B Physics with HISQ

A. Bazavov, C. Bernard, C. DeTar, A. X. El-Khadra, E. Gámiz, Z. Gelzer, Steven Gottlieb, U. M. Heller, A. S. Kronfeld, J. Laiho, Ruizi Li, Yuzhi Liu, P. B. Mackenzie, E. Neil, J. N. Simone, R. Sugar, D. Toussaint, R. S. Van de Water, and A. Vaquero

Fermilab Lattice and MILC Collaborations

USQCD All Hands Meeting
FNAL
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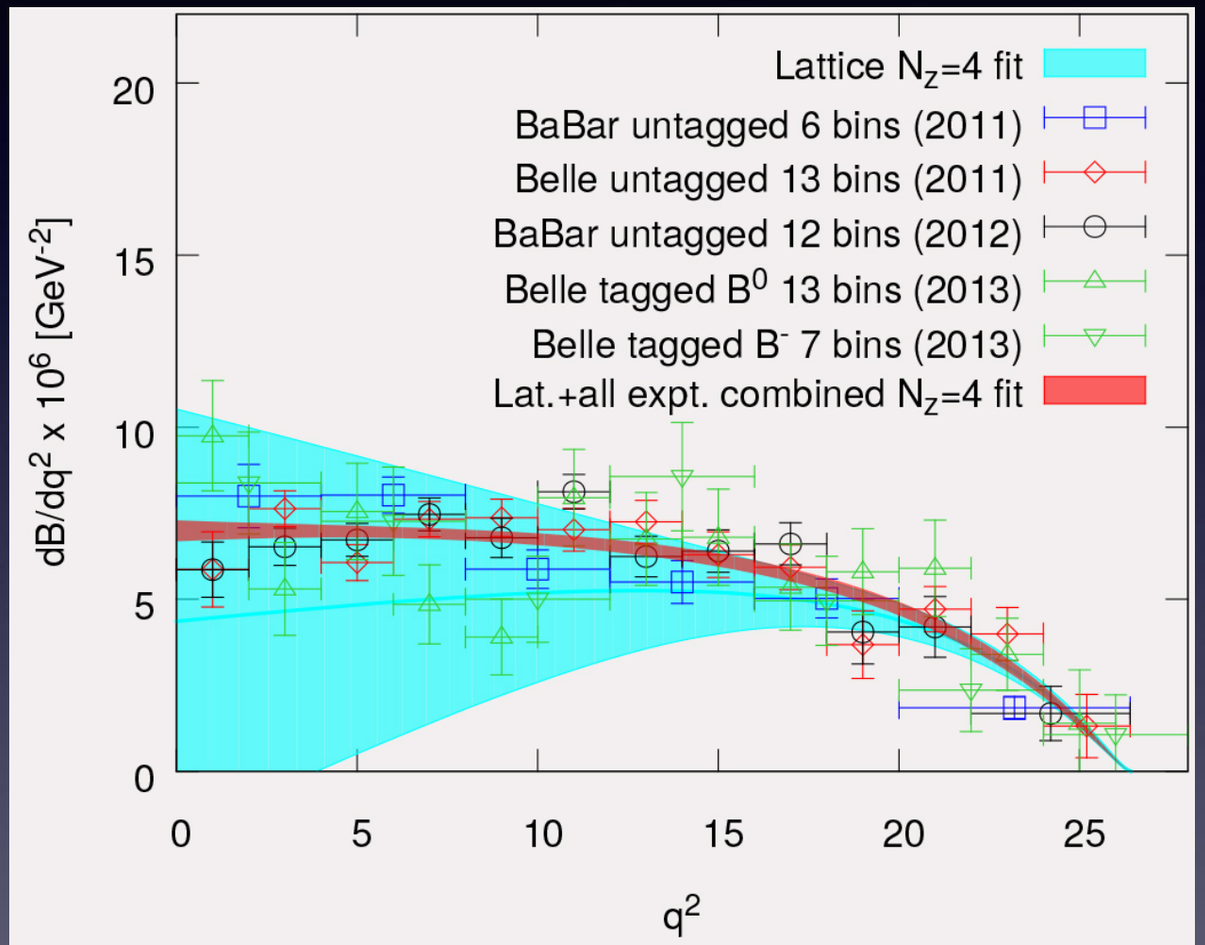
Summary

