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Exploring the phase diagram of sextet QCD

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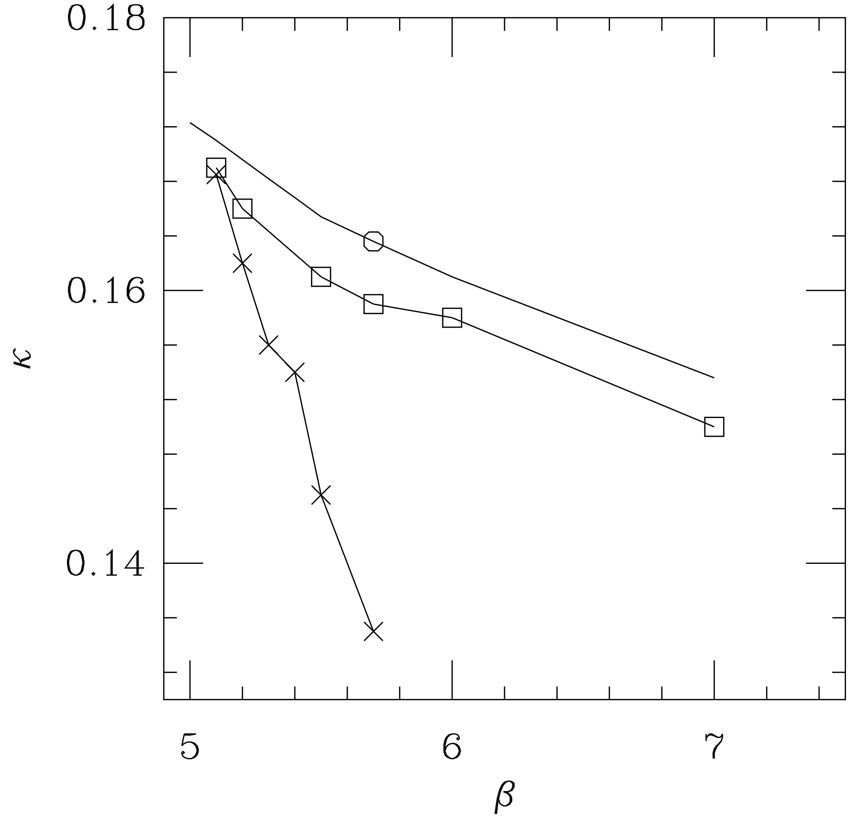
Overview

- Follow up to Schrodinger functional study (Svetitsky's talk)
- What we did
- What we saw
  - Near the $N_t = 8$ deconfinement line
  - Near the $N_t = 8$ chiral restoration line
  - At small quark mass
- Trying to sum up

Disclaimer – this is exploratory, people have not been doing simulations on this model since 1981!

The Big Picture



What we did

- $N_c = 3$, $N_f = 2$, symmetric rep clover fermions
- Scan parameter space, try to find lines of constant physics
- Use finite size as "marker" for scales (as in SF)
- Bulk of simulations
  - $8^3 \times 12$ and 12^4 for spectroscopy, potential
  - $(12 \times 8^2) \times 8$ for chiral and deconfinement crossovers
  - $12^3 \times 8$ for some deconfinement
  - 12^4 search for scaling
- "P+A" trick
- Trade κ, κ_c for AWI quark mass

$$\partial_t \langle A_0(t) X(0) \rangle = 2m_q \langle P(t) X(0) \rangle \tag{1}$$

Connection to conformal physics?

