NEUT analysis

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概 要

I show the analysis of NEUT briefly.
・QDC pedestal:ped run
・TDC Tcal:Tcal run
・dT offset,dT2x(for GATE of slew correction):muon run
・QDC gain(for GATE of slew correction):muon run
・TOF offset(for slew correction easily):Pb+p run, Li(p,n) run
・slew correction:Li(p,n) run
・dT offset(after slew correction):muon run
・QDC vs dT calibration(after slew correction):muon run
・TOF offset(after slew correction):proton beam

1 NEUT analysis

1.1 QDC pedestal (run198,199)

ALraw=ALraw-ped [ch]
ARraw=ARraw-ped [ch]
ペデスタル run198,199 より、QDC のペデスタルピークにガウス関数を fit させ、定数 ped を求めた。1stLayer-Left の結果を図 1,2 に示す。

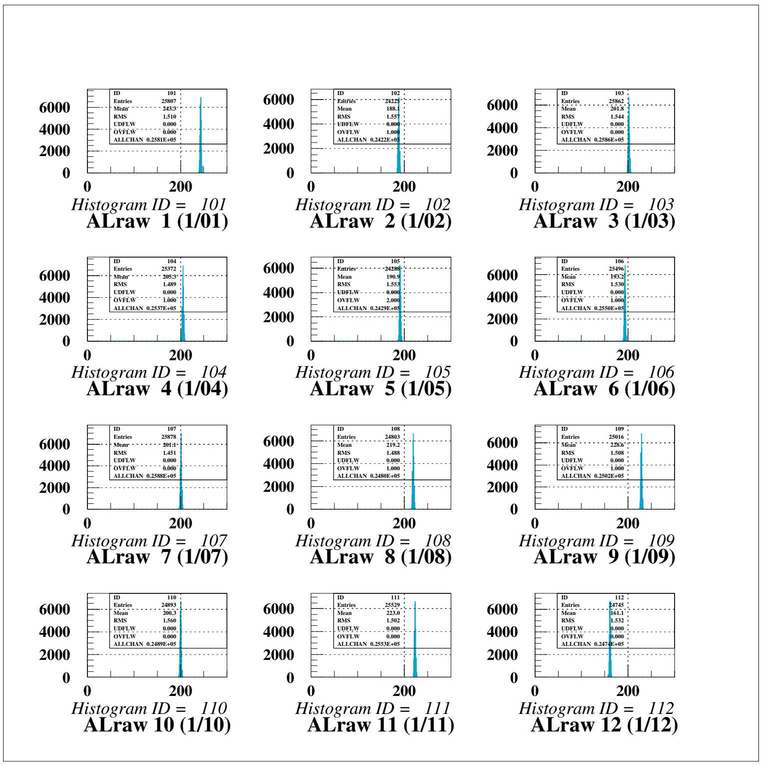

図 1: QDC pedestal(1stLayer-Left)

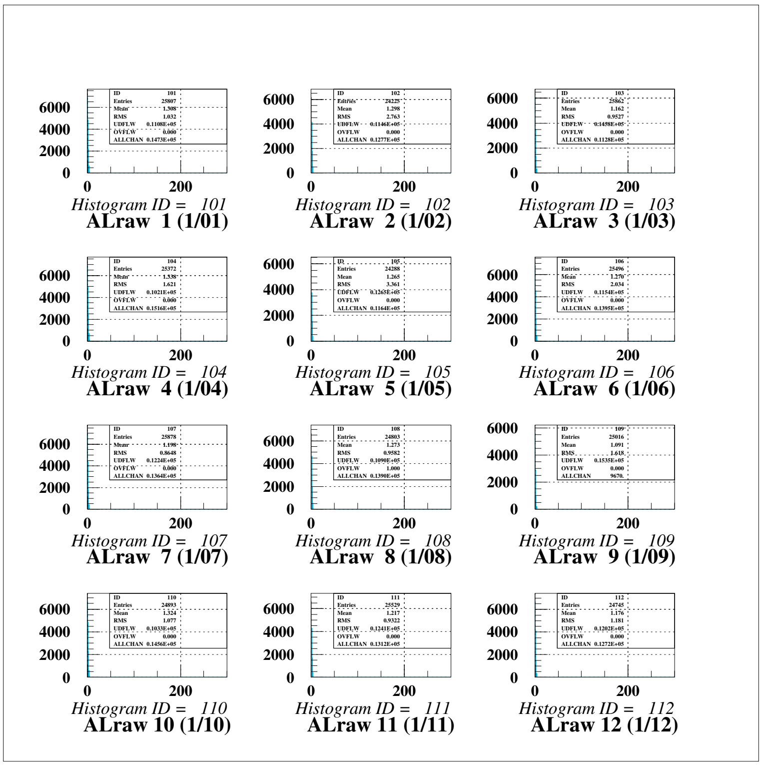

図 2: QDC pedestal を引いた後 (1stLayer-Left)

