The Performance of the Muon, Electron and Photon Triggers at ATLAS

Batool Safarzadeh

University of Sussex

On behalf of the ATLAS Collaboration

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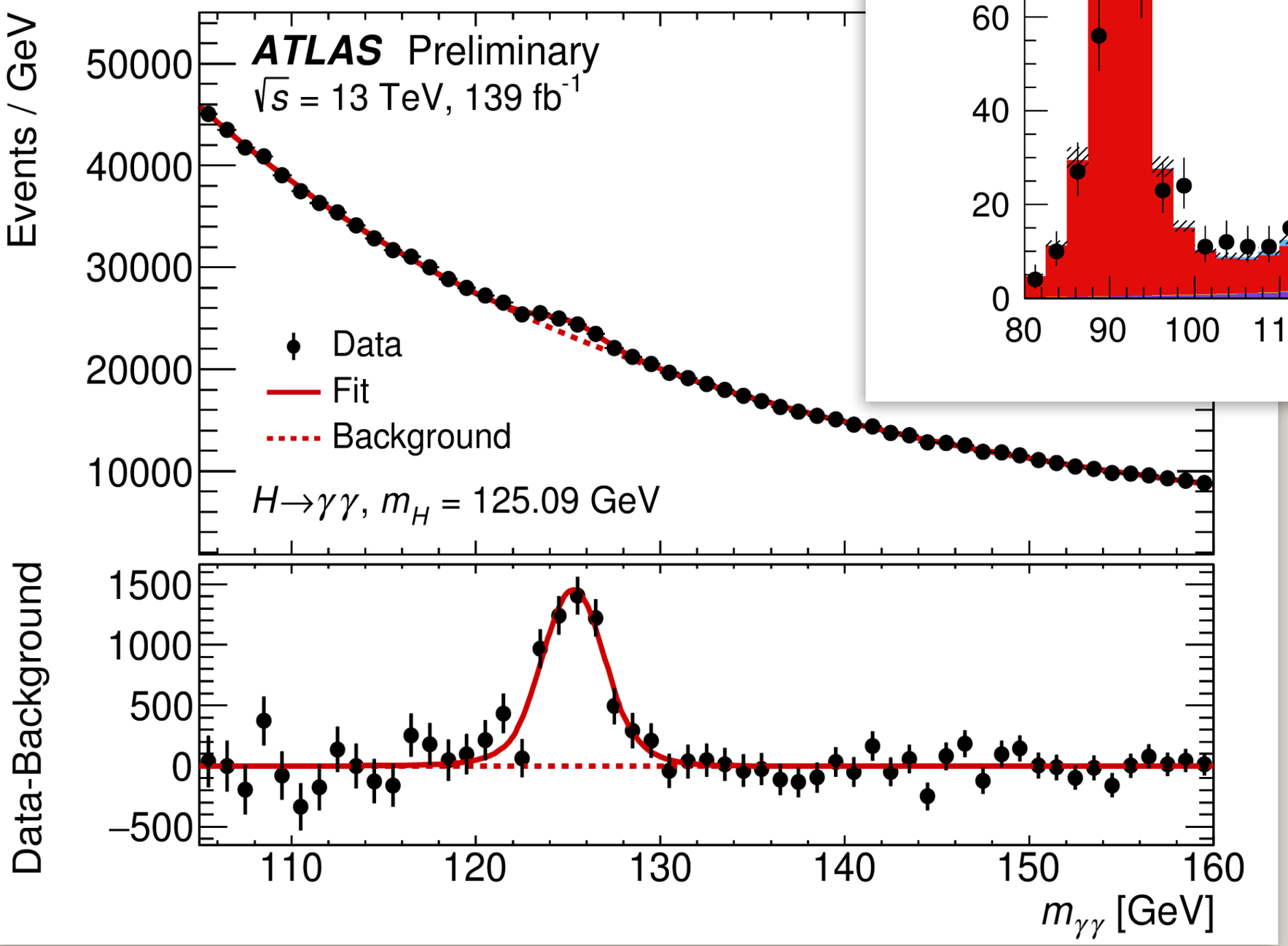
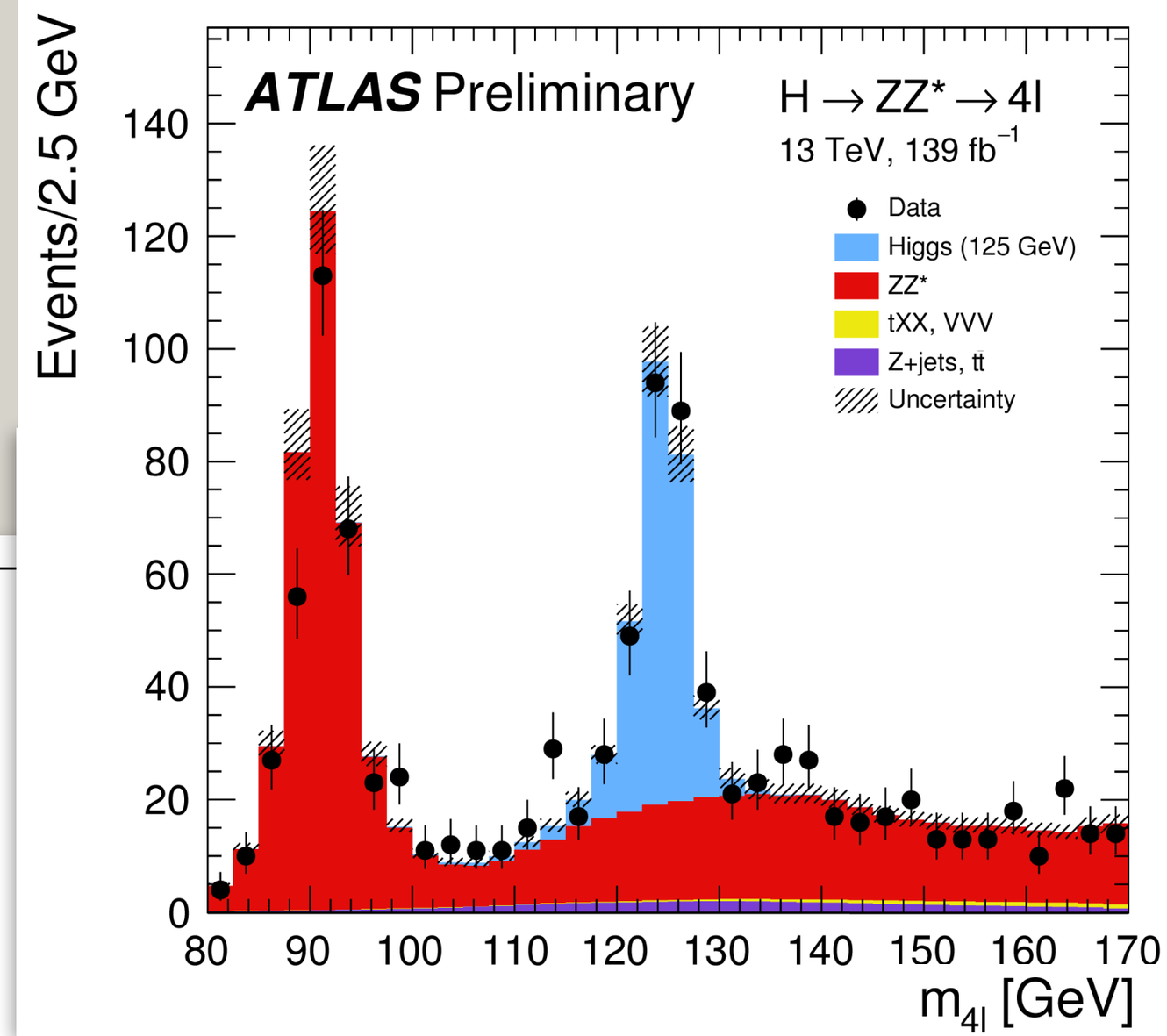
Preface

Why are the electron, photon and muon triggers important?





