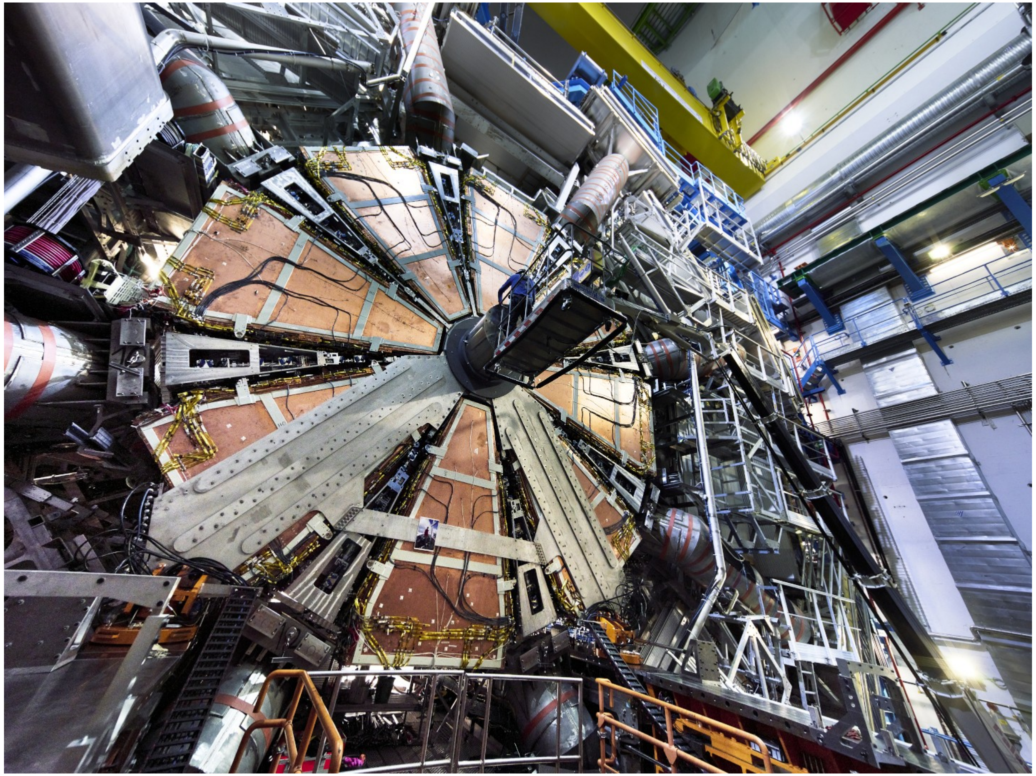
ATLAS New Small Wheel



Patrick Scholer on behalf of the ATLAS Muon Spectrometer

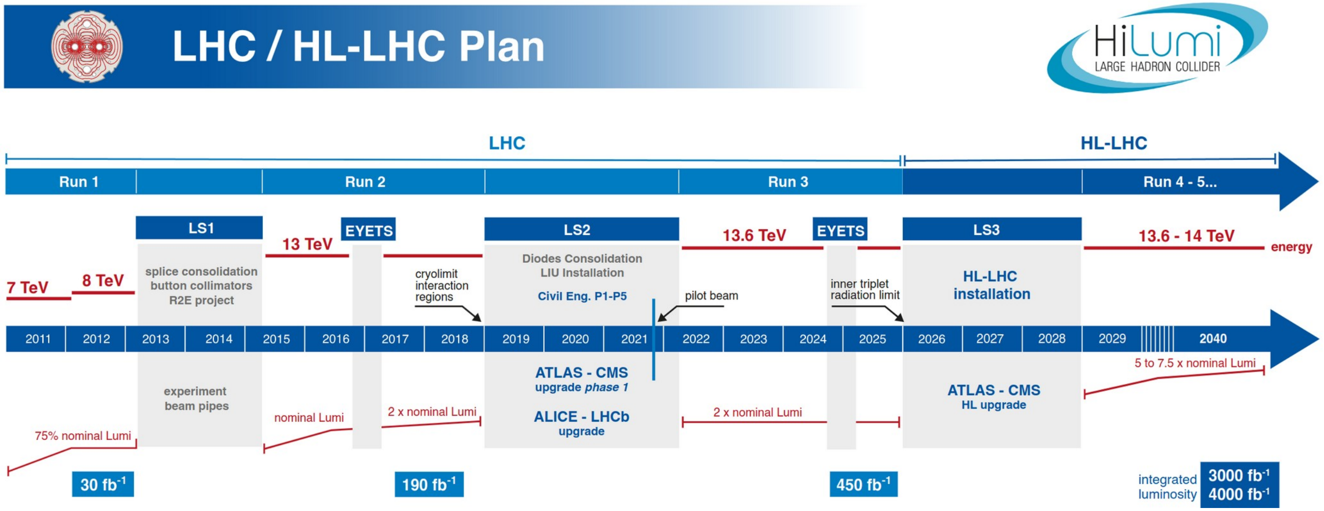
Carleton University

22.02.2024

16th Terascale Detector Workshop

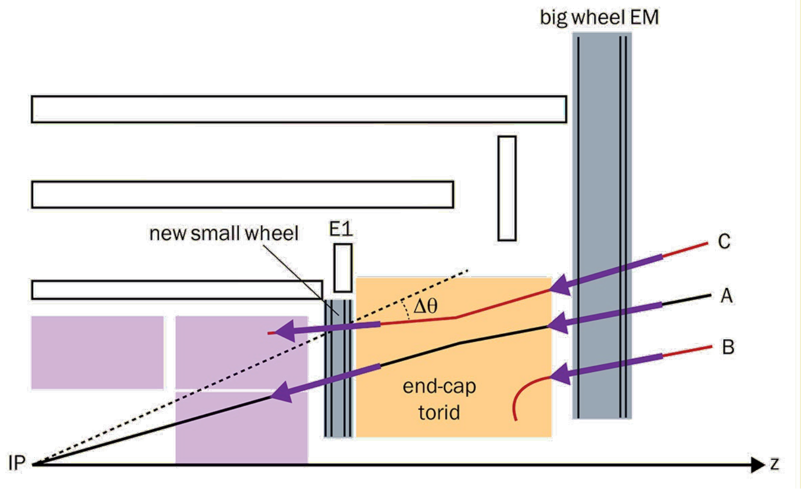
LHC Upgrades

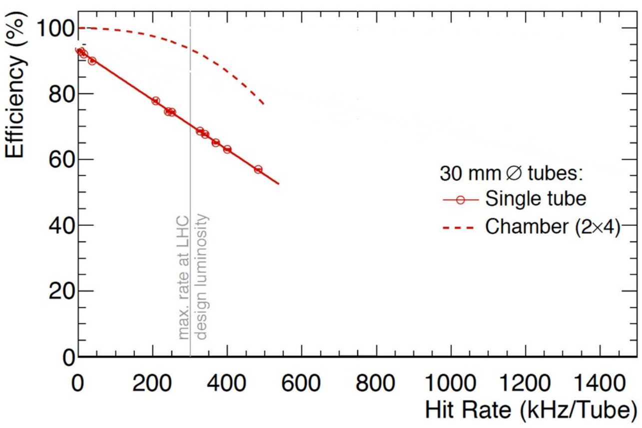
- LHC undergoes several updates to reach higher luminosity
- Ultimate goal after LS3 (2026-2028): L ~ 5-7.5x10^{34} $cm^{-2}s^{-1}$ (about 140-200 p+p interactions per bunch crossing)
- Experiments need to be upgraded in order to deal with the increased instantaneous luminosity

