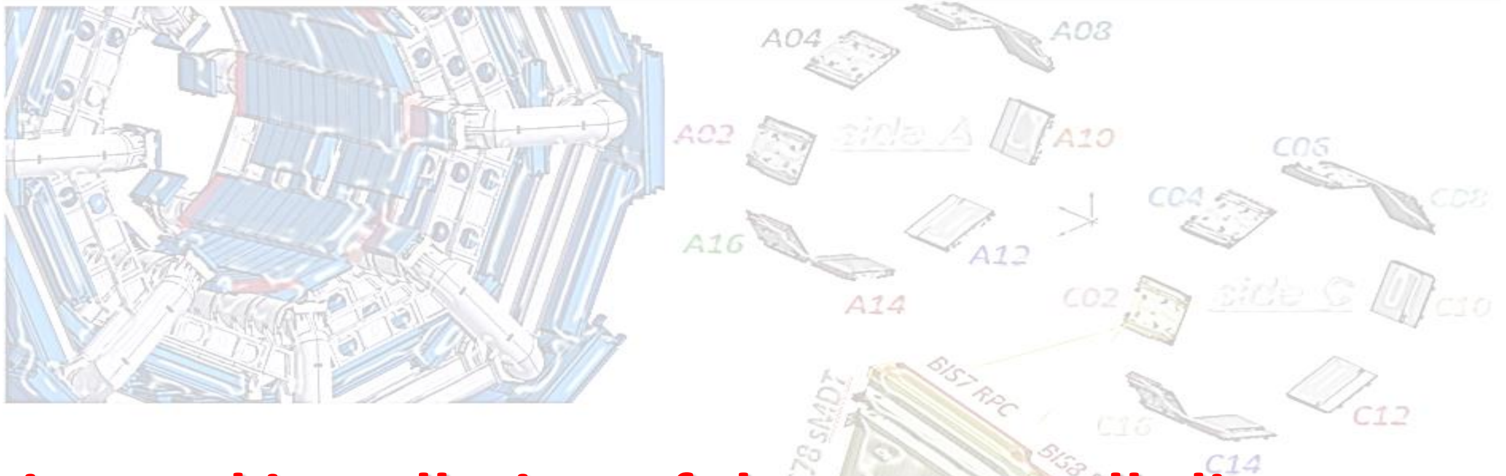
HL-LHC

ATLAS EXPERIMENT



Commissioning and installation of the new small-diameter Monitored Drift Tube detectors for the phase-1 upgrade of the ATLAS muon spectrometer

Elena VOEVODINA

on behalf of MPI Munich sMDT group

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

MAX-PLANCK-GESELLSCHAFT

DPG-Frühjahrstagungen
March 15th-19th, 2021

HL-LHC ATLAS EXPERIMENT

Talk Overview

Introduction

- ***ATLAS Muon Spectrometer Phase-1 Upgrade***
- ***New BIS78 sMDT Detector for the ATLAS Muon System***
- ***Overview of the Surface Commissioning Protocol***

BIS78 sMDT surface commssioning @CERN

- ***Gas Leak Test***
- ***Connectivity and Noise Rate Test***
- ***Cosmic-Ray Test***

BIS78 sMDT and RPC detectors integration

- ***Integration Procedure***
- ***Interference Noise Test***
- ***Final Mechanics & Services Installation***

Installation & commissioning @ATLAS Cavern

- ***Sector Preparation***
- ***Installation***
- ***Commissioning***

Introduction

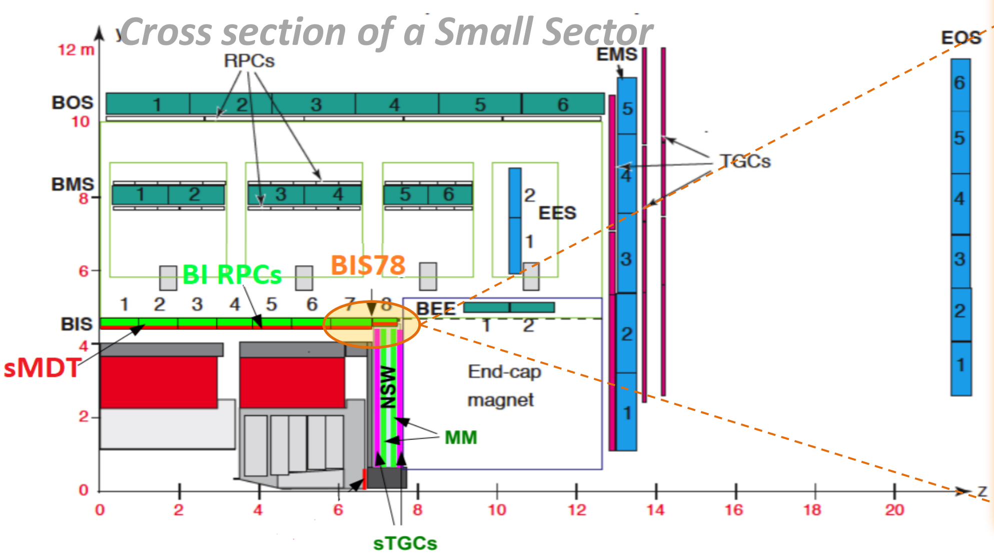
ATLAS Muon Spectrometer Phase-I Upgrade

Barrel muon trigger upgrade at $|\eta| < 1.3$:

The *Barrel Inner (BI) Upgrade* project consists of:

- **new triple-Resistive Plate Chamber (t-RPC) -> 276** detectors for the triggering:
  - to close acceptance gaps by compensating the potential efficiency loss of the present RPC
  - to improve the trigger selectivity
  - to increase the redundancy of the muon system

- **new small Monitored Drift Tubes chambers (sMDT) -> 96** detectors for the tracking:
  - to replace current MDT chambers and allow for a 3-station RPC trigger
  - to increase the tracking rate capability



In 2019/21 (Long shutdown-2) the BIS78 Phase-1 Upgrade project will realize as a pilot for Phase-2:

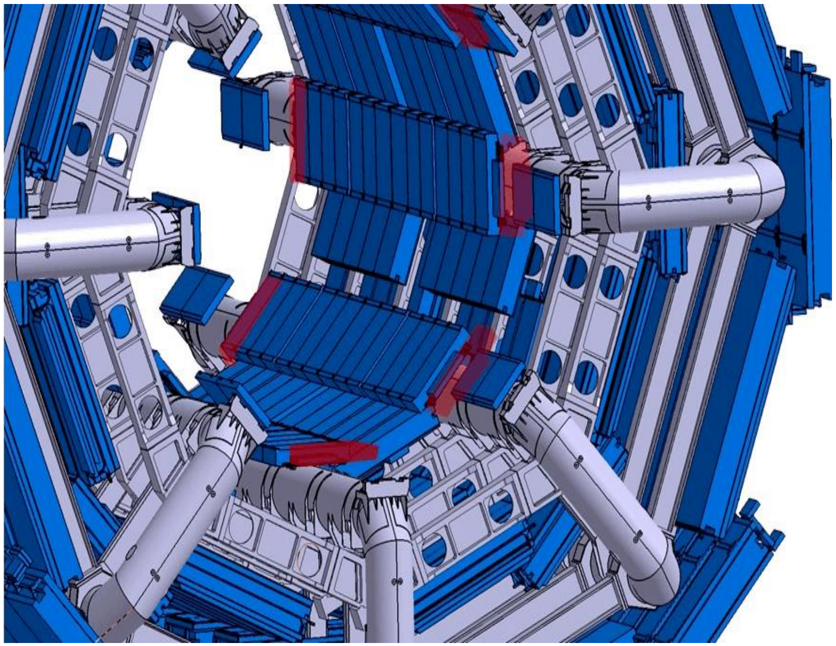
16 sMDT and 16 t-RPC chambers will install in the barrel-endcap transition region at $1.0 < |\eta| < 1.3$

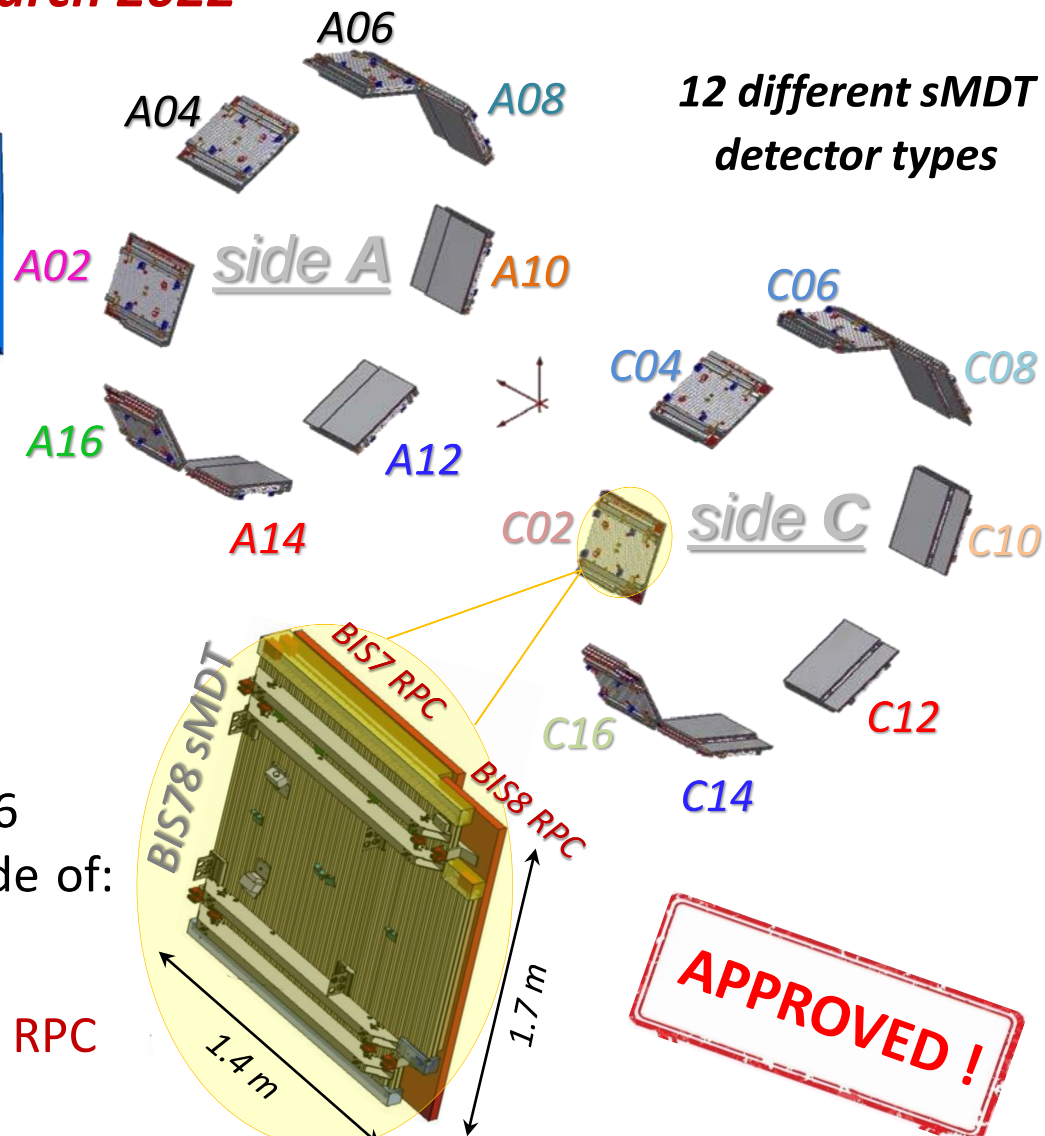
In total: ~ 11000 drift tubes!

