MULTIBARYON RESONANCES WITH B > 5 IN THE MODEL WITH EXCHANGE Δ-N INTERACTION

V.A. Karmanov
Moscow Engineering Physics Institute
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In the present paper we consider multibaryon resonances consisting of the Δ isobar and A nucleons, in a model with the exchange Δ-N potential introduced in [1]. It was shown in [1 - 4] that if the isobar is regarded as a system consisting of a pion and a nucleon, then the interaction of the isobar with the nucleon is determined mainly by the existence of the decay interaction $\Delta \to N\pi$. It turned out that in this case the Δ-N interaction can be described with the aid of a complex potential corresponding to the diagram of Fig. 1, and the problem can be reduced to a solution of the Schrodinger equation with this potential. In [3 - 5] they considered the systems (ΔN), (Δ2N), (Δ3N), and (Δ4N) and it was found that only in the (Δ3N) system with quantum numbers T = 1, $I^P = 1^+$ is the attraction sufficiently strong in order for the existence of the baryon resonance to be probable. It is shown in the present paper that in the system (ΔAN) with A > 4 (B > 5) the increase of the atomic weight A does not lead to an appreciable growth of the potential between the isobar and the nucleus, compared with the potential between the Δ isobar and He^4, making the probable existence of resonances in the system (ΔAN) with A > 4 low.

We shall investigate the interaction of the Δ isobar with the nucleus with the aid of the Schrodinger equation

$$\left\{-\sum_{i=1}^{A}\frac{\hbar^2}{2m}\nabla_i^2 - \frac{\hbar^2}{2m_\Delta}\nabla_\Delta^2 + \sum_{i>j}\hat{V}(ij) + \sum_{i=1}^{A}\hat{V}(i\Delta)\right\}\psi(1,\dots A;\Delta) = E\psi(1,\dots A;\Delta). \qquad (1)$$

The sum $\sum_{i>j}\hat{V}(ij)$ corresponds to the nucleon-nucleon interaction, and the sum $\sum_{i=1}^{A}\hat{V}(i\Delta)$ to the interaction between the nucleons and the isobar. The Δ-N potential obtained in [1] has the following form:

$$V^{s\sigma,\,T\tau}_{s'\sigma',\,T'\tau'}(\mathbf{r}) = 2\sqrt{\frac{\pi}{3}}\sum V_L(r)\,C^{(3/2)s'}_{(1/2)\sigma 1m}\,C^{(3/2)s}_{(1/2)\sigma' 1m'}\,C^{L0}_{10\,10}\,C^{1m'}_{LM|m}\,Y_{LM}(\mathbf{n}) \times C^{(3/2)T'}_{(1/2)\tau 1n}\,C^{(3/2)T}_{(1/2)\tau' 1n}\,\hat{P}_{N\Delta}, \qquad (2)$$

where $\hat{P}_{N\Delta}$ is the operator of the permutation of the spatial coordinates of the isobar and the nucleon. Plots of the functions $V_L(r)$ (L = 0.2) are given in [1]. We neglect the imaginary part of the potential.

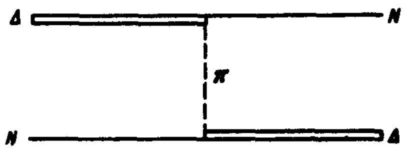

Fig. 1

We shall solve the problem of the eigenvalues of Eq. (1) by the method of K harmonics, developed in [6 - 8], in the approximation $K = K_{min}$. In this approximation, to find the solution of (1) it suffices to solve the equation for the radial functions $\chi_{k\gamma}(\rho)$:

$$\left[\frac{d^2\chi_{K\gamma}(\rho)}{d\rho^2}+\left(\frac{2m}{\hbar^2}E-\frac{L_K(L_K+1)}{\rho^2}-\frac{2m}{\hbar^2}W_{K\gamma}(\rho)\right)\right]\chi_{K\gamma}(\rho)$$

$$=\frac{2m}{\hbar^2}\sum_{\gamma'\neq\gamma}W^{K\gamma'}_{K\gamma}\chi_{K\gamma'}(\rho), \quad (3)$$

where

$$L_K=K_{min}+\frac{3}{2}(A-1);\ W^{K\gamma'}_{K\gamma}(\rho)=\int d\Omega\tilde{u}_{K\gamma'}(\Sigma\hat{V})u_{K\gamma}.$$

