Wilson Many Flavor QCD

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in collaboration with

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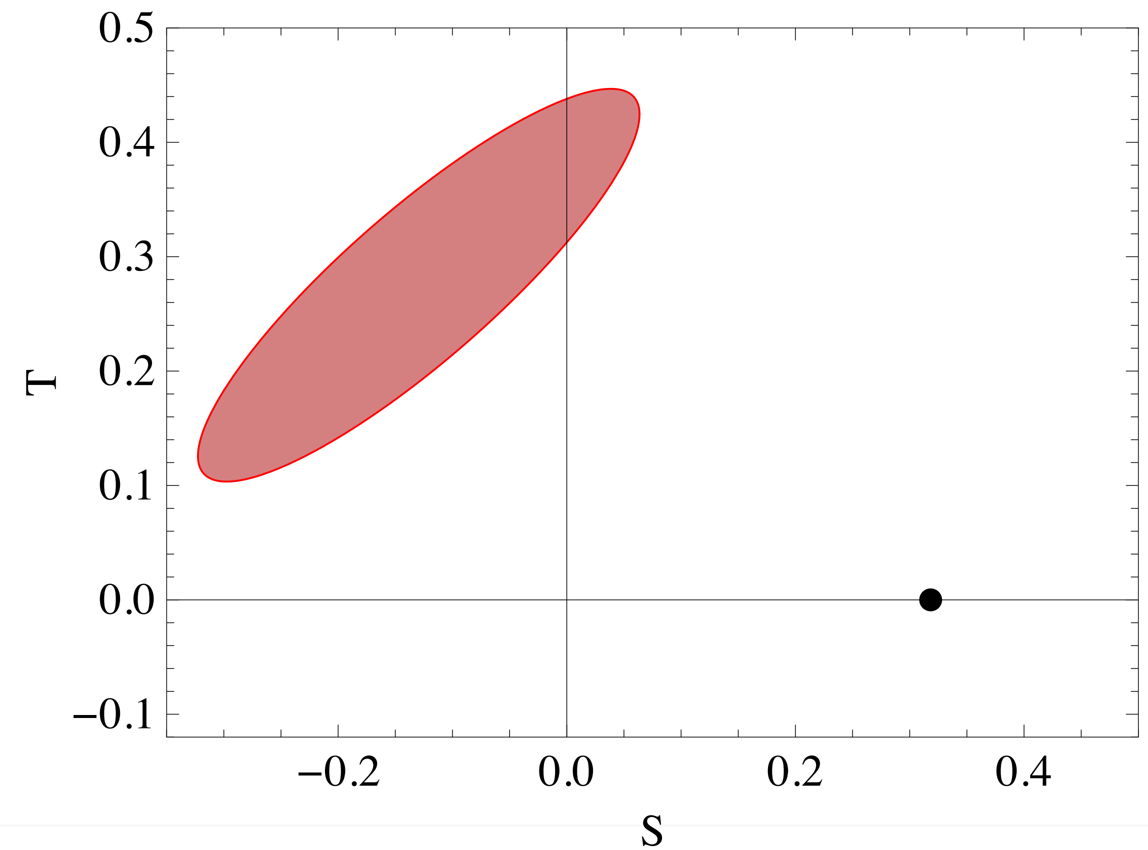
Problems in classical Technicolor

FCNC-m_q

S-parameter

Anderson et al. (2011)



m_{H}=125 GeV is too light?

Naive expectation: $m_H \sim$ O(1 TeV)

Models solving Yukawa hierarchy are complicated.

FCNC-m_q

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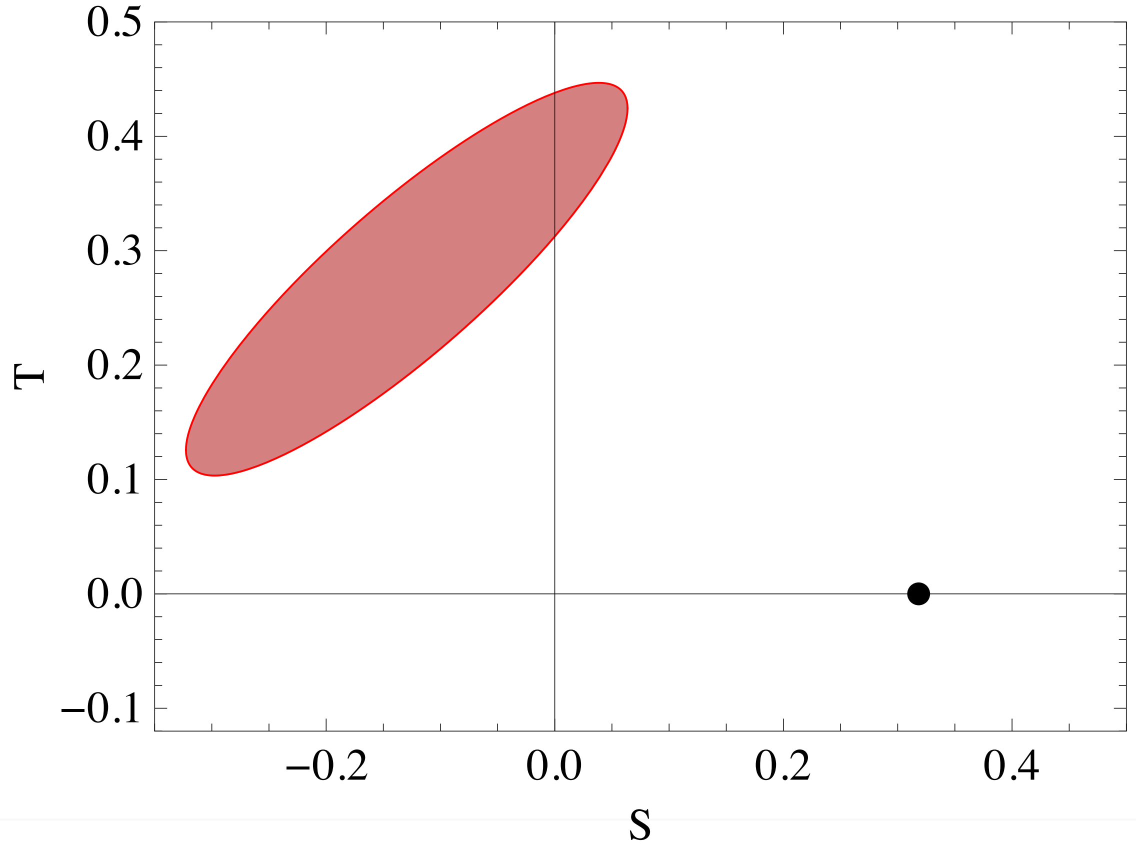

Models solving Yukawa hierarchy are complicated.

They are not really the problem.

FCNC-m_q

⇓

Walking TC

Holdom(1981), Yamawaki, Bando, Matsumoto(1986), Appelquist, Karabali, Wijewardhana(1986), ...

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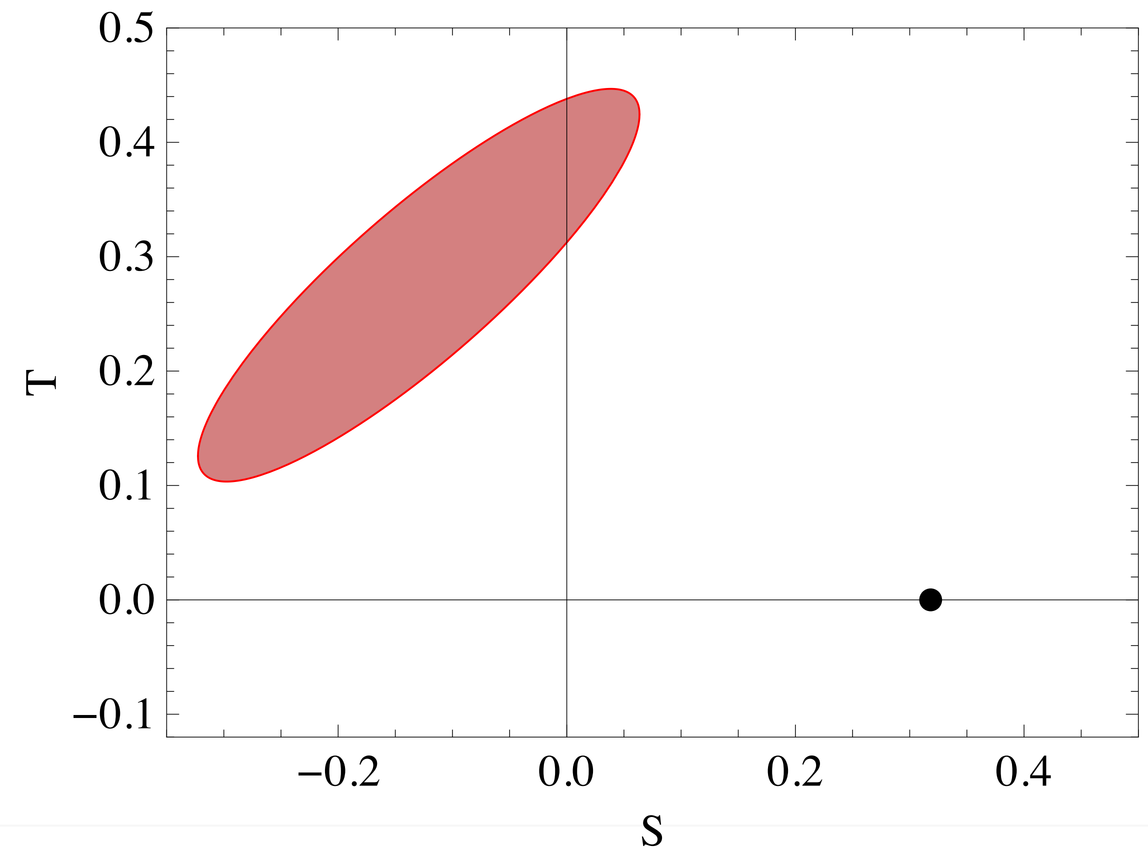

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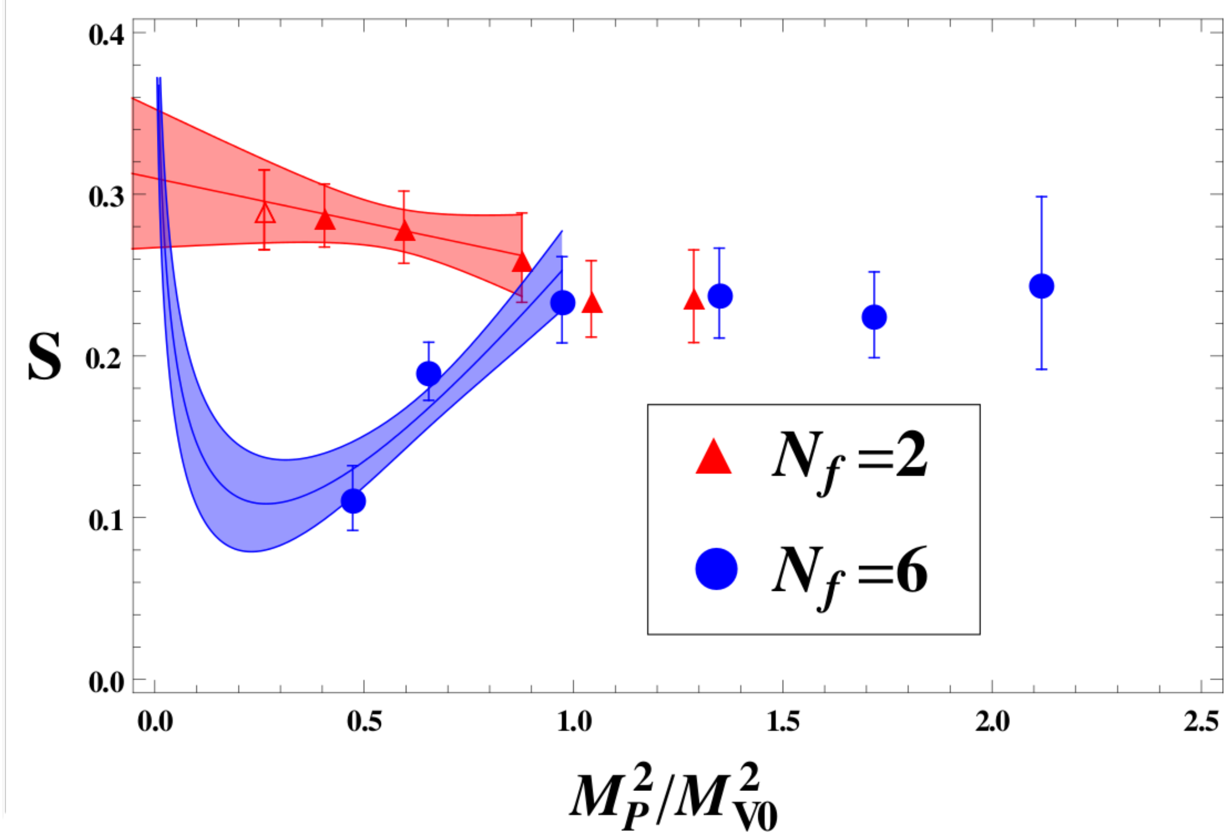

