MESON PRODUCTION IN BARYON NUMBER=2 SYSTEMS*

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The πNN dynamics generates a strong and narrow structure in the cross section of three-body processes in the $I = 0$, $J^P = 0^-$ πNN system at mass $M = 2.06 - 2.09$ GeV with width 30-50 MeV. The origin is the three-body interaction due to the NN^1S_0 and πNS_{11} interactions in the subsystems.

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1. 1. Introduction

An interesting subject on πNN system is whether the system has any resonance or quasi-bound state [1, 2]. The experimental evidences have been reported by Argonne and other groups [3]. We ask whether they need explicitly subhadronic degree to be explained. So far we have studied this problem in the πNN dynamics [2, 4], where we take into account the three-body channels of both πN interacting pair with N spectator and NN interacting pair with π spectator and also the two nucleon channels in a unified and unitary framework.

In 1982, we investigated the analytic structure on the complex energy plane for the NN partial wave amplitudes due to the πNN dynamics [4]. We find a pole at the mass $2116-i61$ MeV for $I = 1, J^P = 2^+$ amplitude and a pole at the mass $2155 - i60$ MeV for $I = 1, J^P = 3^-$ amplitude. Thus it is concluded that the genuine resonances are there. Furthermore, the structures observed in the energy dependence of the $\Delta\sigma_L$ data are reproduced [2].

More recently Bilger et al has reported an evidence for a narrow width πNN resonance near pion threshold in pionic double charge exchange nuclear reactions [5]. They suggest that it is in the $I = 0$, $J^P = 0^-$ channel which decouples with the NN channel.

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In this paper we investigate whether the πNN dynamics generates a resonance in the $I = 0$, $J^P = 0^-$ channel. Near the pion threshold two configurations dominate in the $I = 0$, $J^P = 0^-$ πNN system: One involves NN interacting pair of the ${}^1S_0$ state with the remaining pion in the S state with respect to the NN pair. The other involves πN interacting pair of the S_{11} state with the remaining nucleon in the S state with respect to the πN pair. Let us label the former and latter configurations as $\pi(NN)$ ${}^1S_0$ and $N(\pi N)$ S_{11}.

2. Formulation

The AGS equation for the πNN system is written for anti-symmetrized amplitudes $X_{\alpha\beta}$ as follows.

$$X_{\alpha\beta} = Z_{\alpha\beta} + \sum_{\gamma} Z_{\alpha\gamma}\tau_\gamma X_{\gamma\beta}, \tag{1}$$

where $Z_{\alpha\beta}$ is the particle rearrangement terms and τ_γ is the propagater terms. The α, β and γ denote particle channels: Presently $\pi(NN)$ ${}^1S_0$ and $N(\pi N)$ S_{11}.

For πN S_{11} interaction we use a separable potential which has rank one and one channel form and works enough well for the incident pion laboratory energies, $E_L^\pi \leq 400$ MeV. For the NN ${}^1S_0$ interaction we use the ${}^1S_0$ interaction due to OBEP which is converted to rank two separable form by keeping the same off-shell structure as the original OBEP [6].

$Z_{\alpha\beta}$ in Eq. (1) involves the arguements of $\vec{q}_\alpha(\vec{q}_\beta)$ and E where $\vec{q}_\alpha(\vec{q}_\beta)$ is the relative momentum between an interacting pair and a remaining particle in channel $\alpha(\beta)$ and E is the total three-body kinetic energy. The relative momentum $\vec{p}_\alpha(\vec{p}_\beta)$ between the particles making a pair in channel $\alpha(\beta)$ is fixed by $\vec{q}_\alpha$ and $\vec{q}_\beta$ in the term $Z_{\alpha\beta}$ for the full off-energy shell case.

