RPC with submillimeter spatial resolution

Quanyin Li (USTC)

on behalf of USTC RPC group

The 7th China LHC Physics Workshop

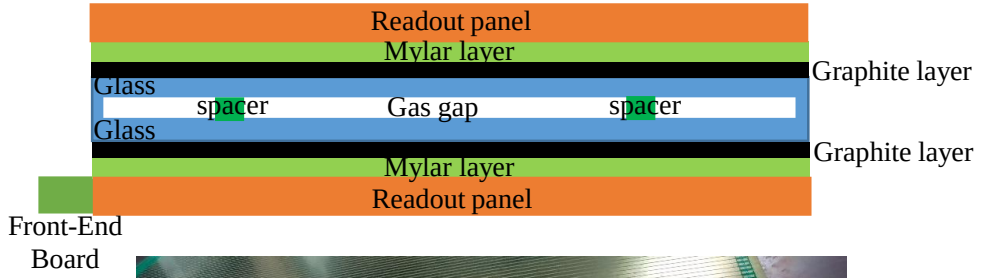
2021.11.27

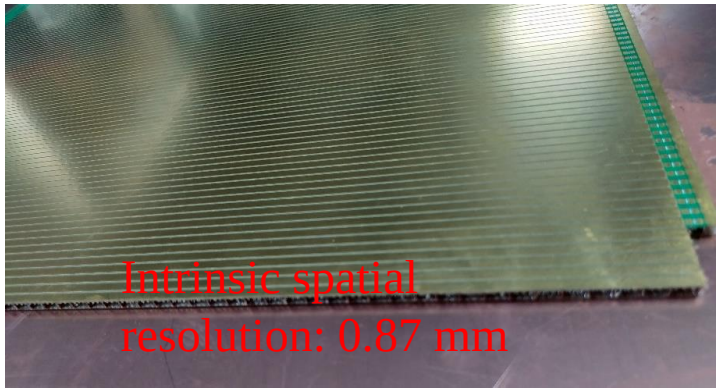
Introduction

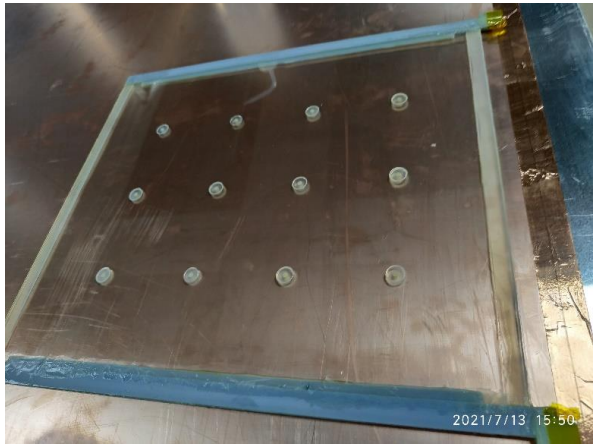
- New type of RPC installed in ATLAS during Phase I and II upgrade
  - BIS7/8 (Phase I)
  - Full BIS/BIL region (Phase II)
- RPC development (gas gap 2 mm → 1 mm):
  - Time resolution: 1.1 ns → 0.4 ns
  - Rate capability: 100 Hz/cm^2 → 3 kHz/cm^2
  - Spatial resolution: ~ 1 cm (pitch/sqrt(12))
- Based on the RPC in ATLAS upgrade, R&D are performed to improve the spatial resolution.

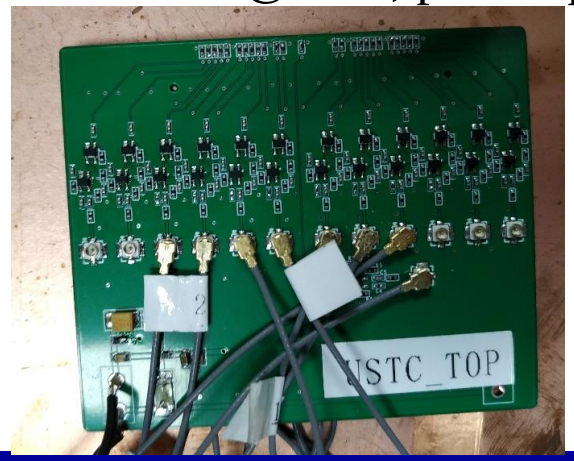
RPC and FEE

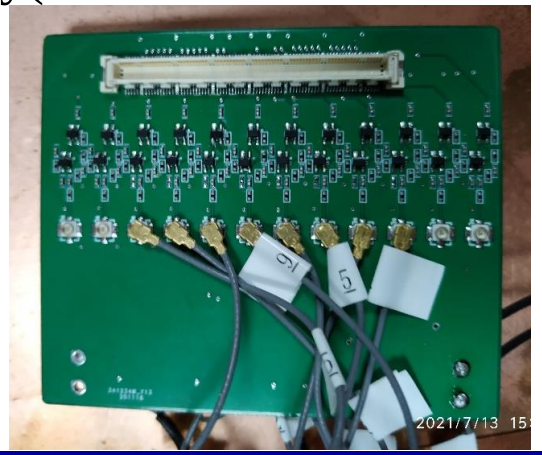
- Detector structure：
  - Glass RPC，thickness of gap 1mm
  - Effective area：27×33 cm
- Readout panel：
  - Pitch: 3mm (2.5mm strip + 0.5mm gap）
  - Thickness of honeycomb: 3mm
- Front-end electronics：
  - Both sides，25ch/board
  - Gain：~20@3.0V, pre-amplifier only(record the waveform for detailed study)

