

Radiative leptonic decay of B -meson with subleading power corrections

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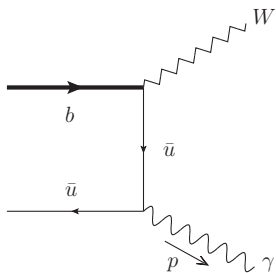
- ▶ Motivation
- ▶ $B \rightarrow \gamma l \nu$ with subleading power corrections
- ▶ Numerical result
- ▶ Summary

Motivation

Extract λ_B :
$$\frac{1}{\lambda_B(\mu)} = \int_0^\infty \frac{d\omega}{\omega} \phi_B^+(\omega, \mu)$$

- ▶ **New physics:** $|V_{ub}|$, $|V_{cb}|$, $R_{K^{(*)}}$, $R_{D^{(*)}}$, rare B decay (FCNC)
- ▶ $B \rightarrow \gamma l \nu$ clean, BELLE II
- ▶ **Subleading power** corrections to $B \rightarrow \gamma l \nu$

Kinematics



In the B -meson rest frame
 p , q and $m_{B\nu}$: photon, lepton-pair
and B -meson momenta

$$q^2 = (m_{B\nu} - p)^2 = m_B^2 + p^2 - 2m_B E_\gamma$$

$$E_\gamma = \frac{m_B^2 - q^2}{2m_B}, \quad \text{large}$$

$$\frac{d\Gamma}{dE_\gamma} = \frac{\alpha_{\text{em}} G_F^2 |V_{ub}|^2}{6\pi^2} m_B E_\gamma^3 \left(1 - \frac{2E_\gamma}{m_B}\right) \left(|F_V|^2 + \left|F_A + \frac{e_l f_B}{E_\gamma}\right|^2 \right)$$

$$\propto \lambda_B^{-2} \quad \text{at leading power in } \frac{\Lambda_{\text{QCD}}}{m_b}$$

SCET result

For energetic photon

M. Beneke and J. Rohrwild 2011

$$F_{V/A}(E_\gamma) = \frac{e_u f_B m_B}{2E_\gamma \lambda_B(\mu)} R(E_\gamma, \mu) + \xi(E_\gamma) \pm \Delta\xi(E_\gamma)$$

$\xi(E_\gamma)$ and $\Delta\xi(E_\gamma)$ terms: power corrections

$$\xi(E_\gamma) = c \frac{f_B}{2E_\gamma}, \quad c \sim [-1, 1]$$

$$\Delta\xi(E_\gamma) = \frac{e_b m_B f_B}{2E_\gamma m_b} + \frac{e_u m_B f_B}{(2E_\gamma)^2}$$

LCSR result

Power correction $\xi(E_\gamma)$

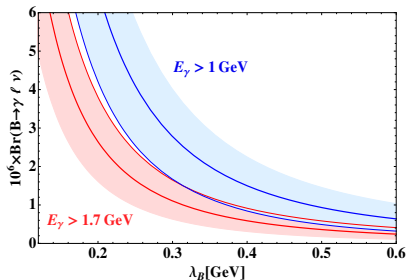
- ▶ hard-collinear: $x^2 \sim 1/(m_b \Lambda_{QCD})$, SCET
- ▶ soft: $x^2 \sim 1/(\Lambda_{QCD}^2)$, LCSR

Two-particle LCDA at tree level [V. M. Braun and A. Khodjamirian 2013](#)

Two-particle LCDA at one-loop level and three-particle LCDA at tree level [Y. M. Wang 2016](#)

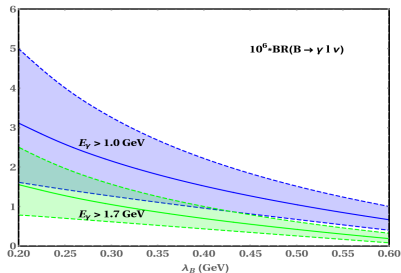
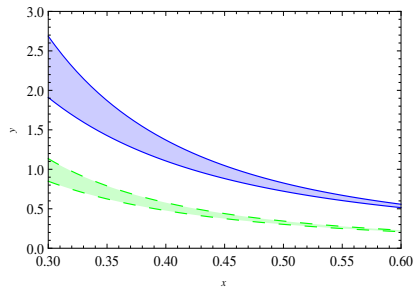
$$F_{B \rightarrow \gamma}(E_\gamma) = F_{B \rightarrow \gamma}^{\text{QCDF}}(E_\gamma) + \xi_{B \rightarrow \gamma}^{\text{soft}}(E_\gamma)$$

Previous results



Upper left: M. Beneke et al. 2011
 Lower left: V. M. Braun et al. 2013
 Right: Y. M. Wang 2016