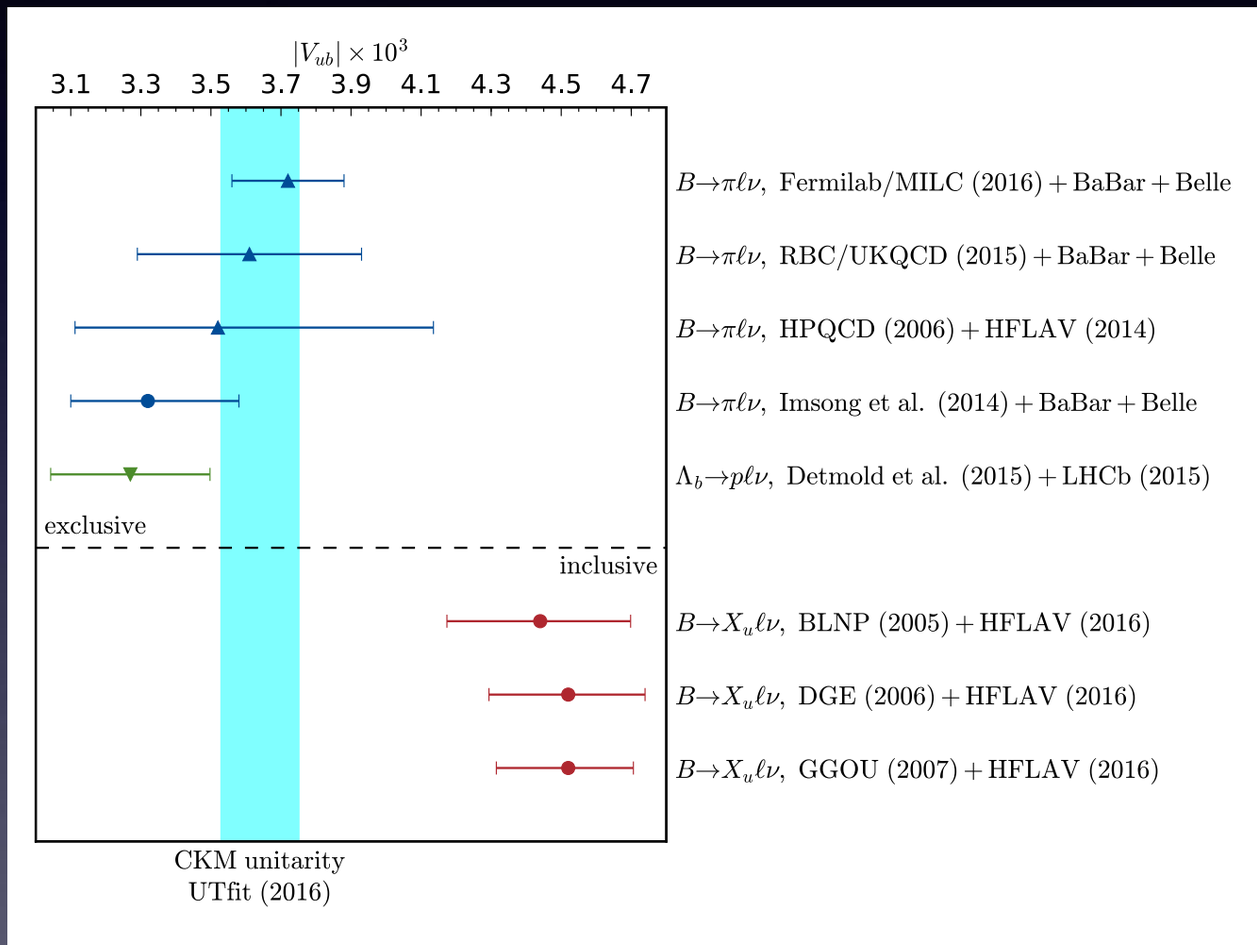
- It is now feasible to do B physics with HISQ.
- Our recent successful “all-HISQ” analysis of B, D, Bs, Ds decay constants resulted in a significant improvement in precision.
- We propose to do the same for B semileptonic decays: B->pi, Bs->K, B->K along with the corresponding D decays.
- Our aim is 1% precision for B form factors and sub percent for D.

Motivation

- Search for new physics
- Precision flavor physics is sensitive to high BSM energy scales.
- |V_ub| and |V_cb| inclusive results differ from exclusive at ~ 3 std dev.
- B -> pi ll and B -> K ll are EW-tree-level suppressed, which could expose new physics

