The ATLAS Muon Trigger Design and Performance

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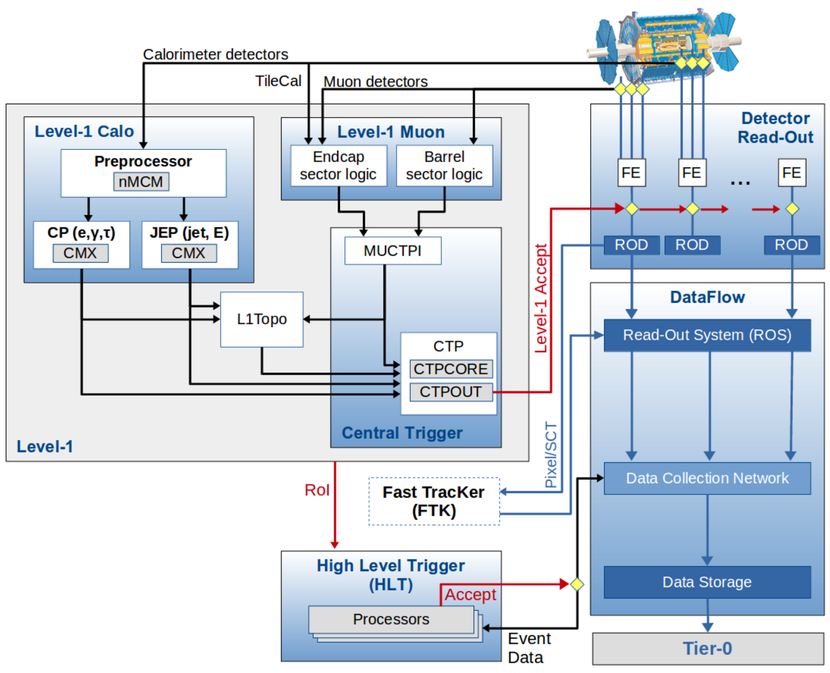
Introduction

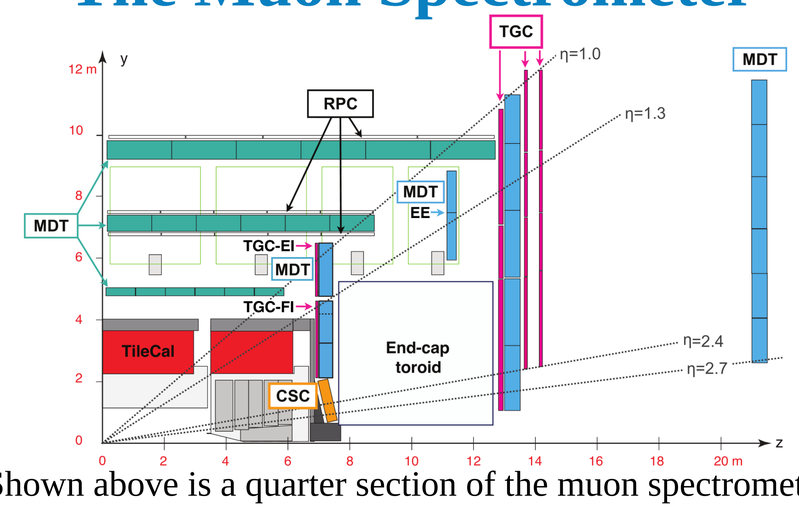
Muon triggers are necessary for both standard model measurements and searches for new physics at ATLAS. The ATLAS muon trigger system is composed of both hardware (Level 1) and software (High Level Trigger) components. This is an overview of how these components trigger on muons, their performance during Run 2 data taking, and improvements being prepared for Run 3.

Trigger System



- Coarse-grained calorimeter and muon spectrometer information is passed to the **Level 1 (L1)** Central Trigger Processor to form the L1 decision.
- The **L1 topological trigger processor (L1Topo),** commissioned in 2016, also packages topological information.
- The L1 trigger passes Regions of Interest (RoI's) to the **High Level Trigger (HLT)**, which then uses full-granularity detector information to make its decision.
- Events accepted by the HLT are exported to a Tier-0 facility for offline reconstruction

The Muon Spectrometer



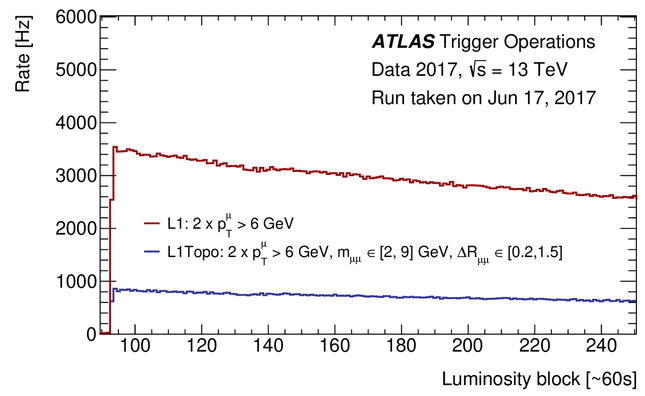
Shown above is a quarter section of the muon spectrometer in a plane containing the beam axis. **Monitored Drift Tubes (MDT)** and **Cathode Strip (CSC) Chambers** determine muon momenta, while **Resistive Plate (RPC)** and **Thin Gap (TGC) Chambers** in the barrel and endcap regions, respectively, provide the triggering.

