Search for Neutrinoless $etaeta$ Decays Involving $K^0_S$ Mesons

CLEO Collaboration

K.K. Gan
The Ohio State University
**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 $\ell\ell (e + \ell) + (1-2)K_S$

\[
\begin{align*}
B(\tau \to eK^0) & \approx 9.82 \times 10^{-16} x_{\tau e}^2 \\
B(\tau \to \ell K^0) & \approx 1.93 \times 10^{-16} x_{\tau \ell}^2 \\
B(\tau \to eK^0 \bar{K}^0) & \approx 6.625 \times 10^{-7} z_{\tau e}^2 \\
B(\tau \to \ell K^0 \bar{K}^0) & \approx 1.282 \times 10^{-7} z_{\tau \ell}^2
\end{align*}
\]

\(x\) and \(z\) depend on heavy neutrino masses and mixings

potentially close to experimental sensitivity!
Current 90% C.L. Upper Limits on Branching Fraction

<table>
<thead>
<tr>
<th>Mode</th>
<th>MARK II</th>
<th>BELLE (LP01)</th>
<th>BELLE (DPF02)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17 pb(^{-1})</td>
<td>23.6 fb(^{-1})</td>
<td>48.6 fb(^{-1})</td>
</tr>
<tr>
<td></td>
<td>6.5 \times 10^{-4}</td>
<td>9.0 \times 10^{-7}</td>
<td>2.9 \times 10^{-7}</td>
</tr>
<tr>
<td></td>
<td>5.0 \times 10^{-4}</td>
<td>9.0 \times 10^{-7}</td>
<td>2.7 \times 10^{-7}</td>
</tr>
</tbody>
</table>
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)
- \(|\cos \theta_{\text{track}}| < 0.90\) \((\text{reject beam-gas events})\)
- \(|\cos \theta_{\text{missing}}| < 0.90\)
- \(E_{total} < 0.95\) \(E_{CM}\) \(\text{ Suppress radiative Bhabha and pair events}\)
Total Energy Cut

- signal Monte Carlo normalization is arbitrary
- cut: $E_{total} < 0.95 \cdot E_{CM}$
Event Shape Criteria

- Event divided into two hemispheres using thrust axis
  - Tag hemisphere:
    - 1 charged track
    - $m_{tag} < m_{\tau}$
    - Undetected in this hemisphere: $0 < \cos \theta_{tag\text{-}missing} < 1.0$
  - Signal hemisphere:
    - 3 or 5 charged tracks
    - $e$ or $\mu + (1\ or \ 2) \ K_S$
$\cos \theta_{\text{tag-missing}}$ in $\boxplus \boxminus$ $eK_S$

- 3 events in $eK_S$ sidebands
- Expect $\sim 0.75$ bkg event
- $\cos \theta_{\text{tag-missing}} < 0.99$
**Particle ID**

- $e^\pm$
  - $0.85 < E/p < 1.10$
  - $dE/dx$ consistent with $e$

- $\bar{p}^\pm$
  - penetrate $> 3$ absorption lengths of iron

- $K_S$
  - $\bar{p}^+ p^-$ final state with detached vertex
  - $485 < \text{mass}(K_S) < 510$ MeV ($3\sigma$)
  - neither $\bar{p}$ consistent with $e$

- Photons
  - $E > 60$ MeV in the barrel ($|\cos\theta| < 0.80$)
  - $E > 100$ MeV in the endcap ($0.80 < |\cos\theta| < 0.95$)
  - $R_{min} > 30$ cm or $E > 300$ MeV
$E$ vs. $M$ of $\ell K_S$

- $|\Delta E| = |E - E_{beam}| < 3\sigma$
- $|\Delta M| = |M - M_t| < 3\sigma$
- 2 events in $eK_S$ sidebands
  - expect ~ 0.50 background event
- 3 events in $K_S$ sidebands
  - expect ~ 0.75 background event
- no events in signal regions
\( \Delta E \) vs. \( \Delta M \) of \( \ell K_S K_S \)

- 3 cuts on \( \Delta E \) and \( \Delta M \)
- No events in signal regions
- No events in sideband regions
### Systematic Errors (\%) 

<table>
<thead>
<tr>
<th>Mode</th>
<th>( \bar{\nu} \eK_{S} )</th>
<th>( L )</th>
<th>Tracking</th>
<th>( K_{S} )</th>
<th>Lepton ID</th>
<th>MC stat.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>( e\K_{S} )</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>1.5</td>
<td>1.9</td>
<td>5.3</td>
</tr>
<tr>
<td>( \bar{\nu}K_{S} )</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>2.2</td>
<td>6.6</td>
</tr>
<tr>
<td>( e\K_{S}\K_{S} )</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>4</td>
<td>1.5</td>
<td>0.6</td>
<td>7.5</td>
</tr>
<tr>
<td>( \bar{\nu}\K_{S}\K_{S} )</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>1.3</td>
<td>8.5</td>
</tr>
</tbody>
</table>
**Results**

- no events observed in any mode

<table>
<thead>
<tr>
<th>Mode</th>
<th>□ (%)</th>
<th>$B(10^{-7})$ (stat.)</th>
<th>$B(10^{-7})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$eK_S$</td>
<td>19.4 ± 0.4</td>
<td>8.5</td>
<td>9.1</td>
</tr>
<tr>
<td>$\Box K_S$</td>
<td>19.0 ± 0.4</td>
<td>8.7</td>
<td>9.5</td>
</tr>
<tr>
<td>$eK_SK_S$</td>
<td>12.1 ± 0.1</td>
<td>20</td>
<td>22</td>
</tr>
<tr>
<td>$\Box K_SK_S$</td>
<td>8.0 ± 0.1</td>
<td>30</td>
<td>34</td>
</tr>
</tbody>
</table>

- set similar limits as BELLE on $\Box \Box$ $\ell K_S$
- set **new** limits on $\Box \Box$ $\ell K_SK_S$
- limits on $\Box \Box$ $\ell K_SK_S$ are more stringent than $\Box \Box$ $\ell K^+ K^-$
- paper accepted as PRD Rapid Communication
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 mixing
- exotic heavy quarks and decays
- $\Delta > 10$ TeV
- new CLEO result on $\Delta K_S$
- $\Delta > 17.3$ TeV for axial vector operator
- $\Delta > 18.2$ TeV for pseudoscalar operator