

Upgrade of the ATLAS Muon Spectrometer with high-resolution Drift Tube Chamber (sMDT) for LHC Run-3



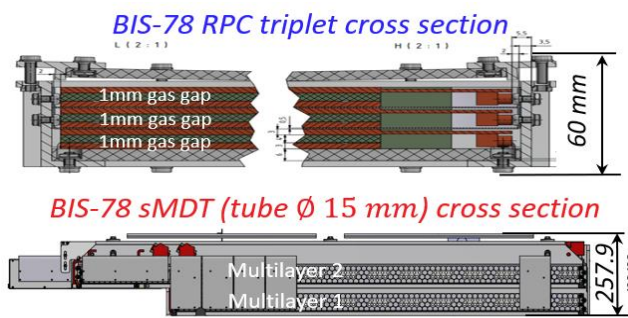
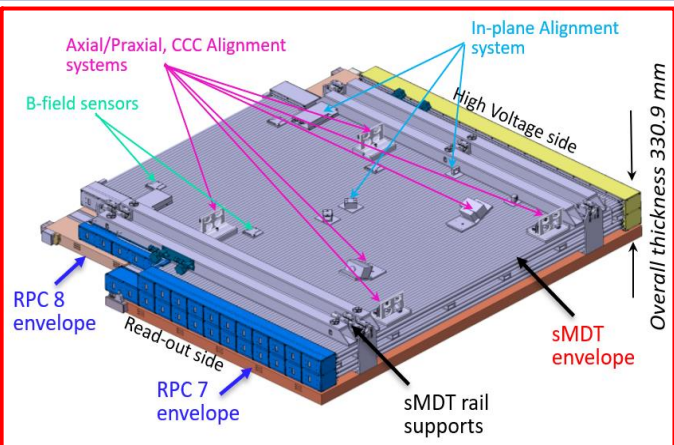
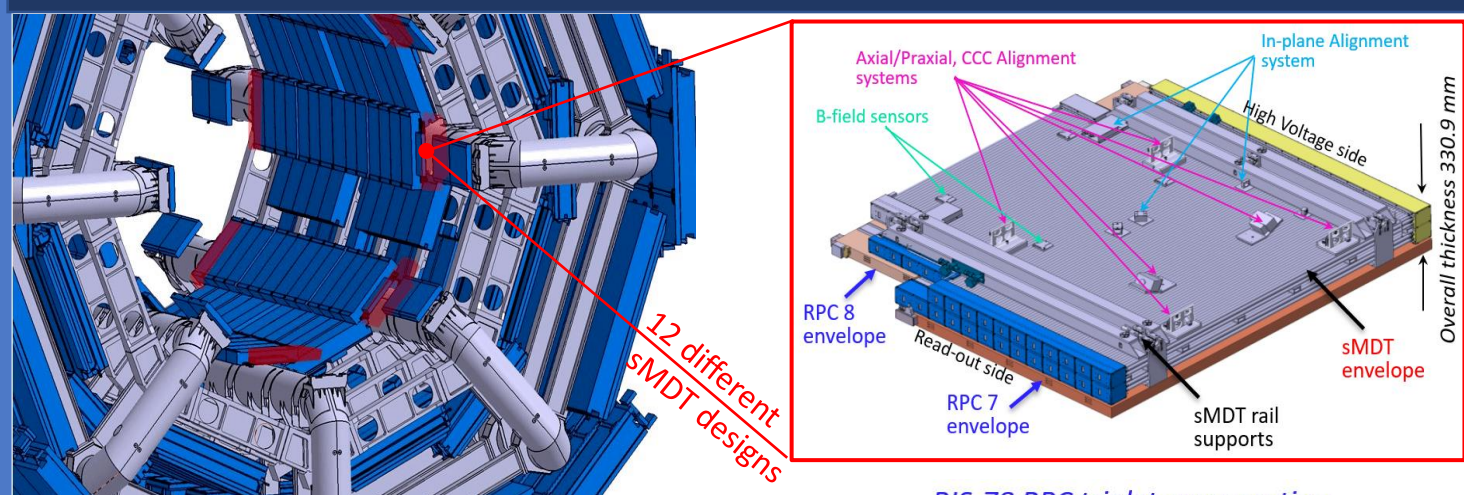
E.Voevodina¹ on behalf of ATLAS Muon Collaboration
¹ Max-Planck-Institute for Physics, Munich (Germany)



Max-Planck-Institut für Physik
 (Werner-Heisenberg-Institut)



New ATLAS Muon Stations for LHC Run-3 (2022/24)

