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 ZEU/0118; AI Topical Day HSZ/AUDI, HSZ/0004, and joint sessions; Poster HSZ OG2)

Plenary Talks of the AI Topical Day

PV XIII	Thu	9:00– 9:45	HSZ/AUDI	**The role of artificial intelligence in modern radiation therapy** — •Guillaume Landry
PV XIV	Thu	9:45–10:30	HSZ/AUDI	**Machine Learning Advances in Particle Physics** — •Lukas Heinrich

Invited Talks

AKPIK 6.1	Thu	11:00–11:30	HSZ/AUDI	**AI Techniques for Event Reconstruction** — •Ivan Kisel
AKPIK 6.2	Thu	11:30–12:00	HSZ/AUDI	**Accelerator operation optimisation using machine learning** — •Pierre Schnizer
AKPIK 6.3	Thu	12:00–12:30	HSZ/AUDI	**Is this even physics? – Progress on AI in particle physics** — •Gregor Kasieczka

Sessions

AKPIK 1.1–1.5	Mon	16:00–18:00	HSZ OG2	**Poster**
AKPIK 2.1–2.8	Tue	17:00–19:00	ZEU/0118	**Applications in Particle and Astroparticle Physics**
AKPIK 3.1–3.6	Wed	14:00–15:30	ZEU/0118	**Neural Networks I**
AKPIK 4.1–4.5	Wed	15:45–17:00	ZEU/0118	**Neural Networks II**
AKPIK 5.1–5.3	Wed	11:00–12:20	ZEU/0250	**AI Topical Day – Neural Networks and Computational Complexity (joint session MP/AKPIK)**
AKPIK 6.1–6.3	Thu	11:00–12:30	HSZ/AUDI	**AI Topical Day – Invited Talks (joint session AKPIK/HK/ST/T/AKBP)**
AKPIK 7.1–7.6	Thu	14:00–15:30	HSZ/0101	**AI Topical Day – Research Data Management and Medical Applications**
AKPIK 8.1–8.6	Thu	15:45–17:15	HSZ/0004	**AI Topical Day – Normalizing Flows and Invertible Neural Networks (joint session AKPIK/T)**
AKPIK 9.1–9.6	Thu	17:30–19:00	HSZ/0004	**AI Topical Day – New Methods (joint session AKPIK/T)**
AKPIK 10.1–10.6	Thu	14:00–15:30	HSZ/0103	**AI Topical Day – Computing II (joint session HK/AKPIK)**
AKPIK 11.1–11.6	Thu	14:00–15:30	ZEU/0146	**AI Topical Day – AI in Medicine (joint session ST/AKPIK)**
AKPIK 12.1–12.6	Thu	14:00–15:30	HSZ/0105	**AI Topical Day – Heavy-Ion Collisions and QCD Phases (joint session HK/AKPIK)**

AKPIK 1: Poster

Time: Monday 16:00–18:00 Location: HSZ OG2

AKPIK 1.1 Mon 16:00 HSZ OG2

Learning Electron Bunch Distribution along a Beamline by Normalising Flows — •Anna Willmann[1], Jurjen Couperus Cabadağ[1], Yen-Yu Chang[1], Richard Pausch[1], Amin Ghaith[1,4], Alexander Debus[1], Arie Irman[1], Michael Bussmann[2], Ulrich Schramm[1,3], and Nico Hoffmann[1] — [1]Helmholtz Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Center for Advanced Systems Understanding, Görlitz, Germany — [3]Technische Universität Dresden, Germany — [4]Synchrotron SOLEIL, Saint-Aubin, Germany

Understanding and control of Laser-driven Free Electron Lasers remain to be difficult problems that require highly intensive experimental and theoretical research. The gap between simulated and experimentally collected data might complicate studies and interpretation of obtained results. In this work we developed a deep learning based surrogate that could help to fill in this gap. We introduce a surrogate model based on normalising flows for conditional phase-space representation of electron clouds in a FEL beamline. Achieved results let us discuss further benefits and limitations in exploitability of the models to gain deeper understanding of fundamental processes within a beamline.

AKPIK 1.2 Mon 16:00 HSZ OG2

Predicting volatile wind energy: Stochastic forward modeling and machine learning — Juan Medina, •Marten Klein, Mark Simon Schöps, and Heiko Schmidt — BTU Cottbus-Senftenberg, Cottbus, Germany

Forecasting power output from wind farms is a standing challenge due to complex dynamical processes in the atmospheric boundary layer that manifest themselves by a strong spatio-temporal variability of the wind field. Statistical postprocessing of numerical weather prediction (NWP) ensemble data using machine learning, e.g., by multivariate Gaussian regression, has been utilized to estimate the probability of power ramp events for near-future power grid regulation. However, predictions on the scale of single turbines are not possible demonstrating that there is a lack in modeling for short-term forecasting. In this contribution, this lack is addressed by an economical stochastic modeling approach that autonomously evolves vertical profiles of the wind velocity and temperature. The model aims to reproduce turbulent cascade phenomenology by a stochastic process, respecting fundamental physical conservation principles in a dimensionally reduced setting. As a first step, standalone model predictions of wind field fluctuations in weakly and strongly stratified atmospheric conditions are analyzed by conventional and event-based statistics, including clustering and regression of model output. Forthcoming research aims at developing an economical tool for physics-informed downscaling of NWP data. Coupling with wind power plant models and abstraction by neural networks might hence provide additional physical details to power grid models.

AKPIK 1.3 Mon 16:00 HSZ OG2

Amortized Bayesian Inference of GISAXS Data with Normalizing Flows — •Maksim Zhdanov[1], Lisa Randolph[2], Thomas Kluge[1], Motoaki Nakatsutsumi[2], Christian Gutt[3], Michael Bussmann[5], Marina Ganeva[4], and Nico Hoffmann[1] — [1]HZDR, Dresden, Germany — [2]European XFEL, Germany — [3]University of Siegen, Siegen, Germany — [4]Forschungszentrum Jülich, Jülich, Germany — [5]CASUS, Görlitz, Germany

Grazing-Incidence Small-Angle X-ray Scattering (GISAXS) is a modern imaging technique used in material research to study nanoscale materials. Reconstruction of the parameters of an imaged object imposes an ill-posed inverse problem that is further complicated when only an in-plane GISAXS signal is available. Traditionally used inference algorithms such as Approximate Bayesian Computation (ABC) rely on computationally expensive scattering simulation software, rendering analysis highly time-consuming. We propose a simulation-based framework that combines variational auto-encoders and normalizing flows to estimate the posterior distribution of object parameters given its GISAXS data. We apply the inference pipeline to experimental data and demonstrate that our method reduces the inference cost by orders of magnitude while producing consistent results with ABC.

AKPIK 1.4 Mon 16:00 HSZ OG2

Control System for Autonomous Race Car — •Vadim Melnik — Bolshaya Semenovskaya str., 38, Moscow, Russia

Self-driving cars help significantly improve safety, universal access, convenience, efficiency, and reduced costs. In order to fulfill SAE level 4 autonomy, no driver must be required, even in emergency situations and under heavy weather conditions. Despite the fact that major part of autonomous driving on public roads will happen in standard situations, a critical aspect to reach full autonomy is the ability to operate a vehicle close to its limits of handling, i.e. in avoidance maneuvers or in case of slippery surfaces.

Testing such systems on closed tracks or in simulators reduces the risks of human injury.

The proposed system uses path planning algorithm based on the information received from cameras and LiDAR, estimates its position using IMU and linear algebra methods, and is controlled by Model Predictive Control technique. Successful completion of tests in simulator allows the system to be transferred to a real vehicle to proceed to live tests and data validation.

AKPIK 1.5 Mon 16:00 HSZ OG2

Quantum machine learning for calorimeter data generation — •Alexis-Harilaos Verney-Provatas[1,2], Kerstin Borras[1,2], and Dirk Krücker[1] — [1]DESY, Hamburg, Germany — [2]RWTH Aachen, Aachen, Germany

Rapid advances in Quantum Computing technology promise applications in a number of computational problems relevant to a wide range of scientific disciplines. Calorimeter simulation is crucial to Experimental High Energy Physics analyses. However, due to the rising computational cost of traditional simulation methods, machine learning has become a tool used to accelerate data generation. Calorimeter data exhibits strong correlations, which many classical machine learning models struggle to recreate. Properties of quantum states, such as entanglement, which directly imply strong correlations, may be a tool for capturing the full data complexity. Preliminary models, using hybrid Quantum-Classical machine learning architectures are presented and explored.

AKPIK 2: Applications in Particle and Astroparticle Physics

Time: Tuesday 17:00–19:00 Location: ZEU/0118

AKPIK 2.1 Tue 17:00 ZEU/0118

Studies of Machine Learning Inspired Clustering Algorithms for Jets — Amrita Bhattacherjee[1], Debarghya Ghoshdastidar[1], Stefan Kluth[2], and •Siddha Hill[2] — [1]Technical University of Munich — [2]Max Planck Institute for Physics, Munich

We study several machine learning inspired clustering algorithms to cluster the particles of hadronic final states in high energy e+e- and pp collisions into jets. We compare their performance against well known algorithms such as JADE or Anti-Kt. Performance indicators are physically motivated and study properties such as energy and angle differences of jets transitioning from parton to hadron level. In addition we also investigate the stability against pileup.

