



Quick report of a beam test for Csl both-end readout system

28/12/2017
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Outline

- KOTO experiment
- Beam test @ELPH
- Energy resolution of PMT
- Conclusion, Prospects



After-party (taken by Shimizu)

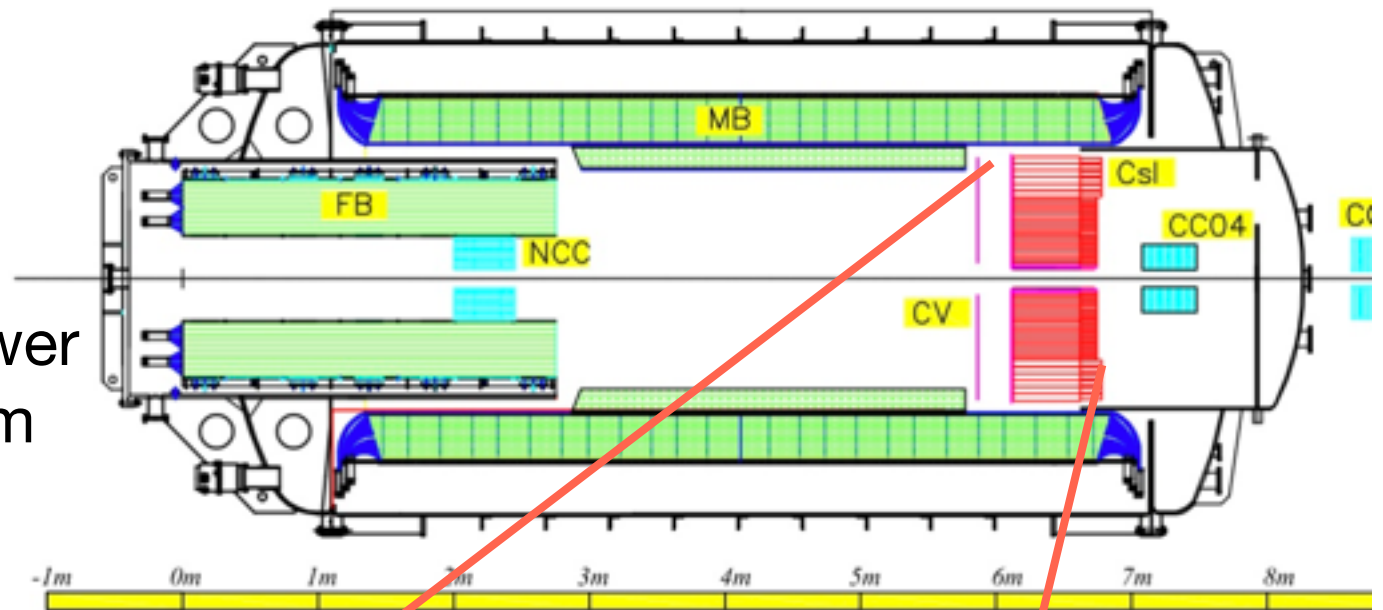
KOTO experiment, halo neutron B.G.

Signal:

$$K_L \rightarrow \pi^0 \nu \bar{\nu}$$

Background:

A beam halo neutron makes hadron shower in a CsI crystal, then another neutron from this shower make another cluster.



