Twist and stout physics

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Theorems and Motivation

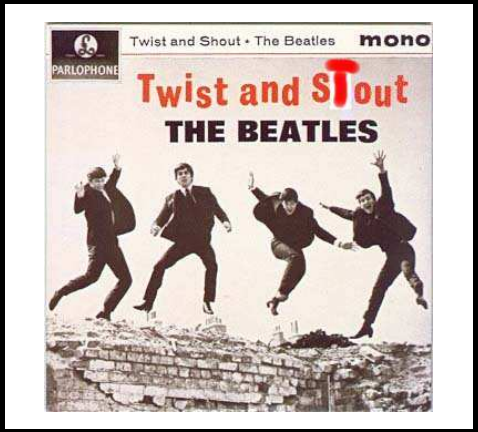
- 2+1+1 <> 2. Although the current twisted configurations are at impressive parameters, groups with 2+1 configurations, even if the pion masses are heavier, will always use the strange quark as a way to claim better results.
- 2 < 3. The current n_f =2 gauge configurations have lattice spacings of around 0.1 and 0.07 fm. To do a continuum extrapolation requires data at a third lattice spacing

Goals

- The aim is to try to use “stout” links in the twisted fermion action to evade the “phase transition” around $a \sim 0.12$ fm. Test the method with n_f =2 and then use it for n_f =2 +1 +1.
- Stout smearing is variant of fat links that have an analytic derivative with the gauge fields, so they can be used in the computation of the force.
- The stouting of the gauge links smooths the gauge fields that couple to the fermion action.

More motivation.

My first physics project based on a Beatles song



The song is available on youtube (google video).

What is stouting?

$$C_\mu(x) = \sum_{\nu\neq\mu} \rho_{\mu\nu}\Big(U_\nu(x)U_\mu(x+\hat{\nu})U_\nu^\dagger(x+\hat{\mu}) + U_\nu^\dagger(x-\hat{\nu})U_\mu(x-\hat{\nu})U_\nu(x-\hat{\nu}+\hat{\mu})\Big),$$

$$Q_\mu(x) = \frac{i}{2}(\Omega_\mu^\dagger(x)-\Omega_\mu(x)) - \frac{i}{2N}\mathrm{Tr}(\Omega_\mu^\dagger(x)-\Omega_\mu(x)),$$

$$\Omega_\mu(x) = C_\mu(x)\, U_\mu^\dagger(x), \quad \text{(no summation over } \mu\text{)}$$

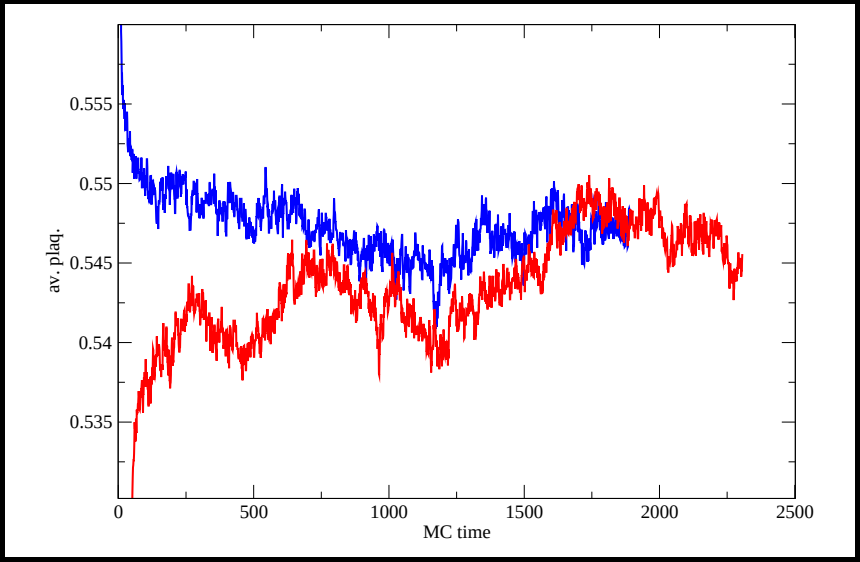
$$U_\mu^{(n+1)}(x) = \exp(iQ_\mu^{(n)}(x))\, U_\mu^{(n)}(x).$$

