# The ATLAS Electron and Photon Trigger

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Lucas Flores, On behalf of the ATLAS Collaboration
The University of Pennsylvania

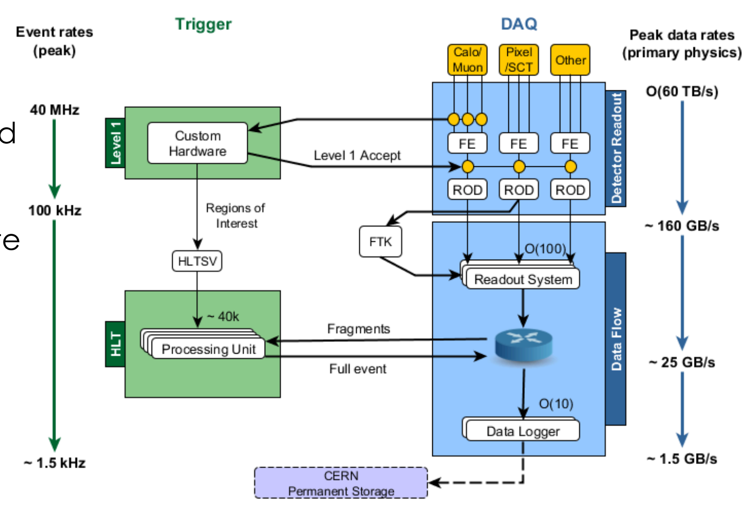
## Abstract

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 in both proton-proton and heavy ion collisions. Main triggers used during Run 2 (2015-2018) for those physics studies were a single-electron trigger with $E_T$ threshold around 25 GeV and a diphoton trigger with thresholds at 25 and 35 GeV. Relying on those simple, general-purpose triggers is seen as a more robust trigger strategy, at a cost of slightly higher trigger output rates, than to use a large number of analysis-specific triggers. To cope with ever-increasing luminosity and more challenging pile-up conditions at the LHC, the trigger selections needed to be optimized to control the rates and keep efficiencies high. The ATLAS electron and photon performance during Run-2 data-taking is presented as well as work ongoing to prepare to even higher luminosity of Run 3 (2021-2023)

## The ATLAS Trigger System

The ATLAS detector has a two-level Trigger system

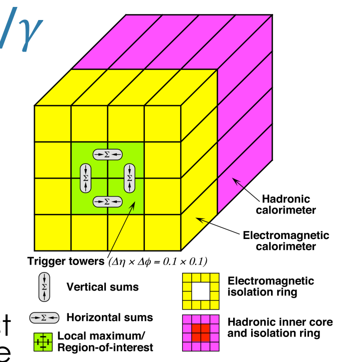
- The Level 1 (L1) hardware trigger
  - Uses low granularity data from calorimeters (trigger towers) and the muon system to identify Regions of Interest(RoIs)
  - Reduces the bunch crossing rate of 40 MHz to below 100 kHz
- The High Level Trigger (HLT) is software based
  - Seeded by RoIs from L1
  - Performs reconstruction and Identification similar to offline
  - Reduces L1 output rate to an average of 1kHz

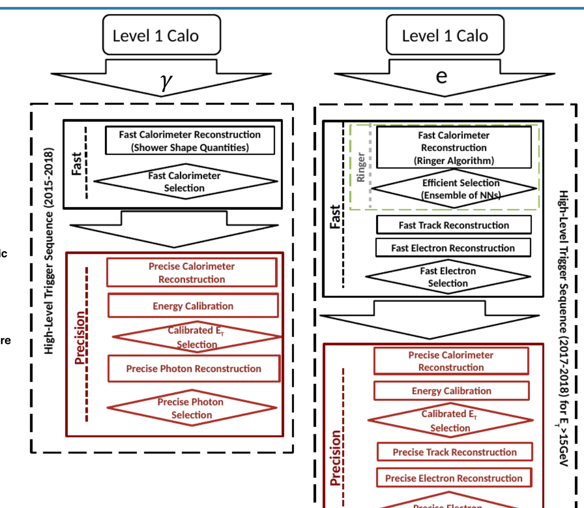



20% of the bandwidth is allocated to electron ($e$) and photon ($\gamma$) triggers