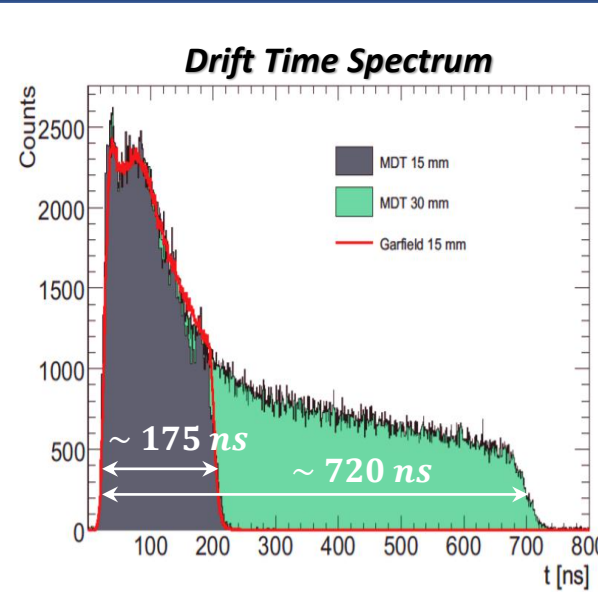


➤ **Layout - 8 new muon stations:**
 16 new **Resistive Plate (RPC)** muon trigger chambers in combination with 8 new **small Monitored Drift Tube (sMDT)** precision muon tracking detectors

➤ **Motivation:**
 sMDT + RPC muon stations will reinforce the fake muon rejection and the selectivity of the muon trigger in the transition region between the ATLAS barrel and endcap $1.0 < |\eta| < 1.3$ for Phase-I (-II)

➤ **BIS78 pilot project** for the Phase-II upgrade of the barrel inner layer:
Aim is to validate the final mechanical installation procedure, verify the services previously installed in the ATLAS cavern, and to obtain early feedback about the front-end electronics response and detection performance.

sMDT Design & Improvements



sMDT baseline parameters		
Properties	MDT	sMDT
Tube Diameter	30 mm	15 mm
Wire & Tube Wall	50 μm W-Re & 400 μm	
Number of tube layers	4	8
Gas Mixture	Ar: CO ₂ (93:7) @ 3 bar	
HV working point	3070 V	2730 V
Gas gain	2 × 10 ⁴	
Single Tube Max. Drift time	~ 720 ns	~ 175 ns
Single tube Space resol. w/o background	83 ± 2 μm	106 ± 2 μm

- New chamber design similar to the current ATLAS MDT**
- **Improvements :**
 - ✓ rate capability factor of 10 greater than current MDT detectors, and 8 times less background detector occupancy
 - ✓ 4 times lower electronics dead time (= max. drift time)
 - ✓ 2 times more tube layers within the same detector volume allowing for additional increase in the muon tracking efficiency
 - ✓ No ageing effect expected at the integrated luminosity of HL-LHC (even up to 9 C/cm)
-
- **Design challenge:**
 4 times denser gas and electrical connection

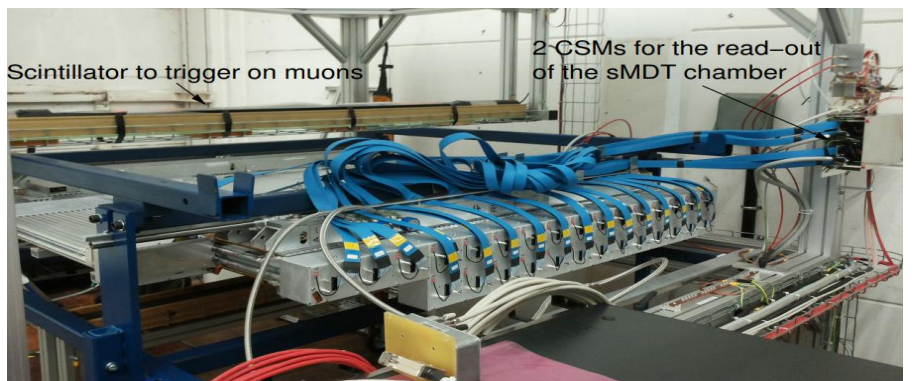
QA/QC Protocol @ MPI Munich

- sMDT - Single Chamber**
2730 V in Ar: CO₂ @ 3 bar
- Gas Leak Test:**
- Pressure drop vs Time
- HV & Broken Wire Identific. Test:**
- Dark current monitoring
- Connectivity & Noise:**
- Accidental hit rates (THR = -39 mV) vs Channel
- Cosmic Ray Test:**
- Spatial resolution
- Efficiency
- Drift time spectrum
- Shipping to the CERN BB5 final commissioning site**

Summary results of all tested BIS78 chambers*:

- ✓ **Gas Leak Test:** all 16 sMDT chambers fulfilled the stringent leak rate limit.
- ✓ **Dark current results for all tube multilayers:** below the maximum dark current limit of ~0.2 μA.
- ✓ **Connectivity & Noise tests:** (0.06 ± 0.01) kHz/tube, well below the upper noise limit of 5 kHz/tube.
- ✓ **Average Single Tube Spatial resolution:** (119.4 ± 3.9) μm with the mult. scattering correction obtained from MC simul. (120.0 ± 10) μm.
- ✓ **Average Single Tube Muon Efficiency:** (98.8 ± 0.3) %.
- ✓ **Average Single Tube Max. Drift Time:** (194.84 ± 1.05) ns.

