Update on V_{ub} from $B \to \tau\nu$

Patrick Fritzsch

Institut für Physik, Humboldt-Universität zu Berlin, Germany

(B2)

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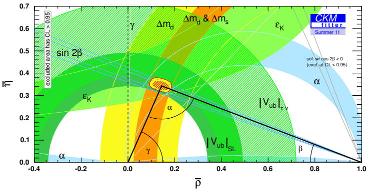
Motivation

Couplings of flavor-changing *weak interactions*:

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$



processes with $b \to u$ transitions

Lattice input

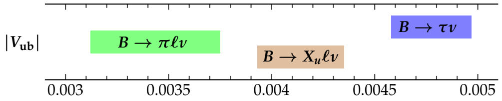
- Inclusive $B \to X_u \ell \nu$
  optical theorem and heavy quark expansion
- Exclusive $B \to \pi \ell \nu$
  hadronic formfactor $f_+(q^2)$
- Leptonic $B \to \tau \nu$
  hadronic decay constant f_B

V_{ub} *puzzle*

$+$

$(\mathcal{B}(B \to \tau\nu), \sin(2\beta))$ discrepancy

Summer 2011: [PDG'10]



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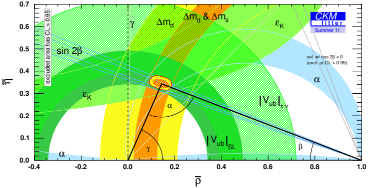

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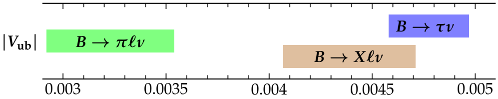
Spring 2012: [PDG'12, preliminary]



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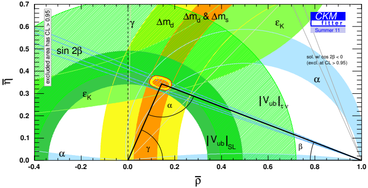

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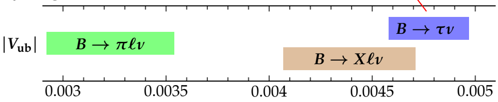
precision??

V_{ub} *puzzle*

$+$

$\left(\mathcal{B}(B \to \tau\nu)\,,\sin(2\beta)\right)$ discrepancy

Spring 2012: [PDG'12, preliminary]



On the lattice

a variety of interfering systematic errors have to be controlled:

- **finite volume** $T \times L^3$**:**

  exponentially small in $m_\pi L$

- **finite lattice spacing** a**:**

  need various lattice spacings, (no. of a) ≥ 3, to take CL ($a \to 0$)

- **discretized action:**

  universality allows to choose different gauge & fermion action,
  with different advantages & shortcomings

- **quark masses:**
  - no. of dynamical (sea) quarks: $N_\mathrm{f} = 0,\ \mathbf{2},\ 2{+}1,\ 2{+}1{+}1$
  - **light quarks:** $m_\pi^{\mathrm{exp}} \lesssim m_\pi \lesssim (250 - 500)\mathrm{MeV}$
    need *chiral extrapolation*
  - **heavy quarks:** $(am_b \sim O(1)) \not\ll 1$
    relativistic treatment of b-quark in large volume not feasible
    $\hookrightarrow$ use of effective theories, NRQCD, . . . , **HQET**

HQET on the lattice

HQET: effective theory of QCD, expansion in powers of $1/m_{\rm b}$

HQET on the lattice:

operator mixing induces power divergences in a^{-1}
$\Rightarrow$ subtractions need to be performed NP'ly

Our approach:

NP matching of HQET and QCD in small physical volume
$\Downarrow$

- b-quark can be simulated relativistically ($L \sim 0.4\text{fm}$)
- running coupling & mass known NP'ly
  $\Rightarrow$ contact to large volume physics
- power divergences subtracted NP'ly (at fixed a)
  $\Rightarrow$ NP parameters of effective theory guarantee renormalizability
- only one input parameter, $m_B^{\rm exp}$, to setup effective theory
  $\Rightarrow$ to static ($n = 0$) or next-to-leading ($n = 1$) order

