Performances of the ATLAS Level-1 Muon barrel trigger during the Run-II data taking

CLHCP 2018 - Wuhan

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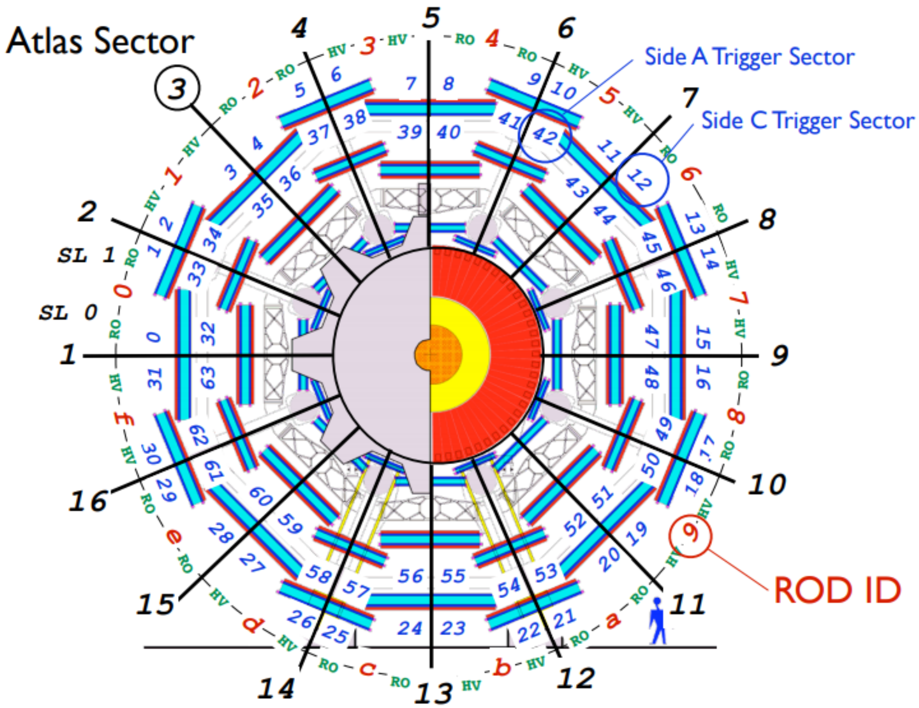
21 December 2018

Outline

- The ATLAS Level-1 muon barrel trigger
- ATLAS Resistive Plate Chambers
- Performance studies based on Run-2 data-taking
- Summary and conclusions

The ATLAS muon barrel trigger

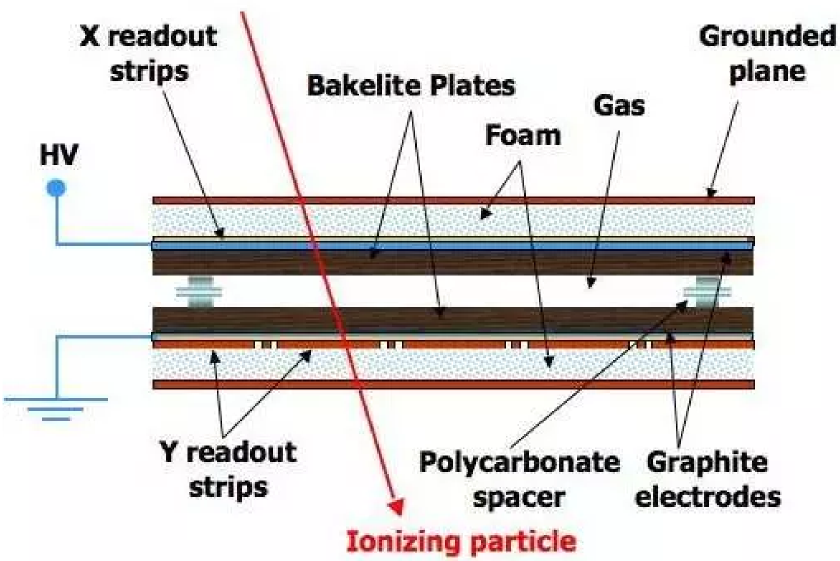
- The Level-1 Muon Barrel Trigger is one of the main elements of the online event selection of the ATLAS experiment at the Large Hadron Collider
- It exploits the Resistive Plate Chambers (RPC) detectors to generate the trigger signal → <u>Intrinsic time resolution ~ 1 ns (for 2 mm gas-gap)</u>
- The RPCs are placed in the barrel region of the ATLAS experiment: they are arranged in three concentric double layers at radius 7 m and 10 m, operating in a toroidal magnetic field of about 0.5 T

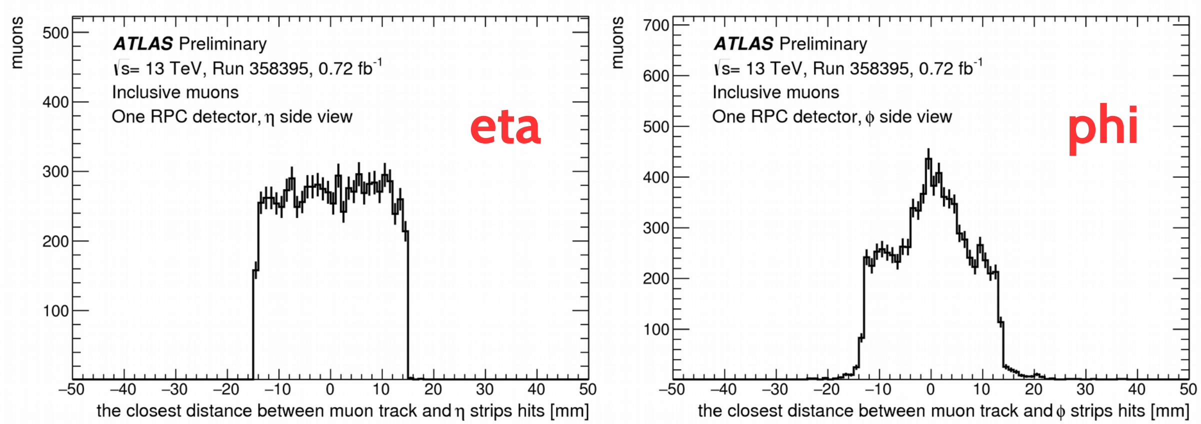


- The Level-1 muon barrel trigger allows to select muon candidates according to their transverse momentum and associates them with the correct bunch-crossing.
- The trigger system is able to take a decision within a latency of about 2.5 µs

The ATLAS Resistive Plate Chambers

- Each RPC detector consists of two gas gaps (2 mm width), read out by two orthogonal planes of strips, in η and φ views, with a width of 25-35 mm
- Gas mixture of $C_2H_2F_4$: C_4H_{10} : SF_6 (94.7 : 5.0 : 0.3)% operated in saturated avalanche mode at 9.6 kV nominal
- RPC detectors cover the pseudo-rapidity range $|\eta| < 1.05$ ($\vartheta < 38°$) for a total surface of about 4000 m^2 and ~3600 gas volumes (with 380k readout channels)
- Besides to provide trigger, RPCs are the only system in the barrel Muon Spectrometer that provides the measurement of the φ muon track coordinate

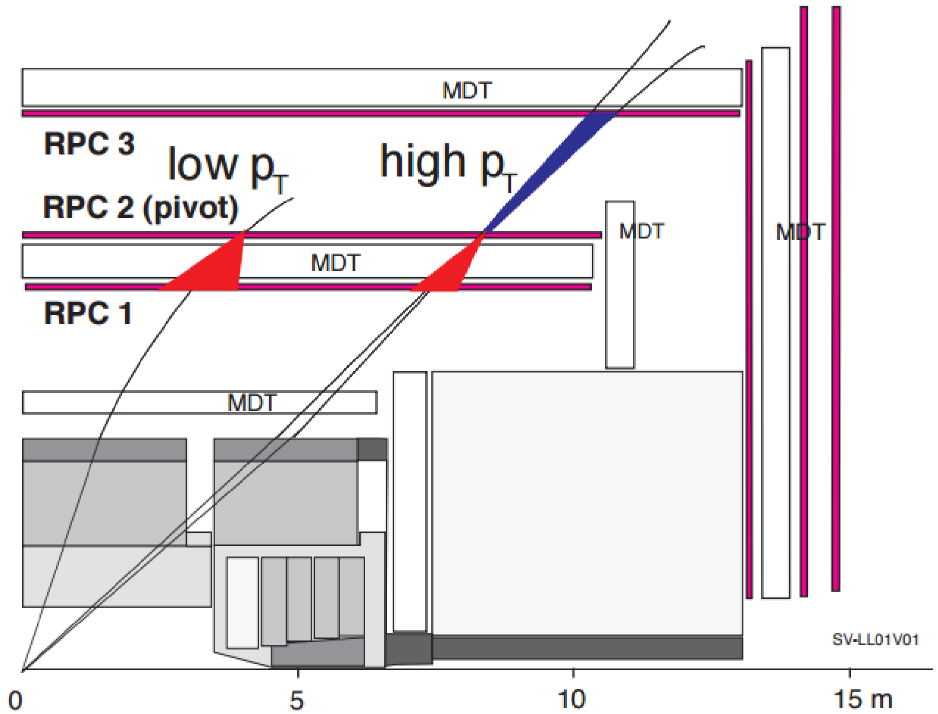




closest distance between muon track and strip hits

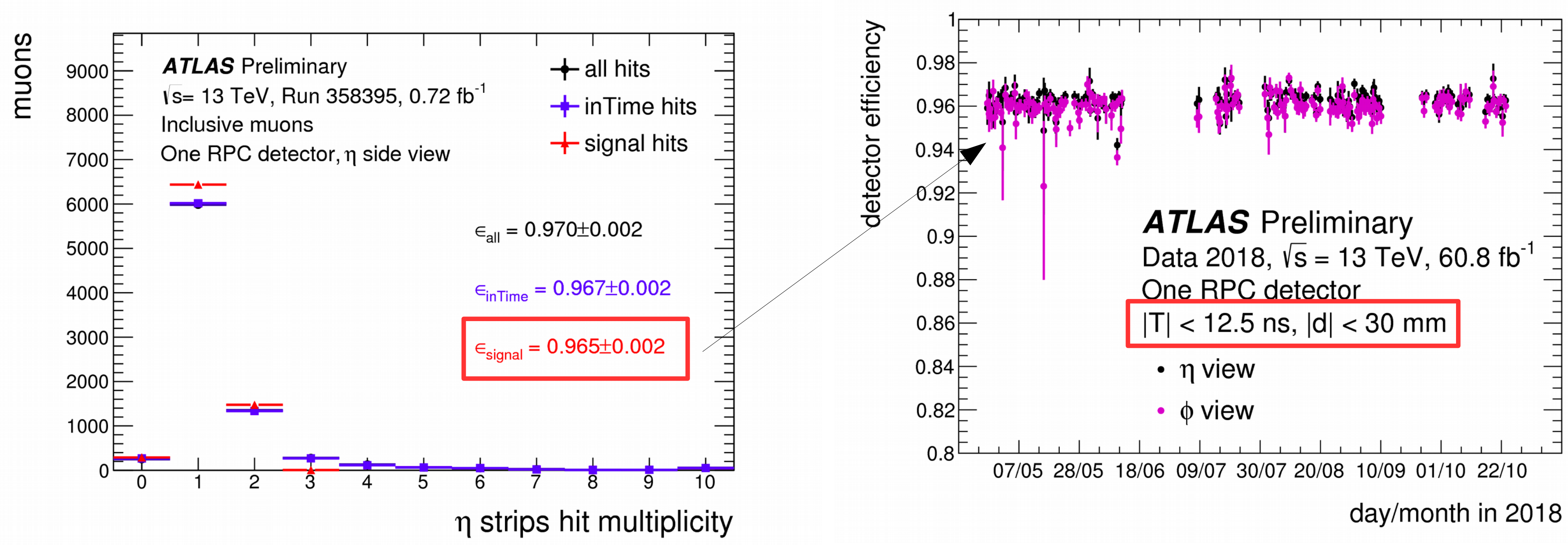
The L1 muon barrel trigger logic

- The RPC trigger system consists of 432 projective trigger towers. It is able to construct and provide to the HLT a Region of Interest (RoI) with a granularity of $\Delta\eta \times \Delta\varphi = 0.1 \times 0.1$ (~3600 ROIs)
- The L1 muon barrel trigger logic is based on the coincidence of hits from different RPC stations (both in η and φ projections)
- Two different p_T-regimes exist:
  - the **low-p_T trigger** requires a coincidence between the two innermost RPC stations (RPC1 and RPC2). It is used to select muons with p_T above 4 GeV (MU4), 6 GeV (MU6) and 10 GeV (MU10). <u>They are used mainly for multi-object triggers and B-physics</u>
  - the **high-p_T trigger** requires an additional confirmation on the third external station (RPC3) and selects muons with p_T above 10 GeV (MU11) and 20 GeV (MU20 and MU21). <u>MU20 is the lowest unprescaled single-muon trigger threshold</u>