AKPIK 2.2 Tue 17:15 ZEU/0118

Providing GPU resources in a HEP analysis environment — Johannes Erdmann[1], Benjamin Fischer[1], Thomas Kress[2], Dennis Noll[1], Andreas Nowack[2], and •Roman Suveyzdis[1] — [1]III. Physikalisches Institut A, RWTH Aachen University — [2]III. Physikalisches Institut B, RWTH Aachen University

Graphics Processing Units (GPUs) have become a key computing resource for advanced physics analyses for example for training and evaluating machine learning models. The local research group's computing cluster is still often limited in GPU resources. Therefore, an efficient and fair use is crucial. HTCondor, a powerful batch job software system that is often used in the HEP physics community, offers the possibility to manage GPU resources. The basic installation of HTCondor only distributes entire GPUs on a per job basis, which leaves some potential resources unused. In this talk, we will present how HTCondor can be configured to cope with the users' need to use GPUs both interactively and in batch job mode. We will report on the first experiences with our setup.

AKPIK 2.3 Tue 17:30 ZEU/0118

Fast Columnar Physics Analyses of Terabyte-Scale LHC Data on a Cache-Aware Dask Cluster — Svenja Diekmann, Niclas Eich, Martin Erdmann, Peter Fackeldey, •Benjamin Fischer, Dennis Noll, and Yannik Rath — III. Physikalisches Institut A, RWTH Aachen University

The development of an LHC physics analysis involves numerous investigations that require the repeated processing of terabytes of data. Thus, a rapid completion of each of these analysis cycles is central to mastering the science project.

We present a solution to efficiently handle and accelerate physics analyses on small-size institute clusters. Our solution uses three key concepts: Vectorized processing of collision events, the “MapReduce” paradigm for scaling out on computing clusters, and efficiently utilized SSD caching to reduce latencies in IO operations. This work focuses on the latter key concept, its underlying mechanism, and its implementation.

Using simulations from a Higgs pair production physics analysis as an example, we achieve an improvement factor of 6.3 in the runtime for reading all input data after one cycle and even an overall speedup of a factor of 14.9 after 10 cycles, reducing the runtime from hours to minutes.

AKPIK 2.4 Tue 17:45 ZEU/0118

ProGamer: PROgressively Growing Adversarial Modified (transformer-)Encoder Refinement — •Benno Käch, Isabell Melzer-Pellmann, and Dirk Krücker — Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

Machine learning-based data generation has become a major research topic in particle physics due to the computational challenges posed by current Monte Carlo simulation approaches for future colliders, which will have significantly higher luminosity. The generation of collider data is similar to point cloud generation, but it is more difficult because of the complex correlations that need to be accurately modeled between the points. A refinement model consisting of normalising flows and transformer encoders is presented. The normalising flow is 3-dimensional, meaning that the generated particle cloud consists of independent and identically distributed objects. This output is then refined by a transformer encoder, which is adversarially trained against another transformer encoder discriminator/critic. As the model is able to produce an arbitrary number of particles, a progressively growing point cloud can be produced.

AKPIK 2.5 Tue 18:00 ZEU/0118

Machine Learning based defect detection for large-scale electrodes — •Sebastian Vetter — Karlsruhe Institute of Technology, Institute for Astroparticle Physics

Like every piece of hardware produced in an industrial setting, detectors in physics experiments are subject to material defects, introduced during the production or handling of individual components. This can greatly influence detector behavior and lead to unexpected experimental results, depending on the affected part and the extent of the defect. Detection and quantification of such defects is therefore an important step in constructing a successful experiment.

It is still quite common for defect inspection to be done by eye. However, recent developments in computer-based inspection methods provide the opportunity to relieve humans from this tedious task, to remove the susceptibility of human error from the inspection step, and to objectively quantify the extent of detected defects.

In this talk, I present the defect inspection of a large-scale electrode mesh, as used for example in liquid noble gas Dark Matter experiments. This inspection was carried out first by hand and then compared to various Machine Learning approaches, ranging from simple decision trees to variational autoencoders.

AKPIK 2.6 Tue 18:15 ZEU/0118

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

The Cherenkov Telescope Array (CTA) will be the next generation ground-based very-high-energy gamma-ray observatory, utilizing tens of Imaging Atmospheric Cherenkov Telescopes at two sites once its construction and commissioning is finished. Like its predecessors, CTA relies on Instrument Response Functions (IRFs) to relate the observed and reconstructed properties to the original properties of primary particles. IRFs are needed for the proper reconstruction of spectral and spatial information and are thus among the data-products issued to the observatory's users. They are derived from Monte Carlo simulations and depend on observation conditions like the telescope pointing direction or the atmospheric transparency. Producing a complete set of IRFs from simulations for every observation taken is a time consuming task and not feasible when releasing data-products on short timescales. Consequently, interpolation techniques on simulated IRFs are investigated to quickly estimate IRFs for specific observation conditions. However, as some of an IRFs constituents are given as probability distributions, specialized methods are needed. This talk summarizes and compares the feasibility of multiple approaches to interpolate IRF components. First results are shown and open challenges are discussed.

AKPIK 2.7 Tue 18:30 ZEU/0118

Estimation of prediction uncertainties for data from Imaging Atmospheric Cherenkov Telescopes — •Cyrus Pan Walther and Maximilian Linhoff — Technische Universität Dortmund, Germany

One main step in the low-level analysis of astroparticle physics data is the reconstruction of the properties of primary particles that induced extensive air showers.

Various methods are applied in different experiments and software packages. In general, these are multi-output and combined regression and classification tasks. The estimation of prediction uncertainties is of crucial importance for the later scientific exploitation of these events. However, most methods do not in themselves provide reliable uncertainty estimates. In this contribution, we want to apply a method that has been used successfully in a Deep Learning reconstruction for the IceCube experiment to data from Imaging Atmospheric Cherenkov Telescopes used for gamma-ray astronomy.

AKPIK 2.8 Tue 18:45 ZEU/0118

Testing Nested Machine Learning Models for the Cherenkov Telescope Array — •Lukas Beiske and Rune M. Dominik for the CTA-Collaboration — Astroparticle Physics, WG Rhode/Elsässer, TU Dortmund University, D-44227 Dortmund, Germany

The Cherenkov Telescope Array (CTA) will be the next-generation ground-based very-high-energy gamma-ray observatory covering an energy range from 20 GeV up to 300 TeV. It will operate tens of Imaging Atmospheric Cherenkov Telescopes (IACTs) on the Canary Island of La Palma (CTA North) and at the Paranal Observatory in Chile (CTA South) once construction and commissioning are finished.

Machine Learning techniques are currently being used to analyze data from IACTs. The tools are used to reconstruct the three main properties of the primary particle: its particle type, energy, and origin. A common approach is to train models on parameters extracted from the shower images observed by the telescopes which in turn give one prediction per telescope image. For events triggering multiple telescopes, these individual predictions can be averaged to obtain a single primary particle prediction for every shower event. However, it is possible to improve these averaged predictions by training a second set of machine learning models using all information available about the shower as seen by the whole telescope array. This talk will show the current results of testing such nested models for CTA.

AKPIK 3: Neural Networks I

Time: Wednesday 14:00–15:30 Location: ZEU/0118

AKPIK 3.1 Wed 14:00 ZEU/0118

"Ahead of Time compilation" of Tensorflow models — •Bogdan Wiederspan, Marcel Rieger, and Peter Schleper — University of Hamburg

In a wide range of high-energy particle physics analyses, ML methods have proven as powerful tools to enhance analysis sensitivity. In the past years, various ML applications were also integrated in central CMS workflows, leading to great improvements in reconstruction and object identification efficiencies.

However, the continuation of successful deployments might be limited due to memory and processing time constraints of more advanced models and central infrastructure. A new inference approach for models trained with Tensorflow, based on Ahead-of-time (AOT) compilation is presented that has the potential to drastically reduce memory footprints while preserving and even increasing computational performance.

AKPIK 3.2 Wed 14:15 ZEU/0118

A multi-layer approach and neural network architectures for defect detection in PBF-LB/M — •Michael Moeckel and Jorrit Voigt — TH Aschaffenburg, Würzburger Str. 45, 63743 Aschaffenburg

The substitution of expensive non-destructive material testing by data-based process monitoring is intensively explored in quality assurance for additive manufactured components. Machine learning show promising results for defect detection but require conceptual adaption to layer wise manufacturing and line scanning patterns in laser powder bed fusion. A multi-layer approach to co-register μ-computer tomography measurements with process monitoring data is developed and a workflow for automatic data set generation is implemented. The objective of this research is to benchmark the volumetric multi-layer approach and specifically selected deep learning methods for defect detection. The volumetric approach shows superior results compared to single slice monitoring. All investigated structured neural network topologies deliver similar performance.

AKPIK 3.3 Wed 14:30 ZEU/0118

Reconstructing jet characteristics using neural networks — •Arne Poggenpohl and Felix Geyer — Astroparticle Physics, TU Dortmund University, Germany

Active galactic nuclei (AGN) are among the most observed objects in the nocturnal sky. Several of these AGN have the capability to accelerate matter in their nuclei to relativistic velocities, resulting in jets. These are frequently studied sources of radio emission. Analysis of the kinematic characteristics of radio jets can provide information about physical properties of the host galaxy. Previously, this was mostly done by tracking Gaussian components of the jets manually, which is difficult to reproduce. Therefore, the goal of this work is to automatically detect Gaussian components in radio jets using a neural network and thus enable kinematic analysis. Big data sets can thereby be processed, because it is no longer necessary to concentrate on each individual image.

For the necessary object detection, an architecture based on YOLO is used. This architecture consists exclusively of convolutional layers and requires only one pass for the prediction. This allows it to be fast and accurate at the same time.

In this talk, the current state of the work is presented and improvements for the future are pointed out.

AKPIK 3.4 Wed 14:45 ZEU/0118

Deep-Learning based Estimation of the Ultra-High Energy Cosmic Ray Spectrum using the Surface Detector of the Pierre Auger Observatory — Ralph Engel, Markus Roth, Darko Veberic, 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. Ground-based experiments indirectly reconstruct the primary particle energy from measurements of the emitted fluorescence light or the time-dependent signal of the shower footprint.

