ATLAS Electron and Photon Trigger

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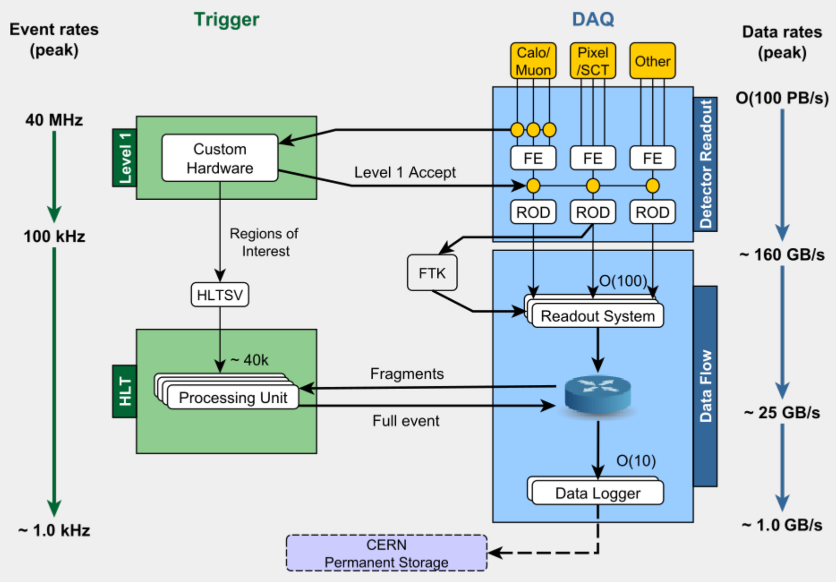
ATLAS electron and photon triggers covering transverse energies from 5 GeV to several TeV are essential to record signals for a wide variety of physics: from Standard Model processes to searches for new phenomena. To cope with ever-increasing luminosity and more challenging pile-up conditions at a centre-of-mass energy of 13 TeV, the trigger selections need to be optimized to control the rates and keep efficiencies high. The ATLAS electron and photon trigger evolution throughout the Run 2 is presented, including new techniques developed to maintain their high performance even in high pile-up conditions as well as first efficiency measurements from the 2018 data taking.

