Symmetries of mesons after unbreaking of chiral symmetry

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Motivation

Spontaneous chiral symmetry breaking (SχSB) and confinement phenomena are the essential features of QCD. However,

- No satisfactory explanation of these phenomena is given in terms of underlying dynamical processes.
- The interelation between SχSB and confinement mechanisms is still an unresolved issue.

We seek for the answers to the following questions

- Will hadrons survive unbreaking of chiral symmetry?
- What symmetries do hadrons follow in the chirally restored regime?

Unbreaking of Chiral Symmetry

Read out the idea from the **Banks-Casher formula**

$$\langle 0|\bar{q}q|0\rangle = -\pi\rho(0). \quad (1)$$

Introduce **reduced quark propagators**

$$S_{RD(k)} = S_{Full} - \sum_{i=1}^{k} \frac{1}{\lambda_i} |\lambda_i\rangle\langle\lambda_i| \quad (2)$$

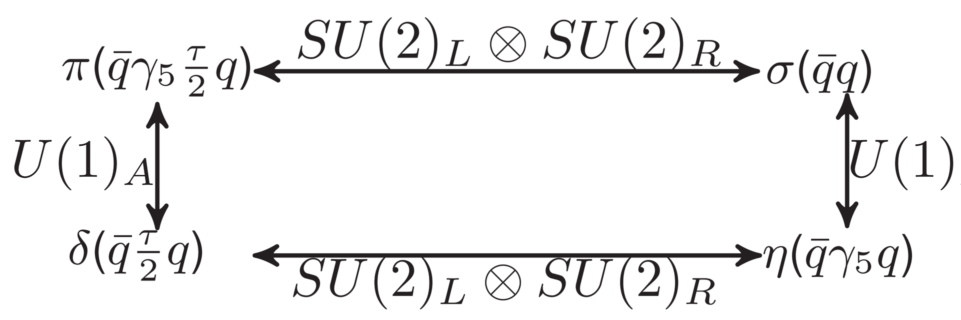
to compute meson observables, where k - is the number of excluded eigenmodes $\{|\lambda\rangle\}$ from the full stochastic all-to-all propagator.

Lattice details:

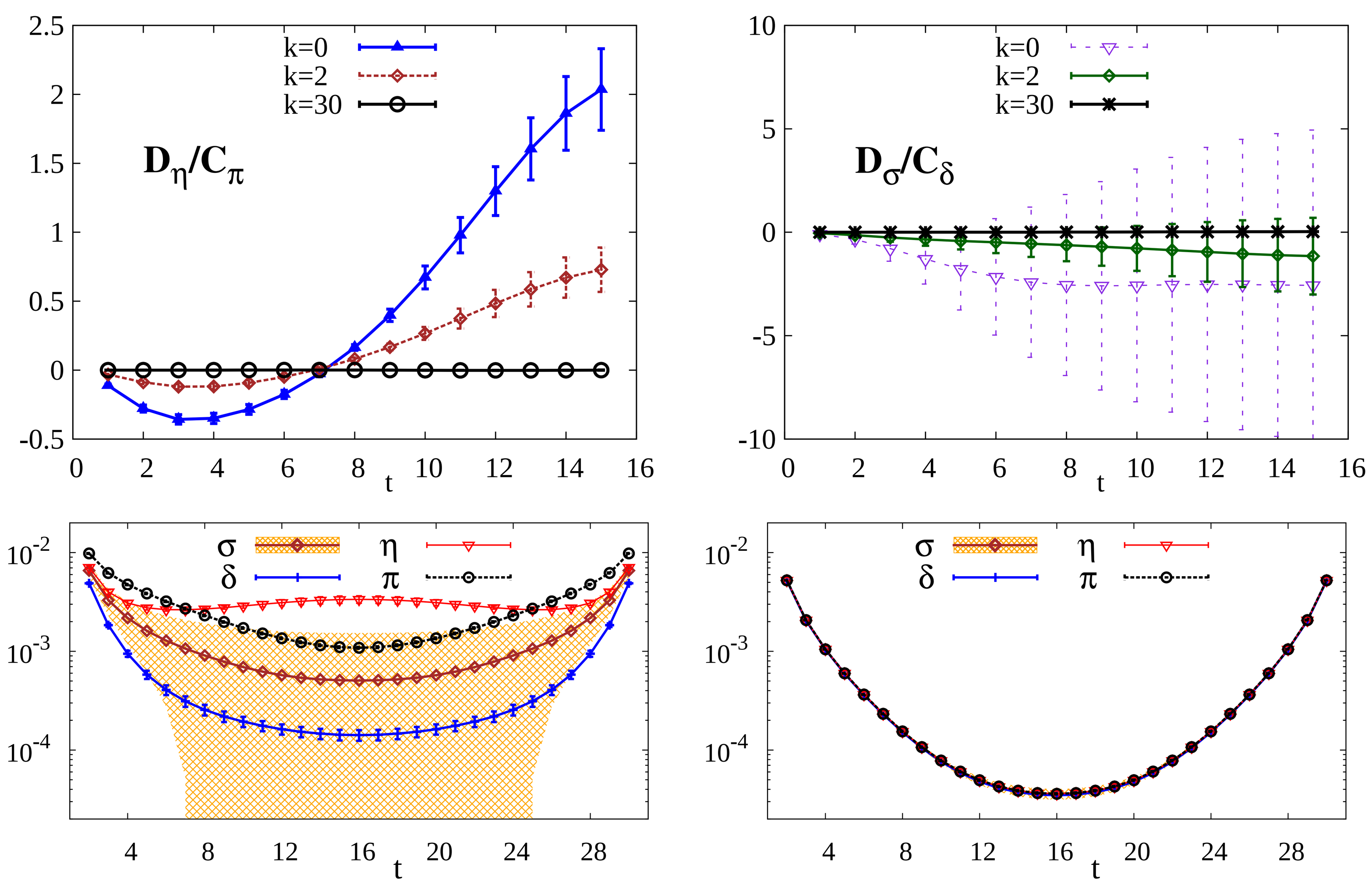
- #conf=100 with $n_f = 2$ dynamical overlap fermions [3, 4]
- N_Sx$N_T = 16^3 \times 32$ with $a \sim 0.12$
- $M_\pi = 289(2)$ MeV

