THE STRONG COUPLING REGIME OF $N_f = 12$ QCD

Work in collaboration with E. Pallante (RuG), M. P. Lombardo (INFN, Frascati), K. Miura (INFN, Frascati) and A. Deuzeman (U. Of Bern); to appear soon

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Tiago Nunes da Silva

FOM

university of groningen

faculty of mathematics and natural sciences

Summary

Recap of results with $N_f = 12$

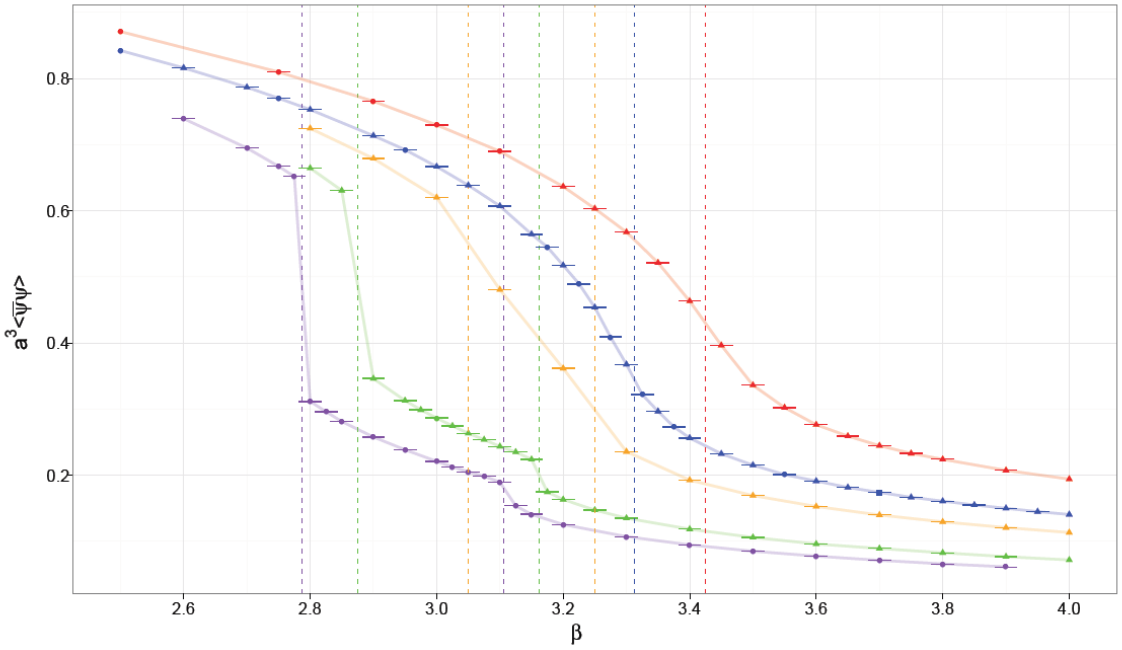
Chiral symmetry restoration at strong coupling

Questions on the lattice

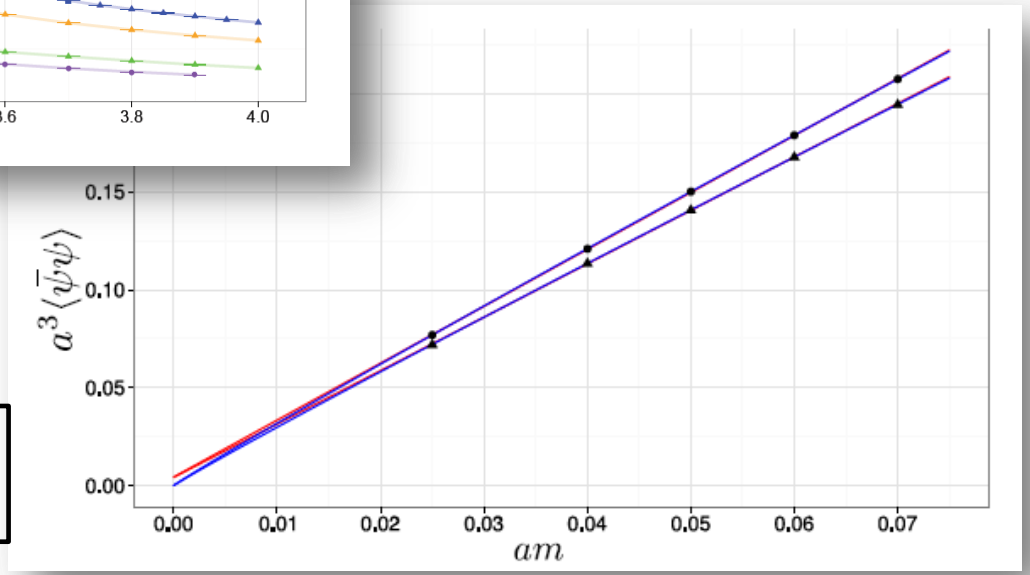
Conformality on the Lattice

Our setup	SU(3) gauge theory with 12 flavours of fundamental fermions
	tree level improved Symanzik gauge + Naik improved staggered fermions
	approach based on the Physics of phase transitions
	simulations performed for ranges of beta values, volumes and masses

Previous results with $N_f = 12$ (I)

