RPC 2018 - Puerto Vallarta - 2018.02.19

Performance of the ATLAS RPC Level-1 Muon trigger during the Run-II data taking

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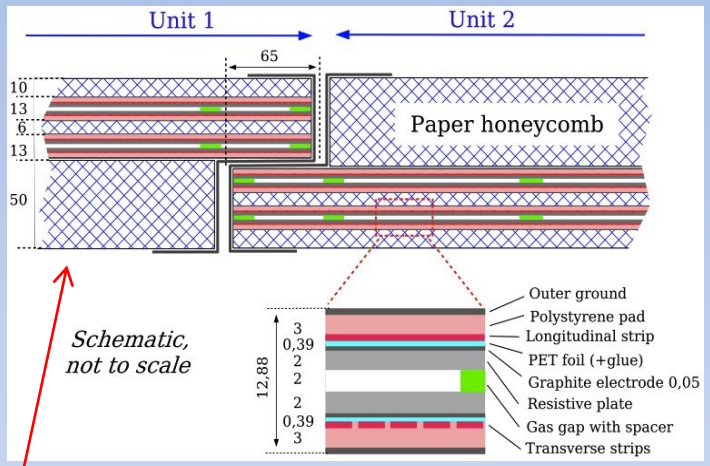
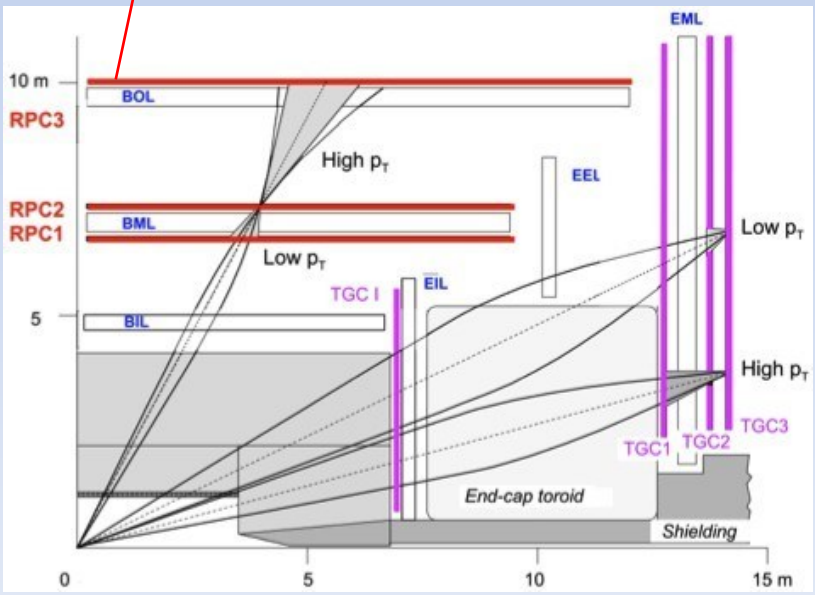
ATLAS RPCs and L1 Barrel Trigger

- RPCs are used in ATLAS as **trigger chambers** in the barrel region
- **Three layers**
  each equipped with a **doublet** of RPCs.
- Each **gas gap** is read out with orthogonal η and φ **strips** : pitch 2.3 - 3.5 cm.
- Approximately 4k gas volumes
- **Two kind of triggers**:

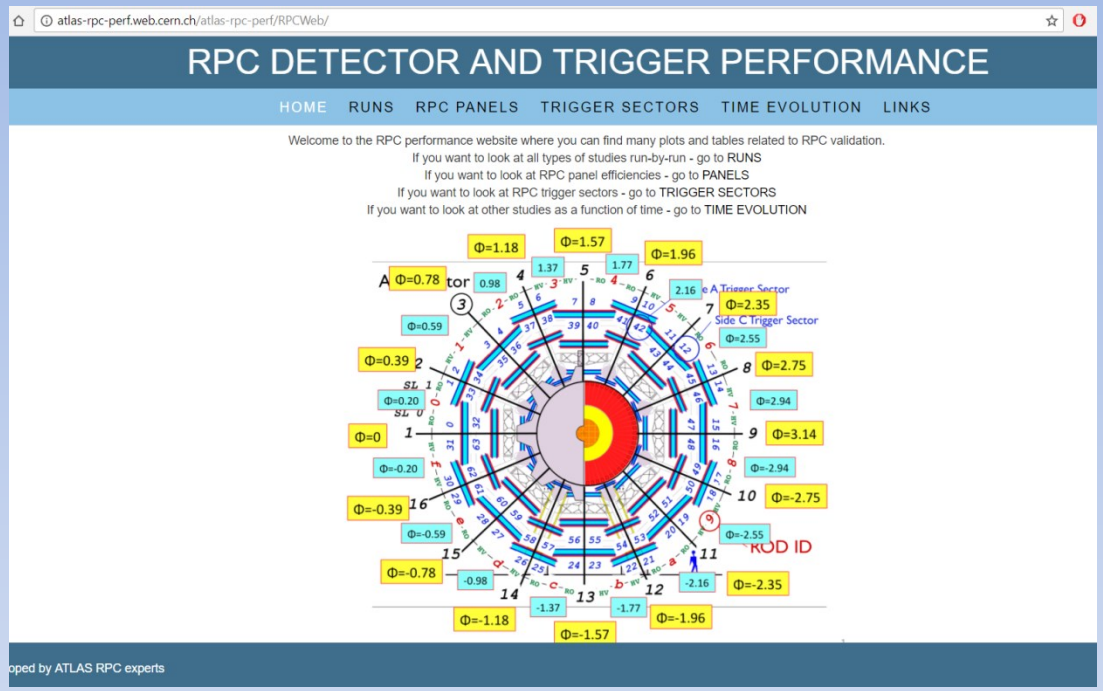
  Low-p_T 2-stations projective coincidence pivot and the middle confirm thresholds between 4 and 10 GeV,

  High- p_T 3-stations projective coincidence low-p_T + outer confirm thresholds between 11 and 20 GeV



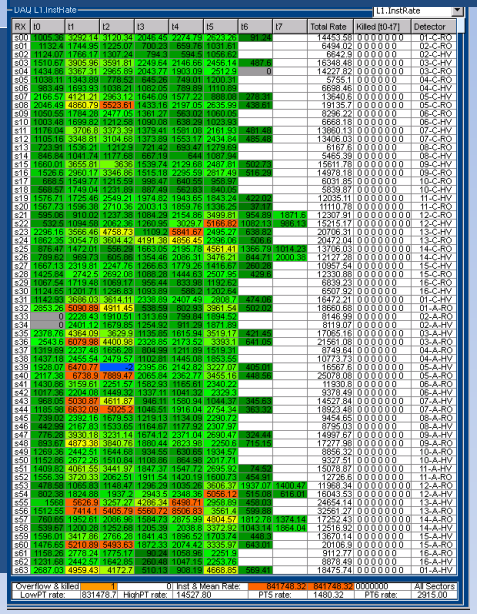


Level-1 Barrel Trigger



Projective towers t0-t7

Trigger sector s00-s63



The trigger system consists of two halves - positive and negative η each divided into 32 azimuthal sectors

Each sector is divided along η in projective towers.

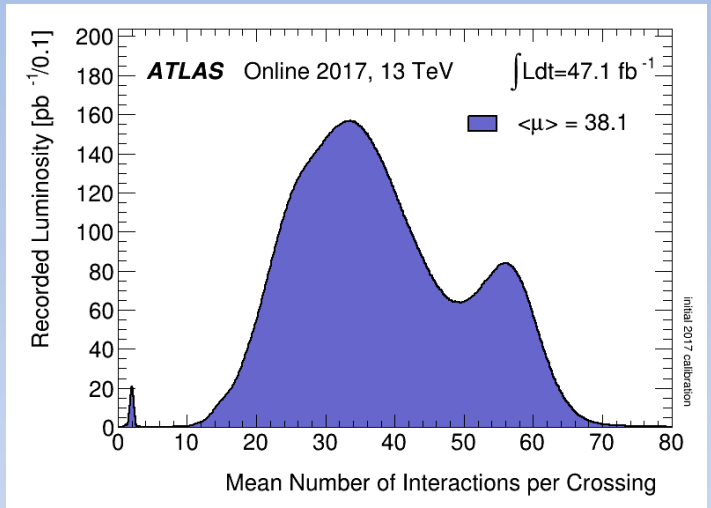
High-pT triggers are used to select events based on single-muon signatures
Low-pT triggers are only used in coincidence with other trigger objects to select multi-object signatures, including muon pairs

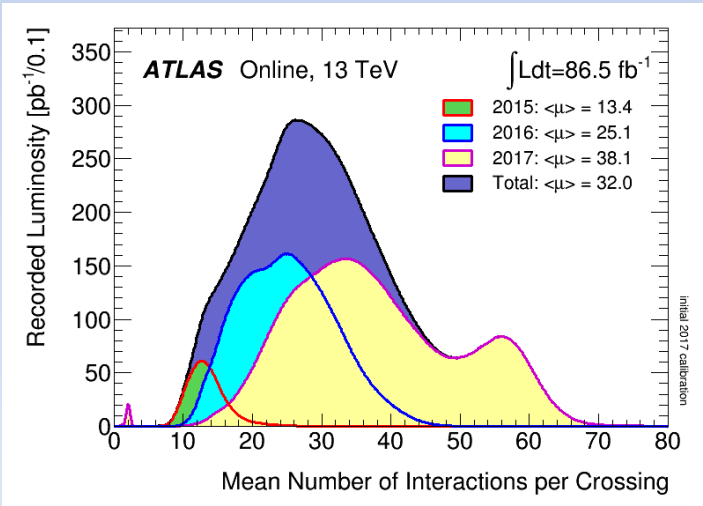
Running Conditions

Peak instantaneus luminosity **20.6 x10^{33} cm^{-2}s^{-1}**
Peak number of interactions
per bunch-crossing (pile-up) **~ 80**
Average number of interactions **38.1**

