Preliminary Measurement of the $\text{BF}(\tau^- \to K^- \pi^0 \nu_\tau)$ using the BABAR Detector

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for the BABAR Collaboration

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Outline

• Motivation

• PEP-II and the BABAR Experiment

• Event Selection:
  • $K^{-}\pi^{0}$ selection and efficiency
  • Systematic errors

• Preliminary Result

• Conclusions and Outlook
Motivation

- Hadronic $\tau$ decays provide a clean laboratory for studying the hadronic weak current

- For decays with overall net strangeness, SU(3)$_f$ symmetry breaking can be used to determine the absolute value of the CKM matrix element $V_{us}$, the strong coupling constant $\alpha_s$ and $m_s$

- The uncertainty in the extraction of $|V_{us}|$ and $m_s$ is dominated by the experimental measurement uncertainties

- The high luminosity provided by PEP-II, coupled with $\sigma_{\tau\tau}=0.89$ nb at BABAR energies, provides a high statistics sample to study $\tau^- \rightarrow K^- \pi^0 \nu_\tau$ decays
PEP-II Performance

PEP-II delivered \( \sim 254 \text{ fb}^{-1} \)
BaBar recorded \( \sim 244 \text{ fb}^{-1} \)

For analysis used 1999-2003 data:
On peak \( 112.1 \text{ fb}^{-1} \)
Off peak \( 12.3 \text{ fb}^{-1} \)
Total Lumi: \( \mathcal{L} = 124.4 \text{ fb}^{-1} \)

Total # of \( \tau \) decays: \( \sim 220 \text{M} \)
The BABAR Detector

1.5 T solenoid

DIRC (PID)
144 quartz bars
11000 PMs
e⁻ (9.0 GeV)
e⁺ (3.1 GeV)

EMC
6580 CsI(Tl) crystals

Drift Chamber
40 stereo layers

Instrumented Flux Return
iron / RPCs (muon / neutral hadrons)

Silicon Vertex Tracker
5 layers, double sided strips
Event topology

- Event divided in two hemispheres defined by the plane perpendicular to the thrust vector.
- Only events with one charged track in each hemisphere are selected:
  - “Signal” hemisphere: track identified as Kaon
  - “Tag” hemisphere: track identified as electron or muon.
Lepton identification and $\pi$ mis-ID

- Efficiency and mis-id measured from data:
  - efficiency: $e^+e^-$ and $\mu^+\mu^\gamma$ sample
  - $\pi$ mis-ID: $D^{*+}\rightarrow D^0\pi^+$, $D^0\rightarrow K^+\pi^-$
Kaon efficiency and $\pi$ mis-ID

Efficiency and mis-ID computed using $D^+ \rightarrow D^0\pi^+$ data sample

Good $K/\pi$ separation using the information from the DIRC
Event selection

- Thrust ≥ 0.9
- \( R_2 = \frac{2^{\text{nd}}}{0^{\text{th}}} \) Fox-Wolfram moment ≥ 0.5
- Missing momentum ≥ 0.5 GeV/c
- Events where both charged tracks are identified as electron are rejected

- Only 1 \( \pi^0 \) in the event
  - Only \( \pi^0 \)s from two separated EMC energy deposits with \( E_\gamma > 50 \) MeV;
  - 100 < \( m_{\pi^0} \) < 160 MeV/c²

- Angle between K and \( \pi^0 \) candidates \( \theta_{K\pi^0} < 1.0 \) rad
- Energy in the “signal” hemisphere not associated with the charged track or \( \pi^0 \) candidate ≤ 50 MeV
Selected events

- After all cuts and selections:
  - 21678 events selected in 124.4 fb⁻¹ of data
    - 12377 with e-tag
    - 9301 with μ-tag

- Signal Efficiency:
  \[ \varepsilon_{\text{sig}} = \frac{N_{\text{sel}}}{N_{\text{gen}}}(\tau_1 \rightarrow K\pi^0\nu_\tau; \tau_2 \rightarrow \text{anything}) \]
  - (1.61±0.01) %
    - (0.92±0.01) % e-tag
    - (0.69±0.01) % μ-tag
Background evaluation

