the source.

In this talk our current progress with the analysis will be illustrated and an outlook towards the future investigation of MSH 15-52 will be given.

T 61.2 Wed 16:30 KS 00.005

Searching for Ultra-High Energy Photons applying Convolutional Neural Networks Using the Surface Detector of the Pierre Auger Observatory — •Fiona Ellwanger, Ralph Engel, Markus Roth, Steffen Hahn, David Schmidt, Darko Veberic, and Pierre Auger Collaboration — Karlsruher Institut für Technologie, Karlsruhe, Germany

Identifying sources of cosmic rays is challenging, as the charged particles are deflected by magnetic fields and do not point back to their sources. Neutral particles, such as ultra-high energy (UHE) γs will point directly to their sources, unless they interact in the interstellar medium or are absorbed. Cosmic ray detectors such as the 3000 km^2 surface array of the Pierre Auger Observatory are capable of observing UHE γs above 10^{18} eV. With increasing energy, their mean free path allows probing extragalactic sources up to a few Mpc. Different methods like BDTs and air-shower universality have been previously applied to the search of γs at different energy ranges. Although no UHE γs have been found, the obtained bounds of the fluxes provide crucial constraints on cosmic-ray acceleration models. Neural networks have the potential to improve discrimination, enhancing the sensitivity to even lower fluxes. In this work, we present a convolutional neural network designed to distinguish between simulated UHE photon and proton showers. We evaluate possible systematics due to the imperfect simulation of air showers and detector effects using an independent test set and a burn sample consisting of 2% of the available data. Steps for a future unblinding of the search sample are discussed.

T 61.3 Wed 16:45 KS 00.005

Shower based cross-calibration of swgo — •Florian Foith, Alison Mitchell, and Martin Schneider for the SWGO-Collaboration — ECAP, FAU Erlangen-Nürnberg

This work discusses the possibility of calibrating the effective efficiencies of Water Cherenkov detectors (WCDs) at the Southern Wide-field Gamma-ray Observatory (SWGO) by utilizing pairwise charge asymmetry parameters. These parameters are computed for single shower events and then averaged over all conducted simulations. The concept, originally proposed for Imaging Atmospheric Cherenkov Telescopes (IACTs), has proven successful for the Cherenkov Telescope Array (CTA) and is now being tested with two possible approaches for asymmetry parameter computation for SWGO. We found that following preliminary testing against grid anomalies, our method demonstrates promising accuracy within the limitations of WCD-based gamma-ray observatories.

T 61.4 Wed 17:00 KS 00.005

Effects of the geomagnetic field on IACT event reconstruction — •Matheus Genaro Dantas Xavier, Tim Unbehaun, Rodrigo Guedes Lang, and Stefan Funk — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

The observation of astrophysical gamma rays by Imaging Atmospheric Cherenkov Telescopes (IACTs) is based on the detection and imaging of Cherenkov light produced along the development of extensive particle air showers. The recorded images are then analyzed to reconstruct fundamental information of the primary gamma ray, such as its energy and direction. Due to Earth's magnetic field, charged particles in the shower are deflected during their trajectory, broadening the lateral development of the shower and the distribution of Cherenkov light on the ground. Consequently, distortions in the camera image can lead to systematic effects in the reconstruction procedure. These effects are especially visible for low energy events ($\sim$ 100 GeV) and are believed to be significant when only one telescope is triggered (monoscopic reconstruction). In this work, we investigate the impact of the geomagnetic field on the largest H.E.S.S. telescope (CT5), based on simulations of gamma-ray-induced air showers. Due to its large light collection area and improved camera design, CT5 is crucial for lowering the energy threshold of observed sources. Therefore, to comprehend the geomagnetic field effects is especially important to quantify and possibly correct systematic errors present on the monoscopic analysis.

T 61.5 Wed 17:15 KS 00.005

Get More for Less - Adaptive Sampling in Event Simulations For the Cherenkov Telescope Array Observatory — •Tristan Gradetzke and Luca Di Bella — TU Dortmund University, Dortmund, Germany

Monte Carlo (MC) simulations of particle induced extensive air showers are crucial to the analysis of observational data taken by Imaging Air Cherenkov Telescopes (IACTs). They serve the purpose of training and test data for the algorithmic reconstruction of particle type, energy, and direction of the originating particle. The performance of this reconstruction on the Monte Carlo data is mathematically described by the Instrument Response Functions (IRFs). Their usage however, comes at the extensive cost of computational resources. Consequently, considerable effort has been invested in improving the efficiency of these MC simulations. The objective of this work is to investigate the potential of adaptive sampling-based methods, that focus on specific phase-space regions to enhance event statistics and, to a certain extent, possibly reduce uncertainties in the IRFs. Thus reducing the extent of Monte Carlo productions. Phase space in this context refers to, among others, detector field of view and primary particle energy . The main challenges arise from the definition of a metric, that is optimized by any given algorithm. Here, a simple event-per-bin based metric is adopted. Possible improvements in efficiencies and an overview of potential avenues for future research are presented.

T 61.6 Wed 17:30 KS 00.005

Determining Telescope Pointing Direction Using Stellar Projections — •Daniel Cecchin Momesso and Christopher van Eldik — Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen Centre for Astroparticle Physics, Nikolaus-Fiebiger-Str. 2, 91058 Erlangen, Germany

This work presents a data-driven approach to improve the pointing accuracy of Imaging Atmospheric Cherenkov Telescopes (IACTs), such as those in the H.E.S.S. array. These telescopes detect Cherenkov light from gamma-ray-induced atmospheric showers, but are also sensitive to diffuse and stellar background light. This Night Sky Background (NSB) contains spatial information associated with the distribution of bright stars in the field of view. Based on stellar positions provided by catalogs, their projections onto the camera coordinates are compared with features observed in the NSB maps. This correspondence is the basis for correcting the pointing direction of the telescope and will be compared to the results of standard calibration methods.

T 62: Cosmic Rays III

Time: Wednesday 16:15–18:15 Location: KS 00.006

T 62.1 Wed 16:15 KS 00.006

Time Dependant Modelling of Astrophysical and DM Secondary Signatures in Dwarf Galaxies — •Jannis Wagner[1,2], Julien Dörner[1,2], Athithya Aravinthan[1,2], Milena Brütting[1,2], and Julia Becker Tjus[1,2,3] — [1]Fakultät für Physik & Astronomie, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [2]Ruhr Astroparticle and Plasma Physics Center (RAPP Center), Germany — [3]Department of Space, Earth and Environment, Chalmers University of Technology, 412 96 Gothenburg, Sweden

Dwarf galaxies are increasingly gaining traction as targets of indirect searches for Dark Matter (DM) due to their high mass-to-light ratios and low star-formation rates. Searches mainly focus on gamma rays in the GeV-TeV range created through different annihilation channels of Weakly Interacting Massive Particles (WIMPs). These signals are distorted by radiative emission of astrophysical Cosmic Rays (CRs), which necessitates joint modelling. Furthermore, the galaxies' decline in star-formation rate and its feedback on the galactic magnetic field require a time-dependent modelling of the CR distribution. Such a modelling would allow for better gauging of the morphological impact of DM and thus support future observation attempts for evidence of DM or in setting stronger constraints on its characteristics.

In this work, we explore this coupled modelling using the Monte-Carlo framework CRPropa, including leptonic DM secondaries and astrophysical CR electrons. We present a comparison of the morphologies of the resulting signatures for basic models of source distribution and magnetic field evolution.

T 62.2 Wed 16:30 KS 00.006

Temporal and Geometrical Effects of the GMF on UHECRs — •Veronika Vašíčková, Leonel Morejon, and Karl-Heinz Kampert for the Pierre Auger-Collaboration — Wuppertal, Germany

To understand the origin of the Ultra-High-Energy Cosmic Rays (UHECRs), it is important to explain features of their spectrum, as well as their arrival directions. Currently, this is done with modelling approaches neglecting time evolution, especially in the galactic magnetic field (GMF). We study the influence of the GMF on the arrival direction of UHECRs and on the spectrum, with the emphasis on temporal and geometrical effects, investigating the rigidity-dependent residence time of extragalactic cosmic rays entering our Galaxy using CRPropa. We probe both constant and time-varying flux scenarios and find that UHECRs entering the Milky Way can experience delays of hundreds of kiloyears. This temporal effect modifies the spectrum, introducing features such as a rigidity-dependent enhancement of the flux, a suppression of particles between $10^{18} - 10^{19}$ V, or a natural softening of spectra with time. The comparatively short residence time of particles above a certain rigidity could explain the common maximum rigidity needed to describe the UHECR spectrum.

Supported by DFG (SFB 1491)

T 62.3 Wed 16:45 KS 00.006

Study of Large scale Cosmic Ray Anisotropy with KASCADE and IceTop — •Joshua Turnwald, Donghwa Kang, and Andreas Haungs for the IceCube-Collaboration — Karlsruher Institut für Technologie (KIT)

We present a study of anisotropies in the arrival directions of cosmic rays using data from KASCADE (KArlsruhe Shower Core and Array DEtector) and IceTop, the surface component of the IceCube Neutrino Observatory. These two experiments, located in the Northern and Southern Hemispheres respectively, provide complementary coverage of the cosmic-ray sky. Our analysis focuses on large-scale anisotropies in the energy range from 100 TeV to about 50 PeV. The relative intensity of the anisotropy is determined using a maximum likelihood method. In this contribution, the results of the dipole amplitude and its systematic studies will be discussed.

T 62.4 Wed 17:00 KS 00.006

Investigation of the Diffusion Tensor for Different Turbulence Levels and Rigidities in the Resonant Scattering Regime — •Jan-Niklas Bohnensack[1] and Julia Becker Tjus[1,2,3] — [1]Theoretical Physics IV: Plasma-Astroparticle Physics, Faculty for Physics & Astronomy, Ruhr-Universityät Bochum, D-44780 Bochum, Germany; Supported by SFB1491 — [2]Ruhr Astroparticle And Plasma Physics Center (RAPP Center), Bochum, Germany — [3]Department of Space, Earth and Environment, Chalmers University of Technology, SE-412 96 Gothenburg, Sweden

The quasi-linear theory (QLT) describes the interactions between charged particles and astrophysical plasmas in the limit of $b/B \ll 1$. The goal of the underlying thesis was to verify the QLT's prediction that for small turbulence levels b/B, where b is the turbulent magnetic field strength and B is the homogeneous magnetic field strength, the diffusion coefficient behaves like $\kappa \propto \rho^\gamma$ with $\gamma = 1/3$. To overcome those restrictions a code was developed in the underlying thesis to utilize methods of parallelization that calculate the running diffusion coefficient from particles propagated with CRPropa faster. The diffusion coefficients were generated for a range of reduced rigidities so that the particles scatter resonantly at any point in space for a given turbulence level. This talk shows new simulated data which better shows the behavior of the spacial diffusion coefficient against different turbulent levels and reduced rigidities. I will further give an outlook on how we will use the diffusion coefficients in future simulations and experiments (e.g. in laboratory plasmas or diffusive transport simulations).

T 62.5 Wed 17:15 KS 00.006

mw-atlas: Inferring the 3D Galactic cosmic ray density of our Milky Way — •Mareike Berkner[1], Torsten Ensslin[2], Hanieh Zandinejad[2], and Philipp Mertsch[1] — [1]RWTH Aachen University, Aachen, Germany — [2]Max-Planck-Institut für Astrophysik, Garching, Germany

Most models of the Galactic cosmic-ray (CR) distribution often rely on simplified source distributions and propagation scenarios. They consequently fail to capture the rich, non-axisymmetric structure of the Milky Way. The true, 3D distribution of CRs is however crucial in identifying CR sources and in understanding the feedback that CRs provide to the interstellar medium. In this contribution, we discuss methodological attempts for a data-driven reconstruction of the 3D CR density using Bayesian inference and Gaussian processes. Information of the CR density is provided by hadronic γ-rays, measured by Fermi-LAT. Morphological matching structure in the γ-ray sky with corresponding ones in spatially resolved gas maps allows reconstructing the smooth, spatially correlated CR density field, including a measure of its uncertainty. This 3D map can be directly compared to predictions from propagation models. This will enable new tests of CR transport scenarios, improve models of diffuse gamma-ray emission, and offer a starting point for integrating CR physics consistently into ISM analyses.

T 62.6 Wed 17:30 KS 00.006

Revised Diffusive Shock Acceleration with CRPropa3.2 for the description of cosmic ray spectra at supernova shocks — •Jakob Dörner[1], Sophie Aerdker[1,2], Lukas Merten[1,2], and Julia Tjus[1,2,3] — [1]Theoretical Physics IV: Plasma-Astroparticle Physics, Faculty for Physics & Astronomy, Ruhr University Bochum, Germany; Supported by SFB1491 — [2]Ruhr Astroparticle and Plasma Physics Center (RAPP Center) — [3]Department of Space, Earth and Environment, Chalmers University of Technology, Gothenburg, Sweden

Supernova remnants (SNRs) play an important role in the acceleration of Galactic cosmic rays (CRs) that gain significant energy by repeatedly crossing the shock front. This acceleration process, known as diffusive shock acceleration (DSA), generally leads to a power-law spectral slope of E^{-2}. However, observations of nonthermal emission of SNRs imply CR energy distributions that are generally softer than E^{-2}, the DSA prediction. In contrast, non-linear theory of DSA would predict an even harder spectrum. Recent studies suggest that such soft spectra may arise from the additional drift of magnetic structures with respect to the thermal plasma downstream of the shock. We incorporate the effect of such drifts by changing the effective compression ratio of the shock in test particle simulations using the CRPropa framework, which solves the transport equation by utilizing stochastic differential equations. We obtain soft energy spectra, depending on the strength of the effective compression ratio, and concave energy spectra when the precursor is taken into account.

T 62.7 Wed 17:45 KS 00.006

Gamma-ray signatures from anisotropic cosmic ray transport in the Milky Way — •Julien Dörner[1,2], Jonas Hellrung[1,2], Julia Becker Tjus[1,2,3], and Horst Fichtner[1,2] — [1]Theoretical Physics IV, Plasma Astroparticle Physics, Faculty for Physics and Astronomy, Ruhr University Bochum, 44780 Bochum, Germany — [2]Ruhr Astroparticle and Plasma Physics Center (RAPP Center), Germany — [3]Department of Space, Earth and Environment, Chalmers University of Technology, 412 96 Gothenburg, Sweden

The magnetic field of the Milky Way is composed of a large-scale coherent background and a turbulent component. The spatial diffusion of cosmic rays (CRs) in this composed magnetic field configuration is expected to become anisotropic. The diffusion coefficient along the field line $\kappa_{\parallel}$ is greater than in the degenerated perpendicular directions $\kappa_{\perp}$.

In this work, we utilize the open-source framework CRPropa to investigate the anisotropic diffusion of CRs within the Milky Way. We phenomenologically vary the ratio $\epsilon = \kappa_{\perp}/\kappa_{\parallel}$, ranging from nearly parallel diffusion ($\epsilon = 10^{-3}$) to purely isotropic diffusion ($\epsilon = 1$). The source parameters are optimized to match the observed CR data at Earth. Afterwards, the line-of-sight integration framework HERMES is used to calculate the all-sky gamma-ray emission. Based on the resulting all-sky maps, the feasibility of gamma-ray observations to constrain not only the parameters of such anisotropic transport but also the structure of the Galactic magnetic field will be discussed.

T 62.8 Wed 18:00 KS 00.006

Forward Photon Measurement in Proton-Oxygen Run at the LHC with the LHCf Experiment — •Vlera Hajdini, Prof. Dr. Cigdem Issever, and Dr. Clara Leitgeb — Physics Insitute, Humboldt University of Berlin

The Large Hadron Collider forward (LHCf) experiment plays a fundamental role in Ultra High Energetic Cosmic Ray (UHECR) physics by providing tuning data for the hadronic interaction models used for Extensive Air Shower (EAS) simulations. LHCf measures neutral particles (γ, π^0, n) in the very forward region ($\eta > 8.4$) produced at the ATLAS interaction point (IP1), using two sampling calorimeters, Arm1 and Arm2, installed 140 m on both sides of the IP1.

In July 2025, LHCf participated in the first proton-Oxygen (p-O) collision run at the LHC, collecting data at $\sqrt{s_{NN}} = 9.6$ TeV. Forward particle production in p-O collisions is particularly relevant for UHECR studies, as it reproduces one of the projectile-target combinations characteristic of atmospheric interactions initiated by primary cosmic rays.

With a photon energy resolution of about 2% and a position resolution better than 40 μm, LHCf is well suited to investigate forward photon production with high precision. This contribution presents the current status of the photon analysis in p-O collisions.

T 63: Invited Overview Talks IV

Time: Thursday 11:00–12:30 Location: AudiMax

Invited Overview Talk T 63.1 Thu 11:00 AudiMax

Binary Black Hole Populations: Scientific Perspectives for the Einstein Telescope — •Michela Mapelli — Institut für Theoretische Astrophysik, Zentrum für Astronomie, Universität Heidelberg, Heidelberg, Germany

The fourth gravitational-wave transient catalog contains more than 200 binary compact-object merger candidates, the vast majority of which involve black holes. These data represent a genuine revolution in black hole science. In this talk, I will focus on the implications of these new observations for our understanding of the astrophysical formation of such systems across cosmic time. I will discuss the challenges of explaining the inferred black hole merger-rate density and of accounting for the most massive systems detected so far – with masses inside or above the pair-instability mass gap. In the second part of the talk, I will briefly touch upon the scientific prospects of next-generation detectors. The Einstein Telescope is expected to observe binary black hole mergers out to redshift $z \sim 100$. Together with LISA, it will open up the opportunity for multi-band gravitational-wave astronomy and will probe the largely uncharted territory of intermediate-mass black holes.

Invited Overview Talk T 63.2 Thu 11:30 AudiMax

JUNO's First Light: High-Precision Reactor Neutrino Oscillations — •Michael Wurm for the JUNO-Collaboration — Johannes Gutenberg-Universität Mainz, Germany

The JUNO experiment in southern China is designed for a high-precision measurement of reactor antineutrino oscillations. With a 20-kiloton liquid scintillator target and 17,600 20-inch photomultiplier tubes, JUNO is the largest detector of its kind and is expected to achieve an exceptional energy resolution of about 3 % at 1 MeV. Located 55 km from the Taishan and Yangjiang nuclear power plants, JUNO is located at the first solar oscillation maximum, enabling precise measurements of the oscillation pattern and sensitivity to the neutrino mass ordering. This configuration also provides outstanding sensitivity to the solar oscillation parameters, θ_{12} and Δm^2_{12}.

JUNO began operations in August 2025. Following a brief calibration phase, 59 days of stable data-taking were analyzed to deliver the first oscillation results, improving the uncertainties on the solar oscillation parameters by a factor of 1.6 relative to the combination of all previous measurements.

Having demonstrated performance consistent with and in some cases exceeding design specifications, JUNO will continue data collection to accumulate the statistics required for a definitive determination of the neutrino mass ordering. In parallel, its unprecedented size makes JUNO a powerful observatory for astrophysical neutrinos, particularly those from the Sun and core-collapse supernovae.

Invited Overview Talk T 63.3 Thu 12:00 AudiMax

Flavour physics at the precision frontier: recent highlights from the LHCb and Belle II experiments — •Evelina Gersabeck — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Gustav-Mie-Haus 02 025, Hermann-Herder-Straße 3b, D-79085 Freiburg im Breisgau

Quark flavour physics focuses on precision tests of the Standard Model and searches for hints of physics beyond the Standard Model by looking for deviations from SM predictions in measured branching fractions, angular observables, matter-antimatter asymmetries etc. The two leading flavour physics experiments, Belle II, located at KEK in Tsukuba, Japan, and LHCb at the LHC, CERN, Switzerland, are actively recording unprecedented amounts of data. In this talk I will discuss recent results from Belle II and LHCb, their complementarity and aspects of possible collaboration.

T 64: Invited Topical Talks III

Time: Thursday 13:45–15:45 Location: AudiMax

Invited Topical Talk T 64.1 Thu 13:45 AudiMax
Charting the Higgs Sector with Effective Field Theories — •Ilaria Brivio — Dipartimento di Fisica e Astronomia, Universita' di Bologna and INFN, Sezione di Bologna, via Irnerio 46, Bologna, Italy

With no clear signs of new resonances at the LHC, searches for physics beyond the Standard Model are increasingly targeting small indirect effects potentially induced by heavy physics beyond the collider's reach, which are captured by Effective Field Theories (EFTs). While the Standard Model EFT (SMEFT) is the established framework for this purpose, there is growing interest in scenarios that lie outside its underlying assumptions. An interesting way to explore them is by adopting the Higgs EFT (HEFT) – also known as electroweak chiral Lagrangian – which provides a more general EFT extension of the SM.

In this talk, I will introduce the basic ideas behind HEFT and explain how it differs conceptually from SMEFT. I will highlight the kinds of phenomenological signatures that distinguish the two approaches and provide an overview of the state of the art in the theoretical development of HEFT and its application at the LHC.

Invited Topical Talk T 64.2 Thu 14:15 AudiMax
Probing CP invariance of Higgs boson production and decay and its interpretation in effective field theories with the ATLAS detector — •Lorenzo Rossini — University of Freiburg

The origin of the observed baryon asymmetry in the universe is one open question that can be explained if the three Sakharov conditions are fulfilled. One of these conditions includes the violation of the invariance under combined charge (C) and parity (P) conjugation. However, the magnitude of CP violating effects in the Standard Model (SM) is not enough to explain the observations. The Higgs boson is a promising candidate to search for additional CP-violating interactions.

The ATLAS experiment at the LHC has a vast program of measurements of the properties of the Higgs boson, and in particular its CP properties in interactions with gauge bosons or fermions. This talk will summarize tests of CP invariance of Higgs boson production and decay, and the interpretation of the results using Effective Field Theory, with focus on analyses in which the decay mode into a pair of tau-leptons is exploited

Moreover, comparison (and future combinations) with other ATLAS analyses will be discussed. This talk will present results from analyses based on proton-proton collision data collected by the ATLAS experiment at a center-of-mass energy of $\sqrt{s}$=13 TeV and $\sqrt{s}$=13.6 TeV during Run 2 and early Run 3.

Invited Topical Talk T 64.3 Thu 14:45 AudiMax
b-tagging unlocks the Higgs potential — •Nicole Hartman — Technical University of Munich — ORGINS Data Science Lab

The Higgs potential governs electroweak symmetry breaking, but its form has yet to be experimentally verified and could impact the future stability of the universe. A first experimental probe of the Higgs potential will come from measuring the simultaneous production of two Higgs bosons (di-Higgs), an exceptionally rare process. This talk presents the latest results from ATLAS on measurements for di-Higgs in the most abundant final state with four b-quarks, as well as searches for additional Higgs bosons predicted in beyond the SM scenarios. The central challenge for these analyses is an accurate prediction of the quantum chromodynamics background, and generative AI techniques (normalizing flows) are showcased to model these challenging-to-simulate backgrounds in high dimensions.

In our quest to discover di-Higgs, the discovery channels will all include b-jets. The state-of-the-art for b-jet identification (or b-tagging) on ATLAS is a transformer model, and we present the latest developments in b-tagging with multi-task, multi-modal models. By increasing the size of these models, we demonstrate that particle physics can benefit from the foundation model scale that launched the AI revolution of Large Language Models. By casting jet taggers as a first foundation model for LHC physics, they can also be customized for our physics goals. We highlight how an end-to-end optimizable analysis can fine-tune a jet-tagger for a HH physics search, and how differentiable building blocks can automate future scientific discovery.

Invited Topical Talk T 64.4 Thu 15:15 AudiMax
Modern Machine Learning for LHC Event Generation — •Ramon Winterhalder — TIFLab, Università degli Studi di Milano & INFN Sezione di Milano, Italy

High-precision simulations from first principles are a cornerstone of LHC physics. With the upcoming high-luminosity phase of the LHC and the significant increase in experimental data, traditional simulation pipelines face growing challenges in terms of computational cost and efficiency. In this talk, I will discuss how modern machine-learning methods and computing paradigms can accelerate event generation while preserving theoretical accuracy. I will focus on three distinct and complementary approaches: neural importance sampling, as implemented in the MadNIS framework; machine-learned surrogate models for expensive matrix-element calculations; and hardware-aware implementations that exploit GPU acceleration and parallelization for efficient large-scale deployment. Together, these developments significantly reduce computational cost and pave the way towards the first ML-based event generator.

T 65: Invited Topical Talks IV

Time: Thursday 13:45–15:45 Location: MED 00.915

Invited Topical Talk T 65.1 Thu 13:45 MED 00.915
Atmospheric neutrino oscillations with IceCube and the IceCube Upgrade — •Jan Weldert — Johannes Gutenberg Universität Mainz

DeepCore, the low-energy extension of the IceCube Neutrino Observatory, detects hundreds of thousands of atmospheric neutrinos per year at the basic filter level. This enables the oscillation properties of these elusive particles to be studied. Even in its current configuration, the detector achieves a level of precision to atmospheric oscillation parameters comparable to that of long-baseline accelerator experiments. One of DeepCore's particular strengths lies in its wide range of baselines, some of which pass through the Earth's dense core. As part of the so-called IceCube Upgrade, additional optical modules were added to the detector earlier this year. Compared to the existing modules, these new modules have larger photo cathode areas and are spaced closer together. This substantially increases the number of atmospheric neutrinos detected, particularly at energies of a few GeV. Additionally, the energy, direction and topology of the detected neutrinos can be reconstructed with greater precision. All of this significantly increases IceCube's sensitivity to atmospheric neutrino oscillation studies, especially the neutrino mass ordering.

In my talk, I will explain how we conduct atmospheric neutrino oscillation studies in IceCube, present our latest results and show the potential of the IceCube Upgrade. The focus will be on the determination of the atmospheric oscillation parameters and the neutrino mass ordering.

Invited Topical Talk T 65.2 Thu 14:15 MED 00.915
Exploring the Gravitational Wave Universe with Pulsar Timing Arrays — •Andrea Mitridate — Imperial College London, London, UK

By tracking the radio emission from a collection of millisecond pulsars, several pulsar timing array collaborations have found evidence for a background of gravitational waves permeating our galaxy. In this talk, I will discuss how we obtained this evidence, the ongoing efforts to identify the source of this signal, and explore its implications for cosmology and astrophysics.

Invited Topical Talk T 65.3 Thu 14:45 MED 00.915
Supernova Remnants as Accelerators of Galactic Cosmic

Rays — •Robert Brose — Universität Potsdam

Particle acceleration in supernova remnants (SNRs) remains a cornerstone for understanding cosmic-ray (CR) origin. Multi-messenger signatures from SNRs are hereby crucial in pinning down the particularities of the acceleration process. Improvements in instrumental sensitivity from radio to gamma-ray energies and improved statistics in direct CR measurements have started to reveal cracks in the long-standing paradigm that SNRs are indeed the solely producers of Galactic CRs.

In this talk, we present a brief and candid overview of the numerical methods and assumptions typically employed in modeling shock acceleration in SNRs . Then we focus on multiwavelength (and multi-messenger) signals from SNRs bridging from very early stages, a few years after the explosion, to times where CRs start to leak out of the SNR's interior and considerably change the observational signatures.

Invited Topical Talk T 65.4 Thu 15:15 MED 00.915

Supermassive black holes and their relativistic jets: a beacon into the early universe — •Lea Marcotulli — Deutsches Elektronen-Synchrotron (DESY), Zeuthen, Germany

About 10% of accreting supermassive black holes (AGN) at the center of galaxies are capable of launching extreme relativistic jets. Shining as bright as a hundred trillion Suns and detected at the dawn of time, these AGNs and their jets have been studied for decades, from radio up to gamma-rays. However, many open questions still remain about* these powerful monsters. When, in the history of the universe, were the most luminous jets more numerous, and what is their connection with rapid supermassive black-hole growth at early cosmic times? Is there an evolutionary sequence linking jets of different power? How can we find and identify more of these extreme jets in the very early universe? In this talk, I will highlight how we can tackle some of these open issues through means of multi-wavelength and time-domain studies, in particular exploiting the capabilities of current and future X-ray and gamma-ray missions.

T 66: Neutrino Physics IV

Time: Thursday 16:15–18:00 Location: AudiMax

T 66.1 Thu 16:15 AudiMax

Tests of a full Monte Carlo simulation for keV-sterile neutrino searches with the KATRIN experiment in a mockup — •Tom Geigle for the KATRIN-Collaboration — Karlsruhe Institute of Technology (KIT), Karlsruhe

Sterile neutrinos in the keV mass range are a compelling dark matter candidate predicted by many extensions of the Standard Model. A distinctive signature would be a kink-like distortion in the tritium β-decay spectrum. While KATRIN currently probes the endpoint region to determine the effective neutrino mass, its next phase, TRISTAN, will extend the search across the full spectrum using a novel multi-pixel silicon drift detector and upgraded readout infrastructure, complemented by dedicated beamline modifications.

Sensitivity in this regime is strongly influenced by systematics such as electron scattering in the source and detector-response effects. To address these challenges, we have developed KAMELEON*a high-efficiency, Geant4-based Monte Carlo simulation of the entire KATRIN beamline. In this presentation, we outline its architecture and performance, compare simulation results with dedicated detector-mockup measurements, and present initial studies of systematic uncertainties relevant for the keV-scale sterile neutrino search.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMFTR (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6).

T 66.2 Thu 16:30 AudiMax

Long-term evolution of the KATRIN background — •Florian Fränkle for the KATRIN-Collaboration — Institute for Astroparticle Physics (IAP), Karlsruhe Institute of Technology (KIT)

The KArlsruhe TRItium Neutrino (KATRIN) experiment is a large-scale effort with the objective to determine the effective electron anti-neutrino mass with an unprecedented sensitivity of better than 0.3 eV/c^2 (90% CL) in a model-independent way based on precision β-decay spectroscopy of molecular tritium. KATRIN completed its neutrino mass measurement campaigns at the end of 2025 and so far has improved the upper bound on the effective electron-neutrino mass to 0.45 eV/c^2 (90% CL) based on data collected before July 2021.

A major limiting factor for the KATRIN sensitivity is a background level which is an order of magnitude higher than the original design specification. This presentation will provide an overview of the long-term evolution of the background during the neutrino mass measurement campaigns and share insights on the underlying background mechanisms.

This work is supported by the Helmholtz Association and by the Ministry for Education and Research BMFTR (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6).

T 66.3 Thu 16:45 AudiMax

Status of Theia simulations — •Johann Martyn, Amala Augusthy, Noah Goehlke, Alfons Weber, and Michael Wurm — Johannes Gutenberg-University Mainz

Theia is a large-scale neutrino detector concept, designed to simultaneously exploit Cherenkov and scintillation light, potentially enabling a broad range of physics goals. The detector concept leverages recent advancments for the separation of Cherenkov and scintillation light, such as water-based liquid scintillator (WbLS), fast photo-detectors, dichroicons, and novel reconstruction techniques. This allows for the reconstruction of the particle direction, as well as particle identification via Cherenkov light while providing an enhanced energy resolution and low energy threshold from the scintillation. The proposed scientific program includes long-baseline neutrino oscillation measurements and CP violation searches, precision solar neutrino studies, search for the diffuse supernova neutrino background (DSNB), and ultimately neutrinoless double beta decay. This talk presents an overview of Theia and the current status of the Geant4 based Theia simulation framework, focusing on the ongoing efforts to optimize the detector configurations.

T 66.4 Thu 17:00 AudiMax

Sensitivity studies for neutron flux measurements in the LEGEND experiment — •Loris Steinhart for the LEGEND-Collaboration — University of Tuebingen

Achieving the ambitious background goals of the next phase of the Large Enriched Germanium Experiment for Neutrinoless Double-Beta Decay (LEGEND) requires a precise understanding of neutron-induced backgrounds within the detector array. In this contribution, sensitivity studies for measuring the neutron flux in LEGEND are presented using a dedicated Gadolinium-loaded polyethylene (GdPE) string introduced into the experimental setup. Neutron captures on gadolinium produce characteristic signatures that can be identified via coincident energy depositions in the surrounding germanium detectors. By exploiting these correlations, neutron capture rates in the GdPE can be reconstructed and used to infer the neutron flux at the center of the detector array. This talk will discuss the underlying analysis strategy, simulation-based sensitivity estimates, and first experimental considerations, and will outline the relevance of this measurement for constraining neutron-related backgrounds and improving the overall sensitivity of LEGEND to the $0\nu\beta\beta$ decay search.

We acknowledge support from the DFG under Germany's Excellence Strategy – EXC 2094 (ORIGINS) and through the Sonderforschungsbereich SFB 1258. We acknowledge support by the BMFTR Verbundprojekt 05A2023 (LEGEND).

T 66.5 Thu 17:15 AudiMax

DUNE-PRISM: An innovative technique for neutrino oscillation analysis — •Ioana Alexandra Caracas — JGU Mainz, Germany

As long baseline neutrino experiments are entering the high-precision era, an increased sensitivity towards constraining the oscillation parameters space is expected. A classical approach for the oscillation predictions is prone to systematic uncertainties, due to the incompleteness of neutrinos interaction cross section modelling. This would in turn limit the capability to obtain the physics goals for modern long baseline experiments, such as the Deep Underground Neutrino Experiment (DUNE). An innovative technique, the Precision Reaction Independent Spectrum Measurement (PRISM) has been proposed and studied within the DUNE collaboration. This novel method is designed to measure and predict neutrino oscillated spectra on a data-driven basis, thus avoiding many neutrino interaction uncertainties. In this regard, the Near Detector (ND) is designed to move off the neutrino beam axis at several locations up to a distance of 28.5 m. Different neutrino fluxes are thus sampled and these ND off-axis results are further used to predict the neutrino oscillated spectrum at the DUNE Far Detector. The prediction obtained with the DUNE-PRISM analysis framework and preliminary results regarding the systematics impact on the oscillation parameters will be presented. Ongoing studies to improve the overall sensitivity to the oscillation parameters and reduce their dependence on the interaction model will also be discussed. The importance of sampling the entire off-axis space will also be high-lighted.

T 66.6 Thu 17:30 AudiMax

JUNO detector response determination through calibration data — •Marco Malabarba[1,2] and Livia Ludhova[1,2] — [1]1GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — [2]2Institute of Physics and EC PRISMA+, Johannes Gutenberg Universität Mainz, Mainz, Germany

JUNO (Jiangmen Underground Neutrino Observatory) is a multipurpose neutrino physics experiment in China. Its construction ended in 2024 and it has been taking data since August 2025. The target consists of 20 kton of organic liquid scintillator. The optical photons are collected by photomultiplier tubes which provide a geometrical coverage of $\sim 78\%$. JUNO has already achieved world leading precision on the neutrino solar oscillation parameters with 59.1 days of data taking. To obtain this result, as well as to achieve its future goal of determining the neutrino mass ordering, an evaluation of the detector response, in terms of temporal stability, detector non-uniformity, energy resolution, and energy non-linearity, is needed. All these quantities can be determined both through calibration (^{137}Cs, ^{54}Mn, ^{68}Ge, ^{40}K, ^{60}Co, AmC, and laser) and natural sources (such as ^{214}Po, spallation neutrons, and some cosmogenic isotopes as ^{12}B and ^{11}C). In this talk, an analysis of the calibration sources will be presented. In particular, different fit models have been developed to take into account the different decay details of each individual nuclide. The results allow to infer the concentration of ^{14}C and, when combined with the spectra of ^{12}B and ^{11}C, also to determine the energy non-linearity for e$^-$, e$^+$, and γ, an essential building block for reactor neutrino analysis.

T 66.7 Thu 17:45 AudiMax

Liquid Handling System and radiopurity of the OSIRIS detector — Manuel Böhles[1], Marcel Büchner[1], Daniela Fetzer[1], Arshak Jafar[1], •Oliver Pilarczyk[1], Tobias Sterr[2], and Michael Wurm[1] — [1]Johannes Gutenberg-University Mainz — [2]Eberhard Karls Universität Tübingen

The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kt liquid scintillator experiment in Jiangmen (China). Its main scientific goal is to determine the neutrino mass ordering by measuring electron antineutrinos from two nearby nuclear power plants at a distance of ˜53 km. To achieve this goal the liquid scintillator had to be thoroughly cleaned to make sure it meets the optical and radiopurity requirements.

The 20m* OSIRIS pre-detector is the last device behind these purification plants in an underground hall close to the main JUNO detector. Its task was to monitor the radiopurity of the purified scintillator before it was filled in the JUNO detector. OSIRIS was operated in batch-mode to qualify the purity of scintillator samples and its own experimental sensitivity before and during JUNO filling. To ensure every batch of the scintillator stays about 24h inside OSIRIS a temperature gradient can be established in the detection volume. This talk covers the operations and results from the commissioning phase of the OSIRIS detector as well as the background levels and sensitivity that were reached for U/Th.

The work is supported by the DFG Research Unit 'JUNO' (FOR5519) and the Cluster of Excellence PRISMA+.

T 67: Top Physics III

Time: Thursday 16:15–18:00 Location: KH 00.011

T 67.1 Thu 16:15 KH 00.011

Towards a top quark mass measurement in the all-jets final state using full Run 2 data — •Lennert Griesing, Peter Schleper, Johannes Lange, Hartmut Stadie, Lukas Schaller, and Yannek Gruel — Institute of Experimental Physics, Hamburg University, Germany

A precise measurement of the top quark mass is important for testing the Standard Model of particle physics. While the CMS experiment has achieved high precision using a profile likelihood fit in the lepton+jets final state, it has not been applied to the all-jets final state, yet. This final state remains challenging due to the large QCD multijet background and the complexities of the event reconstruction.

A new measurement in this channel is being developed using data collected with the CMS experiment at the LHC during Run 2 at $\sqrt{s} = 13\,\text{TeV}$. The analysis strategy combines optimized event selection, data-driven background estimation, and systematic uncertainty studies tailored to the all-jets final state. A profile-likelihood fit is employed to extract the top quark mass while simultaneously constraining systematic uncertainties. Leveraging the full statistical power of the dataset, this analysis aims to provide a complementary, high-precision measurement of the top quark mass. We report on the current status of this analysis.

T 67.2 Thu 16:30 KH 00.011

Comparing Parton-Shower Models in Top-Quark Production and Reweighting Between Models with Machine Learning — •Arshil Shaikh[1,2], Roman Kogler[1,2], and Dominic Stafford[2] — [1]Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Deutsches Elektronen-Synchrotron (DESY), Notkestr.85, 22607 Hamburg, Germany

Accurate modeling of parton-shower dynamics is essential for precision studies of top-quark production. In our setup, next-to-leading-order matrix-element events are generated with POWHEG, which can be interfaced with different parton-shower approaches. These include the transverse-momentum-ordered dipole shower of Pythia8 and the antenna-based shower implemented in Vincia. Their distinct approximations can lead to notable differences in jet and jet-substructure observables.

In this work, we study $pp \to t\bar{t} \to$ semileptonic events produced with POWHEG+Pythia8 and POWHEG+Vincia, comparing the $t\bar{t}$ system kinematics, jet characteristics, and jet-substructure variables such as N-subjettiness, generalised angularities, and energy-correlation functions. Furthermore, we use the DCTR (Deep neural networks using Classification for Tuning and Reweighting) technique to reweight Pythia8 events such that they reproduce Vincia-like distributions, without requiring the computationally expensive step of re-running the full detector simulation. This study highlights key differences between parton-shower models and demonstrates the potential of machine-learning-based reweighting to efficiently bridge them.

