Lattice 2010, Sardinia

Sextet QCD: slow running and the mass anomalous dimension

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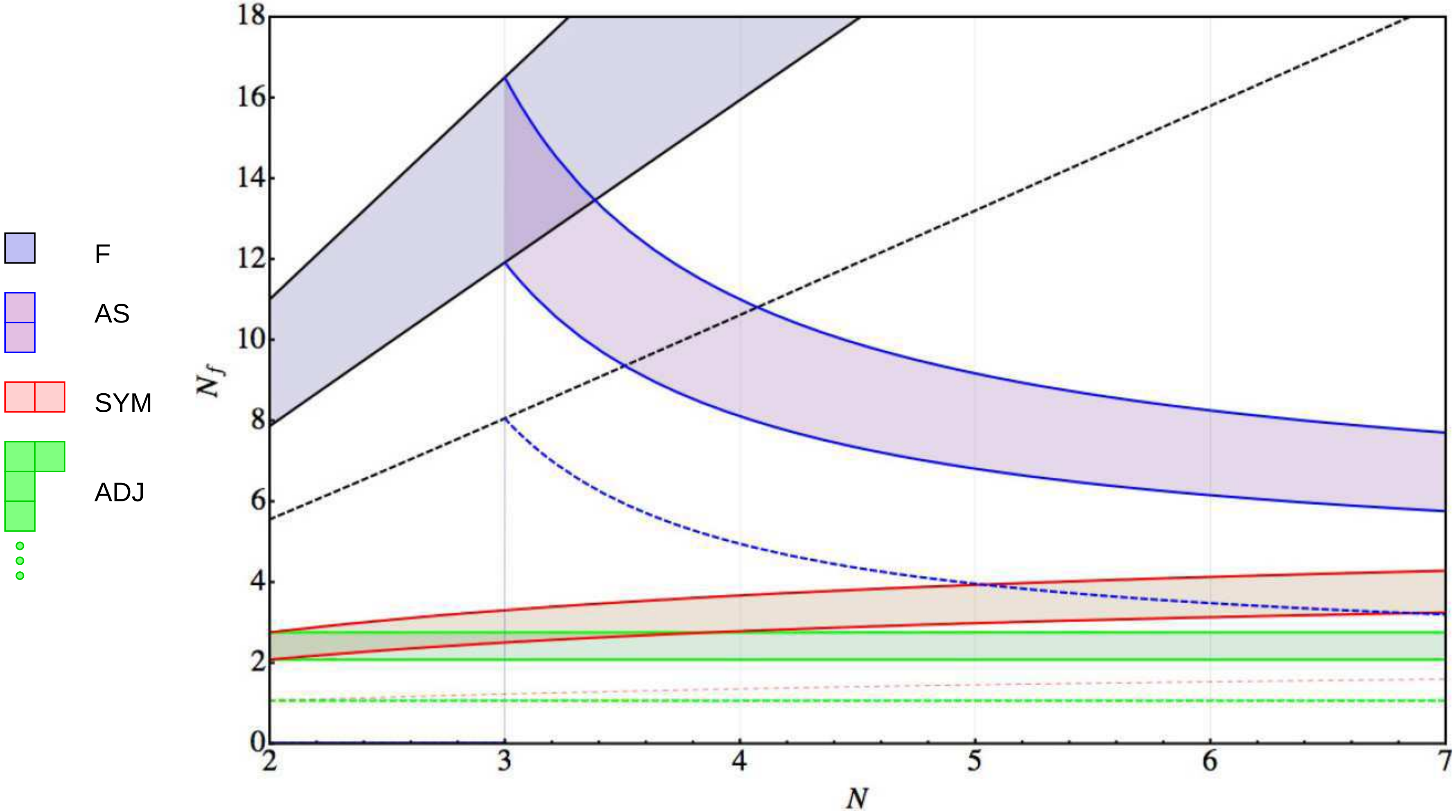
SU(3) gauge theory with $N_f = 2$ fermions in the **6** rep — Wilson–clover fermions, **nHYP** fat links

1. In the conformal window?
2. Phase diagram on a finite lattice ($m, T \neq 0$)
3. The running coupling at $m = 0$: Schrödinger Functional
   $\Longrightarrow$ runs slowly;
   $\Longrightarrow$ IRFP? Inconclusive
4. Mass anomalous dimension $\gamma(g^2)$: Too small for walking technicolor!

(arXiv:1006.0707)

MAPPING THE CONFORMAL WINDOW

(Dietrich & Sannino, PRD 2007)

