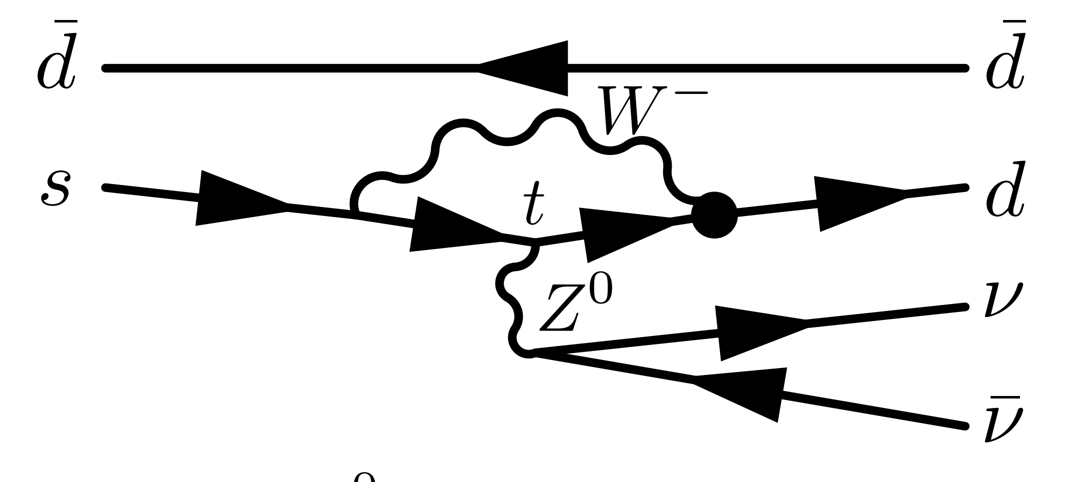
J-PARC E14 K^OTO実験で期待されるCsIカロリメータの性能

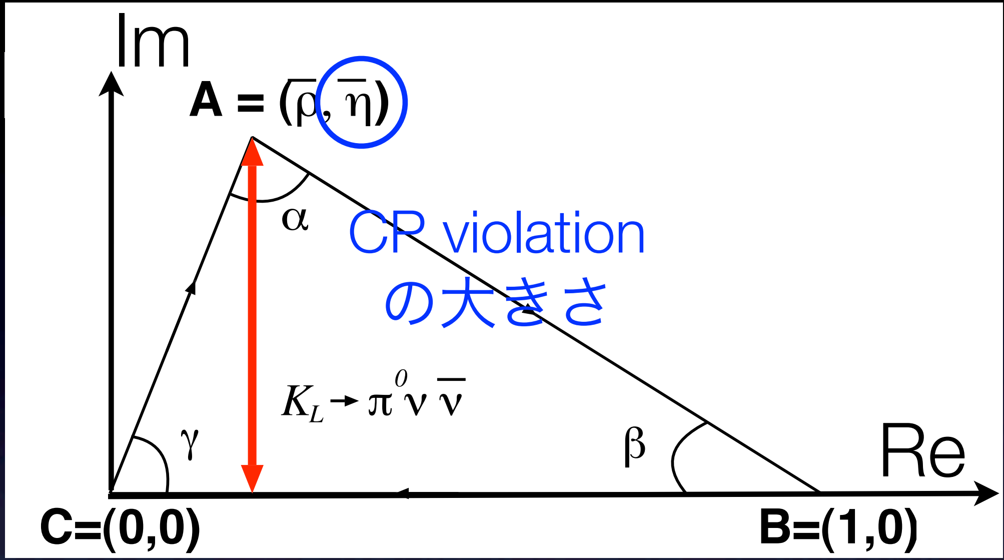
03/25/2011

Eito IWAI, Osaka university

$K_L \to \pi^0 \nu\bar{\nu}$ 崩壊とは？



$K_L \to \pi^0 \nu\bar{\nu}$ 崩壊ダイアグラム

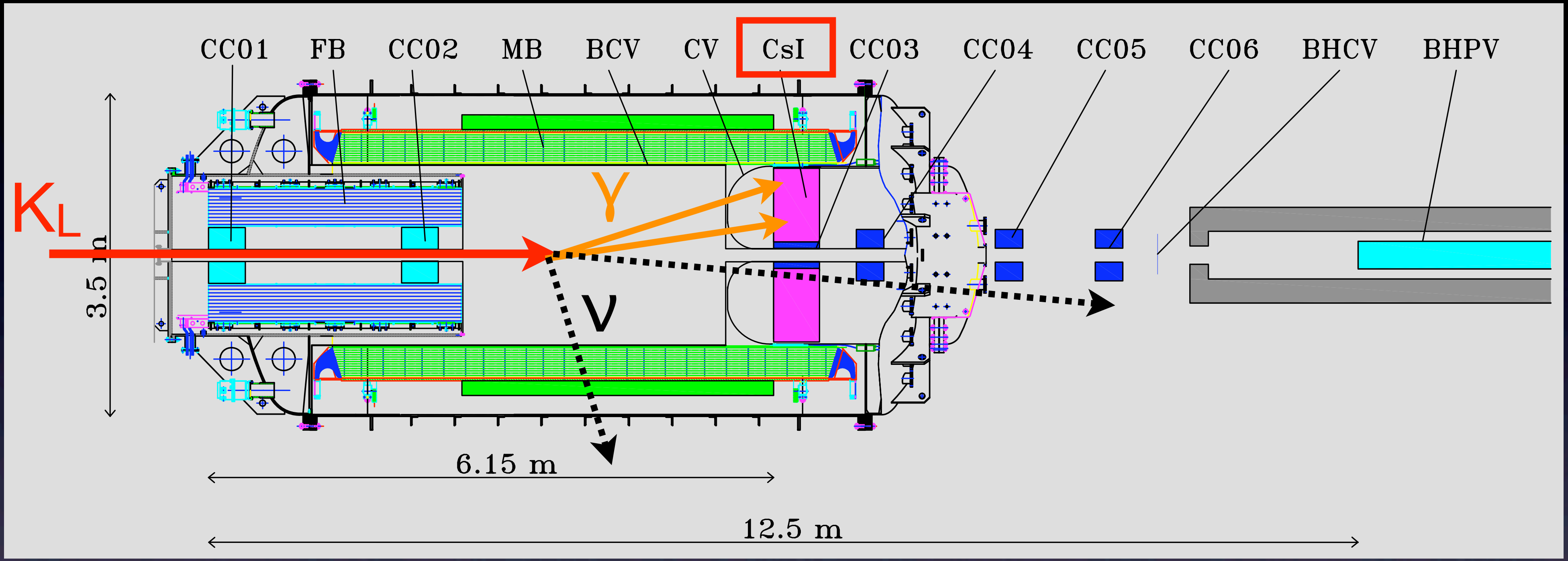


- ループを含むダイアグラム：New Physicsに感度がある！
- CPの破れの大きさを決めるCKM行列の複素成分ηを小さな理論的不定性で決定できる

➡ 標準理論とそれを超える物理への良いプローブ：Golden Mode

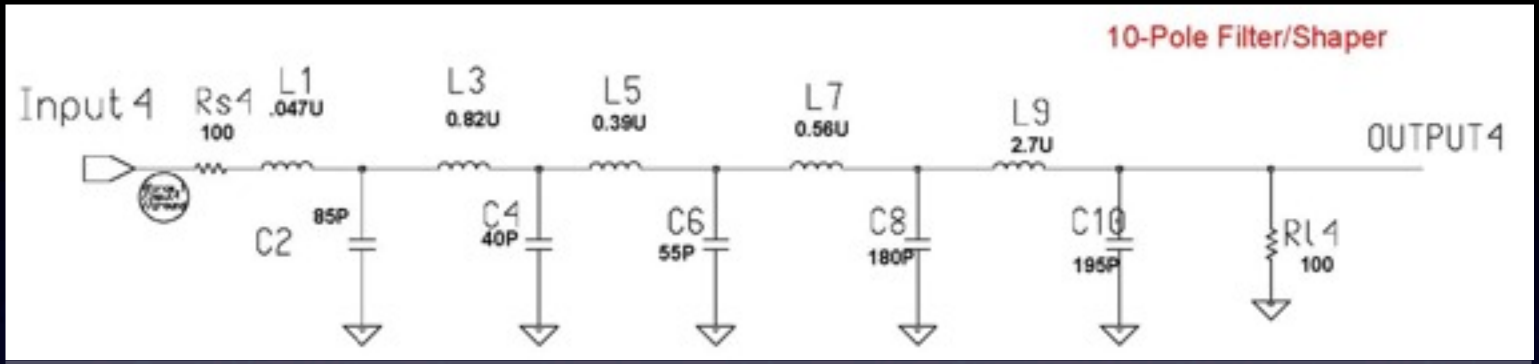
- 非常に稀な崩壊 + 全てが中性の粒子：意欲的な実験！
  $Br \sim 3 \times 10^{-11}$

