объединенный
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E1 - 12393

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Submitted to "Journal of Physics. G"

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Комаров В.И. и др. **E1 - 12393**

Квазисвободное выбивание протонной пары в реакции C (p, 3p) при 640 МэВ

Прямая ядерная реакция C (p, 3p) при 640 МэВ изучается в эксклюзивном эксперименте методикой сцинтилляционных счетчиков. Условия измерений выбраны в соответствии с кинематикой квазиупругого выбивания двух нуклонов в условиях высокой передачи импульса нуклонной паре. Феноменологические модели рассеяния протона протонными парами описывают качественное поведение экспериментальных сечений.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1979

Komarov V.I. et al. **E1 - 12393**

Quasifree Knockout of Proton Pairs in Reaction C(p,3p) at 640 MeV

The direct nuclear reaction C(p,3p) at 640 MeV has been studied in an exclusive experiment. The measuring conditions were chosen in accordance with the kinematics of the two-nucleon quasifree knockout. Phenomenological models assuming proton scattering on proton pairs are in qualitative agreement with the data.

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

Preprint of the Joint Institute for Nuclear Research. Dubna 1979

Investigations of short-range correlations in nuclei should be performed in experiments in which the projectile transfers momenta of at least 200 MeV/c to the struck few-nucleon groups. This type of processes has been studied by measuring nuclear fragment production in quasielastic knockout reactions (see, e.g., ref. /1/). However, nuclear reactions with groups of unbound nucleons in the final state are also of considerable interest. The appearance of additional kinematic variables (for instance, the invariant mass of the knocked out nucleon group) charactezirng these processes opens up new possibilities for the study of the interaction mechanism at large momentum transfers. New reaction channels such as the knockout of proton or neutron clusters become accessible.

One of the simplest reactions under consideration is the quasifree knockout of proton pairs by protons

$$p + A \to p + p + p + B . \qquad (1)$$

The present work was aimed at studying the mechanism of the nuclear reaction C (p, 3p) at 640 MeV. The paper deals with exclusive measurements, where the three energetic protons of the final state have been detected. The kinematic conditions of the experiment correspond to the proton backward scattering (122° lab. s.) according to the "elementary" process

$$p_0 + [pp] \to p_1 + p_2 + p_3 . \qquad (2)$$

This experimental situation guarantees large four-momentum transfers to the intranuclear [pp]-group. Furthermore, the backward emission of energetic protons in hadron-nucleus collisions is of considerable interest at present (see, e.g., refs. /2-4/). The results of the initial stage of our investigation have been published earlier /5/.

The experiment was performed at the proton beam of the Dubna synchrocyclotron. The experimental conditions schematically shown in fig. 1 were chosen in accordance with the

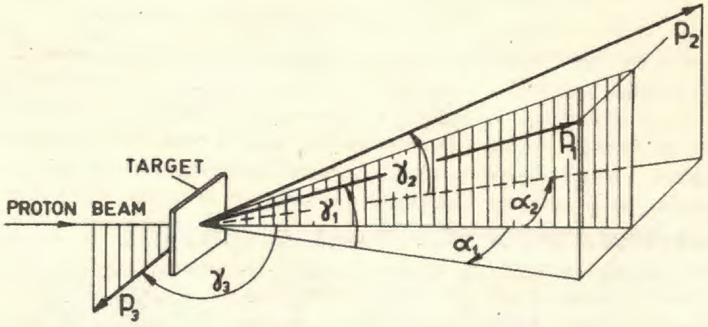

Fig. 1. Geometrical conditions of the experiment.

kinematics of reaction (2) for symmetrical ($\alpha_1 = \alpha_2 \equiv \alpha$, $\alpha_3 = 0$), noncomplanar geometry ($\gamma_1 = \gamma_2 = 12^\circ$, $\gamma_3 = 122^\circ$). The secondary protons p_1, p_2, p_3 with momenta $\vec{p}_1$, $\vec{p}_2$, $\vec{p}_3$, respectively were detected by three plastic scintillation counter telescopes. Two telescopes (solid angles $\Omega_1 = \Omega_2 = 0.02$ sr, angular acceptances $\Delta\alpha_{1(2)} = \Delta\gamma_{1(2)} = \pm 4^\circ$) detecting protons emitted in the forward direction consisted each of four scintillation counters, a Cherenkov counter for pion rejection and copper absorbers determining an energy window of 235-310 MeV. The third telescope (solid angle $\Omega_3 = 1.2$ sr, angular acceptances $\Delta\alpha_3 = \Delta\gamma_3 = \pm 29^\circ$) consisted of a ΔE-E -veto-counter combination and allowed to identify particles and measure the proton energy in the range of 30-105 MeV.

