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LCSRs Discussion

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Future Challenges in Non-Leptonic B Decays: Theory and Experiment, MITP, Mainz

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LCSRs for $B \to \{P, V\}$ Form Factors

Shameless Self Advertisement

- C++ implementation of the LCSRs publicly available
- uses numerical integration so that B-LCDAs can be swapped
- results of recent analysis are contained in the EOS release and as separate machine-readble ancillary files [Gubernari,Kokulu,DvD 1811.00983]

EOS homepage GitHub repository

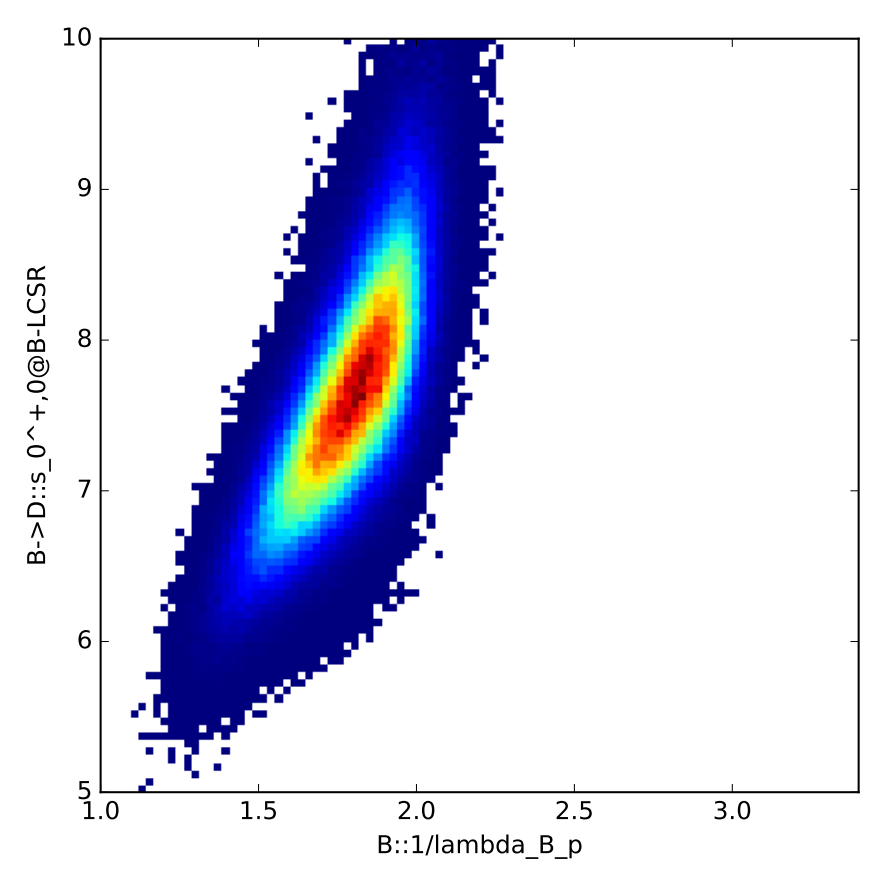
- we are happy to adapt / extend EOS for your needs
  please contact us

