RADIATIVE AND LEPTONIC RARE B DECAYS FROM BELLE

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In this talk, we present recent results on radiative and leptonic rare B decays from the Belle experiment, in particular, in the following decays: $B \to K^{(*)}e^+e^-$, $B \to X_d\gamma$, and $B^+ \to \tau^+\nu_\tau$.

Radiative and leptonic rare B meson decays provide great opportunities for precision tests of the Standard Model and indirect searches for new physics effects. With a high-statistics sample accumulated by the e^+e^- B-factory experiments, more and more of these decays are being measured, hence giving restrictions to the possible new physics models.

1. Semileptonic and Radiative FCNC B Decays

In the Standard Model (SM), flavor-changing neutral current (FCNC) B meson decays such as $b \to s\gamma$ and $b \to s\ell^+\ell^-$[a] are forbidden at the tree-level, but they are allowed via penguin- or loop-diagram processes. Some of these decays have been measured experimentally and recent interests on these processes have shifted to measuring the detailed internal structures of the processes such as the photon energy spectrum of the $b \to s\gamma$ decays, and the q^2-dependent forward-backward asymmetry of the $b \to s\ell^+\ell^-$ decays.

1.1. $\mathbf{A_{FB}}$ *and Wilson Coefficients in* $B \to K^*\ell^+\ell^-$

In the SM, the $b \to s\ell^+\ell^-$ decay rate is described by the effective Wilson coefficiencts $\tilde{C}_7^{\rm eff}$, $\tilde{C}_9^{\rm eff}$ and $\tilde{C}_{10}^{\rm eff}$, which parametrize the strength of the short-

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[a]Charge-conjugate states are implied throughout this paper.

distance interactions. The forward-backward asymmetry ($\mathrm{A_{FB}}$), mainly caused by interference between the electroweak penguin and box diagrams, is defined using the angle θ between the momenta of ℓ^- (ℓ^+) and the B ($\bar{B}$) meson in the dilepton rest frame, and can be expressed in terms of the Wilson coefficients. Measurement of $\mathrm{A_{FB}}$ and differential decay rate as a function of q^2 and θ for $B \to K^*\ell^+\ell^-$ can give substantial constraints on these coefficients[1].

We measure the $\mathrm{A_{FB}}(q^2)$ and ratios of Wilson coefficients in $B \to K^*\ell^+\ell^-$ by using a 357 fb^{-1} data sample of Belle. First, we measure the q^2-integrated asymmetry $\mathrm{A_{FB}}$ by determining the signal yield in each q^2 and forward-backward region and correcting for the efficiency: $\mathrm{A_{FB}}(B \to K^*\ell^+\ell^-) = 0.50 \pm 0.15 \pm 0.02$. A large integrated asymmetry is observed with a significance of 3.4σ. In contrast, for $K^+\ell^+\ell^-$ we obtain the result consistent with zero as expected.

The $K^*\ell^+\ell^-$ candidates are fitted for the ratios of Wilson coefficients. Figure 1 shows the fit results projected onto $\mathrm{A_{FB}}(q^2)$. The fit results for the ratios of Wilson coefficients are summarized below.

	Negative A_7	Positive A_7
A_9/A_7	$-15.3\,^{+3.4}_{-4.8} \pm 1.1$	$-16.3\,^{+3.7}_{-5.7} \pm 1.4$
A_{10}/A_7	$10.3\,^{+5.2}_{-3.5} \pm 1.8$	$11.1\,^{+6.0}_{-3.9} \pm 2.4$

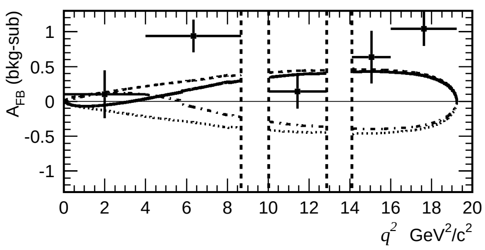

Figure 1. Fit result for the negative A_7 solution (solid) projected onto $\mathrm{A_{FB}}(q^2)$ curves for several input parameters, including the effects of efficiency. The new physics scenarios shown by the dot-dashed and dotted curves are excluded.

1.2. $b \to d\gamma$ *and* $|V_{td}/V_{ts}|$

The $b \to d\gamma$ decays are suppressed by the CKM quark-mixing factor $|V_{td}/V_{ts}|^2$ with respect to $b \to s\gamma$ decay. Therefore, measurements of these decays will allow one to determine $|V_{td}/V_{ts}|$ in the context of the SM and to search for physics beyond the SM, if combined with infromation from other relevant measurements.

