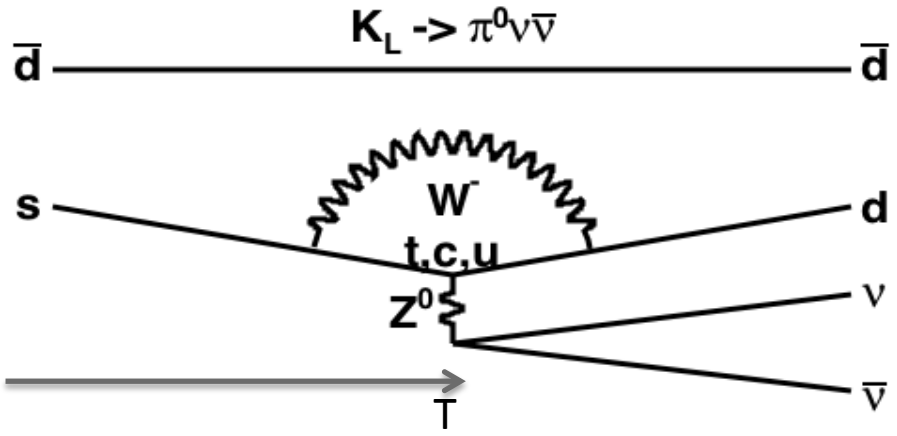
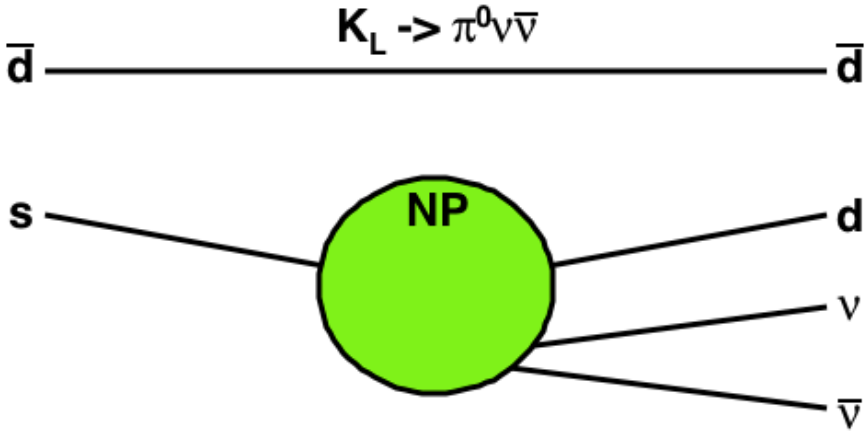
Slide for KPS

