B Decay Charm Counting
Via Topological Vertexing

Aaron Chou
Stanford University

\[ Z \rightarrow b \bar{c} g \rightarrow b\bar{b} \]
for illustrative purposes only!
Why?

$b \rightarrow \phi D : \quad 2.5\% \, J/\psi$

$\sim 1\% \, \ b \rightarrow u \ ? \ \Rightarrow \ V_{ub}$

$\ ? \ b \rightarrow s \ ?$

$b \rightarrow 2D : \quad \text{fixes } b \ \text{semileptonic puzzle?}$

systematics for $b$ lifetime,

$B_d, B_s$ mixing

Analysis:

- Do opposite hemi $b$ tag to get an 'unbiased' $b$ sample.

- Get vertices (ZVTOP3)

- Apply vertexing cuts

- Histogram vertex distributions $\chi^2$ fit,
Strategy

Do a 4 parameter fit to the data histogram

\[ F_i = a_0 M_{o_i} + a_1 M_{l_i} + a_2 M_{2_i} + a_3 M_{b_i} \]

where the \( M_i \)'s are characteristic shape histograms derived from the Monte Carlo for the \( b \rightarrow \phi c, 1c, 2c, \) and background components respectively.

In principle, we can extract \((N_{\text{bins}} - 1)\) pieces of information. This is similar to the \( R_b \) measurement.

\[ \begin{array}{c}
\text{0} \\
\text{1} \\
\text{2} \\
\text{3} \\
\end{array} \]

\# tags

\( \Rightarrow \) Assume MC purity and fit for \( R_b \), \( E \), \( \tau \) but no \( \chi^2 \)

Alternatively, assume MC \( E \) and fit for \( R_b, \tau \).
Hidden dependences on: lifetimes, boost distributions, resolution
Charmonium $\to 2 \text{ sec. } \psi + x$

- $\left| \vec{x}_2 - \vec{x}_1 \right|$
  - Broken $\psi$ or 2 extra $\psi$s
  - Broken IP + long decay length

- $\left| x_1 \right|$
  - Broken IP

- $\left| x_2 \right|$
  - Good $\psi$ vertices

Axes:
- $\left| x_2 - x_1 \right| > 5 \text{ mm}$
Sec. Vertex Distances from IP

Get roughly orthogonal variable for fit.

vtx dist, mc 0D
vtx dist, mc 1D
vtx dist, mc 2D

vtx dist, mc 0D
vtx dist, mc 1D
vtx dist, mc 2D

vtx dist, mc 0D
vtx dist, mc 1D
vtx dist, mc 2D

Total # Sec Vtxs

$B$ Decay Type

# Sec. Vtxs

1

2

3
Why histogram this way?

Poor control of the track resolution and the estimated error caused vertices to be accidentally broken up.

→ Assume a Gaussian broadening of the decay length distribution

Unbroadened \( b \to \phi D \) events will stay in the \( N_{sv} = 1 \) histogram while the broadened distribution will spill over into the \( N_{sv} = 2, 3 \) histograms.

And similarly for \( b \to 1D, 2D \).

→ These histograms contain info about:

\( B, D \) boosts, lifetimes, track resolution

in addition to the charm yield.
Fit to Data radial decay length dists + #sec vtx = 0

#sec vtx = 1

#sec vtx = 2

#sec vtx = 3

bkgd fraction: 0.063 ± 0.004

BR(b →)

φD: 0.045 ± 0.013

1D: 0.709 ± 0.024

2D: 0.246 ± 0.015

χ²/27 df = 1.5

p cut = 0.005, |ipres| = 200 nm

events without VXDVs
Highest weight constraint

\[
\langle \text{# vtxs} \rangle_{\text{Data}} = A \langle \text{# vtxs} \rangle_{\phi D} + B \langle \text{# vtxs} \rangle_{1D} + C \langle \text{# vtxs} \rangle_{2D} + D \langle \text{# vtxs} \rangle_{\text{bkgd}}
\]

Middle weight constraint

\[
\langle \text{# n-vtx hemis} \rangle = A \langle \text{# n-vtx hemis} \rangle_{\phi D} + \ldots
\]

Lowest weight constraints \(\Rightarrow\) enforces correctness of vertex position distribution and hence, vertex resolution.
CLEO Direct/Cascade El

Vary Pt cut to change relative branching fractions in sample.

