The ATLAS Electron and Photon Trigger

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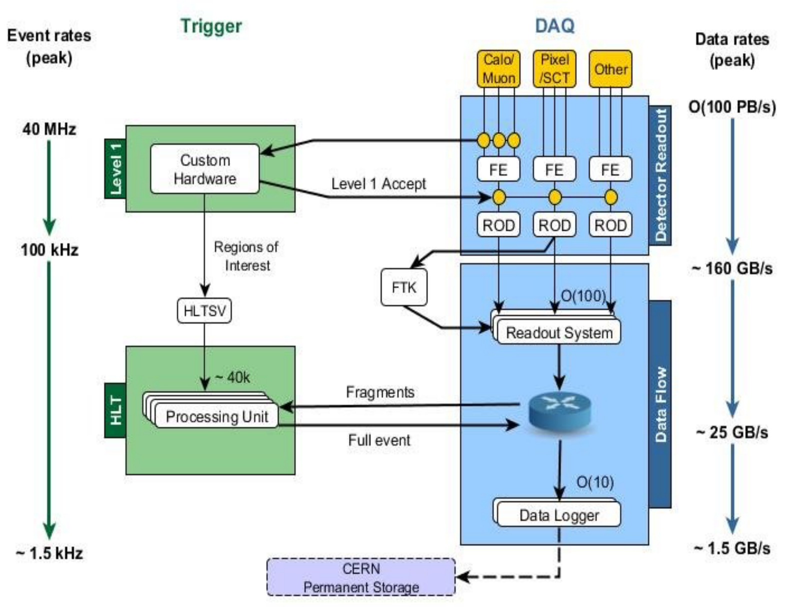
Abstract

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. 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 2015-2018 data-taking is presented as well as work ongoing to prepare to even higher luminosity of Run 3.

ATLAS Trigger System

- The ATLAS has two-level Trigger system that reduces the bunch crossing rate of 40MHz at the LHC to an average final event rate of ~1kHz, of which around 20% are allocated to electron and photon triggers.
- The Level1 (L1) hardware trigger uses
  - low granularity data from the calorimeters (trigger towers) and the muon system to identify Regions of Interest (RoIs).
  - Maximum output rate is 100kHz.
- The High Level Trigger (HLT) is software based
  - seeded by RoIs from L1.
  - Performs reconstruction and identification similar to offline.

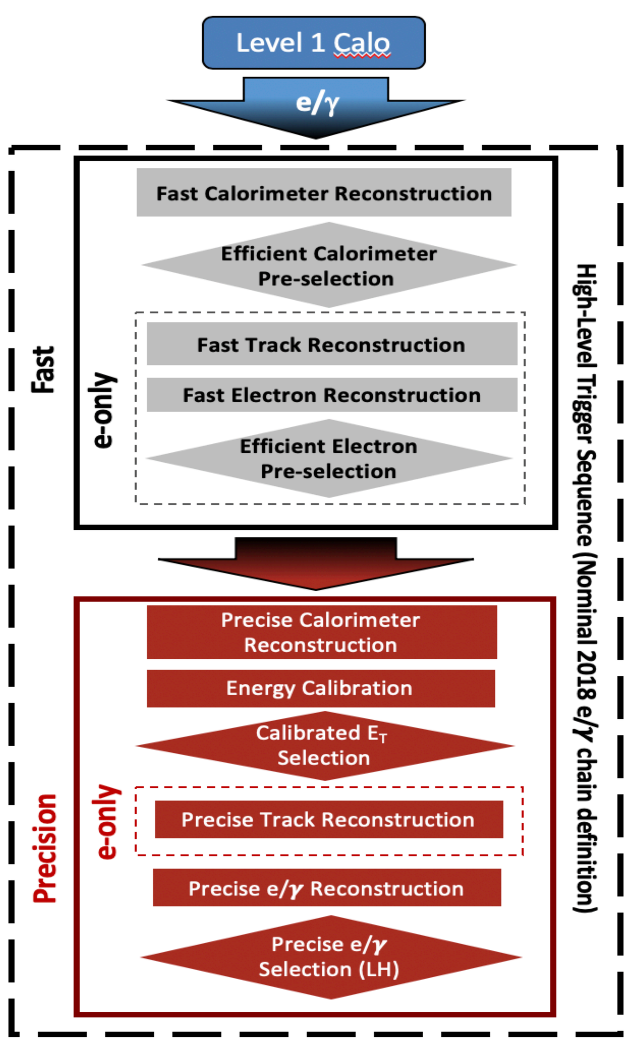


Triggering Electrons and Photons (e/γ)