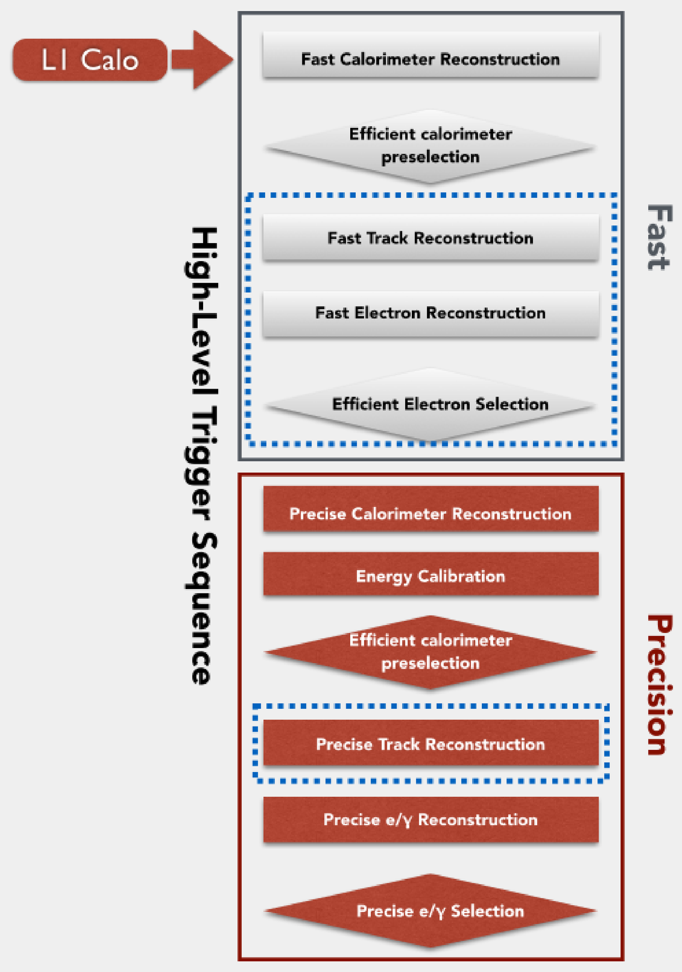
Run-2 ATLAS Trigger/DAQ system

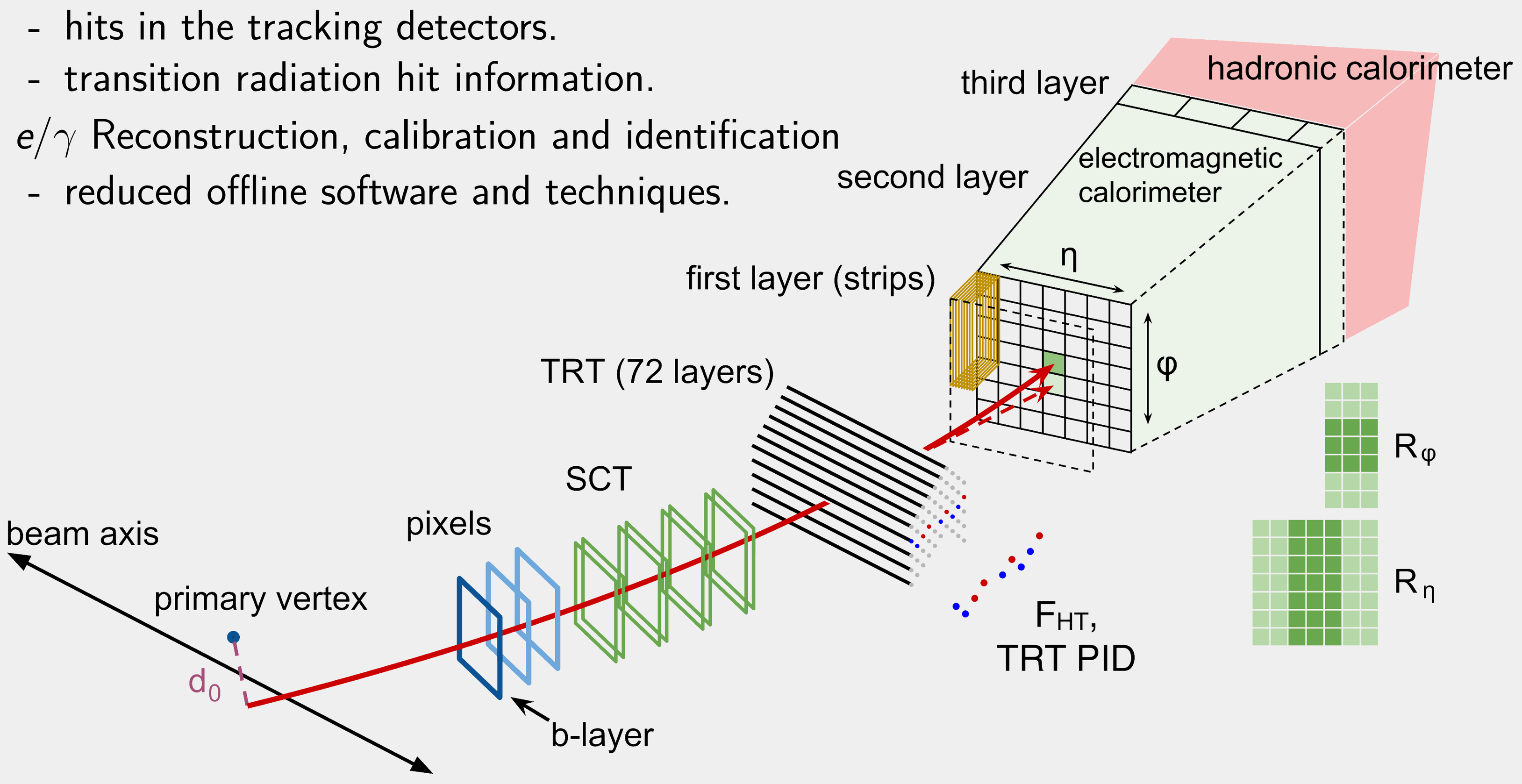
- Two-level system to reduce average event rate recording to ∼1 kHz, from the LHC beam crossing rate of 40 MHz. ∼ 20% allocated for e/γ.
- Hardware-based Level 1 (L1) trigger
  - Uses low granularity data from calorimeters and muon system.
  - Identifies regions of interest (RoIs).
  - Maximum output rate of 100 kHz.
- Software-based high-level trigger (HLT)
  - Full granularity data from all the detector + RoIs from accepted events by the L1.
  - Performs the online particle reconstruction.



