New Results from KTeV on CP Violation

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- Direct CP violation in $K \to \pi\pi$ decays
- $K_L \to \pi^+\pi^-e^+e^-$ angular asymmetry
- BR limits for $K_L \to \pi^0 e^+e^-$, $K_L \to \pi^0 \nu\overline{\nu}$

Summary of CP Violation in $K \to \pi\pi$ Decays

Understand K decay from CP eigenstates

$$K_1 \equiv (K^0 + \overline{K}^0)/\sqrt{2} \qquad CP\ +1$$
$$K_2 \equiv (K^0 - \overline{K}^0)/\sqrt{2} \qquad CP\ -1$$

$K_L \to \pi\pi$ has two contributions

$$K_L = \overset{CP\,-1}{K_2} + \epsilon\, \overset{CP\,+1}{K_1}$$

"Direct" in decay process ϵ'

"Indirect" from asymmetric K^0–$\overline{K}^0$ mixing

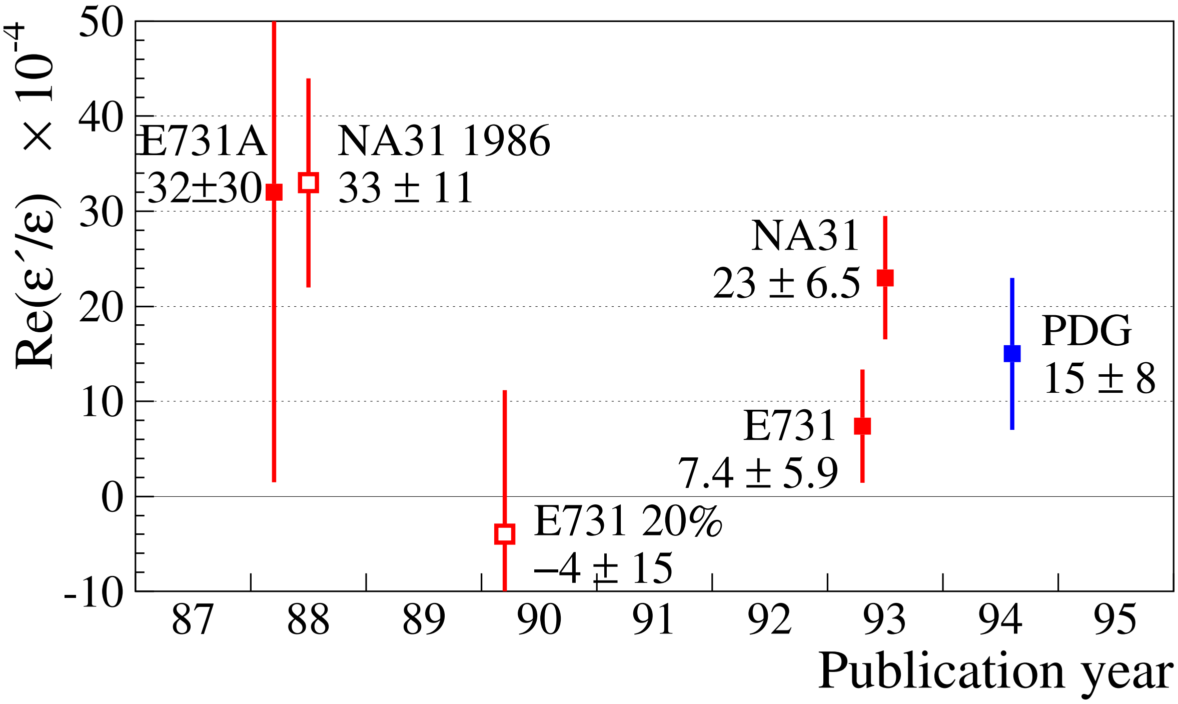
$$\underset{CP\,+1}{\pi\pi}$$

"Direct" contribution is different for $\pi^+\pi^-$ vs. $\pi^0\pi^0$

$$\text{define } R \equiv \frac{\Gamma(K_L \to \pi^+\pi^-)\ /\ \Gamma(K_S \to \pi^+\pi^-)}{\Gamma(K_L \to \pi^0\pi^0)\ /\ \Gamma(K_S \to \pi^0\pi^0)}$$

$$\Rightarrow \quad Re(\epsilon'/\epsilon) \approx (R-1)\ /\ 6$$

Previous Measurements of $Re(\epsilon'/\epsilon)$



First KTeV result: error $\sim 4 \times 10^{-4}$

Ultimate KTeV goal: error $\sim (1 \text{ to } 2) \times 10^{-4}$

Theoretical Predictions for $Re(\epsilon'/\epsilon)$

Some recent Standard Model calculations:

$Re(\epsilon'/\epsilon) = (4.6 \pm 3.0 \pm 0.4) \times 10^{-4}$ (Ciuchini Jan 97)