Signal

gamma

CsI

PMT

PMT

Background

neutron

PMT

neutron

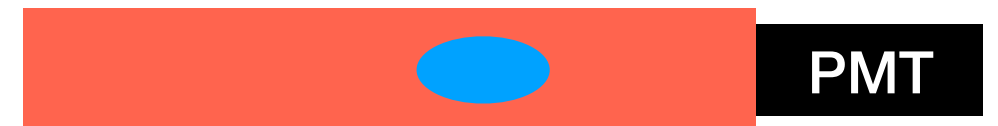
PMT

Csl both-end readout system

Current readout system



Both-end readout system

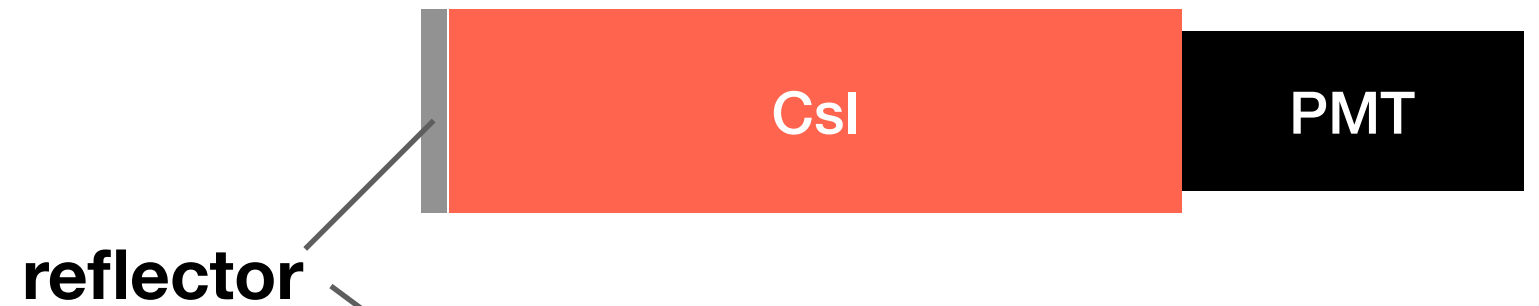


Timing difference between MPPC and PMT = z position



Some detail

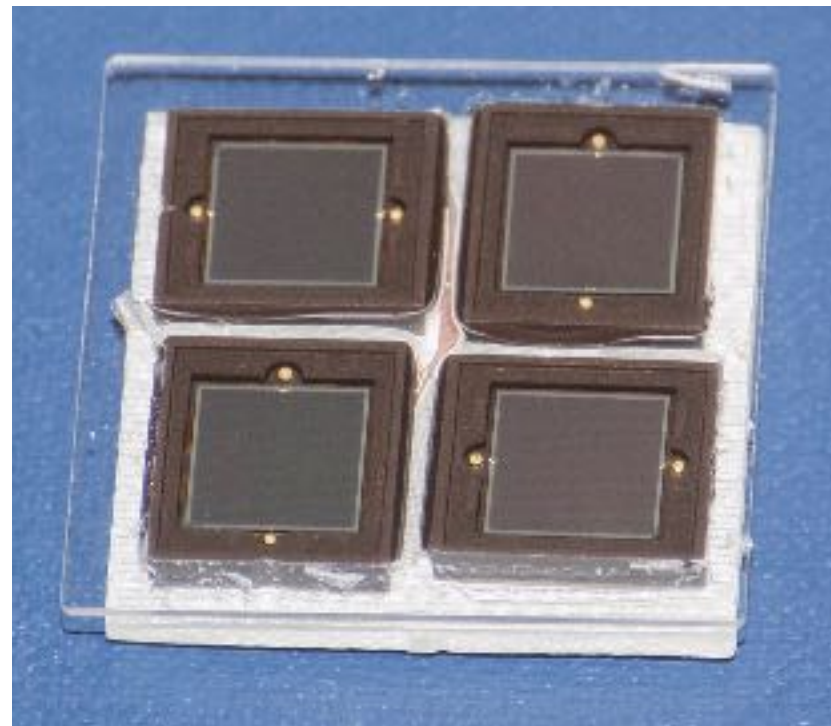
Current readout system



Both-end readout system



4MPPCs + Quartz



Reflector

Energy resolution of the PMT

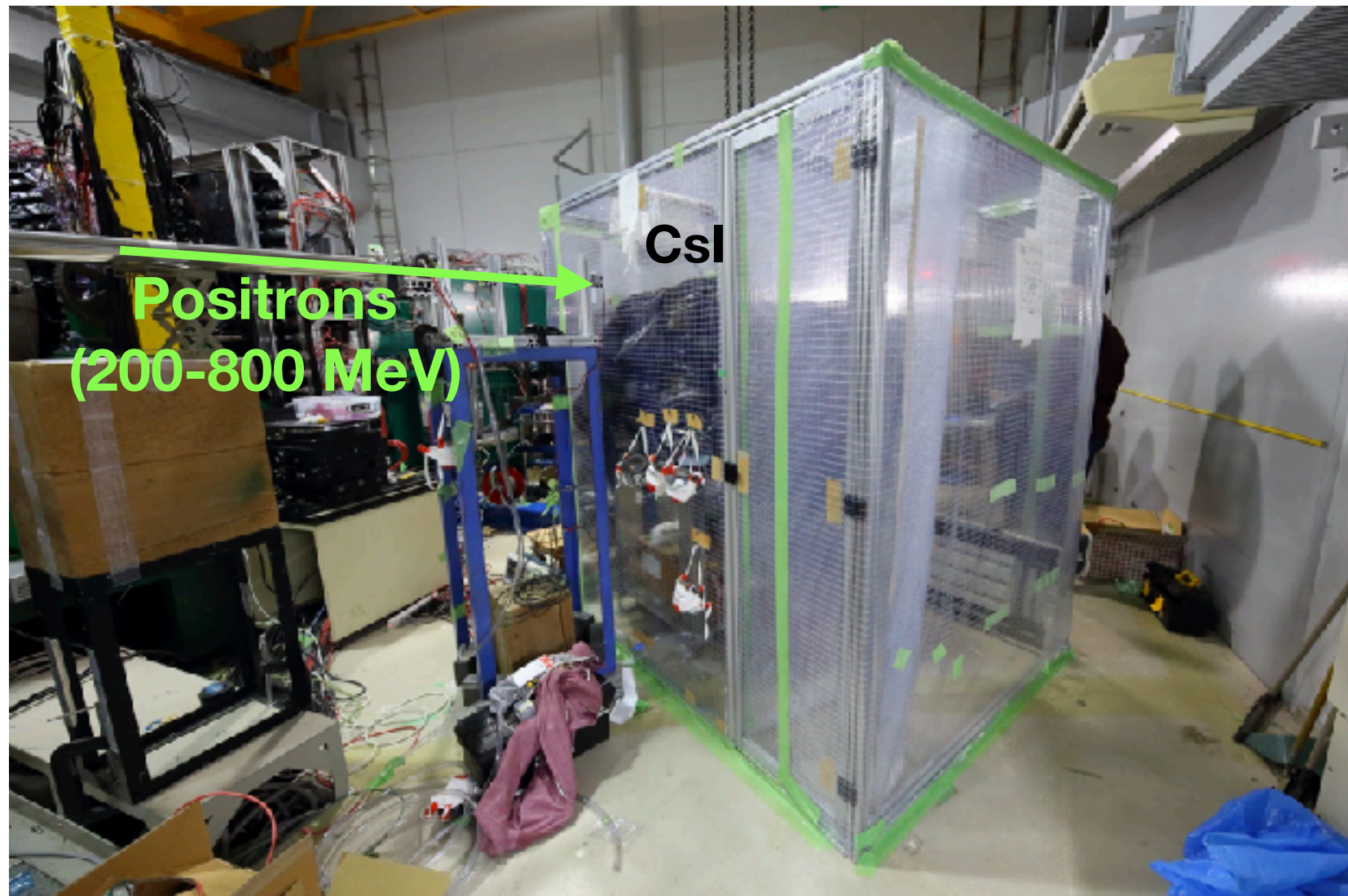
Energy resolution of the PMT is expected to change, because

- Reflector will be replaced with smaller one
 - (material can also be changed)
- MPPCs will cover the upstream surface of CsI

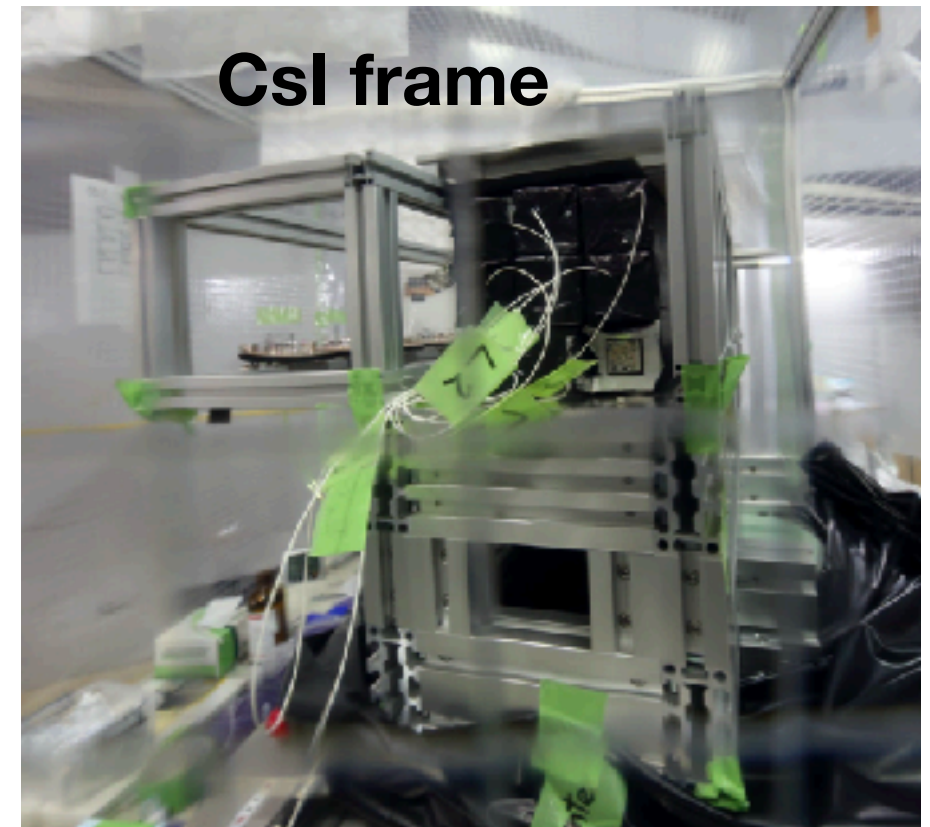
To evaluate σ_E of the PMT...

- 200-800 MeV positron beam data (tested at ELPH)

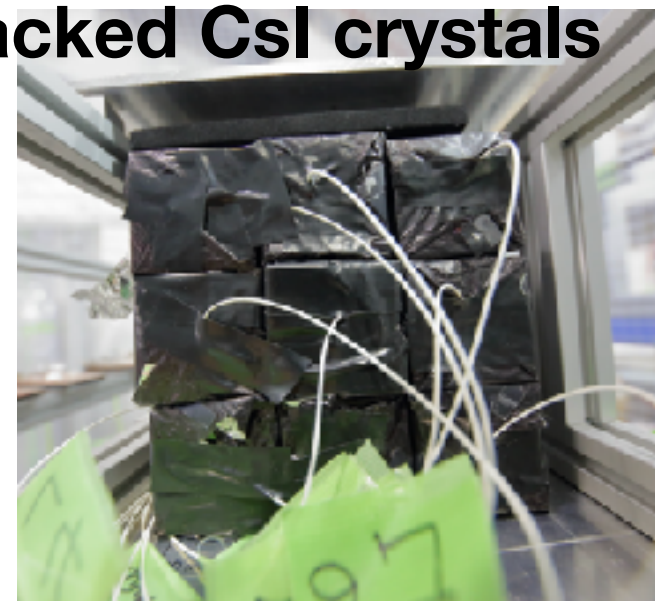
Beam test at ELPH



Cosmic ray data were also acquired while the beam was off.

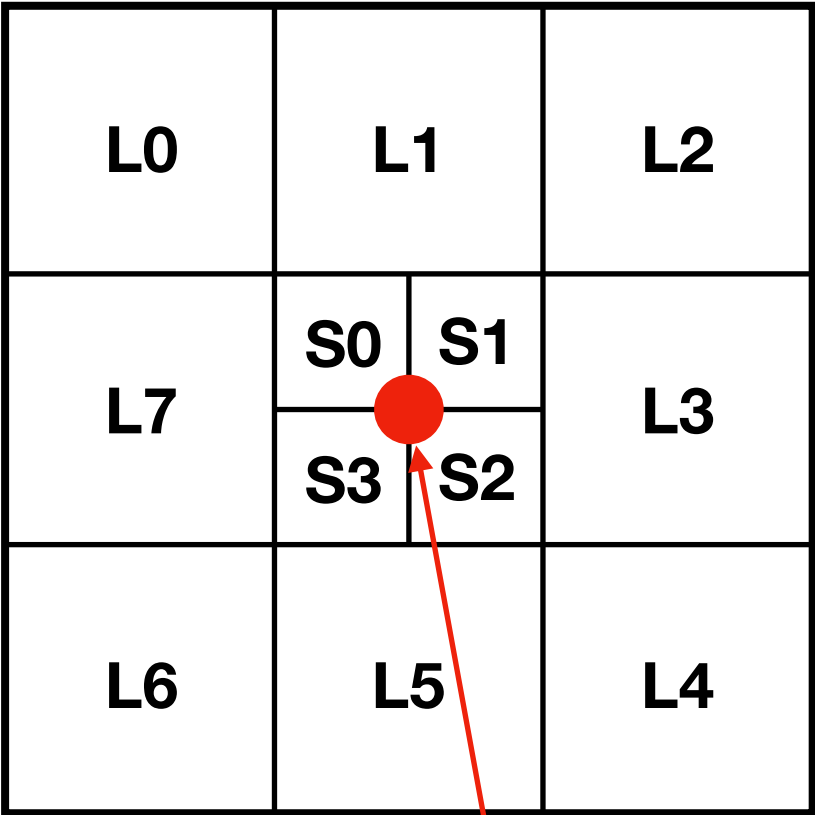


Stacked CsI crystals



Setup

● Beam



beam injection

8 large (50x50x500mm³) CsI crystals
4 small (25x25x500mm³) CsI crystals

	w/o MPPC	w/ MPPC
MPPC	none	4 MPPCs for L crystals 1 MPPC for S crystals
reflector	KOTO-reflector (different between crystals)	Nishimiya-reflector (silver, square hall)
calibration	800MeV positrons	cosmic rays (40mm from the up- stream surface of CsI)
beam-run	200-800 MeV, beam position was the center of the stack	

Other informations:
Beam spot size > 10mm

Beam position shift

L0	L1		L2
L7	S0	S1	L3
	S3	S2	
L6	L5		L4

Large crystals: 50mm x 50mm

Small crystals: 25mm x 25mm

Beam position was deviated 4.5 ~ 6.5 cm
from expected position.

