

R&D on Double-end Readout RPC for ATLAS Phase-II Upgrade

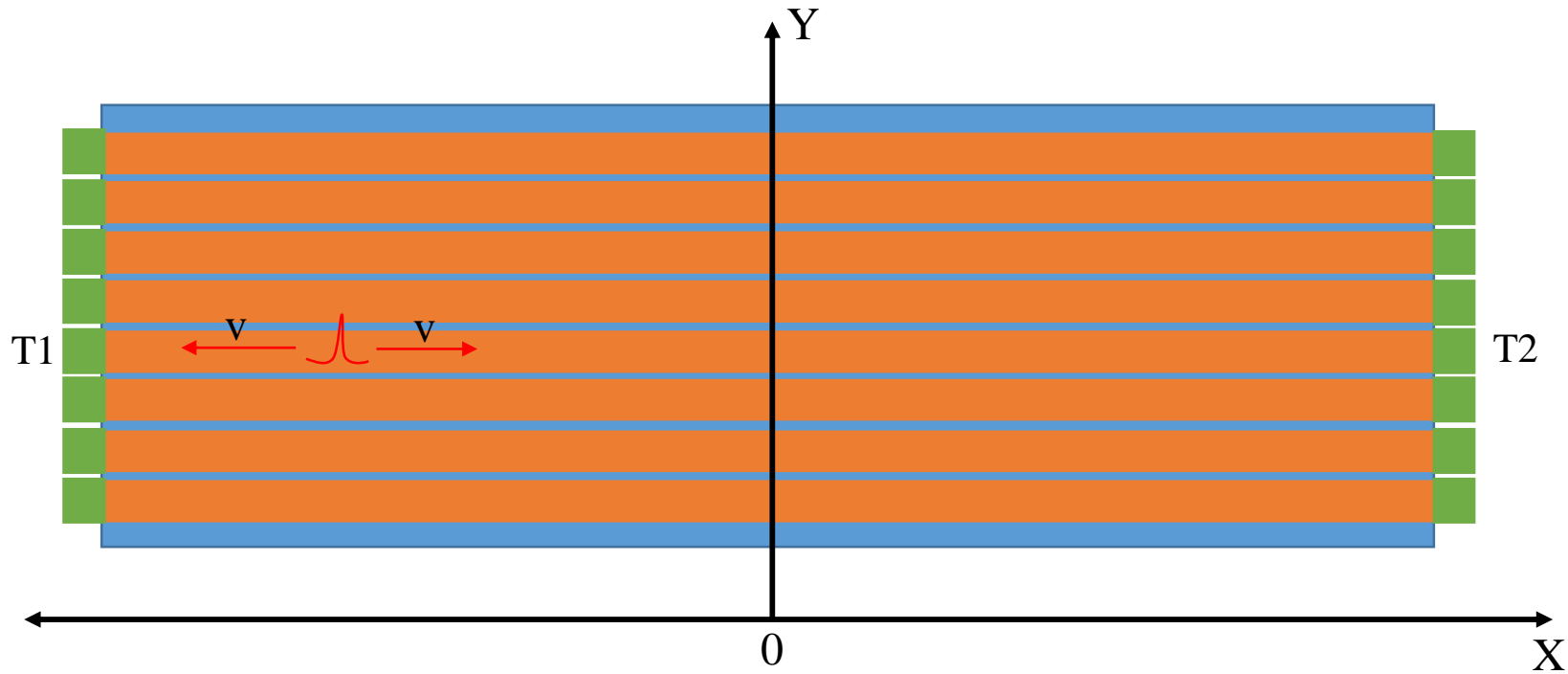
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General Idea



Reconstruct the hit position:

Y: The strip which propagates the signal(pulse)

X: $(T1-T2)*v/2$

v is the transmission speed that need to be calculated.

Introduction of detector components

➤ Glass RPC produced locally @USTC.

- Surface: 140cm * 40cm
- Glued by epoxy adhesive

➤ Honeycomb readout panel.

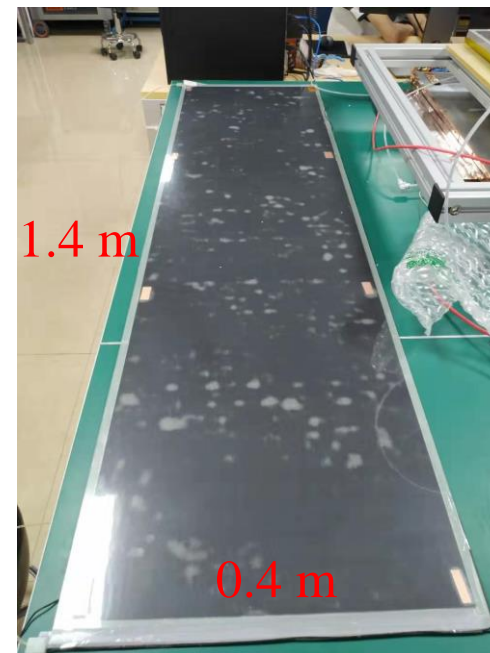
- ~3.5 mm thickness totally
- Honeycomb paper as medium
- Characteristic impedance(assembled): **19.5 ohm**



1 mm thickness glass
with $1\sim 3 \times 10^{12}$ ohm.cm

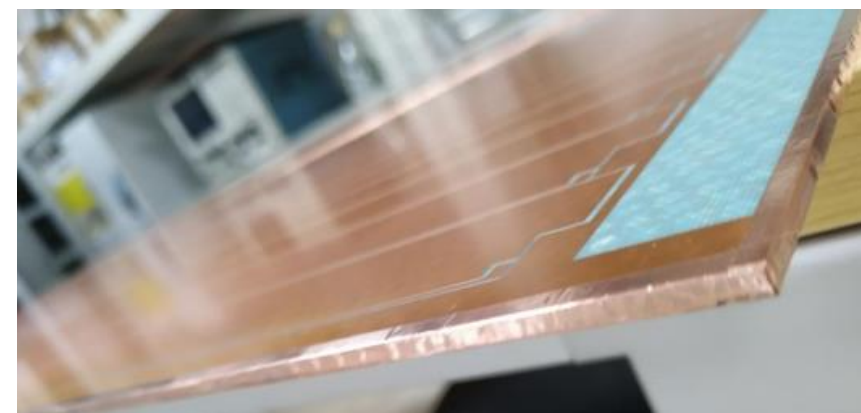
1 mm thickness spacer and gas gap

1 mm thickness glass
with $1\sim 3 \times 10^{12}$ ohm.cm



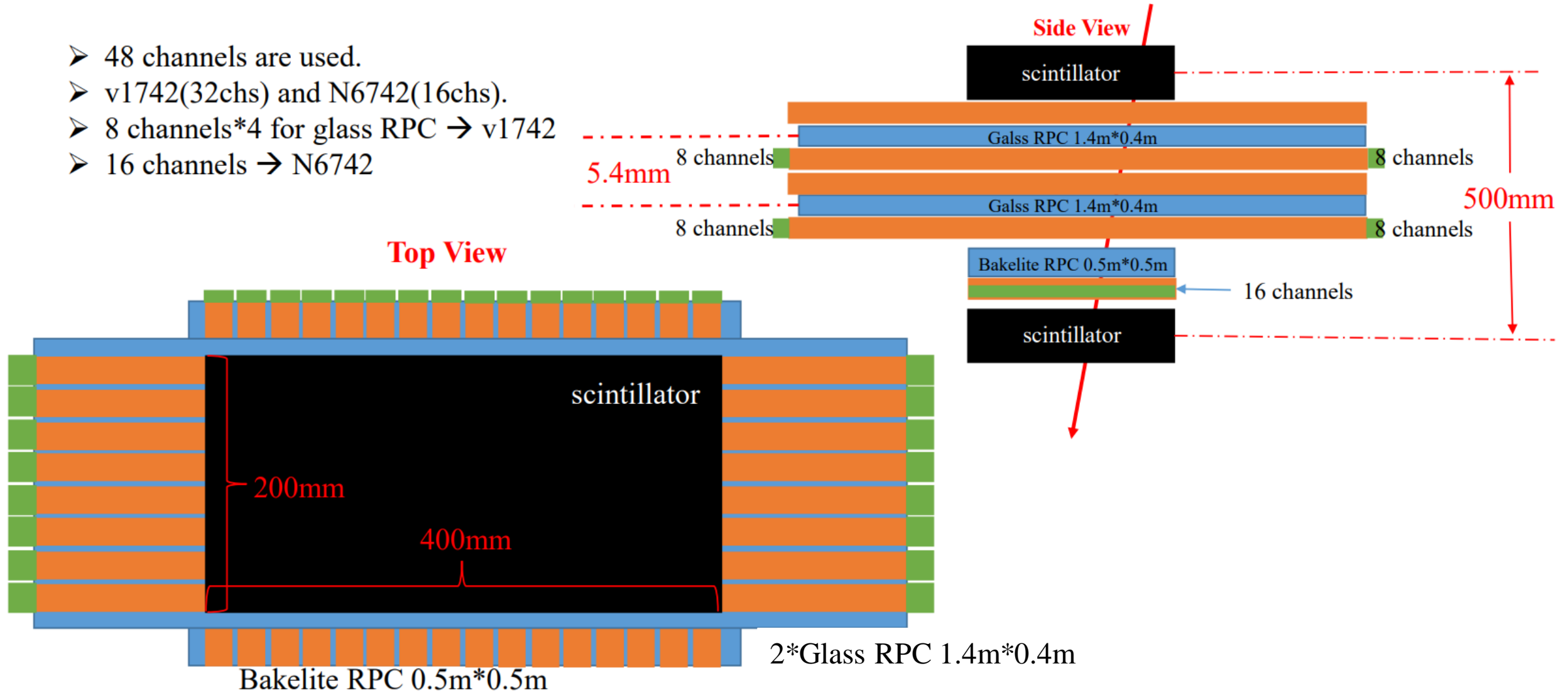
➤ USTC front-end board.

