Double-Ends Readout in RPC Detector

Quanyin Li

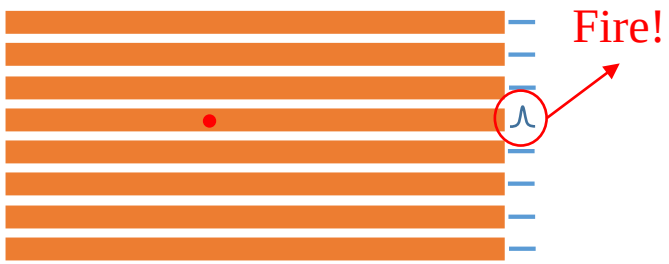
University of Science and Technology of China

2020.11.07

The 6th China LHC Physics Workshop

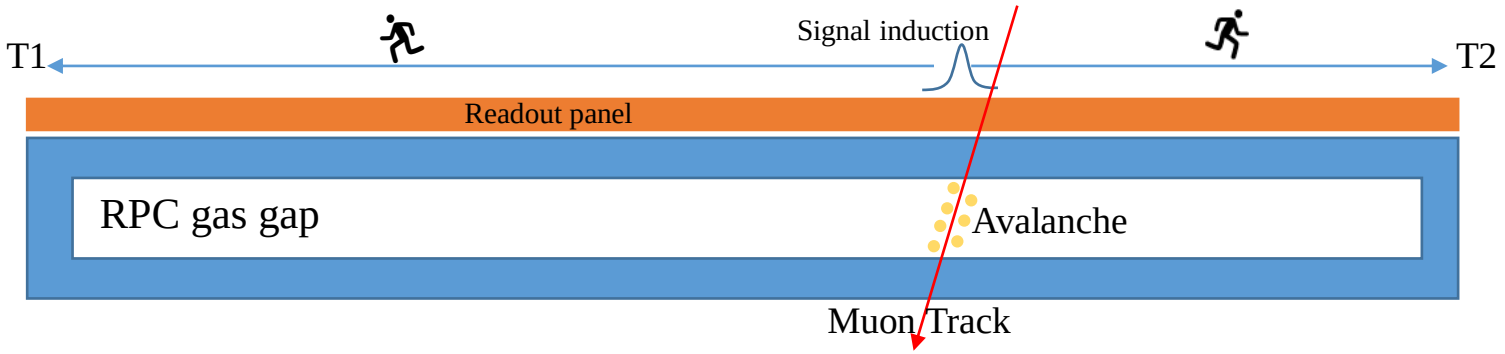
Introduction

- Traditional method:



Spatial resolution: $\frac{Width\ of\ strip}{\sqrt{12}}$

- Double-Ends method:



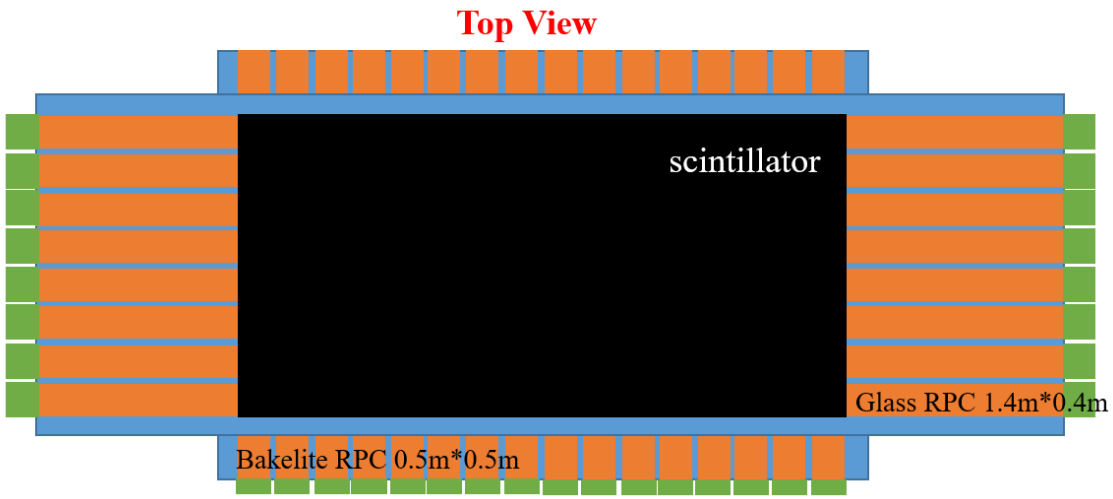
Reconstructed hit position: (T2-T1)*v/2

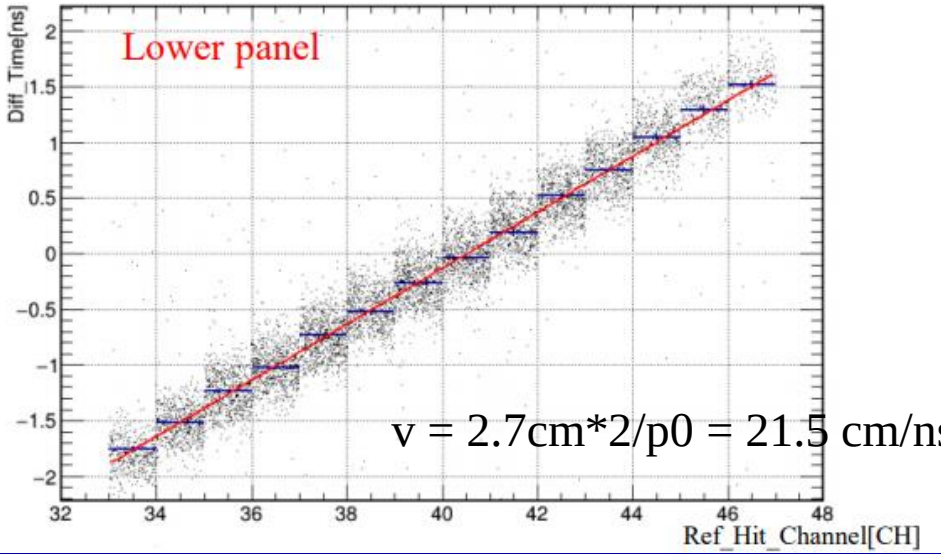
- Resolution contribution of double-ends method:
  - $\sigma_T = \sigma_{Avalanche} \oplus \sigma_{T\_transmission} \oplus \sigma_{FEE} \oplus \sigma_{TDC}$, $\sigma_{Avalanche}$ is dominated.
  - $\sigma_{Avalanche}$ is same for T1 and T2.
  - Determined by $(\sigma_{T\_transmission} \oplus \sigma_{FEE} \oplus \sigma_{TDC}) * v$
  - TDC vx1290A: σ_{TDC} < 35 ps
  - σ_{FEE} ~ 20 ps
  - Transmission speed: ~20 cm/ns

Expected spatial resolution: ~ 1 cm

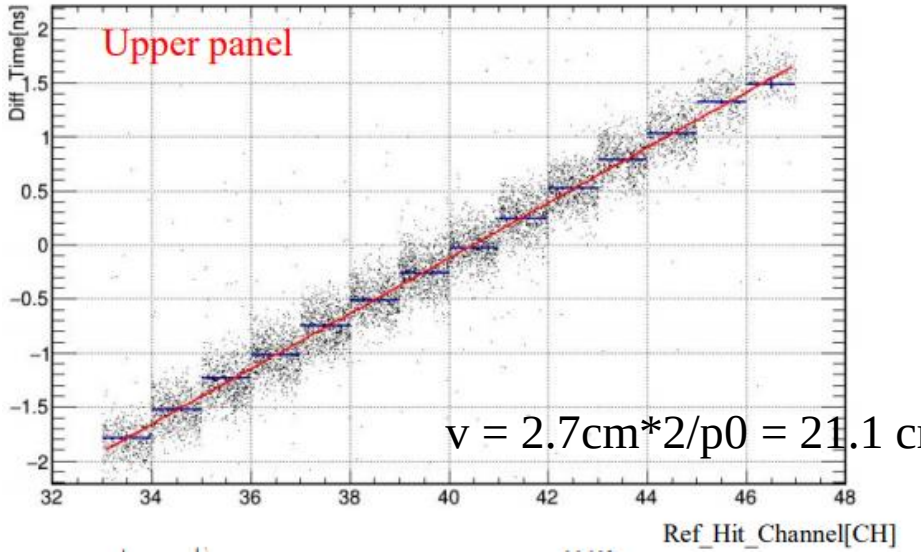
Setup to calculate transmission speed

- Two kinds of gas gaps are used:
  - Bakelite RPC with traditional readout method read signals from vertical strips.
  - Glass RPC with double-ends method read signal from horizontal strips
- Correlation between reconstructed hit position of the 2 gaps could be used for transmission speed calculation:





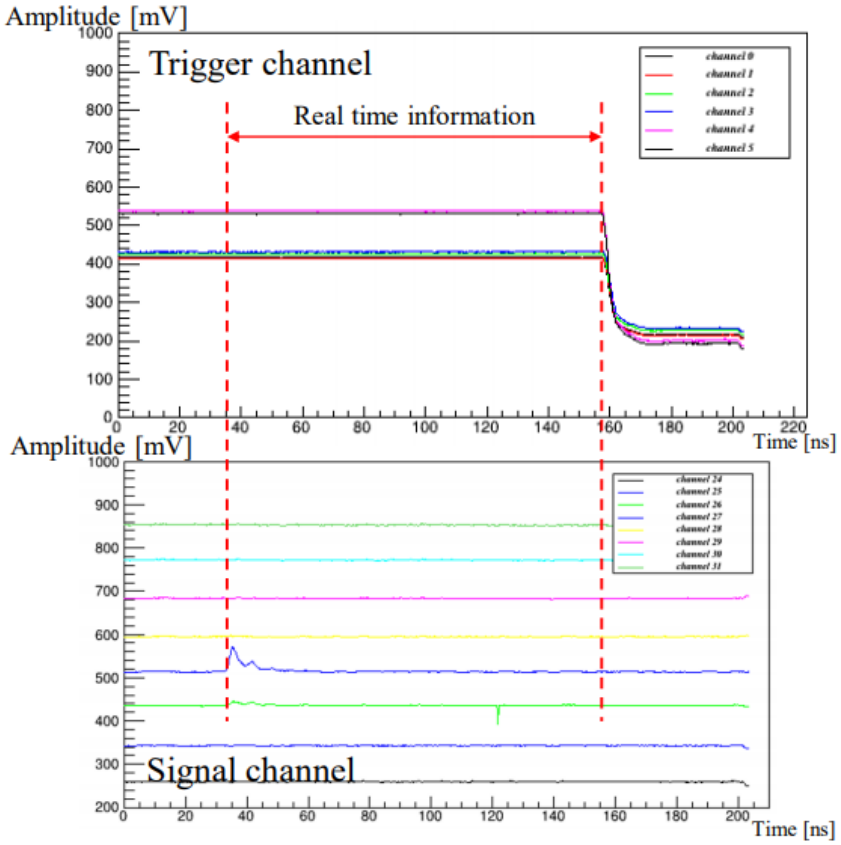
v = 2.7cm*2/p0 = 21.5 cm/ns

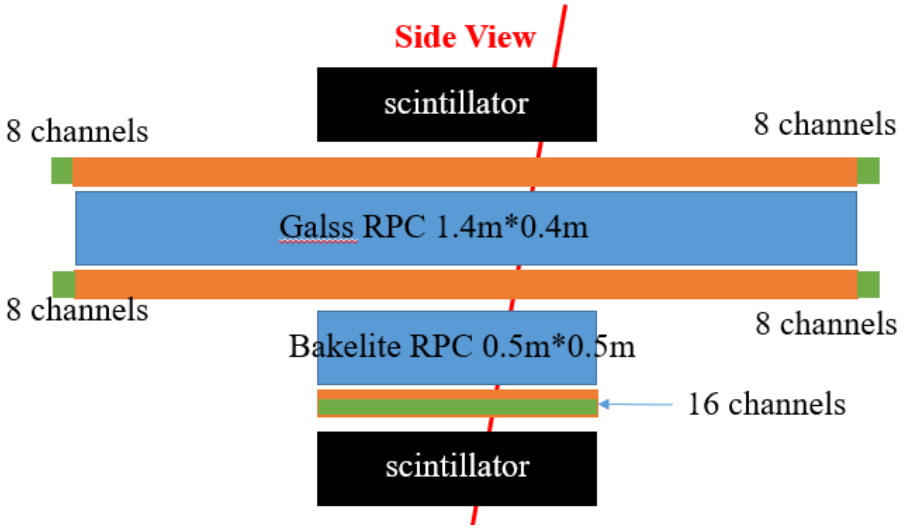


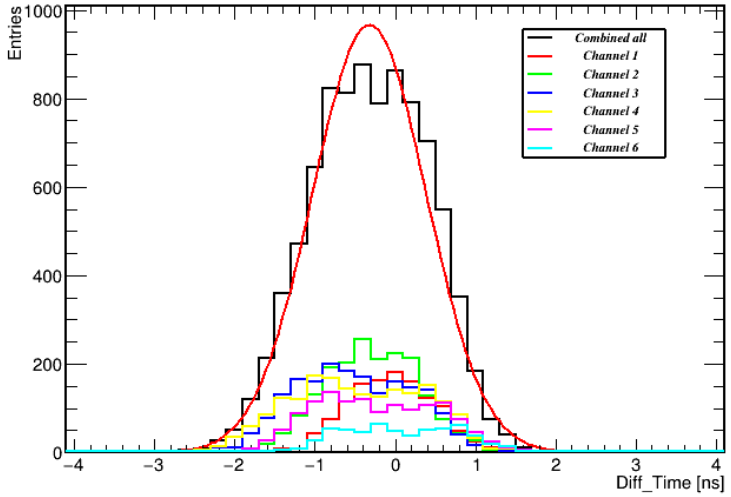
v = 2.7cm*2/p0 = 21.1 cm/ns

Review of the result without discriminator

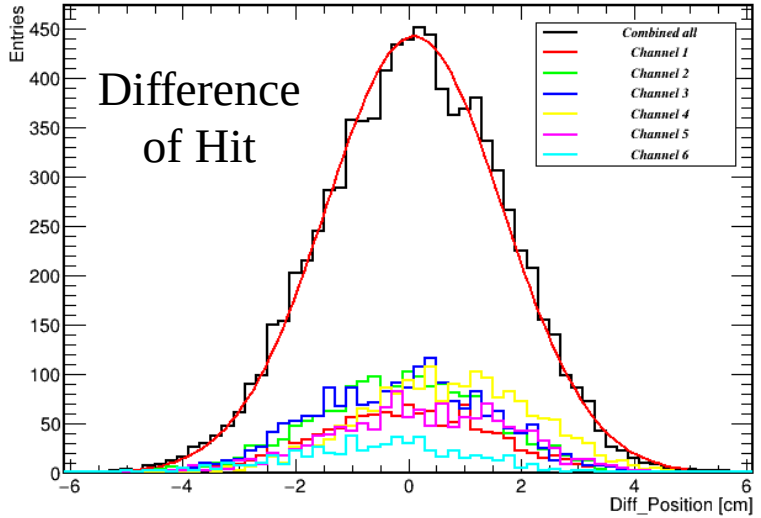
Previous study with analog output(waveform signal before discriminator).