ビーム上流部では

$126.5 - 45 = 81.5$ が crystal の端が beam line

$81.5 - 75 = 6.5\text{mm}$ - 2 側 1: beam

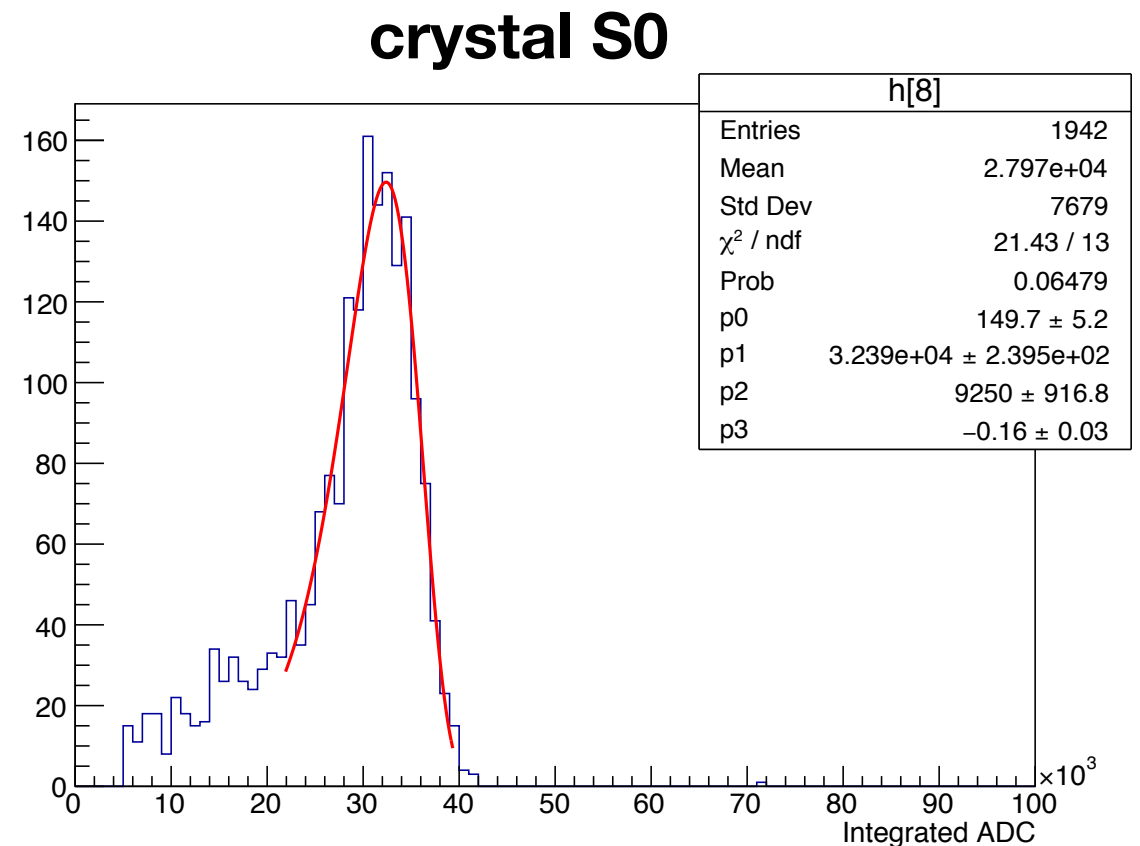
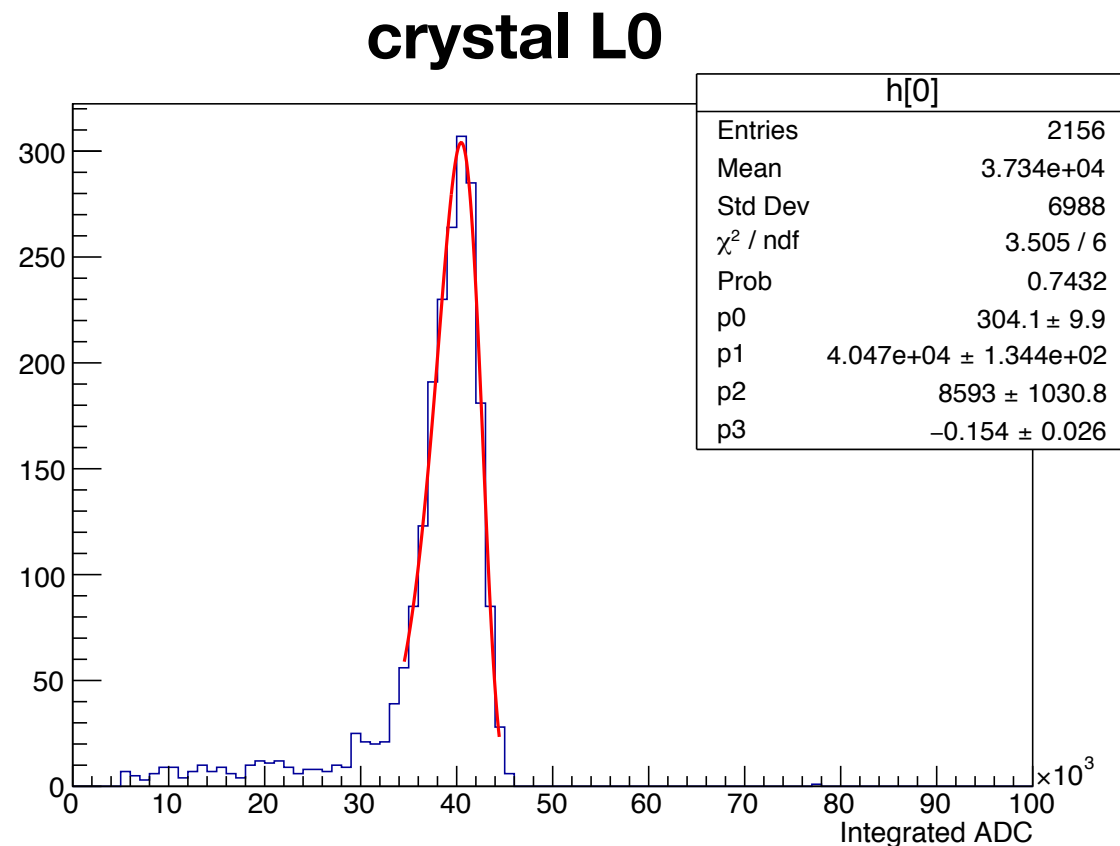
ビーム下流部では

$100.5 - 21 = 79.5$ が crystal 端が beam line

$79.5 - 75 = 4.5\text{mm}$ - 2 側

Calibration (w/o MPPC)

800MeV positron beam was injected at the center of each crystal



- Fitted with asymmetric gaussian

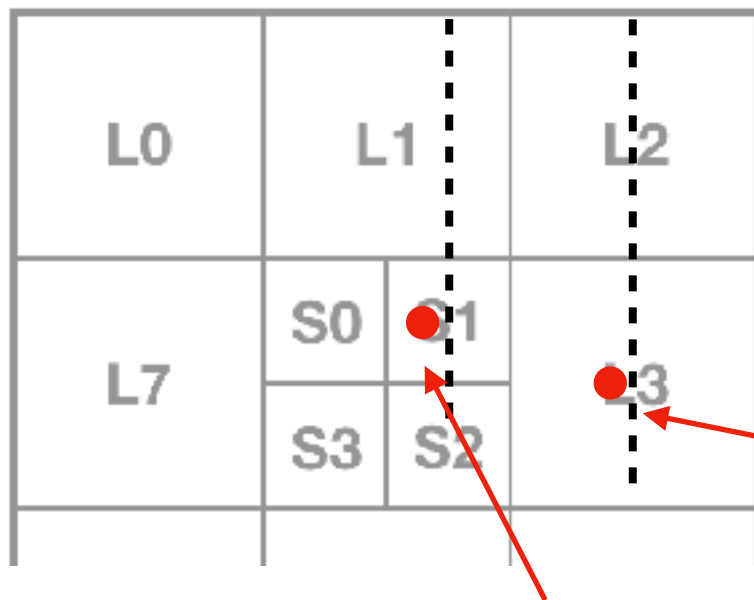
$$G_A(x) = N_0 \exp \left[-\frac{(x - \mu)^2}{2(\sigma_1 x + \sigma_0)^2} \right]$$

