The ATLAS Muon Spectrometer upgrade for High-Luminosity LHC

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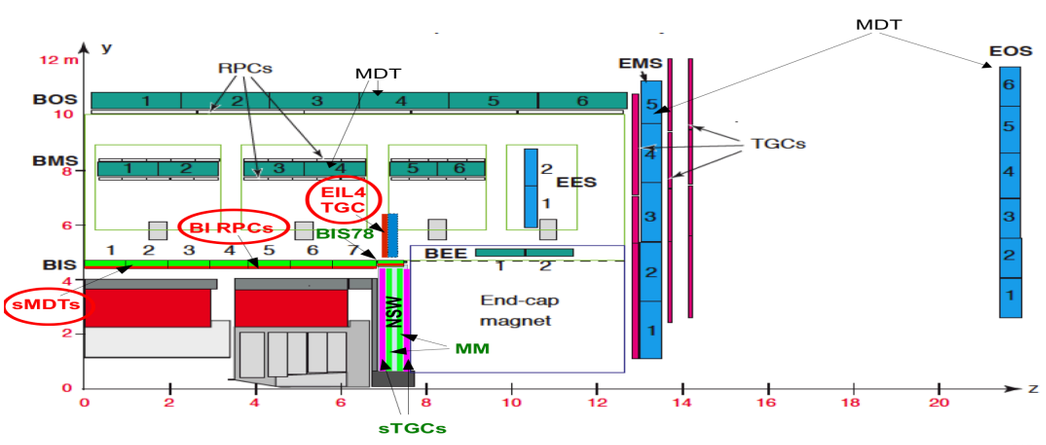
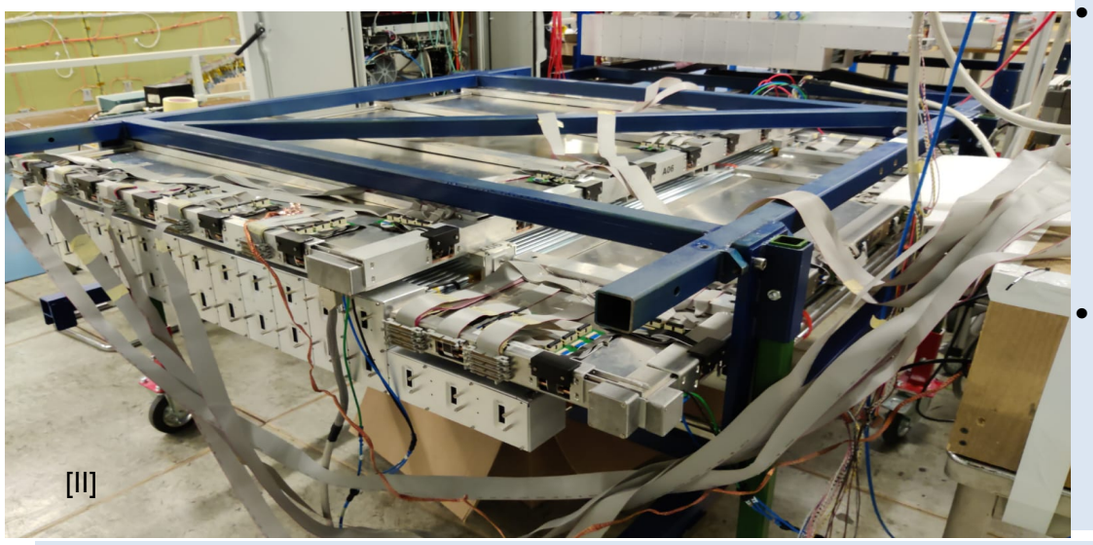
ATLAS muon spectrometer upgrade for HL-LHC

In sight of HL-LHC program, the ATLAS Muon Spectrometer must be able to operate at instantaneous luminosity L of 7.5 × 10^{34} $cm^{-2}s^{-1}$ and at pile-up $<\mu>$ of 200 maintaining its performance. The muon identification and reconstruction performance should not be degraded by the higher particle rates and background. For this reason the detectors must be upgraded to operate well in condition of more pile-up, more radiation and more particle rate. Low momentum threshold must be maintained while keeping the trigger rates at a manageable level. The muon spectrometer should be able to trigger on single muons with high efficiency, with a rate of less than 40 kHz for a p_t threshold greater than 20 GeV. At the same time, lower thresholds, as low as p_t>4GeV, should be viable for multi-muon and combined triggers.



