PWO detector calibration + TOF data analysis

SNU

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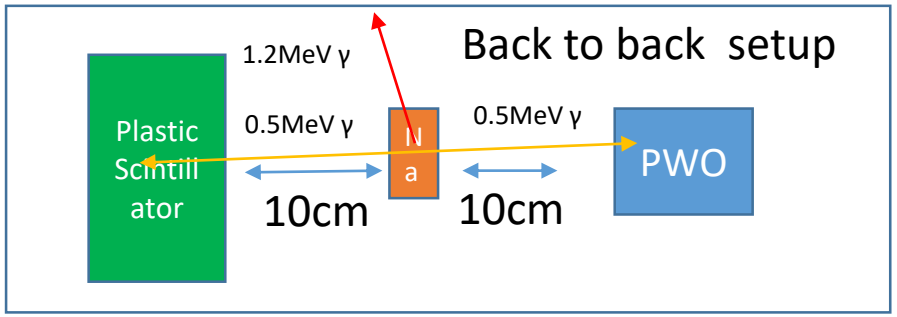
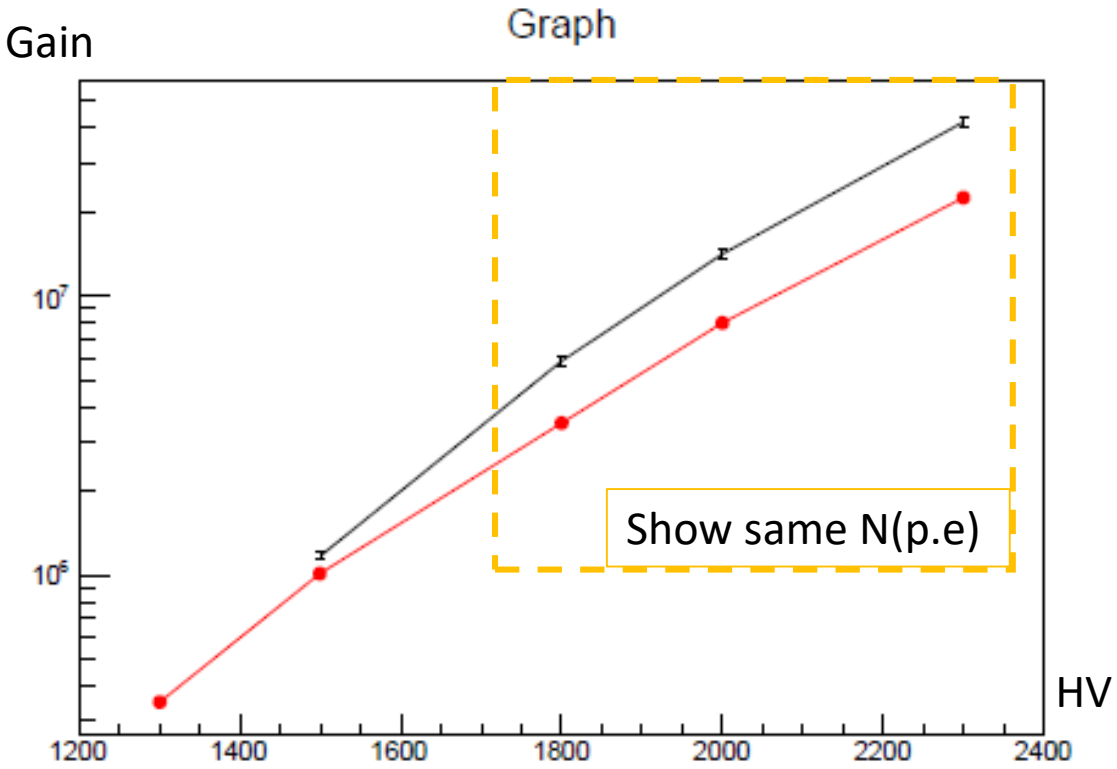
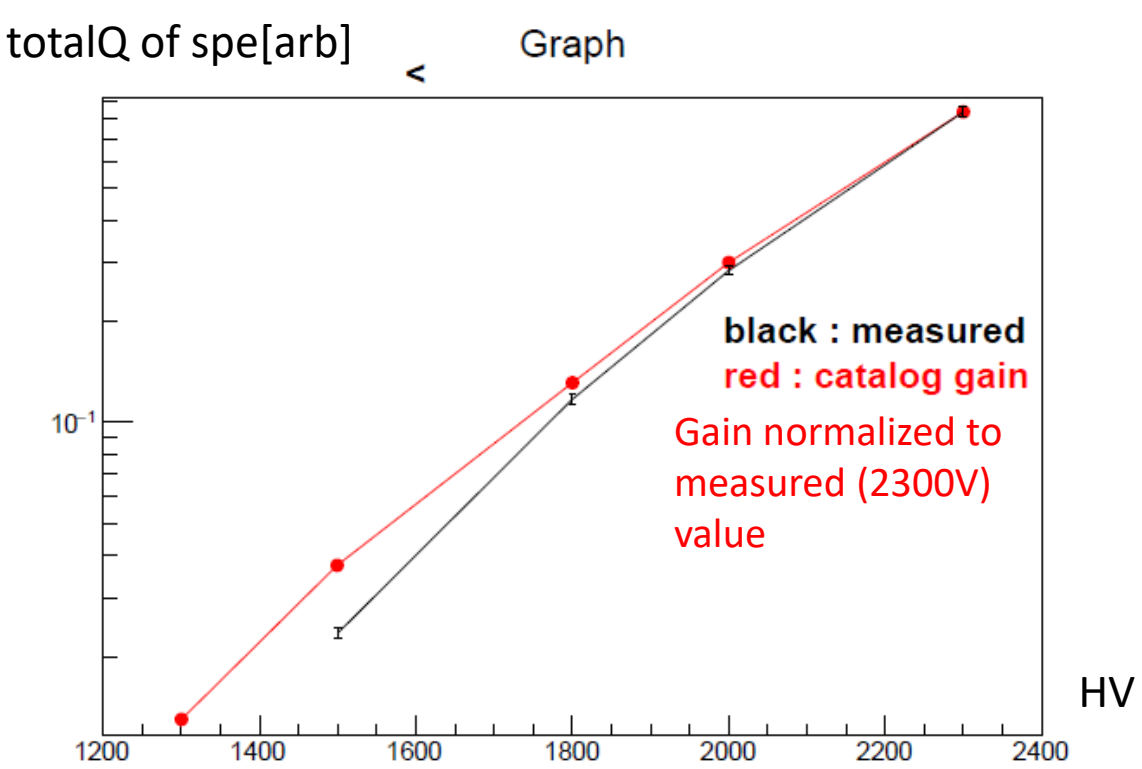
HV gain linearity test

