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S u m m a r y

The experimental search for the direct nuclear reaction of quasielastic knockout of proton pairs by 640 MeV protons from ^{12}C has been carried out. Up to now there is no experimental evidence for such a reaction. The kinematical conditions were chosen to be similar to those of a quasielastic knockout of a proton pair by the incident proton, scattered at 122° in the lab. system. The differential cross section of emission of two protons with energies higher than 260 MeV at small angles with respect to the incident beam and the proton (or ^{2}H, ^{3}H, ^{3}He, ^{4}He), emitted in the backward direction, has been measured.

The knockout of light fragments from nuclei by medium-energy protons has been investigated extensively for many years (see, for example,[1]). The behaviour of nucleons within nuclei at small relative distances is one of the main objects of these investigations. That's why the knockout process is studied under the conditions of a large momentum transfer to the fragment. At the last time two directions of further experimental activities in this field are seen:

(i) kinematically complete measurements of knockout processes [2] and (ii) search for the quasielastic knockout of groups of nucleons which are unbound in the final state. The simplest processes of this type are the knockout of two-nucleon clusters. Up to now there has been no experimental evidence for these processes obviously because of the experimental difficulties[3] (small cross sections, detection of at least two particles in coincidence)*.

The present paper gives the first results of a search for the knockout of two protons from ^{12}C by a proton under the conditions of high momentum transfer to the proton pair.

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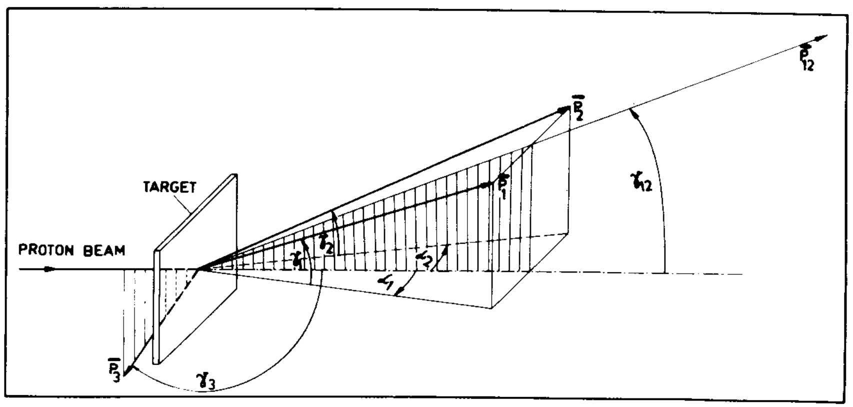
* It seems worth to emphasize that the investigations of effective-mass distributions of two slow protons resulting from an interaction of high energy particles with nuclei (see ref. [4]) is not directly related to the problems discussed in the present paper.

The experiment was performed with the 640 *MeV* proton beam from the JINR synchrocyclotron (the macro duty cycle = 0.65). The beam intensity was limited to about 5×10^7 protons per second to keep the accidental coincidence rate low. An ionization chamber and a special counter system, detecting elastic pp-scattering from a CH_2 - monitor target were used for monitoring.

The beam spot at the main target was about 3.7x2.7 cm^2 FWHM. As a target we used a graphite plate of 2.98 g/cm^2 thickness. Figure 1 shows the geometry of the experimental set-up. The kinematical conditions were chosen to be similar to those of proton scattering on a two-proton cluster with large momentum transfer to the cluster. The knocked out protons, P1 and P2, were detected at a small angle between them ($\alpha_1 + \alpha_2 = 18°$) and at an angle $\gamma_1 = \gamma_2 = 12°$ in order to get the counters out of the incident beam. This leads to an angle of the backscattering $\gamma_3 = 122°$. Thus, the corresponding scattering angle in the c.m. system of the three protons amounts to $\theta_{c.m.} = 155°$ and the momentum, transferred to the two-proton cluster $|\bar{p}_0 - \bar{p}_3| = 7.6\ fm^{-1}$.



Geometrical conditions of the present experiment.

The two protons P1, P2 were detected by two counter telescopes T1 and T2, each consisting of three plastic scintillation counters operating in coincidence and the fourth one in anticoincidence and a Cherenkov counter (C) in anticoincidence for rejection of pions. Copper absorbers placed between the counters allow the protons to be detected in the energy range of 260 to 335 *MeV*. Both the telescopes, T1 and T2, cover an angle interval of $\Delta\alpha_1 = \Delta\alpha_2 = \pm 4°$ and $\Delta\gamma_1 = \Delta\gamma_2 = \pm 4°$, so that the solid angle amounts to $\Omega_1 = \Omega_2 = 1.9 \cdot 10^{-2}\ sr$.

