Performance of New Sampling Calorimeter Detector in E14 experiment with $K_L \to 3\pi^0$

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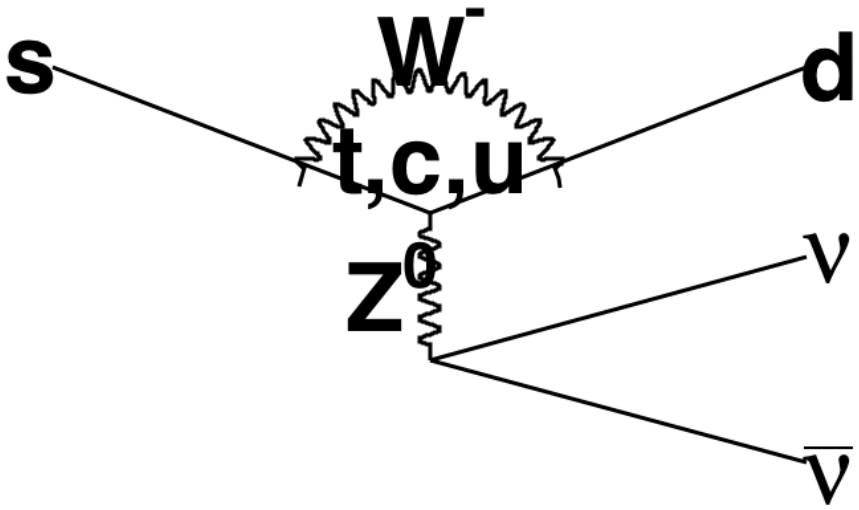
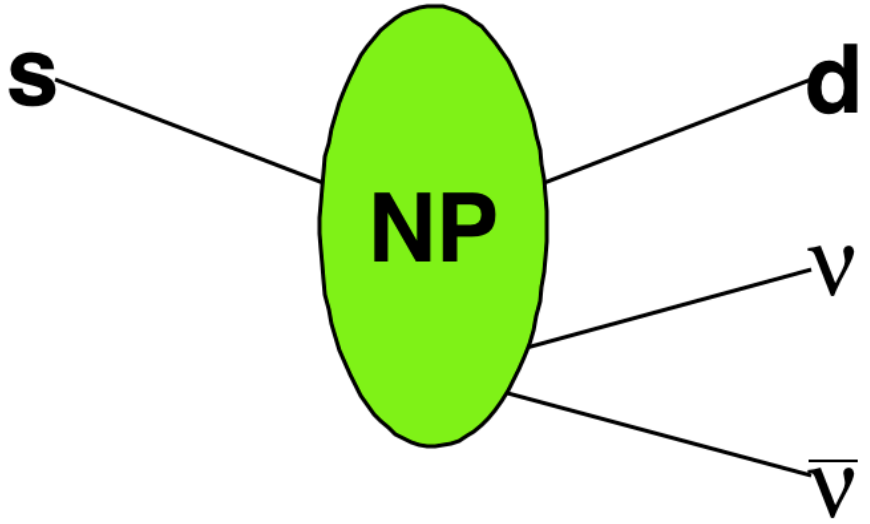
$K_L \to \pi^0 \nu\bar{\nu}$ decay

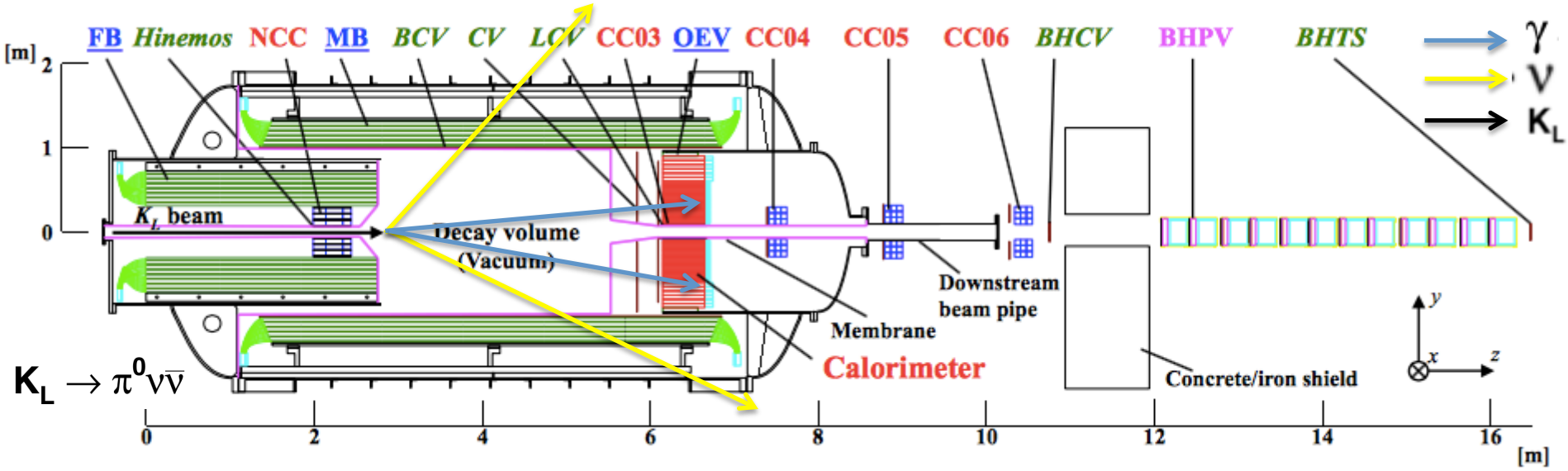
- FCNC process in Standard model
- $Br(K_L \to \pi^0 \nu\bar{\nu}) = (2.8 \pm 0.4) \times 10^{-11}$ predicted by SM
- Clean mode to explore New Physics





