Annual GIF++ User Meeting 2021

ATLAS-(s)MDT setup @ GIF++ facility

Elena VOEVODINA

on behalf of ATLAS-MDT group

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

MAX-PLANCK-GESELLSCHAFT

Outlook

- Introduction
- ATLAS-sMDT Setup Overview with cosmic ray
- ✓ Obtained Results (cosmic Sept. 2020 – Jun.2021)
- ATLAS-sMDT Setup Overview with μ-beam
- ✓ Preliminary Results (test beam Jul. – Nov. 2021)
- General Conclusions
- Plan for 2022

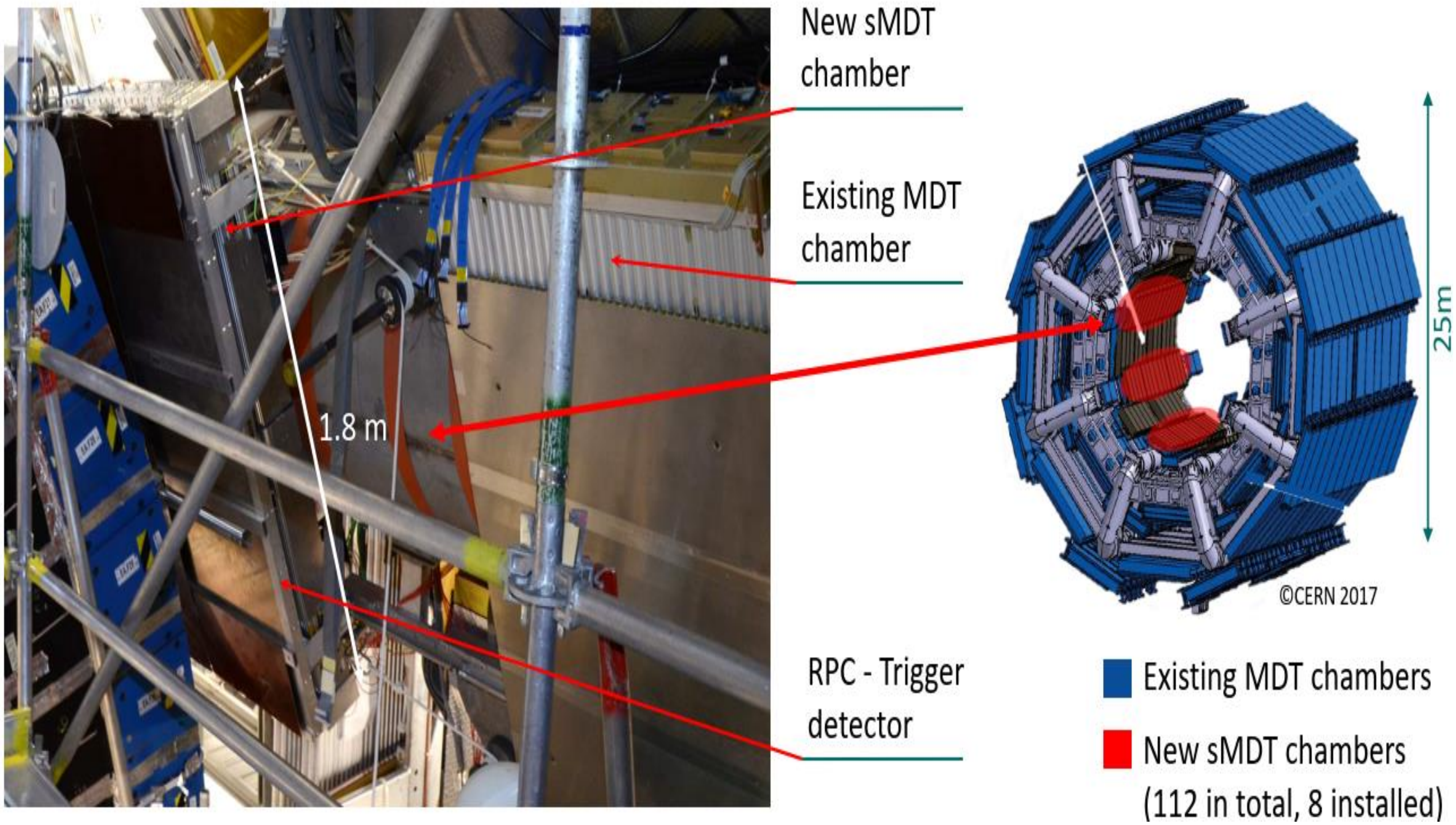
Introduction

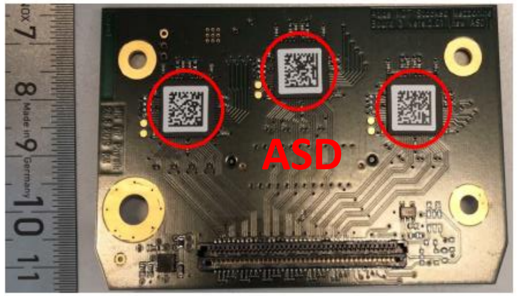
Phase-II upgrade of the ATLAS Muon spectrometer:

BIS -1-6 upgrade (96 in total), series production started.

Front-end readout electronics need to be changed for complete (s)MDT system to cope with new trigger scheme.

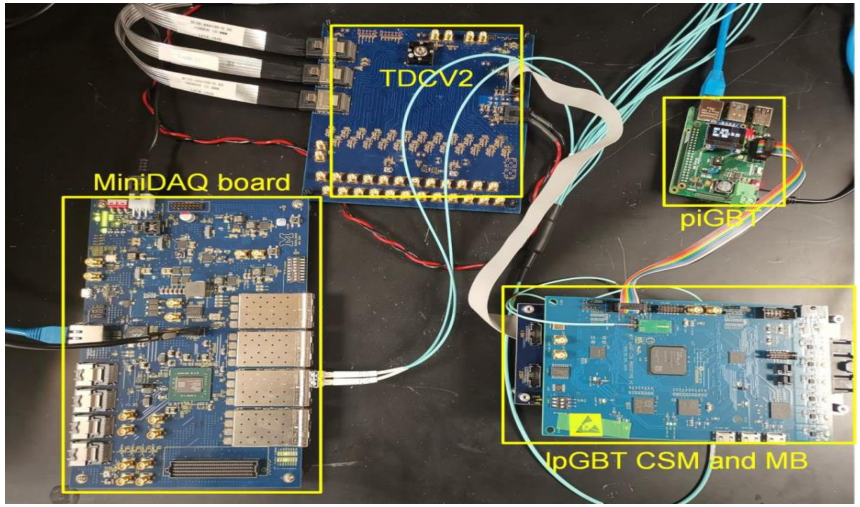
- ✓ *Installation of sMDT muon chamber for the HL-LHC ATLAS upgrade*





