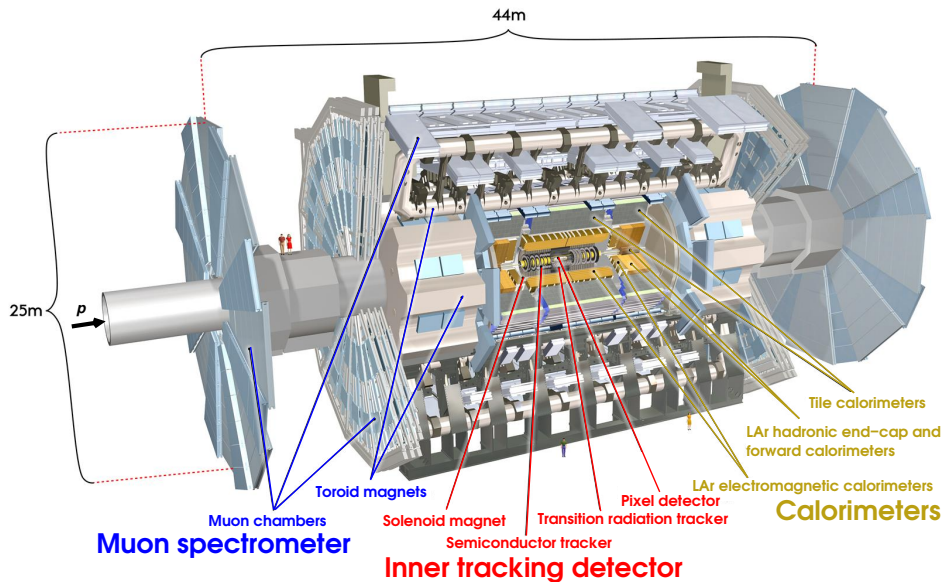# The ATLAS Muon Spectrometer at the LHC and the HL-LHC

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on behalf of the ATLAS Muon Collaboration

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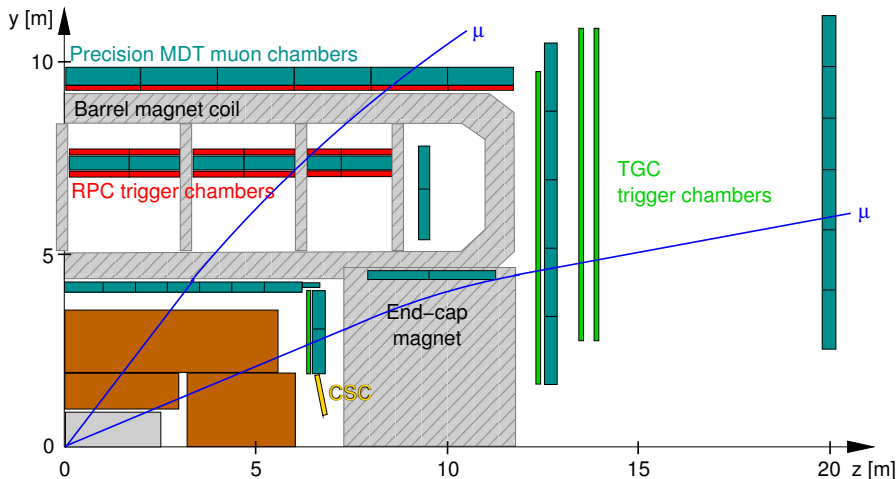
09.03.2016, ACES 2016

- Focus on stand-alone muon reconstruction.
- Air-core toroid $\rightarrow$ minimization of multiple scattering.
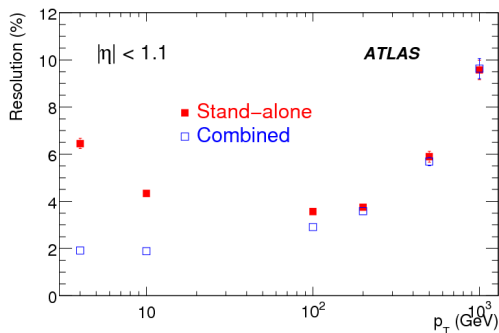
The ATLAS muon spectrometer at the LHC
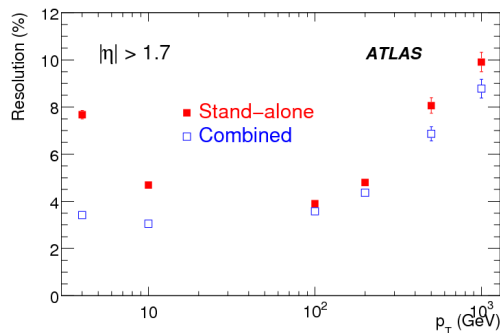

- Fast trigger chambers: RPC, TGC
  (<10 ns time resolution, moderate spatial resolution ~mm-cm).
- High-resolution tracking detectors: CSC, MDT (40 μm spatial resolution).
- Optical alignment system with 50 μm resolution.
- Pseudorapidity coverage: $|\eta| < 2.7$.

