T 71: Data, AI, Computing, Electronics VII

Time: Thursday 16:15–18:00 Location: KH 00.024

T 71.1 Thu 16:15 KH 00.024

Shapes are not enough: Preservattack and its use for finding vulnerabilities and uncertainties in machine learning applications — Philip Bechtle[1], Lucie Flek[2], Philipp Alexander Jung[3], Akbar Karimi[2], •Timo Saala[1], Alexander Schmidt[3], Matthias Schott[1], Philipp Soldin[4], Christopher Wiebusch[4], and Ulrich Willemsen[3] — [1]Institute of Physics, University of Bonn, Germany — [2]Bonn-Aachen Institute of Technology, University of Bonn, Germany — [3]Institute of Experimental physics III B, RWTH Aachen University, Germany — [4]Institute of Experimental physics III A, RWTH Aachen University, Germany

In High Energy Physics, machine learning has become crucial for advancing our understanding of fundamental phenomena. Deep learning models increasingly analyze both simulated and experimental data, supported by rigorous tests of physically motivated systematic uncertainties. Numerical evaluations quantify differences between data and simulation, and comparisons of marginal distributions and feature correlations in control regions are standard. However, physical guidance and regional constraints cannot guarantee capturing of all deviations.

We propose a novel adversarial attack exploiting the remaining space of hypothetical deviations between simulation and data after such tests. The resulting perturbations stay within uncertainty bounds - evading standard validation - while still fooling the underlying model. We also suggest mitigation strategies and argue that robustness to adversarial effects is crucial when interpreting deep learning results in particle physics.

T 71.2 Thu 16:30 KH 00.024

Utilizing Adversarial Training for IceCube's Advanced Northern Track Selection — •Marco Zimmermann, Shuyang Deng, Lasse Düser, Philipp Soldin, Sönke Schwirn, and Christopher Wiebusch — Rwth Aachen

IceCube is a neutrino observatory at the South Pole equipped with over 5000 photomultiplier tubes (PMTs), capable of detecting Cherenkov light from neutrino and cosmic-ray induced muons. The Advanced Northern Track Selection (ANTS) differentiates between these two types of muons with a deep neural network approach. The ANTS network first encodes the charge-time series from each PMT into ten abstract features via a Transformer. These features then serve as input for graph neural networks, which perform the aforementioned differentiation as well as energy and directional reconstructions, and event topology classification. To improve robustness, a network can be trained with adversarial attacks, where the input is modified by adding minimal perturbations with the aim of producing incorrect outputs. We will discuss the application of adversarial training of the ANTS' networks, with the example of the event topology classifier, and present methods to visualize the effect of the added perturbations.

T 71.3 Thu 16:45 KH 00.024

Investigating Robustness of Newtonian Noise Mitigation using Deep Learning at the Einstein Telescope — •Jan Kelleter[1], Markus Bachlechner[2], David Bertram[2], Johannes Erdmann[1], Patrick Schillings[1], and Achim Stahl[2] — [1]III. Physikalisches Institut A, RWTH Aachen — [2]III. Physikalisches Institut B, RWTH Aachen

The Einstein Telescope is a proposed gravitational wave detector of the third generation. It aims to improve sensitivity by at least an order of magnitude compared to current detectors. The dominant noise source in the region of 1 to 10 Hz is expected to be Newtonian Noise (NN) from seismic activity in the surrounding rock. In order to reach the desired sensitivity, NN must be actively mitigated. Seismometers will be installed in boreholes around the mirrors to measure the seismic activity. In this talk, we investigate the robustness of neural networks designed for Newtonian Noise mitigation against different instrumental failures.

