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

28/12/2017
Tomoo Mari
Osaka Univ.

Outline

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

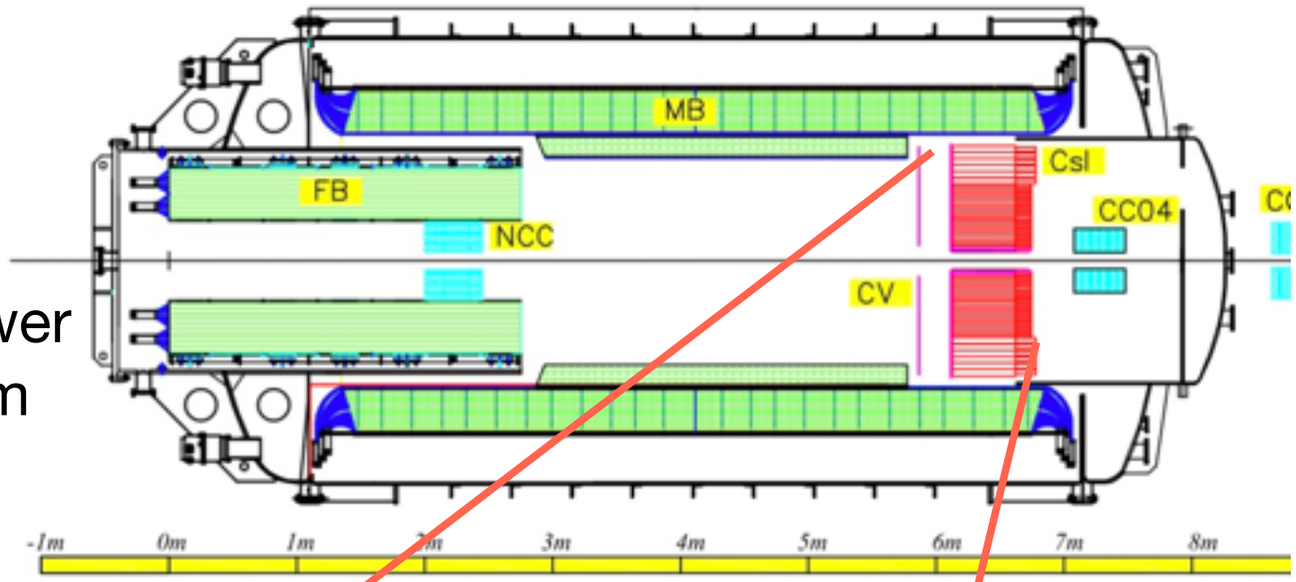
After-party (taken by Shimizu)

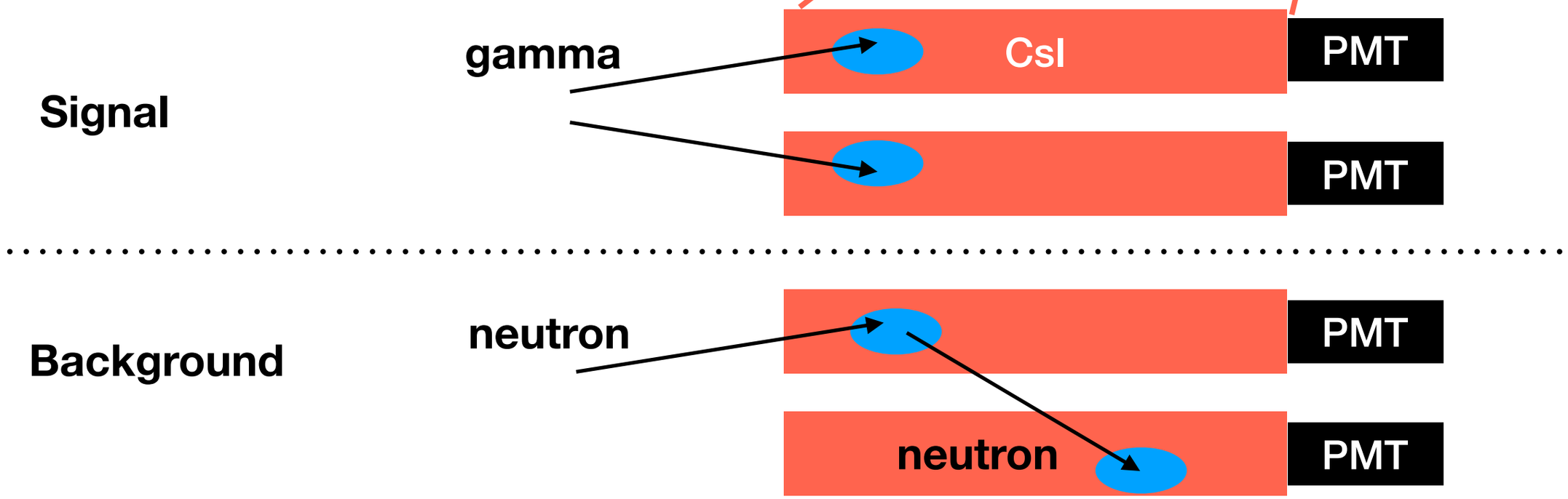
KOTO experiment, halo neutron B.G.

Signal:

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

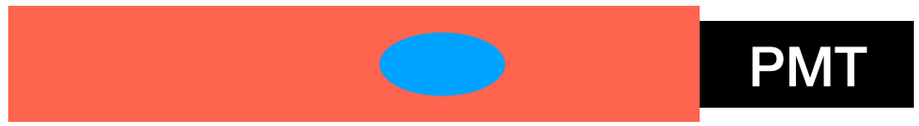
Background:
A beam halo neutron makes hadron shower in a CsI crystal, then another neutron from this shower make another cluster.