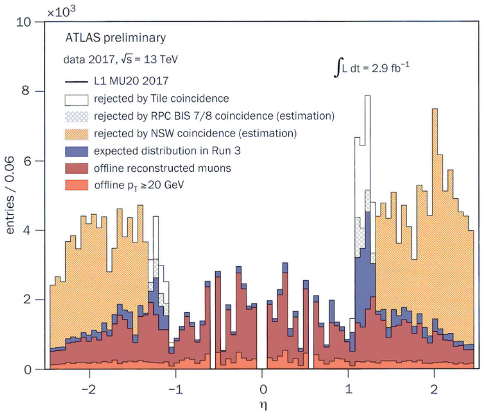


Motivation for the New Small Wheel

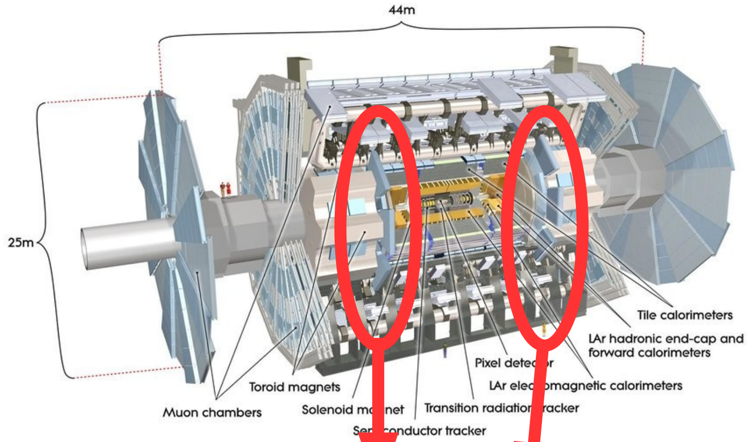
- Goals of the NSW:
  - Reduce muon fake trigger rate in end-cap region
  - Provide precise tracking despite high background particle rate
- Requirements on the NSW:
  - Provide an online segment angle measurement of 1 mrad precision to validate trigger by big wheel
  - Muon $\sigma_{Pt}/Pt < 10\ \%$ → 150-175 μm single layer resolution

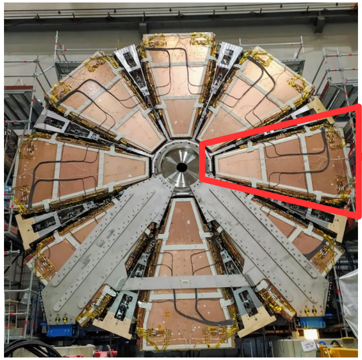




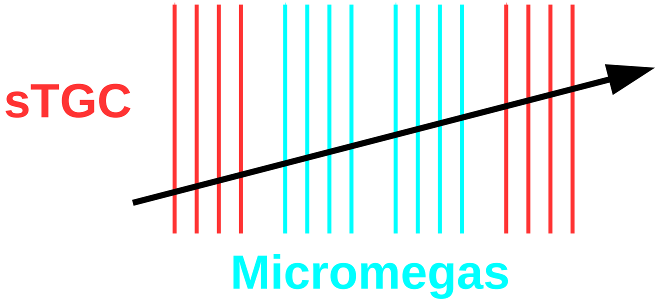


NSW Structure



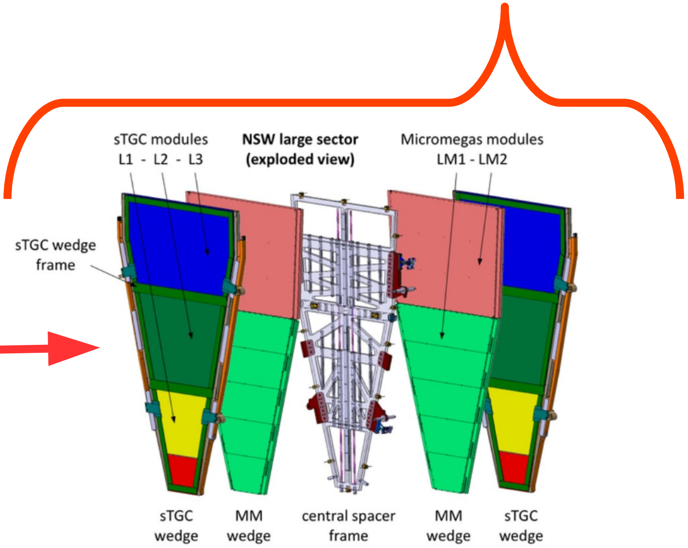


~10m



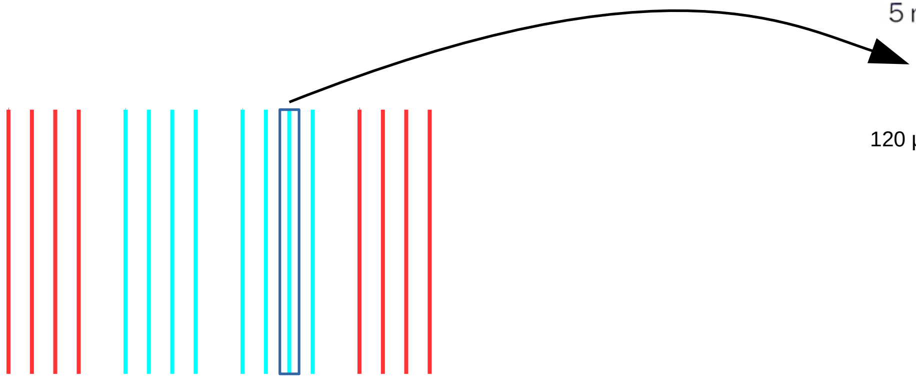
- 16 active layers
- 2 technologies

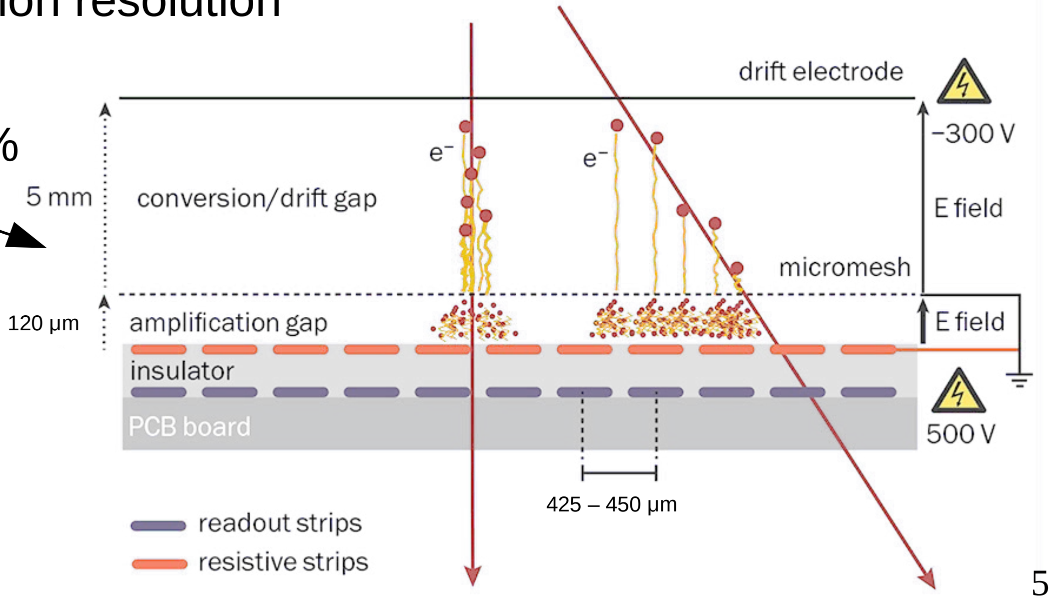
→ high redundancy



Micromegas

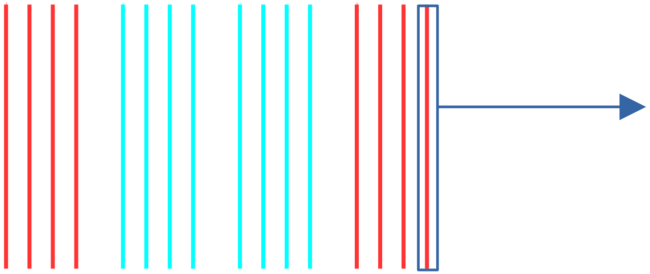
- Micromegas = Micro Mesh Gaseous Structure
- Two gas gaps: separated by stainless steel mesh
- 120 µm thin amplification gap → high rate capability
- Narrow readout strips → excellent position resolution
- Resistive layer → spark protection
- Gas mixture: Ar:CO_2:iC_4H_{10} 93%:5%:2%