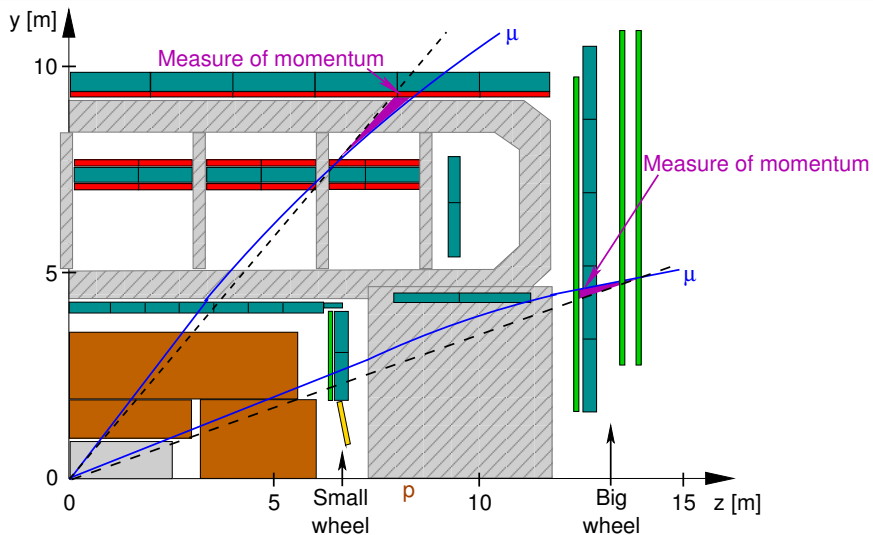# Muon momentum resolution

Barrel region

End-cap region

- ∼4% muon spectrometer stand-alone resolution for $10 \lesssim p_{\mathrm{T}} \lesssim 200$ GeV.
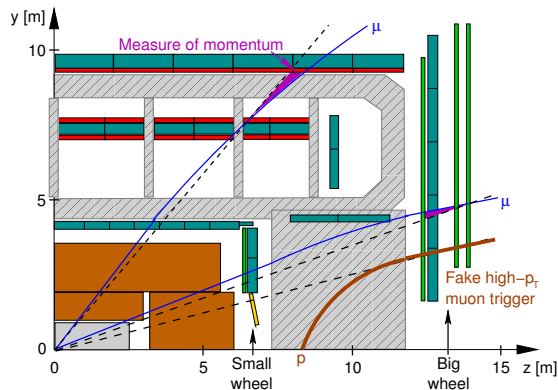- Muon spectrometer crucial to reach 10% momentum resolution at $p_{\mathrm{T}} = 1$ TeV.

- ATLAS uses as 3-level trigger system.
- The level-1 high p_T muon trigger built out of a coincidence of three RPCs in the barrel or three TGCs in the big end-cap wheel.
- Muon momentum estimate from the size of the deviation of hits from an infinite momentum track from the interaction point.
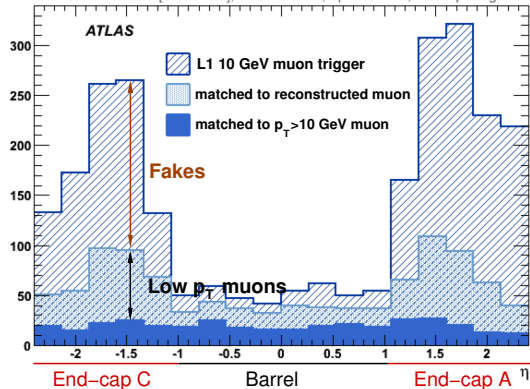
- Muon trigger rate dominated by fake triggers in the end-caps caused by charged particle not emerging from the interaction point.
- Real muon triggers contaminated with sub-p_T-threshold muon due to the reduced momentum resolution caused by the moderate spatial resolution of the trigger chambers.

The ATLAS muon spectrometer at the HL-LHC
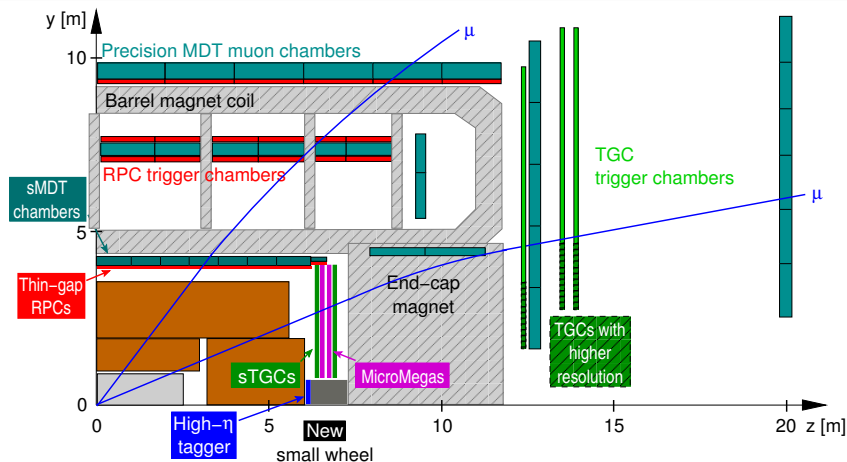
- New small wheel with high-resolution trigger chambers to reject fake muon triggers and improve momentum resolution at trigger level.
- New TGCs with higher resolution to cope with background at $|\eta| \sim 2.7$.
- New thin-gap RPCs to close acceptance gaps of the barrel muon trigger.
- New sMDT chambers to free space for new RPCs.
- High-η tagger to identify muons up to $|\eta| = 4.0$.
- + New on- and off-chamber electronics for new trigger architechture.

