The ATLAS Muon Trigger

Performance in Run-2 in the ATLAS experiment

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1. Abstract

Events containing muons in the final state are an important signature for many analyses being carried out at the Large Hadron Collider(LHC), including both the standard model and new physics searches. To be able to study such events, it is required to have an efficient and well understood muon trigger. Due to high luminosity and pileup conditions in Run-2, several improvements have been implemented to keep the trigger rate low while still maintaining a high efficiency. This poster presents an overview of the algorithm improvements of the ATLAS muon trigger and its performances in 2018 data taking.

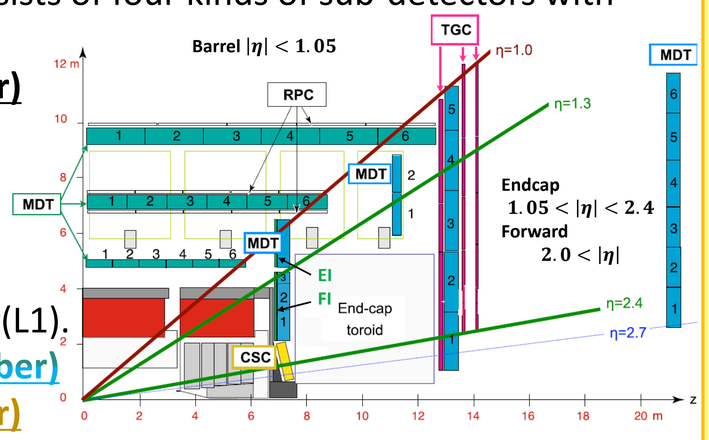
2. The ATLAS muon system

The ATLAS muon system consists of four kinds of sub-detectors with different purposes.

- **RPC(Resistive Plate Chamber)**
  Covering barrel region
- **TGC(Thin Gap Chamber)**
  Covering endcap region

Fast responding detectors
→ Used for hardware trigger(L1).

- **MDT(Monitored Drift Chamber)**
- **CSC(Cathodes Strip Chamber)**



They have high resolutions and provide precise track information.
→ Used for software trigger(HLT) and offline muon reconstruction.

➔ **Estimate transverse momentum, p_T, with these sub-detectors.**
Calculate radius of curvature from muon hits and convert it to p_T.

3. The ATLAS muon trigger

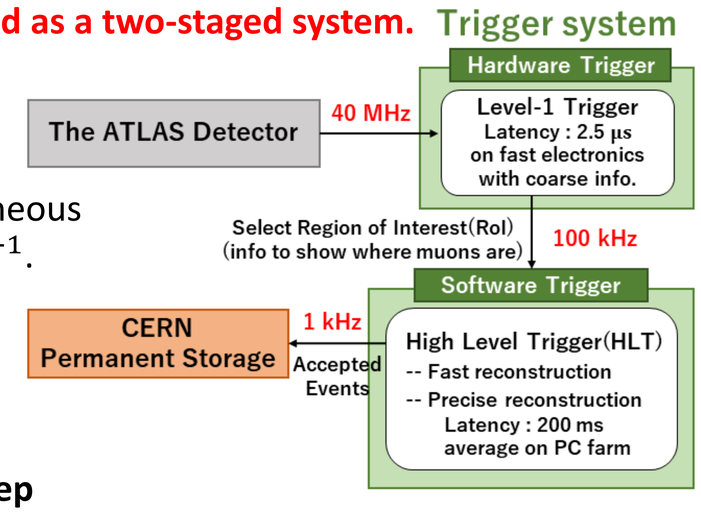
The ATLAS trigger is designed as a two-staged system.

- **Level-1(L1) muon trigger**

Primary threshold $p_T > 20$ GeV for high p_T triggers
Output rate 17 kHz at instantaneous luminosity of $2 \times 10^{34}\ cm^{-2}s^{-1}$.

- **High Level Muon Trigger**

Primary threshold $p_T > 26$ GeV with isolation
Output rate 250 Hz at 2e34.