- Working voltage: 2.7V~3.3V
- Gain: 60(maximum)
- 2 stages amplifier
- Both analog(waveform) and digital(with discriminator) output
- Only analog waveform output is tested now.



Setup of System

- 48 channels are used.
- v1742(32chs) and N6742(16chs).
- 8 channels*4 for glass RPC → v1742
- 16 channels → N6742



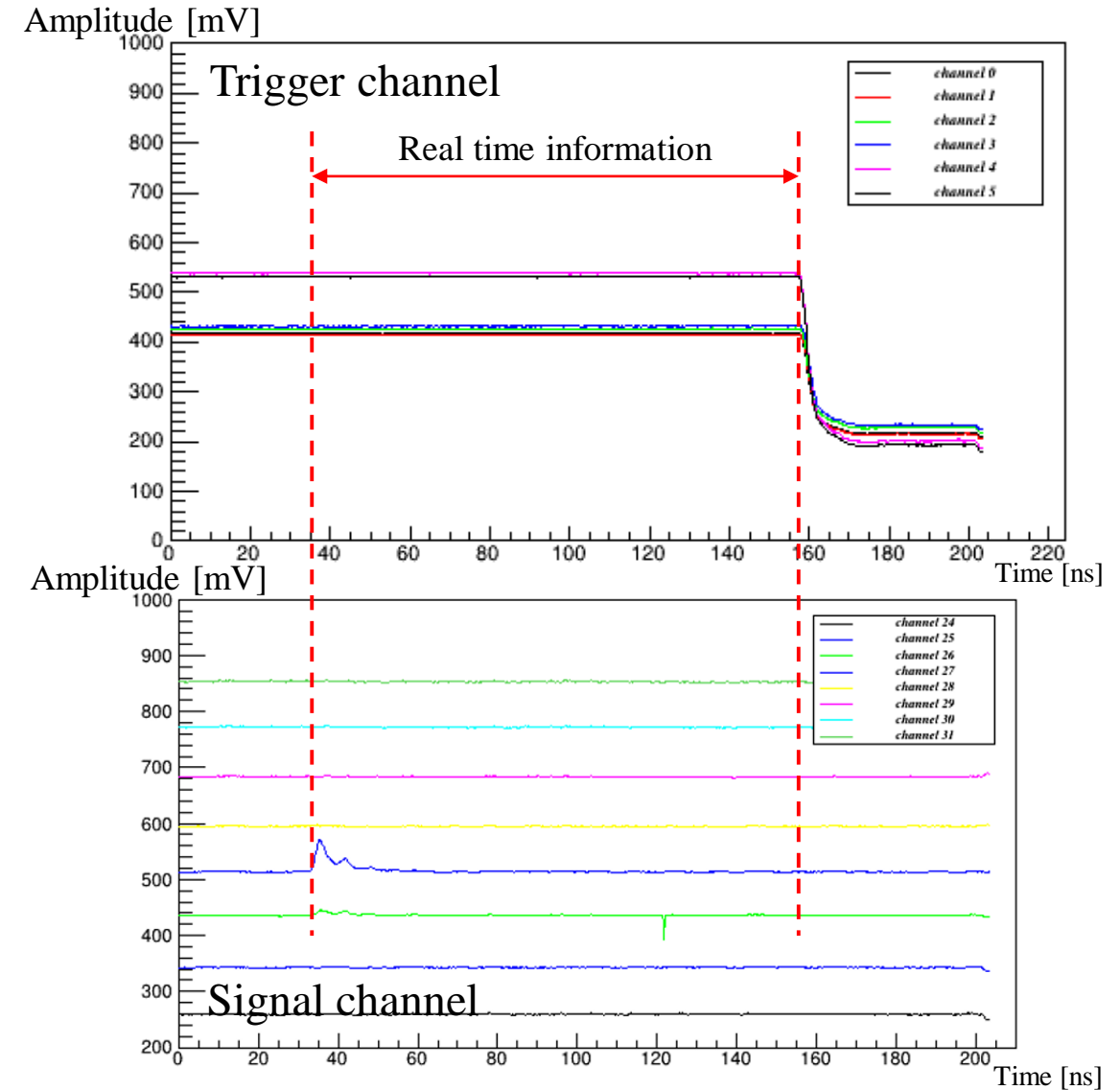
Waveform analysis

➤ Analysis method:

- 10th bin to 125th bin to calculate RMS and mean value
- 125th bin to 400th bin as signal region
- Threshold of trigger: 100 mV
- Threshold of reference RPC: 6 * rms
- Threshold of test RPC: 4, 5, 6 * rms
- Width of signal > 0.8 ns

➤ Time of signal:

- Baseline of trigger channel are calculated channel by channel.
- Real time information are calculated based on time of trigger channel

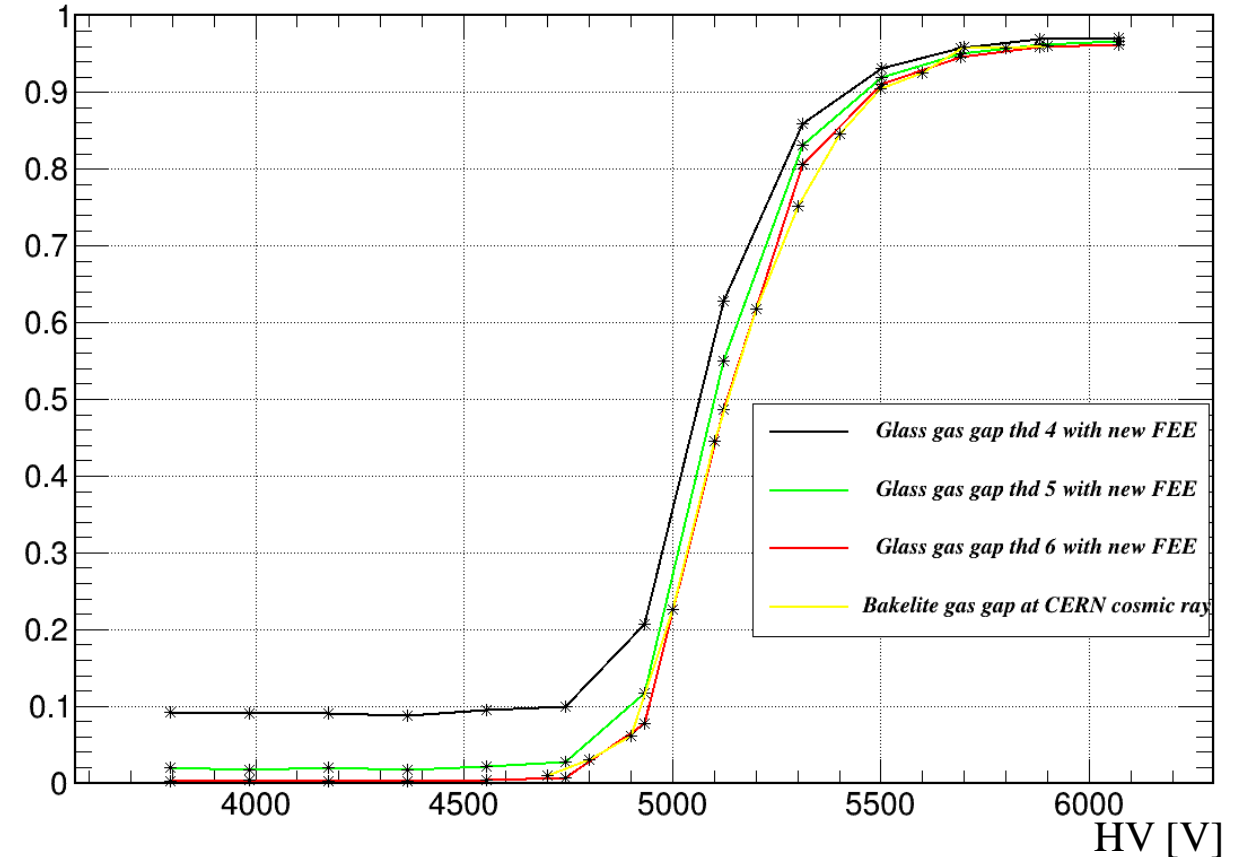


Efficiency

Efficiency calculation:

- Trigger: coincidence of 2 scintillators and reference bakelite RPC
- Number of trigger as denominator
- Signal: coincidence of 2 signals from both ends of fired strip
- Number of signal as numerator
- Different threshold are tested: 4, 5, 6 rms
- High voltage is corrected by pressure

Efficiency [*100%]