L1 Calorimeter trigger creates an RoI as a 2 x 2 trigger tower cluster ($\Delta\eta \times \Delta\phi = 0.4 \times 0.4$) in the EM calorimeter (in $|\eta| < 2.5$ region) for which the sum of the transverse energy from at least one of the four possible pairs of nearest neighbor towers exceeds a predefined threshold.

The following selection is performed at the HLT:

- **Fast Step**
  - Cut-based selection using calorimeter variables for all photon triggers and for electron triggers with thresholds of transverse energy (E_T) below 15 GeV.
  - Neural Network based selection (Ringer) for electron triggers with thresholds $E_T > 15$ GeV.
  - Loose association of tracks to clusters for electrons.
- **Precision Step**
  - Cut-based identification of photons similar to offline algorithms.
  - Likelihood (LH) identification of electrons similar to offline algorithms.
  - Isolation requirement is applied in some cases to further suppress backgrounds.



Changes and Improvements to Electron Chains in Run 2

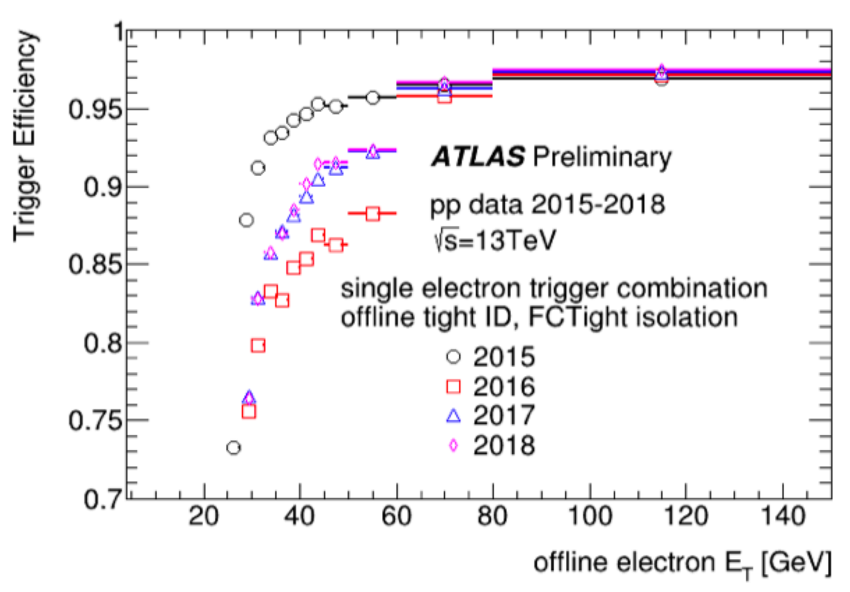
- Yearly updates to the electron thresholds and trigger configuration to optimize trigger performance.

Trigger Type	2015	2016	2017-2018
Single electron	e24_lhmedium_L1EM20VH e120_lhloose	e26_lhtight_nod0_ivarloose e60_lhmedium_nod0 e140_lhloose_nod0	
Di-electron	2e12_ lhloose_L12EM10VH	2e17_ lhvloose_nod0	2e17_ lhvloose_nod0_L12EM15VHI 2e24_ lhvloose_nod0_L12EM20VH

- **e26:** electron $E_T > 26$ GeV.
- **lhvloose, lhloose, lhmedium, lhtight:** likelihood identification.
- **ivarloose:** loose isolation.
- **L1EM20VHI:** L1 extra-requirements.

