T 41: Trigger+DAQ 1

Time: Tuesday 16:00–18:00 Location: Geb. 30.23: 3/1

T 41.1 Tue 16:00 Geb. 30.23: 3/1

Towards an Autonomous Trigger for the Detection of Air-Shower Radio Emission — •Jelena Köhler[1], Lukas Gülzow[1], Tim Huege[1,4], Markus Roth[1], Olivier Martineau[2], Pablo Correa[2], Kumiko Kotera[3,4], and Marion Guelfand[2,3] — [1]Karlsruher Institut für Technologie, Institut für Astroteilchenphysik — [2]Laboratoire de physique nucléaire et des hautes énergies, Paris — [3]Institut d'Astrophysique de Paris — [4]Vrije Universiteit Brussel

Radio detection of air-showers has emerged as a powerful technique for high-energy cosmic ray measurements, leading to the development of a new generation of large-scale radio detectors. The Giant Radio Array for Neutrino Detection (GRAND) represents a significant advancement. It is planned as a vast array of wide-band radio antennas spanning an extensive area of 200 000 km^2.

To effectively detect air-shower events in such large-scale arrays, an efficient and autonomous trigger system is needed. This presentation introduces a novel multi-level radio trigger, which is crucial for large-scale experiments like GRAND. The first-level trigger identifies potential air-shower signals at the station level. However, the true innovation lies in the second-level trigger operating at the detector level. By evaluating the time-integrated power, it makes reliable event decisions based on the scientific knowledge of radio emissions.

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T 41.2 Tue 16:15 Geb. 30.23: 3/1

Development of 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

As part of the High Luminosity LHC upgrade a new module for the first-level trigger of ATLAS aims to efficiently identify electrons in the very forward region (3.2<|eta|<4.9). These modules with powerful FPGAs shall make use of the full granularity of the calorimeters in this region. The studies performed are based on simulated proton-proton collisions. Firstly, different algorithms - including existing classical algorithms and new machine-learning based approaches - are optimized with respect to signal efficiency and background rejection. Subsequently, the implementation in firmware is investigated. In this contribution different algorithms are compared looking at the interplay of latency, resource usage, signal efficiency and background rejection.

T 41.3 Tue 16:30 Geb. 30.23: 3/1

Trigger Algorithm for Electron Identification with Neural Networks and Realization in Firmware — •Moritz Vogt, Dennis Layh, and Stefan Tapprogge — Institute for Physics, Mainz, Germany

As the LHC is upgraded to the High-Luminosity LHC, the instantaneous luminosity will increase significantly. To cope with the additional pile-up and the increase in the rate of background events, the triggering algorithms need to be improved. Following the High-Luminosity upgrade, the new forward Feature Extractor (fFEX) first level trigger module will have real-time access to ATLAS forward ($|\eta| > 2.5$) calorimeter information with full granularity. The accurate identification of electrons in this region should allow a refined measurement of the weak mixing angle using the forward-backward asymmetry of the Z-boson decay.

This contribution will focus on the identification of electrons using neural networks in simulated events of the detector response in the Liquid Argon Endcap Calorimeters of the ATLAS detector ($2.5 < |\eta| < 3.2$). Since the trigger module will be realized with Field Programmable Gate Arrays (FPGA), the optimization of neural networks for deployment in firmware on these components is of utmost importance. Achieving a balance between signal efficiency, background rejection, resource utilization, and latency is the ultimate goal. This talk will present the results of the studies and give an outlook on future extensions.

T 41.4 Tue 16:45 Geb. 30.23: 3/1

Anomaly detection for the level 1 trigger system of the CMS experiment — •Sven Bollweg, Gregor Kasieczka, Karim El Morabit, Susan Sefidrawan, and Artur Lobanov — Universität Hamburg, Hamburg, Deutschland

There exist strong hints for the existence of physics beyond the standard model (BSM). At the CMS experiment only events passing the first selection step, the level 1 (L1) trigger, are recorded and available for further analysis. Assuming that BSM events differ from standard model (SM) events, a trigger selection targeting BSM events could be based on the detection of differing, i.e. anomalous, properties instead of criteria predicted by specific BSM models.

This talk discusses a neural network based implementation of such an anomaly detection trigger. An autoencoder (AE) network is trained to reproduce typical collision events. It is found that the reconstruction quality of anomalous events, such as BSM events or rare SM events, is decreased. The reproduction quality can be used as a basis to identify anomalous events, which could be BSM events. The integration of the AE into the existing L1 hardware and avoidance of overlap with the existing triggers presents additional challenges.

