ε'/ε Results from KTeV

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- Introduction
- The KTeV Detector
- Status of ε'/ε analysis
- Conclusions

The KTeV Collaboration:
Arizona, Chicago, Colorado, Elmhurst, Fermilab, Osaka, Rice, Rutgers, UCLA, UCSD, Virginia, Wisconsin

Indirect vs. Direct CP Violation

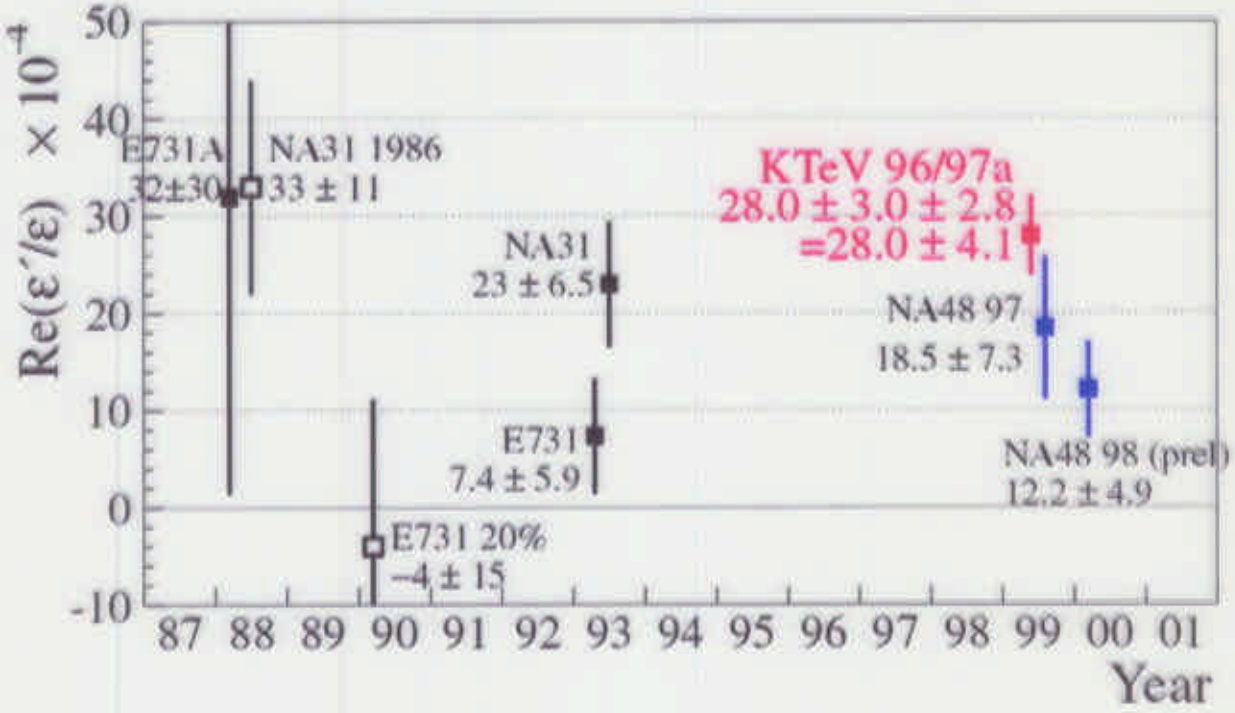
$$K_L \sim K_{odd} + \varepsilon K_{even}$$

"Direct" in decay process — ε' → $\pi\pi$

"Indirect" from asymmetric $K^0 - \overline{K}^0$ mixing → $\pi\pi$

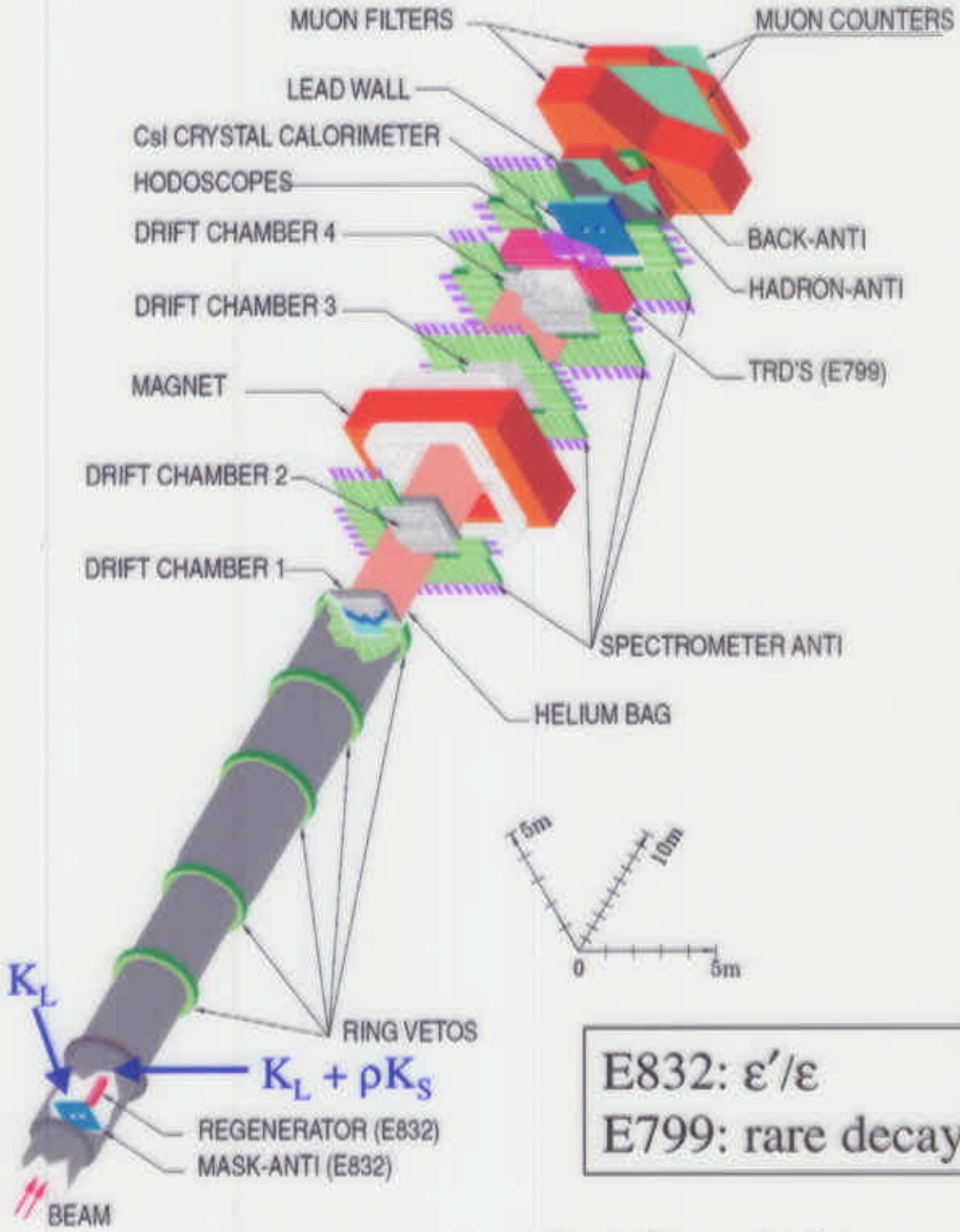
$$\mathrm{Re}(\varepsilon'/\varepsilon) \approx \frac{1}{6}\left[\frac{\Gamma(K_L \to \pi^+\pi^-)/\Gamma(K_s \to \pi^+\pi^-)}{\Gamma(K_L \to \pi^0\pi^0)/\Gamma(K_s \to \pi^0\pi^0)} - 1\right]$$

