Search for New Physics in $b \to u$ Transitions and $B \to \pi$ Form Factor from the Lattice and LCSRs

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based on JHEP 1502(2015)126 and arXiv:1503.09063

Challenges in Semileptonic B Decays, Mainz, 23.04.2015

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Search for NP in Semileptonic $b \to u$ Transitions

Effective Field Theory

$$\mathcal{H}^{\text{eff}}_{b\to u} = -\frac{4G_F V^{\text{eff}}_{ub}}{\sqrt{2}} \sum_X \mathcal{C}_X \mathcal{O}_X + \text{ h.c.}\,.$$

- concentrate on V, A interaction

$$\mathcal{O}_{V,i} = [\bar{u}\gamma^\mu P_i b][\bar{\ell}\gamma_\mu P_L \nu_\ell]$$

  - hadronic current either left or right handed
  - leptonic current only left handed
- consequences for observables:
  - $|V^{B\to\tau\nu}_{ub}|^2 \to |V^{\text{eff}}_{ub}|^2 \left|\mathcal{C}_{V,L} - \mathcal{C}_{V,R}\right|^2$
  - $|V^{B\to\pi\ell\nu}_{ub}|^2 \to |V^{\text{eff}}_{ub}|^2 \left|\mathcal{C}_{V,L} + \mathcal{C}_{V,R}\right|^2$
  - $|V^{\text{incl.}}_{ub}|^2 \to |V^{\text{eff}}_{ub}|^2 \left(|\mathcal{C}_{V,L}|^2 + |\mathcal{C}_{V,R}|^2\right)$

Exp. Constraints

$B^- \to \tau^-\bar{\nu}_\tau$	
BaBar 2009	sl. tag
BaBar 2012	had. tag
Belle 2012	had. tag
Belle 2015	sl. tag
$\bar{B}^0 \to \pi^+\mu^-\bar{\nu}_\mu$	
BaBar 2010	untagged
BaBar 2012	untagged
Belle 2010	untagged
Belle 2013	full recon.
$B \to X_u\ell\bar{\nu}$	
BaBar+Belle	HFAG avg. (GGOU)

Search for NP in Semileptonic $b \to u$ Transitions

Strategy

[Feldmann, Müller, DvD 1503.09063]

- fit $\mathcal{C}_{V,L}$ and $\mathcal{C}_{V,R}$ from data
  - choose global phase as phase of $V_{ub}^{\text{eff}} \cdot \mathcal{C}_{V,L}$
  - $\mathcal{C}_{V,L}$ is real-valued in the fit
- introduce nuisance parameters for exclusive decays, using informative priors
  - $B \to \tau\nu$: B decay constant f_B from 2ptSRs

    [Gelhausen,Khodjamirian,Pivovarov,Rosenthal 1404.0891]
  - $B \to \pi\mu\nu$: form factor $f_+(q^2)$ from LCSRs

    [Imsong, Khodjamirian, Mannel, DvD 1409.7816]
- use several fit scenarios and perform statistical comparison
  1. no right-handed currents: $\mathcal{C}_{V,R} = 0$, fit $\mathcal{C}_{V,L}$
     - equivalent to determination of $|V_{ub}| = |V_{ub}^{\text{eff}} \mathcal{C}_{V,L}|$

  2 real-valued right-handed currents

  2 complex-valued right-handed currents

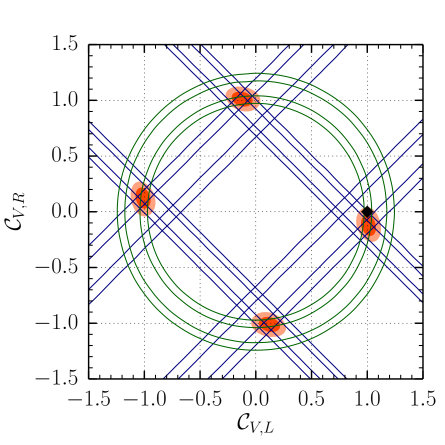
Search for NP in Semileptonic $b \to u$ Transitions

Result: Scenario 1

- $\chi^2 = 18.54$ for 28 degrees of freedom
  - excellent fit with p value of 91%
- however: form factor pull does not enter χ^2
  - 3 form factor parameters
  - pull of $\sim 3\sigma$
- find $|\mathcal{C}_{V,L}| = 1.02 \pm 0.05$ at 68% probability
- corresponds to $|V_{ub}| = (4.07 \pm 0.20) \cdot 10^{-3}$ at 68% prob.

