The ATLAS Electron and Photon Trigger

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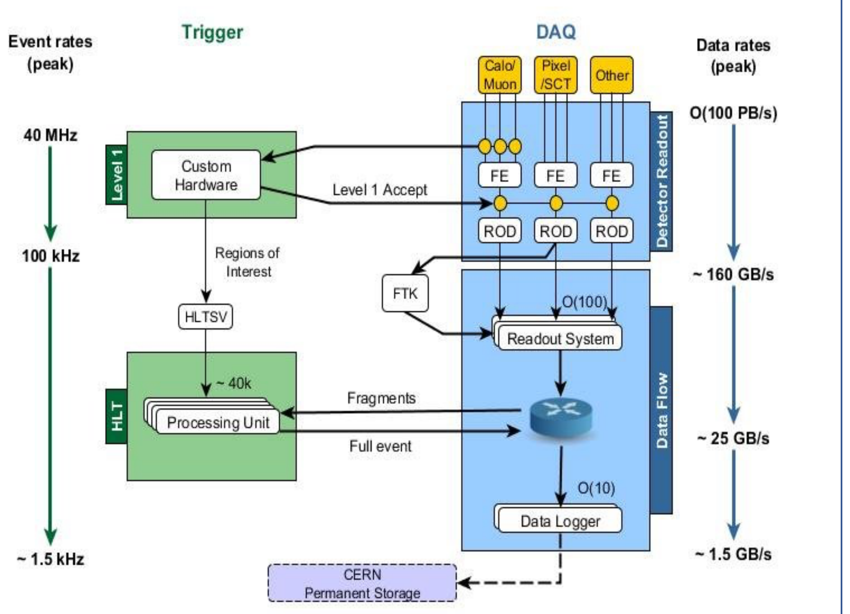
Abstract

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. Primary 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 the 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 pileup 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 (2021-2024).

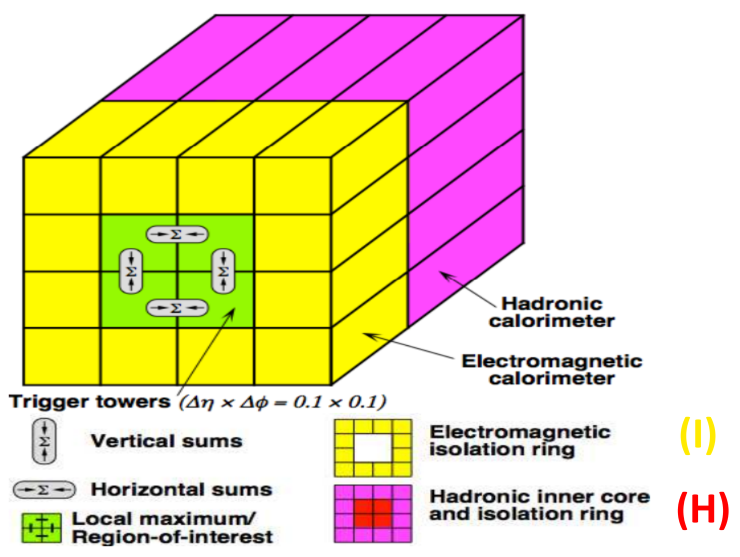
ATLAS Trigger System

The ATLAS has a 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).
  - The 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.



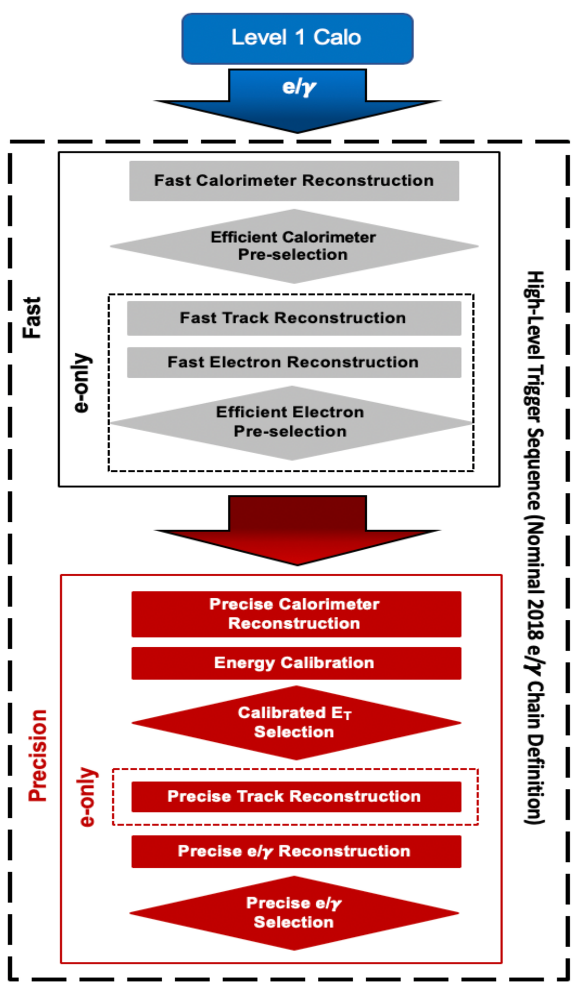
Triggering Electrons and Photons (e/γ)



