Performance of New Sampling Calorimeter in the KOTO Experiment

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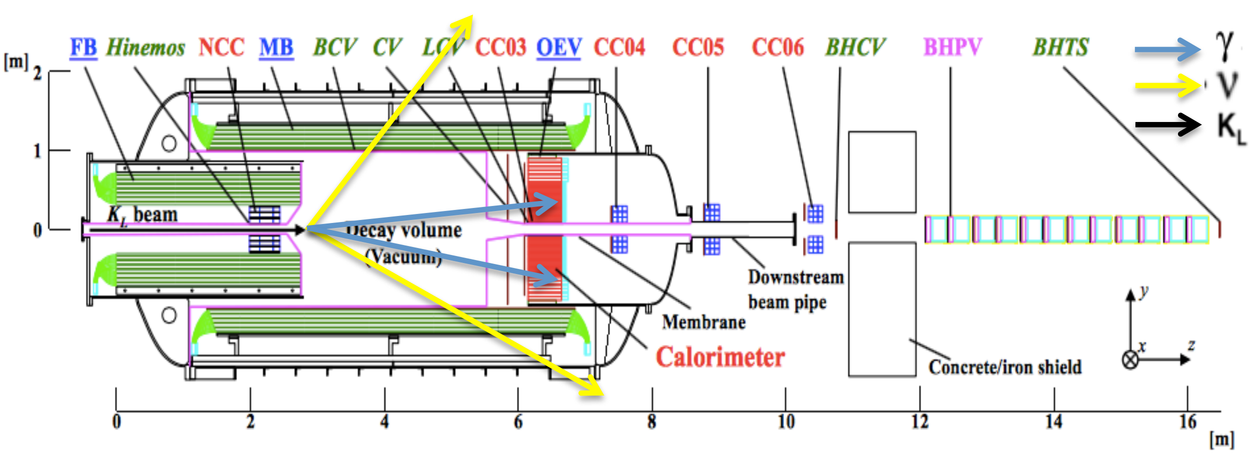
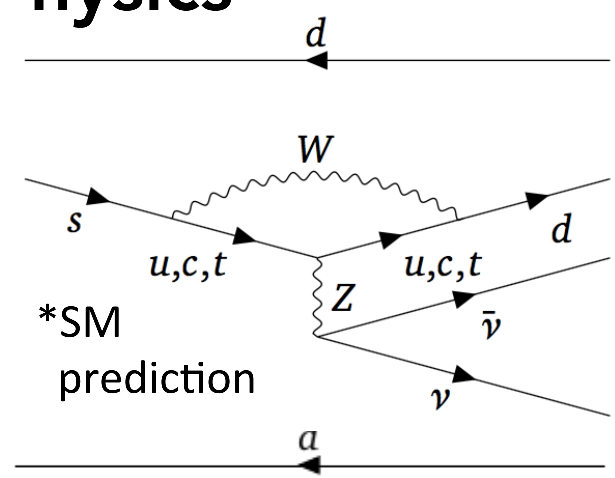
for the KOTO Collaboration 2017 KPS Fall Meeting

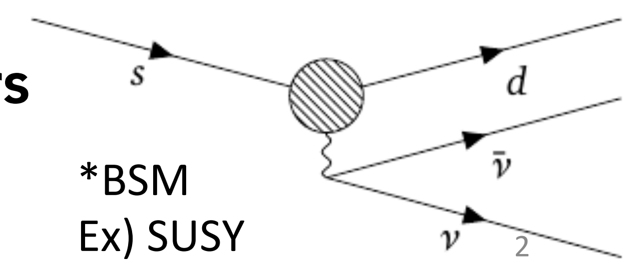
J-PARC KOTO Experiment

- $Br(K_L \rightarrow \pi^0 \nu\bar{\nu}) = (2.8 \pm 0.4) \times 10^{-11}$ predicted by SM
- FCNC process in Standard model (Suppressed)
- Clean mode to explore the New Physics