The T1 and T2 telescopes allow the registration of the two forward protons P1 and P2 with a sum-momentum p_{12} ($p_{12} = |\bar{p}_1 + \bar{p}_2|$) and the relative momentum Δ ($\Delta = |\bar{p}_1 - \bar{p}_2|$) lying in the following intervals: $1460\ MeV/c \le p_{12} \le 1710\ MeV/c$, $120\ MeV/c \le \Delta \le 400\ MeV/c$. This means (i) the sum-momentum essentially exceeds the relative momentum and (ii) the chosen interval of the relative momentum Δ prevents strong final state interaction between the two protons.

It is worth mentioning that the relatively low momentum in the final state is not in contradiction to a possible high relative momentum between the two protons, P1 and P2, in the initial state.

The third counter telescope, T3, (for detecting the back-scattered proton) consists of three scintillation counters. Two counters were put in coincidence and one veto counter was used to reject long-range particles. The energy window for protons was 15 to 92 *MeV* (the corresponding energy window for protons emitted from the target centre amounts to 32 to 98 *MeV*) and the angular spread $\Delta\alpha_3 = \Delta\gamma_3 = \pm 31°$, leading to the large solid angle $\Omega_3 = 1.5\ sr$. The electronic arrangement allows one to measure the number of real triple coincidences N_{EFF} with a resolution time of about 4.5 *ns* along with all types of accidental coincidences of events from T1, T2, T3. The experimental set-up will be described in detail in a forthcoming paper.

The results of several experimental runs, summarized in the table, show that under the conditions of our experiment real triple coincidences have been obtained. We

Table 1

Triple coincidence yield N_{EFF}/N_{Mon} measured under several experimental conditions.

No. of measurement	Time of measurement, $[10^3 s]$	Beam intensity, $[N_{Mon}/s]$	Target	Additional conditions	N_{EFF}/N_{Mon}, $[10^{-3}]$
I	13	1.25	C 9°	-	2.97±1.13
II	35	2.02	C 9°	-	1.26±0.28
III	18	1.69	C 9°	-	1.11±0.52
I+II+III	66	1.78	C 9°	-	1.31±0.24
III	9	8.98	without 9°	-	-0.12±0.07
I+II	7	1.77	C 9°	without 1Č, 2Č anticoincidences	1.02±0.71
I+II	11	2.66	C 9°	8.4 g/cm² Cu in front of T3	0.53±0.40
II	5	2.24	C 9°	16.8 g/cm² Cu in front of T3	-0.31±0.22
II	8	5.17	C 20°	-	0.22±0.36
II	4	2.01	Be* 9°	-	-0.22±0.52

* 3.2 g /cm² thickness.

measured a total number of 154 real events during a time of 18.3 hours.

From the measurement without anticoincidence of the Cherenkov counters, 1Č and 2Č, it follows that a possible admixture of events resulting from pion registration in T1 or T2 is smaller than 5%. Furthermore, the probability for registration of neutrons in T1 and T2 is very low because of the small detection efficiency for neutrons with respect to protons ($\epsilon_n/\epsilon_p \leq 5\cdot 10^{-4}$). If two protons of at least 260 *MeV* energy appear in T1 and T2, then the production of pions and their subsequent registration in T3 is prevented by energy conservation.

For a possible contribution of electrons (arising from the conversion of γ-quanta in the target material and subsequent registration in T3) an upper limit of 20% under our experimental conditions was obtained.

In principle, the counter telescope T3 also allows the registration of ^2H, ^3H, ^3He and ^4He of energies higher than 20, 24, 53 and 59 *MeV*, respectively. The detection of heavier fragments than ^4He, however, is excluded because of the range threshold of T3. (For fragments emitted from the target centre the energy thresholds are $T_{^2H} > 41$ *MeV*, $T_{^3H} > 49$ *MeV*, and the registration of ^3He and ^4He is impossible).

The control measurements with absorbers in front of T3 (see the table) show that in this telescope only short-range particles are detected. As one may expect, coincidences with protons of the energy higher than 130 *MeV* in T3 were not observed.

From our results one can determine the differential cross section of the $p + {}^{12}C$ reaction with two protons of energies 260-335 *MeV*, outgoing in the forward direction and one proton (or a fast fragment such as ^2H, ^3H, ^3He or ^4He) in the backward direction of the energy pointed out above. With the three particles detected in the angle intervals mentioned above the cross section amounts to

$$\frac{d^3\sigma}{d\Omega_1 d\Omega_2 d\Omega_3} = (8.4 \pm 2.2)\cdot 10^{-30} cm^2/sr^3 .$$

The quoted error contains both statistical and systematical uncertainties.

This value is the upper limit for the cross section of the quasielastic $^{12}C(p,3p)^{10}Be$ reaction.

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