Performances of the ATLAS Level-1 muon barrel trigger during the Run 2 data taking

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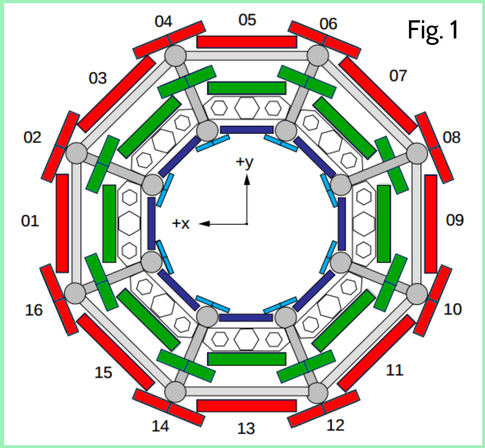
The ATLAS RPC Muon Barrel System

The present ATLAS muon trigger in the barrel region ($|\eta|<1.05$), shown in Fig. 1, is based on three concentric layers of Resistive Plate Chambers (RPCs). RPCs operate in a strong magnetic toroidal field and cover a surface area of about 4000 m^2.

RPC1 and RPC2 stations are located in the Medium Layer (BM) of the Muon Spectrometer (MS), while the third station, RPC3, is in the Outer Layer (BO), as shown in Fig. 1 (BM and BO chambers are drawn, respectively, in green and red colors).



Each RPC detector consists of two gas gaps (2mm width), read-out by two orthogonal planes of strips, in η and Φ views, with a width of 23-35 mm. In this way, RPCs are also able to provide the second coordinate measurement in the MS barrel. RPCs are assembled together with Monitored Drift Tube (MDT) chambers, which are used for precise muon tracking in the bending direction only.

For LHC High Luminosity, it has been proposed to increase the current detector coverage using additional RPC chambers in the inner layer, which is currently not instrumented with RPCs (ATLAS TDR for High Luminosity LHC upgrade in progress).

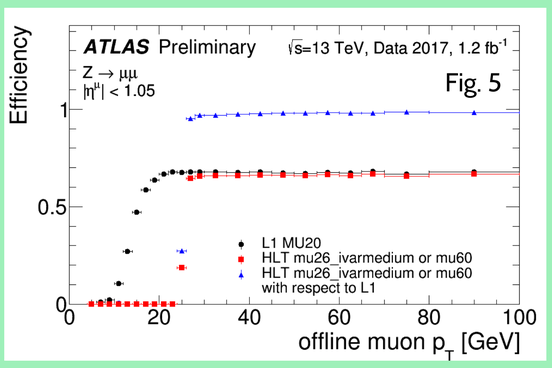
RPC "elevator" chambers upgrade

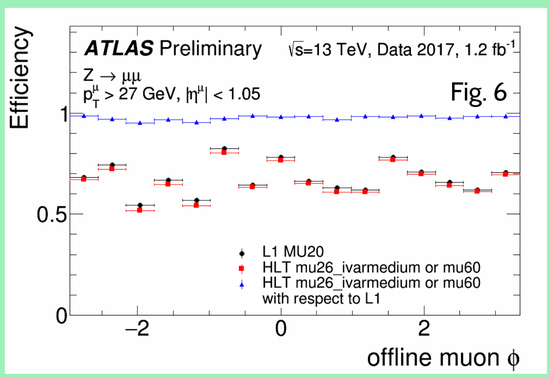
To cover the ~1% acceptance holes, corresponding to two elevator shafts in the ATLAS Muon Spectrometer (Sector 13), new chambers, consisting of two layers of RPC detectors have been installed during 2014. The BME chambers, located in the Medium Layer, are the first large size RPC chambers of new type (1 mm gas gaps); the BOE chambers consist of standard RPCs and are located in the Outer Layer.

Since the new technology of BME chambers will be employed for the upgrades of the Muon Spectrometer for High Luminosity LHC, the test of their performances during ATLAS Run 2 is an essential step. New data have shown that the new chambers are fully working. We are currently working on the trigger commissioning in order to optimize the trigger efficiency.

Trigger performances with early 2017 data

The efficiency of the muon barrel trigger is measured using a tag-and-probe method with $Z \rightarrow \mu\mu$ candidates, with no background subtraction applied, in 13 TeV data from 2017. The plots in Fig. 5 and Fig. 6 show the absolute efficiency of **L1 MU20** trigger and the absolute and relative efficiencies of the OR of **mu26** (isolation requirement dependent on the muon p_T is also applied here) with **mu60 High Level Triggers (HLT),** plotted as a function of p_T and Φ of off-line muon candidates in the barrel detector region. Muons are required to pass "Medium" quality requirement [3]. Only statistical data uncertainties are shown.





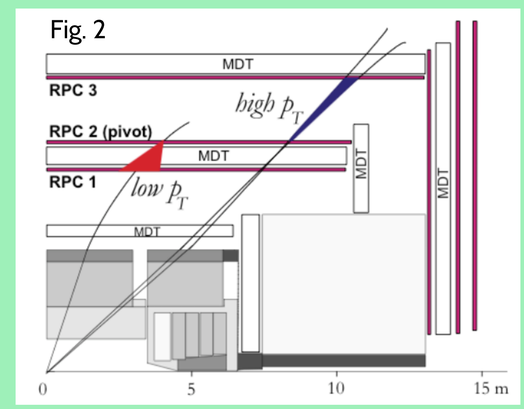
The L1 trigger inefficiency is due mainly to the detector acceptance in the barrel region (~80%). The residual is ascribed to malfunctioning detector elements. Globally, the system shows very good purity, with more than 90% of the L1 triggers that correspond to a good muon reconstructed off-line and originating from the interaction region [1].