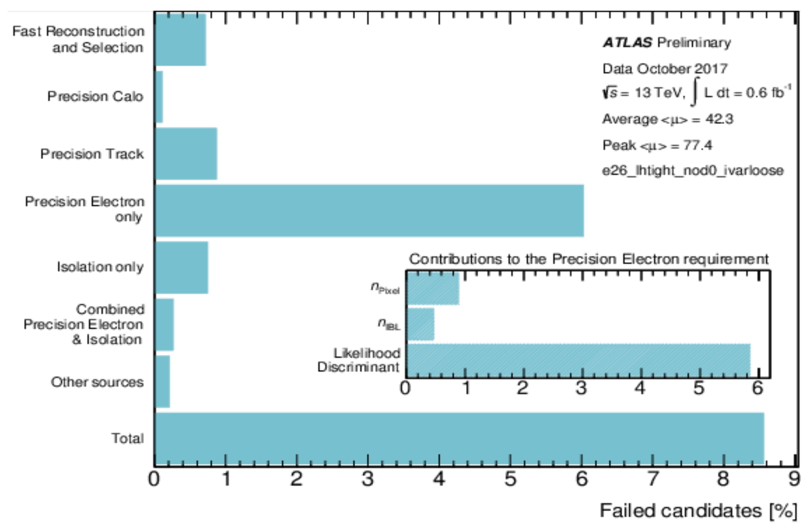
Step	2015	2016	2017	2018
Fast calorimeter Reco and selection	Cut-based		Ringer for $E_T \geq 15$ GeV Tuned on 2016 data	Tuned on 2017 data
Fast electron Selection	track $p_T > 1$ GeV, $\|\Delta\eta\| < 0.2$		track $p_T > 1$ GeV, $\|\Delta\eta\| < 0.3$ for $E_T < 20$ GeV track $p_T > 2$ GeV, $\|\Delta\eta\| < 0.2$ 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 pdf 'smoothing'	2017 data (but 'lhmedium')

- Most of the efficiency loss in 2016-2018 is due to EM isolation at L1.

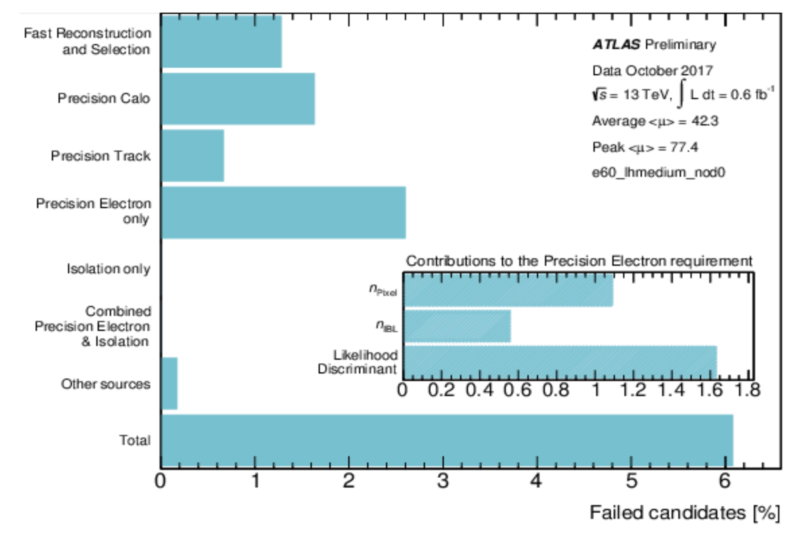


- Isolation at L1 was introduced to reduce the trigger rate at increasing luminosity.
- The efficiency improvements in 2017-2018 are due to usage of Ringer algorithms which allowed better alignment of the online selection with the final offline selection for Run 2.

Sources of Inefficiency for Electron Triggers



- Efficiency losses caused by differences in online and offline reconstruction and selection.



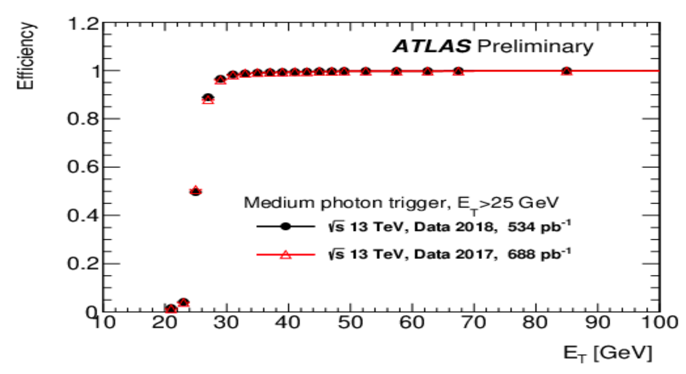
- These differences need to be minimized within HLT CPU and timing constraints.
- for e26 most of the inefficiency is due to electron identification, while for e60 sources are more diverse. In both cases, inefficiency is with respect to tight, non-isolated offline electrons as well as corresponding L1 requirements.

