Last results of N=1 supersymmetric Yang-Mills theory with some topological insights

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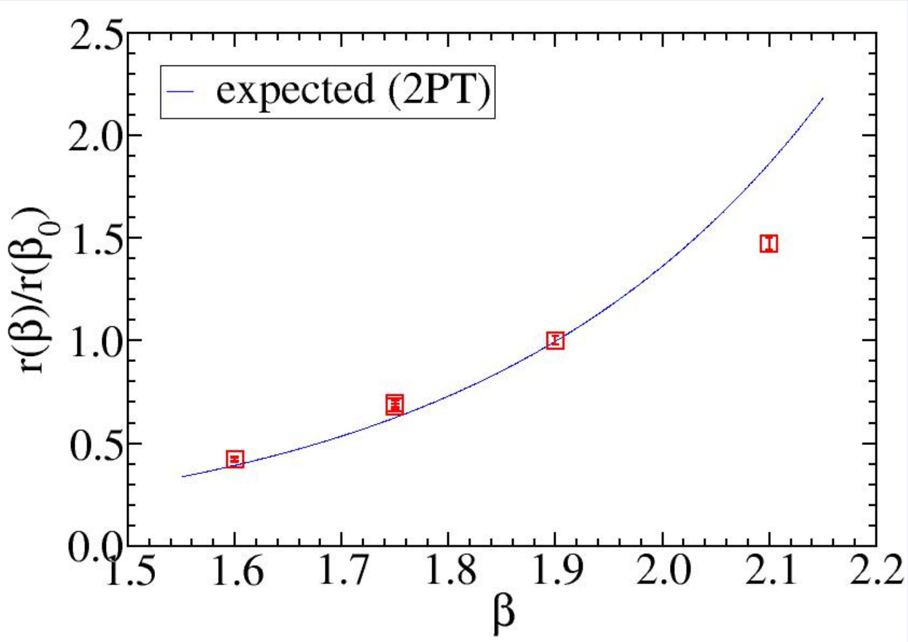


Lattice 2014, NY (USA), 27/June/2014

- Introduction
- Set the scale
- Mass spectrum
- Topology
- Conclusions

SUSY on the lattice is important!

- Looking for non-perturbative mechanisms for sponstaneous breaking of SUSY
- Study of other non-perturbative aspects: confinement/deconfinement, chiral symmetry, topology
- Test effective theories of low energy spectrum
- Orientifold equivalence: $N_f = 1 \;\; QCD \Leftrightarrow \mathcal{N} = 1 \;\; SYM$

Our results are valuable!

- We can set the scale accurately using $r_0 \quad \text{and} \quad w_0$
- We can determine the low mass spectrum
- We can determine the topological susceptibility χ_Q
- We can study the theory at $T \neq 0$ (Talk Stefano Piemonte)

We study N=1 SUSY with gauge group SU(2)

- The Euclidean action in the continuum:

$$S(g, m_g) = \int d^4x \left\{ \frac{1}{4}(F^a_{\mu\nu} F^a_{\mu\nu}) + \frac{1}{2}\bar{\lambda}_a(\gamma^\mu D^{ab}_\mu + m)\lambda_b - \frac{\Theta}{16\pi}\epsilon_{\mu\nu\rho\sigma}F^{\mu\nu}F^{\rho\sigma} \right\}$$

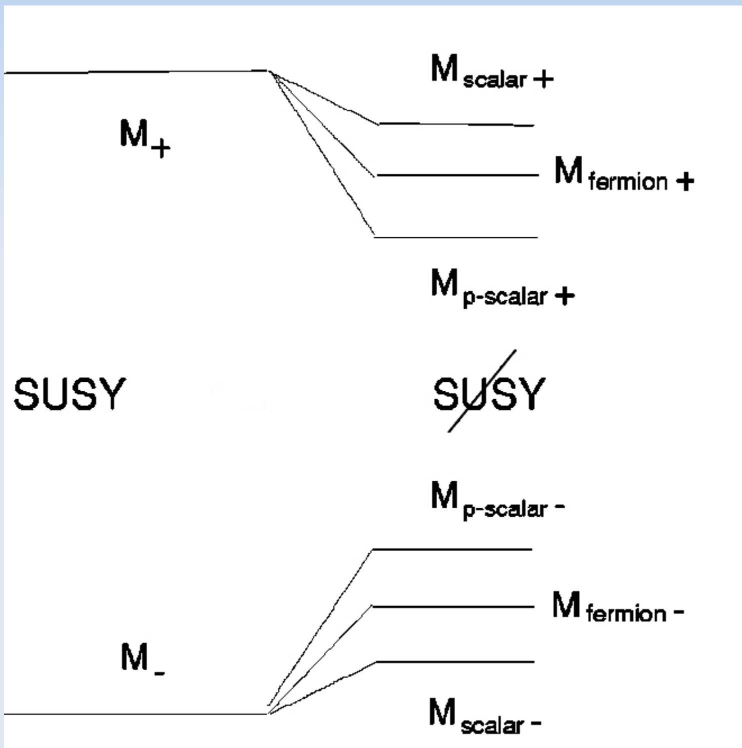
- Gauge fields A_μ (gluons)
- Majorana fermions λ_a (gluinos) in the adjoint representation
- SUSY relates boson gauge fields and fermions:

$$A_\mu(x) \to A_\mu(x) - 2i\bar{\lambda}(x)\gamma_\mu\epsilon$$

$$\lambda^a(x) \to \lambda^a(x) - \sigma_{\mu\nu}F^a_{\mu\nu}(x)\epsilon$$

We consider two supermultiplets at low energy

- Because the gluino mass SUSY is softly broken:



- scalar meson: $\mathrm{a}\!-\!f_0$
- gluino-glue: $\tilde{g}g$
- pseudoscalar meson: $\mathrm{a}\!-\!\eta'$

- pseudoscalar glueball: gg
- gluino-glue: $\tilde{g}g$
- scalar glueball: gg

- G. Veneziano, S. Yankielowicz, Phys. Lett. B113 (1982) 231
- R.Farrar, G.Gabadadze, M.Schwetz, Phys.Rev.D60 (1999) 035002

SUSY is broken on the lattice!

- SUSY is related to infinitesimal translations: $\{Q_\alpha, Q_\beta\} = (\gamma^\mu C)_{\alpha,\beta} P_\mu$
- gluino mass: $m_g \neq 0$

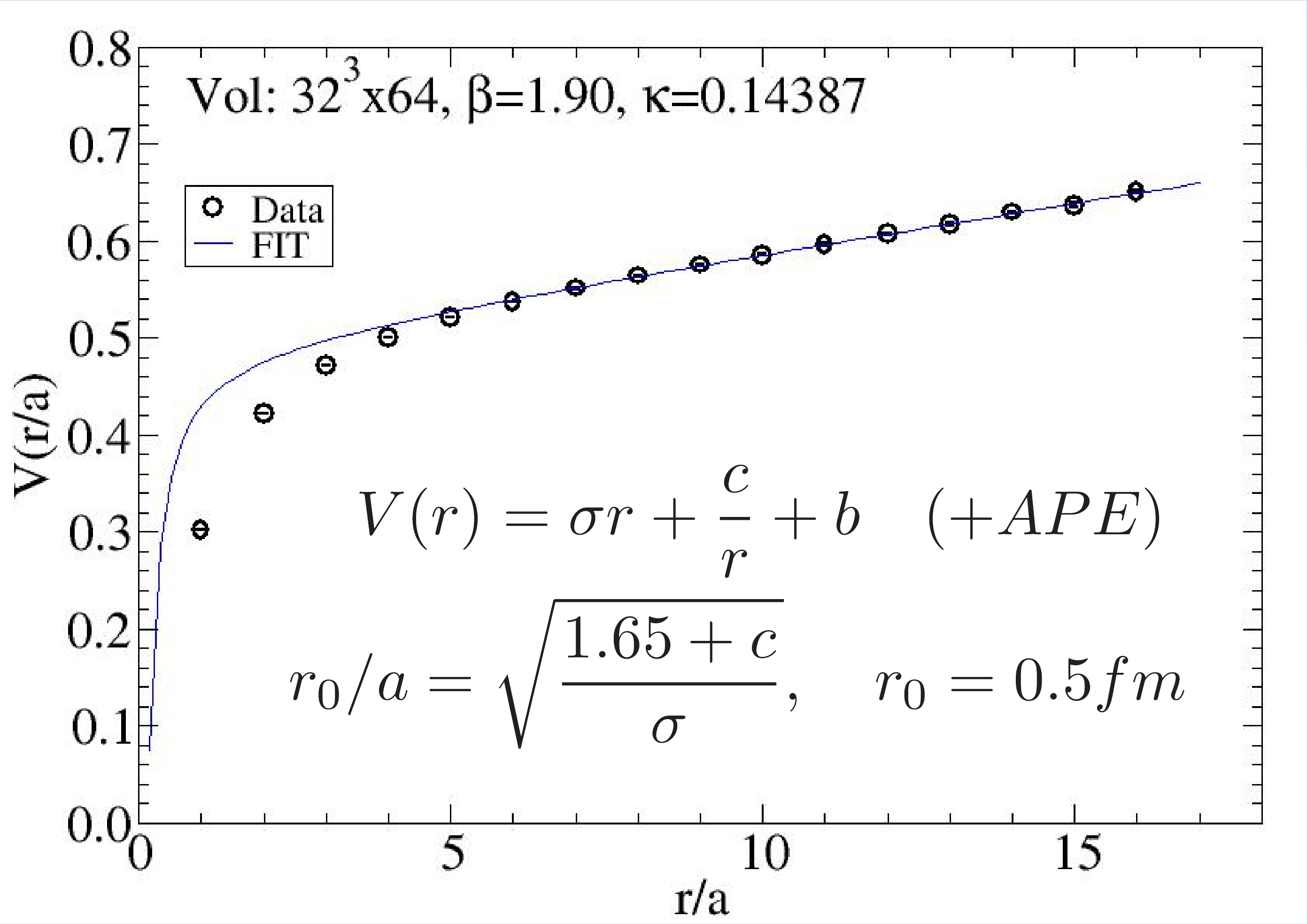
Other two issues:

