KEK PSでの $K_L^0 \to \pi^+\pi^- e^+ e^-$ の探索V

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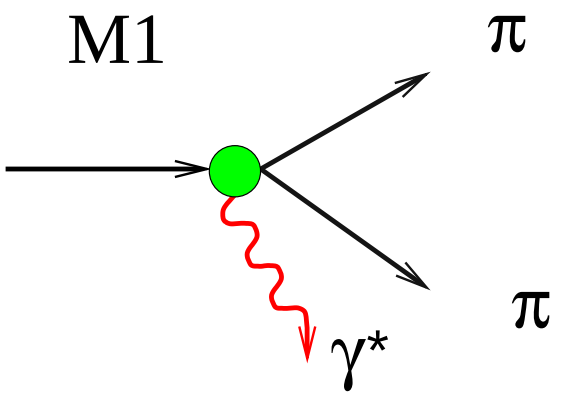
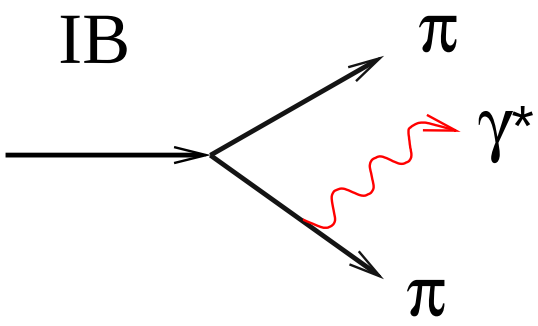
Physics Motivation

direct magnetic dipole transition



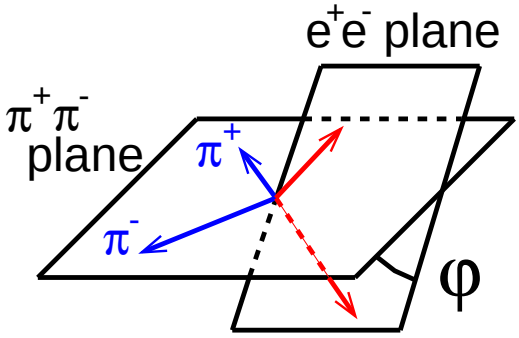
CP odd

Internal Bremsstrahlung



CP even

$Br \cong 3 \times 10^{-7}$ (Theory)



$$\frac{d\Gamma}{d\varphi} = \Gamma_1 \cos^2\varphi + \Gamma_2 \sin^2\varphi + \Gamma_3 \sin\varphi\cos\varphi$$

$$A \equiv \frac{\int_0^{\pi/2} \frac{d\Gamma}{d\varphi} d\varphi - \int_{\pi/2}^{\pi} \frac{d\Gamma}{d\varphi} d\varphi}{\int_0^{\pi/2} \frac{d\Gamma}{d\varphi} d\varphi + \int_{\pi/2}^{\pi} \frac{d\Gamma}{d\varphi} d\varphi} \sim 14\%$$

Experimental Status

- $Br < 4.6 \times 10^{-7}$ ($M_{ee} \geq 4MeV$, 90%CL)

  KEK-E162

  T.Nomura *et al.* ,Phys. Lett. B408,445(1997)

