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OBSERVATION OF CORRELATION BETWEEN TWO FAST PROTONS IN PROTON-NUCLEUS INTERACTIONS AT 640 MeV

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Наблюдение корреляции между двумя быстрыми протонами в протон-ядерных взаимодействиях при 640 МэВ

Методикой сцинтилляционных счетчиков измерено дифференциальное сечение эмиссии назад быстрых протонов с энергией от 50 до 145 МэВ в совпадениях с протонами (255-330 МэВ), вылетающими вперед в протон-ядерных взаимодействиях, с целью изучения механизма такой эмиссии. Экспериментальные условия соответствуют кинематике квазисвободного рассеяния падающих протонов на двух нуклонах ядра мишени. Результаты сравниваются с предсказаниями нескольких моделей эмиссии назад быстрых протонов.

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Observation of Correlation between Two Fast Protons in Proton-Nucleus Interactions at 640 MeV

The differential cross section for the backward emission of fast protons of energies from 50 to 145 MeV has been measured in coincidence with forward outgoing protons (255 to 330 MeV) in proton-nucleus interactions by a scintillation counter method. The experimental conditions correspond to the kinematics of the quasifree scattering of incident protons on two nucleons within the target nucleus. The results are compared with the predictions of several models describing backward fast proton emission.

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

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Recently several models [1-7] have been developed to describe the production of backward emitted protons (BEP) of energies above 30 MeV in hadron-nucleus interactions. Although the models use very different physical processes, the inclusive BEP spectra can be rather well reproduced by all models. Therefore none of the models can be favoured on the basis of inclusive data alone. However, a strongly different behaviour of particles accompanying BEP can be obtained from some of these models. So the model of ref. [2] predicts the forward production of a single proton of an energy $T_0 - T - \epsilon$, if a BEP of the energy T is emitted in a reaction initiated by a proton of the energy T_0 (ϵ being the average nucleon-nucleus interaction energy). From the model of ref. [6] correlations between the BEP and quasi-elastically knocked out fragments (see ref. [8]) or groups of nucleons with an invariant mass close to those of the appropriate fragment must be expected.

The present letter contains the results of measurements performed to observe correlations between BEP and forward outgoing protons from quasi-free scattering of the incident proton on a nucleon pair [pN] within the nucleus:

$$p_0 + [pN] \rightarrow p_1 + N + p_3 . \qquad (1)$$

Here p_1 denotes a proton detected in coincidence with the BEP p_3, and N is a nucleon unobserved under the conditions of this experiment.

The energy intervals for the detection of p_1 and p_3 were chosen in accordance with the kinematics of the process

$$p_0 + [pN] \rightarrow (p_1 N)_{\Delta=0} + p_3 , \qquad (2)$$

i.e., process (1) with zero relative momentum $\Delta_{p_1 N}$ in the c.m.s. of the p_1N -pair. The proton p_1 was detected by a scintillation counter telescope in the energy interval 255 MeV < T1 < 330 MeV determined by the proton range in telescope absorbers. Pion detection in this telescope was suppressed by means of a threshold Cherenkov counter. The BEP energy T3 was measured by a $(\Delta T, T)$ scintillation counter telescope between 50 and 145 MeV with an energy resolution of about 10% (FWHM). Solid angles and angular acceptances were $\Delta\Omega_1 = 0.02$ sr, $\Delta\alpha_1 = \pm 3.4°$ and $\Delta\Omega_3 = 0.1$ sr, $\Delta\alpha_3 = \pm 9°$ for p_1 and p_3, respectively. Experimental conditions for the detection of p_3 were the same as in the inclusive measurement of ref. /9/. The experiment was performed in a coplanar geometry.

The most important correction of the measured cross section (at the level of about 5%) was caused by the background of proton-deuteron coincidences from the quasi-elastic (p, pd) -reaction. The error of the absolute calibration amounts up to 20% and is not included in the quoted errors.

The angular dependence of the cross section on the angle α_3 for a fixed value $\alpha_1 = 12°$ is shown in Fig. 1. The α_3 -distribution is strongly asymmetric with respect to $\alpha_3 = 180°$ and depends noticeably on T3. It should be noted that the kinematics of process (2) for $\alpha_1 = 12°$ leads to the values $\alpha_3 = 124°$ and T3 = 74.4 MeV.

