Rare B decays at BABAR

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I present recent results on rare B decays using data collected by the BABAR detector at the PEP-II asymmetric-energy e+e- collider at the Stanford Linear Accelerator Center. I report measurements of the inclusive $b \to s\gamma$ decay rate, angular distributions in $B \to K(^*)ll$ decays, the exclusive decays $B \to \rho/\omega\gamma$, which are mediated by the $b \to d\gamma$ transition. I also present measurements of and searches for rare leptonic B decays.

1. Motivation

Rare B decays are a sensitive probe of new physics, as well as offering access to poorly-known Standard Model (SM) parameters. There exist potentially large non-SM effects in rare meson decays making them theoretically very interesting, but typically they are also experimentally challenging.

2. Radiative Penguin decays

Radiative penguin decays are flavour changing neutral currents which do not occur at tree level in the SM. They must proceed via one loop or higher diagrams, shown in Figure 1.

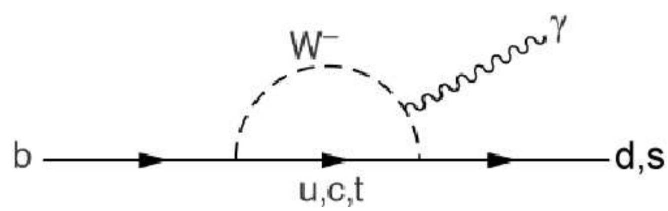

Fig. 1. Feynman diagrams for $b \to s\gamma$ and $b \to d\gamma$ radiative penguin decays.

In the SM the decay is dominated by the top quark contribution, but new physics can appear in the loop with a size comparable to leading SM contributions. For example, the particles in the loop may be replaced by a charged Higgs particle, charginos and/or squarks, as shown in Figure 1.

Radiative penguin decays are experimentally very challenging, with large backgrounds from continuum $q\bar{q}$ (where $q = u, d, s, c$) and generic B decays swamping the signal. Several analysis techniques have been developed to remove these backgrounds taking advantage of the signature high energy photon and the event shape.

2.1. $b \to s\gamma$

The measurement of $BF(b \to s\gamma)$ is one of the most sensitive indirect probes of new physics. Figure 2 shows the different experimental results compared to the theoretical predictions. BABAR has measured $BF(b \to$

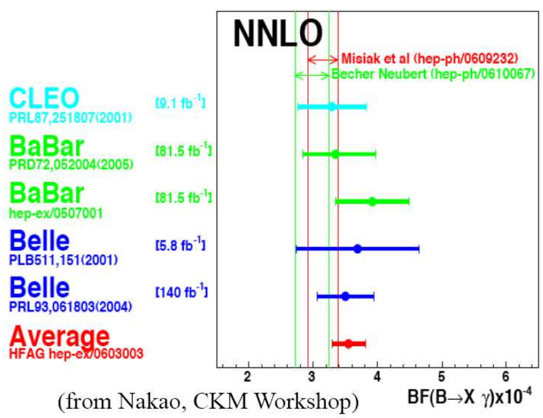

Fig. 2. Experimental results and theoretical predictions for $BF(b \to s\gamma)$.

$s\gamma) = (3.27 \pm 0.18(stat.)^{+0.55}_{-0.40}(syst.)^{+0.04}_{-0.09}(theory)) \times 10^{-4}$ in a semi-inclusive analysis [1], where the $b \to s\gamma$ decays is reconstructed in a sum of 38 exclusive final states, and $BF(b \to s\gamma) = 3.67 \pm 0.29(stat.) \pm 0.34(syst.) \pm 0.29(model)) \times 10^{-4}$ in a fully inclusive analysis [2], where the hadronic part of the decay is not reconstructed.

2.2. $B \to (\rho/\omega)\gamma$

The $b \to d\gamma$ decay is CKM suppressed by a factor 20 compared to $b \to s\gamma$. Of particular interest in the study of this decay is the measurement of the ratio of BFs $B \to (\rho/\omega)\gamma$ and $B \to K^*\gamma$. The ratio of CKM matrix elements V_{td}/V_{ts} can be extracted from this ratio using the formula:

$$\frac{BF(B \to (\rho/\omega)\gamma)}{BF(B \to K^*\gamma)} = |\frac{V_{td}}{V_{ts}}|^2 \left(\frac{1 - m^2_{\rho,\omega}/M^2_B}{1 - m^2_{K^*}/M^2_B}\right)^3 \zeta^2[1 + \Delta R]. \qquad (1)$$

This is a constraint independent from the recent CDF measurement of B_d, B_s mixing and is sensitive to new physics.

