ATLAS full-size RPC assembly and attenuation study

Xiangyu Xie
On behalf of USTC RPC Team

Outline

- Part 1: RPC assembly and test
  - Project motivation
  - RPC singlets assembly
  - Cosmic-ray tests
  - Conclusion

- Part 2: RPC R&D for the signal attenuation
  - Motivation
  - Experiment set-up
  - Results
  - Conclusion

Project motivation

❖ ATLAS Phase-II upgrade
- USTC-SDU-SJTU cluster will produce 50% BIS RPC singlets, Italy will produce the other 50%, and MPI will assemble BIS singlets into triplets
- Singlets will be assembled ant tested locally in China

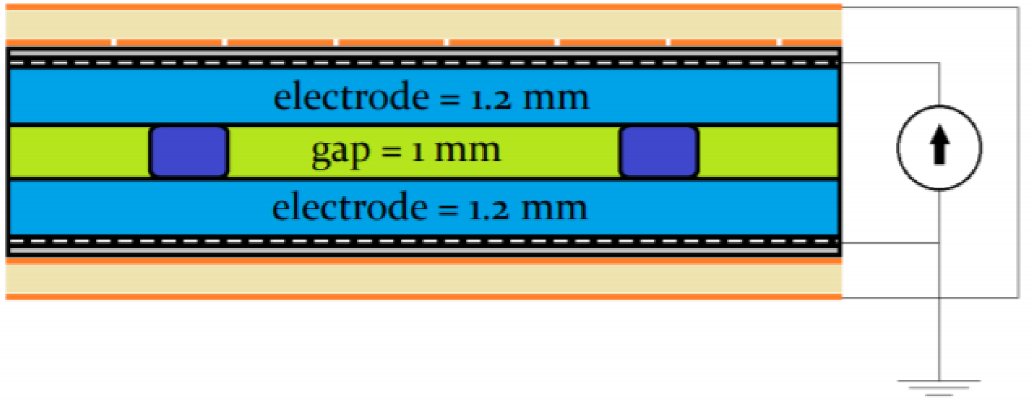
❖ Contribution from China for the ATLAS collaboration

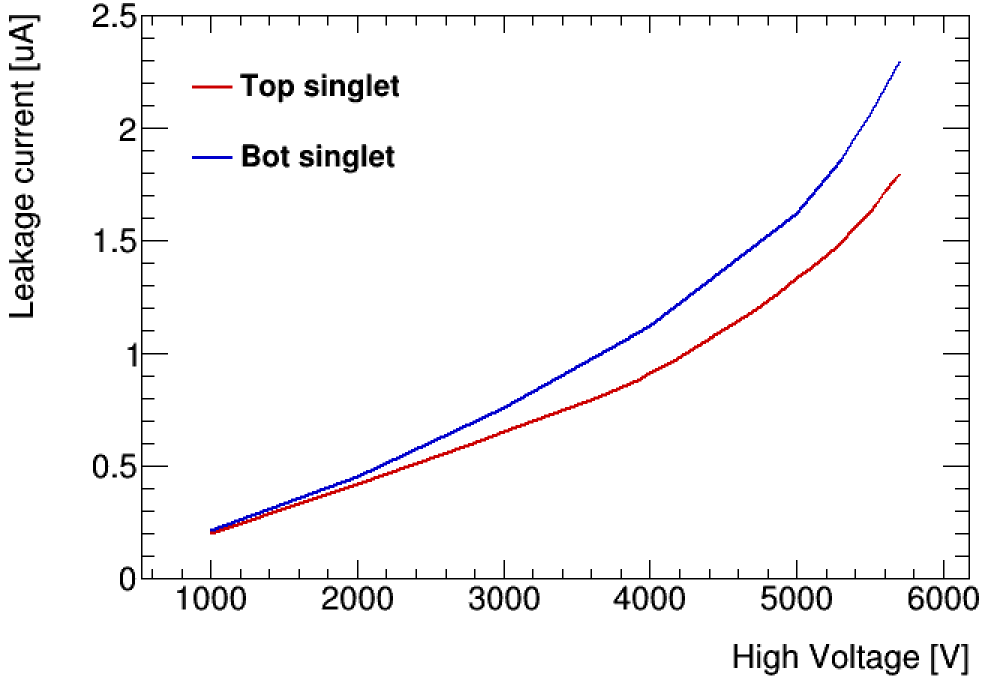
❖ Participate thin-gap RPC R&D

❖ Milestone: full-size RPC singlets assembly and tests
- Done in BB5, CERN, last summer by: Yongjie, Marco, Xiangyu, Man, Kunyu
- To prove the ability of assembly and QC test of full-size singlet RPCs

Assembly: Gas gaps quality control

- BIS7_L type gas gap
  - Size: $1769 \times 1109\ mm$, very similar with the size of Phase-II BIS RPCs
  - Gas gap size: $1\ mm$
  - Bakelite electrode size: $1.2\ mm$
- I_{leak} – HV scan
  - As QC procedure
  - Scan the leakage current for different high voltage applying
  - The on-site test after the one done by the manufactory
- If high-I_{leak} occurs
  - Apply working gas conditioning
  - Apply Argon conditioning
  - Abandoned if I_{leak} remains high



