T 77: Data, AI, Computing, Electronics VIII (Fast ML, Triggers)

Time: Thursday 16:15–18:15 Location: VG 2.102

T 77.1 Thu 16:15 VG 2.102

Optimization of the muon momentum resolution in the ATLAS first-level trigger with machine learning techniques — •Francisco Resende, Davide Cieri, Oliver Kortner, and Sandra Kortner — Max-Planck-Institut für Physik, München

The ATLAS experiment is upgrading its muon trigger system for operation at the High-Luminosity LHC. The necessary significant improvement in the selectivity of muon tracks within the first-level trigger relies on, for the first time, muon tracking data from precision monitored drift-tube (MDT) chambers.

This research explores the feasibility and benefits of integrating machine learning into the challenging real-time environment of the ATLAS trigger system, aiming to enhance the experiment's discovery potential in the high-luminosity era. We investigate the use of machine learning algorithms to improve muon reconstruction for the ATLAS first-level trigger. Various neural network models were developed, with algorithms optimized for potential deployment on powerful FPGA devices. The performance of each model is evaluated and compared to that of the baseline analytic algorithm in terms of trigger efficiency and muon momentum resolution.

T 77.2 Thu 16:30 VG 2.102

Convolutional Neural Networks on FPGAs for Processing of ATLAS Liquid Argon Calorimeter Signals — Anna Franke, Manuel Gutsche, Markus Helbig, Rainer Hentges, Arno Straessner, •Johann Christoph Voigt, and Philipp Welle — Institut für Kern- und Teilchenphysik, TU Dresden

During the Phase-II upgrade of the ATLAS Liquid Argon Calorimeter, more than 500 high-performance FPGAs will be installed to allow for the energy reconstruction of all 182468 detector cells at the LHC bunch crossing frequency of 40 MHz. We trained 1-dimensional convolutional neural networks (CNNs) to improve the energy reconstruction under high-luminosity conditions with respect to the currently used Optimal Filter. The network architecture has been optimized with a hyperparameter search, where the network size is constrained to 400 parameters. This is motivated by resource estimates from the FPGA firmware prototype implementation. Quantization aware training using QKeras is used to adapt the CNNs to 18 bit fixed point numbers. A revised simulation pipeline is in development to produce training samples for clusters of similar cells. To better evaluate the physics impact of the CNN based readout, the networks are being integrated into the ATLAS common detector simulation and analysis framework, Athena. The inference code of these networks has been implemented in the hardware description language VHDL targeting an Intel Agilex FPGA. A test project targeting a Stratix-10 development kit is available to verify the behaviour of the implementation. Recent results of the CNN training and its firmware realisation will be presented.

T 77.3 Thu 16:45 VG 2.102

Using Transformer based Graph Neural Networks to Identify Hadronically Decaying Tau Leptons with the ATLAS trigger — •Athul Dev Sudhakar Ponnu and Stan Lai — II. Physikalisches Institut, Georg-August-Universitaet Goettingen.

The increased luminosity at the LHC poses challenges in efficiently selecting interesting events at the Atlas detector. Identifying events containing tau leptons is particularly difficult due to their predominantly hadronic decay, which often mimics light QCD jet signatures. Therefore, effectively discriminating against background jets during the identification of hadronically decaying tau leptons at the trigger level is crucial.

Building on the success of Transformer-based Graph Neural Networks used for offline Tau ID (GNTau) and b-tagging (GN2), this study explores their application to hadronic tau identification at the High Level Trigger (HLT). The online GNTau algorithm exhibits substantial improvements in background rejection compared to existing Deepset-based algorithms, across a wide phase space and variety of processes. After thorough evaluations, the GNTau is set to be deployed at the HLT for the 2025 data-taking period.

T 77.4 Thu 17:00 VG 2.102

Forward Electron Identification at the ATLAS First Level Trigger for the High Luminosity LHC — •Maximilian Linkert, Stefan Tapprogge, and Adrian Alvarez Fernandez — Institut für Physik, Johannes Gutenberg-Universität, Mainz

As part of the high luminosity LHC the challenge is to properly trigger events in the forward region of ATLAS covering a pseudo rapidity of $2.5 < |\eta| < 4.9$. New first level trigger modules (being under development) based on FPGAs will be used the first time to access the full (transversal and longitudinal) granularity of the calorimeters in this region to efficiently identify electrons and positrons. As a basis for reconstruction and identification a sliding window algorithm will be used. The aim is to use machine learning to gain efficiency compared to classical algorithms. The algorithms need to be optimized to run on the FPGAs, thus dealing with a simultaneous optimization of the signal efficiency, background rejection, resource consumption and latency. Moreover, the algorithm implementation needs to address non trivial changes in the geometrical calorimeter segmentation within the region under consideration. The present status of the investigations and next steps will be presented.