- $Br = [3.2 \pm 0.6 \pm 0.4] \times 10^{-7}$

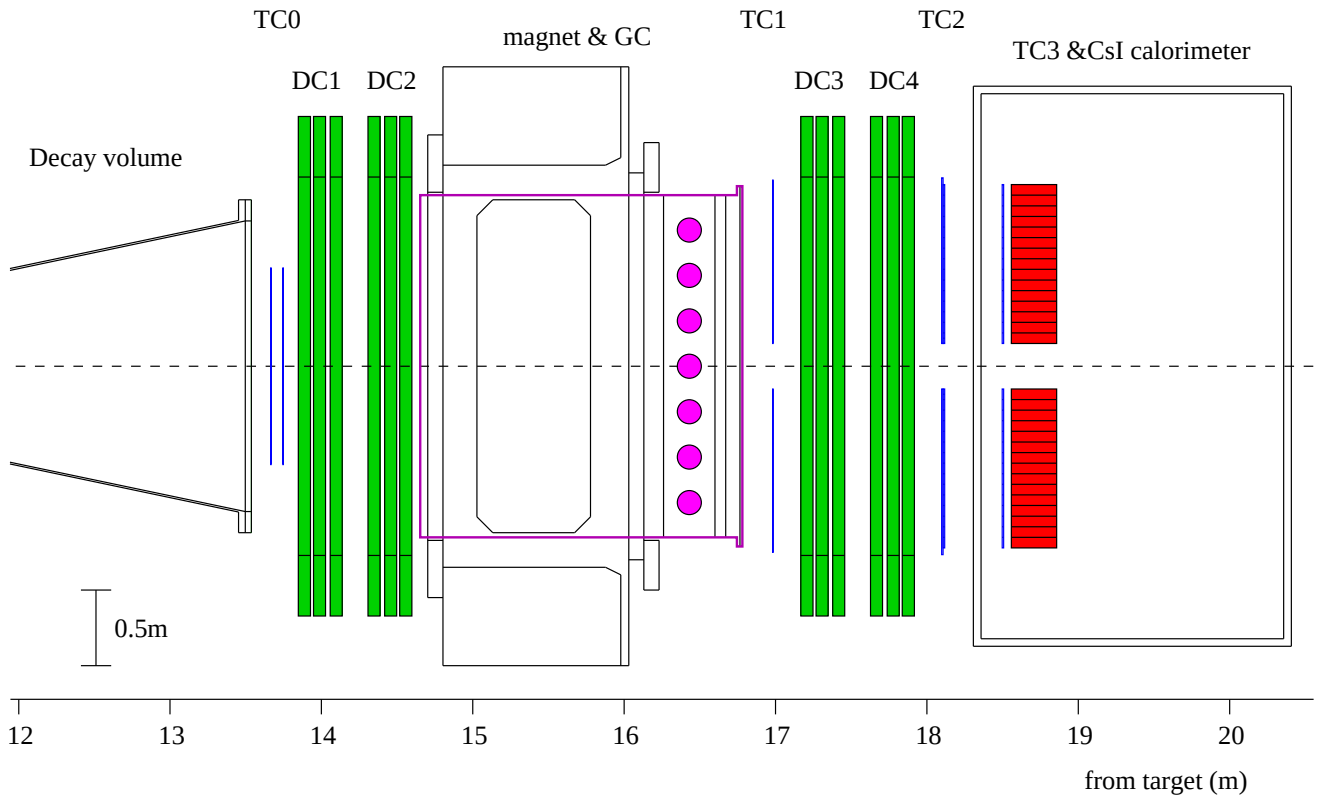
  46 candidates observed

  KTeV(E799-II)

  J.Adams *et al.* ,Phys. Rev. Lett. 80,4123(1998)

E162/CP Setup

<plan view>



Trigger

Level 1 (NIM logic)

N(calorimeter columns,Esum ≥ 300MeV) ≥ 2

(≥ 1 in each bank)

N(GC hits) ≥ 2

N(tracks) ≥ 3

Level 2 (Hardware Processor)

Coarse Tracking Processor

N(e-candidates) ≥ 2 (≥ 1 in each arm)

N(tracks) ≥ 3

Cluster Finding Processor

N(clusters associated with track) ≥ 2

(≥ 1 in each arm)

