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Radiative B Decays at Belle

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We report recent results on radiative B decays at Belle at the KEKB collider.

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1. Introduction

B meson decays via loop diagrams are sensitive probe to new physics (NP). These processes in the SM are suppressed by the Cabibbo-Kobayashi-Maskawa matrix elements, V_{ts} or V_{td}, and a loop factor. Since unobserved heavy particles from some NP models can contributes the decays, the branching fractions, direct CP violation (A_{CP}), photon polarization, isospin asymmetry (Δ_{0+} or Δ_{0-}) and difference of A_{CP} between charged and neutral B mesons (ΔA_{CP}) might differ from the SM predictions. Radiative B decays $b \to s\gamma$, which are mediated by loop diagrams, are experimentally and theoretically clean due to final states having a color singlet photon. Thus these are ideal tools to search for NP.

We report the measurements of radiative B decays with a full data sample of 711 fb^{-1} accumulated by the Belle detector at the KEKB energy-asymmetric collider.

2. Evidence for Isospin Violation in $B \to K^*\gamma$ [1]

We reconstruct $B^0 \to K^{*0}\gamma$ and $B^+ \to K^{*+}\gamma$ decays, where K^* is formed from $K^+\pi^-$, $K^0_S\pi^0$, $K^+\pi^0$ or $K^0_S\pi^+$ combinations. To determine the branching fractions and direct CP asymmetries as well as ΔA_{CP} and isospin asymmetry (Δ_{0+}), we perform extended unbinned maximum likelihood fits to the seven $M_{\rm bc}$ distributions and the results are

$$\begin{aligned}
\mathscr{B}(B^0 \to K^{*0}\gamma) &= (3.96 \pm 0.07 \pm 0.14) \times 10^{-5}, \\
\mathscr{B}(B^+ \to K^{*+}\gamma) &= (3.76 \pm 0.10 \pm 0.12) \times 10^{-5}, \\
A_{CP}(B^0 \to K^{*0}\gamma) &= (-1.3 \pm 1.7 \pm 0.4)\%, \\
A_{CP}(B^+ \to K^{*+}\gamma) &= (+1.1 \pm 2.3 \pm 0.3)\%, \\
A_{CP}(B \to K^*\gamma) &= (-0.4 \pm 1.4 \pm 0.3)\%, \\
\Delta_{0+} &= (+6.2 \pm 1.5 \pm 0.6 \pm 1.2)\%, \\
\Delta A_{CP} &= (+2.4 \pm 2.8 \pm 0.5)\%,
\end{aligned}$$

where the third uncertainty for Δ_{0+} is due to the uncertainty in f_{+-}/f_{00}. We find evidence for isospin violation in $B \to K^*\gamma$ decays with a significance of 3.1σ, and this result is consistent with the predictions in the SM. Measured branching fractions and A_{CP} are most precise to date.

3. Measurement of Time-Dependent CP Violation in $B \to K\eta\gamma$ [2]

A measurement of time-dependent CP violation in $B^0 \to P^0_1 P^0_2 \gamma$ is the most promising method to measure the photon polarization in the $b \to s\gamma$ process, where P^0_1 and P^0_2 are scalar or pseudoscalar mesons and the $P^0_1 P^0_2$ system is a CP eigenstate. We measure the time-dependent CP violation in $B^0 \to K^0_S\eta\gamma$. We determine CP violation parameters, $\mathscr{S}$ and $\mathscr{A}$, by performing an unbinned maximum-likelihood fit to the observed proper time difference distribution in the signal region. The obtained parameters

$$\begin{aligned}
\mathscr{S} &= -1.32 \pm 0.77(\text{stat.}) \pm 0.36(\text{syst.}), \\
\mathscr{A} &= -0.48 \pm 0.41(\text{stat.}) \pm 0.07(\text{syst.})
\end{aligned}$$

are consistent with the null-asymmetry hypothesis within 2σ as well as with SM predictions.

4. Measurements of Isospin Asymmetry and Difference of *CP* Asymmetries in $B \to X_s\gamma$ [3]

Precision measurements of $B \to X_s\gamma$ branching fraction $\mathscr{B}(B \to X_s\gamma)$ [4, 5] and direct *CP* asymmetry [6] are in good agreement with the SM predictions [7, 8] and set strong constraints on NP models. The theoretical uncertainties in the predictions of $\mathscr{B}(B \to X_s\gamma)$ and $A_{CP}(B \to X_s\gamma)$ are about 7% and 2% which are comparable with the experimental uncertainties of the current world averages [9]. The Belle II experiment is expected to measure the branching fraction with a precision of about 3% [10]. Thus, the reduction of the theoretical uncertainty is crucial to further constrain NP models. One of the largest theoretical uncertainties is a resolved photon contribution which can be constrained from the measurement of isospin asymmetry in $B \to X_s\gamma$ [11, 12, 13]. A newly proposed *CP* violation observable is a difference of the direct *CP* asymmetries between the charged and neutral B mesons, which is proportional to a ratio of Wilson coefficients $\mathrm{Im}(C_8/C_7)$, is null in the SM while in some NP models, this value could be as large as 10% [8, 14, 15].

We perform measurements of Δ_{0-} and ΔA_{CP} in $B \to X_s\gamma$ with sum of 38 exclusive X_s final states which cover about 77% of total X_s decay rate. To extract the physics observables, we perform a simultaneous fit with an extended unbinned maximum likelihood method to eight M_{bc} distributions; five for B^-, B^+, $\bar{B}^0$, B^0, and B_{fns} in the on-resonance data, and three for charged B (B^- and B^+), flavor-specific neutral B ($\bar{B}^0$ and B^0), and B_{fns} in the off-resonance data, where B_{fns} is denoted as flavor non-specific final states. The results are

$$\begin{aligned}
\Delta_{0-} &= (-0.48 \pm 1.49 \pm 0.97 \pm 1.15)\%, \\
\Delta A_{CP} &= (+3.69 \pm 2.65 \pm 0.76)\%, \\
A_{CP}^{\mathrm{C}} &= (+2.75 \pm 1.84 \pm 0.32)\%, \\
A_{CP}^{\mathrm{N}} &= (-0.94 \pm 1.74 \pm 0.47)\%, \\
A_{CP}^{\mathrm{tot}} &= (+1.44 \pm 1.28 \pm 0.11)\%, \\
\bar{A}_{CP} &= (+0.91 \pm 1.21 \pm 0.13)\%,
\end{aligned}$$

where the third uncertainty for Δ_{0-} is due to f_{+-}/f_{00}. The measured Δ_{0-} and ΔA_{CP} are consistent with zero. Thus, these measurements can be used to constrain the resolved photon contribution in $B \to X_s\gamma$ and to constrain NP models. All the measurements are most precise to date.

5. Summary

We have measured the branching fractions, isospin asymmetries and *CP* violation observables in radiative B decays at Belle. These measurements strongly constrain NP models. Our measurements of *CP* violation observables are dominated by the statistical uncertainty; thus, the upcoming Belle II experiment will further reduce the uncertainty. To improve the isospin asymmetry at Belle II, reduction of the dominant uncertainty due to f_{+-}/f_{00} is essential, and can be performed at both Belle and Belle II.

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