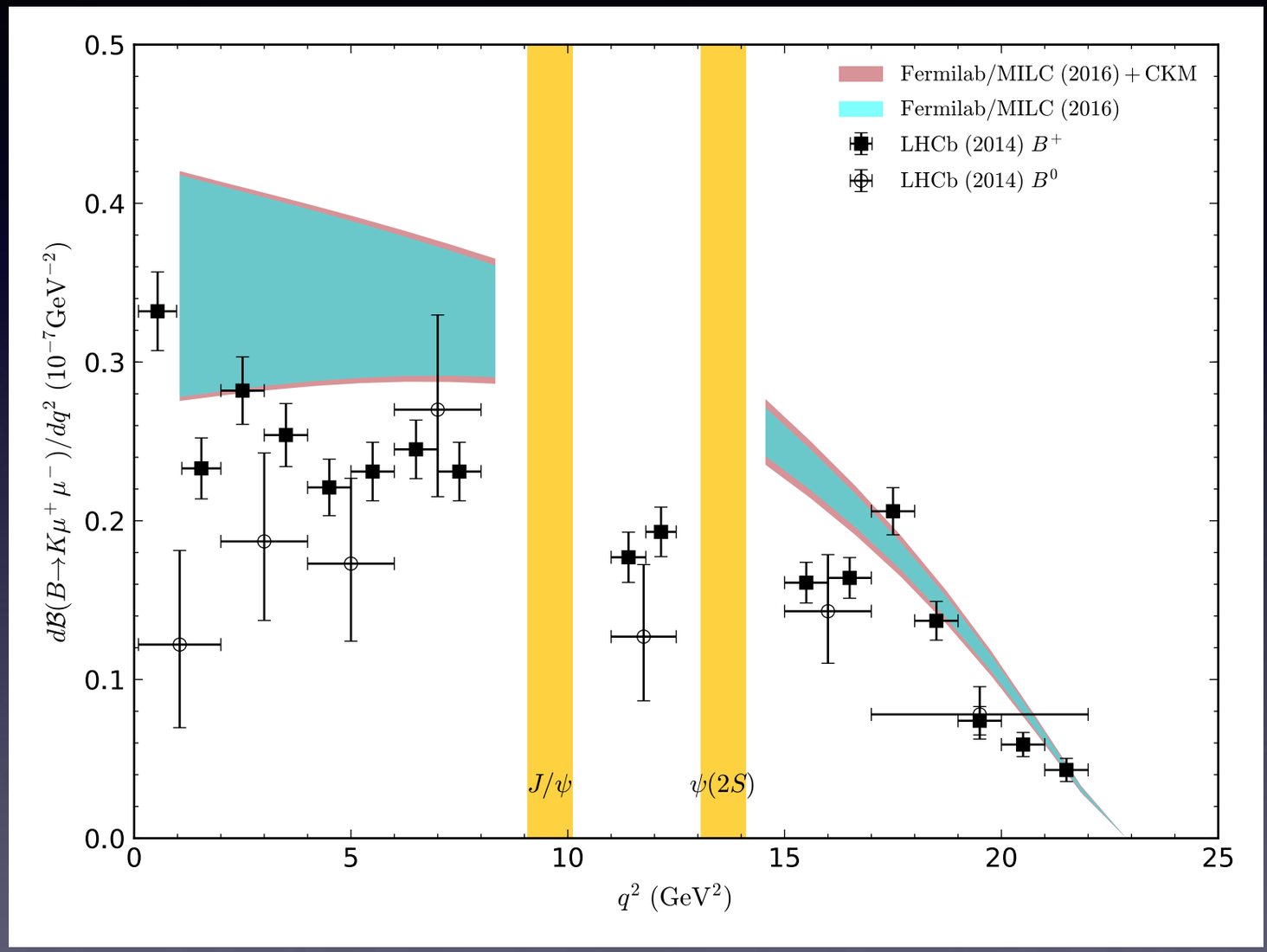
Motivation





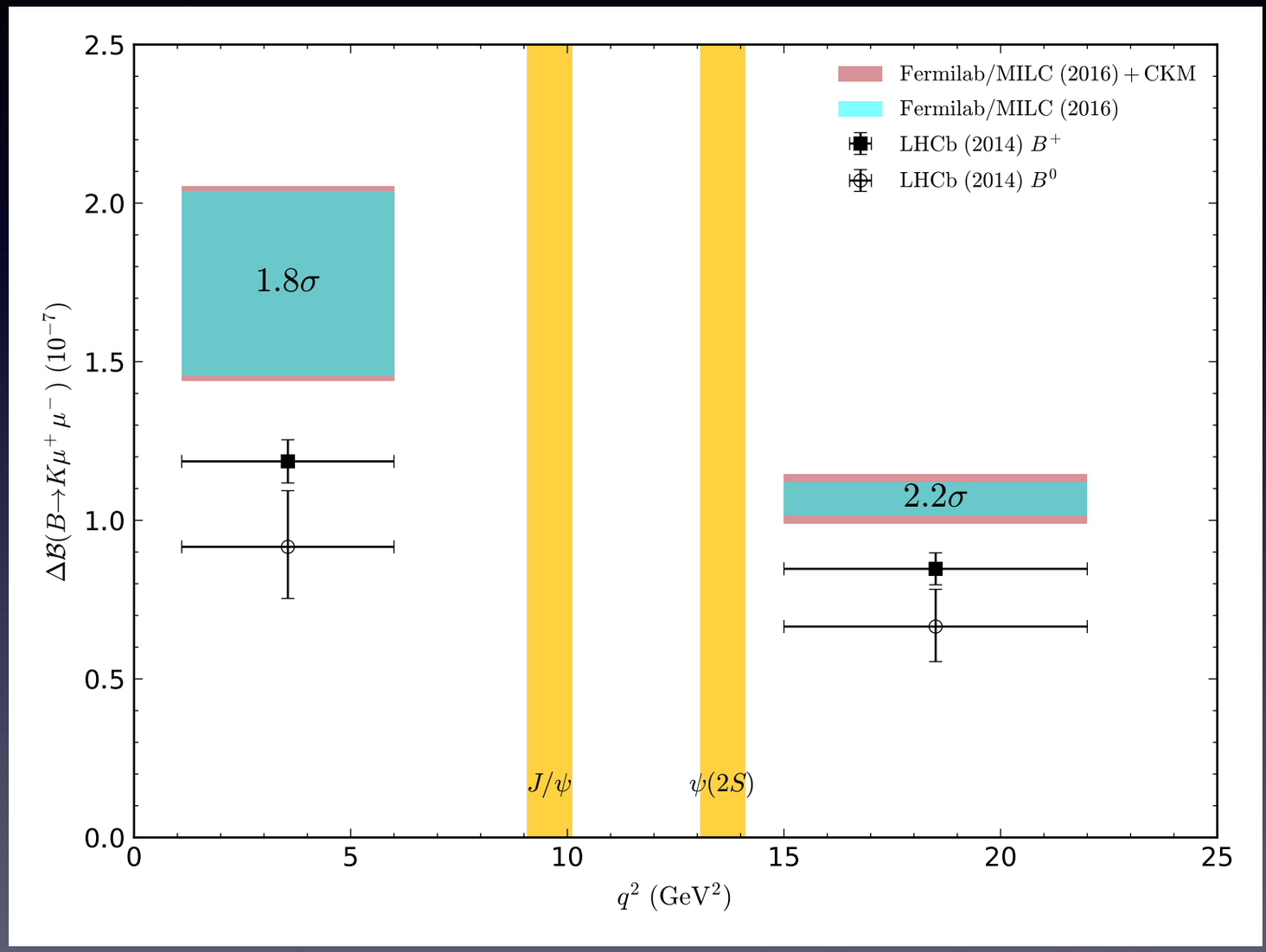
- Reduce errors in exclusive determination of V_ub

