CAN TETRANEUTRON EXIST FROM THEORETICAL POINT OF VIEW?

I.V. SIMENOG[1,2], B.E. GRINYUK[1], YU.M. BIDASYUK[2]

[1]**M.M. Bogolyubov Institute for Theoretical Physics, Nat. Acad. Sci. of Ukraine**
(14b, Metrolohichna Str., Kyiv 03143, Ukraine;
e-mail: ivsimenog@bitp.kiev.ua; bgrinyuk@bitp.kiev.ua),

[2]**Taras Shevchenko Kyiv National University**
(6, Academician Glushkov Prosp., Kyiv 03127, Ukraine)

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To study the problem of the possible existence of a tetraneutron, we show that a system of four Fermi-particles can be bound, whereas two-particle subsystems are unbound in the case where the pairwise interaction potential contains two attractive wells separated by a repulsive barrier. We fit the parameters of the proposed class of potentials by the low-energy neutron-neutron parameters and study the properties of a hypothetical tetraneutron. The anomalous behaviours are revealed for the calculated size, density distribution, and pair correlation functions of the hypothetical "tetraneutron" within the proposed models of interaction.

1. Introduction

The mysterious fact of the experimental registration of tetraneutrons [1–3] in a reaction with loosely bound radioactive ^{14}Be renewed the attention to the theoretical attempts of understanding the problem of hypothetical bound neutron systems and possible resonances in these systems. It is important that, in reactions with other nuclei [1, 3, 4], there were found no indications of the existence of nuclear-stable or resonant states of ^{3}n and ^{4}n (till recently, there was available only one experimental work [5] claiming the existence of coupled neutron clusters). The experiment contradicts the rather old estimates showing the impossibility to form a bound state of a few neutrons interacting by the standard nuclear forces (see review [6]). The recent attempts to study this problem using more modern methods of calculations of the parameters of four-particle systems [7–9] also indicate the impossibility of binding the four-neutron system without adding some exotic many-particle interaction potentials. Moreover, the absence of resonances in a four-neutron system with standard potentials was shown in [10] (though there exists a work [11] showing the existence of the resonance in a tetraneutron with other neutron-neutron potentials).

In the present paper, we study the theoretical problem of the possible existence of a tetraneutron by studying a four-fermion system with short-range pairwise potentials. For this purpose, we develop the precise methods of calculations of the energies of loosely bound states of a four Fermi-particle system. We propose a special idea of constructing the pairwise potentials allowing the four-fermion system to exist in the bound state under the condition of unbound two-particle subsystems, and we try to vary the parameters of the potentials to fit the standard low-energy neutron-neutron data.

2. Basic Equations

To study the properties of the four-neutron system in the state with zero spin ($S = 0$) and zero orbital moment ($L = 0$) under assumption of the central pairwise neutron-neutron interaction potentials, one has to deal with the following Schrödinger equation for one spatial component of the wave function:

$$\left\{\sum_{i=1}^{4}\frac{\mathbf{p}_i^2}{2m}+\frac{1}{2}\sum_{i>j=1}^{4}\left(V_s^+(r_{ij})+V_t^-(r_{ij})\right)+\right.$$

$$+\frac{1}{2}\sum_{(ij)\neq(14),(23)}(-1)^{i+j}\left(V_s^+(r_{ij})-V_t^-(r_{ij})\right)-$$

$$-\frac{1}{2}\sum_{(ij)\neq(12),(34)}(-1)^{i+j}\Bigg(V_s^+(r_{ij})-$$

$$\left.-V_t^-(r_{ij})\Bigg)\hat{P}_{23}\right\}\Phi=E\Phi. \qquad (1)$$

The total antisymmetric wave function of the four-neutron system is expressed in terms of the corresponding spin and spatial components as

$\Psi^a(1,2,3,4) =$

$$= \frac{1}{\sqrt{2}} \left(\Phi'(\mathbf{r}_1, \mathbf{r}_2, \mathbf{r}_3, \mathbf{r}_4)\xi'' - \Phi''(\mathbf{r}_1, \mathbf{r}_2, \mathbf{r}_3, \mathbf{r}_4)\xi' \right). \qquad (2)$$