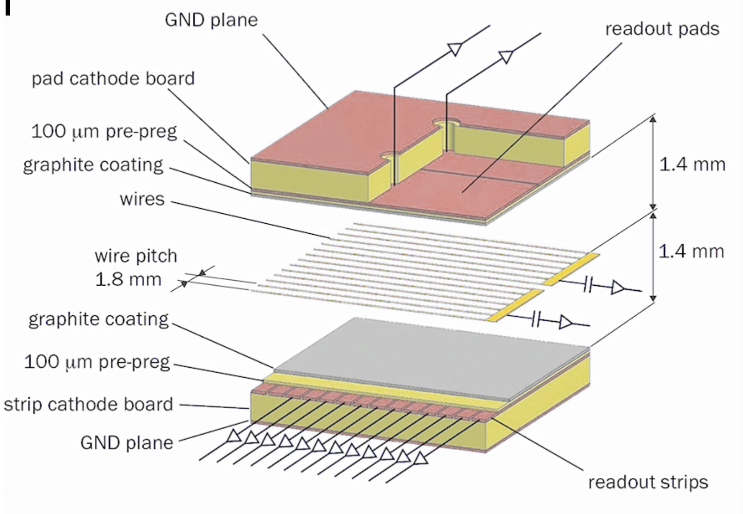




small-strip Thin Gap Chambers

- Multiwire proportional chamber with pad/strip segmented cathodes
- Narrow gas gap for excellent time resolution → BC identification
- Pads: coarse and fast information for trigger
- Strips: excellent spatial resolution for trigger and offline track reconstruction
- Wires: provide 2nd coordinate in offline reconstruction
- Operating gas: 55%:45% CO_2:n-pentane





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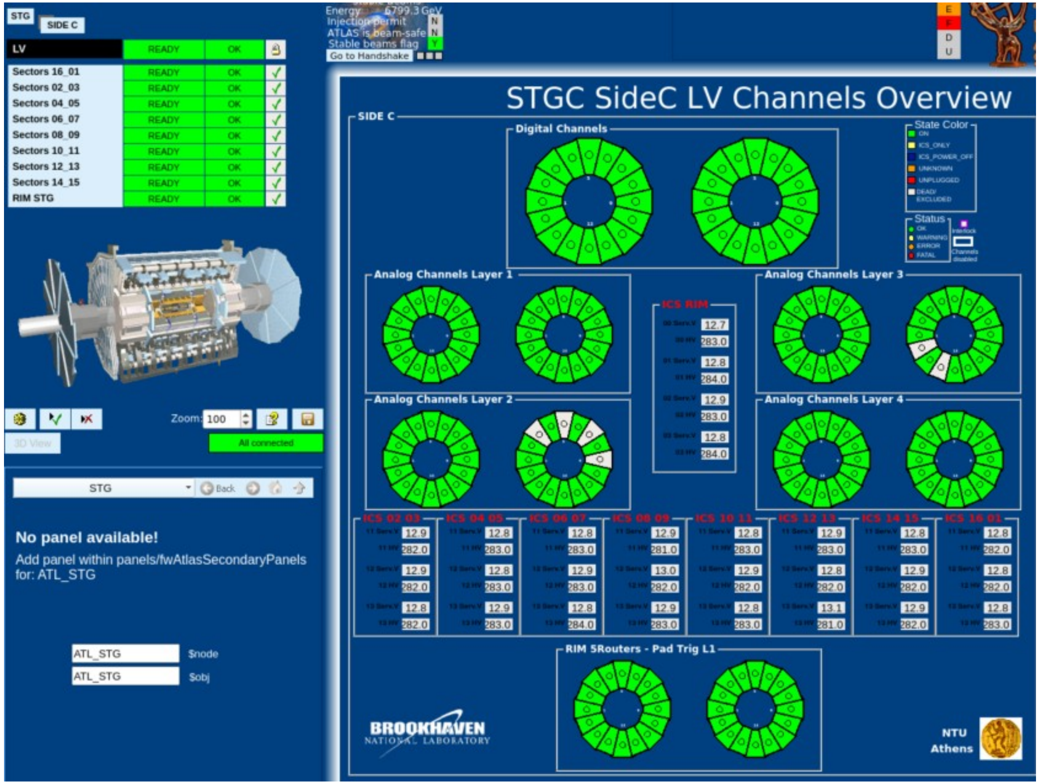
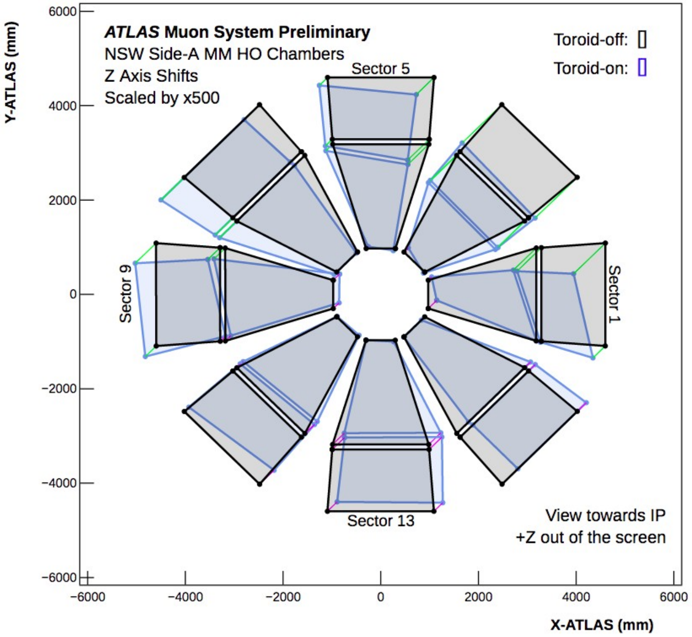
NSW Intergration into ATLAS



- Both NSWs are fully integrated into the ATLAS TDAQ and Detector Control Systems since the start of run 3 (2022)

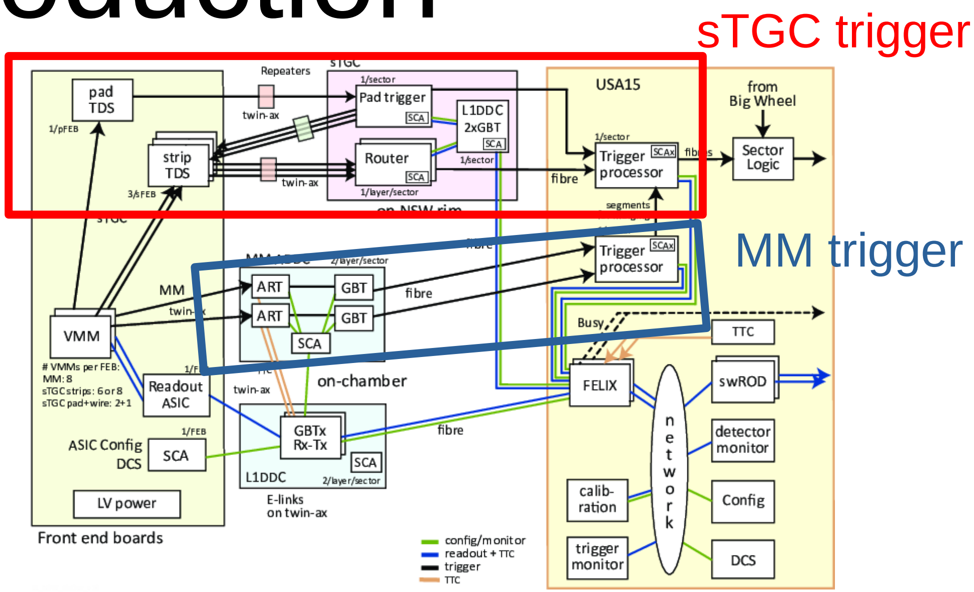
Alignment

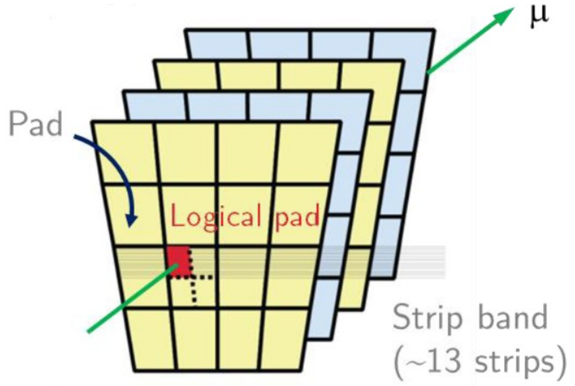
- Movement/deformations of ATLAS muon spectrometer monitored by optical alignment system
- Both NSWs tilt up to 2.7 mm (on average 1mm) when toroid is switched on