T 67.3 Thu 16:45 KH 00.011

Investigation of boosted top quarks and overlapping jets in the all-jets top quark mass measurement — •Yannek Ruwen Gruel, Peter Schleper, Johannes Lange, Hartmut Stadie, Lennert Griesing, and Lukas Schaller — Universität Hamburg, Hamburg, Germany

At high momenta, the distances between the jets of top quark decay products are smaller due to the Lorentz boost. As a result, the jets may overlap or even merge. This study investigates the influence of these effects on the measurement of the top quark mass with a resolved selection in the all-jet channel with the CMS experiment. For the event reconstruction, a kinematic fit is used that operates on the hypothesis of non-overlapping jets. Due to the strict trigger cuts for p_T, a large number of top quarks with high p_T are expected. The number of events with overlapping and merged jets is quantified and the distortion of the event reconstruction is studied.

T 67.4 Thu 17:00 KH 00.011

Unfolding tops - using ATLAS to create detector-independent data — •Elia Schmidt, Richard Nisius, Changqiao Li, Xuewei Jia, and Dimbiniaina Rafanoharana — Max Planck Institute for Physics

The top-quark mass is an important fundamental parameter of the standard model. While its exact value has profound implications for Particle Physics, e.g. the stability of the QCD vacuum, its determination is hampered by theoretical ambiguities. The most precise measurements, performed by the big LHC Collaborations, are systematically limited and suffer from substantial modelling uncertainties.

In this presentation I will give a short overview of the theoretical issues associated with top-quark mass measurements and motivate the concept of data unfolding. The ongoing ATLAS analysis I am involved in has the goal of publishing an unfolded invariant mass distribution of lepton-jet pairs from $t\bar{t}$ decays. I use it as an example to show how data from ATLAS are processed to create a distribution which is essentially independent of detector-related uncertainties. The unfolded distribution can then be compared to all theoretical predictions, allowing conceptually sound top-quark mass determinations within a chosen model.

T 67.5 Thu 17:15 KH 00.011

Measurement of the top-quark mass using singly produced top-quarks in the t-channel — •Lukas Kretschmann, Dominic Hirschbühl, and Wolfgang Wagner — Bergische Universität Wuppertal, Germany

Almost all measurements of the top-quark mass have been performed using top-quark-antiquark pair-production events, measurements in other channels can be important inputs for a global combination. First studies for a measurement of the top-quark mass using t-channel single top-quark events are shown. This channel is statistically independent to the top-quark-antiquark pair-production measurements and has different systematic uncertainties associated to it, e.g. modelling uncertainties from Monte Carlo event generators. The high rate of background-events is a major challenge in this channel, for this a Graph Neural Network (GNN) is trained to enrich the selection in single top-quark t-channel events. For the determination of the top-quark mass the invariant mass of the charged lepton and the b-quark jet is used as a sensitive observable employing a maximum likelihood fit.

T 67.6 Thu 17:30 KH 00.011

Quark mass effects in the gradient flow observables — •Robert Mason and Robert Harlander — TTK, RWTH Aachen University, Aachen, Germany

The gradient flow provides a consistent scheme for matching perturbation theory and lattice field theory. In the continuum this has typically been done with the simplifying assumption that quarks are massless. However, this neither reflects lattice computations nor physical reality. In this talk we discuss the computation of three quantities fundamental to the gradient flow, the vacuum expectation values of the flowed fermion and gluon condensates and the fermion kinetic operator, and consider their quark mass effects to the three loop level. We then briefly discuss the idea of Takaura et. al. to use these mass effects with lattice data for precision estimates of the quark masses.

T 67.7 Thu 17:45 KH 00.011

New method for extracting the mass of valence quarks in protons — •Jianming Wang — Department of Physics, Lanzhou University, Lanzhou, China

In this paper, the extraction of the mass of valence quarks in protons no longer depends on the exact mass of each quark, but seeks the exact mass ratio of different valence quarks in the same system through experiments. By finding the exact ratio of the mass of the up quark and the down quark, the relationship among the three valence quarks can be found. Based on the experimental results of Seaquest carried out by Fermilab in 2021, through analysis, the accurate ratio of up quark to down quark mass ($mu/md = 0.707$) is obtained, and the mass triangle is established. It is deduced that the sum of squares of up quark mass in protons is equal to the square of down quark mass. The mathematical expression is: $mu^2 + mu^2 = md^2$.

T 68: Standard Model Physics III

Time: Thursday 16:15–17:45 Location: KH 00.014

T 68.1 Thu 16:15 KH 00.014

Study of sensitivity of VBS VZjj semi-leptonic final states to vector boson polarisation observables — •Aryan Borkar, Thomas Trefzger, Raimund Ströhmer, and Gia Khoriauli — University of Würzburg

The electroweak symmetry breaking mechanism can be experimentally tested in the electroweak vector boson scattering (VBS) processes that occur in proton-proton collisions at the LHC.

The unitarity of VBS cross sections of longitudinally polarised bosons $V_{1,L}V_{2,L} \rightarrow V_{3,L}V_{4,L}$, where ($V = W^{\pm}, Z$), in the Standard Model are preserved due to inclusion of the Feynman diagrams with the Higgs boson propagator in calculations.Thus, precise measurements of VBS processes of longitudinally polarised vector bosons are important experimental tests of the validity of the Brout-Englert-Higgs mechanism.

We present the preliminary study of the potential of measurements of VZ VBS polarisation observables, in the fiducial phase space as defined by the geometry of ATLAS detector. VBS processes with semi-leptonic final states, where Z decays to a pair of same-flavour oppositely charged leptons and V decays hadronically, are considered in the study.

T 68.2 Thu 16:30 KH 00.014

Measurement of the differential di-boson cross-section in semileptonic final states at $\sqrt{s} = 13$ TeV in $140\,\mathrm{fb}^{-1}$ of pp collisions with the ATLAS detector — •Anubhav Gupta, Chris M. Delitzsch, and Amartya Rej — TU Dortmund University, Otto-Hahn-Str. 4A 44227 Dortmund

The measurement of electroweak vector boson pair (VV) production cross-sections is a critical test of the Standard Model (SM), probing electroweak boson self-interactions and the electroweak theory. While VV production has been well-studied in fully leptonic decay channels at $\sqrt{s} = 13\,\mathrm{TeV}$, semileptonic channels have only been measured at $\sqrt{s} = 8\,\mathrm{TeV}$.

This analysis presents the first measurement of di-boson production in the semileptonic channel (leptons and a large radius jet) at $\sqrt{s} = 13\,\mathrm{TeV}$, taking advantage of its higher branching fraction compared to fully leptonic decays and a cleaner signature than fully hadronic decays. The semileptonic channel is particularly sensitive at high energies, offering strong potential for detecting new physics beyond the SM in the tails of kinematic distributions.

The study includes particle-level inclusive and differential cross-section measurements, along with constraints on dimension-6 Effective Field Theory (EFT) operators in the Warsaw basis, affecting electroweak triple gauge couplings, at the folded level.

T 68.3 Thu 16:45 KH 00.014

Analysis of multi-τ final states of diboson processes with the ATLAS detector — Philip Bechtle, Yann Buchholzer, Klaus Desch, Christian Grefe, and •Simon Thiele — Rheinische Friedrich-Wilhelms Universität Bonn

The process $ZZ \rightarrow 4\tau$ is a theoretically well understood standard model process but has never been observed. In addition to the small cross section and branching ratio there are several challenges posed by this channel. Among them are the fake estimation of combinations of up to four hadronic tau-candidates, the mass reconstruction in final states with at least four neutrinos, the pair-wise combination of the τ's, and the selection of triggers to use.

Additionally to being itself an interesting discovery, the work on multi-τ final states can serve as a template for future $HH \rightarrow 4\tau$ searches, which could add to the discovery potential for triple Higgs couplings at the LHC. Furthermore there is the potential to discover other heavy scalars in the 4τ final state if there is resonant $A \rightarrow HH$ production as opposed to merely the off-shell standard model production.

In this talk I will present an overview of previous efforts and the initial work already done in this analysis, going over theoretical expectations and the analysis strategy.

T 68.4 Thu 17:00 KH 00.014

Sensitivity and background studies related to the measurement of the tau-lepton's anomalous magnetic moment in pro-

ton collisions with the ATLAS detector. — •Ruben Bies, Valerie Lang, and Markus Schumacher — University of Freiburg

Anomalous magnetic moments are a property of leptons that modify their behaviour in electromagnetic fields through higher order corrections in quantum field theory. These quantities have been measured with great precision for electrons and muons and have shown some tensions with the predictions in the Standard Model (SM). Measurements of the tau-lepton's anomalous magnetic moment are predicted to be most sensitive to beyond SM effects, but the tau-lepton's lifetime is too short for similar experiments as for electrons and muons. In recent years, measurements of the anomalous magnetic moment for the tau-lepton have been successfully performed using ultra-peripheral heavy-ion collisions as well as proton collisions at the Large Hadron Collider (LHC).

This presentation will outline the analysis strategy of the ATLAS collaboration to perform a measurement of the tau-lepton's anomalous magnetic moment in proton collisions using the datasets from the second and third running periods of the LHC. Initial studies on the selection optimization and improvements of the signal to background ratio, as well as first background estimates will be shown.

T 68.5 Thu 17:15 KH 00.014

Measuring the τ Lepton Polarization in $Z \to \tau_{\text{lep}}\tau_{\text{had}}$ Decays with ATLAS Run 2 Data — •Laman Guliyeva[1], Philip Bechtle[2], and Christian Grefe[2] — [1]Bergische Universität Wuppertal, Gaußstr. 20, D-42119 Wuppertal — [2]Physikalisches Institut der Universität Bonn, Nußallee 12, D-53115 Bonn

The polarization of leptons produced in Z-boson decays is a key parameter of the electroweak sector, as it provides direct insight into the parity-violating structure of the $Z\ell\ell$ coupling. In particular, τ leptons constitute a sensitive probe of electroweak interactions due to their short lifetime and decays occurring within the detector volume. Their hadronic decay modes are especially sensitive to spin-dependent observables, enabling a precise determination of their polarization in Z-boson decays.

This contribution presents a new measurement of the τ-lepton polarization in $Z \to \tau_{\text{lep}}\tau_{\text{had}}$ decays using ATLAS Run-2 data collected in 2018 at $\sqrt{s} = 13$ TeV. This measurement is based on a statistically independent and substantially larger dataset than the Run 1 analysis, making it fully complementary to the previous ATLAS result.

T 68.6 Thu 17:30 KH 00.014

Sensitivity to lepton-flavour-violating decays of the Z boson using a data-driven background estimate with the ATLAS experiment — •Naman Kumar Bhalla, 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 phenomena beyond the Standard Model (SM) of particle physics. One such phenomenon is lepton flavour violation (LFV), which has already been observed in neutrino oscillations, but not in processes involving charged leptons. A search for LFV in decays of the Z boson with charged leptons in the final state, such as $Z \to e\tau_\mu$ and $Z \to \mu\tau_e$, is of high interest and well motivated by various beyond-SM theories. This search can be performed using a data-driven background estimate, which takes advantage of the idempotency of SM backgrounds under the exchange of an electron and a muon. The symmetry is broken only by the difference in branching ratios between LFV decays with $e\tau$ and $\mu\tau$ final states.

This talk discusses the achievable sensitivities for the search of LFV decays of the Z boson using this data-driven background estimate. The full Run-2 data set is used, which was collected by the Atlas detector in pp collisions at $\sqrt{s} = 13\,\text{TeV}$, corresponding to $L_{\text{int}} = 140\,\text{fb}^{-1}$. The talk presents the data-driven estimate and a new methodology to construct and implement a robust statistical model.

T 69: Methods in Particle Physics IV

Time: Thursday 16:15–17:45 Location: KH 00.020

T 69.1 Thu 16:15 KH 00.020

Investigating the use of fast detector simulation for jet flavor identification algorithms in ATLAS — Diptaparna Biswas, Carolina Costa, Markus Cristinziani, Carmen Diez Pardos, Ivor Fleck, Gabriel Gomes, Jan Joachim Hahn, Nikolaos Kamaras, Vadim Kostyukhin, Nils Benedikt Krengel, •Austin Olson, Inês Pinto, Sebastian Rentschler, Elisabeth Schopf, Katharina Voss, Wolfgang Walkowiak, and Adam Warnerbring — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

In the ATLAS experiment, identification of quark flavor in a given jet is done with machine learning algorithms known as "taggers", trained with simulated events. Taggers' performance depend on accurate simulation of jet constituents. Previously, only tracks associated to jets were used in training, but the latest tagger, GN3, also uses all particle-flow constituents. At the same time, approximation of calorimeter showers with generative modeling (FastSim) is becoming more adopted by the ATLAS Collaboration in lieu of full Geant4 simulation (FullSim).

Many rare signal samples and several background samples are produced using FastSim, making it essential to evaluate the performance of these samples in this new GN3 model. Recent studies indicate significant scope for improving performance of GN3-like models solely by increasing the amount of training data, making FastSim samples a desirable option for model training itself. This talk presents comparisons of FastSim and FullSim samples in the context of ATLAS taggers.

T 69.2 Thu 16:30 KH 00.020

Identification of low p_{T} b-hadrons at the ATLAS experiment — •Hagen Möbius — DESY, Zeuthen, Germany

The identification of b-hadrons in an event, called b-tagging, is an important part of the physics program of the ATLAS experiment, in particular for Standard Model precision measurements, studies of the Higgs boson and searches for physics beyond the Standard Model. The starting point for standard b-tagging techniques in the ATLAS experiment are jets, bundles of particles. This leads to constraints on the energy of both the b-hadron and the surrounding hadronic activity and consequently low p_{T} b-hadrons in a jet below the jet reconstruction threshold are not reconstructed.
This talk presents an algorithm with a jet-independent b-hadron identification strategy. The algorithm, called the NewVrtSecInclusiveTool, reconstructs secondary vertices that can be associated with the decay of low p_{T} b-hadrons. The procedure and performance of the algorithm are discussed. Furthermore, the origins of the tracks contributing to these secondary vertices are examined to assess the accuracy of the b-hadron reconstruction.

T 69.3 Thu 16:45 KH 00.020

Tagging at ATLAS with GN3: Beyond heavy-flavour — •Diptaparna Biswas[1] and ATLAS Collaboration[2] — [1]Center for Particle Physics Siegen, Experimentelle Teilchenphysik, Universität Siegen, Germany — [2]CERN, Geneva, Switzerland

Accurate identification of jets that originate from heavy-flavour hadrons is pivotal for many ATLAS analyses, from Higgs-boson and top-quark measurements to searches for new physics. We present GN3, our newest jet flavour tagger, which introduces a full-transformer architecture tailored to the environment of LHC Run-2 and Run-3.

GN3 processes low-level track, neutral particle, and muon information to extract correlations between the inputs and infer the origin of the jet. Compared with the current Run-3 baseline, GN2, the new model achieves a significantly better separation of b- and c-jets from light-flavour jets across a wide kinematic phase-space.

In this talk, we will discuss the architecture and training workflow, as well as the newest results from GN3. Furthermore, we will highlight the new capabilities added to GN3, which extend its functionality into the realm of s-tagging.

T 69.4 Thu 17:00 KH 00.020

Reconstruction of Heavy Neutral Lepton decaying into lepton + ρ in SHiP — •Harshivraj Jatinbhai Oza for the SHiP-SBT-Collaboration — Humboldt Universität zu Berlin, Berlin, Germany

As part of the ongoing search for physics beyond the standard model, CERN has recently approved a new general-purpose beam dump experiment at SPS: SHiP (Search for Hidden Particles). SHiP aims to explore the intensity frontier by searching for feebly interacting particles in the GeV mass regime. Among several well-motivated candidates, the experiment is optimized for the discovery of Heavy Neutral Leptons (HNLs), hypothetical particles that could explain neutrino masses and mixing, provide a mechanism for baryogenesis, and potentially contribute to the dark-matter sector.

This talk presents the mass reconstruction strategy for the HNL decaying into a $lepton + \rho$ ($->\pi\pi^0$), without explicitly reconstructing the π^0 exploiting the mass constraint $(P_\pi + P_{\pi^0})^2 = m_\rho^2$. Furthermore we explore the feasibility of taking advantage of the Surrounding Background Tagger (SBT) to identify photons from the π^0 decay as a means of improving the signal reconstruction and background suppression.

T 69.5 Thu 17:15 KH 00.020

Reconstruction of Neutrons and Sensitivity to the Decay $B \to Kn\bar{n}$ at Belle II — •Timur Lenkeit, Alexander Heidelbach, Thomas Kuhr, and Thomas Lueck — Ludwig-Maximilians-Universität München (LMU), München, Germany

Neutrons are often not taken into account in the detector design or the reconstruction software, but can nevertheless play an important role in understanding physical processes. We examine methods to improve neutron reconstruction at the Belle II experiment. Unlike photons or electrons, neutrons do not interact electromagnetically; their energy is recorded only indirectly through secondary particles from hadronic interactions, which results in irregular and diffuse signatures in the electromagnetic calorimeter (ECL). These features make it challenging to distinguish neutrons from other neutral particles. To address this, we investigate machine-learning*based classifiers that combine ECL variables to enhance neutron particle identification. In addition, we explore the use of variables related to the K_L^0 and Muon detector to recover information from neutrons that leave no signal in the ECL.

We then assess how these reconstruction strategies affect the background composition and the achievable sensitivity to the decay $B \to Kn\bar{n}$. With these studies, we aim to enable a determination of the corresponding branching fraction.

T 69.6 Thu 17:30 KH 00.020

Measurement of the η Reconstruction Efficiency at Belle II — •Johannes Mirfanger, Thomas Kuhr, and Thomas Lueck — Ludwig-Maximilians-Universität München (LMU), München, Germany

The precise reconstruction of η mesons is essential for a wide range of physics analyses at Belle II. This work presents a data-driven determination of the η reconstruction efficiency using the decay $D^{*+} \to D^0\pi^+$, comparing the two D^0 decay modes $D^0 \to K^-\pi^+$ and $D^0 \to K^-\pi^+\eta$. By forming the ratio of these channels and correcting for the known branching fractions, we extract the η reconstruction efficiency of the Belle II detector. A key strength of this method is the ability to directly compare data and Monte Carlo simulation, enabling a clean assessment of potential discrepancies between them.

The extracted efficiency is further studied as a function of key kinematic variables, including the η momentum and polar angle. This offers detailed insight into detector performance across phase space. Ongoing work focuses on evaluating the robustness of the efficiency under varied event-selection criteria and on optimizing cut strategies for future analyses. The presentation will discuss the current status and give an outlook on the analysis.

T 70: Electronics, Trigger, DAQ III

Time: Thursday 16:15–18:00 Location: KH 00.023

T 70.1 Thu 16:15 KH 00.023

The Hypothesis Firmware for the ATLAS L0 Trigger system for HL-LHC — •Emanuel Meuser — Institut für Physik, Johannes Gutenberg-Universität Mainz

During the upgrade for HL-LHC, parts of the ATLAS detector will be upgraded, and the time-multiplexed L0Global Trigger system will be added to the first-level trigger. As part of this L0Global Trigger system, a hypothesis firmware to evaluate all the trigger objects/candidates of an event in a serialized and non-LHC-synchronous manner will go into operation in 2031.

This hypothesis firmware has to perform multiplicity triggers, as well as topological ones, as configured by a trigger menu. Since this trigger menu can change in periods too short to rebuild and validate new firmware, the hypothesis firmware needs to be runtime-configurable within certain boundaries. The design and implementation of the hypothesis firmware, focusing on resource optimization, robustness, and configuration via a trigger menu, will be discussed.

T 70.2 Thu 16:30 KH 00.023

Commissioning, Validation, and Simulation of the JUNO hardware trigger logic — •Ze Chen[1,2] and Livia Ludhova[1,2] — [1]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — [2]Institute of Physics and EC PRISMA+, Johannes Gutenberg Universität Mainz, Mainz, Germany

The Jiangmen Underground Neutrino Observatory (JUNO) is a large-scale neutrino experiment using a 20-kt liquid scintillator as the Central Detector (CD) surrounded by a 35-kt water Cherenkov veto Detector (WCD). The experiment completed full detector commissioning and subsequently began physics data taking on August 26 2025. Using an exposure of 59.1 days, JUNO has achieved world-leading precision in the measurement of solar neutrino oscillation parameters. Reaching this level of performance requires a robust and accurately functioning hardware trigger system for both subdetectors.

In this talk, we present a comprehensive validation of the JUNO hardware trigger logic using commissioning data. The two JUNO subdetectors employ different trigger logics: the CD uses a multiplicity trigger with dedicated handling of muons, while the WCD adopts a regional scheme that fires when a cluster of Photomultiplier tubes (PMTs) in a local area is hit. To evaluate trigger performance, PMT hit information is analysed across all event categories. In particular, we examine the dynamic CD trigger conditions, which aim to suppress consecutive muon-induced triggers and mitigate DAQ I/O bottlenecks. We also implemented the trigger logic in JUNO's detector simulation framework, enabling future optimization of trigger configurations.

T 70.3 Thu 16:45 KH 00.023

The Mu3e DAQ build system and CI — •Alexandr Kozlinskiy for the Mu3e-Collaboration — Johann-Joachim-Becher-Weg 45, 55128 Mainz, Germany

The *Mu3e* experiment is designed to search for the lepton flavor violating decay $\mu^+ \to e^+e^-e^+$ with the aim of reaching a branching ratio sensitivity of 10^{-16}. The experiment is located at the Paul Scherrer Institute (Switzerland). The existing beam line will provide 10^8 muons per second and at first will allow to reach a sensitivity of a few 10^{-15}.

The readout system of *Mu3e* uses Intel FPGA chips for which the firmware and IP components are compiled with the Quartus software. To improve the development and testing of the *Mu3e* DAQ firmware, custom scripts were developed to build firmware directly from the command line. The continuous integration is used to build and test the firmware on each commit. This allows for faster development of firmware and tracking of regressions during development.

The talk will cover the scripts, tools and the design of the *Mu3e* DAQ build system.

T 70.4 Thu 17:00 KH 00.023

Online Track Reconstruction for the Mu3e Experiment — •Haris Avudaiyappan Murugan for the Mu3e-Collaboration — Institute of Nuclear Physics, Johannes Gutenberg University of Mainz, Germany

The Mu3e experiment aims to find or exclude the lepton flavour violating decay of a positive muon to two positrons and an electron with a branching fraction sensitivity of 10^-16. To observe such a rare event, we require a tracking detector from custom-designed High-Voltage Monolithic Active Pixel Sensors (HV-MAPS) together with timing detectors made from scintillating fibres and tiles for the experiment. The detector will be streaming up to 1 TBit/s of data to the filter farm composed of graphics processing units (GPUs), in which the data rate is reduced to less than 100 MB/s and this filtered data is stored for later analysis. This reduction can be achieved by selecting potential signal events with two positrons and one electron originating from a single vertex through online track and vertex reconstruction on the GPU. During the 2025 beam run we were able to perform/test online tracking and selection of events using the filter farm.

T 70.5 Thu 17:15 KH 00.023

The Tile Calorimeter Trigger and Data Acquisition interface: Realtime and Readout Developments — •Anna Dunz and Thomas Junkermann — Kirchhoff-Institut für Physik, Heidelberg

With the Phase-II Upgrade of the ATLAS experiment, the front- and back-end electronics for the Tile Calorimeter will be replaced. This upgrade is made necessary by the increase in luminosity of the LHC. The new electronics are designed to improve signal reconstruction while coping with more simultaneous Proton-Proton collisions.

The Tile Calorimeter Trigger and Data Acquisition interface (TDAQi) is part of the new electronics design. It is an ATCA rear transition module equipped with an AMD Kintex Ultrascale+ FPGA. The TDAQi provides an interface between the Tile Calorimeter electronics and the ATLAS trigger systems. Following the requirements of the Level-0 trigger subsystems, different algorithms are performed to calculate trigger inputs. Cell energies from the Calorimeter are decoded and high energy cells are identified. Cells are summed up to provide lower granularity objects to the electron and jet triggers. For the muon trigger, cells are summed up at a high granularity, and threshold comparisons are performed. The processing algorithms and data transmission are carried out on the FPGA. An overview of the firmware is presented with a focus on the muon system showcasing the real-time as well as read-out capabilities of the TDAQi.

T 70.6 Thu 17:30 KH 00.023

The DAQ and Trigger System for the DELight Experiment — •Lea Burmeister for the DELight-Collaboration — Kirchhoff-Institute for Physics, Heidelberg University

While heavy WIMP searches have reached unprecedented sensitivities, the light dark matter (DM) sector remains largely unexplored. Probing light dark matter candidates requires novel detector concepts with ultra-low thresholds. The Direct search Experiment for Light dark matter (DELight) will employ superfluid helium-4 as the target medium monitored with MMC-based large-area microcalorimeters (LAMCALs) operating at mK temperatures, which provide excellent energy resolution with a detection threshold of a few eV.

The DELight experiment requires a data acquisition (DAQ) system capable of detecting extremely small energy depositions without acquiring deadtime. This talk presents ongoing R&D work on the DELight DAQ and trigger system, with focus on its FPGA-based Level-1 (L1) trigger. The L1 trigger will process digitized microcalorimeter waveforms in real time using downsampling, filtering, and flexible threshold logic to distinguish low-energy events from noise. The filtering step will be achieved using an FIR filter whose coefficients resemble a time-domain optimal filter.

T 70.7 Thu 17:45 KH 00.023

Development of a Stand-Alone Drift-Tube-Based Muon Trigger for the ATLAS and CRESST Experiments — •Stefan Eder, Davide Cieri, Oliver Kortner, Sandra Kortner, Federica Petricca, Michele Mancuso, and Alexander Langenkämper — Max Planck Institute for Physics

The upcoming High-Luminosity LHC era will require substantially improved selectivity in the ATLAS first-level muon trigger system. To meet these demands, new FPGA-based trigger processor boards have been developed that, for the first time, incorporate precision tracking information from Monitored Drift Tube (MDT) chambers directly into the Level-0 trigger decision. Before operation in Run 4, the MDT detectors, their readout, and trigger processors must be commissioned using cosmic-ray muons. This requires a dedicated track-finding algorithm that relies solely on information from drift-tube detectors.

This presentation introduces a standalone drift-tube-based muon trigger algorithm designed for this purpose, along with its FPGA gateware implementation and expected performance. In addition to cosmic-ray commissioning, the newly developed standalone track reconstruction algorithm enables trigger decisions during ATLAS operation without input from fast trigger detectors. Beyond its application in ATLAS, the algorithm also opens the possibility of serving as a muon veto in the CRESST dark matter experiment by installing spare ATLAS MDT chambers around the cryogenic CRESST detector setup. The adaptation of the algorithm for this use case will also be discussed.

T 71: Data, AI, Computing, Electronics VII

Time: Thursday 16:15–18:00 Location: KH 00.024

T 71.1 Thu 16:15 KH 00.024

Shapes are not enough: Preservattack and its use for finding vulnerabilities and uncertainties in machine learning applications — Philip Bechtle[1], Lucie Flek[2], Philipp Alexander Jung[3], Akbar Karimi[2], •Timo Saala[1], Alexander Schmidt[3], Matthias Schott[1], Philipp Soldin[4], Christopher Wiebusch[4], and Ulrich Willemsen[3] — [1]Institute of Physics, University of Bonn, Germany — [2]Bonn-Aachen Institute of Technology, University of Bonn, Germany — [3]Institute of Experimental physics III B, RWTH Aachen University, Germany — [4]Institute of Experimental physics III A, RWTH Aachen University, Germany

In High Energy Physics, machine learning has become crucial for advancing our understanding of fundamental phenomena. Deep learning models increasingly analyze both simulated and experimental data, supported by rigorous tests of physically motivated systematic uncertainties. Numerical evaluations quantify differences between data and simulation, and comparisons of marginal distributions and feature correlations in control regions are standard. However, physical guidance and regional constraints cannot guarantee capturing of all deviations.

We propose a novel adversarial attack exploiting the remaining space of hypothetical deviations between simulation and data after such tests. The resulting perturbations stay within uncertainty bounds - evading standard validation - while still fooling the underlying model. We also suggest mitigation strategies and argue that robustness to adversarial effects is crucial when interpreting deep learning results in particle physics.

T 71.2 Thu 16:30 KH 00.024

Utilizing Adversarial Training for IceCube's Advanced Northern Track Selection — •Marco Zimmermann, Shuyang Deng, Lasse Düser, Philipp Soldin, Sönke Schwirn, and Christopher Wiebusch — Rwth Aachen

IceCube is a neutrino observatory at the South Pole equipped with over 5000 photomultiplier tubes (PMTs), capable of detecting Cherenkov light from neutrino and cosmic-ray induced muons. The Advanced Northern Track Selection (ANTS) differentiates between these two types of muons with a deep neural network approach. The ANTS network first encodes the charge-time series from each PMT into ten abstract features via a Transformer. These features then serve as input for graph neural networks, which perform the aforementioned differentiation as well as energy and directional reconstructions, and event topology classification. To improve robustness, a network can be trained with adversarial attacks, where the input is modified by adding minimal perturbations with the aim of producing incorrect outputs. We will discuss the application of adversarial training of the ANTS' networks, with the example of the event topology classifier, and present methods to visualize the effect of the added perturbations.

T 71.3 Thu 16:45 KH 00.024

Investigating Robustness of Newtonian Noise Mitigation using Deep Learning at the Einstein Telescope — •Jan Kelleter[1], Markus Bachlechner[2], David Bertram[2], Johannes Erdmann[1], Patrick Schillings[1], and Achim Stahl[2] — [1]III. Physikalisches Institut A, RWTH Aachen — [2]III. Physikalisches Institut B, RWTH Aachen

The Einstein Telescope is a proposed gravitational wave detector of the third generation. It aims to improve sensitivity by at least an order of magnitude compared to current detectors. The dominant noise source in the region of 1 to 10 Hz is expected to be Newtonian Noise (NN) from seismic activity in the surrounding rock. In order to reach the desired sensitivity, NN must be actively mitigated. Seismometers will be installed in boreholes around the mirrors to measure the seismic activity. In this talk, we investigate the robustness of neural networks designed for Newtonian Noise mitigation against different instrumental failures.

T 71.4 Thu 17:00 KH 00.024

A Machine-Learning based Topological Algorithm for the Level-1 Trigger System of CMS — •Lukas Ebeling, Johannes Haller, Artur Lobanov, and Matthias Schröder — Institut für Experimentalphysik, Universität Hamburg

At CMS, the level-1 trigger (L1T) system is crucial to select events of interest in order to keep the data-taking rate at a level that can be processed by the readout and storage system. We present a machine-learning (ML) based algorithm for the L1T system, designed to identify di-Higgs (HH) production events. The algorithm leverages the full event topology and improves the HH signal efficiency at low p_T compared to previous single-object based triggers. Despite being constrained in architecture by strict latency requirements and limited FPGA hardware, the ML trigger achieves high signal efficiencies while maintaining acceptable rates. The talk will highlight the achieved trigger performance, discuss the integration into the CMS software framework as well as the development of a realistic trigger scenario for running in 2026 collisions.

T 71.5 Thu 17:15 KH 00.024

Finding Symbolic Representations of Graph Neural Networks used for Track Finding — •Urs Fischer, Sebastian Dittmeier, and Andre Schöning — Physikalisches Institut, Universität Heidelberg, Germany

Graph Neural Networks (GNNs) have been shown to efficiently solve the combinatorial challenge of track finding at high luminosity collider experiments [1]. The available logic resources of Field-Programmable Gate Arrays (FPGAs) limit the size of possible neural networks that can be deployed in hardware triggers or accelerator cards.

In this study, we apply symbolic regression to the different steps of the GNN track finding process. Symbolic regression fits analytic expressions by combining algebraic operators stochastically to find the best representation in terms of simplicity and accuracy. The resulting algebraic functions have the potential to reduce computational costs of the Multi-Layer Perceptrons for FPGA deployment and allow for interpretation of the internal structure of the neural network, by offering an explicit representation of it.

This talk introduces this method and presents first results on its application to tracking at the ATLAS experiment.

[1] S. Farrell et al., "Novel deep learning methods for track reconstruction", in 4th International Workshop Connecting The Dots 2018. 2018. arXiv:1810.06111.

T 71.6 Thu 17:30 KH 00.024

Symbolic Regression for the Extraction of Detector Response Formulas — •Johannes Merten and Johannes Erdmann — III. Physikalisches Institut A, RWTH Aachen University

Detector simulations are an essential part of high-energy physics research, enabling the interpretation of experimental data and the design of future experiments. Full-scale simulations, such as those based on GEANT4, provide high-fidelity representations of particle interactions within detectors but are computationally expensive. To facilitate large-scale analyses, fast simulation frameworks employ parameterizations to approximate detector responses. These parameterizations rely on simplified functional forms that may not fully capture the underlying complexities of the detector response, which may lead to systematic biases.

In this work a data-driven approach is proposed to derive these interpretable parametrizations directly from high-fidelity simulation data using Normalizing Flows and Kolmogorov-Arnold Networks.

T 71.7 Thu 17:45 KH 00.024

Improving Machine-Learning-Driven Anomaly Detection for New Physics Searches at Belle II — •Gianni Di Paoli, David Giesegh, and Thomas Kuhr — Ludwig-Maximilians-Universität München (LMU), München, Germany

Anomaly detection based on machine-learning techniques, using semi- or unsupervised methods, offers a complementary strategy to traditional theory-driven searches for New Physics beyond the Standard Model. Previous studies have provided a proof of principle by enhancing the visibility of simulated New Physics signals.

In this work, the performance of the existing network architectures is improved. For the autoencoder-based method, refinements of the network design lead to more stable reconstruction-error distributions, and thus to increased visibility of anomalies. For the density-estimation approach, alternative likelihood-estimation techniques and their behavior in high-dimensional feature spaces relevant for Belle II are investigated and implemented to improve sensitivity to anomalies.

Ongoing work focuses on further developing these techniques and preparing them for application to real Belle II collision data, including studies of their behavior under realistic detector and background conditions. This talk will present the current status of the algorithmic developments, and outline the next steps toward an operational anomaly-detection pipeline for model-independent New Physics searches at Belle II.

T 72: Flavour Physics IV

Time: Thursday 16:15–18:15 Location: KH 01.011

T 72.1 Thu 16:15 KH 01.011

Early Studies on rare $B_s^0 \to \mu^+\mu^-$ decays and related control modes in Run 3 at the LHCb experiment — Johannes Albrecht, •Lukas Bertsch, Mick Mulder, Katharina Popp, and Jan Wagner — TU Dortmund University, Germany

Rare $B_{(s)}^0 \to \mu^+\mu^-$ decays provide a sensitive test of the Standard Model owing to their exceptional suppression, clean experimental signature, and precise theoretical predictions. Searches for these decays have been conducted since the start of the LHCb experiment, accomplishing the observation of $B_s^0 \to \mu^+\mu^-$ in 2014, together with the CMS collaboration. However, the more strongly suppressed B^0 meson counterpart of the decay has not yet been measured with statistical significance, due to interfering backgrounds and limited data. Much larger datasets collected during Run 3 of the LHC provide a clear opportunity to find evidence for the $B^0 \to \mu^+\mu^-$ decay, but also pose new challenges due to the busy collision environment. Therefore, early studies on the new dataset are performed in this work, providing a first implementation of required analysis tools and verifying the analysis procedure on Run 3 data. Based on $11\,\text{fb}^{-1}$ of data recorded in 2024 and early 2025, branching fractions of control modes are measured following the signal-channel analysis strategy, and a preliminary estimate of the sensitivity to the $B^0 \to \mu^+\mu^-$ decay is obtained.

T 72.2 Thu 16:30 KH 01.011

Multivariate analysis of the rare decays $B_{(s)}^0 \to \mu^+\mu^-$ in Run 3 at the LHCb experiment — Johannes Albrecht, Lukas Bertsch, Mick Mulder, •Katharina Popp, and Jan Peter Wagner — TU Dortmund University, Dortmund, Germany

Studies of the rare $B_{(s)}^0 \to \mu^+\mu^-$ decays are core to the physics programme of the LHCb experiment, as they provide sensitivity to physics beyond the Standard Model. While the decay $B_s^0 \to \mu^+\mu^-$ has been observed in the previous analyses using data from Run 2 of the LHC, the process $B^0 \to \mu^+\mu^-$ is still to be observed. With the LHCb Upgrade I detector in Run 3, an upgraded strategy is required for the search for these processes. A major challenge arises from the amount of background events caused by random combinations of muons from b-hadron decays, which superimpose the signal processes. Thereby, a powerful tool for the suppression of combinatorial background is provided by considering the isolation of the final state muon tracks with respect to other tracks in the event. This aspect has already proven useful in previous analyses, where a combination of Boosted Decision Trees has been utilised. For the analysis with Run 3 data, the existing strategy for the suppression of combinatorial background is revisited and improvements are pursued, in order to enhance the signal significance of the decay $B^0 \to \mu^+\mu^-$.

T 72.3 Thu 16:45 KH 01.011

Transformer-based classification of $B_s^0 \to \tau^+\tau^-$ decays in $Z \to b\bar{b}$ events at the FCC-ee — •Alejandro Quiroga Trivino[1], Jan Kieseler[1], Markus Klute[1], Joscha Knolle[1], Anuar Sifuentes Name[1], Samuel Wyrowski[1], and Xunwu Zuo[2] — [1]Institute for Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]Ecole polytechnique federale de Lausanne (EPFL), Lausanne, Switzerland

Experimental indications of potential deviations from lepton flavor universality have intensified interest in rare B meson decays involving tau leptons. Among these, the decay $B_s^0 \to \tau^+\tau^-$ remains largely unexplored experimentally due to its challenging final state and the limited sensitivity of current detectors. The high-statistics and low-background environment of electron-positron collisions at the Z pole that will be provided by the FCC-ee creates a unique opportunity to study this process with unprecedented precision. Leveraging these conditions, advanced machine-learning techniques can be brought to bear to enhance the separation between signal candidates and the overwhelming $Z \to b\bar{b}$ background. In this contribution, the application of a transformer model to separate between $Z \to b\bar{b}$ events with and without a $B_s^0 \to \tau^+\tau^-$ decay is discussed. The usage of different sets of input features, relying either on reconstructed hadronic tau lepton candidates or on tracks and neutral particles, are compared. The achieved background rejection paths the way towards the observation of this rare standard model process.

T 72.4 Thu 17:00 KH 01.011

Prospects for $B_s^0 \to \tau^+\tau^-$ searches in final states with six charged pions at the FCC-ee — •Anuar Sifuentes Name[1], Jan Kieseler[1], Markus Klute[1], Joscha Knolle[1], Alejandro Quiroga Trivino[1], Samuel Wyrowski[1], and Xunwu Zuo[2] — [1]Institute for Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]Ecole polytechnique federale de Lausanne (EPFL), Lausanne, Switzerland

Recent results from the LHCb and Belle-II experiments have reported hints of lepton flavor universality (LFU) violation in rare B meson decays. One particularly interesting probe for this potential deviation from the standard model (SM) of particle physics is the measurement of the branching fraction of the rare decay $B_s^0 \to \tau^+\tau^-$, for which the expected LHCb sensitivity at the end of the HL-LHC era is several orders of magnitude away from the SM prediction. The future circular collider (FCC), operated with electron-positron collisions at the Z pole, will offer an experimentally clean environment to search for this decay. In this contribution, an analysis strategy is presented that targets the final state corresponding to the decay chain $B_s^0 \to \tau^+\tau^- \to 6\pi^\pm 2\nu$. Through an optimized set of dedicated kinematic cuts and training of machine-learning discriminants, a sufficient separation between the signal and the background from other $Z \to b\bar{b}$ events is achieved to demonstrate the capability of the FCC to probe LFU in beyond-the-SM scenarios.