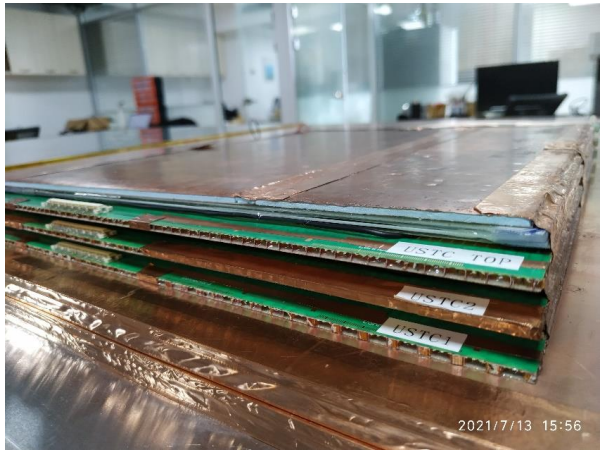






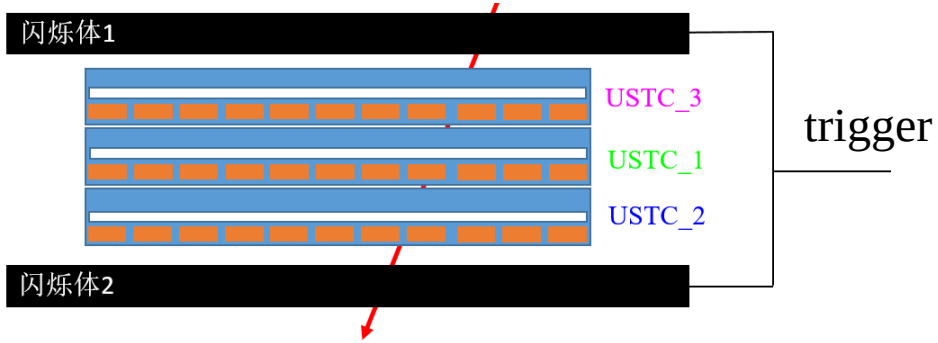


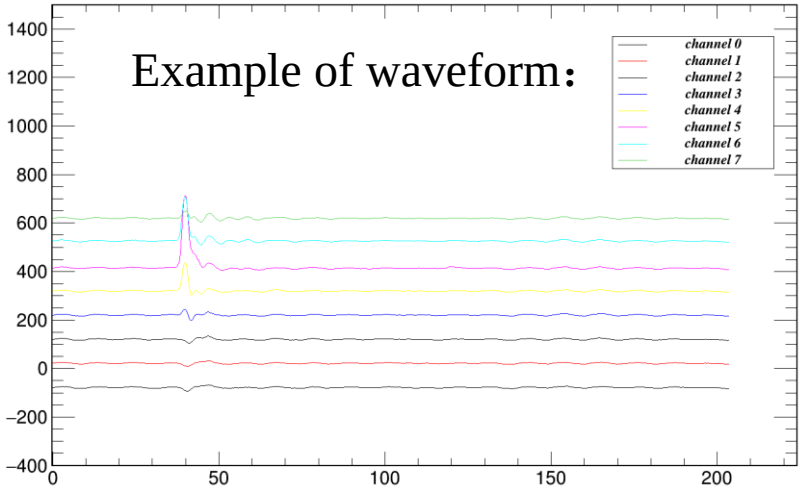




Cosmic ray system

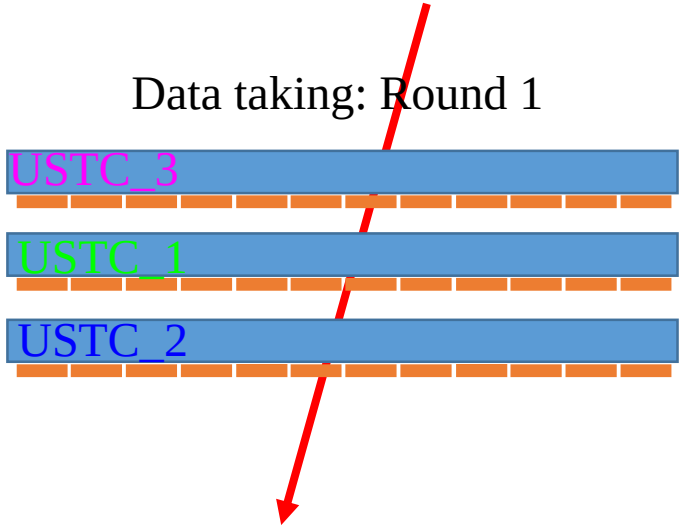
- Setup：
  - Triplet of glass RPC
  - Working voltage： 6200V
  - Scintillator as trigger： 20×40cm
  - 16 * 3 RPC channels used
- DAQ system：
  - Digitizer： CAEN V1742 (32 ch)
    CAEN N6742 (16 ch)
  - Sampling frequency： 5 Gs/s
  - 1024 points/event





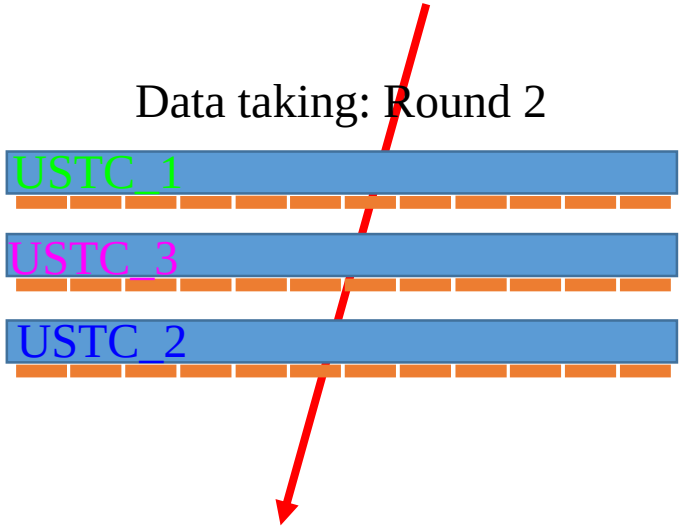
Strategy

Data taking: Round 1



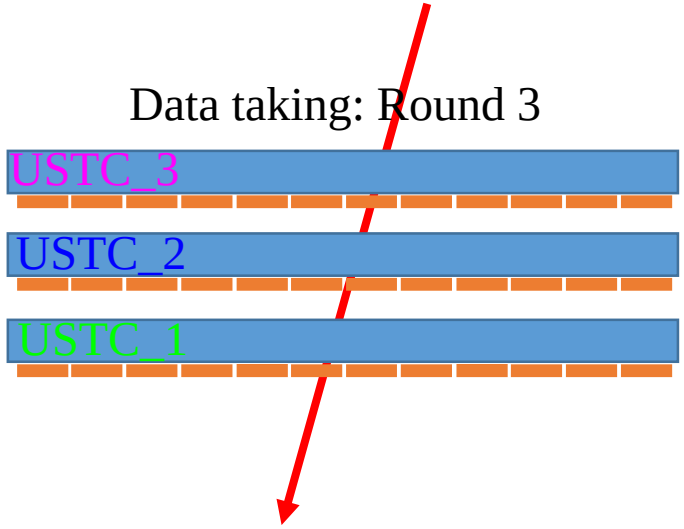
Distribution of
Hit_1 – (Hit_3+Hit_2)/2

Data taking: Round 2



Distribution of
Hit_3 – (Hit_1+Hit_2)/2

Data taking: Round 3



Distribution of
Hit_2 – (Hit_3+Hit_1)/2

$$Hit\ position = \frac{\sum_{i=0}^{n} Ch_i * Weight_i}{\sum_{i=0}^{n} Weight_i}$$

$Weight_i$ could be amplitude, charge, TOT, and so on. Detailed study is performed to guide the design of FEE board in the future.

$$\begin{cases} S_1^2 + \frac{1}{4}S_2^2 + \frac{1}{4}S_3^2 = S_{1-(3+2)/2}^2 \\ S_3^2 + \frac{1}{4}S_1^2 + \frac{1}{4}S_2^2 = S_{3-(1+2)/2}^2 \\ S_2^2 + \frac{1}{4}S_3^2 + \frac{1}{4}S_1^2 = S_{2-(1+3)/2}^2 \end{cases}$$

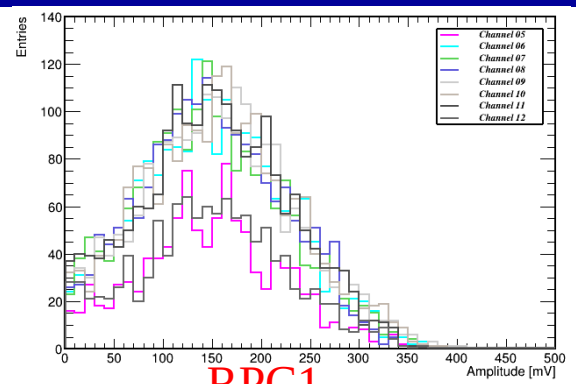
Solve the equations and calculate the three resolutions respectively.

Basic parameters

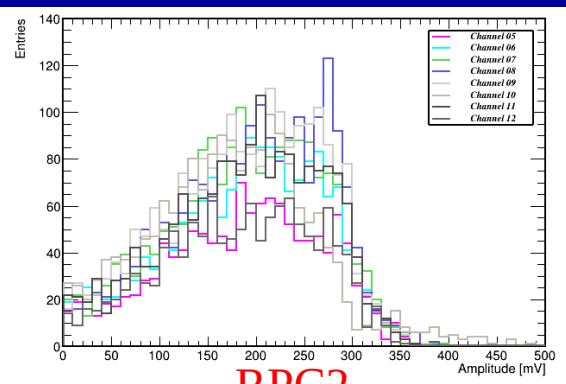
Distribution of amplitude in different channels

