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RARE B DECAYS IN BABAR

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Measurements and searches for rare B decays have been performed with the BaBar detector at the PEP-II e^+e^- asymmetric B Factory, operating at the $\Upsilon(4S)$ resonance. We report some recent branching fraction measurements on hadronic and radiative B decays, occuring from $b \to s/d$ and $b \to u$ transitions. Most of the results presented here are based on a data sample corresponding to a luminosity of 81.9 fb^{-1}.

1. Motivations

Most of the decays of the B meson occur from a $b \to c$ tree transition. This produces final states such as $B \to D\pi$, $B \to D\rho$,...

All the decays that don't belong to this category are referred to as rare decays. These are generated by the $b \to u$ and the $b \to s/d$ loop ("penguin"[1,2]) transitions.

Given the huge data sample available at the B factories, precise measurements of rare B decays could be used to probe new physics. This is particularly true for the penguin diagrams where virtual Higgs bosons or SUSY particles could be involved in the loop. On the other hand rare CP eigen states bring additional information to test the CKM unitarity triangle.

Direct CP (or charge) asymmetry defined as:

$$\mathcal{A}_{\mathcal{CP}} = \frac{\Gamma(\bar{B} \to \bar{f}) - \Gamma(B \to f)}{\Gamma(\bar{B} \to \bar{f}) + \Gamma(B \to f)} \quad (1)$$

is non-zero only if there are at least two contributing diagrams to a given process, with both different weak and strong phases. It is therefore sensitive to extra contributions arising from new physics for processes driven by a single contribution in the Standard Model.

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2. Radiative and electroweak penguins

2.1. $b \to s\gamma$

The $b \to s\gamma$ transition leads to the decay $B \to X_s\gamma$ where X_s is a strange hadronic system recoiling against an energetic photon.
Two approaches have been adopted: a fully inclusive analysis [3] where only the photon is reconstructed (method a) and a semi-exclusive analysis [4] (method b) in which a photon, a kaon and up to three pions are combined to form a B candidate. In both methods, we look for a photon whose energy in the $\Upsilon(4S)$ center of mass frame (E^*_γ) is above 2.1 GeV and below 2.7 GeV. Figure 1 shows the resulting E^*_γ spectrum from method a and the branching ratio as a function of the X_s system invariant mass from method b, respectively.

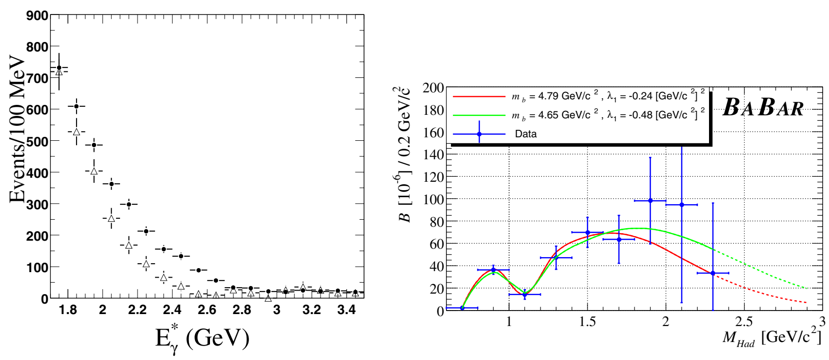


Figure 1. $B \to X_s\gamma$ analyses: inclusive photon energy spectrum (data in solid points, background expectation in open triangles) and branching ratio vs. $m(X_s)$. The curves superimposed on the $m(X_s)$ spectrum represent fits relying on heavy quark effective theory parameters.

A fit to the $m(X_s)$ spectrum enables to extract heavy quark effective theory parameters [5,6].
The total branching ratio is:

$$\mathcal{B}(B \to X_s\gamma) = (3.86 \pm 0.36(stat.) \pm 0.37(syst.)^{+0.43}_{-0.23}(model)) \times 10^{-4}$$

for the inclusive analysis and

$$\mathcal{B}(B \to X_s\gamma) = (4.3 \pm 0.5(stat.) \pm 0.8(syst.) \pm 1.3(model)) \times 10^{-4}$$

for the semi-exclusive analysis.

2.2. $B \to K^{(*)} l^+ l^-$

The search for the electroweak penguin transition $b \to s\ l^+ l^-$ have been done through the reconstruction of the modes $B \to K^{(*)} l^+ l^-$ [7]. A charged or neutral K or K^* is combined to a e^+e^- or $\mu^+\mu^-$ pair to form a B candidate. Background from the charmonium modes $B \to J/\psi K^{(*)}$, $\psi(2S)K^{(*)}$ is vetoed by applying a cut on the lepton pair invariant mass. Figure 2 shows the distribution of beam energy constrained B mass, $M_{ES} = \sqrt{E_{beam}^2 - p_B^{*2}}$, and energy difference, $\Delta E = E_{beam} - E_B^*$, for the Kl^+l^- and $K^*l^+l^-$ modes.

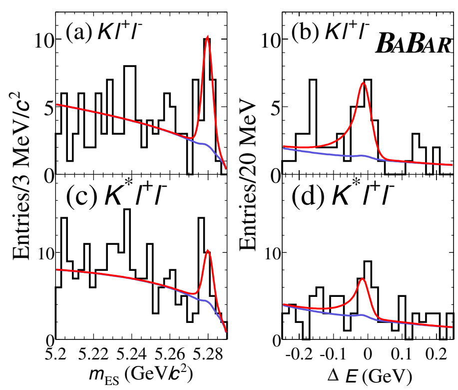


Figure 2. M_{ES} and ΔE projections for the combined $K\ l^+l^-$ (a,b) and $K^*\ l^+l^-$ (c,d) modes.

