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

The decay $B \to X_s\gamma$ 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). In this average of the $B \to X_s\gamma$ branching fraction, we still use the extrapolation factors [1] obtained by O. Buchmüller and H. Flächer and listed in Table 1. The extrapolation factors are defined as the ratios of the $B \to X_s\gamma$ branching fractions with minimum photon energies above and at 1.6 GeV. 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 ± 0.001	0.968 ± 0.002	0.939 ± 0.005	0.903 ± 0.009	0.656 ± 0.031
Neubert SF	0.982 ± 0.002	0.962 ± 0.004	0.930 ± 0.008	0.888 ± 0.014	0.665 ± 0.035
Kagan-Neubert	0.988 ± 0.002	0.970 ± 0.005	0.940 ± 0.009	0.892 ± 0.014	0.643 ± 0.033
Average	0.985 ± 0.004	0.967 ± 0.006	0.936 ± 0.010	0.894 ± 0.016	0.655 ± 0.037

After releasing our average in 2006 [2], two more measurements on the $B \to X_s\gamma$ branching fraction were available: the *BABAR* result [3] using full hadronic tags and the Belle inclusive result [4] with a factor of five more data than the previous measurement. The former used a data sample orthogonal to the lepton tag sample for the early inclusive measurement. Therefore, the new *BABAR* result is included in the average while the Belle measurement supersedes their previous one. In the Belle new measurement, the $B \to X_s\gamma$ branching fraction was obtained with various minimum photon energy requirement, 1.7 to 2.1 GeV. The study shows that there are clearly signal events with photon energy between 1.7 and 1.8 GeV. Although lowering E_γ to 1.7 GeV causes larger systematic error from the background, it will encourage a deeper understanding of the theory uncertainties, especially on those related to the extrapolation. Therefore, we choose the Belle measurement with the minimum photon energy at 1.7 GeV to compute the average.

The six experimental measurements selected for the average are shown in Table 2. They have provided in their papers either the $B \to X_s\gamma$ 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. The errors are, in order, statistical, systematic and shape-function systematic, except for the *BABAR* inclusive where there is a second systematic error (third quoted error) due to theoretical uncertainties. Moreover, in the four inclusive analyses a possible $B \to X_d\gamma$ contamination has been considered according to the expectation of $(4.0 \pm 0.4)\%$. The central value is the same as used in our 2006 average but the uncertainty shrinks by a factor of four, due to better understanding of $|V_{td}/V_{ts}|$ from the B_s-$\overline{B}_s$ mixing and $B \to \rho/\omega\ \gamma$ measurements. 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 are correlated, and the other systematic errors and the statistical errors are Gaussian and uncorrelated. The obtained average is $\mathcal{B}(B \to X_s\gamma) = (352 \pm 23 \pm 9) \times 10^{-6}$ with a χ^2/DOF= 1.00/5, 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 both the semi-inclusive and inclusive 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 for the decay $b \to s\gamma$. All the branching fractions are in units of 10^{-6}. See text for an explanation of the errors. The CLEO measurment on the branching fraction at E_{rmmin} includes $B \to X_d\gamma$ events. The last error of the Belle reported branching fraction in their inclusive analysis is the systematic uncertainty due to the boost of the γ energy from the center of mass frame to the B meson rest frame.

Mode	Reported $\mathcal{B}$	$E_{\rm min}$	$\mathcal{B}$ at $E_{\rm min}$	Modified $\mathcal{B}$ ($E_{\rm min} = 1.6$)
CLEO Inc. [5]	$321 \pm 43 \pm 27^{+18}_{-10}$	2.0	$306 \pm 41 \pm 26$	$329 \pm 44 \pm 28 \pm 6$
Belle Semi.[6]	$336 \pm 53 \pm 42^{+50}_{-54}$	2.24	–	$369 \pm 58 \pm 46^{+56}_{-60}$
BABAR Semi.[7]	$327 \pm 18^{+55+4}_{-40-9}$	1.9	$327 \pm 18^{+55+4}_{-40-9}$	$349 \pm 20^{+59+4}_{-46-3}$
BABAR Inc. [8]	–	1.9	$367 \pm 29 \pm 34 \pm 29$	$392 \pm 31 \pm 36 \pm 30 \pm 4$
BABAR Full [3]	$366 \pm 85 \pm 60$	1.9	$366 \pm 85 \pm 60$	$391 \pm 91 \pm 64 \pm 4$
Belle Inc.[4]	$332 \pm 16 \pm 37 \pm 1$	1.7	$332 \pm 16 \pm 37 \pm 1$	$337 \pm 16 \pm 38 \pm 1$

References

[1] O. Buchmüller and H. Flächer, Phys. Rev. D **73**, 073008 (2006).

[2] The Heavy Flavor Averaging Group, E. Baberio *et al.*, hep-ex/0603003.

[3] *BABAR* Collaboration (B. Aubert *et al.*), Phys. Rev. D **77**, 051103 (2008).

[4] Results presented by Antonio Limosani in Moriond EW 2008.

[5] CLEO Collaboration (S. Chen *et al.*), Phys. Rev. Lett. **87**, 251807 (2001).

[6] Belle Collaboration (K. Abe *et al.*), Phys. Lett. B **511**, 151 (2001).

[7] *BABAR* Collaboration (B. Aubert *et al.*), Phys. Rev. D **72**, 052004 (2005).

[8] *BABAR* Collaboration (B. Aubert *et al.*), Phys. Rev. Lett. **97**, 171803 (2006).