UNIVERSITÉ HASSAN II DE CASABLANCA
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Commissioning of Phase-1 BIS78 upgrade pilot of the ATLAS Muon Spectrometer

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on behalf of the ATLAS Muon Collaboration

First Pan-African Astro-Particle and Collider Physics Workshop

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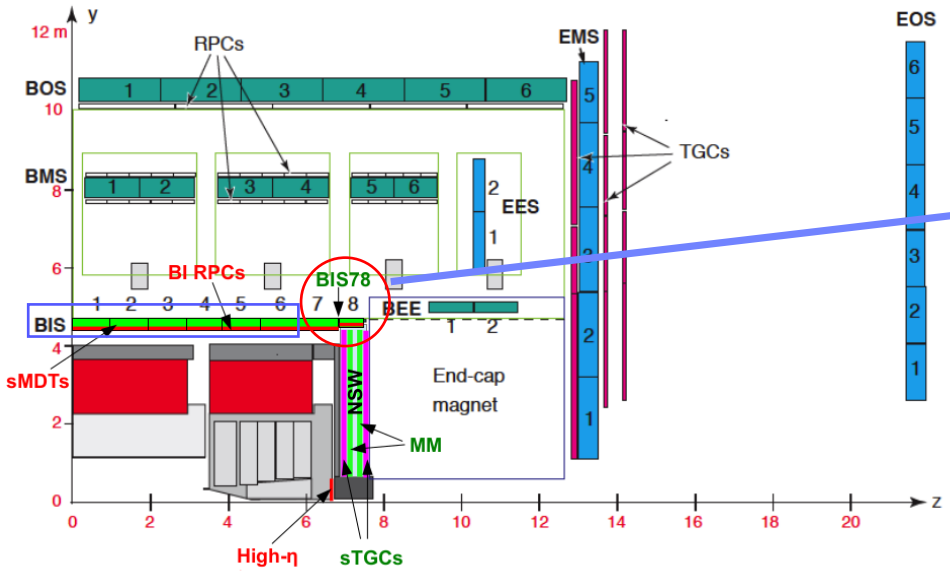
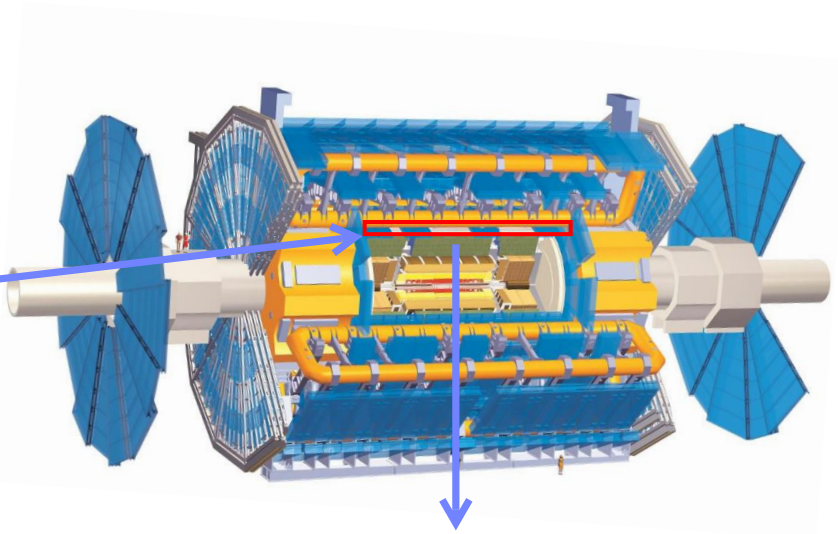
Upgrade of ATLAS Muon Spectrometer barrel inner region

- **Phase-2 upgrade for Muon Barrel Inner region:**
  Install new integrated chamber with small-diameter MDT (sMDT) and thin Resistive Plate chambers (tRPC) in place of the current Monitored Drift Tubes (MDT) chamber in BIS region
  ✓ Add one more trigger station to the barrel region of MS (from 3 stations to 4 stations)

- **BIS78 pilot project:** install 16 sMDT and 32 thin-RPC chambers in the transition region between barrel and endcap (at $1.0 < \eta < 1.3$) instead of 32 MDT chambers

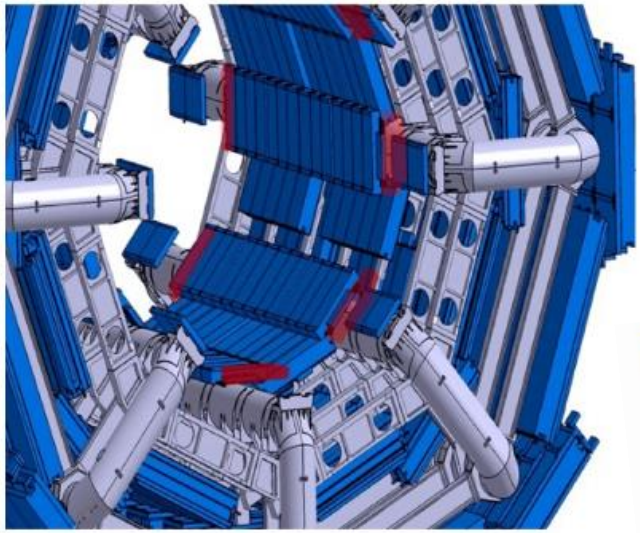




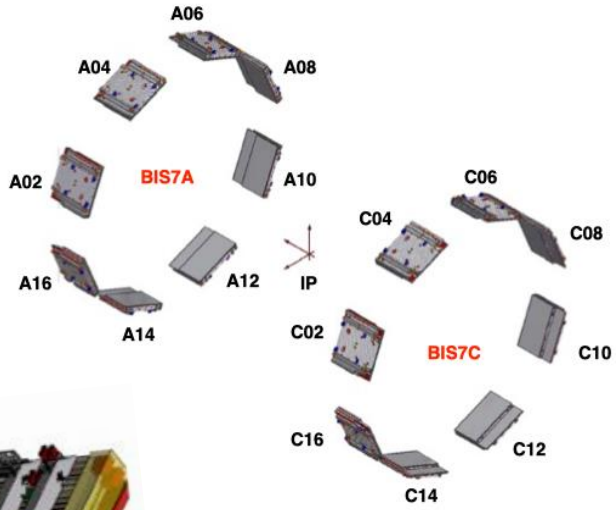
BIS1-6 (phase-2 upgrade) + BIS78 (pilot project upgrade)