Introduction to KOTO

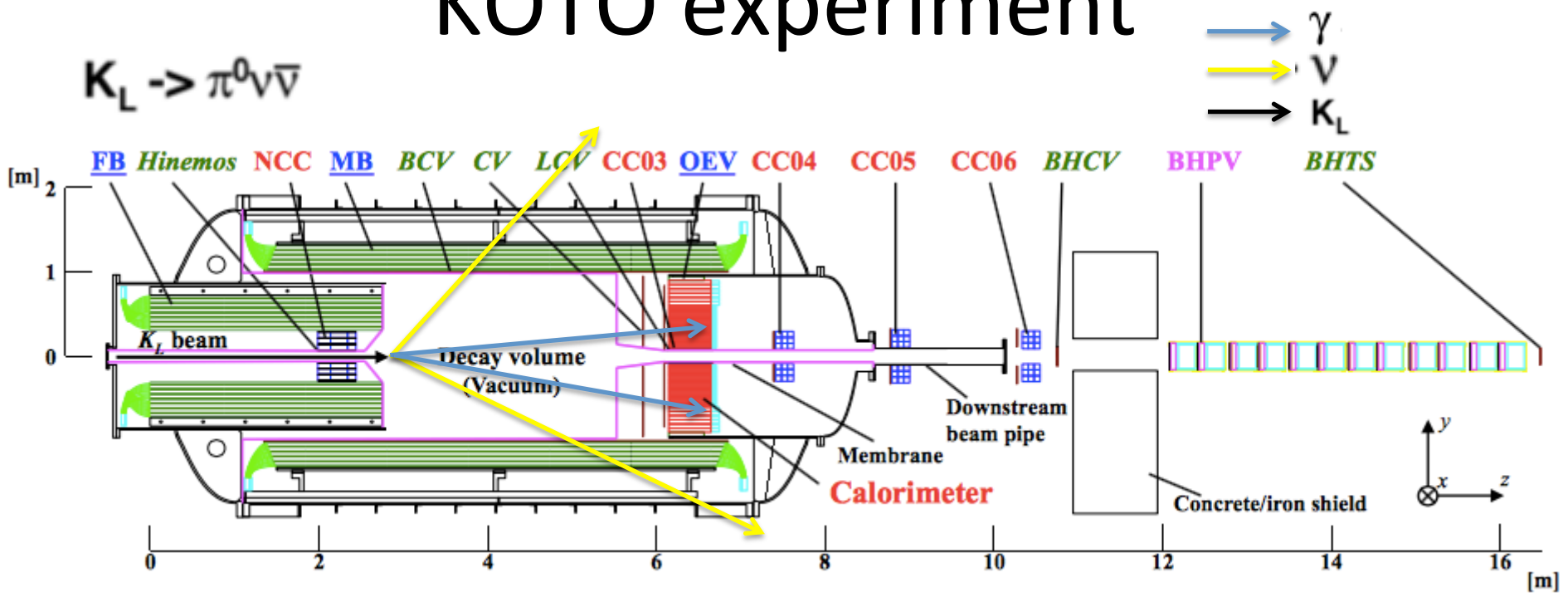
: Searching for $K_L \to \pi^0 \nu \bar{\nu}$

- In standard model
  - Well predicted FCNC Process
  - CP violating process
    - Direct measurement of height of unitary triangle
- Advantages
  - Clean process
    - Low uncertainty of branching ratio of this decay mode (under 10%)
  - Sensitive to new physics
    - In the view of SM, FCNC process is suppressed



