SIMBA: Determining the shape function (and m_b and C_7) using $B \to X_s\gamma$

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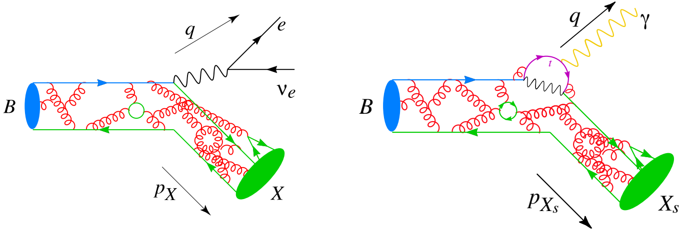
Inclusive B Meson Decays.

$B \to X_q \ell \nu$ $\qquad$ $B \to X_s \gamma$



Inclusive decay rate can be systematically calculated:

- Overall normalization proportional to
  - $|V_{qb}|^2$ for $B \to X_q \ell \nu$
  - $|V_{tb} V_{ts}^* C_7^{\mathrm{incl}}|^2$ for $B \to X_s \gamma$
    - C_7^{incl} sensitive to BSM physics in the loop
- Differential distributions sensitive to m_b and universal shape functions, describing the dynamics of b in B
  - One leading shape function and several subleading shape functions, current fits to $B \to X_s \gamma$ fit the particular combination occuring in $B \to X_s \gamma$

SIMBA.

Global fit

- Simultaneously determine from the data
  - Normalization (overall rates): $|V_{tb}V_{ts}^{*}C_{7}^{\text{incl}}|$, $|V_{ub}|$
  - Input parameters and their uncertainties: m_b, shape function(s)
- Combine different decay modes and measurements
  - Different $B \to X_s\gamma$ and $B \to X_u\ell\nu$ spectra (eventually $B \to X_s\ell^+\ell^-$)
  - Can also impose external constraints on m_b, μ_π^2 (λ_1)

⇒ Minimize uncertainties by making maximal use of all available information
  - "Best" (most sensitive) kinematic region chosen by the fit given experimental uncertainties

Two main theory requirements

1. Consistent theory description across phase space
2. Model-independent treatment of shape function

Basis Expansion for the Shape Function.

Expand $\widehat{F}(k)$ into suitable orthonormal basis

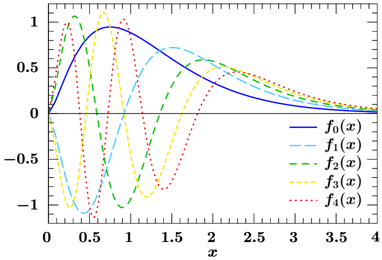
$$\widehat{F}(k) = \frac{1}{\lambda}\Big[\sum_{n=0}^{\infty} c_n f_n\Big(\frac{k}{\lambda}\Big)\Big]^2$$

$$\int \mathrm{d}k\, \widehat{F}(k) = \sum_{n=0}^{\infty} c_n^2 = 1$$

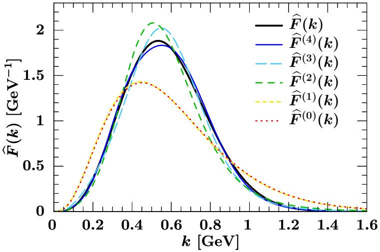
- Given a generating model function f_0, can construct an orthonormal basis from it
- Fit $\widehat{F}(k)$ by fitting basis coefficients c_n
  - Experimental uncertainties and correlations can be properly captured in covariance matrix of fitted coefficients c_n

⇒ Provides model-independent description with *data-driven* estimation of shape function uncertainties

Basis functions



Expansion of Gaussian $\widehat{F}(k)$



Choice of Basis and Truncation.

In practice, series must be truncated

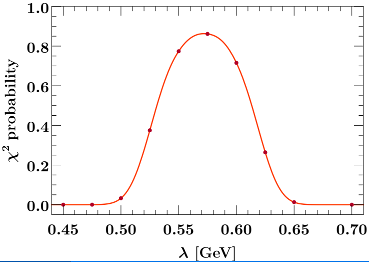
- Induces residual basis (model) dependence

How to determine where to truncate?

- Add coefficients as long as they yield statistically significant fit improvement
- Add one more coefficient to account for truncation error

$\Rightarrow$ Precision of available data determines how many coefficients can be fitted

“Prefit” with only c_0



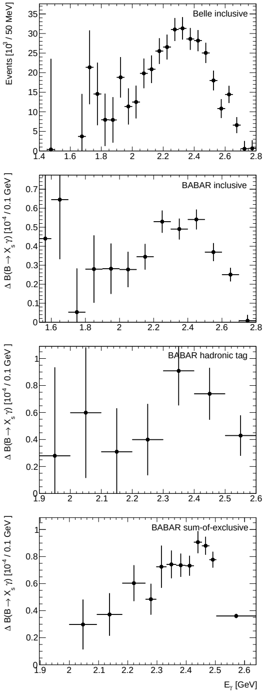
We want a quickly converging basis

- Do not waste limited statistical power on “fixing up” poor basis
- Use a generating model function which by itself already provides a good fit to the data

