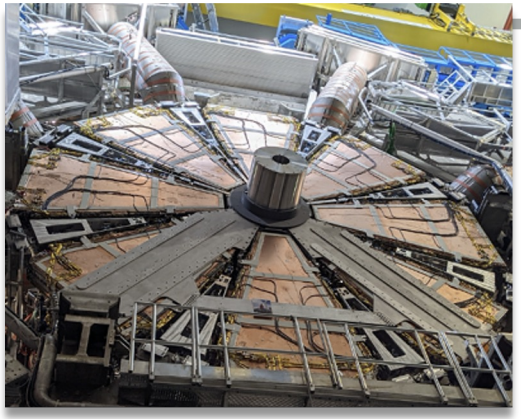
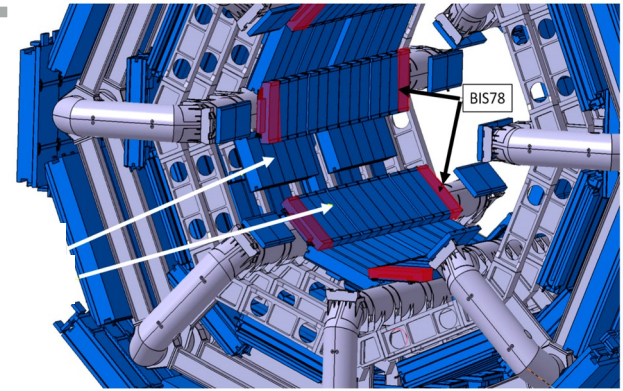
RUN-3 PERFORMANCE OF THE ATLAS MUON SPECTROMETER AND UPGRADES FOR THE HIGH-LUMINOSITY LHC



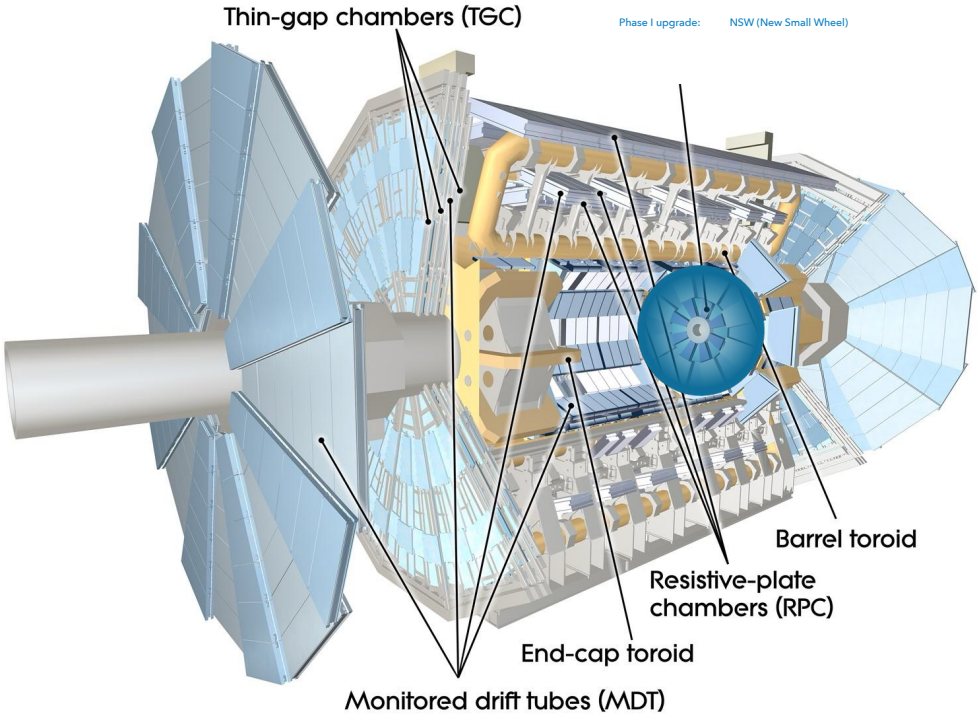
G.GAUDIO

INFN-PAVIA

ON BEHALF OF THE ATLAS MUON COMMUNITY



THE ATLAS MUON SPECTROMETER



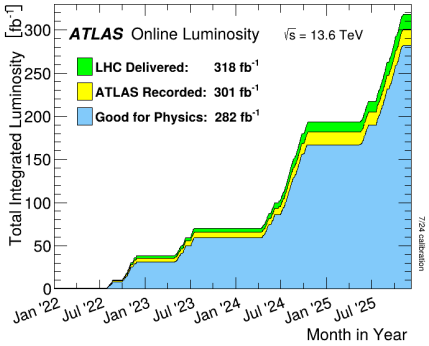
- Complex system with both trigger and tracking detectors
  - 5 technologies
  - Legacy detectors (MDT, RPC and TGC)
  - Phase I upgrade (Micromegas and Small-strip TGC)
- 2T toroidal magnetic field

