New Measurements of Neutral Pion Decays from KTeV

$$BR(\pi^0 \rightarrow e^+e^-)$$

Final

$$BR(\pi^0 \rightarrow e^+e^-\gamma)$$

Preliminary

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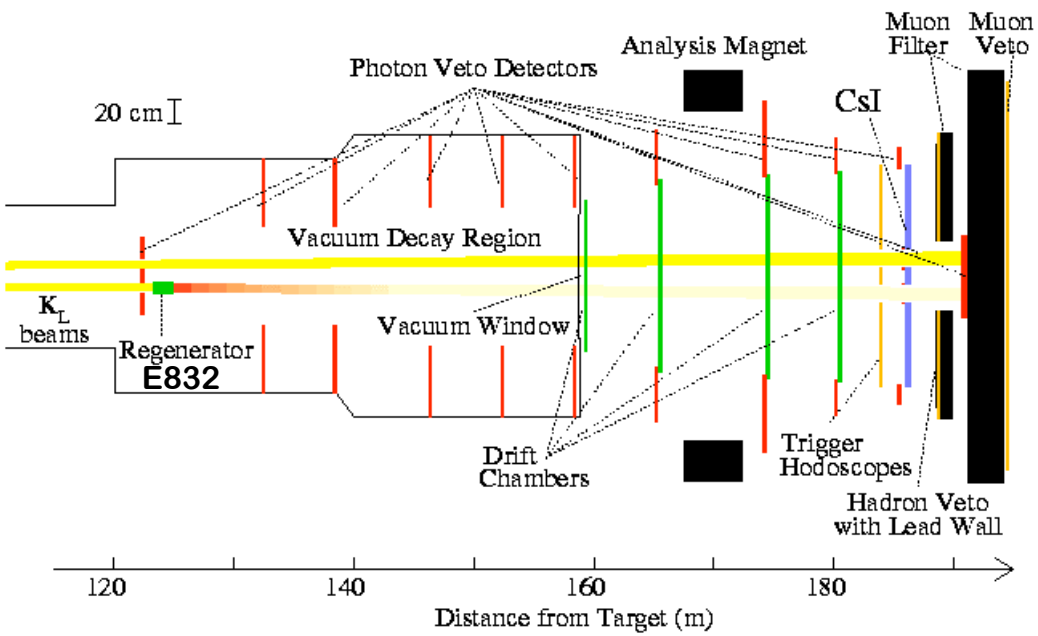
The KTeV Detector



CsI calorimeter: better than 1% energy resolution (γ)

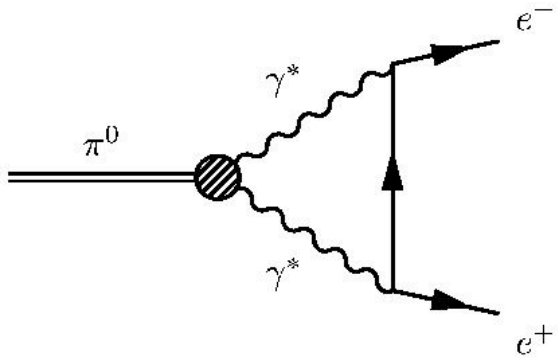
Spectrometer: better than 1% momentum resolution

~few % of a radiation length of material from vacuum window to CsI

The KTeV Collaboration

University of Arizona
UCLA
UCSD
Universidade Estadual de Campinas
University of Chicago
University of Colorado
Elmhurst College
Fermilab
Osaka University
Rice University
Universidade de Sao Paulo
University of Virginia
University of Wisconsin

