Bs Mixing with Lepton
+ D Analysis

K. Hasuko
B_s Mixing with Lepton+D

Kazumi Hasuko
Tohoku University

SLD Collaboration Meeting
Chateau La Cresta
February 11, 1998

- Lepton+D Method
- B_s tags with Lepton+D
- Results for 1996 (+97)
- Summary

• first look
  of B_s mixing
Lepton+D Method

Explicitly reconstruct $B \rightarrow Dl$ decays to determine
decay points
Lepton charge tags $B$ decay flavor

- Select hemispheres with leptons ($\text{highest } P_T$)
- Use ZVTOP to find $D$ vertex candidates
  ZVTOP with special mode (mode 3)
  - search vertices on the plane defined by
    the seed track and the IP
  - downstream & furthest

- Select secondary tracks using L/D cut to the seed vertex
Lepton+D Method

- **D Vertex Reconstruction**
  - Build vertices from ZVTOP secondary tracks
  - Attempt to attach non-secondary tracks to vertices if the charge is bad

  \[ D \text{ Vtx Mass} < 1.95 \text{ GeV/c}^2 \]
  \[ |D \text{ Charge}| \leq 1 \]

- **Selection of Lepton**
  - Transverse momentum w.r.t. D trajectory

  \[ P_T \text{ w.r.t. D} > 0.9 \text{ GeV/c} \]

  \[ \rightarrow \text{ remove mis-ID lepton} \]
  \[ b \rightarrow c \rightarrow l \]
  \[ (\text{also non-}b\bar{b}) \]

- **B Vertex** = Intersection of lepton track and D trajectory
  - Attempt to attach slow \( \pi^0 \)'s for \( B_d \)

\[ B \text{ Charge} = \phi \]
**B_s Tags with Lepton+D**

Basically we can follow the same procedure used for B_d to tag B_s, but ...

- B_s oscillations are faster than B_d
- B_s fraction is smaller than B_d

The efficiency at short proper time is especially important

**Changes to B_s tags**

- Reconstruct only 1-prong B decays
  
  (don't need to take account of the decays involving slow π's for B_s)

- New lepton identification to improve mis-ID fraction
  - Neural Net electron ID
  - Muon ID using CRID information

  mis-ID electron: 10.3% → 3.8%
  muon: 2.7% → 1.4%

- Tune selections to improve the efficiency
Decay length cut: to remove non-\( \bar{b}b \) events

\[\epsilon = \frac{\text{\# tagged } B \rightarrow \ell}{\text{\# all } B \text{ decays}}\]

Low efficiency at short proper time where we expect maximal sensitivity to Bs mixing ...

We need other cut without sacrificing short-time efficiency

SLD Collaboration Meeting - February 10-12, 1998  K. Hasuko
ZVTOP mass tag

in tagged hemi.: dependent on time
in opposite hemi.: independent on time

→ choose the max.
to increase the δ of vertexing

\[ \text{Max ( } M_{\text{tag}}, M_{\text{opp}} \text{ )} \]

- Non-b\bar{b} contamination
  - \( c\bar{c} \): 1.5% → 2.4%
  - uds: 0.5% → 1.0%

- Max-mass tag increases efficiency at short proper time
\( \cos \theta_{BD} \): the cosine of the angle between the IP-to-B and B-to-D directions

b -> l
- B and D decay chain ~ linear
  \[ \Rightarrow \cos \theta_{BD} \sim 1 \]

B decays close to the IP
- B vertex is reconstructed in a random position
  \[ \Rightarrow \text{The linearity of decay chain is not guaranteed} \]
New vertex fit \( \chi^2_{D+1} \)

to remove \( b \rightarrow c \rightarrow 1 \) decays which can be removed by \( \cos \theta_{BD} \) cut

