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Исследование отношения $d\sigma(p,p'd)/d\sigma(p,nd)$ для ядра ^7Li при энергии T_p = 670 МэВ в простой модели

Экспериментальное отношение $d\sigma(p,p'd)/d\sigma(p,nd)$ для ядра ^7Li при T_p = 670 МэВ на большие углы сравнивается с простыми теоретическими оценками, основанными на кластерной модели ^7Li.

Работа выполнена в лаборатории ядерных проблем ОИЯИ.

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Vêgh L., Erő J.

The $d\sigma(p,p'd)/d\sigma(p,nd)$ Ratio for ^7Li at T_p = 670 MeV Calculated in a Simple Model

The experimental cross section ratio of $^7Li(p,p'd)$ and $^7Li(p,nd)$ large angle quasifree scattering at T_p =670 MeV is compared with theoretical estimates based on the cluster model of ^7Li.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

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Recent work[1] describes among others the $^{7}Li(p,p'd)$ and $^{7}Li(p,nd)$ experiments in which a ^{7}Li target was bombarded with 670 MeV protons. Neutrons or protons were detected at lab. angle 147° in coincidence with the forward deuterons at lab. angle 6.5°. This geometry corresponds to large-angle quasifree scattering. They measured the kinetic energies of the deuteron and the backward nucleon. The overall energy resolution was ~20 MeV. This allows easy separation of events involving p-shell nucleons in ^{7}Li only. Evidence has been found for the $^{7}Li(p,nd)$ reaction and the measured $d\sigma(p,p'd)/d\sigma(p,nd)$ cross section ratio was 16.4 ± 2.4 for the p-shell events. A crude theoretical estimate is given in the article for this ratio based on the assumption that the dominant mechanism of the backward neutron production is the $p\langle nn\rangle \to nd$ exchange scattering of protons on correlated neutron pairs in the p-shell of ^{7}Li. In the oversimplified calculation the form of the two nucleon correlation in the $\langle pn\rangle$ and $\langle nn\rangle$ systems was taken to be equal and for the ratios of the elementary cross sections $\sigma(pd\to pd)/\sigma(p\overset{\dagger}{d}\to pd)$ and $\sigma(p\overset{\dagger}{d}\to pd)/\sigma(p\langle nn\rangle\to nd)$ an incorrect value was used.

The present work considers the problem in a simple model following the treatment of ref.[2]. The later work investigates the $A(p,Nd)B$ quasifree reactions at $T_p \sim 600$ MeV bombarding energies at backward angles describing the reaction in terms of the $p\langle NN\rangle\to Nd$ amplitudes within the one-pion-exchange model of Cragie and Wilkin[3]. These amplitudes depend on the small distance behaviour ($r \lesssim 1.5$ fm) of the $\langle NN\rangle$ relative wave functions only.

In calculating the $^{7}Li(p,p'd)$ and $^{7}Li(p,nd)$ quasifree reactions when the bombarding proton interacts with the p-wave nucleons only the use of the alpha-triton cluster model of the ^{7}Li nucleus[4] seems to be useful. This model describes the main features of the ground state of ^{7}Li satisfactorily, the inclusion of other cluster components into the calculations does not change considerably the binding energy and the shape of the nucleus /5/. We assume that the elementary processes correspond to the $p\langle NN\rangle_{^3H} \to Nd$ reactions where $\langle NN\rangle_{^3H}$ are the two-nucleon correlations in the triton-like p-shell of ^7Li. The cross section ratio $d\sigma(p,p'd)/d\sigma(p,nd)$ is not influenced by the kinematic factors and distortion effects as the initial and final states of $^7Li(p,p'd)$ and $^7Li(p,nd)$ reactions in our case, neglecting the differences between proton and neutron, are the same. Figure shows the diagrams which give dominant contributions to the $p\,^3H \to pnd$ reactions corresponding to the $p\langle np,t=0\rangle \to pd$ (t is the isospin), $p\langle np,t=1\rangle \to pd$ and $p\langle nn\rangle \to nd$ elementary processes, respectively.

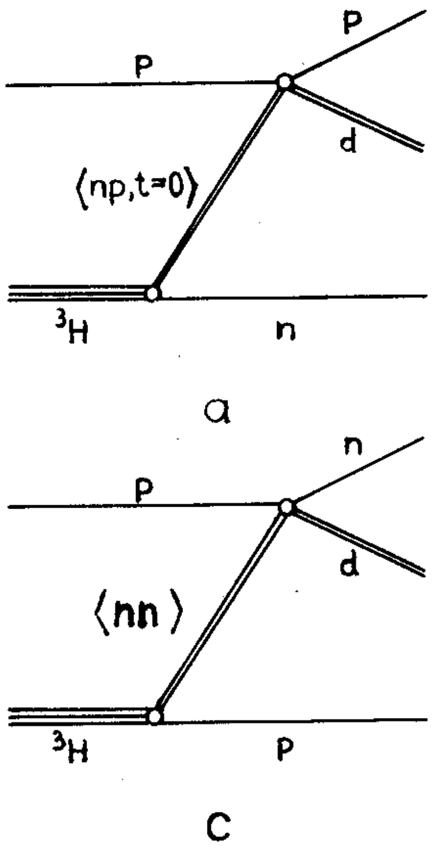

Fig. Diagrams of the $p\,^3H \to pnd$ quasifree scattering via two nucleon correlations (a) $\langle np,t=0\rangle$, (b) $\langle np,t=1\rangle$, (c) $\langle nn\rangle$.