At the Pierre Auger Observatory, the shower footprint is measured by a regular hexagonal grid of water-Cherenkov detectors. Since the shower development is a very intricate process, it non-trivial to find hidden patterns in the spatial and temporal distributions of signals. With large simulation datasets, we are able to train neural networks tackling such a problem.

In this work, we present a neural network that gives an estimate on the energy of the primary particle. The precision of the predictions is studied by evaluating the neural networks on a simulated test data set with particular regard to the mass-dependent bias. Systematic differences between simulations and measured data require special attention to possible biases, which are investigated. Methods to correct for these biases are presented. Furthermore, the energy spectrum from corrected neural network predictions is built and compared to published results.

AKPIK 3.5 Wed 15:00 ZEU/0118

Investigating Waveform Classification Using Neural Networks for the Einstein Telescope — Markus Bachlechner, •Philipp Otto, Oliver Pooth, and Achim Stahl — III. Physikalisches Institut B, RWTH Aachen

The Einstein Telescope (ET) is a proposed third-generation gravitational wave detector aiming to improve the sensitivity by more than an order of magnitude over the whole frequency band compared to the previous generation. Increased sensitivity yields a much higher event rate with overlapping signals, which will dramatically increase the computational resource requirements of conventional pattern matching methods. Neural networks are a promising approach to implement a fast and efficient waveform classification. Fast identification is also essential to allow for multi-messenger astronomy, by quickly alerting other observatories. This talk will present the investigation of a deep learning based waveform classification approach.

AKPIK 3.6 Wed 15:15 ZEU/0118

Estimating Uncertainties for Trained Neural Networks — •Sebastian Bieringer — Universität Hamburg, Hamburg, Germany

Uncertainty estimation is a crucial issue when considering the application of deep neural network to problems in high energy physics such as jet energy calibrations.

We introduce and benchmark a novel algorithm that quantifies uncertainties by Monte Carlo sampling from the models Gibbs posterior distribution. Unlike the established 'Bayes By Backpropagation' training regime, it does not rely on any approximations of the network weight posterior, is flexible to most training regimes, and can be applied after training to any network. For a one-dimensional regression task, as well as energy regression from calorimeter images, we show that this novel algorithm describes epistemic uncertainties well, including large errors for extrapolation.

AKPIK 4: Neural Networks II

Time: Wednesday 15:45–17:00 Location: ZEU/0118

AKPIK 4.1 Wed 15:45 ZEU/0118

Morphological Classification of Radio Galaxies with wGAN-supported Augmentation — •Janis Kummer[1,3], Florian Griese[1,4,5], Lennart Rustige[1,2], Kerstin Borras[2,6], Marcus Brüggen[3], Patrick Connor[1,7], Frank Gaede[2], Gregor Kasieczka[7], Tobias Knopp[4,5], and Peter Schleper[7] — [1]Center for Data and Computing in Natural Sciences (CDCS), Hamburg, German — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg, German — [3]Hamburger Sternwarte, Hamburg, Germany — [4]University Medical Center Hamburg-Eppendorf, Hamburg, Germany — [5]Hamburg

University of Technology,Hamburg, Germany — [6]RWTH Aachen University, Aachen, Germany — [7]Universität Hamburg, Hamburg, German

Supervised deep learning models for the morphological classification of radio galaxies are very important for processing the data of future large radio surveys. However, labelled training data for such models is limited. We demonstrate the use of generative models, specifically a Wasserstein Generative Adversarial Network (wGAN), to generate artificial data for different classes of radio galaxies. Further, we study the impact of augmenting the training data with images from our wGAN on different classification architectures. We find that it is indeed possible to improve models for the morphological classification of radio galaxies with this technique. In addition, fast simulations of radio galaxies with our wGAN are useful to validate new interferometric machine-learning algorithms.

AKPIK 4.2 Wed 16:00 ZEU/0118

Uncertainty estimations for deep learning-based imaging — •Felix Geyer, Arne Poggenpohl, and Kevin Schmidt — Astroparticle Physics WG 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 (VLBI) allows for 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 in Fourier space, 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 inference and analyses.

In traditional methods, the image then undergoes an elongated and mostly manually performed cleaning process in order to remove background artifacts and restore the original source distribution. Contrary, a new and fast approach to reconstructing missing data reasonably is using neural networks. As an additional advantage, these networks can also be used to estimate the uncertainty of the prediction. This is done by not only predicting the mean value of the pixels but also the standard deviation by feeding the input and the prediction to a separate network. All of this is part of our framework called `radionets`, which is another focus of this talk.

AKPIK 4.3 Wed 16:15 ZEU/0118

Partition Pooling for Convolutional Graph Network Applications in Particle Physics — •Philipp Soldin, Markus Bachlechner, Thilo Birkenfeld, Achim Stahl, and Christopher Wiebusch — III. Physikalisches Institut B, RWTH Aachen University

Convolutional Neural Networks (CNN) are often used in particle physics applications for classification and reconstruction tasks. Since the individual sensors in a particle detector are often arranged in complex geometries, the information must be projected onto regular grids to use CNNs. Convolutional Graph Networks (CGN) can encode the individual sensor positions as a static graph to prevent projection effects. However, with the number of sensors in modern particle physics detectors, the CGN performance can be limited by the considerable number of parameters. A dimensionality reduction scheme analogous to conventional pooling on images that uses graph partitioning to create pooling kernels is presented. Different CGN architectures, including partition pooling, are presented with an exemplary vertex reconstruction in an idealized neutrino detector.

AKPIK 4.4 Wed 16:30 ZEU/0118

Gamma Source Detection using Deep Multitask Networks and Noisy Label Learning — •Lukas Pfahler — TU Dortmund University, Artificial Intelligence Group, Dortmund, Germany

Machine learning has been established as an effective tool for data analysis in modern high energy particle experiments. For the FACT telescope, we solve three supervised learning tasks - gamma-hadron separation, energy estimation, and origin estimation - using simulated training data and manual feature extraction. We outline how we can replace the manual feature engineering currently applied with a learned representation trained with multitask supervision. Our approach will train a shared representation that can solve all three prediction tasks with specialized prediction networks build on top of the shared representation. Furthermore, we look into an alternative source of supervision that reduces the burden of simulating training data by using real telescope recordings. We rely on the concept of noisy labels and introduce a novel method for learning under label noise where only one noise rate is known. We show how gamma-hadron separation can be framed in this setting and illustrate that the method allows us to train accurate classifiers.

AKPIK 4.5 Wed 16:45 ZEU/0118

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

As the first of the third-generation of gravitational wave detectors, the proposed Einstein Telescope is expected to be at least an order of magnitude more sensitive compared to current interferometers like LIGO and Virgo. On the one hand, the higher sensitivity increases the observable volume. On the other hand, high sensitivity in the low-frequency band leads to significantly earlier detection and observation for some coalescences like binary neutron stars. These early observations make it possible to send multi-messenger alerts before the merger. Applying a fast analysis handling event detection, classification, and estimation in real time is essential. This talk presents an approach for parameter estimation of binary black holes using deep neural networks.

AKPIK 5: AI Topical Day – Neural Networks and Computational Complexity (joint session MP/AKPIK)

Time: Wednesday 11:00–12:20 Location: ZEU/0250

AKPIK 5.1 Wed 11:00 ZEU/0250

A universal approach to state and operator complexities — •Souvik Banerjee[1] and Mohsen Alishahiha[2] — [1]Julius-Maximilians-Universität Würzburg, Würzburg, Germany — [2]IPM, Tehran, Iran

In this talk, I shall present a general framework in which both Krylov state and operator complexities can be put on the same footing. In our formalism, the Krylov complexity is defined in terms of the density matrix of the associated state which, for the operator complexity, lives on a doubled Hilbert space obtained through the channel-state map. This unified definition of complexity in terms of the density matrices enables us to extend the notion of Krylov complexity, to subregion or mixed state complexities and also naturally to the Krylov mutual complexity. We show that this framework also encompasses nicely, the holographic notions of complexity and explains the universal late-time growth of complexity, followed by a saturation.

Invited Talk AKPIK 5.2 Wed 11:30 ZEU/0250

Deep neural networks and the renormalization group — •Ro Jefferson[1], Johanna Erdmenger[2], and Kevin Grosvenor[3] — [1]Utrecht University — [2]University of Würzburg — [3]Leiden University

Despite the success of deep neural networks (DNNs) on an impressive range of tasks, they are generally treated as black boxes, with performance relying on heuristics and trial-and-error rather than any explanatory theoretical framework. Recently however, techniques and ideas from physics have been applied to DNNs in the hopes of distilling the underlying fundamental principles. In this talk, I will discuss some interesting parallels between DNNs and the renormalization group (RG). I will briefly reivew RG in the context of a simple lattice model, where subsequent RG steps are analogous to subsequent layers in a DNN, in that effective interactions arise after marginalizing hidden degrees of freedom/neurons. I will then quantify the intuitive idea that information is lost along the RG flow by computing the relative entropy in both the Ising model and a feedforward DNN. One finds qualitatively identical behaviour in both systems, in which the relative entropy increases monotonically to some asymptotic value. On the QFT side, this confirms the link between relative entropy and the c-theorem, while for machine learning, it may have implications for various information maximization methods, as well as disentangling compactness and generalizability.

AKPIK 5.3 Wed 12:00 ZEU/0250

Analytic continuation of Greens' functions using neural networks — Johanna Erdmenger, René Meyer, Martin Rackl, and •Yanick Thurn — JMU Würzburg

In quantum many-body physics, the analytic continuation of Greens' functions is a well-known problem. The problem is ill-posed in the sense that the transformation kernel becomes chaotic for large energies and thus small noise creates huge differences in the resulting spectral density function. Some techniques in the field of machine learning, in particular neural networks, are known for handling this kind of problem. Using a neural network and for the problem-optimized loss functions and hyperparameters, a network is trained to determine the spectral density from the imaginary part of the Greens function given by quantum Monte Carlo simulations. The network is able to recover the overall form of the spectral density function, even without adding constraints such as normalization and positive definiteness. There is no need to encode these constraints as regularizations since they are reflected automatically by the solution provided by the network. This indicates the correctness of the inversion kernel learned by the neural network. In the talk, I will explain the structure of the methods used to train the network and highlight the central results.