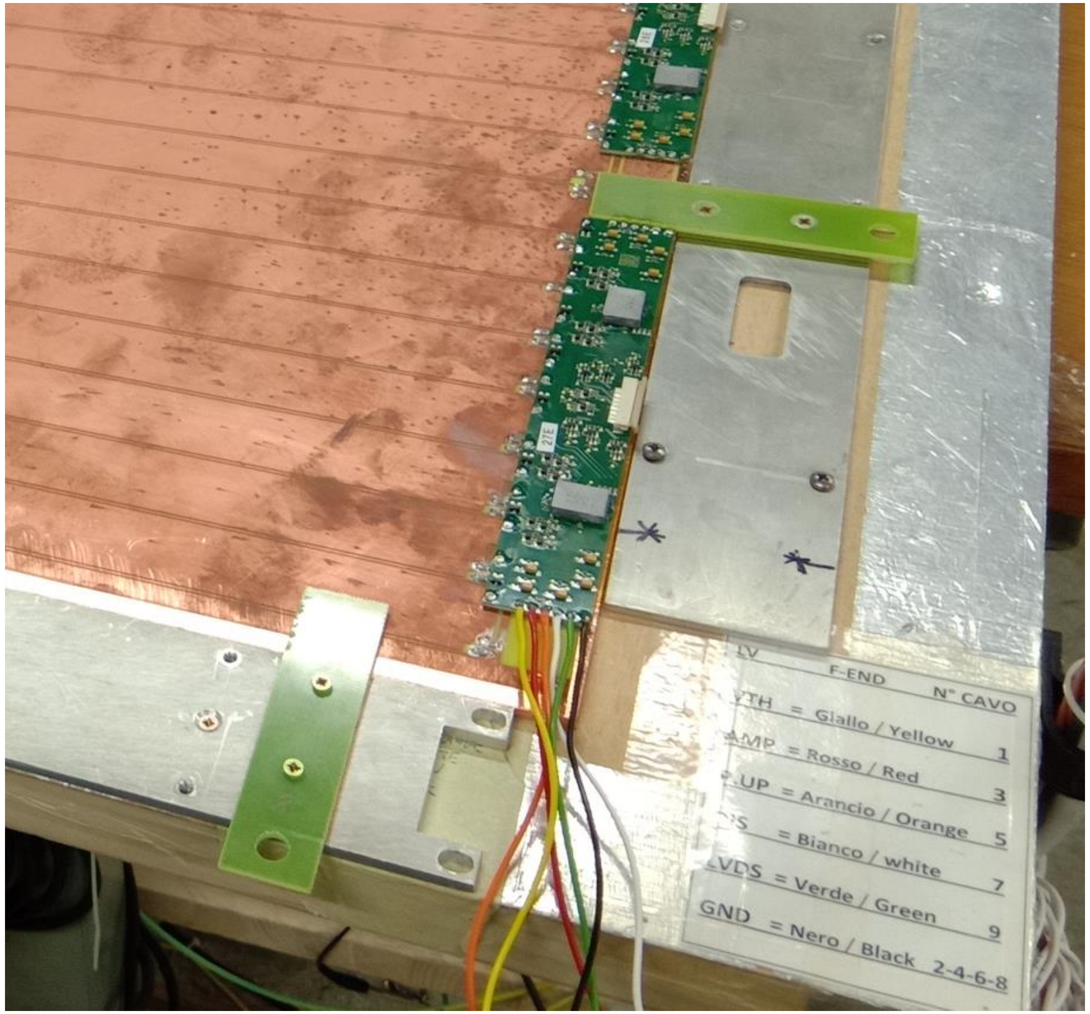


Assembly: FE board test and soldering

❖New FE board
- Based on Si & SiGe technology
- Including amplifiers and discriminators
- Deal with higher muon hit rates under radiation hardness
- Similar with Phase-II FEE

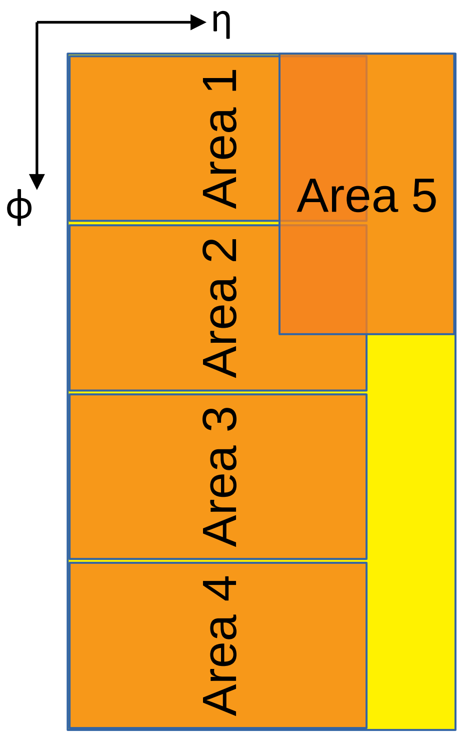
❖FE board test
- Using pulse generator and counter

❖FE board soldering
- FE board soldered on the panel without fly wires
- Team members got trained
- Finished soldering for all the FE boards for the two singlets



Singlet cosmic-ray test: set-up

- Trigger system
  - 3+3 scintillators
- DAQ system:
  - TDC: V1190a, with $100\ ps$ LSB
  - VME controller: V1718
  - Online monitor: details in next page
- Test areas division
  - Due to the limited coverage of scintillators
  - Divided into five areas, covering all η and ϕ channels



Singlet cosmic-ray test: Online monitor

Motivation

- Monitor RPC performance while data taking
- Speed-up the tests by intuitive real-time outputs

