

Search for Neutrinoless
□ Decays Involving K_S^0 Mesons

CLEO Collaboration

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Motivation

- conservation laws are supposed to have associated symmetries in SM
- lepton flavor conservation is experimentally observed phenomena
 - ★ no associated symmetry in SM
- searching for lepton flavor violation is like living in fantasy land
- observation of neutrino oscillations by SuperK and SNO
 - ☞ searching for lepton flavor violation is like day dreaming
- many extensions of the Standard Model allow lepton flavor violation
- some theoretical calculations of lepton flavor violation branching fractions close to experimental sensitivity
 - ☞ search for $\tau\tau \rightarrow (e + \tau) + (1-2)K_S$



Predictions with Heavy Neutrino Mixing

- A. Ilakovac, Phys. Rev. **D 62** 036010 (2000):

$$B(\tau\tau \rightarrow eK^0) \approx 9.82 \times 10^{-16} x_{\tau e}^2$$

$$B(\tau\tau \rightarrow \mu K^0) \approx 1.93 \times 10^{-16} x_{\tau \mu}^2$$

$$B(\tau\tau \rightarrow eK^0\bar{K}^0) \approx 6.625 \times 10^{-7} z_{\tau e}^2$$

$$B(\tau\tau \rightarrow \mu K^0\bar{K}^0) \approx 1.282 \times 10^{-7} z_{\tau \mu}^2$$

☆ x and z depend on heavy neutrino masses and mixings

☞ potentially close to experimental sensitivity!



Current 90% C.L. Upper Limits on Branching Fraction

Mode	MARK II	BELLE (LP01)	BELLE (DPF02)
L	17 pb^{-1}	23.6 fb^{-1}	48.6 fb^{-1}
eK_S	6.5×10^{-4}	9.0×10^{-7}	2.9×10^{-7}
πK_S	5.0×10^{-4}	9.0×10^{-7}	2.7×10^{-7}



General Selection Criteria

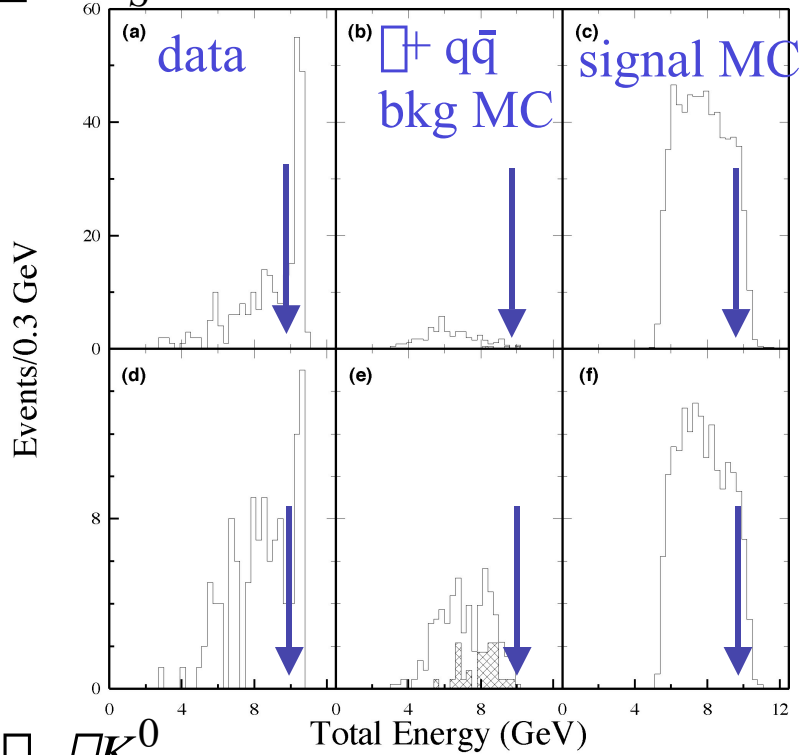
- Data: 13.9 fb⁻¹
- $E_{CM} \sim 10.6$ GeV
- 4 or 6 charged tracks with zero net charge
- $R_{xy} < 5$ mm & $|z| < 50$ mm (*non- K_S tracks*)
- $|\cos\theta_{track}| < 0.90$ (*reject beam-gas events*)
- $|\cos\theta_{missing}| < 0.90$