$BR(\pi^0 \rightarrow e^+e^-)$



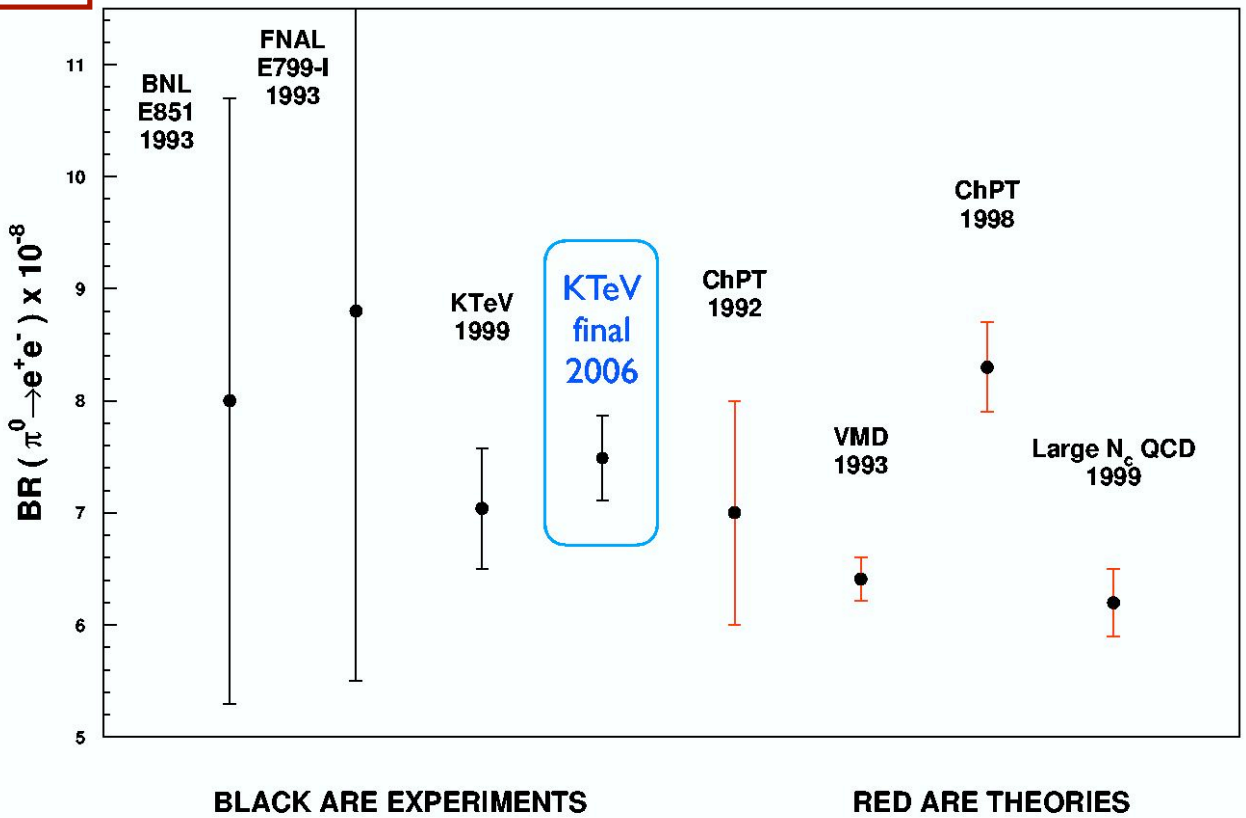
$$BR(\pi^0 \rightarrow e^+e^-) = (6.44 \pm 0.25 \pm 0.22)E-8$$

(Final)

hep-ex/0610072
(submitted to PRD)

At right – effects of FSR removed for comparison to models
Lowest order BR is:

$$(7.48 \pm 0.29 \pm 0.25)E-8$$



Supersedes 1999 result

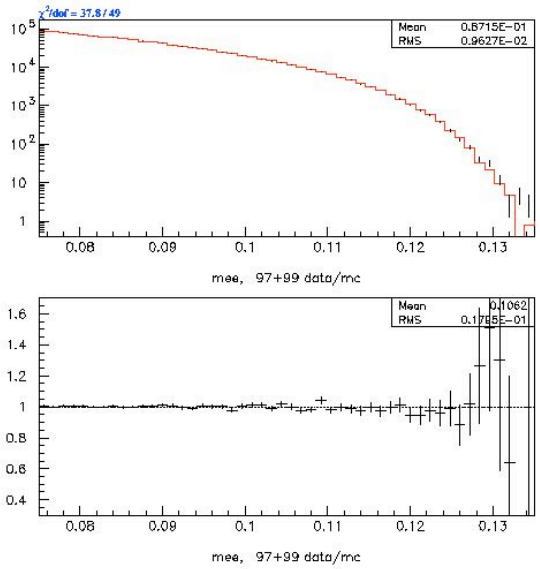
$BR(\pi^0 \to e^+e^-)$

Final

Signal

$$K_L \to \pi^0\pi^0\pi^0$$
$$\hookrightarrow e^+e^-$$

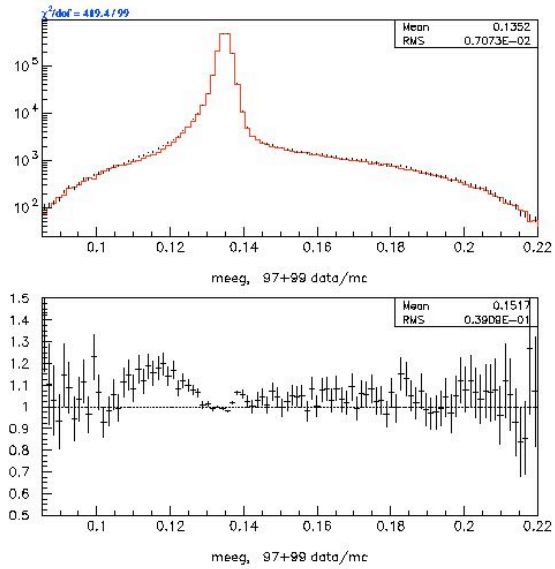
e^+e^- mass



Normalization

$$K_L \to \pi^0\pi^0\pi^0$$
$$\hookrightarrow e^+e^-\gamma$$

$e^+e^-\gamma$ mass



$$BR(\pi^0 \to e^+e^-) = (6.44 \pm 0.25 \pm 0.22)E-8$$

Unitary bound (on-shell photons):

$$BR > 4.69E-8$$

Chiral PT gives a prediction for contribution from off-shell photons

$$\pi^0 \to e^+e^-$$

Gives experimental constraint on calculations

↓

Improves predictions for $P^0 \to l^+l^-$

$BR(\pi^0 \rightarrow e^+e^-\gamma)$ Preliminary

Current PDG Average $\frac{B(\pi^0 \rightarrow e^+e^-\gamma)}{B(\pi^0 \rightarrow \gamma\gamma)} = (1.213 \pm 0.030)\%$