The corresponding rates are:

$$\mathcal{B}(B \to K\ l^+l^-) = (0.78^{+0.24}_{-0.20}(stat.)^{+0.11}_{-0.18}(syst.)) \times 10^{-6}$$
$$\mathcal{B}(B \to K^*\ l^+l^-) = (1.68^{+0.68}_{-0.58}(stat.) \pm 0.28(syst.)) \times 10^{-6} \text{ or}$$
$$< 3 \times 10^{-6} \text{ @ } 90\% \text{ C.L}$$

These results are in the range expected in the Standard Model [8,9,10].

3. Hadronic rare decays

Rare hadronic decays[a] can be separated into two categories: those who are dominated by the penguin $b \to s/d\ g^*$ transition and those who are dominated by the suppressed $b \to u$ tree transition.

3.1. *Gluonic penguins*

The decay $B \to \eta' K$ is dominated by the $b \to sg^*$ transition while $B \to \phi K^{(*)}$ is a pure penguin.

The large rate observed for $B \to \eta' K$ has stimulated a huge amount of theoretical studies [12,13]. The neutral mode $B^0 \to \eta' K^0_S$ is a CP eigen mode and can be used for the extraction of $sin(2\beta)$.

The η' has been reconstructed in both $\eta\pi^+\pi^-$ and $\rho^0\gamma$ channels [14]. Figure 3 shows the M_{ES} and ΔE distributions for $B^\pm \to \eta' K^\pm$ and $B^0 \to \eta' K^0_S$ channels.

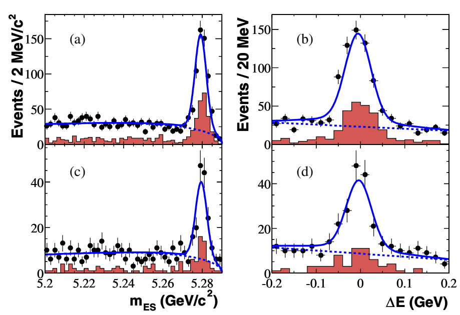


Figure 3. M_{ES} and ΔE projections for $B^\pm \to \eta' K^\pm$ (a,b) and $B^0 \to \eta' K^0_S$ (c,d). Points with errors represent data, solid curves the full fit functions, and dashed curves the background functions; the shaded histogram represents the $\eta'_{\eta\pi\pi} K$ subset.

The measured rates are:

$$\mathcal{B}(B^\pm \to \eta' K^\pm) = (76.9 \pm 3.5(stat.) \pm 4.4(syst.)) \times 10^{-6}$$
$$\mathcal{B}(B^0 \to \eta' K^0) = (55.4 \pm 5.2(stat.) \pm 4.0(syst.)) \times 10^{-6}$$

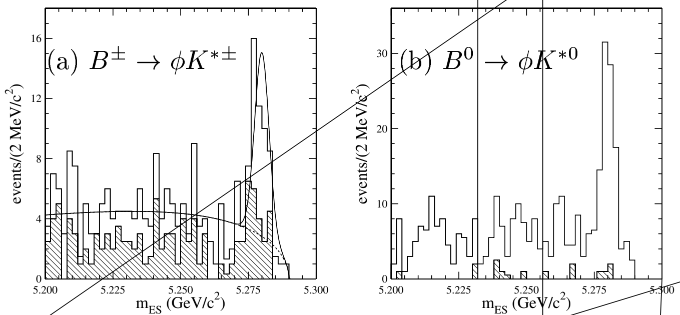
and the measured charge asymetry for $B^\pm \to \eta' K^\pm$,

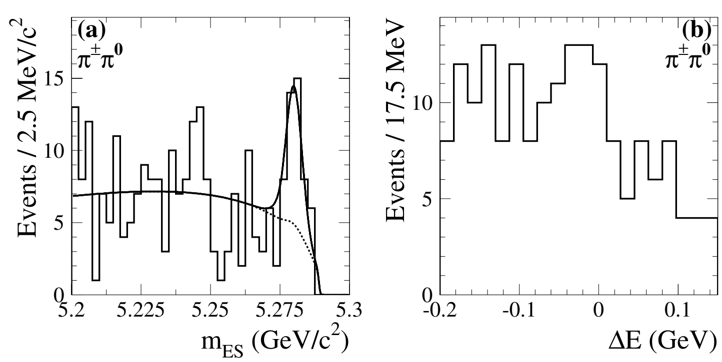
$$\mathcal{A}_{\mathcal{CP}}(\eta' K^\pm) = 0.037 \pm 0.045(stat.) \pm 0.011(syst.),$$

[a]In this note, we only present results on two body modes. Recent measurements of three body charmless decays are detailed in reference [11]

is consistent with zero.

$B \to \phi K^*$ has been studied in both the charged and neutral modes [15] with $K^{*\pm}$ being reconstructed in the channels $K_S^0\pi^\pm$ and $K^\pm\pi^0$ and K^{*0} being reconstructed in the channels $K^\pm\pi^\mp$ and $K_S^0\pi^0$. Figure 4 shows the M_{ES} distribution for $B^\pm \to \phi K^{*\pm}$ and $B^0 \to \phi K^{*0}$.




(a)
π±π0
Events / 2.5 MeV/c²
m_ES (GeV/c²)
(b)
π±π0
Events / 17.5 MeV
ΔE (GeV)