Nonperturbative tests of the renormalisation of mixed clover-staggered currents in lattice QCD

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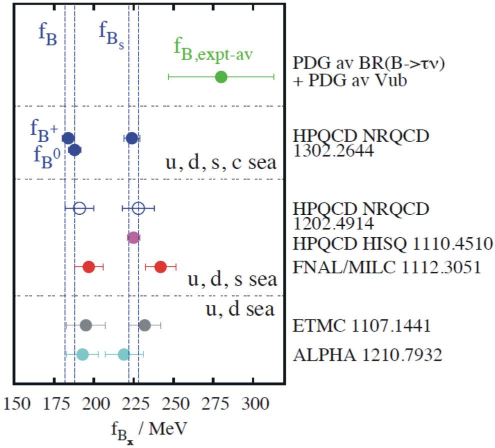
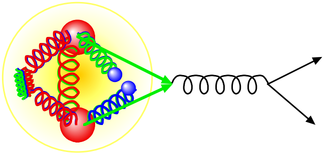
Motivation

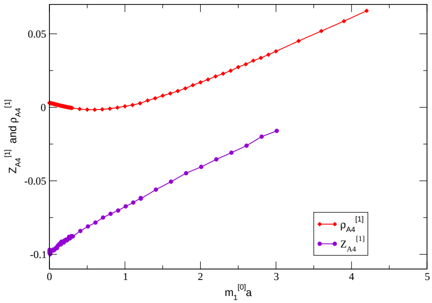




- The leptonic decay constants of heavy-light mesons: Important physical quantities in LQCD
- Different LQCD methods used to compare the systematic errors
- We focus on the systematic errors in the current renormalisations appearing in the Fermilab method

Fermilab Method and Our Aim

- Fermilab used Asqtad light valence quarks and clover bottom and charm quarks (arXiv:1112.3051)
- $Z_{A^{\mu}_{Qq}}$ calculated partly non-perturbatively and partly in one-loop perturbation theory
- Definition: $Z_{A^4_{Qq}} = \rho_{A^4_{Qq}} \sqrt{Z_{V^4_{qq}} Z_{V^4_{QQ}}}$ for local vector currents
- $\rho_{A^4_{Qq}}$ close to unity at 1-loop in lattice perturbation theory
- They believe $\rho_{A^4_{Qq}}$ close to unity for higher orders too

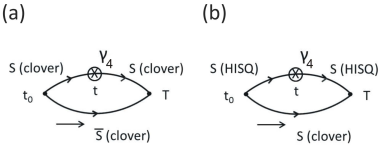


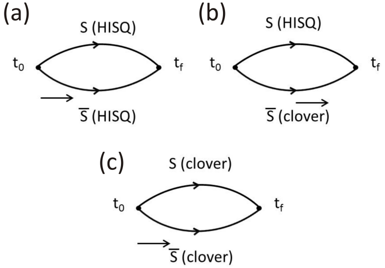
(Aida X. El-Khadra et al., arXiv:0710.1437)

Our Aim : To test the generality of this claim fully non-perturbatively using HISQ-HISQ, Clover-Clover and mixed Clover-HISQ currents made of strange valence quarks

Our method: Non-perturbative Calculation of Z_{A^4} and Z_{V^4}

- Valence strange quark masses tuned to $m_{\eta_s} = 688.5$ Mev (R.J.Dowdall et.al., arXiv:1303.1670)
- The η_s decay constant: $\langle 0|A^4|\eta_s(0)\rangle = m_{\eta_s} f_{\eta_s}$
- Absolutely normalized HISQ-HISQ temporal axial vector current
- $Z_{A^4_{Cl-H}}$ for Clover-HISQ discretization: $Z_{A^4_{Cl-H}} f_{\eta_s}^{Cl-H} = f_{\eta_s}^{H-H}$





- Normalization at zero momentum transfer: $1 = Z_{V^4_{qq}} \langle H_q|V^4_{qq}|H_q\rangle$
- Need to use local vector currents
- Need to use unstaggered (clover) quark at the bottom of the three point functions for HISQ-HISQ local vector current

Lattice Configurations and Parameters

- Three MILC lattice ensembles: $a \approx$0.15fm (very coarse), 0.12fm (coarse), 0.09fm (fine)
- $2+1+1$ flavors of HISQ sea quarks: $m_l/m_s \approx 0.2$