T 77.5 Thu 17:15 VG 2.102

First Level Trigger Algorithm for Electron Identification in ATLAS — •Julia Troppens, Maximilian Linkert, Dennis Layh, and Stefan Tapprogge — Institute for Physics, Johannes Gutenberg University, Mainz

The High Luminosity LHC upgrade aims to significantly increase the collision rate, presenting new challenges for data analysis within the detectors. Therefore, the ATLAS trigger system is being improved and expanded in the Phase II upgrade by incorporating additional information. This includes the planned implementation of a first level trigger algorithm in firmware for electron identification in the forward region (3.2<|eta|<4.9) of the ATLAS detector, based on the full granularity of calorimeters. The studies performed used simulated data to examine various approaches. The benefit of machine learning, as compared to cut-based algorithms, was investigated in terms of optimizing efficiency. Subsequently, studies were conducted to evaluate the feasibility of realising the algorithms in firmware. In conclusion, this contribution compares different algorithms in terms of their interplay between latency, resource usage, signal efficiency, and background rejection.

T 77.6 Thu 17:30 VG 2.102

Development of machine-learning based topological triggers for the CMS Level-1 trigger — •Karla Kleinbölting, Lukas Ebeling, Johannes Haller, Finn Jonathan Labe, Balduin Letzer, Artur Lobanov, Lara Markus, and Matthias Schröder — Institut für Experimentalphyisk, Universität Hamburg

At the CMS experiment, the Level-1 (L1) trigger system is pivotal in thereal-timeselectionofphysicseventsofinterest. Thistalkhighlights recent advancements in enhancing the L1 trigger performance through the integration of machine learning (ML) techniques. Using di-Higgs production as a benchmark process, the proposed ML-based trigger leverages full event topologies instead of individual object-based triggers. This approach allows the trigger system to identify and retain events in previously inaccessible low p_T regions while maintaining acceptable rates. The ML algorithms can be seamlessly integrated into the FPGA-based electronics of the trigger system using frameworks such as *hls4ml.*

T 77.7 Thu 17:45 VG 2.102

Implementation of a two-level AI-enhanced trigger on a single chip with AI cores for live reconstruction — •Patrick Schwäbig for the Lohengrin-Collaboration — Physikalisches Institut, Universität Bonn, Deutschland

For years, data rates generated by modern detectors and the corresponding readout electronics exceeded by far the limits of data storage space and bandwidth available in many experiments. The approach of using fast triggers to discard uninteresting and irrelevant data remains a solution used to this day: Using FPGAs, ASICs or directly the readout chip, a fixed set of rules based on low level parameters is applied as a pre-selection. In contrast to this stands live track reconstruction for triggering, which was rarely possible due to limited computation power in the past. With the emergence of highly parallelized processors for AI inference, attempts to sufficiently accelerate tracking algorithms become viable. The AMD Versal Adaptive Compute

Acceleration Platform (ACAP) is one such technology and combines FPGA and CPU resources with dedicated AI cores. Our approach is to implement a two-level trigger on a single chip by utilizing the tightly integrated combination of FPGA and AI cores to profit from their individual strengths. In this talk our concept for a two-level trigger setup, implemented on an AMD VC1902, including quantized AI algorithms and Timepix3 readout, will be shown. They will be used in an envisioned mid-size ultra-high rate fixed-target dark matter experiment (Lohengrin) at the ELSA accelerator at the University of Bonn.

T 77.8 Thu 18:00 VG 2.102

Performance of a Quantized Neural Network on an FPGA for Next Generation Radio Array DAQ Systems — •Adam Rifaie for the IceCube-Gen2-Collaboration — Bergische Universität Wuppertal, Wuppertal, Deutschland

The IceCube neutrino observatory is a cubic kilometer neutrino detector built into the Antarctic ice at the geographical Southpole. As a result of its success, the next-generation detector for IceCube, IceCube-Gen2, is currently being planned. This will extend the optical array to approximately 10 cubic kilometers and will include a $\sim 500\,\mathrm{km}^2$ radio array, sensitive to Ultra High Energy neutrinos. The state-of-the-art, with respect to phased radio arrays, is the Radio Neutrino Observatory Greenland (RNO-G), where currently 7 of the planned 35 stations have been deployed. These stations enable hardware testing and optimization for the DAQ system of RNO-G. A novel idea for a DAQ system would consist of an FPGA with a trained and Quantized Neural Network implemented. The neural network will read the datastream and discriminate between background and signal in real-time. This will improve the effective volume of the detector by a factor of 3 compared to a standard threshold trigger at certain energies. The performance and comparison of a quantized neural network with a regular neural network will be discussed, followed by the next steps to an all-digital DAQ system for Radio arrays.