A molecular interpretation for the $D^*_{s2}(2573)$ and the prediction of novel exotic charmed mesons

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We review the vector-vector interaction within the hidden gauge formalism in a coupled channel unitary approach. The study of the vector-vector interaction is extended to include all the sectors not studied before. This includes: $C = 0; S = 1$ (hidden-charm), $C = 1, S = 1$, and the flavor exotic sectors $C = 1; S = -1, 2$ and $C = 2; S = 0, 1, 2$. We find nine states. One of them can be identified with the $D^*_{s2}(2573)$ and is interpreted as a D^*K^* molecular state. The other eight resonances can be observed in future experiments at PANDA/FAIR. Some of them are found in the flavor exotic sectors, $C = 1; S = -1$, $C = 2; S = 0, 1$, and can be considered as $D^*\overline{K^*}$, D^*D^* and $D^*_sD^*$ molecular states.

1 Introduction

The interaction of vector mesons with themselves is done using the lagrangians of the hidden gauge formalism, which mix vector mesons with pseudoscalars and respect chiral symmetry [1]. For example, in [2], the authors found two poles in the $\rho\rho$ amplitude that can be clearly identified with the $f_0(1375)$ and the $f_2(1270)$ as $\rho\rho$ resonances states decaying in 2π or 4π by means of a box diagram mechanism. This work has been extended to the general case of two vectors of the 16-plet of SU(4) and many resonances have been obtained as a bound system of two vectors, such is the case of the $K^*_2(1430)$, the $D^*_2(2460)$ or the $Y(3940)$ (see [3–5] for more details).

In this talk we study all the sectors not studied before within the hidden gauge formalism, the $C = 0; S = 1$ (hidden-charm) sector, $C = 1, S = 1$, and the flavor exotic sectors $C = 1; S = -1, 2$ and $C = 2; S = 0, 1, 2$. Unlike other predicted states in the coupled channel unitary approach, these flavor exotic mesons cannot obviously be accomodated in the $q\bar{q}$ spectrum. Looking for these states is a new challenge for the experimentalist.

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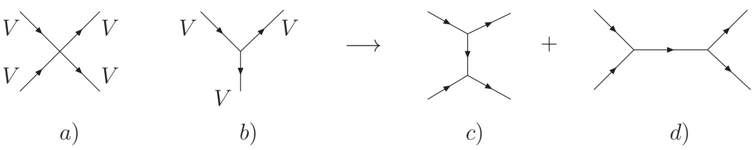

Figure 1: Terms of the $\mathcal{L}_{III}$ Lagrangian: a) four-vector contact term; b) three-vector interaction; c) t and u channels from vector exchange; d) s channel for vector exchange.

2 Formalism

We refer to [6] for a detailled explanation. The hidden-gauge formalism is applied in order to describe the interaction between vector mesons and vector mesons with pseudoscalars and photons [1]. The hidden-gauge Lagrangian, which is consistent with chiral symmetry, provides this former interaction from the term $\mathcal{L} = -\frac{1}{4}\langle \overline{V}_{\mu\nu}\overline{V}^{\mu\nu}\rangle$, from where we can get the four-vector and three-vector interaction depicted in Figs. 1 a) and b) respectively. The last one leads to the diagrams of Figs. 1 c) and d), where a vector meson is exchanged. However only the a) and c) diagrams are considered because those of Fig. 1 d) represent a minor component of s-wave (or p-wave repulsive for equal masses) and can be neglected [3]. We make the approximation of low momenta of the external vectors compared to the mass of the vector mesons, $\vec{k}/M_V \sim 0$, and the polarization vectors of the external vector mesons reduce to the spatial components.

