Upgrades of the ATLAS muon spectrometer with new small-diameter drift tube chambers

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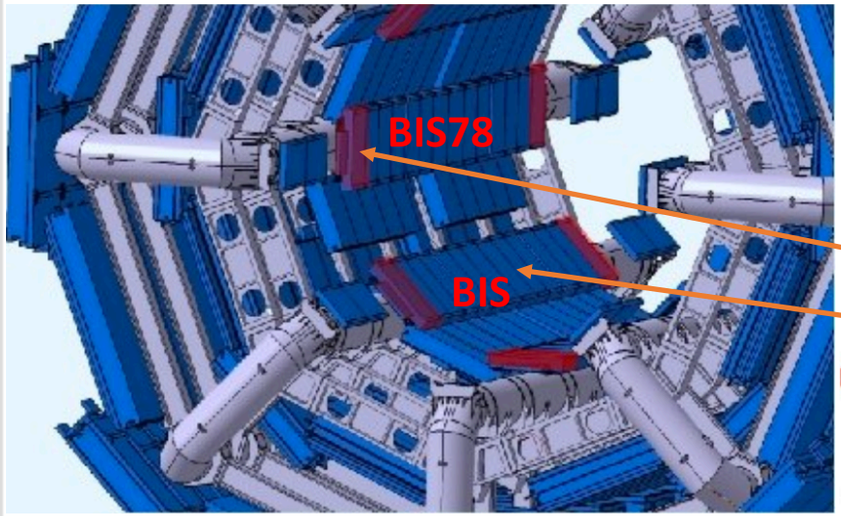
Introduction

The goal of the upgrades of the ATLAS muon spectrometer with new small-diameter (15 mm) Monitored Drift Tube chambers (sMDT) are to make room to install new triple-Restive Plate Chambers (t-RPC) in the inner barrel muon stations to increase the trigger efficiency in the barrel region and to improve the rate capability of the muon chambers in the regions of high background corresponding to the HL-LHC project. Eight new sMDT chambers (sMDT BIS7A) will be installed in the long shutdown 2 (LS2) in the transition region (1 < |eta| < 1.3) between Barrel and Endcap of the muon spectrometer as a pilot project for the whole replacement of the MDT chambers in the small azimuthal sectors of the barrel inner layer (BIS1-6) by new sMDT+t-RPC detectors in the long shutdown 3 (LS3).

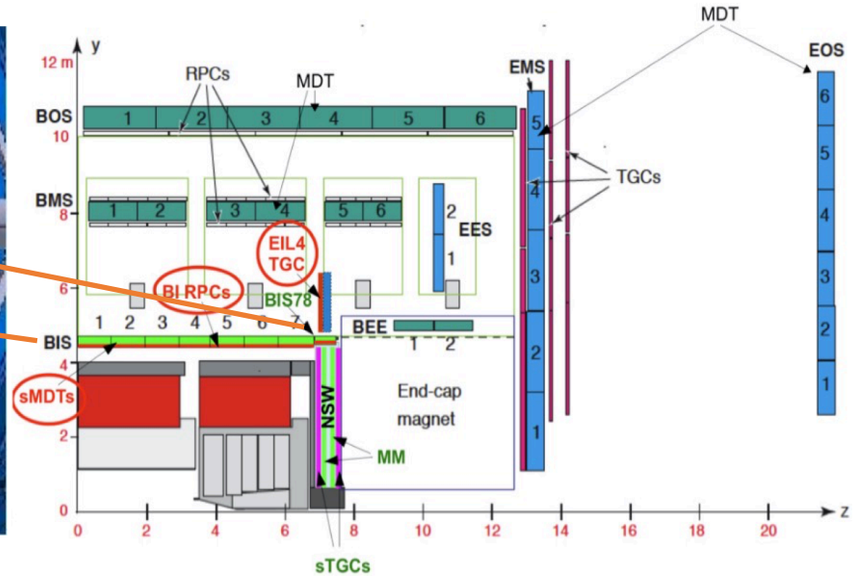
Improvement with respect to the current MDT chambers:

- sMDT chambers developed with half the drift-tube diameter of the current MDT chambers (30 mm):
  - ✓ Reduces the chamber thickness with minimal loss of resolution
  - ✓ Permitting the insertion of t-RPC trigger chambers adding crucial trigger acceptance
  - ✓ With insertion of new t-RPC chambers the geometrical acceptance in the barrel region will increase from 75% to 95%
- sMDTs have 8 times lower background detector occupancy compared to MDTs (factor of 4 from reduction of max drift time, and factor of 2 from smaller diameter)
- Electronics dead time decreased by four times (from 750 ns to 175 ns)
- sMDT operated with Ar:CO2 gas at 3 bar and at HV = 2730 V

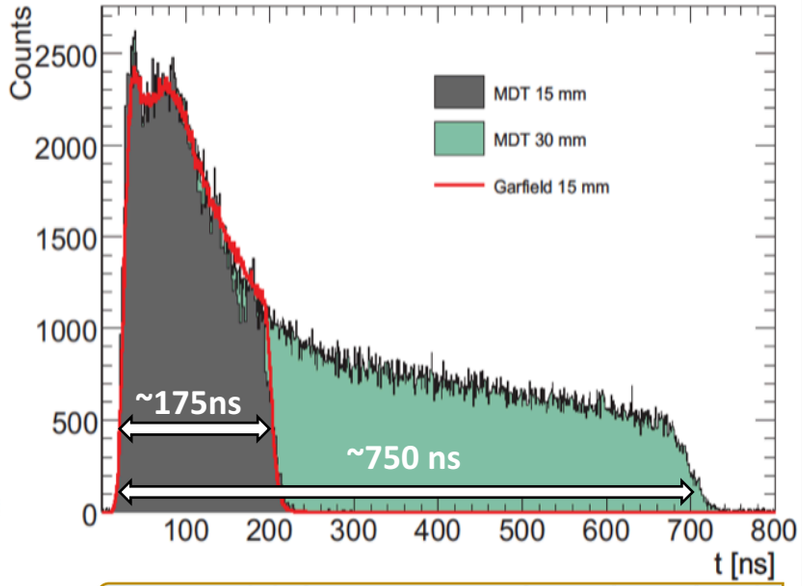
[1]



BIS78 in phase-1, highlighted in red



Cross-section of ATLAS muon spectrometer with new detector

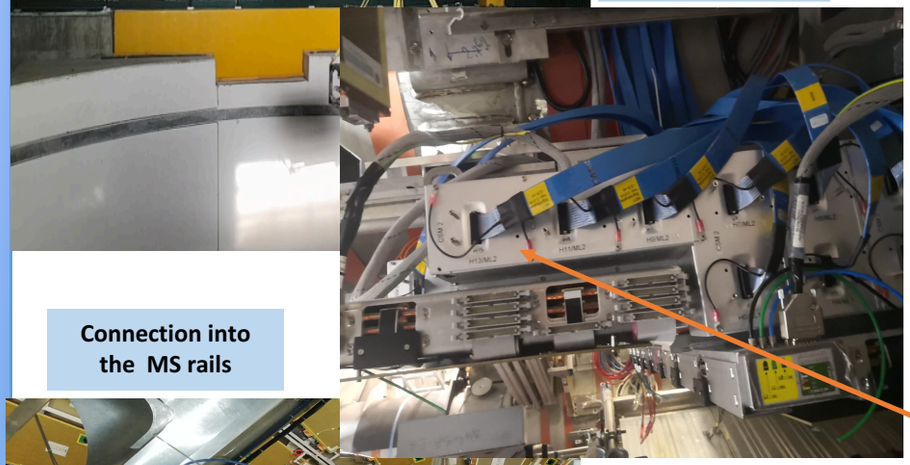


Measured drift time spectra of MDT (green) and sMDT tubes (grey) [1]