A still more pronounced correlation is observed in the α_1 dependence of the cross section at $\alpha_3 = 122°$ (see Fig. 2). A fit with a Gaussian to the experimental points of this dependence yields the mean values $\bar{\alpha}_1 = 10.4° \pm 1.7°$ for 50 MeV < T3 < 90 MeV and $\bar{\alpha}_1 = 10.9° \pm 1.1°$ for

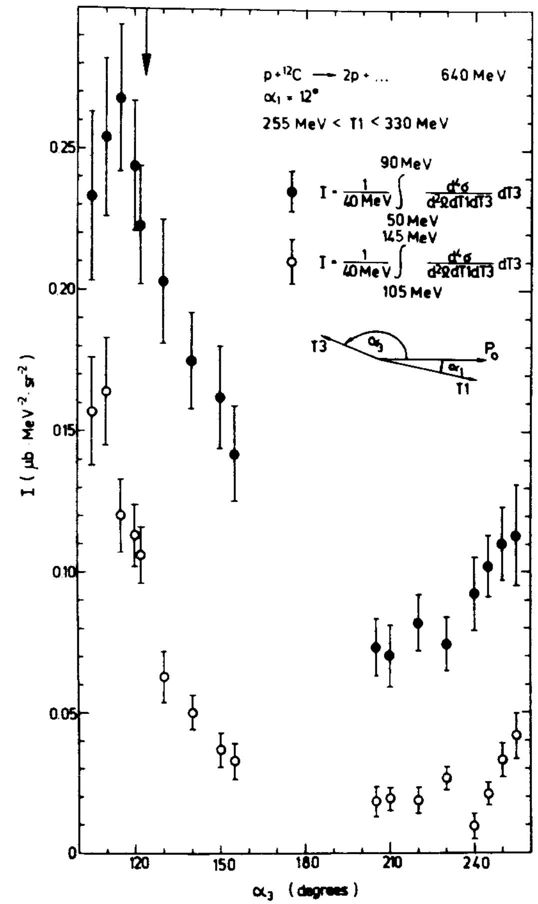

Fig. 1. Differential cross section of the reaction $p + {}^{12}C \rightarrow 2p + ...$ versus α_3 for fixed α_1. The arrow indicates α_3 expected for process (2).

105 MeV < T3 < 145 MeV. These values should be compared with $\alpha_1 = 12.6°$ which follows from the kinematics of process (2).

The BEP energy spectra decrease monotonously with increasing T3 at all the investigated angles α_1, α_3. On the assumption that events at $\alpha_3 > 180°$ are caused by processes in which angular correlation with p_1 is absent, the contribution of process (1) should be more pronounced in the diffe-

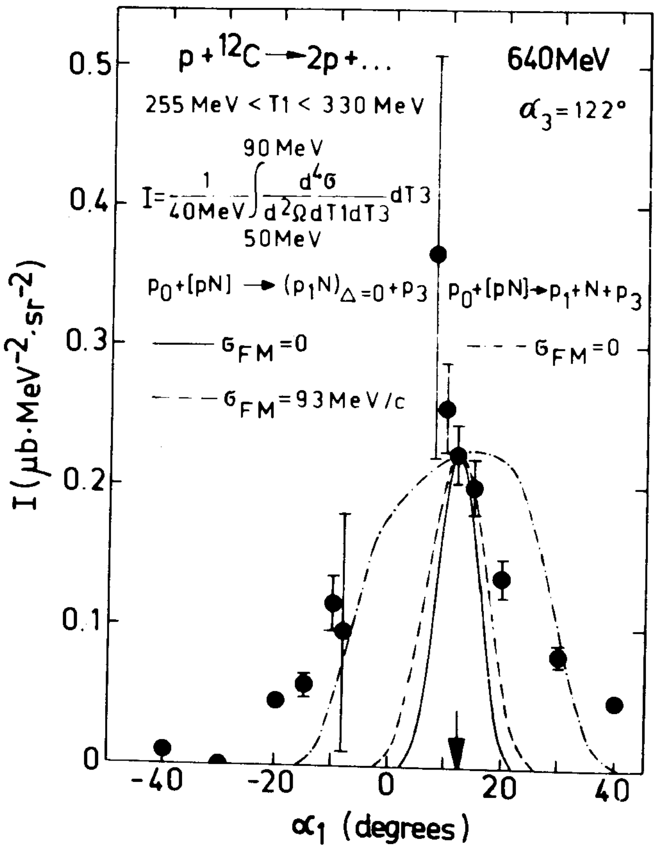

Fig. 2. Differential cross section versus α_1 for fixed α_3. The arrow indicates α_1 expected for process (2). The curves are results of phase space calculations for processes (1) and (2) and are arbitrarily normalized at $\alpha_1 = 12°$.

rence of the spectra at $\alpha_3 = 110° - 130°$ and $\alpha_3 = 230° - 250°$. A broad bump in such a difference spectrum cannot be excluded, indeed (see Fig. 3).

