MEASUREMENT OF $B \to X_s\gamma$ AT BELLE

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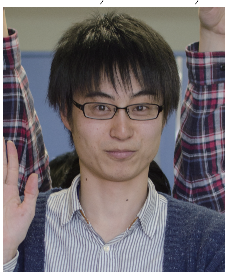


We use 772×10^6 $B\overline{B}$ meson pairs collected at the $\Upsilon(4S)$ resonance with the Belle detector to measure the branching fraction for $B \to X_s\gamma$ with a sum-of-exclusives approach. The inclusive branching fraction in M_{X_s} <2.8 GeV/c^2 is measured to be $\mathcal{B}(B \to X_s\gamma) = (3.51 \pm 0.17 \pm 0.33) \times 10^{-4}$, where the first uncertainty is statistical and the second is systematic.

1 Introduction

The $b \to s\gamma$ process, which is a flavor changing neutral current, is forbidden at tree level in the Standard model (SM) and proceeds at low rate through radiative loop diagrams. Since the loop diagram is dominant, effects of new particles within the loop predicted by many new physics models (NP) can be investigated by precision measurement. The inclusive branching fraction is sensitive to NP as it is theoretically well described in the SM. The SM calculation for the branching fraction has been performed at next-to-next leading order in the perturbative expansion term and the result is $\mathcal{B}(B \to X_s\gamma) = (3.15 \pm 0.23) \times 10^{-4}$ for a photon energy above 1.6 GeV in the B meson rest frame[1,2,3], where X_s means all the hadron combinations that carry a strange quantum number of s quark. We measure the branching fraction experimentally with higher minimum photon energy due to high background at lower energies. The measured branching fraction is extrapolated to a photon energy threshold of 1.6 GeV to compare with the theoretical result. The current measured world average is $\mathcal{B}(B \to X_s\gamma) = (3.55 \pm 0.24 \pm 0.09) \times 10^{-4}$ [4], where the first uncertainty is combined statistic and experimental systematic uncertainties and the final is the systematic due to the photon energy shape function, and is consistent with the SM prediction within the uncertainty.

We report a measurement of the branching fraction of $B \to X_s\gamma$ with a 711 fb^{-1} data set collected at the $\Upsilon(4S)$ resonance containing $772\times10^6 B\overline{B}$ meson pairs recorded by the Belle detector[5] at the KEKB asymmetric-energy e^+e^- collider[6]. Our measurement uses a 'sum-of-exclusives' approach which is to measure as many exclusive final states of the s quark hadronic system, X_s, as possible and then calculate their sum. Exclusive branching fractions measured to date do not saturate the inclusive process, but we can still infer the total branching fraction by estimating the fraction of unmeasured modes using simulated fragmentation processes. In this article, we present a measurement that is an update to a former Belle analysis[7] on only 5.8 fb^{-1} by an improved analysis procedure.

2 Simulation Sample

We use Monte Carlo (MC) simulations to model signal and background events and to optimize the selection prior to opening the signal region in the data.

We generate two types of signal MC samples, according to the X_s mass region: one sample in the $K^*(892)$ region(M_{X_s}<1.15 GeV/c^2) where the $b \to s\gamma$ transition proceeds through $B \to K^*\gamma$, and the other in the inclusive X_s region(M_{X_s}>1.15 GeV/c^2). In the inclusive signal MC, various resonances and final states exist. The photon energy spectrum is produced following a Kagan-Neubert model [8] in the inclusive signal MC. The nominal values of parameters in this model are set with a best fit to the Belle inclusive photon energy spectrum [9].In the inclusive X_s mass region, the light quark pair is generated and final state hadrons are produced in Pythia[10]. The signal reconstruction efficiency depends on the particle content in the final state, and the difference on the fragmentation model between the MC and data induces a systematic uncertainty. Thus, it is important to understand the fragmentation model.

