8th International Conference on New Frontiers in Physics

Crete, Greece

21-30 August 2019

Luca Pizzimento on behalf of ATLAS collaboration

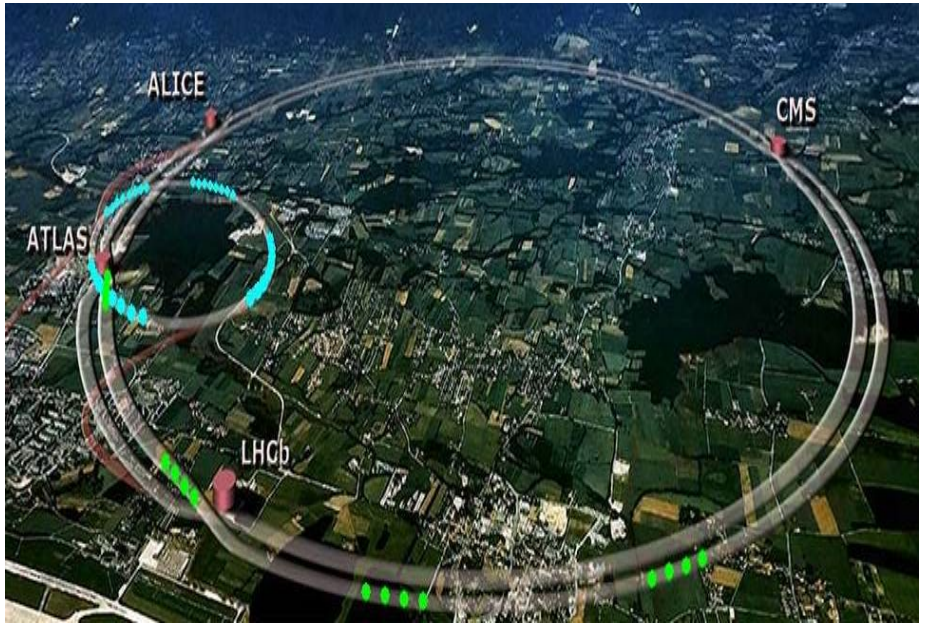
New generation of RPC detector for the ATLAS Muon detector upgrade

luca.pizzimento@roma2.infn.it

Summary

- ***The ATLAS Muon Spectrometer Upgrade***
- ***The new generation of RPC detectors***
- ***BIS78 RPCs performances***
- ***Conclusion***

The ATLAS Muon Spectrometer upgrade



	LHC	LHC (Phase I)	HL-LHC (Phase II)
years	2009-2019	2021-2024	2026
$E_{cm}(TeV)$	7-13	13-14	14
$L(10^{34}cm^{-2}s^{-1})$	1	3	7
$L(fb^{-1})$	30	300	3000

The challenge of Atlas Muon Spectrometer is to preserve its present muon identification and tracking performance, and its standalone and combined (with inner tracker detector) momentum resolution in much harsher conditions in terms of:

- particle rates
- integrated radiation
- pile-up

One of the upgrade scheduled for the HL-LHC, in order to improve the ATLAS muon spectrometer is the Resistive Plate Chamber (RPC) BI project

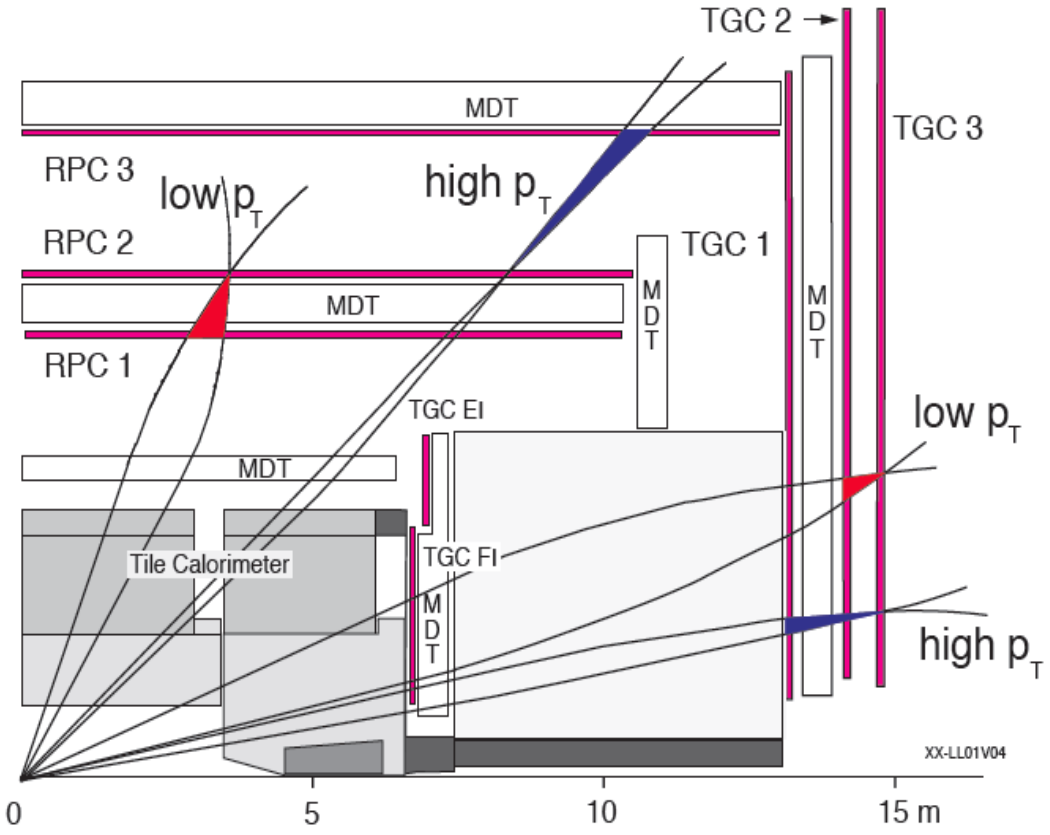
The ATLAS Muon Spectrometer upgrade

- Present RPCs are certified for 100 $\frac{Hz}{cm^2}$ for 10 Years equivalent to 5 HL-LHC years → insufficient reliability

- Rate capability : insufficient for the expected rate in HL-LHC and keeping the same level of trigger efficiency for the following years

- The present geometrical acceptance of the trigger in the barrel is only approximately 80%, primarily due to the toroid coils, support structure and services

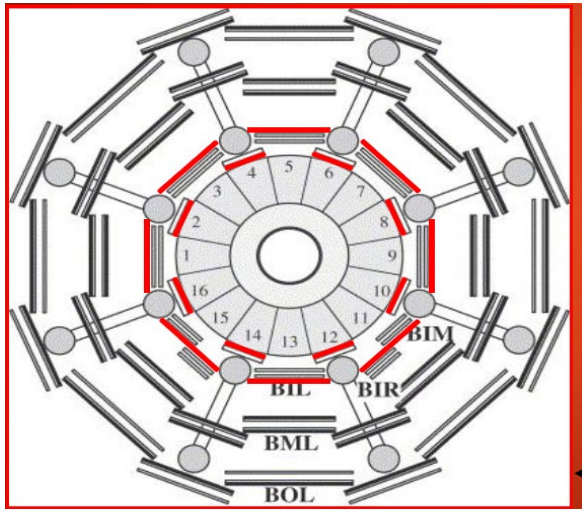
- The present trigger and read out electronics are not compatible with the rate and the latency requirements of Atlas Phase II trigger and data acquisition scheme

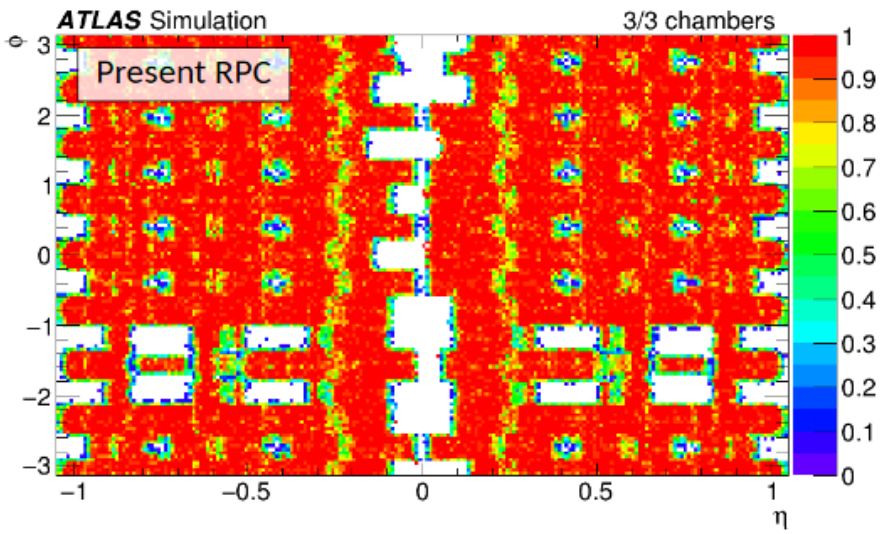


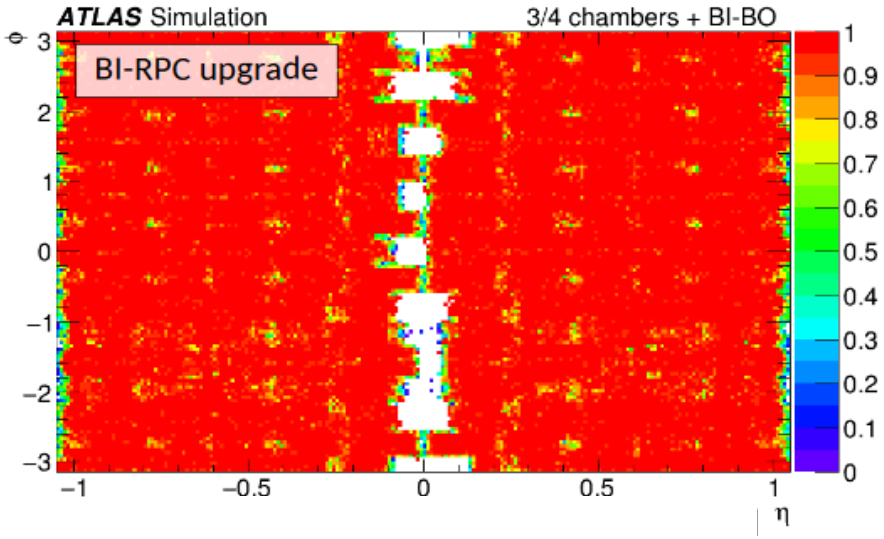
The ATLAS Muon Spectrometer upgrade - BI Project