BIS78 sMDT Detector for ATLAS Muon Spectrometer Phase-I Upgrade

HL-LHC ATLAS EXPERIMENT

BIS78 project in Phase-1/Run-3 March 2022





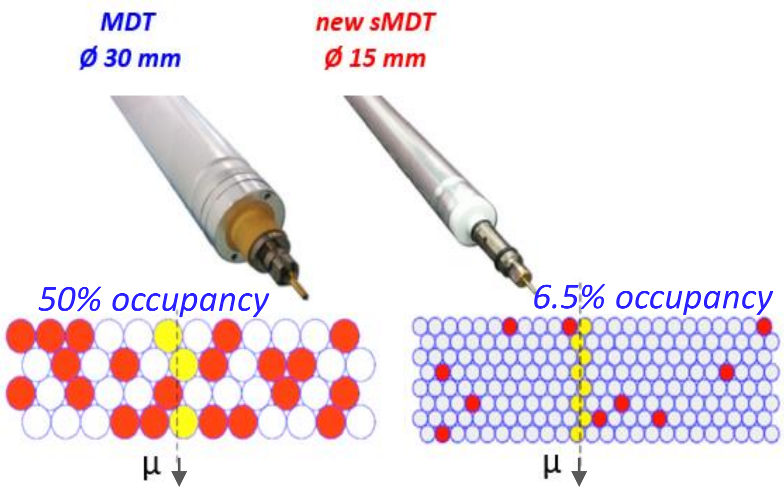
Layout:

16 new muon stations replacing the 16 existing BIS7-8 MDTs. Each station made of:

- one BIS78 sMDT detector
- two t-RPC triplets: BIS7 RPC + BIS8 RPC

New small Drift Tube Chamber Technology

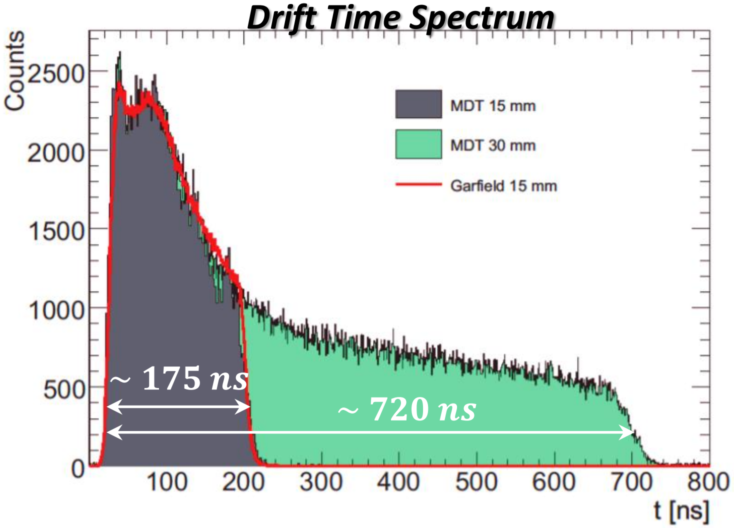
The **sMDT Technology** has been developed since 2008 in order to cope with the expected high background rates at the HL-LHC



sMDT baseline parameters

Properties	*Current MDT*	*New sMDT*
Tube Diameter	$30\ mm$	*15 mm*
Number of tube layers	4	*8*
Operating Gas Mixture	$Ar{:}\ CO_2$ (93:7)	$Ar{:}\ CO_2$ (93:7)
Operating Pressure	$3\ bar$	$3\ bar$
Operating HV working point	*3070 V*	*2730 V*
Gas gain	2×10^4	2×10^4
Max. Drift time	$\sim 720\ ns$	$\sim 175\ ns$
Single tube space resolution	*83 ± 2 μm*	*106 ± 2 μm*

Drift Time Spectrum



Main Advantages of the 15 mm Ø sMDT detector:

- ✓ 10 times high rate capability with respect to the current MDT detectors, i.e. 8 times lower 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 aging effects after foreseen integrated luminosity of HL-LHC (even up to 9 C/cm)

See more info in M. Rendel's talk: Construction of new small-diameter Monitored Drift Tube (sMDT) chambers for the HL-LHC upgrade of the ATLAS muon spectrometer

HL-LHC ATLAS EXPERIMENT

sMDT + RPC BIS78 Validation Tests Protocol @CERN

sMDT QA/QC

- Visual Inspection
- Preparation phase for QC
- Leak Rate Test
- Connectivity & Noise Rate Test
- Cosmic Ray Test

RPC BIS78 QA/QC

- Visual Inspection
- Detector Components Validation:
  - -> Gas gap tightness
  - -> V/A characteristic
  - -> Gap conditioning & stability tests @GIF++
  - -> FE Board Test, etc …
- Singlet/Triplet Assembly
- Singlet/Triplet Cosmic Ray test

sMDT + RPC BIS78 Integration

- Final Mechanics & Services Installation
- Connectivity & Interference Noise Test
- Final Certification Tests

Final BIS78 Detector Module Installation @P1

BIS78 sMDT surface commissioning @CERN BB5

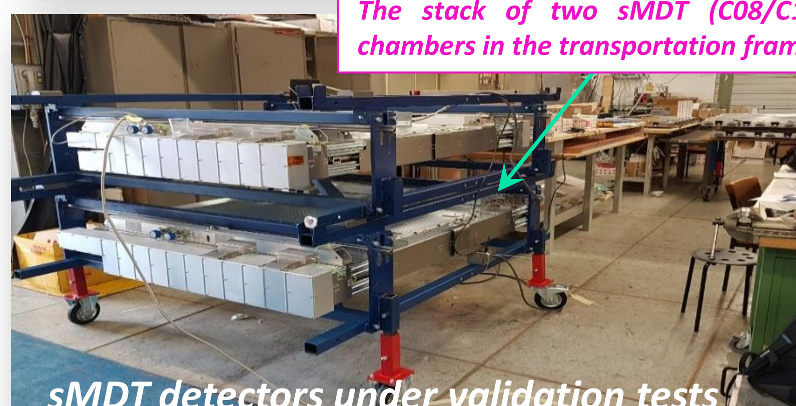
16 BIS78 sMDT @CERN BB5 facility

- ☑ ***8 "A-side" sMDT detectors*** **have been shipped from MPI-Munich to CERN in 2019 year**
- ☑ ***8 "C-side" sMDT modules*** **have been delivered from the MPI-Munich in 2020 when the storage and test spaces at CERN were available**

Assembled sMDT detectors arrived from MPI (Munich) to BB5 facility (CERN, Geneva)

Short-term sMDT storage @CERN BB5

The stack of two sMDT (C08/C16) chambers in the transportation frame



sMDT detectors under validation tests

Gas Leak Rate Measurement

Determination of Gas Leak for each Multilayer (ML)

- **Detector is pressurized at $3\ bar$ in the operating gas mixture $Ar:CO_2\ (93:7)$**
- **Pressure measurement $p(t)$** *-> Baratron pressure gauge*
- **Temperature measurement $T(t)$** *-> 12 on-chamber sensors*
- **Duration: $> 24\ hours$**

sMDT A02 is under Gas Leak Test

MKS Instruments
390HA-00001SP12

Accuracy:
0.3 mbar at 3000 mbar

☑ All 16 sMDT chambers fulfilled the stringent leak rate limit!

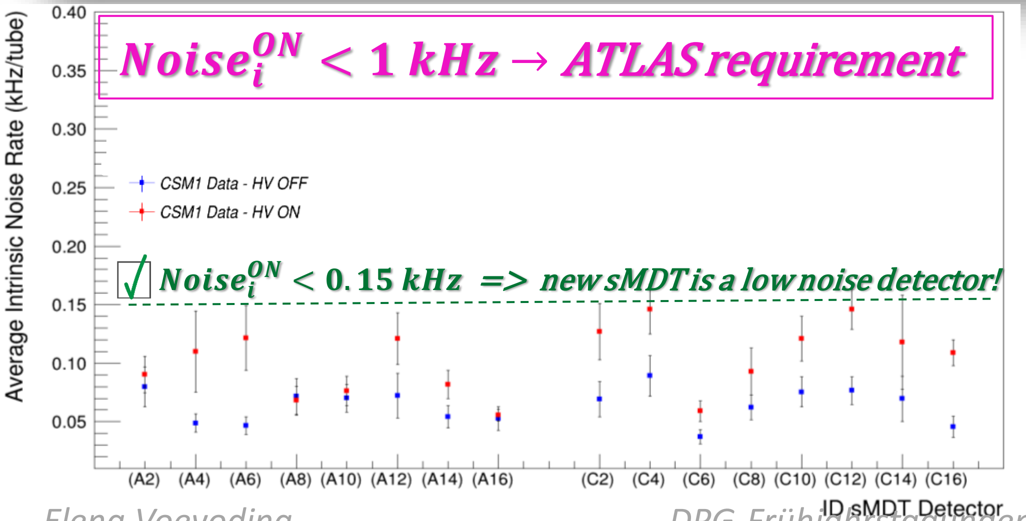
**All data and results obtained at BB5 facility are verified against measurements in MPI!*

Connectivity & Electronics Noise Test

Measurement of the accidental hit rate in each tube with and without high voltage

sMDT setup @CERN BB5: ***WP = 2730V, P = 3*** bar in $Ar:CO_2$ $(93:7)$

Movable service rack



Noise Rate Test Summary:

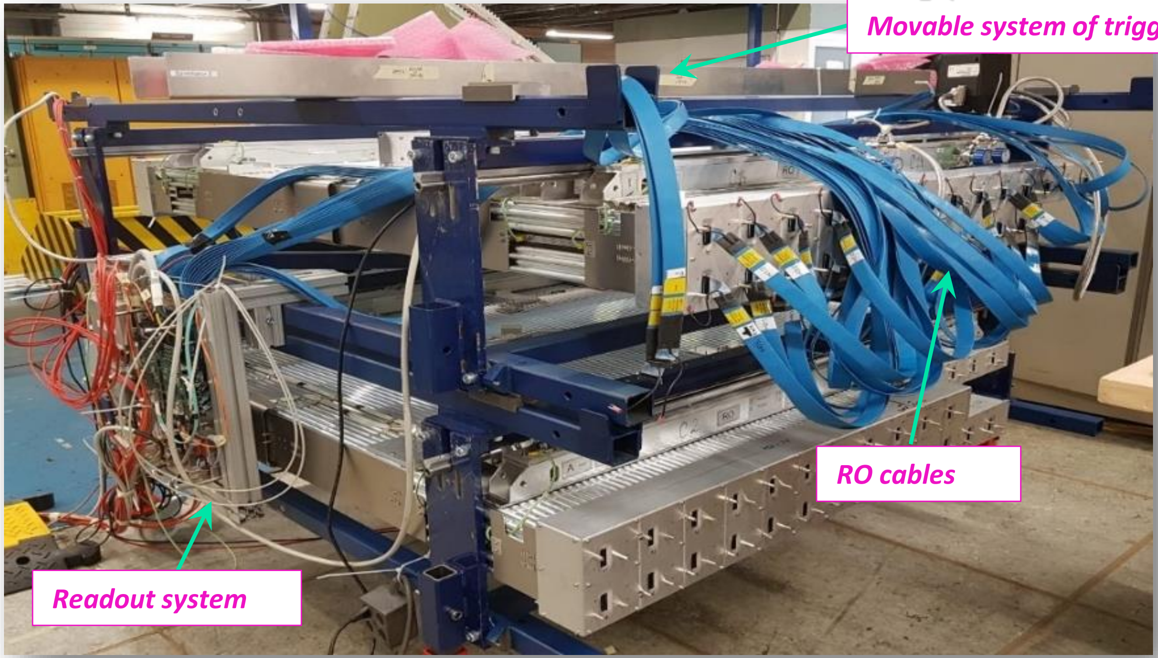
→ *"A/C-side" sMDT chambers*

Noise Rate (HV OFF) = (63.5 ± 6.2) *Hz/tube*
Noise Rate (HV ON) = (102.8 ± 9.7) *Hz/tube*
Number of disconnected tubes: 20/5472

Cosmic Ray Test

Cosmic-ray run to acquire a dataset corresponding to ~1 million cosmic muons through the chamber

sMDT setup @CERN BB5: *WP = 2730V, P = $3\ bar$* in $Ar{:}\,CO_2\ (93{:}7)$



√ **Measurement of the maximum drift-time** → average sMDT max. drift time is (194.84 ± 1.05)ns

At the same operational parameters, maximum drift time for every tube in a chamber should be the same.

√ **Measurement of the single tube resolution** → average sMDT spacial resolution is (141.7 ± 6.2)um

which is in agreement with the expectation from the test beam measurement with high energy muons.

√ **Meas. muon detection efficiency of each tube** → average efficiency is $(97.4 \pm 0.3)\%$

within the ATLAS requirements

The muon efficiency is < 100% because of the efficiency drop close to the tube wall!

HL-LHC ATLAS EXPERIMENT

16 BIS78 sMDT status @CERN

Typical validation test rate: 1 fully validated chamber per 3 days!

