The ATLAS Electron and Photon Trigger Performance in Run 2

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on behalf of the ATLAS collaboration

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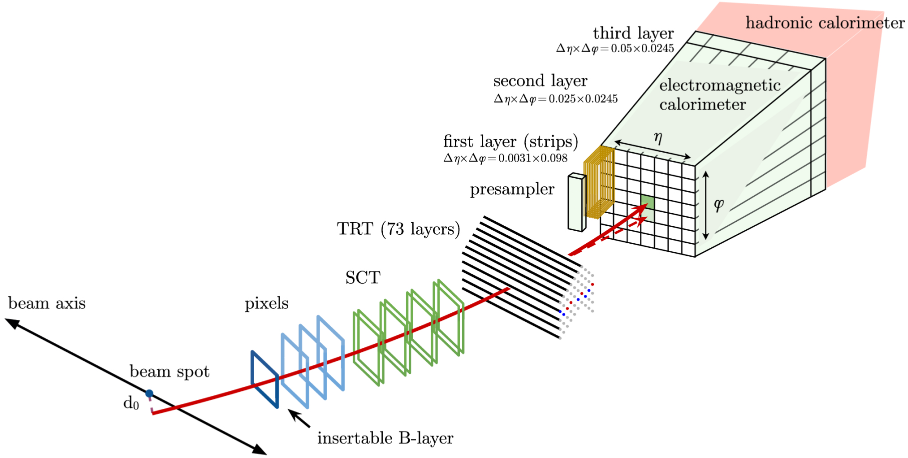
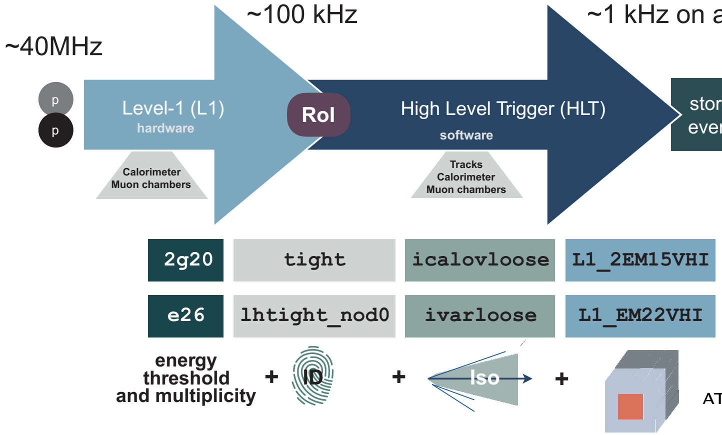
Electron propogation through the ATLAS detector



All plots and results shown are from "Performance of electron and photon triggers in ATLAS during LHC Run 2" paper, Eur. Phys. J. C **80** (2020) 47

The ATLAS trigger system



based on
ATL-DAQ-SLIDE-2019-628

L1 Trigger ($|\eta| < 2.5$)

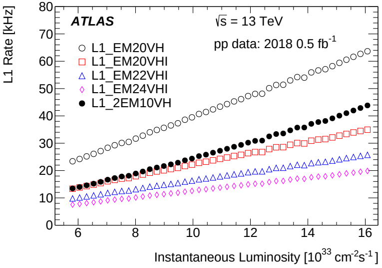
2x2 trigger tower cluster as RoI in EM calorimeter

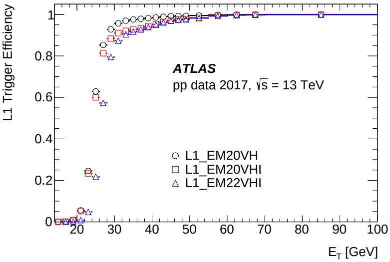
V: Varying E_T threshold within -2 and $+3$ GeV of nominal threshold