- Boundary conditions
- Finite volume

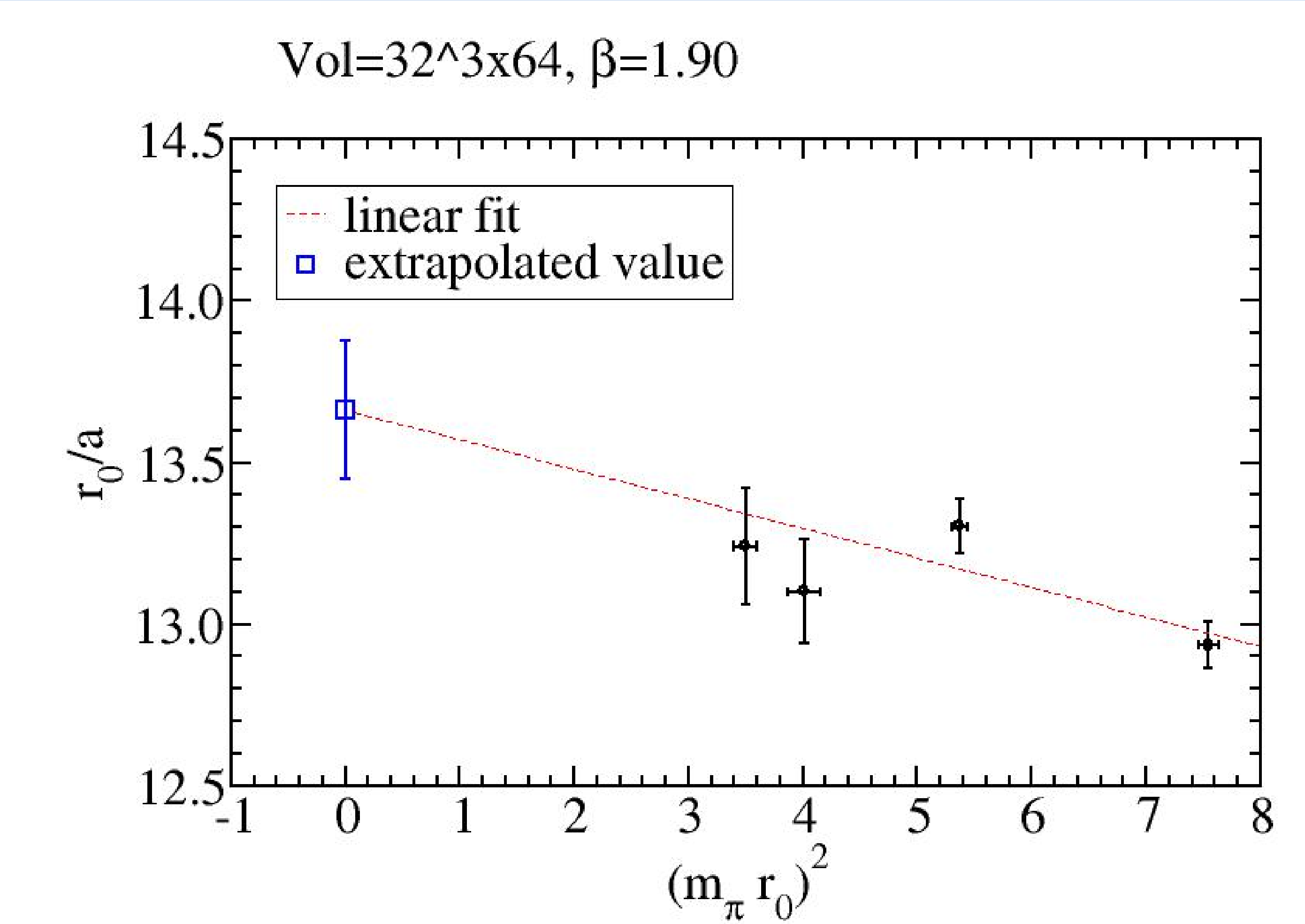
We tune the SUSY limit by $\text{a}\text{–}m_\pi$

- The adjoint pion is not a physical mass!
- It is the connected part of the $\text{a}\text{–}\eta'$ ($\bar{\lambda}\gamma_5\lambda$) correlator...
- Assumption: $m^2_{\text{a}-\pi} \propto m_{\tilde{g}}$
- Well defined in ”Partially Quenched Chiral Perturbation Theory” (see poster Prof. Gernot Munster)

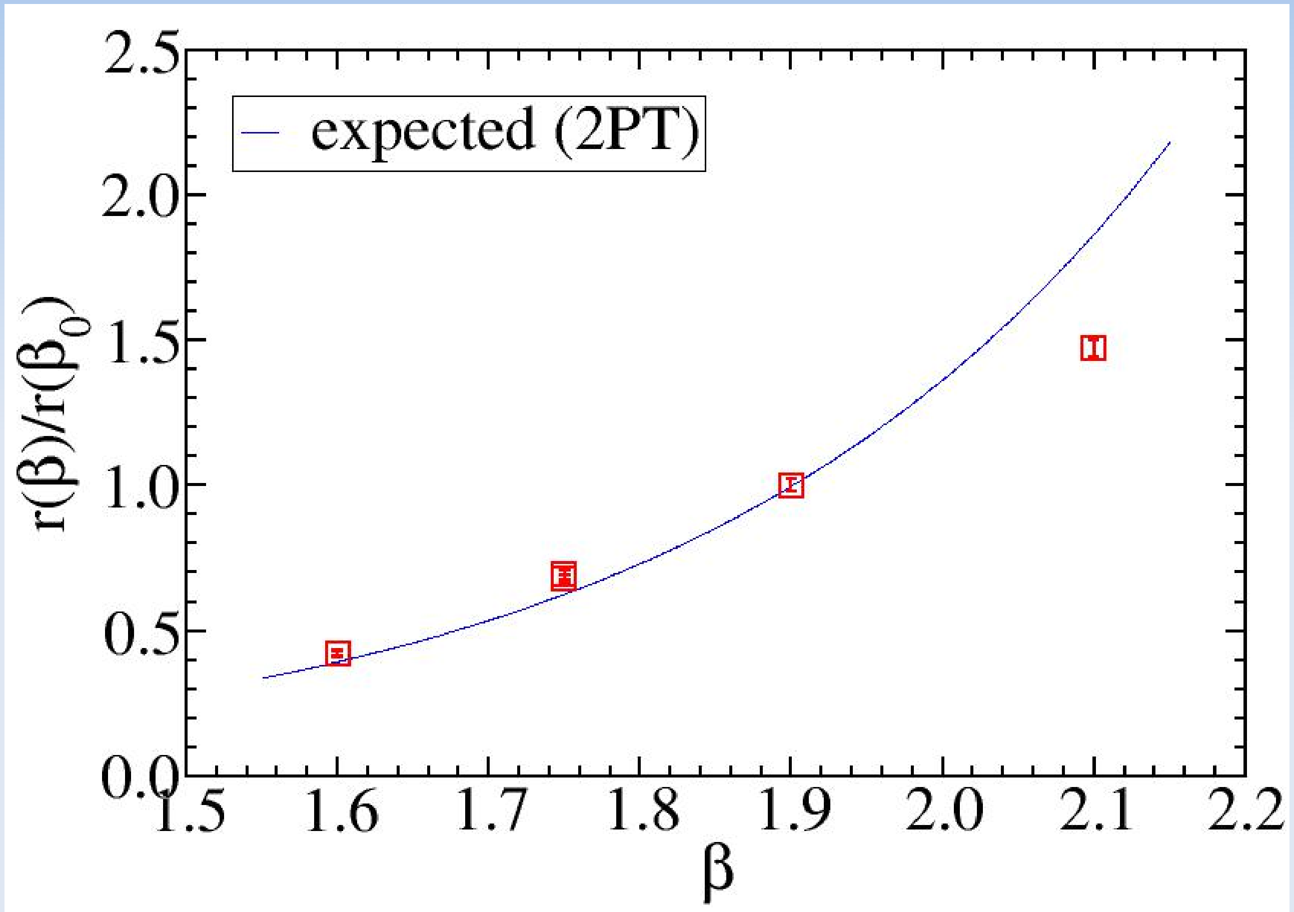
We fix the scale using the Sommer Parameter



