Design and construction of the mechanical structure for thin-gap RPC triplets for the upgrade of the ATLAS muon spectrometer

O. Kortner on behalf of the ATLAS Muon Collaboration

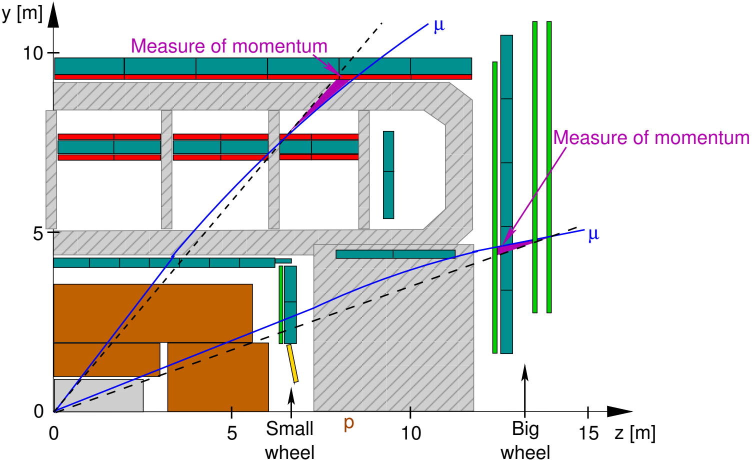
Max-Planck-Institut für Physik, München

12.01.2020

The ATLAS 1^{st} level muon trigger in LHC run I

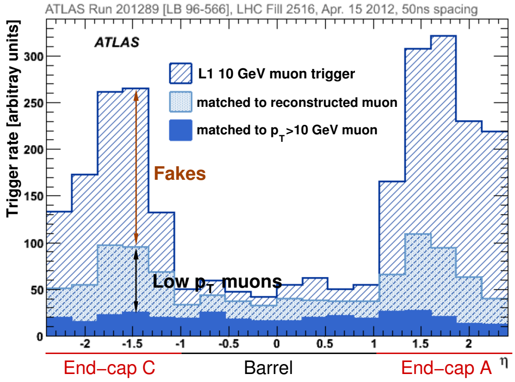
The muon spectrometer upgrade is a muon trigger upgrade.

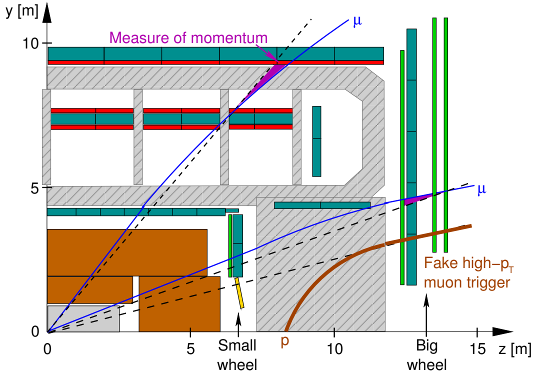
So let me recall the original muon trigger and its weak points!



- The level-1 high p_T muon trigger is built out of a coincindence of three RPCs in the barrel or three TGCs in the big end-cap wheel.
- Muon momentum estimate from the size of the deviation of hits from an infinite momentum track from the interaction point.

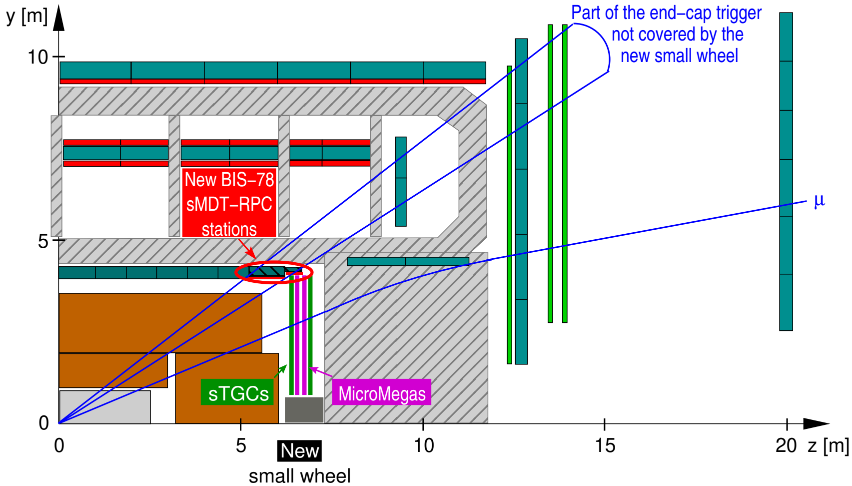
Sources of 1^{st} level muon triggers in LHC run I





- Muon trigger rate dominated by fake triggers in the end-caps caused by charged particle not emerging from the interaction point.
- Real muon triggers contaminated with sub-p_{T}-threshold muon due to the reduced momentum resolution caused by the moderate spatial resolution of the trigger chambers.