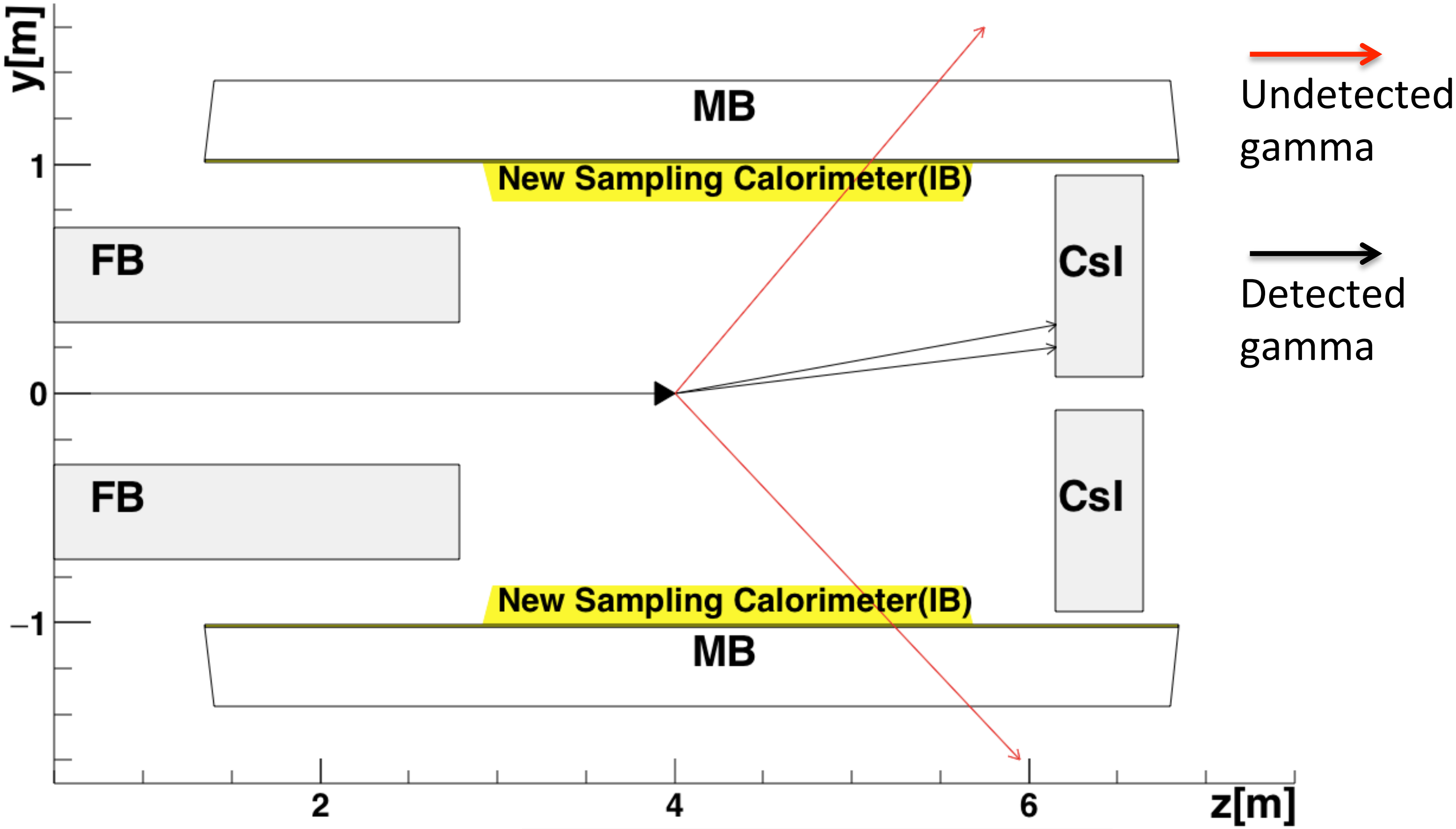


CsI Calorimeter and Hermetic Veto Counters



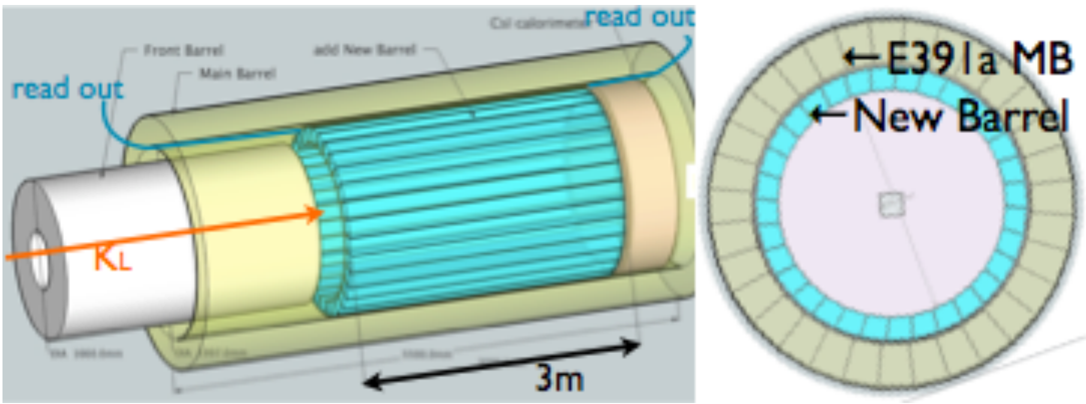


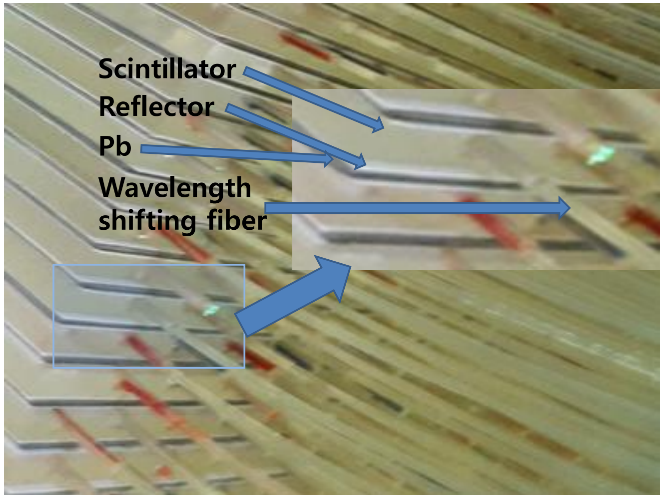
New Pb/Scint Calorimeter



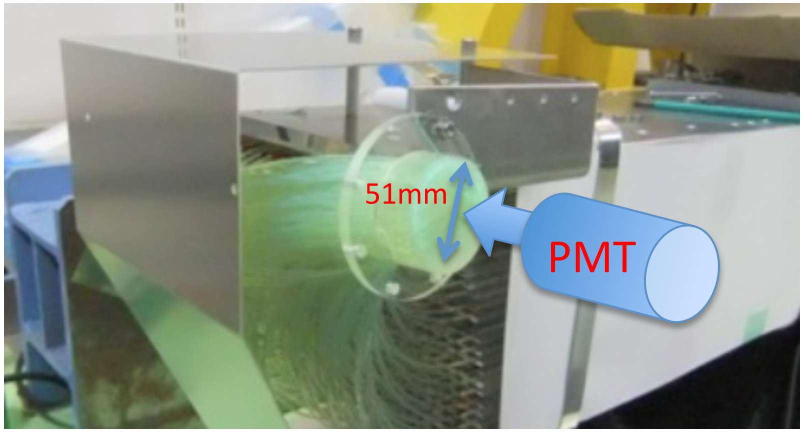
- Main source of the background is detection inefficiency of the sampling calorimeter(MB)
- New sampling calorimeter will reduce the background events as factor of 6.4

