Measurement of $B \to D_s(\ast) D(\ast)$ Branching Fractions at Babar

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Motivation/Theory

- Large Branching Fractions! $\Sigma Br(B \rightarrow D_s(\ast) D^{(\ast)}) \sim 5\%$
  (large sample for systematic study of double-charm $B$ decays…)

**Goals:**

- Measure precisely branching ratios for 8 modes
  $B^0 \rightarrow D_s(\ast)+ D^{(\ast)-}$  $B^+ \rightarrow D_s(\ast)+ \bar{D}^{(\ast)0}$

- Measure transversity amplitudes for $B \rightarrow D_s^{(*)+} \bar{D}^{(*)}$ modes

- Use BR measurements to test theory for hadron dynamics in high $q^2$ two-body decays
Detector & Data

- Used fully reconstructed B mesons from $e^+e^-$ collisions ($\sqrt{s} = 10.58$ GeV)
- Data set: $23 \times 10^6$ $B\bar{B}$ pairs recorded by BaBar detector
Decay Modes

8 modes to study:

\[ \begin{align*}
B^0 & \rightarrow D_s^+ D^- \\
B^0 & \rightarrow D_s^+ D^{*-} \\
B^0 & \rightarrow D_s^{*-} D^- \\
B^0 & \rightarrow D_s^{*-} D^{*-}
\end{align*} \quad \begin{align*}
B^+ & \rightarrow D_s^+ D^0 \\
B^+ & \rightarrow D_s^+ D^{*-} \\
B^+ & \rightarrow D_s^{*-} D^0 \\
B^+ & \rightarrow D_s^{*-} D^{*-}
\end{align*} \]

\[ D_s^{*+} \rightarrow D_s^+ \gamma \]

\[ \phi \pi^+ \rightarrow K^- K^+ \pi^+ \]

\[ D_s^0 \rightarrow D^0 \pi^0 \]

\[ D_s^{*+} \rightarrow D^0 \pi^+ \]

\[ K^- \pi^+ \]

\[ K^- \pi^+ \pi^0 \]

\[ K^- \pi^+ \pi^+ \pi^- \]

\[ D^+ \rightarrow K^- \pi^+ \pi^+ \]

Events selected by cut criteria…

- Kaons required to have particle ID info from dE/dx (Drift chamber) and Cherenkov angle (DIRC)

- Events with B mesons are more spherical – cut on event shape parameters to remove jetty continuum (q\bar{q}) events

- Combine reconstructed tracks to form composite particles, require candidates to pass kinematic constraints (inv. mass cuts, vertexing, etc.)
**D_{s}(*), D(*) Selection**

- Require mass of reconstructed D_{s}’s to be within $\sim 3\sigma$ of nominal D_{s} mass

- Require $\Delta m = \text{mass}(D_{s}\gamma) - \text{mass}(D_{s})$ be within 27 MeV window

**Other cuts:**

<table>
<thead>
<tr>
<th>Cut variable</th>
<th>Window</th>
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</thead>
<tbody>
<tr>
<td>$M_{D^{*+}} - M_{D_{0}}$</td>
<td>6 MeV</td>
</tr>
<tr>
<td>$M_{D^{*0}} - M_{D_{0}}$</td>
<td>6 MeV</td>
</tr>
<tr>
<td>$M_{D_{0}} - M_{\text{PDG}}$</td>
<td>42 MeV</td>
</tr>
<tr>
<td>$M_{\phi} - M_{\text{PDG}}$</td>
<td>16 MeV</td>
</tr>
<tr>
<td>$M_{\pi^{0}}$</td>
<td>35 MeV</td>
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</table>
B Candidate Selection

- Constrain mass of daughters of B candidates and require daughters come from the same vertex.

- Define $\Delta E = E_{B_0}^* - E_{beam}^*$
  For data, require $-28 < \Delta E < 20$ MeV, and choose 'best' B candidate by the lowest $\Delta E$.

- Define $m_{ES} = \sqrt{E_{beam}^* - p_B^*}$
  (* = center of mass frame)

  In data, will fit $m_{ES}$ distribution to determine number of signal events.
Background studies in Monte Carlo:

• Perform analysis on generic $B^0\overline{B}^0$ & $B^+B^-$ events, take out real signal

• Fit background distributions to ARGUS function to parameterize bkgd. contribution

• Constrain background shape in data to what is measured in MC

\[ B^{-} \rightarrow D^{*+}D^{0}, \text{ PRELIMINARY} \]
Signal (Data)