Triggering e/γ

- HLT e/γ trigger reconstructs objects within electromagnetic (EM) RoI provided by the L1 Calorimeter (L1Calo) trigger.
- e/γ HLT sequence
  - Fast algorithms reject events early.
  - Precise algorithms to efficiently identify e/γ
    + Cut-based ID for Photons.
    + Likelihood-based ID for Electrons.
- Clusters are reconstructed with a sliding window algorithm; selection is based on the transverse energy of the cluster (E_T).
- Common shower shape variables for e/γ calculated for identification.
- Photons are reconstructed with only the cluster.
- Electron candidates have tracks loosely matched to the cluster ($\Delta\phi$, $\Delta\eta$).
- Tracks are then extrapolated to 2nd EM layer.
- Electrons have additional information
  - hits in the tracking detectors.
  - transition radiation hit information.
- e/γ Reconstruction, calibration and identification
  - reduced offline software and techniques.





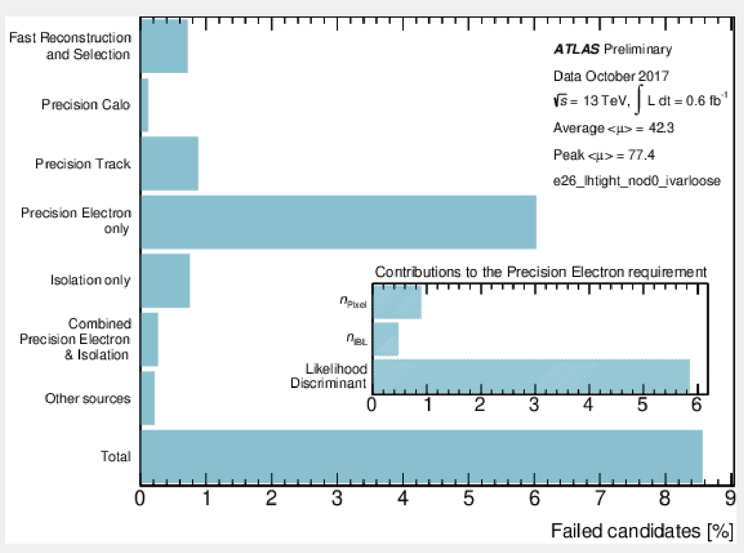
Improvements in Run-2

- Topological cluster based isolation for photons. Online since 2017.
- New Neural Network based algorithm (Ringer) to improve fast calorimeter selection for the electron trigger chains. Re-optimized in 2018.
- Identification for electrons at HLT.
  - Likelihood selection and ID pileup correction updated for 2018 data taking.

Year	Peak inst. lumi [10^{33}cm^{-2}s^{-1}]	Pileup $<\mu>$	$\int L$ [fb^{-1}]
2015	5.0	13.4	3.9
2016	13.8	25.1	35.6
2017	20.9	37.8	46.9
2018	21.4	-	-