Efficiency Measurements

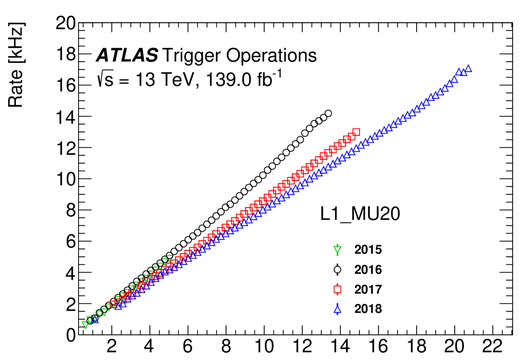
Intermediate- (low-) p_T measurements are made using offline-reconstructed muons from $Z \to \mu\mu$ ($J/\psi \to \mu\mu$) decays. Pairs of oppositely-charged muons from the same vertex are selected with an invariant mass criterion. The trigger efficiency measurement is made using a **Tag-and-Probe** method:

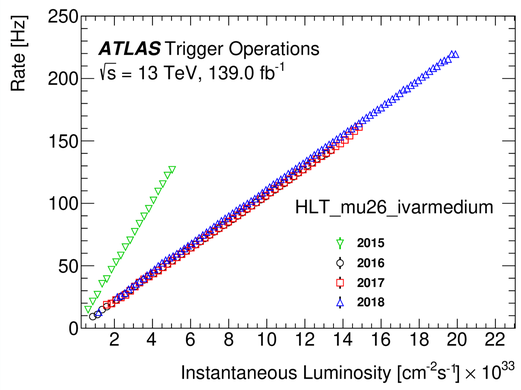
- Tag muon candidates must pass a quality requirement and have a p_T greater than the tag trigger threshold. It is also required to be within $\Delta R < 0.01$ of the object which fired the tag trigger
- The other muon, satisfying offline selection requirements corresponding to the working point of interest, is then a probe candidate. The probe is identified as triggered if it matches the trigger object.

Performance Plots

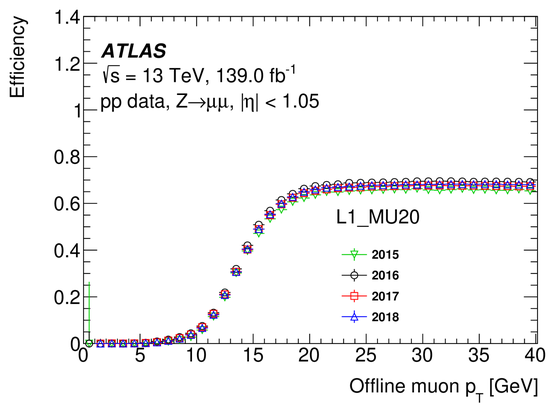


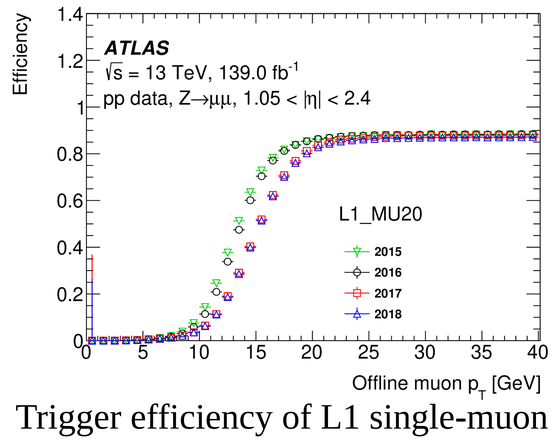
Above: L1 trigger rate for selecting two muons with (blue) and without (red) the L1Topo requirements between the two muons: 2 GeV $< m_{\mu\mu} <$ 9 GeV and $0.2 < \Delta R < 1.5$. Rates are decreased by factor of ~4, allowing low- p_T thresholds to be maintained for B-physics and Light States (BLS) program