ATLAS EXPERIMENT

RUN 3 PERFORMANCES

DETECTOR PERFORMANCE

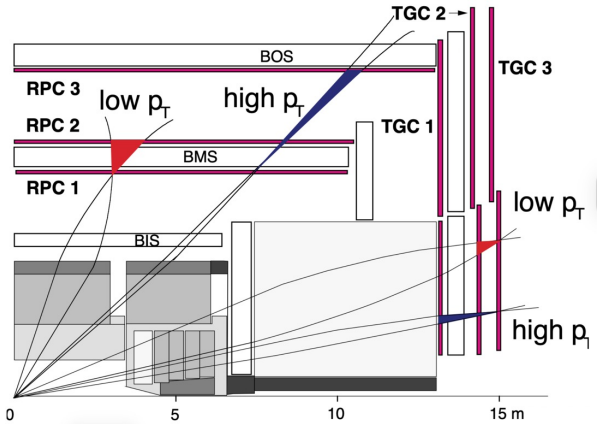
See Muon Object Performance V. Austrup's talk

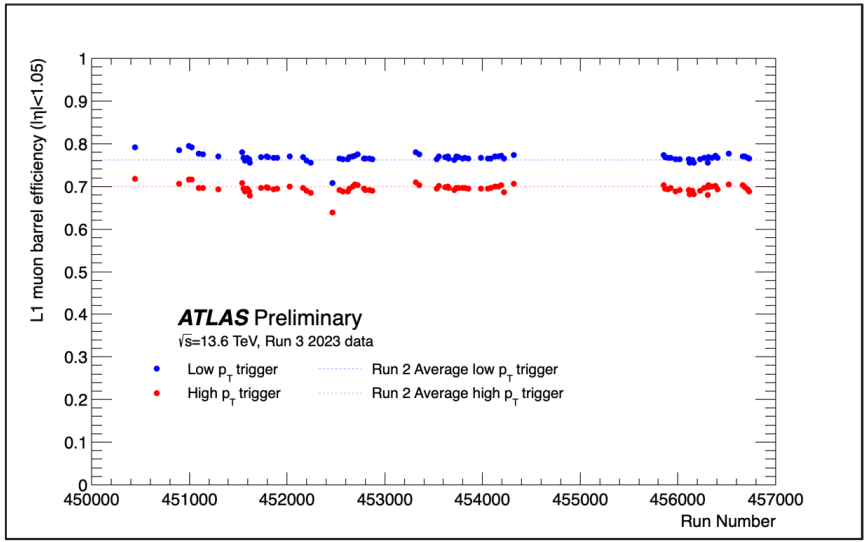


High detector performance in Run 3 (2022-2026)

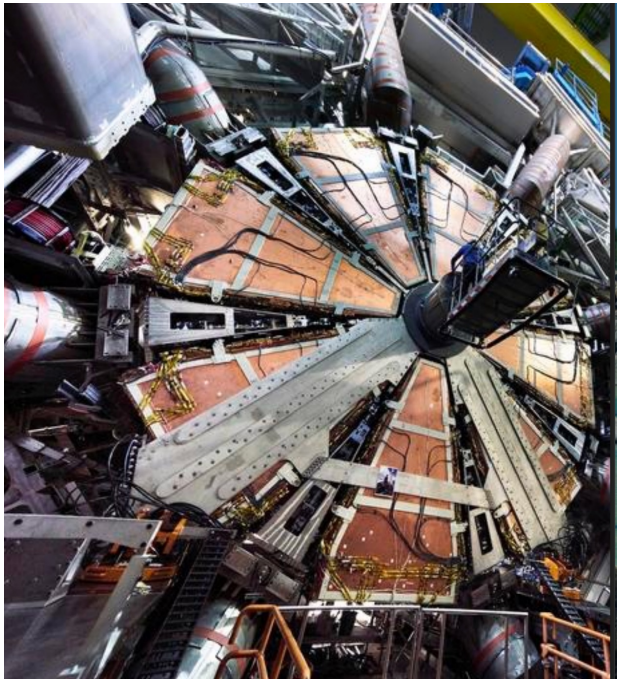
Above 94% of the recorded data is good for Physics

RPC: Most of the inefficiencies are due to geometric acceptance (accounting for 15% of the high-p_T)





MAIN PHASE I UPGRADE – THE NEW SMALL WHEEL (NSW)