Motivation B -> K mu mu



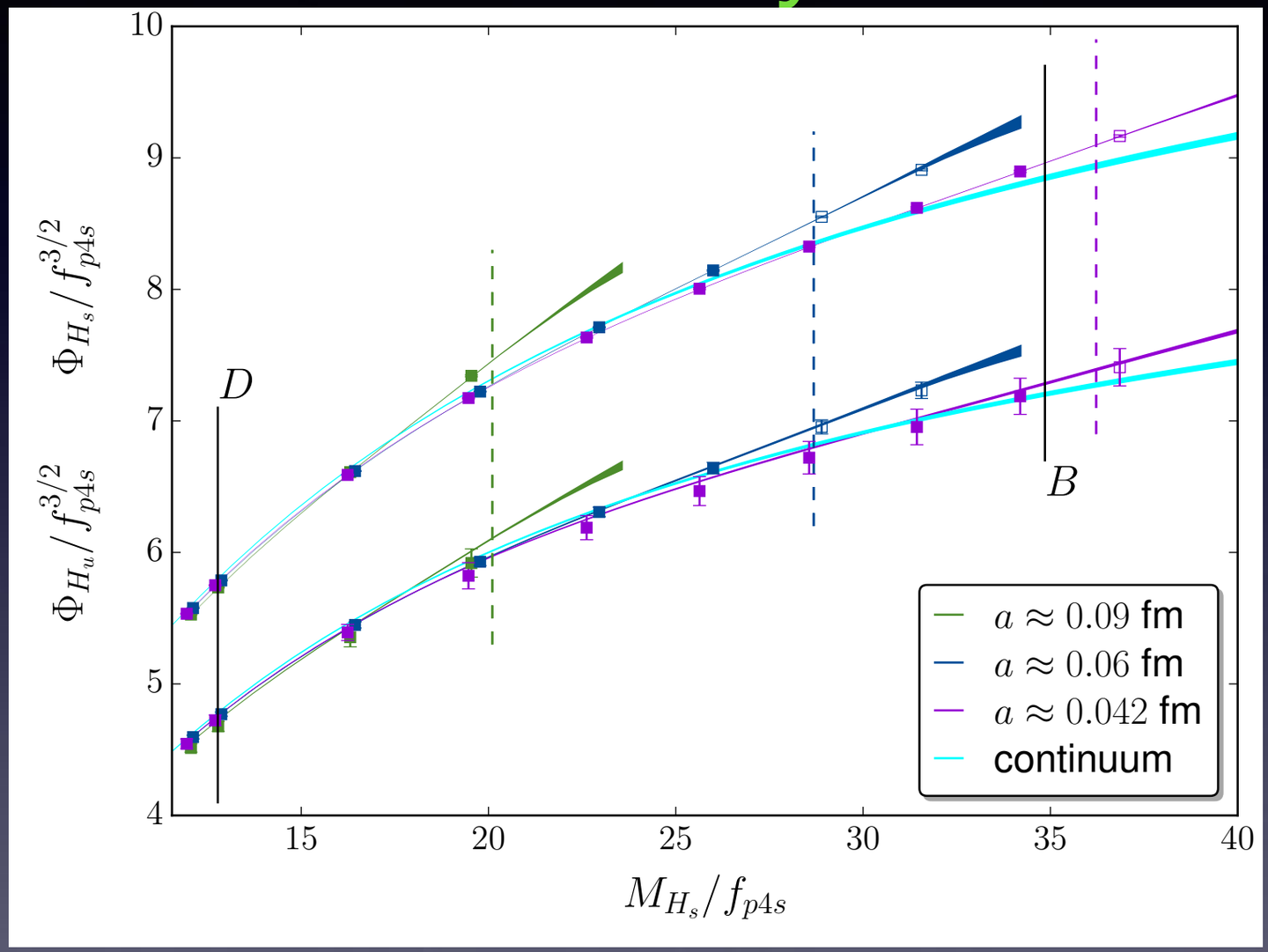
- Theoretical prediction is higher than experiment