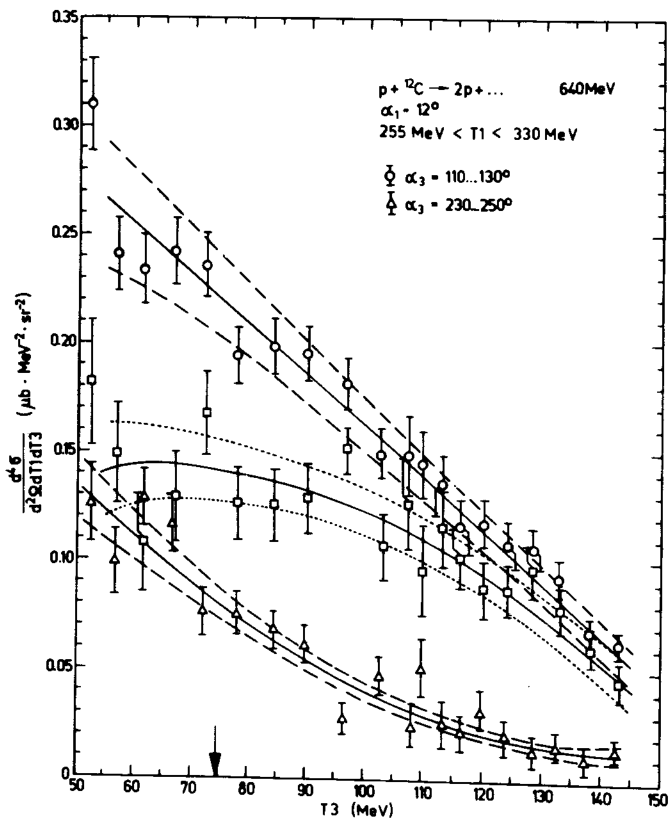

Fig. 3. Energy spectra of backward emitted protons summed up over the two angle regions given in the figure together with the difference between the two spectra (□). The curves with the corridor of errors are second order polynomial fits. The arrow indicates T3 expected for process (2).

The measurements performed at $\alpha_1 = 12°$, $\alpha_3 = 122°$ with Be, C, Al, Cu and Pb targets point out that the discussed production of two fast protons is observable with all these targets and that the cross section per targer nucleon decreases with increasing the target number A (see Fig. 4).

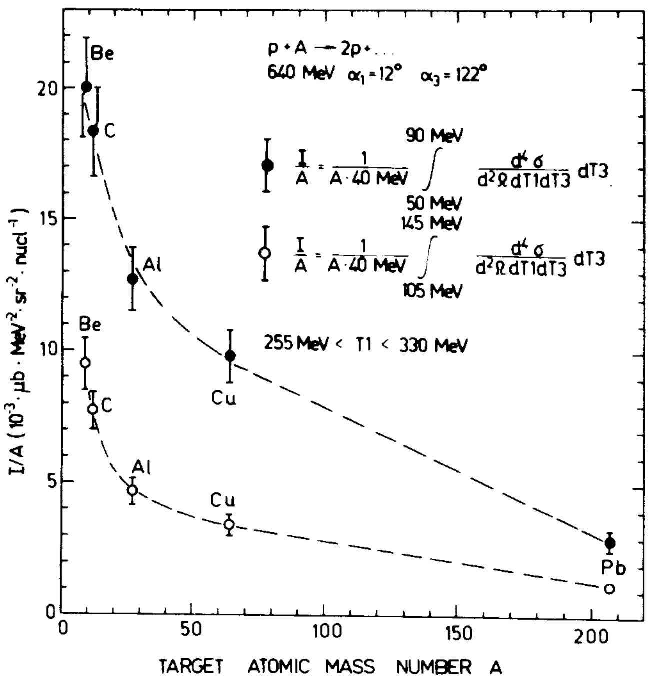

Fig. 4. A-dependence of the differential cross section per nucleon of target nucleus. The curves are drawn to guide the eye.