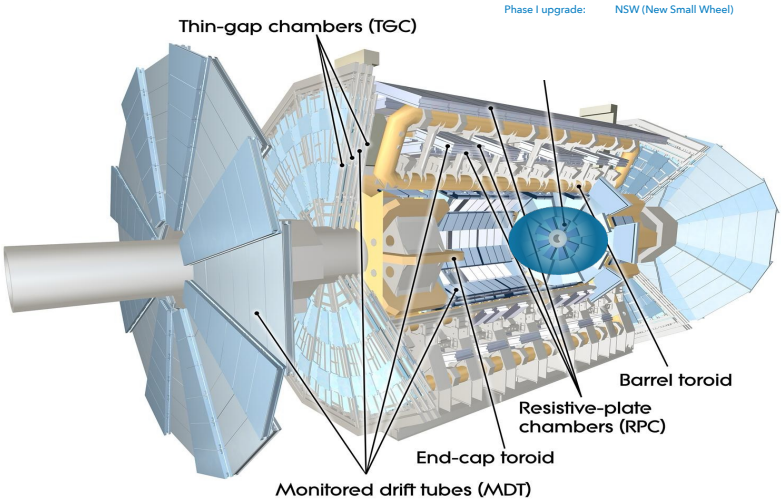


The NSW is designed to cope with HL-LHC rate in the forward muon region

Redundant system with 2 technologies

Micromegas (MMG) and Small-Strip Thin Gap Chambers (sTGC)

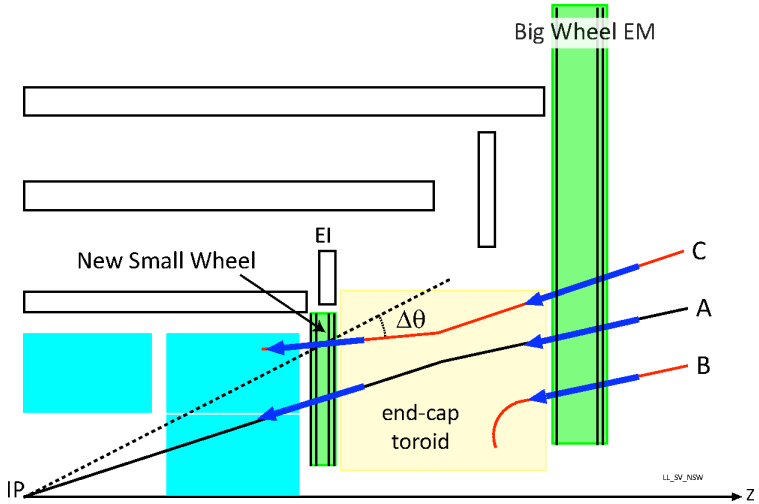
Both with tracking and trigger capabilities