(1.25 ± 0.04)% ~10^3 events Schardt 1981 – Phys. Rev. D 23
(1.166 ± 0.047)% 3071 events Samios 1961 – Phys. Rev. 121
(1.17 ± 0.15)% 27 events Budagov 1960 – JETP 11

Theory:

1.185% R. Dalitz 1951 – Proc. Phys. Soc. A64
1.196% D. Joseph 1960 – Nuovo Cimento 16
1.196% K. Mikaelian & J. Smith 1972 – Phys. Rev. D 5

Analysis Technique

$BR(\pi^0 \to e^+e^-\gamma)$

Signal Mode

$$K_L \to \pi^0\pi^0\pi^0$$

$$\gamma\gamma \quad \gamma\gamma \quad e^+e^-\gamma$$

7 clusters in CsI

2 tracks, well-separated in the drift chambers

Normalization Mode

$$K_L \to \pi^0\pi^0\pi^0 \to 6\gamma$$

6 clusters in CsI

Reconstruction

Fully reconstructed

Choose among 15 photon pairings by requiring the 3 pions to have decayed at the same z position

Decay must occur in 40 m vacuum region

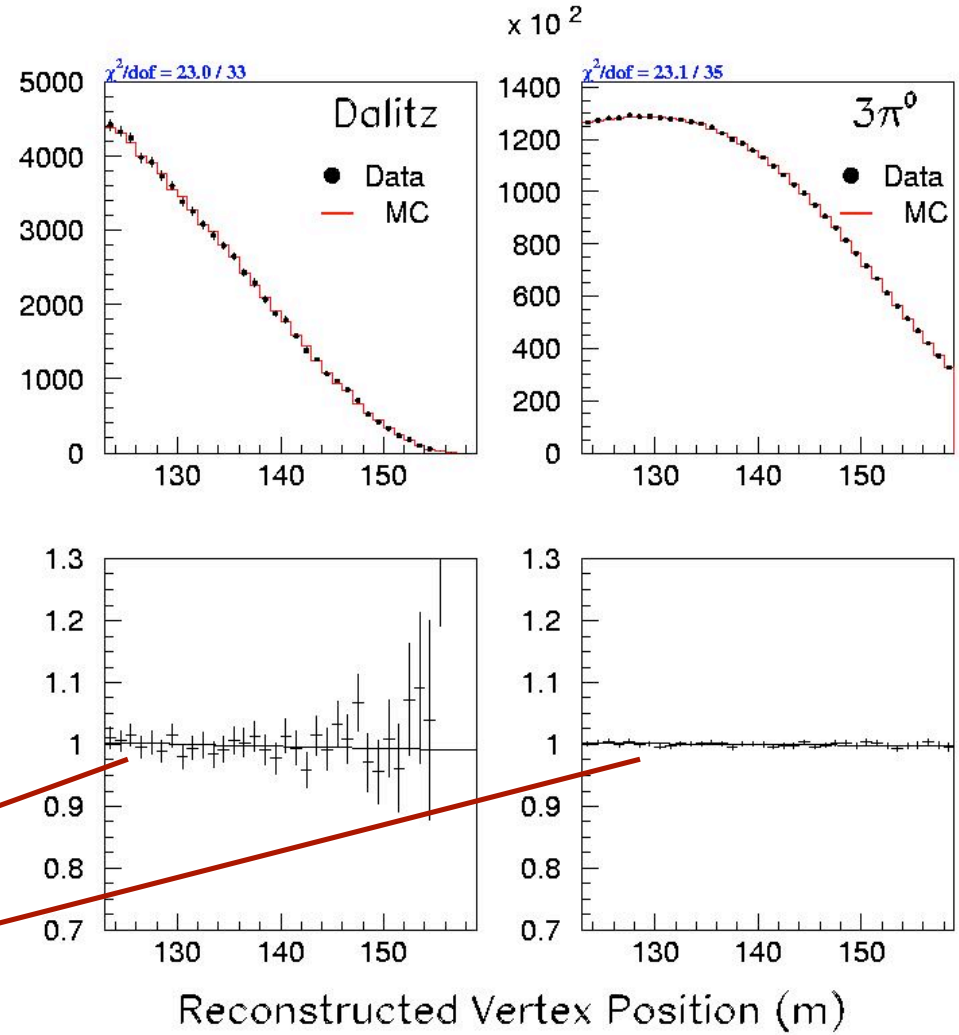
66,000 Dalitz Decays!

