Proposal of Upgrade of the ATLAS muon trigger in the barrel-endcap transition region with RPC

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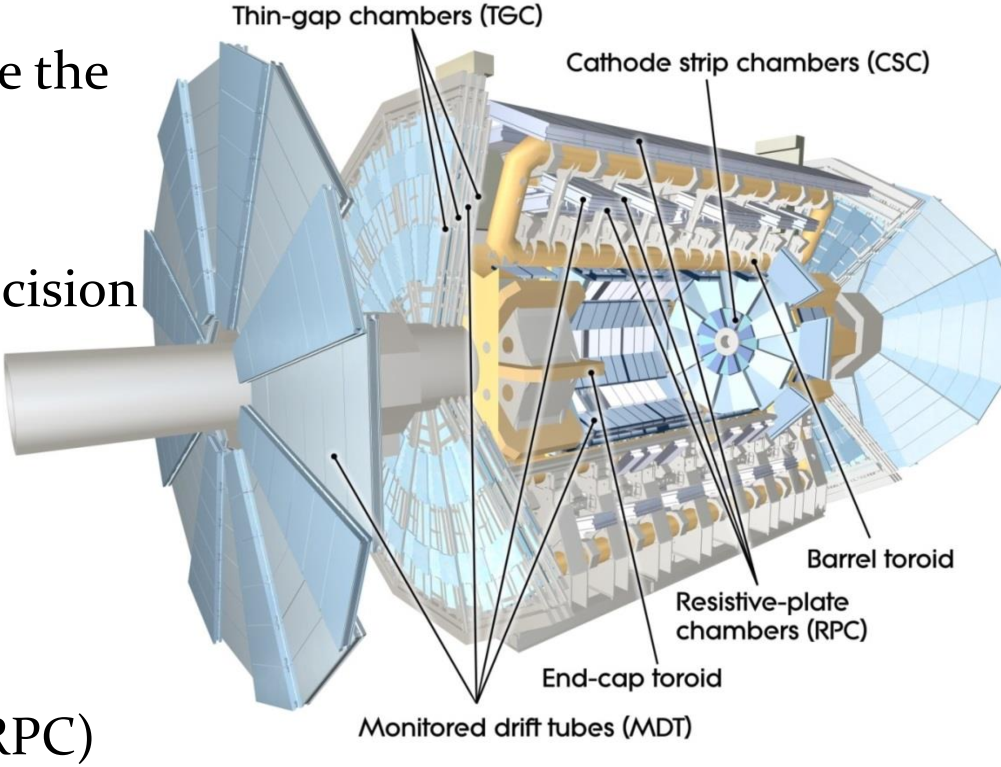
Outline

- ATLAS Muon Trigger
- Performance studies
- Mechanical design
- Conclusions

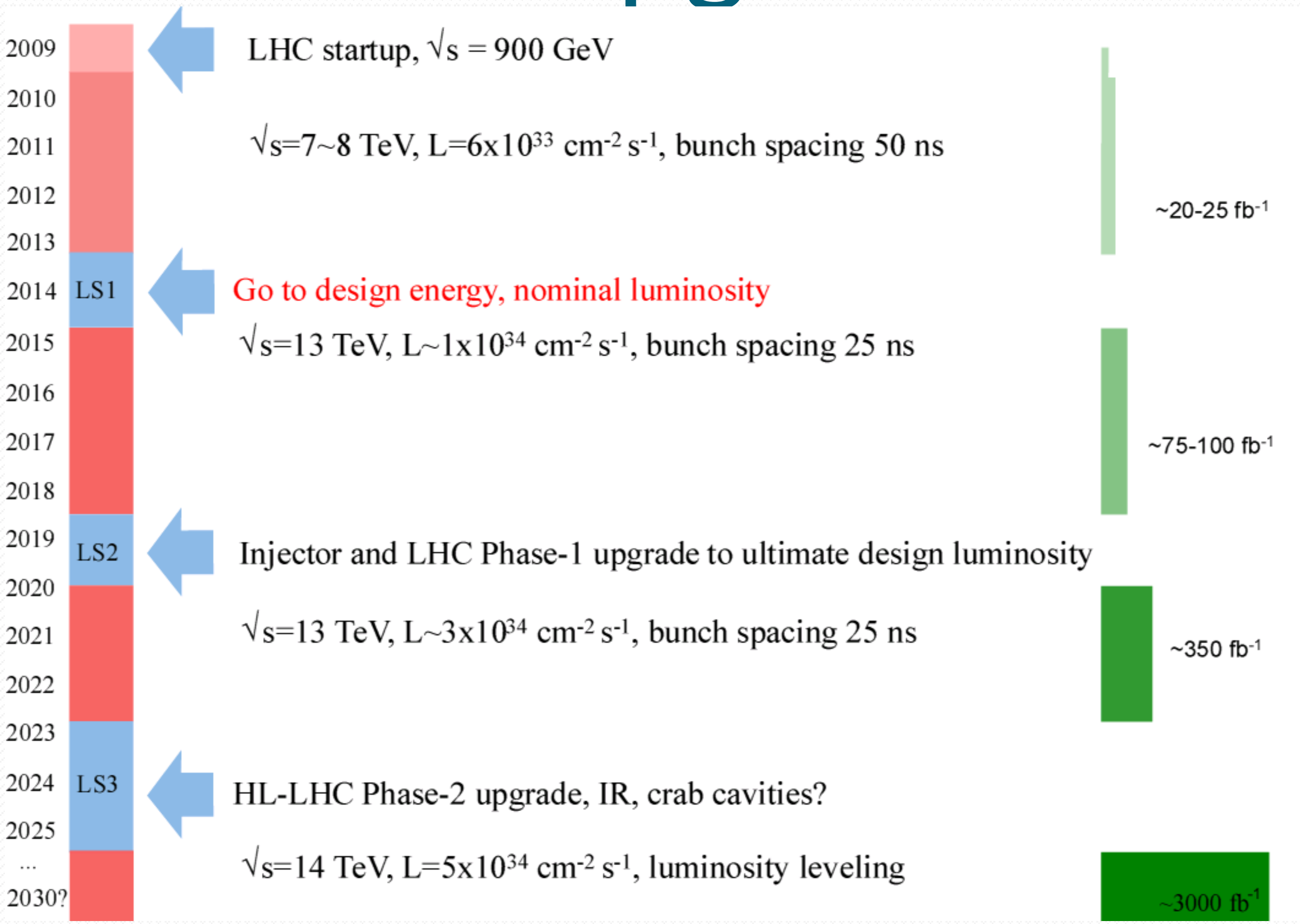
The ATLAS Muon Spectrometer

- Toroidal magnetic system to measure the transverse momentum
- Tracking made with two types of precision chambers:
  - Monitored Drift Tubes(MDT)
  - Cathode Strip Chambers (CSC)
- Two types of trigger chambers:
  - Barrel: Resistive Plate Chambers (RPC)
  - EndCap: Thin Gap Chambers (TGC)



- ATLAS trigger system is based on one hardware based level (L1) and a software based one (HLT). The Level 1 Muon Trigger is based on RPC and TGC hits, linked to significant activity of muons, which define Regions of Interest(ROI).