- Main purpose : check the PDF of total Q distribution to confirm efficiency stability by changing HV.
- If efficiency is fixed, we can just adjust HV for gain change
- With the measured gain curve by s-p.e, gain curve from beam test will be compared. (kind of cross-check and to go to 0.5kV HV range)



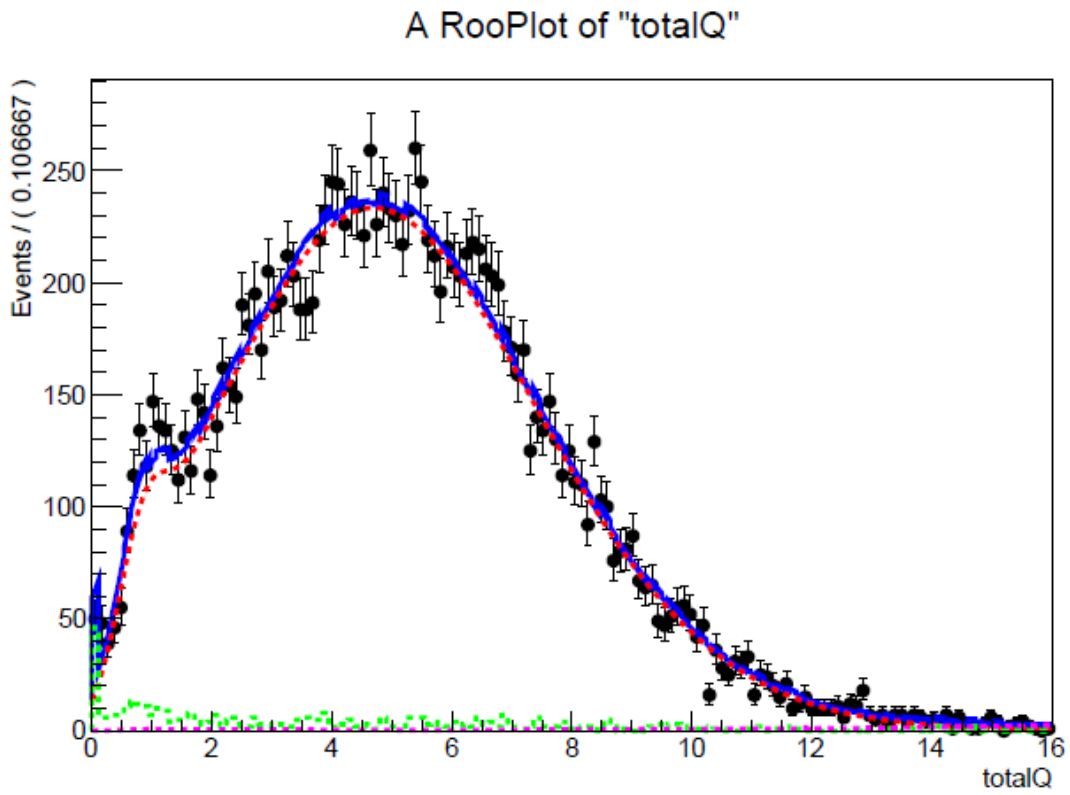
Gain Linearity distribution





- Gain drop from measurement is well agreed with catalog value (if we match value at 2300V then other points are well agreed (right graph)
- p.e number is fixed as 6.75 following fitting of HV -2300V result.