Motivation B -> K mu mu



- Theoretical prediction is higher than experiment

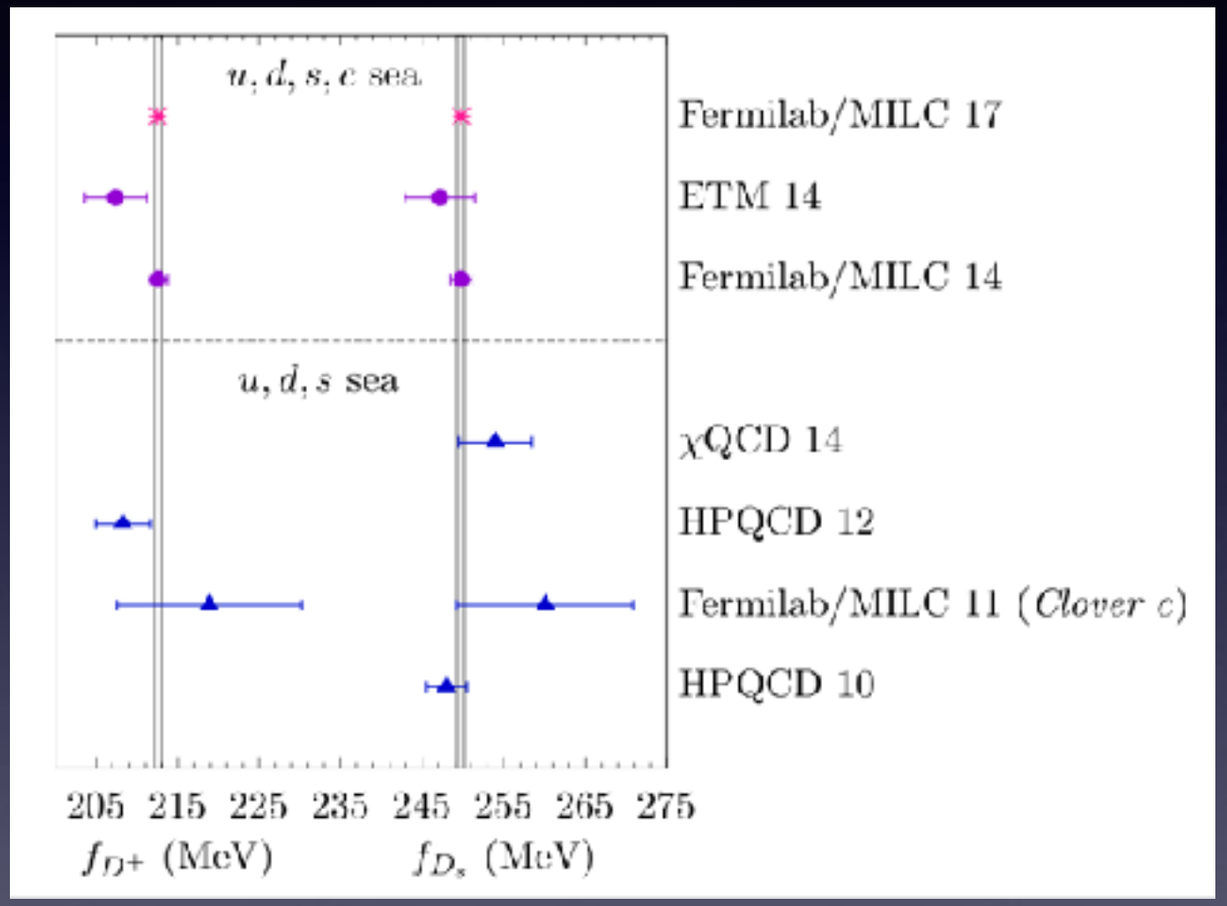
Recent all-HISQ decay constant analysis