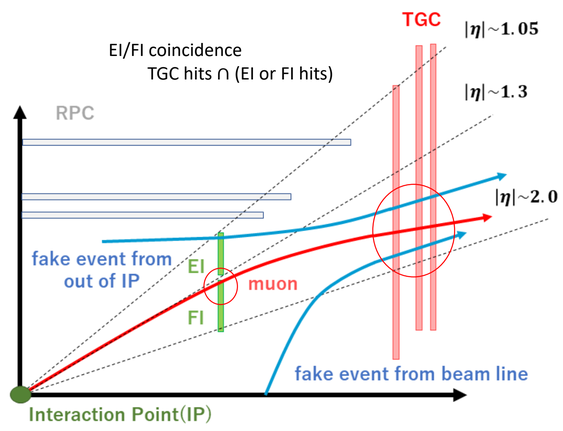


-- Fast muon reconstruction step
with fast tracking in RoI(Region of Interest).

-- Precise muon reconstruction step with precise tracking
(exploiting algorithms close to offline muon reconstruction)

4. Improvement at L1 trigger for Run-2 data taking ~ EI/FI coincidence ~

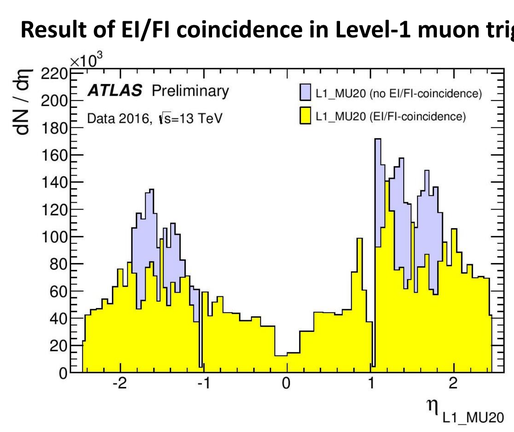
In Run-1, L1 muon rates in the forward region were polluted by low-p_T charged particles (protons) from out of Interaction Point(IP), resulting in significant rate increase. In Run-2, coincidences with inner muon chamber placed before the toroid magnet are used to discard these fake candidates.



Most of the fake charged particles are low-p_T protons originating from beam background.
➔ The protons don't go through ID.

Suppress it with the inner muon chamber(EI/FI).
= EI/FI coincidence (New)
(Further with the extended barrel region of the Tile Calorimeter)

Result of EI/FI coincidence in Level-1 muon trigger



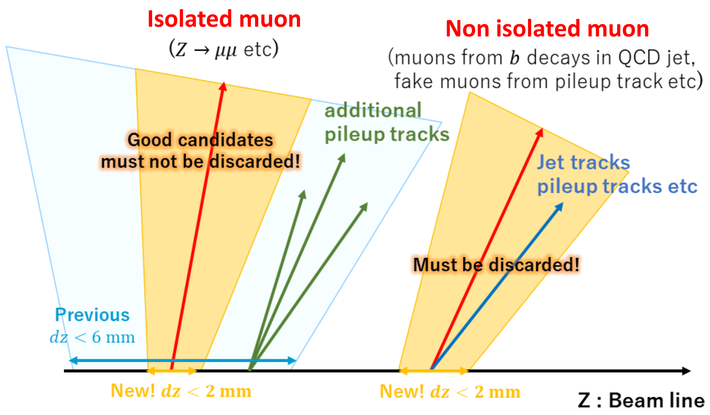
~20% rate reduction for L1 muon candidates with p_T > 20GeV, 1.05 < $|\eta|$ < 2.0 and efficiency loss below 1%.

EI/FI coincidence is useful to reduce L1 muon rate with high efficiency.

5. Recent improvement at HLT for the 2018 data taking ~ Muon Isolation ~

Isolated muon trigger with p_T threshold 26 GeV (mu26_ivarmedium) is primary used for wide range of physics analyses in ATLAS. In 2017 with very high pileup environment a drop in efficiency was observed.