$\varepsilon'/\varepsilon \neq 0$ ⟶ direct CP violation



KTeV Goal: measure ε'/ε to 10^{-4}

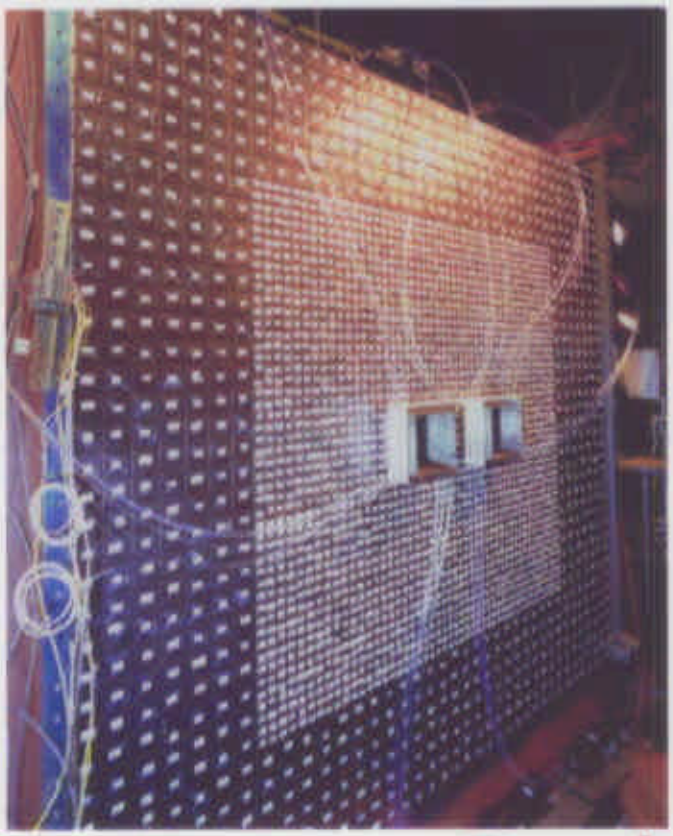
KTeV Detector



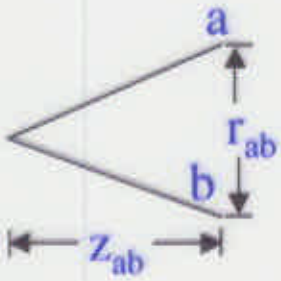
E832: ε'/ε
E799: rare decays

For $E_K \sim 70$ GeV, K_S: $\gamma\beta c\tau \sim 3.5$m
K_L: $\gamma\beta c\tau \sim 2.2$ km

