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THE NEW THEORY OF QUASIELASTIC KNOCK-OUT OF NUCLEONS FROM NUCLEI BY PROTONS

Mirteymur Mirabutalybov
Physics Department, Azerbaijan State Oil and Industrial University
mmmteymur@yahoo.com

Abstract: On the basis of non-relativistic theory in the distorted-wave approximation in three dimensions, a theory of quasielastic knock-out of nucleons from nuclei by nucleons of intermediate energies has been developed. On the basis of this theory the differential cross sections of quasielastic knock-out reactions of protons with shells $1P_{3/2}$,$1P_{1/2}$ and $1S_{1/2}$ in the nucleus ^{16}O have been calculated, which allows to determine the orbital moments of the nucleons in the nucleus before scattering by the angular distribution of emitted protons. The analysis of the obtained results indicates that besides to knocking out of nucleons the collective excitation of the nucleus should be taken into account.

Key words: Quasielastic nucleon scattering. Excitation nucleus. Emitted protons.

1. Introduction

The reaction of knocking out nucleon and nucleon clasters by protons gives two relatively independent types of information: about bipartial forces and properties of the states of residue nuclear systems, and also about wave functions of knocked out particles.

Despite the qualitative progress in the understanding of quasi-elastic processes there are still unsolved problems. First, there is no quantative description of experimental differential sections [1,2].

Experimental data obtained in the study of knocking out reactions undaibtly contain the information about nuclear structure, however complexity of interpretation of reaction mechanism complicates its drawing. Wave function of the nuclear included into matrix element of transition is calculated procuding from shell or claster models of nuclear [3,4].

Based on the theory of direct interactions of nucleons with the surface protons and neutrons of the nucleus, using previously developed theory of the scattering of protons of intermediate energies in distorted-wave approximation [5], and getting the analytical form of expression of the differential cross section, we can receive more accurate information about the knocked-out nucleons before the reaction in the nucleus.

2. The proposed theory

Consider the derivation of the formula determining the angular distribution of protons in the reaction of surface interaction of the incident neutrons on the nucleus of the target. We write the differential cross section for the reaction A (n, np) in the following form:

$$d\sigma_{n,np} = (2\pi)^4 \frac{m}{k} d\mathbf{p}_f d\mathbf{p}_p \delta(E_i - E_f - E_p - E_N - E_R) \frac{1}{2J_i + 1} \sum_{\sigma_i \sigma_f} \sum_{M_i M_f} \left|T_{if}\right|^2 \qquad (1)$$

The matrix element of the nucleus transition is represented as

$$T_{if} =< f\left|\int d\mathbf{r}'d\mathbf{r}_p\psi^{(-)*}_{\mathbf{k}_f}(\mathbf{r}')\psi^{*}_{\mathbf{k}_p}(\mathbf{r}_p)\upsilon(|\mathbf{r}'-\mathbf{r}_p|)\psi^{(+)}_{\mathbf{k}_i}(\mathbf{r}')\psi_{nl}(\mathbf{r}_p)\mathrm{Y}_{lm}(\theta_p.\varphi_p)W(\mathbf{r}_p)\delta(|\mathbf{r}_p-R|)\right|i> \quad (2)$$

where

$$W(\mathbf{r}_p)=\int \psi^{*}_{A-1}(\mathbf{r})U(|\mathbf{r}_p-\mathbf{r}|)\psi_{A-1}(\mathbf{r})d\mathbf{r} \quad (3)$$

The wave functions of the scattered neutrons, obtained from the solution of the nonrelativistic Schrodinger equation.

Thus, the final expression of the differential cross section of quasielastic scattering of nucleons by nuclei is written as:

$$\frac{d^3\sigma}{d\Omega_1 d\Omega_2 dE_f}=\aleph_0(q)\sum_{L=0}^{\infty}i^{2L}(2L+1)\left|\psi_{n'L}(R)\sum_{n=0}^{3}a_n(q)\frac{\partial^n j_L(|\mathbf{q}-\mathbf{k}_p|)}{\partial q^n}\right|^2 \quad (4)$$

where

$$\aleph_0(q)=(2\pi)^5\hbar^4 m^2\sigma^2_{NN}(1+\varepsilon_0^2)\ell^{-\beta_0^2q^2}\left|W(R)\right|^2 E_f^{1/2}(E_i-E_f-E_N-E_R)^{1/2} \quad (5)$$

3. Results and discussions

Results of specific calculations of the reactions A (p, 2p) in nucleus ^{16}O by protons with energy $T_p = 1GeV$, compared with the experimental data are shown in Figure 1.

The calculations are mainly carried out for angles of emission of slow protons $\vartheta_3 = 61^\circ$ at a fixed angle of scattering of fast protons $\vartheta = 13{,}4^\circ$. Analysis of the results shows that the scattering cross section of protons depends on the angles weakly.

