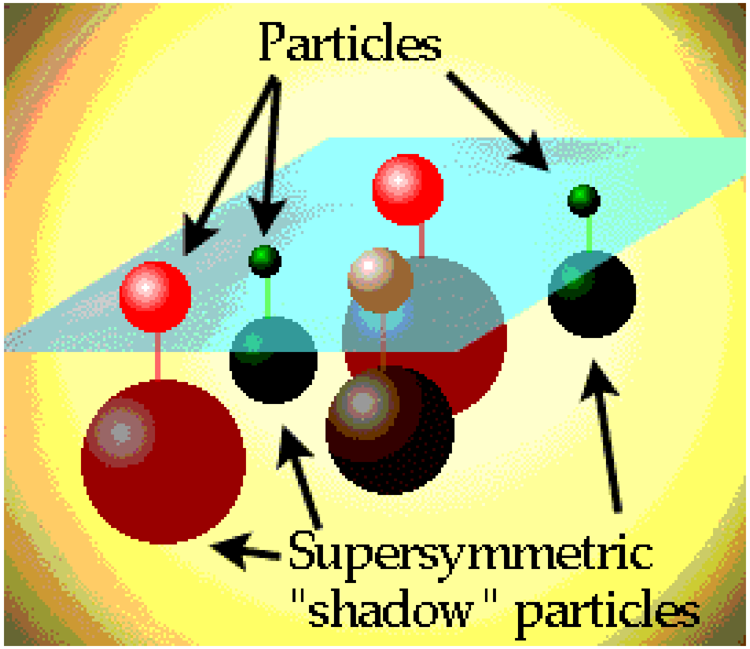
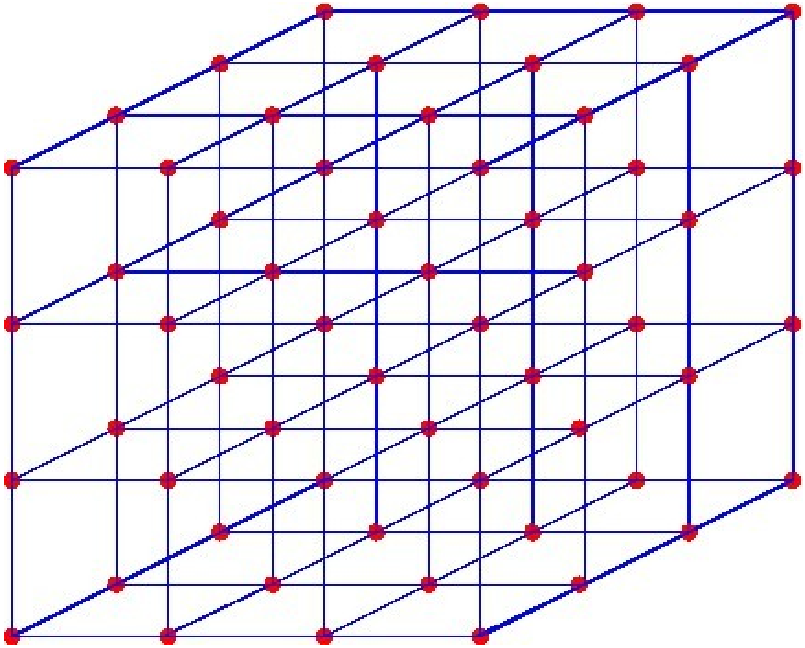
Supermultiplets of the N=1 supersymmetric Yang-Mills theory in the continuum limit

G. Bergner, **P.Giudice**, I. Montvay, G. Münster, S. Piemonte

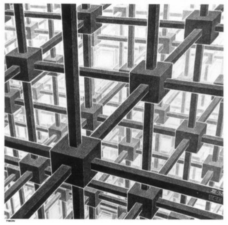
WWU Münster, Uni Bern, DESY Hamburg





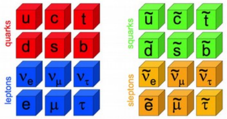
Lattice 2015, Kobe, 18/July/2015

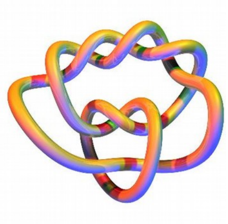
Introduction



Set the scale

Mass spectrum





Topology

Conclusions

SUSY on the lattice is important to test non-perturbative aspects of supersymmetric theories

- We look for non-perturbative mechanisms of spontaneous breaking of SUSY
- We study many non-perturbative aspects: confinement/deconfinement, chiral symmetry, topology
- We test effective theories for the low energy spectrum
- We can test the orientifold equivalence:

  $$N_f = 1 \;\; QCD \Leftrightarrow \mathcal{N} = 1 \;\; SYM$$

We study N=1 Supersymmetric Yang-Mills theory with gauge group SU(2)

- The Euclidean action in the continuum:

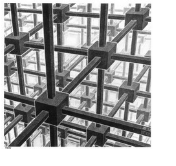
$$S(g, m_g) = \int d^4x \left\{ \frac{1}{4}(F^a_{\mu\nu} F^a_{\mu\nu}) + \frac{1}{2}\bar{\lambda}_a(\gamma^\mu D^{ab}_\mu + m)\lambda_b - \frac{\Theta}{16\pi}\epsilon_{\mu\nu\rho\sigma}F^{\mu\nu}F^{\rho\sigma} \right\}$$

- Gauge fields A_μ (gluons)
- Majorana fermions λ_a (gluinos) in the adjoint representation

- SUSY relates boson gauge fields and fermions:

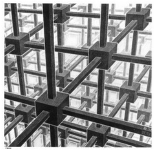
$$A_\mu(x) \to A_\mu(x) - 2i\bar{\lambda}(x)\gamma_\mu \epsilon$$

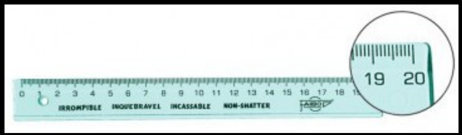
$$\lambda^a(x) \to \lambda^a(x) - \sigma_{\mu\nu}F^a_{\mu\nu}(x)\epsilon$$



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 $m_g \neq 0$
- Finite volume

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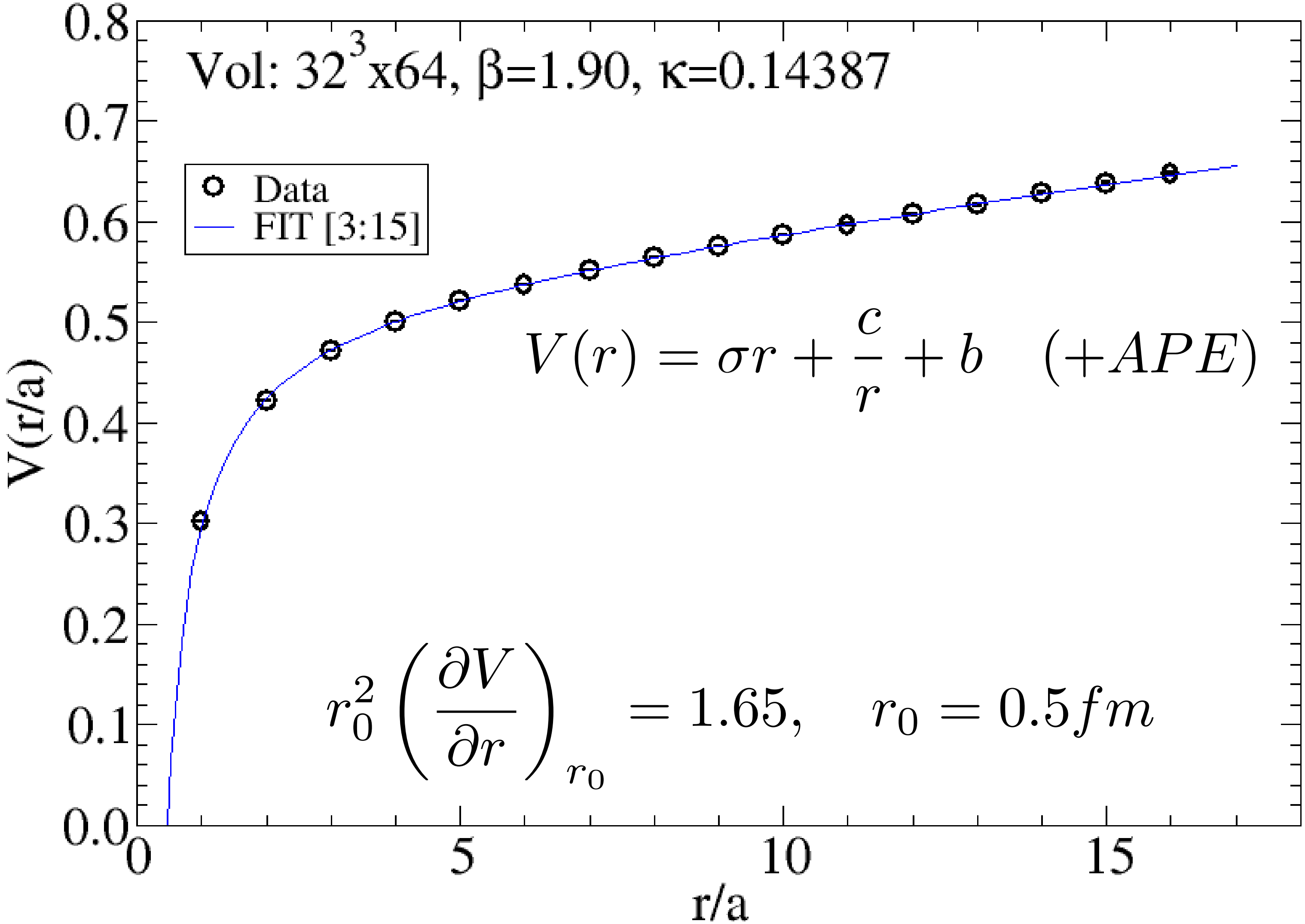
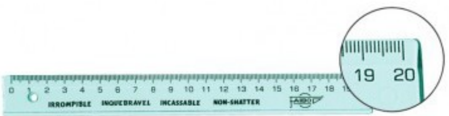
We fix the scale using the Sommer Parameter r_0



