Working Group on Physics, Modern IT and Artificial Intelligence
Arbeitskreis Physik, moderne Informationstechnologie und Künstliche Intelligenz (AKPIK)

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Overview of Invited Talks and Sessions

(Lecture hall AKPIK-H13)

Sessions

AKPIK 1.1–1.9	Mon	16:15–18:30	AKPIK-H13	**Data Integration & Processing**
AKPIK 2.1–2.9	Wed	16:15–18:30	AKPIK-H13	**Data Analytics & Machine Learning**
AKPIK 3	Wed	19:00–21:00	AKPIK-MV	**Mitgliederversammlung AKPIK**
AKPIK 4.1–4.9	Thu	16:15–18:30	AKPIK-H13	**Deep Learning**

Annual General Meeting of the Working Group on Physics, Modern IT and Artificial Intelligence

Wednesday 19:00–21:00 AKPIK-MV

1. Bericht des Vorstandes
2. Entlastung des aktuellen Vorstandes
3. Wahl des neuen Vorstandes
4. Die Zukunft in unserer Hand! (Anregungen und Wünsche)

AKPIK 1: Data Integration & Processing

Time: Monday 16:15–18:30 Location: AKPIK-H13

AKPIK 1.1 Mon 16:15 AKPIK-H13

The PUNCH4NFDI Consortium in the NFDI - status, first results and outlook — •Thomas Schörner for the PUNCH4NFDI-Collaboration — Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg

With the "Nationale Forschungsdateninfrastruktur" (NFDI, national research data infrastructure), a massive effort is undertaken in Germany to provide a coherent research data management, to make research data sustainably utilisable and to implement the FAIR data principles. PUNCH4NFDI is the consortium of particle, astro- and astroparticle, as well as hadron and nuclear physics within the NFDI. It aims for a FAIR future of the data management of its community and at harnessing its massive experience not least in "big data" and "open data" for the benefit of "PUNCH" sciences (Particles, Universe, NuClei and Hadrons) as well as for physics in general and the entire NFDI. In this presentation, we will introduce the work programme of PUNCH4NFDI, its connection to everyday work in the physical sciences and beyond, and in particular the idea of digital research products and the PUNCH science data platform.

AKPIK 1.2 Mon 16:30 AKPIK-H13

Community Initiative for a VHE Open Data Format — •Maximilian Nöthe[1] and Lars Mohrmann[2] — [1]Astroparticle Physics WG Elsässer, TU Dortmund University, Germany — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Germany

The operation of the next-generation gamma-ray telescopes as observatories, the wish of currently operating instruments to archive and publish their data in an accessible format, and enabling multi-instrument analyses are strong reasons for developing an open, software independent format for gamma-ray data.

A first attempt of a common specification has been developed by members of different Imaging Atmospheric Cherenkov Telescopes (IACT) within the "Data formats for gamma-ray astronomy" initiative. The current version defines formats for high-level gamma-ray data, including event lists of candidate photons and instrument response functions, serialized as FITS files.

Open-source software for gamma-ray analyses, including gammapy and ctools, have recently developed support for this format and, as a result, a series of publications relying on standardized datasets and software have been issued.

Currently, an effort to formalize the endeavor is underway, creating a Coordination Committee formed from representatives of the participating instruments to steer the future development of the specification.

In this talk, current developments and future plans will be presented, including the already implemented extension to ground-based wide-field experiments and possible extension to other messengers.

AKPIK 1.3 Mon 16:45 AKPIK-H13

From sample management to workflow integration: Semantic research data management with CaosDB — •Daniel Hornung[1], Florian Spreckelsen[1], and Johannes Freitag[2] — [1]IndiScale Gmbh, Göttingen — [2]Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven

Organizing data from a diversity of sources, from acquisition to publication, can be a tough challenge. We present research data management implementations using the flexible open-source toolkit CaosDB at the Alfred Wegener Institute. CaosDB is used in a diversity of fields such as turbulence physics, legal research, animal behavior and glaciology. CaosDB links research data, makes it findable and retrievable, and keeps data consistent, even if the data model changes.

