MWT: chirally rotated Schrödinger functional scheme

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in coll. with: , R. Arthur, L. Del Debbio, B. Lucini, A. Patella, A. Rago, S. Sint, P. Vilaseca

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CP3 - Origins
Particle Physics & Origin of Mass

University of Southern Denmark

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Outline

- MWT model
- Chirally rotated SF scheme
- Preliminary results (tuning + coupling)

Minimal Walking Technicolor

L. Del Debbio, B. Lucini, A. Patella, CP, A.Rago, Phys. Rev. D82, 014509 (2010)
L. Del Debbio, B. Lucini, A. Patella, CP, A.Rago, Phys. Rev. D82, 014510 (2010)
F. Bursa, L. Del Debbio, L. Keegan, CP, T. Pickup, Phys. Rev. D81 (2010) 014505
E. Kerrane, et al. , Phys.Rev. D84, 034506 (2011)
L. Del Debbio, B. Lucini, A. Patella, CP, A. Rago, PoS LATTICE2011 (2011) 084

Minimal Walking Technicolor

$SU(2)_{TC}$ + 2 Dirac Adjoint fermions

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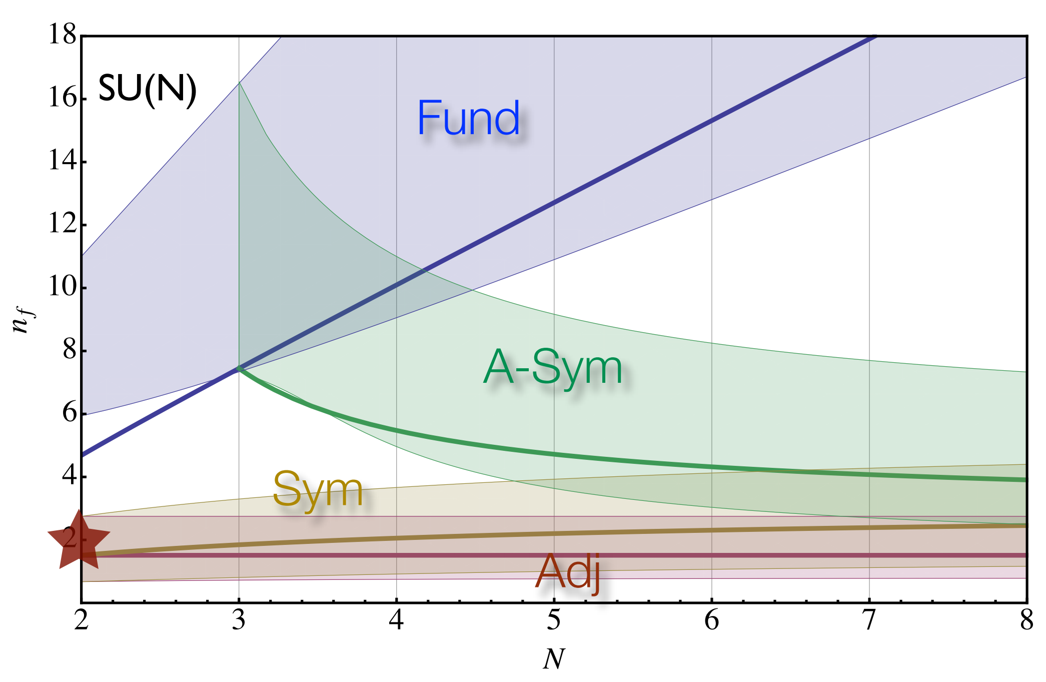
Minimal Walking Technicolor

$SU(2)_{TC}$ + 2 Dirac Adjoint fermions

- close/inside the conformal window by analytic estimates



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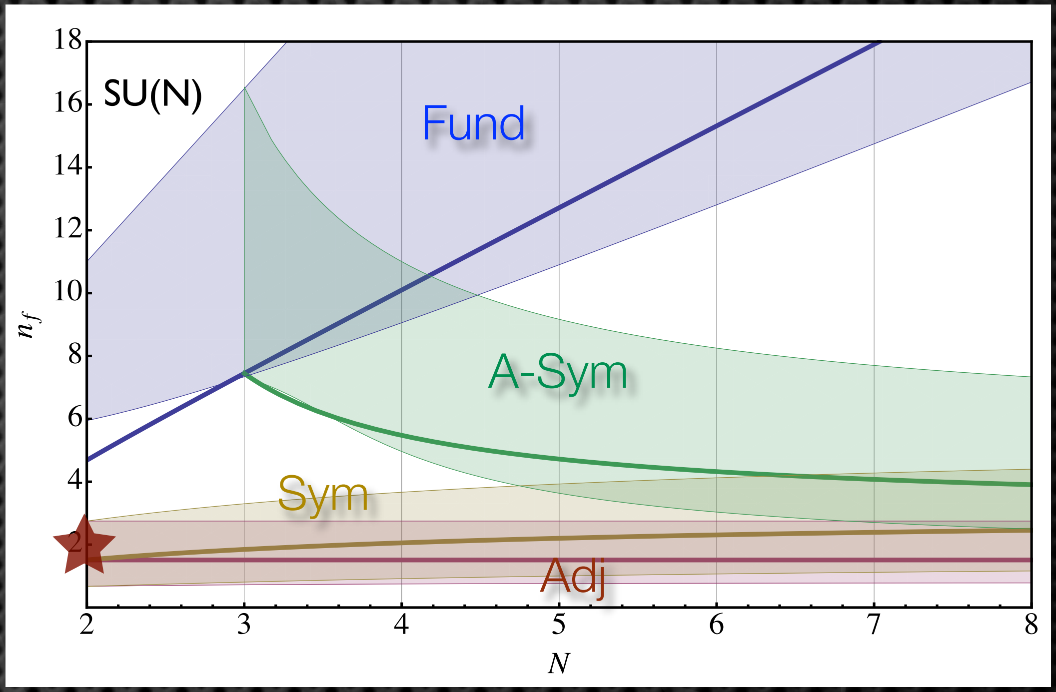

- minimum value of the naïve S-parameter: $S = \frac{N_D d_R}{6\pi}$

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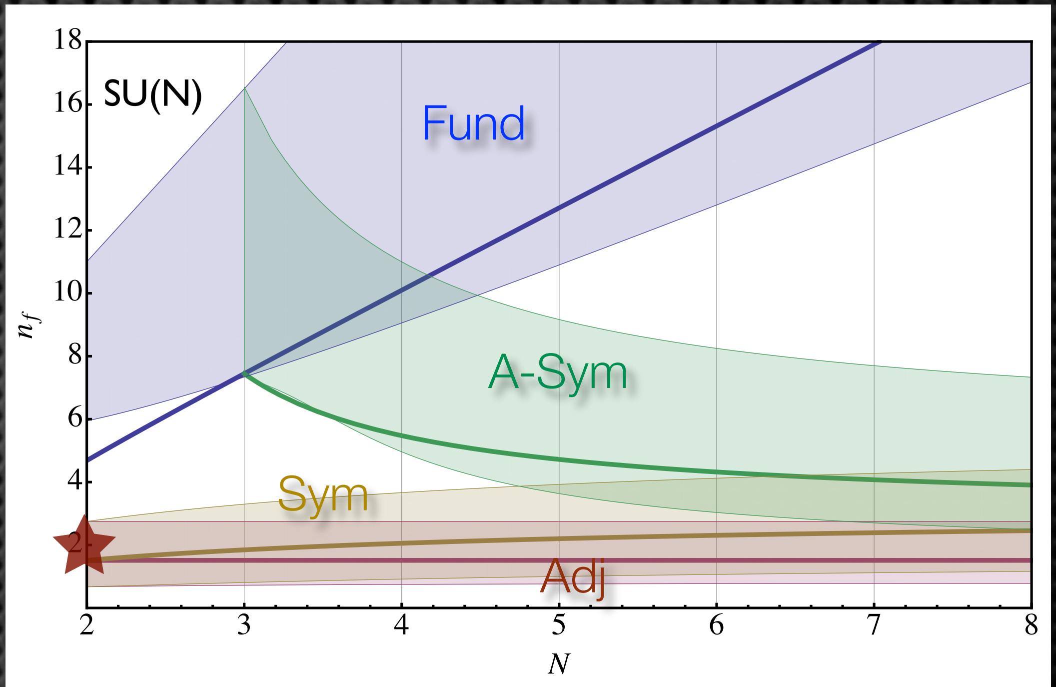

- minimum value of the naïve S-parameter: $S = \frac{N_D d_R}{6\pi}$
- expected SB pattern: $SU(4) \to SO(4)$ $\Rightarrow$ 3+6 GBs

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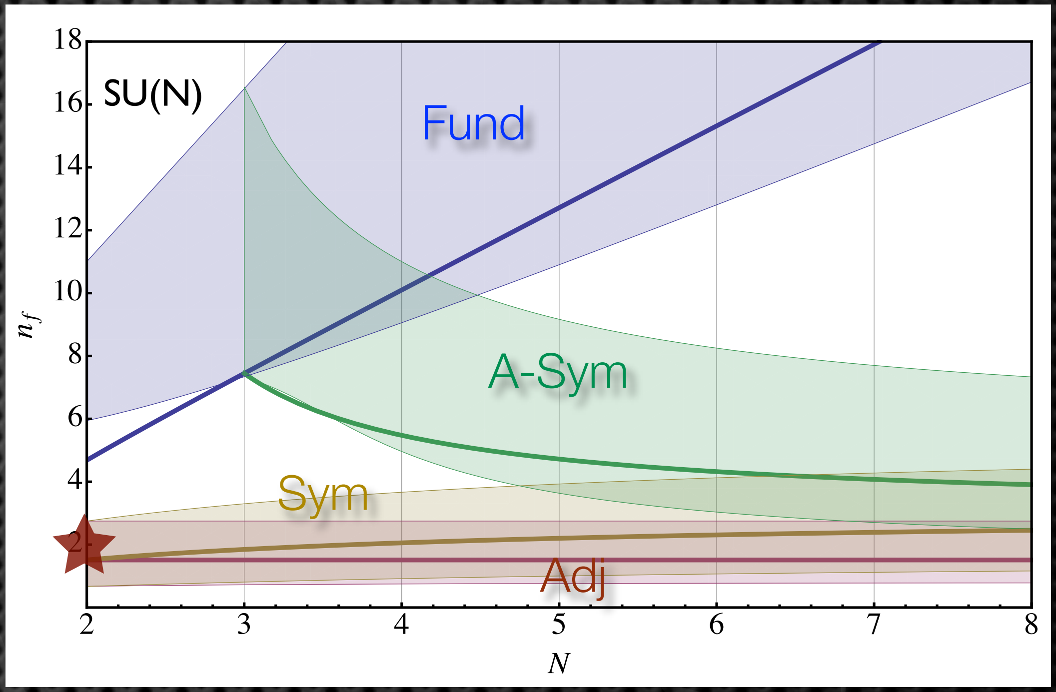

