Charmless hadronic B decays at BABAR

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on behalf of the BABAR collaboration
Outline

• Physics motivation
• Analysis techniques
• Branching fraction measurements
  – $B^0 \rightarrow \pi^+ \pi^-, K^+ \pi^-, K^+ K^-$ \( (22.6 \times 10^6 \ U(4S)) \)
  – other modes \( (8.8 \times 10^6 \ U(4S)) \)
• Perspectives

All results are preliminary!
Charmless hadronic B decays

- B mesons decay dominantly to charm.
- Charmless decays involves:
  - Cabibbo-suppressed tree diagrams
  - Penguin diagrams
  - W exchange diagrams ($B^0 \rightarrow K^+ K^-$)
Physics motivations

• Estimate penguin contribution from $\frac{\Gamma(B^0 \rightarrow \pi^+ \pi^-)}{\Gamma(B^0 \rightarrow K^+ \pi^-)}$.
  – Possibility of extracting $\gamma$.

• Direct CP violation.

• Determination of $\alpha$ from time-dependent decay rate asymmetries (penguin pollution).

• Sensitivity to new physics (higher order loops).
Experimental challenges

• **Rare decays** (branching ratios $\approx 10^{-5}$)  
  $\Rightarrow$ need **high luminosity B factory**

• Modes with **high energy $\pi^+$ or $K^+$**  
  $\Rightarrow$ need **excellent particle identification**
Particle identification

- **DIRC**: Detector of Internally Reflected Cherenkov light.
- Good $\pi^+ / K^+$ separation up to high momentum.
Selection of B candidates

- Energy-substituted mass:
  \[ m_{ES} = \sqrt{E_{\text{beam}}^* - p_B^*} \]

- Energy difference:
  \[ \Delta E = E_B^* - E_{\text{beam}}^* \]

Example of \( B^- \rightarrow D^0 \pi^- \)
(calibration channel)
Continuum background suppression

- Background dominated by $e^+e^- \rightarrow q\bar{q}$
- Use event topology to separate jet-like continuum events from isotropic $B\bar{B}$ events.
- $\cos \Theta_T$: cosine of angle between thrust axes of B candidate and the rest of the event.
- Combine event shape information in a Fisher discriminant, $F$. 

[Graphs showing distribution of $\cos \Theta_T$ and a Fisher discriminant $F$]
Higher multiplicity modes

• Channels: $B^0 \rightarrow \rho^-\pi^+$, $\eta'K^0$, $\omega K^0$, $B^+ \rightarrow K^{*0}\pi^+$, $\rho^0K^+$, $\rho^0\pi^+$, $K^+\pi^\mp$, $\pi^\mp\pi^\mp$, $\eta'K^0$, $\omega K^0$.

• Performed on a partial data set (for summer 2000 conferences): $8.8 \times 10^6 Y(4S)$

• Event counting analysis:
  – apply tight selection
  – count events in signal region
  – estimate background from sidebands

• Analysis on full statistics underway.
Mode with K* or ρ

- Efficiency: 8-12 %
- Cuts on $\cos \Theta_T$, resonance masses and helicity
- Kaon identified by dE/dx and DIRC
- Significant signal in $B^0 \rightarrow \rho^-\pi^+$:
  $Br = (49 \pm 13 \pm 6) \times 10^{-6}$
Modes with $\eta'$ or $\omega$

- Efficiency: 1-8%
- Cuts on $\cos \Theta_T$, $F$, resonance masses and helicity (for $\omega$)
- Significant signal in $B^+ \to \eta'K^+$:
  $\text{Br} = (62 \pm 18 \pm 8) \times 10^{-6}$
Summary

- Branching fractions measurements and upper limits (90% CL) in unit of $10^{-6}$.

<table>
<thead>
<tr>
<th>Channel</th>
<th>BABAR</th>
<th>CLEO</th>
<th>Theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B^+ \to K^{*0} \pi^+$</td>
<td>$&lt; 28$</td>
<td>$&lt; 16$</td>
<td>$3.4 - 13$</td>
</tr>
<tr>
<td>$B^+ \to \rho^0 K^+$</td>
<td>$&lt; 29$</td>
<td>$&lt; 17$</td>
<td>$0 - 6.1$</td>
</tr>
<tr>
<td>$B^+ \to K^+ \pi^- \pi^+$</td>
<td>$&lt; 54$</td>
<td></td>
<td></td>
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<tr>
<td>$B^+ \to \rho^0 \pi^+$</td>
<td>$&lt; 39$</td>
<td>$10 \pm 3 \pm 2$</td>
<td>$0.4 - 13$</td>
</tr>
<tr>
<td>$B^+ \to \pi^+ \pi^- \pi^+$</td>
<td>$&lt; 22$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B^0 \to \rho^- \pi^+$</td>
<td>$49 \pm 13 \pm 6$</td>
<td>$28 \pm 8 \pm 4$</td>
<td>$12 - 93$</td>
</tr>
<tr>
<td>$B^+ \to \eta', K^+$</td>
<td>$62 \pm 18 \pm 8$</td>
<td>$65 \pm 15 \pm 9$</td>
<td>$7 - 41$</td>
</tr>
<tr>
<td>$B^0 \to \eta', K^0$</td>
<td>$&lt; 112$</td>
<td>$47^{+27}_{-20} \pm 9$</td>
<td>$9 - 33$</td>
</tr>
<tr>
<td>$B^+ \to \omega h^+$</td>
<td>$&lt; 24$</td>
<td>$14 \pm 3 \pm 2$</td>
<td>$0.8 - 3.8$</td>
</tr>
<tr>
<td>$B^0 \to \omega K^0$</td>
<td>$&lt; 14$</td>
<td>$&lt; 21$</td>
<td>$0 - 17$</td>
</tr>
</tbody>
</table>
π⁺ π⁻, K⁺ π⁻, K⁺ K⁻ analysis