ID Chamber	Visual Inspection	Gas Leak Rate Test	Connectivity & Electronic Noise Test	Cosmic Ray Test
A02	Validated	Validated	Validated	Validated
A04	Validated	Validated	Validated	Validated
A06	Validated	Validated	Validated	Validated
A08	Validated	Validated	Validated	Validated
A10	Validated	Validated	Validated	Validated
A12	Validated	[illegible]	Validated	Validated
A14	Validated	[illegible]	Validated	Validated
A16	Validated	[illegible]	[illegible]	Validated
C02	Validated	[illegible]	[illegible]	Validated
C04	Validated	Validated	[illegible]	Validated
C06	Validated	Validated	Validated	Validated
C08	Validated	Validated	Validated	Validated
C10	Validated	Validated	Validated	Validated
C12	Validated	Validated	Validated	Validated
C14	Validated	Validated	Validated	Validated
C16	Validated	Validated	Validated	Validated

COMPLETED!

sMDT "C-side "Storage @Meyrin bldg. 175

- ✓ Successful and on-time commissioning of the BIS78 A/C-side sMDT detectors have been fully completed @CERN BB5 facility.
- ✓ 7 tested detectors have been safety stored @CERN Meyrin site (bldg. 175)
- ✓ 1 (C06) chamber has been stored at the BB5 facility for the mechanics improvement activity

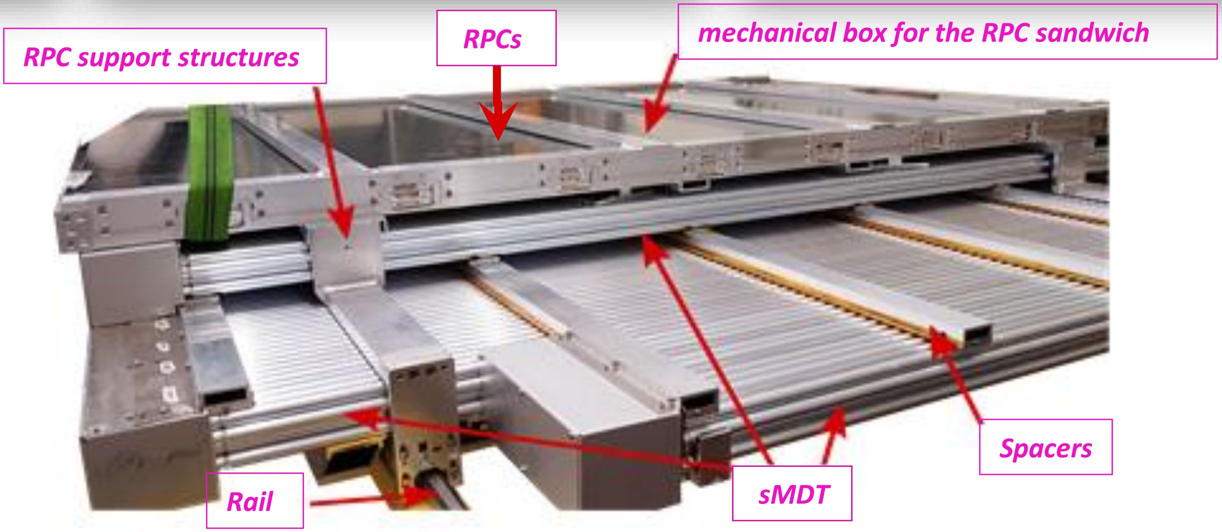
"C-side" chambers will be re-validated again before the final installation!

BIS78 sMDT and RPC Integration

sMDT + RPC Integration

The integrated mechanical design of the two chambers with low tolerances are required.

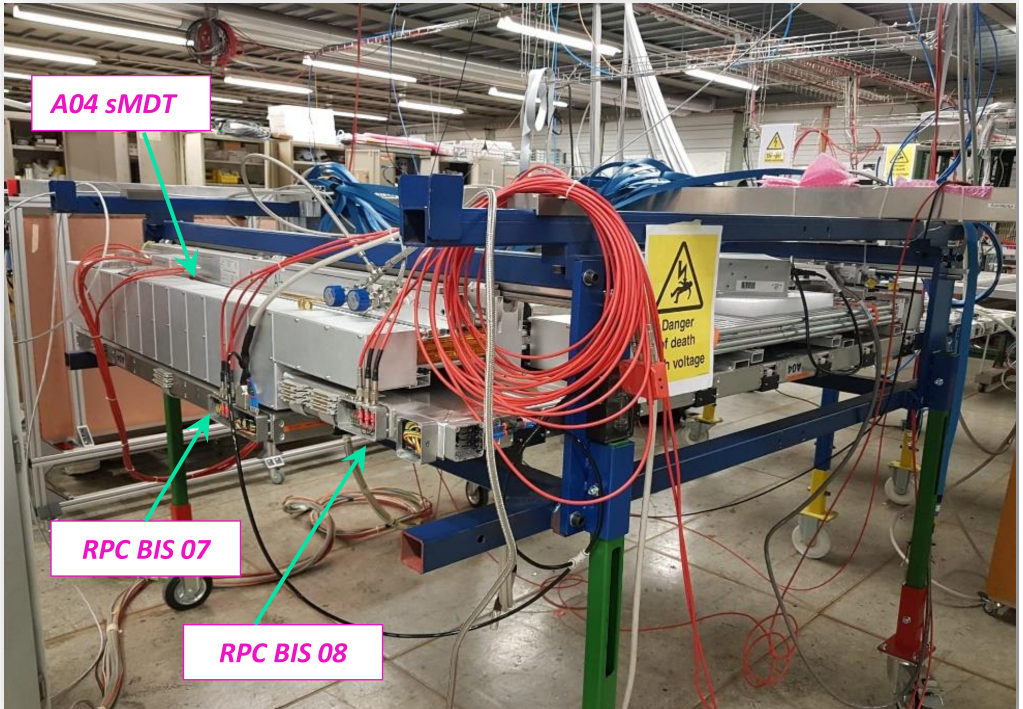
The mechanical adjustment accuracy is about 0.5 mm, fulfilling the requirements on the chamber alignment in the detector.



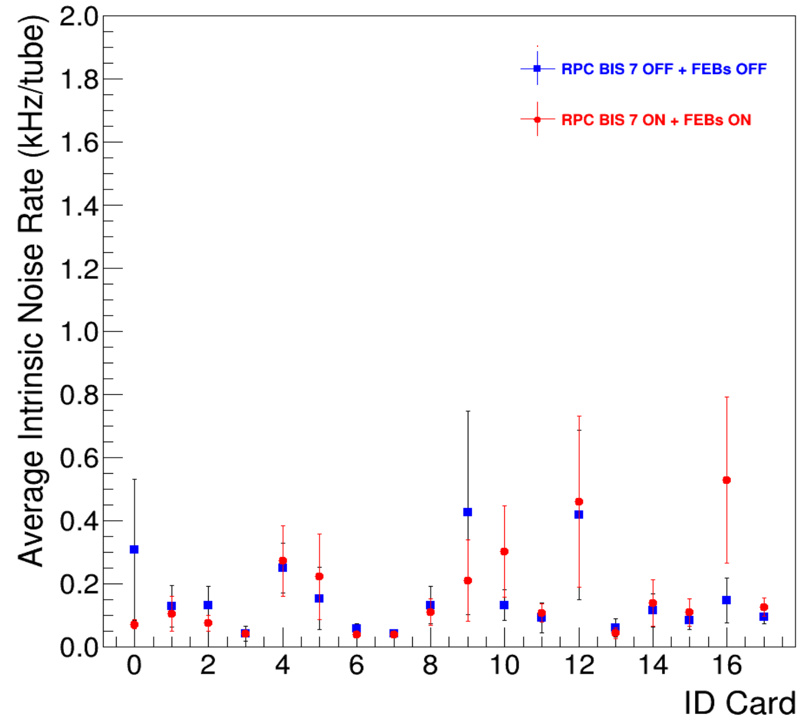
☑ **8 "A-side" sMDT chambers have been successfully integrated with RPCs!**

BIS78 sMDT Interference Test

BIS78 A04 - Interference Study @BB5



BIS78 A04 - Interference Test Result



→ average noise rate for sMDT A04 with **RPC system OFF** is (0.17 ± 0.03) kHz/tube

→ average noise rate for sMDT A04 with **RPC system ON** is (0.43 ± 0.03) kHz/tube

Detailed study shown that the effect of the RPC detector + its electronics is negligible to sMDT system (chamber + its electronics @ operating THR. = -39 V) in the term of noise!

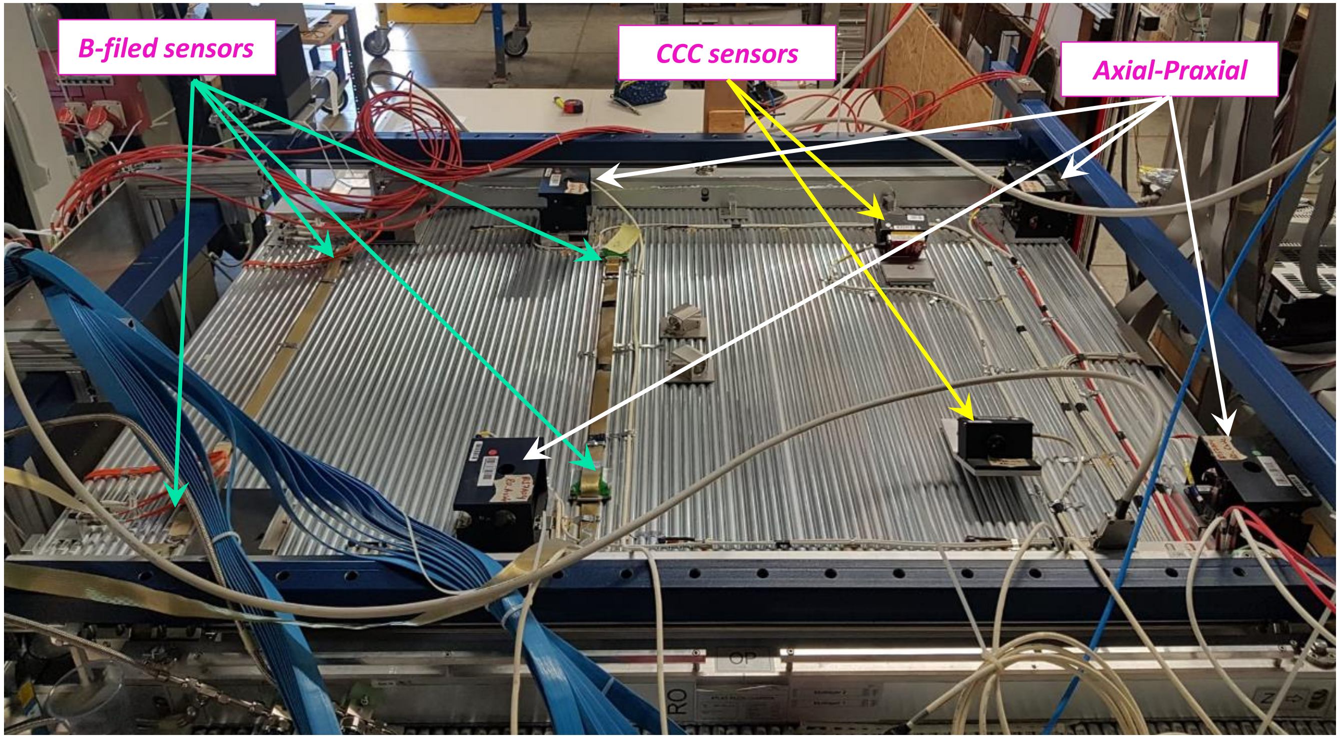
☑ **All 8 “A-side” sMDT chambers have been passed test!**

Final Mechanics & Services Installation

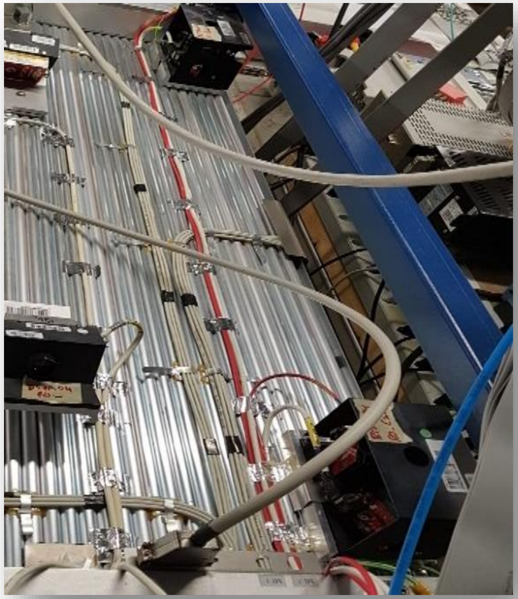
Each BIS78 sMDT detector must be equipped 4 B-field, 4 Axial - Praxial and 2 CCC sensors

The B-field sensors and chamber-to-chamber alignment systems of the MDT chamber are re-used for the new sMDT system again