r_0 is extrapolated to the chiral limit



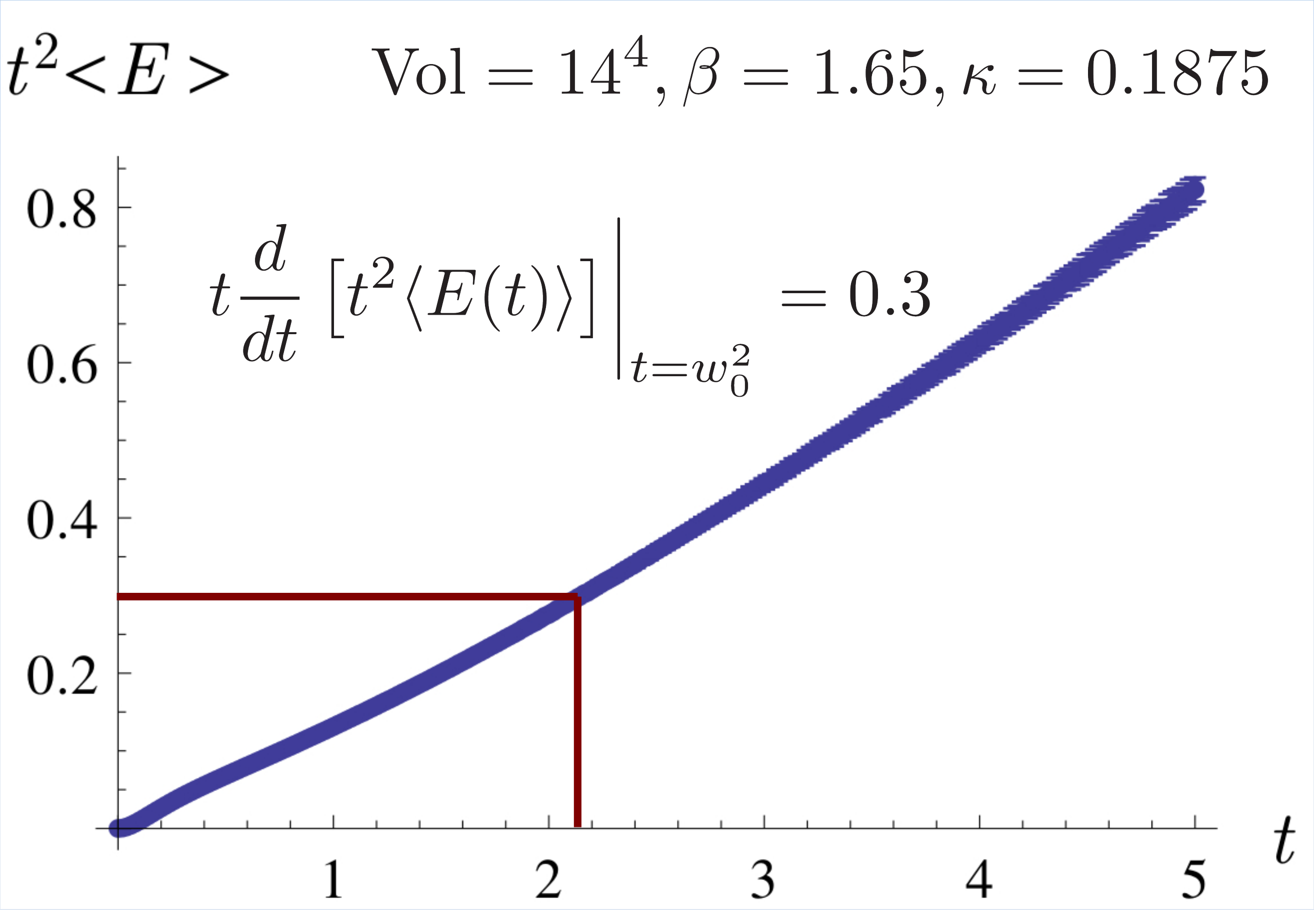
r_0 scales as expected (we verified NSVZ!)



$$\beta(g) = -\frac{g^3}{16\pi^2}\frac{3N}{1-\frac{g^2 N}{8\pi^2}}$$

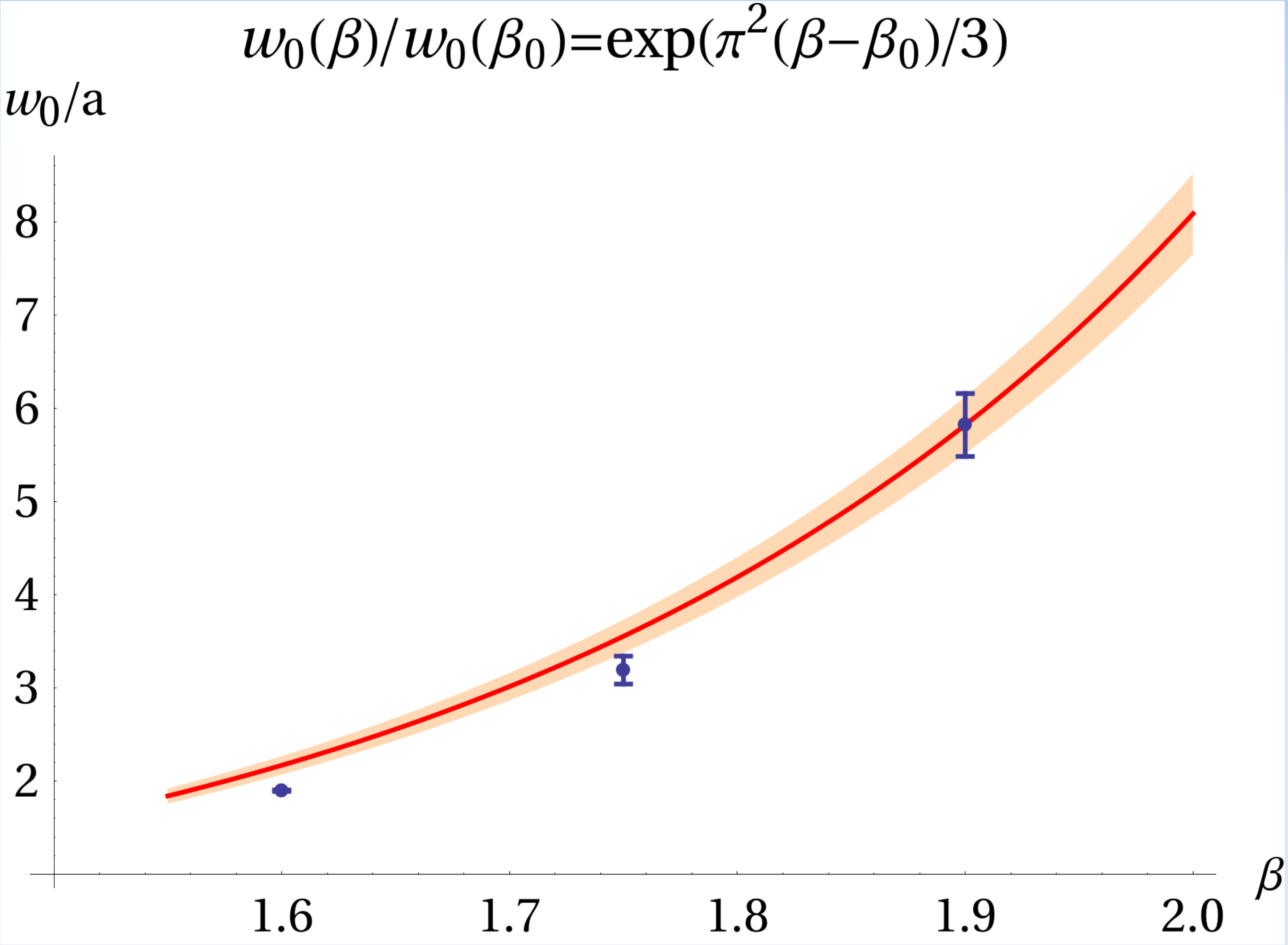
NSVZ: Novikov, Shifman, Vainshtein, Zakharov (1983)

We fix the scale also using the Wilson flow!