$$V(r) = \sigma r + \frac{c}{r} + b \quad (+APE)$$

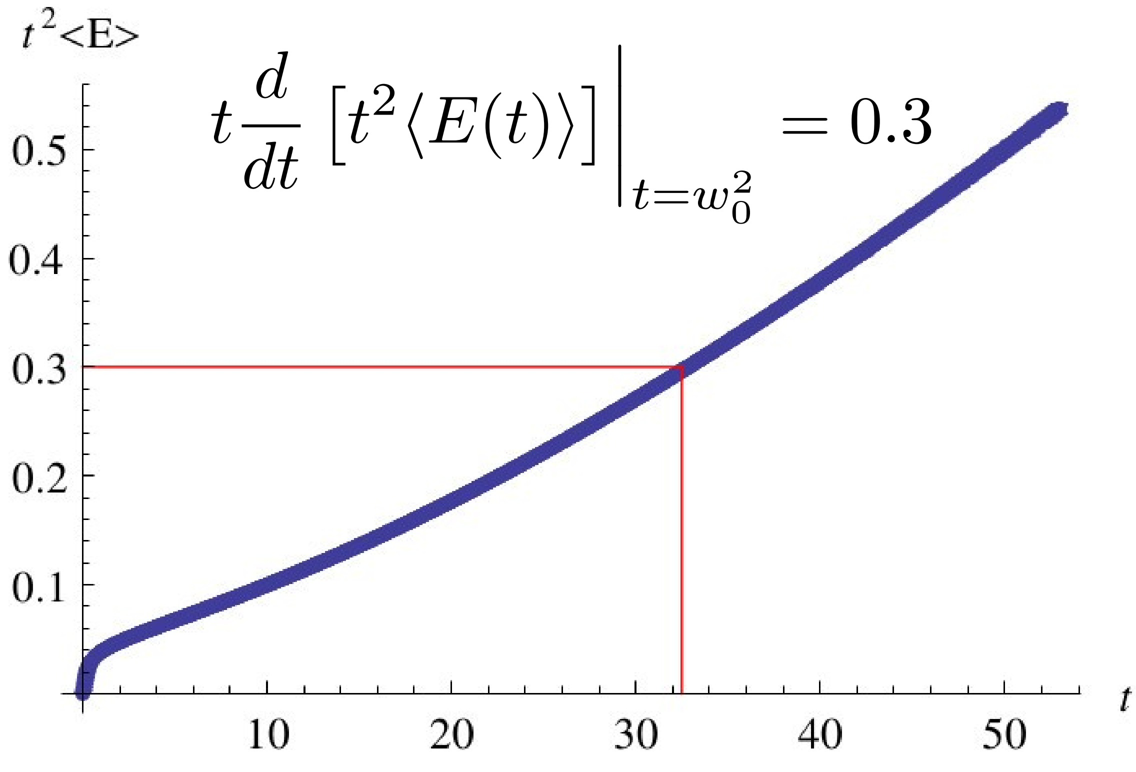
$$r_0^2 \left(\frac{\partial V}{\partial r} \right)_{r_0} = 1.65, \quad r_0 = 0.5fm$$

$$\hat{r}_0 = \sqrt{\frac{1.65 + c}{\sigma}}$$



We fix the scale also using the Wilson flow determining the parameter w_0

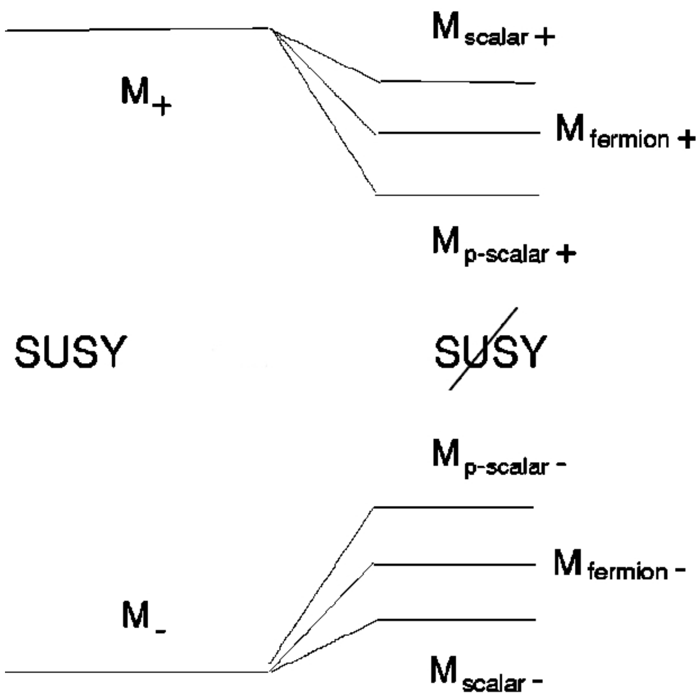
$$\mathrm{Vol} = 32^3 \times 64, \beta = 1.90, \kappa = 0.14435$$



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

There are many works which describe the two lower supermultiplets

- Because the gluino mass SUSY is softly broken we have:



- scalar meson: a–f_0
- gluino-glue: $\tilde{g}g$
- pseudoscalar meson: a–η'

- 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
- A.Feo, P.Merlatti, F.Sannino, Phys.Rev.D70 (2004) 096004