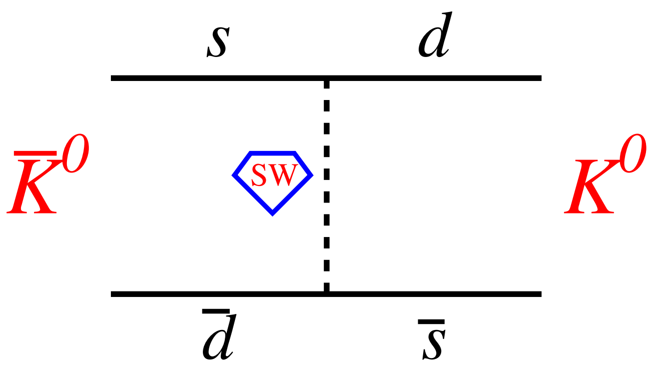
$(5.7 \pm 3.6) \times 10^{-4}$ $m_s = 130 \pm 20$ MeV

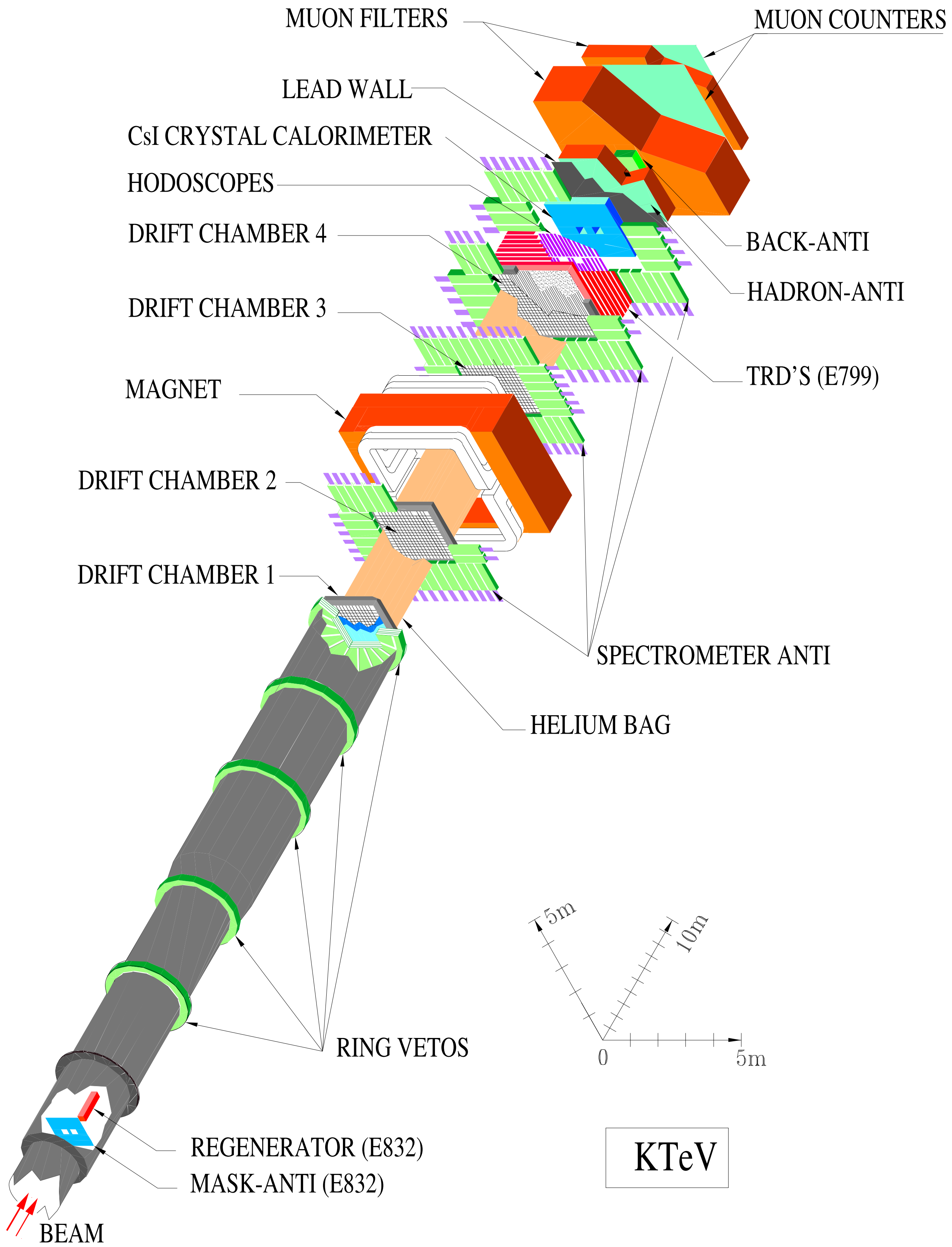
$(9.1 \pm 5.7) \times 10^{-4}$ $m_s = 110 \pm 20$ MeV

(Buras Jan 99)