KOTO experiment

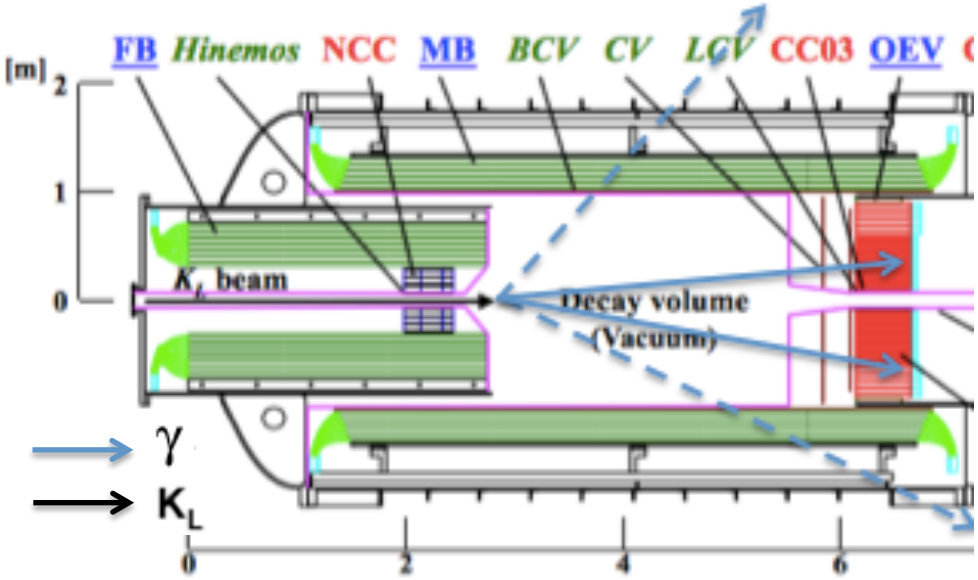
- KL beam line of Hadron Hall at J-PARC



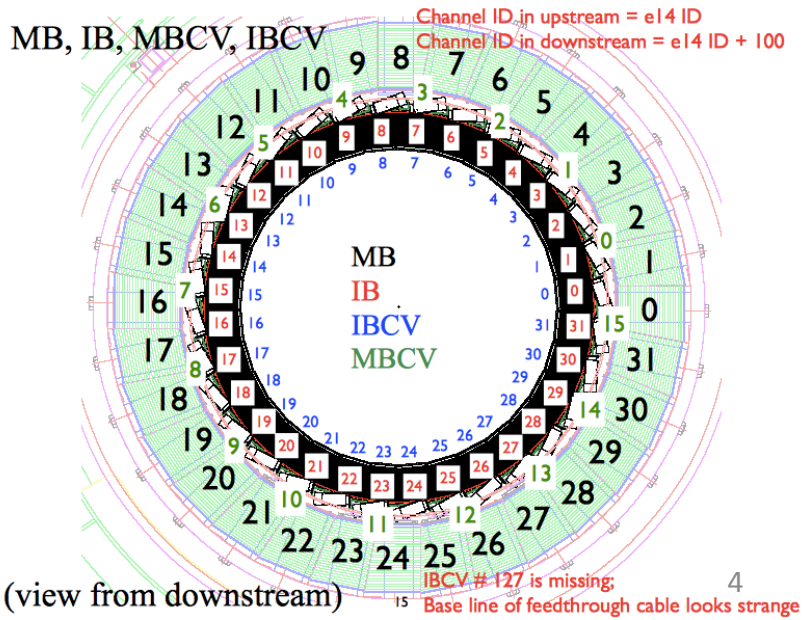
- $\mathbf{K_L \to \pi^0 \nu\bar{\nu}}$ decay leaves 2ϒ hit only.
- CsI Calorimeter detects 2ϒ
- Hermetic veto counters confirm no additional particles.

New Pb/Scint Calorimeter

- Better suppression of background events associated with $K_L \rightarrow 2\pi^0$ decay
- Better timing resolution to identify back-splash events