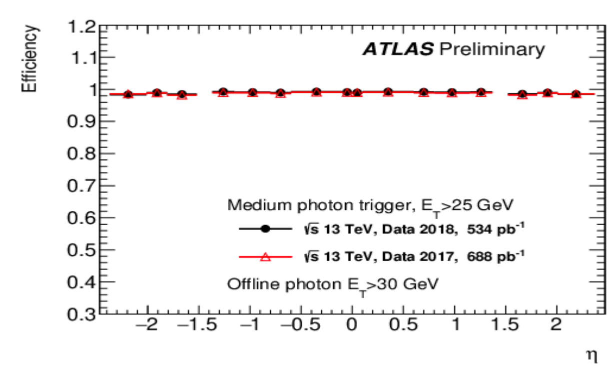
Evolution of Photon Chains in Run 2

Trigger Type	2015	2016	2017-2018
Single photon	g120_loose	g140_loose	
Primary di-photon	g35_loose_g25_loose		g35_medium_g25_ medium _L12EM20VH
Tight di-photon	2g20_tight	2g22_tight	2g20_tight_icalovloose_ L12EM15VHI

- **g20:** photon $E_T > 20$ GeV.
- **medium/loose/tight:** Identification.
- **icalovloose:** calorimeter-only loose isolation.
- **L12EM15VHI:** L1 extra-requirements.

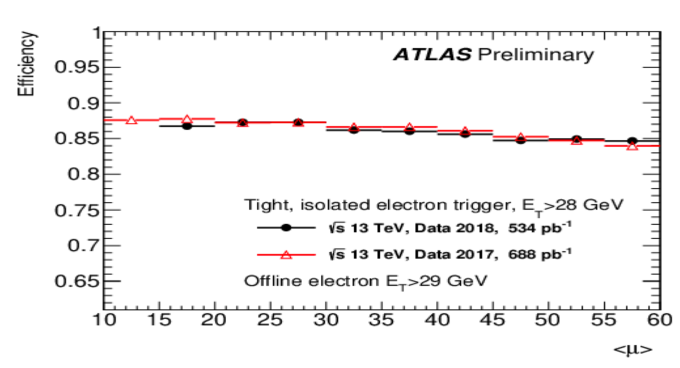
- online 'tight' photon selection re-optimized in 2018 to be in sync with the new offline 'tight' selection.
- The calorimeter only isolation was introduced at the HLT in tight di-photon triggers for the first time in 2017.

