T 16: Data, AI, Computing 1 (anomaly detection)

Time: Monday 16:00–18:00 Location: Geb. 30.33: MTI

T 16.1 Mon 16:00 Geb. 30.33: MTI

Anomaly Detection Using Autoencoders in Belle II Data — •David Giesegh, Nikolai Hartmann, and Thomas Kuhr — Ludwig-Maximilians-Universität München

At Belle II the search for Beyond the Standard Model (BSM) Physics is an ongoing effort that concentrates mostly on dedicated searches inspired by specific BSM models. Since new effects might be hidden in unexpected observables or correlations thereof, these searches should be complemented by model agnostic methods. For this purpose we explore the application of machine learning models, especially autoencoders, for automated anomaly detection in Belle II data. The main idea is to train a model to compress preprocessed event data and use how well the compression works as an indication for how anomalous an event is. As proof of concept, preliminary results of this method on simulated data scenarios will be presented.

T 16.2 Mon 16:15 Geb. 30.33: MTI

VAE-based anomaly detection in dijet events at $\sqrt{s} = 13$ TeV — •Aritra Bal[1], Benedikt Maier[1], Thea Aarrestad[2], Javier Duarte[3], Markus Klute[1], Jennifer Ngadiuba[4], Maurizio Pierini[5], Kinga Wozniak[5], and Irene Zoi[4] — [1]Karlsruhe Institute of Technology — [2]University of Zurich — [3]University of California, San Diego — [4]Fermi National Accelerator Laboratory — [5]CERN

The reconstruction loss of an autoencoder can serve as a generic discriminator enabling anomaly searches. As part of the CMS Anomaly Search Effort (CASE), we present an approach for unsupervised anomaly detection in dijet events, by combining a variational autoencoder (VAE) with a novel technique for decorrelating the anomaly metric (i.e the autoencoder loss) from the dijet mass using a deep Quantile Regression. The resulting unsculpted spectra are then used to perform a bump hunt search that is sensitive to a range of narrow and broad signal resonances.

T 16.3 Mon 16:30 Geb. 30.33: MTI

Deep neural network reconstruction of muon densities from measurements of the underground muon detector of the Pierre Auger Observatory — •Anton Poctarev for the Pierre-Auger-Collaboration — Karlsruhe Institut für Technologie Campus Nord, Geb. 425, Eggenstein-Leopoldshafen

Ultra-High Energy Cosmic Rays (UHECRs) are the most energetic particles discovered by mankind. They are of high interest and their sources and the means by which they are accelerated remain undetermined. To get a clearer picture of UHECRs, it is integral to determine the mass of each incoming particle. Furthermore, the deficit of muons produced by simulations using current hadronic interaction models compared to extensive air showers (EAS) leaves a lot of questions open regarding our understanding of hadronic interactions. Since the number of muons in an EAS is directly linked to the number of nucleons in the primary particle, we can study and refine our theories of hadronic interactions and improve our handle on mass composition by measuring muon multiplicities. The Pierre Auger Observatory employs underground muon counters for this task.
Simulations of the underground muon detector of the Pierre Auger Observatory are used to train a deep learning neural network to reconstruct muon densities. In this contribution we present the method and compare the bias and resolution to traditional reconstruction methods.

T 16.4 Mon 16:45 Geb. 30.33: MTI

Neural network identification of highly inclined muons in water-Cherenkov particle detectors — •Mohsen Pourmohammad Shahvar for the Pierre-Auger-Collaboration — Università degli studi di Palermo, Palermo, Italy — INFN sezione di Catania, Catania, Italy

This contribution focuses on the neural network identification of highly inclined muons in water-Cherenkov detectors, akin to those utilized by the Pierre Auger Observatory. Highly inclined muons serve as a distinctive signature of air showers induced by either neutrinos or cosmic rays arriving at substantial inclinations, offering a lower background rate compared to less inclined atmospheric particles. The transition from conventional statistical approaches to machine learning methodologies is explored to discern highly inclined muons, capitalizing on their unique signatures in the temporal signal distributions of three photosensors uniformly observing the volume of a water-Cherenkov detector. By adopting machine learning, particularly neural network techniques, we seek to improve the identification of highly inclined muons, contributing to the enhancement of triggering schemas designed for detecting neutrino primaries. This study not only advances the identification of highly inclined muons but also investigates the optimization of machine learning models for their efficient recognition within the water-Cherenkov detector setup.