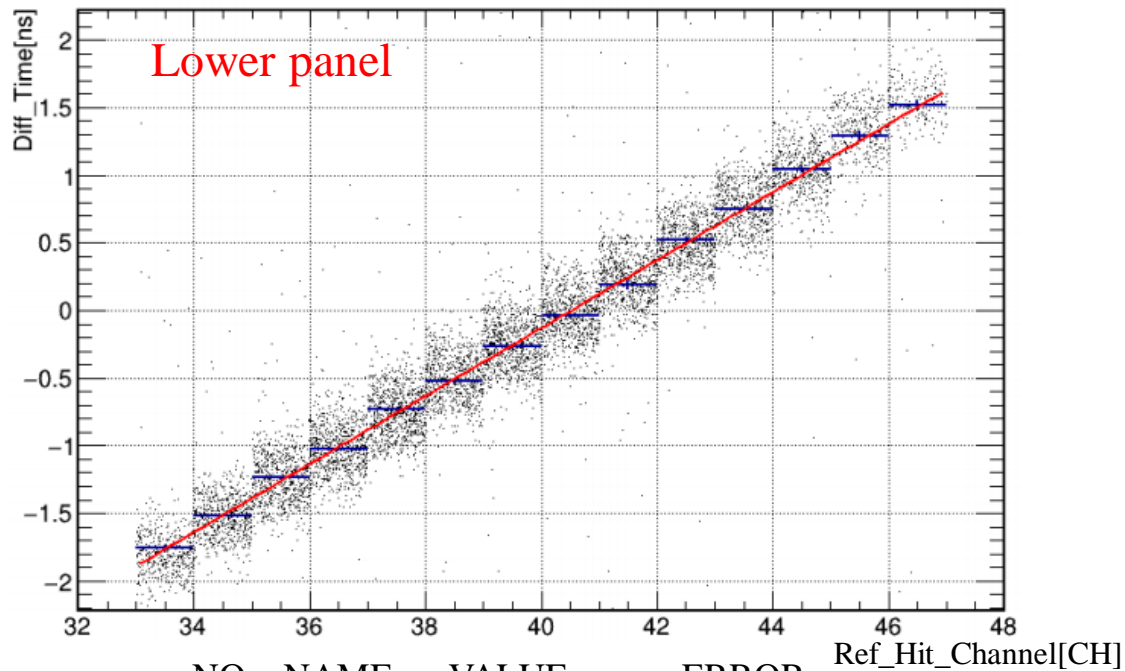


Result with 6*rms is almost same as the CERN BB5 cosmic ray result.

Transmission Speed

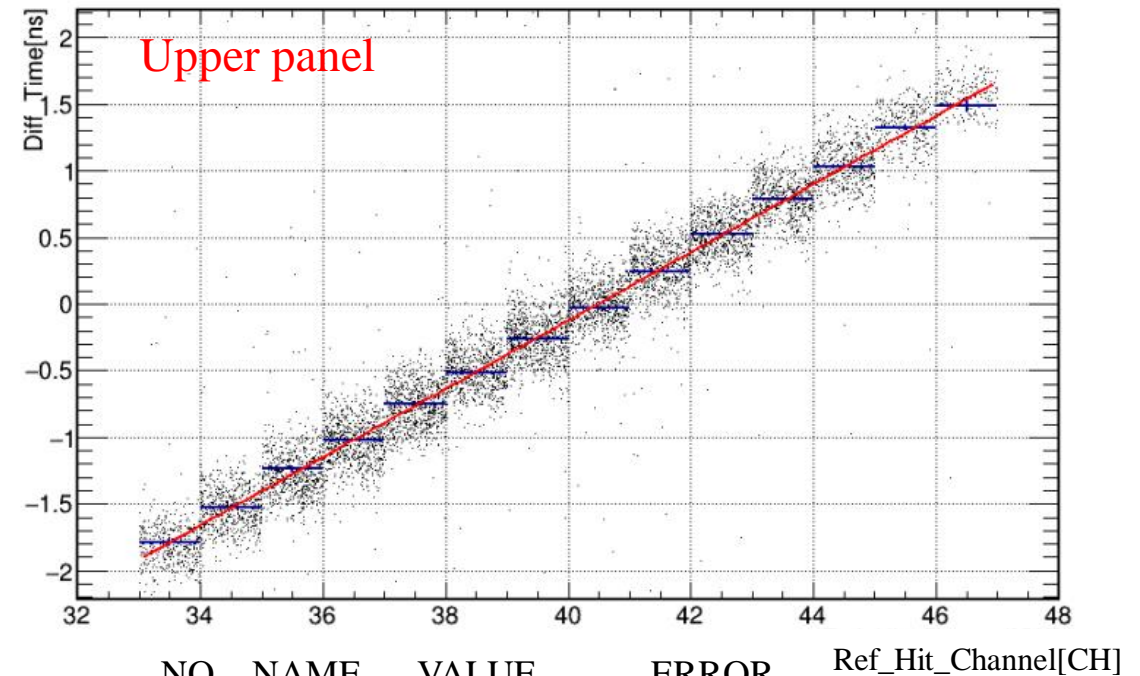
Hit position reconstructed by glass RPC vs Hit position reconstructed by bakelite RPC

- Ref_Hit_Channel: The hit position found by the bakelite RPC.
- Diff_Time: Time difference between 2 ends of every readout panel from glass RPC.



NO.	NAME	VALUE	ERROR
1	p0	0.251482	0.00130799
2	p1	-10.1876	0.0502173

$$v = 2.7\text{cm}^2/p0 = 21.47 \text{ cm/ns}$$



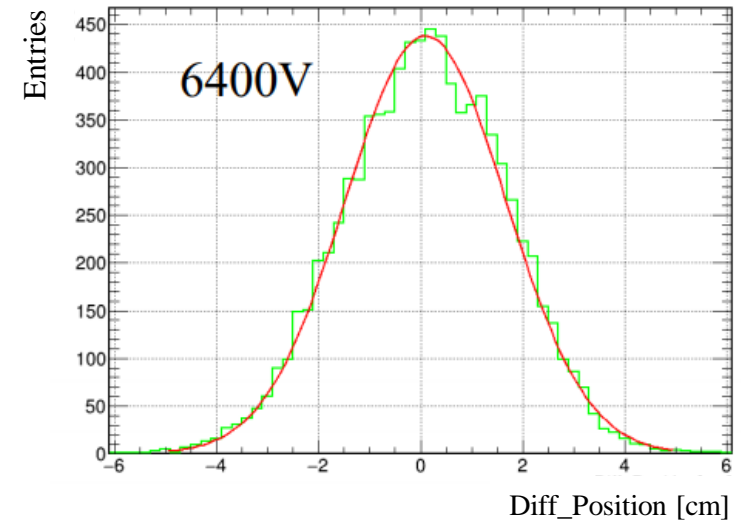
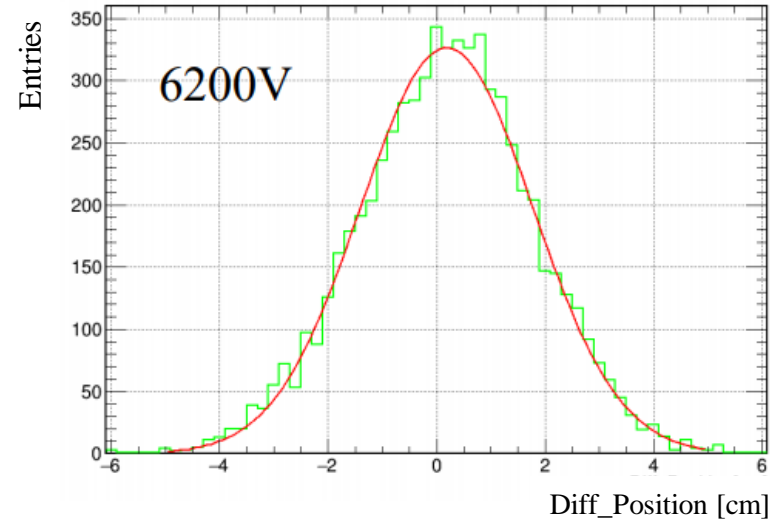
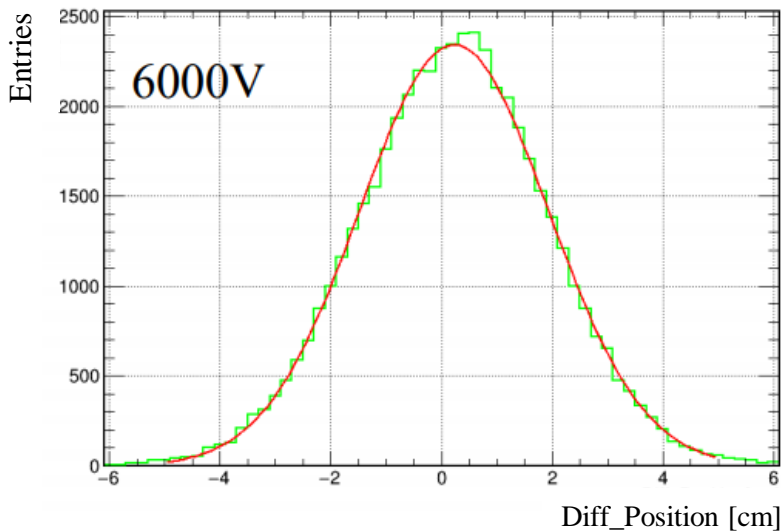
NO.	NAME	VALUE	ERROR
1	p0	0.2559	0.00122028
2	p1	-10.3575	0.0489483

$$v = 2.7\text{cm}^2/p0 = 21.10 \text{ cm/ns}$$

Spatial Resolution(Constant Fraction Discrimination)

- According to the efficiency plateau, $6 \cdot \text{rms}$ is used..
- **Time of 0.5 of the peak value is used.**
- According to the transmission speed, the 2 panels are almost same.