The BI project will consist in the coverage of the inner barrel of the ATLAS experiment with 272 triplets made of the new generation of RPC detectors

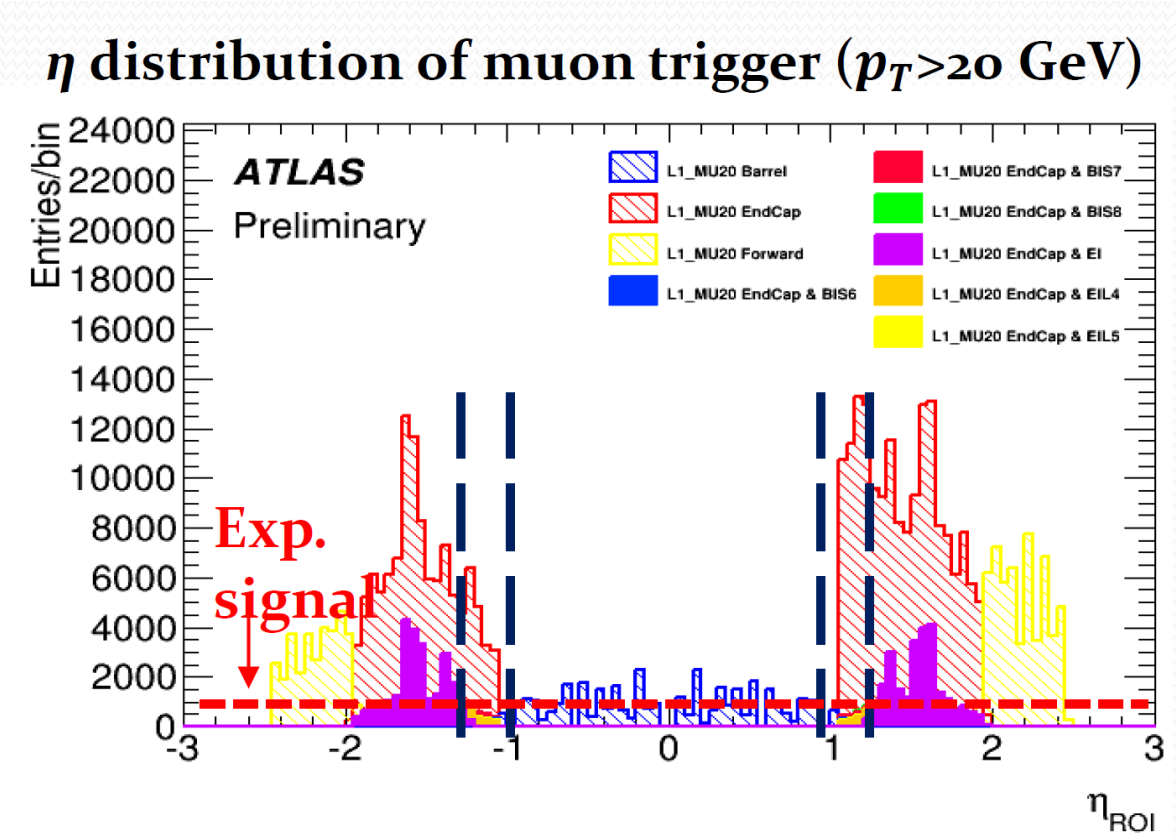
- More Redundancy (6->9layers)
- Longer lever arm(2.3 m->4.5 m)
- More acceptance(80%->96%)
- Enhancement of selected critical chambers in more exposed region (need efficiency > 80%)
- New readout electronics better exploit the RPC performance
- Full trigger performance at 96% coverage any HL-LHC luminosity, with present gap efficiency at 70%-80%
- Better trigger selectivity
- Better tracking







The ATLAS Muon spectrometer upgrade – BIS78 Project



The transition region 1<|η|<1.3 of the muon system will suffer of 2 severe problems with increasing luminosity, concentrated in the far edges of small (even) sectors:

1) High LVL1 fake rate expected and no trigger chambers present between the IP and the Big Wheel

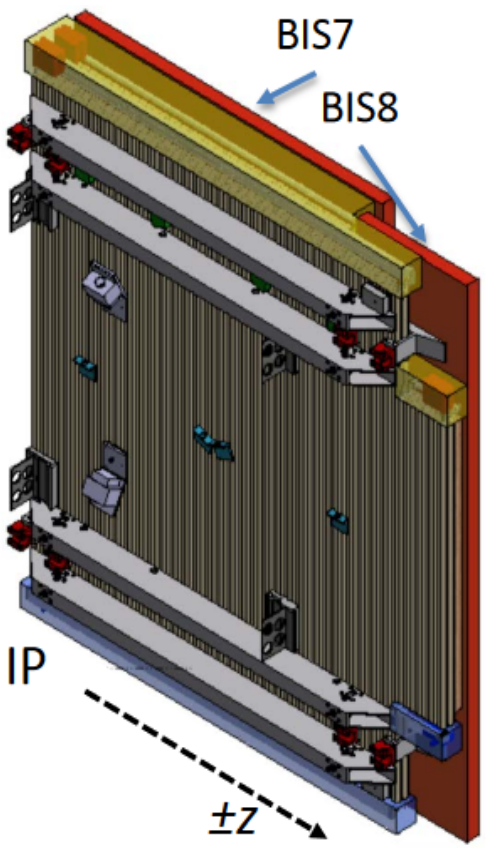
2) High photon induced counting rate, making in particular the BIS7 MDT performance insufficient for Phase II.

Two upgrades scheduled for the ATLAS spectrometer in Phase 1

1) Tracking and trigger upgrade in the η > 1.3 region with the New Small Wheel (NSW)

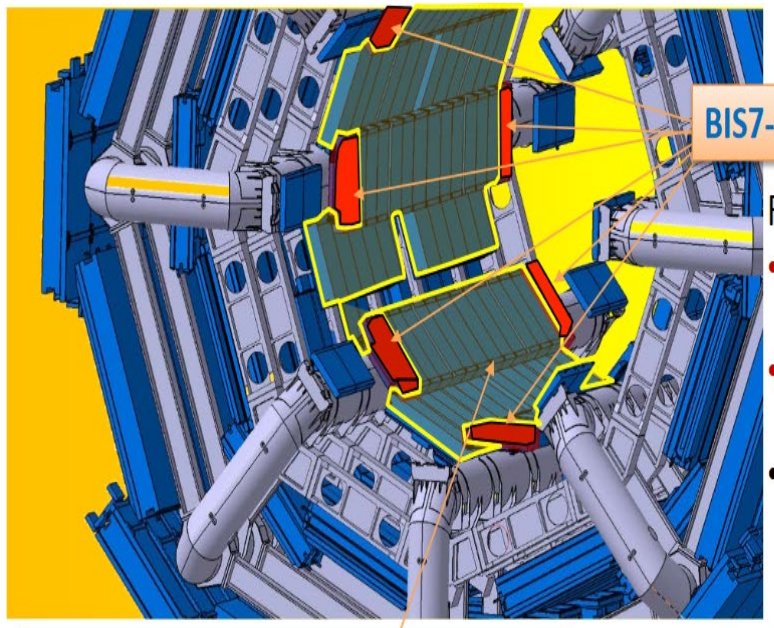
2) Upgrade of the ATLAS muon trigger in the barrel-endcap transition region with RPC

The ATLAS Muon spectrometer upgrade – BIS78 Project



Replace the BIS MDT 7 and 8 chambers with an integrated new generation RPC + sMDT chamber in the same envelope

BIS RPC layout



BIS7-8 in Phase-1/Run-3 2021

RPC BIS78 project:

- 16 BIS7 ≈1820 x 1180 mm^2
  16 BIS8 ≈1820 x 440 mm^2
- 3 independent layers measuring η and ϕ
- Total surface 150 m^2