1.2 TDC Tcal (run198,199)

TLcal [ns] = TLraw [ch] * ch2ns

TRcal [ns] = TRraw [ch] * ch2ns

20ns 置きに発生させられるパルス信号を用いて、TDC のキャリブレーションを行い、定数 ch2ns を求めた。1stLayer-Left-101,102,103,104 の結果を図 3 に示す。NEUT の TDC full range は 300ns である。

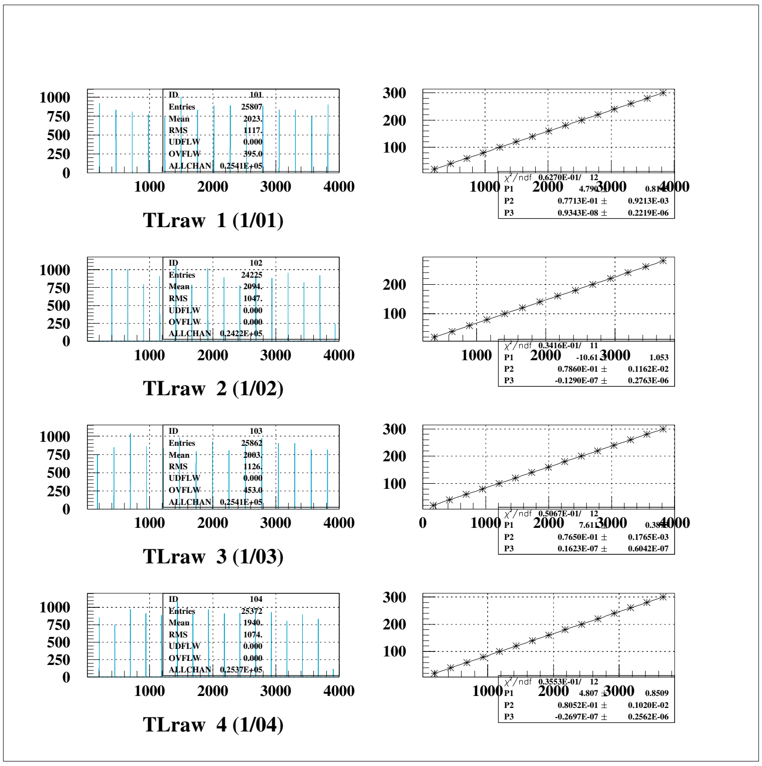

図 3: TDC Tcal(1stLayer-Left-101,102,103,104)

1.3 dT offset,dT2x calibration (muon run)

[1]I used all event in muon run.

$$\mathrm{dTcal} = (\mathrm{TLcal} - \mathrm{TRcal}) - \mathrm{dToffset} \tag{1}$$

$$\mathrm{dt2x} = 2100[\mathrm{mm}]/\mathrm{dTwidth}[\mathrm{ns}] \qquad (\text{for long NEUT}) \tag{2}$$

$$\mathrm{dt2x} = 1120[\mathrm{mm}]/\mathrm{dTwidth}[\mathrm{ns}] \qquad (\text{for short NEUT}) \tag{3}$$

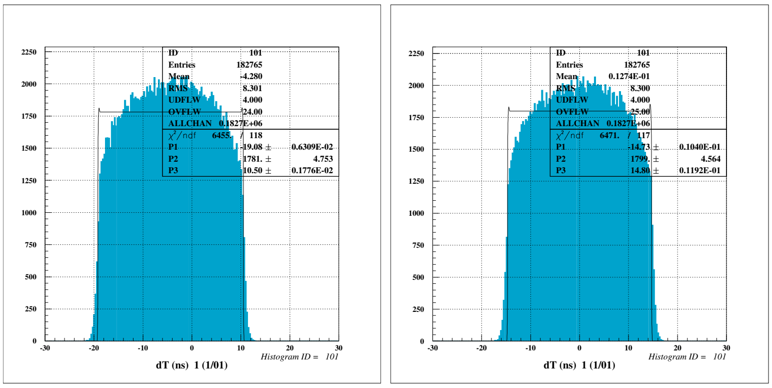

図 4: dT offset fitting (left:before , right:after)