In Eq. (2), ξ' and ξ'' are the corresponding components of the spin functions of four neutrons in the state with zero spin ($S = 0$), and the antisymmetric Φ' and symmetric Φ'' (with respect to the permutations ($1 \rightleftarrows 2$) and ($3 \rightleftarrows 4$)) spatial components are

$$\Phi'(\mathbf{r}_1, \mathbf{r}_2, \mathbf{r}_3, \mathbf{r}_4) \equiv \Phi(\mathbf{r}_1, \mathbf{r}_2, \mathbf{r}_3, \mathbf{r}_4),$$

$$\Phi''(\mathbf{r}_1, \mathbf{r}_2, \mathbf{r}_3, \mathbf{r}_4) \equiv$$

$$\equiv \frac{1}{\sqrt{3}} \left(2\Phi(\mathbf{r}_1, \mathbf{r}_3, \mathbf{r}_2, \mathbf{r}_4) - \Phi(\mathbf{r}_1, \mathbf{r}_2, \mathbf{r}_3, \mathbf{r}_4) \right), \qquad (3)$$

which corresponds to the Young scheme [2 2]. In Eq. (1), $\hat{P}_{23}$ is the permutation operator of spatial coordinates, $V_s^+(r_{ij})$ and $V_t^-(r_{ij})$ are, respectively, the singlet interaction potential in even states and the triplet one in odd states. The bound states of four Fermi-particles are studied by solving the Schrödinger equation (1) using the well-known variational method with the translational invariant Gaussian basis antisymmetrized with respect to the permutations of particles ($1 \rightleftarrows 2$) and ($3 \rightleftarrows 4$),

$$\Phi(\mathbf{r}_1, \mathbf{r}_2, \mathbf{r}_3, \mathbf{r}_4) = \hat{A} \sum_{k=1}^{N} C_k \exp\left(- \sum_{i>j=1}^{4} u_{ij}^k r_{ij}^2 \right), \qquad (4)$$

where $\hat{A}$ is the antisymmetrization operator, N is the basis dimension, and $r_{ij} \equiv |\mathbf{r}_i - \mathbf{r}_j|$. This basis and the special schemes necessary to optimize the nonlinear variational parameters u_{ij}^k enable us to carry on the calculations of loosely bound states with desired accuracy. The variational method with the use of Gaussian bases has proved its high efficiency and precision in a number of few-body problems (see [12]).

3. Spinless Interaction Model

To make the conditions of the four-neutron system binding more clear, consider the simplest case of spinless interaction (i.e. $V_t^-(r_{ij}) = V_s^+(r_{ij})$ in Eq. (1)), where the overestimated attraction in the triplet state may only promote the binding of a four-fermion system. We study the conditions of the appearance of system's bound state varying the coupling constant of potentials of different forms (further, we use the dimensionless units: $V(r) = \frac{\hbar^2}{mr_0^2} U(\frac{r}{r_0}) \equiv \frac{\hbar^2}{mr_0^2} g u(r)$, where r_0 is the radius of interaction, and g is the coupling constant; $\hbar^2/m = 41.4425$ MeV·fm^2 for neutrons). We consider various pairwise potentials taken in the form of a superposition of Gaussian functions.

For the potential with one Gaussian function, $U(r) = -g \exp(-r^2)$, a bound system of four Fermi-particles (with the spatial component of the wave function obeying Eq. (1) and antisymmetrized with respect to the permutations of particles ($1 \rightleftarrows 2$) and ($3 \rightleftarrows 4$)) exists below the decay threshold ($4 \to 2 + 2$) only for $g \geq g_{\rm cr}(4) = 3.911$. This is 1.46 times greater than the critical two-particle coupling constant $g_{\rm cr}(2) = 2.684$. By $g_{\rm cr}(k)$ (for a number of particles $k = 2, 3, 4$), we denote the critical coupling constants such that the bound states of a system of k particles exist beyond the decay threshold into subsystems only at $g > g_{\rm cr}(k)$. We notice that the reliable calculations need basis (4) to be about 150 functions with the optimization of nonlinear parameters. Note that a three-fermion system (with the orbital momentum $L = 0$ and the antisymmetrized spatial component of the wave function with respect to the permutation ($1 \rightleftarrows 2$)) can be bound, for the same potential, below the decay threshold ($3 \to 2 + 1$) only for $g \geq 3.3 g_{\rm cr}(2)$.