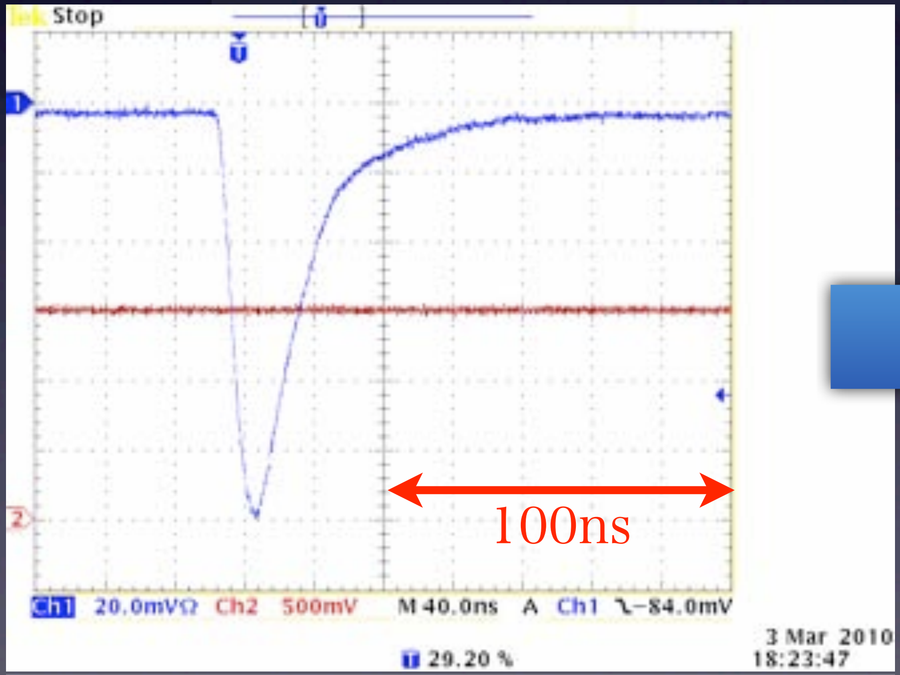
$K^{O}TO$ detector

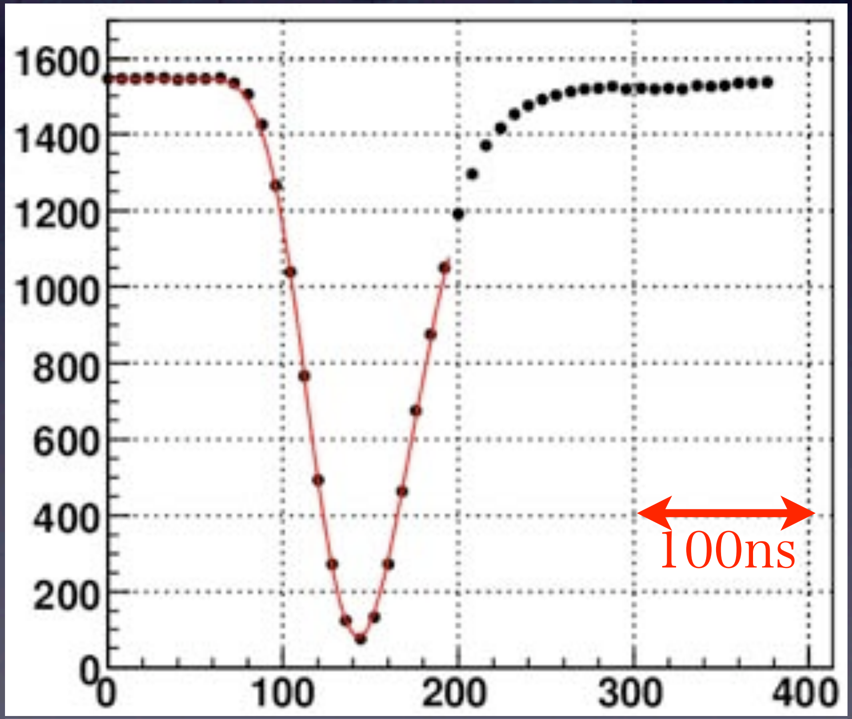


- シグナル事象：π^0からの２つのγ線、それ以外に何も観測されない事象
- 入射するγ線のエネルギーと位置を測定：CsIカロリメータ

Bessel filter

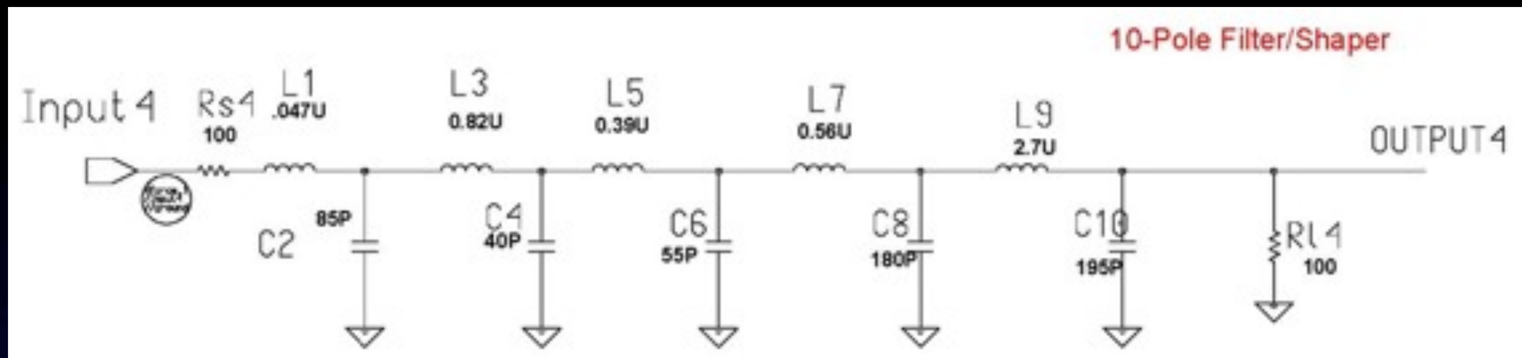


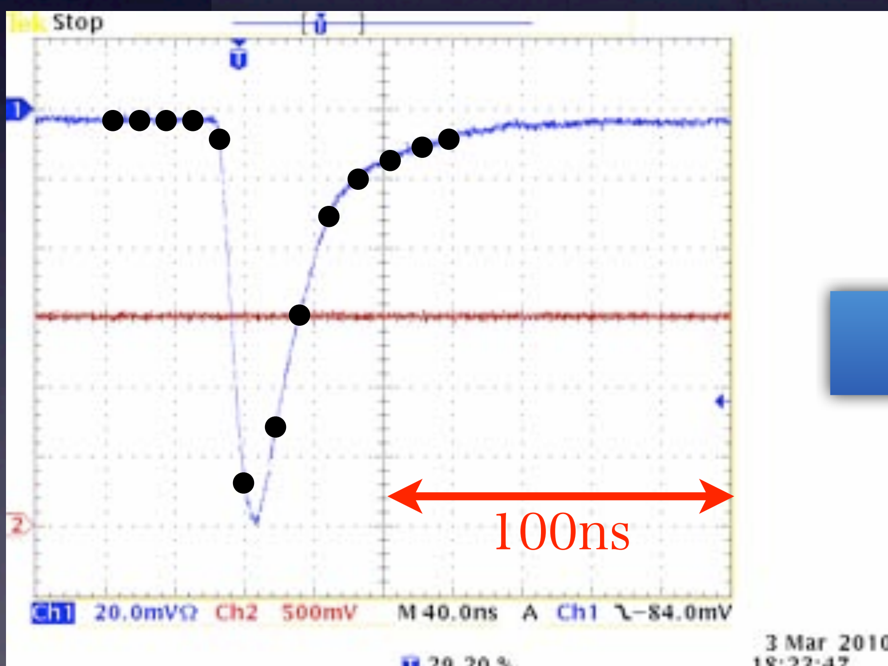


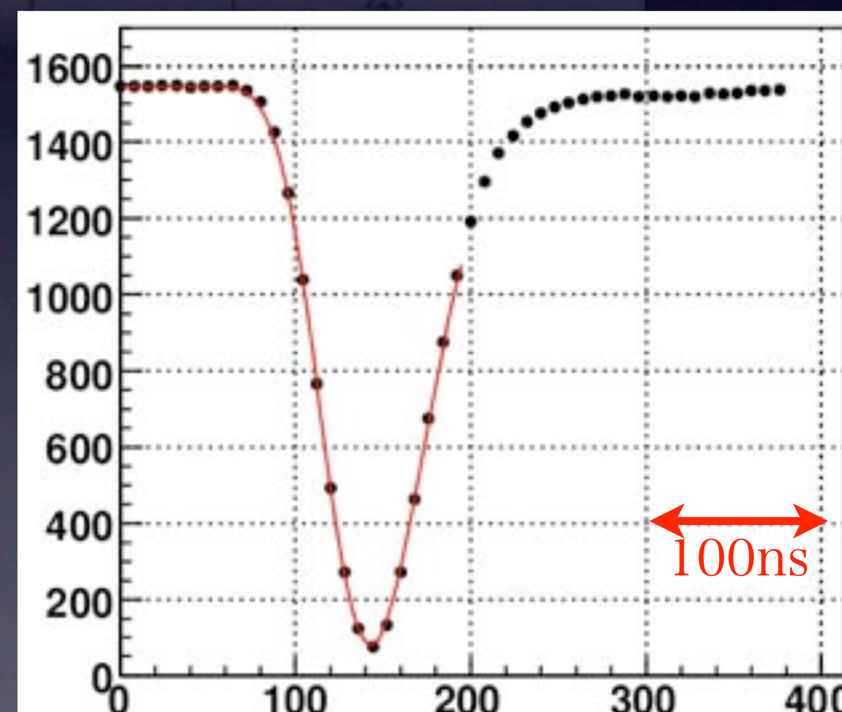


- Bessel filterを通した出力を125MHzのFADCで記録

Bessel filter







- Bessel filterを通した出力を125MHzのFADCで記録

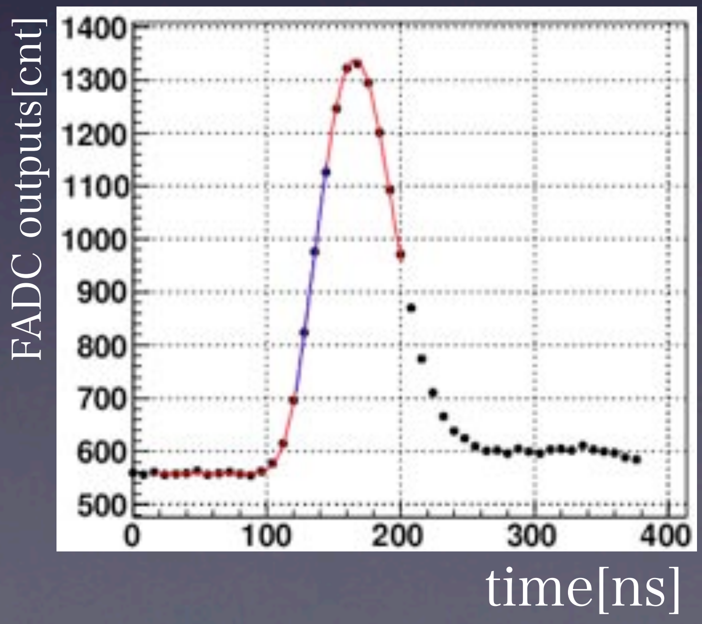
CsI beam test in April

- LNS, Tohoku university
- beam time : 4/12 - 4/17
- energy : up to 800MeV positron
  - (0,10,15,20,30,40) [deg] × (100,200,300,460,600,800) [MeV]

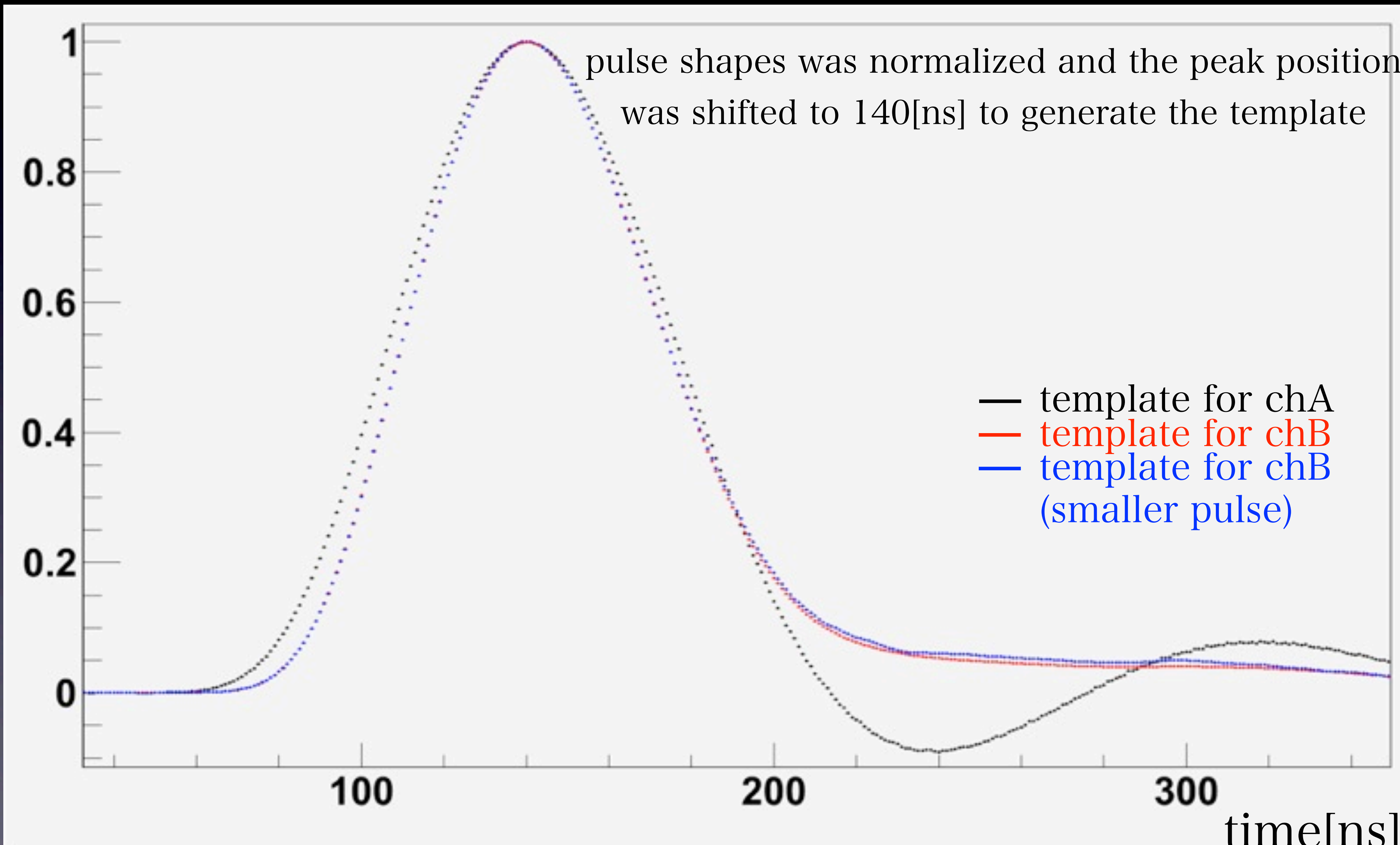
- setup
  - 144(12×12) CsI crystals were stacked
  - scintillating fibers position detector
  - additional scintillator counter taken by 500MHz FADC

getting energy and timing

- fitting method
  - use template for each channel, energy (~ # of p.e.)
    - pulse shape differs channel by channel
    - pulse shape slightly has energy dependence
    - to separate overlapped pulse shapes
  - fit region : do not fit tail part



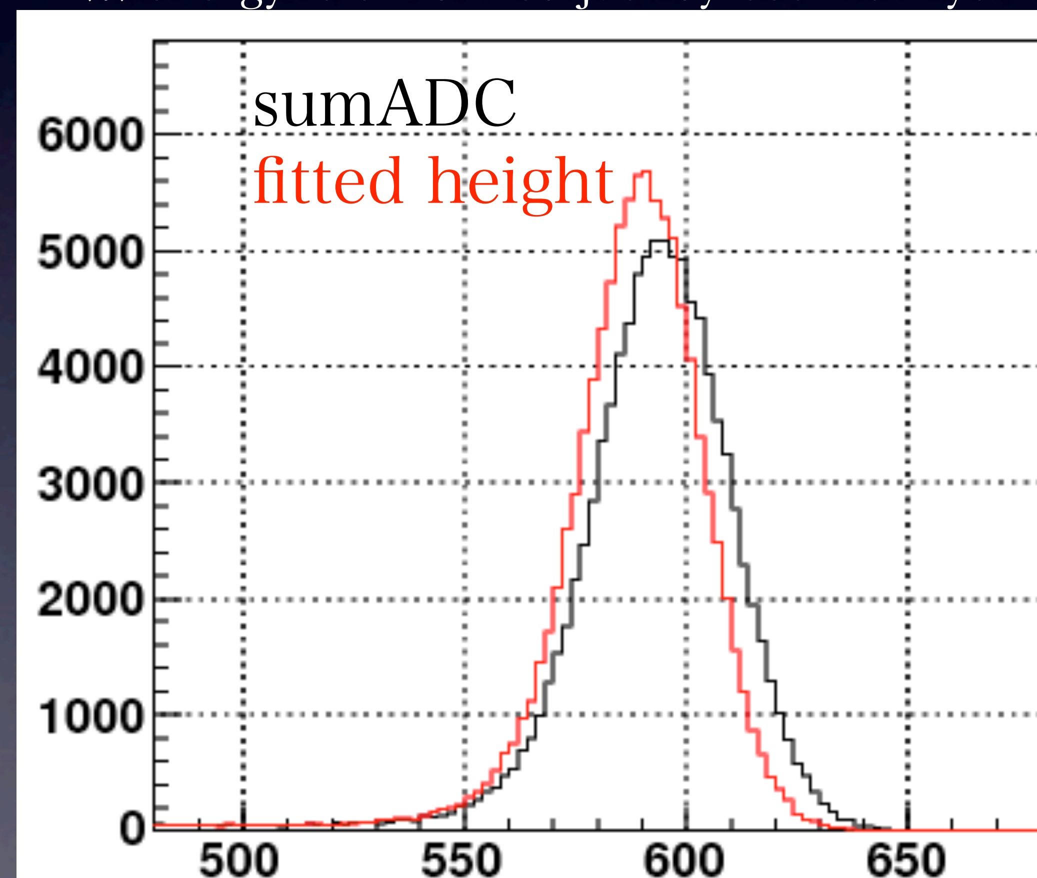
an example of the template



getting energy

- two ways to get energy
  - sumADC : $\Sigma_{i<48}(ADC_i\text{-pedestal})$
  - fitted height

