Hadronic resonances made of multi-vector mesons

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In previous works regarding the interaction of two vector mesons using the techniques of the chiral unitary approach, it was shown that the vector-vector interaction in s-wave with spins aligned is very strong both for $\rho-\rho$ and $K^*-\rho$ to the point to get dynamically the $f_2(1270)$ and $K_2^*(1430)$ resonances. In the work presented in this talk we use the rho-rho and $\rho-K^*$ interaction in spin 2 and isospin 0 channel to show that the resonances $\rho_3(1690)$, $f_4(2050)$, $\rho_5(2350)$ and $f_6(2510)$ and the strange $K_2^*(1430)$, $K_3^*(1780)$, $K_4^*(2045)$, $K_5^*(2380)$ and a not yet discovered K_6^* are basically molecules of increasing number of $\rho(770)$ mesons (with also a $K^*(892)$ in the case of the strange states). We use the fixed center approximation of the Faddeev equations to write the multi-body interaction in terms of the two-body scattering amplitudes. We find the masses of the states very close to the experimental values.

The chiral unitary approach has unraveled the molecular nature of many hadronic resonances [1–7]. As far as the interaction of vector mesons is concerned the $f_2(1270)$ and $K_2^*(1430)$ can be generated from the $\rho\rho$ and $K^*\rho$ unitarized interactions respectively in spin S=2, isospin I=0, with a very strong binding energy [8, 9]. In view of this strong $\rho\rho$ interaction, it is natural to ask whether is it possible to obtain bound systems with increasing number of ρ mesons as building blocks. Regarding this question, it is worth noting that in the PDG [10] there are intriguing mesons with large spin, of the ρ and f_0 type, whose quantum numbers match systems made with 3, 4, 5 and 6 ρ mesons with their spins aligned. These are the $\rho_3(1690)$ (3^{--}), $f_4(2050)$ (4^{++}), $\rho_5(2350)$ (5^{--}) and $f_6(2510)$ (6^{++}) resonances. Whether these systems with spin $J = 2, 3, 4, 5, 6$ can be interpreted as few body systems made of an increasing numbers of $\rho(770)$ mesons is the main aim of the present work.

The basic ingredient for the calculation of the multi-ρ scattering is the two-ρ interaction [8]. From the hidden gauge symmetry Lagrangian [11–14] for vector mesons, the $\rho\rho$ potential can be obtained. The term of interest for the present work to which these Lagrangians lead are a four vector meson contact term and a four vector meson interaction through the exchange of an intermediate vector meson in the t and u channels. From these Lagrangians the potential V can be obtained, to which the contact and ρ-exchange terms contribute. For the present work only the spin $S = 2$ and isospin $I = 0$, $I = 2$, are necessary. Actually, the $\rho\rho$ $S = 2$, $I = 0$ is strongly attractive. This is the most important reason to obtain a bound $\rho\rho$ state with these quantum numbers as we explain below.

With this potential the total $\rho\rho$ scattering amplitude can be obtained. In order to extend the range of applicability of the interaction to the resonance region, the implementation of exact unitarity is mandatory. In this case, we use the Bethe-Salpeter (BS) equation where the kernel is the potential V described above, $T = \frac{V}{1-VG}$, for each spin-isospin channel. In the BS equation, G is the $\rho\rho$ loop function [2, 3], which can be regularized by means of dimensional regularization or using a three-momentum cutoff, which is the only free parameter in the whole model and is chosen such as to produce the peak of $|T|^2$ at the experimental mass of the $f_2(1270)$.

For the multi-ρ systems we evaluate the scattering amplitudes for the interactions of two clusters made up of ρ-mesons. For the interaction of three ρ mesons we consider the interaction of one of the ρ mesons with the other two clustered in and $f_2(1270)$. To this purpose we use the fixed center approximation to the Faddeev equations (FCA), which are written in terms of two partition functions T_1, T_2, which sum up to the total scattering matrix, T, and read

$$T_1 = t_1 + t_1 G_0 T_2 \, , \quad T_2 = t_2 + t_2 G_0 T_1 \, , \quad T = T_1 + T_2 \tag{1}$$

where T is the total scattering amplitude we are looking for, T_i accounts for all the diagrams starting with the interaction of the external particle with particle i of the compound system and t_i represent the $\rho\rho$ unitarized scattering amplitude of a ρ^+ with any of the other ρ in the $I = 0$ $\rho\rho$ system.

In fig. 1 we show the modulus squared of the amplitudes for different number of ρ mesons considering only the single scattering mechanisms (dotted line) and the full model (solid and dashed lines). The difference between the solid and dashed lines is the value of a cutoff present in the form factor [15] needed in the evaluation of the 5ρ and 6ρ meson systems. The position of the maximum in the modulus squared of the amplitudes can be associated with the masses of the corresponding resonances. It is worth noting that the model has no free parameters once a cutoff is chosen in ref. [8] to obtain the experimental mass of the $f_2(1270)$ resonance.

The values of the masses that we obtain are in very good agreement with the experimental values of the masses of the resonances considered in the present work, the $\rho_3(1690)$, $f_4(2050)$, $\rho_5(2350)$ and $f_6(2510)$. This is a remarkable fact given the simplicity of the underlying idea.

An extension of the model to the strange sector including K^* vector mesons has been also done in ref. [16].