- minimum value of the naïve S-parameter: $S = \frac{N_D d_R}{6\pi}$
- expected SB pattern: $SU(4) \to SO(4)$ $\Rightarrow$ 3+6 GBs
- glue-fermion composite states

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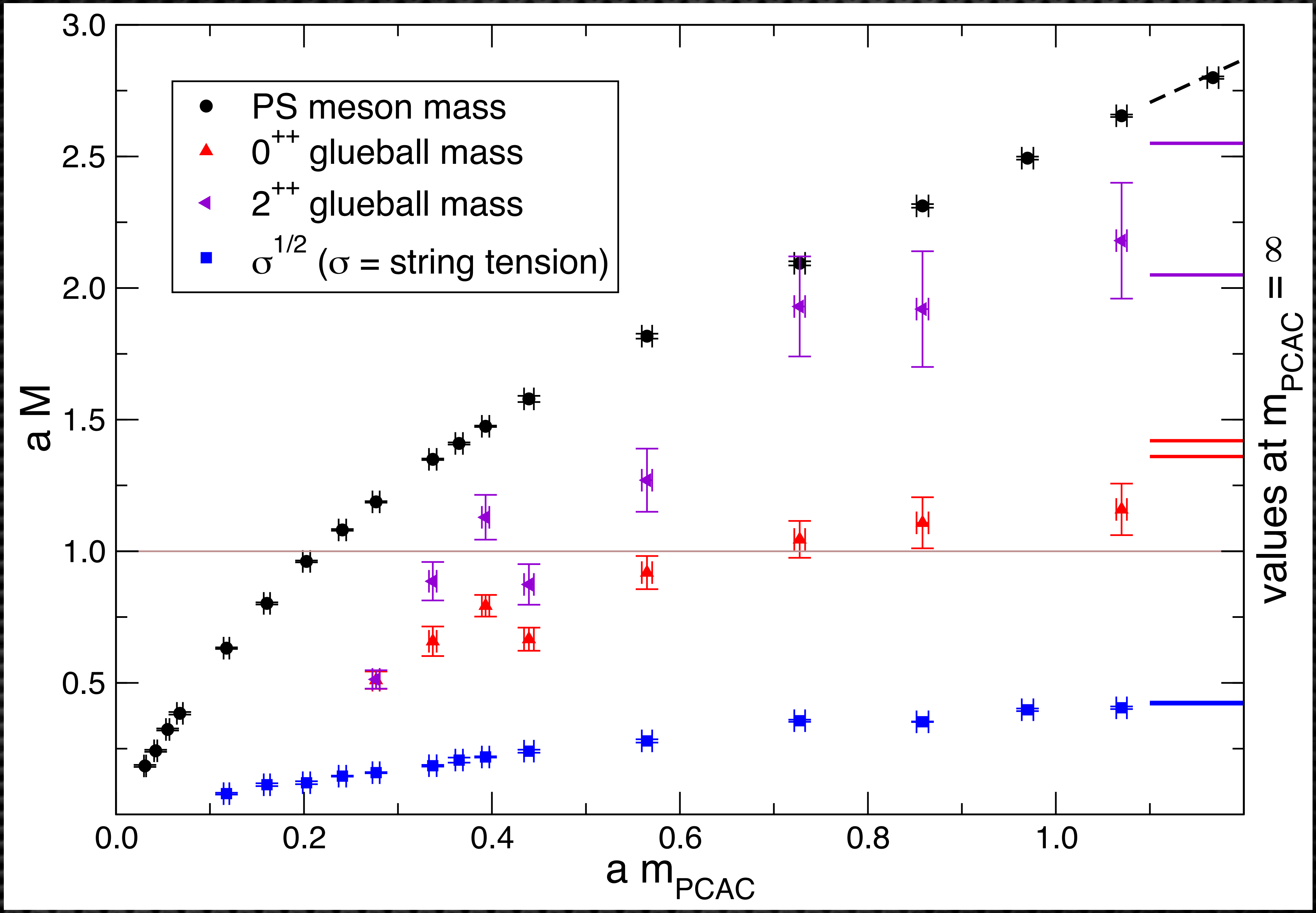
MWT Spectrum



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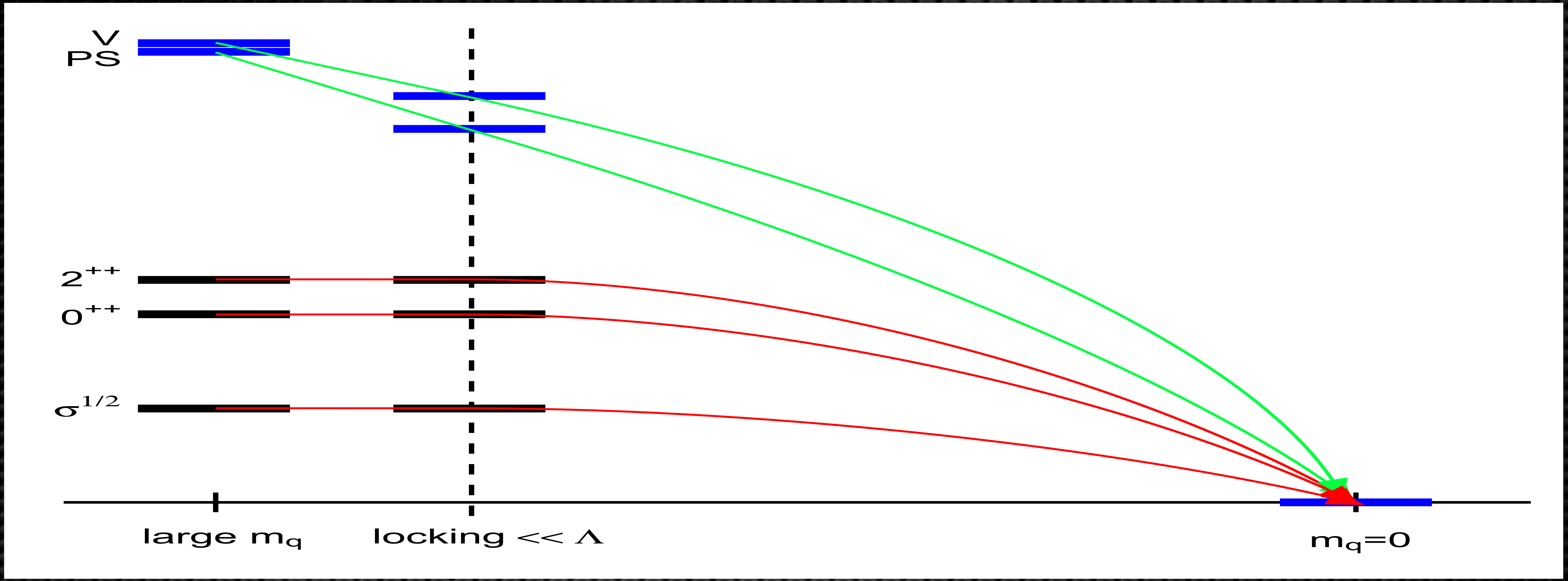
IR conformal scaling



