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$\Delta\rho\pi$ interaction leading to N^* and Δ^* resonances ⋆

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Abstract We have performed a calculation for the three body $\Delta\rho\pi$ system by using the fixed center approximation to Faddeev equations, taking the interaction between Δ and ρ, Δ and π, and ρ and π from the chiral unitary approach. We find several peaks in the modulus squared of the three-body scattering amplitude, indicating the existence of resonances, which can be associated to known $I = 1/2, 3/2$ and $J^P = 1/2^+, 3/2^+$ and $5/2^+$ baryon states.

Keywords Fixed center approximation · Three body system · Chiral unitary model

1 Introduction

Our knowledge on the baryon resonances mainly comes from πN experiments and is still under debate [1,2,3,4]. The information extracted from photon nucleon reactions have helped in making progress in this field, reconforming many known resonances and claiming evidence for new ones [5,6,7,8,9,10,11]. The fact that some known resonances are explained in terms of three body systems of two mesons and one baryon [12,13] should certainly stimulate work looking for resonances in three body final states of reactions. In this sense a suggestion is made in [14] to look for a predicted state of $N\bar{K}K$ [15,16] in the $\gamma p \to K^+K^-p$ reaction close to threshold.

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The main aim of the present work is to investigate the three-body $\Delta\rho\pi$ system considering the interaction of the three components among themselves keeping in mind the expected strong correlations of the $\Delta\rho$ system which generate the N^* and/or Δ^* bound states. For this purpose, we have solved the Faddeev equations by using the fixed center approximation(FCA) in terms of two body $\Delta\pi$ and $\rho\pi$ scattering amplitudes.

The FCA to the Faddeev equations is a tool which has proved to be efficient and accurate to study the interaction of particles with bound states of a pair of particles at very low energies, or below threshold [17,18,19,20]. Recently, this approach was used in Ref. [21] to describe the $f_2(1270)$, $\rho_3(1690)$, $f_4(2050)$, $\rho_5(2350)$ and $f_6(2510)$ resonances as multi-$\rho(770)$ states, and in Ref. [22] to study the $K_2^*(1430)$, $K_3^*(1780)$, $K_4^*(2045)$, $K_5^*(2380)$, and a not yet discovered K_6^* resonances as K^*-multi$-\rho$ states. The success of these works encourages us to extend the method to study the present $\Delta\rho\pi$ system.

2 Formalism and results

For the three body $\Delta\rho\pi$ system, we consider $\Delta\rho$ as a bound state of $N^*(I_{\Delta\rho} = 1/2)$ resonance or $\Delta^*(I_{\Delta\rho} = 3/2)$ resonance, which allows us to use the FCA to solve the Faddeev equations. The external π meson interacts successively with the Δ baryon and the ρ meson which form the $\Delta\rho$ cluster. In terms of two partition functions T_1 and T_2, the FCA equations are

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

$$T_2 = t_2 + t_2 G_0 T_1, \tag{2}$$

$$T = T_1 + T_2, \tag{3}$$

where T is the total three-body scattering amplitude and $T_i (i = 1, 2)$ accounts for the diagrams starting with the interaction of the external particle with the particle i of the compound system and t_i represents the two body $\Delta\pi$ and $\rho\pi$ unitarized scattering amplitudes.

Next, we will show the results obtained from the scattering amplitude of the $\Delta\rho\pi$ system. We evaluate the scattering amplitude T matrix of Eq. (3) and associate the peaks of $|T|^2$ to resonances. In table 1 we show a summary of the findings obtained from our model and the tentative association to known states [1].

3 Discussions and Conclusions

We have performed a Faddeev calculation for the three body $\Delta\rho\pi$ system by using the fixed center approximation, taking the interaction between Δ and ρ, Δ and π, and ρ and π from the chiral unitary approach. The $\Delta\rho$ interaction within the framework of the hidden-gauge formalism in $I = 1/2$ sector describes the $N^*(1675) J^P = 5/2^-$ as a $\Delta\rho$ bound state, then we write the three-body interaction in terms of two-body ($\Delta\pi$ and $\rho\pi$) $s-$wave scattering amplitudes based on the chiral Lagrangians. The three body states found are degenerated in $J^P = 1/2^+, 3/2^+, 5/2^+$. We found candidates in the PDG book which can be associated to the states obtained, but one of them, with isospin 3/2 and mass around 2000 MeV, is missing. It is very interesting to observe

Table 1 The properties of the generated resonances with our model and their possible PDG counterparts.

$I_{\Delta\rho}, I_{total}$	Mass of our model(MeV)	PDG data name	J^P	mass(MeV)	status
$\frac{1}{2}, \frac{1}{2}$	~ 1850	$N^*(1900)$	$3/2^+$	1900	**
$\frac{1}{2}, \frac{3}{2}$	~ 1800	$\Delta^*(1750)$	$1/2^+$	1750	*
		$\Delta^*(2000)^?$	$5/2^+$	1724 ± 61	Ref. [23]
		$\Delta^*(2000)^?$	$5/2^+$	1752 ± 32	Ref. [24]
	~ 1900	$\Delta^*(1905)$	$5/2^+$	$1865 - 1915$	****
		$\Delta^*(1920)$	$3/2^+$	$1900 - 1970$	***
	~ 2200	$\Delta^*(2000)^?$	$5/2^+$	2200 ± 125	Ref. [25]
$\frac{3}{2}, \frac{1}{2}$	~ 2000	$N^*(2000)$	$5/2^+$	2000	**
$\frac{3}{2}, \frac{3}{2}$	~ 2000	?	?	?	?

that, even if the $\Delta\rho\pi$ system allows for $I = 5/2$, the dynamics of the system precludes the formation of these exotic states.

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