Set	β	a(fm)	am_l	am_s	am_c	L_s/a	L_t/a	u_0
VC	5.80	0.1543(8)	0.013	0.065	0.838	16	48	0.85535
C	6.00	0.1241(7)	0.0102	0.0509	0.635	24	64	0.86372
F	6.30	0.0907(5)	0.0074	0.0507	0.4400	32	96	0.87417

- Source: Delta function random color wall with subset corner mask
- Point sink

Set	$am_s{}^{HISQ,val}$	$\kappa_s{}^{Clover,val}$	n_{cfg}	n_t
VC	0.0705(9)(4)	0.14082	1021	12
C	0.0541(6)(3)	0.13990	527	16
F	0.0376(5)(2)	0.13862	504	16

Our Results

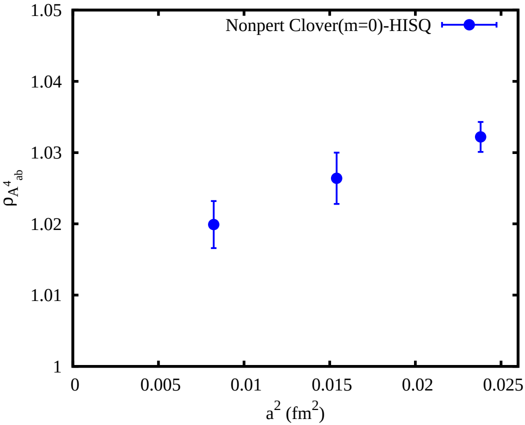
- $Z_{A^4{}_{Cl-H}} = \rho_{A^4{}_{Cl-H}} \sqrt{Z_{V^4{}_{Cl-Cl}} Z_{V^4{}_{H-H}}}$

Set	Combinations	Z_{A^4}	Z_{V^4}	$\rho_{A^4{}_{ab}}$
VC	H-H	1.000	0.9887(20)	-
	Cl-Cl	0.2046(4)	0.2045(3)	-
	Cl-H	0.4642(6)	-	1.0322(21)
C	H-H	1.000	0.9938(17)	-
	Cl-Cl	0.2096(4)	0.2071(4)	-
	Cl-H	0.4656(4)	-	1.0263(36)
F	H-H	1.000	0.9944(10)	-
	Cl-Cl	0.2152(4)	0.2116(4)	-
	Cl-H	0.4679(7)	-	1.0199(33)

- $\rho_{A^4{}_{Cl-H}}$ indeed close to 1.0 up to all orders of lattice perturbation theory
- $Z_{V^4{}_{Cl-Cl}}$ and $Z_{A^4{}_{Cl-Cl}}$ close too

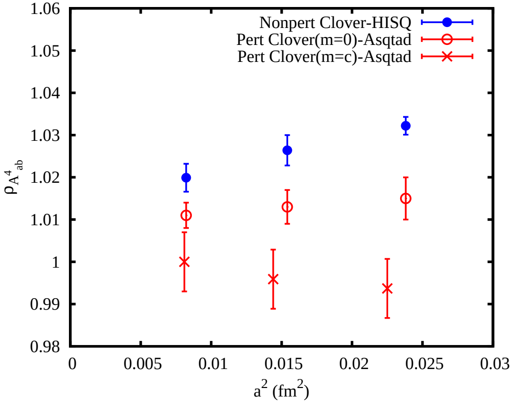
Our results for $\rho_{A^4{}_{Cl-H}}$

- $\rho_{A^4{}_{Cl-H}}$ is close to 1.0 up to all orders of lattice perturbation theory with a maximum deviation of $\sim$ 3% on very coarse lattice



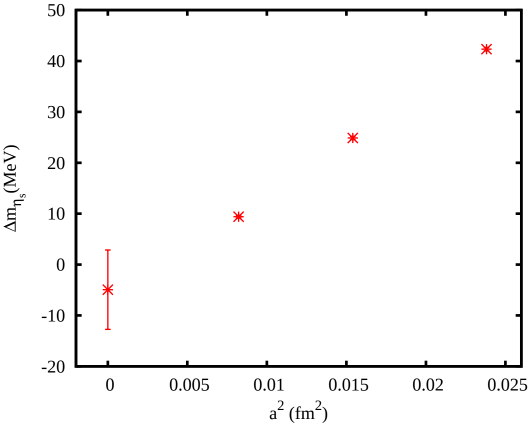
Comparison of $\rho_{A^4_{Cl-H}}$ values