## Triggering on $e/\gamma$

- L1 creates RoI as a 4x4 trigger tower cluster (0.1 x 0.1 granularity in $\eta$ and $\phi$) in the central ($|\eta| < 2.5$) region of EM calorimeter
- Sum of the transverse energy($E_T$) from at least one of the four possible pairs of nearest neighbor towers required to exceed a predefined threshold.




The following selection is performed at the HLT:

**Fast Step**

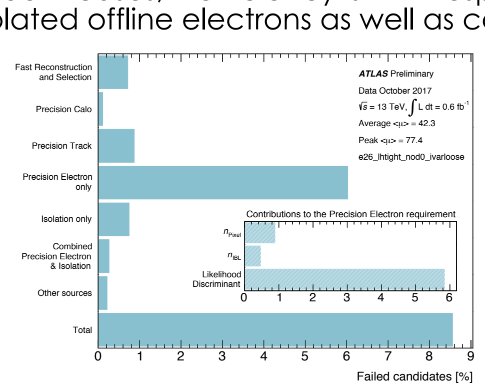
- Cut based selection using calorimeter variables for all $\gamma$ and electron triggers with thresholds of $E_T$ below 15 GeV
- Neural network based selection (Ringer) for electron triggers with thresholds $E_T$>15GeV
- Loose association of tracks to clusters for $e$'s

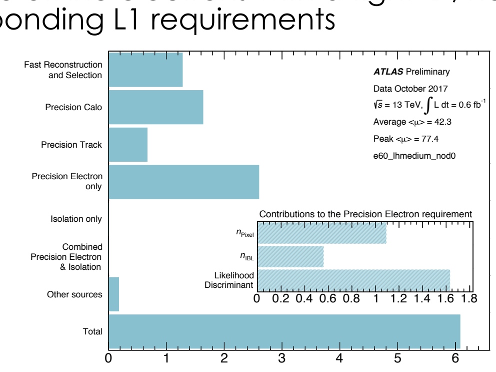
**Precision Step**

- Cut based ID of photons similar to the offline algorithms
- Likelihood (LH) based identification (ID) of electrons similar to offline algorithms
- Isolation requirement is applied in some cases to further suppress backgrounds

## Sources of Inefficiency for Electron Triggers

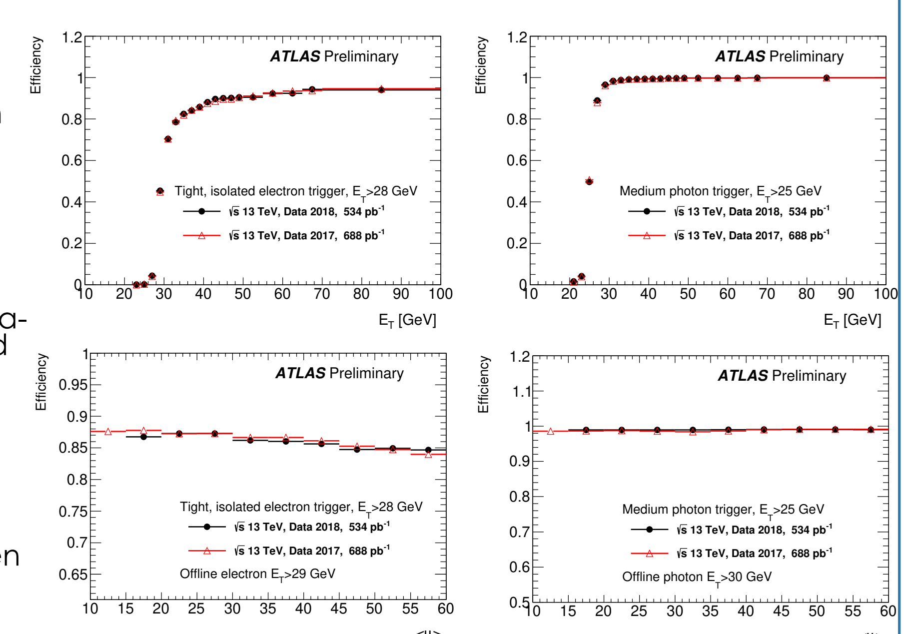
- Efficiency losses caused by differences in online and offline reconstruction and selection
- These differences need to be minimized within HLT CPU and timing constraints
- For 26 GeV electrons most of the inefficiency is due to electron identification
- for 60 GeV electrons sources are more diverse
- In both cases, inefficiency is with respect to offline electrons with a tight ID, non-isolated offline electrons as well as corresponding L1 requirements