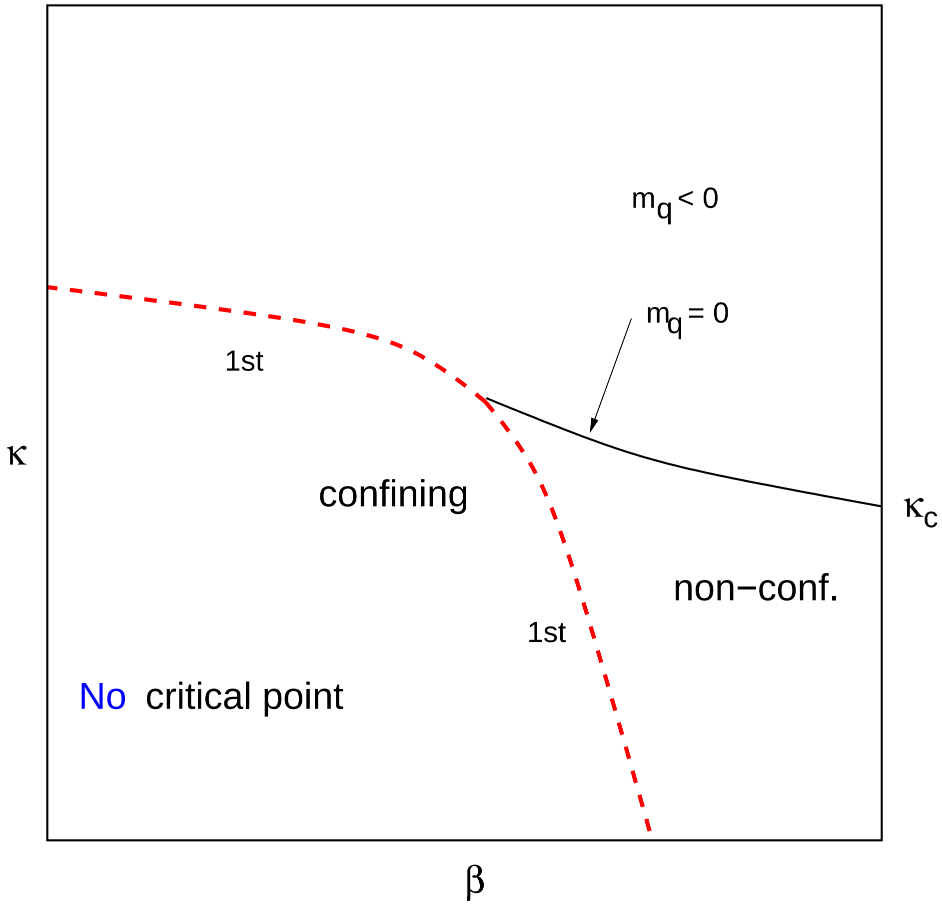


Our work: $N=3$, REP=SYM=$\mathbf{6}$, $N_f=2$

Is there an IRFP?

Ladder approx says NO: $g_*^2 \simeq 10$.

PHASE DIAGRAM:



Bulk / finite temperature transition

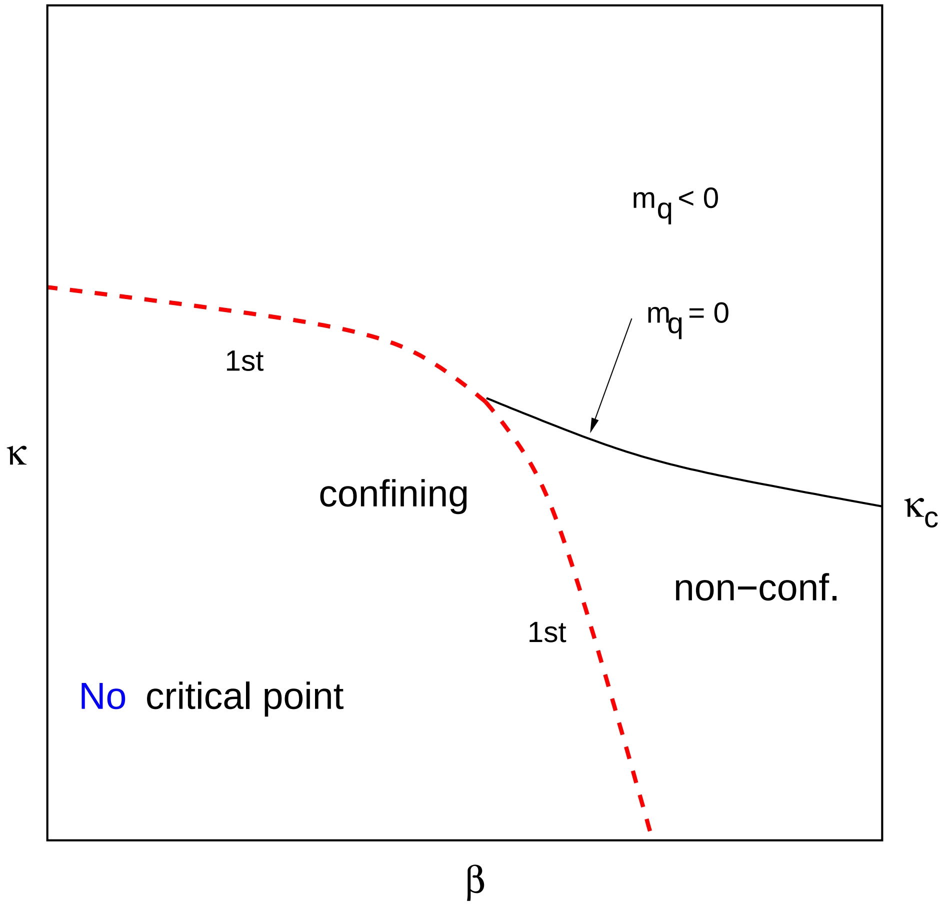
FIRST ORDER

cf. SU(3) with large N_f fund rep

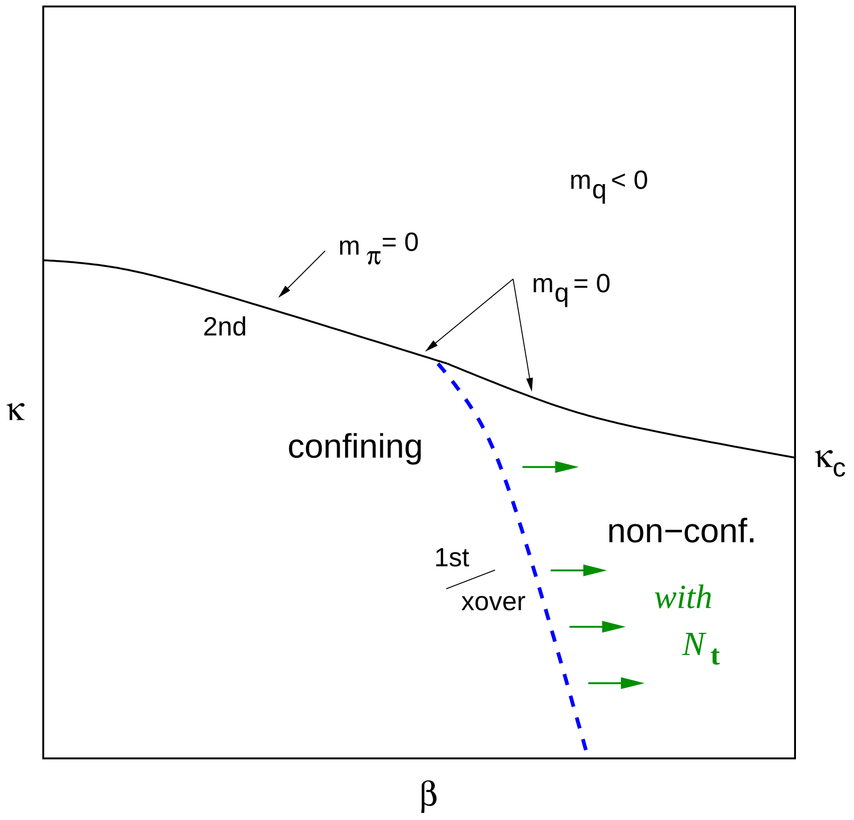
(Damgaard, Heller, Krasnitz, Olesen 1997)

(Iwasaki *et al.* 2002)

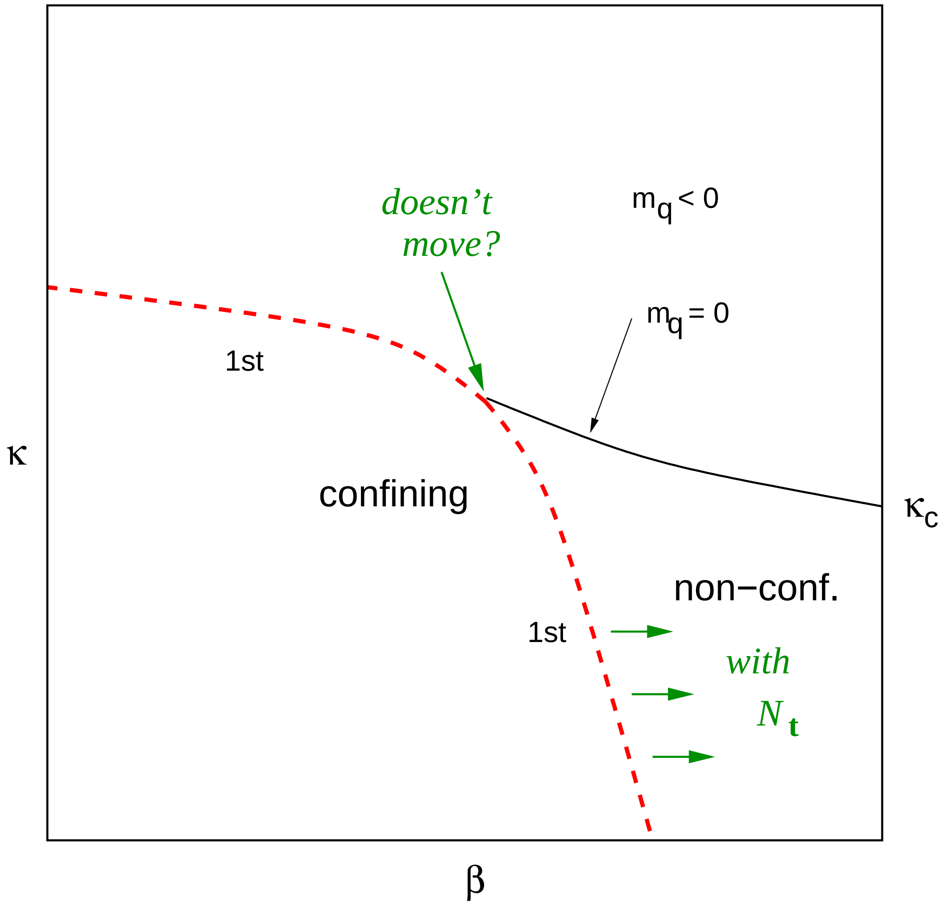
PHASE DIAGRAM:



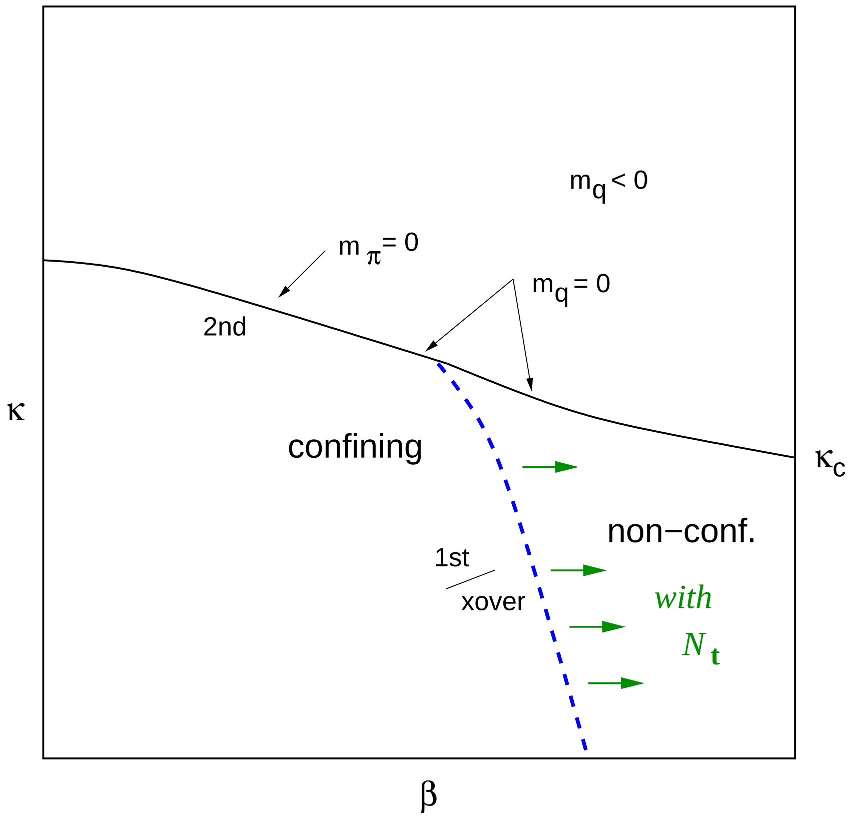
Cf. QCD



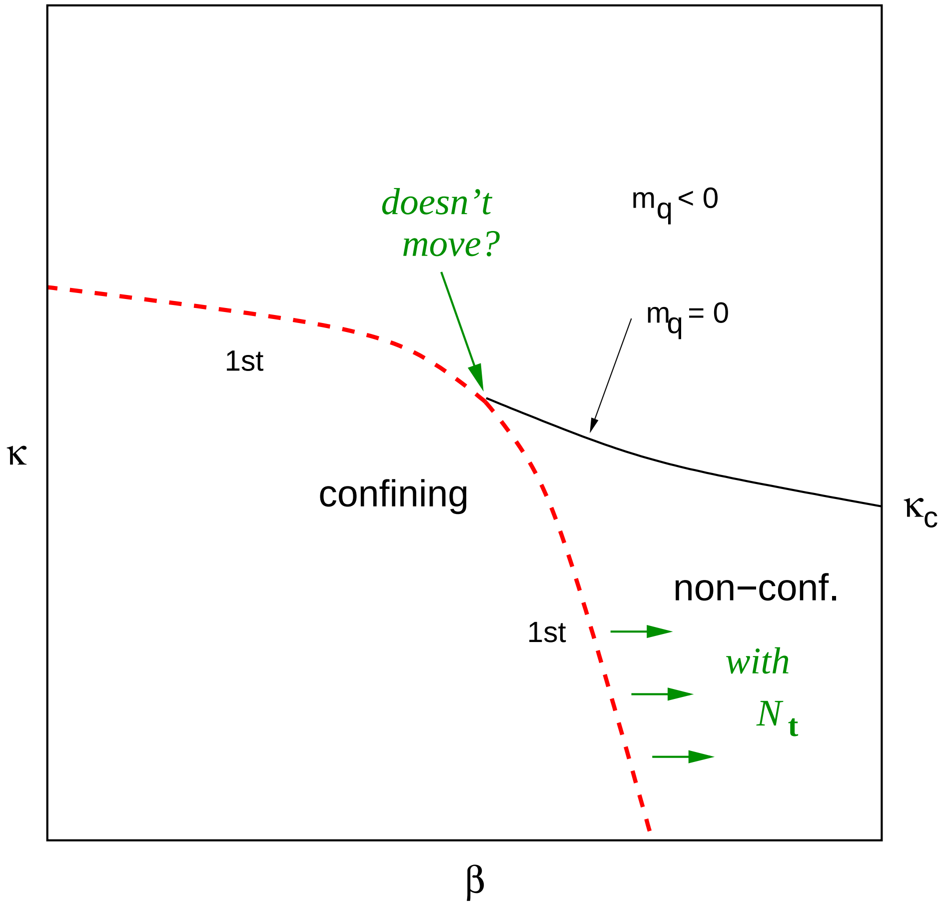
AS N_t INCREASES:



Cf. QCD



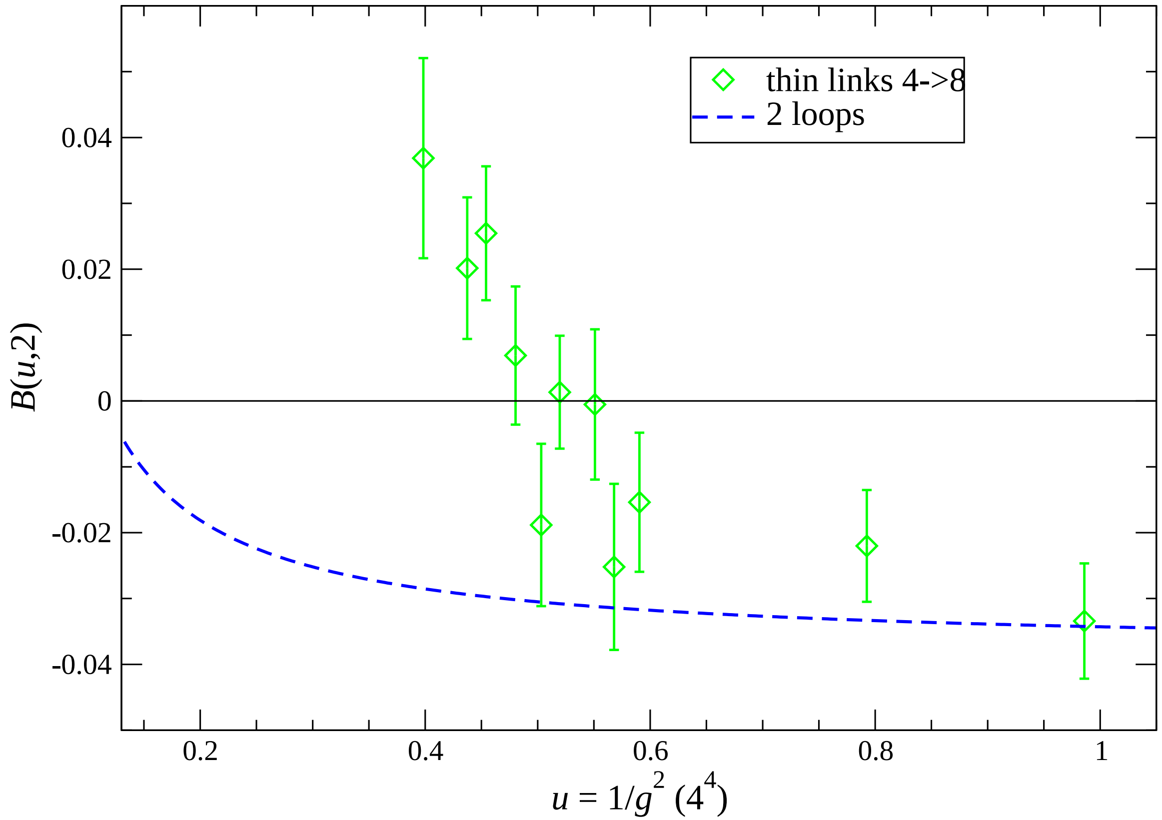
AS N_t INCREASES:



Intersection point moves slowly
(or not at all)

$\Longrightarrow$ slow running
(or conformal phase on κ_c line!)

The DISCRETE BETA FUNCTION (2008)

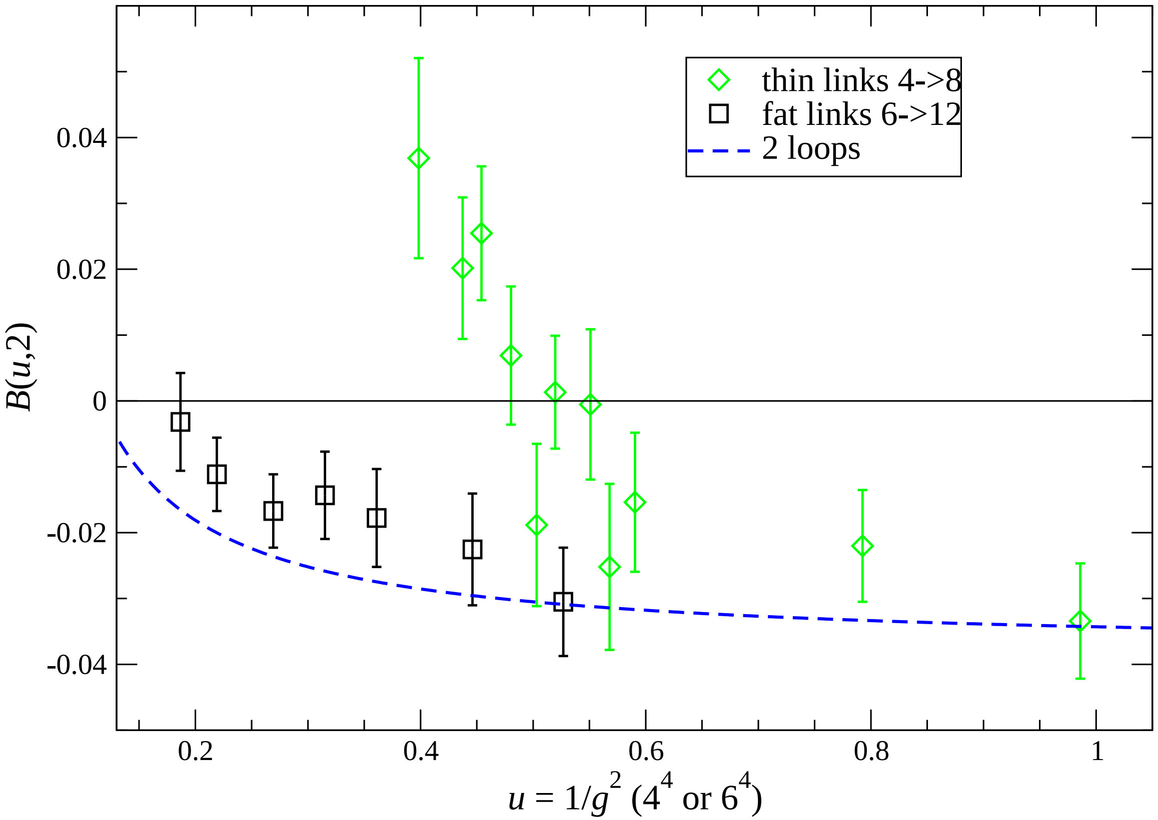


Thin links $4^4 \longrightarrow 8^4$

$B(u,2)$ crosses zero at $g^2 \simeq 2.0$ — a weak coupling.

