SIMBA

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The $B \to X_s \gamma$ decay rate plays an important role in finding indirect evidence for new physics in the flavor sector of the Standard Model. Its determination requires the precise knowledge of the parton distribution function for the quark inside the meson (called the shape function). We implement a model-independent framework for the shape function with reliable theoretical uncertainties based on an expansion in a suitable set of basis functions, cf. [1,2,3,4], and apply it to the measured $B \to X_s \gamma$ photon energy spectra of [5,6,7] to extract m_b^{1S} and $C_7^{\rm incl.}$.

The perturbative and non-perturbative contributions of the shape function can be separated using [1]

$$S(w,\mu) = \int \mathrm{d}k\, \widehat{C}_0(\omega - k, \mu)\, \widehat{F}(k)\,, \qquad (1)$$

Eq. (1) reproduces the correct renormalization group evolution of the shape function. The function $\widehat{F}(k)$ can be assumed to be positive for all values of the light-cone momentum k, and is by definition

$$\int \mathrm{d}k\, \widehat{F}(k) = 1\,, \qquad (2)$$

what allows an expansion of its square-root, i.e.

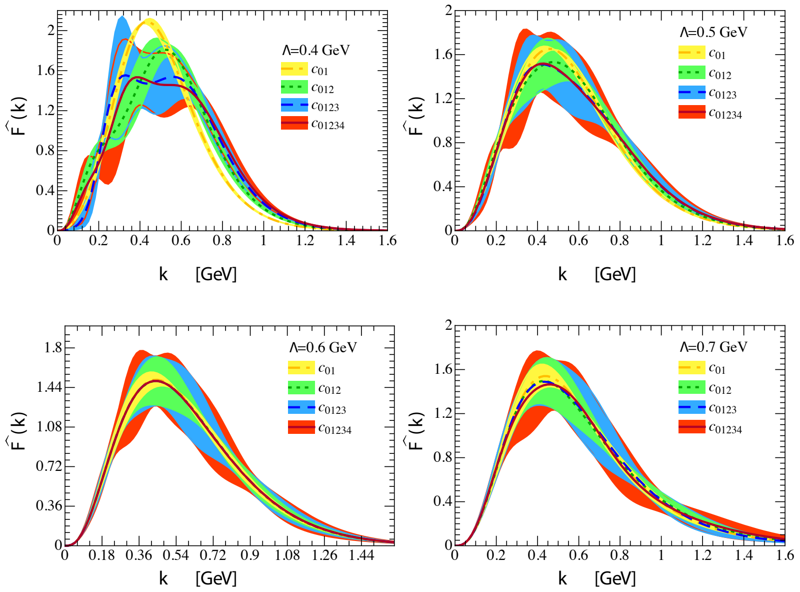
$$\widehat{F}(\lambda x) = \frac{1}{\lambda}\left[\sum_{n=0}^{\infty} c_n\, f_n(x)\right]^2 \qquad (3)$$

where $f_n(x)$ are a complete set of orthonormal functions defind on $[0,\infty)$. The non-perturbative contributions to the shape function are now encoded into the c_n coefficients and by combining Eqs. (2) and (3)

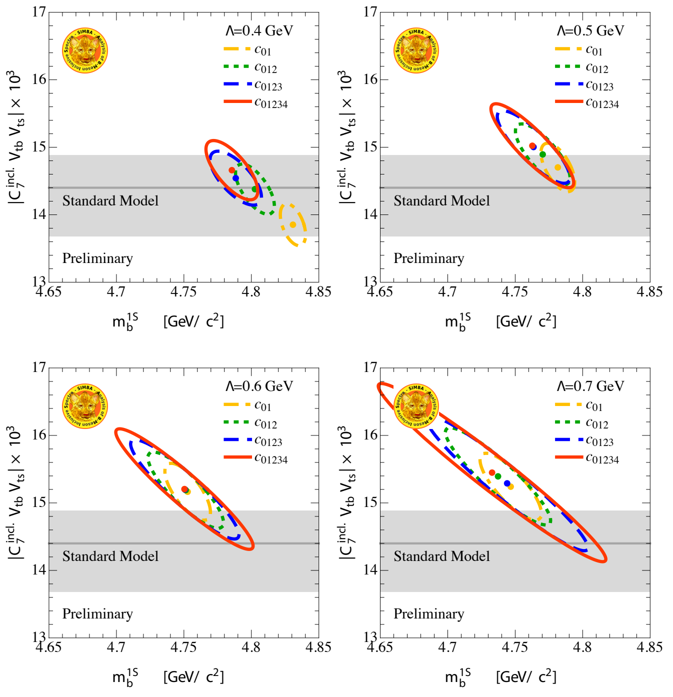
$$1 \;=\; \int \mathrm{d}k \widehat{F}(k) \;=\; \int \mathrm{d}x \left[\sum_{n=0}^{\infty} c_n\, f_n\right]^2 \;=\; \sum_{n=0}^{\infty} c_n^2\;. \qquad (4)$$

