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BABAR MEASUREMENTS ON $B \to K^{(*)}\ell^+\ell^-$ RATES AND RATE ASYMMETRIES

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Based on 471 million $B\overline{B}$ pairs collected with the BABAR detector at the PEP-II e^+e^- collider, we perform a series of measurements on rare decays $B \to K^{(*)}\ell^+\ell^-$, where $\ell^+\ell^-$ is either e^+e^- or $\mu^+\mu^-$. The measurements include total branching fractions, and partial branching fractions in six bins of di-lepton mass-squared. We also measure isospin asymmetries in the same six bins. Furthermore, we measure direct CP and lepton flavor asymmetries for di-lepton mass below and above the J/ψ resonance. Our measurements show good agreement with both Standard Model predictions and measurements from other experiments.

1 Introduction

The decays $B \to K\ell^+\ell^-$ and $B \to K^*\ell^+\ell^-$ [1] arise from flavor-changing neutral-current (FCNC) $b \to s\ell^+\ell^-$ processes, which are forbidden at tree level in the Standard Model (SM). These FCNC processes proceeds at lowest-order via γ/Z penguin and W^+W^- box diagrams [2] shown in Fig. 1. New physics at the electro-weak scale may introduce new box and penguin diagrams at the same order as the SM diagrams [3]. Figure 1 also show examples of these new physics loop processes.

In the decays $B \to K^{(*)}\ell^+\ell^-$, many observables are sensitive to new physics contributions. Due to poor knowledge of the $B \to K^{(*)}$ form factors, the theoretical predictions on decay rates possess large uncertainties. However most of the theoretical uncertainties cancel for the
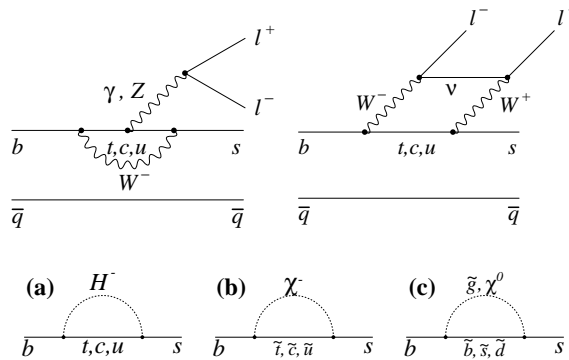

Figure 1: Top: Lowest-order Feynman diagrams for $b \to s\ell^+\ell^-$ in the SM. Bottom: Examples of new physics loop contributions to $b \to s\ell^+\ell^-$: (a) charged Higgs (H^-); (b) squark ($\tilde{t}, \tilde{c}, \tilde{u}$) and chargino ($\chi^-$); (c) squark ($\tilde{b}, \tilde{s}, \tilde{d}$) and gluino ($\tilde{g}$)/neutralino ($\chi^0$).

ratios of these rates, the $B \to K^{(*)}\ell^+\ell^-$ rate asymmetries can be particularly sensitive to new physics contributions due to better theoretical knowledge. By performing the rate asymmetry measurements, we are able to probe for new physics at the TeV scale [4].

2 Measurements

The measurements are based on a data sample of 471 million $B\overline{B}$ pairs collected at the $\Upsilon(4S)$ resonance with the *BABAR* detector [5] at the PEP-II asymmetric-energy e^+e^- collider at the SLAC National Accelerator Laboratory. We reconstruct $B \to K^{(*)}\ell^+\ell^-$ signal events in eight final states with an e^+e^- or $\mu^+\mu^-$ pair, and a K_S^0, K^+, $K^{*+}(\to K_S^0\pi^+)$, or $K^{*0}(\to K^+\pi^-)$, where a K_S^0 candidate is reconstructed in the $\pi^+\pi^-$ final state. We also require selected K^* candidates to have an invariant mass of $0.72 < m_{K\pi} < 1.10$ GeV/c^2. We perform measurements in six bins of di-lepton mass squared $s \equiv m_{\ell\ell}^2$: $0.1 \leq s < 2.0$ GeV^2/c^4, $2.0 \leq s < 4.3$ GeV^2/c^4, $4.3 \leq s < 8.1$ GeV^2/c^4, $10.1 \leq s < 12.9$ GeV^2/c^4, $14.2 \leq s < 16.0$ GeV^2/c^4, and $s \geq 16.0$ GeV^2/c^4. The experimental details on event selection and signal extraction are presented in Ref. [6].