T 72.5 Thu 17:15 KH 01.011

FCC-ee Sensitivity Estimation to the Direct CP-Violating Decay-Rate Asymmetry $A_{CP}(D^0 \to \pi^0\pi^0)$ — •Willy Weber[1,2], Kevin Kröninger[1], Romain Madar[2], and Stéphane Monteil[2] — [1]TU Dortmund University, Department of Physics, Dortmund — [2]Université Clermont-Auvergne, Laboratoire de Physique de Clermont, Clermont-Ferrand

The Future Circular Collider (FCC-ee) is a proposed electron-positron collider designed to enable high-energy collisions. It is expected to produce $O(10^{12})$ $Z \to q\bar{q}$ events, significantly enhancing our ability to perform precision measurements of electroweak observables.

CP violation in D^0 decays to charged particles has been observed by LHCb. Our understanding of CP violation in the charm sector can be further improved by studying the decays into neutral particles. This presentation considers the potential for precise measurement of *CP* violation in $D^{*\pm} \to (D^0 \to \pi^0(\to \gamma\gamma) + \pi^0(\to \gamma\gamma))\pi^\pm$ decays at FCC-ee to complement the knowledge gathered by LHCb with charged modes. Monte Carlo samples, including a simulated detector response based on the IDEA detector concept, are used for this purpose. It is demonstrated that the FCC-ee will significantly improve the precision of the measurement of the *CP*-Violating decay-rate asymmetry $A_{CP}(D^0 \to \pi^0\pi^0)$. Furthermore, the necessary detector requirements for this future measurement are investigated.

T 72.6 Thu 17:30 KH 01.011

Branching fraction measurements of the rare decays $B_{(s)}^0 \to \pi^+\pi^-\mu^+\mu^-$ at LHCb — Johannes Albrecht[1], Thomas Blake[2], Mick Mulder[1], Janina Nicolini[3], and •Jan Peter Wagner[1] — [1]TU Dortmund University, Dortmund, Germany — [2]University of Warwick, Coventry, United Kingdom — [3]CERN, Geneva, Switzerland

Rare flavour-changing neutral-current decays with $b \to q\ell^+\ell^-$ quark transitions ($q = s, d$) provide powerful probes of the Standard Model and are central to the LHCb physics programme. Owing to the smaller CKM matrix elements, $b \to d\ell^+\ell^-$ decays are further suppressed relative to $b \to s\ell^+\ell^-$ processes, making them particularly challenging to observe. Using Run 1 data, the LHCb collaboration observed the decay $B_s^0 \to \pi^+\pi^-\mu^+\mu^-$ with a significance of $7.2\,\sigma$, while evidence for the analogous decay $B^0 \to \pi^+\pi^-\mu^+\mu^-$ was reported with a significance of $4.8\,\sigma$.

This contribution reports the current status of the branching-fraction measurements of $B_{(s)}^0 \to \pi^+\pi^-\mu^+\mu^-$ decays using the full $9\,\mathrm{fb}^{-1}$ data sample recorded by LHCb in Runs 1 and 2 of the LHC. First studies based on Run 3 data are also presented, providing an outlook on the improved sensitivity and future prospects for measurements of rare $b \to d\ell^+\ell^-$ and $b \to s\ell^+\ell^-$ decays with the upgraded LHCb detector.

T 72.7 Thu 17:45 KH 01.011

Measurement of the Energy Dependence of Strong Isospin Violation in $\Upsilon(4S)$ Decays — •Lena Nowatzki, Thomas Kuhr, and Thomas Lück — Ludwig-Maximilians-Universität München (LMU), München, Germany

Precise measurements of B meson branching fractions are essential both for testing Standard Model predictions and for many measurements that rely on accurate modeling of data composition in flavor-physics analyses. At Belle II, B mesons are produced via the process $e^+e^- \to \Upsilon(4S) \to B\bar{B}$. The total number of such events can be determined with high precision, yet using this quantity for B meson branching fraction measurements requires knowledge of the production fractions of neutral and charged B meson pairs in $\Upsilon(4S)$ decays, respectively f_{00} and $f_\pm$. Although strong isospin symmetry predicts equal production rates, recent theoretical studies indicate a possible energy dependence of the ratio $f_\pm/f_{00}$, motivating an experimental investigation.

In this analysis, we aim to measure the energy dependence of the $\Upsilon(4S)$ decay fractions using Belle II data. We employ two different approaches. The first relies on direct B meson energy measurements using the channels $B^+ \to J/\psi K^+$ and $B^0 \to J/\psi K_S^0$. The second includes a multivariate classifier based on event-level observables to distinguish between neutral and charged $B\bar{B}$ pair production. This talk will present the current status and an outlook on future developments of this analysis.

T 72.8 Thu 18:00 KH 01.011

Analysis of Rare Charm Three-Body Decays using LHCb Run 3 data — Dominik Mitzel, Carolina da silva Bolognani, and •Christopher Breitfeld — TU Dortmund University, Dortmund, Germany

Flavor-changing neutral currents in the charm sector provide a sensitive testing ground for the Standard Model. Certain observables, such as *CP* and forward-backward asymmetries are highly suppressed and their measurements therefore constitute null tests. Dominated by non-perturbative long-distance contributions, these decays are also challenging to study theoretically. It is thus essential not only to perform null-test measurements but also to provide experimental information on the resonant structure.

Using data collected with the upgraded LHCb detector during Run 3 of the LHC, the rare decays $D_{(s)}^+ \to \pi^+\mu^+\mu^-$ and $\Lambda_c^+ \to p\mu^+\mu^-$ are studied. The analysis aims to measure the *CP* and the forward-backward asymmetry in bins of the dimuon mass, and to perform an amplitude analysis to disentangle the interference of intermediate resonances.

In this talk, an introduction and the general analysis strategy are presented.

T 73: Calorimeters I

Time: Thursday 16:15–17:45 Location: KH 01.012

T 73.1 Thu 16:15 KH 01.012

Quality Control of Scintillator Tiles for the CMS Endcap High Granularity Upgrade — •Mohammed Adnan Ali — University of Hamburg, Mittelweg 177, 20148 Hamburg — Deutsches Elektronen-Synchrotron (DESY), Notkestr. 85, 22607 Hamburg, Germany)

Preparing the CMS detector for the High-Luminosity LHC (HL-LHC) requires major upgrades, including the installation of the High Granularity Calorimeter (HGCAL) to replace the existing endcap calorimeters. In its hadronic section, plastic scintillator tiles coupled with SiPMs are used in regions exposed to moderate radiation levels.

HGCAL achieves its fine spatial resolution through the use of approximately 280,000 scintillator tiles, with sizes ranging from $2\,\mathrm{cm}^2$ to $30\,\mathrm{cm}^2$; around 160,000 of these tiles will be wrapped and quality-controlled at DESY. Each tile is individually wrapped and integrated through an automated assembly procedure, and the detector design imposes strict mechanical tolerances on their final geometry.

In this talk, I will present the quality control strategy developed at DESY, which includes micron-level dimensional checks after wrapping as well as standardized measurements of the light-yield performance. These studies are essential to ensure uniform detector response and to meet the performance requirements of the HGCAL upgrade.

T 73.2 Thu 16:30 KH 01.012

Ensuring Quality of High Granularity Calorimeter Tileboards for the High-Luminosity upgrade of CMS — •Faruk Kurtulus — University of Hamburg Mittelweg 177, 20148 Hamburg, Germany — Deutsches Elektronen-Synchrotron (DESY) Notkestraße 85, 22607 Hamburg, Germany

The CMS experiment is preparing for an upgrade to operate in the harsh environment of the High-Luminosity Large Hadron Collider (HL-LHC). To function reliably under these conditions, CMS must replace its current end-cap calorimeters, which are already losing detection capability, with the High Granularity Calorimeter (HGCAL), designed to withstand the increased luminosity and pile-up of HL-LHC operation.

In the lower-radiation region of HGCAL, the SiPM-on-Tile technology is used, coupling Silicon Photo-Multipliers (SiPMs) to thin scintillator tiles. SiPMs are soldered onto a common PCB with readout electronics and later combined with scintillators to form a Tilemodule. Before scintillators are installed, the unit is referred to as a Tileboard. Each Tileboard hosts one or two readout chips providing readout for 72 channels. The detector will contain about 3800 Tileboards. Before Tilemodule assembly, a quality-control (QC) procedure is required to verify electrical functionality and readout stability.

This presentation will outline the QC procedure developed for Tileboard certification, including the sequence of tests and qualification criteria. Results from several hundred production boards will be shown, highlighting common issues and the overall readiness of Tileboards for the HGCAL upgrade.

T 73.3 Thu 16:45 KH 01.012

Changes and Upgrades for the ATLAS Liquid Argon Purity System — •Maximilian Linkert, Christopher Engel, and Stefan Tapprogge — Institut für Physik, Johannes Gutenberg-Universität, Mainz

With the high luminosity LHC and the Phase 2 upgrade of the ATLAS Detector the Liquid Argon Purity System faces new operational challenges. The purpose of the system is to measure possible contaminations of the liquid argon, hence calculating the impurity level. Therefore 30 devices with ionization chambers are distributed throughout the calorimeter. Due to upgrades of the low voltage power supply used to power the front end electronics the voltages will change from a positive and negative to a single positive line. Since the purity devices rely critically on the negative voltage, a modified version of the bPOL48V buck DCDC converter will be needed. Moreover the software has been updated to ensure proper operation in the future. The current status of the purity system, the DCDC converter and extended functionalities for the maintenance workflow will be presented.

T 73.4 Thu 17:00 KH 01.012

Shower Direction Reconstruction with the SHiP High-Granularity ECAL — •Sebastian Ritter, Volker Büscher, Rainer Wanke, Matei Climescu, and Claudia Delogu — Johannes-Gutenberg Universität, Mainz

The SHiP experiment at CERN targets the hidden sector by, among others, searching for neutral long-lived particles (LLPs) produced in a high-intensity beam dump. To reconstruct LLP decays into photons, the experiment requires a pointing electromagnetic calorimeter (ECAL). In this talk, test-beam results of the SHiP ECAL prototype are presented.

Using SPS electron beams in the 10*288 GeV range, we measure the transverse and longitudinal shower development to reconstruct the shower direction and extract the pointing resolution based on the calorimeter response and put it into perspective with the physics requirements. Comparisons with GEANT4 simulations are outlined.

We conclude with a status update on preparations for calorimeter construction in Mainz and the installation of the detector in the SHiP experiment at the upgraded beam dump facility.

T 73.5 Thu 17:15 KH 01.012

Processing of ATLAS Liquid Argon Calorimeter Signals by Convolutional Neural Networks and its Impact on Calorimeter Energy Reconstruction — •Manuel Gutsche, Markus Helbig, Arno Straessner, Johann Christoph Voigt, and Philipp Welle — Technische Universität Dresden

During the Phase-II upgrade of the ATLAS detector, over 500 high-performance FPGAs will be installed in the off-detector electronics of the Liquid Argon Calorimeter to cope with the increased luminosity and, therefore, pileup. Under these challenging conditions, the energies of the 182468 detector cells will be reconstructed by the FPGAs. Different methods are being considered. One possible approach is the implementation of 1-dimensional convolutional neural networks (CNNs), which are limited by resource constraints of the Intel Agilex-7 FPGAs to about 400 parameters.

A total of 23 dedicated CNNs are applied to account for differences between cells, mainly in terms of pulse shape and noise. This is achieved by grouping similar cells into clusters, and then training a model of fixed architecture on simulated data expected for a representative cell of each cluster.

These CNNs are integrated into the ATLAS simulation and analysis framework, Athena, in order to compare the performance of the energy reconstruction by CNNs with the current implementation based on an optimal filter. The impact of the two methods on the calculated cell energies, as well as on reconstructed physics objects, is studied.

T 73.6 Thu 17:30 KH 01.012

Fast Hadron Shower Simulation Methods with the CALICE AHCAL Prototype — •André Wilhahn and Stan Lai — Georg-August-Universität Göttingen, Göttingen, Germany

Extensive simulations of particle showers are crucial for high energy physics experiments. As many calorimeters are designed with increasing granularity, while having to cope with higher energy deposits and higher luminosity conditions, the accurate simulation of particle showers in a computationally efficient manner is of utmost importance. This talk describes investigations into a data-driven fast calorimeter simulation that is meant to describe particle showers accurately, without simulating every individual particle interaction with the calorimeter material.

We start by investigating pion showers in the CALICE AHCAL (Analogue Hadron Calorimeter) prototype, which is a highly granular hadronic calorimeter comprising a total of 38 active layers embedded in a stainless-steel absorber structure. Each active layer contains a grid of 24×24 scintillator tiles that are read out individually via silicon photomultipliers. Correlated hit energies have been simulated to obtain good modelling for kinematic shower variables with the help of kernel density estimators. The results and future plans for improving and expanding the fast calorimeter simulation will be discussed.

T 74: Gaseous Detectors II

Time: Thursday 16:15–18:00 Location: KH 01.014

T 74.1 Thu 16:15 KH 01.014

Upgrading the CMS muon end cap for the high-luminosity LHC using ME0 GEM detectors — Erik Ehlert, Kerstin Hoepfner, Daniel Klee, Alexander Schmidt, and •Shawn Zaleski — III. Physikalisches Institut, RWTH Aachen University, Aachen, Germany

Gas electron multiplier (GEM) chambers have been operating as part of the CMS Muon end cap system since the beginning of Run 3. The GE1/1, first GEM system installed alongside the CSC chambers, provides an improved transverse momentum measurement of muons that pass through the CMS end caps. The ME0 system, a planned upgrade of the CMS Muon system for the high-luminosity LHC, is similar in design to that of the GE1/1 system, however it consists of a stack of six triple-GEM chambers. These ME0 stacks will be installed adjacent to the new high granularity hadron calorimeter (HGCAL) and will extend the pseudorapidity reach of the Muon system from 2.4 to 2.8. The GEM collaboration has built more than six stacks that will be installed during Long Shutdown 3 (LS3). All stacks that will be installed must undergo a rigorous set of quality control (QC) checks, the final of which is testing the full ME0 stack using a cosmic ray muon test stand (QC8). This talk will give an overview of the QC8 setup and present some results from the ME0 cosmic ray test stand QC checks.

T 74.2 Thu 16:30 KH 01.014

Integration of new Gas Monitoring Chambers into the ND280 Near Detector Gas System — Stefan Roth, •David Smyczek, Jochen Steinmann, and Nick Thamm — RWTH Aachen University - Physics Institute III B, Aachen, Germany

A new pair of Time Projection Chambers for high angle measurements (HAT) has been installed during the upgrade of the T2K near detector ND280. To improve their calibration, drift velocity and gain are continuously monitored using new Gas Monitoring Chambers (GMC) which were installed in November 2025. One pair of GMCs is monitoring the supply and the exhausts of the ND280 Time Projection Chambers. A second pair of GMCs is monitoring the freshly mixed gas. One of those GMCs has been equipped with resistive Micromegas to compare the results to its counterpart using conventional Micromegas. The first measurements of these new monitoring chambers will be presented.

T 74.3 Thu 16:45 KH 01.014

Modeling Electron Transport Properties in Gaseous Detector Gases — Stefan Roth, •Max Schmit, David Smyczek, Jochen Steinmann, and Nick Thamm — RWTH Aachen University - Physik Institute III B, Aachen, Germany

Electron transport parameters in gases can be derived by solving the Boltzmann equation. Two approaches are commonly used: analytical solutions and Monte Carlo methods. Both modeling approaches are outlined, with emphasis on their treatment of the electron energy distribution function and the use of electron-molecule cross-section data. Differences in required inputs and in the resulting transport coefficients are discussed. Electron drift velocity and diffusion coefficients are evaluated for commonly used detector gases. Comparison results and the current status of the study are presented, highlighting their implications for detector simulations.

T 74.4 Thu 17:00 KH 01.014

Performance Studies on Ecofriendly Gas Alternatives for RPC Detectors — Roberto Guida[2], Stefania Juks[3], •Maximilian Kerker[1], Beatrice Mandelli[2], Gianluca Rigoletti[2], Stefan Roth[1], and Mattia Verzeroli[4] — [1]RWTH Aachen University — [2]CERN — [3]Université Paris Saclay — [4]Shanghai Jiao Tong University

Resistive Plate Chambers are important particle detectors used as muon triggers in many experiments at the Large Hadron Collider. At the ALICE, ATLAS, and CMS LHC experiments, a gas mixture made of 65-95% R-134a, 4.5-10% i-C4H10 and 0.3-0.5% SF6 is used. R-134a and SF6 are greenhouse gases having a significant global warming potential of 1430 and 24300 respectively. In this work, a study was conducted searching for alternatives for SF6. In particular, two chlorinated hydrofluoroolefins, R-1233zd and R-1224yd, were identified as possible SF6 replacements. These gases were tested in different concentrations both in laboratory conditions and at the Gamma Irradiation Facility at CERN under LHC-like conditions. The RPC performance was evaluated by measuring the detector's efficiency, currents, streamer probability, cluster size and time resolution. The results were compared against SF6-based gas mixtures. Preliminary results will be presented.

T 74.5 Thu 17:15 KH 01.014

Replacing SF6 in Resistive Plate Chamber Detectors for HL-LHC Experiments and Beyond — •Giorgia Proto and Oliver Kortner — Max Planck Institute for Physics

The Resistive Plate Chambers (RPC) are gaseous detectors with excellent timing performance and are used for triggering on muons in the LHC experiments. They operate with the standard gas mixture, composed of C2H2F4/i-C4H10/SF6,that has a high Global Warming Potential (GWP) of 1430 due to the presence of C2H2F4(GWP~1450) and SF6(GWP~22400).The C2H2F4 and SF6 are not recommended for industrial uses anymore, thus their availability will be increasingly reduced over time and the search for an alternative gas mixture is of absolute priority. The most critical component to replace is the SF6, because it acts as streamer suppressor, thus allowing for RPC operation at low current, for high rate capability and longevity. In this work the SF6 is replaced with the Chloro-Trifluoropropene (C3H2ClF3, GWP~5), never been tested in the RPC detectors before. The performance of the RPC detector in terms of efficiency, streamer probability and time resolution have been studied in the Gamma Irradiation Facility (GIF++) at CERN at high irradiation rates, as expected at the High Luminosity LHC. The performance of the RPC detector with enivornment-friendly gases and status of the aging campaign performed using the new gas is presented.

T 74.6 Thu 17:30 KH 01.014

Investigation of the protection layers used in GridPix detectors — •Felix Becker, Jochen Kaminski, Klaus Desch, Sabine Hartung, and Yevgen Bilevych — Physikalisches Institut, Universität Bonn

The GridPix detector is a gaseous detector based on the Timepix technology. It is based on a pixel readout ASIC with a grid structure applied on top of it, which grants gas amplification. In the production process of the GridPix, a high-resistive protection layer is applied on the surface of the Timepix. This protection layer helps avoiding the chip getting damaged by sparks inside the detector and increases the longevity immensely. However, the exact electric properties, such as the resistivity of the layer, are not completely known. The main goal of this investigation is to find a reliable method for measuring the layer's resistivity. To do so, the results of multiple measuring methods, are compared. The first method is using charged particles. Because electrons accumulate at the surface of the protective layer if its resistivity is non-zero, a potential builds up on its surface. This potential lowers the effective electric field between the grid and the surface of the protective layer, what lowers the gas amplification. This effect takes place, until a steady state is reached. This charge-up effect and the discharge of the protective layer can be used to calculate the material resistivity. A second method is detaching the grid and measuring the resistivity directly via an voltage-current measurement. The presentation will describe the steps taken in the analysis, including the considerations behind each measurement method.

T 74.7 Thu 17:45 KH 01.014

From Wafer to Detector: GridPix Production at the FTD — •Sabine Hartung, Yevgen Bilevych, Jochen Kaminski, and Klaus Desch — Physikalisches Institut Universität Bonn

GridPix detectors combine a pixel ASIC with an integrated Micromegas-type amplification structure (InGrid). The photolithographic fabrication of the grid directly on the Timepix/Timepix3 ASIC enables precise alignment of grid holes to the pixels and a well-defined amplification gap. This provides single-electron efficiency and an excellent spatial resolution. Such properties make GridPix detectors a promising candidate for precision TPCs as well as X-ray and low-background applications.

The production of GridPixes requires a sequence of photolithographic steps. To reduce the probability of spark damage during the operation, the chip is first coated with a Si_xN_y protection layer. As amplification gap an aluminium grid is built on top of freestanding pillars. Achieving high production yield demands precise control of technological conditions.

In this contribution, the first results of the GridPix production as implemented in the Forschungs- und Technologiezentrum Detektorphysik (FTD) in Bonn are presented.

T 75: Higgs Physics VII

Time: Thursday 16:15–18:15 Location: KH 01.019

T 75.1 Thu 16:15 KH 01.019

Projection Studies of the ttHH 1L Channel for the HL-LHC — •Doğa Elitez[1], Lucia Masetti[2], and Paul Gessinger[1] — [1]CERN — [2]JGU Mainz

The Higgs boson self-coupling is a central ingredient of electroweak symmetry breaking, and constraining this coupling is essential for validating the Standard Model and determining the shape of the Higgs potential. The cross-section for Higgs-pair production in association with top quarks (ttHH) is expected to increase significantly at higher LHC beam energies, making ttHH production a compelling process to study in the high-luminosity LHC (HL-LHC) era. A particularly challenging and informative decay channel is the ttHH(6b) one-lepton channel, in which one of the top quarks decays semi-leptonically and produces an electron or muon, while the Higgs pair decays into four b-quarks. In this talk, projection studies of the ttHH(6b) one-lepton channel for the HL-LHC are presented.

T 75.2 Thu 16:30 KH 01.019

Higgs self-coupling measurement from di-Higgs production at a future e+e- collider — •Julie Torndal[1,2], Jenny List[1], Bryan Bliewert[1,2], Mikael Berggren[1], Junping Tian[3], Taikan Suehara[3], Dimitris Ntounis[4], and Caterina Vernieri[4] — [1]DESY, Harmburg, Germany — [2]Universität Hamburg, Hamburg Germany — [3]SLAC, Menlo Park, United States — [4]The University of Tokyo, Tokyo, Japan

Linear e^+e^- colliders have the energy reach to directly access the Higgs self-coupling at tree-level through di-Higgs production while offering a clean experimental environment. At a centre-of-mass energy of 550 GeV, two processes contribute, who have different dependencies on the value of κ_λ offering a complementarity important for BSM scenarios. The leading contribution comes from Higgs strahlung, ZHH, with a small addition from the WW fusion. In this contribution, the ongoing analysis of the $HH \to 4b$ channel will be presented using fast SGV (Simulation à Grande Vitesse) based simulation of the ILD (International Large Detector) concept with the full SM background. Improvements in flavour tagging and kinematic reconstruction will be discussed, and the status of the event selections using advanced machine learning techniques will be presented before evaluating the cross-section precisions for each channel and translating those into a precision on κ_λ for the SM and BSM case. The precise measurement of the Higgs self-coupling offers new insights central to the Higgs sector, in determining the shape of the Higgs potential and understanding the mechanism behind electroweak symmetry breaking.

T 75.3 Thu 16:45 KH 01.019

Improving the event reconstruction and scalability of the Higgs self-coupling analysis at ILD — Mikael Berggren[1], •Bryan Bliewert[1,2], Jenny List[1], Dimitris Ntounis[3], Taikan Suehara[4], Junping Tian[4], Julie Munch Torndal[1,2], and Caterina Vernieri[3] — [1]Deutsches Elektronen-Synchrotron DESY, Germany — [2]Universität Hamburg, Germany — [3]SLAC National Accelerator Laboratory, USA — [4]University of Tokyo, Japan

The shape of the Higgs potential gives crucial insight into the Higgs mechanism. At future e^+e^--colliders and center-of-mass energies of $\geq$ 550 GeV, the Higgs potential can be probed directly by measuring the self-coupling λ through di-Higgs production. In an ongoing effort, the projected sensitivities for λ are updated assuming the ILD concept at an LCF 550-like facility. In our contribution, we discuss recent advancements in event reconstruction: First, we cover the identification and removal of low-p_t hadrons (overlay) using machine learning (ML) and its effect on the di-jet invariant mass resolution. Second, we present how variables based on leading order matrix elements improve the event selection. Furthermore, we have designed our analysis using a modern distributed pipelining system (luigi/law) and present key concepts of this framework. It covers all steps from detector simulation to sensitivity extraction, greatly improving automation, reproducibility and scalability and producing results in a few hours for 150M events with o(1000) computing nodes. We conclude by showing the impact of the reconstruction advances on the measurement of the di-Higgs cross-section and the corresponding precision on λ.

T 75.4 Thu 17:00 KH 01.019

Assessing uncertainties in the determination of the trilinear Higgs self-coupling from single-Higgs observables — Henning Bahl[1], Philip Bechtle[2], Johannes Braathen[3], Sven Heinemeyer[4], Jenny List[3], •Murillo Vellasco[2], and Georg Weiglein[3,5] — [1]Institute for Theoretical Physics (ITP), Universität Heidelberg, Germany — [2]Physikalisches Institut, Universität Bonn, Germany — [3]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany — [4]Instituto de Física Teórica (UAM/CSIC), Universidad Autónoma de Madrid, Spain — [5]Institut für Theoretische Physik, Universität Hamburg, Germany

Probing the nature of the Higgs potential is a primary objective of the next generation of flagship particle physics experiments, for which measuring λ_{hhh}, the trilinear Higgs self-coupling, will play a crucial role. Despite operating below the di-Higgs production threshold, circular e^+e^- machines will still have indirect access to λ_{hhh} via its loop-level contributions to single-Higgs production observables. In this work, we investigate how well λ_{hhh} can be determined by such indirect effects within a global EFT fit. While most studies to date assume that future measurements will be compatible with SM predictions, here we consider non-SM values of λ_{hhh}, using an inert doublet extension of the SM as an example of a New Physics scenario that could be realised in nature. We find that theory uncertainties related to the truncation of the EFT expansion and to higher-order corrections, which are often neglected, can have a substantial impact on the resulting precision for λ_{hhh}.

T 75.5 Thu 17:15 KH 01.019

Beam-beam effects at the Hybrid Asymmetric Linear Higgs Factory — •Shriyansh Ranjan[1,2], Jenny List[1], and Mikael Berggren[1] — [1]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany — [2]Universität Hamburg, Hamburg, Germany

Since the discovery of the Higgs boson in 2012, probing the Higgs potential has become a primary objective for understanding vacuum stability and searching for Beyond Standard Model (BSM) physics. This precise measurement of the Higgs potential requires the clean environment of an e+e- collider. The Hybrid Asymmetric Linear Higgs Factory (HALHF) utilizes plasma-wakefield acceleration (PWFA), an emerging accelerator technology, to create high-energy collisions capable of such precision.

However, the resulting beam conditions drive strong-field QED processes that reshape the luminosity spectrum and increase detector backgrounds. To address these challenges, advanced simulation tools are required. Our study models these beam-induced backgrounds for HALHF using cutting edge simulation software, providing inputs helpful in designing the asymmetric ILD detector at HALHF.

This talk presents simulation results for the highly asymmetric e+e- collisions at HALHF, evaluating the beam-induced backgrounds as well as the luminosity spectrum and its impact on key physics measurements. The outcomes will be discussed across different center-of-mass energies from 250 GeV to 550 GeV.

T 75.6 Thu 17:30 KH 01.019

Probing Strong First-Order Electroweak Phase Transition scenarios in 2HDM with FCC-ee/CEPC — •Anisha Anisha[1,2], Francisco Arco[3], Stefano Di Noi[1], Christoph Englert[4], and Margarete Mühlleitner[1] — [1]Institute for Theoretical Physics, Karlsruhe Institute of Technology (KIT), Wolfgang-Gaede Straße 1, D-76131, Karlsruhe, Germany — [2]Institute for Astroparticle Physics, Karlsruhe Institute of Technology, Hermann-von-Helmholtz-

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We investigate the potential of future electron-positron colliders, such as FCC-ee and CEPC, to probe 2-Higgs-doublet models (2HDMs) that facilitate a strong first-order electroweak phase transition (SFOEWPT), a necessary condition for electroweak baryogenesis. Focusing on a 2HDM in the CP-conserving limit, we identify parameter regions consistent with an SFOEWPT and evaluate their compatibility with projected precision electroweak and Higgs measurements, as well as searches for exotic Higgs bosons. We show that radiative corrections to $e^+e^- \to hZ$ production introduce deviations in the cross section that are resolvable with the anticipated sub-percent precision at lepton colliders even when experimental outcomes of the LHC and Z pole measurements are in agreement with the SM. This underscores the opportunities of a precision lepton collider to explore BSM quantum corrections to the Higgs sector more broadly.

T 75.7 Thu 17:45 KH 01.019

Higgs Measurements at Photon Colliders — •Ayoade Sotona — Universität Hamburg

The Photon-Collider offers a complementary experimental programm for possible future linear colliders to e+e-. The cross-section of photon-photon collisions can be multitudes higher than those of corresponding electron-positron collisions, which makes them particularly interesting for (Di-)Higgs production and the measurement of trilinear couplings.

T 75.8 Thu 18:00 KH 01.019

Probing the Higgs potential via Higgs pair production at photon-photon colliders — •Gudrid Moortgat-Pick[1,2], Marten Berger[1], Georg Weiglein[2], and Johannes Braathen[2] — [1]University of Hamburg — [2]Deutsches Elektronen Synchrotron

A $\gamma\gamma$ collider, either in conjunction with an e^+e^- linear collider or as a stand-alone facility, offers a very attractive Higgs physics programme at relatively low centre-of-mass (c.m.) energies. A c.m. energy as low as 280 GeV can probe the Higgs potential via the Higgs pair production process providing access to the trilinear Higgs-boson self-coupling. High polarisation of the photon beams (produced via Compton backscattering) can be achieved and adjusted by flipping the polarisation of the incident laser. The prospects for exploring the Higgs pair production process at a $\gamma\gamma$ collider are assessed by comparing different running scenarios utilising different types of the incident laser. The possibility to use photon polarisation has been exploited as well.

T 76: Silicon Detectors VII

Time: Thursday 16:15–18:15 Location: KH 01.022

T 76.1 Thu 16:15 KH 01.022

High-resolution timing measurement of a TJ-Monopix2 DMAPS utilizing a 30ps TDC on FPGA implementation — •Rasmus Partzsch, Christian Bespin, Jochen Dingfelder, Fabian Hügging, Hans Krüger, Ramon Leiser, and Lars Schall — Physikalisches Institut der Universität Bonn, Bonn, Germany

The development and characterization of monolithic active pixel sensors with depleted substrates (DMAPS) in the last years lead the way to various applications in future tracking detectors. Increases in luminosity of high-energy physics experiments demand strict timing conditions on the detectors. To enable characterizations with precise timing, an on-FPGA time-to-digital converter utilizing a tapped delay line has been developed achieving a timing resolution down to 30 ps. TJ-Monopix2 is a large-scale DMAPS designed in TowerJazz 180 nm CMOS technology, and features a small charge collection electrode with a pixel size of 33 x 33 um^2. High-resistivity silicon substrate and high bias voltage capabilities allow for a full depletion of the sensitive volume and fast charge collection enabling operation in high-rate environments, especially after NIEL irradiation. Its successor chip, OBELIX, is designed for the BELLE II vertex detector upgrade (VTX).

This contribution outlines the implementation of the TDC as part of the readout system. Additionally, we present the latest test-beam results for TJ-Monopix2 after irradiation to 1e15 neq/cm^2 NIEL fluence, focussing on its timing performance.

T 76.2 Thu 16:30 KH 01.022

Development of a DMAPS-based beam telescope — •Wiebke Buhmann, Christian Bespin, Jochen Dingfelder, Fabian Hügging, Nico Klein, Hans Krüger, Rasmus Partzsch, Lars Schall, and Alexander Walsemann — Physikalisches Institut der Universität Bonn, Bonn, Germany

Testbeam telescopes serve as high-resolution tracking devices in beam test experiments. A new beam telescope is proposed to utilize depleted monolithic active pixel sensors (DMAPS) combining fast charge collection with high spatial resolution and low material budget.

The first iteration will use TJ-Monopix2 sensors that provide a spatial resolution of <10um and time resolution <2ns with 40MHz hit-timestamping. These characteristics make the telescope applicable for low momenta and high-rate beam environments.

In this contribution, the current development status regarding the data acquisition system, control software and mechanics will be presented. Additionally first test-beam results with TJ-Monopix2 optimized for these conditions will be shown.

T 76.3 Thu 16:45 KH 01.022

Characterization of the AstroPix v3 HVMAPS — Lennart Huth[1], •Stephan Lachnit[1], Richard Leys[2], Elizaveta Sitnikova[1], Simon Spannagel[1], and Nicolas Striebig[2] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [2]Karlsruher Institut für Technologie KIT, Karlsruhe, Germany

AstroPix is a High-Voltage Monolithic Active Pixel Sensor (HVMAPS) designed for space-based medium-energy gamma-ray observatories like NASA's AMEGO-X. It aims to deliver a dynamic range from 25 to 700 keV with an energy resolution of 10 % at 122 keV. To achieve a high quantum efficiency, full depletion of the sensor is essential. Due to power and cooling restrictions in space, the power consumption of the sensor is limited to less than 1.5 mW/cm^2.

The third iteration of the sensor (AstroPix v3) consists of a 35×35 pixel matrix with a pixel pitch of 500 μm. It has been characterized at the DESY II Test Beam Facility in order to evaluate the detection efficiency, spatial resolution and depletion depth of the sensor using charged particles.

In this contribution, laboratory measurements and first results of this test beam campaign will be shown.

T 76.4 Thu 17:00 KH 01.022

Optimising high resolution time measurement in HVMAPS — •Alexander Schmidt for the HVMAPS HD-Collaboration — Physikalisches Institut Heidelberg

The phase 2 upgrade of the Mu3e experiment aims for a time resolution of 100ps to suppress coincidental background events. In the many-channel context of pixel sensors, time measurement circuits (TDCs) are constrained by size and current consumption.

This talk gives an overview on the current-capacitance based ramp approach to time measurement. Current HVMAPS prototypes, such as Telepix, achieve TDC resolution of 100ps at 125MHz base clock with minimal optimisation.

In this type of TDC, current consumption is largely driven by constant current sources. It can be reduced drastically by switched current sources. This talk demonstrates a circuit topology which avoids non-linearity typically introduced by switching transistors.

T 76.5 Thu 17:15 KH 01.022

Systematic studies of photon irradiated HV-CMOS MAPS towards the LHCb Mighty-Tracker — •Niclas Sommerfeld, Hannah Schmitz, Klaas Padeken, and Sebastian Neubert — HISKP Bonn

With the high luminosity upgrade to the LHC during LS3 the instantaneous luminosity at the LHCb experiment will be eventually increased by more than a factor of 6 to $1 \times 10^{34}\,\mathrm{cm^{-2}s^{-1}}$ for Run 5. As a part of Upgrade II the LHCb downstream tracker (Mighty-Tracker) is foreseen to be instrumented with 10m^2 of HV-CMOS MAPS around the beam pipe. This is intended to meet the increased requirements in terms of granularity and radiation tolerance imposed by the higher luminosity.

As a part of the ongoing efforts to develop the HV-CMOS MAPS foreseen for the Mighty-Tracker, the impact of Total Ionizing Dose (TID) damage on key performance requirements is further investigated under experimental conditions. The results of systematic studies of inhouse irradiated sensors are presented within this talk.

T 76.6 Thu 17:30 KH 01.022

Results from an HV-MAPS-Based Detector Prototype for Position-Resolved μSR Measurements — •Lukas Mandok for the HVMAPS HD-Collaboration — Physikalisches Institut, Heidelberg, Germany

Muon Spin Spectroscopy (μSR) is a well-established technique in material science for probing magnetic properties at the atomic scale. Conventional μSR spectrometers based on scintillators are fundamentally limited by coarse granularity and strict pile-up constraints, which restrict the usable muon rate and prevent spatially resolved measurements.

To overcome these limitations, we developed a pixel-based μSR detector using four ultra-thin HV-MAPS tracking layers based on MuPix11 sensor modules, which record incoming muons and decay positrons with high spatial precision. This enables accurate track reconstruction and a sub-millimeter determination of the decay vertex inside the sample. The approach further supports measurements of multiple samples and composite materials, while the resulting spatial information allows three-dimensional sample reconstruction and provides access to local magnetic fields by correlating vertex positions with the position-dependent precession signal.

The detector was operated several times at the πE3 beamline at PSI, demonstrating stable performance at beam intensities two orders of magnitude beyond the limits of scintillator-based systems. Its combination of high-rate capability and precise vertexing marks a significant step toward next-generation μSR spectrometers.

T 76.7 Thu 17:45 KH 01.022

Electrical Simulation and Characterization of All-Silicon Modules for CMOS Monolithic Pixel Detectors — Markus Cristinziani[1], Qader Dorosti[1], Stefan Heidbrink[2], Denise Müller[1], Noah Siegemund[1], •Darshil Vagadiya[1], Wolfgang Walkowiak[1], Jens Winter[2], and Michael Ziolkowski[2] — [1]Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen — [2]Elektronikentwicklungslabor Physik, Universität Siegen

Silicon pixel detectors offer high spatial and temporal resolution with a low material budget. Traditional multi-chip modules add material through bump-bonding, flexible PCBs, cooling, and support structures. A new approach explores post-processing monolithic wafers with redistribution layers interconnecting multiple chips, enabling thin and lightweight structures based on low-power monolithic CMOS sensors. In current production, this concept is used in all-silicon modules that integrate four sensors cut from a single wafer and rely on the OBELIX monolithic active pixel sensor, which reduces component count and support low-material designs suitable for future collider environments. The research in Siegen focuses on the electrical performance of signal and data interconnections at high transmission speeds. Current structures reach 0.25 Gbps, with a target of at least 1 Gbps. Prototype measurements covering impedance, signal integrity, S-parameters, and electrical simulations of differential trace geometry, dielectric layers, and vias are used to identify speed limitations and guide optimization of the interconnection layout for higher data-rate operation.

T 76.8 Thu 18:00 KH 01.022

Thermomechanical Simulation of an All-Silicon CMOS Pixel Detector Ladder — •Nana Chychkalo, Joern Groesse-Knetter, and Arnulf Quadt — Georg-August-Universitaet Goettingen, Goettingen, Germany

This work investigates a new monolithic ladder concept for the All-Silicon CMOS pixel detectors, in which several chips are integrated into a single self-supporting silicon structure. This approach aims to reduce the material budget compared to conventional hybrid assemblies and offers a promising option for future high-luminosity experiments.

A key feature of this concept is the use of a Redistribution Layer (RDL) for both power delivery and data transmission across the ladder, eliminating the need for additional support circuitry. The combination of active CMOS areas and RDL components in a thin monolithic structure, requires, however, careful evaluation of the resulting thermal and mechanical behavior.

This contribution presents thermomechanical simulations performed to understand the ladder heat dissipation under realistic operating conditions. These studies are used to estimate cooling requirements and to define suitable air-cooling parameters for stable operation.

T 77: Higgs Physics VIII

Time: Thursday 16:15–18:15 Location: KH 02.013

T 77.1 Thu 16:15 KH 02.013

ttH Analysis with Two Light Leptons and One Hadronically Decaying Tau Lepton with Run-2 ATLAS Data — Ephrem Alemu, •David Erwin, and André Sopczak — CTU in Prague

The latest results of the ttH analysis in the 2lSS1tau channel are presented with focus on machine learning using ATLAS Run-2 data.