AKPIK 6: AI Topical Day – Invited Talks (joint session AKPIK/HK/ST/T/AKBP)

Time: Thursday 11:00–12:30 Location: HSZ/AUDI

Invited Talk AKPIK 6.1 Thu 11:00 HSZ/AUDI

AI Techniques for Event Reconstruction — •Ivan Kisel — Goethe University, Frankfurt, Germany

Why can we relatively easily recognize the trajectory of a particle in a detector visually, and why does it become so difficult when it comes to developing a computer algorithm for the same task? Physicists and computer scientists have been puzzling over the answer to this question for more than 30 years, since the days of bubble chambers. And it seems that we are steadily approaching the answer in our attempts to develop and apply artificial neural networks both for finding particle trajectories and for physics analysis of events in general.

This talk will present the basics of artificial neural networks in a simple form, and provide illustrations of their successful application in event reconstruction in high energy physics and heavy ion physics experiments. You will get an insight into the application of traditional neural network models, such as deep neural network, convolutional neural network, graph neural network, as well as those standing a little aside from traditional approaches, but close in idea of elastic network and even cellular automata.

Invited Talk AKPIK 6.2 Thu 11:30 HSZ/AUDI

Accelerator operation optimisation using machine learning — •Pierre Schnizer — Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin, Germany

Accelerators are complex machines whose many components need to be accurately tuned to achive design performance. Reliable operation requires frequent recalibration and tuning. Especially for large machines tools have been developed that facilitating this task.

Machine learning allows building such tools using simulations, archiver data or interaction with the real machine, thus making many tools now also available for smaller machines.

This talk will give an overview of different machine learning projects targeted to accelerators, which simplifies accelerator operation or even enable applications not been possible before.

Invited Talk AKPIK 6.3 Thu 12:00 HSZ/AUDI

Is this even physics? – Progress on AI in particle physics — •Gregor Kasieczka — Universität Hamburg

Motivated by the large volume and high complexity of experimental data and mathematical structures, particle physics has a long tradition of employing state of the art computing and analysis techniques. Recent progress in machine learning and artificial intelligence have further pushed this trend, and these approaches are now ubiquitous in our field. This overview attempts to capture key developments such as the rise of unsupervised approaches and the quest for suitable neural network architectures for physics tasks; challenges like ultra-low latency inference and robust predictions; as well as promising new ideas looking forward.

AKPIK 7: AI Topical Day – Research Data Management and Medical Applications

Time: Thursday 14:00–15:30 Location: HSZ/0101

AKPIK 7.1 Thu 14:00 HSZ/0101

Federated Heterogeneous Compute and Storage Infrastructure for the PUNCH4NFDI Consortium — •Alexander Drabent[1], Jörn Künsemöller[2], Matthias Hoeft[1], Christoph Wissing[3], Manuel Giffels[4], Dominik Schwarz[2], Kilian Schwarz[3], and Andreas Henkel[5] — [1]Thüringer Landessternwarte Tautenburg — [2]Universität Bielefeld — [3]DESY, Hamburg — [4]Karlsruher Institut für Technologie — [5]Johannes Gutenberg-Universität Mainz

PUNCH4NFDI is the NFDI consortium of particle, astro-, astroparticle, hadron and nuclear physics.

Compute4PUNCH and Storage4PUNCH concepts are developed to meet the diverse needs of these communities to provide seamless and federated access to compute and storage systems. Those are being federated in a common infrastructure and transparently integrated with an overlay batch system. Both concepts comprise state-of-the-art technologies for resource access and to ensure scalable provisioning of community specific software. Furthermore, existing technologies for caching as well as metadata handling are being evaluated with the aim for a deeper integration. The combined Compute4PUNCH and Storage4PUNCH environment will allow a large variety of researchers to carry out resource-demanding analysis tasks.

In this contribution we will present the Compute4PUNCH and Storage4PUNCH concepts, the current status of the developments as well as first experiences with scientific applications, such as analysing radio-interferometric data, being executed on the available prototypes.

AKPIK 7.2 Thu 14:15 HSZ/0101

VISPA - Cloud Services for Modern Data Analysis — •Niclas Eich, Louis Christoph, Martin Erdmann, Peter Fackeldey, Benjamin Fischer, Leonard Lux, Dennis Noll, Mathilde Pöppelmann, and Malcom Steen — RWTH Aachen University

VISPA (VISual Physics Analysis) realizes a scientific cloud enabling modern scientific data analysis in a web browser. Our local VISPA instance is backed by a small institute cluster and is dedicated to fundamental research and university education. By hardware upgrades (656 CPU threads, 29 workstation GPUs), we have tailored the cloud services to accomplish both, rapid turn-around when developing O(TB) HEP analyses and deep-learning hands-on with O(100) participants through the web browser. With its latest software developments, VISPA now supports the interactive use of Jupyter notebooks on local as well as on batch resources. Additionally, users can optionally execute their analyses on any SSH reachable large-scale resource they desire. New tools such as an improved user management and a monitoring of the batch resources ensure seamless administration. We will present this major advance of the VISPA project and show how a wide range of scientific data analyses can be realized in the web browser.

AKPIK 7.3 Thu 14:30 HSZ/0101

Towards coherent metadata schema for the PUNCH4NFDI open science platform — •Victoria Tokareva for the

PUNCH4NFDI Consortium-Collaboration — Karlsruhe Institute of Technology, Institute for Astroparticle Physics, Karlsruhe, Germany

PUNCH4NFDI is an NFDI consortium of particle, astro-, astroparticle, hadron and nuclear physics, which is addressing common challenges of data-intense physics at large research facilities: data volumes, data complexity, data rates, and data irreversibility, as well as the development and promotion of open science vision and required tools to achieve this. One of the core features in the development of a PUNCH4NFDI software infrastructure is a cloud-based platform and an open data portal, aimed at providing access to a wide range of digital research materials within the PUNCH4NFDI community and ensuring that the FAIR (findability, accessibility, interoperability, reusability) principles are applied for the community's data collections. This requires to navigate the landscape of different established metadata schemas and find common ground to access the data and run programs and workflows using data from different data collections. In order to achieve this goal, we have investigated core concepts and definitions in the field and analyzed user stories and use cases of several data platforms within the PUNCH4NFDI community. From these, essential requirements for the used metadata have been defined. The results will be presented in this contribution. This work is supported by the DFG fund "NFDI 39/1" for the PUNCH4NFDI consortium.

AKPIK 7.4 Thu 14:45 HSZ/0101

Datenanalytische Hilfestellungen für ein festgelegtes Modell zur Personenerkennung — •Jan Michael Bürger und Hans Dominik Werner — HowRyou GmbH, 24976 Handewitt

Für den Bereich der (Alten-)Pflege werten wir Videodaten mit einer Personenerkennung aus, um eine Videokommunikation genau dann zu ermöglichen, sobald sich die Person alleine im Raum aufhält. Insbesondere aus Datenschutzgründen sollte dabei eine Kommunikation nicht möglich sein, sobald sich mehr als eine Person im Raum aufhält. Gleichzeitig sollte die Person erkannt werden, selbst wenn sie zugedeckt im Bett liegt.

Für diese Aufgabe greifen wir auf bereits verfügbare Modelle zur Personenkennung zurück. Um unsere Anforderungen bestmöglich zu erfüllen, wäre es zunächst naheliegend, dass Modell anzupassen bzw. dieses mit geeigneten Trainingsdaten nachzutrainieren. Um vor allem mit einem kleineren Datensatz auszukommen, haben wir den Fokus auf einen anderen Ansatz gelegt: Wir haben eine systematische Datenanalyse der Personenerkennung auf Testdaten durchgeführt.

Auf Grundlage der Ergebnisse dieser Datenanalyse haben wir (einfache) Techniken implementiert, die die Videobilder im Vorfeld graphisch manipulieren und die Ergebnisse auf geeignete Weise verrechnen. Dazu zählt u.a. das Präsentieren des gleichen Bildes in verschiedenen Helligkeiten und ein virtuelles Drehen des Bildes. Diese Hilfestellungen führten zu zum Teil signifikanten Verbesserungen.

In diesem Vortrag werden die Erfahrungen und Ergebnisse zu von uns untersuchten und verwendeten Hilfestellungen dargestellt.

AKPIK 7.5 Thu 15:00 HSZ/0101

Interpretable Machine Learning and evidence-based decision support in clinical Digital Twins — •Carlos Andres Brandl, Anna Nitschke, and Matthias Weidemüller — Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

Personalized medicine is based on including a vast variety of patient-specific data. The Digital Twin technology provides the opportunity for improved personalized patient care by monitoring the patient journey and predicting the best preventive and therapeutic decision options available. We developed a concept which fuses evidence-based methods with machine learning approaches into a single decision-support tool. Our method is independent on the parameter spaces and evidence-based tools being used, provides possibilities to include updated knowledge and is able to offer intuitively interpretable decision options to the clinician. The presentation introduces our architecture of the digital twin and provides details on the fusion approach.