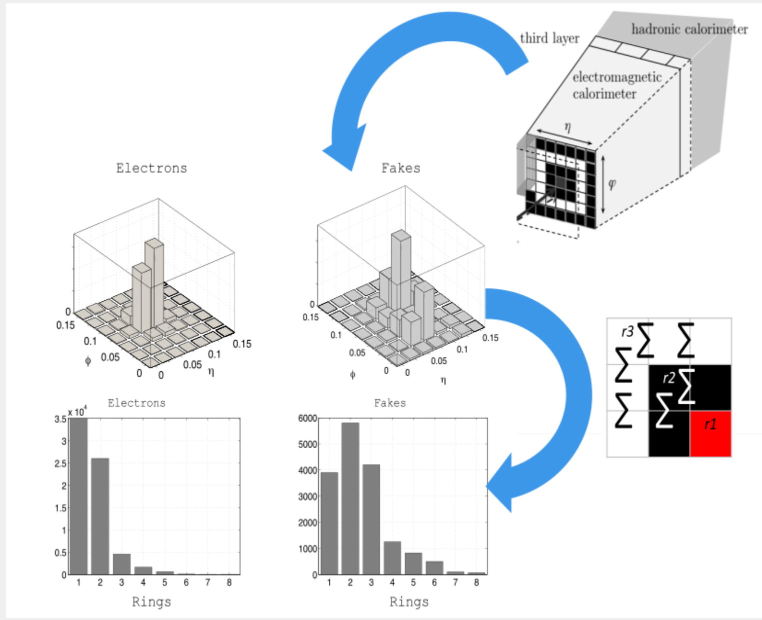
Sources of inefficiency for single electron triggers

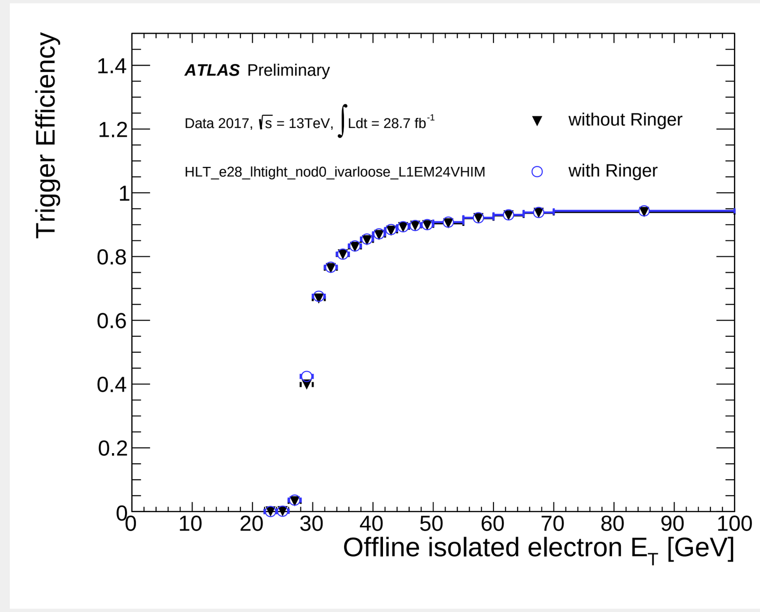
- Study on data 2017, at each selection step in the HLT w.r.t offline reconstruction.
- Try to keep online selection as close as possible to offline.
- Still some differences, mainly in the Precision Electron step
  - In particular in the tracking.
- The trigger developments are made to minimize those differences.



Ringer Algorithm

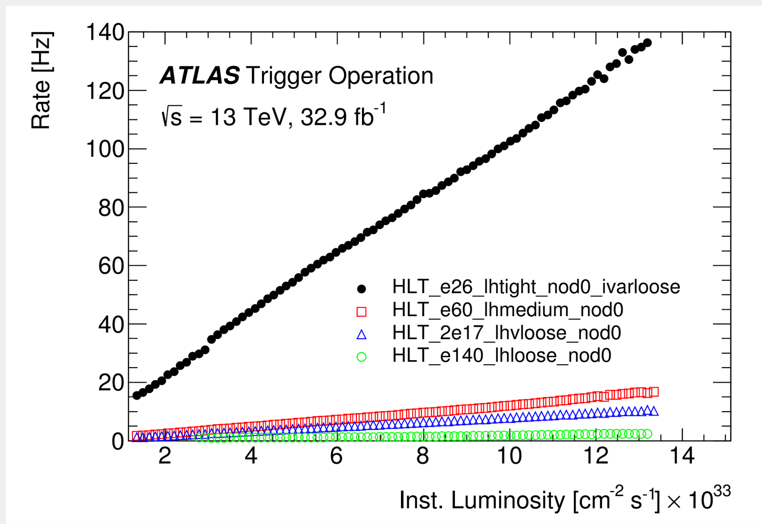
- Build from using all calorimeter layers, centered in a window around the cluster barycenter.
  - First ring in each layer is the cell closest to cluster barycenter.
  - The next ring is the collection of cells around the previous one. Ring value is the sum E_T of all cells composing the ring.
- Same signal efficiency w.r.t cut-based fast calo step.
- Primary chain latency reduction: 200ms to ∼100ms.
- High rejection power (∼2-3X). Electron + photon slice: ∼1/4 latency reduction.