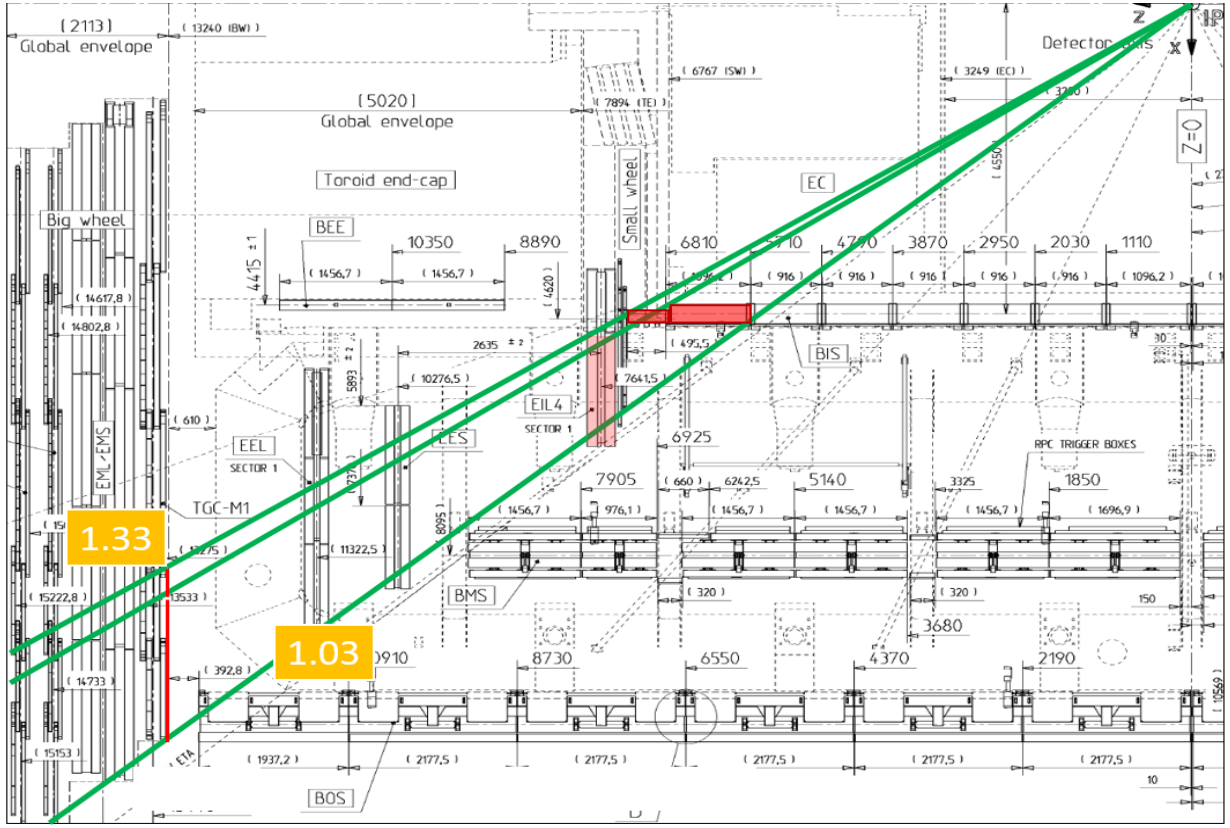
Full BI Layer for Phase-2/Run-4 2026

- In the ATLAS nomenclature RPC-BIS78 are considered a Small Project

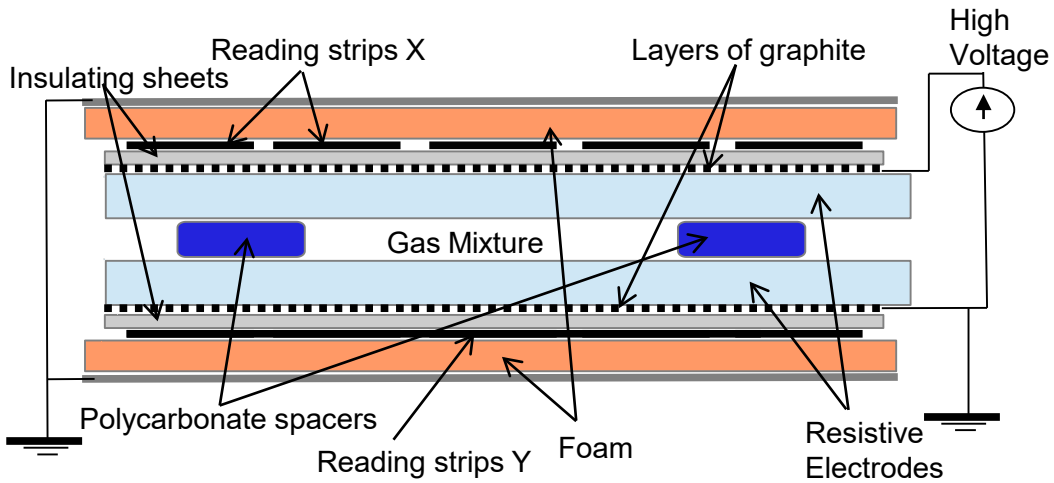
The ATLAS Muon spectrometer upgrade – BIS78 Project

Main advantages for the BIS 7-8 location:

- This area is upstream of the cryostats where most of the fake muons are generated
- Solve the MDT rate problem
- Perfectly projective with the holes
- Robust against pileup
- Provides momentum selectivity

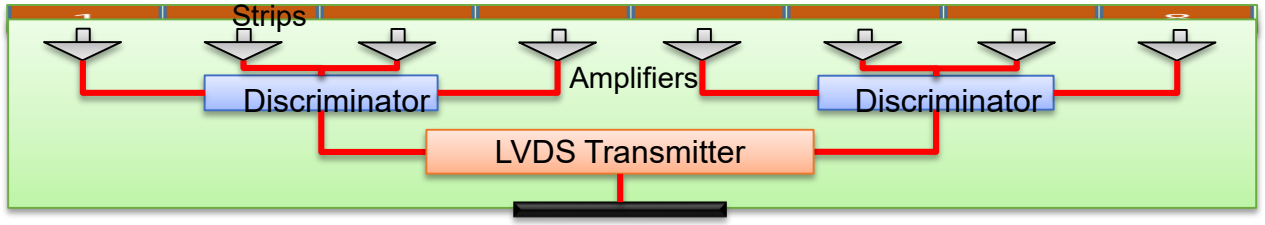


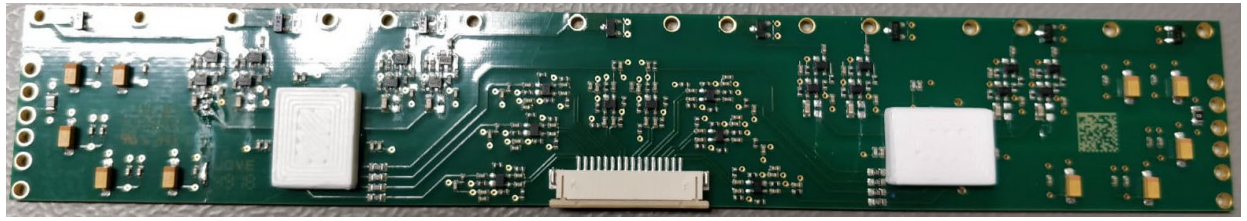
The new generation of RPC detectors



	Atlas Standard RPC	BIS78 RPC
Detector		
Gas Gap width	2 mm	1 mm
Electrode Thickness	1.8 mm	1.2 mm
Gas Mixture	95% TFE, 4.7% i-C4H10, 0.3% SF6	95% TFE, 4.7% i-C4H10, 0.3% SF6
Time Resolution	1 ns	~0.4 ns
Space Resolution	6 mm	1 mm
Gaps per chamber	2	3
Readout electronics	2D orthogonal	2D orthogonal

The new generation of RPC detectors





Amplifier parameters
- Silicon standard components
- Gain: 0.2-0.4 mV/fC
- Power consumption: 3-5 V 1–2 mA
- Band-width: 100 MHz

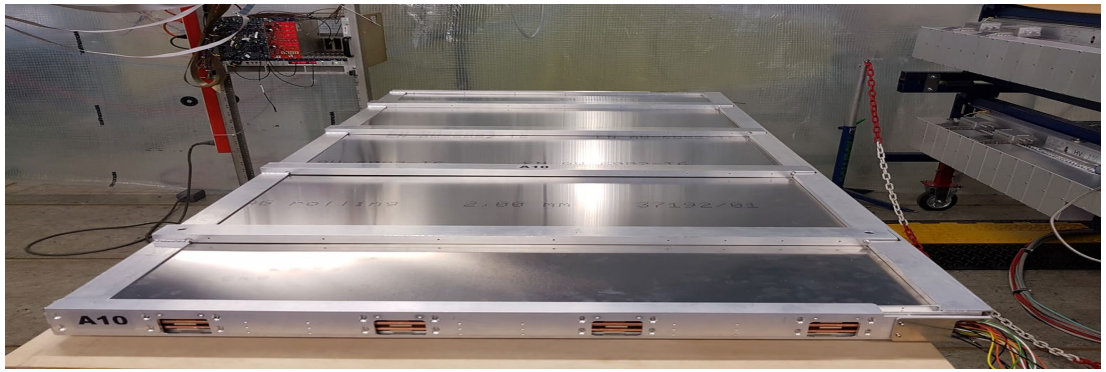
Discriminator parameters
- SiGe full custom
- Power consumption: 2-3 V 4-5 mA
- Threshold: 0.5 mV
- Band-width: 100 MHz

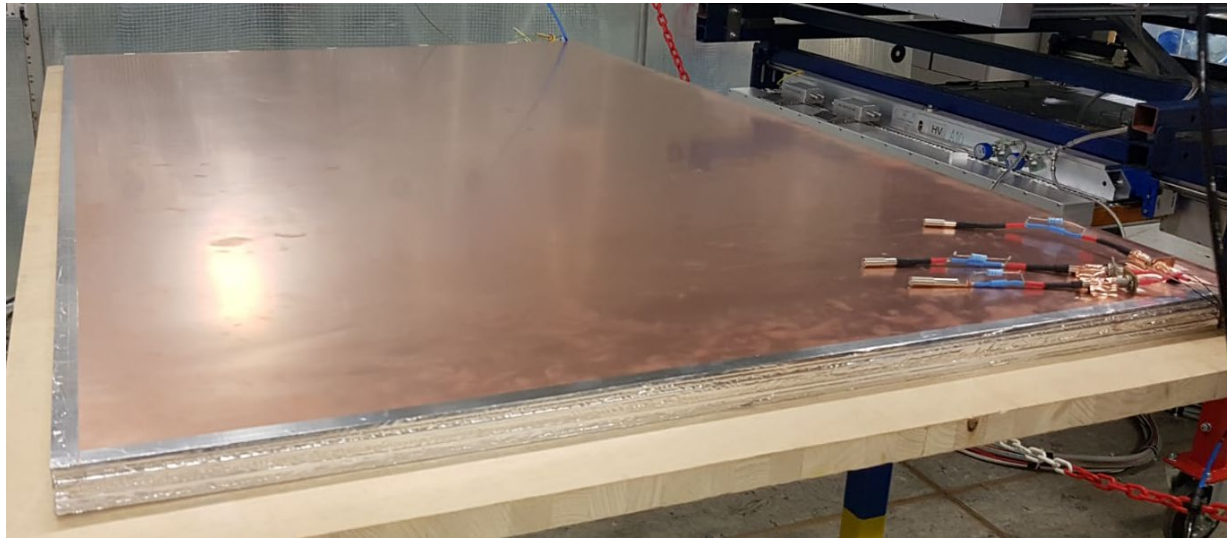
1. Minimum Threshold of 0.3 mV
2. Detectable signal of *1-2 fC*

} Reduction of a factor 10 in the charge produced inside the gas gap → Rate capability up to 10 kHz/cm^2