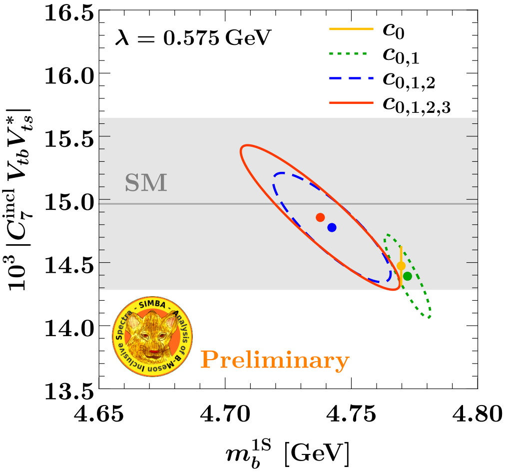
Global Fit to $B \to X_s\gamma$

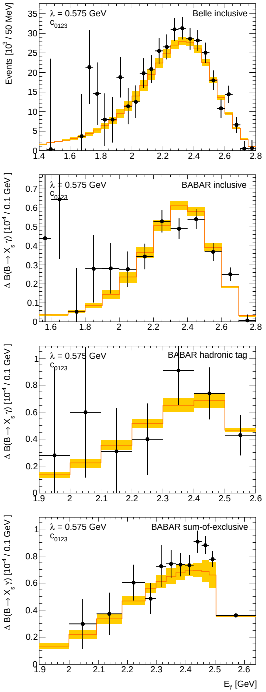
Experimental Inputs

- Belle inclusive [arXiv:0907.1384]
  - Measured in $\Upsilon(4S)$ rest frame
  - Include data for $E_\gamma \geq 1.7\,\mathrm{GeV}$
- *BaBar* inclusive [arXiv:1207.5772]
  - Measured in $\Upsilon(4S)$ rest frame
  - Include data for $E_\gamma \geq 1.8\,\mathrm{GeV}$
- *BaBar* hadronic tag [arXiv:0711.4889]
  - Measured in B rest frame
- *BaBar* sum-over-exclusive modes [arXiv:1207.2520]
  - Measured in B rest frame
  - Sum highest bins containing K^* resonance



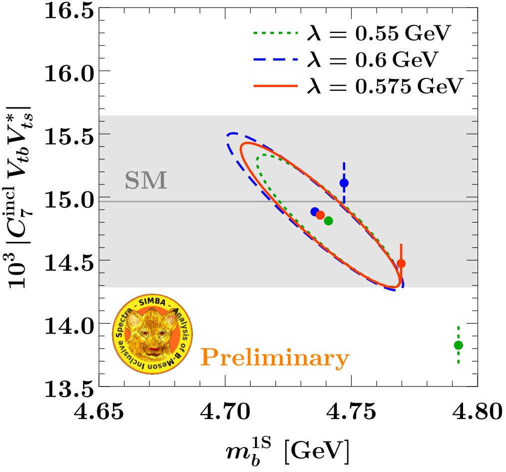
Results.

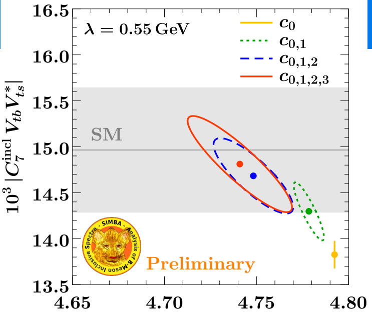


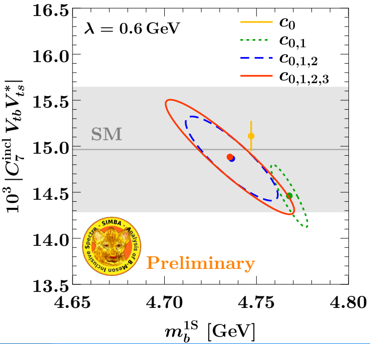


- No perturbative uncertainties included yet
  - Going to be similar in size to fit uncertainties

Basis Independence.







- Different basis expansions converge to the same result

Summary and Outlook.

- Fit to Belle and BABAR $B \to X_s\gamma$ spectra almost complete
  - Fixing parametric inputs and evaluating theory uncertainties
    - Expecting theory uncertainties to be of comparable size to experimental uncertainties
- Main results C_7^{incl}, m_b, ..., and the shape function
  - More robust theory uncertainties compared to previous approaches (model independent within uncertainties)
  - Shape function and m_b important inputs for determination of $|V_{ub}|$
    - Future plan: combined fit to $B \to X_s\gamma$ and $B \to X_u\ell\nu$
    - Requires developments on the theory side $\to$ see Bahman's talk