T 79: Data Analysis, Information Technology and Artificial Intelligence 4

Time: Wednesday 16:15–18:30 Location: T-H38

T 79.1 Wed 16:15 T-H38

K_S^0 tracking efficiency studies at Belle II — •Elisabetta Prencipe[1], Oleksandr Skorenok[2], and Jens Soeren Lange[1] — [1]JLU-Giessen, Giessen, Germany — [2]TSNU-Kyiv, Kyiv, Ukraine

Reconstruction efficiency of low momentum tracks in particle physics is a very important issue. Here we report about a study conducted at Belle II, with MC samples and Phase-3 data, and present a dedicated study of the efficiency to correctly reconstruct $K_S^0 \to \pi^+\pi^-$, whose daughter tracks can have a different efficiency due to their displacement from the primary event origin.

A significant number of analyses in Belle II involve the reconstruction of $K_S^0 \to \pi^+\pi^-$. The reconstruction efficiency of the K_S^0 daughters depends on the K_S^0 transverse momentum, p_T, polar angle, θ_{LAB} and transverse (XY) flight distance, d_{XY}, which is computed as the distance between the primary vertex of the event and the refitted K_S^0 decay vertex.

The general strategy is to subdivide the data and MC events into a large number of samples by choosing an appropriate binning in these variables, determine the number of K_S^0 in each bin, in data and MC samples, and for each of the momentum and polar angle ranges, normalize the ratio of its value in the first bin in d_{XY}, where all tracking effects are well understood. The results here presented are acquired by studying the $B \to K^+K^-K_S^0$ and $B \to \pi^+\pi^-K_S^0$ decay channels at Belle II. They will help in understanding systematic effects of analysis where K_S^0 are involved.

T 79.2 Wed 16:30 T-H38

Clustering Energy Depositions in the Electromagnetic Calorimeter at Belle II using Graph Neural Networks — •Florian Wemmer, Pablo Goldenzweig, and Torben Ferber for the Belle II-Collaboration — Karlsruher Institut fuer Technologie

Electromagnetic calorimeters in particle detectors like at the Belle II Experiment consist of almost ten thousand sensitive crystals providing detailed energy deposition information in space. The correct assignment of energy depositions in those crystals to clusters originating from a distinct particle imposes a huge challenge especially in the presence of beam induced backgrounds, electronic noise and overlapping clusters. Graph Neural Networks (GNNs) allow for a machine learning algorithm to unrestrictedly and elegantly learn a feature space best suited to solve a problem. Using readily available Monte Carlo data we apply a GNN to try and cluster crystalwise energy information as well as distinguishing physics signals from beam background in the Belle II electromagnetic calorimeter. As a starting point to the development of more capable algorithms the - in actuality complex - detector data is simplified to two possibly overlapping clusters and beam background. We give insight to possible loss functions and metrics of the GNN as well as presenting first results of the clustering process.

T 79.3 Wed 16:45 T-H38

Fast Particle Reconstruction in the Belle II Experiment with Graph Neural Networks — •Isabel Haide, Pablo Goldenzweig, and Torben Ferber for the Belle II-Collaboration — Karlsruhe Institute of Technology

The correct clustering and reconstruction of particles in electromagnetic calorimeters are vital to many analyses to ensure a correct reconstruction of the actual event. This clustering poses difficulties such as an unknown number of particles in the calorimeter and the existence of background events and promotes the use of machine learning (ML) algorithms. Due to the irregular geometry of such detectors, graph neural networks (GNNs) are most suitable to provide an improvement over standard algorithms. GNNs do not depend on regular geometries to learn detector-hit representations and have already been successfully applied to simulated data of a simplified calorimeter model. Extending this application to the geometry of real detectors, such as the Belle II electromagnetic calorimeter (ECL), while reconstructing an unknown number of clusters with possible overlap and additional background events, is the goal of this study. In this talk, the concept of using object condensation with GNNs to reconstruct particles in the ECL and the current status of this development is shown. The evaluation method, which is the separation of the signature of the hypothetical dark photon process $e^+e^- \to A'\gamma, A' \to e^+e^-$ to the signature of radiative Bhabha scattering $e^+e^- \to e^+e^-\gamma$, is also explained.

T 79.4 Wed 17:00 T-H38

Identification of pions and muons with the Belle II calorimeter using convolutional neural network — •Abtin Narimani Charan[1] and Torben Ferber[2] for the Belle II-Collaboration — [1]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany — [2]Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

The Belle II experiment is located at the asymmetric SuperKEKB e^+e^- collider in Tsukuba, Japan. The electromagnetic calorimeter (ECL) in Belle II is designed to reconstruct neutral particles. Additionally, the ECL can identify charged particles e.g. electrons, muons and pions. Identification of low-momenta muons and pions in the ECL is crucial if they do not reach the outer muon detector.

This talk presents an application of a convolutional neural network (CNN) to separate muons and pions in the ECL using energy deposition patterns of 7x7 crystal images. Due to the high level of beam background, the performance of the CNN in samples with different beam background levels is studied. Moreover, the impact of adding pulse-shape and timing information in addition to the energy information is investigated and compared with the previous results in different momentum ranges. Finally, the performance of the network is investigated with data control samples of muons and pions.

T 79.5 Wed 17:15 T-H38

Anomaly detection in the searches for inelastic dark matter at Belle II — •Jonas Eppelt, Patrick Ecker, Pablo Goldenzweig, and Torben Ferber for the Belle II-Collaboration — Karlsruhe Institut for Technology, Karlsruhe, Germany

Inelastic Dark Matter (IDM) is a rather complex model containing two Dark Particles and two Mediators. Its expected signatures include one resonant and one non-resonant decay.