- Our numbers are not actually as close to 1.0 as Fermilab's 1-loop Clover-Asqtad results
- May be sensible to increase errors from the one loop calculation up to 2.5% to encompass our numbers



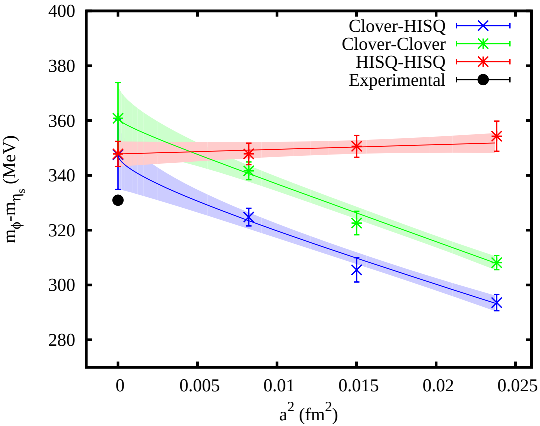
Discretization effects

- The difference of the η_s mass obtained from H-H and Cl-H methods is a discretization effect.



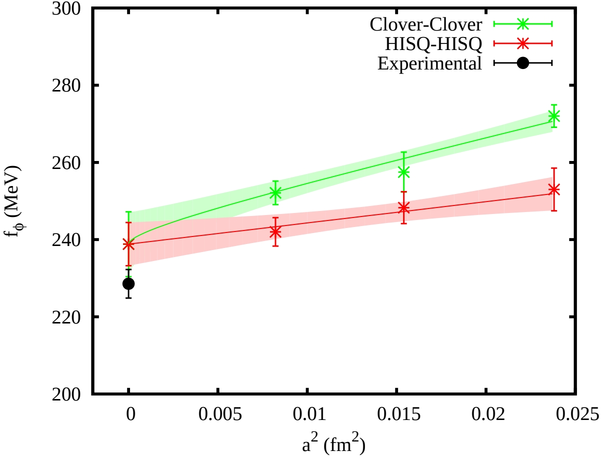
Discretization Errors: $m_\phi - m_{\eta_s}$ extrapolation to $a = 0$

- All three methods of calculating correlators agree in the continuum limit.
- H-H discretization errors much smaller than Cl-Cl and Cl-H discretizations
- Lattice results higher than the experimental result; But ϕ non-gold-plated

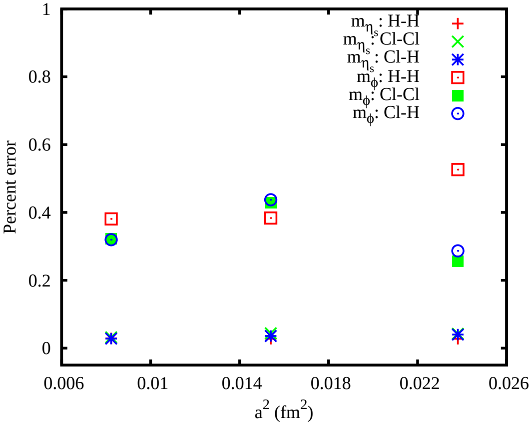


Discretization Errors: f_ϕ extrapolation to $a = 0$

- $Z_{V^4{}_{Cl-Cl}}$ and $Z_{V^4{}_{H-H}}$ used in f_ϕ
- Lattice f_ϕ results match with experimental result up to 1.5σ



Comparing Statistical Errors



- One clover propagator costs ∼4 times as much as one HISQ propagator
- One Clover propagator 16 times bigger than one HISQ propagator
- Statistical errors similar for both methods on coarse and fine lattices

Conclusion and Ongoing Work

- Conclusions:
  - $\rho_{A^4{}_{Cl-H}}$ close to 1.0 with a maximum $\sim 3\%$ deviation using the non-perturbative lattice calculations with pure HISQ, pure Clover and mixed Clover-HISQ currents.
  - Increasing Fermilab's errors from 0.7% to 2.5% in one loop perturbative calculation recommended
  - Discretization errors much smaller from HISQ than Clover
  - Statistical errors similar for Clover and HISQ on coarse and fine lattices, but Clover lot more costly
- Ongoing works:
  - To look at $\rho_{V^4{}_{Cl-H}}$ using $Z_{V^4{}_{Cl-H}}$
  - To study vector meson ϕ on the physical point lattices