PWO -2300V



NO.	NAME	VALUE	ERROR
1	a	6.75384e+00	2.16920e-01 (number of p.e)
2	fr12	7.05256e-03	1.71589e-03 (1.2MeV fraction)
3	mf	8.40770e-01	2.66400e-02 (mean of Gauss for p.e)
4	sf	4.40137e-01	1.60134e-02 (sig of Gauss for p.e)

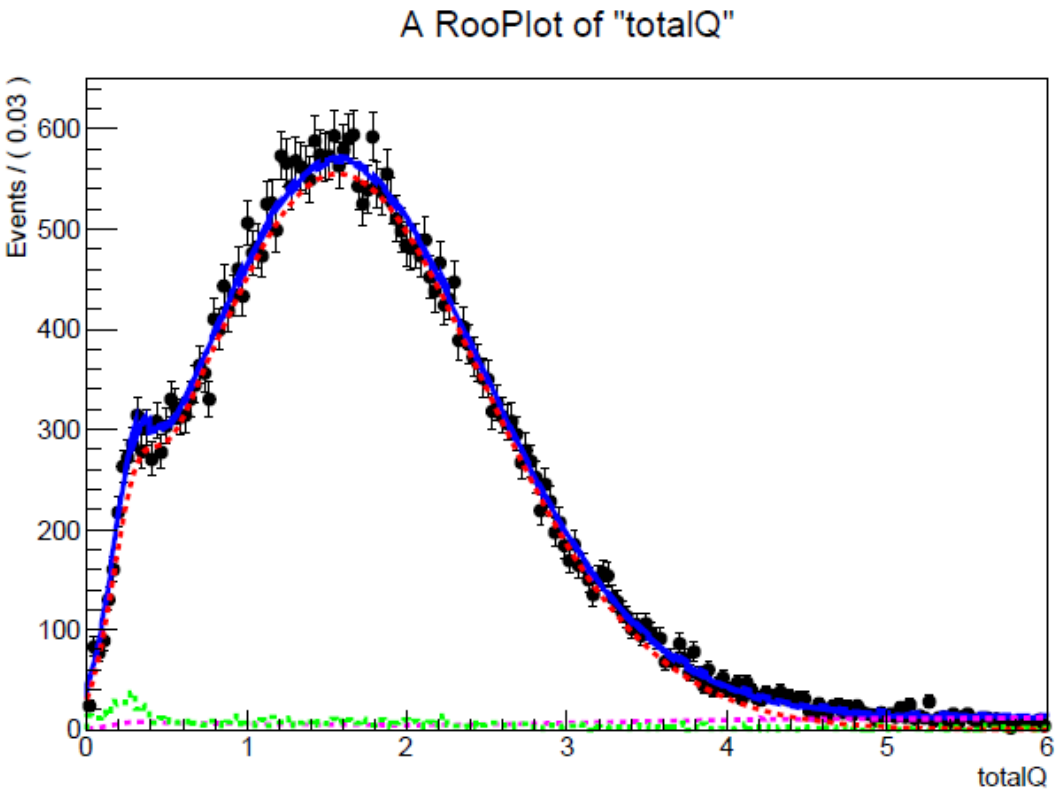
frame1->chiSquare()

(Double_t) 1.193553e+00 (χ^2/NDF)

(1-bgf.getVal())*(1-fr12.getVal())*(hh1->GetEntries())/(PWO->GetEntries())

(double) 7.640497e-02 (Signal event fraction)

PWO -2000V



NO.	NAME	VALUE	ERROR
1	a	6.58958e+00	1.29575e-01
2	fr12	3.23718e-02	2.03329e-03
3	mf	2.89408e-01	5.67725e-03
4	sf	1.48356e-01	3.33866e-03