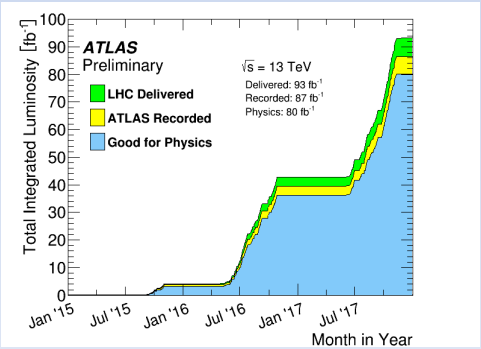
Run - 2 luminosity
LHC delivered **93 fb^{-1}**
ATLAS recorded **87 fb^{-1}**
Good for physics **80 fb^{-1}**

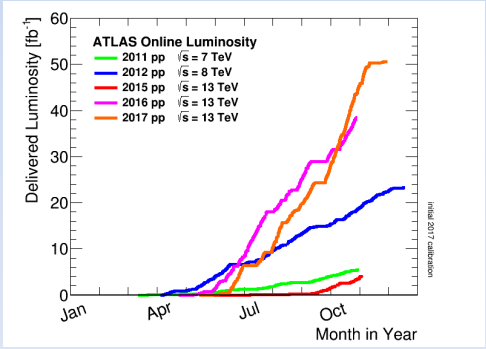
Mean number of interactions





Run - 2





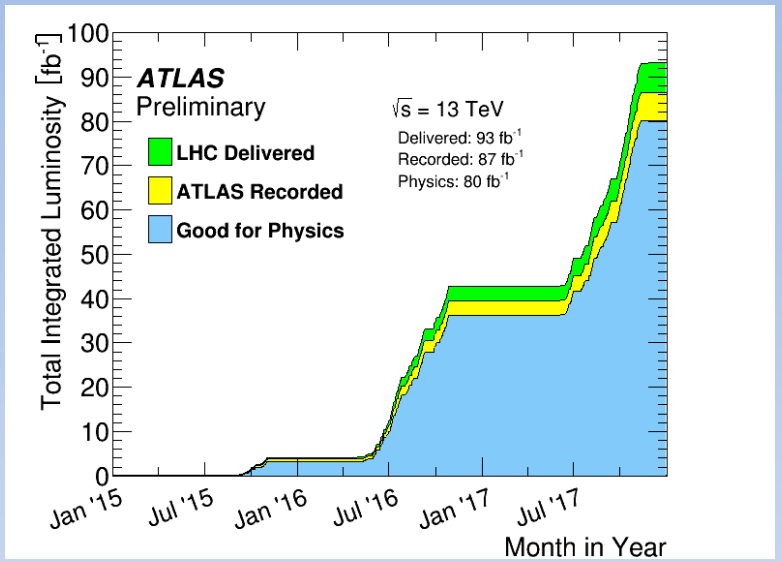
ATLAS Data Taking

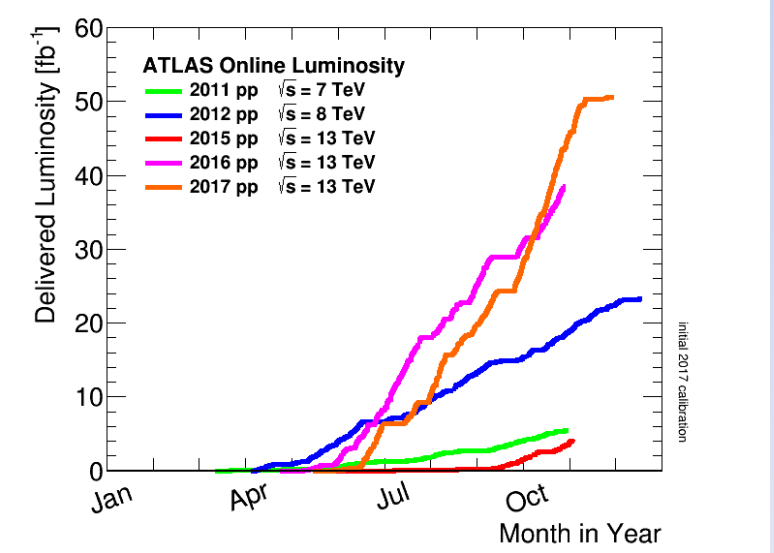
pp collisions at **√s=13 TeV**,
runs with **25ns** bunch spacing

Run - 2 Full Dataset:
delivered integrated luminosity of **93 fb^{-1}**
recorded integrated luminosity of **87 fb^{-1}**
good for physics **80 fb^{-1}**

Active trigger towers: 99.0 - 99.5%
(0~3 off out of 404)

	Number hours Stable Beam	Efficiency % (Ready for Physics)
2017	**1453**	**94.2%**
2016	1832	92.9%
2015	938	91.4%





Monitoring of L1 Trigger Performances

Monitoring of RPC and L1/Barrel trigger is performed at different levels:

- **DCS**: Detector Control System, follows the slow-varying parameters such as HV, currents, temperature,….. and perform the automatic HV adjustment based on pressure and temperature measurements

- **Online Data-Quality monitor**: checks basic functionalities of readout, makes hit maps to spot holes. Histograms are produced online during data taking

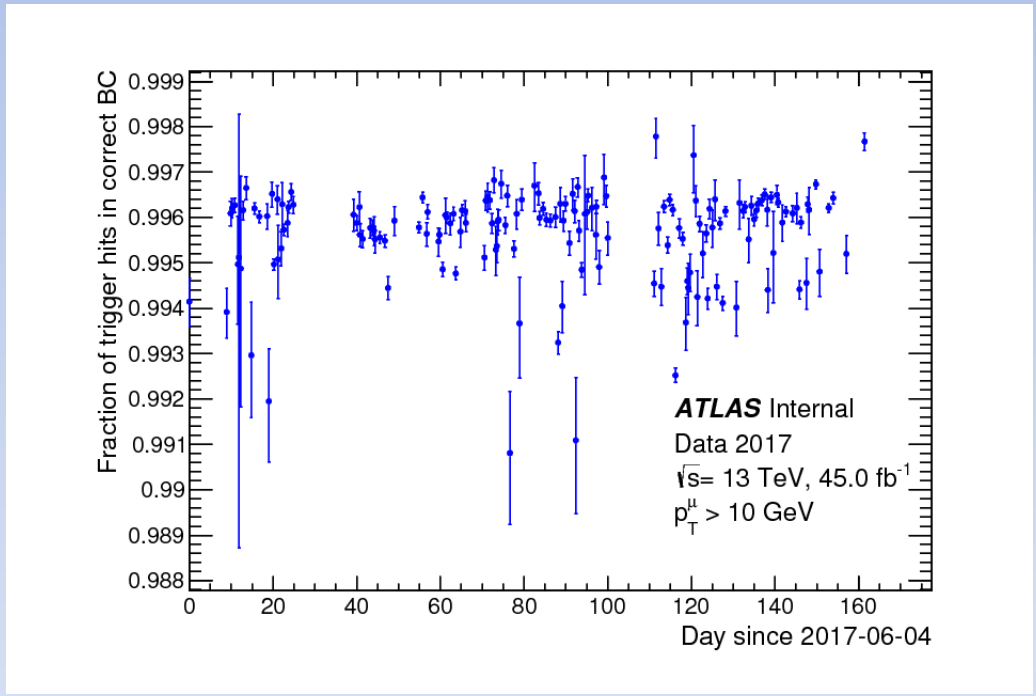
- **Offline RPC Data-Quality monitor** : runs after data reconstruction, produces more detailed plots on detector quantities, such as efficiency, cluster size,……. for each detector unit. Exploits RPC-only muon tracks to select good muons

- **L1-Barrel Calibration program**: runs offline for each run after reconstruction, used to monitor and calibrate timing and momentum selection and to measure trigger quantity such as efficiency. Uses muon-independent triggers and muon tracks reconstructed using inner detector plus monitored drift tubes to select good muon probes