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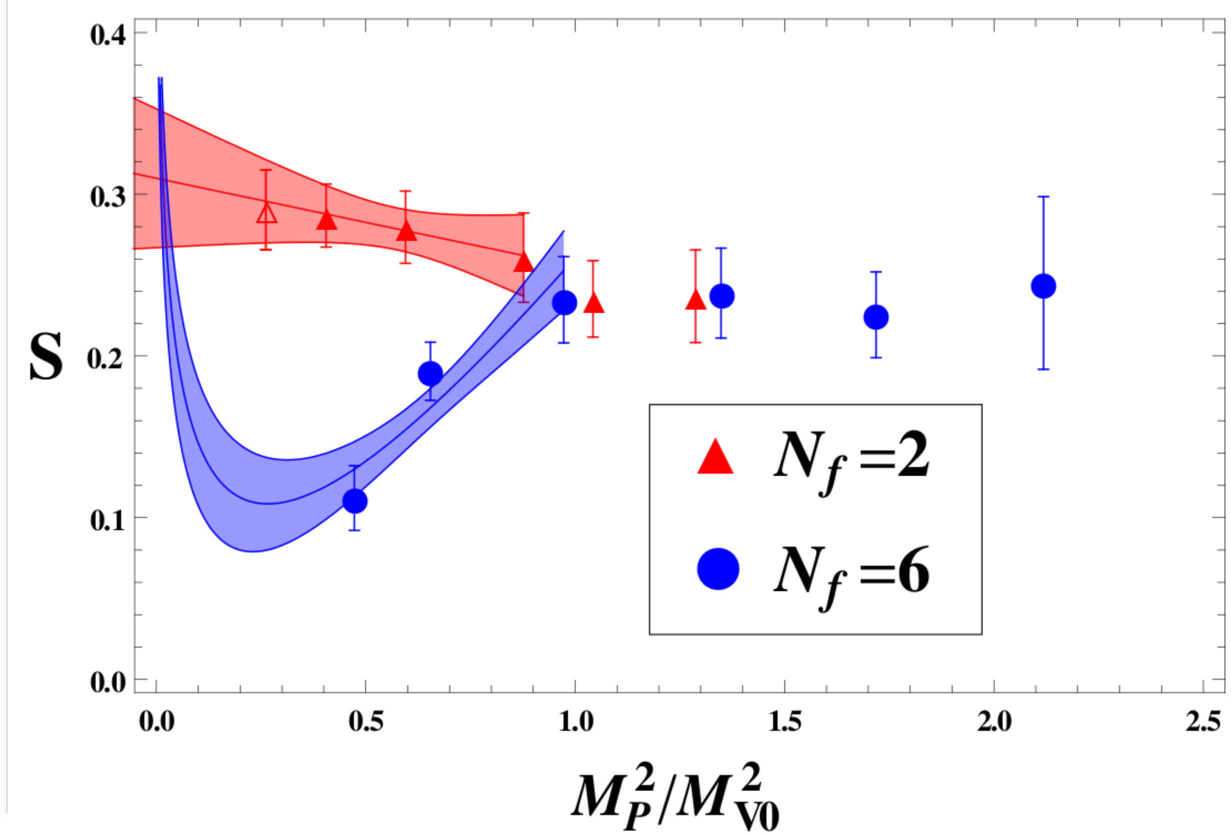
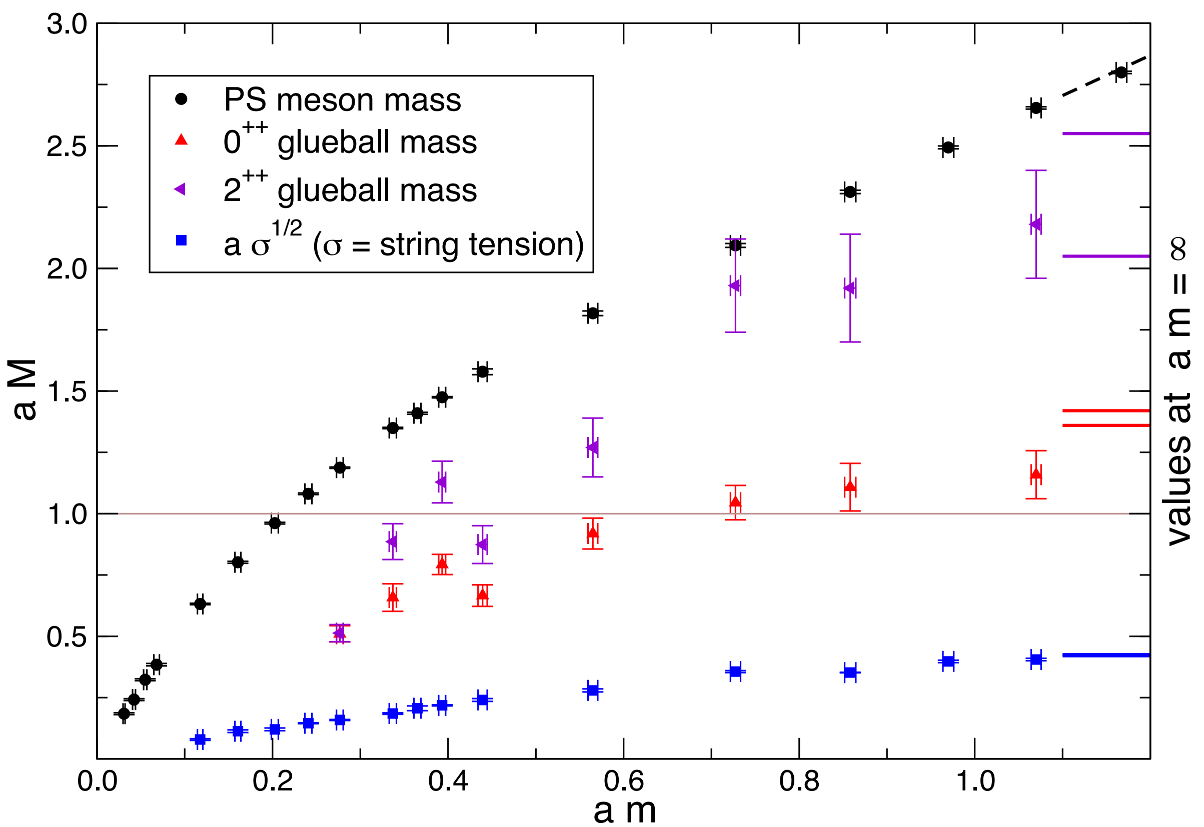


Lightest 0^{++} might be as light as 125 GeV

Del Debbio et al.(2010)



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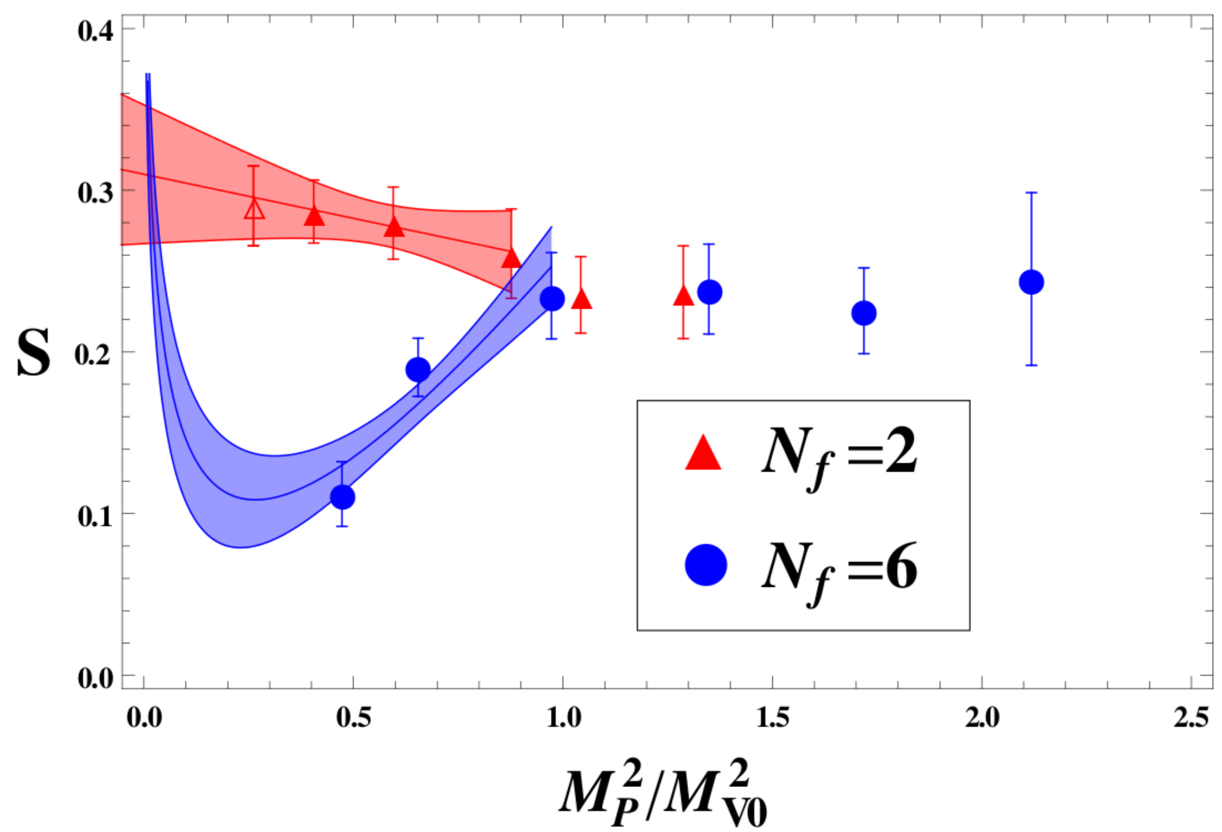

