B_d Mixing with Kaon Tag Update
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- Introduction and Motivation
- Likelihood Parameterization
- Perfect MC Scans
- “Everything but Proper time Resolution”
- Conclusions and Plans
Why study $B_d$ mixing?

A. $B_d$ mixing can determine the $V_{td}$ element of the CKM matrix:

$$\Delta m_d = \frac{G_F^2}{6\pi^2} \eta_B m_{B_d} m_t f_{B_d} B_{B_d} S_0 |V_{td} V_{tb}^*|^2$$

However, the theory is not that good (error on magnitude of $f_{B_d} \sqrt{B_{B_d}} \approx 20\%$). Thus, we need $B_s$ mixing:

$$\frac{\Delta m_s}{\Delta m_d} = \frac{m_{B_s} f_{B_s} B_{B_s}}{m_{B_d} f_{B_d} B_{B_d}} \frac{|V_{ts}|^2}{|V_{td}|^2} = (1.15 \pm 0.05)^2 \cdot \frac{|V_{ts}|^2}{|V_{td}|^2}$$

B. Once a likelihood fit for the Kaon right sign fraction is developed, one could “swap in” other tags and measure the right sign fractions for those tags from the data, giving a cross check for other analyses.
**B_d Mixing with a Kaon tag**

- We tag the initial state using jet charge + polarization.
- We tag the final state using the kaon. Kaons make very good final state tags for B_d events (right sign fraction is currently measured to be (82±5)% (Argus)). However, this is also the largest systematic error in the previous version of this analysis...a goal is to fit to this value instead of inputting it.
Unbinned Log-Likelihood Fit to $\Delta m_d$

For a single event, the probability to mix is:

$$P_{mix} = f_{Bd} P_{mix,Bd} + f_{Bs} P_{mix,Bs} + f_{Bu} P_{mix,Bu} + f_{Baryon} P_{mix,Baryons}$$

Where the individual terms are as follows:

$$P_{mix,Bd} = \frac{\Gamma_{Bd}}{2} e^{-\Gamma_{bd} t} (1 - (1 - 2R_{Bd} - 2i + 4R_{Bd} i) \cos(\Delta m_d t))$$

$$P_{mix,Bu} = \Gamma_{Bu} e^{-\Gamma_{bu} t} (R_{Bu} + i - 2R_{Bu} i)$$

• $B_s$ is analogous to $B_d$, and the Baryons to $B_u$.

• $f_{(b)}$ is the fraction of that B type (parameterized in MC); $i$ is the initial state right sign probability; $t$ is the proper time and will be replaced by a resolution integral.

• $R_{(b)}$ is the Kaon right sign fraction for that B type, parameterized from MC.
Parameterizations from MC

<table>
<thead>
<tr>
<th>Species</th>
<th>R</th>
<th>f</th>
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<tbody>
<tr>
<td>(B_u)</td>
<td>0.817</td>
<td>0.443</td>
</tr>
<tr>
<td>(B_d)</td>
<td>0.771</td>
<td>0.399</td>
</tr>
<tr>
<td>(B_s)</td>
<td>0.479</td>
<td>0.109</td>
</tr>
<tr>
<td>Baryons</td>
<td>0.616</td>
<td>0.049</td>
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</table>

- The eventual goal is to fit to the \(B_d\) RSF as well as \(\Delta m_d\). This concept has been tested in Minuit on the Monte Carlo.
- To be included in the analysis, we require a hemisphere have at least one vertex with a kaon(s) attached and where the sum of the charges of those kaons is non-zero.
Likelihood Scan Fit on Perfect MC

- $\Delta m_d = 0.484 \text{ ps}^{-1}$ in MC.
- Scan 100 $\Delta m_d$ values evenly spaced from 0.40-0.55 ps$^{-1}$.
- $\Delta m_d = 0.485 \pm 0.002$ (33K $B_d$, no other types).
“Everything but Proper Time Resolution”: MC

- Everything reconstructed, including proper time. BUT, the proper time is not parameterized for resolution effects.
- Scan uses 60 steps from 0.40-0.55 ps\(^{-1}\).
- 42k usable vertices in sample.
- 1-D Minuit fit:
  \[ \Delta m_d = 0.483 \pm 0.020 \text{ ps}^{-1} \]
- 2-D Minuit fit results:
  \[ \Delta m_d = 0.463 \pm 0.024 \text{ ps}^{-1} \]
  \[ \text{RSF (B}_d) = 0.720 \pm 0.011 \]
“Everything but Proper Time Resolution”: Data

- 1-D Minuit result: \( \Delta m_d = 0.483 \pm 0.036 \text{ ps}^{-1} \)
- 2-D Minuit result: (this work is in progress)
Plans and Conclusions

Plans:

- Get proper time parameterization (resolution function) working!!!
- Run 2-d fit for Data.
- Perform systematics studies.
- Be ready for DPF release.

Conclusions:

- The likelihood parameterization method works and does well for $B_d$ mixing.
- It is feasible, using Minuit, to do a 2-D (or more) fit to eliminate the large systematic error from the kaon RSF in the previous version of this analysis.

*With a lot of work and a little luck, we will be ready for DPF!!*