● Beam

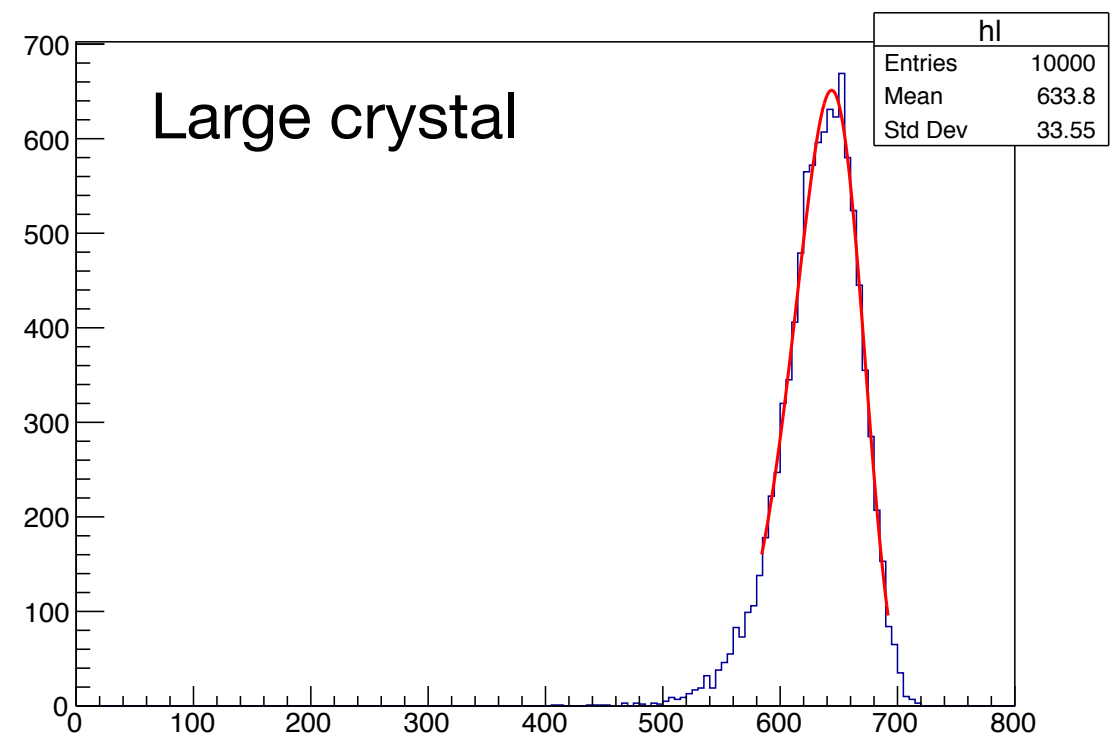
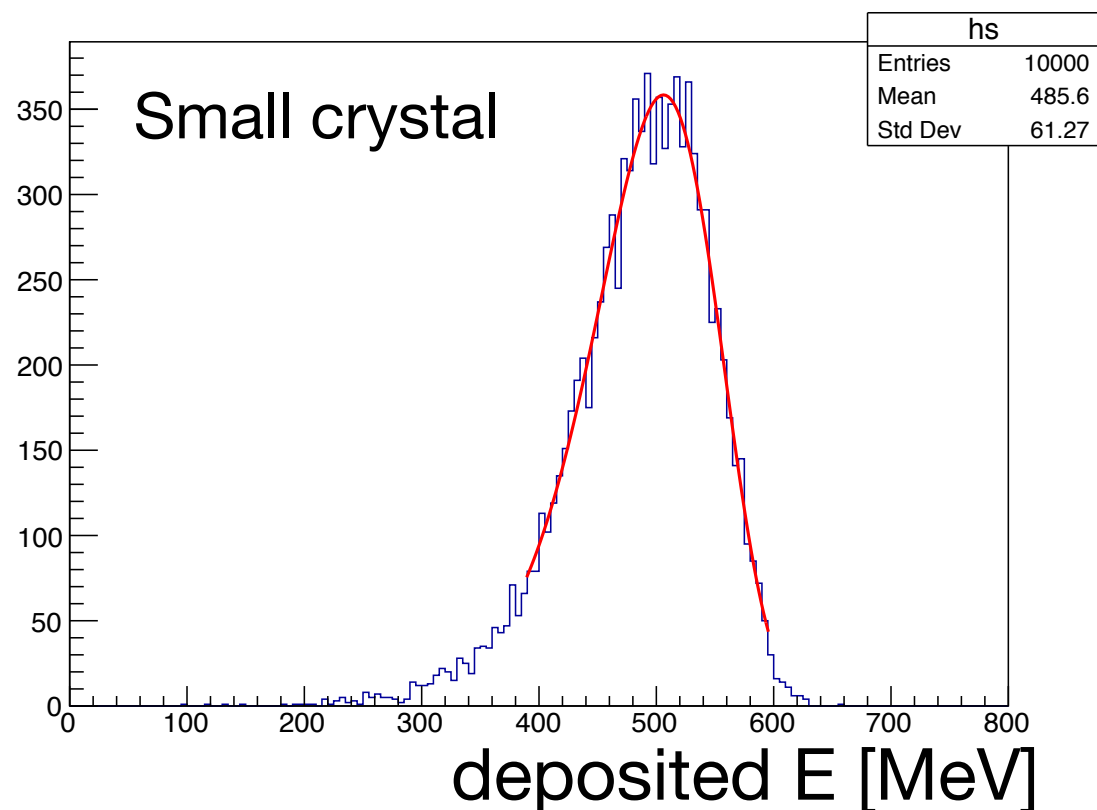
L0	L1		L2
L7	S0	S1	L3
	S3	S2	
L6	L5		L4

Scale factor (w/o MPPC)

Geant4 simulation

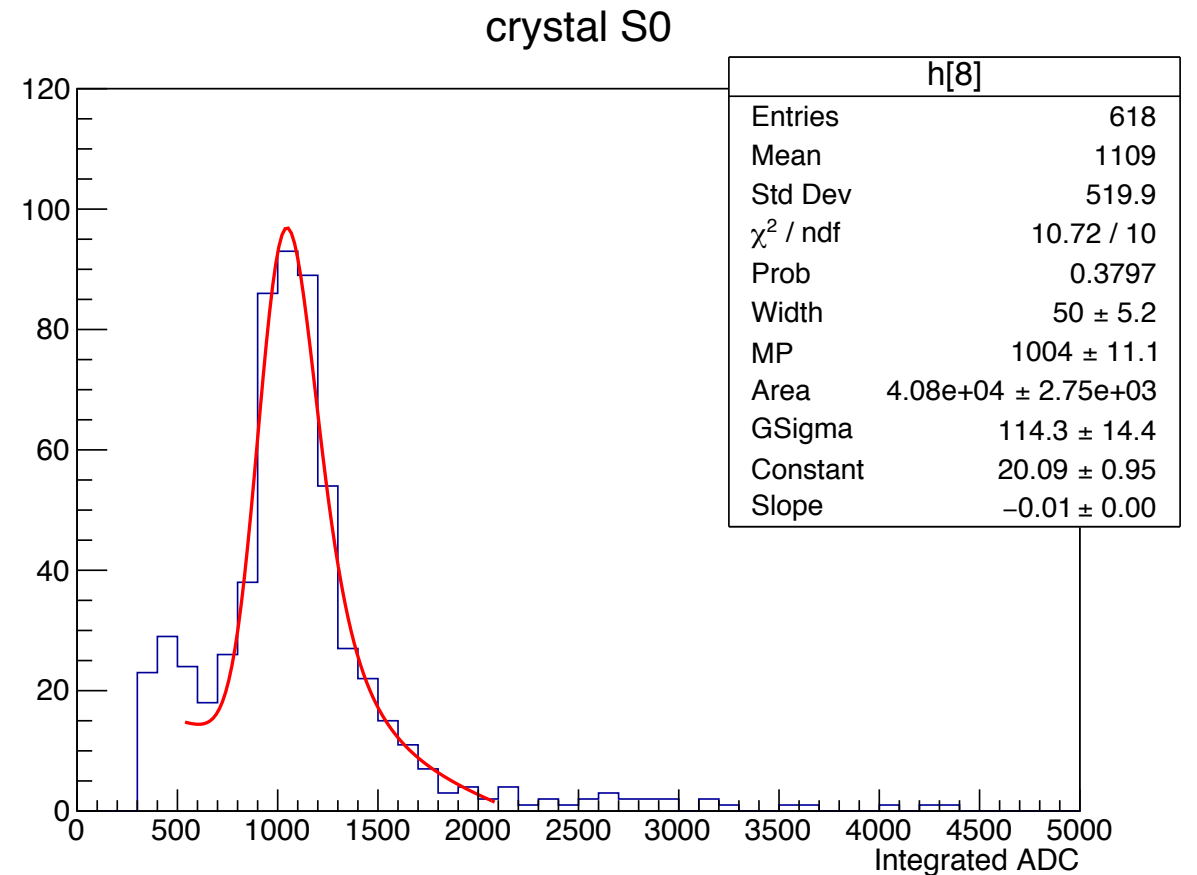
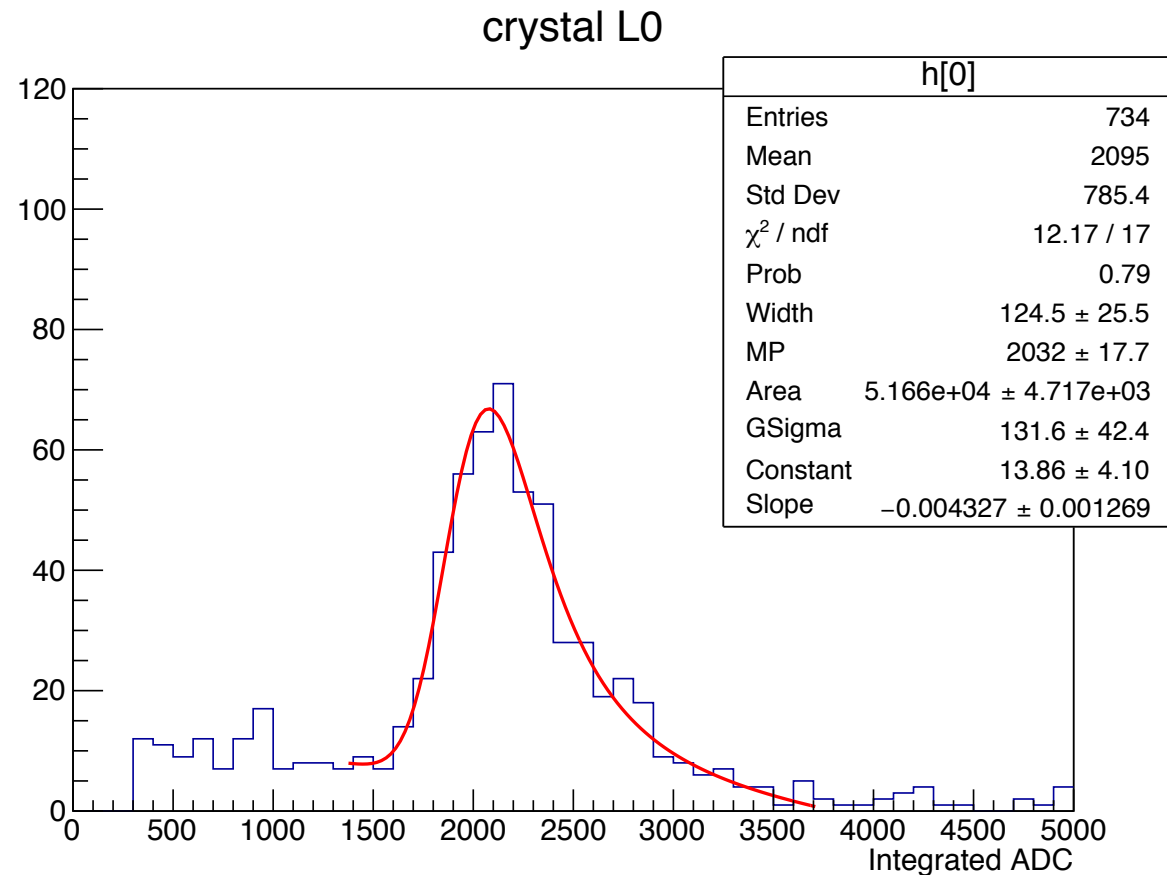


