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RARE B DECAYS AT *BABAR*

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We present recent results on rare B meson decays based on data taken by the *BABAR* detector at the PEP-II asymmetric e^+e^- collider. Included in this report are measurements of branching fractions and other quantities of interest for several hadronic, radiative, electroweak, and purely leptonic decays of B mesons.

In this paper we present measurements of branching fractions and direct CP asymmetries of rare B decays based on data taken at the *BABAR* detector [1]. Measurements of the longitudinal polarization for the charmless vector vector B decays are reported. Most analyses use a sample of approximately 89 million $B\overline{B}$ pairs, while $B^0 \to \pi^0\pi^0$ and $B \to K^{(*)}\ell^+\ell^-$ analyses use a sample of 124 million $B\overline{B}$ pairs.

The rare B decay processes discussed here can be classified as follows.

- *Charmless hadronic decays:* These decays proceed through CKM suppressed tree ($b \to u$) and (or) gluonic penguin amplitudes. Presented here are results of $B \to hh$ ($h = K, \pi$) decays (table 1), vector vector B decays (table 2), and decays involving isoscalar mesons (table 3).

  The decay processes involving penguin loops are sensitive to new physics contributions, as new particles can be virtually created in the loops. Such effects may show up as different branching fractions, CP asymmetries or kinematic distributions rather than those predicted by the Standard Model (SM). Besides the search for hints of new physics, measurements of SM parameters can be obtained from these decays. Some examples of physics implications related to rare hadronic decays are as follows.

  The time-dependent CP asymmetry in the decays $B \to \pi^+\pi^-$ and $\rho^+\rho^-$, $B \to \phi K^0$ and ϕK^* are related to CKM angle α and β, respectively. Measurements of isospin related decays $B \to \pi^0\pi^0$ and $\pi^\pm\pi^0$ ($B \to \rho^0\rho^0$ and $\rho^\pm\rho^0$) can be used to evaluate or constrain α [21]. The ratios of various $\pi\pi$ and $K\pi$ modes are sensitive to the angle γ [22]. The isospin sum rule for $K\pi$ decays shows discrepancy between measurements and SM predictions [22], which with increased statistical significance would imply the possibility of new physics. For vector vector decays, one aspect which is currently not well understood is that longitudinal polarization fractions of the $\rho^+\rho^-$, $\rho^+\rho^0$ and $\rho^0 K^{*+}$ decays are different from that of the ϕK^{*0} and ϕK^{*+} decays. A_{CP} measurements for different penguin dominated decays are potentially sensitive to new physics. In addition, measurements of rates of many of the hadronic decays provide test

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for the accuracy of theoretical predictions, such as, QCD factorization.

- *Radiative and electroweak decays:* Radiative penguin processes include exclusive $B \to K^*\gamma$ and $\rho/\omega\gamma$, and semi-inclusive $B \to X_s\gamma$ decays. Results for branching fraction measurements of the exclusive and semi-inclusive electroweak processes $K^{(*)}\ell^+\ell^-$ and $X_s\ell^+\ell^-$, and exclusive pure electroweak flavor changing neutral current process $B^+ \to K^+\nu\overline{\nu}$ are reported. Results of aforesaid processed are summarized in table 3. These penguin dominated decays are sensitive to new physics. For example, in the SM, a small A_{CP} is predicted for the radiative $s\gamma$ processes, which can be enhanced significantly in various new physics scenarios. In addition, the ratio of $B \to \rho\gamma$ and $B \to K^*\gamma$ rates constrains the ratio of CKM matrix elements $|V_{td}|/|V_{ts}|$.

- *Purely leptonic decays:* We present searches for rare leptonic decays $B^+ \to \mu^+\nu_\mu$ and $B^+ \to \tau^+\nu_\tau$. These decays proceed via annihilation of the $\overline{b}$ and u quarks into a virtual W boson. Branching fraction measurements provide direct measurement of the B meson decay constant f_B. The pure leptonic decays are helicity suppressed, though physics beyond the SM can enhance these processes. Upper limits obtained for these decays are listed in table 3.

At *BABAR*, with the large amount of produced B mesons, many rare decay modes have been observed and branching fractions for many decays are measured with higher precision. No strong evidence of new physics have been found yet, though some of the measurements are not in good agreement with SM expectations. With expected increase in luminosity in near future rare B decays will allow us to explore the SM even further and may offer a glimpse to the physics beyond the SM.

Table 1. Branching fractions ($\mathcal{B}$) and direct CP-violating charged asymmetry (A_{CP}) of the decays $B \to hh$ ($h = \pi, K$). The first and second errors are statistical and systematic, respectively. Upper limits are quoted at 90% confidence level.

Mode	$\mathcal{B}(10^{-6})$	A_{CP}
$\pi^+\pi^-$ [2]	$4.7 \pm 0.6 \pm 0.2$	-
$K^+\pi^-$ [2]	$17.9 \pm 0.9 \pm 0.7$	$-0.102 \pm 0.050 \pm 0.016$
K^+K^- [2]	< 0.6	-
$\pi^+\pi^0$ [3]	$5.5^{+1.0}_{-0.9} \pm 0.6$	$-0.03^{+0.18}_{-0.17} \pm 0.02$
$K^+\pi^0$ [3]	$12.8^{+1.2}_{-1.1} \pm 1.0$	$-0.09 \pm 0.09 \pm 0.01$
$\pi^0\pi^0$ [4]	$2.1 \pm 0.6 \pm 0.3$	-
$\overline{K}^0\pi^+$ [5]	$22.3 \pm 1.7 \pm 1.1$	$-0.05 \pm 0.08 \pm 0.01$
$\overline{K}^0K^+$ [5]	< 2.5	-
$K^0\pi^0$ [5]	$11.4 \pm 1.7 \pm 0.8$	$0.03 \pm 0.36 \pm 0.11$
$K^0\overline{K}^0$ [5]	< 1.8	-

Table 2. Branching fractions ($\mathcal{B}$) and direct CP-violating charged asymmetry (A_{CP}) of the decays $B \to \rho\rho$, ρK^*, $\phi K^{(*)}$ and $\phi\pi$. For vector vector B meson decays longitudinal polarization (f_L) measurements are also listed. The first and second errors are statistical and systematic, respectively. Upper limits are quoted at 90% confidence level.