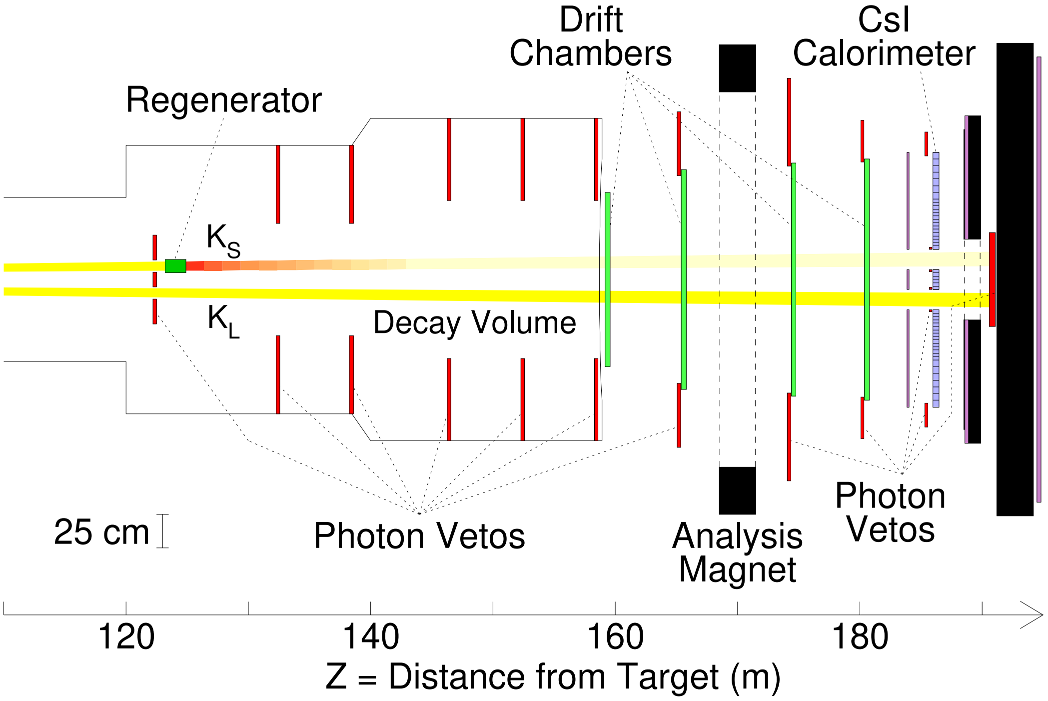
$(17\ {}^{+14}_{-10}) \times 10^{-4}$ (Bertolini Feb 98)

A "superweak" $\Delta S = 2$ interaction could contribute to ϵ, but would give $Re(\epsilon'/\epsilon) = 0$

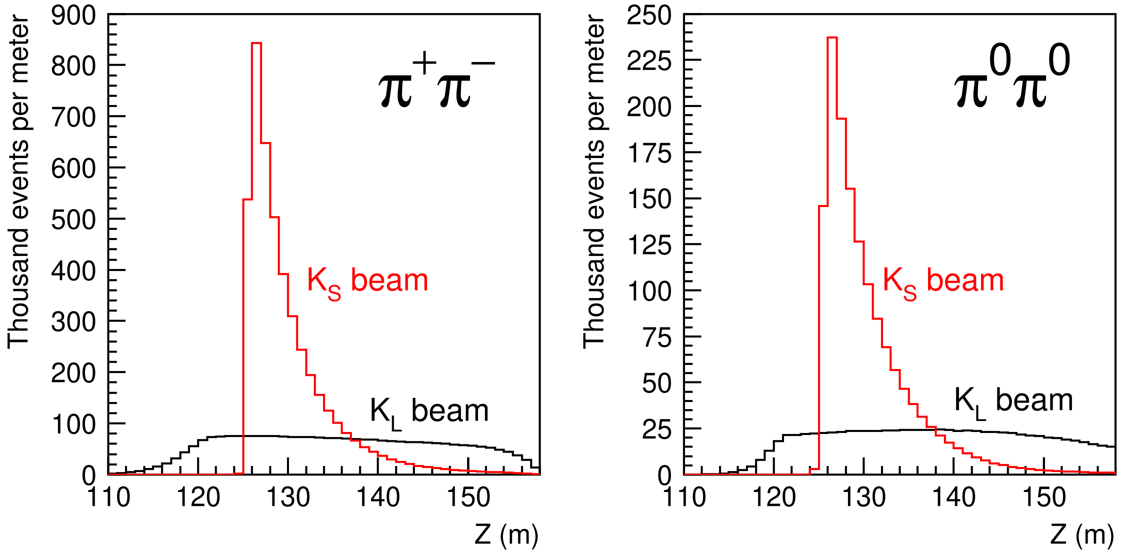



MUON FILTERS
MUON COUNTERS
LEAD WALL
CsI CRYSTAL CALORIMETER
HODOSCOPES
DRIFT CHAMBER 4
BACK-ANTI
HADRON-ANTI
DRIFT CHAMBER 3
TRD'S (E799)
MAGNET
DRIFT CHAMBER 2
DRIFT CHAMBER 1
SPECTROMETER ANTI
HELIUM BAG
5m
10m
0
5m
RING VETOS
REGENERATOR (E832)
MASK-ANTI (E832)
KTeV
BEAM