A04 sMDT Final Services Installation @BB5



Cables installation & routing



B-sensor preparation

Installation & commissioning @ATLAS Cavern

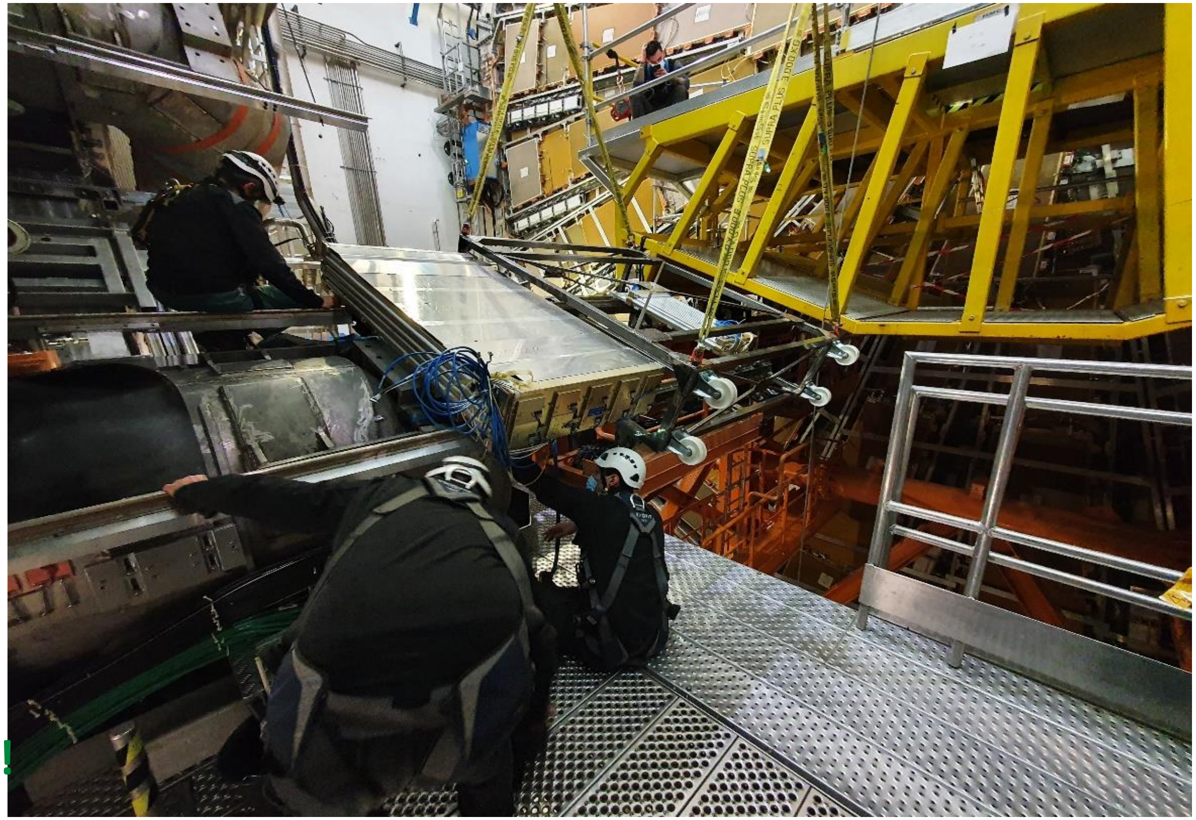
Deinstallation of the MDT system

BIS7A /BIS8A MDT chambers decommissioning

- **Disconnection:**
  - **Gas line**
  - **Mezzanine, HV, B-/T-sensors, grounding & alignment cables**
- **Dismounting**

All activities in the ATLAS Cavern have been agreed upon with the Technical coordination team.

MDT chamber deinstallation



☑ **Old "A-side" MDT subsystem have been removed from ATLAS!**

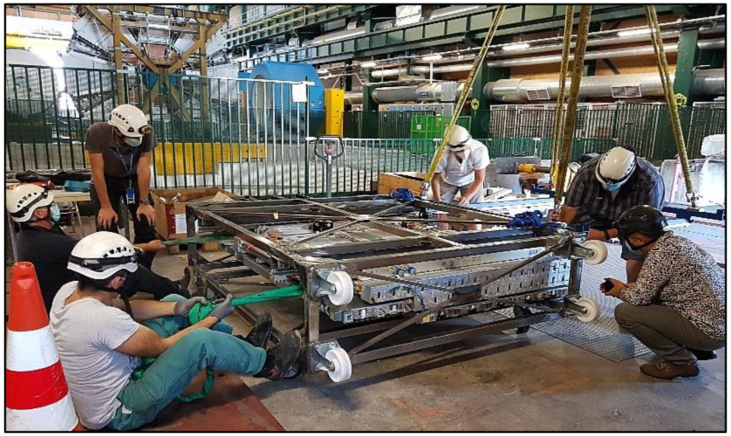
Installation

17th of September 2020 the first BIS78 Detector Module has been successfully installed to the A04 sector of the ATLAS Muon spectrometer.

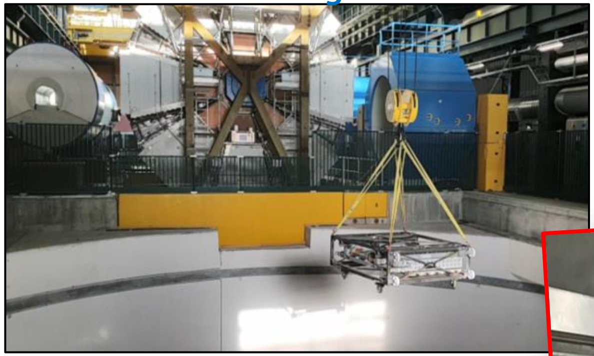
Installation Sequence:

- **Insertion into the installation frame**
- **Lowering into the ATLAS Cavern, change of cranes**
- **Docking of the installation frame to the ATLAS Muon Spectrometer rail system**
- **Installation of the muon station with two winches**
- **Final positioning and fixation of support frame on rails**

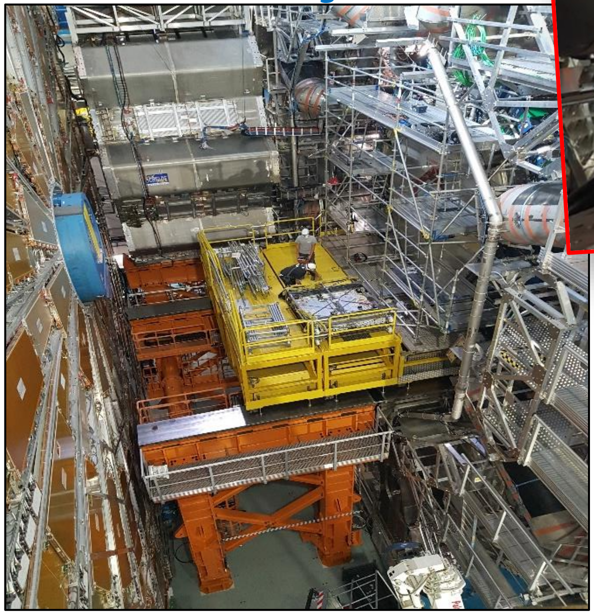
Insertion into the frame



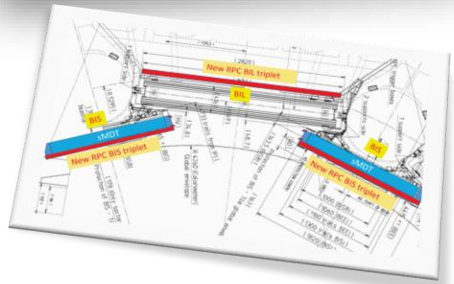
Lowering



Docking



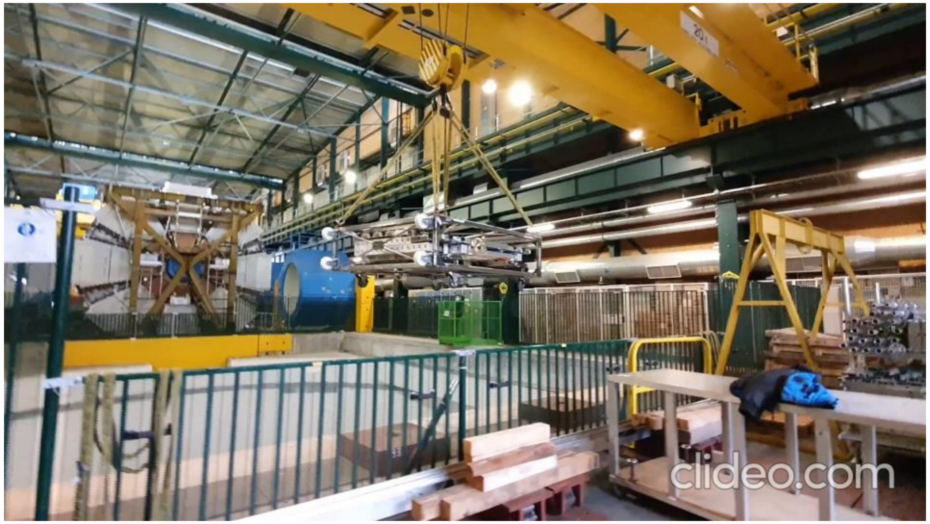
Installation



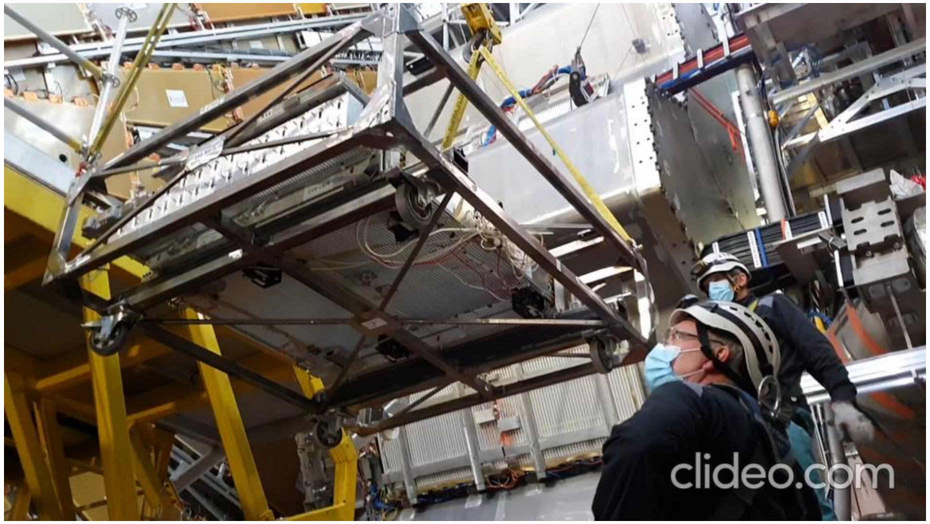
Installation

Insertion into the installation frame

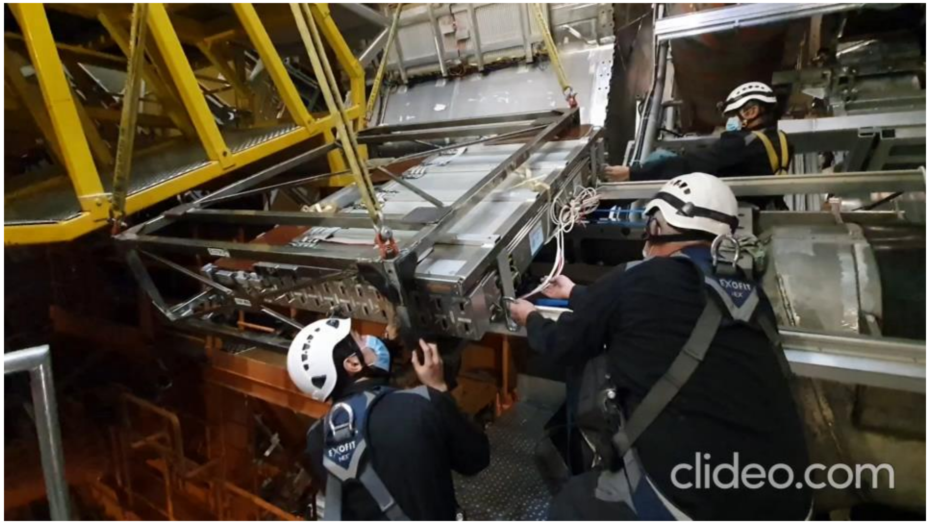
Lowering into the ATLAS Cavern



Docking to the ATLAS Muon System rail system

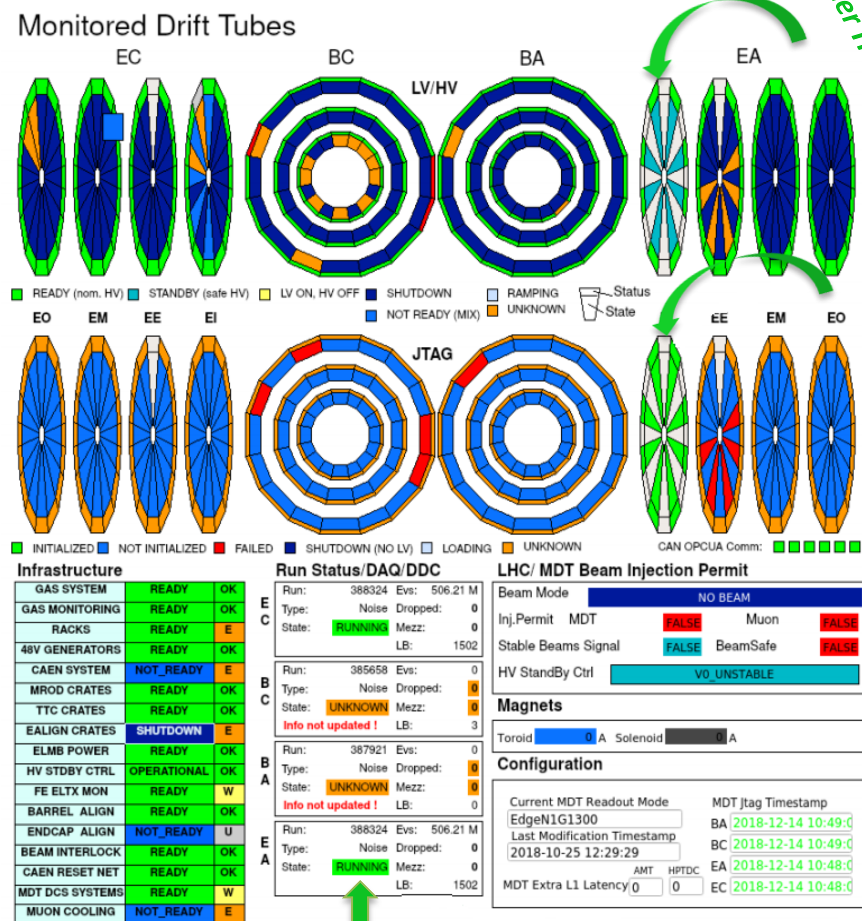


Installation of the station with two winches



BIS78 sMDT Detector Commissioning

The new sMDT subsystem has been successfully implemented/integrated in the ATLAS operational system.