$$\sigma \simeq \sigma^{(YM)}$$

$$M_G \simeq M_G^{(YM)}$$

$$M_V/M_{PS} \simeq 1$$

$$M_{PS} \simeq M_V \simeq 2m_q$$

$$M_V/M_{PS} \simeq 1+\epsilon$$

$$M_{PS} \gg \sigma^{1/2}$$

$$M_G/\sigma^{1/2} \simeq \left[M_G/\sigma^{1/2}\right]^{(YM)}$$

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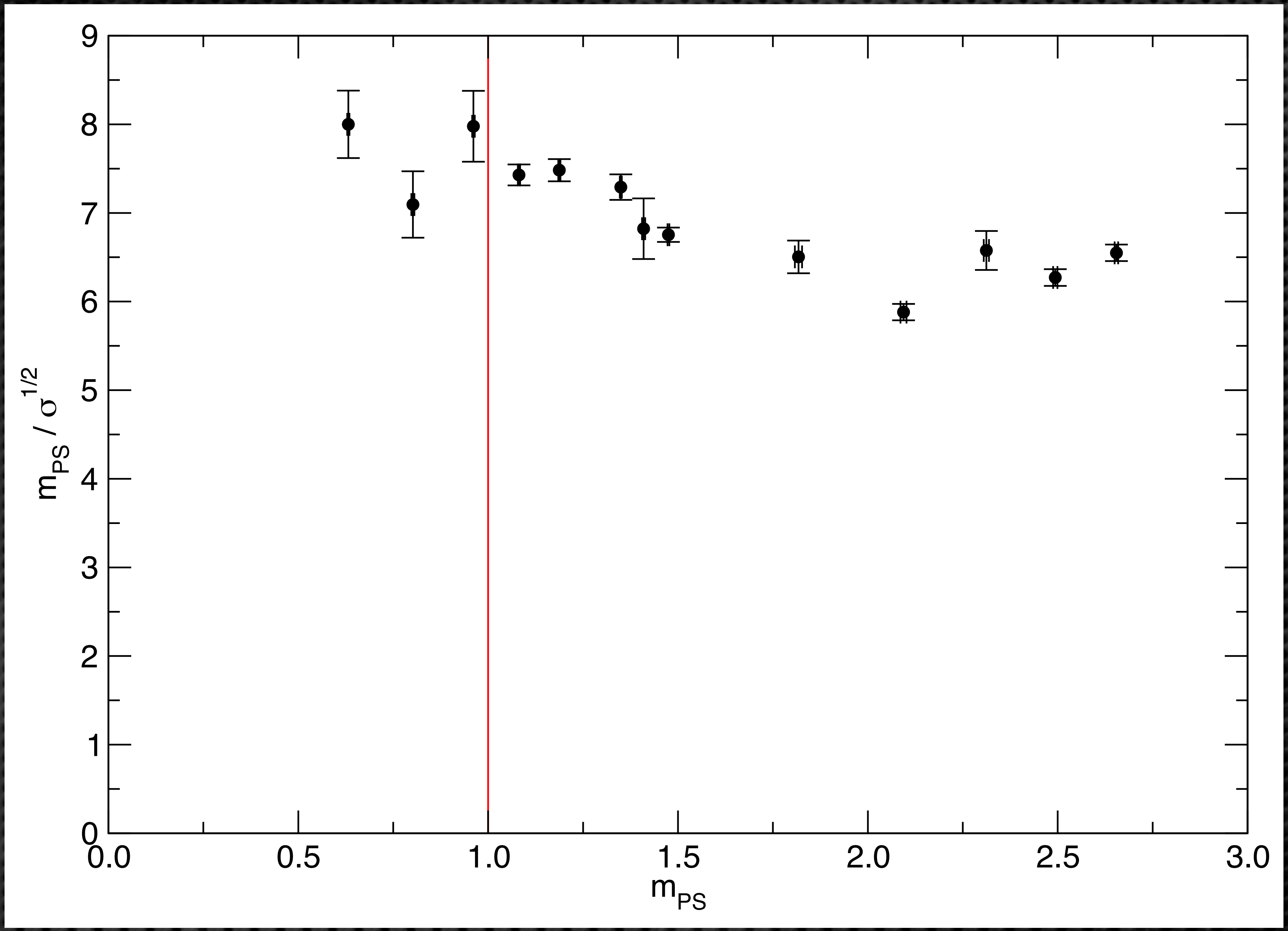
String Tension vs m_{PS}



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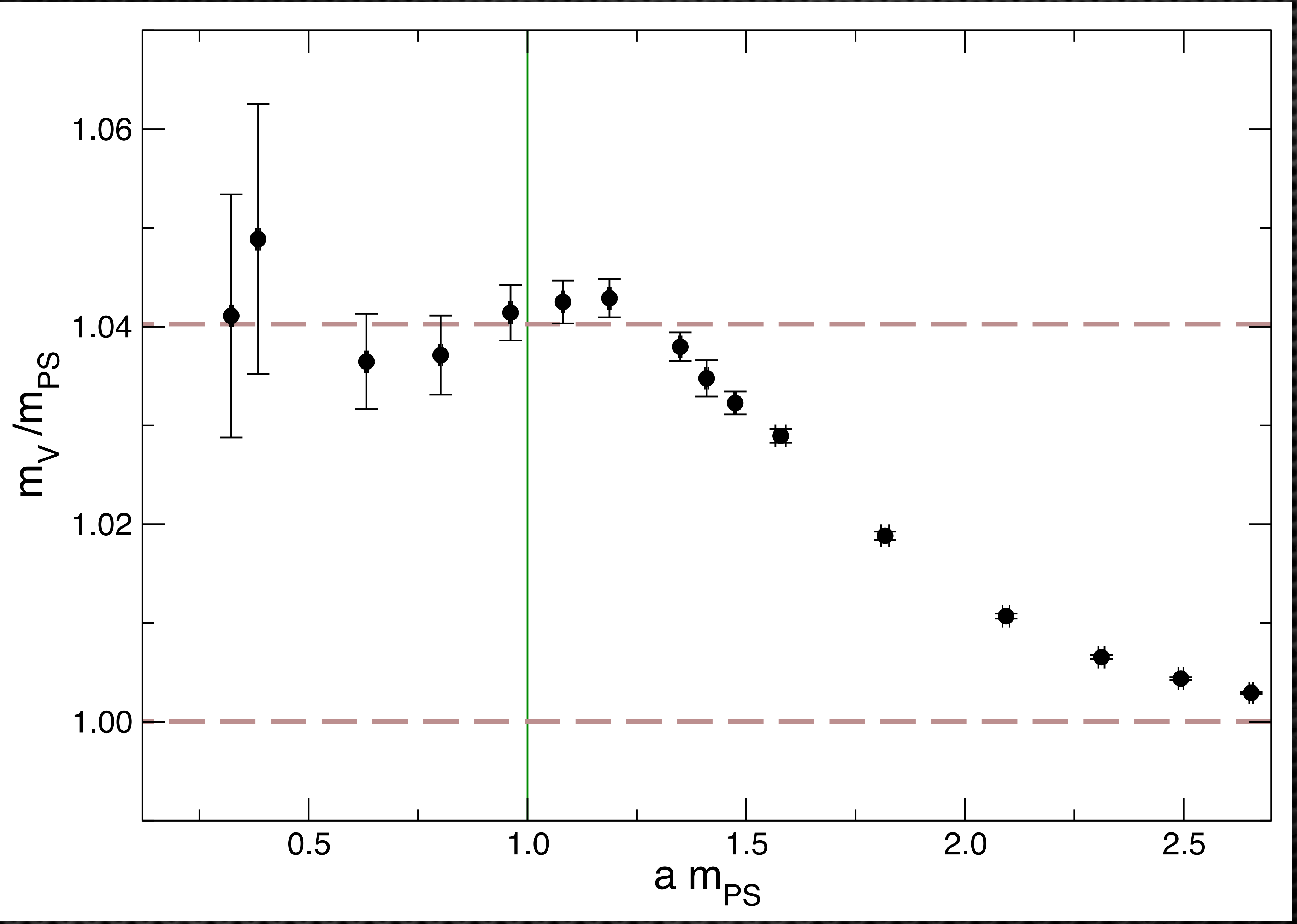
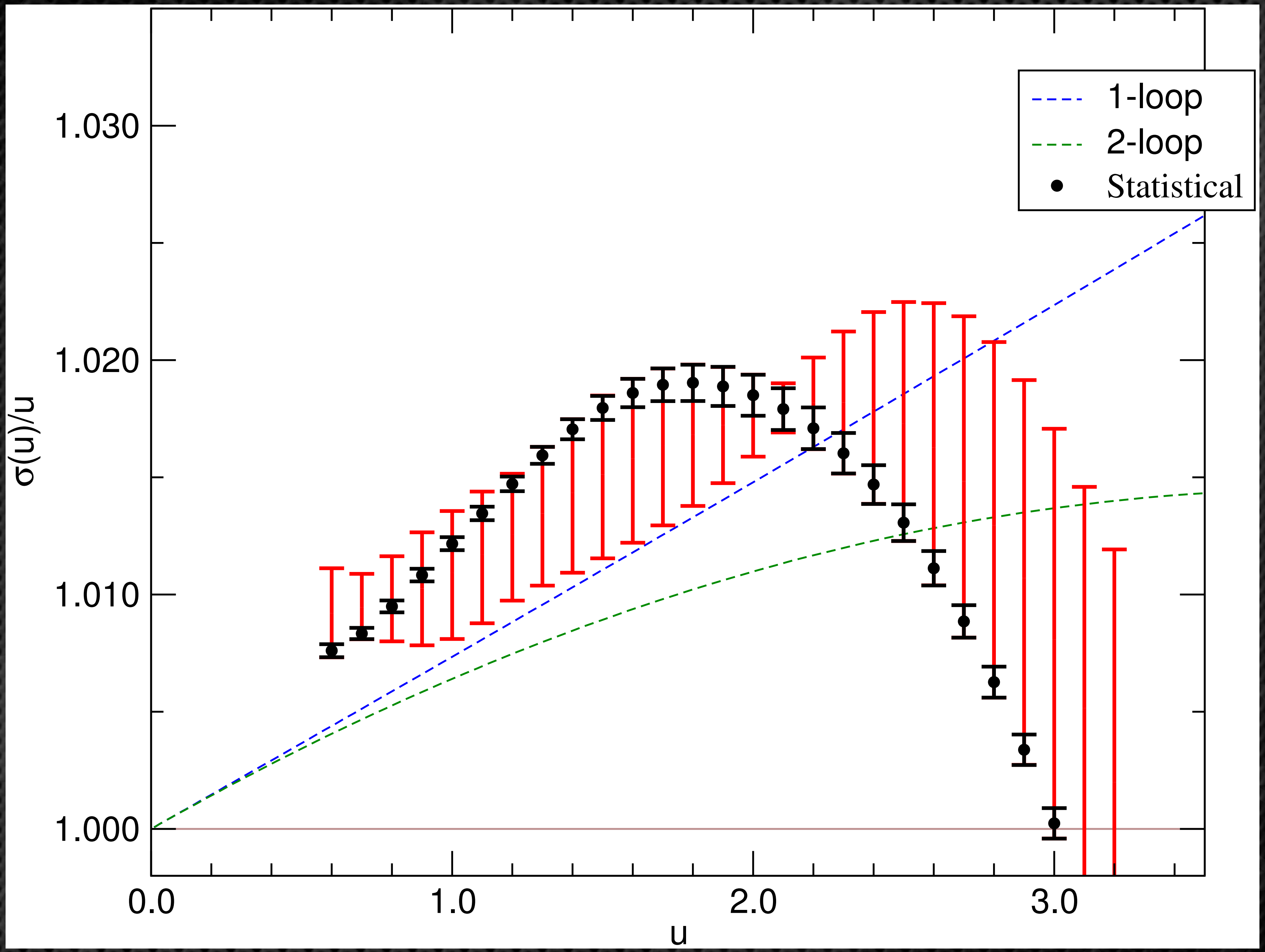
Vector vs Pseudoscalar



