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 $\Delta$ and $\rho$, $\Delta$ and $\pi$, and $\rho$ and $\pi$ 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 $I = \frac{1}{2}, \frac{3}{2}$ and $J^P = \frac{1}{2}^+, \frac{3}{2}^+$ 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 $\pi N$ 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 $\gamma p \rightarrow K^+K^- p$ 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 \( \Delta^* \) 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-\( \rho \) 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 \( \pi \) meson interacts successively with the \( \Delta \) baryon and the \( \rho \) meson which form the \( \Delta \rho \) cluster. In terms of two partition functions \( T_1 \) and \( T_2 \), the FCA equations are

\[
T_1 = t_1 + t_1 G_0 T_2, \quad (1)
\]
\[
T_2 = t_2 + t_2 G_0 T_1, \quad (2)
\]
\[
T = T_1 + T_2, \quad (3)
\]

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 \([\text{I}]\) we show a summary of the findings obtained from our model and the tentative association to known states \([\text{II}]\).

### 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 \( \Delta \) and \( \rho \), \( \Delta \) and \( \pi \), and \( \rho \) and \( \pi \) 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.

<table>
<thead>
<tr>
<th>$I\Delta \rho, I_{\text{total}}$</th>
<th>Mass of our model(MeV)</th>
<th>Name</th>
<th>$J^P$</th>
<th>Mass(MeV)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{1}{2}, \frac{3}{2}$</td>
<td>$\sim 1850$</td>
<td>$N^*(1900)$</td>
<td>$3/2^+$</td>
<td>1900</td>
<td>**</td>
</tr>
<tr>
<td>$\frac{1}{2}, \frac{1}{2}$</td>
<td>$\sim 1800$</td>
<td>$\Delta^*(1750)$</td>
<td>$1/2^+$</td>
<td>1750</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\Delta^*(2000)$</td>
<td>$5/2^+$</td>
<td>1724 ± 61</td>
<td>Ref. [23]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\Delta^*(2000)$</td>
<td>$5/2^+$</td>
<td>1752 ± 32</td>
<td>Ref. [24]</td>
</tr>
<tr>
<td>$\frac{1}{2}, 1$</td>
<td>$\sim 1900$</td>
<td>$\Delta^*(1905)$</td>
<td>$5/2^+$</td>
<td>1865 – 1915</td>
<td>****</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\Delta^*(1920)$</td>
<td>$3/2^+$</td>
<td>1900 – 1970</td>
<td>****</td>
</tr>
<tr>
<td></td>
<td>$\sim 2200$</td>
<td>$\Delta^*(2000)$</td>
<td>$5/2^+$</td>
<td>2200 ± 125</td>
<td>Ref. [25]</td>
</tr>
<tr>
<td>$\frac{3}{2}, \frac{1}{2}$</td>
<td>$\sim 2000$</td>
<td>$N^*(2000)$</td>
<td>$5/2^+$</td>
<td>2000</td>
<td>**</td>
</tr>
<tr>
<td>$\frac{3}{2}, \frac{3}{2}$</td>
<td>$\sim 2000$</td>
<td>$?$</td>
<td>$?$</td>
<td>$?$</td>
<td>$?$</td>
</tr>
</tbody>
</table>

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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References

21. L. Roca and E. Oset, “A description of the $f_0(1270), p_0(1690), f_4(2050), p_4(2350)$ and $f_6(2510)$ resonances as multi-$\rho(770)$ states,” Phys. Rev. D 82, 054013 (2010).