MAIN PHASE I UPGRADE – NSW

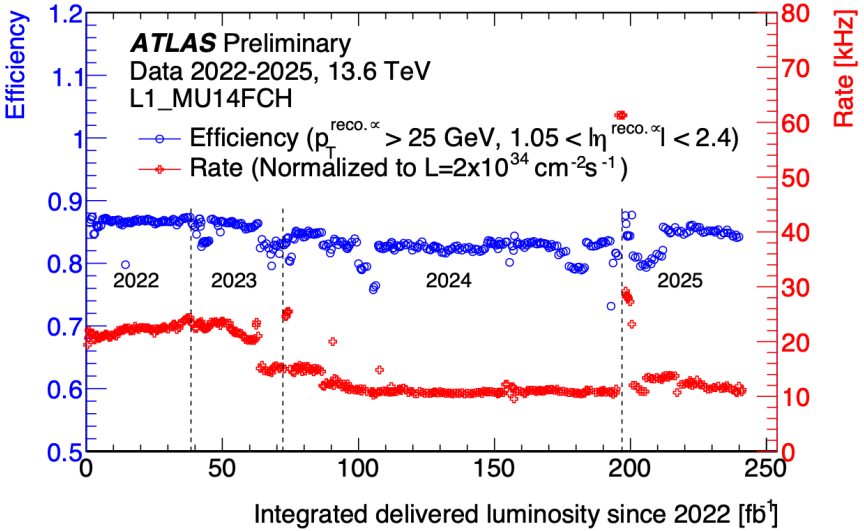
The New Small Wheel

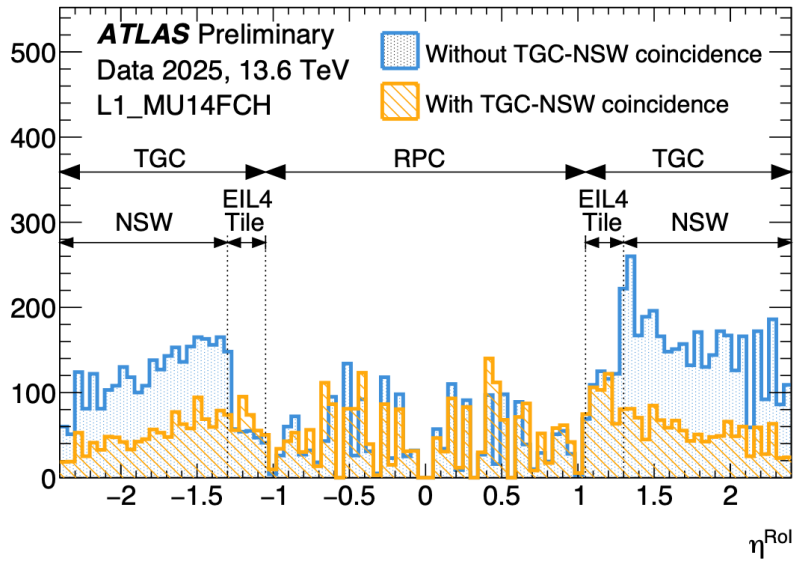
- provides a reduction of fake muons due to protons in the forward regions that originate from nuclear reactions
- maintain the same muon tracking performance in the higher rate conditions in the pseudo-rapidity region of $1.3 < \eta < 2.4$ for triggering and $1.3 < \eta < 2.7$ for tracking.



THE NSW TRIGGER RATE

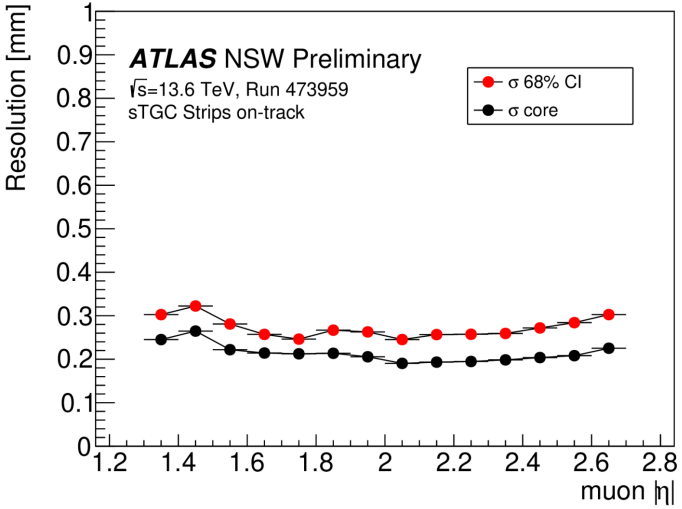
A factor ~2 reduction in the trigger rate due to more efficient background reduction obtained when NSW and TGC coincidence trigger is activated



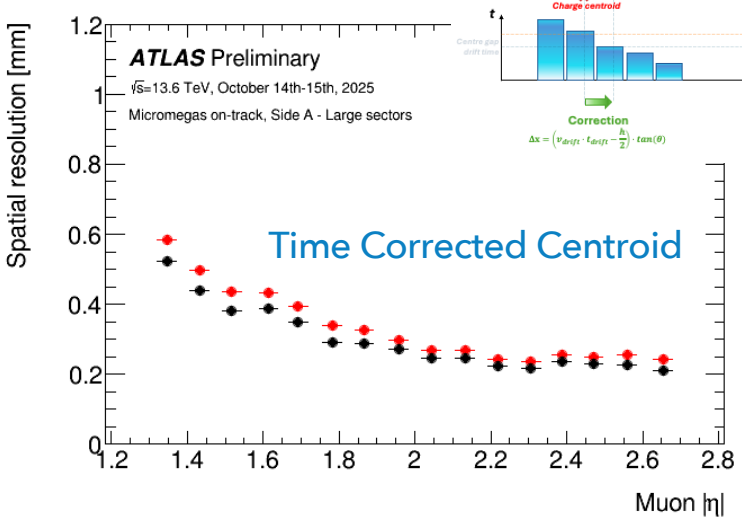


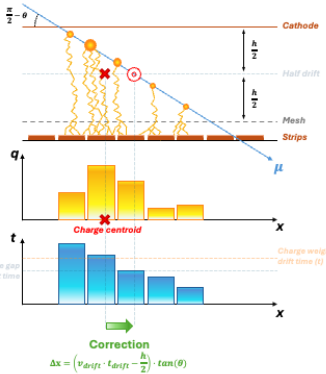
NSW SPATIAL RESOLUTION

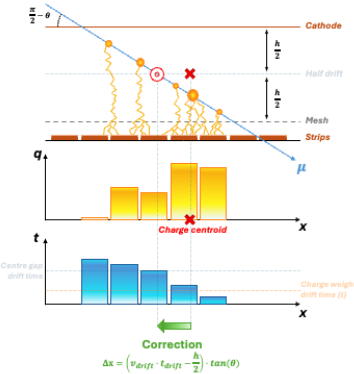
STG



MICROMEGAS







Further improvement on the spatial resolutions for MM and sTGC is expected by optimising alignment, magnetic field corrections and the cluster weighting algorithm

Effect on momentum resolution under study (V. Austrup's talk)