- Background evaluated using MC events
  - generic $\tau$, Bhabha, $\mu+\mu-$, qq and BB samples
- Main contribution comes from non-signal $\tau$ decays
  - for $m_{K\pi^0} \leq 0.8$ GeV/c$^2$ mainly $K^0\pi^0$, $K^0\pi^-$ and $K\pi^0\pi^0$
    - In particular, BF has large measurement uncertainty for:
      - $\sigma_{BF}/BF(\tau\rightarrow KK^0\pi^0) \sim 13\%$
      - $\sigma_{BF}/BF(\tau\rightarrow K\pi^0\pi^0) \sim 40\%$
  - for $m_{K\pi^0} \geq 1.0$ GeV/c$^2$ mainly $\pi\pi^0$ ($\sigma_{BF}/BF \sim 0.5\%$)
- Total background:
  - 6086 events (e+$\mu$ tag)
    - 3524 in the e-tagged sample
    - 2562 in the $\mu$-tagged sample
Systematic uncertainties

<table>
<thead>
<tr>
<th>Systematic</th>
<th>e-tag [%]</th>
<th>(\mu)-tag [%]</th>
<th>Combined [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trk. eff.</td>
<td>1.40</td>
<td>1.40</td>
<td>1.40</td>
</tr>
<tr>
<td>(\pi^0) eff.</td>
<td>3.26</td>
<td>3.26</td>
<td>3.26</td>
</tr>
<tr>
<td>Particle ID</td>
<td>2.20</td>
<td>3.50</td>
<td>2.40</td>
</tr>
<tr>
<td>(L\cdot\sigma_{\tau\tau})</td>
<td>2.30</td>
<td>2.30</td>
<td>2.30</td>
</tr>
<tr>
<td>MC signal stat.</td>
<td>0.87</td>
<td>1.00</td>
<td>0.63</td>
</tr>
<tr>
<td>MC bkgnd stat.</td>
<td>0.83</td>
<td>0.97</td>
<td>0.63</td>
</tr>
<tr>
<td>(\tau) Bkgnds</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5.0</strong></td>
<td><strong>5.7</strong></td>
<td><strong>5.0</strong></td>
</tr>
</tbody>
</table>

All numbers are preliminary
### Branching fraction result

<table>
<thead>
<tr>
<th>Data</th>
<th>e-tag</th>
<th>μ-tag</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real</td>
<td>12377±111</td>
<td>9301±94</td>
<td>21678 ± 147</td>
</tr>
<tr>
<td>(\tau^+\tau^-)</td>
<td>3494 ± 59</td>
<td>2512 ± 50</td>
<td>6006 ± 78</td>
</tr>
<tr>
<td>uds</td>
<td>25 ± 5</td>
<td>48 ± 6</td>
<td>73 ± 8</td>
</tr>
<tr>
<td>ccb</td>
<td>5 ± 2</td>
<td>2 ± 1</td>
<td>7 ± 2</td>
</tr>
<tr>
<td>BBbar</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(\varepsilon_{\text{sig}})</td>
<td>0.92±0.01 %</td>
<td>0.69±0.01 %</td>
<td>1.61±0.01 %</td>
</tr>
</tbody>
</table>

#### Preliminary

<table>
<thead>
<tr>
<th>Sample</th>
<th>(B(\tau \rightarrow K^-\pi^0\nu_\tau)) [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>e-tag</td>
<td>0.436±0.005(stat)±0.022(syst)</td>
</tr>
<tr>
<td>μ-tag</td>
<td>0.442±0.006(stat)±0.025(syst)</td>
</tr>
<tr>
<td>Combined</td>
<td>0.438±0.004(stat)±0.022(syst)</td>
</tr>
</tbody>
</table>

PDG: (0.45±0.03)%

\[
B(\tau \rightarrow K^-\pi^0\nu_\tau) = \frac{1}{2N_{\tau\tau}} \frac{N_{\text{data}} - N_{\text{bkg}}}{\varepsilon_{\text{sig}}} = \frac{1}{2N_{\tau\tau}} \frac{\sigma_{\tau\tau} L_{\text{data}}}{\epsilon_{\text{sig}}} = 111 \times 10^6
\]
In agreement with PDG average
Improved uncertainty
What next?