IRFP, if there, would appear as peculiar behavior

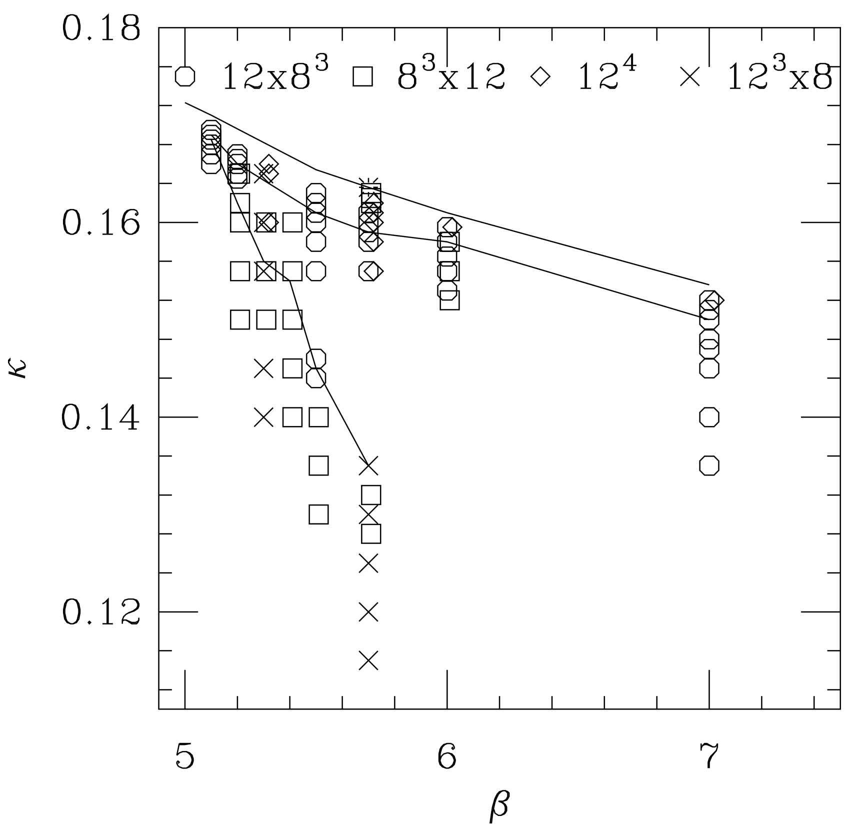
- No confinement, Coulombic potential
- No chiral symmetry breaking, $f_\pi \longrightarrow 0$
- ???

BUT

- Discretization effects break conformal symmetry
- Finite volume breaks conformal symmetry
- Nonzero mass breaks conformal symmetry

