



AIDA 2020

# The BIS78 Resistive Plate Chambers upgrade of the ATLAS Muon Spectrometer for the LHC Run-3

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on behalf of the ATLAS Muon Collaboration

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Roma Tor Vergata
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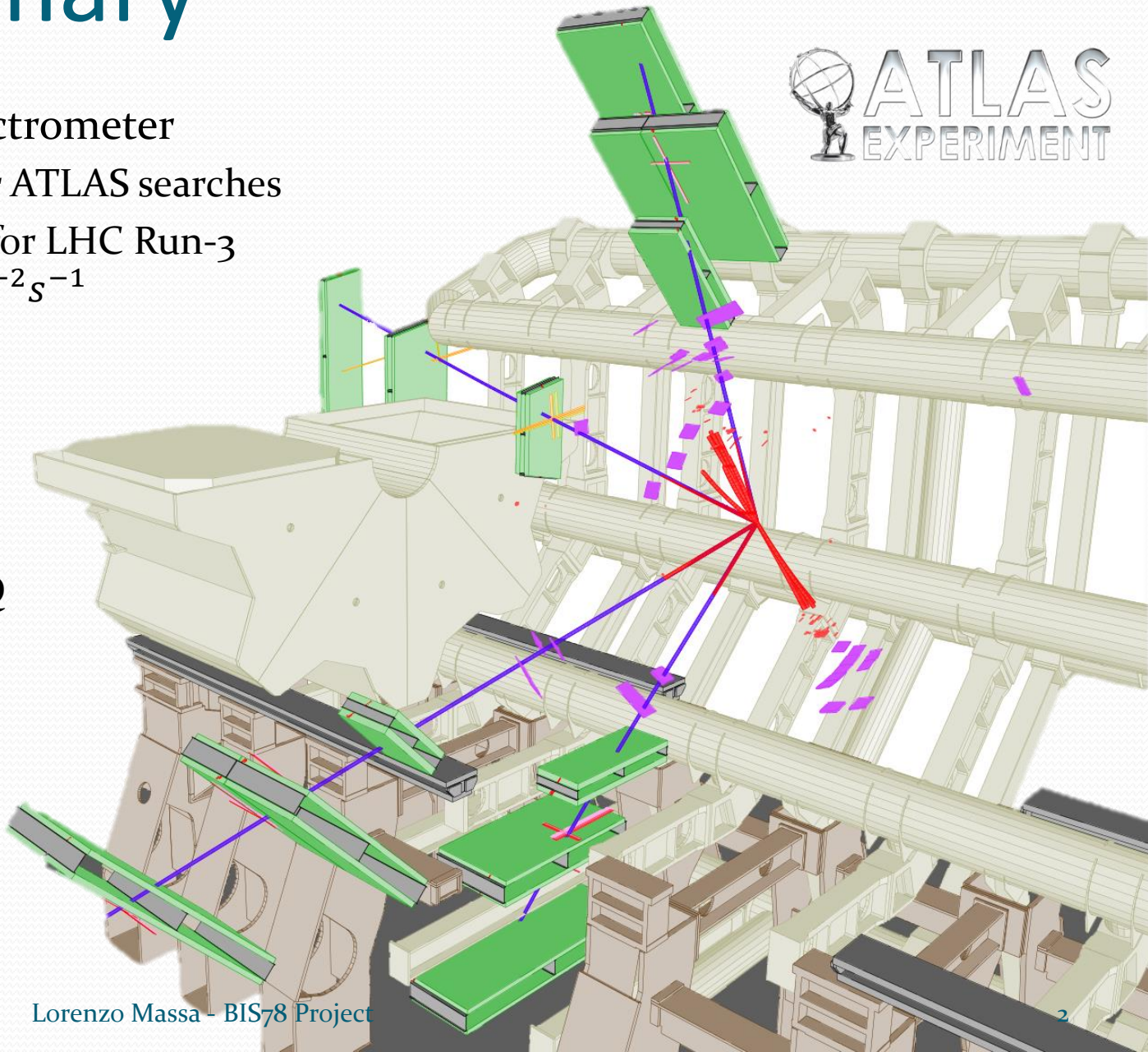
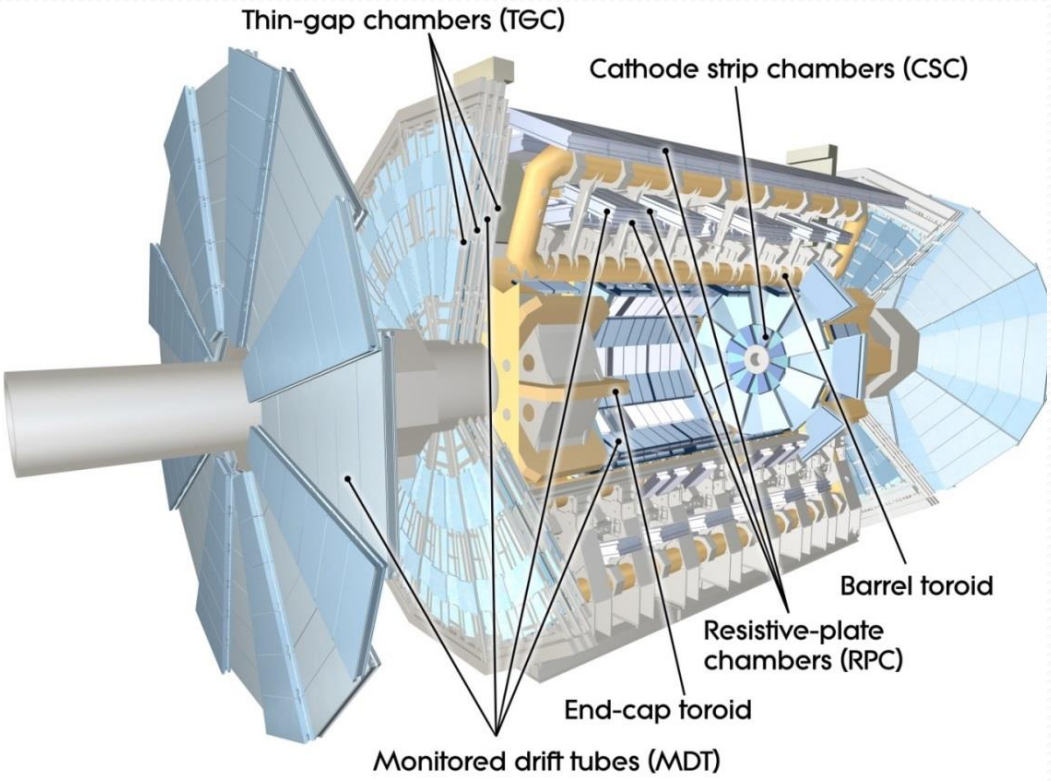
# Summary