Inner Barrel

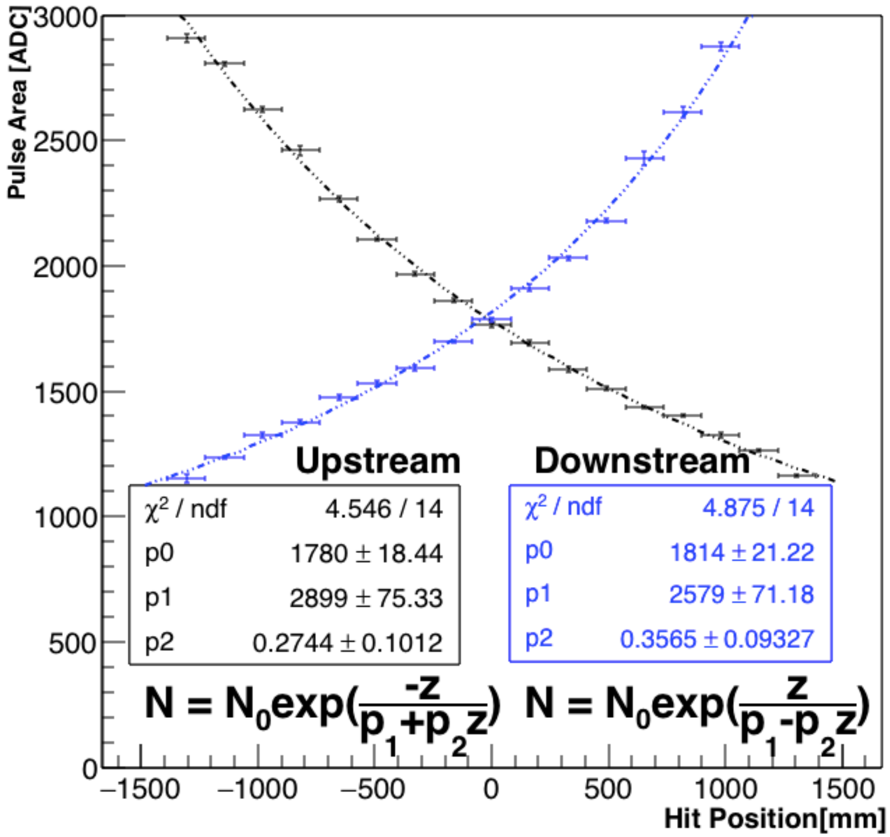


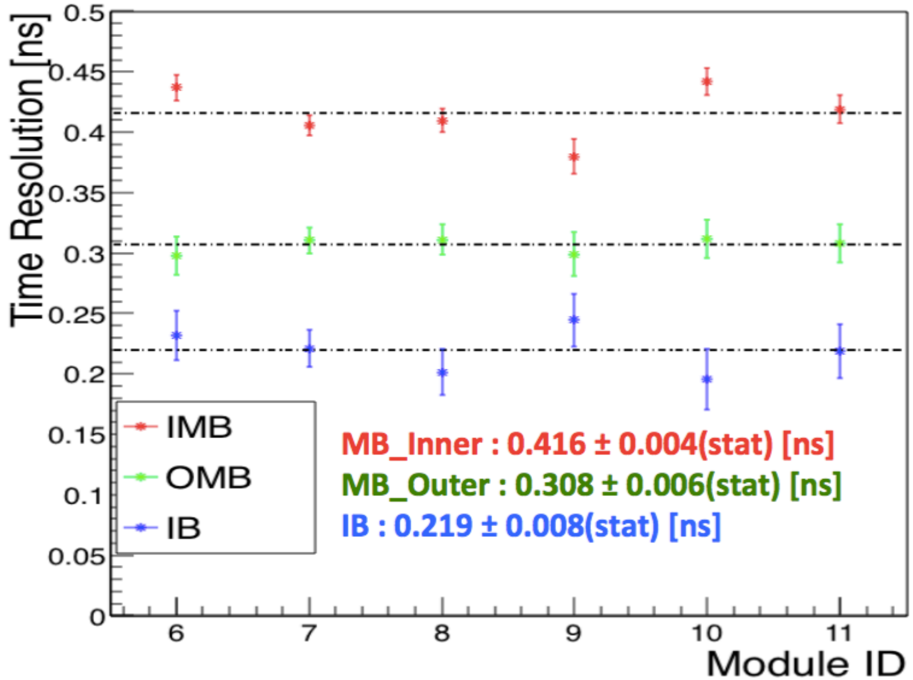


- 25 layers of 1-mm thick Pb sheet and 5-mm thick plastic scintillator
- Add $5X_0$ to $13.5X_0$



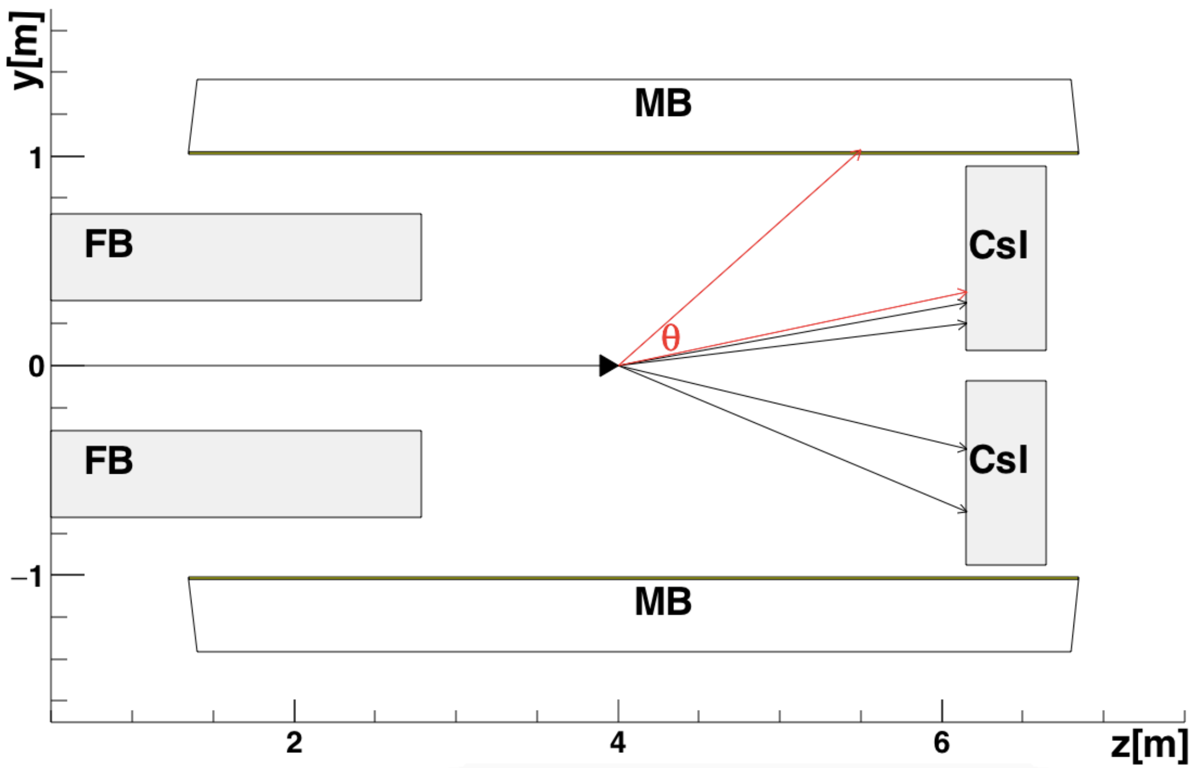
Cosmic Ray Test





- Attenuation curves fitted by two terms.
  - Correction of attenuation effect.
- Superior timing resolution of IB obtained by cosmic-ray.