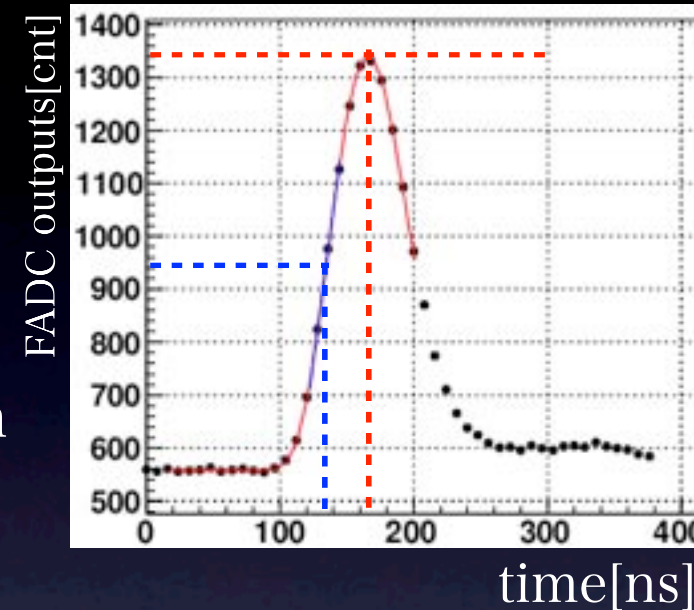
※ energy is calibrated just by cosmic rays



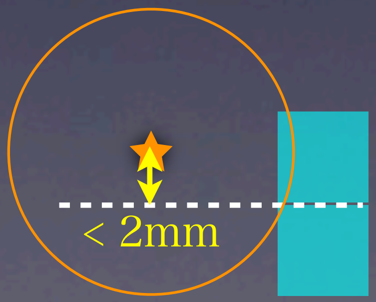
totalEnergy[MeV]

➡ fitted height performs better

getting timing



- two ways to get timing
  - fitted peak
  - "constant fraction" method
    - fit again w/ a few samples just before the fitted peak, and calculate timing of the full maximum
- how to estimate timing resolution
  - select two neighboring crystals, both of them have KOTO's typical light yield and calibration constants.
    - sources of timing resolution (light yield, noise-level/dynamic-range) are close
    - this should be timing resolution at the KOTO exp.
  - energy difference < 10%
  - distance from the perpendicular bisector < 2[mm]



getting timing

- two ways to get timing
  - fitted peak
  - “constant fraction” method
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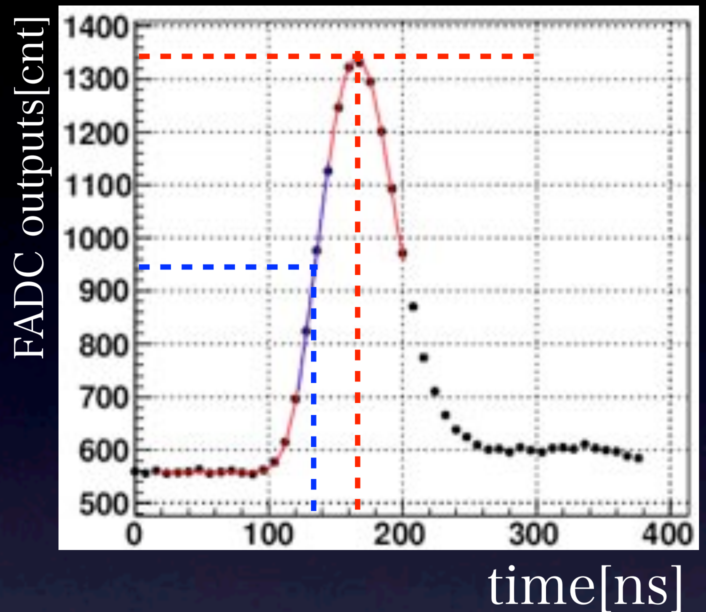
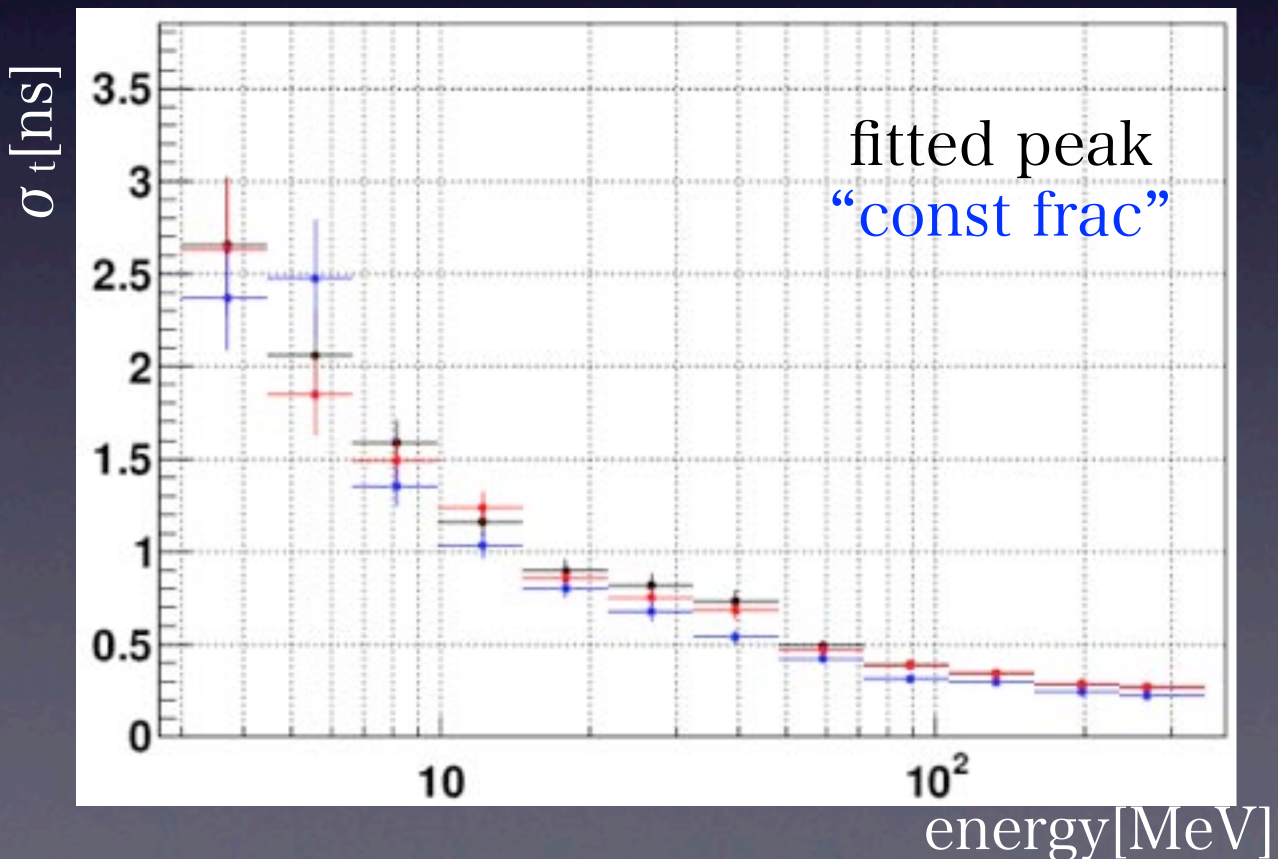
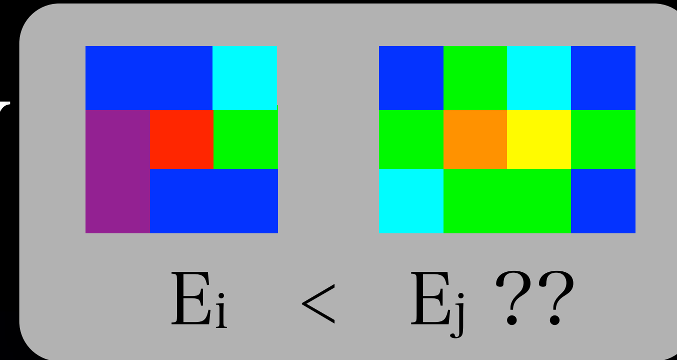