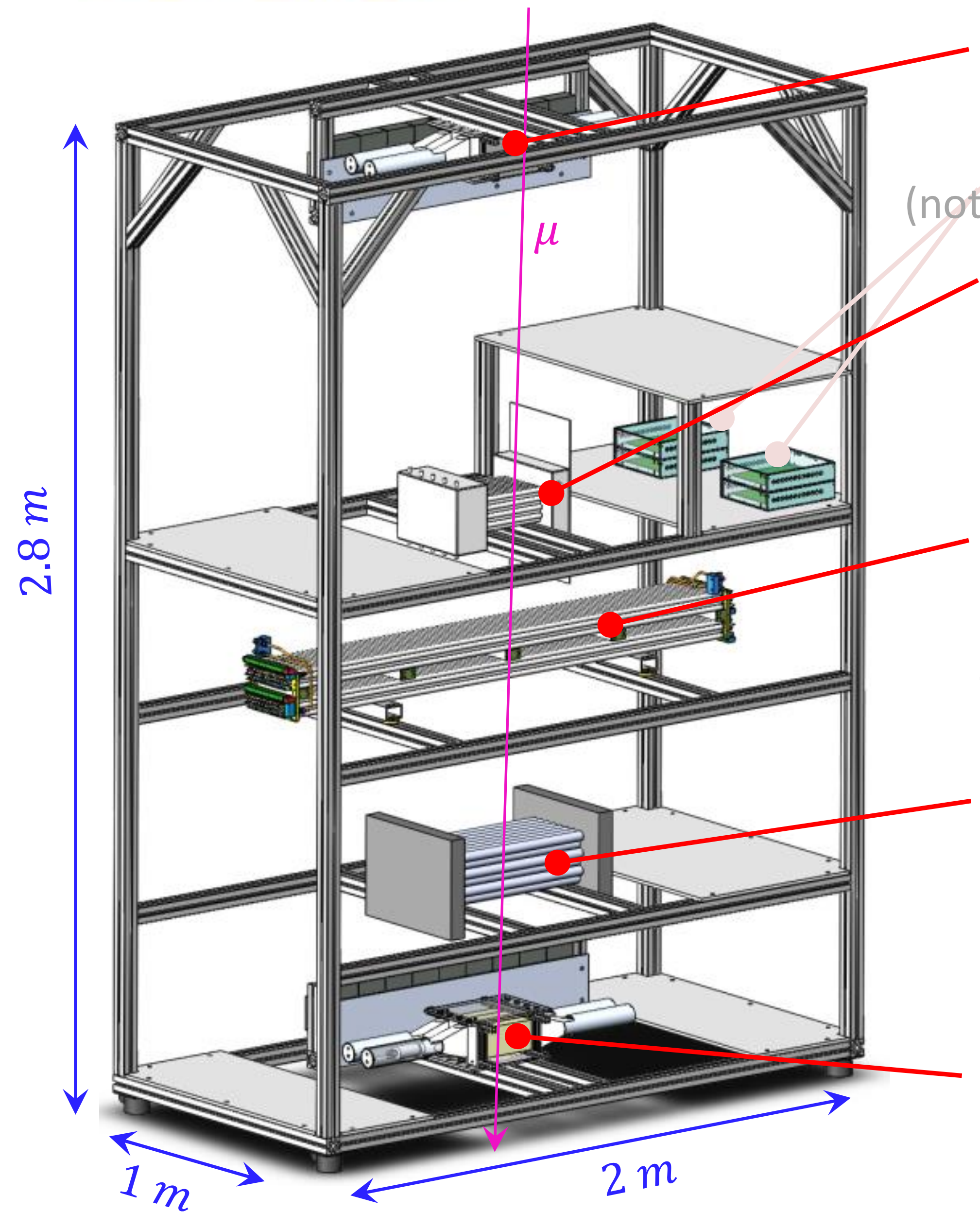
- ✓ *New ASD readout chip with reduced peaking time*

- ✓ *mini-DAQ system has been built to verify the front-end electronics chain with the new TDCv2 together with the final version of the ASD and the CSM*



ATL-(s)MDT setup @ GIF++ (cosmic Sept. 2020 – Jun.2021)

HL-LHC ATLAS EXPERIMENT



Top trigger
hodoscope
(shielded)

BLR boards
(not reported in this talk)

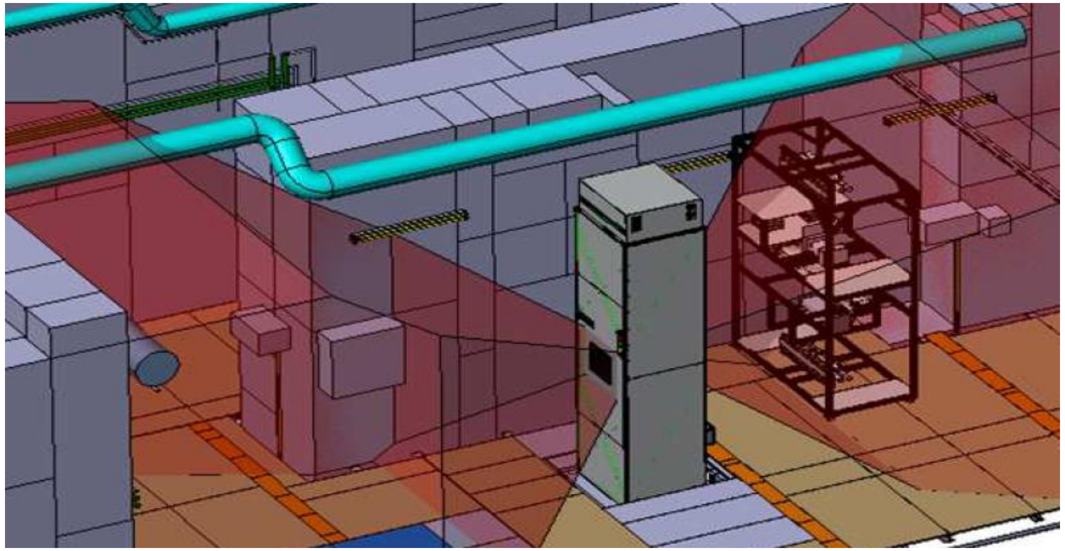
Mini-sMDT:
230 mm tube length,
96 channels
Electronics: old chip