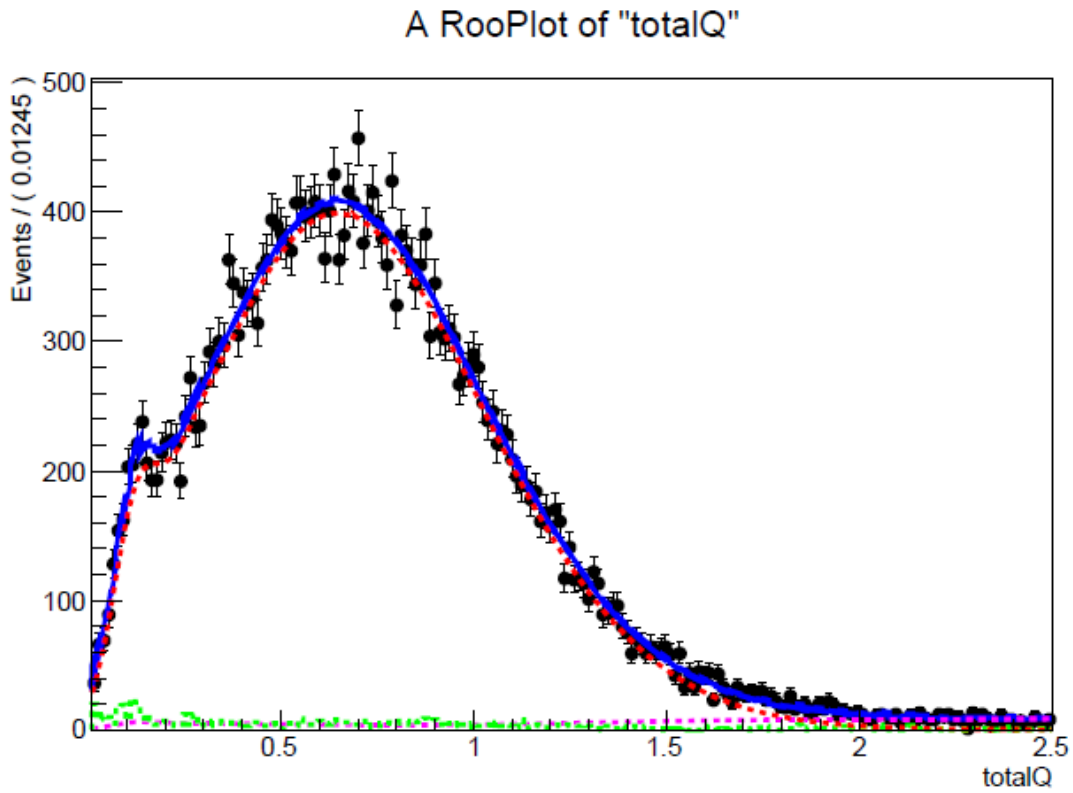
frame1->chiSquare()

(Double_t) 1.321210e+00

root [6] (1-bgf.getVal())*(1-fr12.getVal())*(hh1->GetEntries())/(PWO->GetEntries())

(double) 7.700678e-02

PWO -1800V



NO.	NAME	VALUE	ERROR
1	a	6.53610e+00	1.41725e-01
2	fr12	3.40801e-02	2.35874e-03
3	mf	1.20311e-01	2.59428e-03
4	sf	6.04381e-02	1.68795e-03

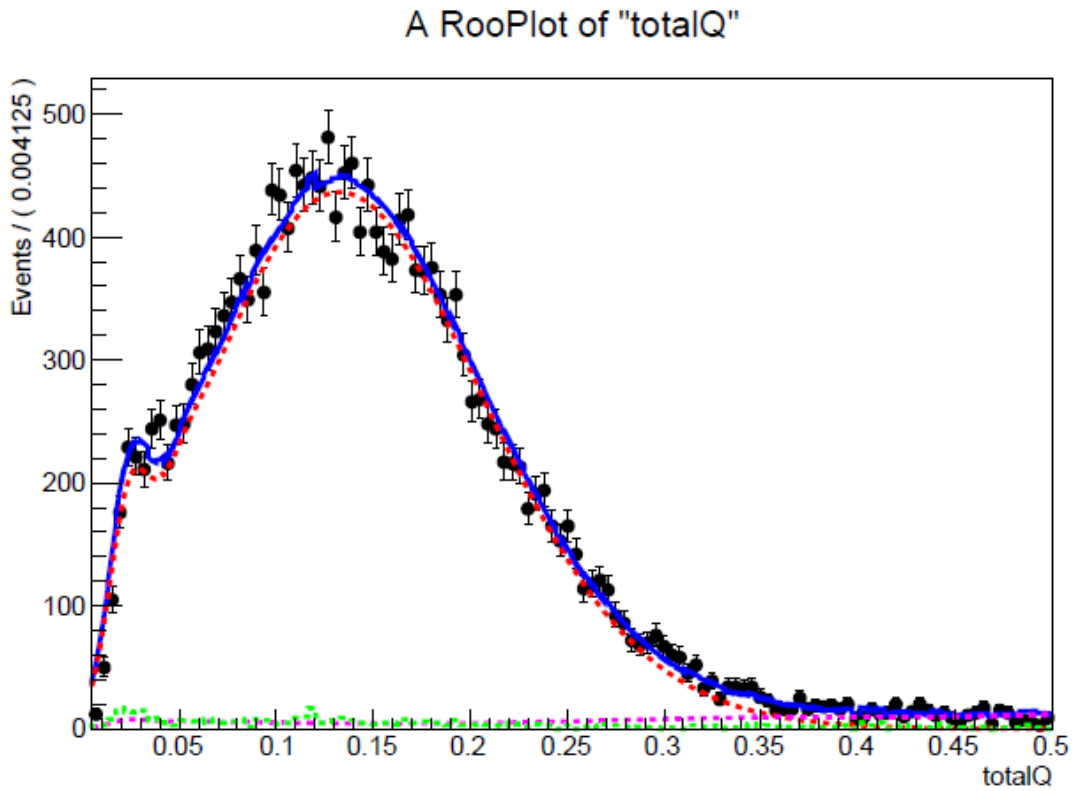
frame1->chiSquare()

(Double_t) 1.125712e+00

root [7] (1-bgf.getVal())*(1-fr12.getVal())*(hh1->GetEntries())/(PWO->GetEntries())