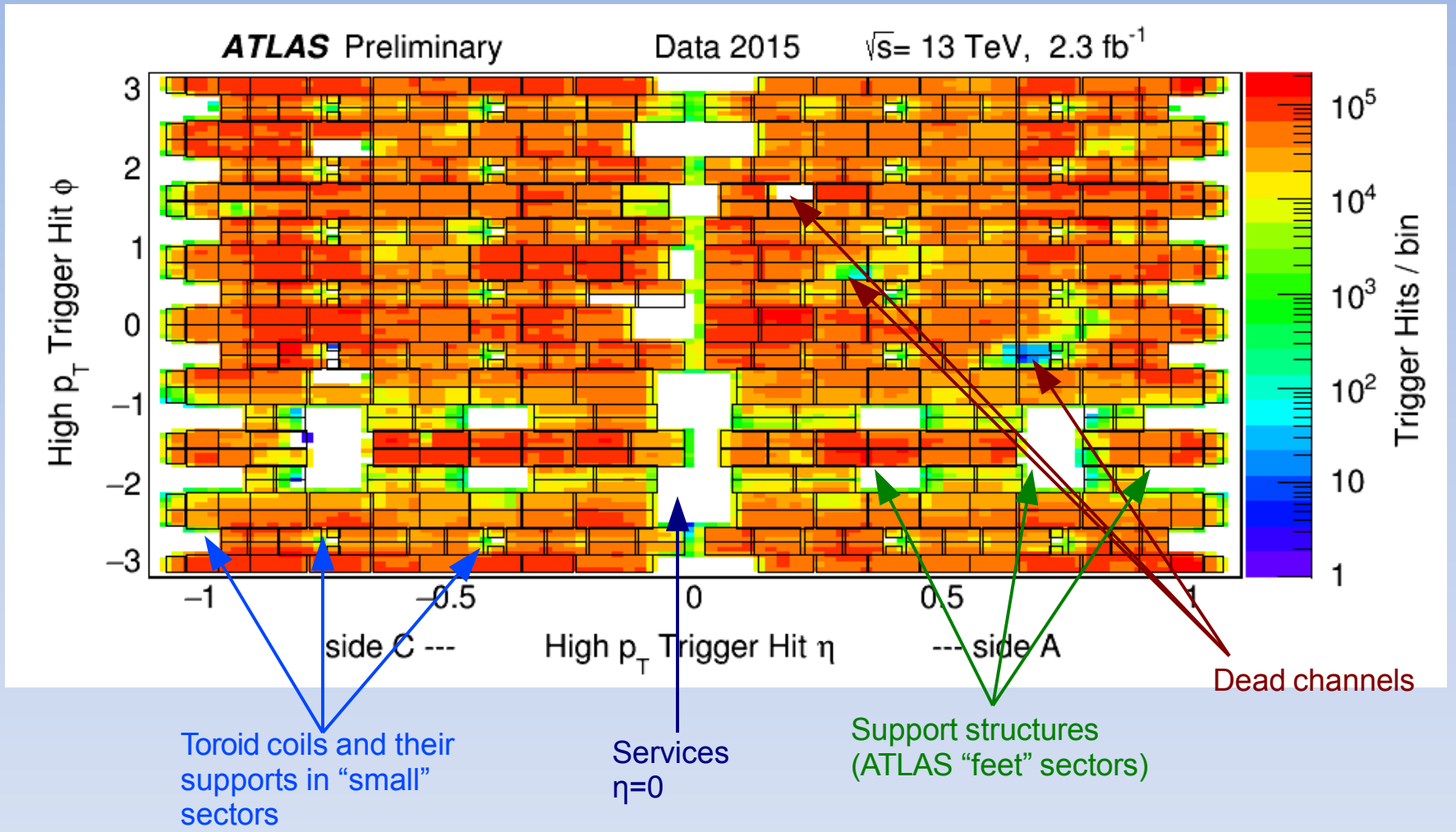
- **Tag and Probe analysis**: performed offline using a clean sample of muon tracks from Z->μμ decays to measure detector and trigger efficiencies.

Trigger Timing and Sincronization

- **Bunch Crossing** Identiification is one of the main tasks of the Level-1 Barrel Trigger
- Hits from RPCs from various planes are synchronized in order to provide online the correct hit timing.
  The calibration is performed using programmable delays in steps of 1/8 BC = 3.125 ns
- Trigger hit time distribution has a width of 2.9 ns and is centered in the collision BC
- 99.9% of L1 Muon Barrel triggers are associated to the correct BC



RPC Trigger Coverage



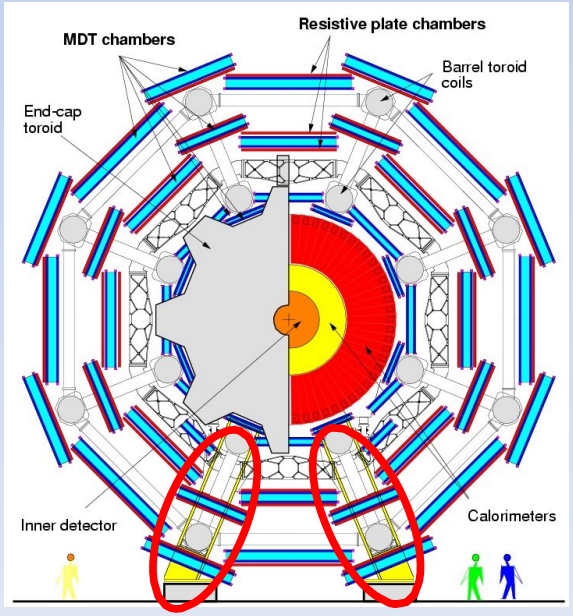
- Hit map from Offline Data-Quality monitor
- All η-φ coincidences on RPC-2 for high- p_T (3 station) trigger
- Acceptance holes well visible (Trigger Acceptance ~78% for |η|<1.05)
- Inefficient regions from dead channels and other problems also visible

"Feet" Upgrade

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

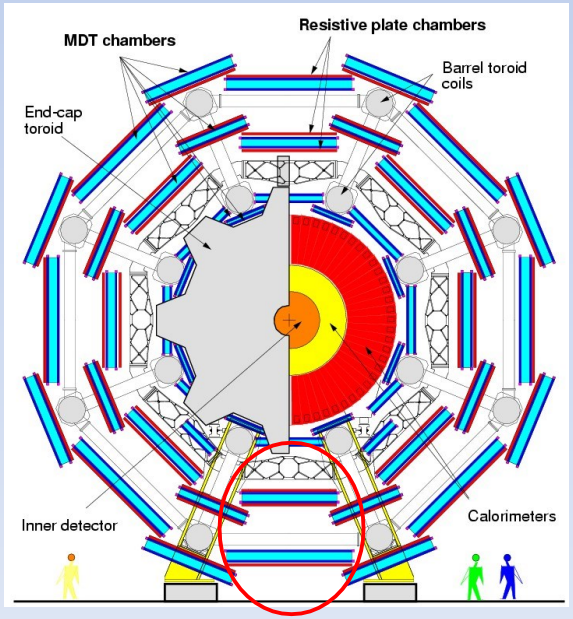
20 RPC chambers installed before 2008, equipped with services and electronics during long shutdown 2013-2014

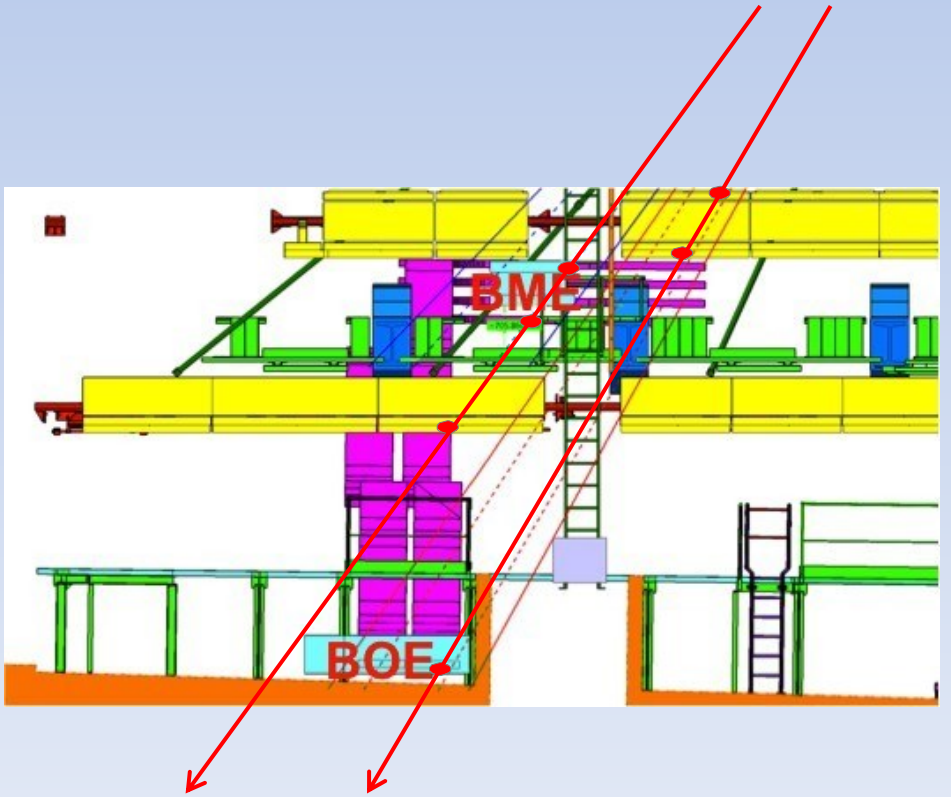
Special trigger "towers" implementing simple two-station coincidences (4 layers)



"Elevator" Upgrade

- 4 new muon stations have been installed
  2 (BME) with new RPCs with 1 mm gas gap
  2 (BOE) of standard type
- cover two holes in bottom sectors (~0.8% coverage) due to the "elevator" shafts