Search for NP in Semileptonic $b \to u$ Transitions

Result: Scenario 2 (w/ real-valued $\mathcal{C}_{V,R}$)



contours at 68% and 95% prob.

- blue stripes, negative slope: $B \to \pi\mu\nu$
- blue stripes, positive slope: $B \to \tau\nu$
- green rings: $B \to X_u \ell\nu$
- orange areas: combination

Search for NP in Semileptonic $b \to u$ Transitions

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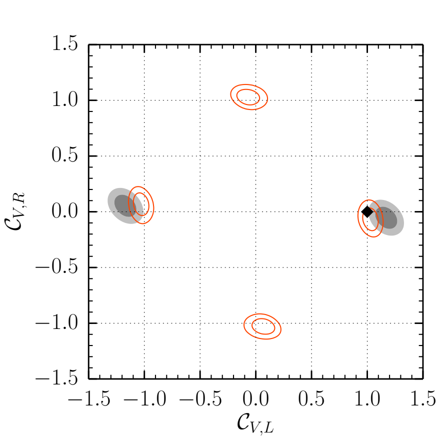

contours at 68% and 95% prob.

- orange areas: combination
- gray area: add. hypo. measurement of A_{FB} in $\bar{B}_s \to K^{*+}(\to K\pi)\ell\nu$

Search for NP in Semileptonic $b \to u$ Transitions

Result: Scenario 2 (w/ real-valued $\mathcal{C}_{V,R}$)

- χ^2 increases to 20.47 for 27 degrees of freedom
  - still very good fit with p value of 81%
- form factor pull decreases to $\sim 2\sigma$
  - $\mathcal{C}_{V,R}$ compensates need to adjust form factor
- solutions Wilson coefficients:
  - $|\mathcal{C}_{V,L}| = 1.02 \pm 0.05$ and $|\,\mathrm{Re}\left(\mathcal{C}_{V,R}\right)| \leq 0.10$ at 68% probability
  - $\mathrm{Re}\left(\mathcal{C}_{V,R}\right) = 1.02 \pm 0.05$ and $|\mathcal{C}_{V,L}| \leq 0.10$ at 68% probability
- looses against scenario 1 in posterior odds with 1 : 27.8

Combining $B \to \pi$ Form Factor Results

Aim

combined fit to Lattice and LCSR results

Task 1: Agree on a mutual model of the spectrum

- both methods need additional input (e.g. from experiment) on excited-state masses
  - Lattice:
    both B and π excitations
  - LCSRs with π-LCDAs (highest precision):
    B excitations only

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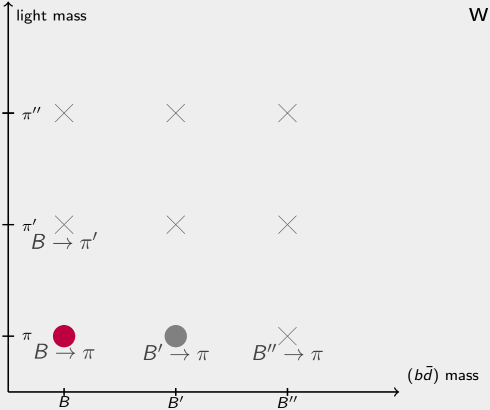

which excitations to consider

- physical result
- consistency check
- × to be marginalised in the fit

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- both methods need additional input (e.g. from experiment) on excited-state masses
  - Lattice:
    both B and π excitations
  - LCSRs with π-LCDAs (highest precision):
    B excitations only
- suggests to aim for parametrization

$$C(T) = e^{-m_B T} \left[f_+^{B\pi} + f_+^{B'\pi} e^{-\Delta_1 T} + p(T) \right]$$

$$C(1/M^2) = e^{-m_B^2/M^2} \left[f_B f_+^{B\pi} + f_{B'} f_+^{B'\pi} e^{-\Delta_1^2/M^2} + \tilde{p}(1/M^2) \right]$$

after marginalization over excited-state quantities beyond B'

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Task 2: Correlations between LCSR result and Lattice Input

- LCSRs can calculate $g_{B^* B\pi}$
  - expect large correlations between $g_{B^* B\pi}$ and $f_+^{B\pi}$
- Lattice results use $g_{B^* B\pi}$ as input parameter
  - expect impact on $f_+^{B\to\pi}$ from shifts in $g_{B^* B\pi}$