(double) 7.860906e-02

PWO -1500V



NO.	NAME	VALUE	ERROR
1	fr12	3.94092e-02	2.90341e-03
2	mf	2.27828e-02	9.64239e-05
3	sf	1.10912e-02	4.46988e-04

←a can't be free (fitting fail)

frame1->chiSquare()

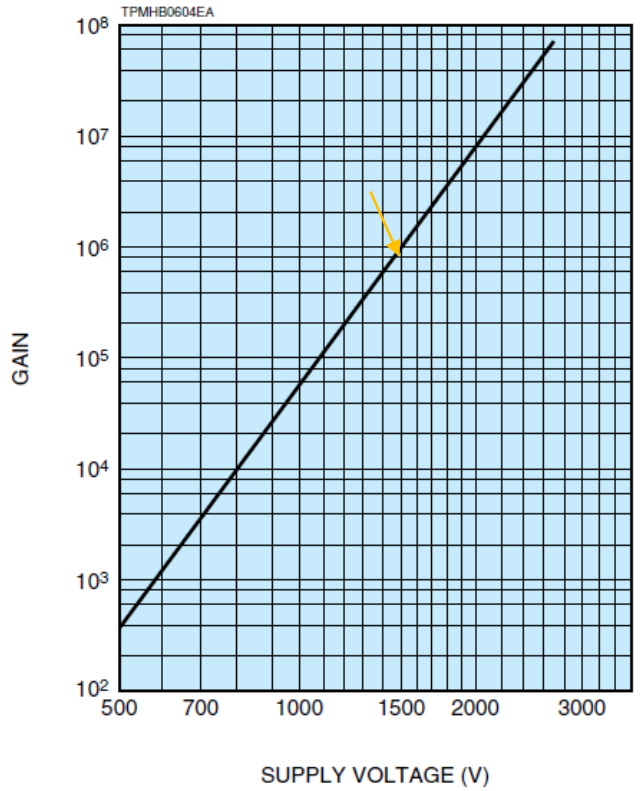
(Double_t) 2.268175e+00

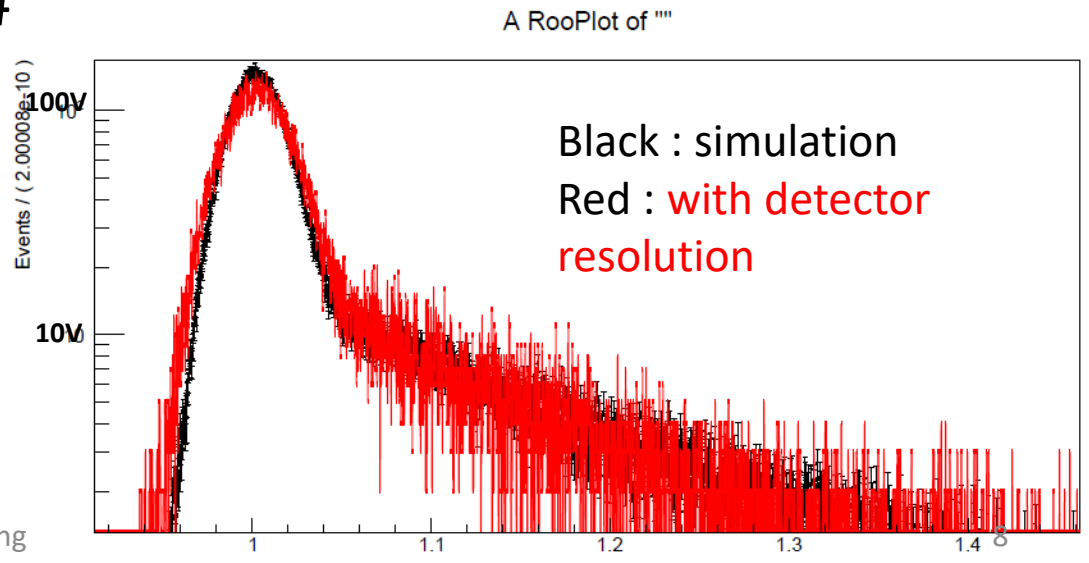
root [6] (1-bgf.getVal())*(1-fr12.getVal())*(hh1->GetEntries())/(PWO->GetEntries())

