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B MESON DECAYS TO QUASI-TWO-BODY CHARMLESS FINAL STATES AT *BABAR*

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We present results for measurements of the decays to charmless final states of B^0 meson to ηK^0, $\eta\omega$, $a_1^+(1260)\pi^-$ with $a_1^+(1260) \to \pi^+\pi^+\pi^-$, and of B^+ to $\eta\rho^+$, $\eta'\pi^+$. Analyses are based on data taken with the *BABAR* detector at the PEP-II asymmetric e^+e^- collider at SLAC. We measure the following branching fractions in units of 10^{-6}: $\mathcal{B}(B^0 \to \eta K^0) = 2.5 \pm 0.8 \pm 0.1$, $\mathcal{B}(B^0 \to \eta\omega) = 1.2 \pm 0.6 \pm 0.2$ (< 2.1, 90% C.L.), $\mathcal{B}(B^0 \to a_1^+(1260)\pi^-) = 42.6 \pm 4.2 \pm 4.1$, $\mathcal{B}(B^+ \to \eta\rho^+) = 8.6 \pm 2.2 \pm 1.1$, and $\mathcal{B}(B^+ \to \eta'\pi^+) = 4.2 \pm 1.0 \pm 0.5$. The charge asymmetries are $\mathcal{A}_{ch}(\mathcal{B}(B^+ \to \eta\rho^+)) = (7 \pm 19 \pm 2)\%$ and $\mathcal{A}_{ch}(\mathcal{B}(B^+ \to \eta'\pi^+)) = (24 \pm 19 \pm 1)\%$. First error is statistical, the second systematic. All results are preliminary.

Keywords: rare decay; branching fraction; charge asymmetry.

The rare decays to charmless quasi-two-body final states of B^0 meson to ηK^0, $\eta\omega$, $a_1^+(1260)\pi^-$, and of B^+ to $\eta\rho^+$, $\eta'\pi^+$ are expected to be dominated by $b \to u$ CKM-suppressed tree amplitudes or by $b \to s$ loop ("penguin") amplitudes.[a] We present in this paper branching fraction and direct *CP* violation measurements of these rare decays. We can test and constrain theoretical models using these measurements.[1,2] We search for direct *CP* violation by measuring the charge asymmetry $\mathcal{A}_{ch} \equiv (\Gamma^- - \Gamma^+)/(\Gamma^- + \Gamma^+)$ in the rates $\Gamma^\pm = \Gamma(B^\pm \to f^\pm)$, for each observed charged final state $f^\pm$. The above-mentioned decay modes with an η or η' in the final state have not been observed definitely, while no experimental measurements exist of B^0 decays to $a_1^+(1260)\pi^-$.[3,4,5] The measurements are based on data collected with *BABAR* detector [6] at the PEP-II asymmetric e^+e^- collider located at the Stanford Linear Accelerator Center. More details on the analyses can be found elsewhere.[7]

A B-meson candidate is characterized kinematically by the energy-substituted

[a]Except as noted otherwise, we use a particle name to denote either member of a charge-conjugate pair.

mass $m_{ES} = ((\frac{1}{2}s + \mathbf{p}_0 \cdot \mathbf{p}_B)^2/E_0^2 - \mathbf{p}_B^2)^{1/2}$ and energy difference $\Delta E = E_B^* - \frac{1}{2}\sqrt{s}$, where the subscripts 0 and B refer to the initial $\Upsilon(4S)$ and to the B candidate, respectively, and the asterisk denotes the $\Upsilon(4S)$ frame. Background arises primarily from random combinations in continuum $e^+e^- \to q\bar{q}$ events ($q = u, d, s, c$). We reject this background with requirements on kinematical variables of resonance daughters and on event-shape variables. We also use as event-shape variable, a Fisher discriminant $\mathcal{F}$ that combines four variables: the angles with respect to the beam axis of the B momentum and B thrust axis (in the $\Upsilon(4S)$ frame), and the zeroth and second angular moments $L_{0,2}$ of the energy flow about the B thrust axis. We obtain yields and $\mathcal{A}_{ch}$ from extended unbinned maximum-likelihood fits, where the likelihood function incorporates m_{ES}, ΔE, $\mathcal{F}$, and other kinematical variables depending on the decay mode.

The branching fraction of the decay mode $B^0 \to \eta K^0$ has been measured using a sample of 182 million $B\overline{B}$ pairs.[7] The results of this measurement are shown in Table 1. The measured branching fraction is comparable with the branching fraction of the decay mode $B^+ \to \eta K^+$ [3] and both these decays are suppressed compared to the B decays to $\eta' K^0$ and $\eta' K^+$ [8]. The reverse happens when in the final states we have K^* mesons instead of K.[5] This pattern had been pointed out by Lipkin in 1991 with the hypothesis of the interference between penguin diagrams that conspires to greatly enhance $B \to \eta' K$ and suppresses $B \to \eta K$.[9] Because the vector K^* has the opposite parity from the kaon, the situation is reversed for the final states with K^*.