H: E_T dependent veto on hadronic leakage

I: E_T dependent isolation of cluster in EM calorimeter

Level-1 trigger performance





- `L1_EM22VHI` trigger (blue line) was used for the most part of the Run 2 data-taking
- Single-electron triggers consume about 20% of the total L1 and HLT available rate

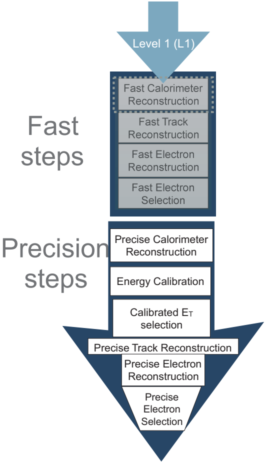
Trigger reconstruction of photons and electrons

Fast step — on each EM RoI defined by L1

- Use calorimeter and inner detector information within the RoI only
- Photons don't use tracking information
- Initial selection of the photons and electrons
- Achieve early background rejection

Precision step

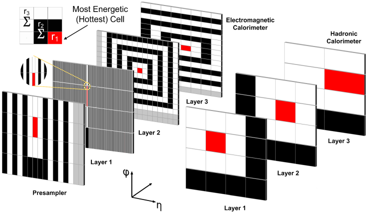
- Precision online algorithms are similar to offline, with some exceptions such as:
  - No bremsstrahlung-aware re-fit of electron tracks
  - No electron and photon topo-clusters
  - Online algorithms use $<\mu>$ for pile-up, number of primary vertices — offline

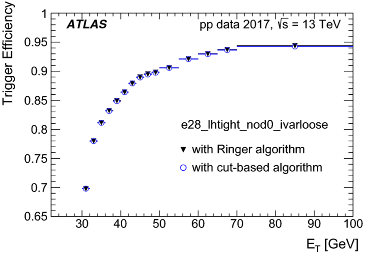


ATL-DAQ-SLIDE-2019-628

Ringer algorithm

- Used from 2017 on to trigger electrons (Fast Calorimeter step) with $E_T > 15\,GeV$
- Uses lateral shower development
- Calculates concentric ring energy sums in each calorimeter layer
- Normalized ring energies fed into multilayer perceptron neutral networks
- Event selection efficiency kept at the same level

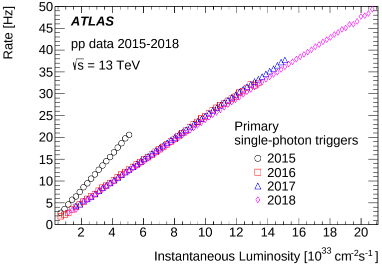


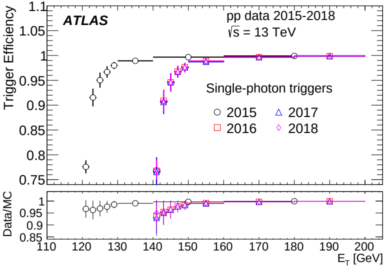


- Reduces input candidates to the tracking: significantly reduces CPU demand
- 50% CPU reduction for the lowest p_T unprescaled single electron trigger

Photon trigger evolution and performance

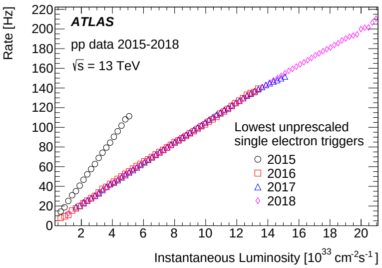
- Single photon trigger had a threshold of 120 GeV (2015) and 140 GeV (2016–2018), more details in the backup

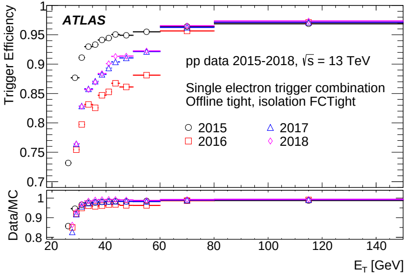




- Bootstrap method used to calculate the efficiency
- Total uncertainties dominated by systematics, in total $O(1\%)$ for E_T 5 GeV above threshold