- Performed on full run 2000 data set: 22.6 10⁶ Υ(4S)

- **Maximum likelihood fit:**
  - apply loose pre-selection (efficiency ~ 45%)
  - determine probability density functions (pdf’s) for expected signal and background for the five input variables: m_{ES}, ΔE, F, θ⁺, θ⁻.
  - maximize the likelihood
Calibration: \( m_{ES}, \Delta E \) and F.

**Signal:** use \( B^- \rightarrow D^0 \pi^- \rightarrow (K^- \pi^+) \pi^- \)

**Background:** use sidebands of charmless decays

**Gaussian** \( \sigma \approx 2.6 \text{ MeV} \)
Calibration: $\theta_c$.

Calibrate $\pi$ and $K$ shapes (offset, resolution and small peak due to other type) using kinematically selected samples of $\pi$ and $K$ in $D^{*+} \rightarrow D^0 \pi^+ \rightarrow (K^- \pi^+) \pi^+$

Distributions of $\theta_c - \theta_c(K)$ for kaons for different momentum bins
Maximum likelihood fit

• Analysis performed using a maximum likelihood method with 8 parameters:
  \( N^s_{\pi\pi}, N^s_{K\pi}, N^s_{KK}, A^s_{K\pi}, N^b_{\pi\pi}, N^b_{K\pi}, N^b_{KK}, A^b_{K\pi}. \)

• For summer 2000 conferences, background was described by 2 parameters only (bias toward more \( \pi\pi \) and less \( K\pi \)).

• Systematics calculated by varying pdf shape distributions.
\[ \pi^+\pi^- / K^+\pi^- / K^+K^- : \text{results} \]

<table>
<thead>
<tr>
<th></th>
<th>(N_{\text{signal}})</th>
<th>(\text{Br BABAR (x10}^6)</th>
<th>(\text{Br CLEO (x10}^6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\pi^+\pi^-)</td>
<td>41 ± 10</td>
<td>4.1 ± 1.0 ± 0.7</td>
<td>(4.3 \pm 1.6)</td>
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<td></td>
<td></td>
<td></td>
<td>(\pm 1.4\pm 0.5)</td>
</tr>
<tr>
<td>(K^+\pi^-)</td>
<td>169 ± 17</td>
<td>16.7 ± 1.6 (\pm 1.2) _{-1.7}</td>
<td>17.2 (\pm 2.5) _{-2.4} \pm 1.2</td>
</tr>
<tr>
<td>(K^+K^-)</td>
<td>(8.2^{+7.8}_{-6.4})</td>
<td>(&lt; 2.5 \text{ (90% CL)})</td>
<td>(&lt; 1.9 \text{ (90% CL)})</td>
</tr>
</tbody>
</table>

\[ \Gamma (B^0 \rightarrow \pi^+\pi^-) / \Gamma (B^0 \rightarrow K^+\pi^-) \approx 0.25 \]
$\pi^+\pi^- / K^+\pi^- / K^+K^-$: event counting

- Event counting analysis performed as a cross-check.
- Lower sensitivity.
- Gives consistent results.
Perspectives

• Run 2000 (20.7 fb\(^{-1}\)):
  – \( \text{Br} \ ( B^0 \rightarrow \pi^+\pi^-) = (4.1 \pm 1.0 \pm 0.7) \ 10^{-6} \)
  – \( \text{Br} \ ( B^0 \rightarrow K^+\pi^-) = (16.7 \pm 1.6 \ ^{+1.2}_{-1.7}) \ 10^{-6} \)
  – new results in a lot of charmless modes soon.

• Run 2001 (32 fb\(^{-1}\)):
  – just started.

• Longer term (500 fb\(^{-1}\) by 2005):
  – extensive study of CP violation in charmless sector.