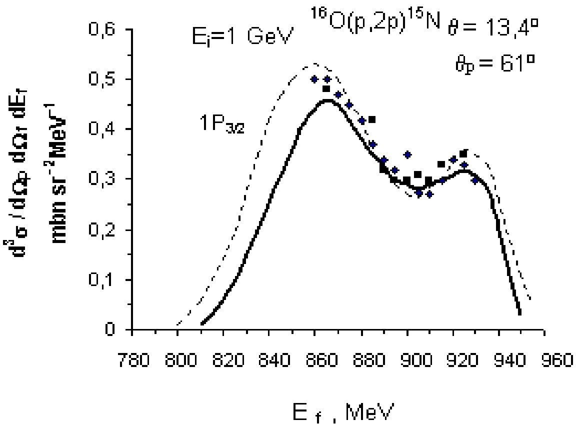

Fig. 1. Experimental (points) and theoretical (solid line) differential cross sections of quasielastic knock-out reactions of protons from sub shell 1P$_{3/2}$ *in the nucleus* ^{16}O *at the angles* $\vartheta_1 = 13{,}4^0$, $\vartheta_3 = 61^0$. *Dotted curves - the results of [6], calculated with the Hartree-Fock wave functions, taking into account the excitation of the nucleus.*

Nucleus ^{16}O may emit protons from levels 1 $P_{3/2}$, 1 $P_{1/2}$, 1 $S_{1/2}$, so the differential cross section has been calculated for each of these cases. In the experiment slow protons were registered at energies

E_p = (60÷105) MeV, (agreement theoretical cross section with the measured at registered fast protons takes place precisely at these values of the energies of slow protons).

As seen from Figure-1 the theoretical curve on proton knock-out from level $1P_{3/2}$, getd two maximum (exception [7], where only one maximum is contained). This is due to the fact that in this work, in addition to knocking out protons the excitation of the residual nucleus is also taken into account.

Thus, we can conclude that the similar calculations are convenient for practical use with analytic wave functions of the nucleus [7].

Theoretical analysis of reactions of knocking out requires a more rigorous review of nuclear wave functions, in particular, consideration of excitation of the residual nucleus and more accurate accounting of distortion in the wave functions of ejected nucleons from nuclei.

References

1. Deb P.K., Clark B.C. Phys. Rev. C. v.72, №1, 014608/25 (2005)
2. Yahiro Massanobu, Minomo Kosho Progr. Theor. Phys. v.120, №4, 767 (2008)
3. Johansson J.I., Sherif H.S., Ghoddoussi F. Nuclear Physics A, v. 665, p.403-415(2000)
4. Toshimi Suda, Haik Simon Progress in Particle and Nucl. Phys, Available online 24 April (2017)
5. Mirabutalybov M.M. Journal of Radiation Research,vol.2, №1, p.64-70 (2015)
6. Vorobev A.V., Dotsenko Yu.V. PNPI, Preprint 1076, 38 (1985)
7. Mirabutalybov M.M. Cumhuriyet Science Journal,vol.37, p.71-78(2016)

НОВАЯ ТЕОРИЯ ВЫБИВАНИЯ НУКЛОНОВ ИЗ ЯДЕР КВАЗИУПРУГИМ РАССЕЯНИЕМ ПРОТОНОВ

Миртеймур Мирабуталыбов

Резюме: На основе полученной искаженно-волновой нерелятивистической теории квазиупругим рассеянием протонов на ядрах исследованы выбивания нуклонов из поверхностной оболочки $1P_{3/2}$,$1P_{1/2}$ и $1S_{1/2}$ ядра ^{16}O при энергии падающих протонов $T_p = 1GeV$. Из анализа полученных результатов следует, что по угловому распределению испускаемых протонов можно определить не только орбитальные моменты выбиваемых нуклонов в ядрах до рассеяния, также выявить степень возбуждения остаточного ядра.

Ключевые слова: Квазиупругое рассеяние протонов, возбуждение ядра, излучаемый протон.

NUKLONLARIN KVAZIELASTIKI SƏPİLMƏCİLƏ PROTONLARIN NÜVƏDƏN QOPARILMASININ YENİ NƏZƏRİYYƏSİ

Mirteymur M.M.

Xülasə: Nuklonların nüvədən kvazielastiki səpilməcilə protonların qoparılmasını tədqiq etmək üçün təklif

olunmuş təhrif olunmuş dalğalar nəzəriyyəsi əsasında, enerjisi $T_p = 1GeV$ olan protonların ^{16}O nüvəsinin səthinin $1P_{3/2}$,$1P_{1/2}$ və $1S_{1/2}$ yarımtəbəqələrindən prononların qoparılması tədqiq edilmişdir. Qopan protonların bucaqlara görə paylanmasından onların prosesdən əvvəl nüvədəki orbital momentlərini müəyyən etməklə yanaşı, qalıq nüvənin həyəcanlaşmasını da müəyyən etmək mümkün olmuşdur.

Açar sözlər: kvazielastiki nüvə səpilməsi, nüvə həyacanlanması, ayrılmış protonlar.