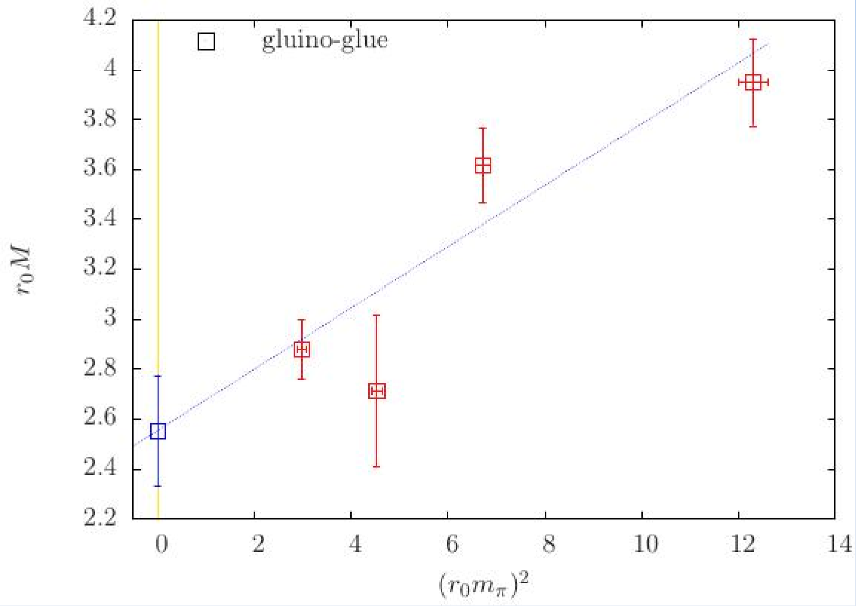


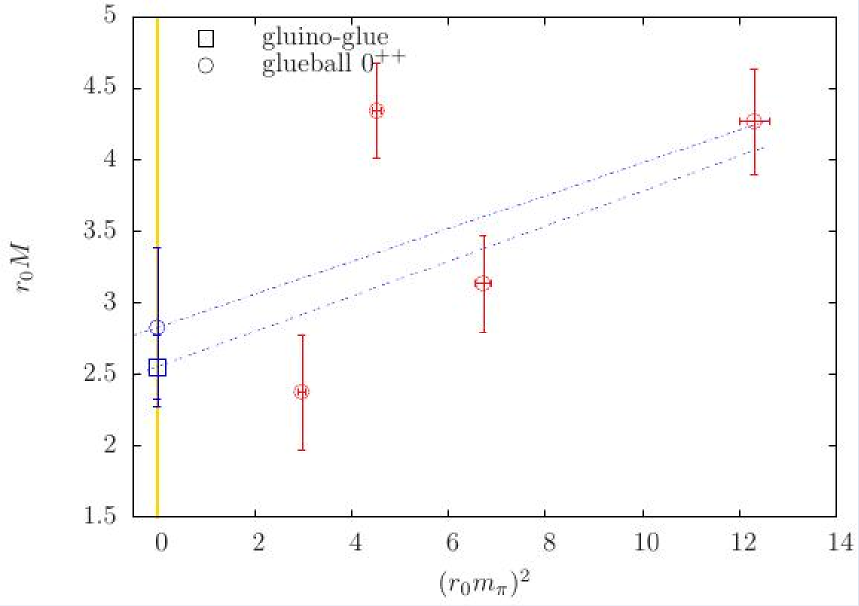
- **Gauge action density** $E = \frac{1}{4} G^a_{\mu\nu} G^a_{\mu\nu}$

Also w_0 scales as expected!

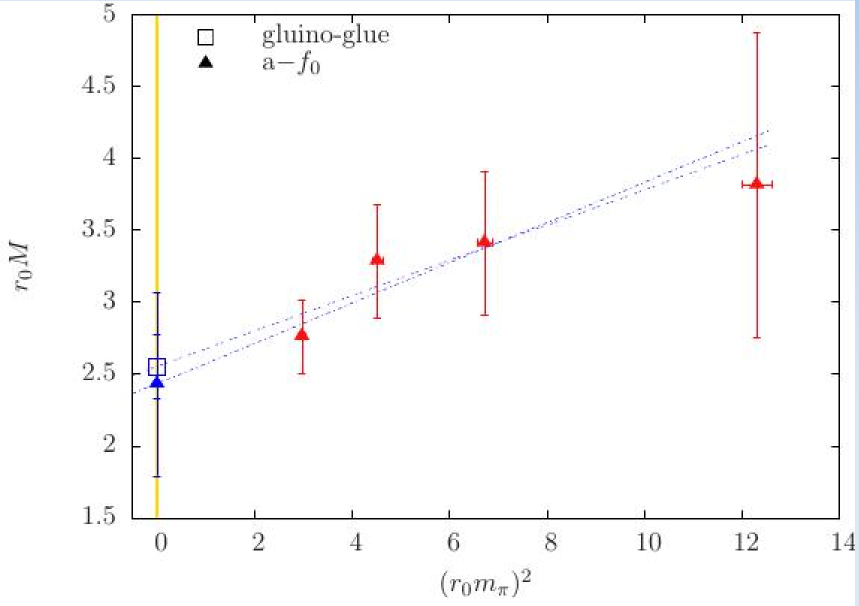


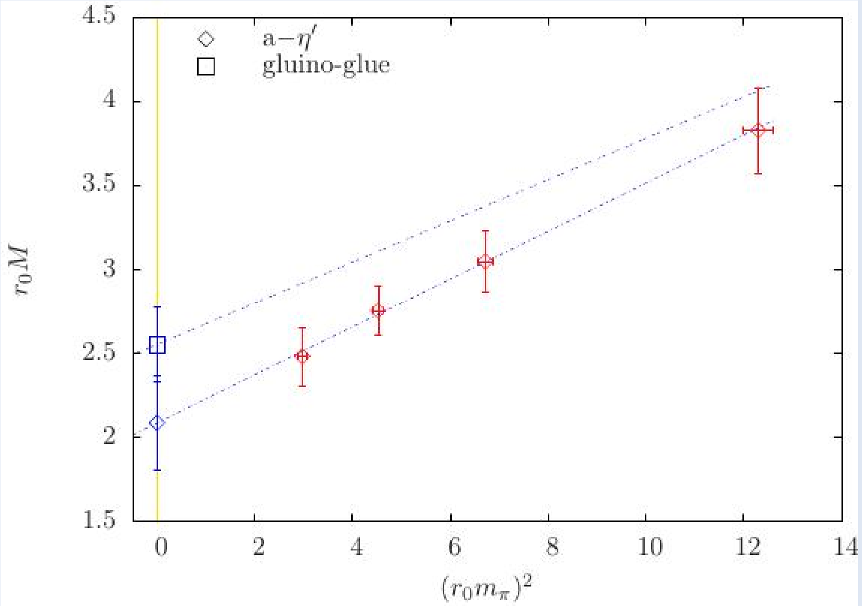
gluino-glue and glueball are "almost" degenerate!