LHC Phase-1 Upgrades



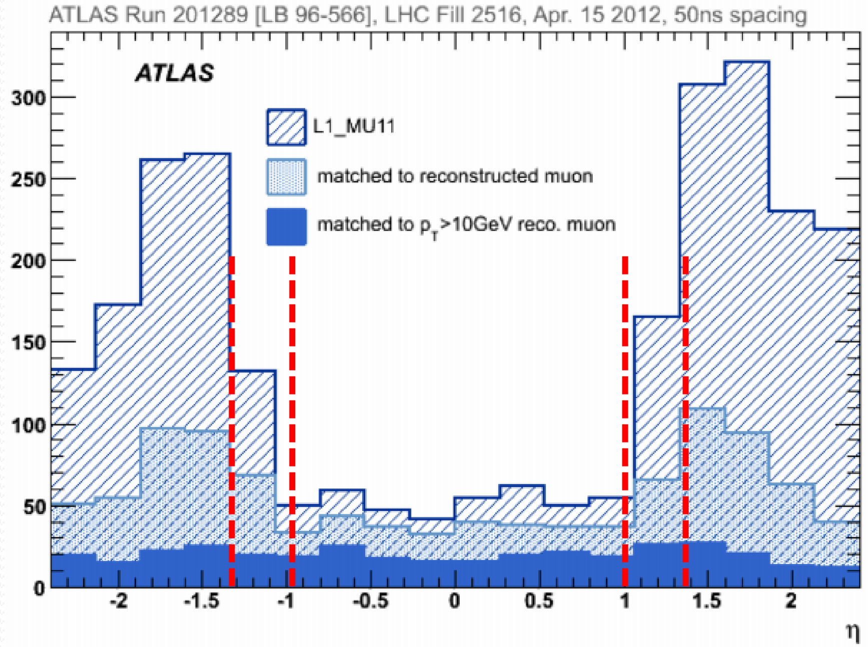
Two upgrades in the Atlas Muon Spectrometer for Phase-1:

- Tracking and Trigger upgrade in the $|\eta| > 1.3$ region with the New Small Wheel (NSW)
- **PROPOSAL:** Upgrade of the ATLAS muon trigger in the barrel-endcap transition region with RPC

High Rate in Transition Region

- During Phase-1, at L= 3x 10^{34} $cm^{-2}s^{-1}$, 25 ns, 13 TeV, the total rate of level 1 single muon trigger (pt>20 GeV) will rise up to 57.6 kHz, while ATLAS can afford only 25 kHz out of a total L1 bandwidth of 100 kHz.

η distribution of ROIs



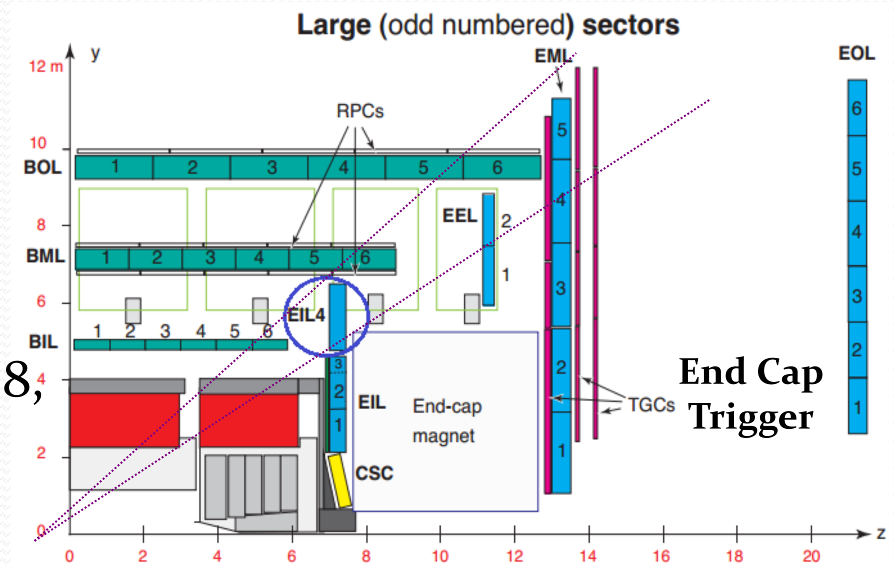
- The trigger request in the NSW will reduce the rate in |η| > 1.3 region

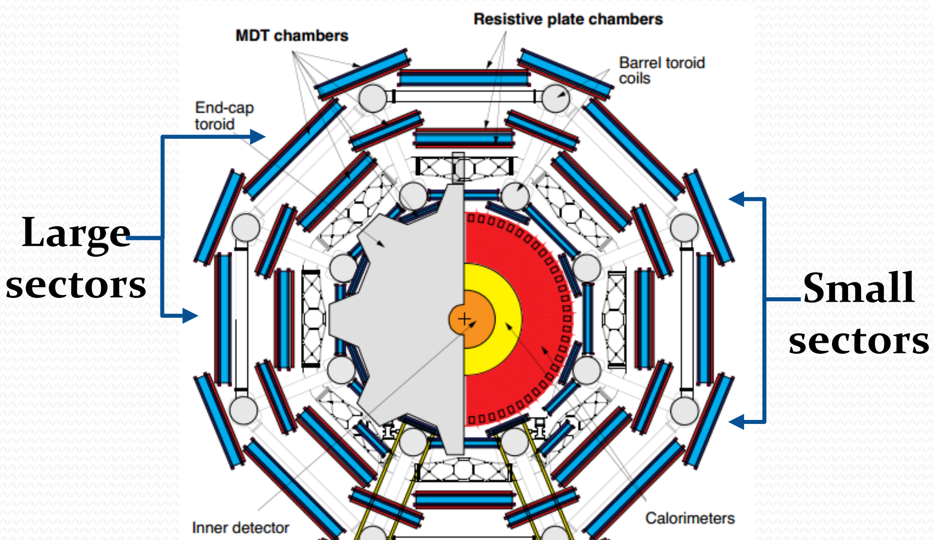
- High fake trigger rate in 1.0 < |η| < 1.3 region. The rate coming from transition region is 21.9%, which corresponds to 12.6 kHz

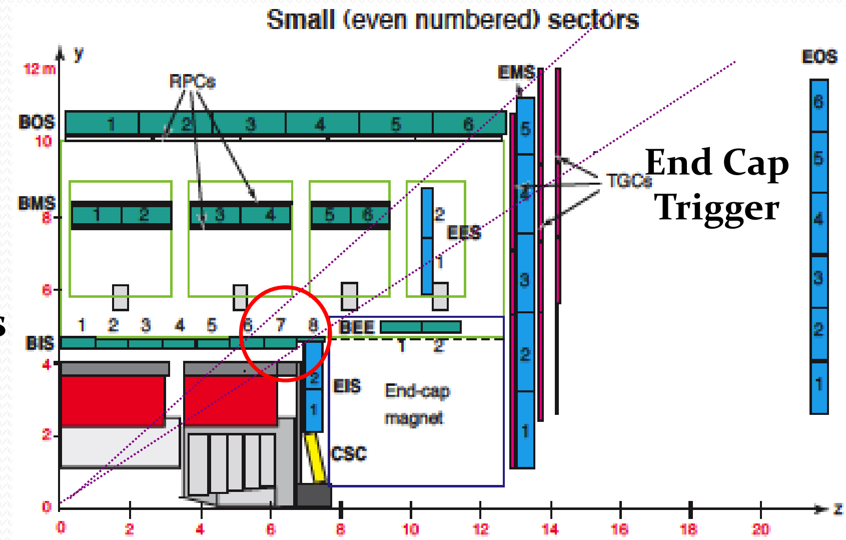
- Studies found that the main source of fake triggers are low-pt protons generated in toroids and shieldings.

Proposal to reduce fake trigger rate

- The rate can be reduced requiring a coincidence between the End Cap trigger and the passage through an inner plane.
- For the large sectors the inner plane is covered by the inner TGC of End Cap.
- **PROPOSAL**: for the uncovered areas (small sectors) add RPCs triplets to BIS 7-8, the inner MDT chambers which cover transition region.