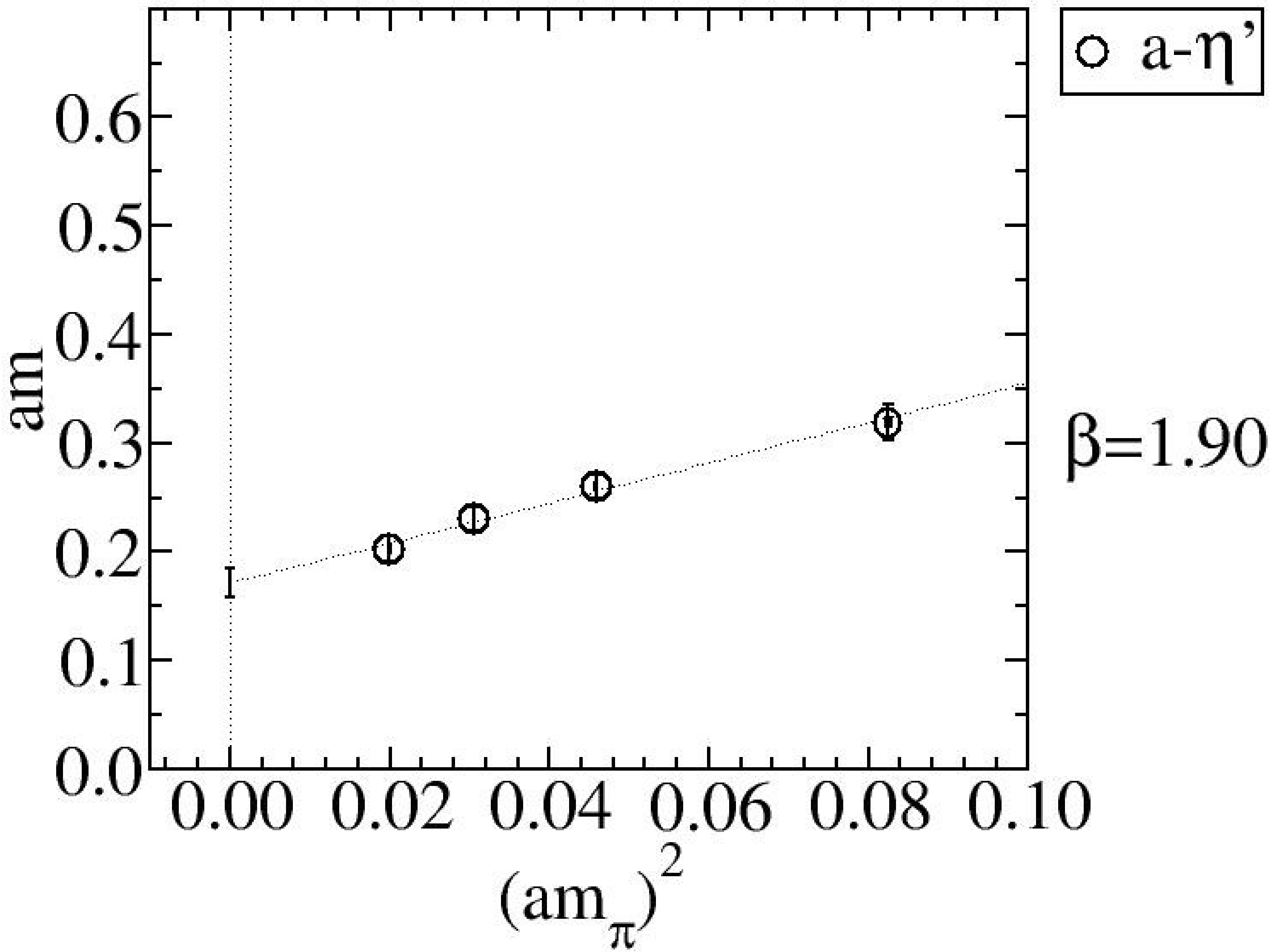
We tune the $\mathrm{m}_g = 0$ limit by $\mathrm{a}\text{–}m_\pi$

- The adjoint pion is not a physical particle!
- It is the connected part of the $\mathrm{a}\text{–}\eta'$ ($\bar{\lambda}\gamma_5\lambda$) correlator
- Assumption: $m^2_{\mathrm{a}-\pi} \propto m_{\tilde{g}}$

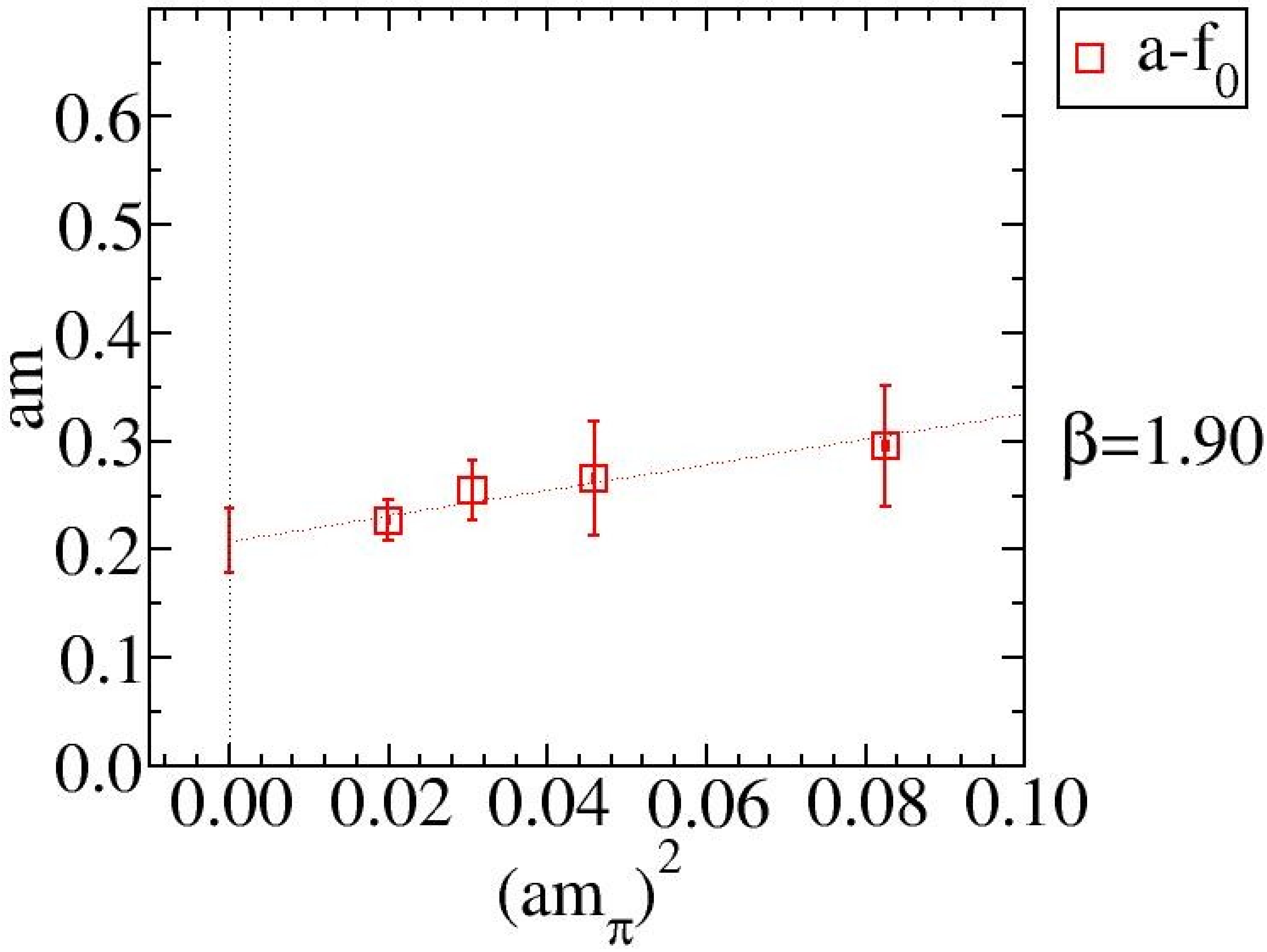
- OZI (Okubo-Zweig-Iizuka) approximation
- Well defined in ”Partially Quenched Chiral Perturbation Theory”
  G.Münster, H.Stüwe, JHEP1405 (2014) 034