Functions

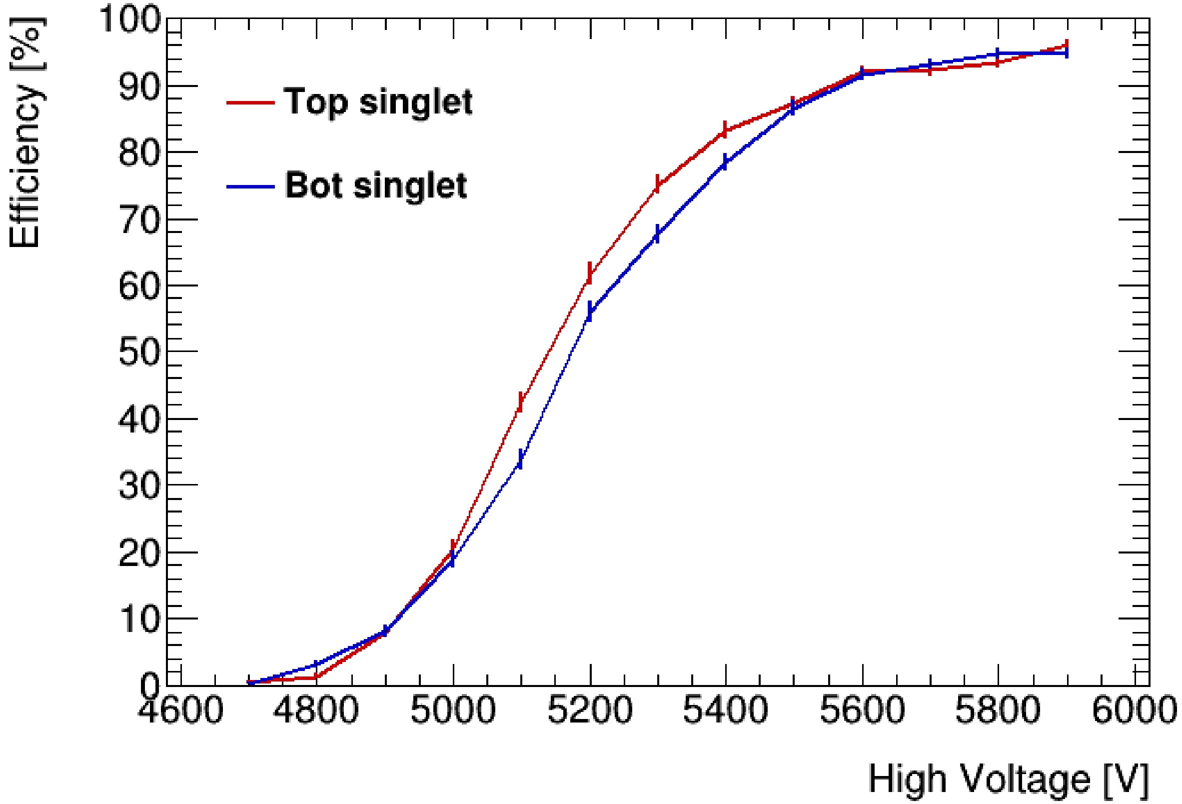
- Control the VME and TDC
- Efficiency
- 2D/1D hit map
- Noise map/noise rate
- Cluster-size
- Raw time resolution
- …

Open source: [git repo]

Singlet cosmic-ray test: efficiency

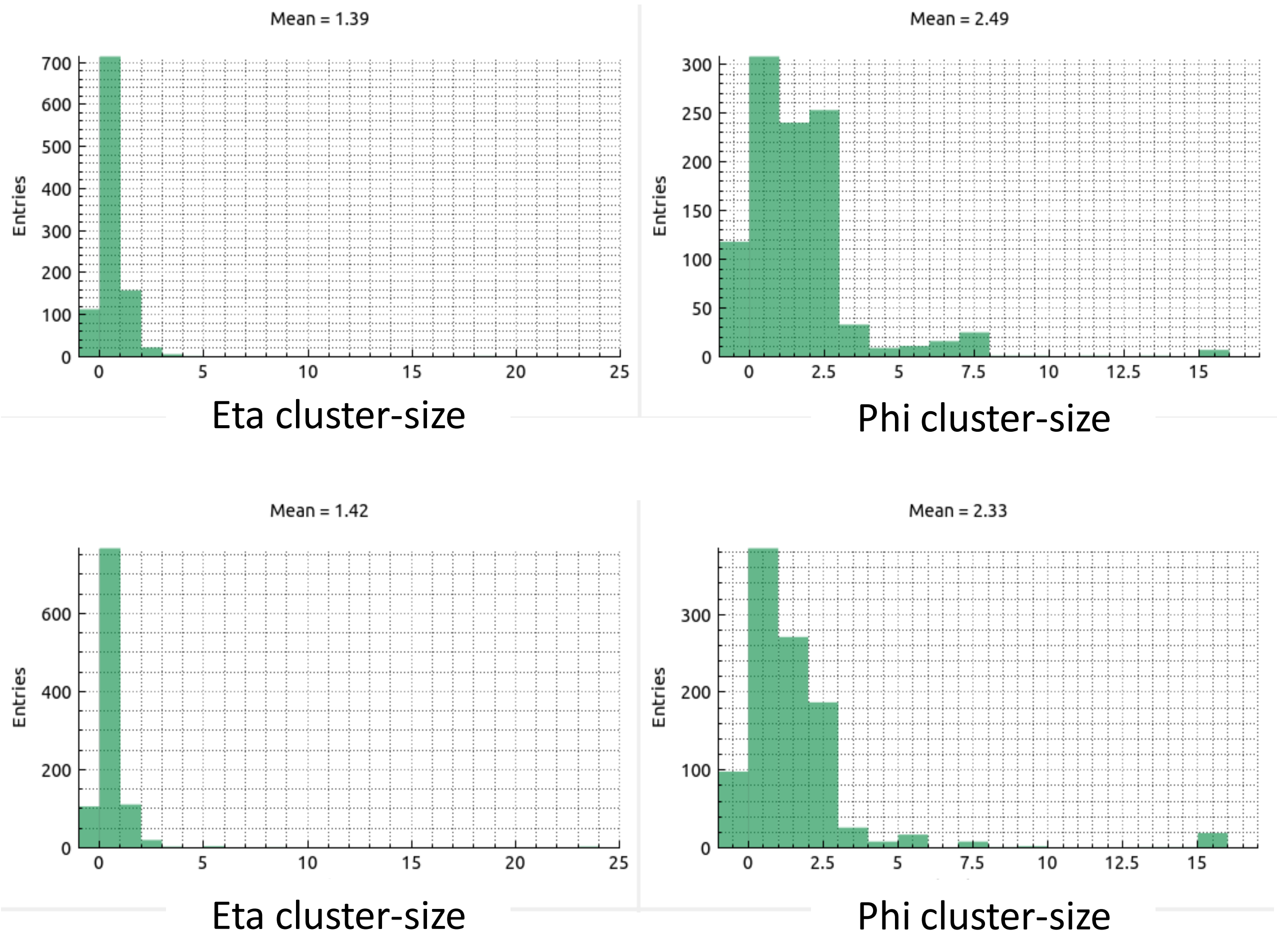
- Algorithm
  - η triggered && ϕ triggered
- Homogeneous performance for all areas at $5.7\ \mathrm{kV}$
  - Featuring the same performance with other BIS7 singlets
  - P.s. RPC designed eff is reached by beam test