- Position is reconstructed by the time difference of 2 ends from the same panel. $\rightarrow (T1-T2) \cdot v/2$
- Difference of position from 2 different panel is used to fit the sigma.



NO.	NAME	VALUE	ERROR
1	Constant	2.34429e+03	1.31540e+01
2	Mean	2.25248e-01	7.74968e-03
3	Sigma	1.70740e+00	5.95892e-03

$$\sigma = 1.21 \text{ cm}$$

NO.	NAME	VALUE	ERROR
1	Constant	3.26593e+02	5.01327e+00
2	Mean	1.86321e-01	2.00176e-02
3	Sigma	1.58907e+00	1.45810e-02

$$\sigma = 1.12 \text{ cm}$$

NO.	NAME	VALUE	ERROR
1	Constant	4.38206e+02	5.70460e+00
2	Mean	9.62643e-02	1.71137e-02
3	Sigma	1.57309e+00	1.16719e-02

$$\sigma = 1.11 \text{ cm}$$

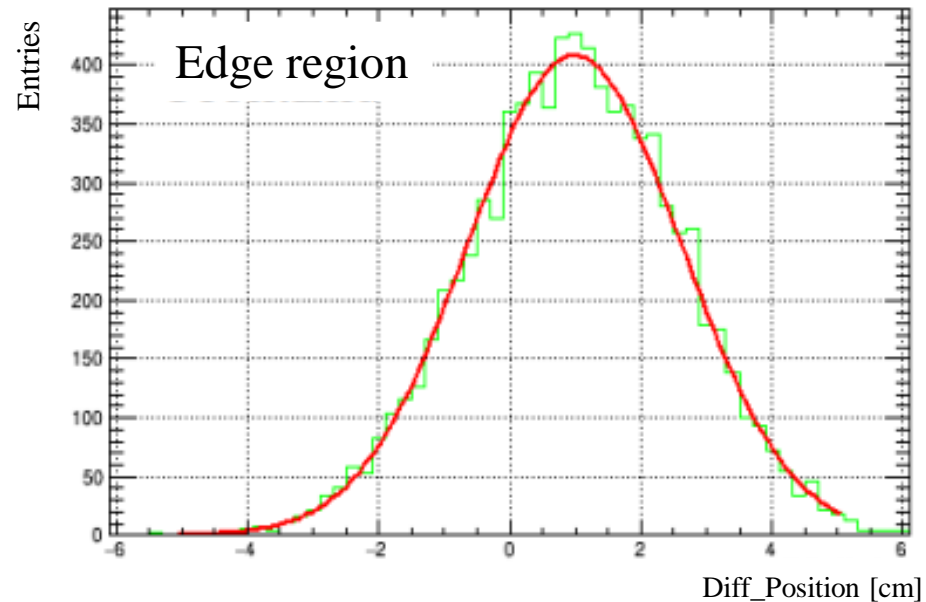
Spatial Resolution(channel by channel)

- 6*rms and 6400V is used.
- Time of 0.5 of the peak value is used.
- According to the transmission speed, the 2 panels are almost same.
- Channel 0 and channel 7 are discarded.

	ch1	ch2	Ch3	ch4	ch5	ch6
Constant	64.98	98.01	94.70	98.02	64.27	27.58
Mean	-0.10	-0.12	-0.11	0.71	0.25	-0.51
Sigma	1.49	1.48	1.55	1.49	1.58	1.55
Spatial Resolution	1.05 cm	1.04 cm	1.10 cm	1.05 cm	1.12 cm	1.10 cm

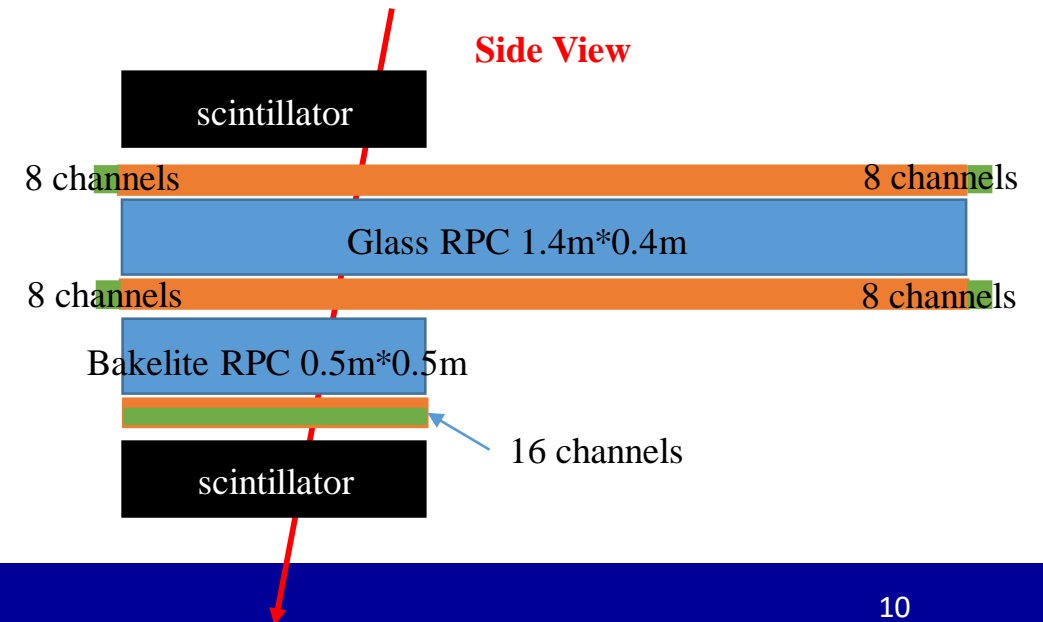
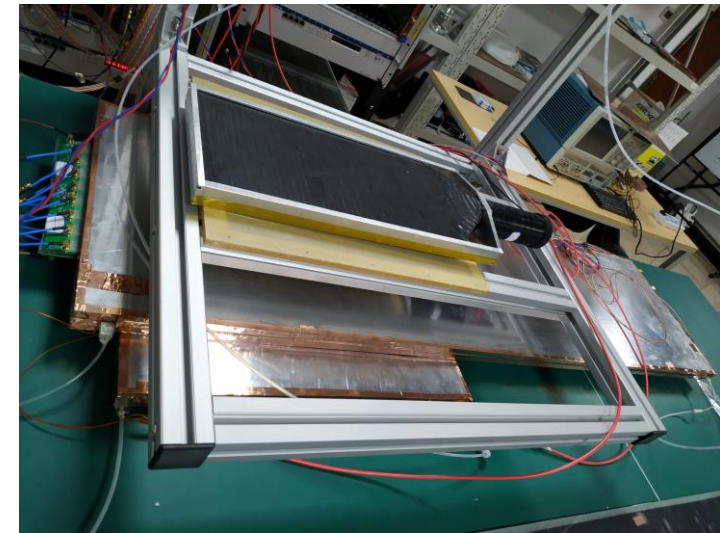
Spatial Resolution(EdgeRegion)

- Test the performance at the edge region of detector.
- Time of leading edge(0.5 of peak) is used.
- 6400V and 6*rms is used.



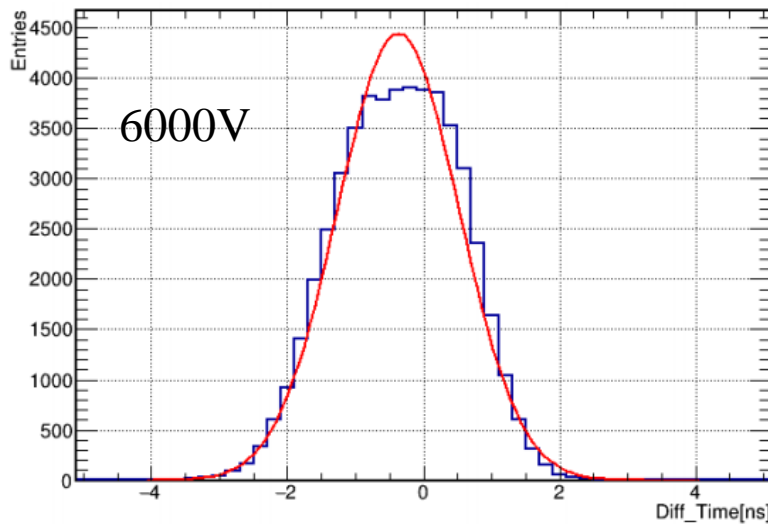
NO.	NAME	VALUE	ERROR
1	Constant	4.07855e+02	5.60118e+00
2	Mean	9.87524e-01	1.83646e-02
3	Sigma	1.63190e+00	1.41173e-02

$$\sigma = 1.15 \text{ cm}$$



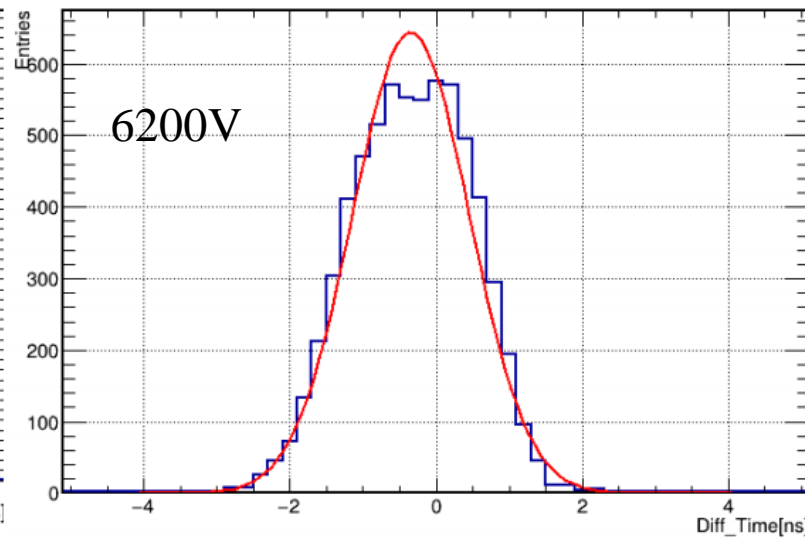
Time Resolution(Constant Fraction Discrimination)

- According to the efficiency plateau, $6 \cdot \text{rms}$ is used..
- **Time of 0.5 of the peak value is used.**
- According to the transmission speed, the 2 panels are almost same.
- Time information from 1 end of strips.