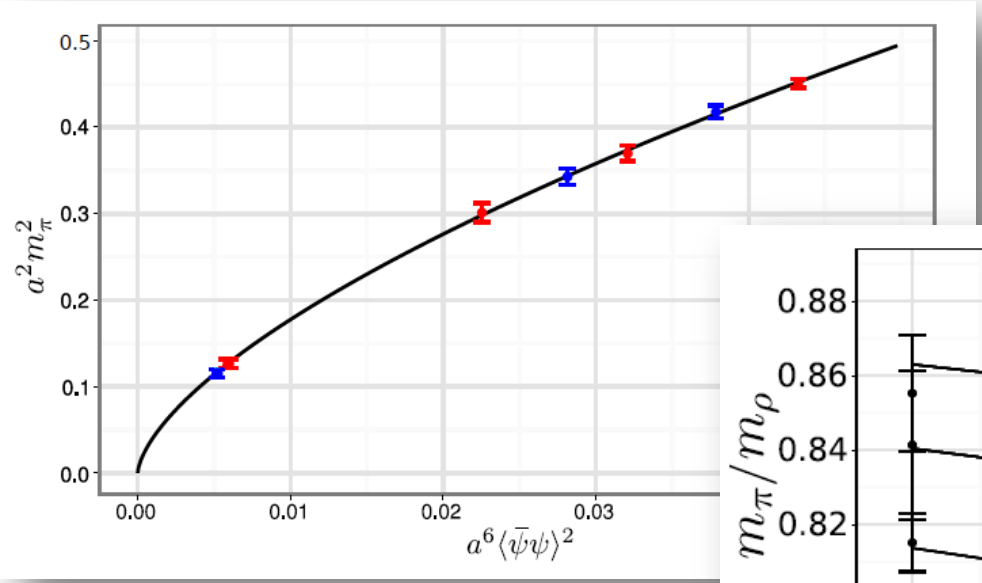


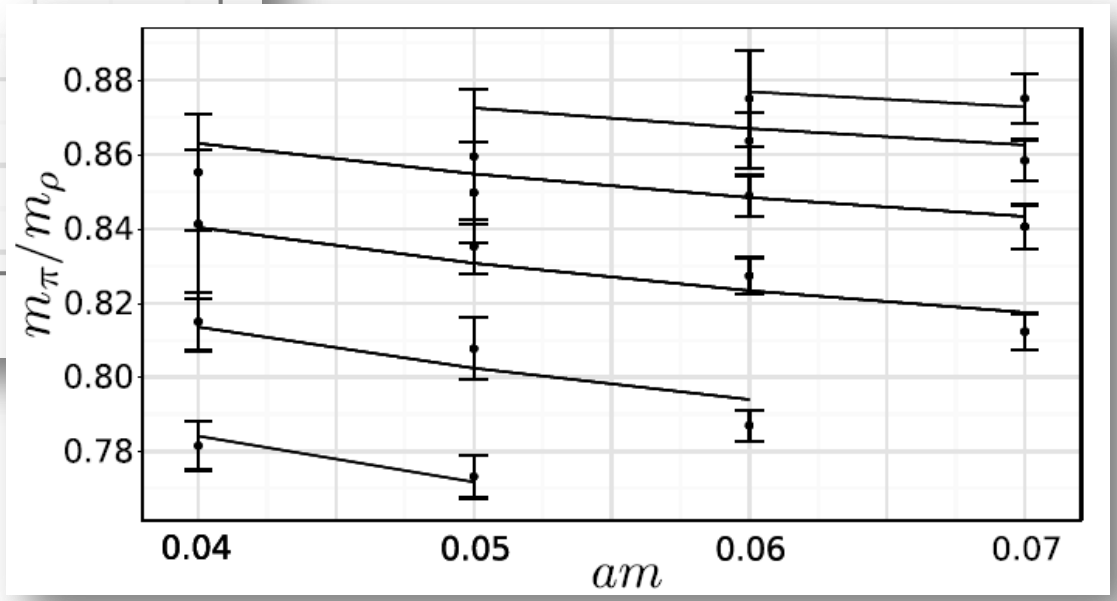
Double jump structure at small quark masses.



Extrapolation of $\langle\bar{q}q\rangle$ at weak coupling is consistent with zero.

Previous results with $N_f = 12$ (II)





Evidence that there is a conformal window and that $SU(3)$ with 12 fundamental flavors lies inside the window. The weak coupling limit of the theory is chirally restored.

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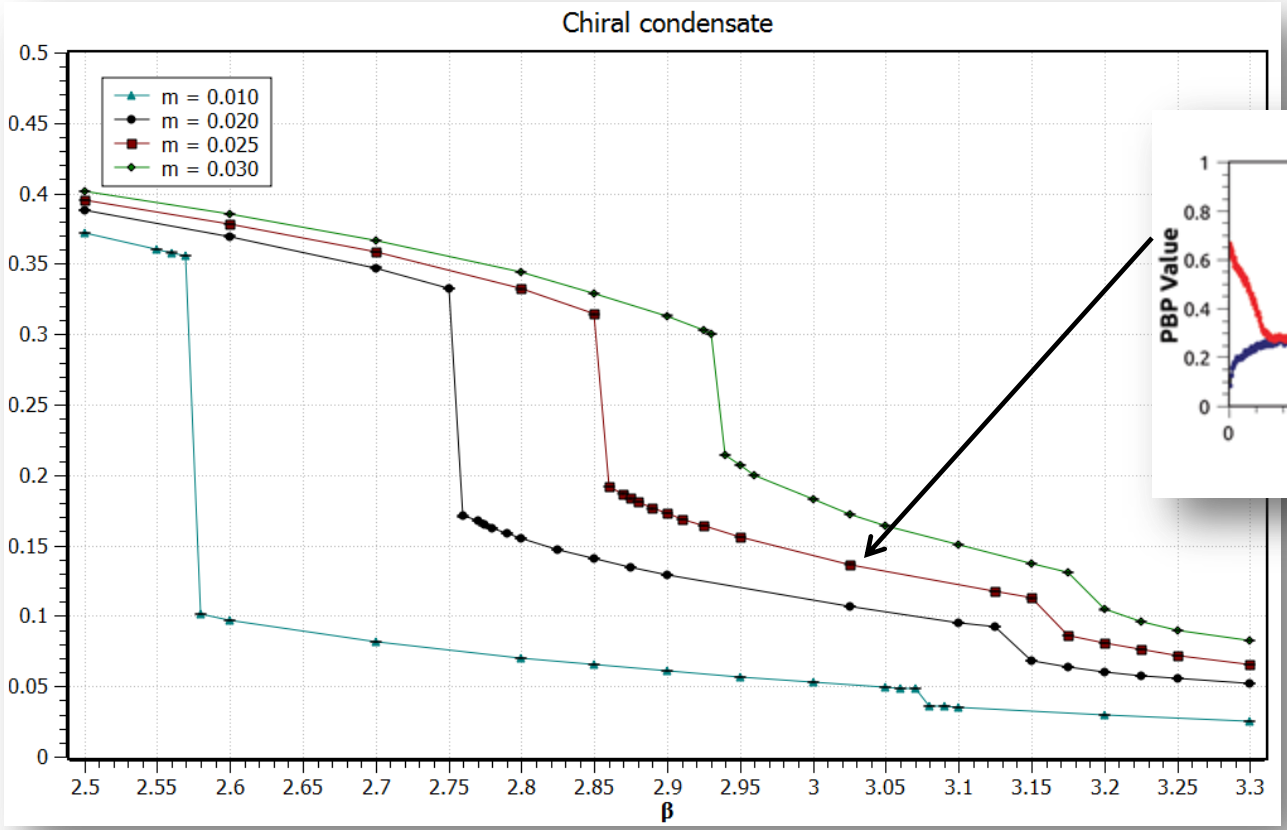
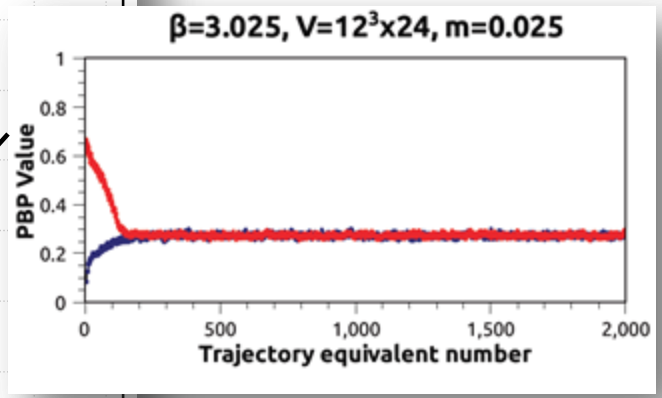
Strong coupling and small mass