The matrix element of the sum of the potentials $\sum_{i=1}^{A}\hat{V}(i\Delta)$, corresponding to the interaction of the isobar and the nucleus, is calculated in analogy with matrix elements in [8] and takes the following form for nuclei with closed shells:

$$W(\rho)=\int\tilde{u}_{K_{min}}(\Omega)\left(\sum_{i=1}^{A}\hat{V}(i\Delta)\right)u_{K_{min}}(\Omega)\,d\Omega=\sum_{\bar{n}}W_{\bar{n}}(\rho),$$

$$W_{\bar{n}}(\rho)=-\frac{1}{3}\sum_{\substack{n\ell m\\ 2n+\ell=\bar{n}}}\int\exp[-r_1^2/b^2]\,\Phi^*_{n\ell m}(r_1)V_0(r_1-r_2)\exp[(-r_2^2/b^2)$$
$$\times(m_\Delta/m_N)]\,\Phi_{n\ell m}(r_2)\,dr_1dr_2, \quad (4)$$

where

$$\Phi_{n\ell m}(\mathbf{r})=\left[\frac{2n!}{\Gamma(n+\ell+\frac{3}{2})}\right]^{1/2}\frac{1}{b^{3/2}}\left(\frac{r}{b}\right)^{\ell}Y_{\ell m}\left(\frac{\mathbf{r}}{r}\right)$$
$$\times L_n^{(\ell+1/2)}\left(\frac{r^2}{b^2}\right),$$

$L_n^{(\ell+1/2)}(r^2/b^2)$ is the Laguerre polynomial and $b=\rho/\sqrt{K_{min}+(3/2)A}$. The action of the permutation operator $\hat{P}_{N\Delta}$ has already been taken into account. The calculation of the sum over the spin-isospin indices yielded -1/3. The function $V_2(r)$ did not enter in the result. Were we to have $V_L(r)\equiv 1$, then $W_{\bar{n}}(\rho)\equiv 0$ for $\bar{n}>0$, for by virtue of the orthogonality we have $\int\Phi_{n\ell m}(\vec{r})\exp(-r^2/b^2)d\vec{r}=0$. This circumstance leads to a decrease of $W_{\bar{n}}(\rho)$ with $n>0$ compared with $W_0(\rho)$, and also with the fact that $W_{\bar{n}}(0)=0$ for $\bar{n}>0$. We emphasize that this effect is due to the presence in the Δ-N potential of the permutation operator of the spatial coordinates of the nucleon and of the isobar. The sum over $\bar{n}$ for the nucleus He^4 ($K_{min}=0$) contains only one term with $\bar{n}=0$, for O^{16} ($K_{min}=12$) there are two terms with $\bar{n}=0$ and 1, and for Ca^{40} ($K_{min}=60$) there are three terms with $\bar{n}=0$, 1, and 2, the main contribution being made by the term $W_0(\rho)$.

Figure 2 shows the values of $W_{\bar{n}}$ as a function of $b=\rho/\sqrt{K_{min}+(3/2)A}$. Curve 1 corresponds to W_0, curve 2 to W_1, and curve 3 to W_2. All the $W_{\bar{n}}(\rho)>0$, therefore the isobar is repelled from the nuclei with closed shells. In the calculation of $W_{\bar{n}}$, the potential $V_0(r)$ was approximated by a triangular well:

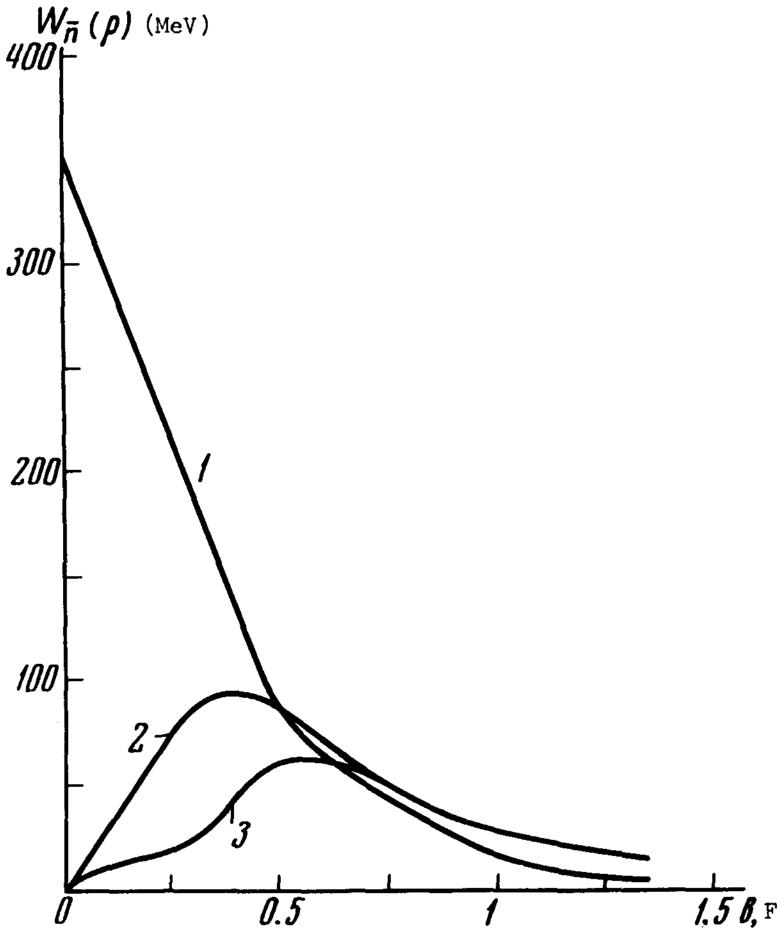

Fig. 2

$$V_0(r) = \begin{cases} -V_0\left(1 - \frac{r}{a}\right), & r < a \\ 0, & r > a \end{cases} \qquad (5)$$

where V_0 = 1080 MeV and a = 1 F.

The mass difference between the isobar and the nucleon was neglected. Without this neglect, the functions $W_{\bar{n}}(\rho)$ change by an amount on the order of $(m_\Delta - m_N)/m_\Delta$.

We now consider nuclei with $4 < A < 16$, with unclosed shell. The potential energy of the interaction of the isobar and the nucleus can in this case be written in the form of two terms, $W(\rho) = W_0(\rho) + W'(\rho)$. The function $W'(\rho)$ is made up of terms of the same type as $W_1(\rho)$, but the terms constituting $W'(\rho)$ may contain coefficients that can make $W'(\rho)$ assume a sign corresponding to attraction. However, $W'(\rho)$ is of the order of $W_1(\rho)$, and it is therefore difficult to expect $W'(\rho)$ to be comparable in magnitude with the strong "repulsion term" $W_0(\rho)$ or exceed it to such an extent that it would lead to the formation of a bound state.

The same reasoning holds for nuclei with $16 < A < 40$, the only difference being that in this case the potential energy is given by $W(\rho) = W_0(\rho) + W_1(\rho) + W''(\rho)$, where $W''(\rho)$, which is analogous in its origin to $W'(\rho)$, is of the same order as $W_2(\rho)$ and must already compete with the sum $W_0(\rho) + W_1(\rho)$. Therefore the formation of resonances in this region is even less probable.

A similar situation holds for nuclei with $A > 40$.

Thus, in the model with exchange Δ-N interaction, the attraction between the Δ isobar and the nucleus is not sufficient for the formation of the bound state, and therefore the existence of resonances in the system (ΔAN) with $A > 4$ is not highly probable.

To obtain this result we used the approximation $K = K_{min}$ of the K-harmonics method, which is a poor approximation because Δ and N are not identical for the system in question. However, the obtained limitation of the growth of the interaction between the Δ isobar and the nucleus has a general character which does not depend on the employed approximation. It is the consequence of the presence in the Δ-N potential of the operator of permutation of the spatial coordinates of the isobar and the nucleon, just as a saturation of the nuclear forces is a consequence of the fact that the nucleon-nucleon Majorana potential contains the operator of permutation of the spatial coordinates of the nucleons.

If multibaryon resonances are ever observed, this will mean that there exists between the isobar and the nucleon an interaction that does not reduce to either the exchange or to induced interaction.

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POSSIBILITY OF OBSERVING QUASINUCLEAR MESON RESONANCES IN COLLIDING e^+e^- BEAMS

O.D. Dal'karov, V.B. Mandel'tsveig, and V.A. Khoze
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In recent papers [1 - 3] there was proposed a mechanism for the formation of quasinuclear meson resonances, which were regarded as nonrelativistic bound states in the $N\bar{N}$ system. Among these there are four mesons with photon quantum numbers ($J^{PC} = 1$). Two of these mesons corresponding to the $^{33}S_1(1727)$ and $^{33}d_1(1855)$ states of the $N\bar{N}$ system with respective widths 94 and 117 MeV have an isospin $I = 1$ and positive G parity, while the other two mesons have negative G parity, $I = 0$, and correspond to the $^{13}S_1(1414)$ and $^{13}d_1(1382)$ states of the $N\bar{N}$ system with widths 63 and 71 MeV. From the quasinuclear nature of the considered meson resonances it follows, in particular, that a correspondence should occur between the partial widths of the decays of the resonances and the cross sections for the annihilation in the same states where, as is well known