SIMBA: Theoretical Basics

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The SIMBA collaboration
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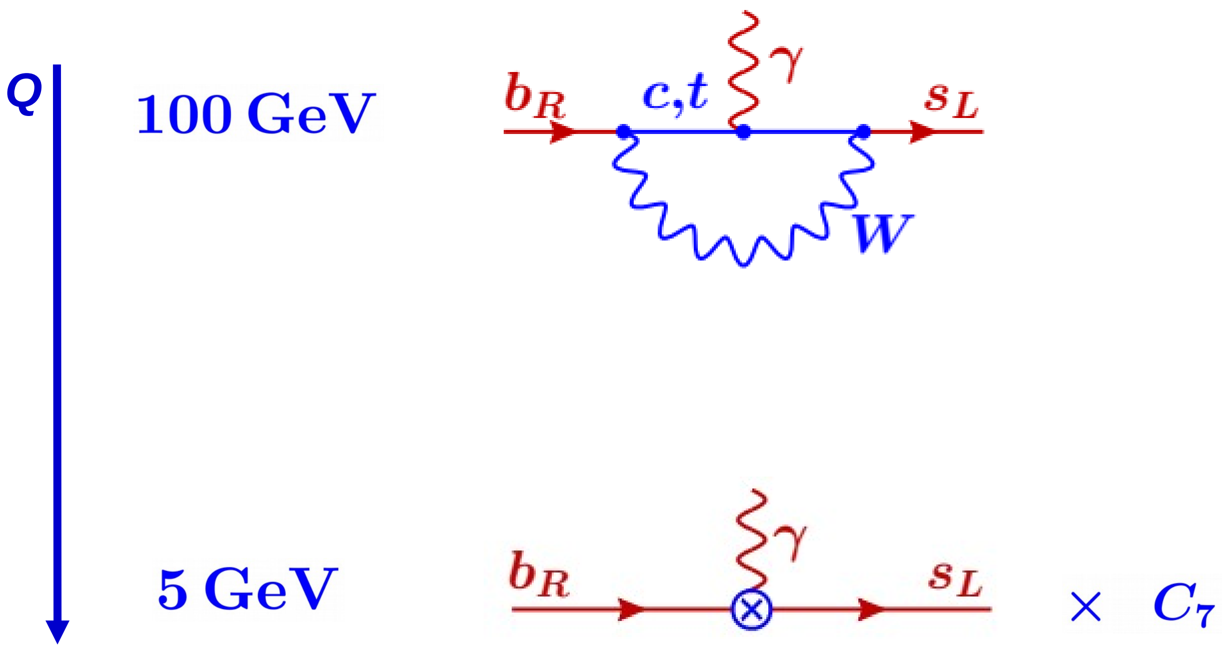
SIMBA collaboration meeting, Nov 12th 2019, Hamburg, Germany