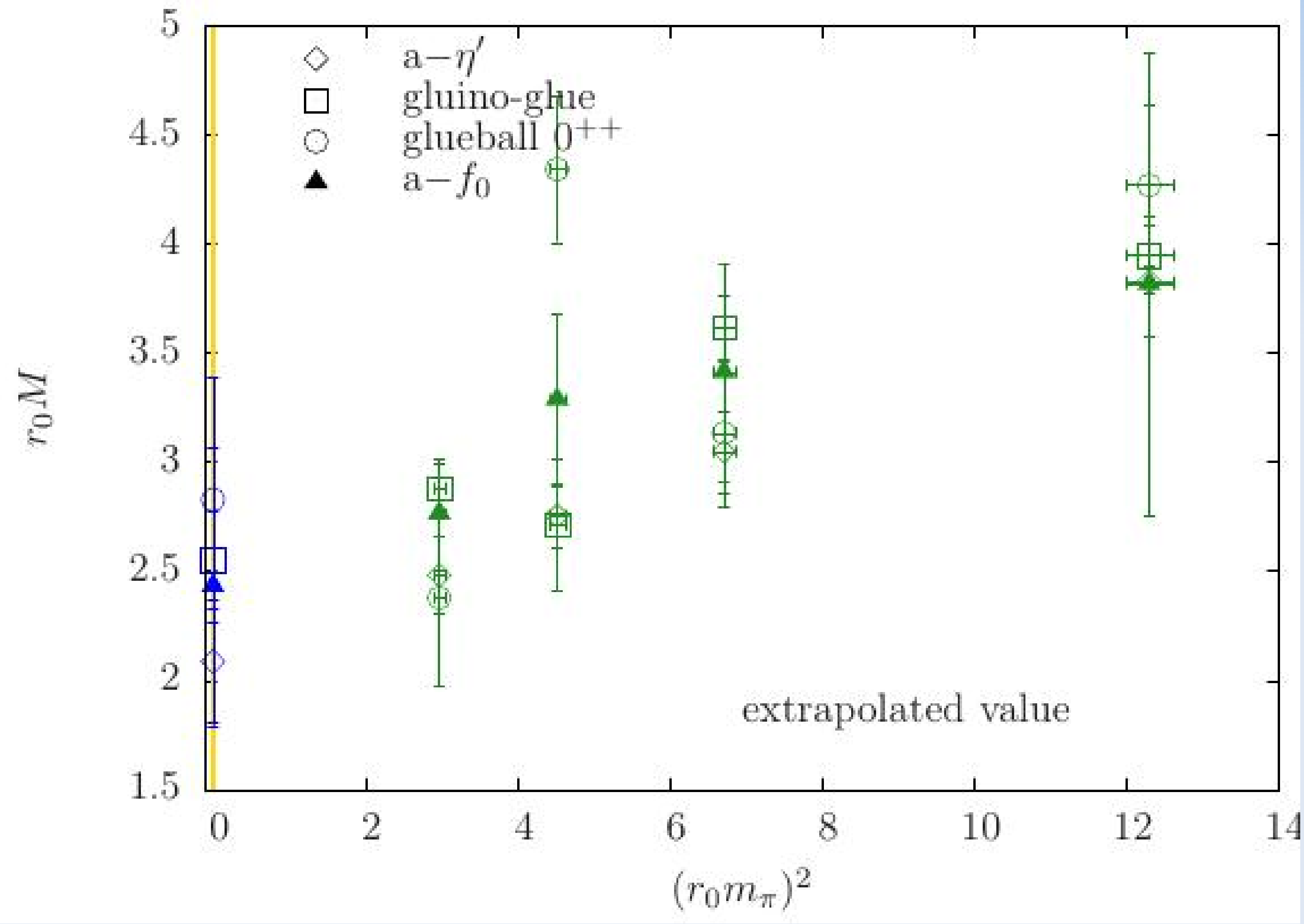


gluino-glue is "almost" degenerate with a–η' and a–f_0



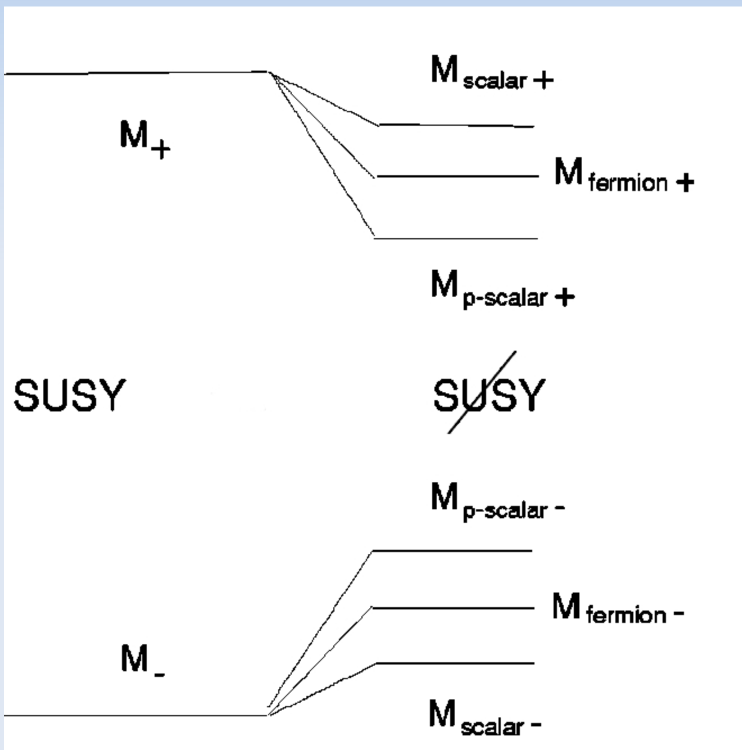


The low spectrum is ”almost” degenerate!



We do not see the gap between the two supermultiplets!

- Because the gluino mass SUSY is softly broken:



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We measure the topological susceptibility

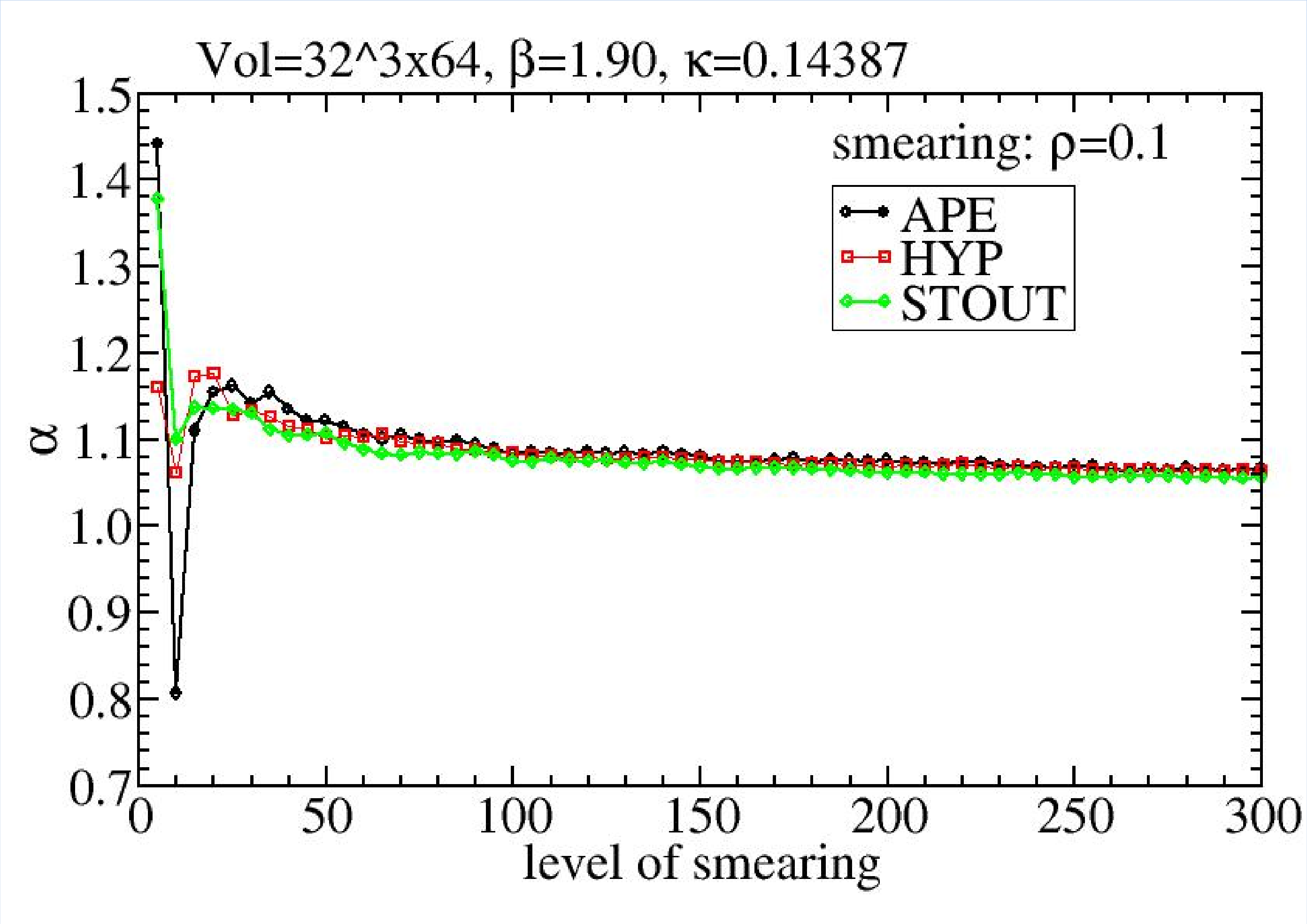
- $$Q_L = \int dx^4 q(x), \quad q(x) = -\frac{1}{32\pi^2}\epsilon_{\mu\nu\rho\sigma}\mathrm{Tr}(F_{\mu\nu}(x)F_{\rho\sigma}(x))$$