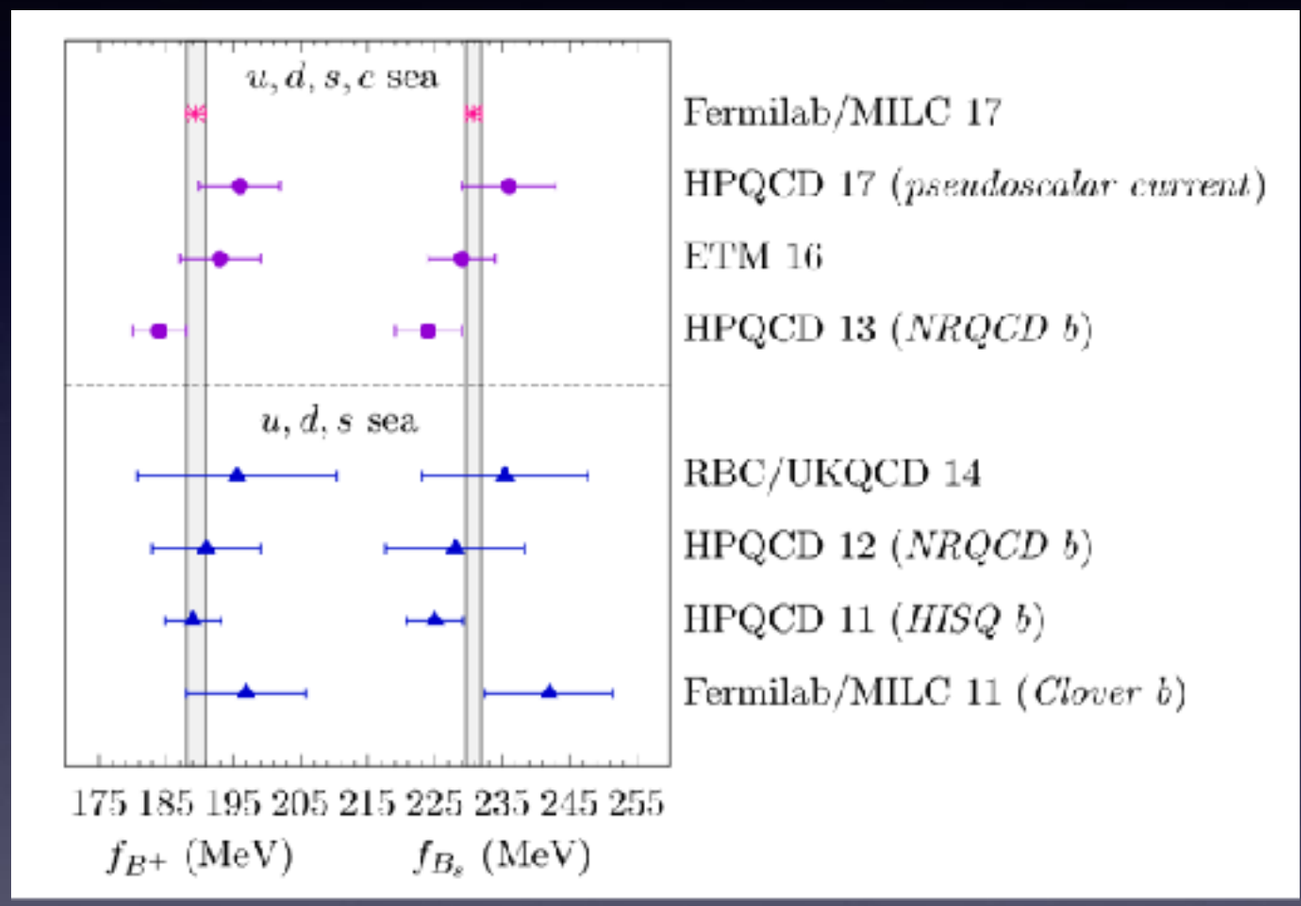


arXiv 1712.09262

- Used successful HQET-inspired model for extrapolating to the B mass. (a la HPQCD)