$K_L \to \pi^0\pi^0\pi^0$ Reconstruction Using 5γ on CsI and 1γ on Barrel

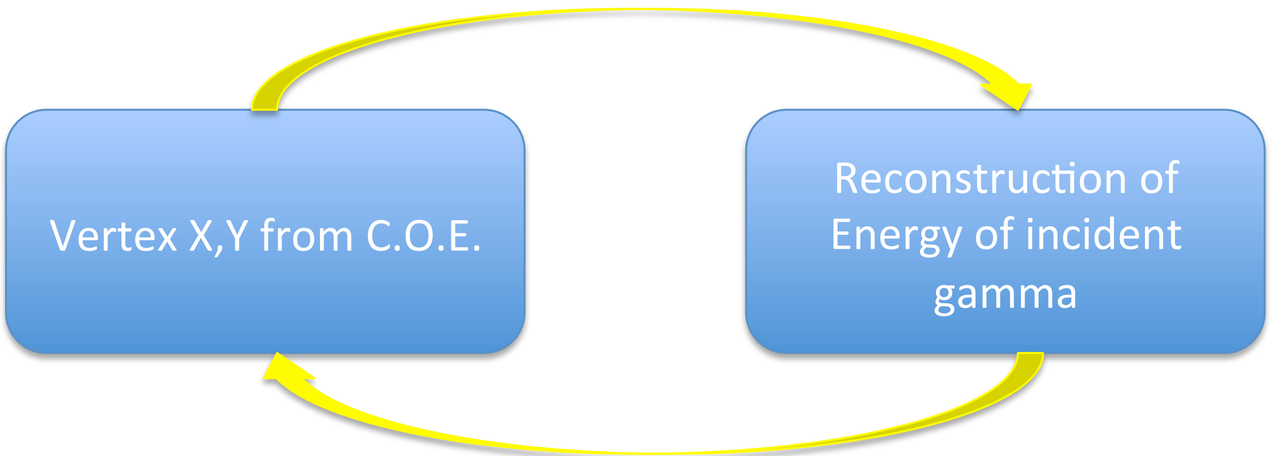


$$E_6 = \frac{M_\pi^2}{2E_5(1-\cos\theta)}$$

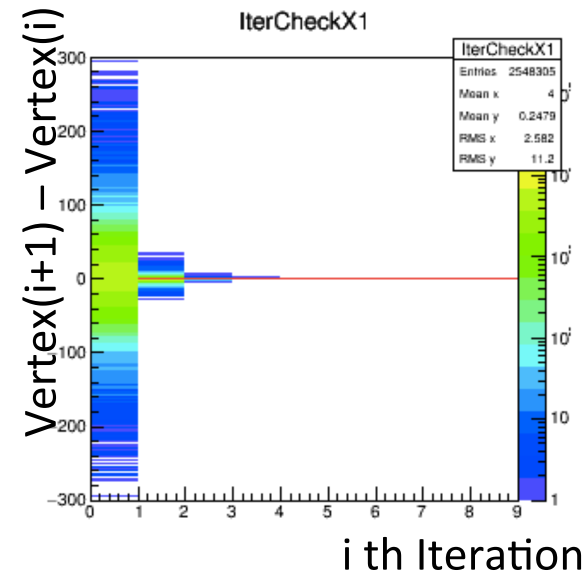
$$M_{K_L}^2 = \left(\sum_{i=1}^{6} E_i\right)^2 - \left(\sum_{i=1}^{6} \vec{p}_i\right)^2$$

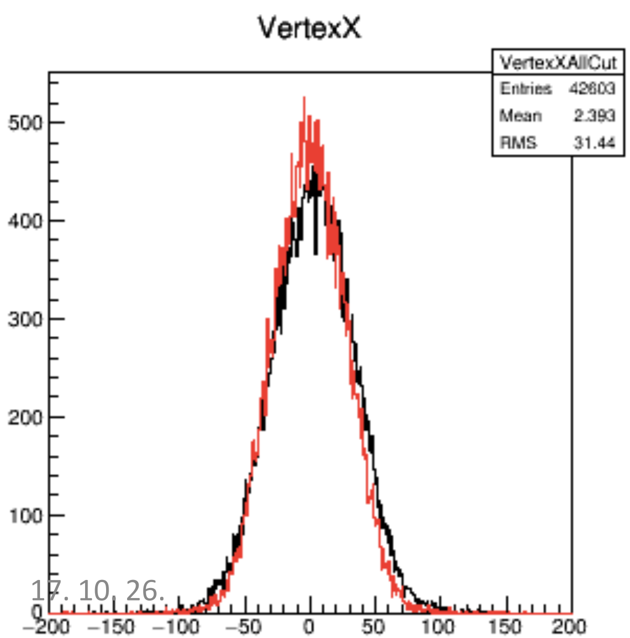
- $K_L \to \pi^0\pi^0\pi^0$ decay samples with 5γs on CsI and 1γ on Barrel
- Reconstruction of 2π^0 from 4γs on CsI
- 1γ Reconstruction from hit information of Barrel (timing and Module ID)
- Reconstruction of the third π^0 from 1γ on CsI and 1γ on Barrel

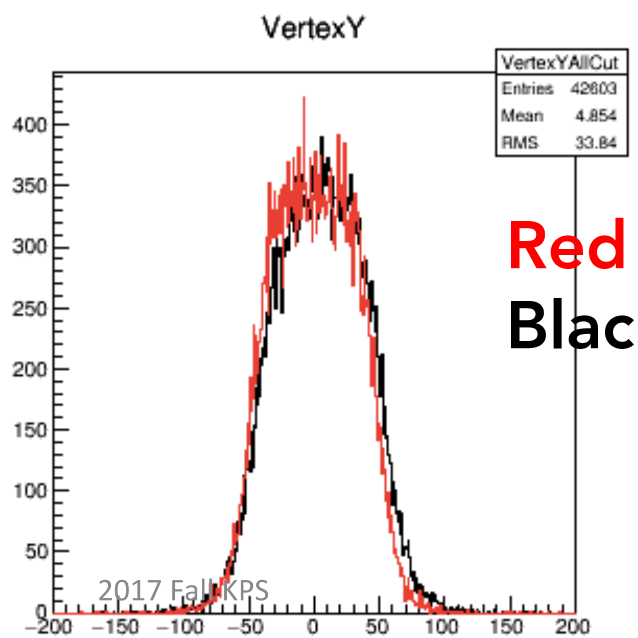
Reconstruction of Vertex X, Y



Iteration (10 times)



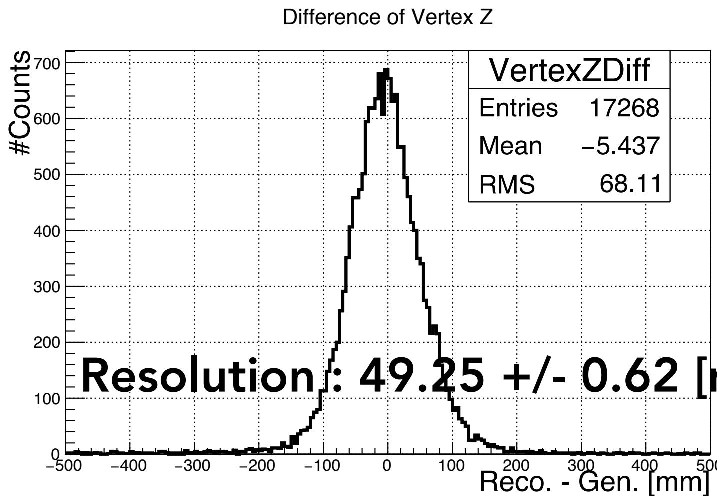




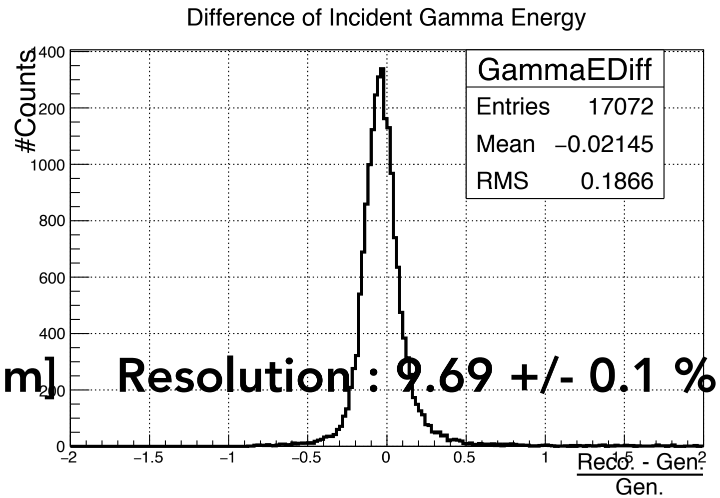
Red : M.C.