Distribution of the hit channel

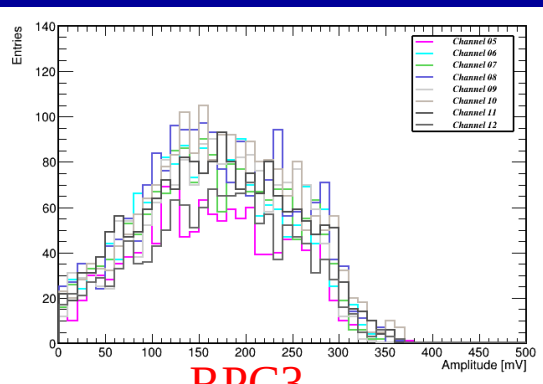
Distribution of leading edge



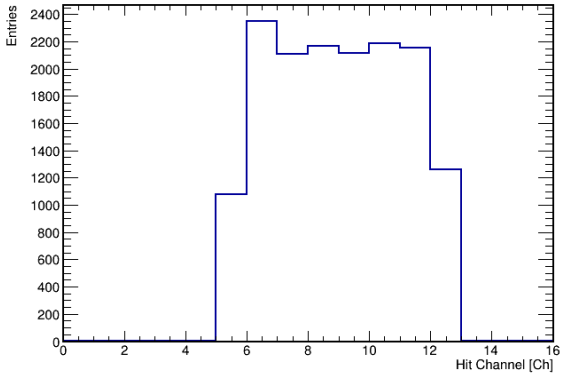
RPC1

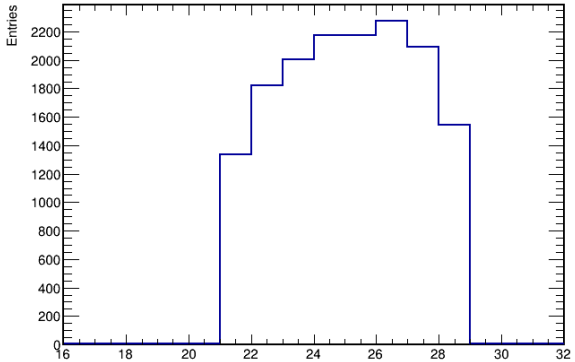


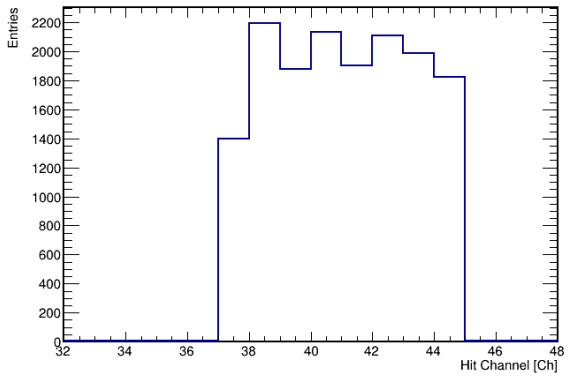
RPC2

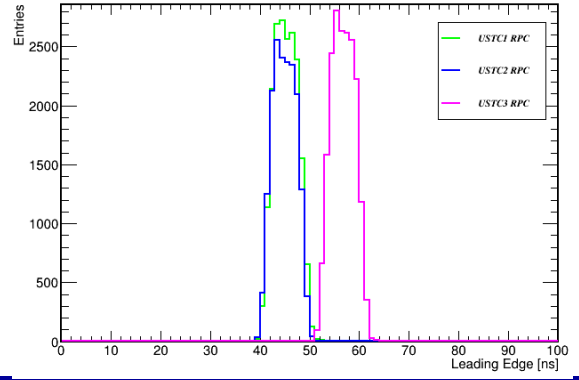


RPC3

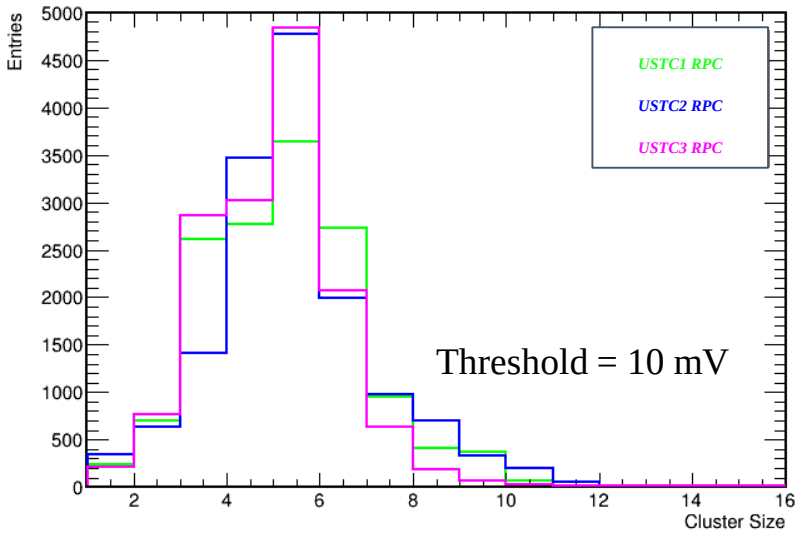


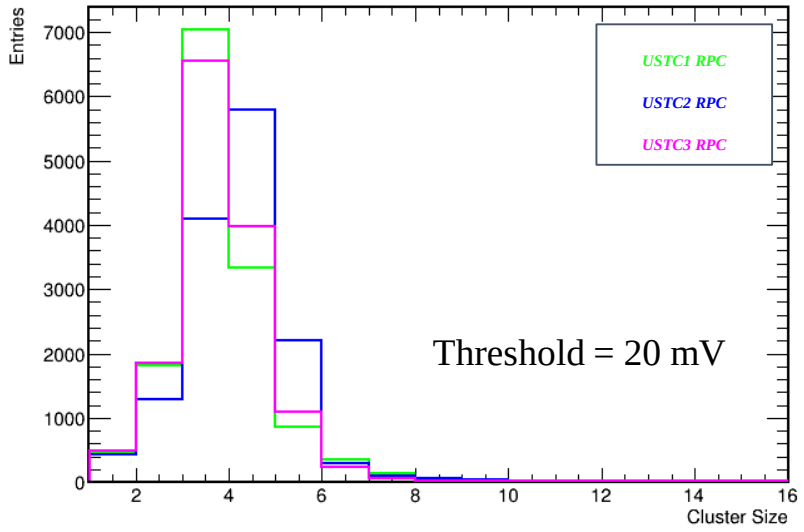


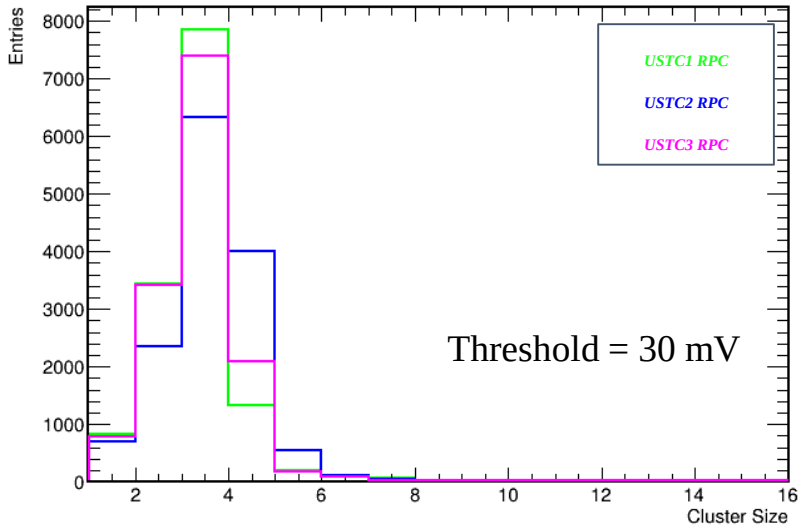


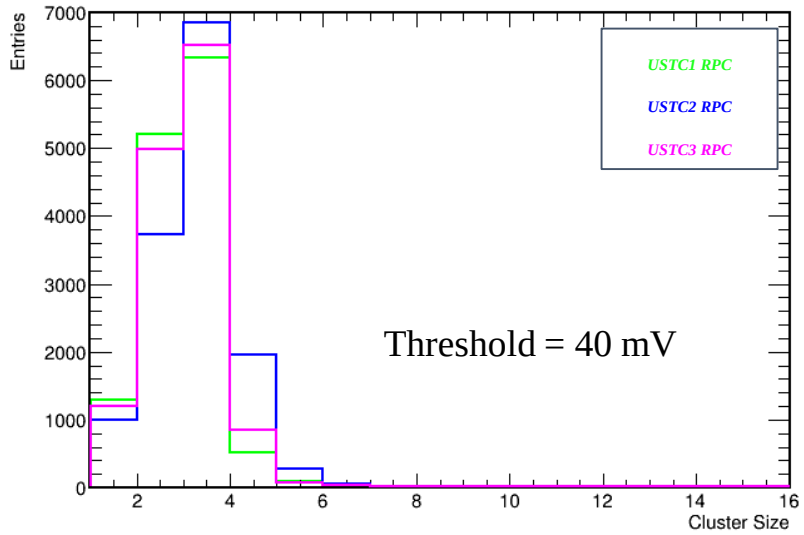


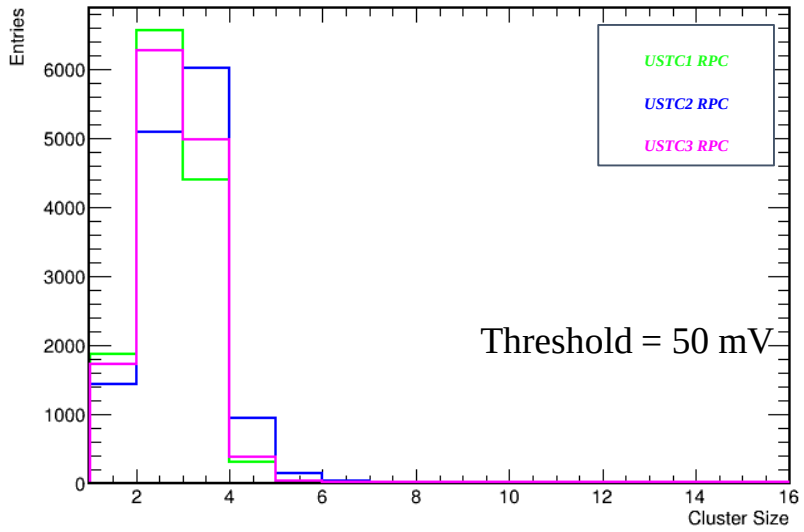
Cluster size vs threshold



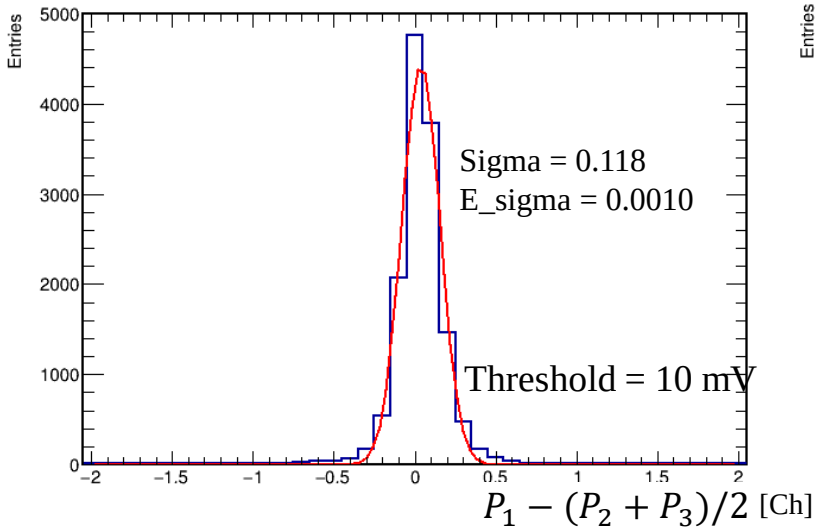


