KEK PS-E391a実験における Engineering Run のデータ解析

坂下　健
（山中研　D2）

1. E391a experiment
2. Status of E391a experiment
3. Engineering Run
4. Analysis
5. Conclusion

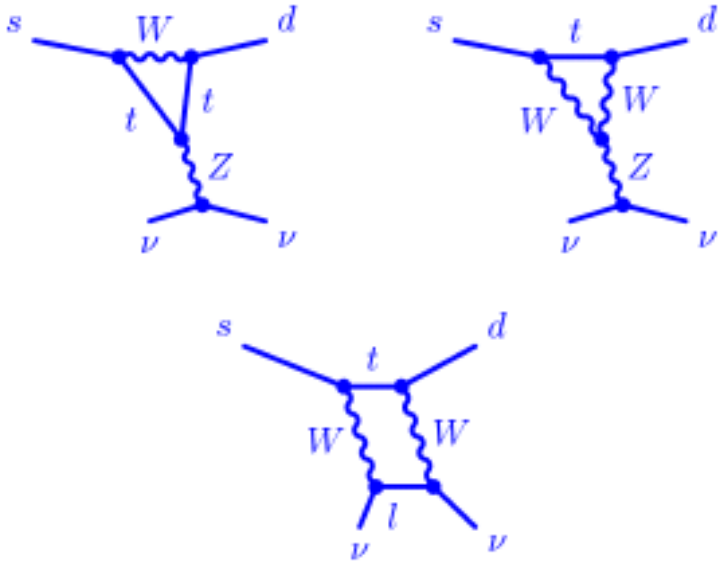
Physics Motivation

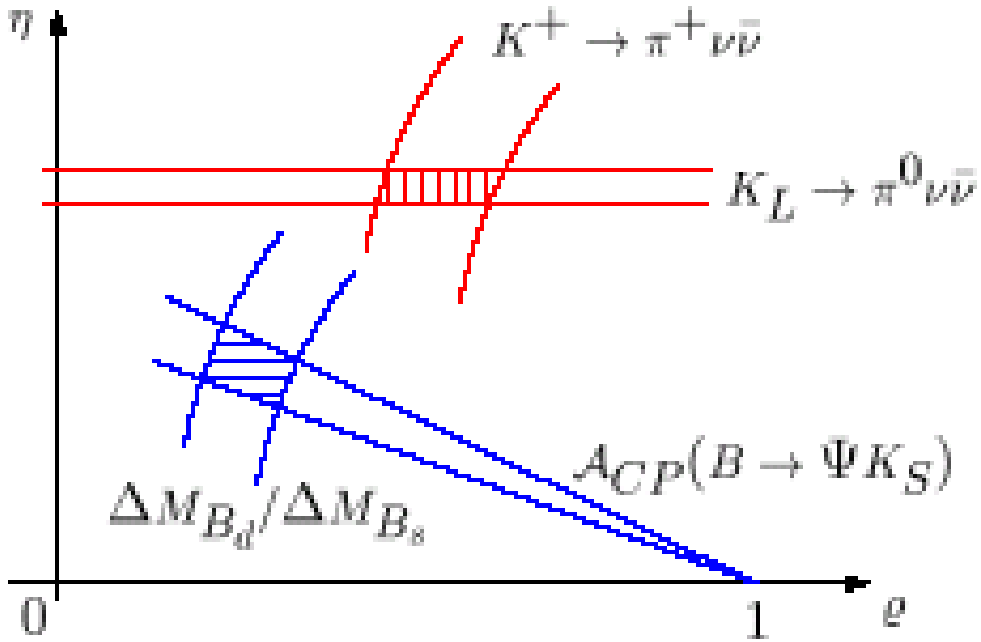
- $K_L \rightarrow \pi^0 \nu\bar{\nu}$
  - Most clean channel to η
  - BR = $1.94 \times 10^{-10}\ \eta^2\ A^4\ X^2$

    $\sim 3 \times 10^{-11}$
  - Signal from π^0 decay
  - Current limit

    BR < 5.9×10^{-7}

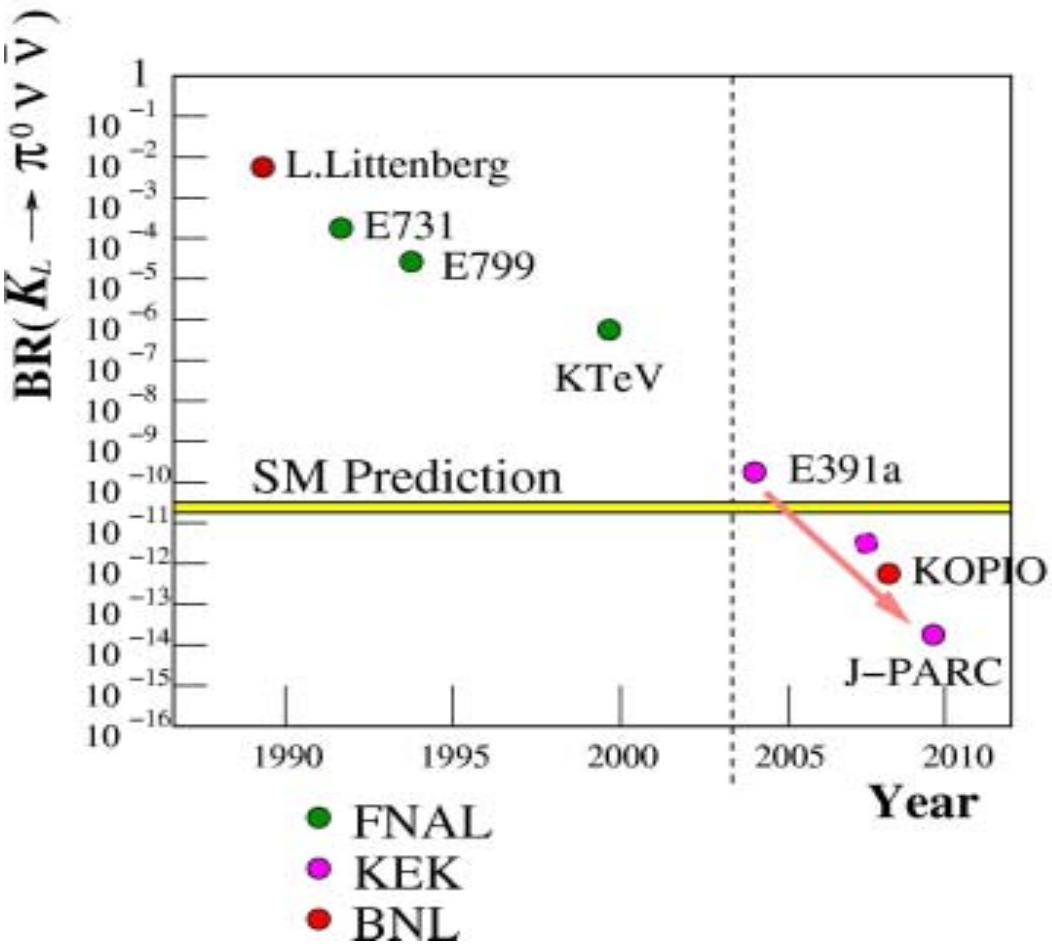
    (KTeV E799-II)





