SLAC-PUB-8696
BABAR-PROC-00/13
August, 2000

Studies of Charmless Two-Body, Quasi-Two-Body and Three-Body B Decays

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Abstract

Preliminary results are presented on a search for several exclusive charmless hadronic B decays, from data collected by the *BABAR* detector near the $\Upsilon(4S)$ resonance. These include two-body decay modes $h^{\pm}h^{\mp}$, three-body decay modes with final states $h^{\pm}h^{\mp}h^{\pm}$ and $h^{\pm}h^{\mp}\pi^0$, and quasi-two-body decay modes with final states X^0h and $X^0K^0_S$, where $h = \pi$ or K and $X^0 = \eta'$ or ω. The measurement of branching fractions for four decay modes, and upper limits for nine modes are presented.

Contributed to the Proceedings of the 30^{th} International Conference on High Energy Physics,
7/27/2000—8/2/2000, Osaka, Japan

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

1 Introduction

Charmless hadronic decays of B mesons provide rich opportunities for exploring a number of CP violation phenomena. In particular, several of these decay modes offer the future possibility of measuring directly the CKM angle α of the Standard Model [1].

Preliminary searches have been carried out for a number of charmless hadronic B decays using the initial *BABAR* data sample. The data consist of $7.7\,\mathrm{fb}^{-1}$ taken at the $\Upsilon(4S)$ resonance, and $1.2\,\mathrm{fb}^{-1}$ taken below the $B\overline{B}$ threshold. The number of $B\overline{B}$ events has been determined from hadronic event selection[2] to be $8.46{\pm}0.14{\times}10^6$.

For all decay modes a simple cut-based analysis has been performed, and additionally for the two-body modes a global likelihood fit has been carried out. A "blind" analysis methodology has been adopted throughout, so that the signal region for each mode remained hidden until all decisions concerning event selection had been taken. The signal region has been represented using the two variables $m_{\mathrm{ES}} = \sqrt{(\sqrt{s}/2)^2 - P_B^{*2}}$ and $E_B^{*} - \sqrt{s}/2$, where E_B^* and P_B^* are the energy and 3-momentum of the B in the cms. Fig.1 shows the distribution of events in the $m_{\mathrm{ES}} - \Delta E$ plane for the mode $B^+ \to \eta' K^+$.

In order to facilitate understanding of the data, use was made of suitable calibration modes $B^+ \to \overline{D}^0\pi^+, \overline{D}^0 \to K^+\pi^-$ and $\overline{D}^0 \to K^+\pi^-\pi^0$. These have similar final state kinematics to the modes of interest, but with $\sim \times 10$ higher branching ratios.

2 Event Selection

The most significant issues for event selection, common to all the rare charmless decay modes, are effective kaon identification and the suppression of continuum background. Additional features of individual modes, such as the reconstructed mass and helicity angle distributions of intermediate resonances, have been used for selection where appropriate (for details see [2],[3]).

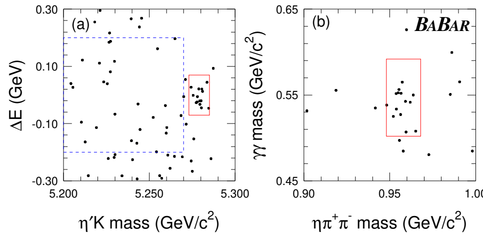

Figure 1: Kinematics of $B^+ \to \eta' K^+$.

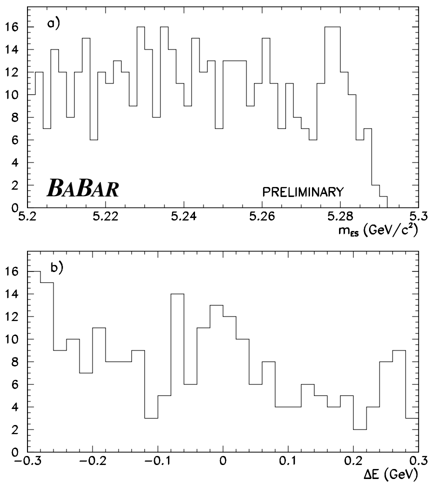

Figure 2: (a) m_{ES} and (b) ΔE distributions for $B^0 \to \rho^{\mp}\pi^{\pm}$.

2.1 Kaon Identification

Excellent kaon identification is essential for all the decay modes of interest. The primary system in *BABAR* for K/π discrimination is the DIRC (Detector of Internally Reflected Cherenkov light), which achieves separation at $> 2\sigma$ for momenta up to 4 GeV[4]. Further information for particle identification is provided by $\mathrm{d}E/\mathrm{d}x$ from the Drift Chamber and the Silicon Vertex Tracker.