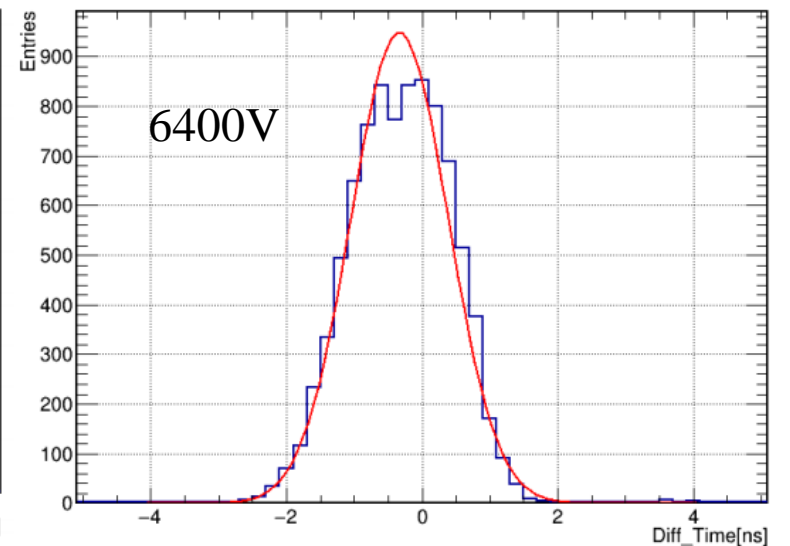
NO.	NAME	VALUE	ERROR
1	Constant	4.44840e+03	2.32964e+01
2	Mean	-3.74544e-01	4.05027e-03
3	Sigma	8.92755e-01	2.41811e-03

$$\sigma = 893/\text{sqrt}(2) \text{ cm} = 631 \text{ ps}$$



NO.	NAME	VALUE	ERROR
1	Constant	6.44621e+02	9.45139e+00
2	Mean	-3.48215e-01	1.00884e-02
3	Sigma	7.97370e-01	6.17848e-03

$$\sigma = 797/\text{sqrt}(2) \text{ cm} = 563 \text{ ps}$$



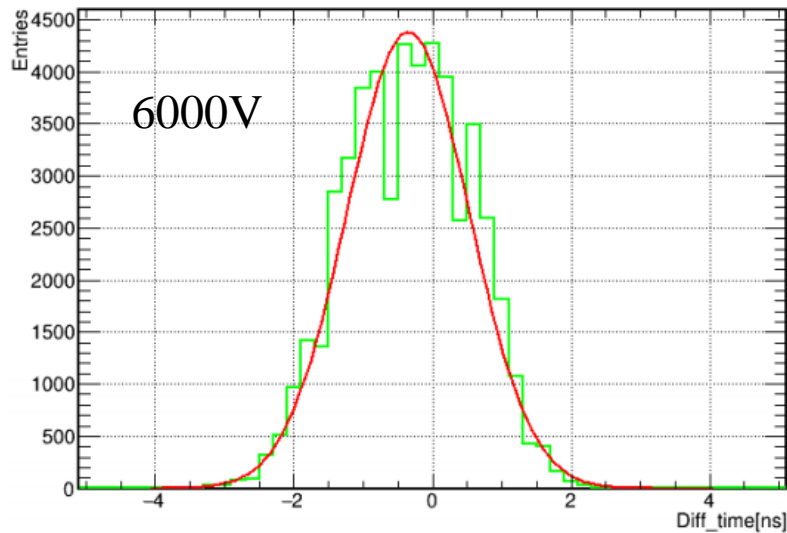
NO.	NAME	VALUE	ERROR
1	Constant	9.48504e+02	1.19962e+01
2	Mean	-3.35018e-01	7.99499e-03
3	Sigma	7.17520e-01	4.68885e-03

$$\sigma = 718/\text{sqrt}(2) \text{ cm} = 507 \text{ ps}$$

Time Resolution(Double-ends improvement)

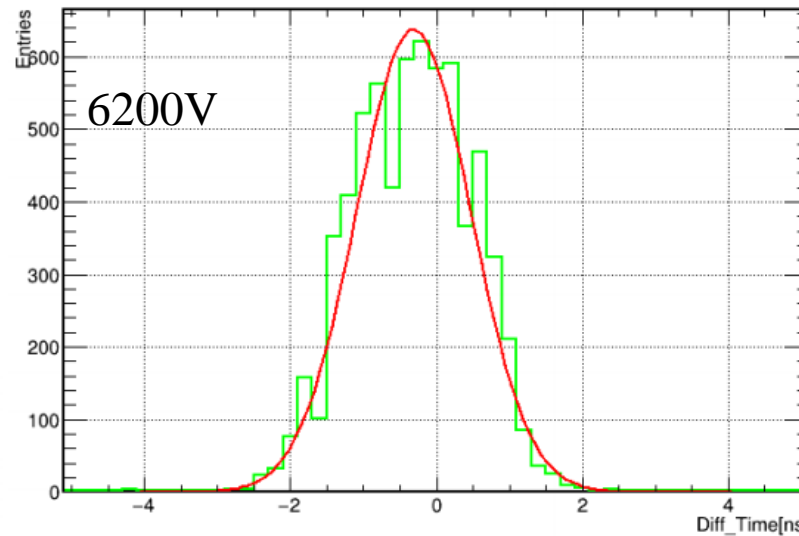
- According to the efficiency plateau, 6*rms is used..
- **Time of 0.5 of the peak value is used.**
- According to the transmission speed, the 2 panels are almost same.
- Averaged time of leading edge from 2 ends of a single panel are used.

Advantage: averaged time is not correlated with hit position.



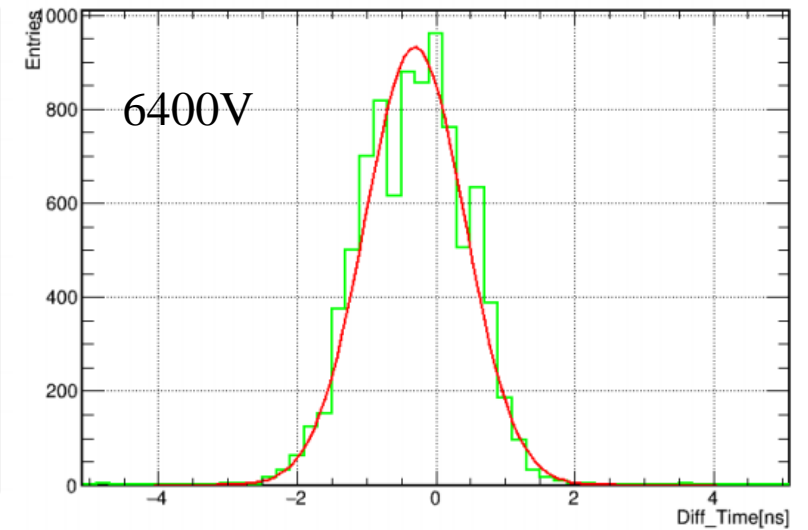
NO.	NAME	VALUE	ERROR
1	Constant	4.37827e+03	2.31562e+01
2	Mean	-3.53389e-01	4.04464e-03
3	Sigma	8.81388e-01	2.38050e-03

$$\sigma = 881/\sqrt{2} \text{ cm} = 623 \text{ ps}$$



NO.	NAME	VALUE	ERROR
1	Constant	6.37540e+02	9.47195e+00
2	Mean	-3.13658e-01	1.00302e-02
3	Sigma	7.83283e-01	6.12206e-03