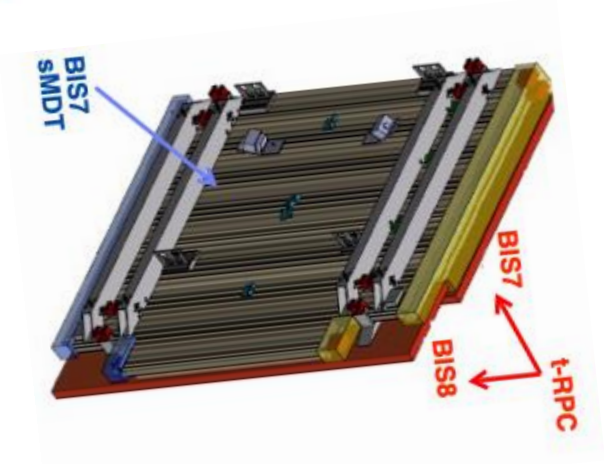
BIS78 phase-2 upgrade for the Muon spectrometer

- **BIS78 phase-1 upgrade serves as a pilot project for phase-2 upgrade**



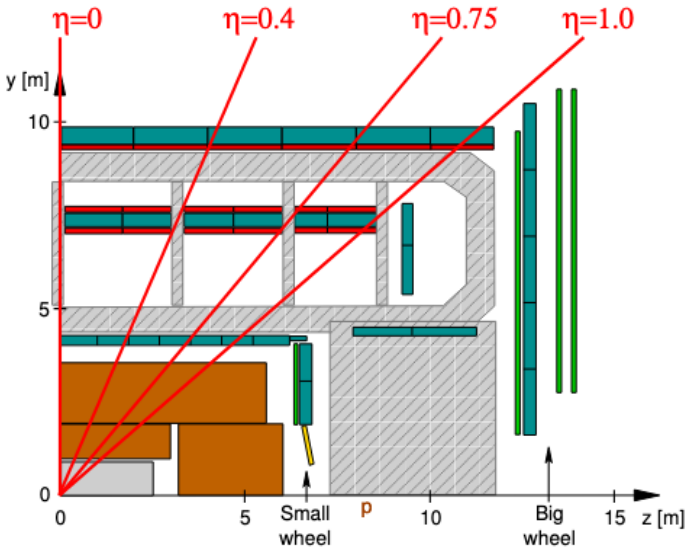
BIS7 chambers in side A already installed

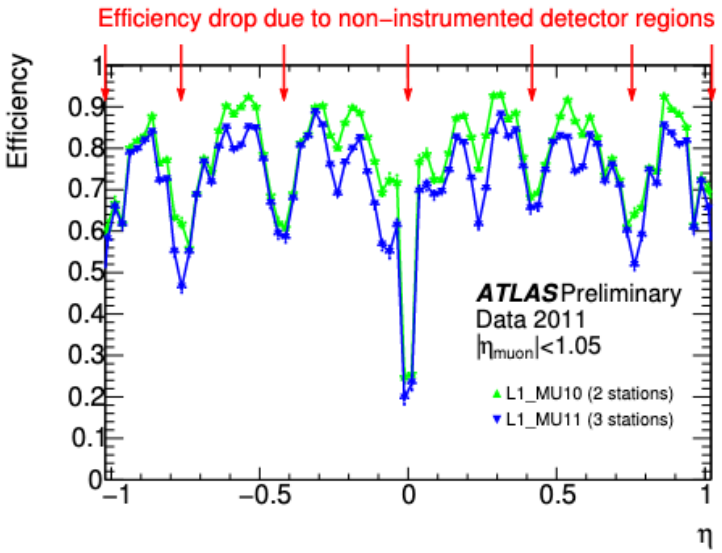




Eight sMDT and 16 tRPC chambers have been installed during the LS2

Barrel muon trigger coverage





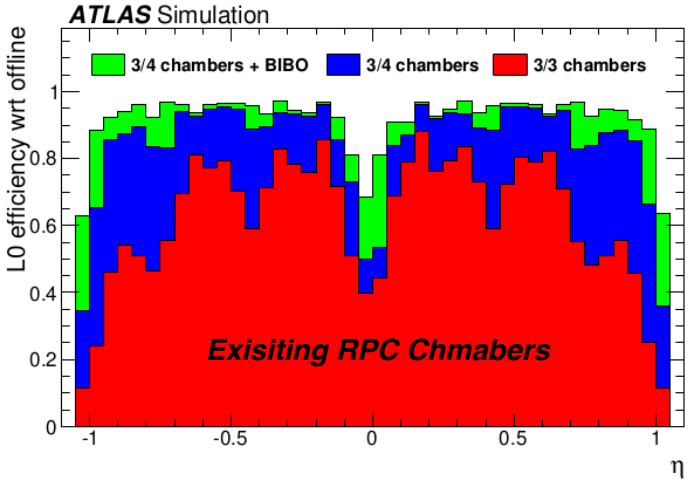
- The acceptance of high **pT** muon trigger is limited to **≈ 72%** due to non-instrumented regions of the muon spectrometer.