To build at electromagnetic (EM) RoI, a sliding window algorithm is used, with a window of 4 x 4 trigger towers. Within this window the algorithm uses the maximum transverse energy (E_T) from the four possible pairs of nearest neighbor EM towers in a 2x2 central region.

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 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.



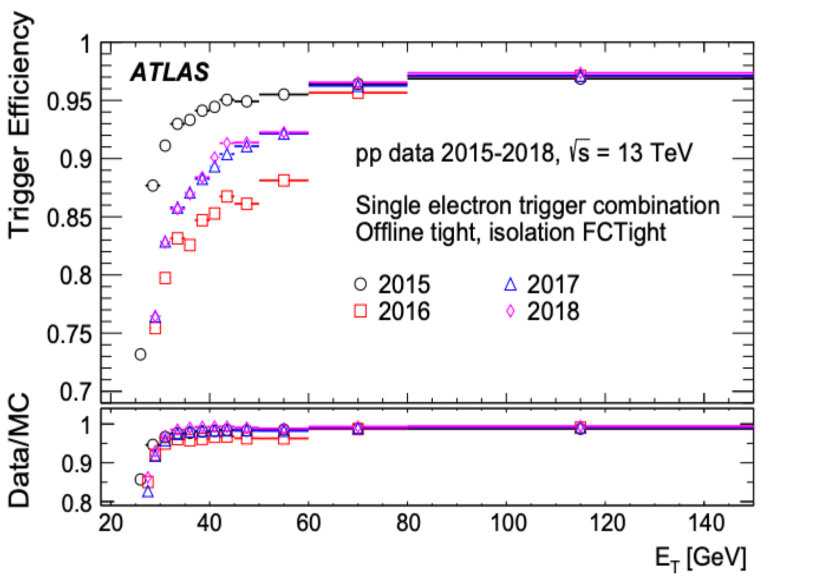
Changes and Improvements to Electron Selection for Run 2

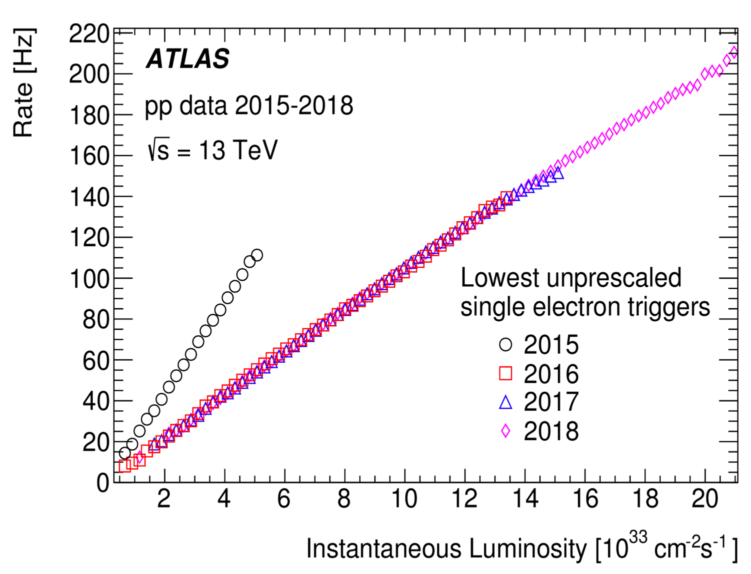
Yearly updates to the electron thresholds and trigger configuration to optimize trigger performance.