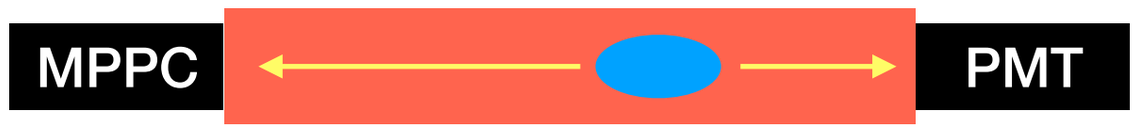


CsI both-end readout system

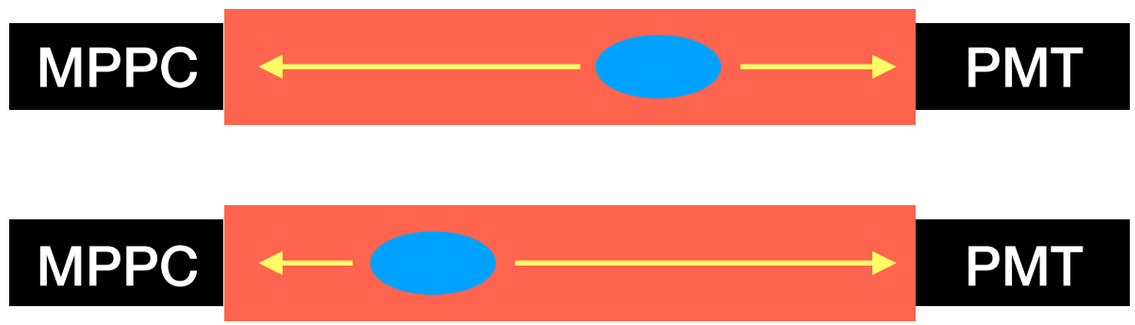
Current readout system



Both-end readout system



Timing difference between MPPC and PMT = z position

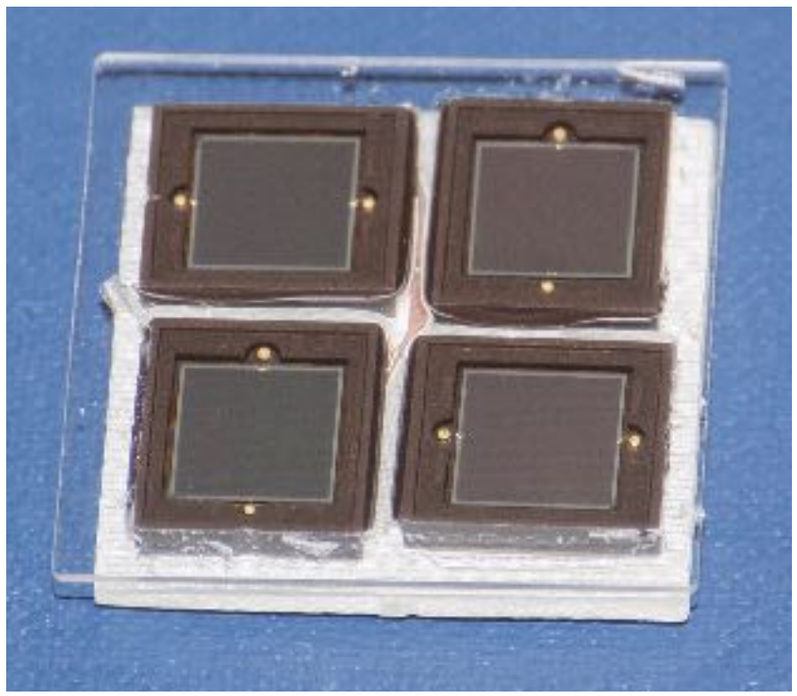


Some detail

Current readout system

Both-end readout system

4MPPCs + Quartz



Reflector

Energy resolution of the PMT

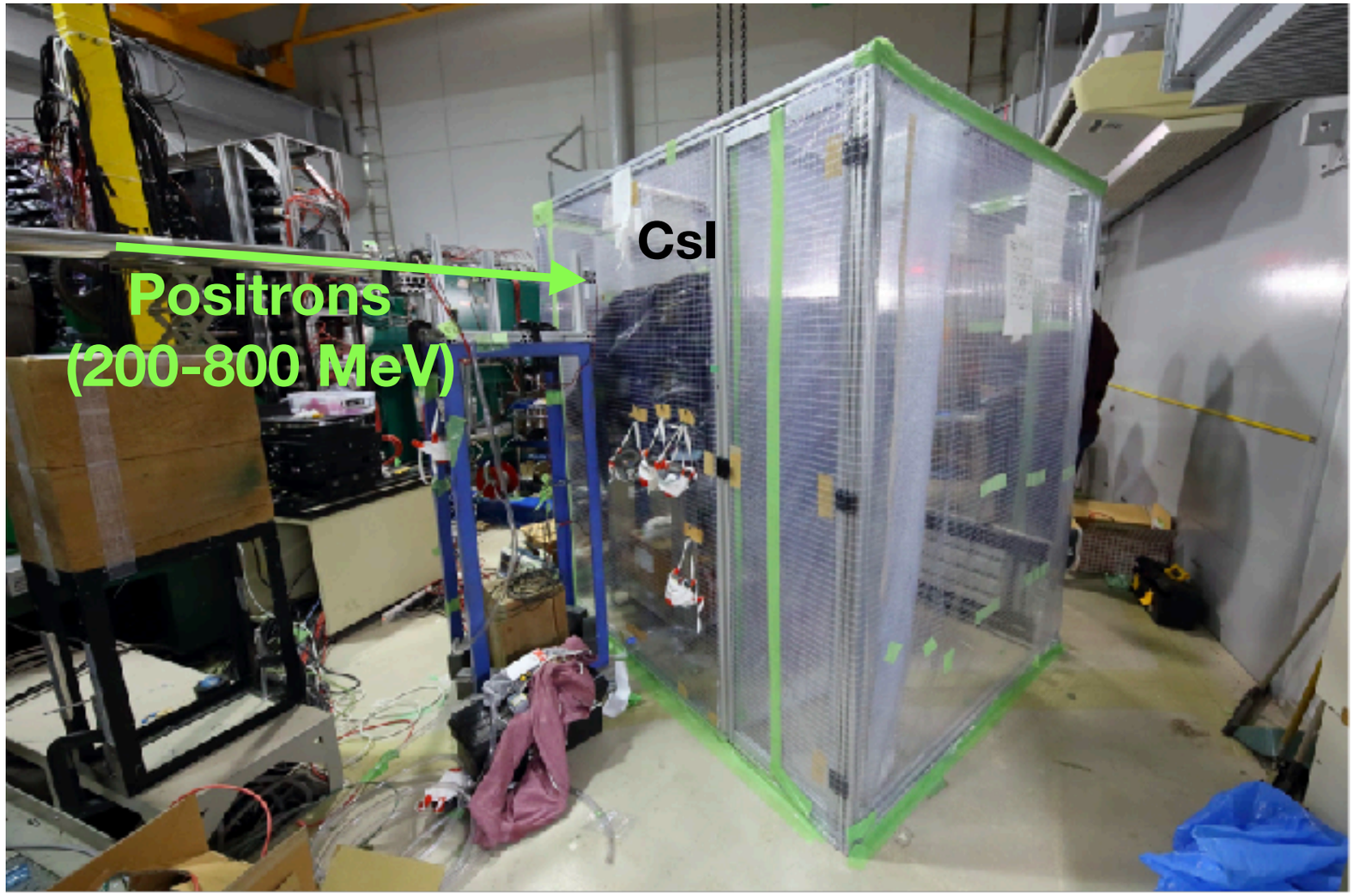
Energy resolution of the PMT is expected to change, because

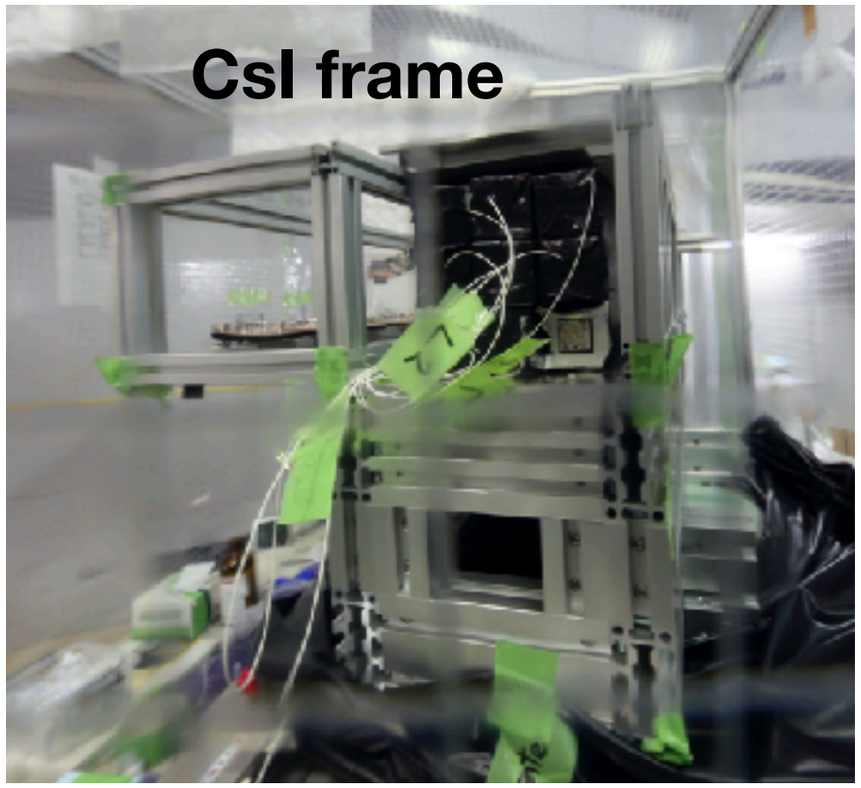
- Reflector will be replaced with smaller one
  - (material can also be changed)
- MPPCs will cover the upstream surface of CsI

To evaluate σ_E of the PMT…

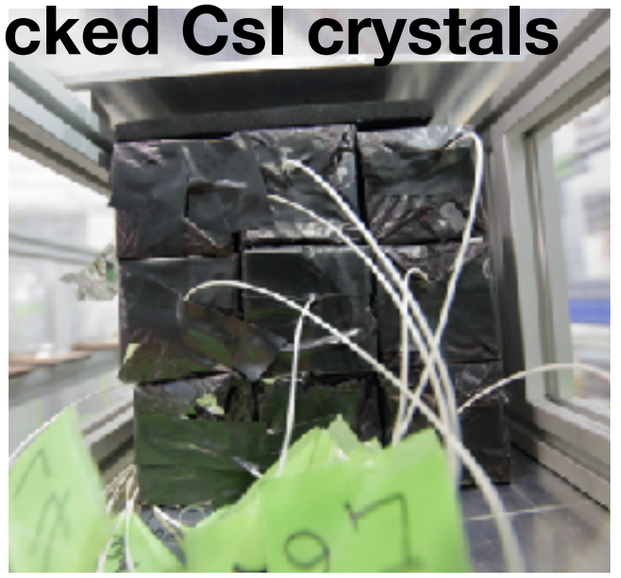
- 200-800 MeV positron beam data (tested at ELPH)