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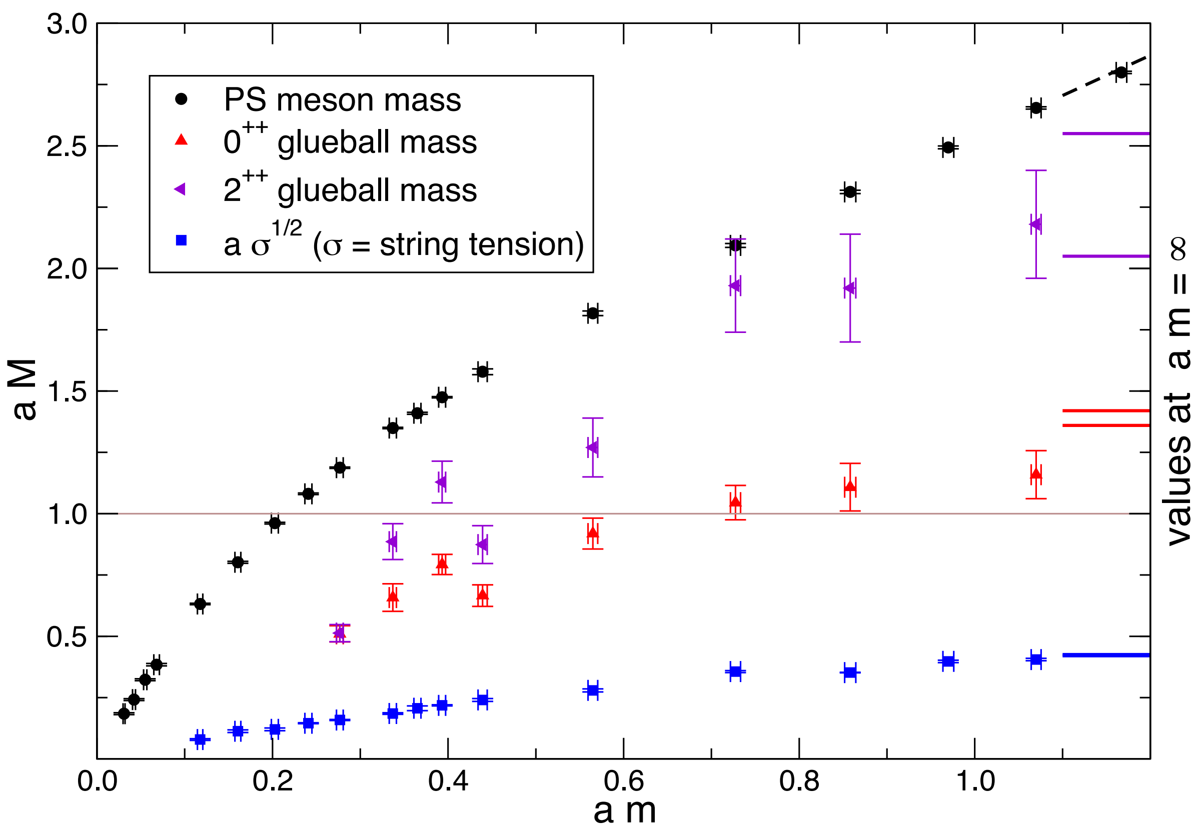


Models are complicated

On the other hand, TC model consists only of gauge and fermion fields!

What a simple!

On the lattice, having two different approaches favorable

1.Step scaling approach:

- ✓ Can tell the existence of IRFP if it's observed.
- ✓ Cannot prove absence of IRFP as it might be larger than the coupling up to which one can explore.

2.Spectroscopy:

- ✓ If data reproduce ChPT predictions and chiral condensate and f_π are finite, that's it.
- ✓ Even if the above is not observed, It's not easy to conclude a theory to be conformal as we do not know in advance whether m_q is small enough and V is large enough.
- ✓ Need to know what should happen if a theory is conformal

We take Wilson fermion.

Disadvantages:

✓Scaling violation

✓Fine-tuning,

✓...

Advantages:

✓Simple, tractable and well understood

✓Many experiences

✓Able to study arbitrary N_F without any subtlety

✓Independent check to KS (or other) results

With Wilson fermion, we are studying

1. Step-scaling approach:
   - $\alpha(\mu)$ and γ_m in 10-flavor QCD
   - (α(μ) and γ_m in 6-flavor two-color QCD)
2. Spectroscopy:
   - 6-flavor two-color QCD
3. Finite temperature study:
   - Many flavor QCD

Flash the status of each study.

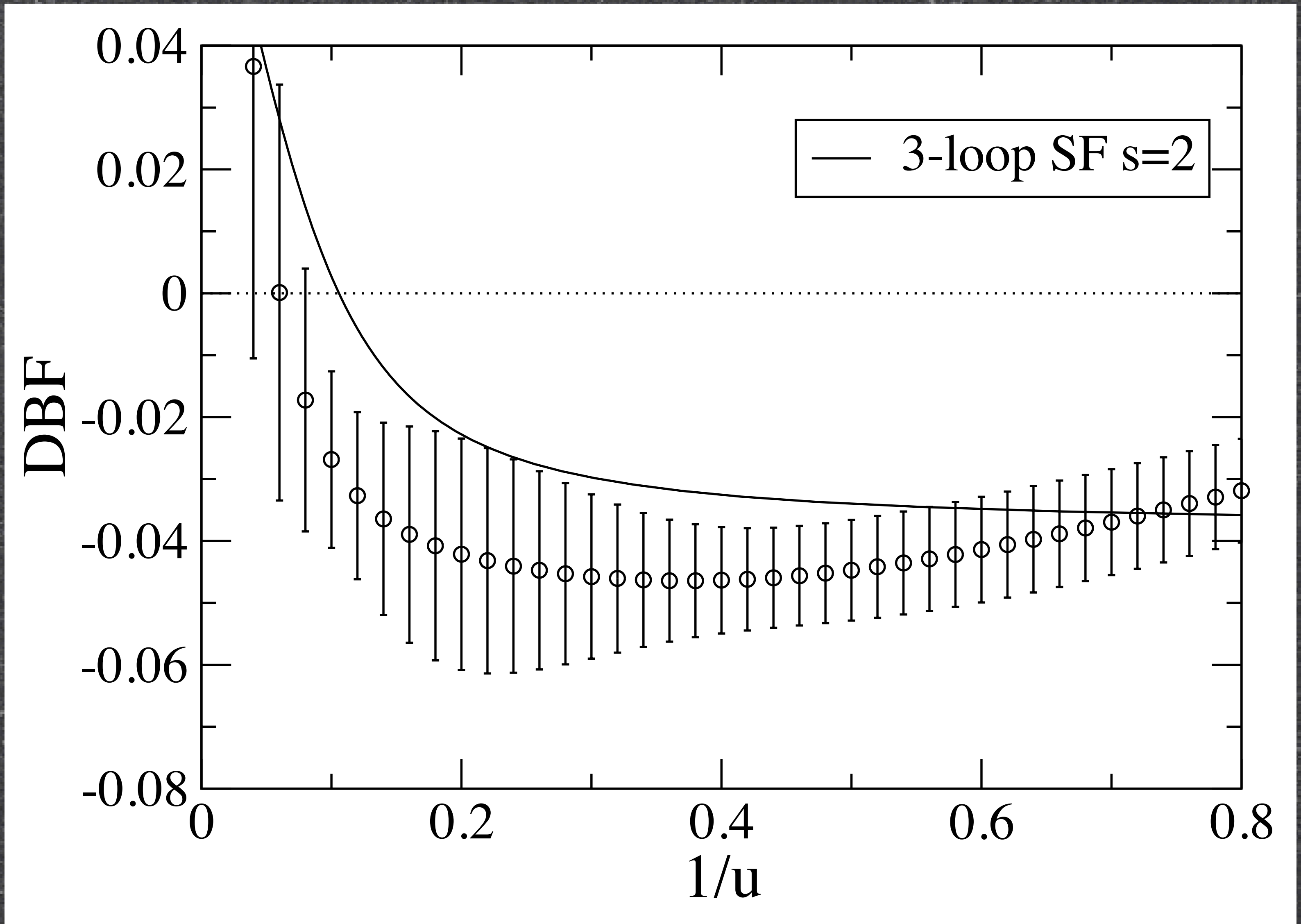
No definite conclusion in this talk.

$\alpha(\mu)$ and γ_m of 10-flavor QCD

$\alpha(\mu)$ of 10-flavor QCD

Hayakawa, Ishikawa, Osaki, Takeda, Uno, NY, PRD(2011) and work in progress

Preliminary



$$B^{\mathrm{SF}}(u,s) = \frac{1}{g^2_{\mathrm{SF}}(u,s)} - \frac{1}{u}$$

DBF ~ β function

DBF=0 ⇒ IRFP

$g^2_{FP} \geq 12$

Continuum extrapolation with two data points.

In order to have more confidence, large V calculation is on-going.

$\alpha(\mu)$ of 10-flavor QCD

Hayakawa, Ishikawa, Osaki, Takeda, Uno, NY, PRD(2011) and work in progress

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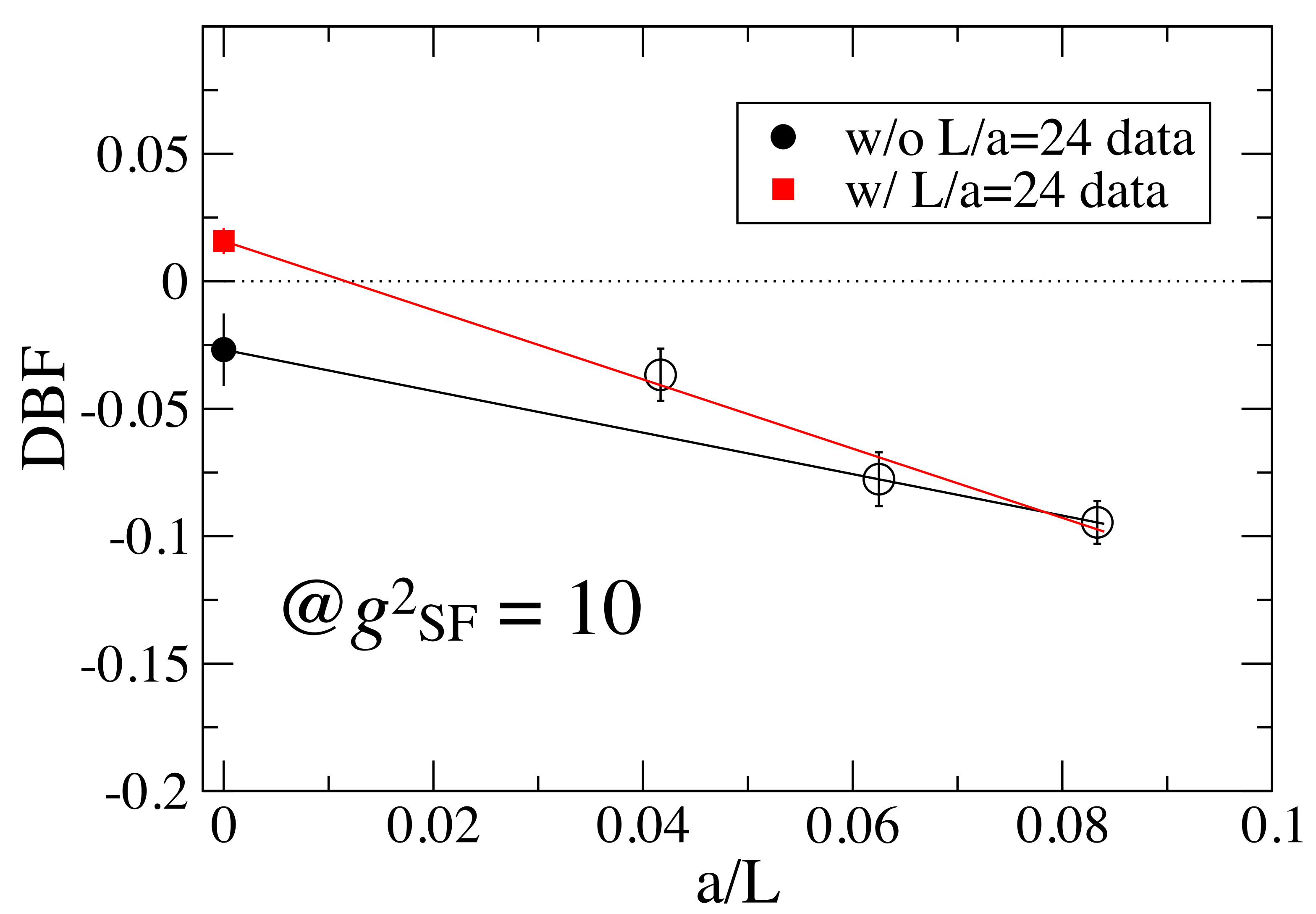


Adding large V data, the continuum limit shits upward.