T 77.2 Thu 16:30 KH 02.013

Mass-decorrelated jet-particle assignment for ttH(bb) events in dileptonic and semileptonic final states using Run 3 CMS Simulation — •Philipp Nattland[1], Kai Adamowicz[1], Lutz Feld[1], Danyer Perez Adan[1], Valeria Botta[1], Matin Torkian[2], Maria Aldaya Martin[2], and Daina Leyva Pernia[2] — [1]RWTH Aachen — [2]DESY

The associated production of a top-quark pair with a Higgs boson (ttH) directly probes the top-Higgs Yukawa coupling in the Standard Model. This study examines the ttH(bb) channel in the semileptonic and dileptonic final states, using Run 3 CMS simulation data. For a robust, data-driven estimation of the dominant tt+bb background the final state is reconstructed using advanced machine learning techniques for jet assignment. To use the invariant mass of jets assigned to the Higgs candidate as an unbiased fit variable, the reconstruction is decorrelated from the Higgs mass.

T 77.3 Thu 16:45 KH 02.013

Mass-decorrelated signal versus background classification for ttH(bb) events in single- and dileptonic final states using Run 3 CMS Simulation — •Kai Adamowicz[1], Lutz Feld[1], Valeria Botta[1], Danyer Perez Adan[1], Philipp Nattland[1], Matin Torkian[2], Maria Aldaya Martin[2], and Daina Leyva Pernia[2] — [1]RWTH Aachen University — [2]DESY

The ttH process provides a direct probe of the top-Higgs Yukawa coupling, an important parameter of the Standard Model. Due to a large and difficult to accurately model ttbb background, its measurement in the H -> bb channel has proven challenging in previous attempts by the CMS and ATLAS collaborations. Using the transformer based neural network architecture "SPANet", the prospect of a mass decorrelated kinematic reconstruction of the final states and event classification is studied on Run 3 CMS simulation. This way, the invariant mass of the jets assigned to the Higgs candidate may be used as an unbiased fit variable.

T 77.4 Thu 17:00 KH 02.013

Analysis of tH(bb) production with ATLAS Run-2 data — •Filip Rucka and André Sopczak — CTU in Prague

The latest results of the analysis tH(bb) are presented with focus on machine learning using ATLAS Run-2 data.

T 77.5 Thu 17:15 KH 02.013

Higgs-to-Bottom Decays at next-to-leading order in the Sherpa Event Generator — •Lea Baumann[1], Frank Siegert[1], Mareen Hoppe[1], and Marek Schönherr[2] — [1]TUD Dresden University of Technology, Institute of Nuclear and Particle Physics — [2]University of Durham, Institute for Particle Physics Phenomenology

Monte Carlo event generators play a central role in particle collider data analysis by providing accurate theoretical predictions of complex scattering processes. Event generators like Sherpa use the narrow-width approximation to describe short-lived resonances as on-shell particles, allowing the factorisation of production and decay of these "hard" particles.

Until now, Sherpa's hard decays have been implemented only at leading order in perturbative quantum chromodynamics (QCD). In this talk, the next-to-leading order (NLO) QCD calculation for the decay of a Higgs boson into a bottom-antibottom pair within the hard-decay framework will be presented. The computation includes the evaluation of virtual loop corrections, real-emission contributions, and the cancellation of infrared singularities using subtraction terms. The resulting NLO matrix element can later be matched to parton shower programmes. This NLO implementation improves the precision of Higgs-decay simulations within Sherpa and enables more accurate modelling of processes.

T 77.6 Thu 17:30 KH 02.013

Search for the Higgs boson decay into charm-anticharm quark pairs in the vector boson associated production mode with the CMS Experiment — •Valentyn Vaulin, Alexander Schmidt, Andrey Pozdnyakov, Patrick Kersten, Pedro Gouveia Pinto Da Costa, Ishmeet Kaur Vohra, Jan Terörde, and Arnd Meyer — III. Physics Institute A, RWTH Aachen University, Aachen, Germany

The most sensitive channel to constrain the Higgs-charm quark coupling is the Higgs boson decay into charm-anticharm quarks in the associated production with vector bosons, the so called VH (H → cc) channel. Results on the searches in this approach have been published by CMS using data from LHC Run 2. This talk will give an overview of the ongoing developments and expectations for this analysis. Highlights include a new analysis framework which provides improved sensitivity using machine learning methods. The analysis now also probes the VH (H → cc) and VH (H → bb) channels at the same time. Preliminary results with data from LHC Run 3 will be shown.

T 77.7 Thu 17:45 KH 02.013

Integration of the PAIReD Tagger for the Higgs-boson Decay into Charm - Anticharm Quark Pairs in Vector-Boson Associated Production with the CMS Experiment — •Ishmeet Kaur Vohra, Alexander Schmidt, Arnd Meyer, Andrey Pozdnyakov, Valentyn Vaulin, Pedro Gouveia Pinto Da Costa, Patrick Kersten, and Jan Terörde — III. Physics Institute A, RWTH Aachen University, Aachen, Germany

Reconstructing hadronically decaying heavy particles at low to moderate boosts is challenging when using only small-radius jets. The PAIReD and PAIReDEllipse approaches address this by forming jet candidates from pairs of small-radius jets and in the elliptical variant, by including all particles inside an extended elliptical region in the η - ϕ plane. Their performance has been studied for Higgs boson decays into bottom-antibottom (bb) and charm-anticharm (cc) quark pairs produced in association with a vector boson (V), using ParticleTransformer-based algorithms for jet regression and classification. The methods show improved reconstruction efficiency and background separation in the lowboost regime compared to standard AK4 techniques, while remaining competitive at higher boosts. This contribution covers the integration of the PAIReD Tagger into the analysis of the VH(H → cc) channel, including an initial investigation of the related systematic uncertainties.

T 77.8 Thu 18:00 KH 02.013

Investigation on the use of multiclass BDTs in the search for the Higgs boson decay to a charm-anticharm pair in vector boson associated production mode at CMS in Run 3 — •Pedro Gouveia Pinto da Costa, Alexander Schmidt, Andrey Pozdnyakov, Valentyn Vaulin, Patrick Kersten, Ishmeet Kaur Vohra, Jan Terörde, and Arnd Meyer — III. Physikalisches Institut A, RWTH Aachen University

The most sensitive channel to search for the decay of the Higgs boson into charm quarks is the vector boson associated production mode (VH channel) in which the Higgs boson is produced along with a W or Z boson. Analyses targeting this channel use multiple different machine learning models to help distinguish between signal and background events. Among the main backgrounds are W/Z plus jet production and top quark pair production. Events are classified into several categories with different signal and background compositions to facilitate a multi-parameter fit. This talk presents a study in which the potential of a multiclass boosted decision tree (BDT) is investigated in comparison to the previously used binary classification.

T 78: Flavour Physics V

Time: Thursday 16:15–18:15 Location: KH 02.014

T 78.1 Thu 16:15 KH 02.014

Measurement of Charm and Beauty Production in Proton–Proton Collisions at $\sqrt{s} = 5$ TeV with the CMS Experiment — •Lucas Karwatzki[1,2], Achim Geiser[1], Alexander Schmidt[2], and Arnd Meyer[2] — [1]Deutsches Elektronen-Synchrotron, Hamburg, Germany — [2]Physics Institute III A RWTH Aachen University, Aachen, Germany

Measuring the charm and beauty production cross sections is not only a crucial test of the Standard Model but also provides valuable input for refining the proton parton distribution functions at low x, and for the determination of the charm and beauty quark masses.

In this talk, I will present a double-differential measurement of the D^*-meson production cross section in transverse momentum p_T and absolute rapidity $|y|$ in proton–proton collisions at $\sqrt{s} = 5$ TeV using the CMS detector. The decay topology of the D^* meson allows access to very low transverse momenta (p_T) and by combining these results for the high-rapidity phase space with LHCb measurements, total cross sections for heavy-flavour production can be measured with only small extrapolation.

D^* mesons can originate either directly from charm-quark hadronisation or from the decay of B hadrons. The longer lifetime of B hadrons enables the use of the impact parameter and decay length significance to effectively separate the two contributions, and therefore allows for the measurement of both the charm and beauty production cross sections.

T 78.2 Thu 16:30 KH 02.014

Measurement of strangeness production in pNe collisions at LHCb — Johannes Albrecht[1], •Theodor Zies[1], Noah Behling[1], Felix Riehn[1], Saverio Mariani[2], and Chiara Lucarelli[2] — [1]TU Dortmund, Germany — [2]Cern

In the Standard Model, the strong interaction is described by quantum chromodynamics (QCD) and is generally well understood. Processes with low momentum transfer (soft QCD) require complex, data-driven models describing hadronic interactions. Measurements of various hadron production cross-sections serve as essential inputs to constrain these models and tune their parameters, ensuring they provide accurate predictions across different energies. A mismatch in the number of muons produced in simulations and data of cosmic-ray induced air showers hints at insufficiencies in current models. In this work, a measurement of the baryon-to-meson and baryon-to-antibaryon strange hadron production cross-section ratios R_{Λ^0/K^0_S} and $R_{\Lambda^0/\bar{\Lambda}^0}$ is performed. Data from fixed-target pNe collisions acquired using the SMOG2 system of the LHCb Upgrade I detector are used, collected during Run 3 of the LHC and corresponding to an integrated luminosity of $\mathcal{L}_{\text{int}} = 225\,\text{nb}^{-1}$ at a center-of-mass energy of $\sqrt{s_{\text{NN}}} = 113\,\text{GeV}$. The results are calculated differentially as a function of transverse momentum and rapidity. A comparison with predictions of the commonly used hadronic interaction models `EPOS-LHC` and `QGSJet` enables the study of how accurately these models describe strangeness production. Overall agreement is observed in most kinematic bins, while the newer tunes of the models show slightly better consistency.

T 78.3 Thu 16:45 KH 02.014

Reconstruction of multi-strange baryons Ξ and Ω in pp collisions at sqrt(s) = 13.6 TeV with the ALICE detector — Bilge Jin ONEN[1] and •Ayben Karasu Uysal[2] — [1]Istanbul Technical University, Istanbul, Turkey — [2]Yildiz Technical University, Istanbul, Turkey

Strangeness production has long been regarded as a key signature of the quark-gluon plasma (QGP), a deconfined state of matter created in ultra-relativistic heavy-ion collisions. Similar features such as collective flow and enhanced yields of strange and multi-strange baryons have also been observed in high-multiplicity small collision systems, including proton-proton (pp) interactions at the LHC. These findings make the study of strangeness a central topic within the ALICE experiment, where pp collisions provide a unique environment to investigate QGP-like effects without the presence of large-volume nuclear matter.

In this work, the reconstruction of the multi-strange baryons Ξ (dss) and Ω (sss) in pp collisions at sqrt(s) = 13.6 TeV is presented using standard topological selections and invariant-mass analysis techniques. The cascade weak decays Ξ- -> Λ π- and Ω- -> Λ K-, with Λ -> p π-, are reconstructed from charged decay tracks identified with the ITS, TPC and TOF detectors. The obtained corrected yields agree with published ALICE results within uncertainties, validating the classical reconstruction. This analysis provides a solid reference for future studies exploring machine-learning-based selection strategies.

T 78.4 Thu 17:00 KH 02.014

Total and differential charm production cross sections in pp collisions at $\sqrt{s} = 13$ TeV — •Aviral Akhil and Achim Geiser — Deutsches Elektronen-Synchrotron, Hamburg, Germany

Charm production sits at the boundary where perturbative QCD begins to lose precision and non-perturbative effects become significant, making it a powerful probe of the strong interaction. To explore this challenging regime, we present measurements of D*-meson differential charm production cross sections at a proton proton center-of-mass energy of $\sqrt{s} = 13$ TeV using the CMS detector. The analysis reconstructs charm hadron decays across the largest accessible phase space to minimize extrapolation to the full charm production region. Results are reported as differential cross sections in transverse momentum and rapidity and compared to QCD predictions as well as to measurements from other LHC experiments. The fiducial cross sections are then extrapolated to the total charm-pair cross section using a data-driven parameterization of charm fragmentation fractions that incorporates recent measurements of meson-baryon ratios dependent on p_T. The use of non-universal, experimentally constrained fragmentation improves the fragmentation treatment relative to earlier extractions. These results provide constraints on key QCD parameters such as the charm-quark mass and parton distribution functions at low momentum fraction and contribute to a more detailed understanding of heavy-flavour production dynamics at the LHC.

T 78.5 Thu 17:15 KH 02.014

$\bar{\Lambda}^0/K^0_S$ production cross-section ratio at LHCb in Run 3 — Johannes Albrecht[1], •Noah Behling[1], Lukas Calefice[2], Biljana Mitreska[3], and Titus Mombächer[4] — [1]TU Dortmund University, Dortmund, Germany — [2]Universitat de Barcelona, Barcelona, Spain — [3]University of Manchester — [4]University of Cincinnati

Hadron production ratios are a useful probe to test and improve hadronisation models. In this work, the production ratio of K^0_S and $\bar{\Lambda}^0$ is studied with Run 3 proton-proton collision data from the upgraded LHCb experiment. These studies are also essential to calibrate and validate the performance of the upgraded detector. The proper operation of all subsystems must be ensured step-by-step to carry out precise measurements with data recorded recently and in the future. The performance of the tracking system can be evaluated with the measured ratio.

Meson-to-baryon ratios and strangeness production also contribute to the understanding of hadronic processes in cosmic-ray-induced extensive air showers, which are dominated by soft-QCD effects in the forward region. In air-shower data, an excess of muons produced with respect to Monte Carlo event generators has been observed, which could originate from mismodelling of the hadronisation process. The LHCb experiment offers a unique environment to test hadronic models in the forward region.

The current status of the analysis and recent studies on detector performance will be presented. Additionally, the connection of collider experiments to air-shower measurements will be discussed.

T 78.6 Thu 17:30 KH 02.014

Charm mesons production asymmetries at LHCb in Run 3 — •Luca Balzani[1], Serena Maccolini[2], and Dominik Stefan Mitzel[1] — [1]TU Dortmund University, Dortmund, Germany — [2]CERN, Geneva, Switzerland

Ahead of Run 3 of the LHC, the LHCb detector was profoundly upgraded to leverage the programmed increase in luminosity. Studying the features of the upgraded detector is of paramount importance in order to reliably perform measurements.

Production asymmetries are ideal candidates to investigate the characteristics of the new LHCb detector. These observables depend on the colliding system characteristics but shall not be influenced by experimental effects. Therefore, having these latter contributions under control is essential to perform a consistent measurement. Precise measurements of production asymmetries also allow for a better understanding of QCD models used in Monte Carlo generators, especially in the high-rapidity region. The production asymmetry for neutral charm meson has been measured for the first time in proton-proton collisions at the LHC energies and is part of the first published result from LHCb with Run 3 data. This contribution will discuss the general strategy and the techniques used for the measurement, providing some insights on the characteristics of the new LHCb Run 3 data.

T 78.7 Thu 17:45 KH 02.014

Charm and beauty separation using reconstructed D* mesons with the b-hive framework in CMS — •Shruti Shetty[1], Lucas Karwatzki[1,2], Alexander Schmidt[1], Achim Geiser[2], and Arnd Meyer[1] — [1]III. Physikalisches Institut A, RWTH Aachen University — [2]DESY, Hamburg

Reliable separation of charm and beauty hadrons is essential for precision measurements and searches involving heavy flavour at the LHC. In this study, reconstructed $D^* \to D^0\pi_s$ candidates, with $D^0 \to K\pi$ decays, are investigated using simulated proton-proton collision samples from the CMS experiment. For the first time, hadron-level particle identification is implemented within the b-hive framework, a modular training framework for state-of-the-art object tagging in the Python ecosystem used by the CMS experiment. This approach provides the basis for future optimization of charm and beauty identification and its application in physics analyses.

T 78.8 Thu 18:00 KH 02.014

Measurement of the Oscillation Frequency Δm_s with 2024 Data of the Upgraded LHCb Experiment — •Johann Nicolas Himbert[1], Stephanie Hansmann-Menzemer[1], Lennart Uecker[1], Sara Celani[2], and Marc Quentin Führing[3] — [1]Physikalisches Institut Heidelberg University, Heidelberg, Germany — [2]CERN, Switzerland — [3]TU Dortmund University, Dortmund, Germany

The measurement of the oscillation frequency Δm_s in the $B^0_s - \bar{B}^0_s$ system is an excellent showcase of the capabilities of the upgrade LHCb experiment in Run 3. The LHCb detector in Run 3 is collecting data at a five times larger instantaneous luminosity than in Run 2. To cope with this increased luminosity, all subdetectors and their readout-electronics have undergone major upgrades and a fully software based trigger has been implemented. The later improves the acceptance of softer decays for multi-body hadronic final states, which results in a three times larger yield of signal candidates per fb^{-1}. For the measurement of Δm_s new dedicated Run 3 flavour-tagging algorithms and the excellent decay time resolution of the upgrade detector are exploited to resolve the oscillation. On a small test data set of 1.2 fb^{-1} the decay channel $B^0_s \to D^-_s\pi^+$ with $D^-_s \to \phi^0(\to K^-K^+)\pi^-$ is studied and the oscillation frequency, Δm_s, resolved with a statistical uncertainty of 0.0156 ps^{-1}.

T 79: Searches/BSM IV

Time: Thursday 16:15–17:45 Location: KH 02.018

T 79.1 Thu 16:15 KH 02.018

Quantum work for deriving and explaining the Lorentz transformations — •Grit Kalies[1], Duong D. Do[2], and Cornelia Breitkopf[3] — [1]HTW University of Applied Sciences, Dresden, Germany — [2]The University of Queensland, Brisbane, Australia — [3]Technical University of Dresden, Dresden, Germany

The Lorentz transformations of mass and time are derived and explained within the framework of quantum-process thermodynamics. To this end, we use various forms of quantum work for describing the behavior of an accelerated particle, for example an electron. We find that during acceleration, a particle does not only change its velocity and (external) motion energy, but also its internal energies and structure. A new equation for the motion energy of an object is presented, which generalizes kinetic and electromagnetic energy. We compare our results with those of special relativity and discuss various microscopic and macroscopic experiments. Since energetic explanations are provided, quantum-process thermodynamics seems well suited to establishing a direct link between classical thermodynamics and quantum physics.

T 79.2 Thu 16:30 KH 02.018

Constraining a Beyond Standard Model Theory with Neutrino Public Data — •Sofia Lonardi[1,2] and Philipp Eller[2] — [1]Arnold Sommerfeld Center, Ludwig-Maximilians-Universität (LMU), Theresienstraße 37, 80333 Munich, Germany — [2]Technical University Munich (TUM), James-Franck-Strasse 1, 85748 Garching, Germany

Neutrino experiments provide a powerful window into physics beyond the Standard Model. While oscillation measurements precisely determine mixing angles and mass splitting parameters, non-oscillation experiments constrain absolute neutrino masses, together offering complementary probes of new physics.

This work relies on a global analysis framework that combines publicly available data from leading experiments: Daya Bay, MINOS, KamLAND, KATRIN, GERDA, and JUNO. These data are used to test the "Nnaturalness" theory, a Beyond Standard Model theory that simultaneously addresses neutrino mass generation and the electroweak hierarchy problem through multiple copies of the Standard Model in hidden sectors with varying Higgs masses.

By fitting the data with this model across different neutrino mass orderings and Majorana or Dirac scenarios, we establish lower bounds on the number of hidden sectors and on the theory's fine-tuning parameter, effectively constraining the parameter space and excluding a class of theory realisations.

T 79.3 Thu 16:45 KH 02.018

Collisionoperators in electroweak baryogenesis — •Johann Plotnikov[1], Margarete Mühlleitner[1], Rui Santos[2], and João Viana[2] — [1]KIT, Karlsruhe, Germany — [2]Universidade de Lisboa, Lisboa, Portugal

It is known that extensions of the Standard Model are necessary to explain the observed Baryon Asymmetry of the Universe (BAU) as they are able to provide a strong first-order phase transition needed for electroweak baryogenesis. During the phase transition bubbles are created which separate the true vacuum from the broken vacuum. As the particles of the plasma collide with the bubble wall, the particles and anti-particles scatter differently to create the BAU. However, at the same time the surrounding plasma tries to wash out this asymmetry via collisions between the plasma particles. In our work we perform a careful derivation of the strength of these collisions and study their influence on the resulting BAU.

T 79.4 Thu 17:00 KH 02.018

Interplay between Dark Matter and the Electroweak Phase Transition — •Tim Vincent Krause[1], André Milagre[2], Johann Plotnikov[1], Milada Magarete Mühlleitner[1], Rui Santos[3], and João Silva[2] — [1]Karlsruher Institut für Technologie — [2]Instituto Superior Técnico, Universidade de Lisboa — [3]Universidade de Lisboa, Campo Grande

Current extensions to the scalar sector of the Standard Model (SM) are able to explain the matter anti-matter asymmetry in the universe via Electroweak Baryogenesis (EWBG) and simultaneously provide a dark matter candidate. In many cases these two phenomena are treated separately as they usually take place at different times in the evolution of the universe. However, there are scenarios where the electroweak phase transition necessary for EWBG and the production of DM take place during the same time period. As the phase transition influences the mass evolution of the SM particles it also plays a crucial role in the calculation of the relic density for DM. In our work we study the interplay between EWBG and DM generation as well as analyze it's impact on the final relic abundance.

T 79.5 Thu 17:15 KH 02.018

Parameter determination for singlino dark matter scenarios in the NMSSM — •Laurenz Kriege[3], Gudrid Moortgat-Pick[1], and Sven Heinemeyer[2] — [1]DESY and Hamburg U., Inst. Theor. Phys. II — [2]Madrid, IFT — [3]UHH

We study the reconstruction of the underlying parameters of the Next-to-Minimal Supersymmetric Standard Model (NMSSM) by assuming certain chargino and neutralino measurements at a future e+e- collider. We take scenarios with singlino dominated dark matter, with bino, wino, and gluino masses obeying the approximate GUT relations and an overall scenario consistent with the measured excesses at ATLAS and CMS and all experimental constraints. We demonstrate that both the dark matter relic density and most of the relevant NMSSM parameters can be reconstructed.

T 79.6 Thu 17:30 KH 02.018

Testing Supersymmetric Dark Matter Scenarios through Electroweakino Parameter Determination — •Nele Peters and Gudrid Moortgat-Pick — Department of Physics, University of Hamburg

Supersymmetric models provide well-motivated candidates for particle dark matter, but testing their viability requires precise knowledge of the underlying electroweakino parameters. In this talk, we investigate how accurately a future International Linear Collider (ILC) could determine the key parameters M1, M2, and μ in dark-matter motivated supersymmetric scenarios, here evaluated for an NMSSM benchmark. Using simulated measurements of polarized chargino-pair production and the masses of the lightest chargino and neutralino, we assess the sensitivity of these observables to the electroweakino sector and quantify the achievable reconstruction precision. From the reconstructed parameter sets, the dark-matter relic density is computed and compared to the benchmark values. The study demonstrates the potential of precision lepton-collider data to constrain supersymmetric dark-matter scenarios and to evaluate their consistency with cosmological observations.

T 80: Axions/ALPs II

Time: Thursday 16:15–17:45 Location: KH 02.019

T 80.1 Thu 16:15 KH 02.019

The IAXO-D1 Demonstrator for the BabyIAXO Intermediate Step — •Jorge Porrón Lafuente — University of Zaragoza — Centro de Astropartículas y Física de Altas Energías (CAPA)

The International AXion Observatory (IAXO) is a large-scale helioscope searching for solar axions and axion-like particles via the Primakoff effect. BabyIAXO, its prototype at DESY, serves both as a testbed for IAXO technologies and a functional helioscope, requiring high efficiency in the 1-10keV range and ultra-low background (<10*-7 counts/keV/cm2/s).

The IAXO-D1 Micromegas X-ray detector in Zaragoza characterizes cosmic background at surface level. It features 20cm lead shielding, a 4π muon veto, and radiopure materials to reduce intrinsic background. Cosmogenic neutrons, which can mimic axion signals, are tagged using the REST-for-Physics framework. Previous detectors achieved 8.6*10-7 counts/keV/cm2/s at surface and approx. 2*10-7 counts/keV/cm2/s underground. Simulations indicate cosmic neutrons produce secondary signals in the veto, enabling identification.

Initial IAXO-D1 measurements without the veto reached 2*10-6 counts/keV/cm2/s. Ongoing improvements in veto design, shielding, and analysis aim to meet the <10*-7 counts/keV/cm2/s goal, enhancing BabyIAXO*s sensitivity and informing the design of the full-scale IAXO experiment.

T 80.2 Thu 16:30 KH 02.019

Towards a low background SDD for IAXO — •Lucinda Schönfeld[1], Christian Buck[1], Susanne Mertens[1], Christoph Wiesinger[1], Michael Willers[2], and Juan Pablo Ulloa Beteta[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, DE — [2]Technische Universität München, Garching, DE

Axions are hypothetical particles that solve the strong CP problem and are candidates for dark matter. The International Axion Observatory (IAXO) is aiming to find these elusive particles by converting solar axions to X-rays. Detecting this rare signal requires highly efficient ultra-low background X-ray detectors, for which Silicon Drift Detectors (SDDs) are well suited. I will present the current status of the TRISTAN SDD for IAXO (TAXO) project, which is developing such an SDD. A particular focus will be the latest results of background measurements, as well as simulations to find an optimal shielding setup.

T 80.3 Thu 16:45 KH 02.019

Axion search with RADES — •Elisa Gabbrielli for the RADES MPP-Collaboration — Max Planck für Physik, Munich

RADES (Relic Axion Detection Exploratory Setup) is a haloscope experiment designed to search for axions originating from the local dark matter galactic halo in the μeV mass range, under the assumption that dark matter is entirely composed of axions. The detection technique relies on a resonant cavity placed inside a strong magnetic field, which enhances the conversion of axions into detectable photons. The collaboration has achieved significant progress regarding the development of new cavity geometries, leading to two physics results at axion masses around 30 μeV.

An innovative RADES setup incorporating transmon qubits is currently being developed within the collaboration. This talk focuses on the activities at the Max Planck Institut für Physik in Garching. To maximise the signal-to-noise ratio, the experiment operates at cryogenic temperatures using a dilution refrigerator that can reach approximately 10 mK. At these extremely low temperatures, superconducting devices such as transmon qubits can be employed as single-photon detectors to further improve signal sensitivity.

T 80.4 Thu 17:00 KH 02.019

First measurements with a MADMAX 8 disk prototype booster system for the search of dark matter — •Umashi Fernando for the MADMAX-Collaboration — Max-Planck-Institut für Physik, Boltzmannstr. 8, 85748 Garching

The main aim of the MADMAX experiment (Magnetised Disc and Mirror Axion Experiment) is to search for the hypothetical particle that solves the strong CP problem and is also an excellent cold dark matter candidate: the axion. The electric field oscillations due to axion conversion to photons in the presence of a strong magnetic field can be detected, but the signal is very weak. Thus, a configuration with dielectric disks in front of a mirror is used to resonantly enhance the signal over a controllable frequency range.

In this talk, measurements taken with an 8-disk closed prototype booster system CB200 will be discussed. Some details of the used receiver chain and data acquisition system will be given.

T 80.5 Thu 17:15 KH 02.019

MADMAX analysis procedures and preliminary results of CB100 cold experiment — •Haotian Wang for the MADMAX-Collaboration — III. Physikalisches Institut A, RWTH Aachen University, Aachen

MADMAX is a dielectric haloscope experiment that searches for QCD axion dark matter in the mass range of a few tens to a few hundred micro-eV by exploiting axion-photon conversion in a strong magnetic field enhanced by a dielectric booster. In this contribution, we present the general MADMAX data analysis procedures, developed for the treatment of large sets of power spectra, including background modeling, the combination of multiple measurements, and the statistical inference of exclusion limits. These methods are then applied to data from the CB100 closed-booster prototype operated in a magnetic field at cryogenic temperatures, and preliminary exclusion limits are shown.

T 80.6 Thu 17:30 KH 02.019

Determining the MADMAX boost factor using the bead pull method — •Lea Stankewitz for the MADMAX-Collaboration — Institut für Experimentalphysik, Universität Hamburg

The MAgnetised Disk and Mirror Axion eXperiment is a dielectric haloscope which aims to search for dark matter axions between 40 μeV and 400 μeV. It converts axions into photons using a strong magnetic field. The conversion probability is enhanced by arranging multiple dielectric disks in a resonant configuration, the so called booster. The boost factor, that quantifies how much the axion signal power is amplified relative to a simple dish-antenna configuration, can be determined from the electric field strength in between the disks. To measure the electric field the bead pull method is used, where a small dielectric object is moved through the setup to measure the electric field at different positions. For the next axion search, which will measure multiple frequency ranges, calibration of multiple disc configurations is required. The bead pull measurements inside the cryostat will have a limited range, therefore good reference measurements are required. In this talk I present the results of the boost factor determination for the open booster setup with a three disks configuration using a high-precision bead pull setup. These measurements will be used to calibrate the system for the first cryogenic axion search with MADMAX in the MORPURGO magnet at CERN.

T 81: Search for Dark Matter III

Time: Thursday 16:15–17:45 Location: AM 00.014

T 81.1 Thu 16:15 AM 00.014

Study of few-electron backgrounds in the XENONnT detector — •Sophie Armbruster — Max Planck Institut für Kernphysik, Heidelberg

When searching for light-mass dark matter with low-energy ionization signals down to the level of a single extracted electron using a dual-phase liquid xenon time projection chamber, it is crucial to understand and mitigate ionization backgrounds in the few-electron regime. Delayed single- and few-electron emissions are small charge signals that appear after a large charge signal but do not stem from independent low-energy interactions. Possible origins include photoionization processes, electron trapping by impurities,and temporary trapping of electrons at the liquid*gas interface. This talk presents a dedicated study of these delayed electron emissions using XENONnT data, focusing on their correlations with detector parameters. The results provide new insight into the phenomenology of few-electron backgrounds and support improved background modeling for future light dark matter searches with liquid xenon detectors.

T 81.2 Thu 16:30 AM 00.014

Novel Purity Sensors in Liquid Xenon Time Projection Chambers — •Tom Sonius — Karlsruhe Institute of Technology, Institute for Astroparticle Physics

The XLZD observatory will be a next-generation, multi-tonne xenon detector capable of probing dark matter and neutrino physics at unprecedented sensitivity. Its design features a dual-phase time projection chamber (TPC) containing 60 tonnes of liquid xenon (LXe).

Attaining the anticipated sensitivities requires extremely pure xenon so that rare event ionization signals are not degraded by their capture by electronegative impurities diffused in the liquid. Achieving this purity relies on advanced purification techniques, continuous recirculation, and dedicated purity monitoring systems.

Conventional LXe purity monitoring modules are bulky and must be placed outside the sensitive detector volume. A novel approach with minimal footprint and scalability is the use of carbon nanotube-based sensors that can be placed directly in the instrumented volume.

In this talk, I will present the current R&D efforts at KIT on the development of purity sensors based on single-layer carbon nanotubes, along with the status of their design and production, as a step towards novel purity sensing technologies for future LXe-TPCs.

This work is supported by the Impuls und Vernetzungsfonds of the Helmholtz Association (grant no. VH-NG-21-02).

T 81.3 Thu 16:45 AM 00.014

Studies of dielectric breakdown in liquid xenon with the MOTION detector — •Keyu Ding — Karlsruhe Institute of Technology, Institute for Astroparticle Physics

Next-generation liquid xenon (LXe) dark matter detectors are expected to double their linear dimensions compared to current-generation experiments. The future XLZD Observatory aims to build a detector with an inner diameter and height of nearly 3 m, hosting 60 tonnes of LXe in a time-projection chamber (TPC). The result, a tenfold increase in mass, enables dark matter searches approaching the neutrino fog, as well as rare-event searches such as neutrinoless double-beta decay and supernova neutrinos.

With the increased TPC height, the voltage delivered to the cathode exceeds previously tested ranges in LXe at this scale. Although LXe is predicted to sustain bulk fields near 1 MV/cm, experiments consistently observe dielectric breakdown at values much closer to the operating fields ($\mathcal{O}$(10–100) kV).

The MOTION detector, an ∼70 kg LXe setup at the Karlsruhe Institute of Technology, is used to study dielectric breakdown in LXe. We investigate how local field enhancement at electrode asperities and stressed electrode areas affect breakdown using various diagnostic methods. This work is supported by the Impuls und Vernetzungsfonds of the Helmholtz Association (grant no. VH-NG-21-02).

T 81.4 Thu 17:00 AM 00.014

Optimization of Gold Collector Pads for remoTES Sensors on NaI Crystals in the COSINUS Experiment — •Moritz Dörfler for the COSINUS-Collaboration — Max Planck Institute for Physics, Garching, Germany

Cryogenic calorimeters based on scintillating sodium iodide (NaI) crystals provide a promising approach for direct dark matter searches, as pursued by the COSINUS experiment (Cryogenic Observatory for SIgnatures seen in Next generation Underground Searches) at the Laboratori Nazionali del Gran Sasso (LNGS). In COSINUS detector modules, particle interactions in the absorber crystal are detected via phonon signals, which are read out by remote Transition Edge Sensors (remoTES). An efficient thermal coupling between the NaI crystal and the sensor is achieved by thin metallic collector pads deposited on the crystal surface and a wire bond connection. This contribution focuses on the development and characterization of gold collector pads used for phonon collection in COSINUS detector modules. The geometry, thickness, and deposition parameters of the gold films are critical for efficient phonon transport from the NaI crystal to the remoTES sensor, while maintaining sufficient mechanical stability and reproducibility. Optimizing the gold*NaI interface is an essential step toward improving the sensitivity and reliability of future COSINUS detector modules and contributes to the overall goal of achieving low-threshold, background-discriminating dark matter searches with NaI-based cryogenic detectors.

T 81.5 Thu 17:15 AM 00.014

Results of a multi-wafer, double TES detector in the CRESST Experiment — •Felix Dominsky for the CRESST-Collaboration — Max-Planck-Institut für Physik, Garching, Germany

CRESST (Cryogenic Rare Event Search with Superconducting Thermometers) is a leading direct-detection experiment for dark matter that implements Transition Edge Sensors (TESs) to measure minute energy depositions in cryogenic target crystals. As several other experiments in this field, CRESST observes an unexpected excess of events close to the detection threshold up to 200eV, commonly referred to as the low-energy excess (LEE). The current detector generation of CRESST employs two TES per crystal to better characterize this excess and investigate possible origins. Following this approach, CRESST has additionally deployed a stacked module, consisting of four vertically stacked, thin silicon on sapphire (SoS) wafer double-TES detectors. Their reduced target mass results in enhanced energy resolution, while the vertical arrangement allows the outer wafers to act as an active veto for the inner ones. This contribution will present the concept and motivation of this stacked-detector module and discuss first preliminary results and insights from its operation.

T 81.6 Thu 17:30 AM 00.014

Low Energy Excess Studies in the CRESST Experiment — •Judith Dohm for the CRESST-Collaboration — Eberhard-Karls-Universität Tübingen, 72076 Tübingen, Deutschland

The Cryogenic Rare Event Search with Superconducting Thermometers (CRESST) is a direct dark matter detection experiment located in the Laboratori Nazionali del Gran Sasso (LNGS) in Italy. CRESST operates cryogenic calorimeters equipped with Transition Edge Sensors (TES) operating in the millikelvin range. In the third phase (CRESST-III), energy thresholds of about 10eV have been reached, placing CRESST-III among the world-leading experiments in the search for sub-GeV dark matter. The experiment's sensitivity in the low mass region is currently limited by an unexplained rise of events below 200eV, the so-called low energy excess (LEE). The latest studies of the temporal behaviour and the energy spectrum of the LEE performed by CRESST will be presented in this talk.

T 82: Neutrino Astronomy IV

Time: Thursday 16:15–18:00 Location: KS H C

T 82.1 Thu 16:15 KS H C

Simulation of the atmospheric neutrino production height with CORSIKA 8 — •Tim Schönauer — TU Dortmund, Dortmund, Germany

Atmospheric neutrinos are produced in cosmic-ray air showers. Yet the neutrino production height remains largely unexplored, although it exhibits significant seasonal and regional variability, especially in polar atmospheres where the density profile undergoes strong annual modulation. To investigate the production height of neutrinos, air-shower simulations were carried out using CORSIKA 8, the recently developed C++-based successor to the established CORSIKA framework. Its architecture enabled controlled variation of physical parameters and allowed detailed comparisons with legacy simulations, providing a basis for validation and for identifying deviations introduced by the modernized implementation. The production heights of atmospheric neutrinos were simulated for summer and winter atmospheric profiles at the South Pole and other geographical locations. The resulting distributions quantified the magnitude and energy dependence of seasonal shifts in the neutrino production region and provide refined input for analyses sensitive to atmospheric model uncertainties in present and future neutrino observatories.

T 82.2 Thu 16:30 KS H C

Water Properties Studies with atmospheric muons in the ORCA/ARCA KM3NeT detector — •Evi Sakkou for the KM3NET-ERLANGEN-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg, Nikolaus-Fiebiger-Str. 2, 91058 Erlangen, Germany

The KM3NeT detector is an underwater neutrino observatory that detects atmospheric neutrinos in a range of energies. ORCA and ARCA detectors rely on precise knowledge of the optical properties of the surrounding water helping to enhance neutrino event reconstruction. In this study, we use atmospheric muons to study the water attenuation length. To this end we compare the light yield of muons between data and Monte Carlo simulations generated with different true values of the water attenuation length.

T 82.3 Thu 16:45 KS H C

Unfolding the Electron Neutrino Spectrum — •Lene Van Rootselaar and Lukas Liland for the IceCube-Collaboration — TU Dortmund, Dortmund, Germany

The IceCube Neutrino Observatory, a cubic-kilometre detector located in the Antarctic ice at the South Pole, provides unique sensitivity to neutrinos over energies spanning from the GeV to the PeV scale. In this energy regime, the observed neutrino flux is expected to arise from a combination of conventional atmospheric neutrinos produced in pion and kaon decays, a possible prompt atmospheric contribution from charmed hadron decays, and an astrophysical component of extragalactic origin. Disentangling these contributions, in particular in the transition region where the prompt flux may become relevant, is essential for advancing our understanding of high-energy particle interactions in the atmosphere.

This contribution describes the current status of an analysis aimed at determining the electron neutrino energy spectrum in IceCube in the range from roughly 1 TeV to 4 PeV using a cascade event sample. A spectral unfolding technique is used to infer the neutrino energy distribution while minimizing dependence on assumed flux models. Ongoing studies of the detector response, Monte Carlo validation, and the impact of systematic uncertainties will be presented.

T 82.4 Thu 17:00 KS H C

Atmospheric tau neutrino appearance analysis with 11 years of IceCube DeepCore data — •Sol Benkel for the IceCube-Collaboration — DESY Zeuthen

DeepCore, a region of the IceCube Neutrino Observatory with denser instrumentation, enables the detection of atmospheric neutrinos between 5 and 150 GeV, where a strong tau neutrino signal has been observed. DeepCore has continually provided high precision measurements of atmospheric neutrino oscillations, repeatedly setting world-leading results. In this talk, I present the design and current progress of a new analysis strategy for atmospheric tau neutrino appearance using 11 years of IceCube DeepCore data. This strategy explores new metrics by which high resolution neutrino events can be isolated from the analysis sample, thus potentially improving the sensitivity to measure muon to tau neutrino oscillations. Rather than applying cuts, which would discard low-purity data, these metrics will only bin the data, thus isolating high-quality events while preserving the statistical power of the full dataset. With this approach, we expect to increase sensitivity to the signatures of ν_τ appearance from ν_μ oscillation, as this binning strategy would provide enhanced discrimination against the background from other cascade events.

