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ELECTROWEAK PENGUIN AND LEPTONIC DECAYS AT BABAR

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Recent BABAR results on electroweak penguin and leptonic decays are reviewed. In particular, the measurements of $B \to K^{(*)}l^+l^-$and the preliminary results on $B \to X_s l^+l^-$are presented. Also summarized are the preliminary limits on $B^+ \to l^+\nu$ $(l = e, \mu)$ and $B^+ \to K^+\nu\overline{\nu}$.

1. Introduction

All decays discussed in this review are sensitive to new physics ("NP"). The flavor changing neutral current decays, such as $b \to sl^+l^-$ and $B^+ \to K^+\nu\overline{\nu}$, do not occur at tree level and the $B^+ \to l^+\nu$ $(l = e, \mu)$ decays, which involve the $u\overline{b}$ annihilation diagram, are suppressed by the dependence on the CKM matrix element, $|V_{ub}|$, and the lepton mass, m_l. Hence, the branching fractions predicted by the Standard Model ("SM") for these decays are low and these are good channels to look for non-standard contributions with the potential for new particles to show up virtually.

2. Electroweak Penguin Decays

In the SM, the amplitudes which contribute to the $b \to sl^+l^-$ and the $b \to s\nu\overline{\nu}$ decays at leading order are: the electromagnetic penguin (only for $b \to sl^+l^-$), the Z penguin and the W^+W^- box diagram. An important consequence of the loop structure of these decays is that their branching fractions and their kinematic variables, such as the transferred momentum squared of the virtual γ/Z $(q^2 = M(l^+l^-)^2)$ and the forward-backward asymmetry of the lepton decay angle (A_{FB}) in the $b \to sl^+l^-$ decays, can be significantly affected by the presence of new particles or couplings predicted in non-standard scenarios.

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

The BABAR analysis[1] is based on a data sample of $123 \cdot 10^6$ $B\overline{B}$ pairs and studies eight final states: $B^+ \to K^+l^+l^-$, $B^0 \to K^0_s l^+l^-$, $B^+ \to K^{*+}l^+l^-$ and $B^0 \to K^{*0}l^+l^-$, where l is either an electron or a muon. $K^{(*)}e^+e^-\gamma$ events are also included in the $K^{(*)}e^+e^-$ signal.

The exclusive reconstruction of the B mesons exploits the kinematic constraints on the beam-energy substituted mass $m_{ES} = \sqrt{E^{*2}_{beam} - p^{*2}_B}$ and $\Delta E = E^*_B - E^*_{beam}$, where E^*_{beam}, p^*_B and E^*_B are the beam energy, the momentum and the energy of the B candidate, respectively, in the center-of-mass ("CM") frame.

The m_{ES}, ΔE and $m_{K\pi}$ (only for the $B \to K^*l^+l^-$mode) distributions are simultaneously fitted to extract the signal (see Figure 1). Signals for

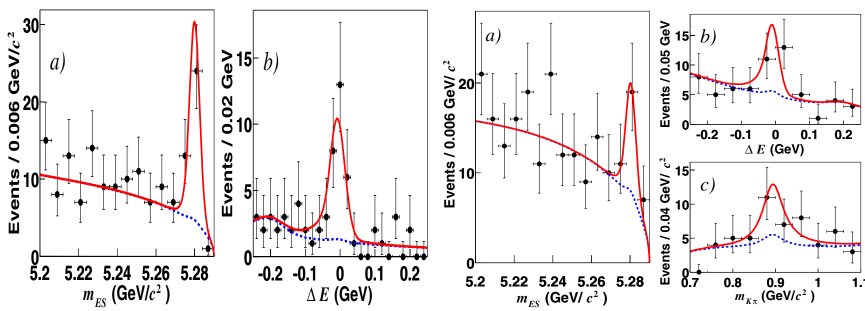

Figure 1. Distribution of m_{ES} and ΔE in $B \to Kl^+l^-$data (*a)* and *b)* on the left) and in $B \to K^*l^+l^-$data, where the $m_{K\pi}$ distribution is also shown (*a)*, *b)* and *c)* on the right). The solid curves are the projections of the simultaneous fit. The dashed curves represent the background components under the signal peaks.