$J = 0$ Mesons

Symmetries relating $I = 0, 1$ isospin mesons to each other



Correlators

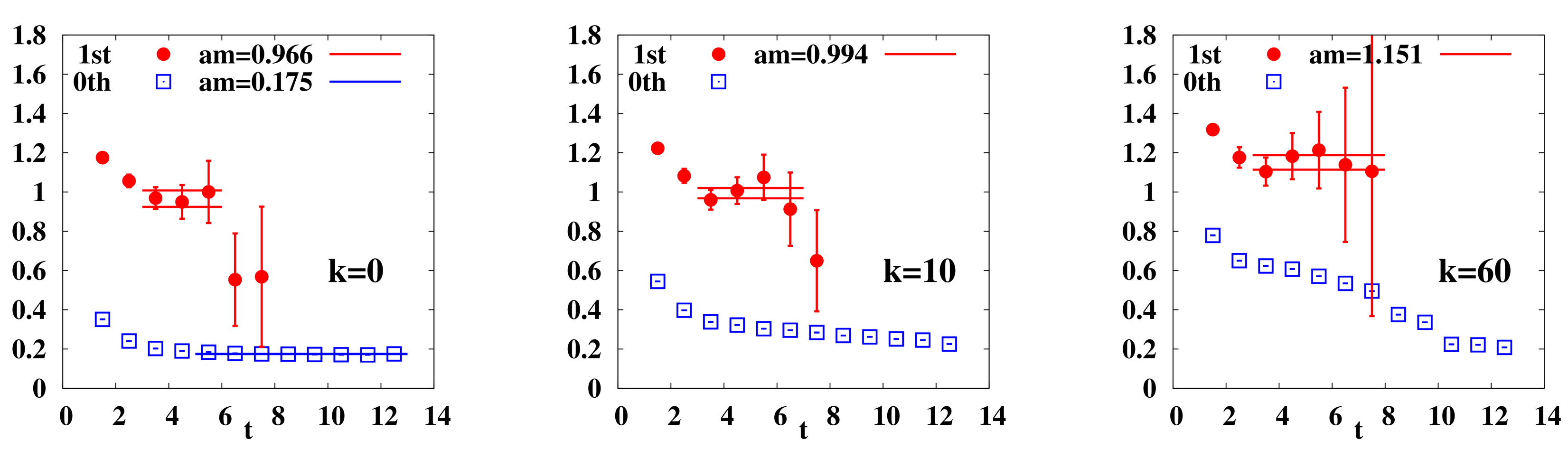


$$C_{\eta(\sigma)}(t) = C_{\pi(\delta)}(t) + D_{\eta(\sigma)}(t), \quad (3)$$

where $C_{\pi(\delta)}(t) = -\langle tr(\Gamma S(0,x)\Gamma^\dagger S(x,0))\rangle$ is the connected part and $D_{\eta(\sigma)} = 2\langle tr(\Gamma S(x,x))tr(\Gamma^\dagger S(0,0))\rangle$ is the disconnected part of $C_{\eta(\sigma)}$.