Dynamical fermion simulations

criteria for subsequent data analysis:

CLS based

- FV effects small by construction

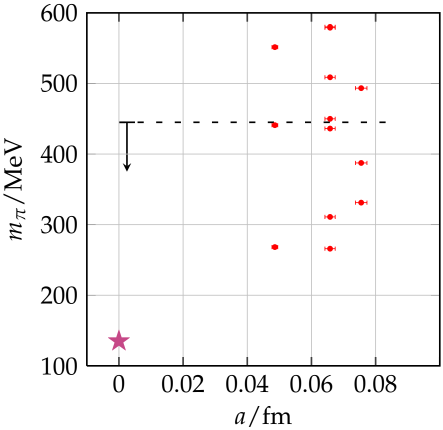
$$Lm_\pi \geq 4.0$$

- data for chiral extrapolation uses

$$(250 \lesssim m_\pi \lesssim 400 - 450)\mathrm{MeV}$$

- lattice spacings

$$(0.048, 0.065, 0.075 < 0.1)\mathrm{fm}$$



7 simulations fulfill our current criteria

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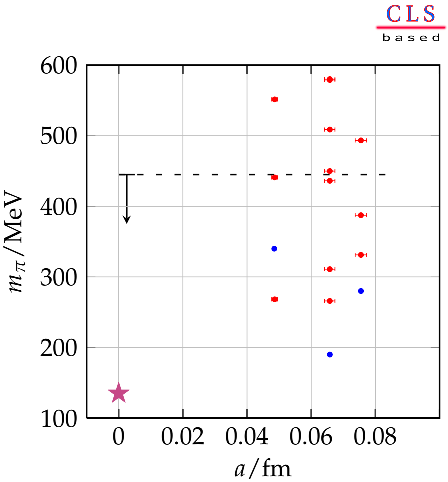


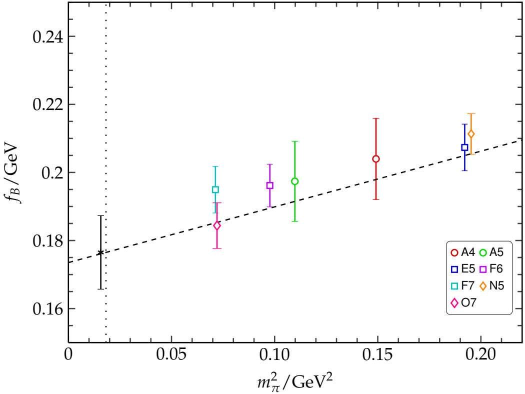
7 simulations fulfill our current criteria

+ 3 more by end of this year

The B-meson decay constant f_{B}

extrapolation to the physical point $f_{\text{B}} \equiv \lim_{(m_\pi,a)\to(m_\pi^{\text{exp}},0)} f_{\text{B}}(m_\pi, a)$ through

$$f_{\text{B}}(m_\pi, a) = b + cm_\pi^2 + da^2 \qquad \text{(LO)}$$



- no mixed term $(am_\pi)^2 \lesssim 0.02$
- $f_{\text{B}} = 176(11)(5)_a$ LO

The B-meson decay constant f_B

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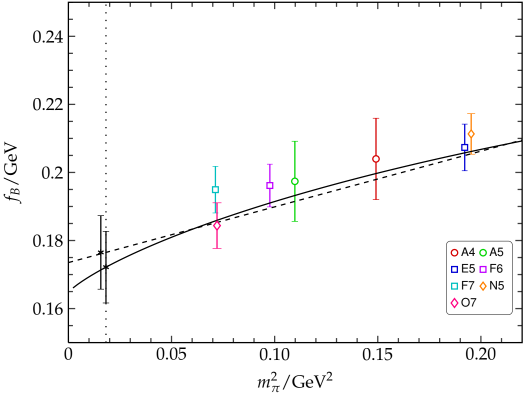
$$f_B(m_\pi,a) = b + cm_\pi^2 + da^2 \qquad \text{(LO)}$$