Muon spectrometer phase-I upgrade (2019-2021)

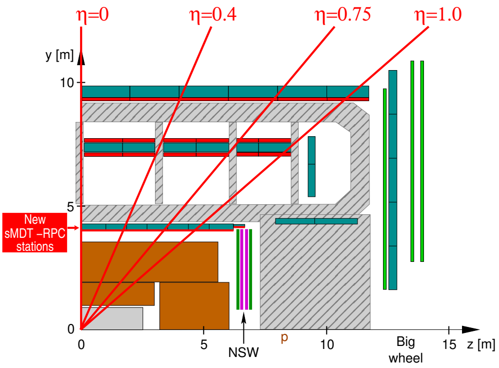


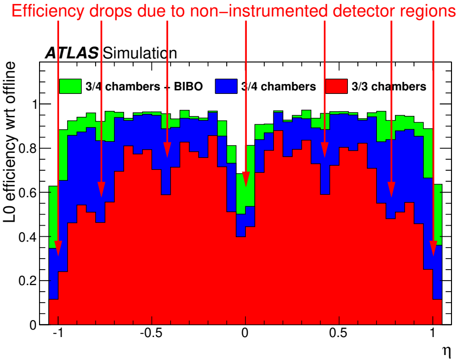
To reject fake muon triggers at trigger level:

- New small wheel with high-resolution trigger chambers.
- New BIS-78 stations:
  - New thin-gap RPCs trigger chambers.
  - New BIS sMDT precision chambers to free space for the new RPCs.

Muon spectrometer phase-II upgrade (2025-2027)

CERN-LHCC-2017-017; ATLAS-TDR-026





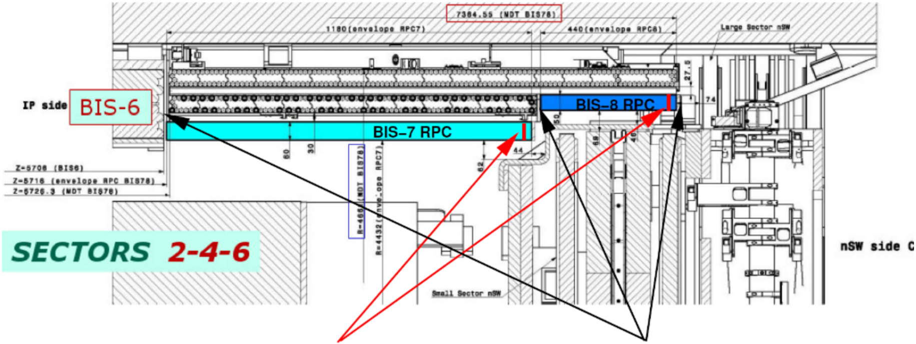
Installation of new sMDT-RPC stations in the barrel inner layer

- to close the acceptance gaps caused by the non-instrumented regions due to toroid and rib structures,
- to recuperate the reduced muon trigger efficiency cause by the reduced efficiency of the present RPCs at high rates.

Installation of new front-end electronics

to cope with the new trigger and read-out scheme.

Challenges for the BI RPC upgrade



Limited space in radial direction **Limited space for RPC support structure in z direction**

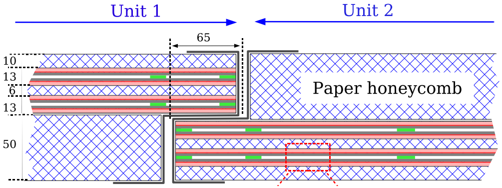
Challenging requirement

- Very compact mechanical structure needed to fit into the limited available space.
- Very rigid mechanical structure required in order to avoid conflicts with the sMDT chamber.