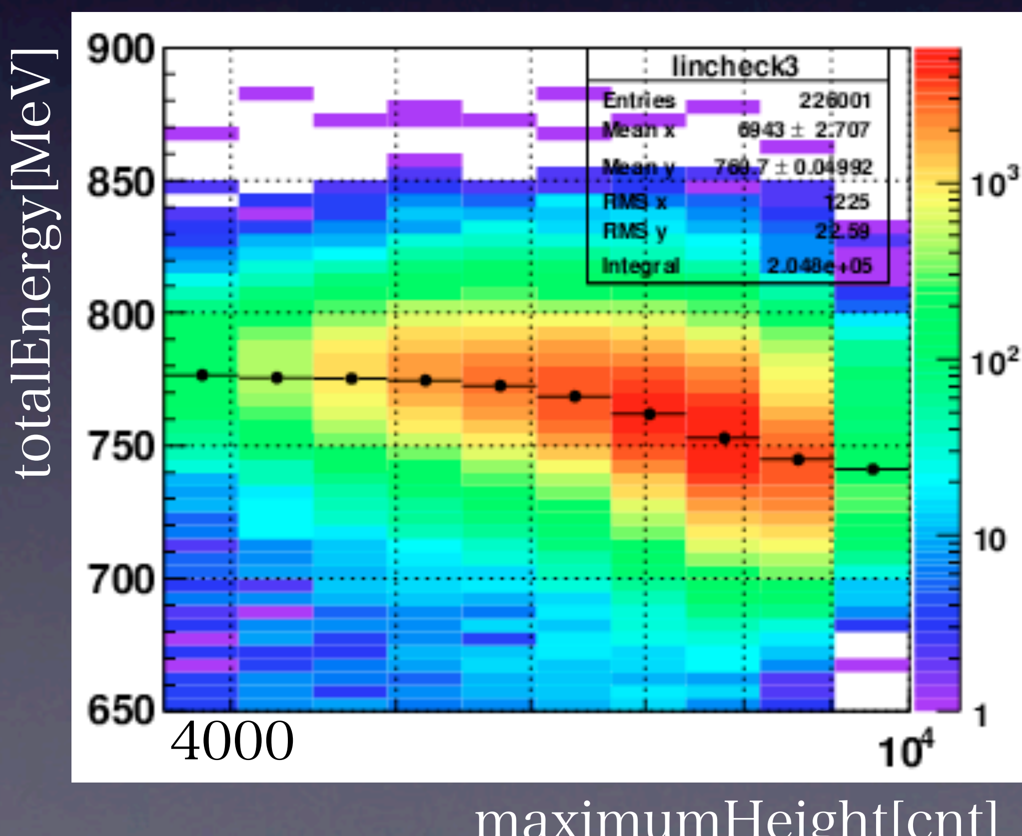


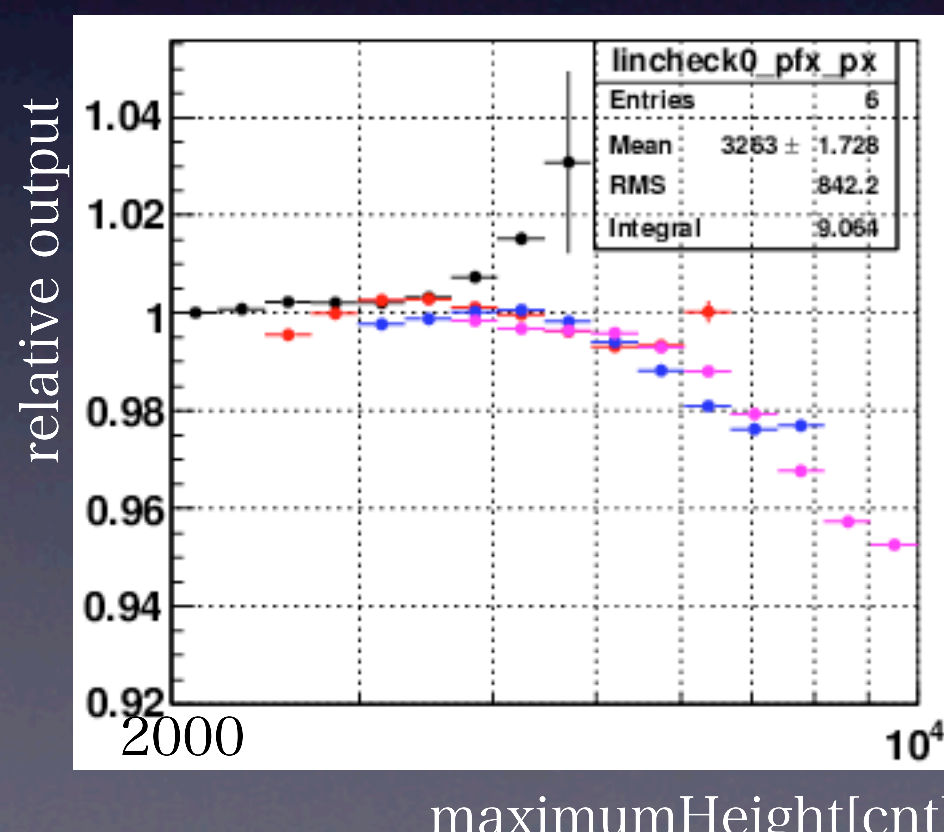
➡ “const frac” performs better

non-linearity



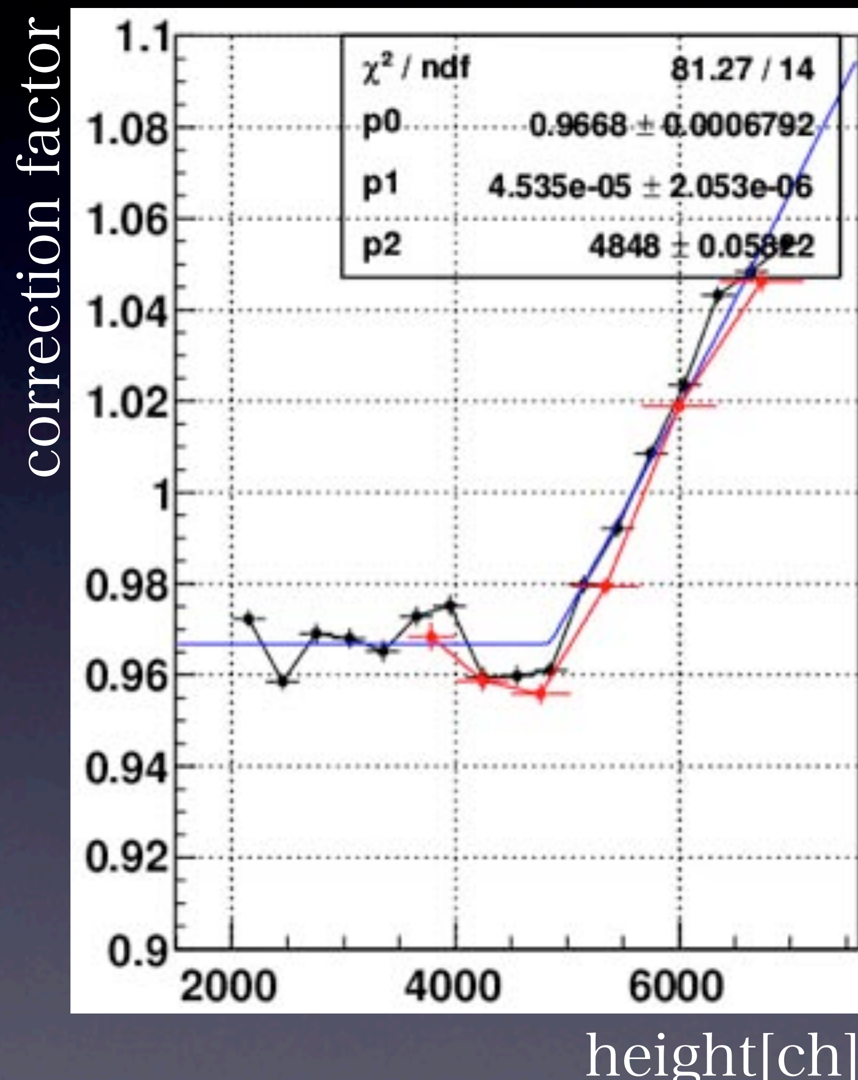
- non-linearity was found
- As amount of non-linearity is related to its pulse height, plot the maximum height in each event versus total energy.
  - $E_{maximum} > 2 \times E_{2nd}$
  - $E_{maximum} > E_{else}$





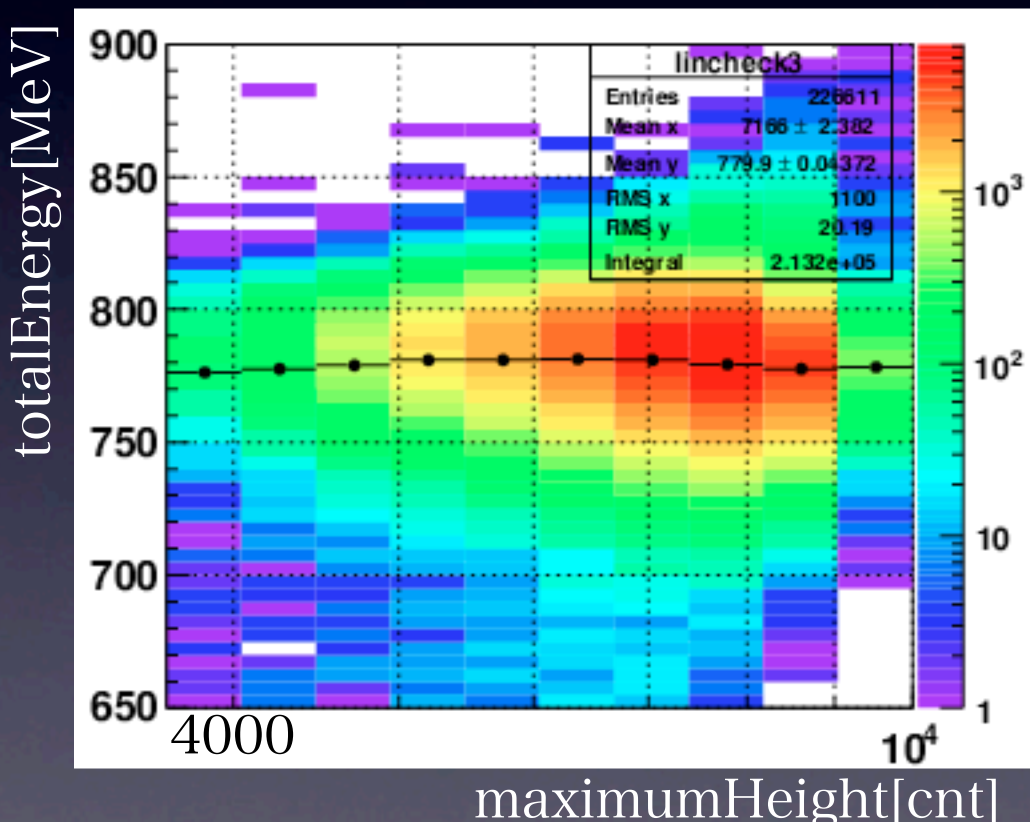
energy calibration w/ non-linearity

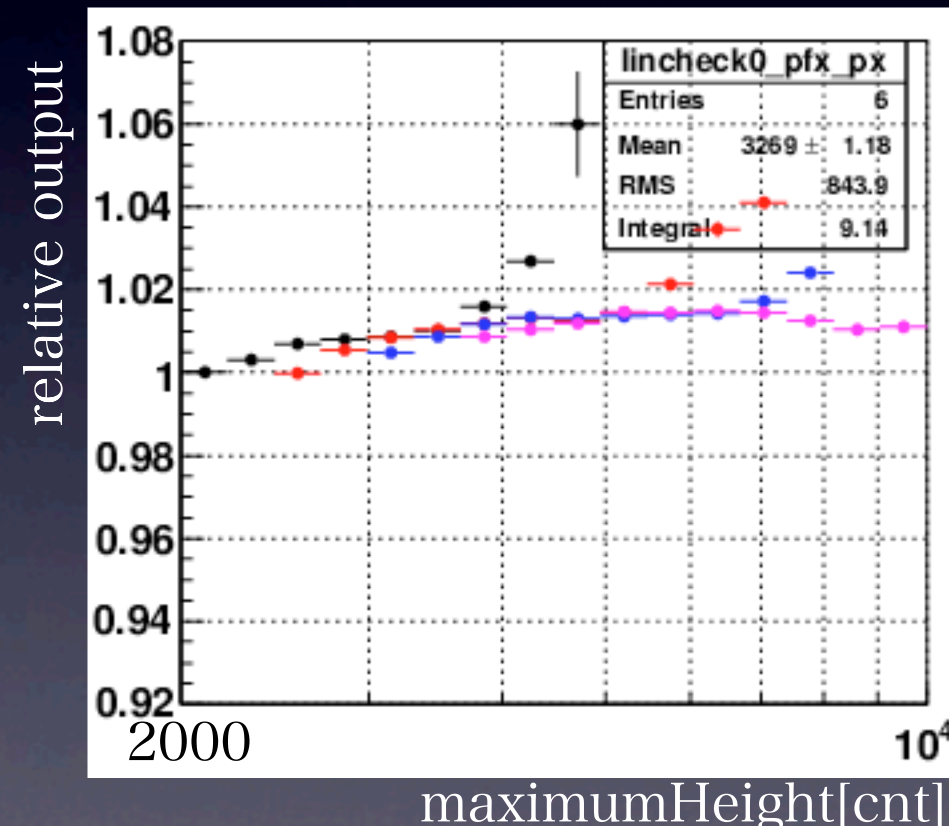
- procedure
  - calibrate constants w/ event in which all crystals have heights < 4000.
  - relax the maximum pulse height constraint step by step, and decide each constant for the additional height region
  - based on the roughly calibrated constants, re-calibrate constants from ones for higher pulse height to ones for smaller pulse height
  - fit the constant for each height w/ some function



consistency check of the correction

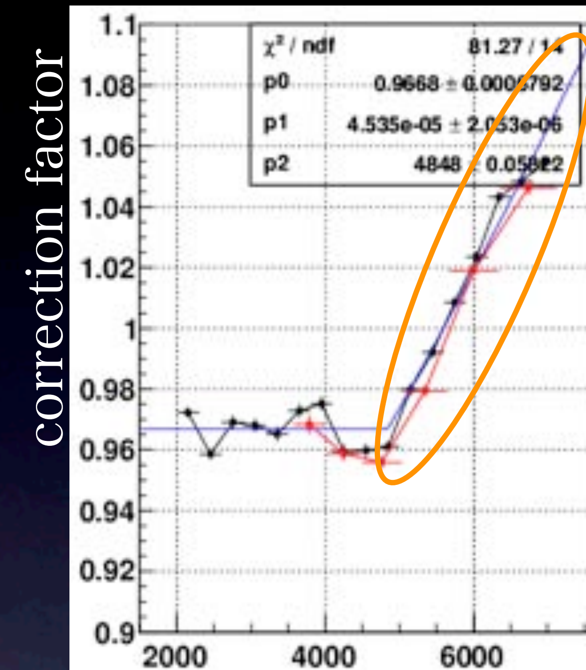
- after applying correction factor by the dedicated run