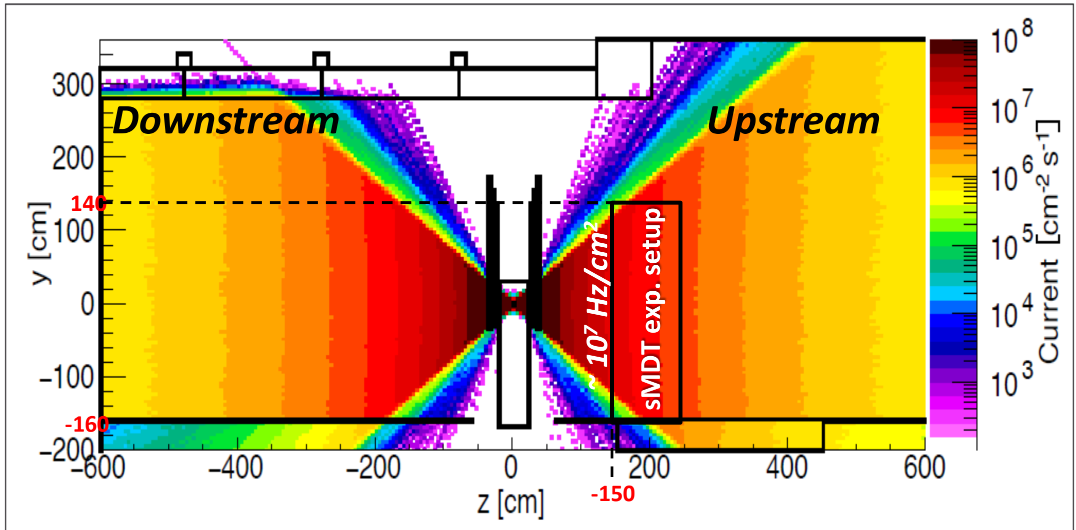
Mini-BIS sMDT:
1615 mm tube length,
96 channels
Electronics: new chip

MDT:
500 mm tube length,
48 channels
Electronics: old chip

Bottom trigger
Hodoscope
(shielded)

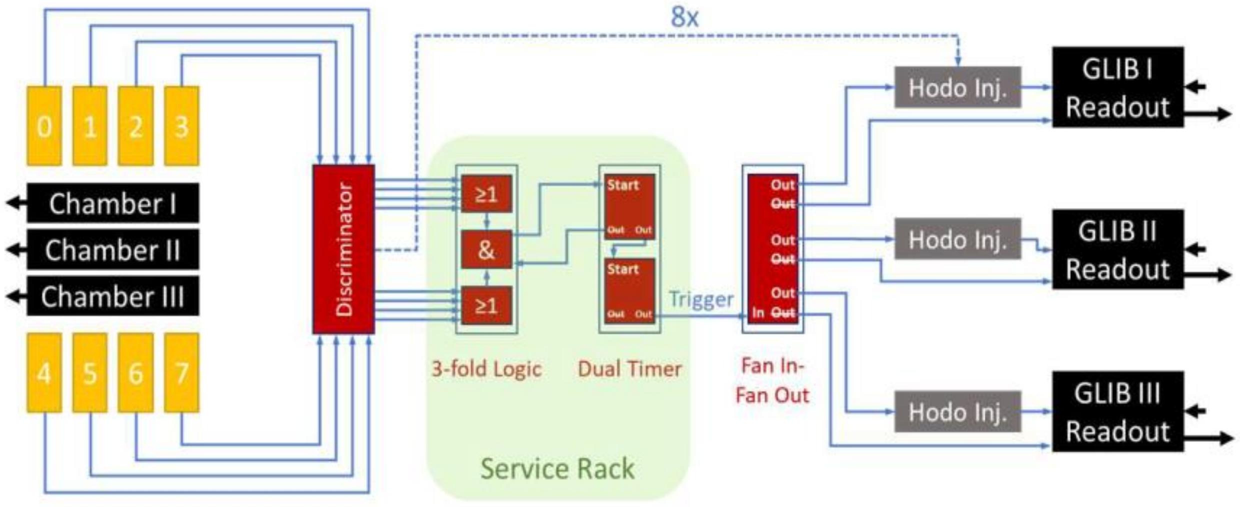
- ✓ **Housing multiple chambers with tube lengths up to 2m**
- ✓ **Background counting rates up to ~2MHz/m tube**