- 800MeV positrons
- $x=5\text{mm}$ shifted from center line
- scale factor := MPV (L) / MPV (S)



Calibration (w/ MPPC)

Cosmic rays at 40mm from the upstream surface of CsI



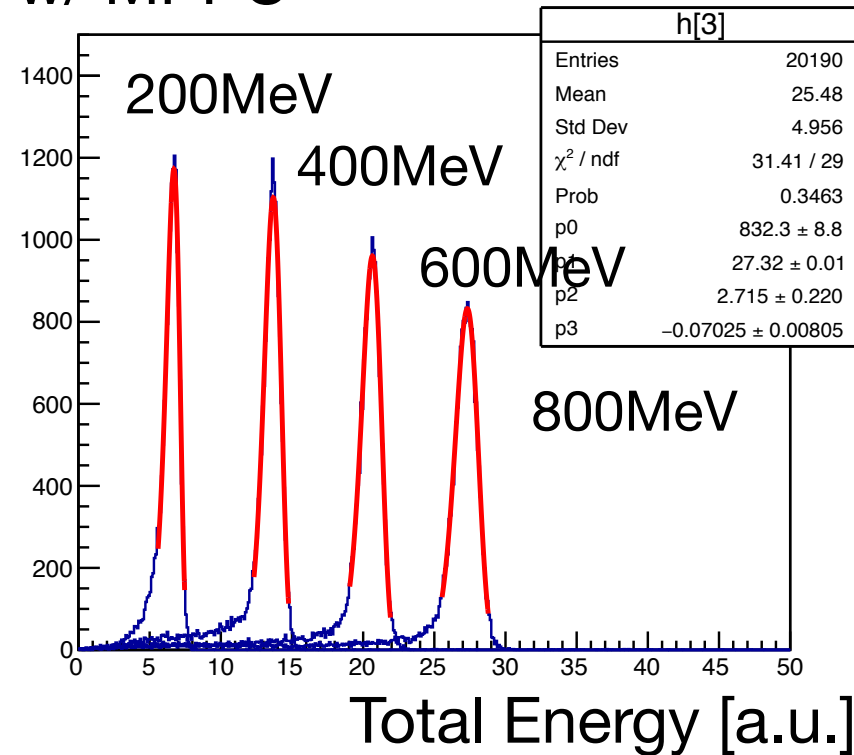
- Fitting function: (landau*gaussian) + pol1
- MPV of landau is used for calibration
- Scale factor between large and small crystal = 2.0

● Beam

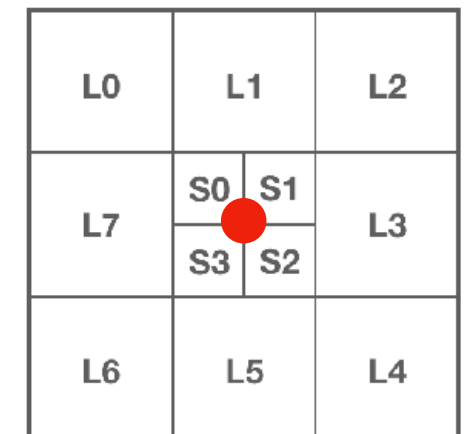
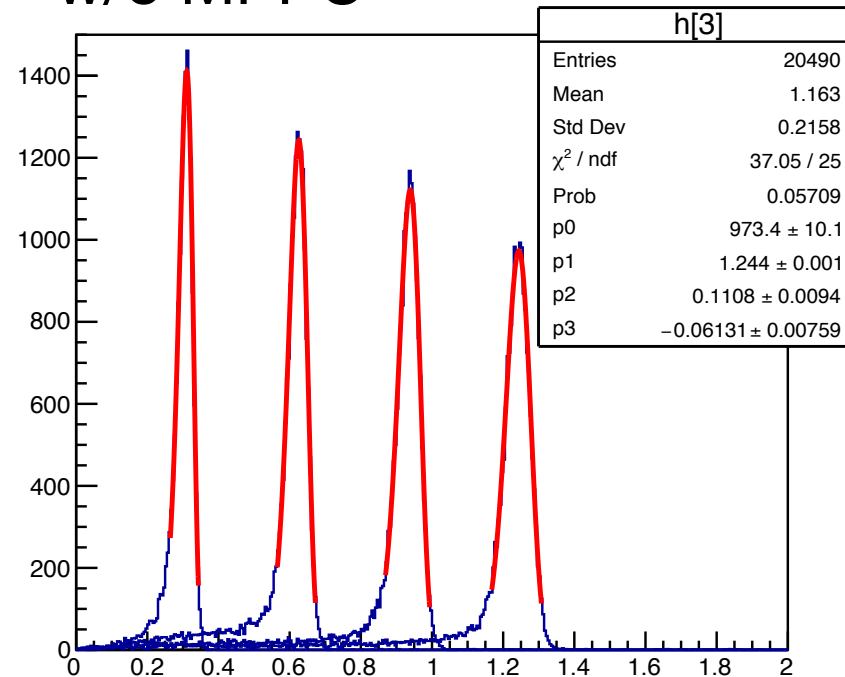
L0	L1		L2
L7	S0	S1	L3
	S3	S2	
L6	L5		L4