- Motivation: What is the nature of the transition? Is there a non-trivial UV fixed point that could realize the (dis)appearance of the conformal window via annihilation of a pair (IR + UV) of fixed points?

- Program: locate the chiral restoration bulk transition and determine its order.

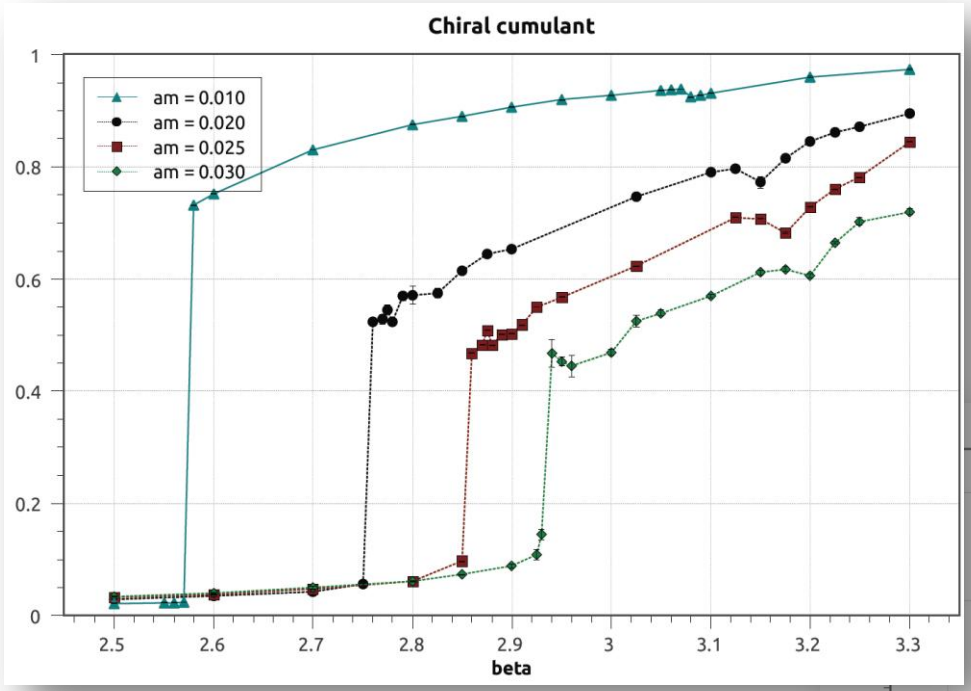
The strong coupling regime



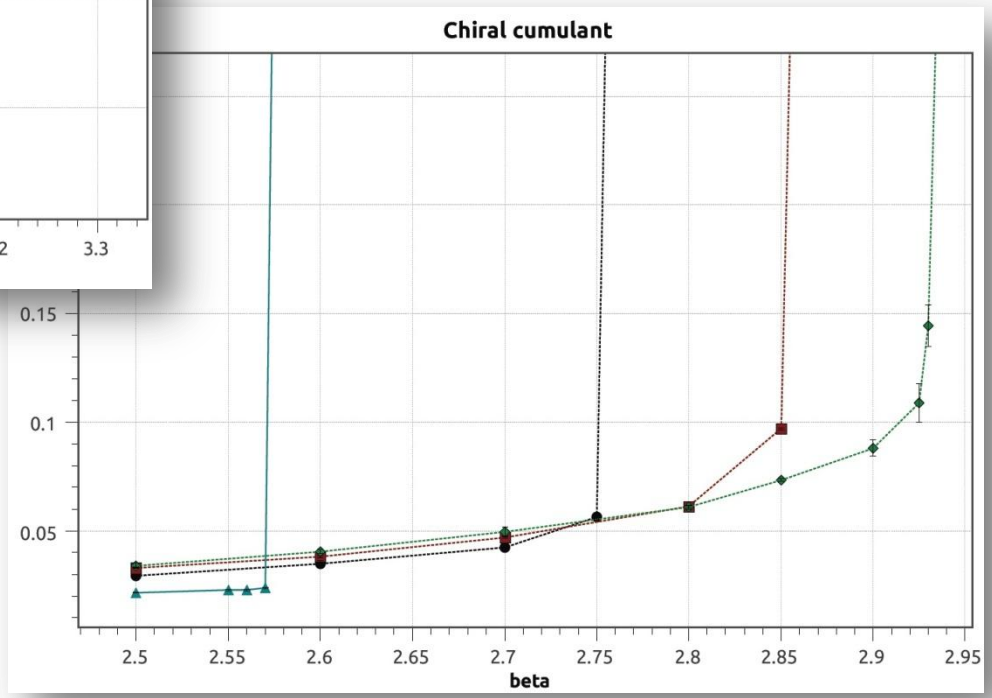


As the chiral limit is approached, the jump at stronger coupling is enlarged, while the jump at weaker coupling shrinks. No hysteresis in the intermediate region.