- Fit $m_{ES}$ distributions
  - **ARGUS** for bkgd.
  - **gaussian** for signal

<table>
<thead>
<tr>
<th>Decay Mode</th>
<th>No. events from fit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B^0 \rightarrow D_s^+ D^-$</td>
<td>$35.8 \pm 6.1$</td>
</tr>
<tr>
<td>$B^0 \rightarrow D_s^+ D^{*-}$</td>
<td>$46.3 \pm 7.2$</td>
</tr>
<tr>
<td>$B^0 \rightarrow D_s^{**} D^-$</td>
<td>$23.9 \pm 5.1$</td>
</tr>
<tr>
<td>$B^0 \rightarrow D_s^{**} D^{*-}$</td>
<td>$44.7 \pm 6.8$</td>
</tr>
<tr>
<td>All $B^0$</td>
<td>$150.7 \pm 12.7$</td>
</tr>
<tr>
<td>$B^+ \rightarrow D_s^+ \bar{D}^0$</td>
<td>$124.9 \pm 11.8$</td>
</tr>
<tr>
<td>$B^+ \rightarrow D_s^+ \bar{D}^{*0}$</td>
<td>$34.1 \pm 6.1$</td>
</tr>
<tr>
<td>$B^+ \rightarrow D_s^{**} \bar{D}^0$</td>
<td>$121.2 \pm 13.2$</td>
</tr>
<tr>
<td>$B^+ \rightarrow D_s^{**} \bar{D}^{*0}$</td>
<td>$42.0 \pm 6.8$</td>
</tr>
<tr>
<td>All $B^+$</td>
<td>$322.1 \pm 19.9$</td>
</tr>
<tr>
<td>$B \rightarrow D_s^{(<em>)} + \bar{D}^{(</em>)}$</td>
<td>$472.8 \pm 23.6$</td>
</tr>
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</table>
Signal (Data)

All $B^0$ modes

All $B^+$ modes
Branching Ratios

\[ \text{Br}(B \to D_s^{(*)+} D^{(*)}) = \frac{1}{N_{BB}} \sum_i \sum_j \text{Br}_i \text{Br}_j \varepsilon_{ij} \]

Number of BB pairs produced

Branching fractions of \(D_s^{(*)}\) and \(D^{(*)}\)

<table>
<thead>
<tr>
<th>Decay Mode</th>
<th>BR(%) (BABAR)</th>
<th>BR(%) (CLEO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(B^0 \to D_s^+ D^-)</td>
<td>0.59 ± 0.10 ± 0.07 ± 0.15</td>
<td>0.85 ± 0.23 ± 0.19 ± 0.21</td>
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<tr>
<td>(B^0 \to D_s^+ D^*^-)</td>
<td>0.74 ± 0.11 ± 0.10 ± 0.18</td>
<td>0.90 ± 0.22 ± 0.16 ± 0.23</td>
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<tr>
<td>(B^0 \to D_s^{*+} D^-)</td>
<td>0.76 ± 0.17 ± 0.11 ± 0.19</td>
<td>0.97 ± 0.34 ± 0.21 ± 0.24</td>
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<tr>
<td>(B^0 \to D_s^{<em>+} D^</em>^-)</td>
<td>1.41 ± 0.22 ± 0.18 ± 0.35</td>
<td>1.97 ± 0.49 ± 0.35 ± 0.49</td>
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<tr>
<td>(B^+ \to D_s^+ \bar{D}^0)</td>
<td>0.93 ± 0.09 ± 0.11 ± 0.23</td>
<td>1.23 ± 0.21 ± 0.24 ± 0.31</td>
</tr>
<tr>
<td>(B^+ \to D_s^+ \bar{D}^{*0})</td>
<td>0.95 ± 0.18 ± 0.13 ± 0.24</td>
<td>1.36 ± 0.42 ± 0.34 ± 0.34</td>
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<tr>
<td>(B^+ \to D_s^{*+} \bar{D}^0)</td>
<td>0.76 ± 0.10 ± 0.10 ± 0.19</td>
<td>0.85 ± 0.26 ± 0.17 ± 0.21</td>
</tr>
<tr>
<td>(B^+ \to D_s^{*+} \bar{D}^{*0})</td>
<td>2.13 ± 0.36 ± 0.31 ± 0.53</td>
<td>3.01 ± 0.86 ± 0.63 ± 0.75</td>
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</tbody>
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Number of Signal events seen

Reconstruction Efficiency for each decay mode (determined in Monte Carlo study)
Summary

- Measured 8 branching fractions for B mesons corresponding to the $b \rightarrow c\bar{c}s$ transition
- Results consistent with previous measurements but with smaller statistical and systematic errors
- Systematic uncertainties dominated by tracking efficiency and errors on secondary branching ratios
- Added large sample of $B \rightarrow D_s^{(*)}D^{(*)}$ decays (~470 events) to the sample of fully reconstructed B mesons
  - Transversity analysis soon to come!