ATLAS Public Results

ATLAS Trigger System in Run2

40 MHz of p-p collisions are reduced to a rate of 100 kHz by the Level-1 (**L1**) Trigger. After further processing by the High-Level Trigger (**HLT**) , the final event recording rate is of ~1 kHz

L1 Trigger:

Fast and coarse, hardware-based trigger

L1 Calo calorimeter trigger for Electrons, Photons, Jets, taus, Missing ET

L1 Muon to trigger on Muons

L1 Topo topological Processor using information from L1CALO and L1Muon

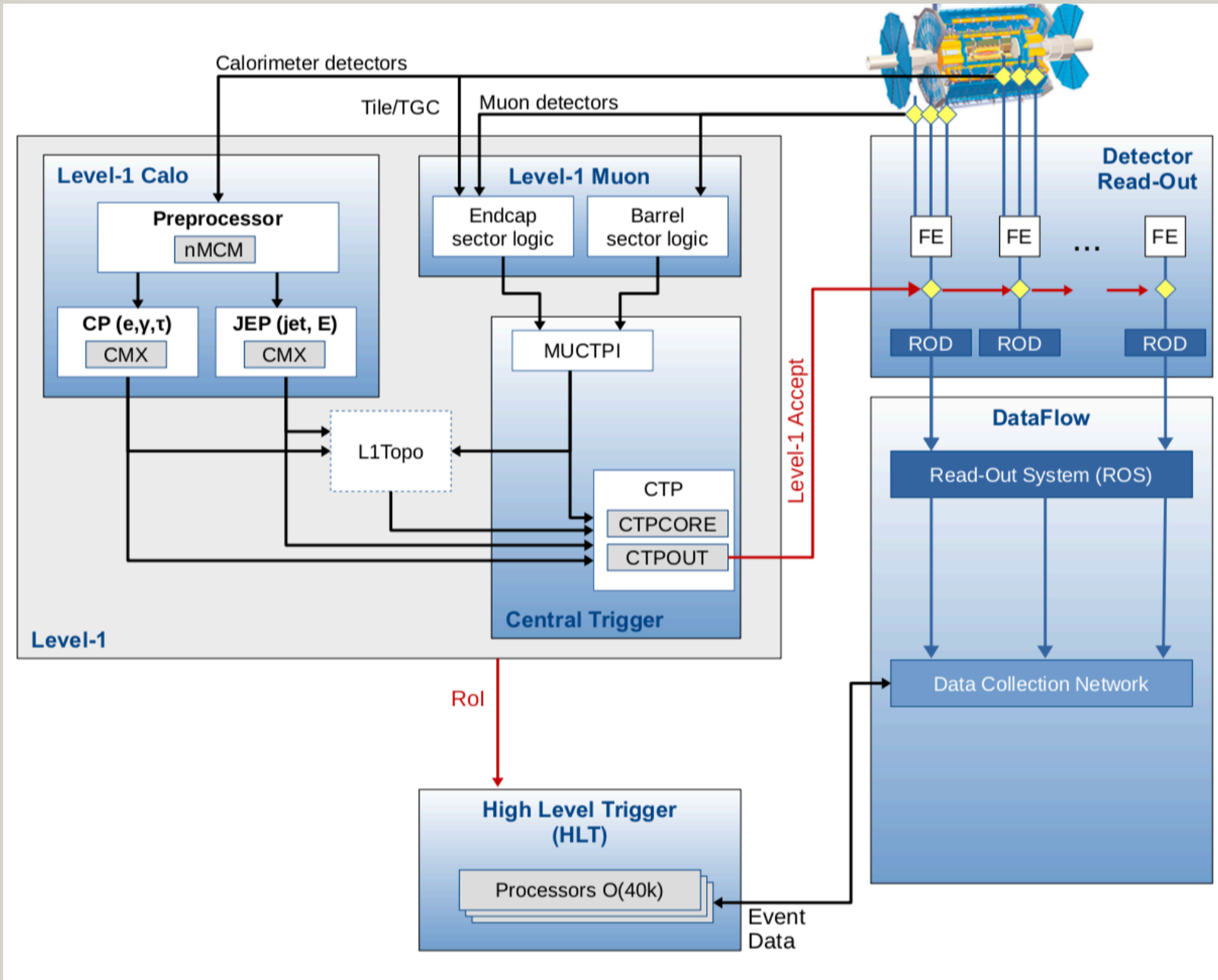
Sends Region-of-Interest (RoI) to HLT for the final decision and data-storage

HLT Trigger:

Software-based trigger

Fast reconstruction inside the given RoI

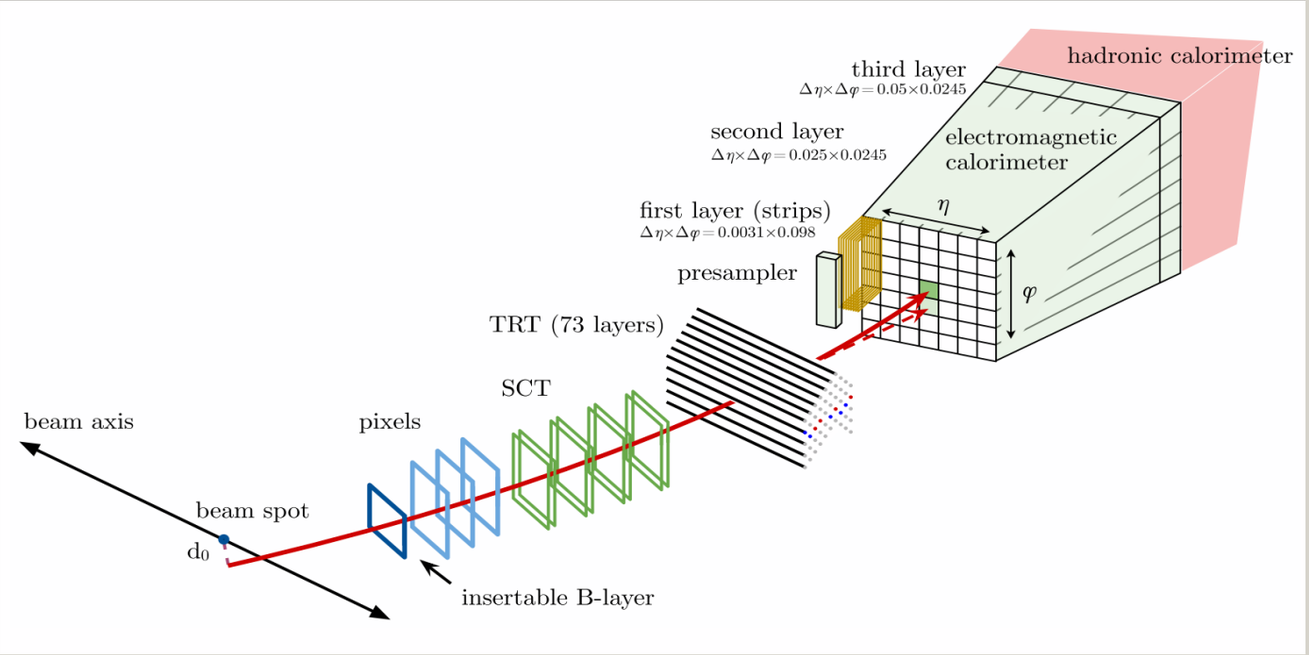
Precise measurements, using offline based reconstruction tools



Trigger public page

Electron/Photon Trigger

- L1 trigger
  - uses calorimeter information in the central ($|\eta| < 2.5$) region to build an EM RoI consisting of 4×4 trigger towers, with granularity 0.1×0.1 in η and φ
  - A sliding–window algorithm identifies a local energy maximum from the four possible pairs of nearest neighbour towers in a 2×2 central region



Electrons HLT

- Fast Calorimeter reconstruction:
  - Neural-network-based (Ringer) algorithm for electrons with ET > 15 GeV
- Shower shape-based selection for electrons < 15 GeV
- Tracks reconstructed in the Inner Detector matched to electromagnetic clusters
- Precision reconstruction:
  - Identification based on a likelihood discriminator
  - ‘loose’ , ‘medium’, ‘tight' working points defined