T 71.4 Thu 17:00 KH 00.024

A Machine-Learning based Topological Algorithm for the Level-1 Trigger System of CMS — •Lukas Ebeling, Johannes Haller, Artur Lobanov, and Matthias Schröder — Institut für Experimentalphysik, Universität Hamburg

At CMS, the level-1 trigger (L1T) system is crucial to select events of interest in order to keep the data-taking rate at a level that can be processed by the readout and storage system. We present a machine-learning (ML) based algorithm for the L1T system, designed to identify di-Higgs (HH) production events. The algorithm leverages the full event topology and improves the HH signal efficiency at low p_T compared to previous single-object based triggers. Despite being constrained in architecture by strict latency requirements and limited FPGA hardware, the ML trigger achieves high signal efficiencies while maintaining acceptable rates. The talk will highlight the achieved trigger performance, discuss the integration into the CMS software framework as well as the development of a realistic trigger scenario for running in 2026 collisions.

T 71.5 Thu 17:15 KH 00.024

Finding Symbolic Representations of Graph Neural Networks used for Track Finding — •Urs Fischer, Sebastian Dittmeier, and Andre Schöning — Physikalisches Institut, Universität Heidelberg, Germany

Graph Neural Networks (GNNs) have been shown to efficiently solve the combinatorial challenge of track finding at high luminosity collider experiments [1]. The available logic resources of Field-Programmable Gate Arrays (FPGAs) limit the size of possible neural networks that can be deployed in hardware triggers or accelerator cards.

In this study, we apply symbolic regression to the different steps of the GNN track finding process. Symbolic regression fits analytic expressions by combining algebraic operators stochastically to find the best representation in terms of simplicity and accuracy. The resulting algebraic functions have the potential to reduce computational costs of the Multi-Layer Perceptrons for FPGA deployment and allow for interpretation of the internal structure of the neural network, by offering an explicit representation of it.

This talk introduces this method and presents first results on its application to tracking at the ATLAS experiment.

[1] S. Farrell et al., "Novel deep learning methods for track reconstruction", in 4th International Workshop Connecting The Dots 2018. 2018. arXiv:1810.06111.

T 71.6 Thu 17:30 KH 00.024

Symbolic Regression for the Extraction of Detector Response Formulas — •Johannes Merten and Johannes Erdmann — III. Physikalisches Institut A, RWTH Aachen University

Detector simulations are an essential part of high-energy physics research, enabling the interpretation of experimental data and the design of future experiments. Full-scale simulations, such as those based on GEANT4, provide high-fidelity representations of particle interactions within detectors but are computationally expensive. To facilitate large-scale analyses, fast simulation frameworks employ parameterizations to approximate detector responses. These parameterizations rely on simplified functional forms that may not fully capture the underlying complexities of the detector response, which may lead to systematic biases.

In this work a data-driven approach is proposed to derive these interpretable parametrizations directly from high-fidelity simulation data using Normalizing Flows and Kolmogorov-Arnold Networks.

T 71.7 Thu 17:45 KH 00.024

Improving Machine-Learning-Driven Anomaly Detection for New Physics Searches at Belle II — •Gianni Di Paoli, David Giesegh, and Thomas Kuhr — Ludwig-Maximilians-Universität München (LMU), München, Germany

Anomaly detection based on machine-learning techniques, using semi- or unsupervised methods, offers a complementary strategy to traditional theory-driven searches for New Physics beyond the Standard Model. Previous studies have provided a proof of principle by enhancing the visibility of simulated New Physics signals.

In this work, the performance of the existing network architectures is improved. For the autoencoder-based method, refinements of the network design lead to more stable reconstruction-error distributions, and thus to increased visibility of anomalies. For the density-estimation approach, alternative likelihood-estimation techniques and their behavior in high-dimensional feature spaces relevant for Belle II are investigated and implemented to improve sensitivity to anomalies.

Ongoing work focuses on further developing these techniques and preparing them for application to real Belle II collision data, including studies of their behavior under realistic detector and background conditions. This talk will present the current status of the algorithmic developments, and outline the next steps toward an operational anomaly-detection pipeline for model-independent New Physics searches at Belle II.