T 38: Data analysis, information technology II

Time: Tuesday 16:00–18:30 Location: Tm

T 38.1 Tue 16:00 Tm

Composition Study of Cosmic Rays with IceCube Observatory using Graph Neural Networks — •Paras Koundal for the IceCube-Collaboration — Institute for Astroparticle Physics, Karlsruhe Institute of Technology, Germany

Concealed deep under the South Pole Antarctic Ice, the IceCube Observatory is a large-scale physics detector used to capture high-energy particles from cosmic events and provide us with new insights into their fundamental behaviour. Besides its principle usage and merits in neutrino astronomy, IceCube is also used for cosmic-ray detection.

The information about the cosmic-ray induced high-energy muons detected primarily in the in-ice part of the IceCube detector and the induced electromagnetic component, detected at the corresponding surface array called IceTop, has proven to be useful for cosmic-ray studies. However, their composition analysis are still prone to large systematic uncertainties. There is a significant dependence of expected particle-flux and primary-particle mass on the hadronic-interaction model one chooses to interpret the air-shower measurements. This talk discusses the ongoing progress made to establish a consistent framework using full event-signal information, for an improved cosmic-ray spectrum analysis in the transition region from Galactic to extragalactic sources, using advanced techniques in Graph Neural Networks. This is a significant progress over the previous analysis which relied primarily on signal information from IceTop. This will help establish IceCube as a unique three-dimensional cosmic-ray detector, providing improved sensitivities for detailed physics analysis.

T 38.2 Tue 16:15 Tm

Deep-Learning-Based Reconstruction of Cosmic-Ray Properties From Extensive Air Shower Measurements — Martin Erdmann, Jonas Glombitza, Berenika Idaszek, and •Niklas Langner — III. Physikalisches Institut A, RWTH Aachen University

Ultra-high-energy cosmic rays colliding with the Earth's atmosphere lead to the formation of extensive air showers. At the Pierre Auger Observatory, showers are measured using the surface detector (SD) on ground and the fluorescence detector (FD) observing the sky above. The depth of shower maximum, directly measurable by the FD, is of particular interest due to its connection to the cosmic-ray mass.

Currently thriving in the field of machine learning, deep neural networks which consist of hundreds of thousands of parameters can be trained to exploit complex data and extract information otherwise hard to access. While such networks are able to achieve remarkable precision, understanding their working principle is challenging due to the large number of parameters. Using deep learning, the depth of shower maximum can be extracted from SD observations.

We present our network to extract properties of air showers by analyzing the signal of water Cherenkov detectors. It utilizes recurrent long short-term memory layers and hexagonal convolutions. The technical setup and method is explained. We investigate the reasoning of the trained network by visualizing inputs relevant for the network's decision. We show the performance of our method using simulations and discuss the incorporation of additional scintillator detectors which are part of the upgrade program of the Pierre Auger Observatory.

T 38.3 Tue 16:30 Tm

Using a conditional Invertible Neural Network to determine the parameters of ultra-high-energy cosmic ray sources — Teresa Bister, Martin Erdmann, and •Josina Schulte — III. Physikalisches Institut A, RWTH Aachen University

The usage of modern machine learning techniques is growing with immense speed and new advanced methods for physics analysis are developed. Often, the task is to estimate the physical parameters of a model, using only a set of measurements without the possibility to formulate an explicit inverse function. Traditionally, the full posterior parameter distributions can be approximated using the Markov Chain Monte Carlo (MCMC) method. This is useful to uncover correlations and to estimate the parameter uncertainties. However, posterior sampling is generally computationally expensive and slow. A new alternative technique, based on Deep Learning, is a so-called conditional Invertible Neural Network. Here, the network implicitly learns the posterior distributions from a large set of training data, whereby a specific loss function ensures convergence. The basic functionality and possibilites of this technique, applied on an example from astroparticle physics, will be presented in this talk. Here, the observable is the binned energy spectrum of ultra-high-energy cosmic rays on Earth. The free parameters of the astrophysical model define the acceleration process at the origin sites, which are currently still unknown. We show that it is possible to find posterior distributions of the free model parameters with the network and compare them to the ones using the classic MCMC method.