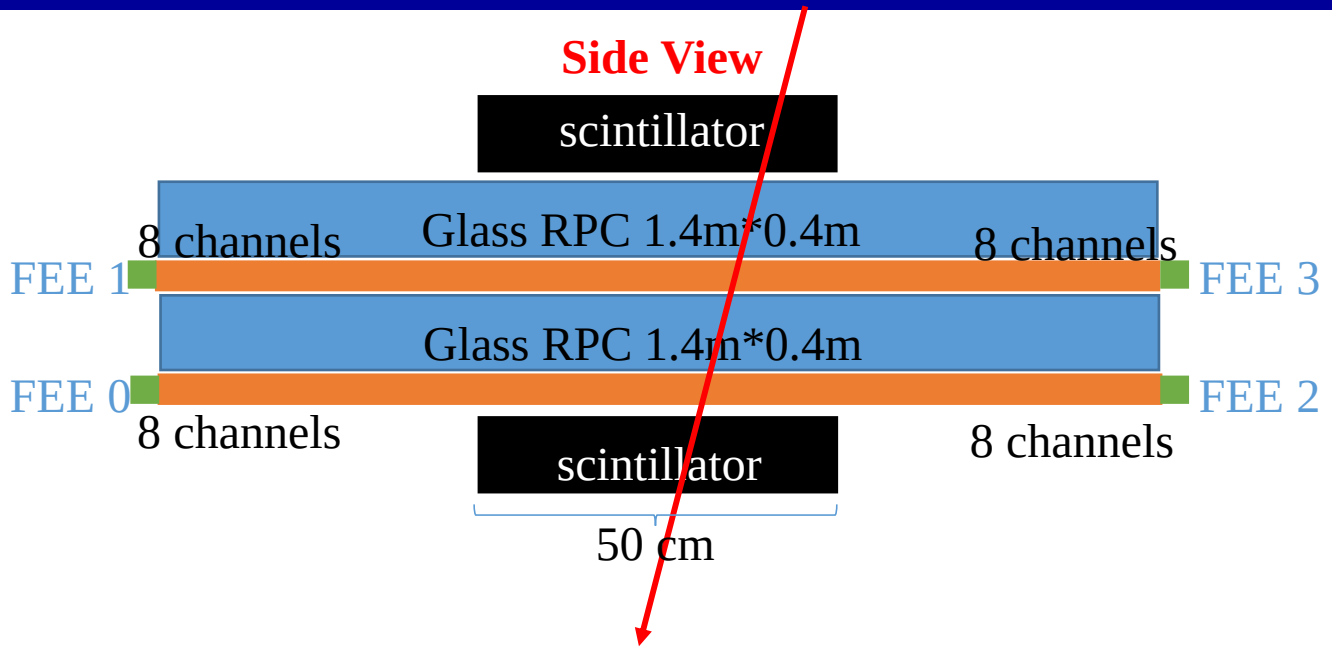
Time resolution = 501 +- 3.2 ps

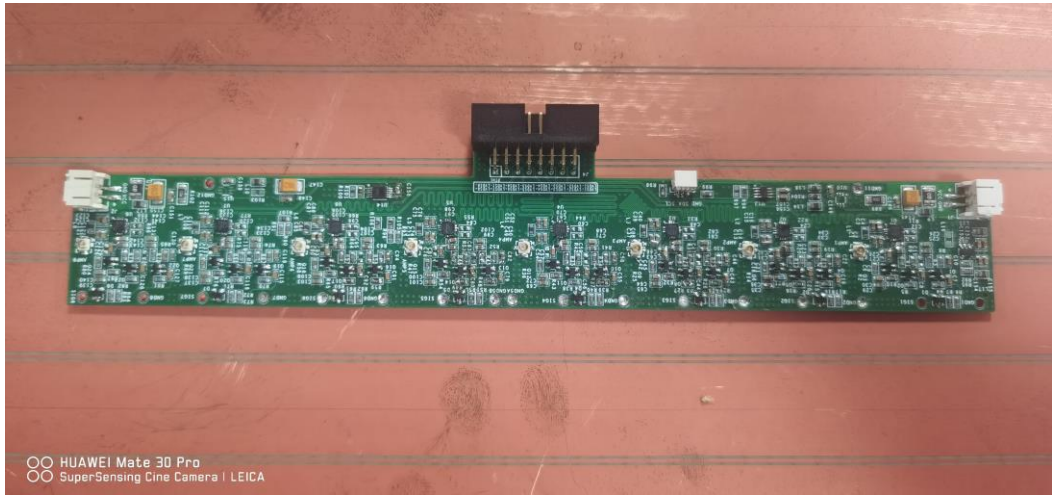


Spatial resolution = 1.11 +- 0.008 cm

Setup of double-ends measurement system

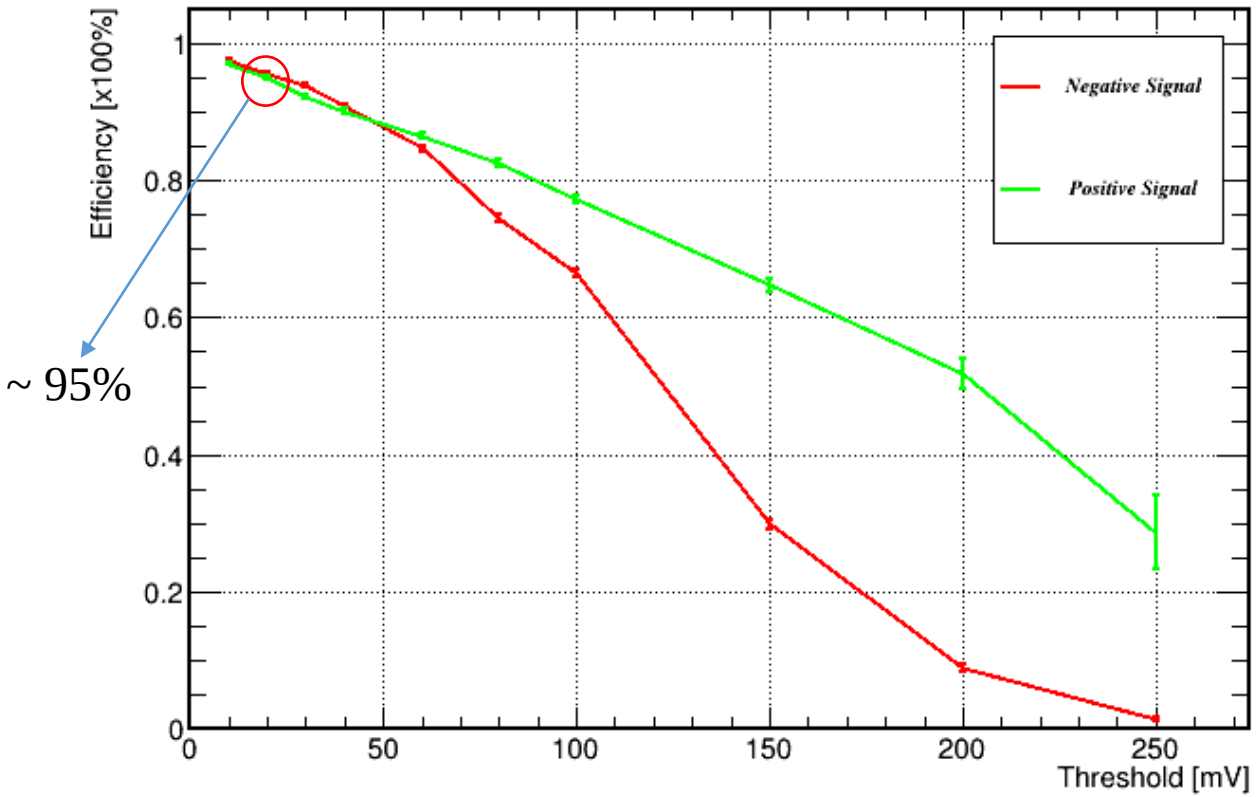
- Trigger: Coincidence of 2 scintillators which covers the region of 8 strips.
- Two glass RPC produced in USTC local lab with 1 mm gas gap.
- HV of RPC: 6400 V
- Totally 4 * 8 channels.
- Parameters of FEE and TDC:
  - FEE board: designed by USTC team with amplifier, discriminator and LVDS output.
  - LV of FEE: 3.3 V
  - Threshold: 1 mV to 2V by step 1 mV.
  - TDC: vx1290A with 25 ps LSB and < 35 ns resolution.





Efficiency of threshold scan

- Threshold of one RPC are set to be 50 mV as reference RPC.
- Vary the threshold of the other RPC from 10 mV to 250 mV as test RPC.
- Cosmic muons are selected by the coincidence of 2 scintillators and reference.
- Calculate the efficiency of signals from the test RPC.