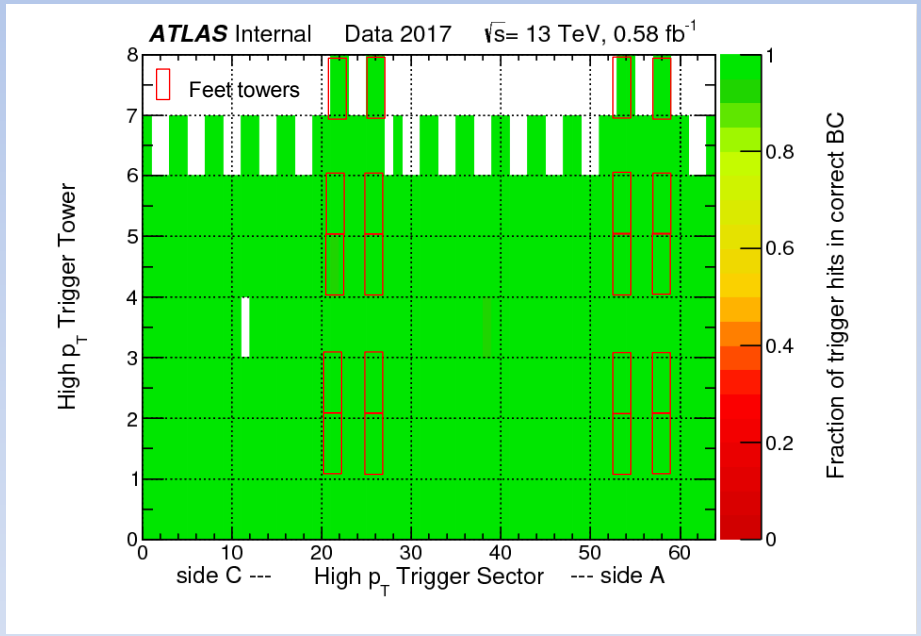


Trigger Feet Upgrades

- Commissioning during 13 TeV pp run
- All “feet” trigger towers finally inserted in the ATLAS trigger at the end of 2015.
- Timing synchronization and tuning of the trigger coincidences that define the p_T thresholds completed in 2016

Elevator chambers:

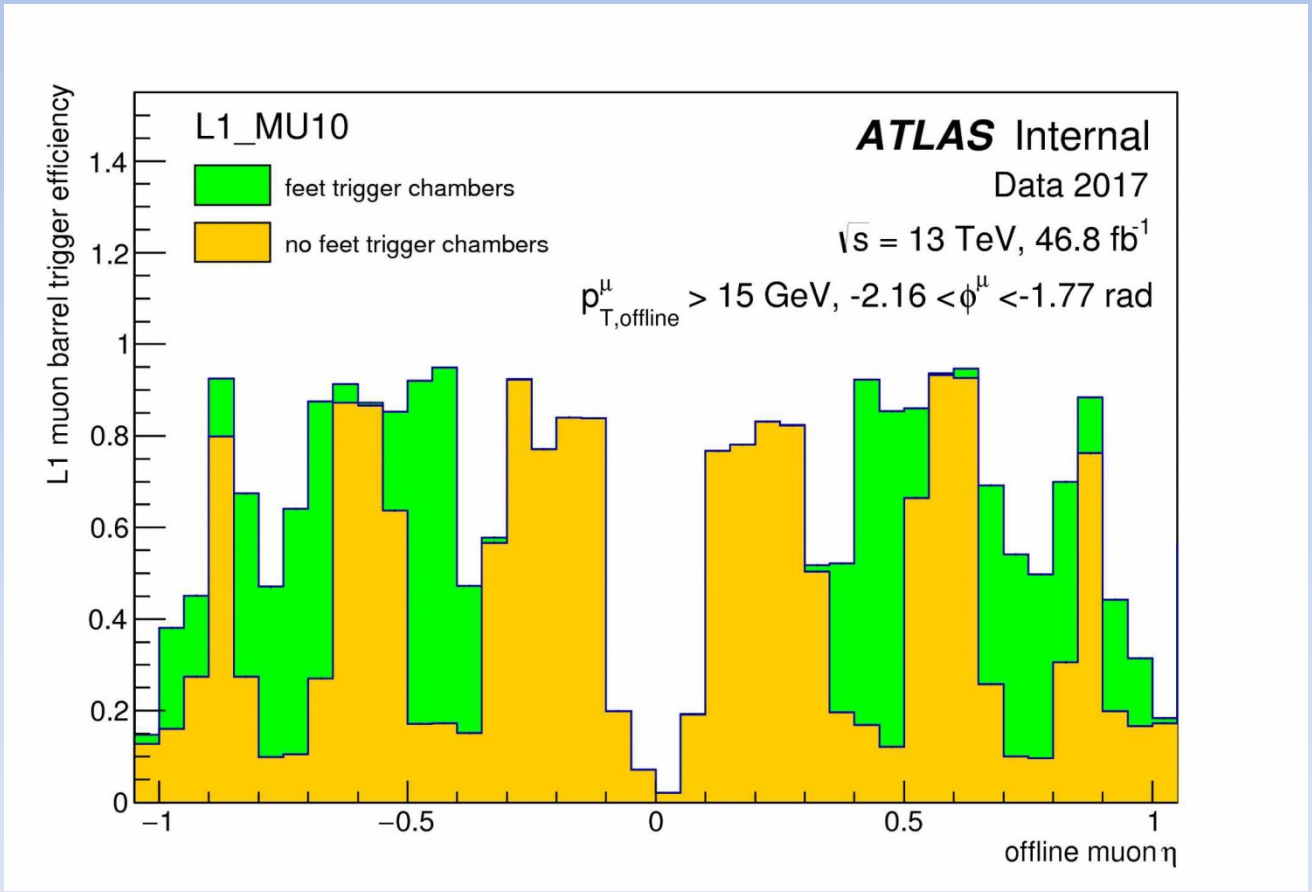
- 2 BME chambers were replaced in 2016-17 shutdown.
  BOE are working



Fraction of the RPC high pT trigger hits associated correctly to the collision Bunch Crossing for each RPC trigger tower

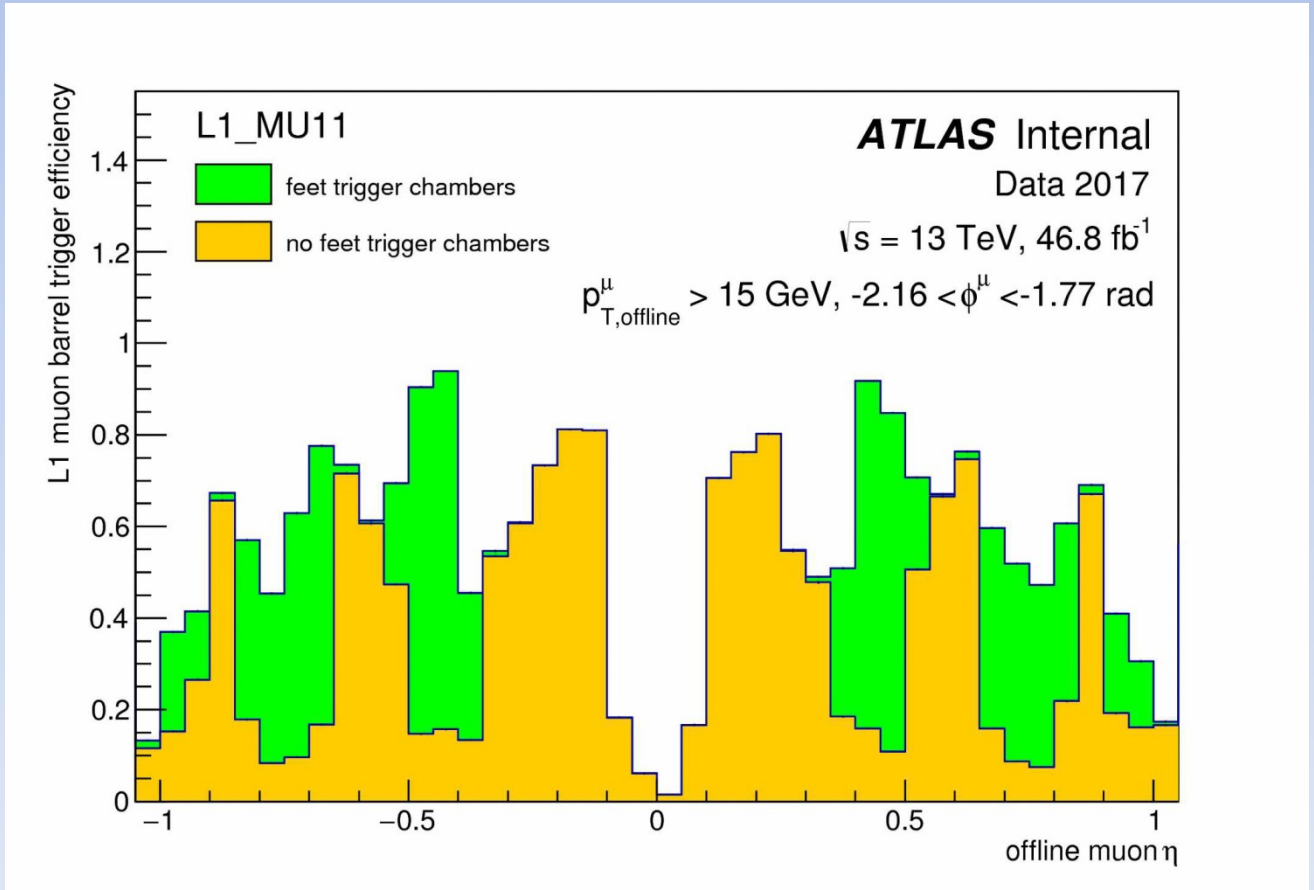
Trigger Upgrade Results

L1 MU10 Low-pt barrel muon trigger efficiency as a function of muon η in 2017 for Sector 12, with and without the “feet trigger chambers”