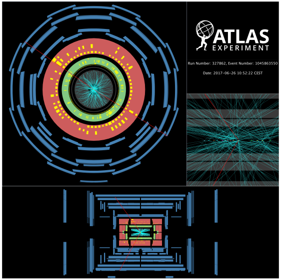
Performance evolution of single electron trigger

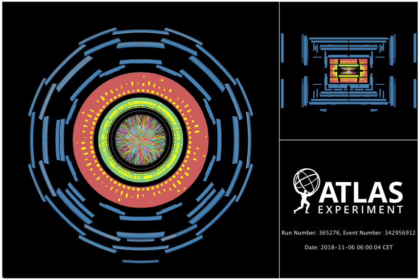




- Efficiency is calculated wrt offline tight identification and isolated electrons, measured with "Z tag and probe" method
- Sharper turn on in 2015 (lower E_T threshold), inefficiencies in 2016 (likelihood calorimeter only selection)
- 2017 data driven likelihood selection, introduction of Ringer algorithm
- The error bars indicate statistical and systematic uncertainties combined in quadrature.

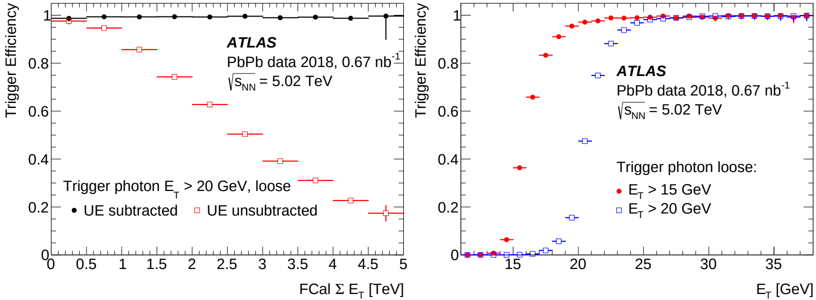
Heavy ion collisions





- Events with a lot of activity in the detector
- Event is charaterised by collision centrality, accounted by $\sum\limits_{FCal} E_T$ $(3.1 < |\eta| < 4.9)$
- Centrality affects trigger efficiency
- Introduced underlying event (UE) subtraction into egamma trigger to minimize efficiency depedence on centrality, allows to use standard identification variables

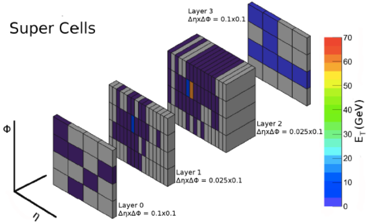
Photon trigger in heavy ion data taking



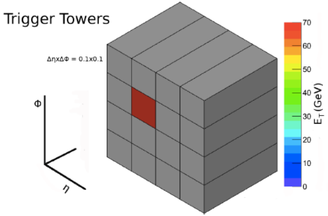
- Photon trigger efficiency evaluated with respect to offline-reconstructed photons measured by bootstrap method
- Efficiency shown with and without subtraction of the underlying event

Run 3 upgrades: L1 Trigger — LAr Super cells

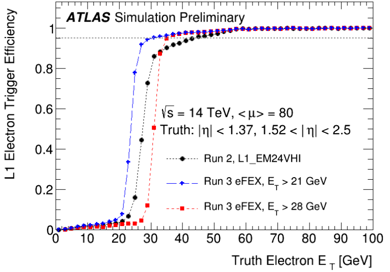
- More fine-grained in lateral and longitudinal directions
- Improve energy resolution and backgrounds discrimination



Electron (70 GeV E_T) seeing with finer granularity



Electron (70 GeV E_T) at current L1 readout



- $E_T > 21$ GeV has the same event rate as in Run 2
- $E_T > 28$ GeV has half event rate

(from L1CaloTriggerPublicResults)