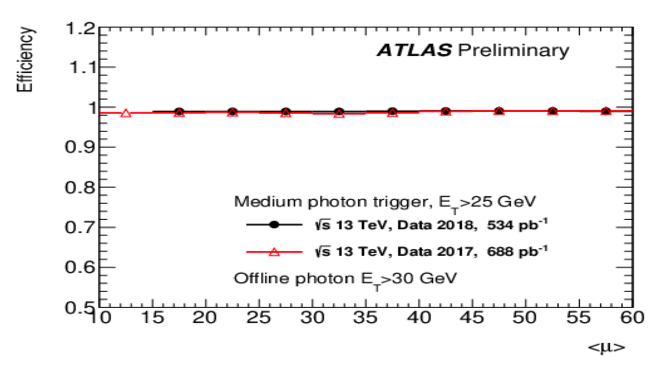




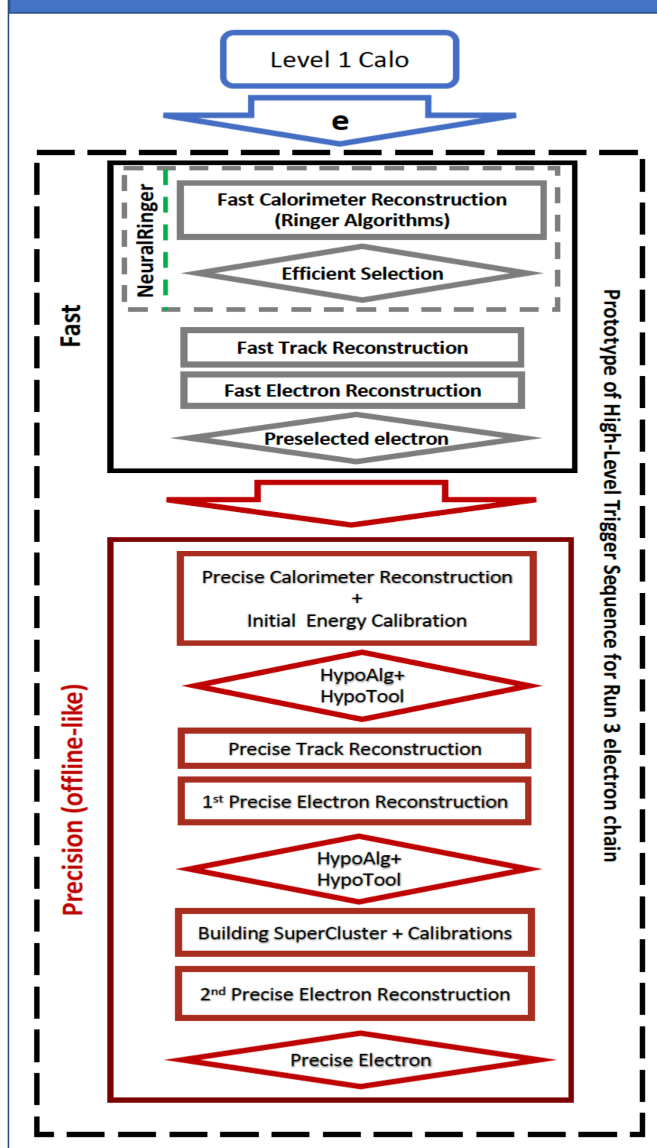
Electron and Photon Trigger Performance vs Pile-up

- Isolated triggers exhibit small pile-up dependence (left). Overall trigger performances (left/right) are stable against pile-up

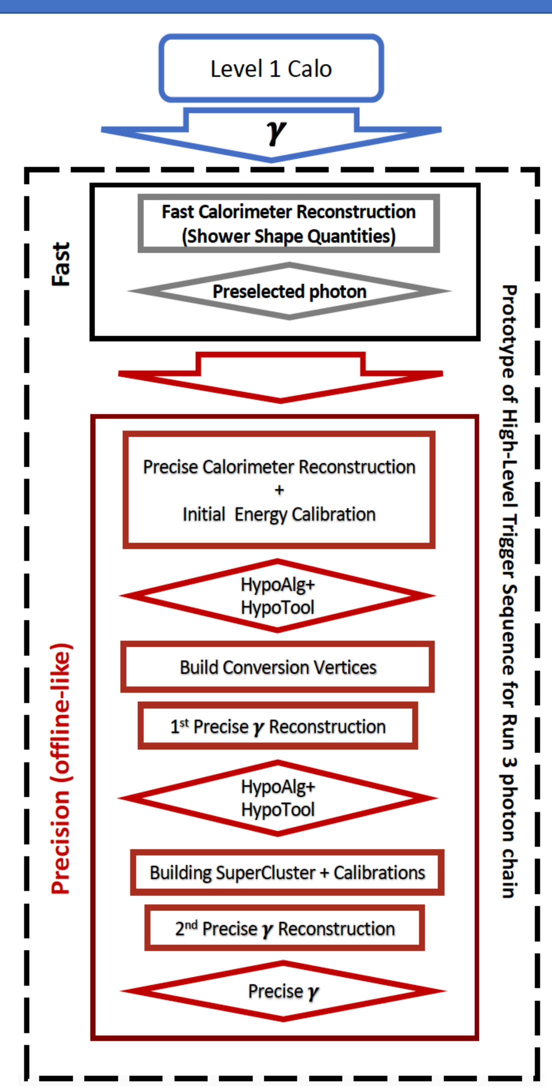




Run 3 : migration to AthenaMT



- L1 Calorimeter trigger upgrade will increase ten-fold its granularity and improve background rejection.
- Run3 trigger algorithms will run in multi-threaded environment of the athena framework (AthenaMT) and will have offline-like access to data.
- The figure (left/right) shows Run 3 trigger e/γ sequence under development.



References: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/EgammaTriggerPublicResults , ATL-COM-DAQ-2018-043