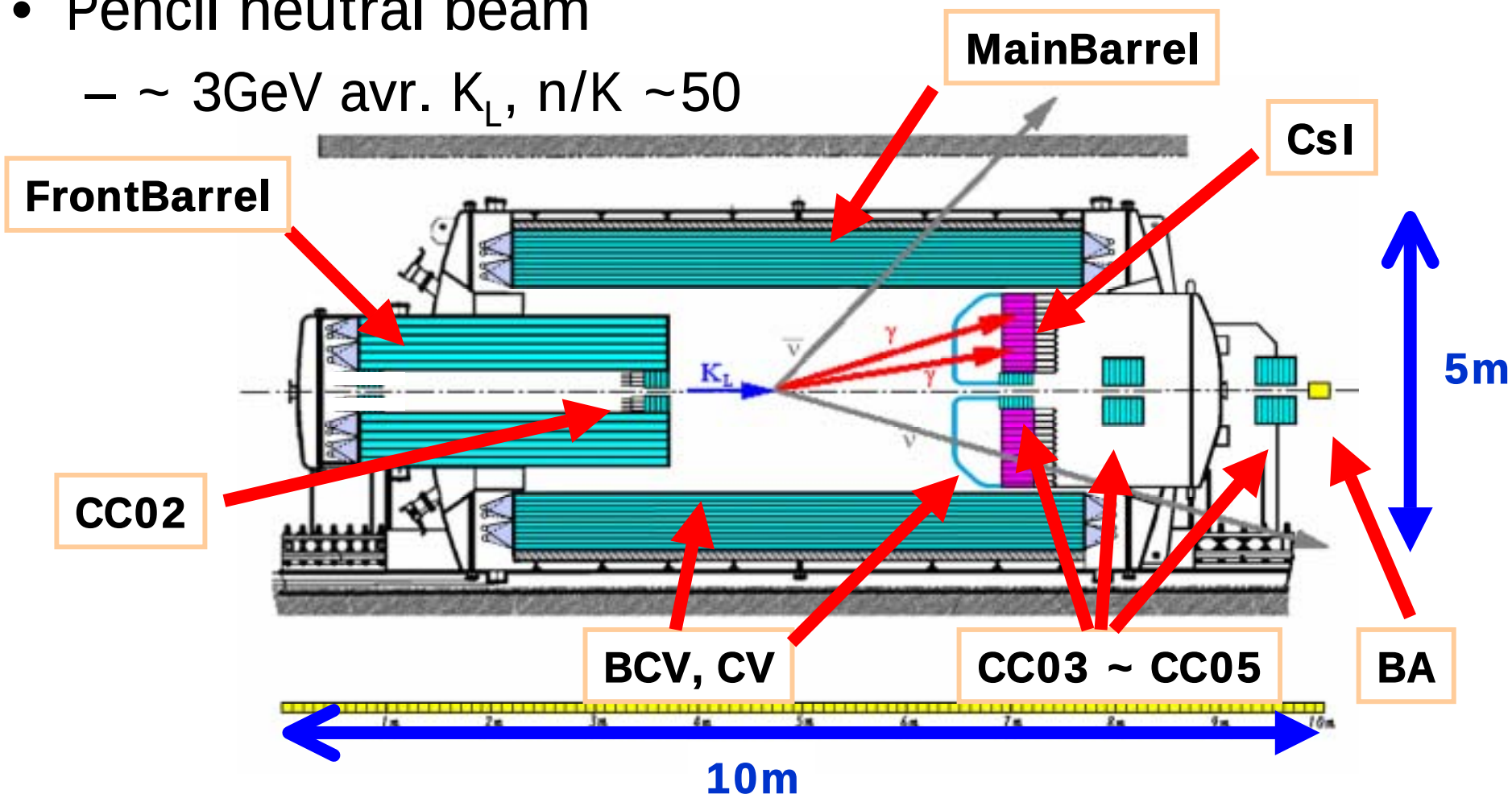
E391a Experiment

- KEK 12GeV PS
- **11の大学･研究機関、約５０名の**collaborator
- **世界初の** $K_L \to \pi^0\nu\nu$ **実験**
- Pilot experiment
  to JPARC
  - **測定方法の確立**
- S.E.S = 3 x 10^{-10}
  - **最終目標は、**
    JPARC**の実験で**
    1000 events



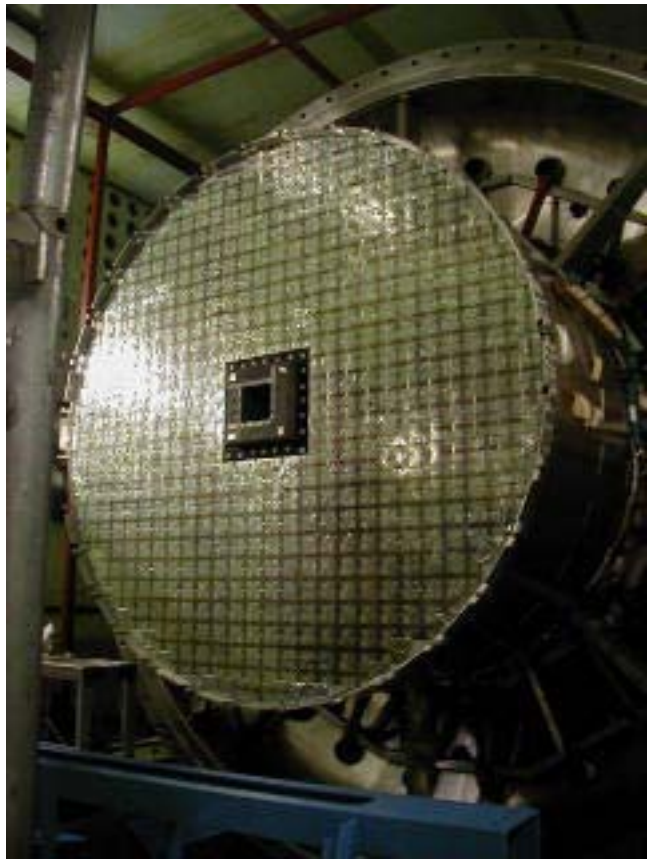
E391a Detector

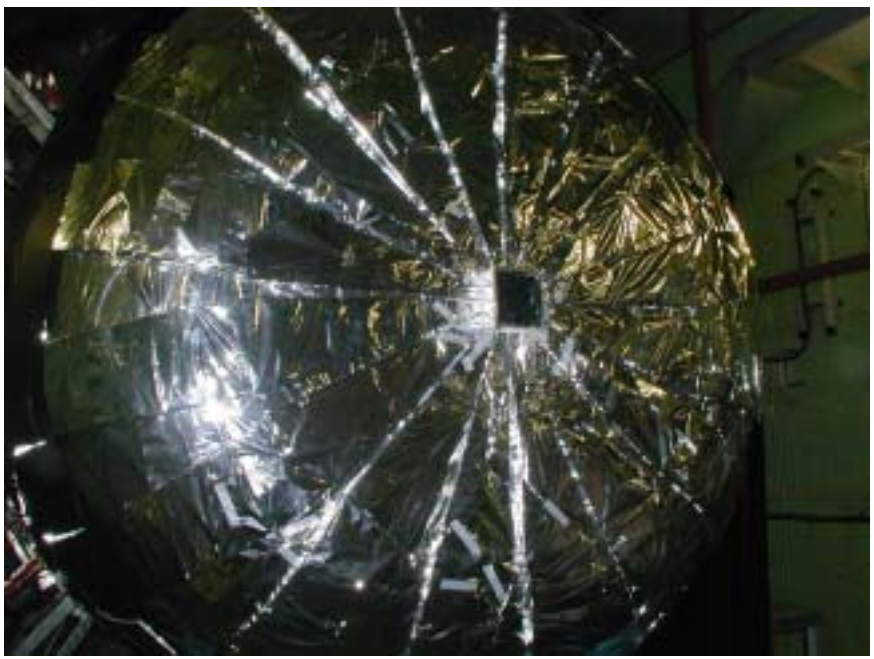
- Signal = 2γ + nothing
- Hermetic photon veto/ CsI calorimeter
- Highly evacuated decay region (~ 10^{-6} Pa)
- Pencil neutral beam
  - ~ 3GeV avr. K_L, n/K ~50



Downstream section

- CsI(pure)
  - 7cm x 7cm x 30cm
  - 576 crystals, 2m diameter
- CC03 (Collar Counter)
- ChargedVeto

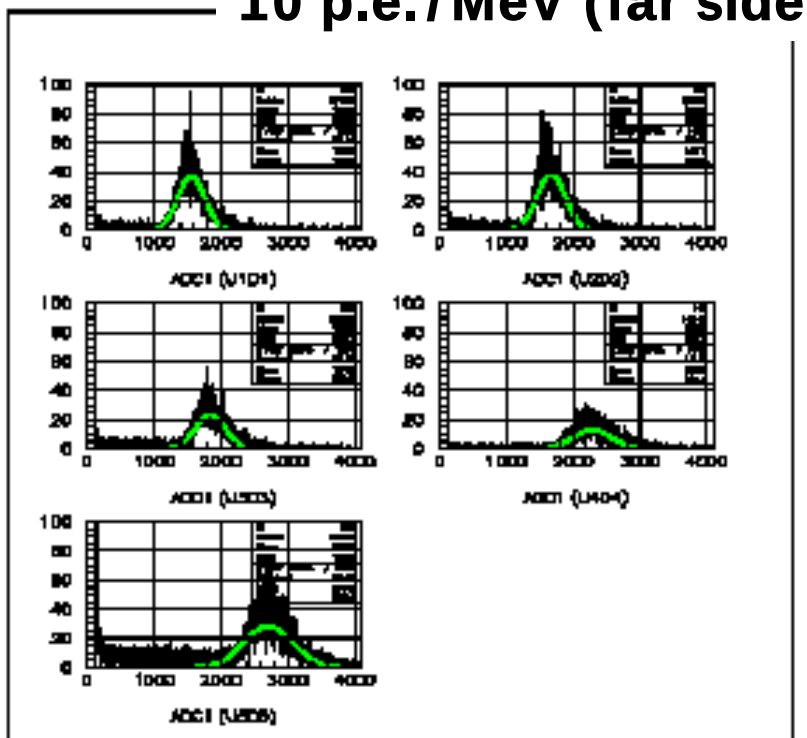




Upstream section

- FrontBarrel module
  - Lead/Scinti 1.5mm5mm 59layers(17.2X_0), **長さ** 3m
  - Cosmic ray test was done