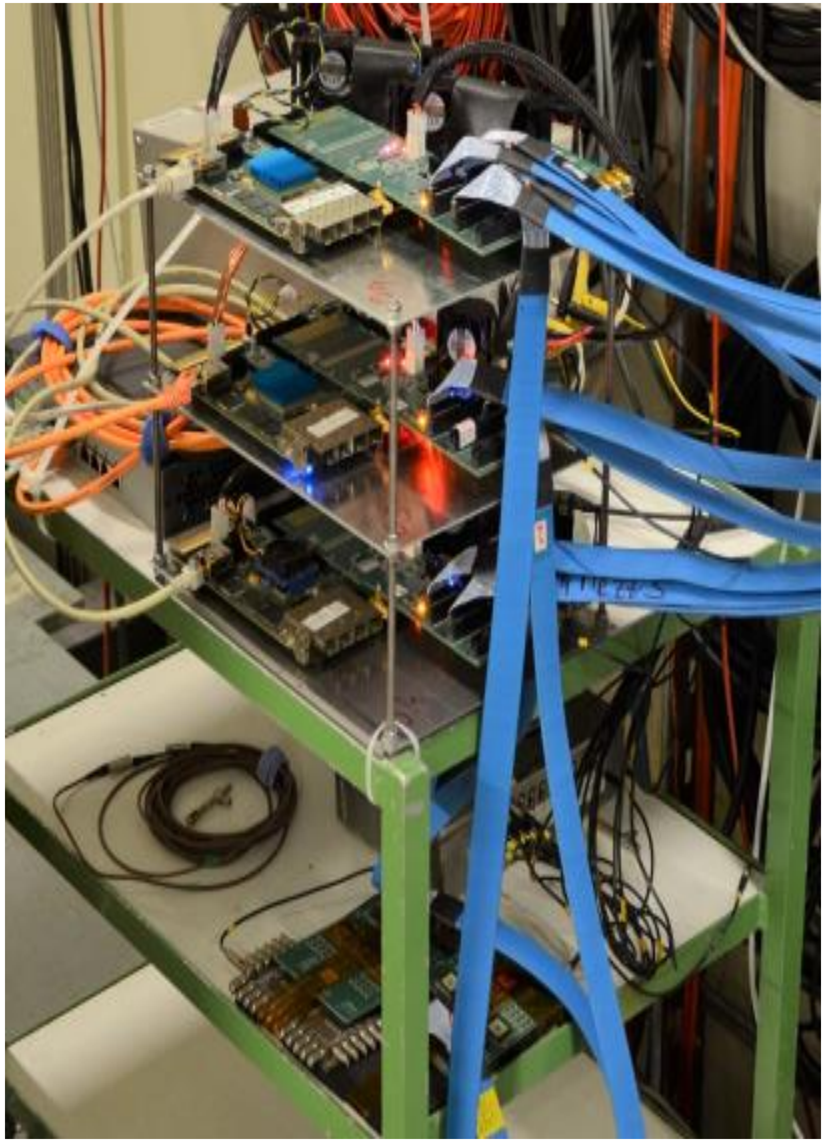


Trigger logic and readout path

Block diagram of the trigger logic and readout scheme



Trolley with GLIB boards



- **One GLIB readout board for each chamber:**

each up to 6x24 channels, programming of ASD and TDC chips and BLR electronic

- **Two hodoscopes:**

4 scintillators each, discriminator inside bunker to feed signals directly into GLIB boards

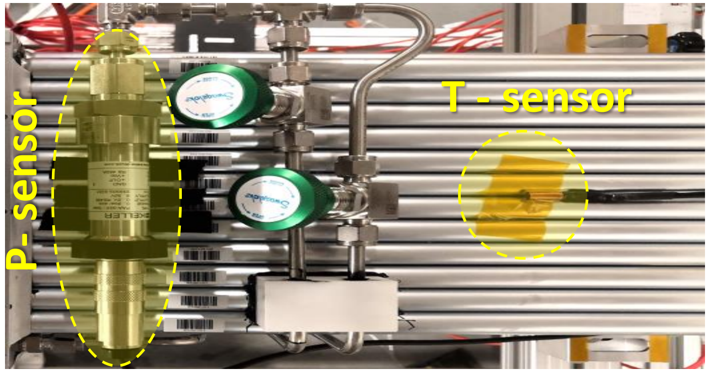
- **Logic unit in service rack:**

final cosmic muon trigger (+random trigger)

Detector control and data acquisition system

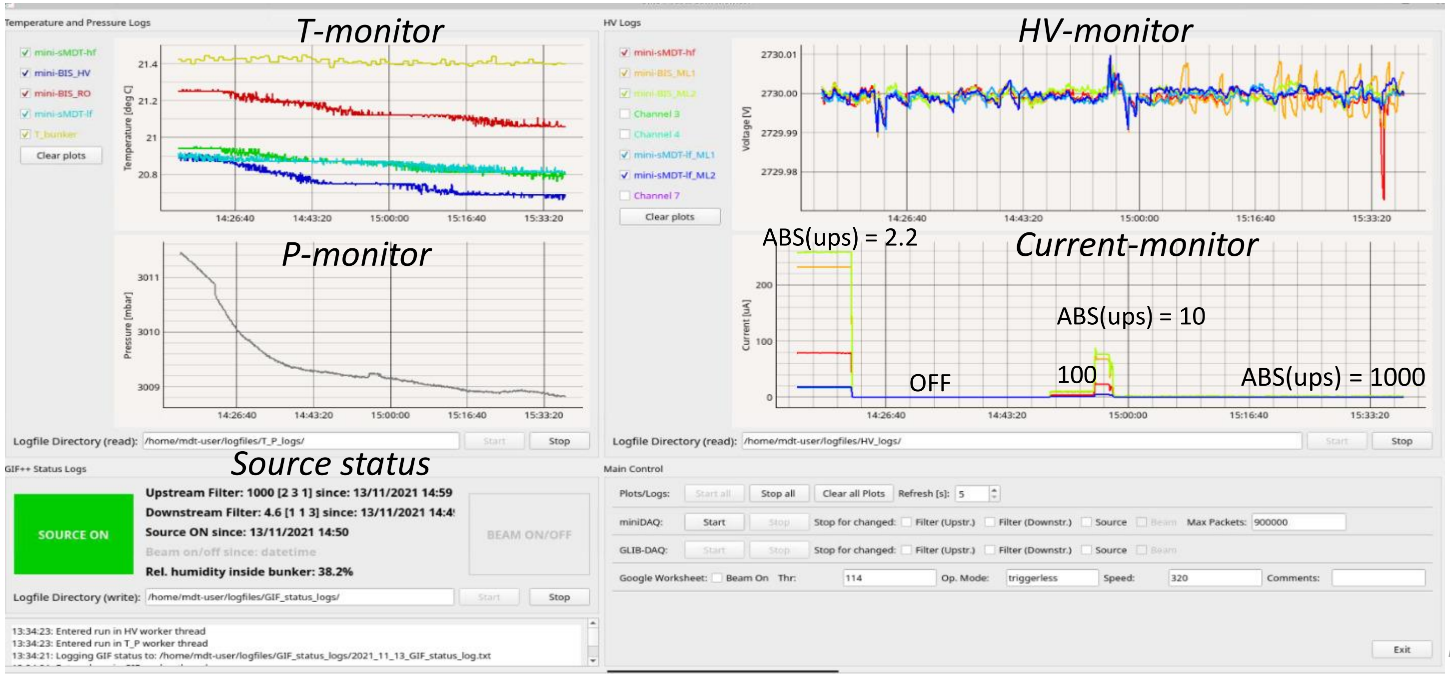
ATL-sMDT setup @GIF++ (09.2020 – 06.2021)

