Running couplings in 12 flavor QCD

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Lattice 2010

Lattice Higgs Collaboration

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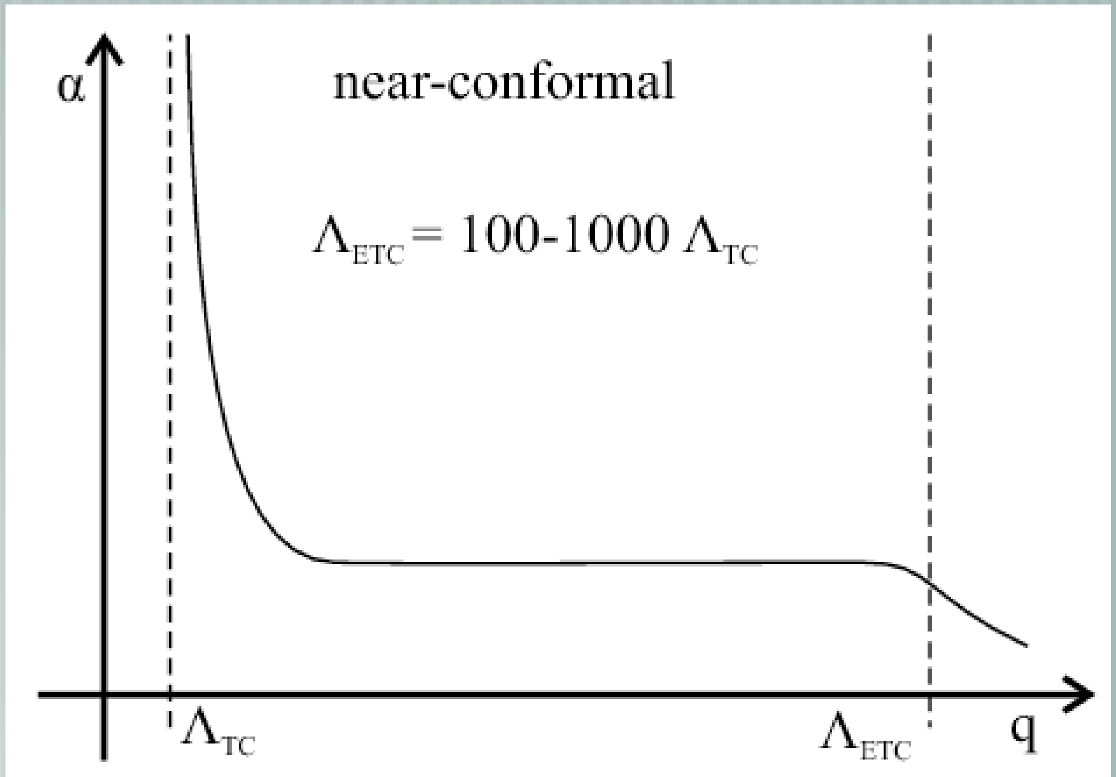
Outline

- why 12 flavors?
- running coupling schemes
- results & interpretation

why 12 flavors?

- technicolor: replace Higgs mechanism, requires SSB
- conformal: IR fixed point gauge coupling g^*, no SSB
- near-conformal: generate separate energy scales
- good for phenomenology?
- several interesting candidates



why 12 flavors?

many possible theories

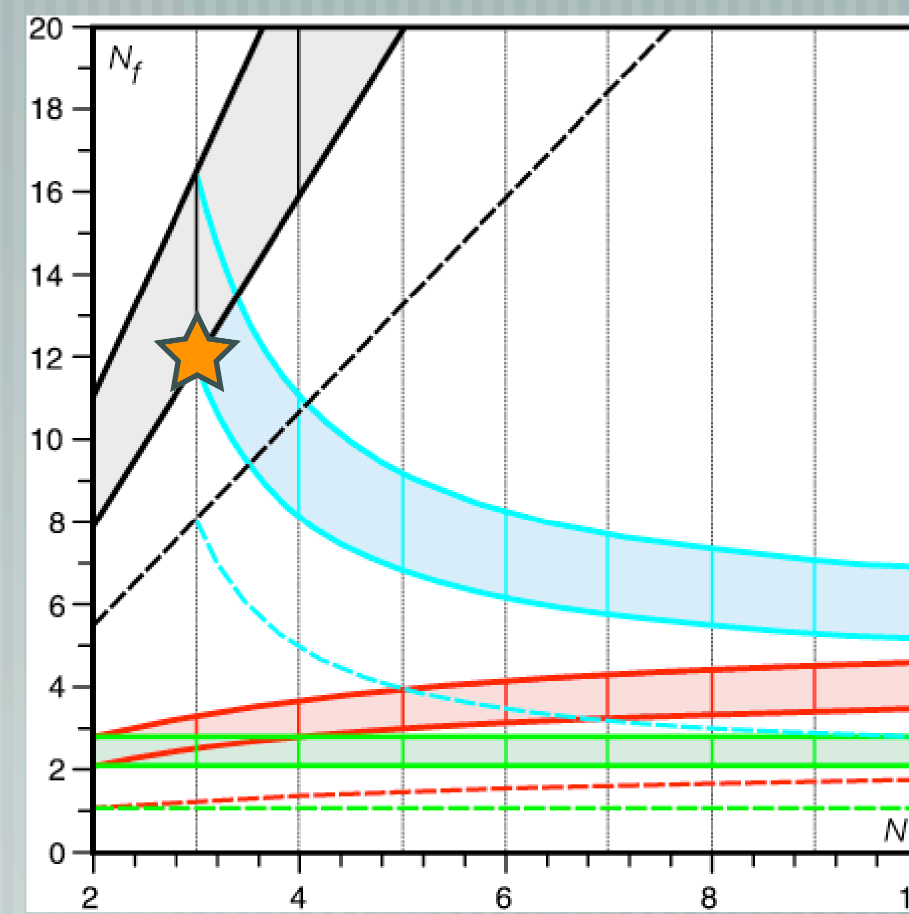
12 flavors near estimated QCD/conformal boundary