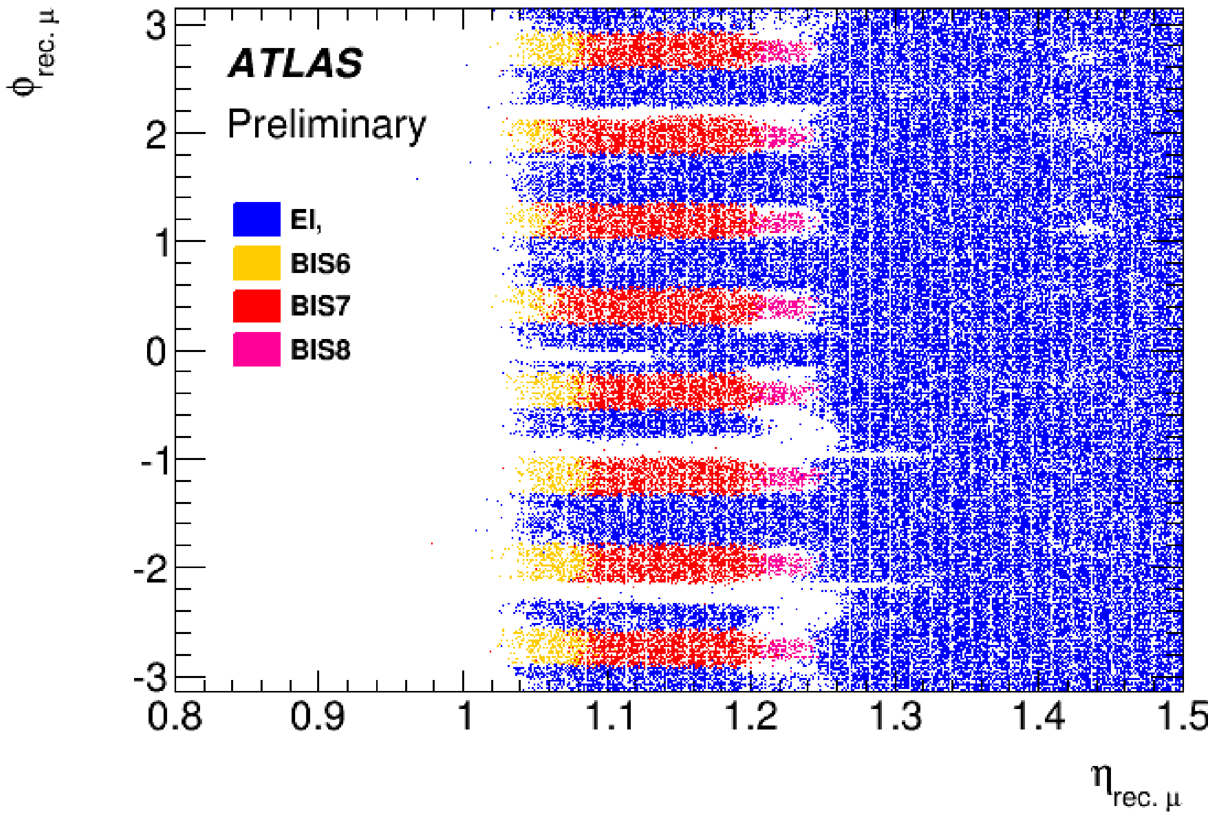
Geometrical Coverage

The picture shows the geometrical coverage in range 1< η <1.3, obtained drawing the η–ϕ coordinates of reconstructed muons from the physics muon stream, associated with EndCap trigger and segments inside the EI, BIS6, BIS7, BIS8 chambers.

BIS 6-7-8 cover small sectors

Coverage of TGC chambers in large sectors limited by holes due to rails, cryo-lines etc.

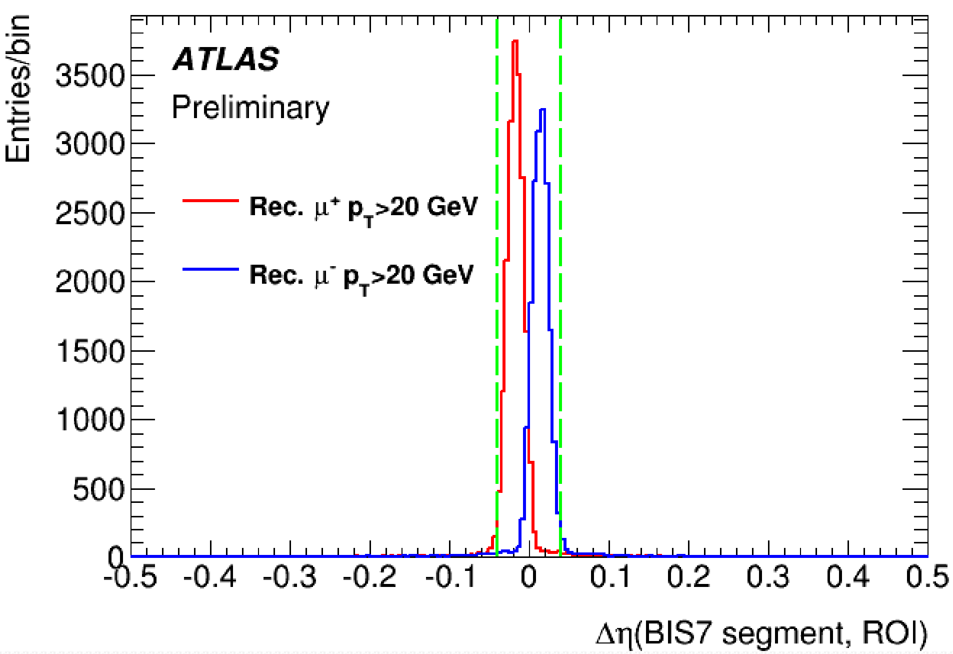
Total BIS+EI coverage (1<|η|<1.3) is 83.5%



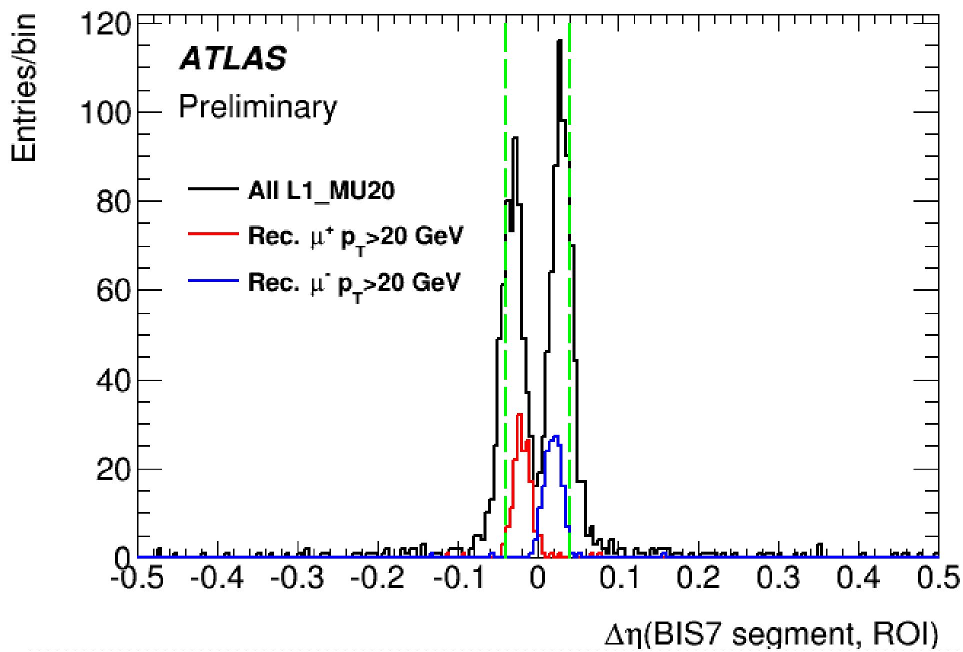
$\Delta\eta$ (seg in BIS7,ROI) distribution

Analysis made with 2012 data, requiring the End Cap Trigger and simulating the RPC hits on the proposed chambers using the Monitored Drift Tube track segments.