T 82.5 Thu 17:15 KS H C

Studying the Diffuse Supernova Neutrino Background with JUNO — •Tim Charissé[1,2], George Parker[2], David Maksimović[2], Marcel Büchner[2], Oliver Pilarczyk[2], Arshak Jafar[2], Manuel Böhles[2], Daniela Fetzer[2], Elena Winiker[2], and Michael Wurm[2] — [1]Helmholtzzentrum für Schwerionenforschung, Planckstrasse 1, D-64291 Darmstadt, Germany — [2]Johannes Gutenberg-Universität Mainz, Institute of Physics and EC PRISMA+

The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kton liquid scintillator detector situated in Southern China that started data taking in August 2025. Its large fiducial volume together with low radiopurity and high photocoverage results in excellent energy resolution. While JUNOs main physics goal is the determination of the neutrino mass ordering and precision measurement of neutrino oscillation parameters, it is also able to detect core-collapse Supernova (CCSN) neutrinos. Apart from directly observing these neutrinos in the rare event of a close-by CCSNe, JUNO also aims to measure the so-called Diffuse Supernova Neutrino Background (DSNB). This predicted isotropic flux consisting of remnant neutrinos from all CCSNe that happened in the visible universe is yet to be observed. Its measurement will offer insides into CSSNe, Astrophysics and Cosmology. Current efforts towards a detection of the DSNB with JUNO will be presented in this talk.

T 82.6 Thu 17:30 KS H C

Machine Learning for DSNB Detection in JUNO: Utilizing Spatial-Temporal PMT Hit Patterns for Background Suppression — •David Maksimovic[1], Michael Wurm[1], Daniel Tobias Schmid[1], and Dhaval J. Ajana[2] — [1]Johannes Gutenberg-University — [2]Florida State University

The detection of the Diffuse Supernova Neutrino Background (DSNB) poses a significant challenge in neutrino astronomy, primarily due to backgrounds mimicking the extremely rare antineutrino events via Inverse Beta Decay (IBD) . The Jiangmen Underground Neutrino Observatory (JUNO) uses a liquid scintillator to detect these neutrinos in the 12 to 30 MeV range. There, especially Neutral-Current (NC) interactions of atmospheric neutrinos dominate the predicted DSNB signal by 1-2 orders of magnitude. In this talk, we present a comparative study of ML discrimination algorithms, ranging from 3D Convolutional Neural Networks (3D CNNs), LSTMs and Convolutional LSTMs (ConvLSTMS) and utilizing Fourier Transformations. These techniques analyze time-sequenced data from photomultiplier tube (PMT) hit patterns to capture the spatial-temporal dynamics of particle interactions. Here we present the resulting background reduction capabilities for JUNO.

T 82.7 Thu 17:45 KS H C

Charm Contributions to Multi-Messenger Emissions in Dense AGN Environments* — •Vladimir Kiselev[1,2], Julia Becker Tjus[1,2,3], Rikard Enberg[4], and Julien Dörner[1,2] — [1]Theoretical Physics IV: Plasma Astroparticle Physics, Ruhr University Bochum — [2]RAPP Center, Bochum — [3]Department of Space, Earth and Environment, Chalmers University of Technology, Gothenburg, Sweden — [4]Department of Physics and Astronomy, Uppsala University, Sweden

Active galactic nuclei (AGN) are compelling sites for high-energy neutrino production, yet the balance between light-meson (π, K) and charm-hadron channels in dense, magnetised environments remains unresolved. We present a simulation-driven framework that couples a version of CRPropa designed for the AGN/jet environment with a Hadronic Interaction Module for pp interactions with secondary tagging. Inclusive energy-differential cross sections $d\sigma/dx_E$ are computed and tabulated using chromo with Sibyll 2.3d, enabling consistent propagation from cosmic-ray injection to neutrino yields on finely sampled energy grids. By comparing decay, synchrotron, hadronic, and adiabatic timescales, regimes are identified in which π/K channels can be suppressed while short-lived charm hadrons remain effectively prompt and can contribute significantly to the neutrino signal. The analysis points to coronae and dense jet substructures as potential "charm factories" within realistic acceleration limits. Validation of these qualitative indications using the framework through the spectral shape and flavour composition to isolate charm contributions is ongoing. *Supported by DFG (SFB 1491)

T 83: Methods in Astroparticle Physics IV

Time: Thursday 16:15–18:00 Location: KS 00.004

T 83.1 Thu 16:15 KS 00.004

The Monte Carlo simulation of JUNO's pre-detector OSIRIS — •Lukas Bieger, Dhanushka Bandara, Silvia Cengia, Jessica Eck, Adrian Keiderling, Florian Kirsch, Tobias Lachenmaier, Anurag Sharma, and Tobias Sterr — Eberhard Karls Universität Tübingen

The Jiangmen Underground Neutrino Observatory (JUNO) is a multi-purpose neutrino experiment with a 20 kt liquid scintillator detector located in southern China. Its primary objective is to determine the neutrino mass ordering by measuring the oscillated energy spectrum of electron antineutrinos from nearby nuclear power plants with unprecedented energy resolution. The scintillator filling of JUNO was completed in August 2025 and JUNO started data-taking. The Online Scintillator Internal Radioactivity Investigation System (OSIRIS) monitored the radiopurity of the liquid scintillator during the filling, ensuring that the required contamination upper limits were met. OSIRIS is an 18 t liquid scintillator detector, instrumented with 64 20-inch PMTs to detect the light produced by events in the detector's sensitive volume. A precise Monte Carlo simulation is essential for understanding the detector's performance and for optimizing analysis methods. This talk will present the comprehensive simulation framework developed for OSIRIS, with particular emphasis on the MC tuning strategy employed to improve the accuracy of the simulation, as well as on its validation using calibration data, which demonstrates good agreement between simulation and measurements.

T 83.2 Thu 16:30 KS 00.004

Validation of Simulation Data for the IceAct Telescopes — •Cem Gür, Lars Heuermann, Lars Marten, Sönke Schwirn, and Christopher Wiebusch — III. Physikalisches Institut B - RWTH Aachen University

AUTHORS: Cem Gür, Lars Heuermann, Lars Marten, Sönke Schwirn, Christopher Wiebusch

TITLE: Validation of Simulation Data for the IceAct Telescopes

ABSTRACT: IceAct is a surface array of Imaging Air-Cherenkov Telescopes stationed at the South Pole as part of the IceCube Neutrino Observatory. Each telescope features a 61 SiPM pixel based camera with a Fresnel lens imaging on to it, resulting in a field-of-view of 12 degrees. The main goals of IceAct include the calibration of the IceTop surface array and the in-ice detector, as well as improving cosmic-ray composition studies. An agreement and understanding of the measured data and simulation is vital to reconstruct relevant parameters of cosmic-ray-induced extensive air showers for IceAct. Detailed comparisons allow the investigation of possible mismatches, their causes, and impact on reconstruction performance. In this talk we present three years of measured data to validate the IceAct simulation.

T 83.3 Thu 16:45 KS 00.004

Simulations of Particle Transmission and Electric Fields for the Munich Electrostatic Storage Ring (ESR) — •Nils Doll, Chiara Brandenstein, Peter Fierlinger, Adil W. Muggo, Dario Rückwarth, Wolfgang Schott, Vitus Schuster, Hans Th. J. Steiger, Konstantin Walter, and Florian Zötl — School of Natural Sciences, Physics-Department, Technical University of Munich, 85748 Garching, Germany

Stored ions or ionic molecules in a non-relativistic electrostatic storage ring can serve as a versatile platform for various fundamental experiments. Through precise control of beam dynamics and polarization, searches for electric dipole moments (EDMs) or axion-like particles (ALPs) become feasible in a rather unique and novel setting. Recent progress on the implementation of such a device is being discussed. COMSOL Multiphysics was used for a detailed field-based analysis of beam propagation, capturing emittance growth, phase-space evolution and nonlinear effects from realistic electrode geometries. A comparative simulation study of ion beam stability in an electrostatic storage ring is presented, focusing on the influence of fringe fields, space-charge effects, and radio-frequency (RF) systems for energy and trajectory control of barium and copper ions.

T 83.4 Thu 17:00 KS 00.004

DPG Abstract: Clustering algorithm for event reconstruction in LiquidO detectors — •Susanna Wakely and Kitzia Hernandez for the NuDoubt-Collaboration — Johannes Gutenberg University, Mainz

LiquidO is an innovative technology that uses opaque liquid scintillators for particle detection. A LiquidO scintillator combines a short scattering length and a long absorption length to stochastically confine optical photons close to their creation point. The result is balls of light where energy is deposited in the detector, with different particles producing different characteristic topologies of light balls. A fine array of wavelength-shifting fibres collects and transports the scintillation light for readout by SiPMs. A LiquidO detector will have unprecedented position resolution compared to current transparent scintillators and be capable of particle identification via event topology.

This talk will outline the development of a clustering algorithm, based on the Cambridge-Aachen jet clustering algorithm, for particle identification in LiquidO detectors. This work is done in the context of the CLOUD and NuDoubt++ experiments.

The CLOUD collaboration is designing a 5-10 ton LiquidO ultra-near reactor anti-neutrino detector. The NuDoubt++ experiment will be the first double-beta-plus ($\beta\beta$++}) decay experiment. It is expected to make the first 5σ observation of the $2\nu\beta\beta$++ decay, and discover or improve the half-life limit of the $0\nu\beta\beta$++ process by 3 orders of magnitude.

T 83.5 Thu 17:15 KS 00.004

A new optical model for LEGEND-200 with the remage simulation stack — •Manuel Huber, Rosanna Deckert, Luigi Pertoldi, and Stefan Schönert — Department of Physics, TUM School of Natural Sciences, Technical University of Munich, 85748 Garching b. München, Germany

To reach ultra-low backgrounds for the detection of the neutrinoless double-beta decay of ^{76}Ge, the Large Enriched Germanium Experiment for Neutrinoless $\beta\beta$ Decay (LEGEND) operates germanium detectors in scintillating liquid argon. A quantitative model of the complex optical instrumentation of the liquid argon is crucial for developing optimal methods to discriminate signal from background. I will present the development of a Monte Carlo model for the number of detected photons in the light readout channels deployed in the currently running stage of the experimental program, LEGEND-200. It is facilitated by the new Monte Carlo simulation stack `remage`, based on Geant4 and our Python-based package ecosystem around `pyg4ometry`, that I will present. To demonstrate the applicability of the new model, comparisons of the simulated detector response with LEGEND-200 characterization data will be presented.

We acknowledge support from the DFG under Germany's Excellence Strategy – EXC 2094 (ORIGINS) and through the Sonderforschungsbereich SFB 1258. We acknowledge support by the BMFTR Verbundprojekt 05A2023 (LEGEND).

T 83.6 Thu 17:30 KS 00.004

Development of an Optimized Liquid Argon Anti-Coincidence Classifier for LEGEND-200 — •Nele Sierig, Rosanna Deckert, Niko Lay, and Stefan Schönert for the LEGEND-Collaboration — Department of Physics, TUM School of Natural Sciences, Technical University of Munich, 85748 Garching b. München, Germany

The LEGEND-200 experiment searches for neutrinoless double beta decay of ^{76}Ge using up to 200 kg of high-purity germanium detectors immersed in instrumented liquid argon (LAr). To ensure ultra-low backgrounds, the experiment is operated deep underground at the Laboratori Nazionali del Gran Sasso. The LAr not only provides shielding and cooling, but also enhances active background suppression through an optical instrumentation system that detects scintillation light emitted upon interactions by ionizing radiation.

In this talk, I will present a novel LAr classifier, developed to tag and reject backgrounds efficiently. Our methodology integrates spatial and temporal information from the LAr scintillation light and utilizes detector-type-specific models. This development is essential for meeting the ambitious background goals and maximizing the overall sensitivity of LEGEND-200.

We acknowledge support from the DFG under Germany's Excellence Strategy – EXC 2094 (ORIGINS) and through the Sonderforschungsbereich SFB 1258. We acknowledge support by the BMFTR Verbundprojekt 05A2023 (LEGEND).

T 83.7 Thu 17:45 KS 00.004

Quantitative Study of Cherenkov-Scintillation Separation for Background Suppression in Large Scale Neutrino Detectors — •Meishu Lu[1], Manuel Böhles[2], Lothar Oberauer[1], Michael Wurm[2], and Stefan Schönert[1] — [1]School of Natural Sciences, Technical University of Munich, 85748 Garching, Germany — [2]Institute for Physics, Johannes Gutenberg University Mainz, 55128 Mainz, Germany

The first physics results from the Jiangmen Underground Neutrino Observatory (JUNO) demonstrate the potential of next-generation large liquid-scintillator detectors. Beyond precision oscillation measurements, improved event reconstruction and background suppression are required for rare-event searches such as the diffuse supernova neutrino background (DSNB) and neutrinoless double-beta decay ($0\nu\beta\beta$). Separation of Cherenkov and scintillation light provides additional timing and topological information and has been firstly demonstrated by the Borexino collaboration. Building on previous tabletop studies at TUM, we present a new investigation of key factors affecting the separation ability, including emission spectra and photon-sensor quantum efficiency. These results indicate the potential of hybrid detection for future large-scale detectors and upgrades. We acknowledge support from the Deutsche Forschungsgemeinschaft under Germany's Excellence Strategy EXC 2094 - 390783311 and EXC 2118 - 390831469 and through the Sonderforschungsbereich SFB 1258 "Neutrinos and Dark Matter in Astro- and Particle Physics", as well as the DFG Forschungsgruppen FOR 2319 - 268668443 and FOR 5519 - 498394246.

T 84: Gamma Astronomy II

Time: Thursday 16:15–17:45 Location: KS 00.005

T 84.1 Thu 16:15 KS 00.005

Enhancing SWGO Sensitivity to Galactic Center PeVatrons with GNNs — •Martin Schneider for the SWGO-Collaboration — ECAP, FAU Erlangen-Nürnberg

The Southern Wide-field Gamma-ray Observatory (SWGO) will provide continuous, wide-field monitoring of the Southern Hemisphere gamma-ray sky, offering unprecedented access to high-energy phenomena in the region around the Galactic Center. A central challenge for SWGO is achieving robust gamma/hadron separation to suppress the overwhelming cosmic-ray background, which is crucial for studies of diffuse emission and potential Galactic PeVatron activity. In this contribution, we present a new study demonstrating the advantages of Graph Neural Networks (GNNs) over traditional machine-learning classifiers. Using two years of simulated SWGO observations, we evaluate how improved background rejection from GNN-based models enhances the sensitivity to a spectral cutoff in the diffuse emission near the Galactic Center. Such sensitivity is essential for testing the PeVatron hypothesis and to disentagle the sources and processes shaping this region.

T 84.2 Thu 16:30 KS 00.005

Progress on the Medium-Sized Telescope Structure for the Cherenkov Telescope Array Observatory — •Bastian Hess for the MST Project-Collaboration — Institut für Astronomie und Astrophysik, Tübingen, Germany

The Cherenkov Telescope Array Observatory (CTAO) will consist of three different sizes of telescope categories: the small-sized telescopes (SSTs), medium-sized telescopes (MSTs), and large-sized telescopes (LSTs). Two MST pathfinder telescopes are currently in production and undergoing pre-assembly. They will be deployed at the CTAO southern site in Paranal, Chile. The MST reflector comprises 86 hexagonal mirror segments, each 1.2 m measured across flats. These mirrors are mounted to the optical support structure using high-precision motorized actuators that enable fine alignment to achieve and maintain optimal telescope optics. This contribution presents an overview of the manufacturing and testing progress of the MST structures, with particular emphasis on the performance and quality assurance of the active mirror control system and its components.

T 84.3 Thu 16:45 KS 00.005

Analysis of the PWNe in the Kookaburra Region with Fermi-LAT and H.E.S.S. — •Lukas Grosspietsch, Giovanni Cozzolongo, and Alison Mitchell for the H.E.S.S.-Collaboration — Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen 91052, Germany

The wings of the Kookaburra region host the two extended very-high-energy gamma-ray sources HESS J1420-607 and HESS J1418-609, forming a rare complex environment of two adjacent pulsar wind nebulae (PWNe) shaped by energetic pulsars and asymmetric ambient conditions. This makes the region a valuable target for studying particle acceleration, transport, and energy losses in evolved PWNe. In this work, we present an analysis of the region using a combination of recent and archival observations from the H.E.S.S. array together with Fermi-LAT data. Advanced background estimation and analysis techniques complement the upgraded H.E.S.S. system to enable a refined investigation of morphology and emission processes in the very-high-energy gamma-ray range. These findings aim to deepen our understanding of the interplay of pulsar-driven outflows and their surrounding medium in the Kookaburra complex.

T 84.4 Thu 17:00 KS 00.005

Analysis of the of the 2016 Flaring Period of 1ES1959+650 with the MAGIC Telescopes using the Database Driven Software autoMAGIC — •Justus Koczwara and Felix Wersig — TU Dortmund University, Dortmund, Germany

When entering the atmosphere, the high-energy gamma-rays interact with atoms and produce showers of high-energy charged particles that move faster than the speed of light in the air, emitting Cherenkov radiation. This effect enables us to observe the remnants of these interactions and reconstruct the energy and origin of a gamma ray from the optical image taken by a ground-based telescope. The MAGIC telescopes are a system of so-called Imaging Air Cherenkov Telescopes that have used this detection method since 2003, accumulating a large dataset over the years. As the standard way of analysing MAGIC telescope data includes various manual interventions, increasing the rate of potential error sources, and is very time-consuming, the database-driven software tool autoMAGIC was developed to automate the low-level analysis up to the community-standard data level 3. In the scope of this work, the strong flaring periods of the BL Lac blazar 1ES 1959+650 in 2016 were re-analyzed as a cross-check for a manual low-level analysis, performing the low-level analysis with autoMAGIC and a high-level analysis with Gammapy. The results from this analysis are then compared with the results of the manual analysis published in a paper by the MAGIC Collaboration to understand whether flare characteristics found in the manual analysis can be reproduced in the autoMAGIC analysis.

T 84.5 Thu 17:15 KS 00.005

Directional Search for Ultra-High-Energy Photons Using the SD-1500 Array of the Pierre Auger Observatory — •Tim Fehler, Marcus Niechciol, and Markus Risse for the Pierre Auger-Collaboration — Experimentelle Astroteilchenphysik, Center for Particle Physics Siegen, Universität Siegen

In addition to its capabilities for precise measurement of ultra-high-energy (UHE, $E > 10^{17}$ eV) cosmic rays through the observation of extensive air showers, the Pierre Auger Observatory offers the potential to effectively detect UHE photons. Their connection to UHE cosmic rays is manifold; constraints on their flux provide valuable hints on the elusive nature of the UHE cosmic rays. Contrary to charged cosmic rays, which are deflected by magnetic fields, UHE photons have the inherent advantage that their origin can be traced back directly, which promotes the search for directional excesses of photon-like events in the sky. This contribution details the full modular analysis pipeline for a new direction-dependent search for UHE photons, based on a novel photon-tagging approach using the paradigm of air-shower universality. With sole dependence on the SD-1500 array, given its 100% duty cycle, the full 19 years of Phase-I data will be available for analysis, providing unprecedented exposure to a potential UHE photon flux. Beyond the methodology, the contribution also covers the first preliminary application to data for final cross-checks.

Supported by the BMFTR Verbundforschung Astroteilchenphysik under project No. 05A23PS1.

T 84.6 Thu 17:30 KS 00.005

Optical Light Curves of Classical Novae from H.E.S.S. Night-Sky Background Data — •Sayak Ghosh, Alison Mitchell, and Gerrit Roellinghoff for the H.E.S.S.-Collaboration — Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen Centre for Astroparticle Physics, Nikolaus-Fiebiger-Str. 2, 91058 Erlangen, Germany

Imaging Atmospheric Cherenkov Telescopes (IACTs) are designed for very-high-energy gamma-ray astronomy, but their large mirror areas and fast cameras also record variations in the optical night-sky background (NSB). In this work, we explore the use of NSB data from the H.E.S.S. telescope array to extract relative optical light curves of classical novae.

We develop an analysis framework based on pixel-level NSB rates from the H.E.S.S. CT1-CT4 cameras. The approach accounts for instrumental and atmospheric effects and isolates time-dependent variations in the NSB signal. Corrected NSB values are combined over selected pixel regions and time intervals to construct relative optical light curves on intra-night and multi-night timescales.

We apply this to H.E.S.S. observations of classical novae, and we discuss variations and limitations of the method. This study shows that NSB data from H.E.S.S. can be used to investigate relative optical variability in bright transient sources, while clearly outlining the constraints of this approach.

T 85: Cosmic Rays IV

Time: Thursday 16:15–17:45 Location: KS 00.006

T 85.1 Thu 16:15 KS 00.006

Simulating Cosmic-Ray Hadronic Interactions: Analytic vs. Monte Carlo — •Leonel Morejon — Bergische Universitaet Wuppertal, Wuppertal, Germany

Cosmic-ray hadronic interactions are important in explaining the production of very-high-energy photons and high-energy neutrinos arriving at Earth. For example, galactic neutrino emissions recently reported by IceCube, are expected to result from cosmic-ray interactions in the central region of the galaxy. Hadronic interactions can be modeled with Monte Carlo codes, but the computational effort to explore a variety of model parameters may produce limitations. Conversely, continuous production models exist and are faster to evaluate, but neglect the inherent stochasticity of these interactions.

An alternative approach is presented in this work, describing sequences of hadronic interactions analytically, using the precomputed tables for the products of individual interactions. This has the advantage of including stochastic effects in the sequence (unlike in continuous models) and reinteractions, while keeping the computation analytic, scalable and efficient. The correctness of this approach is verified by comparing to Monte Carlo simulations.

T 85.2 Thu 16:30 KS 00.006

Pythia 8/Angantyr and CORSIKA 8: Muon Puzzle and tuning* — •Chloé Gaudu for the CORSIKA8-Collaboration — Bergische Universität Wuppertal, Gaußstraße 20, 42119 Wuppertal

The field of air-shower physics seeks to understand the development of cosmic-ray interactions with the Earth's atmosphere. A key challenge in this field is the discrepancy in the muon content of extensive air showers (EAS), widely referred to as the "Muon Puzzle", observed by cosmic-ray experiments when comparing to predictions from commonly used hadronic interaction models. This puzzle might stem from limitations in modeling high-energy hadronic interactions, arising as model parameters are tuned to accelerator data probing lower energies than those relevant to EAS, thus requiring extrapolations into unmeasured phase space. With Pythia 8/Angantyr now fully integrated into the Corsika 8 particle-shower simulation code, analyses of EAS are feasible. Initial studies indicate that its default configuration fails to reproduce key measurements from the Pierre Auger Observatory. The Pythia 8/Angantyr model remains a promising candidate for shedding light on the Muon Puzzle, owing to its user-friendly tunability.

In this work, the first dedicated efforts to tune Pythia 8/Angantyr for air-shower physics using fixed-target measurements are presented. The tuned Pythia configuration is compared to its default configuration, to other hadronic interaction models used in cosmic-ray physics, and to existing experimental data, highlighting the impact of tuning on muon production and other relevant shower properties. **Supported by DFG (SFB 1491)*

T 85.3 Thu 16:45 KS 00.006

Constraints on the Atmospheric Muon Flux from Stopping and High-Energy Muons in IceCube — •Pascal Gutjahr[1,2], Lucas Witthaus[1,2], and Lene Van Rootselaar[1,2] — [1]TU Dortmund University, Dortmund, Germany — [2]Lamarr Institute, Dortmund, Germany

Atmospheric muons detected by the IceCube Neutrino Observatory provide a sensitive probe of cosmic-ray interactions in the atmosphere. These muons originate from conventional pion and kaon decays as well as from prompt decays of short-lived heavy hadrons, with the latter expected to become significant at the highest energies. This contribution presents an unfolding of the atmospheric muon energy spectrum in IceCube, combining low-energy stopping muons with high-energy through-going muons to cover a broad energy range from several hundred GeV to the PeV scale. Stopping muons, which lose all their energy in the ice, constrain the surface muon spectrum at TeV energies, while high-energy muons provide sensitivity to the prompt component. Event classification and energy reconstruction are performed using deep learning techniques to improve resolution and background rejection. The unfolded spectra are used to study the relative contributions of conventional and prompt muons and are compared to predictions.

T 85.4 Thu 17:00 KS 00.006

Testing newly released hadronic interaction models with KASCADE-Grande — •Donghwa Kang and Andreas Haungs for the KASCADE-Grande-Collaboration — Karlsruhe Institute of Technology (KIT)

KASCADE-Grande was designed to study the energy spectrum and mass composition of cosmic rays in the energy range from 10 PeV up to 1 EeV. The measurements revealed a knee-like structure in the heavy components at energies around 100 PeV, consistent with expectations from rigidity-dependent scenarios. In addition, a spectral hardening was observed in the light component near 120 PeV. With the recent release of updated post-LHC hadronic interaction models - QGSJet-III-01, EPOS.LHC-R, and Sibyll 2.3d - we test their validity using KASCADE-Grande data. In this contribution, we present the reconstructed all-particle energy spectra as well as the energy spectra of individual mass groups derived from shower size observables, using the newly released hadronic interaction models.

T 85.5 Thu 17:15 KS 00.006

CORSIKA 8: A modern and universal framework for particle cascade simulations — •Marvin Gottowik for the CORSIKA8-Collaboration — Karlsruher Institut für Technologie, Institut für Astroteilchenphysik, Karlsruhe, Germany

CORSIKA 8 represents a major advancement in the simulation of particle cascades in arbitrary media, building on the long-standing foundation of CORSIKA 7. It has been completely redesigned as a modular, modern C++ framework, overcoming key limitations of its predecessor and providing a flexible platform for both established and emerging use cases. In addition to traditional air-shower simulations, CORSIKA 8 supports applications such as cross-media particle cascades and improved modeling of radio emission, especially propagation through complex media. The framework includes state-of-the-art descriptions of electromagnetic cascades via PROPOSAL and supports hadronic interactions with current and next-generation models, such as EPOS LHC-R, QGSJet-III, and Pythia 8. In this presentation, we will outline the design principles, current capabilities, and ongoing validation efforts of CORSIKA 8, and discuss its role as a versatile simulation tool for future astroparticle and particle-physics experiments.

T 85.6 Thu 17:30 KS 00.006

Classifying photon- and proton-induced air-showers with a transformer-based approach at the Pierre Auger Observatory — •Alexander Doeker, Marcus Niechciol, and Markus Risse for the Pierre Auger-Collaboration — Experimentelle Astroteilchenphysik, Center for Particle Physics Siegen, Universität Siegen

The Pierre Auger Observatory is the world's largest detector for ultra-high-energy (UHE) cosmic rays, capable of observing particles with energies exceeding 10^{20} eV. Only the most extreme cosmic events can accelerate particles to such energies. Detecting an accompanying flux of UHE photons would deepen our understanding of these extreme cosmic events, probe the GZK suppression mechanism, and potentially reveal signatures of exotic scenarios like super-heavy dark matter.

In this work, a transformer-based approach to classify simulated air showers induced by photons and protons will be presented. Transformer networks, with their ability to capture complex patterns in sequential data, offer a promising tool for distinguishing between these signals. The current transformer network uses the photomultiplier tube signals from the water Cherenkov detector stations of the surface detector array as its primary input.

This approach demonstrates the potential of transformer networks to enhance the identification of UHE photon events, possibly advancing our understanding of the most energetic phenomena in the universe.

Supported by the BMFTR Verbundforschung Astroteilchenphysik under project No. 05A23PS1.

T 86: Members' Assembly

Time: Thursday 18:30–19:30 Location: AM 00.014

All members of the Particle Physics Division are invited to participate. Pretzels and drinks will be provided.

T 87: Neutrino Physics V

Time: Friday 9:00–10:30 Location: AudiMax

T 87.1 Fri 9:00 AudiMax

Position and Energy Reconstruction in OSIRIS — Thilo Birkenfeld, •Elisabeth Neuerburg, Achim Stahl, and Christopher Wiebusch — RWTH Achen

During the filling of the Jiangmen Underground Neutrino Observatory (JUNO) in 2025, the Online Scintillator Internal Radioactivity Investigation System (OSIRIS) monitored the radiopurity of the liquid scintillator (LS). OSIRIS has 64 20"-PMTs surrounding a cylindrical acrylic vessel holding 20-ton batches of LS. Uranium and Thorium impurities are estimated by counting the Bismuth-Polonium coincidence occurring in both decay chains, identified using time, distance, and energy cuts. The position of an event is reconstructed using a maximum-likelihood estimation, with Lookup Tables to calculate the expected amount of light. The energy is reconstructed from the event's position and the amount of light detected. The resolutions are estimated from simulation data and cross-checked against calibration data obtained by lowering a multi-gamma source into the vessel. In this talk, the position and energy reconstruction methods in OSIRIS and their respective performances are presented.

T 87.2 Fri 9:15 AudiMax

Gravitationally induced Decoherence in Neutrino Oscillations: Bridging between Phenomenological and Microscopic Models — Alba Domi[1], João Coelho[3], Kristina Giesel[1], Max Joseph Fahn[2], Renata Ferrero[1], and •Roman Kemper[1] — [1]Friedrich-Alexander Universität Erlangen-Nürnberg, Germany — [2]Università di Bologna, Italy — [3]APC, Paris

In this talk, the role of gravitationally induced decoherence in open quantum systems is discussed in the context of neutrino oscillations. Often in phenomenological models, the decoherence parameters appear as free parameters encoded in a vectorised dissipator. The properties of a class of such dissipators are examined. Possible links to underlying gravitational microscopic models are discussed, which can provide a physical interpretation of the involved decoherence parameters. In addition, it is considered how different physical assumptions entering the decoherence model are reflected in the resulting neutrino oscillation probabilities.

T 87.3 Fri 9:30 AudiMax

Quantum Decoherence with KM3NeT/ORCA — •Mays Massarwa for the KM3NET-ERLANGEN-Collaboration — Friedrich-Alexander-Universität Erlangen-Nürnberg, ECAP, Erlangen, Germany

KM3NeT is a research infrastructure currently under construction in the Mediterranean Sea, that consists of two water Cherenkov detectors: ARCA, whose main purpose is to search for cosmic neutrinos in the TeV-PeV range and ORCA that uses atmospheric neutrinos for measurements of neutrino oscillations. ORCA is sensitive to effects beyond the standard model (BSM), such as quantum decoherence.

Treating neutrinos as an open quantum system interacting with an external environment leads to non-unitary time evolution, which can be described by a Lindblad master equation. This results in deviations from the standard neutrino oscillation probabilities and provides a phenomenological description of neutrino decoherence.

Several models propose that quantum gravity could leave a potentially observable imprint in the evolution of the neutrino as an open quantum system. This motivates the study of neutrino decoherence with the ORCA detector by investigating deviations from the expected standard 3-flavour neutrino oscillations. This contribution will report the projected sensitivity of an intermediate detector configuration of ORCA to this effect.

T 87.4 Fri 9:45 AudiMax

Electron-nucleus scattering at MAMI as a benchmark for precision neutrino interaction models. — •Khwaja Idrees Hassan and Luca Doria — Institut für Kernphysik, JGU Mainz

Achieving the precision required for next-generation neutrino experiments depends critically on a detailed understanding of the fundamental processes governing neutrino-nucleus interactions in detectors. At present, uncertainties associated with these interactions remain at the O(10%) level, whereas upcoming experiments demand O(1%) precision.

Electron-nucleus scattering provides a high-precision benchmark for event generator codes used in neutrino experiments, helping reduce systematic uncertainties and ensure the consistency of nuclear models.

The A1 Collaboration at MAMI has initiated an experimental program to precisely measure nuclear cross sections relevant to neutrino physics, with particular emphasis on the needs of future long-baseline experiments such as DUNE and Hyper-Kamiokande. In this contribution, we present current results on ^{12}C and ^{40}Ar cross-section measurements and provide an outlook on future experiments for ^{16}O.

T 87.5 Fri 10:00 AudiMax

Extended range measurement of the KATRIN energy loss function up to 200 eV — •Volker Hannen for the KATRIN-Collaboration — Universität Münster, Institut für Kernphysik, Wilhelm-Klemm-Str. 9, 48149 Münster

The Karlsruhe Tritium Neutrino Experiment (KATRIN) aims to determine the effective electron neutrino-mass via a precision measurement of the endpoint region of the tritium beta-decay spectrum. One of the dominant systematic uncertainties of the measurement are energy losses of the decay electrons due to inelastic scattering off tritium molecules while traversing the gaseous tritium source of the experiment. Measurements of the energy loss function in a range up to 60 eV, which is relevant for the neutrino mass analysis, have already been performed using an angular selective, mono-energetic photo-electron source. The energy loss function is also required for the determination of the column density of the tritium source where regular measurements are taken at selected surplus energies up to 200 eV. To avoid uncertainties related to the extrapolation of the current energy loss function to this value, we have performed extended range measurements of the inelastic electron scattering up to 200 eV. The talk will present results of the analysis of the new energy loss data in this extended range. This work is supported by BMFTR under contract number 05A23PMA.

T 87.6 Fri 10:15 AudiMax

The Plasma Systematic in the KATRIN Experiment — •Karo Erhardt for the KATRIN-Collaboration — Karlsruher Institut of Technologie

The KATRIN experiment aims at a direct kinematic measurement of the absolute neutrino mass with an expected sensitivity below 300 meV (90% CL), achieved through high-resolution, high-statistics spectroscopy of tritium beta decay. To reach this sensitivity, systematic effects that modify the measured electron spectrum must be modeled and controlled via dedicated calibration measurements. One key systematic effect is related to the starting potential of electrons in the gaseous molecular tritium source, which behaves as a cold plasma in a tesla-scale magnetic field. In this talk, after introducing the starting-potential-related effects, we present the analysis of calibration measurements using gaseous krypton-83m. The impact on the neutrino mass analysis is evaluated, and steps toward a robust source-potential description are discussed. This work is supported by the Helmholtz Association and by the Ministry for Research, Technology and Space BMFTR (grant numbers 05A23PMA, 05A23PX2, 05A23VK2 and 05A23WO6)

T 88: Top Physics IV

Time: Friday 9:00–10:30 Location: KH 00.011

T 88.1 Fri 9:00 KH 00.011

Measurement of $t\bar{t}$ spin correlations using Run 2 and 3 data with the ATLAS detector — Diptaparna Biswas, Carolina Costa, Markus Cristinziani, Carmen Diez Pardos, Ivor Fleck, Gabriel Gomes, Jan Joachim Hahn, •Nikolaos Kamaras, Vadim Kostyukhin, Nils Benedikt Krengel, Austin Olson, Inês Pinto, Sebastian Rentschler, Elisabeth Schopf, Katharina Voss, Wolfgang Walkowiak, and Adam Warnerbring — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

The top quark is the heaviest known elementary particle and decays before hadronization. Consequently, measurements of the angular distributions of top quark decay products provide direct access to the top quark's spin, enabling a precise test of perturbative Quantum Chromodynamics in top-antitop quark pair ($t\bar{t}$) production. This contribution presents studies towards the measurement of $t\bar{t}$ spin correlations using the Run 2 and Run 3 datasets collected with the ATLAS detector from proton-proton collisions at a centre-of-mass energy of 13 TeV and 13.6 TeV, respectively. The analysis focuses on the dilepton decay channel, requiring two leptons of opposite charge (electrons or muons) and at least two jets, with at least two identified as originating from a b-quark. To reconstruct the top quark kinematics and subsequently the angular distributions of the decay products, several top reconstruction methods are employed. The $t\bar{t}$ spin correlation coefficients will be extracted from these angular distributions using a standard profile likelihood fit for unfolding to both parton and particle level.

T 88.2 Fri 9:15 KH 00.011

Quantum entanglement in top-quark pairs using events with large transverse momentum with the ATLAS detector — •Chiara Deponte and Andrea Knue — Technische Universität Dortmund, Deutschland

Quantum entanglement of top-quark pairs is studied by measuring the full spin density matrix using data recorded with the ATLAS experiment in Run 2. Since top quarks have a very short lifetime, their spin information is transferred to its decay products. The angular distributions of these particles in a helicity-based coordinate system in the $t\bar{t}$ rest frame are then used to measure the entries of the spin density matrix. After the reconstruction of the full $t\bar{t}$ event, Profile Likelihood Unfolding is performed to remove detector and reconstruction effects. Entanglement is predicted at the $t\bar{t}$ production threshold and for high $M_{t\bar{t}}$. The presented analysis is performed in a phase-space region with high top-quark velocities and production angles. In this region the expected number of events is low so the analysis is statistically limited. Therefore, the single-lepton channel is used to find a balance between statistical and systematic uncertainties. This talk focuses on studies regarding the size of the jet-related systematic uncertainties.

T 88.3 Fri 9:30 KH 00.011

Quantum Spin Correlations at Colliders — •Monika Alexandra Wüst and Thorsten Ohl — University of Würzburg, Institute of Theoretical Physics and Astrophysics, Würzburg

The study of beyond-classical correlations in final states at colliders has received a lot of attention recently. For example, entanglement of particle pairs has been observed at the LHC. Most importantly, measurements of such correlations provide new tests of the Standard Model. More complicated final states are being studied and future colliders with polarized initial states will boost the interest even further. Experimentally, the challenge is to reconstruct the spin-density matrix of a final state from phase space distributions. As a practical matter, the computation of spin-density matrices is beyond the reach of analytical calculations for multi-particle final states. While the event generator Whizard has computed the spin density matrix from the beginning, most of it is projected out in the common event formats. We present first results from an automated framework for the computation of general density matrices and quantum observables using event samples generated by Whizard. We discuss applications for spin-1/2 (qubit) and spin-1 (qutrit) particles in bipartite and tripartite quantum states at colliders. Analytic calculations are used to test components of Whizard matrix elements that have not been tested by comparing cross sections and classical correlations.

T 88.4 Fri 9:45 KH 00.011

Is Assignment All You Need? — •Siemen Aulich, Katharina Behr, and Eleanor Jones — DESY, Hamburg, Germany

Many of the recent highlights of particle physics research are related to top quark physics'. These include both the tests of spin correlations and quantum effects in pairs of top quarks ($t\bar{t}$), and the observation of a possible quasi-bound state resonance in the $t\bar{t}$ invariant mass spectrum. Both effects are predominantly studied in dilepton decays in a mass range close to the production threshold.

Probing this system requires a precise reconstruction of the top quarks, which is complicated by the presence of the two neutrinos. While analytical regression strategies primarily focus on inferring the neutrino momenta, the problem of correctly assigning b-jets to their parent top quarks remains largely unstudied. However, many of the sensitive variables used in $t\bar{t}$ precision measurements depend critically on the correct assignment of the jets. Inspired by the success of machine learning architectures in tackling the assignment challenge for hadronic decay channels, this work investigates using a transformer model for the dilepton channel. An architecture specifically tailored to this channels topology is shown to outperform all existing methods. Furthermore, it is investigated how these efforts can be combined with neutrino regression methods to offer a full reconstruction pipeline. Applying these methods to existing and upcoming analyses promises further enhancements in the sensitivity and precision of searches and measurements alike.

T 88.5 Fri 10:00 KH 00.011

ML-Based Kinematic Top Quark Reconstruction in Dileptonic Decays — •Mads Hansen Baattrup[1], Alexander Grohsjean[2], Peer Stelldinger[3], and Christian Schwanenberger[1,2] — [1]Deutsches Elektronen-Synchrotron, Notkestr. 85, 22607 Hamburg, Germany — [2]Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Hochschule für Angewandte Wissenschaften Hamburg, Berliner Tor 5, 20099 Hamburg, Germany

Reconstruction of the full kinematic properties of dileptonic $t\bar{t}$ events is important for precision tests of the standard model and also plays a role for many searches beyond the standard model (BSM). It is intrinsically challenging because of the presence of two undetected neutrinos, leaving the system underconstrained. Conventional analytical methods rely on assumptions and fixed mass constraints to close the system of equations. These methods introduce significant biases in important observables - particularly in the $m_{t\bar{t}}$ threshold region, which is highly relevant for both precision measurements and BSM-sensitive analyses.