The amplitudes of the diagrams in Fig. 1 a) and c) are projected in isospin, spin and s-wave, then, they are inserted into the Bethe-Salpeter equation, $T = (\hat{1} - VG)^{-1}\, V$, as the kernel V, being G a diagonal matrix where the matrix elements are the two meson loop functions for each channel, which are evaluated by means of dimensional regularization. In the complex plane of $\sqrt{s}$, bound states appear as poles over the real axis and below thresholds on the first Riemann sheet. In contrast, resonances are identified by poles on the second Riemann sheet above the thresholds of the channels which are open. The convolution of the G two-meson function loop is included to take into account the width of ρ and K^* mesons decaying in 2π and πK respectively. The use of the convoluted loop function provides larger widths of the states than without convolution, but the width obtained by means of this mechanism is small. Another way to consider the decay of the vector mesons into pairs of pseudoscalar is to include a box-type Feynman diagram where all the lines of the box are pseudoscalar mesons. This diagram takes into account the decay of these VV states into two pseudoscalars and has only $J^P = 0^+, 2^+$ quantum numbers. Therefore, the states with $J^P = 1^+$ are obtained in the model with a small width of a few KeV due to only the convolution of the G loop function. For the evaluation of this box diagram, two form factors are included in the PPV vertex, one is $F_1(q^2) = \frac{\Lambda_b^2 - m_1^2}{\Lambda_b^2 - (k_1^0 - q^0)^2 + |\vec{q}|^2}$ (Model A), and the other one is an exponential parametrization for an off-shell $\pi(K)$, $F(q^2) = e^{((q^0)^2 - |\vec{q}|^2)/\Lambda^2}$, together with this last form factor we use the experimental value of $g_D = 8.95$ (Model B).

C, S	$I[J^P]$	$\sqrt{s}$	$\Gamma_A(\Lambda = 1400)$	$\Gamma_B(\Lambda = 1000)$	State	$\sqrt{s}_{exp}$	Γ_{exp}
$1, -1$	$0[0^+]$	2848	23	25			
	$0[1^+]$	2839	3	3			
	$0[2^+]$	2733	11	22			
$1, 1$	$0[0^+]$	2683	20	44			
	$0[1^+]$	2707	4×10^{-3}	4×10^{-3}			
	$0[2^+]$	2572	7	18	$D_{s2}(2573)$	2572.6 ± 0.9	20 ± 5
	$1[2^+]$	2786	8	9			
$2, 0$	$0[1^+]$	3969	0	0			
$2, 1$	$1/2[1^+]$	4101	0	0			

Table 1: Summary of the nine states obtained. The width is given for the model A, Γ_A, and B, Γ_B. All the quantities here are in MeV.

3 Results

3.1 Resonances from the VV interaction

We evaluate the pole positions in the sectors where we find attractive interaction and calculate the couplings to each channel from the residue of the amplitudes. In the sectors $C = 1; S = -1; I = 0$, $C = 1; S = 1; I = 0, 1$, $C = 2; S = 0; I = 0$, $C = 2; S = 1; I = 1/2$ the interaction is atractive enough to get bound states or resonances whereas the attraction is too small to bind the system or repulsive in the sectors $C = 0; S = 1; I = 1/2$ (hidden charm), $C = 1; S = -1; I = 1$, $C = 1; S = 2; I = 1/2$, $C = 2; S = 0; I = 1$ and $C = 2; S = 2; I = 0$. In Table 1 we give a summary of the states obtained for the models A and B with $\Lambda = 1400$ and 1000 respectively, together with the only experimental counterpart observed so far. The evaluation of the coupling constants show that the three states found in the $C = 1; S = -1; I = 0$ sector couple strongly to $D^*\overline{K}^*$ (the only possible channel in this sector). This sector is flavor exotic and there is not any experimental counterpart observed yet. In the $C = 1; S = 1$ sector, three states are found for $I = 0$ coupling mostly to D^*K^*, being the other two channels, $D_s^*\omega$ and $D_s^*\phi$, less dominant. For $I = 1$ one state is found that couples to D^*K^* and $D_s^*\rho$, also in this case the D^*K^* contribution is dominant. In this sector, the state with $I = 0$ and $J = 2$ is assigned to the $D_{s2}(2572)$. In the sectors $C = 2; S = 0$ and $C = 2; S = 1$ only one state for $J = 1$ is found for each sector, coupling to D^*D^* and $D^*D_s^*$ respectively. These two sectors are also flavor exotic and there is not any observation of such kind of states up to now.

4 Conclusions

We studied dynamically generated resonances from vector-vector interaction in the charm-strange and hidden-charm sectors and extended for the first time the formalism to flavor exotic sectors. Our analysis of the T matrix resulted in nine bound states, with only one that has an experimental counterpart, the $D^*_{s2}(2573)$. We get new narrow structures with $C = 1$, $S = -1$ and $C = 2$, $S = 0, 1$ that cannot be accomodated in the $q\bar{q}$ spectrum. We encourage to the experimentalist to look for these new flavor exotic states at the PANDA/FAIR facility.

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