	Bottom	Top
Area 1	93.0%	92.0%
Area 2	91.8%	95.2%
Area 3	94.0%	95.9%
Area 4	93.9%	91.8%
Area 5	90.8%	92.4%



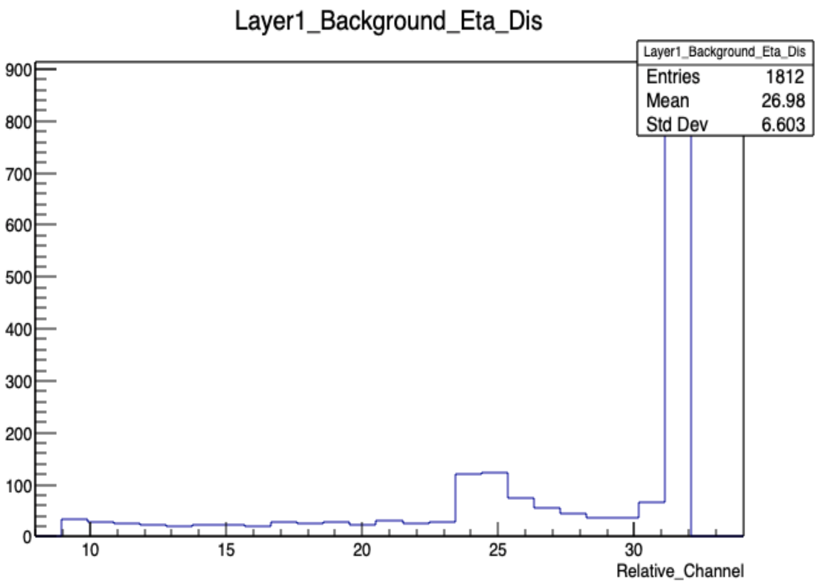
Singlet cosmic-ray test: cluster-size

- Cluster−size: the number of strips fired by one muon hit
  - Strips are required to be adjacent to each other
  - Expected to be less than three
- η panel cluster ~ 1.4
- ϕ panel cluster size ~ 2.4
- The difference in cluster-size distribution due the wrong matching resistors
  - Additional resistors soldered onto the readout panels in parallel with original ones, in order to lower the matching resistor

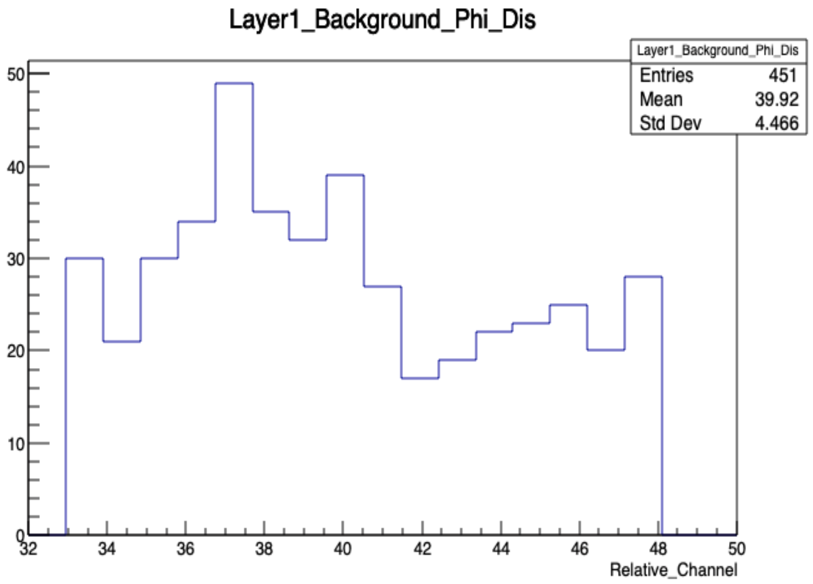


Singlet cosmic-ray test: noise rate

- Studied with randomly triggered data
- Average noise rate for η and ϕ panels at $5.7\ kV$
  - η panel: $1.9\ \mathrm{Hz/cm^2}$
  - ϕ panel: $1.4\ \mathrm{Hz/cm^2}$
- One noisy η channel, which is next to the low voltage supply