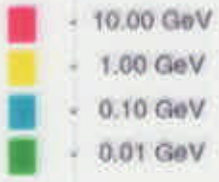
KTeV CsI Electromagnetic Calorimeter

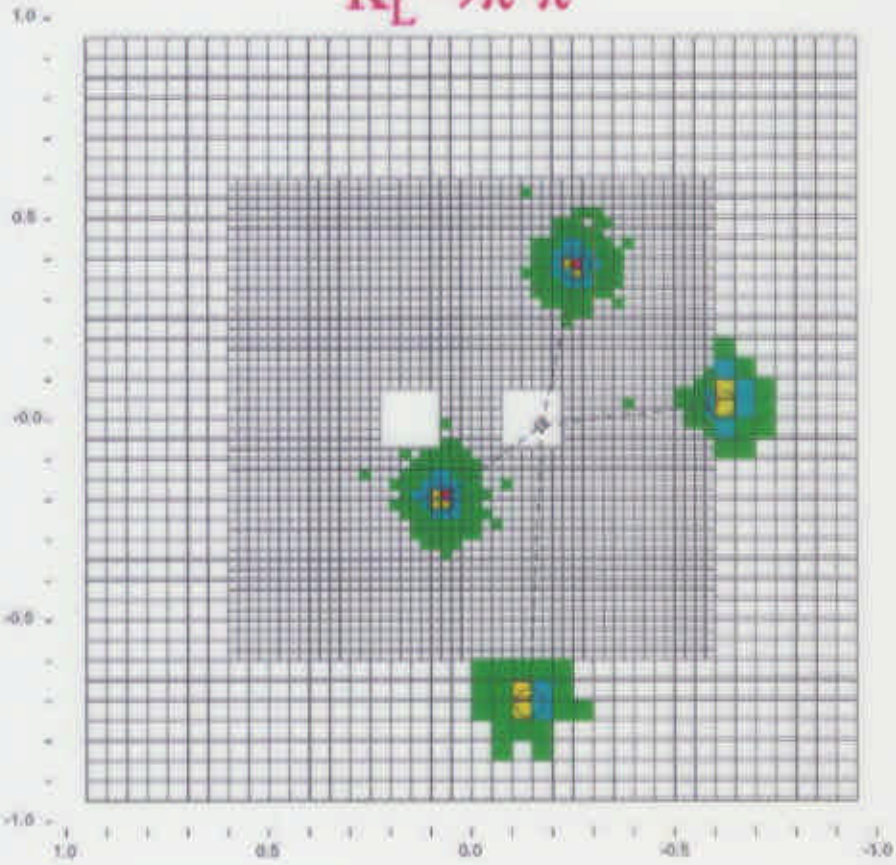


$K_L \rightarrow \pi^0\pi^0$

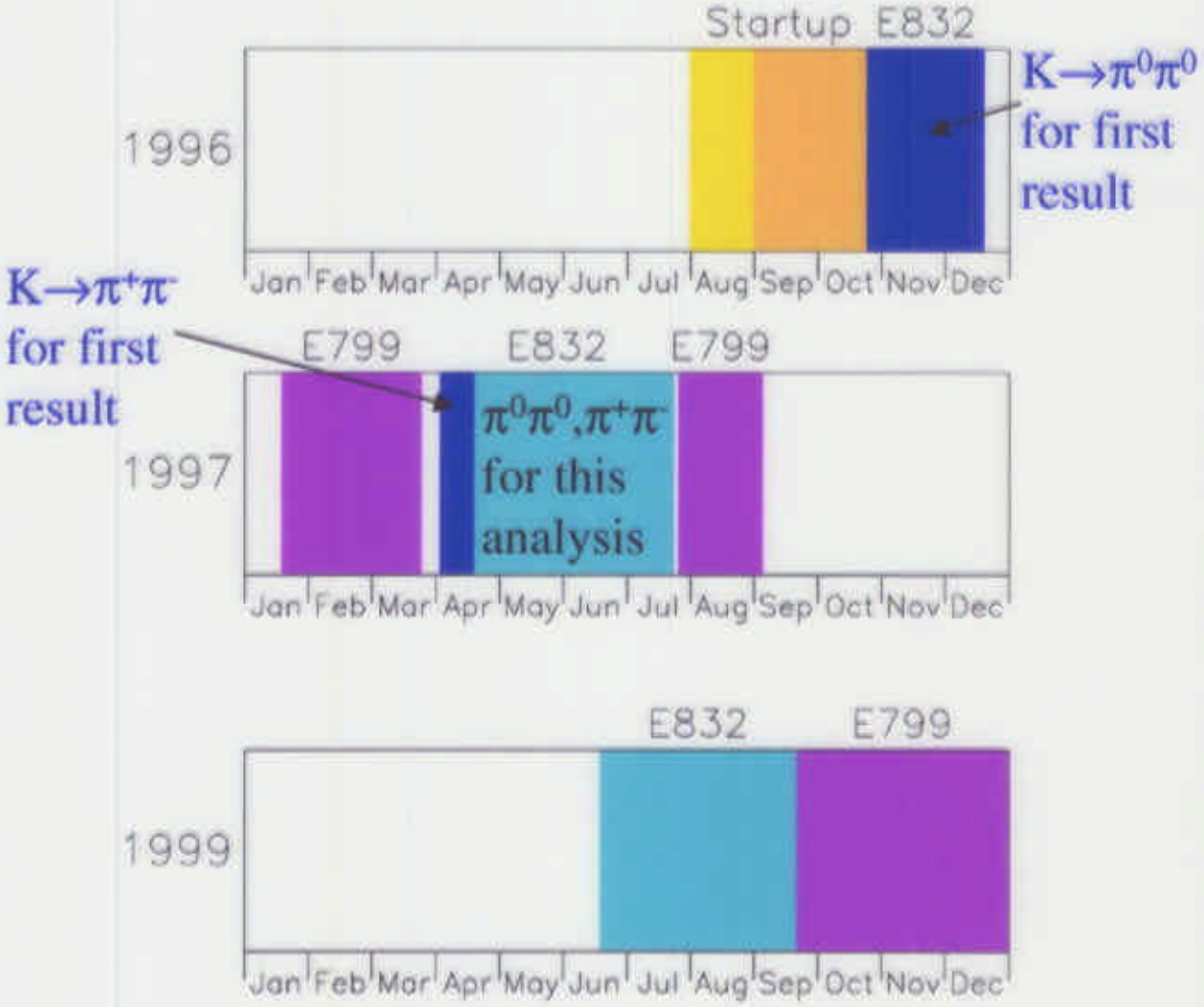


$$z_{ab}^2 \approx \frac{E_a E_b r_{ab}^2}{m_{\pi^0}^2}$$





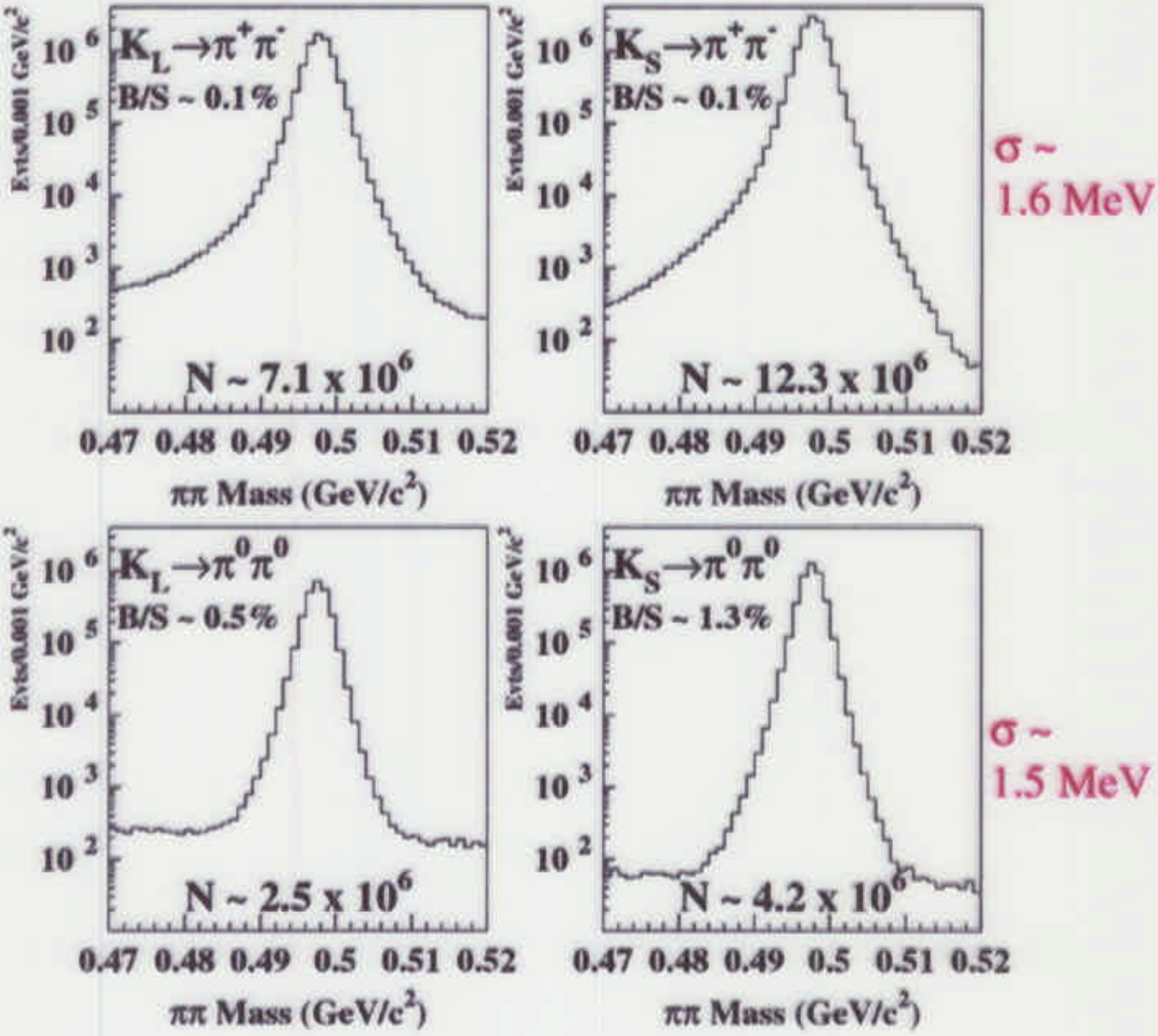
KTeV Datataking



- First result used $\pi^0\pi^0$ from 1996 and $\pi^+\pi^-$ from first 18 days of 1997 E832 run (1997a).
- Current analysis is based on remaining 1997 data -- ~3× larger sample than first result.
- 1999 ε'/ε run ≈ 1996 + 1997 with better systematics

1997 Reconstructed Mass Distributions

(before background subtraction)