In the presented example, CaosDB keeps track of ice core samples and to whom samples are loaned for analyses. It made possible additional features such as: A revision system to track all changes to the data and the sample state at the time of analysis. Automated gathering of information for the publication in FAIR-DO meta-data repositories, e.g. Pangaea. Tools for storing, displaying and querying geospatial information and graphical summaries of all analyses performed on each ice core. Automatic data extraction and refinement into data records in CaosDB to minimize manual users interaction. A state machine which guarantees certain workflows, simplifies development and can be extended to trigger additional actions upon transitions.

We demonstrate how CaosDB simplifies semantic data in science and enables advanced data processing and understanding.

AKPIK 1.4 Mon 17:00 AKPIK-H13

CaosDB – a scientific research data management toolkit — •Daniel Hornung[1], Florian Spreckelsen[1], and Johannes Freitag[2] — [1]IndiScale Gmbh, Göttingen — [2]Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven

Processing interconnected, multi-modal data poses a challenge in many fields, especially when the data model, i.e. the way how data is organized, changes over time or when its structure is poorly documented. The open-source software **CaosDB** is a toolkit for research data management which was originally developed at the Max Planck Institute for Dynamics and Self-Organization (Göttingen) because existing software could not fulfill the needs of the scientists.

We present examples where CaosDB helped make data FAIR (Findable, Accessible, Interoperable, Retrievable) and how it can simplify the workflows for researchers: Automated data collection and integration, export to data repositories, API libraries for third-party programs, integrated revisioning and workflow state machines. If the data model needs to change, existing data can remain as-is and future search queries will return matching results containing "old" and "new" data. We demonstrate how raw and processed data, analysis settings and results, and even labnotebooks and publications can be linked against each other, to improve long-term usability of data and reproducibility of results.

AKPIK 1.5 Mon 17:15 AKPIK-H13

Data curation in astroparticle physics data centers on example of KCDC and GRADLCI — •Victoria Tokareva[1], Andreas Haungs[1], Doris Wochele[1], Jürgen Wochele[1], Frank Polgart[1], Alexander Kryukov[2], Minh-Duc Nguyen[2], Andrey Mikhailov[3], and Alexey Shigarov[3] — [1]Karlsruhe Institute of Technology, IAP, 76021 Karlsruhe, Germany — [2]Moscow State University, SINP, Moscow 119991, Russia — [3]Matrosov Institute for System Dynamics and Control Theory, Irkutsk 664033, Russia

The KASCADE Cosmic Ray Data Center (KCDC), introduced in 2013, is a multi-functional public data center for high-energy astroparticle physics. Its distinctive features include use of open standards and technologies, providing materials and service both for professional scientists and a broad outreach audience and furnishing open access to scientific data. The GRADLCI (German-Russian Astroparticle Data Life cycle Initiative), which spawned from KCDC in 2018, proposed an alternative approach to metadata management and utilized the optimized models and algorithms for processing requests. Today, the work on organizing flexible cross-collaboration data sharing is going on in various areas of science within the framework of the EOSC project and others, such as PUNCH4NFDI. A big share of this work includes collection and analysis of the data curation practices in order to reach a more abstract and complex understanding of the challenges of data curation committing into new advanced solutions ready for further extension. In this report the use cases of the KCDC and GRADLCI data centers will be considered.

AKPIK 1.6 Mon 17:30 AKPIK-H13

Optimizing Computer Vision for Radiosource Detection — •Janis Sowa and Kevin Schmidt — Astroparticle Physics AG Elsässer, TU Dortmund University, Germany

Earthbound radio astronomy utilizes interferometric arrays to achieve the highest possible resolution by combining the measurements of multiple telescopes. The resolution then depends on the distance between telescopes as opposed to the diameter of a single dish. Modern improvements in computing performance and telescope design are allowing radio astronomers to collect increasing amounts of data. In sky surveys, information about hundreds of thousands of astronomical sources are obtained. On this scale, a manual analysis is a time-consuming task. Deep Learning-based source detection thus naturally comes to mind as a candidate for identifying these individual objects. In a previous work, a Convolutional Neural Network architecture was shown to be faster but less accurate in comparison to the state-of-the-art source detection tool PyBDSF, when tested on simulated data. This talk will showcase how the existing model can be further improved and fine-tuned for application on real data.