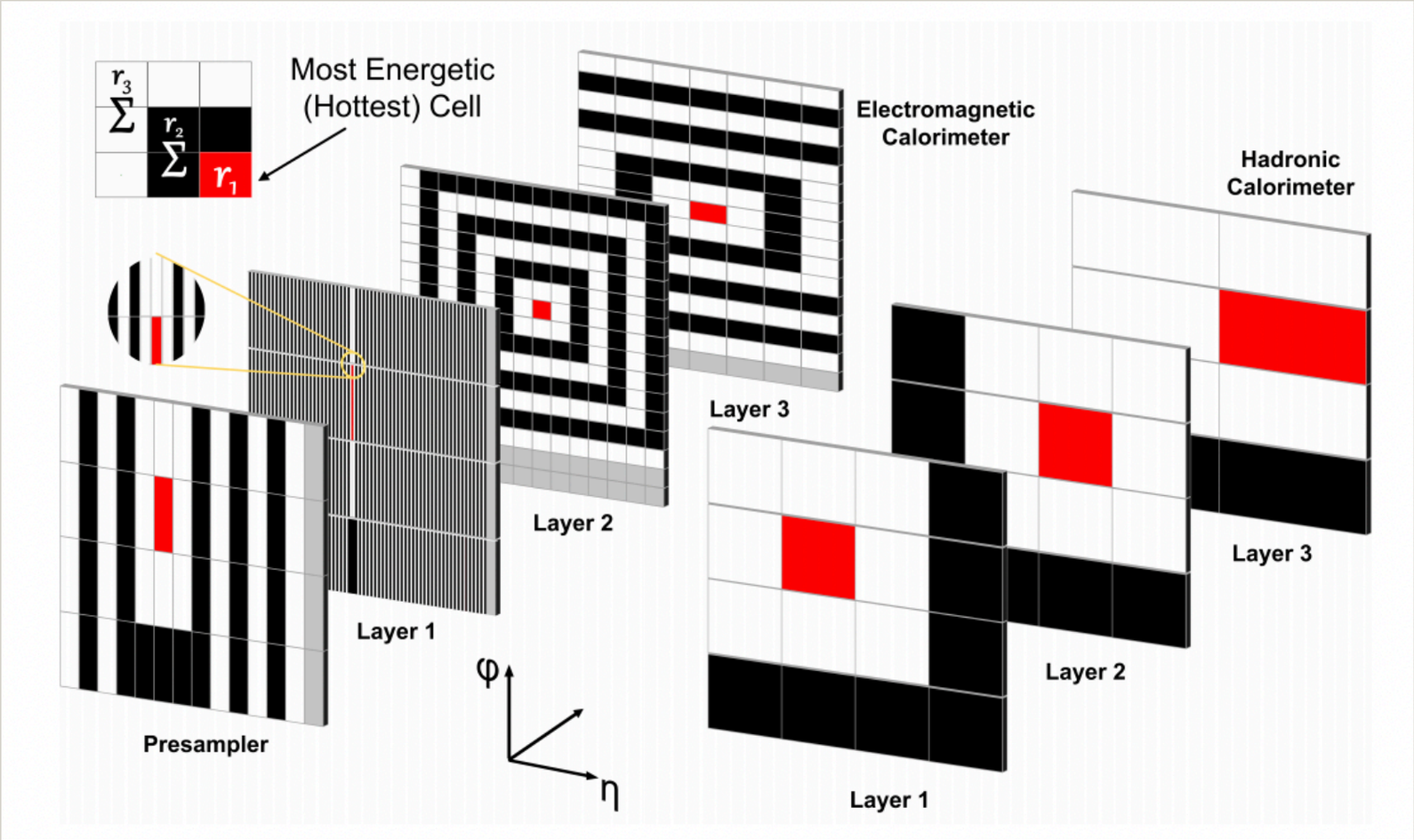
Photons HLT

- Fast Calorimeter reconstruction:
  - Calorimeter-only selection
- Precision Reconstruction:
  - Rectangular cuts on calorimeter shower shapes
  - 'Loose', 'Medium' and 'Tight' identification working points
  - No tracking used for photons at HLT

arXiv:1909.00761

Ringer Algorithm

- Since 2017
- Use lateral shower development
- Concentric ring energy sums in each calorimeter layer
- Transverse energy in each ring normalised to total transverse energy in the RoI
- Ring energies fed into multilayer perceptron (MLP) neutral networks

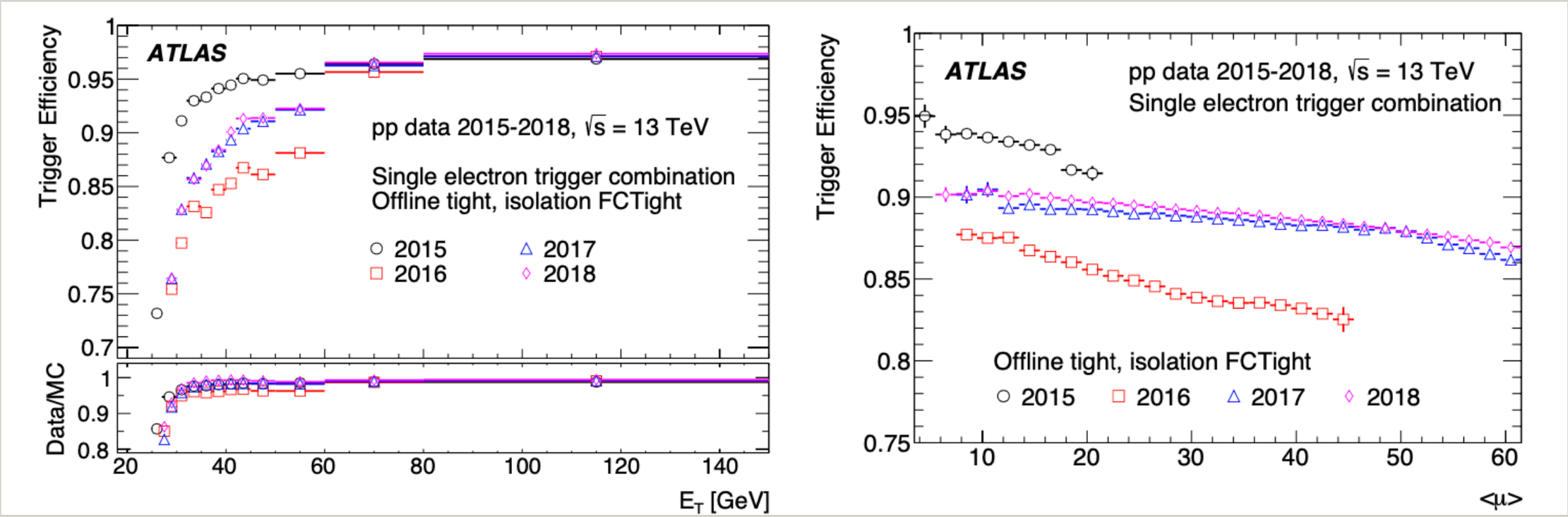


- Ringer increases fast calorimeter step reconstruction time, but reduces input candidates to the tracking
- significantly reduced CPU demand
- 50% CPU reduction at the HLT for the lowest p_T un-prescaled single electron trigger

arXiv:1909.00761

Electron Trigger Performance

- Trigger performance is evaluated using tag and probe method using Z→ ee events
  - Tag : lowest un-prescaled single-electron trigger
  - Probe: used to measure the trigger efficiency, opposite charge to tag
- single electron trigger combination: un-prescaled single-electron triggers with lowest thresholds
- Efficiency is measured in respect to offline electron



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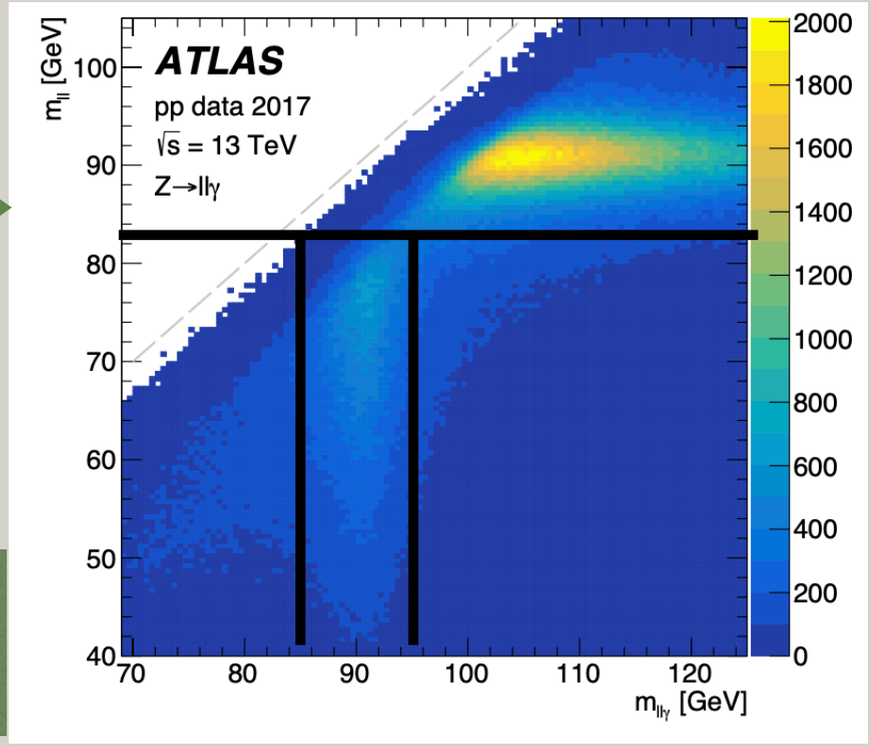
- Sharper turn on in 2015: Lower threshold, no isolation, looser identification
- Inefficiencies in 2016:
  - MC-based Likelihood in precision calorimeter step
- 2017-2018: data-driven likelihood Id, introduction of Ringer algorithm
- pileup dependency reduced towards end of Run 2