Black : Data(Run62)

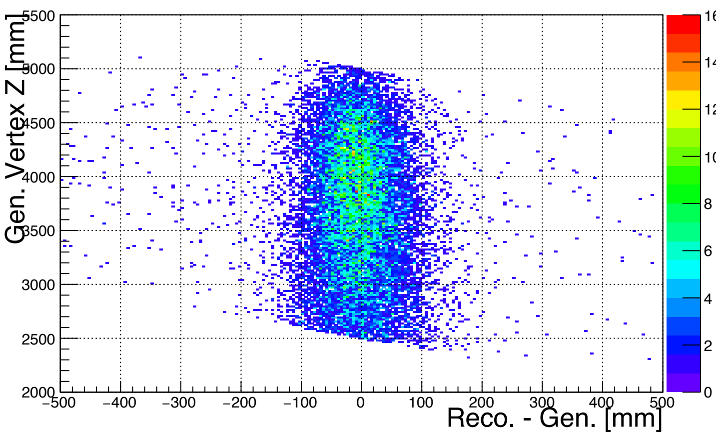
Reconstruction Quality

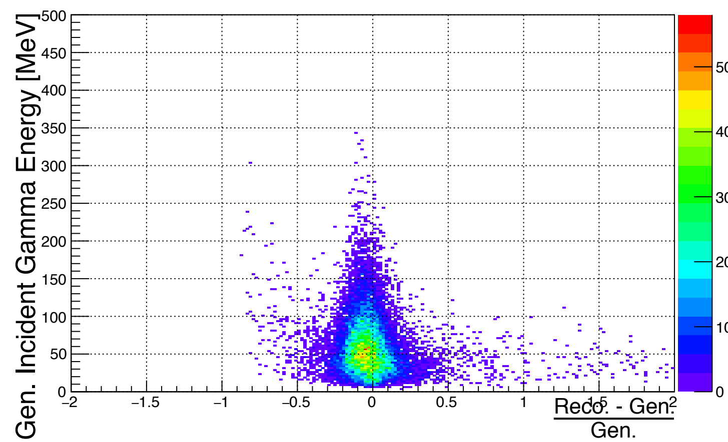


Resolution : 49.25 +/- 0.62 [mm]