Trigger type	2015	2016	2017–2018
Single electron	e24_lhmedium (EM20VH) e120_lhloose e200_etcut	e26_lhtight_nod0_ivarloose (EM22VHI) e60_lhmedium_nod0 e140_lhloose_nod0 e300_etcut	
Dielectron	2e12_lhloose (2EM10VH)	2e17_lhvloose_nod0 (2EM15VH)	2e17_lhvloose_nod0 (2EM15VHI) 2e24_lhvloose_nod0 (2EM20VH)

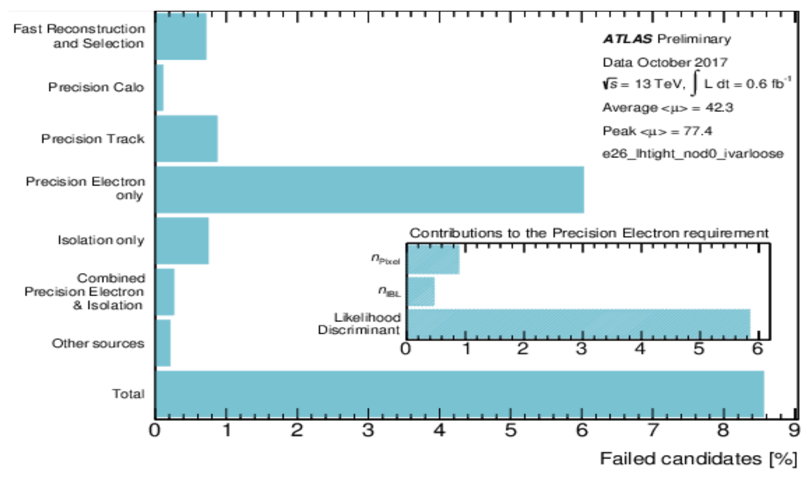
- **e26:** electron E_T > 26 GeV.
- **lhvloose, lhloose, lhmedium, lhtight:** likelihood identification.
- **ivarloose:** loose isolation.
- **L1EM20VHI:** L1 extra requirements.

- Most of the efficiency loss in 2016-18 is due to EM isolation at L1 introduced in 2016.
- 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.

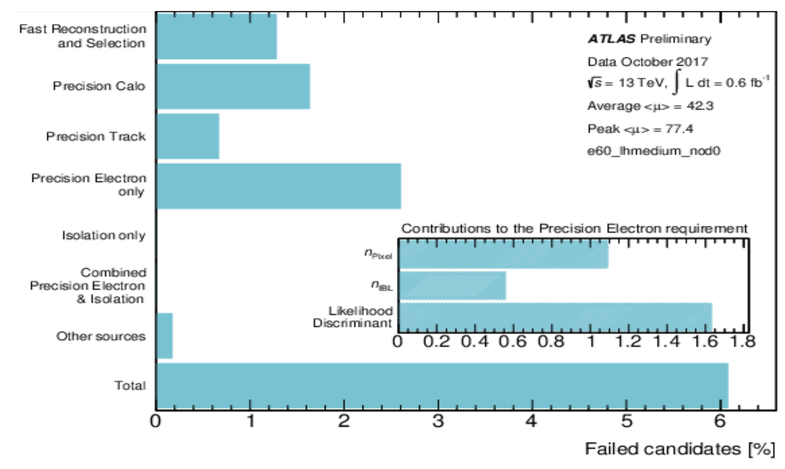




Sources of Inefficiency for Electron Triggers



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



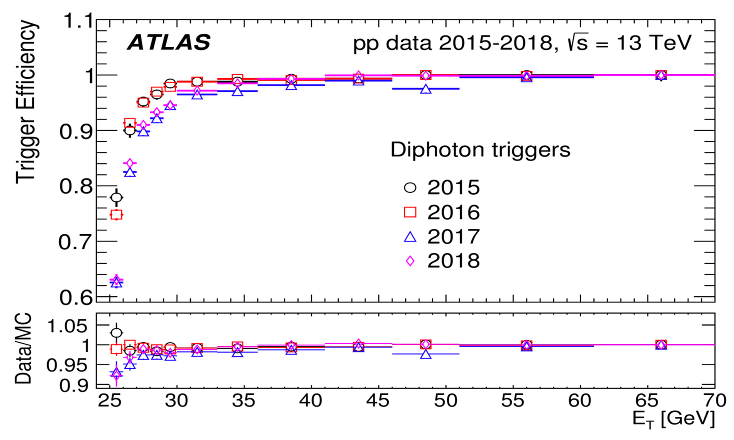
- These differences need to be minimized within HLT CPU and timing constraints.
- For the 26 GeV-threshold single electron trigger (e26_lhtight_nod0_ivarloose) most of the inefficiency is due to electron identification, while for the 60 GeV-threshold single electron trigger (e60_lhmedium_nod0), sources are more diverse. In both cases, inefficiency is with respect to tight, non-isolated offline electrons as well as corresponding L1 requirements.

