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Charmless Hadronic B Decays at *BABAR*

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Abstract

We present preliminary results of several searches for rare charmless hadronic decays of the B meson using data collected by the *BABAR* detector at the Stanford Linear Accelerator Center's PEP-II storage ring. We search for the decays h^+h^-, $h^+h^-h^+$, $h^+h^-\pi^0$, X^0h^+, and $X^0K^0_S$, where $h = \pi$ or K, and $X^0 = \eta'$ or ω. In a sample of 8.8 million $B\overline{B}$ decays we measure the branching fractions: $\mathcal{B}(B^0 \to \pi^+\pi^-) = (9.3^{+2.6+1.2}_{-2.3-1.4}) \times 10^{-6}$, $\mathcal{B}(B^0 \to K^+\pi^-) = (12.5^{+3.0+1.3}_{-2.6-1.7}) \times 10^{-6}$, $\mathcal{B}(B^0 \to \rho^-\pi^+) = (49 \pm 13^{+6}_{-5}) \times 10^{-6}$, and $\mathcal{B}(B^+ \to \eta' K^+) = (62 \pm 18 \pm 8) \times 10^{-6}$. We calculate upper limits for the modes without a significant signal.

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1 Introduction

Charmless hadronic B decays will play an important role in the study of CP violation. Indirect CP violation arises in B^0–$\overline{B}^0$ mixing due to interference between direct and mixed decays. The CKM angle α can be measured by observing the resulting time-dependent asymmetry in decays to $\pi\pi$ and $\rho\pi$ final states. Direct CP violation results from interference between two or more weak amplitudes and can arise in any decay mode where both tree and penguin contributions are non-negligible. Several modes reported in this paper are "self-tagging", providing efficient samples for direct CP violation searches. Finally, accurate branching fraction measurements provide important tests of factorization models, which facilitate calculation of α in the presence of significant penguin amplitudes, and can also be used to constrain the CKM angle γ. [1]

In this paper we summarize preliminary results of searches for the following charmless hadronic B decays: [2]

- $\pi^+\pi^-$, $K^+\pi^-$, K^+K^-,
- $K^{*0}\pi^+$, $\rho^0 K^+$, $\rho^0\pi^+$, $\rho^-\pi^+$, $K^+\pi^-\pi^+$, $\pi^+\pi^-\pi^+$,
- $\eta' K^+$, $\eta' K^0_S$, ωh^+, ωK^0_S,

where charge conjugate modes are assumed throughout. The dataset consists of 8.8 million $B\overline{B}$ decays collected by the *BABAR* detector [3] at the PEP-II storage ring between January and June 2000.

2 Candidate Selection and Analysis Method

We use only good quality tracks with a minimum transverse momentum of $100\,\mathrm{MeV}/c$ in the laboratory (LAB) frame. Charged pions and kaons are identified by their energy loss (dE/dx) in the tracking system and the angle θ_c of Čerenkov photons produced while traversing quartz bars [3]. Neutral kaons are reconstructed in the mode $K^0_S \to \pi^+\pi^-$, requiring the K^0_S flight length to exceed 2 mm and the angle between the flight direction and momentum to be less than 40 mr. Photon candidates are defined as calorimeter energy deposits unassociated with a track and having a shower shape consistent with the photon hypothesis. Candidate π^0 and η mesons are formed from pairs of photons with a minimum LAB energy of 50 MeV. Candidate η' mesons are reconstruced in the channel $\eta\pi^+\pi^-$, where the η mass is constrained to the world average value. The ω meson is reconstructed in the dominant decay channel, $\omega \to \pi^+\pi^-\pi^0$, keeping all candidates within $50\,\mathrm{MeV}/c^2$ of the known ω mass. The ρ and K^* resonances are reconstructed in the corresponding $\pi\pi$ and $K\pi$ channels.

We select candidate B mesons based on the energy-substituted mass $m_{\rm ES}$, where $\sqrt{s}/2$ is substituted for the candidate's energy, and the difference ΔE between the B-candidate energy and $\sqrt{s}/2$. The dominant background for all modes is continuum $q\bar{q}$ production, which exhibits a jet-like structure that distinguishes it from the more spherically symmetric $B\overline{B}$ events. To suppress this background we use the cosine of the angle $\theta_{\rm T}$ ($\theta_{\rm S}$) between