20 p.e./MeV (near side)
10 p.e./MeV (far side)

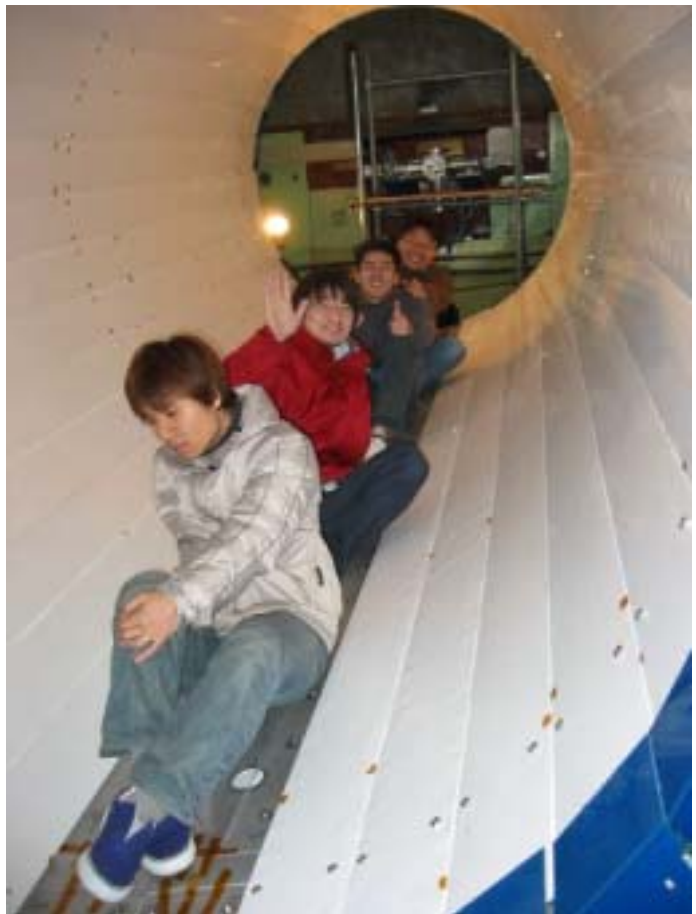


Upstream section

- 16 module組み立て
- 真空 vesselへインストール
- 現在、真空中でcosmic test中

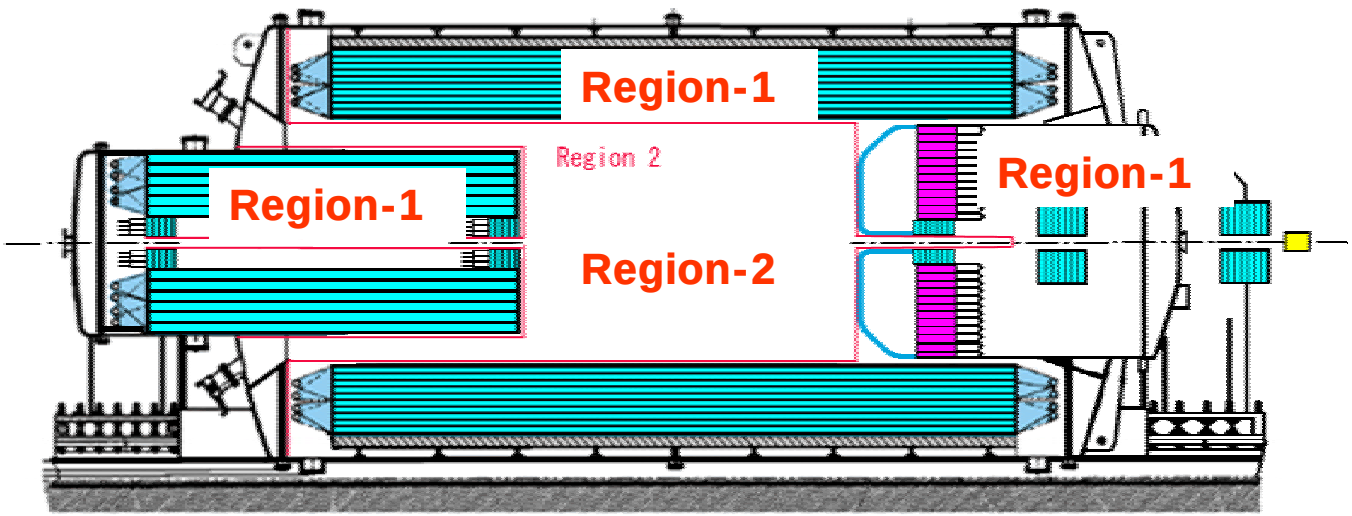
Middle section

- MainBarrel
  - Lead/Scint. ~13.5 X_0 **長さ　5m**
- Installation into vacuum vessel
  - MainBarrel 32 modules + BCV 32 modules
  - **これから**PMT**取り付け** etc...



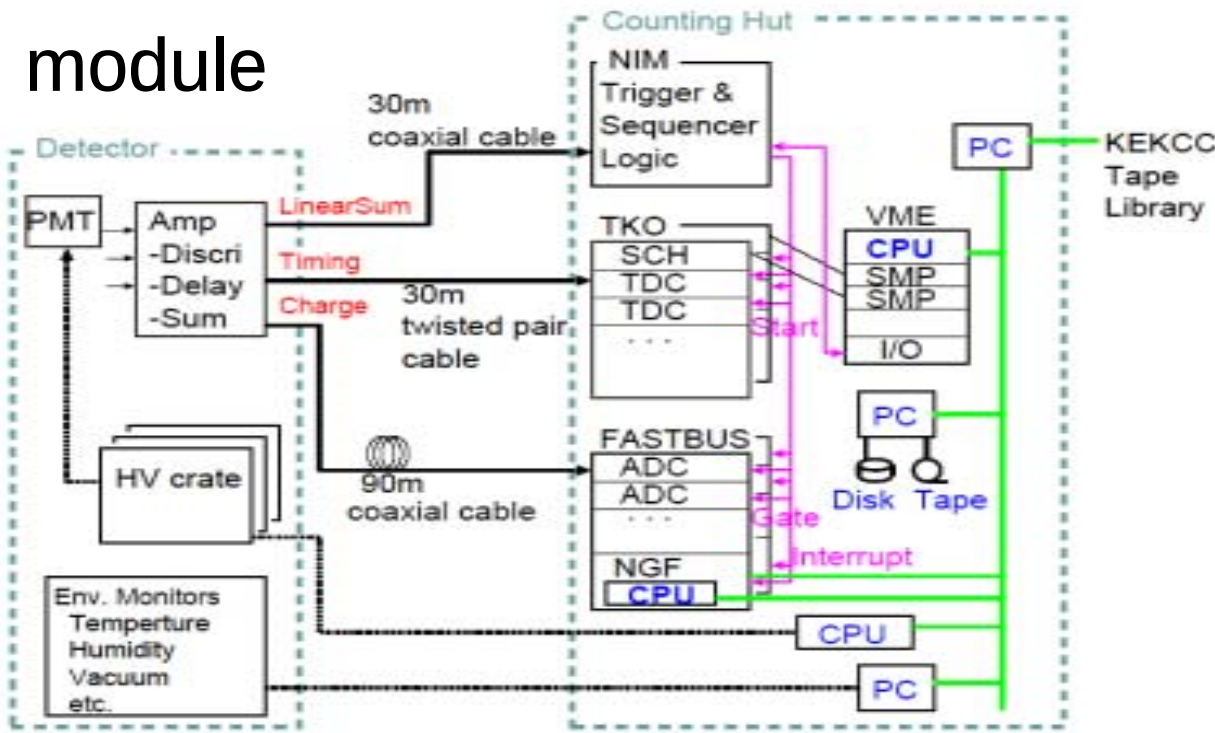
Vacuum system

- Differencial pumping system
  - Region-1 ~10^{-1} Pa , Region-2 ~10^{-6}Pa
  - Tolerance against out-gassing
- **全てのPMTは、真空(Resion-1)の中**
  - **真空テストベンチでテスト(動作、放電、温度)**
  - Water cooling system



