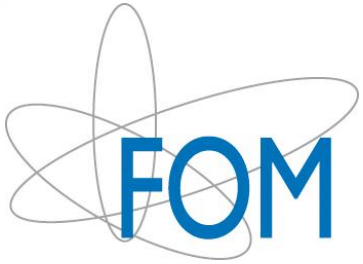


university of groningen

faculty of mathematics and natural sciences

more results on theories inside the conformal window

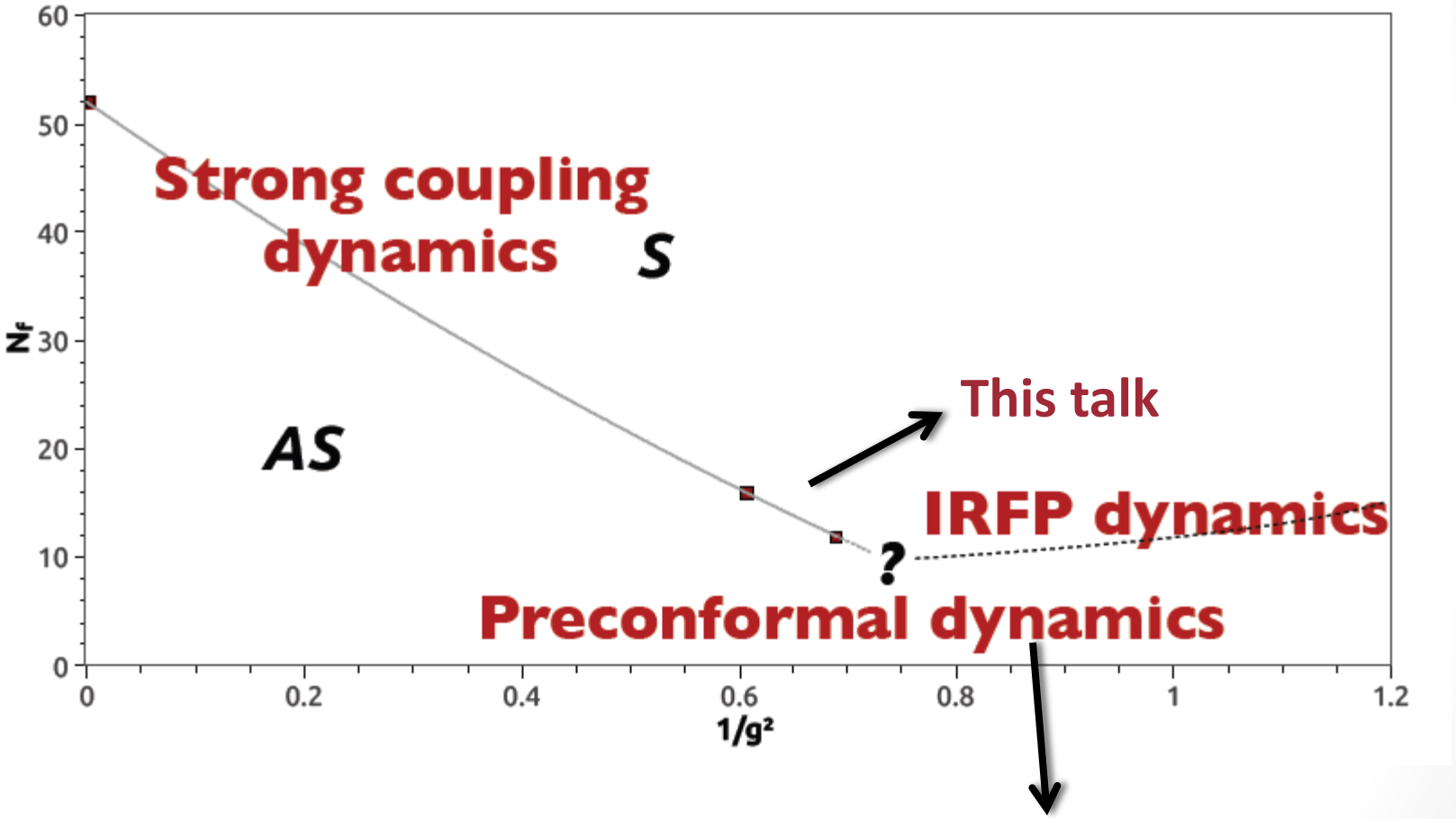
Tiago Nunes da Silva

LATTICE 2013

our collaboration

A. Deuzeman, University of Bern, Switzerland -> Plenary on Friday
M.P. Lombardo, INFN, Italy
K. Miura, Nagoya University, Japan -> Parallel yesterday
T. Nunes da Silva, University of Groningen, The Netherlands -> Me!
E. Pallante, University of Groningen, The Netherlands