Pressure and temperature sensor installed on the mini-BIS detector



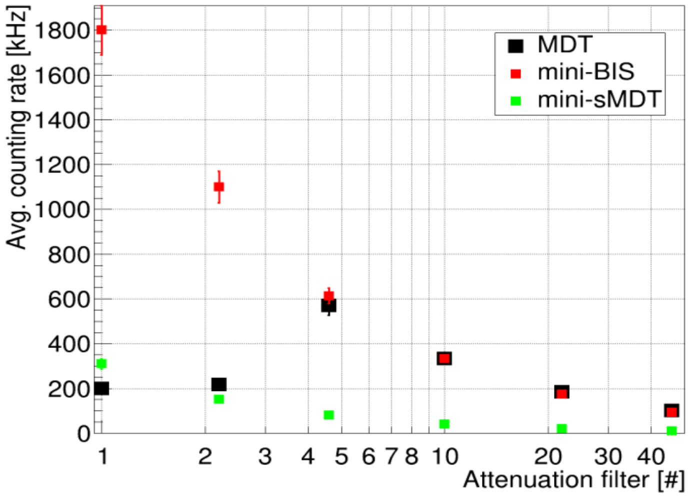
Sensor readout and processing box based on the Arduino bus line

The new graphical user interface for the ATLAS-sMDT detector control and data acquisition systems

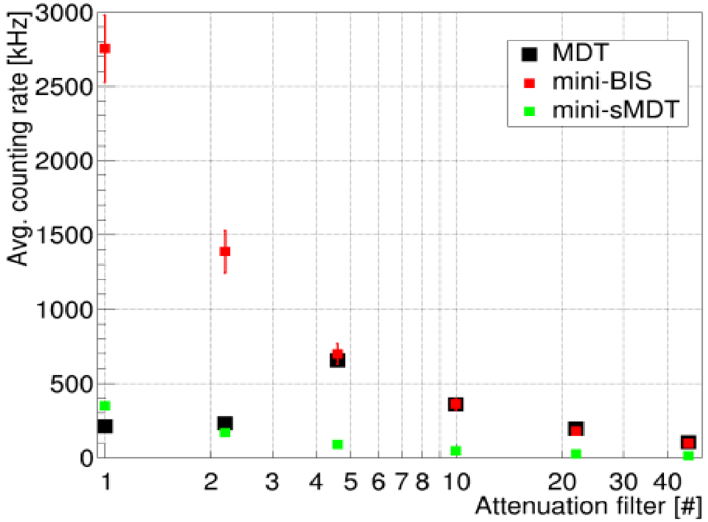


Attenuation Filter Scan (cosmic Sept. 2020 – Jun.2021):