Schrödinger Functional coupling



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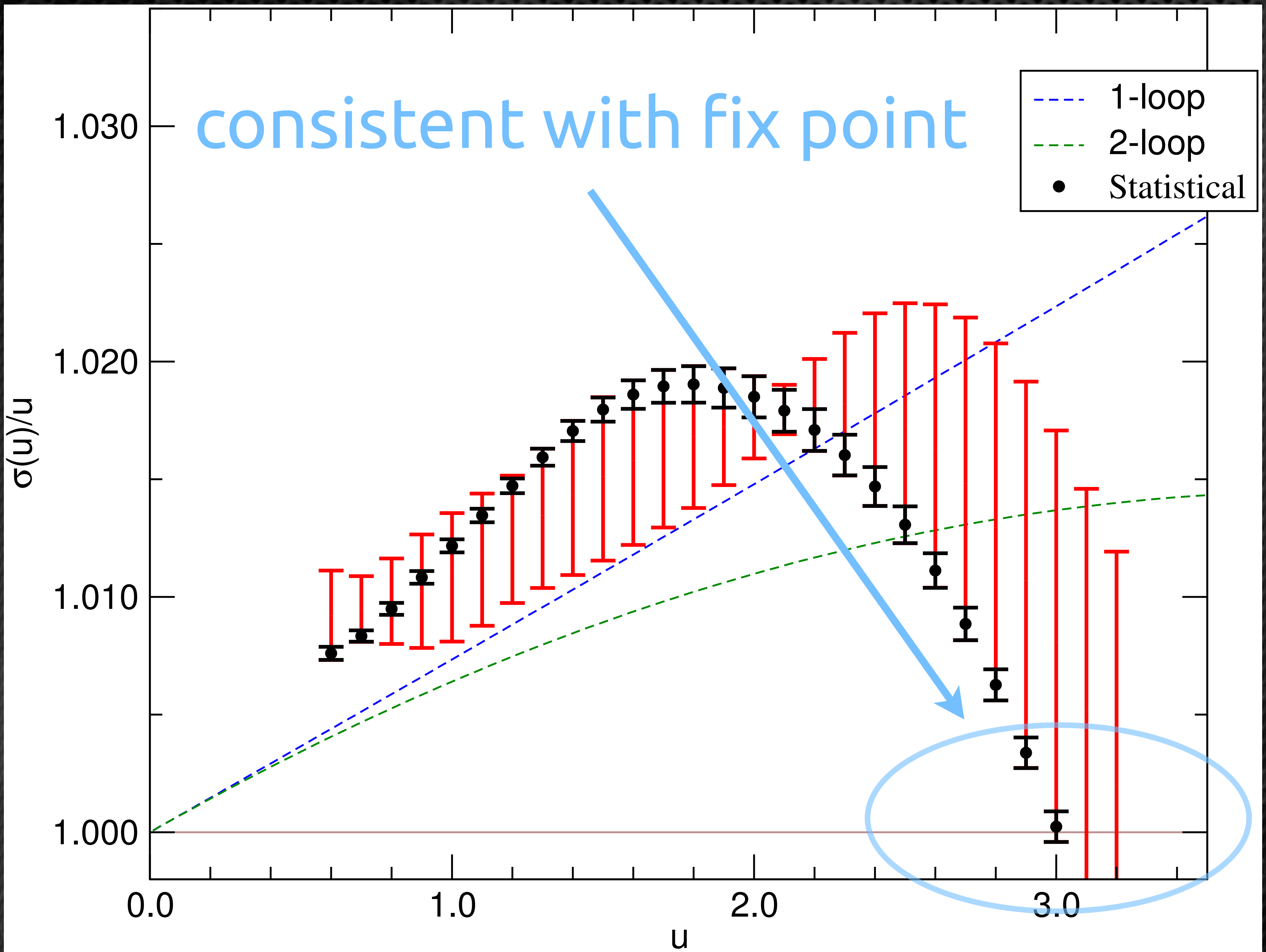
Schrödinger Functional coupling



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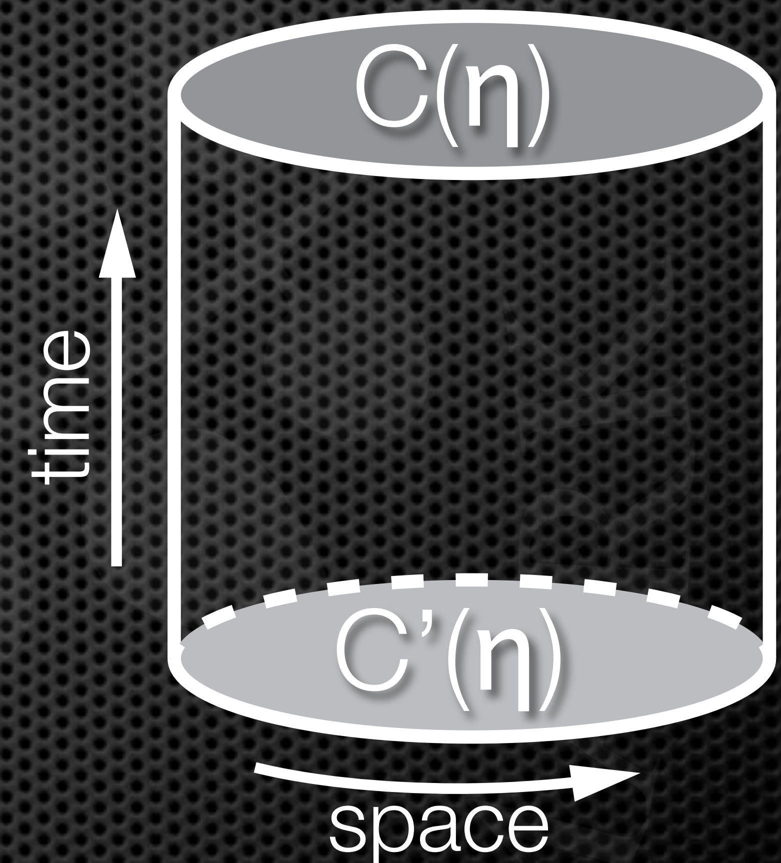
Chirally rotated Schrödinger Functional

S. Sint, PoS LAT2005 (2006) 235
S. Sint, Nucl. Phys. B847 (2011) 491-531
S. Sint & P. Vilaseca, PoS LATTICE2011 (2011) 091
S. Sint & P. Vilaseca, PoS LATTICE2012 (2012) 031

χSF

We consider the functional integral on a hypercylinder with periodic spacial B.B. and Dirichlet B.C. in time with boundary fields C(η) and C'(η):

$$Z[\eta] = e^{-\Gamma[\eta]} = \int_\eta DUD\psi D\bar{\psi} e^{-S[U,\psi,\bar{\psi}]}$$



For SU(2) we use:

$$C: \quad U_k(t=0) = \exp[-i\phi\tau^3/L]$$

$$C': \quad U'_k(t=0) = \exp[-i\phi'\tau^3/L]$$

with

$$\phi = \eta \quad ; \quad \phi' = \pi - \eta$$

We will also consider HALF background field configurations with:

$$\phi_{HB} = \phi/2 \quad ; \quad \phi'_{HB} = \phi'/2$$

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χSF

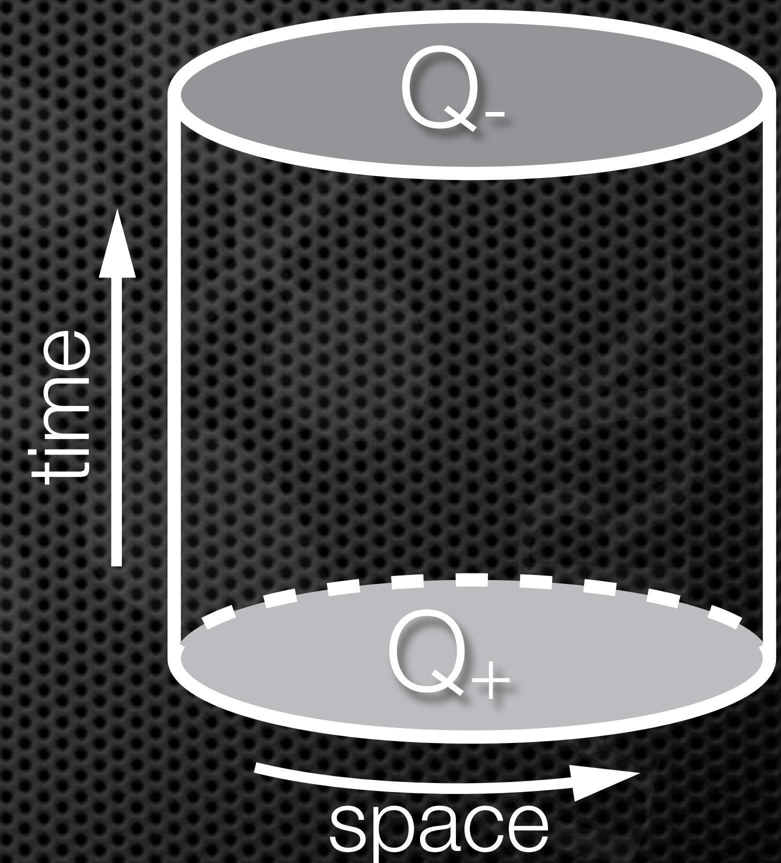
For the fermions B.C. we have for Nf=2:

$$\tilde{Q}_+ \Psi(t=0) = 0 = \tilde{Q}_- \Psi(t=L)$$

$$\overline{\Psi}(t=0)\tilde{Q}_+ = 0 = \overline{\Psi}(t=L)\tilde{Q}_-$$

with:

$$\tilde{Q}_\pm = \frac{1}{2}(1 \pm i\gamma_0\gamma_5\tau^3)$$



This is related to the standard SF via a chiral rotation:

$$\Psi \to R(\alpha)\Psi \quad , \quad R(\alpha) = \exp(i\alpha\gamma_5\tau^3/2)$$

and the projections are:

$$P_\pm(\alpha) = \frac{1}{2}[1 \pm \gamma_0 \exp(i\alpha\gamma_5\tau^3)]$$

χSF

O(a) improving requires 3 boundary counterterms: c_t, z_f, d_s

In perturbation theory: $$c_t = 1 + c_t^{(1)} g_0^2 + \mathcal{O}(g_0^4)$$

$$d_s = 1/2 + d_s^{(1)} g_0^2 + \mathcal{O}(g_0^4)$$

We use d_s=1/2 and the 1-loop expression for c_t.