From the qualitative point of view, the similar conditions for the appearance of a bound state of four Fermi-particles take place for other traditional purely attractive potentials. Thus, under the condition that a two-fermion system is unbound, there is no possibility, because of the Pauli exclusion principle, for a four Fermi-particle system (nothing to say of a three-fermion one) to form a bound state with traditional attractive potentials. An analogous conclusion can be drawn in the case of common nuclear potentials with repulsion at short distances. For example, for the widely used Volkov potential, one has $k \equiv g_{\rm cr}(4)/g_{\rm cr}(2) = 1.44$. Moreover, the attempt to find a better ratio k by varying the parameters of the two-component potentials with attraction and short-range repulsion led us only to a potential $U(r) = g\left(1.5 \exp(-(r/0.9)^2) - \exp(-r^2)\right)$ giving rise to k about 1.27. We can assume that it is impossible to form a bound system of four Fermi-particles also for other standard interaction potentials with attraction and short-range repulsion if a two-particle subsystem is unbound. Moreover, in the more realistic case where the neutron-neutron triplet interaction potential acting in odd states is mainly repulsive, the four-neutron system with standard potentials is not bound, of course. This conclusion is in agreement with the recent calculations [7–9].

In principle, a possibility for a bound system of four Fermi-particles to exist, under the condition of unbound two-particle subsystems, can be realized with some

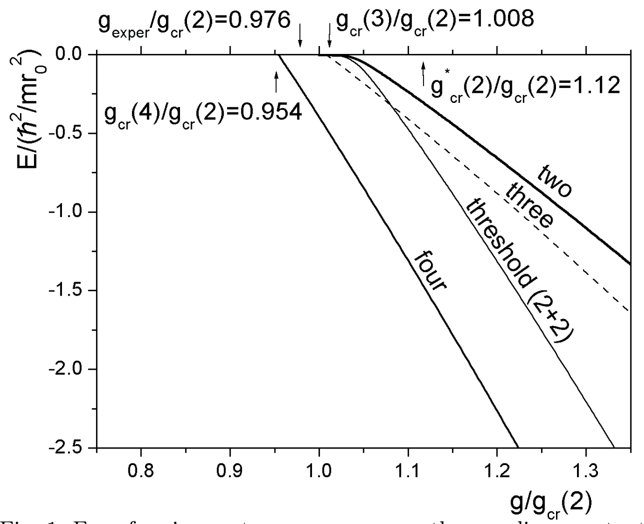

Fig. 1. Four-fermion system energy versus the coupling constant of potential (5) acting both in the singlet and triplet states ($r_0 = 0.488519$ fm is the radius of the interaction potential (5))

exotic pairwise interaction potentials having two regions of attraction separated by a repulsive barrier. Since we are going to develop a model of four neutrons, an external attractive potential well of greater radius is necessary, first of all, to fit the experimental low-energy two-neutron scattering parameters in the singlet state, and it has to be in the typical range of nuclear forces of about or greater than 1.5 fm. Fitting the singlet interaction potential, we use the following low-energy neutron-neutron scattering parameters: the scattering length $a_{s(nn)} = -18.9$ fm and the effective radius $r_{0s(nn)} = 2.75$ fm. The internal attractive potential well of a smaller radius is important for binding the four-fermion system, while the repulsive barrier between the attractive wells makes the two regimes of attraction somewhat independent. In a hypothetical tetraneutron, the number of pairs of particles in the singlet state, as well as that in the triplet one, equals three. The Pauli principle reveals itself only in the triplet state, and the internal potential well acting in the singlet state plays the main role in binding the four-particle system. A class of potentials with two attractive wells of different radii, which give rise to the bound state of the system of four Fermi-particles without binding the two-particle subsystems, under the assumption $V_t^-(r_{ij}) = V_s^+(r_{ij})$, is rather wide. We have a number of potentials in the form of a superposition of three- or four-component (Gaussian) functions. One of the variants is the four-component singlet potential acting in even states

$$U_s^+(r) = g\Big\{0.43\exp\Big(-(r/0.6)^2\Big) - \exp\left(-r^2\right) + +1.085\exp\Big(-(r/1.3)^2\Big) - 0.42\exp\Big(-(r/1.5)^2\Big)\Big\}, \quad (5)$$

where the distance is measured in units of $r_0 = 0.488519$ fm, and the potential in dimensional units is obtained as $V(r) = \frac{\hbar^2}{mr_0^2}U(\frac{r}{r_0})$. At $g = g_{\rm exper} = 322.40$, potential (5) reproduces the experimental values of $a_{s(nn)}$, $r_{0s(nn)}$, and the commonly used recommended singlet neutron-neutron phase shift up to the energies $E_{\rm lab} \approx 80$ MeV. Unfortunately, at higher energies, the phase shift increases having a broad peak with a maximum of about $\delta \approx 160°$ at the energies of about 100—150 MeV, which is not typical of the recommended neutron-neutron phase shifts and breaks the charge-independence of nuclear forces.