Relative Acceptance

$BR(\pi^0 \to e^+e^-\gamma)$

Rely on Monte Carlo to model acceptance over the ~40 m decay region

Data-MC z distribution agreement within each mode is essential



Z Slopes

Dalitz: $(-3.6 \pm 6.2)E-4$

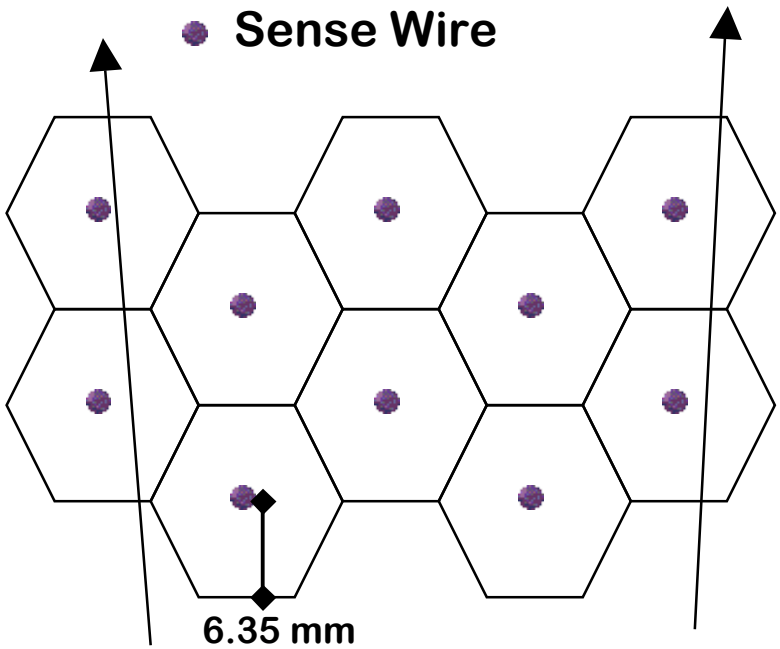
$3\pi^0$: $(-8.7 \pm 6.1)E-5$

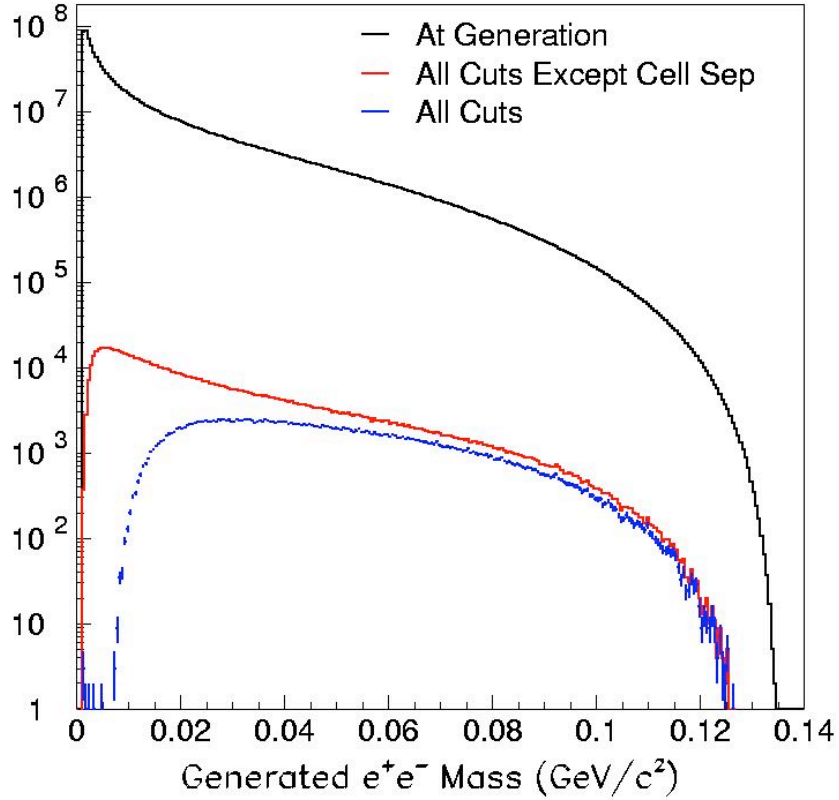
Track Separation Requirement

$BR(\pi^0 \rightarrow e^+e^-\gamma)$

Track Cell Separation Requirement: >3 cells → **Effective e^+e^- Mass Cutoff**

Drift Chamber Cells





(~1 MeV/c^2 e^+e^- mass resolution)

