Momentum distribution of protons and deuterons from ^{3}He fragmentation by carbon at 10.78 GeV/*c* and zero angles

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The differential cross sections of the reactions (^{3}He,d) and (^{3}He,p), in which the fragments are emitted in the forward direction over a broad range of momenta, are measured for the first time. These spectra, which are presented as functions of the relativistic intrinsic momentum, are shown to be similar. The spectrum of the (^{3}He,d) reaction is compared with the calculations with use of the wave functions of ^{3}He.

The differential cross sections of the reactions (^{3}He,d) and (^{3}He,p), with the release of fragments at angles $\theta < 0.4°$ at an incident-particle momentum $p_0 = 10.78$ GeV/c, were measured using the AL'FA apparatus.[1] The preliminary results were reported at two conferences.[1,2]

The experimental arrangement is essentially the same as that described previously.[2] The measurement part of the apparatus is placed behind the magnet, which separates the secondary particles from the beam particles, making it possible to carry out the measurements at intensities up to 10^{10} particles/cycle. To identify the particles in the overlap region of the momentum spectra of secondary particles (protons, deuterons, inelastically scattered ^{3}He nuclei), we separated the particles according to the velocities[2] (by means of the Čerenkov counters) and according to the charges (by analyzing the amplitudes of the signals from the scintillation counters). The proton spectrum near $p = p_0/2$ was not measured, since the magnetic hardness of these protons is the same as that of the primary-beam particles. To normalize the spectra which we obtained, we measured the differential cross sections of the reaction (^{3}He,d) at $p_d \simeq (2/3)p_0$. The experimental arrangement is the same as that described in Ref. 3. The systematic error of the absolute normalization of our data is estimated to be $\approx 12\%$ and the background contribution from the "empty target" is no greater than 10% over the entire measurement range.

The measured spectra are plotted in Fig. 1 as a function of the momentum q of the fragment in the rest frame of ^{3}He. These spectra are plotted in Fig. 2 as a function of the relativistic intrinsic momentum k of the fragment in the nucleus. The variable k arises in the description of the fragmentation by analogy with the parton model: Before the interaction the ^{3}He(pr) projectile nucleus virtually dissociates into a participant fragment (p) and an observer fragment (s). The variable k is related to the observable momentum of the fragment by (see, e.g., Ref. 4a)

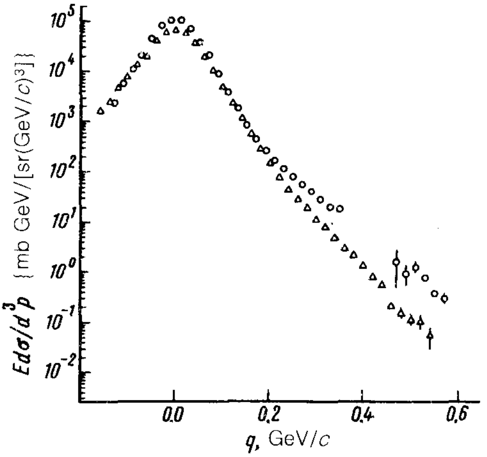

FIG. 1. Invariant cross sections for the fragmentation of ^3He. O—$^{12}C(^3He,p)$; Δ—$^{12}C(^3He,d)$. Only the statistical errors are given. The momentum of the fragment in the rest frame of ^3He is plotted along the abscissa.

$$k^2 = \lambda(M_{\text{eff}}^2, m_s^2, m_p^2)/4M_{\text{eff}}^2,$$

where

$$\lambda(a, b, c) = a^2 + b^2 + c^2 - 2ab - 2ac - 2bc.$$

The effective mass M_{eff} is found from the relation[4)]

$$M_{\text{eff}}^2 = \frac{m_s^2(1-\alpha) + m_p^2\alpha}{\alpha(1-\alpha)},$$

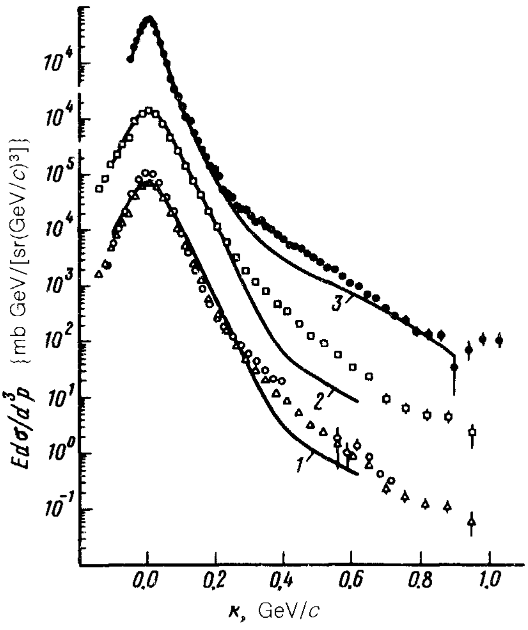

FIG. 2. Invariant cross sections of the reactions. O—$^{12}C(^3He,p)$; ▲—$^{12}C(^3He,d)$; □—$p(^3He,d)$ (see the text proper); ●—$p(d,p)$ (Ref. 6). Curves 1 and 2—the calculation carried out in Ref. 6 with the use of the momentum distributions[5]; curve 3—the calculations of Ref. 6 with the use of the deuteron wave function for the Paris potential.[11] All curves are normalized to the experimental data at the maximum. The relativistic intrinsic momentum is plotted along the abscissa.

where α is the part of the momentum of the projectile nucleus carried off by the observer fragment in the infinite-momentum frame:

$$\alpha = (E_s + p_s)/(E_{pr} + p_{pr}).$$

At large E_{pr} the variable α becomes the Feynman variable x. In determining k for the proton spectrum we should keep in mind that the participant fragment is the $(n\text{-}p)$ system whose mass is, strictly speaking, not specified. We assumed that the mass of this system is the same as the deuteron mass. The value of k in this case is minimal. We see that the shapes of the deuteron and proton spectra, which are expressed as functions of k, are similar over essentially the whole range of variation.

Figure 2 shows the results of calculation of the cross section of the $(^3\text{He},d)$ reaction, carried out with the help of the momentum distribution of deuterons in ^{3}He taken from Ref. 5. The discrepancy between this calculation and the data at small values of k can be attributed to the effect which we observed in the deuteron-fragmentation experiments[6]: The ratio of the cross sections for fragmentation of a deuteron by a nucleus and a proton changes markedly at $k < 150$ MeV/c and then remains constant. For carbon the behavior of this ratio is described satisfactorily by the equation

$$R_{C/p}(k) = 2,4\exp(-k^2/0.01) + 2.6.$$

Assuming that the same effect is present in the case of ^{3}He fragmentation, we have plotted in Fig. 2 the expected shape of the spectrum for the $p(^3\text{He},d)$ reaction. We see that at $k \leqslant 250$ MeV/c there is a good agreement between the experimental data and calculation. We also see that at $k \geqslant 300$ MeV/c for the deuteron and ^{3}He fragmentation spectra the model which takes into account only the nucleon degrees of freedom in terms of the impulse approximation is at variance with the experiment. The inadequacy of such models is also evident in the analysis of the data on the deuteron and ^{3}He form factors[7–9] and on the reaction[10] $^3\text{He}p \to ppd$.

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[4)]A similar expression for the parton model was also obtained in Ref. 4b.

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