In the background study, we use $e^+e^- \to q\overline{q}(q = u, d, s, c)$ and $B\overline{B}$ MC samples. In the $B\overline{B}$ background samples, $e^+e^- \to \Upsilon(4S) \to B\overline{B}$ events are generated.

3 B Meson Reconstruction and Background Suppression

We reconstruct the B meson from a high energy photon and 38 X_s final states, which consist of one or three kaons with at most one K_s^0, at most one η, and at most four π with at most two π^0's. The 38 measured final states cover 56% of the total X_s rate, according to the MC simulation. Assuming the isospin symmetry between K_L and K_s, the fraction is 69%. The B meson candidate is selected by two kinematic variables defined in the $\Upsilon(4S)$ rest frame, the beam energy constrained mass, $M_{bc} = \sqrt{E^{*2}_{beam} - |\overrightarrow{p^*_B}|^2}$, and the energy difference, $\Delta E = E^*_B - E^*_{beam}$, where E^*_{beam} is beam energy and $(E^*_B, \overrightarrow{p^*_B})$ is the reconstructed four-momentum of the B candidate. We require M_{bc} >5.24 GeV/c^2 and -0.15< ΔE <0.08 GeV.

A large background still remains after the signal reconstruction. There are three dominant types of background. The first is events with D meson decay, especially $B \to D^{(*)}\rho^+$, which makes a peak in the signal region of M_{bc}. For suppression of such background, a D meson candidate is reconstructed as a combination of particles used in the X_s reconstruction. The candidate whose D mass is the closest to the nominal D mass in an event is rejected in M_{X_s} >2.0 GeV/c^2(D veto). The second is $q\overline{q}$ events, which is largest source of background. To mitigate this background we apply an selection criterion based event shape. In $B\overline{B}$ events B meson products are distributed isotropically, in contrast, for $q\overline{q}$ events, the quarks yield a back-to-back fragmentation into two jets of light hadrons. For an effective background suppression, we perform a multivate analysis with the neural network[12]. We attain a neural network classifier between -1 and +1 and can get a good separation of the signal from the $q\overline{q}$ background. As a result, 52% signal is kept, on the other hand, the $q\overline{q}$ background reduces to 2% in the MC. The last major type of background is 'cross-feed' background defined as signal events in which B meson candidates are incorrectly reconstructed. On average, there are approximately 2 B meson candidates in a given event since 38 final states are reconstructed at the same time. For suppression of such background, a candidate with the largest neural network output for the $q\overline{q}$ background suppression in an event is selected(Best Candidate Selection, BCS), and the efficiency evaluated by the MC is 85 %.

4 Systematic Uncertainties

The systematic uncertainties are reported in Table 1. The uncertainty on the total amount of B mesons collected by the Belle is 1.4%. The data-MC ratio on the detector response associated with photon detection, tracking of charged particles, K_s^0, π^0 and η reconstruction, and $K^\pm/\pi^\pm$ identification is 0.94±0.03. The efficiency is corrected by this value and the error is taken as the systematic uncertainty. The background rejection uncertainty from D veto, $q\overline{q}$ background suppression and BCS is evaluated by the control modes in data. To evaluate the uncertainty on the M_{bc} PDF we use a variation in the signal yield when changing the parameter values in the PDF. The largest uncertainty comes from the fragmentation model. The uncertainty on the fragmentation model is taken from the change in the reconstruction efficiency when modifying the model by the uncertainty of the model in data. The fraction of missing final states that are not included in our reconstructed modes has an effect on the reconstruction efficiency. The uncertainty on the fraction of the 38 measured final states is evaluated by changing the fragmentation model in the MC by parameters in Pythia within parameter region which is consistent with the model of the data within the errors.