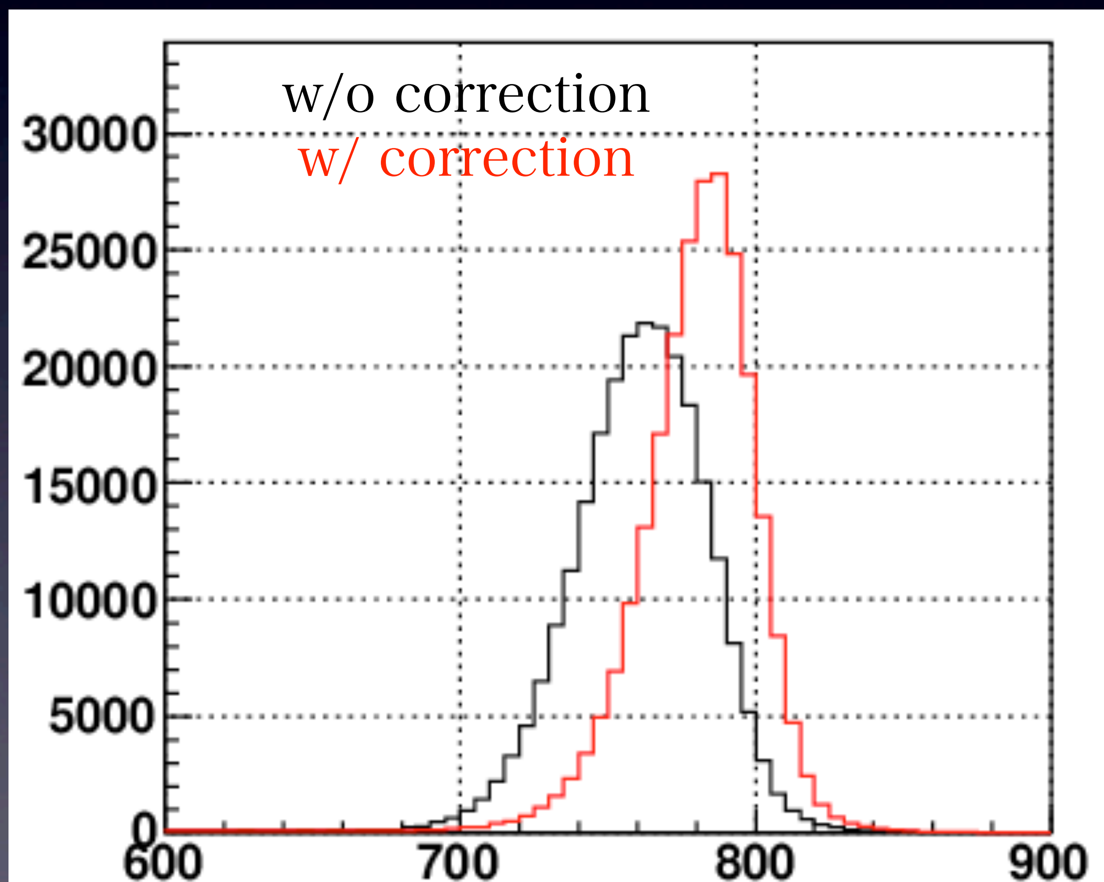


consistency check of the correction

- correction for the non-linearity part

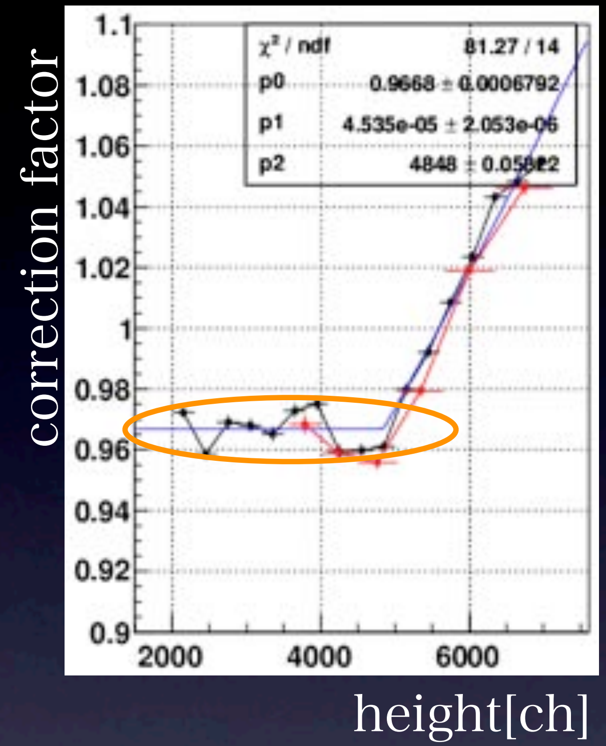


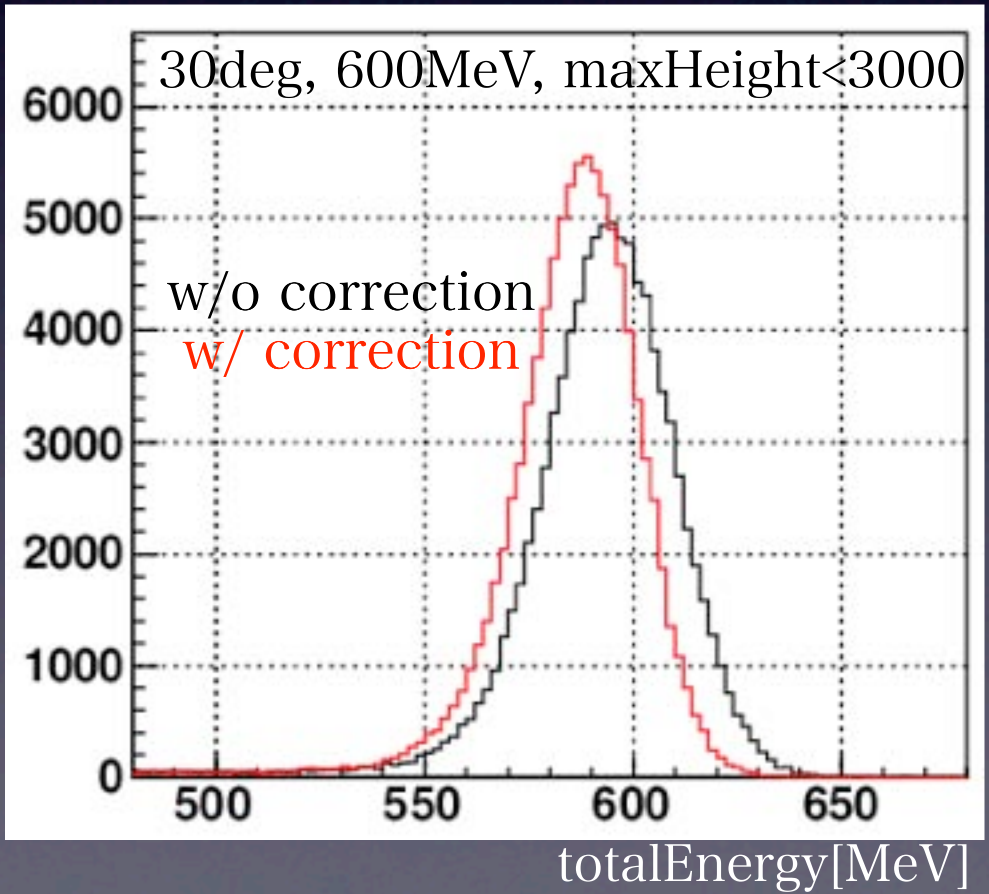
0deg, 800MeV



consistency check of the correction

- correction for the linear part
  - width : getting a bit better
  - peak : shift a bit toward reasonable direction (594.7 → 588.8 ⇔ 590@0deg by MC)





more about timing

- some applications of timing information
  - from some activities in a cluster, define one cluster timing
  - get shower developing information

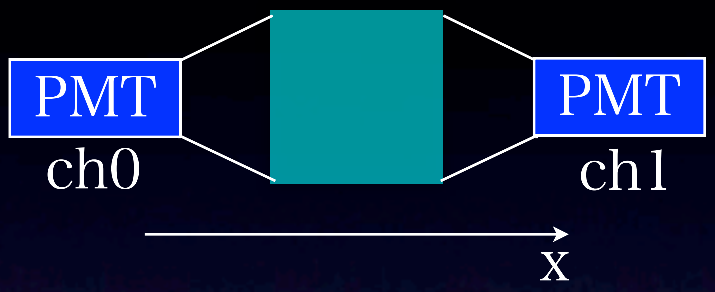
➡ relative timing between each channel is necessary

✳ ... before evaluating relative timing, we should check energy dependence of timing w/ our method
(some kind of time skew)

➡ use extra scintillator taken by 500MHz FADC to define a reference timing

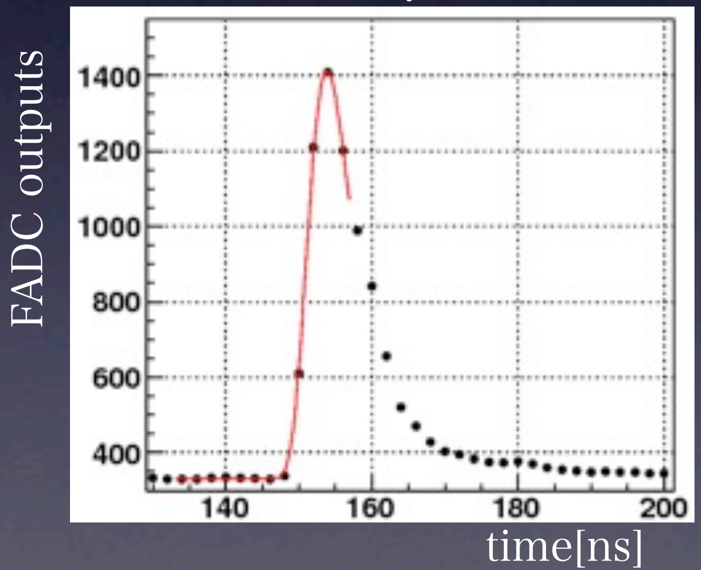
additional scintillator

- In some runs, additional scintillator was installed as a reference of timing
  - 2 PMTs : each channel was taken by 500MHz FADC



- strategy
  - use $(t_0+t_1)/2$ as a reference timing
  - calculate $\sigma_{(t0+t1)/2}$ by σ_{t0-t1}

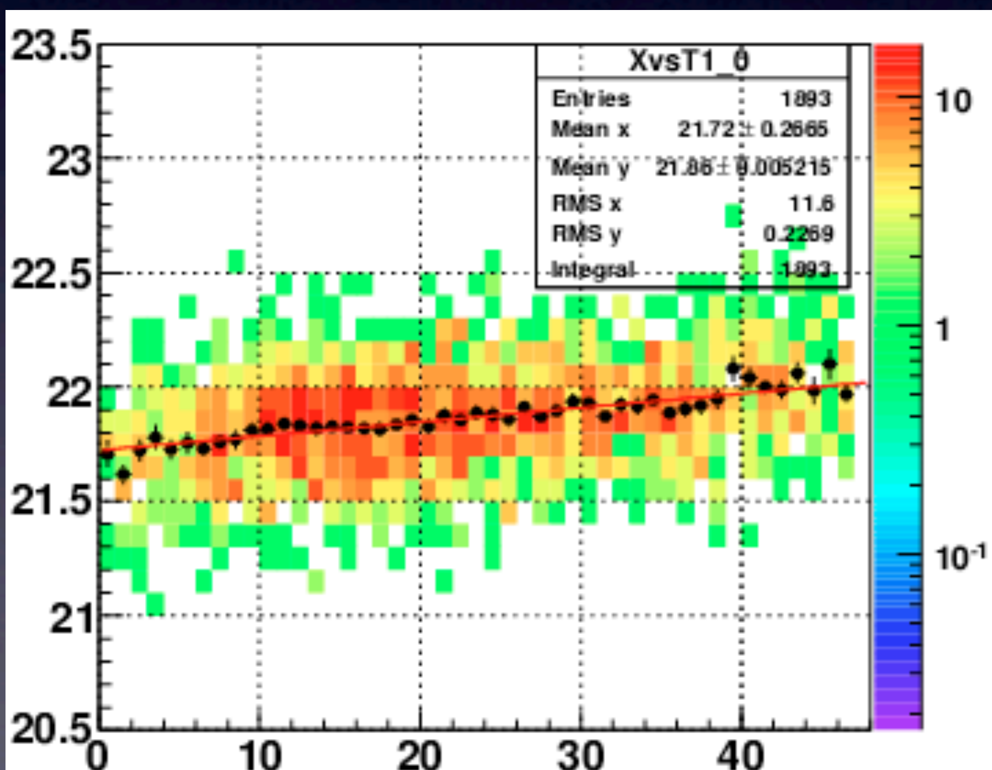
an event recored by 500MHz FADC



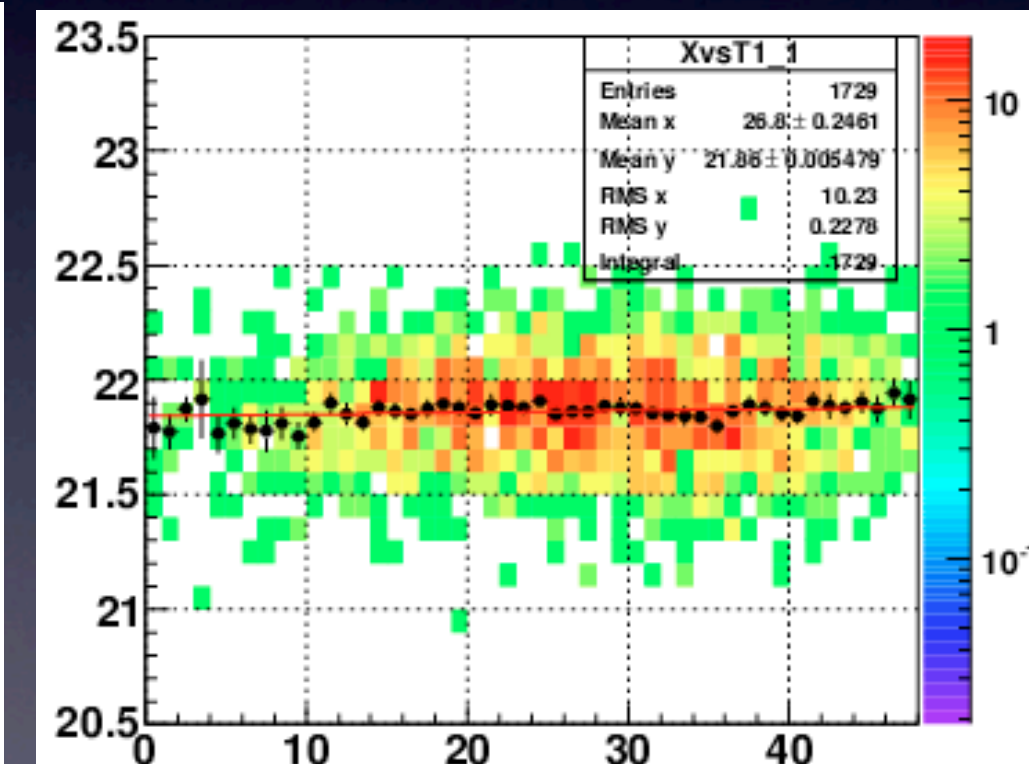
additional scintillator

- only t_0-t_1 has its incident position dependence
  (t_0+t_1 : canceled)