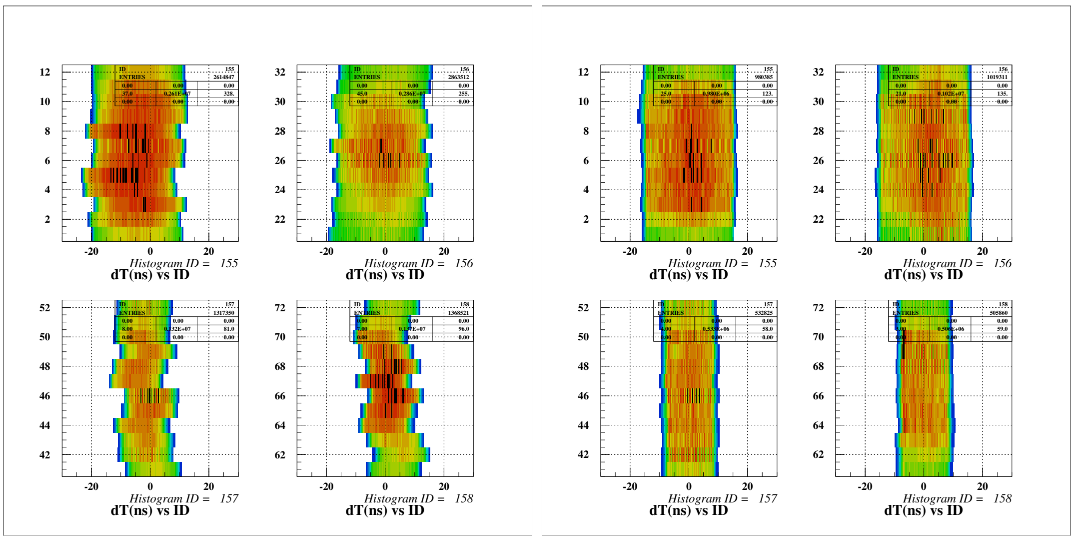

図 5: before/after dT offset (dT vs ID)

[1]slew 補正で X の gate をかけるためのキャリブレーション。slew 補正後に再びきちんと行う。

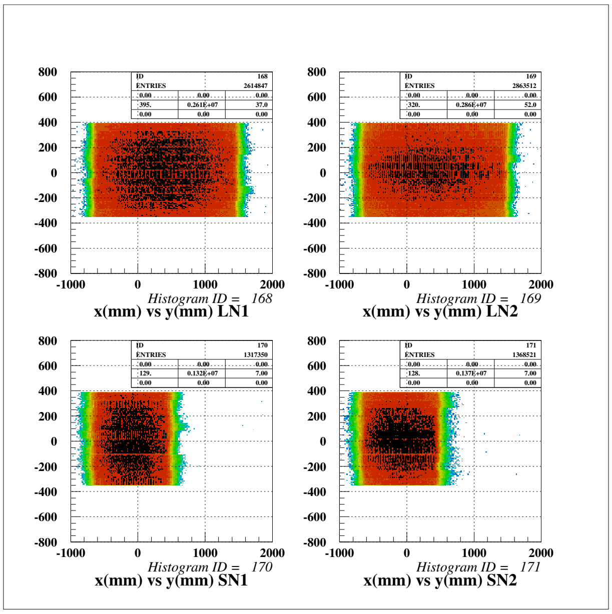

図 6: after dt2x calibration (x vs y)

1.4 QDC gain(muon run)

$$\mathrm{Acal} = \sqrt{\mathrm{ALraw} * \mathrm{ARraw}}/\mathrm{qgain} * \mathrm{dE} \tag{4}$$

[2]I used muon run(1044,23,36,39,40,41,42,43,44). I used following gate for each neutron wall to select only cosmic ray.
・-250mm $\leq$ x local position (center of scintillator = 0 mm) $\leq$ 250mm
・NEUT multiplicity = 12

Energy loss of muon in 60mm scintillator is dE=11.7MeVee. I fit landau function for landau peak and got parameters 'qgain' from [ch] of QDC to [MeVee].

gate	Wall 1	Wall 2	Wall 3	Wall 4
all	1062346	1211015	917443	928582
multi=12	237564	254112	190692	192228

表 1: multiplicity=12 gate (muon run)