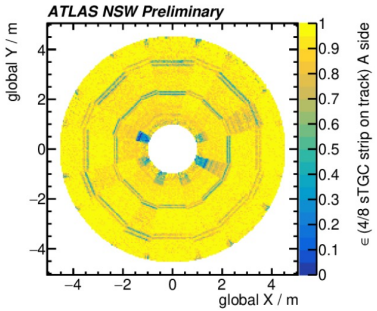
NSW RECONSTRUCTION EFFICIENCY

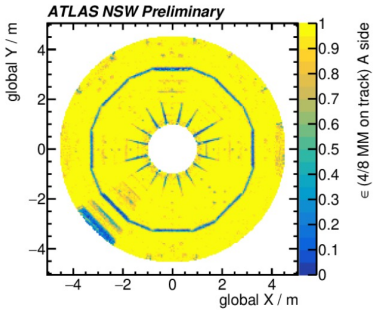
STG

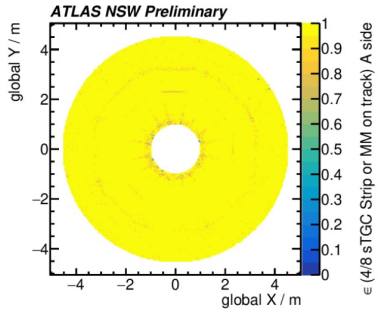
MM

TRACK RECONSTRUCTION

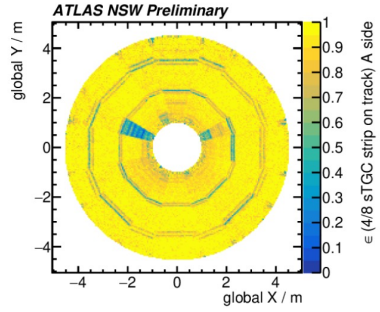
A

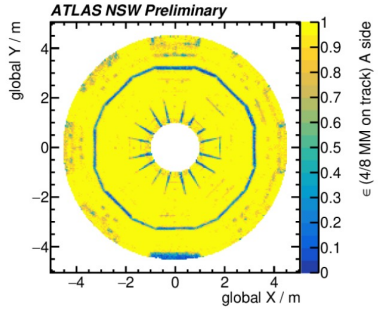


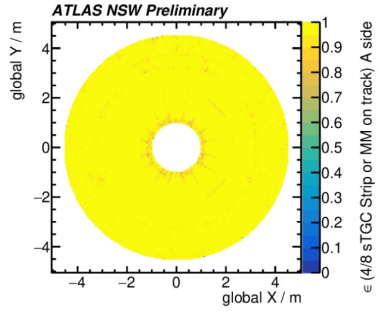




C







NSW is contributing to the muon track reconstruction in the ATLAS end-caps

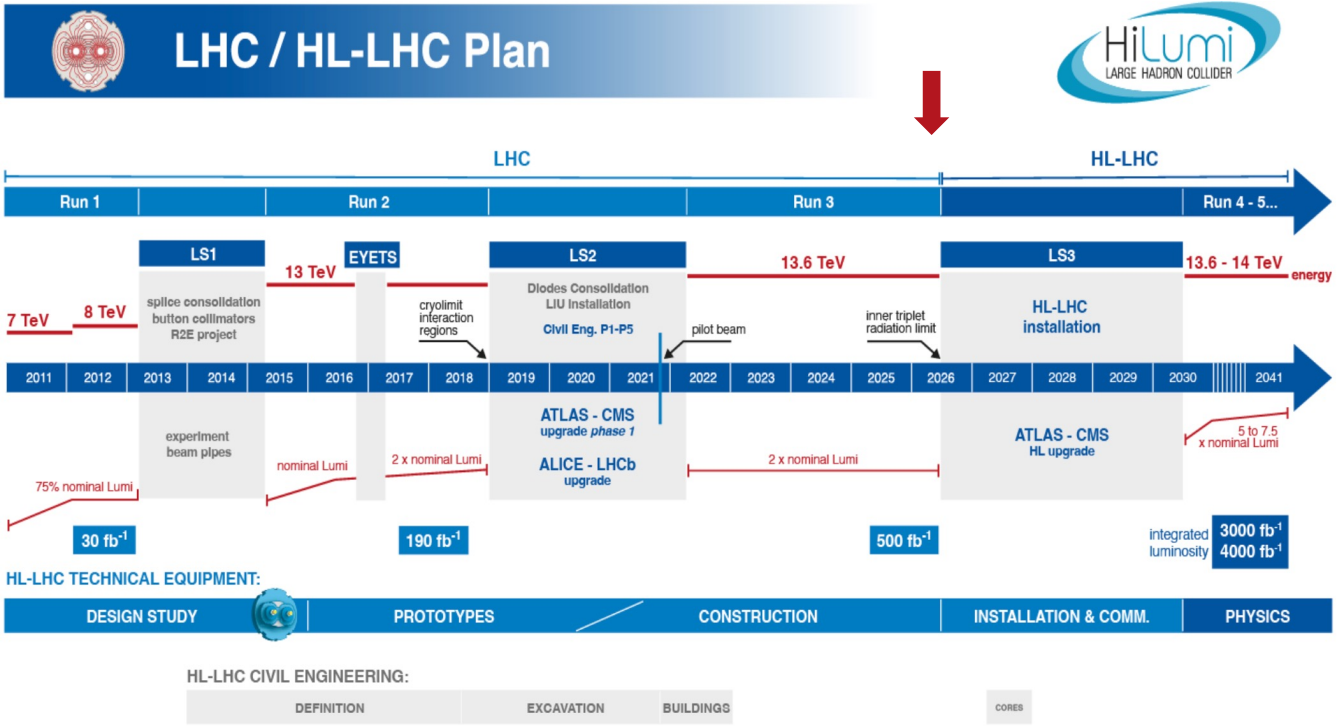
- Efficiency of having at least 4 out of 8 hit layers per detector
- Efficiency for track reconstruction defined as

