Predictions for NDK, $\bar{K}DN$ and $ND\bar{D}$ molecules

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(Dated: January 26, 2012)

In this work baryon systems made of three hadrons which contain one nucleon and one D meson, and in addition another meson, $\bar{D}, K$ or $\bar{K}$, are investigated using the Fixed Center Approximation to the Faddeev equations. In this work we use $\Lambda_c(2595)$, X(3700) and $D^*_{s0}(2317)$ bound states as a cluster and a third particle scattering form that clusters. In all cases we find bound states and quasibound states.

PACS numbers: 14.40.Lb; 14.20.Lq; 21.45.-v

I. INTRODUCTION

The charm sector has not yet been explored for such three body systems and this is the first incursion in that field. For this purpose we have selected systems that have a nucleon and a D meson. The DN system, in collaboration with coupled channels, leads to the formation of a dynamically generated state, the $\Lambda_c(2595)$ [1–4]. On top of it we add a $K, \bar{K}$ or $\bar{D}$ meson and we study the stability of the system. The case of scattering of N on the DK cluster, which is known to generate the $D^*_{s0}(2317)$ [5–7], is also considered. On the other hand, the $D\bar{D}$ system leads to a bound state in isospin I=0 [7], which might have already been observed [8]. We add a nucleon to it and study the interaction of the three body system.

II. MULTI-BODY INTERACTION FORMALISM

The FCA to the Faddeev equations are an effective tool to investigate multi-hadron interaction [9–12]. They are particularly suited to study system where a pair of particles cluster together and the cluster is not much modified by the third particle.

The FCA approximation to Faddeev equations assumes a pair of particles (1 and 2) forming a cluster. Then particle 3 interacts with the components of the cluster, undergoing all possible multiple scattering with those components. This is shown in Fig. 1. First, one defines two partition functions T_1, T_2 which sum all diagrams of the series of Fig. 1 which begin with the interaction of particle 3 with particle 1 of the cluster (T_1), or with the particle 2 (T_2), then the total scattering

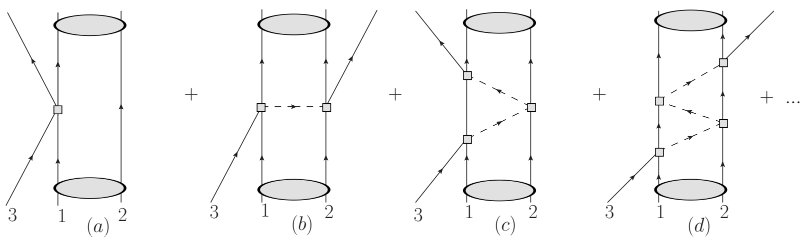

FIG. 1: Diagrammatic representation of the FCA to Faddeev equations. The equivalent diagrams where the particle 3 interacts first with the particle 2 should be added.

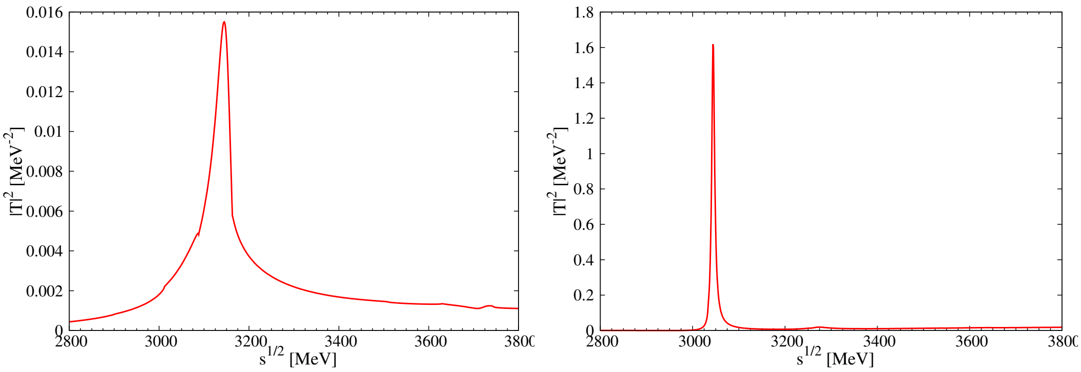

FIG. 2: Modulus squared of the scattering amplitude for $\bar{K}\Lambda_c(2595)$ (left) and $ND^*_{s0}(2317)$ (right).

amplitude is sum of T_1 and T_2.