As beam monitors an ionization chamber and a special counter system detecting protons from the elastic pp scattering from a CH_2 monitor target were used. The experimental set-up has been described in detail /6-8/.

In order to separate random coincidences correctly from the true triple coincidences events the time intervals τ_{12} and τ_{13} between the signals in the respective pairs of the telescopes were measured. Figure 2 shows a two-dimensional $\tau_{12} - \tau_{13}$ time spectrum obtained at an angle $\alpha = 7.5^\circ$ where the background was on its highest level. The measurements have been carried out at a mean beam intensity of about 10^8 protons/s on a carbon target of 0.36 g/cm^2 thickness.

Using a full Monte Carlo simulation of the experiment we derived from the data the cross section $dI(\alpha, T3)/dT3$ which is the differential cross section $d^6\sigma/d\Omega_1 dT1\, d\Omega_2 dT2\, d\Omega_3 dT3$

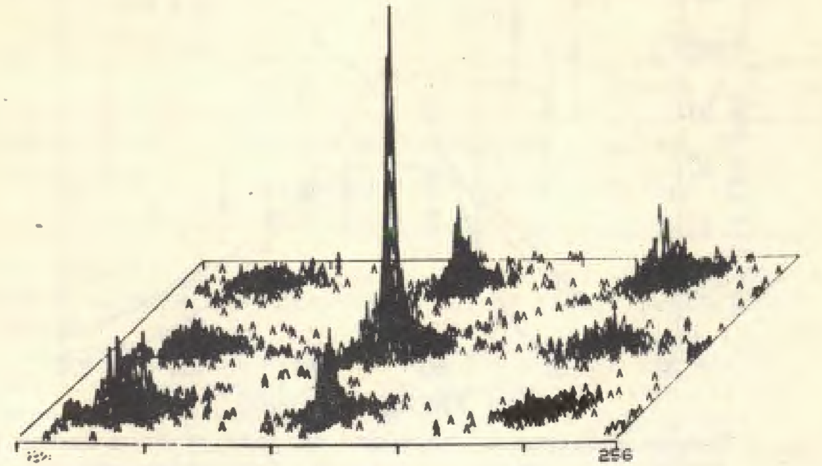

Fig. 2. Two-dimensional $\tau_{12} - \tau_{13}$ time spectrum. The narrow peak contains true triple coincidence events, the 9 broad peaks represent random events from protons of three pulses of beam micropulsation with a period of 71 ns.

averaged over the acceptances mentioned above. The error of the absolute calibration amounts to 25% and is not included in the quoted errors.

The T3 energy spectra $dI/dT3$ measured at six values of the forward angle α decrease with increasing T3 (see fig. 3). The cross section maximum expected for process (2) has a considerable width (about 50 MeV FWHM) mainly due to the Fermi motion of the [pp]-cluster and the detector acceptances. Moreover, at the low-energy part of the spectra there may be contributions of processes different from the direct two-proton knockout (for instance, rescattering of backward ejected protons in the final nucleus). Therefore, the model calculations presented in fig. 3 agree with the data only for energies $T3 \geq 50$ MeV.

As shown in fig. 4, the cross section decreases monotonically with increasing the angles between the protons emitted forward. The angular distribution $I(\alpha) = 1/(T3_{max} - T3_{min}) \int (dI/dT3) dT3$ is the narrower, the larger T3, as is demonstrated in the table. Such a dependence is expected from the kinematics of process (2). Indeed, with increasing

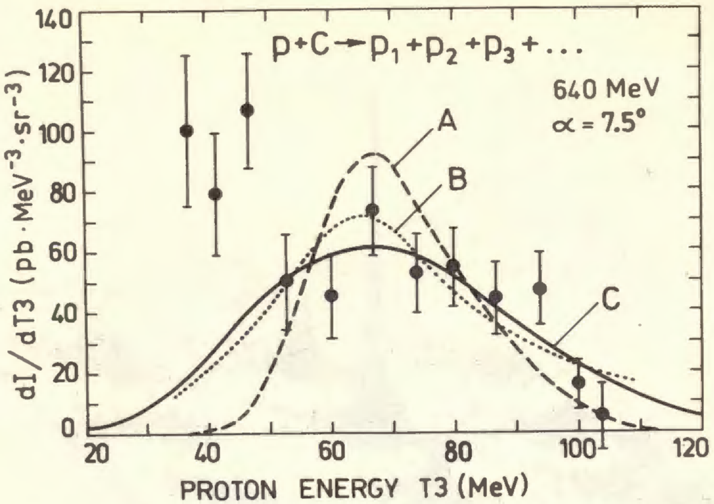

Fig. 3. Energy spectrum of backward emitted protons measured in the triple coincidence experiment. The curves represent phase space calculations for process (2) and are normalized to the experimental T3 spectrum between 52 and 104 MeV. A, without the Fermi motion of the [pp]-pair taken into account; B, with the Fermi motion; C, with the Fermi motion and the $|T|^2$ dependence according to relation (4) with a_{ch}=0.3 fm.