many recent studies

lattice essential

no consensus yet

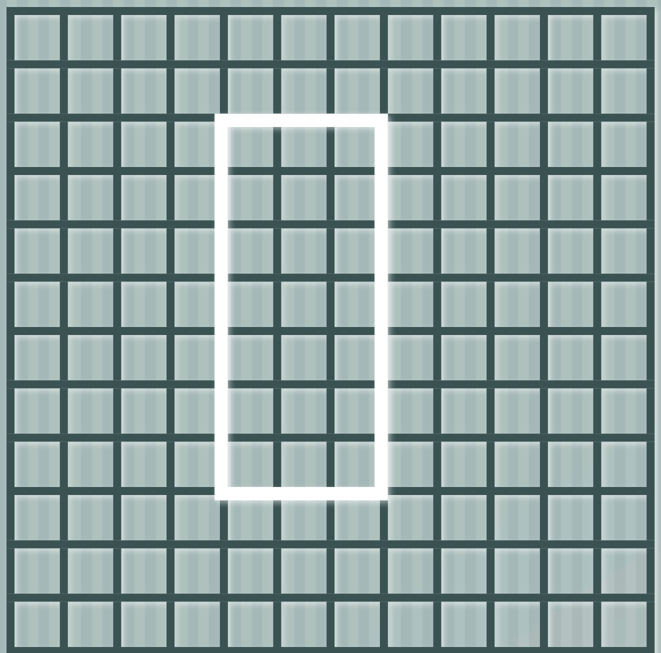
N_f



gray: fundamental
blue: 2-index antisymmetric
red: 2-index symmetric
green: adjoint

Dietrich&Sannino N_c

QQ running coupling



Wilson loop $W(R,T)$

quark-antiquark potential

$$V(R) = \lim_{T\to\infty} \left(-\frac{\partial}{\partial T} \ln\langle W(R,T)\rangle\right)$$

$$F(R) = \frac{dV}{dR} = C_F \frac{\alpha_{qq}(R)}{R^2}, \quad \alpha_{qq}(R) = \frac{g_{qq}^2(R)}{4\pi}$$

lattice

$$V(R) = \lim_{T\to\infty} \left(-\ln \frac{\langle W(R,T+1)\rangle}{\langle W(R,T)\rangle}\right)$$

$$F(R) = V(R+1) - V(R)$$

running in QQ scheme known to 3-loop

want large volume physics, but also probe running at UV scale

QQ running coupling

compare simulations with pert theory

$$V(R) - V(R_0) = C_F \int_{R_0}^{R} \frac{\alpha_{qq}(R')}{R'^2} dR'$$

measure $\alpha_{qq}(R_0)$ directly from simulations at reference R_0

run $\alpha_{qq}(R')$ according to 1-,2- or 3-loop pert thy

Improved lattice force $F(R^*) = V(R+1) - V(R)$

Symanzik gauge action: small effect e.g.

$$R = 4.5 \Rightarrow R^* = 4.457866...$$

Simulations

2-stout dynamical staggered fermions] identical to chiral runs
tree-level Symanzik gauge action

Kuti Tues 8:30

range of volumes and masses

largest $32^3 \times 48$

lightest $m = 0.001$

statistics: several thousand trajectories

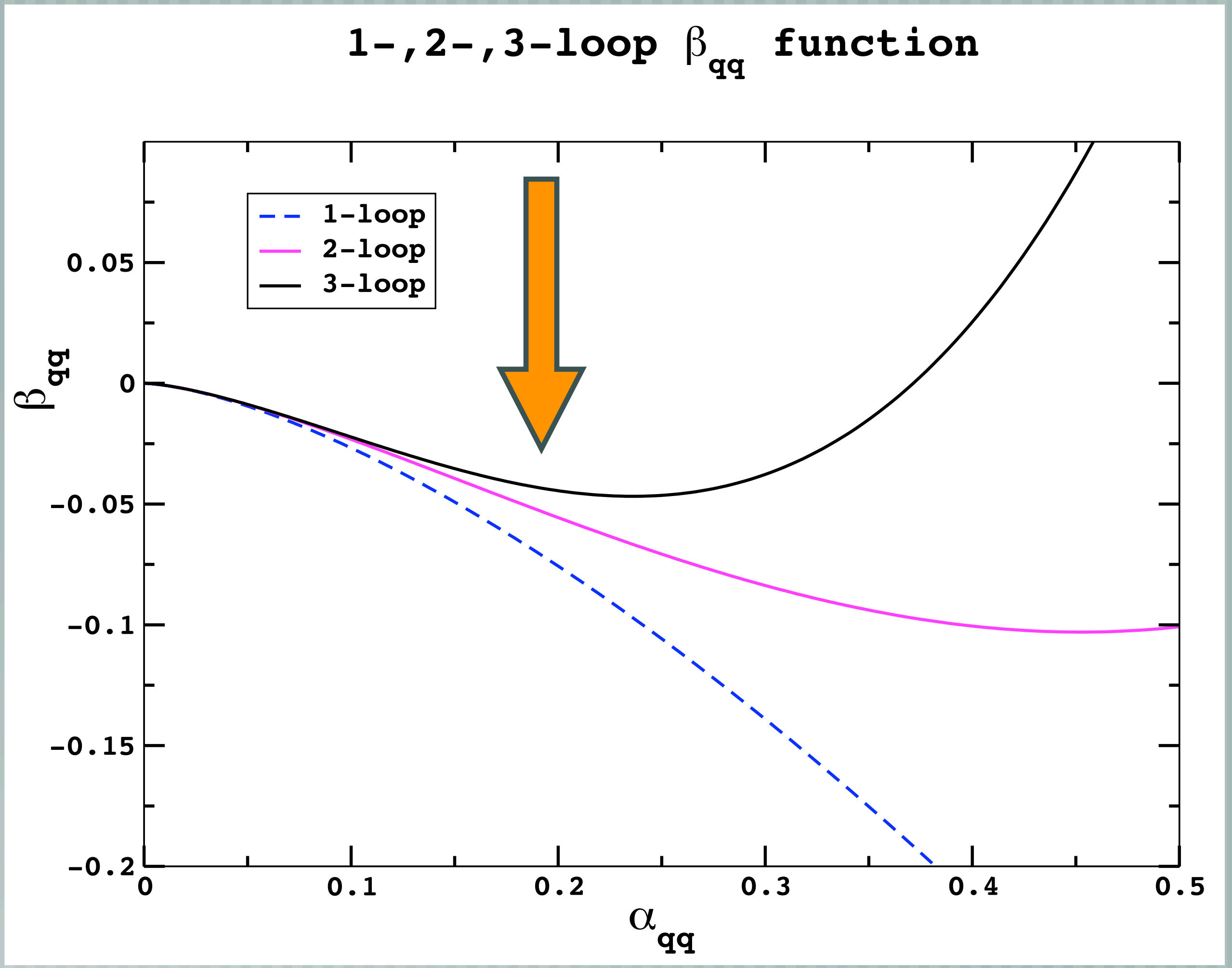
HYP smearing used for potential measurement