  4 out of 8 MM OR 4 out of 8 sTGC.
- Even if the single technologies present some inefficiencies area, thanks to the designed redundancy, the NSW delivers excellent efficiency overall.
- The layer is considered efficient if a cluster is found within ±5 mm with respect to the extrapolated track position.

ATLAS EXPERIMENT

UPGRADES FOR HIGH-LUMI LHC

PHASE II UPGRADE



- Increased instantaneous luminosity of up-to 7.5 10^{34} cm^{-2} s^{-1}

=> higher trigger rate

- Up to 200 interaction per bunch crossing (pileup) on average

=> higher detector occupancy

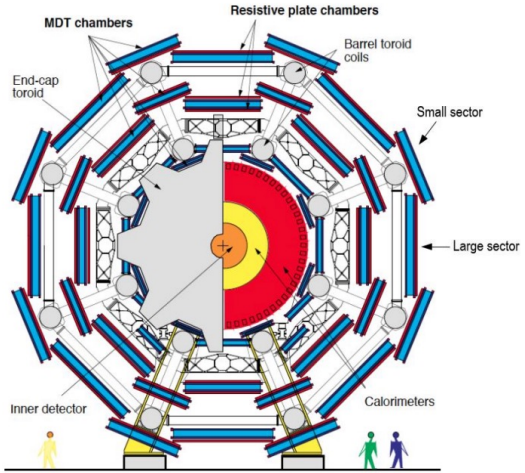
- Integrated luminosity up to 4000 fb-1

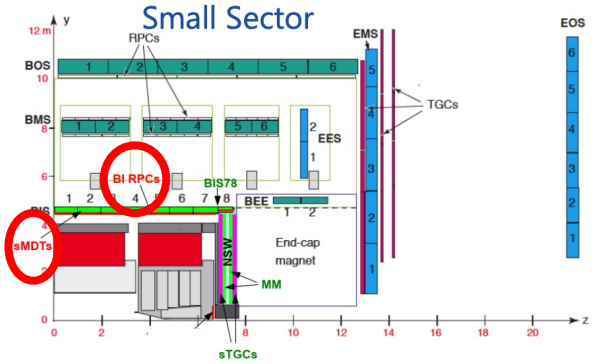
=> radiation hardness

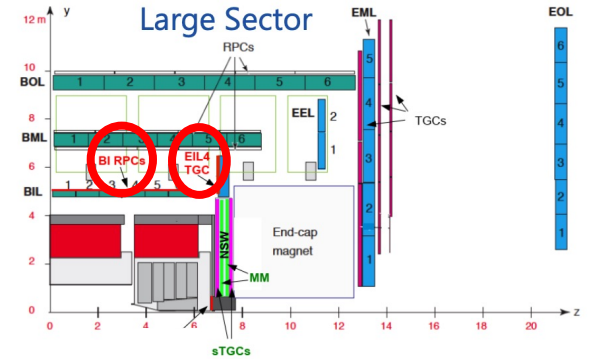
ATLAS EXPERIMENT

UPGRADES IN THE MUON SPECTROMETER

- Installation of small-diameter MDTs in high-occupancy regions
- Integration of MDT chambers in the new level-0 trigger
- New RPC chambers with 1 mm gas gaps in the inner barrel
- Replacement of TGC doublets with triplet chambers in the barrel–endcap transition region
- Power system completely renewed