Suppress radiative Bhabha
and $\mu\mu$ pair events
- $E_{total} < 0.95 E_{CM}$

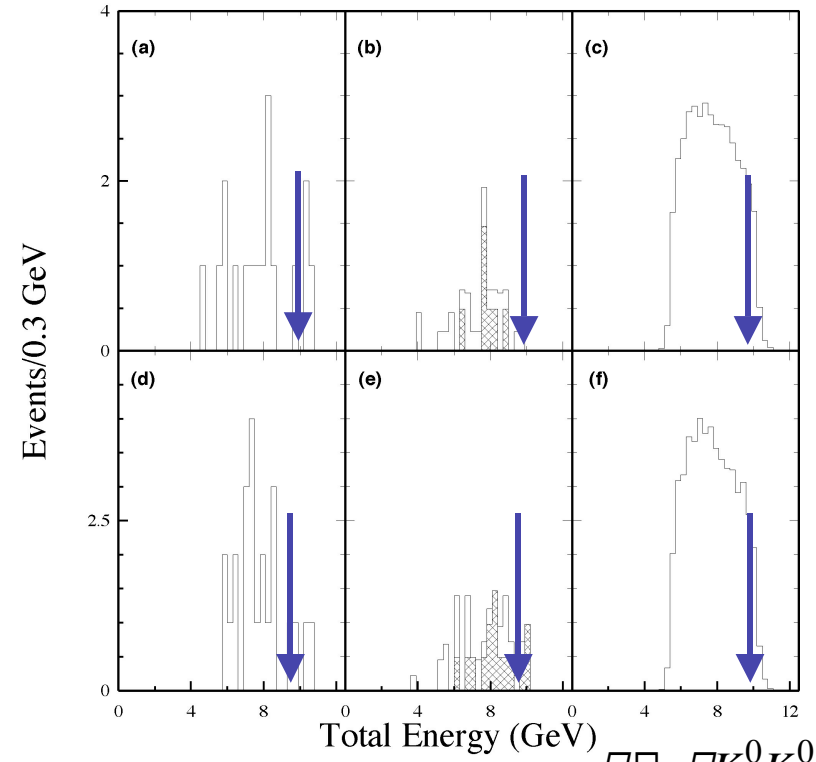


Total Energy Cut

eK_S^0



$eK_S^0K_S^0$



K_S^0

- signal Monte Carlo normalization is arbitrary

- cut: $E_{total} < 0.95 E_{CM}$

$K_S^0K_S^0$

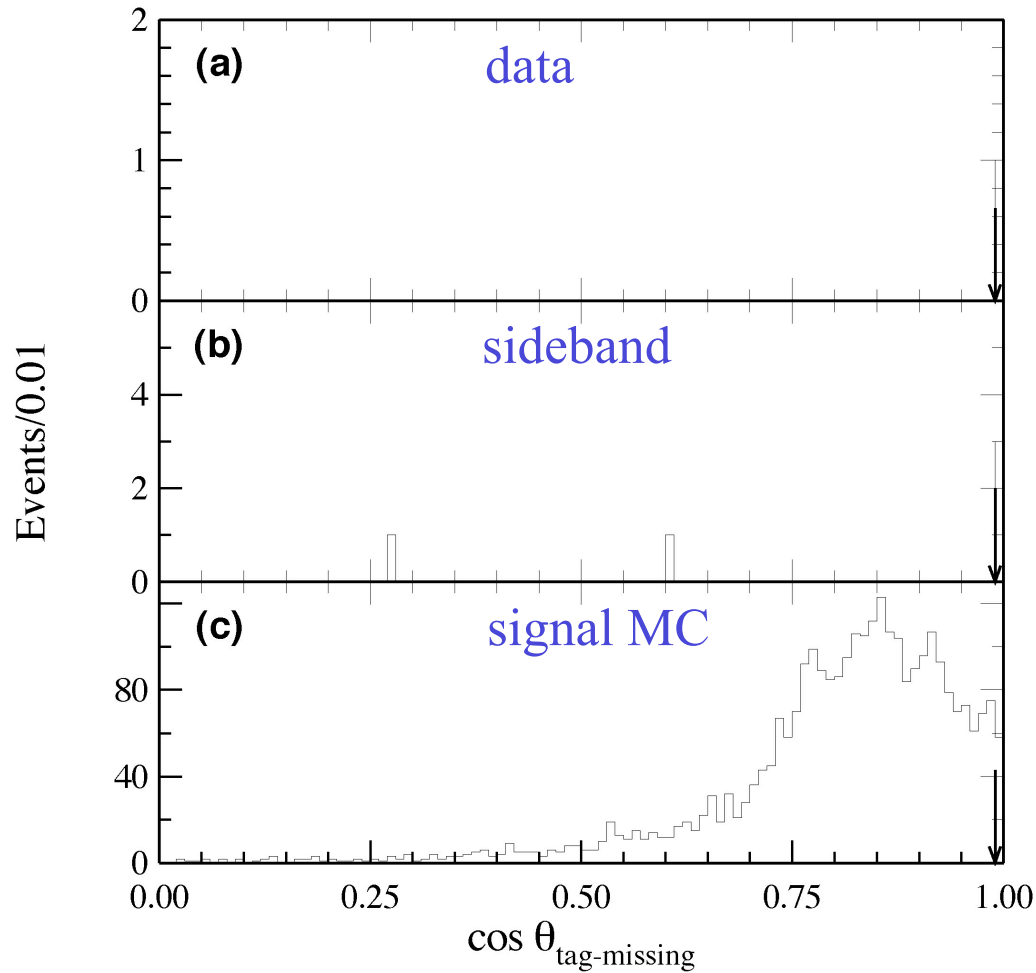


Event Shape Criteria

- event divided into two hemispheres using thrust axis
 - ☆ tag hemisphere:
 - 1 charged track
 - $m_{tag} < m_{\square}$
 - undetected \square_{\square} in this hemisphere: $0 < \cos \square_{tag-missing} < 1.0$
 - ☆ signal hemisphere:
 - 3 or 5 charged tracks
 - e or $\square + (1 \text{ or } 2) K_S$