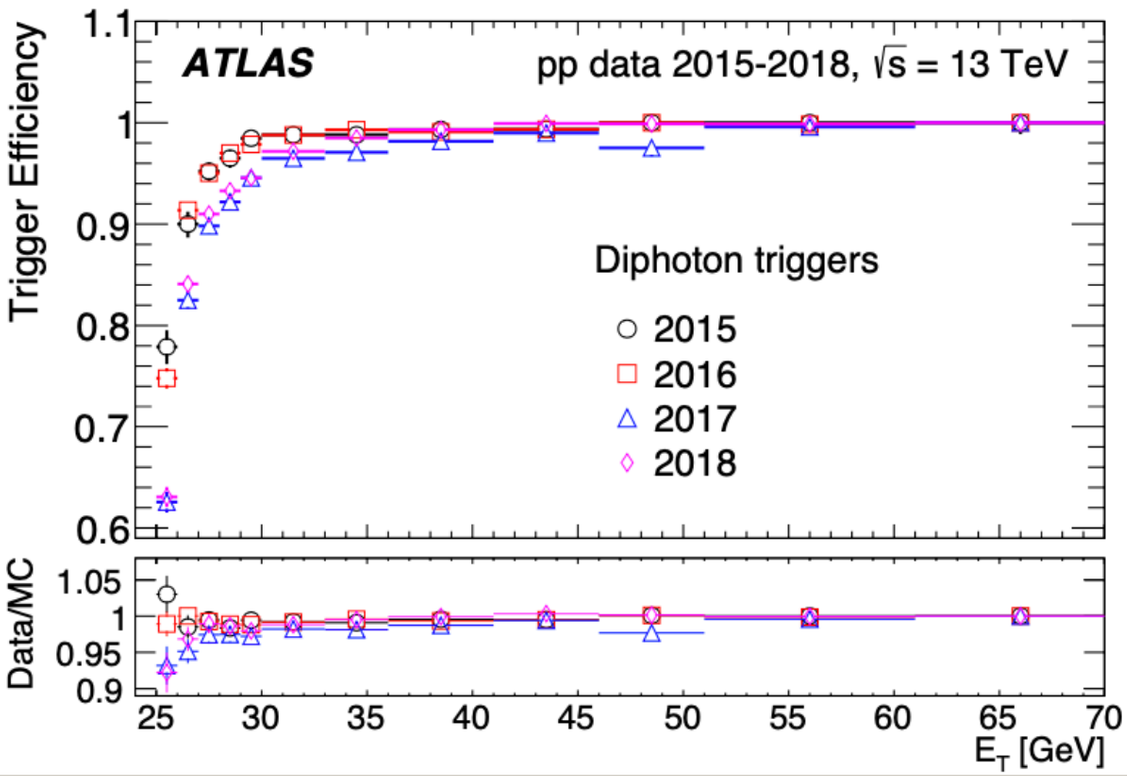
Photon Trigger Performance

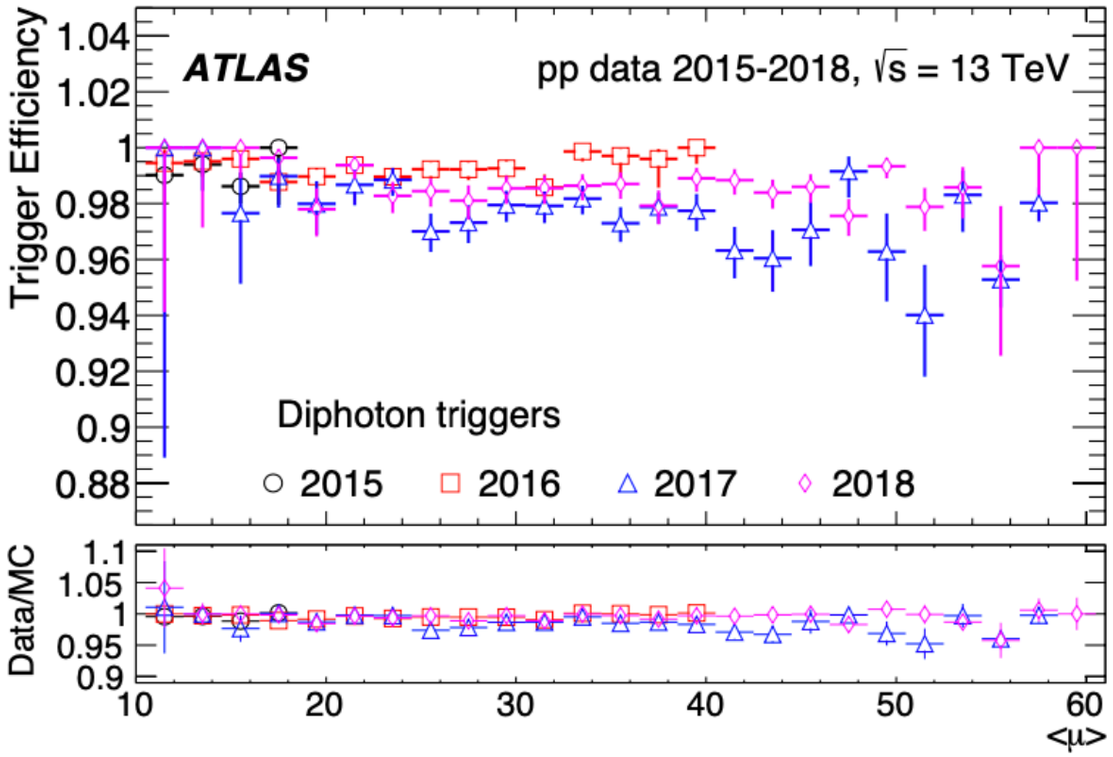
- Trigger efficiency :
- measured using Z radiative decay method using $Z \to ll\gamma$
- Tag and probe selection:
  - tag: electrons or muons from lowest p_T un-prescaled single and double leptonic trigger
  - probe: tight photon candidate



Slightly lower efficiency in 2017-2018 due to the tightening of photon ID

Sharp turn on and small dependency on pileup





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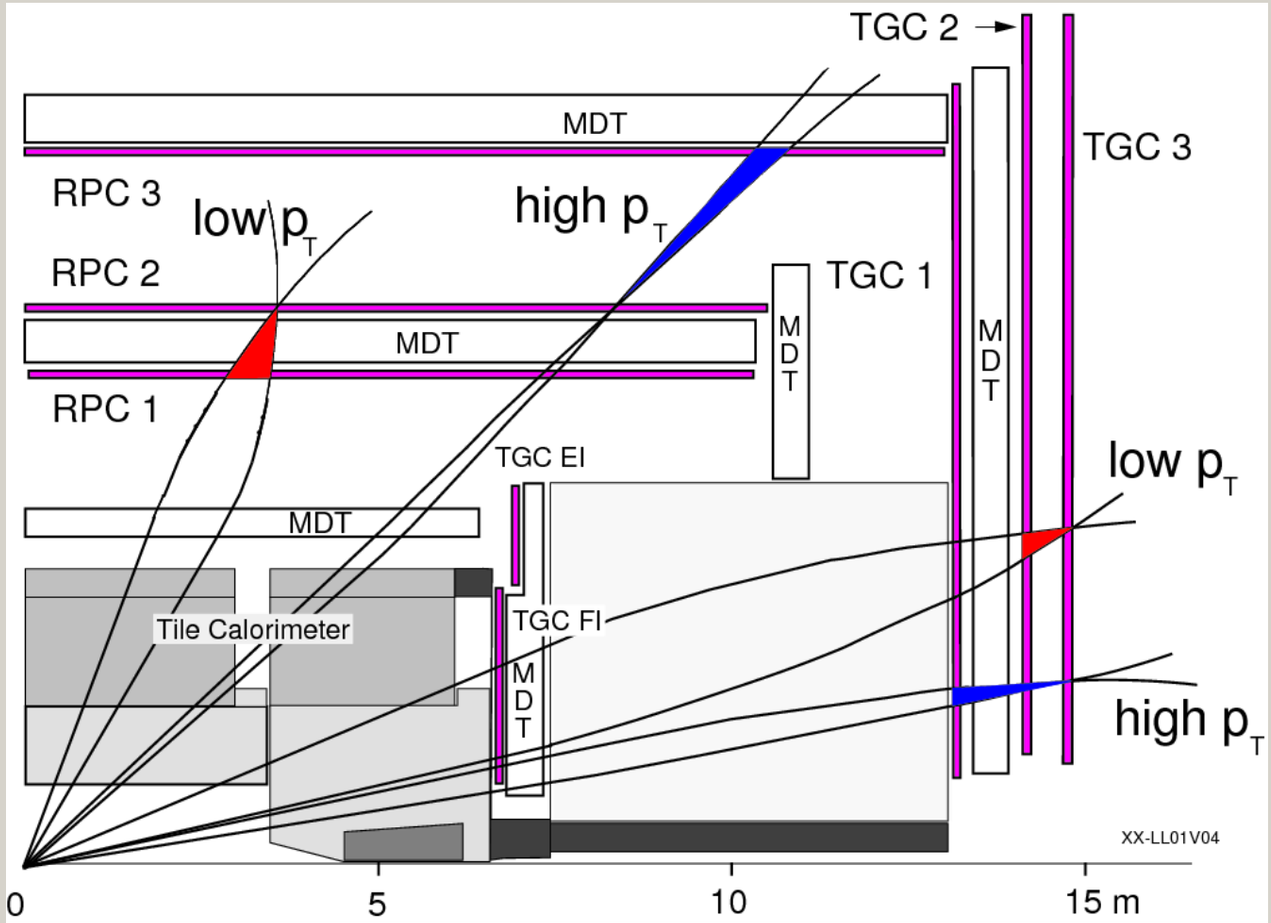
Muon Trigger

- Muon Spectrometer (MS) in toroidal field (2 - 7.5 Tm)
- L1 Muon trigger:
  - Only some part of MS information
  - L1 trigger acceptance: $|\eta| < 2.4$
- HLT :
  - Uses full MS information for track segments and tracks reconstructed in the Inner Detector (ID)
  - Combined muons then formed from the muon segments and ID tracks

