Two-Color Schrödinger Functional with Six Flavors of Stout Smeared Wilson Fermions

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Lattice Strong Dynamics (LSD) Collaboration

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Motivation

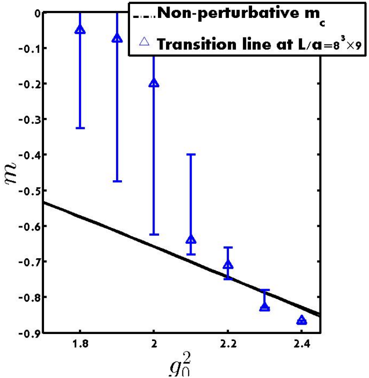
- A technicolor model based on a walking gauge theory may explain electroweak symmetry breaking while avoiding experimental constraints for SM fermion masses and flavor-changing neutral currents. Such a theory is expected to reside just below the conformal window.
- $SU(2)$ gauge theories are special in that there is an enhanced $SU(2N_f)$ global symmetry.
- Even color theories might be particularly interesting for dark matter model building.
- Evidence for IRFP at 8[1] and 10 flavors and χSB at 4 flavors[2]. Several inconclusive 6 flavors calculations.

[1] Itou et al.

[2] Karavirta et al

Smearing Motivations

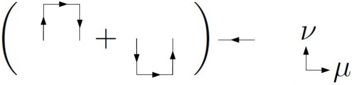
- Previously were unable to reach sufficiently large *SF* $\bar{g}^2$ with six flavors of Wilson fermions due to presence of bulk phase transition along m_c line.
- Try to get to stronger renormalized coupling by smearing the gauge field in the fermion part of the action.



Stout Smearing[3]

- Smearing technique which is analytic and therefore can be implemented in tandem with HMC algorithm.
- $\Omega_\mu(x) = \left[\sum_{\nu\neq\mu} \rho_{\mu\nu} \left(U_\nu(x)\, U_\mu(x+\hat{\nu})\, U_\nu^\dagger(x+\hat{\mu}) + U_\nu^\dagger(x-\hat{\nu})\, U_\mu(x-\hat{\nu})\, U_\nu(x-\hat{\nu}+\hat{\mu}) \right)\right] U_\mu^\dagger(x)$

  $= \sum_{\nu\neq\mu} \rho_{\mu\nu}$

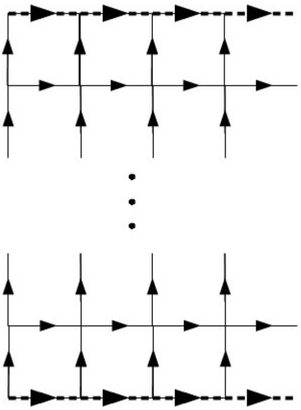
  

- $Q_\mu(x) = \frac{i}{2}\left(\Omega_\mu^\dagger(x) - \Omega_\mu(x)\right) - \frac{i}{2N}\mathrm{Tr}\left(\Omega_\mu^\dagger(x) - \Omega_\mu(x)\right)$
- $U_\mu^{(n+1)}(x) = \exp\left(iQ_\mu^{(n)}(x)\right) U_\mu^{(n)}(x)$

[3] C. Morningstar and M. Peardon

Stout Smearing with Dirichlet BC

- Care must be taken to implement smearing in such a way that the boundary gauge field is not smeared by the bulk gauge field.



Smearing of:

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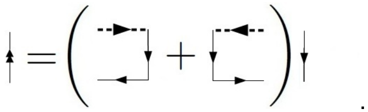

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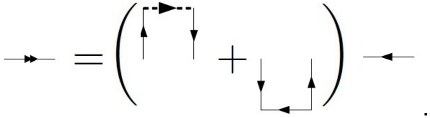

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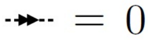

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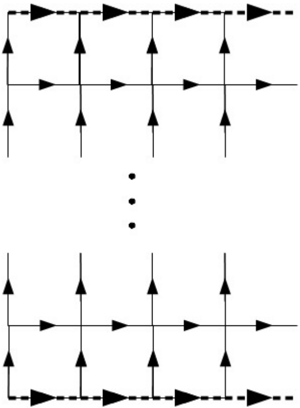