$g^2_{FP} \geq 12 \Rightarrow g^2_{FP} \lesssim 10$

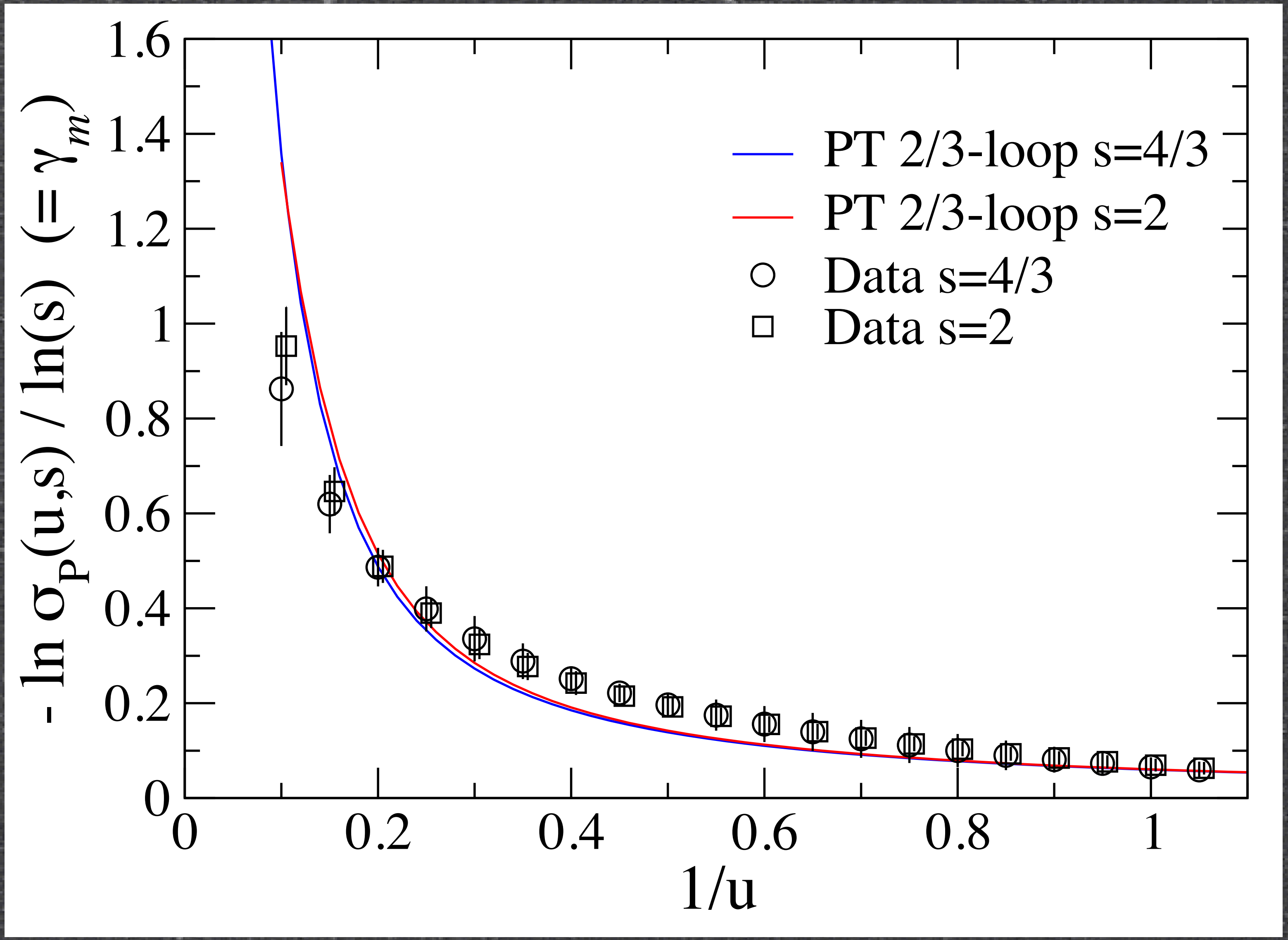
⬇

Likely to be conformal.

γ_m of 10-flavor QCD

Hayakawa, Ishikawa, Osaki, Takeda, Uno, N.Y., work in progress

Preliminary



Two different step scaling factors give consistent result.
Consistent with PT.
Assuming $g_{\mathrm{FP}}^2 \sim 10$, $\gamma_m \sim 1$!

Finite temperature in Many Flavor QCD

Finite temperature in MF QCD

Motivation:

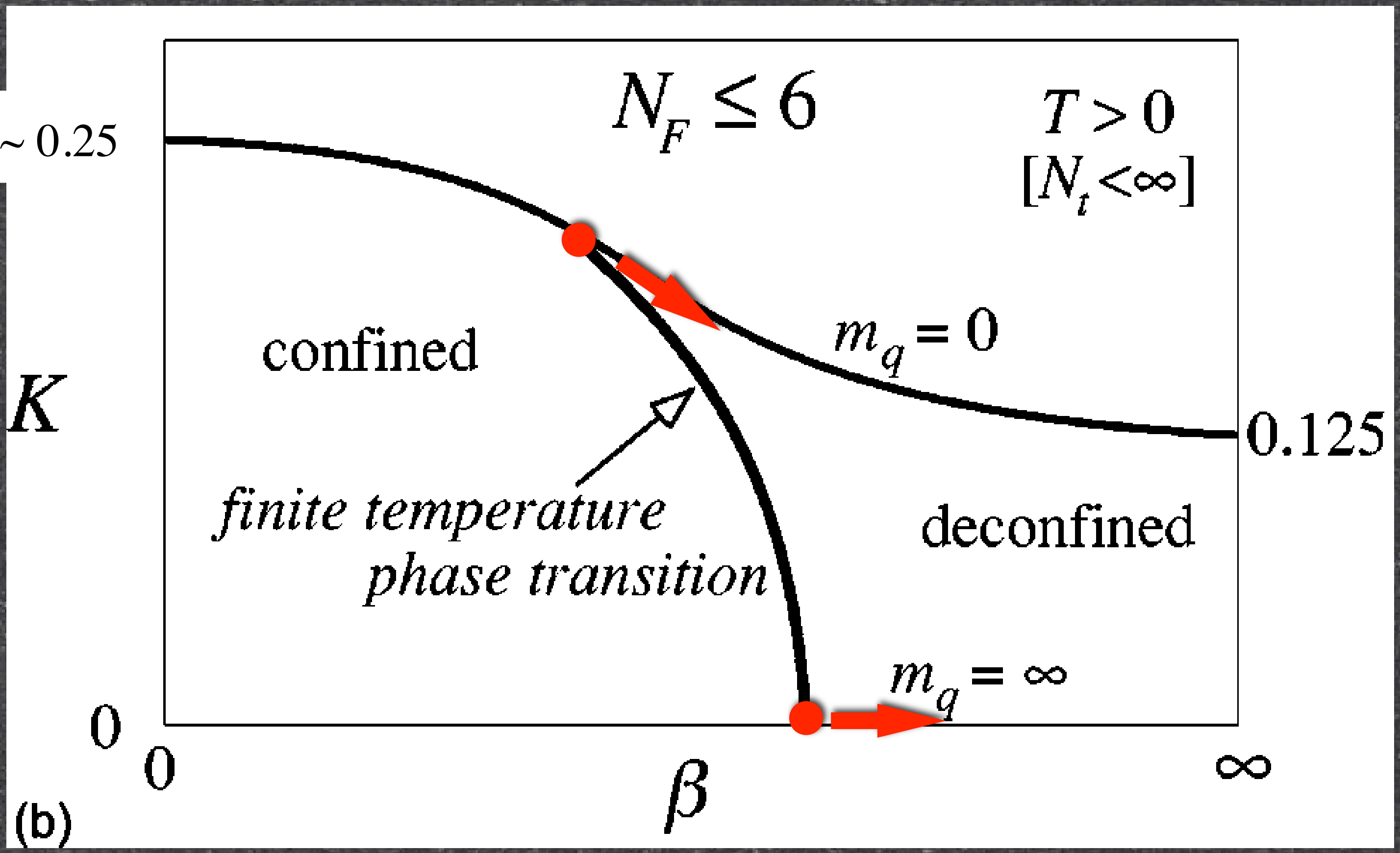
- ✓ Pinning down N_F^C is not easy.
- ✓ N_F=8 is still interesting.
- ✓ Return to the naive and straightforward method.

Strategy:

- ✓ Look for finite temperature transition.
- ✓ Examine whether the transition is thermal or bulk and 1st, 2nd or crossover.
- ✓ We start with N_F=6.

Phase diagram of Wilson fermion

Iwasaki et al. (91,04)



If the theory is confining, the transition line move to the right as T decreases (or V increases).

Both are 1st order.

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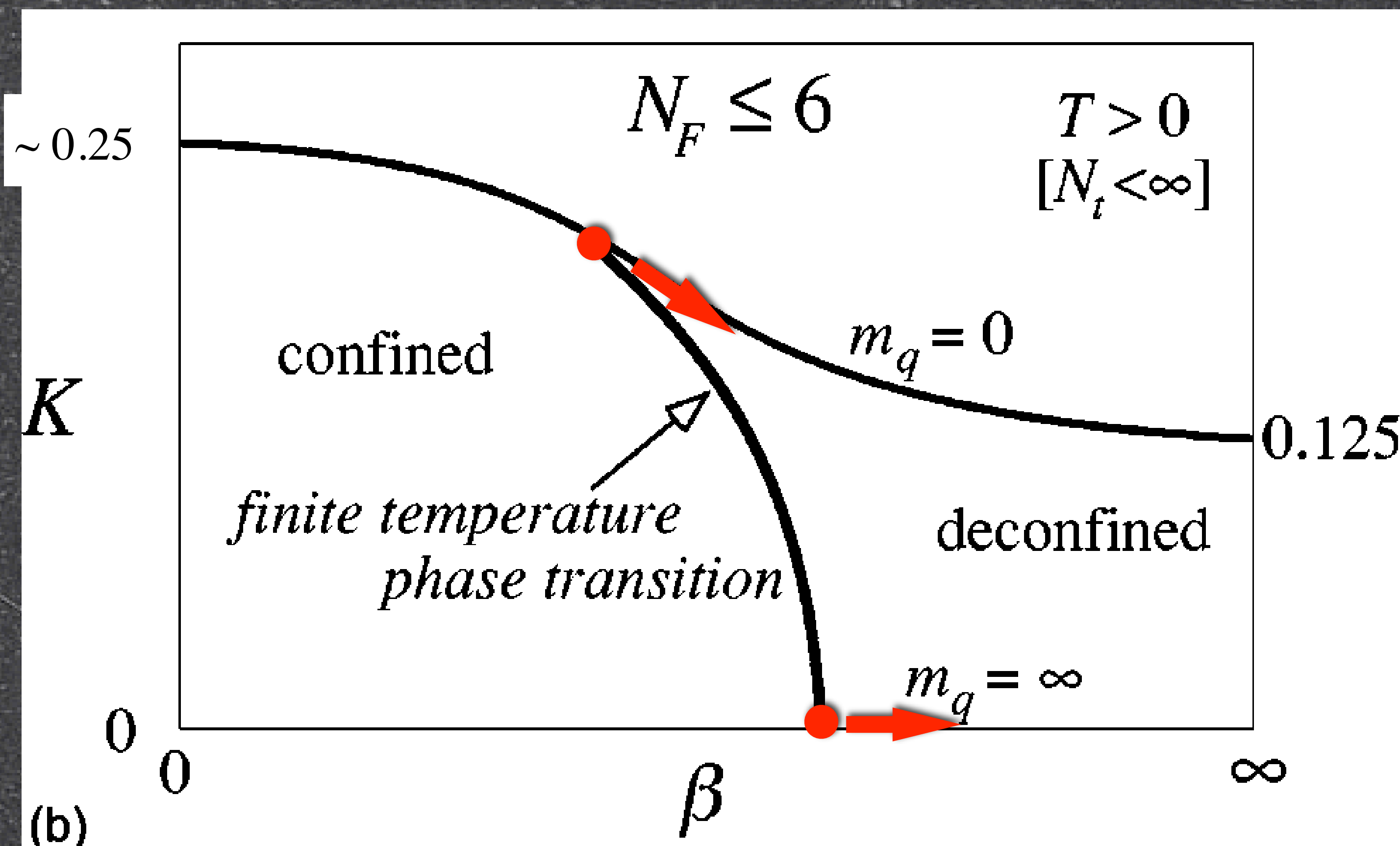