The contribution of the different diagrams to the reactions depends on the sort and the energy of the backward scattered nucleon. At the energies, which correspond to the scattering on a two-nucleon system having small total momentum, the contribution of diagram c can be neglected when a backward going particle is a proton because it is a spectator in this case and its internal motion in ^3H has very few large momentum components (around 360 MeV/c in the present case). Similarly in the case of backward neutron the diagrams on figures a and b contribute only negligibly. Accordingly the $R = d\sigma(^7Li(p,p'd))/d\sigma(^7Li(p,nd))$ ratio is given by the sum of contributions of figures a and b divided by the contribution of Fig. c.

For evaluation of the terms in the Figure we follow the treatment of ref.[2]. The factors of the $^3H \to \langle NN \rangle N$ vertex which appears in the cross section ratio are extracted from the triton three-body wave function of[6]. It can be shown that the $p\langle NN \rangle \to Nd$ elementary cross section appears in a separate form in the cross section of the $^3H(p,Nd)N$ quasi-free scattering if the relative angular momentum of N and $\langle NN \rangle$ or the $\langle NN \rangle$ internal orbital momentum is equal to zero[7,2]. After spin summing of the amplitudes for R we get:

$$R = \frac{P(^3S_1)I_{01}^2(^3S_1) + P(^3D_1)I_{21}^2(^3D_1) + P(^1S_0)\frac{1}{9}(\frac{1}{2} - \frac{1}{2}10|\frac{1}{2} - \frac{1}{2})^2 I_{01}^2(^1S_0)}{P(^1S_0)\frac{2}{9}(\frac{1}{2}\,\frac{1}{2}1-1|\frac{1}{2} - \frac{1}{2})^2 I_{01}^2(^1S_0)}, \qquad (1)$$

where $P(^{2s+1}L_j)$ are the probabilities of the corresponding two-body correlations in triton given in[6]. The square of the Clebsch-Gordan coefficients gives the weight of the suitable isospin components. The origin of factors $\frac{1}{9}$, $\frac{2}{9}$ and the definition of $I_{\ell\ell\pm1}(^{2s+1}\ell_j)$ are from[2] and[8]:

$$I_{\ell\ell\pm1}(^{2s+1}\ell_j) = \int_0^\infty e^{-\gamma r}\phi_{\ell sj}(r)(1+\gamma r)j_{\ell\pm1}(pr), \qquad (2)$$

where $\phi_{\ell sj}(r)$ is the relative two-body wave function, $j_\ell(x)$ is a spherical Bessel function, the definition of γ and p which depend on the kinetic energy of backward nucleon can be found in[2]. In the experiment the most likely kinetic energy of the backward nucleon is equal to 65 MeV and the corresponding values are $\gamma = 0.74$ and $p = 1.69$. In formula (1) we have neglected those components which give very small contributions to R .

If the forms of the $\phi_{\ell sj}(r)$ two nucleon correlations were the same the (2) integrals would be identical and R would be 7.8. If, in calculations, we use the $^3S_1$, $^3D_1$ and $^1S_0$ two nucleon correlations obtained in /6/ solving the Faddeev equations with Reid soft-core interaction we get $R = 9.8$. The increase in R can be understood since in the triton the $^3S_1$ and $^3D_1$ correlations are of shorter range than the $^1S_0$ correlation /6/. The experimental value in /1/ is $R = 16.4 \pm 2.4$.

The cause of difference between the experimental and theoretical values may be explained if we apply for the ground state of ^7Li a cluster model which includes not only $^4He - ^3H$ but $^6Li - n$ component, as well /5/. In later configuration only the $p \langle np, t=0 \rangle \to pd$ reaction is probable on the p-shell nuclleons, because the mean distance between the n and p-shell neutron of ^6Li is larger as the mean nn distance in the triton. Taking into account the strong exponential decreasing factor the value of integral (2) for this $\langle nn \rangle$ correlation may be negligible. In estimate similar to formula (1) assuming in the ground state of ^7Li the weights as 55% for $^4He - ^3H$ and 45% for $^6Li - n$ component we can reproduce the experimental ratio.

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