Theory overview

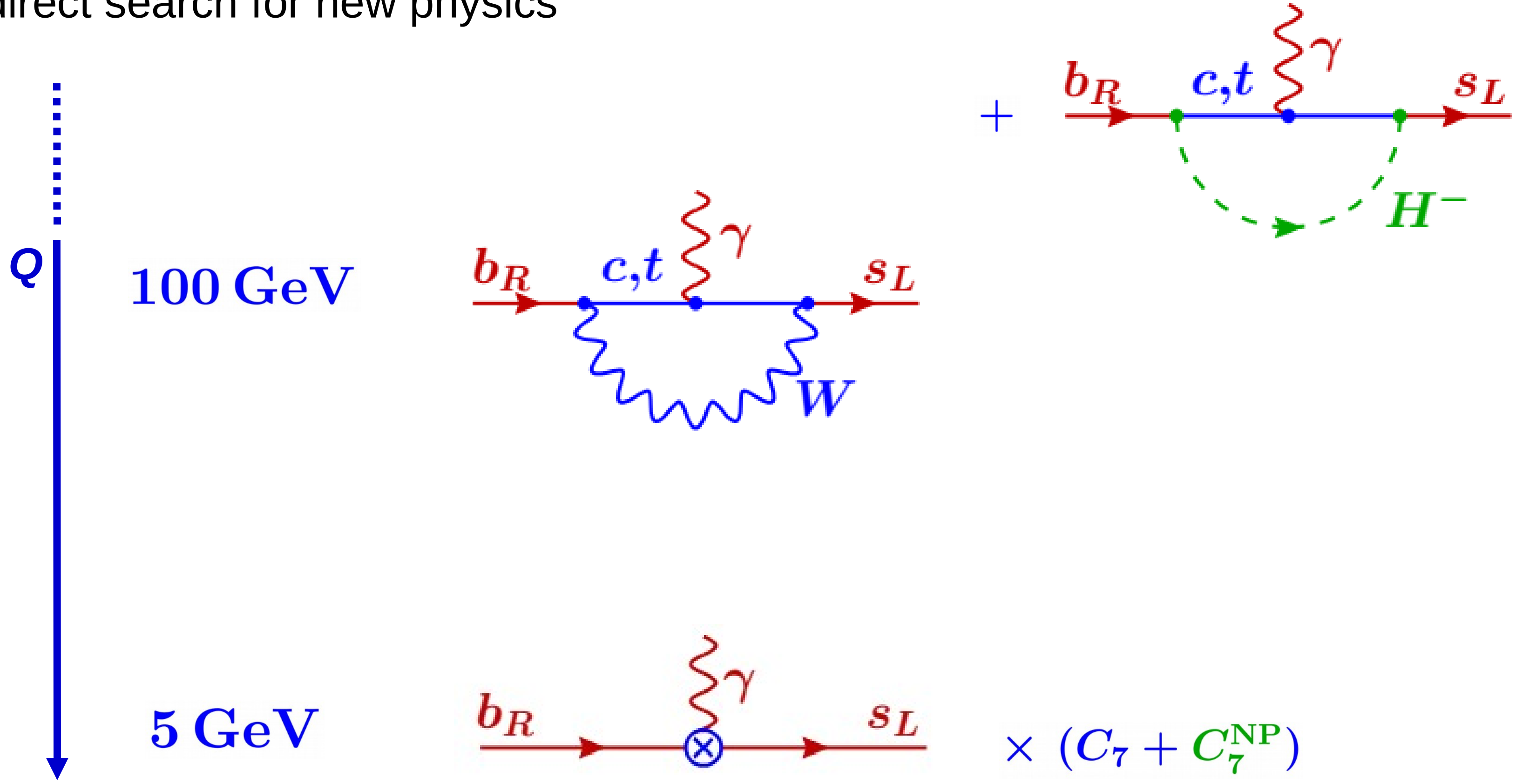
$B \to X_s \gamma$

Effective weak interaction at low energies



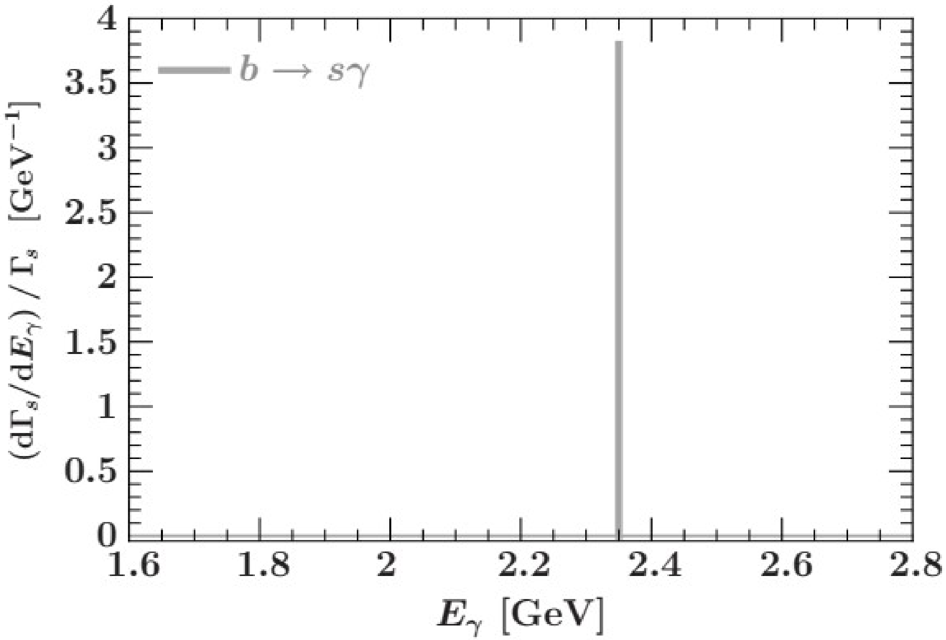
$B \to X_s \gamma$

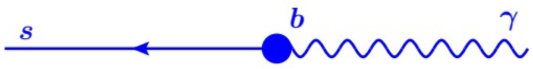
Indirect search for new physics