All-HISQ decay constant analysis



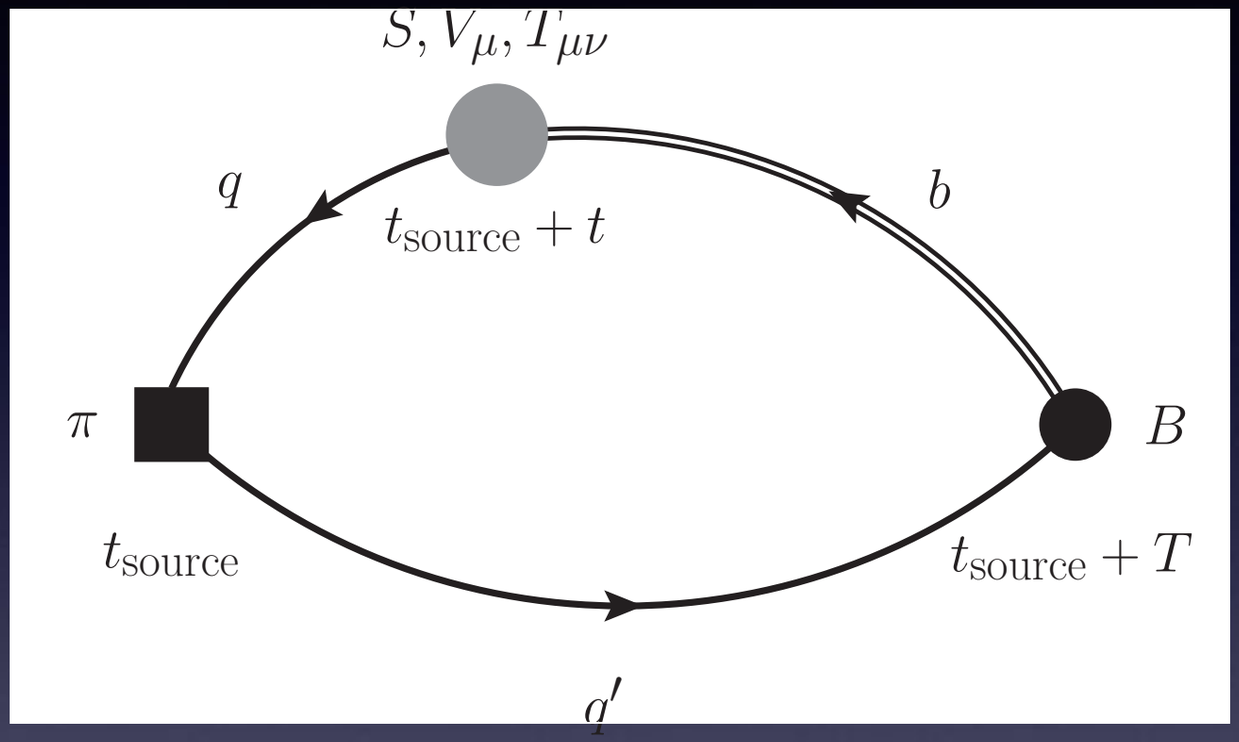


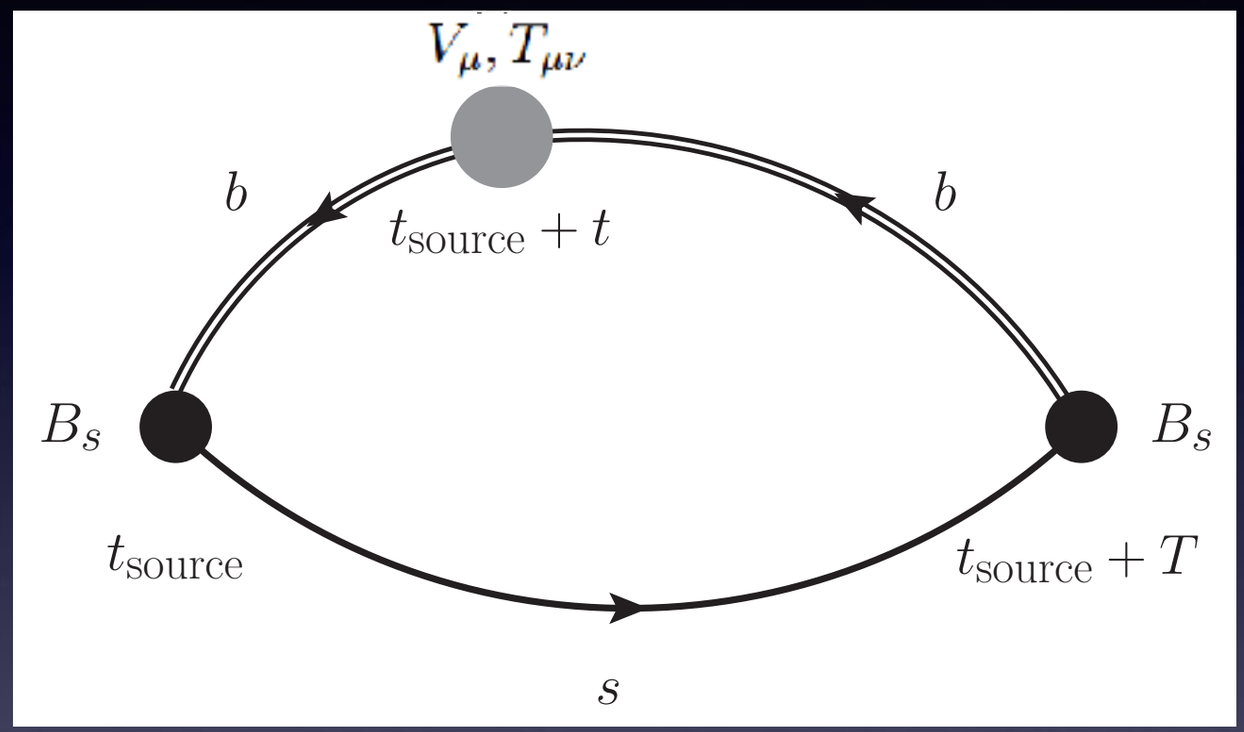
- Precision: f_D (0.2 %), f_Ds (0.2%), f_B (0.7%), f_Bs (0.5%)
- ~3X smaller than last FLAG errors
- Powerful method should be applied to form factors