All sMDT BIS7A Det. under HV 2730V

Mezzanines and CSMs on 8 sector configured

Stable long DAQ without any mezzanine

- ✓ Alignment connected and checked -> chamber in expected positions;
- ✓ Gas line connected, flushed and @3 bar;
- ✓ 2 of each CSMs, CSM-motherboards and MDMs installed and checked;
- ✓ Service cables (mezzanine, HV, B-/T-sensors and grounding) connected;
- ✓ LV and fibers checked to ensure right mapping;
- ✓ B-/T-sensor and front-ends V-/T-sensor readout checked;
- ✓ LV and HV applied and all currents in expected range.

✓ **sMDT subsystem is ready for physics data-taking campaigns!**

Conclusions

√ BIS78 sMDT production and commissioning:

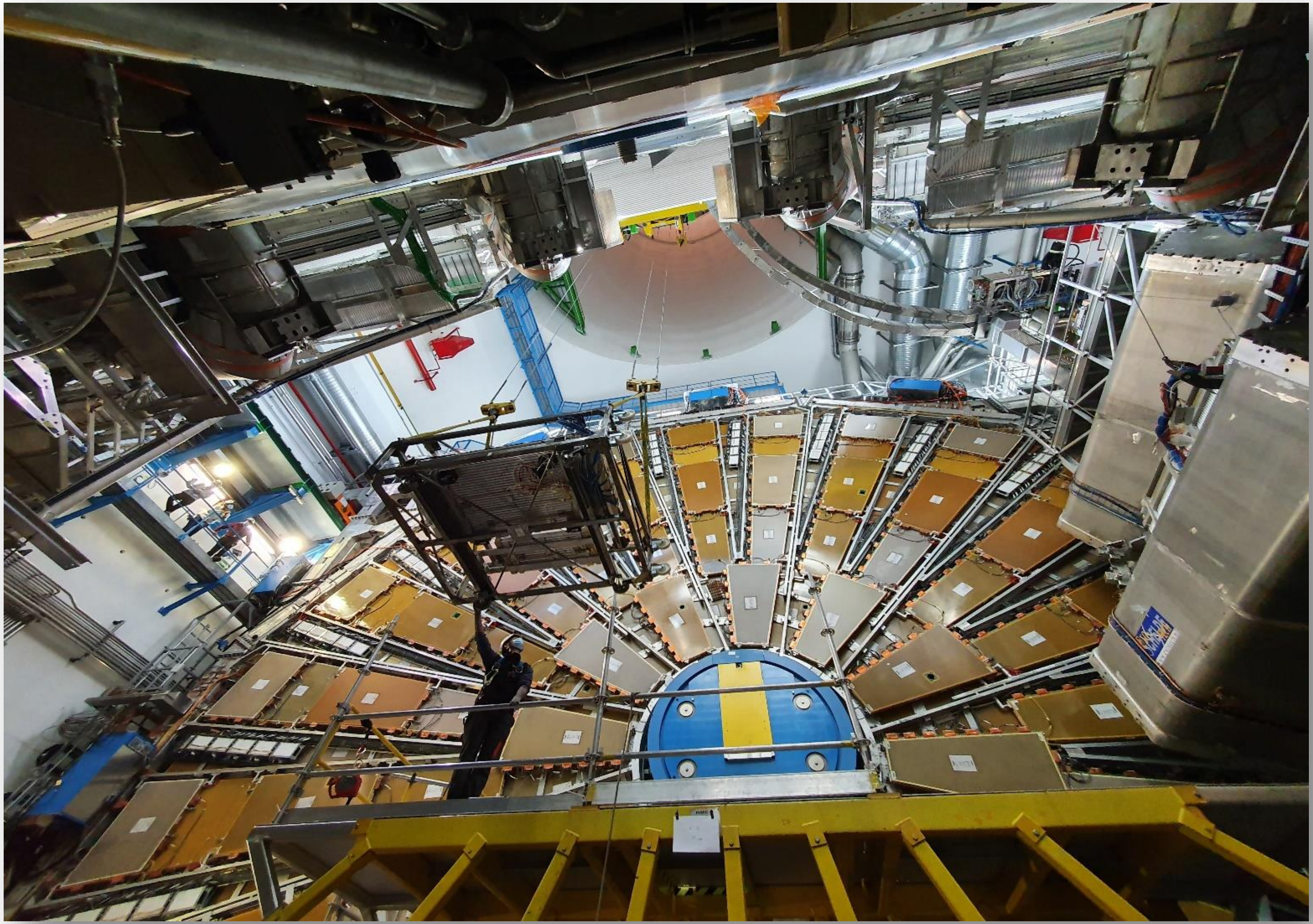
- Successful and on-time production of both A/C-side BIS78 sMDT detectors (~11 000 drift tubes => 16 detectors) from 2017 to 2019.
- 16/16 chambers have been fully assembled and validated at MPI
- In 2019/2020, the 16 A/C-side BIS78 sMDT chambers have been shipped to CERN BB5 facility.
- Each detectors have been fully validated @CERN BB5 facility.
- 8 “A-side” sMDT detectors have been integrated with two new trigger RPC chambers.

√ BIS78 Muon module installation and commissioning:

- 8/16 BIS78 Muon station successful installed in ATLAS from Sept. 2020 to Jan. 2021
- 8 sMDT BIS7A have been commissioned!
- 8 sMDT chambers had been integrated into ATLAS DAQ.
- Stable DAQ after long time debug and tests was obtained.
- **1st recorded dataset with all sMDT BIS7A data from ATLAS combined run in M5 has been completed.**
- **The analysis of data is ongoing!**

We gained valuable experience for the future BIS 1-6 sMDT upgrade project!

Thank you to all who helped building, testing, integrating and installing the BIS78 sMDT detectors!

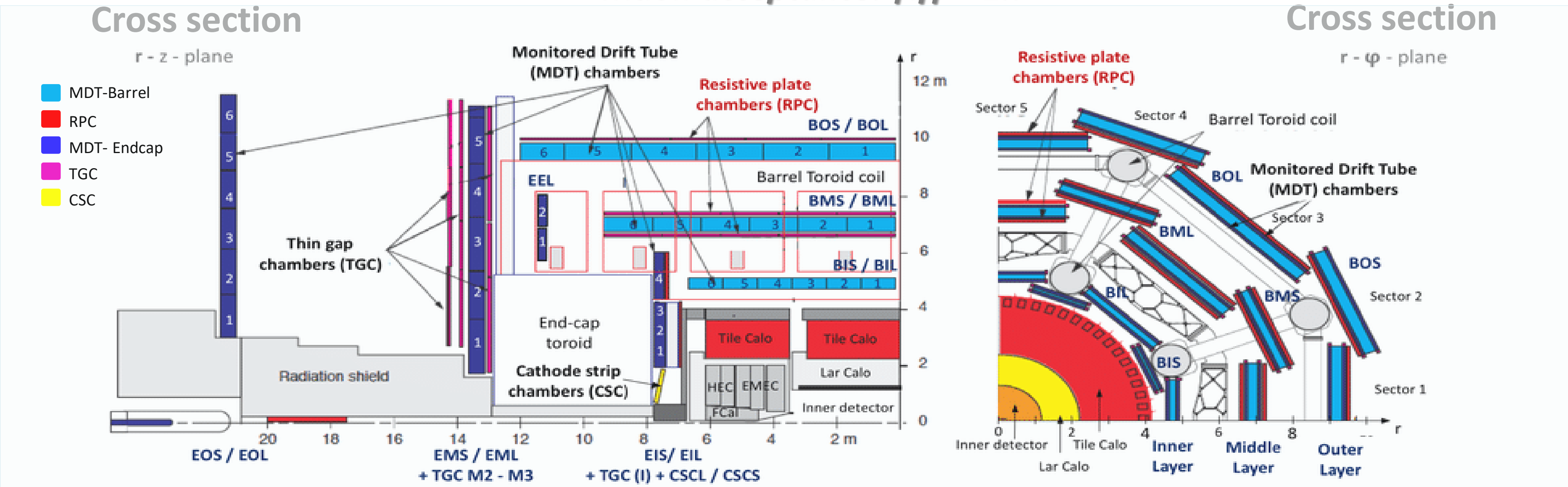


Backup slides

Current status of the ATLAS Muon Spectrometer

The **ATLAS Muon Spectrometer** was designed to provide muon identification, excellent triggering, timing and momentum measurements at LHC nominal luminosity of $10 \times 34\ cm^{-2}s^{-1}$.

Muon acceptance: |η| < 2.7



Four Technologies used for the Muon System:

✓ ***Precision Tracking Chambers***

- *MDT (Monitored Drift Tubes),* $|\eta| < 2.7$:
- *CSC (Cathode Strip Chambers),* $2.0 < |\eta| < 2.7$:

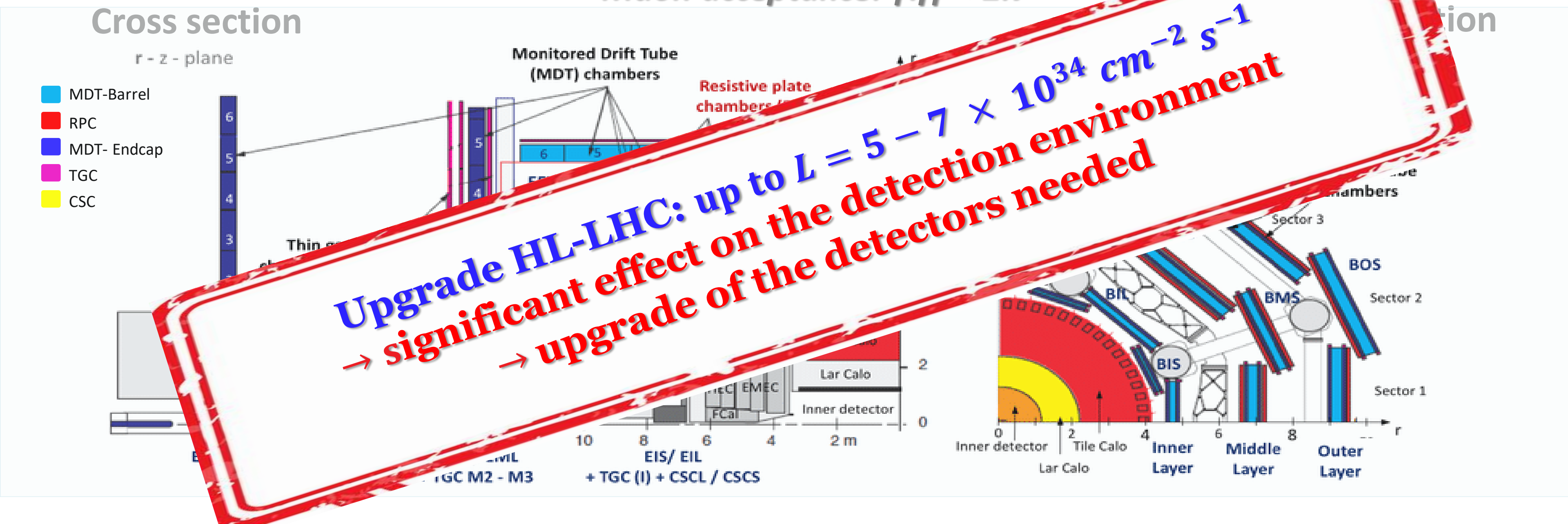
✓ ***Primary Trigger Chambers***

- *RPC (Resistive Plate Chamber),* $|\eta| < 1.05$
- *TGC (Thin Gap Chamber),* $1.05 < |\eta| < 2.4$

Current status of the ATLAS Muon Spectrometer

The **ATLAS Muon Spectrometer** was designed to provide muon identification, excellent triggering, timing and momentum measurements at LHC nominal luminosity of $10 \times 34\ cm^{-2}s^{-1}$.

