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THE NUCLEON-NUCLEON CORRELATIONS AND THE INTEGRAL CHARACTERISTICS OF THE POTENTIAL DISTRIBUTIONS IN NUCLEI

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INTRODUCTION

In papers [1,2] the semimicroscopic approach (SMA) to the interaction of low energy nucleons with nuclei has been developed. This approach was applied to the analysis of the nucleon scattering [1,2] . The generalization of the SMA was used in [3] for description of the interaction of the low energy α-particles and heavy ions with nuclei. In the framework of the SMA the optical potentials (OP) and the inelastic transition form-factors (ITF) are constructed on the basis of the effective nucleon-nucleon forces having regard to the exchange and many-particles nucleon-nucleon correlations. It has been shown [1-3] that for a successful description of the experimental data including the nucleon and α-particle cross-sections the correlations of both types should be taken into account.

In the present paper the influence of the nucleon-nucleon correlations on the integral characteristics of the potential distribution in nuclei is investigated. The first section deals with the SMA calculational scheme for the volume integrals, the mean square radii of the OP's, the moments of the ITF's and the parametrization of the transition density. The second section gives details of such matters as the contribution of the correlations into the integral characteristics and their energy dependence as well. In conclusion we formulate main results.

1. The calculational scheme

For the quantities $U_\lambda(r)$ in the SMA we have :

$$U_\lambda(r) = U_{d\lambda}(r) + U_{\ell\lambda}(r) + U_{\rho\lambda}(r) + \delta U_\lambda(\beta_L^\rho). \qquad (1)$$

Here λ =0 corresponds to the OP, $\lambda \neq 0$ – to the ITF. The first (direct) term in the expr.(1) is constructed with the help of the standard folding procedure [4] , in the second term the exchange nucleon-nucleon correlations are taken into consideration in the density matrix formalism [5] . The third one includes the contribution of the density dependent part of the effective nucleon-nucleon forces into the OP's and the ITF's. The last term in the exp.(1) gives the correlations connected with the second order terms for the static and dynamic deformation parameters. The detailed expressions for the right-hand terms in formula (1) can be seen in papers [1,2].

Let us discuss the choice of the effective nucleon-nucleon interaction. For the density independent part of the effective forces we use the conventional form :

$$V_{eff}(\vec{r}_1,\vec{r}_2) = V_0 \cdot f(s)\{a_0 + a_\tau(\vec{\tau}_1\vec{\tau}_2) + a_\sigma(\vec{\sigma}_1\vec{\sigma}_2) + a_{\sigma\tau}(\vec{\sigma}_1\vec{\sigma}_2)(\vec{\tau}_1\vec{\tau}_2)\} \quad (2)$$

$$f(s) = exp(-s^2/a^2) \quad (2a)$$

$$\vec{s} = \vec{r}_1 - \vec{r}_2 . \quad (2b)$$

We take the values of the parameters in (2) corresponding to the Schmid-Wildermuth interaction [6] on the base of which the free low energy NN and $\alpha\alpha$-scattering as well as the cluster properties of light nuclei are successfully described. In refs. [1-3] these interaction was modified by introducing the density dependence in the following form :

$$V_{eff}(\rho, \vec{r}_1, \vec{r}_2) = d\rho\left(\frac{\vec{r}_1+\vec{r}_2}{2}\right)\delta(\vec{r}_1-\vec{r}_2) . \quad (3)$$

The effective nucleon-nucleon forces constructed in such a manner have successfully been utilized for analysis of elastic and inelastic scattering of low energy protons, neutrons and α-particles from the nuclei in the framework of SMA in view of strong channel coupling [1-3]. As has been found out, the "d" parameter is almost constant within 15% accuracy for the transition from light nuclei to ^{208}Pb nucleus.