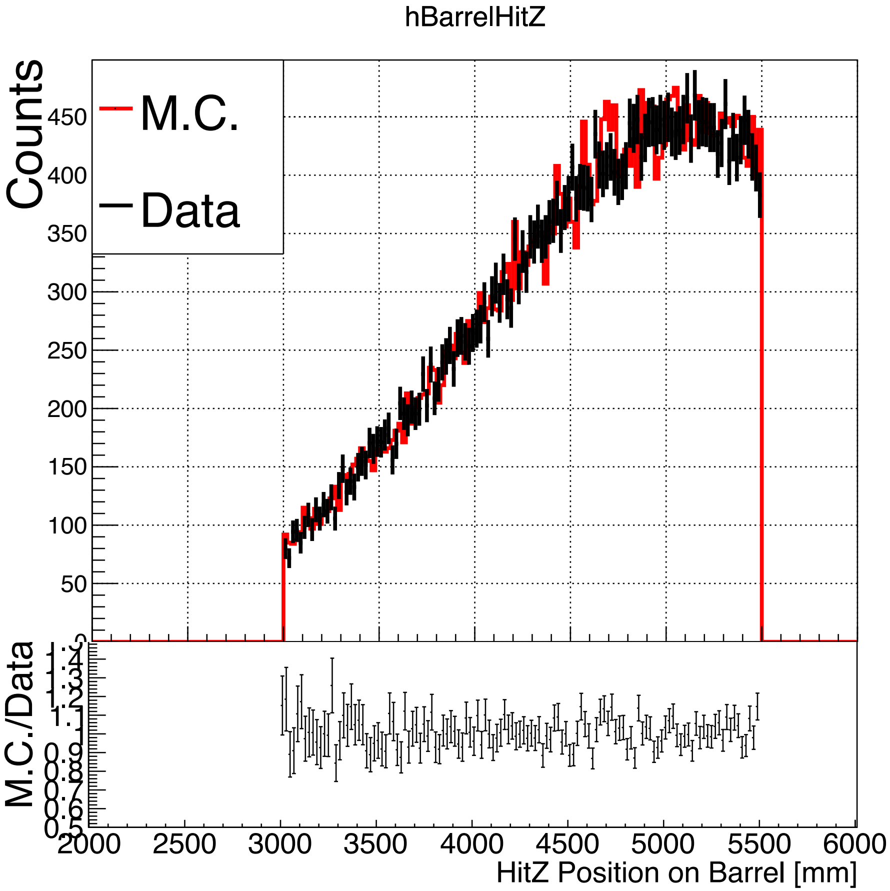
Resolution : 9.69 +/- 0.1 %

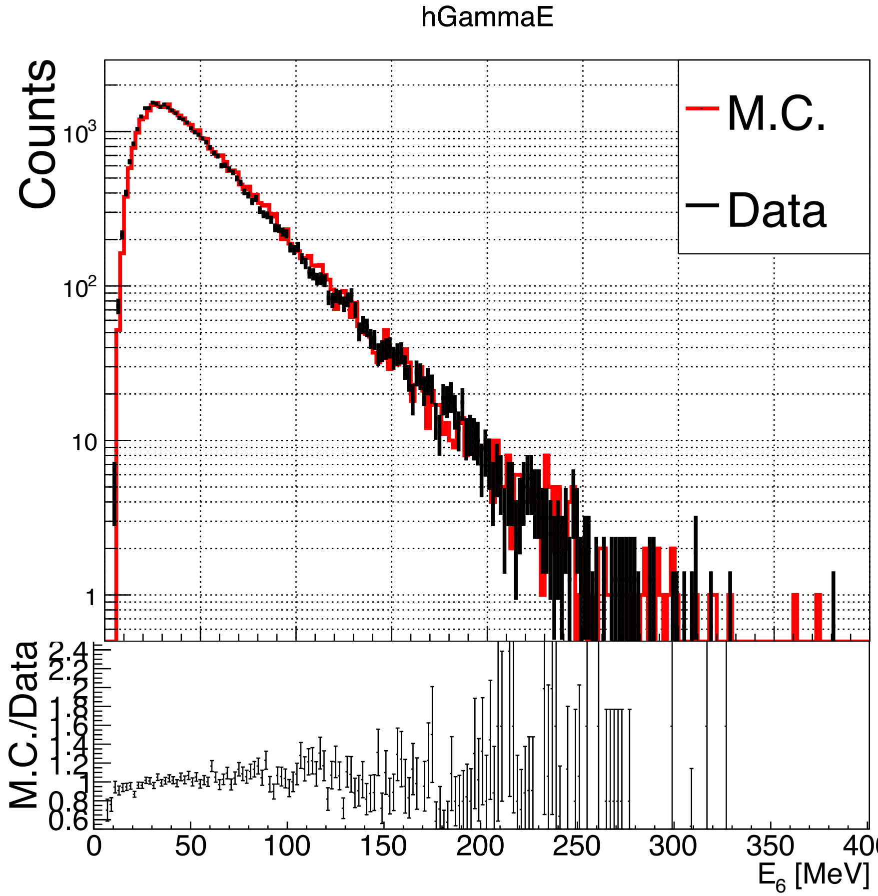




$K_L \rightarrow \pi^0\pi^0\pi^0$ Monte Carlo Generation

Response Comparison





- **Good agreement between M.C. and Data**

Reconstruction Quality

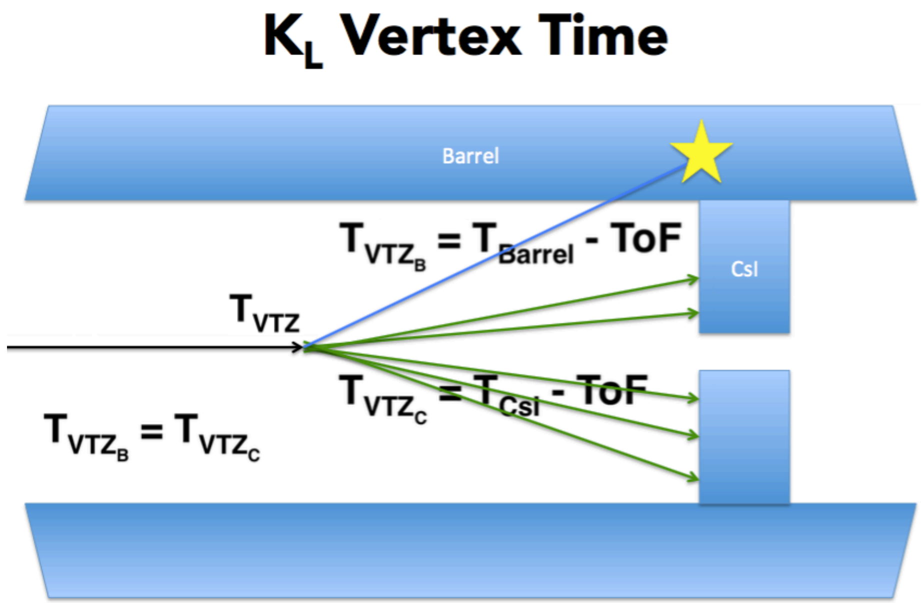
Background	Probability
Dalitz Decay of pion	5.25×10^{-6}
Ineff. of other Det.	1.87×10^{-3}
Fusion	5.25×10^{-6}

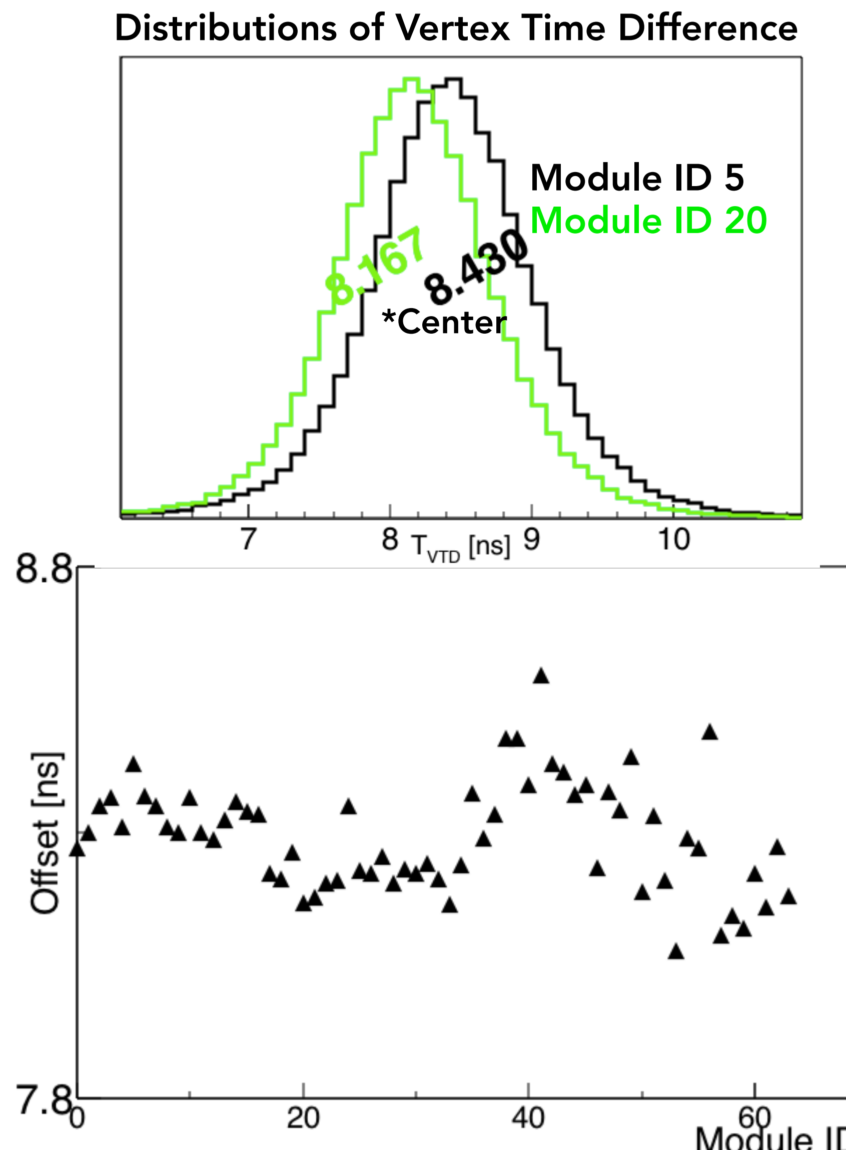
→

Detector	Probability
CsI	1.04×10^{-3}
FB	5.70×10^{-4}
Beam Pipe	8.14×10^{-5}
BHPV	1.71×10^{-4}

- Mis-reconstruction due to inefficiency of other detectors.
- Gamma selection with 99.8% accuracy.