Measure the branching fraction of the $\tau^- \rightarrow K^0 \pi^- \nu_\tau$ decay and combine it with the presented result

$\tau^- \rightarrow (K\pi)^- \nu_\tau$ branching fraction

Study the mass spectrum of $\tau^- \rightarrow (K\pi)^- \nu_\tau$

Use $\tau^- \rightarrow (K\pi)^- \nu_\tau$ studies as input into the total strange spectral function
Conclusions

A preliminary measurement of the $\tau^- \to K^- \pi^0 \nu_\tau$ branching fraction has been obtained using 124.4 fb$^{-1}$ of data taken at BABAR:

$$B(\tau^- \to K^- \pi^0 \nu_\tau) = (0.438 \pm 0.004\text{(stat)} \pm 0.022\text{(syst)})\%$$

Measurement consistent with world average (PDG 2004)

This analysis represents a significant improvement on previously published results

$\tau^- \to (K\pi)^- \nu_\tau$ is a clean laboratory for studying hadronic weak currents

more results to follow!
Backup Slides
## τ background systematic

<table>
<thead>
<tr>
<th>Decay Channel</th>
<th>( w/10^{-2} )</th>
<th>( \sigma^{(PDG)}/\mathcal{B}^{(PDG)} ) [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \tau^- \rightarrow e^- \nu_e \nu_\tau )</td>
<td>0.159</td>
<td>0.34</td>
</tr>
<tr>
<td>( \tau^- \rightarrow \mu^- \nu_\mu \nu_\tau )</td>
<td>0.020</td>
<td>0.35</td>
</tr>
<tr>
<td>( \tau^- \rightarrow \pi^- \nu_\tau )</td>
<td>0.062</td>
<td>0.99</td>
</tr>
<tr>
<td>( \tau^- \rightarrow \pi^- \pi^0 \nu_\tau )</td>
<td>20.063</td>
<td>0.55</td>
</tr>
<tr>
<td>( \tau^- \rightarrow a_1^- \nu_\tau )</td>
<td>0.426</td>
<td>1.10</td>
</tr>
<tr>
<td>( \tau^- \rightarrow K^- \nu_\tau )</td>
<td>0.264</td>
<td>3.35</td>
</tr>
<tr>
<td>( \tau^- \rightarrow K^0 \pi^- \nu_\tau )</td>
<td>0.821</td>
<td>4.49</td>
</tr>
<tr>
<td>( \tau^- \rightarrow 2\pi^- \pi^+ \pi^0 \nu_\tau )</td>
<td>0.060</td>
<td>2.05</td>
</tr>
<tr>
<td>( \tau^- \rightarrow \pi^- 3\pi^0 \nu_\tau )</td>
<td>0.003</td>
<td>9.30</td>
</tr>
<tr>
<td>( \tau^- \rightarrow K^- K^+ \pi^- \nu_\tau )</td>
<td>0.009</td>
<td>9.14</td>
</tr>
<tr>
<td>( \tau^- \rightarrow K^- K^0 \pi^0 \nu_\tau )</td>
<td>4.456</td>
<td>12.90</td>
</tr>
<tr>
<td>( \tau^- \rightarrow K^- \pi^0 \pi^0 \nu_\tau )</td>
<td>0.791</td>
<td>39.70</td>
</tr>
<tr>
<td>( \tau^- \rightarrow K^- \pi^- \pi^+ \nu_\tau )</td>
<td>0.010</td>
<td>15.15</td>
</tr>
<tr>
<td>( \tau^- \rightarrow \pi^- \pi^0 K^0 \nu_\tau )</td>
<td>0.029</td>
<td>11.11</td>
</tr>
<tr>
<td>( \tau^- \rightarrow \eta \pi^- \pi^0 \nu_\tau )</td>
<td>0.003</td>
<td>13.79</td>
</tr>
<tr>
<td>( \tau^- \rightarrow K^- K^0 \nu_\tau )</td>
<td>0.338</td>
<td>10.38</td>
</tr>
</tbody>
</table>

Systematic error due to the uncertainty in the BF of τ background decays used in generated MC

\[
\sigma_{\tau MC} = \sqrt{\sum_i (w_i \frac{\sigma_i^{PDG}}{\mathcal{B}_i^{PDG}})^2}
\]