In this work, we investigate supervised machine-learning-based reconstruction methods using transformer architectures and conditional generative models. We aim to learn the conditional phase-space distribution of parton-level quantities given event observables. This will reduce reconstruction biases while improving resolution relative to traditional analytical methods.

T 88.6 Fri 10:15 KH 00.011

Enhancing Top-Quark Reconstruction Across Topologies in ATLAS — •Constantin Eckardt — DESY, Zeuthen, Germany

Searches for beyond-the-standard-model physics at particle detectors such as ATLAS often involve top-quark associated events. Top-quark reconstruction in most searches is typically optimized for a specific decay topology. By incorporating multiple reconstruction algorithms, each tailored to different top-decay configurations, one can further expand the reconstruction reach and improve overall efficiency. This work presents studies of a range of top-quark reconstruction algorithms developed for different decay topologies and applied to a variety of physics cases. These studies are used to guide the further optimization of a recently launched umbrella tool within ATLAS – THAT (Top Hacker Across Topologies) – which recommends the most effective reconstruction algorithm on a per-event basis. Such a tool has the potential to enhance many different analyses that rely on accurate and efficient top-quark reconstruction.

T 89: Higgs Physics IX

Time: Friday 9:00–10:30 Location: KH 00.014

T 89.1 Fri 9:00 KH 00.014

Test of CP invariance in Higgs boson production via vector boson fusion at the HL-LHC exploiting the $H \to \tau\tau$ decay mode — •Daniel Bahner, Lorenzo Rossini, and Markus Schumacher — Albert-Ludwigs-Universität, Freiburg, Deutschland

The observed baryon asymmetry of the Universe can be accounted for only if the three Sakharov conditions are satisfied, one of which is the violation of CP invariance. However, the amount of CP violation predicted by the Standard Model is insufficient to generate the observed asymmetry through electroweak baryogenesis. Precision measurements of the Higgs boson therefore offer a promising avenue to search for additional sources of CP violation. In particular, the vector-boson fusion (VBF) production mode provides sensitivity to potential CP-violating contributions in the HVV coupling.

This talk focuses on VBF Higgs boson production followed by its decay into a pair of tau leptons. ATLAS published an analysis in 2025 that set the most stringent limits to date on the CP-violating coupling parameters in the HVV vertex using data collected from 2015 to 2018 corresponding to an integrated luminosity of $\mathcal{L}_{\text{int}} = 140$ fb^{-1}. Building on that work, the extrapolation of the analysis to the High-Luminosity LHC dataset, corresponding to $\mathcal{L}_{\text{int}} = 3000$ fb^{-1} at $\sqrt{s} = 14$ TeV, will be discussed. The study performs a profile-likelihood fit to the CP-odd optimal observable to test CP invariance and to constrain the magnitude of possible new CP-violating interactions. Results from the published analysis, the extrapolation methodology, and the expected sensitivity to the coupling parameter at the HL-LHC will be presented.

T 89.2 Fri 9:15 KH 00.014

Measurements of $H \to \tau\tau$ CP properties at FCC-ee — •Sofia Giappichini[1], Markus Klute[1], Matteo Presilla[1], and Xunwu Zuo[2] — [1]Institute for Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]Ecole Polytechnique Federale de Lausanne (EPFL), Lausanne, Switzerland

The Future Circular Collider (FCC-ee), a key pillar of the European Strategy for Particle Physics, offers unprecedented precision for studying the Higgs boson. The decay $H \to \tau\tau$ stands out due to its sizable branching ratio, clean experimental environment, and sensitivity to tau polarization, making it an ideal channel to probe the CP properties of the Yukawa couplings and search for signs of CP violation beyond the Standard Model. We highlight the prospects for measuring CP-odd components in the $H \to \tau\tau$ decays through angular and polarization observables in associated ZH production at a center-of-mass energy of 240 GeV within the Anomalous Coupling and the Effective Field Theory frameworks.

T 89.3 Fri 9:30 KH 00.014

Probing CP invariance in the decay $H \to \tau\tau$ at a future e^+e^- Linear Collider — •Lea Kuttler, Michael Böhler, and Markus Schumacher — Institute of Physics, Albert-Ludwigs-University Freiburg, Freiburg, Germany

Sources of CP violation (CPV) beyond the Standard Model (SM) are required to explain the baryon asymmetry observed in our universe (BAU). The Yukawa coupling of the Higgs boson to the tau lepton may deliver a sufficient source of CPV, which allows explaining the observed size of the BAU.

This analysis investigates the CP-nature of the $H\tau\tau$ Yukawa coupling, considering $ee \to ZH$ events at an e^+e^- linear collider, operating at $\sqrt{s} = 250$ GeV, assuming an integrated luminosity of 2 ab^{-1} and e^-/e^+ beam polarizations of 80%/30%. Events are simulated for the International Large Detector concept.

In $H \to \tau\tau$ decays, the strength of CP violation can be parametrized by a single mixing angle ψ_τ. Two observables sensitive to ψ_τ are the azimuthal angle difference $\Delta\phi$ between the tau lepton polarimeter vectors and the matrix-element-based optimal observable $\mathcal{OO}$.

This contribution demonstrates the use of these observables to constrain ψ_τ at a future e^+e^- linear collider using the decay modes $\tau \to \rho\nu$ and $\pi\nu$ and compares their sensitivity. In this context, methods for fully reconstructing the tau leptons and for identifying hadronic tau decays are presented.

T 89.4 Fri 9:45 KH 00.014

Future collider perspective on Higgs CP violation — •Yuyang Zhang[1,3], Aidan Robson[1], Christoph Englert[2], Andrew Pilkington[2], Jay Nesbitt[1], Jenny List[3], and Junping Tian[4] — [1]U of Glasgow, Glasgow, UK — [2]U of Manchester, Manchester, UK — [3]DESY, Hamburg, Germany — [4]U of Tokyo, Tokyo, Japan

Future Higgs factories based on electron-positron colliders are expected to provide unprecedented precision in the measurement of Higgs boson properties, offering a new window for the discovery of physics beyond the Standard Model. In particular, the observation of CP-violation in Higgs interactions would serve as an important indication for electroweak baryogenesis.

In this work, we study the sensitivity to CP-violating Higgs couplings at future Higgs factories within the framework of the SM Effective Field Theory. We focus on Higgs production via the Higgsstrahlung process at $\sqrt{s}$=250 GeV and top-quark-associated Higgs production at $\sqrt{s}$=550 GeV at a linear collider facility with polarised beams.

The introduction of machine-learning techniques benefits the analysis in two ways. By constructing observables to discriminate between the CP-even and CP-odd contributions we demonstrate that the interference introduced by dimension-six operators can lead to sensitivity to CP-violating Higgs interactions. We also enhance sensitivity through improved reconstruction techniques. The use of polarised beams further increases the CP-sensitive interference contributions. Overall, the sensitivity obtained at a linear collider becomes comparable to that expected at circular colliders with higher luminosity.

T 89.5 Fri 10:00 KH 00.014

Impact of polarized beams for Electroweak and Higgs Physics
— •Gudrid Moortgat-Pick[1,2], Cheng Li[4], Jayita Lahiri[5], and Juhi Dutta[3] — [1]University of Hamburg — [2]Deutsches Elektronen Synchrotron — [3]IMSc Chennai — [4]SYSU, Guangzhou — [5]Krakow University

Polarized beams are substantial to achieve the precision requirements in the electroweak and Higgs sector. Mmost of the future high-energy lepton collider designs offer the availability of beam polarization. In this talk we summarize the polarization-related results for different Beyond the Standard Models Extensions (MSSM, 2HDMS, inflation models) and discuss CP-violating effects, flavour aspects, high precision electroweak observables and Higgs couplings.

T 89.6 Fri 10:15 KH 00.014

Study of CP-violation in extended Higgs sectors at a Gamma-Gamma collider
— •Muriel Blenck[1], Gudrid Moortgat-Pick[1,2], Marten Berger[1], and Ayoade Sotona[1] — [1]II. Institut für Theoretische Physik, Universität Hamburg, Luruper Chaussee 149, Hamburg — [2]Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, Hamburg

A $\gamma\gamma$ collider offers a rich Higgs physics program at relatively low center of mass energies. The polarisation of the photon beams, which are obtained via Compton backscattering, are controlled by the incident laser and can reach high levels. This allows the study of CP-violating effects in extended Higgs sectors by constructing CP-odd observables that have higher sensitivity to CP-violating effects when transverse or longitudinal polarisation is used. The SM predicts the Higgs boson to be scalar-even particle, but BSM models like the 2HDM and 2HDMS allow an admixture of CP-even and CP-odd states, which could introduce additional CP-violating effects that would help explain the large baryon-antibaryon asyymetry in the universe. In this talk we present the possibility to use a $\gamma\gamma$ collider to measure these effects and determine the CP-mixing angle in the extended Higgs sectors.

T 90: Calorimeters II

Time: Friday 9:00–10:15 Location: KH 00.015

T 90.1 Fri 9:00 KH 00.015

Integrated Cooling Solutions for a Highly Granular Scintillator-Based Hadronic Calorimeter
— •Andre Klotzbücher[1], Lucia Masetti[1], Reinhold Degele[1], Steffen Schönfelder[2], and Konrad Briggl[3] — [1]Institut für Physik, Johannes-Gutenberg Universität Mainz — [2]Prisma+ Detektorlabor, Johannes-Gutenberg Universität Mainz — [3]Kirchhoff-Institut für Physik, Universität Heidelberg

This talk discusses the adaptation of the analogue hadronic calorimeter (AHCAL), originally developed by the CALICE collaboration for the International Linear Collider (ILC), to meet the demanding requirements of future circular colliders. The AHCAL is based on the SiPM-on-tile technology, where the HCAL Base Units (HBUs) combine scintillator tiles read out by silicon photomultipliers (SiPMs) with embedded front-end electronics. For the linear collider environment, no integrated cooling system was necessary, as power consumption was effectively managed through power pulsing. However, this approach is no longer feasible due to the significantly higher interaction rate in circular colliders, requiring the electronics to remain continuously powered. This must be achieved with a small temperature gradient to ensure uniform SiPM gain and with minimal additional material to preserve the detector's physics performance. To address this challenge, an integrated cooling system is being developed. In this context, a dedicated dummy PCB was designed to allow systematic tests of different cooling strategies. Initial tests with a copper plate thermally coupled to the PCB and the resulting PCB temperatures will be presented.

T 90.2 Fri 9:15 KH 00.015

Wrapping 160.000 scintillators in 300 days. HGCAL upgrade challenges
— •Jorge Ortiz — Deutsches Elektronen-Synchrotron (DESY), Notkestr. 85, 22607 Hamburg, Germany — Universität Hamburg, Mittelweg 177, 20148 Hamburg, Germany

The High Granularity Calorimeter (HGCAL) will replace the current endcap calorimeters of the CMS detector to meet the challenging conditions of the High-Luminosity LHC, including unprecedented radiation levels and pile-up. The hadronic section of the HGCAL requires approximately 280,000 plastic scintillator tiles in 35 different sizes, which are produced in the US. At DESY, around 160,000 of these tiles will be wrapped in reflective foil and subjected to quality control. Given the scale of the task, automation is essential.

In this talk, I will present the system developed at DESY to automate the wrapping, detailing the technical challenges and the current performance of the setup based on the first production batch of more than 10.000 tiles.

T 90.3 Fri 9:30 KH 00.015

Quality Control of the Tilemodules for the High Granularity Calorimeter upgrade of the CMS experiment
— •Anurag Sritharan — Deutsches Elektronen-Synchrotron (DESY), Notkestraße 85, 22607 Hamburg, Germany

The CMS experiment will upgrade its detectors to cope with higher luminosities and collision rates during the High-Luminosity era of the LHC. One key upgrade of the CMS is the High Granularity Calorimeter (HGCAL), which will completely replace the current end-cap calorimeter. The hadronic calorimeter is split into two sections using different technologies, depending on the expected amount of radiation damage at the end of life. Where the expected fluence is below $5{\times}10^{13} n_{eq}/cm^2$, the SiPM-on-Tile technology was chosen. It consists of small scintillator tiles read out by silicon photo-multipliers on a PCB, named "Tilemodule". A Tilemodule will house 1 or 2 readout chips (called HGCROCs), and each can read out 72 channels. To test and qualify the Tilemodules and the functionality of the readout chips, a robust and modular software framework for quality control has been developed. Additionally, in September 2025, 15 Tilemodules were tuned through the software framework, assembled into a stainless steel absorber stack, and tested at CERN SPS. The test setups, results, and a first look into the analysis of the calorimetric stack will be presented.

T 90.4 Fri 9:45 KH 00.015

Upcoming Upgrades of the ATLAS Liquid Argon Purity System for the High-Luminosity Upgrade
— •Christopher Engel, Maximilian Linkert, and Stefan Tapprogge — Institut für Physik, Johannes Gutenberg-Universität, Mainz

The ATLAS Liquid Argon Purity system monitors the possible impurities of the Liquid Argon within the calorimeter system ensuring excellent data taking quality. In preparation of the upcoming Long Shutdown of the LHC for the High Luminosity Upgrade, the Purity system has to undergo some changes and upgrades. This includes a complete redesign of the power distribution board due to the incoming voltage changing from a positive and negative voltage to a single higher positive voltage. The monitoring modules need to have negative voltage resulting in an on-board solution creating the voltage locally. The current design, test setup and production status of the power distribution board is presented.

T 90.5 Fri 10:00 KH 00.015

Optimisation of the SHiP calorimeter system
— •Matei Climescu[1], Volker Büscher[2], Claudia Delogu[3], Sebastian Ritter[2], and Rainer Wanke[2] — [1]Ghent University — [2]University of Mainz — [3]INFN Genova

The SHiP/NA67 experiment is an approved beam-dump experiment which will be located in the CERN North Area and is scheduled to start taking data starting 2032. It will operate at very high intensities and requires no background. To this effect, its calorimeter system consists of a SplitCal electromagnetic section and a hadronic section which are optimised for particle identification and high-resolution vertexing of neutral final states from Feebly-Interacting-Particle decays. The optimisation of the calorimeter system is presented.

T 91: Methods in Particle Physics V

Time: Friday 9:00–10:15 Location: KH 00.020

T 91.1 Fri 9:00 KH 00.020

Positron Source for Future Collider Designs (HALHF, LCF, ILC, CLIC) — •Gudrid Moortgat-Pick[1,2], Niclas Hamann[2], Manuel Formela[2], Malte Trautwein[1], Gregor Loisch[2], Tim Lengler[3], Dieter Lott[3], and Sabine Riemann[2] — [1]University of Hamburg — [2]Deutsches Elektronen Synchrotron — [3]Hereon

Higgs Physics and Beyond Standard Model Physics require high-energetic lepton colliders of at least a cms of 550 GeV. In particular the positron source is a challenge for all future lepton colliders. In the talk new R&D developments for polarized positron sources for the high-energy designs as Hybrid Asymmetric Linear Higgs Factory (HALHF), Linear Collider Facility at CERN (LCF), International Linear Collider (ILC) and Compact Linear Collider (CLIC) are discussed. The talk includes physics requirements, status of target and OMD prototypes, automatized simulation tools.

T 91.2 Fri 9:15 KH 00.020

Jet energy resolution in future e^+e^- Higgs factory experiments with ML and 5D calorimetry — •Bohdan Dudar and Lucia Masetti — Johannes Gutenberg-Universität Mainz, Mainz, Germany

The Pandora particle-flow algorithm (PFA) remains one of the best tools for event reconstruction aiming at an excellent jet energy resolution for future e^+e^- collider experiments. Moreover, the rapid development of picosecond-timing sensors and their potential implementation in the calorimeter would allow for developing a new PFA with timing information, with improved performances in shower separation and particle tracking. Yet, this needs to be integrated in a full PFA reconstruction framework.

In this study, we examine the potential impact of timing in calorimetry on jet energy resolution, using an approach entirely based on machine learning. We develop an energy regression neural network (NN) with and without time information, and compare our results to the Pandora PFA. We use beam-background-free MC samples of $Z \to q\bar{q}$ $(q = u, d, s)$ reconstructed with the International Large Detector (ILD) in full simulation.

T 91.3 Fri 9:30 KH 00.020

Calibration of calorimeter signals in theATLAS experiment using an uncertainty-awareneural network — •Isabel Sainz Saenz-Diez — Kirchhoff Institute for Physics, Heidelberg University

The measurement of energy deposits in the calorimeters is a key aspect of particle reconstruction. In the case of the ATLAS experiment at the Large Hadron Collider (LHC), the calorimeter signals are reconstructed as clusters of topologically connected cells (topo-clusters) and need to be calibrated for energy losses that take part in hadronic showers and do not leave energy in the calorimeter cells. Machine Learning (ML) methods have been proposed in order to perform the hadronic calibration of the clusters. The talk will present the current status of the implementation and performance of a Deep Neural Network (DNN) which predicts both the energy of the clusters and its uncertainty. The impact of this new calibration in jet reconstruction and its outperformance with respect to the current calibration is discussed and both results at cluster-level and jet-level will be presented.

T 91.4 Fri 9:45 KH 00.020

Background suppression of neutrino inelastic interactions in SHiP with a GNN using the Surrounding Background Tagger — •Darja Lund for the SHiP-SBT-Collaboration — Humboldt Universität zu Berlin, Berlin, Germany

The SHiP (Search for Hidden Particles) fixed target experiment will be realised in a dedicated beam-dump facility in the ECN3 cavern in CERN's north area. It will take advantage of the 400 GeV SPS proton beam to search for feebly interacting long-lived particles at the MeV-GeV scale over many orders of magnitude in coupling. The search for decay signatures will be facilitated by the full reconstruction and particle identification of Standard model final states using the detector setup. Located downstream of the hadron stopper and the magnetic muon shield is the 50m long decay volume, encased by the SBT (Surrounding Background Tagger). A major focus of the experiment, and a key functionality of the SBT, is the detection and suppression of muon and neutrino inelastic scattering background inside the 50m long decay volume. For this, a GNN (Graph Neural Network) to identify background is in constant development. This talk will give an overview of the neutrino background suppression using a GNN-based veto.

T 91.5 Fri 10:00 KH 00.020

Background suppression in the SHiP experiment with the Surround Background Tagger and different selection criteria — •Katharina Albrecht for the SHiP-SBT-Collaboration — Institut für Physik, Humboldt-Universität zu Berlin, Berlin, Germany

SHiP (Search for Hidden Particles) is an experiment that will be installed in a dedicated beam-dump facility in the ECN3 cavern, located in the CERN north area. SHiP will search for feebly interacting particles (FIPs) produced by 400 GeV/c protons from the SPS impinging on a heavy-metal target. Over a 15-year span, the objective is to accumulate 6×10^{20} protons on target with a detector setup that allows suppression of possible background to a negligible level. The experiment focuses on optimizing the sensitivity for models featuring long-lived FIPs below 10 GeV/c^2 by minimizing backgrounds induced by the huge flux of neutrinos and muons emerging from the beam-dump target. The Surround Background Tagger (SBT) is a critical component surrounding the 50 m long helium-filled decay volume. The SBT is instrumental to detect charged particles entering the decay volume from the sides as well as inelastic interactions of neutrinos and muons taking place inside the helium-filled decay volume, but also in the SBT itself. The presentation will discuss the suppression of these backgrounds from simulation studies, focusing on different selection criteria between standard and modified cuts.

T 92: Electronics, Trigger, DAQ IV

Time: Friday 9:00–10:15 Location: KH 00.023

T 92.1 Fri 9:00 KH 00.023

Implementation of a two-level AI-enhanced trigger on a single chip with AI cores for live reconstruction — •Patrick Schwäbig for the Lohengrin-Collaboration — Physikalisches Institut, Universität Bonn, Deutschland

For years, data rates generated by modern detectors and the corresponding readout electronics exceeded by far the limits of data storage space and bandwidth available in many experiments. The approach of using fast triggers to discard uninteresting and irrelevant data remains a solution used to this day: Using FPGAs, ASICs or directly the readout chip, a fixed set of rules based on low level parameters is applied as a pre-selection. In contrast to this stands live track reconstruction for triggering, which was rarely possible due to limited computation power in the past. With the emergence of highly parallelized processors for AI inference, attempts to sufficiently accelerate tracking algorithms become viable. The AMD Versal Adaptive Compute Acceleration Platform (ACAP) is one such technology and combines FPGA and CPU resources with dedicated AI cores.

Our approach is to implement a two-level trigger on a single chip by utilizing the tightly integrated combination of FPGA and AI cores to profit from their individual strengths. In this talk our concept for a two-level trigger setup, implemented on an AMD VC1902, including classical and quantized AI algorithms, Timepix3 readout, as well as first testbeam results, will be shown. A similar setup will be used in an envisioned mid-size ultra-high rate fixed-target dark matter experiment (Lohengrin) at the ELSA accelerator at the University of Bonn.

T 92.2 Fri 9:15 KH 00.023

Track Finding with Graph Neural Networks at the ATLAS Event Filter — •Giulia Fazzino, Sebastian Dittmeier, and André Schöning — Physikalisches Institut, Universität Heidelberg, Germany

The upcoming High Luminosity upgrade of the Large Hadron Collider will increase the number of simultaneous interactions per bunch-crossing in the ATLAS experiment from $\langle\mu\rangle \approx 56$ to $\langle\mu\rangle \approx 200$.

To cope with the computational demands resulting from the corresponding rise in data rate, the Trigger and Data Acquisition System of the experiment will undergo several upgrades. The trigger will consist of a hardware trigger and a software trigger, the Event Filter. In the latter, charged particle tracks in the Inner Tracker (ITk) will be reconstructed for event selection. To reduce the computational resources required for this task, the possibility of using hardware accelerators and new tracking algorithms has been extensively investigated over the last years.

One promising approach uses Graph Neural Networks (GNNs) for track finding, one of the most computationally expensive steps of track reconstruction. The algorithm first builds a graph from the hits in the ITk, then uses a GNN to score its edges, and lastly applies a segmentation procedure to generate track candidates. The high parallelizability of the method makes it suited for implementation on FPGAs or GPUs.

This talk will present an overview of GNN-based track finding for the ATLAS Event Filter, with a focus on its implementation and optimization for FPGA deployment.

T 92.3 Fri 9:30 KH 00.023

Graph Neural Network based Algorithms for the Belle II Upgrade of the Electromagnetic Calorimeter Trigger on Versal SoCs with integrated AI Engines — •Thomas Lobmaier, Isabel Haide, and Torben Ferber — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

In order to reach the target design luminosity of Belle II, the instantaneous luminosity has to be increased by adjustments of the SuperKEKB accelerator. Especially with the planned long shutdown II in 2030 a significant gain in luminosity is expected, which directly increases trigger rates.

Planned upgrades for the electromagnetic calorimeter electronics increase the readout granularity, which also allows the subsequent trigger algorithms to access higher granularity inputs. In addition to the associated better energy and position resolutions, this enables the utilization of shower shape information to reconstruct the event more accurately and improves background suppression.

We show a first implementation of a GNN on Versal SoCs with integrated AI Engines, which enables the processing of up to 256 inputs per event. We present the performance on datasets with different input reduction strategies for the Belle II Long Shutdown 2 upgrade.

T 92.4 Fri 9:45 KH 00.023

Low-latency GNN-based hit filtering for the Belle II Level-1 track trigger — •Greta Heine[1], Fabio Mayer[2], Marc Neu[2], Giacomo De Pietro[1], Jürgen Becker[2], and Torben Ferber[1] — [1]Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]Institute for Information Processing Technology, Karlsruhe Institute of Technology, Karlsruhe, Germany

The Belle II experiment encounters increasing beam-induced background with rising instantaneous luminosity, which places tighter requirements on online and offline tracking algorithms. The Level-1 trigger must maintain a high efficiency for physics signals while operating under strict latency and bandwidth constraints. To keep trigger rates within data acquisition limits, effective background suppression, in particular in the Central Drift Chamber (CDC), is essential.

This talk presents a Graph Neural Network (GNN)-based hit filter for the Belle II Level-1 CDC hardware trigger, with a focus on the hardware-aware design workflow for FPGA deployment, including model compression via quantization-aware training and network pruning. Performance results are presented in terms of the trade-off between filtering performance and resource utilization: hit-level background rejection, impact on subsequent track reconstruction and trigger rates, as well as resource usage and sub-microsecond latency for an AMD Ultrascale FPGA implementation that meets timing after place-and-route.

T 92.5 Fri 10:00 KH 00.023

AI-enabled FPGA trigger for autonomous radio detection of cosmic rays — Alperen Aksoy[3], Ilja Bekman[3], Markus Cristinziani[1], Eric-Teunis de Boone[1], •Vesselin Dimitrov[1], Qader Dorosti[1], Chimezie Eguzo[3], Stefan Heidbrink[2], Waldemar Stroh[2], Jens Winter[2], and Michael Ziolkowski[2] — [1]Experimentelle Astroteilchenphysik, Center for Particle Physics Siegen, Universität Siegen — [2]Elektronikentwicklungslabor des Departments Physik, Universität Siegen — [3]Peter Grünberg Institute - Integrated Computing Architectures, Forschungszentrum Jülich

Radio detection of extensive air showers induced by ultra-high-energy cosmic rays provides crucial information on their origin, composition and energy. Radio arrays detect these events, but cosmic-ray signals are exceedingly rare compared to the overwhelming radio noise and RFI. Since storing all data is not feasible, a trigger system must decide in real time which data to record. FPGAs are a fitting option for this requirement because they provide deterministic low latency and low energy consumption compared to CPUs or GPUs. In this collaborative work between the University of Siegen and the Forschungszentrum Jülich, we investigate a novel approach where a machine-learning-based trigger is implemented on an FPGA. The goal is to achieve reliable discrimination between cosmic-ray signals and background, by employing a quantized neural network with minimal latency and power consumption. We aim to validate the quantized model on an FPGA and assess resource usage, latency, power consumption and trigger efficiency, while strongly reducing the false-trigger rate for cosmic-ray events.

T 93: Data, AI, Computing, Electronics VIII

Time: Friday 9:00–10:15 Location: KH 00.024

T 93.1 Fri 9:00 KH 00.024

Electromagnetic Shower Shape Correction using Normalizing Flows — •Marius Melcher, Arno Straessner, and Asma Hadef — Technische Universität Dresden

The interplay between data and simulation is essential for precision measurements at the ATLAS experiment. The Geant4-based simulation of electromagnetic showers in the calorimeter, however, exhibits notable discrepancies with data, particularly in derived shower-shape variables used for electron and photon identification. These mismatches can impact the efficiency and background rejection of identification algorithms, making corrections to simulated showers crucial for physics analyses.

This talk presents a machine-learning-based approach using normalizing flows to correct shower-shape variables in simulation. This model is applied to electron shower-shapes measured by ATLAS during LHC Run 3. Resulting improvements in data-simulation agreement are discussed.

T 93.2 Fri 9:15 KH 00.024

Speeding up the MC Background Simulation at Belle II — •Oliver Schumann, Nikolai Krug, Thomas Kuhr, and Thomas Lück — Ludwig-Maximilians-Universität München (LMU), München, Germany

By striving for ever-higher luminosities, the Belle II detector is set to observe rare decay signals. However, these high luminosities correspond to an increased demand for MC-generated background. Therefore, an efficient algorithm to simulate background events for the detector in large quantities is vital for the successful interpretation of Belle II's data. While the generation and skimming of events in the MC simulation chain are quick and easy to compute, the detector simulation and reconstruction of these particles are a slow task. A neural network (NN) is introduced into the chain to classify skim-passing events and discard those which fail to pass the NN before the detector response simulation, thereby saving valuable computing resources and time.

This work explores a new approach for parallelisation of the NN training process, in hopes of achieving convergence with the resources available in less (real) time. It involves an on-the-fly training pipeline on multiple machines, retrieving the updated NN, and redistributing it to the clients. This talk aims to provide an overview of the current work in progress and to give an outlook on future prospects.

T 93.3 Fri 9:30 KH 00.024

CaloHadronic: review and updates — •Martina Mozzanica[1], Gregor Kasieczka[1], Frank Gaede[2], and Katja Krüger[2] — [1]University of Hamburg — [2]DESY, Hamburg

Simulating showers of particles in highly-granular calorimeters is a key frontier in the application of machine learning to particle physics. Achieving high accuracy and speed with generative machine learning models can enable them to augment traditional simulations and alleviate a major computing constraint. Recent developments have shown how diffusion based generative shower simulation approaches that do not rely on a fixed structure, but instead generate geometry-independent point clouds, are very efficient. We present CaloHadronic: a diffusion model for the generation of hadronic showers in both the highly granular electromagnetic and hadronic calorimeters of the International Large Detector, ILD. In addition, we detail several updates to the dataset and architectural design.

T 93.4 Fri 9:45 KH 00.024

OmniJet-alpha for Calorimeters - Autoregressive generation of Calorimeter Showers — Joschka Birk[1], Frank Gaede[2], Anna Hallin[1], Gregor Kasieczka[1], Martina Mozzanica[1], and •Henning Rose[1] — [1]Institute for Experimental Physics, Universität Hamburg Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany

We present an autoregressive approach for the generation of high-granularity calorimeter showers based on the OmniJetAlpha architecture. The proposed method directly embeds individual calorimeter shower hits, enabling end-to-end autoregressive generation without relying on discrete tokenization or vector-quantized codebooks. To model hit features efficiently, the architecture employs separate prediction heads for each feature dimension, allowing the overall model size to remain compact even at very high spatial and energy granularities, while avoiding codebook collapse and related representational bottlenecks. This design facilitates stable training and scalable generation in regimes where traditional token-based approaches become impractical. Our results demonstrate that generative pre-training can be performed directly at the data level for calorimeter shower modeling, removing the need for intermediate representations. This is a significant step toward leveraging transformer-based foundation models in high-energy physics, as autoregressive pre-training has proven exceptionally effective in generative modeling, as evidenced by recent advances in large language models.

T 93.5 Fri 10:00 KH 00.024

PanShower: One model for all calorimeter showers — •Thorsten Buss[1,2], Henry Day-Hall[2], Frank Gaede[2], Gregor Kasieczka[1], and Katja Krüger[2] — [1]Universität Hamburg, Hamburg, Germany — [2]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

Accurate and efficient detector simulation is essential for modern collider experiments. To reduce the high computational cost, various fast machine learning surrogate models have been proposed. Traditional surrogate models for calorimeter shower modeling train separate networks for each particle species, limiting scalability and reuse. We introduce PanShower, a unified generative model that simulates calorimeter showers across multiple particle types using a single generative model. PanShower is a continuous normalizing flow model with a Transformer architecture, enabling it to generate complex spatial and energy correlations in variable-length point cloud representations of showers. Trained on a diverse dataset of simulated showers in the highly granular ILD detector, the model demonstrates the ability to generate realistic showers for electrons, photons, charged and neutral hadrons over a wide range of incident energies and angles without the need for retraining.

T 94: Flavour Physics VI

Time: Friday 9:00–10:30 Location: KH 01.011

T 94.1 Fri 9:00 KH 01.011

Semileptonic Kaon Decays at NA62 — •Atakan Akmete — Mainz University

Semileptonic charged kaon decays $K^+ \to \pi^0 \ell^+ \nu(\gamma)$ ($K_{\ell 3}$) provide a clean test of e-μ lepton universality and a direct probe of the first row of the CKM matrix unitarity $|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 1$. Current measurements indicate a near three-sigma tension in the determination of V_{ud} and V_{us}, with semileptonic kaon decays alone contributing at the 2.6σ level.

This study aims to update the branching fractions of $K_{\ell 3}$ together with the other dominant K^+ modes using an unbiased low-intensity dataset collected by the NA62 experiment at CERN, providing a clean environment for per-mille-level statistical precision.

From this dataset, events with a single positively charged downstream track are selected, defining a topology that allows all six main decay modes to be measured simultaneously without explicit particle identification. This approach naturally separates decay modes into distinct kinematic regions, effectively acting as a PID substitute and reducing the systematic uncertainties associated with neutral-pion reconstruction and calorimetry.

In this talk, I will present the current status of the analysis, including preliminary results and ongoing systematic studies.

T 94.2 Fri 9:15 KH 01.011

Search for $B \to D^{(*)}\eta\ell\nu$ at Belle II — •David Giesegh, Thomas Kuhr, and Thomas Lück — LMU Munich, Germany

Even though semileptonic B meson decays have been a field of intensive study over the past decades, there are still unresolved questions. One of these is the so-called gap problem, which describes a discrepancy between measurements of the inclusive semileptonic branching fraction and the sum of exclusive semileptonic branching fractions. This difference could be attributed to one or several as of yet unobserved decays, an example for which is $B \to D^{(*)}\eta\ell\nu$, which is allowed within the Standard Model and commonly used in MC simulations of generic B meson decays to fill the gap.

In the analysis presented here we aim to measure this branching fraction for the first time using data collected by the Belle II Experiment. We leverage Belle II's well known initial state kinematics to derive the angle between the decaying B meson and its visible daughters, which is used for signal extraction. Additionally, MVA methods are employed for candidate selection and background suppression, which is especially important in the reconstruction of η candidates. In the talk we will discuss the current status and future outlook of this analysis.

T 94.3 Fri 9:30 KH 01.011

Measurement of the Branching Ratio and q^2-spectrum of $B \to D^{**}\ell\nu$ decays at Belle II — •Eylül Ünlü, Thomas Kuhr, and Thomas Lück — Ludwig-Maximilians-Universität München (LMU), München, Germany

There is currently some tension between the measured value of $R(D^*) = \mathcal{B}(B \to D^*\tau\nu_\tau)/\mathcal{B}(B \to D^*\ell\nu_\ell)$ and the Standard Model prediction, hinting at lepton universality violation. Semileptonic B meson decays to D^{**} mesons are background to the $R(D^*)$ measurement, where D^{**} denotes the orbitally excited P-wave charm mesons: $D_1(2420)$, $D_2^*(2460)$, $D_0^*(2300)$, and $D_1^{'}(2430)$. These decays are not well understood, and discrepancies have been observed between past measurements of their yields made by BaBar and Belle. Hence, improving understanding of these decays reduces an important systematic uncertainty on $R(D^*)$ measurements.

The present study aims to use data from the Belle II experiment to study these decays, particularly to determine the q^2 spectrum, which is a key input for theory predictions.

We reconstruct one of the B mesons from the $\Upsilon(4S) \to BB$ decay in the signal channel, $B \to D^{**}(D^{(*)}\pi)\ell\nu$, and the other B meson in various hadronic modes using the Full Event Interpretation algorithm. The signal yield is determined by a maximum likelihood fit to the mass difference $M(D^{(*)}\pi) - M(D^{(*)})$. The resulting q^2 spectrum is fitted using a differential decay rate model after correcting for detector resolution effects. The status of the analysis will be presented including results on simulation and a first assessment of systematic uncertainties.

T 94.4 Fri 9:45 KH 01.011

Angular analysis of $B^0 \to D^*\tau\nu$ in Run 2 at the LHCb experiment — Tobias Knospe[1], Johannes Albrecht[1], Greg Ciezarek[2], Marco Gersabeck[3], Lucia Grillo[4], •Biljana Mitreska[5], Chris Parkes[5], Manuel Schiller[4], Derek Yeung[5], and Havva Hasret Nur[4] — [1]TU Dortmund University, Dortmund, Germany — [2]CERN, Geneva, Switzerland — [3]Albert-Ludwigs-Universität Freiburg, Freiburg, Germany — [4]University of Glasgow, Glasgow, UK — [5]The University of Manchester, Manchester, UK

The global average of the ratio $R(D^*)$ between the $B^0 \to D^*\tau\nu$ and $B^0 \to D^*\mu\nu$ branching fractions is at tension with the SM prediction. The angular structure of the $b \to c\ell\nu$ transition using effective field theory allows to probe potential New Physics (NP) effects with greater sensitivity than a measurement of the branching fraction. An angular analysis of the $B^0 \to D^*\tau\nu$ decay is presented, based on proton-proton collision data collected by the LHCb experiment, corresponding to an integrated luminosity of $1.6\,\text{fb}^{-1}$. The signal distribution is extracted through a multidimensional fit to the data, using templated distributions derived from both simulation and data control samples. The $R(D^*)$ ratio and several NP Wilson coefficients are measured in different combinations. Additionally, the $R(D^*)$ ratio as well as the hadronic form factors are measured in a Standard Model scenario using BGL and BLPR parameterizations.

T 94.5 Fri 10:00 KH 01.011

***R(D*)* measurements with ATLAS Run 2 data** — •Laily Sultanaliyeva[1], Leonid Gladilin[2], and Vladimir Tikhomirov[2] — [1]University of Bonn, Bonn, Germany — [2]Moscow, Russia

Semileptonic decays of hadrons can be used for testing the equality of the couplings of the three charged leptons to the gauge bosons, i.e. Lepton Flavour Universality (LFU). Sensitive to LFU violation ratios of branching fractions for various hadrons decays have been previously studied by BaBar, Belle and LHCb experiments. The aim of this analysis is to measure $R(D^*) \equiv \mathcal{B}(B^0 \to D^{*-}\tau^+\nu_\tau)/\mathcal{B}(B^0 \to D^{*-}\mu^+\nu_\mu)$ with proton-proton (pp) collisions data collected by the ATLAS experiment during LHC Run 2 and compare with the current world-average result, which now exceeds the Standard Model predictions by $\sim 2.7\sigma$.

The ratio of branching fractions $R(D^*)$ is measured with data recorded during pp collisions with $\sqrt{s} = 13\,\text{TeV}$ corresponding to the integrated luminosity of $140\,\text{fb}^{-1}$. The $\tau^\pm$ leptons are reconstructed through the semileptonic decay $\tau^\pm \to \mu^\pm\bar{\nu_\mu}\nu_\tau$, while for D^* mesons the following decay chain is used: $D^{*\pm} \to D^0\pi^\pm \to (K^\mp\pi^\pm)\pi^\pm$. Both $\tau-$ and $\mu-$ decay modes of B^0 mesons have the same number of detectable particles in the final state, and thus can be selected and analysed together. A multi-dimesional fit then can be used to separate two signal processes from each other as well as from background processes. In this talk the current state of the analysis will be presented.

T 94.6 Fri 10:15 KH 01.011

R(D) and R(D*) Measurement using an Inclusive Tagging Method — •Fabio Novissimo[1], Tia Crane[2], Thomas Lück[1], and Thomas Kuhr[1] — [1]Ludwig-Maximilians-Universität München (LMU), München, Germany — [2]DESY - Universität Hamburg

Lepton flavour universality (LFU) is a fundamental symmetry of the Standard Model (SM). This symmetry states that the three generations of leptons (electrons, muons and tauons), couple with equal strength to the W boson. Any deviation from this symmetry is a clear sign of new physics. In this regard, the semileptonic decays of B mesons are an invaluable portal for LFU tests. More specifically, the measurement of the ratios R(D) and R(D*) defined as

$$R(D^{(*)}) = \frac{\mathcal{B}\left(B \to D^{(*)}\tau\nu_\tau\right)}{\mathcal{B}\left(B \to D^{(*)}\ell\nu_\ell\right)}$$

are two great ways to probe this symmetry, since the ratios allow many uncertainties to cancel and are predicted with a very high precision in the SM. Latest averaged results show that there is a 3.8σ tension with the SM prediction, making this measurements very relevant. The analysis presented in this talk aims to obtain an even more precise measurement of the ratios R(D) and R(D*) using Belle II data, and adopts an inclusive tagging approach, which allows increased statistics at the expenses of higher background levels. This talk will provide an overview of the analysis, as well as the current status and future outlook.