Smearing of:

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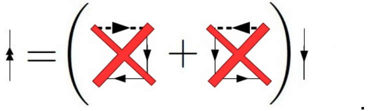

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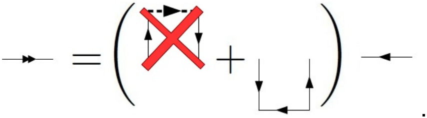

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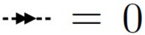


Critical Mass I

- Wilson fermion mass is additively renormalized, no chiral symmetry at $m_0 = 0$.
- Need to determine the critical mass $m_c\left(g_0^2\right)$, i.e. the input bare mass that result in zero renormalized quark mass.
- Define[4] a renormalized quark mass using the lattice PCAC relation:

$$\left\langle \frac{1}{2}\left(\partial_\mu^* + \partial_\mu\right)\left(A_{\mathrm{R}}\right)_\mu^a(x)\,\mathcal{O}\right\rangle = 2m_{\mathrm{R}}\left\langle \left(P_{\mathrm{R}}\right)^a(x)\,\mathcal{O}\right\rangle + O\left(a^2\right).$$

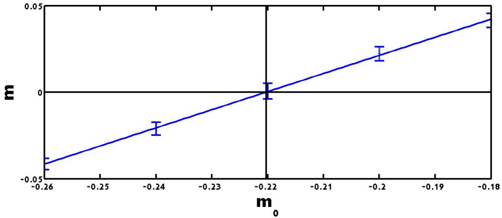
- Calculate m_{R} using Schrödinger Functional. For details see [5]

[4] M. Lüscher, S. Sint, R. Sommer, and P. Weisz

[5] M. Lüscher, S. Sint, R. Sommer, P. Weisz, and U. Wolff (1996)

Critical Mass II

- At fixed g_0^2 and L/a calculate m at a variety of m_0, around $m(m_0) = 0$, interpolate with a linear polynomial to determine



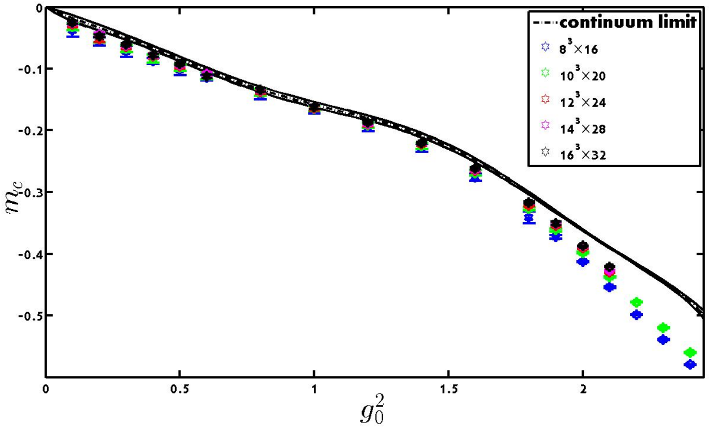
m_c:

- Do this for variety of g_0^2 and $L/a = 8, 10, 12, 14$, and 16. Fit all $m_c(g_0^2, a/L)$ to polynomial