Locating the chiral sym. restoration

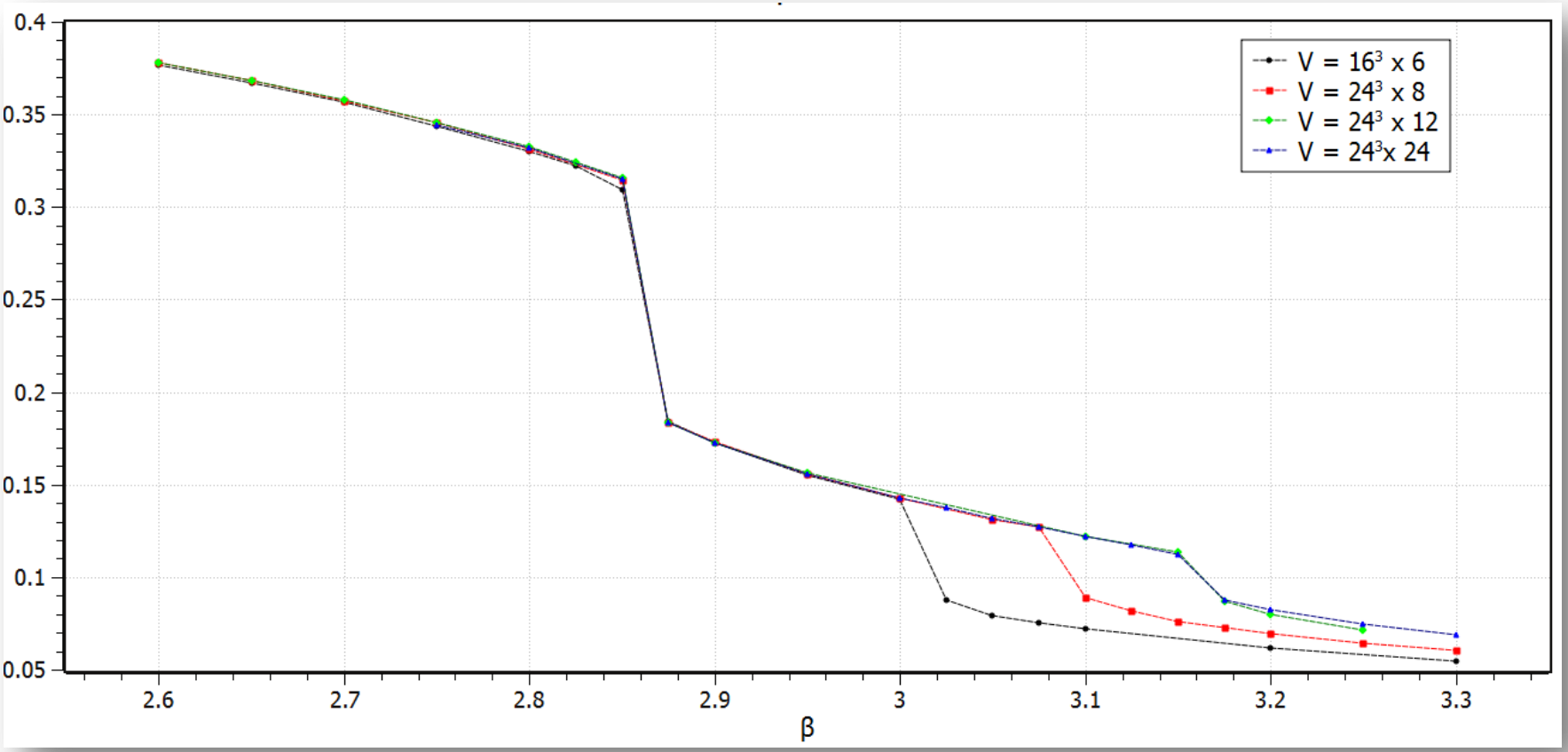


$$R = \frac{\frac{\partial(\langle \bar{q}q \rangle)}{\partial m}}{\frac{\langle \bar{q}q \rangle}{m}} = \frac{\chi_\sigma}{\chi_\pi}$$



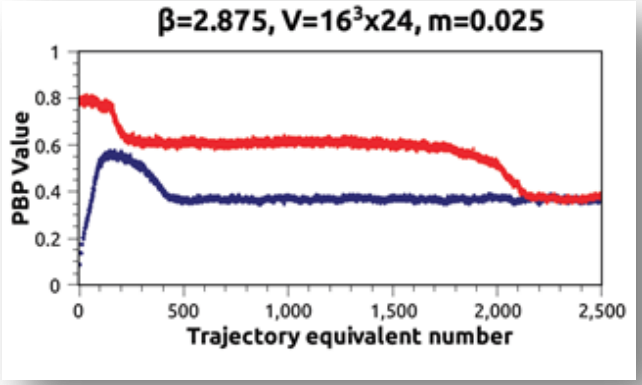
Chiral symmetry is restored @ the “big” jump