the phase diagram

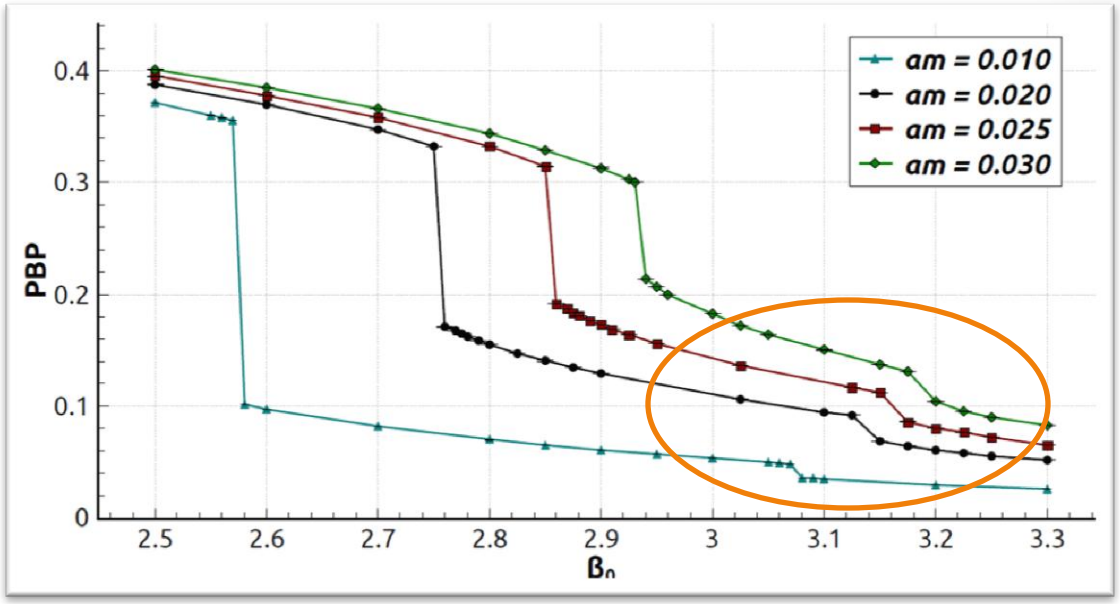


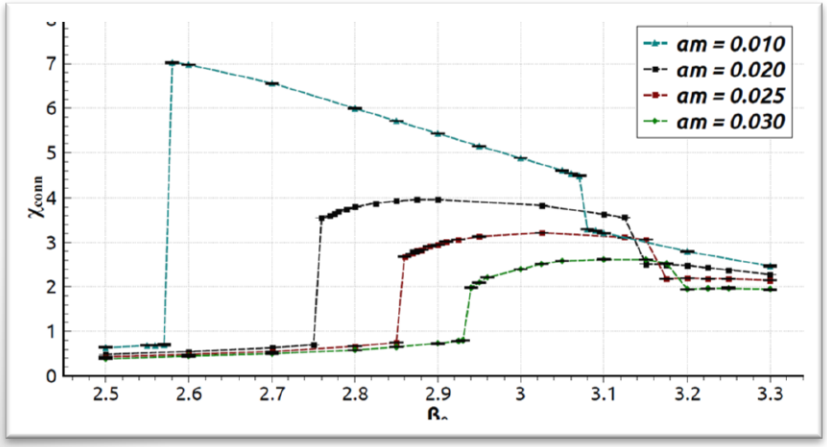
K. Miura talk yesterday

a tale of two jumps

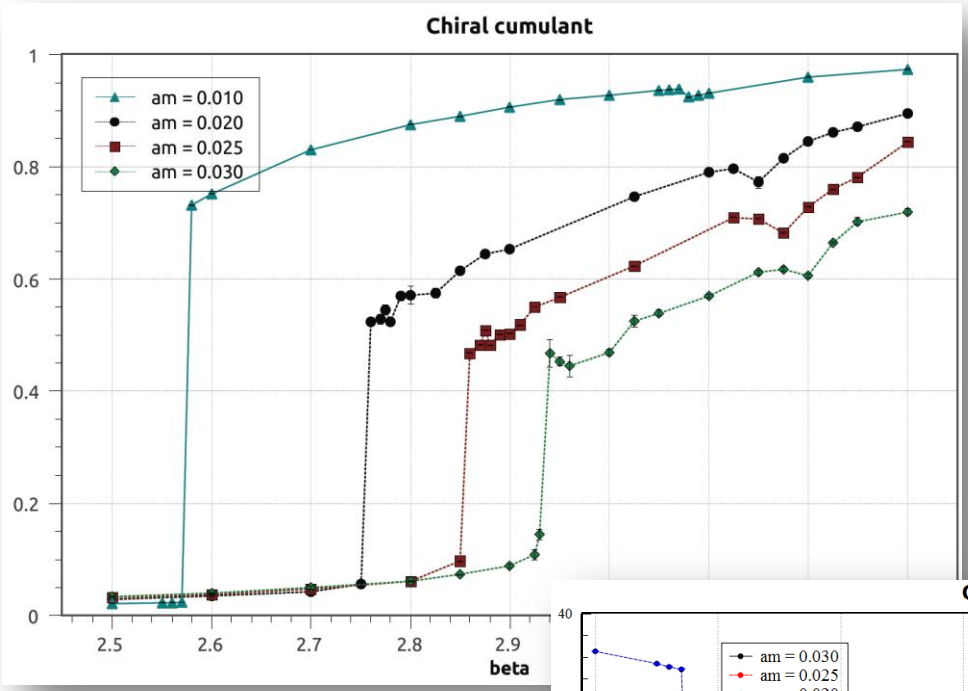
SU(3) with $N_f = 12$ fundamental flavors

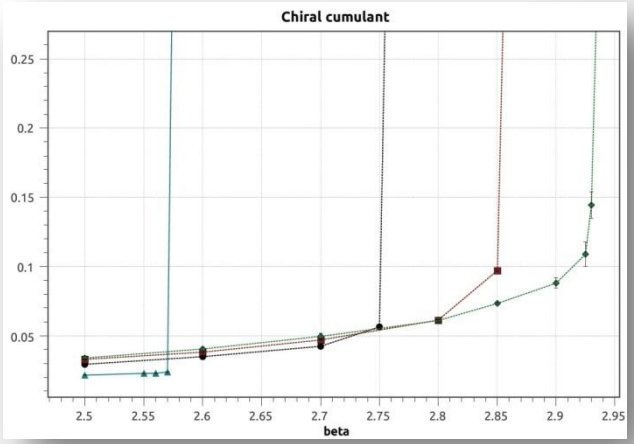
Tree level Symanzik + Naik improved action