Beam test at ELPH



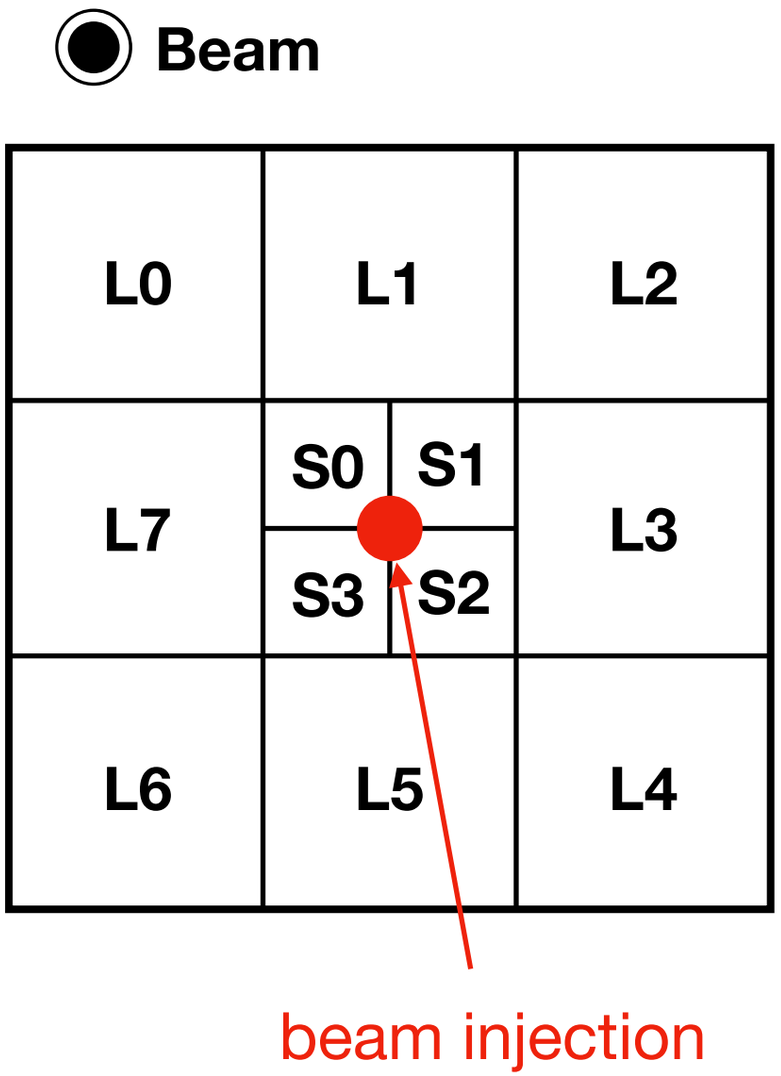


Stacked CsI crystals



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

Setup

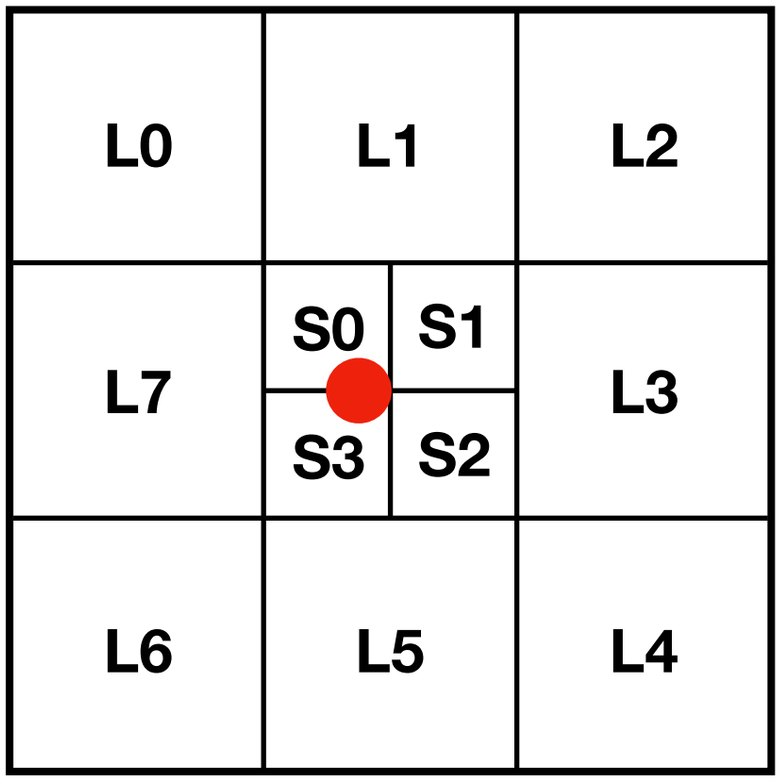


8 large (50x50x500mm^3) CsI crystals
4 small (25x25x500mm^3) CsI crystals

	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	

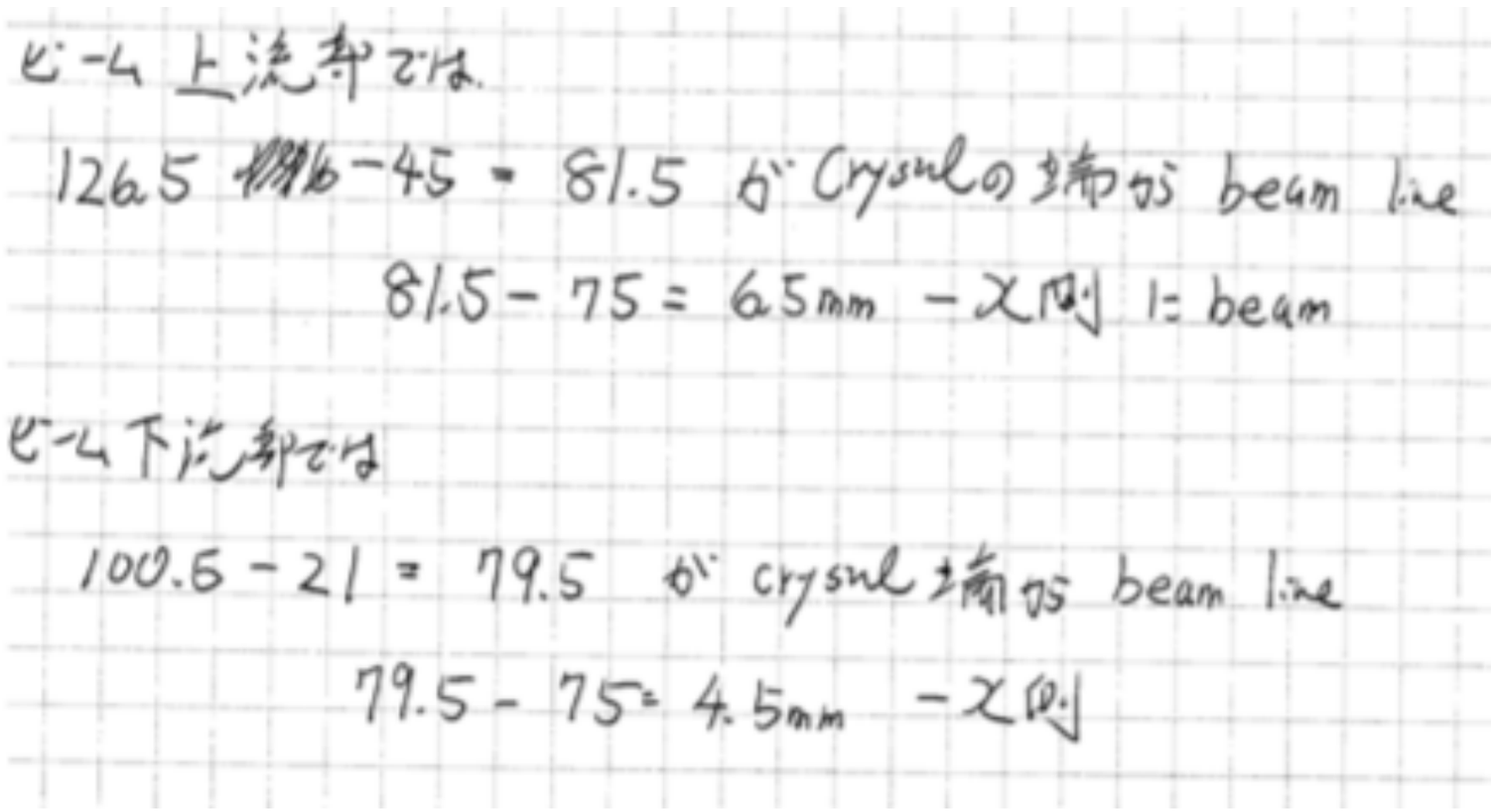
Other informations:
Beam spot size > 10mm

Beam position shift



Large crystals: 50mm x 50mm
Small crystals: 25mm x 25mm

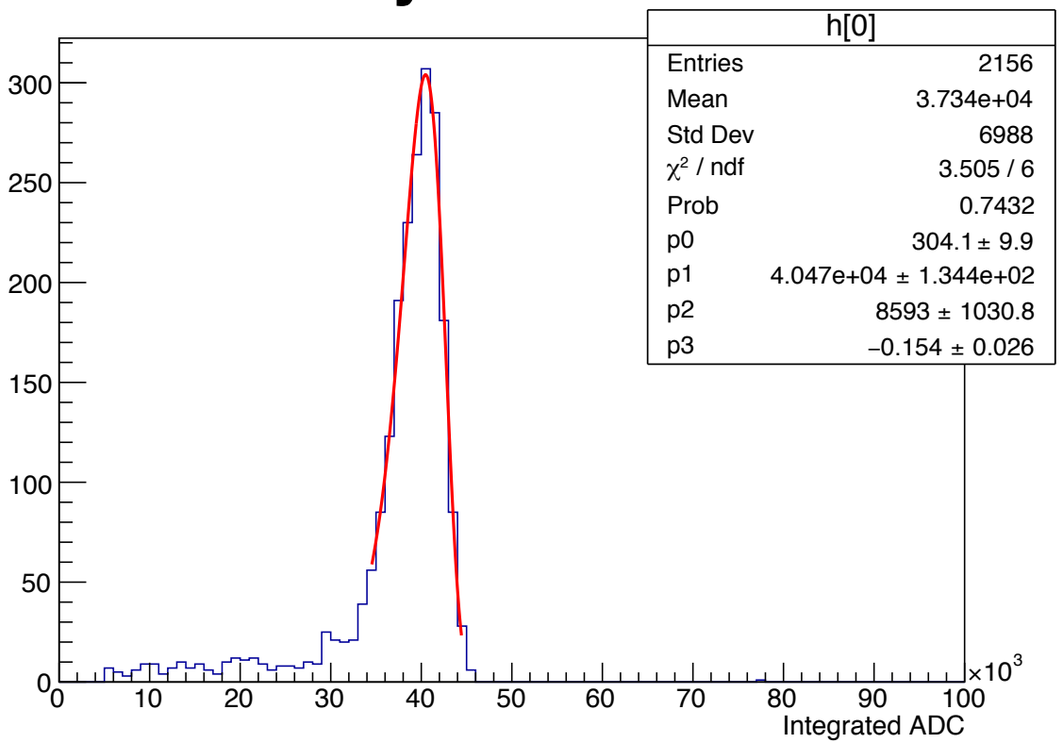
Beam position was deviated 4.5 ~ 6.5 cm
from expected position.