AKPIK 7.6 Thu 15:15 HSZ/0101

Radiomics for two-dimensional prompt gamma-ray based proton treatment verification — •Sonja M Schellhammer[1,2], Theresa Lenk[1,3], Steffen Löck[1,3,4], and Toni Kögler[1,2] — [1]OncoRay – National Center for Radiation Research in Oncology, Faculty of Medicine and University Hospital Carl Gustav Carus, Technische Universität Dresden, Helmholtz-Zentrum Dresden - Rossendorf, Dresden, Germany — [2]Helmholtz-Zentrum Dresden - Rossendorf, Institute of Radiooncology – OncoRay, Dresden, Germany — [3]German Cancer Consortium (DKTK), Partner Site Dresden, and German Cancer Research Center (DKFZ), Heidelberg, Germany — [4]Department of Radiotherapy and Radiation Oncology, Faculty of Medicine and University Hospital Carl Gustav Carus, Technische Universität Dresden, Dresden, Germany

There is a growing need for on-line verification systems to further increase the safety and efficacy of cancer treatment with proton therapy. For this purpose, we propose a radiomics-based analysis of two-dimensional time-energy distributions of secondary prompt gamma-rays and apply it to realistic data measured in a proton therapy facility. In comparison to previously used methods based only on temporal gamma-ray distributions, we show that the accuracy of the range verification is improved by 38 % (1.5 mm). These results demonstrate that radiomics and machine learning are valuable tools to enhance proton treatment verification for cancer therapy.

AKPIK 8: AI Topical Day – Normalizing Flows and Invertible Neural Networks (joint session AKPIK/T)

Time: Thursday 15:45–17:15 Location: HSZ/0004

AKPIK 8.1 Thu 15:45 HSZ/0004

Efficient Sampling from Differentiable Matrix Elements with Normalizing Flows — •Annalena Kofler[1,2], Vincent Stimper[2,3], Mikhail Mikhasenko[4], Michael Kagan[5], and Lukas Heinrich[1] — [1]Technical University Munich — [2]Max Planck Institute for Intelligent Systems, Tübingen — [3]University of Cambridge, UK — [4]ORIGINS Excellence Cluster, Munich — [5]SLAC National Accelerator Laboratory, Menlo Park, USA

The large amount of data that will be produced by the high-luminosity LHC imposes a great challenge to current data analysis and sampling techniques. As a result, new approaches that allow for faster and more efficient sampling have to be developed. Machine Learning methods such as normalizing flows, have shown great promise in related fields. There, access to not only the density function but also its gradient has proven to be helpful for training. Recently, software for accessing differentiable amplitudes, which serve as densities in particle scattering, have become available that allow us to obtain the gradients and benchmark these new methods. The described approach is demonstrated by training rational-quadratic spline flows with differentiable matrix elements of the hadronic three-body decays, $\pi(1800) \to 3\pi$ and $\Lambda_c^+ \to pK^-\pi^+$. To boost the ability to accurately learn and sample from complex densities whilst also reducing the number of training samples, we explore the use of the newly proposed method Flow Annealed Importance Sampling Bootstrap. Building on prior work, we plan to extend the approach to examples with more particles in the final state via the differentiable matrix elements provided by MadJax.

AKPIK 8.2 Thu 16:00 HSZ/0004

Generating Accurate Showers in Highly Granular Calorimeters Using Normalizing Flows — •Thorsten Buss — Institut für Experimentalphysik, Universität Hamburg, Germany

The full simulation of particle colliders incurs a significant computational cost. Among the most resource-intensive steps are detector simulations. It is expected that future developments, such as higher collider luminosities and highly granular calorimeters, will increase the computational resource requirement for simulation beyond availability. One possible solution is generative neural networks that can accelerate simulations. Normalizing flows are a promising approach in this pursuit. It has been previously demonstrated, that such flows can generate showers in low-complexity calorimeters with high accuracy. We show how normalizing flows can be improved and adapted for precise shower simulation in significantly more complex calorimeter geometries.

AKPIK 8.3 Thu 16:15 HSZ/0004

Introspection for a normalizing-flow-based recoil calibration — •Lars Sowa, Jost von den Driesch, Roger Wolf, Markus Klute, and Günter Quast — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

Normalizing flows (NFs) are neural networks, that preserve the probability between their input and output distributions. NFs can be promising candidates either as surrogates for the fast generation of new samples or as universal approximators of arbitrary probability density functions, based on which confidence intervals may be determined, both of which are interesting properties in high-energy physics (HEP). This work presents the case study of recoil calibration on LHC Run- 3 data and Monte Carlo simulation with the goal to better understand the behavior of NFs. The result of the NF is compared to a deep ensem- ble of feed-forward neural networks created to compare the calibration results and the different coverage in the value space.

AKPIK 8.4 Thu 16:30 HSZ/0004

Normalising Flows for Parameter Estimation from Gravitational Wave Signals — Johannes Erdmann[1], •Jon Hoxha[1], and Shichao Wu[2,3] — [1]III. Physikalisches Institut A, RWTH Aachen University — [2]Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) — [3]Leibniz Universität Hannover

The Einstein Telescope (ET) is a proposal for a next generation ground-based gravitational wave detector. Due to higher sensitivity, ET is expected to receive orders of magnitude more gravitational wave signals than the current 2nd generation detectors LIGO, Virgo and KAGRA. Additionally, these signals will also be in the frequency band of the detector for a longer time, which would cause overlaps of signals. The analysis methods currently in use, which are based on Markov Chain Monte Carlo (MCMC) nested sampling methods, are unsuitable for handling such data and would take up significant computing resources. Therefore, new efficient analysis methods are required. Deep learning methods form a promising approach for this task. Specifically, normalizing flows promise to provide a more efficient means for signal parameter estimation. We use mock data to estimate signal parameters through normalizing flows and compare them to the current standard approach.

AKPIK 8.5 Thu 16:45 HSZ/0004

A method for inferring signal strength modifiers by conditional invertible neural networks — •Mate Zoltan Farkas, Svenja Diekmann, Niclas Eich, and Martin Erdmann — III. Physics Institute A, RWTH Aachen

The continuous growth in model complexity in high-energy physics collider experiments demands increasingly time-consuming model fits. We show first results on the application of conditional invertible networks (cINNs) to this challenge. Specifically, we construct and train a cINN to learn the mapping from signal strength modifiers to observables and its inverse. The resulting network infers the posterior distribution of the signal strength modifiers rapidly and for low computational cost. We present performance indicators of such a setup including the treatment of systematic uncertainties. Additionally, we highlight the features of cINNs estimating the signal strength for a vector boson associated Higgs production analysis carried out at an LHC experiment on simulated data samples.

AKPIK 8.6 Thu 17:00 HSZ/0004

Reconstruction of SAXS Data using Invertible Neural Networks — •Erik Thiessenhusen[1], Melanie Rödel[1], Thomas Kluge[1], Michael Bussmann[2], Thomas Cowan[1], and Nico Hoffmann[1] — [1]HZDR, FWKT, Dresden, Germany — [2]CASUS, Görlitz, Germany

The understanding of laser-solid interactions is important to the development of future laser-driven particle and photon sources, e.g., for tumor therapy, astrophysics or fusion. Currently, these interactions can only be modeled by simulations which need verification within the scope of pump-probe experiments. This experimental setup allows us to study the laser-plasma interaction that occurs when an ultrahigh-intensity laser hits a solid density target. We employ Small-Angle X-Ray Scattering (SAXS) to image the nanometer-scale spatial- and femtosecond temporal resolution of the laser-plasma interactions. However, the analysis of the SAXS pattern is an ill-posed inverse problem meaning that multiple configurations of our target might explain the same measurement due to the loss of the phase information. We approach the ambiguities of the inverse problem by a conditional Invertible Neural Network (cINN) that is returning a probability density distribution over target parameters explaining a single SAXS pattern. We will show that the domain gap between generated training and experimental data can be approached by integrating perturbations of experimental data into the training workflow. We assess the applicability of our approach to a selected set of grating targets in terms of a comprehensive evaluation on simulation and experimental data.

AKPIK 9: AI Topical Day – New Methods (joint session AKPIK/T)

Time: Thursday 17:30–19:00 Location: HSZ/0004

AKPIK 9.1 Thu 17:30 HSZ/0004

Neural networks for cosmic ray simulations — •Pranav Sampathkumar[1], Tanguy Pierog[1], and Antonio Augusto Alves Junior[2] — [1]Institute for Astroparticle Physics (IAP), KIT, Germany — [2]Brazilian Synchrotron Light Laboratory (LNLS), CNPEM, Brazil

Simulating cosmic ray showers at high energies is memory and time intensive. Apart from the traditional methods such as thinning and cascade equations, novel methods are needed for the modern needs in astroparticle physics.

A hybrid model of generating cosmic ray showers based on neural networks is presented. We show that the neural network learns the solution to the governing cascade equation in one dimension. We then use the neural network to generate the energy spectra at every height slice. Pitfalls of training to generate a single height slice is discussed, and we present a sequential model which can generate the entire shower from an initial spectrum. Errors associated with the model and the potential to generate the full three dimensional distribution of the shower and detector footprints are discussed.

AKPIK 9.2 Thu 17:45 HSZ/0004

Transformer-Based Eventwise Reconstruction of Cosmic-Ray Masses at the Pierre Auger Observatory — Martin Erdmann, •Niklas Langner, and Dominik Steinberg — III. Physikalisches Institut A, RWTH Aachen University

As one aspect of the AugerPrime upgrade, scintillators (SSDs) will be added to the water Cherenkov detectors (WCDs) that form the surface detector of the Pierre Auger Observatory. This combined measurement offers the possibility to distinguish individual components of extensive air showers, potentially increasing the mass sensitivity. To efficiently exploit this new potential, novel methods are needed.

We introduce a Transformer-based neural network to reconstruct cosmic-ray masses from joint WCD and SSD measurements that outperforms both recurrent and convolutional networks. Efficient Transformers are employed to analyze and relate the two different sets of time traces on station level while ensuring a reasonable degree of computational demands. A Vision Transformer is then applied to the hexagonal grid of detector stations to process the whole shower footprint.