We remain with one parameter z_f we tuned non-perturbatively.

This is done tuning to zero a $\gamma_5 \tau^1$-odd operator.

In this work we use $g_{A+}^{ud}(x_0)$

χSF

The χSF coupling is defined as usual: $\bar{g}^2 = \left.\frac{\Gamma_0'(\eta)}{\Gamma'(\eta)}\right|_{\eta=\pi/4}$

From the step scaling function:

$$\Sigma(u,s,a/L) = \left.\bar{g}^2(g_0, sL/a)\right|_{\bar{g}^2(g_0,L/a)=u}$$

we can obtain the beta function:

$$\sigma(u,s) = \lim_{a/L\to 0} \Sigma(u,s,a/L) \qquad -2\log s = \int_u^{\sigma(u,s)} \frac{dx}{\sqrt{x}\beta(\sqrt{x})}$$

$$\beta(u) = 0 \;\Rightarrow\; \sigma(u,s) = u$$

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Preliminary Lattice results

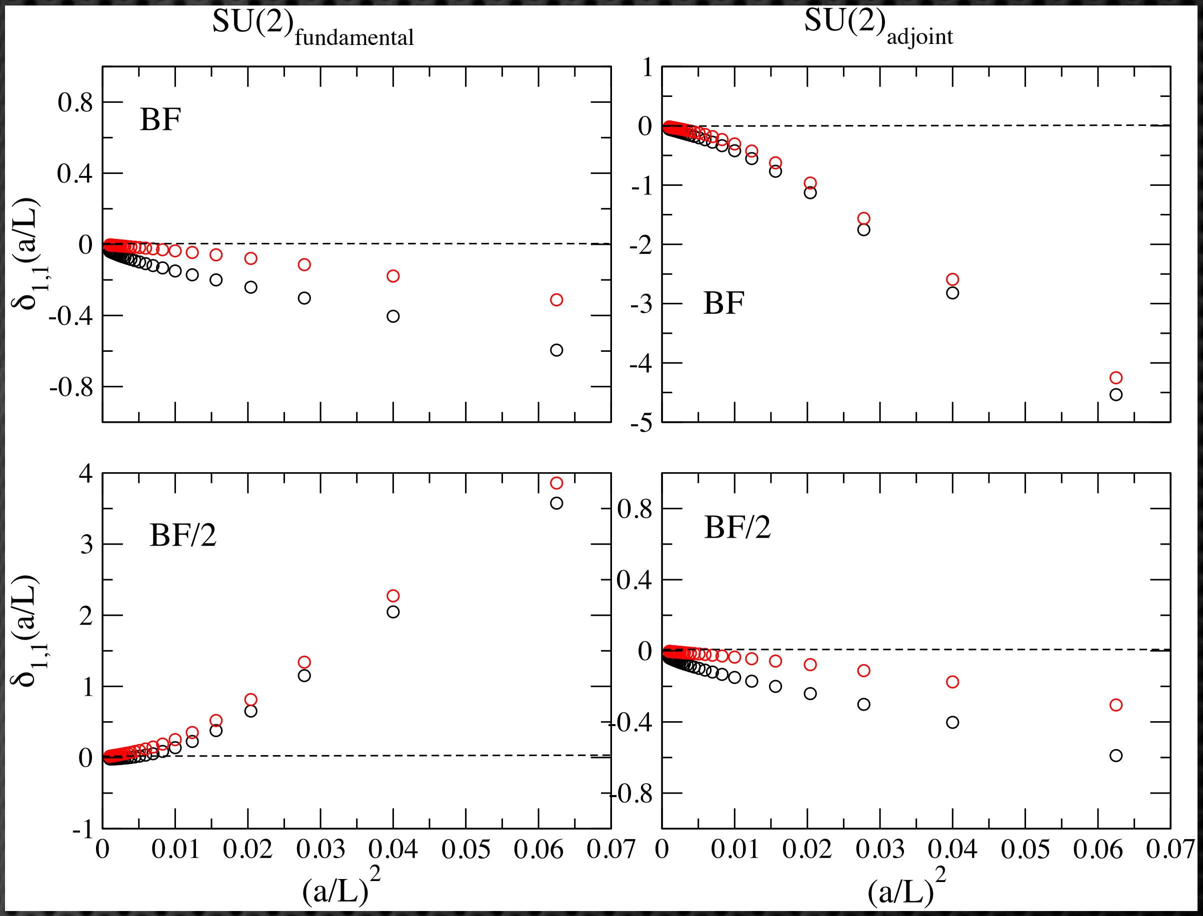
R. Arthur, L. Del Debbio, B. Lucini, A. Patella, CP, A.Rago, S. Sint, P. Vilaseca *in preparation*

Simulation details

$$\Sigma(u,2,a/L) = u + \Sigma_1(a/L)\,u^2 + \mathcal{O}(u^3)$$

$$\sigma(u,2) = u + \sigma_1 u^2 + \mathcal{O}(u^3)$$

$$\delta_1(a/L) = \frac{\Sigma_1(a/L) - \sigma_1}{\sigma_1}$$



For fermion fields we use spatial B.C. periodic up to a phase:

$$\Psi(x+L\hat{k}) = e^{i\theta}\Psi(x) \quad ; \quad \overline{\Psi}(x+L\hat{k}) = e^{-i\theta}\overline{\Psi}(x)$$

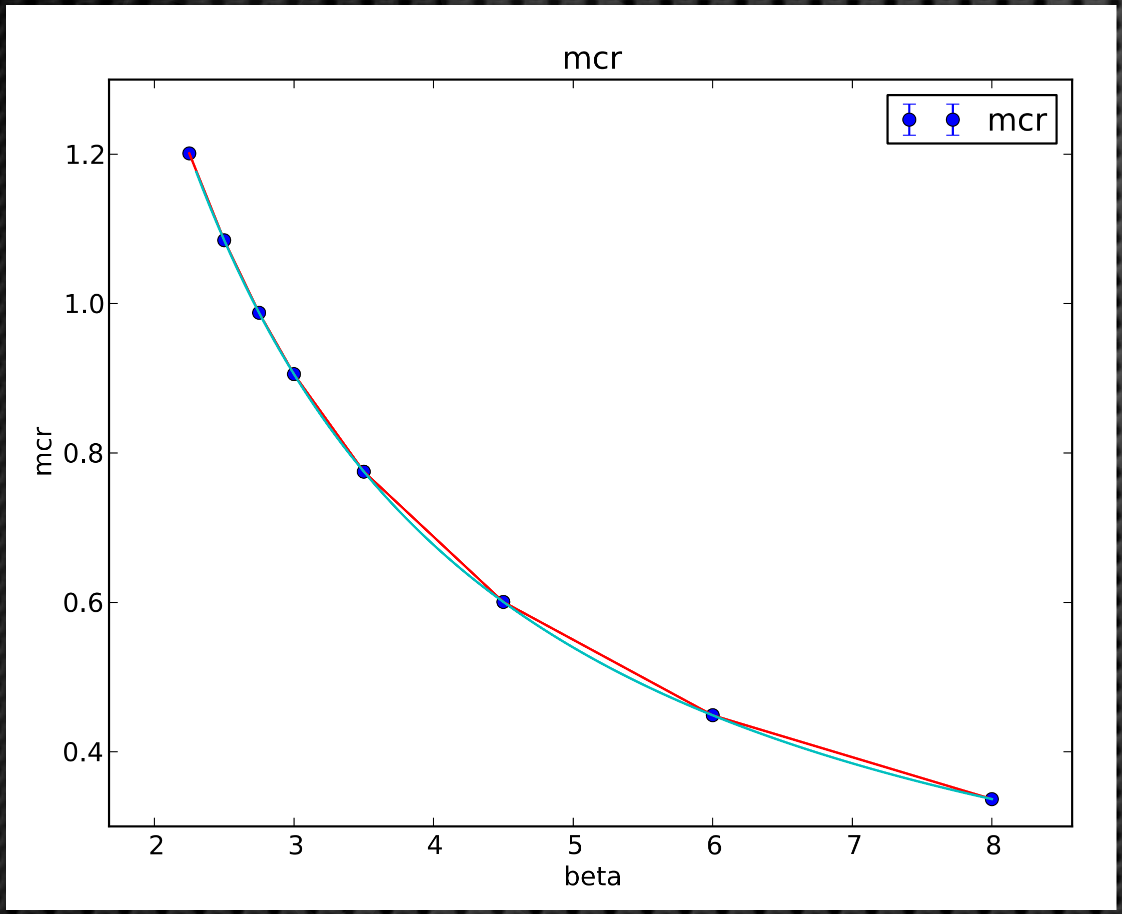
to maximise the lowest eigenvalue of the Dirac operator.