Strategy for this presentation: Concentrate on the BIS-78 pilot project in which all challenges of the BI upgrade are present and are addressed.

Requirements/boundary conditions for the BI upgrade

Structure of the current ATLAS RPC



Current ATLAS RPC

- Double-gap structure.
- 50 mm thick honeycomb structure provides mechanical rigidity.
- Height: 92 mm.

New BI RPC

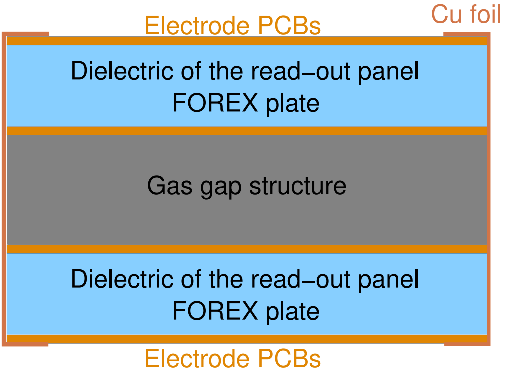
- Triple-gap system.
- Available space: 60 mm.

Development tasks for the new BI RPCs

- Thin RPC singlets which can be assembled without an external Faraday cage.
- Rigid mechanical structure to support the RPC triplet independently of the accompanying sMDT chamber
- Rigid mechanical frame for the RPC singlet which stays within the tight 60 mm envelope including its deformations under gravity.

Structure of an RPC singlet

- RPC singlet inclosed in its own Faraday cage consisting of the copper back plates of the read-out electrodes and an attached lateral copper foil.
- New dielectric, FOREX PVC foam instead of polyester foam in the old RPCs, was chosen to guarantee minimal thickness variations and increased rigidity of the read-out panels.
  (In the future the FOREX foam will be replaced by 3 mm thick paper honeycomb.)



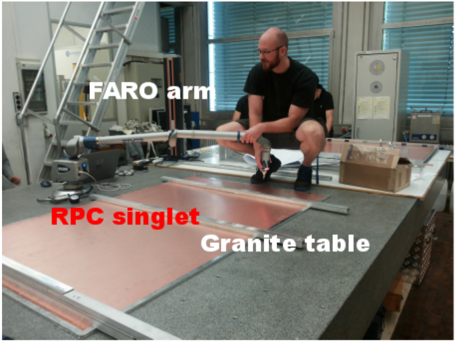
Component	Thickness [mm]
Electrode PCB	0.3
FOREX plate	3.00 ± 0.25
Gas gap	4.2 ± 0.2
PET foil	0.2
Cu foil	0.1

$\Rightarrow$ Thickness of an RPC singlet:

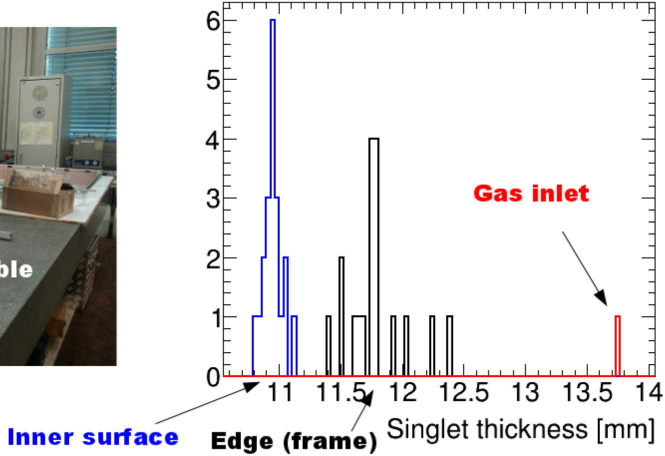
$\boxed{(11.8 \pm 0.7)\ \text{mm}}$

Measurement of the thickness of prototype RPC singlets

Measurement on a granite table



Measurement result



- Maximum thickness in the region of the RPC frame (as expected).
- Outlier at the location of the gas inlet has been avoided for the series chambers by a cut-out in the read-out panels.