- $$Q = \mathrm{round}(\alpha Q_L) \quad \Leftarrow \quad \langle(\alpha Q_L - \mathrm{round}(\alpha Q_L))^2\rangle$$

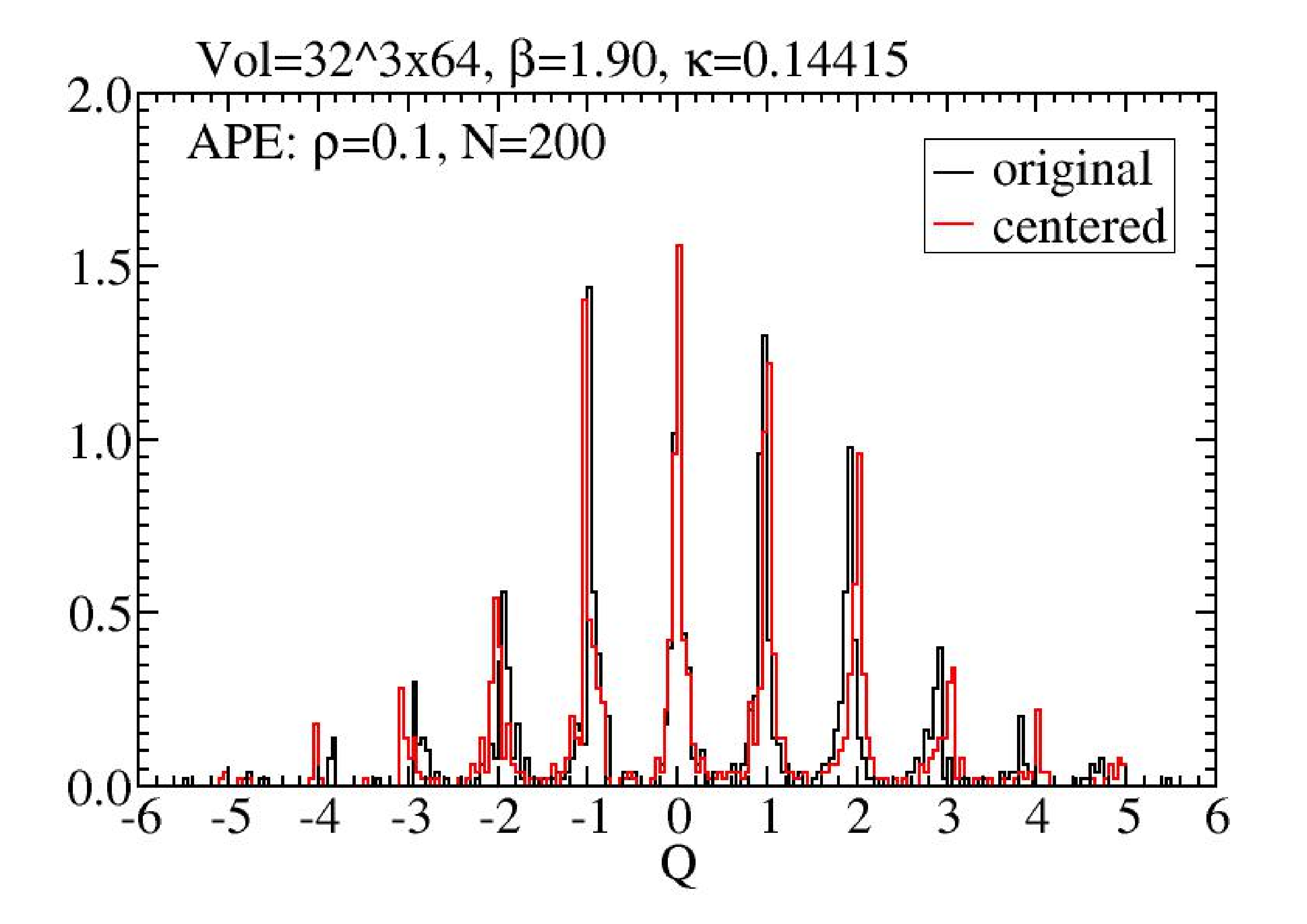
- $$\chi_Q = \frac{1}{V}\left(\langle Q^2\rangle - \langle Q\rangle^2\right)$$

- Smearing: APE, HYP, STOUT and Wilson flow!

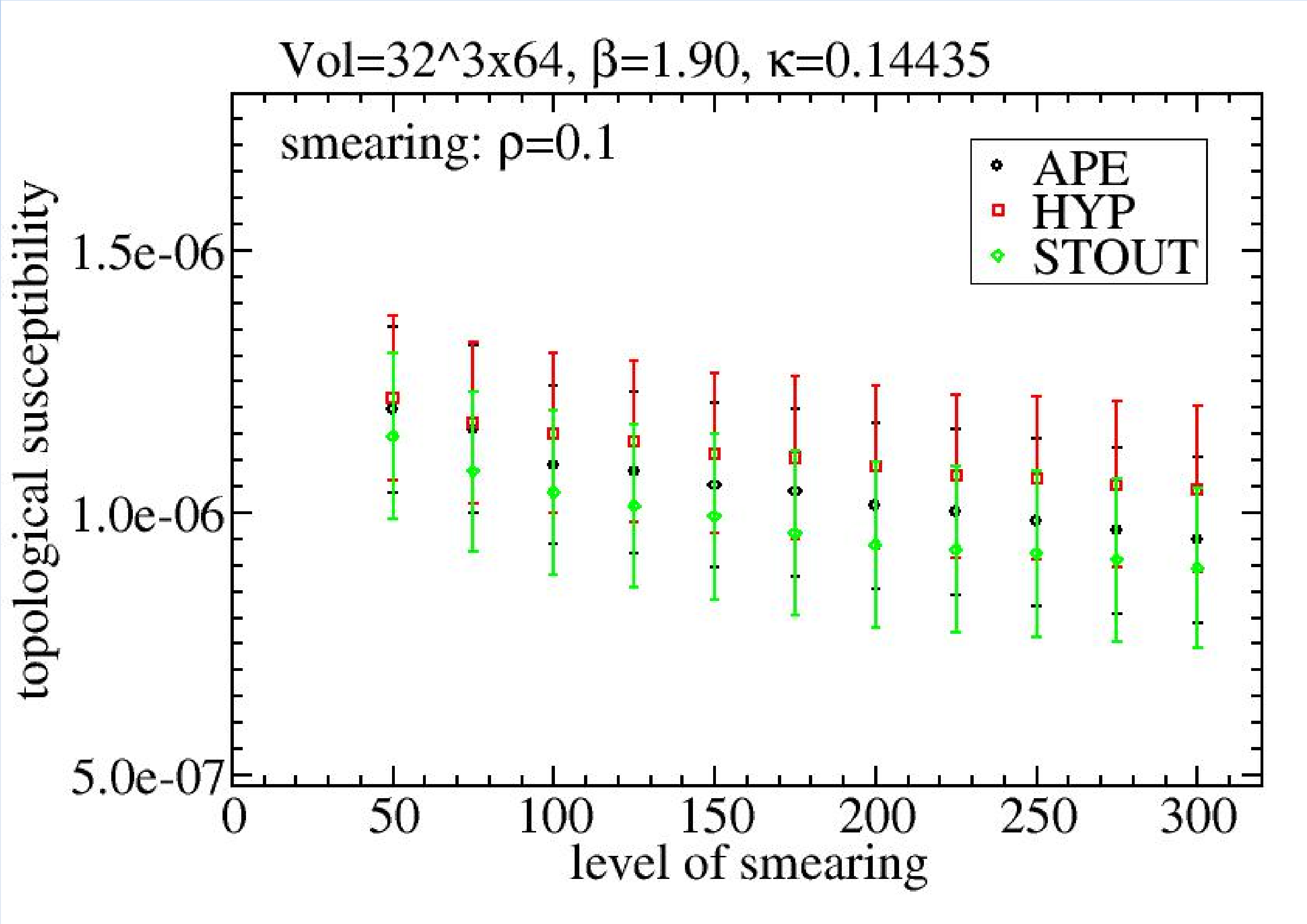
The parameter α behaves very nicely!



