N_c dependence of light resonances properties

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We review our recent study of the N_c dependence of the parameters of the lightest scalar and vector mesons and other highly $1/N_c$ suppressed observables in a model independent way, showing that the expansions need unnaturally large coefficients for the scalars. We also study their mass and width N_c evolution by means of Unitarized Chiral Perturbation Theory to compare with the $\bar{q}q$ scaling $M \sim 1$, $\Gamma \sim 1/N_c$. We see that the vectors follow the $\bar{q}q$ scaling whereas the scalars do not, although we might be seeing a subdominant $\bar{q}q$ component in the $f_0(600)$ with a mass around 1 GeV in the two-loop analysis.

The nature of the scalar mesons is still the object of an intense debate and different models suggest that they may not be ordinary quark-antiquark mesons, but tetraquarks, meson molecules, glueballs, or a complicated mixture of all these. The problem, of course, is that we do not know how to solve QCD at low energies. However, since the QCD $1/N_c$ expansion is applicable at all energies, and the mass and width of $\bar{q}q$ mesons scale as $O(1)$ and $O(1/N_c)$, respectively, the N_c dependence of resonances becomes a powerful tool to study the nature of these resonances. Another useful approach is to extrapolate the pion mass up to the region where Lattice results are available. Results on this matter were shown in the poster, but due to space limitations here we prefer to focus on the more recent results on N_c extrapolation and particularly on the study of highly $1/N_c$ suppressed observables and refer the reader to the original publications on chiral extrapolation [1, 2].

Mass and width dependence on N_c We first study the mass and width behavior of light resonances using ChPT—which is the QCD low energy effective Lagrangian—and unitarization with a dispersion relation. The poles of the $\rho(770)$ and $K^*(982)$ vectors behave predominantly as expected for $\bar{q}q$ states whereas those of the $f_0(600)$, also called σ, and $K(800)$ scalars do not. Still, a possible subdominant $\bar{q}q$ component for the $f_0(600)$ may arise naturally at two loops [3] within ChPT (less so at one loop), but with a mass around 1 GeV or more. We refer the reader to papers [3, 4] for a more detailed discussion.

Highly $1/N_c$ suppressed observables In this section we provide adimensional observables with corrections suppressed further than $1/N_c$, that can also be applied directly to real data at $N_c = 3$, without the need to extrapolate to larger N_c using unitarized ChPT.

	$\rho(770)$	$K^*(892)$	$f_0(600)$	$K(800)$
a	-0.06 ± 0.01	0.02	-252^{+119}_{-156}	-2527
b	$0.37^{+0.04}_{-0.05}$	0.16	77^{+28}_{-24}	162

Table 1: Normalized coefficients of the $1/N_c$ expansion for different resonances. For $\bar{q}q$ resonances, all them are expected to be of order one or less.

Let $s_R = m_R^2 - im_R\Gamma_R$ be the pole position of a resonance that behaves as a $\bar{q}q$. Making use of the scaling behavior found in [5] for $\delta(m_R)$ and $\delta'(m_R)$, we can write down the following adimensional observables whose corrections are suppressed further than just $1/N_c$:

$$\left.\frac{\frac{\pi}{2} - \mathrm{Re}\, t^{-1}/\sigma}{\delta}\right|_{m_R^2} \equiv \Delta_1 = 1 + \frac{a}{N_c^3}, \tag{1}$$

$$-\left.\frac{[\mathrm{Re}\, t^{-1}]'}{\delta'\sigma}\right|_{m_R^2} \equiv \Delta_2 = 1 + \frac{b}{N_c^2}, \tag{2}$$

where $t(s)$ is the partial wave, $\sigma = 2k/\sqrt{s}$, k is the meson center of mass momentum and derivatives are taken with respect to s. The coefficients a and b should naturally be $O(1)$ or less. It is relatively simple to make a and b much smaller than one with cancellations with natural higher order $1/N_c$ contributions, but very unnatural to make them much larger. In Table 1 we show the resulting a and b for the lightest resonances found in $\pi\pi$ and πK elastic scattering. We observe that for the $\rho(770)$ and $K^*(892)$ vector resonances all parameters are of order one or less, as expected for $\bar{q}q$ states. In contrast, for the $f_0(600)$ and $K(800)$ scalar resonances we find that all parameters are larger, by two orders of magnitude, than expected for $\bar{q}q$ states, which makes the $\bar{q}q$ interpretation of both scalars extremely unnatural. Furthermore, unitarized ChPT can be used to calculate the $\Delta_i - 1$ observables, in order to show that, for scalars, what really happens is that they do not even follow the $1/N_c$ expansion of $\bar{q}q$ states given in Eqs. (1) and (2). For this analysis we refer the reader to [6]

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References

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