T 16.5 Mon 17:00 Geb. 30.33: MTI

Nested Machine Learning Models for the Cherenkov Telescope Array — •Lukas Beiske[1,2] and Maximilian Linhoff[1] for the CTA-Collaboration — [1]Astroparticle Physics, WG Rhode/Elsässer, TU Dortmund University, D-44227 Dortmund, Germany — [2]Institute for Theoretical Physics IV, PAT, Ruhr University Bochum, D-44780 Bochum, 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 performance of such nested models for CTA.

T 16.6 Mon 17:15 Geb. 30.33: MTI

Low-frequency noise classification using Machine Learning for the SuperCDMS experiment — •Sukeerthi Dharani for the SuperCDMS-Collaboration — Karlsruhe Institute of Technology, Institute for Astroparticle Physics — University of Hamburg, Institute for Experimental Physics

The SuperCDMS experiment uses semiconductor crystal detectors operated at cryogenic temperatures to search for low-mass dark matter. Vibrations observed during the SuperCDMS Soudan experiment generated broadband low-frequency (LF) noise, which due to its similarity in the pulse shape to the low-energy signal events are difficult to remove at low energies. In the final low ionization threshold analysis, a strong event selection criterion was applied to remove LF noise events which raised the analysis threshold and thus reduced the sensitivity of the experiment to low-mass dark matter. An LF noise selection criterion using machine learning is currently being studied. Under investigation is a convolutional neural network that yields better signal purity while also retaining signal efficiency. This talk discusses the preliminary results of the machine learning-based classification of LF noise.

T 16.7 Mon 17:30 Geb. 30.33: MTI

Machine-Learning-based Background Identification for the Radio Neutrino Observatory Greenland — •Philipp Laub for the RNO-G-Collaboration — ECAP, FAU Erlangen-Nürnberg

The Radio Neutrino Observatory Greenland (RNO-G) is currently being built to detect ultra-high energy (UHE) neutrinos above 10 PeV. UHE neutrinos are detected by measuring radio waves, which are created via the Askaryan effect when UHE neutrinos interact in the ice. Located at Summit Station in Greenland, RNO-G is designed as a wide-spread station array, where each station is equipped with several radio antennas, which are positioned either close to the surface or deep in the ice. Despite the remote and relatively radio-quiet location at Summit, various backgrounds, often of anthropogenic origin, occur in the radio frequency regime. Among them is a rather unexplored background that is correlated to time periods of high wind speed. These "wind events" are impulsive signals of unknown origin, appear in different forms, and can pose a considerable threat to analyses such as cosmic ray searches. Since only little is known about this wind-correlated background and other backgrounds are present in the data, it is difficult to analyze wind events separately from other events.

In this contribution, multiple wind event classes are identified by clustering recorded events into clusters and analyzing event clusters primarily with respect to wind speed. The clustering is performed by first representing events in a low-dimensional latent feature space using a variational autoencoder and then applying the clustering algorithm HDBSCAN to these representations to obtain event clusters.

T 16.8 Mon 17:45 Geb. 30.33: MTI

ANNs for enhanced Pulse Shape Discrimination in GERDA

— •Vikas Bothe — Max-Planck-Institute for Nuclear Physics, Heidelberg

The GERDA experiment searches for the rare neutrinoless double-beta decay of 76Ge using enriched high-purity Germanium diodes as a source as well as a detector. The experimental sensitivity can be improved significantly by employing active background suppression techniques such as Pulse Shape Discrimination(PSD) based on the analysis of time-profile of signals.

The unique challenge arises from coaxial detectors showcasing spatial dependence of pulse shapes which makes traditional mono-parametric PSD techniques ineffective. To address this, we implement artificial neural networks (ANNs) in a multivariate analysis, leveraging their capacity to model complex patterns. This work presents advancements in ANN based PSD within the GERDA experiment to effectively reject background events, such as alpha particles and Compton scattered photons, while maintaining high signal efficiency for double beta decay-like events.

I will give a brief review of the development of ANNs for PSD in GERDA, highlighting the exploration of various machine learning models and diverse approaches to input feature manipulation to achieve improved PSD performance.