Trigger Introduction

- Two sTGC trigger levels:
  - Pad trigger: fast coarse information, seeds strip trigger (deployed in 2023 data taking)
  - Strip trigger: Reconstructs strip cluster and uses them for precise measurement of the segment angle (under commissioning, needed for HL-LHC)
- Independent MM trigger (under commissioning, will be deployed in 2024)
- Merged MM and sTGC trigger segments forwarded to sector logic

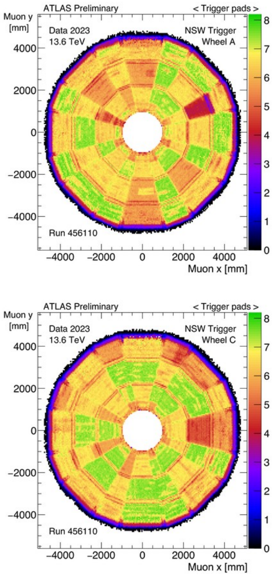


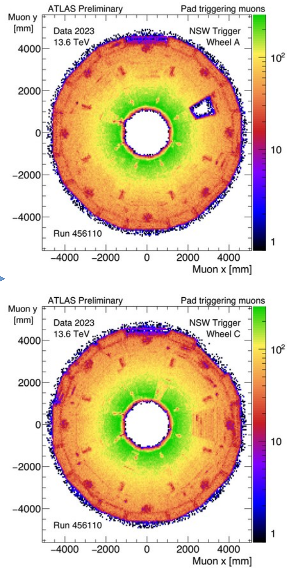


Pad Trigger Results

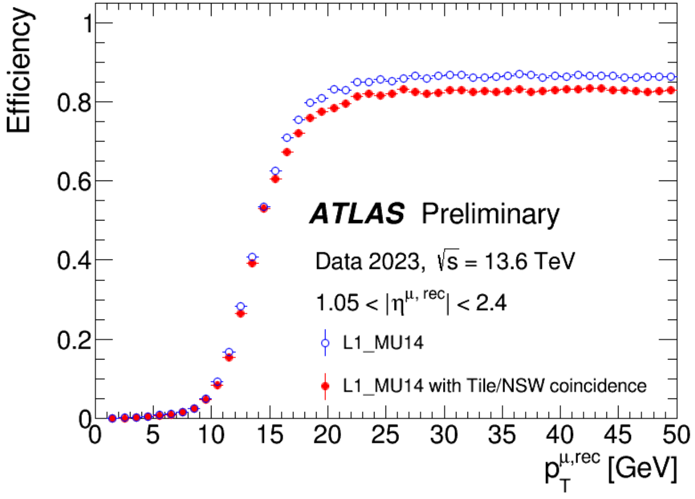
- 2023: Large fraction of the sTGC pad-only trigger included in ATLAS trigger
- Effect on the ATLAS trigger efficiency is 4%
- Ongoing efforts to improve logic and efficiency at every level

<N> Pad trigger hits per muon



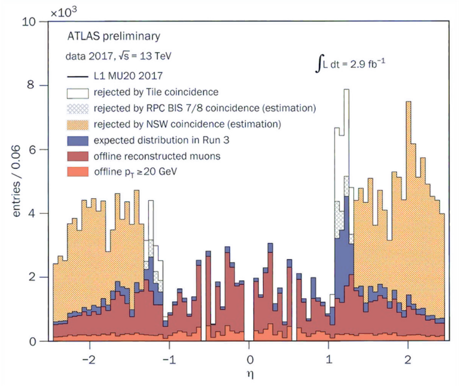


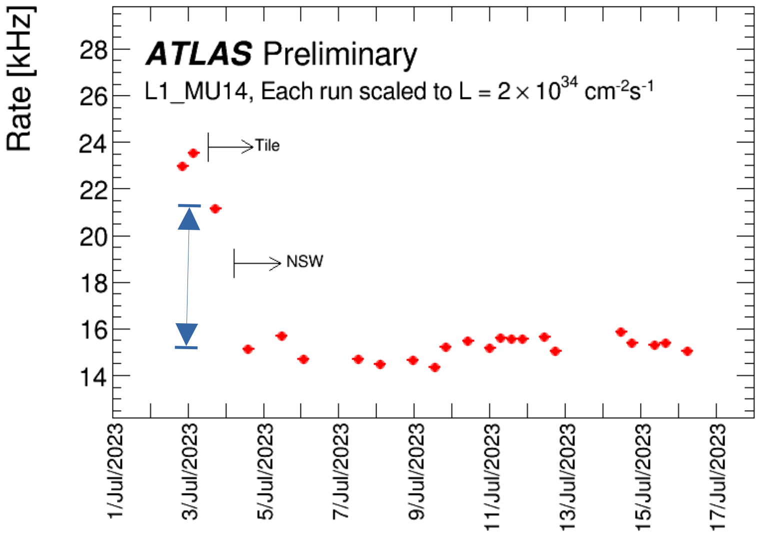
<N> muons triggered by pad trigger

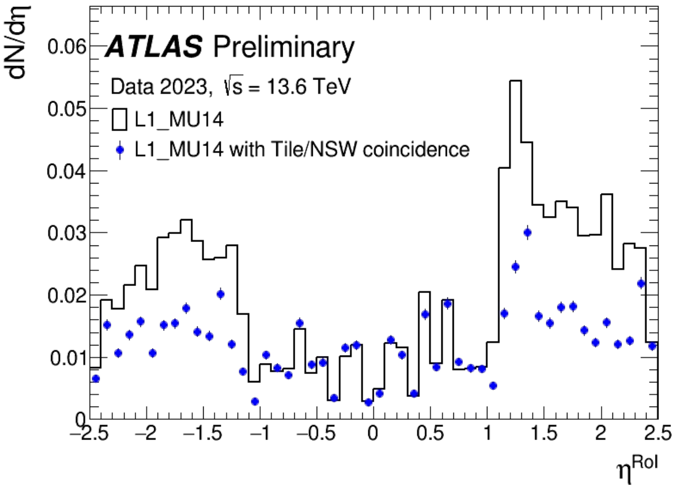


Pad Trigger Results cont.

