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.