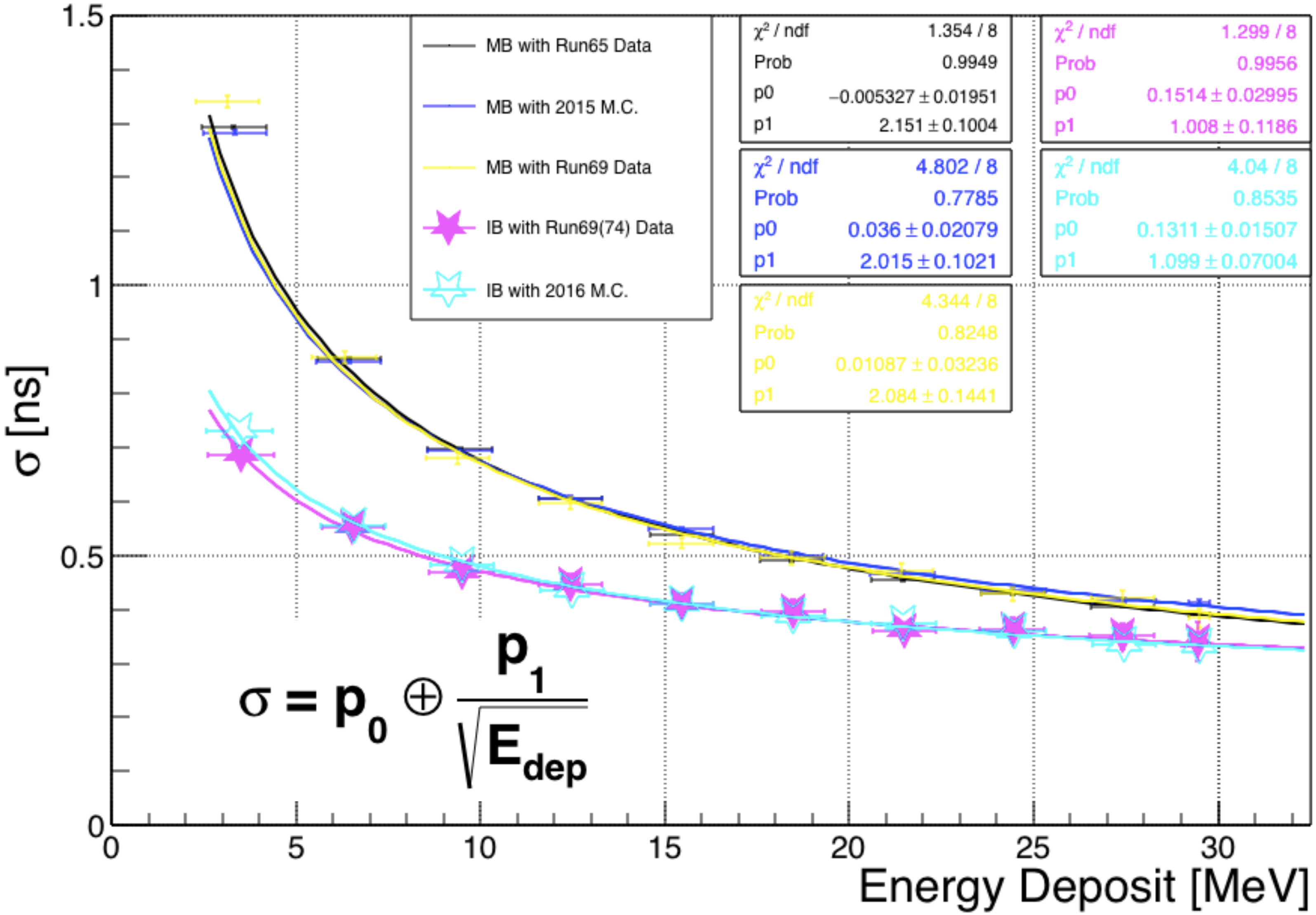
Vertex Time Difference





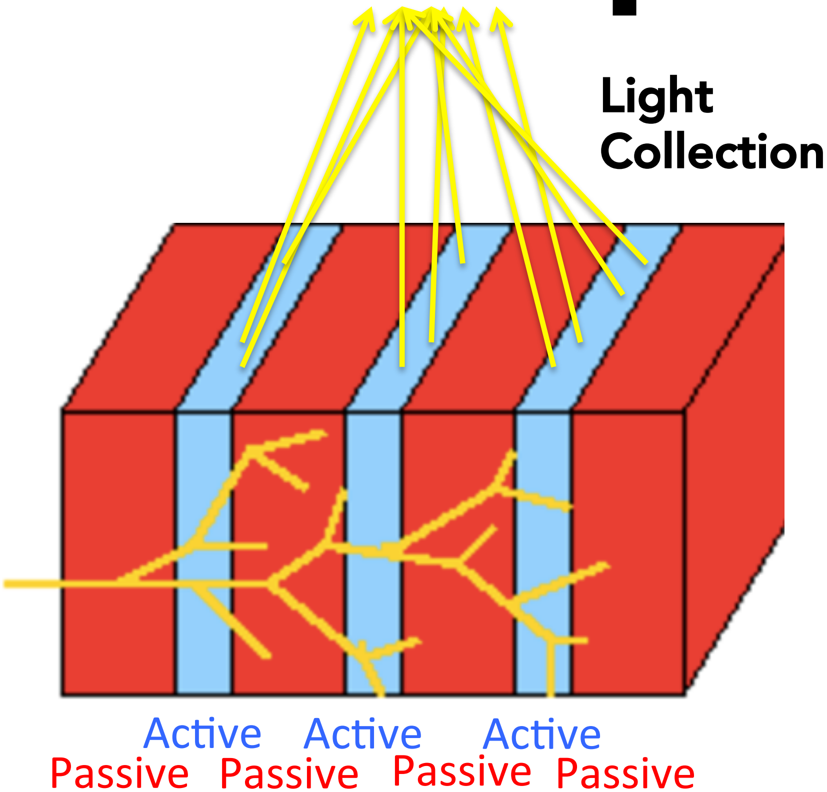
- Vertex Time Reconstruction with
  - Barrel
  - CsI Calorimeter
- Vertex Tine Difference
  - Invariant