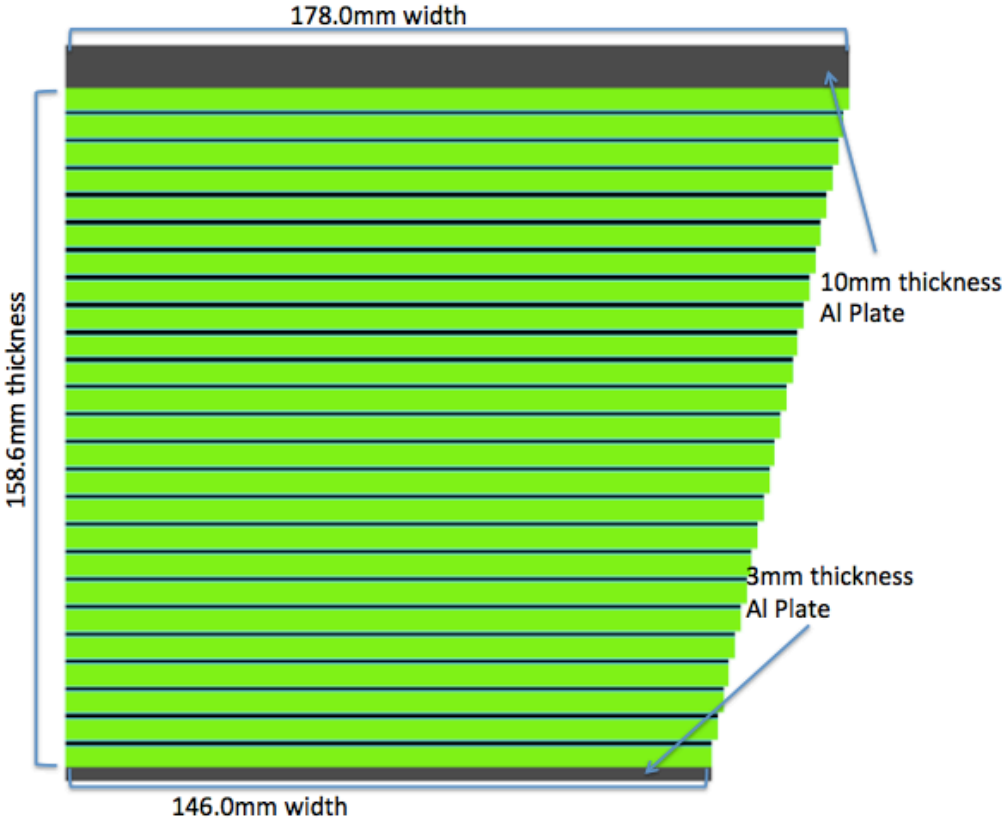


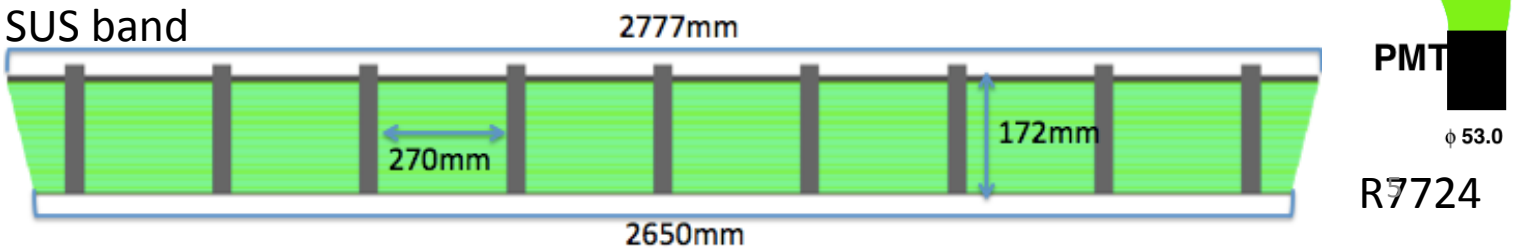
Not detected 2γ (inefficiency of barrel)



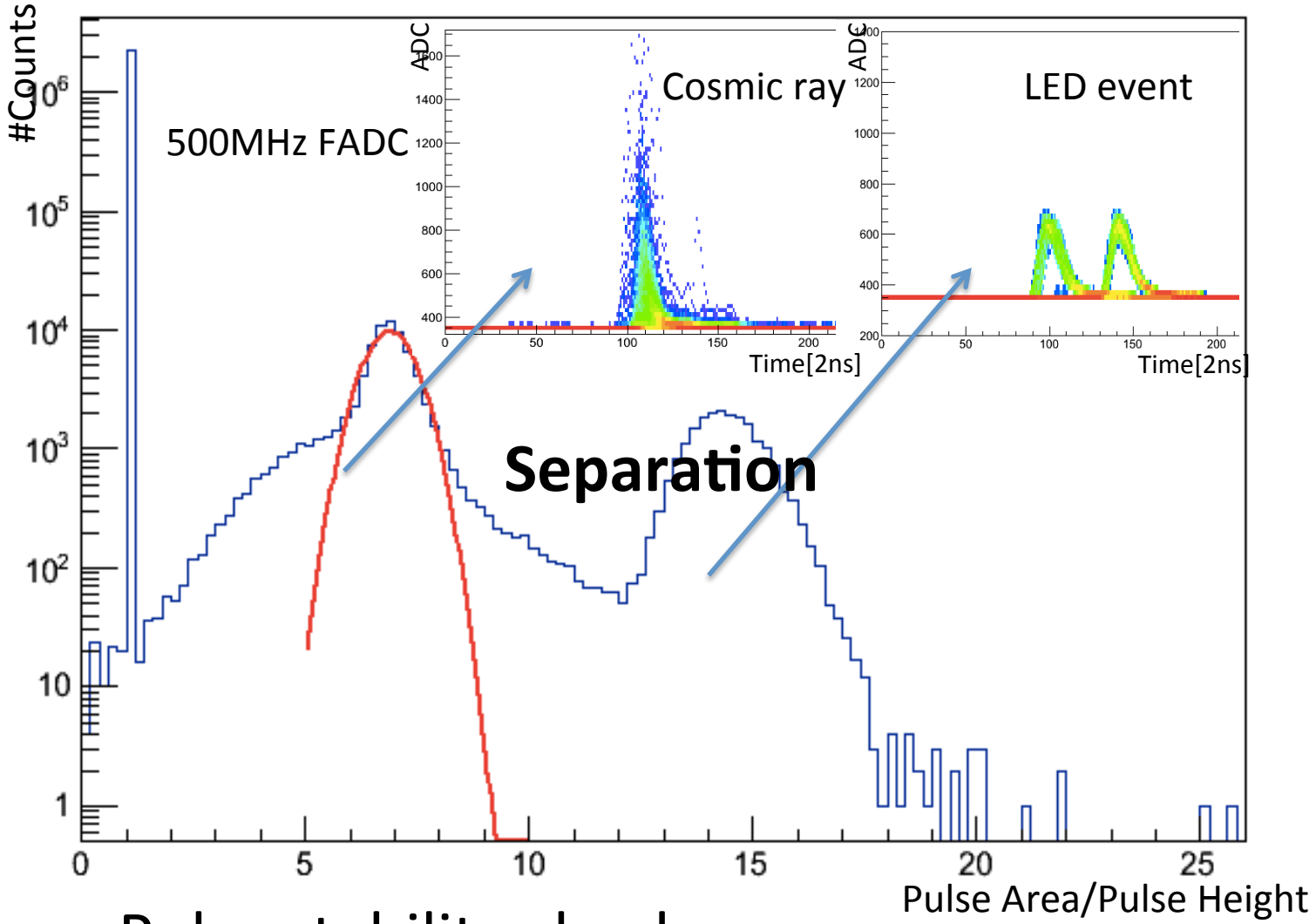
Inner Barrel

- Scintillators consist of
  - PS 80% + MMA 20%
- BCF-92 WLS(Saint)
  - Decay time : 2.7ns
- $5X_0$ radiation length
  - Lead : $4.28X_0$
  - Scintillator : $0.52X_0$
  - Al : $0.15X_0$
- Both end read out