AKPIK 1.7 Mon 17:45 AKPIK-H13

Evaluation of deep learning accelerators for the usage in the cosmic ray simulation CORSIKA~8 — •Dominik Baack and Jean-Marco Alameddine for the CORSIKA 8-Collaboration — Astroparticle Physics, WG Elsässer, TU Dortmund University, D-44227 Dortmund, Germany

The proliferation of neural networks has led to the acquisition of specialized hardware to accelerate training and application at an increasing number of scientific sites.

To take advantage of this growth, we investigated the extent to which this hardware can be used to accelerate the complex simulation of cosmic particle showers and which parts of the simulation benefit most.

A number of examples based on CORSIKA~8 are presented to illustrate advantages, disadvantages, and limitations in the choice of methods. In particular, the widely used Nvidia accelerators that was used very successfully for ray tracing of optical photons (e.g. Cherenkov light) will be discussed.

AKPIK 1.8 Mon 18:00 AKPIK-H13

Structured Sparsity for CNNs on Reconfigurable Hardware — •Hendrik Borras, Günther Schindler, and Holger Fröning — Institute of Computer Engineering; Heidelberg University; Heidelberg (Germany)

While Convolutional Neural Networks (CNNs) are gaining crucial importance for various applications, including modern analysis and trigger systems, their memory and compute requirements are increasing steadily and the requirements of many CNNs impose serious challenges for achieving high inference throughput and low latency on edge devices, situated close to an experiment. To improve the performance of CNNs on such resource-constrained devices, model compression through quantization and pruning has been proposed and evaluated as a possible solution in the past. Field Programmable Gate Arrays (FPGAs) are a prime example of low-power devices and suitable for a pervasive deployment. Here, FINN is one of the most widely used frameworks for deploying highly quantized CNN models on edge devices. In this work, we extend FINN for pruning by introducing two methods for column pruning, enabling further compression of CNN-based models. The two techniques vary in their granularity and implementation complexity. The coarse-grain method only prunes blocks of columns, while the fine-grained method is able to prune single columns. Both approaches are then evaluated on the CIFAR10 image classification task. We demonstrate significant throughput improvements of on average 83% while keeping the accuracy degradation within reasonable bounds (4.2%) at 50% sparsity.

AKPIK 1.9 Mon 18:15 AKPIK-H13

IEA-GAN: Intra-Event Aware GAN for the Fast Simulation of PXD Background at Belle II — •Hosein Hashemi, Nikolai Hartmann, Thomas Kuhr, and Martin Ritter — Faculty of Physics, Ludwig Maximilians University of Munich, Germany

The pixel vertex detector (PXD) is the newest and the most sensitive sub-detector at the Belle~II. Data from the PXD and other sensors allow us to reconstruct particle tracks and decay vertices. The effect of background processes on track reconstruction is simulated by adding measured or simulated background hit patterns to the hits produced by simulated signal particles that originate from the processes of interest. This model requires a large set of statistically independent PXD background noise samples to avoid a systematic bias of reconstructed tracks. However, the fine-grained PXD data requires a substantial amount of storage. As an efficient way of producing background information for fast simulation, we introduce the idea of an on-demand PXD background generator with Intra-Event Aware GAN (IEA-GAN), conditioned over the number of PXD sensors in order to produce sensor-dependent PXD images by approximating the concept of an "event" in the detector as these PXD images share both semantic and statistical features that makes it extremely hard for even the State of the Art GANs to mimic these exact properties. As a result, we developed the IEA-GAN model which captures these dependencies by imposing relational inductive bias over the batch dimension.