DAQ/Electronics

- Detector**側からの要求**(total 1000ch)
  - 1 MeV threshold for γ veto
- DAQ/Electronics
  - Distributed parallel processing
  - 15 bits ADC (LRS 1885F), 12bits HR-TDC
  - Amp-Discri-Sum module
- Trigger
  - N_γ multiplicity



E391a実験の現状

- 2002.Aug　Construction of downstream section
- 2002.Dec　Engineering Run
- 2003.Jan ~　Construction of upstream section
  Vacuum test etc...
- 2003.Dec　Construction of middle section

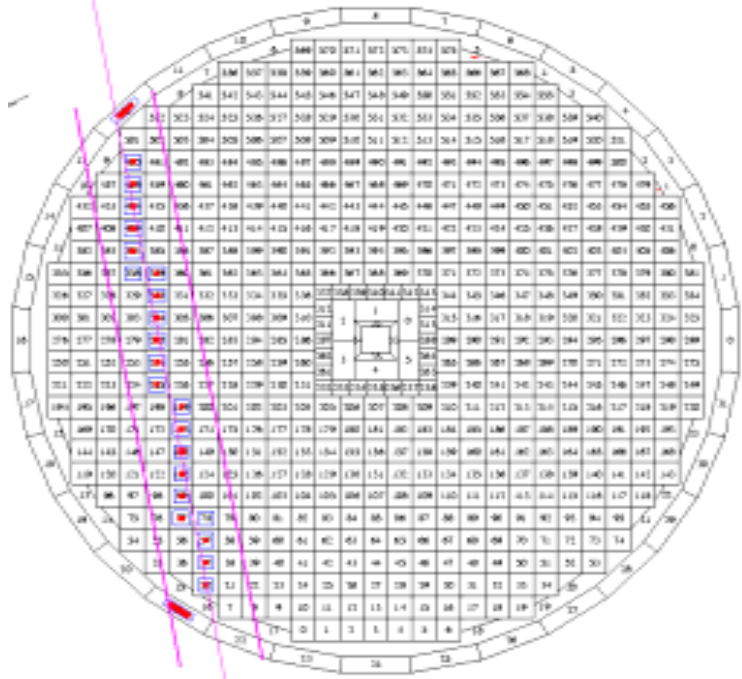
- 2004.Feb ~　Run

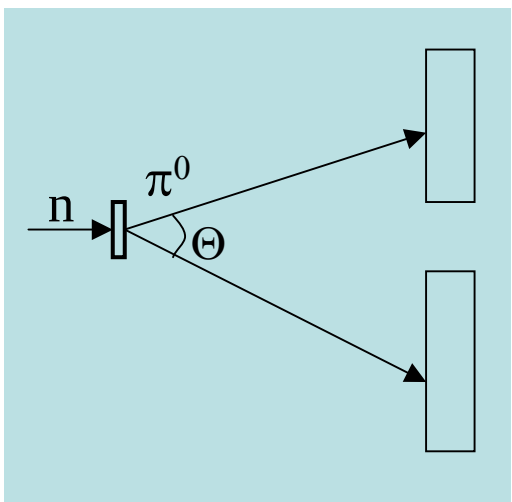
Engineering Run

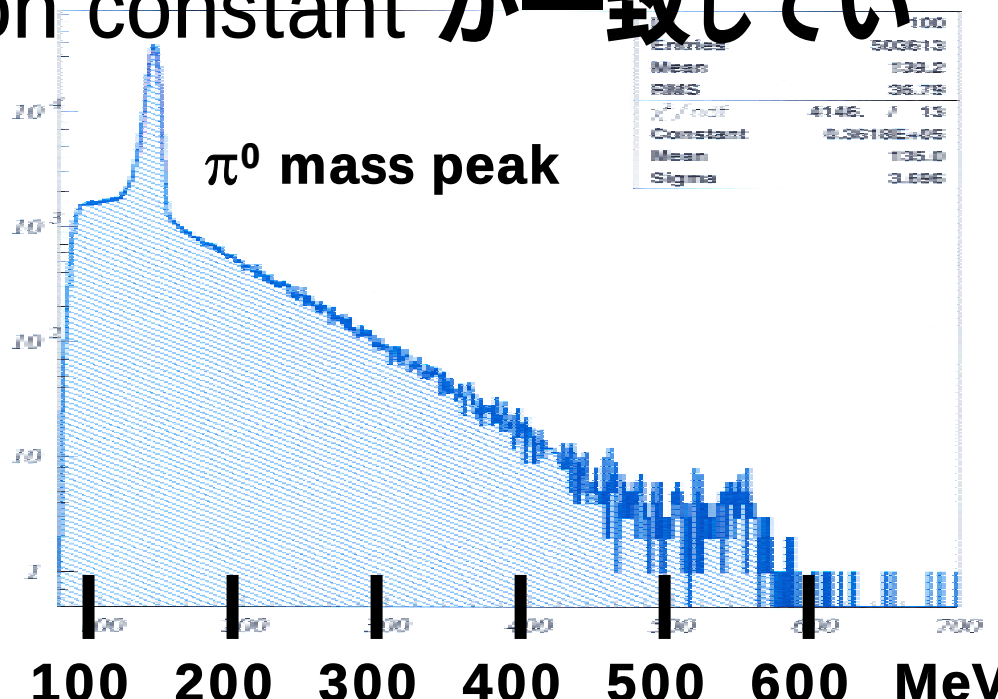
- Downstream section**だけでのテスト**Run
  - Detector calibration
  - Beam line**のチェック**(KL yield, momentum etc...)
  - DAQ/Electronics**のチェック**
  - **昨年12月に実験が行われて、いろいろな解析が行われてきた**

Calibration

- Muon (MIP)
  - Cosmic ray
  - Muon from upstream of the beam line
- Pi0 from target
- **3つの方法で** calibration constant **が一致している**