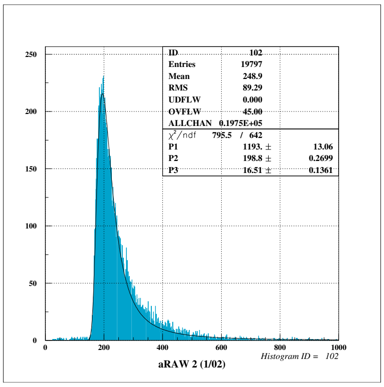

図 7: fitting of the landau function

[2]slew 補正で ADC の gate をかけるためのキャリブレーション。slew 補正後に再びきちんと行う。

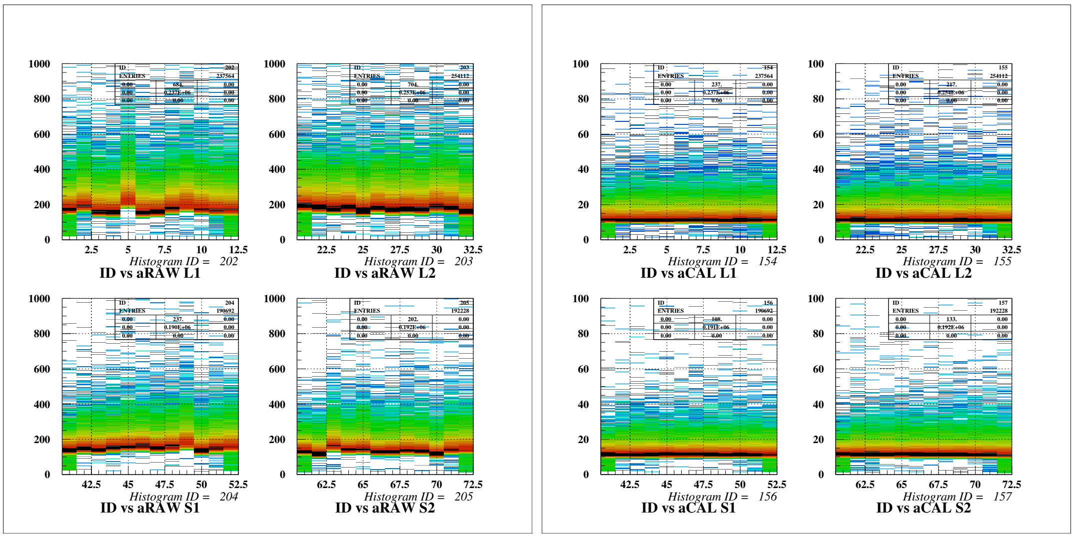

図 8: before/after QDC gain calibration (ID vs Araw)

1.5 TOF offset (Pb+p run)

$$\left(\frac{\mathrm{TLcal}+\mathrm{TRcal}}{2}\right)_{\mathrm{NEUT}}=\left(\frac{\mathrm{TLcal}+\mathrm{TRcal}}{2}\right)_{\mathrm{raw}}-\mathrm{TOFoffset} \tag{5}$$

[3]Before slew correction, I calibrated TOF offset using Pb+p run(run 4).

In this run, gamma ray was emittd. The velocity of gamma ray is same of the velocity of light.

I determined TOF offset so that TOF of gamma ray was to be 0[ns]+FL/c. It is easier to correct slewing.

I used following gate to select only gamma ray.

・VETO hit = 0

・NEUT multiplicity = 1

・pulse height of QDC $\geq$ 2.0MeVee

gate	count (after gate)	analysis event/all event
all	236038	100.0%
VETO	213545	90.5%
multi=1	163297	69.2%
2MeVee	118908	50.4%

表 2: gate for TOF offset (run4)

[3]slew 補正を簡単に行うための offset。gamma 線の run を使って、48 本の各シンチレータの時間情報が同程度の範囲に収まるように定数を差し引きした。TOF の offset は slew 補正後に再びきちんと行う。

1.6 slew correction (Li(p,n) run)

$$\mathrm{TOF_{raw}} = \left(\frac{\mathrm{TLcal} + \mathrm{TRcal}}{2}\right)_{\mathrm{NEUT}} - \left(\frac{\mathrm{TLcal} + \mathrm{TRcal}}{2}\right)_{\mathrm{F2}} \tag{6}$$

$$\mathrm{TOF_{slew}} = \mathrm{TOF_{raw}} - \frac{\mathrm{P_L}}{\sqrt{\mathrm{ALraw}}} - \frac{\mathrm{P_R}}{\sqrt{\mathrm{ARraw}}} \tag{7}$$

$$\mathrm{TLslew} = \mathrm{TLcal} - \frac{2\mathrm{P_L}}{\sqrt{\mathrm{ALraw}}} \tag{8}$$

$$\mathrm{TRslew} = \mathrm{TRcal} - \frac{2\mathrm{P_R}}{\sqrt{\mathrm{ARraw}}} \tag{9}$$

I corrected slewing of neutron counter using Li(p,n) run(run 6-10,12-20).

In this run, neutron of mono-energy was emittd, so TOF should be same and not dependent on the pulse height of QDC.

I used following gate to select only neutron from Li(p,n) interaction.