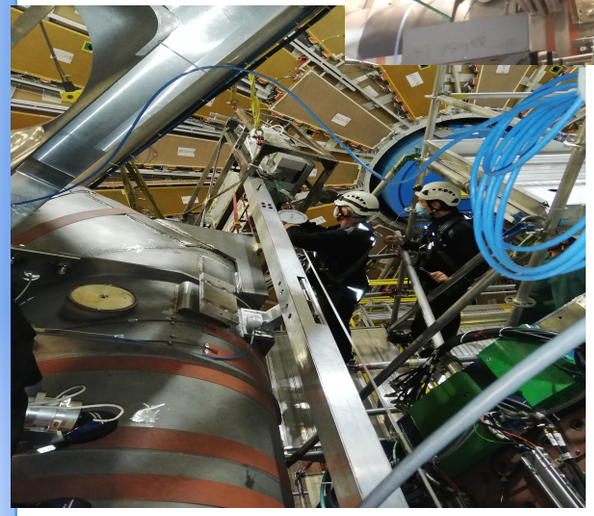
sMDT BIS7 Installation @ ATLAS cavern

Lowering to ATLAS cavern

@Final position



Connection into the MS rails



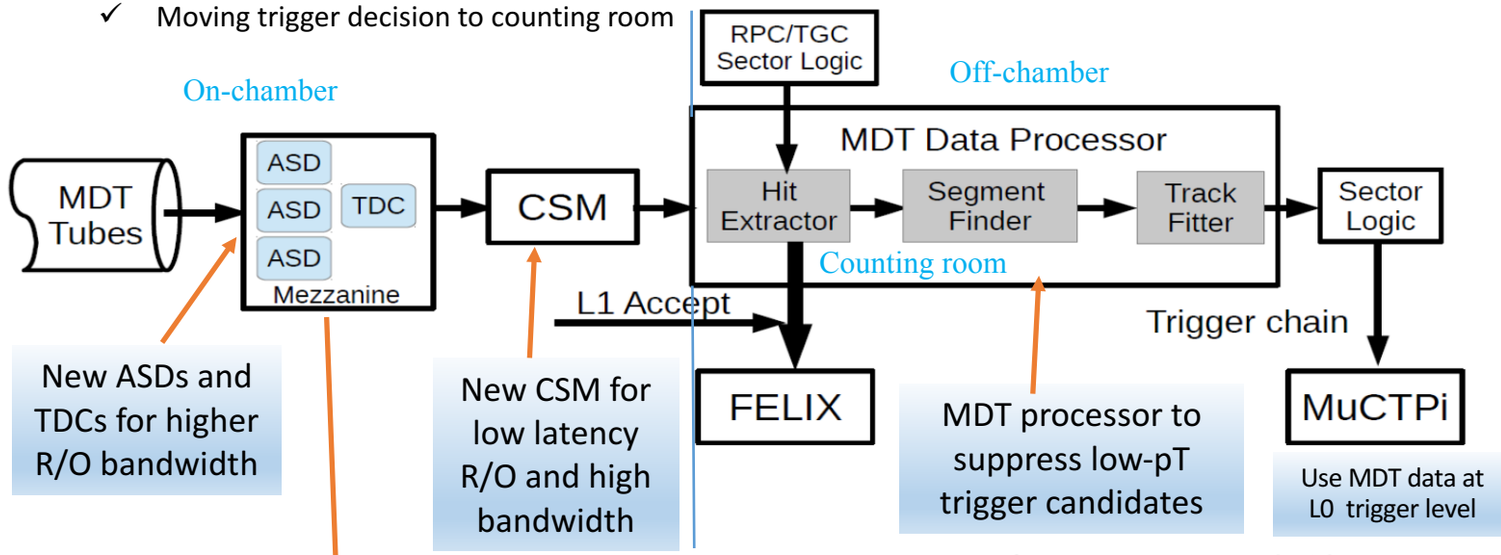
sMDT trigger and read-out electronics for HL-LHC