3. Time-over-threshold measurement achievable directly within the Front-End

BIS78 RPCs construction



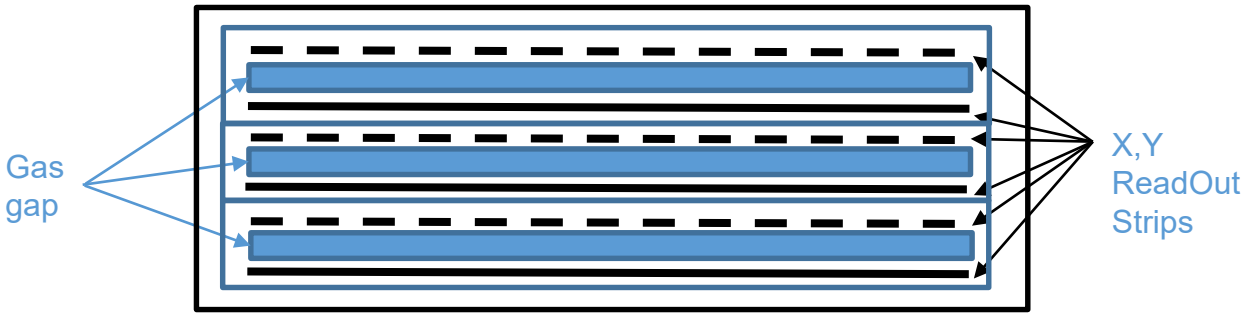


- BIS7S 288 FE channels
- BIS7L 312 FE channels
- BIS8L 264 FE channels
- BIS8S 240 FE channels

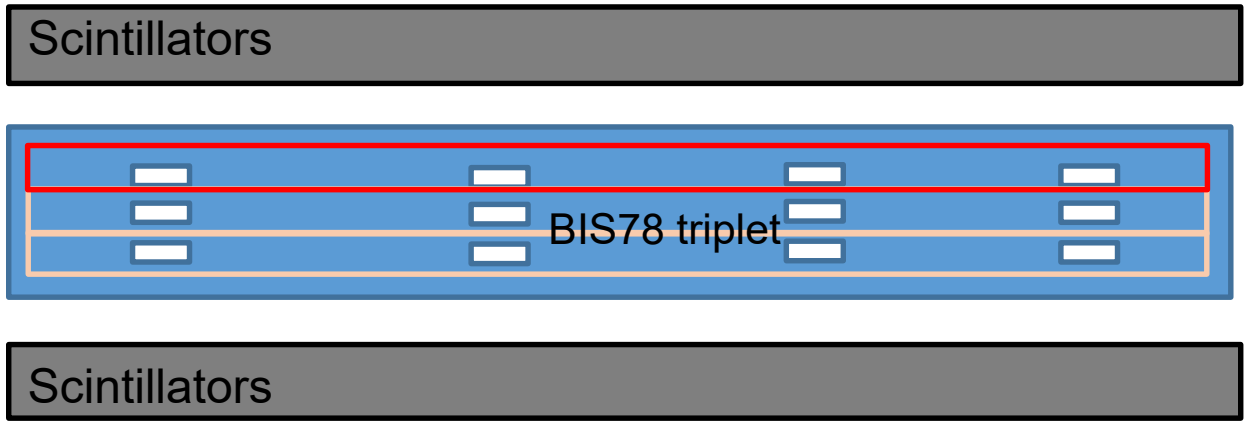
BIS7 Modules assembled:

- 2 BIS7L
- 2 BIS7S

BIS8 in construction



BIS78 RPCs performance – Cosmic ray test



- 2 layers of scintillators (20 cm x 60 cm) as trigger coincidence + 1 chamber at fixed HV
- 100 ns coincidence window
- 15 Hz trigger rate

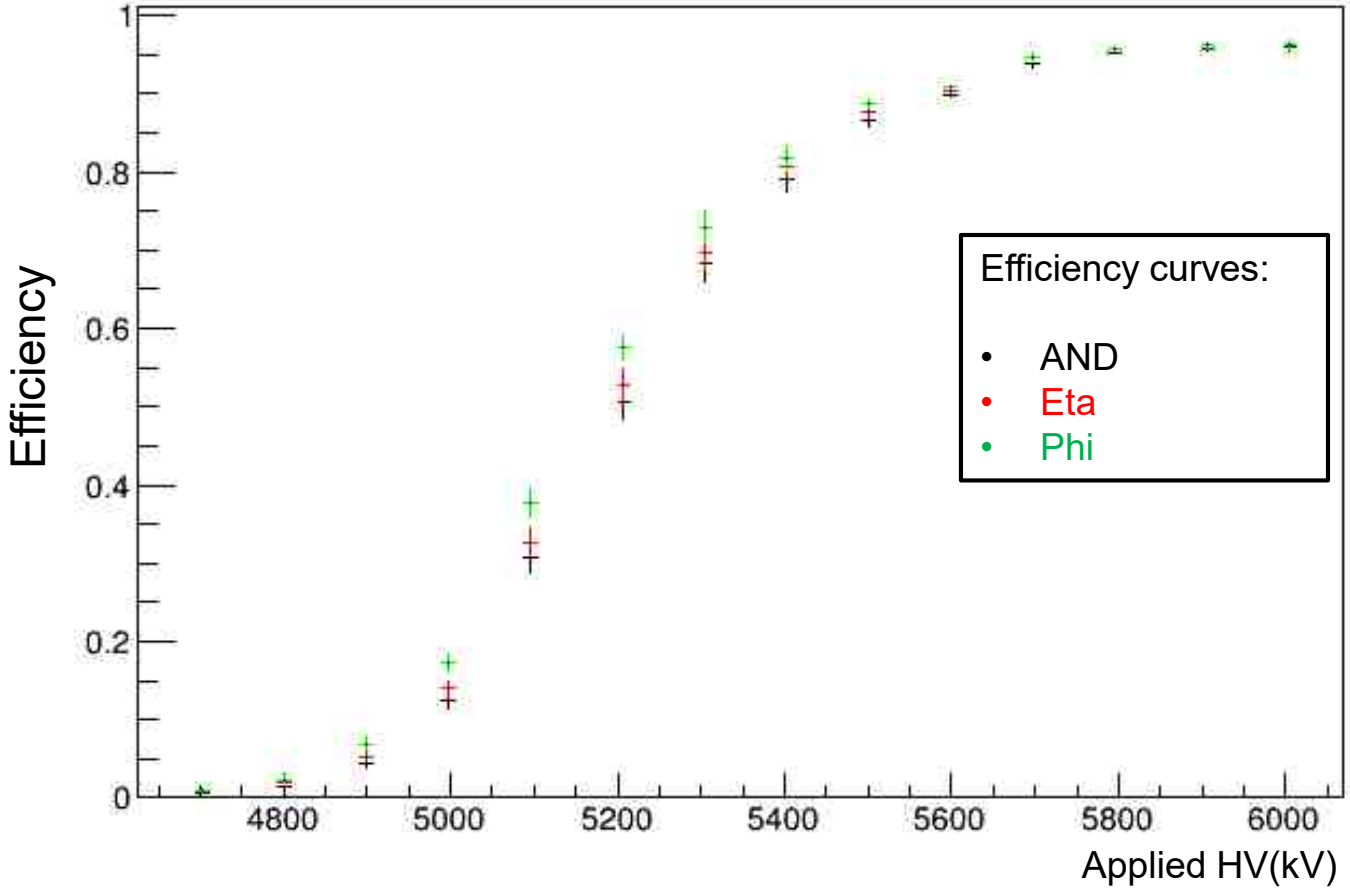
Performance tests:

- Efficiency scan vs position
- Cluster size vs position
- Channels profile
- Noise rate map
- Output Width distribution
- Time Resolution

The BIS7s Module 1 middle singlet performance are reported. The parameters averaged all over the surface are taken at the knee point of the plateau (5.6 kV)

BIS78 RPCs performance – Efficiency curves

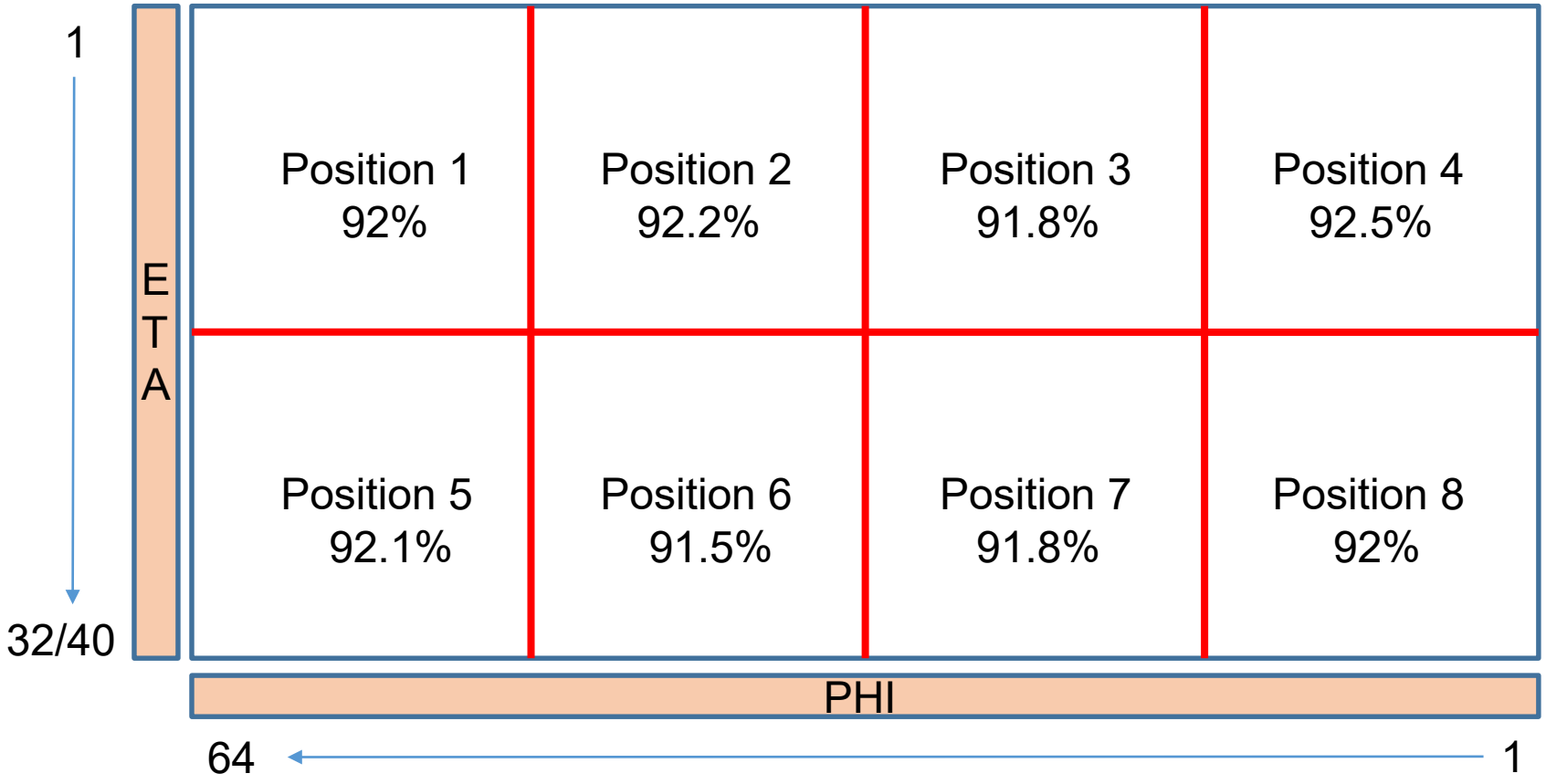
Efficiency curve averaged all over the singlet surface