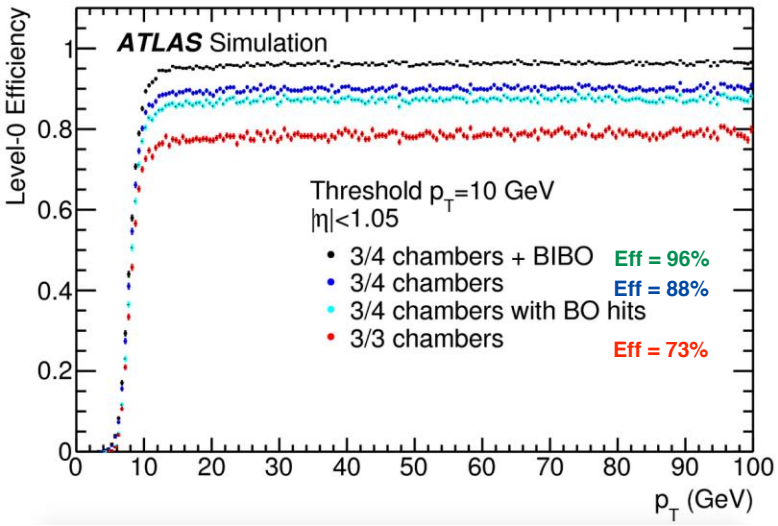
  - η =0: this region of the muon spectrometer is No-instrumented to provide space for services of the inner detector and the calorimeters

  - η =0.4, 0.75, 1.0: Non-instrumented region because of the toroid rib

Reinforcement of the barrel muon trigger

- New thin Resistive Plate Chambers (tRPC):
  - ✓ filling the acceptance holes due to the barrel magnet ribs
  - ✓ recuperate loss of efficiency for existing RPC trigger
- New samll diameter Monitored Drift Tube chambers (sMDT):
  - ✓ Free space for new tRPC chambers
  - ✓ Increase the background rate capability compared to the current MDTs
- **Selectivity improvement of the first-level muon trigger**
  - ✓ Including the sMDT information into LVL1 muon trigger to improve muon momentum resolution at the trigger level





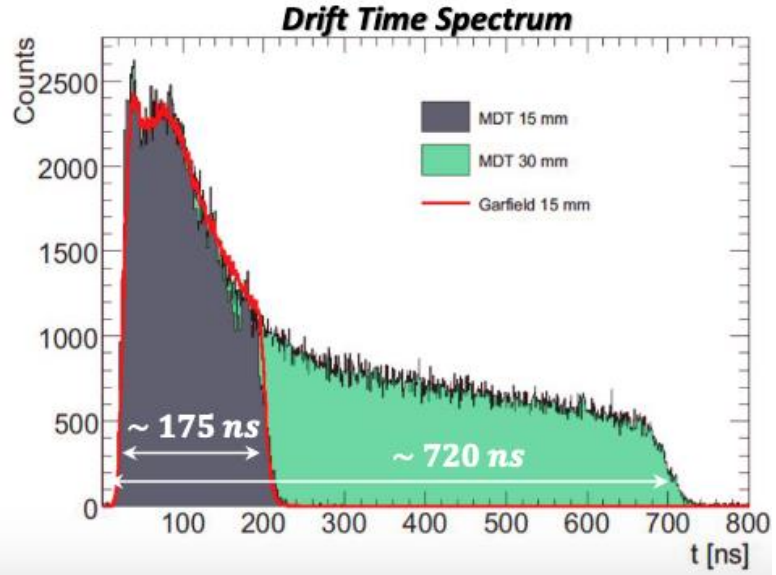
Overview of the BIS78 sMDT detector

➢ Improvement with respect to the current MDT detectors

- Reduce the chamber thickness with minimal loss of resolution
- Adding crucial trigger acceptance by allowing the insertion of tRPC trigger chambers
- 8 times lower background detector occupancy (factor of 4 from reduction of max drift time, and factor of 2 from smaller diameter)
- 4 times lower electronics dead time (= maximum drift time)

30mm (MDT) **15mm (sMDT)**

Characteristics	MDT	sMDT
Operating gas mixture	Ar:CO2 (93:7)	Ar:CO2 (93:7)
Operating Pressure	3 bar	3 bar
Operating HV working point	3070 V	2730 V
Gas gain	2 x 10^4	2 x 10^4
Maximum drift time	~ 720 ns	~ 175 ns
Single tube space resolution	83 ± 2 µm	106 ± 2 µm



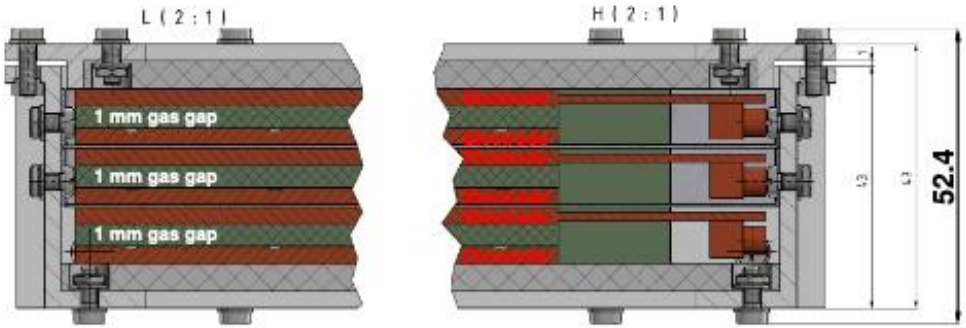
Overview of the BIS78 tRPC detector

Improvement with respect to the standard RPC detectors

- Thinner gas gap ⟹ improved time resolution
- Reduced thickness and weight ⟹ easier installation
- Almost one half the current operating voltage
- New Front-End electronics ⟹ Improved rate capability
  - **Rate capability up to 10 kHz/cm2**

