Form Factors For Heavy → Strange Semileptonic Decays

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HPQCD

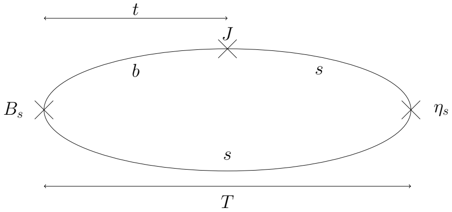
Supervisor: Dr. Chris Bouchard
B. Chakraborty: Today, 16:20, this session
D. Hatton: Tomorrow, 17:00, Had. Spec.

Overview

- Overview of heavy HISQ
- Results for $B_s \to \eta_s$ and what we can learn from it
- Moving towards $B \to K\ell^+\ell^-$
- Preliminary $B \to K\ell^+\ell^-$ and $D \to K\ell^-\bar{\nu}$ results

Overview of heavy HISQ

- Calculate meson form factors over the full range of $q^2 = (p_{\text{parent}} - p_{\text{daughter}})^2$ values
- Interested in $f_+(q^2)$ and $f_0(q^2)$ form factors for pseusoscalar to pseudoscalar decays
- Require three-point correlators with scalar and vector current insertions

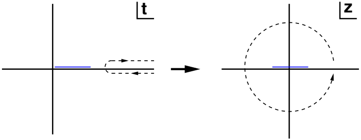


Overview of heavy HISQ

- MILC HISQ 2+1+1 ensembles. All valence quarks HISQ
- 0.09fm 0.06fm and 0.045fm lattices for $B_s \to \eta_s$
- Physical b is $am_b \approx 0.9$ on finest lattice
- Choose several heavy masses and daughter momenta for each ensemble
- Combine heavy mass fit with continuum extrapolation
- $D_s \to \eta_s$ comes 'for free'
- Cover whole physical q^2 range

Overview of heavy HISQ

$\Lambda_{\text{QCD}} = 0.5\text{GeV}$

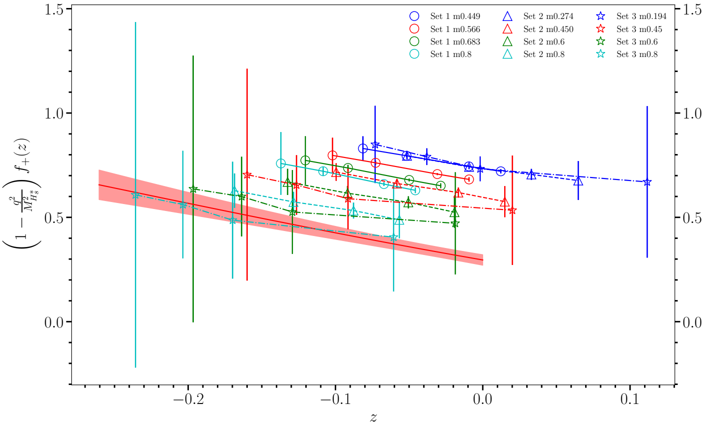


$$f_0(q^2) = \frac{1}{1 - \frac{q^2}{M^2_{H_s^0}}} \sum_{n=0}^{N-1} a_n^0 z^n,$$

$$f_+(q^2) = \frac{1}{1 - \frac{q^2}{M^2_{H_s^*}}} \sum_{n=0}^{N-1} a_n^+ \Big(z^n - \frac{n}{N}(-1)^{n-N} z^N \Big), \tag{1}$$