In the chirally restored regime one have to find degenerate meson two-point current correlators of π and δ with the corresponding disconnected contributions identical to zero.

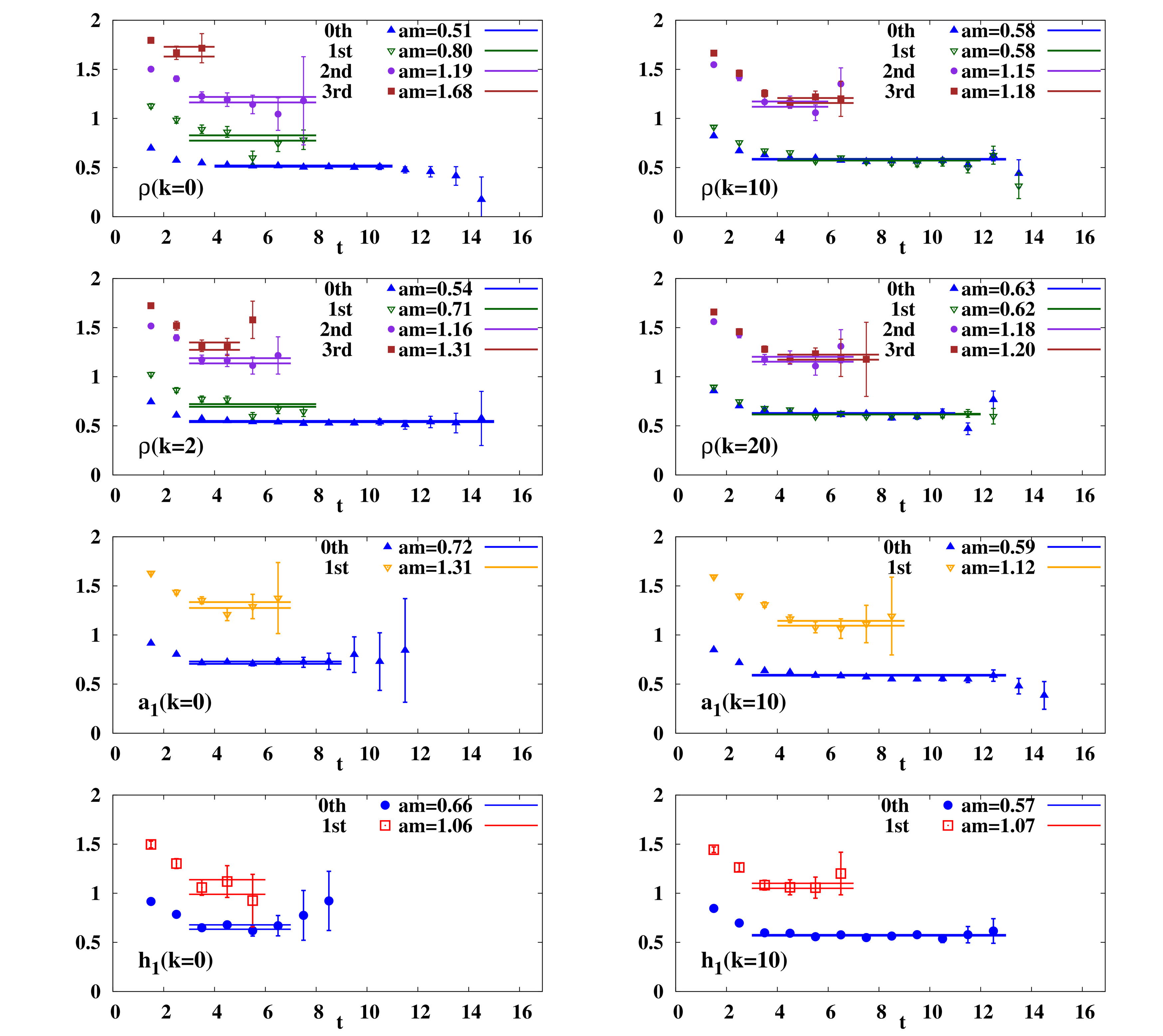
π effective masses



- Only the 1st excited state survives the unbreaking of chiral symmetry

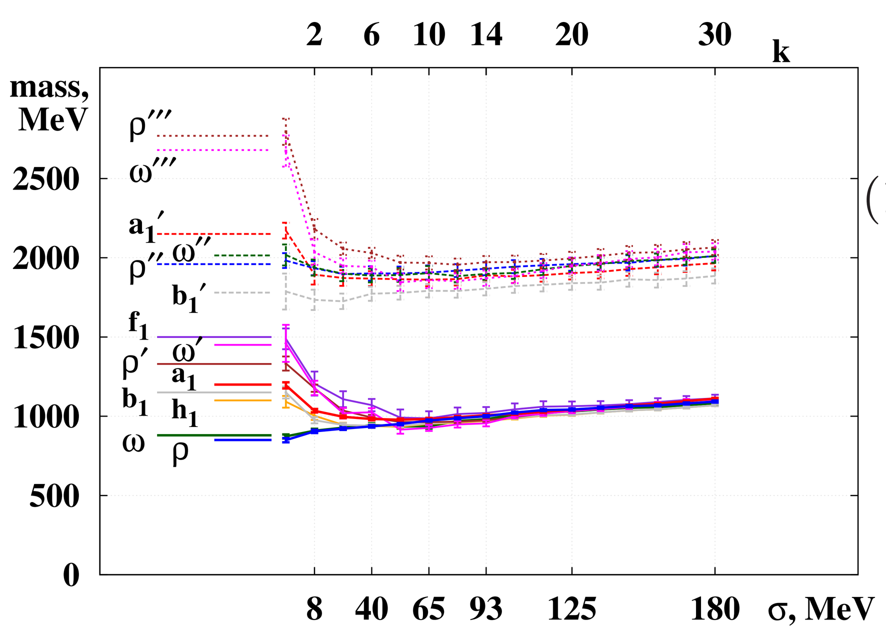
$J = 1$ Mesons

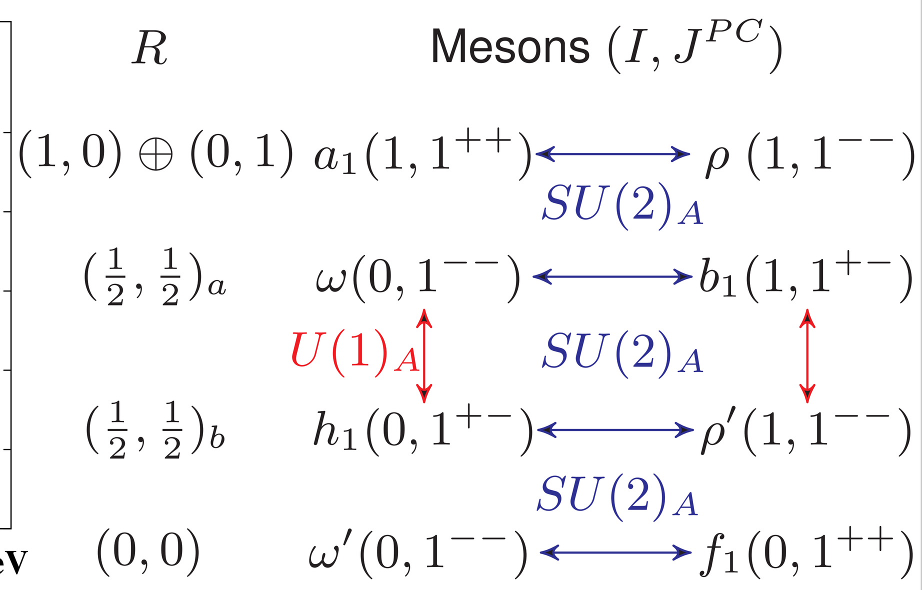
Effective masses:



$J = 1$ mesons follow a richer set of multiplets of the parity-chiral group $SU(2)_L \otimes SU(2)_R \otimes C_i$.

Evolution of $J = 1$ meson masses





- After unbreaking of chiral symmetry $J = 1$ meson spectrum is likely to follow

$$E^2 \propto (n+1)M_0^2 \quad (4)$$

energy quantization law with $M_0 \sim 1$ GeV (volume corrections are wanted).
- Mesons must fall into the same irreducible representation of some larger group

Summary

Upon unbreaking of chiral symmetry

- Disconnected contributions become neglegibly small
- Both $SU(2)_L \otimes SU(2)_R$ and $U_A(1)$ symmetries are restored in $J = 0$ and $J = 1$ meson sectors

In the chirally restored regime

- Ground states of $J = 0$ mesons disappear
- All non-exotic $J = 1$ mesons are degenerate with $M_0 \sim 1$ GeV

  (hint: higher symmetry)

References

[1] M. Denissenya, L. Y. Glozman and C. B. Lang, Phys. Rev. D **89**, 077502 (2014);
[2] L. Y. Glozman, C. B. Lang and M. Schröck, Phys. Rev. D **86**, 014507 (2012).
[3] S. Aoki *et al.* [JLQCD Collaboration], Phys. Rev. D **78**, 014508 (2008).
[4] J. Noaki *et al.* [JLQCD and TWQCD Collaborations], Phys. Rev. Lett. **101**, 202004 (2008)