Collect K_L and K_S Decays Simultaneously

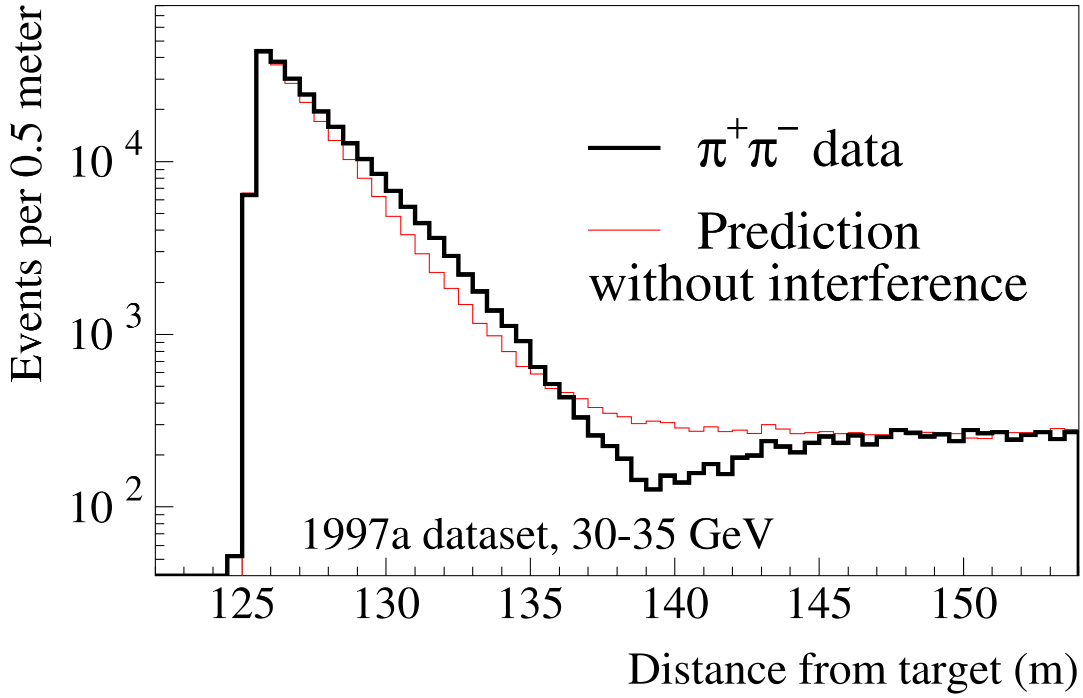


Vertex Z Distributions



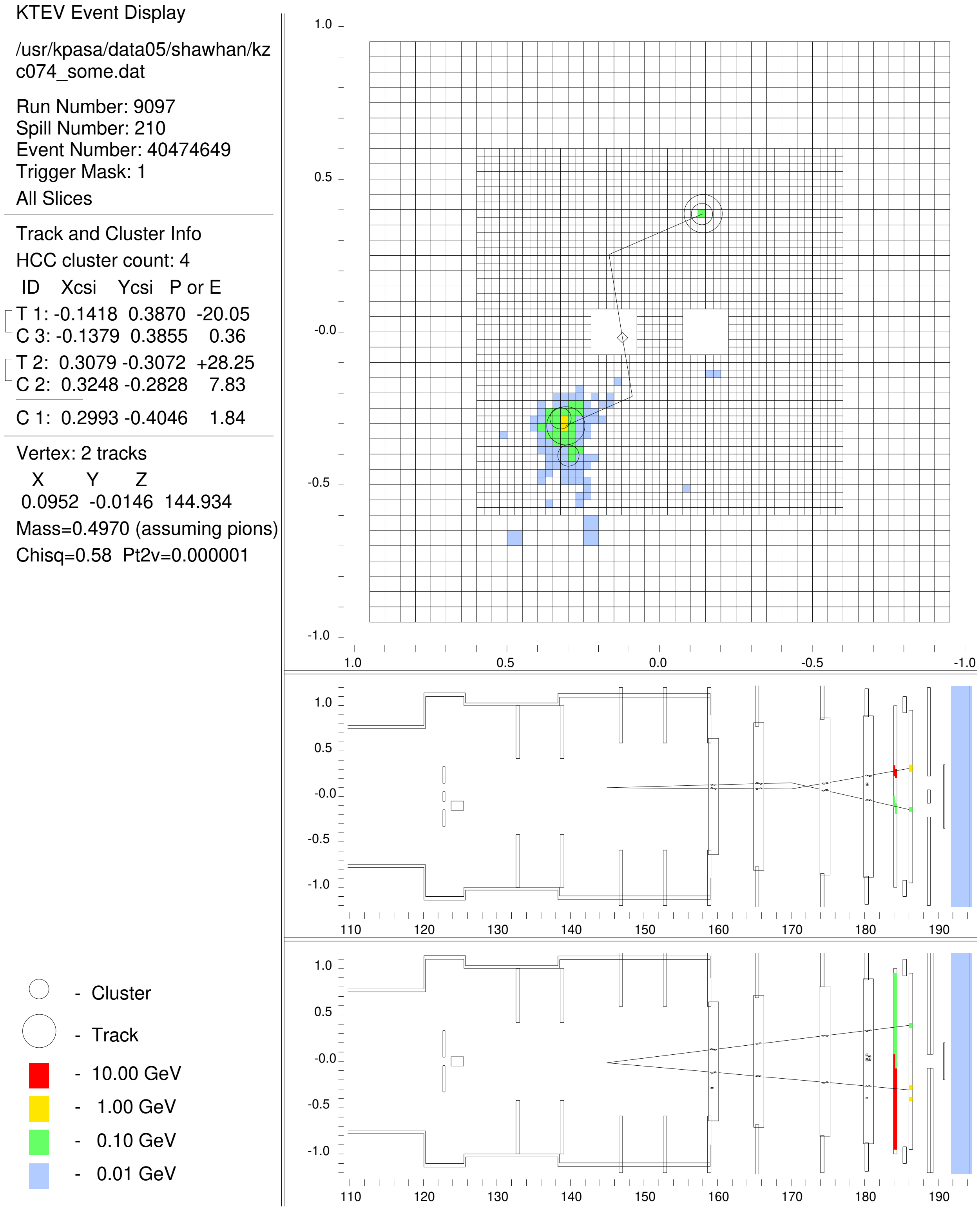
KTeV Regenerator

Coherently converts $K_L \to K_L + \rho K_S$