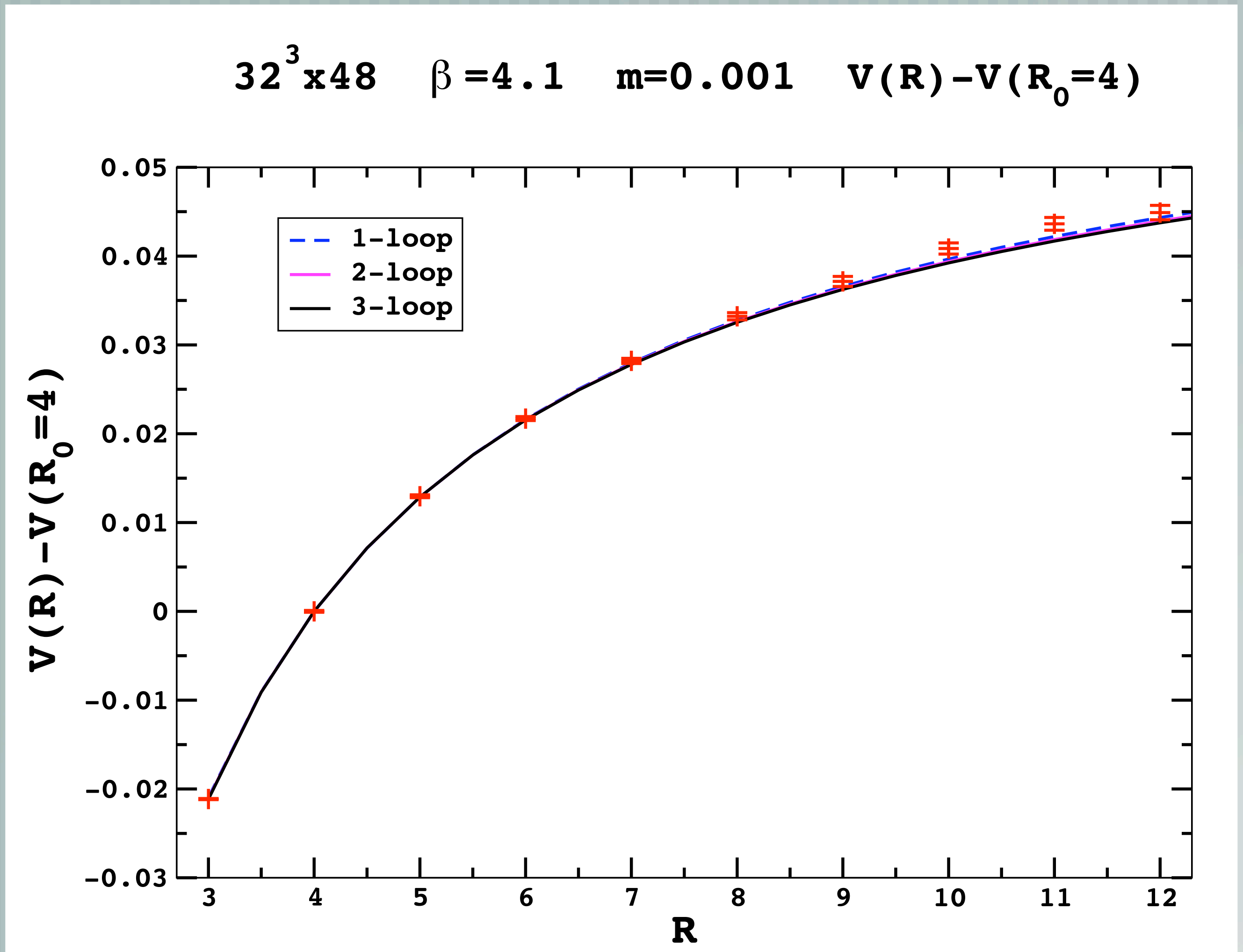
weak coupling

bare coupling

$$\beta = 4.1 \Rightarrow \alpha_{qq}(R_0) \approx 0.19$$

1,2,3-loop beta functions similar



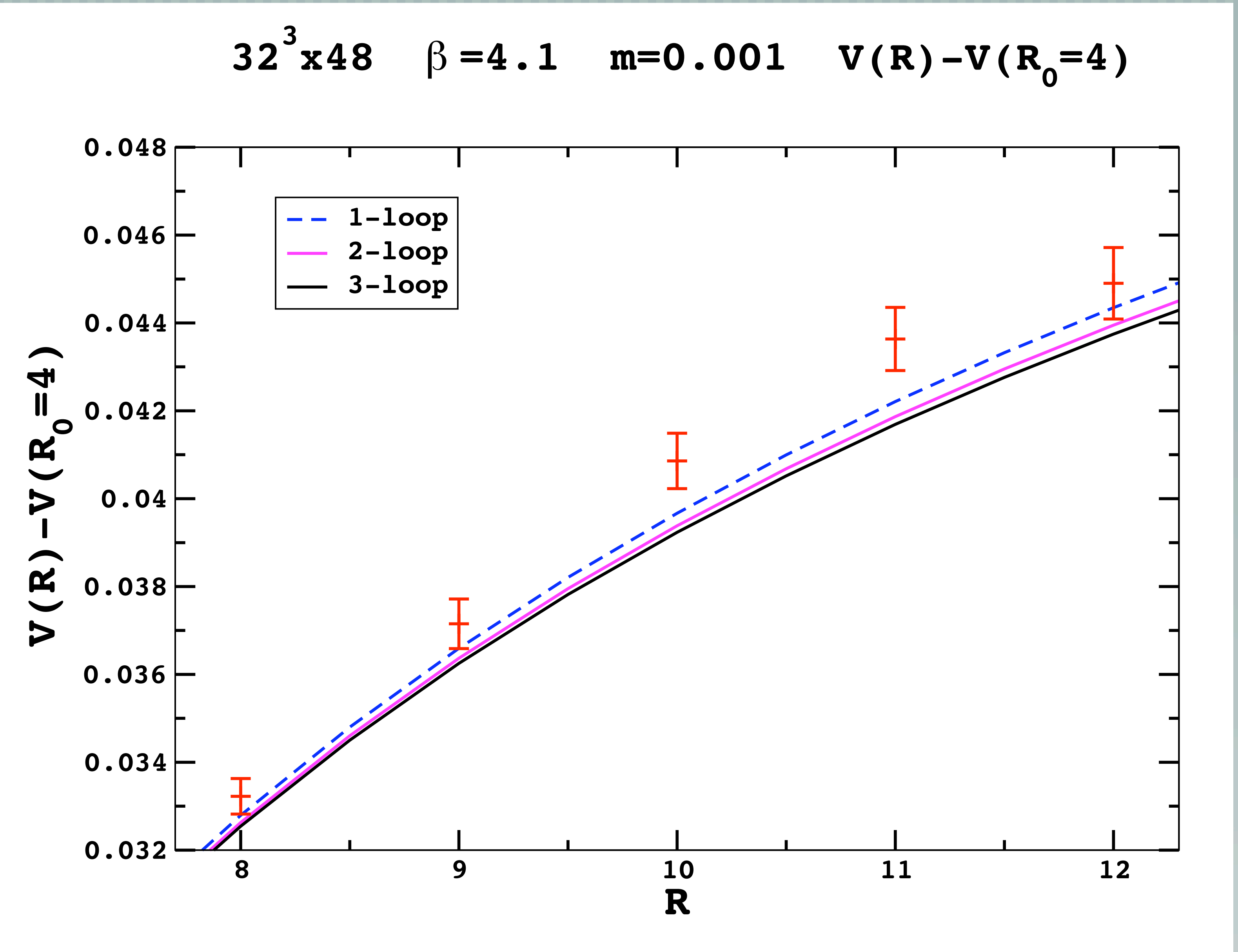