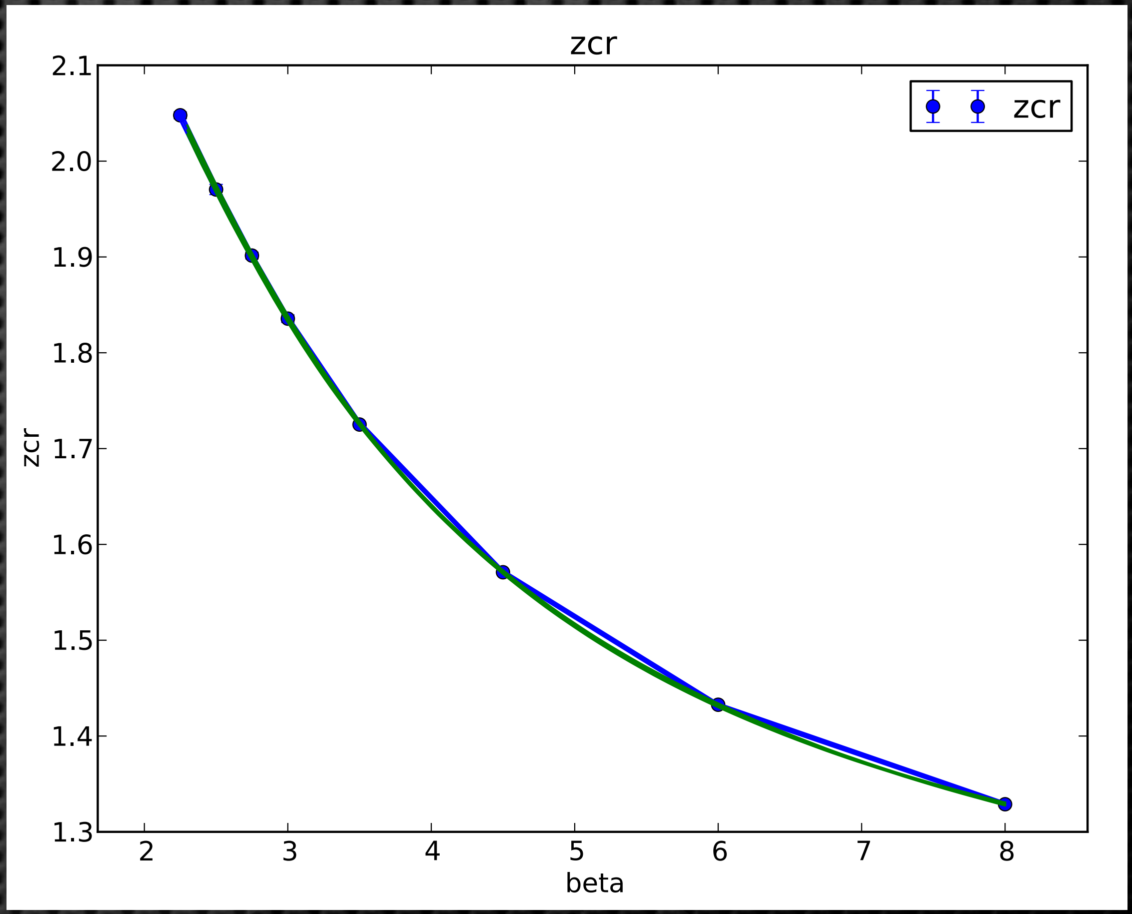
Simulation details

L = 6, 8, 12, 16 ; we plan also L = 24

β = 2.25 ... 8

s = 2 (scaling factor)





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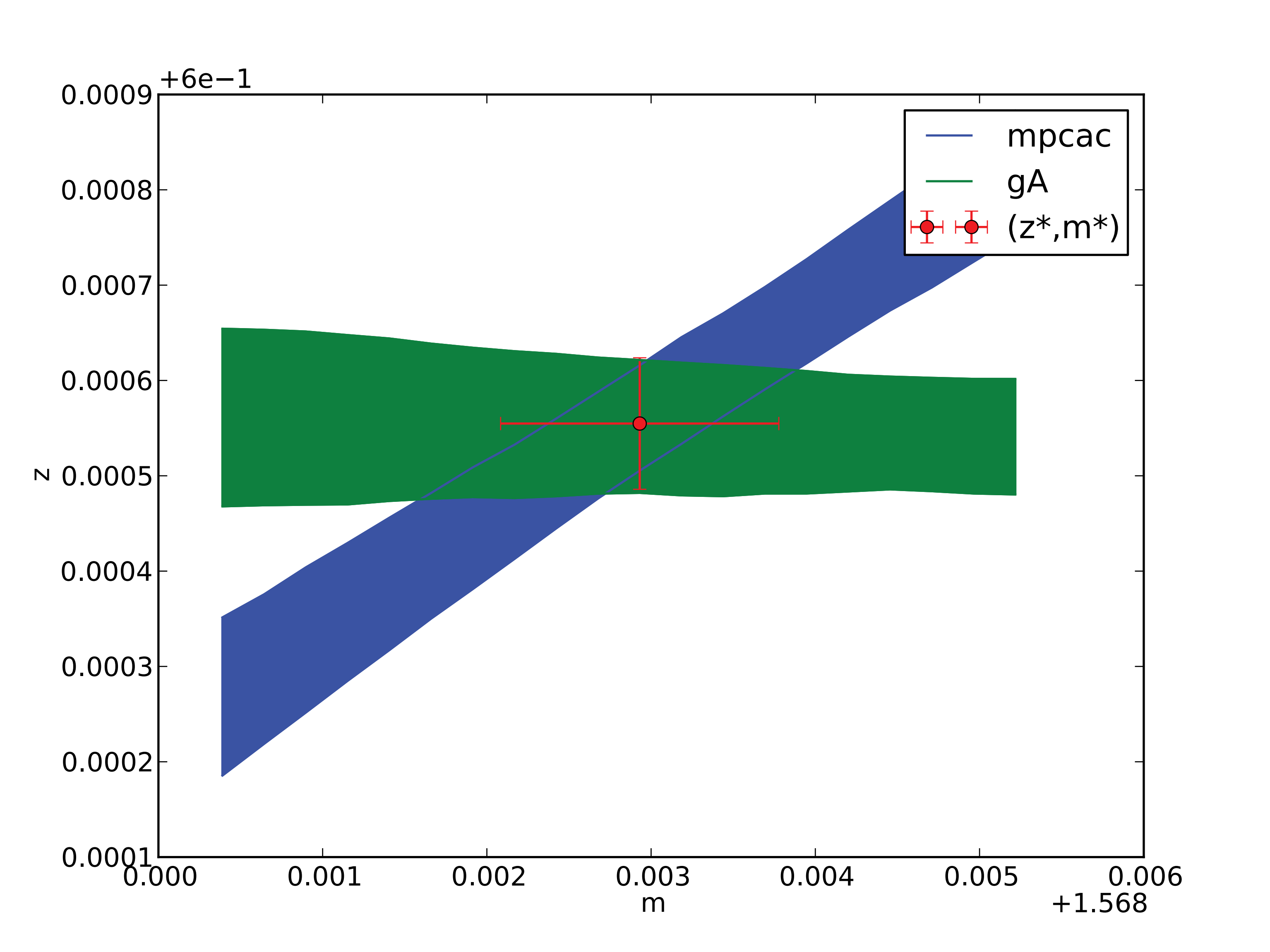
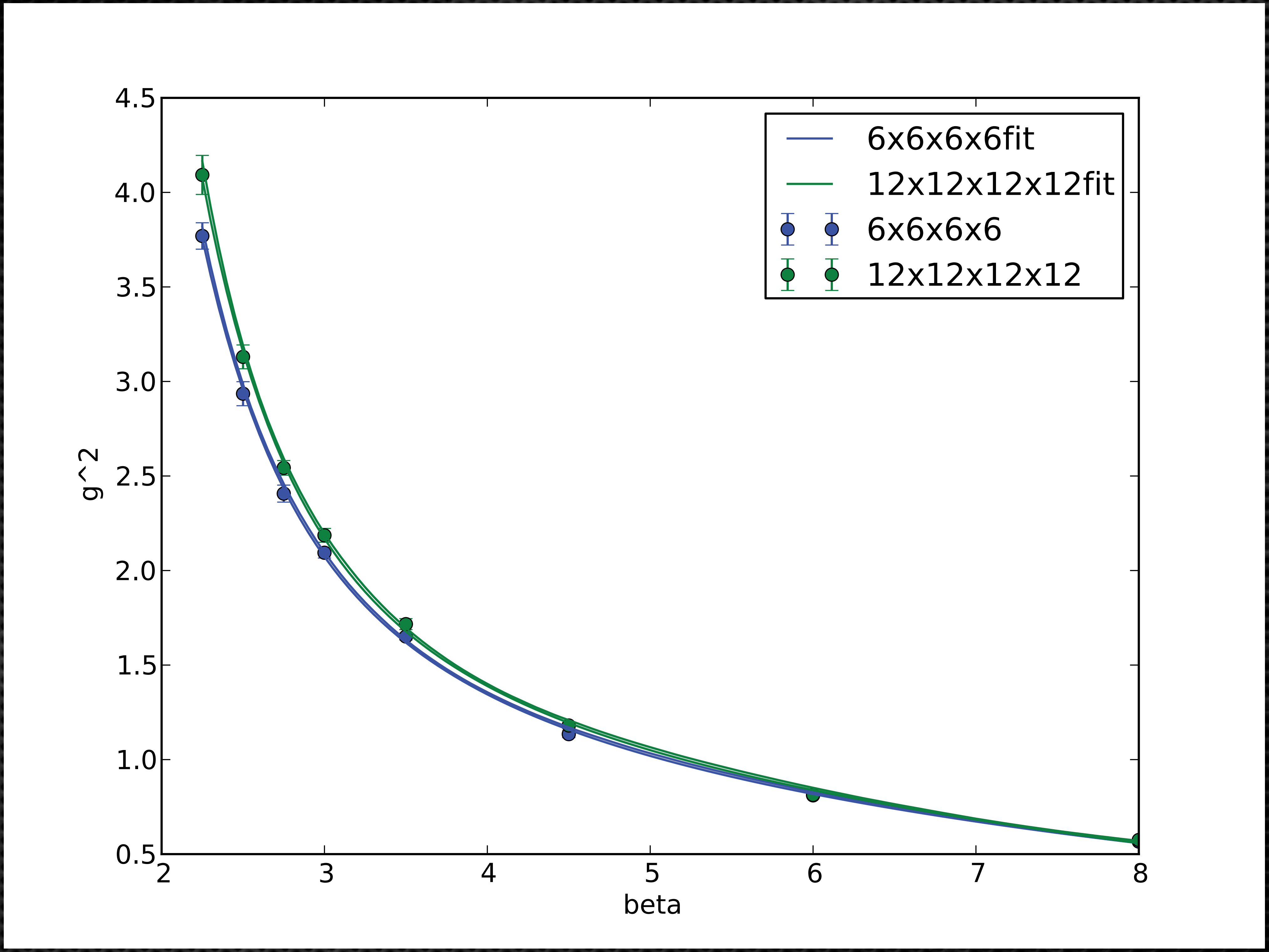
Tuning