2本以上の electron like を含む track が 3 本以上

Offline Analysis

Basic Event Selection

--- require $\pi^+\pi^-e^+e^-$ with common vertex

in beam region in decay volume

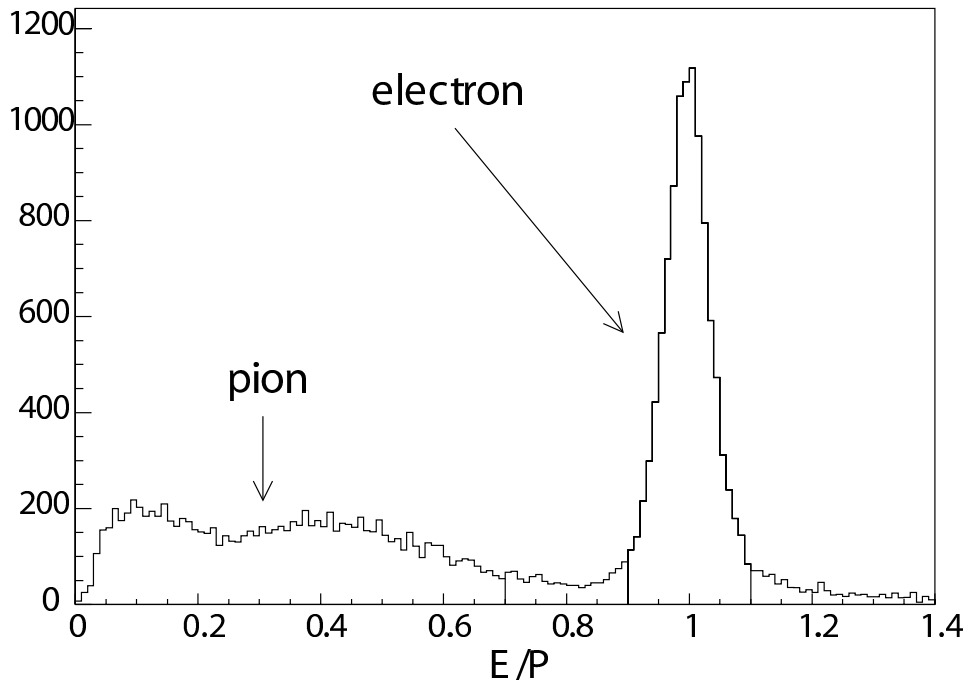
N (π-candidates) = 2 (both charge)

matched track & E/p < 0.7

N(e-candidates) = 2 (both charge)

matched track & 0.9 $\leq$ E/p $\leq$ 1.1 & GC hit

$E_{cluster} \geq$ 200MeV, on-time cut ($\pm$3.5ns window)



Normalization process

$$K_L \to \pi^+\pi^-\pi^0 \hookrightarrow e^+e^-\gamma \qquad \left[K_L \to \pi^+\pi^-\pi^0_D\right]$$

Event Identification

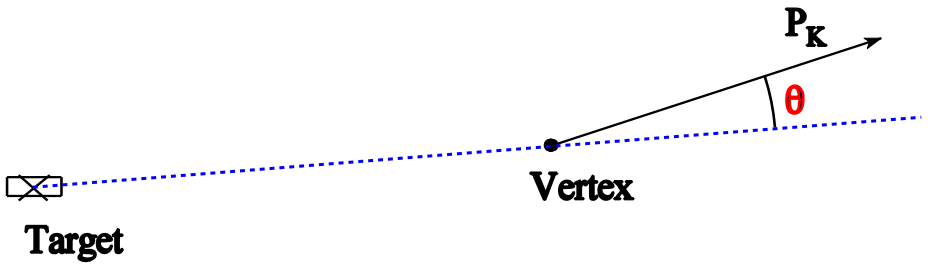
$E_{\gamma\text{-cluster}} \geq 200\text{MeV}$ が存在

signal box (3σ相当)

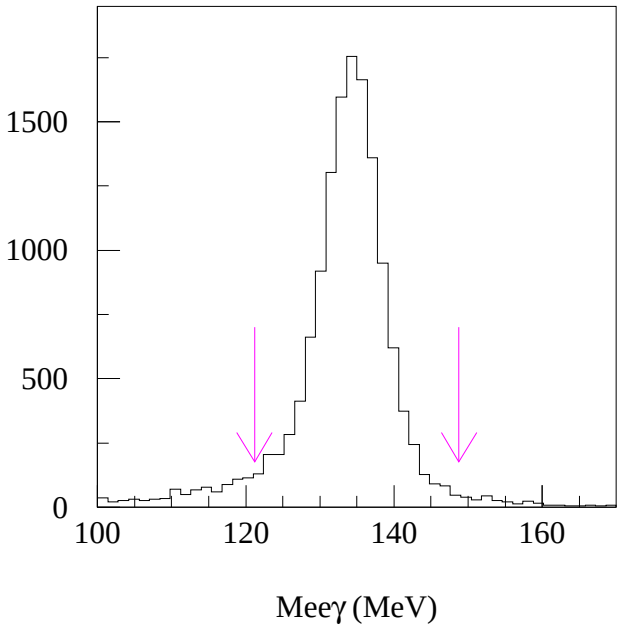
$$|M_{e^+e^-\gamma} - M_{\pi^0}| < 13.8 \text{ MeV}$$