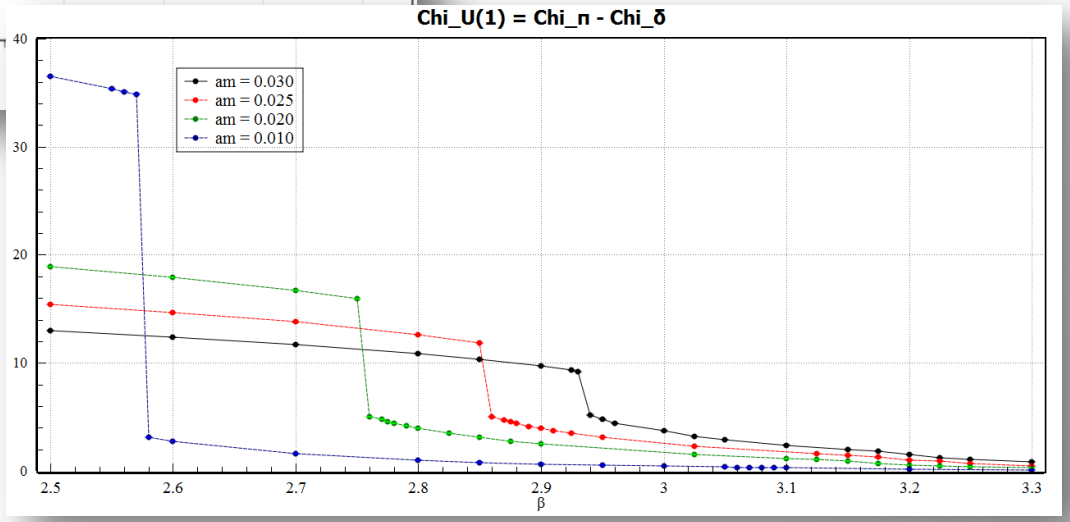


a game of symmetries



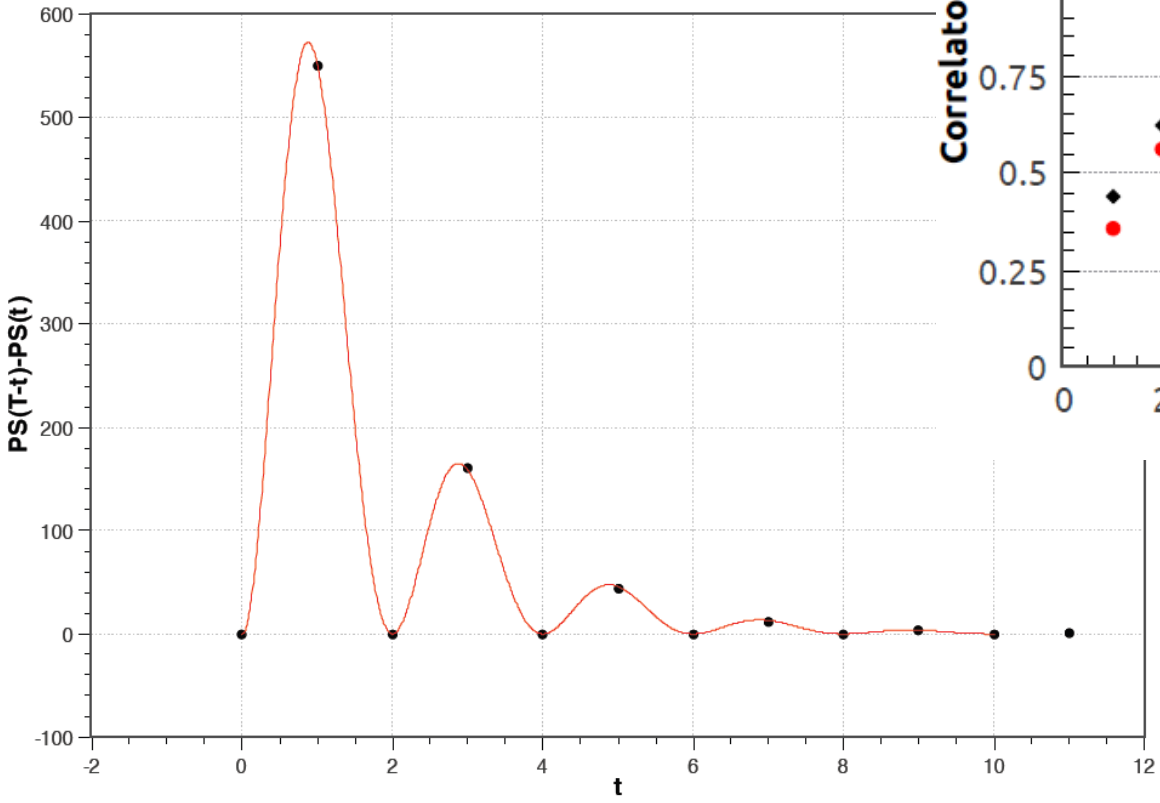


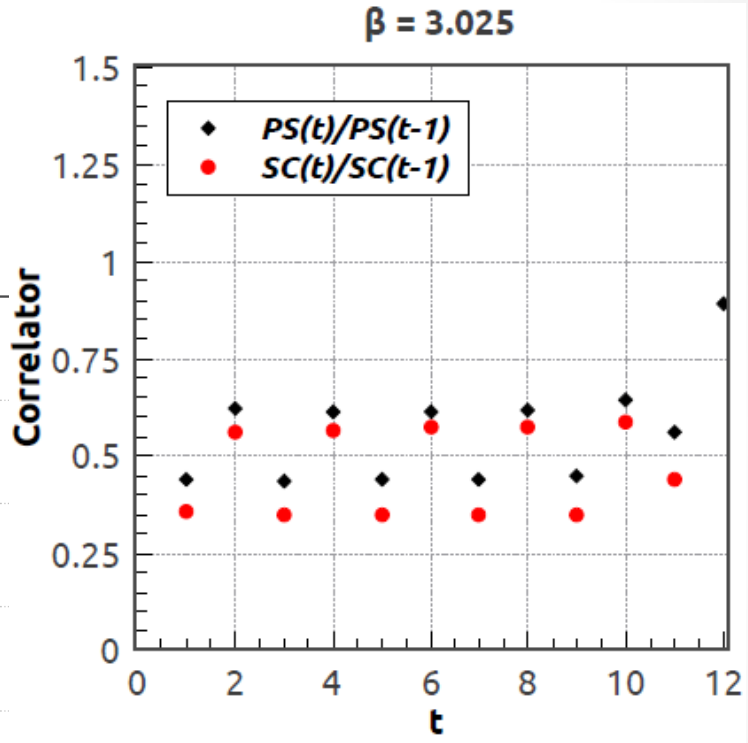
$$R = \frac{\frac{\partial(\langle \bar{q}q \rangle)}{\partial m}}{\frac{\langle \bar{q}q \rangle}{m}} = \frac{\chi_\sigma}{\chi_\pi}$$



signatures of the exotic phase

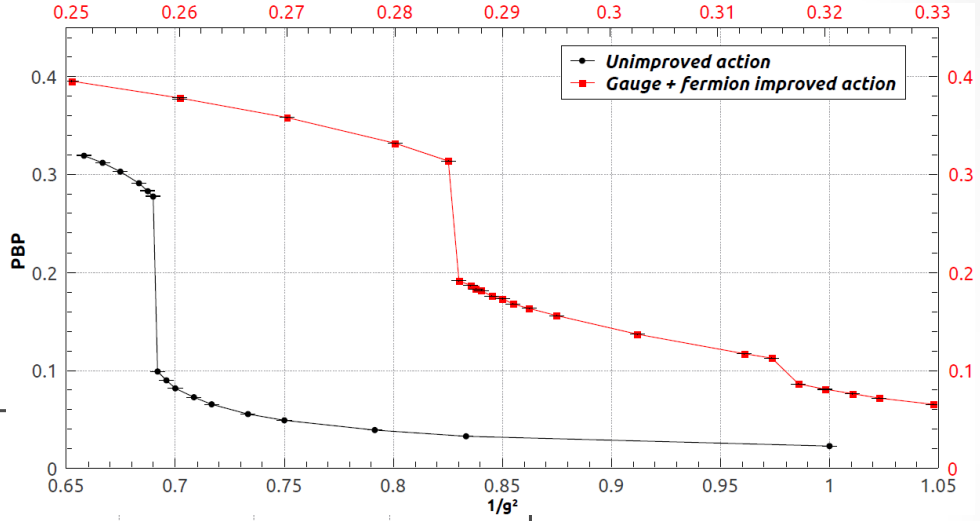
$$Asym \propto C(1-(-1)^t)(e^{-mt}-e^{-m(T-t)})$$

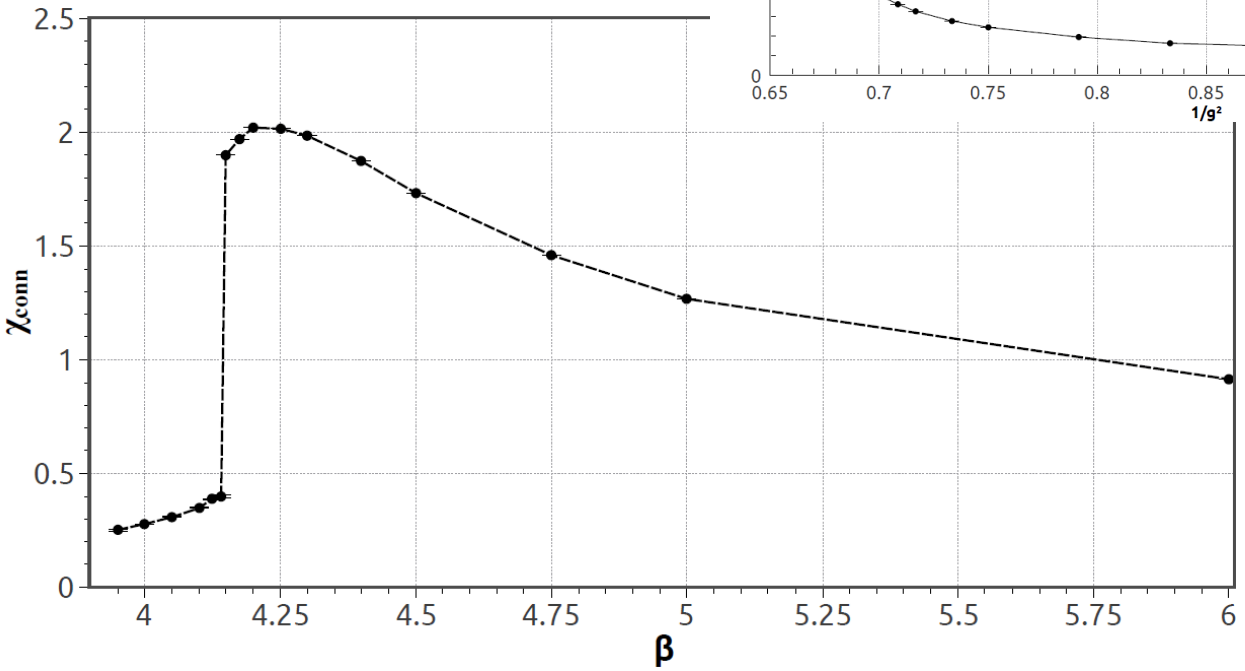




effect of improvement I

Second jump disappears with an unimproved action!