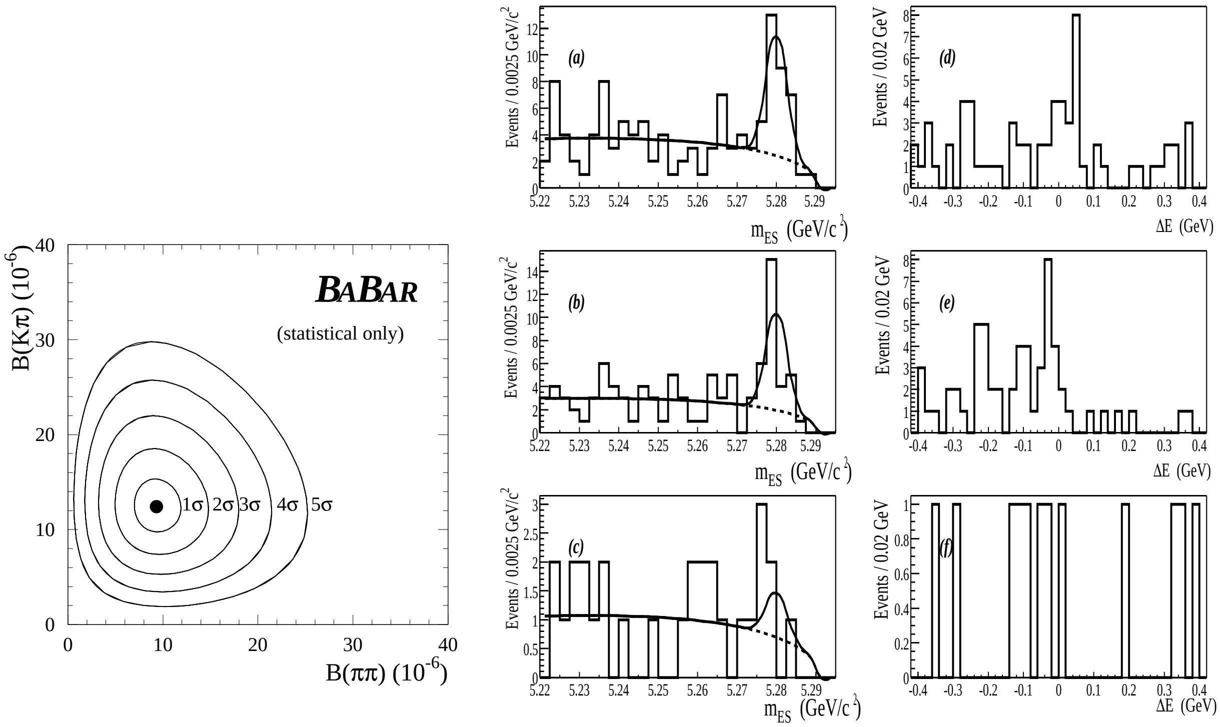

Figure 1: Left: The central value (filled circle) for $\mathcal{B}(B^0 \to \pi^+\pi^-)$ and $\mathcal{B}(B^0 \to K^+\pi^-)$ along with the $n\sigma$ statistical contour curves for the global likelihood fit. Right: $m_{\rm ES}$ and ΔE for (a,d) $\pi\pi$, (b,e) $K\pi$, and (c,f) KK candidates in the cut-based analysis.

the thrust (sphericity) axis of the B candidate and the rest of the event, and the cosine of the angle $\theta_{\rm B}$ between the candidate's flight direction and the beam axis. In some cases we include several event-shape variables into a single Fisher discriminant.

3 Results for h^+h^- Modes

We select $B^0 \to h^+h^-$ candidates satisfying $5.22 < m_{\rm ES} < 5.3\,{\rm GeV}/c^2$ and $|\Delta E| < 0.420\,{\rm GeV}$. No explicit particle identification is required and the pion mass hypothesis is assumed for both tracks. We require $|\cos\theta_{\rm S}| < 0.9$ and construct a Fisher discriminant $\mathcal{F}$ from nine variables describing the momentum flow of charged and neutral particles around the B candidate thrust axis.

Signal yields in all three modes are determined simultaneously from an unbinned maximum likelihood fit incorporating $m_{\rm ES}$, ΔE, $\mathcal{F}$, and the measured θ_c for each track. A sample of D^*-tagged $D^0 \to K^+\pi^-$ decays is used to parameterize the θ_c distributions for pion and kaon tracks as a function of momentum. The K/π separation varies from 2 to 8σ across the relevant momentum range. All candidates in the region $-0.200 < \Delta E < 0.140\,{\rm GeV}$ are included in the fit. We find signal yields of $N(\pi\pi) = 29^{+8}_{-7}$, $N(K\pi) = 38^{+9}_{-8}$, and $N(KK) = 7^{+5}_{-4}$. As a cross-check we perform a cut-based analysis requiring a tighter cut on $\cos\theta_{\rm S}$ and additional cuts on $\cos\theta_{\rm B}$ and $\mathcal{F}$. Signal yields are determined by applying particle identification criteria to isolate independent samples of candidates corresponding to each mode and then fitting the $m_{\rm ES}$ distribution in each sample. The results are consistent with the global likelihood fit. Figure 1 shows the global fit likelihood contour curves for the $\pi\pi$ and $K\pi$ modes, and the $m_{\rm ES}$ and ΔE distributions for the cut-based analysis. The results are summarized in the upper section of Table 1. For the KK mode we calculate the 90% confidence level upper limit. The dominant systematic errors are due to tracking efficiency and the shapes of the ΔE and $\mathcal{F}$ distributions.