T 95: Gaseous Detectors III

Time: Friday 9:00–10:30 Location: KH 01.014

T 95.1 Fri 9:00 KH 01.014

Background Studies at the SHiP Spectrometer Straw Tracker — •Hannah Limberg, Caren Hagner, Daniel Bick, Wei-Chieh Lee, and Walter Schmidt-Parzefall — Institute of Experimental Physics, University of Hamburg, Hamburg, Germany

SHiP (Search for Hidden Particles) is a general-purpose beam-dump experiment currently in preparation at the CERN SPS. The experiment is designed to explore physics beyond the Standard Model by searching for feebly interacting particles (FIPs), which are predicted by several theoretical models of the hidden sector. When the high-intensity proton beam from the SPS hits a thick target, the collisions can potentially create hidden particles. These particles enter a 50 m decay volume and decay into Standard Model particles. They are detected by the spectrometer straw tracker located behind the decay volume. While only moderate particle rates from the target are expected, backgrounds from secondary interactions, for example in the tracker frames, will contribute significantly to the total number of hits in the spectrometer. The influence of background and its impact on the detection efficiency are investigated through simulation studies. The results will be presented in this talk.

T 95.2 Fri 9:15 KH 01.014

Implementation of 2nd coordinate measurement for 3D tracking with Drift Tube Chambers — •Nick Meier, Julia Okfen, and Oliver Kortner — Max-Planck-Institute for Physics, Garching, Germany

This work investigates the implementation of a second coordinate measurement in drift-tube detectors to enable full 3D hit reconstruction in drift tube chambers. Two concepts are studied: the Twin-Tube configuration, where signals are looped through paired tubes, and a Double-Sided Readout with independent readout on both ends. For ATLAS muon drift-tube (MDT) chambers, measurements of signal propagation and attenuation allow reconstruction of the hit position along the wire. Using the signal propagation delay measurement, a second coordinate resolution of approximately 200 mm is achieved at various tube lengths. A second-coordinate measurement efficiency exceeding 96% can be achieved under HL-LHC background conditions. For small diameter muon drift-tube (sMDT) chambers, resolutions between 100-140 mm are obtained at the different positions along the tube, reaching 95 mm for a 100 GeV muon beam and 52 mm when combining the information of four tubes. The utilization of the second coordinate for the rejection of γ background hits in track reconstruction will also be discussed in the presentation. Overall, the results demonstrate that a second coordinate can be integrated into gaseous drift-tube detectors with high efficiency, providing a promising option for future high γ background rates as expected for the muon systems at the HL-LHC and the FCC.

T 95.3 Fri 9:30 KH 01.014

Testbeam Performance of 20x20 cm^2 triple GEM Detector — •Nick Schneider, Otmar Biebel, Valerio D'Amico, Ralf Hertenberger, Eshita Kumar, Lilla Schneider, Chrysostomos Valderanis, and Fabian Voggel — LMU Munich

Micro-Pattern Gaseous Detectors are heavily used for the detection of charged particles with excellent temporal and spatial resolution. The investigated detector is a triple-GEM detector with a size of 20x20 cm^2. Additionally the GEM-foils are split into 4 sectors on the top sides to reduce the capacity in case of a violent discharge, making it less likely for the foils to be damaged in such an event. While testing the detector in the lab with a ^{55}Fe source a charge-up effect was noticed. To further investigate this effect and determine efficiency and resolution of this detector it is tested in a 120 GeV muon testbeam at CERN and a high-rate $\approx$3 GeV electron testbeam at ELSA (University of Bonn). For the muon testbeam additional tracking detectors are used to determine the efficiency and the resolution of detector under test. Due to multiple scattering, it is very difficult to track the particles in the electron testbeam. Consequently, the high electron flux of this beam is used to further investigate high-rate and charge-up effects. Some of the results of these testbeams will be presented.

T 95.4 Fri 9:45 KH 01.014

Rate characteristics of triple GEM detectors with results from the ELSA testbeam measurements — Erik Ehlert, Kerstin Hoepfner, Stella Israel, •Daniel Klee, Markus Merschmeyer, Alexander Schmidt, and Shawn Zaleski — III. Physikalisches Institut, RWTH Aachen University, Aachen, Germany

Gas electron multipliers (GEM detectors) are often used in challenging conditions. For example in the CMS experiment the new ME0 detector will see particle-fluxes of up to 150 kHz/cm^2. For a muon detector it is not trivial to cope with such high rates. GEM detectors are particularly well suited for this environment because of their high rate capability and good spatial resolution. This talk will present results on studies of operating a GEM detector at high and highest rates. In particular, we present the influence of boundary conditions, such as variation of protection resistors. Besides measuring the rate capability of a triple GEM test detector with an X-Ray source, the presented results also include measurements recorded at the Elektronen-Stretcher-Anlage (ELSA) in Bonn. Here we were able to reach even higher rates, pushing the GEM detector to its limits.

T 95.5 Fri 10:00 KH 01.014

BASTARD: A GEM based neutron detector with VMM readout — •Jan Glowacz[1], Thomas Block[1], Klaus Desch[1], Saime Gürbüz[1], Jochen Kaminski[1], and Markus Köhli[2,3] — [1]University of Bonn — [2]Heidelberg University — [3]StyX Neutronica GmbH

In the neutron science community the high price of helium-3 pushes the use of solid neutron converters like boron or gadolinium in detectors. The boron based multi stage tracking detector (BASTARD) is such a detector with focus on high spatial resolution and high readout rates. It is a multi-layer gaseous detector, where a boron coated cathode is used to convert neutrons into helium and lithium ions. A GEM-like gas amplification stage is used to detect the ions. The readout is implemented using VMM3a hybrids and the DRD1 Scalable Readout System. A prototype detector with an active area of 10cm x 10cm is currently under development. We present our first results form tests with the prototype.

T 95.6 Fri 10:15 KH 01.014

A Time-Projection-Chamber for Neutron Science — •Thomas Block[1], Klaus Desch[1], Jochen Kaminski[1], Markus Köhli[2,3], Saime Gürbüz[1], Jan Glowacz[1], and Can Cetinkaya[1] — [1]Physikalisches Institut, Rheinische Friedrich-Wilhelms Universität Bonn — [2]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg — [3]StyX Neutronica GmbH, Mannheim

Due to the increased price of helium-3, alternative approaches for detectors in neutron science are highly demanded. This work combines the concept of a time projection chamber (TPC) with a boron-coated scintillator and optical guides. The GridPix-based readout with high granularity and high time resolution makes it a suitable candidate for imaging instruments and mid-rate scattering experiments. The enriched boron absorbs incoming thermal neutrons and decays into an alpha particle and a lithium ion. One ion enters the drift volume of the TPC and creates a trace of electron-ion pairs, which subsequently is projected onto the readout. The other ion of the same decay, which is emitted in the opposite direction, creates photons in the scintillator layer, which is used to trigger the readout. The light is coupled via an optical guide to a FPGA-controlled silicon photomultiplier trigger board. This timing information is necessary to reconstruct the three-dimensional ionisation track and hence the point of neutron conversion. We present the detector concept, its current stage of development and first measurements.

T 96: Outreach II

Time: Friday 9:00–10:30 Location: KH 01.020

T 96.1 Fri 9:00 KH 01.020

From Research to Impact: Outreach and Knowledge Transfer Across the German LHC Community — •Daniel Heuchel, Kim Wegner, and Sophia Haves — LHC Germany Office, Hamburg, Germany

The LHC-ErUM-FSP Office coordinates outreach and knowledge- and technology-transfer activities within the German LHC community. All 29 German universities and research institutes participating in ALICE, ATLAS, CMS, and LHCb are supported through structures that enhance communication, visibility, and strategic interaction beyond the academic environment. These activities reinforce public engagement, enable interdisciplinary exchange, and highlight the broader impact of frontier research at the LHC. In this context, latest strategic emphasis is placed on fostering and supporting knowledge transfer towards industry and on communicating the societal benefit of research outcomes.

In this contribution, outreach and transfer initiatives of the LHC-ErUM-FSP office will be presented, newly developed formats will be outlined, and their contribution to building the bridge between the German LHC community, our society, industry, and politics will be illustrated.

T 96.2 Fri 9:15 KH 01.020

Teilchenphysik Outreach im Wandel der Zeit - Chancen und Herausforderungen in der Nachwuchsgewinnung — •David Borgelt und Christian Klein-Bösing für die Netzwerk Teilchenwelt-Kollaboration — Institut für Kernphysik, University of Münster, Münster, Germany

Das Netzwerk Teilchenwelt, NRW-FAIR und weitere Outreach-Akteure kommunizieren moderne Teilchenphysik-Forschung, um Jugendliche zu gewinnen, ihnen Teilhabe zu ermöglichen und sie zu informieren. Dabei werden bewährte Methoden wie Masterclasses oder Praktika genutzt, welche von Vermittler:innen aus der Forschung geleitet sind. Um weiterhin der jungen Zielgruppe gerecht zu werden, werden neue Wege entwickelt, über welche Jugendliche erreicht werden können. Hierbei ist besonders der Umgang mit Social Media für Kommunikation und Interaktion, sowie die gemeinsame Arbeit mit Jugendlichen auf Augenhöhe, angelehnt an Peer Teaching, zu nennen. In diesem Talk werden Erfahrungen mit Social Media für den Outreach und partizipativer Wissenschaftskommunikation vorgestellt, sowie niedrigschwellig zu adaptierende Methoden um junge Leute zu begeistern, präsentiert.

T 96.3 Fri 9:30 KH 01.020

Universe in Creation: Student Art Inspired by Dark Matter Research — •Markus Klute and Michael Hoch — KIT, Karlsruhe, Germany

Over the course of a full school year, KIT and the ZKM collaborated with an all-girls Gymnasium in Karlsruhe to explore dark matter and the universe through the lens of artistic creation. Girls aged 11-14 met bi-weekly at KIT and the ZKM, where particle physicists and art educators introduced them to concepts from particle physics and cosmology and supported them in developing their own creative interpretations.

Working at the intersection of science and art, the pupils transformed ideas about the invisible universe into drawings, installations, and digital works. The project culminated in a public exhibition at the ZKM, showcasing their artworks and highlighting how creative practice can empower young women to engage confidently with complex scientific themes. The collaboration explores the value of longer term STEAM programs in fostering curiosity and participation in physics.

T 96.4 Fri 9:45 KH 01.020

EXPLORE: a multi-experiment open-access platform for education and training with LHC open data — •Baida Achkar, Arnulf Quadt, and Sebastian Wozniewski — II. Physikalisches Institut, Georg-August-Universität Göttingen, Germany

EXPLORE is an open-access analysis platform developed at the University of Göttingen within PUNCH4NFDI, the NFDI consortium for Particle, Astro-, Nuclear, and Hadron Physics. The service provides FAIR-aligned, barrier-free access to ATLAS Open Data, enabling students, educators, and the public to carry out realistic particle-physics analyses without requiring CERN credentials or local software installations. Its technical foundation consists of an HTCondor overlay batch system, containerized environments via CVMFS and Apptainer, and dynamic resource provisioning through the COBalD/TARDIS framework. Users currently access 145 ATLAS Open datasets and structured tutorial examples supporting sustainable learning workflows. EXPLORE is actively used in the HEP Masterclasses at Göttingen University and was introduced as a global resource during the ATLAS Open Data Tutorial (24 - 27 November 2025) at CERN. Since entering full production in late 2024, the platform has onboarded 28 users and processed around 190,000 analysis jobs. To broaden its educational reach, EXPLORE is being expanded to also support CMS Open Data workflows, with deployment planned ahead of the DPG Spring Meeting. The contribution will present the platform architecture, operational experience, educational deployments, and upcoming multi-experiment capabilities for LHC Open Data.

T 96.5 Fri 10:00 KH 01.020

Erfahrungsbericht zum Science Camp Teilchen- und Astroteilchenphysik mit erweitertem CERN-Programm — Michael Gauss, Michelle Gensmann, Christian Goffing, Dorian Guthmann, Carolin Quast, Günter Quast, Cedric Verstege und •Christian Winter — Karlsruhe Institute of Technology, Karlsruhe, Germany

Das Science Camp Teilchen- und Astroteilchenphysik am KIT bietet Schülerinnen und Schülern jährlich mit einer Verbindung aus theoretischen Impulsen, selbstständiger Projektarbeit und authentischen Einblicken in die Forschung die Möglichkeit, Teilchenphysik praxisnah zu erleben. Durch die Projektarbeit und Masterclasses lernten die Jugendlichen typische wissenschaftliche Arbeitsweisen z.B. kritischen Umgang mit Messdaten kennen, um diese dann selbstständig durchzuführen und auszuwerten. Besonders der Besuch am CERN als Höhepunkt beim diesjährigen Camp wirkte als starker motivierender Faktor, da die Teilnehmenden Forschung nicht nur konzeptuell, sondern hautnah erleben durften. Mit Führungen bei sieben Forschungsanlagen und Experimenten, sowie einem Besuch beim neuen Science Gateway und durch die direkte Begegnung mit Wissenschaftlerinnen und Wissenschaftlern wurden die theoretischen Konzepte greifbar und eine realistische Berufsorientierung ermöglicht. Dieser Vortrag vermittelt insbesondere unsere Erfahrungen und das Feedback des Besuchs am CERN, in dem die Teilnehmende direkten Kontakt zur aktuellen Forschung erfahren durften.

T 96.6 Fri 10:15 KH 01.020

Outreach Module for Supersymmetric Particle Search — Nikolai Chaunin[1], Jerzy Pryga[2], André Sopczak[1], and •Vladyslav Tabaciniuc[1] — [1]CTU in Prague — [2]Jagiellonian University in Kraków

We present a new model as a part of the Czech Particle Physics Project (CPPP). This module is intended as a leaning tool in masterclasses aimed at high-school students (ages 15 to 18). The module is dedicated to the detection of new supersymmetric particles by separating signal from background. The chosen process is scalar top pair-production in the final state containing a b-jet, a c-jet, a light lepton, and large missing transverse energy (MET). The user will compare simulated signal and background distributions with actual recorded data. The module can be accessed at the following link: http://cern.ch/cppp.

T 97: Silicon Detectors VIII

Time: Friday 9:00–10:15 Location: KH 01.022

T 97.1 Fri 9:00 KH 01.022

MIP detection on a plastic scintillator and SiPM system in very noisy environments — •Katjana Neumann, Massimiliano Antonello, Lukas Brinkmann, Erika Garutti, and Jörn Schwandt — Universität Hamburg, Hamburg, Deutschland

Radiation damage to a silicon photomultiplier (SiPM), as occurs during the lifetime of the planned CMS HGCAL detector, increases the dark current and degrades the signal to noise (S/N) separation and thus the minimum ionizing particles (MIP) detection efficiency. To investigate this, a system consisting of a plastic scintillator tile directly coupled to a SiPM is used to detect the MIP from a ^{90}Sr source. The aim of this thesis was to compare the effects of true radiation-induced damage with a method that increases the dark-count rate (DCR) exclusively through DC light illumination. This second approach does not induce any physical structural damage. This allows the isolation of the effect of increased DCR as the primary factor degrading the SiPM response. The results show that an increase in the DCR, regardless of whether it was induced by irradiation or DC illumination, leads to a comparable reduction in the MIP-response and the S/N ratio. This confirms that the dominant factor for the performance degradation is the increased DCR itself and not additional damage or defects introduced in the silicon. This study highlights a significant insight: the primary consequence of radiation damage on SiPMs can be effectively mimicked under laboratory settings using optical illumination to increase the DCR.

T 97.2 Fri 9:15 KH 01.022

A digital SiPM in liquid xenon — •Tiffany Luce — Physikalisches Institut, Universität Freiburg, 79104 Freiburg, Germany

Silicon PhotoMultipliers (SiPMs) are photosensors commonly used in many experiments. However, achieving single-photon sensitivity in the experiments is limited by the high dark count rate (DCR) of these devices. Digital SiPMS, where the digitization happens directly on the chip, can show DCRs competitive to that of traditional photomultiplier tubes (PMTs) with the added benefit of not needing analog to digital converters and greatly reducing the data rate. This would open up to cheaper and thus larger systems. We present results of the test of a digital SiPM in cryogenic liquid xenon, one of the most important detector target for dark matter searches.

T 97.3 Fri 9:30 KH 01.022

Characterisation of commercially available SiPMs — Theodoros Avgitas[1], Zoe Balmforth[1], Ioannis Manthos[1], Konstantinos Nikolopoulos[1,2], and •Christos Toukmenidis[1] — [1]University of Hamburg (UHH) — [2]University of Birmingham (UoB)

Silicon Photomultipliers (SiPMs) are increasingly employed in particle physics experiments thanks to a number of desirable properties such as single-photon sensitivity, high intrinsic gain, and compact design. Nevertheless, their performance depends strongly on the operating conditions such as the applied voltage and temperature. In this talk, a detailed characterisation of commercially available SiPMs is presented over an extended range of temperatures and SiPM bias. Key performance parameters are studied including breakdown voltage, gain, dark count rate (DCR), afterpulsing probability, and optical crosstalk.

T 97.4 Fri 9:45 KH 01.022

Radiation damage of red sensitive SiPMs — •Momo Scharf, Massimiliano Antonello, Lukas Brinkmann, Erika Garutti, Katjana Neumann, and Joern Schwandt — Universität Hamburg

A new generation of red sensitive Silicon Photomultipliers (SiPMs) are being developed by Broadcom. These feature a high Photo Detection Effiency (PDE) for near infrared light with a peak PDE of 38 % at 700 nm and a wide dynamic range due to the small pixel pitch with 6216 SPADs per mm^2. The influence of radiation damage on the performance of this new SiPM design is investigated. Sets of samples have been neutron irradiated in the TRIGA reactor facility at JSI (Ljubljana) at four different fluences up to $1 \times 10^{13}\,\mathrm{cm}^{-2}$. The characterization of the SiPMs includes performance parameters such as breakdown voltage, gain, correlated noise, dark count rate and non-linear response. The correction function is obtained with the single-step method on non-irradiated samples and the applicability to irradiated samples tested. This presentation shows first results of the comparison for irradiated and non-irradiated samples.

T 97.5 Fri 10:00 KH 01.022

On the temperature, voltage, gate-length, and pixel-pitch dependence of the SiPM non-linear response — •Lukas Brinkmann, Massimiliano Antonello, Erika Garutti, Katjana Neumann, Momo Scharf, and Jörn Schwandt — Universität Hamburg, Hamburg, Germany

The finite number of pixels in a silicon photomultiplier (SiPM) limits its dynamic range to light pulses up to typically 80 % of the total number of pixels in a device. Correcting the non-linear response is essential to extend the SiPM's dynamic range. One challenge in determining the non-linear response correction is providing a reference linear light source. Instead, the single-step method used to calibrate PMTs is applied, based on the difference in responses to two light sources.

A systematic study of the SiPM's response dependence on the operating voltage, temperature and gate length is performed for a KETEK SiPM design with different pixel sizes. The correction function, determined at reference conditions ($T = 20\,°\mathrm{C}$, $\Delta V = 5\,\mathrm{V}$), is applied to data spanning a temperature range of $-20\,°\mathrm{C}$ to $+20\,°\mathrm{C}$ and an overvoltage range of 3 V to 5 V.

The method successfully corrects the non-linearity of the SiPM response across this parameter space for sub-nanosecond illumination with light intensities up to a mean number of Geiger discharges equal to the number of pixels, with an average deviation from linearity below 3 %. No significant dependence of the correction function on temperature, overvoltage, gate length or pixel size is observed for the tested devices.

T 98: Higgs Physics X

Time: Friday 9:00–10:30 Location: KH 02.013

T 98.1 Fri 9:00 KH 02.013

Towards a CP-independent cross section measurement of $t\bar{t}H$ and tH production in the $H \to \gamma\gamma$ decay channel at CMS — Johannes Erdmann, Jan Hermanns, •Florian Mausolf, and Peter Wissmann — III. Physikalisches Institut A, RWTH Aachen University

The top-quark Yukawa coupling, the Higgs boson's strongest interaction with fermions, plays a central role in theory and experiment. While a purely CP-odd structure has been excluded experimentally, the possibility of a significant CP-odd admixture remains consistent with current LHC constraints. The presence of a CP-odd component or a change in the CP-even coupling strength would influence both the cross sections and kinematics of top-quark-associated Higgs-boson production processes. Particularly, the effect on the kinematics can lead to model dependencies of the measurement due to its effect on selection efficiencies.

This talk presents a measurement of $t\bar{t}H$ and tH production cross sections, with a special focus on minimizing model dependencies related to the CP-properties of the top-quark Yukawa coupling. This is achieved by using neural network classifiers trained with a decorrelation against such model assumptions in the training samples. The events are then categorized with a novel differentiable categorization optimization technique and the cross sections are extracted via a maximum likelihood fit using data recorded in 2022 and 2023 with the CMS detector.

T 98.2 Fri 9:15 KH 02.013

Focusing the Inference Lens: Probing the top-Higgs CP Structure with Neural Simulation-Based Inference — •Stefan Katsarov[1], Levi Evans[1], Alexander Held[2], Stephen Jiggins[1], Judith Katzy[1], Nino Kovacic[3], Jay Sandesara[2], and Chris Scheulen[4] — [1]DESY, Hamburg — [2]University of Wisconsin-Madison — [3]University of Zagreb — [4]University of Geneva

Neural Simulation-Based Inference (NSBI) is an emerging statistical framework that leverages modern neural networks as powerful function approximators to achieve the statistical objective of accurately estimating probabilistic relationships between data and parameters of interest. This approach enables inference directly from the full dimensionality of reconstruction-level data.

We implement NSBI to measure the CP structure of the top-Higgs coupling in a ttH and tH enriched signal region. This measurement is directly sensitive to a CP-odd top-Higgs coupling, which has not yet been experimentally excluded. It could provide direct evidence of physics beyond the Standard Model, potentially hinting at an explanation for the observed matter-antimatter asymmetry in the Universe.

The ttH and tH processes exhibit interference effects, leading to degenerate structures in conventional observables. These otherwise prohibitive features lend themselves well to the high-dimensional approach of NSBI. I will outline the methodology used to construct our likelihood ratio function and compare the resulting fits with an analysis that used physics-motivated observables and a conventional classifier.

T 98.3 Fri 9:30 KH 02.013

Searching for $H \to c\bar{c}$ in $t\bar{t}H$ production with the ATLAS detector — Diptaparna Biswas, Carolina Costa, Markus Cristinziani, Carmen Diez Pardos, Ivor Fleck, Gabriel Gomes, Jan Joachim Hahn, Nikolaos Kamaras, Vadim Kostyukhin, •Nils Benedikt Krengel, Austin Olson, Inês Pinto, Sebastian Rentschler, Elisabeth Schopf, Katharina Voss, Wolfgang Walkowiak, and Adam Warnerbring — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

Since the discovery of the Higgs boson in 2012, its couplings to other particles have been investigated extensively by the LHC experiments as key tests of the Standard Model. Significant effort is now directed toward measurements of the Yukawa couplings to second-generation fermions. The measurement of the charm-quark-Yukawa coupling with the ATLAS experiment is being expanded by an additional mode $t\bar{t}H(c\bar{c})$, in which a Higgs boson is produced in association with a top–antitop quark pair and decays into a charm–anticharm quark pair.

The experimental challenges of $t\bar{t}H(c\bar{c})$ lie in the efficient simultaneous identification of bottom and charm jets and the discrimination of signal from background processes. Especially in the all hadronic channel, the rejection of QCD multijet background is challenging, yet the addition of this channel, if feasible, can provide a significant boost to the sensitivity of the analysis. This presentation will showcase first investigations of the all-hadronic channel and how modern machine learning methods, such as transformers, can help overcome the experimental challenges.

T 98.4 Fri 9:45 KH 02.013

Search for $H \to c\bar{c}$ in the Vector Boson Fusion Channel with CMS Run-3 Data — •Jialiang Sun, Konstantinos Nikolopoulos, and Philipp Gadow — University of Hamburg, Hamburg, Germany

Quark Yukawa couplings to the Higgs boson have so far been experimentally established only for the third generation. Observation of Higgs decays to a charm quark-antiquark pair would provide direct access to the charm Yukawa coupling, testing the Higgs coupling to second-generation quarks and probing potential deviations from the Standard Model. Currently, the most stringent constraints on this coupling are obtained by searches for associated Higgs production with a vector boson or a top-quark pair. Further improvements are expected by combining these results with the vector boson fusion (VBF) production mode using Run-3 data. In this talk we present a sensitivity study of Higgs decays to a charm quark-antiquark pair in the VBF channel, using CMS proton-proton collision data collected in 2024 at a center-of-mass energy of 13.6 TeV. Backgrounds from QCD multijet production and Z/W+jets are estimated using data-driven methods. A boosted decision tree is trained to suppress the overwhelming QCD background, and a preliminary expected upper limit on the $H \to c\bar{c}$ signal strength is derived.

T 98.5 Fri 10:00 KH 02.013

Investigation of a boosted event topology in the search for the Higgs boson decay to a charm-anticharm pair in vector boson associated production mode at CMS in Run 3 — •Patrick Kersten, Alexander Schmidt, Andrey Pozdnyakov, Valentyn Vaulin, Pedro Gouveia Pinto Da Costa, Ishmeet Kaur Vohra, Jan Terörde, and Arnd Meyer — III. Physikalisches Institut A, RWTH Aachen University

The search for the Higgs boson decay into a charm-anticharm pair in events where the Higgs boson is produced in association with a W or Z boson is an important contribution to the aim of measuring the Higgs boson coupling to charm quarks. In addition to the so-called "resolved" event topology, the topology with highly energetic Higgs boson decays, resulting in a boosted event topology is explored. The potential improvement on the analysis sensitivity when adding the boosted topology is investigated. This talk presents the first expected results using early Run-3 data recorded by the CMS experiment focusing on the preliminary expected limits on the Higgs-charm coupling.

T 98.6 Fri 10:15 KH 02.013

Investigations on the κ_c/κ_b ratio measurement using Higgs boson decays to charm quarks in the vector boson associated production mode at CMS — •Jan Terörde, Alexander Schmidt, Andrey Pozdnyakov, Valentyn Vaulin, Patrick Kersten, Pedro Gouveia Pinto Da Costa, Ishmeet Kaur Vohra, and Arnd Meyer — III. Physikalisches Institut A, RWTH Aachen University

The associated production of a Higgs boson and a vector boson (Z or W boson), is one of the most promising channels in the search for the decay of the Higgs boson to charm (c) quarks. The simultaneous treatment of the H → cc and H → bb channels improves the overall sensitivity and enables to extract combined limits as well as to potentially constrain the κ_c/κ_b ratio. This contribution focuses on the κ_c/κ_b ratio measurement, the systematic uncertainties of the analysis and how these uncertainties affect the measurement of κ_c/κ_b.

T 99: Searches/BSM V

Time: Friday 9:00–10:30 Location: KH 02.014

T 99.1 Fri 9:00 KH 02.014

Next-to-Leading-Order QCD and EW Corrections to the Dark Matter Relic Density in the Framework of the CxSM — •Pavao Brica[1], Karim El Yaouti[1], Pedro Gabriel[2], Milada Margarete Mühlleitner[1], and Rui Santos[2] — [1]Karlsruher Institut für Technologie — [2]Universidade de Lisboa

This talk presents the computation of the next-to-leading-order (NLO) QCD and electroweak (EW) corrections to the annihilation of dark matter particles into the dominant final states, processes that play a key role in determining the dark matter relic density. The analysis is performed within the Complex Singlet Extension of the Standard Model (CxSM), which enlarges the Standard Model scalar sector by a complex singlet field and provides a viable dark matter candidate. The treatment of the ultraviolet (UV) and infrared (IR) divergences encountered in the calculation is briefly discussed. The relic density is evaluated at NLO accuracy, and the impact of the QCD and EW corrections on the final prediction is examined together with its phenomenological implications.

T 99.2 Fri 9:15 KH 02.014

Dark Matter phenomenology in an Effective Field Theory framework — •Maria Gonçalves[1,2], Margarete Mühlleitner[1], Rui Santos[2,3], and Tomás Trindade[2] — [1]Karlsruher Institut für Technologie - ITP, Karlsruhe, Germany — [2]Faculdade de Ciências da Universidade de Lisboa - CFTC, Lisboa, Portugal — [3]Instituto Politécnico de Lisboa - ISEL, Lisboa, Portugal

Dark matter (DM) remains one of the greatest mysteries in modern physics. From a particle physics perspective, effective field theories (EFTs) provide a powerful tool to explore possible extensions of the Standard Model (SM). In this work, we use current experimental data to constrain the coefficients of higher-dimensional operators in the EFT description. This approach allows us to identify promising directions for extending the SM to include viable DM candidates.

T 99.3 Fri 9:30 KH 02.014

AutomaticConstruction of Green's Bases for Effective Field Theories with AutoEFT — •Lars Bündgen[1], Robert Harlander[1], and Magnus Cornelius Schaaf[2] — [1]RWTH Aachen University, Germany — [2]Technical University of Munich, Germany

Effective field theories (EFTs) are an important tool in particle physics. They can be used both for describing the low-energy behavior of Standard Model processes, as well as for model-independent searches for BSM physics.

Working in an EFT requires a basis of independent operators. There are two types of bases: One is the on-shell basis, where each Wilson coefficient is an independent parameter to the observables. The other basis is one of independent Green's functions. It contains additional operators and is required for calculations such as renormalization and RGE evolution, which happen at the level of Green's functions.

In this talk I present a new version of the program AutoEFT that can construct both on-shell and Green's bases for EFTs. The algorithm supports EFTs with particles of spin 0 and spin 1/2, as well as gauge bosons of internal $SU(n)$ and $U(1)$ symmetries. A group-theoretical approach is used to determine the invariants of the Lorentz and gauge groups and to eliminate the redundancies between them.

Finally I will explore how a projection algorithm for EFT operators can be implemented. This is important because the choice of basis operators is arbitrary, so different authors may be using different bases for their calculations. A projection algorithm will facilitate the translations of results between different bases.

T 99.4 Fri 9:45 KH 02.014

New Physics Models in Recola2 — •Luis Miguel Marques Lourenco — JMU, Emil-Hilb-Weg 22, 97074 Würzburg

Our understanding of fundamental interactions depends on our ability to make high precision predictions for observables that can be compared with experimental measurements. After the Higgs discovery, the focus in elementary particle physics has shifted toward precision tests of the Standard Model (SM) and the search for possible extensions motivated by the unresolved shortcomings of the SM. Precise theoretical predictions for BSM scenarios are needed to interpret deviations and identify which model they might indicate.

In recent years, the automation of one-loop QCD and electroweak corrections has substantially improved our ability to produce such predictions across a wide range of models. Recola2 provides automated one-loop matrix elements, including QCD and EW corrections, in the SM as well as for several BSM scenarios. A central ingredient in this progress is the use of flexible universal model formats that can encode not only tree-level interactions but also the counterterm information needed for higher-order calculations. The UFO framework, and its extended version UFO2, provide a practical way to supply such information to modern matrix-element generators. In this talk, I will present a new UFO2 interface for Recola2, which translates the UFO2 files into Recola's Fortran model files. This tool will enable the use of Recola for external models that already include the necessary counterterms, and streamline the path from model building to more precise phenomenological studies, which will be the objective of future work.

T 99.5 Fri 10:00 KH 02.014

Simulation of Heavy Neutral Lepton production and decay with the Sherpa event generator. — •Antonia Bähr[1], Marzieh Bahmani[2], Michael Kobel[1], and Frank Siegert[1] — [1]IKTP, TU Dresden, Dresden, Germany — [2]HU Berlin, Berlin, Germany

Although the Standard Model has been proven to be a successful theory for explaining the fundamentals of particle physics, some question still remain unanswered: Contrary to its initial assumption, neutrinos have been shown to possess mass. However, their masses are much lighter ($m < 0.45$ eV) than those of all other fundamental fermions ($m \sim 0.5$ MeV $\ldots 0.2$ TeV).
There are numerous theories trying to explain these findings. In this talk, we focus on the type 1 see-saw mechanism, where heavy neutral leptons (HNLs) emerge as additional mostly right-handed mass eigenstates.
I will present the implementation of production and decay of HNLs, for masses of a few GeV at the LHC with Sherpa, a Monte Carlo event generator for the simulation of high-energy particle reactions. Besides validating the simulation results by comparing them to simulations done by Madgraph+Pythia, I will especially focus on the inclusion of semileptonic decay channels and the successful consideration of spin-correlation in the Sherpa simulations, which is not available for the other generators.

T 99.6 Fri 10:15 KH 02.014

On-the-fly reweighting for beyond Standard Model parameter variations in the Sherpa Event Generator — •Florens Förster and Frank Siegert — TUD Dresden University of Technology, Institute of Nuclear and Particle Physics

The research for Beyond the Standard Model physics relies on the study of different models containing higher dimensional operators. The effects of these models, which depend on certain model parameters, can be simulated, for example using the Sherpa event generator. Currently, the simulation with different parameters can only be done by changing their values manually and running the event generation once for each variation, which is neither user friendly nor particularly efficient.

In this study, the variation of model parameters is implemented within the Sherpa event generator using on-the-fly reweighting. This is supposed to save computational resources and make the usage of BSM Models easier in Sherpa. The newly implemented features are then tested and validated by studying the effects of BSM physics on certain scattering processes, particularly the electroweak $\gamma\gamma$jj production.

T 100: Miscellaneous

Time: Friday 9:00–9:45 Location: KH 02.016

T 100.1 Fri 9:00 KH 02.016

On a supplement to special relativity — •Fritz Riehle — Physikalisch Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

It is well known that the restricted orthochronous Lorentz transformations form a group which contain the ‘right’ symmetries (rotations and boosts) of special relativity. They represent direct isometries where not only the magnitude of every angle is preserved but also the sense of the angle (clockwise or counterclockwise). This group is a subgroup in the Poincaré group containing all isometries of Minkowski space. We found that the transformations associated with the derived energy-momentum relationship in Einstein’s basement [1] correspond to reflections in velocity space. We investigate how these transformations can be identified with opposite isometries and discuss some of their consequences.

[1] Fritz Riehle and Sebastian Ulbricht, arXiv:2402.13679 [gr-qc]

T 100.2 Fri 9:15 KH 02.016

The mass quantum and the upper limit of particle masses — •Herrmann Hans-Dieter — Berlin

A particle model is proposed living in a circular extra space, called basic space. The particle mass has two sources: The rotational energy of circulating mass quanta and the Coulomb self-energy of circulating elementary charges. The hadron models contain mass quanta enhanced by circulating charge clusters. This allows to calculate particle masses up to the TeV region, however, such particles are not realized in nature. A predicted parton mass at 1.5 TeV could not be found experimentally. The top quark seem to represent the highest model mass realized in nature. Models of the Z and Higgs bosons could not be achieved using the regular model formulas. One obtains plausible models of the bosons only by assuming a cluster splitting from 48 charges per cluster into 2 x 24 or into 3 x 16 charges. We conclude, that masses above the mass of the top quark are not realized. We predict an upper limit of particle masses near the mass of toponium, at around 400 GeV. The planning of future experiments should be focused on particles already discovered such as neutrinos, the Z and the Higgs boson. Possibly the TeV region could be empty of particles. An overview on the dual space concept is given in https://tonsa.de/

T 100.3 Fri 9:30 KH 02.016

Particle QM results are improved by a classical model — •Albrecht Giese — Taxusweg 15, 22605 Hamburg

Quantum mechanics is widely accepted as the correct approach to understanding elementary particles. However, a classical model can provide improved results, including quantitative ones, where QM cannot. Take inertial mass, for example. Here, the classical model is physically more meaningful and produces accurate results, unlike the Higgs model. Another example of the limits of QM is the inadequate definition of the Planck constant, ’h’, which leads to measurement deviations. In the history of QM, these deviations have been explained by the introduction of vacuum polarization. However, this is not necessary if ’h’ is defined as derived from the model. This also circumvents the inherent problems of vacuum polarization/energy.

For details: www.ag-physics.org/rmass

T 101: Searches/BSM VI

Time: Friday 9:00–10:30 Location: KH 02.018

T 101.1 Fri 9:00 KH 02.018

Search for X → HY production in bb$\tau\tau$ final states at the CMS experiment — •Moritz Molch[1], Ulrich Husemann[2], Nikita Shadskiy[1], Nicolò Trevisani[1], and Roger Wolf[1] — [1]Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT) — [2]Deutsches Elektronen-Synchrotron (DESY), Hamburg

Extensions of the Standard Model (SM), like the Next-to-Minimal Supersymmetric Standard Model (NMSSM), introduce additional Higgs bosons in addition to the SM Higgs boson H. This talk presents a search for the resonant decay of a heavier scalar particle X into a lighter resonance Y and H at the CMS experiment, using data from the LHC Run 3. The analysis considers final states, in which either the Y or the H boson decays into a pair of bottom quarks, and the other one into a pair of τ leptons. Backgrounds from jets which are misidentified as hadronic τ lepton decays (τ_h) pose a challenge in this search as they are difficult to model in simulation. Therefore, data-driven techniques are used to control these backgrounds. For signal extraction, a parametric deep neural network is used, which enables the treatment of all signal hypotheses with a single neural network at once. Expected upper limits on the signal cross sections times branching fractions are presented to quantify the sensitivity of this search in the parameter space spanned by the unknown masses of the X and Y bosons.

T 101.2 Fri 9:15 KH 02.018

Studies towards a search for heavy resonances X→YH→t$\bar{t}$b$\bar{b}$ in the single-lepton final state with CMS — •Syed Sajal Hasan, Matteo Bonanomi, Mathis Frahm, Johannes Haller, Lara Sophie Markus, and Matthias Schröder — Institut für Experimentalphysik, Universität Hamburg

Many theories of physics beyond the Standard Model (SM) predict additional heavy particles, such as new scalars in extended Higgs sectors. In this study, we explore a generic scenario in which a heavy resonance X decays into a lighter new particle Y and a SM-like Higgs boson (H), X→YH, followed by Y→t$\bar{t}$ and H→b$\bar{b}$ decays. This cascade topology has not yet been probed at the LHC. The analysis uses simulated CMS data at a centre-of-mass energy of 13.6 TeV and targets events with a single isolated lepton and multiple jets. Candidate events are selected based on jet and b-tagged-jet multiplicities, and a neural network classifier is employed to enhance the separation between signal and SM backgrounds. Expected exclusion limits are presented as a function of the masses of X and Y for the signal production cross-section.

T 101.3 Fri 9:30 KH 02.018

Probing Dark Matter via the mono-Higgs signature in the $\tau^+\tau^-$ final state with the ATLAS detector — •Athul Dev Sudhakar Ponnu and Stan Lai — II. Physikalisches Institut, Georg-August-Universität Göttingen

This analysis searches for physics beyond the Standard Model using the mono-Higgs signature, in which a Higgs boson decaying to a pair of tau leptons ($H \to \tau^+\tau^-$) recoils against significant missing transverse momentum ($E_\mathrm{T}^\mathrm{miss}$). This event topology provides a sensitive and direct probe of the dark-matter sector. The results can be interpreted within the framework of the Two Higgs Doublet Model extended by a pseudoscalar mediator (2HDM + a), considering both Type-I and Type-II Yukawa coupling scenarios.