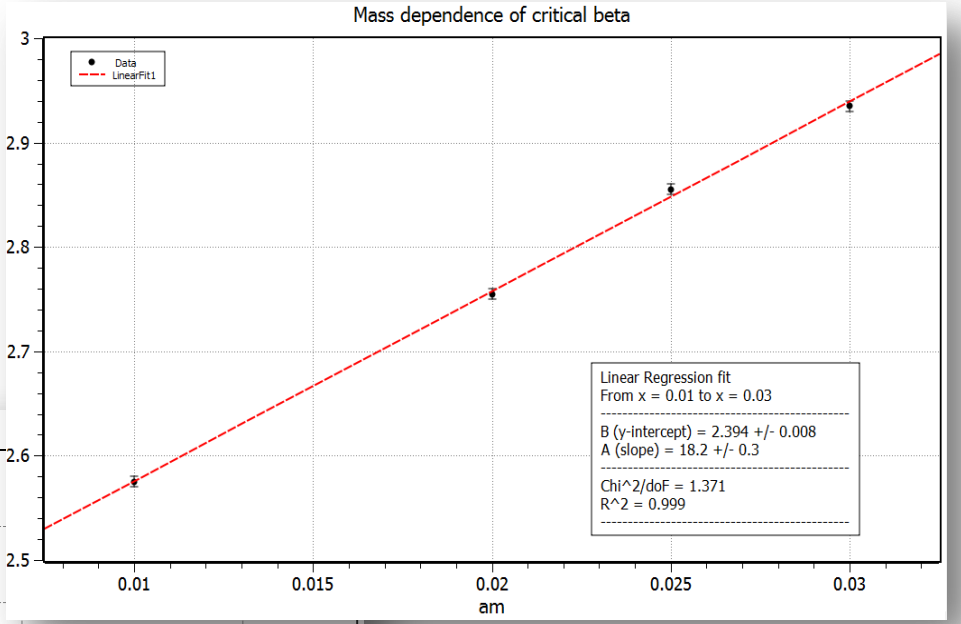
N_t dependence

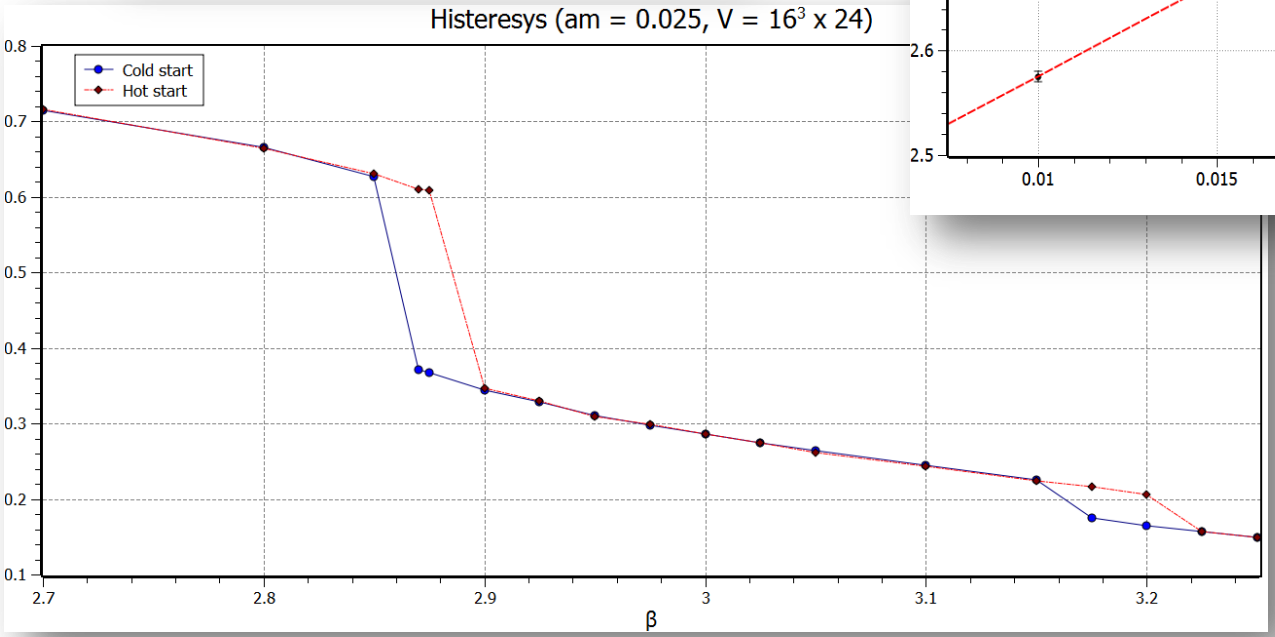


No N_t dependence (thermal behaviour) is observed for the jump at stronger coupling and for the jump at weaker coupling for $N_t \geq 12$.

Order of the transition







First order bulk transition!

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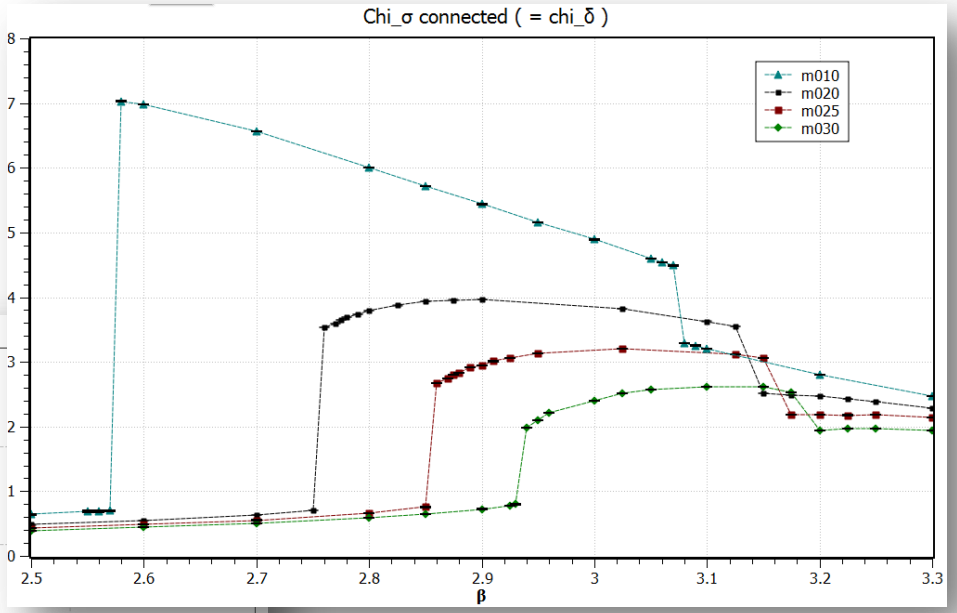
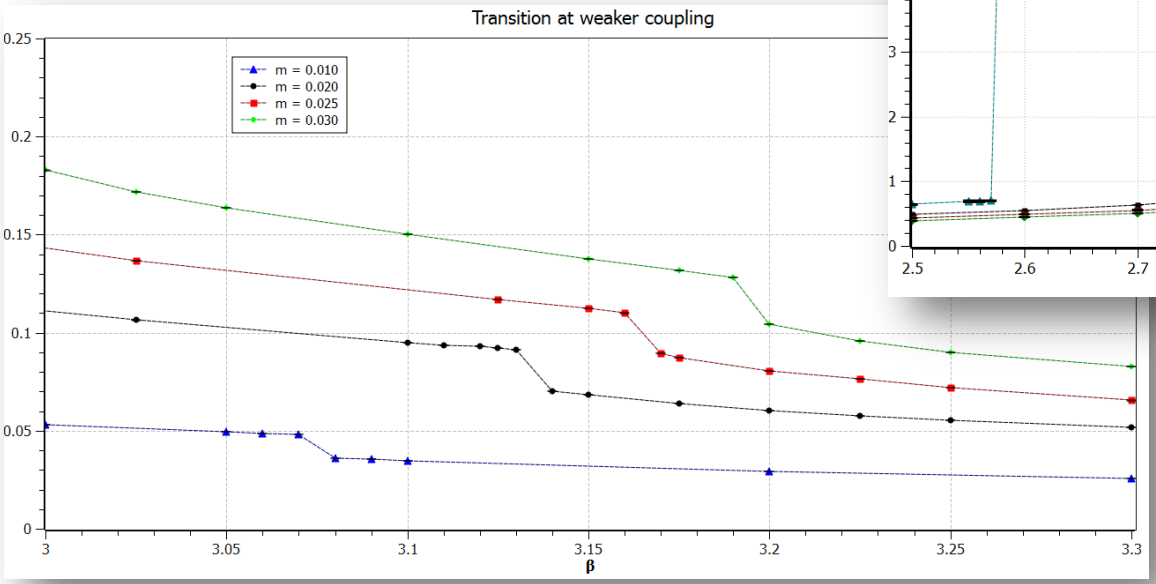
Chiral symmetry restoration at strong coupling