Fig. 1 shows the dependence of the four-fermion system energy (curve "four"), as well as that for three- and two-fermion subsystems (curves "three" and "two", respectively) on the coupling constant g of potential (5) in the "spinless" case ($U_t^-(r_{ij}) = U_s^+(r_{ij})$). Note that the decay threshold of the system of four fermions into $2+2$ (as well as the decay threshold of the three-fermion system into $2+1$) as a function of the coupling constant has two regimes of behaviour. The first regime of a rather weak binding of the two-particle system at $g \longrightarrow g_{\rm cr}(2) = 330.42$ (where the two-particle bound state appears) takes place due to the presence of the attraction of a greater radius in potential (5). The second regime with the almost linear dependence of the threshold in a wide range of the coupling constant is present due to the attraction of a smaller radius. The repulsive barrier between the attractive wells contributes to the sharpness of changing the two regimes of the threshold behaviour. Note also that the excited two-particle S-state lies anomalously close to the ground state at $g^*_{\rm cr}(2)/g_{\rm cr}(2) = 1.12$, which is caused to a great extent by the presence of two almost independent attractive wells in potential (5). It is essentially important that the four-fermion system is bound already at $g \geq g_{\rm cr}(4) = 315.2 = 0.954 g_{\rm cr}(2)$, where the two-fermion subsystem is still unbound ($g \leq g_{\rm cr}(2) = 330.42$). Moreover, at the coupling constant $g = g_{\rm exper} = 322.40 = 0.976 g_{\rm cr}(2)$, where potential (5) reproduces the experimental low-energy neutron-neutron parameters, the four-fermion system is already bound. At the same time, a three-fermion system with the considered potential is not allowed to be bound since the ratio $g_{\rm cr}(3)/g_{\rm cr}(2) = 1.008$ is greater than 1, although being close to it. Note the fact that the dependence of the four-fermion energy on g looks like almost a straight line parallel to the energy threshold $(2+2)$ dependence in a wide interval of coupling constants ($g/g_{\rm cr}(2) \gtrsim 1.1$), and this line is rather close to the $(2+2)$ threshold. This fact indicates that, in this region of g, the four-fermion system in the bound state exists due to the presence of the internal potential well of a smaller radius, and the four-particle state is of the two-cluster $2+2$ nature. A similar consideration concerns the three-fermion bound system as well: in a wide interval of coupling constants, this system is the cluster state (2+1) with the essential role of the attractive well of a smaller radius. This is confirmed also by the approximate relation for the energies of the ground states $E_4 - 2E_2 \approx 2\,(E_3 - E_2)$, where the subscripts denote the number of particles of the systems.

Note that we constructed some other variants of potentials $U_s^+(r)$, for example,

$$U_s^+(r) = g\Big\{0.315\exp\left(-\left(r/0.5\right)^2\right) - \exp\left(-r^2\right) +$$

$$+1.278\exp\left(-\left(r/1.31\right)^2\right) - 0.54\exp\left(-\left(r/1.5\right)^2\right)\Big\},$$

which yields $g_{\rm cr}(4)/g_{\rm cr}(2) = 0.9525$ for the bound four-fermion system to exist and reproduces the low-energy parameters of n–n scattering at $g_{\rm exper}/g_{\rm cr}(2) = 0.9935$ ($g_{\rm cr}(2) = 187.5$, and the interaction radius $r_0 = 1.2608$ fm). For this potential, even a three-fermion bound state can exist on the unbound two-particle subsystems, since the ratio $g_{\rm cr}(3)/g_{\rm cr}(2) = 0.9564$ is less than unity. But the more strict condition $g_{\rm cr}(3) < g_{\rm exper}$ necessary for the trineutron existence is not valid. In addition, the n–n singlet phase shift for this potential becomes too large already at rather low energies, and this is not acceptable. We have found no variant of the potential which would give rise to the bound state of a three-fermion system in the case $V_t^- = V_s^+$ at experimental low-energy n–n singlet parameters and simultaneously would give a reasonable phase shift at least at low energies.