- Attempt to attach the lepton track to the D vertex
- If the \( \chi^2_{D+1} \) improves with the lepton attached, the decay is removed as \( b \rightarrow c \rightarrow 1 \)

\[
\begin{align*}
    b \rightarrow c \rightarrow 1 & : 6.6\% \rightarrow 9.5\% \\
    \bar{c}c & : 0.3\% \rightarrow 2.4\%
\end{align*}
\]

- New vertex fit increases efficiency at short proper time
Result of Event Selection

Use 1996 data
Number of Neutral Sample in Data: 329

<table>
<thead>
<tr>
<th>Event fractions:</th>
<th>Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>b</td>
<td>96.6%</td>
</tr>
<tr>
<td>c</td>
<td>2.4%</td>
</tr>
<tr>
<td>uds</td>
<td>1.0%</td>
</tr>
<tr>
<td>$B_u$</td>
<td>16.6%</td>
</tr>
<tr>
<td>$B_d$</td>
<td>59.8%</td>
</tr>
<tr>
<td>$B_s$</td>
<td>14.2%</td>
</tr>
<tr>
<td>$\Lambda_b$</td>
<td>5.4%</td>
</tr>
</tbody>
</table>

$b \rightarrow c \rightarrow \ell \quad 9.5\%$

mis-1D $\ell \quad 5.2\%$
# B Hadron Fractions

<table>
<thead>
<tr>
<th></th>
<th>(B_u)</th>
<th>(B_d)</th>
<th>(B_s)</th>
<th>(\Lambda_b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>.173</td>
<td>.614</td>
<td>.155</td>
<td>.059</td>
</tr>
<tr>
<td>(b \rightarrow l^-)</td>
<td>.702</td>
<td>.854</td>
<td>.829</td>
<td>.813</td>
</tr>
<tr>
<td>(b \rightarrow c \rightarrow l^+)</td>
<td>.145</td>
<td>.065</td>
<td>.084</td>
<td>.083</td>
</tr>
<tr>
<td>(b \rightarrow \bar{c} \rightarrow l^-)</td>
<td>.018</td>
<td>.014</td>
<td>.018</td>
<td>.020</td>
</tr>
<tr>
<td>(b \rightarrow X^+)</td>
<td>.042</td>
<td>.019</td>
<td>.017</td>
<td>.023</td>
</tr>
<tr>
<td>(b \rightarrow X^-)</td>
<td>.054</td>
<td>.024</td>
<td>.031</td>
<td>.034</td>
</tr>
<tr>
<td>(b \rightarrow (\text{others})^+)</td>
<td>.019</td>
<td>.005</td>
<td>.005</td>
<td>.004</td>
</tr>
<tr>
<td>(b \rightarrow (\text{others})^-)</td>
<td>.020</td>
<td>.019</td>
<td>.016</td>
<td>.023</td>
</tr>
</tbody>
</table>

**Probability of correct final tag**

\[
\bar{P} = (b \rightarrow l^-) + (b \rightarrow \bar{c} \rightarrow l^-) + (b \rightarrow X^-) + (b \rightarrow \text{others}^-)
\]

**Graphs**

- \(dN/d(0.5\text{ps})\) vs. \(B_d\)
- \(dN/d(0.5\text{ps})\) vs. \(B_s\)

---

SLD Collaboration Meeting - February 10 -12, 1998

K. Hasuko
Efficiencies

\[ \varepsilon(t) = a \frac{1 - e^{bt}}{1 + e^{bt}} + c. \]

\[ \chi^2/\text{ndf} = 121.4 / 36 \]

\begin{tabular}{lcc}
  P1 & 0.6047E-02 & 0.3451E-02 \\
  P2 & -25.85 & 11.47 \\
  P3 & 0.1922E-02 & 0.3482E-02 \\
\end{tabular}

\[ \bar{\varepsilon} \sim 0.8\% \]

\[ \chi^2/\text{ndf} = 74.91 / 47 \]

\begin{tabular}{lcc}
  P1 & 0.2856E-01 & 0.1375E-02 \\
  P2 & -3.770 & 0.4208 \\
  P3 & 0.7006E-02 & 0.1371E-02 \\
\end{tabular}