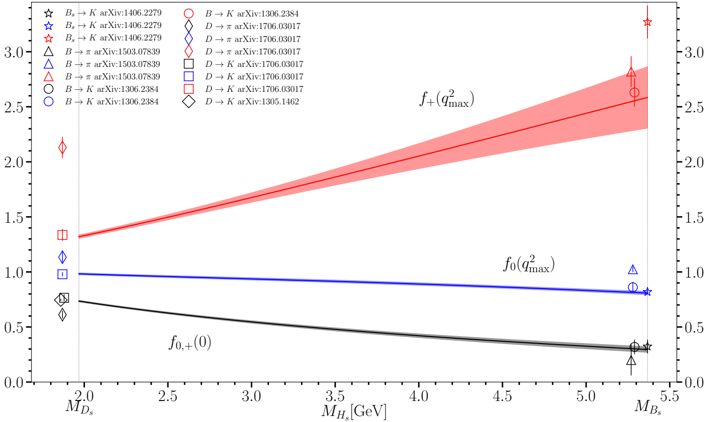
$$a_n^{0,+} = \left(1 + \rho_n^{0,+} \log\left(\frac{M_{H_s}}{M_{D_s}}\right)\right) \times \sum_{i,j,k=0}^{N_{ijk}-1} d_{ijkn}^{0,+} \Big(\frac{\Lambda_{\text{QCD}}}{M_{H_s}}\Big)^i \Big(\frac{am_h^{\text{val}}}{\pi}\Big)^{2j} \Big(\frac{a\Lambda_{\text{QCD}}}{\pi}\Big)^{2k} \times (1 + \mathcal{N}_n^{0,+}). \tag{2}$$

$B_s \to \eta_s$ results



Continuum result at the b mass in red. h-HISQ allows us to evaluate at any mass from c to b.

$B_s \to \eta_s$ results



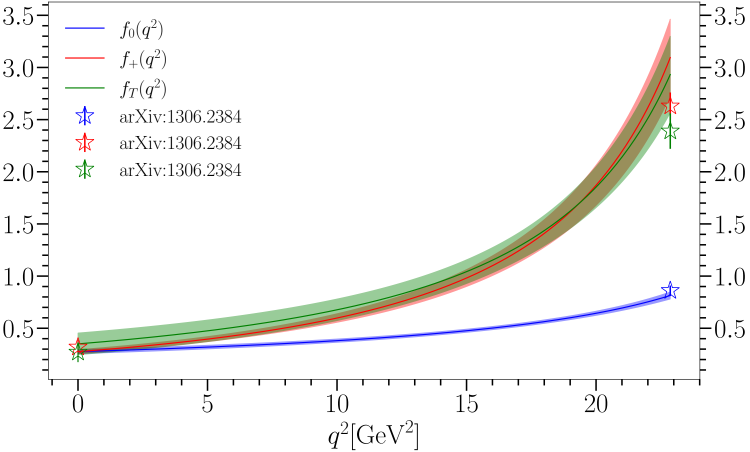
Form factors largely independent of spectator quark mass

Moving to $B \to K$

- Change spectator to light
- Calculate tensor form factor, using accurate tensor normalisation
- Include lattices with physical light quarks
- Include an overall chiral log term:

$$\text{logs} = 1 - \frac{9g^2}{8} \frac{m_l}{10m_s^{\text{tuned}}} \left(\log \left(\frac{m_l}{10m_s^{\text{tuned}}} \right) + \delta_{FV} \right) \tag{3}$$

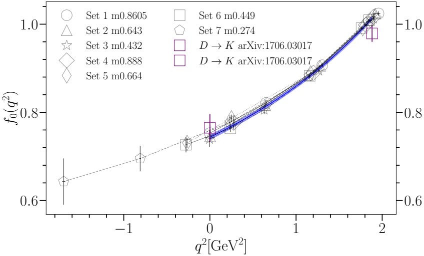
$B \to K$ preliminary results

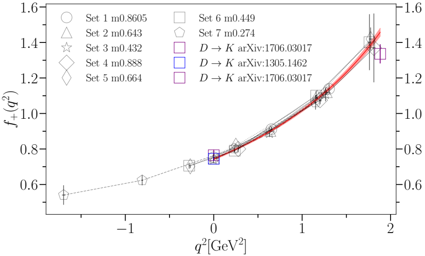


Tensor important for SM $B \to K$ due to $b \to s$ transition
Normalisation with $\mu = 2$GeV, matched to $\overline{\text{MS}}$ at 3 loop at b mass

$D \to K$ preliminary results (*B. Chakraborty, C. T. H. Davies*)