We emphasize that it is necessary to carry on the variational calculations with special schemes of optimization of basis (4) in order to obtain the above results for the four-fermion system with reliable accuracy. We used about 220 functions with the optimization of the basis to achieve the desirable accuracy. A rather large number of the basis components is caused by both the complicated antisymmetrized four-fermion wave function of the near-threshold state and the potential containing essentially different components.

4. A Model of Interaction with Regard for a Spin

To make the model of four Fermi-particles more similar to a model of four neutrons, we fix the singlet potential in the form of Eq. (5) and consider more realistic models of the triplet interaction potential $U_t^-(r)$ ($U_t^- \neq U_s^+$), when $U_t^-(r)$ should be mainly repulsive, and thus the conditions for the existence of the bound state of the four-particle system are somewhat less appropriate. The model of four bound fermions with the spin-dependent interaction potential is further called "tetraneutron", or a "system of four neutrons", in spite of the fact that the interaction potential (5) reproduces only the low-energy part of the phase shift and, of course, the scattering length and the effective radius. If we put $U_t^-(r)$ to be zero in Eq. (1), we get an unbound tetraneutron within the proposed class of singlet potentials, because only a half of 6 pairs interacts in this case. Thus, it is necessary to have some additional attraction in odd orbital states to bind ^{4}n. On the other hand, the commonly recommended phase shifts of the scattering in odd orbital states are rather negative corresponding to the effective repulsion. It appears that there exists a class of triplet potentials which together with the singlet potential (5) can bind the ^{4}n system and are repulsive with the exception of the typical nuclear distances of about $1.5-2$ fm, where these potentials reveal some attraction correlated with the external attractive potential well of the singlet potential. Such a potential (in the same dimensionless units, as potential (5)) can have the form

$$U_t^-(r) = g_t\Big\{2.212\exp\left(-\left(r/2\right)^2\right) -$$

$$-2.334\exp\left(-\left(r/3\right)^2\right) + \exp\left(-\left(r/4\right)^2\right)\Big\} \qquad (6)$$

with $g_t = 14$. This potential has negative phase shift in the P-state in the whole energy interval, although with a nonmonotone energy dependence.

Potential (6) together with the singlet one (5) result in the bound state of a tetraneutron with the binding energy $B(^4{\rm n}) \gtrsim 0.5$ MeV (this value is the variational estimation with the use of about 400 Gaussian functions). A more accurate calculation needs much greater efforts mainly because of the complicated structure of the potentials and the many-component antisymmetrized wave function of four particles. In addition, the ultimate result for the binding energy is a few orders of magnitude less than the contributions

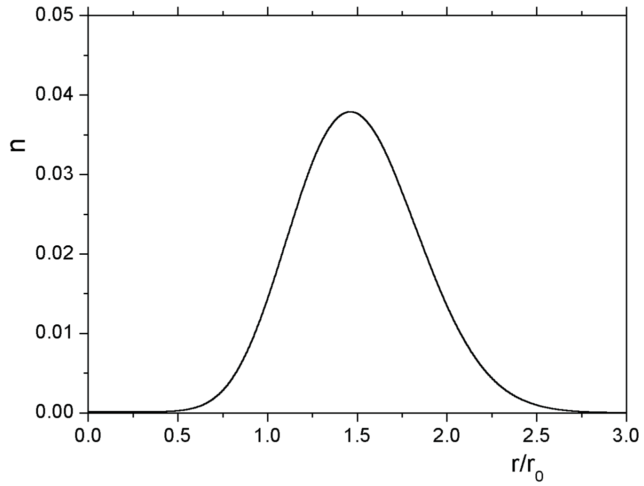

Fig. 2. Profile of the density distribution $n(r)$ of neutrons of a hypothetical tetraneutron (r_0 is the same as in Fig. 1)