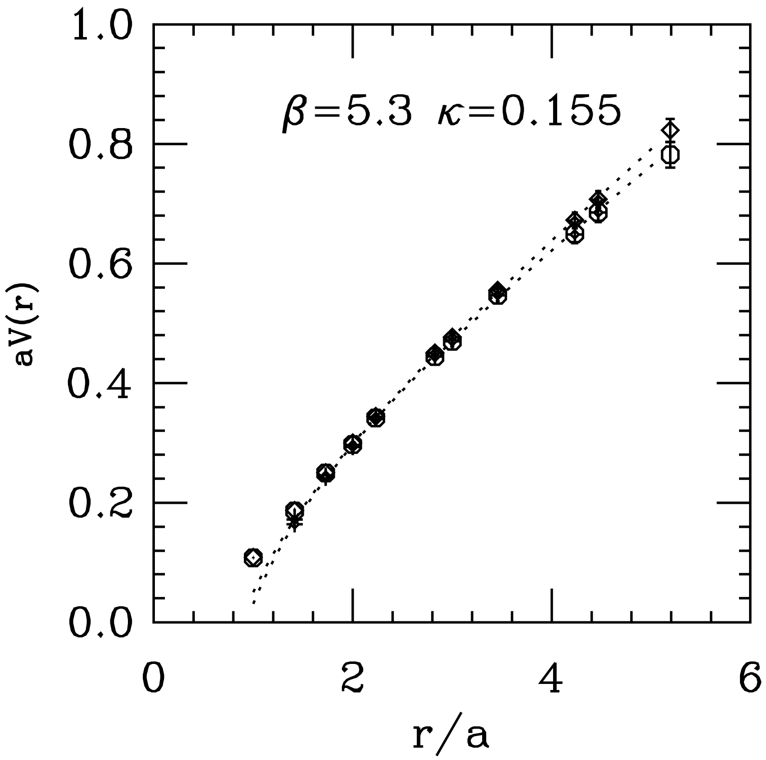
Where we simulated

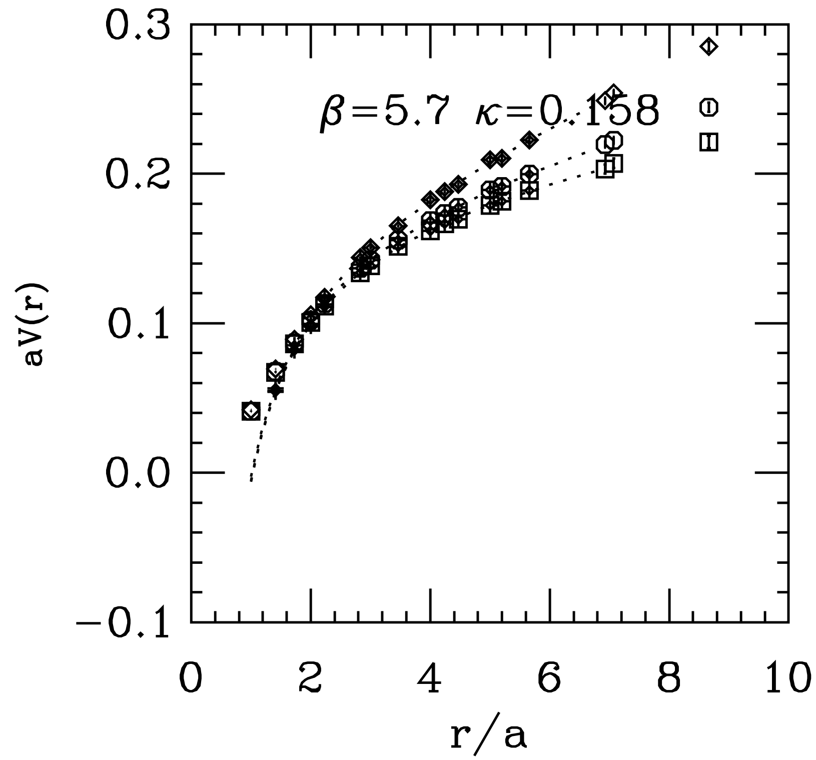
- 8^4, $(12 \times 8^2) \times 8$ as rounded finite temperature ($N_t = 8$)
- $8^3 \times 12$ when confinement physics sets in, for $V(r)$
- $12^3 \times 8$ slightly better finite temperature
- 12^4 slightly better zero temperature



Along the $N_t = 8$ deconfinement line

- Observe order-disorder transition in Polyakov loop
- "Conventional" $V(r)$ measurements show rapid increase in r_0/a, rapid fall in $a^2\sigma$ as β rises, m_q falls