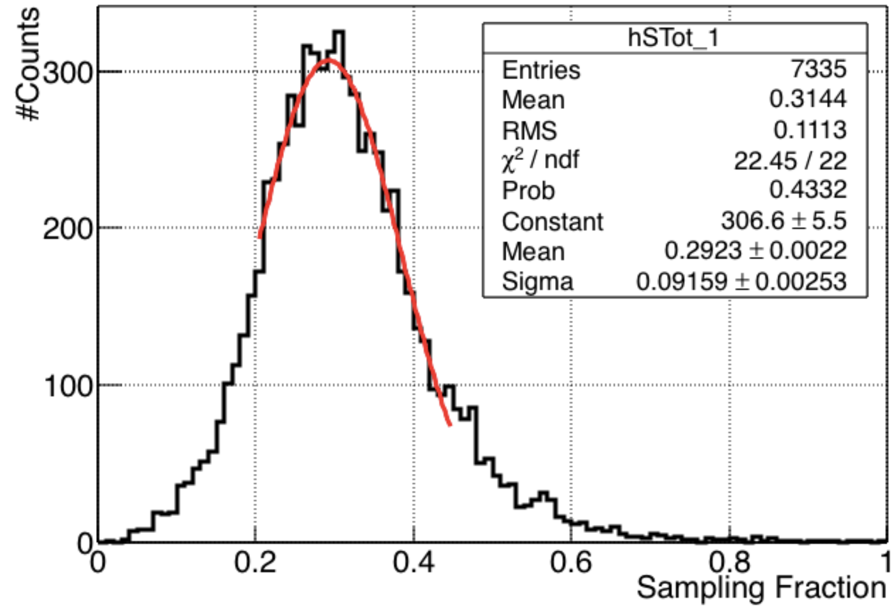
Timing Resolution from K_L signal

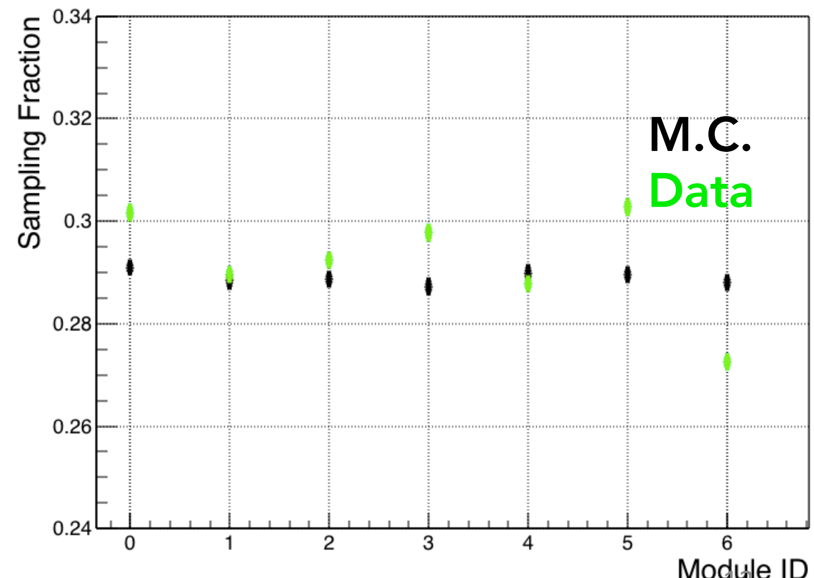


$$\sigma = p_0 \oplus \frac{p_1}{\sqrt{E_{dep}}}$$

Sampling Fraction

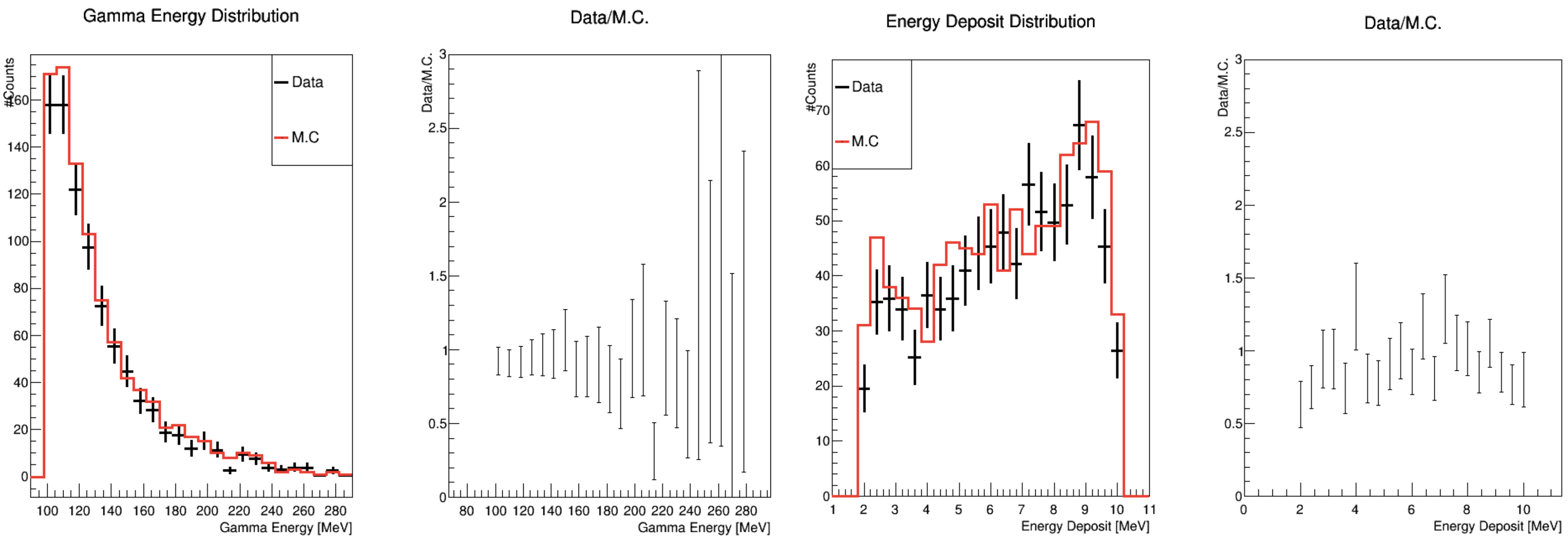






- Sampling Calorimeter collects signal only from Active
  - Plastic scintillator
- Passive induces interaction with high Z number
  - Lead plate

Data/M.C. @ Low S.F.



- Low sampling event selection
  - Gamma Energy > 100 MeV & Deposited Energy < 10 MeV
- Even if in extreme region, agreement between M.C. and Data is shown.

Summary

- Additional sampling calorimeter to improve background rejection.
  - Installed on April. 2016.
  - $5X_0$ more and better timing resolution
- Calibration method for the sampling calorimeter was developed from $K_L \to \pi^0\pi^0\pi^0$ reconstruction.
  - Gamma selection entering sampling calorimeter with 99.8% accuracy.
  - Good performance to align origin of timing of individual modules
  - Timing resolution as a function of deposited energy
  - Detailed study of detector response and good agreement between M.C. and data.