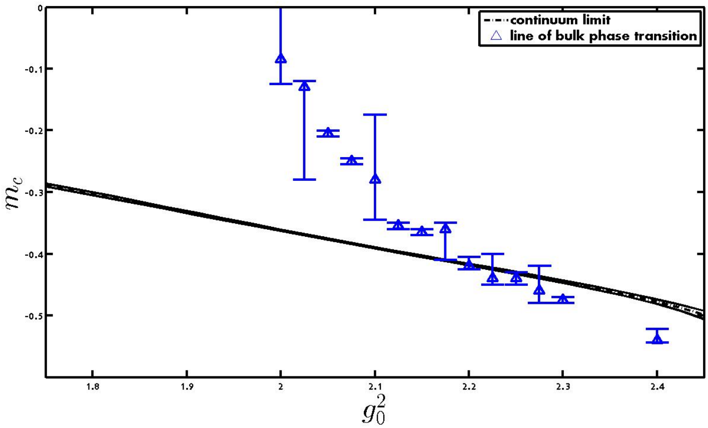
$$m_c^{\mathrm{fit}}\left(g_0^2, \frac{a}{L}\right) = \sum_{i=1}^{n}\sum_{j=0}^{1} a_{ij} g_0^{2i} \left(\frac{a}{L}\right)^j .$$

- Finally use $m_c^{\mathrm{fit}}\left(g_0^2, 0\right)$, as the critical mass to use in current and future SF $\bar{g}^2$ calculations.

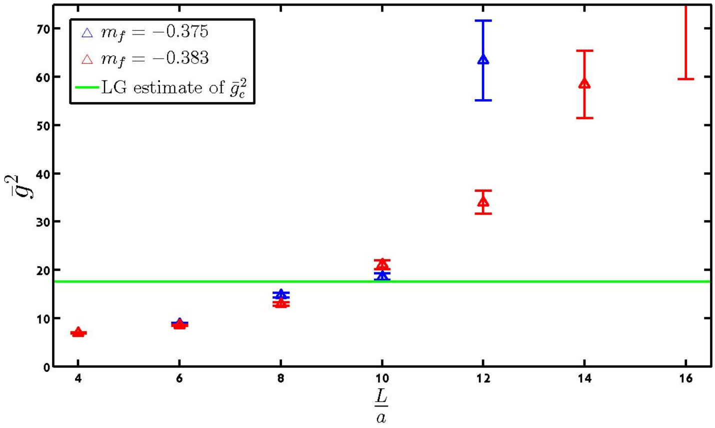
Critical Mass III



Critical Mass and Bulk Phase Transition



SF Renormalized Coupling at fixed $g_0^2 = 2.1$

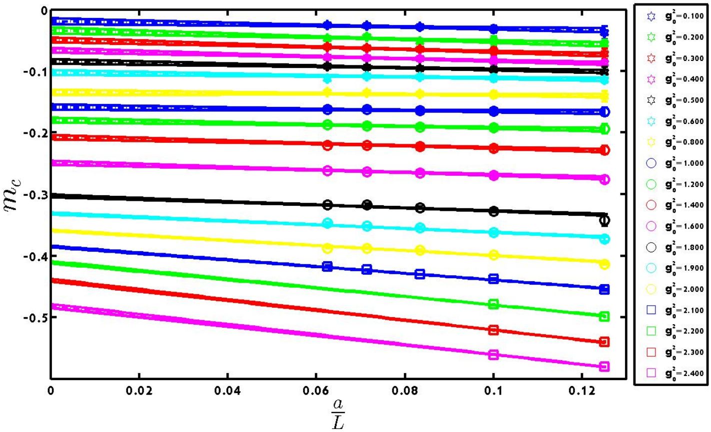


Conclusions

- Preliminary indication that $N_f = 6$ is chirally broken in the IR.
- This is not definitive. Much more running at other values of g_0^2 and a full step-scaling analysis with a continuum extrapolation is required and in progress.
- Can certainly reach a $\bar{g}^2$ sufficiently strong (according to ladder gap equations[6]) to break chiral symmetry on moderate lattice volumes without running past a lattice bulk phase transition.

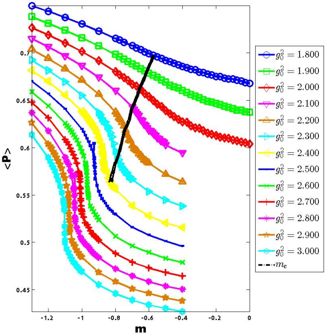
[6] K. Higashijima, A. Cohen, and H. Georgi

Backup Slide I



Backup Slide II

- Not Stout Smeared



- Stout Smeared