Hadron spectra and Δ_{mix} from overlap quarks on a HISQ sea.

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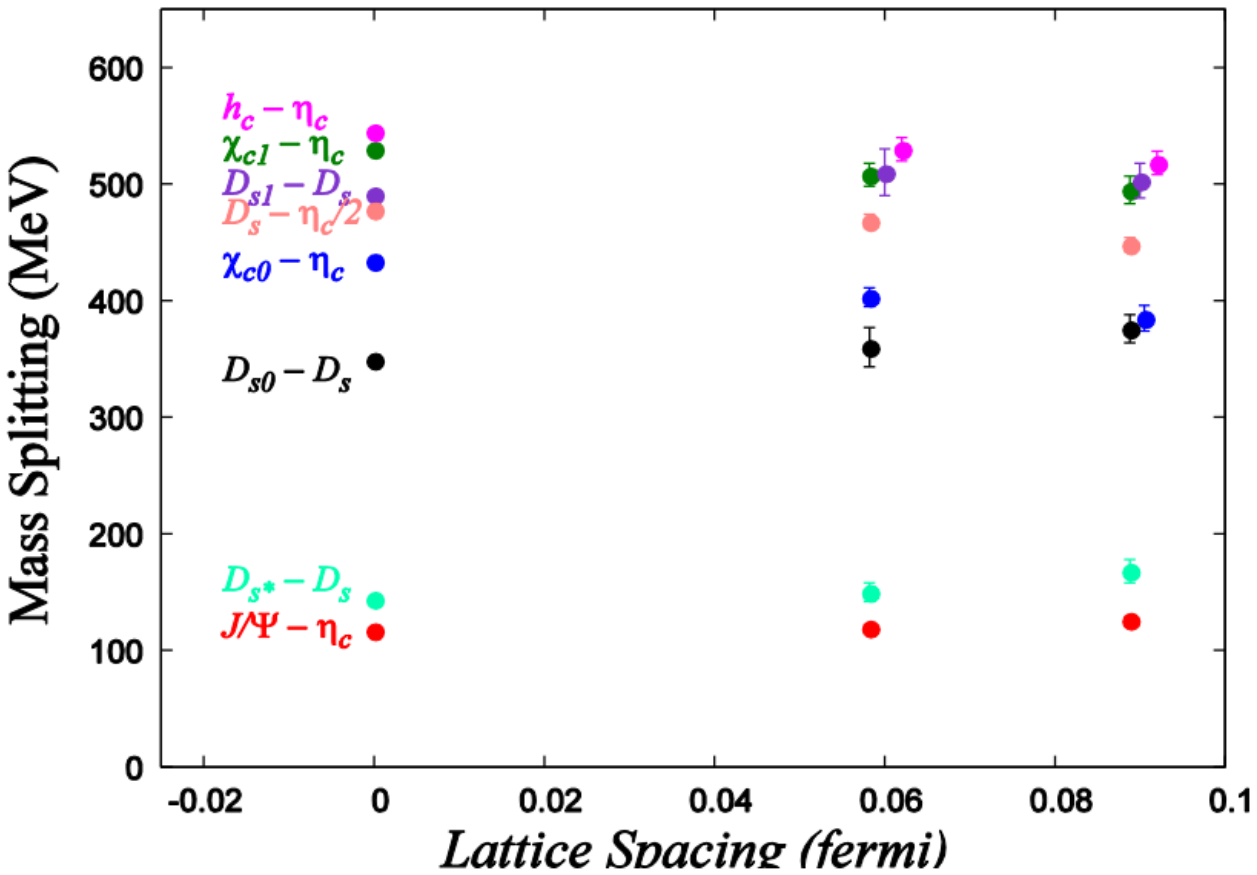
Intro/Motivation

- ILGTI program studying meson and baryon spectra, heavy-light decay constants.
- Using a mixed-action approach:
  - MILC-generated 2+1+1 HISQ ensembles, with overlap valence fermions.
  - $\rightarrow$ Fully dynamical charm at several lattice spacings, with a theoretically clean (but computationally expensive) valence sector.
- We would like to characterise mixed-action effects, which in MAχPT manifest in a single parameter, Δ_{mix}.
- Determination of Δ_{mix} is of general interest for mixed-action strategies using the HISQ ensembles.

Outline

- Ensembles
- Theory Background.
- Results.
- Comparative Analysis.
- Summary.