- Results compatible with SUSY Ward Identity

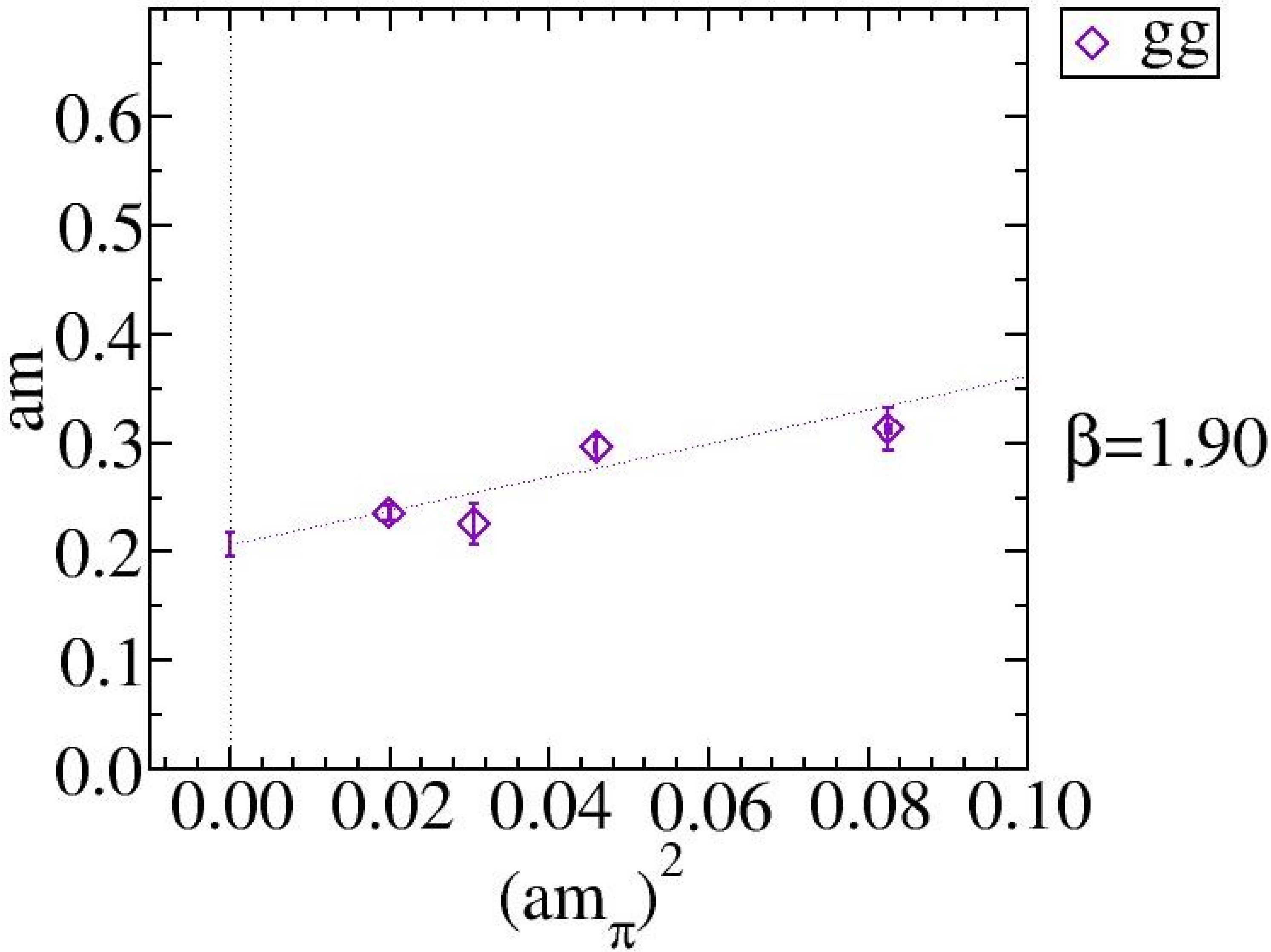
η' is linear in $(am_\pi)^2$



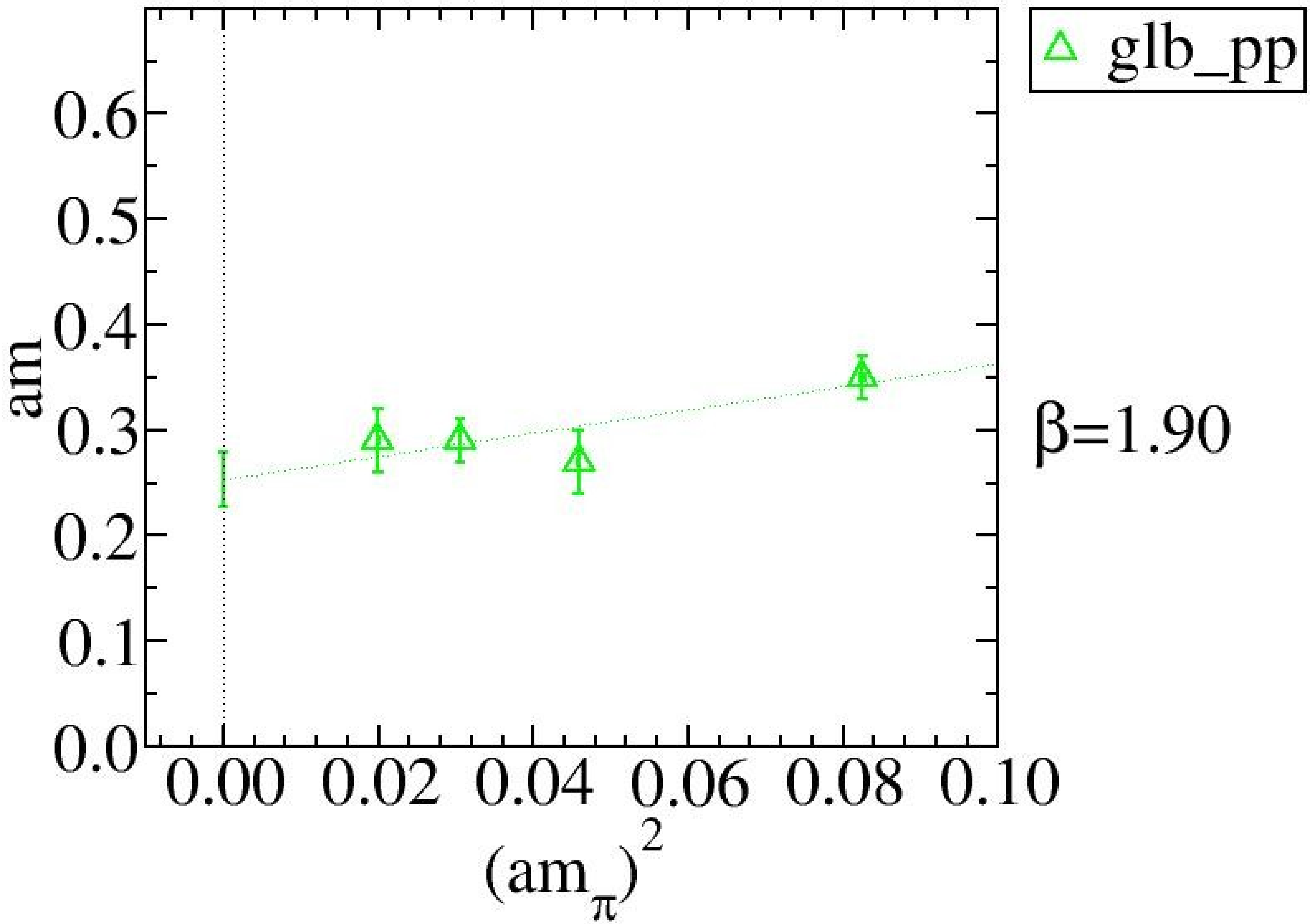
f_0 is linear in $(am_\pi)^2$



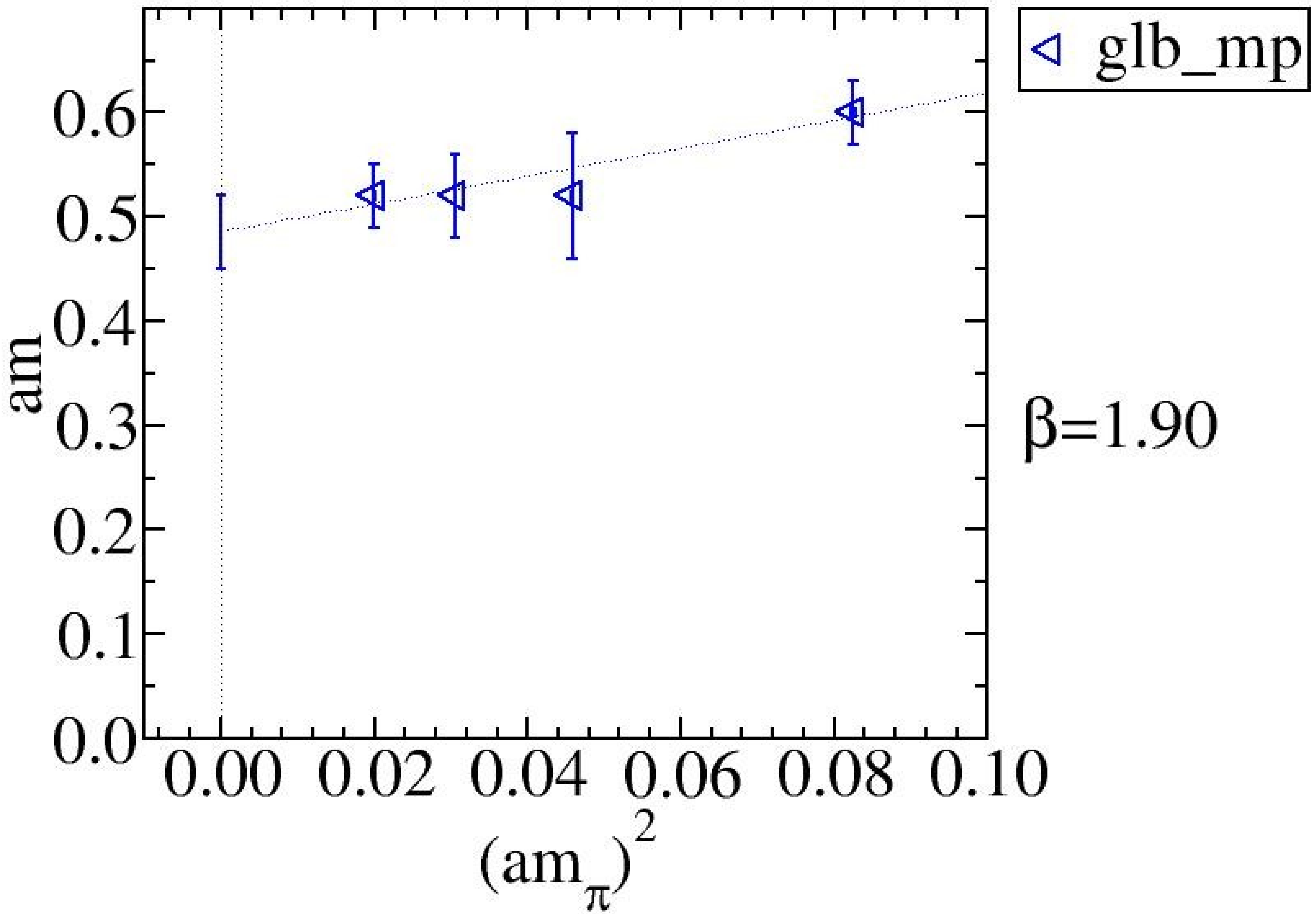
$\tilde{g}g$ is linear in $(am_\pi)^2$