Conclusions

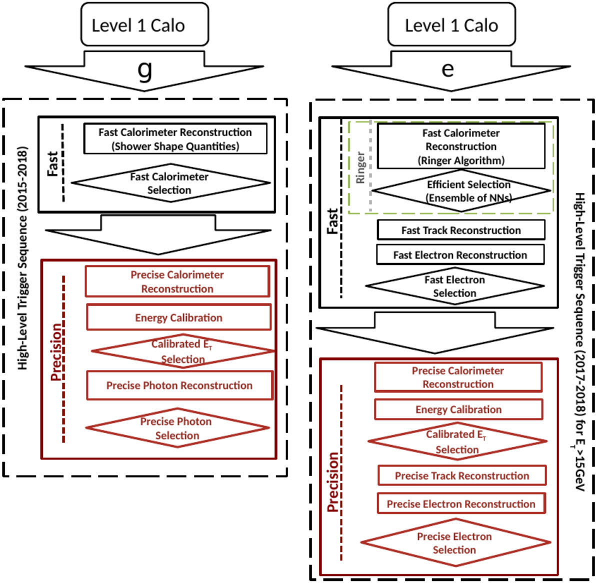
- Electron and photon trigger performed well during Run 2
- Significant complication of experimental environment from 2015 to 2018 requires trigger chains modification and development/adoption of new algorithms (Ringer)
- Using of adapted offline reconstruction algorithms (GSF, Superclusters) for future data-taking is expected to improve energy and momentum resolution at trigger stage
- Run 3 upgrades are in progress:
  - planned to extend η coverage of the HLT to include forward regions
  - L1 Trigger: LAr Super cells
  - . . . and others

References

1. "Performance of electron and photon triggers in ATLAS during LHC Run 2", The ATLAS Collaboration, Eur. Phys. J. C **80** (2020) 47
2. "The ATLAS Electron and Photon Trigger Performance in Run-2 for ICNFP 2019", ATL-DAQ-SLIDE-2019-628, `https://cds.cern.ch/record/2688727`
3. Level-1 Calorimeter Trigger Public Results, https://twiki.cern.ch/twiki/bin/view/AtlasPublic/L1CaloTriggerPublicResults
4. Event Displays from Run 2 physics analyses, https://twiki.cern.ch/twiki/bin/view/AtlasPublic/EventDisplayRun2Physics

Backup

High Level Trigger sequence



'Offline' Electron and photon reconstruction and identification

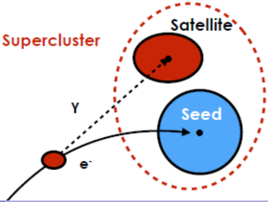
Electrons

- Identification based on a likelihood discriminator
- 'loose', 'medium' and 'tight' working points considered
- Using GSF (Gaussian-Sum Filter) as a generalisation of the Kalman fitter, better account for energy loss in Inner Detector

Photons

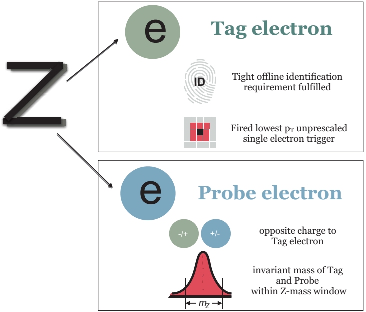
- Identification based on calorimetric variables
- Two identification working points: 'loose' and 'tight'
- 'loose': second EM layer + Hadronic calorimeters
- 'tight': 'loose' + first EM calo layer

Using Supercluster to improve electron and photon energy reconstruction in cases with Bremsstrahlung or pair production



Performance measurement techniques — electrons

Z tag-and-probe method



$$\epsilon_{total} = \epsilon_{offline} \times \epsilon_{trig} = \left(\frac{N_{offline}}{N_{all}}\right) \times \left(\frac{N_{trig}}{N_{offline}}\right)$$

