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Projected ATLAS Electron and Photon Trigger Performance in Run 3

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ATLAS electron and photon triggers covering transverse energies from 5 GeV to several TeV are essential to record signals for a wide variety of physics: from Standard Model processes to searches for new phenomena.
During LHC Run 3 (expected to start in 2021 or 2022 until 2024), the main triggers used for those physics studies will be a single-electron trigger with transverse energy threshold around 25 GeV, and a diphoton trigger with thresholds at 25 and 35 GeV. Relying on those simple, general-purpose triggers is a robust trigger strategy, tested already in Run 2 (2015–2018), at a cost of slightly higher trigger output rates, rather than to use a large number of analysis-specific triggers. In preparation for Run 3 data-taking, the ATLAS detector is undergoing an upgrade of the hardware-based Level-1 calorimeter trigger and the trigger software is being migrated to the multi-threaded framework AthenaMT. The impact from these modifications on the electron and photon triggers as well as their projected performance in Run 3 is presented.

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1. Introduction

The trigger system [1] of the ATLAS detector [2] plays a crucial role during data taking, selecting which events are saved for later use in data analysis. In particular, processes with photons (γ) and electrons (e) in the final state are essential for many physics analyses, like Standard Model (SM) precision measurements, and also searches for physics Beyond the Standard Model (BSM).

One of the objectives of the trigger system is to reduce the LHC collision rate of 40 MHz to an average output rate of around 1 kHz, of which 20% is allocated to electron and photon triggers. For that purpose, the ATLAS trigger is designed as a two-level system responsible for deciding rapidly if an event has to be saved or not. First, a hardware-based Level-1 trigger system (L1) reduces the direct output of the LHC from 40 MHz down to ~100 kHz. It uses low granularity data from the calorimeters and the muon system to identify Regions of Interest (RoIs). Then, the software-based High Level Trigger (HLT) performs object reconstruction for electrons and photons using the full granularity data from the detector within the RoIs provided by the L1.

A sequence of L1 and HLT trigger algorithms is called a "trigger" and is meant to identify one or more particles of a given type and a given threshold of transverse energy or momentum. For example, electron and photon triggers are meant to select events with one or more electrons or photons in the detector. The configuration of the trigger is controlled by the "trigger menu", which defines a full list of L1 and HLT triggers and their configurations. The main triggers for Run 3 will be a single-electron trigger with transverse energy threshold around 25 GeV, and a diphoton trigger with thresholds at 25 and 35 GeV.

2. L1 upgrade for Run 3

The L1 trigger uses the information from the calorimeter to build electromagnetic (EM) RoIs. In Run 2, they were made of 4×4 trigger towers in η and ϕ with a granularity of 0.1×0.1. To reconstruct the EM energy, a sliding–window algorithm was used to identify the local energy maximum from the four possible pairs of nearest neighbor towers in a 2×2 central region. Optionally, an isolation requirement could be applied, only for photon and electron candidates with a reconstructed E_{T} at L1 below 50 GeV [3].

For Run 3 the ATLAS Liquid Argon calorimeter readout is upgraded to increase ten fold the longitudinal and transverse granularity of the calorimeter information provided to the L1 trigger system. Instead of a single trigger tower which combines all four EM calorimeter layers, they are read out separately, and in Layer-1 and Layer-2 of the EM calorimeter the granularity is increased four times in η. This new structure is called Supercell and described in Figure 1 (left). Also a new electron Feature EXtractor (eFEX) processor with different reconstruction algorithms will be installed. These algorithms use a 0.3×0.3 window, and select the local maximum of energy only in the Layer-2 of the EM calorimeter. Then, the most energetic neighboring cell in ϕ is selected, and with this, the cluster with 0.3×0.2 cells in fine layers, and 0.1×0.2 in coarse layers is built. A schematic display of this algorithm procedure is shown in Figure 1 (right). The finer granularity of the Supercells enables more sophisticated rejection of jet backgrounds than in Run 2 through the use of shower shape variables [4]. Similarly to Run 2, this additional selection is unnecessary for the L1 EM objects above 60 GeV.

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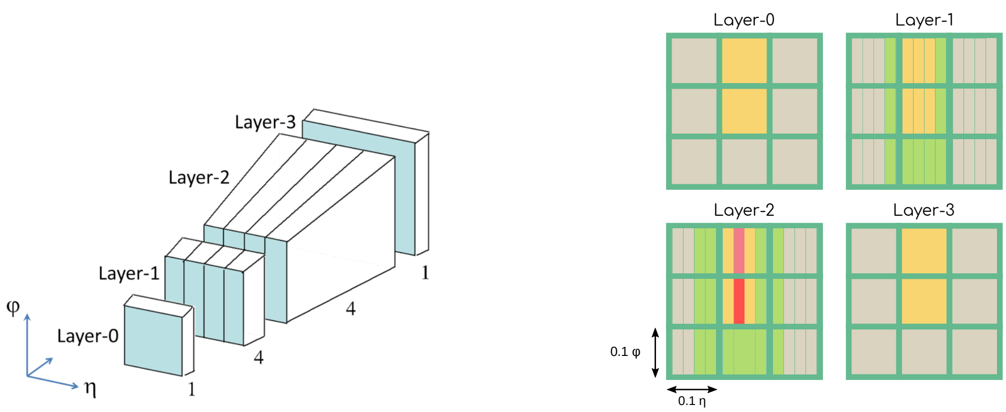

Figure 1: (Left) Granularity of the Supercells in the different layers of the EM calorimeter [4]. (Right) Cells of the EM calorimeter layers used by the L1 algorithm to build the RoIs: the red cell represents the local maximum, the pink is the most energetic ϕ neighbor, clustering is represented by yellow cells, and the green ones are used for the isolation cuts.