Charmed hadron spectroscopy.



See upcoming talk by Padmanath M.

Ensembles

MILC-generated gauge configurations w/ $N_f = 2+1+1$ HISQ (highly improved staggered) action. [1212.4768]

- charm quark $\sim$ physical
- strange quark $\sim$ physical
- $m_l/m_s = 1/5$

$24^3 \times 64$	$a = 0.121$ fm	$m_\pi = 305$ MeV
$32^3 \times 96$	$a = 0.089$ fm	$m_\pi = 313$ MeV
$48^3 \times 144$	$a = 0.058$ fm	$m_\pi = 319$ MeV

We generate overlap propagators on these configurations for a range of masses (multi-mass methods).

- No $\mathcal{O}(a)$ errors.
- Good chiral properties.
- Computationally expensive.

Δ_{mix} – Theory Background

- Low energy chiral effective Lagrangian can be described using MAχPT.
- The mixed action Lagrangian contains only one additional operator + a low energy constant, $C_{\text{mix}}\langle\tau_3\Sigma\tau_3\Sigma^\dagger\rangle$. [0503009]
- This operator shifts "mixed" meson masses in chiral formulae: $m_{vs}^2 \to m_{vs}^2 + a^2\Delta_{\text{mix}}$, [0706.0035] with $\Delta_{\text{mix}} \equiv 16C_{\text{mix}}/f^2$
- Δ_{mix} generically enters extrapolation formulae at the one-loop level, and in particular expressions for pseudoscalar decay constants, and baryon masses. [0508019]

Theory Background (cont.)

Leading order expressions for pion masses constructed from valence (v) and sea (s) action propagators are given as follows:

$$m_{vv'}^2 = B_{\mathrm{ov}}(m_v + m_{v'}) \tag{1}$$

$$m_{ss'}^2 = B_{\mathrm{HISQ}}(m_s + m_{s'}) + a^2\Delta_t \quad [\Delta_{\mathrm{GB}} = 0] \tag{2}$$

$$m_{vs}^2 = B_{\mathrm{ov}} m_v + B_{\mathrm{HISQ}} m_s + a^2\Delta_{\mathrm{mix}}\,. \tag{3}$$

Δ_{mix} can be determined for example from the y-intercept of the function

$$\delta m^2(m_v) \equiv m_{vs}^2 - m_{ss}^2/2 = B_{\mathrm{ov}} m_v + a^2\Delta_{\mathrm{mix}}\,. \tag{4}$$

Correlator fits

- We construct pion correlation functions using propagators of both the valence and the sea action.
- Mixed-meson correlation functions are constructed using one overlap propagator and one *Wilsonized* staggered propagator:

$$G_{\psi_s}(x,y) = \Omega(x)\Omega^\dagger(y) \times G_\chi(x,y)\,, \tag{5}$$

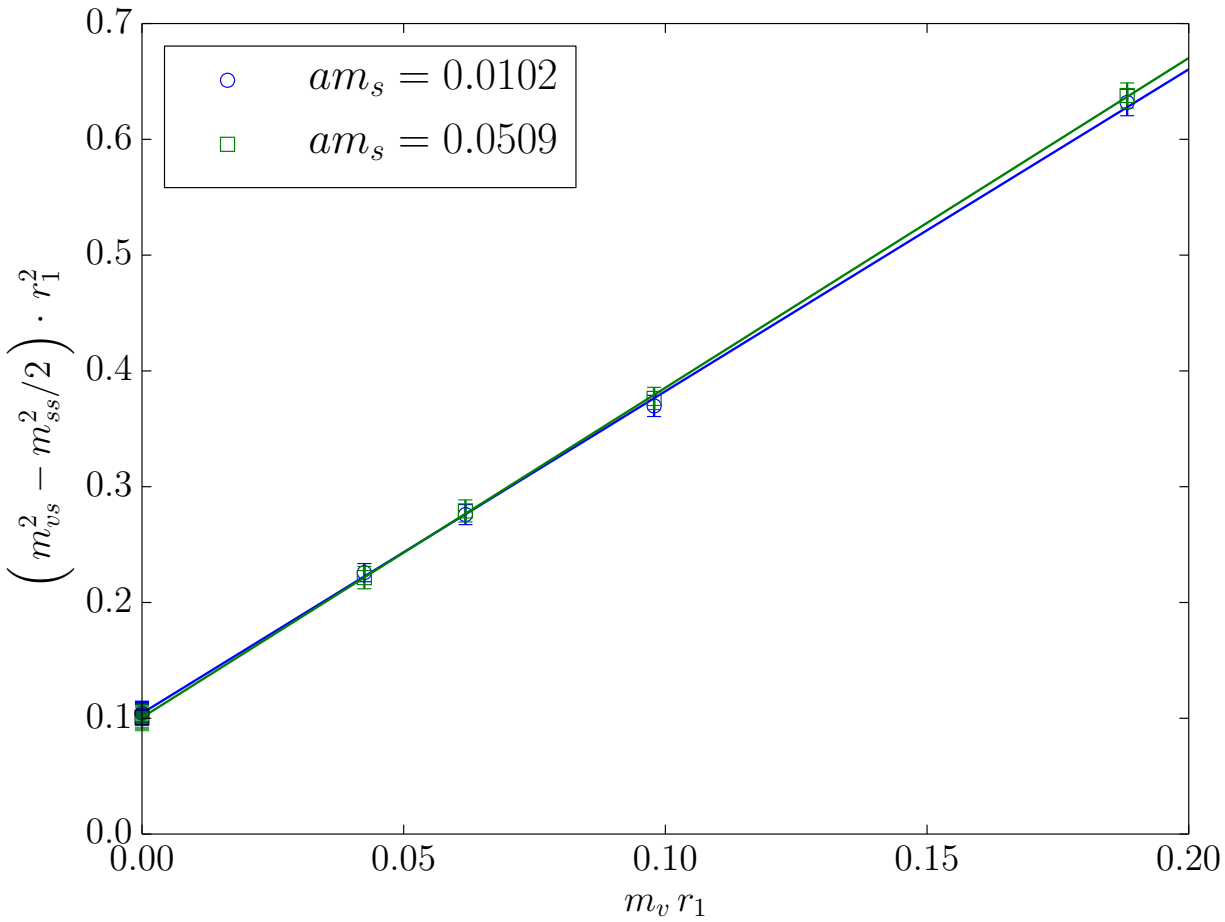
where $\Omega(x)$ is the Kawamoto-Smit transformation

$$\Omega(x) = \prod_\mu (\gamma_\mu)^{x_\mu}\,. \tag{6}$$

- Mixed-meson correlators are fit to the form

$$C^\Gamma_{vs}(t) \sim [A + (-1)^t B] \cosh(m_{vs}(t - T/2))\,. \tag{7}$$

Results – $\delta m^2(m_v)$



$\rightarrow r_1^2 a^2 \Delta_{\text{mix}} = 0.104(9)$. Result is insensitive to m_s.

Comparative Analysis

On the coarse ($a \sim 0.12$ fm) HISQ ensemble we obtain $r_1^2 a^2 \Delta_{\text{mix}} = 0.104(9) \rightarrow \Delta_{\text{mix}} \simeq 0.11$ GeV^4.

Other results in the literature include

- DW on Asqtad ($a \sim 0.12$ fm):
  $r_1^2 a^2 \Delta_{\text{mix}} = 0.207(16) \rightarrow \Delta_{\text{mix}} \simeq 0.21$ GeV^4 [0803.0129]