The c_n coefficients can be obtained by analyzing the $B \to X_s \gamma$ decay rate and the shape function, with absorbed $1/m_b$ corrections, can be determined:

$$\widehat{F}(k) \;\to\; \widehat{\mathcal{F}}(k) \;=\; \widehat{F}(k) + \frac{1}{m_b}\sum_{i=1}^{4} \widehat{F}_i(k)\;. \qquad (5)$$



The extracted non-perturbative function $\widehat{F}(k)$ for two to five coefficients and $\lambda = 0.4 - 0.7$ GeV are depicted, with the spectra of References [5,6,7] as input.



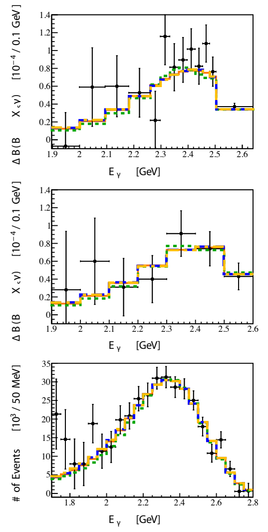
The effect of the convergence of the shape function on m_b^{1S} and $|C_7^{\rm incl.} V_{tb} V_{ts}|$ for different bases and with fits for with two (c_{01}), three (c_{012}), four (c_{0123}), and five (c_{01234}) coefficients. The ellipses denote the corresponding $\Delta\chi^2 = 1$ confidence regions as calculated by the experimental uncertainties.

In Ref. [2], the $B \to X_s \gamma$ decay rate is calculated using soft-collinear effective theory at NNLO/NNLL. It includes all singular contributions proportional to $C_7^{\rm incl.}$, and the dominant non-singular corrections. By fixing the Wilson coefficients of the non-singular contributions at their expected values from the Standard Model, a precision test for the Standard Model prediction of $C_7^{\rm incl.}$ can be implemented.

The master formula for the $B \to X_s \gamma$ decay rate is given as

$$\propto |C_7^{\rm incl.}|^2 \sum_{n,m=0}^{N} c_n\, c_m \left\{ \widehat{W}_{nm}^{77} + \sum_{i,j\neq 7} \frac{|\bar{C}_i\, \bar{C}_j^*|}{|C_7^{\rm incl.}|^2} \widehat{W}_{nm}^{ij} + \sum_{i \neq 7} \frac{2\Re\left(\bar{C}_i\, C_7^{\rm incl.}\right)}{|C_7^{\rm incl.}|^2} \widehat{W}_{nm}^{i7} \right\} \qquad (6)$$

The simultaneous fit for the shape function coefficients and the normalization (which is proportional to the absolute value of $C_7^{\rm incl.}$ squared), allows a model independent extraction of m_b^{1S} and the Wilson coefficient.



The analyzed $B \to X_s \gamma$ spectra from from References [5] (top), [6] (middle), and [7] (bottom) are shown. The fit results is for four coefficients, dotted green corresponds, solid orange, dashed blue, and dash-dotted yellow correspond to the basis expansion with $\lambda = 0.4 - 0.8\,$GeV. All fits have an acceptable $\chi^2/$n.d.f .

References:

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