reference: $R_0 = 4$ accurate

simulation agrees with pert thy

zoom in

weak coupling



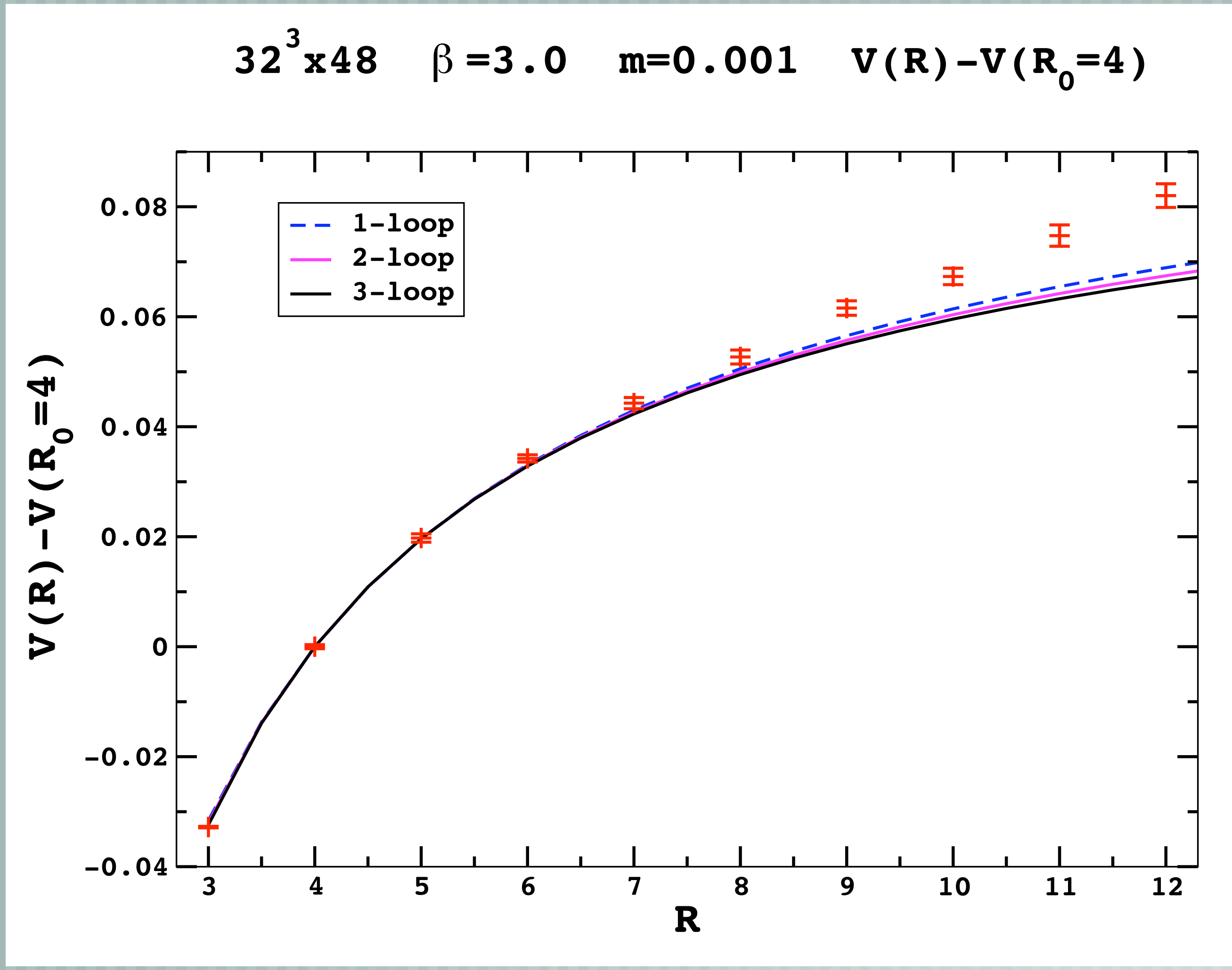
data consistent with PT from small to large R