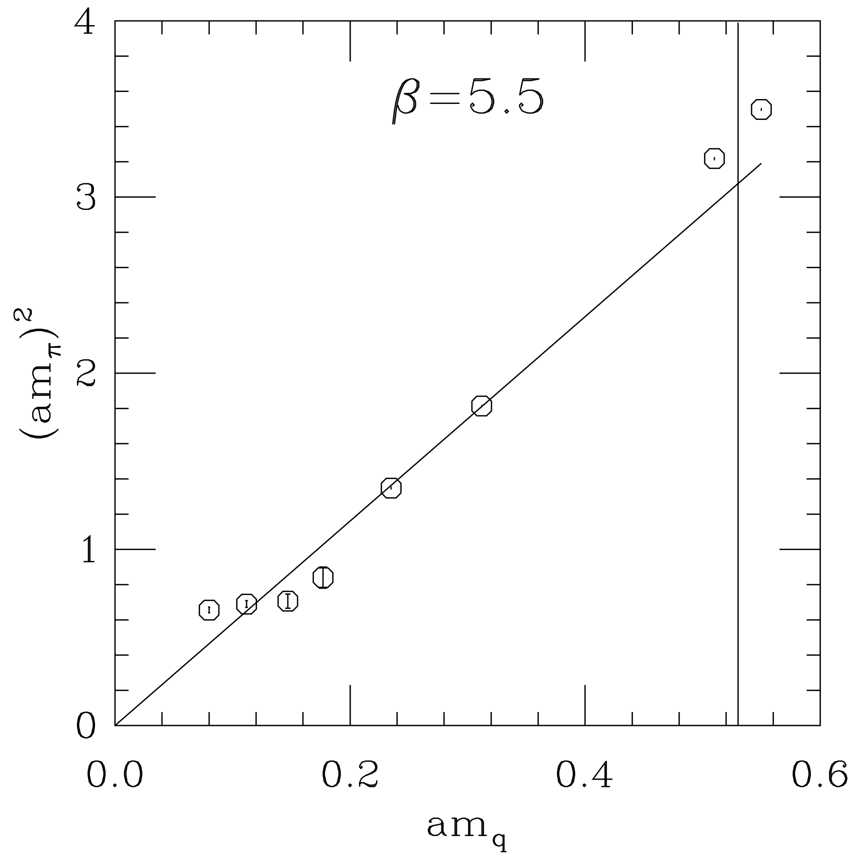




Confinement length (as seen by T_c and $V(r)$) is squeezed out of the volume

Scale separation - I