Characteristics	Standard RPC	tRPC
Gap thickness [mm]	2	1
Electrode thickness [mm]	1.8	1.2
Number of gas gaps	2	3
HV	9600	5800
Time resolution	1 ns	0.4 ns

Gas = C2H2F4 (94.7%) + iso-butane C4H10 (5.0%) + SF6 (0.3%)



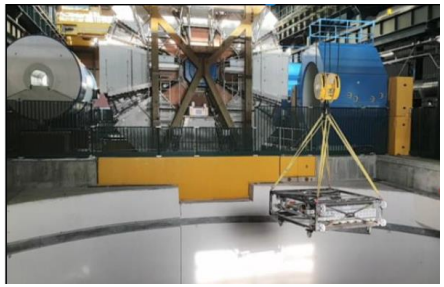
Very challenging space constraints:

- ~5 cm space for a triplet of 1 mm gas gaps

Installation of BIS78 sMDT-tRPC chambers in ATLAS Point-1

The first BIS78A Detector has been successfully installed to the A04 sector of the ATLAS Muon spectrometer on 17 th of September 2020

Lowering

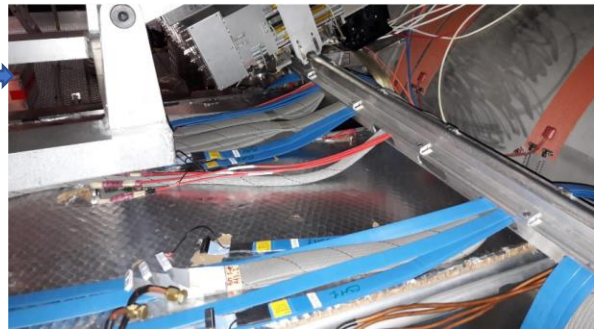


Installation

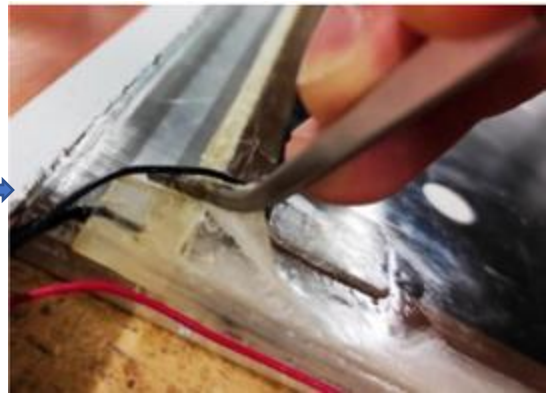
Multiple challenges were faced during the installation

- Cables go through the new holes on supporting rails to avoid interference with BIL6A13 movement

Rearrange BIS7A12/14 Cables



- Gas leak found on one layer of tRPC station extracted from cavern and repaired on the surface



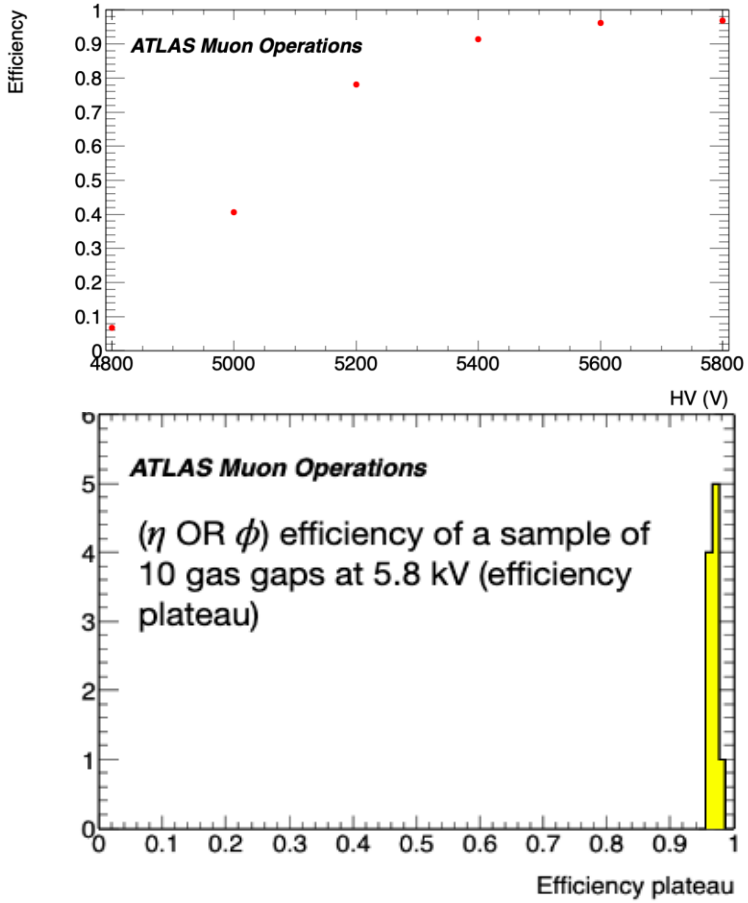
- Cable conflicts in some sectors

BIS78 t-RPC Performance

➢ Singlet efficiency curve of a BIS7 chamber obtained using cosmic rays

- The curve is obtained considering the logical OR of the two read-out planes (η or Φ)

- Ongoing measurement of the efficiency with data collected with cosmic trigger (new results expected in the ongoing Milestone week: M12)