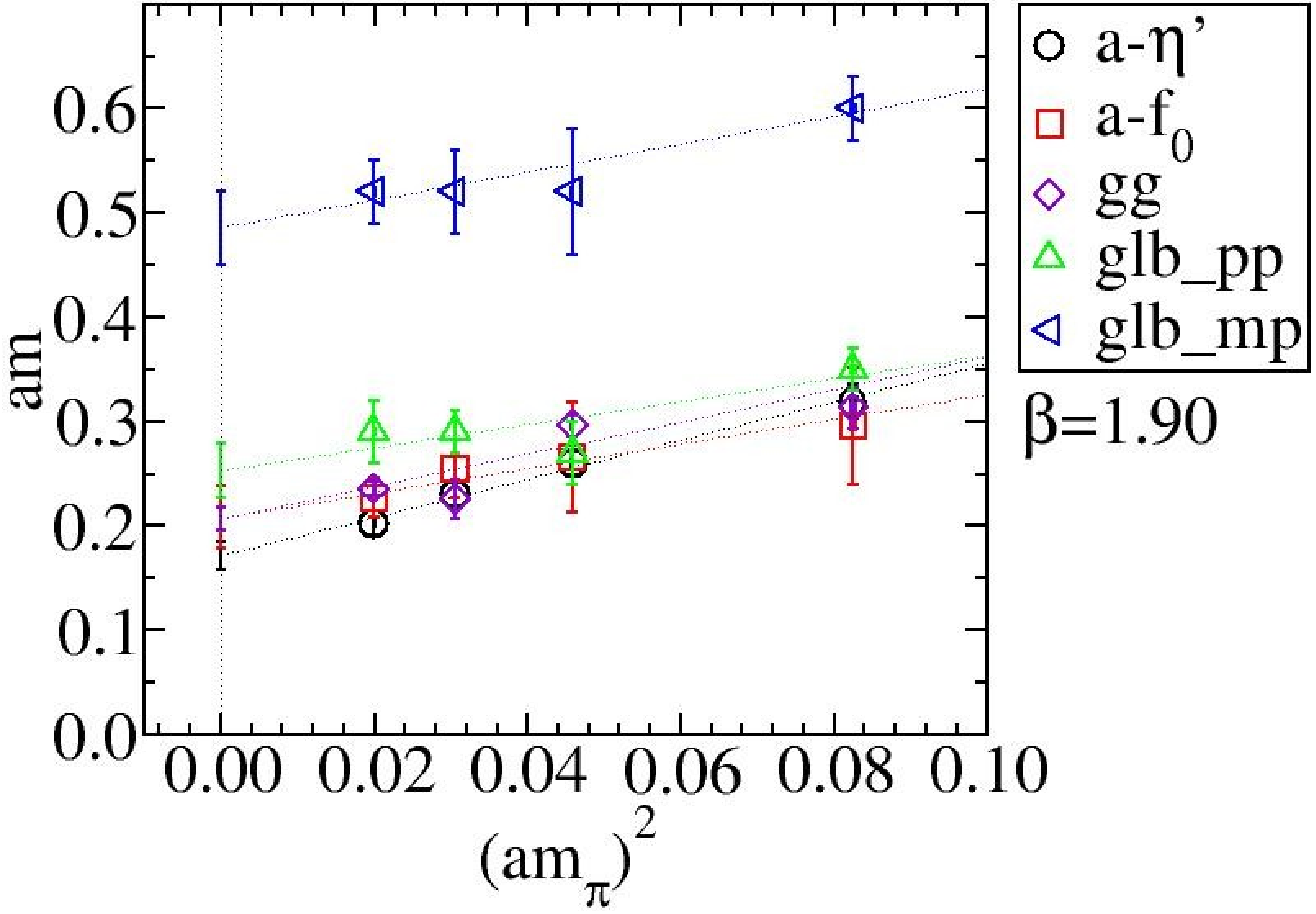
Glueball 0^{++} is linear in $(am_\pi)^2$

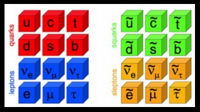


Glueball 0^{-+} is linear in $(am_\pi)^2$



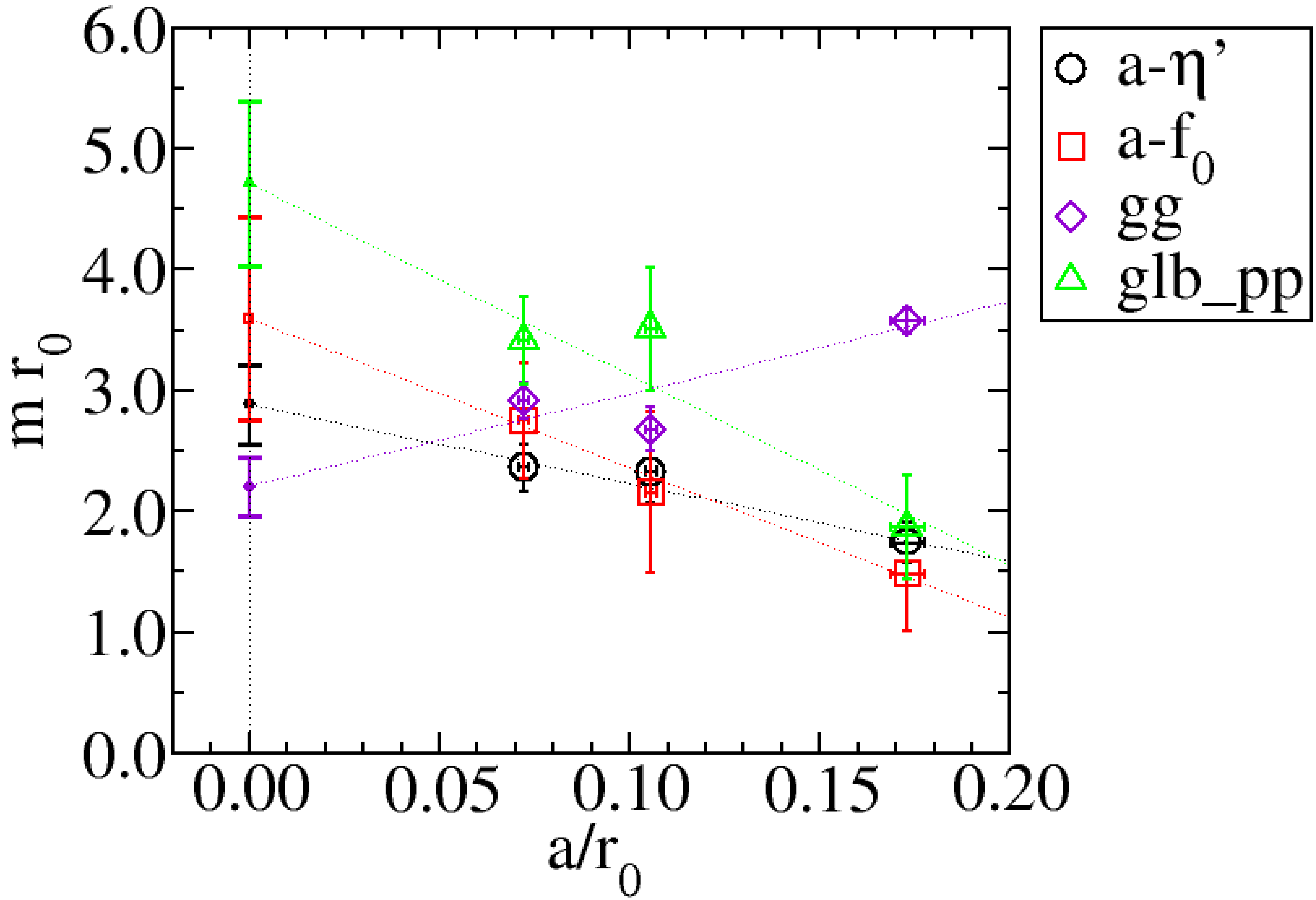
All masses are linear in $(am_\pi)^2$ and we can see a degeneracy in the first supermultiplet