50ns (more statistics)



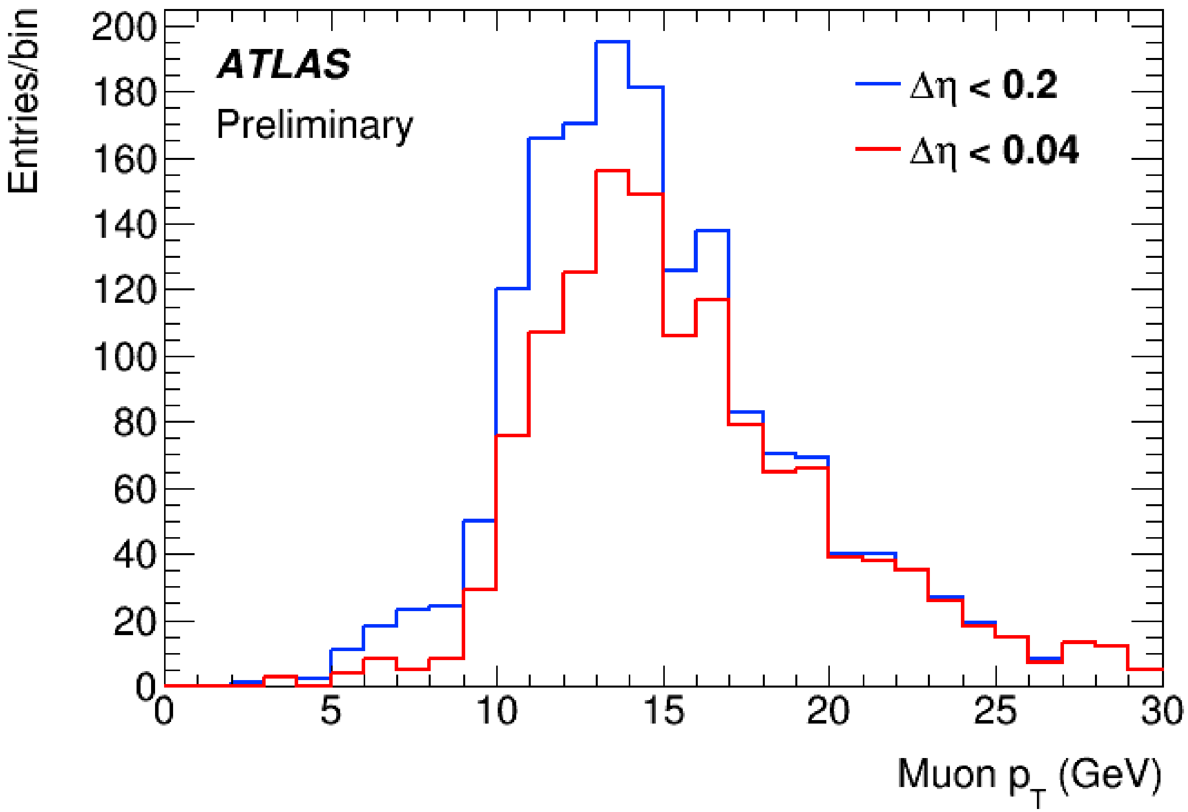
25ns (more realistic background)



Almost all the signal is concentrated in the region $|\Delta\eta| < 0.04$

A $\Delta\eta$ criterium in the algorithm permits to reject more background.

Effects of $\Delta\eta$ cut

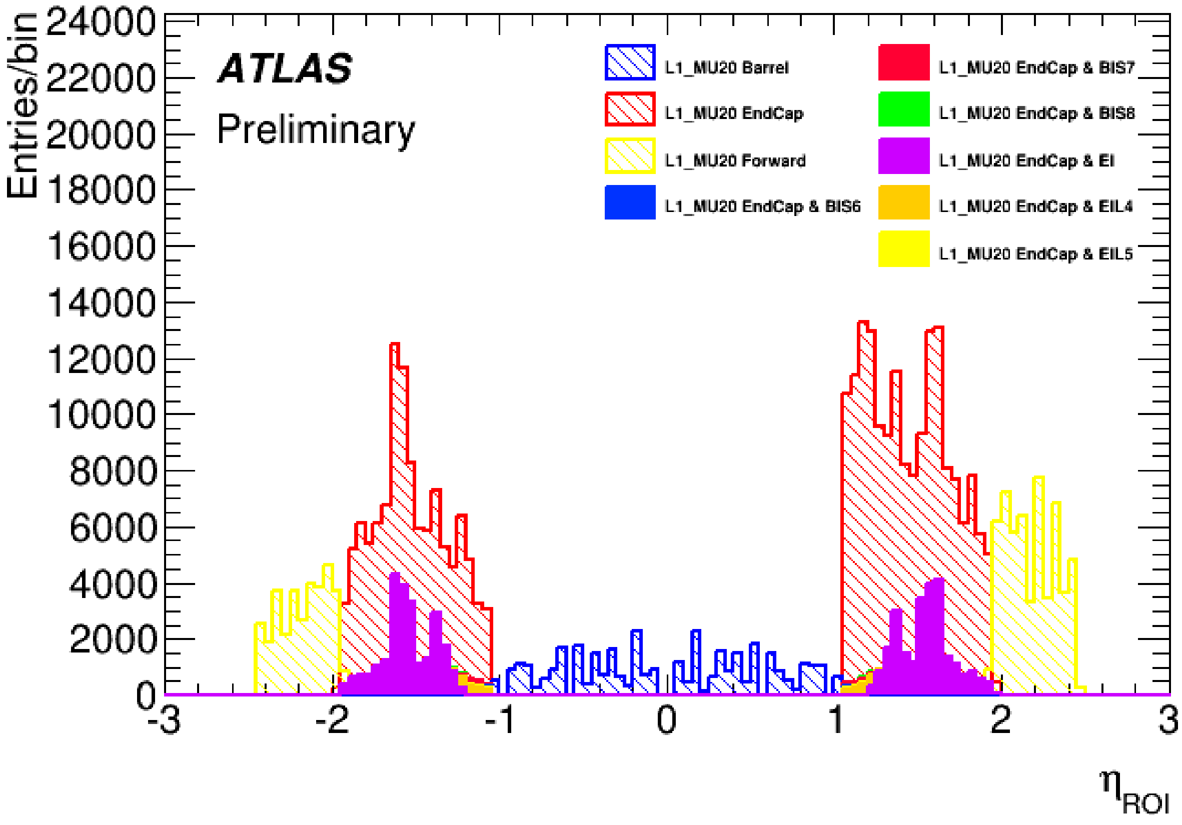


- 30% of the rate is removed with the Δη cut.
- Main reduction comes from removing low-pt muons (leading to sharper Turn-On Curve)
- Some improvement expected by applying a variable Δη cut and adding a ΔΦ cut.

- A spatial resolution better than ~4 cm is required for a cut resolution Δη~0.005 ($\frac{\Delta\eta}{\Delta z}$~$0.00013\ \mathrm{mm}^{-1}$)

η distribution of ROIs

25ns (more realistic background)



- The hatched distribution is the one obtained with the actual trigger.
- The full colored distribution shows how the distribution in End Caps changes applying the request of RPC hits in BIS6, BIS7 and BIS8.