$$\sigma = 783/\sqrt{2} \text{ cm} = 554 \text{ ps}$$

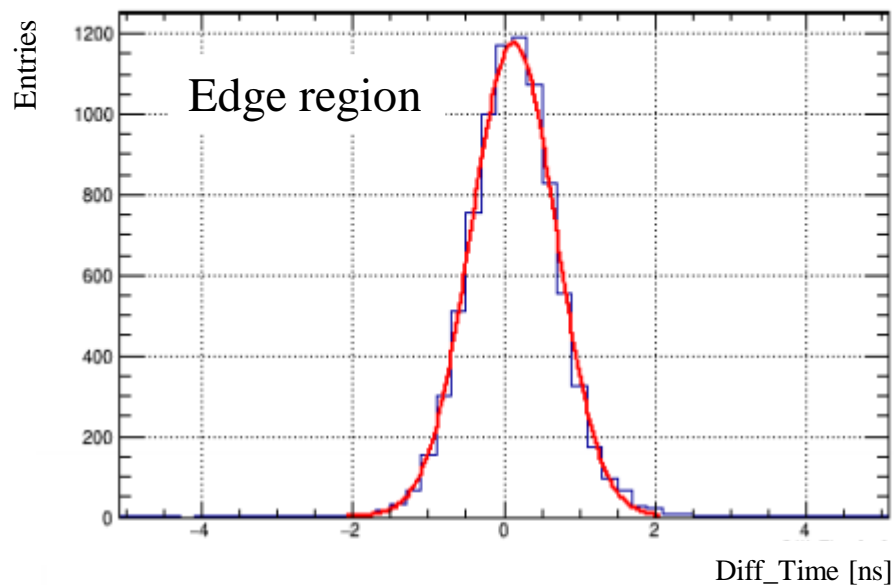


NO.	NAME	VALUE	ERROR
1	Constant	9.32715e+02	1.18528e+01
2	Mean	-3.04847e-01	7.84862e-03
3	Sigma	7.18182e-01	4.67391e-03

$$\sigma = 718/\sqrt{2} \text{ cm} = 507 \text{ ps}$$

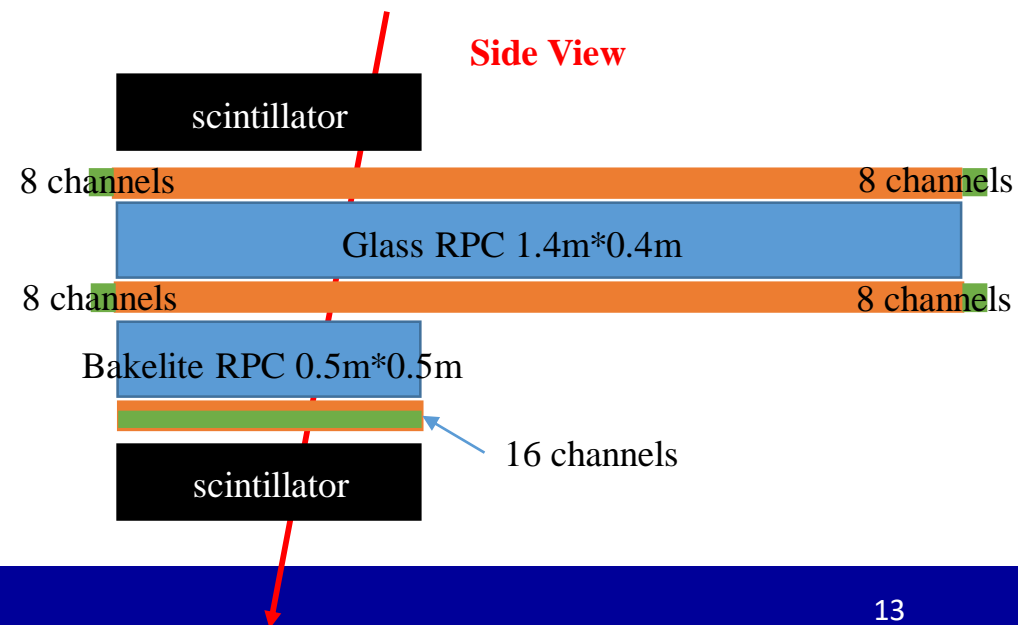
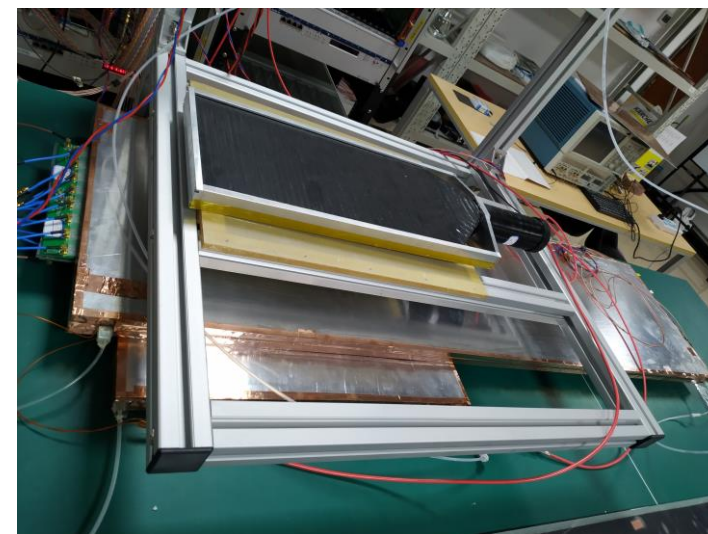
Time Resolution(EdgeRegion)

- Test the performance at the edge region of detector.
- Time of leading edge(0.5 of peak) is used.



NO.	NAME	VALUE	ERROR
1	Constant	1.17638e+03	1.64398e+01
2	2 Mean	1.26428e-01	6.22083e-03
3	3 Sigma	5.65436e-01	4.92479e-03

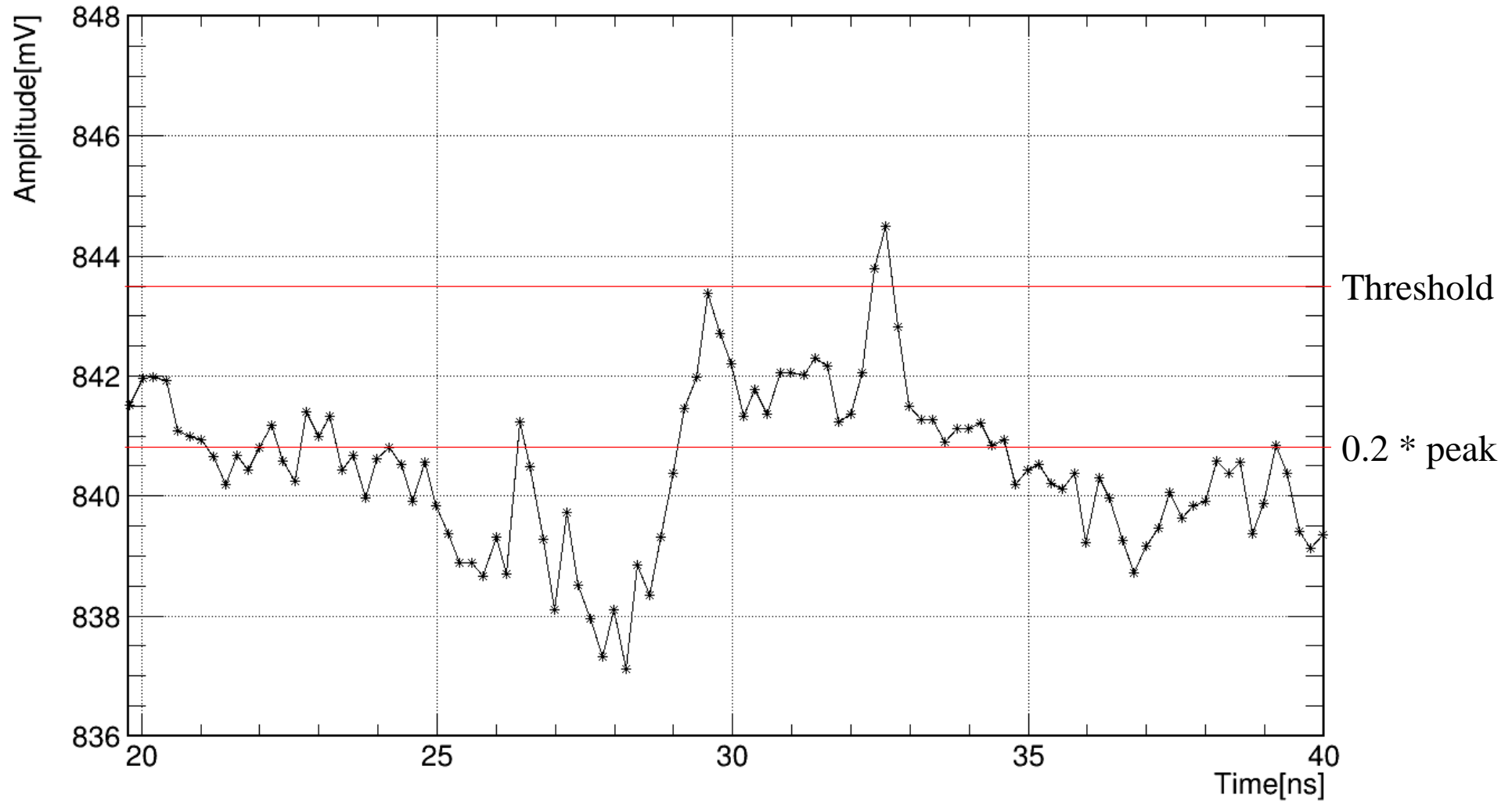
$\sigma = 565/\sqrt{2} \text{ cm} = 399 \text{ ps}$



Summary

- Double-ends readout method works well in long strips.
- ~ 1.04 cm spatial resolution at the best case(channel by channel).
- Overall ~ 1.15 cm @ edge region.
- 400 ps \sim 500 ps time resolution as expected.

