T 43: Data, AI, Computing 3 (pointclouds & graphs)

Time: Tuesday 16:00–18:15 Location: Geb. 30.33: MTI

T 43.1 Tue 16:00 Geb. 30.33: MTI

CaloClouds: Fast Geometry-Independent Highly-Granular Calorimeter Simulation — Erik Buhmann[1], Sascha Diefenbacher[2], Engin Eren[3], Frank Gaede[3,4], Gregor Kasieczka[1,4], •Anatolii Korol[3], William Korcari[1], Katja Krüger[3], and Peter McKeown[3] — [1]Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Physics Division, Lawrence Berkeley National Laboratory, 1 Cyclotron Rd, Berkeley, CA 94720, USA — [3]Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany — [4]Center for Data and Computing in Natural Sciences CDCS, Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany

Simulating showers of particles in highly granular detectors is a key frontier in applying machine learning to particle physics. Achieving high accuracy and speed with generative machine learning models would enable them to augment traditional simulations and alleviate a significant computing constraint. This contribution marks a significant breakthrough in this task by directly generating a point cloud of O(1000) space points with energy depositions in the detector in 3D-space. Importantly, it achieves this without relying on the structure of the detector layers. This capability enables the generation of showers with arbitrary incident particle positions and accommodates varying sensor shapes and layouts.

T 43.2 Tue 16:15 Geb. 30.33: MTI

Flow Matching Beyond Kinematics: Generating Jets with Particle-ID and Trajectory Displacement Information — •Joschka Birk[1], Erik Buhmann[1], Cedric Ewen[1], Gregor Kasieczka[1], and David Shih[2] — [1]Universität Hamburg — [2]Rutgers University

Generative machine learning models are extensively researched in HEP for applications like anomaly detection and fast detector simulation. So far, the development of methods for jet generation has mainly focused on the JetNet dataset. However, as the complexity of generative models trained on the JetNet dataset increased, the lack of statistics in this dataset started to become a bottleneck. We present the first generative model trained on the more complex JetClass dataset, which was originally introduced with the ParT jet tagging algorithm. The JetClass dataset is much larger and contains more jet types as well as additional features that are not included in the JetNet dataset, which opens up new possibilities for jet generation development. Our model generates jets at the constituent level and is a permutation-equivariant continuous normalizing flow (CNF) trained with the flow-matching technique. It is conditioned on the jet type so that a single model can be used to generate the ten different jet types of the JetClass. For the first time, we also introduce a generative model that goes beyond the kinematic features of the jet components by including features such as the particle ID and the track impact parameter. We show that our CNF can accurately model these additional features as well, extending the versatility of existing methods for jet generation.

T 43.3 Tue 16:30 Geb. 30.33: MTI

Graph Neural Network based Hit Classification for Tracking at Belle II — •Greta Heine, Torben Ferber, Lea Reuter, and Slavomira Stefkova — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

Over the next few years, the Belle II Experiment will increase its instantaneous luminosity, which will also lead to a significant increase in the beam background, affecting the efficiency of both online and offline tracking algorithms. To overcome this challenge and to facilitate the identification of displaced vertices for the discovery of new physics phenomena, Belle II needs a more robust tracking algorithm on trigger level.

Graph Neural Networks (GNNs), with their ability to model complex relationships within detector hits, are well suited for tracking and are currently under investigation by Belle II, particularly in the context of object condensation for the Belle II Central Drift Chamber. Due to strict timing constraints, especially in the real-time application in the hardware trigger system, it becomes imperative to clean-up the detector hits from background noise. This talk presents first studies on hit clean-up in the context of anticipated high beam background conditions of the Belle II Experiment based on GNN edge classification using detector-level information.

T 43.4 Tue 16:45 Geb. 30.33: MTI

Graph Neural Network based Tracking at Belle II — •Lea Reuter, Giacomo De Pietro, Torben Ferber, and Slavomira Stefkova — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

Displaced vertices are an important signature in Standard Model analyses involving K_S and many searches for New Physics. However, the current Belle II tracking algorithm falls short when dealing with particles that decay after a large distance, resulting in a decrease in tracking efficiency with increasing displacement.

In this work, we show a novel track finding algorithm that combines the Object Condensation algorithm with Graph Neural Networks. This approach simultaneously identifies all tracks in an event and determines their respective parameters. Additionally, we integrated the new track finding algorithm into the Belle II analysis software framework, improving the resolution through additional track fitting.

Our results show significant improvements compared to the existing Belle II track finding algorithm for displaced tracks, while keeping a similar efficiency and fake rate for prompt tracks originating from the interaction point.