t_0-t_1[ns]



x[mm] on the scifi tracker



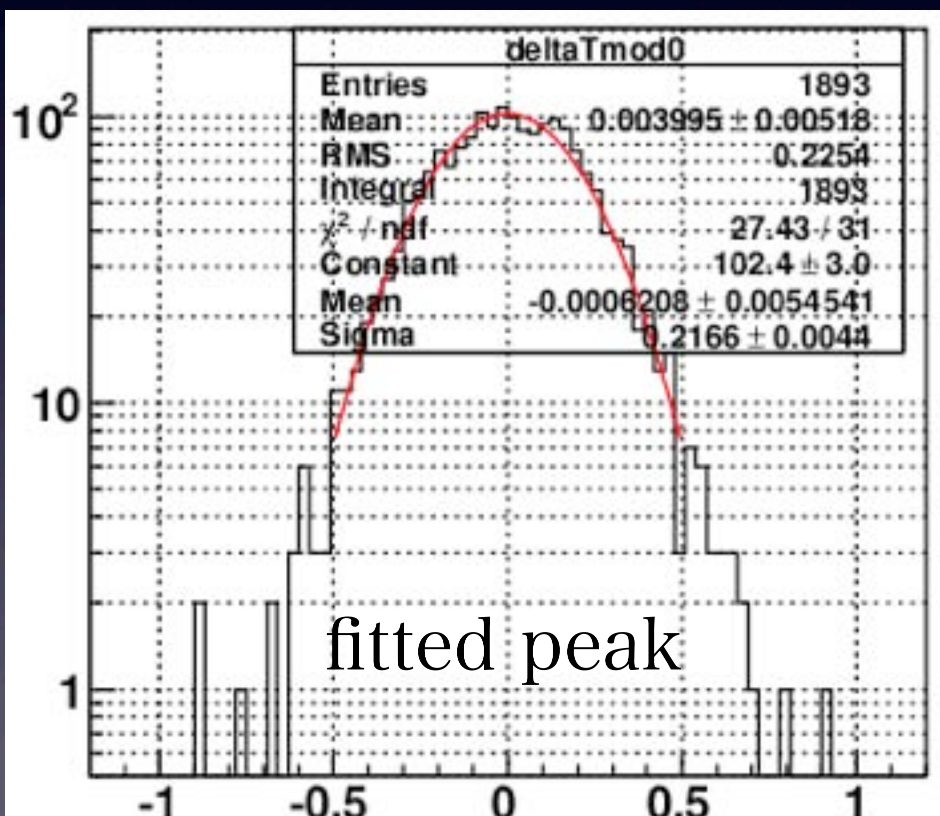
y[mm] on the scifi tracker

applying the incident position correction

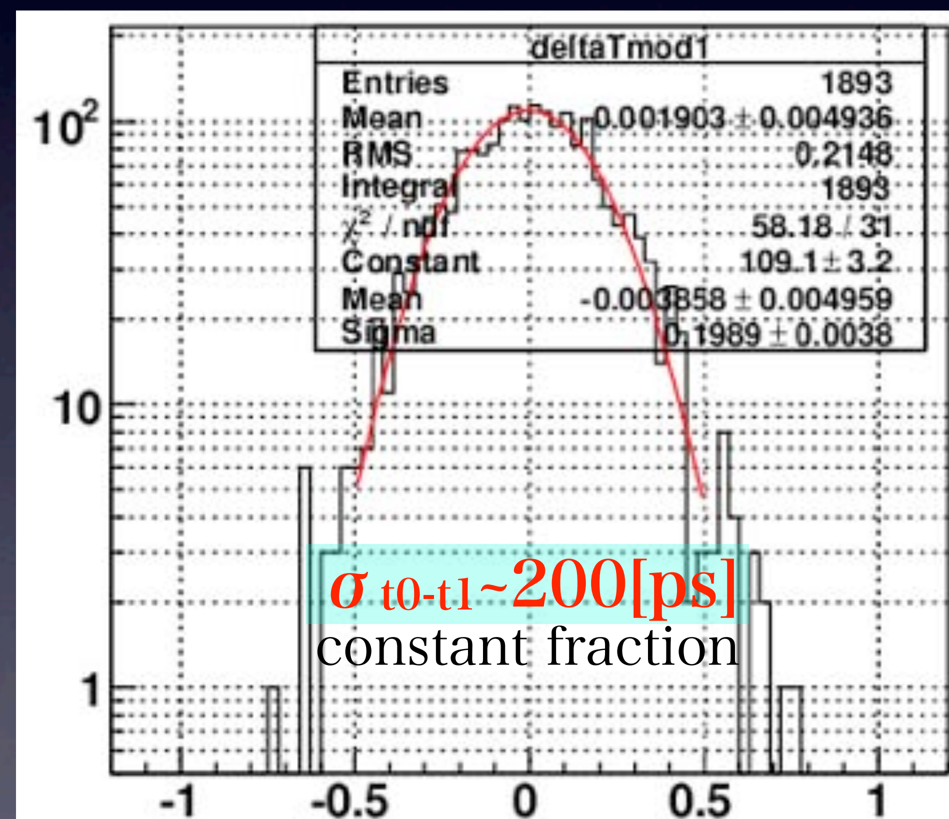
- "constant fraction" method performs better again...

➡ expected timing resolution as a reference

$\sigma_{(t0+t1)/2} \sim \sigma_{t0-t1}/2 = 100$[ps]



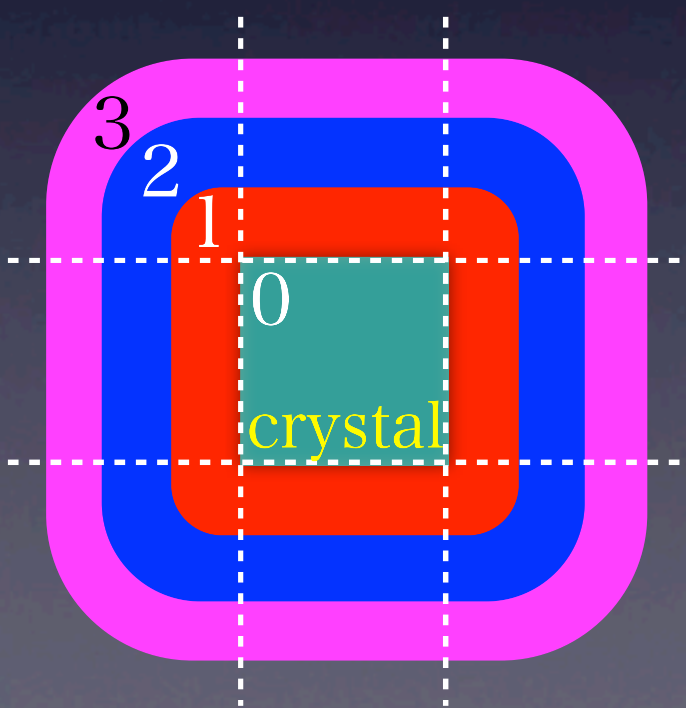
t_0-t_1[ns]



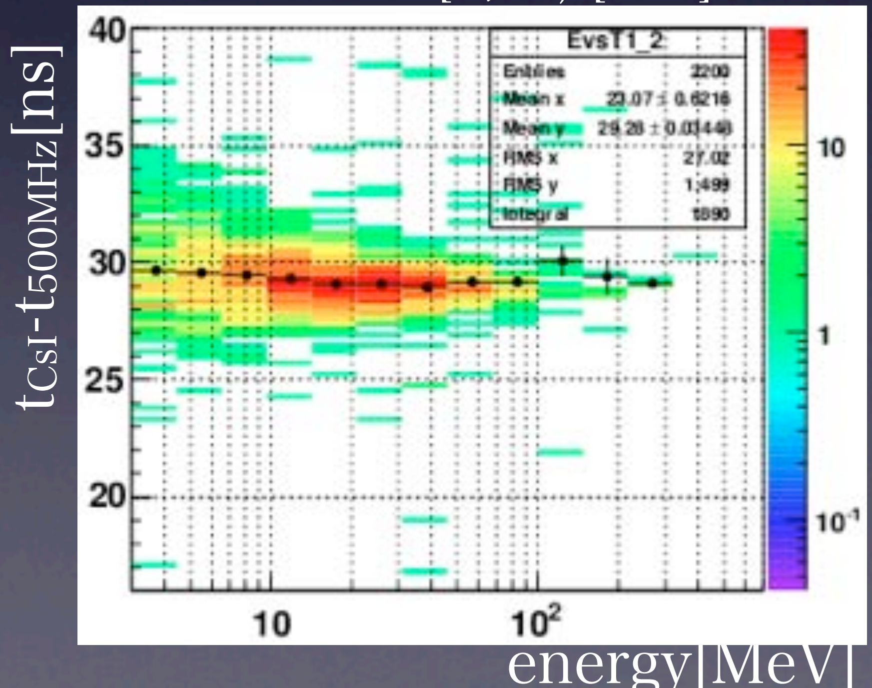
t_0-t_1[ns]

energy dependence of timing

- check the energy dependence of CsI timing for each distance of closest approach from a certain crystal (to get rid of timing spread by shower developing)
  - hit on the crystal
  - distance from the crystal : < n×8[mm]

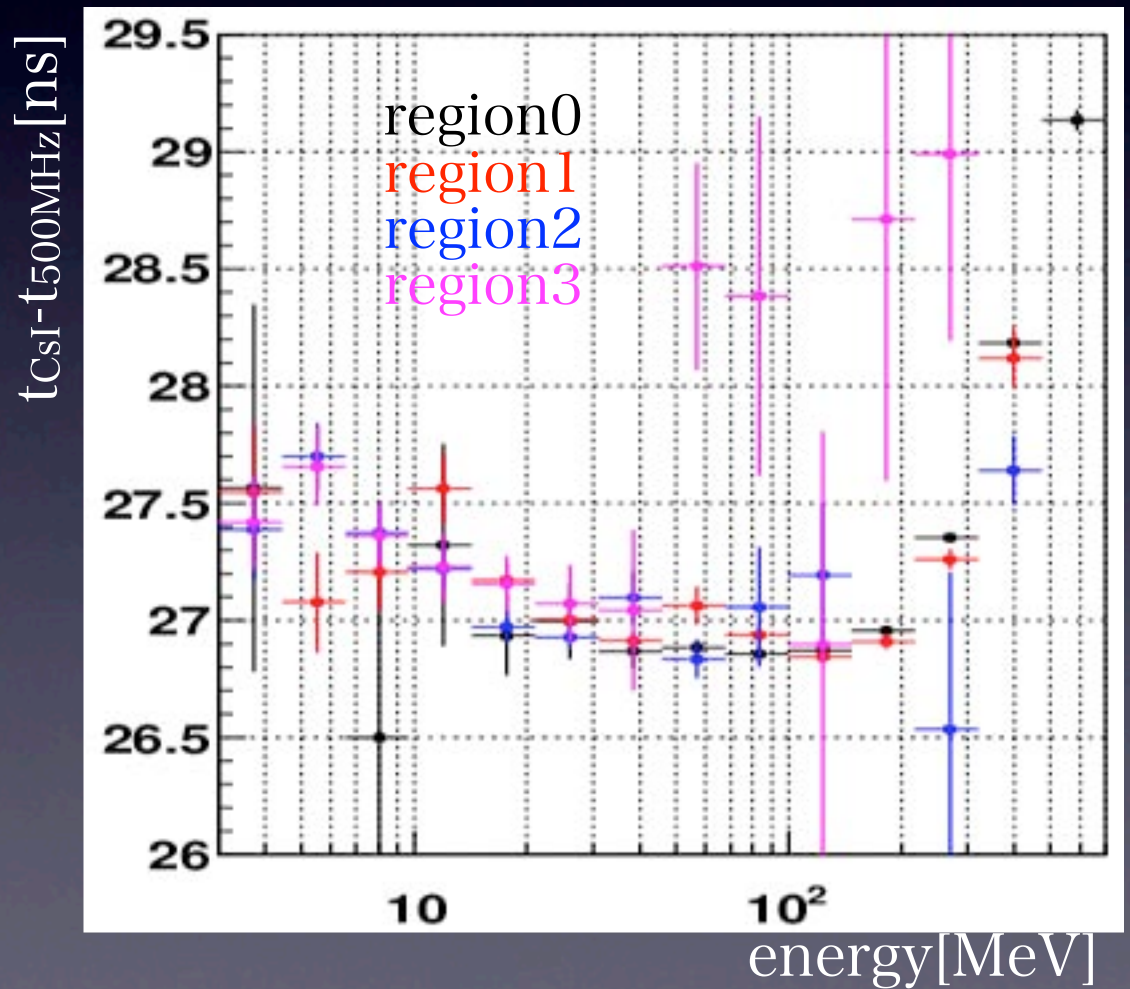


distance : [8,16) [mm]



