Massachusetts Institute of Technology

Technische Universität München

Precision measurements at low-q^2: theory perspective (five brief points)

Javier Virto

Massachusetts Institute of Technology

and

Technische Universität München

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Topics

- Non-local effects
- Light-hadron intermediate states
- A brief comment on Form factors
- Other modes
- LFNU does not save our lives

$B \to K^\star \ell\ell$ in a nutshell

$$\mathcal{A}_\lambda^{L,R} = \mathcal{N}_\lambda \left\{ (C_9 \mp C_{10}) \mathcal{F}_\lambda(q^2) + \frac{2 m_b M_B}{q^2} \left[C_7 \mathcal{F}_\lambda^T(q^2) - 16\pi^2 \frac{M_B}{m_b} \mathcal{H}_\lambda(q^2) \right] \right\}$$

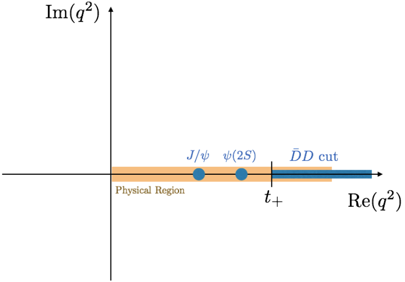
- Local (Form Factors) : $\mathcal{F}_\lambda^{(T)}(q^2) = \langle \bar{M}_\lambda(k) | \, \bar{s} \Gamma_\lambda^{(T)} \, b \, | \bar{B}(k+q) \rangle$
- Non-Local : $\mathcal{H}_\lambda(q^2) = i \mathcal{P}_\mu^\lambda \int d^4x \, e^{iq\cdot x} \langle \bar{M}_\lambda(k) | \, T\{ \mathcal{J}^\mu_{\rm em}(x), \mathcal{C}_i \mathcal{O}_i(0) \} \, | \bar{B}(q+k) \rangle$
- CKM structure : $\mathcal{H}_\lambda = -\frac{\lambda_u}{\lambda_t} \mathcal{H}_\lambda^{(u)} - \frac{\lambda_c}{\lambda_t} \mathcal{H}_\lambda^{(c)} \quad \Rightarrow \; \mathcal{O}_i \sim (\bar{c}b)(\bar{s}c)$

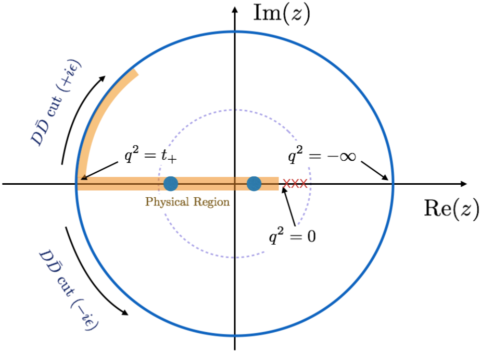
(($\mathcal{F}_\lambda(q^2)$ and $\mathcal{H}_\lambda(q^2)$ will be discussed on Wednesday))

Non-local effects

In the language of BCvDV 1707.07305

Charm-loop effect, neglecting OZI-suppressed "light-hadron" cut.

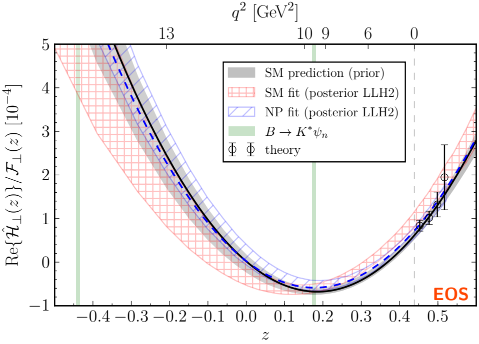




- Improve $B \to \psi_n K^*$ measurements as much as possible.
- Provide all (smallish) bins between ~ 6 GeV^2 and $M^2_{\psi(2S)}$.

Non-local effects

In the language of BCvDV 1707.07305



(a) Two-step : 1. SM predictions, followed by 2. NP fit. (My preferred)

(b) Simultaneous fit to all data.

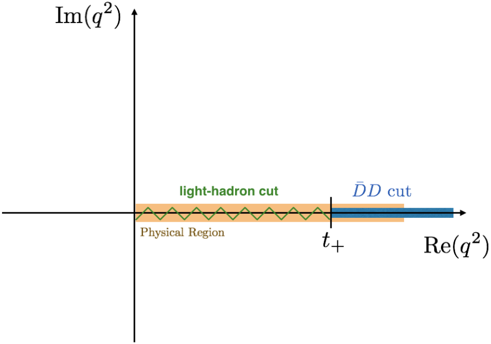
Can go higher in z-expansion and can do w/o theory. (A. Mauri, Wednesday)

Very good for SM predictions from $b \to see$ (LFNU).

(**Note:** Number of parameters depends on mode.)