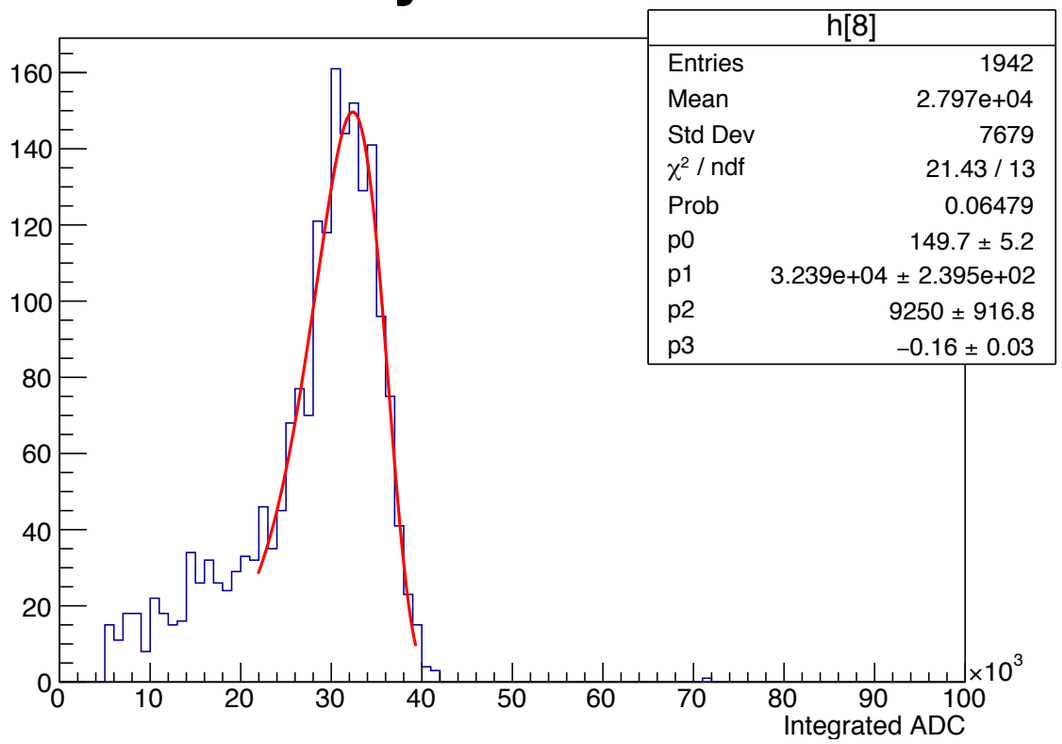
Calibration (w/o MPPC)

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

crystal L0



crystal S0



- Fitted with asymmetric gaussian

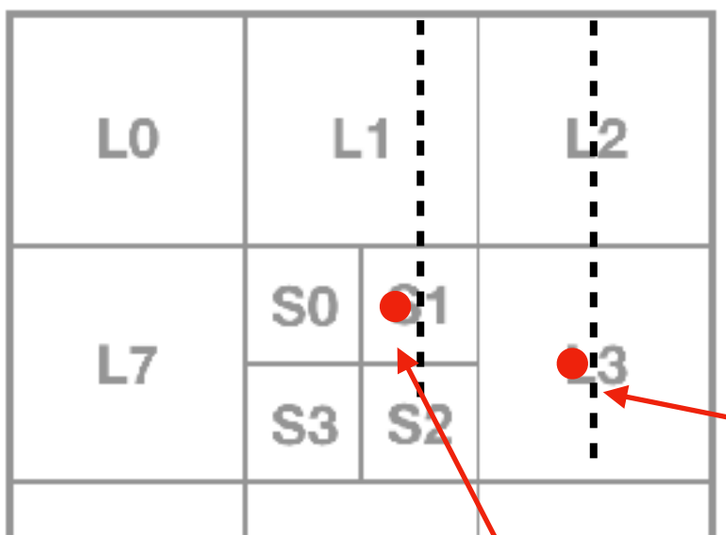
$$G_A(x) = N_0 \exp\left[-\frac{(x-\mu)^2}{2(\sigma_1 x + \sigma_0)^2}\right]$$

Beam

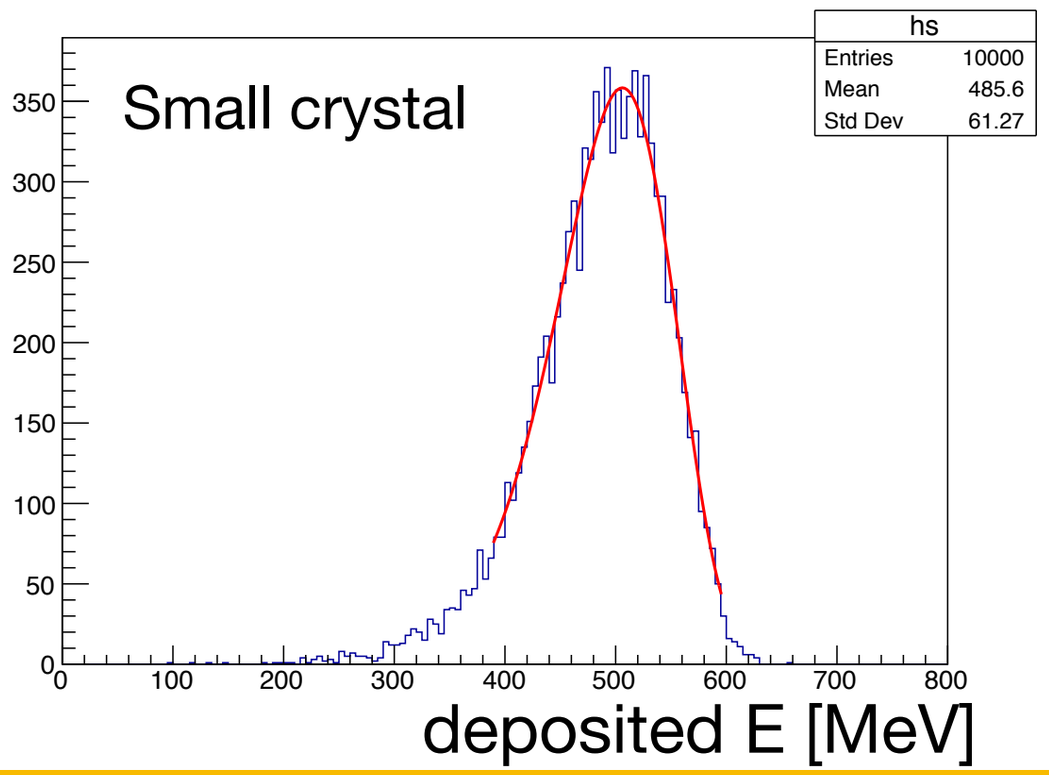
L0	L1		L2
L7	S0	S1	L3
	S3	S2	
L6	L5		L4

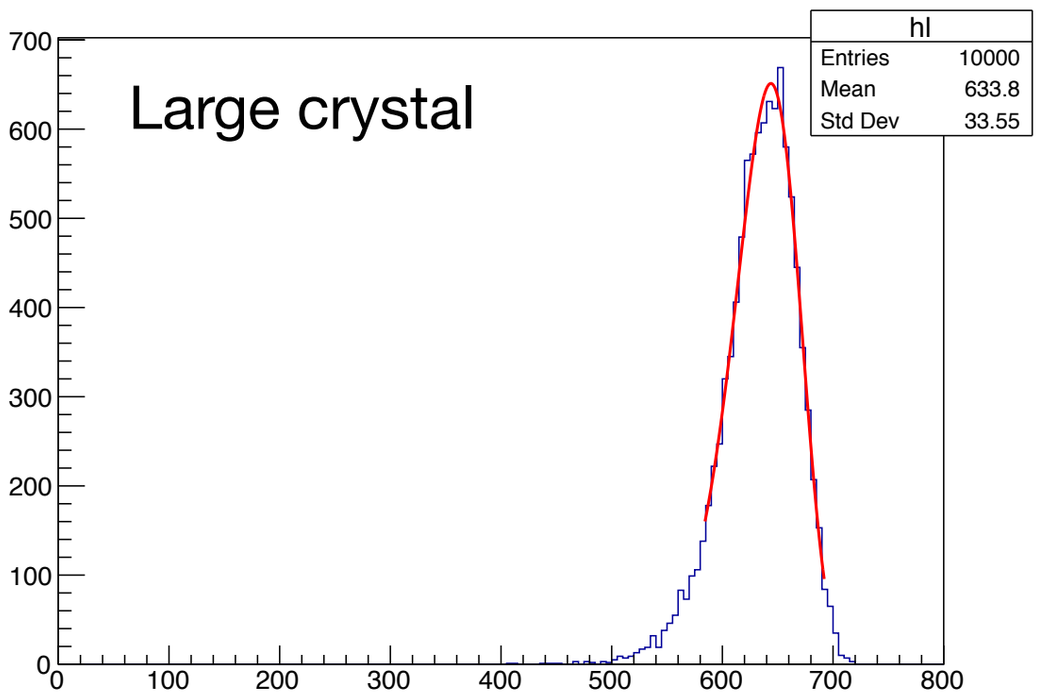
Scale factor (w/o MPPC)