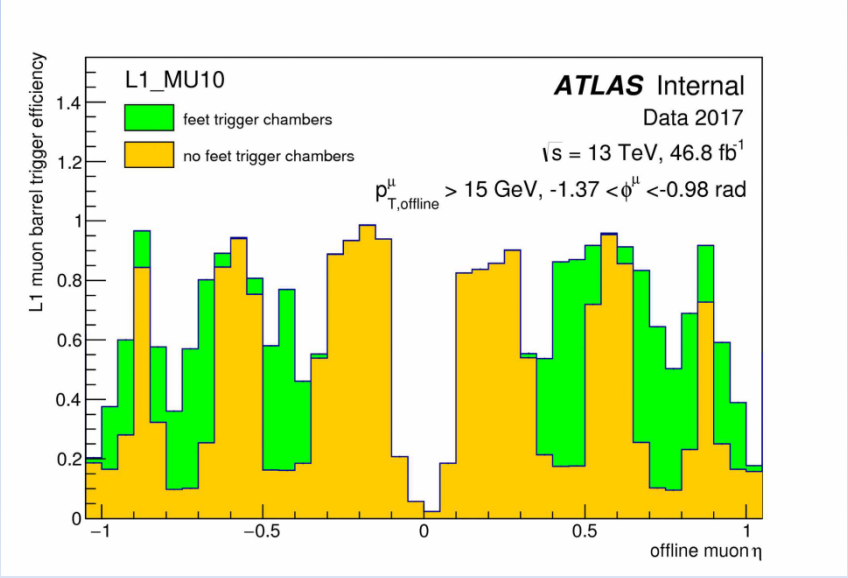
Trigger Upgrade Results

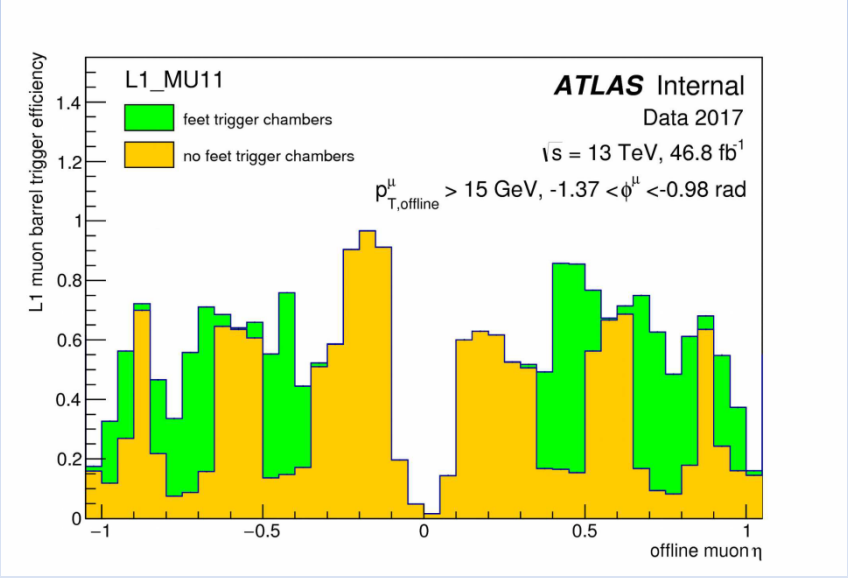
L1 MU11 High-pt barrel muon trigger efficiency as a function of muon η in 2017 for Sector 12, with and without the “feet trigger chambers”



Trigger Upgrade Results

L1 MU10 and 11 barrel muon trigger efficiency as a function of muon η in 2017 for Sector 14, with and without the “feet trigger chambers”

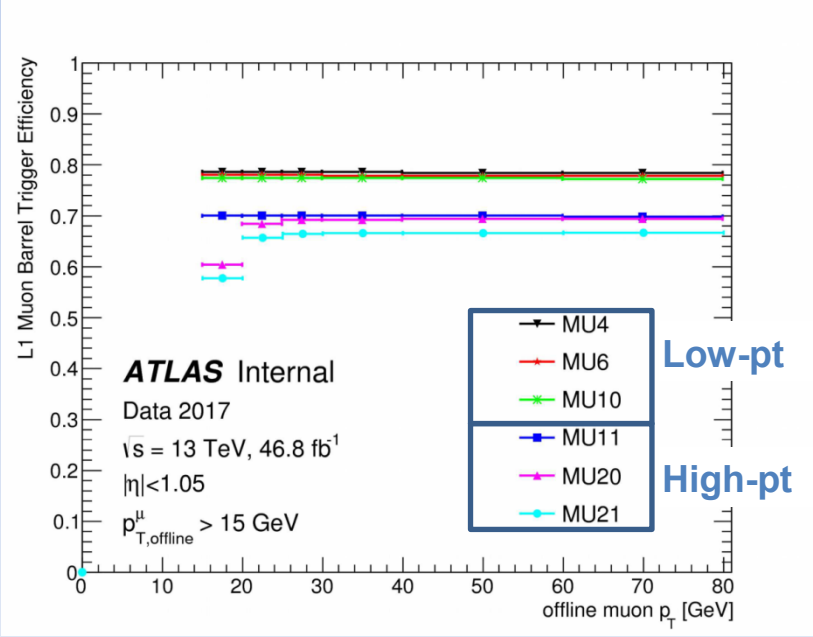




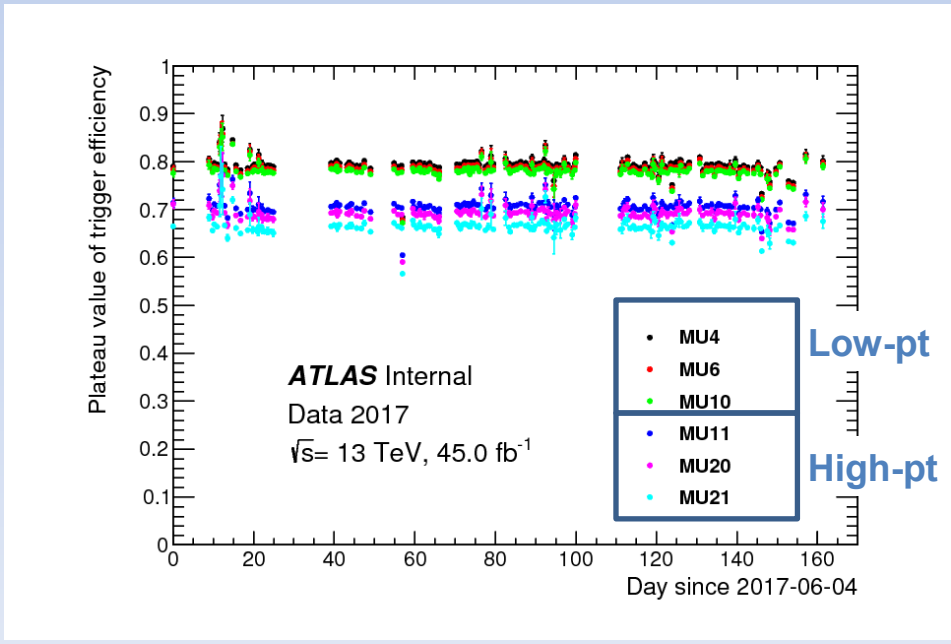
Trigger Efficiency in 2017

High-pt trigger efficiency ~ **70%**
Low-pt trigger efficiency ~ **80%**

L1 Barrel muon trigger efficiency with 2017 data



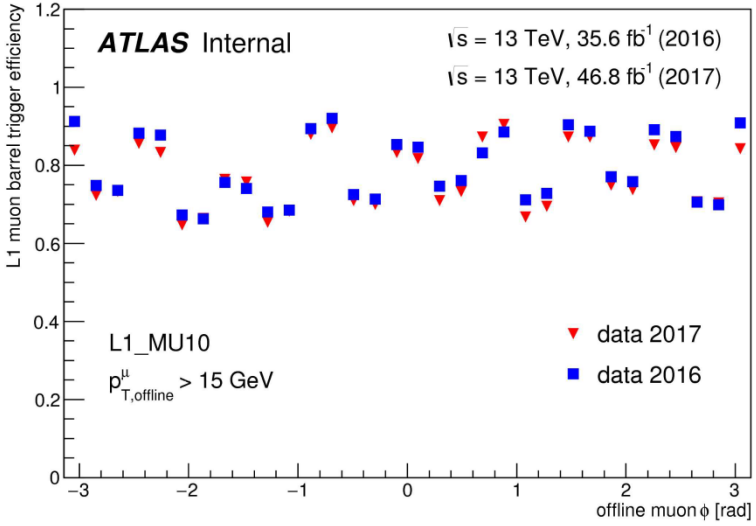
Plateau value of the L1 Barrel muon trigger efficiency for many runs in 2017 dataset



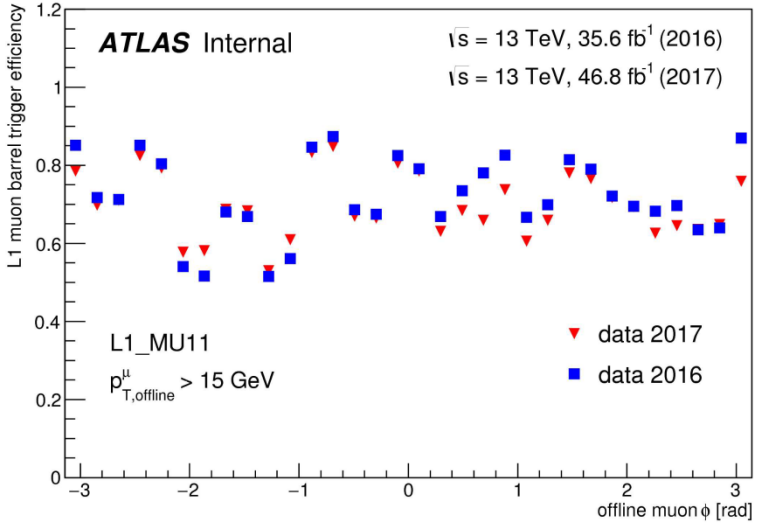
Trigger Efficiency in 2017

L1 Barrel muon trigger efficiency as a function of the azimuthal coordinate ϕ
with 2016 and 2017 data
for the trigger threshold MU10 and MU11