The Transformer network is trained to simultaneously reconstruct the depth of the shower maximum $X_{\max}$ as well as the shower's number of muons on ground R_μ. Both observables can be combined to estimate the primary cosmic-ray mass with an accuracy higher than what can be achieved individually.

AKPIK 9.3 Thu 18:00 HSZ/0004

Quantum Angle Generator for Image Generation — •Florian Rehm[1,2], Sofia Vallecorsa[1], Michele Grossi[1], Kerstin Borras[2,3], Dirk Krücker[2], Simon Schnake[2,3], Alexis-Harilao Verney-Provatas[2,3], and Valle Varo[3] — [1]CERN, Switzerland — [2]RWTH Aachen University, Germany — [3]DESY, Germany

The Quantum Angle Generator (QAG) is a new generative model for quantum computers. It consists of a parameterized quantum circuit trained with an objective function. The QAG model utilizes angle encoding for the conversion between the generated quantum data and classical data. Therefore, it requires one qubit per feature or pixel, while the output resolution is adjusted by the number of shots performing the image generation. This approach allows the generation of highly precise images on recent quantum computers. In this paper, the model is optimised for a High Energy Physics (HEP) use case generating simplified one-dimensional images measured by a specific particle detector, a calorimeter. With a reasonable number of shots, the QAG model achieves an elevated level of accuracy. The advantages of the QAG model are lined out - such as simple and stable training, a reasonable amount of qubits, circuit calls, circuit size and computation time compared to other quantum generative models, e.g. quantum GANs (qGANs) and Quantum Circuit Born Machines.

AKPIK 9.4 Thu 18:15 HSZ/0004

Photon identification at hadron colliders using graph neural networks — •Ali Malyali Choban[1], Johannes Erdmann[1], Florian Mausolf[1], and Christopher Morris[2] — [1]III. Physikalisches Institut A, RWTH Aachen University — [2]Fachgruppe Informatik, RWTH Aachen University

At hadron colliders like the LHC, photons are essential physics objects in a wide range of analyses. For example, they allow the study of the Higgs boson using the diphoton decay channel. At a typical particle detector, the main signatures of photons are energy depositions in the electromagnetic calorimeter. However, other objects can leave similar signatures in the electromagnetic calorimeter, leading to misidentification as photons. Jets are abundant at the LHC and they include a high number of light hadrons, most notably neutral pions decaying into two photons. The decay of pions produces photons that are often close to each other and they are likely to be reconstructed as a single photon. However, photon candidates from jets have different attributes that can help to discriminate them from real photons. Specifically, they tend to produce wider signatures in the calorimeter, and to be accompanied by more additional particles.

Graph neural networks (GNNs) are flexible neural architectures well suited for dealing with input data of irregular structure and variable shape. Hence, they are particularly suited for classifying photon candidates as often a variable number of particles surrounds them. In this talk, our study of the applicability of GNNs for photon identification and comparisons with convolutional neural networks are presented.

AKPIK 9.5 Thu 18:30 HSZ/0004

Data-driven Simulation of Target Normal Sheath Acceleration by Fourier Neural Operator — Jeyhun Rustamov[1,2], Thomas Miethlinger[1], Thomas Kluge[1], Michael Bussmann[1,3], and •Nico Hoffmann[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]TU Dresden, Dresden, Germany — [3]CASUS, Görlitz, Germany

Particle-in-Cell simulations are a ubiquitous tool for linking theory and experimen- tal data in plasma physics rendering the comprehension of non-linear processes such as Laser Plasma Acceleration (LPA) feasible. These numerical codes can be considered as state-of-the-art approach for studying the underlying physical processes in high temporal and spatial resolution. The analysis of experiments is performed by optimising simulation parameters so that the simulated system is able to explain experimental results. However, a high spatio-temporal resolution comes at the cost of elevated simulation times which makes the inversion nearly impossible. We tackle that challenge by introducing and studying a reduced order model based on Fourier neural operator that is evolving the ion density function of Laser-driven Ion acceleration via 1D Target Normal Sheath acceleration (TNSA). The ion density function can be dynamically generated over time with respect to the thickness of the target. We show that this approach yields a significant speed-up compared to numerical code Smilei while retaining physical properties to a certain degree promising applicability for inversion of experimental data by simulation-based inference.

AKPIK 9.6 Thu 18:45 HSZ/0004

RootInteractive tool for multidimensional statistical analysis, machine learning and analytical model validation — •Marian Ivanov[1] and Marian Ivanov jr.[2] for the ALICE Germany-Collaboration — [1]GSI Darmstadt — [2]UK Bratislava

ALICE, one of the four large experiments at CERN LHC, is a detector for the physics of heavy ions. In a high interaction rate environment, the pile-up of multiple events leads to an environment that requires advanced multidimensional data analysis methods.

Our goal was to provide a tool for dealing with multidimensional problems, to fit and visualize multidimensional functions including their uncertainties and biases, to validate assumptions and approximations, to easy define the functional composition of analytical parametric and non-parametric machine learning functions, to use symmetries and to define multidimensional "invariant" functions/alarms.

RootInteractive is a general-purpose tool for multidimensional statistical analysis. Its declarative programming paradigm makes it easy to use for professionals, students, and educators. RootInteractive provides functions for interactive, easily configurable visualization of unbinned and binned data and extraction of derived aggregate information on the server (Python/C++) and client (Javascript). We support client/server applications using Jupyter, or a stand-alone client-side interactive application/dashboard.

AKPIK 10: AI Topical Day – Computing II (joint session HK/AKPIK)

Time: Thursday 14:00–15:30 Location: HSZ/0103

AKPIK 10.1 Thu 14:00 HSZ/0103

Exploiting Differentiable Programming for the End-to-end Optimization of Detectors — The MODE Collaboration[1] and •Anastasios Belias[2] — [1]mode-collaboration.github.io — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

Machine-learning Optimized Design of Experiments, the MODE Collaboration, targets the end-to-end optimization of experimental apparatus, by using techniques developed in modern computer science to fully explore the multi-dimensional space of experiment design solutions. Differentiable Programming is employed to create models of detectors that include stochastic data-generation processes, the full modeling of the reconstruction and inference procedures, and a suitably defined objective function, along with the cost of any given detector configuration, geometry and materials.

The MODE Collaboration considers the end-to-end optimization challenges in its generality, providing software architectures for machine learning to explore experiment design strategies, information on the relative merit of different configurations, with the potential to identify and investigate novel, possibly revolutionary solutions. In this contribution we present use cases, and highlight the potential for on-going and future experiment design studies in fundamental physics research.

AKPIK 10.2 Thu 14:15 HSZ/0103

Klassifikation von Pulsdaten mit neuronalen Netzwerken auf einer FPGA Accelerator Card — •Robert Ufer, Bastian Auer, Helene Hoffmann, Oliver Knodel, Mani Lokamani und Stefan Müller — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Zur Analyse der entstehenden Detektordaten bei dem Mu2e Experiment am Fermilab soll die Datenauswertung mit Field Programmable Gate Array (FPGA) erfolgen. Diese übernehmen die notwendige Vorverarbeitung und Reduktion der Messdaten, noch während der Durchführung der Messung. Die dabei ausgeführten Anwendungen werden standardmäßig durch Algorithmen realisiert. Eine dieser Anwendungen führt die Klassifikation der ermittelten Pulsdaten durch. Mit den Testläufen an der gELBE Bremstrahlungs-Beamline am Helmholtz-Zentrum Dresden-Rossendorf (HZDR) konnte für das zukünftige Experiment eine große Menge dieser Datensätze erfasst werden. Diese dienen zur Charakterisierung des Detektorsystems und wurden mit einem Lanthanbromid (LaBr) Detektor gemessen. Für die Pulsdatenklassifikation wird auf der Basis des Algorithmus und der erfassten Datensätze, ein neuronales Netzwerk erstellt, trainiert und validiert. Um bei diesen Schritten etablierte Machine Learning Frameworks zu verwenden, wird für die Portierung des Netzwerks in eine High-Level Synthese (HLS) Sprache die Software hls4ml verwendet. Dabei werden verschiedene Konfigurationen genutzt, um unterschiedlich optimierte Implementierungen zu generieren. Zum Evaluieren erfolgt die Ausführung der Implementierungen auf einer Xilinx Alveo Accelerator Card.

AKPIK 10.3 Thu 14:30 HSZ/0103

Pattern recognition using machine learning for the mCBM

mRICH detector — •Martin Beyer for the CBM-Collaboration — Justus-Liebig-Universität Gießen

The Compressed Baryonic Matter experiment (CBM) is designed to explore the QCD phase diagram at high baryon densities using high-energy heavy ion collisions at high interaction rates. The Ring Imaging Cherenkov detector (RICH) contributes to the overall particle identification by reconstruction of rings from electrons with their respective radius, position and time. The miniCBM (mCBM) detector is the test setup for the CBM experiment, with the purpose of testing both hardware and software including the triggerless free-streaming data acquisition and data reconstruction algorithms. The miniRICH (mRICH) detector in the mCBM setup is a proximity focussing RICH detector with a photon detection plane consisting of 36 MultiAnode Photo Multipliers (MAPMTs). This setup results in charged particles passing directly through the MAPMTs resulting in quite some additional signals typically inside ring structures and reducing the overall ring finding efficiency based on the Hough Transformation.

In this talk a machine learning approach is presented to classify those signals in ring centers and thus improving the overall ring finding efficiency and precision.