SLD MC B/non B leptons

Lepton Pt W.r.t. Vertex Axis
The points are correlated, but the data seems to favor a lower b. semileptonic BR. (15% lower)
Systematics

<table>
<thead>
<tr>
<th></th>
<th>0D</th>
<th>1D</th>
<th>2D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using no VX0V sample</td>
<td>0.005</td>
<td>0.010</td>
<td>0.010</td>
</tr>
<tr>
<td>( b \rightarrow 1D ) mixture \ (Vary 10% ( D^0 ), 10% ( D^+ ), 25% ( D_s ), 30% c-baryon)</td>
<td>0.005</td>
<td>0.010</td>
<td>0.010</td>
</tr>
<tr>
<td>( b ) fragmentation type \ (Vary 10% ( B_d ), 10% ( B_u ), 25% ( B_s ), 30% b-baryon)</td>
<td>0.003</td>
<td>0.006</td>
<td>0.007</td>
</tr>
<tr>
<td>( b ) energy \ (X_b = 0.707, X_b = 0.714) \ ( X^2 ) rapidly gets worse as decay length is shortened</td>
<td>0.003</td>
<td>0.014</td>
<td>0.009</td>
</tr>
<tr>
<td>( \text{Pcut} = (0.010, 0.005, 0.001) )</td>
<td>0.006</td>
<td>0.017</td>
<td>0.016</td>
</tr>
<tr>
<td>Tracking efficiency \ (reject 1.6% of 1, 2 prong ( \text{vtxs} ))</td>
<td>0.010</td>
<td>0.010</td>
<td>0.016</td>
</tr>
<tr>
<td>Total</td>
<td>0.013</td>
<td>0.027</td>
<td>0.033</td>
</tr>
</tbody>
</table>

Still to do: lifetimes, decay multiplicities...
By cutting far in the tails, we can effectively ignore any slight mismatch in impact param. resolution.
Consistent with a resolution mismatch.

Need to cut further in the tails: $P_{\text{cut}} = 0.005$

$3\sigma \sim 100$ mm, B,D separation \~ 0 mm \Rightarrow still can discriminate between 1D, 2D
Excess MC tracks are in high mult. vertices.

Most of discrepancy is at generator level
(high mult inclusive modes to reproduce low p^2 pion dist.)
**TK & correction Assumptions**

- Adding TKS makes the \#vtxs increase.
  
i.e. the extra tk won't cause separated vtxs to coalesce.

  ![Diagram](Perhaps_stealing_tks_from_old_vtxs)

  The added tk will either form a new vtx
  or be grommed onto an existing vtx.

  \[ \Rightarrow \text{Removing tks causes the \#vtxs to decrease.} \]

- Lost vtxs are most likely low multiplicity vtxs.

  \[ \Rightarrow \text{Remove an appropriate fraction of 1, 2 prong vtxs from MC.} \]
  \[ \left(\% \text{ tk discrepancy}\right) \times \left(\text{prob. tk is in 1, 2 prong}\right) \approx 1.6\% \]
**Summary**

<table>
<thead>
<tr>
<th>BR($b \rightarrow \phi D$)</th>
<th>stat</th>
<th>sys</th>
</tr>
</thead>
<tbody>
<tr>
<td>1D</td>
<td>0.045 ± 0.013 ± 0.013</td>
<td></td>
</tr>
<tr>
<td>2D</td>
<td>0.709 ± 0.024 ± 0.027</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.246 ± 0.015 ± 0.033</td>
<td></td>
</tr>
</tbody>
</table>

$\langle N_c \rangle = 1.20 \pm 0.08$

To Do: - lifetimes, decay multiplicities,
- Include entire sample with VXOVs: stat x 1.6
- Do tracking E carefully, replacing PHCHRGs with PHVXOVS