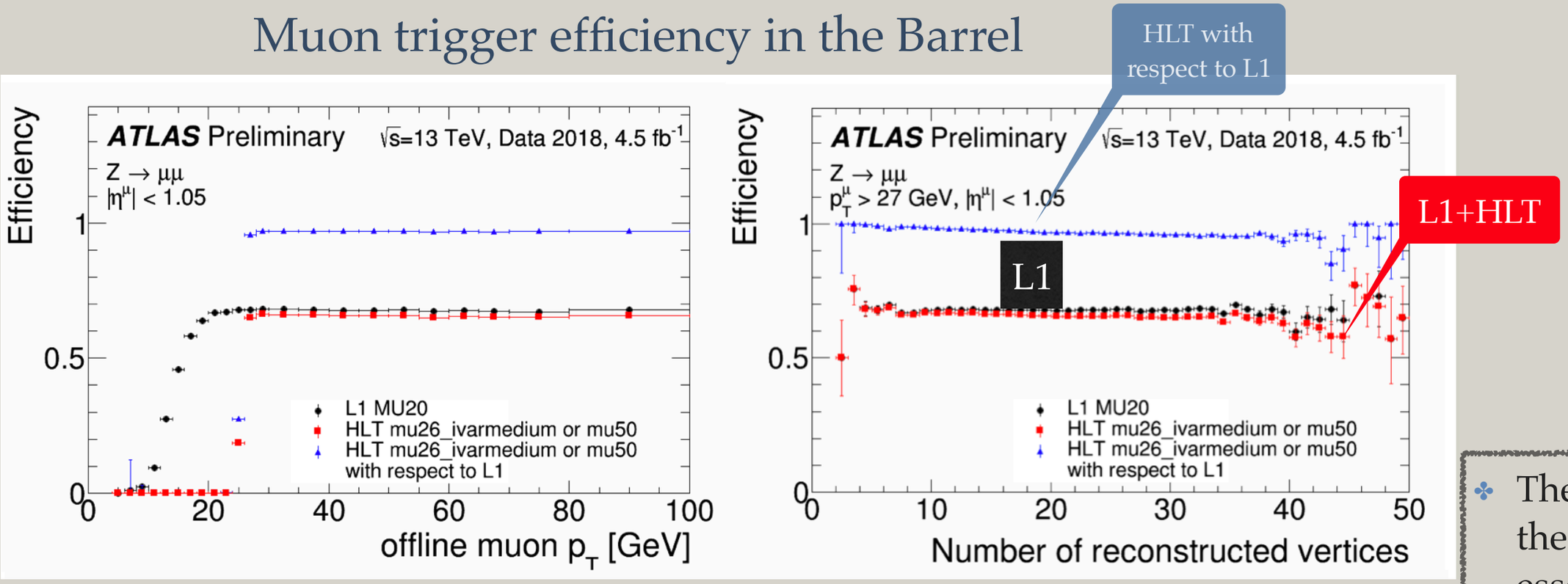


Muon Trigger Sequence

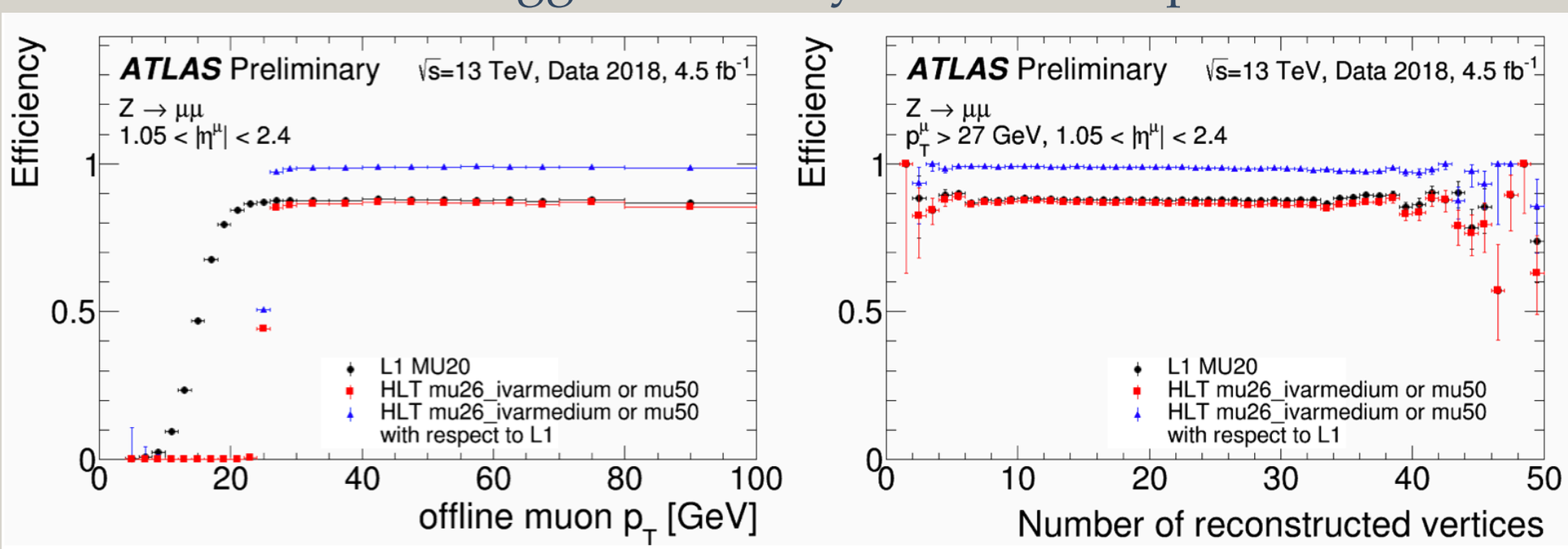
L1 RoI → Fast MS Tracking → Fast ID tracking + MS-ID comb → Precision MS tracking → Precision ID tracking + MS-ID comb