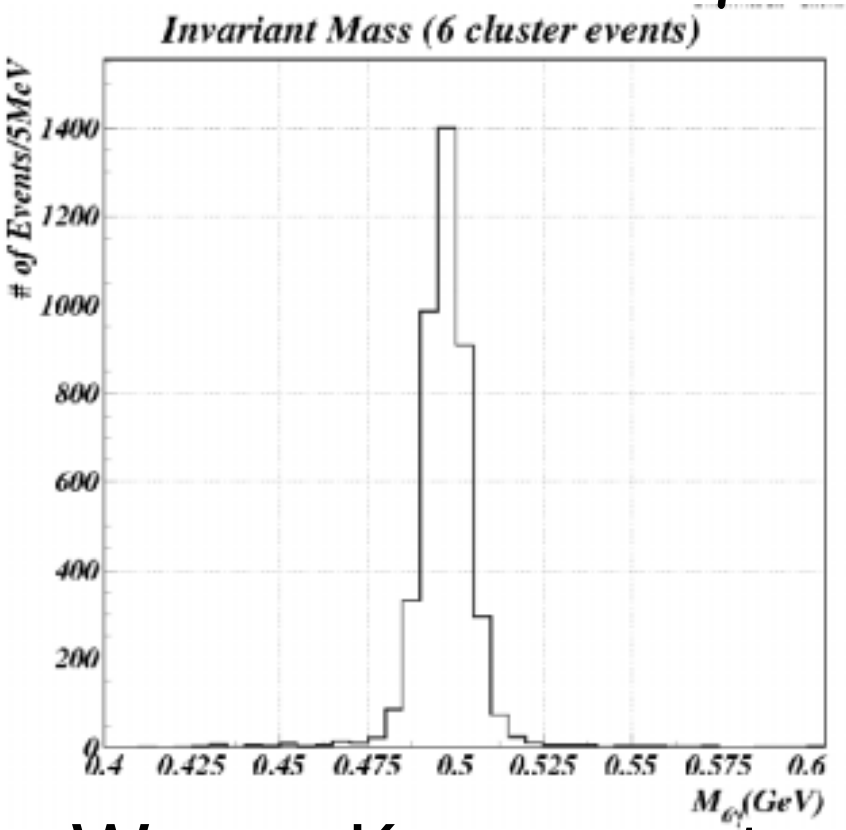


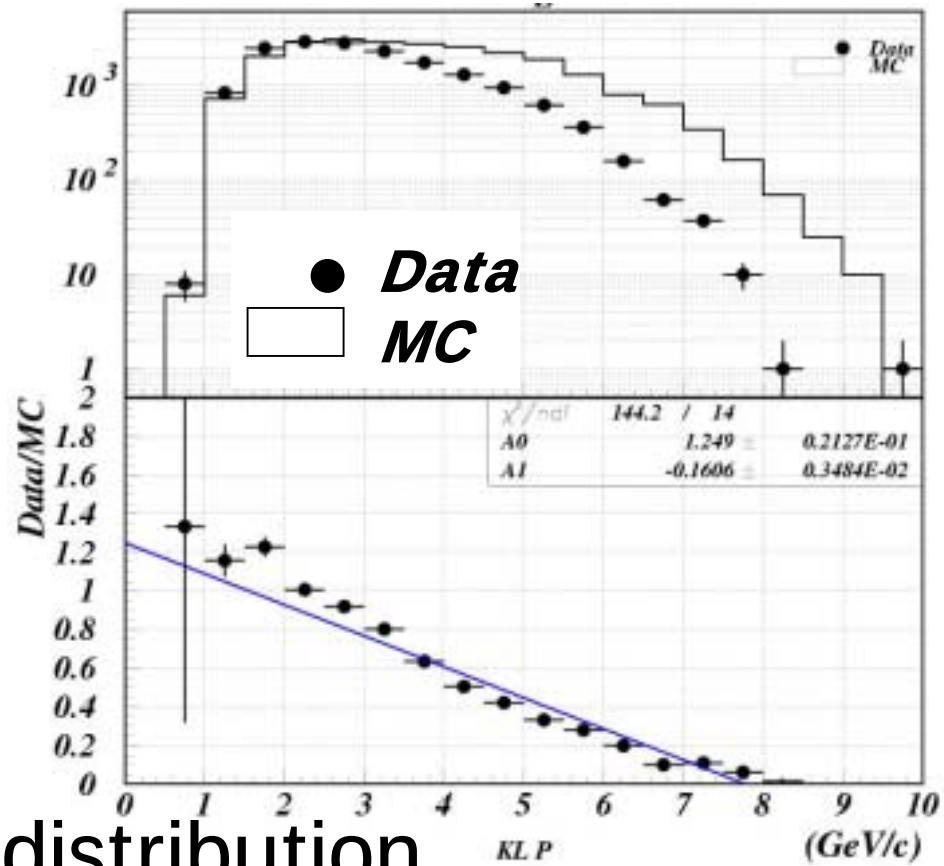




K_L->$3\pi^0$ Data vs MC

- Invariant mass of 6 γ # of KL Data/MC = 0.74





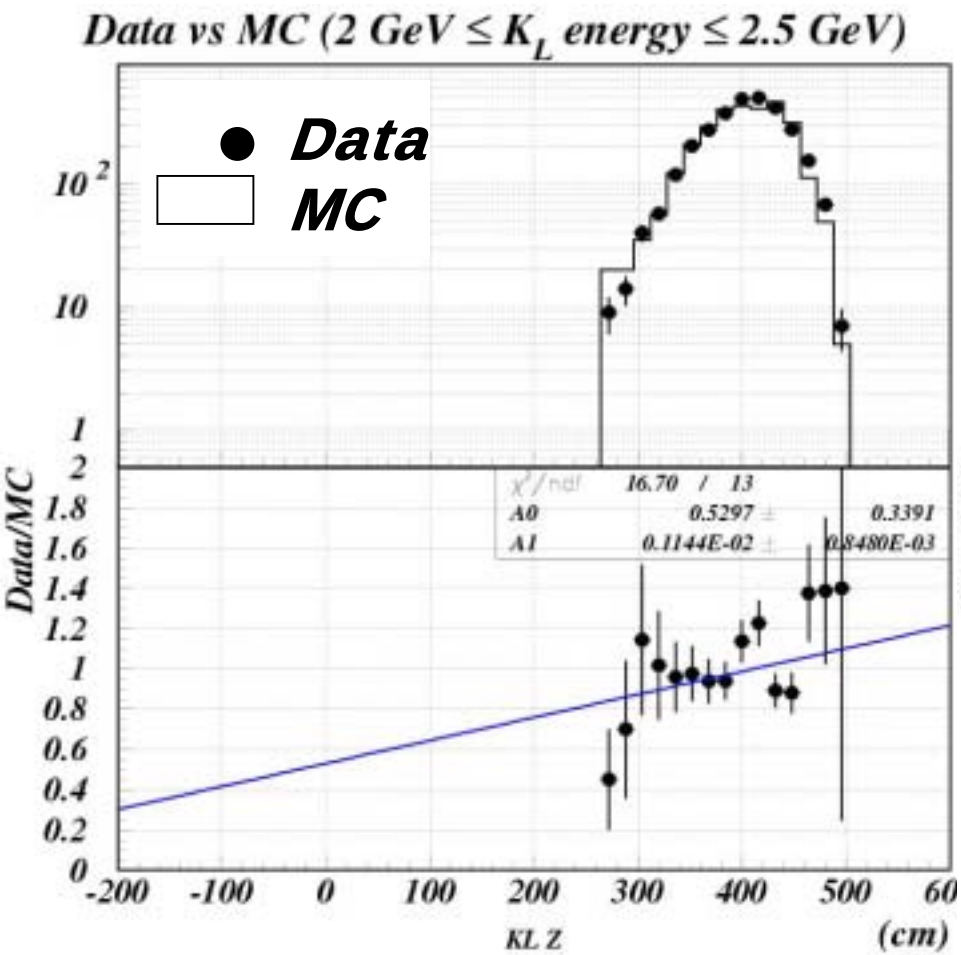
- Wrong K_L momentum distribution

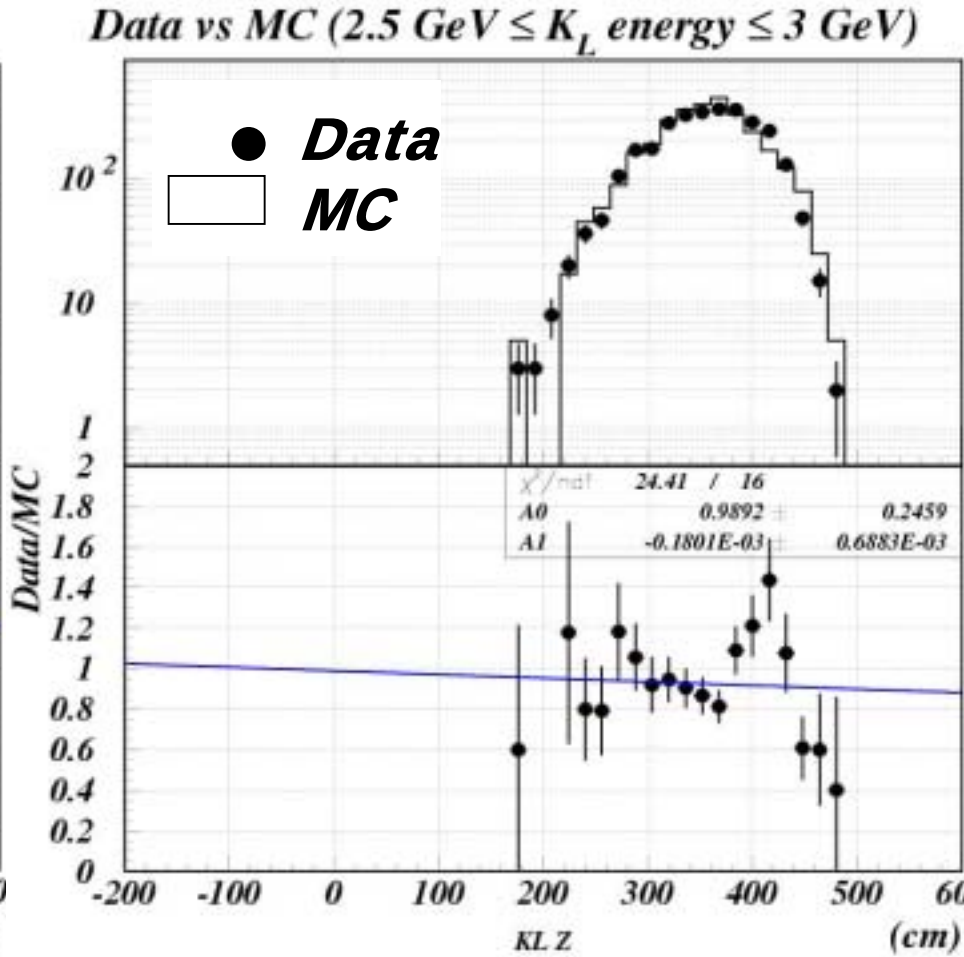
Is the problem due to **input K_L momentum** or **detector response** ?