2.2 Background Characterisation and Suppression

All rare charmless B decays suffer from high levels of background from continuum events. This background can be substantially reduced by exploiting the differences in topology between $B\overline{B}$

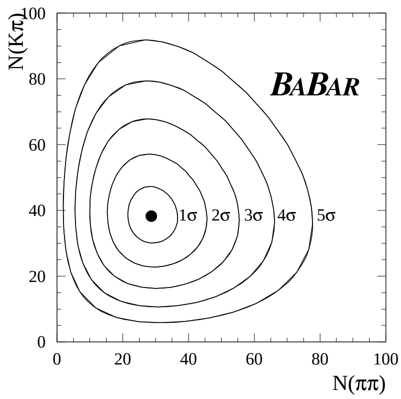

Figure 3: Likelihood contours for $\pi^{\pm}\pi^{\mp}$ and $K^{\pm}\pi >^{\mp}$.

events and continuum events. In the cms, a $B\overline{B}$ event is approximately isotropic, and there is no correlation between the decay topologies of the two Bs. A continuum event, however, exhibits a two-jet structure, so that the directions of the decay products are highly correlated. A number of event shape variables have been used in the analyses to discriminate signal events from continuum background. Following background discrimination cuts, a significant amount of background remained. This has been estimated using both on- and off-resonance data. In the on-resonance case, the background has been characterised by fitting the m_{ES} distribution to an ARGUS function[5] using the sidebands, and extrapolating to the signal region. In the off-resonance case, the number of events in the sidebands and signal region were counted directly.

3 Analysis

For the simple counting analyses, cut optimisation was performed with respect to the predicted sensitivity of a measurement, using the expected signal yield and the estimated efficiency. Fig.2 shows the distributions of m_{ES} and ΔE for the mode $B^0 \to \rho^{\mp}\pi^{\pm}$.

For the two-body modes, a global likelihood fit was carried out. A likelihood function was constructed to determine the signal and background yields, using the parameters m_{ES}, ΔE, the Fisher Discriminant formed from a set of event shape variables, and the Cherenkov angles of the two decay products. The probability density functions used in the fit were obtained from studies of the data where possible. The likelihood contours for $\pi^{\pm}\pi^{\mp}$ and $K^{\pm}\pi >^{\mp}$ are shown in Fig.3.

The results of searches for 13 decay modes are presented in Table 1.

References

[1] P. F. Harrison and H. R. Quinn, eds., "The *BABAR* Physics Book", SLAC-R-405 (1998).

[2] *BABAR* Collaboration, B. Aubert *et al.*, "Measurements of charmless three-body and quasi-two-body B decays", *BABAR*-CONF-00/15, SLAC-PUB-8537.

[3] *BABAR* Collaboration, B. Aubert *et al.*, "Measurement of branching fractions for two-body charmless B decays to charged pions and kaons at *BABAR*", *BABAR*-CONF-00/14, SLAC-PUB-8536.

[4] *BABAR* Collaboration, B. Aubert *et al.*, "The first year of the BABAR experiment at PEP-II", BABAR-CONF-00/17, SLAC-PUB-8539.

[5] ARGUS Collaboration, H.Albrecht *et al.*, Phys. Lett. B **254** (1991) 288.

[6] Particle Data Group, D.E. Groom *et al.*, Eur.Phys.Jour.C 15, 1 (2000).

Table 1: Summary of Results.

Decay mode	yield	*BABAR* BR/10^{-6}	CLEO[6] BR/10^{-6}
$B^0 \to \pi^\pm \pi^\mp$	25 ± 8	$9.3^{+2.6+1.2}_{-2.3-1.4}$	$4.3^{+1.6}_{-1.4} \pm 0.5$
$B^0 \to K^\pm \pi^\mp$	26 ± 8	$12.5^{+3.0+1.3}_{-2.6-1.7}$	$17.2^{+2.5}_{-2.4} \pm 1.2$
$B^0 \to K^\pm K^\mp$	1 ± 4	< 6.6	< 1.9
$B^+ \to \omega h^+$	6 ± 4	< 24	$< 14.3 \pm 3.6$
$B^0 \to \omega K^0_S$	0	< 14	< 21
$B^+ \to \eta' K^+$	12 ± 4	$62 \pm 18 \pm 8$	80 ± 10
$B^0 \to \eta' K^0_S$	1 ± 1	< 112	$< 89 \pm 18$
$B^+ \to K^{*0} \pi^+$	10 ± 5	< 28	< 16
$B^+ \to \rho^0 K^+$	11 ± 5	< 29	< 17
$B^+ \to K^+ \pi^- \pi^+$	19 ± 6	< 66	< 28
$B^+ \to \rho^0 \pi^+$	25 ± 8	< 39	$< 10.4 \pm 3.4$
$B^+ \to \pi^+ \pi^- \pi^+$	5 ± 6	< 22	< 41
$B^0 \to \rho^\mp \pi^\pm$	36 ± 10	$< 48.5 \pm 13.4^{+5.8}_{-5.2}$	$< 27.6 \pm 8.4$