(double) 7.700111e-02

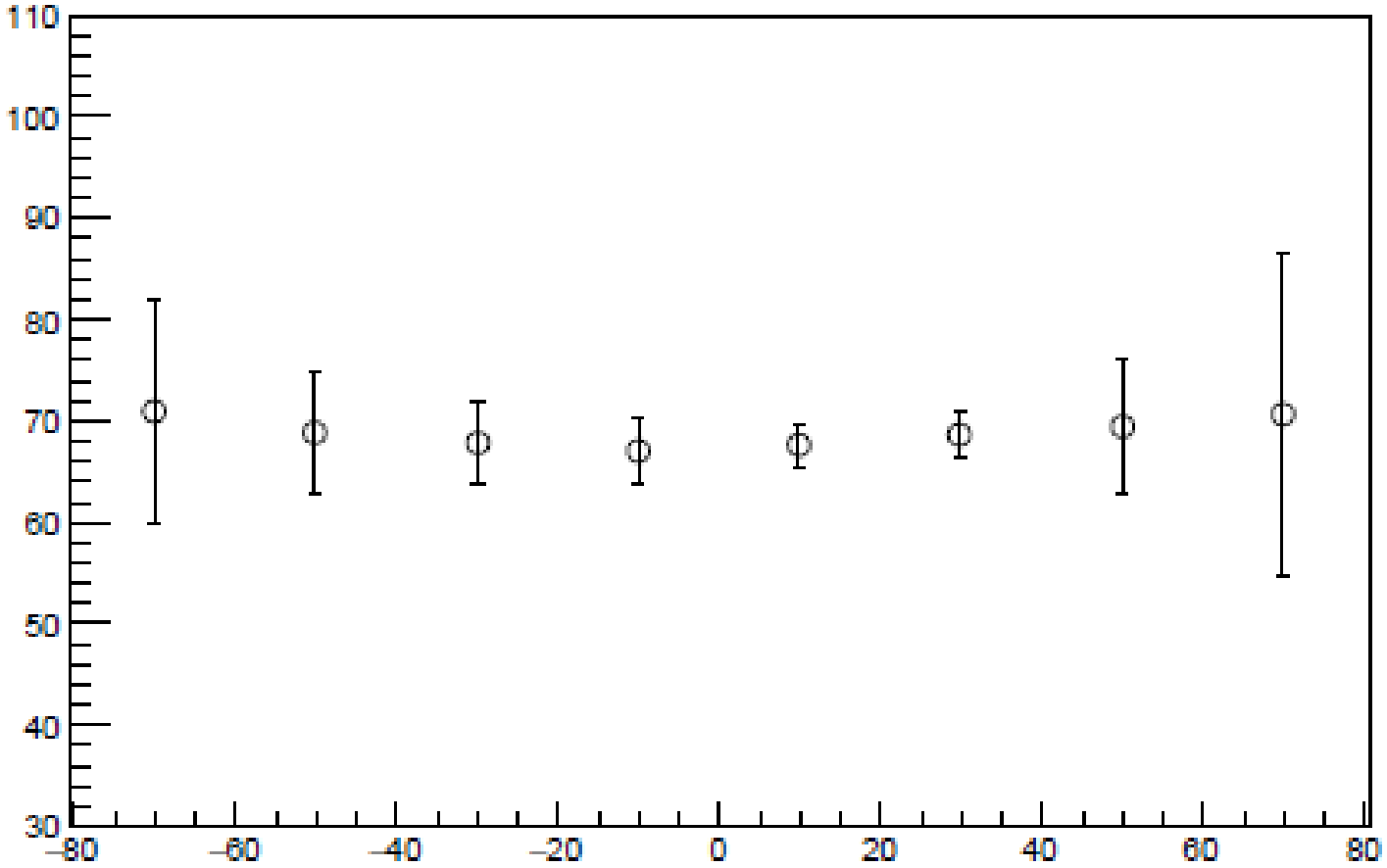
About signal height

- Spec) 100mA→2.5V (2% dev), 200mA→5V (5% dev)
- Coverage of oscilloscope (up to 10V)
- Geometrical acceptance : 1.3%
- Total Q (HV-1500V) 0.1586Vx0.2ns/0.4645MeV
- About 160V expected to I(e^+) = 1.e^{+7}#/pulse
- 0.8kV to PMT to measure range to ~1.e^9#





Mean of bar2~9



So

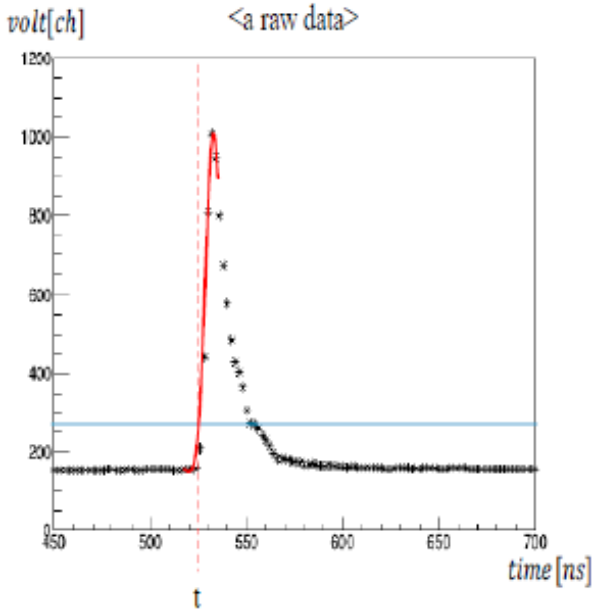


Figure 4: A sample of the raw signal from a cosmic ray. Red line shows the fitted Bessel function by inverse interpolation method. The crossing point between the blue line as 10% height and the fitted Bessel function shows a determined time of the signal.