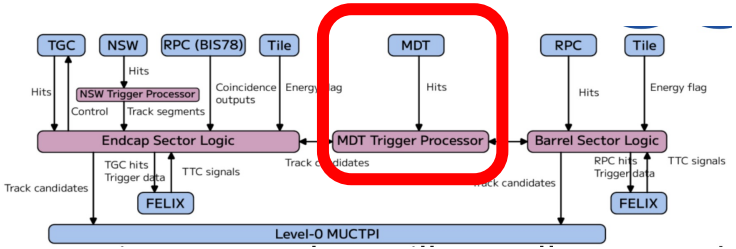


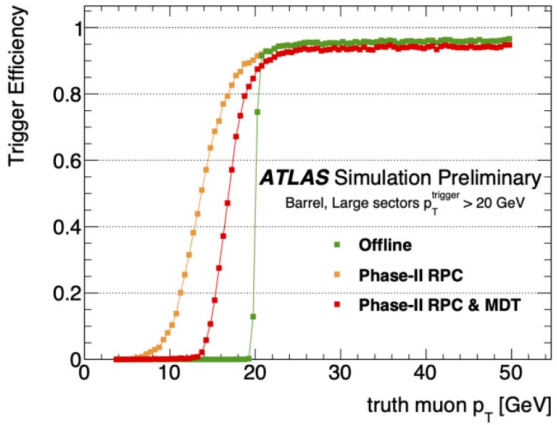




MUON "LEVEL-0" TRIGGER AND TRIGGER DAQ UPGRADE

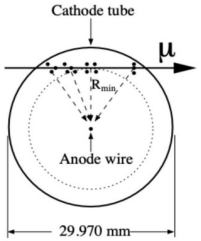
- Hardware based Level-0 Trigger: output rate upgraded from 100 kHz to 1 MHz, without changing existing thresholds
  - Trigger latency of ~10 μs (compared with the current 2.5 μs) allows for more complex trigger algorithms
  - MDT information will be included in the Level-0 muon trigger, refining the muon p_T measurement and reducing the trigger rate by making the trigger turning on curve steeper
  - MDT electronics will be replaced to cope with the new data taking
- Software based Event Filter (EF): trigger output rate upgraded from 1 kHz to 10 kHz
- Readout system to be upgraded to handle higher dataflow rates (up to 4.6 TB/s from detector, 60 GB/s from EF)

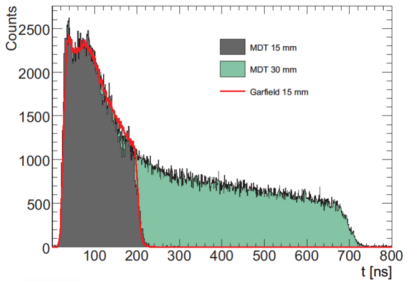




More in K. Todome's talk

S-MDT UPGRADE





- Monitored Drift Tubes (MDT) is the main tracking detector in both barrel and endcap
- sMDT has a reduced tube diameter (30mm => 15 mm)
  - maximum drift time is reduced from ~700 ns to ~200 ns
- Lower High Voltage: 3080 V → 2730 V
- Same gas mixture, gas pressure, and gain

Can sustain ~10 times higher rate

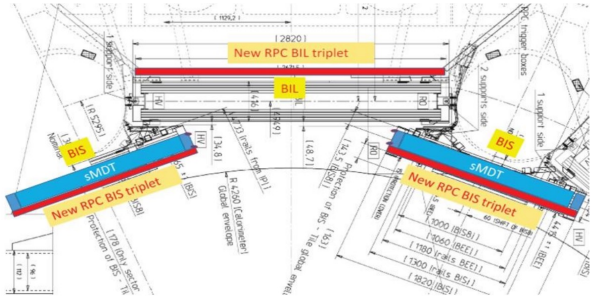
All chambers have been produced and certified for gas leaks, dark current and HV test

Ready for integration with RPC

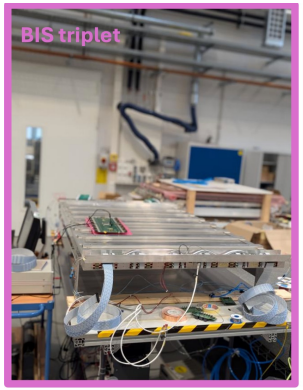
ATLAS EXPERIMENT

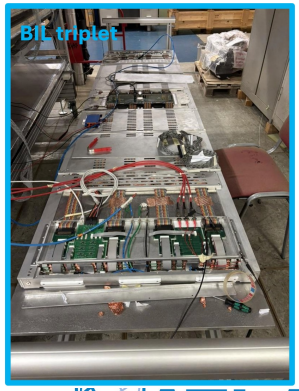
RPC

- Legacy RPC: To reduce possible ageing effect, plan to work at reduced gas gain → 15-35% efficiency loss
- New RPC triplets (1mm gas gap) will be added in the innermost muon layer (BIL 130 + BIS 96) except for the feet sectors => outer layers (80 BOMBOR)
  - Improve trigger performance
  - Increase barrel trigger acceptance from ~78% to ~96%
  - Improved intrinsic time resolution 1.1 ns → 0.4 ns
  - New frontend electronics with better signal amplification capability
- Production status
  - Gas volumes ~50% ready and tested
  - Readout strip panel for inner layers production completed
  - Singlet prepared ~15%
  - Mechanics being produced