Energy resolution of PMT

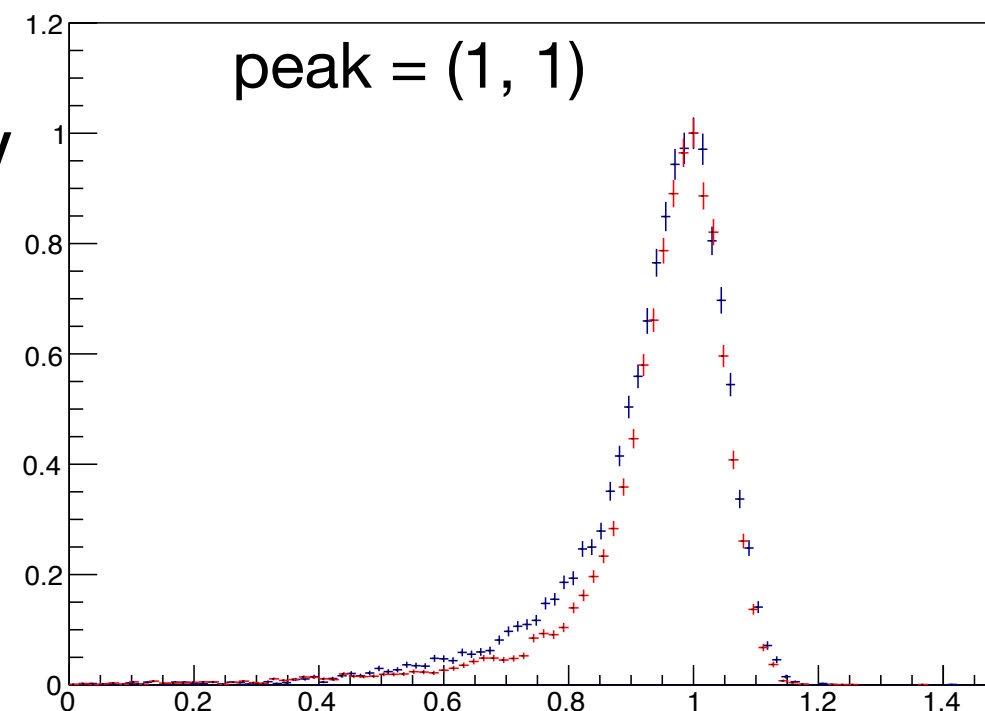
w/ MPPC



w/o MPPC



comparison @200MeV



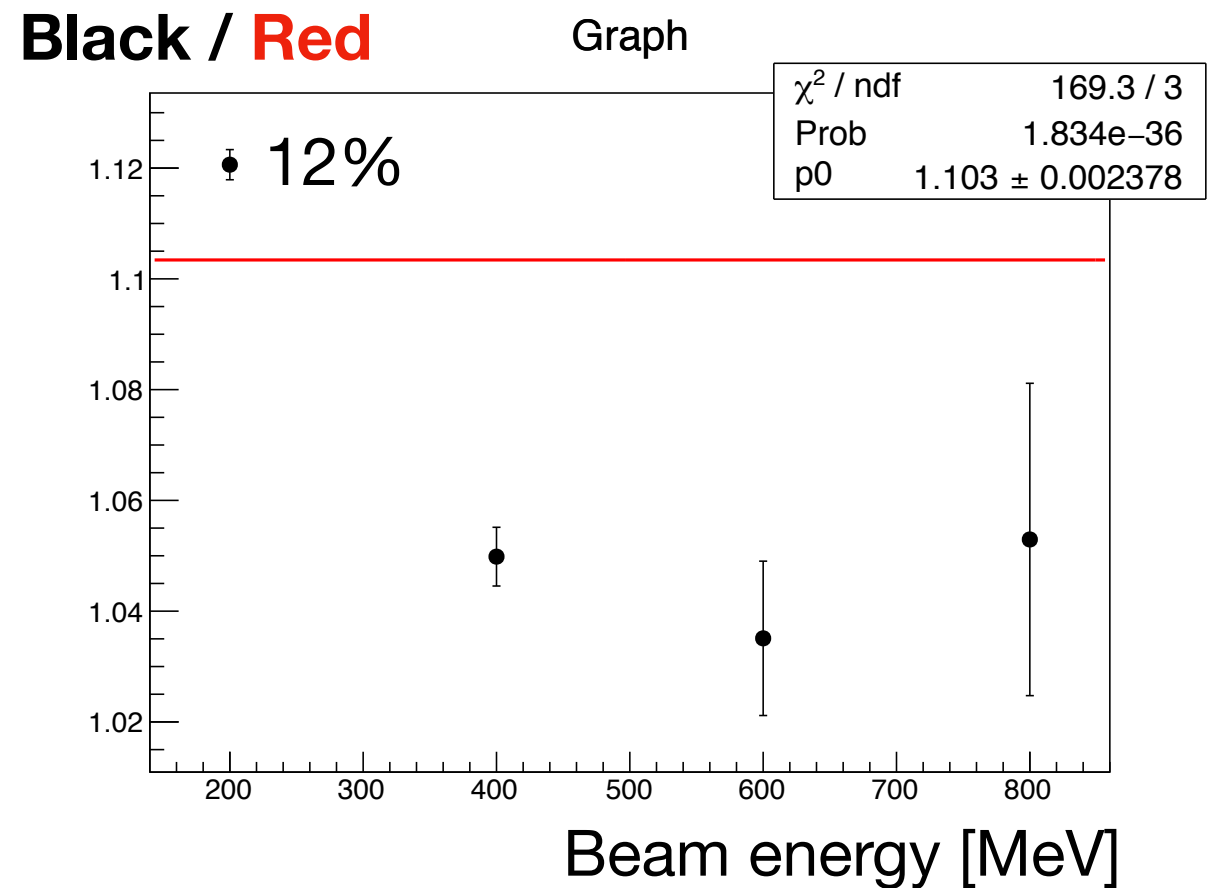
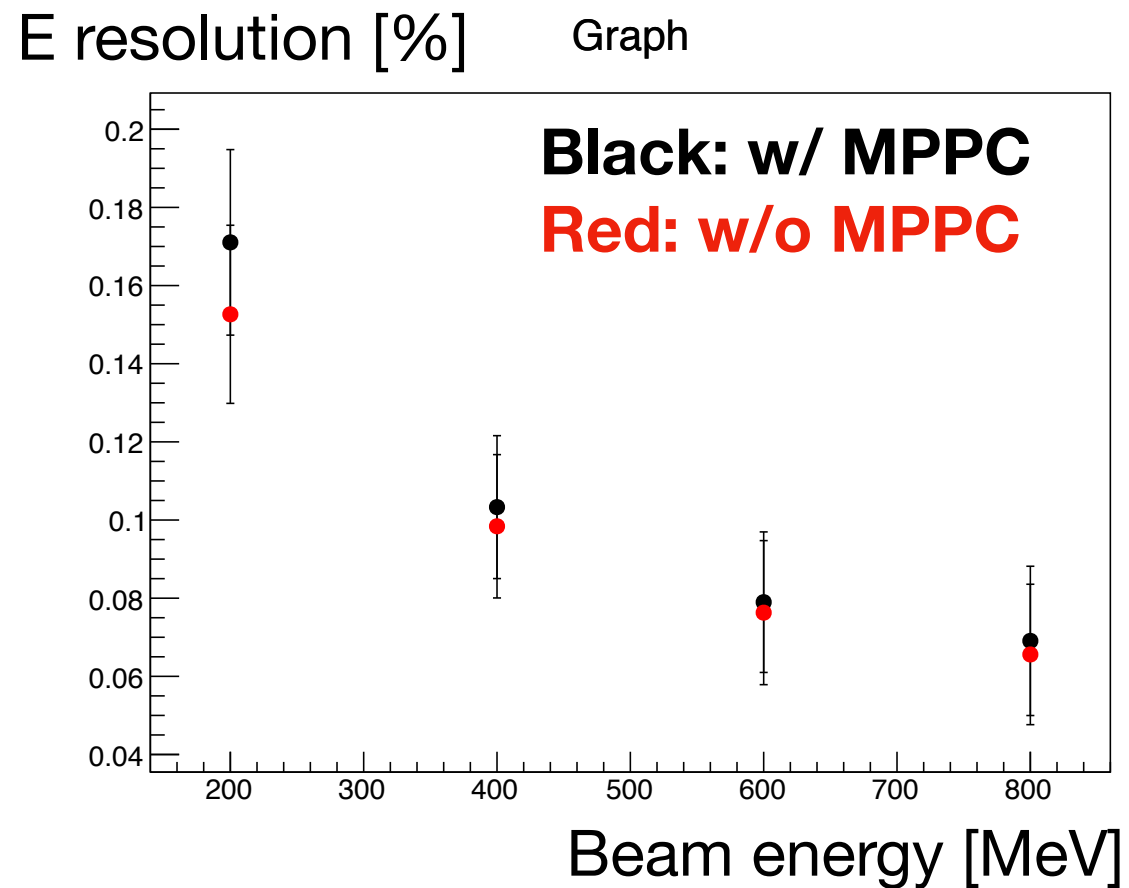
Blue: w/ MPPC

Red: w/o MPPC

w/ MPPC is wider than w/o.