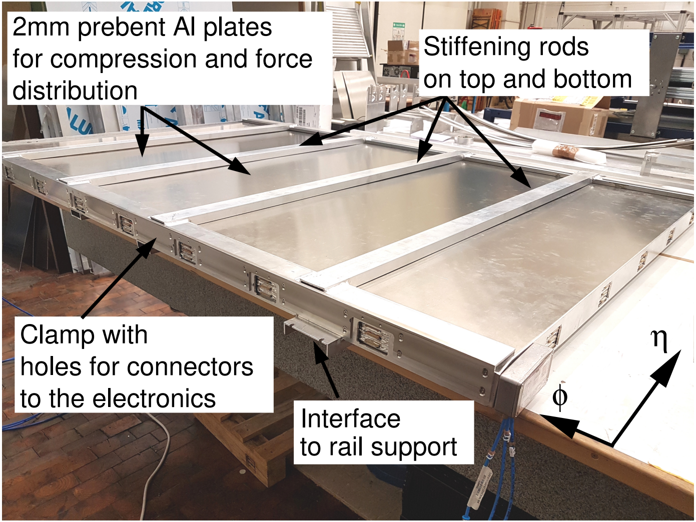
⇒ Maximum singlet thickness compatible with expectations.

Mechanical structure for BIS-78 RPC triplets

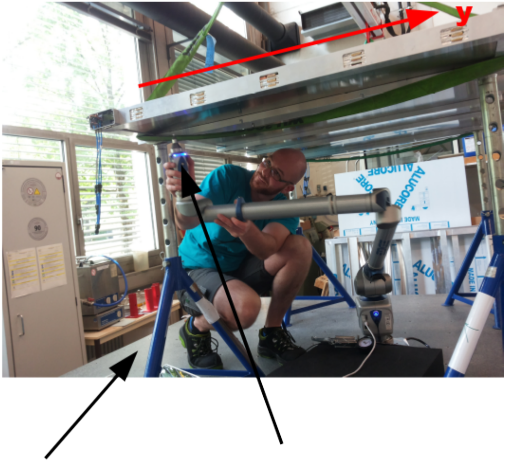
- Rigidity of present RPCs achieved by 5 cm thick honeycomb plates.

⇒ Impossible within 6 cm envelope of BIS-78.

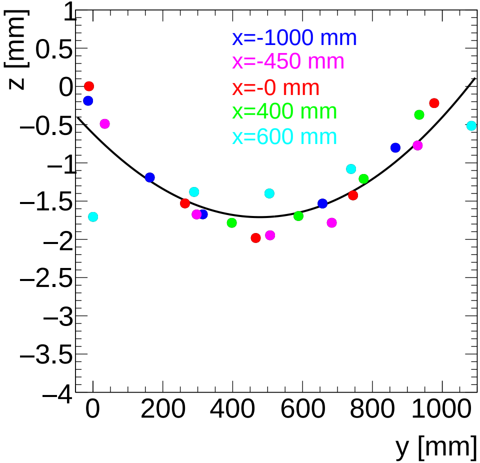
Solution for BIS-78



Measurement of the height of the bottom of the mechanical structure under the load of an RPC triplet



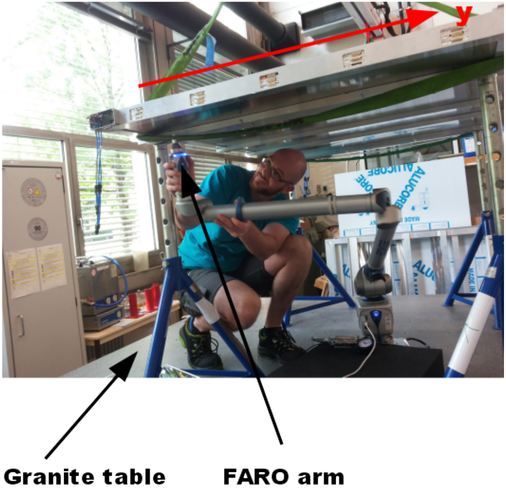
Granite table **FARO arm**

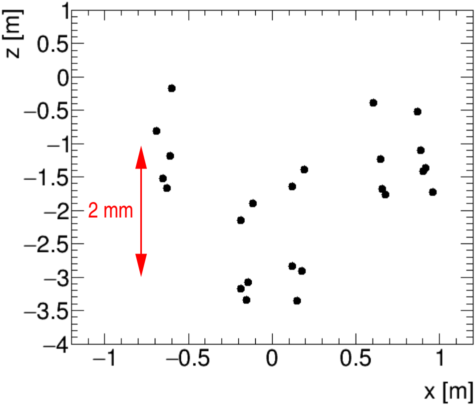


Sag of the stiffening rods <2 mm.