- ATLAS Muon Spectrometer
  - Fundamental for ATLAS searches
  - To be upgraded for LHC Run-3
    $L = 2 \times 10^{34} cm^{-2} s^{-1}$
- BIS78 Project
  - RPC Production
  - Trigger and DAQ



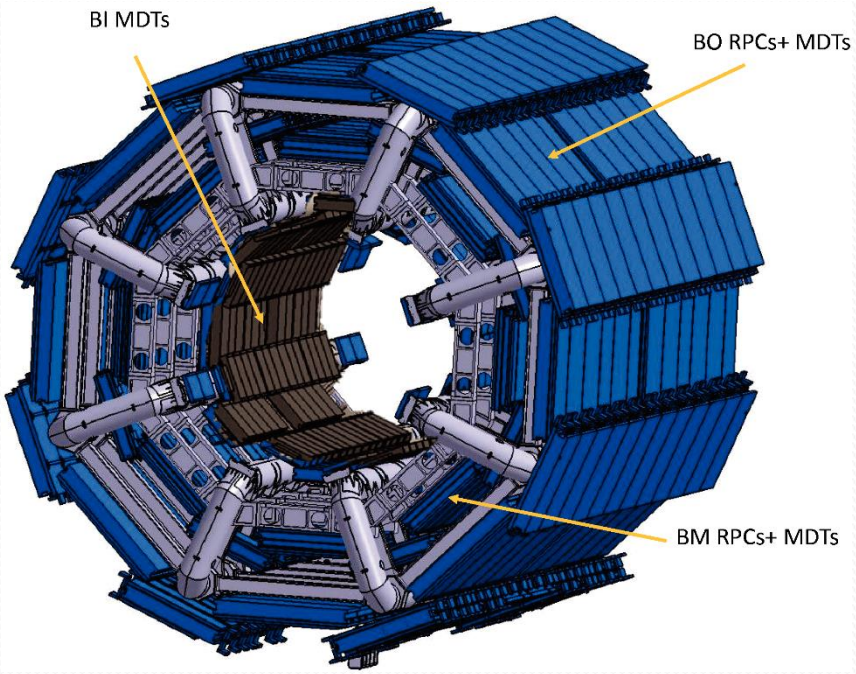
# The ATLAS Muon Spectrometer

- Huge spectrometer
  - 46 m x 25 m
- Muon's trajectory bent by a toroidal magnetic system ($B \approx 4T$)
- Momentum measured through almost 4000 detectors



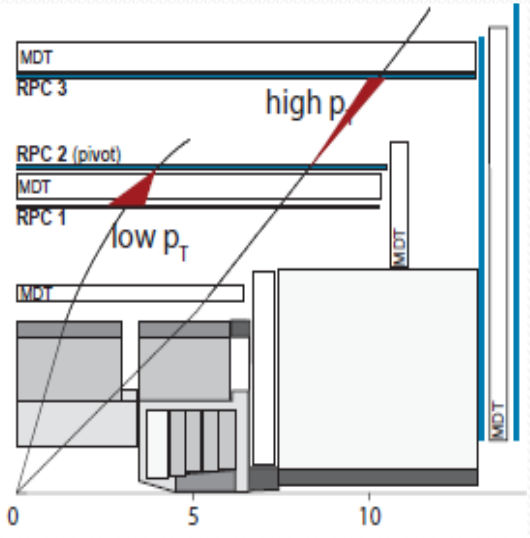

- Tracking made with two types of precision detectors
  - Monitored Drift Tubes(MDT)
  - Cathode Strip Chambers (CSC)
- Trigger made with two types of fast detectors
  - Barrel: Resistive Plate Chambers (RPC)
  - EndCap: Thin Gap Chambers (TGC)

# ATLAS RPC system



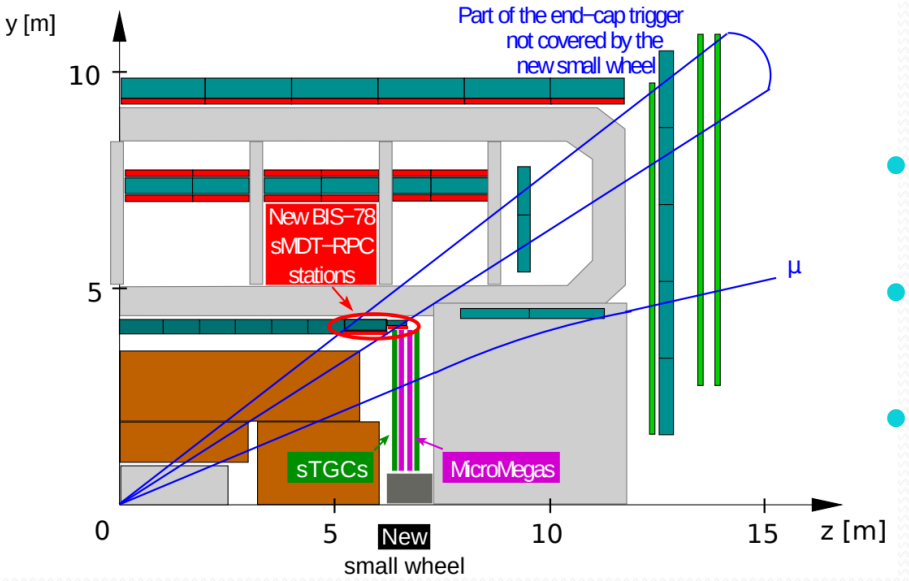

- RPCs are responsible for L1 muon trigger in the Barrel $|\eta|<1.05$
  - Total surface 7000 $m^2$
  - About 1000 RPC doublets
- Three concentric stations (RPC doublets)
  - 2 in Barrel Middle BM region
  - 1 in Barrel Outer BO region
  - No RPCs in Barrel Inner BI region, project to install a new layer of RPC for Phase II (see Y. Sun talk)