Geant4 simulation



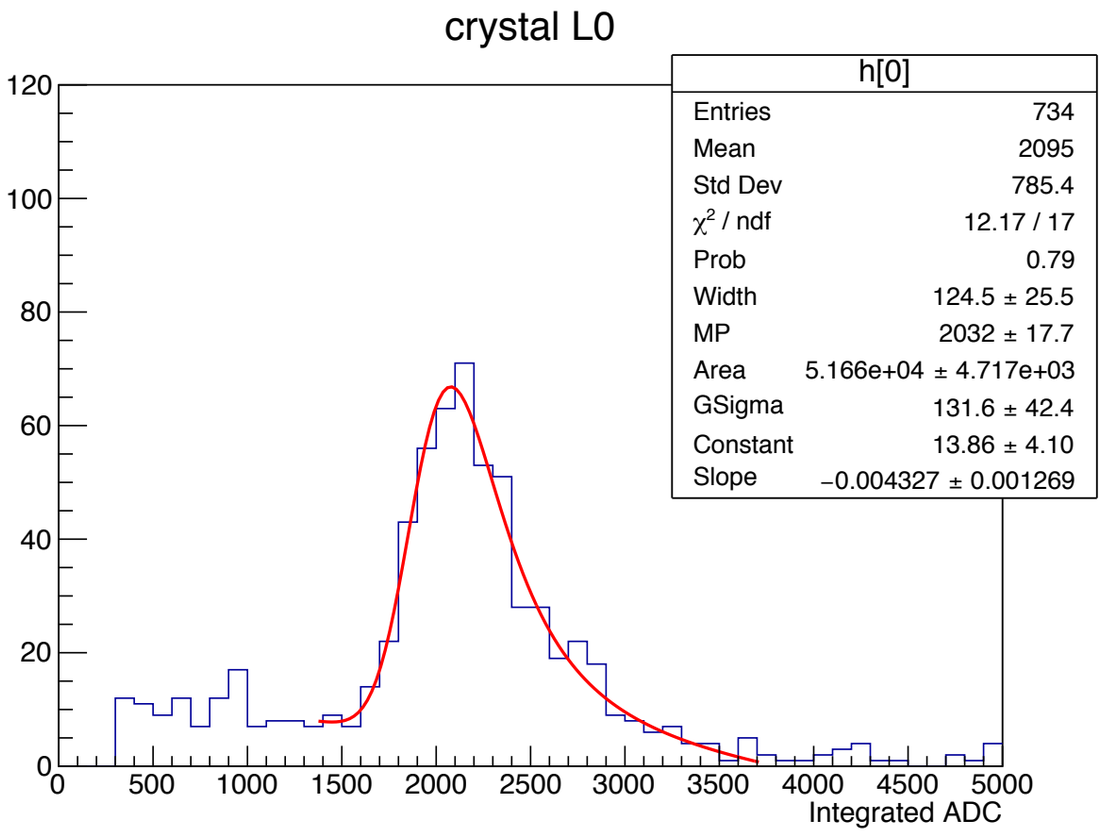
- 800MeV positrons
- x=5mm shifted from center line
- scale factor := MPV (L) / MPV (S)

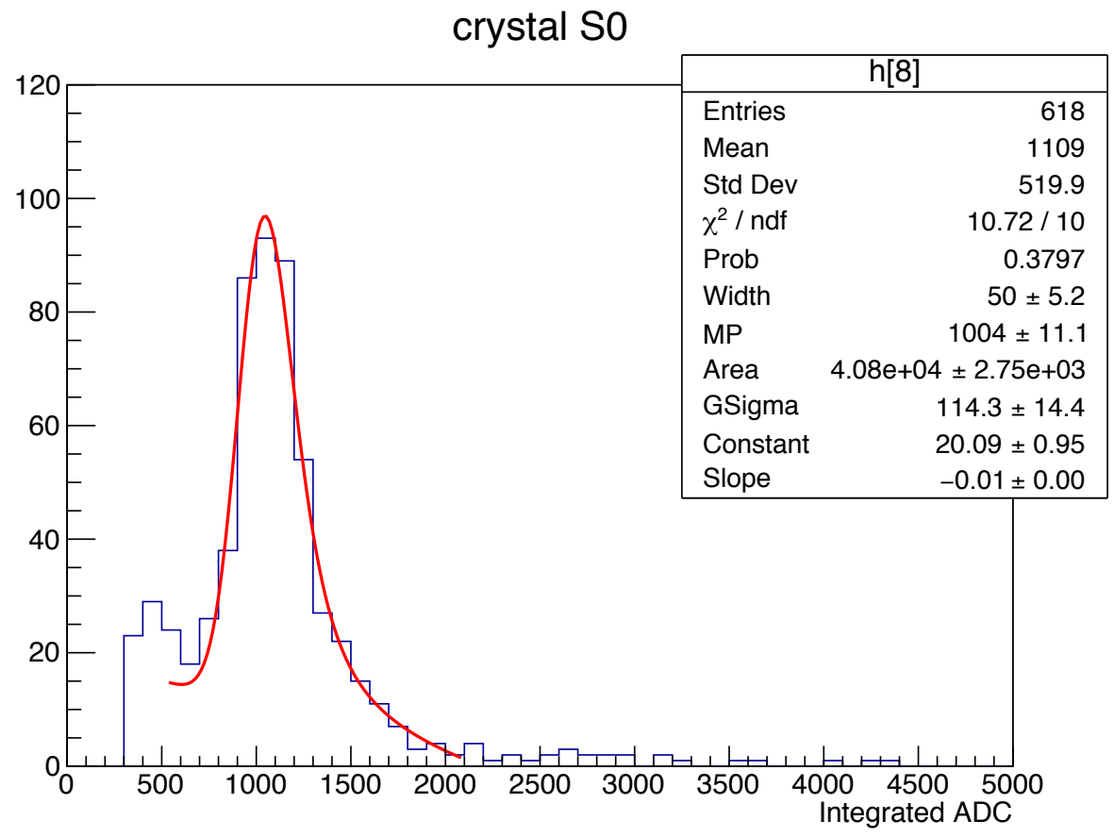




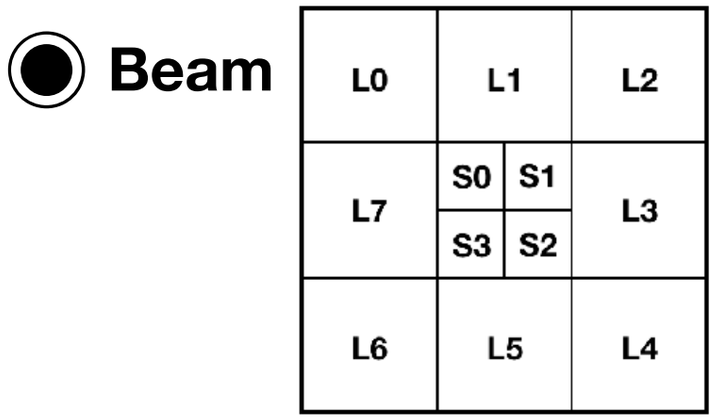
Calibration (w/ MPPC)

Cosmic rays at 40mm from the upstream surface of CsI



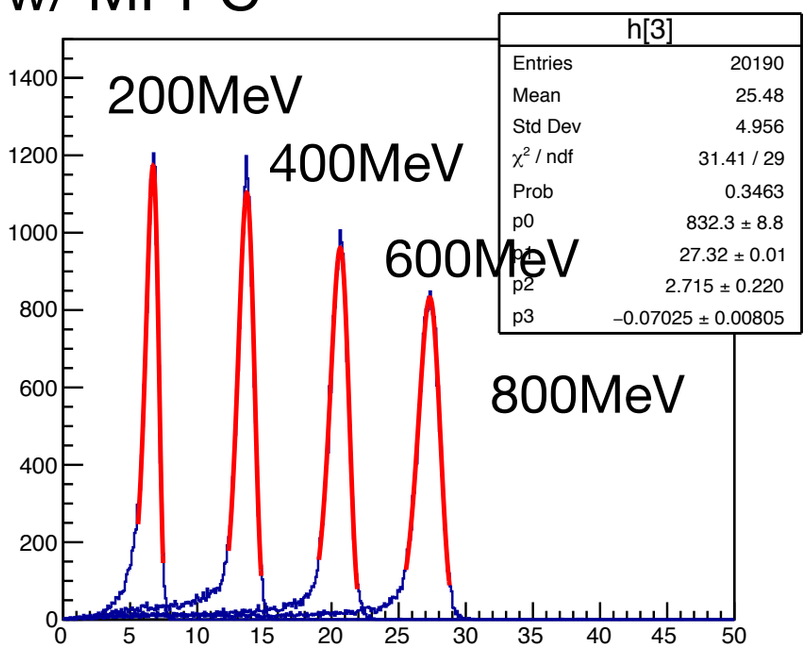


- Fitting function: (landau*gaussian) + pol1
- MPV of landau is used for calibration
- Scale factor between large and small crystal = 2.0