## $e/\gamma$ Trigger Performance in 2018

- **Electron** efficiency is measured using a tag-and- probe method with Z→ee events
  - Good agreement seen with 2017 data
- **Photon** efficiency measured based on data-driven bootstrap method with L1 trigger
  - Close to 100% efficiency at a few GeV above trigger threshold
  - Good agreement seen with 2017 data.




## Changes and Improvements in Run 2

### Photon Chains

| Trigger type | 2015 | 2016 | 2017–2018 |
|---|---|---|---|
| Single photon | g120_loose (EM22VHI) | g140_loose (EM22VHI) | |
| Primary diphoton | g35_loose_g25_loose (2EM15VH) | g35_medium_g25_medium (2EM20VH) | |
| Tight diphoton | 2g20_tight (2EM15VH) | 2g22_tight (2EM15VH) | 2g20_tight_icalovloose (2EM15VHI) |

- 20: photon ET > 20 GeV.
- loose, medium, tight: identification.
- icalovloose: calorimeter-only loose isolation working point
- L1EM15VHI: an electromagnetic cluster with an $\eta$-dependent $E_T$ cut (V) of 15 GeV and hadronic energy veto (H) and electromagnetic isolation (I) which seeds the HLT trigger chain
- online 'tight' photon selection re-optimized in 2018 to be in sync with the new offline 'tight' selection
- The calorimeter only isolation was introduced at the HLT in tight diphoton triggers for the first time in 2017

### Electron Chains

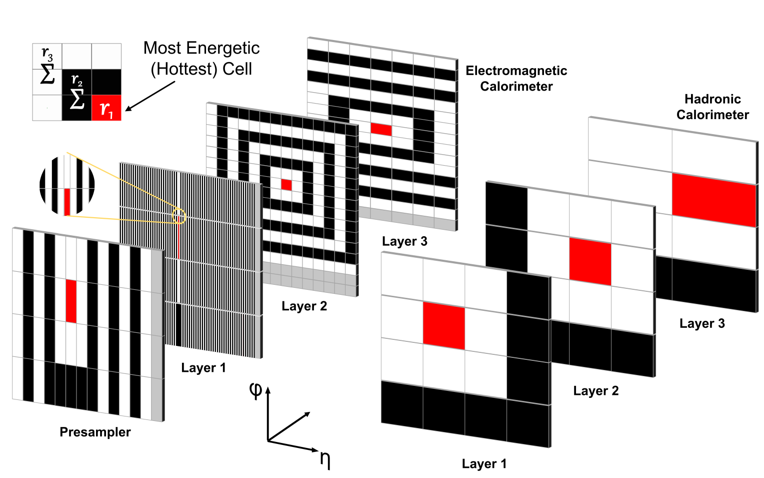
| Trigger type | 2015 | 2016 | 2017–2018 |
|---|---|---|---|
| Single electron | e24_lhmedium (EM20VH) e120_lhloose | e26_lhtight_nod0_ivarloose (EM22VHI) e60_lhmedium_nod0 e140_lhloose_nod0 | |
| Dielectron | 2e12_lhloose (2EM10VH) | 2e17_lhvloose_nod0 (2EM15VH) | 2e17_lhvloose_nod0 (2EM15VHI) 2e24_lhvloose_nod0 (2EM20VH) |

