The D_s, D^+, B_s and B^+ decay constants from $2 + 1$ flavor lattice QCD

Fermilab Lattice and MILC collaborations
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31 July 2013

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The *D* and *B* decay constants

- Among simplest Weak matrix elements to compute.
- Test of lattice technology: *e.g.*, heavy quark mass sensitivity, HQ formalisms, chiral extrapolations.
- The *D* and *B* decay constants provide tests of the CKM picture *e.g.*, $B^0 \to \mu^+\mu^-$ in SM and $|V_{ub}|$ from $B^+ \to \tau^+\nu$.
- This talk: Decay constants from three-flavor MILC asqtad lattices using asqtad light and clover (Fermilab interpretation) heavy valence quarks. PRELIMINARY.
- *D* decay constants with HISQ charm on MILC four-flavor HISQ lattices see talks by:

C. Bernard	Wed 11:00 session: 6C
D. Toussaint	Thu 17:50 session: 8C

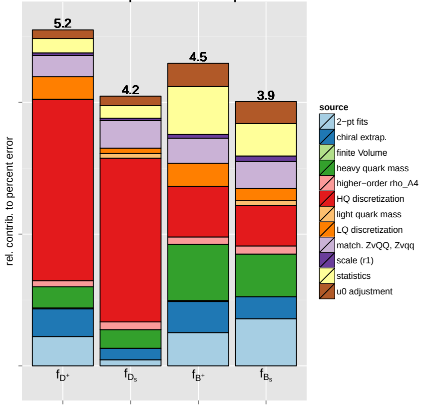
We have published results from our previous asqtad study. . .

Conclusions from our previous study

PRD.85.114506,

arχiv:1112.3051

Contributions in quadrature to percent error



D-meson system

$$f_{D^+} = 218.9 \pm 11.3 \text{ MeV}$$
$$f_{D_s} = 260.1 \pm 10.8 \text{ MeV}$$
$$f_{D_s}/f_{D^+} = 1.188 \pm 0.025$$

B-meson system

$$f_{B^+} = 196.9 \pm 8.9 \text{ MeV}$$
$$f_{B_s} = 242.0 \pm 9.5 \text{ MeV}$$
$$f_{B_s}/f_{B^+} = 1.229 \pm 0.026$$

Our current study addresses many of these sources of error...

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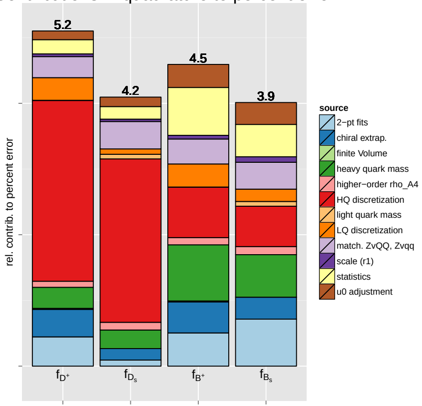
Contributions in quadrature to percent error



Improvements in current study:

- No u0 adjustment.
- HQ discretization, LQ discr., chiral extrap. and statisical errors reduced by including finer $a \approx 0.058$ and $0.043\,\mathrm{fm}$ lattices and higher 2-pt statistics.
- Nearer to physical $m_l/m_h = 1/20$ helps in chiral extrap.

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Conclusions from our previous study

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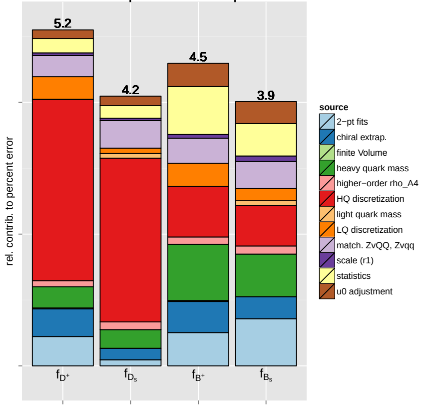
Contributions in quadrature to percent error



. . . and more improvements:

- Better kappa tuning to reduce HQ mass errors.
- Better runs to compute $Z_{V^4_{QQ}}$ and $Z_{V^4_{qq}}$.
- New 2-pt fit technolgy to control 2-pt fit errors.

