Search for $B^+ \rightarrow K^+ \ell^+ \ell^-$ and $B^0 \rightarrow K^{*0} \ell^+ \ell^-$

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On behalf of the BaBar Collaboration

- Theoretical predictions and experimental status
- Analysis methods
- Signal properties
- Main background categories
  - $J/\psi \ [\psi(2S)] K$ and $J/\psi \ [\psi(2S)] K^*$ events
- Results
Theoretical issues

<table>
<thead>
<tr>
<th>Mode</th>
<th>Predicted Br. Fr.* (~35% uncertainty)</th>
<th>Product Br. Fr.</th>
<th># produced events / 10 fb⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B^+ \rightarrow K^+ l^+ l^-$</td>
<td>$5.7 \times 10^{-7}$</td>
<td>$5.7 \times 10^{-7}$</td>
<td>12.0</td>
</tr>
<tr>
<td>$B^0 \rightarrow K^{*0} e^+ e^-$ ($K^{*0} \rightarrow K^+ \pi^-$)</td>
<td>$2.3 \times 10^{-6}$</td>
<td>$1.5 \times 10^{-6}$</td>
<td>16.1</td>
</tr>
<tr>
<td>$B^0 \rightarrow K^{*0} \mu^+ \mu^-$ ($K^{*0} \rightarrow K^+ \pi^-$)</td>
<td>$1.9 \times 10^{-6}$</td>
<td>$1.3 \times 10^{-6}$</td>
<td>13.3</td>
</tr>
<tr>
<td>TOTAL events produced</td>
<td></td>
<td></td>
<td>41.4</td>
</tr>
</tbody>
</table>

For now, we are only looking at $3.15 \text{ fb}^{-1}$ of data

• this is the first stage of a blind analysis
• we expect to have $20 \text{ fb}^{-1}$ by the end of the year

Experimental status

- 90% CL limits from CLEO (3.33 x 10^6 B\bar{B} data set) and CDF (88 pb\(^{-1}\)):

<table>
<thead>
<tr>
<th>Mode</th>
<th>CLEO*</th>
<th>CDF**</th>
</tr>
</thead>
<tbody>
<tr>
<td>K^+\mu^+\mu^-</td>
<td>&lt; 9.7 x 10^{-6}</td>
<td>&lt; 5.2 x 10^{-6}</td>
</tr>
<tr>
<td>K^0\mu^+\mu^-</td>
<td>&lt; 31.0 x 10^{-6}</td>
<td></td>
</tr>
<tr>
<td>K^{*+}\mu^+\mu^-</td>
<td>&lt; 33.0 x 10^{-6}</td>
<td></td>
</tr>
<tr>
<td>K^{*0}\mu^+\mu^-</td>
<td>&lt; 9.5 x 10^{-6}</td>
<td>&lt; 4.0 x 10^{-6}</td>
</tr>
<tr>
<td>K^+e^+e^-</td>
<td>&lt; 11.0 x 10^{-6}</td>
<td></td>
</tr>
<tr>
<td>K^0e^+e^-</td>
<td>&lt; 17.0 x 10^{-6}</td>
<td></td>
</tr>
<tr>
<td>K^{*+}e^+e^-</td>
<td>&lt; 38.0 x 10^{-6}</td>
<td></td>
</tr>
<tr>
<td>K^{*0}e^+e^-</td>
<td>&lt; 14.0 x 10^{-6}</td>
<td></td>
</tr>
</tbody>
</table>

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Analysis Methods (1)

- **Basic ideas:**
  - Perform a blind analysis
  - Select charged particle modes only:
    - $B^+ \rightarrow K^+e^+e^-$, $B^+ \rightarrow K^+\mu^+\mu^-$, $B^0 \rightarrow K^{*0}e^+e^-$, $B^0 \rightarrow K^{*0}\mu^+\mu^-$ (where $K^{*0} \rightarrow K^+\pi$)
  - use $\Delta E$ vs. $m_{ES}$ plane to select signal region

$$m_{ES} = \sqrt{(\sqrt{s} / 2)^2 - (p_B^*)^2}$$

$$\Delta E = E_B^* - \sqrt{s} / 2$$

- $E_B^*(p_B^*)$ is the $B$ candidate energy (momentum) in the CM frame
- $\sqrt{s}$ = center-of-mass energy

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**MC truth tagged signal**

$B^+ \rightarrow K^+e^+e^-$
Analysis Methods (2)

- Select electrons with $p_{\text{LAB}}^e > 0.5$ GeV/c and muons with $p_{\text{LAB}}^\mu > 1.0$ GeV/c
- Require high multiplicity events (with # of tracks > 4); veto $\gamma$ conversions
- Veto $J/\psi$, $\psi(2S)$ resonance regions
- Suppress continuum background using Fisher discriminant
- Particle ID:
  - electron ID based on energy deposition in the CsI calorimeter
  - muon ID based on the penetration length in the Instrumented Flux Return
  - hadron ID based on combined drift chamber dE/dx and Cherenkov angle information