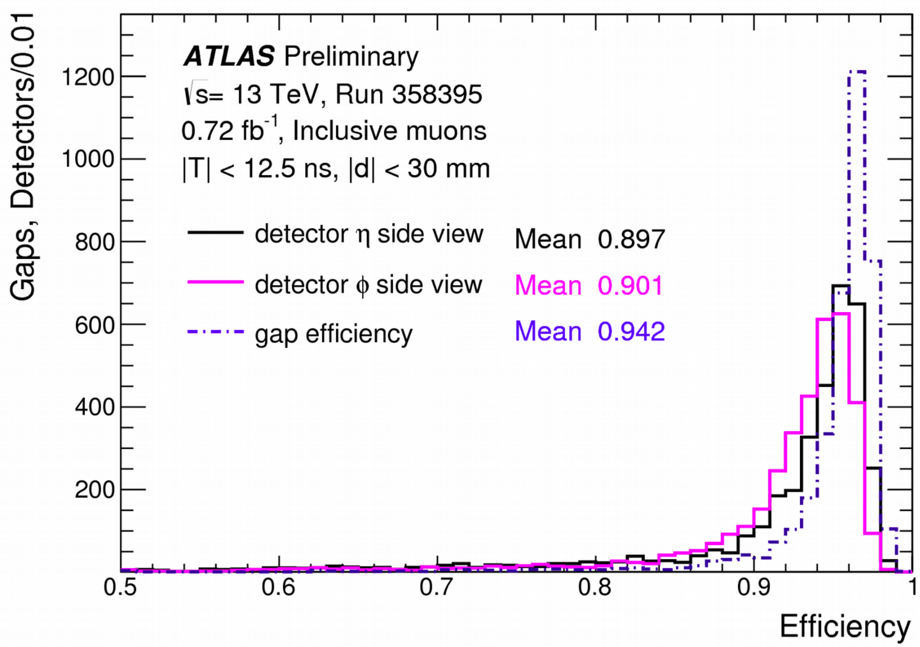
RPC detector efficiency

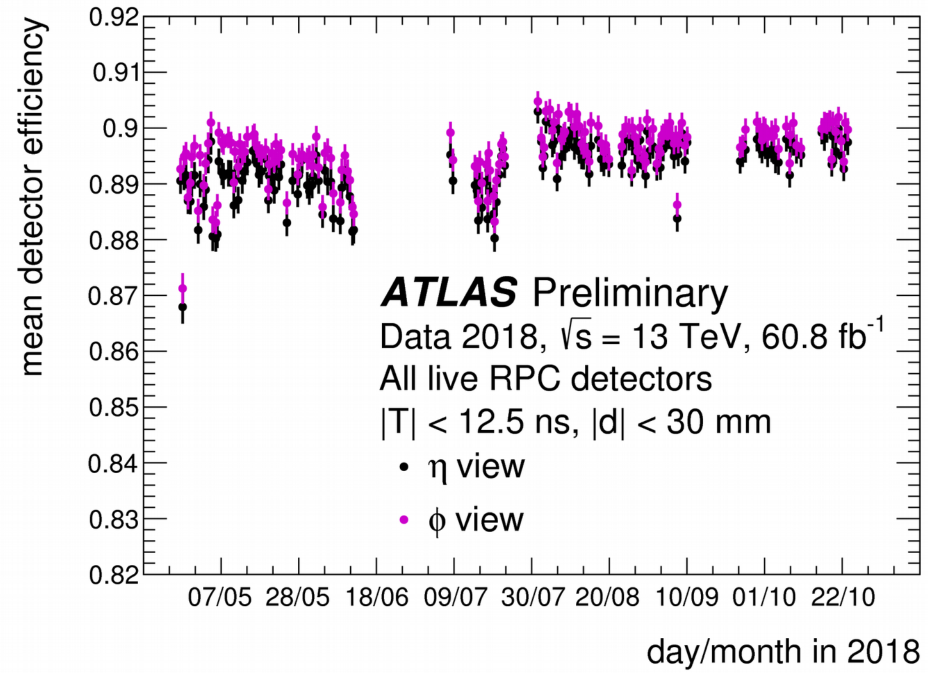
- RPC detector efficiency is computed as the fraction of hits matched with the extrapolated position of the muon track within a distance of 30 mm from the centre of the strip and within 12.5 ns from the triggered bunch crossing (BCO)
- **Left plot**: strip hit multiplicity and detector efficiency for η and φ side views
- **Right plot**: detector efficiency for η and φ side views for each ATLAS run recorded in 2018 → stable performance during the year



RPC detector efficiency

- **Left plot**: distribution of the panel efficiencies of all live RPC panels in 2018
- **Right plot**: mean detector efficiency as a function of time of all live RPC panels in 2018. Each point corresponds to a different ATLAS run recorded in 2018 during pp collisions at $\sqrt{s}$ = 13 TeV
- On July 2018, many discriminator thresholds in the RPC front-end electronics were re-adjusted, causing a slight increase of the mean detector efficiency

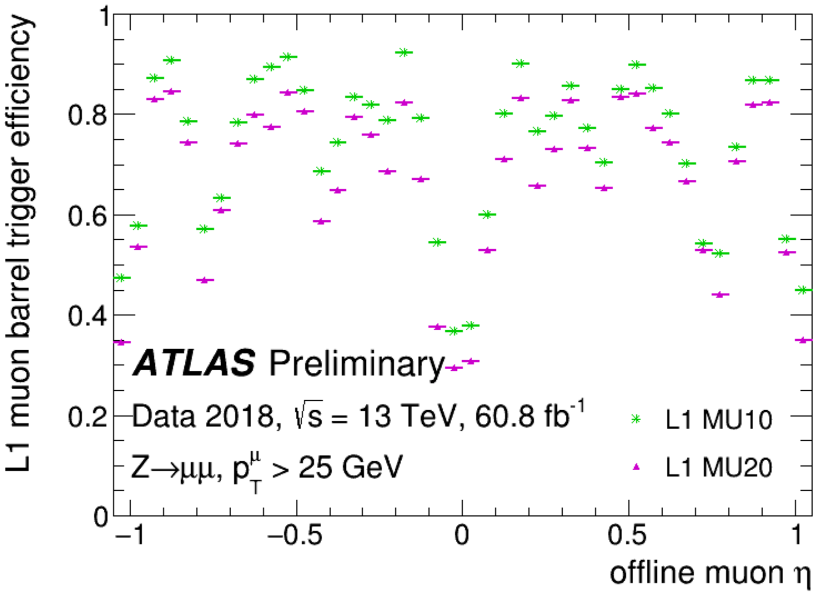


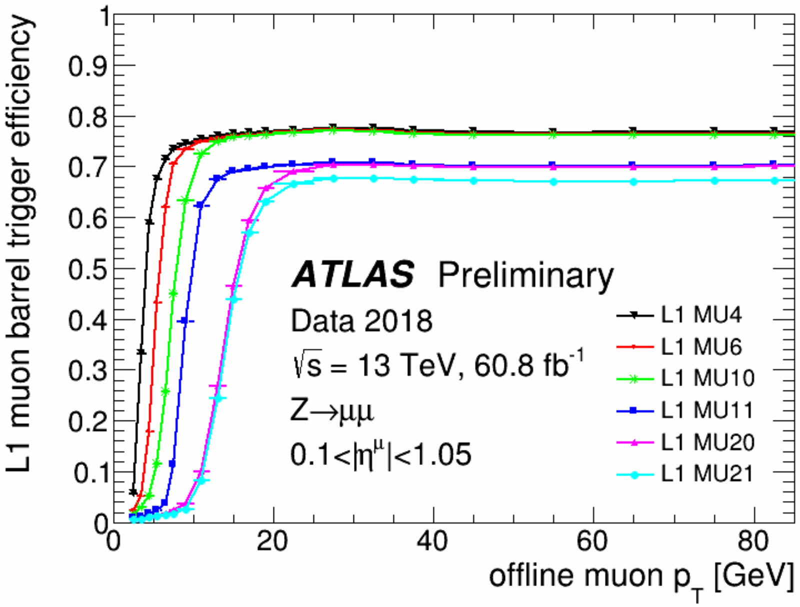


Trigger efficiency

- Trigger efficiency is one of the key parameters of the L1 muon barrel trigger
- Efficiency limited in the barrel region by toroid support structures and ATLAS "feet" supports
- Further reduction due to gas-gaps disconnected from HV (gas leaks) → mostly located on the external layer (BO chambers)
- Unbiased muons from Z boson decays are used to compute the trigger efficiency (Z Tag&Probe)

Trigger efficiency x Acceptance for reconstructed muons with 0.1 < |eta| < 1.05



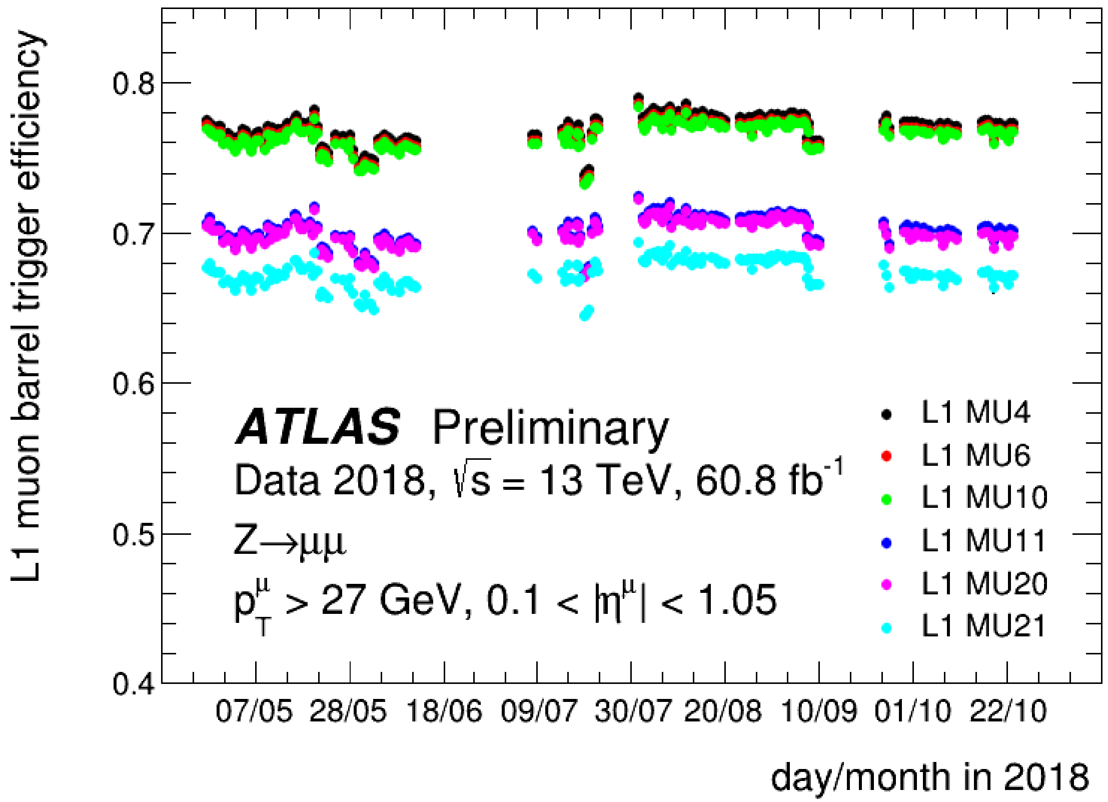


Plateau values:

- MU10 → 76.5%
- MU20 → 70.0%

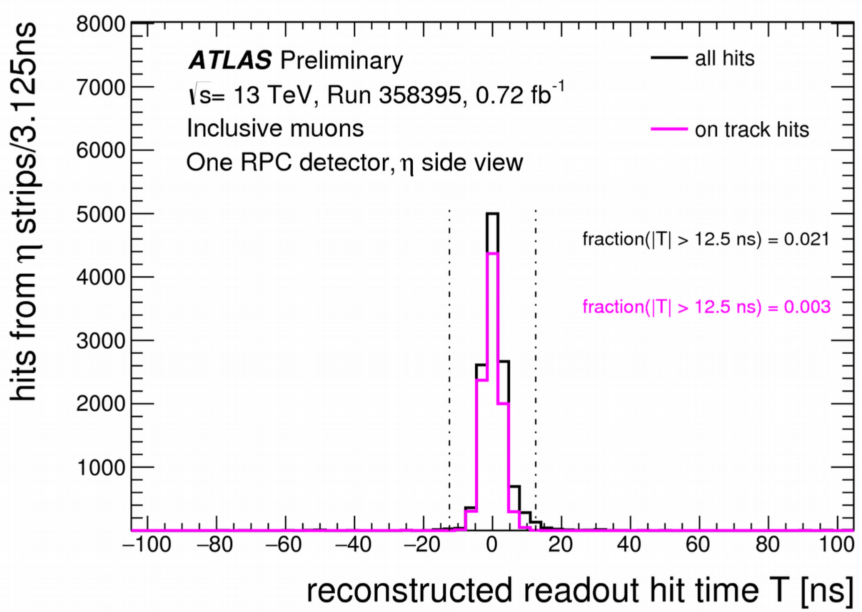
Trigger efficiency vs time

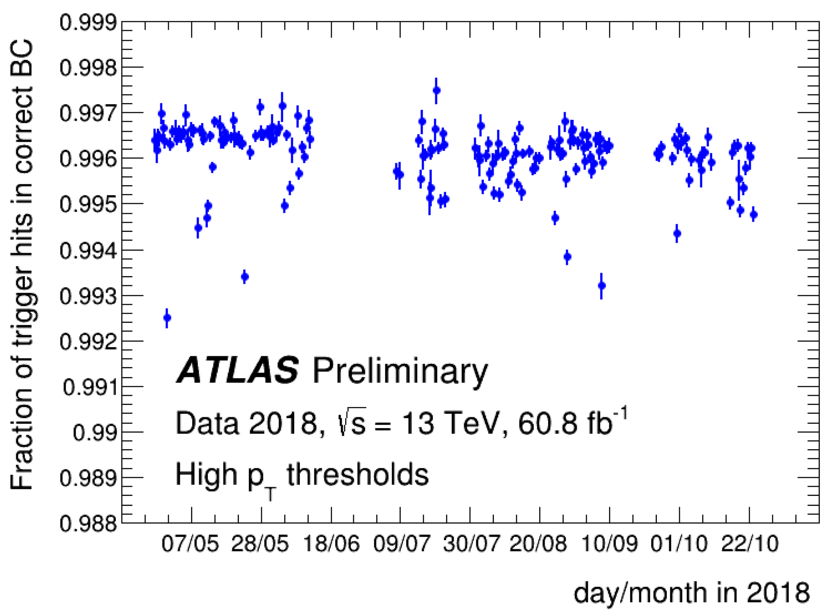
- Trigger efficiency is one of the key parameters of the L1 muon barrel trigger → monitored in each single run
- Plateau values of the trigger efficiency as a function of time for six different L1 thresholds
- Each point corresponds to a different ATLAS run recorded in 2018 during pp collisions at centre-of-mass energy $\sqrt{s}$ = 13 TeV
- Very good stability during the year has been achieved



Timing performance

- Bunch crossing (BC) identification is one of the main task of the L1 muon barrel trigger
- Hits from various RPC detectors are calibrated in order to provide the correct timing
- The "online" calibration is performed using programmable delays in steps of 1/8 BC (3.125 ns)
- 99.6% of the L1 muon barrel triggers are associated to the correct BC





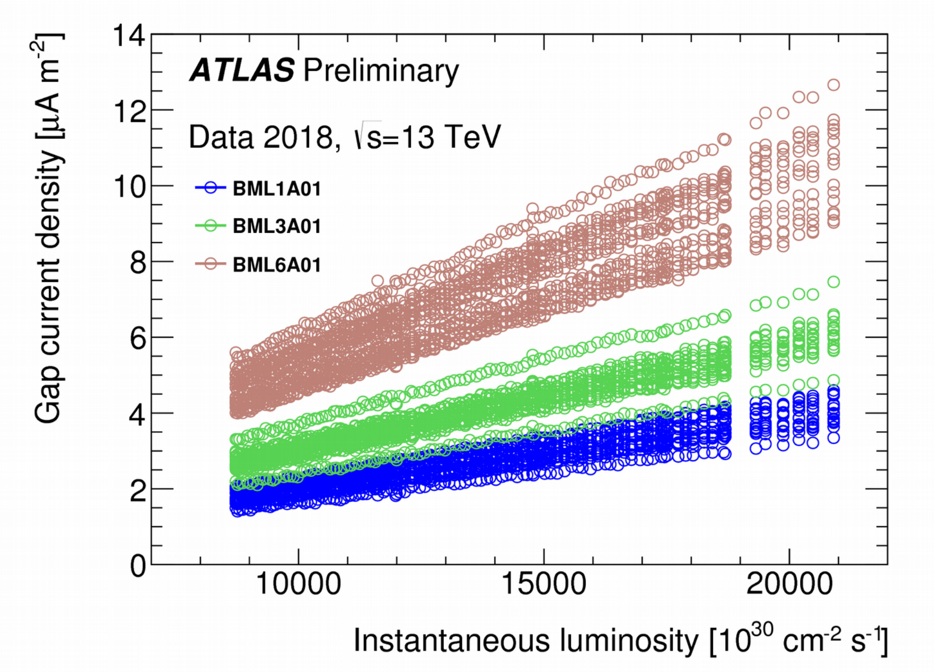
Each point corresponds to a different ATLAS run recorded in 2018

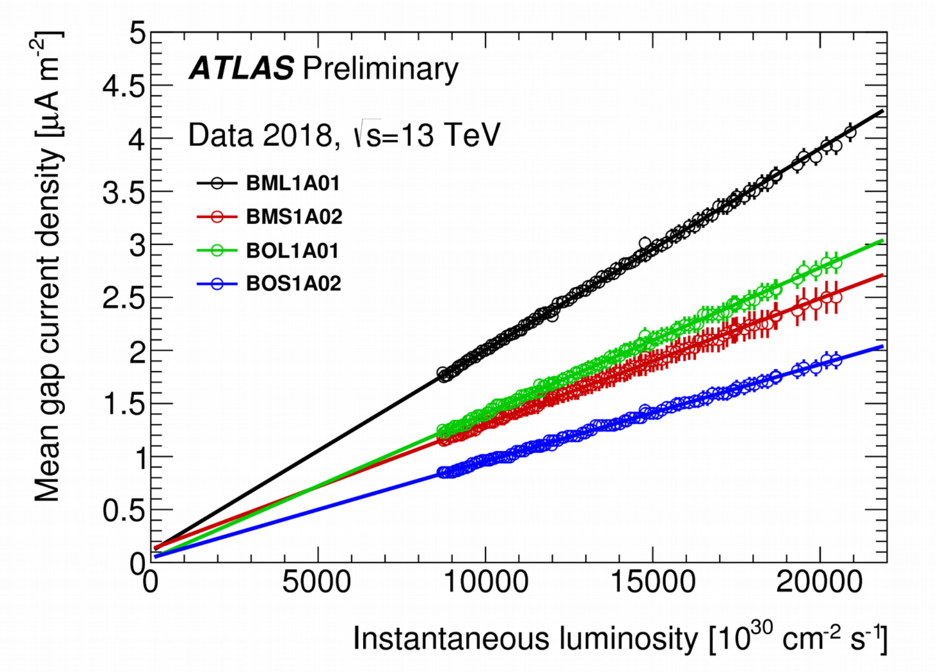
Very good stability during the year

Studies for HL-LHC

See talk from Yongjie Sun

- Gas-gap currents (normalized to the gap area) as a function of instantaneous luminosity with 2018 data
- Aim to predict safe operating HV settings for each gas gap for HL-LHC
- Current proportional to the luminosity → this shows that the present RPC system is in a very good status

