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NEW TYPE OF BARYON RESONANCES

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In [1 - 4] there were considered nonrelativistic (quasinuclear) bound states of the nucleon-antinucleon system, i.e., boson resonances with masses close to two nucleons (from 1300 to 1860 MeV). It was found that the spectrum of these bosons includes 17 particles with isospins $I \leq 1$, spins $J \leq 3$, and widths Γ from 60 to 150 MeV.

In the present paper we report results of an analysis of quasinuclear bound states of a system of three particles - two nucleons and one antinucleon ($2N\bar{N}$). Such systems have a baryon number $B = 1$ and should appear as baryon resonances with masses in the region 2 - 3 GeV. A distinguishing feature of these baryon resonances is that the decay channel $N^* \rightarrow N + X$ (X is one of the light bosons π , η , or ρ) should not be dominating for these resonances. Therefore the quasinuclear baryon resonances can hardly appear in πN scattering. The most probable should be decays into a nucleon and several (4 - 5) pions (more accurately, into a nucleon plus the annihilation products of the $N\bar{N}$ pair in definite states).

For a theoretical investigation of the quasinuclear states of the $2N\bar{N}$ system, we use in the present paper a potential approach: we take as the interaction Hamiltonian the sum of the pair potentials

$$H = V(r_{NN}) + \bar{V}(r_{N\bar{N}}) + \bar{V}(r_{N'\bar{N}}) \quad (1)$$

Here V and \bar{V} are the Bryan-Scott (BS) [5] and Bryan-Phillips (BP) [6] potentials for the NN and $N\bar{N}$ interactions. These potentials, which are modifications of the OBEP, describe satisfactorily the experimental data on the NN and $N\bar{N}$ scattering, and can be transformed into each other by G-conjugation. The BP potential was used in the cited papers on the NN quasinuclear bound states.

Two primary questions arise in connection with the $2N\bar{N}$ systems: a) does the Hamiltonian (1) yield nonrelativistic bound states, and b) of what order of magnitude are the widths of such states? The first question is connected with the fact that even in the $N\bar{N}$ system the binding energy is on the average much larger than for ordinary nuclei. It might therefore turn out that the binding energy per particle in the $2N\bar{N}$ system is larger than the mass of the nucleon and consequently there exists no nonrelativistic approach to the theory of such systems. The question of the widths is not trivial for the following reason: at first glance it seems that the annihilation width of the $2N\bar{N}$ system should be 1.5 - 2 times larger than the width of the NN two-particle state. Since the latter itself reaches 150 MeV, the expected width of the quasinuclear baryons turns out to be on the order of 300 MeV. But then a relatively small (by a factor 1.5) increase of the particle density in the annihilation region may turn out to be critical for the existence of the resonance.

The energy spectrum and the wave functions of the $2N\bar{N}$ system were investigated by us with the aid of the multidimensional harmonic method [7]. The wave function was constructed in a multidimensional harmonic basis with allowance for the generalized Pauli principle. According to this principle, the wave function of the $2N\bar{N}$ system should be antisymmetrical against permutation of the coordinates, spins, isospins, and baryon charges of any two particles. Thus, the wave function is represented in the form of the series

$$\Psi(N, N', \bar{N}) = \rho^{-3/2} \sum_{K\nu} \chi_{K\nu}(\rho) U_{K\nu}(\Omega) \phi_{\nu} \quad (2)$$

of which the first few terms were retained. In formula (2), ρ denotes the collective radial variable

$$\rho^2 = \frac{1}{3} (r_{NN'}^2 + r_{N\bar{N}}^2 + r_{N'\bar{N}}^2) \quad (3)$$