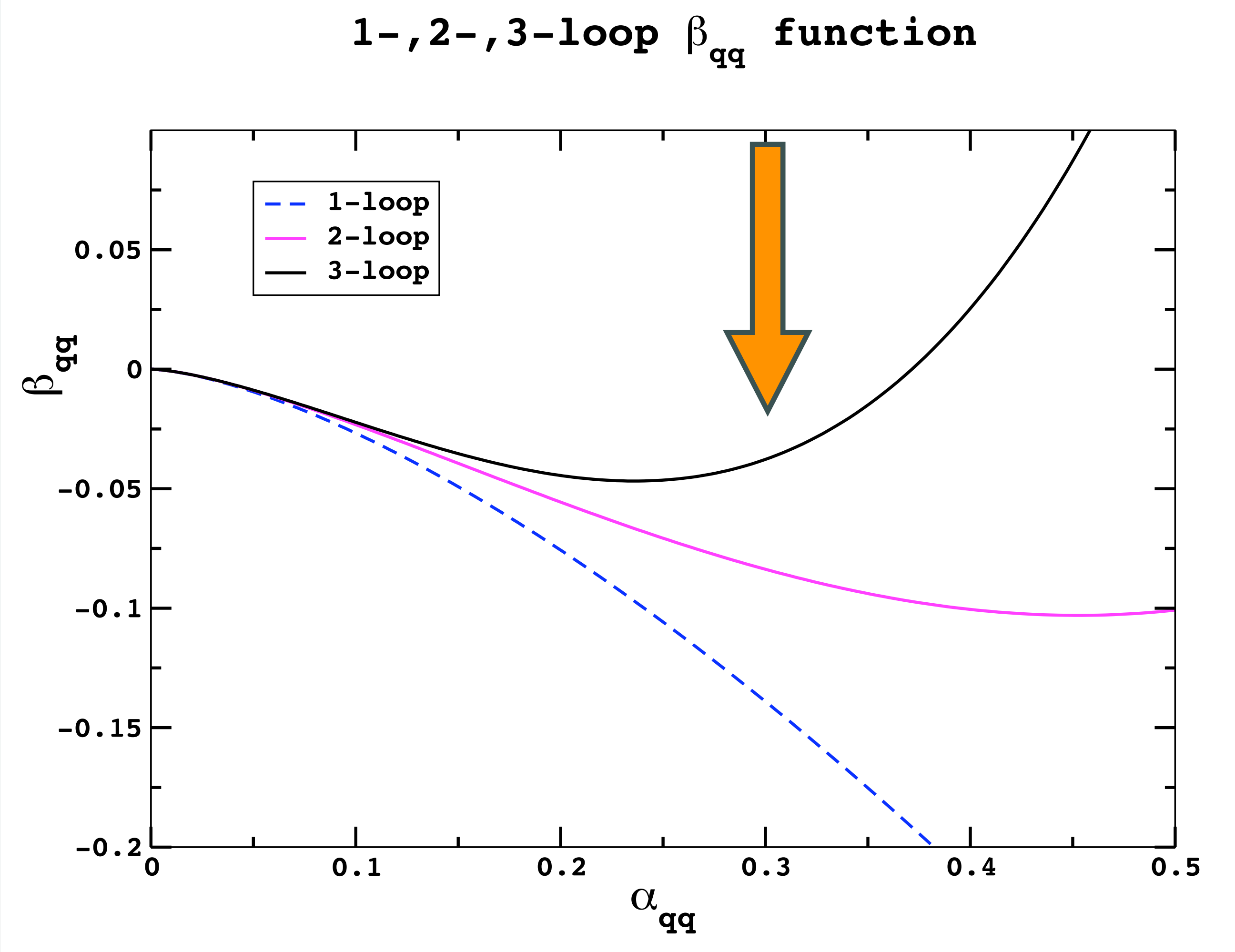
no surprises

bare coupling

$$\beta = 3.0 \Rightarrow \alpha_{qq}(R_0) \approx 0.30$$

1,2,3-loop beta functions fan out

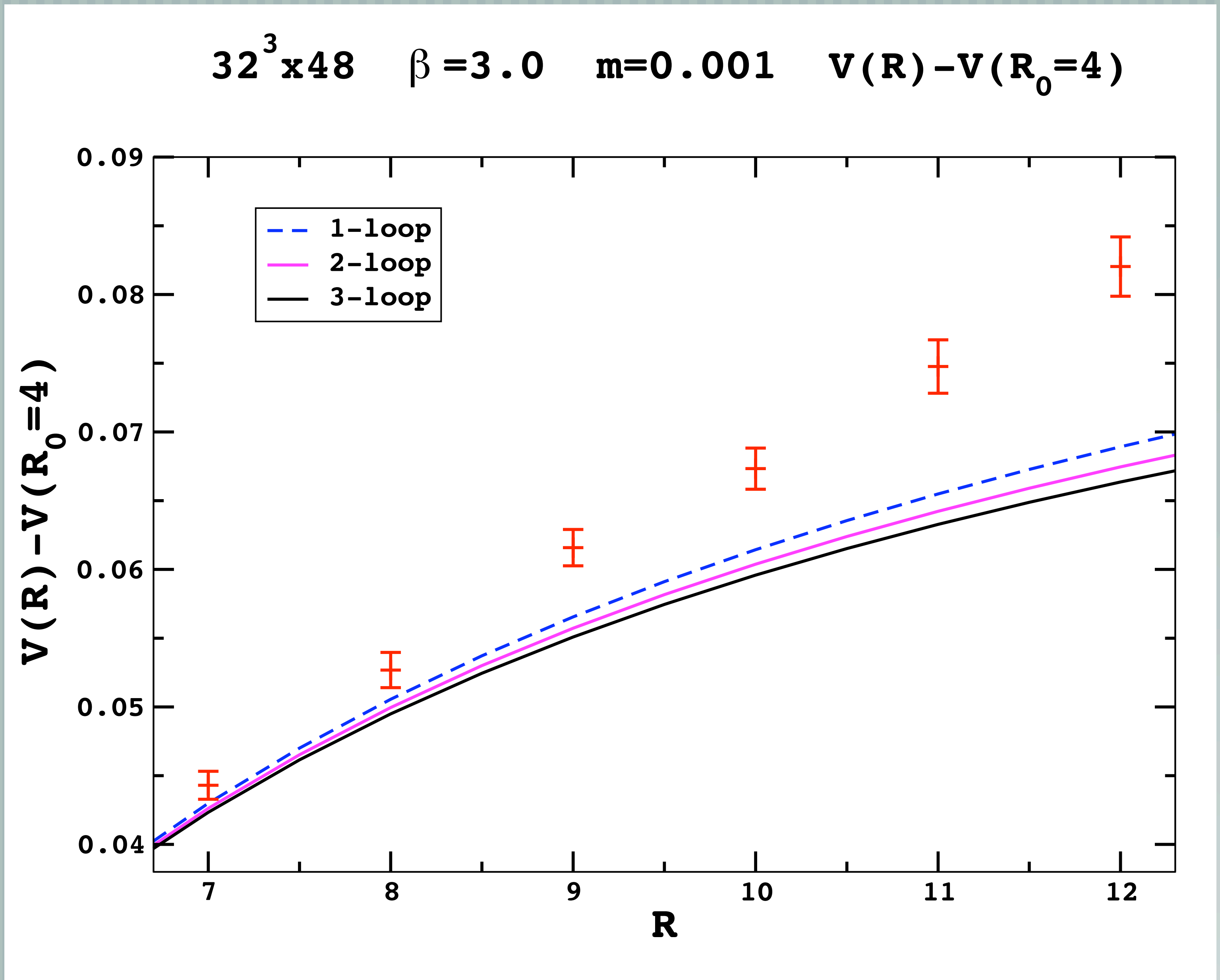




QQ scheme 3-loop $\alpha^*_{qq} = 0.371$