In Fig. 2 we show the modulus squared of the different multy-body scattering amplitudes with strangeness. The resonant structure of the amplitudes is clearly evident in the plot, which can be associated to the resonances labeled in the figures with masses given by the position of the maxima.

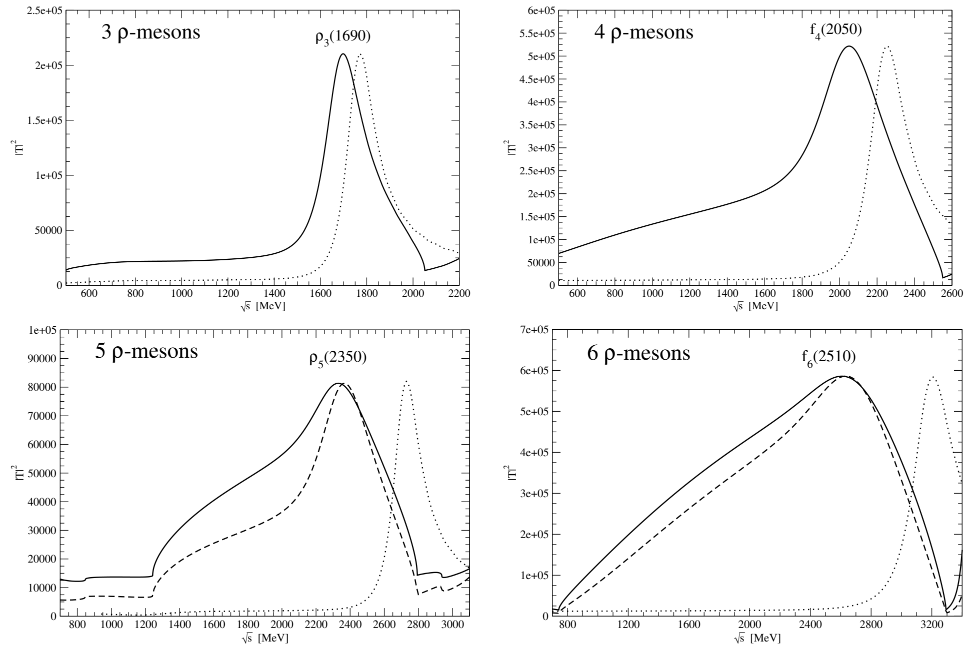

Figure 1: Modulus squared of the unitarized multi-ρ amplitudes. Solid line: full model with cutoff form factor = 1500 MeV; dashed line: full model with cutoff form factor = 875 MeV; dotted line: only single-scattering contribution.

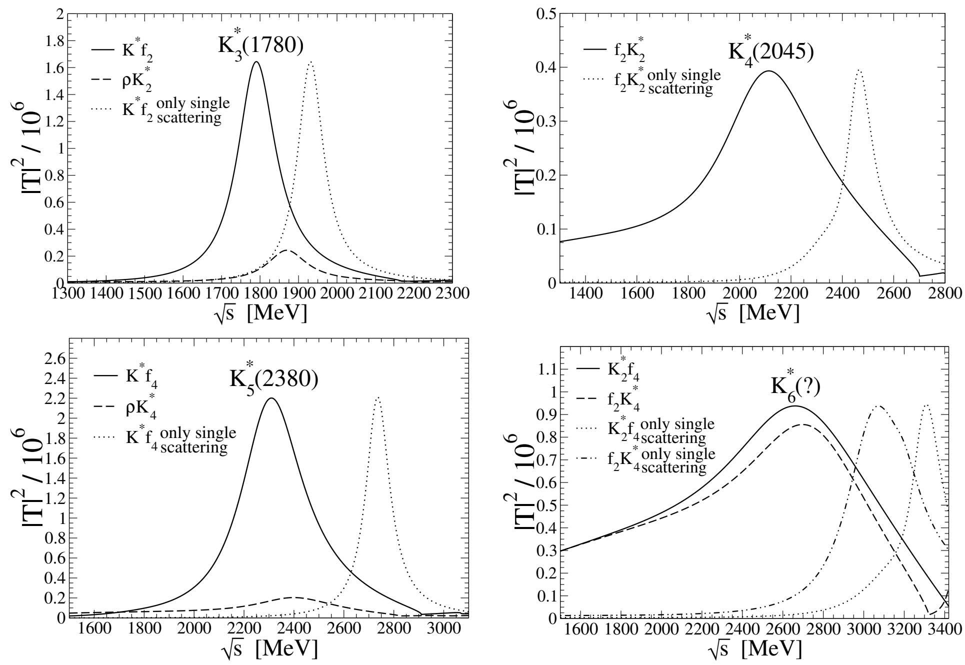

Figure 2: Modulus squared of the unitarized K^{*}–multi-ρ amplitudes.

The claims made here that the already observed states up to $J = 6$ correspond to multi ρ and/or K^* states is a novel idea worth consideration. New studies with different formalisms and different points of view would be most welcome, as well as possible experimental tests which could help unveil the real nature of these states.

Acknowledgments

This work is partly supported by DGICYT contracts FIS2006-03438, FPA2007-62777 and the EU Integrated Infrastructure Initiative Hadron Physics Project under Grant Agreement n.227431.

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