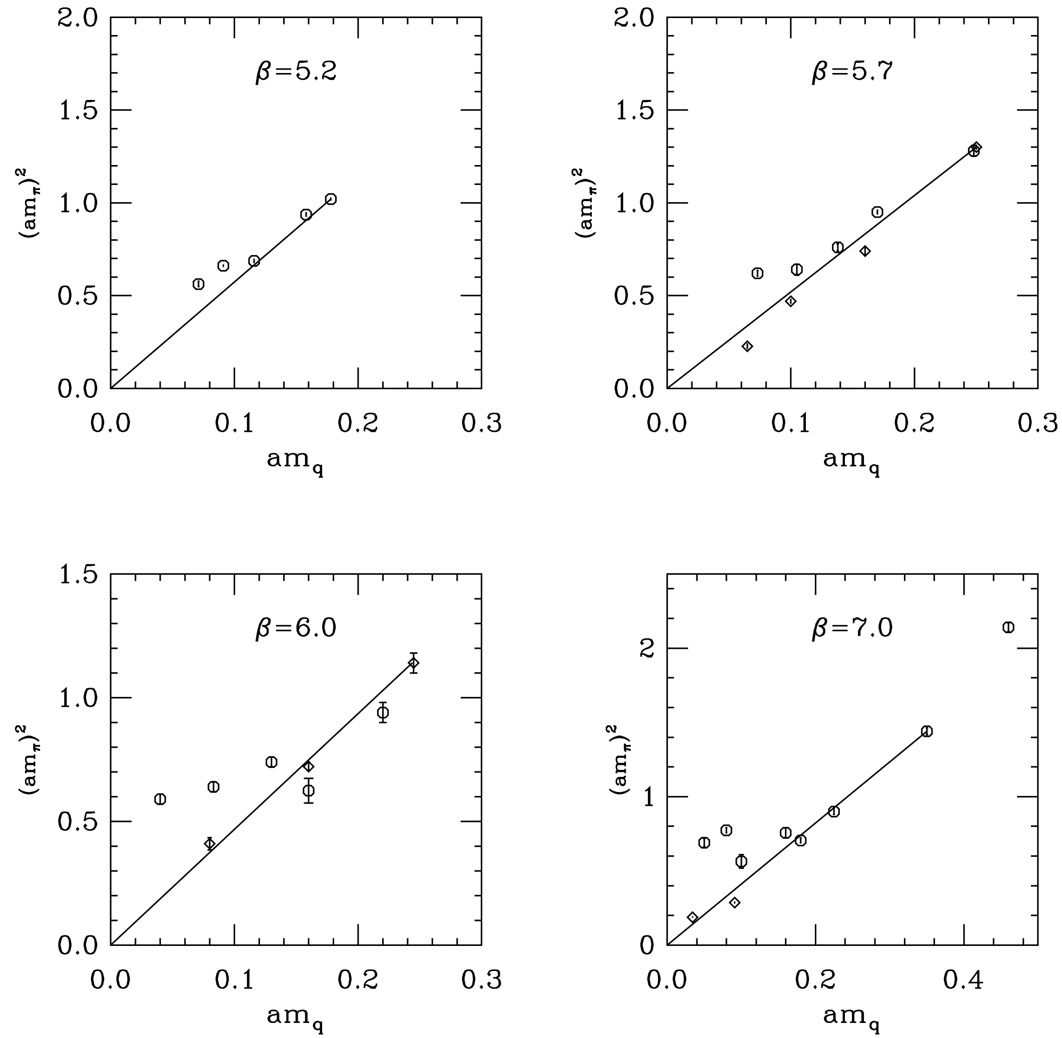
Deconfinement transition has no apparent effect on pion mass (there is a deconfined, chirally broken phase)