・BEAM $\times$ NEUT
・VETO hit $= 0$
・NEUT multiplicity $= 1$
・pulse height of QDC $\geq$ 6.0MeVee
・-150mm $\leq$ x hit position (center of beam = 0 mm) $\leq$ 150mm

gate	count (after gate)
all	8442187
VETO	3727439
multi=1	2520492
6MeVee	626802
x 150mm	106341 (Wall1:34541,2:28922,3:21498,4:21380)

表 3: gate for slew correction (run6-10,12-20)

	before	after
LN 1	0.682	0.338
LN 2	0.703	0.344
SN 1	0.676	0.349
SN 2	0.685	0.359
all	0.686	0.347

表 4: $\mathrm{T_{NEUT}} - \mathrm{T_{F2}}$ timing resolution ΔT(ns) (TOF=0ns offset)

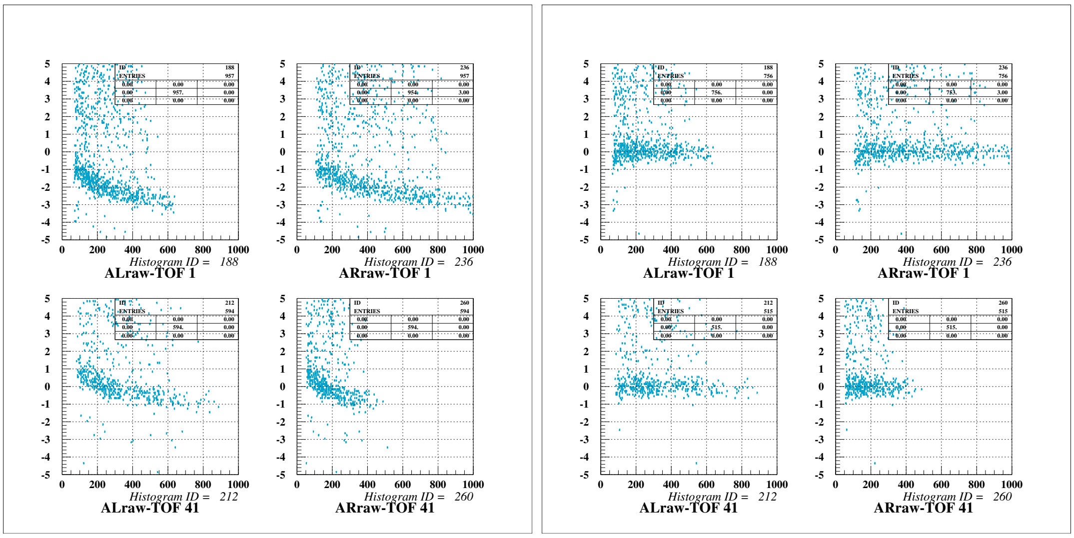

図 9: before/after slew correction (up:long-NEUT L/R , down:short-NEUT L/R)

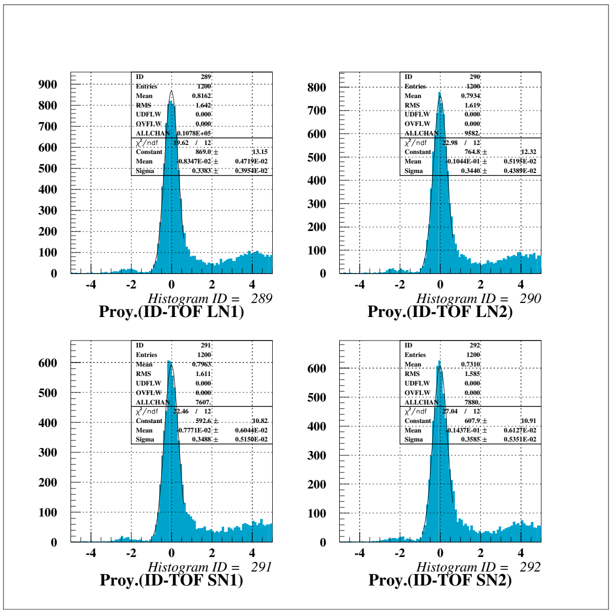

図 10: timing resolution of neutron peak after slew correction (neutron TOF = 0ns offset)

1.7 dT offset,dT2x calibration (muon run)

$$\mathrm{dTslew} = (\mathrm{TLslew} - \mathrm{TRslew}) - \mathrm{dToffset_{slew}} \tag{10}$$

$$\mathrm{dt2x_{slew}} = 2100[\mathrm{mm}]/\mathrm{dTwidth_{slew}}[\mathrm{ns}] \qquad (\mathrm{for\ \ long\ NEUT}) \tag{11}$$

$$\mathrm{dt2x_{slew}} = 1120[\mathrm{mm}]/\mathrm{dTwidth_{slew}}[\mathrm{ns}] \qquad (\mathrm{for\ \ short\ NEUT}) \tag{12}$$