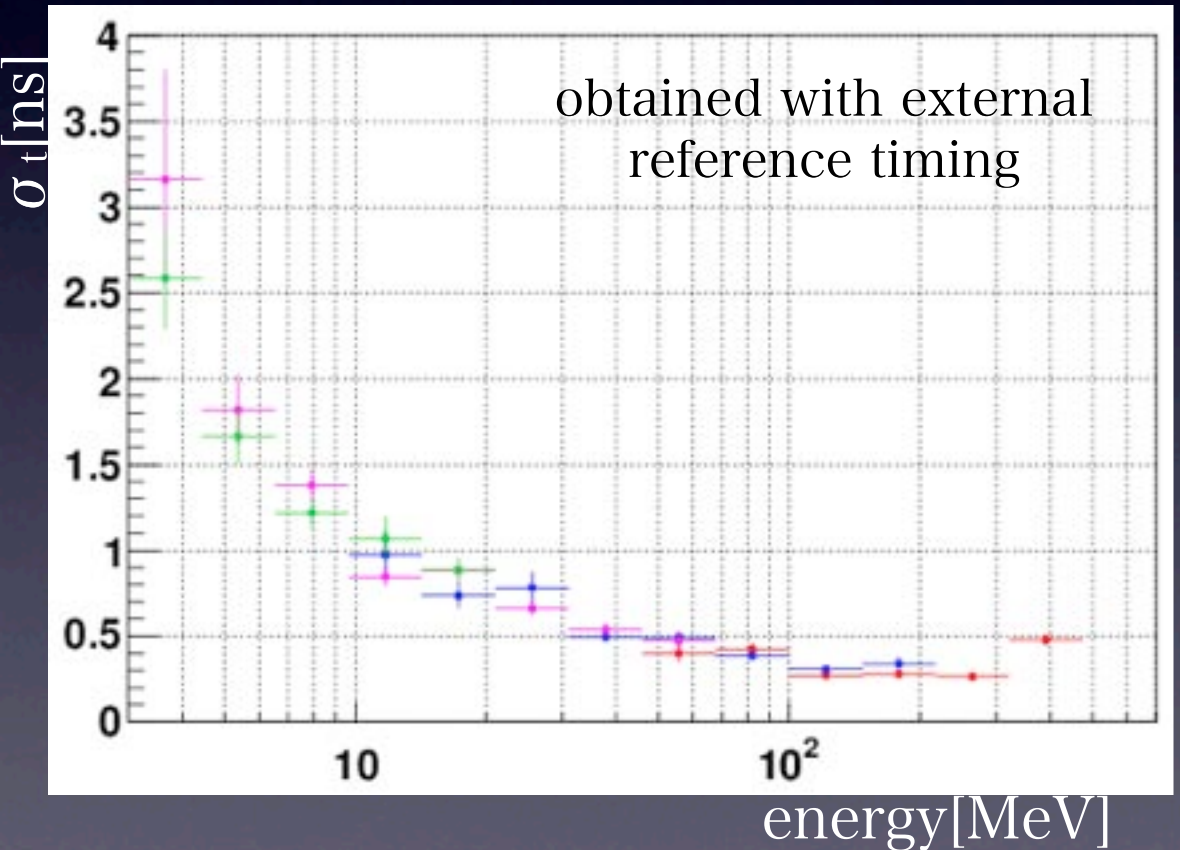
energy dependence of timing

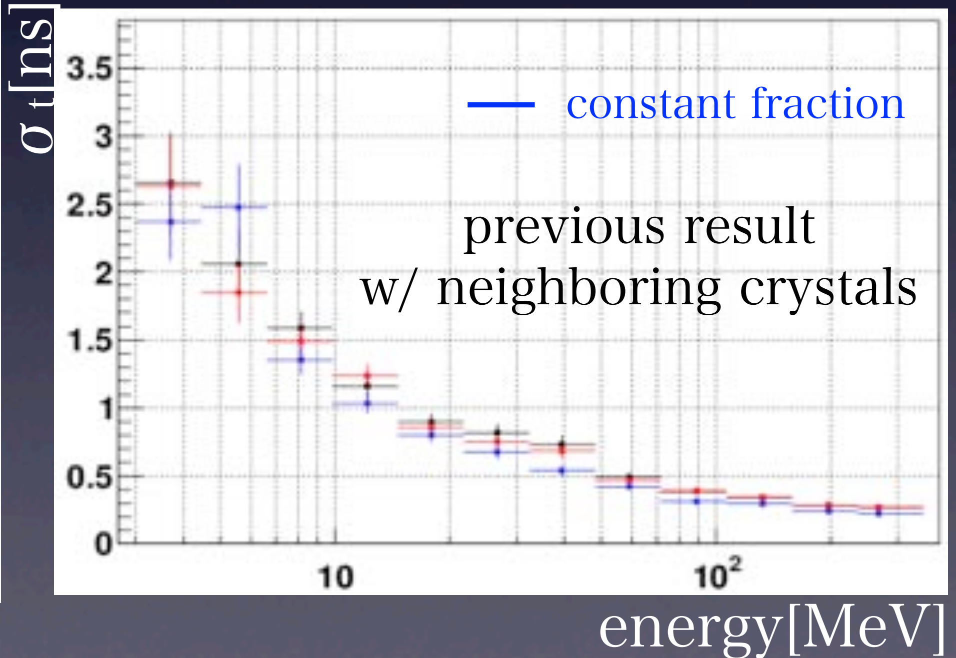
- about 2[ns] timing shift at higher energy region
- some dependence also in lower energy region?



timing resolution w/ external reference timing

- evaluate timing resolution again with the external reference timing



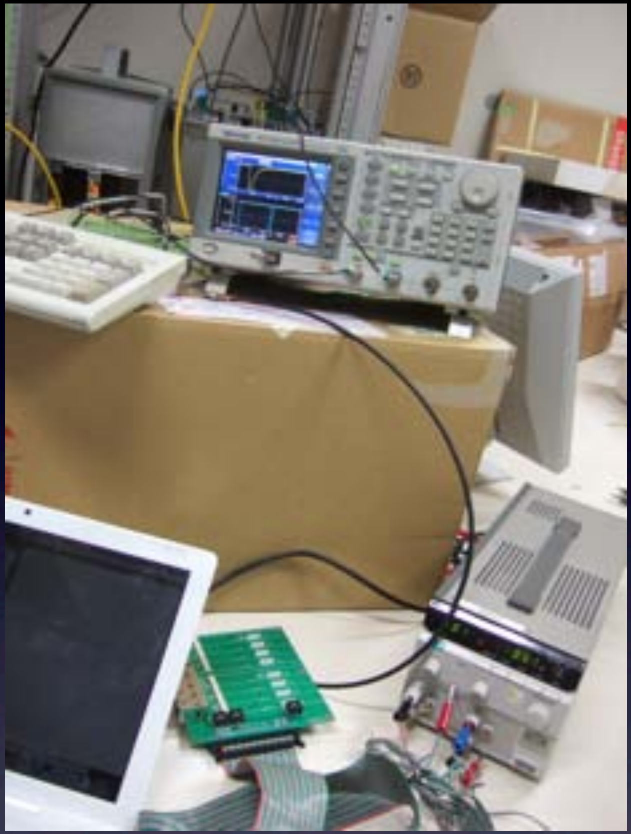


non-linearityの要因

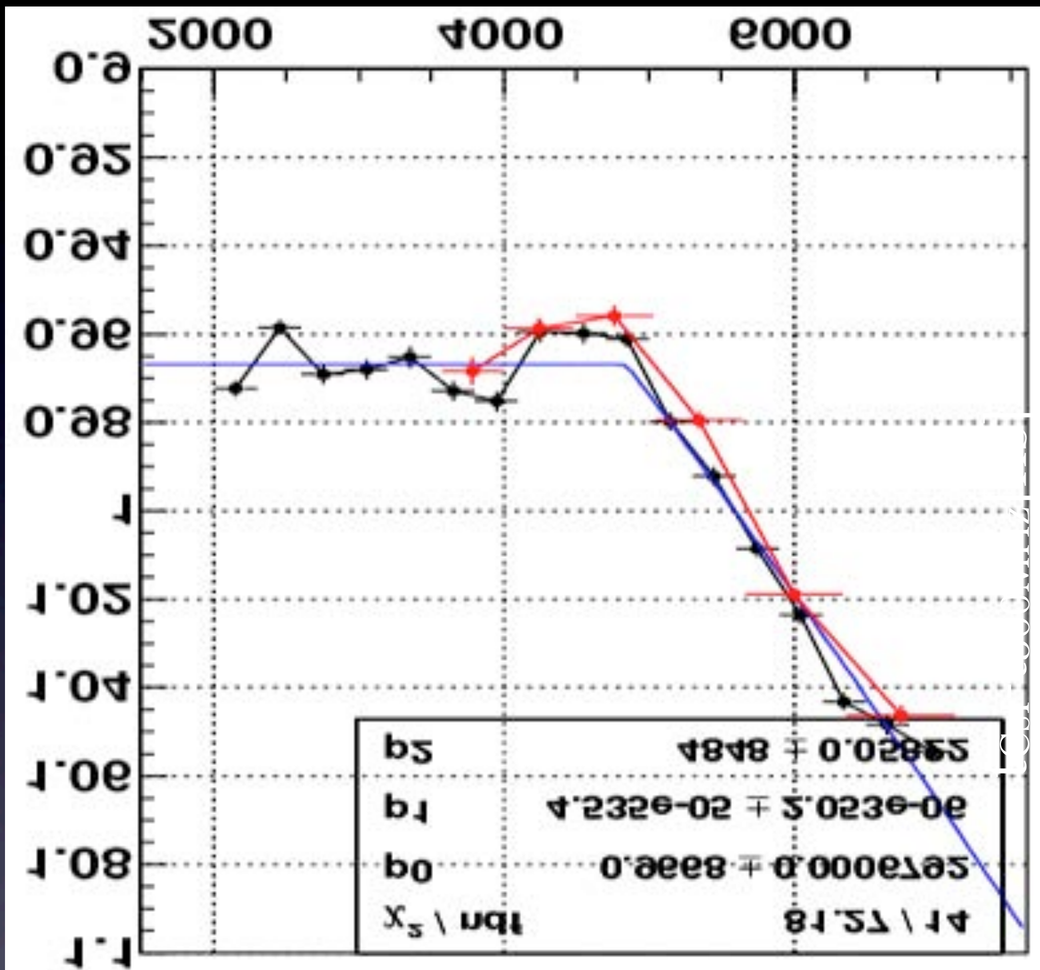
- CsI - PMT - CW/preamp - FADC
  - PMTは単独で4GeV相当まで問題ない事が確認されている by Jwlee
  - FADCにも問題がない事が確認されている by Chicago