MILC asqtad $N_f = 2 + 1$

Current study includes

id	a [fm]	beta	m_l/m_h	am_h	m_h/m_s	r_1/a	N_{config}	N_{tsrc}
A	0.043	7.81	0.2	0.014	1.079	7.208	801	4
B	0.059	7.46	0.1	0.018	1.019	5.307	827	4
C	0.058	7.465	0.139	0.018	1.024	5.330	801	4
D	0.058	7.47	0.2	0.018	1.028	5.353	673	8
E	0.058	7.48	0.4	0.018	1.037	5.399	593	4
F	0.083	7.075	0.05	0.031	1.255	3.738	791	4
G	0.083	7.08	0.1	0.031	1.256	3.755	1015	4
H	0.083	7.085	0.15	0.031	1.262	3.772	984	4
I	0.082	7.09	0.2	0.031	1.267	3.789	1931	4
J	0.081	7.11	0.4	0.031	1.290	3.858	1996	4
K	0.11	6.76	0.1	0.05	1.489	2.739	2099	4
L	0.11	6.76	0.14	0.05	1.489	2.739	2110	4
M	0.11	6.76	0.2	0.05	1.489	2.739	2259	4
N	0.11	6.79	0.4	0.05	1.534	2.821	2052	4
O	0.14	6.572	0.2	0.0484	1.156	2.222	631	24

Cf. our previous study:

- Two finer lattice spacings: 0.043 and 0.058 fm (id=A-E).
- Sea quarks nearer to physical: $m_l/m_h = 1/20$ (F).
- Better statistics: around $3.6\times$ more $N_{config} \cdot N_{tsrc}$.

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Charm and Bottom 2-pt functions

On each ensemble, for $H =$ charm, bottom and a range of m_q compute six 2-pt functions

$$
\begin{aligned}
C^{(j,k)}(t) &= \left\langle O^{(j)\dagger}_{H_q}(t) \;\; O^{(k)}_{H_q}(0) \right\rangle \\
C^{(k)}_{\mathcal{A}_4}(t) &= \left\langle \; \mathcal{A}^{\dagger}_4(t) \;\; O^{(k)}_{H_q}(0) \right\rangle
\end{aligned}
$$

with smearings $j, k \in \{point, smeared\}$.
The quantity $\phi_{H_q} = f_{H_q}\sqrt{M_{H_q}}$ is found from the overlap

$$
\frac{\langle\, 0 \mid \mathcal{A}_\mu \mid H_q(p)\,\rangle}{\sqrt{m_{H_q}}} = (p_\mu / m_{H_q})\phi_{H_q}
$$

$O(a)$-improved $\mathcal{A}_4$ is matched to continuum by factor

$$
\sqrt{Z^{QQ}_{\mathcal{V}^4} Z^{qq}_{\mathcal{V}^4}}\,\rho^{Qq}_{\mathcal{A}_4}
$$

with nonperturbative $Z_{\mathcal{V}^4}$ and small one-loop $\rho_{\mathcal{A}_4}$ correction.

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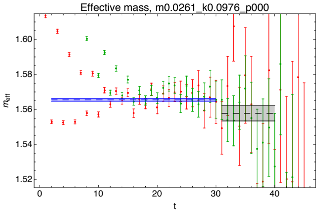
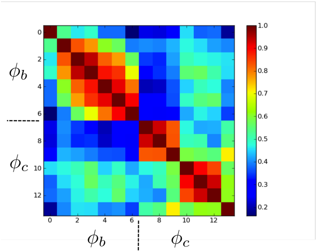
2-pt fitting details



ϕ_{Hq}-$\phi_{H'q'}$ correlation coeff.