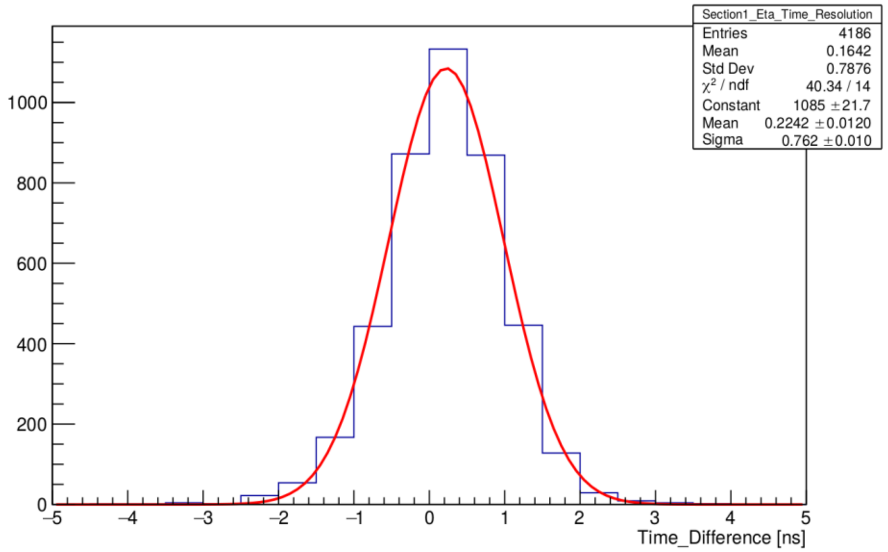
η panel noise distribution



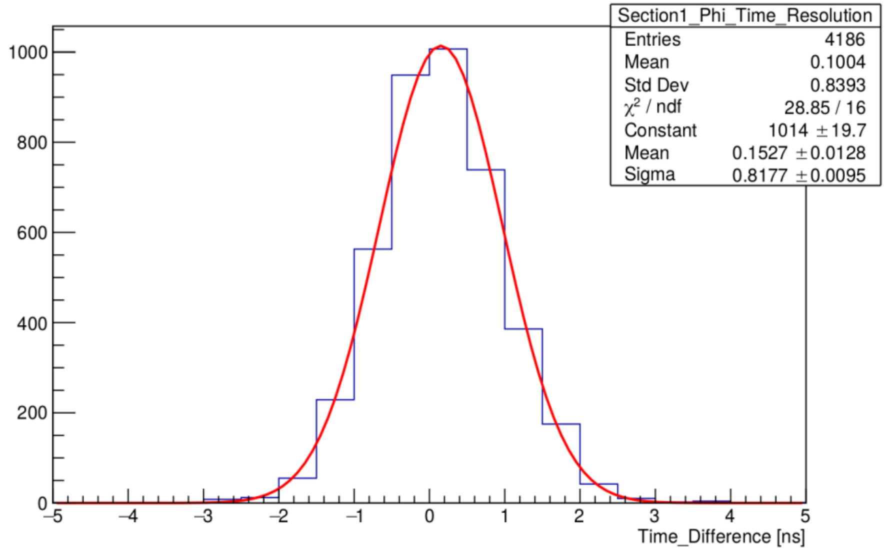
ϕ panel noise distribution

Singlet cosmic-ray test: time resolution

- Selections
  - Cluster-size = 1 for η and ϕ panels
  - η, ϕ channels of two singlets are identical
- $\sigma_t(\eta) = 538\ ps, \sigma(\phi) = 578\ ps$
  - Time walk correction not considered



η panel ToF distribution
HV = 5.7 kV



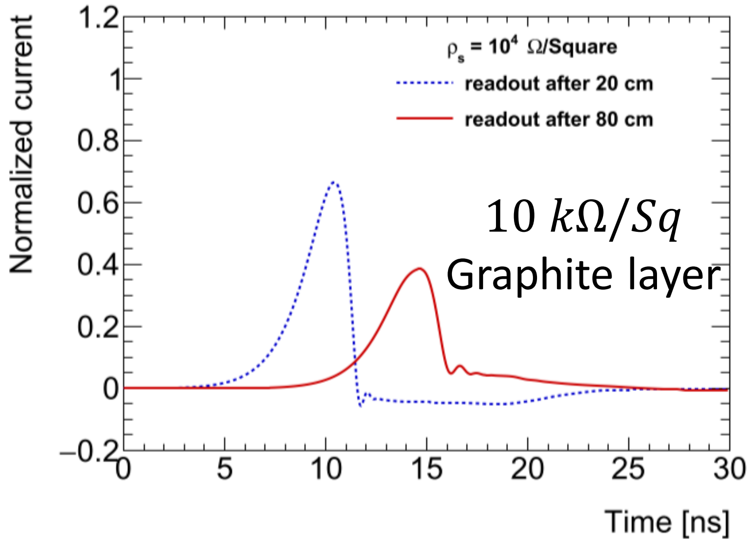
ϕ panel ToF distribution
HV = 5.7 kV

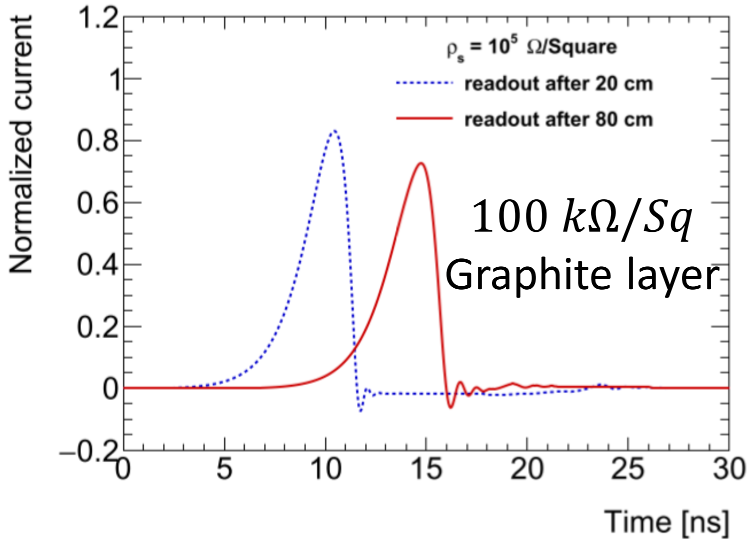
Conclusion of singlets assembly and tests