➡ Compare in 0.5 GeV energy bin

$K_L \to 3\pi^0$ Data vs MC(0.5GeV E_{KL} bin)

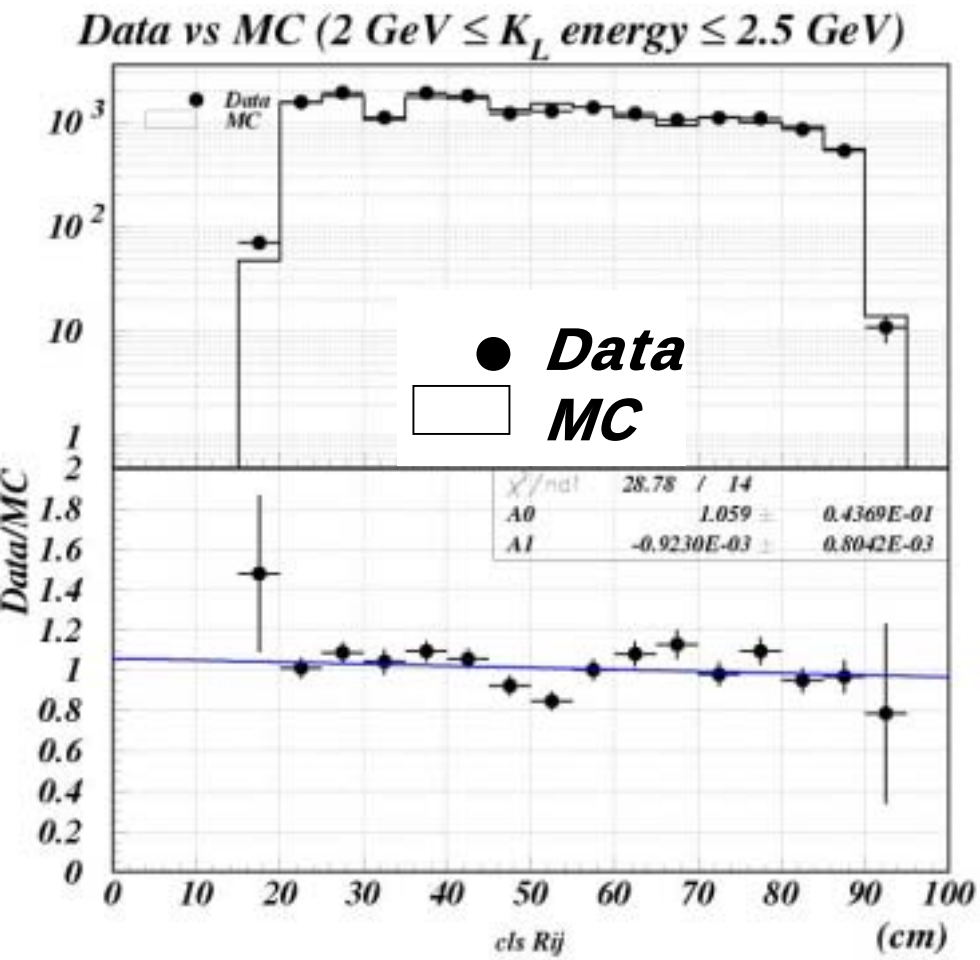
- Vertex Z distribution
  - Sensitive to energy response

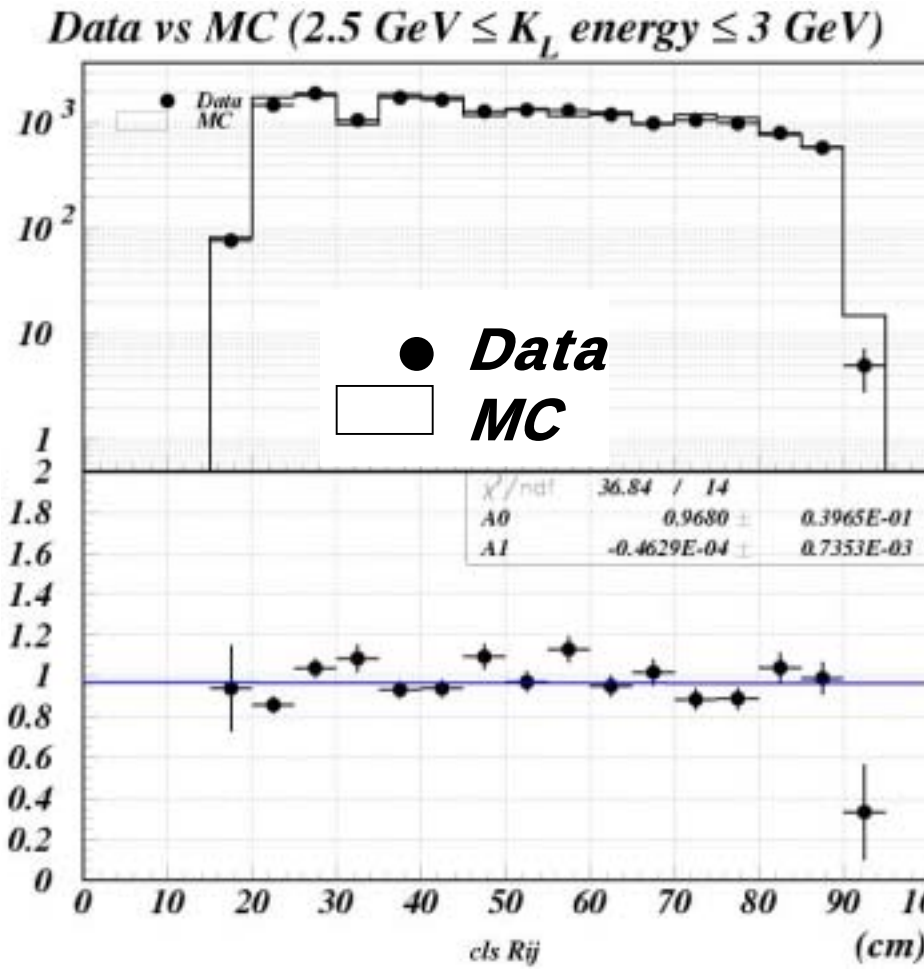




K_L->$3\pi^0$ Data vs MC(0.5GeV E_{KL} bin)

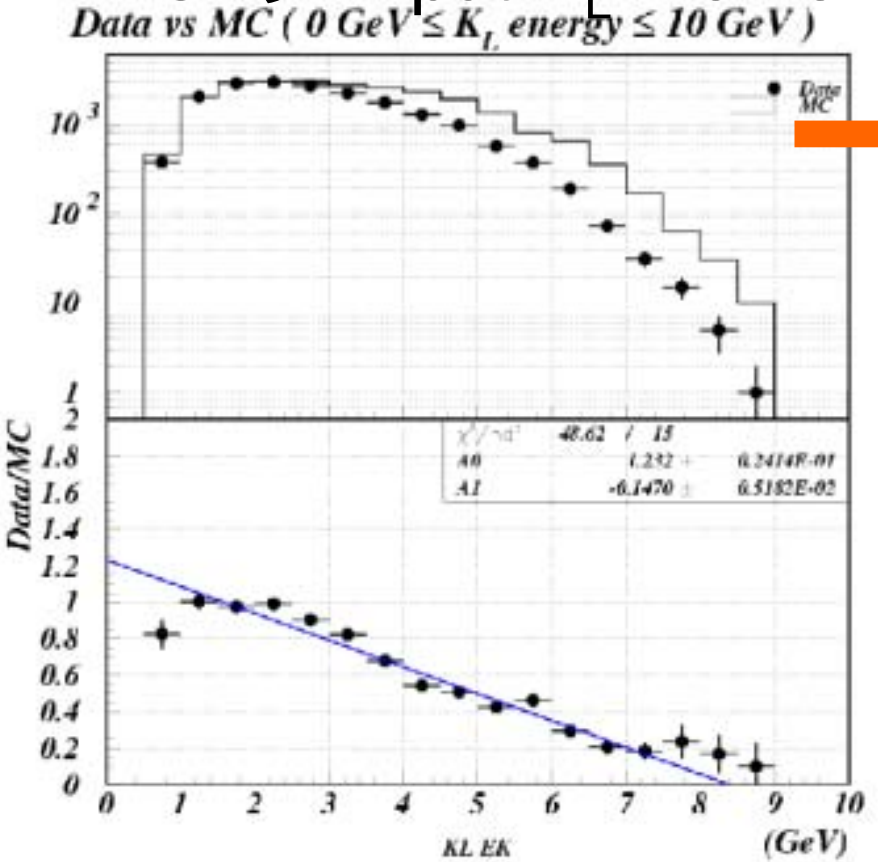
- Cluster Hit Position (distance from the center)
  - Sensitive to detector response