- N_{all} — number of produced electrons,
- N_{trig} — number of triggered electron candidates,
- $N_{offline}$ — number of isolated, identified and reconstructed offline electron candidates
- $\epsilon_{offline}$ — offline efficiency

Trigger efficiency computed with respect to offline electron definitions

Bootstrap method

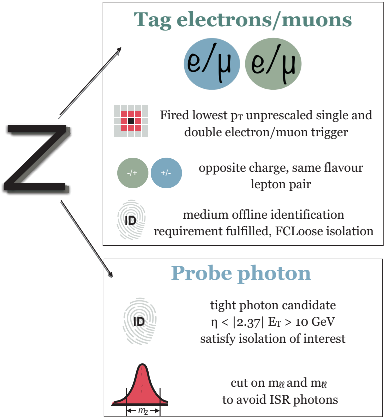
$$\epsilon^{\gamma}_{trig} = \epsilon_{HLT|BS} \times \epsilon_{BS}$$

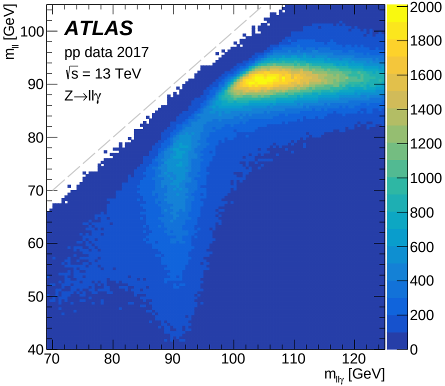
- ϵ^{γ}_{trig} — **HLT efficiency with respect to offline selection**
- $\epsilon_{HLT|BS}$ — **HLT efficiency on bootstrap sample**
  bootstrap sample collected by L1-only triggers or by loose, low-E_T photon triggers
- ϵ_{BS} — **Bootstrap sample efficiency with respect to offline selection**
  computed on events selected by special 'random' trigger