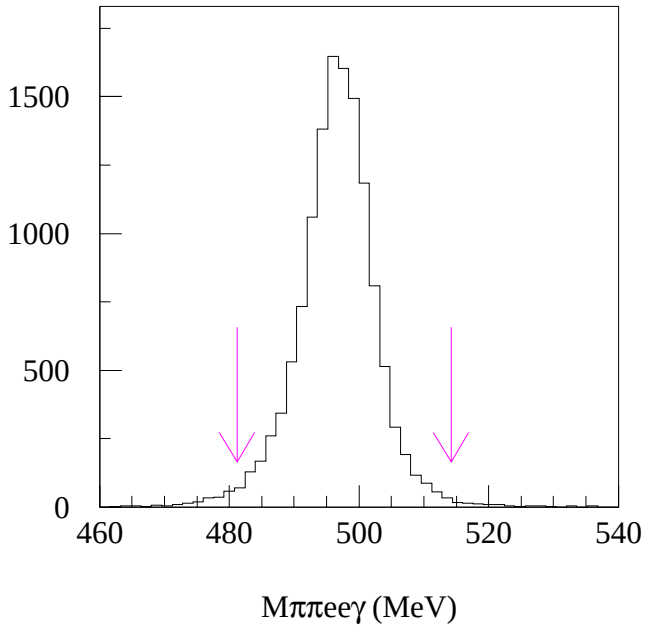
$$|M_{\pi^+\pi^-e^+e^-\gamma} - M_{K_L}| < 16.5 \text{ MeV}$$

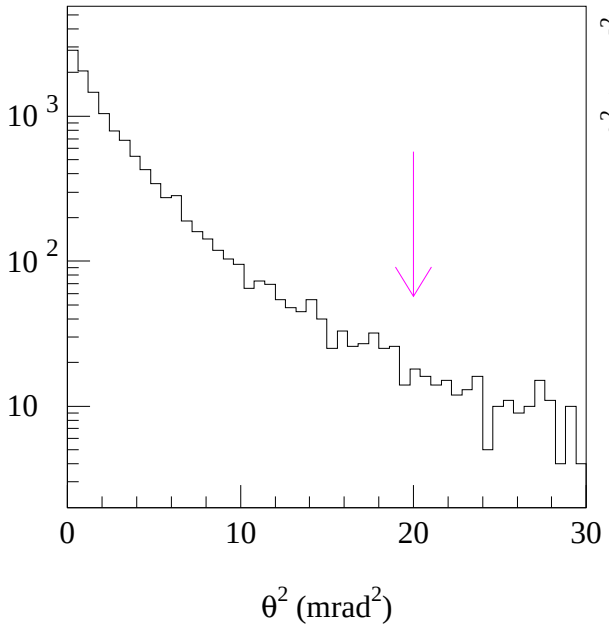
$$\theta^2 < 20 \text{ mrad}^2$$

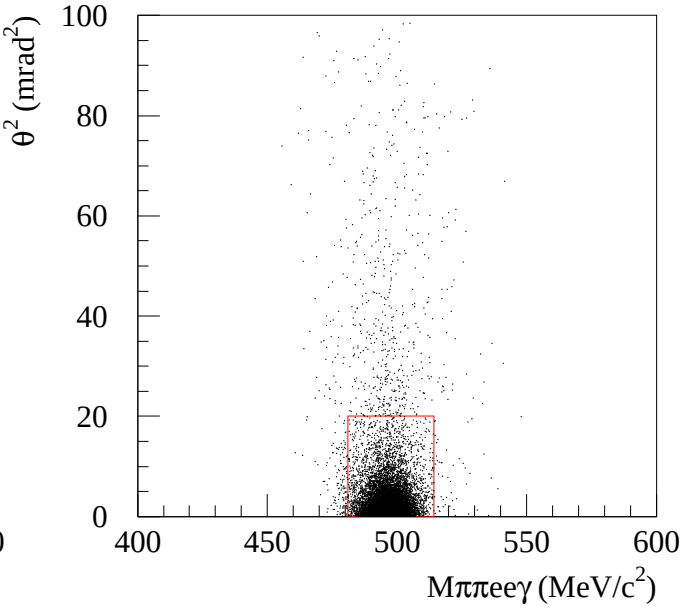


Reconstructed $K_L \rightarrow \pi^+\pi^-\pi^0$(D)