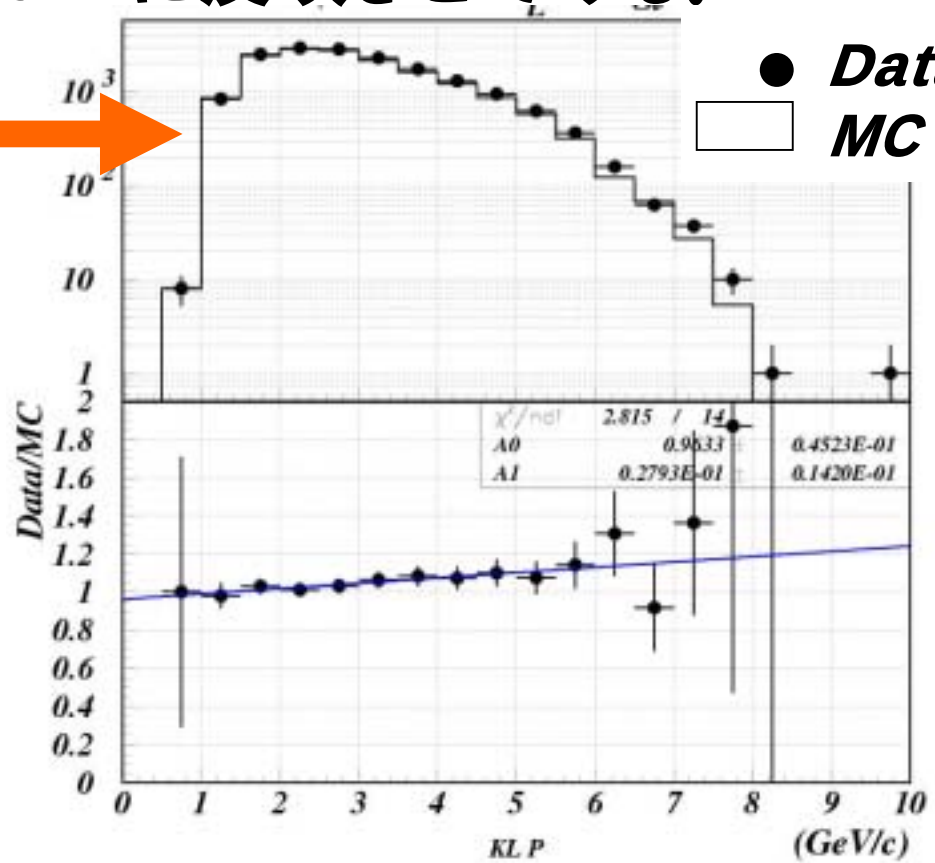




Reweighted input K_L momentum

- MCは、よく detector を再現しているように見える。
- 実験で得られた K_L momentum を、
  MC の input K_L momentum に反映させてみる。



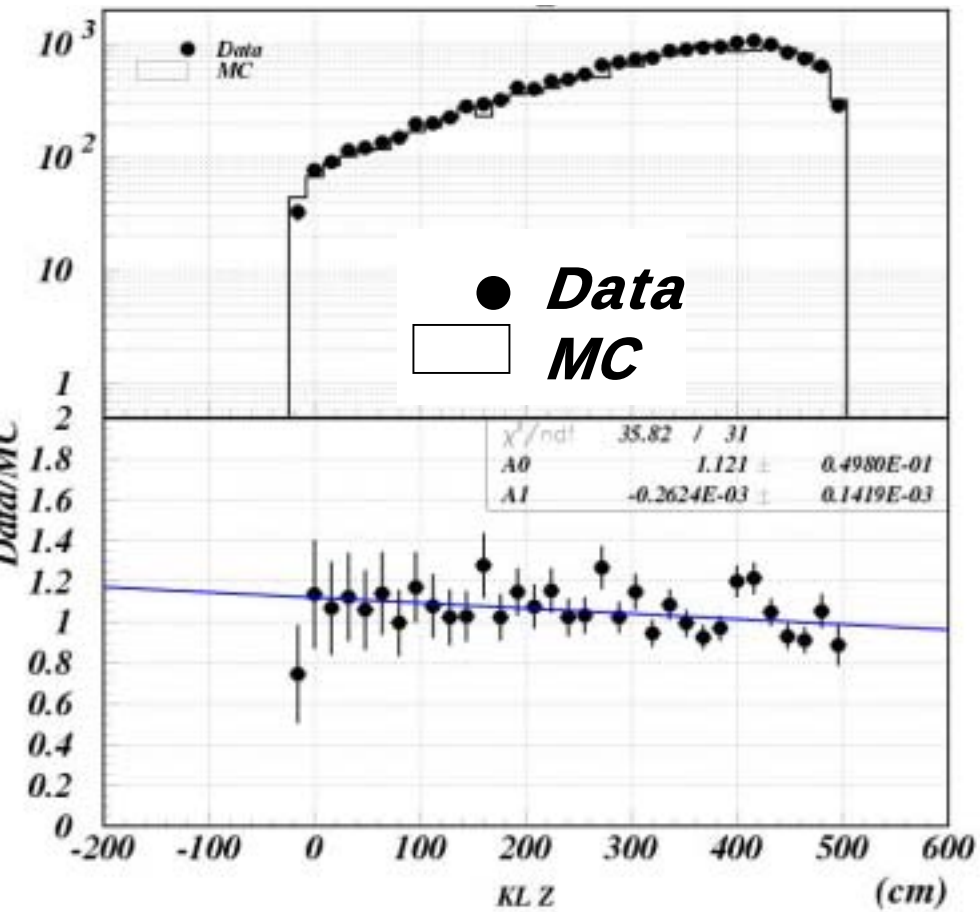


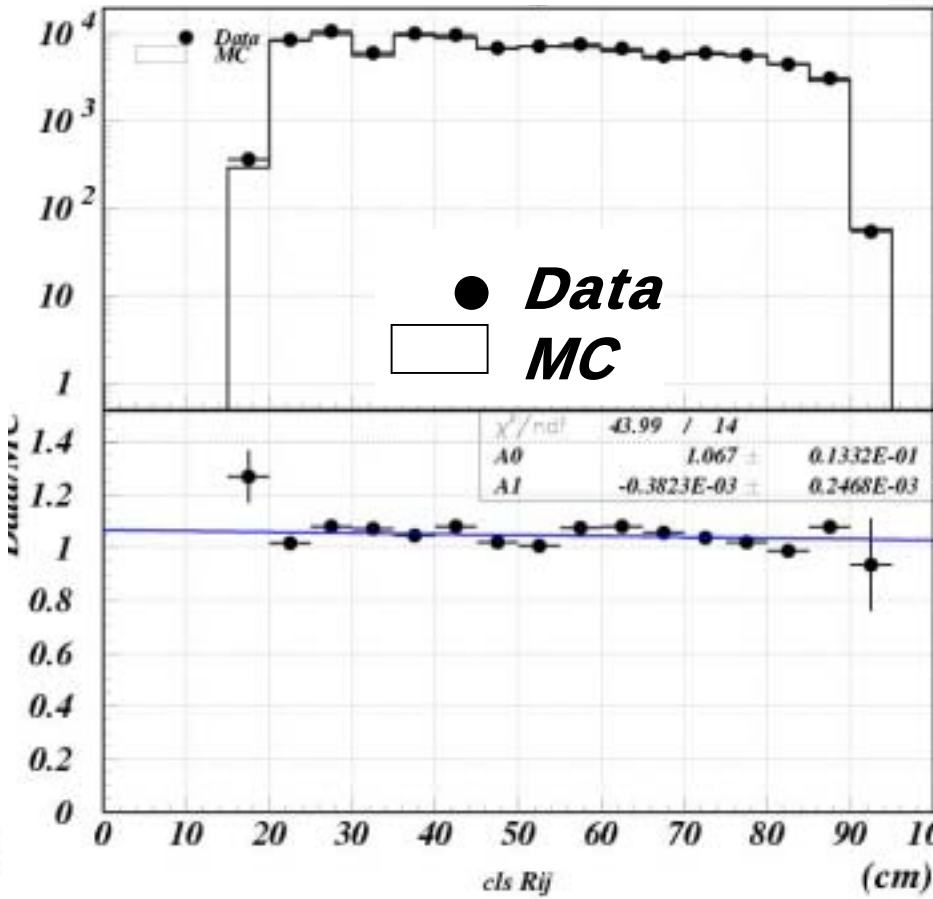
✓ K_L momentum is softer than estimated one.