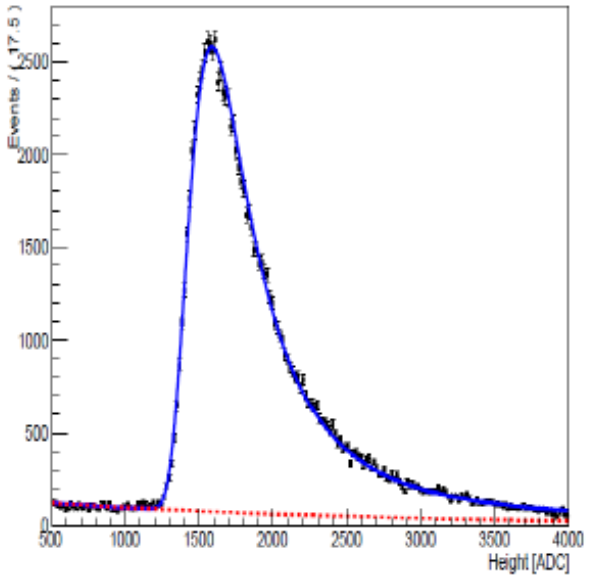


Figure 5: Distribution of the signal amplitude as a mean of signal amplitudes from two PMTs with fitting by a Landau function (Blue line) with an exponential function (Red dotted line).

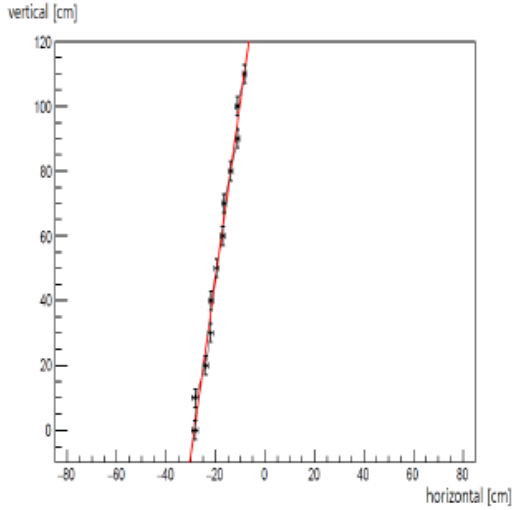


Figure 6: Cosmic muon track as a example which is reconstructed as a 1^{st} order polynomial function (red line) fitted to 12 data points by χ^2 fitting method.

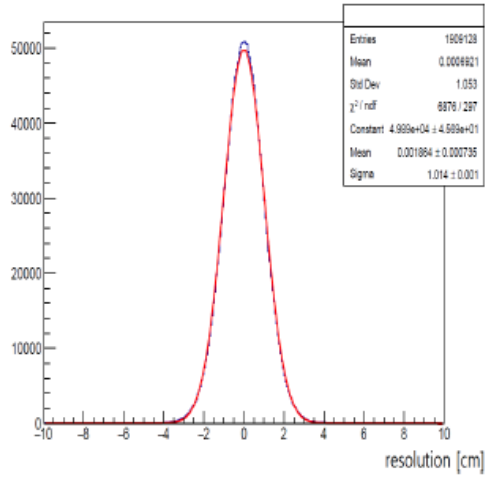


Figure 7: The distribution of a difference between the track and the measured hit position. Red line shows the fitted Gaussian function by χ^2 method. The spatial resolution for the wall of the TOF detector is 1.014(1)cm

Bar	Resolutuion [cm]	Bar	Resolution [cm]
1	0.96	7	1.02
2	0.99	8	1.11
3	1.01	9	1.05
4	1.05	10	0.92
5	1.05	11	0.95
6	1.03	12	0.98

Table 1: Spatial resolution of each bar in the TOF wall.

Bar	Resolutuion [ps]	Bar	Resolution [ps]
3	70 (2)	7	65 (8)
4	70 (8)	8	72 (3)
5	67 (3)	9	66 (6)
6	67 (5)	10	66 (3)

Table 2: Time resolution for each bar (From Bar 3 to Bar 10) in the TOF wall.

Detail of calculation

- $\bar{t}_j - \frac{\sum_{i=2(i\neq j)}^{9} \bar{t}_{i\to j}}{7} = \bar{t}_j - \frac{\sum_{i=2}^{9}(\bar{t}_i) - \bar{t}_j}{7} - \sum_{i=2}^{9} \frac{0.1m\times(i-j)}{7\times c\times cos\theta}$

$= \bar{t}_j - \frac{\sum_{i=2}^{9}(\bar{t}_i) - \bar{t}_j}{7} - \frac{0.1\times(44-8\times j)}{7\times c\times cos\theta}$