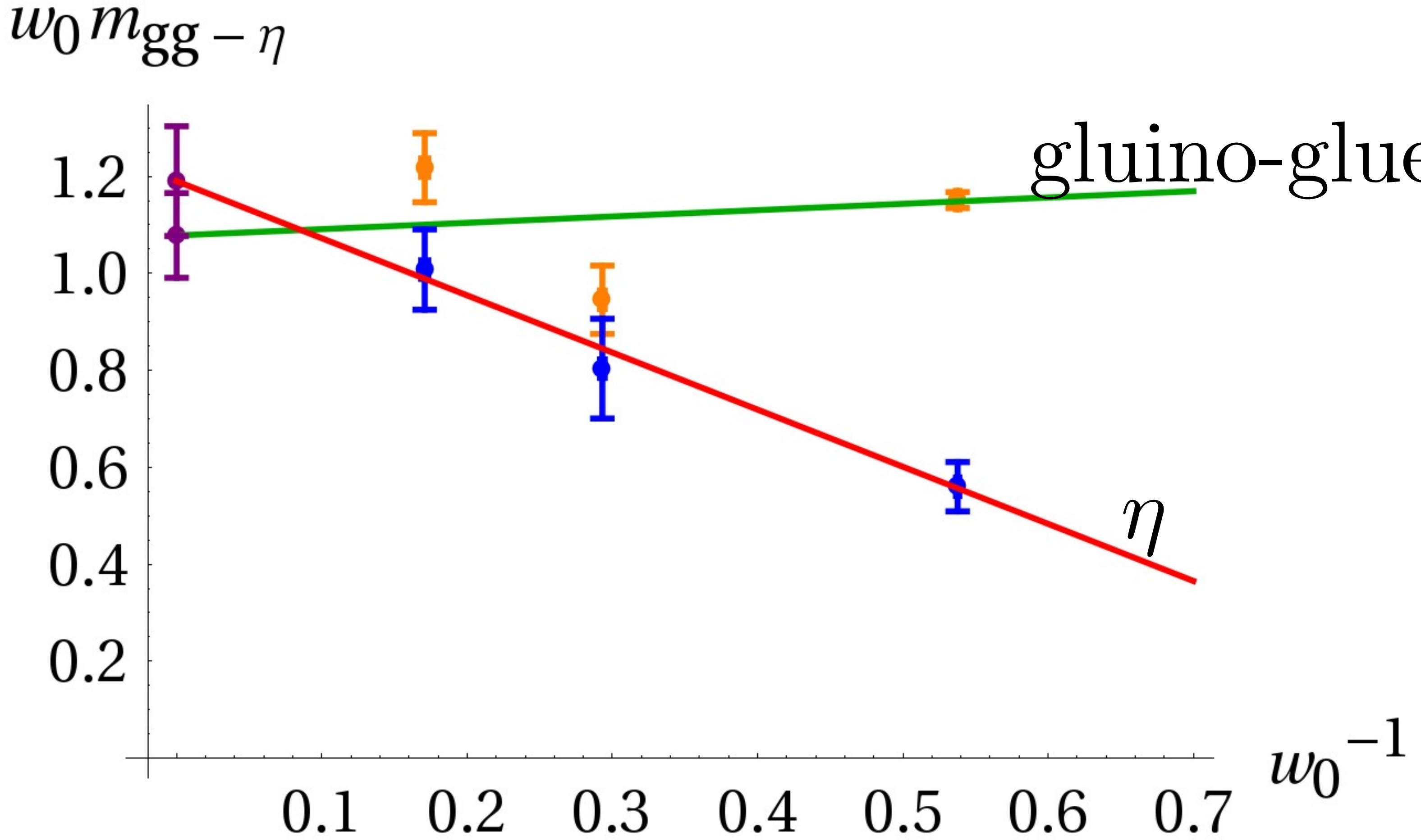


quarks
u c t
d s b
leptons
ν_e ν_μ ν_τ
e μ τ
squarks
$\tilde{u}$ $\tilde{c}$ $\tilde{t}$
$\tilde{d}$ $\tilde{s}$ $\tilde{b}$
sleptons
$\tilde{\nu}_e$ $\tilde{\nu}_\mu$ $\tilde{\nu}_\tau$
$\tilde{e}$ $\tilde{\mu}$ $\tilde{\tau}$

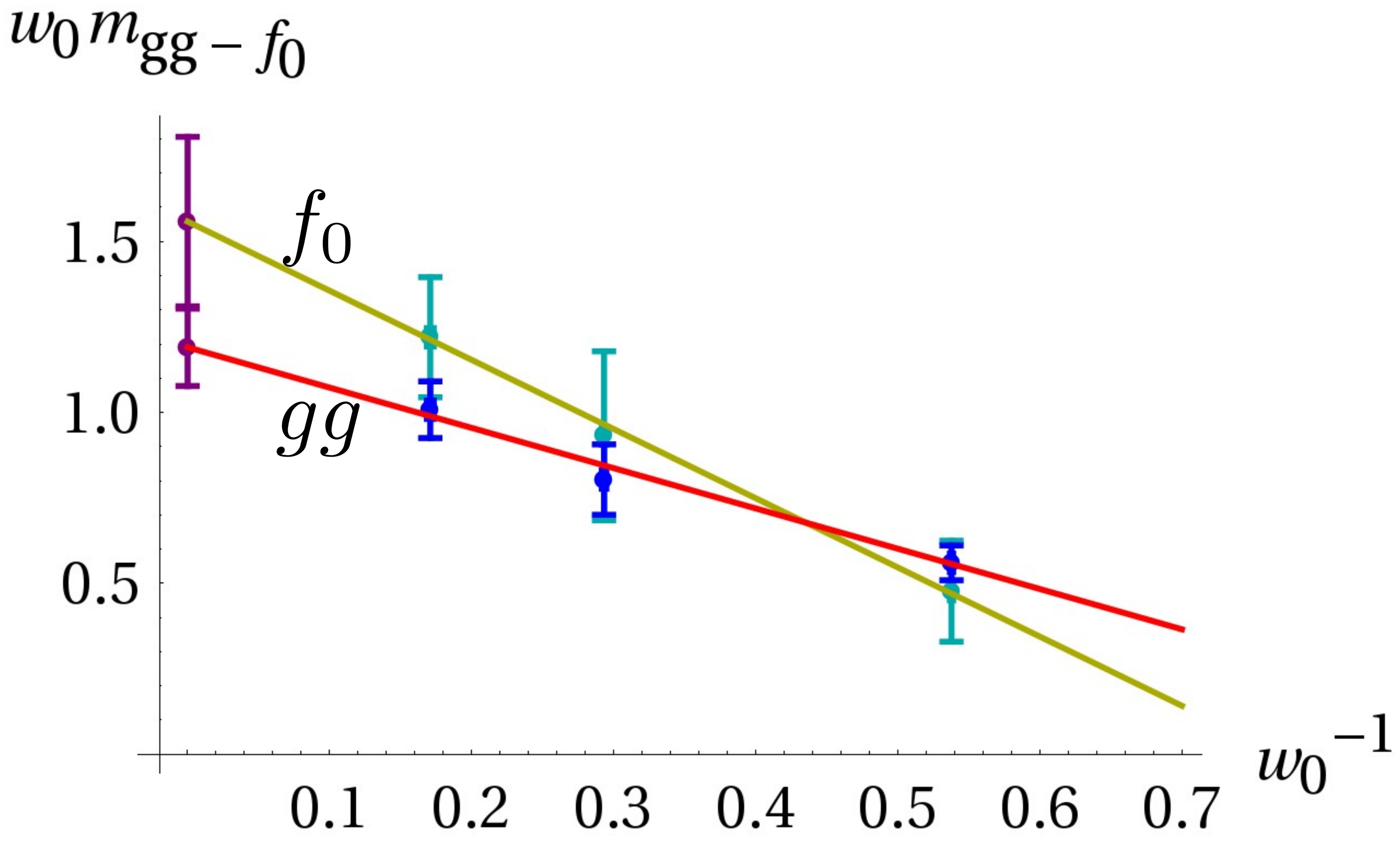
Using r_0 we can see a degeneracy in the continuum limit within two standard deviations