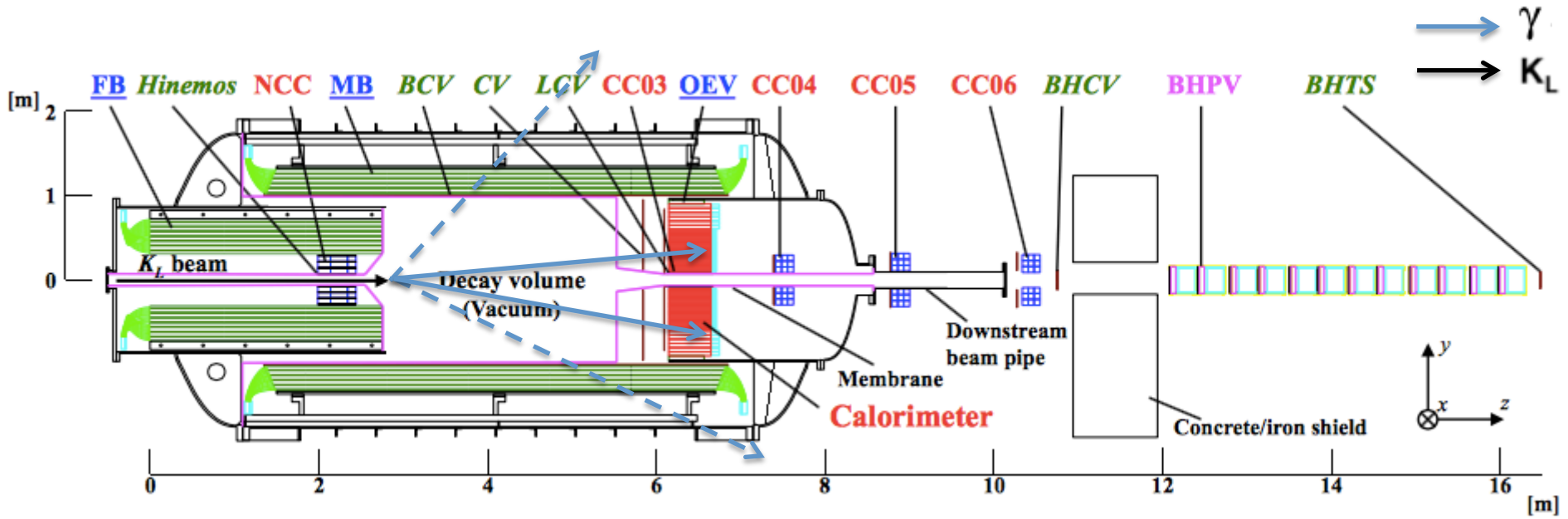


KOTO experiment



- 2γ + nothing
  - CsI Calorimeter for 2γ
  - Hermetic veto detectors for nothing
    - Reduction of charged particles
    - Reduction of gammas which is not going to CsI
    - Reduction of pi0 which has zero of tangential momentum

Motivation of Inner Barrel

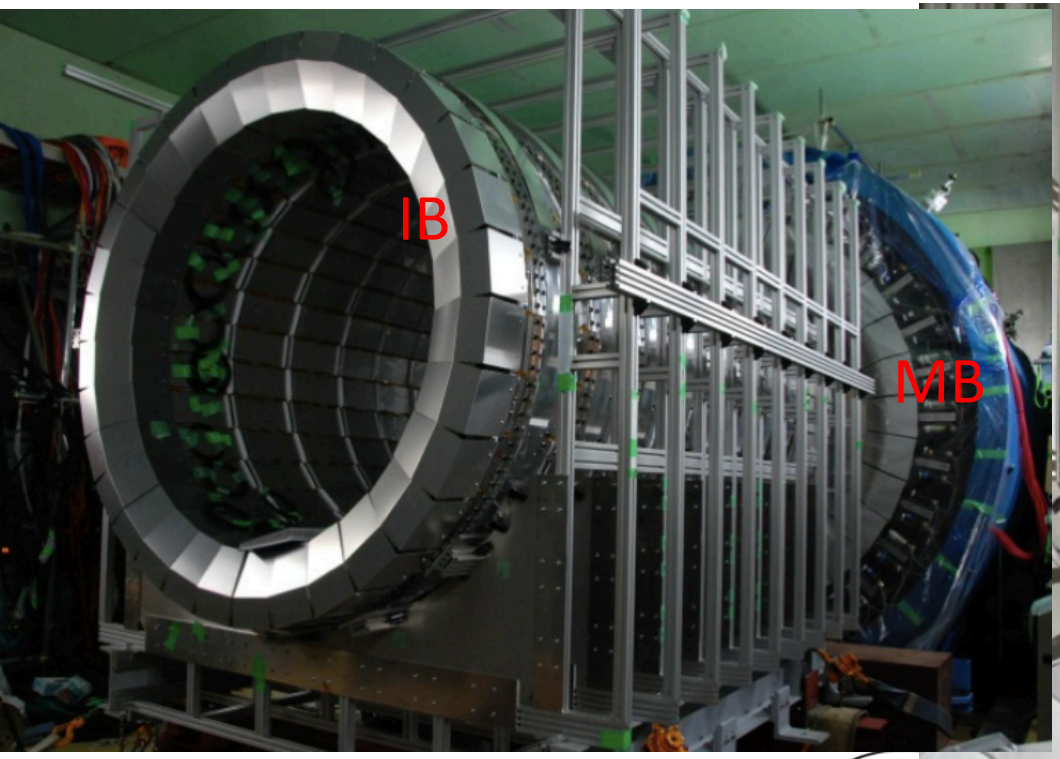


Not detected 2 γ (inefficiency of barrel)