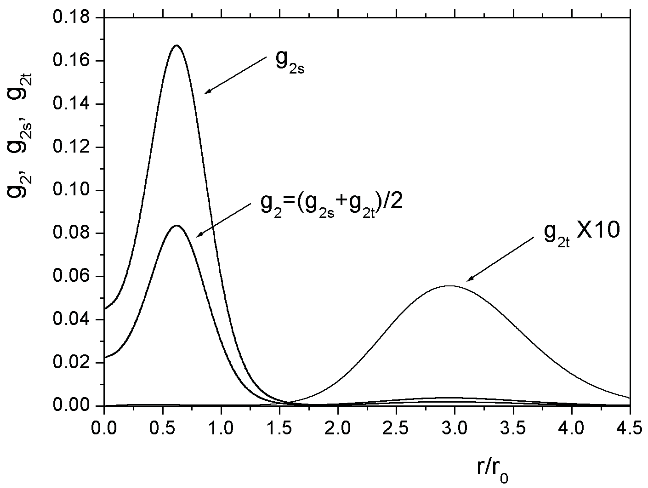

Fig. 3. Profiles of the singlet $g_{2s}(r)$, triplet $g_{2t}(r)$, and total $g_2(r) = \frac{1}{2}(g_{2s}(r) + g_{2t}(r))$ pair correlation functions of the hypothetical bound ^4n system (r_0 is the same as in Fig. 1)

of the kinetic or potential energies calculated separately with rather good accuracy, and these contributions almost cancel each other having opposite signs. The proposed phenomenological pairwise potentials fitted to describe the low-energy neutron-neutron scattering parameters demonstrate the possibility for a tetraneutron to be bound. Note that one can easily change the binding energy of ^{4}n in a wide range (from zero to dozens of MeV) by changing slightly potentials (5) and (6). On the other hand, if the potentials of type (5) with repulsive barriers are changed in such a way that to weaken the internal attractive potential well, a bound state of four neutrons is transformed to a resonance in the system of four neutrons.

Let us consider the main structure functions of the hypothetical tetraneutron. Note that the structure functions can be calculated much more accurately by using basis (4) of a lesser dimension than that used in the calculation of the energy. Fig. 2 presents the one-particle density distribution of ^{4}n (normalized as $\int n(r)d\mathbf{r} = 1$) versus the dimensionless distance, for potentials (5), (6). Due to the Pauli principle, the density distribution has essential minimum at short distances, i.e. the tetraneutron is a "bubble" system with the almost Gaussian near-surface distribution of neutrons. In the model under consideration, the hypothetical tetraneutron has anomalously small (on the nuclear scale) r.m.s., $\langle r^2 \rangle^{1/2} = 1.704 r_0 = 0.83$ fm, which is caused by the attraction well of a smaller radius in potential (5). Changing the singlet potential (5), one can somewhat increase the above value. But, in any case, the size of a tetraneutron will be less, in spite of its extremely small binding energy, than the typical nuclear radii. This means that, at such short distances, the quark structure of neutrons may appear to be important.

Figure 3 depicts the singlet $g_{2s}(r)$ and triplet $g_{2t}(r)$ pair correlation functions which reflect, to a great extent, the behaviour of the corresponding potentials. The singlet correlation function $g_{2s}(r)$ has significant maximum in the region of internal short-range attraction of the singlet potential, since the Pauli principle does not reveal itself in the singlet state. Some decrease of $g_{2s}(r)$ at very short distances is caused by the presence of short-range repulsion in potential (5), and it should not be present if the repulsion were absent. The secondary maximum is present in $g_{2s}(r)$ due to the existence of the external attractive potential well in $V_s^+(r)$. In the triplet state, the repulsion at short distances makes a small contribution to the energy because of the Pauli principle, and the maximum of $g_{2t}(r)$ is located in the attractive area of the triplet potential. That is why, the contribution of the triplet potential to the energy of ^{4}n is negative, and the system cannot be bound without the contribution of this comparatively small effective attraction. The short-range attraction in the singlet state plays the main role in binding the ^{4}n system. This is confirmed by calculations of the average singlet and triplet potential energy contributions,

$$\langle V \rangle = 3 \left\{ \int V_s^+(r) g_{2s}(r) d\mathbf{r} + \right.$$

$$\left. + \int V_t^-(r) g_{2t}(r) d\mathbf{r} \right\} \equiv \langle V_s^+ \rangle + \langle V_t^- \rangle ,$$

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where $\langle V_s^+ \rangle = -1296.7$ MeV and $\langle V_t^- \rangle = -158.7$ MeV, which together with the kinetic energy $\langle \hat{K} \rangle = 1454.9$ MeV result in the negative energy of the system $E_{^4n} \lesssim -0.5$ MeV indicated above.