Energy resolution of PMT

Energy resolution := FWHM / MPV



Conclusion / Prospects

Conclusion

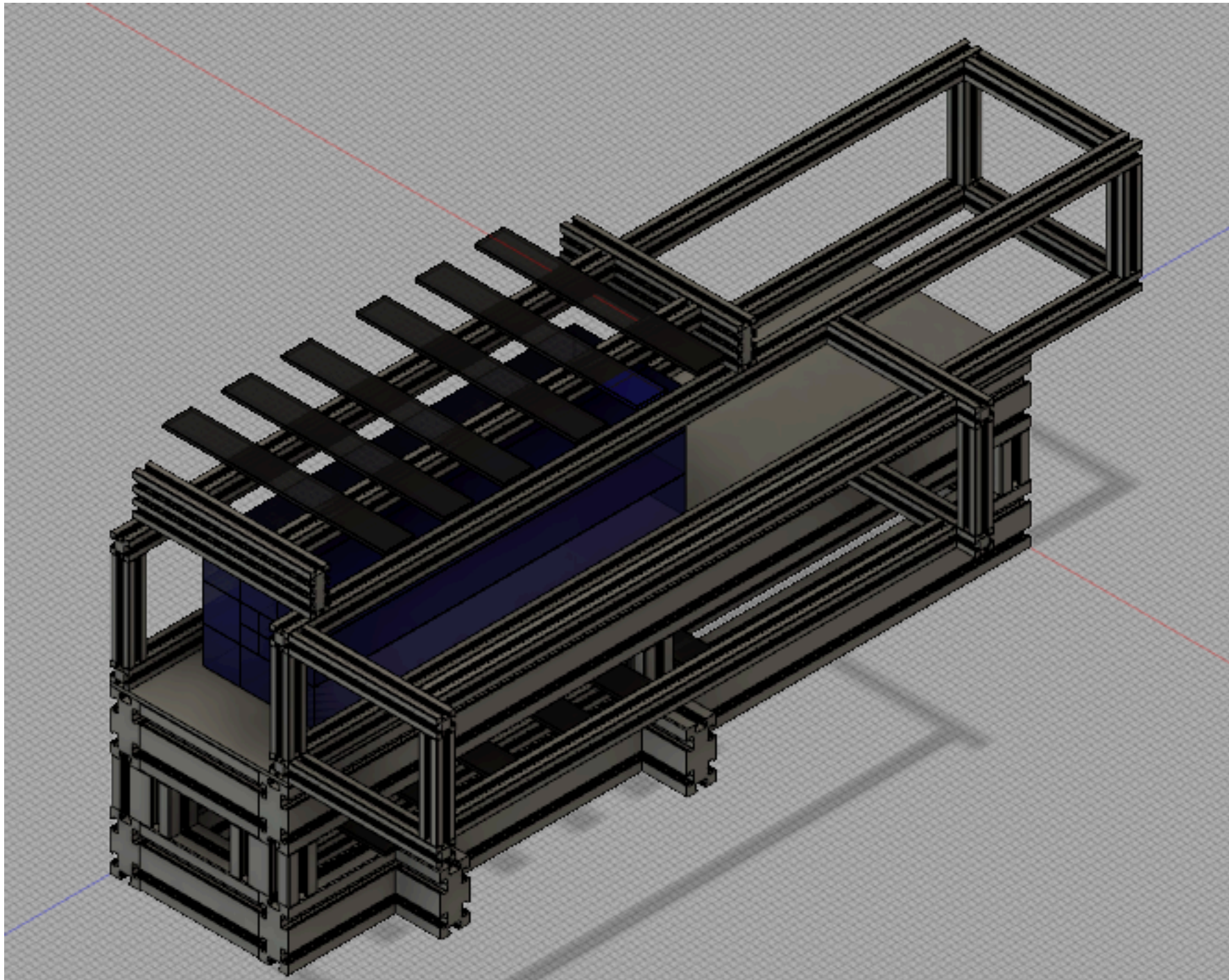
- We tested new Csl readout system for the calorimeter upgrade.
- I checked how the MPPCs affect energy resolution of PMTs.
 - Energy resolution got worse (max: 12% @200MeV)

Prospects

- Analysis of timing resolution of both-end readout system
- Analysis of other runs (backward run, rotated run, etc...)
- Optical photon simulation

Back up

Setup



Asymmetric Gaussian

$$G_A(x) = N_0 \exp \left[-\frac{(x - \mu)^2}{2(\sigma_1 x + \sigma_0)^2} \right]$$

4 parameters: $N_0, \mu, \sigma_0, \sigma_1$

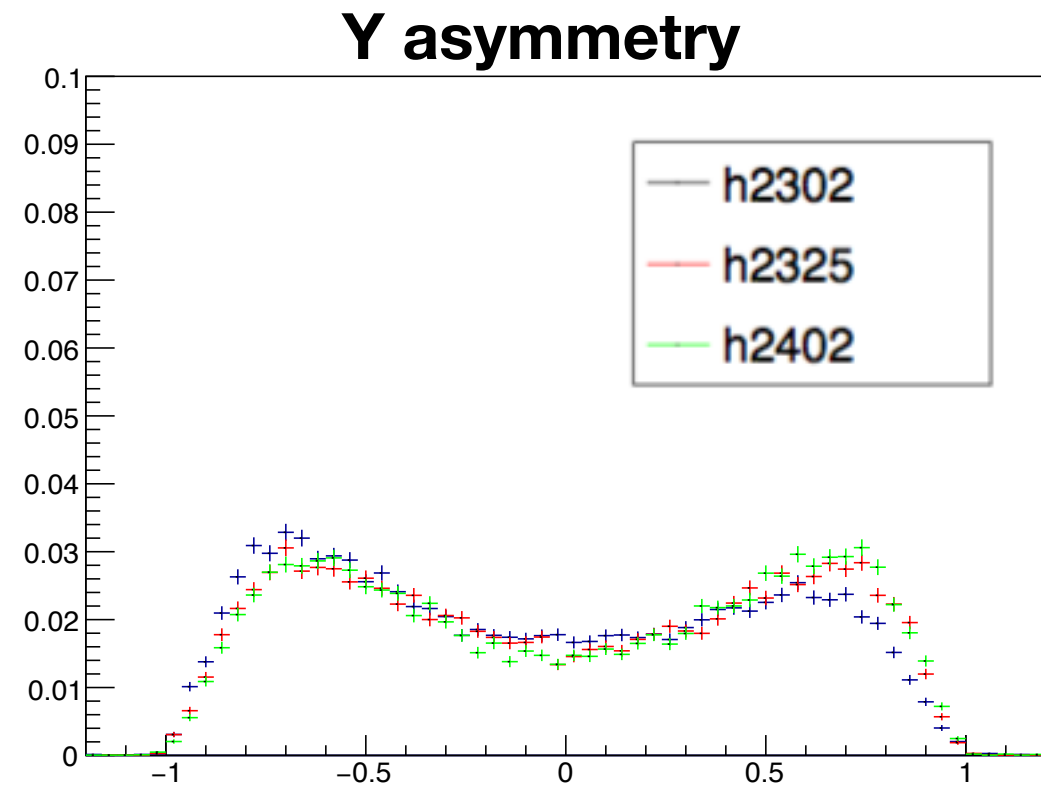
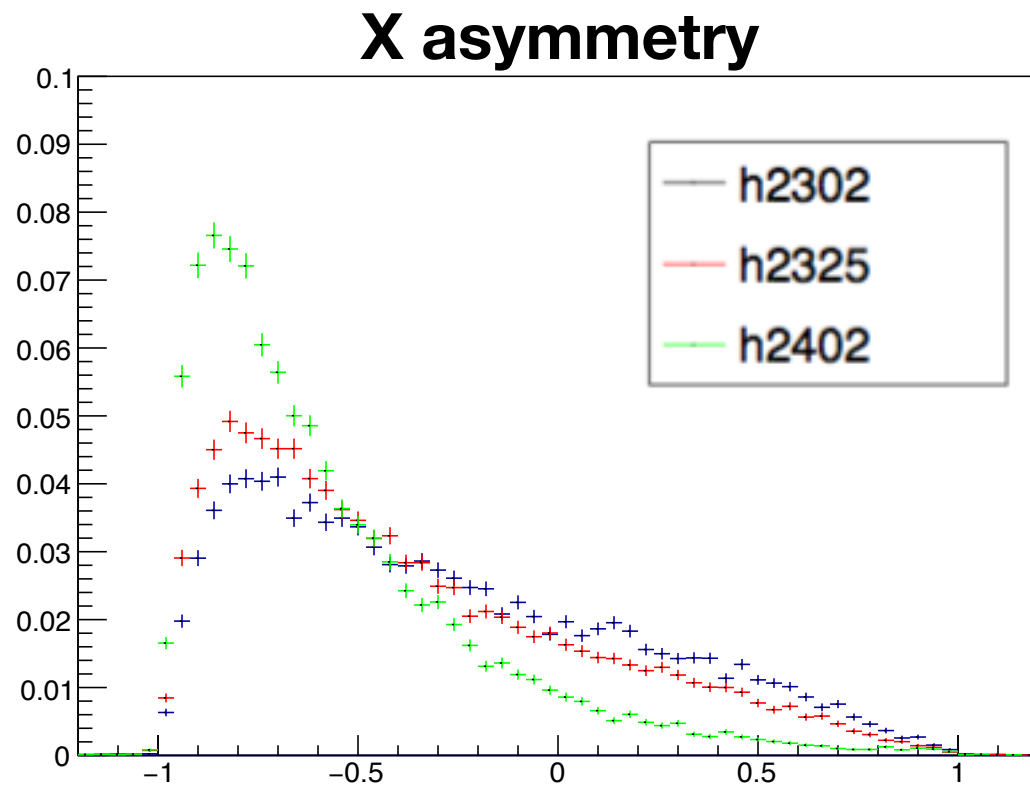
$$MPV = \mu$$

$$\text{error} = \delta\mu$$

$$FWHM = \frac{\mu + \xi\sigma_0/2}{1 - \xi\sigma_1/2} - \frac{\mu - \xi\sigma_0/2}{1 + \xi\sigma_1/2} \quad \xi \equiv 2\sqrt{2 \ln 2}$$

$$\text{error} = \sqrt{\frac{\xi}{1 - (\xi\sigma_1/2)^2} [(\sigma_1\delta\mu)^2 + (\delta\sigma_0)^2] + \left(\frac{\xi}{2}\right)^2 \left[\frac{\mu - \xi\sigma_0/2}{(1 + \xi\sigma_1/2)^2} - \frac{\mu + \xi\sigma_0/2}{(1 - \xi\sigma_1/2)^2} \right] (\delta\sigma_1)^2}$$