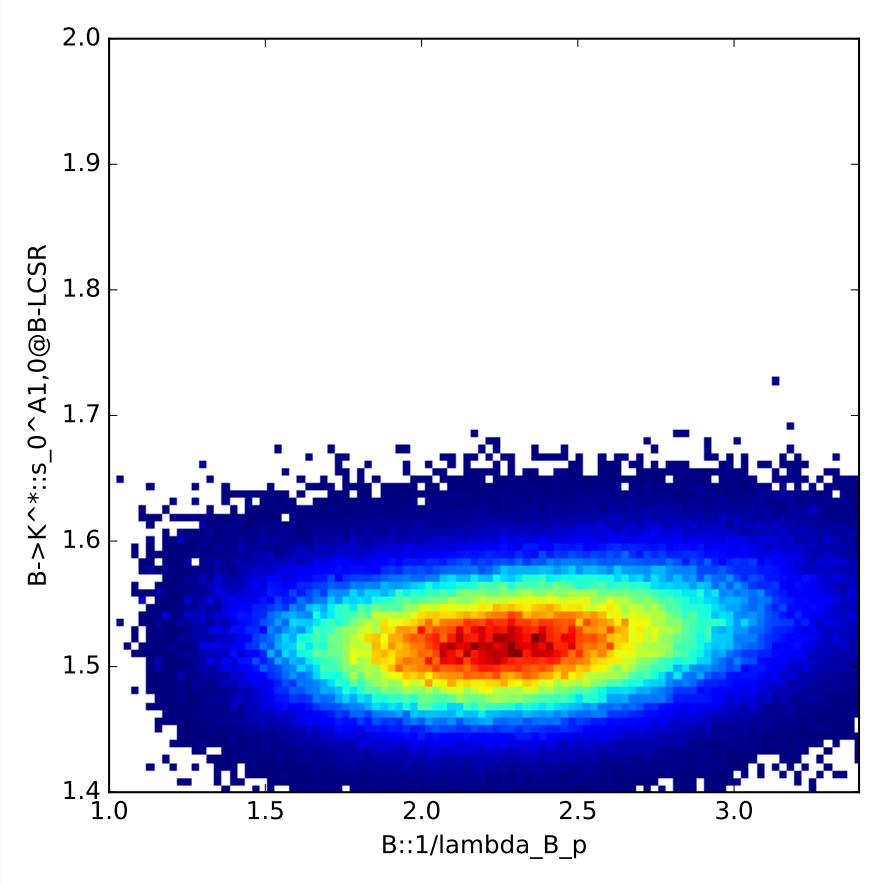
Interesting observation

when determining the threshold parameters for all $\bar{B} \to D$, $\bar{B} \to D^*$, and $B \to K^*$ form factors

- each form factor has an independent threshold parameter
- posteriors show weak correlation between threshold parameter and LCDA input λ_B^+
- in combination posterior contains surprising amount of information on λ_B^+
- take with a grain of salt: this is probably higly model dependent, still investigating

Interesting observation





LCSR Input: $1/\lambda_B^+$ from $B^- \to \gamma \ell^- \bar{\nu}$

$B^- \to \gamma \ell^- \bar{\nu}$: Belle 2 back-of-an-envelope projections

Assuming a lower cut $E_\gamma \leq 1\,\text{GeV}$ [B2TIP Report 1808.10567]

Table 46: Expected statistical error in 10^{-6} for Belle and Belle II for a simulated partial branching fraction of $\Delta\mathcal{B}(B^+ \to \ell^+ \nu_\ell \gamma) = 5.0 \times 10^{-6}$.

Belle New analysis	Belle II $5\,\text{ab}^{-1}$	Belle II $50\,\text{ab}^{-1}$
+1.48	+0.56	+0.18
-1.39	-0.53	-0.17

- projected central value larger than existing Belle upper bound

$$\mathcal{B}(B^- \to \gamma \ell^- \bar{\nu})\big|_{E_\gamma \leq 1.\text{GeV}} < 3.5 \cdot 10^{-6} \quad @ \quad 90\%\text{CL}$$ [Belle 1810.12976]

- present central value

$$\mathcal{B}(B^- \to \gamma \ell^- \bar{\nu})\big|_{E_\gamma \leq 1.\text{GeV}} = (1.4 \pm 1 \pm 0.4) \cdot 10^{-6}$$ [Belle 1810.12976]

- assuming the uncertainty to be dominantly statstical in nature for the current central value, the projection reads

$$\frac{\delta\mathcal{B}}{\mathcal{B}} \simeq 3.6\% \times \sqrt{\frac{5.0 \cdot 10^{-6}}{1.4 \cdot 10^{-6}}} \simeq 7\%$$

[adapted from B2TIP Report 1808.10567 & Belle 1810.12976]

Combining $B \to \gamma\ell\nu$ with $B \to \mu\nu$

schematically: $\dfrac{\mathcal{B}(B \to \gamma\ell\nu)}{\mathcal{B}(B \to \mu\nu)} \propto \dfrac{1}{\lambda_{B,+}} +$ three part./soft contributions

theory

$B \to \tau\nu$

- removes normalization $|V_{ub}| f_B$

$B \to \gamma\ell\nu$

- hard contrib. known to NLL precision

  [Beneke/Rohrwild 1110.3228]
- soft contrib. known in disp. approach

  [Braun/Khodjamirian 1210.4454]
- 3-particle contr. [Wang 1609.09813]