[I]



[II]

General Muon Upgrade plans

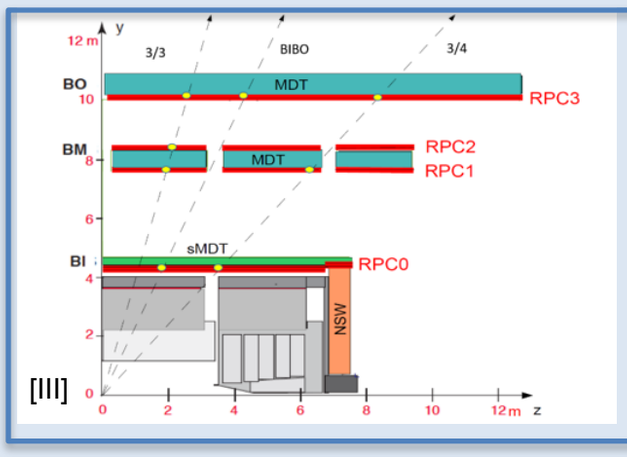
- **Thin Gap Chambers(TGCs) :** In order to obtain a uniform level of purity for triggered muons over all the regions covered by the endcap trigger, the current EIL4 TGC doublet chambers will be replaced by TGC triplets with finer readout granularity. In this way a more robust 2/3 majority logic and smaller coincidence windows can be used, reducing the rate of random coincidences to a negligible level.

- **New Small Wheels(NSW):** The Small Wheels will be replaced with the New Small Wheels(NSWs) during Phase-I upgrade. The NSW is composed by MicroMegas (MM) and small-strip TGC chambers(sTGC), which will replace the Cathode Strip Chambers(CSC) and the MDT chambers of the innermost endcap wheels. These detectors can provide the muon Level-1 trigger system with online track segments of good angular resolution, in order to confirm that muon tracks originate from the IP. In this way the end-cap fake triggers will be considerably reduced.

- **Monitored Drift Tubes(MDTs) and Resistive Plate Chambers(RPCs):** in order to maintain a high trigger efficiency, triplets of new RPC chambers with increased rate capability will be installed on the inner (BI) MDT chambers of the barrel. Because of the reduced space available, in the small sectors MDT chambers will be replaced with sMDT chambers with reduced overall thickness, in order to be coupled with BI RPCs in the same envelope as the original MDT chambers. The BI project is part of Phase-II upgrade. During Phase-I upgrade the realization of this project will start with the installation of these chambers in Sector 7 and Sector 8 (BIS78 project). In figure II you can see the final chamber composed by two triplets of RPCs on the top (one BIS7-type and one BIS8-type) and the sMDTs on the bottom.

- **Trigger and readout electronics :** The *trigger* system, as well as the data acquisition, will be redesigned to have a Level-0 *trigger* working at a rate of 1 MHz, to maintain similar trigger thresholds as in Run-2 but at higher luminosity. Most of the present components have hard limits on the maximum first-level trigger latency and rate they can operate at, and therefore they have to be replaced. The trigger logic will be moved from on-detector custom ASICs to off-detector boards based on programmable FPGAs allowing for more complex and flexible algorithms. MDT hits will be used in the first level trigger to refine candidates based on RPC, TGC and NSW data

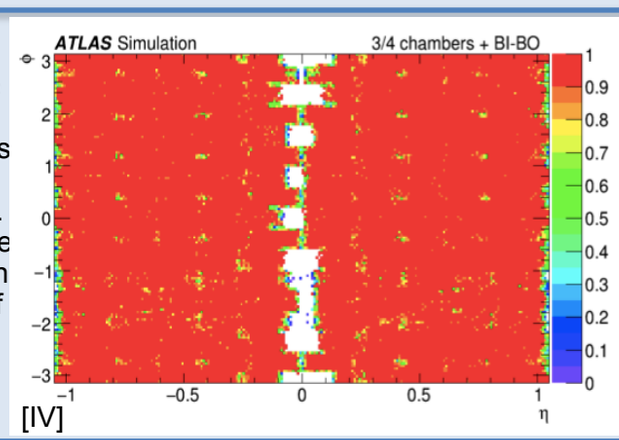
RPC system upgrade in the inner barrel : the BI project