Signal Mode

$$K_L \to \pi^0\pi^0\pi^0$$

$$\gamma\gamma \quad \gamma\gamma \quad e^+e^-\gamma$$

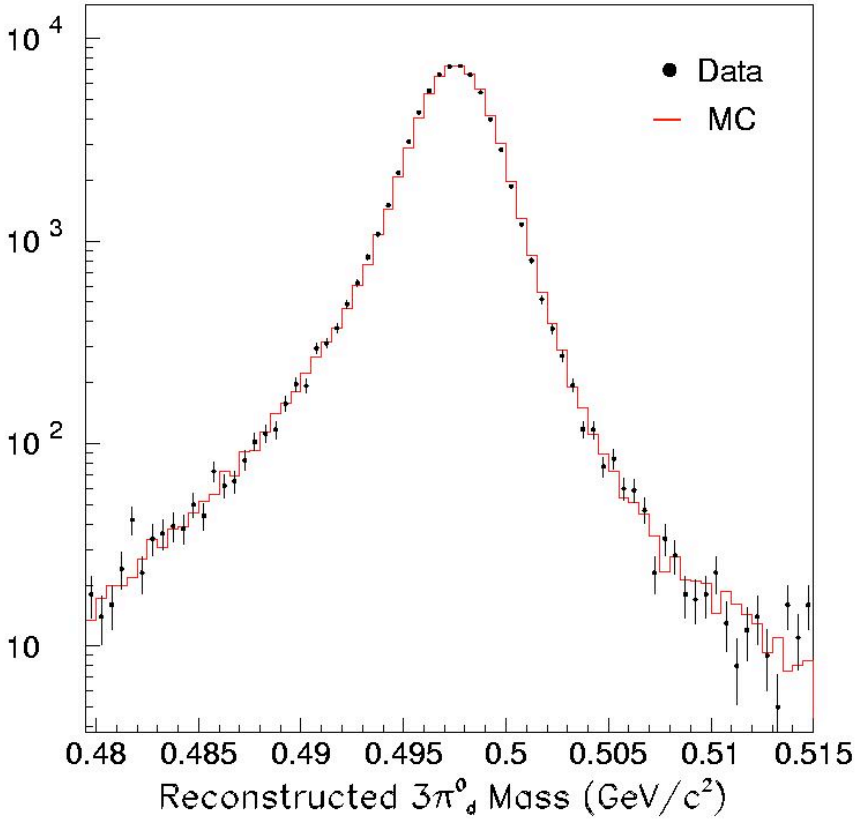
$$(K_L \to 3\pi^0_d)$$

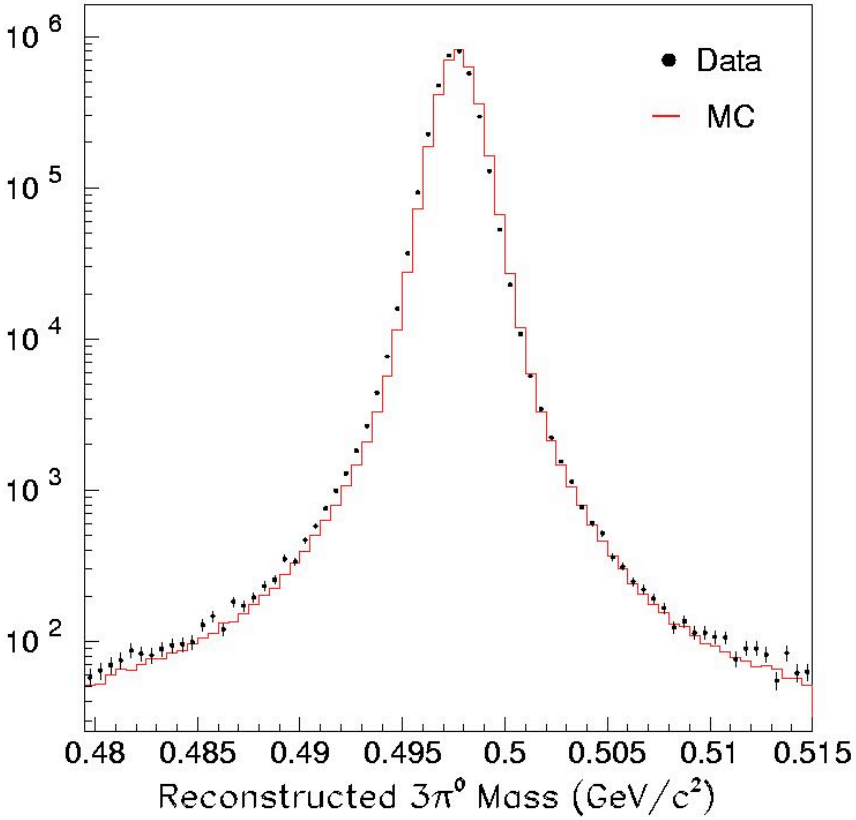
Normalization Mode

$$BR(\pi^0 \to e^+e^-\gamma)$$

$$K_L \to \pi^0\pi^0\pi^0 \to 6\gamma$$

$$(K_L \to 3\pi^0)$$





Systematics

$BR(\pi^0 \rightarrow e^+e^-\gamma)$

Preliminary

Source of Systematic Error	Uncertainty
Radiative Corrections	1.02%
Tracking Inefficiency	0.68%
Detector Material	0.37%
Accidentals	0.10%
Trigger Inefficiency	0.14%
Trigger 6 Prescale	<0.1%
Form Factor	0.07%
Photon Inefficiency	0.01%
Background	<0.1%
Cut Variations	<0.1%
Monte Carlo Statistics	0.19%
Total Systematic Error	**1.32%**