AKPIK 2: Data Analytics & Machine Learning

Time: Wednesday 16:15–18:30 Location: AKPIK-H13

AKPIK 2.1 Wed 16:15 AKPIK-H13

Interpolation of Instrument Response Functions for the Cherenkov Telescope Array — •Rune Michael Dominik and Maximilian Nöthe for the CTA-Collaboration — Astroparticle Physics WG Elsässer, TU Dortmund University, Germany

In very-high-energy gamma-ray astronomy, the Instrument Response Function (IRF) relates the observed and reconstructed properties to the original properties of the primary particles. The IRFs are usually factored into multiple components, namely the Effective Area, the Energy Dispersion and the Point Spread Function that are needed for the proper reconstruction of spectral and spacial information. These quantities are derived from Monte Carlo Simulations but depend on observation conditions like telescope pointing direction or atmospheric transparency. Producing a complete IRF for every observation taken is a time consuming task and not feasible on the short timescales needed to release e.g. an alert for a transient event. In consequence, IRFs are typically produced at fixed combinations of observation conditions. To derive the optimal IRFs for a given observation, interpolation techniques are investigated. This talk will summarize interpolation strategies that are being tested for the Cherenkov Telescope Array IRFs.

AKPIK 2.2 Wed 16:30 AKPIK-H13

Investigating the Potential Application of Neural Networks for Data Denoising at the Einstein Telescope — •David Bertram, Markus Bachlechner, and Achim Stahl — III. Physikalisches Institut B, RWTH Aachen

The Einstein Telescope is a proposed third-generation gravitational wave detector aiming to improve the sensitivity over the whole frequency band compared to the previous generation. For this purpose solely hardware improvements could turn out to be insufficient and novel data processing techniques are crucial. A promising idea for the latter is the implementation of neural networks that can operate on potential irregularly structured additional inputs like seismic sensors. This talk investigates the potential of such techniques in terms of data denoising.

AKPIK 2.3 Wed 16:45 AKPIK-H13

Anomaly detection for Belle II PXD cluster data — •Stephanie Käs, Jens Sören Lange, Johannes Bilk, and Timo Schellhaas — Justus-Liebig-Universität Gießen

The Belle II pixeldetector (PXD) has a trigger rate of up to 30 kHz for 8 M pixels. Highly ionizing particles such as antideuterons, pions with small transverse momenta $<$100 MeV ("slow pions"), magnetic monopoles or stable tetraquarks generate characteristic clusters in the PXD. A large fraction of those does not reach outer detectors and therefore does not generate reconstructable tracks. We study their identification based exclusively on the PXD data, by means of anomaly detection algorithms. In this presentation, we show results from multivariate statistics analysis and tree-based multiclassifiers. In a first step, principal component analysis, linear discriminant analysis, t-distributed stochastic neighbor embedding and random forests are used for each anomaly to investigate the separability of signal and background. In a second step, a multiclassifier system shall be used. The design and output of this approach will be presented, including results on accuracy and sensitivity as well as a comparison to other methods such as Convolutional Neural Networks and Support Vector Machines.

AKPIK 2.4 Wed 17:00 AKPIK-H13

Fast simulation of the HGCAL using generative models — soham bhattacharya[1], samuel bein[2], engin eren[1], frank gaede[1], gregor kasieczka[2], •william korcari[2], dirk kruecker[1], peter mckeown[1], and moritz scham[1] — [1]DESY — [2]Universität Hamburg

Accurate simulation of the interaction of particles with the detector materials is of utmost importance for the success of modern particle physics. Software libraries like GEANT4 are tools that already allow the modeling of physical processes inside detectors with high precision. The downside of this method is its computational cost in terms of time.

Recent developments in generative machine learning models seem to provide a promising alternative for faster and accurate simulations to accelerate this process. For the challenges of the High Luminosity phase of the LHC, CMS will deploy the High Granularity Calorimeter (HGCal), an imaging calorimeter for the endcap region with a high cell density, and irregular geometry. In this talk, we will show the taken steps in the development of a GraphGAN for the simulation of particle showers in the HGCal and the first achieved results.