Data Analysis Results

The values calculated in 1.05<$|\eta|$<1.24 show that the BIS+EIL requirement leads to a great reduction of rate and background, against only a small drop in efficiency.

Inner plane requirement	BIS+EIL everywhere	EIL in EIL acceptance	BIS+EIL in BIS+EIL acceptance
Efficiency	80.1%	99.8%	98.9%
Rate Fraction	6.8%	54.5%	35.2%
Background Fraction	5.5%	53.7%	34.1%

The second and third columns contain the values obtained requiring hits in EIL (or BIS) for ROIs in the EIL (or BIS) chambers acceptance, and not applying any requirement for all other ROIs.

Efficiency:

$$\frac{N_{MuonReco}(\text{EndCap \& (BIS6 || BIS7 || BIS8 || EI)})}{N_{MuonReco}(\text{EndCap})}$$

Rate Fraction:

$$\frac{N_{ROI}(\text{EndCap \& (BIS6 || BIS7 || BIS8 || EI)})}{N_{ROI}(\text{EndCap})}$$

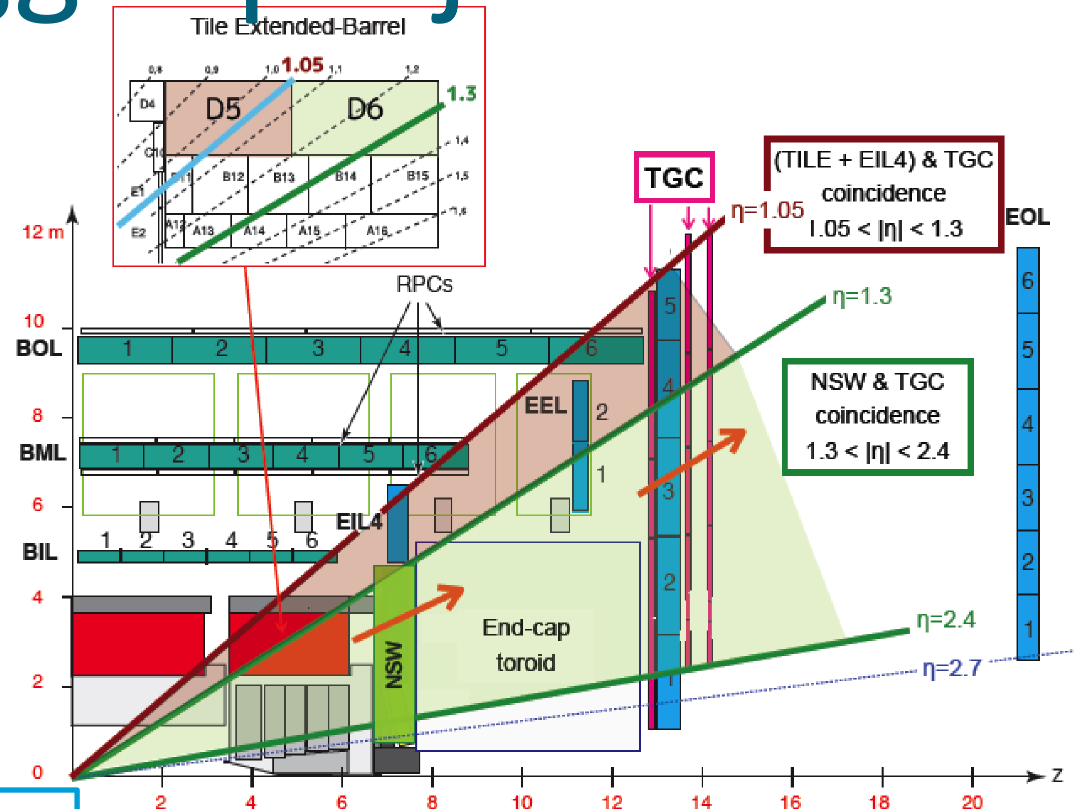
Background Fraction:

$$\frac{N_{ROI}(\text{EndCap \& (BIS6 || BIS7 || BIS8 || EI) \& !MuonReco})}{N_{ROI}(\text{EndCap})}$$

Tile +EIL trigger project

Other measures are foreseen for muon L1 rate reduction: the Tile + EIL4 project is well advanced and will be ready for 2015 (TDAQ Phase-1 TDR)

- Uses the sum of calorimeter cells' signal to detect muons
- High efficiency (~97%)
- Expected surviving rate fraction of ~18% in 1<|η|<1.3



An opportune combination of Tile, BIS and EIL chambers could lead to a high efficiency trigger (~97%) with a surviving rate fraction of almost ~10% and higher robustness against pile up effects.

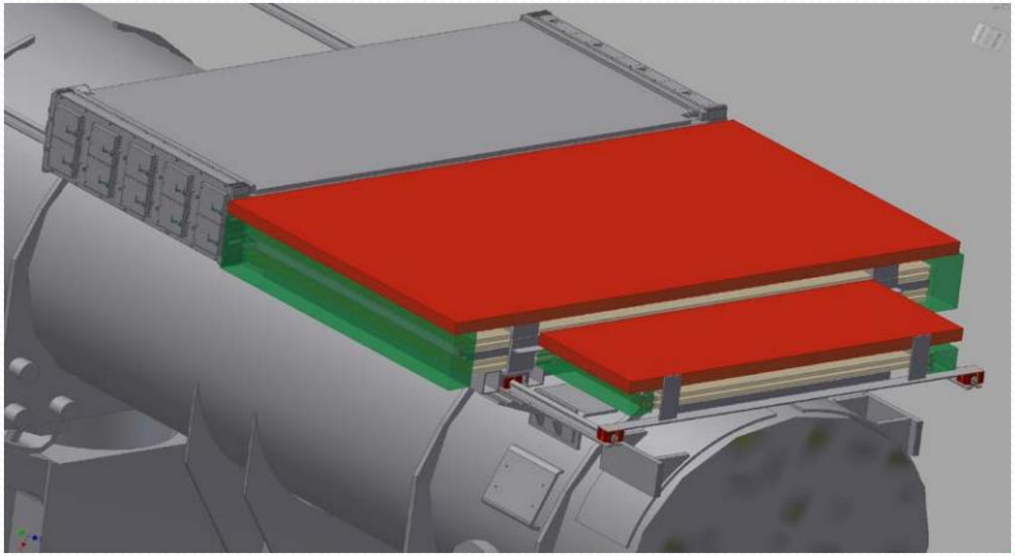
Trigger	Total Rate
Actual trigger	57 kHz
New Small Wheel	22 kHz
New Small Wheel + Tile	12 kHz
New Small Wheel + BIS 7-8	**~10 kHz**

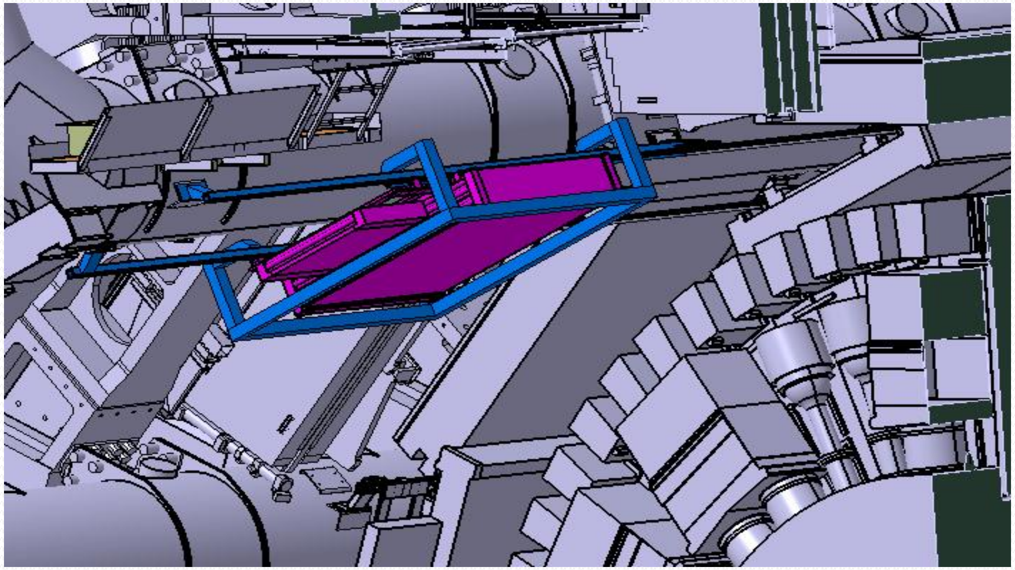
Mechanical layout

The mechanical layout is challenging, because of the limited available space.