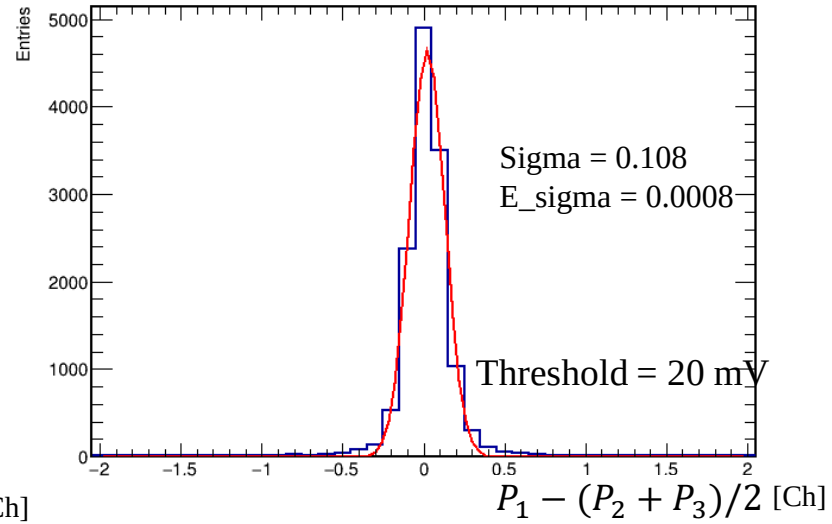


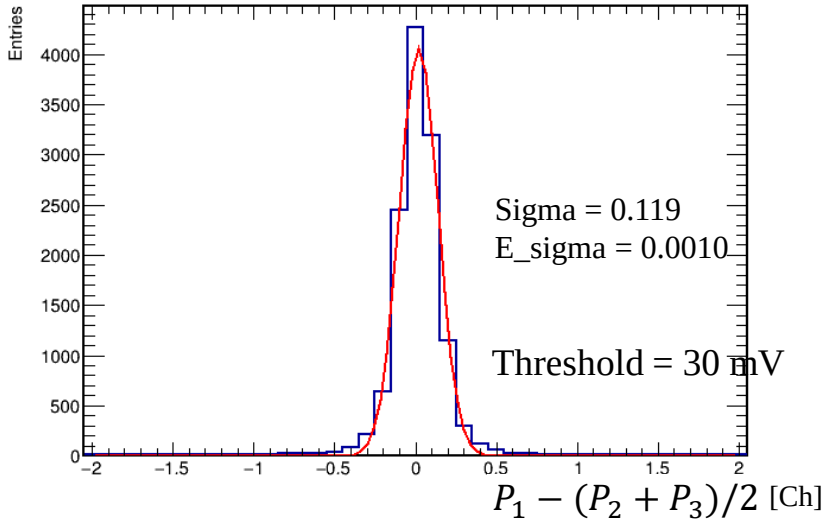


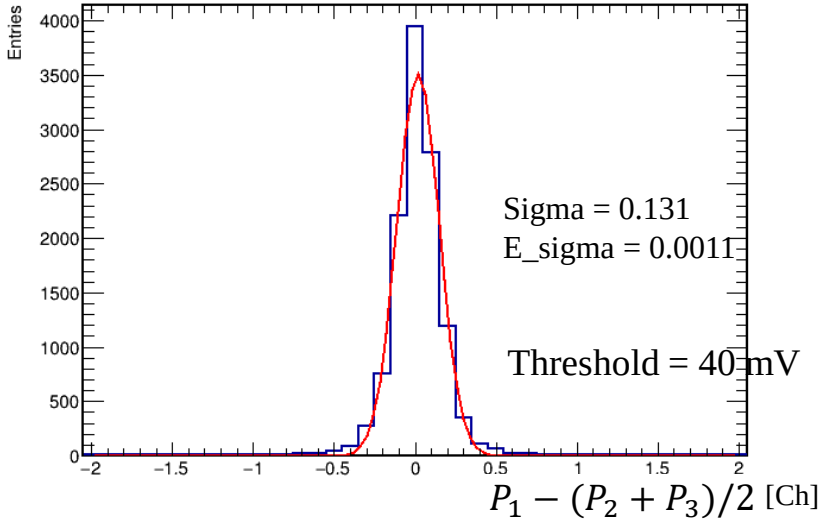


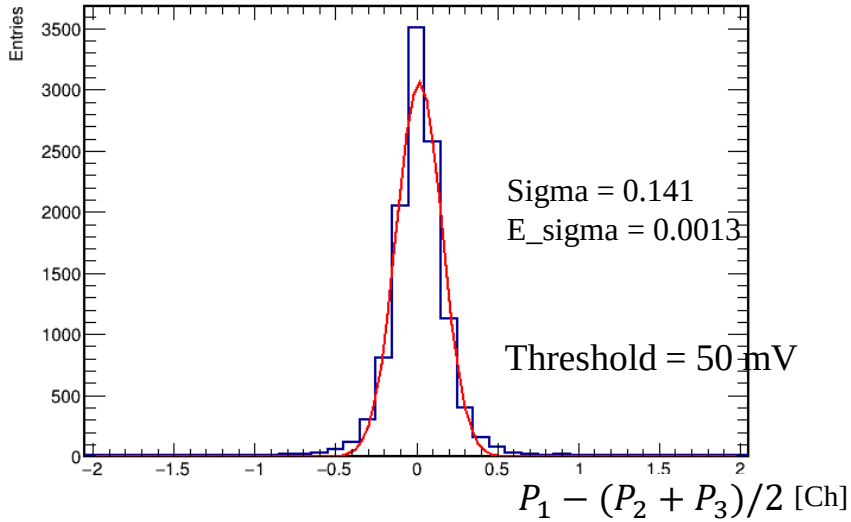
Hit residual with different threshold





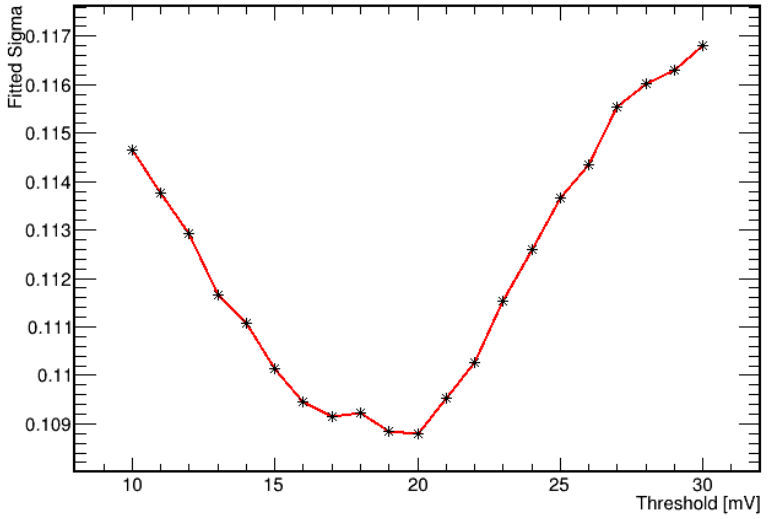




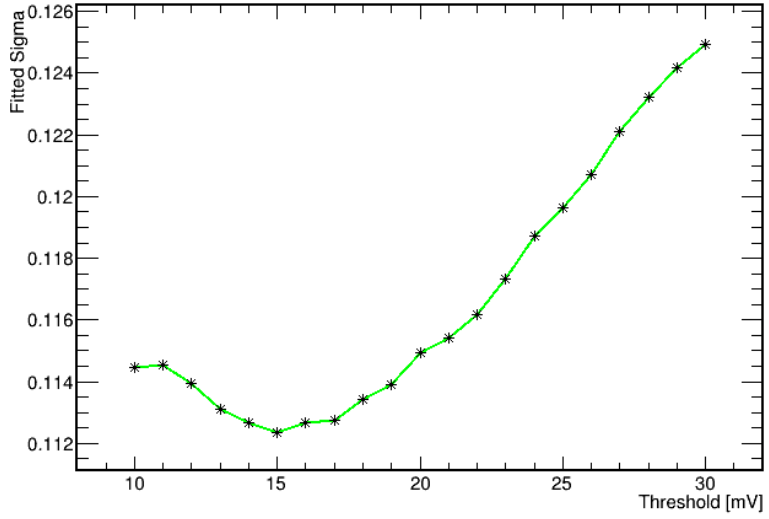


Threshold scan

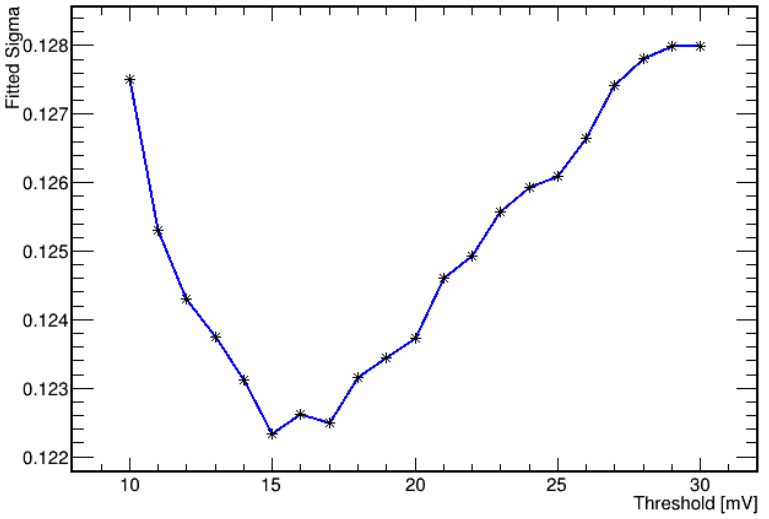
- Tune the threshold one by one:
  - Fix the threshold of the two outer RPCs @30mV
  - Vary the threshold in the middle RPC



RPC1: 20 mV



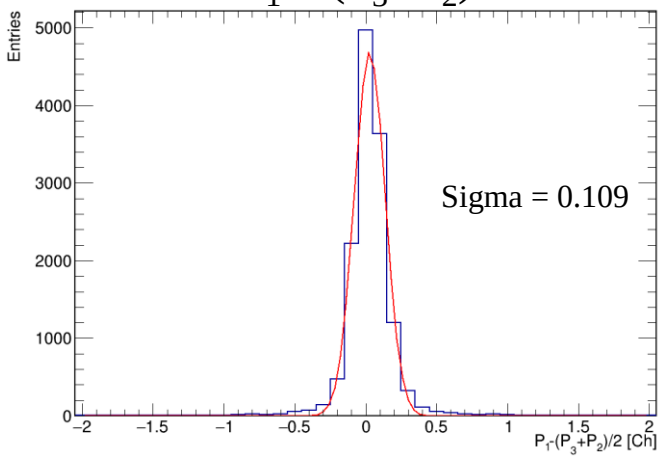
RPC2: 15 mV