- Precise measurement of $b \to s\gamma$ rate at low scale gives access to possible new physics contributions at high energies

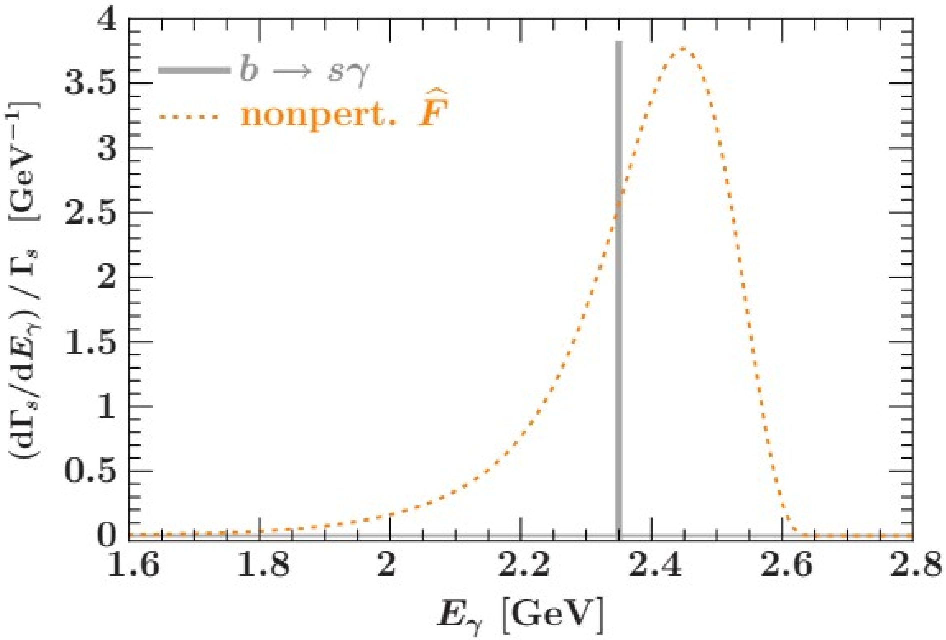
$B \to X_s \gamma$

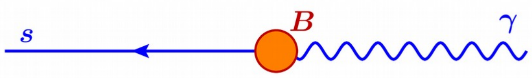




- $b \to s\gamma$ transition rate: $\mathrm{d}\Gamma/\mathrm{d}E_\gamma = |C_7|^2\,\delta(E_\gamma - m_b/2)$