- Including 100/144 pad-only trigger sectors in trigger coincidence reduced L1 rate by 6kHz already
- Studies ongoing, plenty of room for improvement



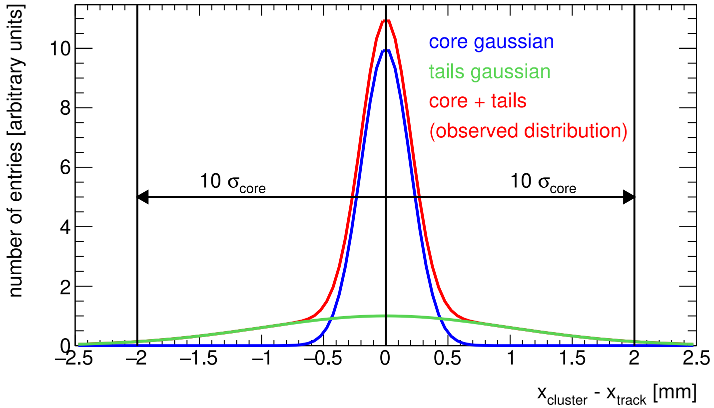


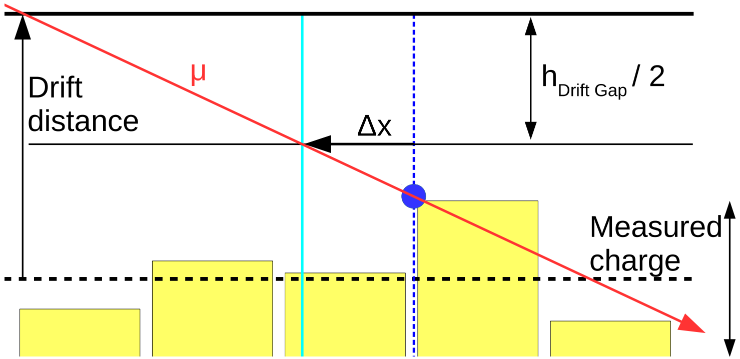


Muon Reconstruction

- The NSW is fully integrated into the ATLAS simulation and reconstruction software athena

Muon Hits
↓
STGC/MM Clusters
↓
2D Track Segments
↓
3D Track Segments
↓
ATLAS Muon Spectrometer tracks
↓
Combined Muon Tracks

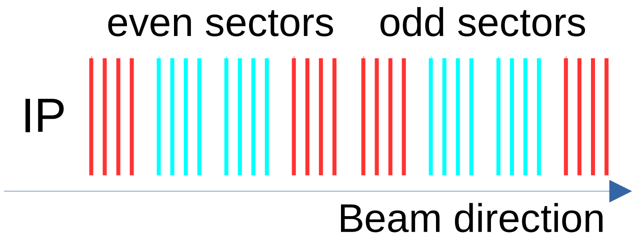


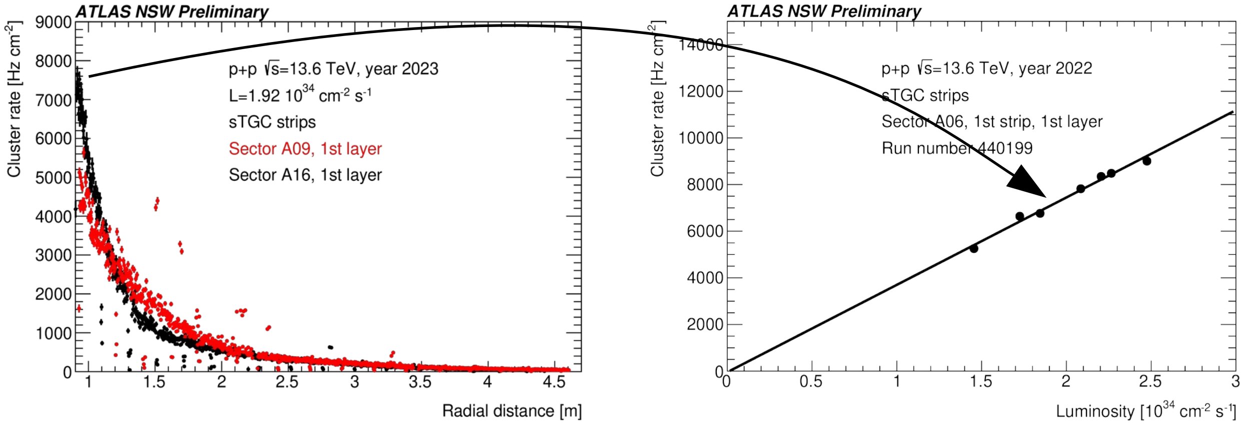


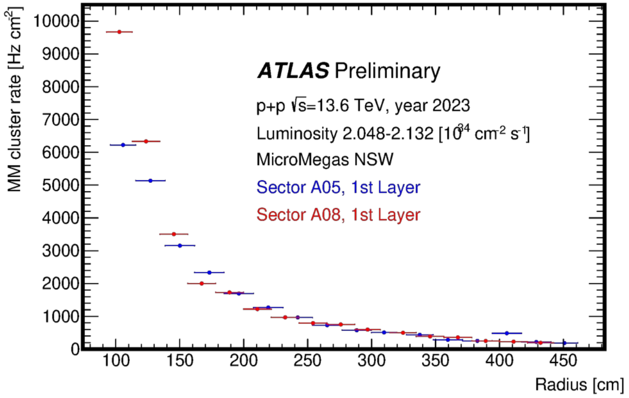
- Resolution extracted with double gaussian fit to track or layer residual
- Width of inner gaussian quoted in next slides
- Cluster position currently reconstructed by charge centroid
- Improved methods under study

Background Rates

- MM detectors show higher rate than sTGCs due to higher sensitivity to photons and neutrons
- Strong dependency of the rate to the layer position along the beam line
  - Small sectors are closer to IP → show higher rate



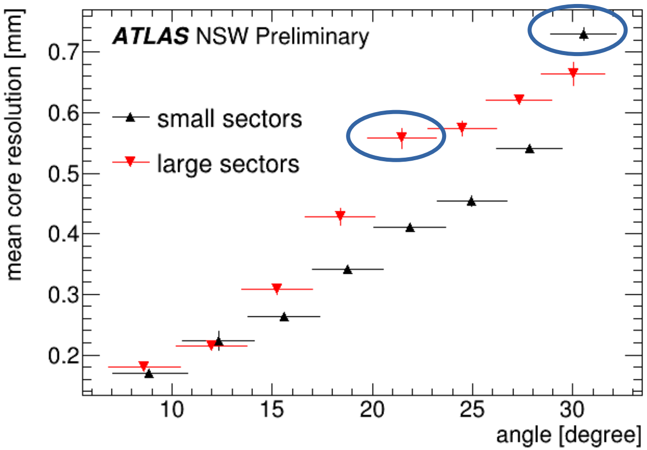




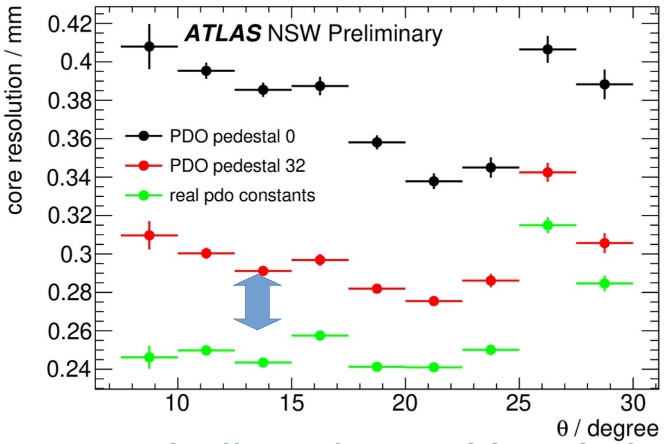
Reco Resolution

- Single layer resolution still sub-optimal:
  - Affected by layer-layer misalignment and residual global misalignment
  - Huge improvement expected once those corrections are in place; efforts ongoing
  - Further improvements expected from improved cluster position reconstruction methods (MM: use time information; sTGC: fit charge profile with gaus/parabola)