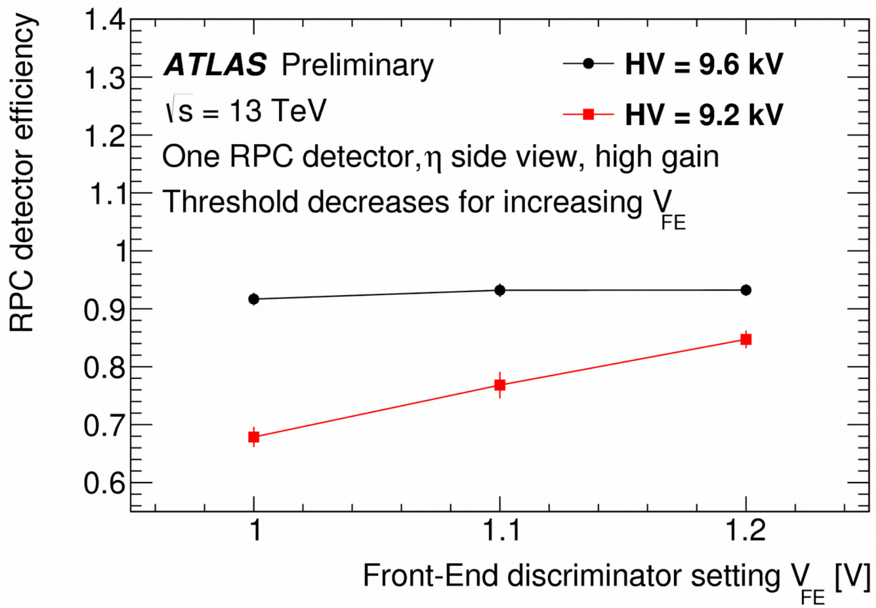


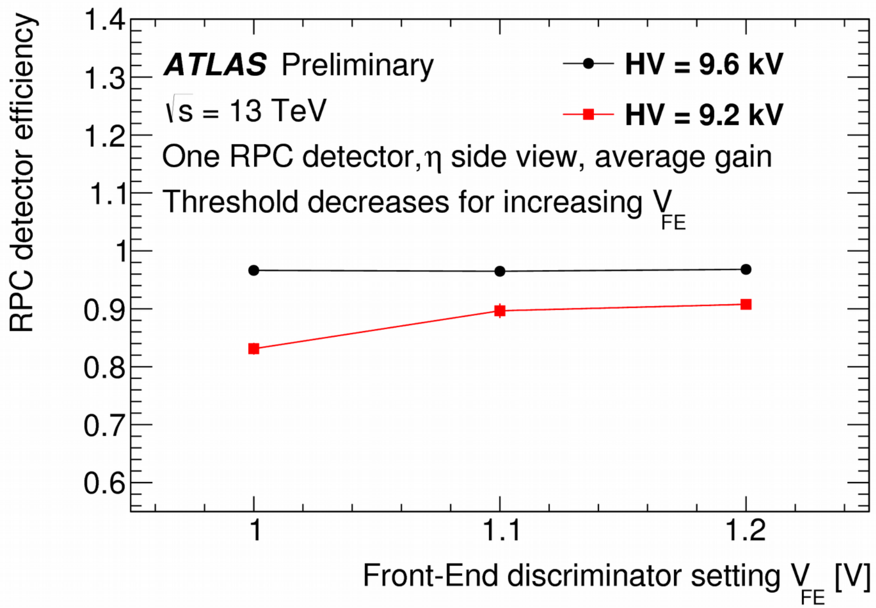


Studies for HL-LHC

See talk from Yongjie Sun

- Study the response of few RPC chambers with lower HV and thresholds
- At HL-LHC (~7.5 • 10^{34} cm^{-2} s^{-1}) the integrated charge collected in the avalanche will be enough high to limit the detector lifetime
- In order to keep the performance of current system stable during years, it is needed to lower the HV in the RPC gas-gaps (9.6 kV → 9.2 kV). At the same time, new RPCs will be installed in the innermost layer of the Muon Barrel Spectrometer to increase the redundancy of the trigger system and the trigger efficiency
- This study demonstrates that part of the efficiency lost by reducing the RPC HV can be recovered by lowering the thresholds of the Front-End discriminator (10% on average)



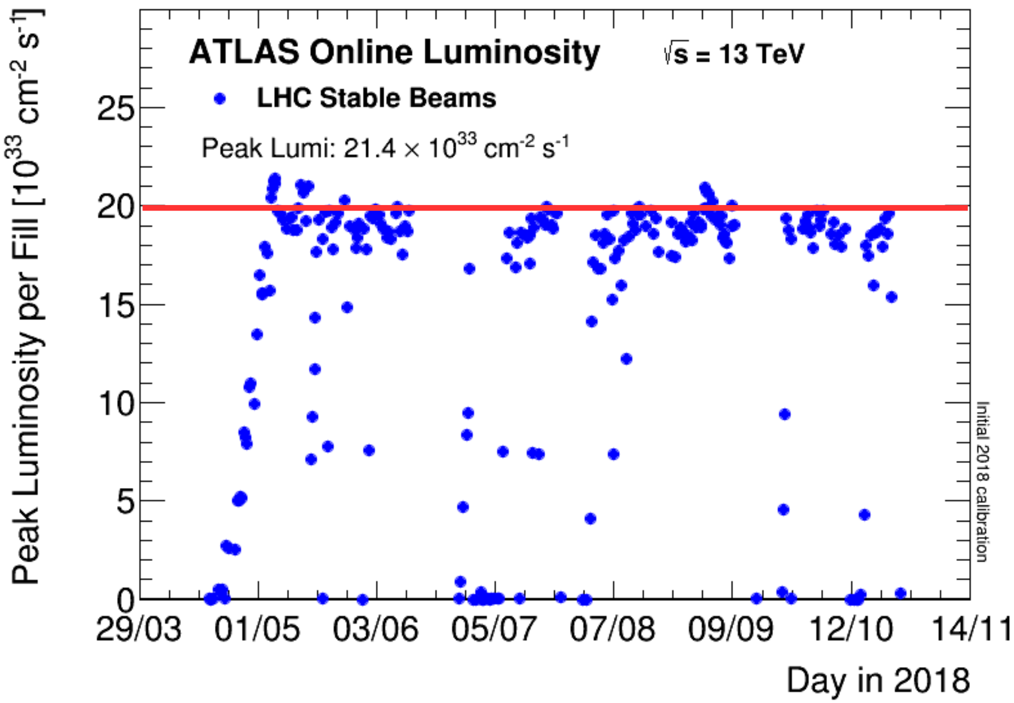


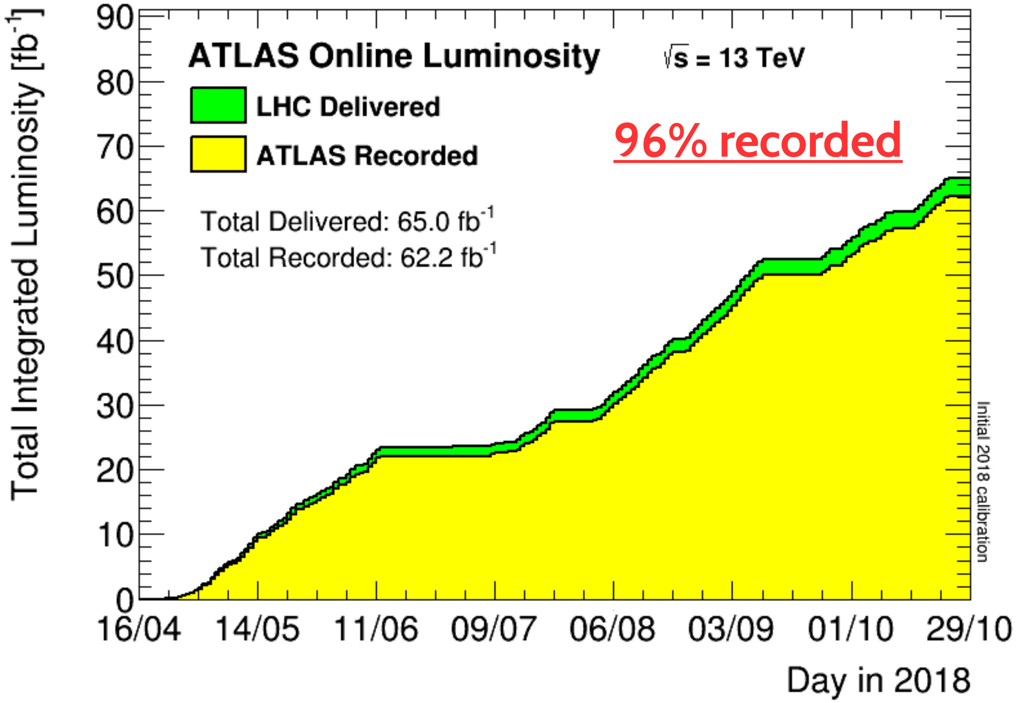
Summary and conclusions

- Muon triggers are of crucial importance for fulfilling the physics program of the ATLAS experiment
- ATLAS RPCs worked for long time with stable performance (both detector and trigger efficiencies) and operations with a factor of 2 larger than the design instantaneous luminosity
- Very large effort to monitor the RPC performance continuously during the year → today USTC group plays a primary role
- No major upgrades are foreseen for Run-3, but for Phase-II a completely new trigger system is expected (RPC in the BI layer + new trigger electronics)
- Many performance plots approved recently using the full 2018 data-set → **link1 link2**

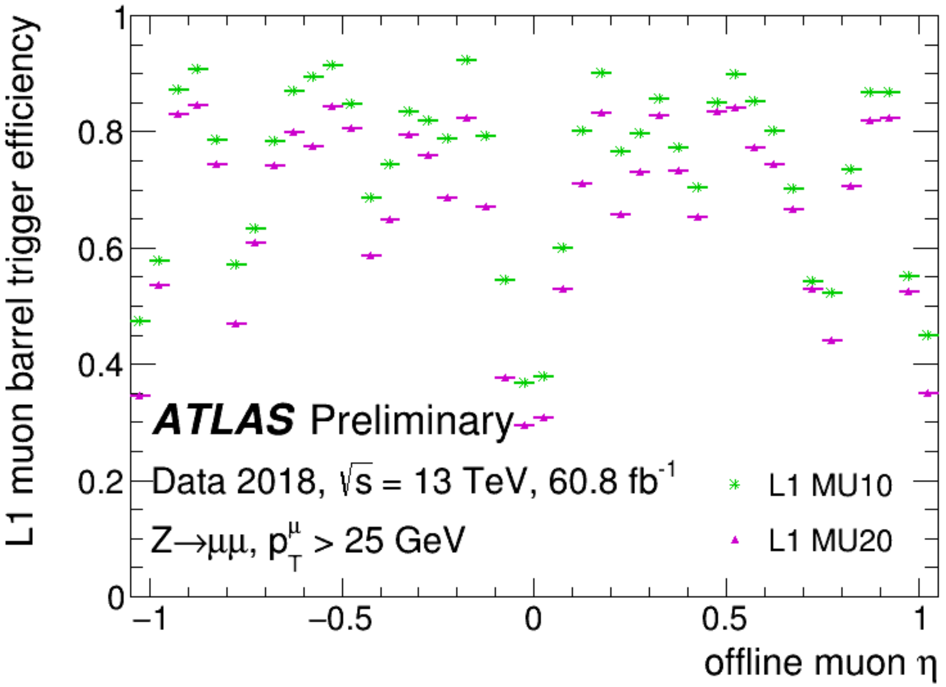
Back-up slides

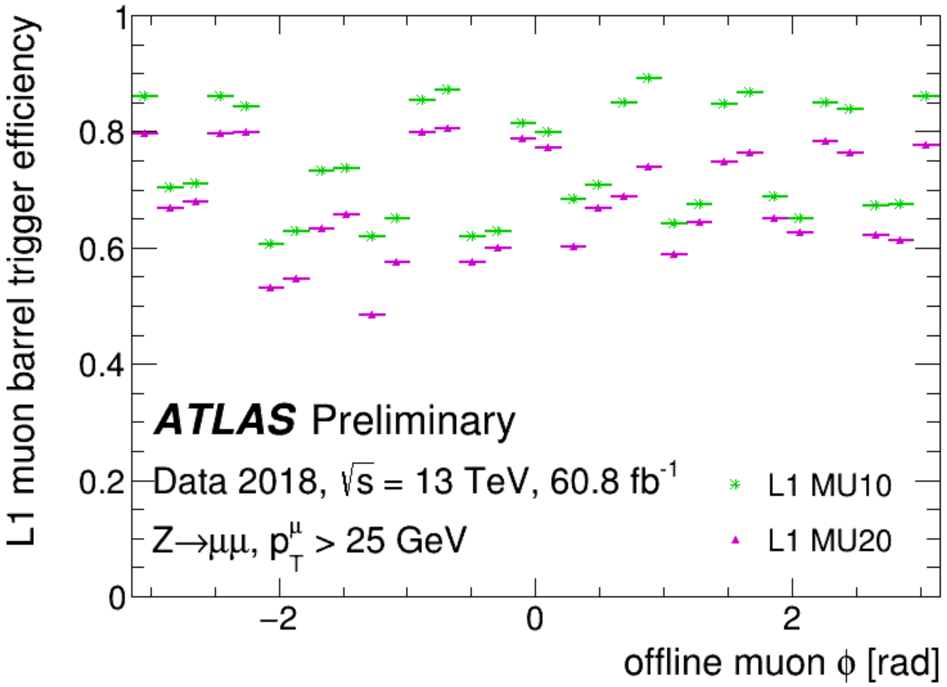
ATLAS data-taking performance during 2018