Muon Trigger Performance

Muon trigger efficiency in the Barrel

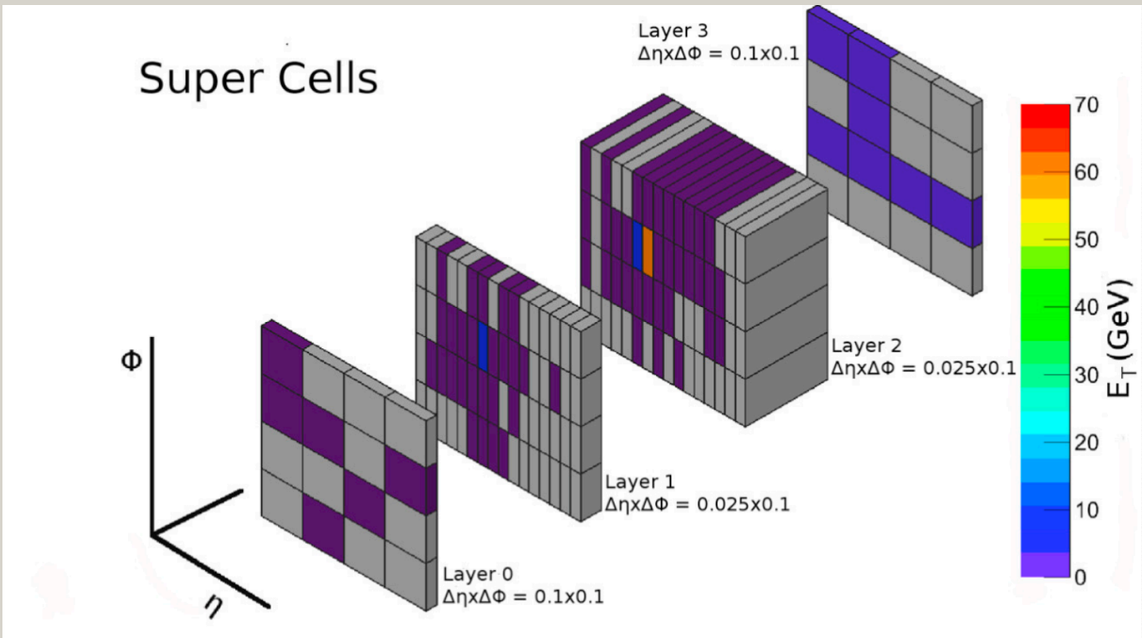


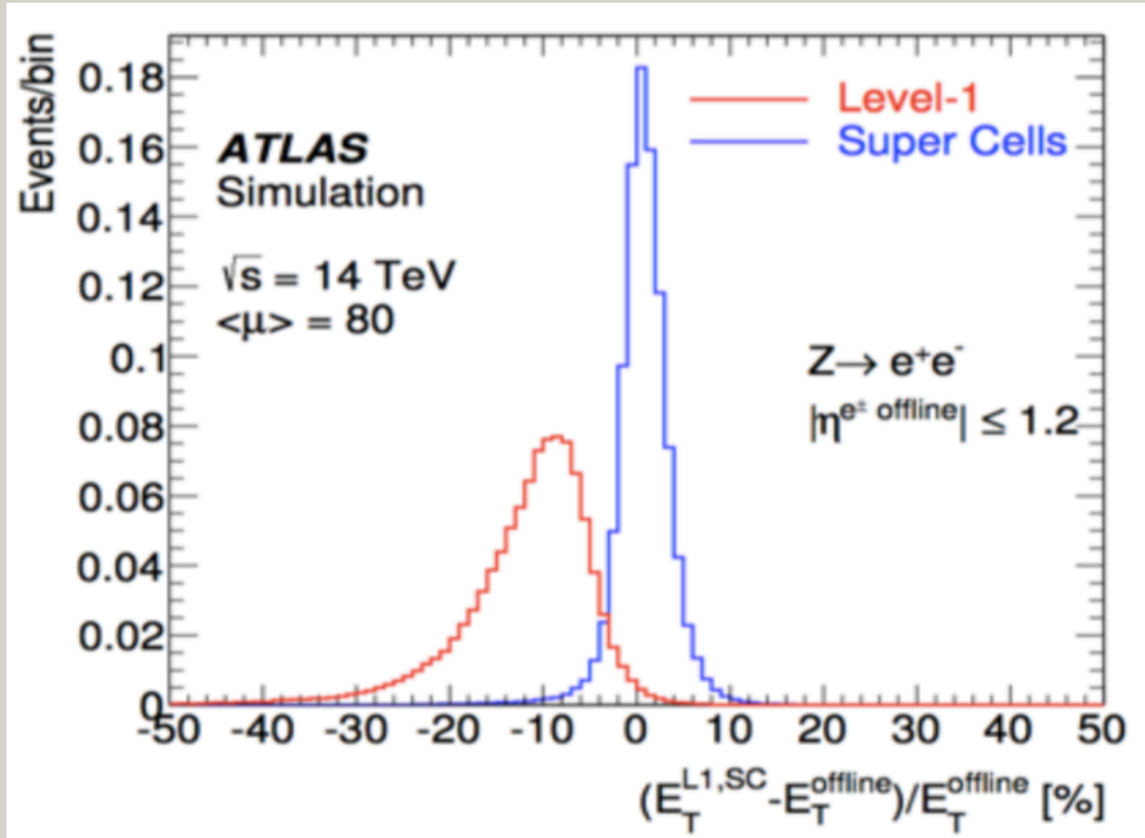
Muon trigger efficiency in the Endcap

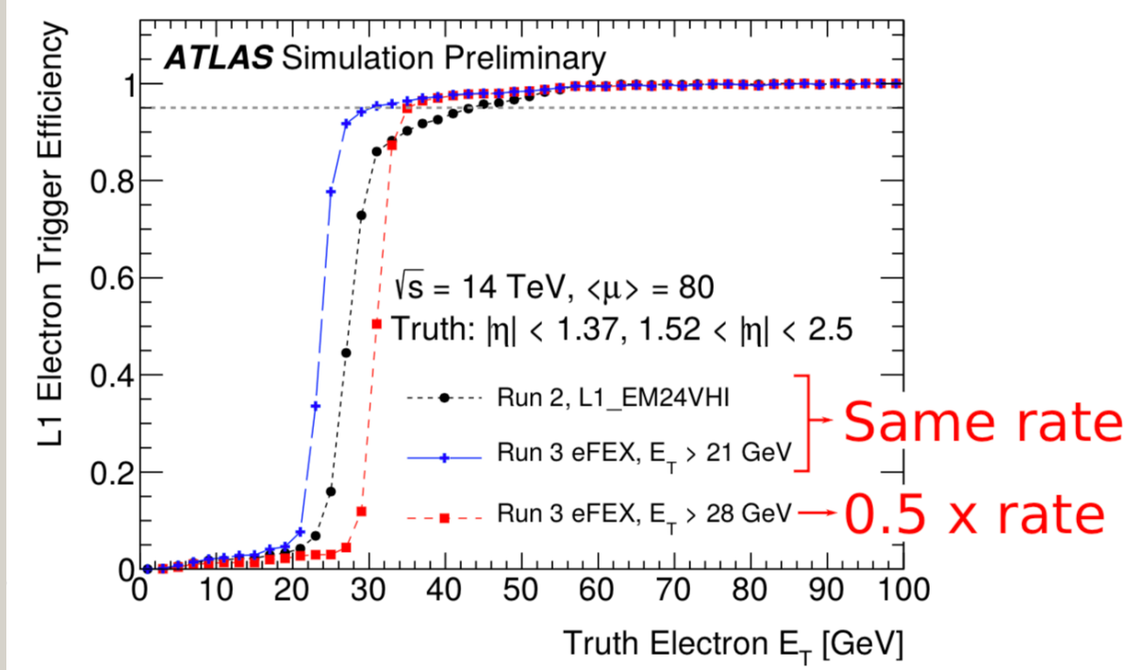


- The efficiency loss in the barrel is essentially due to uncovered detector regions - eg the ATLAS supporting legs
- HLT is 100% efficiency relative to L1
- Almost no pileup dependency

Electron, Photon Triggers Upgrade in Run 3







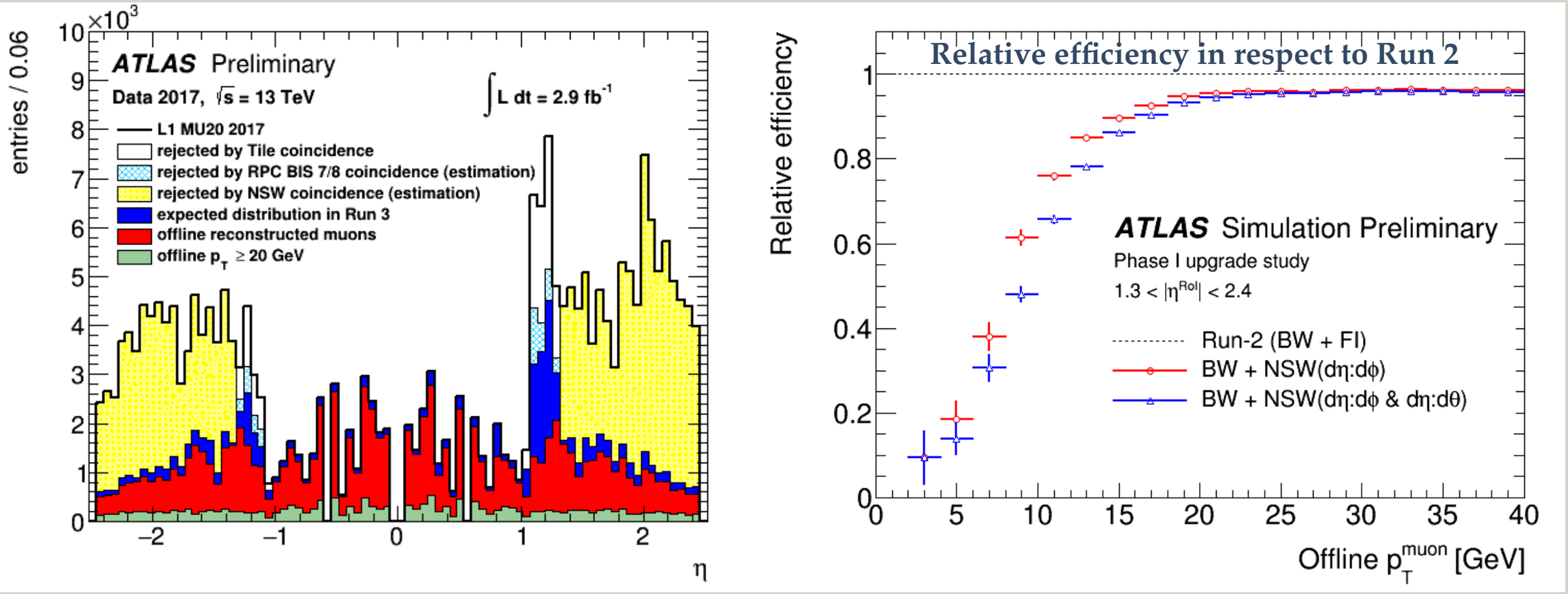
L1 CALO

- The Run-3 LAr calorimeter's trigger digitised readout improved with finer granularity
- New suite of L1 hardware designed to take advantage of this
  - Finer granularity of the super cells allows to use shower shapes closer to offline
  - Better resolution
  - Sharper trigger turn-on

Trigger public page

Muon Upgrade in Run 3

- The chambers of the muon innermost layer will be replaced with higher granularity detectors, New Small Wheels (NSW) , provide precise tracking information



L1 Muon Trigger

Rate reduction by NSW is due to requiring additional inner coincidence of the big wheel to reject fakes, and also to re-calculate the p_T

- only with few % drop in efficiency, ~50% rate reduction is expected for L1 MU20

Summary

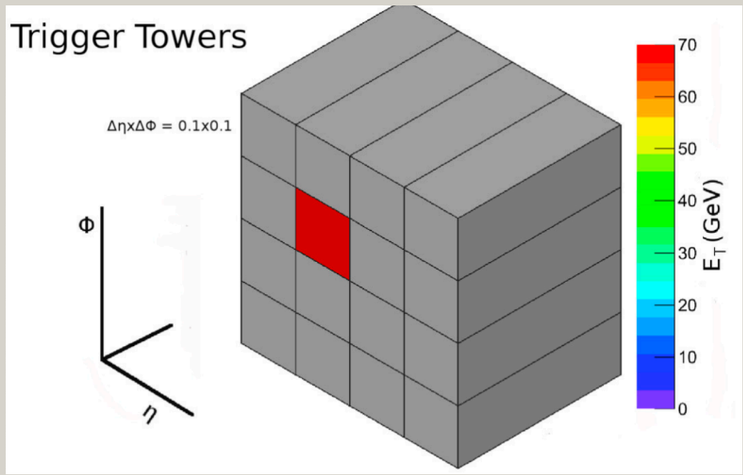
- Good understanding of the electron, muon and photon trigger performance during Run 2
- All measurements show stable performance during Run 2 and efficient triggering of electrons, muons and photons.
- Many ongoing efforts to improve trigger performance toward Run 3
  - Aim to get closer to offline selections than in Run 2
  - Multithreading techniques for HLT