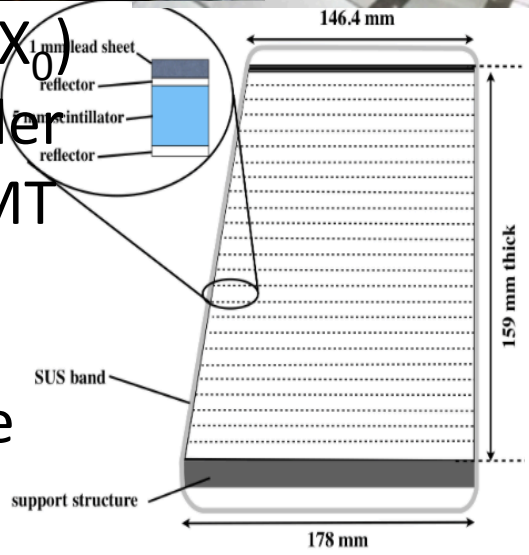
- In KL->2pi0 decay mode, background events could be induced from inefficiency of barrel detectors
  - Need more radiation length on barrel detector

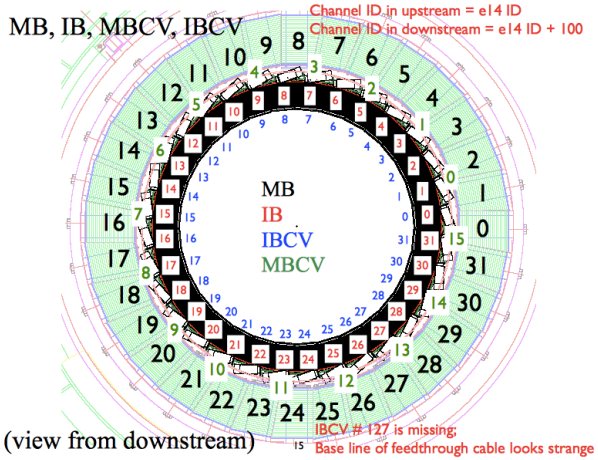
Detector setup	#events remained from 2pi0 background (MC)
E391 MB	2.90
E391 MB + 5X_0	**1.39**
E391 MB + 10X_0	1.30