Let us consider the integral characteristics of the potential and nuclear matter distributions. For the volume integrals, mean square radii and moments we have by definition :

$$J^f = \int f(\vec{r})\, d\vec{r} \qquad (f = \rho, v) \quad (4)$$

$$\langle r^2 \rangle_v = \int U(\vec{r})\, r^2\, d\vec{r} / J^v \quad (5)$$

$$q^f_\lambda = \int f(\vec{r})\, Y_{\lambda 0}(\omega_{\vec{r}})\, r^\lambda\, d\vec{r} = \int_0^\infty f_\lambda(r)\, r^{\lambda+2}\, dr . \quad (6)$$

We introduce the normalized multipole moments [7] :

$$Q^f_\lambda = q^f_\lambda / J^f . \quad (7)$$

It is interesting to analyse the ratio of multipole moments for

the potential and matter distributions, namely,

$$\eta_\lambda = Q^v_\lambda / Q^\rho_\lambda = q^v_\lambda / q^\rho_\lambda \cdot J^\rho / J^v . \quad (8)$$

Satcher has got the relationship between the geometries of the density and the potential distribution [8]. The so-called Satcher's theorem was formulated in [7] . In accordance with the mentioned theorem for the case of effective finite range forces with arbitrary radial dependence the normalized multipole moments for the potential and matter distributions are equal for any λ . This is true for only when the exchange nucleon-nucleon correlations and density dependence of effective forces are not taken into consideration, i.e., only for the "direct" term in the exp.(1).Thus the analysis of η_λ makes it possible to find out how essential are the "breakings" of Satcher's theorem.

The calculations of integral characteristics (4)-(6) within the frames of SMA are performed in the following way : on the base of effective nucleon-nucleon forces constructed in accordance with the choice mentioned above and on the base of information on matter density distribution in the nucleus the values of $U_\lambda(r)$ are calculated (the $\delta U_\lambda(\beta^\rho_L)$ term is neglected). We use conventional parametrization for $\rho_0(r)$ and $\rho_\lambda(r)$ [9]:

$$\rho_0(r) = \rho_0 / (1 + exp\frac{r-C}{z}) \quad (9)$$

$$\rho_\lambda(r) = \beta^\rho_\lambda\, r\,(r/c)^{\nu-2}\, d\rho_0(r)/dr \qquad (\nu = 1,2,\lambda) . \quad (10)$$

Further the integral values are calculated in accordance with the eqs.(4)-(6) by using $U_0(r)$ and $U_\lambda(r)$ obtained.

2. The integral characteristics analysis

Let us use the above scheme of integral characteristics analysis. Table 1 contains the volume integrals, moments and mean square radii for the potentials calculated for the ^{58}Ni nucleus (C =4.31 F, z =0.465 F) in the nucleon energy region from 10 MeV to 40 MeV. When $d \neq 0$, the density dependence of the effective forces is considered (here d =500 MeV F^6), while d=0 represents only the exchange nucleon-nucleon correlations.

Let us discuss the results obtained. One can see that the inclusion of density dependence leads to the decrease of volume integrals and moments, while the mean square radii are growing. This growth can be explained by the fact that $V_{eff}(\rho)$ influences mainly the denomi-

Table 1. The integral characteristics of the potential distribution for the ^{58}Ni nucleus

E MэВ	$J^v/10^3\cdot 4\pi$ MэВ·фм^3		$q_2^v/10^4\,\beta_2^\rho$ MэВ·фм^5		$q_4^v/10^5\cdot\beta_4^\rho$ MэВ·фм^7		$\langle r^2\rangle_v^{1/2}$ фм	
	$\alpha=0$	$\alpha\neq 0$	$\alpha=0$	$\alpha\neq 0$	$\alpha=0$	$\alpha\neq 0$	$\alpha=0$	$\alpha\neq 0$
10	2.21	2.01	2.91	2.72	4.70	4.49	4.178	4.260
17.5	2.15	1.94	2.82	2.63	4.50	4.29	4.174	4.258
25	2.09	1.88	2.74	2.54	4.32	4.10	4.169	4.258
32.5	2.04	1.82	2.66	2.46	4.16	3.54	4.165	4.258
40	2.00	1.78	2.60	2.39	4.02	3.79	4.163	4.259

nator in the exp.(5) and not the numerator. Here it should be noted that the exchange nucleon-nucleon correlations and density dependence factor make the contributions to OP's and ITF's of opposite signs. The greatest changes of integral characteristics correspond to the volume integrals (about 10%), for the moments with λ =2 they are about 7% and for λ =4 they are less than 5%. In this energy region all the moments are decreasing with the growth of energy, the energy dependence is growing stronger for the higher values of λ and also taking into account the density dependence of V_{eff}. Simultaneously with that the energy dependence of V_{eff} is weakening for α=0.