Codes and things

The hmc application in the chroma package has code to generate twist+stout n_f=2 configurations.
Chroma has been used to generate configurations on a BlueGene (Karl and Carsten) and some 256 node QCDOC machines.
I added code to stout smear the gauge configuration in the "ETMC" code. (The stout smearing has NOT been added to the force term).
We use ρ = 0.1 and 1 iteration of stouting.

Past problems

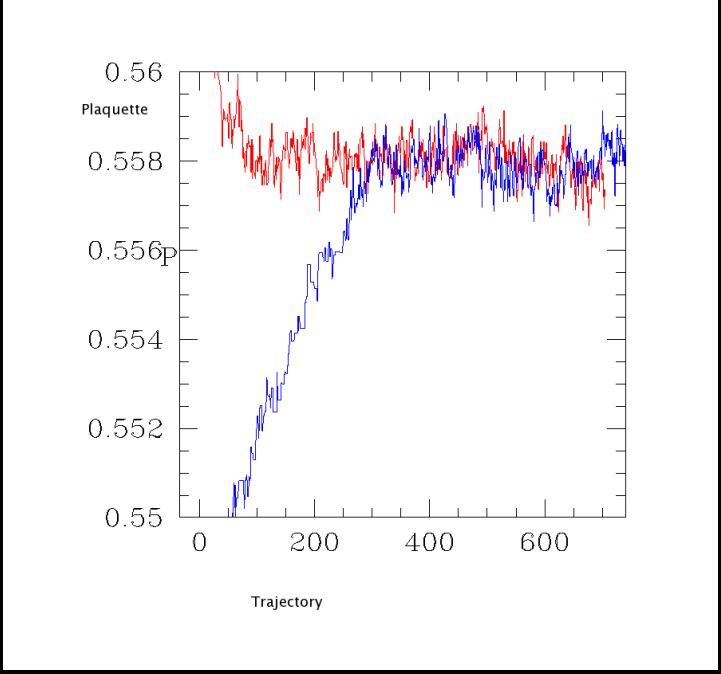
From hep-lat/0509131, using twisted mass fermions with tree level Symanzik gauge action at β = 3.65, $12^3\ 24$.



At β = 3.75 the minimum pion mass was found to be 400 MeV (hep-lat/0509131).

No nasty phase transition (yet)

For the parameters κ = 0.1525, β = 3.75, μ = 0.005, $16^3\ 32$, with stout smearing. Plaquette as a function of trajectory from cold and hot starts.



Where are we in parameter space?

Very preliminary results, $16^3\ 32\ \mu = 0.005$, β = 3.75.

κ	a m_{pcac}	a m_π	r_0/a
0.1475	0.416(7)	1.25(2)	2.73(5)
0.150	0.313(3)	1.07(1)	3.16(5)
0.1525	0.186(1)	0.791(8)	4.5(2)

$\frac{1}{a} \sim 2$ GeV, so the pions are very heavy.
The r_0/a values were computed by Chris Richards (graduate student at Liverpool).

Possible problems

- Fattening or stouting will probably reduce renormalisation factors. This may not be important when non-perturbative renormalisation is used, but it is useful to have one loop expressions.
- For staggered fermions the smoothing reduced flavour symmetry violation. This was explained by Lepage as a form factor.
- The stouting of the gauge links in the fermion action is perhaps a a bit ugly.

Conclusions

- The twist and stout tuning runs are ongoing. No “show-stopers” seen yet.
- Most of the analysis code is set up, so project should speed up.
- For production this is both more work, and yet less work. Lattices smaller than $24^3\ 48$ are easier to work with.

If the collaboration had configurations with 300 MeV pions, 2+1+1 flavours of sea quarks, and continuum limits using three lattice spacings, then we would be solving QCD.