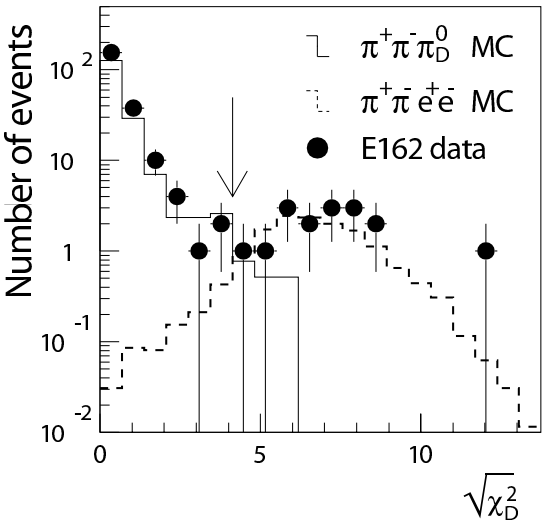
Signal mode $K_L^0 \to \pi^+\pi^- e^+ e^-$ Analysis

1. To reject $K_L \to \pi^+\pi^-\pi^0_D$ reconstructed events

   and (π^0-inclusive) Nuclear interaction events

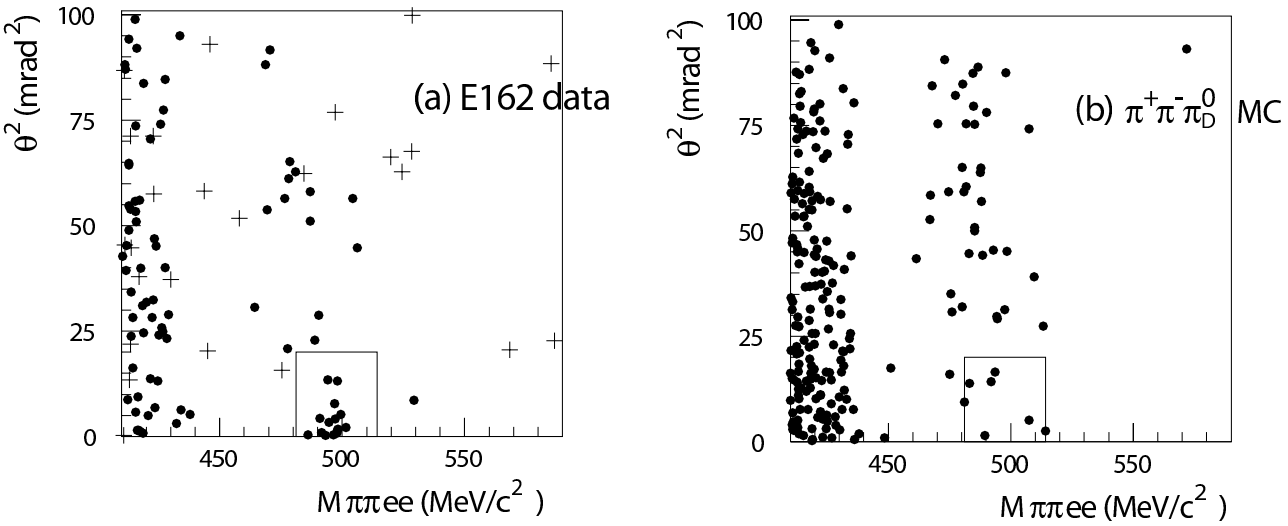
2. To reject $K_L \to \pi^+\pi^-\pi^0_D$ ($\pi^0 \to ee\gamma$)