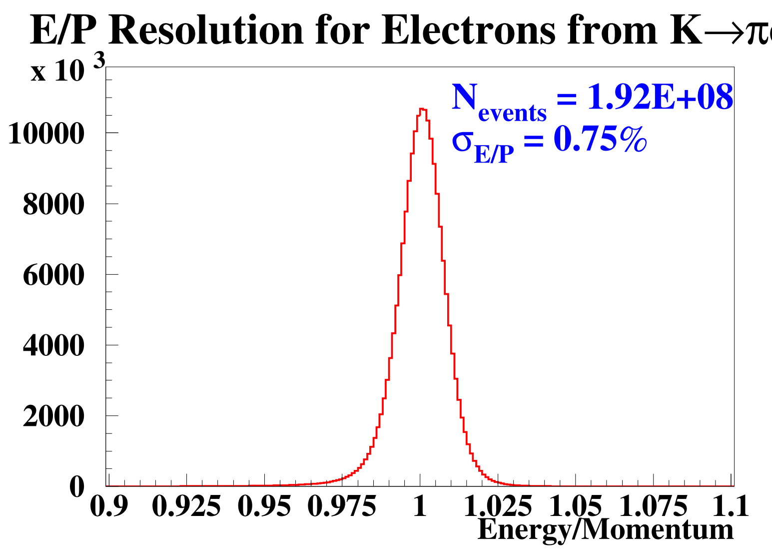


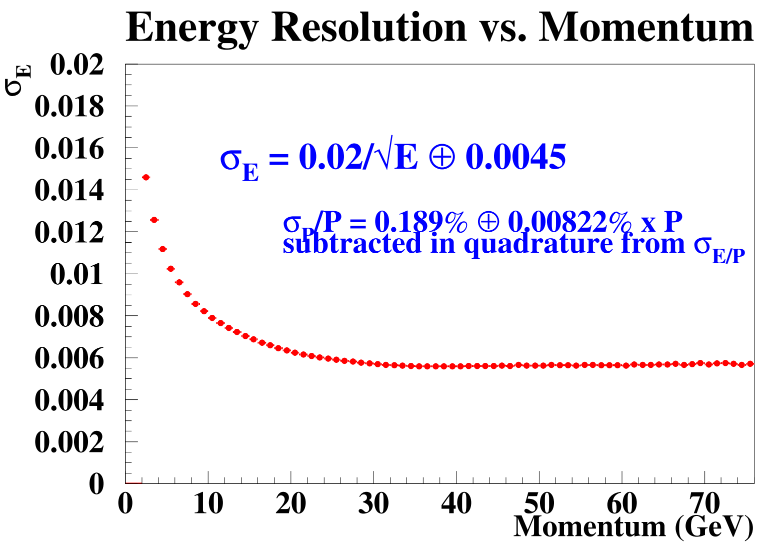
Made of plastic scintillator with PMTs to detect recoil products from inelastic interactions