The total correlation function $g_2(r) = \frac{1}{2}(g_{2s}(r) + g_{2t}(r))$ reflects the average neutron pair correlations and has the main maximum at short distances and the secondary one in the region of attraction in the triplet state (where the singlet potential also has an external attractive well).

5. Discussion

To summarize, we note the following.

1) A bound tetraneutron could exist due to the pairwise interaction potentials if the interaction in the n–n singlet state contains two attractive wells separated by a repulsive barrier. Unfortunately, as a result of such an assumption, we get an anomalously high maximum in the singlet scattering phase shift $\delta_s \approx 160°$ at the energies of neutrons of the order of 100—150 MeV. The problem of constructing the potentials, which bind ^{4}n and give reasonable phase shifts in agreement with the charge-independence of nuclear forces, is to be further studied. Our preliminary estimates show that the use of some small additional intercluster potentials could enable one to construct the singlet potentials giving the phase shifts with somewhat suppressed maximum. In any case, we give an example of the pairwise interaction potential fixed by the low-energy neutron-neutron scattering parameters which enables the system of four Fermi-particles (hypothetical tetraneutron), in spite of the Pauli exclusion principle, to be bound under the condition of unbound subsystems.

2) We also calculated the ^{3}H and ^{4}He bound states using the proposed potentials in order to verify the assumption about a possible overbinding of these nuclei. Strange though it may seem, the few-nucleon systems are even essentially underbound with the n–n potentials (5) and (6) used together with the standard n–p ones. In particular, with the Minnesota potential used as the n–p interaction, one has the ^{3}H system underbound by about 2 MeV and the ^{4}He by more than 4 MeV. If one uses potential (5) instead of all the singlet nucleon-nucleon potentials, the above systems are even less bound. This fact is related to the essentially different spatial dependences of the proposed n–n singlet potential and the standard n–p triplet one playing an important role in the formation of the above systems. Thus, to adjust the binding energies of the few-nucleon systems, it is necessary to fit the parameters of the potentials like (5) and (6) taking into account the concordance with the $n-p$ triplet potential. This also indicates that there exist some reserves in variations of potential (5) in order to enhance the external potential well and, thus, to somewhat decrease the undesirable maximum in the phase shift and, simultaneously, to increase the calculated binding energies of light nuclei.

3) The proposed interaction potentials give rise to a loosely bound state of four neutrons, and this state becomes a low-lying resonance if one weakens a little the attraction.

4) The model of a hypothetical tetraneutron with the proposed potentials results in the anomalously small size and, at the same time, the small binding energy of the system. It is interesting to study the probability of the "presence" of such a cluster in a ^{14}Be nucleus.

5) Potentials (5) and (6) satisfy the saturation conditions necessary for the stability of the neutron matter. The interesting and nontrivial questions arise concerning the models of heavier multineutron systems with such a type of potentials. In particular, a system of 8 neutrons could be a more stable system than ^{4}n, because the number of particles is magic and also because the eight-neutron system may be similar to two tetraneutron clusters. We notice that the multineutron systems with standard potentials can exist [13] only for the number of neutrons starting from $N \gtrsim 5 \times 10^2 \div 10^3$, and this estimation is valid only for the potentials not satisfying the saturation condition.

Thus, we see that there exists, in principle, a theoretical possibility for the bound state of a tetraneutron (and more so for resonances) to exist with some specific pairwise interaction potentials. But the potentials we have at our disposal are not satisfactory by a number of reasons: in particular, there exist some problems with the n–n phase shifts, and it is necessary also to adjust the description of the few-nucleon systems. We see some prospects in this way.

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ЧИ МОЖЕ ТЕОРЕТИЧНО ІСНУВАТИ ТЕТРАНЕЙТРОН?

І.В. Сименог, Б.Є. Гринюк, Ю.М. Бідасюк

Р е з ю м е

З метою дослідження можливості існування тетранейтрона, показано, що система чотирьох фермі-частинок може мати зв'язаний стан при незв'язаних двочастинкових підсистемах у випадку, коли парний потенціал взаємодії містить дві притягувальні потенціальні ями, розділені відштовхувальним бар'єром. Вивчено властивості гіпотетичного тетранейтрона із запропонованим класом потенціалів, параметри яких вибрано так, щоб описати низькоенергетичні нейтрон-нейтронні дані. Виявлено аномальну поведінку розрахованих розмірів, розподілу густини і парних кореляційних функцій гіпотетичного тетранейтрона із запропонованими моделями взаємодії.