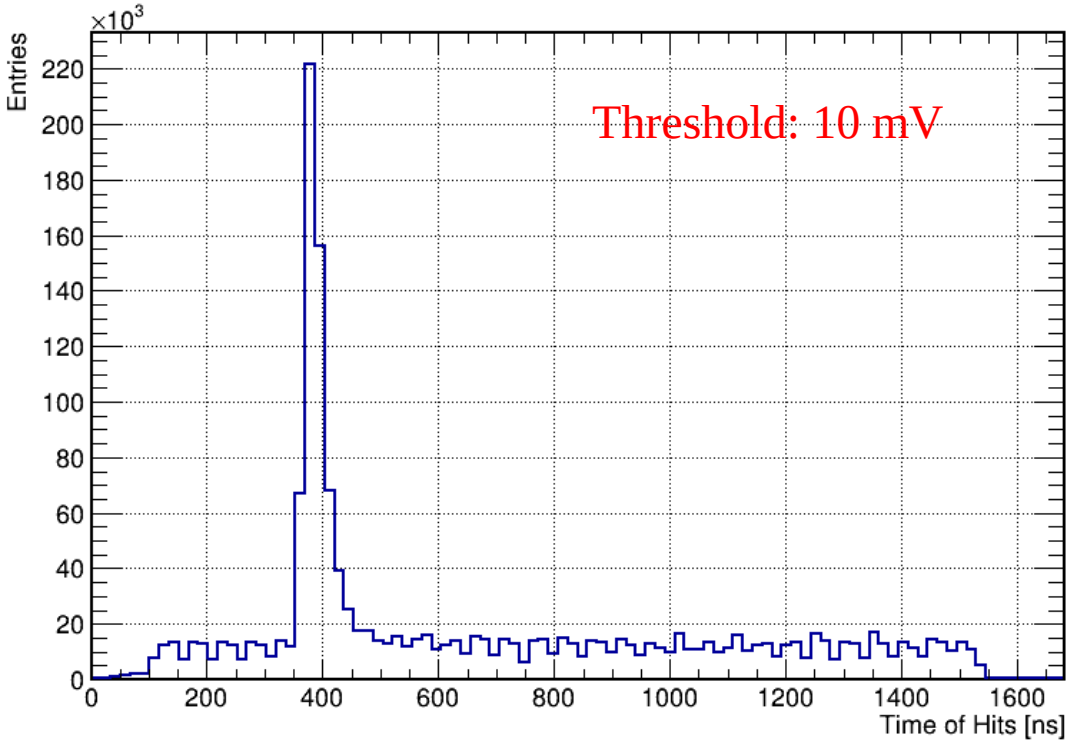


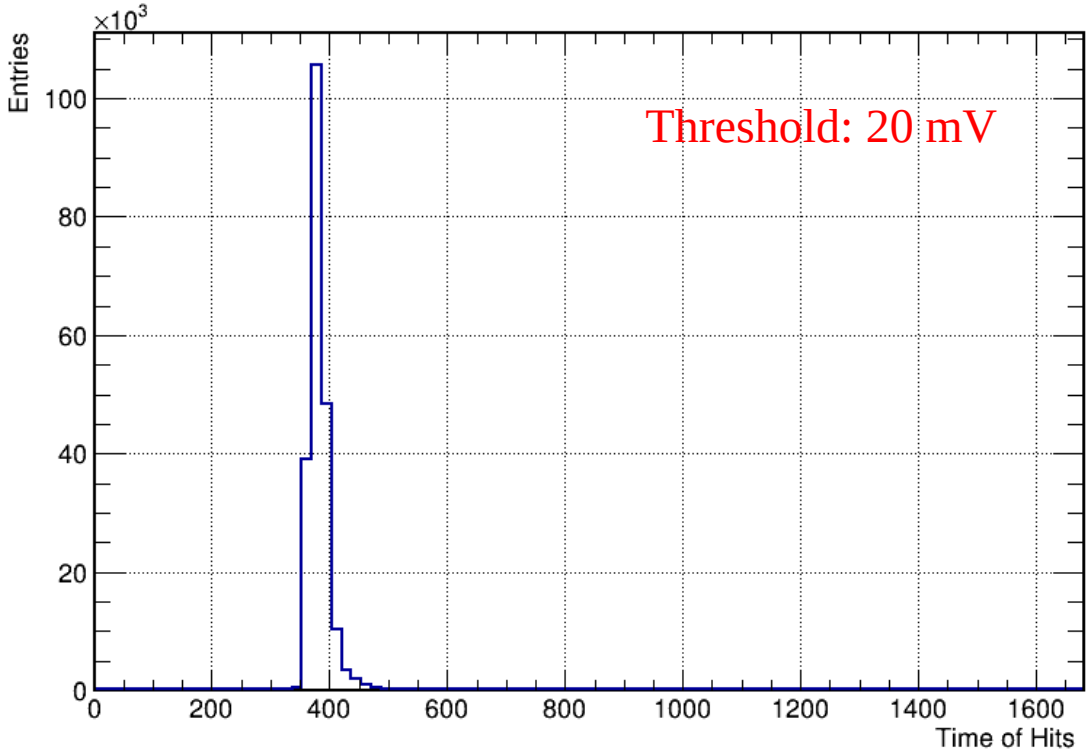
For cosmic ray test, ~95% is a very good efficiency.

Amplification for positive and negative signals are different.

Noisy rate

Time of all hits include signal(360 ns to 450 ns) and noise(other time region)



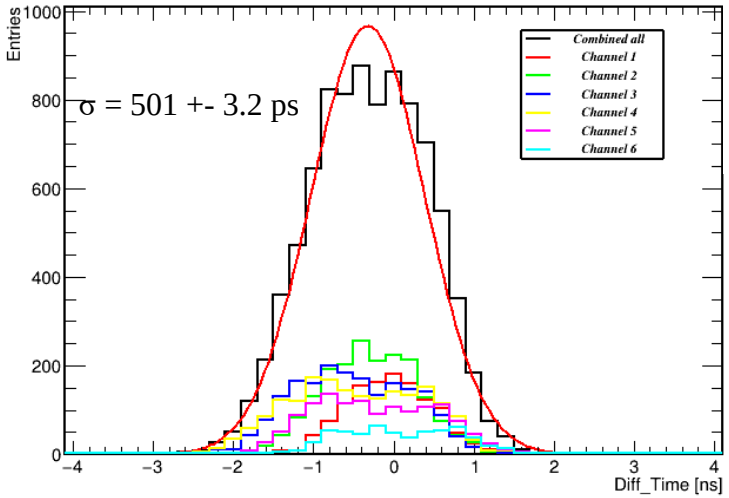


Noise rate @10mV: 8.5 kHz/cm^2.
Accidental coincidence counting rate: 1.16 Hz
Unacceptable!

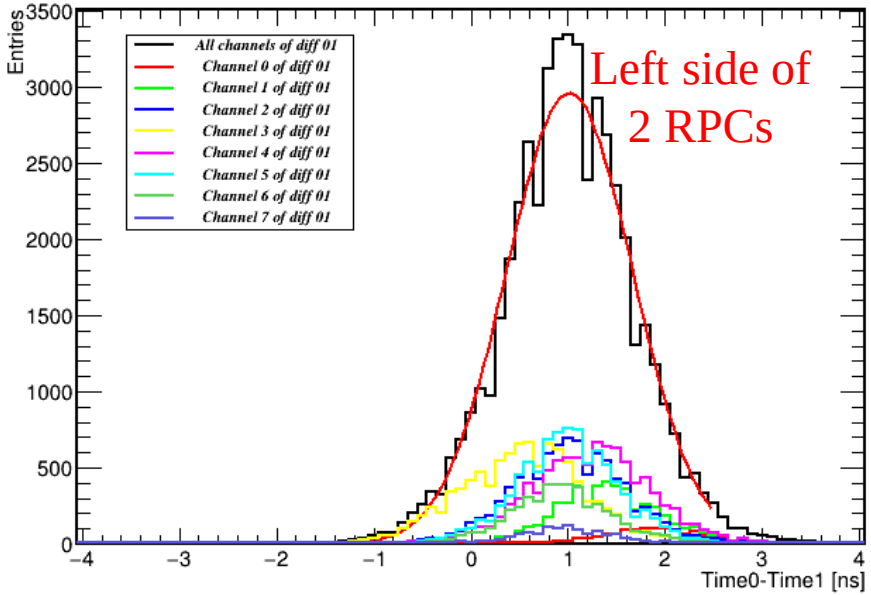
Efficiency of 10 mV is better than the other threshold points. But this channel is too noisy.