$B \to X_s \gamma$





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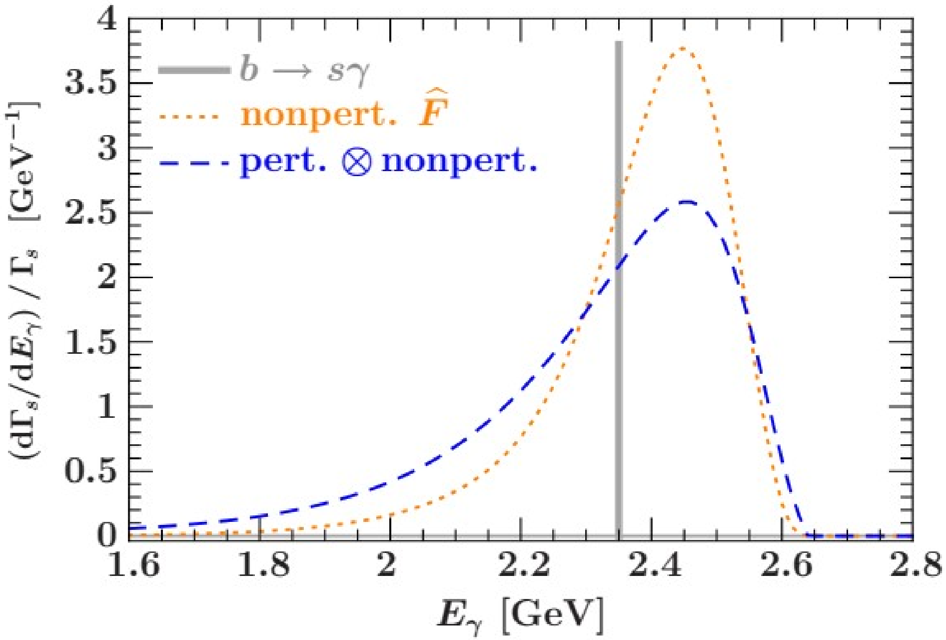

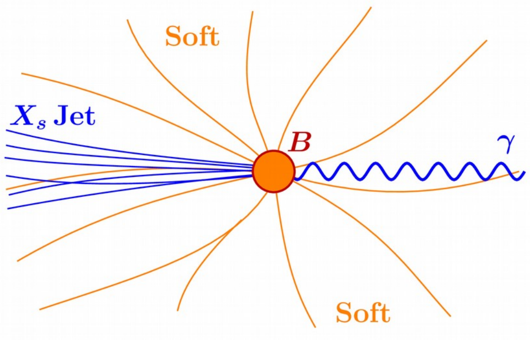

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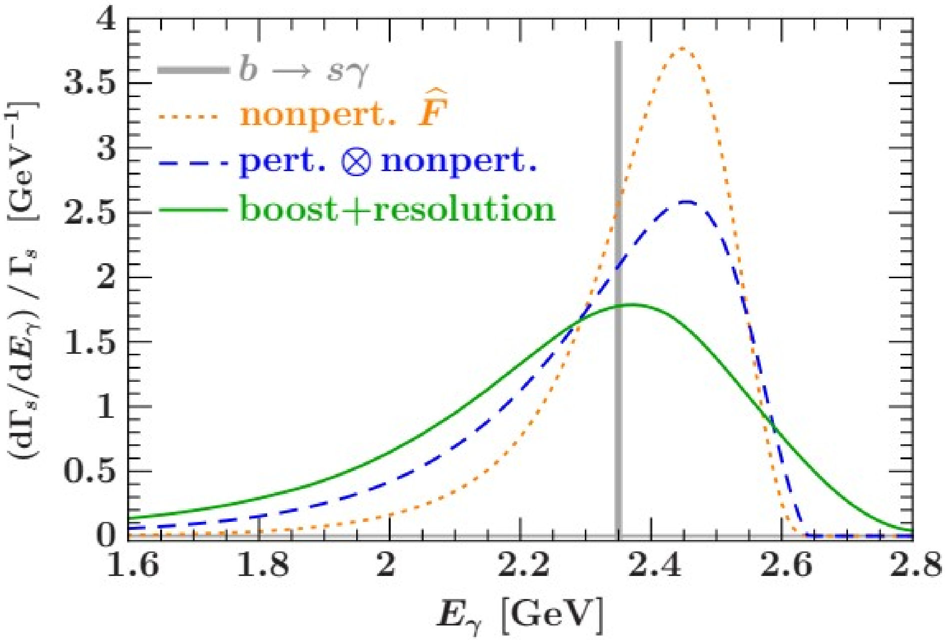

