The ATLAS Muon RPC system upgrade for the High Luminosity LHC

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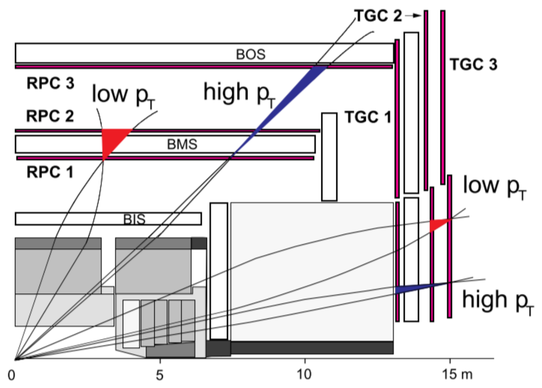
1. Th present ATLAS Muon RPC system

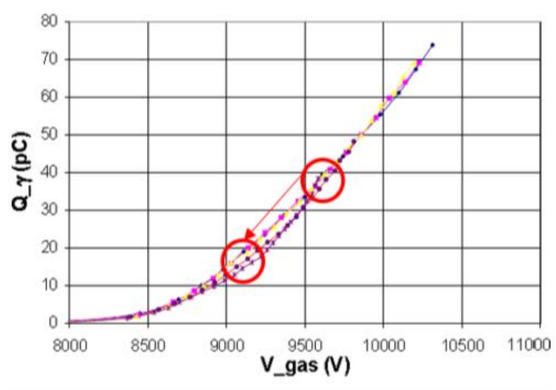
- 1094 RPC doublet chambers
- One layer of RPC chamber in Barrel Outer
- Two layers of RPC chambers in Barrel Middle
- Geometrical acceptance $\approx 70\%$
- No RPCs in BI region

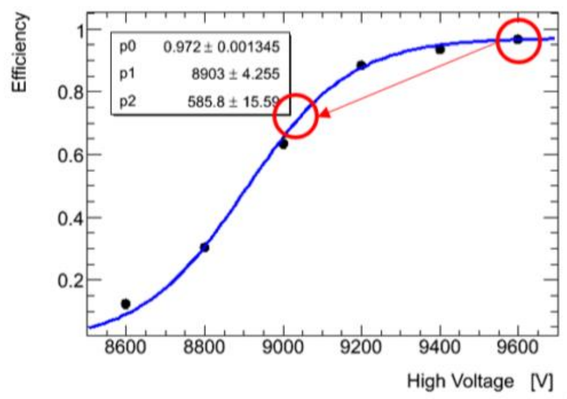


- Provides the Level-1 muon trigger at a rate of $100\ \mathrm{kHz}$
- Has been working smoothly since the beginning of ATLAS

2. Limitation of present RPC system for HL-LHC

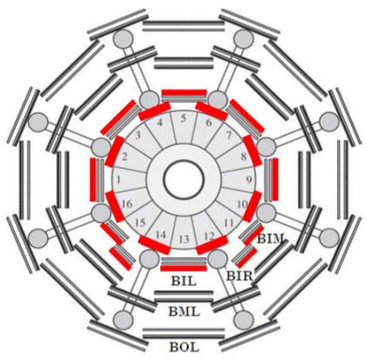
- Level-1 readout latency and trigger rate
  - Incompatible with the requirements of Phase-II trigger scheme
  - To replace the electronics (splitter, Pad boxes)
- Geometrical acceptance $\approx 70\%$
  - Primarily due to the toroid coils, support structures, and services
- Expected hit rate reaches up to 340 $\mathrm{Hz/cm^2}$ [1]
  - The rate capacity for present RPCs is limited to 100 $\mathrm{Hz/cm^2}$, to avoid integrated charge damaging the electrode of RPCs [2]
  - To lower the average charge per hit by a factor of 3 by decreasing the high voltage applied
  - Efficiency of single-hit will be reduced by 15% to 35% [1]
  - To be compensated by installing a new BI layer of RPCs

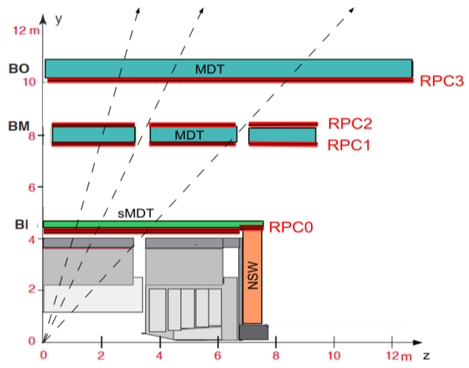




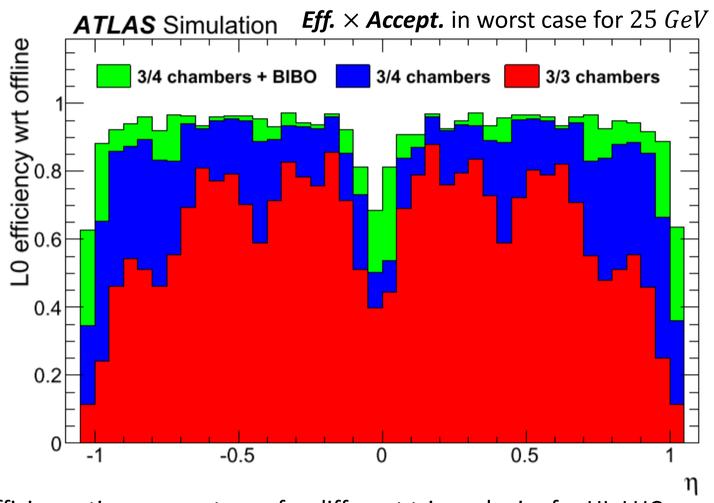
3. BI RPC upgrade project

A layer of 272 new generation RPC triplets in the inner barrel (BI), to increase the redundancy, the selectivity, and provide almost full acceptance.