- Two RPC singlets been assembled and tested with good performance
  - Efficiency measured to be 93% for both singlets at $5.7\ \mathrm{kV}$
  - Cluster size < 3
  - Noise rate $< \ 2\ \mathrm{Hz/cm^2}$
  - Time resolution $< 600\ \mathrm{ps}$
- One singlets would be installed onto ATLAS during the Phase-I upgrade
- The USTC RPC team showed the ability to perform RPC singlet assembly and test

RPC R&D: signal attenuation study

- After avalanche, before FEE: signal induction and propagation
  - Signal induction loss has been studied extensively
  - Signal attenuation in propagation remains unclear
- Smaller signal for the thin-gap RPCs
  - Potential signal attenuation is crucial for the trigger efficiency
- Simulation results indicates attenuation exist
  - Correlated with the graphite layer

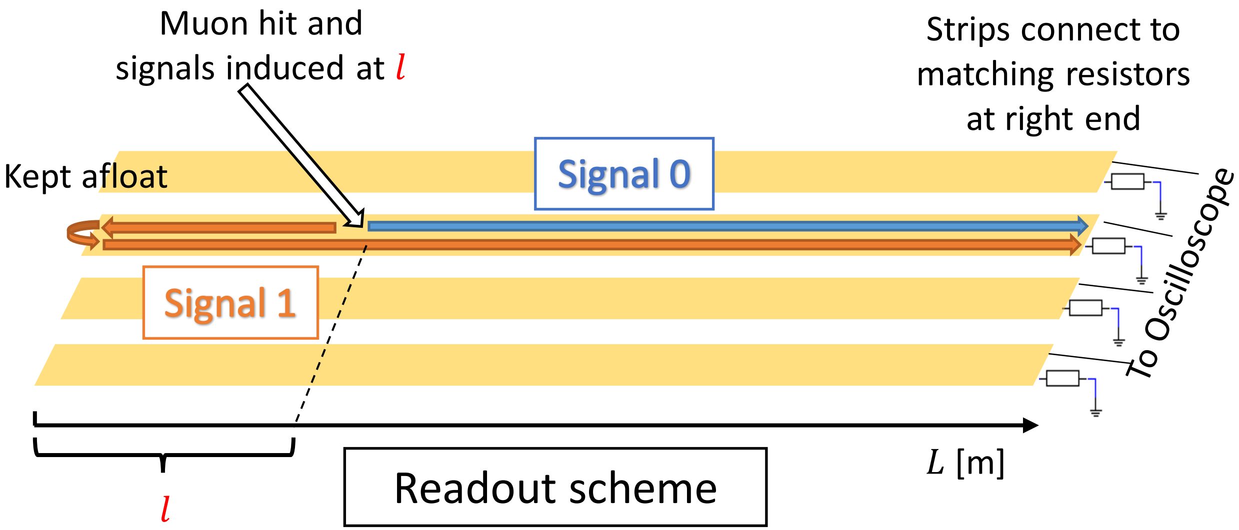




Experiment set-up

❖Readout scheme

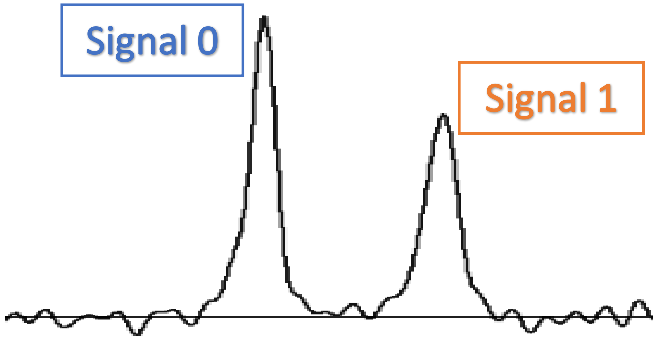
- Readout strips kept afloat at left end
- Signal 0 and 1 induced identically
- Signal 1 got reflected at left end
- Signal 1 readout at right end, following signal 0, with different propagation distance ($2l$)
- Readout by oscilloscope without FEE



Readout scheme

❖Reconstruction of propagation distance difference

- $2l = LE_{difference} \times velocity$



A typical event

❖Study the loss in charge as a function of the propagation distance difference($2l$)

Signal attenuation

❖ Definition

- Charge: integral between 10% points
- Charge ratio: $Charge_{sig1}/Charge_{sig0}$

❖ Quantify the attenuation rate A_{charge}

- Fit function: $y = e^{-A_{\text{Charge}} \cdot x}$
- $A_{\text{charge}} = \ 0.106 \pm 0.001\ [\text{m}^{-1}]$