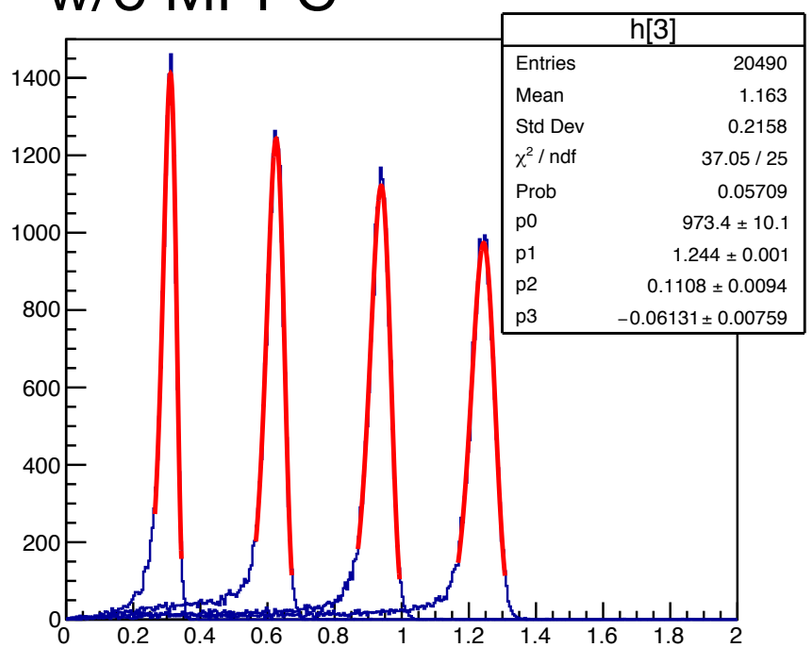


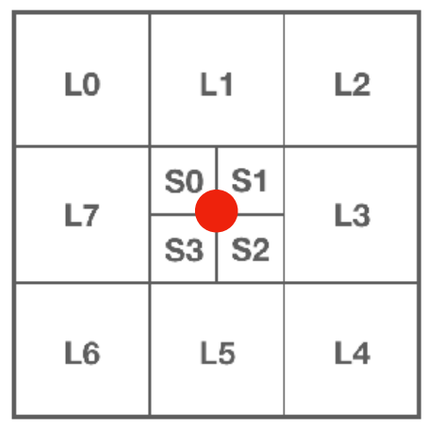
Energy resolution of PMT

w/ MPPC

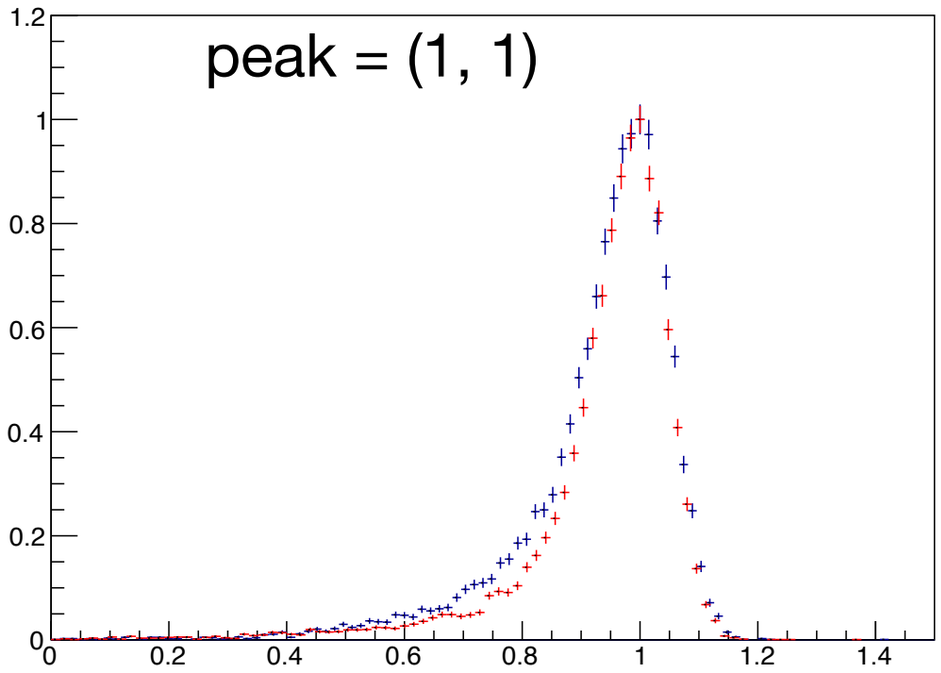


w/o MPPC





comparison @200MeV

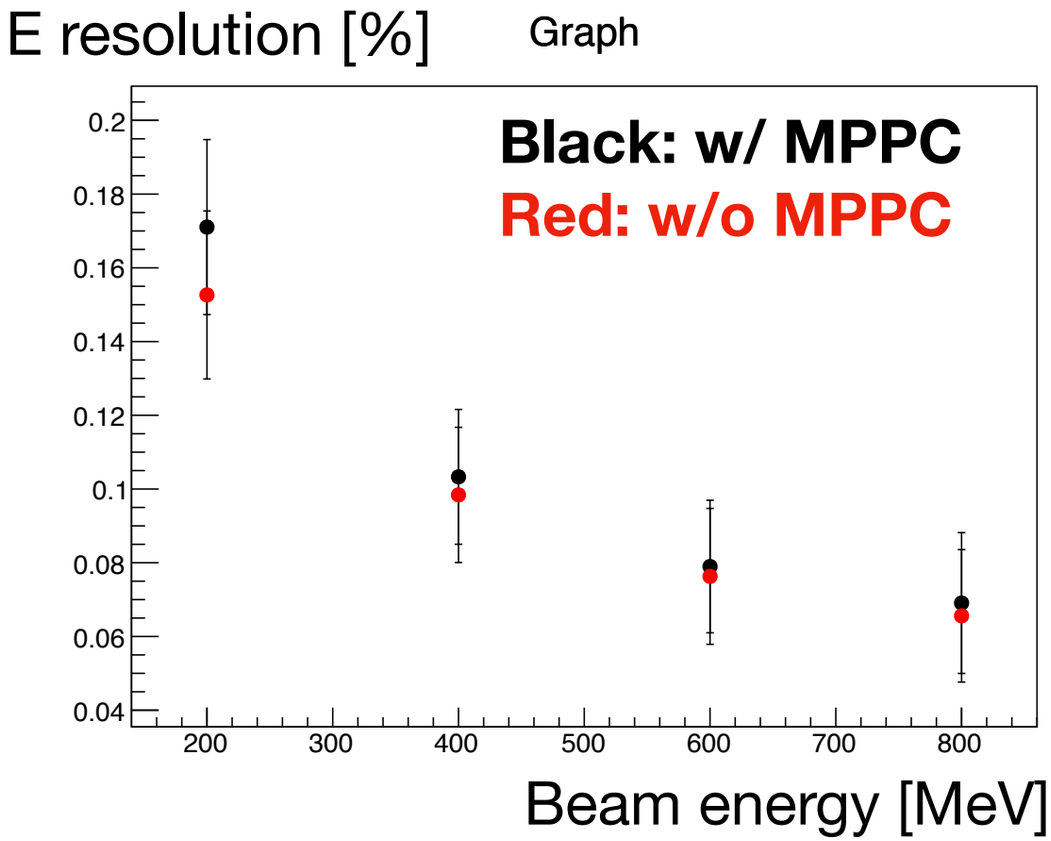


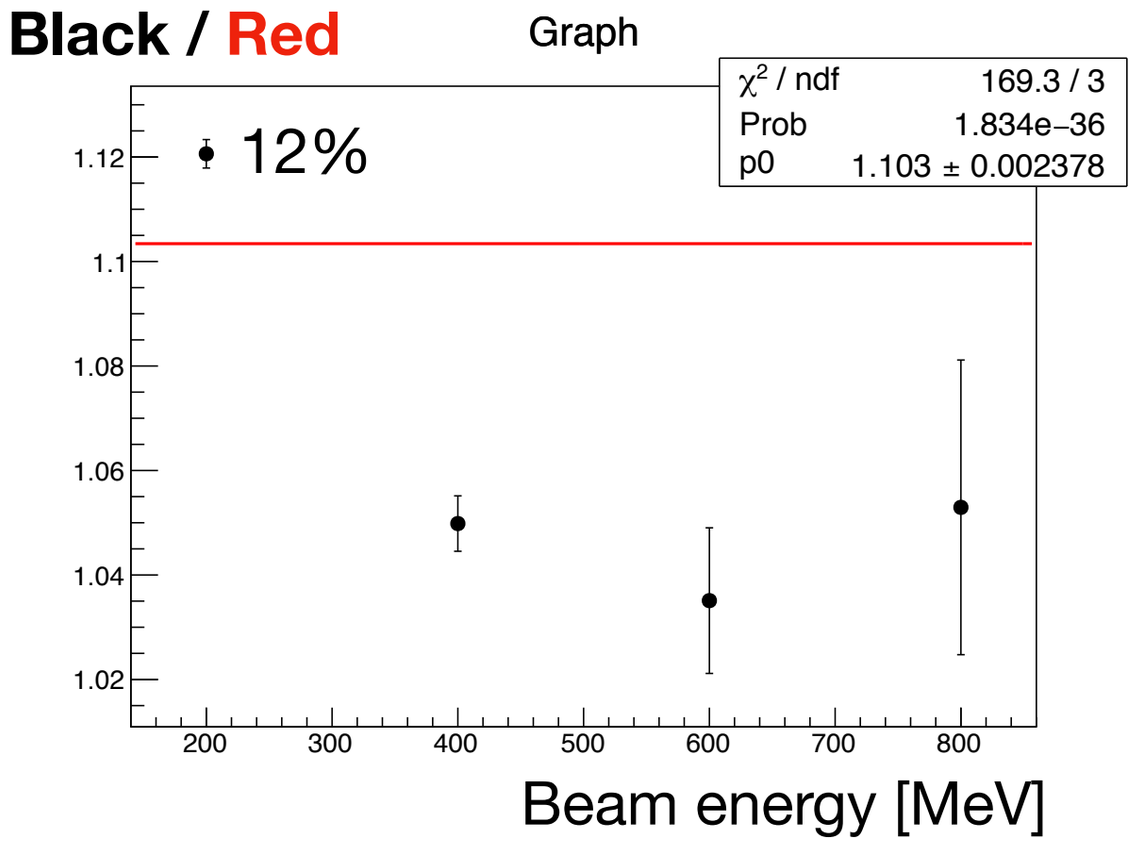
Blue: w/ MPPC
Red: w/o MPPC

w/ MPPC is wider than w/o.