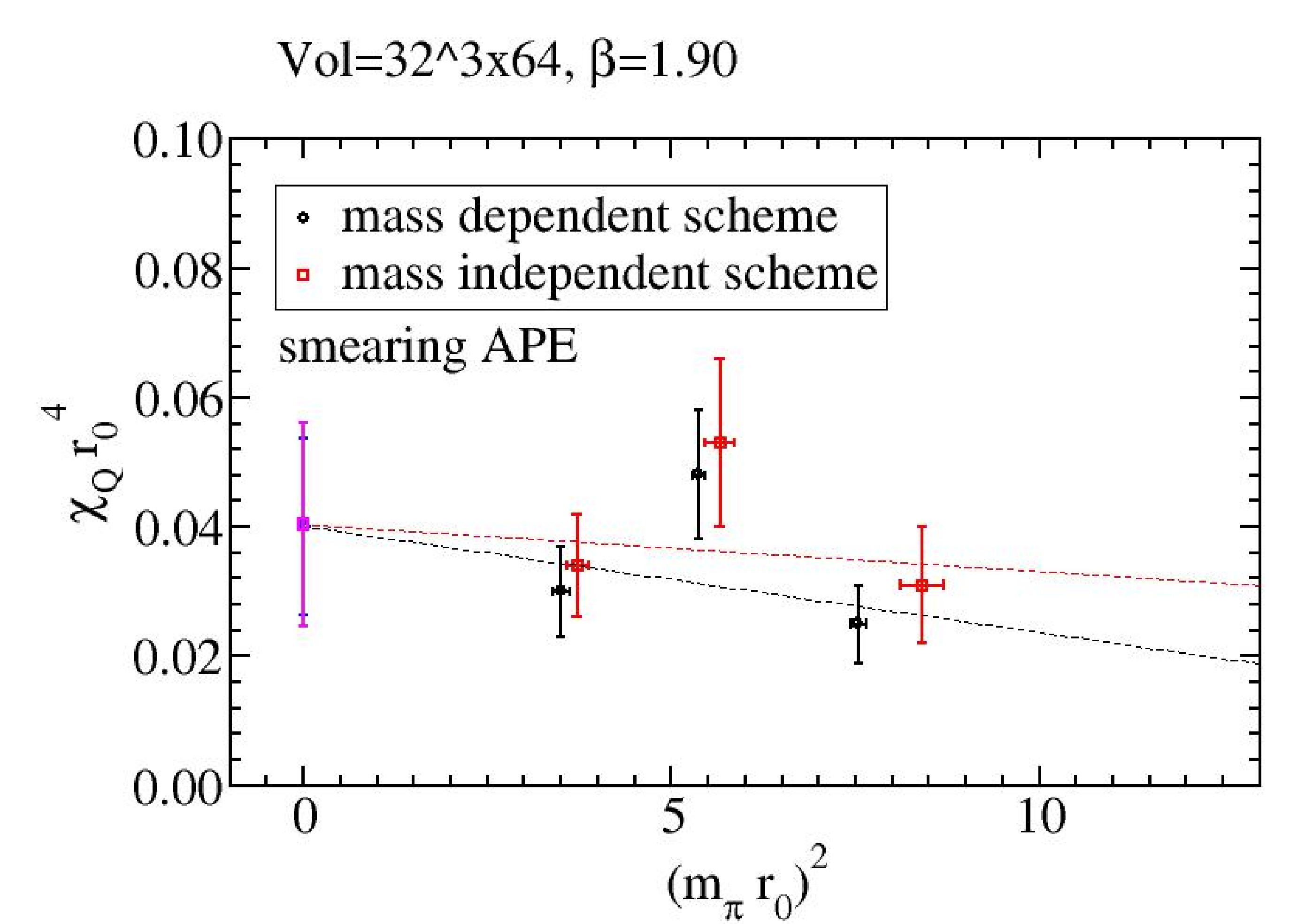
α helps to center the distribution!



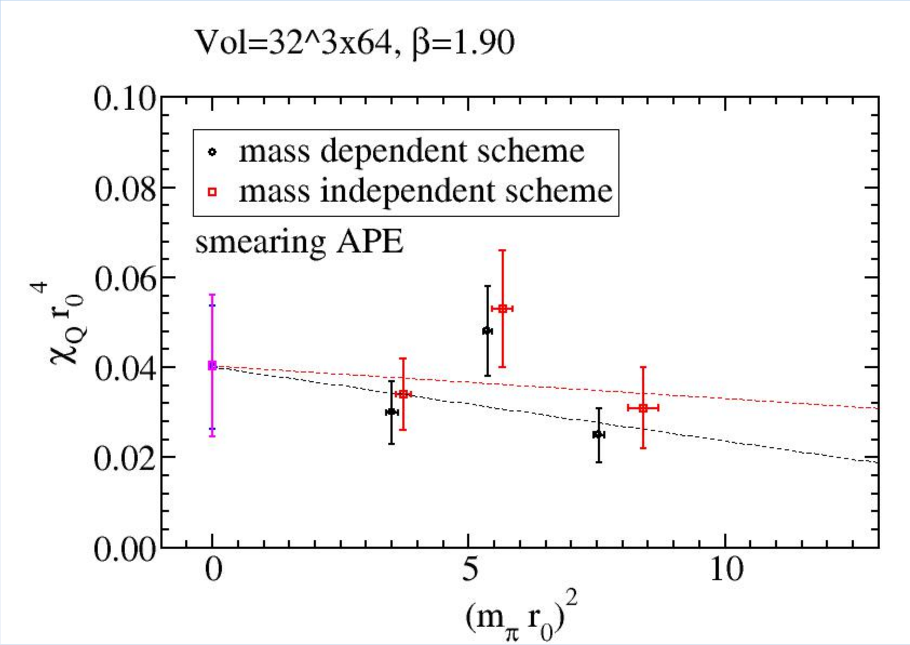
The systematic effects are under control!

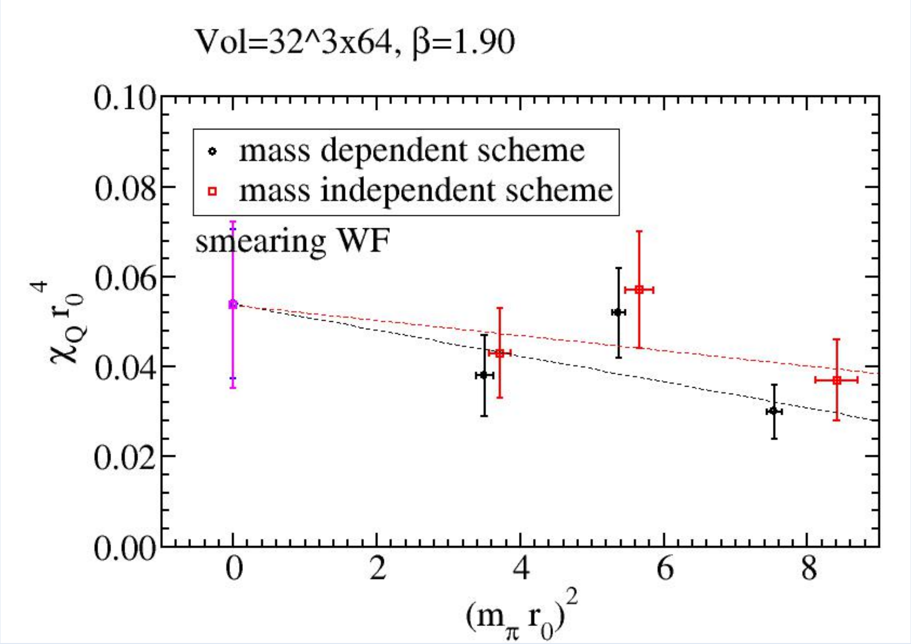


χ_Q is extrapolated to the chiral limit!