- Between 92%-93% of efficiency at 5,6kV for each singlet and 95% at 5,7kV
- The Front-End electronics threshold is set to the middle of its dynamic range for both readout layers

Efficiency curve shows the expected behaviour with the desired efficiency level

BIS78 RPCs performance – Modules homogeneity

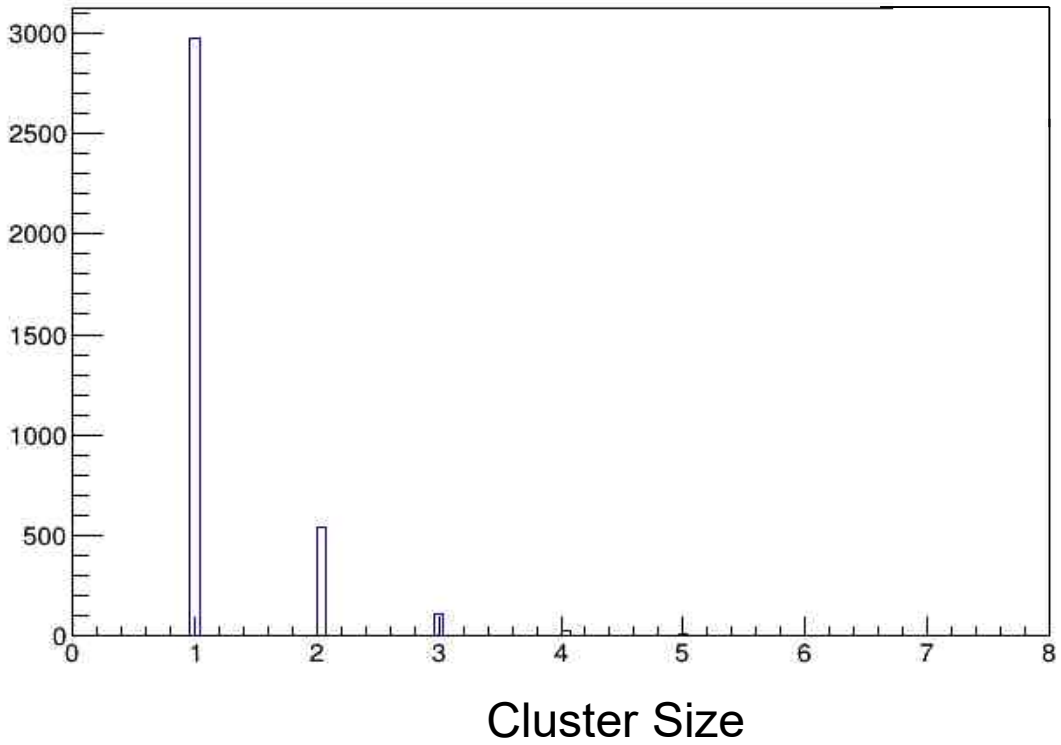


Efficiency at 5.6 kV
For each position tested

The efficiency shows an homogeneous behaviour all over the singlet surface within the statistical fluctuation