$\Longrightarrow$ IRFP

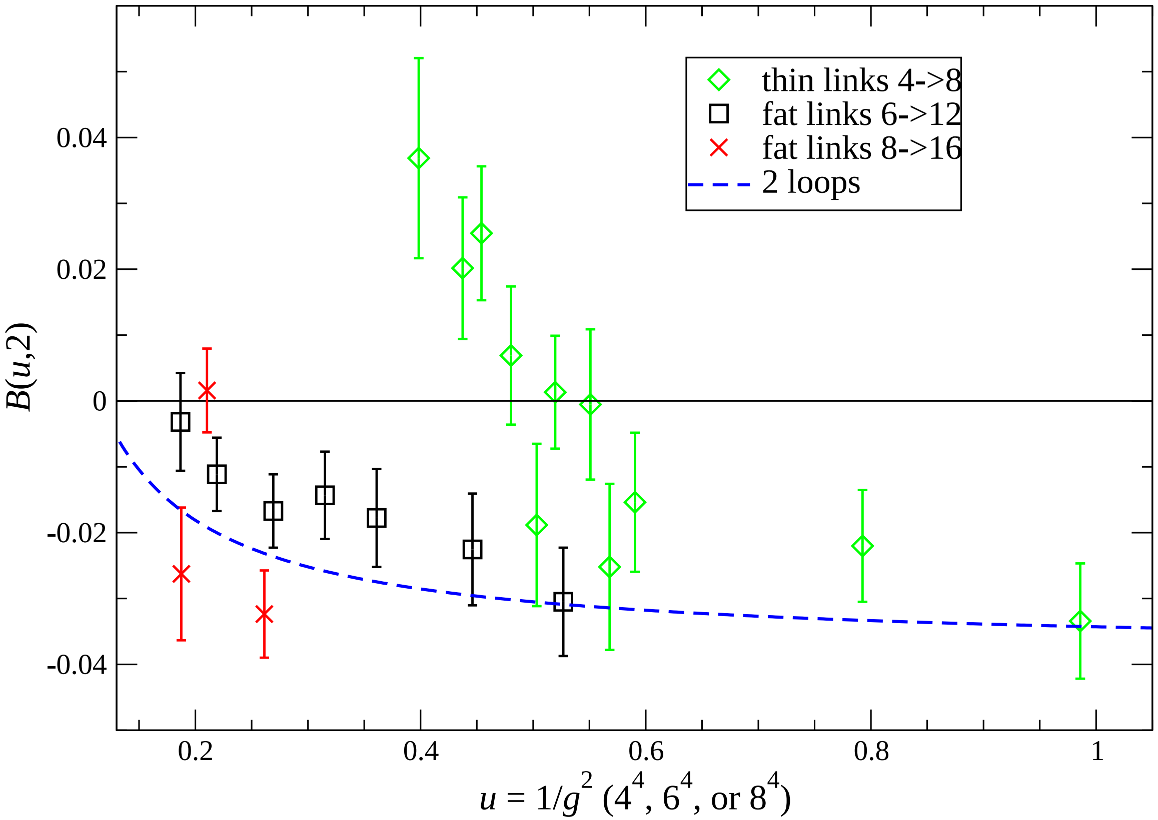
The DISCRETE BETA FUNCTION (2009–10)



FAT links $6^4 \longrightarrow 12^4$

1. Rules out old IRFP
2. Go to stronger coupling? Stopped by 1st order phase transition!
3. No clear IRFP
4. SLOW running