Inner Barrel

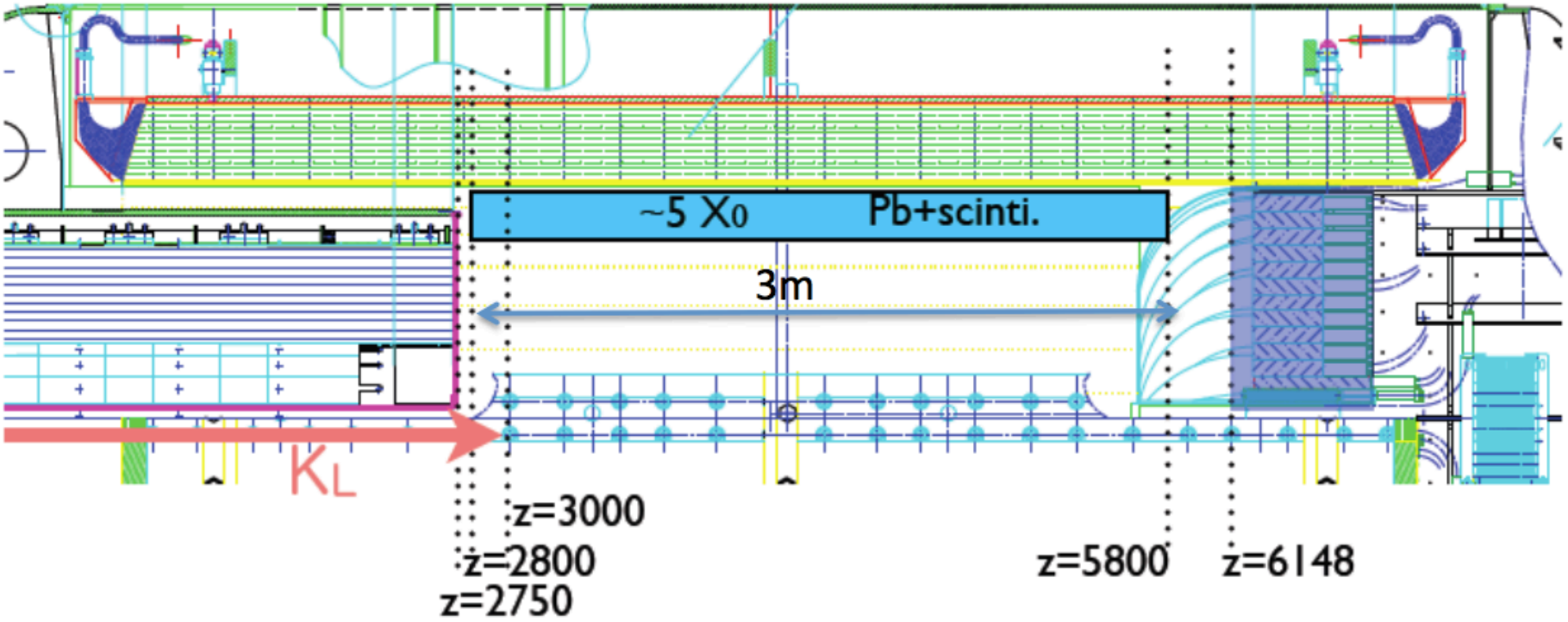


- 25-layer Pb/Scintillator.($5X_0$)
- 32modules forming cylinder
- Both end readout with PMT
  - Upstream : R329EGP
  - Downstream : R7724
- Charged Veto(IBCV) inside Inner Barrel





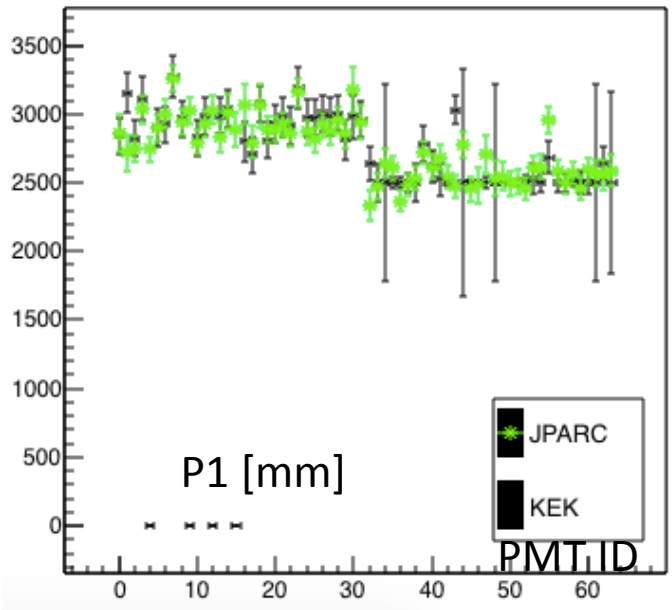
Performance of Inner Barrel

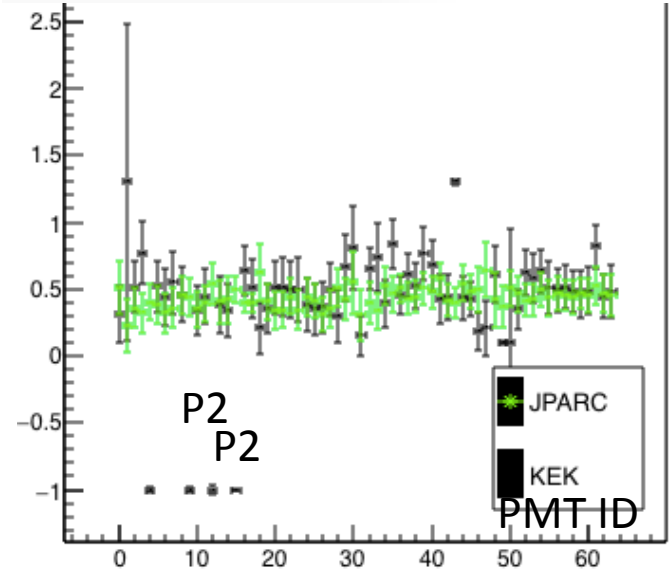


- Inner Barrel = New Pb/Scintillator detector
  - $5X_0$ radiation length
    - Decrease gamma detection inefficiency.
  - **Better timing resolution (than MB)**
    - **Decrease acceptance loss caused by back-splash or veto timing window.**