MM spatial resolution between clusters on two back to back layers



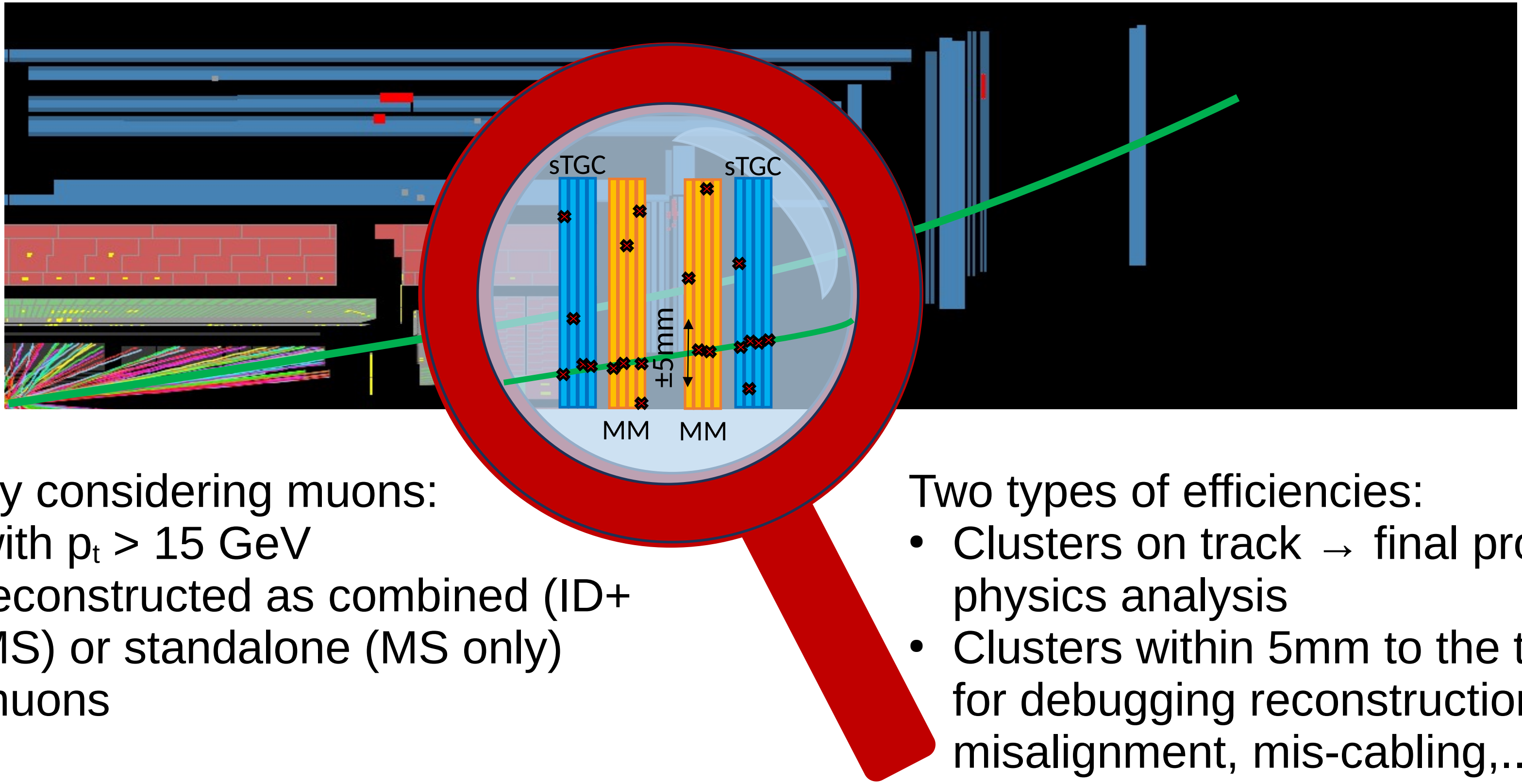
B-Field effects; corrected recently



sTGC spatial resolution between a cluster and a combined muon track

Including channel level charge calibration

Efficiency Measurement



- Only considering muons:
  - with p_t > 15 GeV
  - reconstructed as combined (ID+ MS) or standalone (MS only) muons

Two types of efficiencies:

- Clusters on track → final product for physics analysis
- Clusters within 5mm to the track → useful for debugging reconstruction and initial misalignment, mis-cabling,...

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MM Single Layer Efficiency

- Inefficient regions due to LV/HV/readout problems
- Efficiency > 90% for regions not affected by above problems

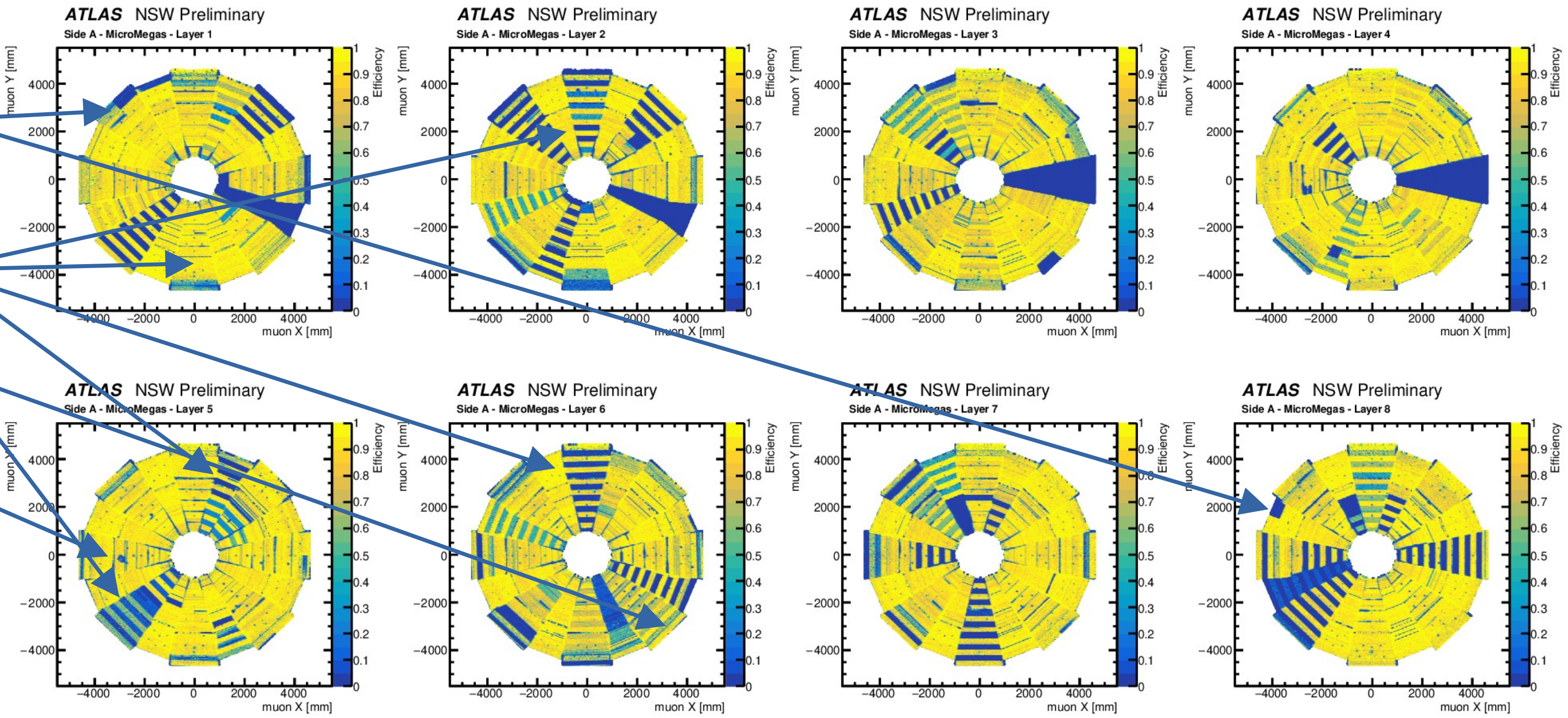
Half HV section disconnected

LV / readout board problem

Reduced HV

Local defects

Readout instabilities affecting 2023 data recently fixed



+- 5 mm

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sTGC Single Layer Efficiency