The muon barrel trigger logic

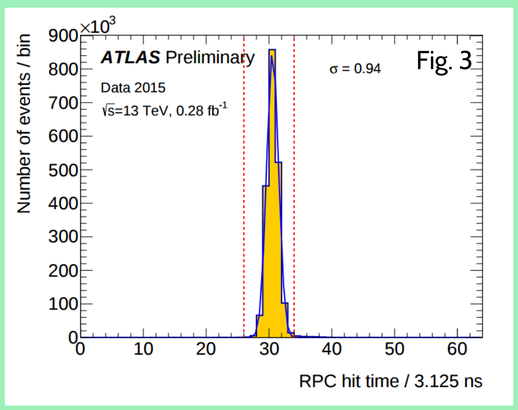
The Level-1 (L1) trigger algorithm is based on hit coincidence of three concentric RPC stations (both in η and Φ projections).

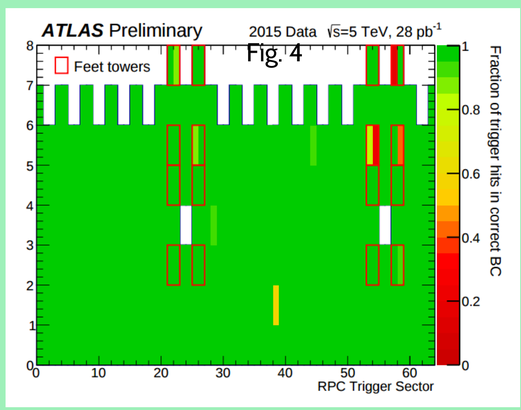
2 different p_T-regimes, shown in Fig. 2, exist:

- the **Low-p_T trigger** requires a coincidence between the innermost two RPC stations (BM). It is used to select muons with p_T thresholds between 4 and 10 GeV;
- the **High-p_T trigger** requires an additional confirmation on the third external station (BO) and selects muons with p_T thresholds between 11 and 20 GeV.



During ATLAS Run 2, only the high-p_T triggers are used for single-muon signatures, while the low-p_T triggers are used in coincidence with other trigger objects to select multi-object signatures, including muon pairs.



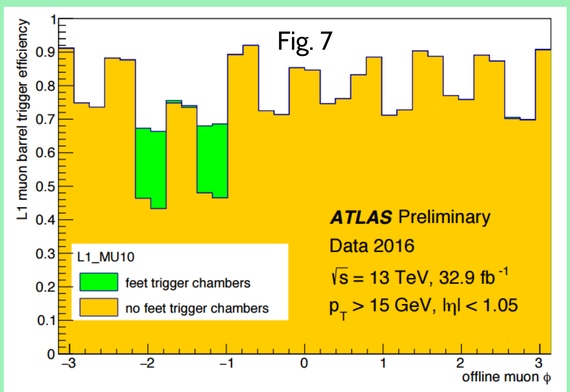


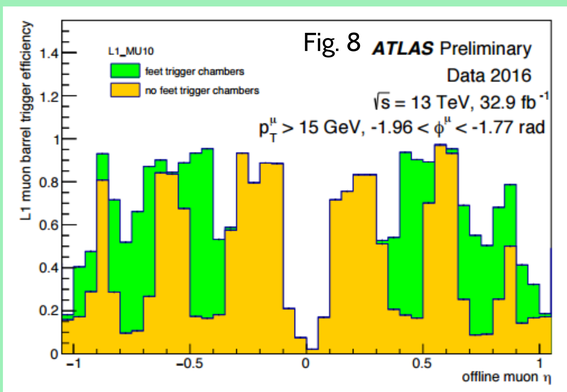
One of the main requirements of the L1 trigger system is the association of the triggering muon to the correct collision bunch crossing (BC). Fig. 3 shows the time distribution (2.9 ns width) of the trigger hits associated to reconstructed muons, compared to the interval corresponding to the collision BC. Fig. 4 shows the fraction of RPC trigger hits associated correctly to the collision BC for each of the Barrel Muon trigger towers. The fraction of reconstructed muons with p_T > 10 GeV associated to the correct BC is 99.7% [1].

RPC "feet" sector trigger upgrade

New trigger RPC chambers have been installed and commissioned by the end of 2015 to cover the acceptance holes in the "feet" regions of the detector, corresponding to RPC sectors 12 (-2.16 < Φ < -1.77) and 14 (-1.37 < Φ < -0.98). A 4th layer of RPCs has been added in the projective region of the holes, in order to improve the barrel geometrical acceptance of about 3% [1].

Fig. 7 shows the efficiency increase (about 20%) obtained using the new trigger RPC chambers. The efficiency is plotted as a function of the azimuthal angle Φ of the muon candidates in the barrel detector region [2]. In Fig. 8, the trigger efficiency as a function of the muon pseudo-rapidity is shown for a specific feet sector.





The efficiency is evaluated on an inclusive sample, selected using all non-muon L1 ATLAS triggers with no background subtraction applied, in 13 TeV data from 2016 data-taking. Muons are required to pass "Medium" quality requirement [3] and have a transverse momentum of at least 15 GeV.

[1] M. Corradi, Performance of ATLAS RPC Level-1 muon trigger during the 2015 data taking, 6032 Journal of Instrumentation 11 (2016) C09003

[2] ATLAS Collaboration, ATL-COM-DAQ-2017-035

[3] ATLAS Collaboration, Muon reconstruction performance of the ATLAS detector in proton–proton collision data at √s = 13 TeV, Eur. Phys. J. C (2016) 76: 292.