T 43.5 Tue 17:00 Geb. 30.33: MTI

Search for fractionally charged particles with Graph Neural Networks — •Alexander Sandrock and Timo Stürwald — Bergische Universität Wuppertal, Wuppertal, Deutschland

Fractionally charged particles are hypothetical particles with a charge smaller than the electron charge. These particles are predicted in various theories Beyond the Standard Model of particle physics, for instance in versions of supersymmetry. The IceCube neutrino observatory as a very large volume detector shielded by a kilometer-thick ice shield is ideally suited to search for signatures of rare particles such as fractionally charged particles.

Graph neural networks have been successfully applied in the last few years to the classification and reconstruction of events in the IceCube detector. This presentation discusses the application of graph neural networks to the discrimination between simulated fractionally charged particle events and standard model simulations.

T 43.6 Tue 17:15 Geb. 30.33: MTI

Photon Reconstruction with Graph Neural Networks at Beamdump Experiments — •Kylian Schmidt, Torben Ferber, Alexander Heidelbach, Jan Kieseler, and Markus Klute — Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT)

Axion-Like Particles (ALPs) are hypothetical weakly interacting light particles predicted by theories Beyond the Standard Model which could be mediators between a dark sector and the Standard Model. Some of these theories predict light ALPs which decay into two photons and could be detected at future beamdump experiments such as LUXE-NPOD and SHADOWS.

To investigate the properties of such ALPs, an accurate reconstruction of the decay vertex from the hits measured in the detector can aid the search significantly. For this purpose, the photon shower direction needs to be reconstructed precisely, combining techniques from shower and track reconstruction. This task is a prime candidate for modern methods of photon reconstruction based on Machine Learning such as Graph Neural Networks.

In this talk we present a new application of GravNet, which is able to reconstruct the decay vertex of ALPs from the sparse detector hits of the two photon showers.

T 43.7 Tue 17:30 Geb. 30.33: MTI

Improvement of GNN energy regression for KM3Net/ORCA with weighted training samples — •Bastian Setter for the ANTARES-KM3NET-ERLANGEN-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

KM3NeT/ORCA is a water Cherenkov detector currently under construction in the Mediterranean Sea, near the coast of France. It specializes in the detection of atmospheric neutrinos in the GeV range. It will be used for many different types of analysis such as the determination of the neutrino mass ordering, constraining the elements of the PMNS matrix or Lorentz invariance violation. For each of these analyses a good resolution in energy regression is important. This talk will present the impact of so-called weighted data-sets in the training of Graph Neural Networks for an early stage of KM3NeT/ORCA with 6 detection units. In addition, it will discuss the increase in performance that could be achieved compared to training strategies without data-set optimisation and to traditional reconstructions using maximum-likelihood estimator techniques.

T 43.8 Tue 17:45 Geb. 30.33: MTI

Enhancing Neutrino Event Classification in the IceCube Observatory Using a Neural-Network Approach — •Philipp Soldin, Jakob Böttcher, Philipp Fürst, Erik Ganster, Michael Handt, Johanna Hermannsgabner, and Christopher Wiebusch — RWTH Aachen University

The IceCube Neutrino Observatory is a particle detector located at the geographic south pole. It is a cubic kilometer in size and detects neutrinos by measuring the Cherenkov light from their interaction products. One of the main challenges in IceCube is accurately classifying neutrino events based on these measured signals. Previous attempts achieved high accuracy but had to aggregate large amounts of data for processing. However, new deep learning techniques, such as transformer and graph-based architectures, allow for the use of more signal data without prior aggregation. This pure signal data enables the utilization of intricate signal details and improves the selection efficiency. The talk presents the latest advances in this approach and its results.

T 43.9 Tue 18:00 Geb. 30.33: MTI

Position reconstruction of Ge-detector events with a deep neural network — •Christoph Seibt for the LEGEND-Collaboration — Technische Universität Dresden

The LEGEND experiment, a ton-scale experiment focused on neutrinoless double beta decay using enriched Germanium-76, aims to explore half-lives exceeding 10^28 years. The complexity of experiment-generated data has led to a growing interest in machine learning analyses, which can provide deeper insights compared to classical methods.

This work presents a machine learning approach for the challenging task of reconstructing event positions within Ge-detectors using differences in detector pulse signals in the LEGEND experiment. Due to the absence of an analytical method for precise position reconstruction, we employ a Long Short-Term Memory (LSTM)-based neural network.

The model is trained and tested using simulated pulses closely resembling real experiment data. While real data analysis is a future prospect, this presentation provides an update on the ongoing progress in implementing an LSTM-based neural network for Ge-detector event position reconstruction. With a future application on real data in plan, the machine learning model may serve as an innovative tool for data analysis and data cleaning and brings machine learning more into the scope of experimental physics.