effect of improvement

- The Transfer matrix of a Symanzik improved lattice gauge action is no longer Hermitean. (Luscher, Weisz 1984).
- The appearance of complex eigenvalues opens up the possibility of the emergence of new phases.
- Where and how these phases appear will depend on the specifics of the improvement being used.

effect of improvement II

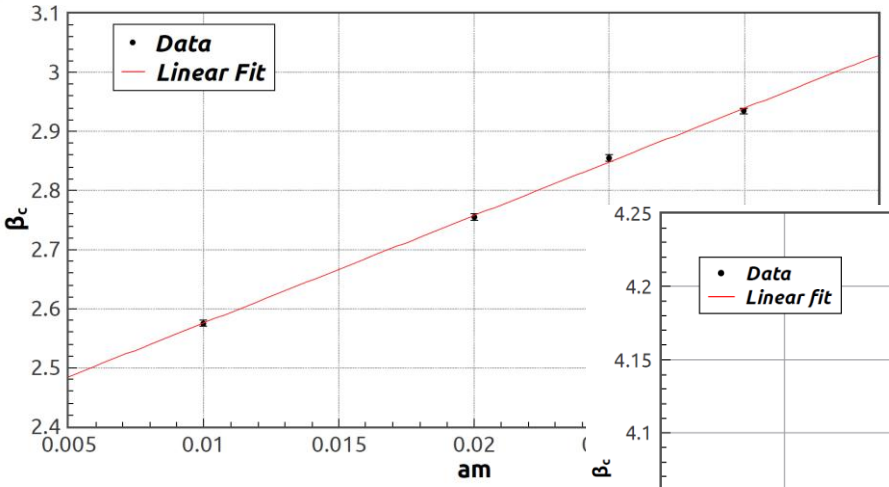
- In our specific case, the exotic phase will appear as a consequence of the competition between nearest and third nearest interactions introduced by Naik improvement.

- But this is a general feature of improved theories at strong coupling and such exotics may be observed by other groups using different actions (e.g. maybe the S^4 broken phase observed by A. Hasenfratz et al.).

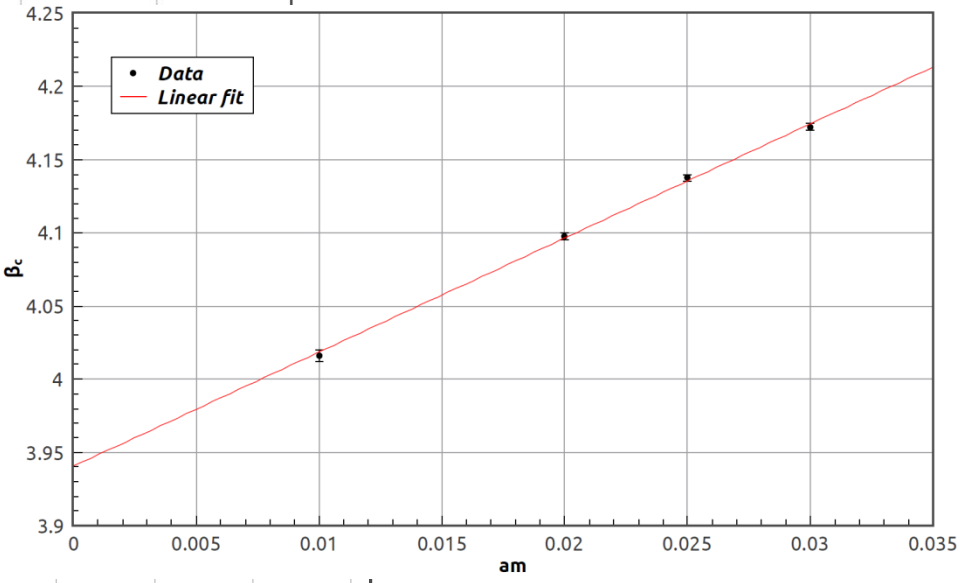
- Since our studies on chiral symmetry restoration were carried at weaker couplings these results are not affected by this exotic.