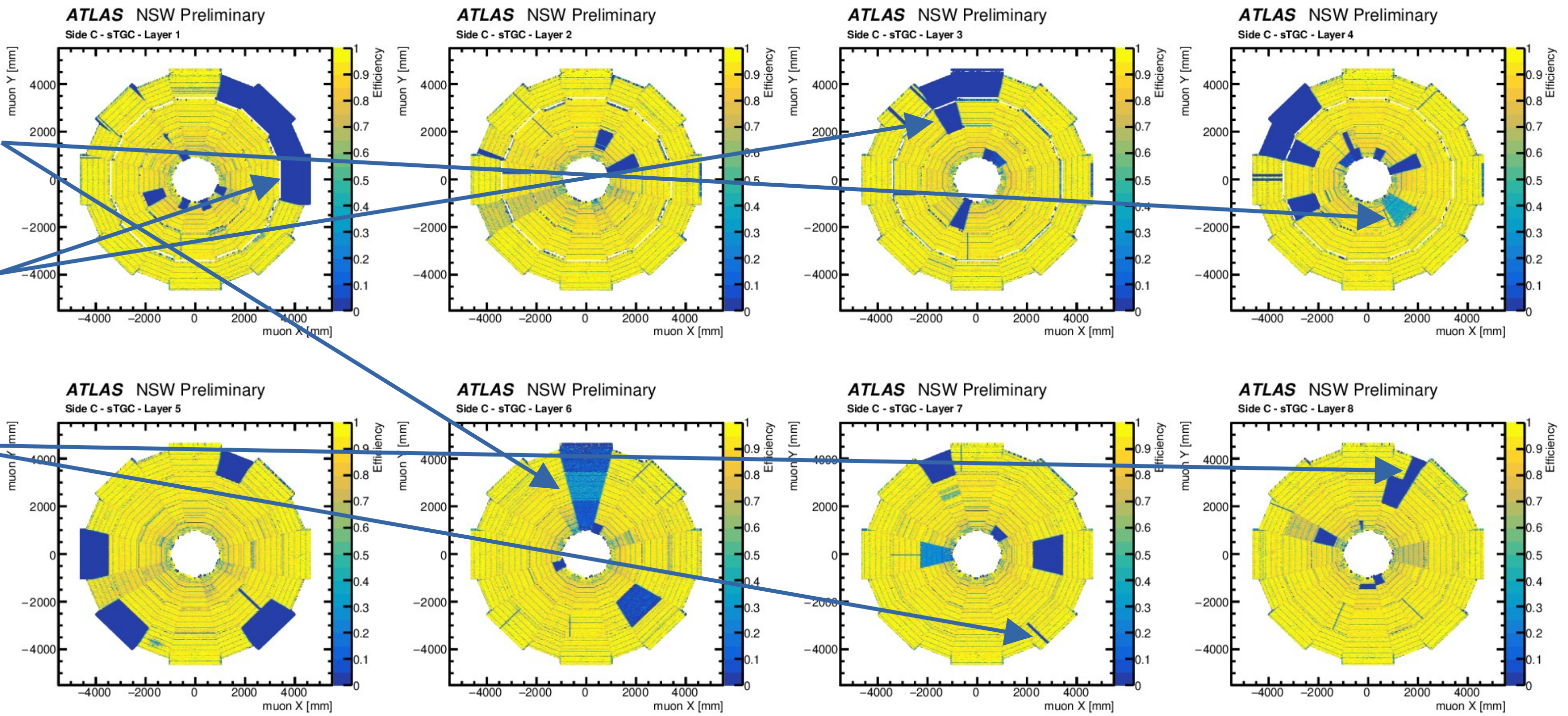
- Inefficient regions due to LV/HV/readout problems
- Efficiency > 90% for regions not affected by above problems

HV trip or readout dropped during run

HV/ LV / readout board problem

Wire group disconnected

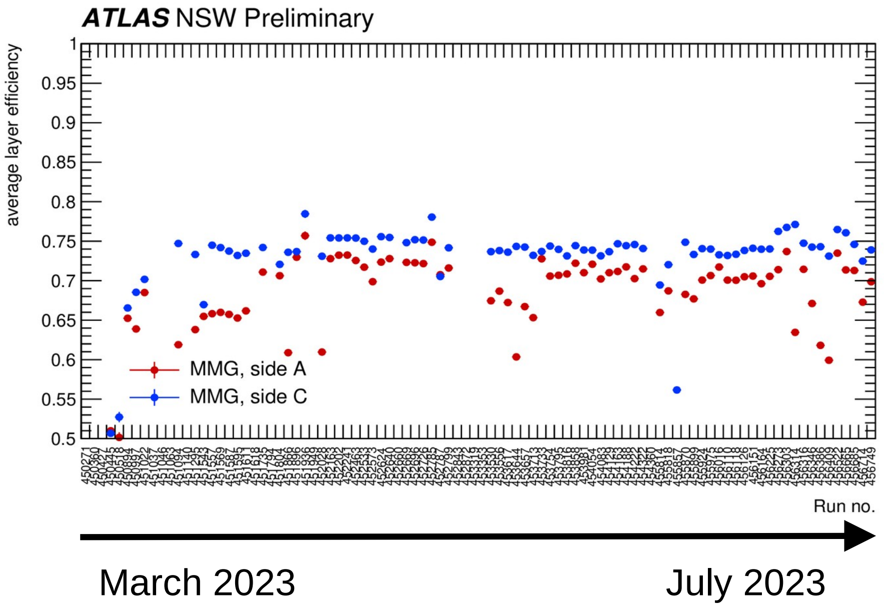
Readout instabilities affecting 2023 data recently fixed

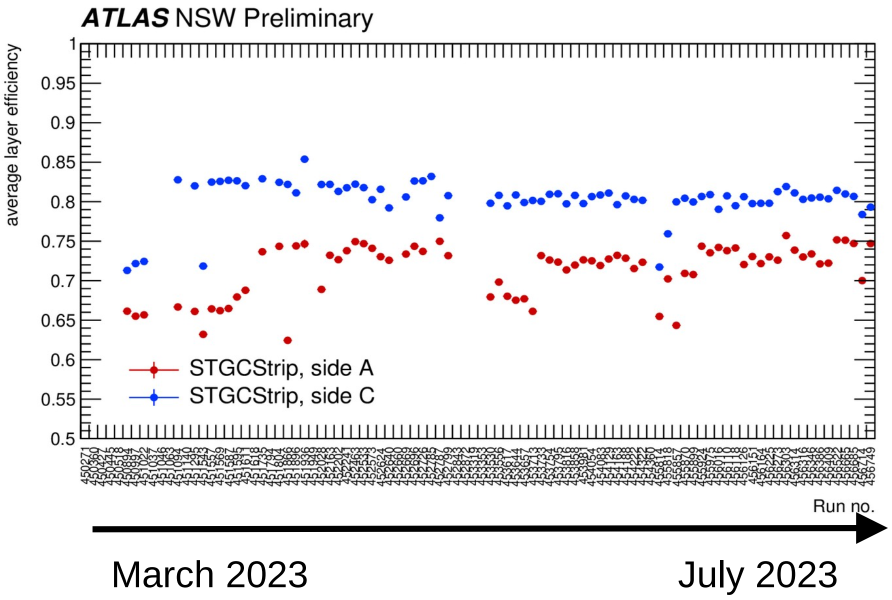


Single Layer efficiency over time

+- 5 mm

- Average single layer efficiency affected by detector and readout issues during the run
- Average single layer efficiencies of ~65% - 85%, stable over time





on track

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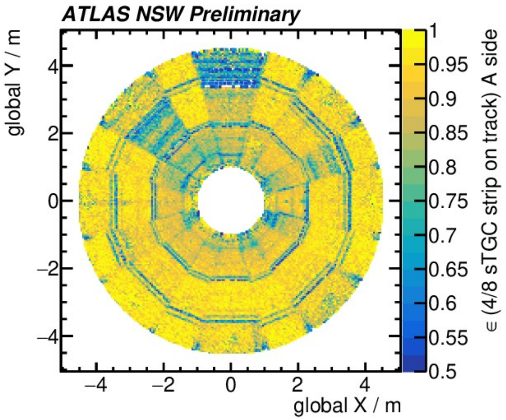
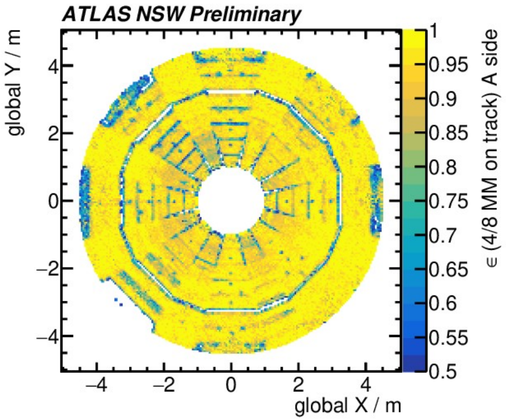
NSW for Physics Analysis