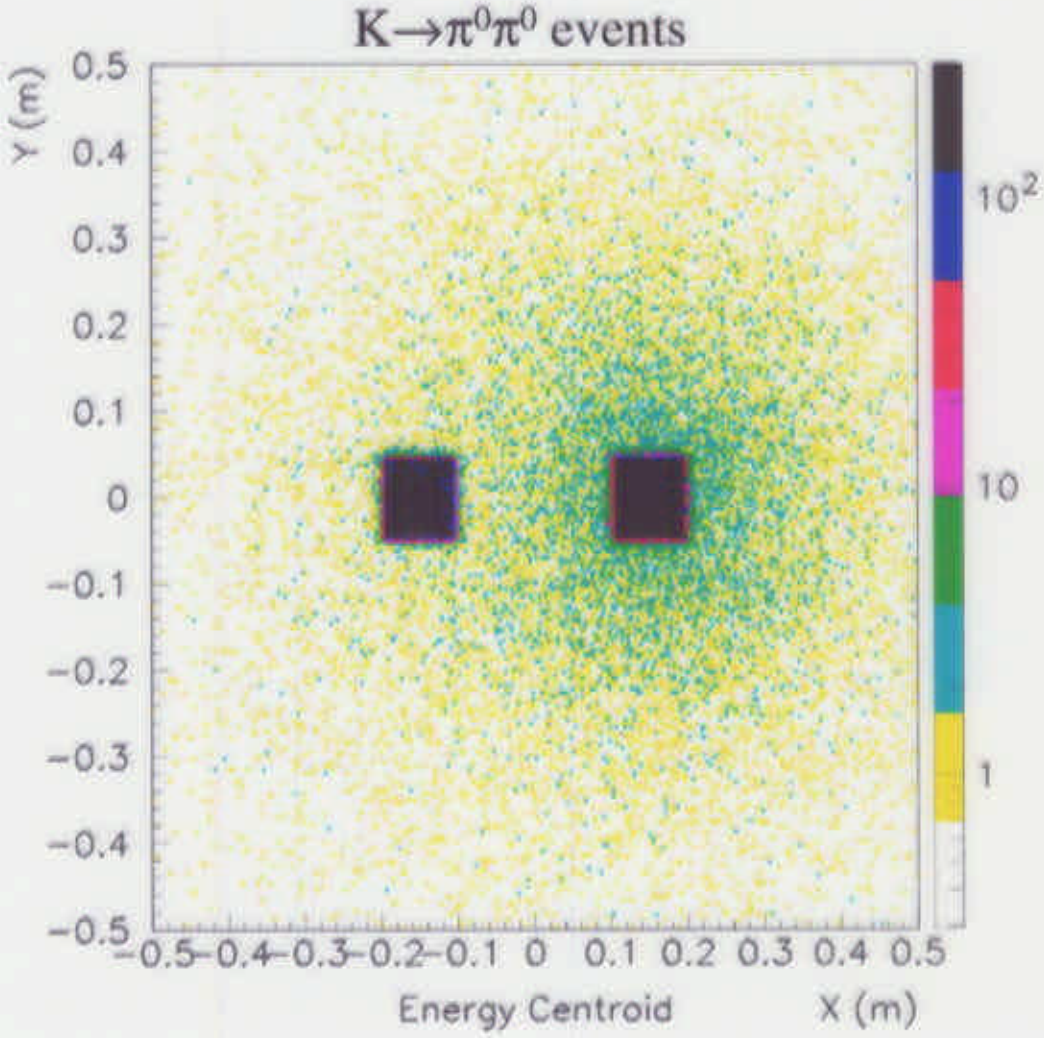


($\pi^+\pi^-$ distributions exclude 1997a data used in publication.)

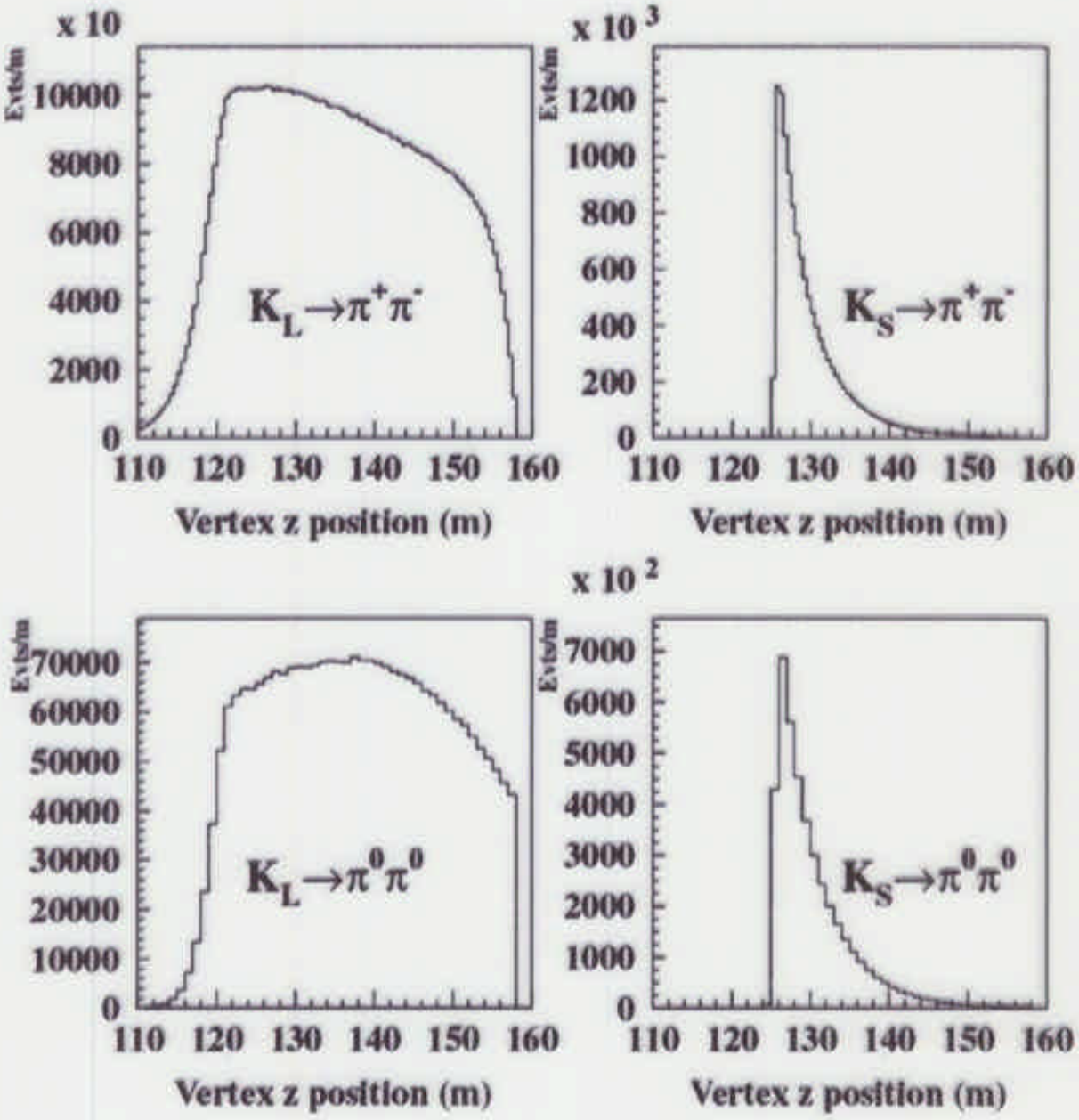
Backgrounds

Main classes of background:

- Misidentified kaon decays
  - For $K \to \pi^+\pi^-$: $K_L \to \pi e \nu$, $K_L \to \pi \mu \nu$
  - For $K \to \pi^0\pi^0$: $K_L \to \pi^0\pi^0\pi^0$
- Scattered $K \to \pi\pi$ events
  - From regenerator and final collimator



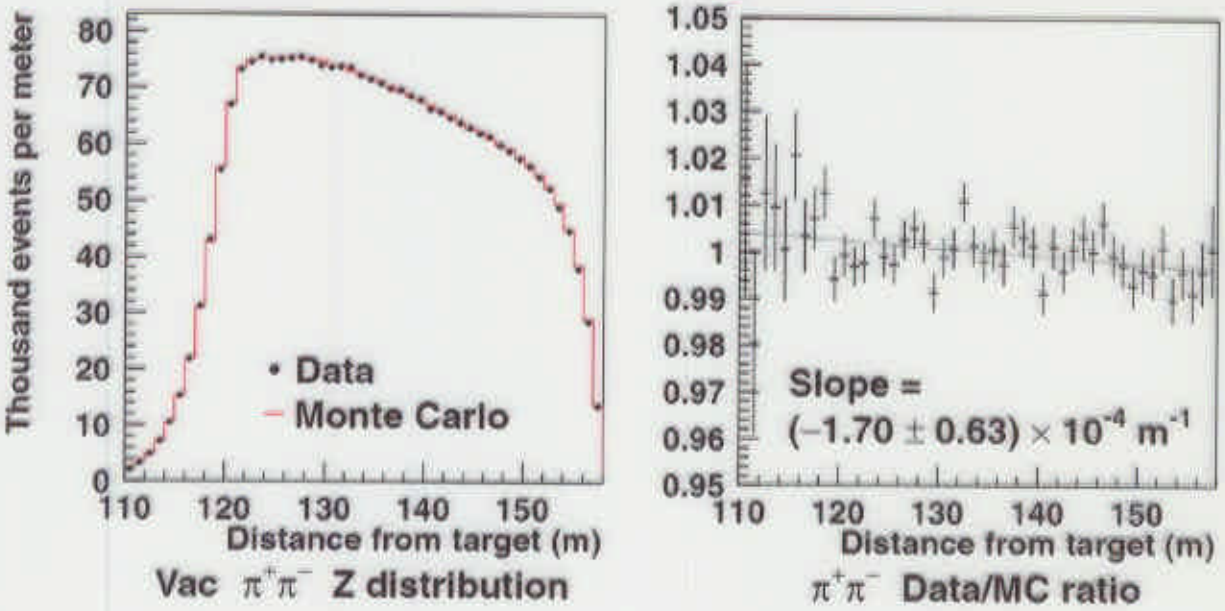
1997 Reconstructed Vertex z Distributions



Acceptance

- Acceptance correction based on detailed Monte Carlo simulation.
- High statistics decay modes (e.g., $K \to \pi e \nu$, $K \to 3\pi^0$) are used to check MC simulation.
- Largest systematic error in first result came from data/MC comparison of z distributions for $K \to \pi^+\pi^-$:

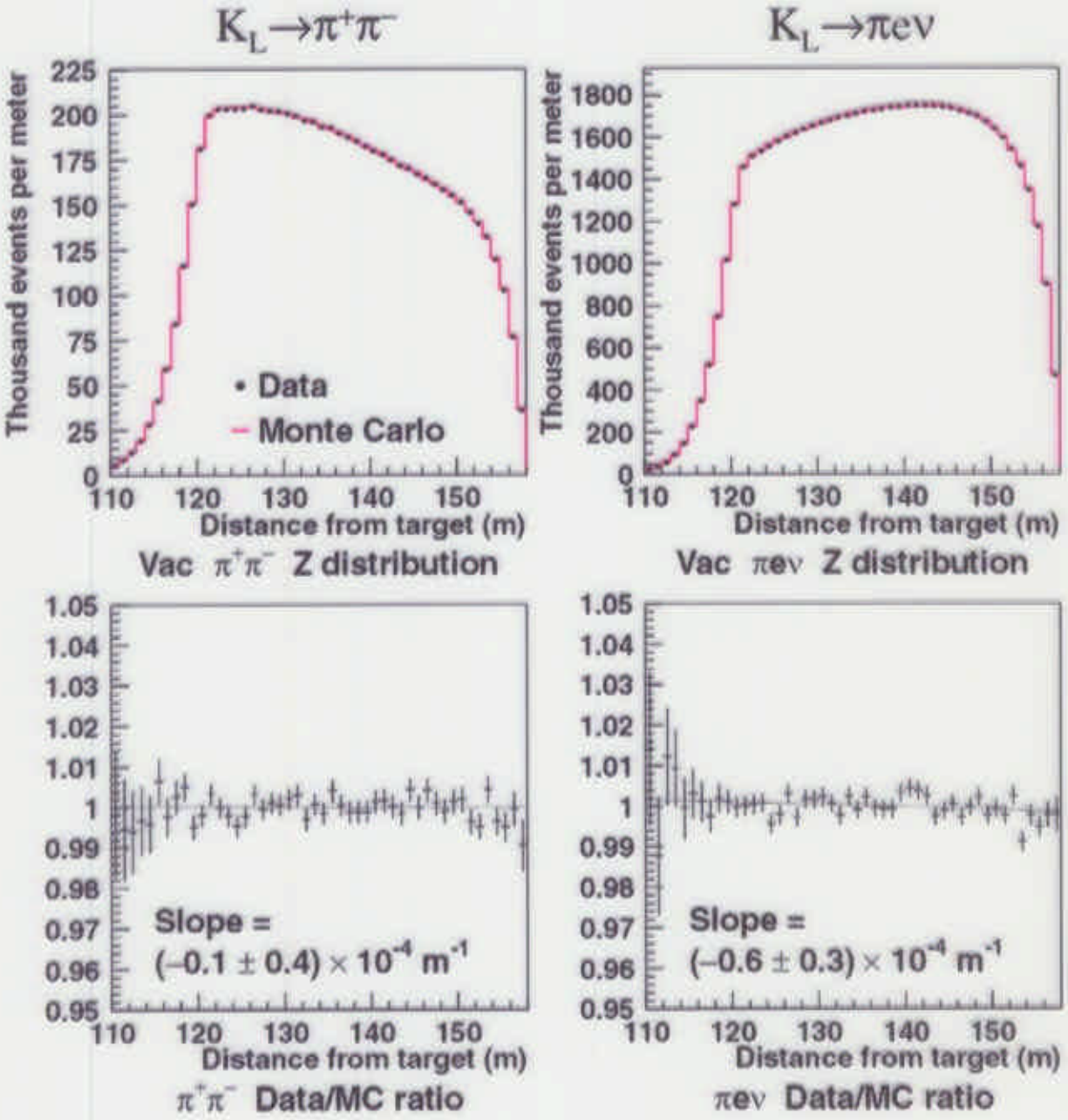
1997a $K \to \pi^+\pi^-$ Data / MC Comparison from first result