| Step | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|
| Fast calorimeter Reco and selection | Cut-based | | Ringer for $E_T \geq 15$ GeV Tuned on 2016 data | Tuned on 2017 data |
| Fast electron Selection | track $p_T > 1$ GeV, $\|\Delta\eta\| < 0.2$ | | track $p_T > 1$ GeV, $\|\Delta\eta\| < 0.3$ for $E_T < 20$ GeV; track $p_T > 2$ GeV, $\|\Delta\eta\| < 0.2$ for $E_T \geq 20$ GeV | |
| Precision calorimeter | LH calo only selection | | $E_T$ requirement | |
| Precision LH variables | Like offline without $\Delta p/p$ | Same as before without $d_0$, $\|d_0/\sigma(d0)\|$ | | |
| Precision LH inputs, tunes | MC-only | | 2016 data for $E_T \geq 15$ GeV MC for $E_T < 15$ GeV; smoothing | 2017 data (but 'lhmedium') |

- e26: electron ET > 26 GeV
- lhvloose, lhloose, lhmedium, lhtight: likelihood identification working point
- ivarloose: HLT track-based isolation
- EM22VHI: an electromagnetic cluster with an $\eta$-dependent $E_T$ cut (V) of 22 GeV and hadronic energy veto (H) and electromagnetic isolation (I) which seeds the HLT trigger chain
- Yearly updates to the electron thresholds and trigger configuration to optimize trigger performance

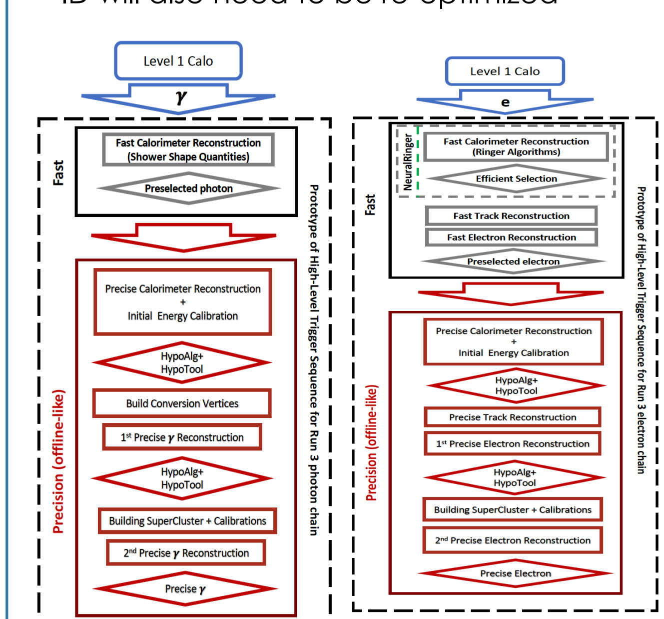
### Ringer Algorithm

- The algorithm is a neural-network based fast-calorimeter reconstruction algorithm
- Uses all calorimeter layers, centered in a window around the cluster barycenter
- Each ring is the collection of cells around the previous one. Ring value is the sum $E_T$ of all cells of that ring
- Achieves same signal efficiency as cut-based method but with a 50% reduction in CPU demand for the lowest unprescaled single electron trigger




## Run 3: New Hardware and Multi-Threading

- L1 Calorimeter trigger upgrade will increase granularity ten-fold and will improve background rejection
- Trigger algorithms will run in the multi-threaded environment of the athena framework(AthenaMT) and will have offline-like access to data
- The figure shows Run 3 trigger $e/\gamma$ sequence under development
- ID will also need to be re-optimized




**References:** https://twiki.cern.ch/twiki/bin/view/AtlasPublic/EgammaTriggerPublicResults