\[ \bar{\varepsilon} \sim 3.1\% \]

\[ \chi^2/\text{ndf} = 36.42 / 37 \]

\begin{tabular}{lcc}
  P1 & 0.2564E-01 & 0.2437E-02 \\
  P2 & -4.291 & 1.114 \\
  P3 & 0.5221E-02 & 0.2794E-02 \\
\end{tabular}

\[ \bar{\varepsilon} \sim 2.7\% \]

\[ \chi^2/\text{ndf} = 28.33 / 28 \]

\begin{tabular}{lcc}
  P1 & 0.1152E-01 & 0.2583E-02 \\
  P2 & -3.872 & 1.752 \\
  P3 & 0.7717E-02 & 0.2596E-02 \\
\end{tabular}

\[ \bar{\varepsilon} \sim 1.7\% \]

SLD Collaboration Meeting - February 10-12, 1998

K. Hasuko
Decay Length Residuals

$$\Delta L = L_{\text{rec}} - L_{\text{true}}$$

fitted with double Gaussians (core = 60%)

$$\sigma_{\text{core}} = 111 \mu m$$
$$\sigma_{\text{tail}} = 313 \mu m$$

$$B_s \rightarrow l$$

$$\sigma_{\text{core}} = 149 \mu m$$
$$\sigma_{\text{tail}} = 625 \mu m$$

$$B^0 \rightarrow c \rightarrow l$$

$$\sigma_{\text{ct}}^2 = \left( \frac{\sigma_{\text{ct}}}{n_{\beta c}} \right)^2 + \left( \frac{\sigma_{\text{ct}}}{n_{\beta c}} \tau \right)^2$$

$$h \rightarrow X$$

SLD Collaboration Meeting - February 10-12, 1998

K. Hasuko
Relative Boost Residuals

\[ \Delta \eta_\beta = \frac{\eta_\beta^{\text{rec}} - \eta_\beta^{\text{true}}}{\eta_\beta^{\text{true}}} \]

fitted with double Gaussians (core = 60%)

\[ \sigma_{\text{core}} = 6.7\% \]
\[ \sigma_{\text{tail}} = 23.7\% \]

\[ \sigma_{\text{core}} = 9.6\% \]
\[ \sigma_{\text{tail}} = 31.8\% \]

\[ \delta_\tau^2 = \left( \frac{\sigma_{\text{core}}}{\eta_\beta} \right)^2 + \left( \frac{\sigma_{\text{tail}}}{\eta_\beta} \right)^2 \]

SLD Collaboration Meeting - February 10-12, 1998

K. Hasuko
Lepton+D 96MC

Corresponds to $1M^{0}$
Polarization = 100%
Generated $\Delta m = 6.45\text{ps}^{-1}$

$\Delta m = 6.59 \pm 0.48\text{ps}^{-1}$
Lepton+D 96MC

Test of \( L \)

- \( \phi \) Recon. vertex
- \( \tau \) Fitted prob.

Bu Trec (ps)

Bd Trec (ps)

Bs Trec (ps)

Lb Trec (ps)

Bs oscillation can be seen!
Lepton+D 1996-97 Data

# selected decays: 994

-Log Lik vs. delta m

Amplitude vs. delta m

-Log Lik vs. amplitude

\[ \Delta m = 0 \]

\[ \Delta m = 6.5 \text{ ps}^{-1} \]
Summary

• Lepton+D method used for $B_d$ mixing basically works for $B_s$ mixing with the following changes
  - 1-prong $B$ reconstruction
  - New lepton ID (to improve mis-ID fraction)
  - Decay length cut $\rightarrow$ ZVTOP max mass cut
  - $\cos \theta$ cut $\rightarrow \chi^2_{D+1}$ cut
  (to improve the efficiency at short proper time)

• We have parametrized the likelihood function for 1996 analysis (first version)

• We tried amplitude fit for 96+97 data

• Tuning of selection and parametrization are still needed.