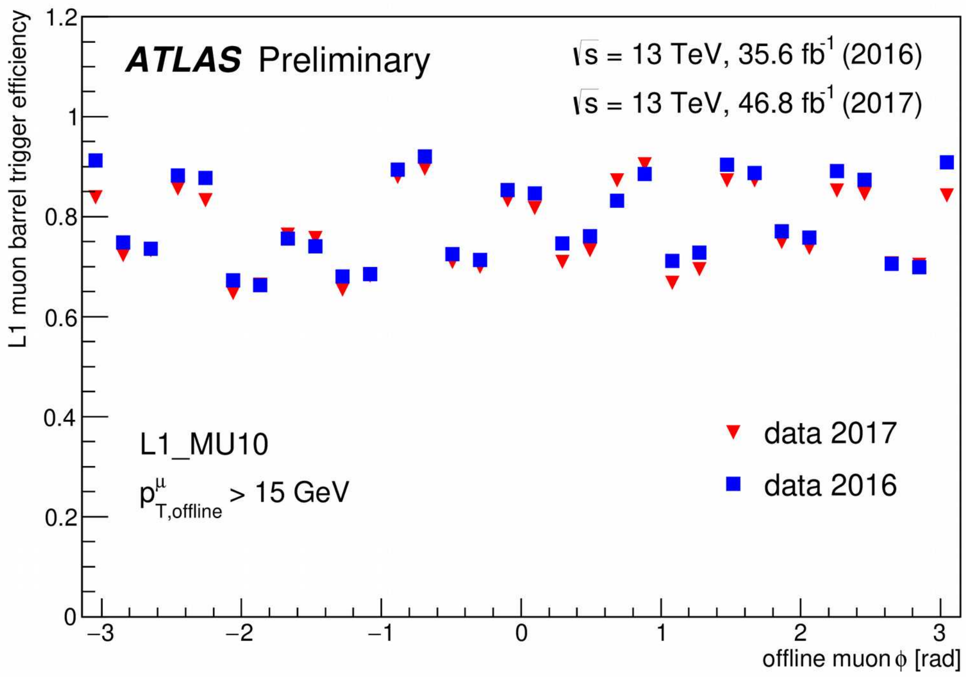


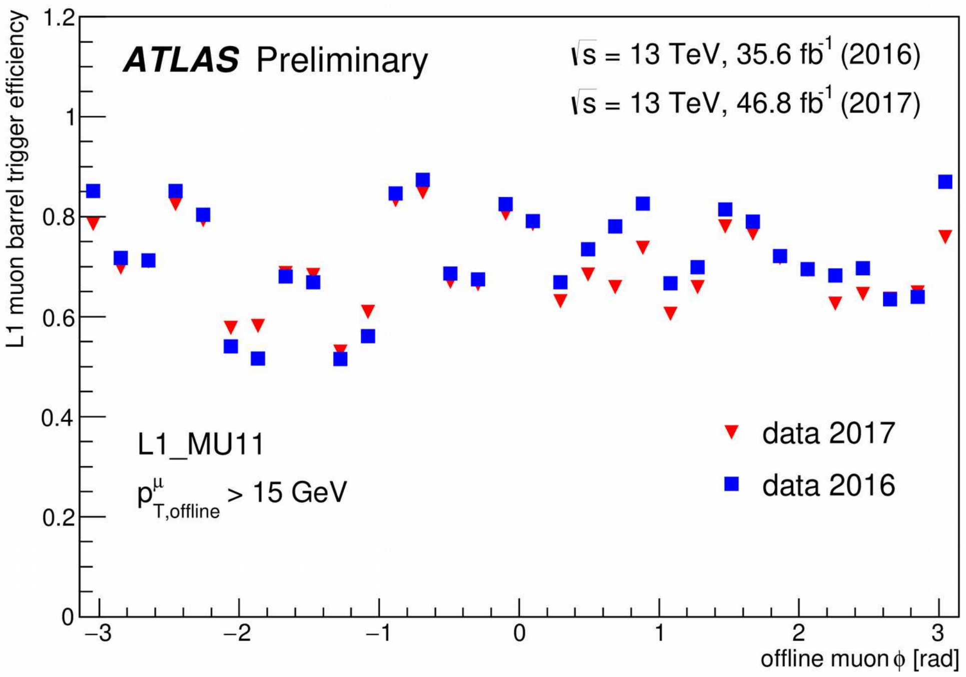
Trigger efficiency as a function of η and φ (2018)



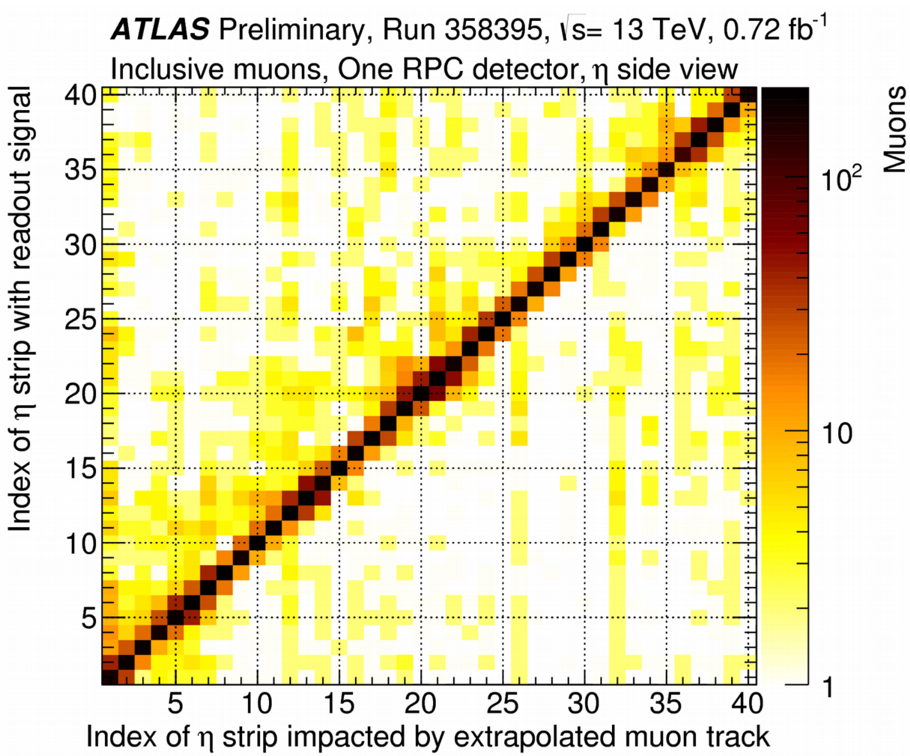


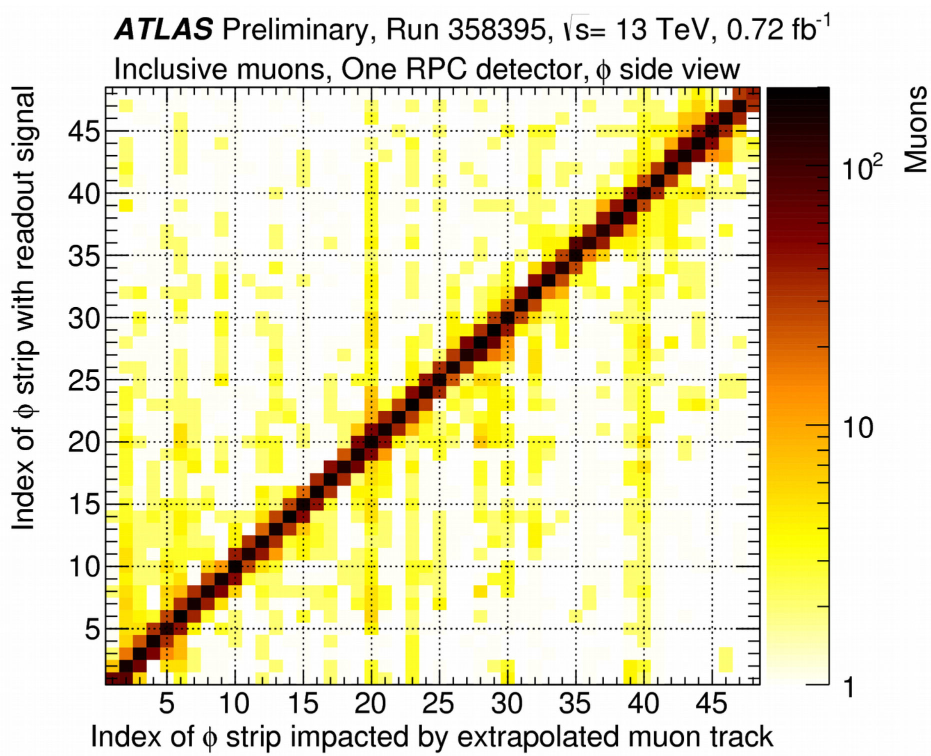
Trigger efficiency as a function of eta or phi (2016/2017)