The expected efficiencies for a typical Run 2 trigger as well as for Run 3 L1 triggers with shower shape requirements are shown in Figure 2. This Figure shows that a Run 3 trigger tuned to the same rate as a Run 2 trigger can have a much lower E_T requirement, while if the E_T requirements for Run 2 and Run 3 triggers are similar, the expected rate of the Run 3 trigger is twice lower.

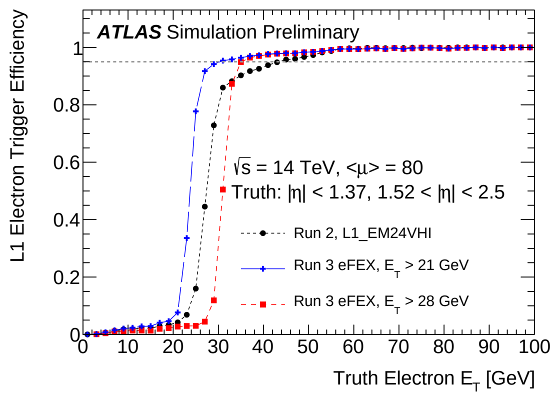

Figure 2: L1 trigger efficiency with respect to truth electrons as a function of their transverse energy. Black and blue curves have the same rate but different thresholds, and use different algorithms. The red curve has half of the rate of the black curve [5].

3. HLT upgrade for Run 3

The main update for the Run 3 trigger algorithms is the implementation of a multi-threaded environment of the Athena framework to run them. In Run 2, electrons and photons at HLT were reconstructed using a sliding-window algorithm to identify clusters of cells in the EM calorimeter. For Run 3, they will be reconstructed using dynamic variable-size clusters, called Superclusters, as used in the offline reconstruction [6].

The Run 2 electron triggers with E_T requirement of 15 GeV and above have a neural-network based fast-calorimeter reconstruction algorithm called "Ringer" as part of their HLT sequence. This algorithm allows to maintain the same signal efficiency as a cut-based method which relies on a set of shower shape variables [3], but with a 50% reduction in CPU demand for the lowest unprescaled single electron trigger. During Run 3 the Ringer algorithm will be used for all electron triggers. The usage of this algorithm for HLT photon selection is also being investigated for Run 3.

A diagram showing the different steps in the Run 3 HLT trigger sequence of algorithms for electrons and photons is shown in Figure 3.

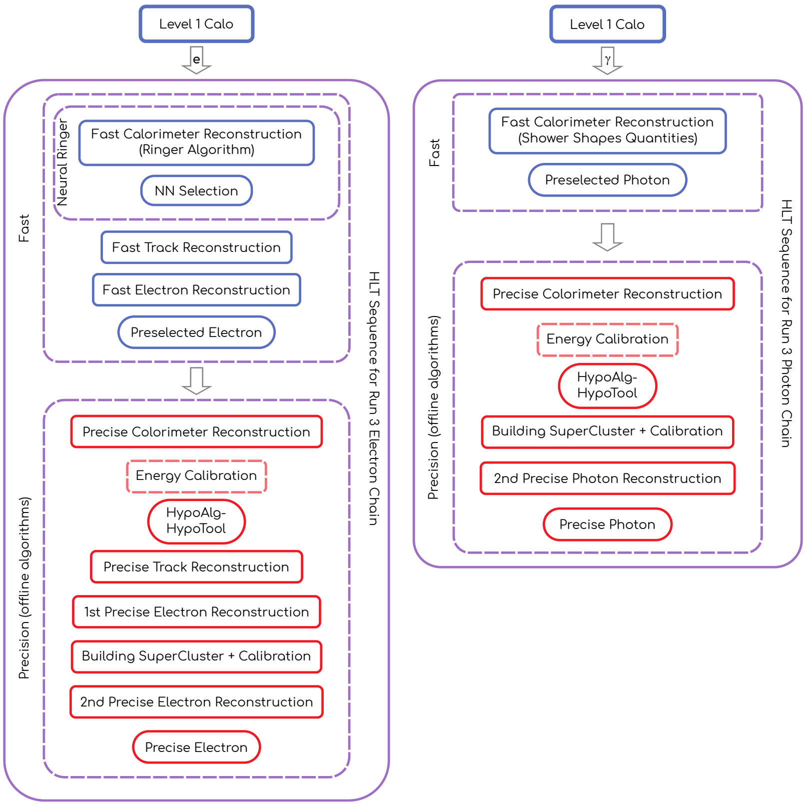

Figure 3: Simplified electron (left) and photon (right) HLT trigger algorithm sequences.

4. Conclusions

The ATLAS Trigger System is a key part of the ATLAS data taking process. During Run 2 the performance of the electron and photon triggers fulfilled the ATLAS physics analysis requirements.

For the Run 3 of the LHC, ATLAS electron and photon trigger reconstruction and selection will benefit from the improvements presented in this document and is expected to achieve a performance superior to that of Run 2.

References

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