Proposed layout:

replacement of the BIS7 and BIS8 MDTs (diameter of 30 mm) with an integrated chamber holding the sMDT (diameter of 15 mm) and RPC in the same envelope.

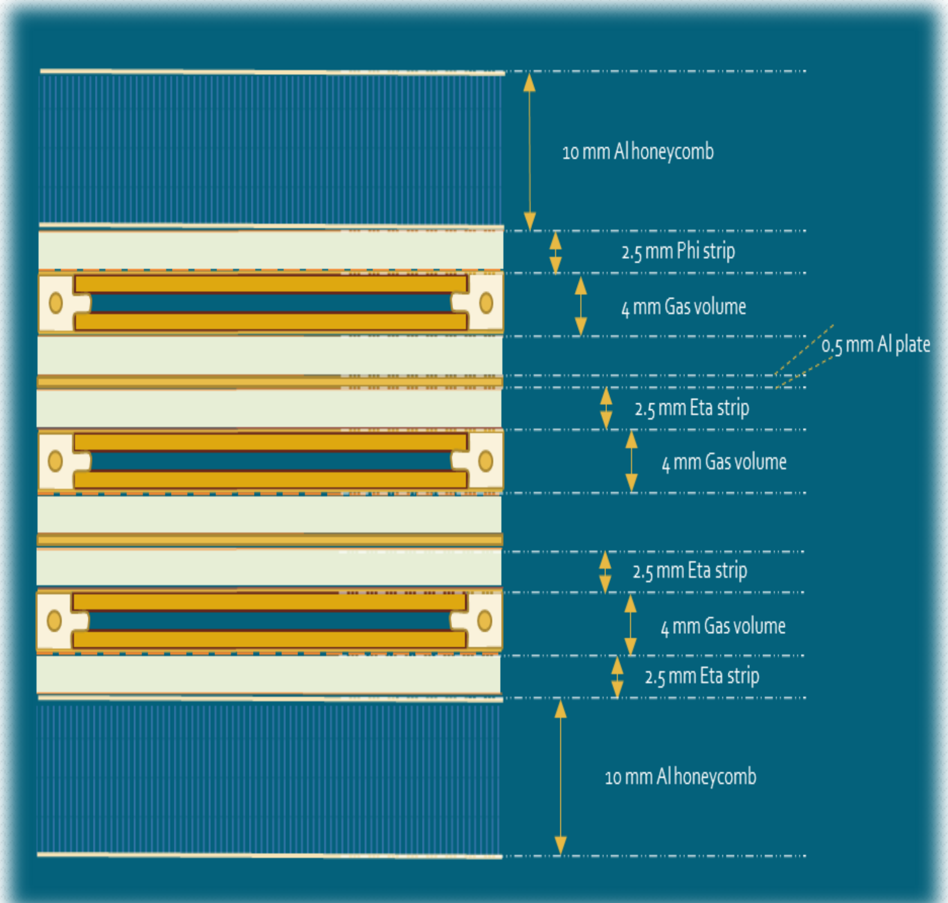




Some advantages:

- The new sMDT tubes have better rate capability, which is particularly important in this region, where the highest rate on the MDTs is expected.
- Optimal geometrical coverage.

Resistive Plate Chamber design



Basic layout: 48 mm

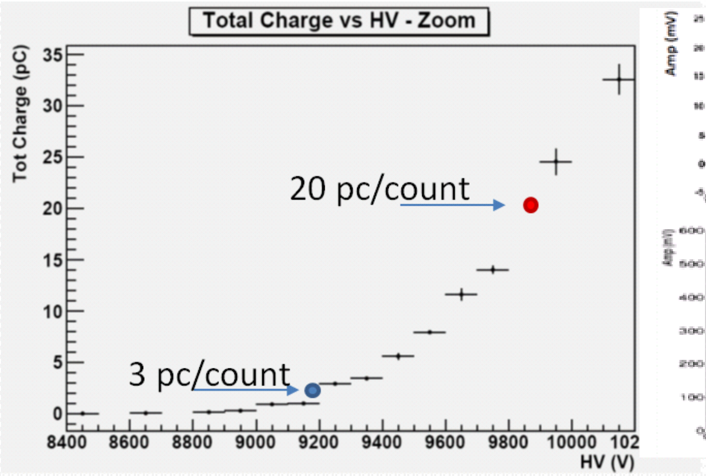
- **3-layer detector** operated with a 2/3 majority ideal configuration
  - Possible local 5-10 ns coincidence: high rejection of the noise
- **thin gas gaps** (1 mm) equipped with a new front end elettronics which will reduce the delivered charge:
  - Higher rate capability
  - Improved aging
  - Better time resolution
- **thinner electrode plates** (about 1.2 mm) with respect to the usual RPC
- **much thinner supports** of higher mechanical quality with respect to the usual RPC
- **Full-custom Front-End chip** with high S/N amplifier designed in SiGe technology
- **Strip PHI:** traditional, or meantimer with double Eta FE

Development of a new amplifier

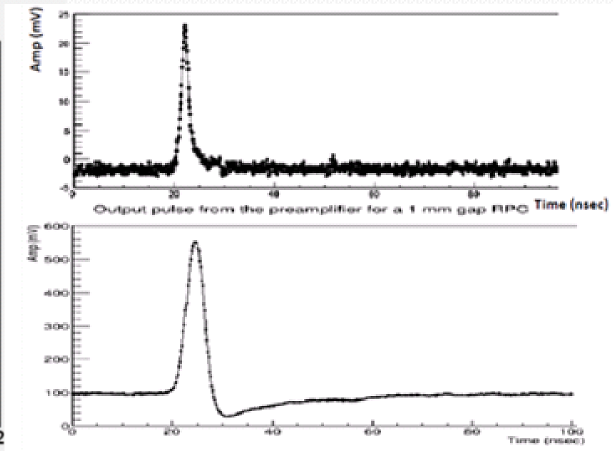
A custom charge-to-voltage amplifier in BJT technology was purposely developed for this application, in order to have extremely good S/N , radiation hardness and possibility to match low impedance transmission line.