Phase-I: MDT, sMDT and Trigger chambers are read out independently

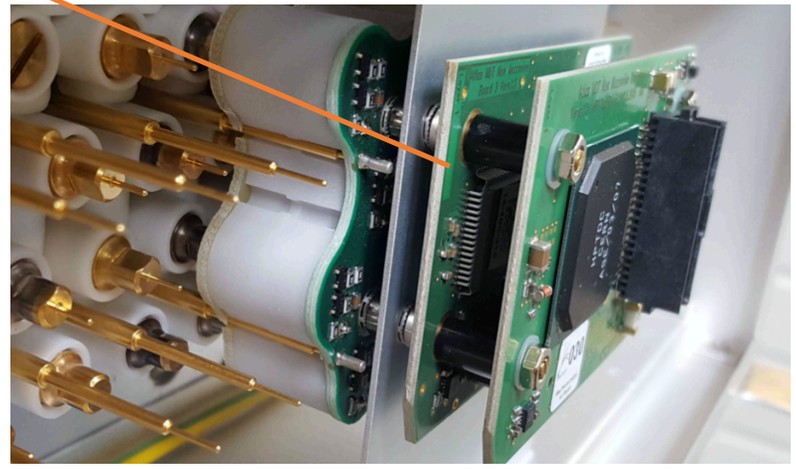
- ✓ MDT/sMDT R/O only on L1 trigger, saving bandwidth
- ✓ Trigger chambers use hardware logic at the frontend to select trigger candidates

Phase-II: MDT data are used to sharpen the trigger decision (Pt > 20Gev):

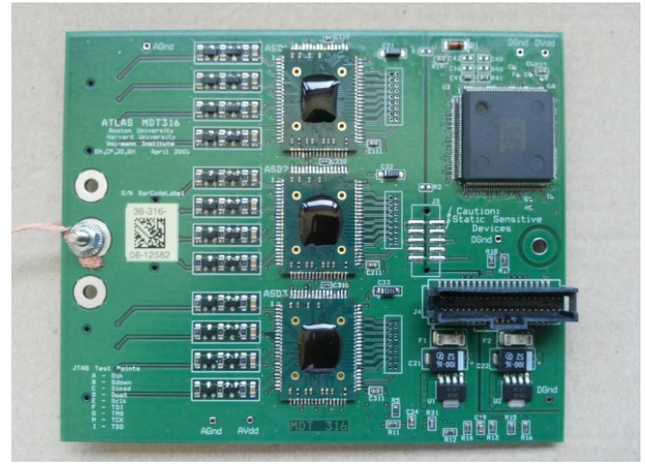
- ✓ Find accurate pT using ROI seed from trigg. ch's and confirm/reject trigger hypothesis
- ✓ Moving trigger decision to counting room