The analysis focuses on the $\tau_\mathrm{had}\tau_\mathrm{had}$ and $\tau_\mathrm{lep}\tau_\mathrm{had}$ final states using $\sqrt{s}$ = 13.6 TeV collision data. Monte Carlo samples of $t\bar{t}$, single-top, diboson, W/Z+jets, and Higgs processes are used to model the Standard Model backgrounds, while dedicated signal samples spanning multiple mass hypotheses are employed to assess sensitivity to new physics. The early stages of the study, including data-MC agreement checks and multivariate analysis training, are presented in this talk.

T 101.4 Fri 9:45 KH 02.018

Search for an Intermediate-Mass Higgs Boson in the $\tau + \tau$ Channel with Run 2 Data — •Luka Vomberg[1], Christian Grefe[2], Philip Bechtle[1], and Klaus Desch[1] — [1]Physikalisches Institut Bonn, Käthe-Kümmel-Str. — [2]1, Esplanade des Particules, Meyrin, Switzerland

A search for additional Higgs bosons decaying to $\tau + \tau$ in the intermediate mass range, as motivated by extended Higgs sector models such as the 2HDM, is presented. The analysis targets the $\tau_{had} + \tau_{had}$ and $\tau_{lep} + \tau_{had}$ final states and considers both ggF and VBF production modes. Limits are derived on the production cross-section times branching ratio, following a model-independent approach.

This is the first ATLAS analysis probing the 80 GeV to 200 GeV mass range in the $\tau\tau$ final state using full Run 2 data, complementing existing high-mass searches. This analysis is a re-interpretation of the standard model $H \to \tau\tau$ cross section measurement.

Preparations for a follow up analysis using run 3 data are ongoing, with the primary focus on improving suppression of the dominant $Z \to \tau\tau$ background using spin sensitive observables to increase sensitivity in the low-mass region, as well as including effects of interference near the Z-pole.

T 101.5 Fri 10:00 KH 02.018

Exploring boosted top quark decays using Run 3 data collected by the CMS experiment — •Johanna Matthiesen[1], Johannes Haller[1], Roman Kogler[2], and Daniel Savoiu[1] — [1]Institut für Experimentalphysik, Universität Hamburg — [2]DESY, Hamburg

Highly energetic top quarks produced in proton-proton collisions at the LHC can result in decay products that are highly collimated, appearing as a single large-radius jet in the CMS detector. These jets exhibit a distinctive internal substructure, enabling discrimination between top quark jets and those arising from other QCD processes. This boosted topology offers a unique opportunity to probe for new heavy particles decaying into top-antitop quark pairs. This presentation provides first insights from the ongoing data taking at the LHC, focusing on the top-antitop quark mass spectrum as a potential window to new physics phenomena with a focus on heavy Z′ bosons. The analysis strategy as well as first results will be presented.

T 101.6 Fri 10:15 KH 02.018

Anomaly detection for multi-jet resonances. — •Chitrakshee Yede, Louis Moureaux, Gregor Kasieczka, and Tore von Schwartz — University of Hamburg, Hamburg, Germany

The search for physics beyond the standard model is one of the main focuses in high-energy physics. Conventional searches at the LHC, though comprehensive, have not yet shown signs for new physics. Machine learning based anomaly detection has emerged as a powerful tool to widen the discovery horizon, offering a model-agnostic path as a way to enhance the sensitivity of generic searches as compared to those targeting specific signal models. CATHODE (Classifying Anomalies THrough Outer Density Estimation), one of these methods, is a two-step method that combines a data driven background estimation with a classifier flagging potential signal. To date, most studies have mainly focused on dijet resonances. In this work, we explore signals with multiple decays modes, leading to a more challenging detection scenario. We present the first application of CATHODE to multi-jet resonances, which enhance the sensitivity beyond the dijet regime and increase the robustness of weakly supervised anomaly detection, thereby broadening its applicability.

T 102: Axions/ALPs III

Time: Friday 9:00–10:30 Location: KH 02.019

T 102.1 Fri 9:00 KH 02.019

X-ray Telescopes for Axion Searches — •Francisco Rodríguez Candón — Fakultät für Physik, TU Dortmund, Otto-Hahn-Str. 4, 44221 Dortmund, Germany

X-ray telescopes have become powerful tools in the search for weakly interacting slim particles (WISPs), in particular QCD axions and axion-like particles (ALPs). Through the Primakoff effect, astrophysical magnetic fields can induce axion-photon conversion, giving X-ray observatories unique sensitivity over a broad axion-mass range. This talk reviews recent progress in ALPs searches with NASA's NuSTAR, the first and currently only focusing hard X-ray space telescope. First, observations of the starburst galaxy M82 yield stringent constraints on heavy decaying ALPs in the 30-500 keV range, probing axion-photon couplings in previously unexplored regions of parameter space. Second, NuSTAR observations of the red supergiant Betelgeuse set new and competitive limits on axion-nucleon couplings for masses below the neV, exploiting axion production via nuclear transitions in stellar interiors. Together, these results improve upon earlier astrophysical bounds and motivate future X-ray space missions such as Athena and AXIS, which are expected to extend sensitivity to even fainter axion signatures.

T 102.2 Fri 9:15 KH 02.019

Axion searches with LOFAR — •Merle Gizinski and Dominik J. Schwarz — Fakultät für Physik, Universität Bielefeld, 33613 Bielefeld

The axion is a promising candidate for cold dark matter, originating as a solution to the strong CP problem. The search for axions in neutron star magnetospheres provides a promising opportunity for detection and is complementary to existing laboratory experiments. The plasma surrounding of a neutron star and its strong magnetic field provide the environment for an axion to convert into a photon. This conversion results in a characteristic, sharp radio line, which may be detectable in the spectrum of the neutron star. The observed frequency of the line is directly linked to the axion mass. Since frequencies below 250 MHz are very hard to access in lab experiments and thus have not been tested, LOFAR (10 – 240 MHz) provides an unique opportunity to constrain the axion to photon coupling in the axion mass range $0.04 - 0.99\,\mu$eV.

T 102.3 Fri 9:30 KH 02.019

Tuning structure of a dielectric haloscope for axion dark matter detection, MADMAX — •Dominik Bergermann for the MADMAX-Collaboration — III. Physikalisches Institut A, RWTH Aachen University

Axions are promising candidates for cold dark matter and the absence of CP violation in strong interaction. The **MA**gnetized **D**isc and **M**irror **A**xion e**X**periment is a future dielectric haloscope experiment targeting axion dark matter in a mass range of 40 to 400 μeV. It consists of multiple, consecutive and movable dielectric discs to amplify the weak microwave signal of axion photon conversion in a strong magnetic field.

Covering this range with a single experimental setup, while simultaneously being able to finetune the resonance on potential signals, necessitates repositioning the experimental hardware continuously and automatically. The disc positions as parameter-space can be tuned to produce desired signal shapes, with reliably achieving sub 10 μm accuracy as the prime challenge. All respective hardware is required to be compatible with the high magnetic field strengths, vacuum and cryogenic temperatures.

This talk presents the piezo-motor driven MADMAX disc assembly and its control system, with the first results on disc positioning accuracy.

T 102.4 Fri 9:45 KH 02.019

MADMAX Open Booster 300 Receiver Chain and Power Calibration — •Alan Aliyali for the MADMAX-Collaboration — Insitut für Experimentalphysik, Universität Hamburg, Deutschland

Originally proposed to solve the strong CP problem of QCD, the axion is also a prominent candidate for cold dark matter. Using the axion-to-photon conversion inside a magnetic field, the MAgnetized Disk and Mirror Axion eXperiment aims to probe the axion mass range of 40 to 400 μeV, corresponding to microwaves in the 10 to 100 GHz range. MADMAX makes use of a so-called booster, a series of dielectric disks placed in front of a metallic mirror, to resonantly enhance the expected axion signal over a frequency range adjustable via the spacing of the disks.

The Open Booster 300 is a booster configuration consisting of an aluminum mirror and three sapphire discs, all with a 300 mm diameter. In this configuration, the axion induced current excites gaussian modes that gets measured by a corrugated horn antenna. The resulting signal is amplified and filtered by a low-noise receiver chain, down-converted using heterodyne detection, and digitized by an ADC performing real-time FFTs from which power spectra are recorded.

Accurate measurements of the signal requires precise characterization of the entire receiver chain. In this presentation we show how the receiver chain is calibrated using the Y-factor method to determine the frequency dependent gain and noise temperature.

T 102.5 Fri 10:00 KH 02.019

3D simulations of a dielectric haloscope for axion dark matter detection, MADMAX — •Sebastian Baltschun for the

MADMAX-Collaboration — III. Physikalisches Institut A, RWTH Aachen University

Axions are promising candidates for cold dark matter and the absence of CP violation in strong interaction. The MAgnetized Disc and Mirror Axion eXperiment is a planned dielectric haloscope experiment targeting axion dark matter in a mass range of 40 to 400 micro eV. It consists of multiple, consecutive and movable dielectric discs to amplify the weak microwave signal of axion photon conversion in a strong magnetic field.

This talk discusses the 3D simulation used to calculate the amplification factor of a certain disk configuration and differences between a narrowband scan and a broadband scan, two different strategies towards positioning disks.

T 102.6 Fri 10:15 KH 02.019

Development of a radiopure GridPix detector for BabyIAXO — •Johanna von Oy, Klaus Desch, Jochen Kaminski, and Tobias Schiffer — Physikalisches Institut der Universität Bonn

BabyIAXO is the intermediate stage experiment of the International AXion Observatory (IAXO), a next generation helioscope for the search for axions. BabyIAXO is planned to be built at DESY in Hamburg, and its components are currently under construction. Helioscopes consist of a magnet, where solar axions can convert into X-ray photons, optics to focus the X-rays and detectors to detect them.

Due to the existing stringent limits on the axion-photon coupling, the probability of an axion-induced X-ray reaching the detector is low. Therefore, all detectors built for IAXO and BabyIAXO have to have a low intrinsic background and be combined with active and passive shielding.

A detector technology that is suitable to detect X-rays in the energy range of different solar axion models is a GridPix detector. It is a gas-filled detector with an aluminium grid on top of a pixelated readout chip, which can detect individual electrons produced by particles in the gas. This detector can be constructed in a relatively radiopure form as most of its components can be made out of very pure copper, Teflon and Kapton.

The detector is currently in the assembly and commissioning phase, with the radiopure components having been produced last year. This talk will focus on the developments and steps necessary to reach the background levels required for BabyIAXO.

T 103: Search for Dark Matter IV

Time: Friday 9:00–10:15 Location: AM 00.014

T 103.1 Fri 9:00 AM 00.014

Simulations of the MainzTPC2 to observe the Migdal effect — •Peter Gyorgy, Alexander Deisting, Christopher Hils, Johannes Merz, Uwe Oberlack, and Constantin Szyszka — Johannes Gutenberg-Universität Mainz, Institut für Physik & Exzellenzcluster PRISMA+

The MainzTPC2 is a small-scale dual-phase xenon time projection chamber (TPC), destined to make a measurement that could prove the Migdal effect for Xe atoms. The Migdal effect manifests in the form of an additional electron recoil signature paired with the typical nuclear recoil signal that an elastic scatter e.g. a neutron or WIMP produces. For large dual-phase TPCs — like XENONnT, XLZD — this effect would decrease their detection threshold, extending their sensitivity to lower dark matter masses.

To ensure the success of the experiment, a detailed simulation must be made of the MainzTPC2. This requires extensive modeling and simulations in GEANT4, including neutron scattering, detector effects, optical physics, position reconstruction, and a Migdal signal model.

The measurement itself is expected to take place at the CN facility at LNL, Italy, in the form of neutrons from a beam undergoing an elastic backscatter off the TPC into a secondary scintillator detector. As such, beam characteristics and neutron flight paths must also be modeled. The use of data quality cuts such as time-of-flight and neutron multi-scatter is expected to reduce the background sufficiently to obtain a clear population of Migdal events in their region of interest. This presentation will summarize results from this simulation process.

T 103.2 Fri 9:15 AM 00.014

Results of a Cryogenic Multi-Channel 4π Veto Module in the CRESST Experiment — •Àfrica González Pedraza for the CRESST-Collaboration — Technical University of Munich, Garching

CRESST is a cryogenic experiment searching for sub-GeV dark matter via direct scattering off a target crystal's nucleus. The resulting energy transfer causes a nuclear recoil that increases the target's temperature, measured by a Transition-Edge Sensor (TES) enabling energy thresholds of O(10 eV).

Currently, one of the main sensitivity limitations is an unexpected rise in the event rate below 200 eV, known as the Low-Energy Excess (LEE). One of the leading hypotheses attributes the LEE to mechanical stress stored at material interfaces. To investigate the holder-induced stress component, CRESST employs a dedicated three-channel module that integrates an instrumented holder and a beaker-shaped, large-coverage light detector in addition to the standard CRESST detector configuration.

To precisely characterize the detector response to sub-keV nuclear recoils, the signature of dark matter, CRESST is transitioning to a novel calibration method based on thermal neutron capture, which has the additional advantage of not increasing the backgrounds outside the dedicated calibration campaigns.

This talk presents the latest results from the CRESST beaker module operated at LNGS on the LEE and demonstrates that low-energy nuclear-recoil calibration is achievable in CRESST sapphire detectors.

T 103.3 Fri 9:30 AM 00.014

Fast Template-Based Inference via Conditional Normalizing Flows for XENONnT — •Johannes Merz for the XENON-Collaboration — Institut für Physik & Exzellenzcluster PRISMA^{++}, Johannes Gutenberg-Universität Mainz

Template-based likelihood analysis is a cornerstone of the inference in the XENONnT experiment. It's limited in computational efficiency and flexibility by its reliance on histogram based templates. In this talk, we present a fast inference approach that replaces traditional templates with continuous, differentiable models based on conditional normalizing flows. The models provide an accurate representation of detector response distributions while enabling efficient likelihood evaluation. This significantly accelerates and simplifies parameter inference across the parameter spaces. Our results demonstrate that normalizing flow based templates offer a scalable and efficient alternative to classical template methods for XENONnT.

T 103.4 Fri 9:45 AM 00.014

Status of large-area cryogenic microcalorimeter (LAMCAL) development for DELight — •Lena Hauswald[1], Christian Jeup[1], Friedrich Wagner[1], and Sebastian Kempf[1,2] — [1]Institute of Micro- and Nanoelectronic Systems, Karlsruhe Institute of Technology (KIT), Germany. — [2]Institute for Data Processing and Electronics, Karlsruhe Institute of Technology (KIT), Germany.

The Direct Search Experiment for Light Dark Matter (DELight) is a pioneering initiative aimed at probing light dark matter (LDM). By utilizing superfluid ^{4}He as target material, DELight will enable the exploration of weakly interacting DM candidates with masses notably below $100\,\mathrm{MeV/c^2}$. To achieve the required detector sensitivity for resolving the various signal channels of the superfluid, both in terms of time and energy resolution, DELight focuses on the development of large-area cryogenic microcalorimeters (LAMCALs) based on magnetic microcalorimeter (MMC) technology.

In contrast to state-of-the-art MMCs, each LAMCAL will be operated as athermal phonon detector. Here, the energy of athermal phonons generated by a energy deposit and propagating ballistically within the absorber is converted into a temperature rise of the paramagnetic temperature sensor via Al-based superconducting phonon collectors. Consequently, the signal rise time is governed by the phonon collection time, while the absorber heat capacity becomes negligible to first order, enabling excellent energy resolution. This contribution presents the current status of LAMCAL development for DELight, highlighting their potential and the challenges encountered to date.

T 103.5 Fri 10:00 AM 00.014

Signal Processing and Machine Learning for Light Dark Matter Detection in DELight — •Dowling Wong for the DELight-Collaboration — KIT, Karlsruhe, DE

The parameter space for dark matter below a few hundred MeV remains largely unexplored, motivating detectors with ultra-low energy thresholds. The DELight experiment aims to directly detect light dark matter using superfluid helium-4 instrumented with about 60 large-area microcalorimeters (LAMCALs) based on magnetic microcalorimeter (MMC) technology. Each LAMCAL achieves an eV-scale energy resolution, yielding a nuclear-recoil threshold around 10 eV. To further lower the threshold, robust and noise-aware reconstruction across the multi-channel readout is essential. I present a unified signal-processing and machine-learning framework developed for DELight. At the waveform level, we implement optimal filtering and principal component analysis estimators tuned to measured pulse shapes with noise spectra captured under preliminary operating conditions in the DELight LAMCALs. With physics-informed features, we develop a transformer-based attention architecture that captures inter-channel correlations to improve event reconstruction, while exploring data-driven filters to suppress non-stationary system noise and enhance sensitivity near threshold. I will discuss the architecture of the reconstruction pipeline and its performance on simulated and calibration R&D data, with a focus on trigger efficiency in offline scans. This work is supported by the Heidelberg Karlsruhe Strategic Partnership (HEiKA STAR), with personnel funded by the Alexander von Humboldt Foundation.

T 104: Neutrino Astronomy V

Time: Friday 9:00–10:30 Location: KS H C

T 104.1 Fri 9:00 KS H C

Searching for Periodic Neutrino Emission from Pulsars with KM3NeT — •Robert Petri, Thomas Eberl, and Rodrigo Gracia-Ruiz for the KM3NET-ERLANGEN-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP) Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

Neutrino observatories such as KM3NeT enable exploratory searches in the time domain. In this feasibility study, we investigate whether the count rates of the photo-sensors, induced by optical background and potentially by low-energy neutrinos in the GeV range, can be used to probe periodic neutrino emission through precise timing alone. Following up on recent suggestions for neutrino emission scenarios, we investigate promising pulsars and develop an analysis pipeline. The pipeline includes a barycentric time correction and focuses on a Fast Fourier Transform approach to search for a count rate excess with the pulsar spin frequency. The contribution demonstrates the potential and limitations of periodicity searches and evaluates the sensitivity of KM3NeT to derive meaningful constraints on temporally modulated neutrino sources.

T 104.2 Fri 9:15 KS H C

Simulation Studies for Characterization of a Calibration Device for the IceCube Upgrade — •Selina Rudolph for the IceCube-Collaboration — Technical University of Munich (TUM)

The IceCube neutrino observatory at the geographic South Pole has officially begun its Upgrade campaign after successfully operating for over ten years. In addition to the existing 86 strings instrumented with over 5,000 photosensors, the IceCube Collaboration will deploy seven new strings. The Upgrade focuses on improving the lower-energy regime and sensitivity to neutrino oscillation parameters, as well as enhancing the recalibration of the gigaton glacial ice detector medium. One of the instruments deployed in the campaign is the Precision Optical Calibration Module (POCAM), which was developed and assembled at Technical University of Munich (TUM). Over 20 next-generation POCAMs will be utilized to further reduce existing detector systematics. This talk provides an overview of the simulation efforts, specifically for a series of special operations carried out during the installation. These Monte Carlo simulation studies are conducted to predict the POCAM's ability to characterize certain ice parameters, which are crucial for calibration and analysis studies.

T 104.3 Fri 9:30 KS H C

Improving tau neutrino reconstruction and identification with the IceCube Upgrade — •Despoina Mousadi for the IceCube-Collaboration — Deutsches Elektronen Synchrotron (DESY) Zeuthen — Friedrich-Alexander-Universität (FAU) Erlangen-Nürnberg

The IceCube Neutrino Observatory is a 1km3 neutrino detector located at the South Pole. It consists of optical modules which can detect Cherenkov light from charged neutrino interaction products in the Antarctic ice. Measuring the flavor composition of astrophysical neutrinos on Earth can give significant insight in their production mechanisms. However, even though tau neutrinos exhibit a unique double cascade (*double bang*) signature which cannot be attributed to the other two neutrino flavors, identifying these signatures remains the most challenging, with only few such events confidently identified so far. This is mainly due to the contrast between the large distance between sensors and the usually short tau decay length, but is also in part caused by limitations in modeling of the surrounding ice and reconstruction algorithm. Starting its operation in 2026, the IceCube Upgrade will provide new possibilities to improve tau neutrino reconstruction and identification, with more densely packed multi-PMT modules containing calibration devices which enable the creation of artificial *double bang* events. Such events can serve as benchmarks for validation of ice models and reconstruction methods, paving the way for improved tau neutrino identification and for better understanding of the underlying physics.

T 104.4 Fri 9:45 KS H C

Search for the DSNB in JUNO: Development of new Methods for Background Event Identification — •Matthias Mayer, Ulrike Fahrendholz, Shijiao Gao, Meishu Lu, Lothar Oberauer, Stefan Schönert, and Armin Siebert — School of Natural Science, TU München, James-Franck-Str. 1, 85748 Garching b. München

The diffuse supernova neutrino background (DSNB) describes the constant flux of neutrinos from past core-collapse supernovae over the entire visible universe. The Jiangmen Underground Neutrino Observatory (JUNO), a 20 kton liquid scintillator detector currently plans to observe the DSNB through the inverse beta decay (IBD) detection channel. While other $\bar{\nu}_e$ sources will cause irreducible IBD background, we aim to use various pulse-shape discrimination (PSD) techniques to reduce non-IBD backgrounds such as muon-induced fast neutrons and NC interactions of atmospheric neutrinos. For this talk, we compare the performance of different PSD techniques for the DSNB search and discuss our recent measurements towards the energy dependence of the neutron flourescence time profile in the JUNO scintillator. Given the current release of JUNO's first physics results and detector performance, we will also include a preliminary analysis using JUNO real data for background estimation in the region of interest (ROI) of DSNB. Besides, we will give an outlook into our upcoming publication discussing the JUNO detection potential for different DSNB models. This work has been supported by the Cluster of Excellence ORIGINS as well as the DFG Collaborative Research Center "NDM" (SFB1258) and the DFG Research Units 2319 and 5519.

T 104.5 Fri 10:00 KS H C

Background estimation for CC-Supernova neutrino searches in JUNO — •Tobias Kramer, Thilo Birkenfeld, Achim Stahl, and Christopher Wiebusch — III. Physikalisches Institut B, RWTH Aachen

The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kt liquid scintillator detector, which started data taking in August 2025. Its large target mass is well-suited for Core-Collapse Supernova (CC-SN) neutrino detection. Our goal is to identify individual CC-SN bursts up to nearby extragalactic distances, since galactic CC-SNe are rare events; the only CC-SN observed via neutrinos was almost 40 years ago in 1987. The search for distant CC-SNe requires optimized background suppression in the relevant supernova neutrino energy range, where the main detection channel is the inverse beta decay (IBD). In this talk, a general strategy for background estimation and suppression, and its impact on the distant CC-SNe search in JUNO, is discussed.

T 104.6 Fri 10:15 KS H C

Expanding Stochastic Acceleration in the AGN Corona — •Marc Hubert[1,2], Björn Eichmann[1,2], and Julia Becker Tjus[1,2,3] — [1]Theoretical Physics IV: Plasma Astroparticle Physics, Ruhr University Bochum, Germany — [2]RAPP Center, Bochum, Germany — [3]Department of Space, Earth and Environment, Chalmers University of Technology, Gothenburg, Sweden

In the field of astroparticle physics, understanding the mechanisms responsible for the acceleration of charged particles in astrophysical environments is of central interest. The so-called Fermi-II process describes stochastic acceleration in turbulent magnetic fields. Previous studies have presented a semianalytical solution of the isotropic steady-state momentum-diffusion equation that includes continuous and catastrophic momentum changes for weak magnetic turbulence constrained to a finite range. Within this framework, the solution is valid only in the momentum interval in which interactions with the turbulence occur. In my master thesis, I aim to extend this framework to lower momenta and to investigate how pre-acceleration processes, e.g. magnetic reconnection, affect the resulting particle spectra. Furthermore, I apply the extended model to the AGN corona in NGC 1068 and examine the compatibility of the predicted neutrino flux with current observations. In this talk, I present first results, including the extension to lower momenta and the influence of pre-acceleration processes.

T 105: Methods in Astroparticle Physics V

Time: Friday 9:00–10:30 Location: KS 00.004

T 105.1 Fri 9:00 KS 00.004

Neutron Detection with Gadolinium-loaded water based liquid scintillator — •Amala Augusthy, Noah Goehlke, Johann Martyn, Philipp Kern, and Michael Wurm — JGU Mainz

ANNIE is an accelerator neutrino experiment at the Booster Neutrino Beam at Fermilab. It is a 26-ton Gadolinium-loaded water Cherenkov detector designed to measure CC interaction cross-sections and neutron multiplicity. In addition, ANNIE serves as a testbed for novel detector technologies amongst which is Water-based Liquid Scintillator (WbLS). WbLS is a novel detection medium that allows the simultaneous detection of scintillation and Cherenkov light. To test the detection capabilities with WbLS, a 366 L cylindrical vessel, filled with Gadolinium (Gd) loaded WbLS, dubbed SANDI was deployed in ANNIE in fall 2024. The energy carried away by final-state neutrons is a major source of systematic uncertainty in long baseline neutrino oscillation experiments, hence it is very important to tag neutrons efficiently. To investigate neutron detection efficiency in Gd-WbLS, an AmBe source was deployed. Extracting the neutron detection efficiency requires a well-tuned Monte Carlo simulation. This talk presents an overview of the ongoing Monte Carlo tuning efforts aimed at quantifying the neutron detection efficiency in Gd-loaded WbLS.

T 105.2 Fri 9:15 KS 00.004

A high-precision nuclear recoil calibration facility at the TU Wien TRIGA reactor — •Andreas Erhart — Technische Universität München, München, Deutschland

Cryogenic calorimeters are a key technology for experiments aiming to measure coherent neutrino-nucleus scattering at the low-energy frontier or to directly search for sub-GeV dark matter particles. A detailed understanding of the detector response at the 100 eV scale is hereby indispensable. The CRAB collaboration has developed a novel, direct and model-independent calibration method based on nuclear recoils induced by the radiative capture of thermal neutrons. Following a successful feasibility study at TU München, where CRAB achieved the first observation of a monoenergetic peak at 112.5 eV from ^{182}W recoils and the observation of two ^{27}Al nuclear recoil peaks at 575 eV and 1145 eV, respectively, the project now enters its high-precision phase.

For this purpose, a dedicated calibration facility has been established at the TU Wien TRIGA reactor, providing a pure, low-intensity thermal neutron beam to the target detectors mounted inside a wet dilution refrigerator. Stable cryostat operation on a month-scale and excellent detector energy resolution below 5 eV have since been demonstrated. These results enable high-statistics calibration measurements of various detector materials such as $CaWO_4$, Al_2O_3, germanium and silicon in the near future, and open the prospect of an extensive associated physics program.

T 105.3 Fri 9:30 KS 00.004

Implementation of a Bi-Po Coincidence Cherenkov Source for Hybrid Calibration in JUNO — •Manuel Böhles[1], Marcel Büchner[1], Tim Charissé[1], Arshak Jafar[1], Meishu Lu[2], Johann Martyn[1], Oliver Pilarczyk[1], Hans Steiger[2], and Michael Wurm[1] — [1]Johannes Gutenberg University Mainz, Institute for Physics, 55128 Mainz, Germany — [2]Technical University of Munich, School of Natural Sciences, 85748 Garching, Germany

Hybrid Cherenkov/scintillation analyses in the JUNO experiment require dedicated calibration tools to improve event identification and background suppression. A precise characterization of Cherenkov light and its separation from scintillation light is essential for enhancing the sensitivity to rare event searches. A compact Cherenkov calibration source based on MeV-scale beta electrons and a delayed coincidence trigger has been designed and realized. The source is loaded with Th-228, providing Bi-Po-212 decay sequences with a well-defined time correlation. The prompt beta decay produces Cherenkov light, while the subsequent alpha decay generates a scintillation signal in a fast plastic scintillator, enabling efficient event tagging. Laboratory tests are underway, and deployment in the OSIRIS pre-detector is planned prior to JUNO calibration campaigns. These measurements will support hybrid Cherenkov/scintillation analyses in JUNO with enhanced sensitivity to solar neutrinos, searches for the Diffuse Supernova Neutrino Background (DSNB), and potential future neutrinoless double beta decay ($0\nu\beta\beta$) studies. The development is funded by the DFG Research Unit "JUNO" (FOR 5519).

T 105.4 Fri 9:45 KS 00.004

Calibration and Long-term Monitoring for IceCube Upgrade mDOMs without Artificial Light Sources — •Carolin Klein and Summer Blot — DESY, Zeuthen, Germany

Since 2011, the IceCube Neutrino Observatory has yielded important results in neutrino astronomy and neutrino physics. The IceCube Upgrade expands this detector. A higher photomultiplier (PMT) density decreases the energy threshold of the experiment, enabling more detailed studies of atmospheric neutrino oscillations at the GeV scale. Current calibration routines of the multi-PMT digital optical module (mDOM) included in the IceCube Upgrade require artificial light produced by LEDs. In this talk, calibration methods without such light sources are presented, enabling calibration even in the case of an LED dysfunction. The calibration of the PMT gain and mainboard electronics is instead performed using dark noise, mainly induced by radioactive decays in the glass components of the module. The dark noise based methods can also be used in-situ for long-term monitoring of the calibrated properties during detector up-time. A long-term monitoring test stand based on these approaches was setup and operated in a laboratory. The goal is to assess the stability of calibration constants and mDOM performance over time in a well-controlled laboratory environment. In this talk, the first results of these measurements will be presented.

T 105.5 Fri 10:00 KS 00.004

The IceAct PiRATE: A Realtime Snow Accumulation Monitoring and Telescope Calibration System — •Lars Heuermann, Oliver Bosch, Cem Güer, Jan Nicklaus, Andreas Nöll, Jochen Steinmann, Christopher Wiebusch, and Simon Zierke — RWTH Aachen - III. physikalisches Institut B, Aachen, Germany

IceAct is an array of Imaging Air Cherenkov Telescopes located on the ice-surface of the IceCube Neutrino Observatory. It aims to calibrate IceTop and the in-ice detector, improve cosmic-ray composition studies, and potentially enhance IceCube's veto capability for atmospheric neutrinos. The telescope design is optimized to be cost-efficient and to operate reliably in the harsh environmental conditions of the South Pole. This is achieved by a Fresnel-lens-based optics and a camera with 61 SiPMs, resulting in a total field of view of 12 degrees per telescope. For stable operation, it is also important to monitor the changing environmental conditions. The Raspberry Pi-based Real-time snow Accumulation monitoring and Telescope calibration Enhancement (Pi-

RATE) has been developed for this purpose. It features a nanosecond LED light pulser for in-situ camera calibration and a CCD-camera-based snow monitoring system, mounted inside the telescope. The PiRATE is designed to operate at extreme cold temperatures and with minimized emission of electromagnetic interference in the radio band. This talk will present the current status of the PiRATE, report on integration, function, and performance tests, as well as give an outlook on the future deployment at the South Pole.

T 105.6 Fri 10:15 KS 00.004

Optical calibration of the ice stratigraphy logger in the IceCube Upgrade — •Andrei Chubarov, Anna Eimer, and Martin Rongen for the IceCube-Collaboration — Erlangen Center for Astroparticle Physics (ECAP)

The IceCube Neutrino Observatory, deployed in the Antarctic glacier, detects atmospheric and astrophysical neutrinos using Cherenkov radiation from secondary charged particles. Limited knowledge of the ice optical properties is currently the dominant systematic for many analyses. The recently deployed IceCube Upgrade includes several new types of calibration modules, enabling additional measurements of the optical properties of the ice. The LOMlogger is such a device, which measured the backscattered light from a collimated light source to analyse the ice stratigraphy in two Upgrade drill holes. This new data covers 150m below the previously explored ice depths and serves as a technology demonstrator for potential large-scale stratigraphy logging in IceCube-Gen2.

In this talk, laboratory characterizations of the light source employed by the LOMlogger will be presented. This includes the pulsed intensity and the angular profile of the laser beam emitted into the ice.

T 106: Gamma Astronomy III

Time: Friday 9:00–10:15 Location: KS 00.005

T 106.1 Fri 9:00 KS 00.005

Unsupervised Machine Learning for Muon Ring Classification in Imaging Atmospheric Cherenkov Telescopes — •Giovanni Cozzolongo[1], Alison Mitchell[1], and Samuel Spencer[2] — [1]ECAP, FAU Erlangen-Nürnberg — [2]CTAO SDMC, Zeuthen, Germany

Muons from extensive air showers create ring-like patterns in Imaging Atmospheric Cherenkov Telescopes (IACTs). These ring images encode valuable information about muon properties such as energy and direction, making them important for studying the physics of muons in air showers. However, automated identification of muon events remains challenging, particularly for partial rings and mixed events containing both muon rings and air shower components. We present an unsupervised deep learning approach to classify muon events in H.E.S.S. CT5 data using clustering techniques to automatically separate events into categories like complete muon rings, partial rings, mixed events, and standard air showers. This represents one of the first deep learning applications to the analysis of muons in IACT data, offering significant advantages over manual classification and analytical methods that focus primarily on identifying complete rings.

T 106.2 Fri 9:15 KS 00.005

Exploring goodness of fit methods to improve gamma-hadron separation for the CTA Observatory — •Jayendra Pundarikaksha Kavipurapu[1,2], Georg Schwefer[1,2], and James Anthony Hinton[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117, Heidelberg, Germany — [2]Fakultät für Physik und Astronomie, Universität Heidelberg, Im Neuenheimer Feld 226, 69120, Heidelberg, Germany

Background rejection of hadrons is one of the limiting factors for the performance of IACTs. Unfortunately, hadron showers look similar in telescope cameras, even if they produce broader images. A promising approach to differentiate between them is to implement goodness-of-fit measures based on the per-pixel charge probability distribution. In this talk, we explore these goodness-of-fit metrics exploiting the differences between the reconstructed and predicted charges. We do this using methods from likelihood-free inference and simulations of the Cherenkov Telescope Array Observatory, allowing us to create classification criteria to differentiate shower observations

T 106.3 Fri 9:30 KS 00.005

Analysis of Condition Monitoring Data for the Large Sized Telescope — •Luca Davide Di Bella and Tristan Gradetzke — TU Dortmund University

The Cherenkov Telescope Array Observatory (CTAO) is the next generation high energy gamma ray observatory. It reaches higher sensitivities than current instruments, between several GeV to hundreds of TeV by facilitating different types of telescopes in the array, which differ mainly in their size. The LST-1 is the first prototype of a Large Sized Telescope of the array, sensitive to the lower energies. It is currently finishing commissioning at the CTAO-North array site, located at the Roque de los Muchachos Observarory (ORM) on La Palma.

As Imaging Air Cherenkov Telescope (IACT) measurement time is limited by dark hours, maintenance is essential to ensure smooth operation and maximize the uptime. In order to find problems in structural dynamics of the telescope, condition monitoring and predictive maintenance can be performed using sensors placed across the structure. In the years since start of operations, different kinds of sensors have been installed, including linear displacement sensors, vibration sensors and so-called load pins. Methods of data acquisition and a preliminary analysis of recent data from these sensors is presented.

T 106.4 Fri 9:45 KS 00.005

Characterization of ANTARES Photomultiplier Tubes for Sustainable Reuse in SWGO — •Saujanya Dubale, Alison Mitchell, and Oleg Kalekin — Erlangen Centre for Astroparticle Physics, Friedrich Alexander Universität Erlangen-Nürnberg, Nikolaus-Fiebiger-Str. 2, 91058 Erlangen, Germany

Modern astroparticle physics experiments face growing pressure to balance scientific performance with cost and sustainability. In this contribution, we explore the possibility of reusing photomultiplier tubes (PMTs) that were previously operated in the ANTARES neutrino telescope for use in the future Southern Wide-field Gamma-ray Observatory (SWGO). A dedicated laboratory setup has been constructed to study the long-term operability and general performance behaviour of these PMTs after extended use deep in the Mediterranean sea, including their quantum efficiency. The aim is to evaluate whether these PMTs remain suitable for use in next-generation Water Cherenkov Detectors. By investigating reuse as a viable option, this work addresses both economic and environmental considerations and supports more sustainable detector development strategies.

T 106.5 Fri 10:00 KS 00.005

Probing Energy-dependent Morphology in the Pulsar Wind Nebula HESS J1303-631 — •Maximilian Bohle, Alison Mitchell, and Katharina Egg — Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen Centre for Astroparticle Physics, Nikolaus-FiebigerStr. 2, 91058 Erlangen, Germany

Pulsar Wind Nebulae (PWN) exhibit complex morphologies that are often known to be energy-dependent. These morphological variations across energy bands can provide useful insights into the underlying physical mechanisms. In this work, detailed morphological studies of the very-high-energy gamma-ray source HESS J1303-631 are presented, using H.E.S.S. data analysed with the open source software gammapy. Previous studies based on more limited data found the source to be significantly energy-dependent. This energy-dependent nature is probed in more detail by analysing over 20 years of data for several energy ranges and therefore quantifying its morphological energy-dependency. HESS J1303-631 is found to be consistently elongated and highly extended, yet the results suggest that HESS J1303-631 exhibits a weaker energy dependence than previously reported.

T 107: Invited Overview Talks V

Time: Friday 11:00–12:30 Location: AudiMax

Invited Overview Talk T 107.1 Fri 11:00 AudiMax
Beyond the Main Detectors: An Overview of Smaller Experiments at the LHC — •Felix Kling — Universität Bonn, 53113 Bonn, Germany

While the Large Hadron Collider (LHC) is best known for its large multipurpose experiments — ATLAS, CMS, LHCb, and ALICE — it also hosts a diverse set of smaller experiments that complement its physics program. These include LHCf and TOTEM, which focus on forward QCD measurements and hadronic interactions; FASER and SND@LHC, which perform neutrino measurements and search for physics beyond the Standard Model; as well as MilliQan and MoEDAL, designed to search for particles with anomalous electromagnetic charges. In this talk, I will provide an overview of these smaller LHC experiments and present their recent results. I will also discuss ongoing and proposed initiatives for additional small experiments during the remaining LHC running and at future collider facilities.

Invited Overview Talk T 107.2 Fri 11:30 AudiMax
Pimp my ride: Overhauling the ATLAS and CMS experiments to ride the High Luminosity Highway at the LHC — •Stefan Maier — Karlsruhe Institute of Technology, Germany

The upcoming high-luminosity upgrade of the Large Hadron Collider (HL-LHC) will provide a unique opportunity to significantly extend the physics research program of the general-purpose experiments ATLAS and CMS. With its harsh environment, operation at the HL-LHC will bring experimental and instrumental challenges such as increased radiation levels and particle collisions per bunch crossing. In order to fully exploit the physics potential, the ATLAS and CMS collaborations are upgrading their detector systems—both physically and conceptually. These versatile improvements are summarized in the Phase-2 Upgrades. While some subsystems will be partially enhanced with new electronics, others, such as the tracking systems, will be fully replaced or will complement the current detector systems, like the new timing layers.

This talk rides you through the detector upgrades of both experiments and highlights a selection of subdetector systems that do not just get a new paint job but pursue novel detection and readout concepts.

Invited Overview Talk T 107.3 Fri 12:00 AudiMax
Overview of the solar model and LUNANOVA — •Daniel Bemmerer — Helmholtz-Zentrum Dresden-Rossendorf (HZDR)

The standard solar model describes the physics of the solar interior. Input parameters include the solar elemental composition, the total energy radiated from the sun, and microphysics such as nuclear reactions and radiation transport. The model can be validated observing the fluxes of neutrinos produced in the solar core and the sound waves at the solar surface. There were two main challenges to the model. First, the solar neutrino problem, which was solved by the discovery of neutrino flavour oscillations. Second, the solar abundance puzzle, caused by discrepant data on the solar composition. In order to solve this puzzle, we will build a new laboratory, LUNANOVA, and measure the rates of several neutrino-producing reactions in the sun. The new data will break the degeneracy between abundances and radiation transport, enable to use the sun as a calibrated particle source, and decisively improve the models of solar-like stars in general.