For each volume and bare coupling, we tune 2 parameters: m_0 and z_f.

This is done by imposing the vanishing of the PCAC mass and of g_{A+}^{ud}

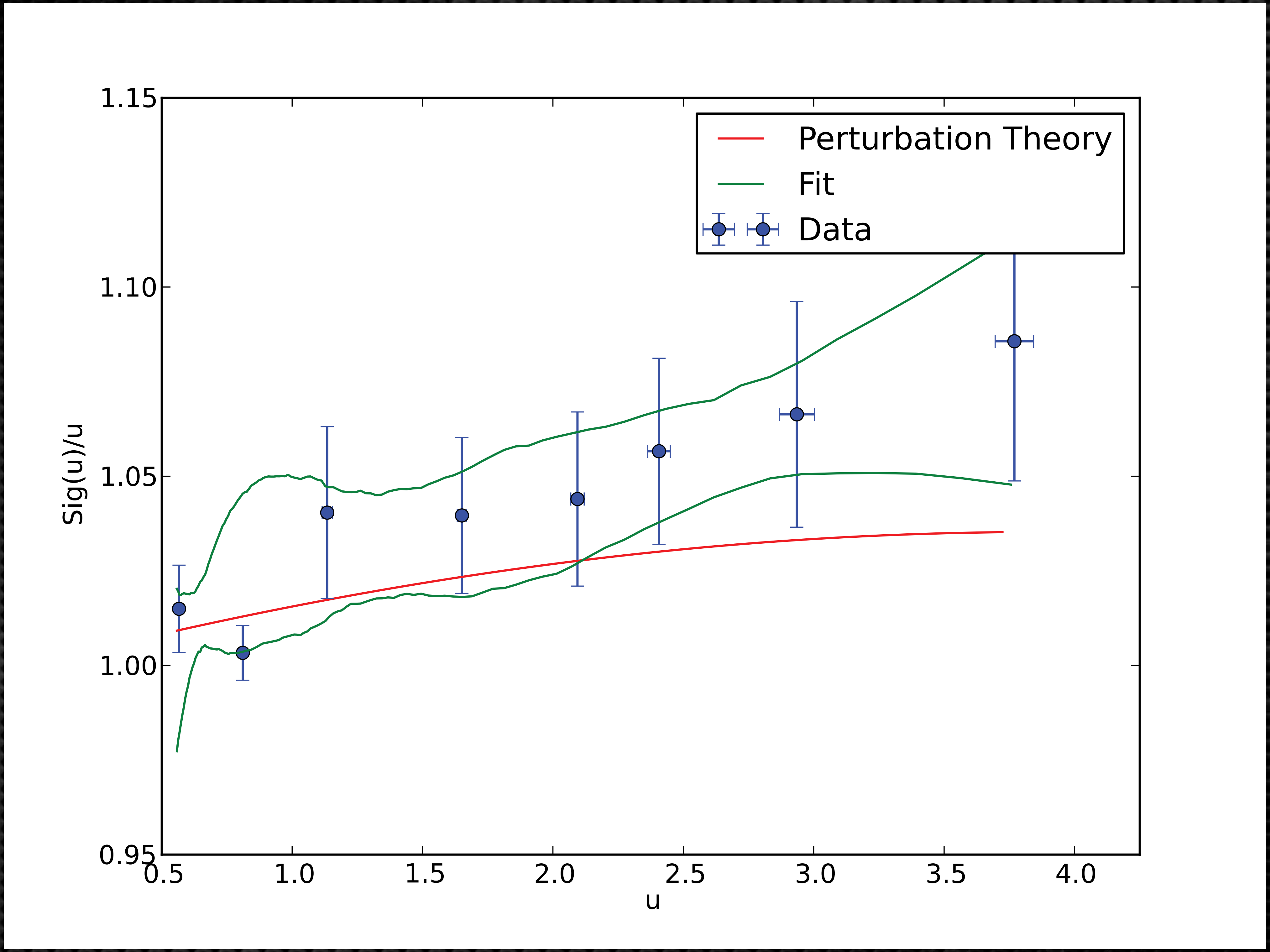


Coupling

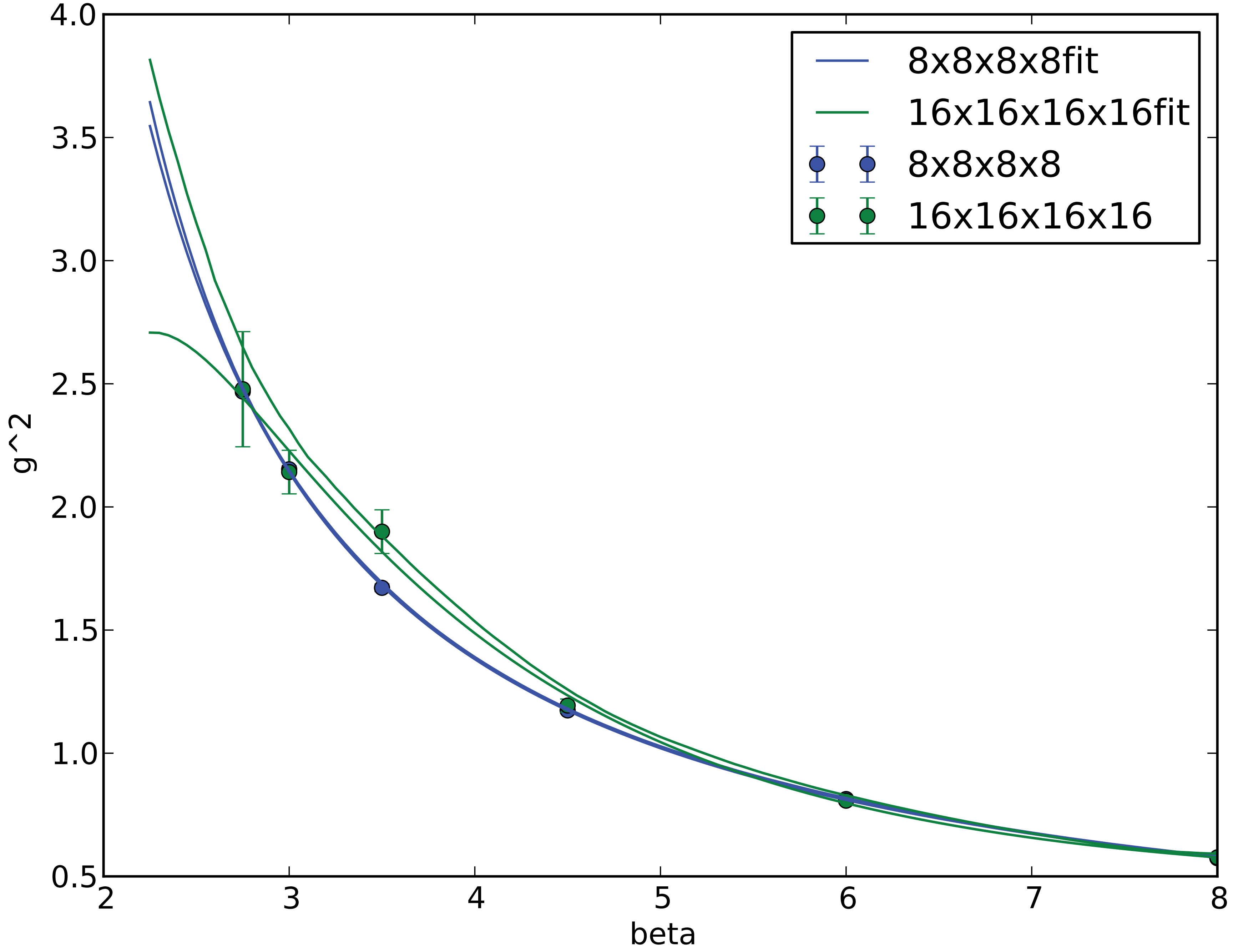


g^2
beta
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
2
3
4
5
6
7
8
6x6x6x6fit
12x12x12x12fit
6x6x6x6
12x12x12x12