AKPIK 10.4 Thu 14:45 HSZ/0103

Machine Learning Algorithms for Pattern Recognition with the PANDA Barrel DIRC — •Yannic Wolf[1,2], Roman Dzhygadlo[1], Klaus Peters[1,2], Georg Schepers[1], Carsten Schwarz[1], and Jochen Schwiening[1] — [1]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt — [2]Goethe-Universität Frankfurt

Precise and fast hadronic particle identification (PID) is crucial to reach the physics goals of the PANDA detector at FAIR. The Barrel DIRC (Detection of Internally Reflected Cherenkov light) is a key detector for the identification of charged hadrons in PANDA. Several reconstruction algorithms have been developed to extract the PID information from the measured location and arrival time of the Cherenkov photons. In comparison to other Ring Imaging Cherenkov detectors, the hit patterns observed with DIRC counters do not appear as rings on the photosensor plane but as complex, disjoint 3D-patterns.

Using the recent advances in machine learning (ML) algorithms, especially in the area of image recognition, we plan to develop new ML PID algorithms for the PANDA Barrel DIRC and compare the results to conventional reconstruction methods. In search for the best performance, different network architectures are currently under investigation.

AKPIK 10.5 Thu 15:00 HSZ/0103

Optimization of the specific energy loss measurement for the upgraded ALICE TPC using machine learning — •Tuba Gündem for the ALICE Germany-Collaboration — Institut fuer Kernphysik, Frankfurt, Germany

The Time Projection Chamber (TPC) is the primary detector used in the ALICE experiment for tracking and particle identification (PID). PID is accomplished by reconstructing the momentum and the specific energy loss ($\mathrm{d}E/\mathrm{d}x$) of a particle. The $\mathrm{d}E/\mathrm{d}x$ for a given track is calculated using a truncated mean on the charge signals associated to the track. The readout plane, on which the signals are measured, is radially subdivided into four regions with different pad sizes. Since the measured signals depend on the pad size, an optimization of the $\mathrm{d}E/\mathrm{d}x$ calculation based on the pad size can be performed.

In this talk, a method for optimizing the $\mathrm{d}E/\mathrm{d}x$ calculation using machine learning (ML) algorithms will be presented. By performing realistic simulations of the generated signals on the pads, various effects such as the different pad sizes and track geometry are modeled. These simulations are used as inputs for the training of the ML model and are investigated using RootInteractive.

Supported by BMBF and the Helmholtz Association.

AKPIK 10.6 Thu 15:15 HSZ/0103

Deep Leaning Based PID with the HADES detector — •Waleed Esmail[1] and James Ritman[1,2,3] for the HADES-Collaboration — [1]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany — [2]Forschungszentrum Jülich, 52428 Jülich, Germany — [3]Ruhr-Universität Bochum, 44801 Bochum, Germany

The main purpose of a particle identification (PID) algorithm is to provide a clean sample of particle species needed to conduct a physics analysis. The conventional approach used in the HADES experiment is to apply the so-called "graphical cuts" around the theoretical Bethe-Bloch curves of the energy loss as a function of the particle momentum. However, this approach is not optimal, since the distributions resulting from the different particle species overlap. A better approach is based on deep learning algorithms. In our preliminary studies done with the p(4.5 GeV)+p data recently collected by HADES, we were able to improve the separation power of the particle species. The algorithm is based on Domain Adversarial Neural Networks (DANN) trained in a semi-supervised way to simultaneously look at simulated and real data to learn the discrepancies between the two data domains. In this talk we will present our preliminary results, which show that this technique significantly improves the classification of particle species in the experimental data.

AKPIK 11: AI Topical Day – AI in Medicine (joint session ST/AKPIK)

Time: Thursday 14:00–15:30 Location: ZEU/0146

AKPIK 11.1 Thu 14:00 ZEU/0146

Multimodal image registration with deep learning — •Alexander Ratke[1], Christian Bäumer[2], Kevin Kröninger[1], and Bernhard Spaan[1] — [1]TU Dortmund University, Dortmund, Germany — [2]West German Proton Therapy Centre Essen, Essen, Germany

In radiation therapy, precise localisation of tumour and risk structures is important for treatment planning. Medical imaging methods, such as computed tomography (CT) and magnetic resonance imaging (MRI), allow a differentiation between these structures. Planning systems typically align CT and MRI scans rigidly to compensate inaccurate immobilisation of the patient, but distortions in MRI or movement of organs still remain.

In this project, a data set of CT and MRI scans of the head and neck areas is used to study unsupervised deformable image registration with deep learning. First, the scans are pre-processed, which includes rigid registrations and the equalisation of the image formats. Then, deep learning is employed to filter structures of an image through multiple layers and to match them to a second image. The registration model strongly depends on the choice of its parameters. Therefore, variations of these parameters are investigated on the data set. The results are presented as well as the overall workflow including the pre-processing.

AKPIK 11.2 Thu 14:15 ZEU/0146

Position reconstruction in proton therapy with proton radiography and machine learning — •Jolina Zillner, Carsten Burgard, Jana Hohmann, Kevin Kröninger, Florian Mentzel, Olaf Nackenhorst, Isabelle Schilling, Hendrik Speiser, and Jens Weingarten — TU Dortmund University, Department of Physics, Germany

In proton therapy precise patient positioning is essential for treatment quality. Current research in proton radiography (pRad) enables imaging of the patient immediately prior to irradiation. The idea is to use such pRad images to verify the patients position.

Therefore a 3D Convolutional Neural Network will be developed in order to predict pRad images depending on the CT image of an object and different translations and orientations. A minimization algorithm can then find the translation and rotation vector for which the predicted image has the smallest difference to a measured pRad image of the object, which can be used to correct the objects position. To predict pRad images, the CNN needs to be trained with pRad images and their related object translation and rotation and the CT-image.

This talk introduces the simulation used to generate these pRad training data. Simulations and reference measurements are performed with a primitive elbow phantom: a 3D-printed 3x3x3 cm^3 cube with a T-cavity for gypsum-inlays representing a stretched or bent elbow. The target is implemented in GEANT4 based on CT-data.

AKPIK 11.3 Thu 14:30 ZEU/0146

Event identification in the SiFi-CC Compton camera for

imaging prompt gamma rays in proton therapy via deep neural networks — •Alexander Fenger[1], Ronja Hetzel[1], Jonas Kasper[1], George Farah[1], Achim Stahl[1], and Aleksandra Wrońska[2] — [1]III. Physikalisches Institut B, RWTH Aachen University — [2]M. Smoluchowski Institute of Physics, Jagiellonian University Kraków, Poland

One of the biggest challenges in proton therapy is ensuring that the dose is delivered to the right position. A promising approach for online monitoring of the beam range is the detection of prompt gamma rays using a Compton camera, as it provides the possibility to reconstruct the 3D distribution of the deposited dose.

The SiFi-CC (SiPM and scintillating Fiber-based Compton Camera) project is a joint collaboration of the RWTH Aachen University, the Jagiellonian University in Kraków and the University of Lübeck. The two modules of the SiFi-CC, the scatterer and the absorber, both consist of stacked LYSO fibres and are read out by SiPMs. Deep neural networks are employed to separate valid Compton events from background and reconstruct the direction and energy of prompt gamma rays. First implementations of neural networks show promising results in classification of Compton events as well as full reconstruction of the event topology and kinematics. The next step is to further optimize the current neural network implementation to gain sensitivity towards a detectable range shift in the source position. Different neural network designs as well as an evaluation of their performance are presented.

AKPIK 11.4 Thu 14:45 ZEU/0146

Selection of Compton events in the SiFi-CC camera using convolutional neural networks — •George Farah[1], Ronja Hetzel[1], Jonas Kasper[1], Alexander Fenger[1], Achim Stahl[1], and Aleksandra Wrońska[2] — [1]III. Physikalisches Institut B, RWTH Aachen University — [2]M. Smoluchowski Institute of Physics, Jagiellonian University Kraków, Poland

Proton therapy is a promising form of cancer treatment that uses charged protons to target and kill cancer cells. One of the main challenges in proton therapy is accurately determining the depth at which the protons will deposit their energy in the tumor.

The SiFi-CC (SiPM and scintillating Fiber-based Compton Camera) aims to enable range detection in proton therapy. It consists of multiple scintillating LYSO fibers generating signals that get read by SiPMs attached to both ends of the fibers. The camera utilizes the Compton effect and photoelectric effect to detect the prompt gamma rays produced in nuclear interactions of the protons with the nuclei in the tumor. This allows restricting the origin of the prompt gamma to a cone surface and by reconstructing many of such cones it is possible to reconstruct the source distribution of the prompt gammas.

The most recent SiFi-CC geometry has four fibers coupled to one SiPM in a shifted manner, so signals from multiple fibers get read by a single SiPM. In this talk, we present how three-dimensional neural networks can be advantageous by taking into consideration this new geometry. Hence improving the detection of Compton events, which improves the accuracy of range detection in proton therapy.

AKPIK 11.5 Thu 15:00 ZEU/0146

Fast dose predictions for conformal synchrotron microbeam irradiations — •Marco Schlimbach[1], Micah Barnes[2], Kevin Kröninger[1], Florian Mentzel[1], Olaf Nackenhorst[1], and Jens Weingarten[1] — [1]TU Dortmund, Germany — [2]University of Wollongong, Australia

An important optimization goal of radiation therapy is to apply the prescribed dose to the tumor while minimizing the dose deposition to surrounding healthy tissue. The new preclinical irradiation method, called Microbeam Radiation Therapy (MRT), enables higher control for certain tumors by spatial fractionation of photon beams compared to conventional irradiation methods. At the same time, the exposure of normal tissue remains the same.

Currently, the dose for MRT is mostly calculated with time-consuming Monte-Carlo simulations. However, for transfer to clinical application, a fast dose calculation is essential, so that therapies can be planned in a sufficiently short time. Recent studies show that MRT doses can be predicted accurately within milliseconds using neural networks. These studies, however, are limited to predicting the dose from a fixed MRT field size.