Using a sample of 386×10^6 B meson pairs from Belle, we reconstruct three signal modes, $B^+ \to \rho^+\gamma$, $B^0 \to \rho^0\gamma$ and $B^0 \to \omega\gamma$, and two control samples, $B^+ \to K^{*+}\gamma$ and $B^0 \to K^{*0}\gamma$, and perform an unbinned extended maximum likelihood fit to candidates satisfying $|\Delta E| < 0.5$ GeV and $M_{\rm bc} > 5.2$ GeV$/c^2$, individually and simultaneously for the three signal modes. We also simultaneously fit the two $B \to K^*\gamma$ modes. The events in the fit region are described using by sum of the signal, continuum, $K^*\gamma$ (for the three signal modes only), and other background hypotheses. The $K^*\gamma$ background component in each signal mode is constrained using the fit to the $K^*\gamma$ events and the known misidentification probability. The other backgrounds are fixed using known branching fractions or upper limits [2].

We constrain branching fractions in the simultaneous fit using isospin relation. The simultaneous fit gives $\mathrm{B}(B \to (\rho,\omega)\gamma) = (1.32\,^{+0.34}_{-0.31}\,^{+0.10}_{-0.09}) \times 10^{-6}$. The significance of this result is 5.1 σ.

The ratio $\mathrm{B}(B \to (\rho,\omega)\gamma)/\mathrm{B}(B \to K^*\gamma)$, which we extract by a separate fit, is used to determine $|V_{td}/V_{ts}|$. We obtain $|V_{td}/V_{ts}| = 0.199\,^{+0.026}_{-0.025}(\mathrm{exp.})\,^{+0.018}_{-0.015}(\mathrm{theo.})$. This result is in agreement with the range favored by a fit to the unitarity triangle assuming $|V_{ts}| = |V_{cb}|$.

2. Purely Leptonic B Decays

The purely leptonic decays $B^+ \to \ell^+\nu_\ell$ are allowed in the SM via annihilation of initial-state quarks, $\bar{b}$ and u, into a virtual W boson. It provides a direct determination of $f_B\,|V_{ub}|$ where f_B is the B meson decay constant. The branching fraction is given by

$$\mathrm{B}(B^+ \to \ell^+\nu_\ell) = \frac{G_F^2 m_B m_\ell^2}{8\pi}\left(1 - \frac{m_\ell^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B.$$

Because of helicity suppression, the expected branching fraction to $\tau^+\nu_\tau$ mode is larger than the others by a few orders of magnitude. Physics beyond the SM, such as supersymmetry or two-Higgs doublet models, could modify $\mathrm{B}(B^+ \to \tau^+\nu_\tau)$ through the introduction of a charged Higgs boson [3]. Purely leptonic B decays have not been observed in past experiments.

To search for this decay we use 447×10^6 B meson pairs from Belle. To improve signal purity we fully reconstruct one of the B mesons in the event ($B_{\rm tag}$), and compare properties of the remaining particle(s) ($B_{\rm sig}$) to those expected for signal and background. We estimate the number of $B_{\rm tag}$'s and their purity in the selected region to be 6.80×10^5 and 0.55, respectively.

In the events where a $B_{\rm tag}$ is reconstructed, we search for decays of $B_{\rm sig}$ into a τ and a neutrino. Candidate events are required to have one or three charged track(s) on the signal side with the total charge being opposite to that of $B_{\rm tag}$. The τ lepton is identified in the five decay modes, $\mu^-\bar{\nu}_\mu\nu_\tau$, $e^-\bar{\nu}_e\nu_\tau$, $\pi^-\nu_\tau$, $\pi^-\pi^0\nu_\tau$ and $\pi^-\pi^+\pi^-\nu_\tau$, which taken together correspond to 81% of all τ decays.

The most powerful variable for separating signal and background is the remaining energy in the CsI electromagnetic calorimeter, denoted as $E_{\rm ECL}$, which is sum of the energy of photons that are not associated with either the $B_{\rm tag}$ or the π^0 candidate from the $\tau^- \to \pi^-\pi^0\nu_\tau$ decay. For signal events, $E_{\rm ECL}$ must be either zero or a small value arising from beam background hits, therefore, signal events peak at low $E_{\rm ECL}$. On the other hand background events are distributed toward higher $E_{\rm ECL}$ due to the contribution from additional neutral clusters. We find a significant excess of events in the $E_{\rm ECL}$ signal region.

The branching fraction is determined by fitting the obtained $E_{\rm ECL}$ distributions:

$$\mathrm{B}(B^+ \to \tau^+\nu_\tau) = (1.79^{+0.56+0.39}_{-0.49-0.46}) \times 10^{-4} \ .$$

The significance of the signal, after including the systematics, is 3.5 σ. Using the HFAG average value for $|V_{ub}|^2$, we obtain $f_B = 0.229^{+0.036+0.030}_{-0.031-0.034}$ GeV, the first direct determination of the B meson decay constant.

References

1. For example, E. Lunghi *et al.*, Nucl. Phys. B **568**, 120 (2000) and other references therein.
2. Heavy Flavor Averaging Group, winter 2005 results, (http://www.slac.stanford.edu/xorg/hfag/).
3. W. S. Hou, Phys. Rev. D **48**, 2342 (1993).