$B \to Kl^+l^-$have been observed ($\sim 8\sigma$ of significance) and evidence for $B \to K^*l^+l^-$has been obtained (3.3σ of significance). The measured branching fractions:

$$\mathcal{B}(B \to Kl^+l^-) = (0.65^{+0.14}_{-0.13} \pm 0.04) \cdot 10^{-6} \quad (1)$$

$$\mathcal{B}(B \to K^*l^+l^-) = (0.88^{+0.33}_{-0.29} \pm 0.10) \cdot 10^{-6} \quad (2)$$

are consistent with the range of predictions based on the SM.

2.2. $B \to X_s l^+l^-$

The $B \to X_s l^+l^-$branching fraction is computed in the SM with smaller theoretical uncertainties than $B \to K^{(*)}l^+l^-$.

BABAR measured the $B \to X_s l^+ l^-$branching fraction[2] on a data sample of $89 \cdot 10^6$ $B\overline{B}$ pairs by reconstructing the final state from pairs of electrons or muons and ten different hadronic states: K^+, $K^+\pi^0$, $K^+\pi^-$, $K^+\pi^-\pi^0$, $K^+\pi^-\pi^+$, K^0_s, $K^0_s\pi^0$, $K^0_s\pi^+$, $K^0_s\pi^+\pi^0$ and $K^0_s\pi^+\pi^-$.

A signal of $41 \pm 10(stat) \pm 2(syst)$ events with a statistical significance of 4.6 was observed (see Figure 2). The branching fraction result:

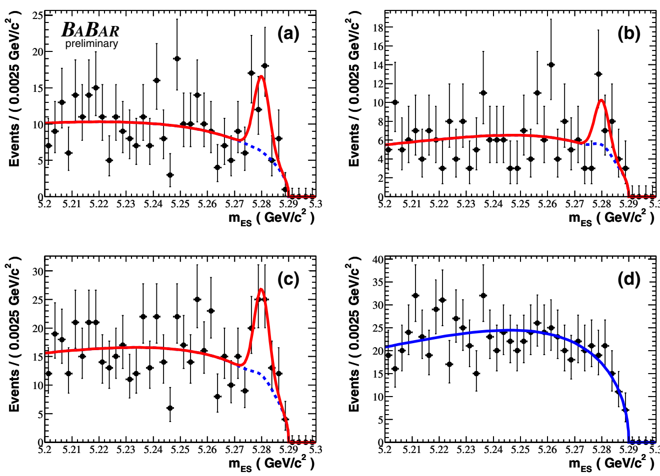

Figure 2. m_{ES} distributions for *(a)* $B \to X_s e^+e^-$, *(b)* $B \to X_s \mu^+\mu^-$, *(c)* $B \to X_s l^+ l^- (l = e, \mu)$ and *(d)* $B \to X_s e^+\mu^-$candidates. The solid lines represent the result of the fits and the dashed lines the background components under the signal peaks.

$$\mathcal{B}(B \to X_s l^+ l^-) = (6.3 \pm 1.6^{+1.8}_{-1.5}) \times 10^{-6} \qquad (3)$$

agrees with the theoretical prediction by Ali *et al.* [3] and the measurement performed by the Belle Collaboration [4].

2.3. $B^+ \to K^+ \nu\overline{\nu}$

The $B^+ \to K^+\nu\overline{\nu}$ decay measurement is experimentally challenging due to the presence of two unobserved neutrinos. To identify the signal, the other B in the event has to be fully reconstructed.