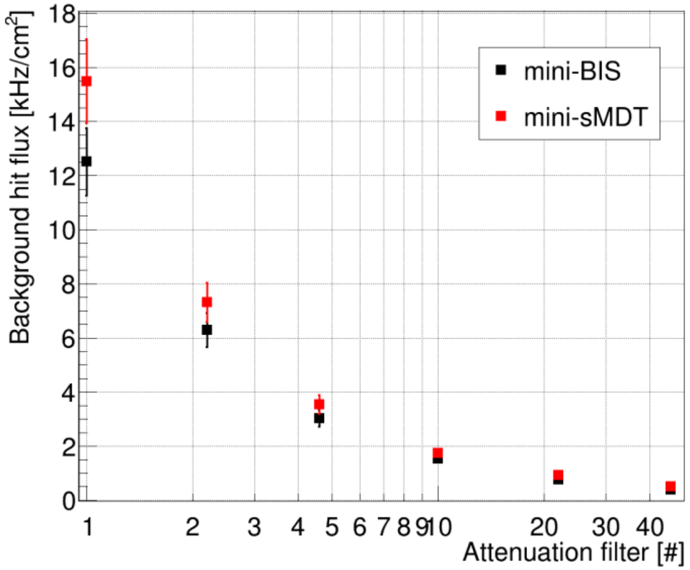
Observed counting rate



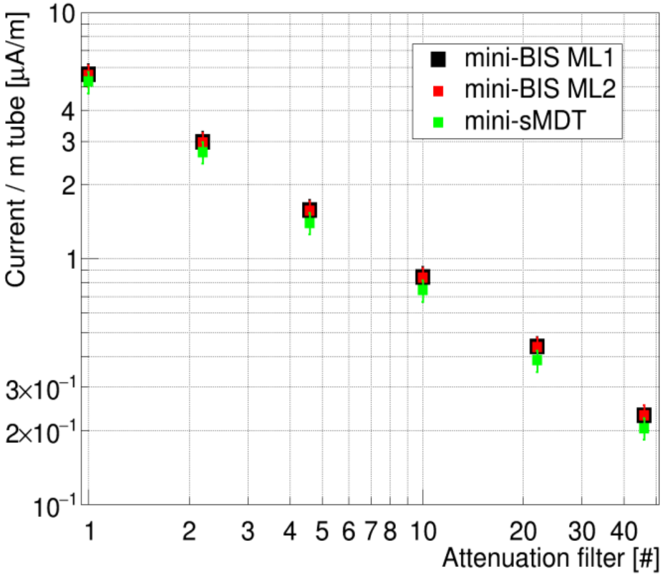
Dead time corrected counting rate



γ-background hit flux



Detector Currents Under Irradiation

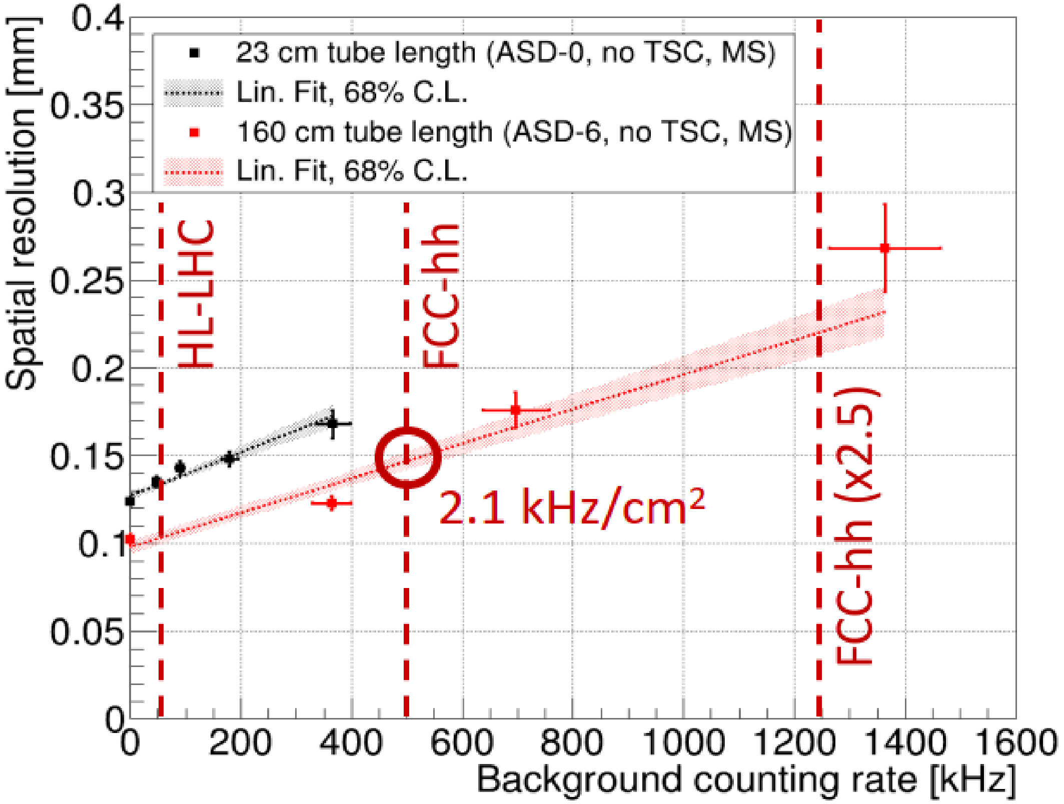


- The counting rates at different irradiation fluxes from the γ source are studied to determine the appropriate attenuation filter settings for the long cosmic ray data taking runs.
- The measured counting rates in combination with the currents drawn by the chambers under irradiation provide the necessary information for the adjustment of the operating voltage to compensate for the gain drop in the drift tubes

*CERN-THESIS-2021-061-G.Eberwein

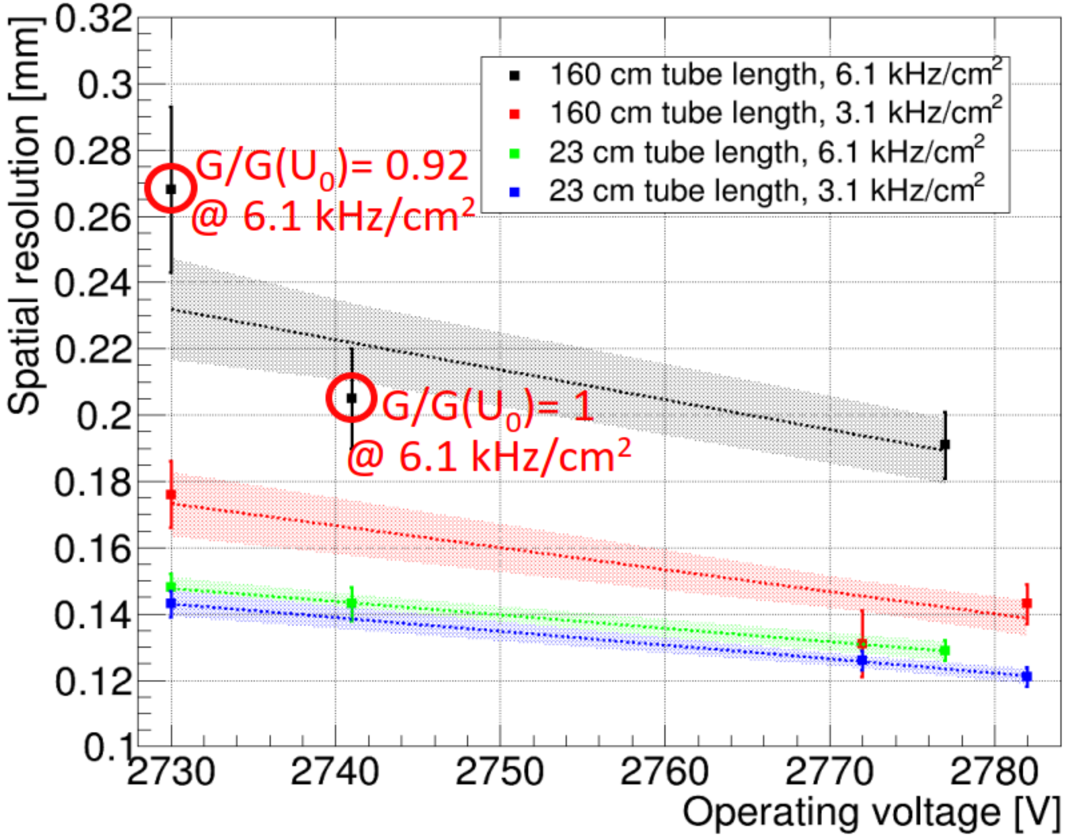
sMDT Spatial Resolution (cosmic Sept. 2020 – Jun.2021):

sMDT drift tube spatial resolution depending on the background counting rate



- Improvement of spatial resolution with new chip by 20-30%.
- Operation up to 2.0 MHz counting rate/tube (expected for FCC-hh) feasible.

Further improvements of spatial resolution



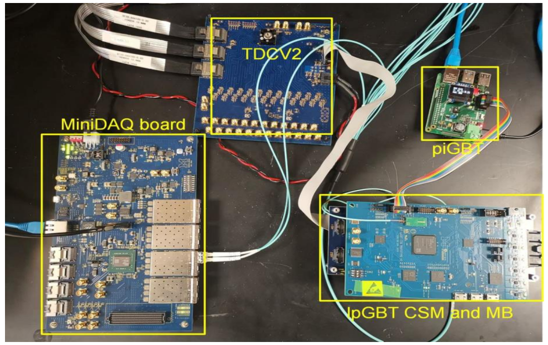
- Adjustment of operating voltage and gas gain at high rates indicate significant improvement of spatial resolution.
- Increase operating voltage such, that space charge reduces the gain to the nominal value of 2×10^4.