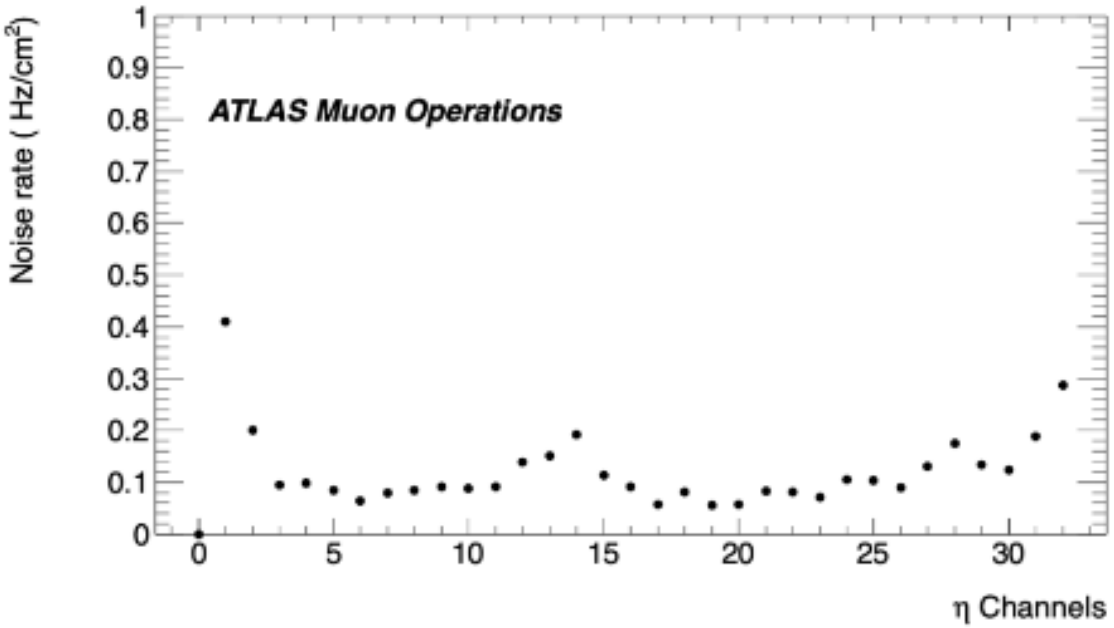


➡ **The efficiency plateau value is uniform over the production**

BIS78 t-RPC Performance

➢ Electronic and chamber noise rate map at the 5.8 kV for a BIS7 singlet

- The noise rate is measured by using a random trigger and keeping the detector at fixed voltage.
- The noise rate is evaluated by counting the number of the efficient events in a given time window.

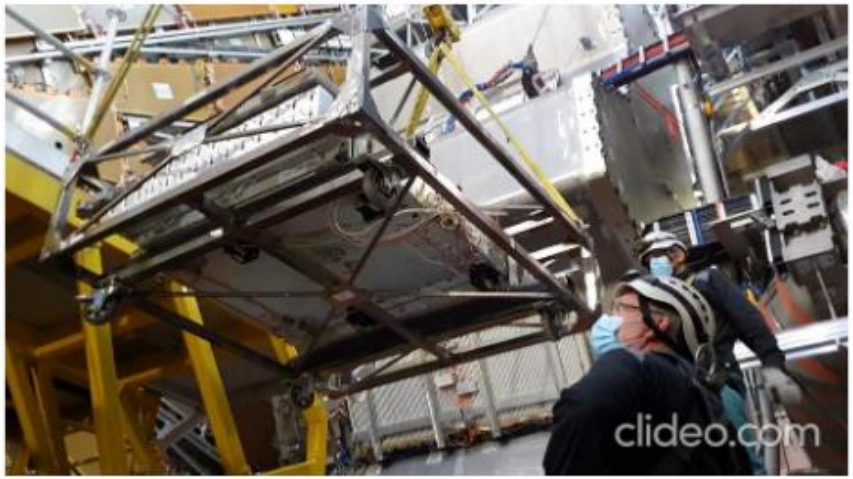


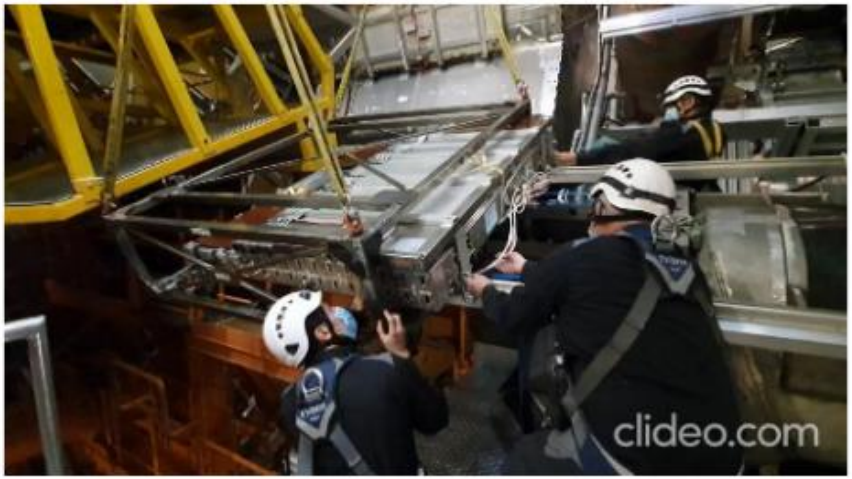
- The total counted events are normalized channel by channel to the whole time window acquired and to the strip surface. Noise rate < 1Hz/cm^2

BIS78 sMDT detectors commissioning

- **The new BIS7A sMDT modules had been successfully integrated into the ATLAS combined system:**
  - ✓ Integrated new sMDT chambers into MDT configuration DB
  - ✓ Integrated new sMDT chambers into MDT DCS, TDAQ and online monitor GNAM
  - ✓ No gas leak on sMDT+tRPC chambers seen
  - ✓ All sMDT BIS7A Chambers under nominal HV 2730V and nominal LV
  - ✓ Read-out system on 8 sectors configured
  - ✓ Front-end electronics in normal ranges
  - ✓ Stable long DAQ without any mezzanine and chamber drop