In this talk current efforts are presented to approach searches for IDM at Belle II with anomaly detection via machine learning. This approach aims to train algorithms on (simulated) background events in order to recognize previous unknown signals. It seeks to reduce limitations due to the chosen model and parameter space in searches for physics beyond the Standard Model.

The current status on employing anomaly detection in an IDM search at Belle II will be given.

T 79.6 Wed 17:30 T-H38

Implementing a graph-based approach for semi-inclusive tagging in Belle II — Florian Bernlochner, •Axel Heimeroth, William Sutcliffe, and Ilias Tsaklidis — Physikalisches Institut, University of Bonn, Germany

In the Belle II experiment pairs of B-mesons are produced from electron-positron collisions. The clean experimental environment allows for constraining kinematically the second B-meson if the other one is correctly reconstructed. The current tagging algorithm used in Belle II, called Full Event Interpretation, has relatively low tagging efficiency since all the intermediate decays of the second B-meson must be explicitly reconstructed. This can be critical for searches of extremely rare decays. A semi-inclusive approach, where one reconstructs only partially the tag-side, instead of an exclusive one, can be used in order to increase the overall efficiency. In this work we explore how graph neural networks can improve the purity and efficiency of a semi-inclusive approach, where only a charmed hadron, instead of a B-meson, is reconstructed. In this talk I present a proof of concept on a generic phasespace dataset and a realistic application on $B- > D^*l\nu$ decays from the official Belle II Monte Carlo.

T 79.7 Wed 17:45 T-H38

Performance portability for the Physics Object Reconstruction Software of the CMS Experiment — •Wahid Redjeb — RWTH University, III. Physikalisches Institut A, Aachen, Germany

The High Luminosity upgrade of the LHC will pose unprecedented challenges for the offline and online computing. The higher luminosity and pileup will require larger processing power, not achievable with the current CPUs. Heterogeneous computing will play a fundamental role in the physics object reconstruction software to fully exploit the reach of the HL-LHC. Several computing architectures are available for the CMS software, but specialized implementations for each of them is not sustainable in terms of development, maintenance and validation. Performance Portability libraries allow performance portability across different hardware architectures with a single code basis. In this talk, we present the last results of the first usage of the Alpaka performance portability library on a standalone version of the reconstruction of tracks and vertices in the CMS silicon pixel detector. Porting the pixel tracks and vertices reconstruction to Alpaka demonstrates the possibility of writing a single source code that can be executed on different devices with different parallelization strategies, achieving similar performance with respect to the native implementations.

T 79.8 Wed 18:00 T-H38

Designing VQE ansatz circuits for track reconstruction with Quantum Computers at LUXE — Arianna Crippa[1], Lena Funcke[3], Tobias Hartung[4], Beate Heinemann[1,2], Karl Jansen[1], Annabel Kropf[1], Stefan Kühn[5], Federico Meloni[1], •David Spataro[1], Cenk Tüysüz[1], and Yee Chinn Yap[1] — [1]Deutsches Elektronen Synchrotron DESY — [2]Albert-Ludwigs-Universität Freiburg — [3]Massachusetts Institute of Technology — [4]University of Bath — [5]CaSToRC, The Cyprus Institute

The recently proposed Laser Und XFEL Experiment (LUXE) enables the study of Quantum Electrodynamics (QED) in the strong-field regime, where QED becomes non-perturbative. In this regime, the production of electron-positron pairs by field-induced tunneling out of the vacuum is realised in the interaction of a high energy electron beam from the European XFEL and a high power laser.

Positron track reconstruction on a silicon pixel tracking detector becomes a demanding combinatorial problem at high laser intensity. It is expected to measure up to 10^6 positrons on the four consecutive detector layers. A Quadratic Unconstrained Binary Optimization (QUBO) formulation enables the use of quantum computers and a Variational Quantum Eigensolver (VQE) to reconstruct tracks. For this, designing a suitable ansatz circuit which maps the track candidates to qubits is an important part of the VQE heuristic. Results are compared to common hardware efficient ansatzes. In addition, the final track reconstruction efficiency is compared to a classical approach.

T 79.9 Wed 18:15 T-H38

Benchmarking Variational Quantum Algorithms for track reconstruction at LUXE — Arianna Crippa[1], Lena Funcke[3], Tobias Hartung[4], Beate Heinemann[1,2], Karl Jansen[1], •Annabel Kropf[1], Stefan Kühn[5], Federico Meloni[1], David Spataro[1], Cenk Tüysüz[1], and Yee Chinn Yap[1] — [1]Deutsches Elektronen-Synchrotron DESY — [2]Albert-Ludwigs-Universität Freiburg — [3]Massachusetts Institute of Technology — [4]University of Bath — [5]CaSToRC, The Cyprus Institute

The primary aim of the recently proposed LUXE experiment is to investigate the transition into the non-perturbative regime of Quantum Electrodynamics. For this, the interaction of photons with electrons, or photons with photons is measured at field strengths where couplings to charges become non-perturbative. In these interactions, up to 10^6 positrons are produced that then impinge on a four-layered silicon pixel tracking detector. The accurate reconstruction of the positrons' trajectories from a set of hits is a combinatorial problem challenging for a classical computer to solve. For LUXE, a novel approach is explored that expresses pattern recognition as a quadratic unconstrained binary optimisation, allowing the algorithm to be mapped onto a quantum computer. Variational quantum algorithms provide a promising approach to solve combinatorial optimisation problems on noisy quantum devices. Here, we benchmark the accuracy of two such algorithms, the Variational Quantum Eigensolver and the Quantum Approximate Optimisation Algorithm, against classical tracking using data from an idealised LUXE detector set-up.