The jump at weak coupling

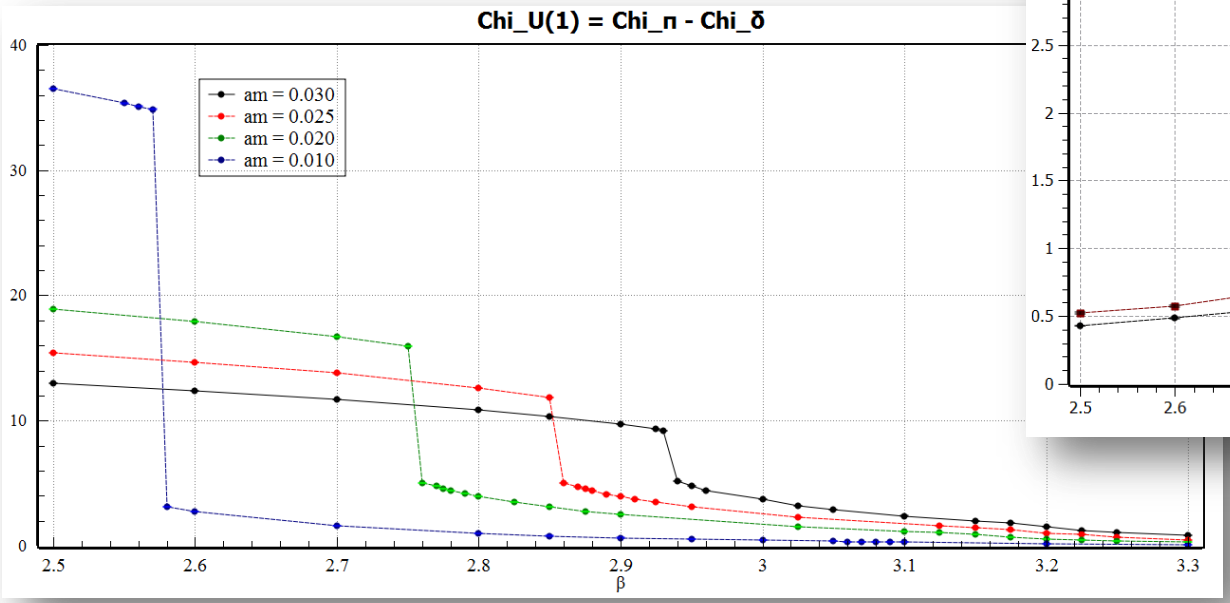
A tale of two signals

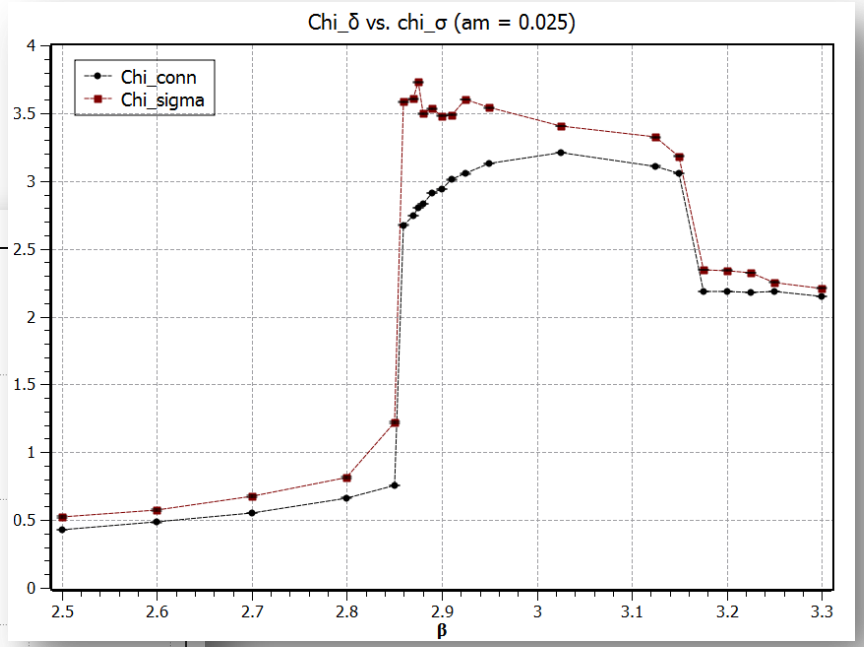




Discontinuity in $\langle \bar{q}q \rangle$ diminishes as the chiral limit is approached, while discontinuity in χ_σ^{conn} grows.