AKPIK 2.5 Wed 17:15 AKPIK-H13

Ephemeral Learning - Augmenting Triggers with online-trained normalizing flows — •Sascha Diefenbacher — Institut für Experimentalphysik, Universität Hamburg, Germany

The high collision rates at the Large Hadron Collider (LHC) make it impossible to store every single observed interaction. For this reason, only a small subset that passes so-called triggers – which select potentially interesting events – are saved while the remainder is discarded. This makes it difficult to perform searches in regions that are usually ignored by trigger setups, for example at low energies. However a sufficiently efficient data compression method could help these searches by storing information about more events than can be saved offline. We investigate the use of a generative machine learning model (specifically a normalizing flow) for the purpose of this compression. The model is trained to learn the underlying data structure of collisions events in an online setting, meaning we can never have a repeated look at past data. After the training the underlying distribution encoded into the network parameters can be analyzed and, for example, probed for anomalies. We initially demonstrate this method for a simple bump hunt, showing that the online trained flow model can recover sensitivity compared to a classical trigger setup. We then extend this demonstration to more complex examples using the LHC Olympics Anomaly Detection Challenge dataset.

AKPIK 2.6 Wed 17:30 AKPIK-H13

Simulation of High-Granularity Calorimeter Showers for the ILD Using Normalizing Flows — •Imahn Shekhzadeh — Universität Hamburg, Hamburg, Deutschland

The large computational cost of Monte Carlo simulations together with recent advances in deep learning motivate using deep generative models to speed up simulations. This talk explores the use of normalizing flows (NFs) for high-granularity calorimeter simulations, such as the ones planned for the International Large Detector (ILD). We show that NFs are able to generate high-fidelity showers of simulated photons in the electromagnetic calorimeter of the ILD. Strictly monotonic rational quadratic spline flows are used to enhance the fidelity in comparison to the generally used affine-linear transformations. Finally, we compare the generative performance of the NFs to other state-of-the-art generative network architectures

AKPIK 2.7 Wed 17:45 AKPIK-H13

Identifying Slow Pions using Support Vector Machines — •Timo Schellhaas[1], Jens Sören Lange[2], and Stephanie Käs[3] — [1]II. Physikalisches Institut, JLU Gießen, Germany — [2]II. Physikalisches Institut, JLU Gießen, Germany — [3]II. Physikalisches Institut, JLU Gießen, Germany

Finding new physics beyond the standard model is of highest interest. Pions with a low transversal momentum (slow pions) are linked to interesting decay scenarios and are therefore studied at the Belle II experiment. However, it is dificult to detect slow pions due to their low momenta: a large amount of them does only reach the Belle II pixeldetector (PXD), but not the outer detectors (e.g. the drift chamber). In order to improve the detection rate it is suggested to use a machine learning model. One possible model is the support vector machine (SVM) algorithm. Therefore a simulated data set is used to train the SVM model with different parameters, including a modified kernel, with the goal of reaching better results than other models.

AKPIK 2.8 Wed 18:00 AKPIK-H13

Deep Learning Accelerated Maximum Likelihood Reconstruction of IACT Events — •Noah Biederbeck and Maximilian Nöthe for the CTA Consortium — Astroparticle Physics WG Elsässer, TU Dortmund University, Germany

The Cherenkov Telescope Array will be the next generation ground-based gamma-ray observatory, consisting of tens of Imaging Atmospheric Cherenkov Telescopes (IACTs) at two sites once its construction is finished.

In this talk we present a deep learning accelerated maximum likelihood reconstruction of gamma-ray events. A generative neural network predicts IACT camera images from a set of physical event parameters. These generated images are then compared to Monte Carlo simulated event images using a Poissonian likelihood loss in order to reconstruct the event properties, e.g. the energy of the primary particle and its direction.