Muon acceptance: $|\eta| < 2.7$



Upgrade HL-LHC: up to $L = 5 - 7 \times 10^{34}\ cm^{-2}\ s^{-1}$
→ significant effect on the detection environment
→ upgrade of the detectors needed

Four Technologies used for the Muon System:

✓ ***Precision Tracking Chambers***

- *MDT (Monitored Drift Tubes), $|\eta| < 2.7$:*
- *CSC (Cathode Strip Chambers), $2.0 < |\eta| < 2.7$:*

✓ ***Primary Trigger Chambers***

- *RPC (Resistive Plate Chamber), $|\eta| < 1.05$*
- *TGC (Thin Gap Chamber), $1.05 < |\eta| < 2.4$*

ATLAS Muon Spectrometer Phase-I Upgrade

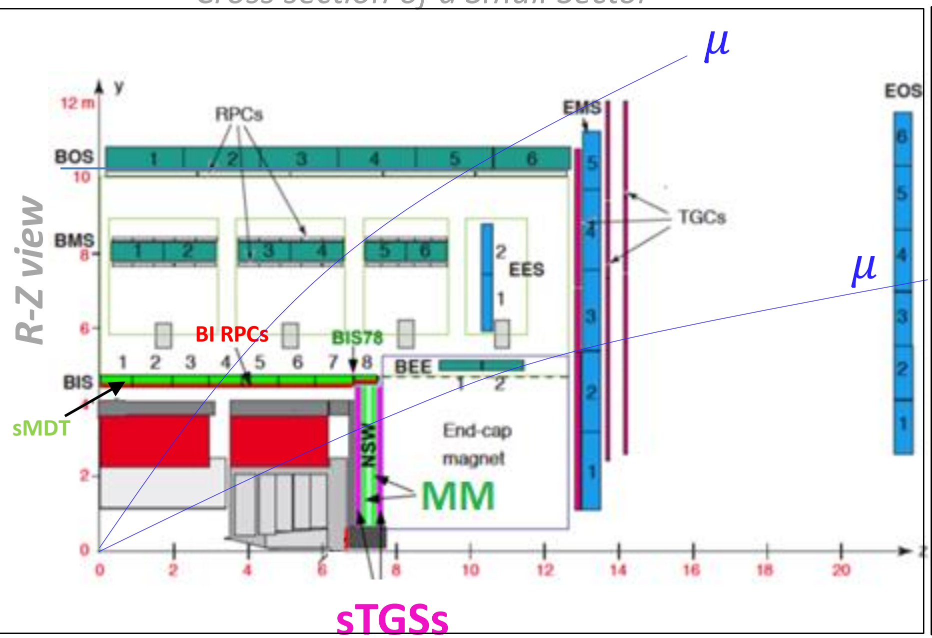
ATLAS Muon Spectrometer upgrade is motivated by the improving of the high p_T muon trigger system

1. Endcap muon tracking and trigger upgrade at $1.3 < |\eta| < 2.7$:

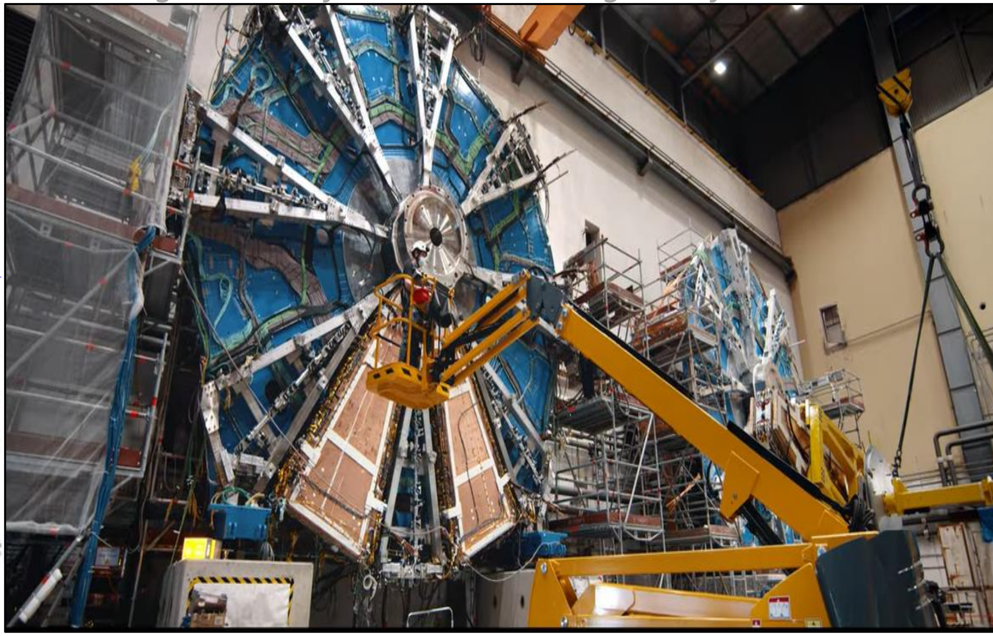
The *New Small Wheels* project combine the two different gaseous detector technologies:

- high-resolution **small-strip Thin Gap Chamber (sTGC) - > 96** detectors for the triggering
- Micro-pattern gaseous detector - **Micromegas (MM) -> 64** detectors for the tracking

Cross section of a Small Sector



CERN Bldg. 191 - Surface commissioning site of the ATLAS NSW



HL-LHC ATLAS EXPERIMENT

Preparation of the chamber for the functional test with cosmic muons

1. Evacuate the chamber to $< 10\ mbar$ in order to extract the contamination of the chamber gas with ethanol from the leak testing.
2. Fill the chamber with $Ar: CO_2$ $(93:7)$ to *3 bar* absolute pressure.
3. Wait for 30 minutes to get a temperature equilibrium between the chamber and the gas.
4. Measure the chamber temperature and the gas pressure and close all valves on the chamber.
   → Needed for a measurement of the leak rate of a fully equipped chamber.
5. Apply the nominal operating voltage of $2730\ V$ and measure the dark current of the chamber.
   Requirement: Current $< 2\ nA/tube$ at $< 60\%\ humidity$.
6. Measurement of the accidental hit rate in each tube with and without high voltage.
7. Cosmic-ray run to acquire a dataset corresponding to ~1 million cosmic muons through the chamber (15 h with the set-up at MPI/BB5, can be shortened by increasing the trigger surface).
8. Measurement of the maximum drift time of each tube to obtain a measure for the uniformity of the space drift-time relationship across the chamber.
9. Measurement of the muon detection efficiency of each tube.
10. Measurement of the single tube resolution.
11. After >24 h measurement of the chamber temperature and the gas pressure for each multilayer separately to obtain the leak rate of each multilayer.

Gas Leak Rate Test

Identify the Gas Leak Rate of the detector by monitoring the drop of the internal pressure as a function of time and check the gas tightness

- The detector is pressurized at $3\ bar$ in the operating gas mixture $Ar{:}\ CO_2\ (93{:}7)$
- The pressure drop is measured for each individual multi layers (ML 1 and ML 2) after $24\ hours$ During the test, the gas valves remain closed.
- Instrumentations: pre-mixed gas bottle, MKS Baratron and 12 temperatures sensor glued on the surface of the sMDT detector
- MKS Baratron heated reference differential manometer Accuracy: 0.3 mbar at 3000 mbar
- The detector gas leak are estimated by the following equation:

Reference temperatures (293.15 K)

Final & Initial pressures

$$\Delta p = \frac{T_{ref}}{(t_f - t_i)} \times \left(\frac{p_f}{T_f} - \frac{p_i}{T_i}\right) \times \frac{V_{DUT}}{N_{Endplug}}$$

Final & Initial Temperatures

- Accuracy of the pressure drop measurement:

$$\delta(\Delta p) \approx \sqrt{2(\delta p)^2 + 2\left(3000\ mbar\,\frac{\delta T}{T_{ref}}\right)^2} = 1.6 - 2\ mbar$$

MKS Instruments 390HA-00001SP12

→ ***Acceptance criteria***

The detector under test is validated if the pressure drop in the detector + gas system does not exceed:

$$\Delta p \leq 2n_{tubes} \times 10^{-8}\ bar \times Liters \times s^{-1}$$

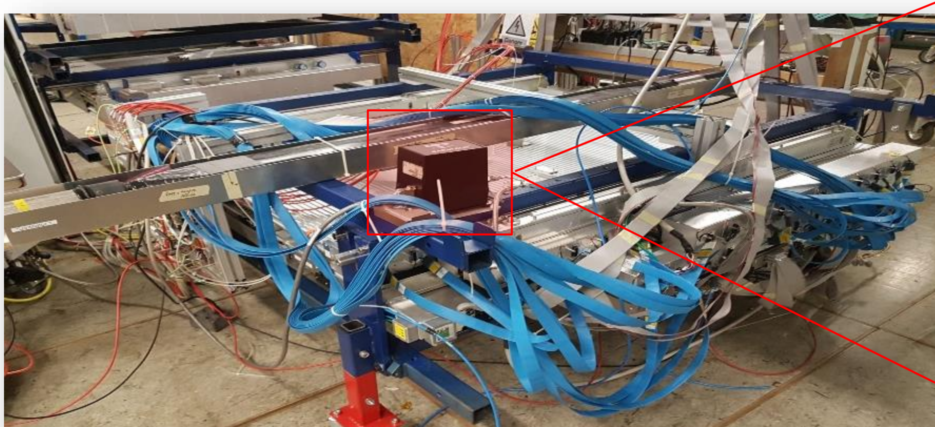
Gas Leak Rate Measurement

Determination of Gas Leak for each Multilayer (ML)

- Detector is pressurized at ***3 bar*** in the operating gas mixture $Ar:CO_2\ (93:7)$
- Pressure measurement $p(t)$
- Temperature measurement $T(t)$
  (12 on-chamber sensors)
- Duration: $> 24\ hours$
- Gas Leak estimation: $$Leak\ Rate = [\,p_f \cdot \frac{T_{ref}}{T_f} - p_i \cdot \frac{T_{ref}}{T_i}\,] \cdot \frac{V}{(t_f - t_i)\cdot N_{plugs}}$$

$T_{ref} = 293.15\ K - reference\ temperature$
$p_i, p_t; T_i, T_t - initial, final\ pressures\ and\ temperatures$
$V, N_{plugs} - volume\ under\ test\ and\ number\ of\ the\ tube\ end\ plugs$

sMDT A02 is under Gas Leak Test



MKS Instruments 390HA-00001SP12

Accuracy:
0.3 mbar at 3000 mbar

→ ***ATLAS acceptance criteria***

Detector under test is validated if the pressure drop in the detector + gas system doesn't exceed:

$$\Delta p \leq 2n_{tubes} \times 10^{-8}\ bar \times Liters \times s^{-1}$$

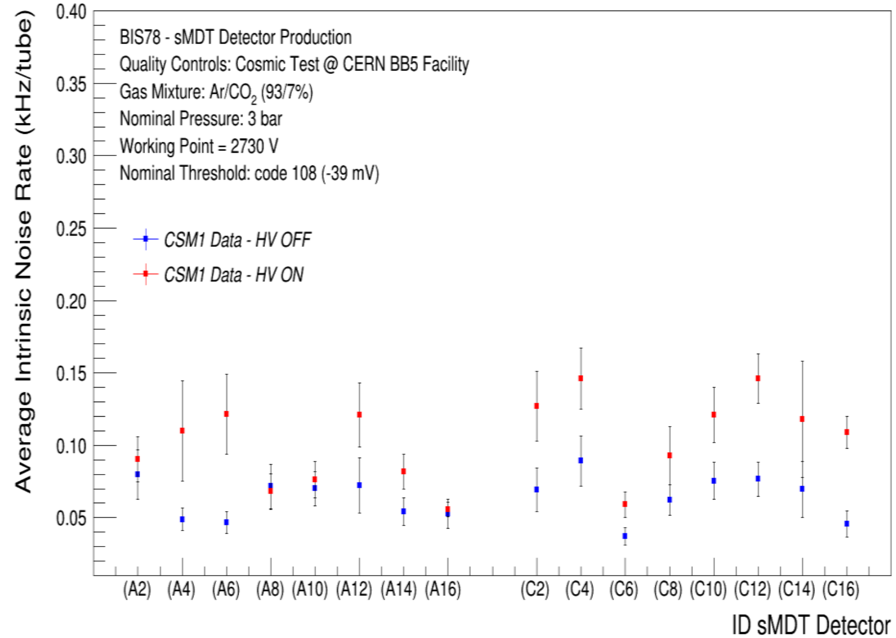
All data and results obtained at BB5 facility are verified against measurements in MPI.