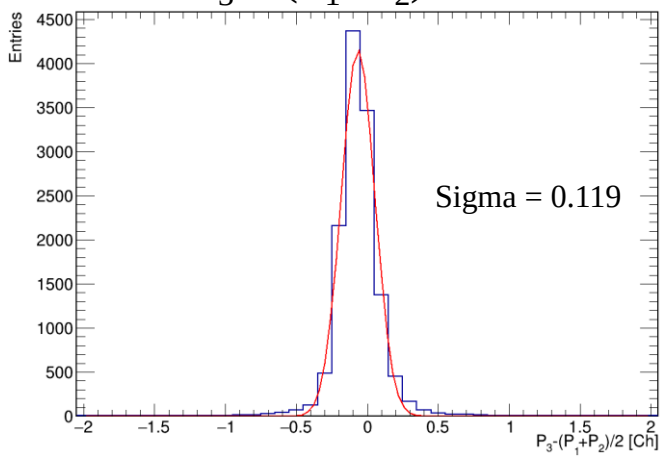
RPC_3: 15 mV

Spatial resolution: center of amplitude algorithm

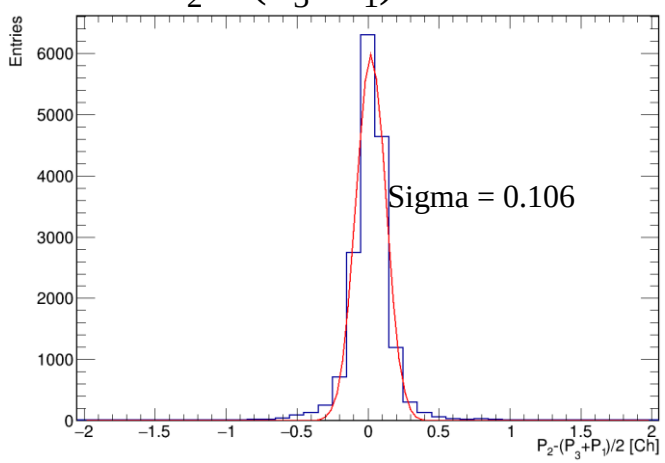
$P_1 - (P_3+P_2)/2$



$P_3 - (P_1+P_2)/2$



$P_2 - (P_3+P_1)/2$



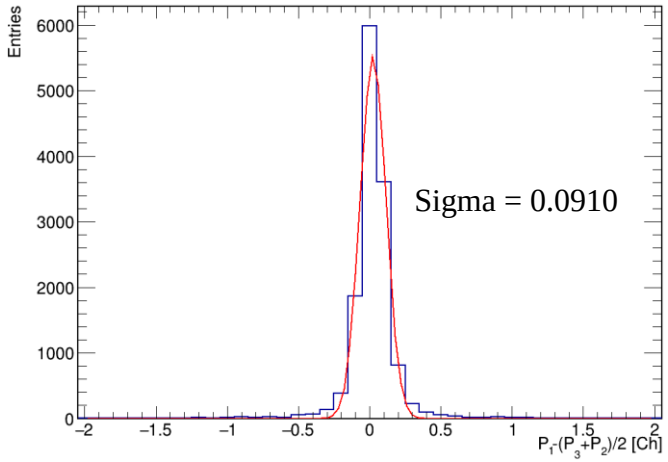
$$Hit\ position = \frac{\sum_{i=0}^{n} Ch_i * Peak_i}{\sum_{i=0}^{n} Peak_i}$$

$$\begin{cases} S_1^2 + \frac{1}{4}S_2^2 + \frac{1}{4}S_3^2 = S_{1-(3+2)/2}^2 \\ S_3^2 + \frac{1}{4}S_1^2 + \frac{1}{4}S_2^2 = S_{3-(1+2)/2}^2 \\ S_2^2 + \frac{1}{4}S_3^2 + \frac{1}{4}S_1^2 = S_{2-(1+3)/2}^2 \end{cases}$$