$$f_B(m_\pi,a) = b'\left[1 - \frac{3}{4}\frac{1+3\hat{g}^2}{(4\pi f_\pi)^2} m_\pi^2 \ln(m_\pi^2)\right] + c' m_\pi^2 + d' a^2 \qquad \text{(HM}\chi\text{PT)}$$



- no mixed term $(am_\pi)^2 \lesssim 0.02$
- $f_B = 176(11)(5)_a$ LO
- $f_B = 172(11)(5)_a$ HMχPT

$f_\pi = f_\pi^{exp},\ \hat{g} = 0.51(2)$

[PoS-Lat'10:BulavaETAL]

The B-meson decay constant $f_{\rm B}$

extrapolation to the physical point $f_{\rm B} \equiv \lim_{(m_\pi,a)\to(m_\pi^{\rm exp},0)} f_{\rm B}(m_\pi, a)$ through

$$f_{\rm B}(m_\pi, a) = b + c m_\pi^2 + d a^2 \quad \text{(LO)}$$

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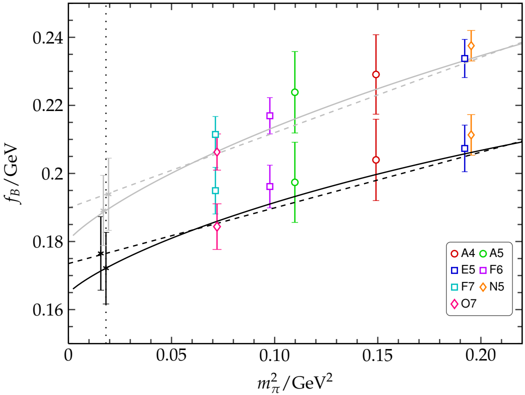

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$f_\pi = f_\pi^{\rm exp}$, $\hat{g} = 0.51(2)$

[PoS-Lat'10:BulavaETAL]

- static theory

  $f_{\rm B} = 194(11)(5)_a$ LO

  $f_{\rm B} = 189(11)(5)_a$ HMχPT

Our estimate of V_{ub}

$$\mathcal{B}_{\rm SM}(B \to \tau\nu) = f_{\rm B}^2 |V_{ub}|^2 \frac{G_F^2 m_{\rm B} \tau_{\rm B}}{8\pi} m_\tau^2 \left[1 - \frac{m_\tau^2}{m_{\rm B}^2}\right]$$

using PDG values and

$$f_{\rm B} = 174(11)(5)_a(2)_\chi \text{MeV}, \qquad \mathcal{B}_{\rm SM}(B \to \tau\nu)_{\rm CKMfit} = (7.57^{+0.98}_{-0.61}) \times 10^{-5}$$

$$|V_{ub}|_{\rm lept.} = (5.57^{+0.65}_{-0.59}) \times 10^{-3}$$

$$|V_{ub}|_{\rm lept.} = (5.00^{+0.37}_{-0.27}) \times 10^{-3}$$

our determination

$f_{\rm B} = 194(7)\text{MeV}$ [Lat'11]

our current value slightly increases the tension

⇒ experiment and theory have to improve further

Summary & outlook

- possible sources of tension in $|V_{ub}|$:

  lattice input $\leftrightarrow$ exp. measurements $\leftrightarrow$ new physics

- precise $N_\mathrm{f} = 2$ determination of f_B in the continuum limit:

$$f_\mathrm{B} = 174(11)(5)_a(2)_\chi \mathrm{MeV}$$

  improvement possible in near future

- HQET observables from first principles at NLO in $1/m_\mathrm{b}$, renormalized NP'ly ✓
- systematic errors seem to be well controlled ✓
- more observables from NP'ly renormalized HQET:

$$m_\mathrm{b}(\overline{\mathrm{MS}}) = 4.23(13)(3)_a(6)_z \mathrm{GeV}, \quad f_+(q^2), \quad f_{\mathrm{B_s}}, \quad \ldots$$