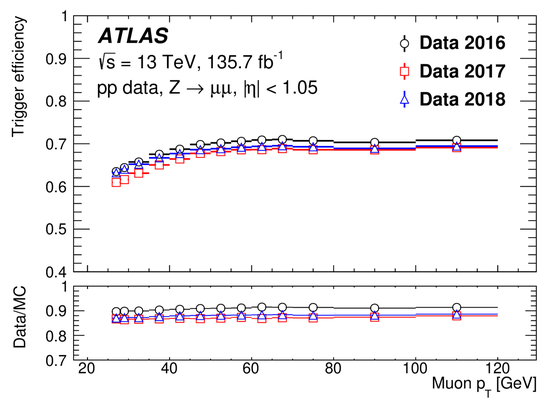


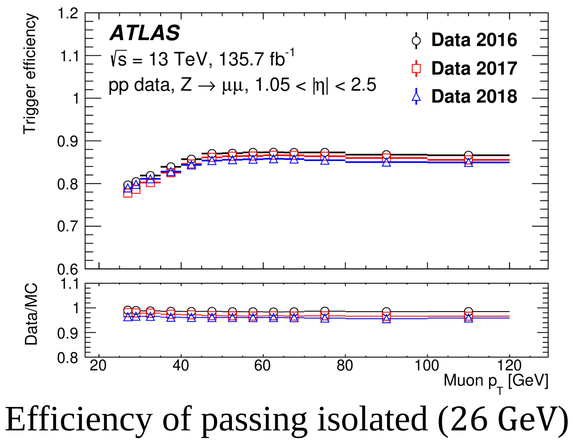
Trigger rates as a function of instantaneous luminosity for the lowest unprescaled L1 (top) and HLT (bottom) single-muon triggers



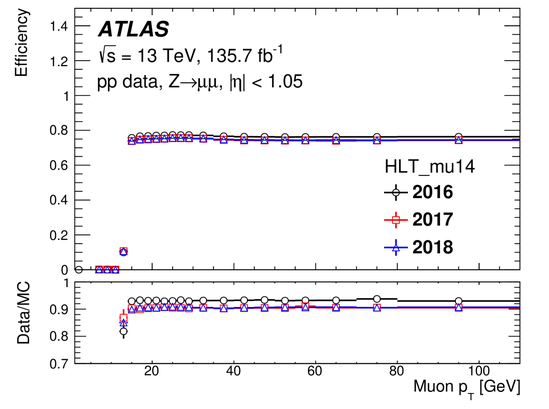


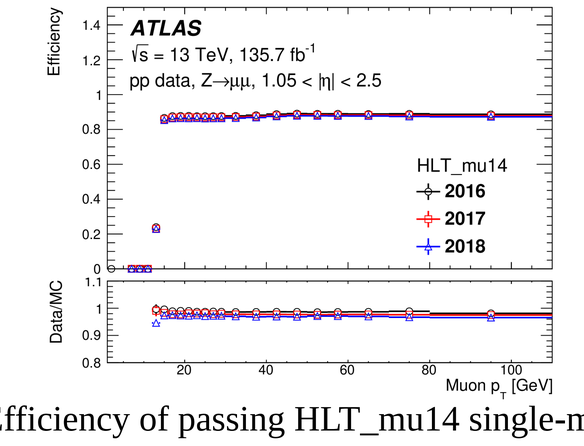
Trigger efficiency of L1 single-muon triggers as a function of muon p_T in barrel (top) and endcap (bottom) regions for 20 GeV threshold





Efficiency of passing isolated (26 GeV) non-isolated (50 GeV) HLT single-muon trigger as a function of muon p_T in the barrel (top) and endcap (bottom) regions





Efficiency of passing HLT_mu14 single-muon trigger as a function of muon p_T in the barrel (top) and endcap (bottom) regions. Multi-muon trigger efficiencies are products of single-leg efficiencies

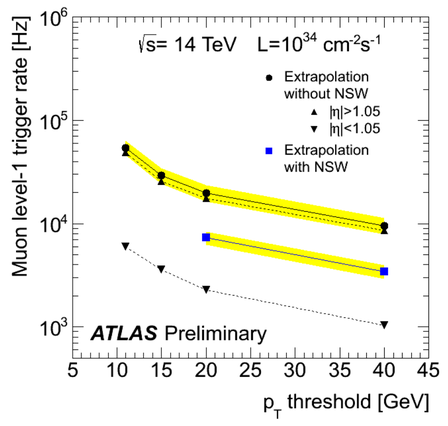
Run 2 Summary

- Single-muon trigger efficiencies ~68% (~85%) in barrel (endcap) region
- Multi-muon trigger efficiencies ~75% (~87%) in barrel (endcap) region (higher than single-muon trigger efficiencies due to looser L1 requirements)
- Efficiencies in heavy-ion data are comparable
- L1Topo requirement significantly reduced low-p_T thresholds for BLS program while maintaining efficiency

Future Improvements

In order to handle the higher luminosities of Run 3, several modifications will be made, including:

- Replacing the innermost muon chamber layers with higher-granularity New Small Wheels (NSW) in $1.3 < |\eta| < 2.7$ (Right: NSW trigger rate reduction extrapolation)
- New RPC chambers at $1.0 < |\eta| < 1.3$ to reduce L1 fakes
- Migration of the HLT software to a multi-threaded platform to decrease CPU memory usage; validations and performance evaluations are in progress



References: TRIG_2018_01 (https://arxiv.org/abs/2004.13447 , submitted to JINST) ATL-DAQ-PROC-2016-003
NSW Preliminary: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/MuonTriggerPublicResults

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