Backup

References

- **Performance of electron and photon triggers in ATLAS during LHC Run 2, CERN-EP-2019-169, arXiv:1909.00761**
- **Web References**
  - **https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TriggerPublicResults**
  - **https://twiki.cern.ch/twiki/pub/AtlasPublic/EgammaTriggerPublicResults**
  - **https://twiki.cern.ch/twiki/bin/view/AtlasPublic/L1MuonTriggerPublicResults**
  - **https://twiki.cern.ch/twiki/bin/view/AtlasPublic/MuonTriggerPublicResults**

L1 Electron/Photon Trigger



Trigger performance is evaluated using tag and probe method using Z→ ee events
Tag : lowest un-prescaled single-electron trigger
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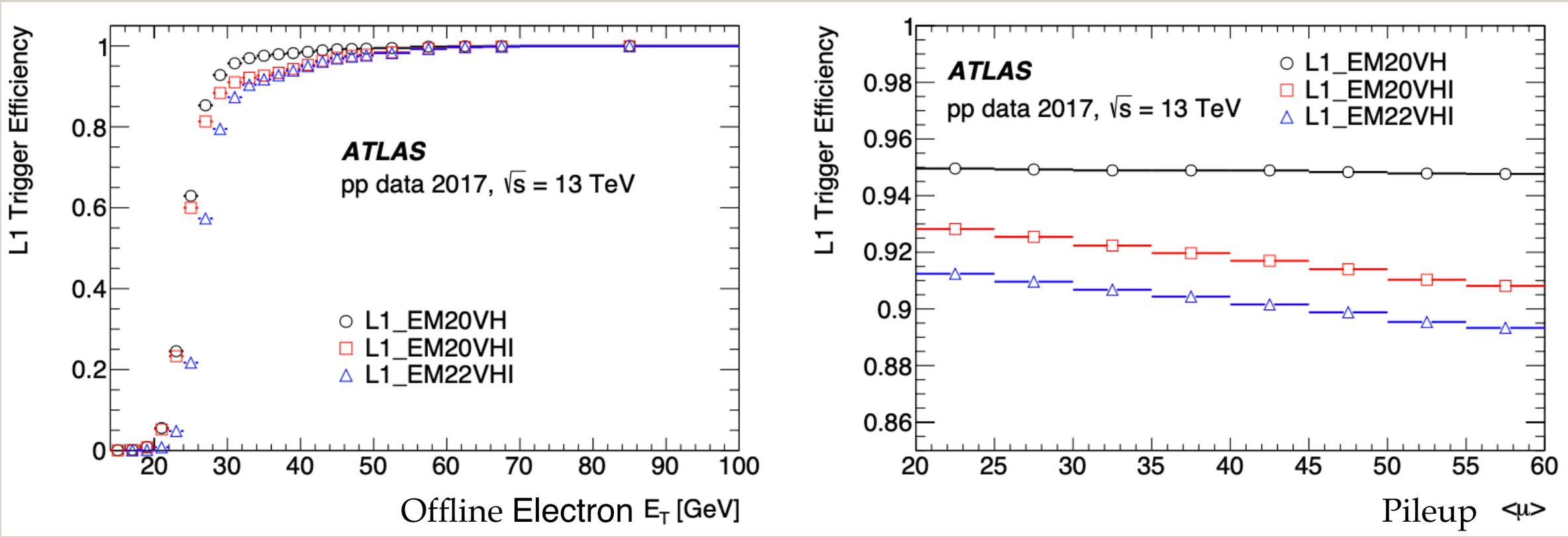

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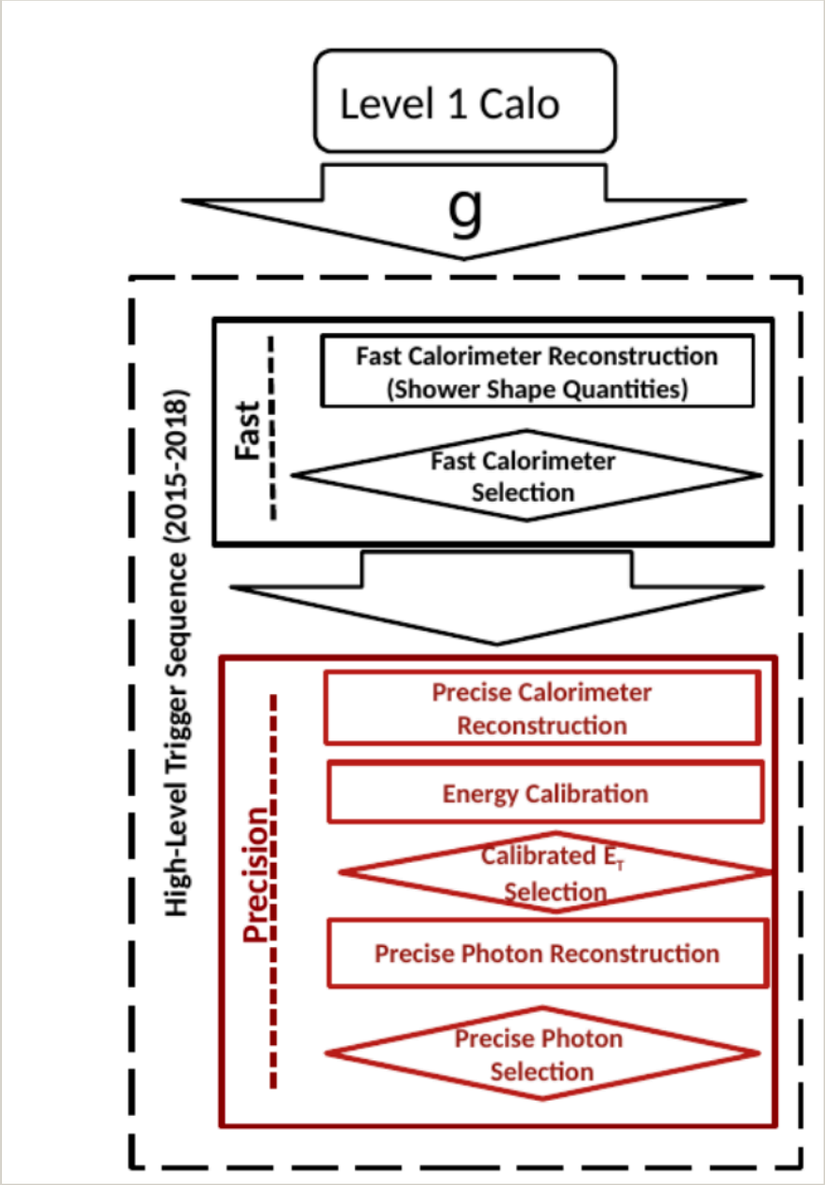
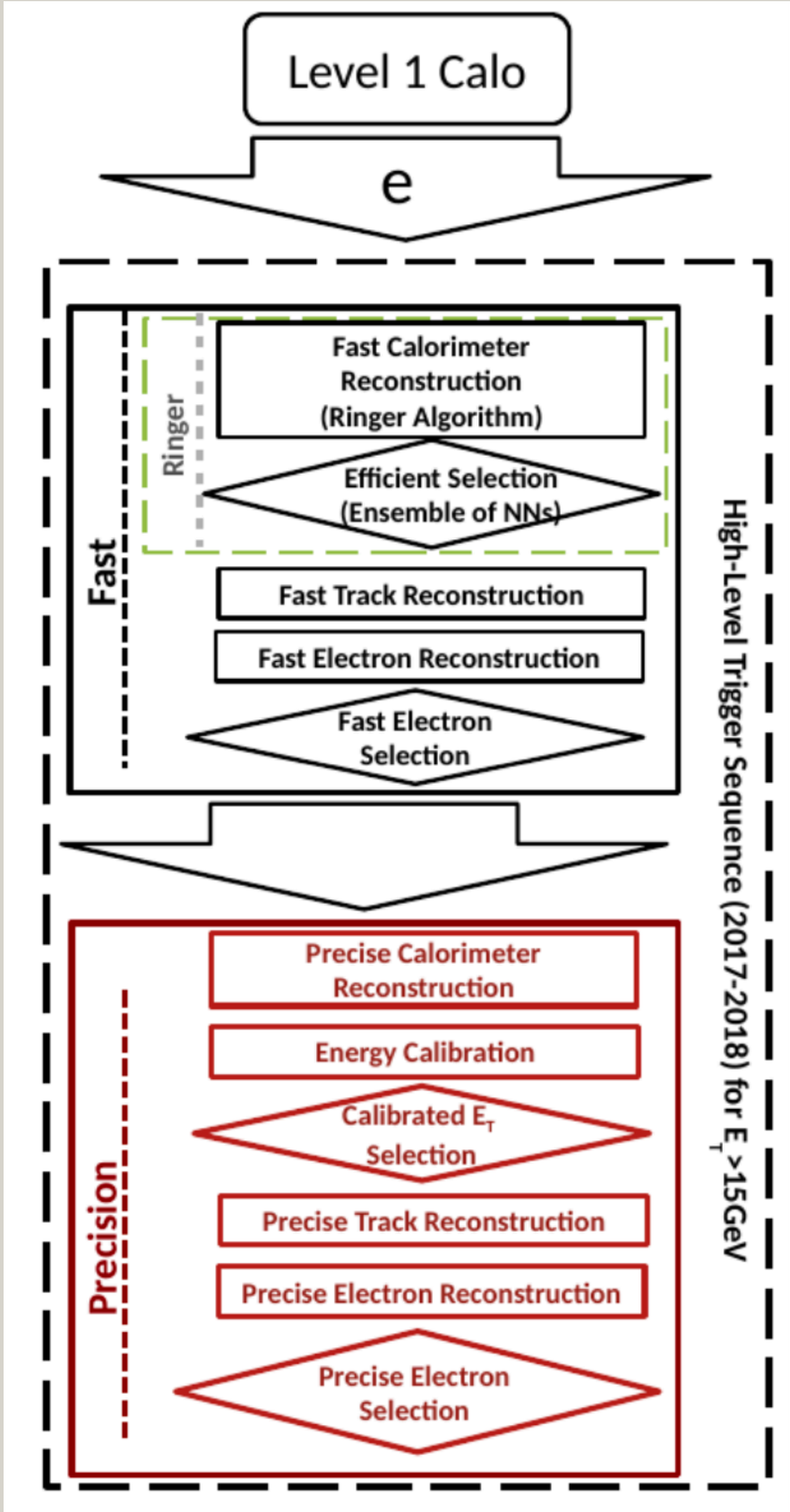
Electron/Photon HLT Reconstruction