   γ: not detected



Background subtraction and Final signal

After all cuts



- Vacuum data

  Background $\pi^+\pi^-\pi^0_D$ MC consistent

- Helium data

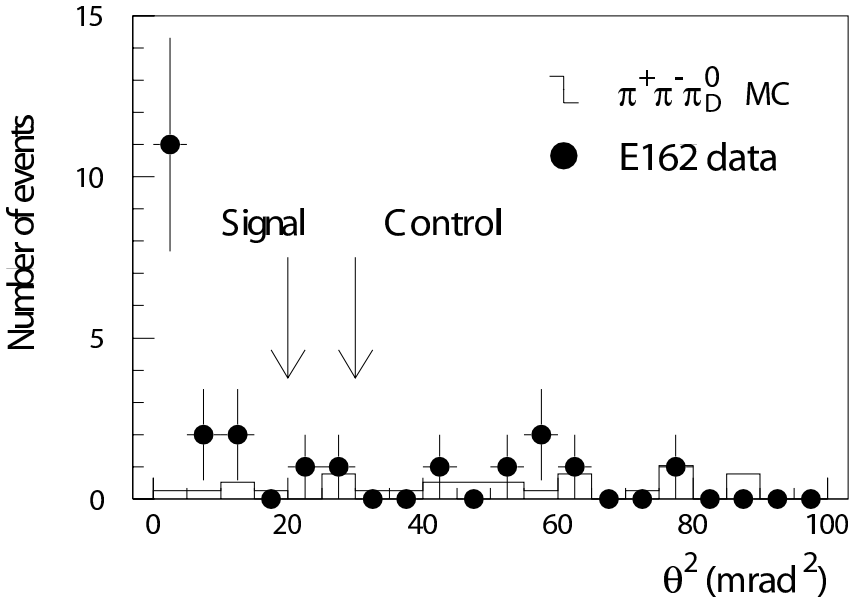
  $M_{\pi\pi ee}$ θ^2 Background

  Nuclear interaction events

  Background $\pi^+\pi^-\pi^0_D$ Nuclear interaction

  θ^2 flat

Projection onto θ^2-axis $|M_{\pi^+\pi^-e^+e^-} - M_{K_L}| < 3\sigma_K$



- Data

  $\theta^2=0$ signal peak

  θ^2 flat background

- Control region $30 \leq \theta^2 \leq 100$ mrad^2

- Control region $\pi^+\pi^-\pi^0_D$ MC normalize

  Estimated background in the signal region 1.5 ± 1.0

- final signal events

  15 - 1.5 = 13.5 ± 4.0

Branching ratio and Systematic error

$$\mathrm{Br}(K_L \to \pi^+\pi^- e^+ e^-) = \mathrm{Br}(K_L \to \pi^+\pi^-\pi^0_D) \times \frac{A(\pi^+\pi^-\pi^0_D)}{A(\pi^+\pi^- e^+ e^-)} \times \frac{\eta(\pi^+\pi^-\pi^0_D)}{\eta(\pi^+\pi^- e^+ e^-)} \times \frac{N(\pi^+\pi^-\pi^0_D)}{N(\pi^+\pi^- e^+ e^-)}$$

Summary of systematic errors

Source	% uncertainty
K_L momentum spectrum	4.8%
Matrix element	3.9%
Others	3.1%
Background subtraction	7.4%
Nuclear interaction	3.6%
Other contamination	1.4%
$\mathrm{Br}(K_L \to \pi^+\pi^-\pi^0_D)$	3.1%
Total	11.3%

$$\mathrm{Br}(K_L \to \pi^+\pi^- e^+ e^-) = [\ 4.4 \pm 1.3\ (\mathrm{stat.}) \pm 0.5\ (\mathrm{syst.})\ ] \times 10^{-7}$$

Conclusion

- Experimental Search for the Decay Mode

  $K_L^0 \rightarrow \pi^+\pi^- e^+ e^-$

- Data sets

  Helium data('96)

  Vacuum data('97)

- Observed events

  N(signal) = 13.5 ± 4.0

- Branching ratio

  $Br = [4.4 \pm 1.3(stat.) \pm 0.5(syst.)] \times 10^{-7}$

  consistent with

  $Br = 3\times10^{-7}$ (theoretical prediction)

  $Br = [3.2 \pm 0.6 \pm 0.4] \times 10^{-7}$ (KTeV)