Time resolution:

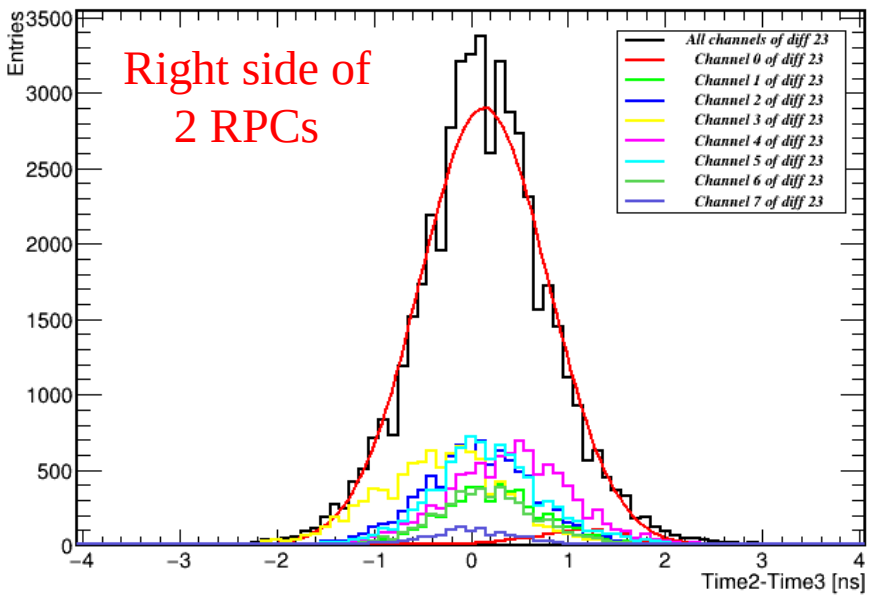
- Distribution of time difference from 1 end of the strips.
- Fit the distribution with Gaussian function.
- Time resolution = sigma/sqrt(2).



Time resolution in waveform analysis



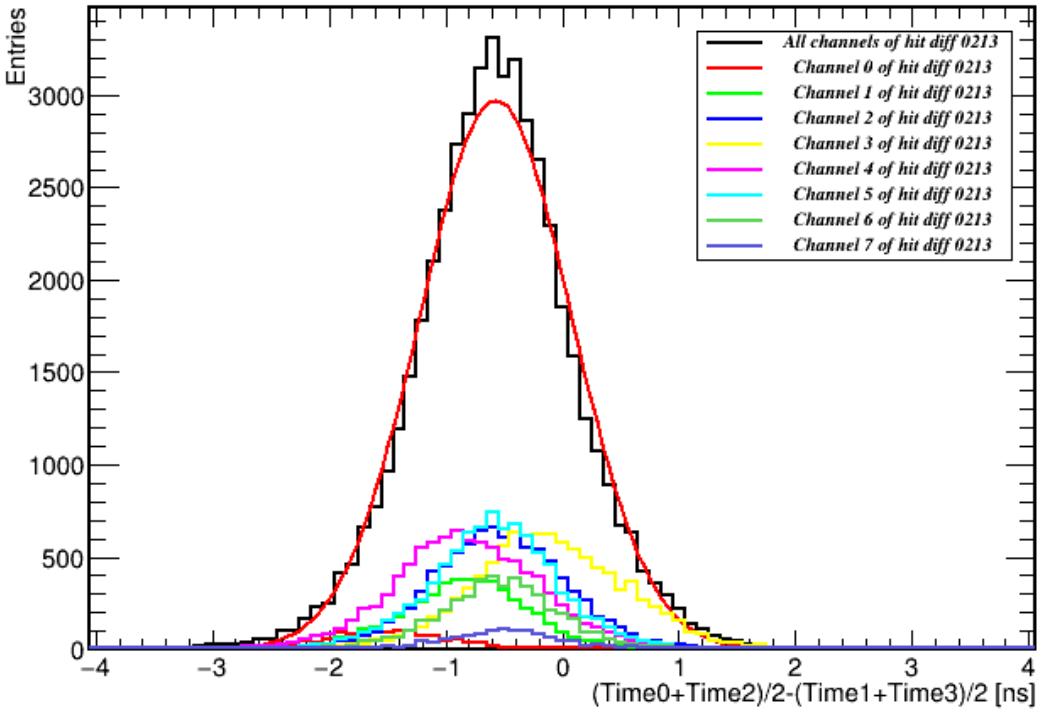
Time resolution: 459 +- 1.9 ps



Time resolution: 467 +- 1.9 ps

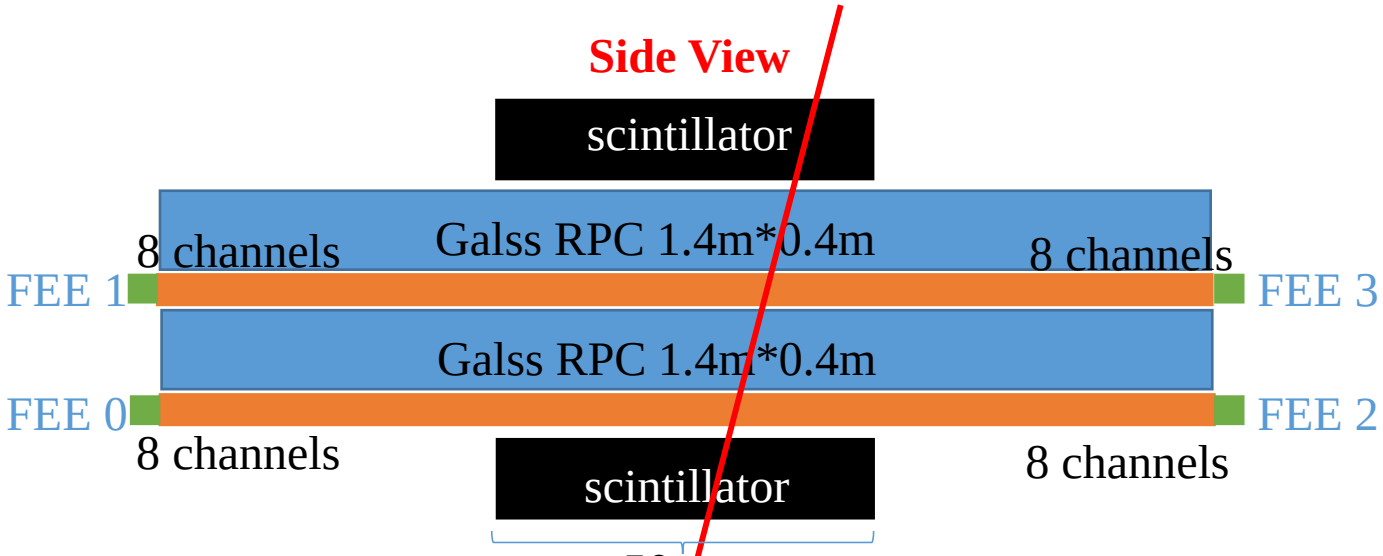
Time resolution calculated in different threshold are similar.
Time resolution of threshold 50 mV as example.

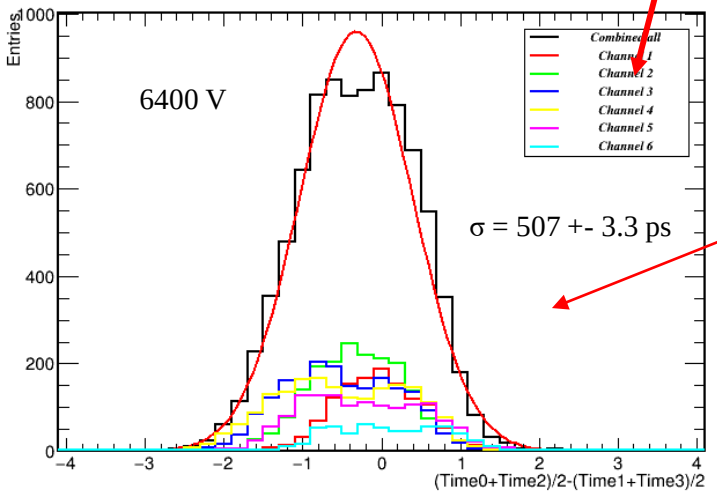
Time resolution improvement:



Time resolution: 461 +- 1.82 ps

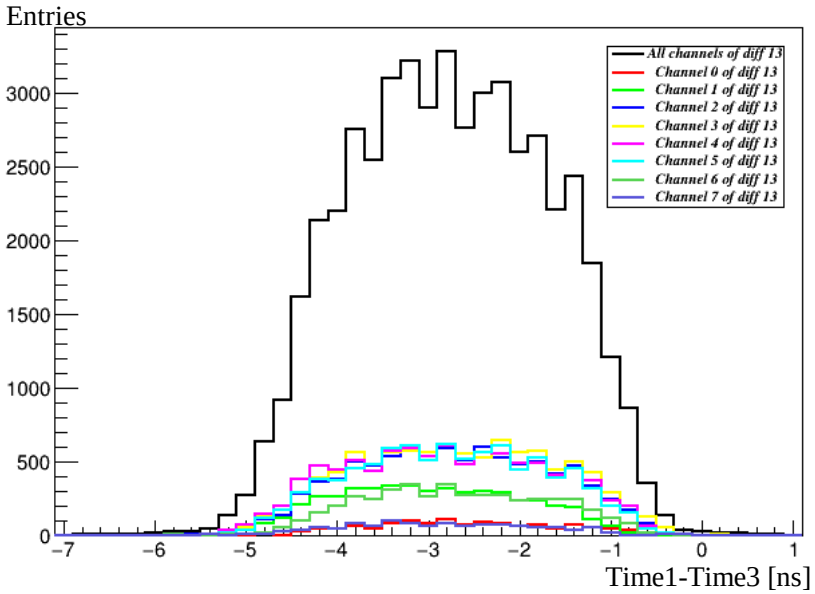
- In this test, there is no obvious improvement since the hit position in 2 RPCs are same.
- This improvement will eliminate the time jitter caused by signal transmission.



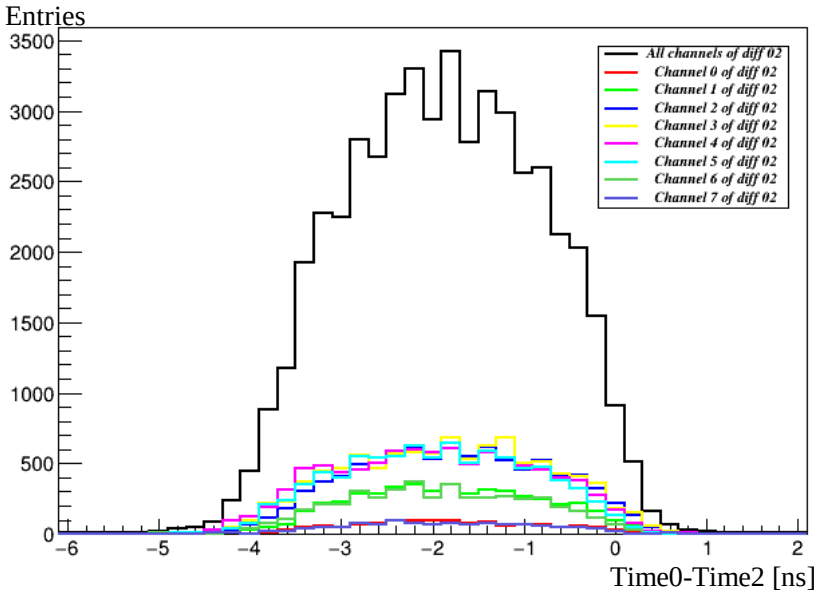


Same time resolution improvement in waveform analysis.

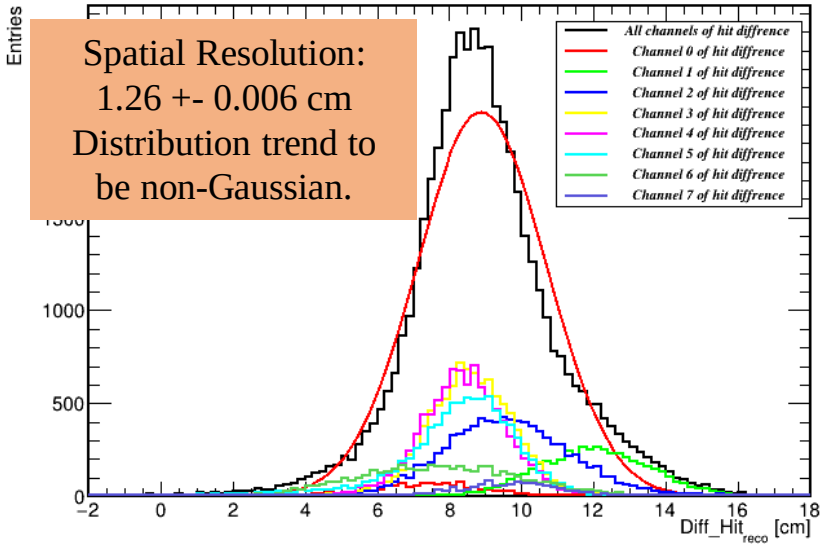
Hit position and spatial resolution



Hit position of every channel are not coincident.

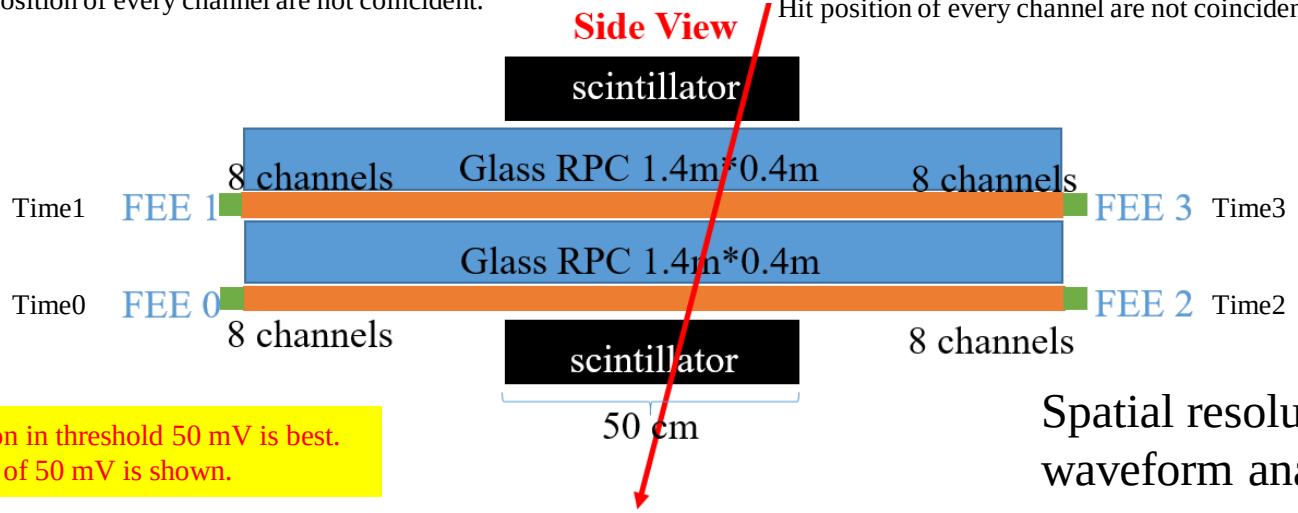


Hit position of every channel are not coincident.



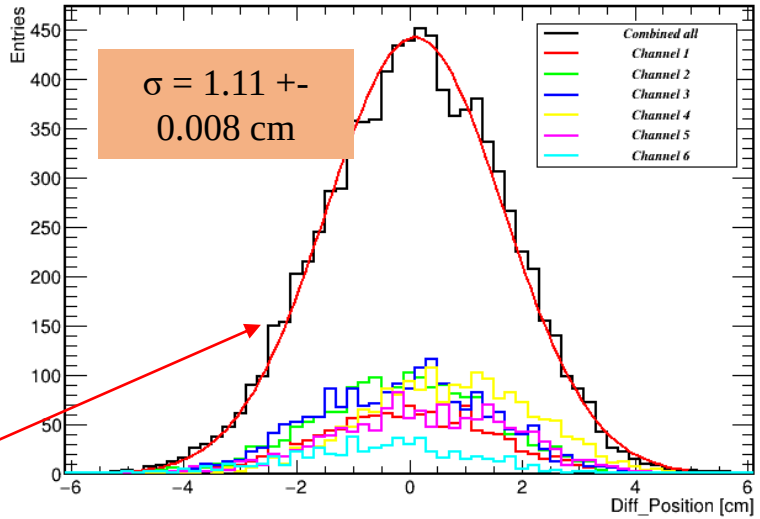
Spatial Resolution: 1.26 +- 0.006 cm
Distribution trend to be non-Gaussian.