First results on simulated single-telescope events will be presented and extensions to predictions of array events will be outlined.

AKPIK 2.9 Wed 18:15 AKPIK-H13

Adding Errors to the Quantum Circuit Model — •Tom Weber[1], Matthias Riebisch[1], Kerstin Borras[2,4], Karl Jansen[3], and Dirk Krücker[2] — [1]Universität Hamburg, Hamburg, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [3]Deutsches Elektronen-Synchrotron DESY, Zeuthen, Germany — [4]RWTH Aachen University, Aachen, Germany

The full potential of quantum computers cannot yet be realised because existing quantum hardware is still error-prone. It is essential to understand the impact of these errors on calculations to counteract them with methods like quantum error mitigation. Models can provide this understanding of the complexity of quantum noise. In addition, they can be a tool for communication between different quantum computing stakeholders who do not necessarily have an education in physics. While the quantum circuit model is commonly used to model gate-based quantum computation, errors are modelled mathematically by quantum operations on density operators. However, the quantum circuit model is restricted to the description of error-free processes. On the other hand, mathematical models are difficult to understand without a background in theoretical physics. Therefore, we present a way to couple both models, combining the comprehensibility of the quantum circuit model with the mathematical models' ability to represent quantum noise accurately.

AKPIK 3: Mitgliederversammlung AKPIK

Time: Wednesday 19:00–21:00 Location: AKPIK-MV

AKPIK Mitgliederversammlung.

AKPIK 4: Deep Learning

Time: Thursday 16:15–18:30 Location: AKPIK-H13

AKPIK 4.1 Thu 16:15 AKPIK-H13

Using Graph Neural Networks for improving Cosmic-Ray Composition Analysis at IceCube Observatory — •Paras Koundal for the IceCube-Collaboration — Institute for Astroparticle Physics, KIT Karlsruhe, Germany

Graph Neural Networks (GNNs) is one of the most emerging and promising research topics in the field of deep-learning. Described using nodes and edges, graphs allow us to efficiently represent relational data and learn hidden representations of input data to obtain better model-prediction accuracy. The success of GNNs is mainly attributed to their unique ability to represent complex input data in its most natural representation. GNNs have hence accelerated and extended the pattern learning, inference drawing of standard deep-learning architectures. This has also made it possible for faster and more precise analysis in astroparticle physics, enabling new insights from massive volumes of input data. IceCube Neutrino Observatory, a multi-component detector concealed deep under the South Pole ice provides a suitable test-case to implement such methods.

The talk will discuss the GNN-based methods for improving cosmic-ray composition understanding in the transition region from Galactic to extragalactic sources, at IceCube Observatory. The implementation benefits by using full signal-footprint information, in addition to reconstructed cosmic-ray air shower parameters. The talk will also explain improvement to individual GNN based model by ensemble methods. The implementation will reduce the time and computing cost for performing cosmic-ray composition analysis while boosting sensitivity.

AKPIK 4.2 Thu 16:30 AKPIK-H13

Amplifying Calorimeter Simulations with Deep Neural Networks — •Sebastian Guido Bieringer[1], Anja Butter[2], Sascha Diefenbacher[1], Engin Eren[3], Frank Gaede[3], Daniel Hundshausen[1], Gregor Kasieczka[1], Benjamin Nachman[4], Tilman Plehn[2], and Mathias Trabs[5] — [1]Institut für Experimentalphysik, Universität Hamburg, Germany — [2]Institut für Theoretische Physik, Universität Heidelberg, Germany — [3]Deutsches Elektronen-Synchrotron, Hamburg, Germany — [4]Physics Division, Lawrence Berkeley National Laboratory, Berkeley, CA, USA — [5]Fachbereich Mathematik, Universität Hamburg, Germany

Speeding up detector simulation over the computationally expensive Monte Carlo tools is a key effort for upcoming studies at the LHC and future colliders. Machine-learned generative surrogate models show great potential to accelerate such and other simulations. However, estimating the relation between the statistics of the training data and the generated distribution of the model is essential to determine the gains and use-cases of these methods.