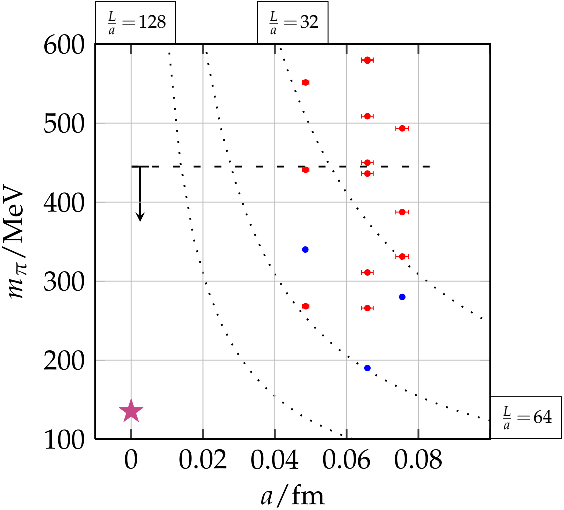
- only truncation error $O\left((\Lambda/m_\mathrm{b})^2\right)$ remain (but usually negligible)

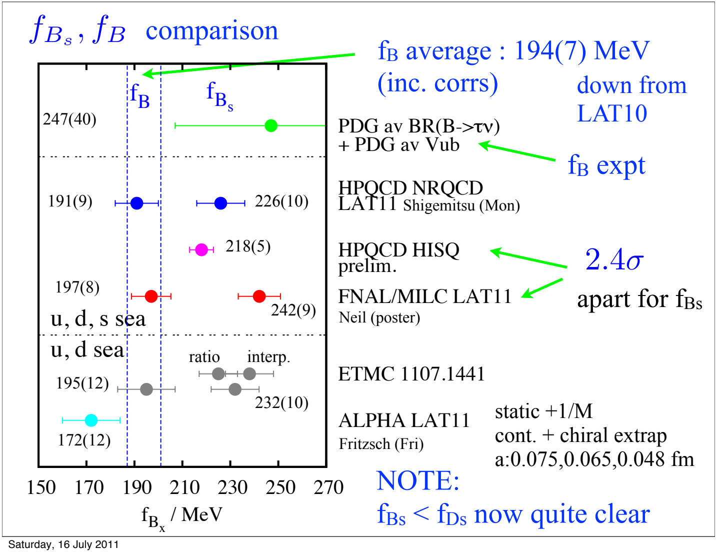
watch out for *FLAG-2* = Flavor Lattice Averaging Group (phase 2):

FLAG-2 (EU+Japan+US) will review light- and *heavy-quark* related quantities (end 2012) backup slides

CLS simulations

$V_4 = L^3 \times T$, $T = 2L$ (dotted curves at $Lm_\pi \equiv 4$)





f_{B_s}, f_B comparison
fB average : 194(7) MeV
(inc. corrs)
down from
LAT10
fB
fBs
247(40)
PDG av BR(B->τν)
+ PDG av Vub
fB expt
191(9)
226(10)
HPQCD NRQCD
LAT11 Shigemitsu (Mon)
218(5)
HPQCD HISQ
prelim.
2.4σ
197(8)
242(9)
FNAL/MILC LAT11
Neil (poster)
apart for fBs
u, d, s sea
u, d sea
ratio
interp.
ETMC 1107.1441
195(12)
232(10)
172(12)
ALPHA LAT11
Fritzsch (Fri)
static +1/M
cont. + chiral extrap
a:0.075,0.065,0.048 fm
150
170
190
210
230
250
270
fBx / MeV
NOTE:
fBs < fDs now quite clear
Saturday, 16 July 2011