- New trigger scheme:
  - Only two trigger levels: level 0 (L0) and high-level trigger (HLT).
  - L0 rate: 1 MHz. L0 latency: 6-10 μs.

$\Rightarrow$ In this scheme all muon chambers have to send their data off to USA15 continuously for further processing.

$\Rightarrow$ New on-chamber (MDT ASD and TDC chips, multiplexers) and off-chamber electronics (trigger logic, Felix) needed!
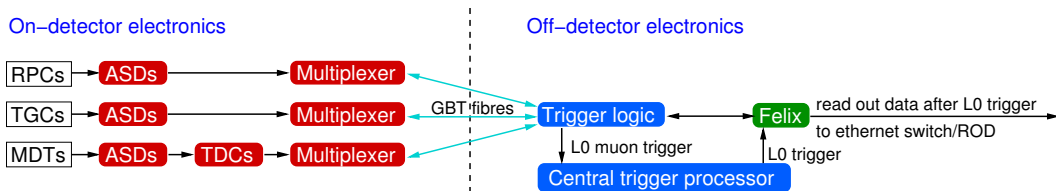
# The ATLAS 1st level muon trigger at the HL-LHC
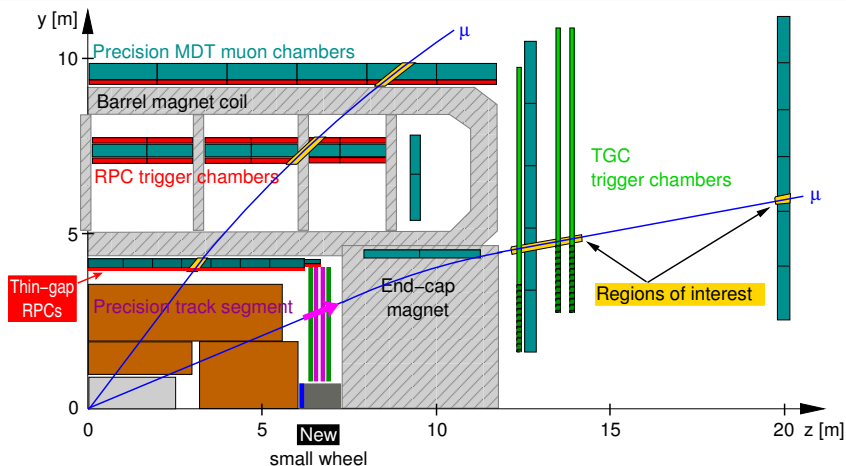
Processing step	Time after pp collision
1. Continuous stream of muon hit data to off-detector trigger logic.	1 μs
2. Pre-muon-trigger based on coincidences of trigger-chamber hits in the inner, middle, and outer layers.	2 μs
3. Use of precision NSW and MDT hits for the refinement of muon p_T measurement in regions of interest defined by the trigger chambers.	3 μs
4. Final muon trigger based on refined momentum measurement.	6 μs

Single-muon trigger rates
(estimated from run-I data)
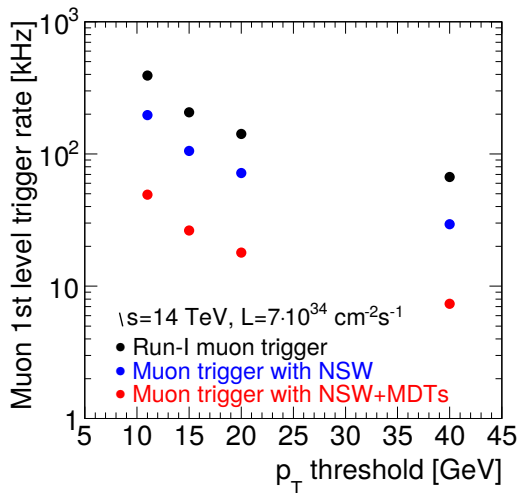
- Unacceptably high rate of run-I 20 GeV muon trigger: ~150 kHz.
- Removal of fake triggers by including the NSW in the trigger coincidence.
  ⇒ Rate reduced to ~ 70 kHz.
- Sharpening of the turn-on curve with MDT data reduces trigger rate to ~ 18 kHz.

⇒ ~ 130 kHz free for other triggers!

The figure axes read:
- y-axis: Muon 1st level trigger rate [kHz], range from 1 to 10^3
- x-axis: p_T threshold [GeV], range 5 to 45

Legend:
\s=14 TeV, L=7·10^{34} cm^{-2}s^{-1}
- Run-I muon trigger
- Muon trigger with NSW
- Muon trigger with NSW+MDTs