Properties of the preamplifier

Voltage supply	3-5 Volt
Sensitivity	2-4 mV/fC
Noise (up to 20 pF input capacitance)	1500 e^- RMS
Input impedance	100-50 Ohm
B.W.	10-100 MHz
Power consumption	10 mW/ch
Rise time input	300 – 600 ps
Radiation hardness	1 Mrad, 10^{13} n cm^{-2}



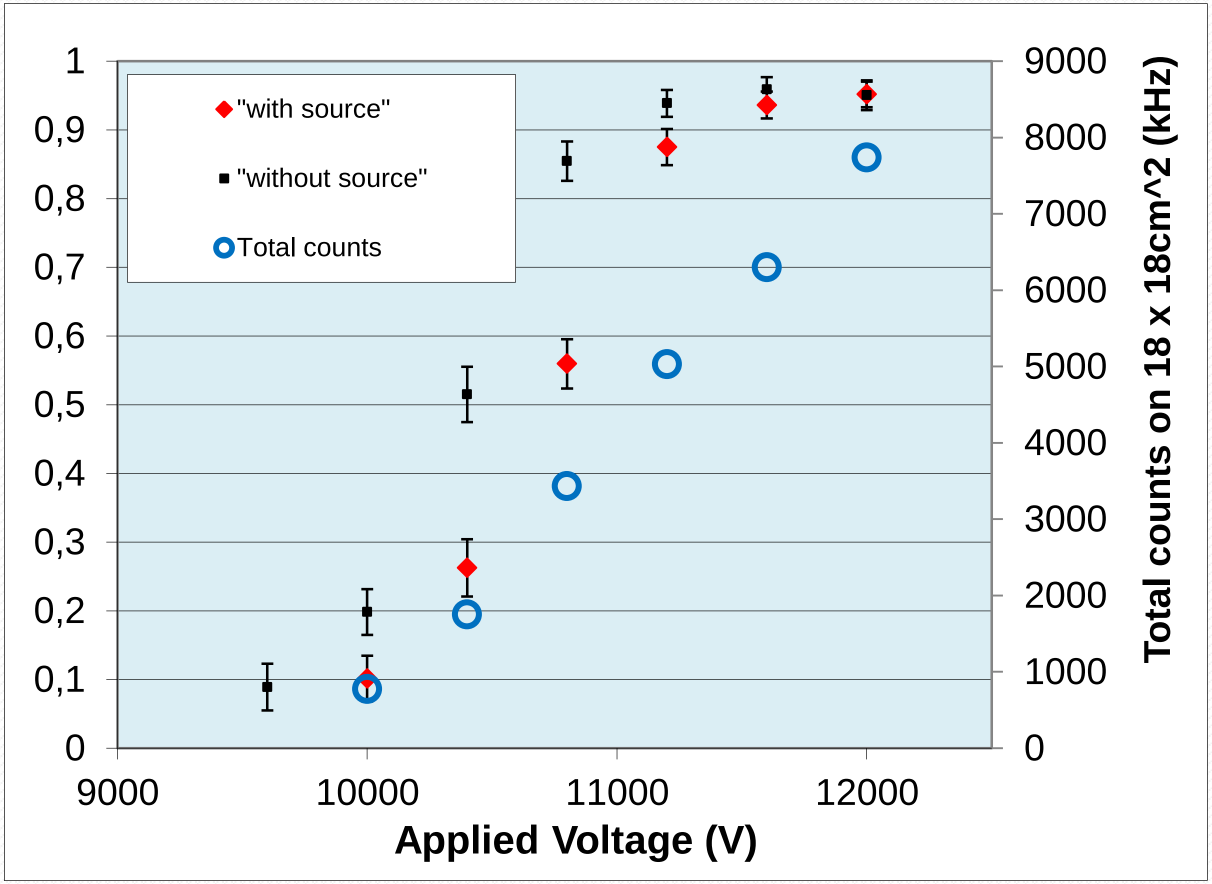
Example of Input pulse (above) and relative output pulse (below)



- Reduction on average charge per count by use of a new fast charge amplifier in Silicon BJT technology. From 20 to 3 pC/count for MIPS
- The introduction of the new preamplifier permits to operate at a lower working point thus at a lower gas gain.

Improvement of detector rate capability

Efficiency vs Applied voltage for a 1+1 mm bigap RPC



Full efficiency at a counting rate of 11 kHz/cm²

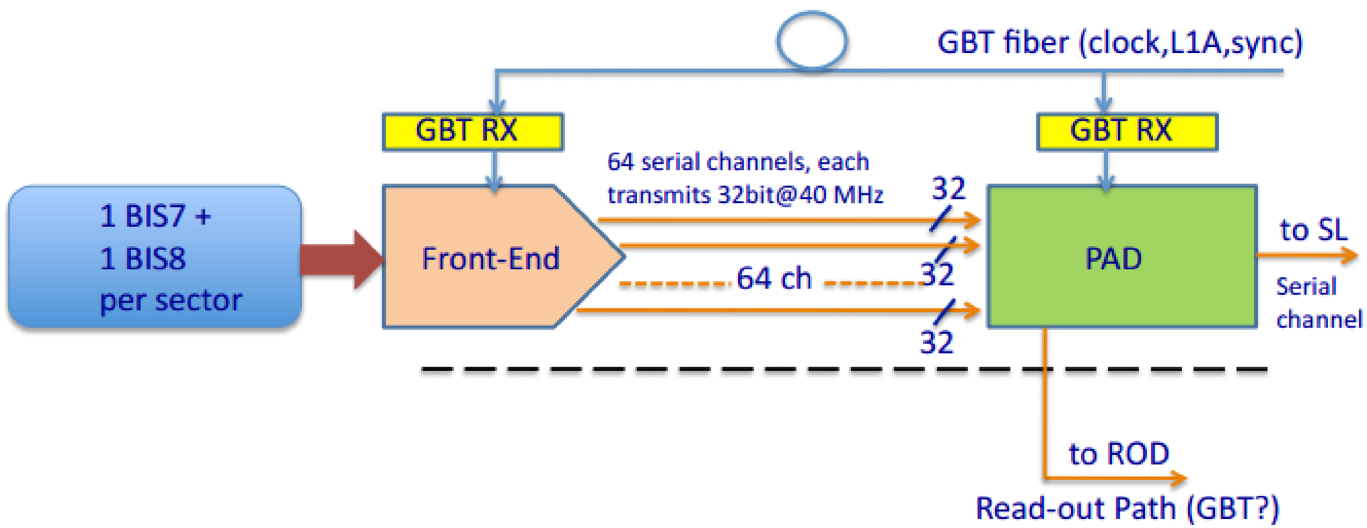
- Test carried out with a 1+1 mm bi-gap RPC operated with the new preamplifier.
- Total charge per count ~2pc/count, to be compared to the ATLAS standard gap and FE of 30 pc/count

Conclusions

- An upgrade of the ATLAS muon trigger in the barrel-endcap transition region with RPC has been proposed in order to reduce the fake trigger rate.
- Performance studies made with 2012 data show that the proposed upgrade consistently reduce the rate keeping almost all the signal. A combination between Tile, BIS7-8 and EIL chambers can lead to a really efficient and powerful L1 trigger.
- The project will use new RPC technology (2mm → 1 mm gaps) and small MDTs (30mm → 15mm diameter).