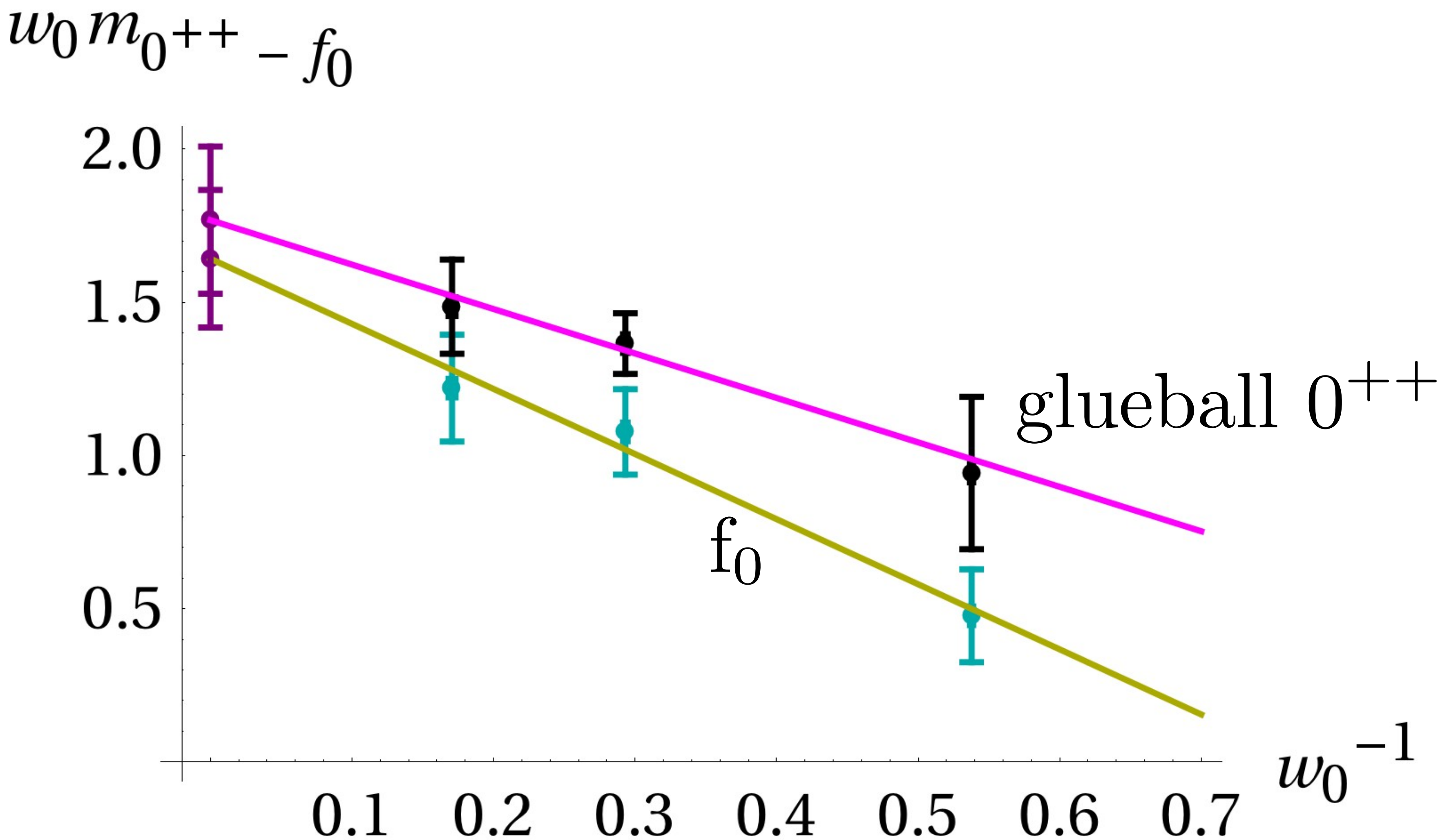
Using w_0 we can see a degeneracy in the continuum limit within one standard deviation for $gg-\eta$



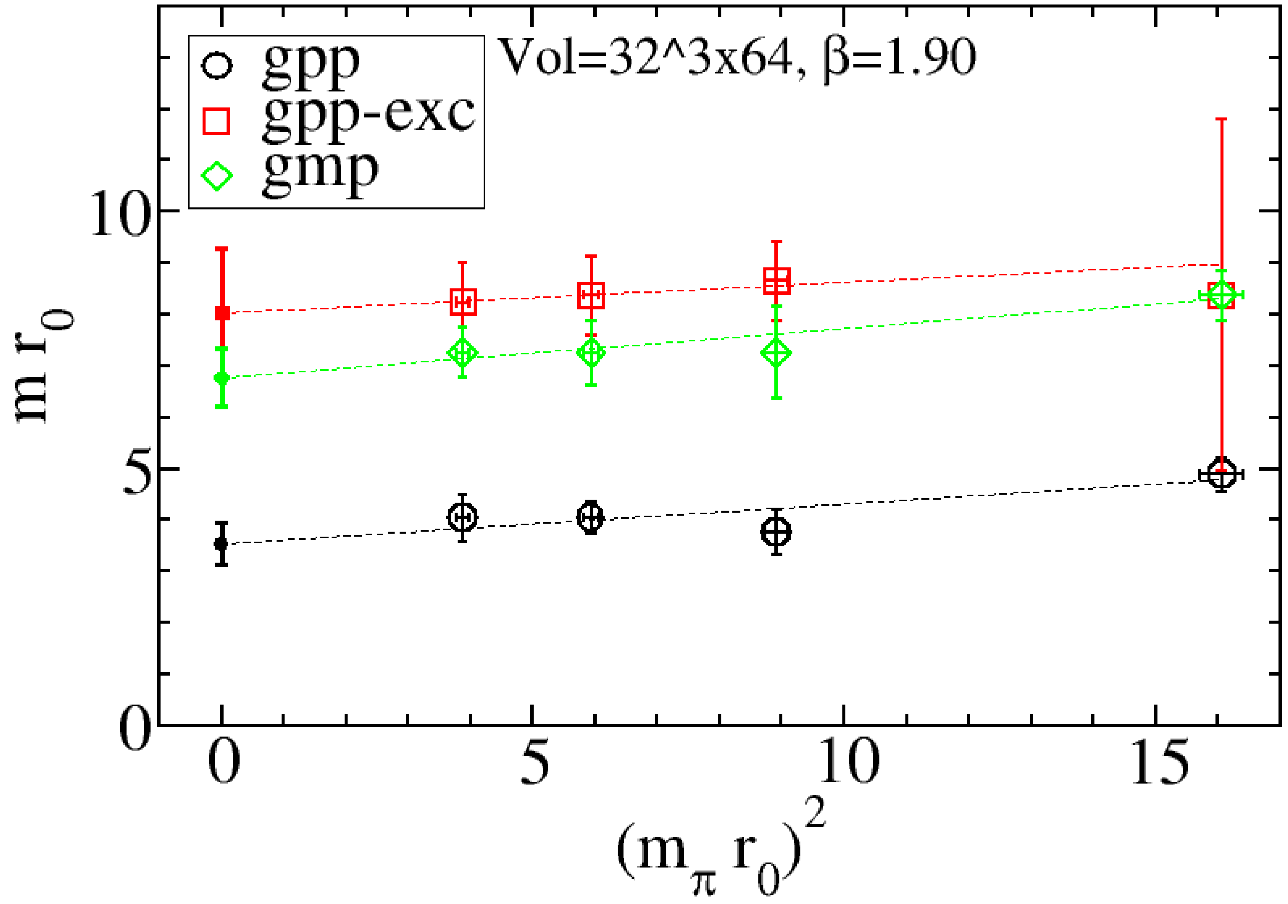
Using w_0 we can see a degeneracy in the continuum limit within one standard deviation for $gg - f_0$

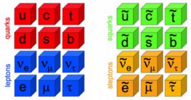


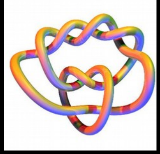
Using w_0 we can see a degeneracy in the continuum limit within one standard deviation for $0^{++} - f_0$



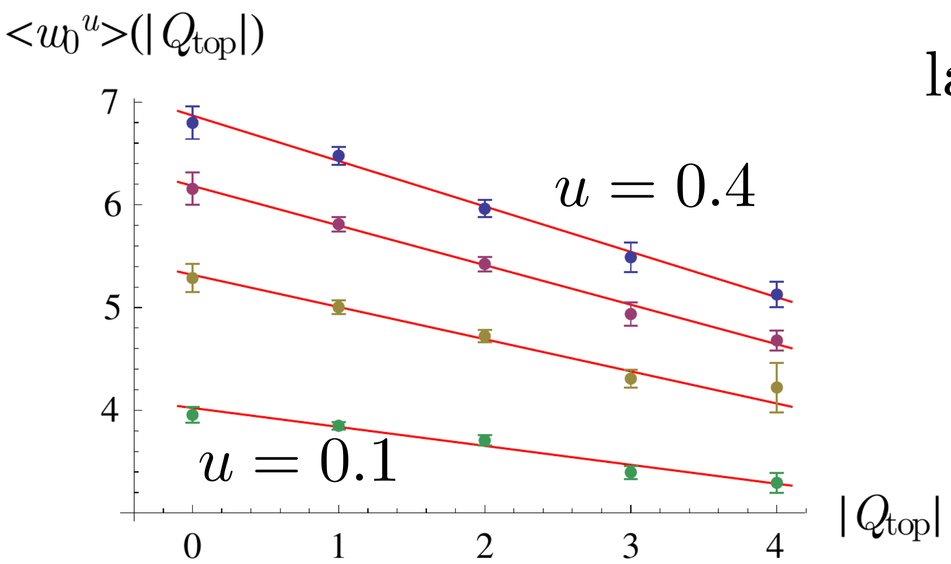
The excited state of glueball 0^{++} seems to be compatible with the fundamental state of the 0^{-+}