Mode	$\mathcal{B}(10^{-6})$	A_{CP}	f_L
ϕK^{*+} [7]	$12.7\,^{+2.2}_{-2.0} \pm 1.1$	$+0.16 \pm 0.17 \pm 0.03$	$0.46 \pm 0.12 \pm 0.03$
ϕK^{*0} [7]	$11.2 \pm 1.3 \pm 0.8$	$+0.04 \pm 0.12 \pm 0.02$	$0.65 \pm 0.07 \pm 0.02$
$\rho^0 K^{*+}$ [7]	$10.6^{+3.0}_{-2.6} \pm 2.4$	$+0.20\,^{+0.32}_{-0.29} \pm 0.04$	$0.96\,^{+0.04}_{-0.15} \pm 0.04$
$\rho^0\rho^0$ [7]	< 2.1	-	-
$\rho^+\rho^-$ [6]	25^{+7+5}_{-6-6}	-	$0.98^{+0.02}_{-0.08} \pm 0.03$
ϕK^+ [8]	$10.0^{+0.9}_{-0.8} \pm 0.5$	$0.04 \pm 0.09 \pm 0.01$	-
ϕK^0 [8]	$8.4^{+1.5}_{-1.3} \pm 0.5$	-	-
$\phi\pi^+$ [8]	< 0.41	-	-

Table 3. Branching fractions ($\mathcal{B}$) and direct CP-violating charged asymmetry (A_{CP}) of $B \to \eta^{(')}K^*$, $\eta^{(')}\pi$, $\eta^{(')}\rho$, combinations of two charmless isoscalar mesons, radiative, electroweak and purely leptonic B decays. The first and second errors are statistical and systematic, respectively. Upper limits are quoted at 90% confidence level.

Mode	$\mathcal{B}(10^{-6})$	A_{CP}	Mode	$\mathcal{B}(10^{-6})$
$\eta' K^+$ [9]	$76.9 \pm 3.5 \pm 4.4$	$0.037 \pm 0.045 \pm 0.011$	$\eta'\rho^+$ [11]	< 22
$\eta' K^0$ [9]	$60.6 \pm 5.6 \pm 4.6$	-	$\eta'\rho^0$ [11]	< 4.3
$\eta\pi^+$ [10]	$5.3 \pm 1.0 \pm 0.3$	$-0.44 \pm 0.18 \pm 0.01$	$\eta'\pi^0$ [11]	< 3.7
ηK^+ [10]	$3.4 \pm 0.8 \pm 0.2$	$-0.52 \pm 0.24 \pm 0.01$	$\omega\pi^0$ [11]	< 1.2
ηK^0 [10]	< 5.2	-	$\phi\pi^0$ [11]	< 1.0
$\eta'\pi^+$ [10]	< 4.5	-	$\eta\eta$ [12]	< 2.8
ηK^{*+} [11]	$25.6 \pm 4.0 \pm 2.4$	$+0.13 \pm 0.14 \pm 0.02$	$\eta\phi$ [12]	< 1.0
ηK^{*0} [11]	$18.6 \pm 2.3 \pm 1.2$	$+0.02 \pm 0.11 \pm 0.02$	$\eta\omega$ [12]	< 6.2
$\eta\rho^+$ [11]	< 14	-	$\eta\eta'$ [12]	< 4.6
$\eta\rho^0$ [11]	< 1.5	-	$\eta'\eta'$ [12]	< 10
$\eta\pi^0$ [11]	< 2.5	-	$\eta'\omega$ [12]	< 2.8
$\eta' K^{*+}$ [11]	< 14	-	$\eta'\phi$ [12]	< 4.5
$\eta' K^{*0}$ [11]	< 7.6	-	$\phi\phi$ [12]	< 1.5
$K^{*0}\gamma$ [14] $K^{*+}\gamma$ [14]	$39.2 \pm 2.0 \pm 2.4$ $38.7 \pm 2.8 \pm 2.6$	$-0.013 \pm 0.036 \pm 0.010$	$\rho^0\gamma$ [13] $\rho^+\gamma$ [13]	< 1.2 < 2.1
$K\ell^+\ell^-$ [16]	$0.65^{+0.14}_{-0.13} \pm 0.04$	-	$\omega\gamma$ [13]	< 1.0
$K^*\ell^+\ell^-$ [16]	$0.88^{+0.33}_{-0.29} \pm 0.01$	-	$K^+\nu\overline{\nu}$ [18]	< 70.0
$X_s\ell^+\ell^-$ [17]	$6.3 \pm 1.6^{+1.8}_{-1.5}$	-	$\mu^+\nu_\mu$ [19]	< 6.6
$X_s\gamma$ [15]	-	$0.025 \pm 0.05 \pm 0.015$	$\tau^+\nu_\tau$ [20]	< 410

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