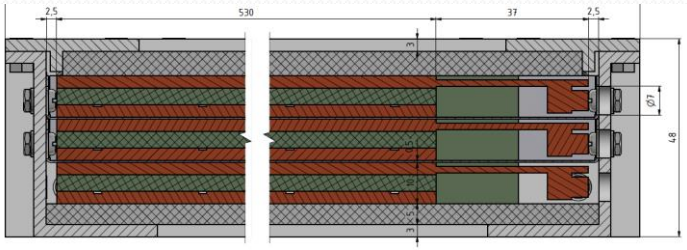
- Trigger algorithm based on RPC hit coincidence
  - Low-$p_T$ trigger ($p_T$< 10 GeV) uses the BM stations
  - High-$p_T$ trigger ($p_T$> 10 GeV) requires an additional confirmation on the BO station

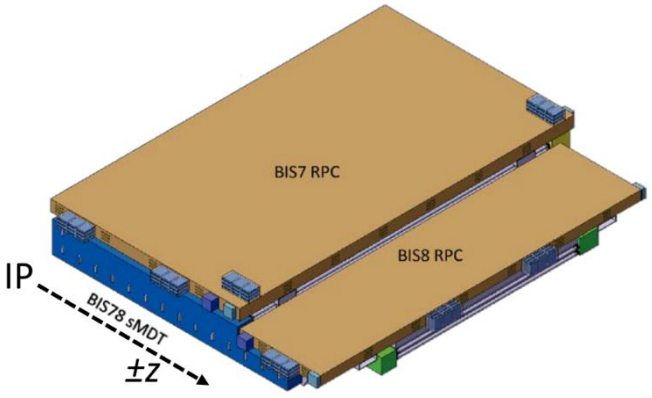


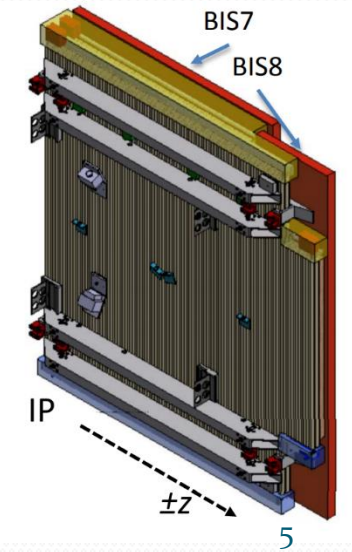
# BIS78 Upgrade

- The existing 32 BIS7 and BIS8 MDT will be replaced by 16 new muon stations made of:
  - one sMDT BIS7+8 chamber
  - two RPC triplets (BIS7 and BIS8)
- Selectivity in transition region improved by adding a new trigger layer
- 8 stations for one end cap (side A) to be installed in 2020
- BIS78 can be considered as a pilot project for the Phase II BI upgrade.