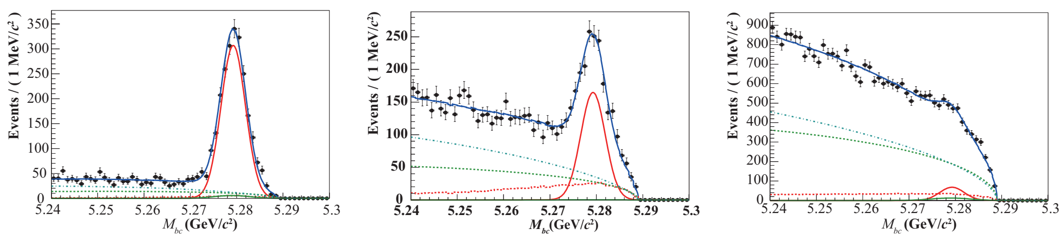
Table 1: Systematic uncertainties(%)

Source	Uncertainty(%)
Number of B meson	1.4
Detector Response	3.0
Background Rejection	3.4
M_{bc} PDF	5.1
Fragmentation Model	6.7
Missing Mode	1.6

5 Branching Fractions

The signal yields are obtained in 100 MeV/c^2 width bins in the low mass region, 0.6< M_{X_s} <2.2 GeV/c^2, and 200 MeV/c^2 width in the high mass region, 2.2< M_{X_s} <2.8 GeV/c^2, to obtain an exact branching fraction by a method independent from the X_s mass shape to minimize model dependence.

Figure 1 shows the M_{bc} distribution fits in each M_{X_s} bin. The differential branching fractions



(a) 0.8< M_{X_s} <0.9 GeV (b) 1.4< M_{X_s} <1.5 GeV (c) 2.2< M_{X_s} <2.4 GeV

Figure 1 – M_{bc} fits in M_{X_s} bins.The signal(red solid line), the cross-feed(red dashed line), the peaking background(green solid line), non-peaking component from $B\overline{B}$ decay(dashed green line) and $q\overline{q}$ background(cyan line) are shown.

on M_{X_s} are in Fig. 2.

We also report the total inclusive branching fraction in M_{X_s} <2.8 GeV/c^2,

$$\mathcal{B}(B \to X_s\gamma) = (3.51 \pm 0.17 \pm 0.33) \times 10^{-4}, \quad (1)$$

where the first uncertainty is statistical and the second is systematic. The statistical uncertainty is based on the sum in quadrature of them on each of the X_s mass bin yields. We compare the

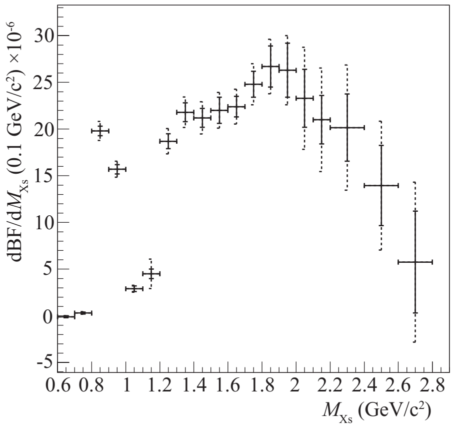


Figure 2 – Differential branching fraction. The first solid error is the statistical one and the second dashed error is a quadratic sum of the statistical and systematic errors.

branching fraction with a minimum photon energy of 1.6 GeV with the SM prediction and this result is extrapolated to $E_\gamma > 1.6$ GeV by the method in Ref. [14],

$$\mathcal{B}(B \to X_s\gamma) = (3.74 \pm 0.18 \pm 0.35) \times 10^{-4}. \tag{2}$$

This result is consistent with the SM prediction within 1.3σ.

6 Conclusion

We measure the branching fraction of $B \to X_s\gamma$ by the sum-of-exclusives approach using the entire data in the Belle. The measured branching fraction with M_{X_s} <2.8 GeV/c^2 is

$$\mathcal{B}(B \to X_s\gamma) = (3.51 \pm 0.17 \pm 0.33) \times 10^{-4}, \tag{3}$$

where the first uncertainty is statistical and the second is systematic. This result is the best precision in the sum-of-exclusive approach.

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