Light-hadron cut

The non-local ME of $O^c_{1,2}$ also contains a cut at low q^2 from intermediate "light-hadron" states:



$$\mathrm{Disc}[\mathcal{H}_\lambda(q^2 > t_+)] \sim \sum_X \langle 0|j_{\mathrm{em}}|X^{1^{--}}_{cc}\rangle\langle X^{1^{--}}_{cc} K^*|(\bar{s}c)(\bar{c}b)|\bar{B}\rangle$$

$$\mathrm{Disc}[\mathcal{H}_\lambda(0 < q^2 < t_+)] \sim \sum_X \langle 0|j_{\mathrm{em}}|X^{1^{--}}\rangle\langle X^{1^{--}} K^*|(\bar{s}c)(\bar{c}b)|\bar{B}\rangle$$

Light-hadron cut

⋆ Support for $\langle X^{1^{--}} K^* | (\bar{s}c)(\bar{c}b) | \bar{B} \rangle \ll \langle X_{cc}^{1^{--}} K^* | (\bar{s}c)(\bar{c}b) | \bar{B} \rangle$:

- OZI rule.
- $\mathcal{B}(B \to K^{(*)}\omega) \approx 2 \text{ - } 5 \cdot 10^{-6}$ (in agr. with QCDF from $[\bar{s}q][\bar{q}b]$)

$$\Rightarrow \langle K^* \omega | (\bar{s}c)(\bar{c}b) | \bar{B} \rangle \lesssim \underbrace{C_q / C_c}_{\textit{few}\,\%} \langle K^* \omega | (\bar{s}q)(\bar{q}b) | \bar{B} \rangle$$

- Same argument for $\mathcal{B}(B \to K^{(*)}\phi)$
- In absence of OZI, the natural size of these BRs is 10^{-3} not 10^{-6} :

$$\mathcal{B}(B \to KJ/\psi) = 9 \times 10^{-4} \qquad \mathcal{B}(B \to K^* J/\psi) = 1.3 \times 10^{-3}$$
$$\mathcal{B}(B \to K[D^* \bar{D}]) = 6 \times 10^{-3} \qquad \mathcal{B}(B \to K[D^* \bar{D}^*]) = 8 \times 10^{-3}$$
$$\mathcal{B}(B \to K[D\bar{D}]) = 5 \times 10^{-4}$$

- Note also the **total** BR: $\mathcal{B}(B \to K^{(*)}[\bar{K}K]) \sim 10^{-5} \ll 10^{-3}$
- Test: $\mathcal{B}(B \to K^{(*)} X^{1^{--}}(\text{high mass})) \ll 10^{-3}$

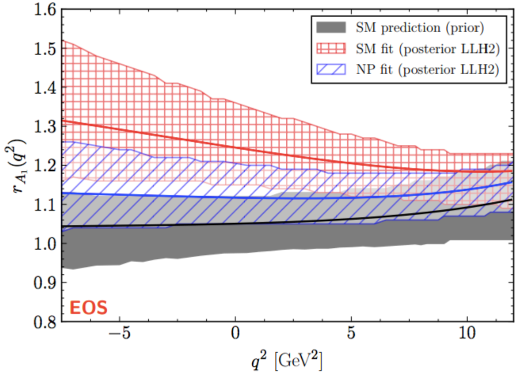
Light-hadron cut

Conclusion: OZI $\rightarrow$ Two order of magnitude suppression.

- But CKM- and penguin-suppressed light-quark loops are there.
- Not OZI suppressed.
- Must be constrained if precision is sought (but rough estimate might suffice).
- Can do dispersive analysis Khodjamirian, Mannel, Wang 2012 ...
- Could use $b \rightarrow d$ analogues. (**measure, please**)

Form Factors

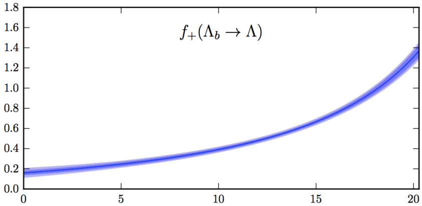
If our non-local effect is fine, then our ‘only’ alternative to NP is:

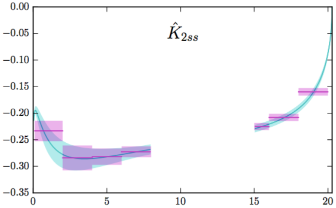


- Form factors will be discussed Wednesday in M. Wingate’s session.
- Beyond narrow width (not huge effect but needed for precision)

Other Modes

- All this applies to all other modes: $B \to K\ell\ell$, $B_s \to \phi\ell\ell$, $\Lambda_b \to \Lambda\ell\ell$...
- $\Lambda_b \to \Lambda\ell\ell$ especially interesting at this point:
  - ☐ Rich source of orthogonal info — Blake, Kreps
  - ☐ Form factors well known in the full q^2 region — Detmold, Meinel



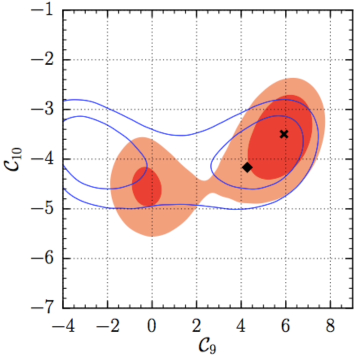


  - ☐ Should aim to fits analogous to $B \to K^*\mu\mu$

Other Modes

☐ Puzzling available low-recoil fit

Meinel, van Dyk



Only low-recoil (no deep reason)

- Non-local effects :
  - ☐ LCSR calculation.
  - ☐ **Need** $\Lambda_b \to \Lambda J/\psi$ and $\Lambda_b \to \Lambda J/\psi(2S)$

LFNU ratios not a substitute !

- LFNU ratios are smoking guns for NP .... but not much more

  (compared to the regular $B \to M\ell\ell$ observables)

- $R_M = \dfrac{a + bC_{9\mu}^{NP} + cC_{10\mu}^{NP} + \cdots}{a + bC_{9e}^{NP} + cC_{10e}^{NP} + \cdots}$

  $\Rightarrow$ Interpretation requires knowledge of hadronic parameters b/a, etc.

- Knowing **both** $\mu^+\mu^-$ and e^+e^- independently *does* solve the problem

  (if assumed no NP in e^+e^- e.g.)

  1. Use e^+e^- mode and a **good** parametrization to fix precisely Had Pars.
  2. Produce (precise) **SM predictions** for $\mu^+\mu^-$ mode.
  3. Fit for NP.

Important to insist on this out there.