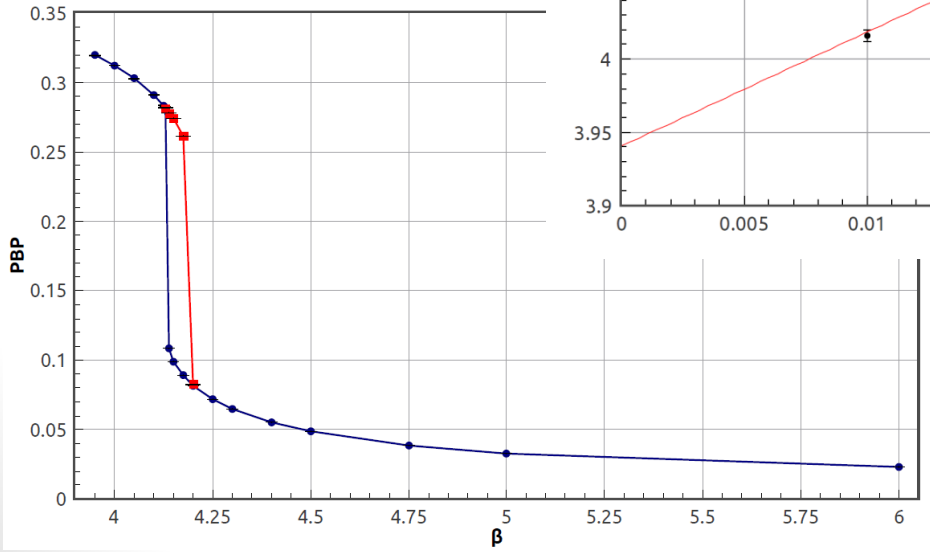
order of the transition

gauge + fermion improved action



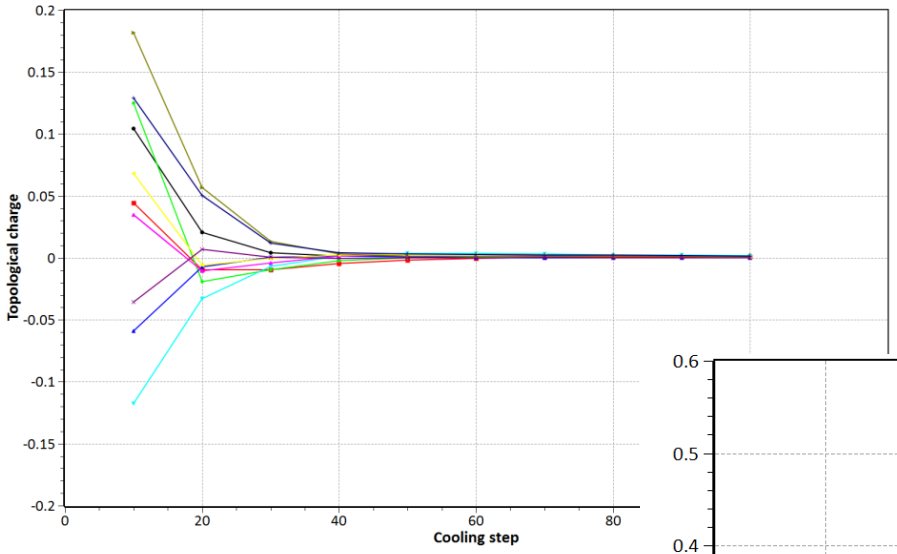
naive action



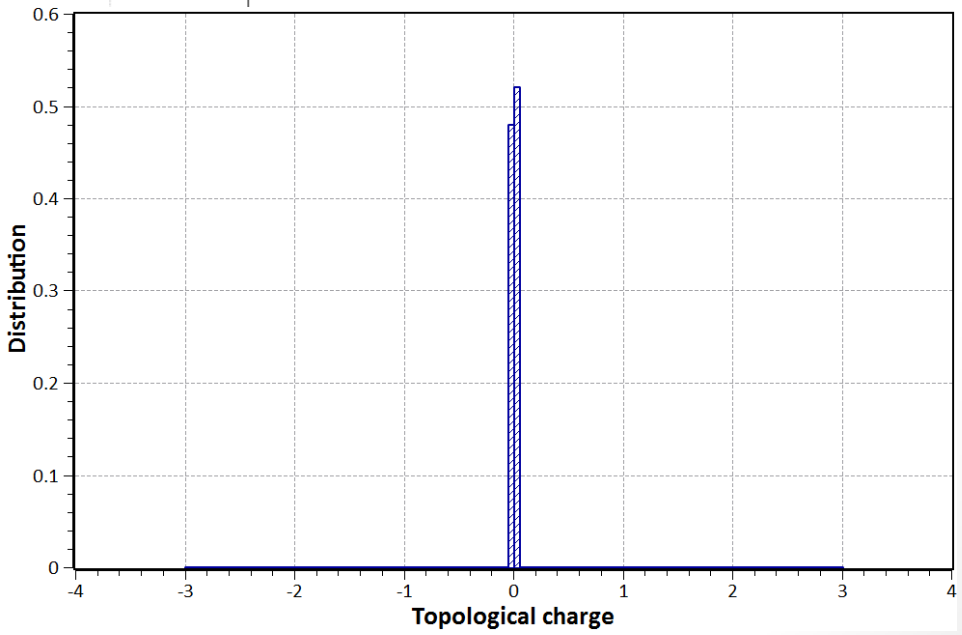


the topological charge

Sample lattices

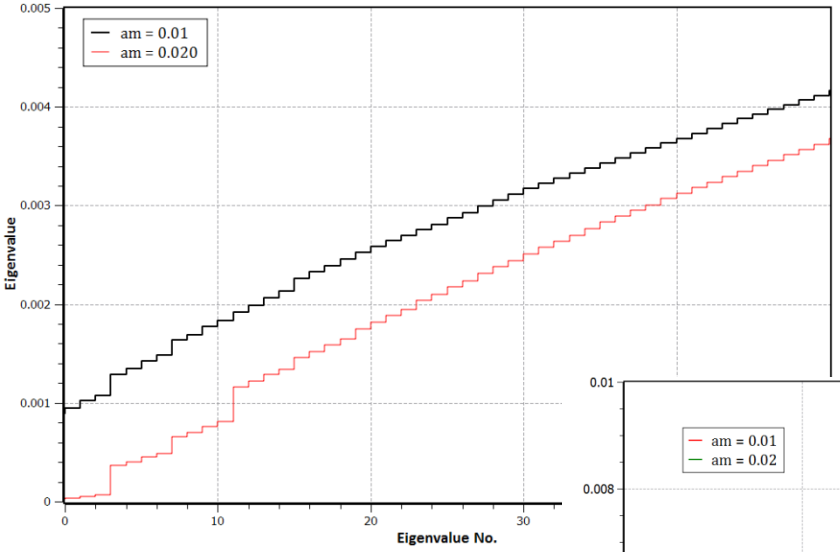


$N_f = 12$, am = 0.01,
V= 32x32, $\beta = 3.9$;