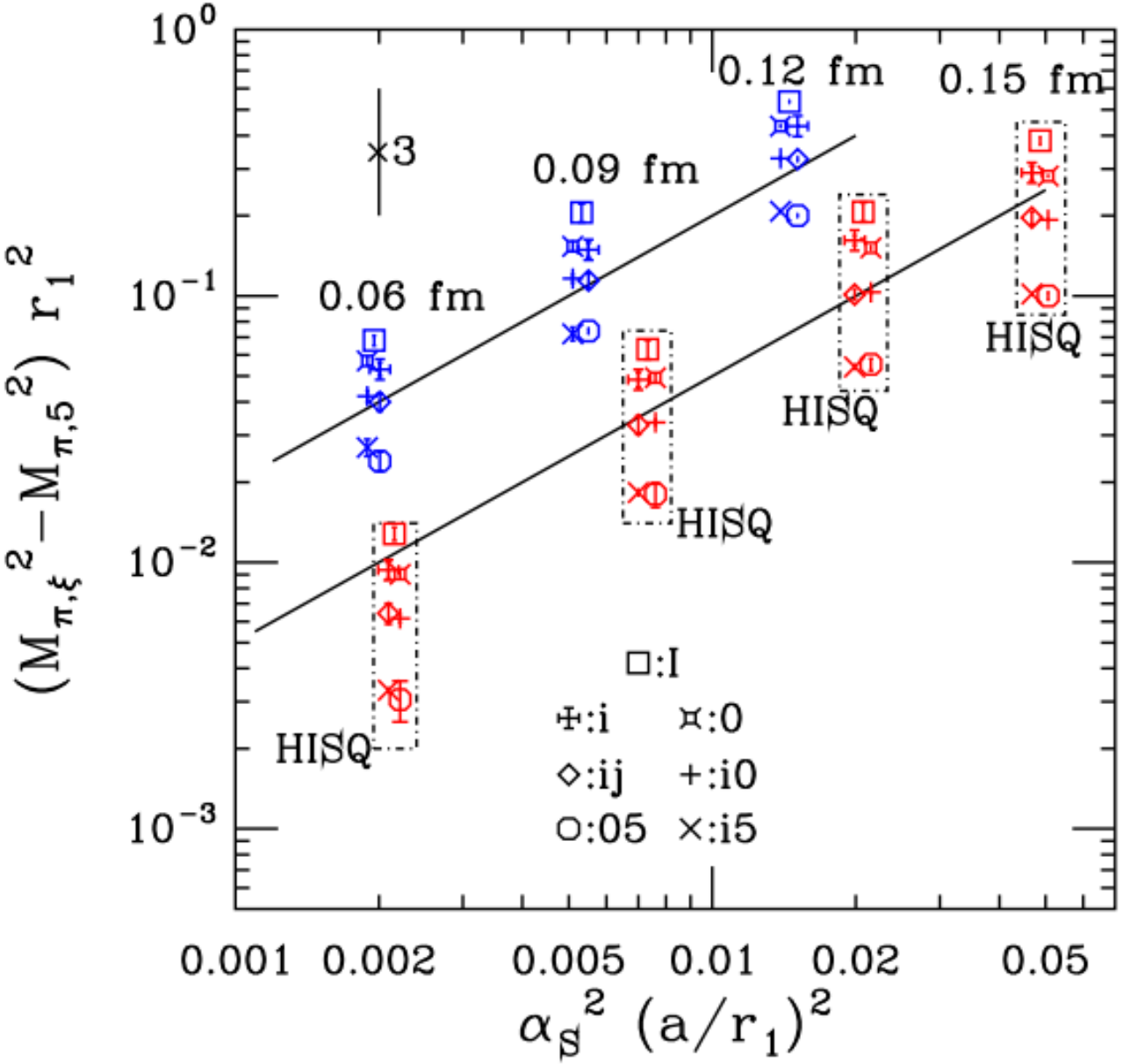
- Overlap on DW: $\Delta_{\text{mix}} \simeq 0.03$ GeV^4 [1204.6256]

Comparative Analysis (cont.)

Comparison with taste splittings Δ_t.

- It was pointed out in [0803.0129] that for DW on Asqtad $\Delta_{t(=A)} \sim \Delta_{\text{mix}}$.
- Taste splittings Δ_t for the HISQ action are reduced by a factor $\gtrsim 3$ relative to Asqtad. [1212.4768]

Comparative Analysis (cont.) [1212.4768]



Comparative Analysis (cont.)

- It was pointed out in [0803.0129] that for DW on Asqtad $\Delta_{t(=A)} \sim \Delta_{\text{mix}}$.
- Taste splittings Δ_t for the HISQ action are reduced by a factor $\gtrsim 3$ relative to Asqtad. [1212.4768]
- We find a comparable ($\sim 2\times$) reduction in Δ_{mix} for DW on Asqtad $\rightarrow$ overlap on HISQ.
  - DW on Asqtad: $r_1^2 a^2 \Delta_{\text{mix}} = 0.207(16)$
  - Overlap on HISQ: $r_1^2 a^2 \Delta_{\text{mix}} = 0.104(9)$