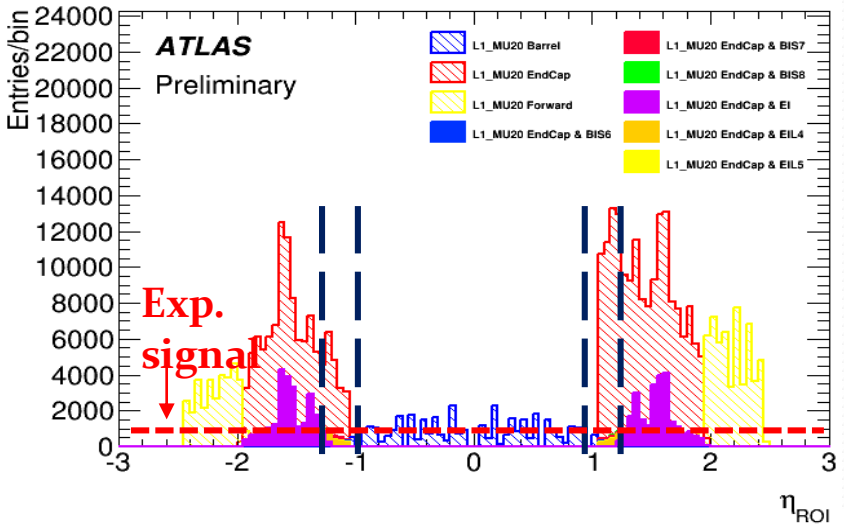


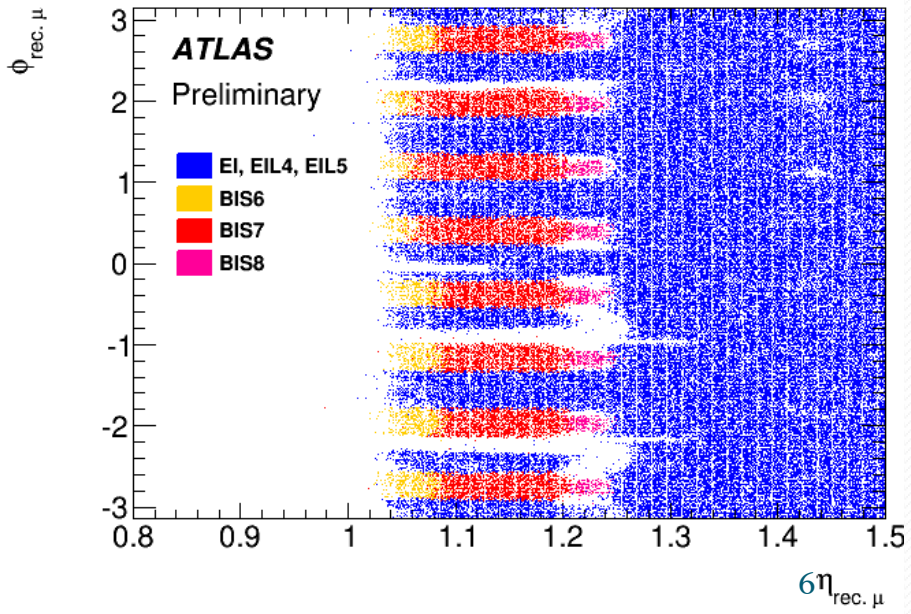



# High trigger rate in |η|>1

- High fake trigger rate expected for |η|>1, due mainly to low-$p_T$ protons generated in toroids and shieldings.
- The rate in forward region (|η|>1.3) will be reduced by New Small Wheel
- Half of the rate in the barrel-endcap transition region (1<|η|<1.3) will be reduced by the existing TGCs
- The other half of the fake trigger rate in transition region will be reduced by the BIS78 stations

**$\eta$ distribution of muon trigger ($p_T$>20 GeV)**

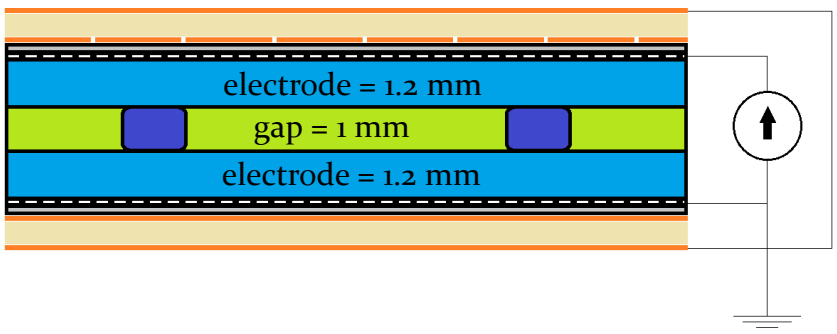


# New generation of RPCs

## New Gas Gap

- Thinner gas gap (2 mm → 1 mm)
- Thinner electrodes (1.8 mm → 1.2 mm)
  - Lower detector weight
  - Thinner supports allowed
  - More efficient signal collection
  - Almost halve the applied HV
  - Improved charge distribution
  - Double time resolution




## New Front End Electronics

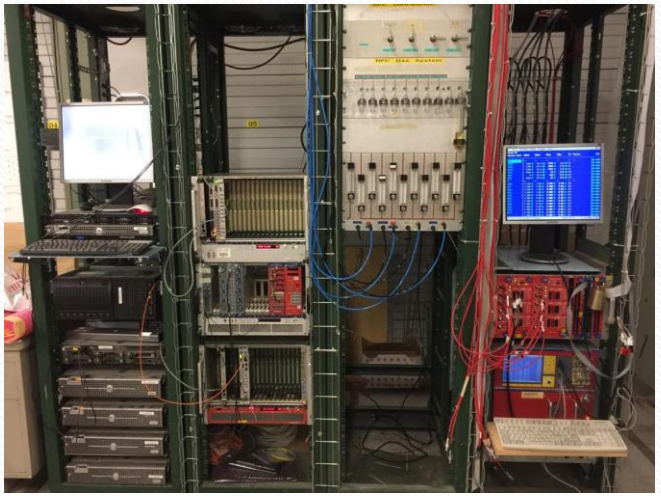
- New amplifier and discriminator
  - Higher rate capability
  - Radiation hardness
  - Better space-time resolution
  - Inexpensive high performance low power FE
  - More details in L. Pizzimento's talk

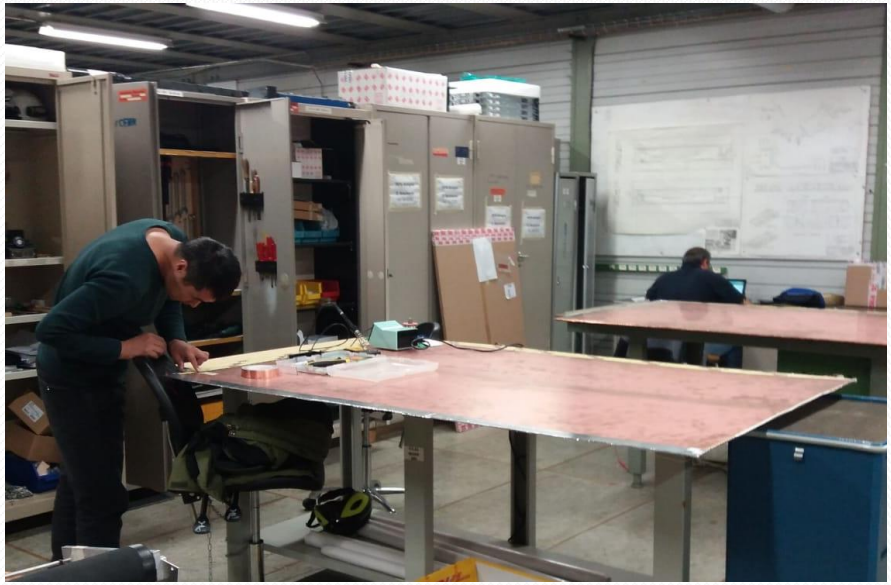
| Amplifier in Silicon | |
|---|---|
| Gain | 0.2-0.4 mV/fC |
| Power Consumption | 3-5 V 1–2 mA |
| Band width | 100 MHz |