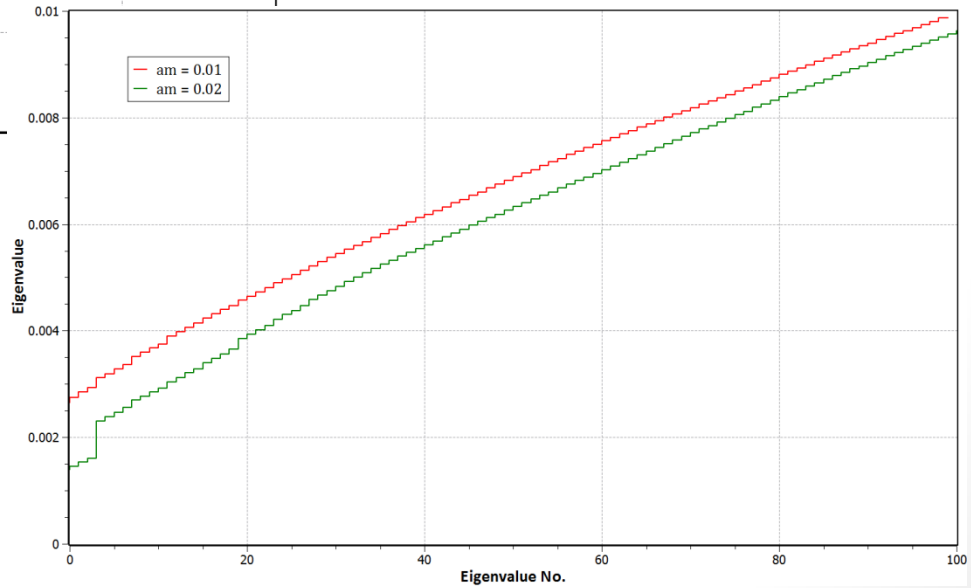
mass dependence of eigenvalues

$N_f = 12, V = 32 \times 32, \beta = 3.900$

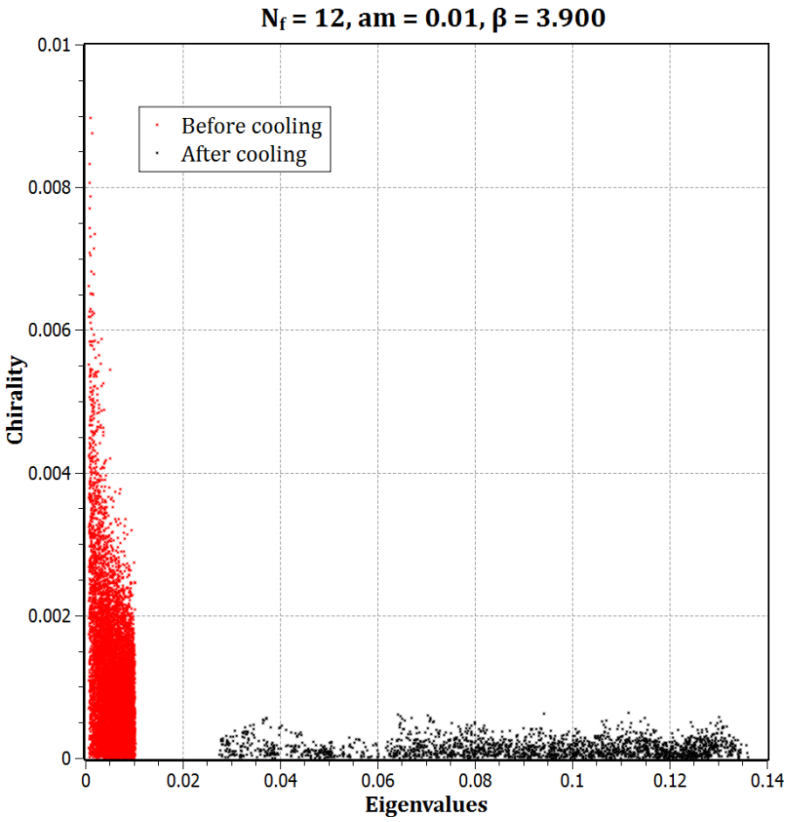


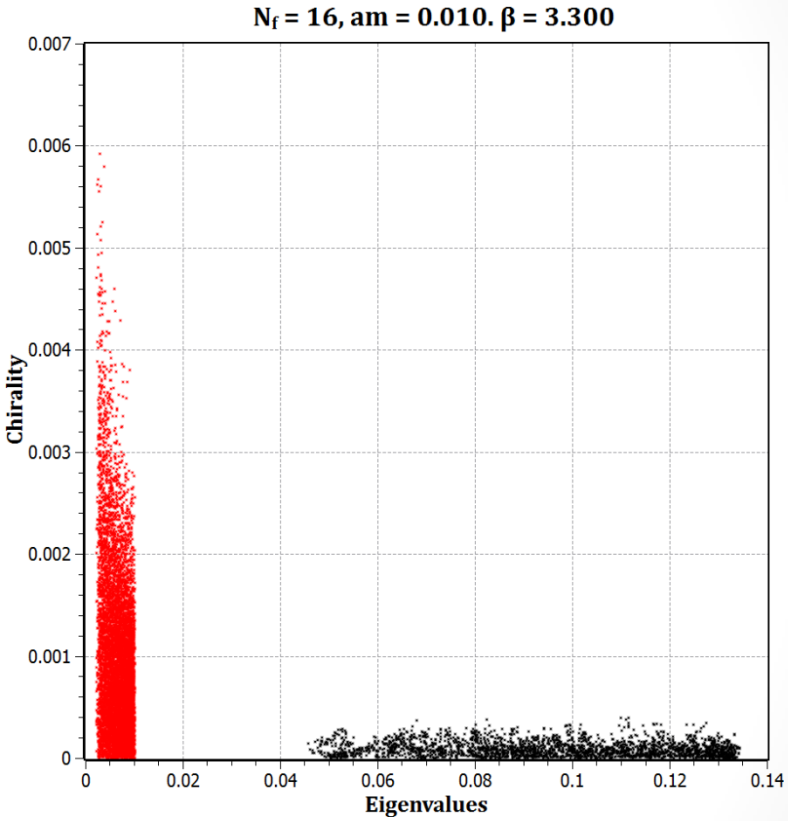
No zero modes!

$N_f = 16, V = 32 \times 32, \beta = 3.300$



chirality





Smearing pushes eigenvalues to higher values and suppresses chirality

mass ratios

QCD :

$m_\pi \propto \sqrt{m_q}$

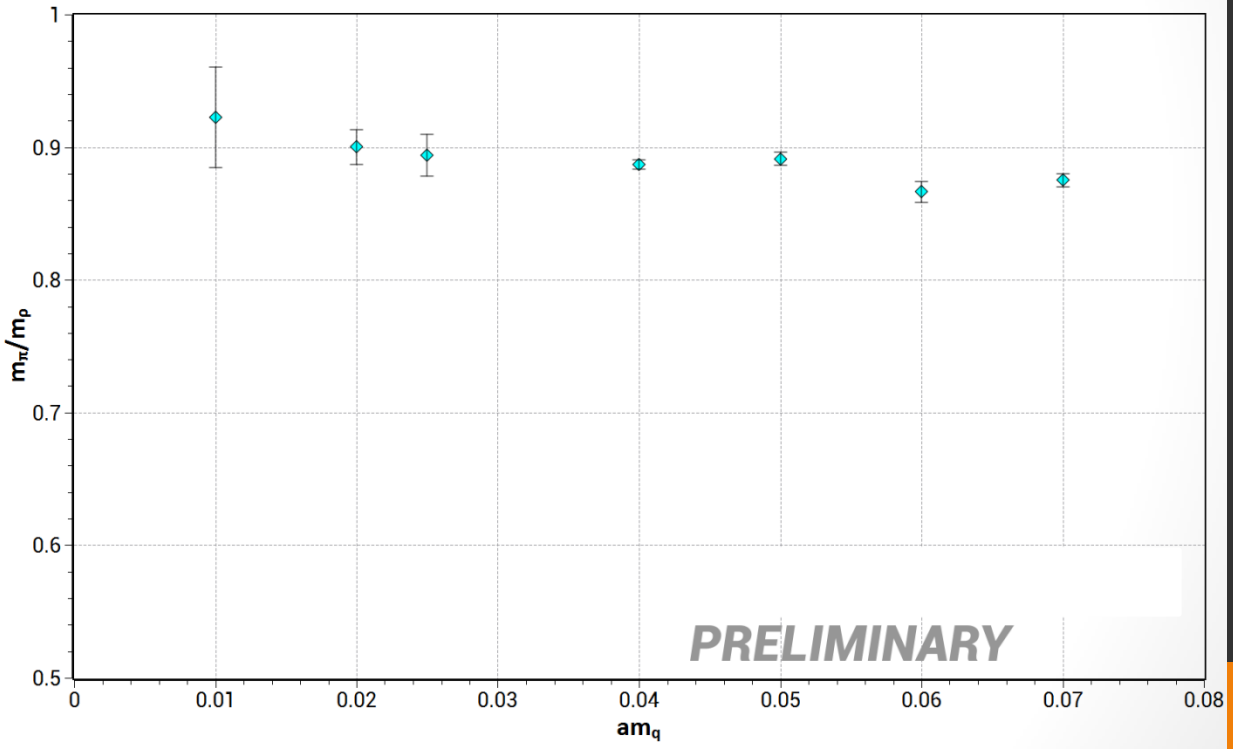
$m_\rho \propto m_0 + bm$

$\frac{m_\pi}{m_\rho} \propto \sqrt{m_q}$

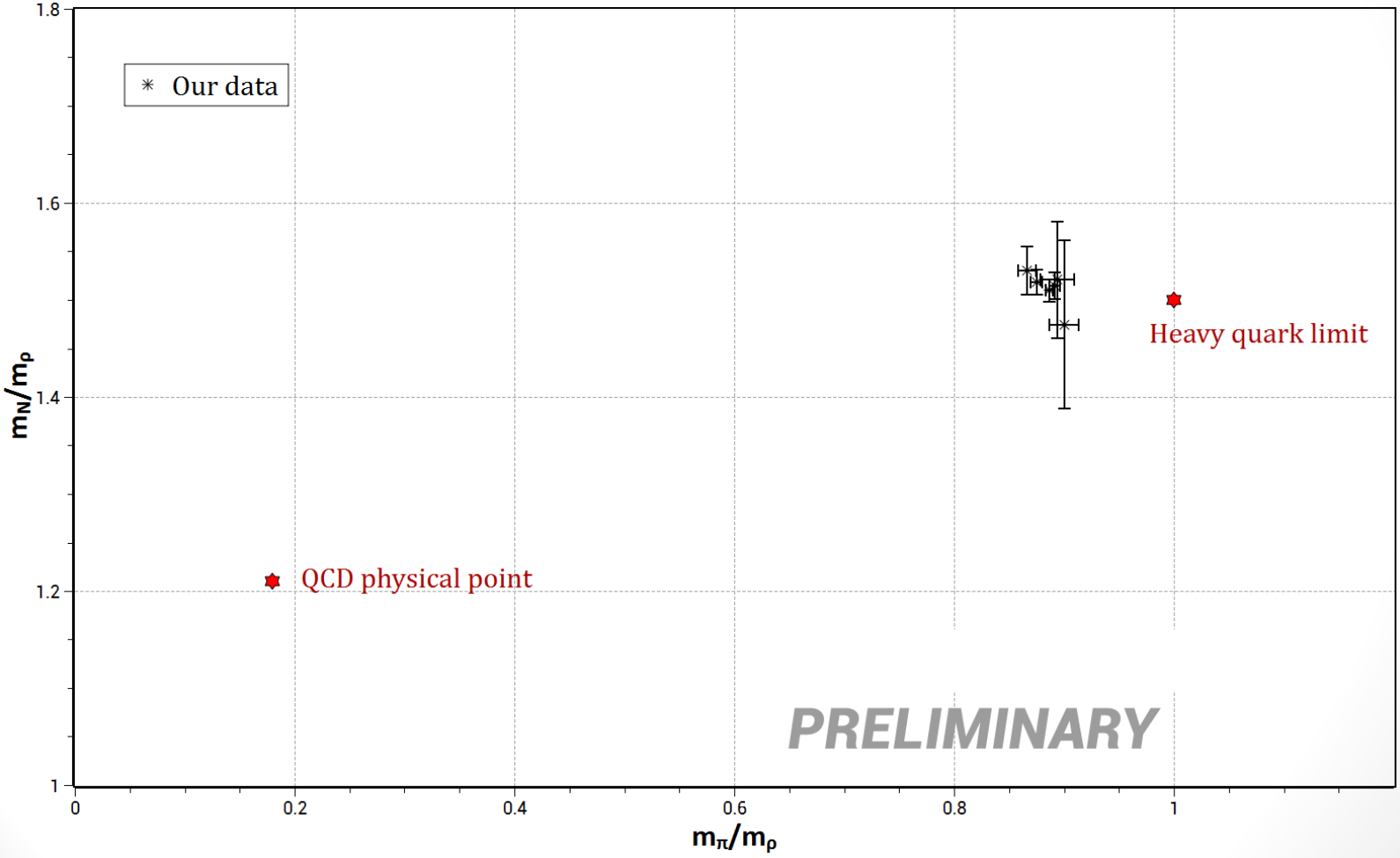
Conformal:

$m_\pi \,\&\, m_\rho \propto m^\alpha$

$\frac{m_\pi}{m_\rho} \approx 1$



the Edinburgh plot

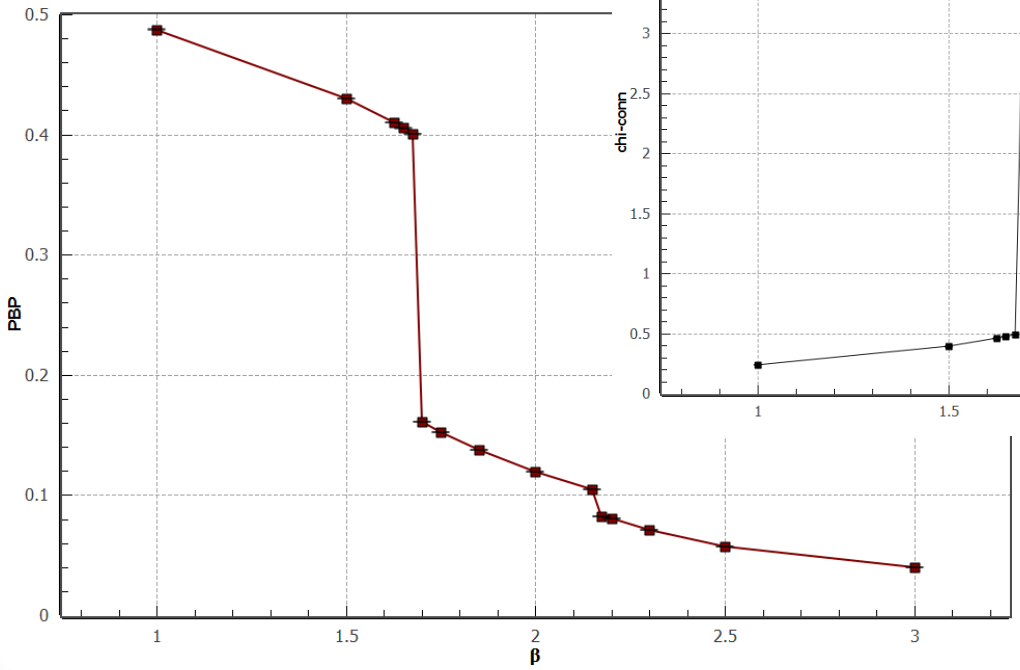


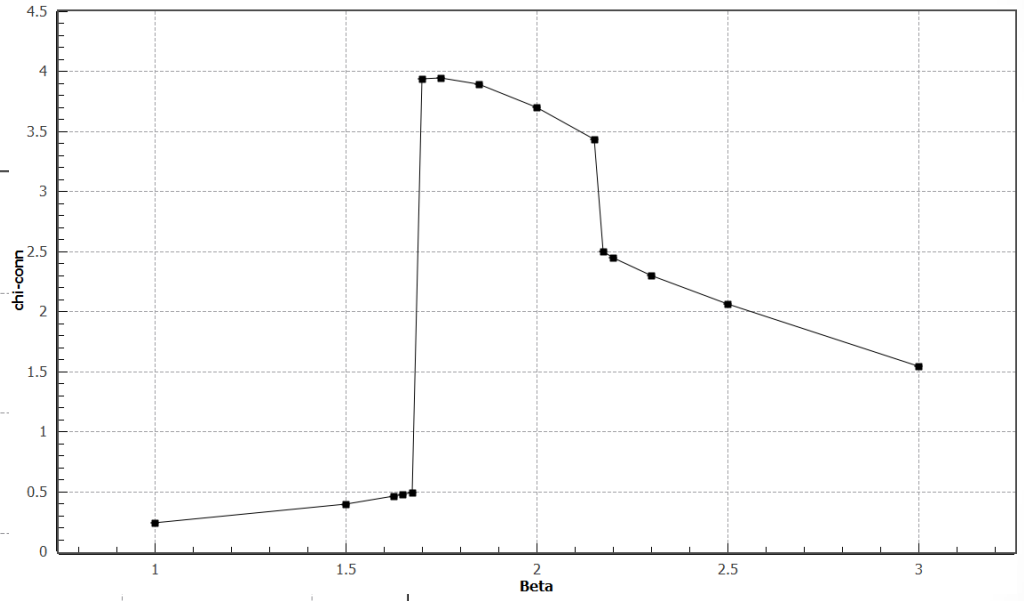
Conclusions and outlook

- Improved lattice theories might develop exotic phases at strong coupling
- Behavior of eigenvalues and chirality in the weak coupling region is consistent with chiral symmetry restoration
- Preliminary analysis of our spectrum data at larger volume agrees with previous results
- Final results on the way -> stay tuned!
- Thank you!

Backup – bulk $N_f = 16$

SU(3) with $N_f = 16$,
am = 0.025, V = 16x24





backup - improvement

- Consider the free lattice fermion propagator:

$$S_F(p)^{-1} = \sum_{\mu} i\gamma_\mu \left(\frac{9}{8} \sin p_\mu - \frac{1}{24} \sin 3p_\mu \right)$$

- Contributions from the interacting theory can modify the coefficients of each sine term.