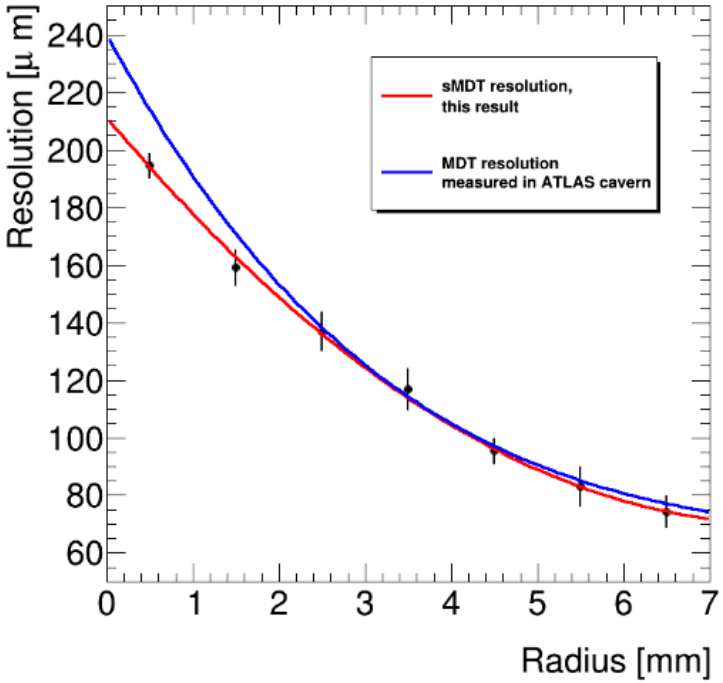
BIS7A module in the ATLAS cavern

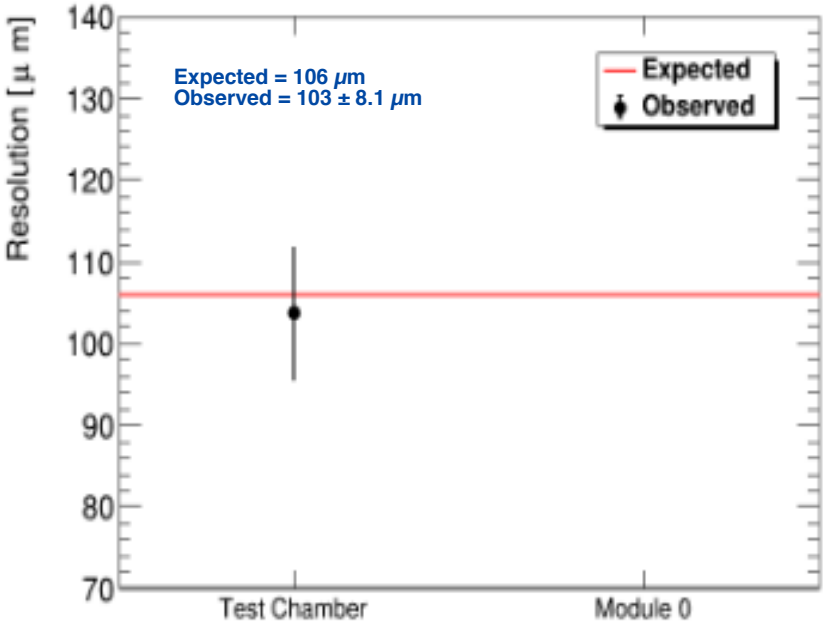




BIS7 sMDT Performance

- **Observed resolution for single-hit as a function of radius, with all corrections applied and measured under the same operating conditions**

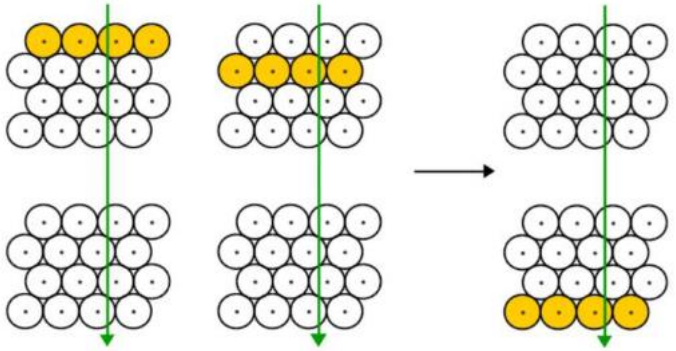




- **Ongoing measurement of resolution with data collected from sMDT BIS7A modules by muon triggers**

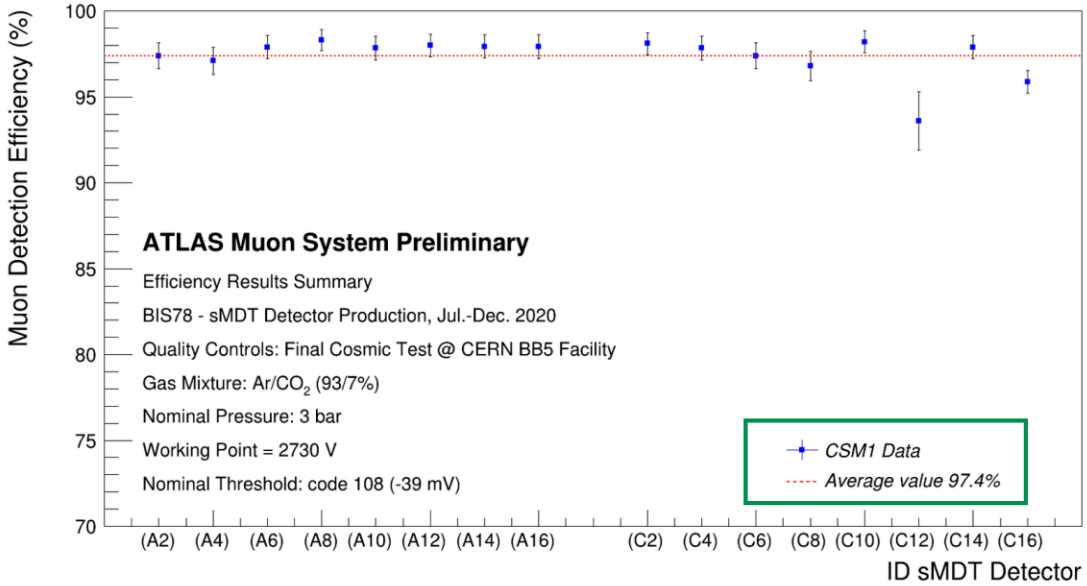
BIS78 sMDT Performance

➢ **The efficiency of each tube of a chamber was measured using tracks of muons from cosmic rays**