The measured distributions show that the main contribution to the cross section is due to process (1). This is verified especially by the fact that the experimental cross section as a function of α_1 is very close to the phase space distribution for process (1) (see fig. 2), whereas the phase space distributions for such reactions as $p + [p2N] \to p_1 + N + N + p_3$, $p + {}^{12}C \to p_1 + p_3 + {}^{11}B$ or $p + {}^{12}C \to p_1 + p_2 + p_3 + {}^{10}Be$ differ essentially from the experimental one. Furthermore, the kinematics for $p + [p2N] \to p_1 + N + N + p_3$ with small relative momenta in the system $p_1 + N + N$ and $\alpha_3 = 122°$ determines $\alpha_1 \approx 18°$, $T1 \approx 155$ MeV, and $T3 \approx 180$ MeV.

The experimental cross section $d\sigma_{13}(255 \text{ MeV} < T1 < 330 \text{ MeV}, \alpha_3 = 122°)/(d\Omega_1\, d\Omega_3)$ can be integrated over Ω_1, if the angular distribution of forward outgoing protons is assumed to be axially symmetrical around the direction given by $\bar{\alpha}_1 = 10°$. The result $d\sigma_{13}(\alpha_3 = 122°)/d\Omega_3$ can be compared with the cross section $d\sigma_{incl}(\alpha_3 = 122°)/d\Omega_3$ of BEP production in inclusive measurements [9]. The absorption of forward outgoing protons in the target nucleus is taken into account by a factor $\gamma \approx 0.66$. This gives $(d\sigma_{13}(\alpha_3 = 122°)/d\Omega_3)/(\gamma \cdot d\sigma_{incl}(\alpha_3 = 122°)/d\Omega_3) = 0.28 \pm 0.04$ (statistical error), i.e., the process measured in the present work contributes considerably to the inclusive measured cross section. This conclusion is confirmed by the fact that there are forward emitted protons of energies T1 outside the interval 255 MeV to 330 MeV. The existence of such protons follows from the measured T1-dependence for $\alpha_1 = 12°$, $\alpha_3 = 122°$ in the region of 180 MeV < T1 < 330 MeV, in which the cross section changes weakly (from 0.16 to 0.23 $\mu b\, MeV^{-2} sr^{-2}$).

The mechanism proposed in ref. [2] predicts a correlation between BEP and forward outgoing protons which have energies 470 MeV < T1 < 565 MeV under the conditions of the present experiment. These energies are remarkably out of the used T1-region. Therefore, it seems to be questionable to extract information on the high momentum components of the single particle wave function of the nucleus from inclusive measurements [2].

The inclusive BEP spectra have been explained in ref. [6] by the quasi-elastic backscattering on clusters which do not break up during the interaction. Following this model we have calculated the phase space distribution using a Gaussian for the density of the momentum distribution of the [pN] clusters in ^{12}C with a dispersion σ^2_{FM} known from experiments on quasi-elastic deuteron knock-out [10]. The calculated distributions are remarkably narrower than the experimental ones (e.g., see Fig. 2). An agreement can be achieved only, if in contrast to ref. /6/ the relative momenta Δ_{pN} up to several 100 MeV/c are included in the calculations.

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REFERENCES

1. Efremov A.V. In: Proc. of the XVIII Int. Conf. on High Energy Phys., Tbilisi, 1976. JINR, D1,2-10400, Dubna, 1977, p.A6-12.
2. Amado R.D., Woloshyn R.M. Phys.Rev.Lett., 1976, 36, p.1435.
3. Kopeliovich V.B. Jad.Fiz., 1977, 26, p.168.
4. Weber H.J., Miller L.D. Phys.Rev., 1977, C16, p.726.
5. Strikman M.I., Frankfurt L.L. Phys.Lett., 1977, 69B, p.93.
6. Fujita T. Phys.Lett., 1977, 72B, p.16.
7. Burov V.V., Lukyanov V.K., Titov A.I. JINR, E2-10680, Dubna, 1977.
8. Komarov V.I. et al. Nucl.Phys., 1976, A256, p.362.
9. Komarov V.I. et al. Phys.Lett., 1977, 69B, p.37.
10. Albrecht D. et al. JINR, E1-8935, Dubna, 1975.

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