Step scaling



Coupling



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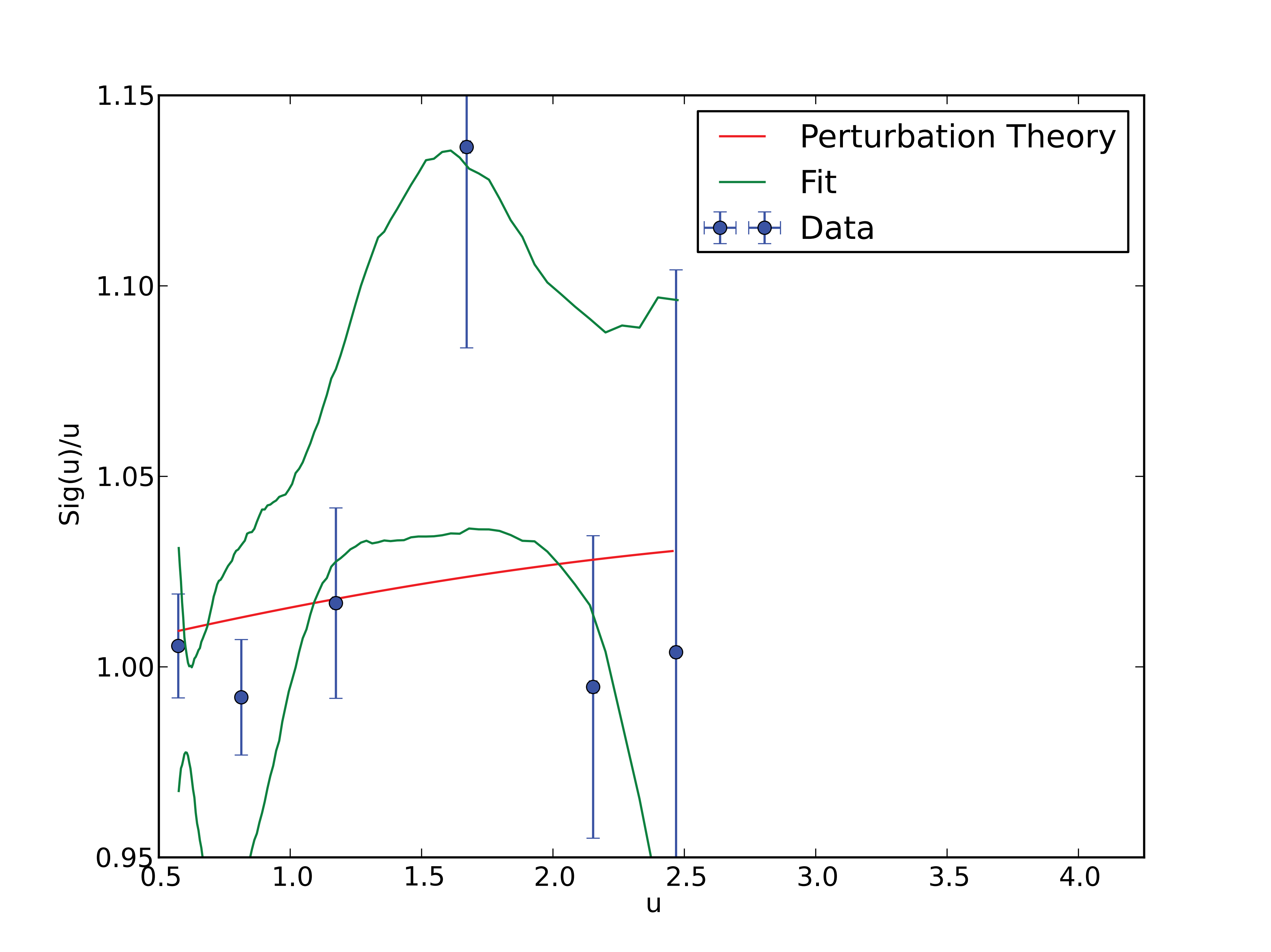
Step scaling



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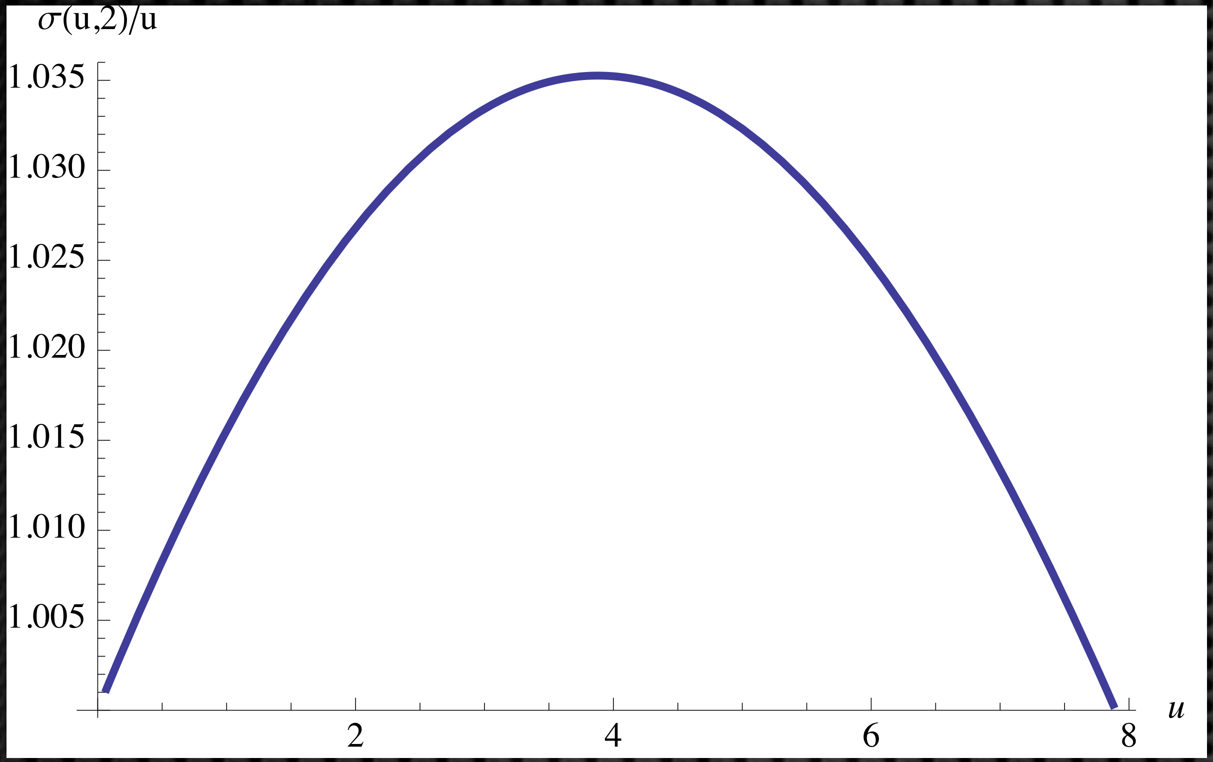
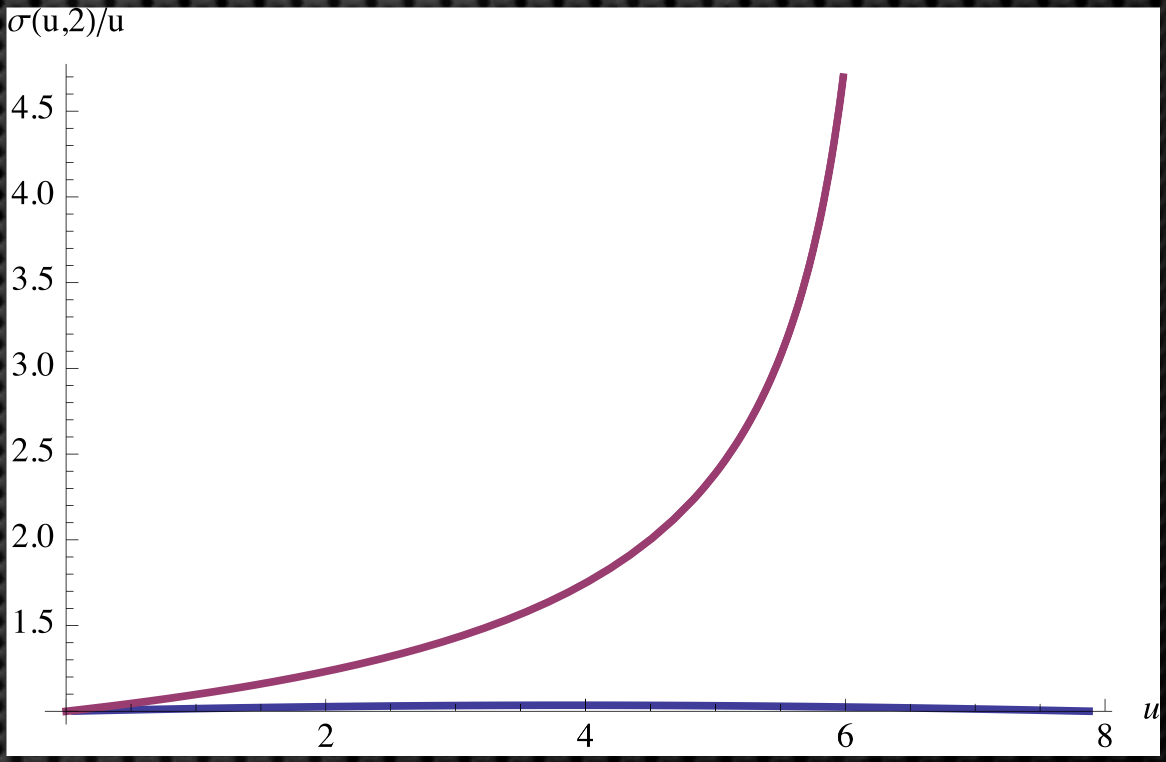
2-loop beta function

MWT



QCD nf=2



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Conclusions

- χSF tuning seems to work as expected, but expensive at stronger couplings
- need more statists to reduce errors on the step scaling functions
- continuum extrapolation is needed to investigate the presence of the IR fixed point
- models close or inside the CW are expensive to study on the Lattice!