- Procedure for tube efficiency measurement:
  - ✓ Exclude one layer
  - ✓ Reconstruct muon track with the remaining hits
  - ✓ Measure the efficiency on the excluded layer

✓ Tube efficiency is computed as: the number of hits matched the track over the number of track crossing the tube: $Eff_{tube} = N_{hit}/N_{trk}$

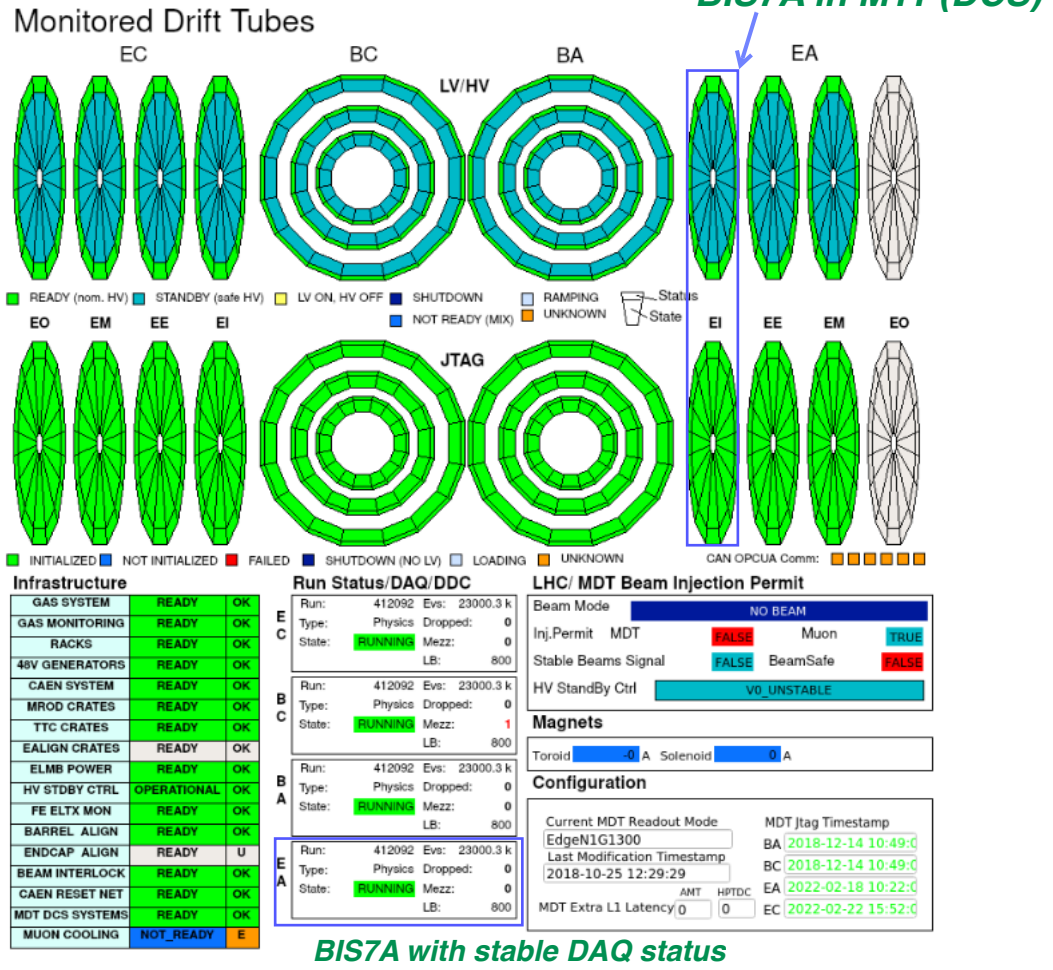


BIS78 sMDT in the ATLAS combined runs

- **All installed sMDT BIS7A chambers have been checked and included in the the last Milestone week (M11) on February 2022.**

- ✓ Chambers ran smoothly during various combined runs, where most of the ATLAS sub-systems were included
- ✓ All relevant-components were carefully investigated through the runs, including DAQ and DCS.
- ✓ Looking forward to study BIS7A sMDT chamber performance from cosmic rays triggered by muon triggers.

BIS7A in M11 (DCS)



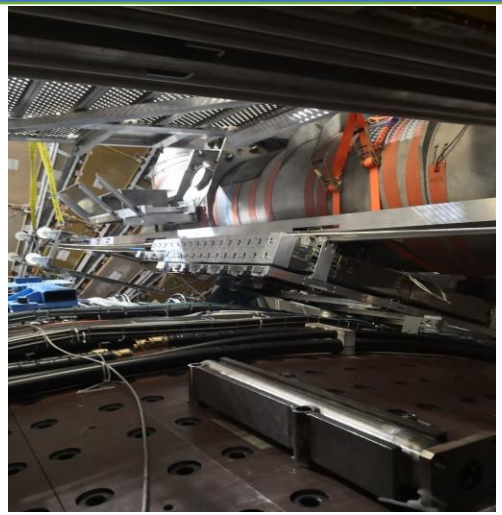
BIS7A with stable DAQ status

Conclusion

- **8 BIS78 sMDT and 16 t-RPC chambers have been installed in the BIS of the Muon Spectrometer during the Long Shutdown 2 (from 2019 to 2022)**
- All modules have been validated and commissioned in the surface before their installation in the ATLAS cavern