Energy resolution of PMT

Energy resolution := FWHM / MPV





Conclusion / Prospects

Conclusion

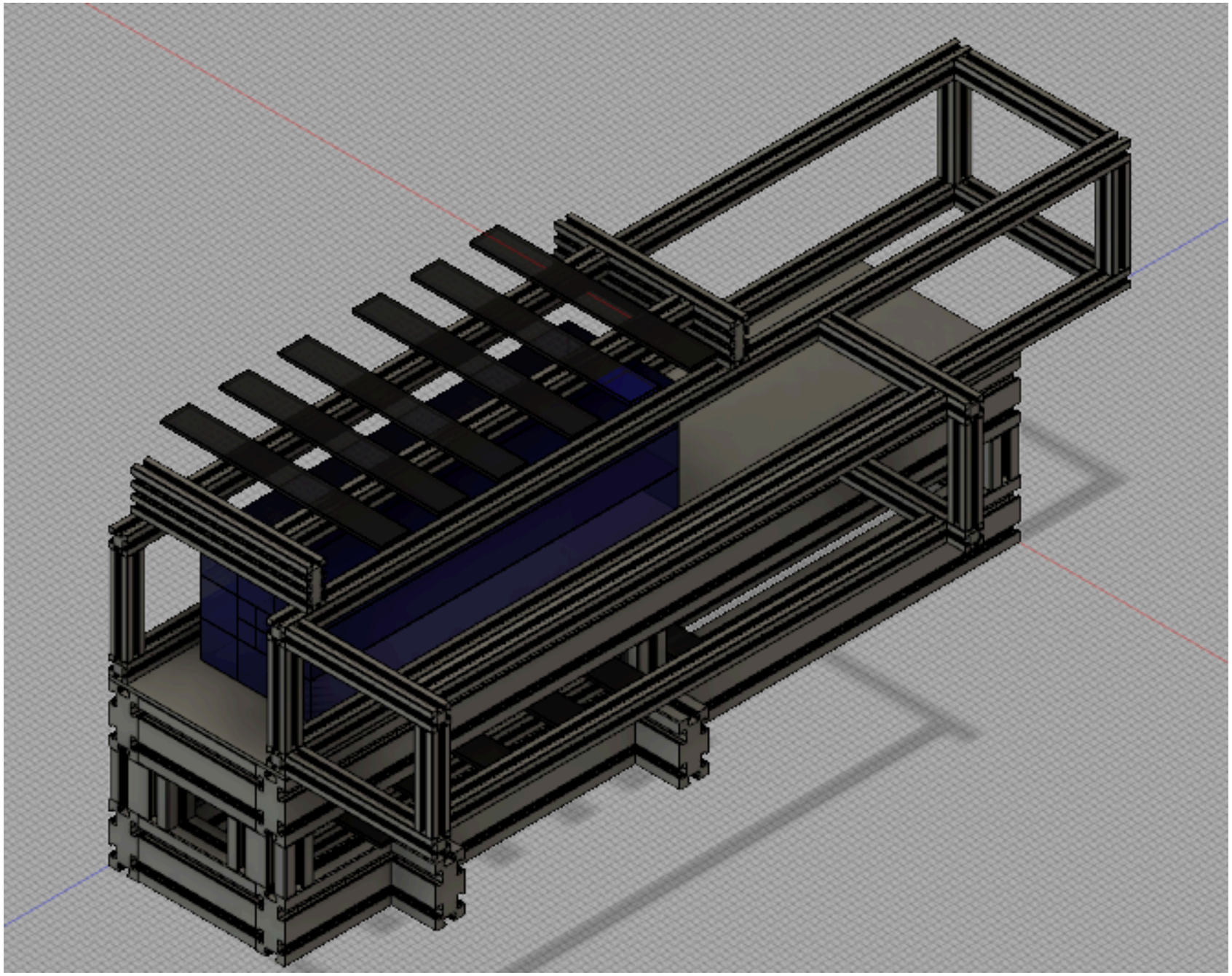
- We tested new CsI readout system for the calorimeter upgrade.
- I checked how the MPPCs affect energy resolution of PMTs.
  - Energy resolution got worse (max: 12% @200MeV)