$\cos\theta_{\text{tag-missing}}$ in eK_S



- 3 events in eK_S sidebands
- ☞ expect ~ 0.75 bkg event
- ☞ $\cos\theta_{\text{tag-missing}} < 0.99$

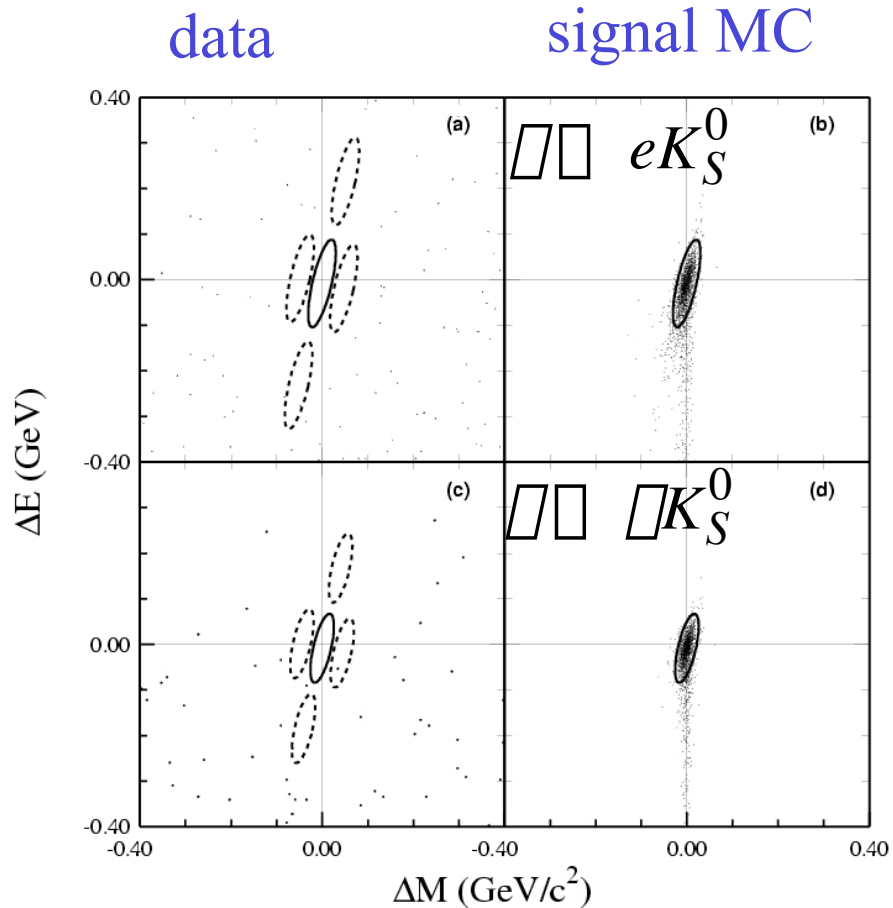


Particle ID

- e^\pm
 - $0.85 < E/p < 1.10$
 - dE/dx consistent with e
- π^\pm
 - penetrate > 3 absorption lengths of iron
- K_S
 - $\pi^+\pi^-$ final state with detached vertex
 - $485 < \text{mass}(K_S) < 510 \text{ MeV}$ (3 σ)
 - neither π consistent with e
- photons
 - $E > 60 \text{ MeV}$ in the barrel ($|\cos\theta| < 0.80$)
 - $E > 100 \text{ MeV}$ in the endcap ($0.80 < |\cos\theta| < 0.95$)
 - $R_{min} > 30 \text{ cm}$ or $E_\pi > 300 \text{ MeV}$