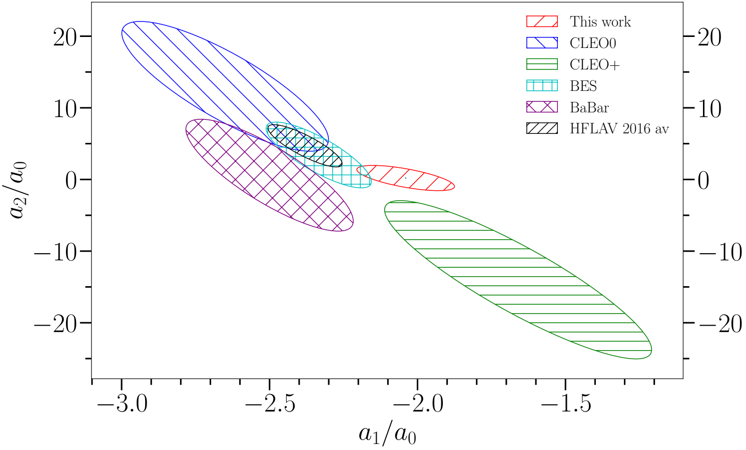
Sets 1-3 physical v. coarse to fine Sets 4-7 $m_s/m_l = 5$, *v.coarse to superfine*





- Charm mass easy to reach on ensembles
- Full q^2 range $\implies$ can compare bin by bin with exp. partial decay rate data
- Lots of good exp. data available, can compare shape

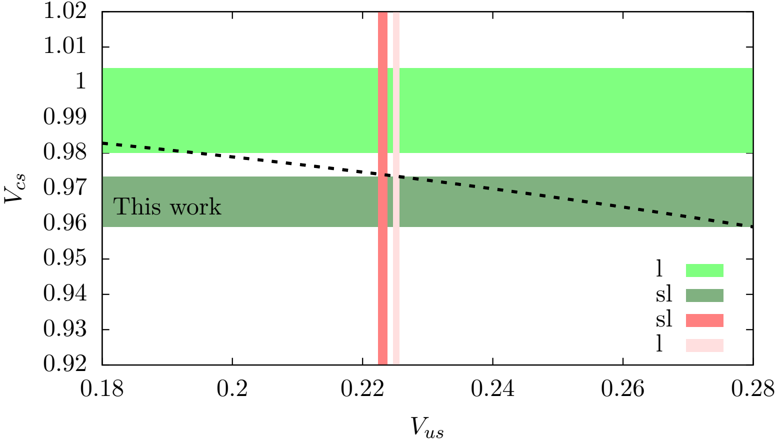
$D \to K$ preliminary results (*B. Chakraborty, C. T. H. Davies*)



One σ error ellipses. Ratios of f_+ z expansion coefficents a_n, directly comparable with experiment.

$D \to K$ preliminary results *(B. Chakraborty, C. T. H. Davies)*

Preliminary $V_{cs} = 0.9662(71)$, improvement on current PDG sl value of $0.967(25)$



Conclusions

- Heavy HISQ an effective method for studying heavy to strange decays and form factors
- Form factors largely independent of spectator quark mass
- Can improve upon $B \to K\ell^+\ell^-$ and $D \to K\ell\bar{\nu}$ results
- Improvement on V_{cs} determination from $D \to K\ell^-\bar{\nu}$ using bin by bin comparisons with experiment

Thanks for listening. Any questions?

Extra Slides

$$
\begin{aligned}
&Z_V^0 Z_{\text{disc}} \langle \eta_s | V^0 | \hat{H}_s \rangle = \\
&f_+^{H_s \to \eta_s}(q^2) \Big(p^0_{H_s} + p^0_{\eta_s} - \frac{M^2_{H_s} - M^2_{\eta_s}}{q^2} q^0 \Big) \\
&+ f_0^{H_s \to \eta_s}(q^2) \frac{M^2_{H_s} - M^2_{\eta_s}}{q^2} q^0,
\end{aligned} \tag{4}
$$

$$
Z_{\text{disc}} \langle \eta_s | S | H_s \rangle = \frac{M^2_{H_s} - M^2_{\eta_s}}{m_h - m_s} f_0^{H_s \to \eta_s}(q^2), \tag{5}
$$

Extra Slides

$$z(q^2) = \frac{\sqrt{t_+ - q^2} - \sqrt{t_+ - t_0}}{\sqrt{t_+ - q^2} + \sqrt{t_+ - t_0}}. \tag{6}$$

$$\frac{m_l}{m_s} \approx \frac{M_\pi^2}{M_{\eta_s}^2} \tag{7}$$