✓ consistent with results of the Beam survey.

K_L ->$3\pi^0$ Data vs MC(reweighted)

- Vertex Z match well
- Cluster Hit position (R_{ij}) still match





Engineering Runのまとめ

- downstream section + 本番とほぼ同じDAQ/Electronics のセットアップで、大きな問題なくデータ収集ができた
- Amp-Discr-Sum moduleに問題が見つかったが、今年9月までに解決
- KL yield が予想よりも少なめ
  - Neutral beam lineのalignmentの精度を向上
  - Primary beam lineのoptimization
- その他、いくつか問題が見つかったが、全て対策済み
  - Replacement PMTs for CV etc...

Summary

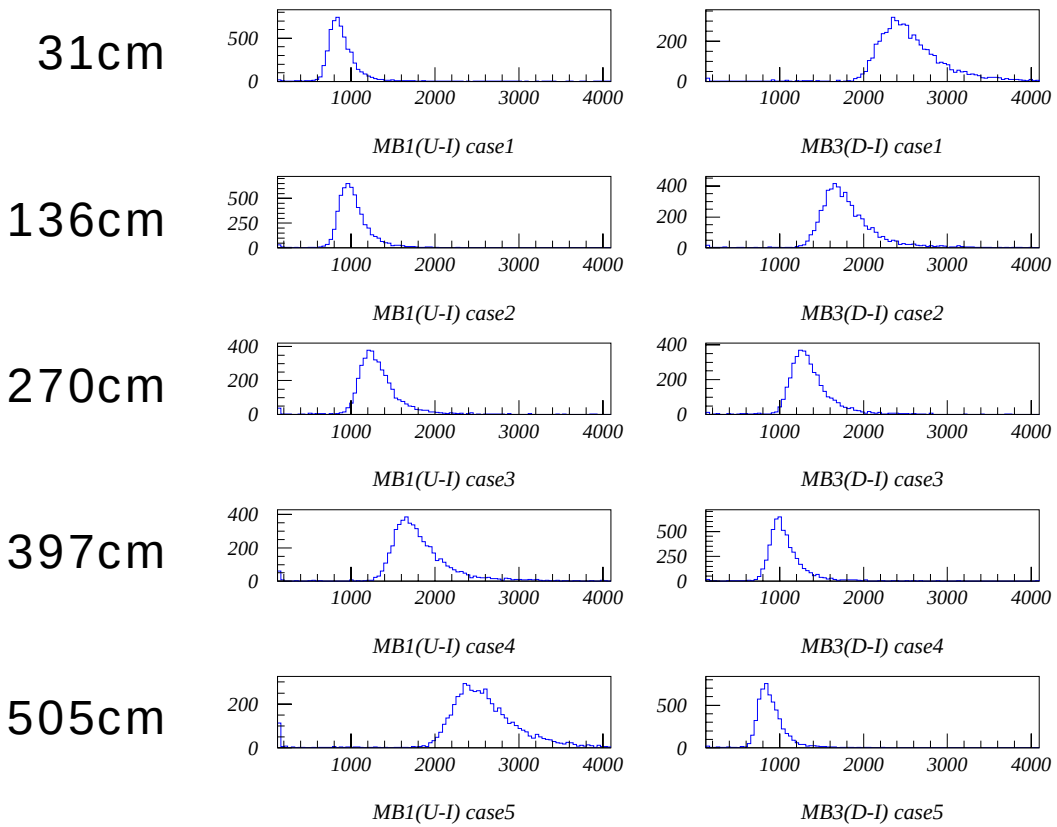
- First dedicated $K_L \rightarrow \pi^0\nu\bar{\nu}$ experiment
- **実験の準備は順調**
  - MainBarrelのPMT**取り付け**、cosmic test
  - 3 section**のドッキング**
  - **真空ひき (約1週間)**
- Engineering run
  - Detector/Beam line/DAQ/Electronics**のテスト**
  - **実験でわかった問題についていろいろと対策を行ってきた**
- **来年2月16日から実験開始**

予備OHPs

Middle section

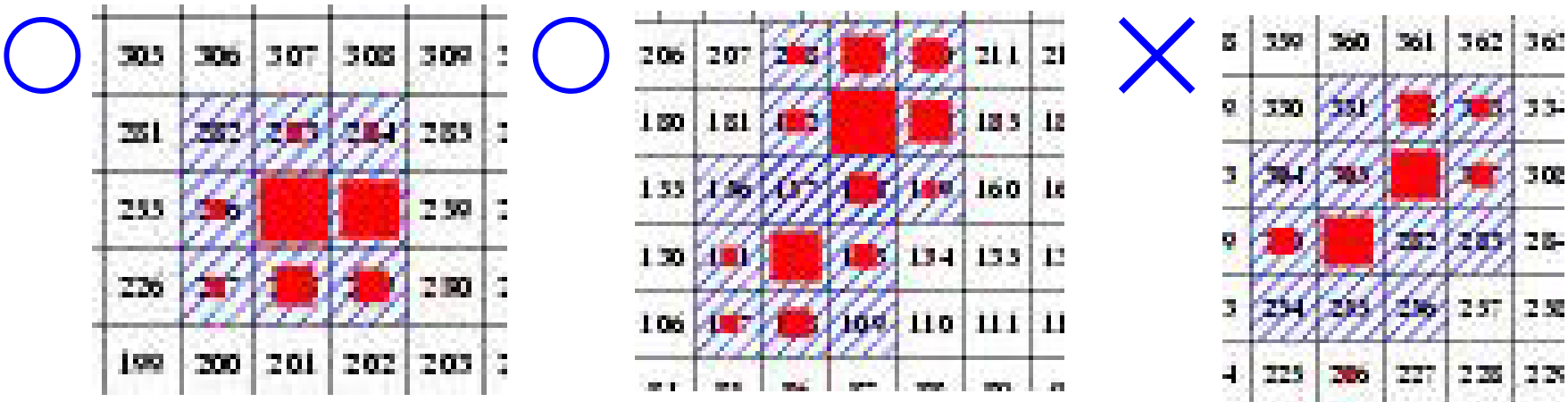
- MainBarrel
  - Lead/Scint. 13.5 X0
  - 5m

13.7 p.e./MeV @ 325cm from PMT



A Software Gamma clustering

- Method
  - Typically 3x3 crystals
    - Local maximum w/ threshold = 40MeV
    - Cluster position = C.O.E.
    - No angular correction
  - Correction of overlapping events
    - Check distance (d) of 2 cluster
    - If d < 7cm x $\sqrt{2}$ (= 9.9cm) 2 cluster -> 1 cluster
  - Shape-chi2 (compare to shower-lib.)



K_L->$3\pi^0$ Z reconstruction

1. Make 3 gamma pairs from 6 clusters
   - Reconstruct Z vertex by assuming Mπ^0 from 2γ
2. Calculate vertex chi square for 15 combinations of $3\pi^0$

$$\chi^2 = \sum_{i=1}^{N\pi^0} \frac{(avr.Z_i - Z_i)^2}{\sigma_{Z_i}^2}$$

3. Select best χ^2 combination for K_L candidate