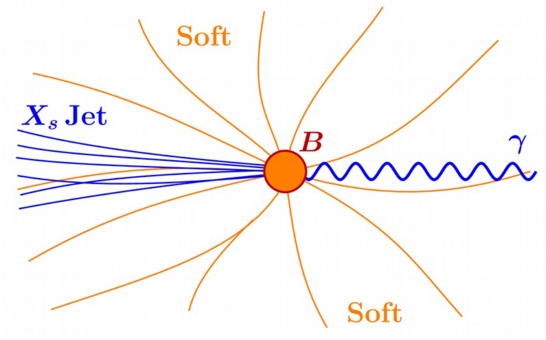

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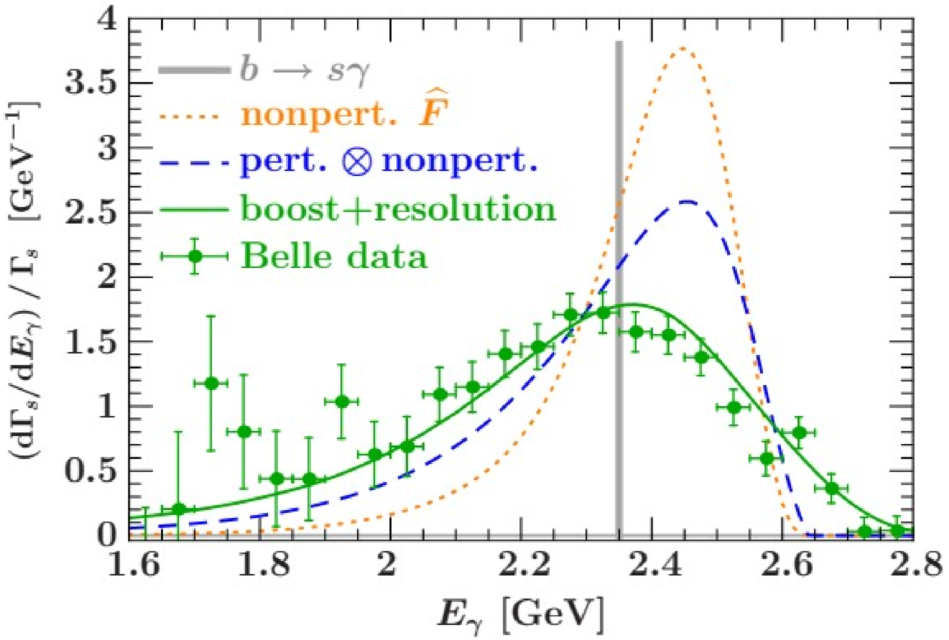

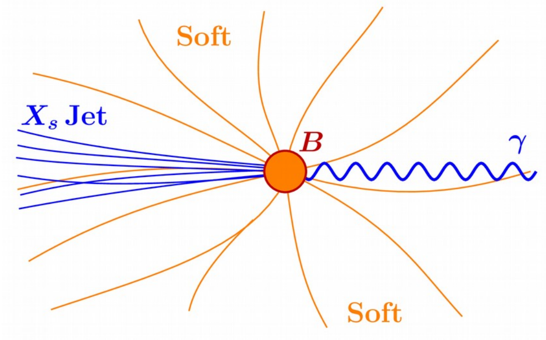

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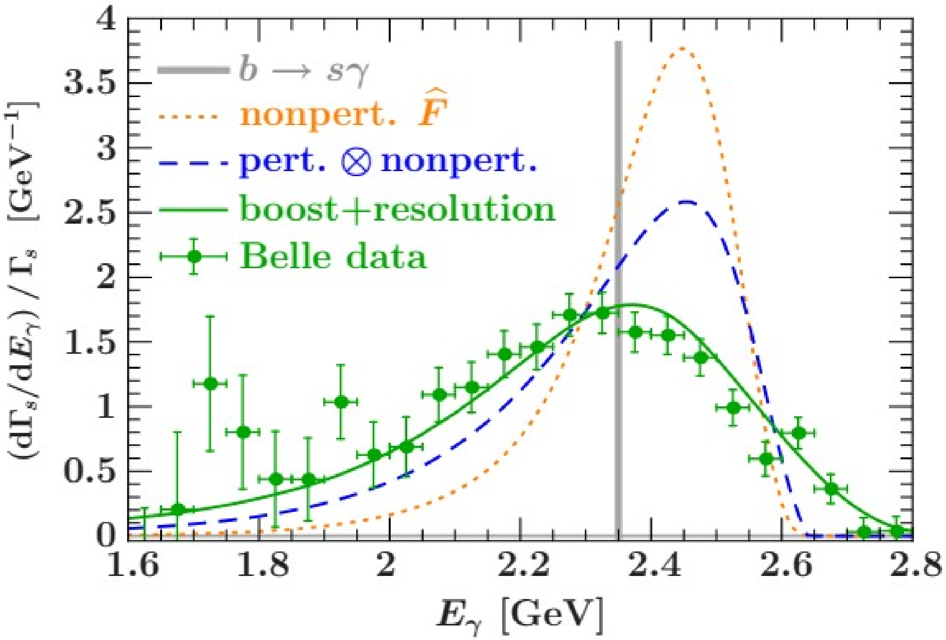