We should note that the contribution of density dependence to the moments was also studied in paper [10] . But there the exchange nucleon-nucleon correlations were not taken into account. The influence of such correlations on the volume integrals of potential and on the moments was considered in [11] but without taking into account the density dependence of V_{eff}.

As was mentioned above, taking into account both the types of correlations is essential. The results obtained in the present paper are in a qualitative agreement with the conclusions on the energy dependence of J^v and $\langle r^2\rangle_v^{1/2}$ obtained in [12] in the framework of local density approximation of the nuclear matter theory.

In Table 2 there are ratios of normalized multipole moments of potential and matter distributions calculated for the ^{58}Ni nucleus and for λ =2 and λ =4. One can see that the deviation of the va-

Table 2. The ratios of the normalized multipole moments of the potential and nuclear matter distributions

E MэВ	ν	$\lambda=2$		$\lambda=4$	
		$\alpha=0$	$\alpha\neq 0$	$\alpha=0$	$\alpha\neq 0$
10	2	1.04	1.07	1.12	1.18
17.5	2	1.03	1.07	1.11	1.17
25	1	1.01	1.02	1.07	.12
	2	1.03	1.07	1.09	1.16
	λ	1.03	1.07	1.14	1.22
32.5	2	1.02	1.06	1.07	1.14
40	2	1.02	1.06	1.06	1.13

lues η_λ from the 1 i.e., the Satcher's theorem "breaking" is not great. It gives the value from 1% to 7% for λ =2 and from 6% to 22% for λ =4 dependent on energy, density dependence account and the way of $\rho_\lambda(r)$ parametrization. This conclusion is in agreement with the conclusion obtained in [13] for the ^{154}Sm nucleus for the local density approximation. Let us note some peculiarities of the results from Table 2. The values η_λ are increasing with the growth of λ and also taking into account the density dependence and they are decreasing with increasing energy. The relative contribution of manyparticle correlations into the values η_λ is increasing with increasing energy. As to the way of $\rho_\lambda(r)$ parametrization, the influence of $\rho_\lambda(r)$ choice on the values of η_λ is balanced with the influence of density dependence account.

In papers [14,15] some efforts were made to consider the influence of V_{eff} density dependence factor on the value of η_λ (it was denoted in [14,15] as C_L). But the exchange nucleon-nucleon correlations were not account for. Thus, it is possible to consider that phenomenologically the density dependence of V_{eff} introduced in [14,15] effectively takes into account the exchange nucleon-nucleon correlations. The study of C_L factor performed in [15] on the base of α-particle scattering analysis for the large group of nuclei (from ^{20}Ne to ^{208}Pb) and λ =2,3,4,5 shows that the value of C_L is in the region from 1.0 to 1.3 (and is increasing for the higher L). As it follows from Table 2 data, the values of η_λ are changing from

1.01 to 1.22. The calculations accomplished in the framework of SMA show that the values η_λ are weakly dependent on the mass number. Thus, the present semimicroscopic analysis lends support to the validity of the conclusions obtained at the phenomenological level in paper [15] .

Let us formulate the main results :

1. Within the frames of semimicroscopic approach to the interaction of low energy nucleons with nuclei on the base of exchange nucleon-nucleon correlations provided by Pauli principle and manyparticle nucleon-nucleon correlations modelled by the density dependence of effective forces, the volume integrals, mean square radii and moments of the potentials are considered.

2. The influence of the density dependent factor on the integral characteristics of potentials is investigated. It is established that the account of this factor leads to the decreasing of volume integrals and moments and to the increasing of mean square radii.

3. The ratio of normalized multipole moments of potential and matter distributions is analyzed and it is shown that the deviation of this value from 1 is from 1% to 22% depending on the energy, the density dependence of effective forces account, the way of density parametrization and on the multiplicity.

4. Energy dependence of integral characteristics of the potential is investigated. The inclusion of the density dependence of effective forces leads to the strengthening of energy dependence on the volume integrals and moments of potential and to the weakening of mean square radii energy dependence.

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