sMDT mezzanine card



Prototype of sMDT mezzanine card with 3 ASDv5 chips, serving 24 sMDT channels



sMDT BIS7 Commissioning status

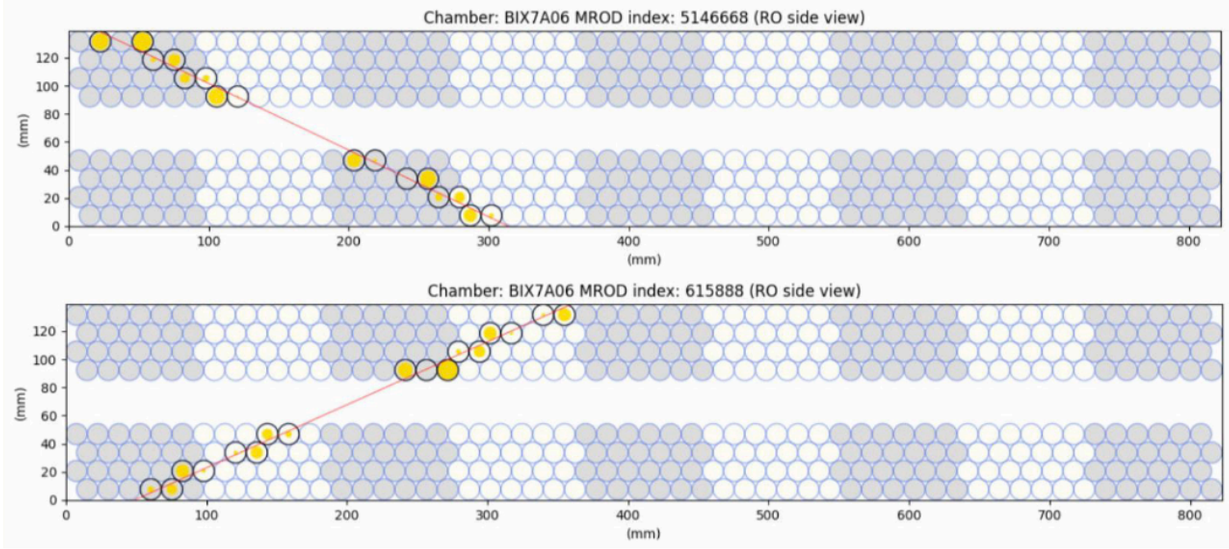
Chamber	Gas	HV	Align.	RDout	B-s	T-s	FE V-s	FE T-s	JTAG	DAQ
BIS7A02	✓	✓	✓	BIX7A02	✓	✓	✓	✓	✓	✓
				BIY7A02	NA	NA	✓	✓	✓	✓
BIS7A04	✓	✓	✓	BIX7A04	✓	✓	✓	✓	✓	✓
				BIY7A04	NA	NA	✓	✓	✓	✓
BIS7A06	✓	✓	✓	BIX7A06	2 - to be fixed	✓	✓	✓	✓	✓
				BIY7A06	NA	NA	✓	✓	✓	✓
BIS7A08	✓	✓	✓	BIX7A08	✓	✓	✓	✓	✓	✓
				BIY7A08	NA	NA	✓	✓	✓	✓
BIS7A10	✓	✓	✓	BIX7A10	✓	✓	✓	✓	✓	✓
				BIY7A10	NA	NA	✓	✓	✓	✓
BIS7A12	✓	✓	✓	BIX7A12	✓	✓	✓	✓	✓	✓
				BIY7A12	NA	NA	✓	✓	✓	✓
BIS7A14	✓	✓	✓	BIX7A14	✓	✓	✓	✓	✓	✓
				BIY7A14	NA	NA	✓	✓	✓	✓
BIS7A16	✓	✓	✓	BIX7A16	✓	✓	✓	✓	✓	✓
				BIY7A16	NA	NA	✓	✓	✓	✓

B/T/V-s: B/T/V-sensors, NA : Not Apply

- Found BIX7A06 B-sensor 3 dead (resulted in bad readout on all B-sensors and T-sensors which pointed to a bad MDM) after scaffolding dismount ➔ disconnected the B-sensor cable #1 ➔ 2 B-sensor no readout

Cosmic ray event display from pit commissioning

Yellow circles show tube drift circles and red lines present reconstructed tracks

