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ЛАБОРАТОРИЯ ТЕОРЕТИЧЕСКОЙ ФИЗИКИ

CALCULATION OF THE BODY-FORM FACTOR FOR THE ^{3}He AND ^{3}H NUCLEI BY MEANS OF THE MODIFIED BKR POTENTIAL

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Беляев В.Б., Шульц Г. E4-6353

Расчет "body"-формфакторов ядер ^3He и ^3H с модифицированным потенциалом BKR

На основе решения уравнений Фаддеева с модифицированным потенциалом Бресслера-Кермана-Рубена рассчитаны "body"-формфакторы ядер ^3H и ^3He. Установлено, что при условии $r^s_{core} \neq r^t_{core}$ в зарядовом формфакторе ^3H возникает 2 минимума при больших переданных импульсах q^2.

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Calculation of the Body-Form Factor for the ^3He and ^3H Nuclei by Means of the Modified BKR Potential

On the basis of the solution of Faddeev equation the body-form factors for the nuclei ^3H and ^3He have been calculated employing a modified Bressler-Kerman-Ruben potential. It has been formed that using different hard-core radii for the singlet and triplet part of the nucleon-nucleon interaction the charge form factors have 2 minima at large q^2 and both minima are strongly marked for the ^3H - charge form factors.

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In the last years the calculation of electromagnetic form factors for the ^3He and ^3H nuclei achieved increasing interest, because it was possible to theoretically predict some physical properties of these nuclei on the basis of realistic nucleon-nucleon potentials. Such theoretical calculations could be performed without referring to some model or any other a priori conception about the behaviour of the 3-particle wave functions. Moreover there exist now new experimental data for the charge form factor of ^3He, which indicates a deep minimum at high momentum transfer /1/.

Several physical reasons have been considered in order to explain the appearance of such a deep minimum in the charge form factor /2,3,4/ . An argument comes from the fact that the hard core in the nucleon-nucleon interaction gives oscillating contributions to the density of the charge distribution in the nucleus. Further, because the nucleons in the nuclei might be at various shells, e.g. the s– and p-shell, therefore the different nucleon distribution in these two shells leads for such nuclei to the formation of a deep minimum in the charge form factor at small momentum transfer q^2. Finally, the occurence of dimensional structures in nuclei like clasters or a clearly pronounced nuclear surface gives also rise to minimums in the form factors.

In this paper we represent the calculations for the so-called "body"-form factor F_{LC} and F_{OC} of ^3He and ^3H, respectively. The quantities F_{0LC} and F_{LC} are defined in ref /5/ :

$$F_{0C}(q^2) = \int e^{i\vec{q}\vec{r}} (\psi_s^2 + 2\psi^s \psi'' + \psi'^2 + \psi''^2) d\tau , \quad \text{(Ia)}$$

$$F_{LC}(q^2) = \int e^{i\vec{q}\vec{r}} (\psi_s^2 - \psi^s \psi'' + \psi'^2 + \psi''^2) d\tau , \quad \text{(Ib)}$$

where the function ψ^s – is the symmetric part of the triton wave function, while ψ' and ψ'' are that part of the wave function, which has a mixed symmetry. The functions ψ^s, , ψ' and ψ'' can be immediately calculated, if the solution of the Faddeev equation has been found. We solved the Faddeev equation using a modified Bressler-Kerman-Ruben potential /6/ of the form:

$$V(x) = \begin{cases} V_0 & x \leq x_c \\ V_1(x) & x > x_c \end{cases} \tag{2a}$$

$$V_1(x) = 0.08 \frac{\mu}{3} (\vec{\tau}_1 \vec{\tau}_2)(\vec{\sigma}_1 \vec{\sigma}_2)\, Y(x)\, [1 + a Y(x) + b Y^2(x)] \tag{2b}$$

$$x = \mu r / \hbar c, \qquad Y(x) = e^{-x}/x .$$

As can be seen only the central part of the full potential has been employed. The triplet potential has been modified so, to fit the experimental $^3S_1$ -phases up to 360 MeV, while the singlet potential is the same as in the original BKR-potential. The new triplet potential parameters, fitted by a least square procedure and those for the singlet potential are the following:

$$V_0^t = 670\,\text{MeV}, \quad a^t = 2.1373, \quad b^t = 36.767, \quad r_c^t = 0.770\,fm$$

$$\mu = 133.08\ \text{MeV}$$

$$V_0^s = 670\ \text{MeV}, \quad a^s = 8.7075, \quad b^s = 10.600, \quad r_c^s = 0.719\ fm$$

$$\mu = 133.08\ \text{MeV}$$

The s -wave Furier-component $V/k\ ,k'/$ for this effective nucleon-nucleon potential has been represented in a separable form by means of Bateman's method /7/ :

$$V^N(k,k') = \sum_{l,j=1}^{N} (d^{-1})_{lj}\, V(k,s_l)\, V(k',s_j)\ ; \quad d_{lj} = V(s_l, s_j) \tag{3}$$

and from the beginning the higher partial wave contribution has been neglected. From eq. (3) it can be seen, that in the case k or k' equal s_l the approximate separable potential coincides with the exact one. The sum in eq. (3) has been out at $N = 6$, because the quantity

$$\chi_N^2 = \min_s \frac{\int |V(k,k') - V^N(k,k',s_1,\ldots,s_N)|^2 dk\,dk'}{\int V^2(k,k')\, dk\, dk'} \tag{4}$$

varies for $N > 6$ only by small amounts. The values for the parameters s_l given in table I have been also adjusted by a least square fitting procedure.