- **Cause of efficiency loss** : Muon isolation requirement $dz < 6$ mm



dz : distance between muon track and the other track (pileup track and jet track)

Additional pileup tracks near isolated muon are picked up due to too wide cone($dz < 6$ mm).
→ **Good candidates were also discarded** in high pileup environment.
pileup=60 in 2017 : **efficiency loss 4%**

Loosen requirement to increase efficiency

- **Solution for 2018 data taking** : Loosen requirement with dz

2017 configuration : $dz < 6\ mm$
➔ **2018 configuration : $dz < 2\ mm$ (New)**

The efficiency is recovered at pileup=60 in 2018 data!
A small rate increase is caused mainly by low p_T muons close to the thresholds.
➔ **The increase is acceptably low.**

The selection $dz < 2$ mm in isolated muon trigger has good performance for the 2018 data taking.

6. Efficiency measurement in 2018 data

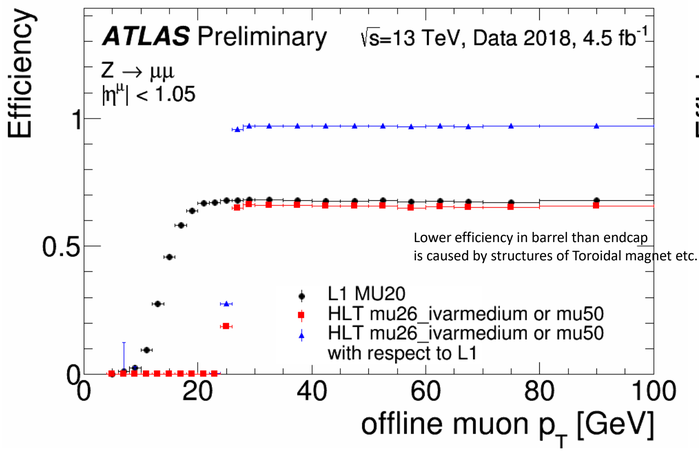
The muon trigger efficiency is measured using a tag-and-probe method with $Z \to \mu\mu$.

Tag-and-Probe Method
1. Select $Z \to \mu\mu$ events.
2. Use probe muons to measure trigger efficiency by the following function.

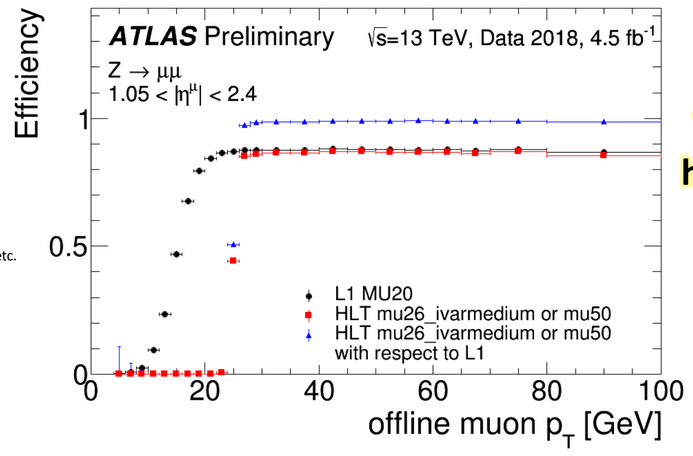
Tag : Offline muon matched to trigger muon.
Probe : The other offline muon

$$Efficiency = \frac{Number\ of\ probe\ muon\ matched\ to\ trigger\ muon}{Number\ of\ probe\ muon} \times 100$$

Barrel region $|\eta| < 1.05$



Endcap region $1.05 < |\eta| < 2.4$



The ATLAS muon trigger has very good efficiencies both at Level-1 and High Level Trigger!
↓
Ready for the luminosity production year 2018.

7. Summary

Several improvements were implemented in muon trigger system to cope with high luminosities and pileup. We are ready with excellent performance for the luminosity production year 2018.