Example $K_L \to \pi^+\pi^-$ Event



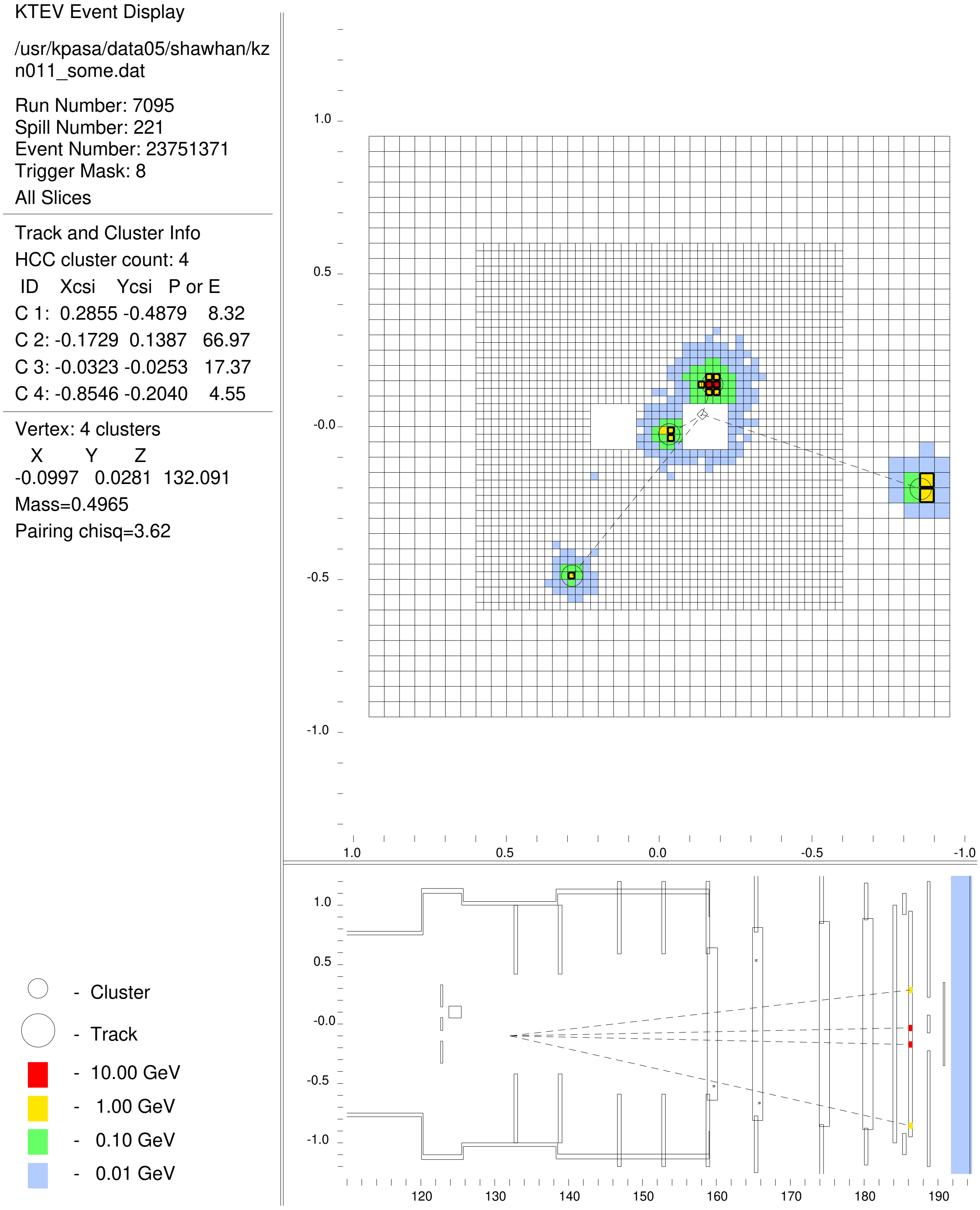
CsI Calorimeter Performance



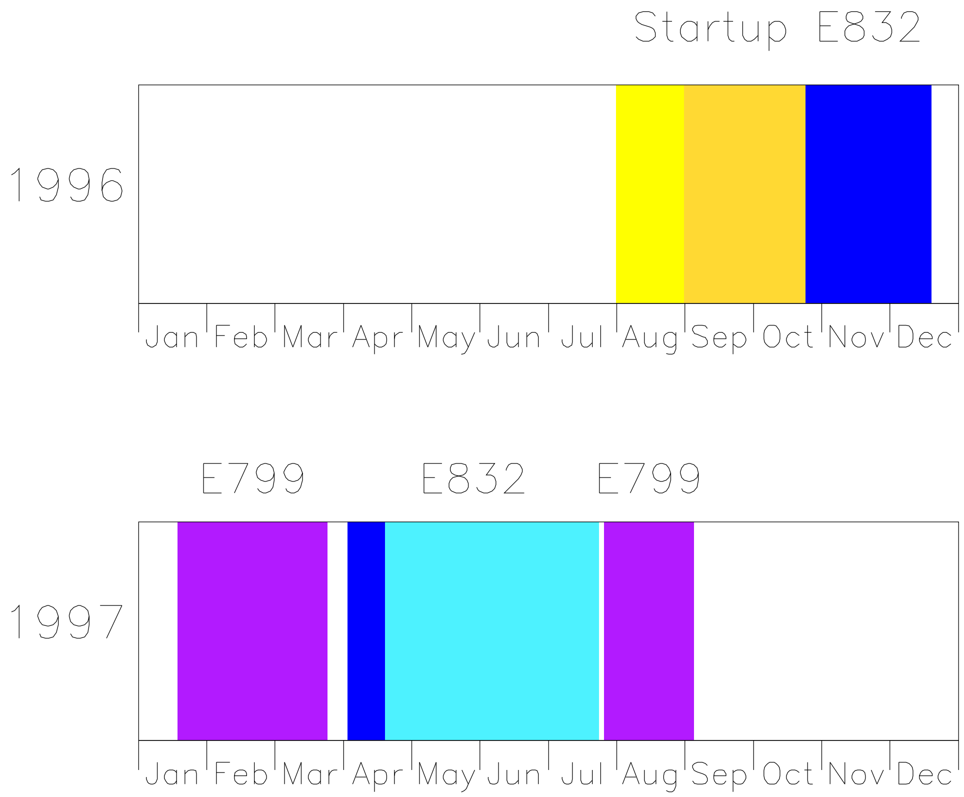


CsI is Calibrated with Electrons from $K \to \pi e \nu$ Decays.