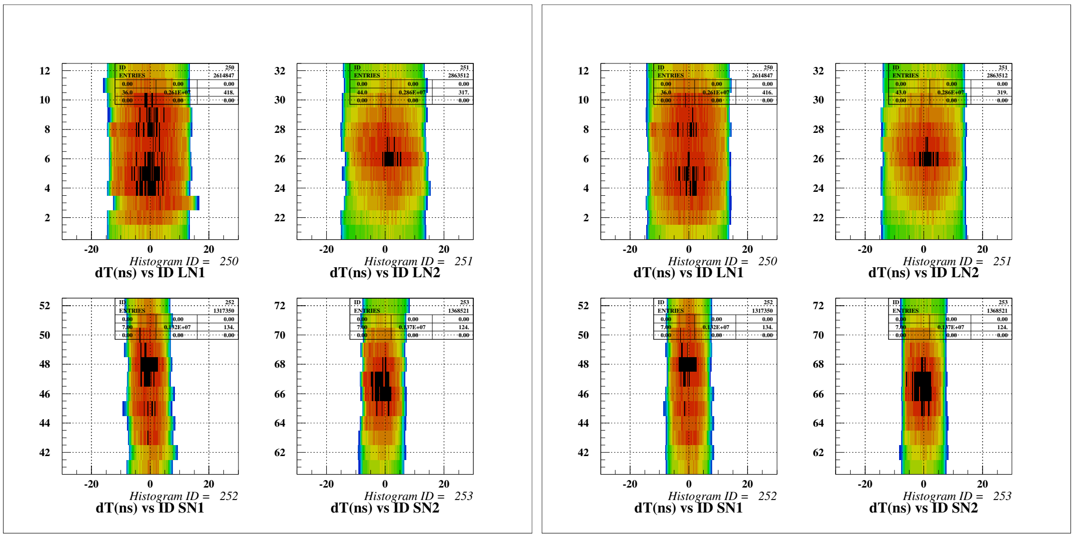

図 11: before/after dT offset (after slew correction) (dT vs ID)

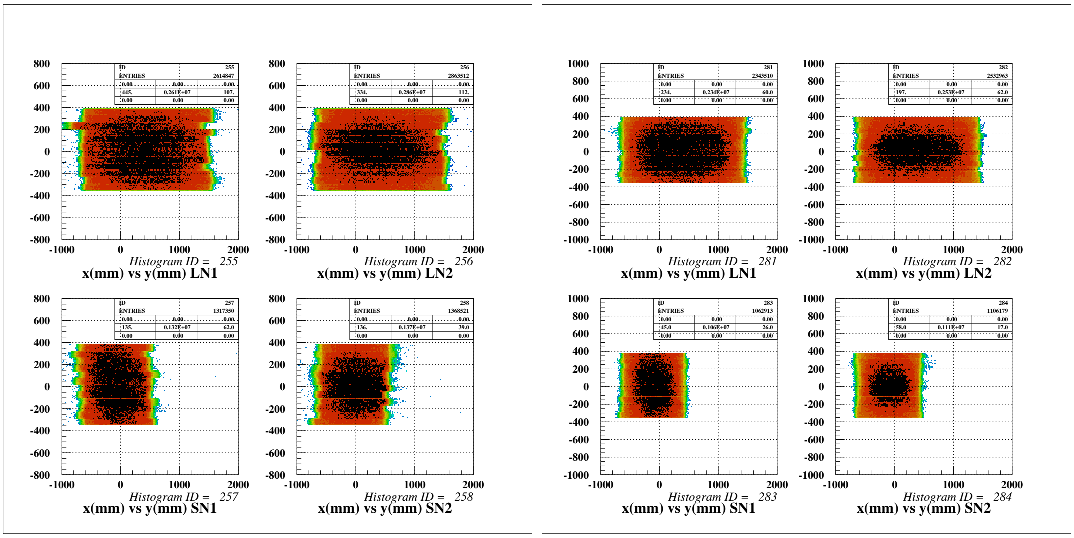

図 12: before/after dT2x calibration (after slew correction) (x vs y)

1.8 QDC vs dT calibration (muon run)

$$\mathrm{Aslew} = (\mathrm{Araw} - (\mathrm{P}_1 * \mathrm{dT}^2 + \mathrm{P}_2 * \mathrm{dT}^4))/\mathrm{qgain}_{\mathrm{slew}} * \mathrm{dE} \tag{13}$$

I used muon run(1044,23,36,39,40,41,42,43,44). I used following gate for each neutron wall to select only cosmic ray.

・NEUT multiplicity = 12

Energy loss of muon in 60mm scintillator is dE=11.7MeVee. I fit landau function for landau peak and got parameters 'qgain$_{slew}$' from [ch] of QDC to [MeVee].