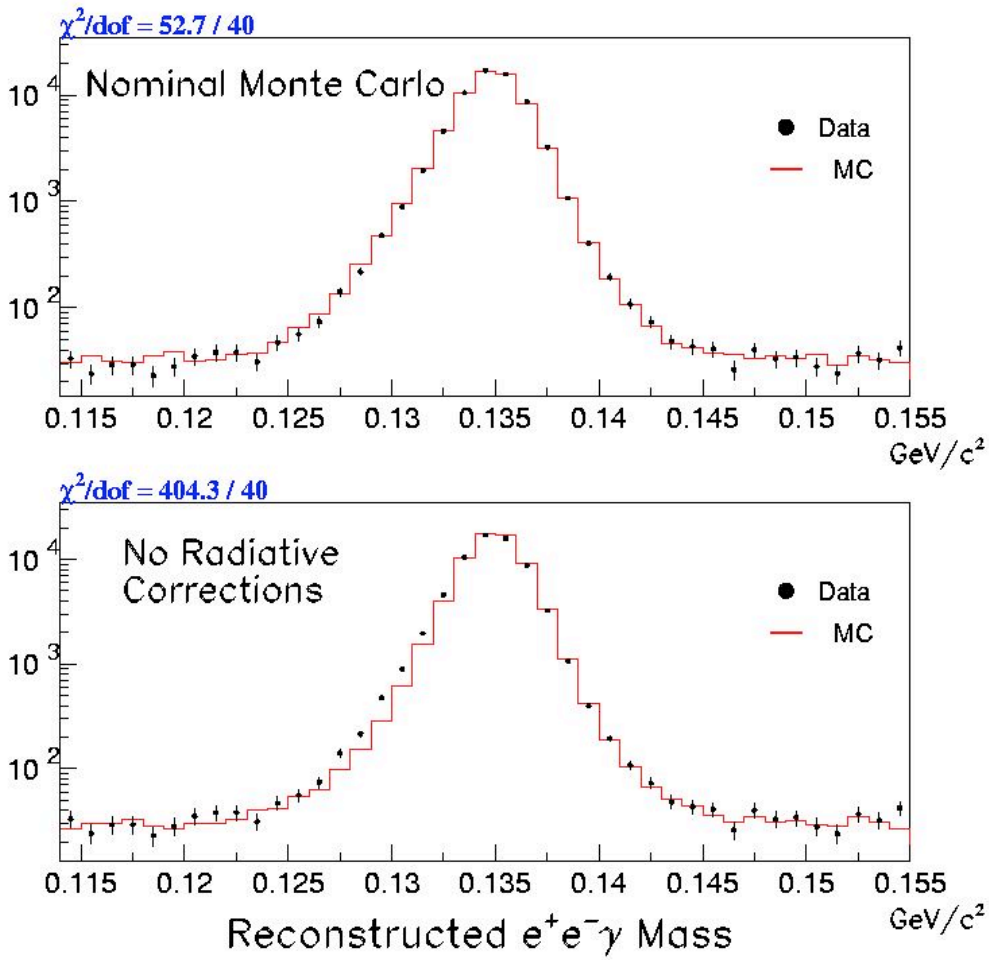
66,432 Dalitz events

↓

0.39% relative statistical uncertainty

Radiative Corrections

$BR(\pi^0 \rightarrow e^+e^-\gamma)$



MC without Radiative Corrections

Acceptance increases by ~5%

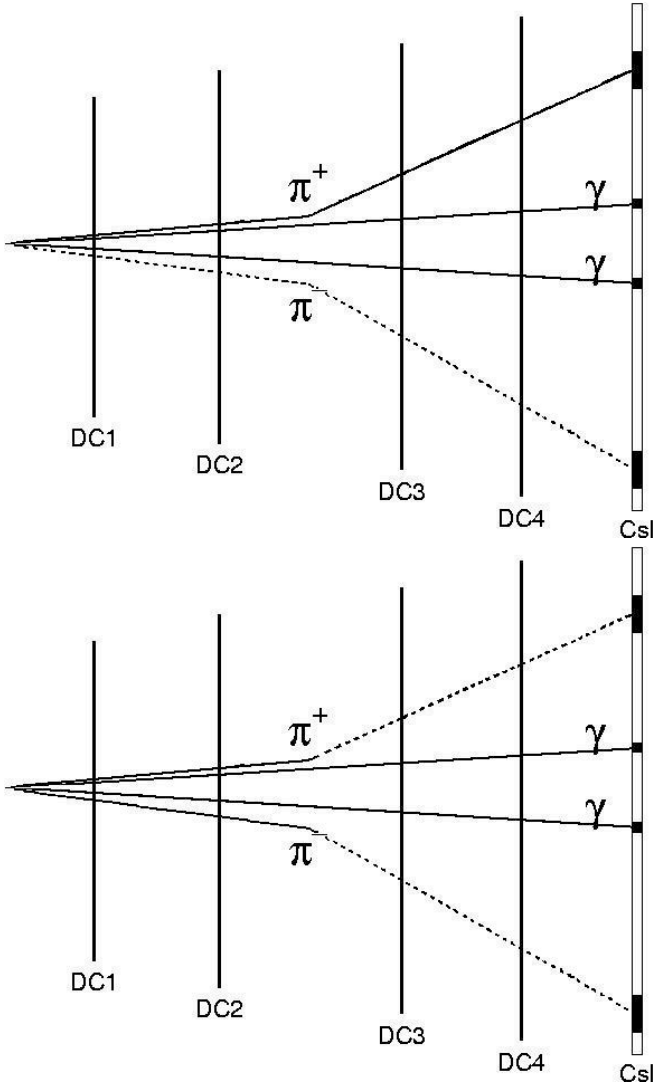
Width of $e^+e^-\gamma$ mass distribution disagrees with data