Example $K_L \to \pi^0 \pi^0$ Event



1996–1997 Fixed Target Run

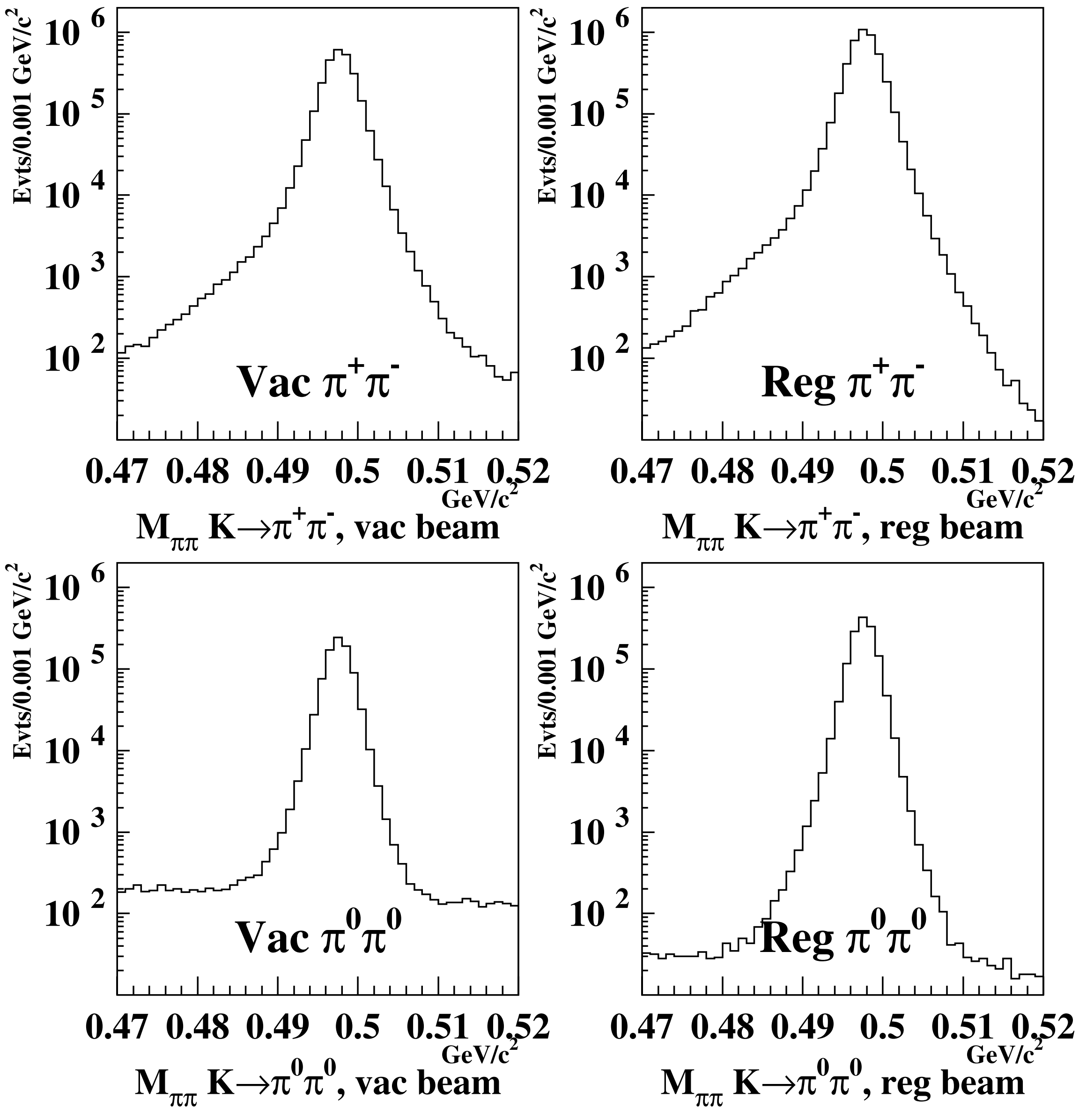


Data sets used for this analysis

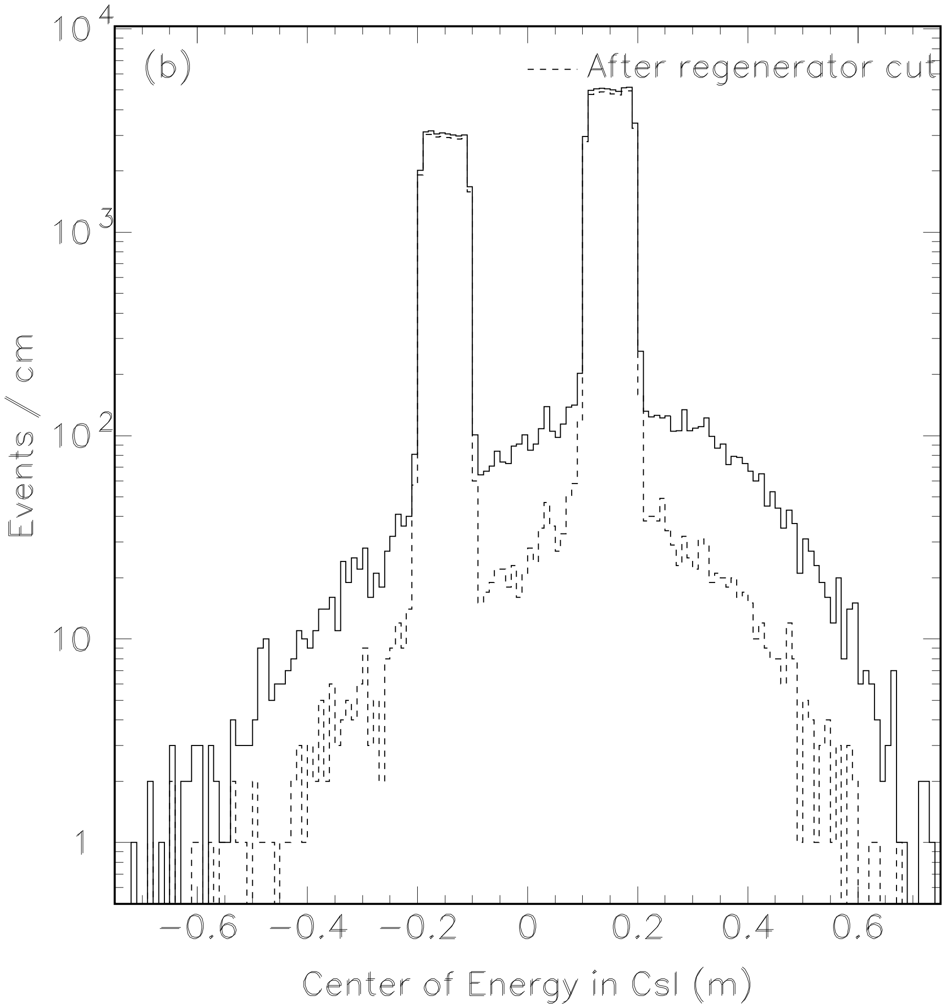
- $K \to \pi^0\pi^0$ data from 1996 ($\sim$ 23% of total)
- $K \to \pi^+\pi^-$ data from first 18 days of E832 running in 1997

Reconstructed Mass Distributions

not background subtracted



Kaon Scattering in Regenerator



Largest background to $K_S \to \pi^0\pi^0$, even after cutting on energy deposit in regenerator

Also a significant background to $K_L \to \pi^0\pi^0$

Scattering distribution is studied using $K \to \pi^+\pi^-$ decays

Backgrounds

Background levels in percent:
(Determined using data sidebands)

	Vac $\pi^+\pi^-$	Reg $\pi^+\pi^-$	Vac $\pi^0\pi^0$	Reg $\pi^0\pi^0$
Misidentified:				
$K_L \to \pi e \nu$	0.04	~ 0	—	—
$K_L \to \pi \mu \nu$	0.03	~ 0	—	—
Extra particles:				
$K_L \to 3\pi^0$	—	—	0.27	0.01
Scattered kaons:				
by regenerator	—	0.08	0.29	1.07
by collimator	0.01	0.01	0.18	0.16
Totals	0.08	0.09	0.74	1.24

Systematic error on $Re(\epsilon'/\epsilon)$ from
background subtraction $= 0.8 \times 10^{-4}$

Yield after Background Subtraction

	Vac Beam	Reg Beam
$K \to \pi^+\pi^-$	2607274	4515928
$K \to \pi^0\pi^0$	862254	1433923

Raw double ratio
(No acceptance correction!)

$$R = \frac{2607274/4515928}{862254/1433923} = 0.960$$