We present a detailed study of this relation for the concrete physics example of photon showers in a highly granular calorimeter. For established metrics on calorimeter images, the amplification properties of a VAE-GAN model are examined in terms of an approximation to the Jenson-Shannon-divergence between generated data, training data and a high-statistics batch.

AKPIK 4.3 Thu 16:45 AKPIK-H13

Deep Learning-based Imaging in Radio Interferometry — •Felix Geyer and Kevin Schmidt — Astroparticle Physics AG Elsässer, TU Dortmund University, Germany

Radio interferometry is used to monitor and observe distant astronomical sources and objects with high resolution. Especially Very Long Baseline Interferometry allows achieving the highest resolutions by combining the data of multiple telescopes. This results in an effective diameter corresponding to the greatest distance between two telescopes. The taken data consists of visibilities, which depend on the baselines between the telescopes. Because the distribution of these baselines is sparse, the sample of visibilities is incomplete. After transforming this sample to spatial space, this so-called "dirty image" is inadequate for physical analyses. Thus, the image undergoes an elongated and mostly manually performed cleaning process in order to remove background artifacts and to restore the original source distribution. We developed a new and fast approach to reconstruct missing data reasonably using Neural Networks. This talk will present the current state of the `radionets` framework and an outlook on upcoming projects. One focus will be on the simulation improvements using the RIME formalism.

AKPIK 4.4 Thu 17:00 AKPIK-H13

Binary Black Hole Parameter Reconstruction using Deep Neural Networks — •Markus Bachlechner, David Bertram, and Achim Stahl — III. Physikalisches Institut B, RWTH Aachen

The proposed Einstein Telescope, as the first of the third generation of gravitational wave detectors, is expected to be an order of magnitude more sensitive compared to current interferometers like LIGO or Virgo. On the one hand the higher sensitivity increases the observable volume. On other hand the frequency range is broadened, which in return bares the potential to extend the observable time of binary coalescences from seconds to hours. These long observable times make it possible to send multi-messenger alerts before the end of the coalescences. For this it is essential to apply a fast real-time analysis handling event detection, classification, and reconstruction. In this talk an approach for the parameter reconstruction of binary black holes using deep neural networks is presented.

AKPIK 4.5 Thu 17:15 AKPIK-H13

A Recurrent Neural Network for Radio Imaging — •Stefan Fröse and Kevin Schmidt — Astroparticle Physics WG Elsässer, TU Dortmund University, Germany

In radio astronomy, an array of correlated antennas, called a radio interferometer, is used to produce high-resolution images of the sky. The measurements take place in the complex Fourier space due to the pairwise correlation of antennas. Therefore, the amount of information to receive from such an array is restricted by the number of antennas. The resulting spatial dirty map of these measurements will be cleaned using a Neural Network. The architecture for this network is based on a Recurrent Neural Network (RNN). RNNs can be used to extract information from sequential data, like text or speech. In the context of inverse problems the RNN can be derived directly from a *maximum a posteriori* approach. Furthermore the iterative behaviour of the network can be exploited to construct a `CLEAN`-like network to reconstruct a map of the sky. This results in the so-called `RIM` architecture published by Patrick Putzky & Max Welling (arxiv:1706.04008). The Neural Network is able to clean given dirty maps for simulated radio images and also shows convergence for the EHT dataset of M87.

AKPIK 4.6 Thu 17:30 AKPIK-H13

Measurement of the Mass Composition using the Surface Detector of the Pierre Auger Observatory and Deep Learning — Martin Erdmann, •Jonas Glombitza, and Niklas Langner for the Pierre Auger-Collaboration — III. Physics Institute A, RWTH Aachen

Measuring the mass composition of ultra-high energy cosmic rays (UHECRs) constitutes one of the biggest challenges in astroparticle physics. Nowadays, the most precise measurements can be obtained from measurements of the depth of maximum of air showers, $X_{\max}$, with the use of Fluorescence Detectors (FD), which can be operated only during clear and moonless nights.