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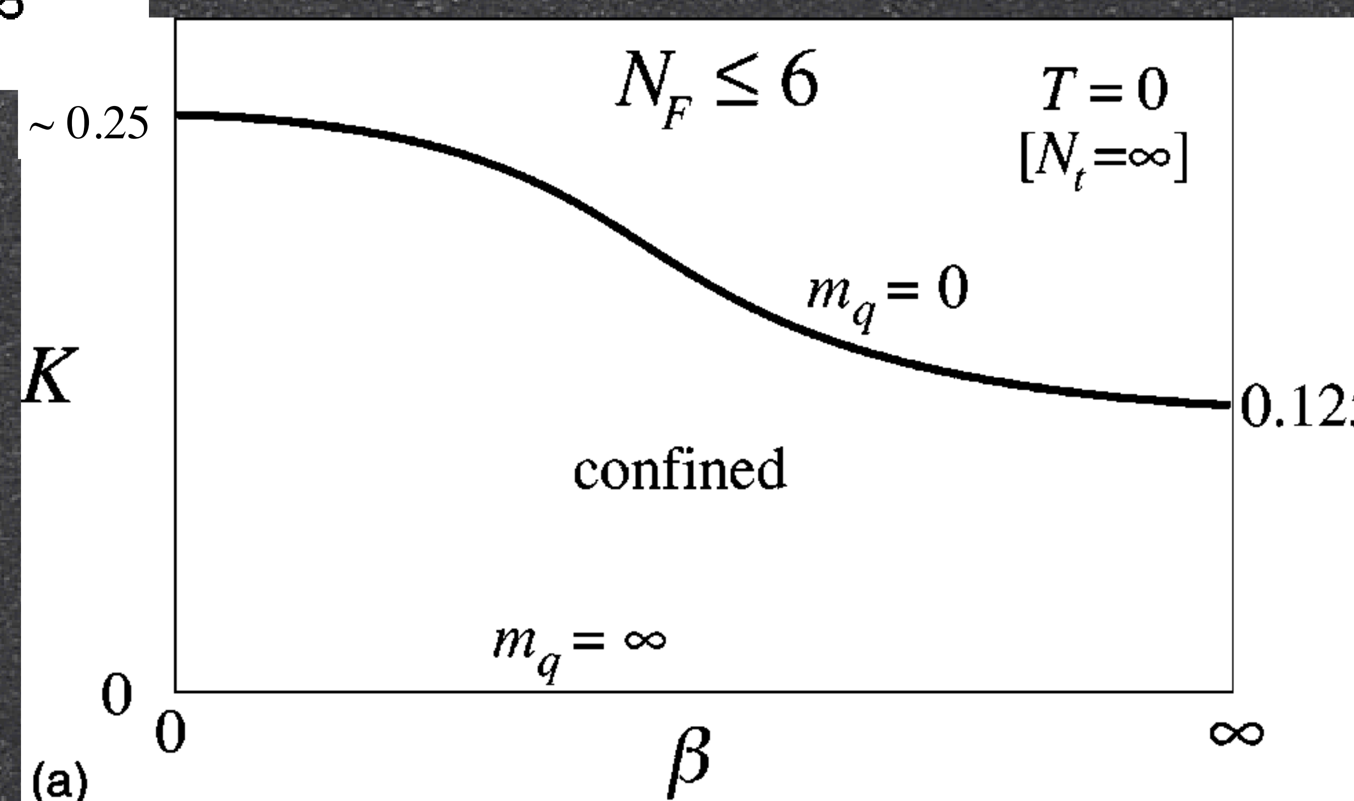
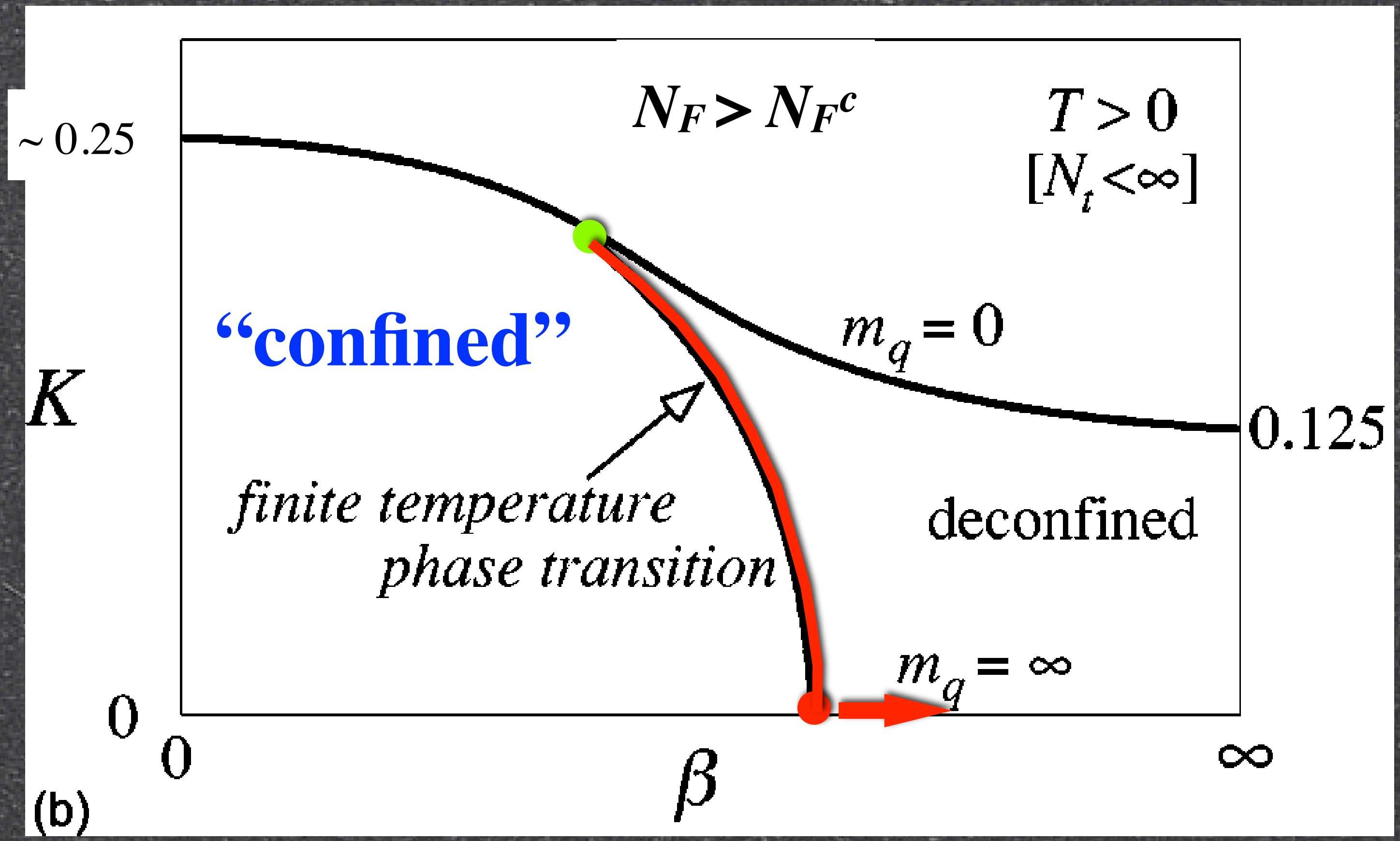


Eventually, the whole parameter space including the continuum limit is covered by confining phase.

Phase diagram of Wilson fermion

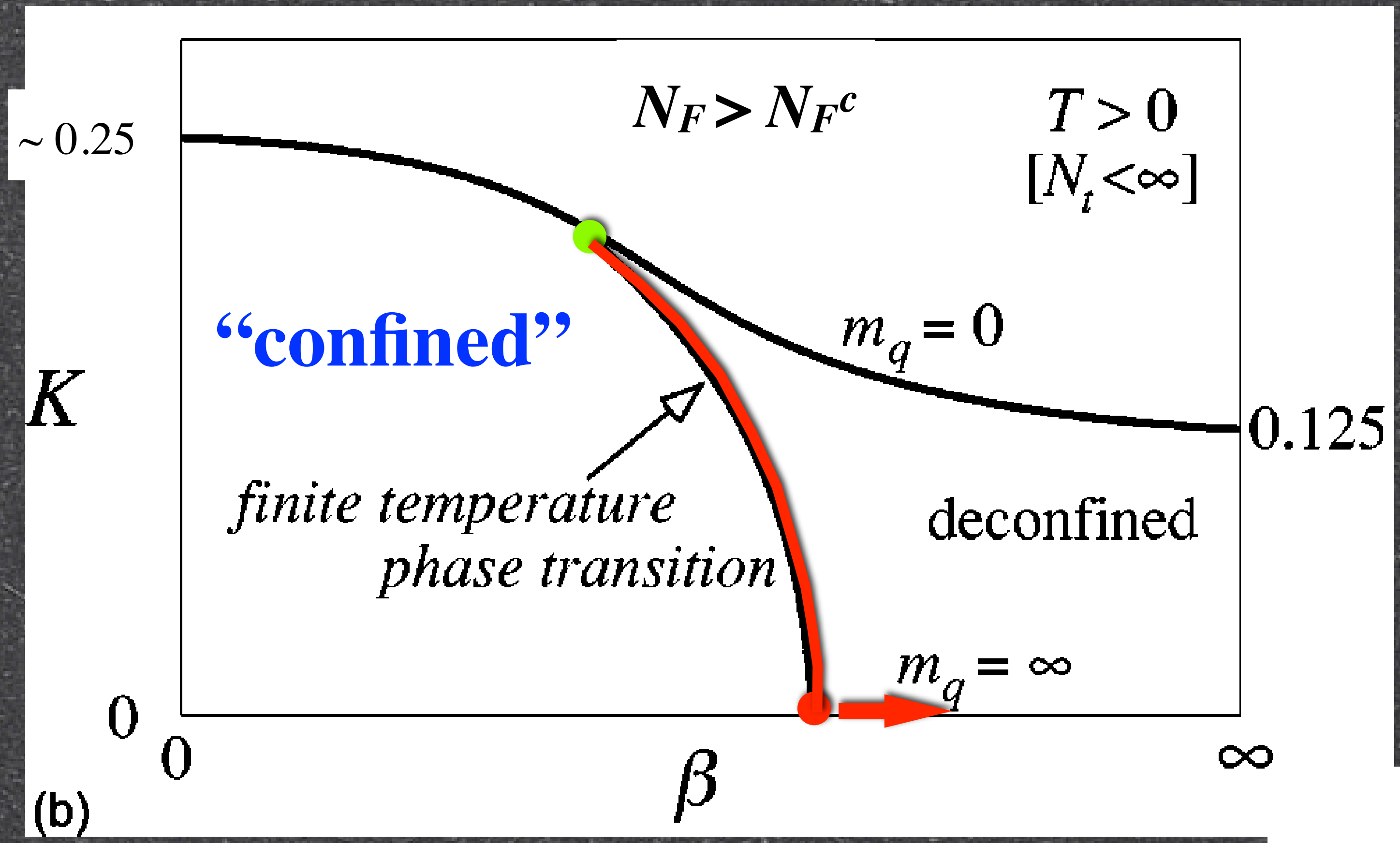
Speculation



If the theory is conformal, the one end of the line (1st) moves to the right as before, while the other (2nd or c.o.) won't.