$\pi^+\pi^-$ Data/MC z slope:	$\Delta\varepsilon'/\varepsilon = 1.6\times10^{-4}$	(from first result)
Total syst. error from $K\to\pi^+\pi^-$:	$\Delta\varepsilon'/\varepsilon = 2.0\times10^{-4}$	
Total systematic error:	$\Delta\varepsilon'/\varepsilon = 2.8\times10^{-4}$	

KTeV 1997* Data / Monte Carlo Comparison

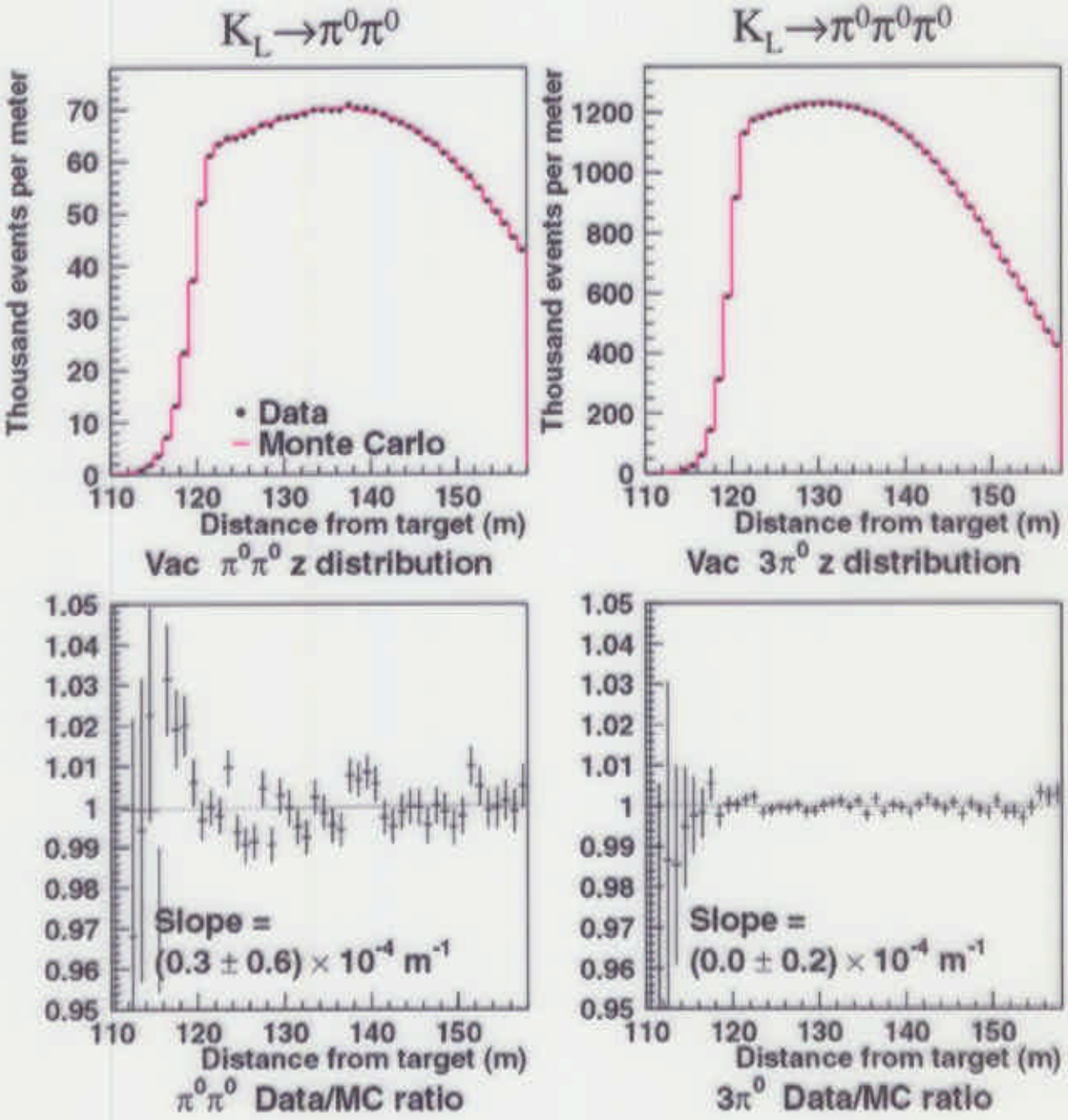
(preliminary)



* excludes 1997a data used in publication.