reference: $R_0 = 4$ accurate

small R: data & pert thy agree



zoom in

data at larger R run faster than PT

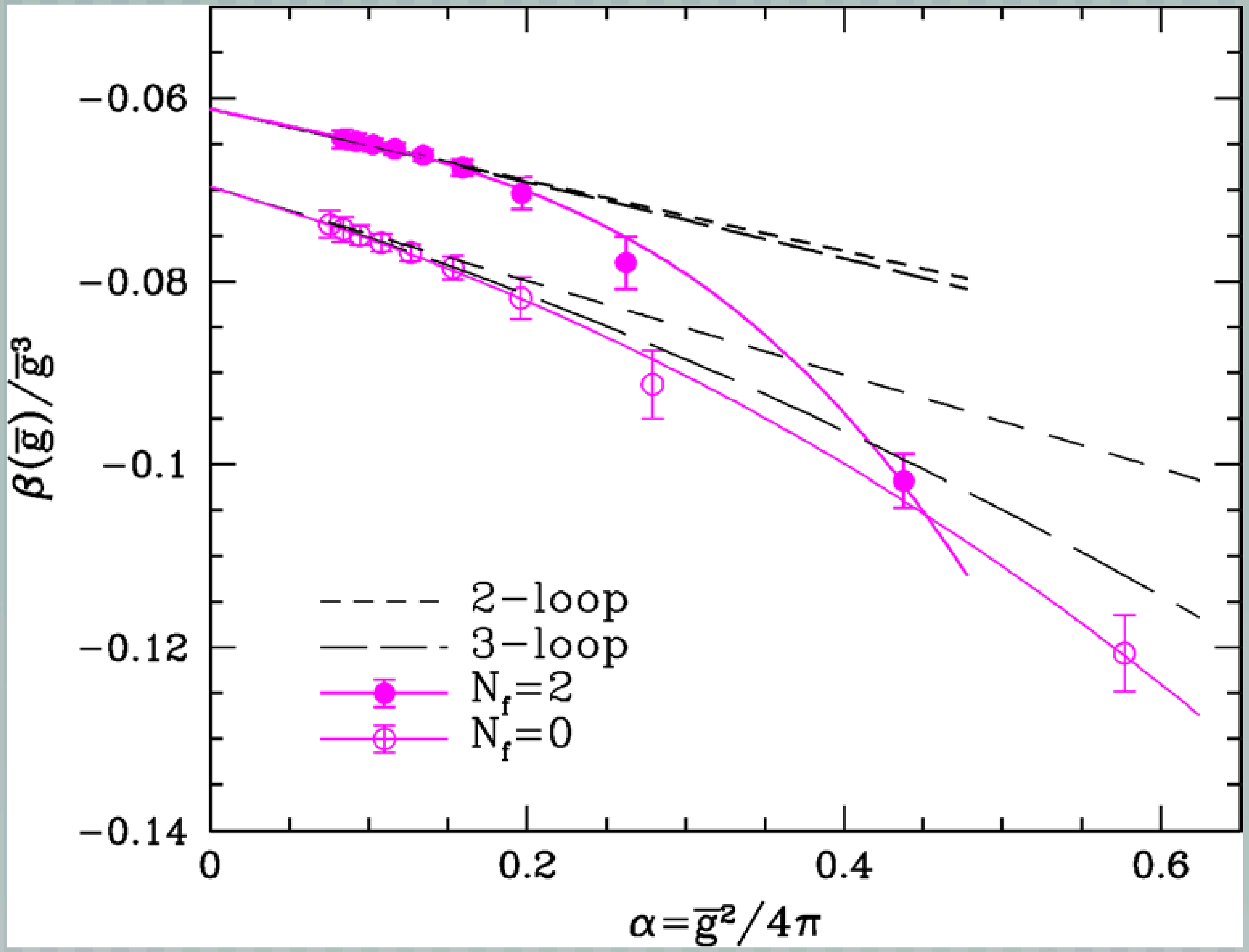
1-loop is fastest PT running

no indication of IRFP

QQ scheme 3-loop

$$\alpha^*_{qq} = 0.371$$

an old warning?