The recent BABAR measurement [3] found $BF(B \to (\rho/\omega)\gamma) = (1.25^{+0.25}_{-0.24}(stat.) \pm 0.09(syst.)) \times 10^{-6}$. Figure 3 shows the results from recent BABAR and BELLE analyses. The experimental uncertainties are currently compatible with theoretical uncertainties and no deviation from the standard model is found. The constraint on V_{td}/V_{ts} from the combined

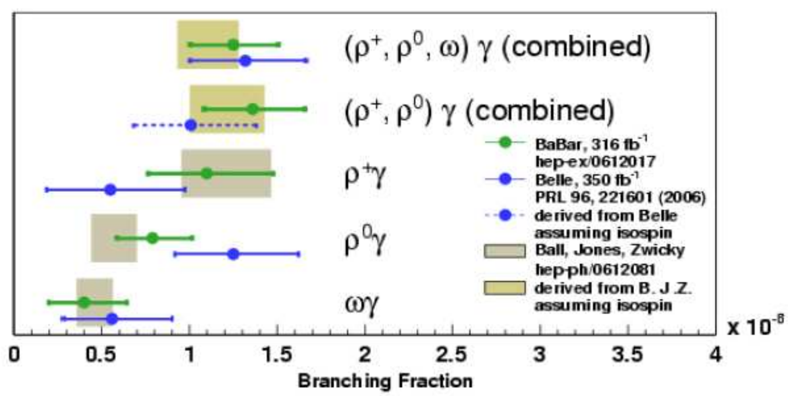

Fig. 3. (a) - Experimental results and theoretical predictions for the $b \to d\gamma$ BF. (b) - Experimental constraints on V_{td}/V_{ts}.

world average branching fraction is shown in Figure 3, in good agreement with the CDF B-mixing result.

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

In a recent analysis [4], BABAR measured the branching fractions of the radiative decays $B \to Kl^+l^-$ and $B \to K^*l^+l^-$ to be $BF(B \to Kl^+l^-) = (0.34 \pm 0.07(stat.) \pm 0.02(syst.)) \times 10^{-6}$ and $BF(B \to K^*l^+l^-) = (0.78^{+0.19}_{-0.17}(stat.) \pm 0.11(syst.)) \times 10^{-6}$, in agreement with SM predictions. The $B \to X_s l^+l^-$ decay receives contributions from several diagrams (see Figure 4, with interference between the contributing amplitudes producing

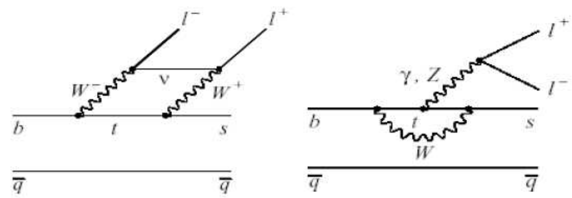

Fig. 4. Feynman diagrams for $B \to K^{(*)}l^+l^-$.

asymmetries in lepton angular distribution. This analysis also measured the forward-backward asymmetry, which is sensitive to non-SM Wilson coefficients. The results, shown in Figure 5(a) favour the SM in the high q^2 region but are less consistent in low q^2. Figure 5(b) shows the results of the analysis of longitudinal component of polarisation F_L, which is the first measurement of K^* polarisation in this mode. It is consistent with the SM.

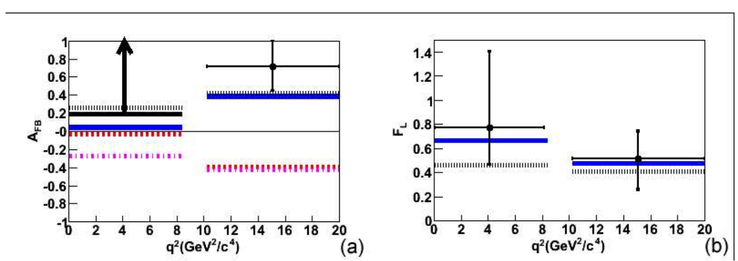

Fig. 5. Results of measurements of asymmetries in $B \to K^{(*)}l^+l^-$ decays. Black points are data, blue lines are SM predictions, other lines are non-SM predictions. (a) Lepton forward-backward asymmetry, (b) K^* longitudinal component of polarisation.