- Fit four (five) 2-pt functions.
- New two stage fit process:
  1. Set empirical Bayesian priors for ground-state from $1 + 1$ state fits at large time.
  2. Use (broadened) priors in fit over a wide range of smaller non-overlaping times.
- Good isolation of ground-state using $4 + 4$ or $5 + 5$ states
- Bootstrap fits clearly show (expected) correlations.

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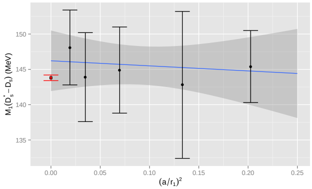
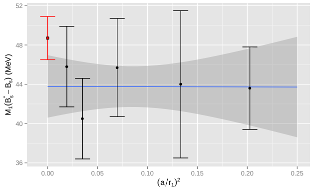
Clover c- and b-quark kappa tuning

Checks: D_s HFS



... and B_s HFS



Expt. ΔM shown at zero

Want $m_2(\kappa) = m(D_s)$ or $m(B_s)$

$$E(\vec{p})^2 = m_1^2 + \left(\frac{m_1}{m_2}\right)^2 \vec{p}^2 + \mathcal{O}(p^4)$$

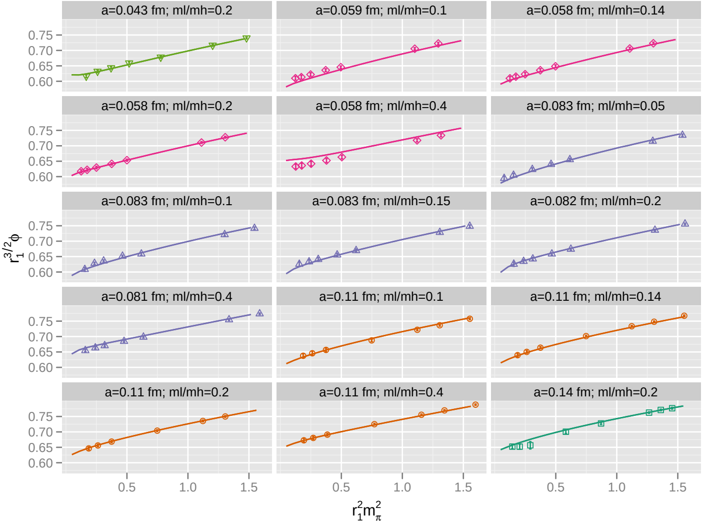
- High-statistics 2-pt tuning runs on $m_l = 0.2 m_h$ ensembles.
- $E(\vec{p})$ *vs* $\vec{p}$ fits include priors for $\mathcal{O}(p^4)$ effects.
- Tunings corrected for sea-quark effects.
- Predict tuned kappa for all ensembles.

Chiral fits

- Correct simulation $\phi = f\sqrt{M}$ for any kappa mistuning.
- NLO expression for ϕ from partially-quenched staggered chiral perturbation theory [Aubin and Bernard, arχiv:hep-lat/0510088].
- Add NNLO analytic (quadratic in quark mass) terms.
- Model both light- and heavy-quark discretization effects in the fits.
- Distance scale r_1, quark masses m_s, m_d and m_u and $O(a^2)$ LECs from MILC light meson fits.