↓

Set a limit on our sensitivity to radiative corrections of ~1%

Measuring Tracking Inefficiency with $K_L \rightarrow \pi^+\pi^-\pi^0$

$BR(\pi^0 \rightarrow e^+e^-\gamma)$



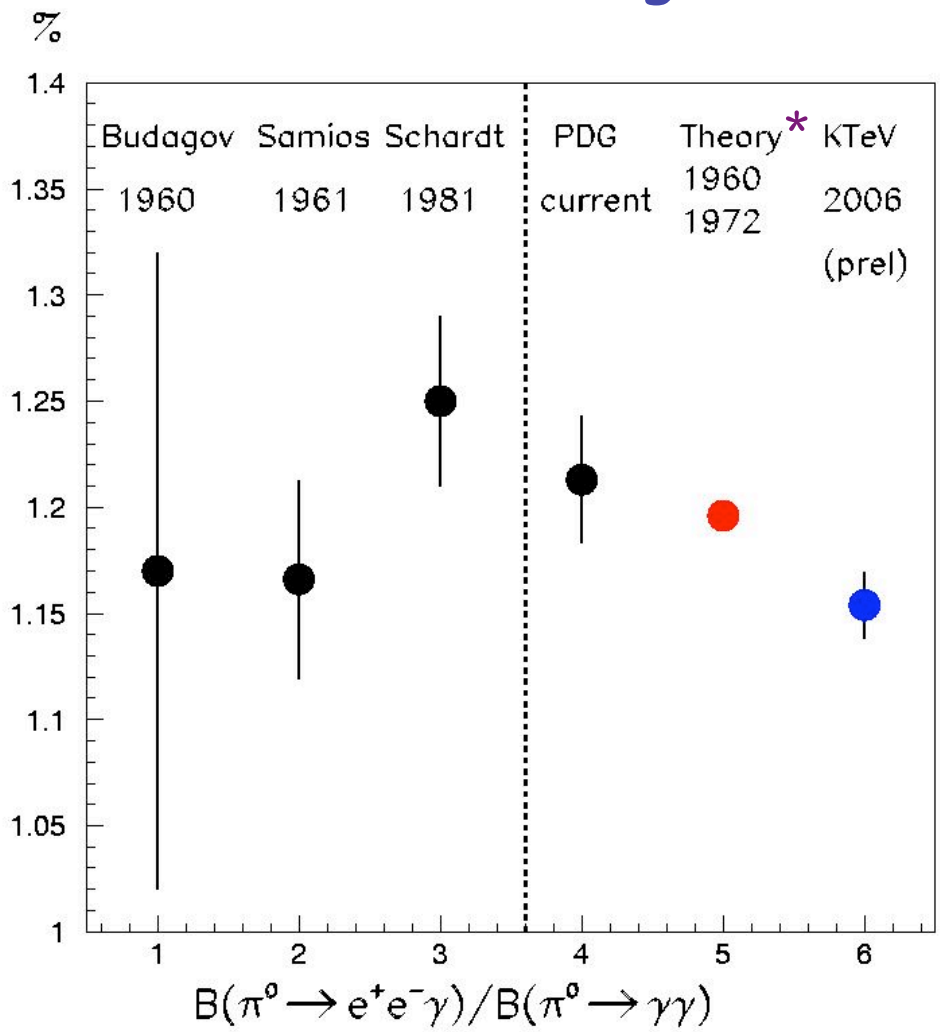
	Tracking Inefficiency
Data	4.39%
MC	3.71%
Correction	0.68%

Correction lowers acceptance in Dalitz mode

Entire correction taken as systematic uncertainty

Preliminary KTeV Result

$BR(\pi^0 \to e^+e^-\gamma)$



$$\frac{BR(\pi^0 \to e^+e^-\gamma)}{BR(\pi^0 \to \gamma\gamma)} = (1.1539 \pm 0.0045 \pm 0.0152)\%$$