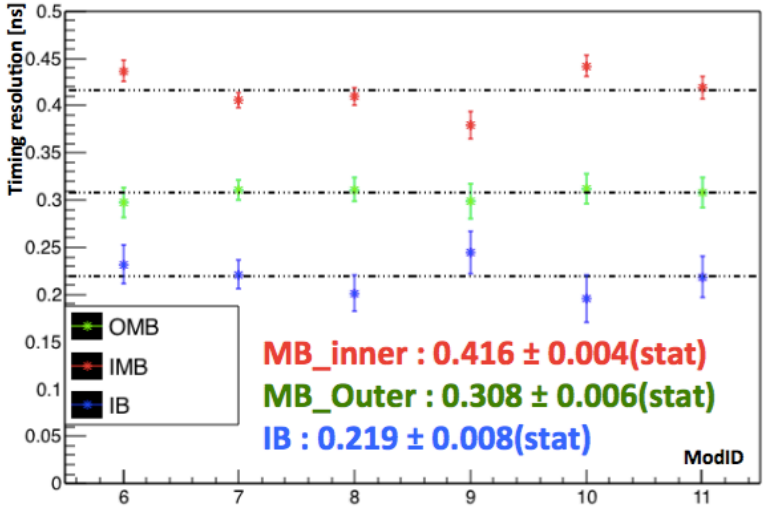
result of cosmic ray data analysis

Attenuation effect

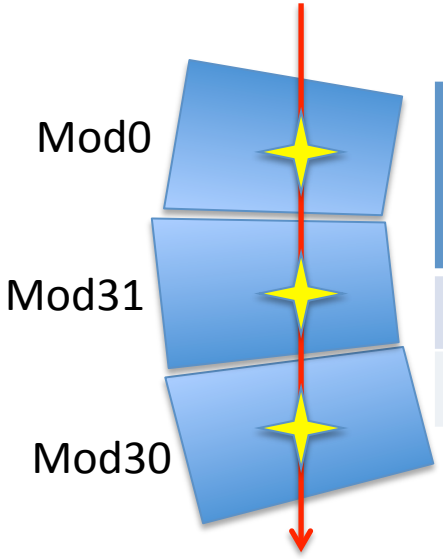




Timing resolution from Run69 cosmic ray data



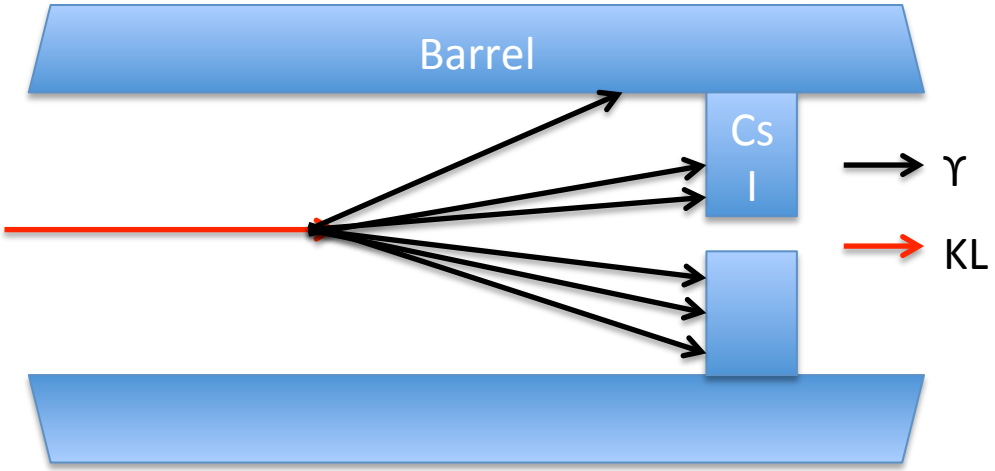
Special track selection for FADC effect on Timing Resolution