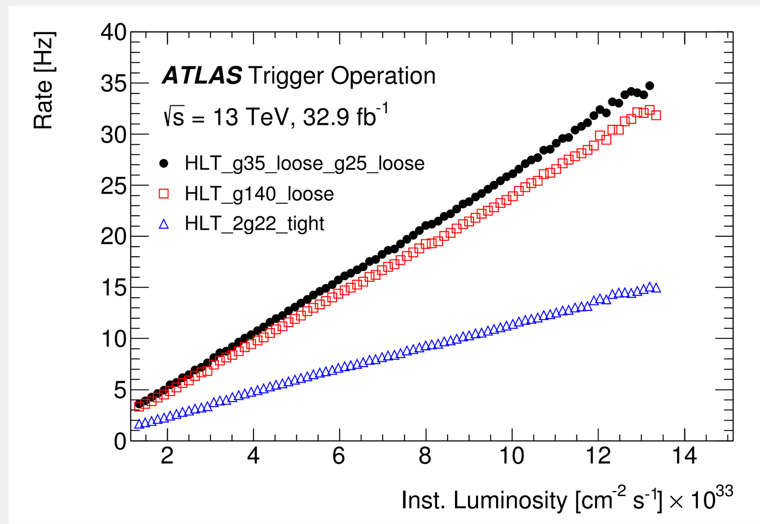




Electron and Photon HLT trigger rates

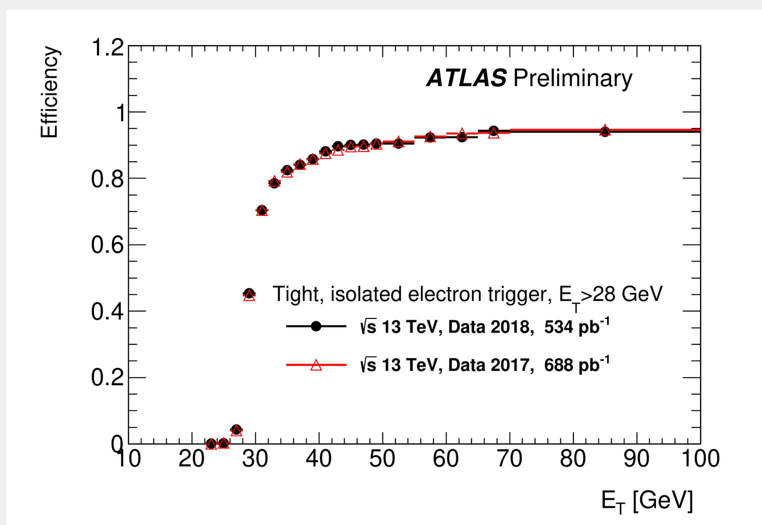
- Both electron (left) and photon (right) trigger rates have a roughly linear dependence on the instantaneous luminosity