Consistent with previous measurements and with theory

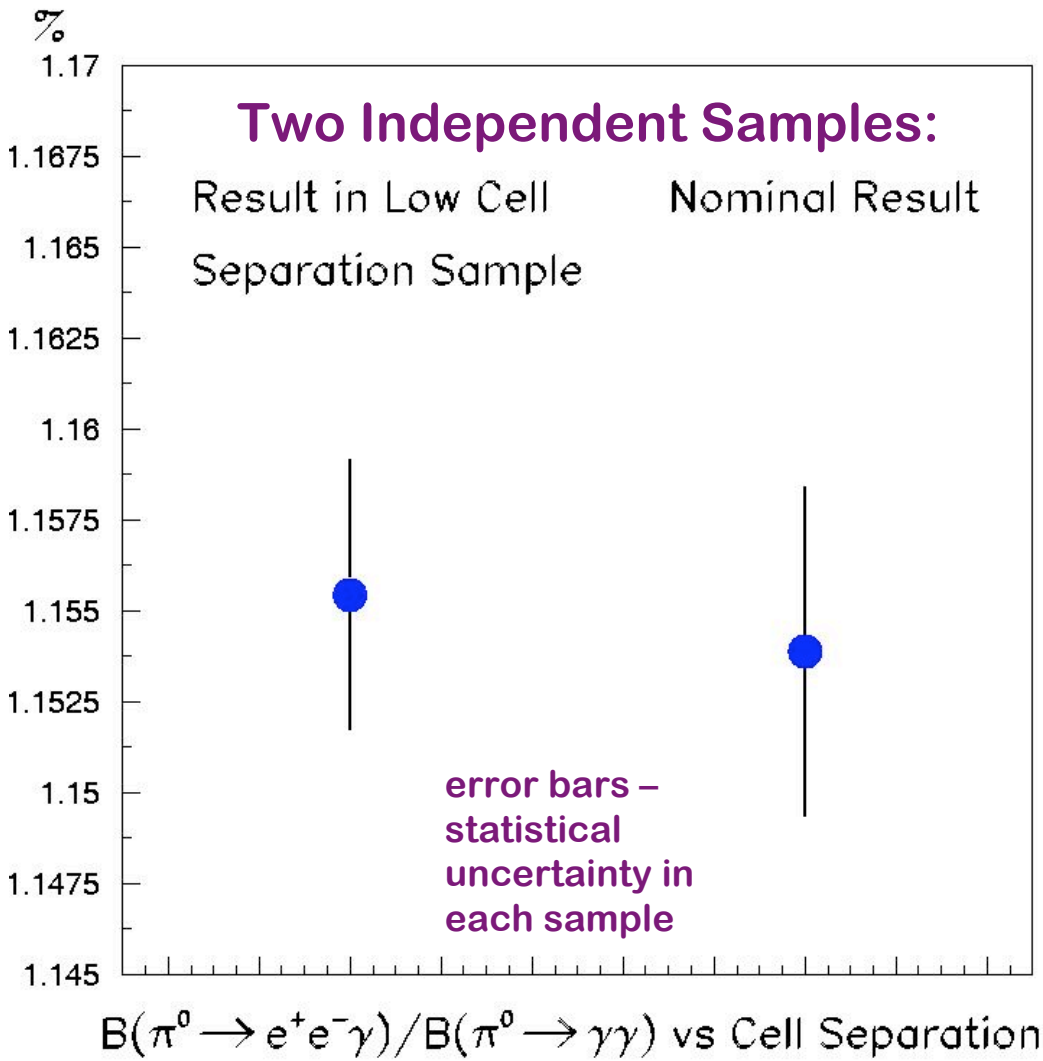
Half the uncertainty of current PDG average

2.5 times as good as previous best measurement

* **D. Joseph 1960 – Nuovo Cimento 16**
K. Mikaelian & J. Smith 1972 – Phys. Rev. D 5

Cross Check

$BR(\pi^0 \to e^+e^-\gamma)$



Branching Ratio for close tracks (low cell separation sample) is consistent with BR for well-separated tracks (nominal result)

Conclusions

- New KTeV Final Result: hep-ex/0610072

$$BR(\pi^0 \to e^+e^-) = (6.44 \pm 0.25 \pm 0.22)E-8$$

- New KTeV Preliminary Result: still working to reduce systematic error

$$\frac{BR(\pi^0 \to e^+e^-\gamma)}{BR(\pi^0 \to \gamma\gamma)} = (1.1539 \pm 0.0045 \pm 0.0152)\%$$

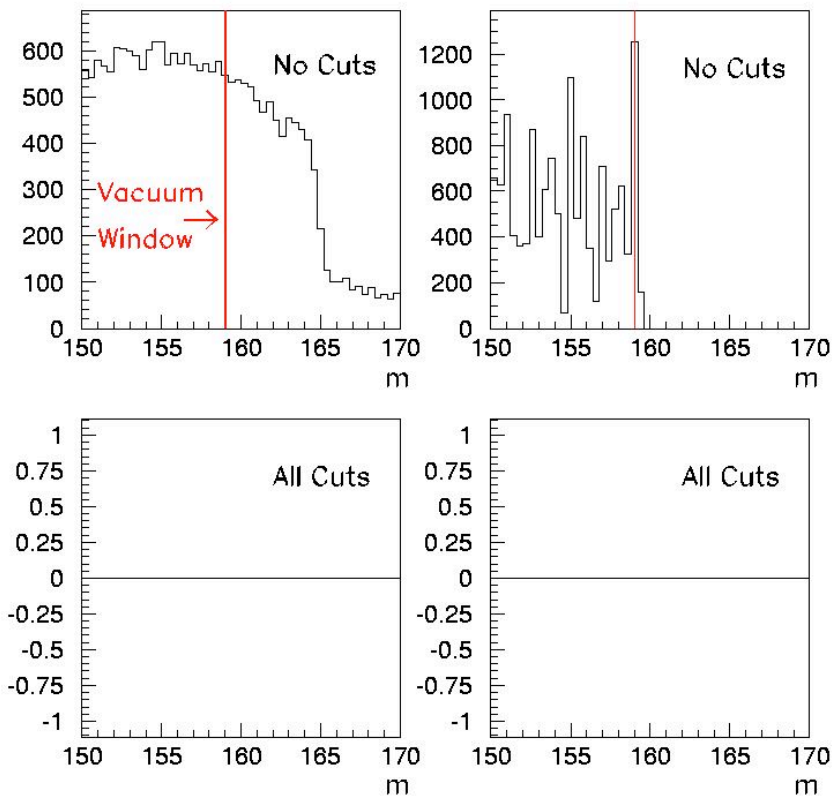
- Many other measurements depend on π^0-Dalitz branching fraction, and will need to be updated (for example, $BR(\pi^0 \to e^+e^-)$)

Extra Slides

Background

$BR(\pi^0 \rightarrow e^+e^-\gamma)$

Preliminary



$3\pi^0$s with a photon conversion at the vacuum window

Generated this background in MC

Selection requirements remove large fraction of background