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Search for $b \to d\gamma$ decays

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We report search results for flavor-changing neutral current process $b \to d\gamma$ with a data sample containing 275 million B meson pairs accumulated at $\Upsilon(4S)$ resonance. We studied the exclusive decays $B^+ \to \rho^+\gamma$, $B^0 \to \rho^0\gamma$ and $B^0 \to \omega\gamma$, and find no significant signal. We set an upper limit for combined branching fraction $\mathcal{B}(B \to (\rho,\omega)\gamma) < 1.4 \times 10^{-6}$ at 90% confidence level.

1. Introduction

The $b \to d\gamma$ process is a flavor changing neutral current transition that proceeds via loop diagrams in the Standard Model (SM). It is suppressed with respect to $b \to s\gamma$ by the Cabbibo-Kobayashi-Maskawa (CKM) factor $|V_{td}/V_{ts}|^2 \sim 0.04$. No inclusive $b \to d\gamma$ measurements have been reported to date, and the exclusive modes $B \to \rho\gamma$ and $B^0 \to \omega\gamma$, which are presumably dominant, have not been observed either. These are also suppressed with respect to $B \to K^*\gamma$ by $|V_{td}/V_{ts}|^2$. The expected branching fractions are in the range $(0.9 - 2.7) \times 10^{-6}$ in the SM [1,2]. Measurement of these exclusive branching fractions would improve the constraints on V_{td} in the context of the SM.

In this report, we present the results [3] of a search for the $b \to d\gamma$ process using a data sample of $(275 \pm 3) \times 10^6$ $B\overline{B}$ pairs accumulated at the $\Upsilon(4S)$ resonance. The data are produced in e^+e^- annihilation at the KEKB energy-asymmetric collider [4] and collected with the Belle detector [5].

2. Analysis Techniques

We reconstruct the following final states: $B^+ \to \rho^+\gamma$, $B^0 \to \rho^0\gamma$, and $B^0 \to \omega\gamma$. We also reconstruct control samples of $B \to K^{*-}\gamma$ and $B \to \bar{K^{*0}}\gamma$. The following decay chains are used to reconstruct the intermediate states: $\rho^+ \to \pi^+\pi^0$, $\rho^0 \to \pi^+\pi^-$, $\omega\pi^+\pi^-\pi^0$, $K^{*-} \to K^-\pi^0$, $\bar{K^{*0}} \to K^-\pi^+$, and $\pi^0 \to \gamma\gamma$.

Photons with the largest center-of-mass (CM) energy in the range $1.8\,\mathrm{GeV} < E^*_\gamma < 3.4\,\mathrm{GeV}$ are selected as primary photon candidates. To suppress backgrounds from $\pi^0 \to \gamma\gamma$ and $\eta \to \gamma\gamma$ decays, we veto the event if the reconstructed mass of the primary photon and any other photon of 30 (200) MeV or more is within ± 18 (32) MeV/c^2 of the π^0 (η) mass. Charged kaons and pions are reconstructed as tracks in a central drift chamber (CDC) and a silicon vertex detector (SVD). We veto the charged tracks coming from a K_s candidates. Invariant masses for ρ and ω candidates are required to be within windows of $\pm 150\,\mathrm{MeV}/c^2$ and $\pm 30\,\mathrm{MeV}/c^2$, respectively around their nominal masses.

We have two major sources of background, the continuum background and the background from misidentified $B \to K^*\gamma$. We also have backgrounds from higher K^* resonances, $B \to \rho\pi^0$, $B \to \omega\pi^0$, $B \to \rho\eta$, $B \to \omega\eta$ and other charmless rare B decays. To suppress continuum, we use a Fisher discriminant [7] of event shape variables [6], the B polar angle in $\Upsilon(4S)$ rest frame, separation of decay vertices along z-axis and flavor tag information. Particle identification (PID) plays an important role in the suppression of $B \to K^*\gamma$ background. Along with PID information, we use the variable $M_{K\pi}$, which is the invariant mass of two pions, assuming a kaon mass for one of them, to further suppress $B \to K^*\gamma$. The residual $B \to K^*\gamma$ background is estimated from real data and is fixed during the fit. Backgrounds from $B \to \rho\pi^0$, $B \to \omega\pi^0$, $B \to \rho\eta$ and $B \to \omega\eta$ are suppressed with the help of the helicity angle. The $B\overline{B}$ backgrounds other than $B \to K^*\gamma$ are estimated using Monte Carlo.