<table>
<thead>
<tr>
<th>Mode</th>
<th>$K^+e^+e^-$</th>
<th>$K^+\mu^+\mu^-$</th>
<th>$K^{*0}e^+e^-$</th>
<th>$K^{*0}\mu^+\mu^-$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency, %</td>
<td>13.1</td>
<td>8.6</td>
<td>7.7</td>
<td>4.5</td>
</tr>
</tbody>
</table>
Predicted distributions for $q^2 = M_{l+l-}^2$

$B \to K \mu^+\mu^- :$

$B \to K^{*0} \mu^+\mu^-$ (pole at $q^2 = 0$):

- Solid line + blue bands: SM range (± 35%); Ali et al. form factors
- Dotted line: SUGRA model ($R_7 = -1.2$, $R_9 = 1.03$, $R_{10} = 1$)
- Long-short dashed line: SUSY model ($R_7 = -0.83$, $R_9 = 0.92$, $R_{10} = 1.61$)
Generated distributions for $q^2 = M_{l+l}^2$

We have implemented event generators using the model of Ali et al.

$B \rightarrow K \mu^+\mu^-$

$B \rightarrow K^{*0} \mu^+\mu^-$ (pole at $q^2 = 0$)
Background categories

- **$B \rightarrow J/\psi \ K(K^\ast), \ \psi(2S) \ K(K^\ast)$ is the most serious background**
  - this background can be controlled by a cut in $\Delta E$ vs. $m_{l+l^-}$ plane
  - also possible to have $J/\psi (\rightarrow \mu^+ \mu^-) \ K$ with $K$ and $\mu$ swapped
    - re-assign particle masses and cut on the $J/\psi$ mass

- **$B^+ \rightarrow D^0 (\rightarrow K^+ \pi^-) \pi^+ \ with \ \pi^- \ misidentified \ as \ \mu^- \ and \ K^+ \ as \ \mu^+$**
  - re-assign particle masses and veto the $D^0$

- **Continuum ($e^+e^- \rightarrow \bar{q}q$)**
  - suppressed by using a 4-variable Fisher discriminant

- **Combinatorial from $B \bar{B}$ events**
  - suppressed by using vertexing
The most serious background for this analysis, $J/\psi [\psi(2S)] K^{(*)}$ events, is suppressed by using a correlated selection in the $\Delta E$ vs. $m_{l+l^-}$ plane.

- This is needed to account for bremsstrahlung and track mismeasurement.

**Signal $B \rightarrow J/\psi K$ and $B \rightarrow \psi(2S) K$ Monte Carlo**
$B \rightarrow J/\psi [\psi(2S)] K(*)$ events (2)

$B \rightarrow J/\psi [\psi(2S)] K(*)$ control sample (8 fb$^{-1}$ of data)

$J/\psi [\psi(2S)] K(*)$ events are also used as a control sample to verify the analysis efficiency
Results (1)

For the purpose of setting the limit, we assume that all events in the signal region could be due to signal processes.

- Background is not subtracted
## Results (2)

<table>
<thead>
<tr>
<th>Mode</th>
<th># obs. evts</th>
<th># bkg. evts</th>
<th>Preliminary 90% C.L. limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K^+ e^+e^-$</td>
<td>2</td>
<td>0.20</td>
<td>$&lt; 12.5 \times 10^{-6}$</td>
</tr>
<tr>
<td>$K^+ \mu^+\mu^-$</td>
<td>0</td>
<td>0.25</td>
<td>$&lt; 8.3 \times 10^{-6}$</td>
</tr>
<tr>
<td>$K^{*0} e^+e^-$</td>
<td>1</td>
<td>0.50</td>
<td>$&lt; 24.1 \times 10^{-6}$</td>
</tr>
<tr>
<td>$K^{*0} \mu^+\mu^-$</td>
<td>0</td>
<td>0.33</td>
<td>$&lt; 24.5 \times 10^{-6}$</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3</strong></td>
<td><strong>1.3</strong></td>
<td></td>
</tr>
</tbody>
</table>

The number of **background** events is extracted from sideband in data

- Expect **1 signal** event based on Geant MC (Ali et al. predictions).
A candidate $B^+ \rightarrow K^+ e^+ e^-$ event
Summary

• We have searched for the rare decays $B^+ \rightarrow K^+ \ell^+ \ell^-$ and $B^0 \rightarrow K^{*0} \ell^+ \ell^-$ using a sample of $3.67 \times 10^6 B \bar{B}$ events
  – We are using this sample to better understand our backgrounds
• We have found 3 candidate events total and set preliminary 90% C.L. limits
  – The limits for the $B \rightarrow K \ell^+ \ell^-$ modes are comparable to those set by other experiments
  – The limits for the $B \rightarrow K^{*0} \ell^+ \ell^-$ modes are less sensitive with this data sample
• We are planning to analyze substantially more data in the near future
  – BaBar will have 20 fb$^{-1}$ by the end of the year and an extra 30 fb$^{-1}$ by next year