T 38.4 Tue 16:45 Tm

Muon bundle reconstruction with KM3NeT/ORCA using graph convolutional networks — •Stefan Reck for the ANTARES-KM3NeT-Erlangen-Collaboration — Friedrich-Alexander-Universität Erlangen-Nürnberg, ECAP

KM3NeT/ORCA is a water-Cherenkov neutrino detector, currently under construction in the Mediterranean Sea at a sea depth of 2450 meters. The project's main goal is the determination of the neutrino mass hierarchy by measuring the energy- and zenith-angle-resolved oscillation probabilities of atmospheric neutrinos traversing the Earth.

Deep Learning techniques provide promising methods to analyse the signatures induced by the particles traversing the detector. Despite being in an early stage of construction, the data taken so far already provide large statistics to investigate the signatures from atmospheric muons. This talk will cover a deep-learning based approach using graph convolutional networks to reconstruct atmospheric muon bundles, and results on both simulations and data will be presented. Furthermore, the performances are compared to the ones of classical approaches, showing good agreement.

T 38.5 Tue 17:00 Tm

CNN classification and regression for ANTARES — •Nicole Geisselbrecht for the ANTARES-KM3NeT-Erlangen-Collaboration — Friedrich-Alexander-Universität Erlangen-Nürnberg, ECAP

ANTARES is the largest undersea neutrino detector, installed in the Mediterranean Sea, and is primarily sensitive to neutrinos in the TeV-PeV energy range. Data taking with the telescope has been continuous since 2008. One of the central goals of ANTARES, next to searches for neutrino signals from point, transient, and extended sources, is an independent detection and investigation of the diffuse cosmic neutrino flux discovered by IceCube. The suppression of backgrounds, in particular of atmospheric muons, is essential to further increase the sensitivity of the data analysis.
The contribution reports on the design and application of deep Convolutional Neural Networks to ANTARES telescope data. Data preprocessing concepts, image generation, and performance investigations of an event-topology classifier as well as first studies with energy regression will be presented.

T 38.6 Tue 17:15 Tm

graFEI: Full Event Interpretation using Graph Neural Networks at Belle II — •Lea Reuter[1], James Kahn[2], Ilias Tsaklidis[3], and Pablo Goldenzweig[1] — [1]Institut für Experimentelle Teilchenphysik (ETP), Karlsruher Institut für Technologie (KIT) — [2]Steinbuch Centre for Computing (SCC), Karlsruher Institut für Technologie (KIT) — [3]Physikalisches Institut, Universität Bonn, Germany

At the Belle II experiment, flavor physics and charge parity violation are investigated at the $\Upsilon(4S)$ resonance. By colliding electrons and positrons, the Belle II experiment ensures a clean collision environment, where the initial state is fully defined. Neutrinos or other missing particles that cannot be directly detected, can therefore be identified using conservation laws. To analyse such processes, it is necessary to reconstruct the full $\Upsilon(4S)$ decay process.

The currently used Full Event Interpretation algorithm utilises Boosted Decision Trees to reconstruct the decay processes step-wise, and is therefore heavily dependent on the previous steps. The decays must be explicitly defined, which restricts the branching fraction coverage of the algorithm.

Recent works have explored Graph Neural Network approaches, since a natural representation of a decay process is a tree graph. Given their success, this work explores their application to Belle II and integrating them into the analysis software framework. Ultimately, the aim is to apply the Graph Neural Network approach to the measurement of missing energy decays.