Connectivity & Electronics Noise Test

Determination of Noise Rate for each Chamber Service Module (CSM)

- Detector is pressurized at ***3 bar*** in the operating gas mixture $Ar: CO_2\ (93:7)$
- Random Trigger
- Measurement Hits/Tube
- Convert to noise rate using active time window of read-out electronics
- Nominal $THR =$ *108 ASD (-39 mV)*
- Detector configurations: HV turned OFF and ON

  operating $HV_{WP} = 2730\ V$



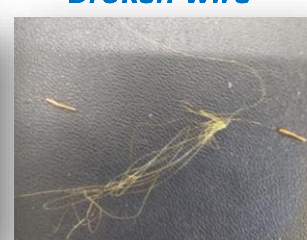
→ ***Criteria for excluding noisy tube:***

$$Noise_i^{ON} > 5\ kHz\ and\ Noise_i^{ON} > 2 \times Noise_i^{OFF}$$

The potential high noise rate sources in the sMDT detectors:

Discharge of the electr. components

Broken wire



Noise Rate Test Summary:

→ ***"A-side" sMDT chamber***

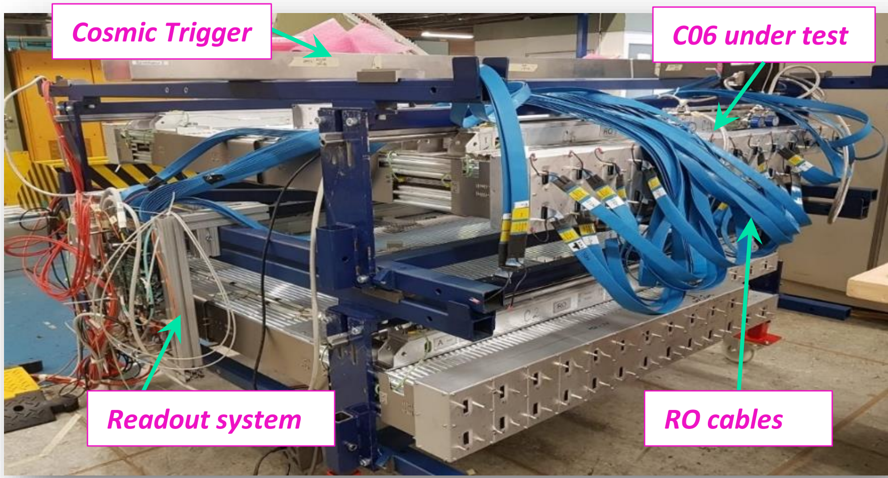
Noise Rate (HV OFF) = (61.3 ± 8.3) *Hz/tube*
Noise Rate (HV ON) = (90.6 ± 9.3) *Hz/tube*
Rejected tube = 0.1 %

→ ***"C-side" sMDT chamber***

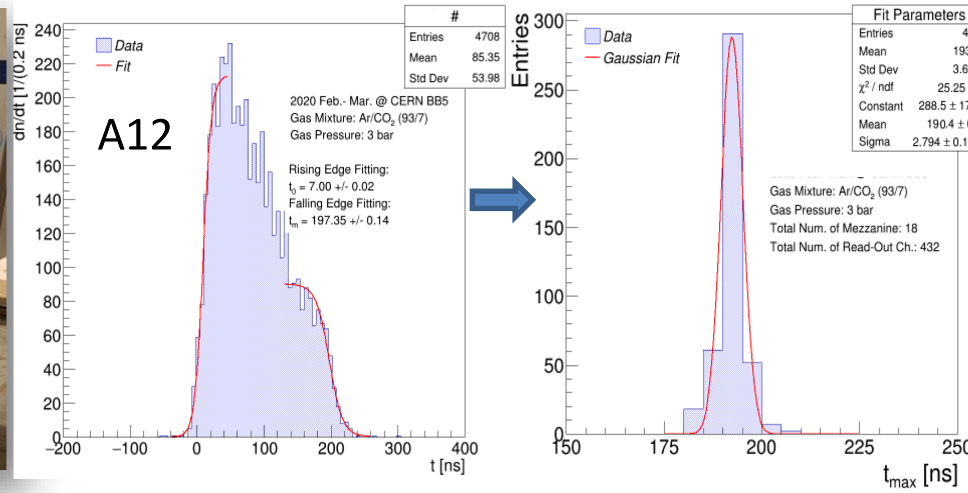
Noise Rate (HV OFF) = (65.7 ± 6.0) *Hz/tube*
Noise Rate (HV ON) = (114.9 ± 10.1) *Hz/tube*
Rejected tube = 0.7 %

Cosmic Ray Test

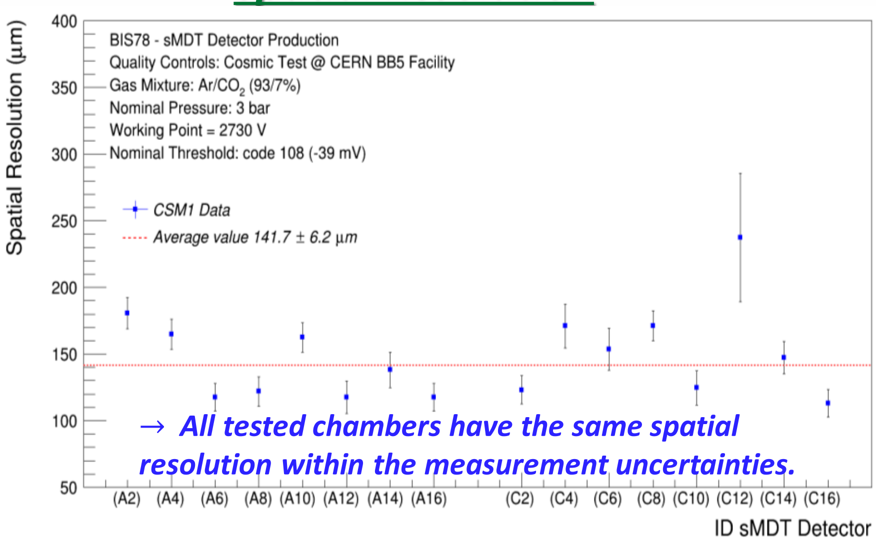
sMDT setup @CERN BB5: ***WP = 2730V, P = 3 bar*** in $Ar: CO_2$ (93:7)



Maximum drift-time

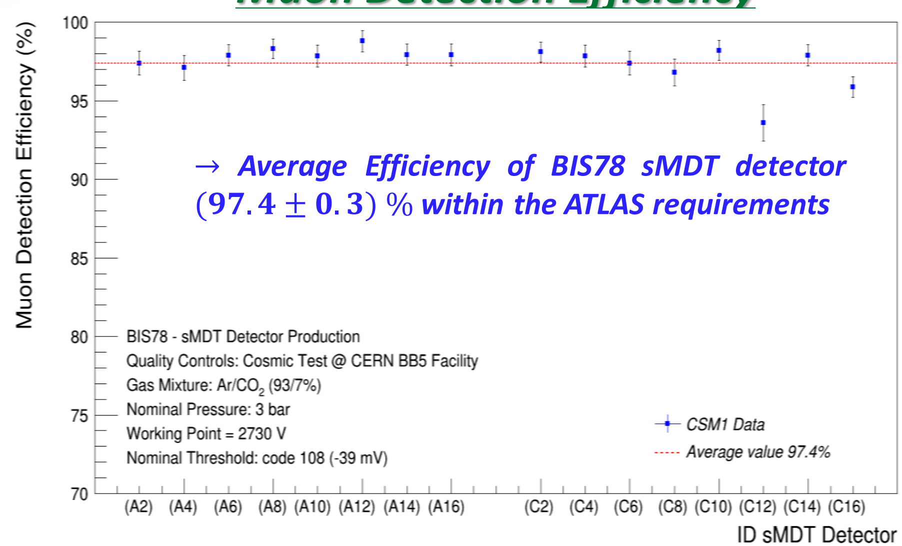


Spatial Resolution



→ *The average chamber spacial resolution is 141.7 um which is in agreement with the expectation from the test beam measurement with high energy muons.*

Muon Detection Efficiency



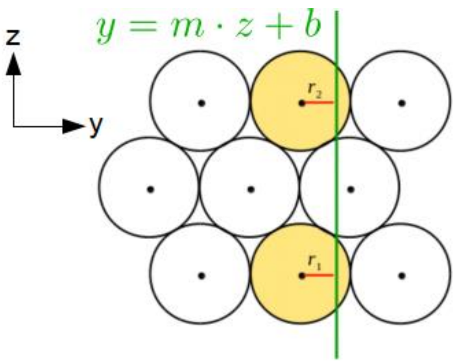
→ *The muon efficiency is < 100% because of the efficiency drop close to the tube wall*

Cosmic Ray Test (I)

The last commissioning test is the Spatial Resolution & Muon Efficiency Measurements which allows to check that the drift tube is recorded hit, if a reconstructed track is passing through the tube

- The detector is operated at the ***WP = 2730 V*** and the $3\ bar$ in gas mixture $Ar: CO_2\ (93:7)$
- The duration of the data taking is *15 hrs* per CSM.
- The cosmic trigger active area is $114\ cm\ x\ 9\ cm$.
- Expected trigger rate is $17.1\ Hz$.

Spatial Resolution



- Select nearly ***vertical muon tracks***

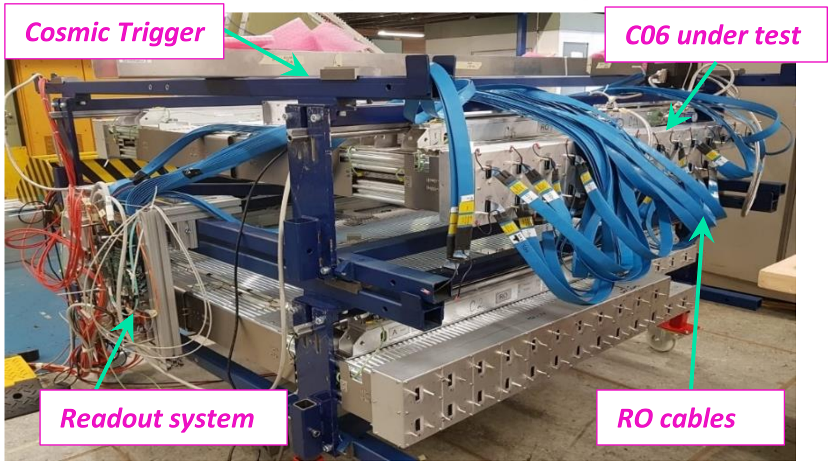
→ **For perfectly vertical tracks:**

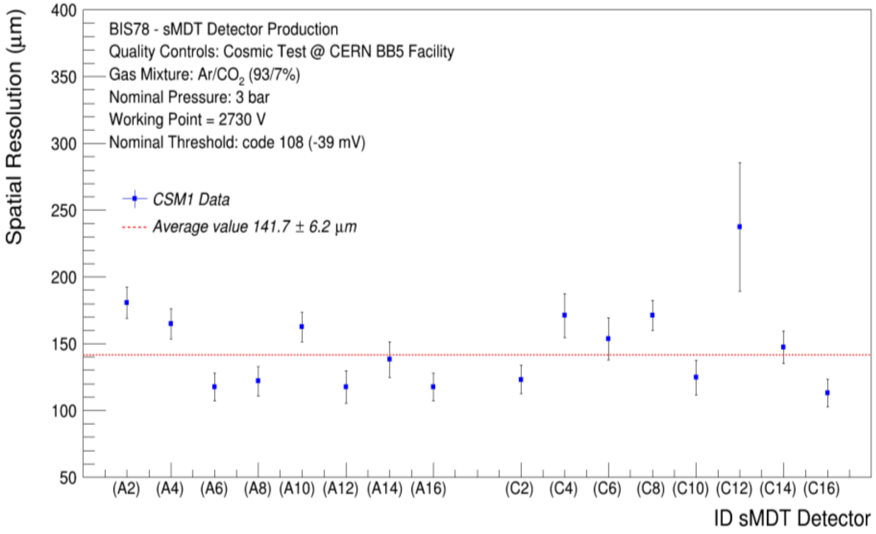
$$\sigma(r_1) = 2^{-0.5} \cdot \sigma(r_2 - r_1)$$

- **For tracks with inclination $|m| < 0.01$:**

$$\sigma(r_{1/2}) = \sigma\left(\frac{r_2 - r_1}{\sqrt{2}} \mp \frac{m \cdot (z_2 - z_1)}{\sqrt{2 \cdot (1 + m^2)}}\right)$$

sMDT setup @CERN BB5 facility

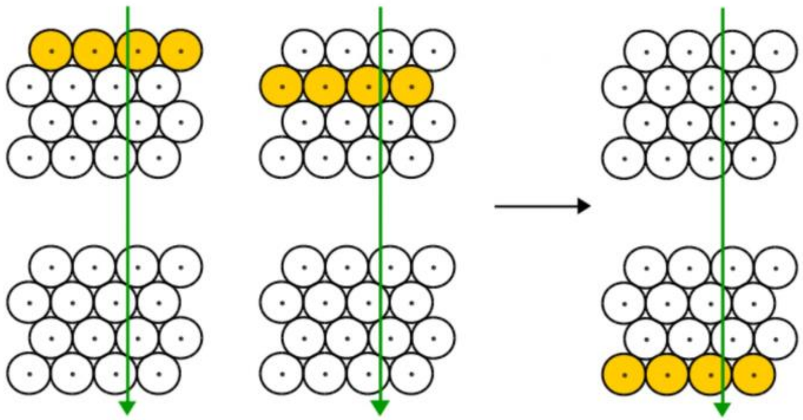




Cosmic Ray Test (II)