Situation	Timing Resolution [ns]
KEK(125MHz FADC)	0.28
JPARC(500MHz FADC)	0.18

Reconstruction of $K_L \to \pi^0\pi^0\pi^0$

- Motivation
  - Position of ϒ on Barrel
    - Obtained from timing difference
  - Better timing resolution
    - Improvement of kaon mass distribution



- Calculation of direction of 1 missing ϒ.
  - 5ϒs on CsI
    - $2\pi^0$ vertex from 4ϒs
    - Minimum vertex-chi2
  - 1ϒ on barrel
    - Z position from timing difference
    - X, Y position from Module ID.
- Kinematics of 6th ϒ
  - 6ϒ Invariant mass

$$2\left(E_{5th}E_{6th} - \vec{P}_{5th}\cdot\vec{P}_{6th}\right) = {m_\pi}^2$$

$$\vec{P}_{5th}\cdot\vec{P}_{6th} = E_{5th}E_{6th}cos\theta$$

$$E_{6th} = {m_\pi}^2/(2E_{5th}(1-cos\theta))$$

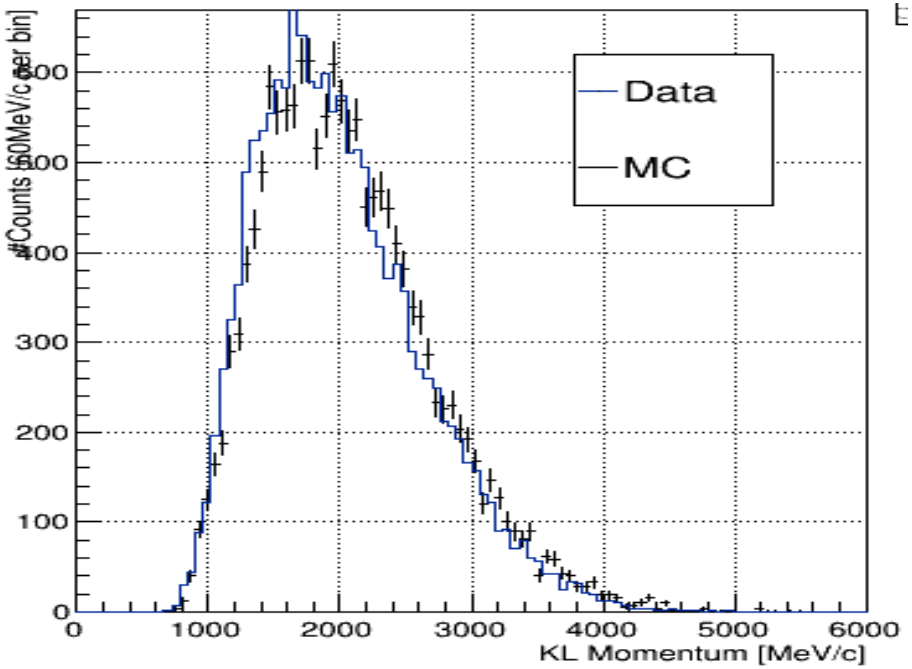
$${M_{K_L}}^2 = (\sum E_i)^2 - (\sum \vec{p}_i)^2$$

$$\chi^2_{vertex} = \sum_{i=1}^{2} \frac{(VTZ_{ithPi0} - VTZ_{K_L})^2}{\sigma^2_{vertex}}$$

Analysis

- Data Information
  - CSI Trigger + Barrel coincidence data
    - 5ϒs on CsI
    - 1ϒ on Barrel(IB, MB)