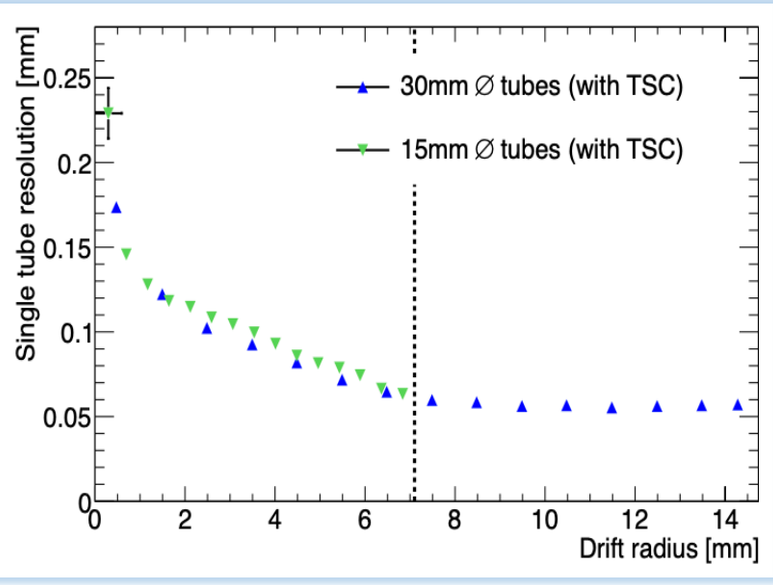


- All installed sMDT chambers were checked with nominal HV of 2730 V
- Each mezzanine recorded at least one track passing through it, and most tracks pass through two multilayer as expected.
- Noise level low (typical cosmic track is pretty clean without extra noise hit)
- Validated sMDT tube mapping and front-ends connections

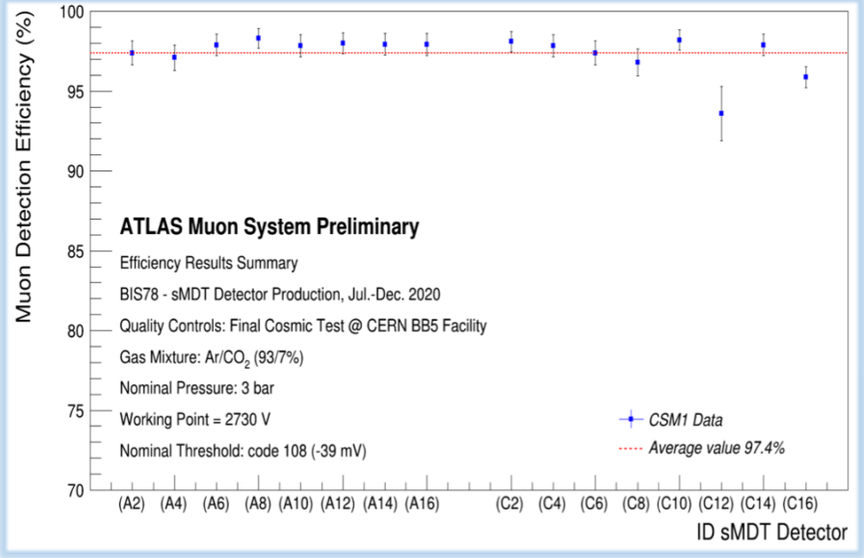
sMDT detectors performance

- Spatial resolution after time-slewing corrections (TSC) , measured under the same operating conditions in the high energy muon beams at CERN without background irradiation
- As expected, the results for 15 and 30 mm diameter tubes are in good agreement for drift radii below 7.5 mm.

sMDT/MDT single tube Resolution [2]



sMDT BIS7A/C chambers efficiency [3]



- Muon track is reconstructed by excluding one layer of tubes
- The efficiency of each tube of a chamber was measured using tracks of muons from cosmic rays
- Inefficient or Dead tubes were noted down in the tube database
- Average drift tube muon detection efficiency of 16 - BIS78 sMDT detectors obtained during the final commissioning test at CERN BB5 is (97.4 +/- 0.2)%

Summary

- 8 sMDT BIS7A chambers were installed into the rails of the Muon Spectrometer
  - All of them have been commissioned and integrated into MDT DAQ and worked well.
  - Plan to take cosmic ray data together with RPC trigger chambers during one of 2021 ATLAS TDAQ milestone weeks to study those sMDT chambers performance before RUN3.

References

- [1] ATLAS Collaboration, ATLAS-TDR-026, https://cds.cern.ch/record/2285580/
- [2] ATLAS Collaboration, Nucl. Instrum. Meth. **A 732** (2013) 250
- [3] ATLAS Collaboration, https://cds.cern.ch/record/2771332