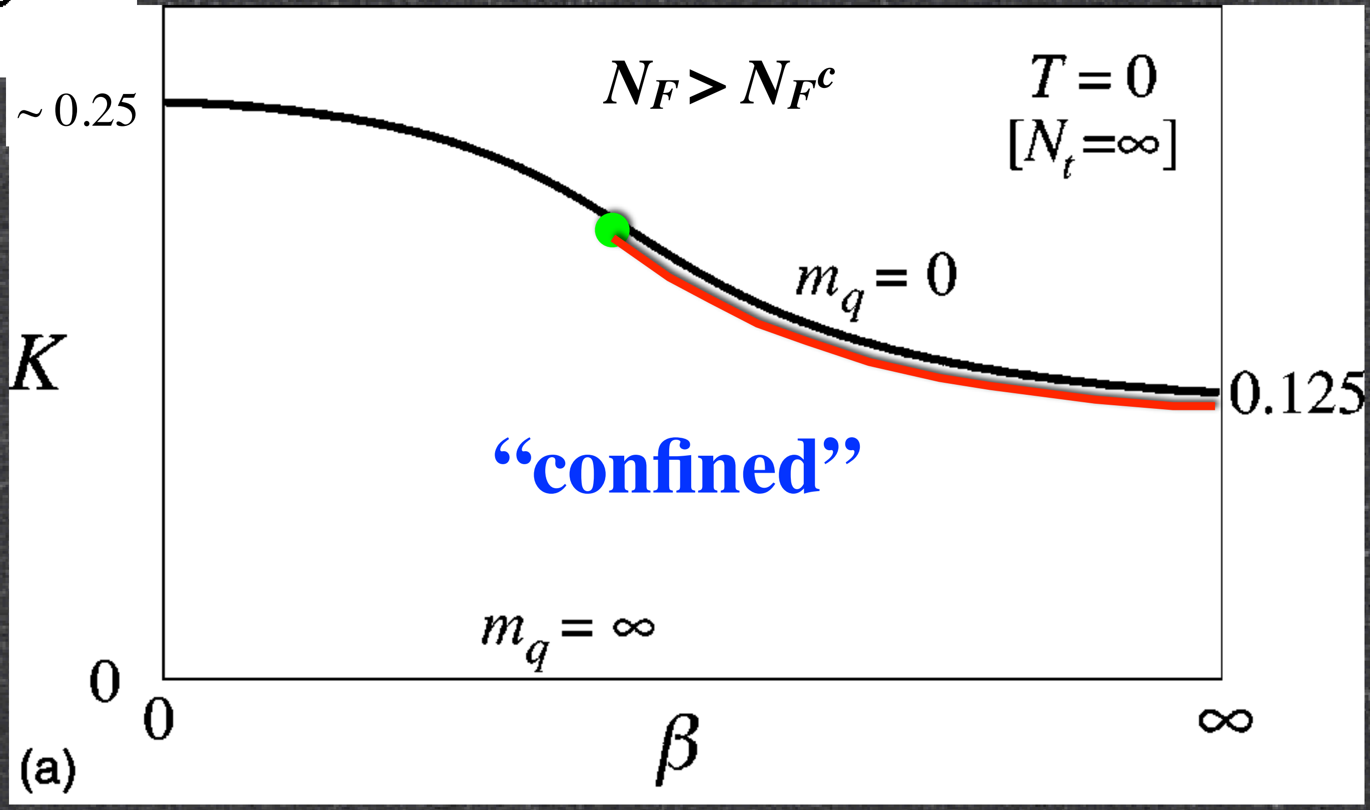
Phase diagram of Wilson fermion

Speculation



If the theory is conformal, the one end of the line (1st) moves to the right as before, while the other (2nd or c.o.) won't.

In the large V limit, the whole parameter space is covered by "confined" phase except for the chiral limit.



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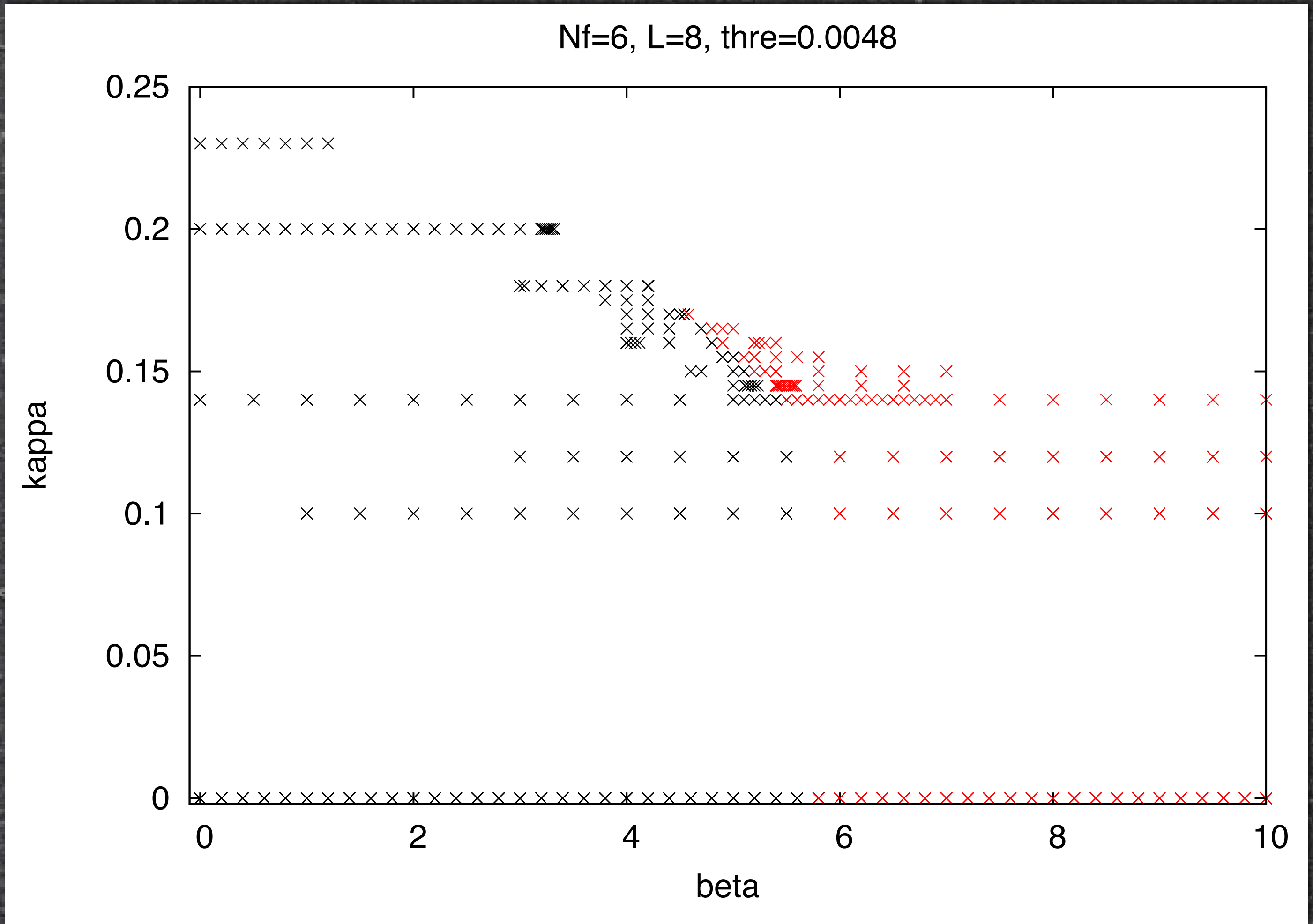
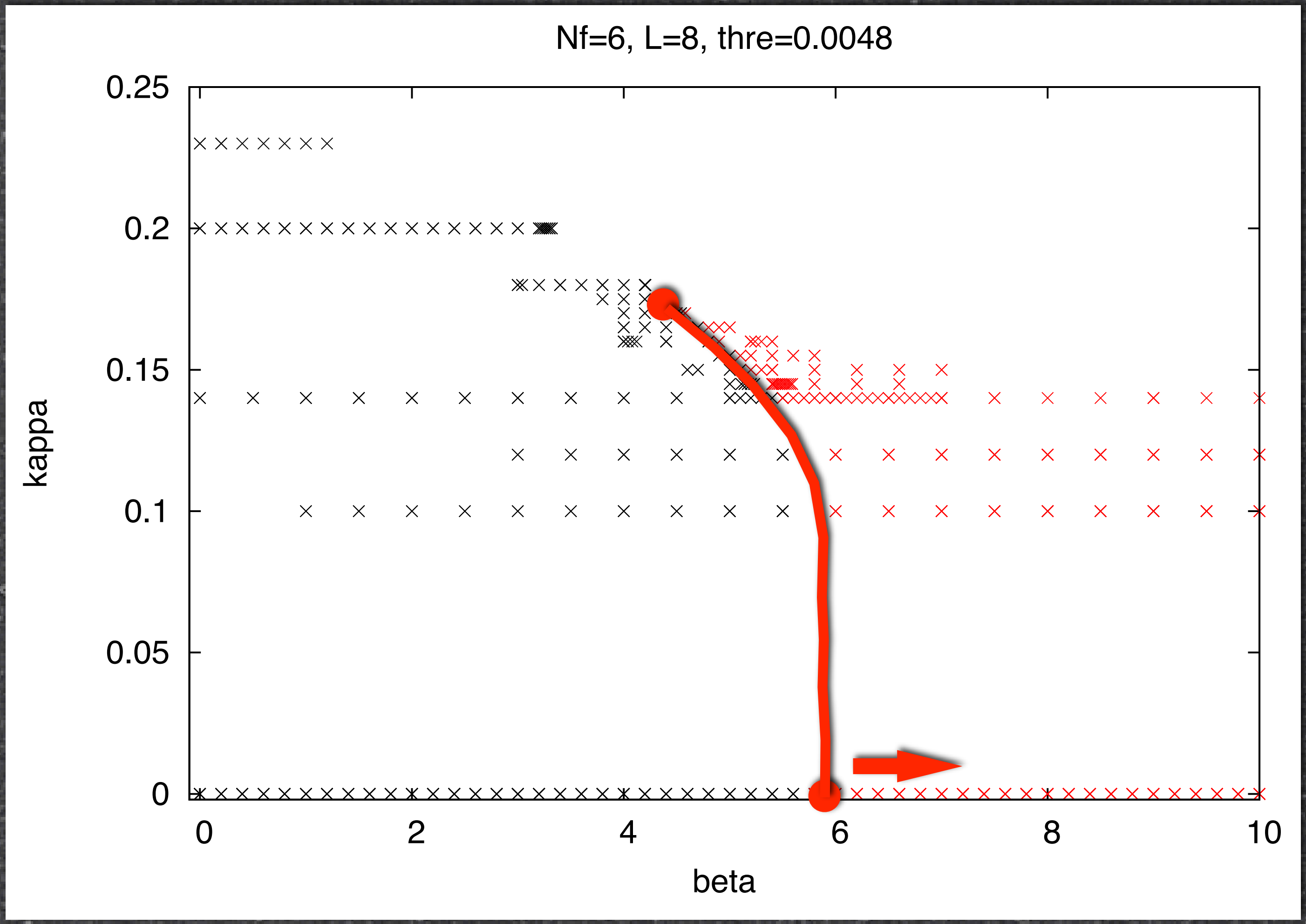


We started with N_F=6.

