KOTO Csl calorimeter

Sato Kazufumi (Osaka Univ.)

22 Avril in CHEF2013

contents

- what is KOTO?
- KOTO Csl calorimeter
- shower shape on Csl

what's KOTO?

$K_L \rightarrow \pi^0 \nu \overline{\nu}$

KOTO : **Br(K_L\rightarrow \pi^{0}\nu\nu)** measurement in Japan

in SM, CP violation is caused by imaginary part of CKM matrix elements

$Br(K_L \rightarrow \pi^0 \nu \bar{\nu}) \propto |Im(V_{td})|^2$

 \cancel{x} theoretical uncertainty : I ~2% only

d

t

⇒sensitive to new physics beyond SM

☆ SM expectation : **Br(K_L→π⁰νν)=3e-II**

upper limit = 2.6e-8 (90% CL) by KEK E391A ⇒ high intensity K_L beam @ J-PARC

strategy Csl K_L • Only 2 γ s from π^0 are observable • $K_L \rightarrow \pi^0 \nu \nu$ has an unique final state

 $2\gamma + Pt$



strategy



KOTO detector Csl calorimeter



← decay region

5m

z=0m 3m

llm

gamma energy



γ energy [MeV]

KOTO Csl calorimeter

Csl calorimeter

- diameter :1.9m
- consist of 2716 crystals
 - used in KTeV exp. at Fermilab
 - undoped Csl
- •length:50cm(= $27X_0$)
 - →ensure good energy resolution = good π^0 reconstruction
 - cross section: 2.5x2.5cm, 5x5cm
 - smaller than R_M (=3.57cm)
 - → shower shape information

Csl calorimeter resolution

• measured using electrons from $K_L \rightarrow \pi e \nu$ decay in 2012, before installing veto detectors



Csl calorimeter resolution

• tested using electrons from $K_L \rightarrow \pi e \nu$ decay in 2012, before installing veto detectors



E/p width



Csl calorimeter resolution E resolution



subtract the contribution of materials and spectrometer resolution

electron momentum [MeV]

$\sigma_{\rm E}/E = 1.9\%/\sqrt{E[GeV]}$

pos. resolution



position resolution

pos. resolution



subtract the contribution of materials and spectrometer resolution

electron momentum [MeV]

 $\sigma_x \text{[mm]} = 1.8 + 2.8 / \sqrt{E[GeV]} + 1.73 / E[GeV]$

Shower Shape Information

fusion BG discrimination

• Y angle discrimination



fused cluster

fused cluster



single photon cluster





$$\chi^2 = \sum_{CsI} \left(\frac{E_{measured} - E_{simulated}}{RMS_{simulated}}\right)^2$$

fusion BG suppression



90% BGs are rejected with 85% signal acceptance

Y angle from shower shape

can derive γ incident angle from shower shape

 $\theta = 10 \deg$



 θ = 30 deg



$\begin{array}{ll} \eta \ background \\ \text{ex) beam neutron interacts} \\ \text{with material} \ \Rightarrow \ \eta \rightarrow 2\gamma \end{array}$





likelihood

calculate Likelihood for each assumption ($L_{\pi,}L_{\eta}$)

$$L_{i} = \prod_{j;\gamma} \prod_{x,y} \prod_{k;row} P(e_{k}|E_{j}, d_{k}, \theta_{ij}, \phi_{j})$$

$$(i=\pi, \eta)$$

PDFs are prepared for various E, Φ , θ



likelihood ratio apply cut for likelihood ratio L_{π^0} $\overline{L_{\pi^0} + L_{\eta}}$ η BG rejection -**†**--0.99 black: π⁰νν 0.98 10⁻¹ red: n 0.97 0.96 10⁻² 0.95 0.94 10⁻³ 0.93 0.92 10⁻⁴ 0.91 0.9^上⊥ 0.6 0.65 07 0.75 0.8 0.85 0.9 0.95 0.5likelihood ratio signal acceptance

94% of η BGs can be rejected with 90% efficiency

summary

- KOTO = measurement for $K_L \rightarrow \pi^0 vv$
 - observe 2γ from π^0 with the CsI calorimeter
- beam test in 2012
- $\sigma_{\rm E}/{\rm E} = 1.89\%/\sqrt{\rm E[GeV]}$

 $\sigma_x \text{[mm]} = 1.8 + 2.8 / \sqrt{E[GeV]} + 1.73 / E[GeV]$

- shower shape information is useful
 - shape chi2
 - $2\pi 0$ fusion BG $\rightarrow x 1/10$ (85% signal acc.)
 - angle discrimination
 - $\eta BG \rightarrow x I/20$ (90% signal acc.)

back up

ene. and pos. resolution

E resolution



source of energy (MC study)



FADC ground noise

• FADC pedestal fluctuates due to ground noise (σ ~2.05cnt) = ~ 0.2MeV



RMS of ground noise



pi0 reconstruciton







clustering procedure

clustering









η backgrounds

impact of angle discrimination



MC reproduction



Al target run in E391A

Probability Density Function prepare PDF for each incident angle



$$L_{i} = \prod_{j;\gamma} \prod_{x,y} \prod_{k;\text{row}} P(e_{k}|E_{j}, d_{k}, \theta_{ij}, \phi_{j})_{j}$$



likelihood ratio

apply cut for likelihood ratio



95% of 20° difference can be separated with 90% efficiency

shape chi2