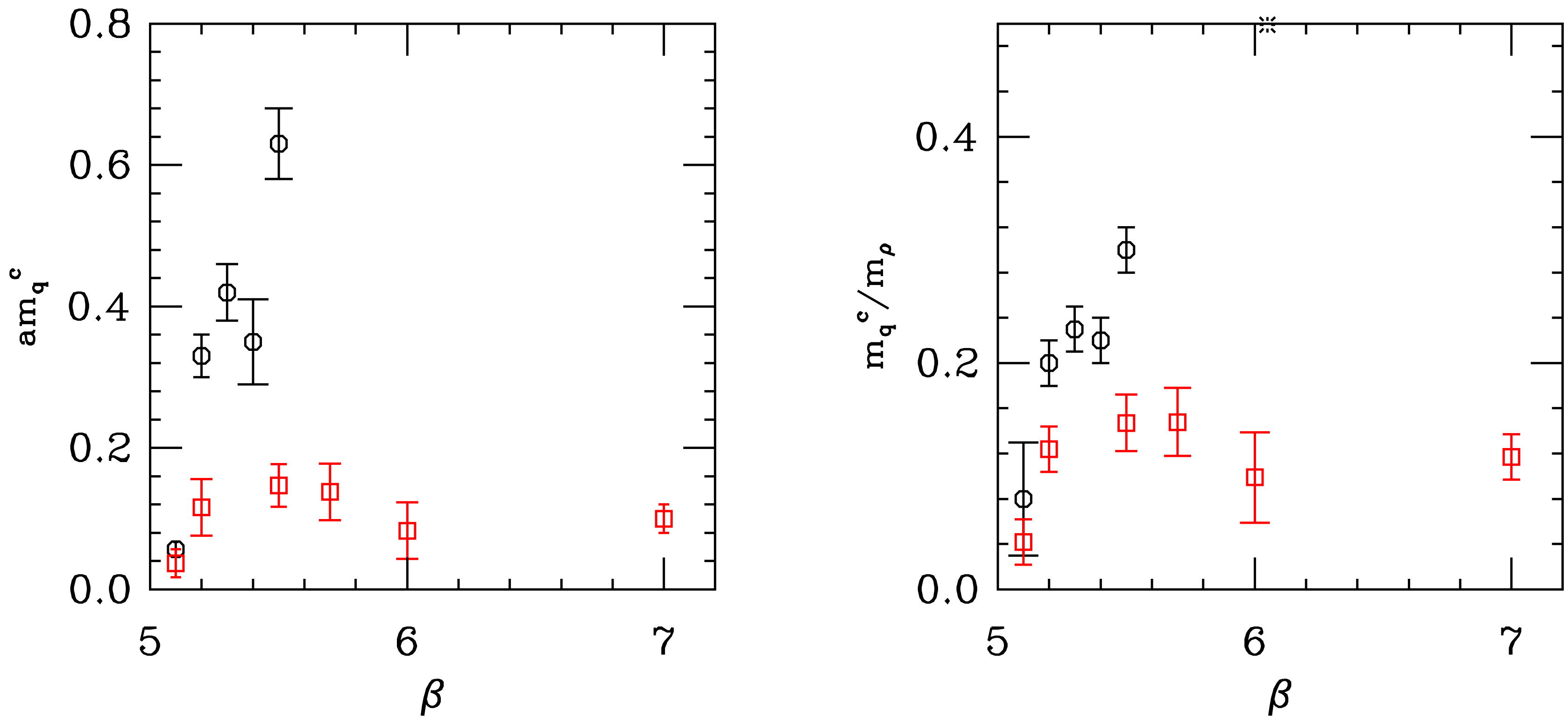
$\beta = 5.5$

Along the $N_t = 8$ chiral restoration line

With $N_t = 8$ the fermions see AP b.c.'s at $m_\pi^2 \sim (2(\pi/8))^2$: m_π^2 no longer $\sim m_q$