D system fit

PRELIMINARY



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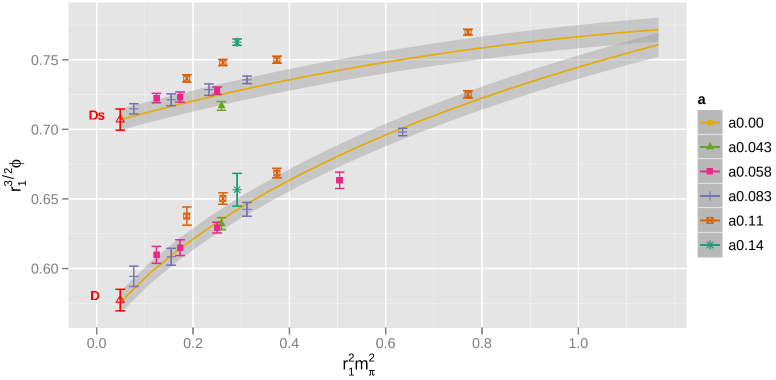
Extrapolations for D^+ and D_s

PRELIMINARY analysis and data are still blinded.



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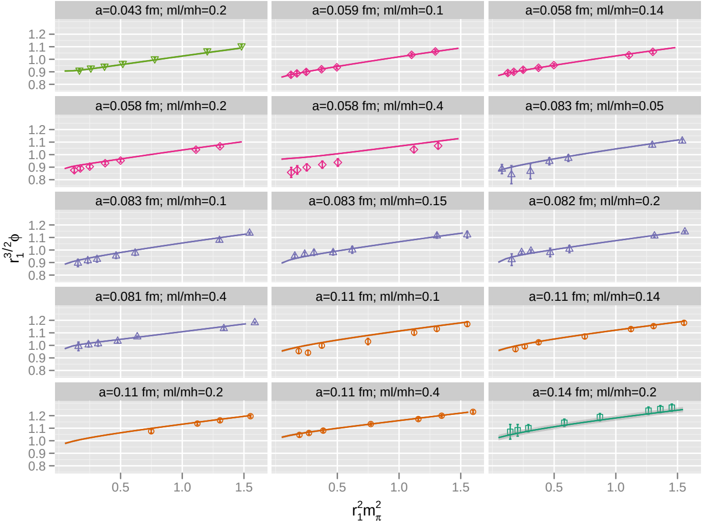
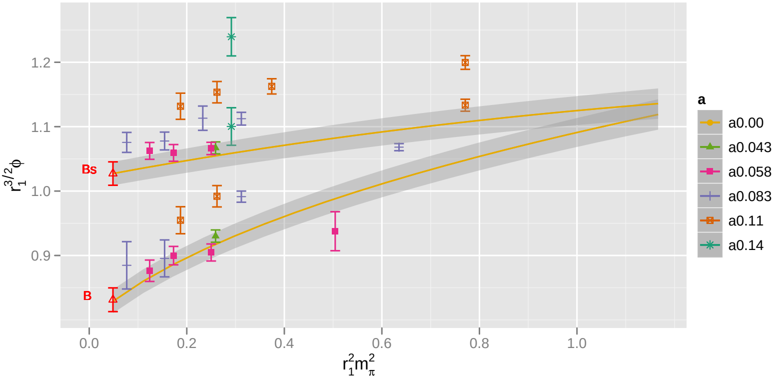
B system fit

PRELIMINARY



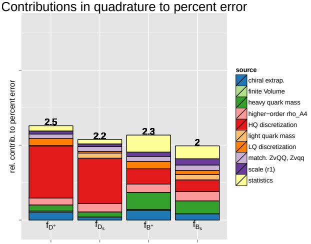
Extrapolations for B^{+} and B_s

PRELIMINARY analysis and data are still blinded.



Summary

Current study (predicted)



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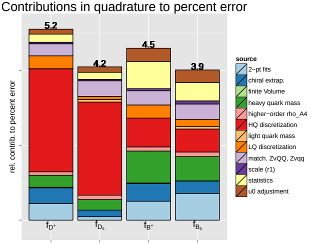

- Error budget is work in progress.
- Current projections shown on left.
- Anticipate reductions in systematic errors compared to our previous study.
- Underway: final cross-checks of this analysis and full error budget for this three-flavor asqtad study.
- Next: clover bottom quark calculations on MILC four-flavor HISQ lattices – including *e.g.*, f_{B+}/f_{D+} with HISQ charm.