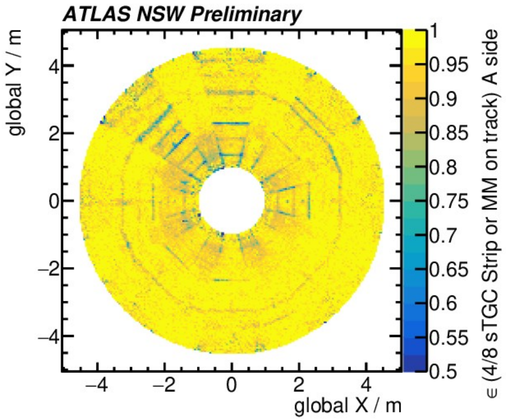
- Physics working points require a definition of having a NSW segment contributing to the reconstructed muon; e.g. require 3 stations for highPt muon WP
- Defined the OR of having 4/8 layers with a hit on track in either technology as input for the WP → makes use of the high redundancy
- Average 4/8 layers efficiency is > 95%



sTGC



MM



sTGC || MM

on track

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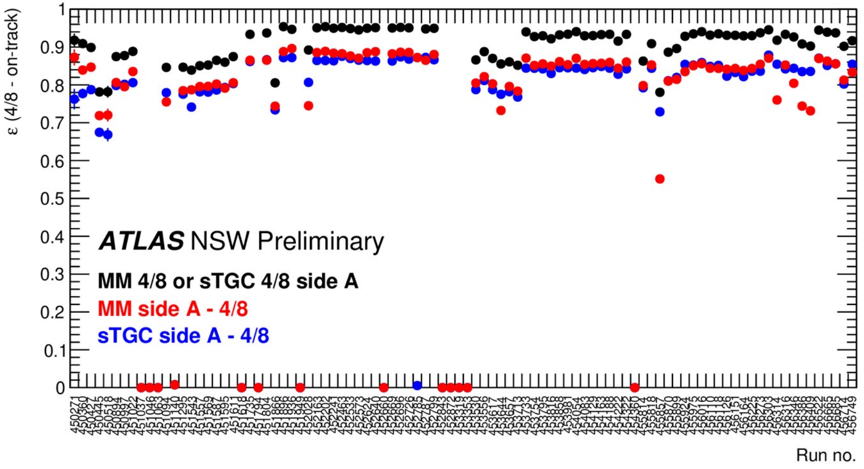
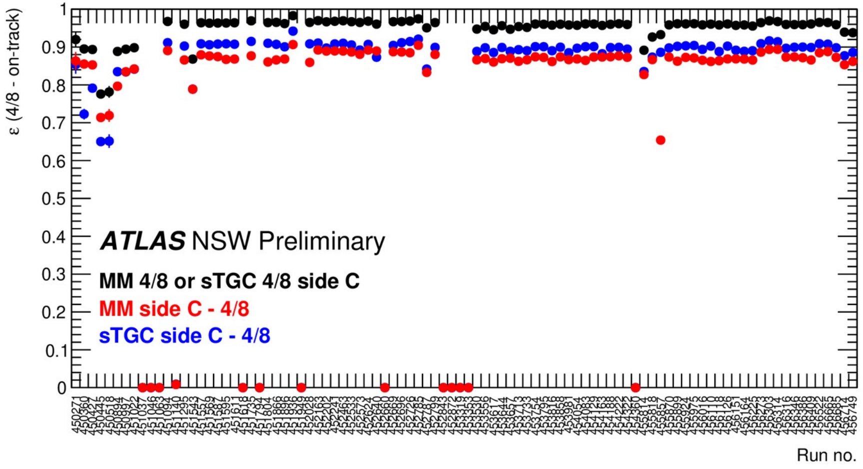
4/8 Layers Efficiency over Time

- 4/8 efficiency stable over time and > 95%

  → The NSW is contributing the ATLAS muon reconstruction with a high efficiency



March 2023 → July 2023



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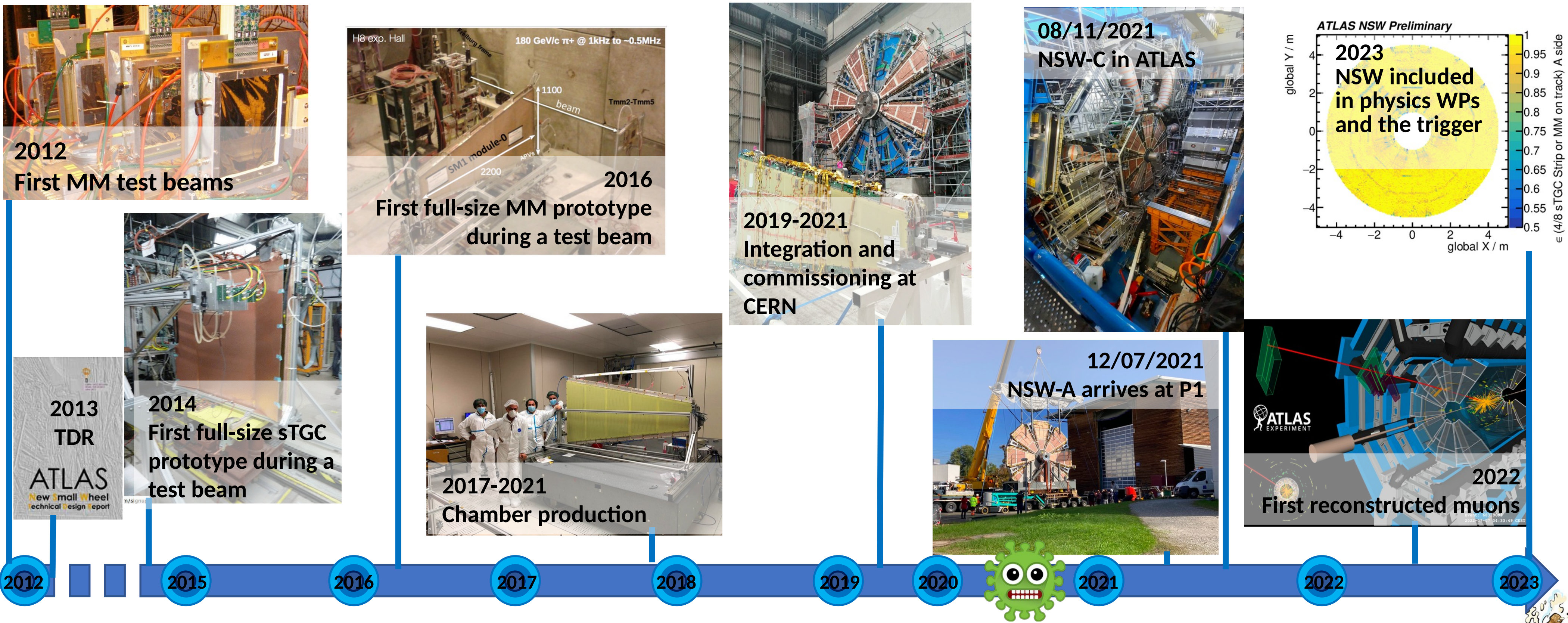

- The NSW was one of the largest phase 1 upgrades in the LHC experiments
- Despite many problems to overcome both NSWs are installed in ATLAS → outstanding achievement
- There are still problems to be solved, but the NSW is already significantly contributing to the ATLAS muon trigger and tracking in the forward region