Backup

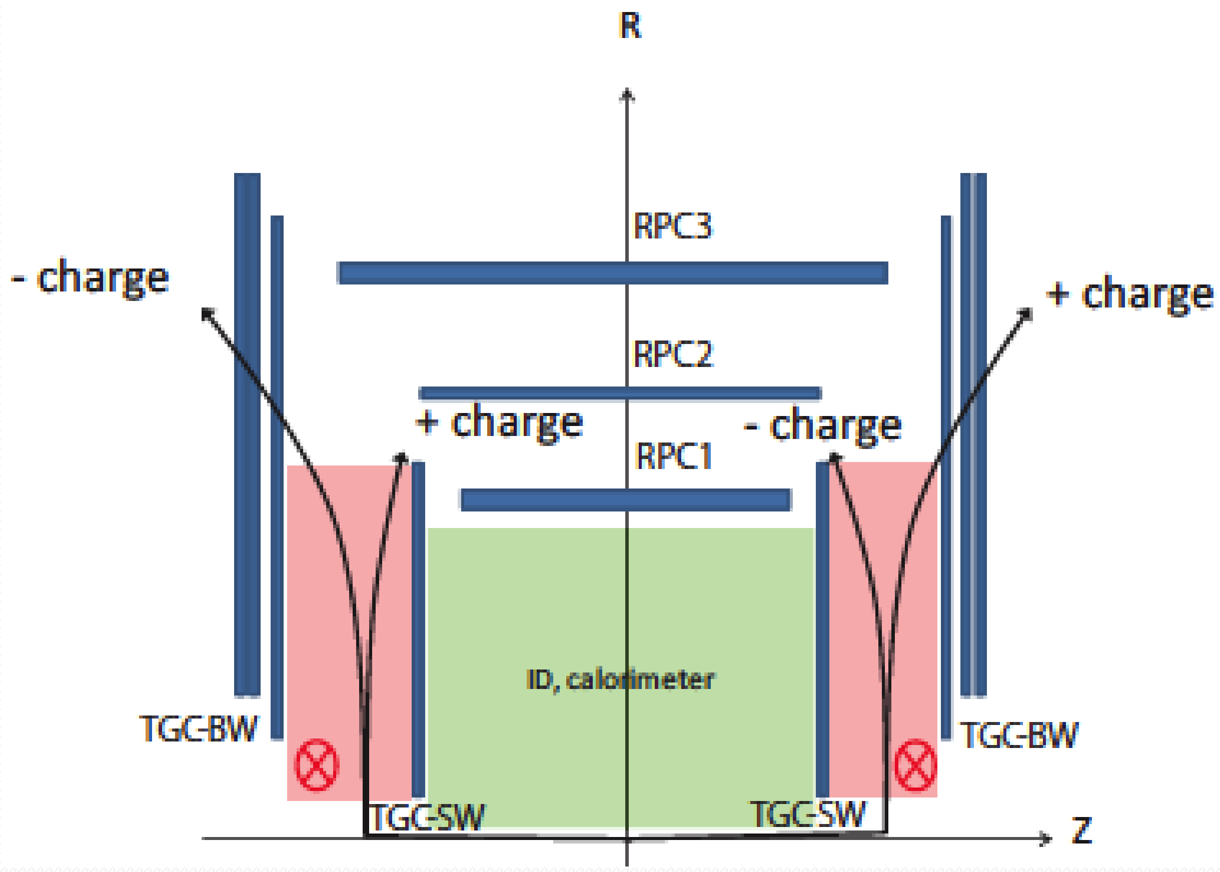
Block diagram of a possible TDAQ chain



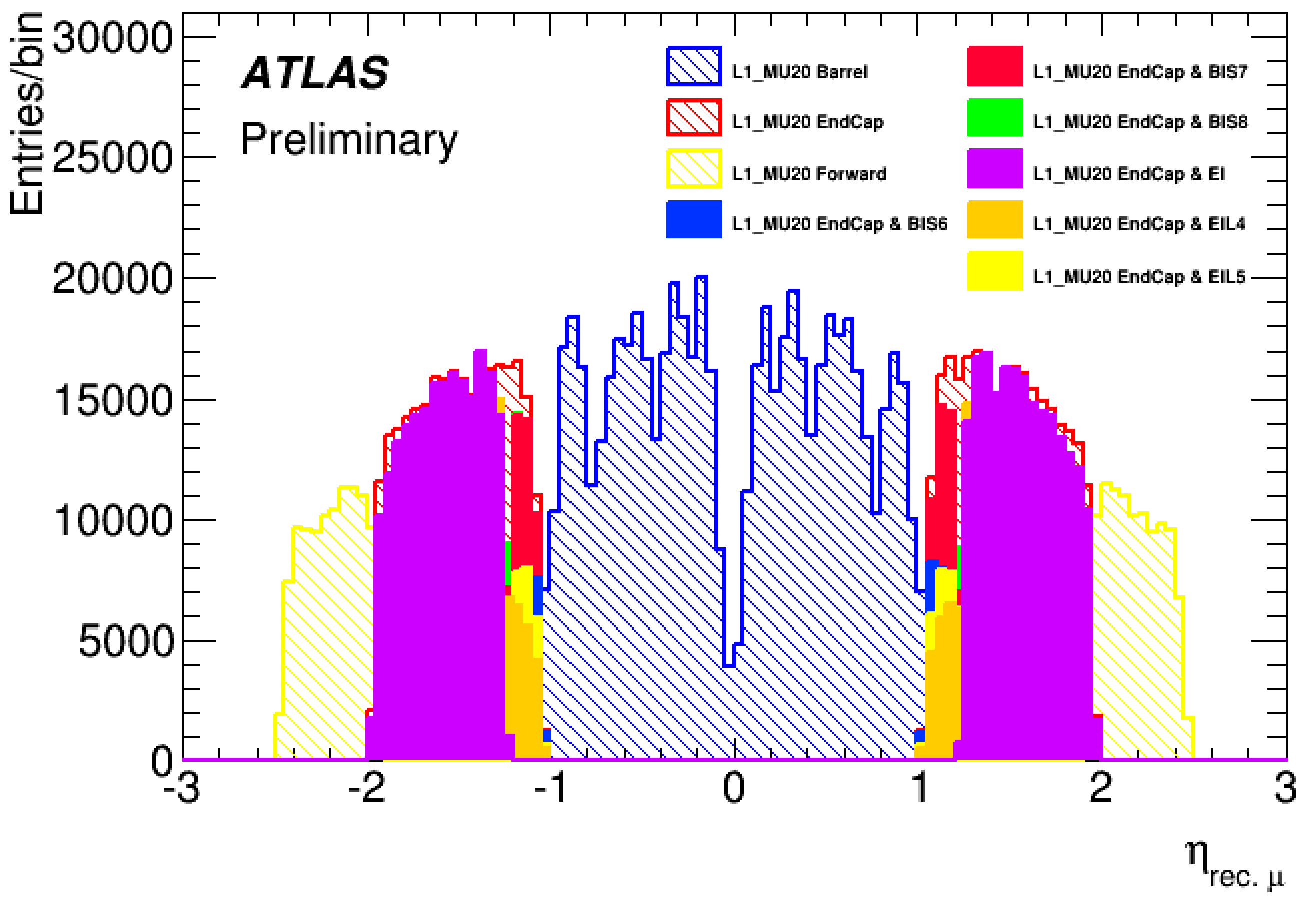
- Full-custom Front-End chip with high S/N amplifier is being designed in SiGe technology
- Possibility of using part of the New Small Wheel trigger hardware (sTGC PAD) with some (small) modifications on the firmware is presently still being evaluated

Origin of Fakes

- Studies found that the main source of fake triggers are low-pt protons generated in toroids and shieldings
- A-C asymmetry explained by charge/B-field effect
- Increase with 25ns consistent with origin and low-β



- The picture shows the η distribution of the reconstructed muons
- The hatched distribution is the one obtained with the actual trigger
- the full colored one shows how the distribution in EndCaps changes applying the request of RPCs in BIS6, BIS7 and BIS8.



The picture shows the L1_MU20 Efficiency with respect to all reconstructed muons as a function of the muon momentum, for two different cuts in $\Delta\eta$ between the segments inside the chambers and the L1_MU20 ROIs. The curve obtained with $\Delta\eta < 0.2$ is drawn in blue, while the one obtained with $\Delta\eta < 0.04$ is drawn in red.