- **BIS78 t-RPC:**
  - ✓ Read-out electronics and PSs have been validated
  - ✓ Chambers performance meet the expectation

- **BIS78 sMDT:**
  - ✓ Chambers have been successfully integrated into the ATLAS DB, DCS and DAQ
  - ✓ Checked tube mapping and cable connection using data collected from standalone runs by random trigger
  - ✓ Detectors have been included in many milestone runs and ran smoothly for long period
  - ✓ Good resolutions and efficiencies as expected
- **Performance studies with cosmic tracks ongoing**

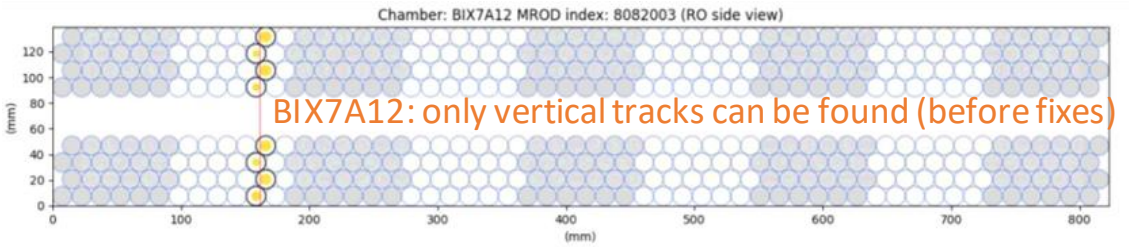


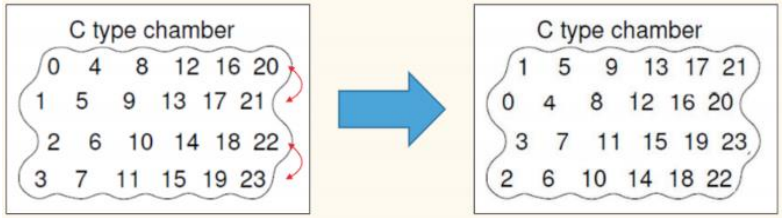
BACKUP

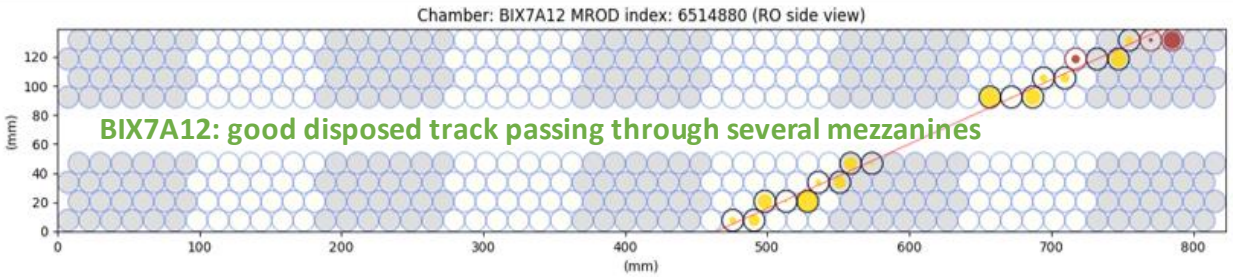
BIS78 sMDT tube Mapping

➢ Tube mapping and cable connection have been checked with cosmic tracks

- ✓ BIS7A12 wrong tube mapping found
- ✓ Swapping odd-numbered layer with even-numbered layer fix the problems
- ✓ with new map, good tracks with slopes on BIS7A12 are found and normal statistics of cosmic tracks
- ✓ Now all BIS7A chambers tube mapping and cables connection with cosmic tracks are as expected

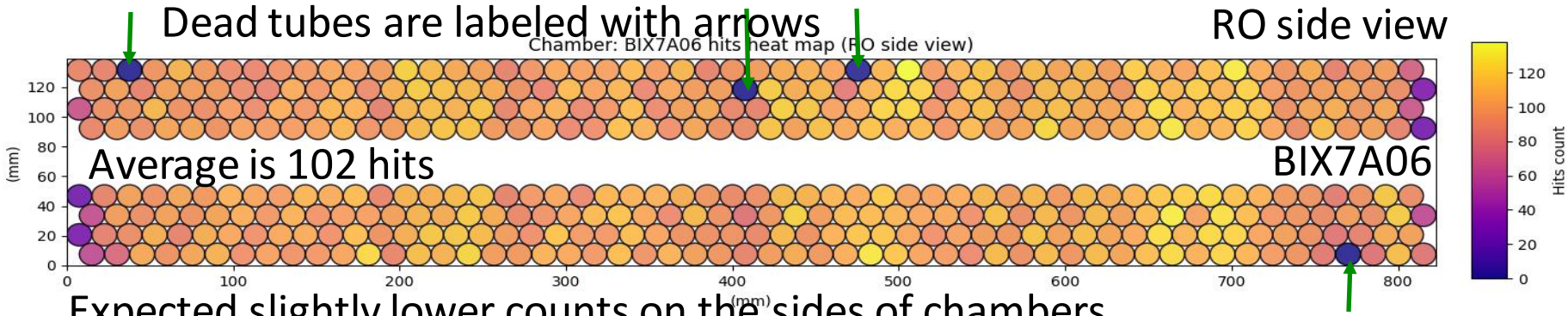






Investigating Dead tubes on BIS78 sMDT chambers

- Used data collected by **random triggers** to check dead tube with **hit rates** and **hit counts** on cosmic tracks



In total, 28 out of 5472 dead tubes have been found over all installed tubes (0.5%)