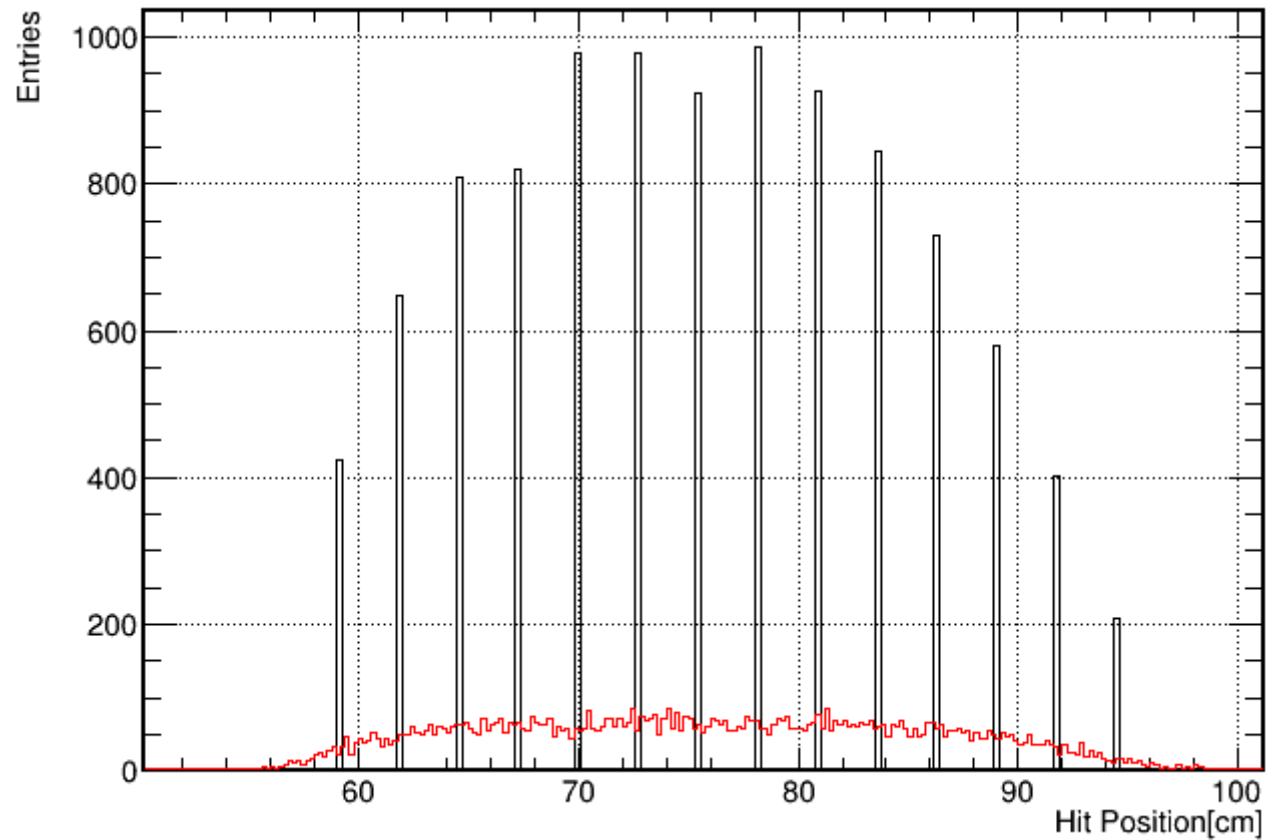
Backup



Bug found just before the meeting: Width of $0.2 * \text{peak} > 0.8 \text{ ns}$ instead of width of $\text{threshold} > 0.8 \text{ ns}$. Will be fixed soon.

[Back](#)

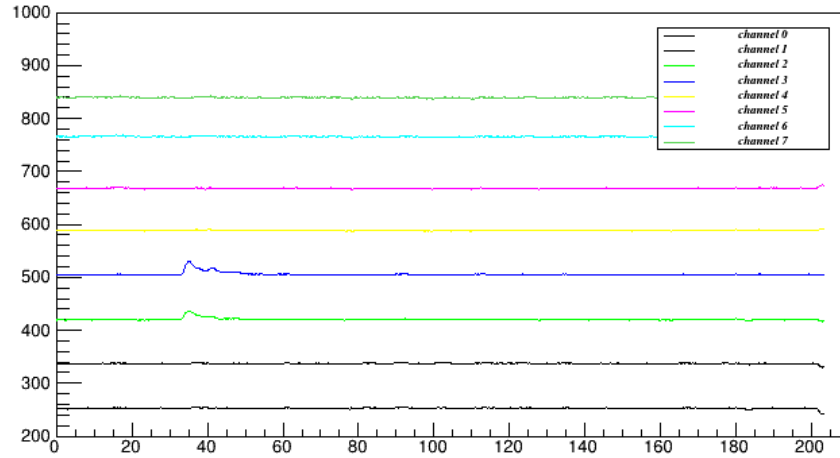
Backup



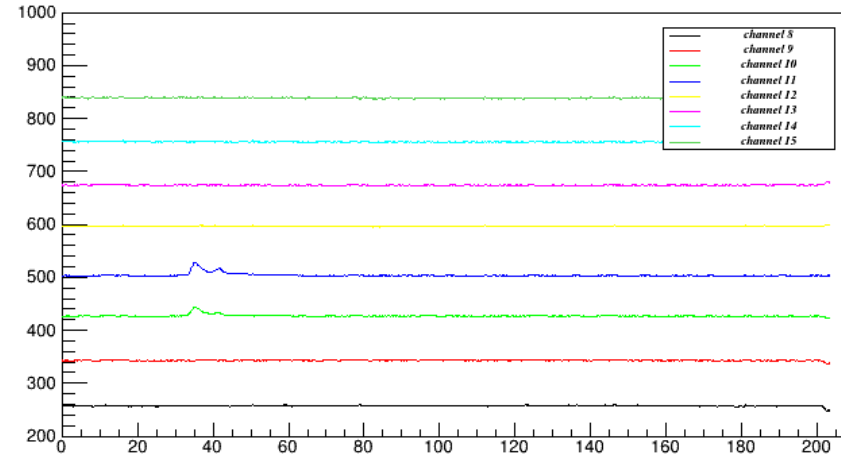
Black: Hit position strip by strip
Red: Hit position reconstructed
by double-ends method

