Investigation of the quasielastic proton pair knock-on process from Li^6 and C^{12} nuclei by 640-MeV protons

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The $(p,3p)$ reaction was first reported in Ref. 1. This article presents results of a more detailed investigation of this reaction using equipment consisting of triggered spark chambers which permit determination of the energy and outgoing direction of each of the three protons. The experimental geometry corresponds to the scattering of a proton by a pair of nuclear protons at the angle of 118° in the cms of the colliding particles. Two spark chambers were placed to the left of the proton beam at angles of 22.5 and 31.5°; the third chamber was placed to the right of the beam at 80°. The energy of each proton was determined from its range in a chamber in the interval from 135 to 315 MeV. The graphite target was 3.51 g/cm^2 thick; the lithium target consisted of 90% Li^6 isotope and its thickness was 1.50 g/cm^2. The data was recorded photographically. When processing the photographs care was taken to completely exclude the contribution of events originating outside a target, and also the background associated with the random triggering of the camera control system.

Analysis of the experimental data on the energy distribution of particles and their interaction with the chamber plate material showed that the contribution from π-meson production and double p, p-scattering—which may simulate the quaielastic proton pairs knock-on reaction—is small.

Figure 1 shows the spectra of the total energy T_a of three protons for the Li^6 and C^{12} nuclear targets. The mean error in the total proton energy was 15–20 MeV.

Figure 1 shows that the upper boundaries of spectra are shifted from the initial

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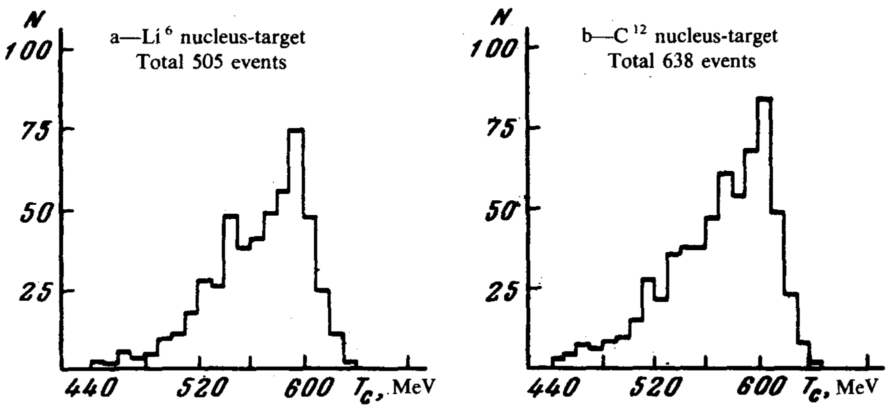

FIG. 1. Aggregate energy spectra of three protons for Li^6 and C^{12} nuclear targets.

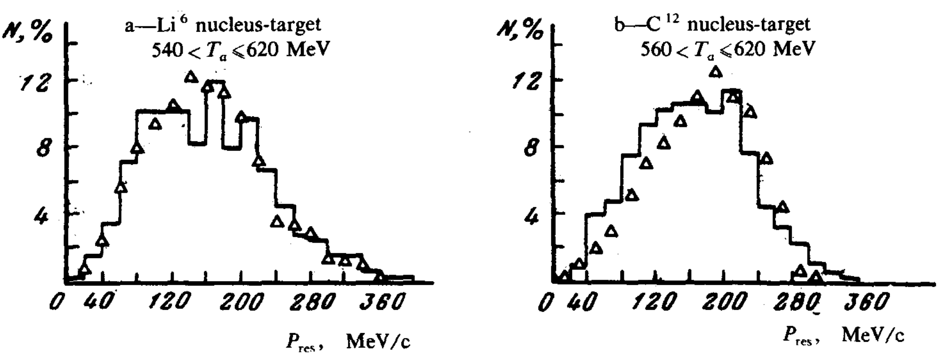

FIG. 2. Spectra of momenta of residual nuclei for Li^6 and C^{12} nuclear targets.

energy by approximately 30–35 MeV which corresponds to an energy loss due to detachment of a proton pair from a nucleus and to a transfer of a small amount of energy to the residual nucleus. This fact serves as proof that the proton-pair knock on process recorded in this experiment is quasielastic:

$$p + Li^6 \rightarrow p + p + p + (p + 3n)$$

$$p + C^{12} \rightarrow p + p + p + Be^9.$$

The shape of the total energy spectra is similar to the spectra for two fast protons[2–4] which are generated when π-mesons are captured by n, p-pairs of nucleons of Li^6 and C^{12} nuclei. The only difference is that our spectra are more broadened in the direction of lower energies due to a drop in the proton energy in the course of inelastic interaction in the chambers.

Figure 2 shows the recorded spectra of momenta of the residual nuclei. Triangles in Fig. 2a indicate the spectrum of momenta of the residual nuclei in the reaction

$$\pi^+ + Li^6 \rightarrow p + p + He^4,$$

where a pion is captured by an n, p-pair from the s-shell.[5] In Fig. 2b the triangles correspond to a spectrum of the momenta of the residual nuclei for the reaction

$$\pi^- + C^{12} \rightarrow n + n + B^{10},$$

where the excitation energy of the residual nucleus lies in the range from 0 to 15 MeV.[4] According to the analysis in Ref. 6, this energy range fully includes π^--meson capture by the np-pairs from the p-shell and the main share of capture by the np-pairs whose nucleons belong to different shells.

There is agreement among the spectra for the two direct nuclear reactions shown above. It indicates that in the case of the Li^6 nucleus the knock-on of proton pairs occurs from the s-shell, and in the case of the C^{12} nucleus the basic contribution to reaction derives from the pp-pairs from the p-shell.

The cross sections of a quasielastic pair knock-on reaction—for a total energy from 540 to 620 MeV—, are:

$$\frac{d^3\sigma}{d\omega_1 d\omega_2 d\omega_3} = (0.41 \pm 0.12)\cdot 10^{-28}\ \text{cm}^2/\ \text{sterad}^3 \qquad \text{for}\ Li^6,$$

$$\frac{d^3\sigma}{d\omega_1 d\omega_2 d\omega_3} = (1.19 \pm 0,35)\cdot 10^{-28}\ \text{cm}^2/\ \text{sterad}^3 \qquad \text{for}\ C^{12}.$$

The cross section we obtained for the C^{12} nucleus is an order of magnitude higher than a similar value obtained elsewhere.[1] The divergence of cross section values is due to the energy intervals within which the $(p,3p)$ reaction protons are recorded, being nearly three times broader in our experiment than those described in Ref. 1.

As investigations continue, it is of special interest to compare the cross section of the $(p,3p)$ reaction with that of direct deuteron knock-on. Such a comparison would, in our opinion, allow one to explain whether during the act of simultaneous interaction between an incident particle and a group of nucleons only quasielastic scattering off the group occurs, as is the case off a single particle. The presence of an inelastic process in which the bombarding nucleon destroys the group and imparts comparable energies to the nucleons that comprise it, cannot be excluded *a priori*.

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