3. Leptonic B decays

Purely leptonic B decays offer theoretically clean access to the SM parameter $f_B|V_{ub}|$. In addition, new physics contributions, for example from a charged Higgs (see Figure 6) may enhance or reduce the SM BF. These rare decays have many experimental challenges - the final state contains more than one neutrino and so there are few kinematic constraints that can be applied. Instead, the non-signal B (the 'tag' B) is fully reconstructed, and all other particles in the events are attributed to the signal B candidate.

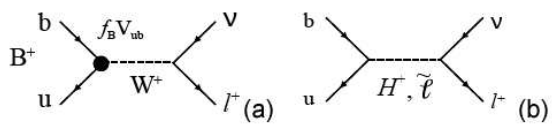

Fig. 6. Feynman diagrams for leptonic B decays. (a) Standard Model contribution. (b) New physics contribution.

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

The BABAR analysis [5] used the quantity E_{extra}, the sum of neutral and charged energies remaining when the tag B has been reconstructed, to extract the signal. As shown in Figure 7, signal concentrates at $E_{extra} <$ 500MeV.

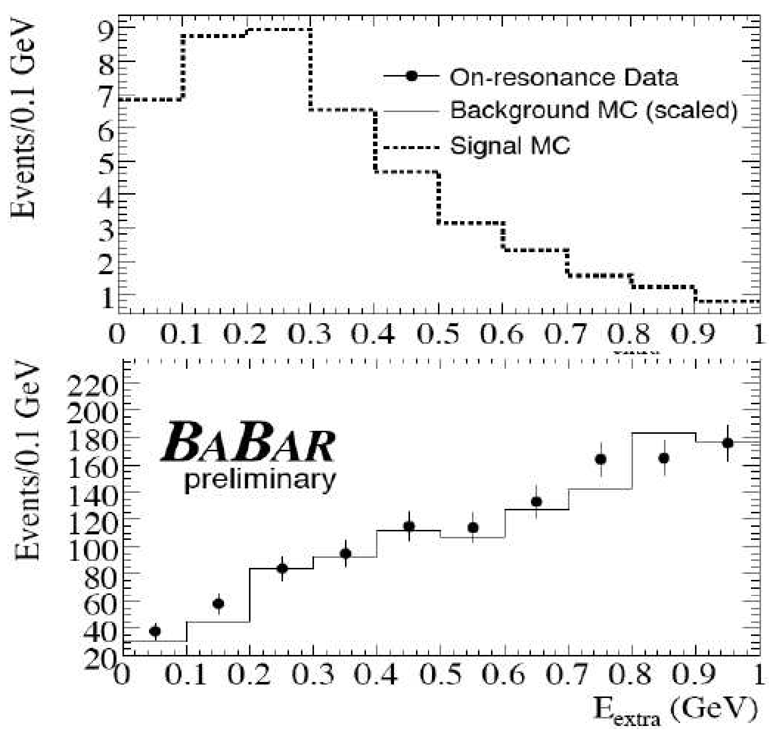

Fig. 7. Distribution of E_{extra} for (a) signal Monte Carlo simulation and (b) background Monte Carlo simulation and data.

BABAR measured $BF(B^+ \to \tau^+\nu_\tau) = (0.88^{+0.68}_{-0.67}(stat.) \pm 0.11(syst.)) \times$

10^{-4}, giving $f_B|V_{ub}| = (7.0^{+2.3}_{-3.6}(stat.)^{+}0.4_{0.5}(syst.)) \times 10^{-4}$GeV. An upper limit at 90% confidence level was set at $BF(B^+ \to \tau^+\nu_\tau) < 1.8 \times 10^{-4}$.

4. Conclusion

Rare B decays measured at BABAR offer valuable constraints on little-known SM parameters and are a unique probe into physics beyond the Standard Model.

References

1. B. Aubert *et al*, the BABAR collaboration *Phys. Rev.* **D72** , 052004 (2005).
2. B. Aubert *et al*, the BABAR collaboration *Phys. Rev. Lett.* **97** , 171803 (2006).
3. B. Aubert *et al*, the BABAR collaboration *Phys. Rev. Lett.* **98**, 151802 (2007) .
4. B. Aubert *et al*, the BABAR collaboration *Phys. Rev.* **D73** , 092001 (2006).
5. B. Aubert *et al*, the BABAR collaboration *hep-ex/0608019.*