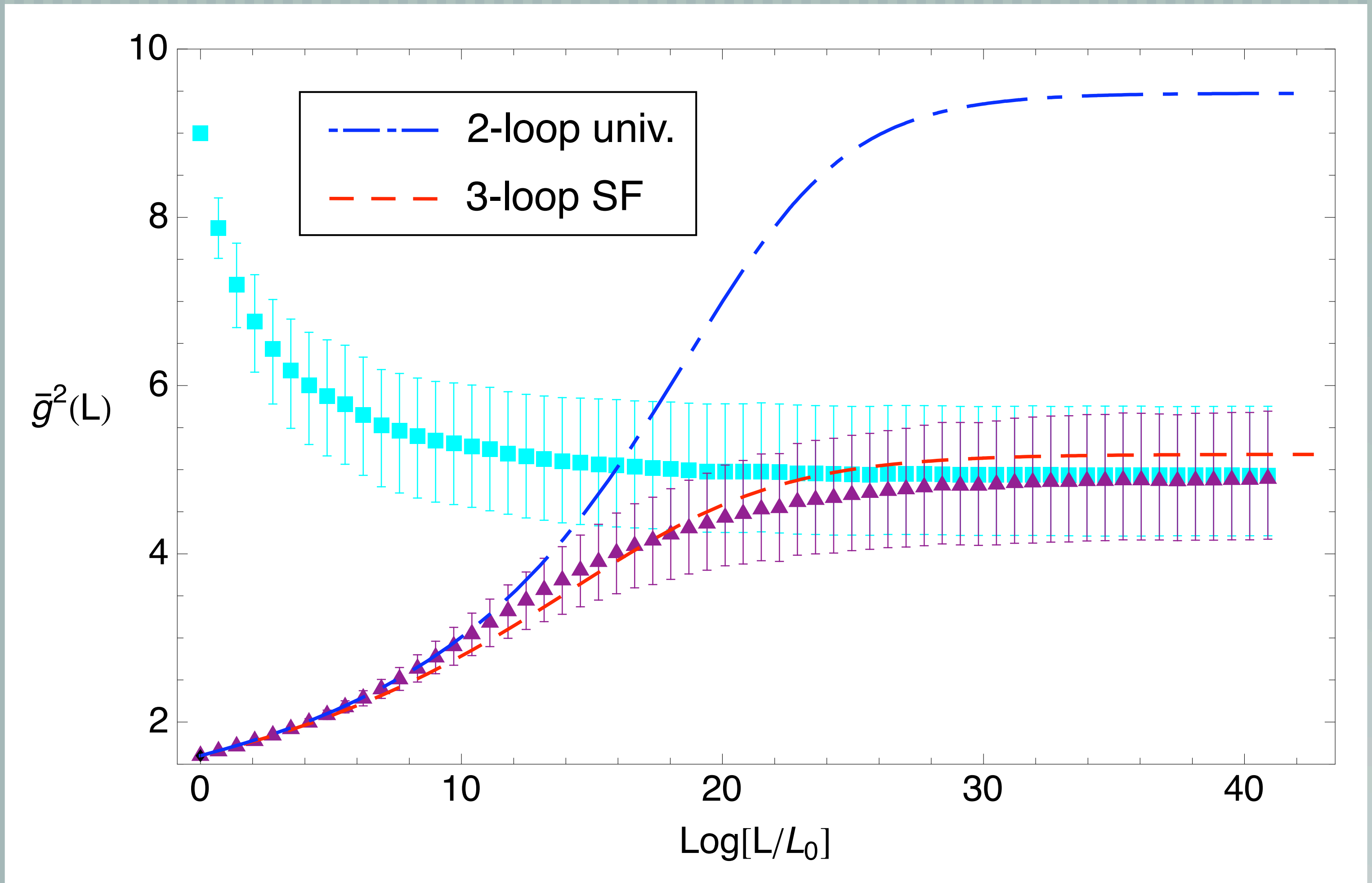
ALPHA Collab NPB713 (2005)

Schrodinger Functional

0 and 2 flavor QCD

2 flavor runs faster than PT, even where 2- and 3-loop almost identical

other 12 flavor studies



Appelquist, Fleming, Neil
arXiv: 0712.0609, 0901.3766

Schrodinger functional

12 flavor QCD

find IR fixed point very close to 3-loop prediction

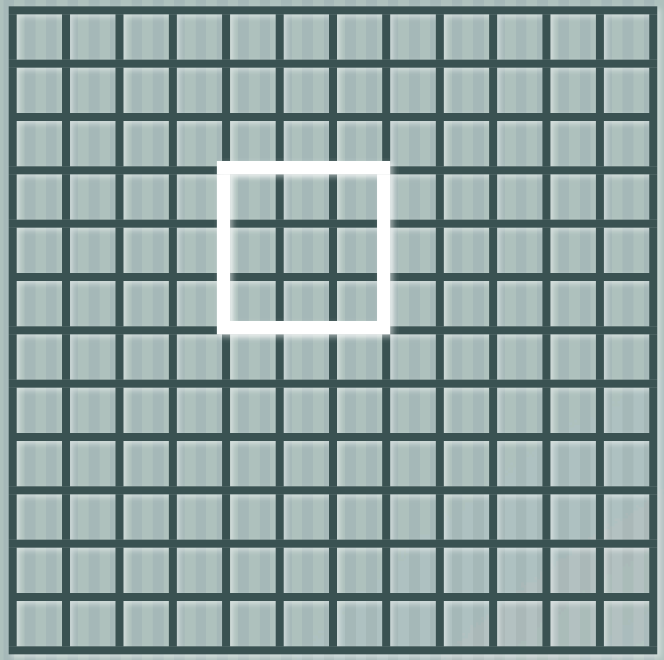
no consensus

Other work:

Lombardo et al   Hasenfratz

Jin & Mawhinney   Bilgici et al

Wilson running coupling



continuum

Campostrini et al. PLB349, 499 (1995)

$$\alpha_W(R/L, L) = -\frac{R^2}{4\pi k}\frac{\partial^2}{\partial R \partial T}\ln\langle W(R,T,L)\rangle|_{T=R}$$

lattice

$$\alpha_W(R/L, L) = -\frac{(R+1/2)^2}{4\pi k}\ln\frac{\langle W(R+1,R+1,L)\rangle\langle W(R,R,L)\rangle}{\langle W(R+1,R,L)\rangle\langle W(R,R+1,L)\rangle}$$