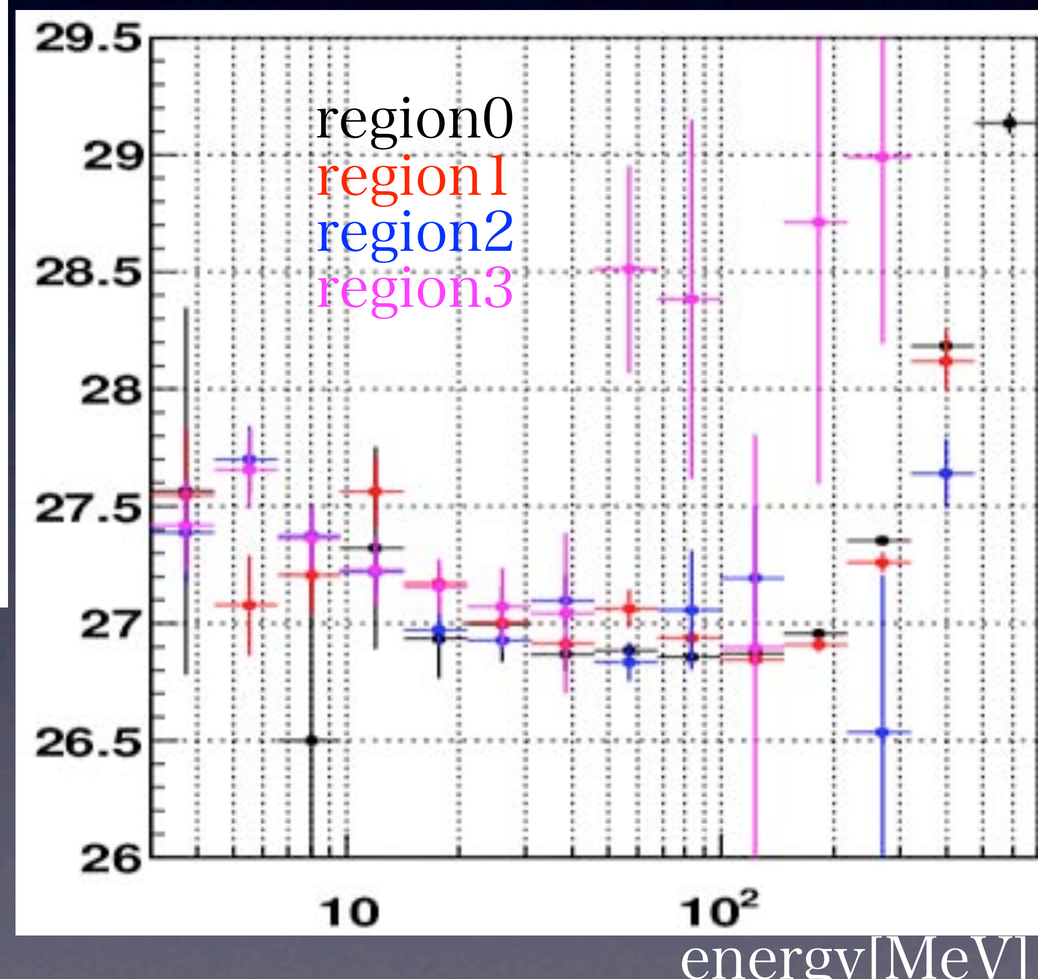
➡ CW/preamp が原因？

- CsIの波形をFunctionGeneratorで生成、CW内のpreampカードを通してFADCで記録



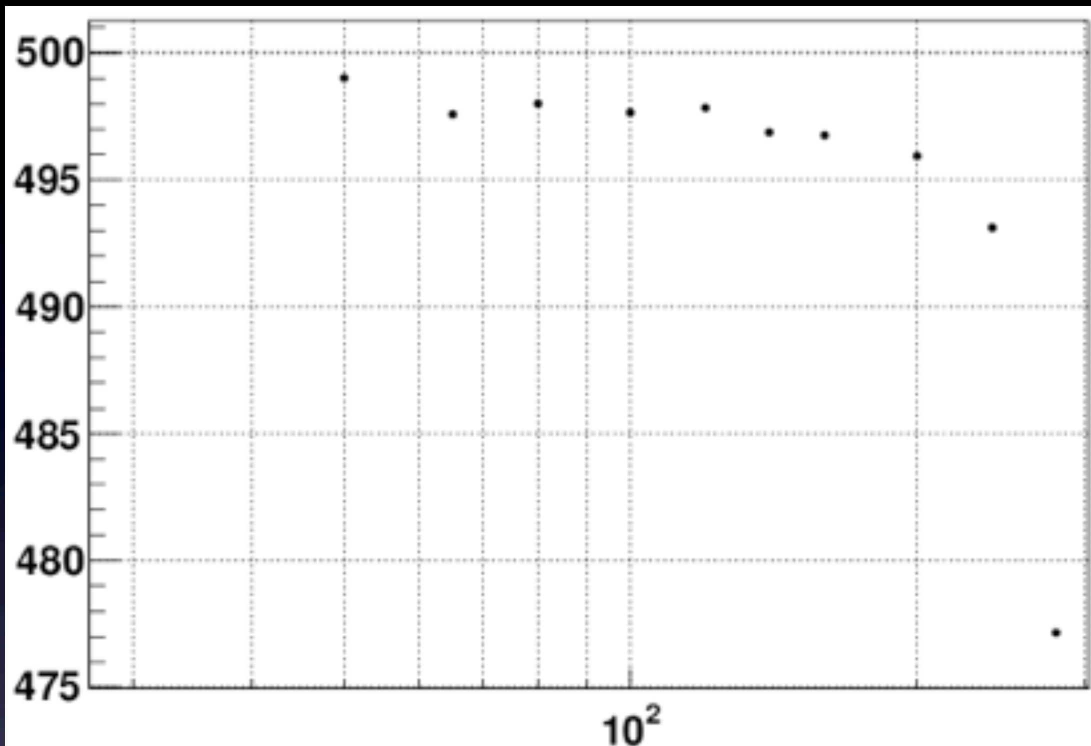
ビームテストのデータ

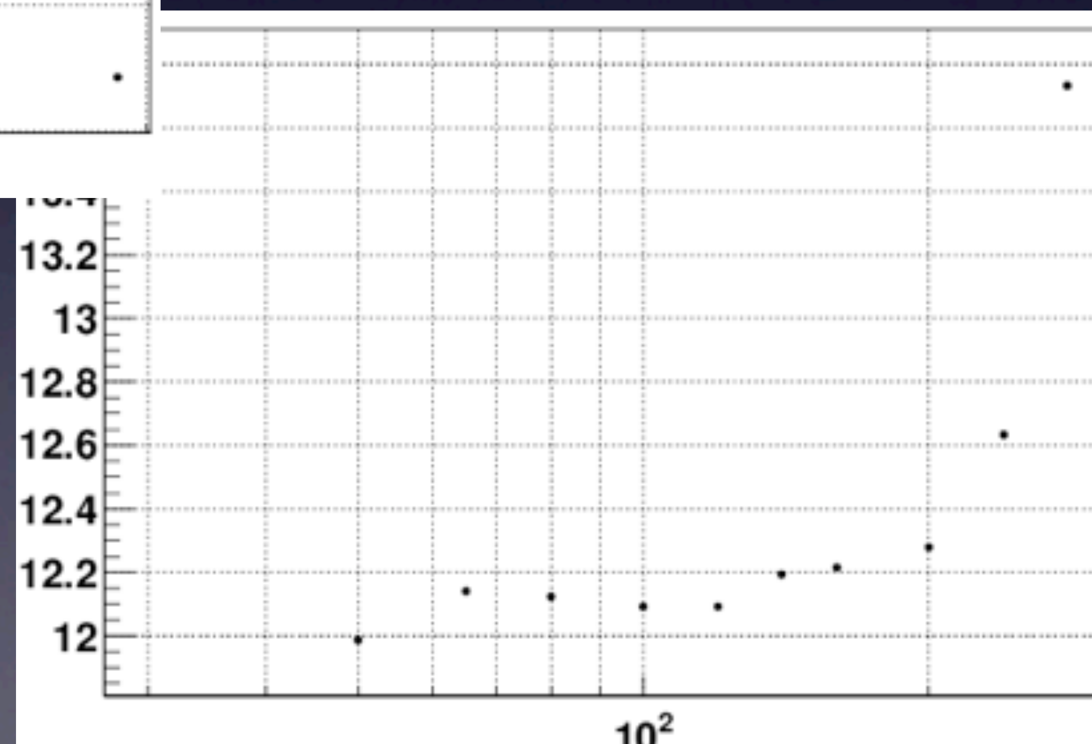




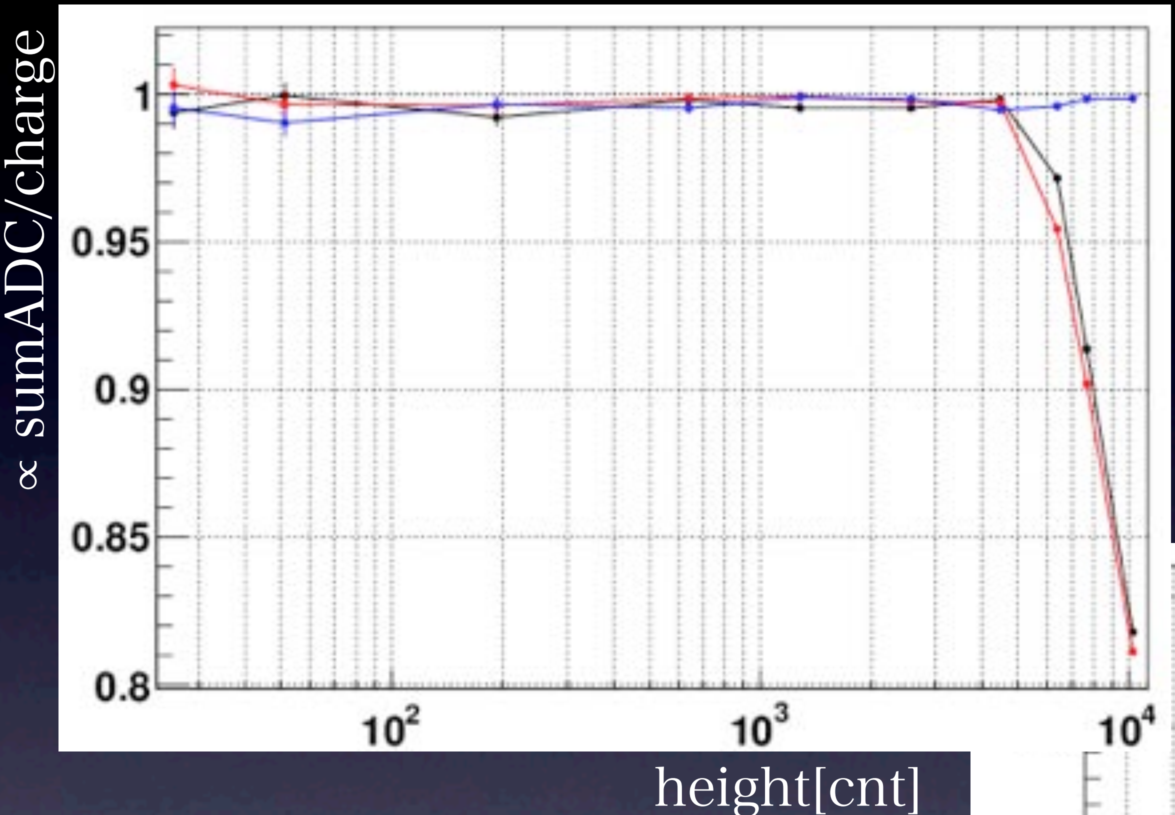
region0
region1
region2
region3
29.5
29
28.5
28
27.5
27
26.5
26
10
10^2
energy[MeV]

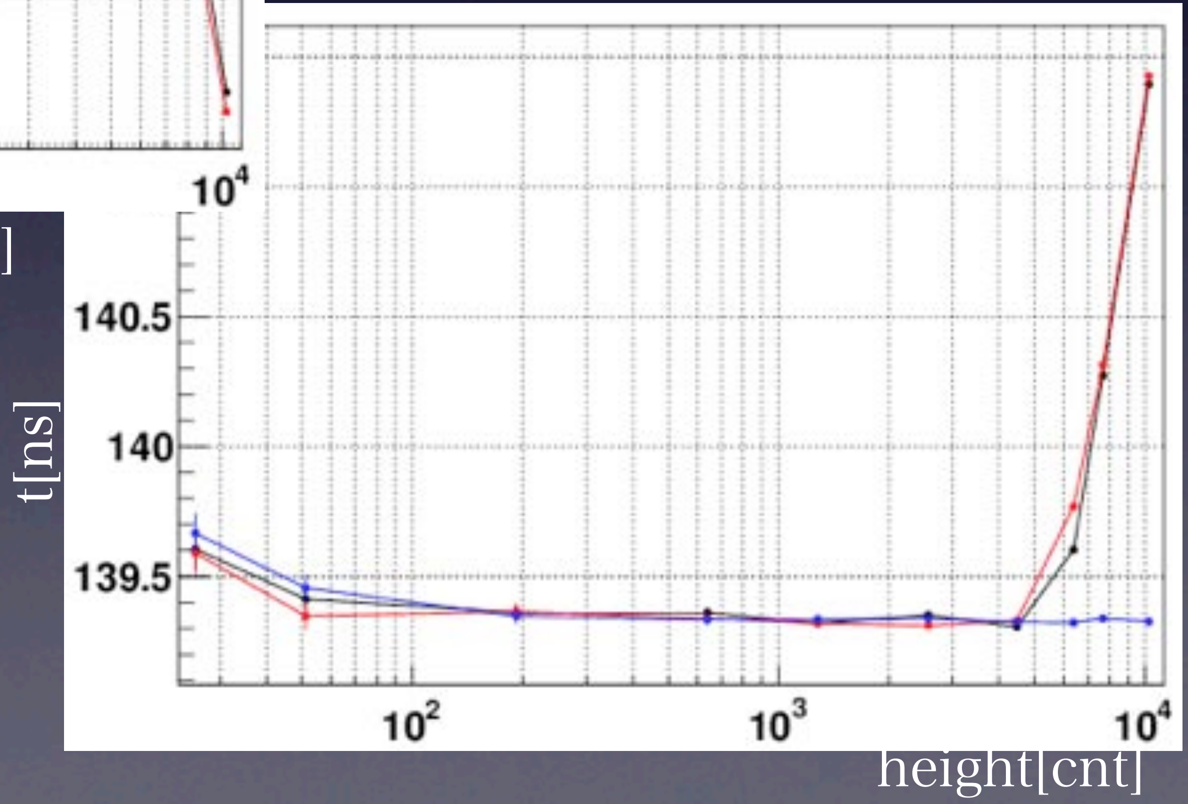
追試験の結果


∝ sumADC/入力
500
495
490
485
480
475
10^2
入力電圧[mV]


Δt[ns]
13.2
13
12.8
12.6
12.4
12.2
12
10^2
入力電圧[mV]

toy-simulation





Summary

- 読み出した波形データからエネルギーと時間を再構成する方法を確立
- non-linearityが見つかった
  - エネルギーにおける効果の補正はできそう
  - 時間情報における効果のスタディはまだ始めたばかり
  - non-linearityはCW base内のpreampが原因と思われる