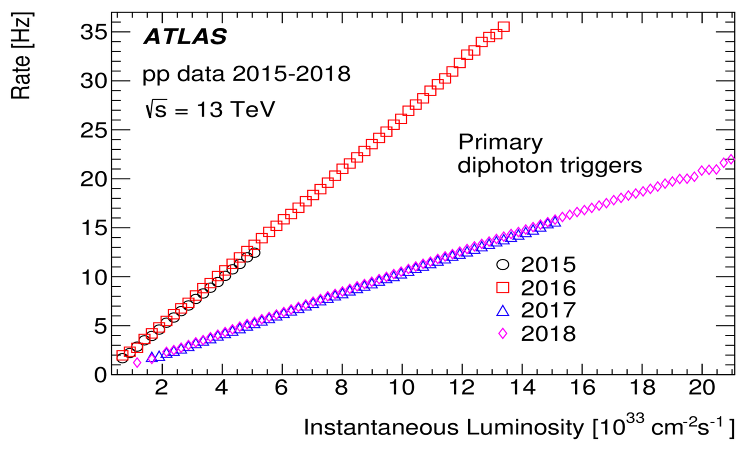
Evolution of Photon Chains in Run 2

Trigger type	2015	2016	2017–2018
Single photon	g120_loose (EM22VHI)	g140_loose (EM22VHI)	
Primary diphoton	g35_loose_g25_loose (2EM15VH)		g35_medium_g25_medium (2EM20VH)
Loose diphoton			2g50_loose (2EM20VH)
Tight diphoton	2g20_tight (2EM15VH)	2g22_tight (2EM15VH)	2g20_tight_icalovloose (2EM15VHI)

- **g120:** photon E_T > 120 GeV.
- **medium/loose/tight:** Identification.
- **icalovloose:** calorimeter-only loose isolation.
- **L12EM15VHI:** L1 extra-requirements.

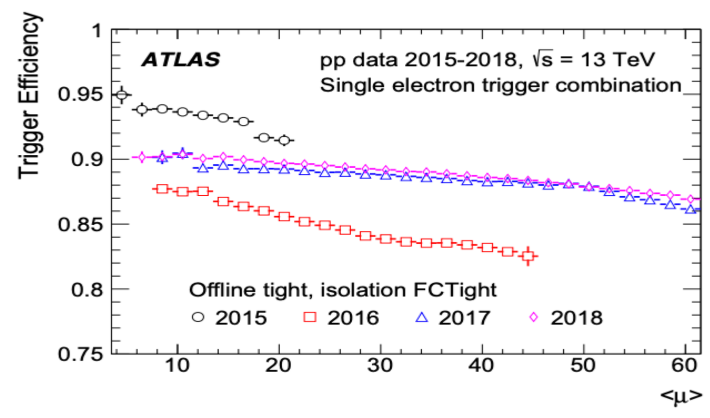
- Online 'tight' photon selection re-optimized in 2018 to be in sync with the new offline 'tight' selection.
- The calorimeter only isolation was introduced at the HLT in tight diphoton triggers for the first time in 2017.