We measure the total branching fractions for decays $B \to K\ell^+\ell^-$ and $B \to K^*\ell^+\ell^-$ at $(4.7 \pm 0.6 \pm 0.2) \times 10^{-7}$ and $(10.2^{+1.4}_{-1.3} \pm 0.5) \times 10^{-7}$, respectively. Here, the first uncertainty is statistical, and the second is systematic. Figure 2 show our total branching fraction results in good agreement with measurements from Belle [7] and CDF [8] and predictions from Ali *et al.* [3] and Zhong *et al.* [9]. Figure 3 shows our results on $B \to K^{(*)}\ell^+\ell^-$ partial branching fractions together with other recent experimental results from Belle [7], CDF [8], and LHCb [10]. Our results are also shown to be consistent with the predictions from Ali *et al.* [3].

The direct *CP* asymmetry

$$\mathcal{A}_{CP}^{K^{(*)}} \equiv \frac{\mathcal{B}(\overline{B} \to \overline{K}^{(*)}\ell^+\ell^-) - \mathcal{B}(B \to K^{(*)}\ell^+\ell^-)}{\mathcal{B}(\overline{B} \to \overline{K}^{(*)}\ell^+\ell^-) + \mathcal{B}(B \to K^{(*)}\ell^+\ell^-)} \tag{1}$$

is expected to be $\mathcal{O}(10^{-3})$ in the SM. However new physics at the electroweak weak scale may bring in significant enhancement to $\mathcal{A}_{CP}^{K^{(*)}}$ [12]. The lepton flavor ratio

$$\mathcal{R}_{K^{(*)}} \equiv \frac{\mathcal{B}(B \to K^{(*)}\mu^+\mu^-)}{\mathcal{B}(B \to K^{(*)}e^+e^-)} \tag{2}$$

is expected to be consistent with unity to within a few percent for $s > (2m_\mu)^2$ in the SM [13]. According to two-Higgs-doublet models, the presence of a neutral Higgs boson at large $\tan\beta$ might increase $\mathcal{R}_{K^{(*)}}$ by up to 10% [14]. In Fig. 4, our $\mathcal{A}_{CP}^{K^{(*)}}$ and $\mathcal{R}_{K^{(*)}}$ results below and above the J/ψ resonance are shown to be in agreeement with the SM.
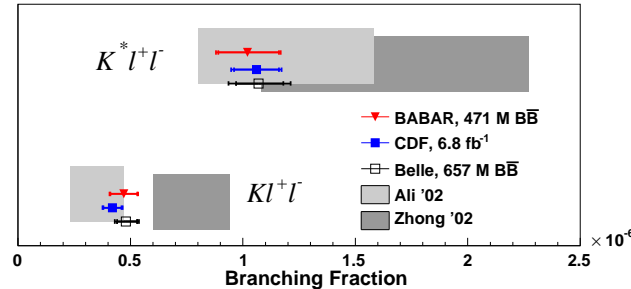

Figure 2: Total branching fractions for the $K\ell^+\ell^-$ and $K^*\ell^+\ell^-$ modes compared with Belle [7] and CDF [8] measurements and with predictions from the Ali *et al.* [3], and Zhong *et al.* [9] models.

We also measure the CP-averaged isospin asymmetry

$$\mathcal{A}_I^{K^{(*)}} \equiv \frac{\mathcal{B}(B^0 \to K^{(*)0}\ell^+\ell^-) - r_\tau \mathcal{B}(B^+ \to K^{(*)+}\ell^+\ell^-)}{\mathcal{B}(B^0 \to K^{(*)0}\ell^+\ell^-) + r_\tau \mathcal{B}(B^+ \to K^{(*)+}\ell^+\ell^-)}, \tag{3}$$

where $r_\tau \equiv \tau_{B^0}/\tau_{B^+} = 1/(1.071 \pm 0.009)$ is the ratio of B^0 and B^+ lifetimes [15]. In the SM, $\mathcal{A}_I^{K^{(*)}}$ is expected to be small of a few percent. As $s \to 0$, the SM expectation of $\mathcal{A}_I^{K^*}$ arrives at its maximum of $+6\%$ to $+13\%$ [16]. Figure 5 shows our $\mathcal{A}_I^{K^{(*)}}$ results compared to the Belle results in the six s bins. In addition, in the low s region $(0.10 < s < 8.12 \text{ GeV}^2/c^4)$, we measure $\mathcal{A}_I^K = -0.58^{+0.29}_{-0.37} \pm 0.02$ and $\mathcal{A}_I^{K^*} = -0.25^{+0.20}_{-0.17} \pm 0.03$, where the first uncertainty is statistical and the second is systematic. Our $\mathcal{A}_I^K$ and $\mathcal{A}_I^{K^*}$ results are consistent with SM expectations of zero at 2.1σ and 1.2σ, respectively. These results also agree with the Belle measurements [7].
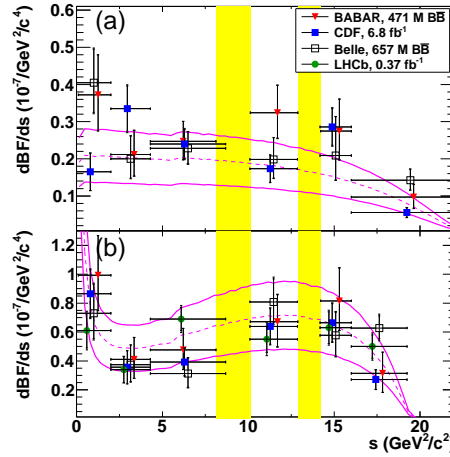