KTeV 1997 Data / Monte Carlo Comparison

(preliminary)



Status of ε'/ε Analysis of 1997 Data

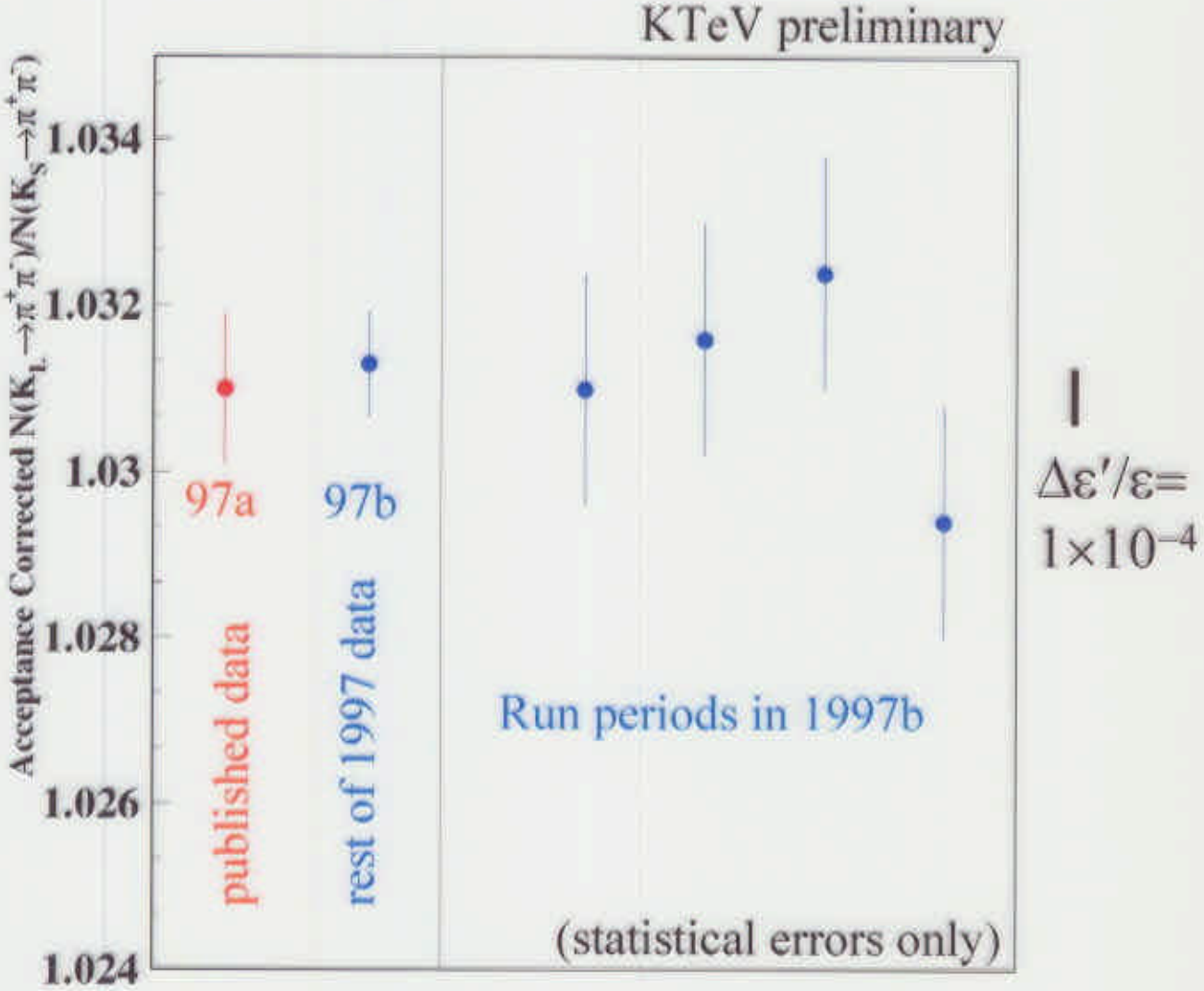
- $K \rightarrow \pi^+\pi^-$: ~ complete; all systematics have been evaluated (current $\pi^+\pi^-$ sys. error ~ 2/3 $\pi^+\pi^-$ sys. error in first result). Work to reduce systematic error is continuing.

- $K \rightarrow \pi^0\pi^0$: completing systematic studies.

The 1997 analysis has been done blind.

➡ The value of ε'/ε is still hidden.

Stability of Vacuum Beam (K_L) / Regenerator Beam ("K_S") Ratio for $\pi^+\pi^-$



- 1997b $K\rightarrow\pi^+\pi^-$ data are consistent with 1997a $K\rightarrow\pi^+\pi^-$ data used in published result.
- $K\rightarrow\pi^0\pi^0$ ratio <u>and ε'/ε</u> are still hidden.

Conclusions

- Published KTeV result:

$$\mathrm{Re}(\varepsilon'/\varepsilon) = (28.0 \pm 3.0\ (\mathrm{stat}) \pm 2.8(\mathrm{syst})) \times 10^{-4}$$
$$= (28.0 \pm 4.1) \times 10^{-4}$$

- Analysis of remaining 1997 sample is almost complete. Statistical error on this independent data sample will be 1.7×10^{-4}.
- Full KTeV data sample (96+97+99) will reduce the statistical error on ε'/ε to $\sim 1 \times 10^{-4}$.

  $\Rightarrow \varepsilon'/\varepsilon$ may be measured to $\pm 5\%$!
- KTeV data sample will also provide precise measurements of Δm, τ_S, ϕ_{+-}, ϕ_{00}, $\Delta\phi$, and δ.