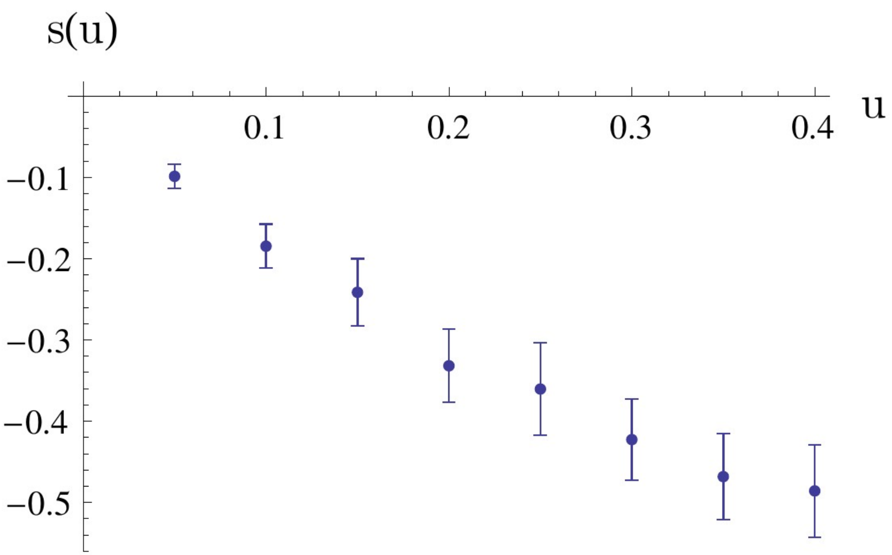


The slope of the scale w_0 versus the topological charge, depends on the choosen reference

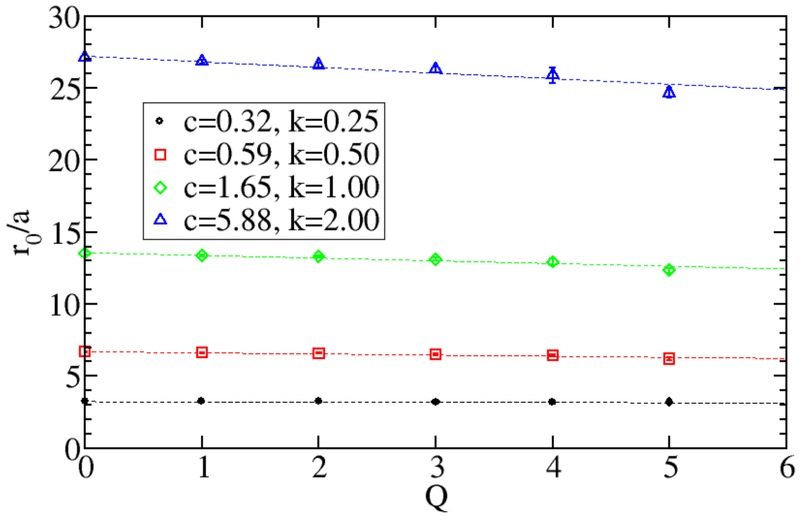


$$\text{lattice } 32^3 \times 64, \beta = 1.9, \kappa = 0.14435$$

$$t\frac{d}{dt}t^2\langle E(t)\rangle = u$$

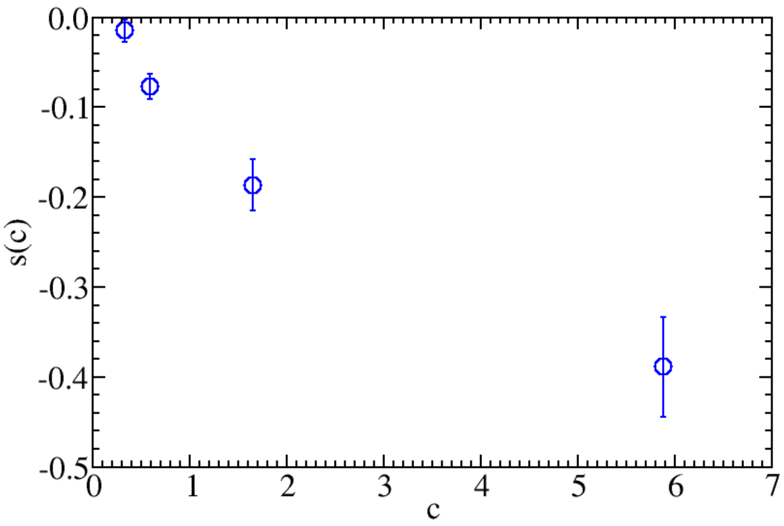


The slope of the scale r_0 versus the topological charge, depends on the choosen reference



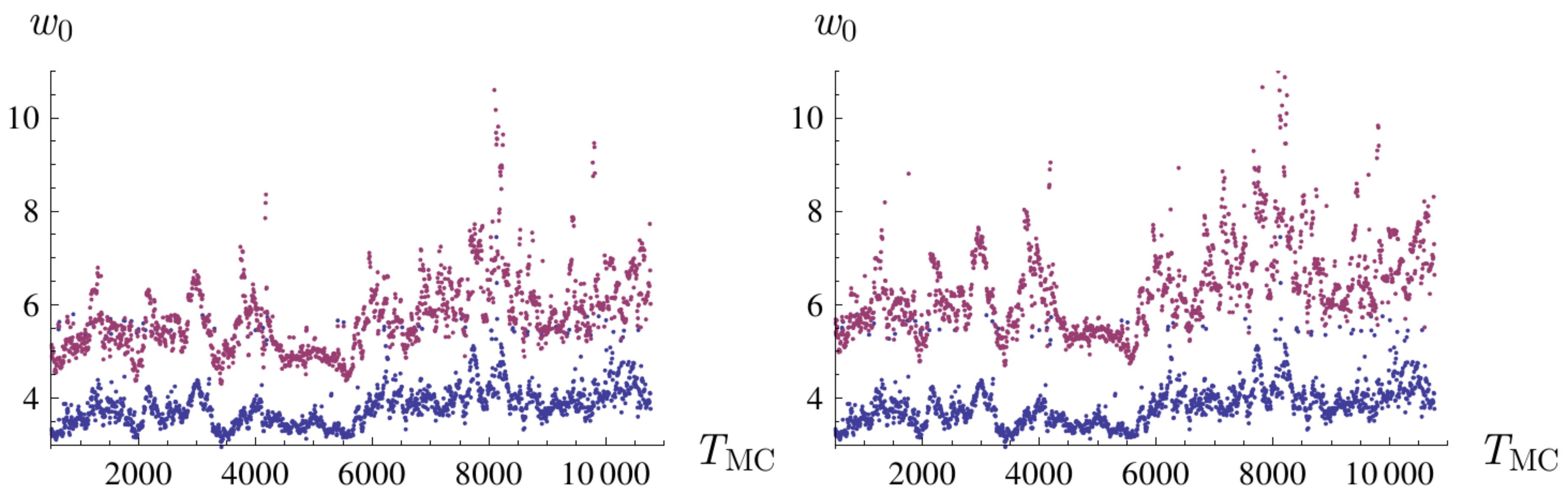
lattice $32^3 \times 64, \beta = 1.9, \kappa = 0.14435$

$$r_0^2 \left(\frac{\partial V}{\partial r}\right)_{r_0} = c$$



Increasing the value of the reference in the scale (u or c), will increase the fluctuations

lattice $32^3 \times 64, \beta = 1.9, \kappa = 0.14435$



(a) $w_0^{0.1}$ versus $w_0^{0.3}$ (b) $w_0^{0.1}$ versus $w_0^{0.4}$

"Influence of topology on the scale setting", arXiv:1411.6995 [hep-lat]


THE END

Conclusions

- We fix the scale both with r_0 and w_0 (the second gives better results)
- We see degeneracy in the fundamental supermultiplet in the continuum limit
- We have studied the dependence of the scales on the reference energy

Outlook

- Excited states
- Effect of the clover term