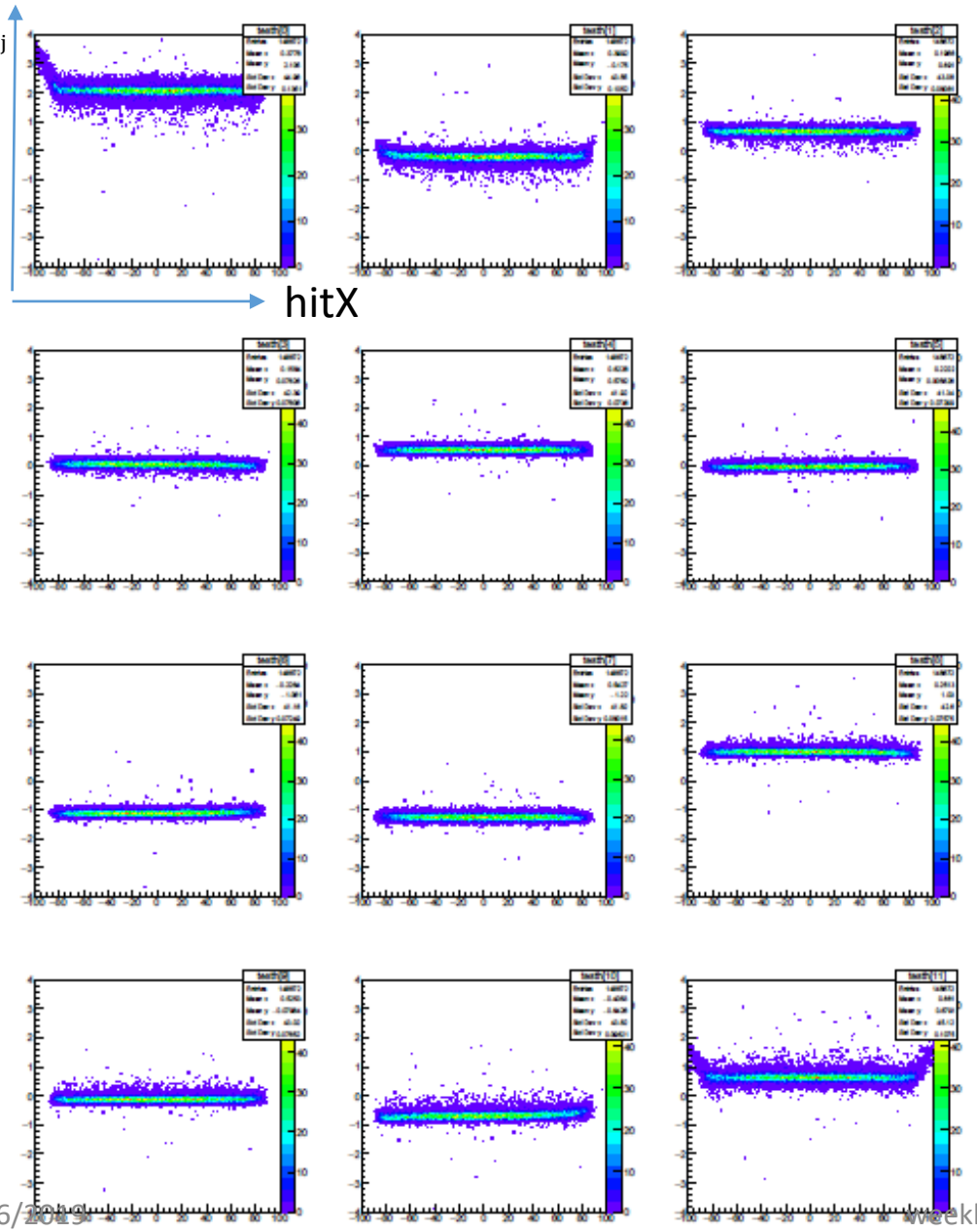
- $\sigma_j' = \sigma\left(\left(\frac{\sum_{i=2}^{9}\bar{t}_i - \bar{t}_j}{7}\right) - \bar{t}_j + \frac{44-8\times j}{7\times c\times \cos\theta}\right) \sim \sqrt{\frac{\sum_{i=2}^{9}\sigma_i^2}{49} + \frac{48\times\sigma_j^2}{49}}$
- $\sigma_j = \sqrt{-\frac{\sum_{i=2}^{9}\sigma_i'^2}{56} + \frac{49\times\sigma_j'^2}{48}}$
- $Err_{pos}(\sigma_j') = just\ fitting\ error$
- $Err_{pos}(\sigma_j) \sim \sqrt{\sigma\left(\sigma_j'\right)^2 + \left((\bar{t}_j - \overline{t_{j.pos}})/2\right)^2}$
- Diff(M(Δt)- M_i(Δt))/2 as error.

TOF time resolution

Bar #	Time resolution [ps]	ERR	Note
1	8.155469e+01	5.005548e+00	no use
2	8.232206e+01	1.224403e+01	no use
3	6.985364e+01	1.885954e+00	
4	6.950353e+01	7.853380e+00	
5	6.675766e+01	3.297951e+00	
6	6.651230e+01	4.542207e+00	
7	6.507726e+01	7.723484e+00	
8	7.246711e+01	2.683870e+00	
9	6.601373e+01	6.428965e+00	
10	6.573203e+01	3.185557e+00	
11	7.696025e+01	1.821386e+01	no use
12	8.045786e+01	4.639422e+00	no use

Cos>0.9

$$\left(\frac{\sum_{i=2}^{9}\bar{t}_i - t_j}{7}\right) - t_j + \frac{44 - 8\times j}{7\times c\times \cos\theta}$$



Zoom up