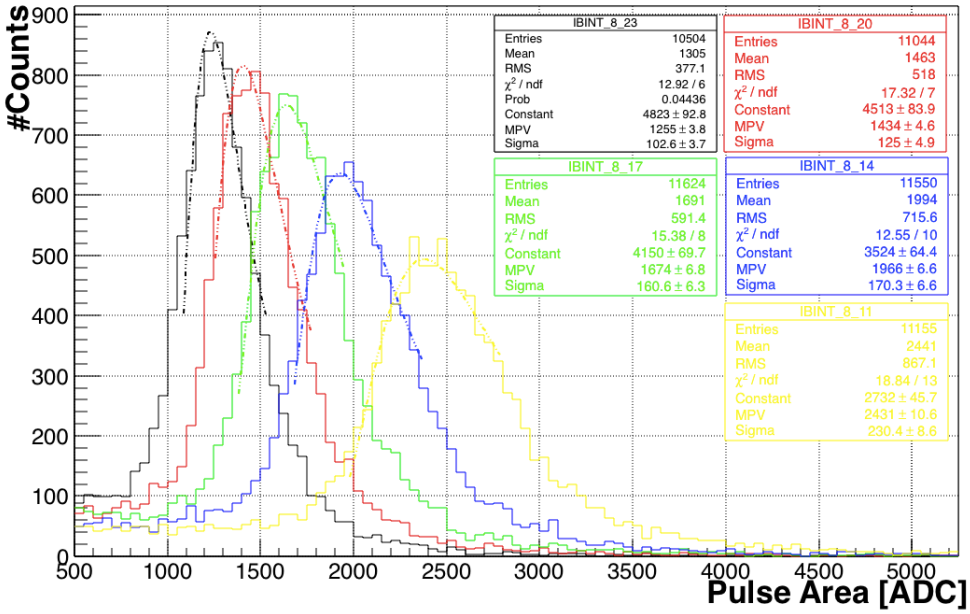


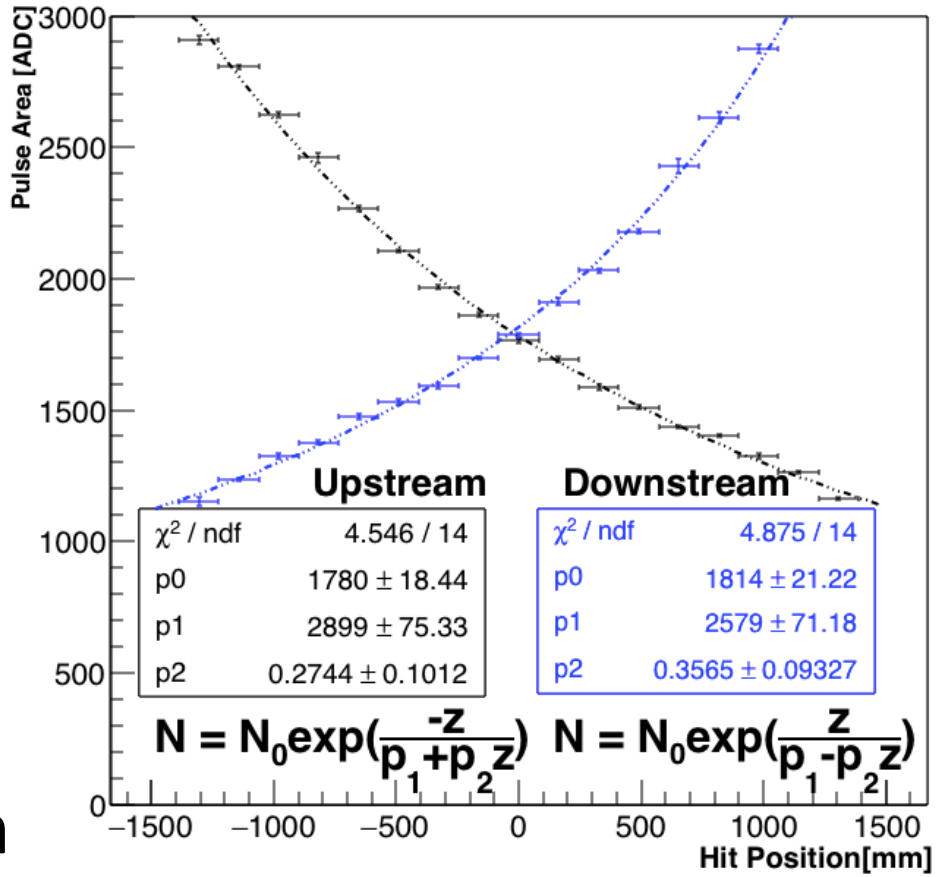
Data selection of cosmic ray



- Pulse stability check
- Separation of source of signal

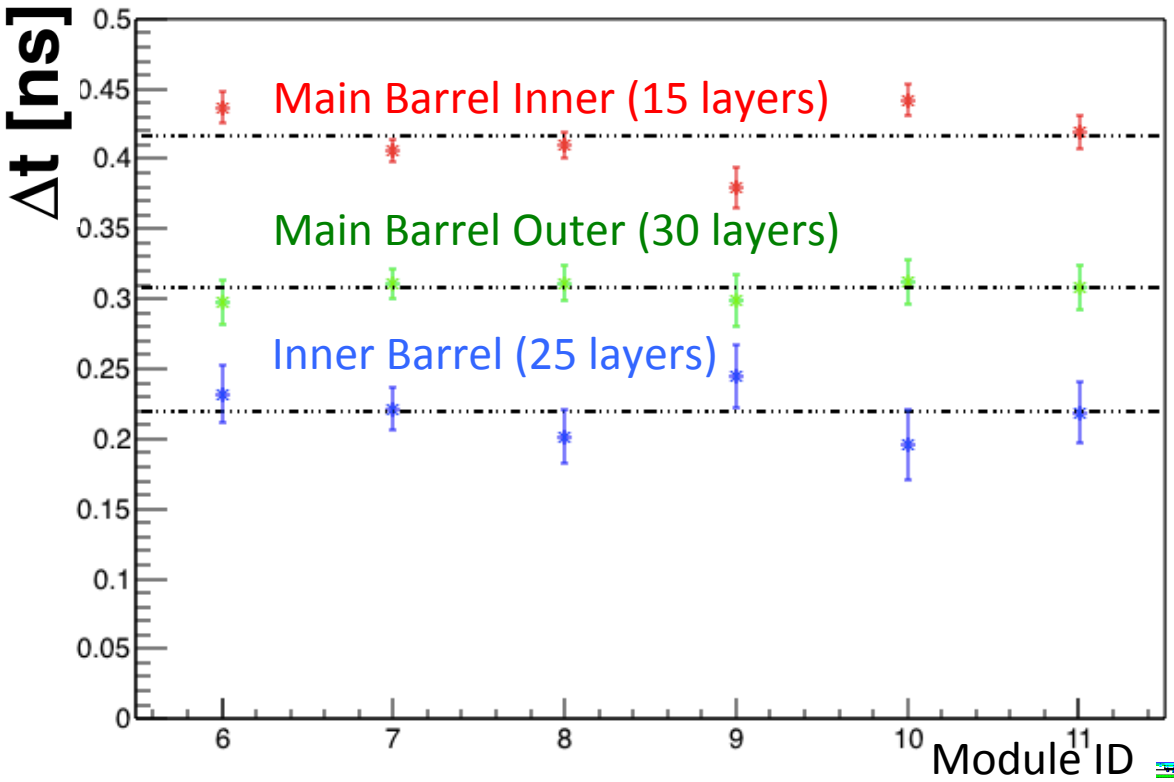