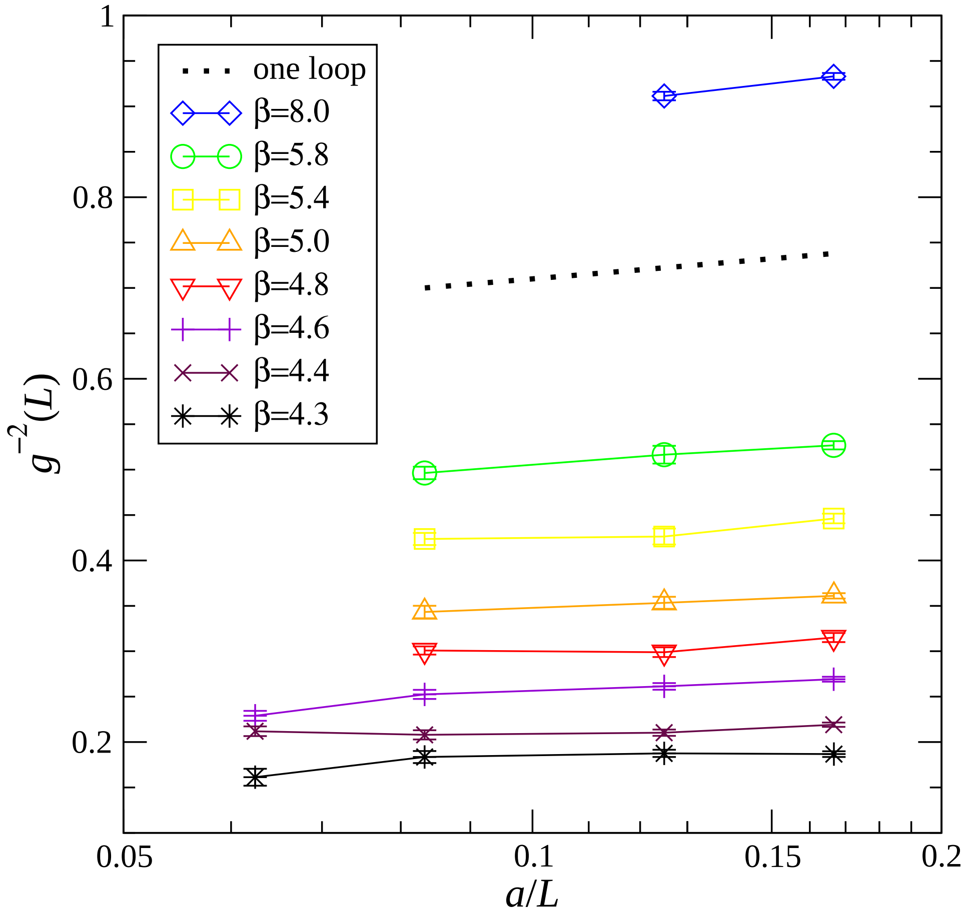
The DISCRETE BETA FUNCTION (2009–10)



FAT links $8^4 \longrightarrow 16^4$

Not much help . . .

How SLOW is SLOW?



$< 15\%$ variation as $L = 6 \rightarrow 16$

Remember this . . .

MASS ANOMALOUS DIMENSION

A technicolor theory needs to enhance the techniquark condensate from $\Lambda_{TC} \to \Lambda_{ETC}$ according to

$$\langle \bar{\Psi}\Psi \rangle_{ETC} = \langle \bar{\Psi}\Psi \rangle_{TC} \times \exp\left[\int_{\Lambda_{TC}}^{\Lambda_{ETC}} \frac{d\mu}{\mu} \gamma(g^2(\mu)) \right]$$

[enhance m_q while suppressing FCNC]

Walking technicolor: $g^2 \simeq g_*^2$ nearly constant during running, so

$$\langle \bar{\Psi}\Psi \rangle_{ETC} \simeq \langle \bar{\Psi}\Psi \rangle_{TC} \times \left(\frac{\Lambda_{ETC}}{\Lambda_{TC}} \right)^{\gamma(g_*^2)}$$

WANTED: $\gamma(g_*^2) = 1$ (or *very* close to 1) (Chivukula & Simmons, arXiv:1005.5727)

What does the lattice say about this?

MASS ANOMALOUS DIMENSION — the calculation

(Bursa et al. arXiv:0910.4535)

Correlation functions on lattice:

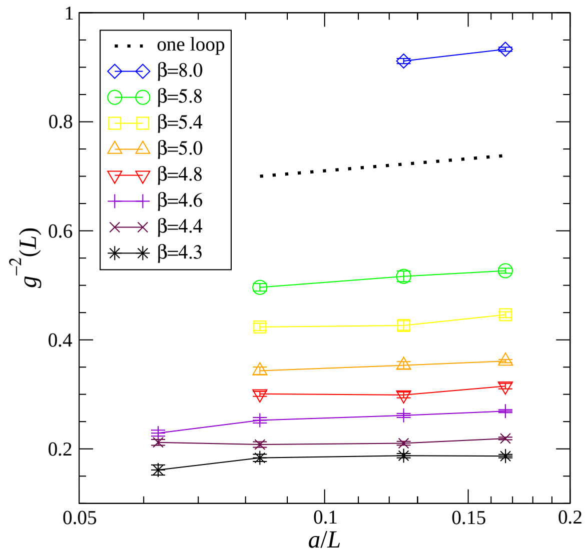
$$\left\langle P^b(t)\,\mathcal{O}^b(t'=0)\right\rangle\Big|_{t=L/2} = Z_P\, Z_{\mathcal{O}}\, e^{-m_\pi L/2}$$

$$\left\langle \mathcal{O}^b(t=L)\,\mathcal{O}^b(t'=0)\right\rangle = Z_{\mathcal{O}}^2\, e^{-m_\pi L}$$