Figure 3: Partial branching fractions for the (a) $K\ell^+\ell^-$ and (b) $K^*\ell^+\ell^-$ modes as a function of s showing *BABAR* measurements, Belle measurements[7], CDF measurements[8], LHCb measurements[10], and the SM prediction from the Ali *et al.* model[3] with $B \to K^{(*)}$ form factors[11] (magenta dashed lines). The magenta solid lines show the theory uncertainties. The vertical yellow shaded bands show the vetoed s regions around the J/ψ and $\psi(2S)$.
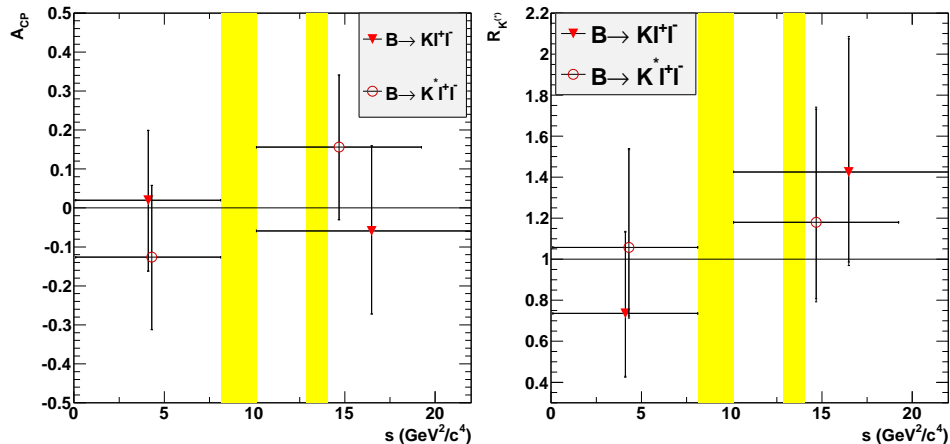

Figure 4: (left) CP asymmetries $\mathcal{A}_{CP}$ and (right) $R_{K^{(*)}}$ for $K\ell^+\ell^-$ modes and $K^*\ell^+\ell^-$ modes as a function of s. The vertical yellow shaded bands show the vetoed s regions around the J/ψ and $\psi(2S)$.
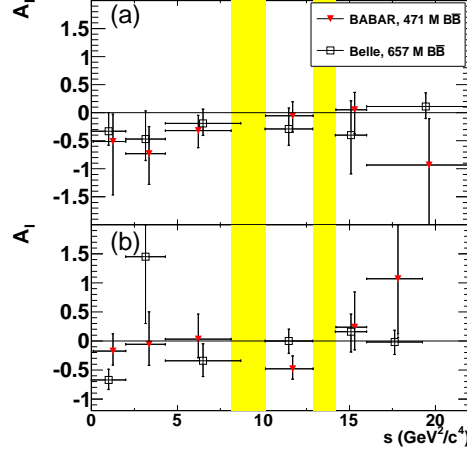
Figure 5: Isospin asymmetry $\mathcal{A}_I$ for the (a) $K\ell^+\ell^-$ and (b) $K^*\ell^+\ell^-$ modes as a function of s, in comparison to results from Belle [7]. The vertical yellow shaded bands show the vetoed s regions around the J/ψ and $\psi(2S)$.

3   Summary

In summary, we have performed measurements on total and partial branching fractions, direct CP asymmetries, lepton-flavor ratios, and isospin asymmetries in the rare decays $B \to K^{(*)}\ell^+\ell^-$ using the full BABAR dataset of 471 million $B\bar{B}$ pairs. All our results are in good agreement with the SM predictions and those from Belle, CDF, and LHCb. We notice negative isospin asymmetries in $B \to K^{(*)}\ell^+\ell^-$ modes at low s values as seen by Belle.

Acknowledgments

References

1. Charge conjugation is implied throughout except as explicitly noted.
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