Attenuation of Scintillation light

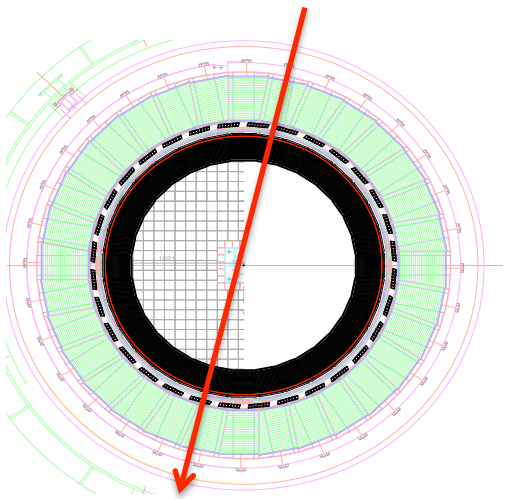


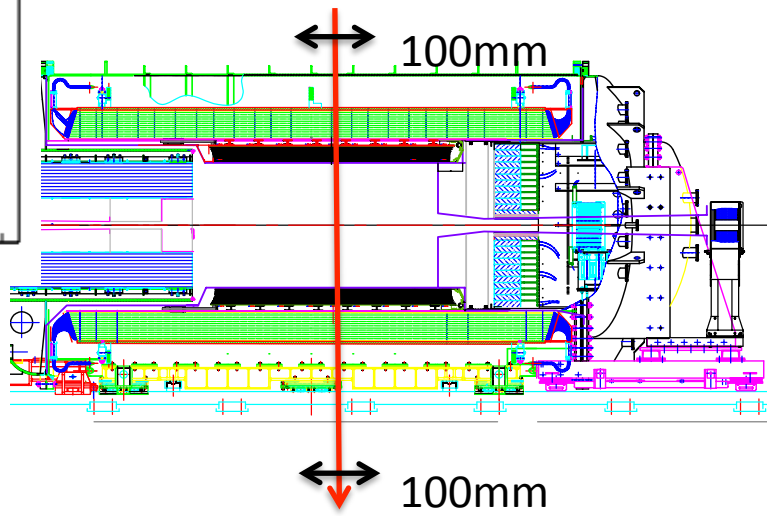


- Linear term(P_2) in the attenuation length describes the wave-length dependence.