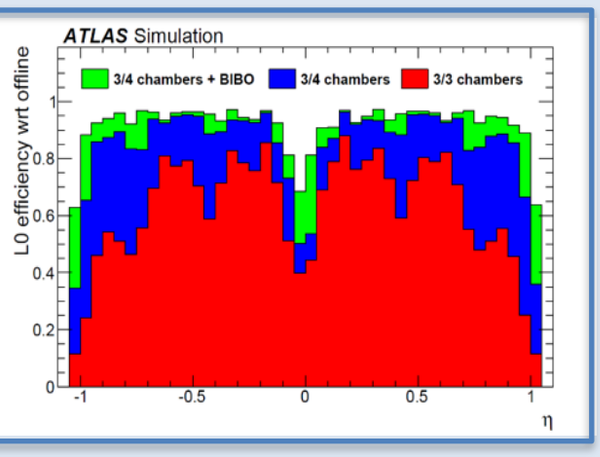
[III]

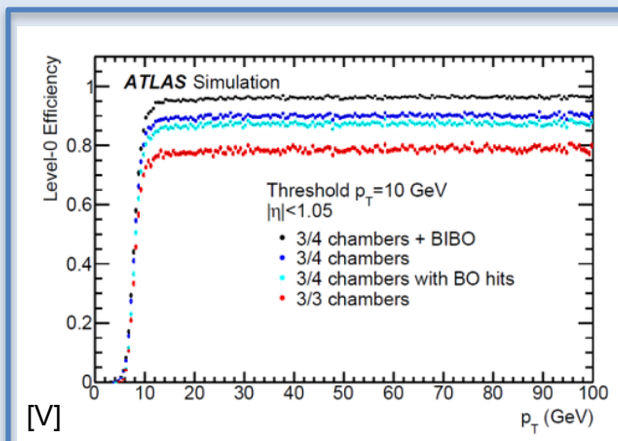
Improvement of the trigger redundancy, using 9 measurements planes instead of 6. Definition of different trigger logic schemes. The 3/3 chambers logic scheme corresponds to the current high-p_t trigger

Improved acceptance (80%->96%). With new trigger logics also the trigger efficiency is improved. The figure assumes the worst case scenario, in which the efficiency of old RPCs is highly reduced

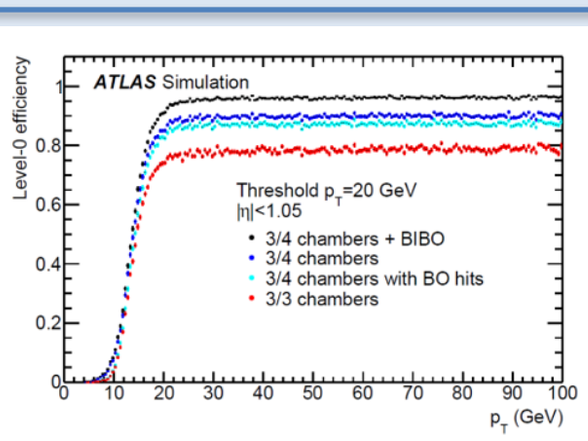


[IV]



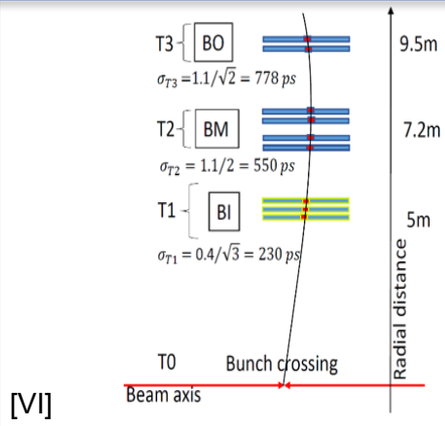


[V]