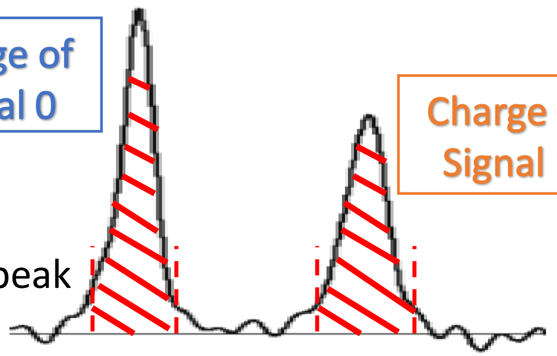
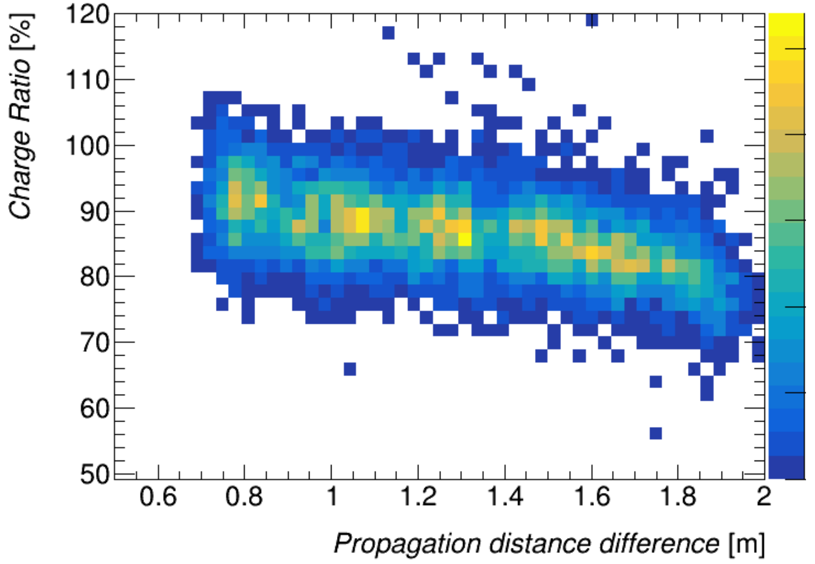
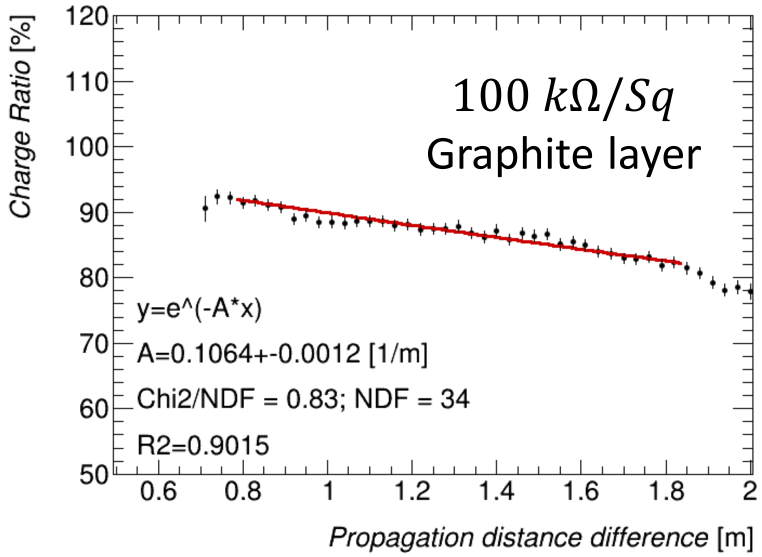