Ω is the aggregate of the angle variables of the three particles, K is the degree of harmonic polynomial $\rho^K U_{K\nu}(\Omega)$, ν is a set of quantum numbers characterizing the $2N\bar{N}$ system and ϕ_{ν} is the part of the total wave function containing the spin, isospin, and charge variables of the three particles. The radial functions $\chi_{K\nu}(\rho)$ satisfy a system of coupled one-dimensional Schrodinger equations (the Hamiltonian (1) goes over into a matrix, the order of which depends on the number of terms retained in the expansion (2)). From the general analysis of the convergence of the method of multidimensional harmonics it follows that at the expected binding energies per particle on the order of 100 - 200 MeV, a 10% accuracy in the calculation of the energy spectrum can be obtained by retaining 5 - 7 terms of the harmonic series (2). Since, however, we can satisfy ourselves with much lower accuracy (on the order of 50 - 100%) in order to answer the foregoing questions, the calculations in the present paper were carried out using three harmonics ($K = 0, 1, 2$). The problem reduces then to a solution of fourteen equations of the Schrodinger type, the maximum order of the matrix, which plays in these equations the role of the interaction Hamiltonian, is equal to eight. In the present article we present the results of the calculation of the spectrum of the levels for states with quantum numbers $I(J^P) = 3/2 (5/2^+)$ (see the table). In this case the Hamiltonian turns out to be a matrix of first order (owing to the maximum spin and isospin symmetry of the Ψ function). As seen from the table, some bound states of the $2NN$ system are characterized by the presence of nodes with respect to the collective radial variable ρ , whereas all the bound states of the two-particle system NN are without nodes (see [1 - 4]). The appearance of nodes with respect to ρ is connected with the fact that the depth and width of the effective potential well in ρ -space is much larger than for the NN interaction.

Bound States in the $2NN$ System with Quantum Numbers $I(J^P) = 3/2(5/2^+)$

Mass, MeV	Width, MeV	Nodes of wave function
2090	710	0
2540	450	1
2740	180	2
2800	40	3

The level widths are calculated from the formula ($\hbar = c = 1$)

$$\Gamma = (v\sigma_a)_{v \rightarrow 0} \int | \Psi(NN'\bar{N}) |^2 \delta(r_{N\bar{N}}) + | \Psi(NN\bar{N}) |^2 \delta(r_{N'\bar{N}}) d\vec{\eta} d\vec{\xi} \quad (4)$$

Here v and σ_a are the NN relative velocity and annihilation cross section ($(v\sigma_a)_{v \rightarrow 0} = 45$), $\vec{\eta}$ and $\vec{\xi}$ are the Jacobi coordinates of the three-body problem. Formula (4) is valid if the annihilation radius r_a is much smaller than the radius of action of the forces (1) ($r_a \approx 1/M$, $R \approx 1/\mu$, where M and μ are the

masses of the pion and the nucleon). Under this significant assumption we calculated also the binding energies (the annihilation shift was not calculated - its order of magnitude is $\leq \Gamma$, see [3, 4]). It is seen from the table that the widths Γ decrease strongly with increasing number of nodes. This can be readily understood by bearing in mind that, as follows from [4], Γ is inversely proportional to the cube of the radius of the orbit in p space (which increases with increasing number of nodes). In view of the cutoff of the harmonic series (2), the masses and apparently also the widths given in the table are higher than the true ones. This, however, can hardly change the main conclusion, namely that the calculations point to the existence of sufficiently narrow bound quasinuclear states in the three-particle system 2NN. Thus, the quasinuclear model predicts baryon resonances of a new type.

The results of the present paper make quite likely the hypothesis of existence of four-particle quasinuclear systems of the type $2N.2\bar{N}$, which could appear as boson resonances with isospin $I \leq 2$ and with masses in the interval 2500 - 3500 MeV.

A detailed exposition of the work is being planned in another article. The authors are grateful to S.I. Guseva, A.I. Volovik, V.E. Maiorov, and I.A. Rumyantsev for help in the numerical calculations, and L.N. Bogdanova, V.A. Karmanov, and L.A. Kondratyuk for useful discussions.

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CORRELATIONS BETWEEN REDUCED NEUTRON AND RADIATIVE WIDTHS ON NEUTRON RESONANCES IN COMPOUND NUCLEI WITH ODD NUMBER OF NEUTRONS

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There has been increased interest recently in experimental determination of the correlations between the reduced neutron widths Γ_{n1}^0 and the reduced partial radiative widths $\Gamma_{\gamma 1f}^0$ on neutron resonances (see [1 - 3]). This question was considered theoretically in [4, 5]. In [5], the correlations between Γ_{n1}^0 and $\Gamma_{\gamma 1f}^0$ were investigated on the basis of the semi-microscopic approach developed in [6, 7]. In the present note we consider cases convenient for experimental study, when large correlations can occur between Γ_{n1}^0 and $\Gamma_{\gamma 1f}^0$ on neutron s and p resonances for compound nuclei with odd neutron numbers.

We regard the (n, γ) reaction as a two-step reaction: first neutron capture, followed by $E1$ or $M1$ transitions. According to [5, 7], the correlations between Γ_{n1}^0 and $\Gamma_{\gamma 1f}^0$ take place in those cases when the main contribution to both processes is made by the same components of the wave functions of the