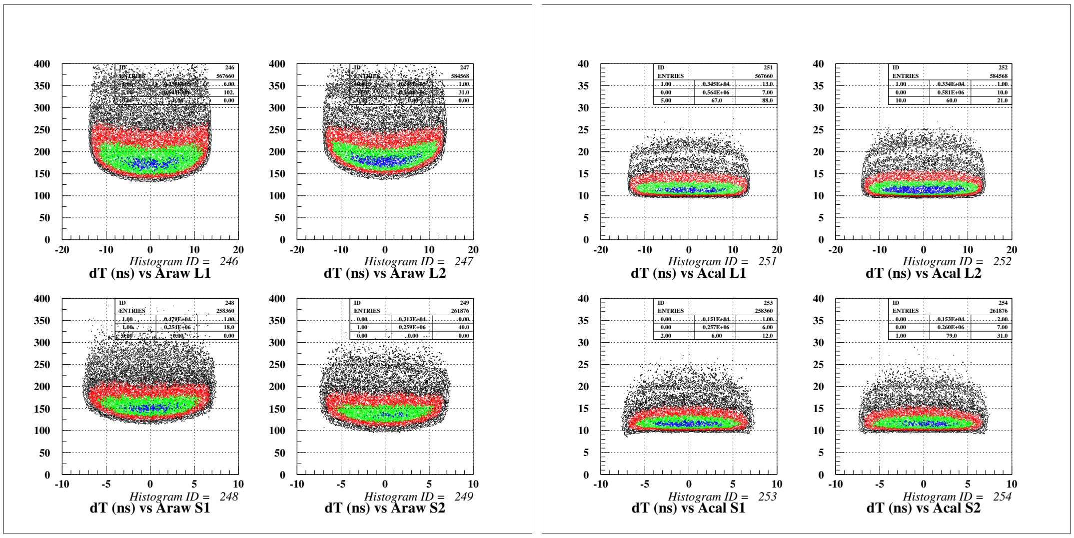

図 13: before/after QDC gain calibration

1.9 TOF offset (proton beam run)

I tried two method of TOF offset for proton beam.

- used gamma-ray from Pb+p run
- used neutron peak from Li(p,n) run

And,I compare TOF resolution of neutron emitted from Li(p,n) reaction with following gate to select only neutron from Li(p,n) interaction.

- BEAM $\times$ NEUT
- VETO hit $= 0$
- NEUT multiplicity $= 1$
- pulse height of QDC $\geq$ 6.0MeVee
- -150mm $\leq$ x hit position (center of beam = 0 mm) $\leq$ 150mm

I got higher TOF resolution of neutron by method 'used neutron peak from Li(p,n) run'.

1.9.1 used gamma-ray from Pb+p run

I used Pb+p run(#4) for TOF offset of proton-beam. [4]

$$\mathrm{TOF(tgt-NEUT)_{slew}} = \frac{\mathrm{TLslew} + \mathrm{TRslew}}{2} - \mathrm{TOFoffset_{slew}} + \mathrm{gpeak} \quad (14)$$

I determined TOF offset so that TOF of gamma ray was to be 0[ns]+gpeak.
Where, 'gpeak' is the peak of $\mathrm{FL}_{slew}/\mathrm{c}$.
I used following gate to select only gamma ray in Pb+p run.

- VETO hit = 0
- NEUT multiplicity = 1
- pulse height of QDC $\geq$ 2.0MeVee

And,I got TOF resolution of neutron emitted from Li(p,n) reaction.

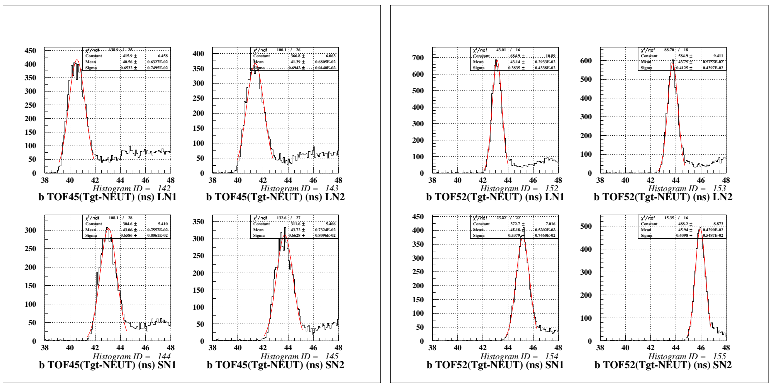

図 14: TOF of neutron emitted from Li(p,n) run (before/after slew correction)

	before	after
LN 1	0.65320	0.38350
LN 2	0.69422	0.41252
SN 1	0.65863	0.53789
SN 2	0.66284	0.40979

表 5: TOF 1σ resolution(ns) of neutron peak emitted from Li(p,n) run (TOF(F2-tgt)=const.)