Asymmetry of energy deposition



Blue -> (Rotated run) -> Red -> (Backward run) -> Green

L0	L1	L2
L7	S0	S1
	S3	S2
L6	L5	L4

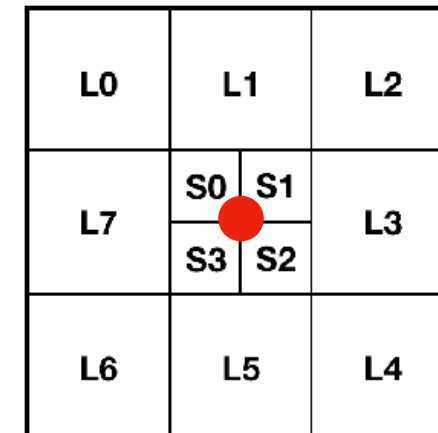
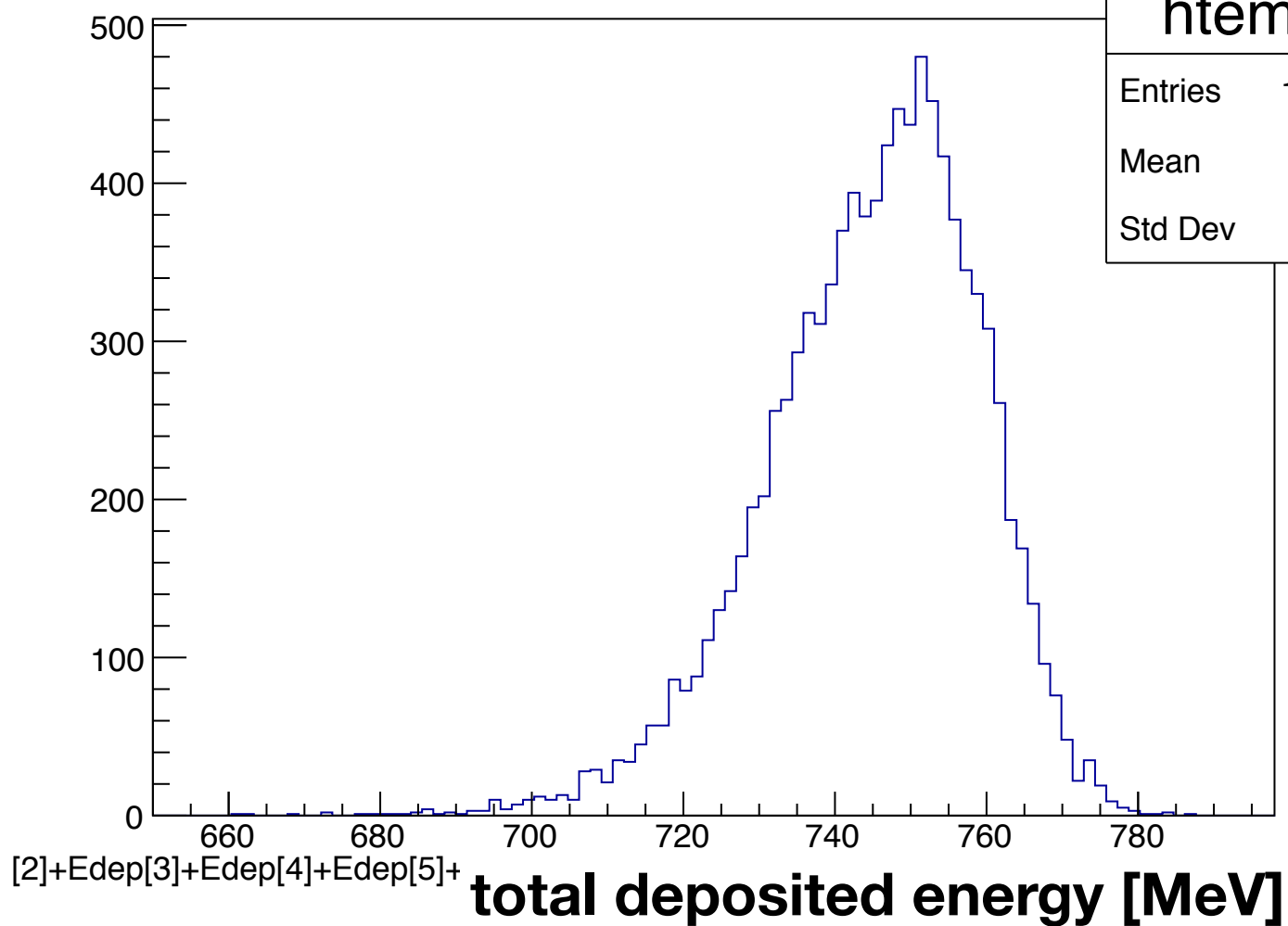
X asymmetry: S1 - S0
Y asymmetry: S0 - S3

Total energy deposition (Geant)

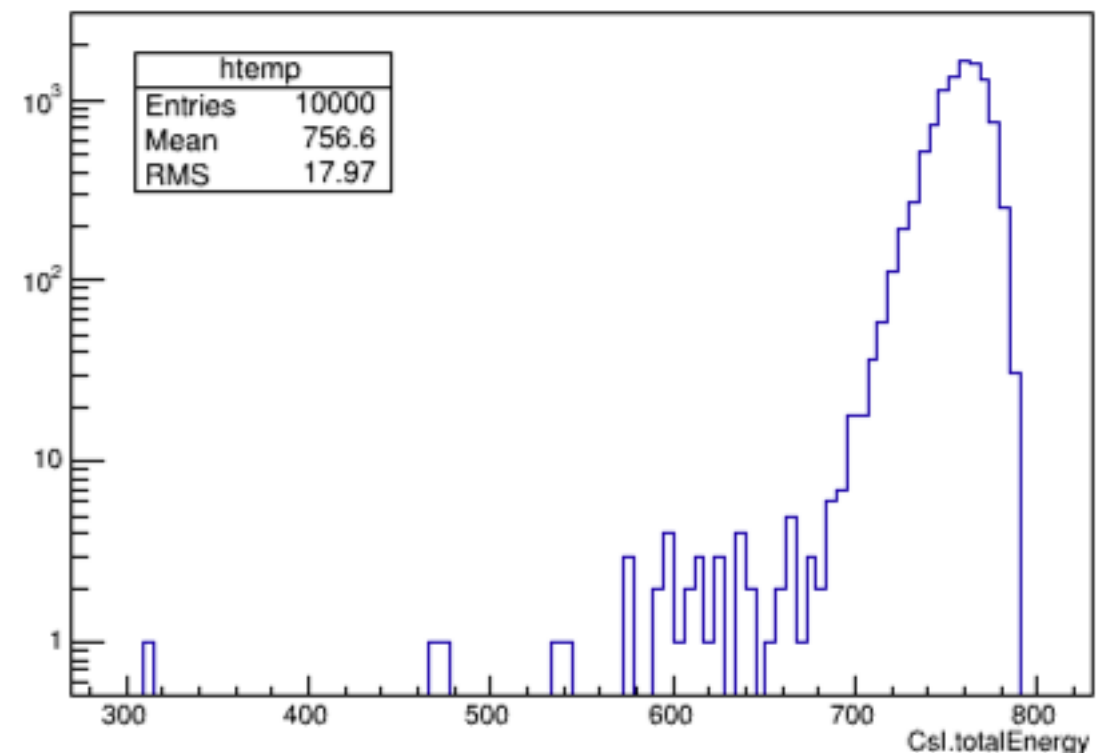
Geant4 simulation.

Incident beam energy 800 MeV

Edep[0]+Edep[1]+Edep[2]+Edep[3]+Edep[4]+Edep[5]+Edep[6]+Edep[7]+Edep[8]+Edep[9]+Edep[10]+Edep[11]



MC by gsim4



Low energy tail does not exist...