T 41.5 Tue 17:00 Geb. 30.23: 3/1

Convolutional Neural Networks on FPGAs for Processing of ATLAS Liquid Argon Calorimeter Signals — Anne-Sophie Berthold, Anna Franke, Nick Fritzsche, Markus Helbig, Rainer Hentges, Arno Straessner, and •Johann Christoph Voigt — IKTP, TU Dresden

During the Phase-II upgrade of the ATLAS Liquid Argon Calorimeter, over 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. In particular, the performance for overlapping pulses is demonstrated for 6 representative detector cells. The network architecture has been optimized with a hyperparameter search, where the network size is constrained to 100 parameters to be able to fit onto the FPGA.

The inference code of these networks has been implemented in VHDL targeting an Intel Agilex FPGA. This firmware can run at 480 MHz and applies 12-fold time-division multiplexing to reduce the resource requirements. This allows the design to process the readout of up to 384 detector cells per FPGA, while meeting the latency constraints of the ATLAS trigger. Quantization aware training using QKeras is used to adapt the CNNs to 18 bit fixed point numbers. To better evaluate the physics performance, the networks are being integrated into the ATLAS ATHENA detector simulation.

T 41.6 Tue 17:15 Geb. 30.23: 3/1

Comparison of a Linearized Track Fitting Algorithm, Implemented on GPU and FPGA — •Joachim Zinsser, Sebastian Dittmeier, and André Schoening — Physikalisches Institut, Heidelberg, Germany

For the Event Filter System of the ATLAS experiment at the High-Luminosity LHC, studies on accelerating the online track reconstruction for the Inner Tracker (ITk) are conducted, which possibly lead to a heterogeneous system using GPUs or FPGAs. This study focusses on the implementation of one block of a linearized track fitting pipeline that can be used for quick fake track rejection and track parameter estimation. This algorithm can be implemented in a highly parallel way and is, therefore, suited for hardware acceleration. The algorithm is implemented on a Intel Stratix 10 FPGA and a NVIDIA A6000 GPU are used. The physics performance of the two implementations, are compared to the results from the fast emulation as presented in the ATL-DAQ-PUB-2023-001 document, using the same data. Furthermore, the computing performance are compared with each other.

T 41.7 Tue 17:30 Geb. 30.23: 3/1

FPGA-Based Implementation of Graph Neural Networks with FINN for particle track reconstruction in ATLAS — •Philipp Hematty[1,2], Sebastian Dittmeier[1], Hendrik Borras[2], Andre Schöning[1], and Holger Fröning[2] — [1]Physikalisches Institut, Universität Heidelberg, Heidelberg, Germany — [2]Institut für Technische Informatik, Universität Heidelberg, Heidelberg, Germany

In particle physics, research increasingly focuses on specialized neural network architectures such as Graph Neural Networks (GNN). These models show promising potential to computationally surpass traditional algorithms used in the field, especially in classifying particle hits into track candidates. The GNN4ITK project proposes a pipeline architecture for ATLAS at the HL-LHC which uses GNNs for the identification of track candidates. Because of the relative novelty of GNNs in the field of machine learning, current implementations work primarily with general-purpose hardware, such as CPUs or GPUs. Field Programmable Gate Arrays (FPGAs), however, could potentially deliver large gains in performance and cost. Their innate flexibility allows for compression methods which could greatly improve the efficiency of such networks. Previously, the complexity of programming FPGAs acted prohibitively on the implementation of complex neural networks. The recent rise of frameworks built on top of high-level-synthesis tools, such as FINN, promise to mitigate this hurdle. FINN is part of a software suite that translates high-level neural network definitions into formats that can be used directly on FPGAs. In this work, we analyze the capabilities of this approach in the aforesaid context.

T 41.8 Tue 17:45 Geb. 30.23: 3/1

Dilepton selections for the LHCb experiment Run 3 trigger
— Johannes Albrecht, •James Andrew Gooding, and Biljana Mitreska — TU Dortmund University, Dortmund, Germany

A central focus of the LHCb experiment is the measurement of B meson decays with multiple leptons in the final state. Multi-lepton B decays provide access to many tests of the Standard Model, e.g., tests of lepton-flavour universality. Measurements of such decays rely on high-quality lepton selection, particularly the selection of dilepton events, i.e., events containing a lepton pair, typically performed through cuts on kinematic and topological variables.

During the Run 3 data-taking period of the LHC, the LHCb experiment will process collisions at 30 MHz, employing a software-based trigger system to select only physics-relevant events in real time. Within this framework, an inclusive cut-based trigger has been developed to select dilepton events, complementing existing selection strategies. This contribution presents the status of the inclusive cut-based dilepton trigger, placing particular emphasis on trigger development and commissioning.