Hit position difference between 2 RPCs are not around 0.



Spatial resolution in threshold 50 mV is best.
Result of 50 mV is shown.

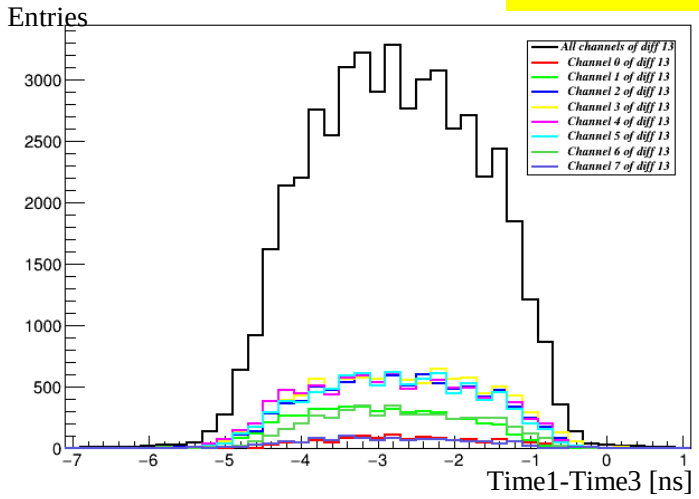
Spatial resolution in waveform analysis

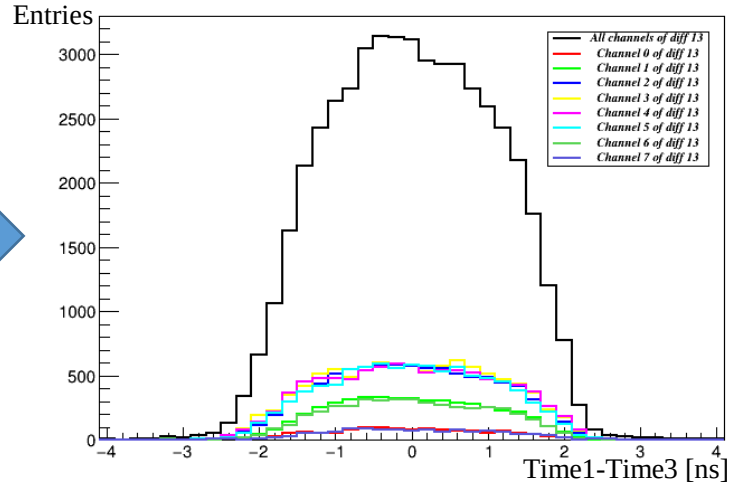


Calibration of hit position

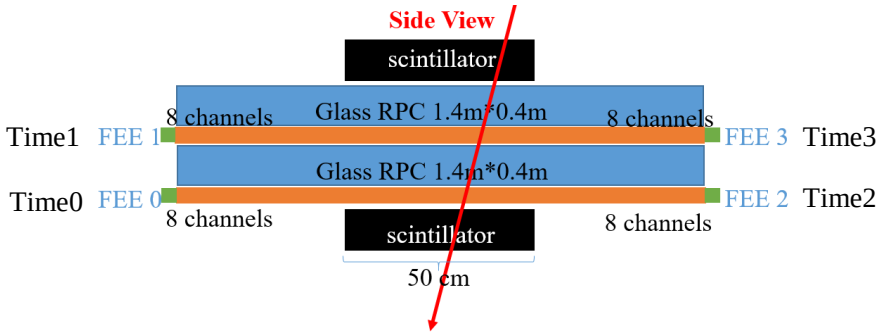
1. Get the mean value of distribution channel by channel
2. Shift the mean value of every channel to 0.

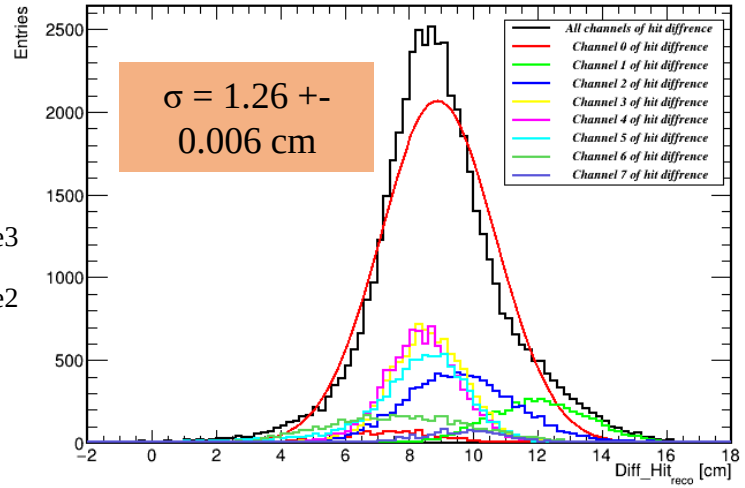
Center of hit distribution move to 0.

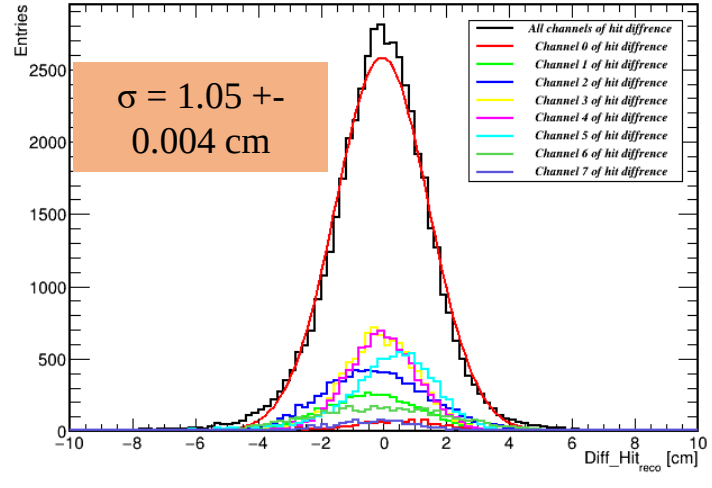




Difference of hit position in all of the channels are moved to 0.