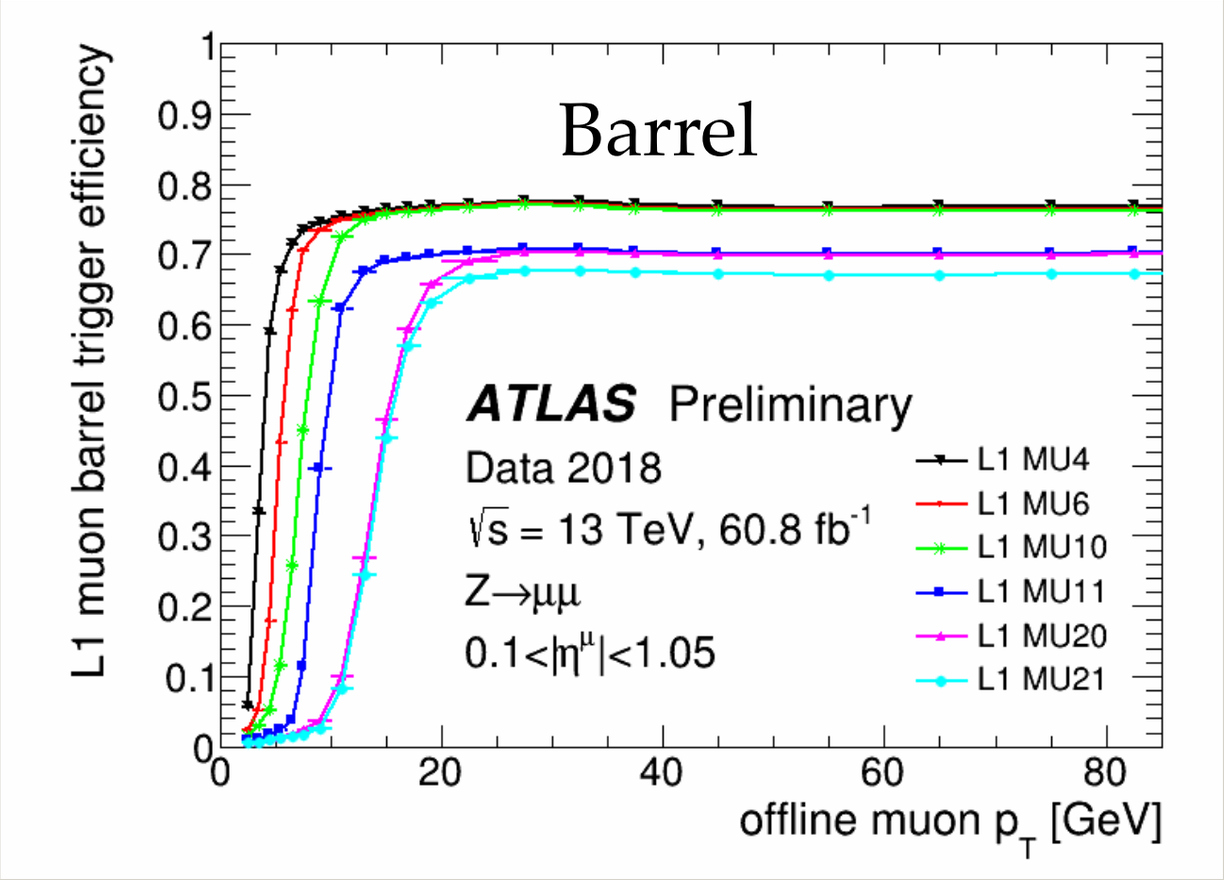


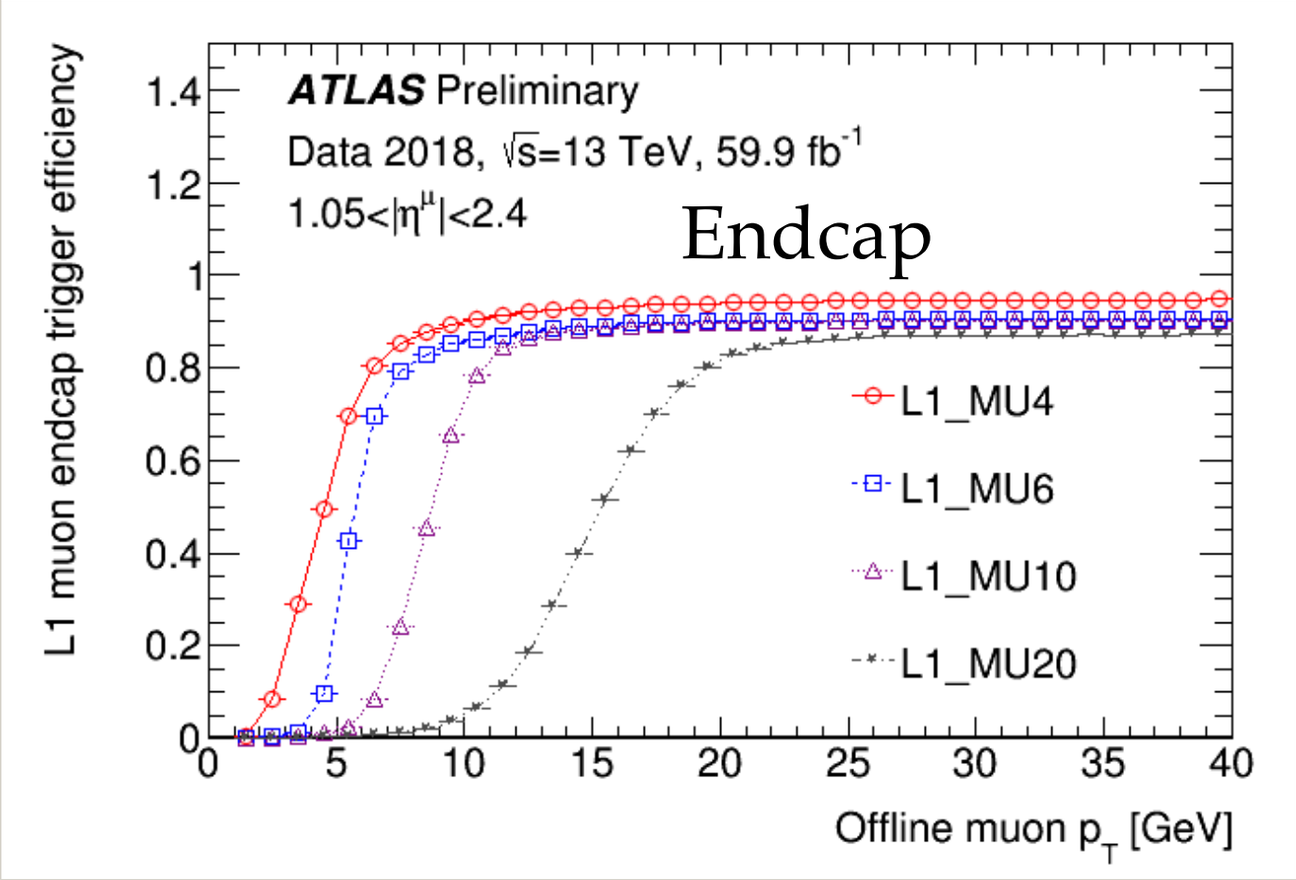
arXiv:1909.00761

L1 Muon Trigger

Trigger performance is evaluated exploiting tag and probe method using $Z \rightarrow \mu\mu$ events or $J/\psi \rightarrow \mu\mu$ at lower p_T

Efficiency is measured in respect to offline muon





- Efficiency is about 90% in the endcap and nearly 70% in the barrel
- The efficiency loss in the barrel is essentially due to uncovered detector regions - eg the ATLAS supporting legs