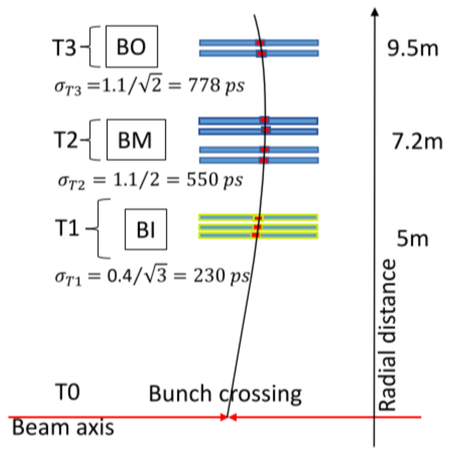


- Better longevity and rate capacity of new BI RPC detectors
  - Thanks to the lowered charge per count due to the reduced gap size
  - Rate tolerance of BI RPCs of a few tens of $\mathrm{kHz/cm^2}$ covers the maximum extrapolated rate in the BI region ($\sim 300\ \mathrm{Hz/cm^2}$ [1])
- Covers most of the acceptance (up to $\sim 96\%$ [1])
- Maintain the high trigger efficiency with new trigger scheme
  - The additional detector plane allow different trigger logic scheme
  - 3/3 trigger logic (present high p_T logic) has degraded performance
  - 3/4 trigger logics maintain the high trigger efficiency for the scenario of HL-LHC at the same time lowers the demand on the legacy RPCs



Efficiency times acceptance for different trigger logics for HL-LHC scenario

- Improve trigger selectivity
  - 3-point sagitta measurements provided by BI, BM and BO RPC chambers improve the momentum selectivity
  - Measurements of the ϕ coordinate by BI RPCs improve the performance of the pattern recognition in the high-background conditions of the HL-LHC
  - The new L0 trigger involving MDT hits information further suppress fake RPC triggers by requiring a simple coincidence with MDT hits
- Time-of-flight (ToF) measurements
  - Precise ToF measurements is key in searches for charged long-lived particles
  - New BI RPCs have an excellent time resolution of 0.4 ns
  - An overall β resolution could reach $\sim 1\%$



4. BIS78 pilot project

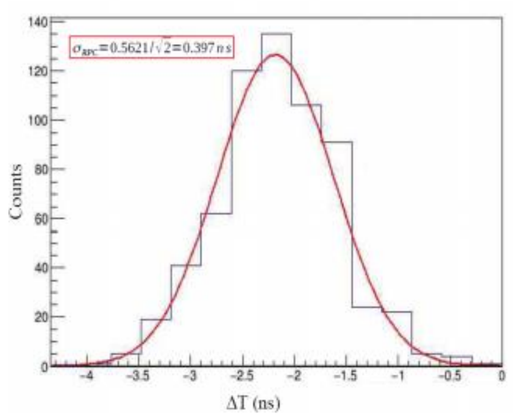
As the pilot of the BI RPC upgrade, sMDT and 32 new RPC triplets are being installed into the outer ends of the BI layer (BIS78) in LS2. This region is characterized by the highest background rates in the barrel

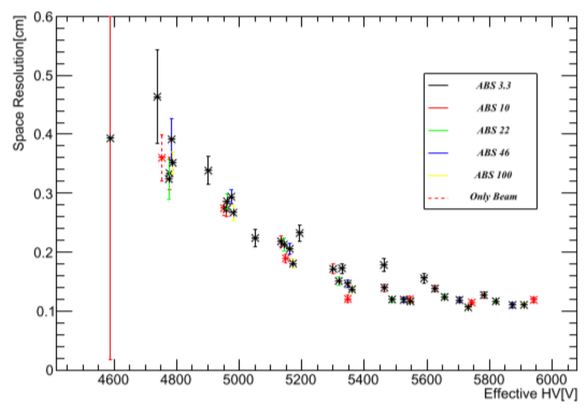
- New RPC designs for limited space
  - Gas gap reduced from 2 mm to 1 mm, and thus a lower operating voltage
  - Electrode thickness reduced from 1.8 mm to 1.2 mm
- New front-end electronics (FEE) [3]
  - For smaller signals and higher rate capability

Amplifier (Si)	
Gain	0.2–0.4 mV/fC
Power consumption	3–5 V, 1–2 mA
Band width	100 MHz

Discriminator (SiGe)	
Threshold	0.5 mV
Power consumption	2–3 V, 4–5 mA
Band width	100 MHz

- Performance
  - Single-gap efficiency better than 95 % [4]
  - Rate capacity reached 9 $\mathrm{kHz/cm^2}$ with an efficiency above 80% [4]
  - Time resolution reached 0.4 ns without time walk correction [4]
  - Space resolution reached ~ 1 mm at operating voltage [1]





- Further R&D for the rest BI RPCs
  - Replace the readout strips filler with paper honeycomb
  - Readout from both ends of the strips and use time information to determine the hit position along the strip

References

[1] ATLAS collaboration, *Technical Design Report for the Phase-II Upgrade of the ATLAS Muon Spectrometer*, CERN-LHCC-2017-017.
[2] G. Aielli et al., *New results on ATLAS RPC's aging at CERN's GIF*, IEEE Trans. Nucl. Sci. 53 (2006) 567.
[3] L. Massa, *The BIS78 Resistive Plate Chambers upgrade of the ATLAS Muon Spectrometer for the LHC Run-3*, JINST 15 (2020), pg. C10026
[4] L. Pizzimento, *Performance of the BIS78 RPC detectors: a new concept of electronics and detector integration for high-rate and fast timing large size RPCs*, JINST 15 (2020), pg. C11010