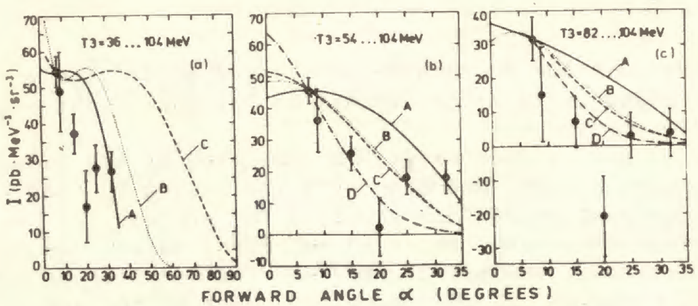

Fig. 4. Angular dependence of the cross section $I(\alpha)$ for three T3 energy intervals of the backward ejected proton. (a) The curves are phase space distributions for the following reactions: A, process (2) with the Fermi motion; B, $p+[ppN]\to p_1+p_2+p_3+N$; C, $p+{}^{12}C\to p_1+p_2+p_3+{}^{10}Be$. (b), (c) Calculations for process (2) with the Fermi motion. A, $|T|^2$ = const., B, $|T|^2$ according to relation (3) with E_{ch}= 0.15 GeV; C, $|T|^2$ according to relation (4) with a_{ch}=0.3 fm; D, the same as C with a_{ch} = 0.5 fm. The curves are normalized to the experimental data at 7.5°.

Table

Ratio of the cross sections $I(\alpha)/I(7.5°)$ depending on the energy interval T3

	36-59 MeV	59-82 MeV	82-104 MeV
$I(32.1°)/I(7.5°)$	0.63±0.04	0.50±0.08	0.19±0.27
$I(25°)/I(7.5°)$	0.68±0.03	0.45±0.06	-0.13±0.17

the angle α both the energy T3 and the emission angle of the proton p_3 decrease, putting $\vec{p}_3$ out of the telescope acceptance.

The phase space distributions for process (2) are in qualitative agreement with the experimental data, if one takes the Fermi motion of the proton pair into account (see curves A in fig. 4). The calculations for other reactions with three fast protons in the final state (curves B, C in fig. 4a) are noticeably different from the data points.

A possible dependence of the matrix element T for process (2) on the kinematic variables have been considered using two phenomenological models:

$$\text{(i)}\quad |T|^2 \sim \exp(-E_{12}/E_{ch}), \qquad (3)$$

where $E_{12}=M_{12}-2m$, M_{12} being the invariant mass M_{inv} of the p_1p_2 -pair in the final state, m being the nucleon mass and E_{ch} a parameter characterizing the probability of the M_{inv} increase during the backward scattering of the projectile.

$$\text{(ii)}\quad |T|^2 \sim \sum_{i=1,2} \exp[-(\theta^*_{0i}\, p^*_0\, a_{ch})^2] \qquad (4)$$

where θ^*_{0i} and p^*_0 are the c.m. scattering angle and momentum, respectively. In this small-angle scattering mechanism the parameter a_{ch} characterizes the size of the struck proton pair.

Figures 3 and 4 show the calculations according to relations (3) and (4) which agree qualitatively with the data. It should be mentioned that with the same parameter values E_{ch} = 0.15 GeV and a_{ch}= 0.3 fm used here we were able to describe the two-proton coincidence data too /9/.

We consider forward scattering mechanism (4) to be preferential because of the lower four-momentum transfers $\sqrt{|t|}$ needed. Indeed, at the angle α = 7.5° the average value $\sqrt{|t_{03}|}$ between p_0 and p_3 according to (3) amounts to

7.1 fm^{-1}, whereas $\sqrt{|t_{01}|}$ $(=\sqrt{|t_{02}|})$ results in 2.2 fm^{-1} by using relation (4). It is essential to note that in the latter case the invariant mass of the p_{23} (or p_{13}) pair increases on the average by 270 MeV. Such great changes of the invariant masses of few-nucleon systems involve, obviously, inelastic processes (pion production or isobar excitation in the intermediate states), which are known to play an important role in the production mechanism of fast protons emitted backward (see, e.g., refs.[10,11]). Therefore we conclude that such proton ejection in hadron-nucleus collisions at medium energies depends not only on the short-range nucleon-nucleon correlations (see, e.g., refs.[12,13]), but also on the properties of intranuclear nucleon groups suffering high excitations of several hundreds MeV.

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Received by Publishing Department
on April 17 1979.