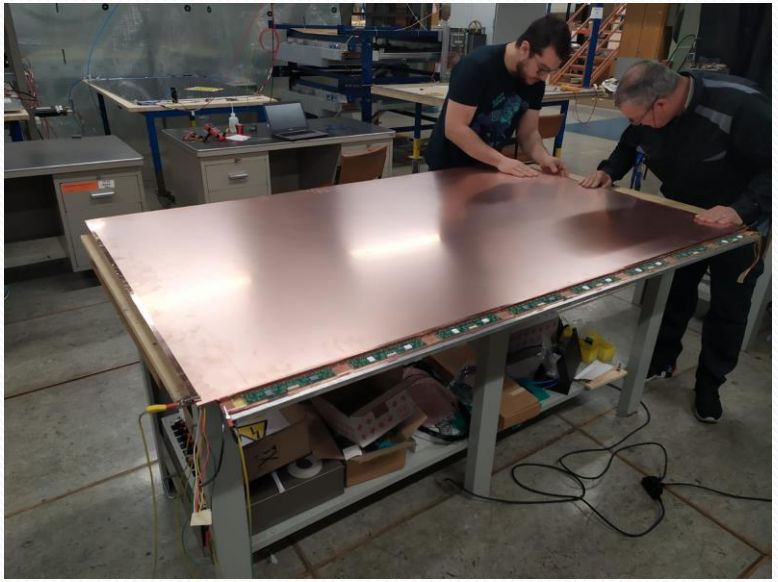
| Discriminator in SiGe | |
|---|---|
| Threshold | 0.5 mV |
| Power Consumption | 2-3 V 4–5 mA |
| Band width | 100 MHz |

**New Generation RPCs' Space-Time Resolution: 1 mm x 0.4 ns**

# Production site at CERN







# BIS 78 RPC Production stages at CERN

- Strip panels glueing on forex insulator
- FE Boards test
- Soldering of the matching resistors and FE boards
- ReadOut Panels test
- Gas gaps conditioning
- Gas gaps HL-LHC test

- Gas gap and ReadOut panel coupling
- Test on singlets
- Singlets and mechanics coupling
- Service and cabling integration
- Integration with sMDT
- Final test

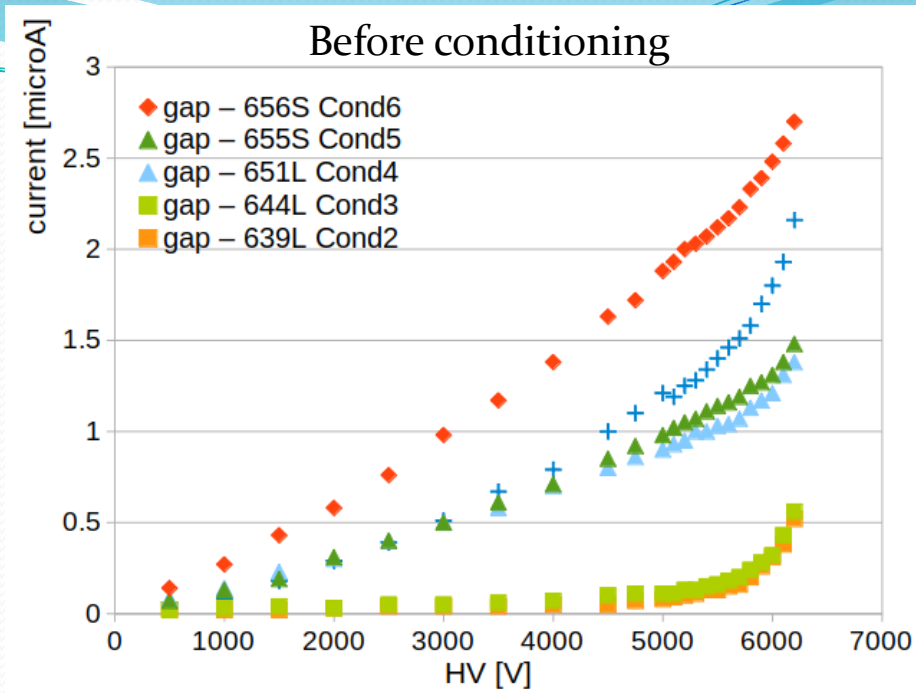
# Gas gap QA/QC

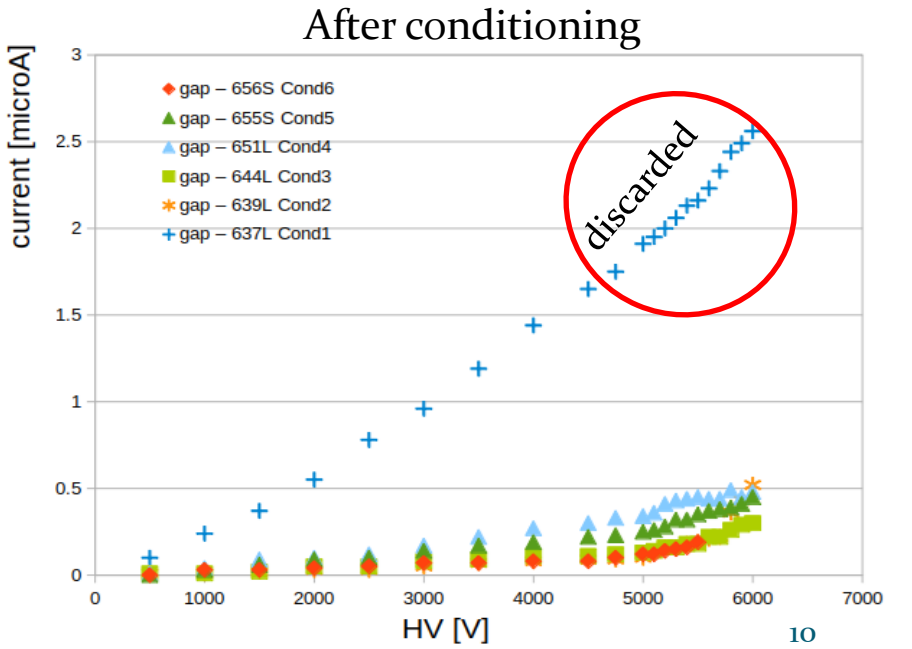
Acceptance test at the production site (General Tecnica)

- Electrode resistivity
- Spacer gluing strength test
- V/A characteristic
- Gas tightness
- HV insulation test