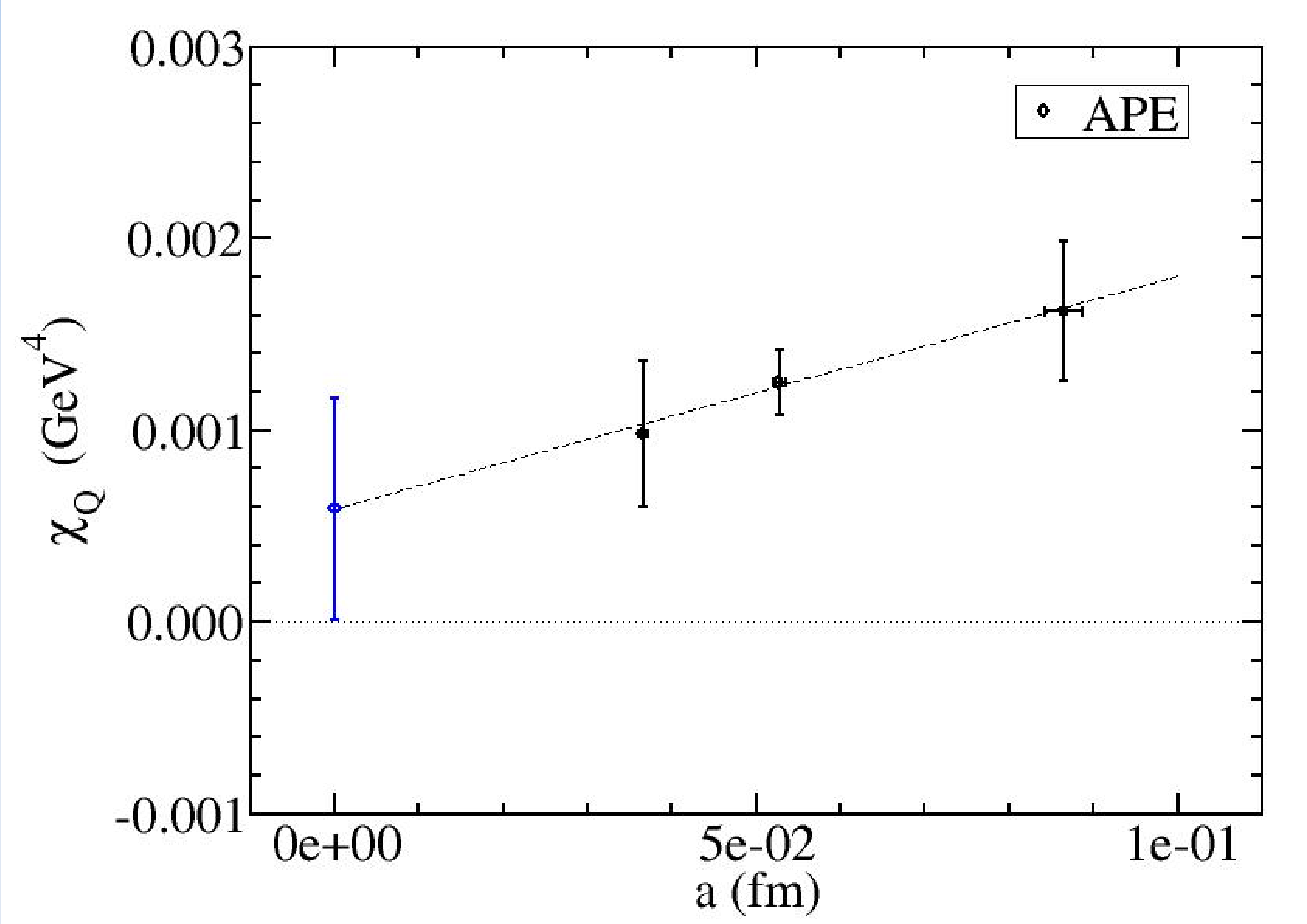


χ_Q is independent of the smearing procedure!

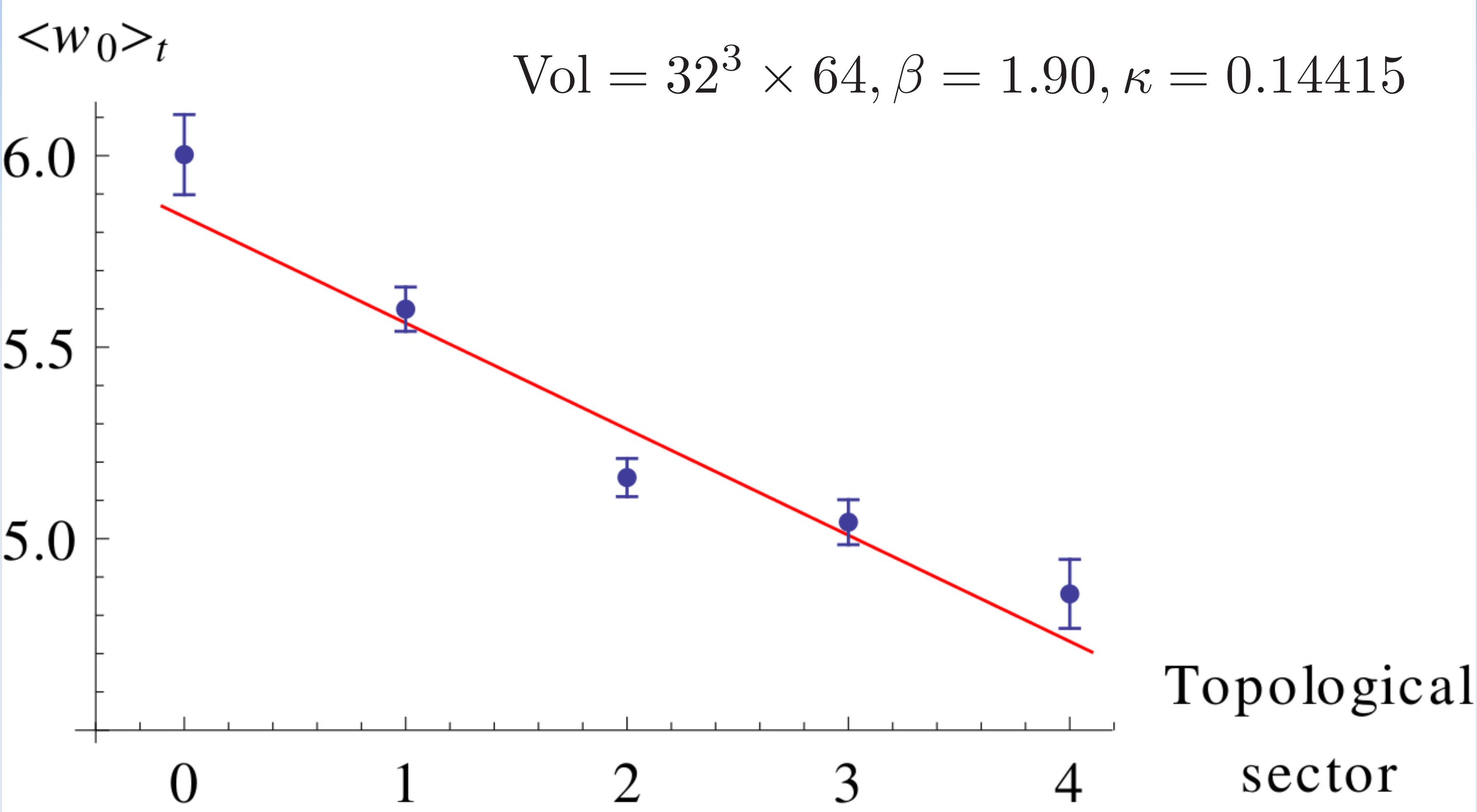




χ_Q is extrapolated to the continuum limit!



Warning: the scale depends strongly on the topological sector!



Conclusions!

- We can fix the scale both with r_0 and w_0
- We see a ”full” degeneracy between the two supermultiplets
- We are ready to extrapolate into the continuum limit
- χ_Q scales as $(m_\pi)^2$ and it is compatible with zero in the continuum limit!