The decays $B^+ \to \eta\rho^+$ and $B^+ \to \eta'\pi^+$ have been measured using 182 million $B\overline{B}$ pairs [7] (results shown in Table 1). These decay modes are expected to be dominated by CKM-suppressed $b \to u$ tree amplitudes. These amplitudes may interfere significantly with penguin amplitudes, possibly leading to large direct *CP* violation in $\eta\rho^+$ and $\eta'\pi^+$.[2] Both decay modes are observed with a statistical significance $S > 4\sigma$ and no evidence is seen of direct *CP* violation.

The branching fraction of the decay mode $B^0 \to \eta\omega$ has been measured using 182 million $B\overline{B}$ pairs [7] (results shown in Table 1). This measurement with the other ones (branching fractions or upper limits) of B^0 meson decays to charmless isoscalar pairs [4] can be used to constrain the difference $\Delta S = S - \sin 2\beta$ between the parameter S appearing in the sinusoidal term of the time evolution of penguin-dominated decays (like $B^0 \to \eta' K_S^0$) and $\sin 2\beta$ as measured in the charmonium-K_S^0 decays [10].

Using 124 million $B\overline{B}$ pairs, we have measured the branching fraction of the B^0 meson decay to $a_1^+(1260)\pi^-$ with $a_1^+(1260) \to \pi^+\pi^+\pi^-$ [7] (results shown in Table 1). In this preliminary measurement we do not distinguish between the main intermediate states $a_1 \to (\pi\pi)_\rho\pi$ and $a_1 \to (\pi\pi)_\sigma\pi$. Background contributions from B^0 decays to $a_2(1320)\pi$ and $\pi(1300)\pi$ are assumed to be negligible. A substantial signal is seen in the mass region of $a_1^+(1260)$ meson. We have also fitted the values of the $a_1^+(1260)$ mass parameters: $m_{a_1} = 1.19 \pm 0.02$ GeV/c^2 and $\Gamma_{a_1} = 0.312 \pm 0.055$ GeV/c^2. These values are close to those found in hadronic

Table 1. Signal yield Y, detection efficiency ϵ, daughter branching fraction product, significance S (with systematic uncertainties included), measured branching fraction, signal ($\mathcal{A}_{ch}$) charge asymmetry for each mode.

Mode	Y	ϵ (%)	$\prod \mathcal{B}_i$ (%)	S σ	$\mathcal{B}$ (10^{-6})	$\mathcal{A}_{ch}$ (%)
$\eta_{\gamma\gamma} K^0$	19^{+8}_{-7}	29	14	3.7	$2.7^{+1.1}_{-1.0}$	
$\eta_{3\pi} K^0$	6^{+5}_{-4}	22	8	2.1	$1.8^{+1.6}_{-1.1}$	
$\boldsymbol{\eta K^0}$				**4.2**	$\mathbf{2.5 \pm 0.8 \pm 0.1}$	
$\eta_{\gamma\gamma}\omega$	12^{+7}_{-6}	13	35	2.4	$1.4^{+0.7}_{-0.6}$	
$\eta_{3\pi}\omega$	-1^{+7}_{-5}	13	20	0.0	$-0.2^{+1.4}_{-1.0}$	
$\boldsymbol{\eta\omega}$				**2.2**	$\mathbf{1.2 \pm 0.6 \pm 0.2}$	
$\eta_{\gamma\gamma}\rho^+$	110^{+31}_{-29}	16	39	3.2	$8.1^{+2.9}_{-2.7}$	20 ± 23
$\eta_{3\pi}\rho^+$	53^{+19}_{-17}	11	23	2.8	$9.7^{+4.3}_{-3.9}$	-18 ± 32
$\boldsymbol{\eta\rho^+}$				**4.2**	$\mathbf{8.6 \pm 2.2 \pm 1.1}$	$\mathbf{7 \pm 19 \pm 2}$
$\eta'_{\eta\pi\pi}\pi^+$	55^{+12}_{-11}	27	18	4.9	$5.4^{+1.4}_{-1.3}$	19 ± 21
$\eta'_{\rho\gamma}\pi^+$	30^{+15}_{-14}	18	30	1.2	$1.9^{+1.6}_{-1.4}$	47 ± 44
$\boldsymbol{\eta'\pi^+}$				**4.8**	$\mathbf{4.2 \pm 1.0 \pm 0.5}$	$\mathbf{24 \pm 19 \pm 1}$
$\boldsymbol{a_1^+(1260)\pi^-}$	472 ± 47	18	50	**13.8**	$\mathbf{42.6 \pm 4.2 \pm 4.1}$	

production of the $a_1^+(1260)$ meson.

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