Prospects

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

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

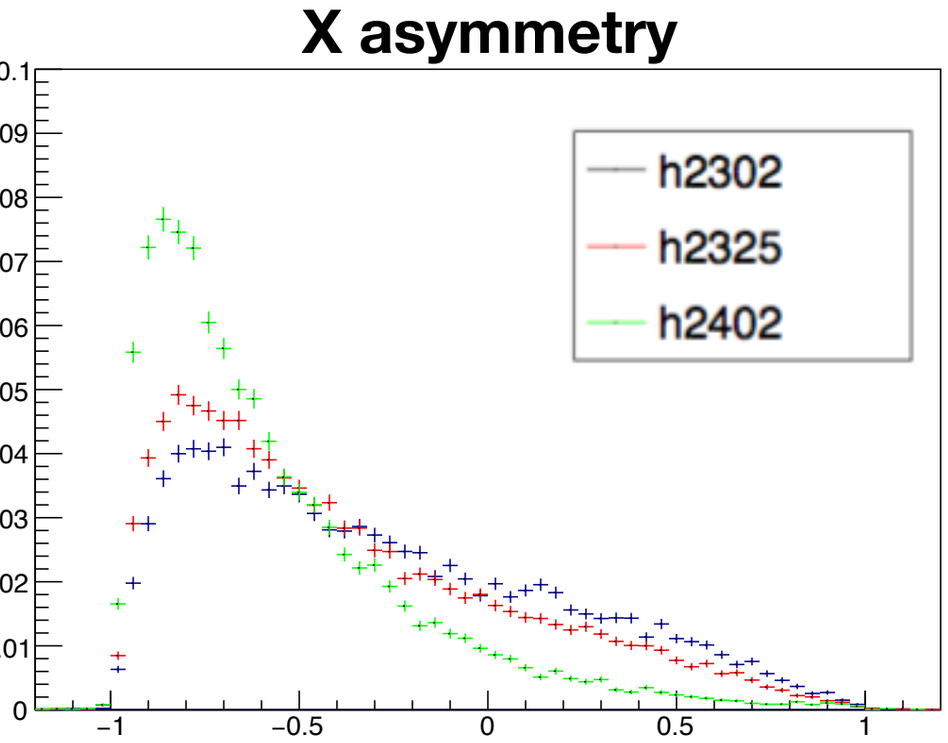
$$MPV = \mu$$

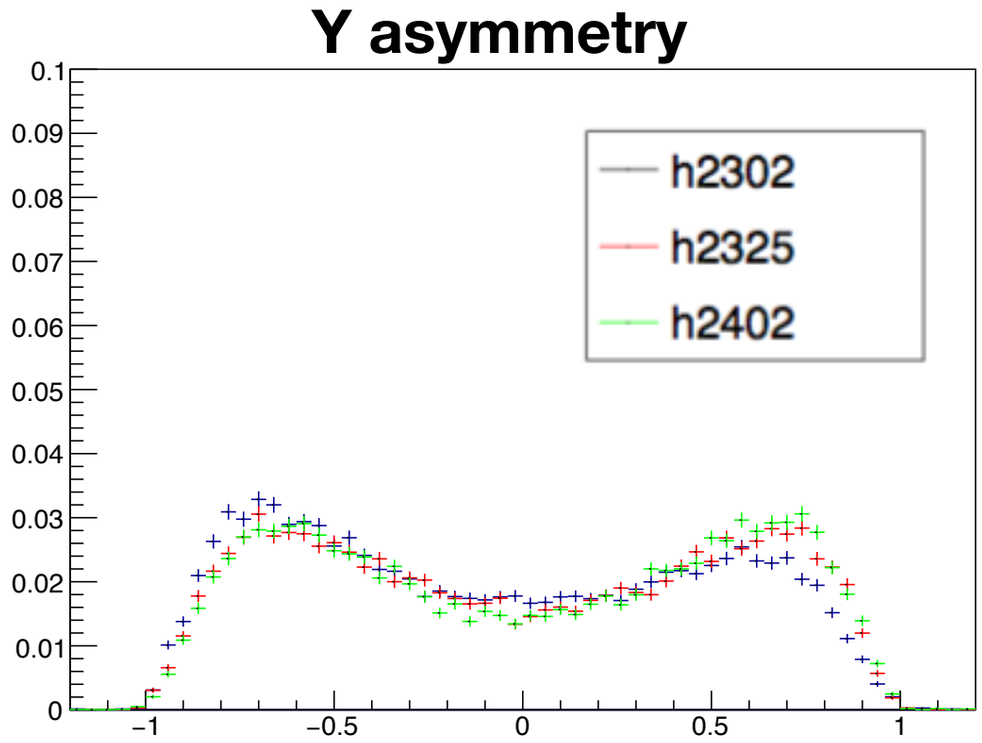
$$\text{error} = \delta\mu$$

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

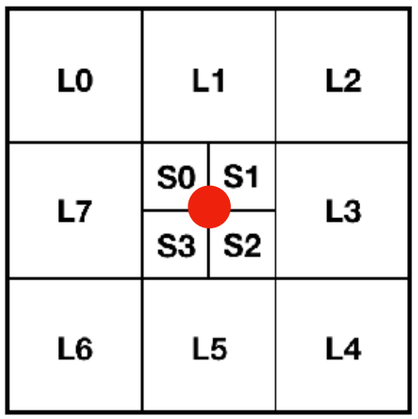
$$\text{error} = \sqrt{\frac{\xi}{1-(\xi\sigma_1/2)^2}[(\sigma_1\delta\mu)^2 + (\delta\sigma_0)^2] + \left(\frac{\xi}{2}\right)^2 \left[\frac{\mu - \xi\sigma_0/2}{(1+\xi\sigma_1/2)^2} - \frac{\mu + \xi\sigma_0/2}{(1-\xi\sigma_1/2)^2}\right](\delta\sigma_1)^2}$$

Asymmetry of energy deposition





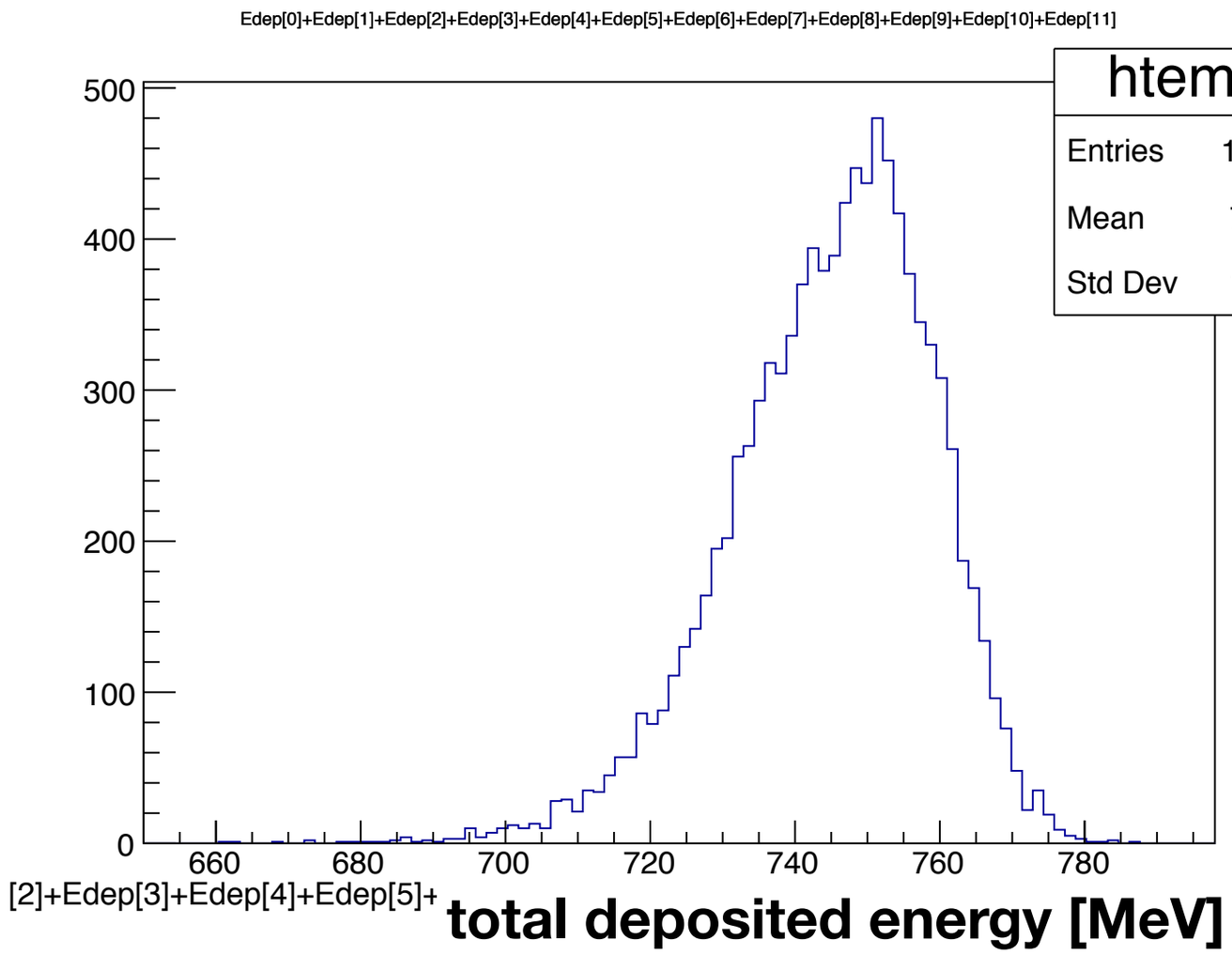
Blue -> (Rotated run) -> Red -> (Backward run) -> Green

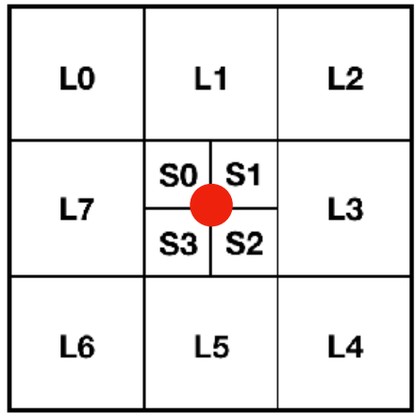


X asymmetry: S1 - S0
Y asymmetry: S0 - S3

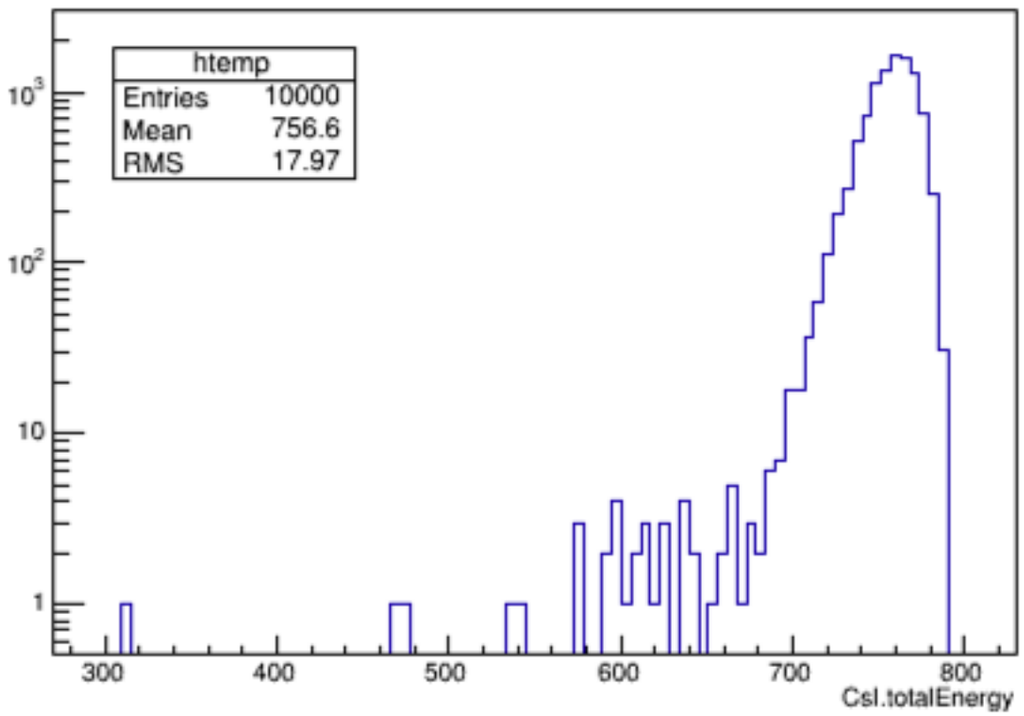
Total energy deposition (Geant)

Geant4 simulation.
Incident beam energy 800 MeV





MC by gsim4



Low energy tail does not exist…