BELLE: $\Delta \text{BR}(1\text{GeV}) < 3.5 \times 10^{-6}$



Power corrections: hard-collinear

Match the QCD current to HQET

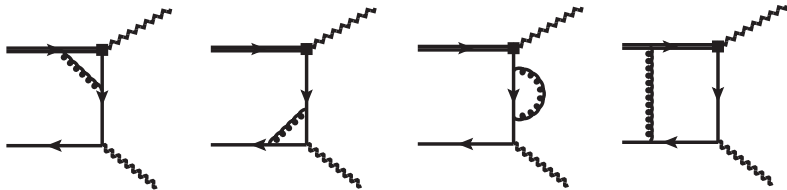
$$\bar{q}\gamma_\mu b = \bar{q}\gamma_\mu h_\nu + \frac{1}{2m_b}\bar{q}\gamma_\mu i \not{D} h_\nu + \dots$$

Equation of motion \longrightarrow model independent

$$\begin{aligned}\xi^{\text{ht}}(E_\gamma) = & -\frac{e_u f_B m_B}{2E_\gamma^2} \left\{ \frac{2(\lambda_E^2 + 2\lambda_H^2)}{6\bar{\Lambda}^2 + 2\lambda_E^2 + \lambda_H^2} + \frac{1}{2} \right\} \\ & + \frac{e_u f_B m_B}{4m_b E_\gamma} \left\{ \frac{\bar{\Lambda}}{\lambda_B} - 2 + \frac{4(\lambda_E^2 - \lambda_H^2)}{6\bar{\Lambda}^2 + 2\lambda_E^2 + \lambda_H^2} \right\}\end{aligned}$$

Power corrections: soft

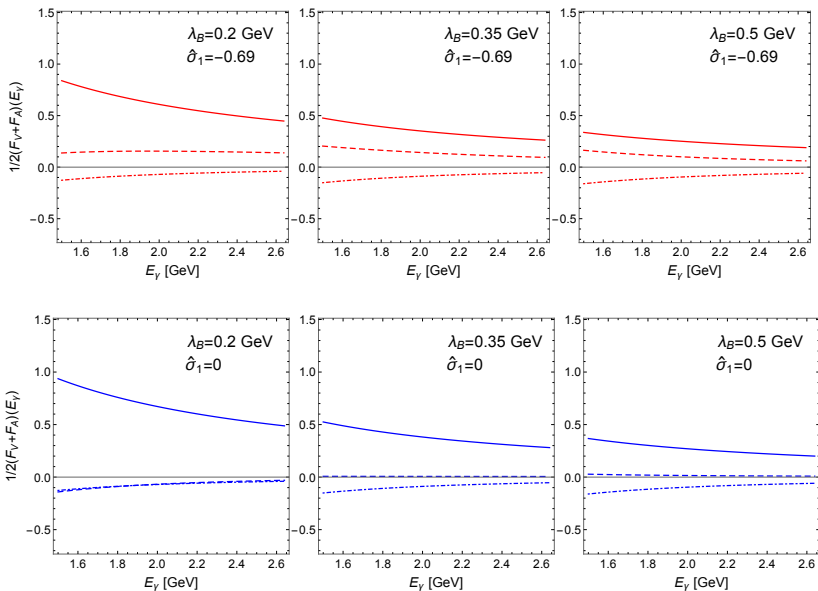
Factorization: $H(m_b) \otimes J(\sqrt{m_b \Lambda_{QCD}}) \otimes \Phi(\Lambda_{QCD})$



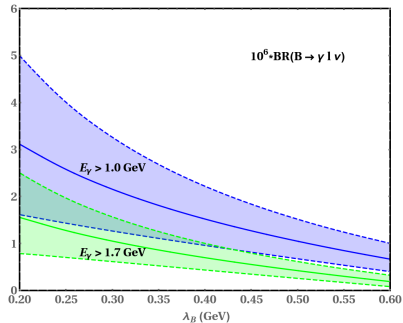
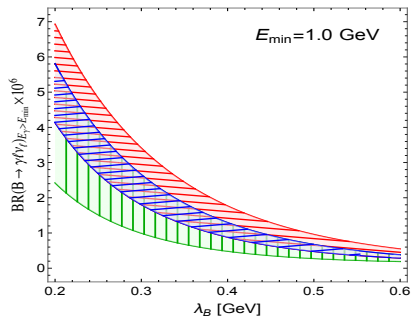
NLL resummation, RG equation of LCDA \rightarrow dual space

$$\frac{d\phi_+(\omega, \mu)}{d \ln \mu} = - \left[\Gamma_{\text{cusp}} \ln \frac{\mu}{\omega} + \gamma_+ \right] \phi_+(\omega, \mu) - \int_0^\infty d\omega' \omega' \Gamma(\omega, \omega', \mu) \phi_+(\omega', \mu)$$

Numerical result



Numerical result



Still can NOT constrain λ_B

Summary & Outlook

- ▶ **Subleading power** corrections to $B \rightarrow \gamma l \nu$
 - ▶ **Hard-collinear** correction: QCD factorization
 - ▶ **soft** correction: light-cone sum rules
- ▶ **Equation of motion** at tree level: hard-collinear contribution \rightarrow model independent
- ▶ Complete subleading power correction: SCET

Thank you!