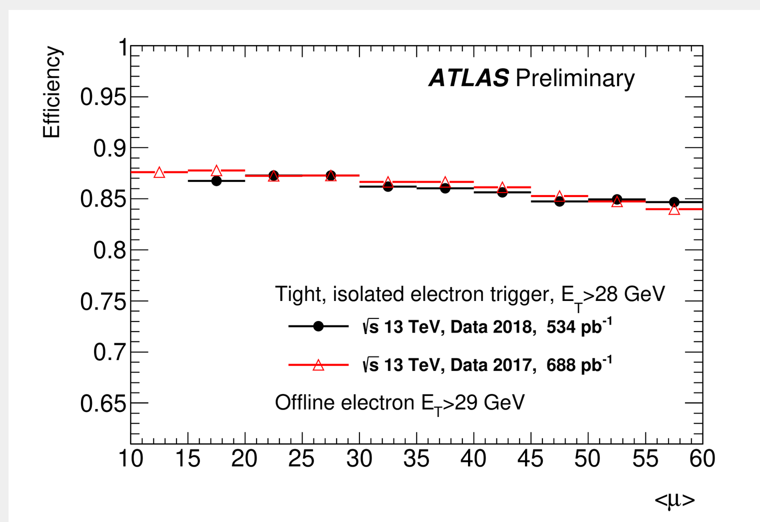




Electron Trigger Performance

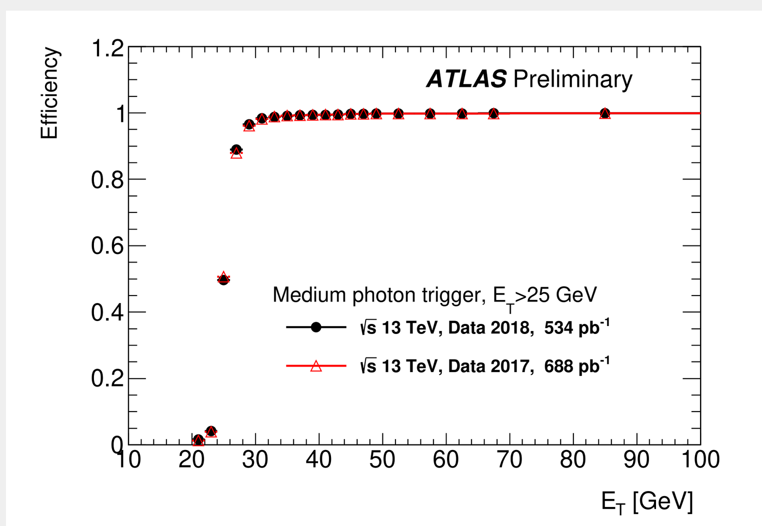
- Efficiencies measured with a tag-and-probe method.
  - Using $Z \rightarrow ee$ decays in early 2018 data and late 2017 data.
- Offline reconstructed electrons are required to pass a likelihood-based ID.
- The error bars show statistical uncertainties.
- Achieving same performance in 2018 conditions as in 2017. Robust against pileup.

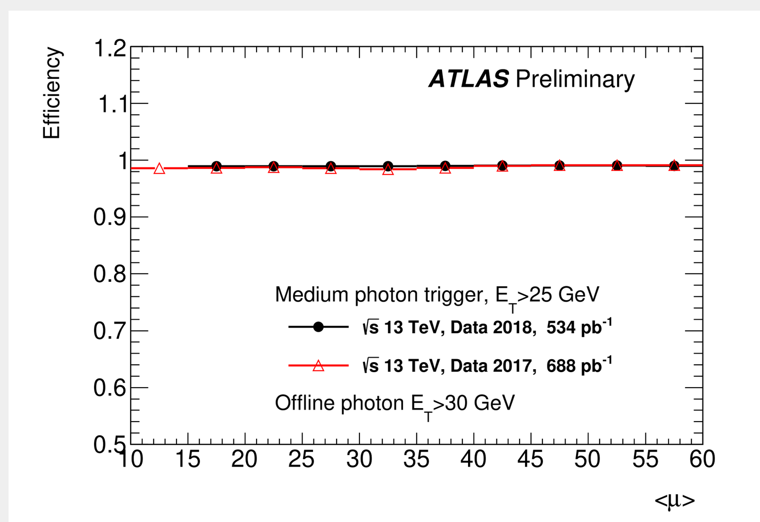




Photon Trigger Performance

- Efficiencies measured based on a data-driven bootstrap method.
  - Events selected from a fully efficient reference trigger to measure the performance of the offline trigger.
- No background subtraction is applied. Bayesian statistical uncertainty.
- Good trigger performance. Robust against pileup.





twiki.cern.ch/twiki/bin/view/AtlasPublic/EgammaTriggerPublicResults

References: CERN-EP-2016-241 (arXiv:1611.09661), ATL-DAQ-PROC-2016-016, ATL-COM-DAQ-2017-016, ATL-COM-DAQ-2018-005, ATL-COM-DAQ-2018-007