1 week of gamma irradiation at CERN

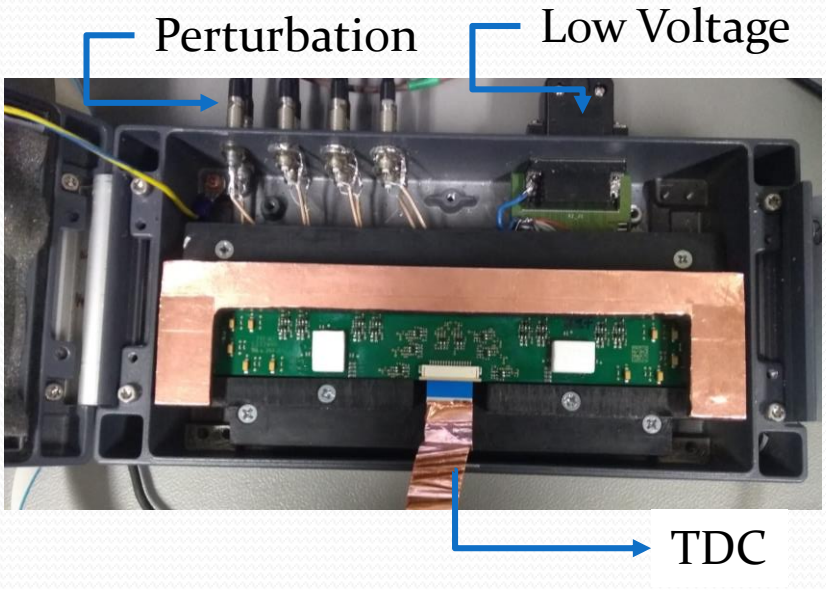
- Slow turn on at high rate (conditioning): all the gaps have to reach 40 µA in steps of 10 µA, which take around half day each.
- Stability test at HL-LHC like conditions: no change in the V/A characteristics after irradiation



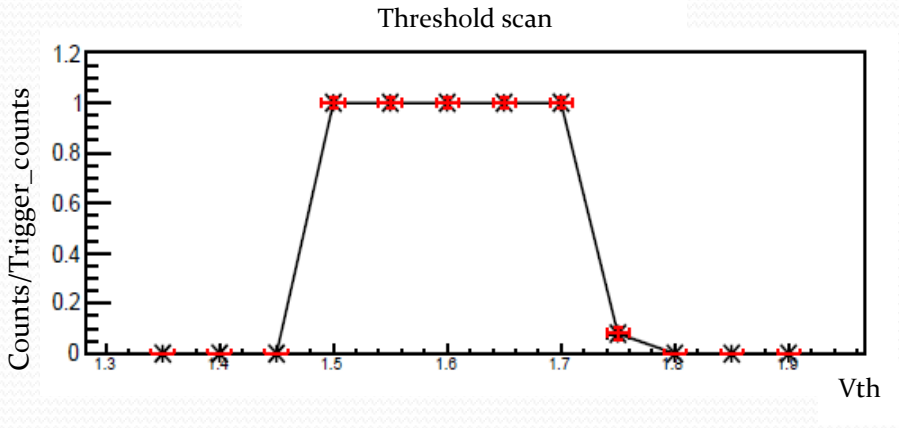



# Front End Boards QA/QC

- New FE Boards tested carefully
- Each board tested moving the threshold *Vth* parameter
- For each *Vth* value, the 8 channel inputs are perturbed with a metal spring probe and the output signals are acquired with a TDC
  - Counts vs *Vth*
  - Time distributions
  - Time width distributions

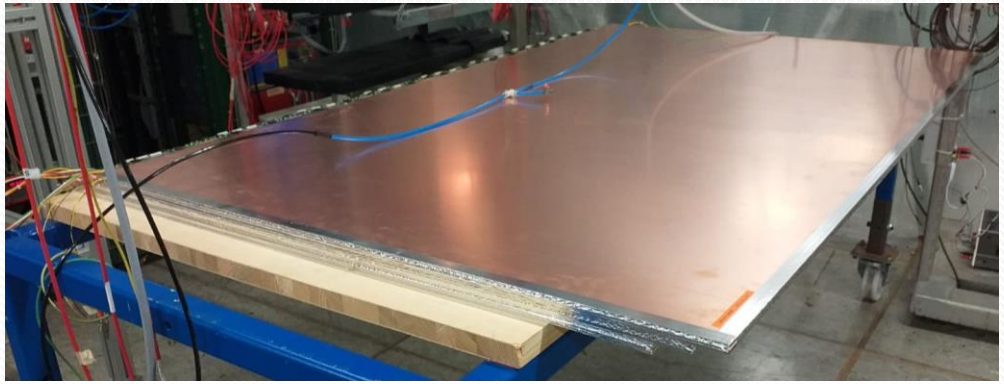


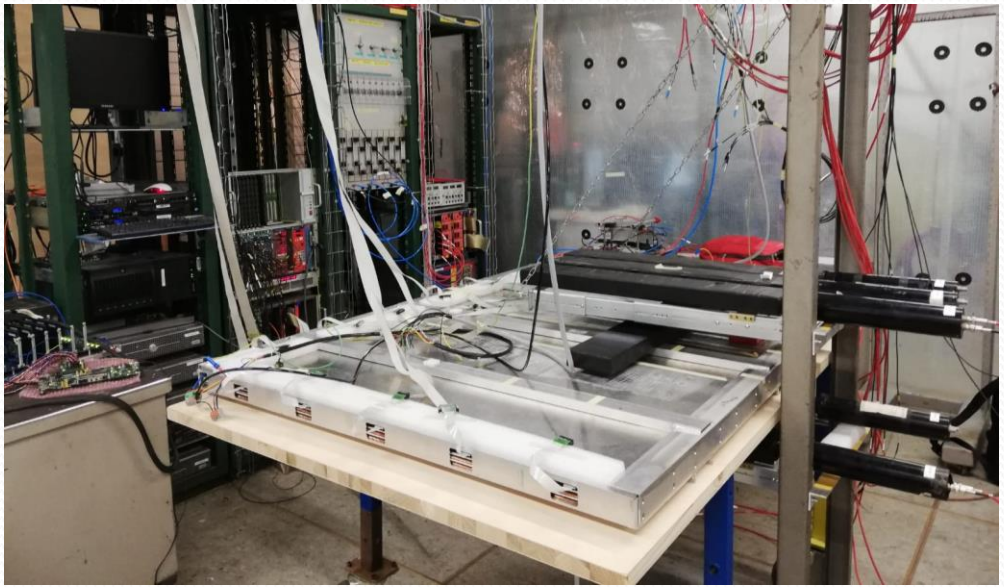

- The FE boards fulfill the QA/QC test when all input channels work varying the threshold within a range of at least 200 mV (1.5V ≤ *Vth* ≤ 1.7 V) and there is no crosstalk
- With these criteria, there is a yield of 90% of accepted boards