[*] Š. Hadžić. CERN-THESIS-2019-150



Detector Commissioning @ CERN BB5 facility

- sMDT - Single Chamber**
2730 V in Ar: CO₂ @ 3 bar
- Visual Inspection
- Gas Leak Test
- HV Stability Test
- Connectivity & Noise test
- Cosmic Ray Test
- sMDT+RPC - Integrated**
- Final Mechanics & Services Installation
- Connectivity & Interfer. Noise Test
- Final Certification Tests of the detector + services
- Shipping to ATLAS P1**

BIS78 sMDT - QC Overview:

Spatial Resolution
 ATLAS Muon System Preliminary
 Resolution (μm) = 117 ± 4
 Pass mult. scatt. (μm) = 120 ± 11

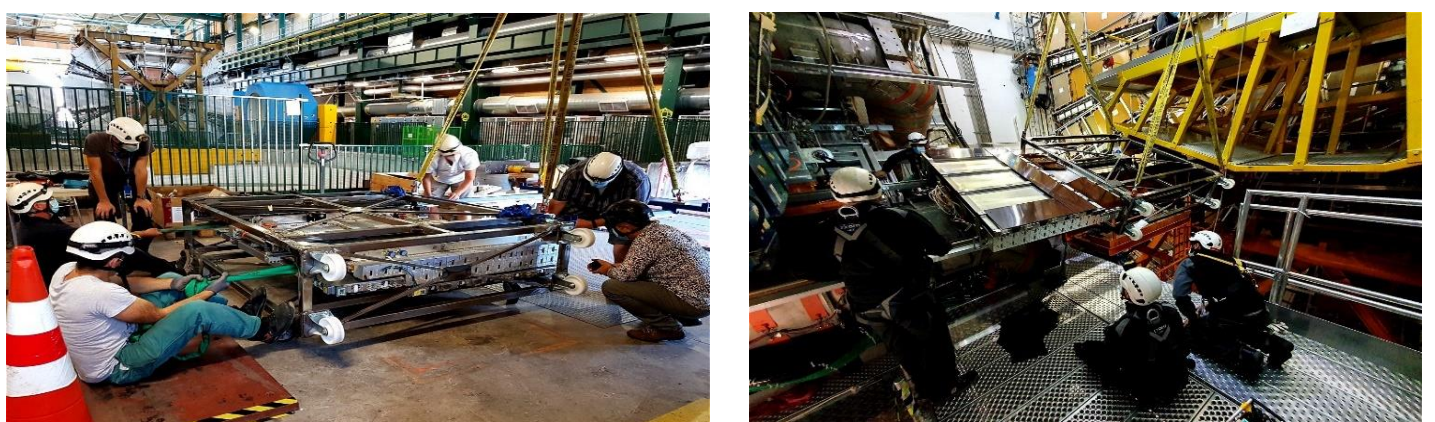
Muon Efficiency
 ATLAS Muon System Preliminary
 Average value 0.98 ± 0.01

Maximum Drift Time
 ATLAS Muon System Preliminary
 Max. drift time (ns) = 194.84 ± 1.05

✓ **8 sMDT chambers** have been integrated with 16 RPCs and installed.

BIS78 Module Installation @ P1

- ✓ Installation of 8 Muon stations for the A-side of Inner Barrel Small sectors completed in Jan. 2021
- ✓ Commissioning phase is completed
- ✓ sMDT subsystem has been included in the cosmic ray data-taking campaign



Summary

- ✓ Max Planck Institute for Physics in Munich (MPI) has built 16 new BIS78 sMDT for the ATLAS experiment (~11 000 drift tubes => 16 detectors - from 2017 to 2019).
- ✓ 16/16 sMDT detectors have been fully validated following a strict quality control protocol at MPI and passed the acceptance tests at CERN.
- ✓ 8/16 BIS78 Muon station (A-side) successfully installed in ATLAS from Sept. 2020 to Jan. 2021 (while the rest will be installed during the Long Shutdown-3 of LHC).
- ✓ A new sMDT subsystem has been commissioned!
- ✓ All detectors had been integrated into ATLAS DCS/DAQ/DQ systems.
- ✓ The recorded dataset with all sMDT BIS7A data from ATLAS combined run has been completed.