Form factors to be calculated

$$
\begin{aligned}
B &\to \pi\ell\nu \\
B &\to K\ell\nu \\
B_s &\to K\ell\nu \\
B &\to K\ell\ell \\
B &\to \pi\ell\ell \\
B &\to \pi\ell\nu \\
D &\to \pi\ell\nu \\
D_s &\to K\ell\nu
\end{aligned}
$$

Methodology





- Random wall sources
- AMA to be explored

Methodology

$$
\begin{aligned}
Z_{V^0}\langle K|V^0|B\rangle &= (M_B + M_K) f_0(q^2_{\rm max}) \\
f_0(q^2) &= \frac{m_{0,c} - m_{0,s}}{M_B^2 - M_K^2}\langle K|S|B\rangle
\end{aligned}
$$

- Vector-current renormalization: Zero-recoil Ward identity (HPQCD)
- Tensor-current renormalization using “mostly nonperturbative” method (FNAL)

HISQ ensembles in place

$\approx a$ (fm)	m_l/m_s	$N_s^3 \times N_t$	$M_\pi L$	M_π (MeV)	N_{lattices}
0.15	1/5	$16^3 \times 48$	3.78	306.9(5)	1020
0.15	1/10	$24^3 \times 48$	3.99	214.5(2)	1000
0.15	1/27	$32^3 \times 48$	3.30	131.0(1)	1000
0.12	1/5	$24^3 \times 64$	4.54	305.3(4)	1040
0.12	1/10	$24^3 \times 64$	3.22	218.1(4)	1020
0.12	1/10	$32^3 \times 64$	4.29	216.9(2)	1000
0.12	1/10	$40^3 \times 64$	5.36	217.0(2)	1020
0.12	1/27	$48^3 \times 64$	3.88	131.7(1)	1000
0.09	1/5	$32^3 \times 96$	4.50	312.7(6)	1011
0.09	1/10	$48^3 \times 96$	4.71	220.3(2)	1000
0.09	1/27	$64^3 \times 96$	3.66	128.2(1)	1585
0.06	1/5	$48^3 \times 144$	4.51	319.3(5)	1016
0.06	1/10	$64^3 \times 144$	4.30	229.2(4)	1246
0.06	1/27	$96^3 \times 192$	3.69	135.5(2)	1003
0.042	1/5	$64^3 \times 192$	4.35	309.3 (9)	1167
0.042	1/27	$144^3 \times 288$	4.17	134.2(2)	452
0.03	1/5	$96^3 \times 288$	4.84	308.7(1.2)	829

Ensembles in place

To analyze on LQCD Clusters

$\approx a$ (fm)	m_l/m_s	$N_s^3 \times N_t$	$M_\pi L$	M_π (MeV)	N_{lattices}
0.15	1/5	$16^3 \times 48$	3.78	306.9(5)	1020
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Resource requirement

$\approx a$ (fm)	m_l/m_s	m_h/m_c	N_{cfg}	cost (M Jpsi core-h)
0.12	1/27	{0.9, 1.0, 2.0}	1000	1
0.09	1/5	{0.9, 1.0, 2.0, 3.0}	1000	1
0.09	1/10	{0.9, 1.0, 2.0, 3.0}	1000	2
0.09	1/27	{0.9, 1.0, 2.0, 3.0}	1000	21
0.06	1/5	{0.9, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0}	1000	5
0.06	1/10	{0.9, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0}	1000	21
0.06	1/27	{0.9, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0}	1000	–
0.042	1/5	{0.9, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5}	1000	21
0.03	1/5	{0.9, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0}	1000	–
Total				75

Status of MILC/Fermilab-Lattice flavor-physics projects

- Asqtad light + clover (Fermilab) heavy: Completing B->D* and Bs->K at nonzero recoil

- HISQ light + clover(Fermilab) heavy: Analysis is about 2/3 complete. First papers should be out this year. Currently running on non-USQCD resources.

- All-HISQ: Codes and scripts are ready. Methodology being tuned: includes testing AMA