Low-pt



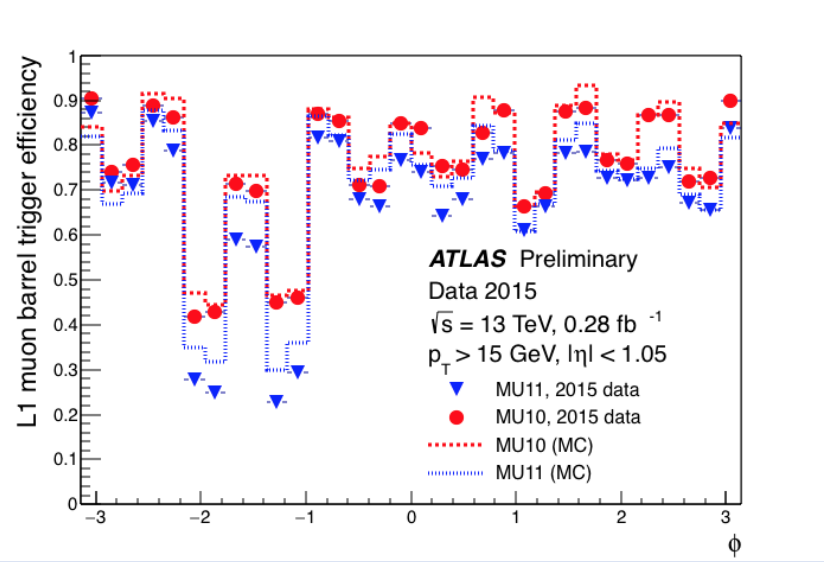
High-pt



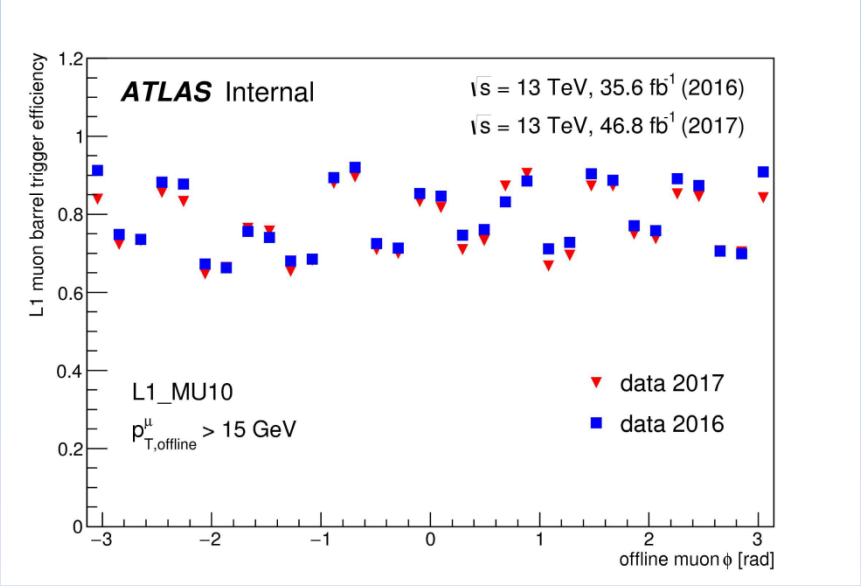
Trigger Efficiency

L1 Barrel muon trigger efficiency as a function of the azimuthal coordinate ϕ for the trigger threshold MU10 and MU11

2015



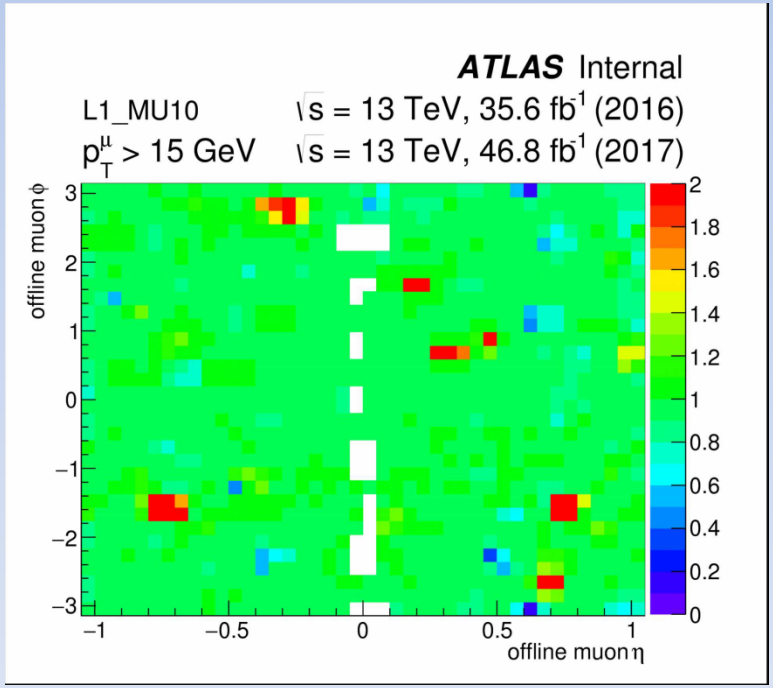
2016 - 2017



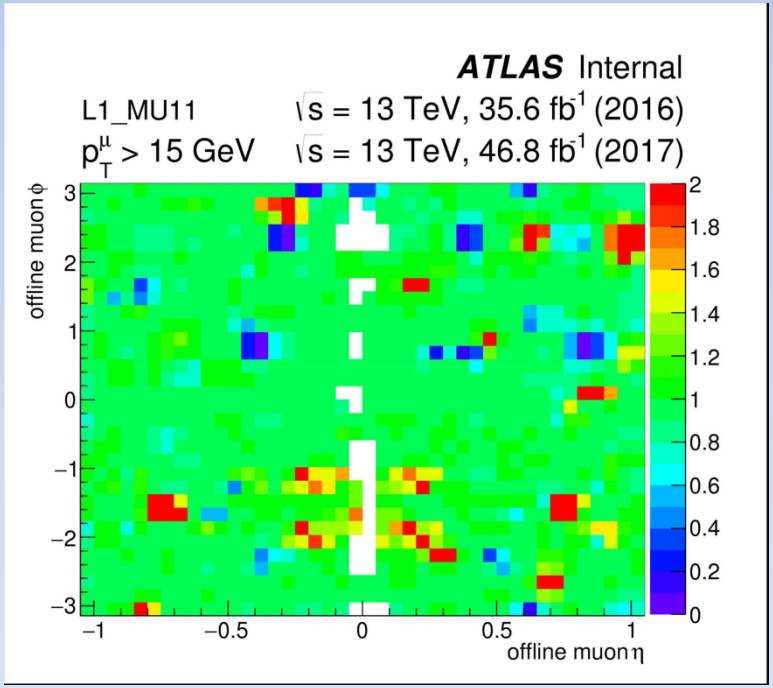
Trigger Efficiency

η and φ map of the ratio between the L1 Barrel muon trigger efficiency η ϕ in 2017 and 2016