4 Results for Three-body Modes

We search for resonant three-body decays by combining a ρ or K^{*0} resonance with a charged pion or kaon. Kaons are required to be positively identified using dE/dx and θ_c information, while tracks not identified as kaons are assumed to be pions. We veto any combination consistent with the decay $D^0 \to K^-\pi^+$. The selection criteria consist of optimized cuts on $\cos\theta_{\rm T}$, resonance mass, and the angle between the resonance daughters and the B candidate momentum calculated in the rest frame of the vector meson. We also explicitly search for non-resonant $K^+\pi^-\pi^+$ and $\pi^+\pi^-\pi^+$ decays by removing all $K\pi$ and $\pi\pi$ combinations with invariant mass less than $2\,{\rm GeV}/c^2$, and all three-body combinations consistent with the decay $B^+ \to J/\psi K^+$.

We define a signal region within $6\,{\rm MeV}/c^2$ of the B mass in $m_{\rm ES}$ and $\pm 70\,{\rm MeV}$ in ΔE. The signal yield is determined by direct background subtraction, where the background in the signal region is estimated from the number of events in the region $5.2 < m_{\rm ES} < 5.27\,{\rm GeV}/c^2$. This method is cross-checked using off-resonance data. The results are summarized in the middle section of Table 1. The dominant systematic errors are due to tracking efficiency, π^0 efficiency, and the background subtraction technique.

5 Results for Modes with η' or ω

We search for the modes $\eta' K^+$, $\eta' K^0_S$, ωh^+, and ωK^0_S. For $\eta' K$ the kaon is positively identified, while for ωh^+ the charged hadron is assumed to be a pion and the ΔE signal window is increased ($-0.113 < \Delta E < 0.070\,{\rm GeV}$) to take into account the resulting shift in energy when the mass is mis-assigned. The angle between the decay plane of the ω daughters and the B direction in the ω rest frame is used to reduce combinatoric background. We require $|\cos\theta_{\rm T}| < 0.9$ and optimize with respect to $\mathcal{F}$. Signal yields are determined by background subtraction, where the background is determined from off-resonance data. The results are summarized in the lower third of Table 1. The dominant systematic errors are the same as in the three-body analysis.

Table 1: Branching fraction results. Signal yields (N_S) for the h^+h^- modes are determined from a likelihood fit, the rest are obtained by a direct background subtraction. Efficiencies (ϵ) include intermediate branching fractions.

Mode	N_S	Stat. Sig. (σ)	ϵ(%)	$\mathcal{B}\,(10^{-6})$
$B^0 \to \pi^+\pi^-$	29^{+8+3}_{-7-4}	5.7	35	$9.3^{+2.6+1.2}_{-2.3-1.4}$
$B^0 \to K^+\pi^-$	38^{+9+3}_{-8-5}	6.7	35	$12.5^{+3.0+1.3}_{-2.6-1.7}$
$B^0 \to K^+K^-$	7^{+5}_{-4} (< 15)	2.1	35	< 6.6
$B^+ \to K^{*0}\pi^+$	10.2 ± 4.8	2.4	10	< 28
$B^+ \to \rho^0 K^+$	10.7 ± 5.1	2.2	10	< 29
$B^+ \to K^+\pi^-\pi^+$	16.3 ± 5.8	3.2	6	< 54
$B^+ \to \rho^0\pi^+$	24.9 ± 8.2	3.3	12	< 39
$B^+ \to \pi^+\pi^-\pi^+$	5.4 ± 5.7	0.7	8	< 22
$B^0 \to \rho^-\pi^+$	35.5 ± 9.8	4.5	8	$49 \pm 13^{+6}_{-5}$
$B^+ \to \eta' K^+$	12.1 ± 3.7	5.3	3	$62 \pm 18 \pm 8$
$B^0 \to \eta' K^0$	1.4 ± 1.4	1.1	0.6	< 112
$B^+ \to \omega h^+$	5.9 ± 3.6	1.7	7.5	< 24
$B^0 \to \omega K^0$	-0.8 ± 0.0	0.0	2	< 14

6 Summary

We have presented preliminary results of searches for several charmless hadronic B decays. Table 1 summarizes the results. In all cases, our results are consistent with recent measurements reported by the CLEO [4] and Belle [5] collaborations at this conference.

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References

[1] M. Neubert, "QCD Factorization and CP Violation in Hadronic B Decays", contributed to this conference.

[2] For more detailed descriptions of these results see: *BABAR* Collaboration, B. Aubert *et al.*, *BABAR*-CONF-00/14 and *BABAR*-CONF-00/15, submitted to the XXXth International Conference on High Energy Physics, Osaka, Japan, July 2000.

[3] *BABAR* Collaboration, B. Aubert *et al.*, *BABAR*-CONF-00/17, submitted to the XXXth International Conference on High Energy Physics, Osaka, Japan, July 2000.

[4] D. Urner, "Rare B Decays at CLEO", contributed to this conference.

[5] B. Casey, "Rare B Decays without Charm from BELLE", contributed to this conference.