# Cosmic Ray tests

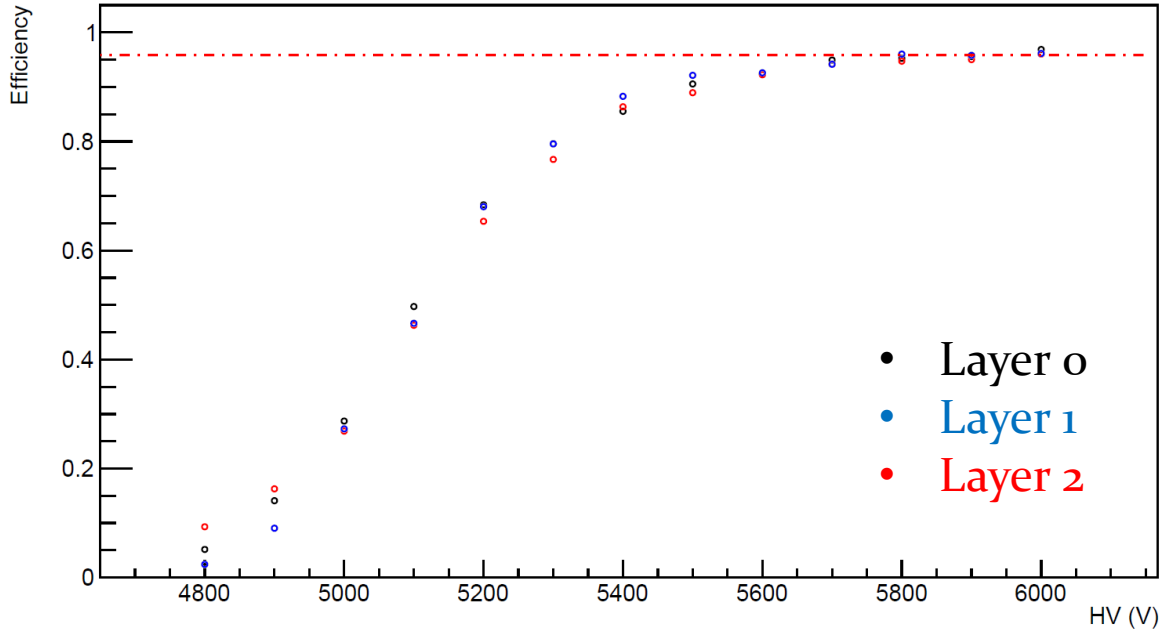
- All assembled singlets and triplets are tested with cosmic rays.
- Trigger:
  - 2 layers of scintillators (20 cm x 60 cm)
  - 1 singlet at fixed HV as reference
  - coincidence window: 100 ns
- Data acquired with a CAEN TDC (time resolution: 100 ps)
- QA/QC criteria:
  - Efficiency >95%
  - Noise < 1 Hz/cm$^2$
  - Dead channels < 1%
  - Cluster size ≤ 3

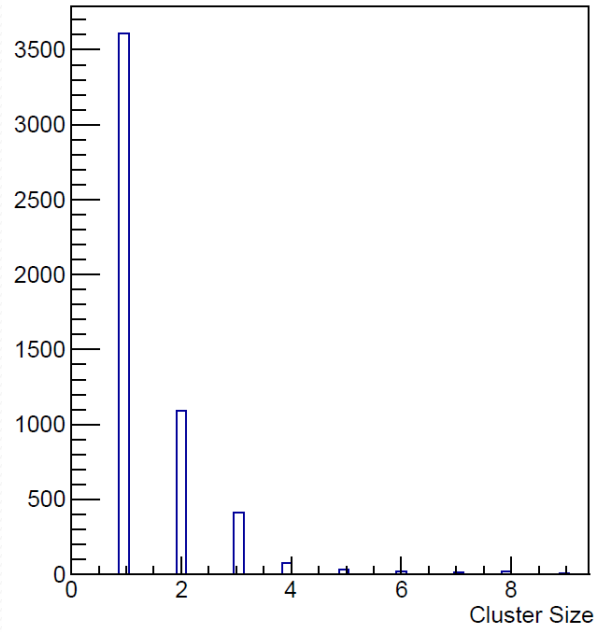




# Module Zero

- Module Zero integrated with mechanical frame on 8 May 2019.
- Efficiency >95% at 5.8 kV
- Average cluster size < 3