MU10

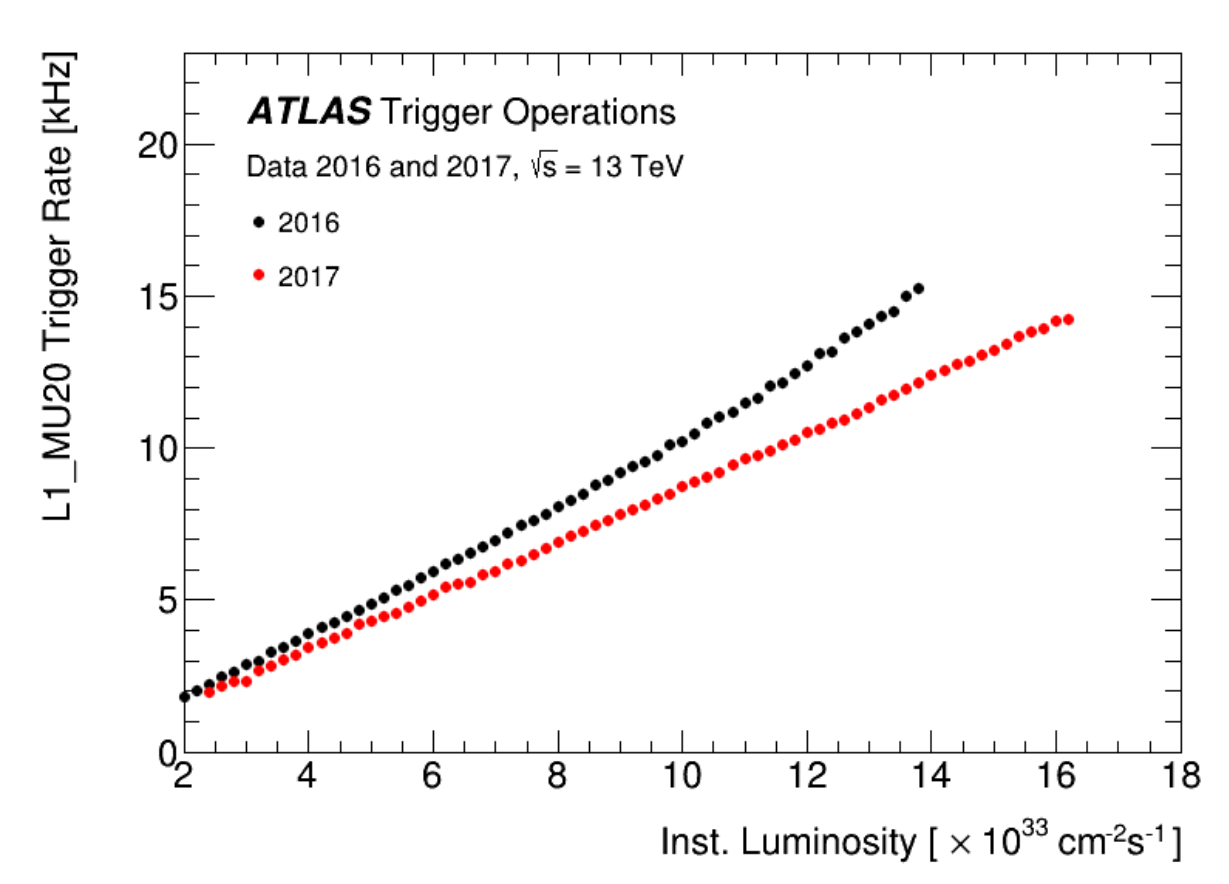


MU11



BO Issues

Trigger Rate



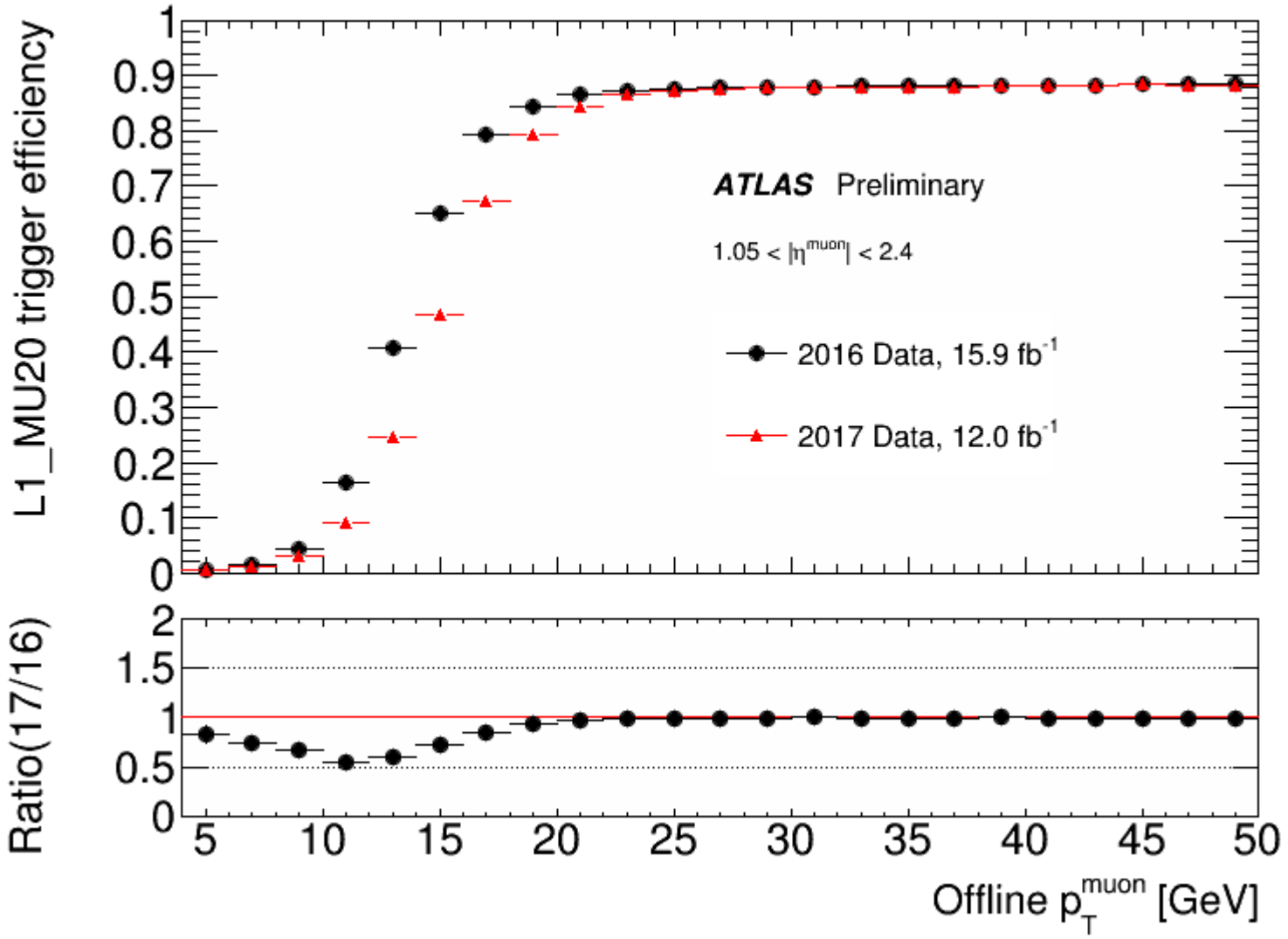
Summary

- ATLAS RPC system operated with high reliability Run-2
  providing the “barrel” level-1 muon trigger for ATLAS

- Detector performances (efficiency, cluster size) measured with different methods
  stable and close to nominal / run-1 results

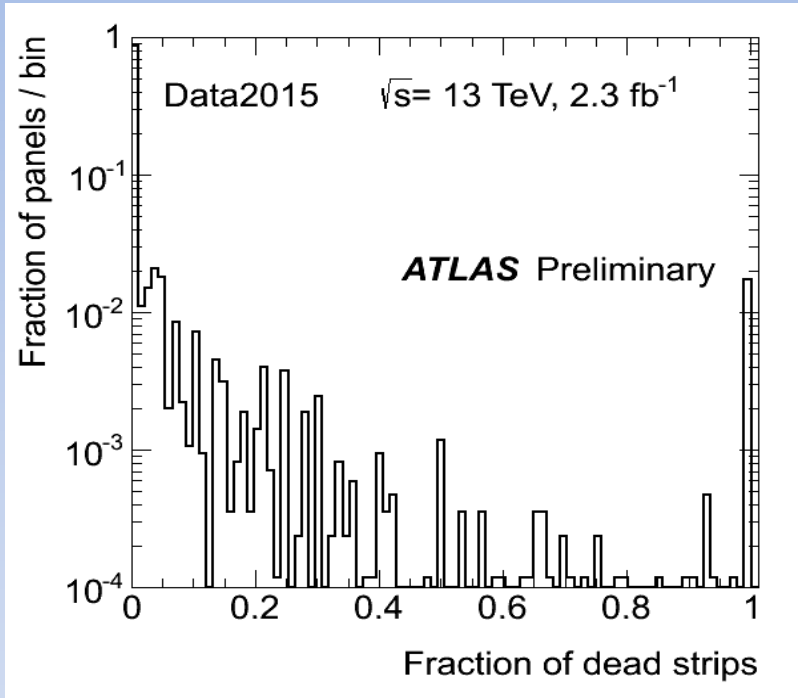
- Trigger performances:
  very good rate, efficiency slightly lower than in run-1, mainly due to chambers disconnected due to gas leak.
  ongoing repair campaign to (partly) fix the remaining leaks.

- Minor upgrades (feet / elevators):
  Commissioning during 2015,
  Feet chambers finally included in the trigger in the last (5 TeV) runs
  Feet and BOE elevator chambers part of the trigger from 2016
  BME elevator chambers replaced at the end of 2016


L1_MU20 trigger efficiency
ATLAS Preliminary
1.05 < |η^muon| < 2.4
2016 Data, 15.9 fb^-1
2017 Data, 12.0 fb^-1
Ratio(17/16)
Offline p_T^muon [GeV]

Dead Channels

- Total fraction of dead channels in Run-2 approximately 3.5%
- Gas volumes disconnected from HV :
  - approx. 2.5%
  - mostly because of gas leaks
  - partly from sparking chambers being recovered with Ar flux
- Masked noisy strips (mostly due to grounding problems)
- Problems with trigger/readout electronics ~0.25%



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Detector Efficiency

- Efficiency measured for each strip panel:
  "Detector" (or panel) efficiency :
  probability to see >=1 hit in a given strip panel

  "Gap" efficiency :
  probability to see >=1 hit in at least 1 of the 2 strip panels (η or φ) attached to a gas volume

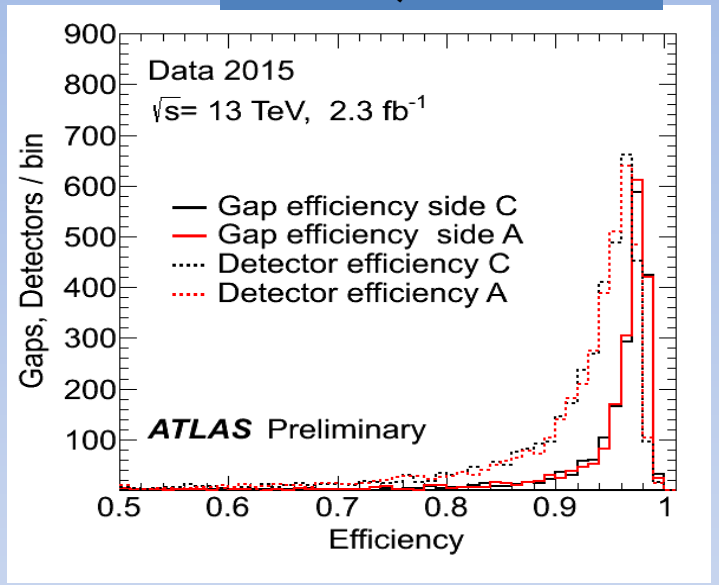
- Gap efficiency peaks at ~98%
  (~1% inefficiency from spacers)

