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# World Average Branching Fraction for $B \to X_s\gamma$

The decay $b \to s\gamma$ proceeds through a process of flavor changing neutral current. Since the charged Higgs or SUSY particles may contribute in the penguin loop, the branching fraction is sensitive to physics beyond the Standard Model. Experimentally, the branching fraction is measured using either a semi-inclusive or an inclusive approach. A minimum photon energy requirement is applied in the analysis and the branching fraction is corrected based on the theoretical model for the photon energy spectrum (shape function). Where there are multiple experimental results from an experiment, we use only the ones that are independent for BABAR and Belle to avoid dealing with correlated errors. Furthermore, the model uncertainties from the shape function should be highly correlated but no proper action was made in our older averages. To perform the average with better precision and good accuracy, it is important to use as many experimental results as possible and to handle the shape function issue in a proper way. In this note, we report the updated average of $b \to s\gamma$ branching fraction by implementing a common shape function.

Several shape function schemes are commonly used. Usually one is chosen to obtain the extrapolation factor, defined as the ratio of the $b \to s\gamma$ branching fractions with minimum photon energies above and at 1.6 GeV, and the difference between various schemes are treated as the model uncertainty. O. Buchmüller and H. Flächer have calculated the extrapolation factors [1]. Table 1 lists the extrapolation factors with various photon energy cuts for three different schemes and the average. The appropriate approach to average the experimental results is to first convert them according to the average extrapolation factors and then perform the average, assuming that the errors of the extrapolation factors are 100% correlated.

Table 1: Extrapolation factor in various scheme with various minimum photon energy requirement (in GeV).

| Scheme | $E_\gamma < 1.7$ | $E_\gamma < 1.8$ | $E_\gamma < 1.9$ | $E_\gamma < 2.0$ | $E_\gamma < 2.242$ |
|---|---|---|---|---|---|
| Kinetic | $0.986 \pm 0.001$ | $0.968 \pm 0.002$ | $0.939 \pm 0.005$ | $0.903 \pm 0.009$ | $0.656 \pm 0.031$ |
| Neubert SF | $0.982 \pm 0.002$ | $0.962 \pm 0.004$ | $0.930 \pm 0.008$ | $0.888 \pm 0.014$ | $0.665 \pm 0.035$ |
| Kagan-Neubert | $0.988 \pm 0.002$ | $0.970 \pm 0.005$ | $0.940 \pm 0.009$ | $0.892 \pm 0.014$ | $0.643 \pm 0.033$ |
| Average | $0.985 \pm 0.004$ | $0.967 \pm 0.006$ | $0.936 \pm 0.010$ | $0.894 \pm 0.016$ | $0.655 \pm 0.037$ |

After surveying all available experimental results, the six shown in Table 2 are selected for the average. They have provided in their papers either the $b \to s\gamma$ branching fraction at a certain photon energy cut or the extrapolation factor used. Therefore we are able to convert them to the values at $E_{\rm min} = 1.6$ GeV using the information in Table 1. In the inclusive and full hadronic tag analysis, a possible $B \to X_d\gamma$ contamination has been considered according to the expectation $(4.2 \pm 0.3)\%$. Compared to the other systematic uncertainties, the error that arises from the $B \to X_d\gamma$ fraction is too small to be considered. We perform the average assuming that the systematic errors of the shape function and the $d\gamma$ fraction are correlated, and the other systematic errors and the statistical errors are Gaussian and uncorrelated. The obtained average is $\mathcal{B}(B \to X_s\gamma) = (343 \pm 21 \pm 7) \times 10^{-6}$ with a $\chi^2/DOF = 0.55/5$, where the errors are combined statistical and systematic, and systematic due to the shape function. The second error is estimated to be the difference of the average after simultaneously varying the central value of each experimental result by $\pm 1\sigma$. Although a small fraction of events was used in multiple analyses in the same experiment, we neglect their statistical correlations. Some other correlated systematic errors, such as photon detection and the background suppression, are not considered in our new average.

Table 2: Reported branching fraction, minimum photon energy, branching fraction at minimum photon energy and converted branching fraction $\mathcal{B}^{\rm cnv}$ for the decay $b \to s\gamma$. All the branching fractions are in units of $10^{-6}$. The errors are, in order, statistical, systematic and theoretical (if exists) for $\mathcal{B}$, and statistical, systematic and shape-function systematic for $\mathcal{B}^{\rm cnv}$. Theoretical errors in $\mathcal{B}(\mathcal{E}_\gamma > \mathcal{E}_{\rm min})$ are merged into the systematic error of $\mathcal{B}^{\rm cnv}$ during conversion. The CLEO measurement on the branching fraction at $E_{\rm min}$ includes $B \to X_d\gamma$ events. The correction of $B \to X_d\gamma$ fraction for inclusive and full reconstruction methods is applied when calculating $\mathcal{B}^{\rm cnv}$.

| Mode | $\mathcal{B}$ | $E_{\rm min}$ | $\mathcal{B}(E_\gamma > E_{\rm min})$ | $\mathcal{B}^{\rm cnv}(E_\gamma > 1.6)$ |
|---|---|---|---|---|
| CLEO Inc. [2] | $321 \pm 43 \pm 27^{+18}_{-10}$ | 2.0 | $306 \pm 41 \pm 26$ | $328 \pm 44 \pm 28 \pm 6$ |
| Belle Semi.[3] | $336 \pm 53 \pm 42^{+50}_{-54}$ | 2.24 | – | $369 \pm 58 \pm 46 \pm 60$ |
| Belle Inc.[4] | – | 1.7 | $345 \pm 15 \pm 40$ | $350 \pm 15 \pm 41 \pm 1$ |
| *BABAR* Semi.[5] | – | 1.9 | $329 \pm 19 \pm 48$ | $352 \pm 20 \pm 51 \pm 4$ |
| *BABAR* Inc. [6] | – | 1.8 | $321 \pm 15 \pm 29 \pm 8$ | $332 \pm 16 \pm 30 \pm 9$ |
| *BABAR* Full [7] | $391 \pm 91 \pm 64$ | 1.9 | $366 \pm 85 \pm 60$ | $390 \pm 91 \pm 64 \pm 4$ |
| Average | | | | $343 \pm 21 \pm 7$ |

# References


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