m_π and N_c dependence of ρ and σ mesons from unitarized chiral perturbation theory.

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Abstract. We review the N_c and m_π dependence of the $\rho(770)$ and σ (or $f_0(600)$) resonances generated with the Inverse Amplitude Method. The σ N_c behavior is at odds with being dominantly a $\bar{q}q$ state, but there is a hint of a subdominant $\bar{q}q$ component with a mass above 1 GeV. We find fair agreement with lattice results for the chiral extrapolation of the ρ mass, and that the $\rho\pi\pi$ coupling is almost m_π independent whereas the $\sigma\pi\pi$ coupling depends strongly on m_π.

Keywords: Scalar mesons, chiral Lagrangian, $1/N_c$ expansion
PACS: 14.40.Cs, 12.39.Fe, 13.75.Lb,11.15.Pg

We have calculated in [1, 2] the leading $1/N_c$ scaling and the m_π dependence of the $\rho(770)$ and the σ (or $f_0(600)$) mass and width with the Inverse Amplitude Method (IAM). The IAM uses Chiral Perturbation Theory (ChPT) to evaluate the subtraction constants and the left cut of a dispersion relation for the inverse of the $\pi\pi$ scattering partial waves where the right cut is taken into account exactly using elastic unitarity. Hence, it satisfies elastic unitarity and matches the chiral series at low energies. Also, it generates the ρ and σ poles on the 2nd Riemann sheet of the corresponding partial waves, and can be systematically extended to higher chiral orders. It is obtained only from analyticity, elastic unitarity and ChPT, without further model dependencies in the approach. Thus, we can use it to study how the ρ and σ properties depend on m_π and on the QCD number of colors, N_c, through the dependence of the ChPT parameters.

The $1/N_c$ expansion gives a clear definition of $\bar{q}q$ states: Their mass and width scale as $O(1)$ and $O(1/N_c)$, respectively. Obtaining the ρ and σ pole positions with the IAM for several values of N_c, we can check if their mass and width (defined from the pole position as $\sqrt{s_{pole}} = M - i\Gamma/2$) N_c behavior is consistent with a $\bar{q}q$ nature. It is shown in [1] that the ρ follows very well the $\bar{q}q$ scaling but the σ does not, since its mass and width grow with increasing N_c. This allows us to conclude that its dominant component is not $\bar{q}q$. However, with the two loop IAM, for $N_c \gtrsim 8$, the σ mass becomes constant around 1.1 GeV and the width starts decreasing (left panel of figure). This may hint to *a subdominant $\bar{q}q$ component* of the σ, arising as the loop contributions – which play a crucial role in determining the σ pole position despite being subdominant in $1/N_c$ – become suppressed as N_c grows. This supports the picture of two low energy scalar nonets, one of non $\bar{q}q$ nature below 1 GeV and another of ordinary $\bar{q}q$ nature above.

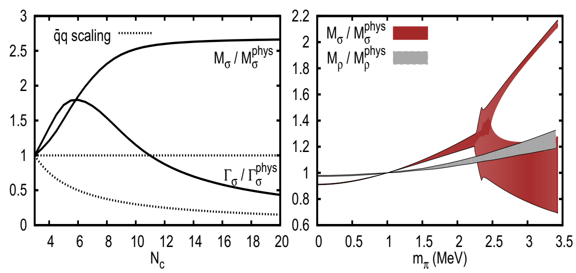

FIGURE 1. Left: σ mass and width leading $1/N_c$ behavior. Right: m_π dependence of the ρ and σ mass.

In Ref. [2] we study with the IAM the m_π dependence of the ρ and σ mass, width and coupling. This could serve as a guide to lattice studies, whose computations are made with unphysical quark masses. Both ρ and σ poles move closer to threshold and they approach the real axis as m_π increases. The ρ poles reach the real axis at threshold and one of them jumps into the first sheet becoming a bound state. In contrast, the σ poles move below threshold with a finite imaginary part and they quickly reach the real axis, on the 2nd sheet, becoming virtual states. As m_π is increased further one of the poles moves towards threshold and eventually jumps into the 1st sheet through the branch point, while the other remains on the second sheet. That is why we show two masses for the σ in the right panel of the figure. The ρ mass behavior compares well with some lattice results and its coupling to pions is almost m_π independent. In contrast, the $\sigma\pi\pi$ coupling depends strongly on m_π.

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The IX International Conference on Quark Confinement and the Hadron Spectrum - QCHS IX
AIP Conf. Proc. 1343, 632-632 (2011); doi: 10.1063/1.3575125