Time resolution of Inner Barrel



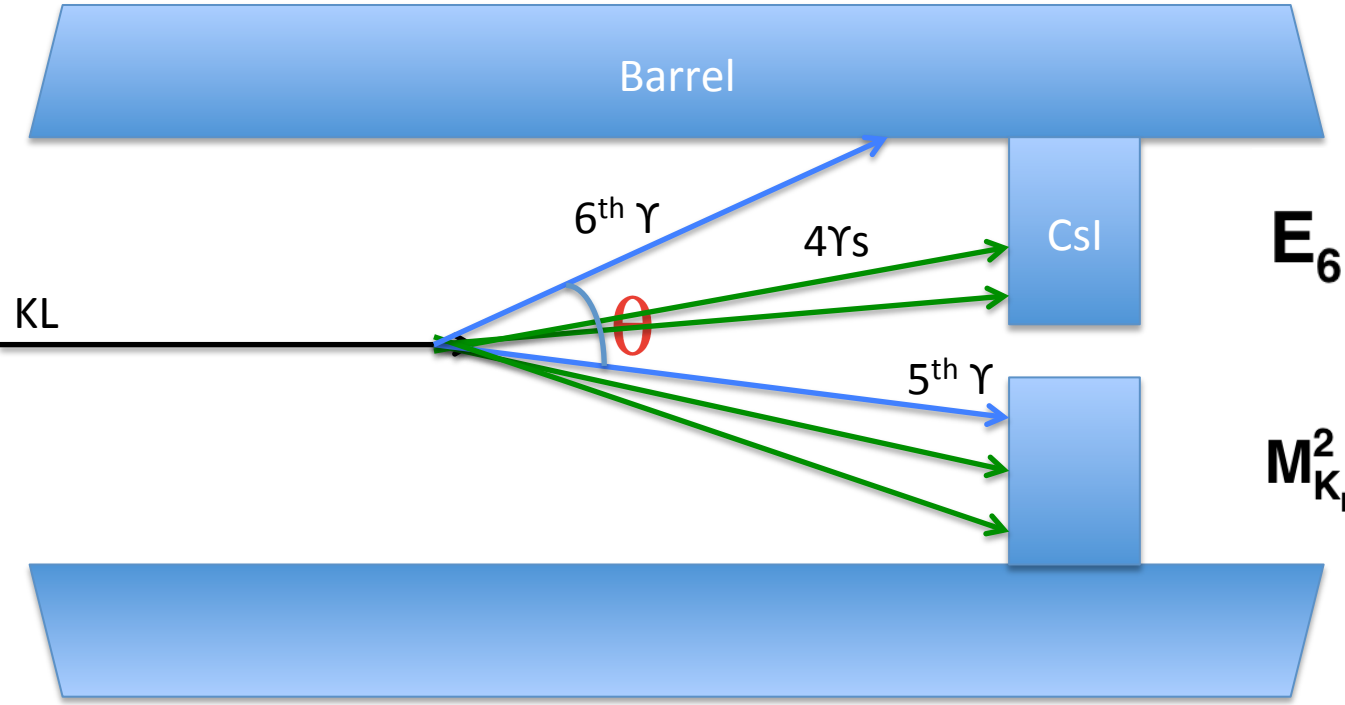




Selected cosmic ray track

- Time resolution of IB was found to be superior to those of Main Barrels using cosmic-ray data
- $\Delta t_{IB} = 219 \pm 8$ ps while $\Delta t_{MBOut} = 308 \pm 6$ ps and $\Delta t_{MBIn} = 416 \pm 4$ ps

$K_L \to \pi^0\pi^0\pi^0$ Reconstruction Using 5Y on CsI and 1Y 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 5ϒs on CsI and 1ϒ on Barrel
- Reconstruction of $2\pi^0$ from 4ϒs on CsI
- 1ϒ Reconstruction from hit information on Barrel (timing and segment ID)
- Reconstruction of the last π^0 from 1ϒ on CsI and 1ϒ on Barrel

Selections

- Mis-reconstruction of 2pi0 with 5th γ
- Dalitz Cut
  - Graphical cut about phase space of Three body decay

Cut Variables	Selected region
Klong Vertex	2500<VTZ<5000 [mm]
Gamma Energy on CSI	100<e<2000 [MeV]
Distances btw gammas	D>175 [mm]
Fiducial distance	150<r<900[mm]
Chi2_1st	Chi2<4
Chi2_2nd	Chi2>10
ShapeChi2	Chi2<10
Pi0 mass	Mass difference<5MeV
Difference btw 2pi0 mass	Mass difference<5MeV
Klong Pt	Pt<40[MeV/c]
Dalitz Cut	