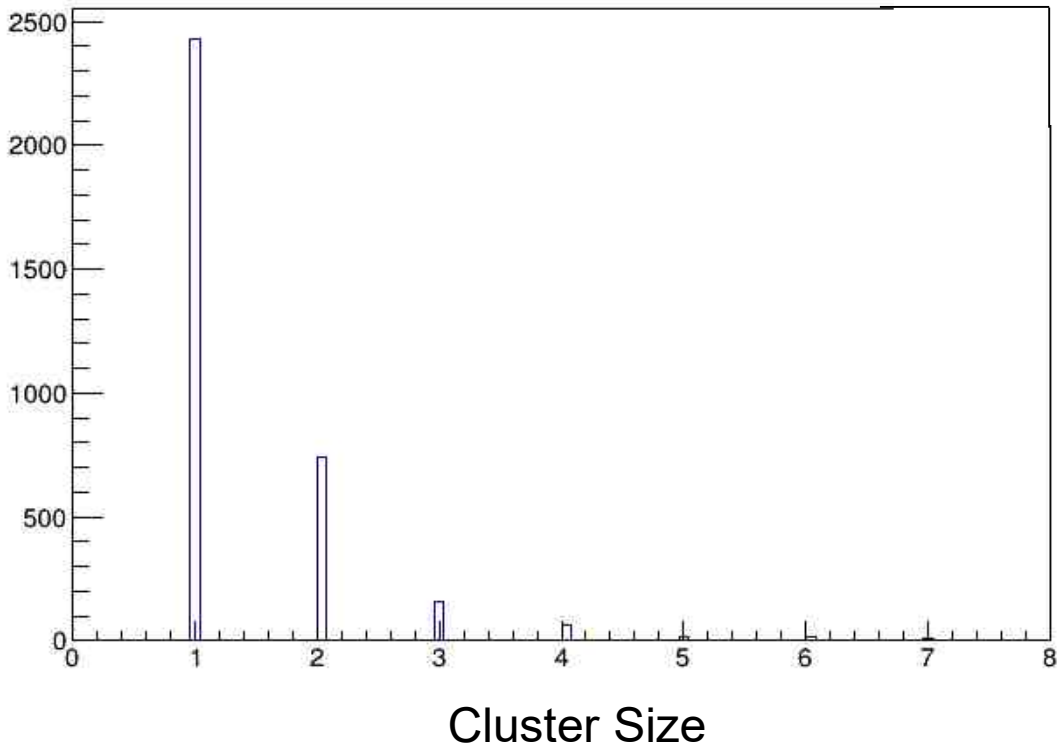
BIS78 RPCs performance – Cluster size

Cluster Size of ETA layer Averaged all over the surface



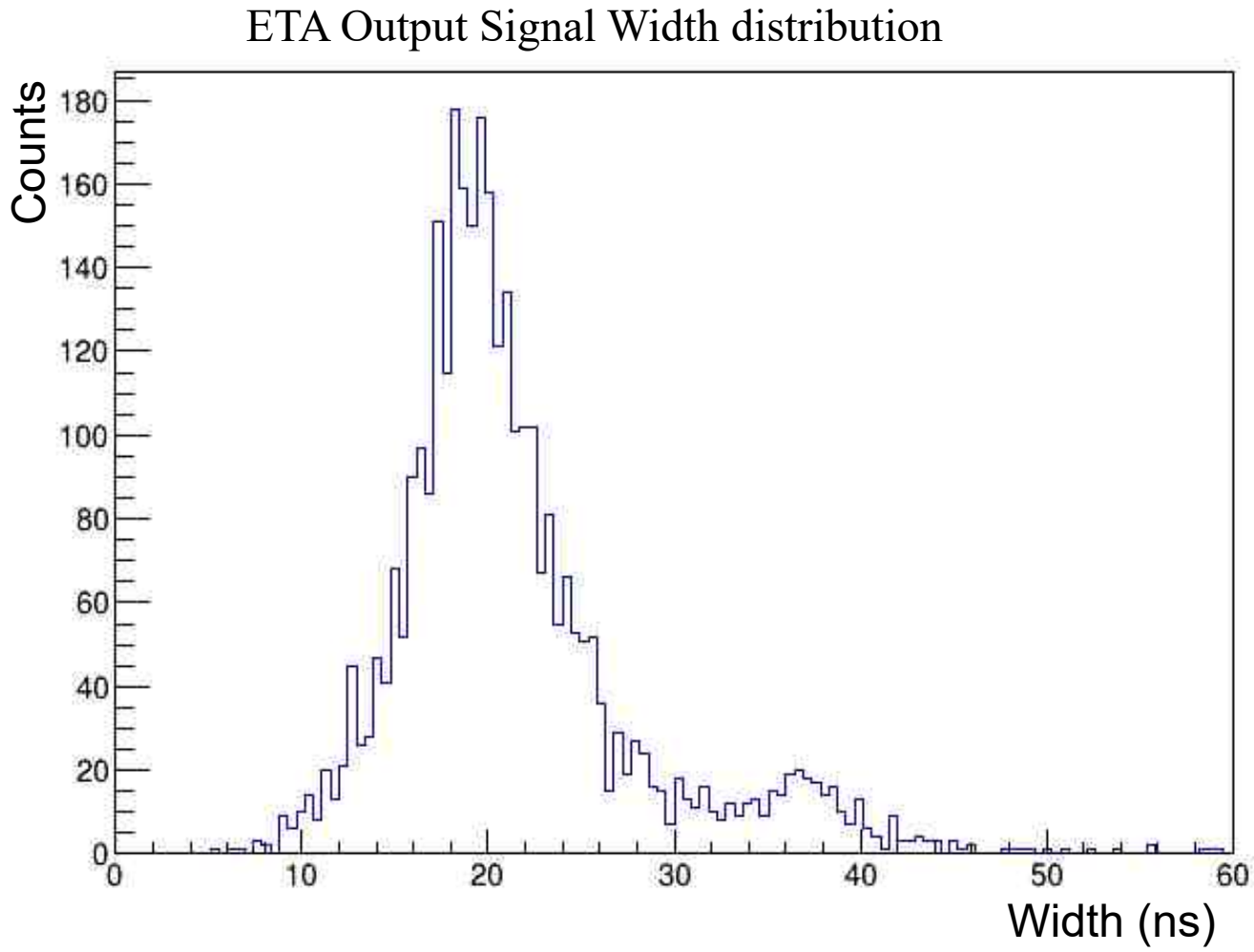
Average cluster size eta = 1.3 - 1.5

Cluster Size of PHI layer Averaged all over the surface



Average cluster size phi = 1.4 - 1.8

BIS78 RPCs performance – Output signal width distribution

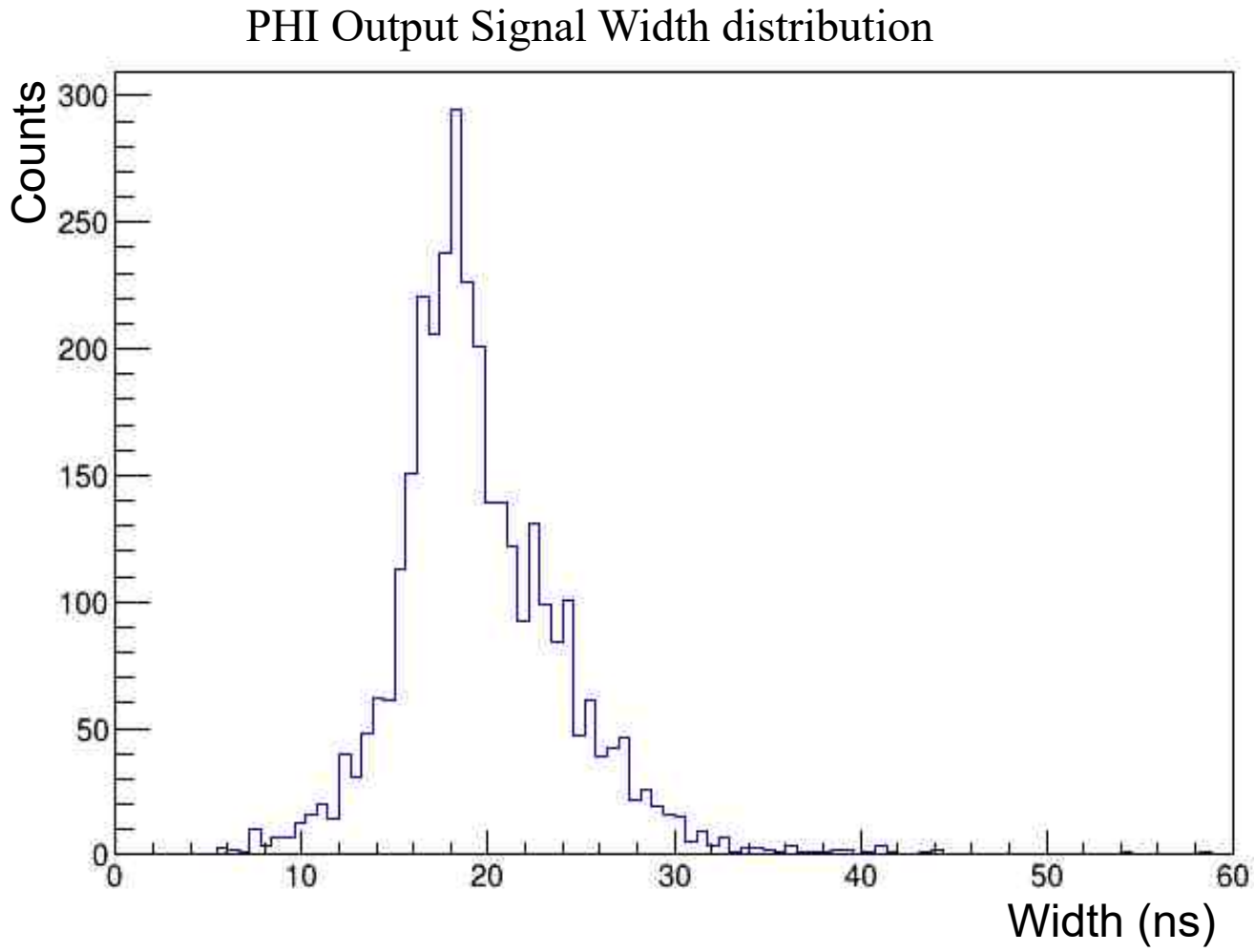


Distribution of Width of the output signals of the ETA layer

Obtained by taking the width of the first signal of each cluster

- Time over Threshold measurement
- Time walk correction for the time resolution

BIS78 RPCs performance – Output signal width distribution



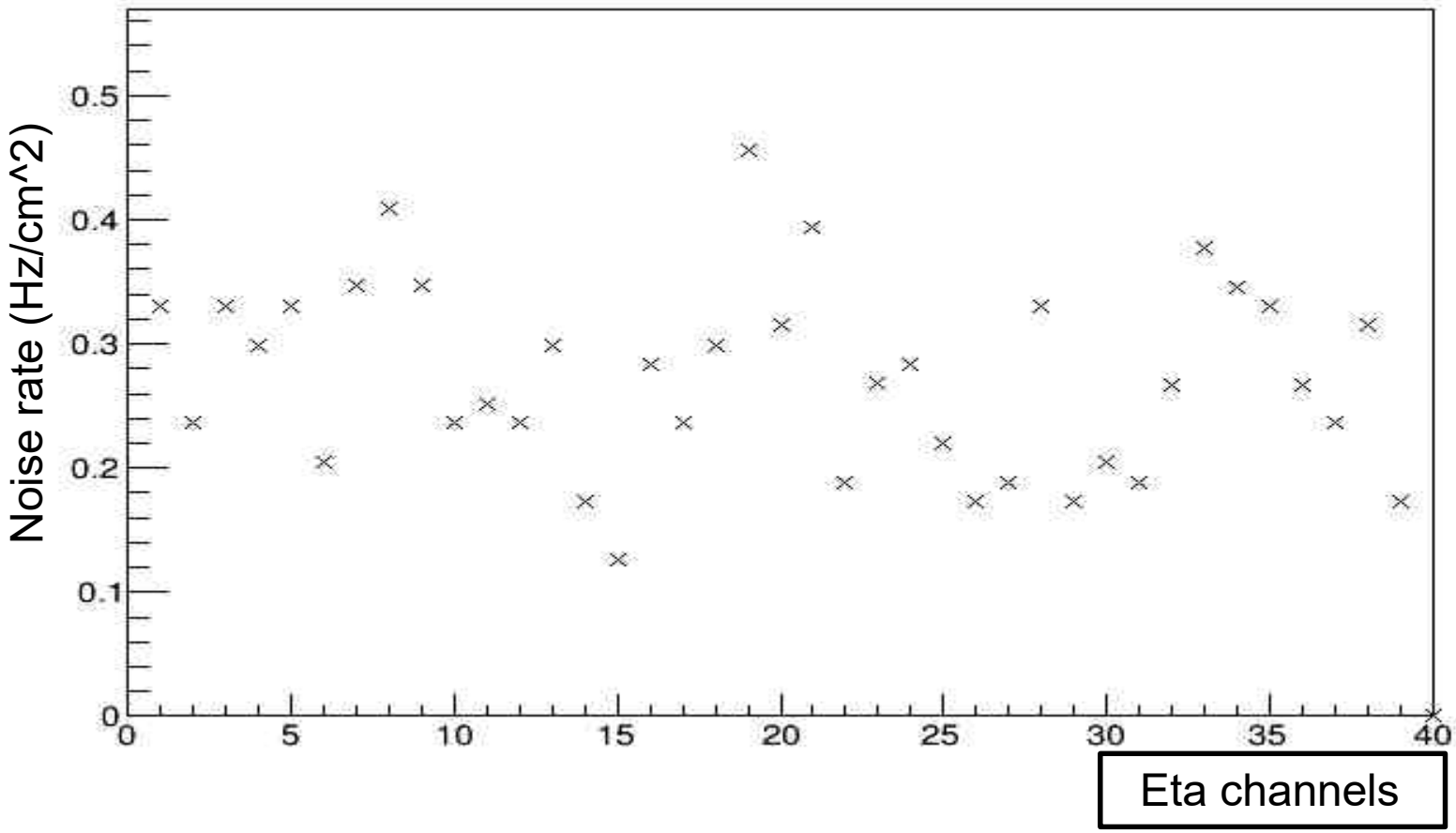
Distribution of Width of the output signals of the PHI layer