Illustration of charge



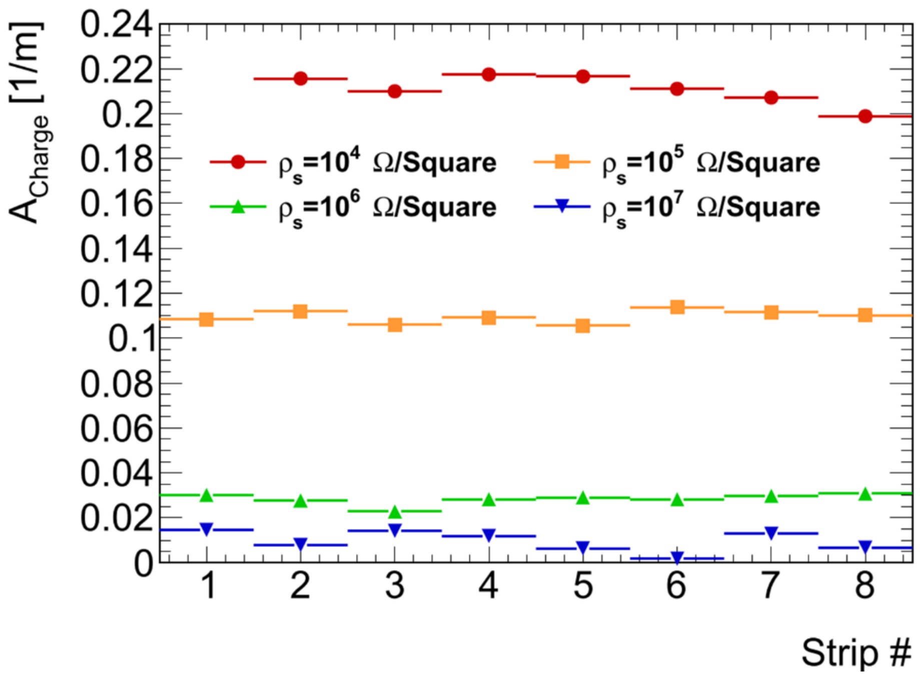
Profile the histogram along X axis



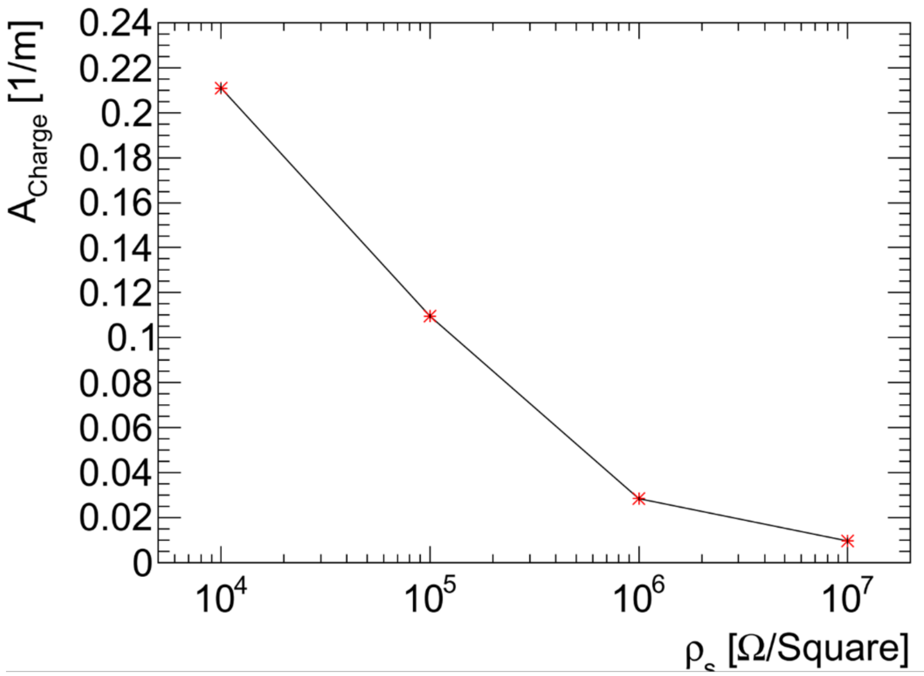
Signal attenuation rate Vs. graphite ρ_s

❖ Same measurements performed on different RPCs

- Surface resistivity of the graphite layers $\rho_s = 10k, 100k, 1M, 10M\ \Omega/\mathrm{Sq}$
- Strongly depending on the ρ_s
- When ρ_s is high, attenuation can be suppressed



A_{charge} distribution along strips



average A_{charge} VS ρ_s

More resistive graphite is better?

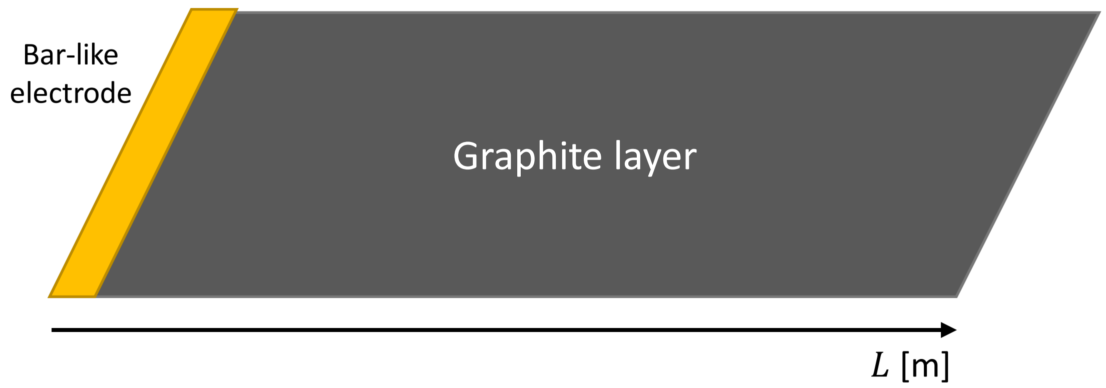
❖ Voltage drop ΔV for BI RPCs

- Caused by current flowing along the graphite layer
- $\Delta V(l) = \frac{1}{2} r q \rho_s l^2$
- r, the count rate, $= 300\ Hz/cm^2$
- q, average charge delivered per count, $= 2\ pC$ for thin-gap RPC
- ρ_s, the graphite surface resistivity, $= 620\ k\Omega/Sq$
- For BI RPCs, $\Delta V_{Max} = \Delta V(2.5) \approx 10\ V$

❖ Currently negligible

❖ Need to be taken care if

- RPC getting larger
- Cope with higher count rate

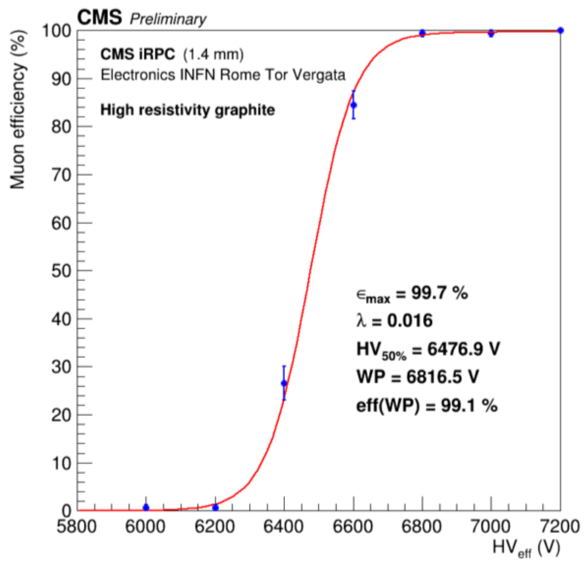


Conclusion of signal attenuation study

- Attenuation in signal propagation has been measured
- High surface resistivity of graphite layer could suppress the attenuation in propagation
- The V_{th} of the FEE should be taken care
- Phenomenon met by CMS RPC group could be explained

High Resisitivity Graphite : 600 kΩ

Working point - 6.82 kV ; Efficiency - 99.1 %.



Low Resisitivity Graphite : 50 kΩ

Working point - 6.89 kV ; Efficiency - 97.3 %.