With the advent of deep learning, it is now possible for the first time to perform an event-by-event reconstruction of $X_{\max}$ using the Surface Detector (SD) of the Pierre Auger Observatory. Therefore, previously recorded data can be analyzed for information on $X_{\max}$, and thus the cosmic-ray composition. Since the SD features a duty cycle of nearly 100%, the gain in statistics is a factor of 15 for energies above $10^{19.5}$ eV compared to the FD.

This contribution introduces the neural network specifically designed for the SD of the Pierre Auger Observatory. We evaluate its performance using three different hadronic interaction models and verify its functionality using Auger hybrid measurements. Finally, we quantify the expected systematic uncertainties and determine the UHECR mass composition using the first two moments of the $X_{\max}$ distributions up to the highest energies.

AKPIK 4.7 Thu 17:45 AKPIK-H13

Graph Neural Networks for Low Energy Neutrino Reconstruction at IceCube — •Rasmus Ørsøe — Trøjborggade 6, 3.sal, 1757 Copenhagen

A presentation on the application of graph neural networks for low energy neutrino reconstruction of IceCube events. Comparisons with current methods will be shown. Brief introduction to graph neural networks and motivation is included.

AKPIK 4.8 Thu 18:00 AKPIK-H13

Event-by-event estimation of high-level observables with data taken by the Surface Detector of the Pierre Auger Observatory using deep neural networks — •Steffen Hahn[1], Markus Roth[1], Darko Veberic[1], David Schmidt[1], Ralph Engel[1], and Brian Wundheiler[2] — [1]KIT, IAP, Germany — [2]UNSAM, ITEDA, Argentina

Probing physics beyond the scales of human-made accelerators with cosmic rays requires accurate estimation of high-level observables, such as the energy of the primary particle or the maximum of the shower depth. Measurements of the shower cascade, however, consist mainly of various, hard-to-interpret time signals which potentially contain non-trivial correlations. Deep neural networks are a convenient way to tackle such a problem in a general way.

The shower footprint measured by the surface detector of the Pierre Auger Observatory provides us with time slices of the ground signal of a shower cascade. This gives us an ideal test bed to determine the quality of network based reconstruction methods compared to that of regular analysis methods. However, a caveat of this approach is that the networks must be trained on Monte-Carlo simulations. Since present hadronic interaction models for energies beyond 10 EeV are extrapolations there are discrepancies between simulations and real data for which we have to correct for.

Here, we present a multi-purpose architecture and correction-method to predict high-level observables on measured data as well as physics results.

AKPIK 4.9 Thu 18:15 AKPIK-H13

Reconstruction of primary particle energy from data taken by the Surface Detector of the Pierre Auger Observatory using deep neural networks — Ralf Engel, Markus Roth, Darko Veberic, David Schmidt, Steffen Hahn, and •Fiona Ellwanger for the Pierre Auger-Collaboration — Karlsruhe Institute of Technology (IAP), Karlsruhe, Germany

To probe physics beyond the scales of human-made accelerators with cosmic rays demands an accurate knowledge of their energy. Indirect, ground-based experiments reconstruct this primary particle energy from measurements of the emitted fluorescence light or the time-signal of the shower footprint. Using fluorescence detectors, one is able to estimate former with good accuracy. These, however, exhibit a rather low duty cycle.

At the Pierre Auger Observatory the shower footprint is measured by a regular triangular grid of water-Cherenkov detectors. Since the shower development is a very intricate process the time signals of the detectors are fairly complex. Additionally, the sheer amount of data makes it non-trivial to find hidden patterns in their spatial and temporal distributions. Neural networks provide a straightforward way of tackling such a problem doing a data-driven analysis.

With large simulation data sets we are able to train more complex networks. Systematic differences between simulations and measured data require special attention to possible biases, which are quantified. In this work, we present a neural network architecture that gives an estimate on the energy for real data.