Table I. The values for the parameters s_l

	s_1	s_2	s_3	s_4	s_5	s_6 (fm^{-1})
singlet	0	0.76	1.80	3.32	5.30	7.23
triplet	0	0.74	1.78	3.28	5.28	7.18

Using the separable potential of the form (3) we get for the Faddeev equation a system of 12 one-dimensional integral equations. The solution of this system has been yielding a binding energy for the triton nucleus of 8.267 MeV and with the help of the corresponding triton bound state wave function the body form factors F_{0C} and F_{LC} have been calculated according to eqs. (1). The bahaviour of these body form factors depending on the transferred momentum q^2 has been presented in the figure. As can be seen, each body form factor has 2 minima. In both cases the position of the second minimum at about $q^2 \sim 14$ fm^{-2} agrees with the obtained in calculations using the correct BKR potential /3,8/ . Note, that similar calculations employing the correct BKR potential yield only one minimum for each form factor. As was mentioned above the strong repulsion of small distances might be responsible for the existence of the minimum and therefore, it can be expected that the presence of the second minimum is due to the fact that we have different hard-core radii for the singlet and triplet states, respectively. (Remember, that in the original BKR potential $r_c^s = r_c^t$). It seems to be worth to note that the first minimum at $q^2 \sim 10\, fm^{-2}$ with a width of about 0.5 fm^{-2} appears strongly marked at the triton charge form factor which is proportional to $F_{0C}(q^2)$ if the neutron charge form factor is zero $F_{nc}(q^2) = 0$. On the contrary, in the charge form factor for the ^3H nucleus the appearance of the first minimum is not so pronounced. Therefore, a careful measurement of the charge form factor of the triton at $q^2 > 8\, fm^{-2}$ should give a useful information about the range of the hard core for the singlet and triplet part of the nucleon-nucleon interaction.

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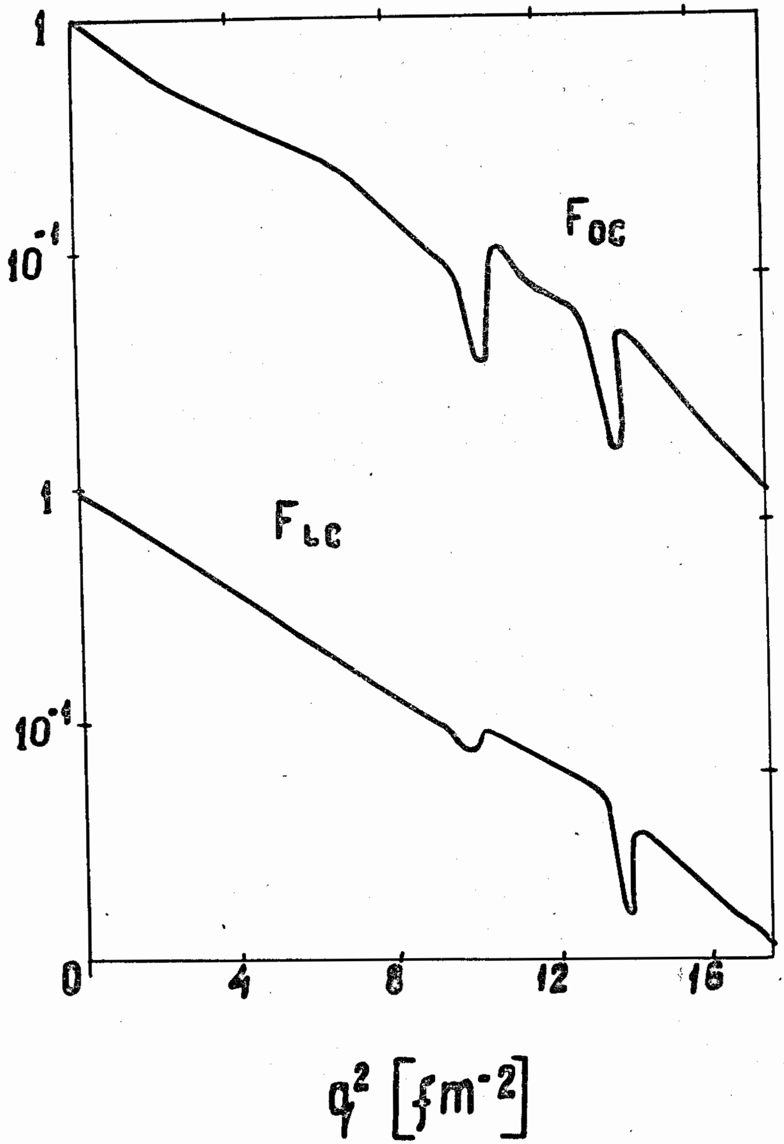
1
10^{-1}
F_{OC}
1
F_{LC}
10^{-1}
0
4
8
12
16
q^2 [fm^{-2}]