SEARCHING FOR TETRAQUARKS ON THE LATTICE

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MOTIVATION

It is still not known whether the lightest observed nonet of scalar mesons σ(600), a0(980), f0(980), κ(800) are conventional $\bar{q}q$ states or tetraquark $\bar{q}\bar{q}qq$ states. Therefore it is important to determine whether QCD predicts any scalar tetraquark $\bar{q}\bar{q}qq$ states below 1 GeV from a first principle calculation.

METHOD

We calculate the energy spectrum of scalar tetraquark states with I=0, 2, 1/2, 3/2 in lattice QCD for two cases: simulation with dynamical *u/d* quarks and quenched simulation.

We extract the energies of the ground and one or two excited states. So far, all simulations studied only the ground state, with exception of [1].

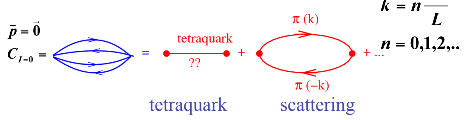
The energies of the states are extracted from correlation functions $C_{ij}(t)$, where states with $J^{PC}=0^{++}$ and given I are created at time 0 and annihilated at later time t:

$$C_{ij}(t) \equiv \langle 0|O_i(t)O_j^+(0)|0\rangle = \sum_n Z_i^n Z_j^{n*} e^{-E_n t}$$

$$O_{i,j} = PP,\ \sum_{i=1,2,3} V_i V_i,\ \sum_{i=1,2,3} A_i A_i,\ [qC\gamma_5 q][\bar{q}C\gamma_5\bar{q}],\ [qCq][\bar{q}C\bar{q}]$$

All physical scalar states *n* with given I propagate between the source and the sink. Besides possible tetraquark states, there are unavoidable contributions from two pseudoscalar scattering states, which have discrete momenta $k=n*2\pi/L$. **Our main question is whether we find some additional light state on top of scattering states in I=0,1/2 channels.**

$$\vec{k} = \vec{n}\frac{2\pi}{L}, \quad n = 0,1,2,..$$



attractive (non-exotic) channels	I=0	σ = *udud* ?		π π
	I=1/2	κ = *udds* ?		K π
repulsive exotic channels	I=2		no resonance expected	π π
	I=3/2		no resonance expected	K π

We extract energies E_n from eigenvalues of the generalized eigenvalue problem [2]:

$$C(t_0)^{-\frac{1}{2}} C(t) C(t_0)^{-\frac{1}{2}}\ \vec{v}_n(t) = \lambda_n(t)\vec{v}_n(t)\,, \quad \lambda_n(t) \to e^{-E_n(t-t_0)}$$

DETAILS OF SIMULATION

- <u>dynamical simulation:</u> Chirally Improved quarks [3],
  a=0.15 fm, $L^3xT=16^3x32$, m_π= 318, 469, 526 MeV
- <u>quenched simulation:</u> overlap quarks,
  a=0.2 fm, $L^3xT=16^3x28$, m_π= 230, 342, 478 MeV

RESULTING SPECTRUM for I = 0, 2, 1/2, 3/2

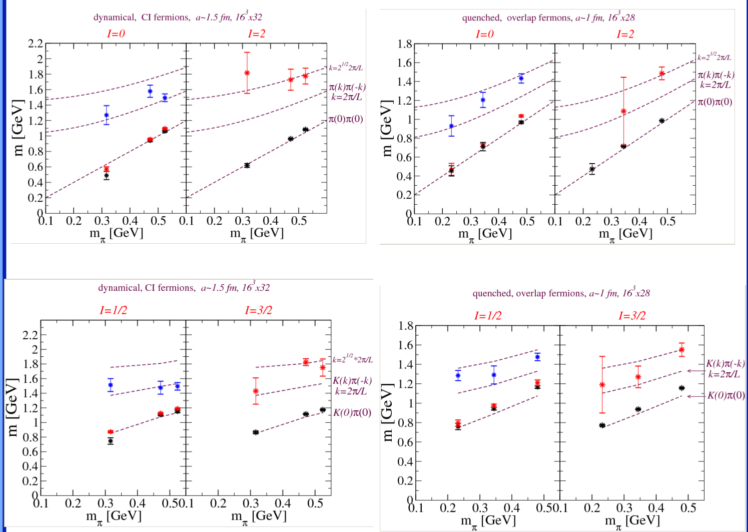


Fig: Points present extracted energies on the lattice. Lines are energies of non-interacting ππ or *Kπ*, with back-to-back momenta *k=n*2π/L*.

CONCLUSIONS

- <u>I=0:</u> We find candidates for lowest two **ππ** scattering states and additional light state, which can be possibly related to **σ with strong tetraquark component**.
- <u>I=2:</u> We find candidates for lowest two **ππ** scattering states and no additional light state, as expected (no resonance is expected in this repulsive channel).
- <u>I=1/2:</u> We find candidates for lowest two ***Kπ*** scattering states and additional light state, which can be possibly related to **κ with strong tetraquark component**.
- <u>I=3/2:</u> Only candidates for lowest two ***Kπ*** scattering states are found and no additional light state, as expected.

REFERENCES

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