3. Results and discussion

Signal extraction is done using an unbinned extended maximum likelihood fit. A combined branching fraction $\mathcal{B}(B \to (\rho,\omega)\gamma) = \mathcal{B}(B^+ \to \rho^+\gamma)$ is also defined using isospin relations, $\mathcal{B}(B^+ \to \rho^+\gamma) = (\tau_{B^+}/\tau_{B^0}) \cdot 2\mathcal{B}(B^0 \to \rho^0\gamma) = (\tau_{B^+}/\tau_{B^0}) \cdot 2\mathcal{B}(B^0 \to \omega\gamma)$, where $\tau_{B^+}/\tau_{B^0} = 1.086 \pm 0.017$ [?]. Similarly $\mathcal{B}(B \to K^*\gamma) \equiv \mathcal{B}(B \to K^{*+}\gamma) = (\tau_{B^+}/\tau_{B^0}) \cdot \mathcal{B}(B \to K^{*0}\gamma)$ is also assumed. We perform a fit to the data in the $(M_{\rm bc}, \Delta E)$ fit region bounded by $|\Delta E| < 0.3\,\mathrm{GeV}$ and $M_{\rm bc} > 5.2\,\mathrm{GeV}/c^2$, simultaneously for three signal modes (collectively referred as $B \to (\rho,\omega)\gamma$) and two $B \to K^*\gamma$ modes. Using a data sample of 275×10^6 $B\overline{B}$ pairs we have obtained a combined branching fraction, $\mathcal{B}(B \to (\rho,\omega)\gamma) = (0.72^{+0.43}_{-0.39}(\mathrm{stat})^{+0.28}_{-0.27}(\mathrm{syst})) \times 10^{-6}$ with a significance of 1.9 standard deviations. The fit results are shown in Fig. 1. We have also set upper limits [8] $1q.4 \times 10^{-6}$, 2.2×10^{-6}, 0.8×10^{-6}, 0.8×10^{-6} at 90% confidence level for $B \to (\rho,\omega)\gamma$, $B^+ \to \rho^+\gamma$, $B^0 \to \rho^0\gamma$ and $B^0 \to \omega\gamma$ respectively. The ratio, $\mathcal{B}(B \to (\rho,\omega)\gamma)/\mathcal{B}(B \to K^*\gamma) < 0.035$ at 90% confidence level is also obtained which can be used to constrain V_{td}.

According to the prescription given in Ref. [1], the ratio of the branching fractions of $B \to (\rho,\omega)\gamma$ to $B \to K^*\gamma$ is given by

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

where the form factor ratio is $\zeta = 0.85 \pm 0.10$ and SU(3) breaking effect is $\Delta R = 0.1 \pm 0.1$. Using this, we have obtained the upper limit $|V_{td}/V_{ts}| < 0.21$ at 90%

confidence level.

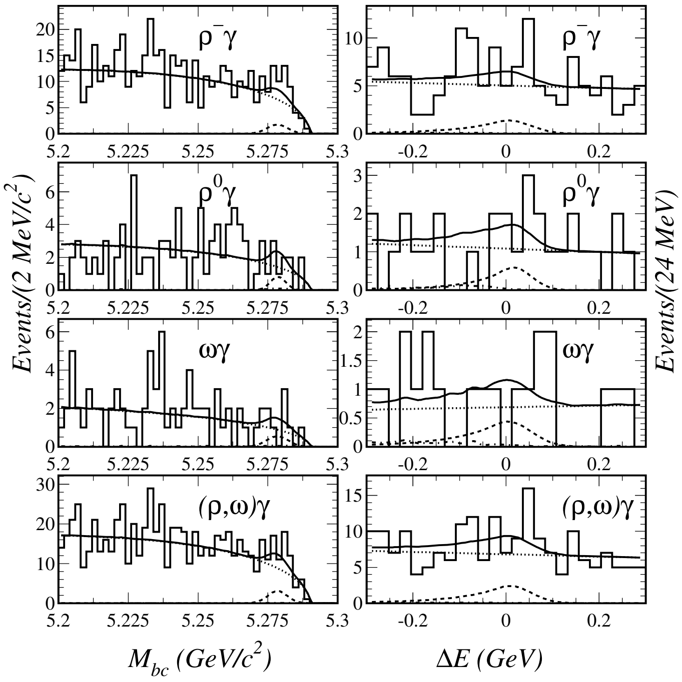

Fig. 1. *Projections of simultaneous fit results to $M_{\rm bc}$ (in the region -0.1 GeV $< \Delta E <$ 0.08 GeV) and ΔE (in the region 5.273 GeV/c^2 $< M_{\rm bc} <$ 5.285 GeV/c^2) for the individual modes and the sum of them. Lines represent the total fit results (solid), signal (dashed), continuum (dotted), and B decay background (dot-dashed) components.*

4. Summary

We find no clear evidence of exclusive $b \to d\gamma$ decays with a data sample of $253\,\mathrm{fb}^{-1}$. The upper limit we obtain is already within the range of SM predictions [1,2] and can be used to constrain $|V_{td}|$.

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