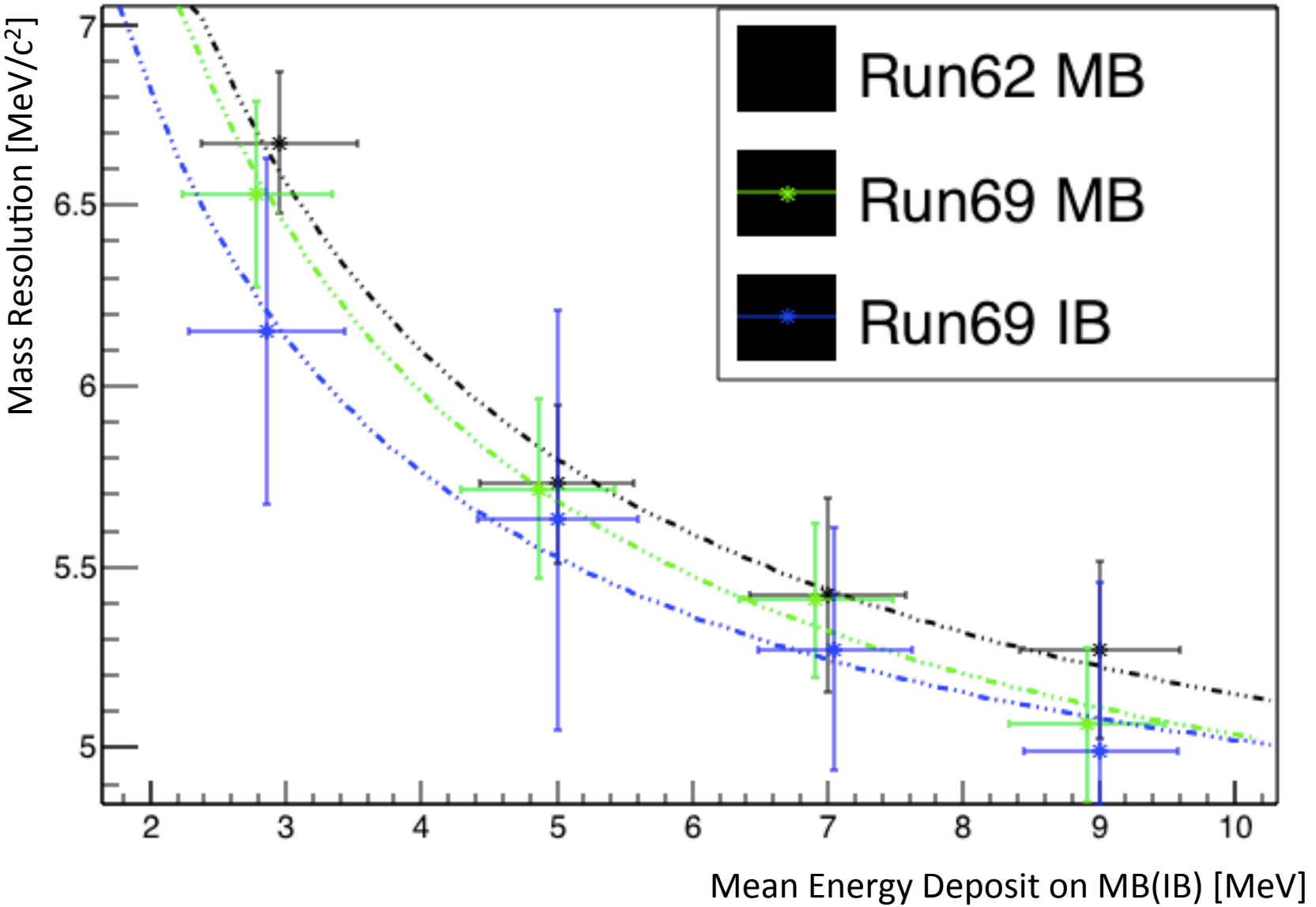
Selected Incident KL momentum



- Event selection

Cut Variable	Range

Mass resolution



Summary

- KOTO experiment finished to install Inner Barrel
- Calibration of Inner Barrel is done with cosmic ray data
  - From cosmic ray data, timing resolution of barrel detectors are calculated.
  - Consistent with 2013 analysis.
- KL3pi0 reconstruction is done with barrel detector output
  - Only invariant mass of 6gamma
    - Need to study about pi0s with dalitz plots