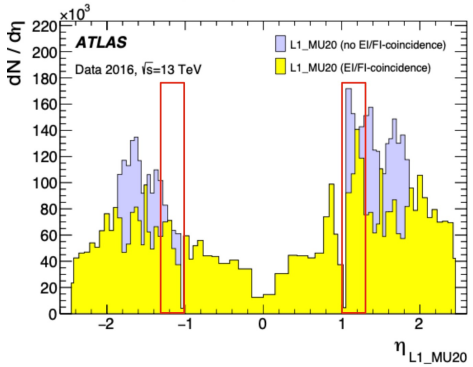


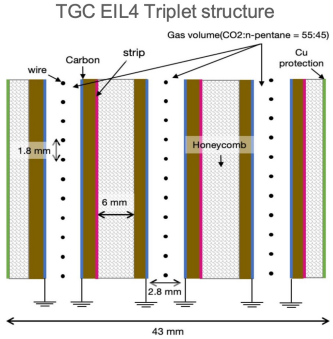
Modules 0 triplets ready and under test



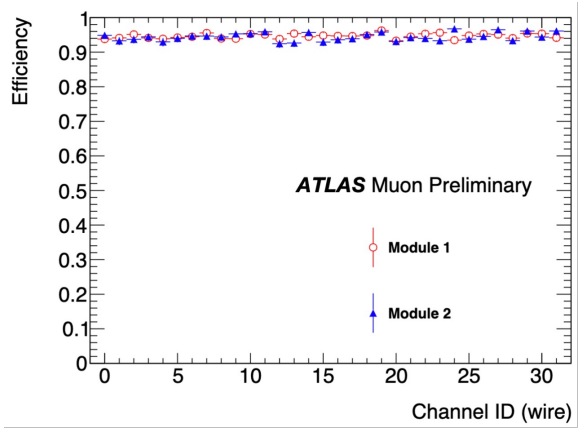


NEW TGC TRIPLET





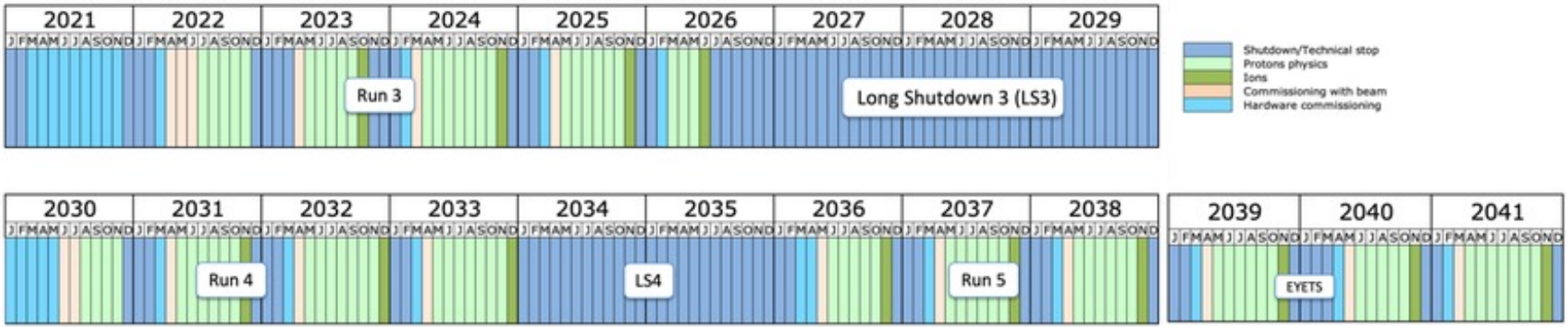
Pilot sector (3 chambers) installed in 2024-2025 YETS



- Thin Gap Chambers provides trigger in the forward region of the spectrometer and measures the track azimuthal angle (ϕ) with strip and polar angle (η) with wires
- Phase-II upgrade in EIL4 transition region between barrel and end-cap
  - New TGC triplet chambers inside the same envelope
  - Triplet structure enables a 2/3 majority trigger logic for enhanced reliability
  - 50 TGC triplets to improve trigger efficiency and fake rejection
- Production status:
  - All gaps show very low current, very low noise and stable operation.
  - Only a few missing channels were observed
  - 28 units were sent to CERN
  - 3 Units were already installed

OUTLOOK

- Significant effort and progress in all sub-projects
- Production is proceeding well. Some items are already complete
  - Limited contingency for some upgrade items, but important progress ongoing
  - Preparations are being accelerated toward the start of the LS3 installation
- Complex installation schedule in the coming years



BACKUP