The last commissioning test is the Spatial Resolution & Muon Efficiency Measurements which allows to check that the drift tube is recorded hit, if a reconstructed track is passing through the tube

Muon Detection Efficiency

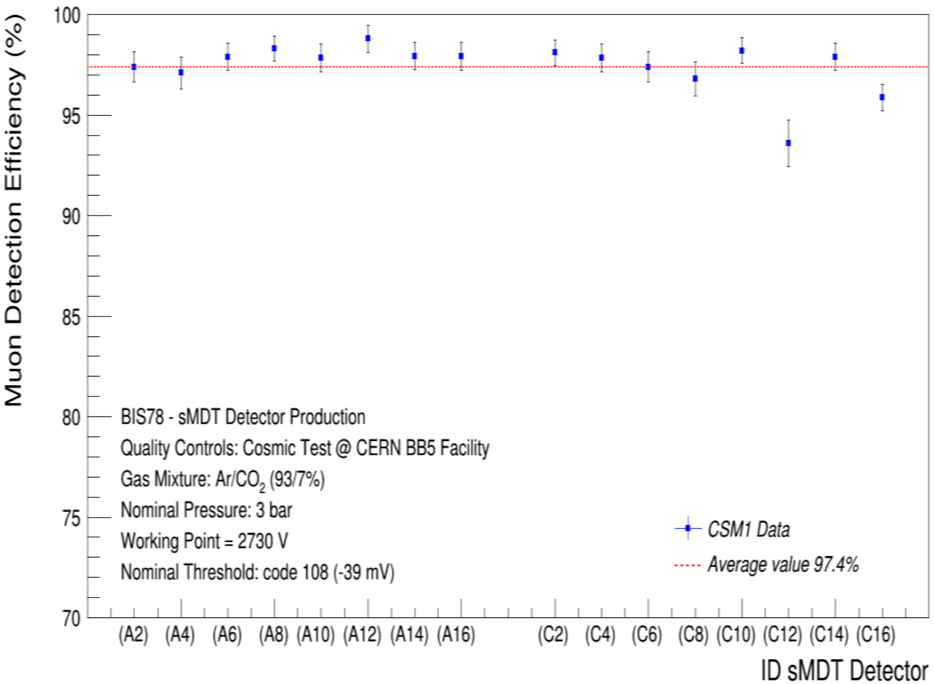


- **Measurement reproduces know dependence of the efficiency on the distance of the muon track from anode wire**

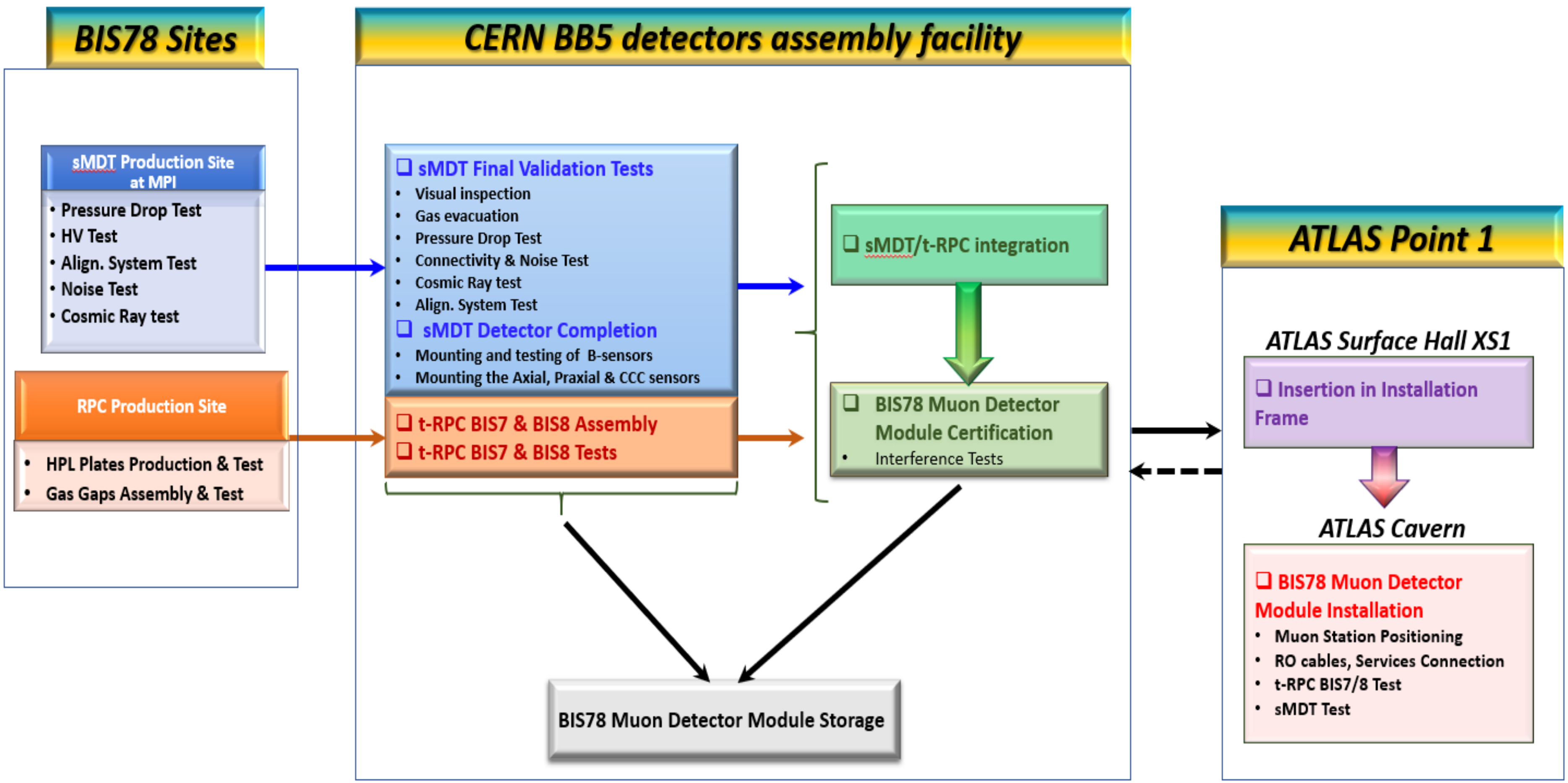
→ ***Average Efficiency of BIS78 sMDT detector $(97.4 \pm 0.2)\ \%$ within the ATLAS requirements***

→ ***The muon efficiency is < 100% because of the efficiency drop close to the tube walls***

- **Muon track is reconstructed by excluding one layer of tubes**
- **Muon detection efficiency of a tube is determined as to how often does an excluded tube have a hit when its gas volume is traversed by a reconstructed muon track**



from Production to Installation …



sMDT "C-side" module status @ BB5

HL-LHC ATLAS EXPERIMENT

Summary of BIS78 C-side sMDT status and progress @ BB5 facility

	Visual Inspection	Gas Leak Rate Test	Connectivity & Electronic Noise Test	Cosmic Ray Test	Storage Location
C02	Validated	Validated	Validated	Validated	Meyrin bldg. 175
C04	Validated	Validated	Validated	Validated	Meyrin bldg. 175
C06	Validated	Validated	Validated	Validated	BB5 facility
C08	Validated	Validated	Validated	Validated	Meyrin bldg. 175
C10	Validated	Validated	Validated	Validated	Meyrin bldg. 175
C12	Validated	Validated	Validated	Validated	Meyrin bldg. 175
C14	Validated	Validated	Validated	Validated	Meyrin bldg. 175
C16	Validated	Validated	Validated	Validated	Meyrin bldg. 175

All chambers have been fully validated !

C-side sMDT Storage @Meyrin bldg. 175

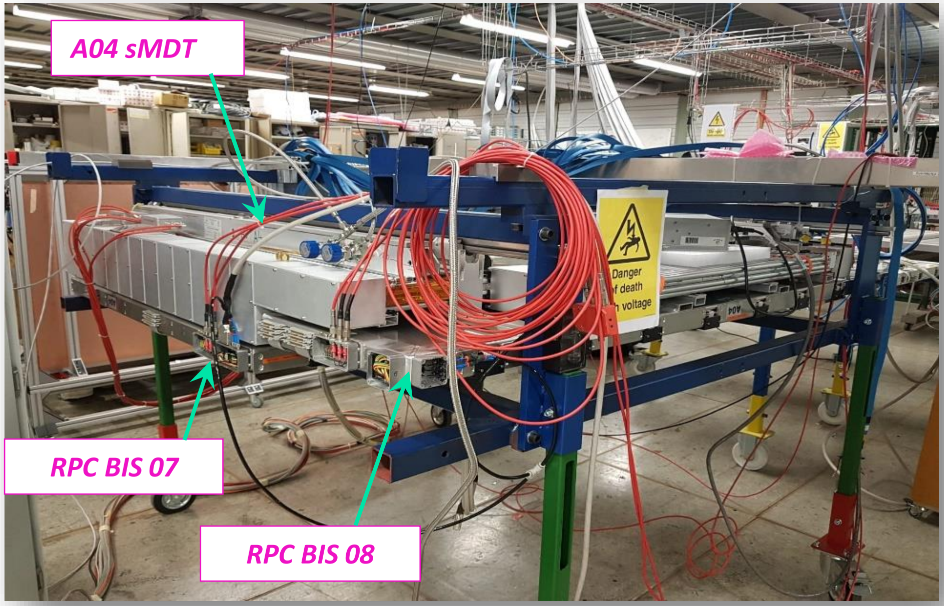
- ✓ 8 "C-side" sMDT BIS78 modules have been delivered from the MPI-Munich at the beginning of June 2020 when the storage and test spaces at CERN were available
- ✓ 8 C-side sMDT chambers have been fully validated @CERN BB5 facility
- ✓ 7 tested detectors have been safety stored @CERN Meyrin site (bldg. 175)
- ✓ 1 (C06) chamber has been stored at the BB5 facility for the mechanics improvement activity
- ✓ All chambers will be re-validated again before the final installation

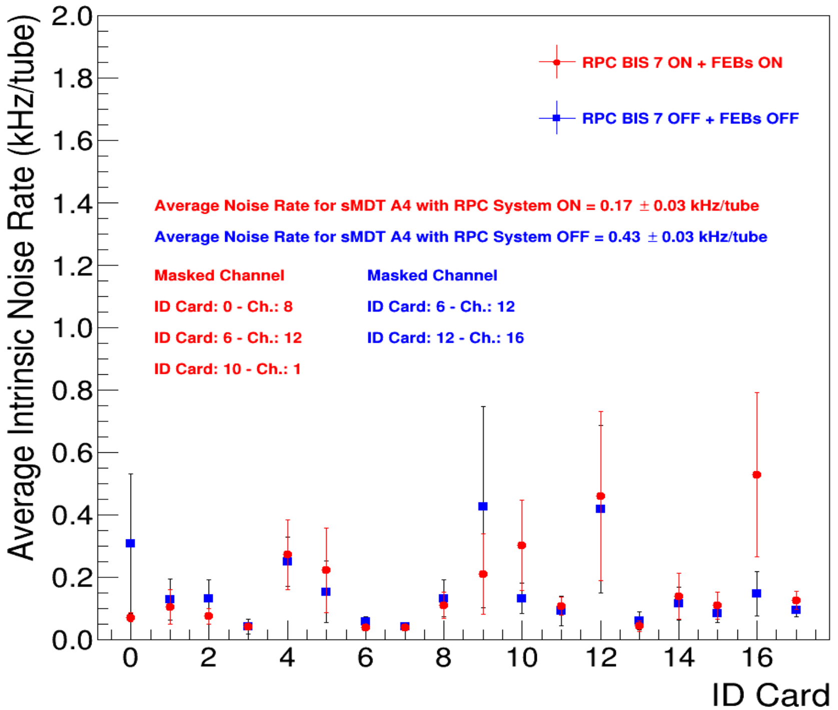
BIS78 sMDT Interference Test

Sequence:

- Check connectivity of the electr. components
- Monitor the communication stability
- Noise level measurement
- Identification the noisy/dead channels

BIS78 A04 - Noise Study @BB5





Detailed study shown that the effect of the RPC detector + its electronics is negligible to sMDT system (chamber + its electronics @ operating THR. = -39 V) in the term of noise!