Obtained by taking the width of the first signal of each cluster

- Time over Threshold measurement
- Time walk correction for the time resolution

BIS78 RPCs performance – Noise rate map

Noise rate map of the ETA side



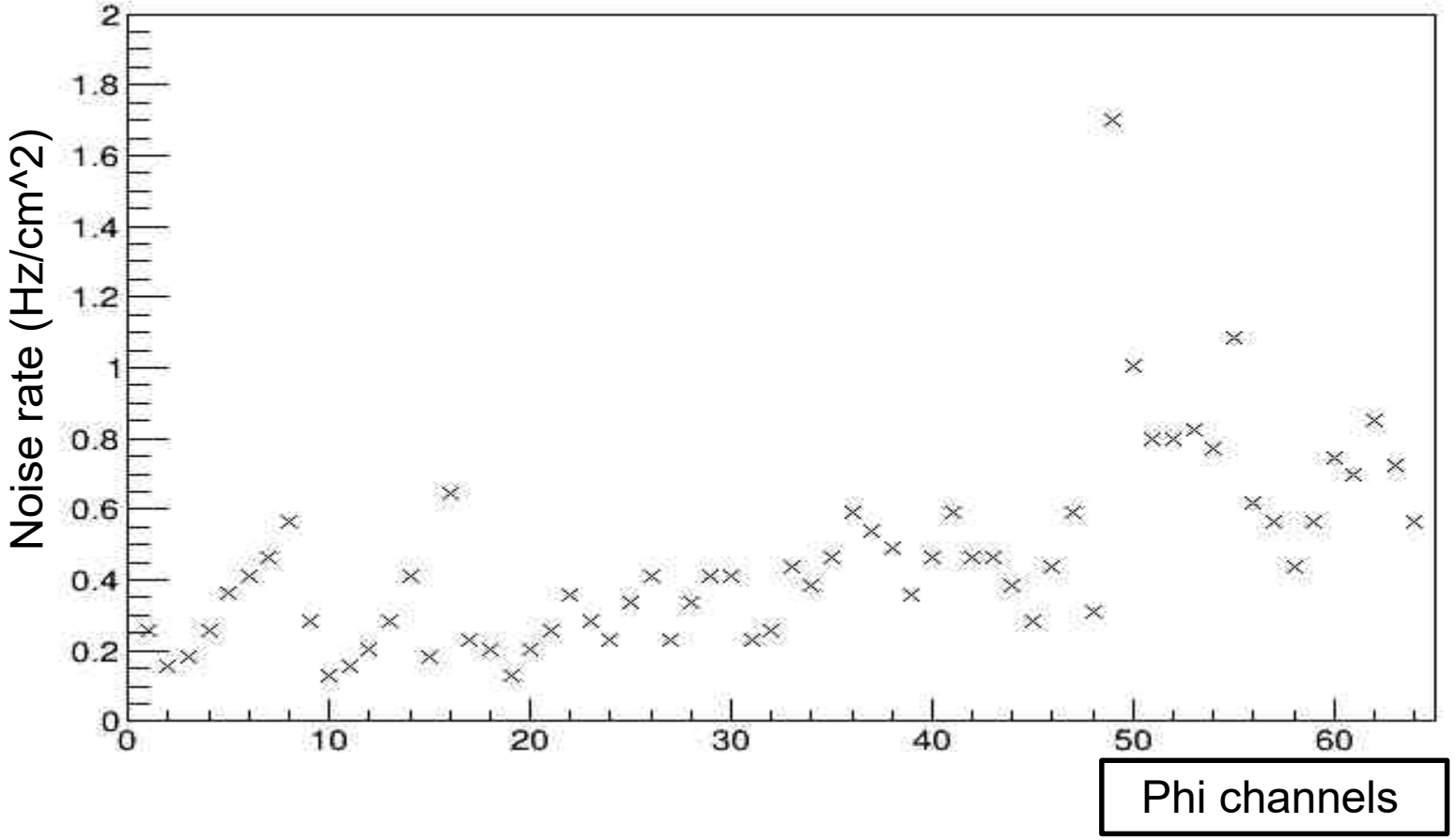
The map of the noise rate for each channel of the readout layer

Average channel noise of 0.2-0.3 Hz/cm^2

The noise rate shows the expected behaviour, since it is lower than 1-2 Hz/cm^2 which is the requirement

BIS78 RPCs performance – Noise rate map

Noise rate map of the PHI side



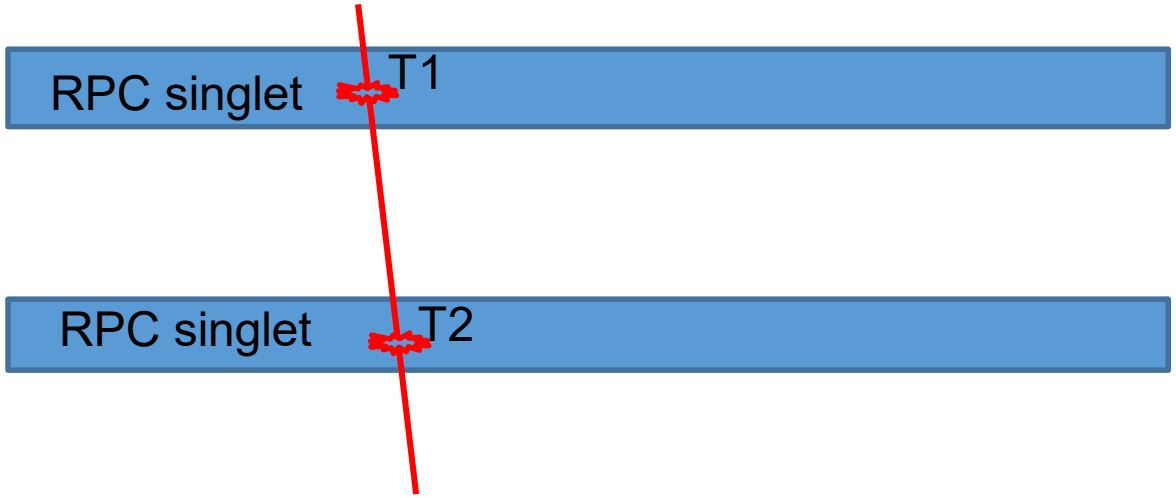
The map of the noise rate for each channel of the readout layer

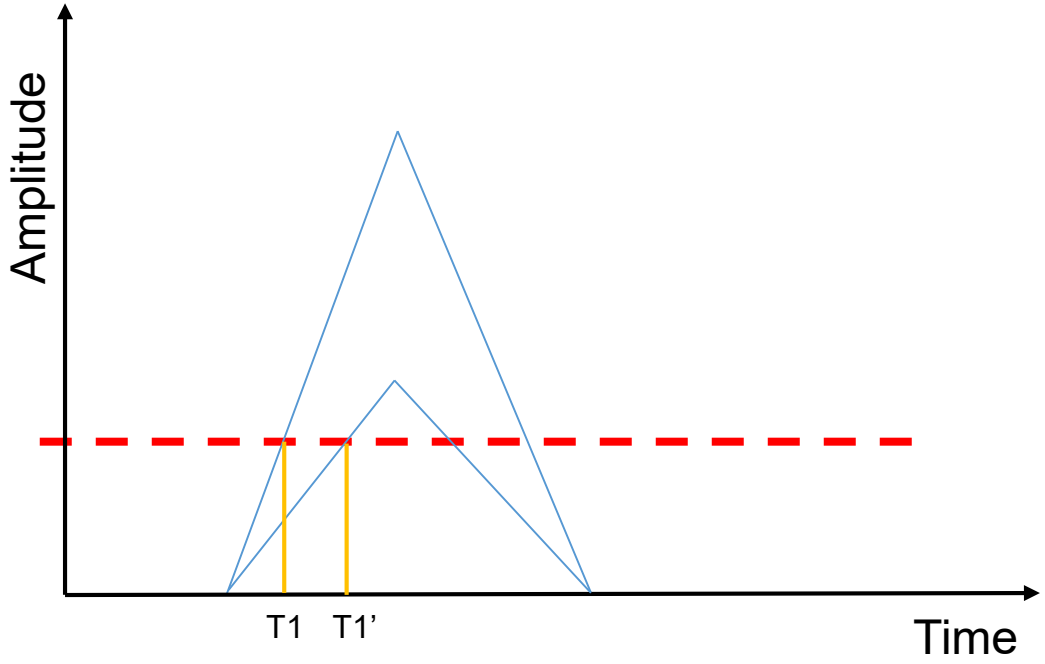
Average channel noise of 0.4-0.6 Hz/cm^2

The noise rate shows the expected behaviour, since it is lower than 1-2 Hz/cm^2 which is the requirement

BIS78 RPCs performance – Time resolution

Time of Flight method for Time resolution calculation



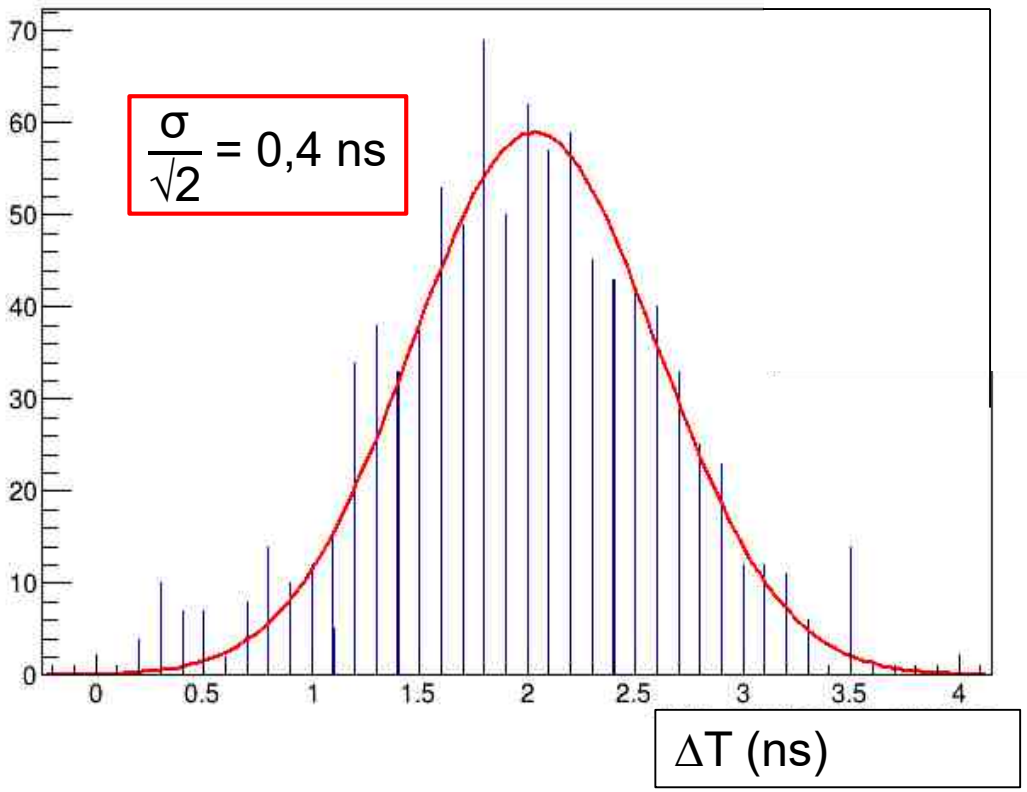


Time resolution calculated as the sigma of the gaussian fit over the distribution of the difference between the arrival time of the signals of the 2 singlets (ΔT)