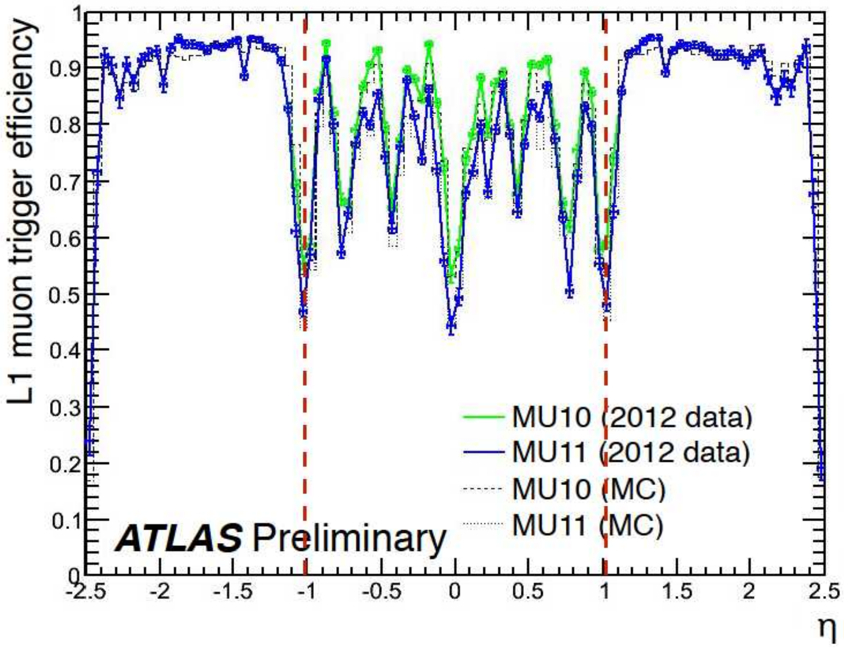


Muon position vs strip hit

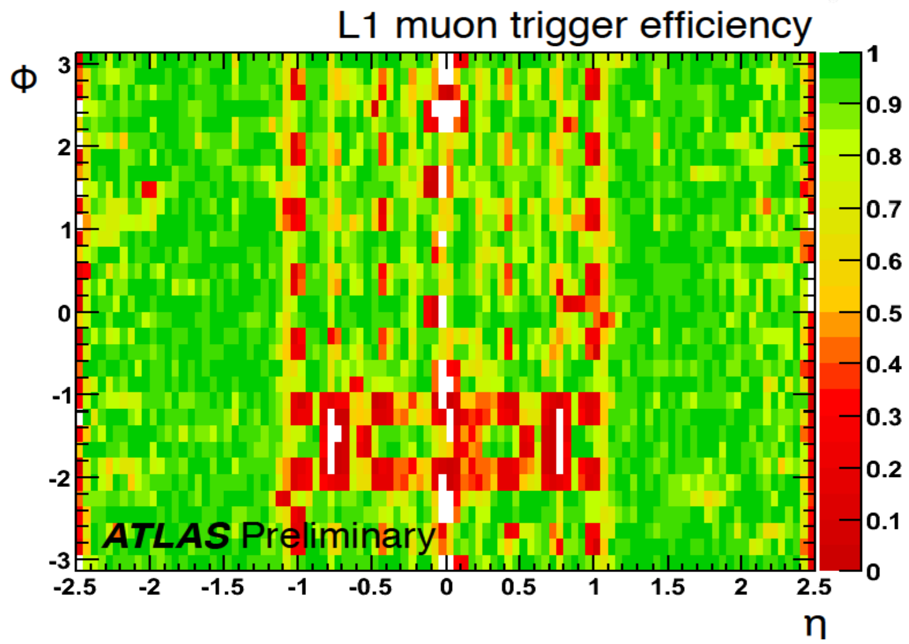


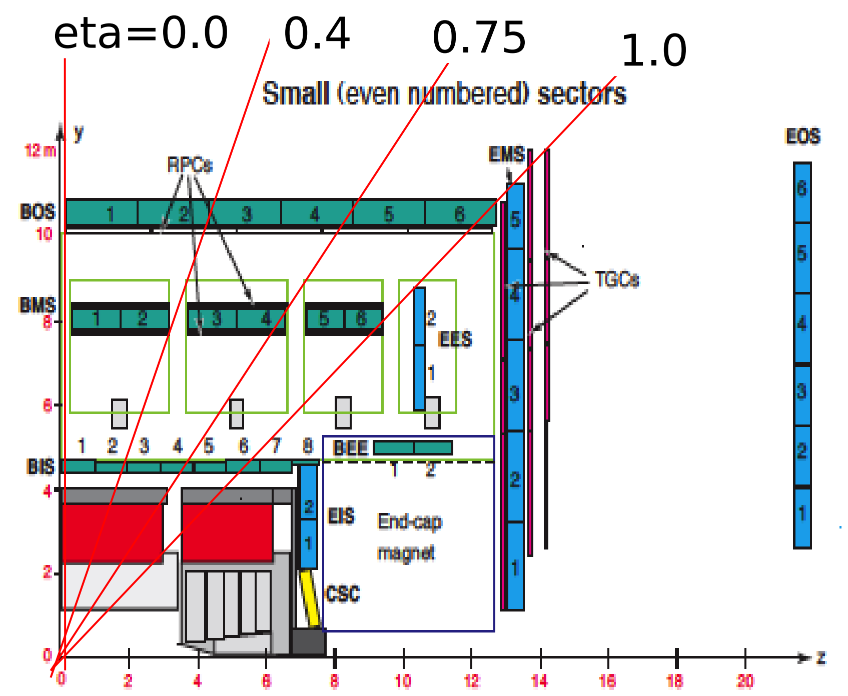


Muon barrel acceptance limits



- Acceptance holes of the L1 Muon Barrel trigger ~22%
- Holes due to toroid ribs (Small Sectors) and Z=0 crack (Large Sectors) + holes in feet region and bottom sector (elevator)



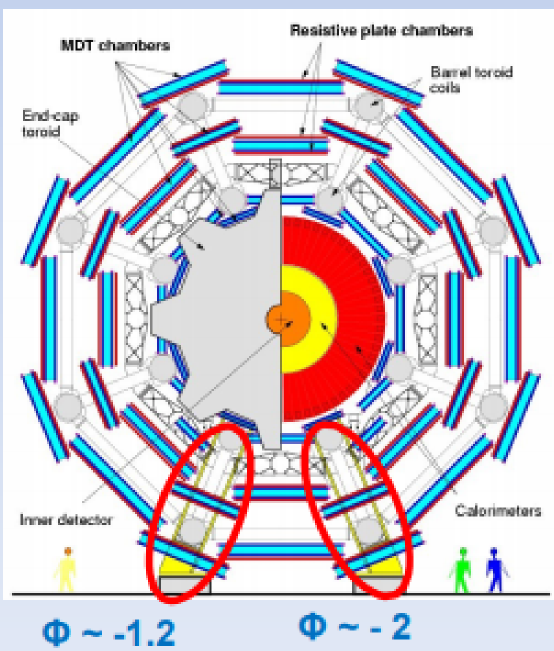


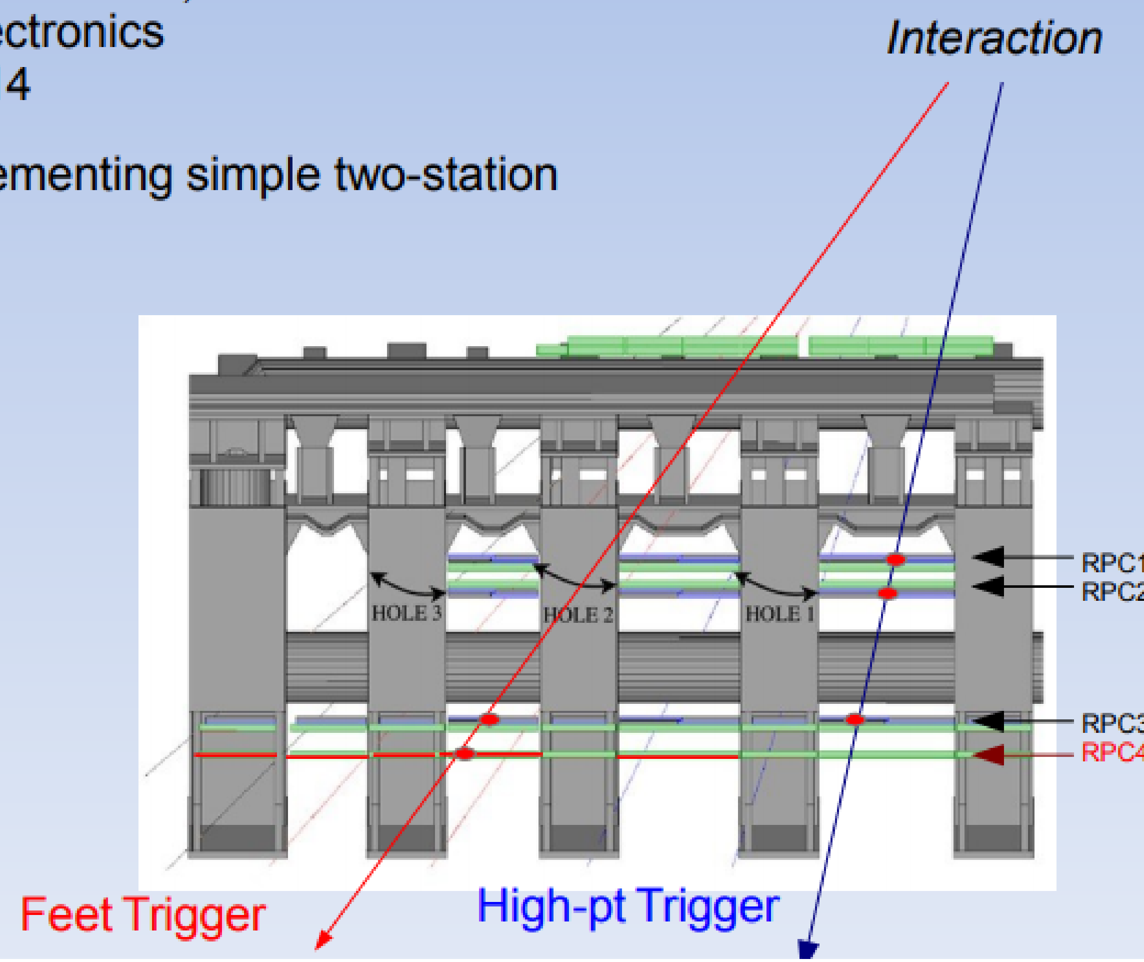
L1 muon barrel trigger: feet region

Upgrade project to cover acceptance holes in the “feet” sectors (12-14) 4th RPC layer
2.8% increase of barrel acceptance

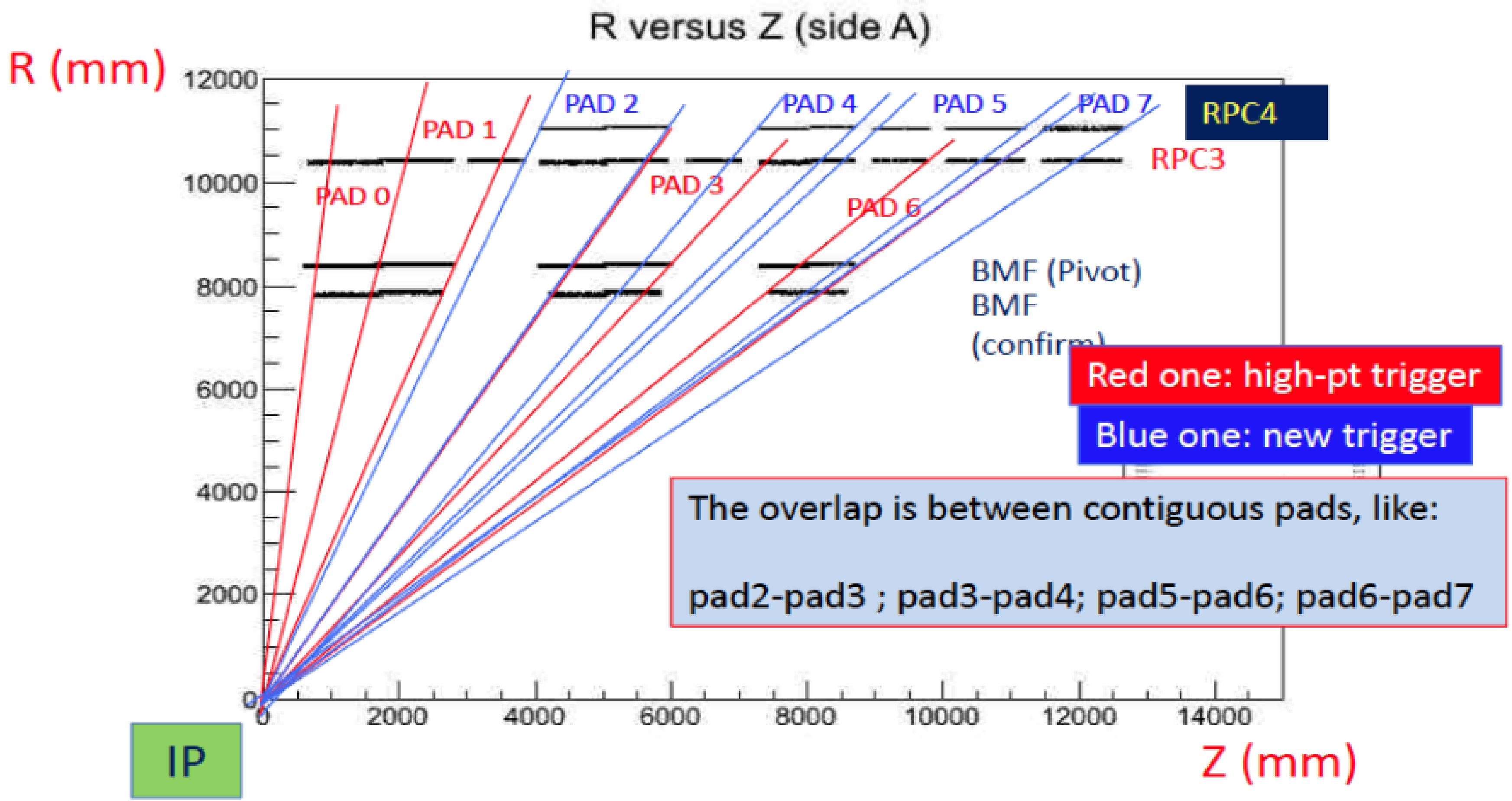
20 RPC chambers installed before 2008, equipped with services and electronics during long shutdown 2013-2014