This work presents a method to extend the developed machine learning model to predict the doses from MRT irradiation fields of variable size and shape. Since there is no data from the clinic for MRT compared to conventional irradiation methods, the models are trained using a Geant4 Monte-Carlo simulation of a rodent head irradiation at the Imaging and Medical beamline at the Australian Synchrotron.

AKPIK 11.6 Thu 15:15 ZEU/0146

Thermoluminescence glow curve generation using generative adversarial networks (GANs) — •Evelin Derugin[1], Olaf Nackenhorst[1], Florian Mentzel[1], Jens Weingarten[1], Kevin Kröninger[1], and Jörg Walbersloh[2] — [1]Department of Physics, TU Dortmund University — [2]Materialprüfungsamt NRW

Personal dose monitoring is essential for a successful radiation protection program for occupationally exposed persons. The Materialprüfungsamt NRW (MPA NRW) provides thermoluminescence (TL) dosimeters based on LiF:Mg,Ti. Proof-of-concept studies to predict the day of irradiation have been successfully performed on measured TL glow curves using artificial neural networks (ANN). However, large data sets are required to train an ANN to predict the parameters of new measurements. Therefore the Department of Physics at TU Dortmund is developing multivariate methods for generating TL glow curves using generative adversarial networks (GANs). These generated glow curves will be used as training data for the irradiation day prediction model. This study trains GANs to generate glow curves using a measured data set of 4100 glow curves with 28 irradiation dates. In this talk, we present the comparison of the simulated glow curves with the measured ones and provide information about the performance and optimization of the GAN.

AKPIK 12: AI Topical Day – Heavy-Ion Collisions and QCD Phases (joint session HK/AKPIK)

Time: Thursday 14:00–15:30 Location: HSZ/0105

AKPIK 12.1 Thu 14:00 HSZ/0105

Modelling charged-particle production at LHC energies with deep neural networks — •Maria Calmon Behling for the ALICE Germany-Collaboration — Institut für Kernphysik, Goethe-Universität Frankfurt, Germany

Particle production at the Large Hadron Collider (LHC) is driven by a complex interplay of soft and hard QCD processes. Modelling these interactions across center-of-mass energies and collision systems is still challenging for Monte Carlo event generators. Concise experimental data is indispensable to characterize the final state of a collision. The ALICE experiment with its unique tracking capabilities down to low transverse momenta is perfectly suited to study the bulk particle production in high-energy collisions. During the data taking campaigns of LHC Run 1 and Run 2 (2009 - 2018), a large amount of data were collected of a variety of collision systems at different center-of-mass energies. A recent measurement of charged-particle production covering all of these collision systems provides a comprehensive set of fundamental observables like the charged-particle multiplicity distributions and transverse momentum spectra as well as their correlation.

In this talk, we discuss the possibility of extending this set of discrete experimental data points into unmeasured regions by means of machine learning techniques. Training deep neural networks with ALICE data gives the unique opportunity to measure the evolution of multiplicity dependent charged-particle production across collision system sizes and energies.

Supported by BMBF and the Helmholtz Association.

AKPIK 12.2 Thu 14:15 HSZ/0105

Measurement of the Λ separation energy in hypertriton with ALICE using machine learning techniques — •Regina Michel for the ALICE Germany-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung — Technische Universität Darmstadt

Hypertriton ${}^{3}_{\Lambda}\mathrm{H}$ is the lightest hypernucleus, consisting of a Λ hyperon, a proton and a neutron. It is structured as a halo nucleus, where the Λ hyperon is very loosely bound to a "deuteron core". Measurements of the Λ separation energy can be used as a test for QCD, for some models of neutron stars and to constrain the possible difference of the lifetimes of ${}^{3}_{\Lambda}$H and Λ. The Λ separation energy can be measured via the invariant mass of the hypertriton decay products. The two-body-decay ${}^{3}_{\Lambda}\mathrm{H} \rightarrow {}^{3}\mathrm{He}+\pi$ is considered. Monte Carlo simulations are conducted to simulate the hypertriton interactions and decays while propagating through the detector. A data sample from Pb-Pb collisions at a center-of-mass energy of $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV recorded with ALICE at the LHC is analyzed using machine learning techniques.

AKPIK 12.3 Thu 14:30 HSZ/0105

Physics performance studies on Ξ^- Baryon at CBM — •Lisa-Katrin Kümmerer[1,2], Andrea Dubla[2], and Ilya Selyuzhenkov[2] for the CBM-Collaboration — [1]Physikalisches Institut, Universität Heidelberg — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt

The Compressed Baryonic Matter (CBM) experiment at FAIR will investigate the QCD phase diagram in the region of high net-baryon densities ($\mu_B > 500$ MeV) in the collision energy range of $\sqrt{s_{NN}} = 2.7 - 4.9$ GeV with high interaction rate, up to 10 MHz, provided by the SIS100 accelerator. The (multi)strange baryons are crucial in determining the chemical freeze-out and its connection to hadronization from deconfined QCD matter.

In this contribution the performance for Ξ^- selection in Au-Au collisions at $\sqrt{s_{NN}} = 4.93$ GeV in the CBM experiment will be presented. The Ξ^- hyperon is reconstructed via the weak decay channel $\Xi^- \rightarrow (\Lambda \rightarrow p\pi^-)\pi^-$ using the Particle-Finder Simple package.

For the reduction of the data size, which is driven by the large combinatorial background, specific skimming pre-selection criteria are optimized in this work. To obtain an optimal and stable separation between signal and background candidates the machine learning tool XGBoost is used. Machine learning allows for efficient, non-linear and multi-dimensional selection criteria to be implemented in a heavy-ion collision environment, enabling to extract and correct the Ξ^- raw yield in different rapidity and transverse momentum intervals.

AKPIK 12.4 Thu 14:45 HSZ/0105

Multi-differential Λ Yield Measurement in the CBM Experiment using Machine Learning Techniques — •Axel Puntke[1] and Shahid Khan[2] for the CBM-Collaboration — [1]Institut für Kernphysik, WWU Münster — [2]Eberhard Karls University of Tübingen

The Compressed Baryonic Matter (CBM) experiment at FAIR will investigate the QCD phase diagram at high net-baryon densities (μB > 500 MeV) with heavy-ion collisions in the energy range of $\sqrt{s}_{\mathrm{NN}} = 2.9$-4.9 GeV. Precise determination of dense baryonic matter properties requires multi-differential measurements of strange hadron yields, both for the most copiously produced K^0_s and Λ as well as for rare (multi-)strange hyperons and their antiparticles.

The strange hadrons are reconstructed using methods based on a Kalman Filter algorithm that has been developed for the reconstruction of particles via their weak decay topology. The large combinatorial background needs to be suppressed by applying selection criteria according to the topology of the decay. This selection is optimized by training a boosted decision tree-based machine learning model with simulated data from two event generators, UrQMD and DCM-QGSM-SMM. After the signal has been selected, the yield of the strange hadron is computed.

In this talk, the analysis procedure for the most abundant Λ baryon is presented and the performance of the non-linear multi-parameter selection method is evaluated. A fitting routine is implemented to extract the Λ yield, on which the performance gain of training a separate model for each p_{T}-y interval will be discussed.

AKPIK 12.5 Thu 15:00 HSZ/0105

Full beauty-hadron reconstruction with J/ψ: feasibility study for Run 3 with ALICE — •Guillaume Taillepied for the ALICE Germany-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

The study of the production of hidden and open heavy-flavour hadrons in proton-proton (pp) collisions provides an essential test of quantum chromodynamics, involving both the perturbative and non-perturbative regimes. The J/ψ meson allows to study both the charm sector, via the measurement of prompt J/ψ, and the beauty sector through the measurement of the non-prompt component, coming from the decay of beauty hadrons. With the recent upgrades of the ALICE apparatus, the full reconstruction of beauty hadrons in exclusive decay channels containing non-prompt J/ψ mesons is now possible, providing a new way to study beauty physics in hadronic collisions.

In this talk, a feasibility study of the $\mathrm{B}^+ \rightarrow \mathrm{J}/\psi\ \mathrm{K}^+$, $\mathrm{J}/\psi \rightarrow \mathrm{e}^+\mathrm{e}^-$ process in pp collisions at $\sqrt{s} = 13.6$ TeV with ALICE will be presented. The analysis makes use of the KFParticle package for a precise reconstruction of the B^+ and non-prompt J/ψ decay chain. The package also provides important information for the training of a machine learning model, increasing the signal selection efficiency and signal-over-background ratio. Discussions on the perspectives in lead-lead collisions for Run 3, based on the results of this feasibility study, will be shown.

AKPIK 12.6 Thu 15:15 HSZ/0105

Photon reconstruction in the Transition Radiation Detector of ALICE — •Peter Stratmann for the ALICE Germany-Collaboration — Institut für Kernphysik, Wilhelm-Klemm-Str. 9, 48149 Münster

The Transition Radiation Detector (TRD) of the ALICE detector at the Large Hadron Collider has the main purpose of identifying electrons and triggering on electrons and jets. Furthermore, it improves the resolution in track reconstruction at high transverse momenta. The working principle is based on transition radiation, which is produced by charged particles transversing boundaries of material with different dielectric constants.

In a rather new approach, the TRD should be used for measuring the photon production through the detection of conversion electrons. This is facilitated by the large material budget located in front and inside of the TRD. For this purpose, stand-alone tracking independent of the Inner Tracking System and the Time Projection Chamber had already been implemented. So far, this is achieved by a Kalman filter. As a new method, the photons are reconstructed in the TRD using Graph Neural Networks. These have the advantage that they operate well on the high-dimensional and sparse nature presented by the TRD data. In this talk, we will present the principles of the TRD, the direct photon reconstruction in the stand-alone tracking, and first results obtained with the Graph Neural Network.

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