Performance measurement techniques — photons

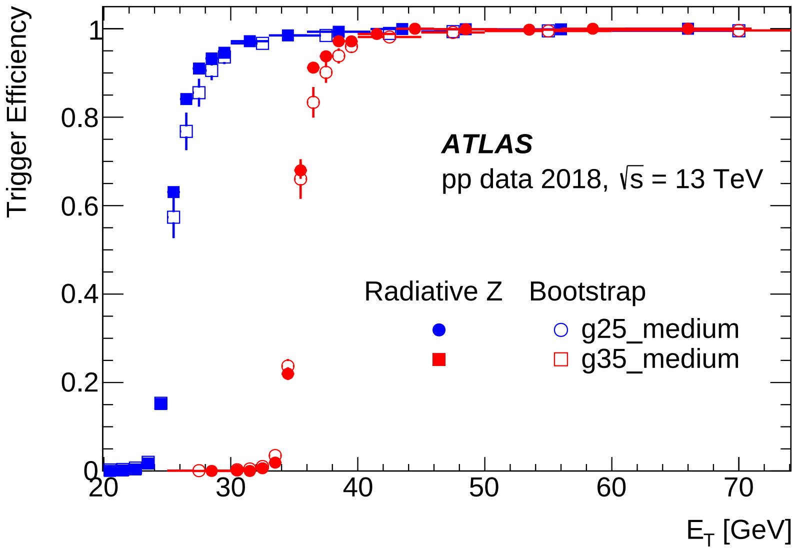
Z radiative decay method

used for diphoton triggers

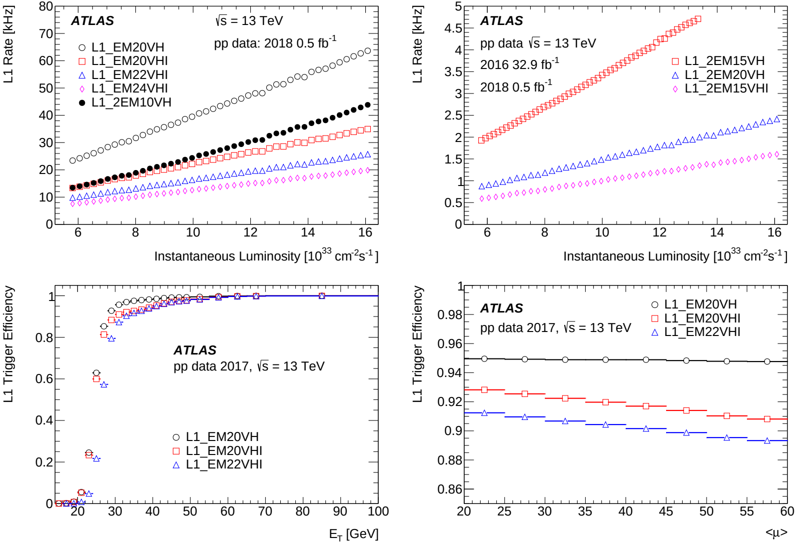




Photon trigger efficiency

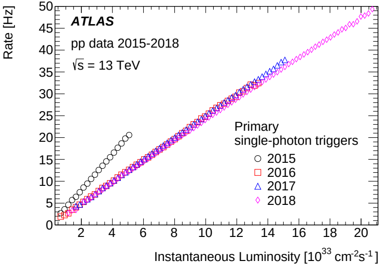


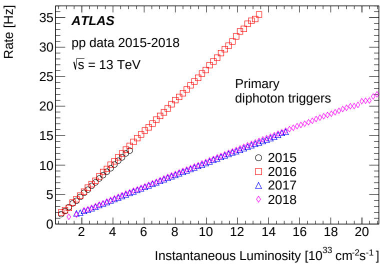
Level-1 trigger performance



Photon trigger evolution and performance

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)





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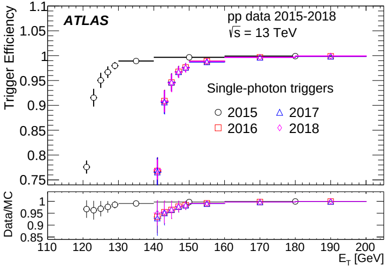
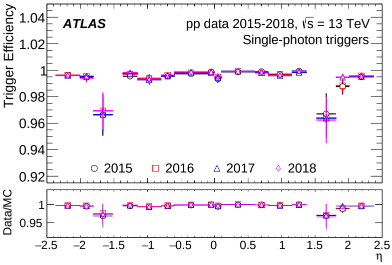
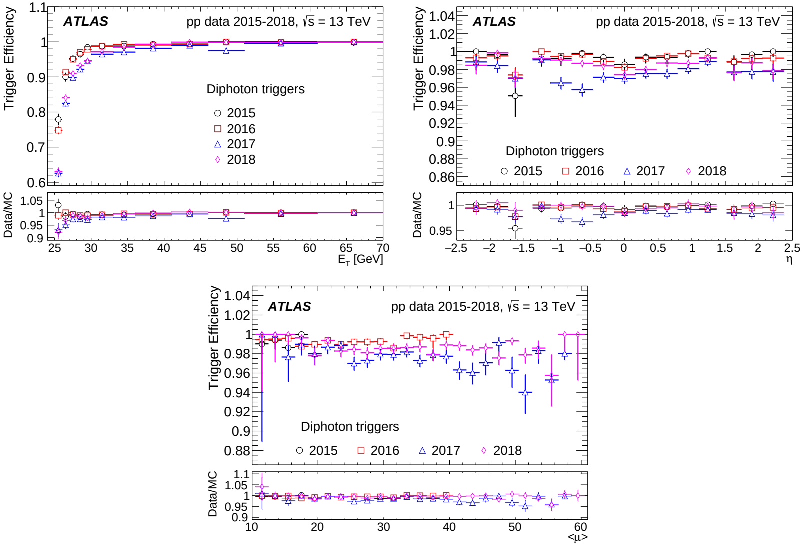