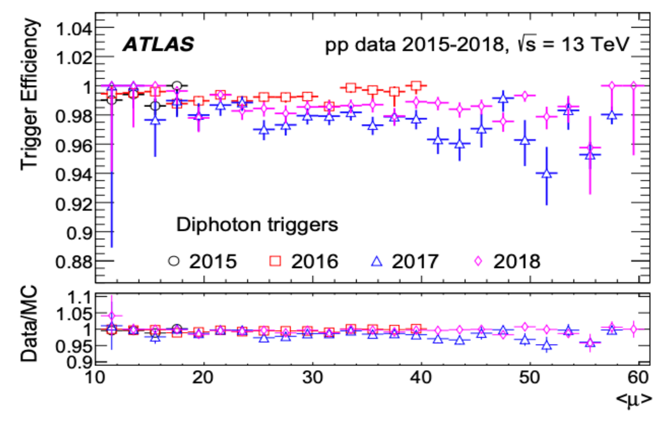




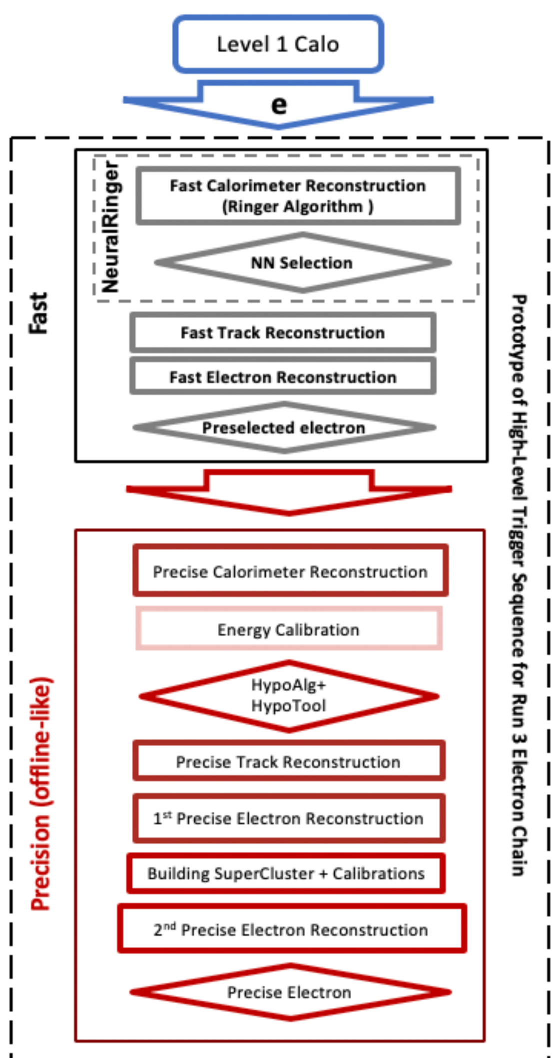
Electron and Photon Trigger Performance vs Pile-up

Isolated triggers exhibit small pile-up dependence (left).

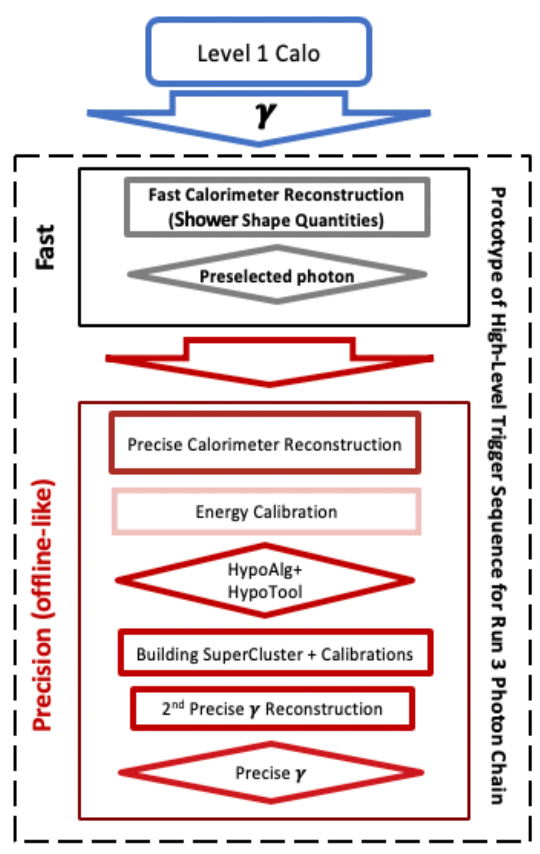




Run 3: migration to AthenaMT



- L1 Calorimeter trigger upgrade will increase ten-fold its granularity and improve background rejection.
- Run 3 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 , ATLAS Collaboration, Eur. Phys. J. C 80 (2020) 47