Backup

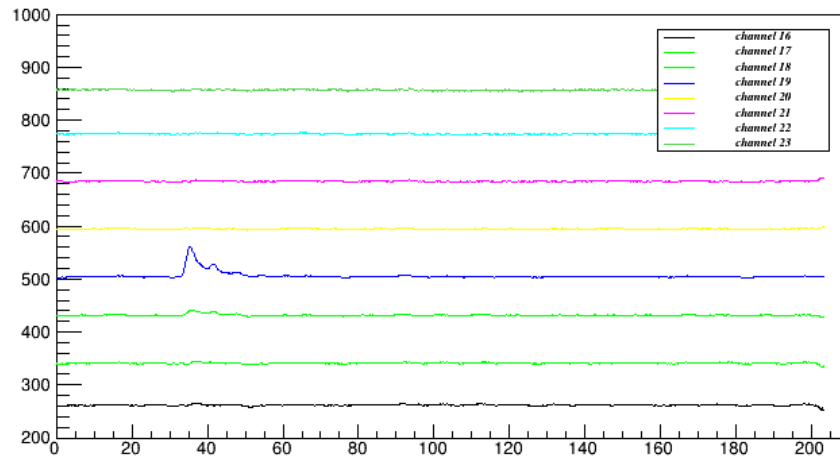
Graph



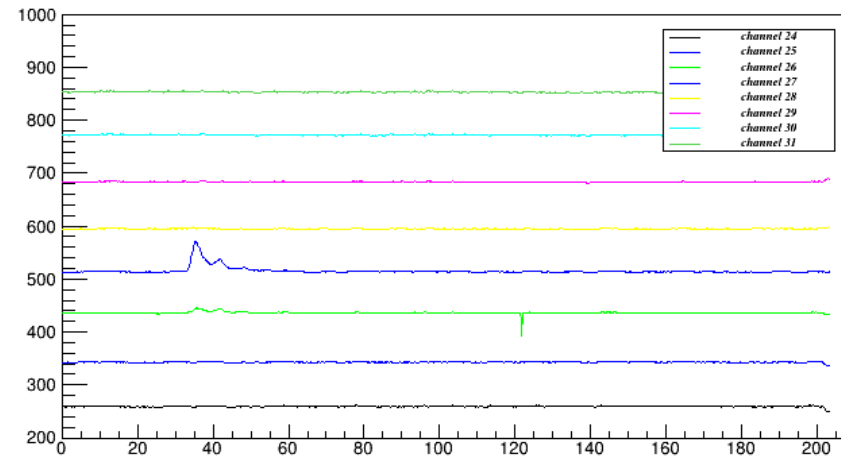
Graph



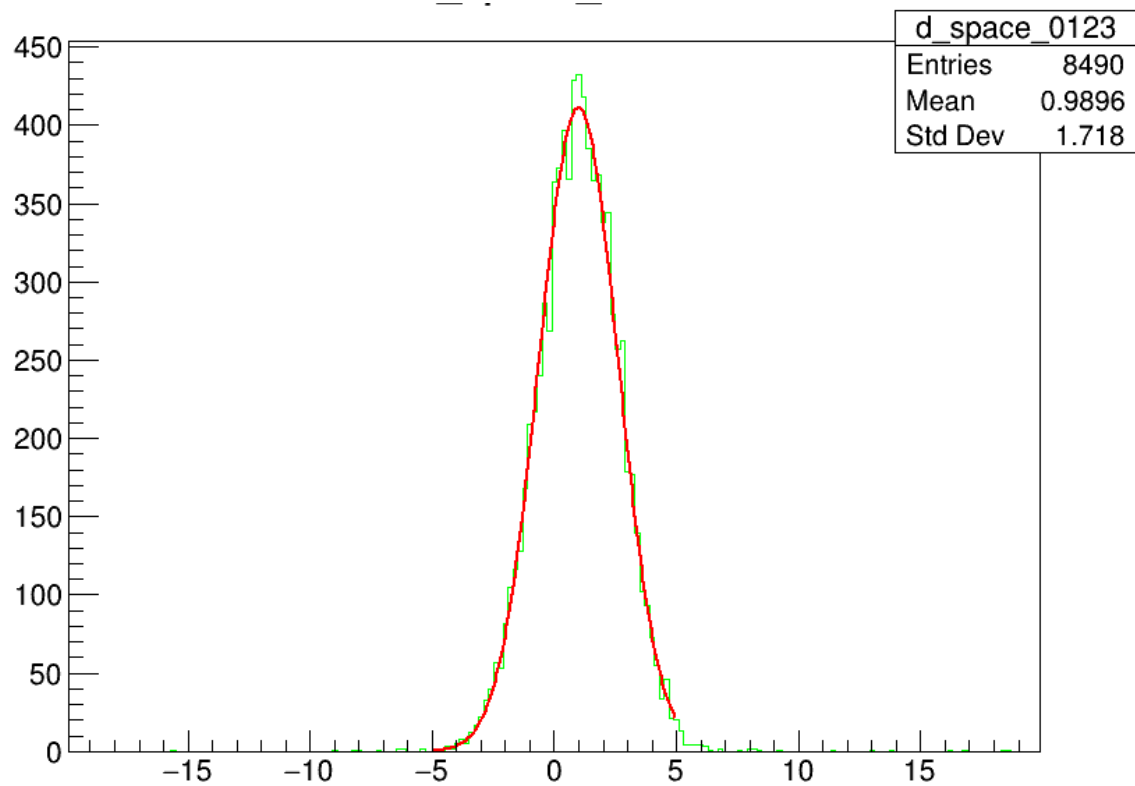
Graph



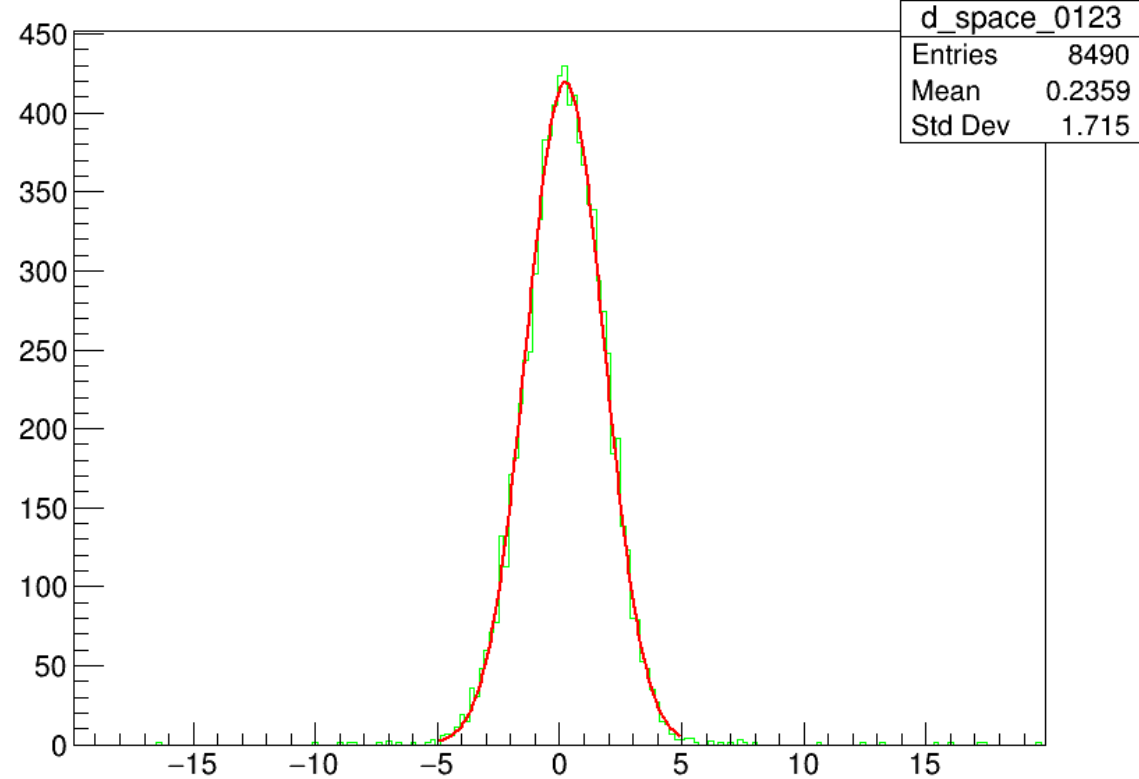
Graph



Backup

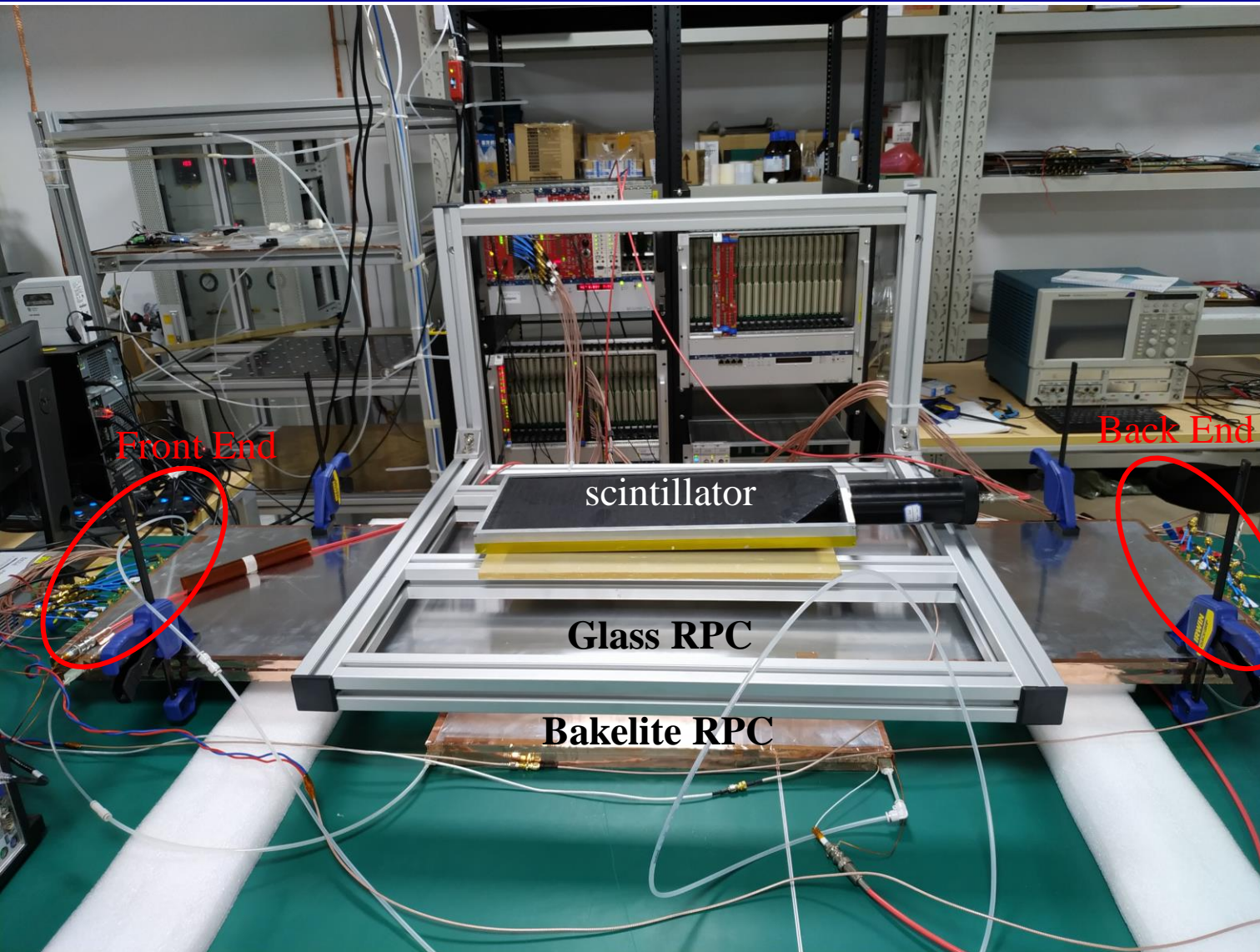


Using different speed for different panel



Using same speed for different panel

Photo of System



Trigger cable to control Synchronization

Trigger cable connected with digitization