Phase diagram of Wilson fermion



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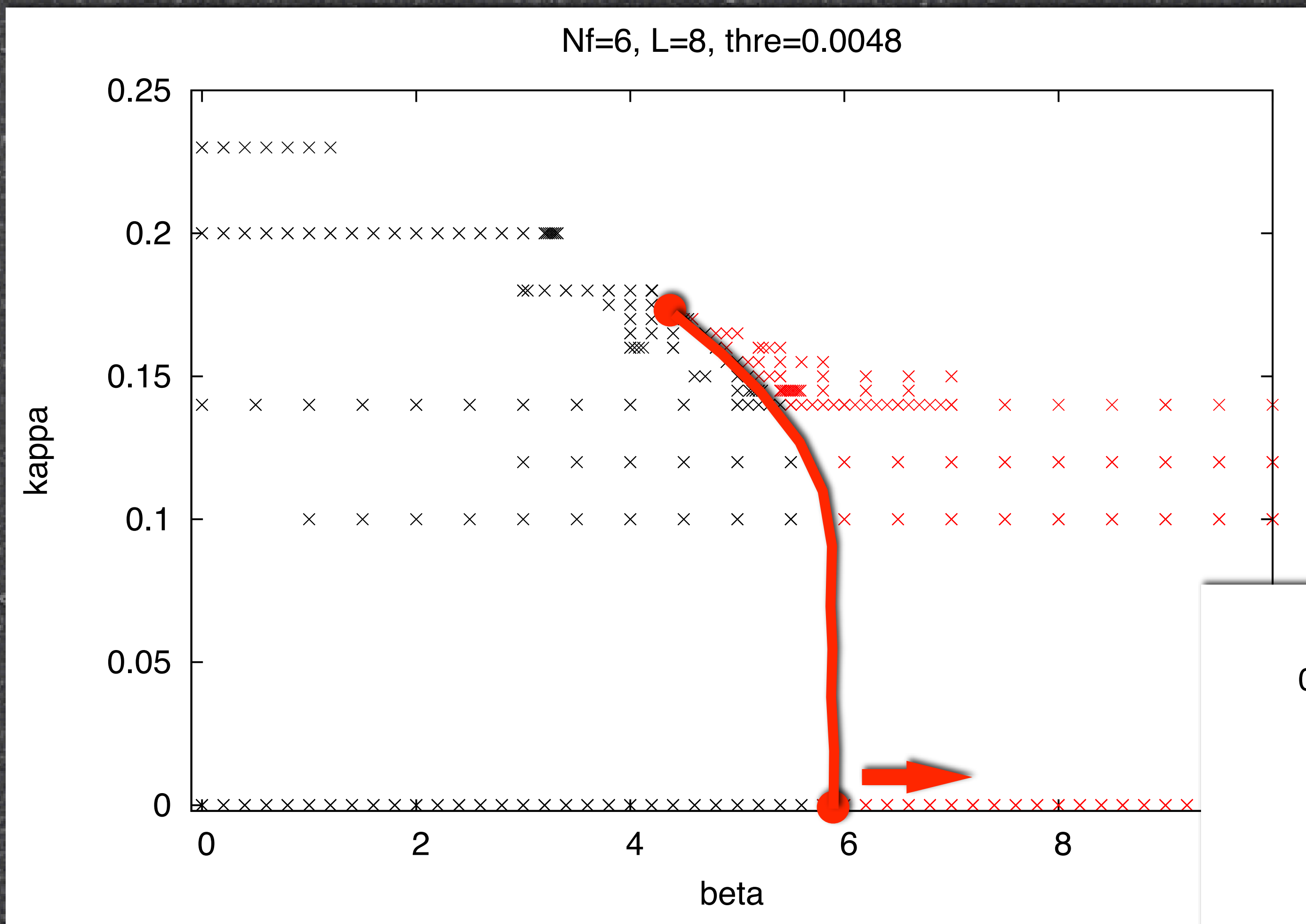

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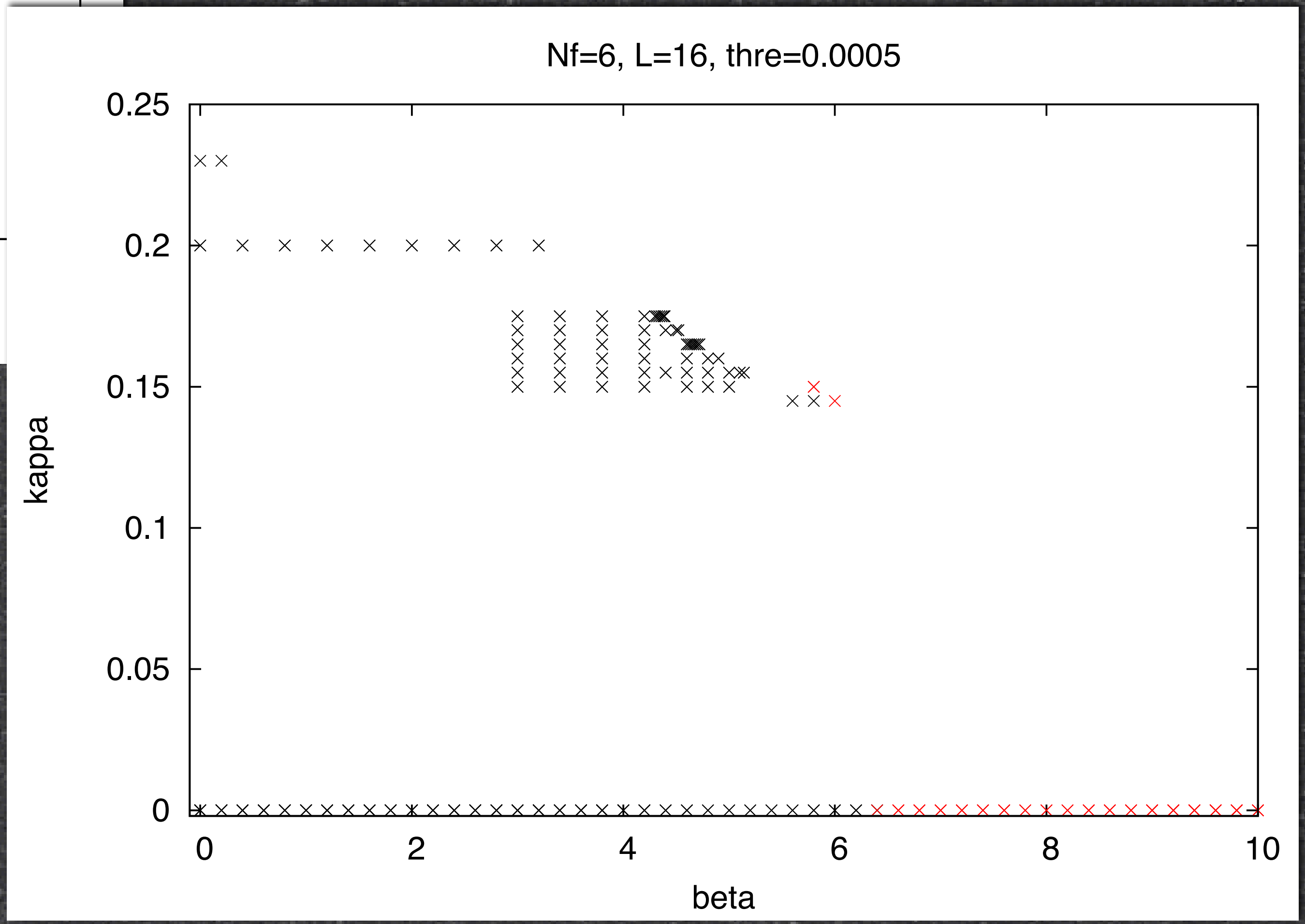


Extraction of $T_c/\Lambda_{\overline{MS}}$ (test in quench)

K. Miura, M. P. Lombardo, E. Pallante (2011)

$$\frac{1}{N_{t,s}} = T_c a(\beta_c(N_{t,s})) = \left[\frac{T_c}{\Lambda_{L,\mathrm{imp}}}\right]\left[a(\beta_c(N_{t,s}))\Lambda_{L,\mathrm{imp}}\right]$$

$$a(\tilde{\beta}_0)\Lambda_{L,\mathrm{imp}} = \exp\left[-\frac{\tilde{\beta}_0}{2N_c b_1}\right]\left(\frac{N_c b_1}{\tilde{\beta}_0}\right)^{-\frac{b_2}{b_1^2}}$$

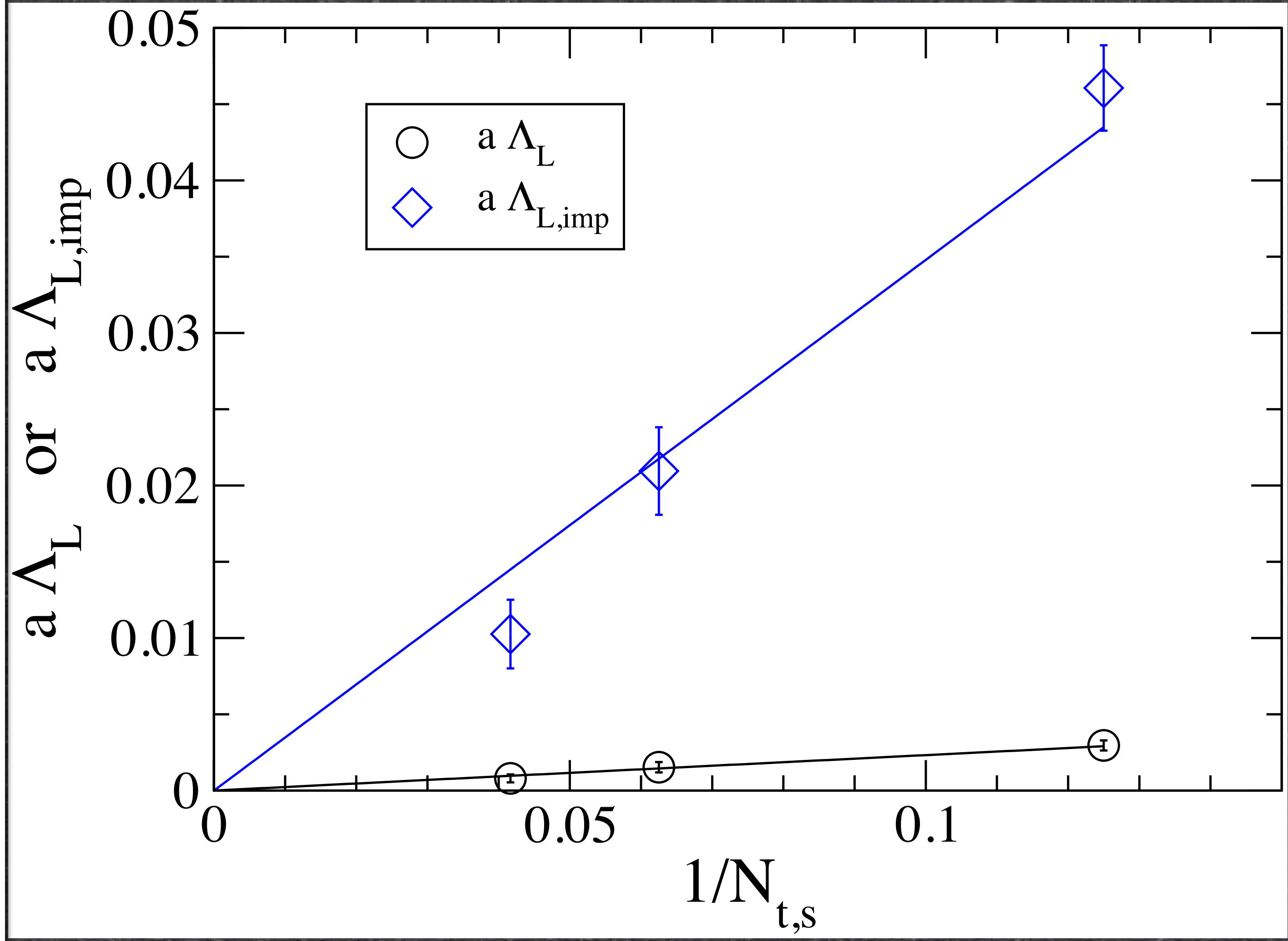
$$\tilde{\beta}_0 = \beta_0 u$$

$$\frac{T_c}{\Lambda_{L,\mathrm{imp}}} = 2.87(23), \quad \frac{\Lambda_{L,\mathrm{imp}}}{\Lambda_{\overline{MS}}} = 0.3798$$

$$\frac{T_c}{\Lambda_{\overline{MS}}} = 1.09(9) \quad \text{with boosted coupling,}$$