*CERN-THESIS-2021-061-G.Eberwein

ATL-(s)MDT setup @ GIF++ (test beam Jul. – Nov. 2021)

ATL-sMDT setup during the Sept. TB period

CSM and MiniDAQ system



- **mini-sMDT-lf (low flux) chamber:**
  23 cm active length tube, 96 channels/tubes
  3.5 m read-out cables
- **mini-BIS sMDT chamber:**
  1.56 m active length tube, 96 channels/tubes
  5 m read-out cables
- **Two stacked mezzanine cards (one on each multilayer):**
  ASD-6 and *TDCv2 chips* were operated on the chamber
- **Mezzanine cards read-out system:**
  Phase-II CSM prototype and the new MiniDAQ system

TDCv2 operating modes

➢ Baseline operating mode of the TDCv2 chip for HL-LHC

- Triggerless operation.
- Hits stored in 32 bit words in pair mode (leading and trailing edge information in one word).
- Data transmission via two 320 Mbps lines. ⇒ Maximum allowed hit rate: 666 kHz/channel.
- Optional reduced transmission rate: 160 Mbps/line (for data transmission over long readout cables

➢ Legacy mode

- Triggered mode mimicking the present AMT TDC chip.

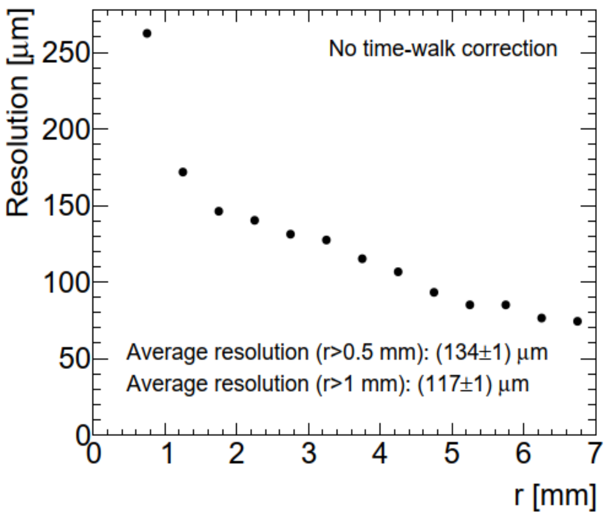
Main Goals(test beam Jul. – Nov. 2021):

- ✓ **Efficiency and resolution studies without γ background to check the integrity of the new CSM with the Mini-DAQ readout system and the offline analysis code.**
- ✓ **Muon tube efficiency measurement at different γ background hit rates to ensure that the TDCv2 chip loses no data.**
- ✓ **Spatial resolution study of the sMDTs to illustrate the performance of the sMDT chambers at different γ background levels.**
- ✓ **Detailed study of the adjustment of the sMDT operating voltage at high background hit flux.**

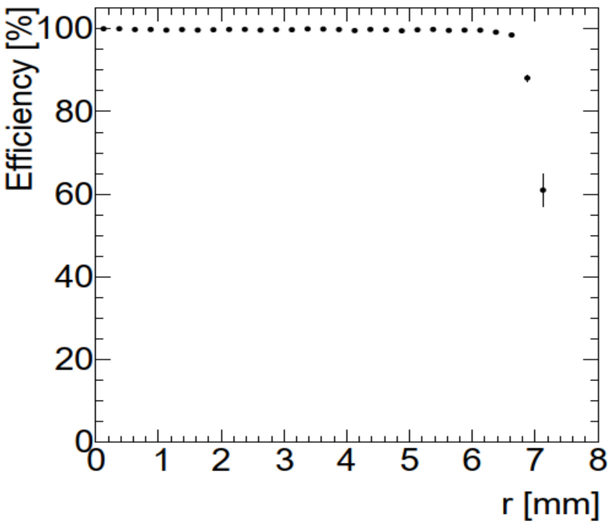
Main Results (test beam Jul. – Nov. 2021):