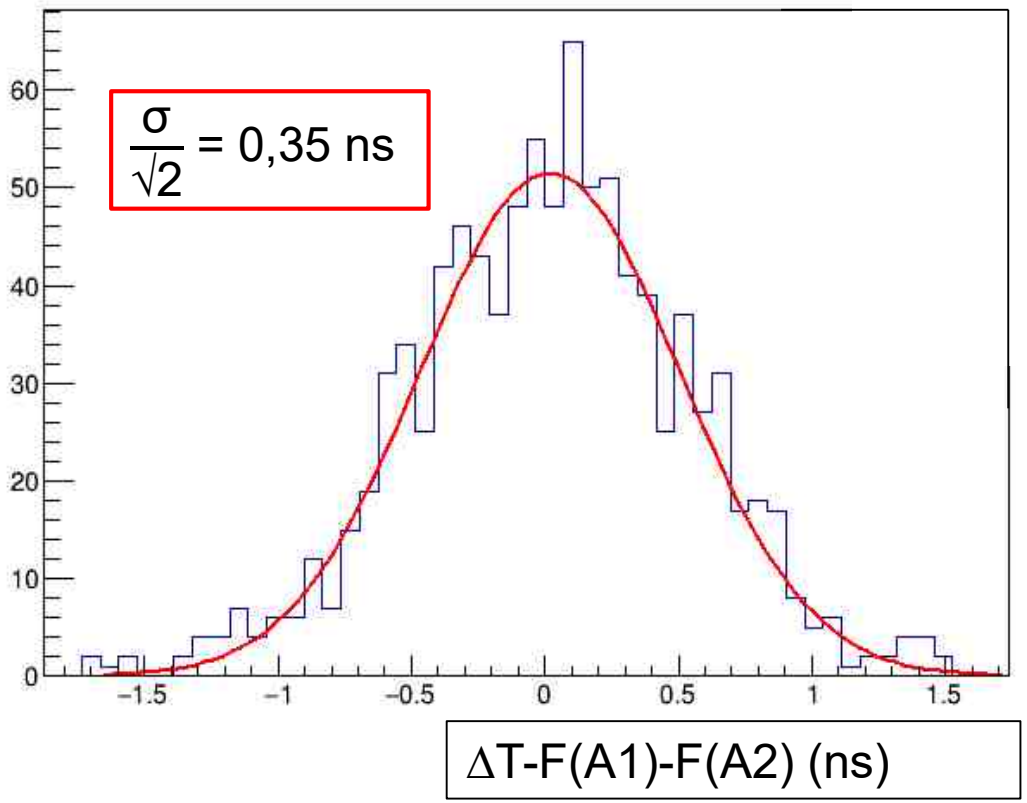
Time walk effect can be corrected by using the function F(Amplitude), which correlate the time when the signal passes the threshold and its amplitude

BIS78 RPCs performance – Time resolution

Time resolution without correction



Time resolution with time walk correction



Conclusion

The BIS78 project is under construction and its installation is scheduled for March 2020

The perfomance obtained by this new generation of RPCs is the one expected and perfectly suitable for ATLAS Phase-1 and Phase-2

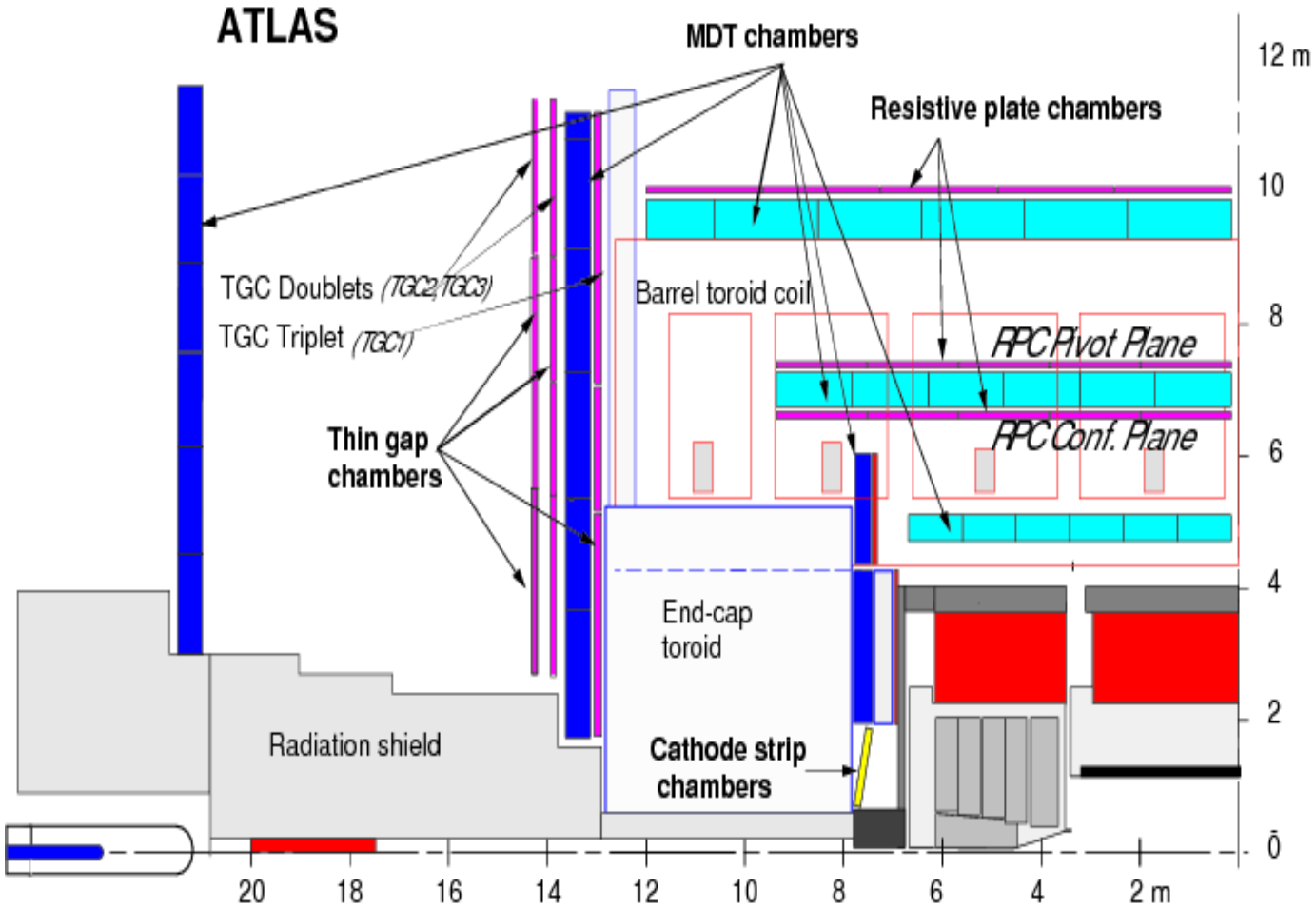
The BIS78 modules tested up to now showed a consistent behaviour between each other and the following performance:

- Between 92%-93% of efficiency at 5,6kV and 95% at 5,7kV for each singlet
- Cluster size of 1.3-1.5 for Eta layer and 1.5-1.8 for Phi layer
- Channel noise of 0.4 Hz/cm^2 for eta layer and 0.6 Hz/cm^2 for phi layer
- Time resolution of 400 ps raw and 350 ps with time walk correction

Conclusion

Thank you!

The ATLAS Muon Upgrade



Subsections of the Muon System:

- Thin Gap Chambers
  - For triggering and 2nd coordinate measurement (non-bending direction) at ends of detector.
- **Resistive Plate Chambers**
  - For triggering and 2nd coordinate measurement in central region.
- Monitored Drift Tubes
  - Measure curves of tracks with a of resolution 80 μm
- Cathode Strip Chambers
  - Measure precision coordinates at ends of detector with a resolution of 60 μm

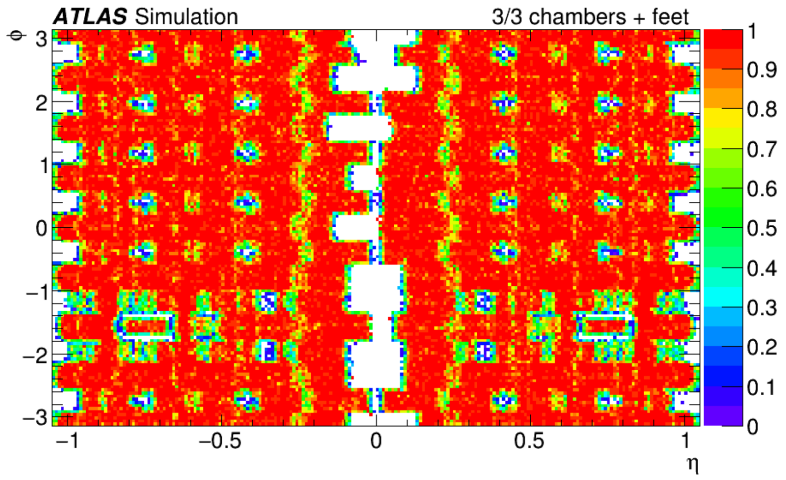
The ATLAS Muon Upgrade

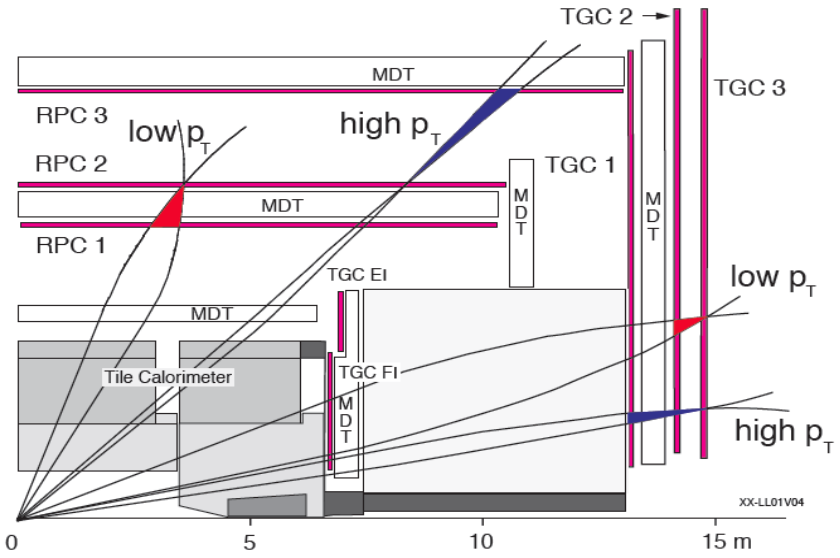
- Present RPCs are certified for 100 $\frac{Hz}{cm^2}$ for 10 Years equivalent to 5 HL-LHC years → insufficient reliability

- Rate capability : insufficient for the expected rate in HL-LHC and keeping the same level of trigger efficiency for the following years

- The present geometrical acceptance of the trigger in the barrel is only approximately 80%, primarily due to the toroid coils, support structure and services

- The present trigger and read out electronics are not compatible with the rate and the latency requirements of Atlas Phase II trigger and data acquisition scheme





LHC / HL-LHC Plan