Measurement of the rigidity of the BIS-7 mechanics

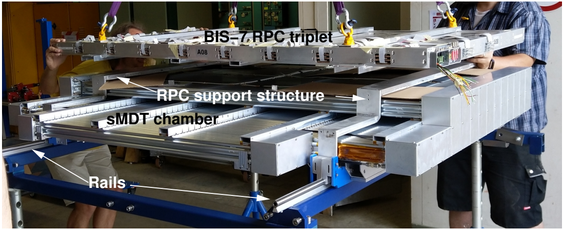
Measurement of the height of the bottom of the mechanical structure under the load of an RPC triplet



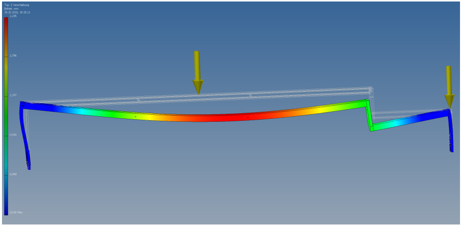


Maximum sag ∼2 mm.

RPC support structure



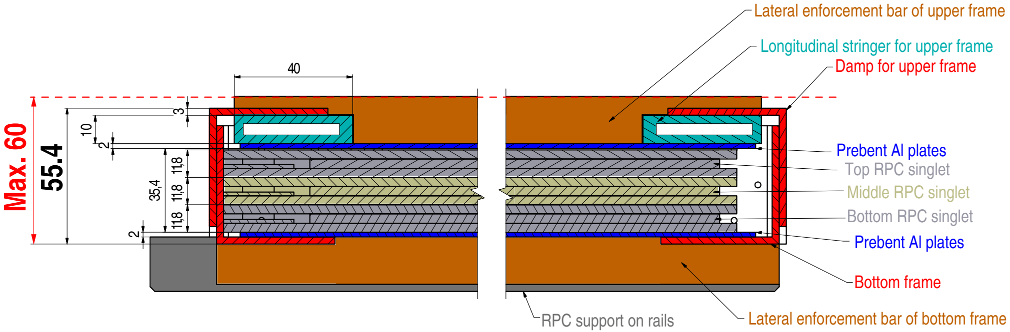
FEA calculation of the deformation of the support structure



- RPC support structure to slide and keep the RPC triplet on rails.
- Deformation of the support structure under the weight of the BIS-78 RPC of 158 kg: 2.2 mm.

$\Rightarrow$ Acceptable deformation preventing interference with the sMDT chamber and leaving 60 mm for the RPC frame.

Mechanical structure for BIS RPC triplets



- Nominal height: 55.4 mm within 60 mm envelope.
- RPC triplet thickness tolerances of 3x0.7 mm = 2.1 mm.
- Thickness tolerance of the frame plates of 3x0.3 mm = 0.9 mm.
- Total thickness tolerance of 3 mm corresponding to 58.4 mm.
- Sag: 1-2 mm (measured), 2.2 mm (FEA simulation).

$\Rightarrow$ $\boxed{\text{Design within the 60 mm envelope at the level of } \sim 1 \text{ mm.}}$

Validation of the mechanical frame

- Crucial for the RPC operation: gap size not decreased due to external mechanical forces between the spacers.
- A decreased gap size would lead to a larger electric field and higher current at the same operating voltage.
- To prove that the gap size is preserved with the present design of the mechanical frame a voltage-current curve was measured under different mechanical stresses.

$\Rightarrow$ No effect was observed due to the large rigidity of the frame and the force distribution by the aluminium plates!

Summary

- The inner layer of the barrel part of the ATLAS muon spectrometer will be instrumented with a triplet of thin-gap RPCs to recuperate the efficiency losses of the present RPC system at the HL-LHC.
- The presence of these RPCs in the small sectors will also close most of the acceptance gaps of the barrel muon trigger raising the acceptance from the current 78% to 95%.
- In order to provide the required space for the RPCs in the small sectors the existing MDT chambers will be replaced by sMDT chambers.
- A mechanical structure for the thin-gap RPC triplets with a height of less than 60 mm and the required mechanical rigidity was successfully designed and produced for the upgrade of the ATLAS muon spectrometer.