The BaBar analysis [5], performed on a data sample of $87 \cdot 10^6$ $B\overline{B}$ pairs, fully reconstructs the hadronic decay $B^- \to D^0 X^-$ of the other B, where X^- is a hadronic sistem composed of up to three charged pions or kaons and up to two π^0 with a net charge of -1. Candidates events are then required to possess only one kaon with CM momentum greater than 1.5 GeV/c. Three candidates are found, which leads to an upper limit of $\mathcal{B}(B^+ \to K^+\nu\overline{\nu}) < 10.5 \times 10^{-5}$ (90% CL). BaBar also set a preliminary limit of 9.4×10^{-5} [5] by reconstructing the semileptonic decay of the other B. The combined upper limit is:

$$\mathcal{B}(B^+ \to K^+\nu\overline{\nu}) < 7.0 \times 10^{-5}(90\%\ CL) \tag{4}$$

which is still an order of magnitude higher than the SM prediction $\mathcal{B}(B^+ \to K^+\nu\overline{\nu}) = (3.8^{+1.2}_{-0.6}) \cdot 10^{-6}$.

3. Leptonic Decays

The study of the purely leptonic $B^+ \to l^+\nu$ decays can provide sensitivity to some SM parameters and also act as a probe of NP.

In the SM, the branching fraction can be cleanly computed:

$$\mathcal{B}(B^+ \to l^+\nu) = \frac{G_F^2 m_B m_l^2}{8\pi}\left(1 - \frac{m_l^2}{m_B^2}\right) f_B^2 |V_{ub}|^2 \tau_B \tag{5}$$

where G_F is the Fermi coupling constant, m_l and m_B are the charged lepton and B meson masses, τ_B is the B^+ lifetime and f_B the B decay constant. Using data from Ref. 7 the SM expectations are $\mathcal{B}(B^+ \to \tau^+\nu) \sim 7.5 \times 10^{-5}$ and $\mathcal{B}(B^+ \to \mu^+\nu) \sim 4 \times 10^{-7}$.

A measurement could provide either the first direct determination of f_B, given the CKM matrix element $|V_{ub}|$, or evidence for NP since a non SM amplitude could enhance the predicted branching fraction.

3.1. $B^+ \to \tau^+\nu$

BABAR has searched the $B^+ \to \tau^+\nu$ decay on a data sample of $89 \cdot 10^6$ $B\overline{B}$ pairs. Due to the presence of at least two neutrinos in the final state, the semileptonic and the hadronic decays of the other B have been reconstructed, as in the $B^+ \to K^+\nu\overline{\nu}$ analysis.

After reconstructing the other B, the signal signature is given by one or up to tree charged tracks, depending on the τ decay mode, and low neutral energy left in the detector (E_{left}). In the analysis using the semileptonic tag[8], only the $\tau^+ \to e^+\nu_e\overline{\nu}_\tau$ and $\tau^+ \to \mu^+\nu_\mu\overline{\nu}_\tau$ decays are reconstructed and a fit to E_{left} is performed. In the analysis using the hadronic tag[9], the hadronic τ decays into $\pi^+\overline{\nu}_\tau$, $\pi^+\pi^0\overline{\nu}_\tau$ and $\pi^+\pi^-\pi^+\overline{\nu}_\tau$ are also included and the number of events with the $E_{left} < 100$ MeV is counted. The two samples are then combined to obtain:

$$\mathcal{B}(B^+ \to \tau^+\nu) < 4.1 \times 10^{-4}(90\%\ CL) \tag{6}$$

which improves the upper limit given by L3 [10].

3.2. $B^+ \to \mu^+\nu$

The $B^+ \to \mu^+\nu$ decay has been searched by BaBar on a data sample of $88 \cdot 10^6$ $B\overline{B}$pairs.[11] After identifying a muon, all remaining particles are associated with the decay of the other B. Once the other B is reconstructed, the muon momentum is calculated in the rest frame of the signal B. The signal muon momentum distribution is expected to peak at 2.64 GeV/c. No significant signal excess has been observed and the obtained upper limit:

$$\mathcal{B}(B^+ \to \mu^+\nu) < 6.6 \times 10^{-6}(90\%\ CL) \tag{7}$$

is the most stringent upper limit set so far for the $B^+ \to \mu^+\nu$ branching fraction.

4. Conclusion

No deviations from the SM have been found in electroweak and leptonic B decays, yet, but limits on several exclusive modes have been improved and the observation of $B \to K^*l^+l^-$and $B \to X_s l^+l^-$opens the way to a new rich area of search for new physics.

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