T 38.7 Tue 17:30 Tm

Pixel Detector Background Generation using Generative Adversarial Networks at Belle II — •Hosein Hashemi[1], Thomas Kuhr[2], Martin Ritter[3], Nikolai Hartman[4], and Matei Srebre[5] — [1]Ludwig-Maximilians-Universität München — [2]Ludwig-Maximilians-Universität München — [3]Ludwig-Maximilians-Universität München — [4]Ludwig-Maximilians-Universität München — [5]Ludwig-Maximilians-Universität München

The pixel detector (PXD) is an essential part of the Belle II detector recording particle positions. Data from the PXD and other sensors allow us to reconstruct particle tracks and decay vertices. The effect of background hits on track reconstruction is simulated by adding measured or simulated background hit patterns to the hits produced by simulated signal particles. This model requires a large set of statistically independent PXD background noise samples to avoid the systematic bias of reconstructed tracks. However, data from the fine-grained PXD requires a substantial amount of storage. As an efficient way of producing background noise, we explore the idea of an on-demand PXD background generator using conditional Generative Adversarial Networks (GANs), adapted by the number of PXD sensors in order to both increase the image fidelity and produce sensor-dependent PXD hit maps.

T 38.8 Tue 17:45 Tm

GANplifying Event Samples — Anja Butter[1], •Sascha Diefenbacher[2], Gregor Kasieczka[2], Benjamin Nachman[3], and Tilman Plehn[1] — [1]Institut für Theoretische Physik, Universität Heidelberg, Deutschland — [2]Institut für Experimentalphysik, Universität Hamburg, Deutschland — [3]Physics Division, Lawrence Berkeley National Laboratory, Berkeley, CA, USA

Generative machine learning models have been successfully used in order to speed up or augment many simulation tasks in particle physics, ranging from event generation to fast calorimeter simulation to many more. This indicates that generative models have great potential to become a mainstay in many simulation chains. One question that still needs to be addressed, however, is whether the data produced by a generative model can offer increased precision compared to the data the model was originally trained on. In other words, can one meaningfully draw more samples from a generative model than the ones it was trained with. We explore this using a simplified model and demonstrate that generative models indeed have the capability to amplify data sets.

T 38.9 Tue 18:00 Tm

Fast Simulation of High Granularity Calorimeters with Deep Generative Models — •Peter McKeown — DESY, Hamburg, Germany

Simulation is a key corner stone of modern high energy physics experiments- not only to characterise and optimise the design of detectors, but also to investigate the compatibility of experimental observations and theoretical models. Monte Carlo techniques provide a powerful method to build simulation tools, however these simulations require a large amount of compute time and will prove to be a major bottleneck at the high luminosity phase of the LHC and for future colliders. A particularly time consuming part of simulation involves calorimeter showers, which require a large number of computations to be performed to account for the many interactions that occur.

Deep generative models provide a promising solution to reduce the computing time for such simulations. Recent work in our group has demonstrated the ability to reproduce physically realistic showers in highly granular calorimeters with a high degree of fidelity. While this work focused on the specific case of a particle entering orthogonally to the calorimeter face, in order for such a simulation scheme to be used in practice, arbitrary angles of incidence must be incorporated and correctly simulated. This talk will describe the principles of using generative networks for accurate particle shower simulations and then focus on the efforts of adding conditioning on the particle incident angle.

T 38.10 Tue 18:15 Tm

Optimization of Selective Background Monte Carlo Simulation with Graph Neural Networks at Belle II — •Boyang Yu, Thomas Kuhr, and Nikolai Hartmann — Ludwig-Maximilians-Universität München

When measuring rare processes such as $B \to K^{(*)}\nu\bar{\nu}$ or $B \to l\nu\gamma$, a huge luminosity is required, which means a large number of simulations are necessary to determine signal efficiencies and background contributions. However, this process demands high computation costs while most of the simulated data, in particular in case of background, are discarded by the event selection. Thus filters using neural networks are introduced after the Monte Carlo event generation to speed up the following processes of detector simulation and reconstruction.

In this work, we study optimizations of the performance of neural networks by implementing different architectures with graph neural networks based on moderner libraries and validate them on large datasets. Efficiency, accuracy, ROC curves and AUC values are considered as major criteria.