Wilson loop $W(R,R)$

lattice size L^4

possibilities

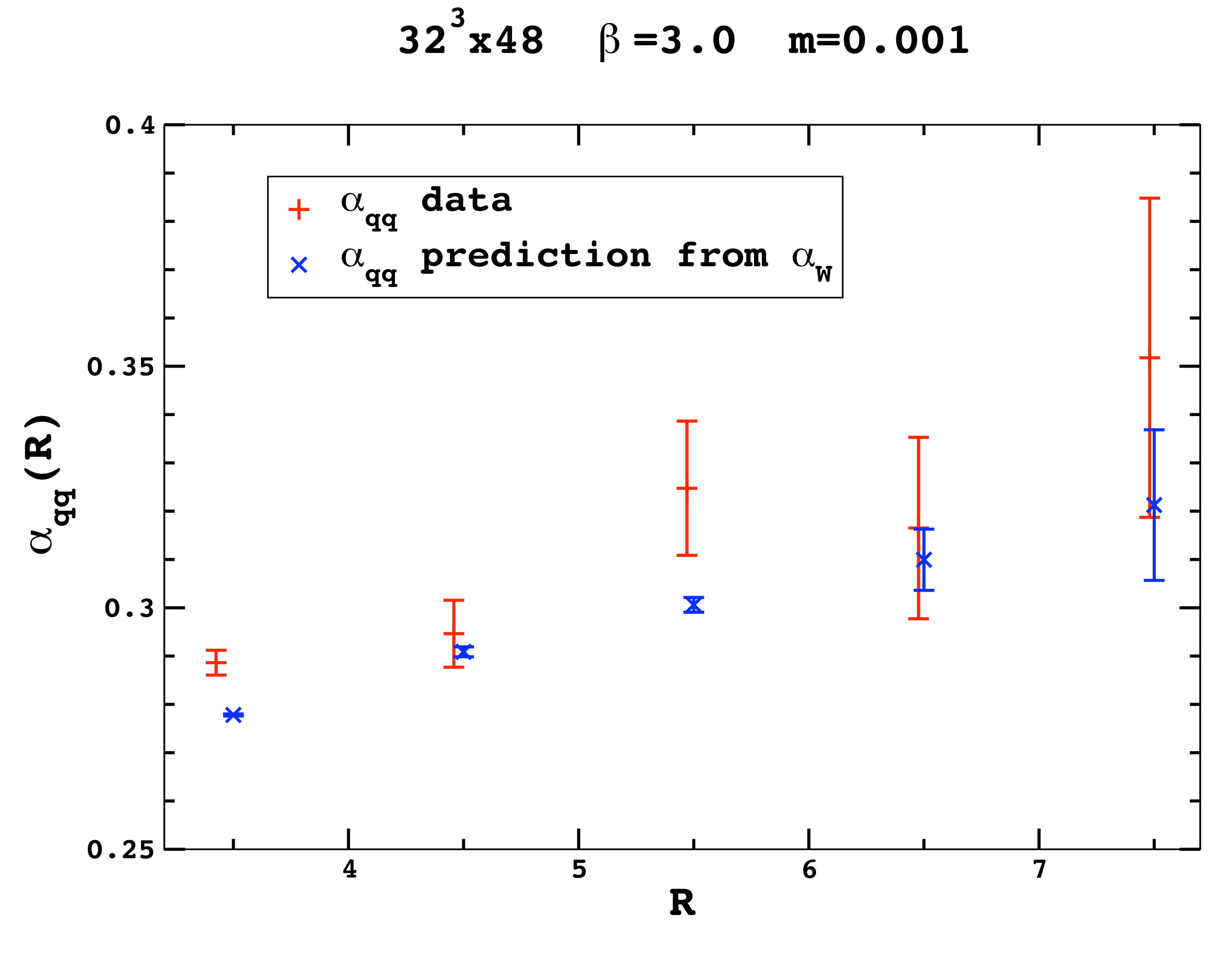
a. $L \to \infty \Rightarrow \alpha_W(R)$

b. (R/L) fixed $\Rightarrow \alpha_W(L)$

connect to QQ scheme

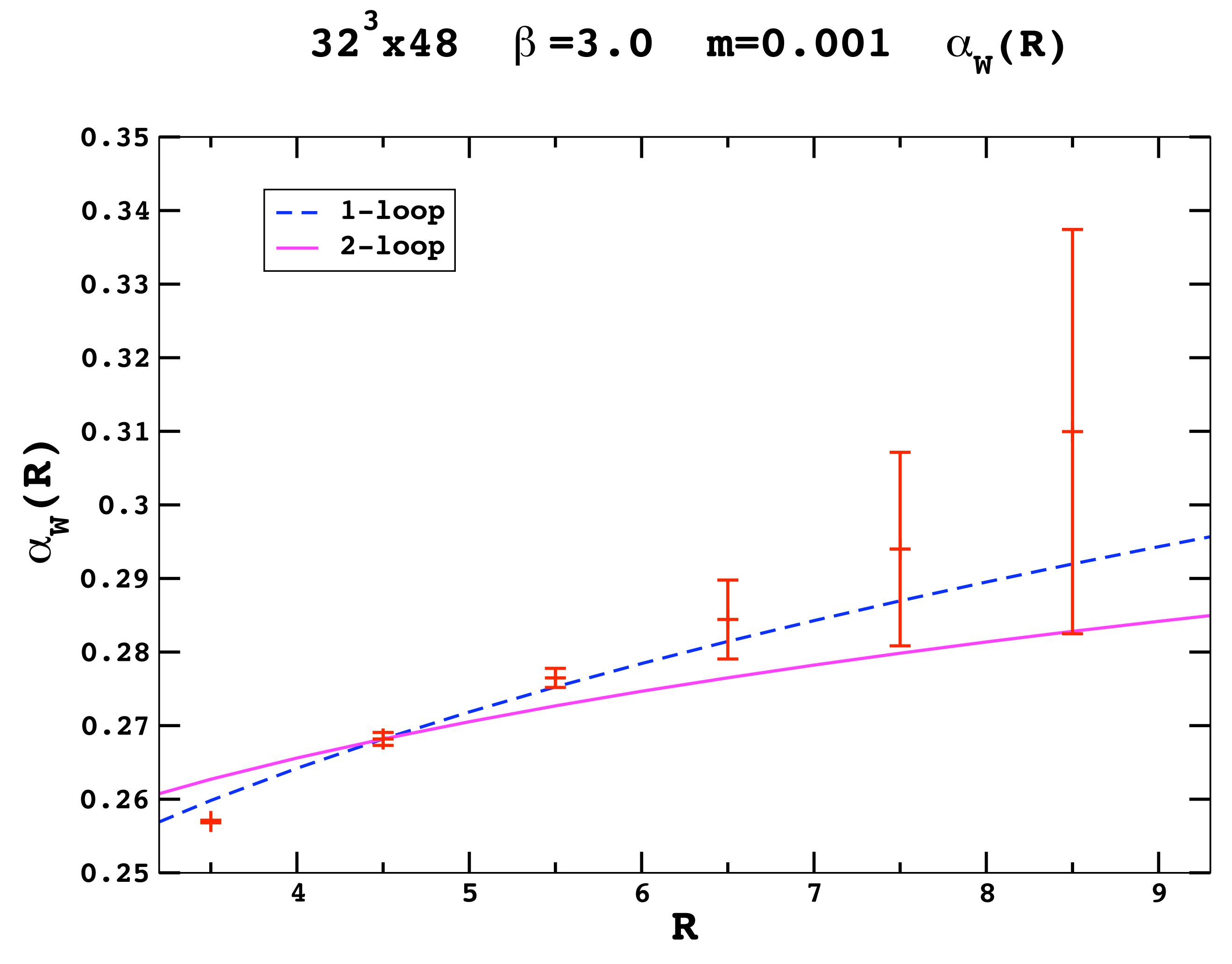
$$\alpha_{qq}(R) = \alpha_W(R)[1 + 0.31551\,\alpha_W(R) + \mathcal{O}(\alpha_W(R)^2)]$$

compare schemes



QQ and Wilson schemes consistent

Wilson coupling also running fast



- running consistent with pert thy at weaker coupling
- running faster than pert thy at stronger coupling
- no indication of infrared fixed point i.e. looks QCD-like
- consistent with our 12 flavor spectroscopy results
- more to do: bare running, other schemes, continuum limit