[4] gamma 線による TOF 合わせは、陽子ビームが F2-tgt 間で、ある一定値の TOF を持つという仮定の元で行われている。

1.9.2 used neutron peak from Li(p,n) run

I used Li+p run(#4) for TOF offset of proton-beam. [5]

$$\mathrm{TOF}(\mathrm{tgt}-\mathrm{NEUT})_{\mathrm{slew}} = \frac{\mathrm{TLslew}+\mathrm{TRslew}}{2} - \mathrm{TOFoffset}_{\mathrm{slew}} + \mathrm{peakT} \qquad (15)$$

I determined TOF offset so that TOF of gamma ray was to be 0[ns]+peakT.

Where, 'peakT' is result of calculation of Li(p,n)Be reaction. [6]

I used following gate to select only neutron in Li+p run.

・BEAM × NEUT

・VETO hit = 0

・NEUT multiplicity = 1

・pulse height of QDC $\geq$ 6.0MeVee

And,I got TOF resolution of neutron emitted from Li(p,n) reaction. We can see that timing resolution gets worse with back of plane.

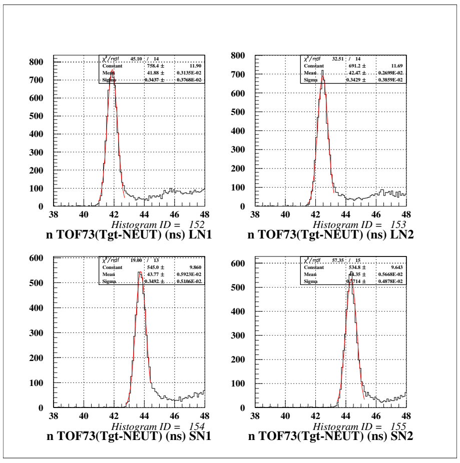

図 15: TOF of neutron emitted from Li(p,n) run (after slew correction)

	TOF	1σ resolution(ns)
LN 1	41.89	0.344
LN 2	42.47	0.343
SN 1	43.77	0.349
SN 2	44.35	0.371

表 6: TOF 1σ resolution(ns) of neutron peak emitted from Li(p,n) run

[5] ここでの neutron peak による TOF 合わせは、陽子ビームが F2-tgt 間で、ある一定値の TOF を持つという仮定の元で行われている。

[6] 放出された中性子の運動エネルギーは放出された角度に依存した値。どのような角度で放出された中性子がどのような運動エネルギー、速度を持つかを計算し、各シンチレータにおいて FL から TOF を計算した。

And, I got neutron beta,gamma,Energy,momentum spectrum from TOF(tgt-NEUT) and FL in Li(p,n) run.

$$\beta = \frac{\mathrm{FL}}{\mathrm{TOF_{NEUT}} * \mathrm{c}} \tag{16}$$

$$\gamma = \frac{1}{\sqrt{(1-\beta)(1+\beta)}} \tag{17}$$

$$E = \frac{\mathrm{M_n}}{\sqrt{1-\beta^2}} - \mathrm{M_n} \qquad (\mathrm{M_n} = 939.56\mathrm{MeV/c}) \tag{18}$$

$$\mathrm{P} = \mathrm{M_n}\beta\gamma \qquad (\mathrm{M_n} = 939.56\mathrm{MeV/c}) \tag{19}$$

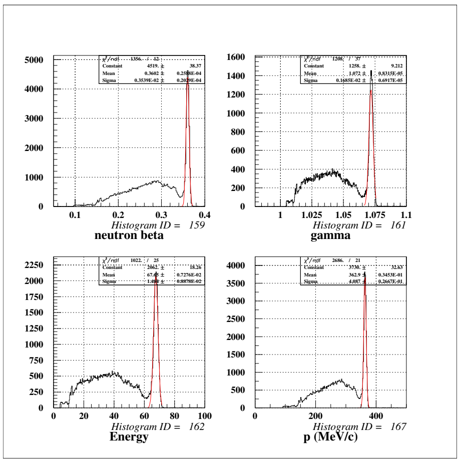

図 16: beta,gamma,Energy(MeV/u) spectrum of neutron emitted from Li(p,n) reaction

	mean	1σ
beta	0.3603	0.0035
gamma	1.072	0.0017
Energy(MeV/c^2/u)	67.65	1.48
momentum(MeV/c/u)	362.86	4.09

表 7: beta,gamma,Energy,momentum of neutron emitted from Li(p,n) reaction