Special trigger “towers” implementing simple two-station coincidences (4 layers)





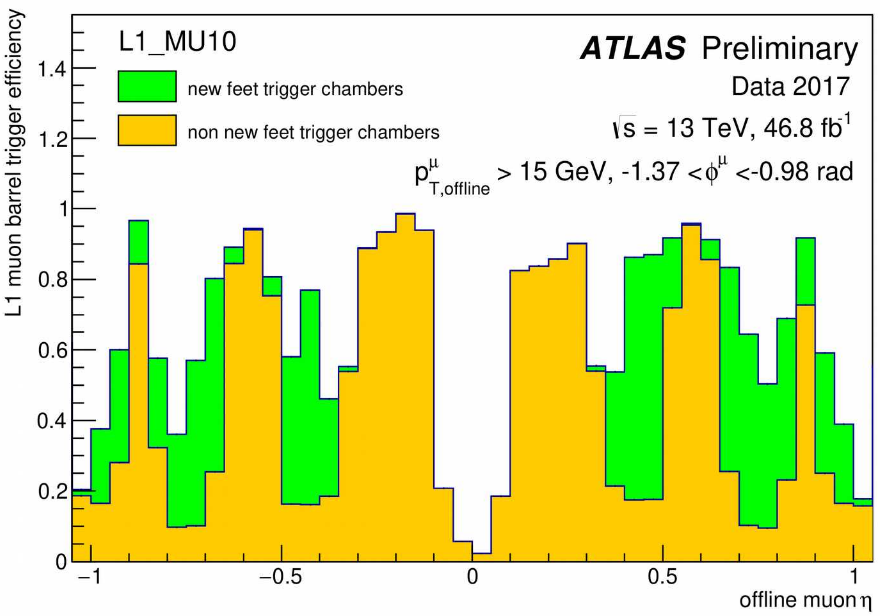
L1 muon barrel trigger: feet region

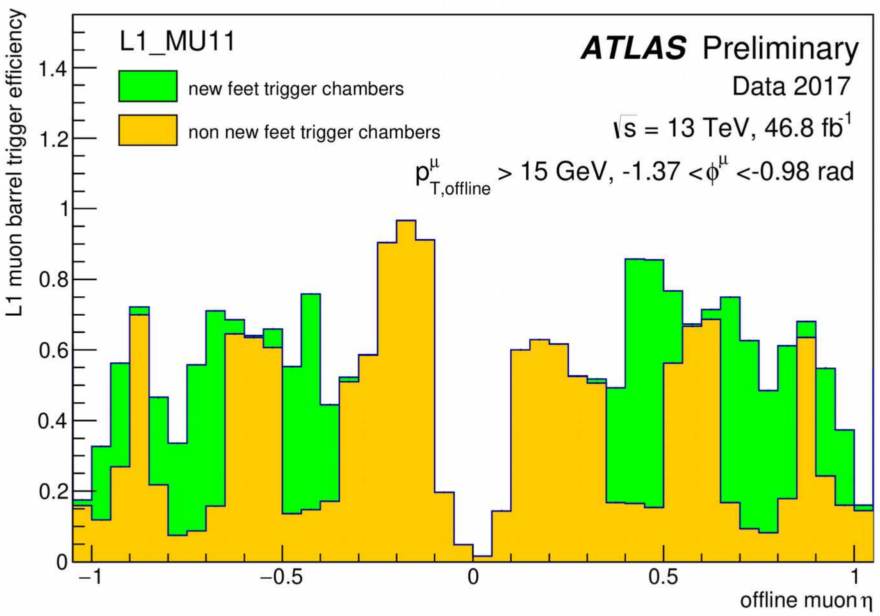


The overlap is between contiguous pads, like:

pad2-pad3 ; pad3-pad4; pad5-pad6; pad6-pad7

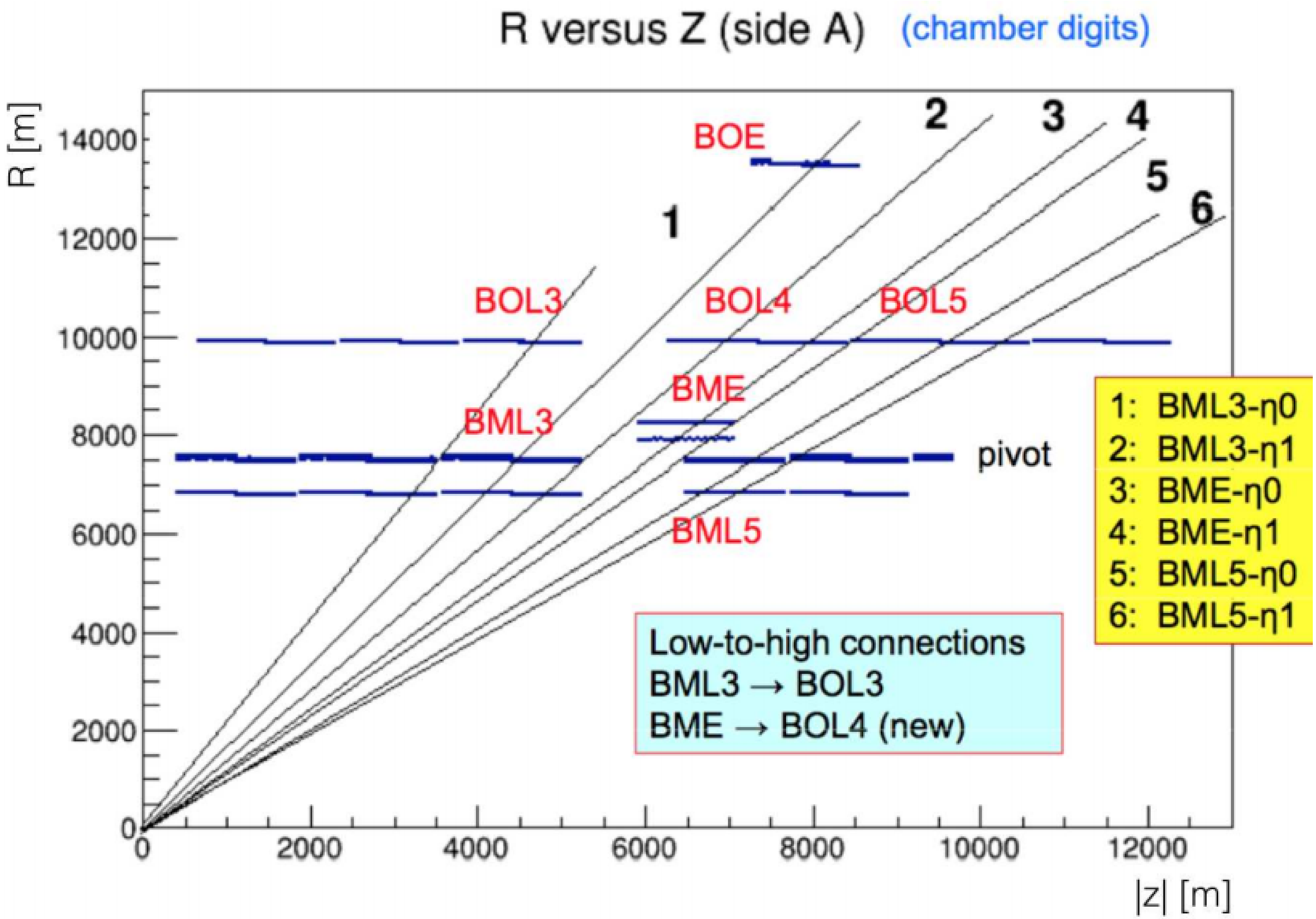
Trigger efficiency in one feet sector (2017)



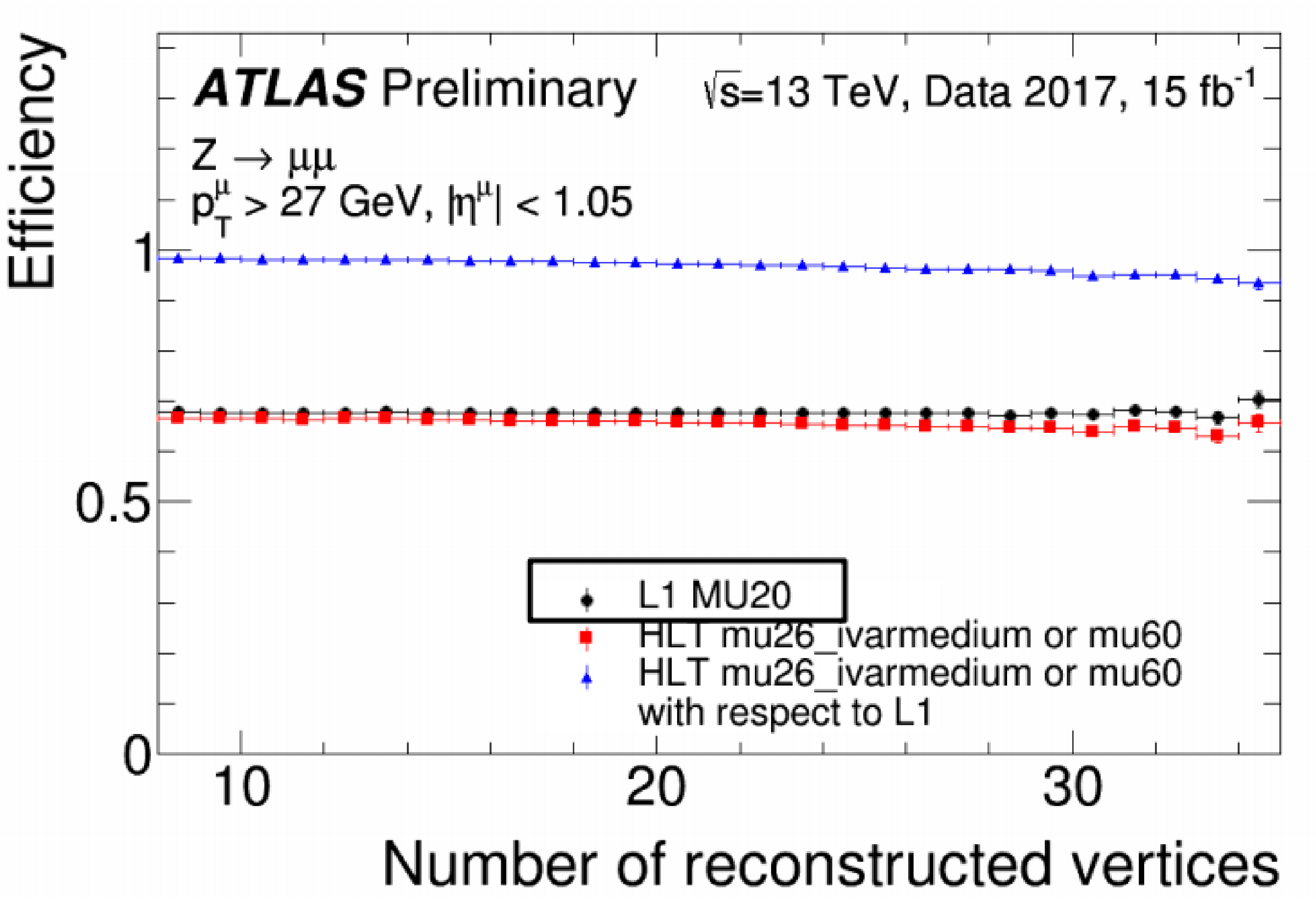


- The MU10 trigger requires that a candidate passed the 10 GeV threshold requirement of the Level 1 muon trigger system, using medium trigger chambers.
- The MU11 trigger requires that a candidate passed the 10 GeV threshold requirement of the Low-p_T Level 1 muon trigger system, with a coincidence with a High-p_T RPC chamber.
- The efficiency is measured on an inclusive sample selected using all non-muon Level 1 ATLAS triggers, in 13 TeV data from 2017 with 25 ns LHC bunch spacing.