The improvement of the redundancy in the trigger logic allows to work with comparable efficiency performance observed in Run2, despite the reduction of old RPCs efficiency working point

The excellent time resolution can be used for time of flight measurements, very important in many searches (for example for long lived particles)



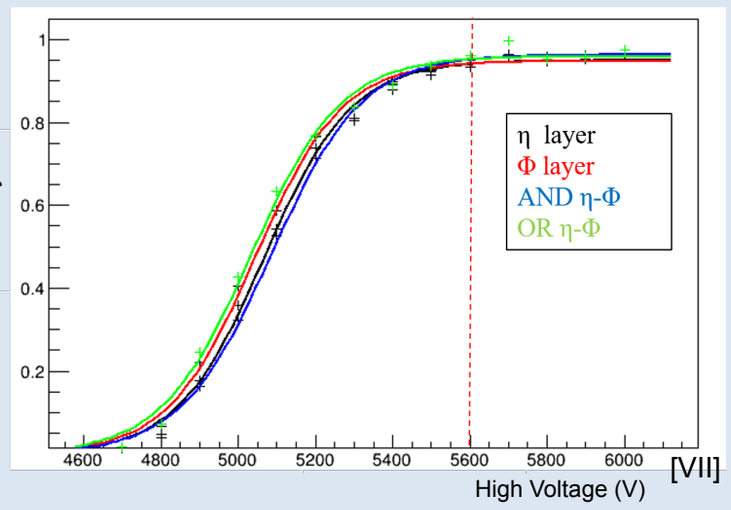
[VI]

One BI RPC station (triplet) consists in three RPCs (singlets)

- Thinner gas gap with respect to the RPCs already installed (**2 mm-> 1 mm**)
- Thinner electrodes (**1.8 mm ->1.2 mm)**
- New Front-End electronics

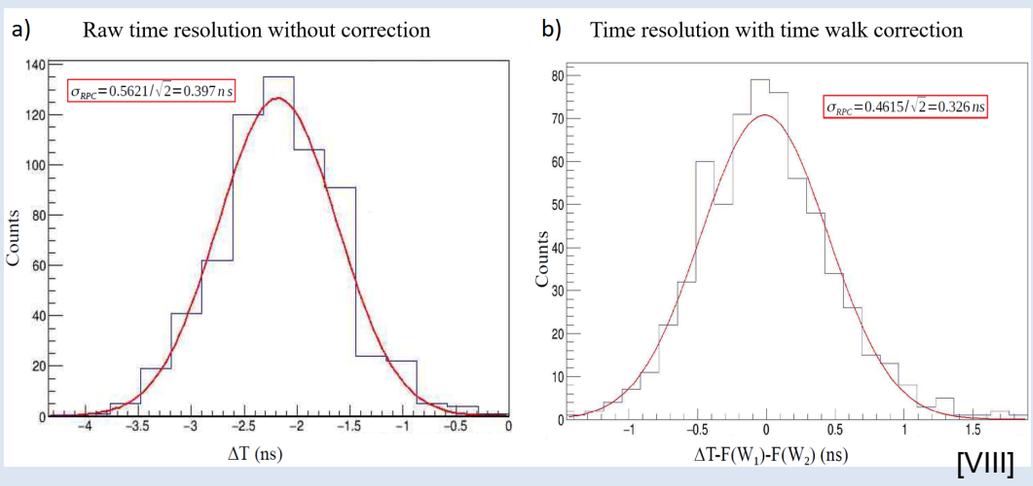
The reduction of the gas gap width results in a time resolution of ≈ 0.4 ns and allow to work at almost half of the high voltage if compared to the RPCs already installed. Moreover the total charge per hit generated inside the gas for a given efficiency is also reduced, resulting in an improvement of the rate capability and in a slower ageing of the electrodes at fixed counting rate

Efficiency



[VII]

Time resolution



[VIII]

References
CERN-LHCC-2017-017; ATLAS-TDR-026
cds.cern.ch/record/2720934