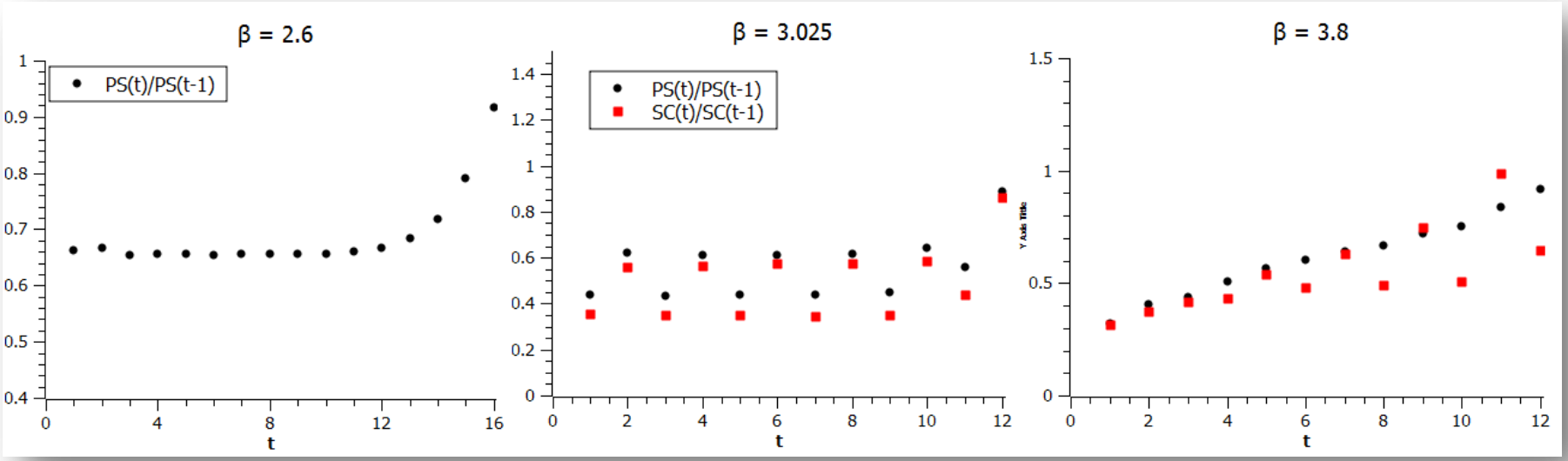
Connection to $U_A(1)$?





The continuum order parameter would suggest $U_A(1)$ restoration together with chiral restoration; but intermediate region shows splitting between σ and δ. We are at finite lattice spacing, so this has to be studied in terms of lattice symmetries.

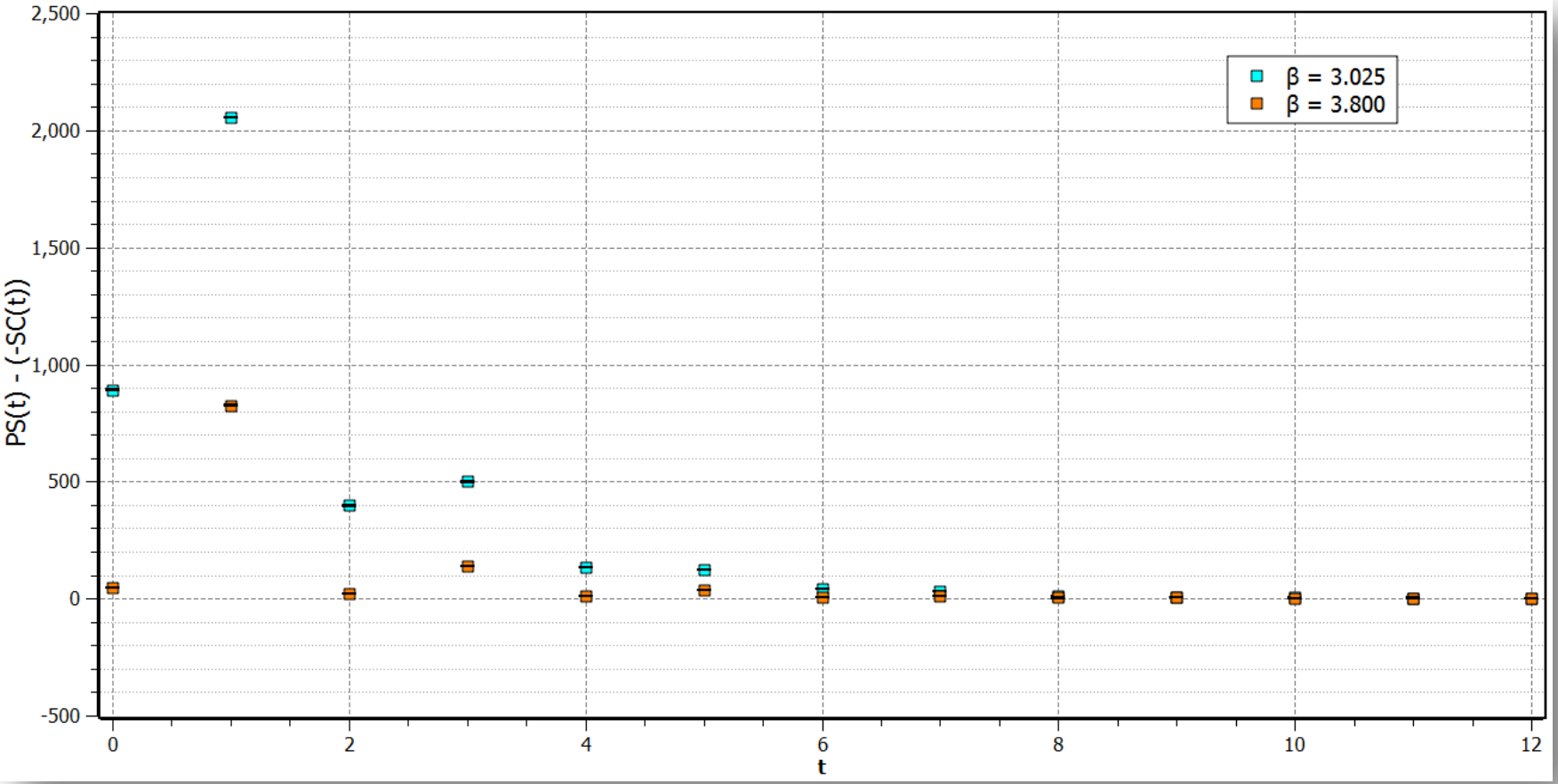
The spectrum (I)



$$\chi_\pi = \frac{\langle \bar{q} q \rangle}{m} = \int C_\pi(t) = \int [\, C_\pi^{non-osc} + C_\pi^{osc}]$$

The pseudoscalar correlator acquires an oscillatory component only in the intermediate region. Abrupt disappearance of C_π^{osc} will induce discontinuity in χ_π and a change of slope in $\langle \bar{q} q \rangle$.