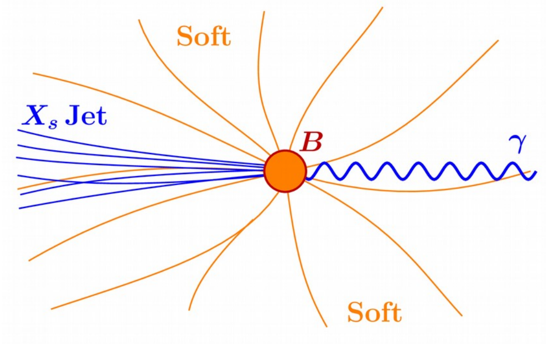

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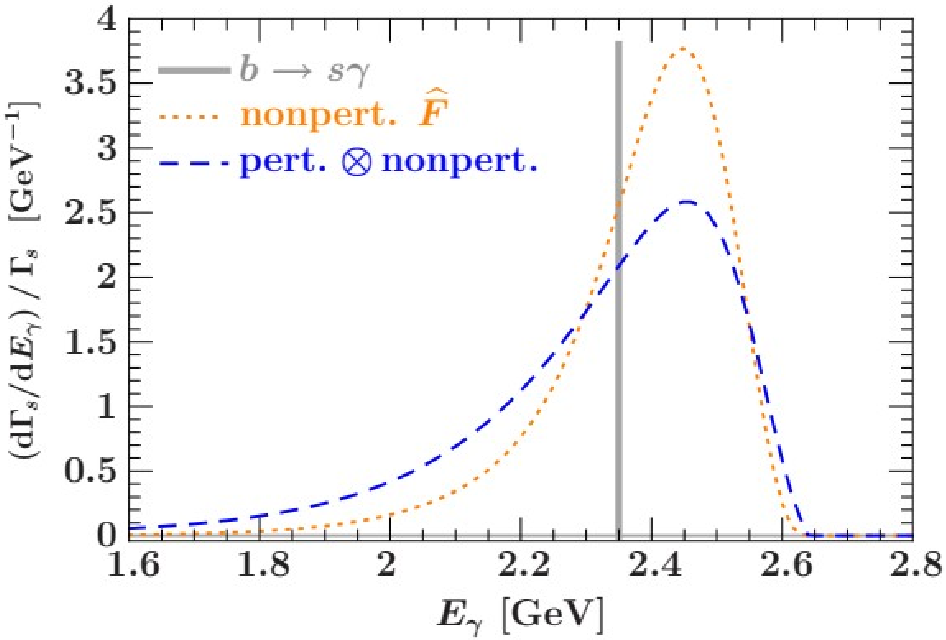
Ready for global fit to inclusive $B \to X_s\gamma$ measurements

current status
Kerstin's talk

What to do next?

Theory Uncertainty



$B \to X_s \gamma$

pert. $(\mu_H, \mu_J, \mu_S) \otimes$ nonpert.