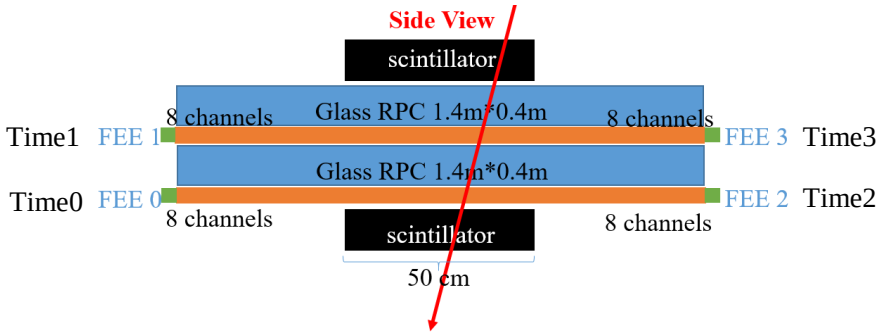




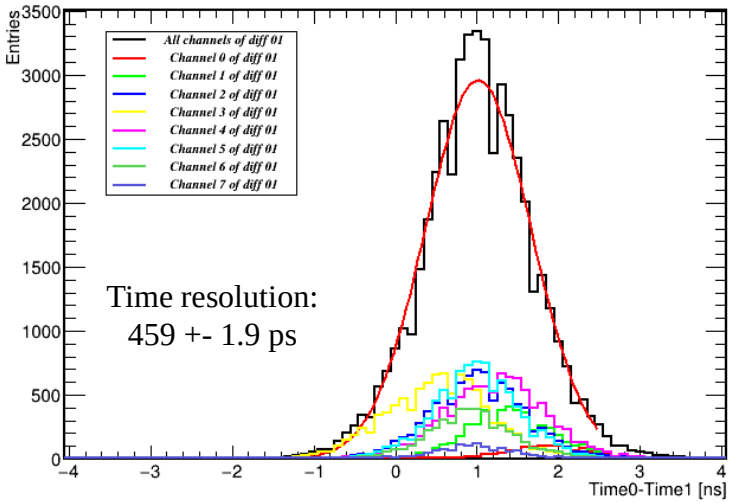
Calibration of time

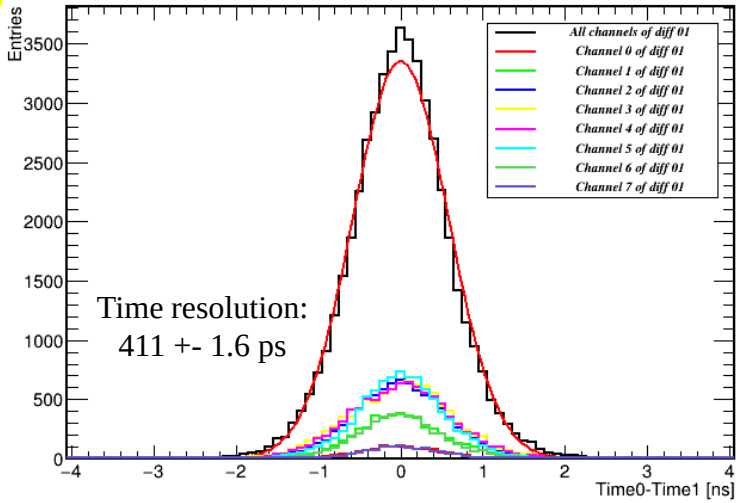
1. Get the mean value of distribution channel by channel
2. Shift the mean value of every channel to 0.

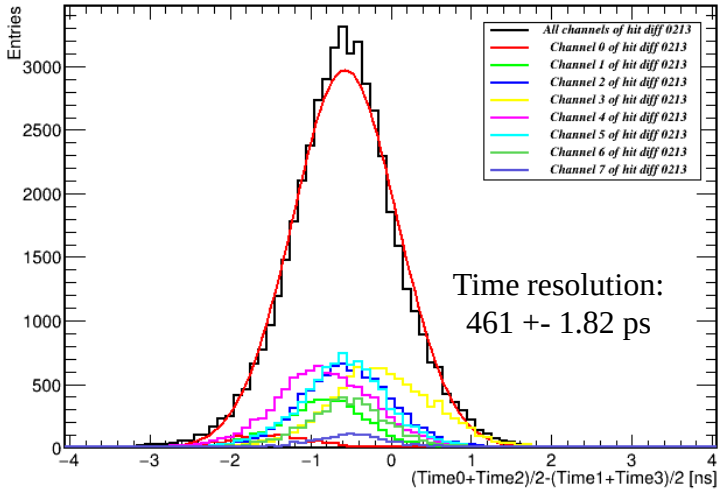
Difference of hit position in all of the channels are moved to 0.

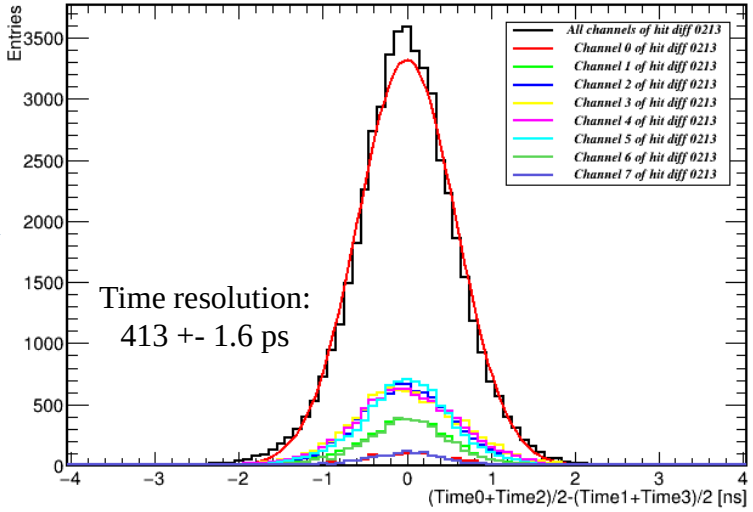


Center of hit distribution move to 0.





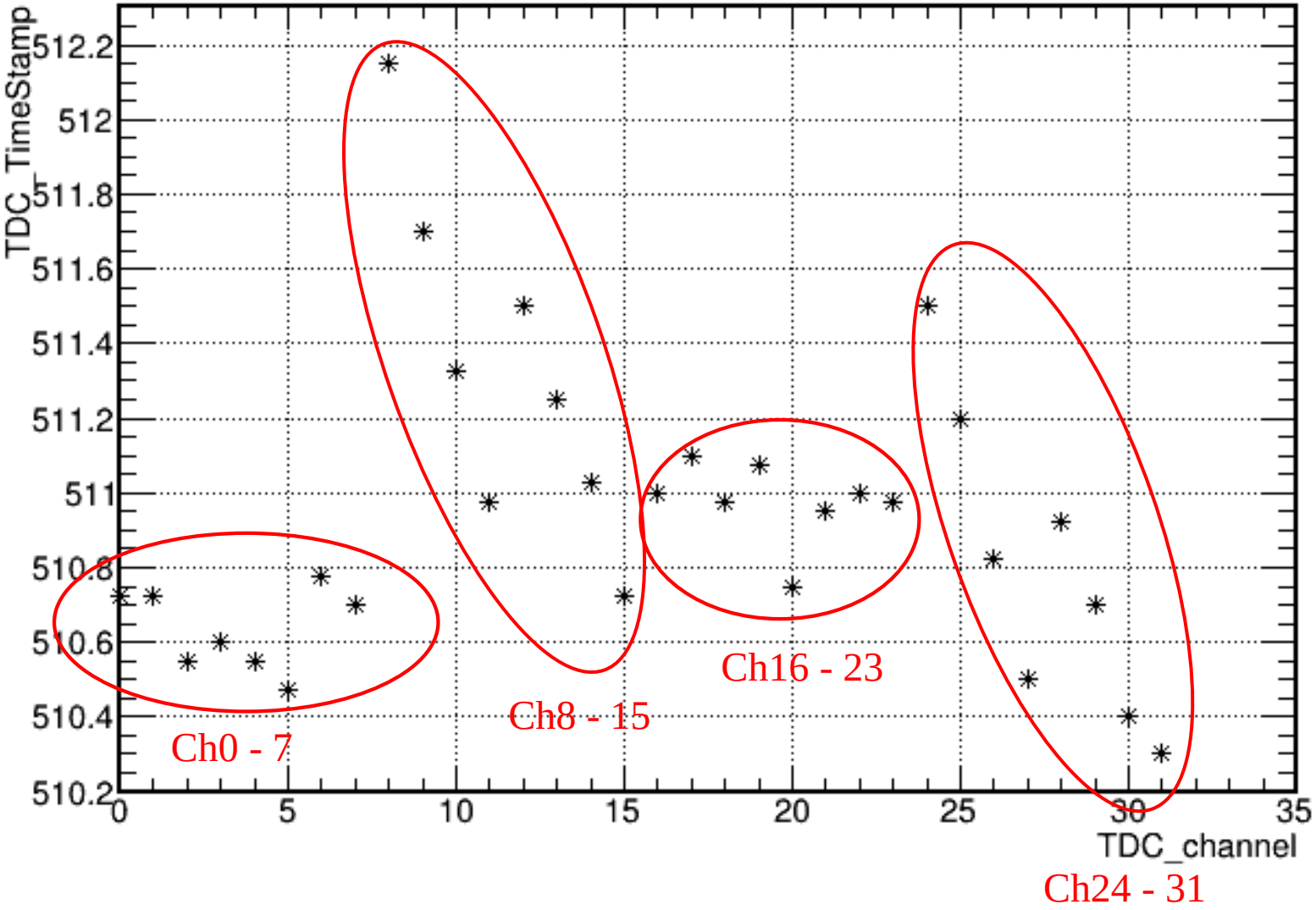




Summary

- Double-ends method to reconstruct hit position shows a good performance.
- Efficiency is ~95% @ 20 mV threshold.
- Time resolution: ~411 ps
- Spatial resolution: ~1.05 cm
- Satisfy the requirement of ATLAS Phase II Upgrade.

Backup



Time of signal generated by signal generator.