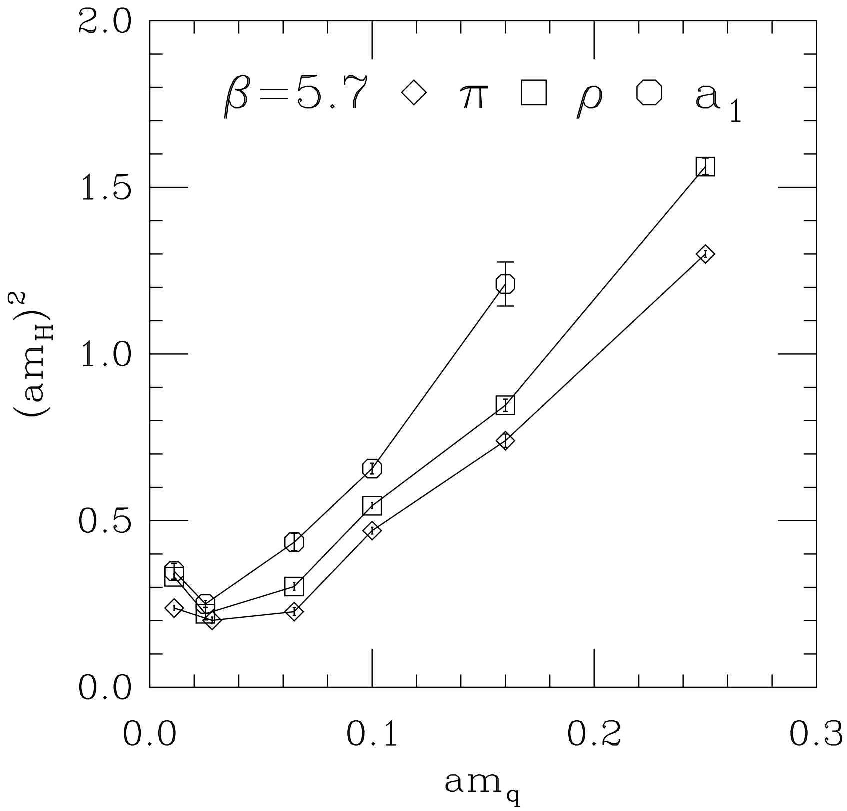
The two transitions



Octagons – $N_t = 8$ deconfinement, squares – $N_t = 8$ chiral restoration

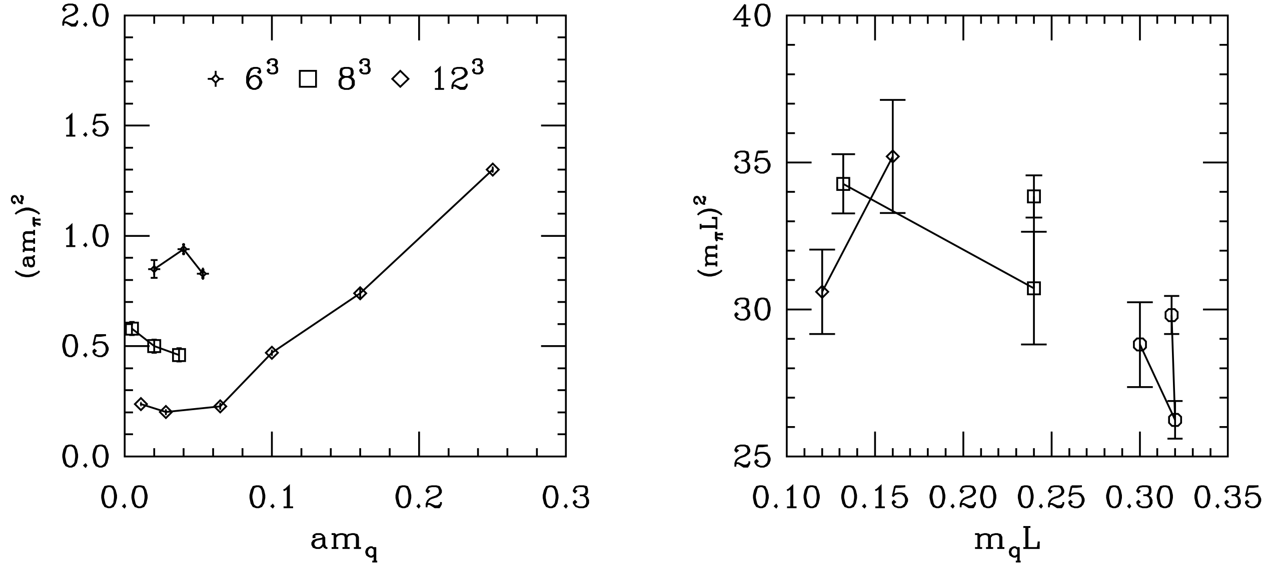
In the deconfined, chirally broken phase, life is strange

- $m_\pi^2/m_q \sim$ constant
- Never get small m_π/m_ρ
- m_{a_1}/m_ρ quite close to 1
- f_π quite m_q - dependent, drops a lot as $m_q \to 0$, can't tell if it vanishes at $am_q = 0$
- $am_\rho(\beta, am_q) = f(am_q)$, nearly β independent for $5.2 < \beta < 7$