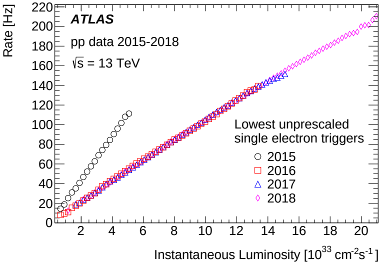
- Bootstrap method used to calculate the efficiency
- Total uncertainties dominated by systematics, in total $O(1\%)$ for E_T 5 GeV above threshold

DiPhoton trigger evolution and performance

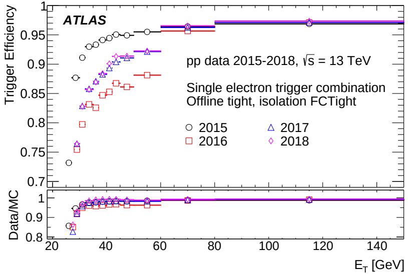


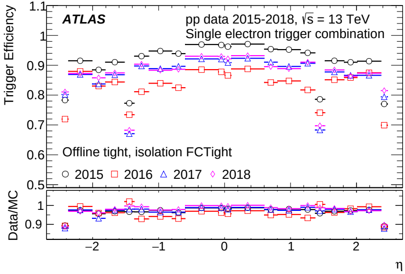
Electron trigger evolution and performance

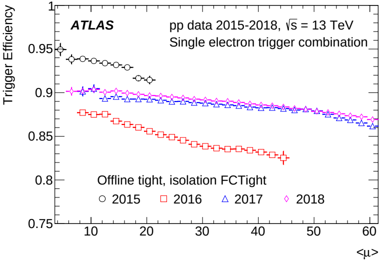
Trigger type	2015	2016	2017–2018
Single electron	e24_lhmedium (EM20VH)	e26_lhtight_nod0_ivarloose (EM22VHI)	
		e60_lhmedium_nod0	
	e120_lhloose	e140_lhloose_nod0	
	e200_etcut	e300_etcut	
Dielectron	2e12_lhloose (2EM10VH)	2e17_lhvloose_nod0 (2EM15VH)	2e17_lhvloose_nod0 (2EM15VHI) 2e24_lhvloose_nod0 (2EM20VH)



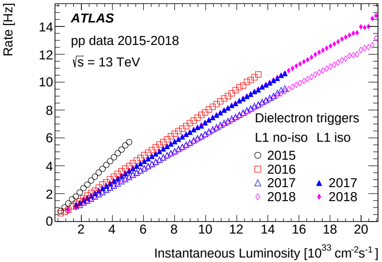
Single Electron trigger evolution and performance

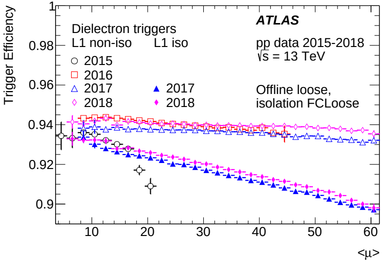


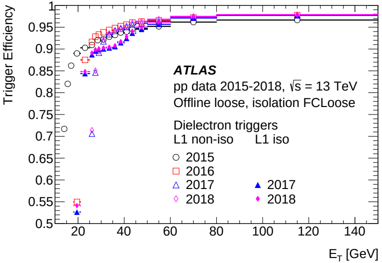


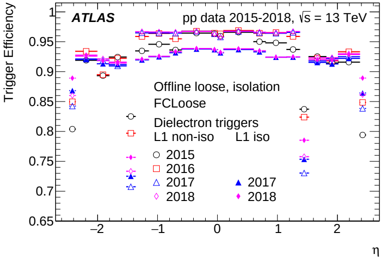


DiElectron trigger evolution and performance









Electron trigger in heavy ion data taking