L1 muon barrel trigger: sector 13



Trigger efficiency vs pile-up

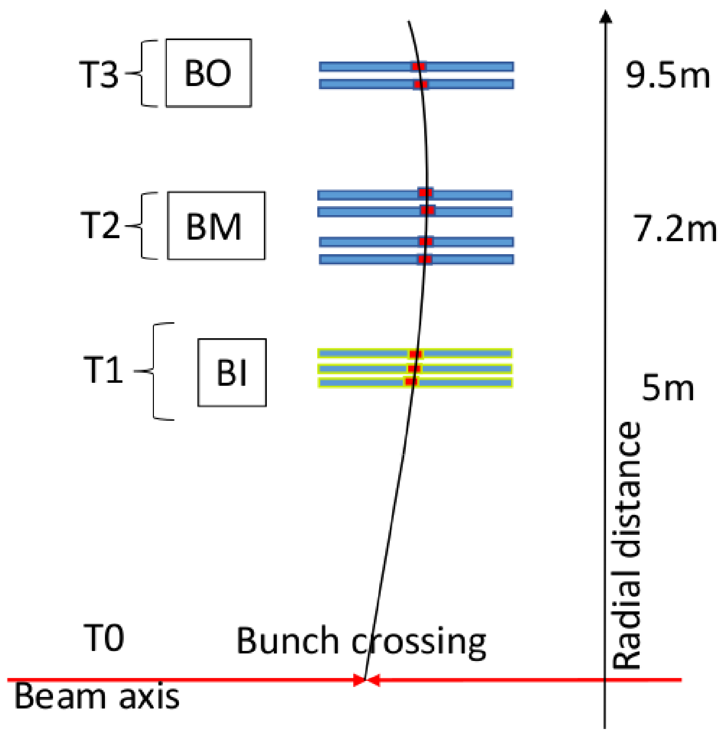


Trigger rates in 2017

ATL-DAQ-PUB-2018-002

Trigger	Typical offline selection	Trigger Selection		Level-1 Peak Rate (kHz)	HLT Peak Rate (Hz)
		Level-1 (GeV)	HLT (GeV)	$L = 1.7 \times 10^{34}$ cm^{-2}s^{-1}	
Single leptons	Single isolated μ, $p_{\mathrm{T}} > 27$ GeV	20	26 (i)	15	180
	Single isolated tight e, $p_{\mathrm{T}} > 27$ GeV	22 (i)	26 (i)	28	180
	Single μ, $p_{\mathrm{T}} > 52$ GeV	20	50	15	61
	Single e, $p_{\mathrm{T}} > 61$ GeV	22 (i)	60	28	18
	Single τ, $p_{\mathrm{T}} > 170$ GeV	100	160	1.2	47

Trigger performance expected for Run-3



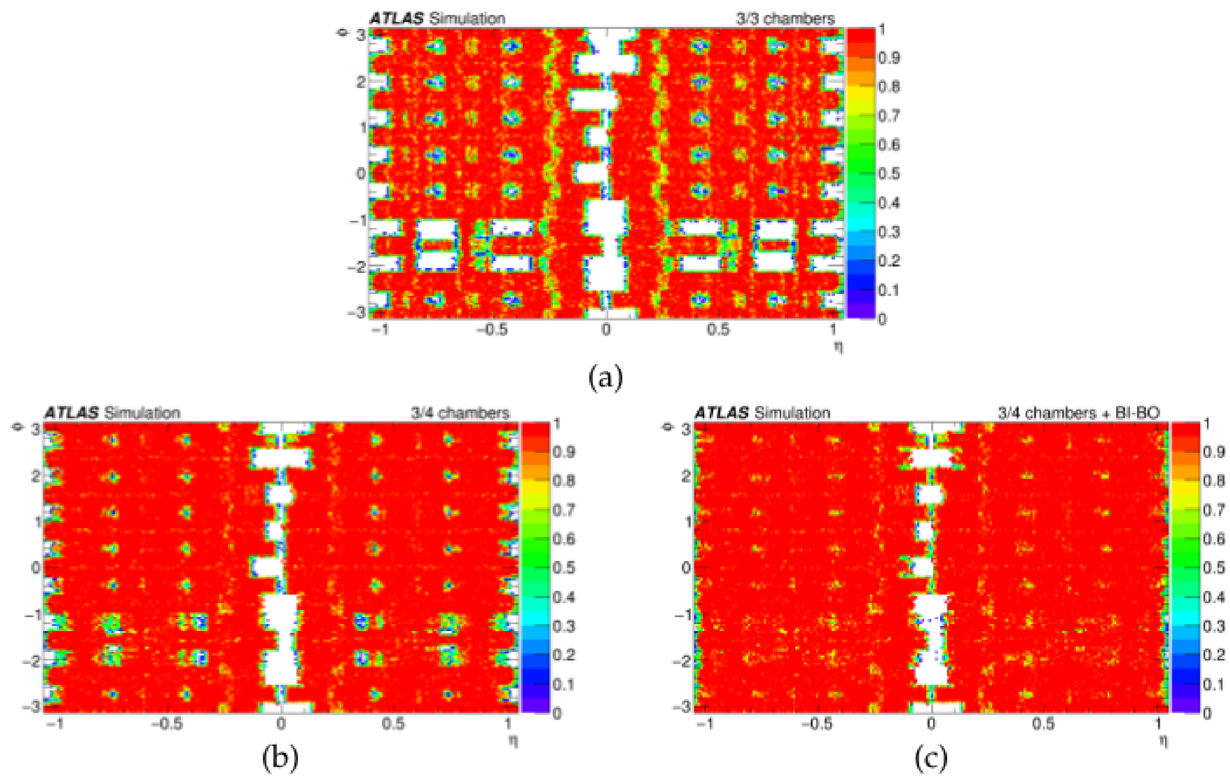
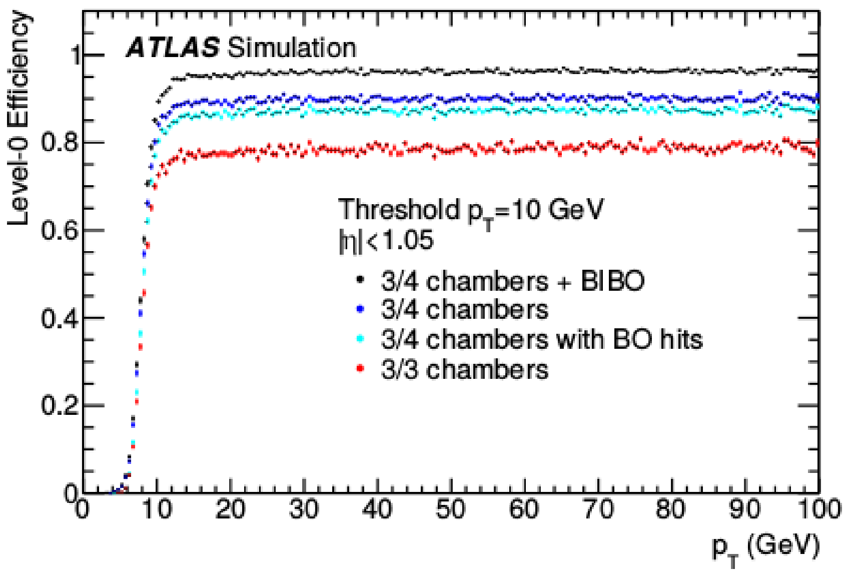


Figure 3.5: Geometrical acceptance of the L0 barrel trigger with respect to reconstructed muons with $p_T = 25$ GeV in the η-ϕ plane. Figures (a), (b), and (c) show the acceptance for the different trigger coincidence logic schemes: 3/3 chambers, 3/4 chambers, and 3/4 chambers + BI-BO, respectively

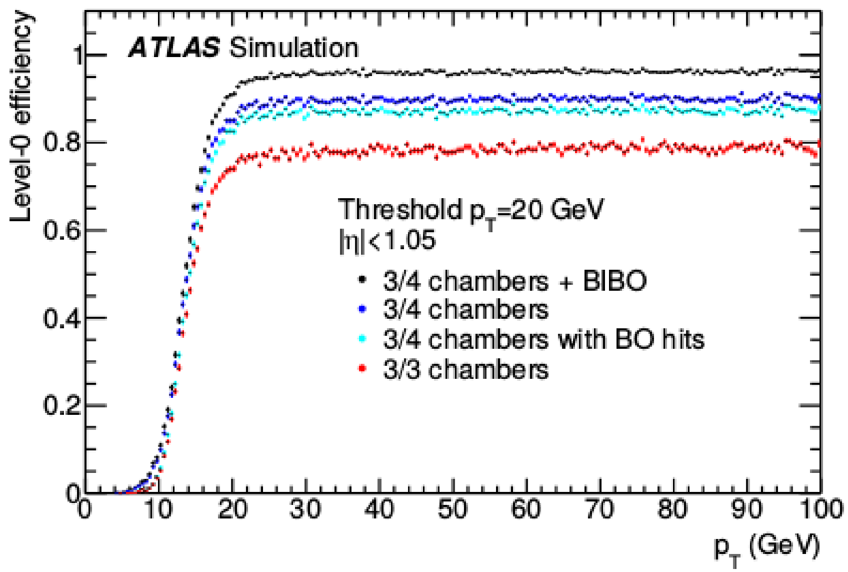
BM and BO efficiency (%)	Trigger efficiency × acceptance (%)		
	3/3 chambers	3/4 chambers	3/4 chambers + BI-BO
100	78	91	96
90	73	90	95
80	62	87	93
Worst case	63	85	92

Lowered HV in BM and BO

Trigger performance expected for Run-3



(a)



(b)

Requirement	Rate
3/3 chambers	20 kHz
3/4 chambers	30 kHz
3/4 chambers + BI-BO	85 kHz
3/4 chambers + BI-BO (*)	45 kHz

Expected rates at 7.5×10^{34} cm^{-2} s^{-1} for L1 MU20

(*) indicates the rate for a BI-BO trigger that is restricted to acceptance gaps