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

where T is the total three-body scattering amplitude that we are looking for. The amplitudes t_1 and t_2 represent the unitary scattering amplitudes with coupled channels for the interactions of particle 3 with particle 1 and 2, respectively. Besides, G_0 is the propagator of particle 3 between the components of the two-body system. For the detailed formalism one can look at the original paper [13].

III. THE FORMALISM FOR THE FCA IN THE THREE BODY SYSTEM

Our strategy proceeds as follows: first we generate the resonance or bound state in the compound system, then calculate the form factor and G_0 propagator and take the t_1 and t_2 amplitudes from the unitary coupled channel approach, finally the total scattering amplitude T is evaluated.

We investigated two three body scattering, $N-(DK)_{D^*_{s0}(2317)}$ and $K-(DN)_{\Lambda_c(2595)}$, in the NDK system since the resonance $D^*_{s0}(2317)$ is dynamically generated in $I=0$ from KD scattering and the $\Lambda_c(2595)$ is produced in $I=0$ from the DN interaction. The result of the $ND^*_{s0}(2317)$ system is represented in Fig. 2. We found a peak around 3050 MeV which is about 200 MeV below the $D^*_{s0}(2317)$ and N threshold. This reflects the strong attraction in the DN system that leads to the $\Lambda_c(2595)$. The width of the state is smaller than 10 MeV. We do not find a counterpart in the PDG and the quantum numbers, with positive strangeness, correspond to an exotic state. But the combination of $K-(DN)_{\Lambda_c(2595)}$ is too small comparing with the $ND^*_{s0}(2317)$ configuration. This means that the $K(DN)$ configuration in the wave function of the KDN system has a very small weight. Hence, we predict a bound state of NDK mostly made of a N orbiting around a bound DK cluster forming the $D^*_{s0}(2317)$. In Fig. 2 we also show the results of $|T|^2$ for the $\bar{K}\Lambda_c(2595)$ scattering. We find a peak around 3150 MeV, slightly above the threshold of the $\Lambda_c(2595)+\bar{K}$ mass (3088 MeV) and below the threshold of the $\bar{K}DN$ system (3298 MeV). The width of the peak is about 50 MeV. Finally, we obtain the T matrix for the $ND\bar{D}$ interaction by means Eq. (1), and show the results of $|T|^2$ in Fig. 3. From this figure we can see that there is a clear peak of $|T|^2$ around 4400 MeV and the width is very small, less than 10 MeV.

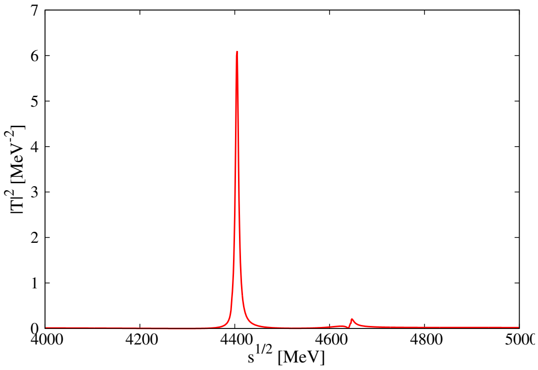

FIG. 3: Modulus squared of the $NX(3700)$ scattering amplitude.

IV. CONCLUSIONS

We have investigated the $\bar{K}DN$, NDK and $ND\bar{D}$ three body systems. In all cases we find bound or quasibound states, relatively narrow, with energies 3150 MeV, 3050 MeV and 4400 MeV, respectively. All these states have $J^P = 1/2^+$ and isospin $I = 1/2$ and differ by their charm or strangeness content, $S = -1, C = 1$, $S = 1, C = 1$, $S = 0, C = 0$, respectively. The first state could perhaps be associated to the $\Xi(3123)$, which has unknown J^P, but the width obtained is a bit too large. The second state is of exotic nature and there is no counterpart in the PDG. The third state is a regular N^* state as to quantum numbers, but it contains hidden charm. It lies in an energy region where baryon states have not yet been investigated. We are thus making predictions in the frontier of this field and hope that with the coming Facilities of FAIR, or the BELLE upgrade, such states can be systematically studied and that our predictions can be confirmed.

Acknowledgments

This work is partly supported by DGICYT contract FIS2006-03438, the Generalitat Valenciana in the program Prometeo and the EU Integrated Infrastructure Initiative Hadron Physics Project under Grant Agreement n.227431. M. Bayar acknowledges support through the Scientific and Technical Research Council (TUBITAK) BIDEP-2219 grant.

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