SLAC–PUB–8695
BABAR-PROC–00/27
hep-ex/0011031
November 2000

Charmless Hadronic B Decays at *BABAR*

J. Olsen
Physics Department, University of Maryland
College Park, MD, 20742-4111

(representing the *BABAR* Collaboration)

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.

Contributed to the Meeting of the Division of
Particles and Fields of the American Physical Society
Columbus, Ohio, USA
August 9–August 12, 2000

Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309

Work supported in part by Department of Energy contract DE-AC03-76SF00515.

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

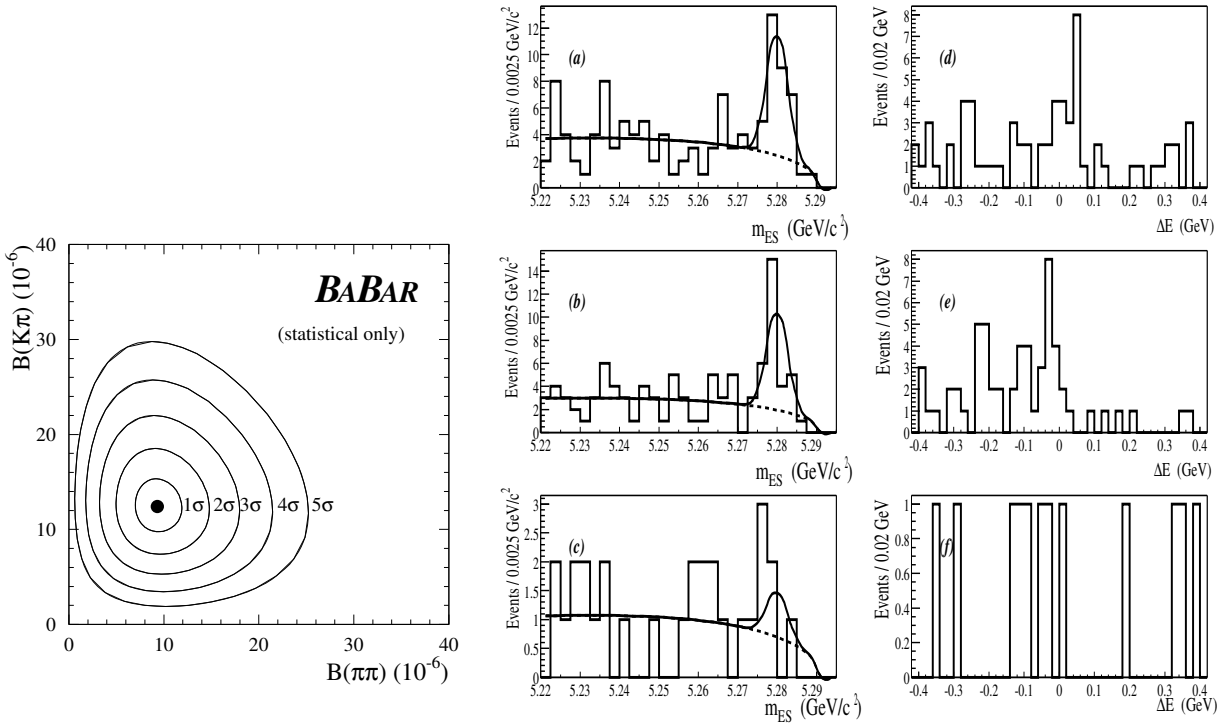

Figure 1: Left: The central value (filled circle) for $\mathcal{B}(B^0 \to \pi^+\pi^-)$ and $\mathcal{B}(B^0 \to K^+\pi^-)$ along with the $n\sigma$ statistical contour curves for the global likelihood fit. Right: $m_{\rm ES}$ and ΔE for (a,d) $\pi\pi$, (b,e) $K\pi$, and (c,f) KK candidates in the cut-based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

tional 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)	$\epsilon(\%)$	$\mathcal{B}\,(10^{-6})$
$B^0 \to \pi^+\pi^-$	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.

Acknowledgments

We are grateful for the contributions of our PEP-II colleagues in achieving the excellent luminosity and machine conditions that have made this work possible. We acknowledge support from the Natural Sciences and Engineering Research Council (Canada), Institute of High Energy Physics (China), Commissariat à l'Energie Atomique and Institut National de Physique Nucléaire et de Physique des Particules (France), Bundesministerium für Bildung und Forschung (Germany), Istituto Nazionale di Fisica Nucleare (Italy), The Research Council of Norway, Ministry of Science and Technology of the Russian Federation, Particle Physics and Astronomy Research Council (United Kingdom), the Department of Energy (US), and the National Science Foundation (US). In addition, individual support has been received from the Swiss National Foundation, the A. P. Sloan Foundation, the Research Corporation, and the Alexander von Humboldt Foundation. The visiting groups wish to thank SLAC for the support and kind hospitality extended to them.

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.