- In particular, a change in the sign of the second term will induce imaginary poles and ghosts and signal the emergence of the exotic phase.

backup - improvement

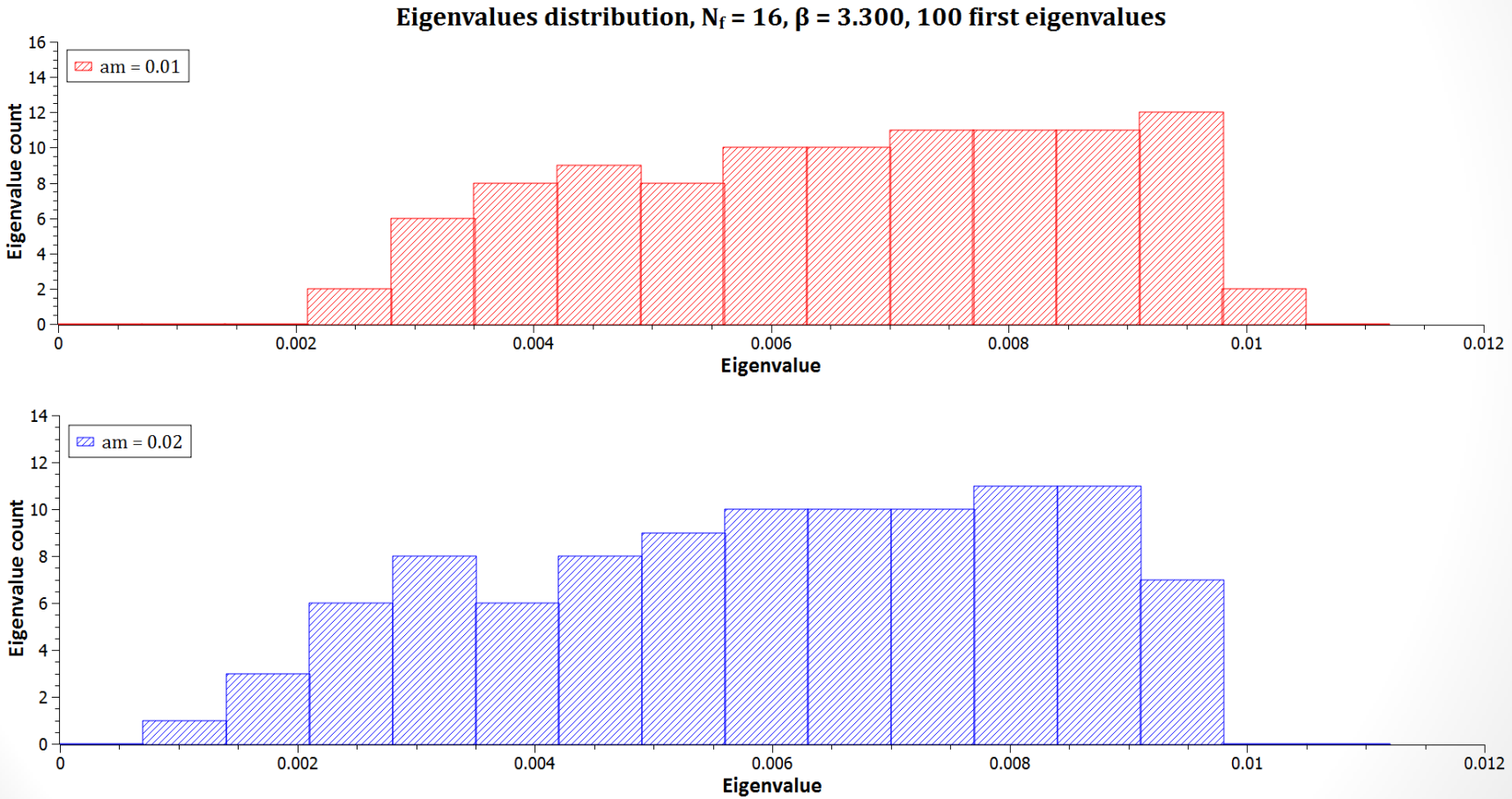
- Baryon number density will receive contributions from nearest and third nearest interactions:

$$n(\mu) = \frac{d}{d\mu} \log Z(\mu) = n_1(\mu) + n_3(\mu)$$

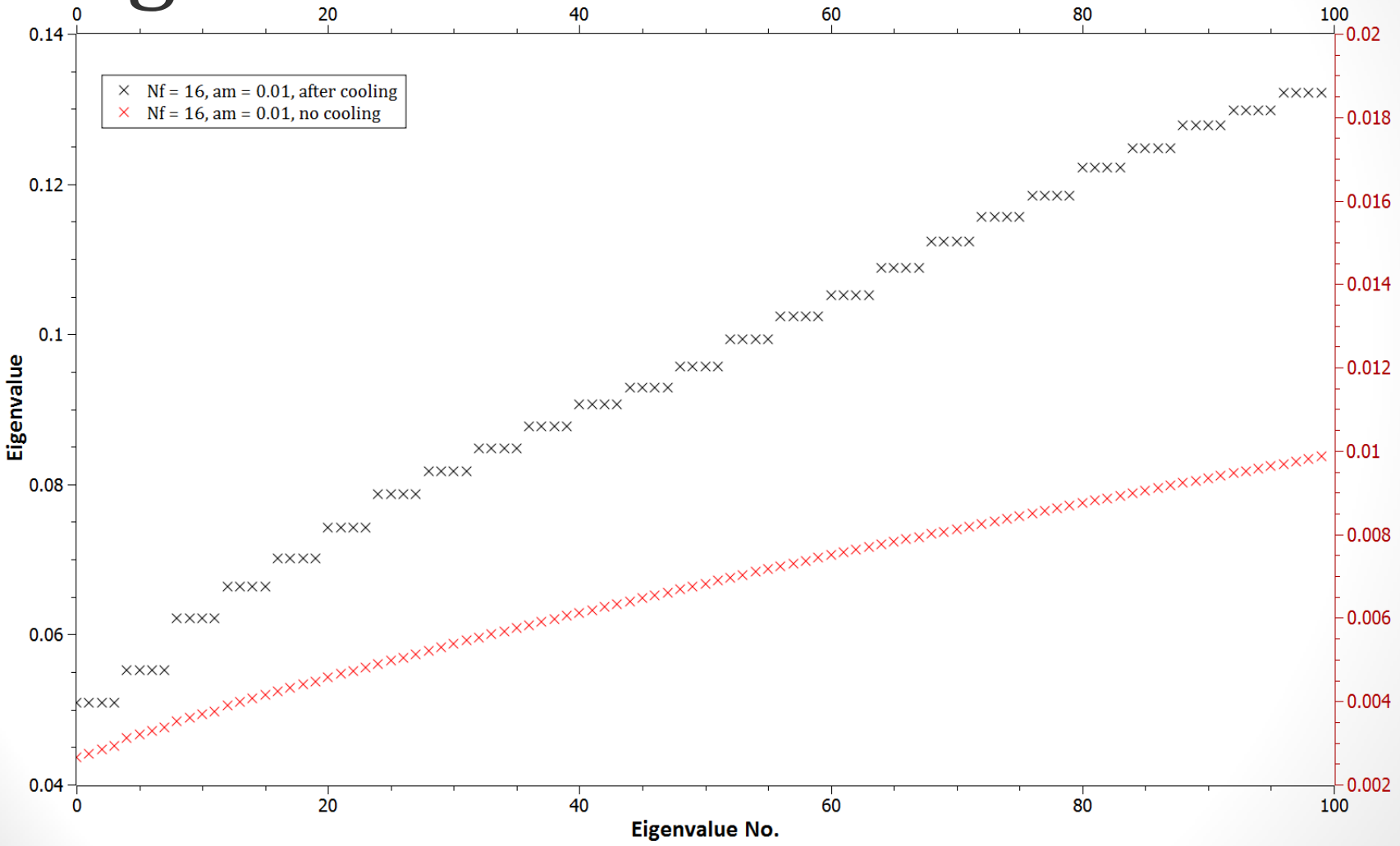
- Baryon number conservation at $\mu = 0$ can be realized with $n_1 = n_3 = 0$ or with $n_1 = -n_3 \neq 0$.

- At strong coupling, when third nearest interactions become relevant, the second realization is possible. A non-zero value of $n_1(\mu)$ allows for both an oscillation term in the PS correlator and the time asymmetry in all correlators.

backup I – eigenvalue distribution



backup II – cooling effect on eigenvalues



backup - relation to chiral condensate