Very small quark mass

At even smaller quark masses, finite volume is everything, $mL \sim$ constant

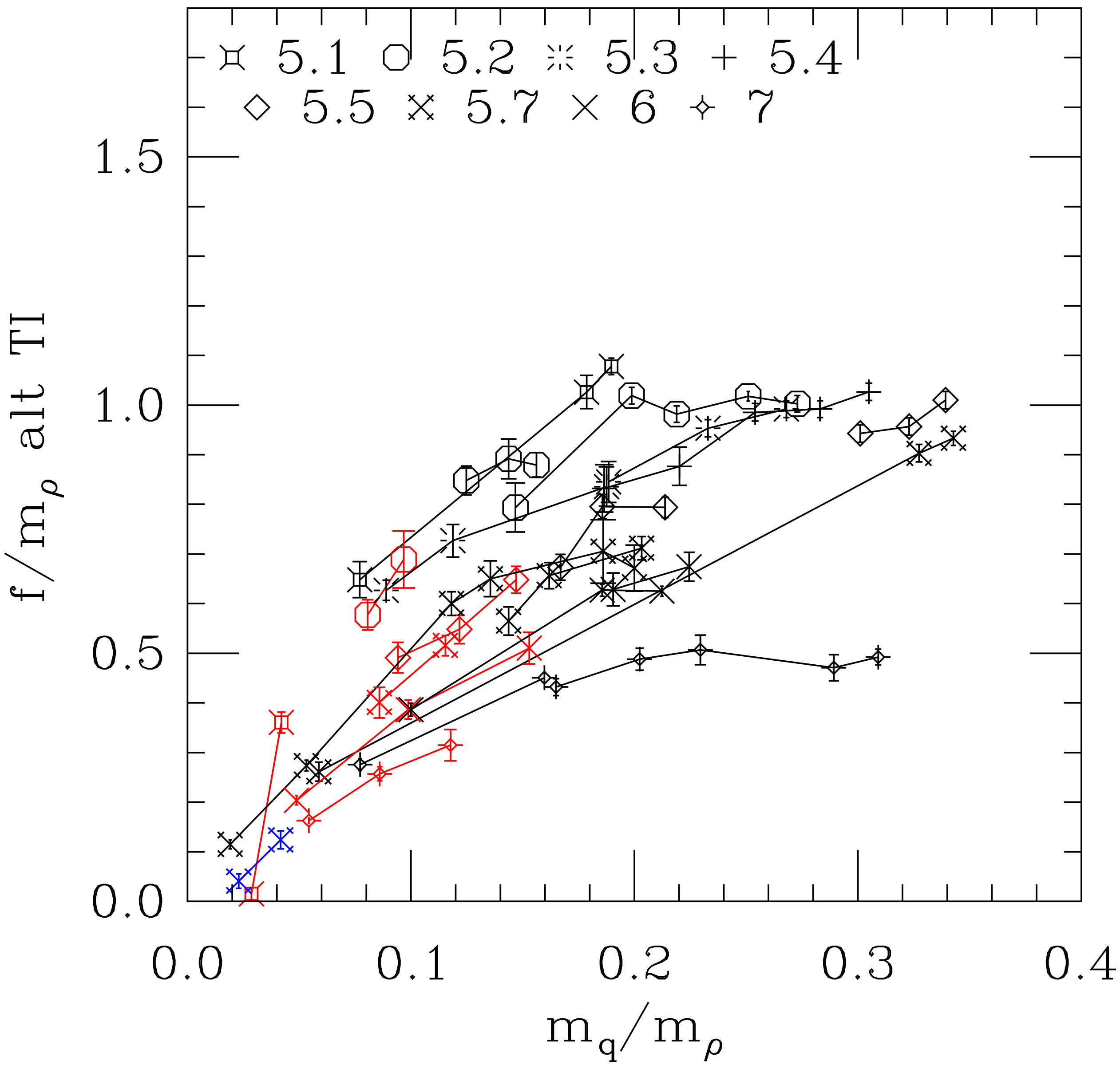


f_π –A crucial diagnostic?

- In technicolor models $f_\pi =$ Higgs VEV (246 GeV) sets the scale
- $f_\pi / m_\rho \to m_\rho$ – New physics, the technirho mass
- In large N_c, sextet $f_\pi \sim N_c$, vs fundamental rep $f_\pi \sim \sqrt{N_c}$
- With an IRFP, no chiral symmetry breaking, $f_\pi \to 0$ as $m_q \to 0$

But, simulational dirt can mar the result

- Lattice to continuum conversion
  - $a f_\pi^L = Z_A \langle 0 | A_0(x) | \pi \rangle$
  - $Z_A = (1 + \frac{g^2}{16\pi^2} C(R) W)(1 - \frac{6\kappa}{8\kappa_c})$
- Finite volume effectively restores chiral symmetry
  - $m_\pi L < 1$, $f_\pi L > 1$ – epsilon regime
  - $f_\pi L < 1$ – hell regime



f_π/m_ρ falls to zero as m_q goes to zero, even if volume too big for chiral transition

Conclusions

$N_f = 2$ sextet QCD is not like low-N_f fundamental rep QCD!

- Scale separation: $T_{th} << T_{ch}$
- Funny "chirally broken" phase
- Still to do: can "slow running" of g^2 be seen in aM?
- Direct search for IRFP in spectroscopy seems difficult, as hard as seeing asymptotic freedom in spectroscopy was in QCD
- But never mind! Discoveries await, even though existing language may be inadequate...

"P+A" trick

- Add quark propagators with antiperiodic (A) and periodic (P) temporal b.c.'s
- $C(t) = Z(\exp(-mt) \pm \exp(-m(2N_t - t)))$