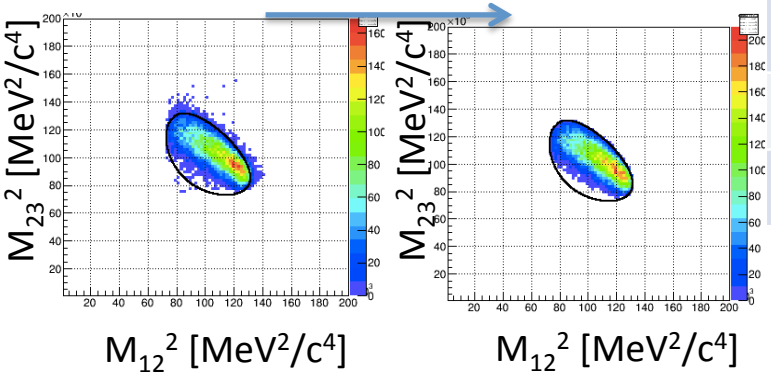
Bad Pair Ratio

~35%

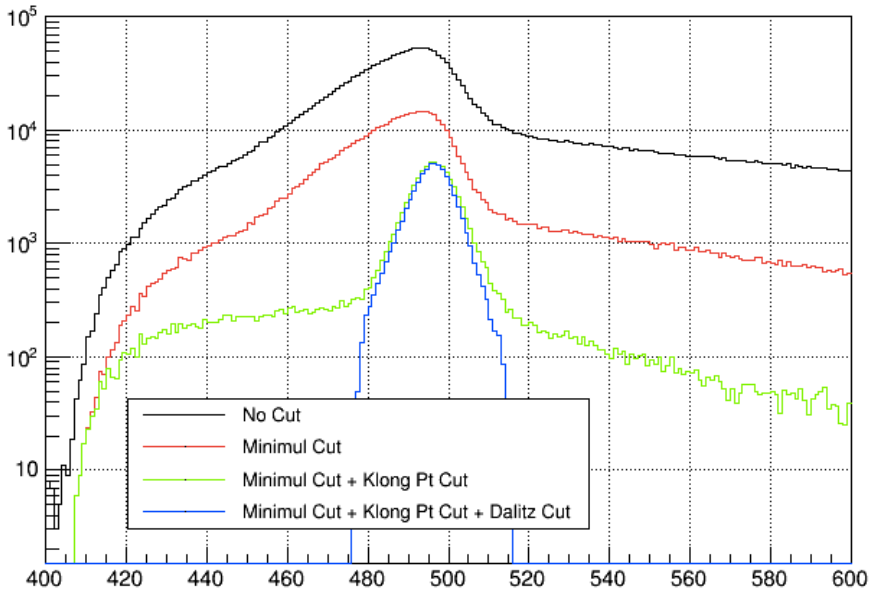
~23%

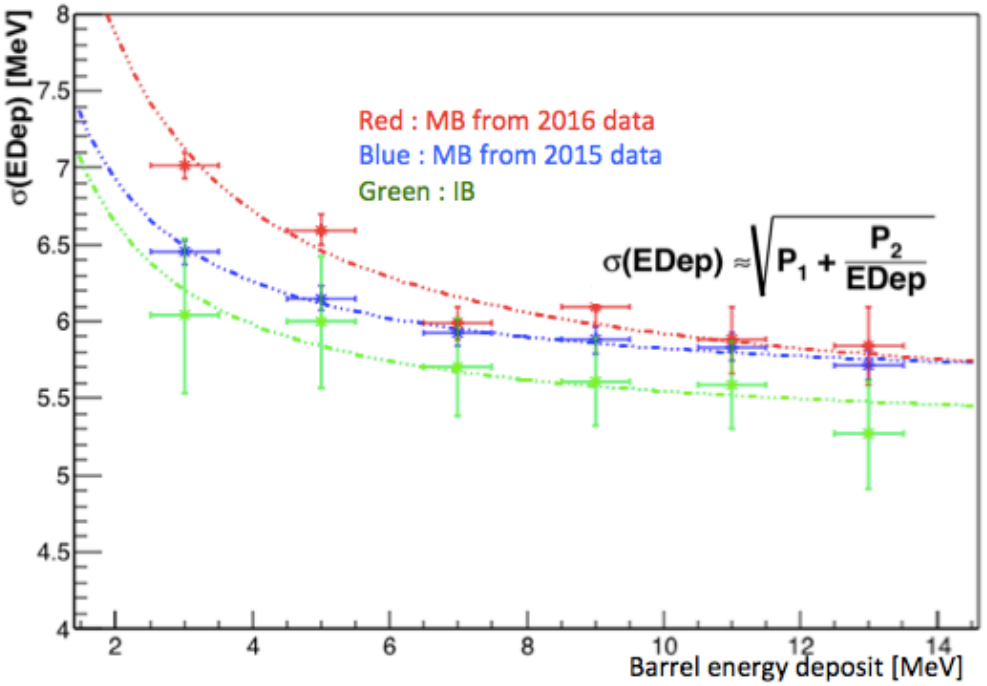
~6%

Dalitz Cut



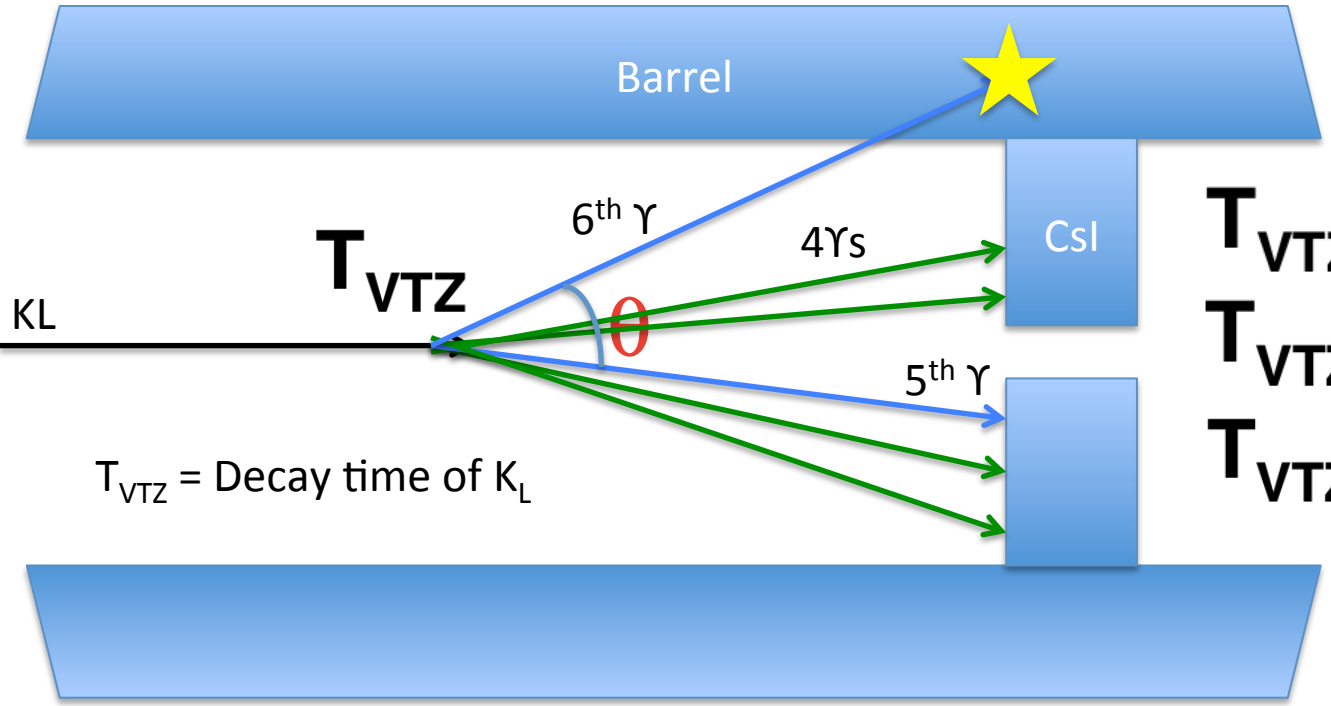
K_L Mass distributions





- Higher mass resolution due to IB
- Be able to know particle which gives signal to Barrel is gamma

K_L Vertex Time



$$ToF = \frac{L}{c}$$

L : path length of photons

$$T_{VTZ_B} = T_{Barrel} - ToF$$

$$T_{VTZ_C} = T_{CsI} - ToF$$

$$T_{VTZ_B} = T_{VTZ_C}$$

- Estimation of decay time of K_L using Barrel Detector and CsI Detector independently