➢ Integrity checks without γ radiation background

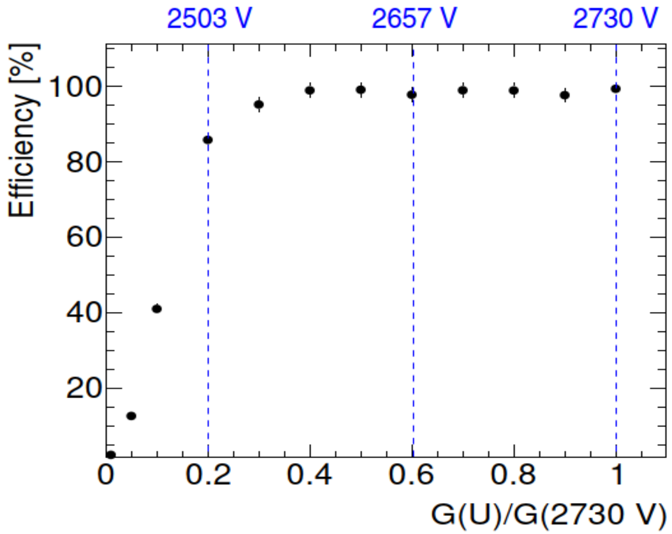
Spatial resolution of a tube



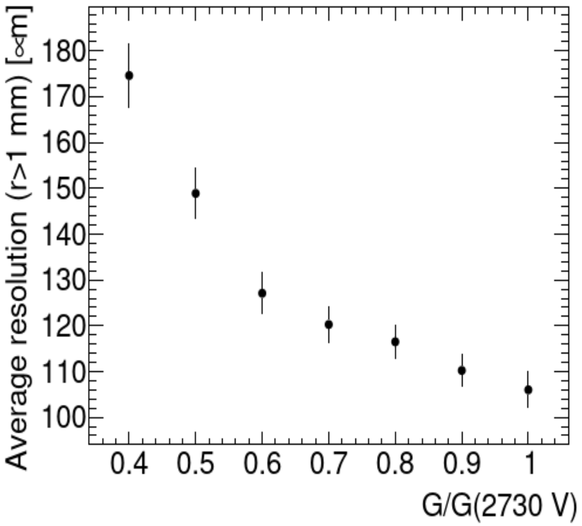
Muon Efficiency of a tube



Efficiency at different gas gains

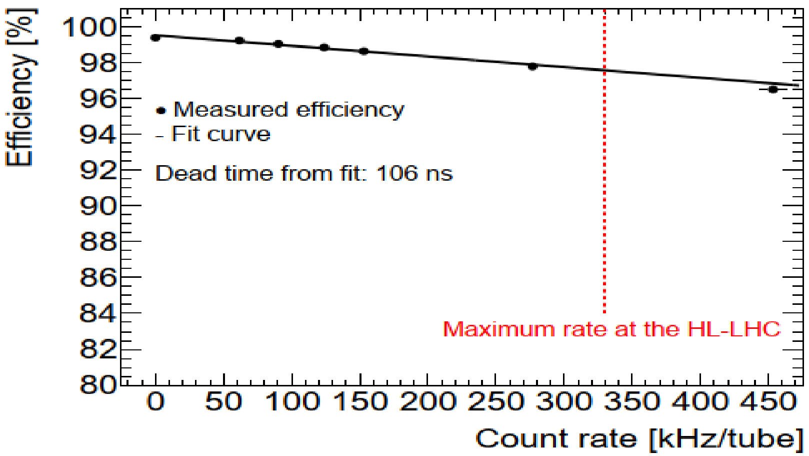


Resolution at different gas gains

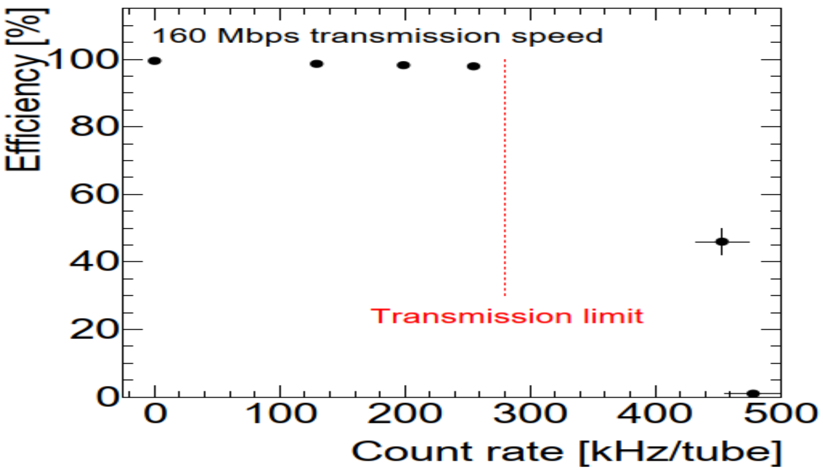


➢ Test of the TDCv2 chip under high γ background

320 Mbps transmission speed



160 Mbps transmission speed



Conclusions

Cosmic ray test Sept. 2020 – Jun.2021:

- ✓ **sMDT** precision muon tracking detectors with **new readout electronics** are well suited for operation at the **HL-LHC and future hadron colliders.**
- ✓ **Optimization** of readout electronics to fully **exploit the sMDT rate capability**.
- ✓ Confirmed that **faster signal shaping** (as in new readout chip) **improves the spatial resolution** of sMDT drift tubes with and without background radiation.
- ✓ **Adjustment of the operating voltage** to compensate for **gas gain loss** at high rates due to space charge has the potential for **further improvement of the spatial resolution.**
- ✓ **Next step** of rate capability improvement: Development of readout electronics with **active baseline restoration** (results were not presented here).

More details of the studies: CERN-THESIS-2021-061-G.Eberwein

Test beam period Jul. – Nov. 2021:

- ✓ High-quality test-beam data recorded in the present test-beam campaign.
- ✓ **Test of the TDCv2 chip** in pair and **triggerless mode at 2× 160 Mbps and 2×320 Mbps** data transmission speed at different levels of γ background flux.
- ✓ **320 Mbps**: **Data loss** observed for hit rates above limit of **666 kHz/tube**
- ✓ **160 Mbps: Efficiency loss** at count rates above the transmission limit ~ 300 kHz/tube.
- ✓ **Error Words** : **TDC correctly sends out error words** when buffers are full for both transmission speeds.
- ✓ **System tested** also with **legacy mode** of the chip. No data loss observed at GIF++ condition.

HL-LHC ATLAS EXPERIMENT

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Plan for 2022

Plan:

- Continue to test the functionality of the **baseline restoration (BLR)** circuitry to counter pile-up effects and increase spatial resolution and efficiency.
- Further measurements of the **operation at adjusted high-voltage** levels to counter gain drop at high background radiation due to space charge.
- Continue to study/validate the **performance of the new on- (ASD-6b, TDC chips) and off- (CSM) detector electronics components** and as well as the **chamber read-out system** together with the small-diameter Muon Drift Tube (sMDT) detector technology **for the Phase-II upgrade of the ATLAS muon spectrometer.**

Additional RPC detector technology within the ATL-sMDT setup:

- Real size of the **BIS RPC detector prototype** with dimensions 1.2 m x 1.8 m x 0.6 m [length x height x width] produced by the MPI MDT group is planned to be installed in the CERN GIF++ facility.
- **Gas mixture:** 94.5% of R134a (C2H2F4), 5% of iC4H10, 0.5% of SF6 with the relative humidity of about 45 % (i.e. 8000–12000 ppmV). **Operating voltage: ~5600 V.**
- **Required services:** gas line, HV/LV, LEMO cables must be properly routed from the Gas / Electronics rack to the irradiation area where the ATL-sMDT is located. An extra Electronics rack is required to accommodate HV/LV power supplies and a PC with the detector control and data acquisition systems.
- **Motivation:** the precision study of the performance of the new ATLAS RPCs detector developed by the MPI MDT group

Time:

- Irradiation window: ***January - December 2022***
- ***Moun Beam Time will be requested separately in April - November 2022 = (4 x 2 weeks)***

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