Residual scale dependencies are used to assign a perturbative uncertainty

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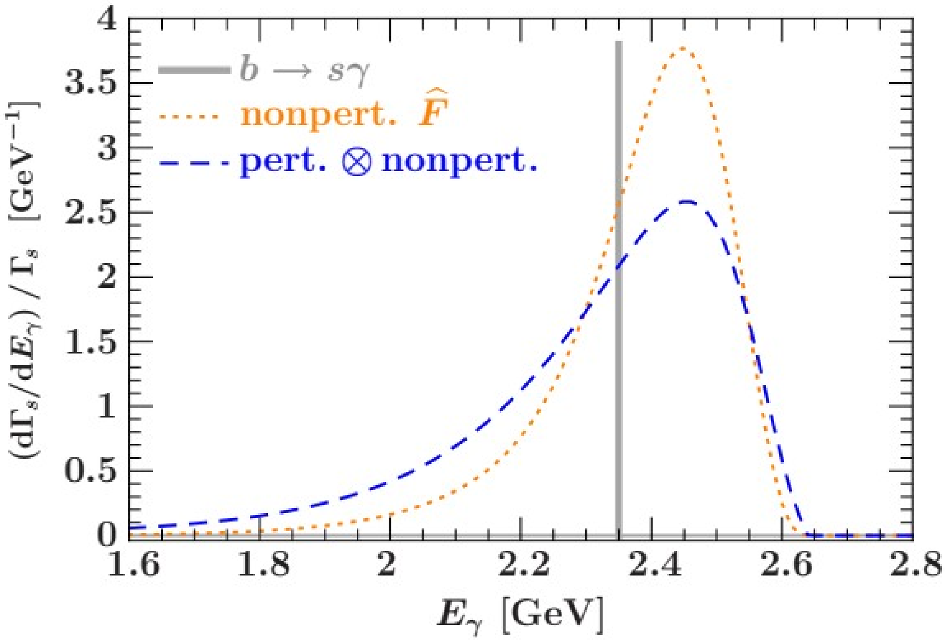

$B \to X_s\,\gamma$

pert. $(\mu_H, \mu_J, \mu_S) \otimes$ nonpert.

Residual scale dependencies are used to assign a perturbative uncertainty

- ✘ **Scales are not physical parameters** with an uncertainty that can be propagated, they simply specify a particular perturbative scheme

- ✘ **Scale** variation **does not provide** any insight into the **correlation** in the spectrum!

Theory Uncertainty

$B \to X_s \gamma$

Unknown corrections at higher orders are the actual sources of perturbative theory uncertainty

$$c_0 + \alpha_s(\mu)\left[c_1 + \alpha_s(\mu)\, c_2\right] + \mathcal{O}(\alpha_s^3)$$

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Frank Tackmann [2019]

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➢ **Task:** Implement the full next order in terms of unknown parameters

(work in progress) BD, Ivan Novikov

$B \to X_u \ell \bar{\nu}$

- Similar theoretical framework for $B \to X_u \ell \bar{\nu}$
  - $B \to X_u \ell \bar{\nu}$ is a 3-body problem → extended phase space
  - Sub-leading corrections (and shape functions) play crucial role

$B \to X_s \gamma$: absorb all the sub-leading shape functions into the leading shape function

$$\widehat{\mathcal{F}}_s(k) = \widehat{F}(k) + \frac{1}{m_b}\left[\widehat{F}_1(k) + \widehat{F}_2(k) - \widehat{F}_3(k) + \widehat{F}_4(k)\right]$$

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✓ The aim:

- Global $B \to X_u \ell \bar{\nu} + B \to X_s \gamma$ fit using also Belle II measurements
- Simultaneously determine $|V_{tb}V_{ts}^* C_7^{\mathrm{incl}}|$, $|V_{ub}|$, m_b

Summary and Outlook

- EFT for weak interactions at low energies (e.g. inclusive B meson decay rates)
- Global fit to inclusive $B \to X_s \gamma$ measurements [current status]
- Theoretical developments [work in progress]
  - Better control on theoretical uncertainties with nuisance parameters
  - Provide a more efficient implementation for theory (C++ program)
  - Fine-tune the theoretical framework for $B \to X_u \ell \bar{\nu}$
  - Global $B \to X_s \gamma$ + $B \to X_u \ell \bar{\nu}$ fit using also Belle II measurements

Thank you for your attention!