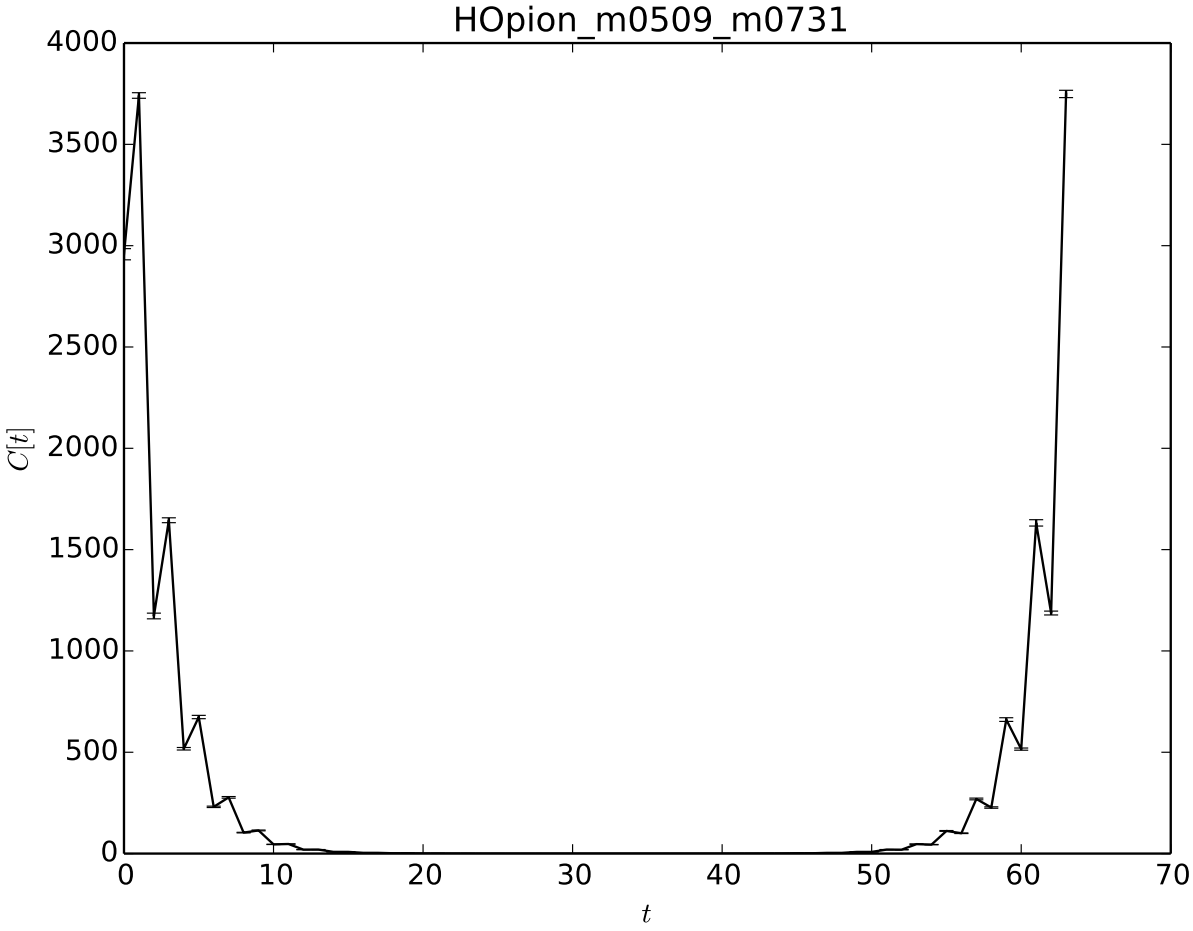
Summary

- Δ_{mix} encodes unphysical mixed-action effects, which enter chiral formulae (e.g. for baryon masses and decay constants) at the one-loop level.
- Its determination fixes the single additional LEC entering MAχPT at LO.
- On the coarse MILC HISQ ensembles ($a \sim 0.12$ fm) we find $r_1^2 a^2 \Delta_{\text{mix}} = 0.104(9)$.
- This is $\sim 2\times$ reduction in Δ_{mix} from the corresponding Asqtad ensemble, and is roughly consistent with the reduction in taste splittings from Asqtad to HISQ.
- The calculation needs to be performed on $a \sim 0.09$ fm, $a \sim 0.06$ fm? ensembles to verify a^2 scaling.

Thank you!

Additional Slides

Correlator fits



$$C^{\Gamma}_{vs}(t) \sim [A + (-1)^t B] \cosh(m_{vs}(t - T/2))$$

Correlator fits

The mixed-meson correlators $C^{\Gamma}_{vs}(t)$ all couple to the pion: $m_0 = m_{vs}$. [0705.0572]