  [Braun et al. 1804.04962]

fit yields lower limit on the uncertainty

$\sigma(\lambda_{B,+}) = 0.035\,\text{GeV}$ [assuming $\lambda_{B,+} = 0.35\,\text{GeV}$]

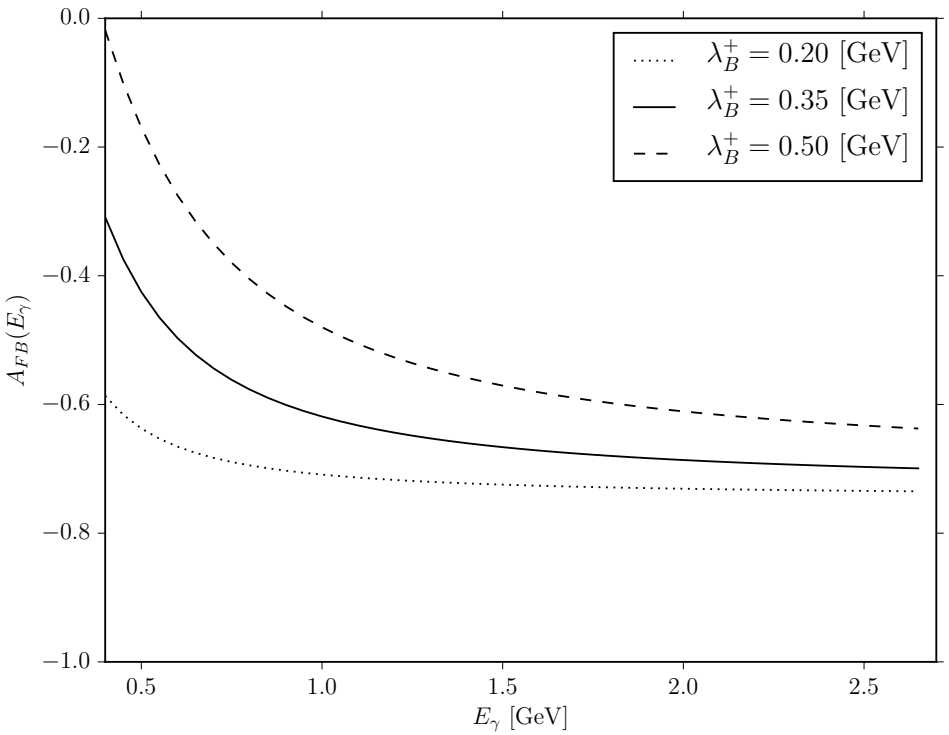
experiment

- expected uncertainty on $B \to \mu\nu$ for Belle II $\sim$ **7%** for $\mathcal{B} \simeq 3.5 \cdot 10^{-7}$

  [adapted from B2TIP Report 1810.12976]
- expected uncertainty on $B \to \gamma\ell\nu$ for Belle II $\sim$ **3.5%** for $\mathcal{B}|_{E_\gamma > 1.0\,\text{GeV}} \simeq 5 \cdot 10^{-6}$

  [adapted from B2TIP Report 1810.12976]

Angular distribution of $B \to \gamma \ell \nu$



- use hypothetical measurements of binned A_{FB}
  - [1.7 GeV, 2.0 GeV]
  - [2.0 GeV, 2.3 GeV]
  - [2.3 GeV, $M_B/2$]
- assume a lower limit of **5%** on the uncertainty in each bin

scan yields a lower limit on the precision:

$$\sigma(\lambda_{B,+}) = 0.05\,\text{GeV} \qquad \text{[assuming } \lambda_{B,+} = 0.35\,\text{GeV]}$$

D_s-meson LCDAs?

$D_s^- \to \gamma \ell^- \bar{\nu}$ in QCDF ?

- adapting QCDF results for $B^- \to \gamma \ell^- \bar{\nu}$ seems straightforward
- convergence doubtful, even for $E_\gamma \leq 1\,\text{GeV}$
- no data available yet!
- however ...

$$\mathcal{B}(D_s^- \to \mu^- \bar{\nu}) = (5.5 \pm 0.23) \cdot 10^{-3}$$

[Particle Data Group]

- laboratory for the $B^- \to \gamma \ell^- \bar{\nu}$ interested?
- potential applications: $D_s \to \{K, \phi\} \ell \bar{\nu}$ LCSRs