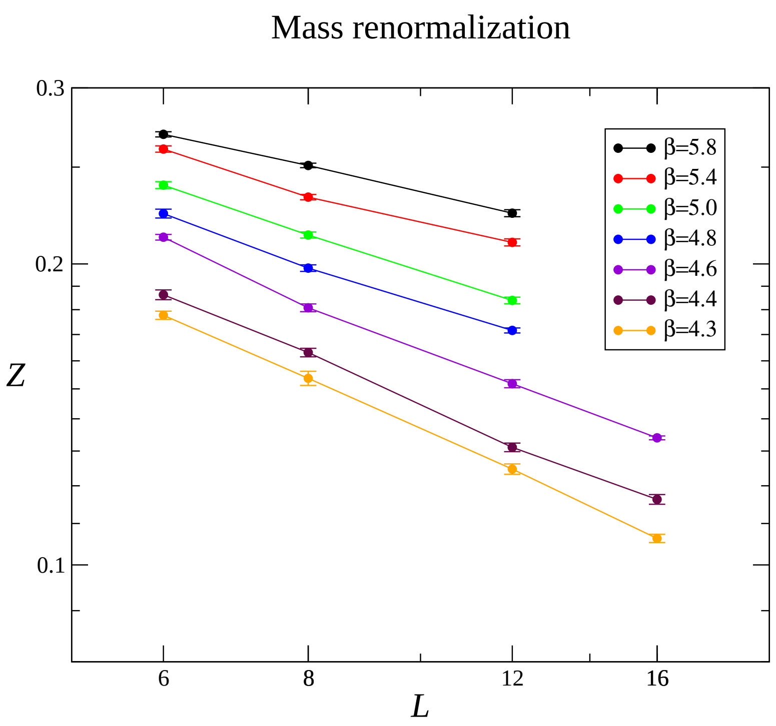
Take ratio, extract $Z_P(L)$, whence

$$\frac{Z_P(L)}{Z_P(L_0)} = \left(\frac{L}{L_0}\right)^{-\gamma}$$

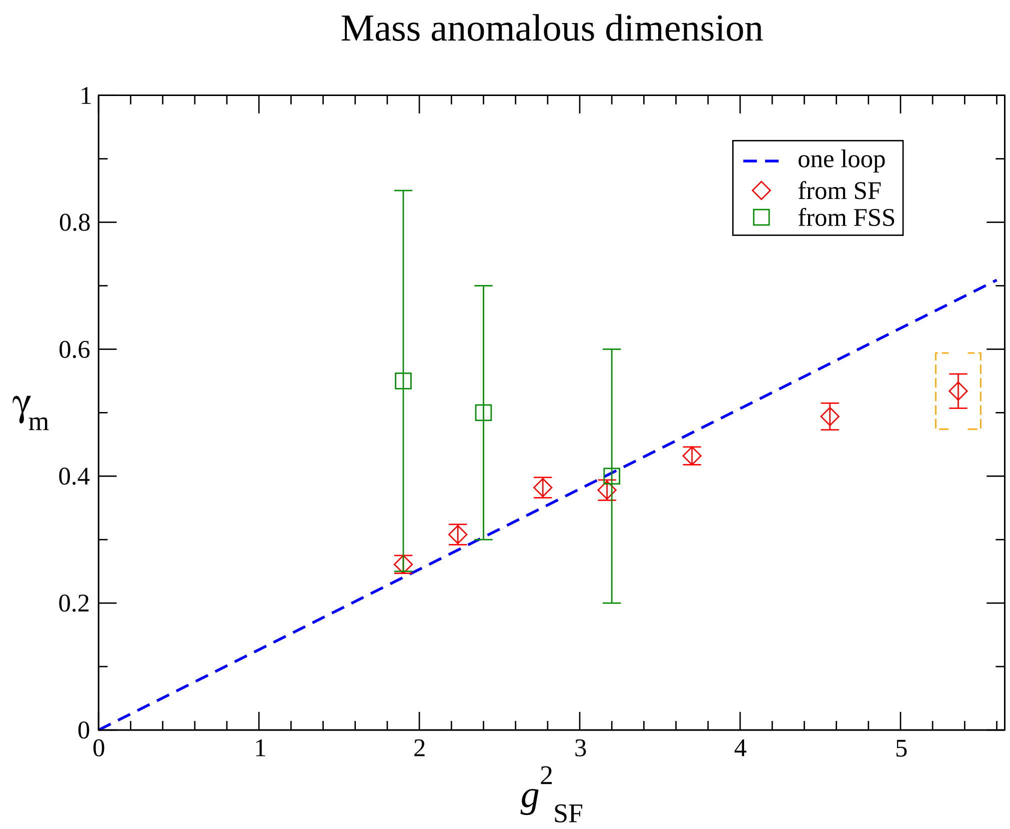
assuming $\gamma \simeq \mathrm{const}$ as $L_0 \to L$, since the coupling (almost) doesn't run:



MASS ANOMALOUS DIMENSION — result



$\Longrightarrow$



slope $= -\gamma_m(g^2)$

Cf. one loop: $\gamma = \dfrac{6C_2(R)}{16\pi^2}\, g^2$

(FSS: DeGrand, arXiv:0910.3072)

WHAT HAVE WE LEARNED?

Two possibilities:

1. We have NO IR fixed point:
   - 1st order transition will slide towards $\beta = \infty$ as $N_t \to \infty$
   - Theory has confinement $/\chi SB$
   - β function doesn't approach zero; it's just smaller than two loops, and *much* smaller than in QCD. The theory doesn't walk (but it runs slowly).
   - $\gamma_m \lesssim 0.6$: no good for extended technicolor [cf. SU(2)/adj (Bursa et al. arXiv:0910.4535)]
2. We have an IR fixed point:
   - 1st order transition ($m_q = 0$) is stuck: can't penetrate conformal phase
   - The zero of the β function is around the corner (change lattice action?)
   - $\gamma_m \lesssim 0.6$ at IRFP: The theory is well inside the conformal window.*

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* since γ_m should $= 1$ at the edge of the window

(Cohen & Georgi 1989; Kaplan, Lee, Son, Stephanov arXiv:0905.4752)