We will investigate the energy dependent structure of the half off-energy shell amplitudes where the final πNN state is on energy shell: $E = E_\pi(k_\pi) + E_1(k_1) + E_2(k_2)$, while the initial state is off energy shell. A partial wave ampltitude for a three-body eigenstate is derived from Eq. (1) as follows.

$$X_{\alpha\beta}(q_\alpha, q_\beta, E) = Z_{\alpha\beta}(q_\alpha, q_\beta, E) + \sum_{n=1}^{\infty} Z_{\alpha 1}(q_\alpha, q_1, E)\tau(w(q_1))$$

$$Z_{12}(q_1, q_2, E)\tau(w(q_2))Z_{23}(q_2, q_3, E)\ldots\tau(w(q_n))Z_{n\beta}(q_n, q_\beta, E), \tag{2}$$

where the integrations are understood with respect to the variables $q_1, \ldots, q_n$. The relative momentum $\vec{q}_\alpha$ in the final state is put on energy shell, while the relative momentum $\vec{q}_\beta$ is put off energy shell. Since in Eq. (1) the integration with respect to the relative momentum $\vec{q}$ in the intermediate state is made along a deformed path for complex variable $q = |q|e^{-i\phi}$, we put also q_β in Eq. (2) as a complex variable: $q_\beta = |q_\beta|e^{-i\phi}$.

In order to see the energy dependence, we define the two amplitudes averaged over the magnitude of the final relative momentum q_α:

$$\bar{X}_1(\alpha, \beta; q_\beta; E) = K(E)\ q_m^{-1} \int_0^{q_m} dq_\alpha X_{\alpha\beta}(q_\alpha, q_\beta, E), \tag{3}$$

$$\bar{X}_2(\alpha, \beta; q_\beta; E) = K(E)\ q_m^{-1} \int_0^{q_m} dq_\alpha\ g_\alpha(p_\alpha)\ \tau(w_\alpha(q_\alpha))\ X_{\alpha\beta}(q_\alpha, q_\beta, E), \tag{4}$$

where $\bar{X}_1$ and $\bar{X}_2$ are the averaged amplitudes without and with the final state interaction respectively; q_m in Eqs. (3) and (4) is the maximum magnitude of the relative momentum q_α; $g_\alpha(p_\alpha)$ in the right-hand side in Eq. (4) is the form factor. A kinematical factor due to the phase space, $K(E)$, is multiplied in the right-hand side in Eqs. (3) and (4), where $K(E) = E$.

Let us define a pseudo partial cross section corresponding to the partial wave amplitude $\bar{X}_2(\alpha, \beta; q_\beta; E)$ as follows,

$$\sigma(\alpha, \beta; q_\beta; E) = |\bar{X}_2(\alpha, \beta; q_\beta; E)|^2. \tag{5}$$

3. Numerical results and conclusion

We have investigated the partial wave-amplitudes $\bar{X}_i(\alpha, \beta; q_\beta; E)$ of $I = 0$, $J^P = 0^-$, where α and β are taken over $N(\pi N)\ S_{11}$ and $\pi(NN)\ {}^1S_0$ three-body channels. We find that major amplitudes are the ones for the two transitions from $\beta = N(\pi N)\ S_{11}$ to $\alpha = N(\pi N)\ S_{11}$ and $\alpha = \pi(NN)\ {}^1S_0$. Let us denote these amplitudes as $\bar{X}_i(S_{11}; q_\beta; E)$ and $\bar{X}_i({}^1S_0; q_\beta; E)$ with i=1 and 2.

We made Argand plots of these amplitudes at $q_\beta = 0.92 - i0.18$ fm^{-1} and at $E = 10 - 160$ MeV. We find that all the amplitudes make anti-clock wise looping.

We show the pseudo partial cross sections in Fig. 1. We find a strong and narrow structure in both $\sigma(S_{11}; E)$ and $\sigma({}^1S_0; E)$.

In conclusion we have found that the πNN dynamics generates a strong and narrow structure in the $I = 0$, $J^P = 0^-$ πNN amplitude with width 30-50 MeV at $E = 40 - 70$ MeV ($M = 2.06 - 2.09$ GeV). The structure is generated by the $NN\ {}^1S_0$ and $\pi N\ S_{11}$ interactions in the πNN system.

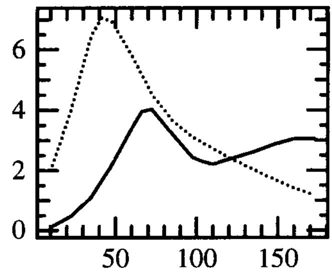

Fig. 1. The pseudo partial cross sections for the transitions from $N(\pi N)S_{11}$ to $N(\pi N)S_{11}$ and $\pi(NN)^1S_0$ are shown by solid and dotted curves respectively. The abscissa indicates the total kinetic energy E in CMS in units of MeV.

It is likely that the dibaryon evidence suggested by Bilger et al is closely related with the structure found in this paper.

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