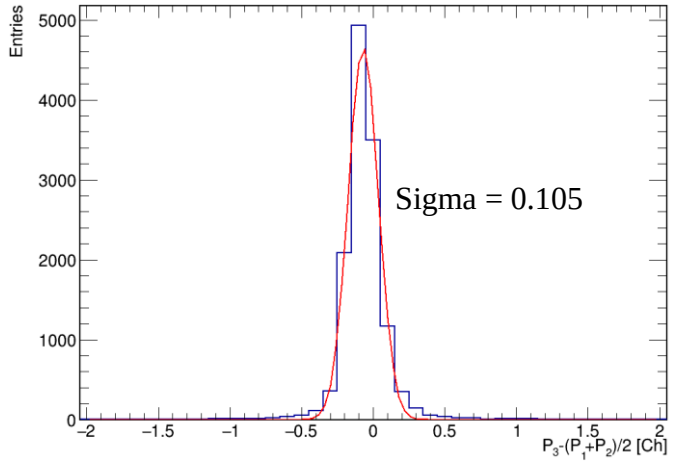
Spatial Resolution:
RPC3 = 0.31 [mm]
RPC1 = 0.29 [mm]
RPC2 = 0.28 [mm]

Spatial resolution: center of charge algorithm

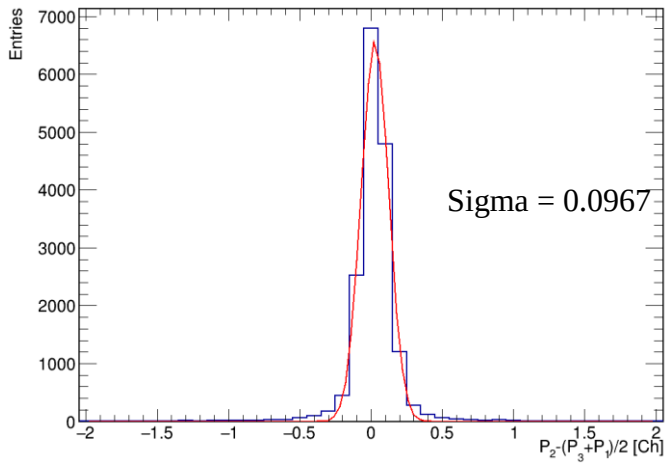
$P_1 - (P_3+P_2)/2$



$P_3 - (P_1+P_2)/2$



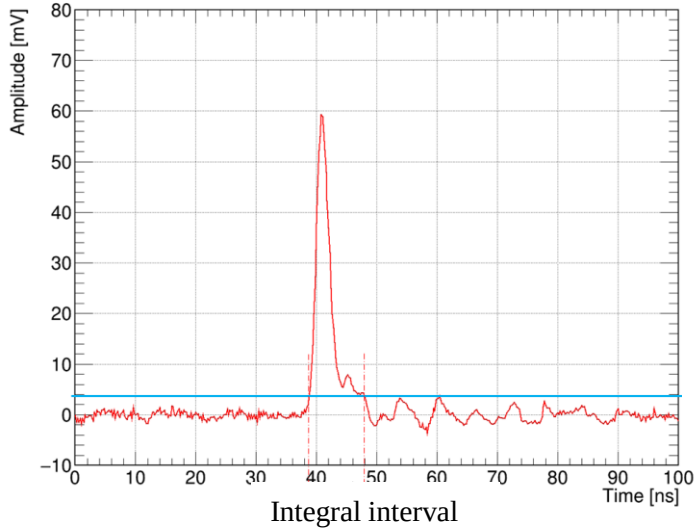
$P_2 - (P_3+P_1)/2$



$$Hit\ position = \frac{\sum_{i=0}^{n} Ch_i * \mathrm{Charge}_i}{\sum_{i=0}^{n} \mathrm{Charge}_i}$$

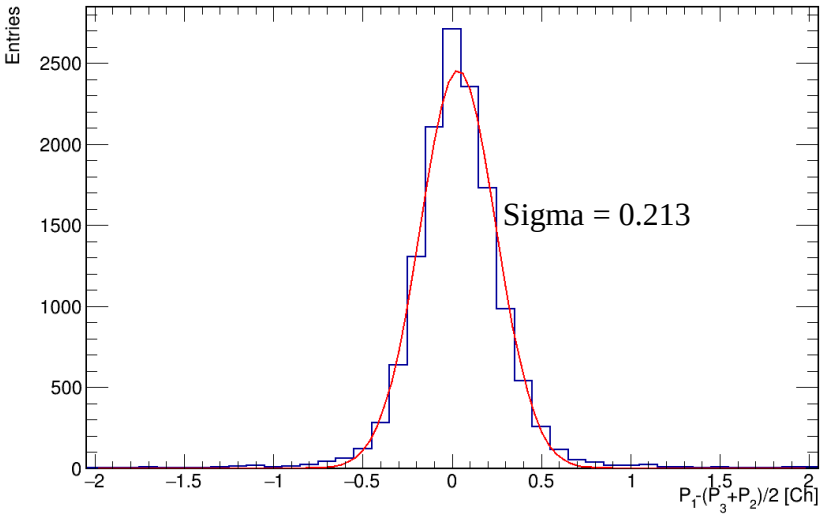
$$\begin{cases} S_1^2 + \frac{1}{4}S_2^2 + \frac{1}{4}S_3^2 = S_{1-(3+2)/2}^2 \\ S_3^2 + \frac{1}{4}S_1^2 + \frac{1}{4}S_2^2 = S_{3-(1+2)/2}^2 \\ S_2^2 + \frac{1}{4}S_3^2 + \frac{1}{4}S_1^2 = S_{2-(1+3)/2}^2 \end{cases}$$

Spatial Resolution:
RPC3 = 0.28 [mm]
RPC1 = 0.24 [mm]
RPC2 = 0.25 [mm]

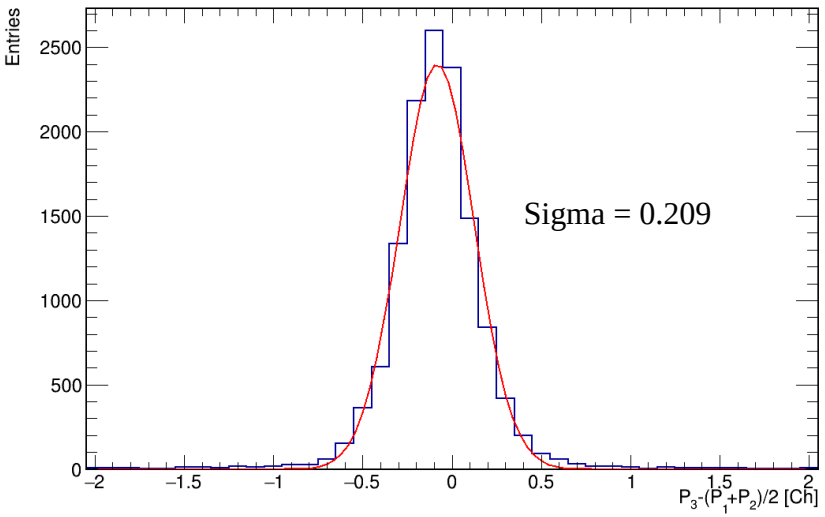


Spatial resolution: center of TOT algorithm

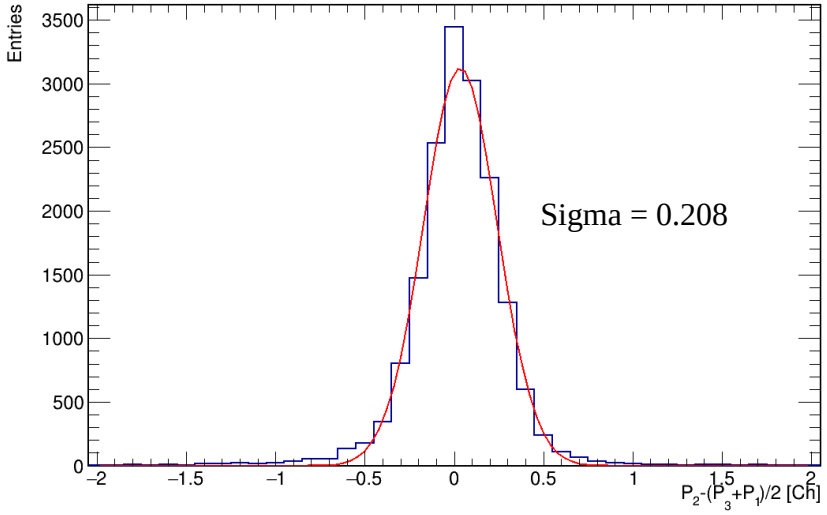
$P_1 - (P_3+P_2)/2$



$P_3 - (P_1+P_2)/2$



$P_2 - (P_3+P_1)/2$



$$Hit\ position = \frac{\sum_{i=0}^{n} Ch_i * \mathrm{TOT}_i}{\sum_{i=0}^{n} \mathrm{TOT}_i}$$

$$\begin{cases} S_1^2 + \frac{1}{4}S_2^2 + \frac{1}{4}S_3^2 = S_{1-(3+2)/2}^2 \\ S_3^2 + \frac{1}{4}S_1^2 + \frac{1}{4}S_2^2 = S_{3-(1+2)/2}^2 \\ S_2^2 + \frac{1}{4}S_3^2 + \frac{1}{4}S_1^2 = S_{2-(1+3)/2}^2 \end{cases}$$