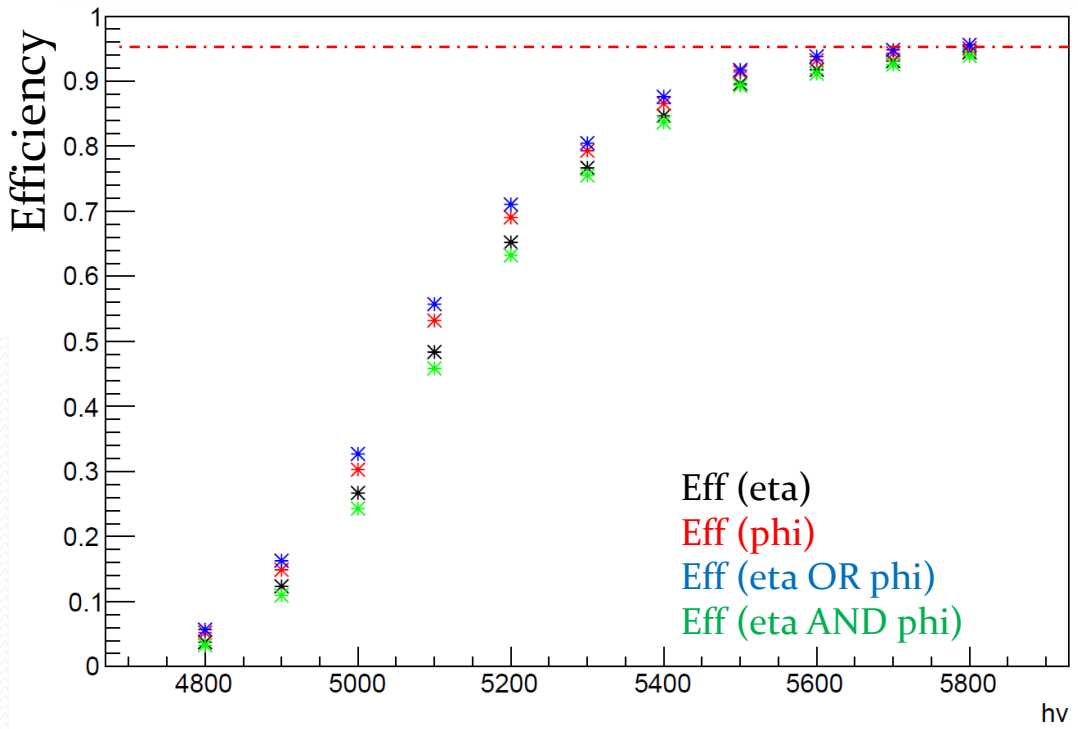



- No dead channels
- No interference with sMDT

# Tests on triplets

- 3 BIS7 and 3 BIS8 triplets assembled and tested with cosmic rays, confirming the performances of Module Zero
- Efficiency >95% in the plateau region
- The observed performances are uniform in all regions of all the produced triplets
- More details on performances on L.Pizzimento's talk.

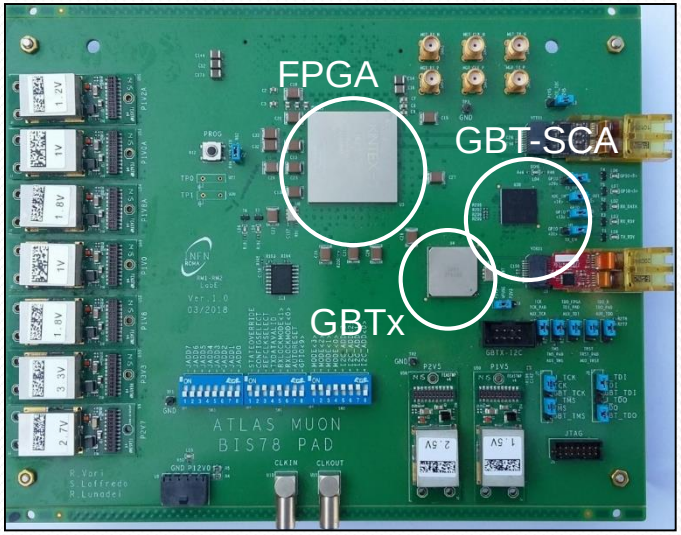
# Chamber Production

| Station | Chamber | Gap produced | Gap Ready | Panels Ready | Singlet Assembly | Singlet CR Test | Triplet Assembly | Triplet CR Test | BIS78 Integration |
|---|---|---|---|---|---|---|---|---|---|
| Mod. 0 | BIS7 | | | | | | | | |
| A02 | BIS7 | | | | | | | | |
| | BIS8 | | | | | | | | |
| A04 | BIS7 | | | | | | | | |
| | BIS8 | | | | | | | | |
| A06 | BIS7 | | | | | | | | |
| | BIS8 | | | | | | | | |
| A08 | BIS7 | | | | | | | | |
| | BIS8 | | | | | | | | |
| A10 | BIS7 | | | | | | | | |
| | BIS8 | | | | | | | | |
| A12 | BIS7 | | | | | | | | |
| | BIS8 | | | | | | | | |
| A14 | BIS7 | | | | | | | | |
| | BIS8 | | | | | | | | |
| A16 | BIS7 | | | | | | | | |
| | BIS8 | | | | | | | | |

- Integration of the BIS78 stations with sMDTs starting in February
- Installation in ATLAS Cavern of the first 8 stations forseen by May-June 2020

# BIS78 Trigger and DAQ status

- Work on Trigger and DAQ ongoing, in good shape
- Front End digitization done with HP-TDCs with 3x32 channels, 200 ps time resolution
- PAD Trigger Board hosting
  one FPGA (Xilinx Kintex 7 family),
  one GBTx chip and one GBT-SCA chip
- The FPGA trigger algorithm perform a 2/3 majority logic (3 RPC gas gap) to select a muon candidate.
- Data acquisition through FELIX, the standard ATLAS Phase2 Board
- Prototype version of TDC+PAD+FELIX system tested reading successfully an entirely cabled BIS7 chamber (4 eta + 8 phi FE of all 3 layers) and sending data to Felix at 320 Mb/s




# Conclusions

- The BIS78 upgrade will provide new integrated sMDT+RPC chambers to be installed in the transition region ($1.0<|\eta|<1.3$) as part of the Phase-1 ATLAS Upgrade
- BIS78 stations make use of new generation RPCs, with a better space-time resolution and rate capability with respect to the present ATLAS RPCs
- 6 production triplets have been assembled and tested, showing all an efficiency greater then 95% in the plateau region
- A preliminary version of the TDC+PAD+FELIX system has been tested successfully with a BIS7 triplet
- The installation in the ATLAS cavern of the first 8 BIS78 stations is foreseen by May-June 2020
- The installation of the second 8 BIS78 stations is forseen in LS3