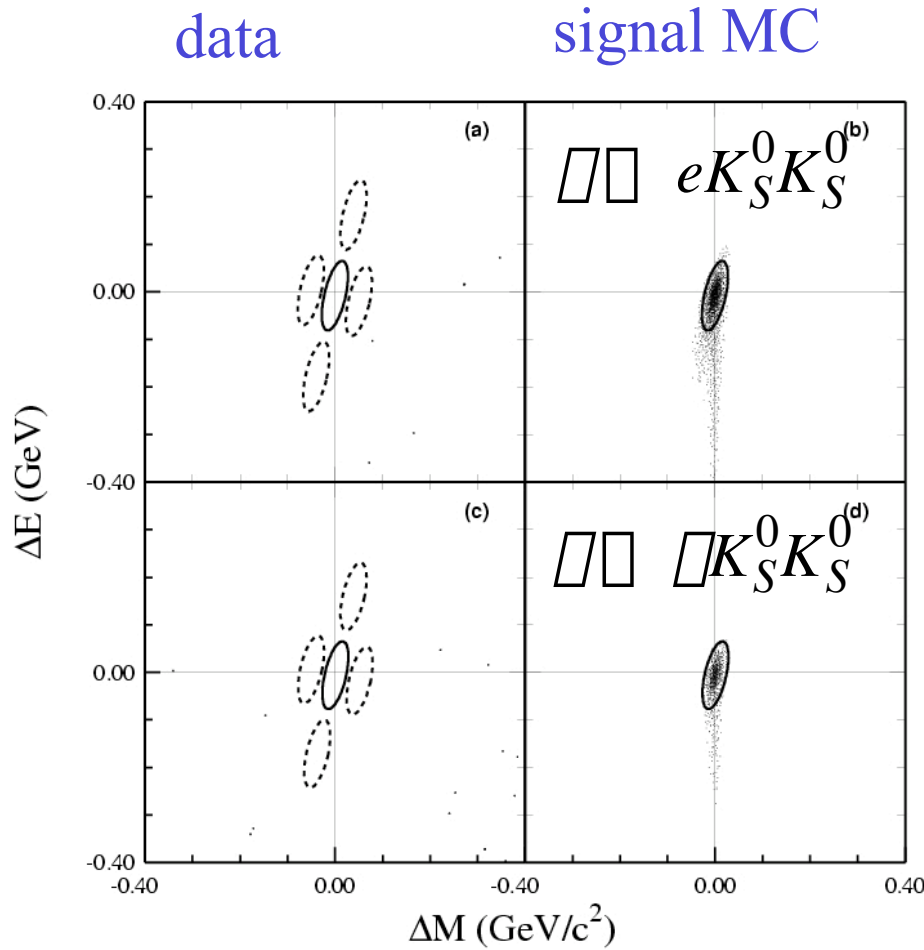
ΔE vs. ΔM of $\tau\tau \ell K_S$



- $|\Delta E| = |E - E_{beam}| < 3\sigma$
- $|\Delta M| = |M - M_{\tau}| < 3\sigma$
- 2 events in eK_S sidebands
☞ expect ~ 0.50 background event
- 3 events in τK_S sidebands
☞ expect ~ 0.75 background event
- no events in signal regions



ΔE vs. ΔM of $\tau \rightarrow \ell K_S K_S$



- 3 σ cut on ΔE and ΔM
- no events in signal regions
- no events in sideband regions



Systematic Errors (%)

Mode	\square_{\square}	L	Tracking	K_S	Lepton ID	MC stat.	Total
eK_S	1	1	4	2	1.5	1.9	5.3
$\square K_S$	1	1	4	2	4	2.2	6.6
$eK_S K_S$	1	1	6	4	1.5	0.6	7.5
$\square K_S K_S$	1	1	6	4	4	1.3	8.5



Results

★ no events observed in any mode

Mode	$\mathcal{B}(\%)$	$\mathcal{B}(10^{-7})$ (stat.)	$\mathcal{B}(10^{-7})$
eK_S	19.4 ± 0.4	8.5	9.1
μK_S	19.0 ± 0.4	8.7	9.5
$eK_S K_S$	12.1 ± 0.1	20	22
$\mu K_S K_S$	8.0 ± 0.1	30	34

- set similar limits as BELLE on $\mu\mu \ell K_S$
- set **new** limits on $\mu\mu \ell K_S K_S$
- limits on $\mu\mu \ell K_S K_S$ are more stringent than $\mu\mu \ell K^+ K^-$
- paper accepted as PRD Rapid Communication



Constraints on New Physics Scale

- D. Black, T. Han, H.J. He, and M. Sher, hep-ph/0206056:
 - ☆ analyzed constraints on new physics scale for dimension-six effective operators involving $\chi\chi$ mixing
 - ☆ exotic heavy quarks and χ decays
 - ☞ $\Lambda > 10$ TeV
- new CLEO result on $\chi\chi \rightarrow \chi K_S$
 - ☞ $\Lambda > 17.3$ TeV for axial vector operator
 - ☞ $\Lambda > 18.2$ TeV for pseudoscalar operator