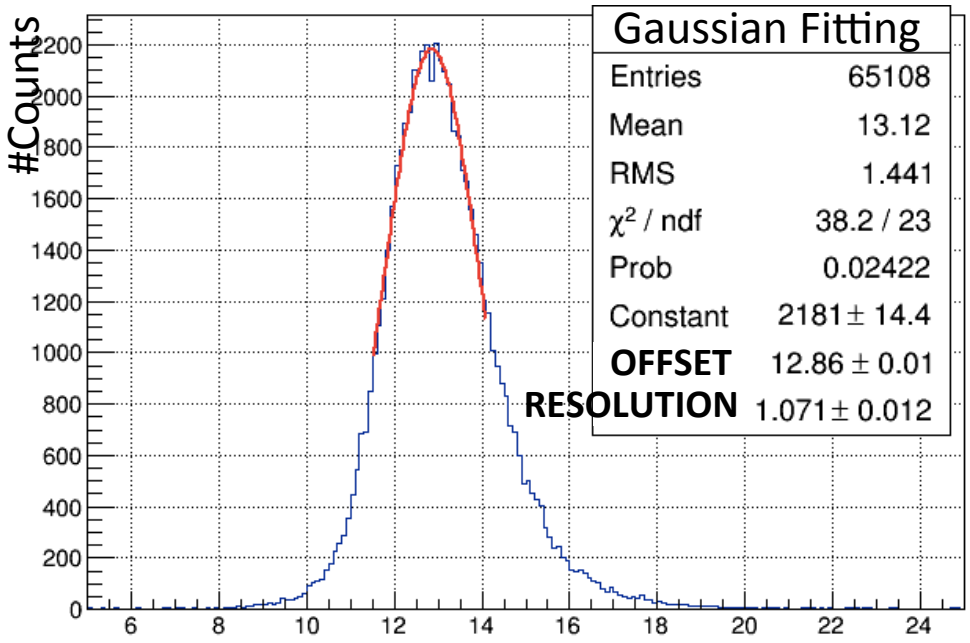
Vertex Time Difference

- From $T_{VTZB} = T_{VTZC}$, T_{VTZB}-T_{VTZC} should be in offset with resolution of detectors

$$\sigma^2 = \sigma^2_{Barrel} + \sigma^2_{CsI}$$

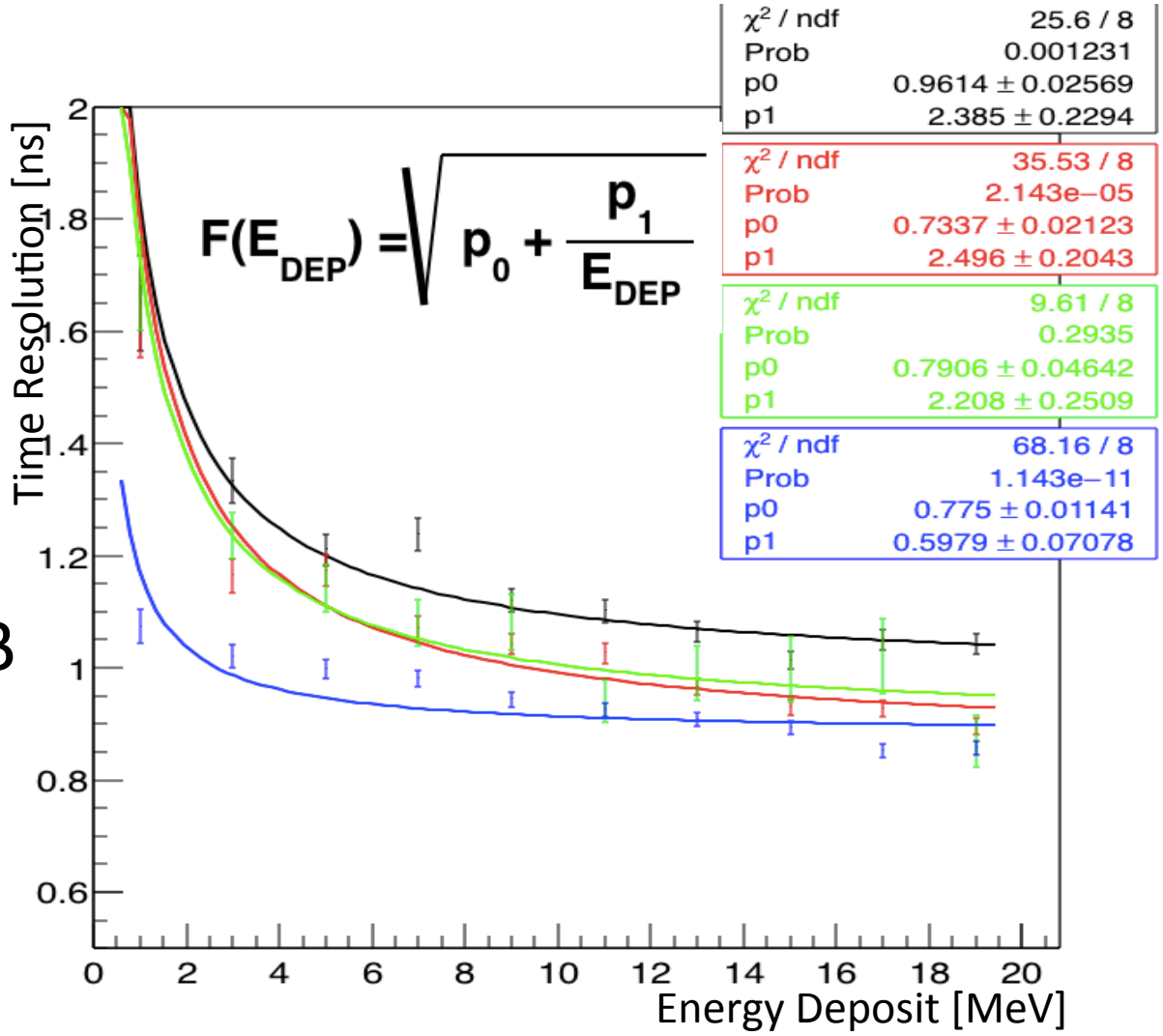
- From Photon statistics,

$$\sigma_{Barrel} \sim \frac{1}{\sqrt{E_{DEP}}}$$



Vertex Time Difference Resolution

- Higher energy deposit makes higher resolution
- IB has better resolution than MB



Summary

- IB has better resolution than MB
  - IB gives better mass resolution
  - IB gives better T_{VTZ} resolution
- From $\mathbf{K_L} \to \pi^0\pi^0\pi^0$ analysis, be able to select ϒ interacting with Barrel more clearly
  - T0 calibration check with this ϒ
  - Measurement of energy resolution with this ϒ