- Detector efficiency has lower tails due to **dead strips** and channels with **"harder" thresholds** to prevent noise

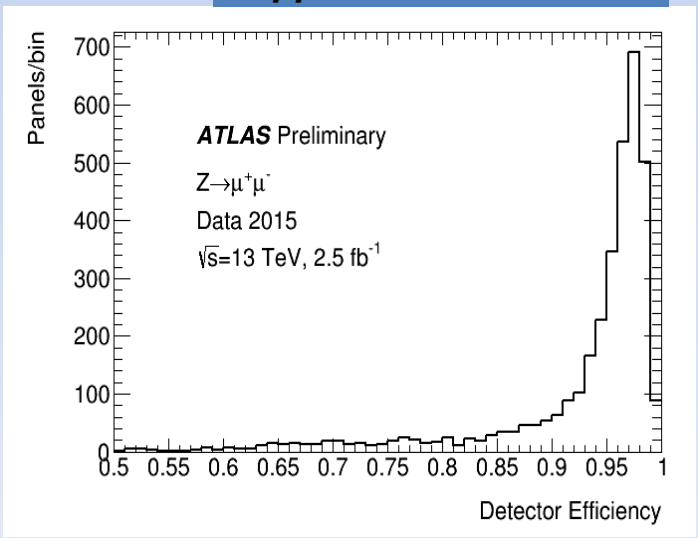
- No visible deterioration w.r.t. Run-1

- **Offline Data Quality**
  RPC standalone tracks and Z->μμ agree at ~1% level.

Offline DQ measurement

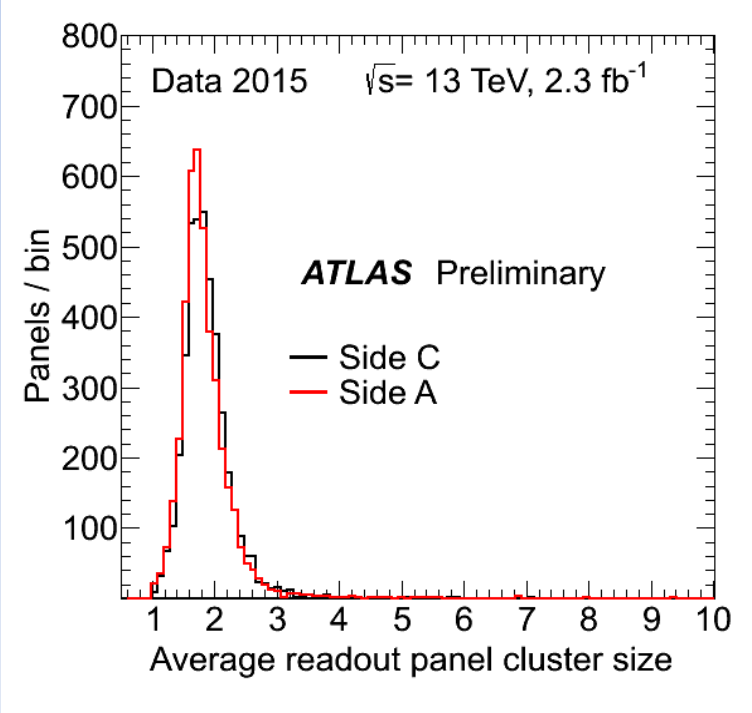


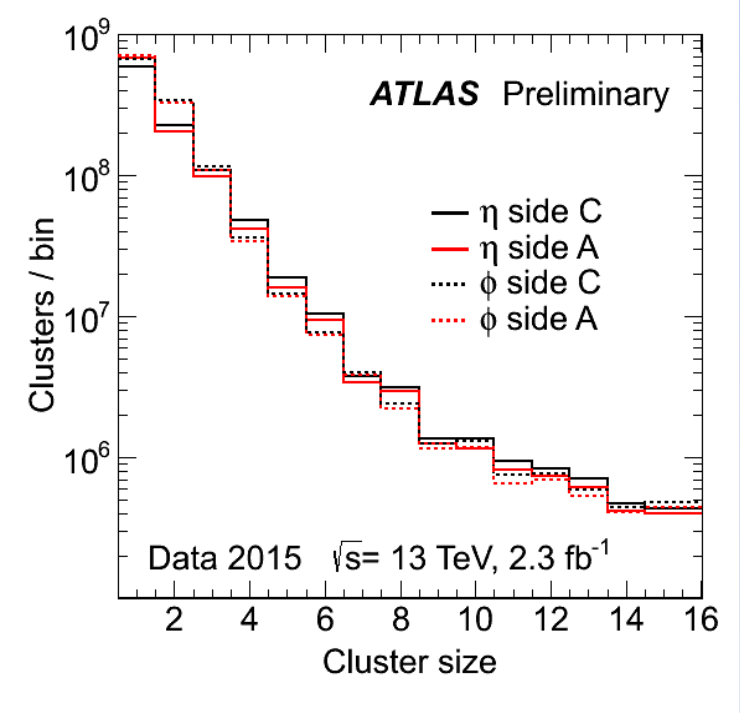
Z->μμ T&P measurement



Cluster Size

- Several quantities are monitored by Offline Data-Quality
- Example : cluster size
- Average cluster size 1.64 (for cluster with ≤ 8 strips)
- Consistent with RUN-1





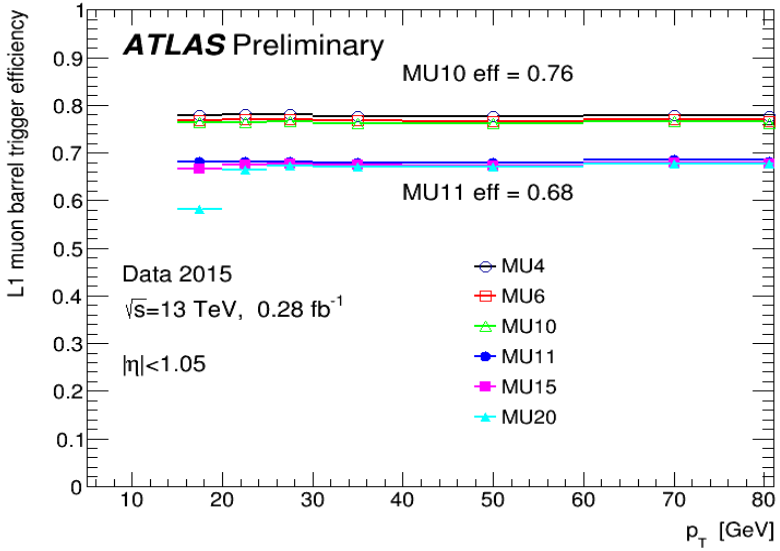
Trigger Performance

- Efficiency of Barrel Trigger for reconstructd muons with |η|<1.05

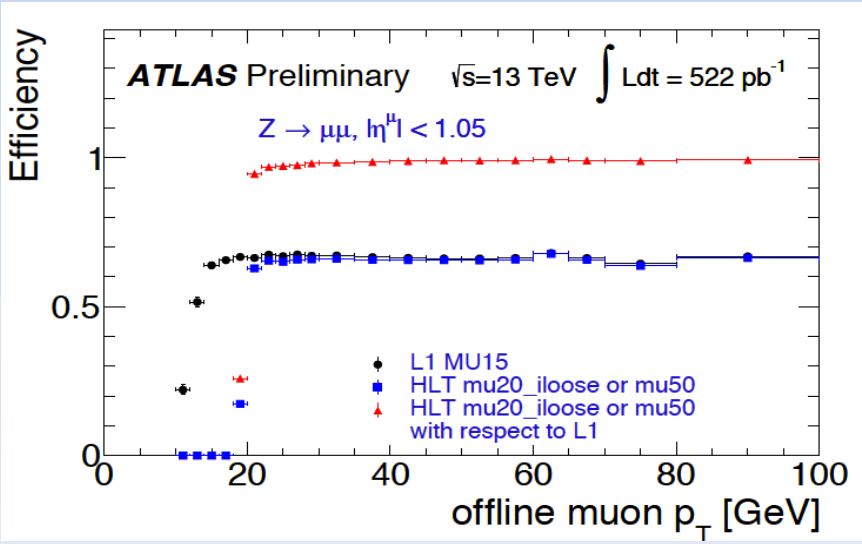
Acceptance x efficiency	2015	2012
Low-p_T (2 stations)	76%	78%
High-p_T (3 stations)	68%	72%

- Inefficiency mostly related to dead channels or inefficient RPC detectors (next page)
- Agreement between run-by-run measurements based on “orthogonal triggers” and Z->μμ “tag and probe” analysis
- Lowest p_T threshold for single muon triggers:
  MU15 (full efficiency for p_T >15 GeV)
  Rate (barrel) : 600 Hz @ L=3x10^{33} cm^{-2}s^{-1}
  small fraction of ATLAS L1 rate (100 kHz)

Single run (L1 Barrel calibration)



Z->μμ tag and probe



Trigger Efficiency and Simulation

- Trigger efficiency x acceptance in η, φ (larger structures are acceptance holes)

- Special MC simulation with measured RPC detector efficiencies.

- Reasonable data-MC agreement
  Residual differences ascribed to trigger electronics (1%) and to RPC efficiency in MC set to nominal value in regions were efficiency measurements were not available.