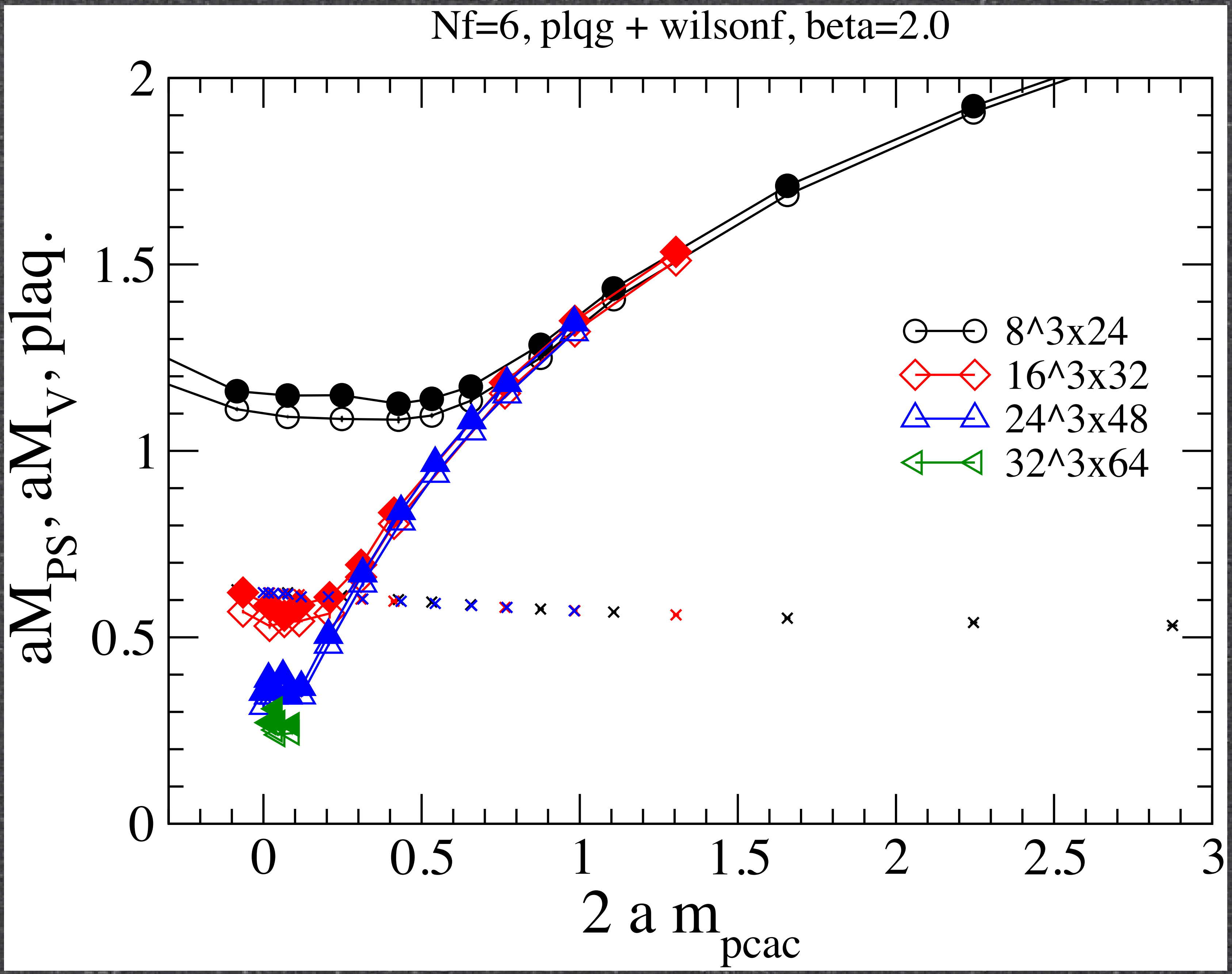
$$\frac{T_c}{\Lambda_{\overline{MS}}} = 1.49(7) \quad \text{with bare coupling,}$$

Demonstration in quenched approximation



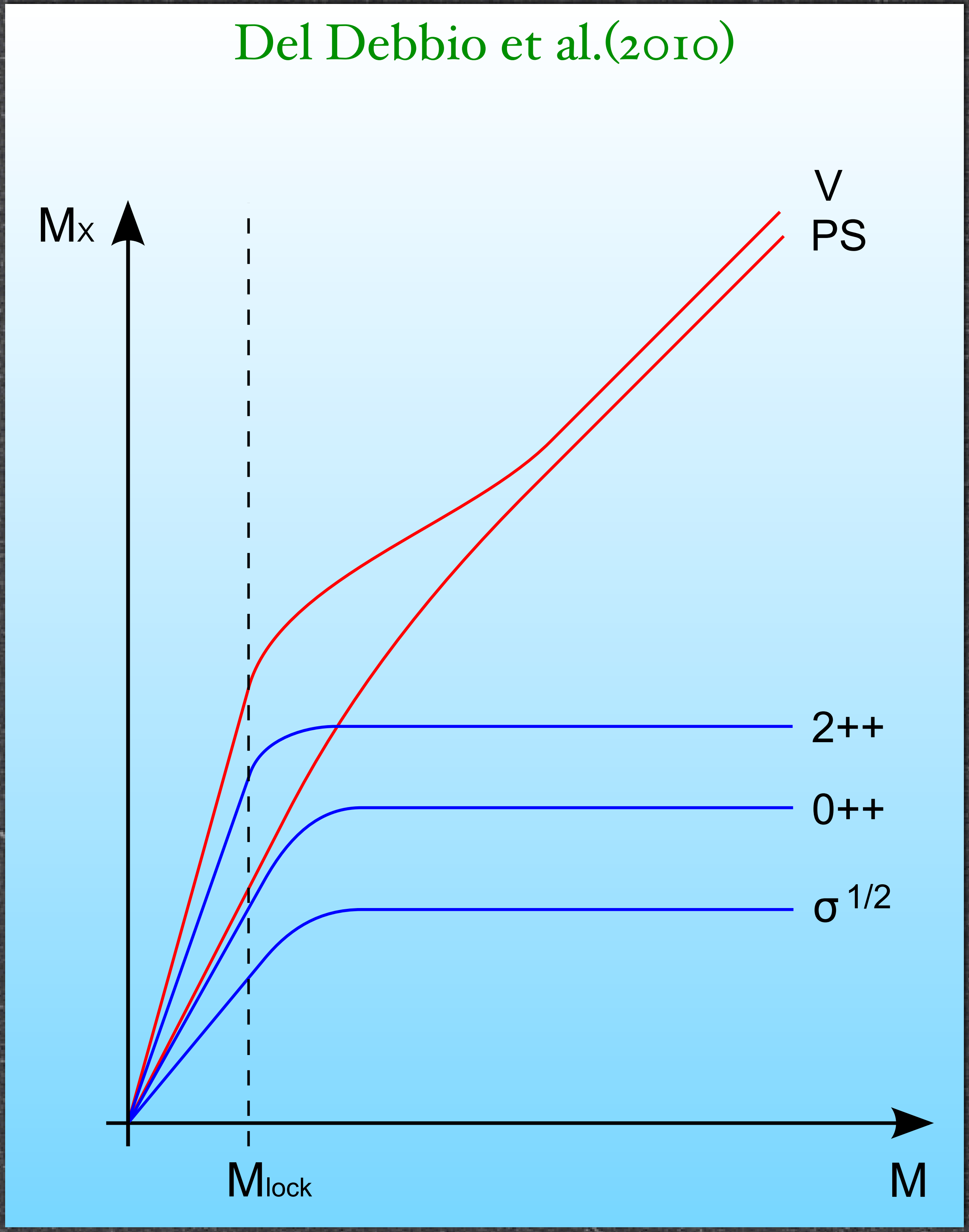
Spectrum of 6-flavor two-color QCD

Finite Volume effect



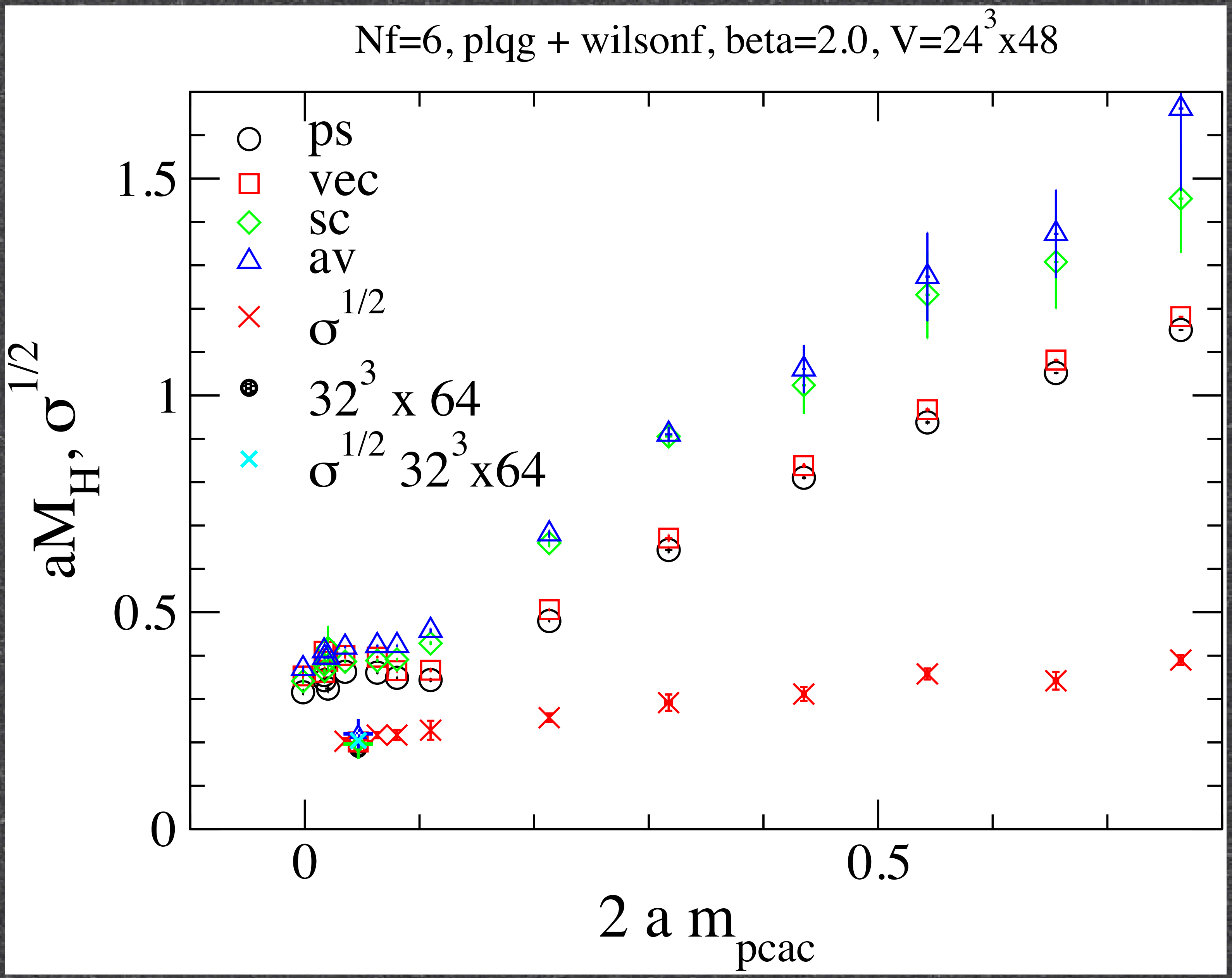
- Finite volume effect is significant.
- Masses are bounded from below.
- Minimum decreases as volume → large.

Expected behavior in Conformal Window



- Static limit = Quench
- In the massless limit, everything becomes massless.
- Dynamical scale (e.g. Λ_{QCD} in QCD) also vanishes there in contrast to QCD.
- Therefore, mass dependence of gluonic quantities is the key.

M_H and σ



- $M_P \approx M_V$ and $M_S \approx M_{AV}$ are typical pattern in the presence of heavy quark symmetry.
- $\sigma^{1/2}$ is smaller than M_H in most region.
- At $V=32^3 \times 64$, $\sigma^{1/2} \approx M_H$
- FVE is small for $\sigma^{1/2}$.
- $\sigma^{1/2}$ seems to remain finite in the chiral limit.
- Confinement?

Summary

✓ We employ Wilson fermion to explore conformal window with several complementary approaches.

✓ In future, actions may be replaced with improved ones, depending on the first survey with no improvement.

Special Thanks!

to KMI people working on “φ”.