Spatial Resolution:
RPC3 = 0.51 [mm]
RPC1 = 0.52 [mm]
RPC2 = 0.51 [mm]

Summary

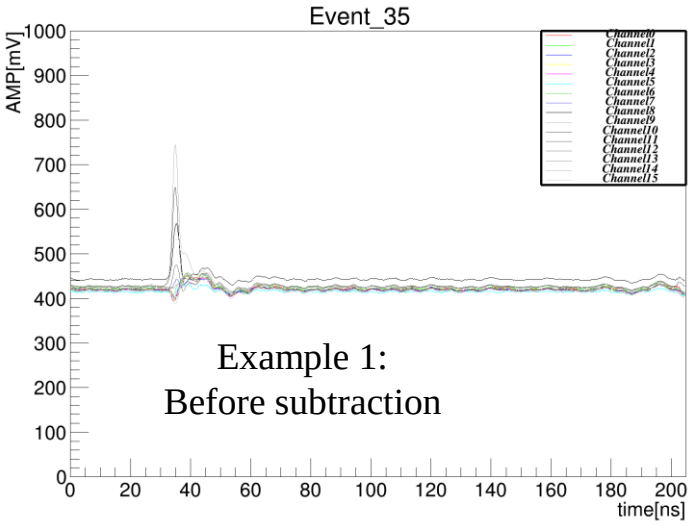
- Produced glass RPC with submillimeter spatial resolution
- A self-based cosmic system to measure the spatial resolution：
  - Center of charge： ~0.25 mm
  - Center of amplitude： ~0.3 mm
  - Center of TOT： ~0.5 mm

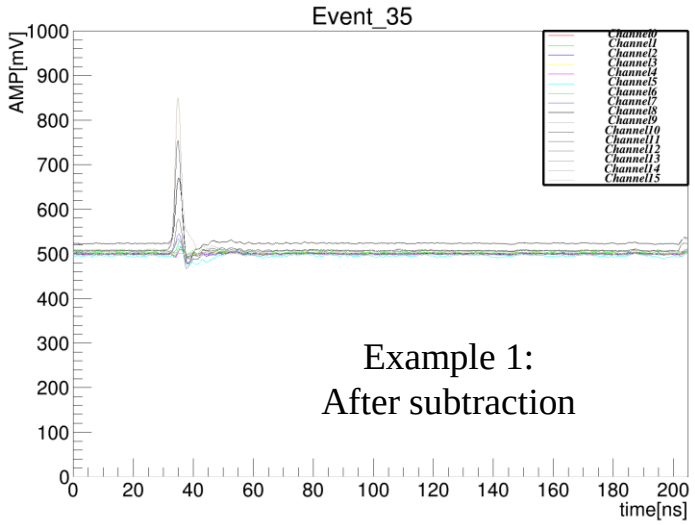
➢ Application prospect: tracking detector, tomography …

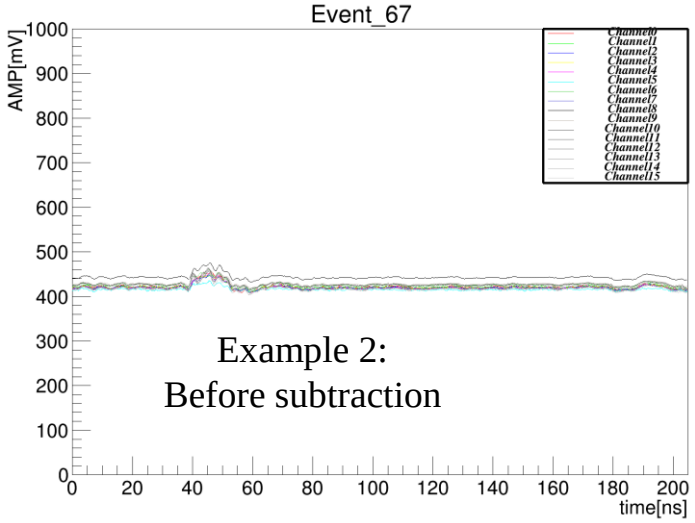
Result of the second panel

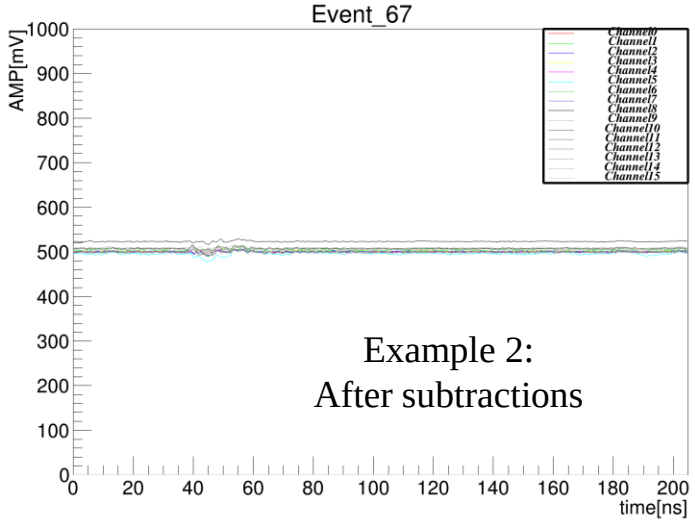
Waveform pre-analysis

Noise subtraction：



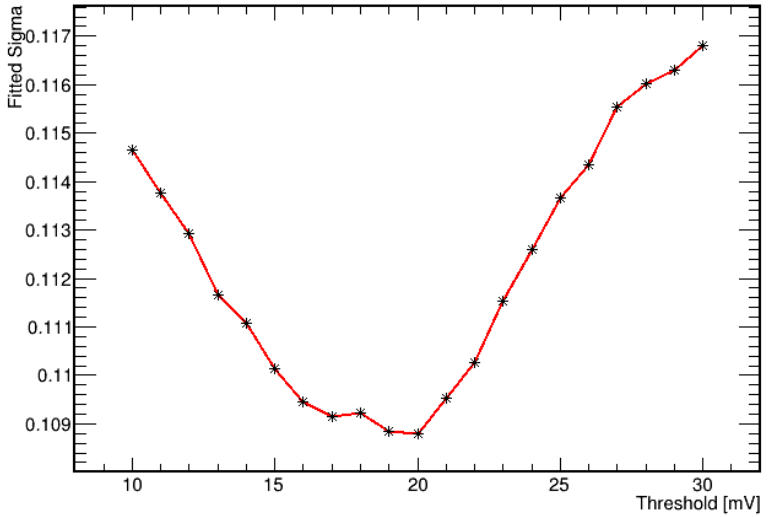




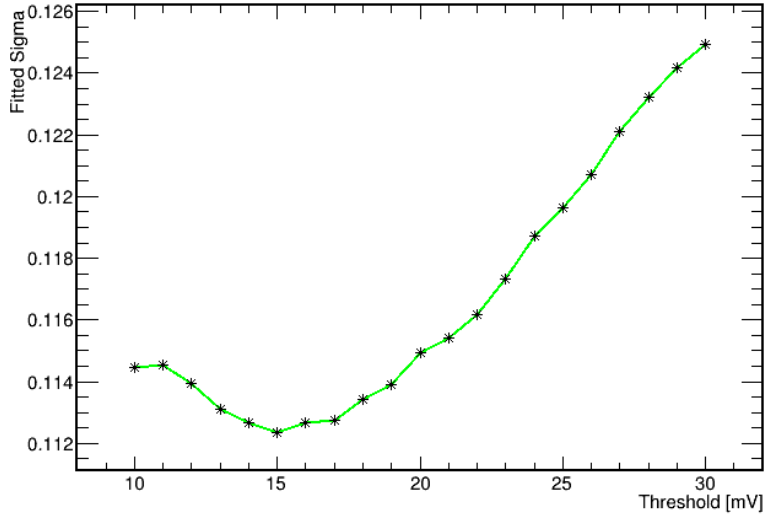


Threshold selection:

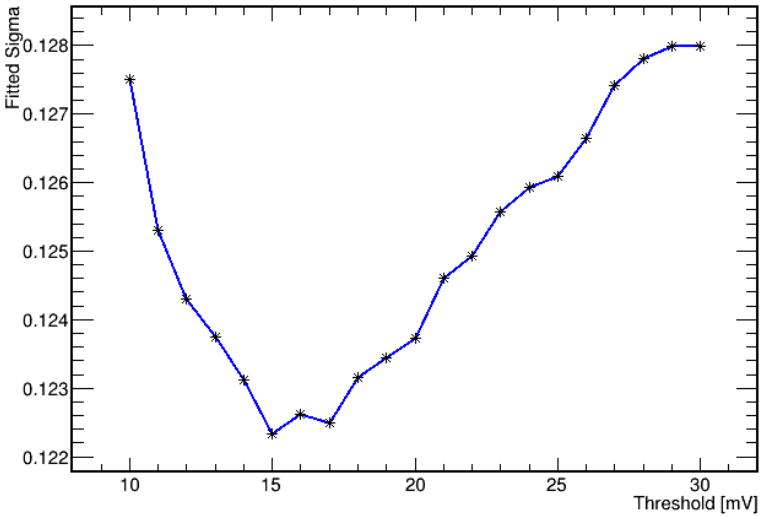
- Tune the threshold one by one:
  - Fix the threshold of the other two RPC @30mV
  - Vary the threshold in the test RPC



RPC1: 20 mV

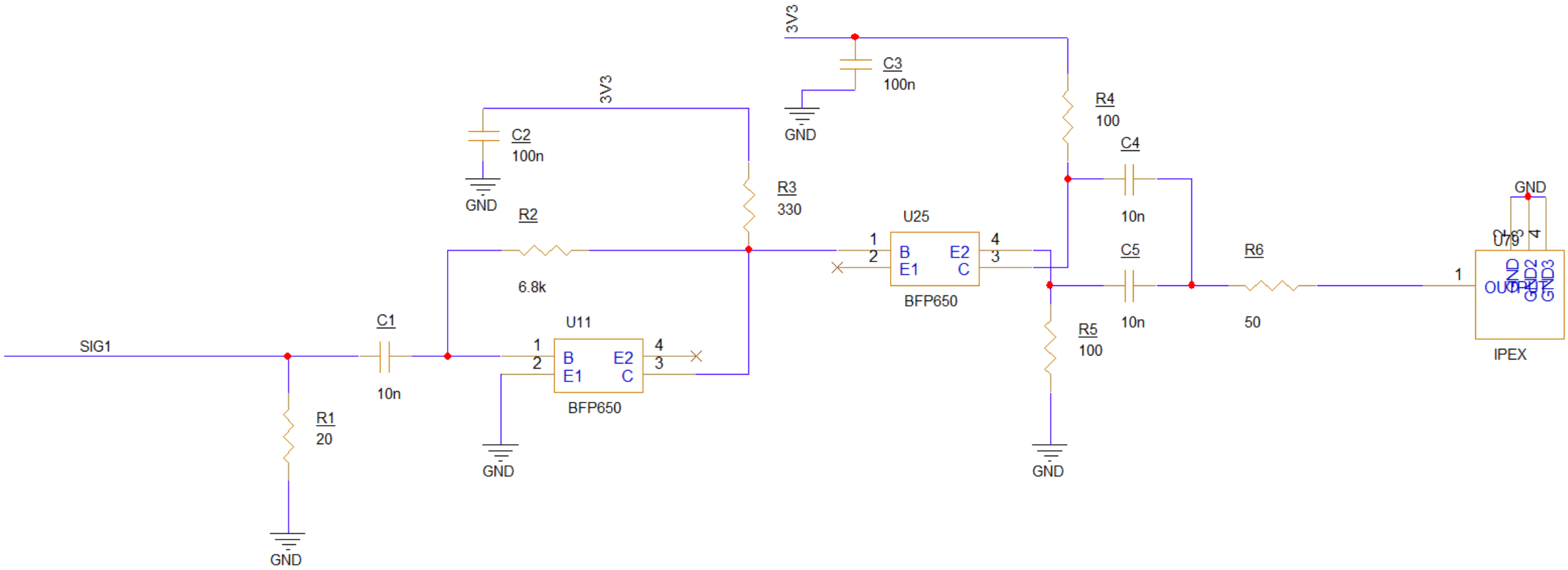


RPC2: 15 mV

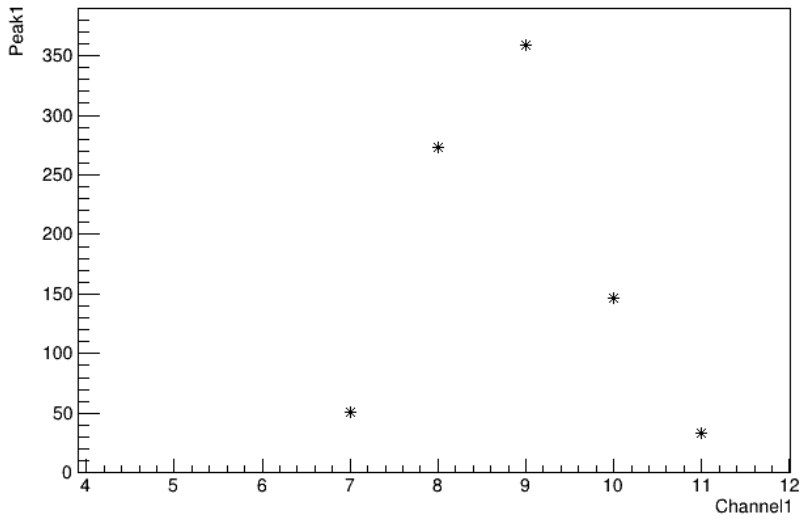


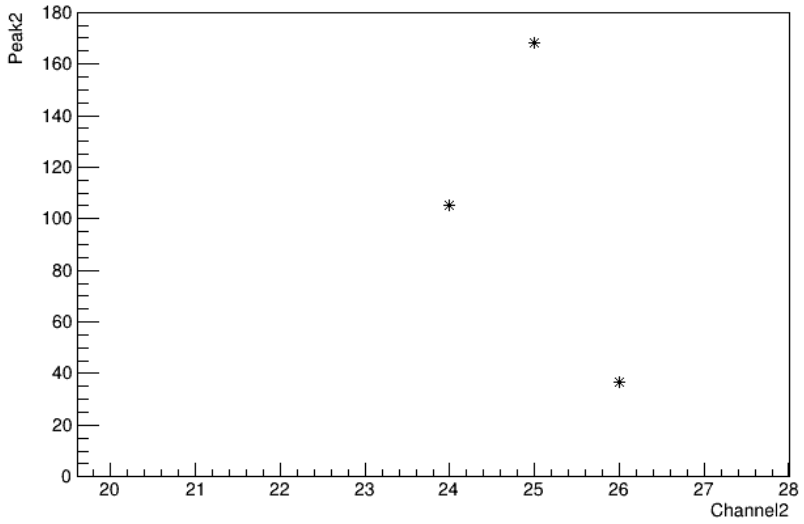
RPC_TOP: 15 mV

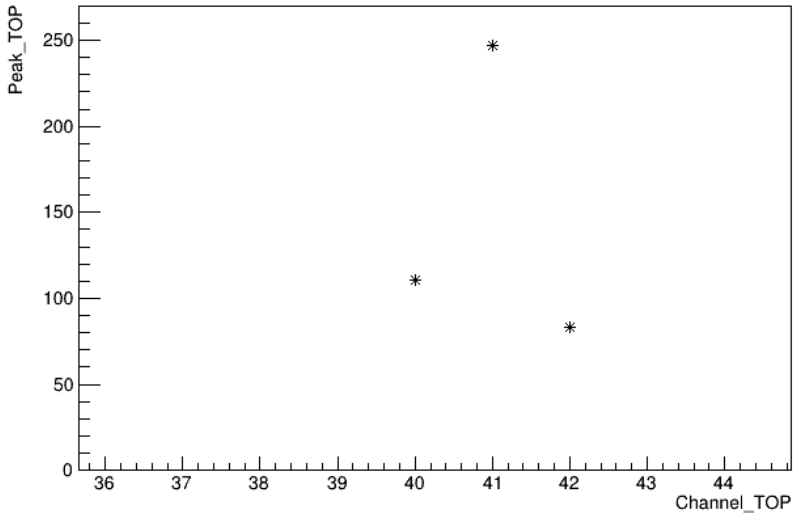
RPC FEE structure



Spatial resolution: center of amplitude algorithm







$$Hit\ position = \frac{\sum_{i=0}^{n} Ch_i * Peak_i}{\sum_{i=0}^{n} Peak_i}$$