The spectrum (II)

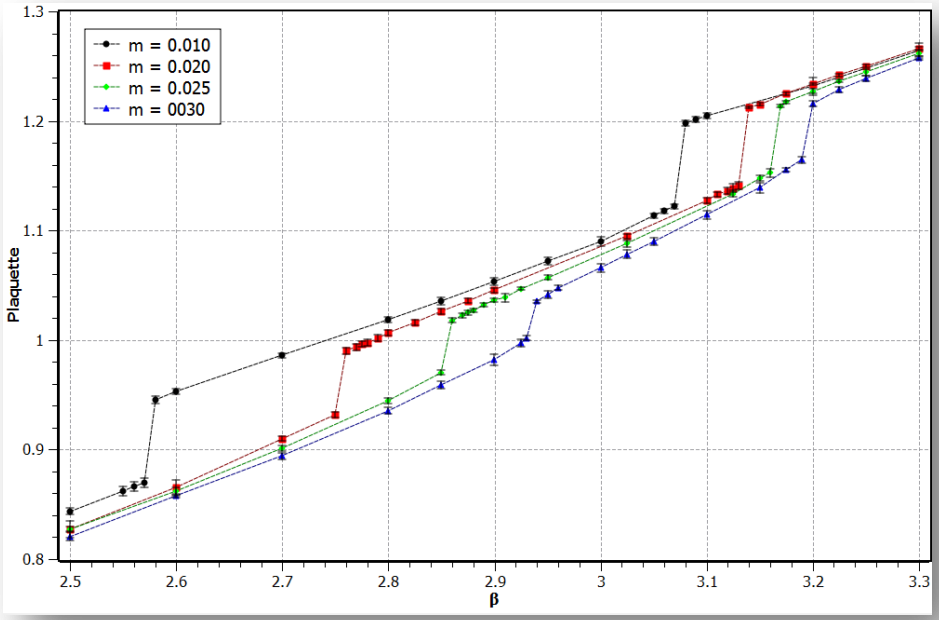


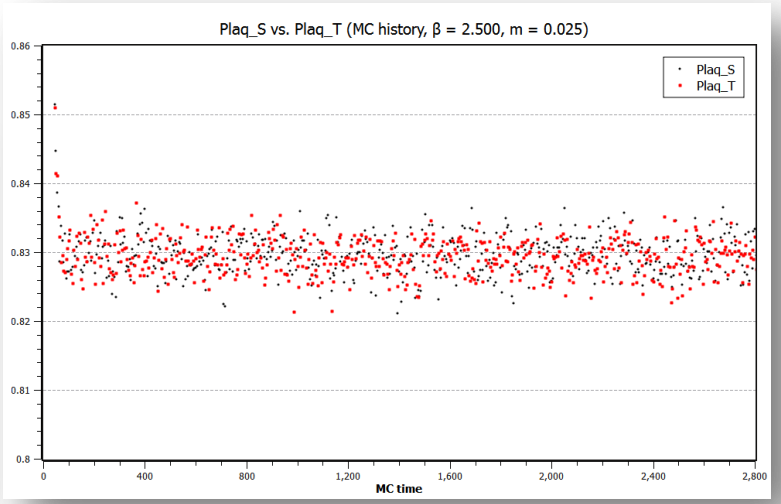
The non-degenaracy of the pseudoscalar and scalar-connected correlators indicates a residual breaking of $U_A(1)$.

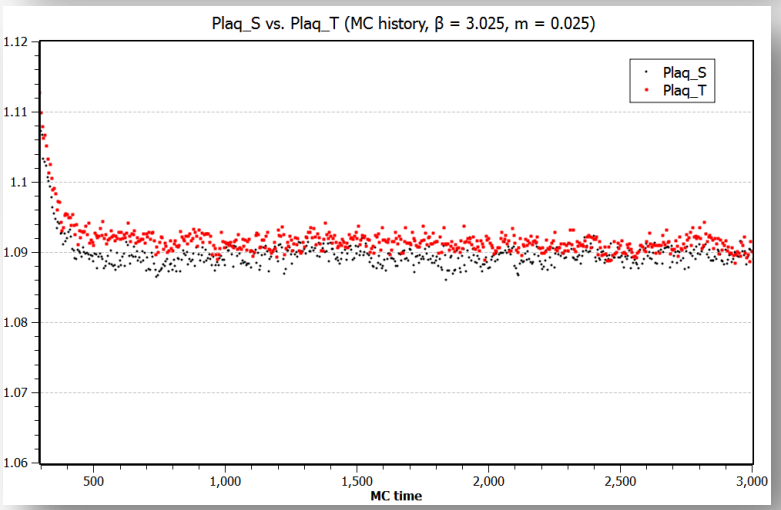
Conclusions and outlook

Conclusions	Study of the strong coupling and low bare mass regime of the theory agrees with the existence of a conformal window and with SU(3) with $N_f = 12$ being inside the window.
	For small bare masses, a bulk chiral symmetry breaking transition is observed at strong coupling. Its first order nature excludes the possibility of a non-trivial UV fixed point.
	The double jump structure appears to be a consequence of an extra oscillatory component acquired by the pseudoscalar meson in the intermediate region. The presence of this component explains the change of slope of $\langle \bar{q}q \rangle$ and the discontinuities of the chiral susceptibilities at weaker coupling.
	The non-degenaracy of the pseudoscalar and scalar-connected correlators indicates a residual breaking of $U_A(1)$.
Outlook	The described phenomena in the spectrum and susceptibilities are peculiar of a (coarse) lattice theory that has no correspondence in the continuum. A more detailed study of genuine lattice symmetries/artefacts and operators is ongoing.
	Further simulations are running to better understand the behaviour of the spectrum of the theory in the small mass/strong coupling regime.

Backup I – Plaquette







Backup II – χ_π