Measurement of the tensor analyzing power of the reaction $^{12}C(d,p)$ with zero-angle proton emission at a deuteron momentum of 9.1 GeV/*c*

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The tensor analyzing power T_{20} of the reaction $^{12}C(d,p)$ has been measured over the interval 0–0.4 GeV/*c* of the proton momentum in the rest frame of the deuteron. The results of the measurements are compared with predictions of various theoretical models.

Our earlier cycle of studies[1–3] on the fragmentation of relativistic nuclei, *d* and ^{3}He, in which the fragments were detected at a zero angle led to the conclusion that the high-momentum component of the wave functions of these nuclei is larger than predicted by calculations based on the known *NN* potentials. This conclusion has been supported by studies of the (d,p) reaction carried out under other kinematic conditions and also by an analysis of data on the electrodisintegration of light nuclei and elastic *pd* backscattering (see Ref. 2 and the references there; see also Ref. 4). The need for corresponding experiments with polarized deuterons is discussed in Ref. 13, among other places.

In the present letter we report measurements of the tensor analyzing power T_{20} of the reaction $^{12}C(d,p)$ with emission of the proton at an angle $\theta < 0.4°$ and at a momentum $p_d = 9.1$ GeV/*c*, carried out at the synchrophasotron of the Joint Institute for Nuclear Research. Preliminary data have been reported at conferences.[2,5]

The POLYaRIS apparatus[6] was used to organize a reproducible sequence of acceleration cycles: 1) unpolarized deuterons; 2) deuterons with an alignment[7] $\rho_{20}(+)>0$; 3) deuterons with an alignment $\rho_{20}(-)<0$. The beam intensity ($\sim 5\times 10^8$ particles/cycle) did not depend on the polarization modes. To evaluate the alignment, we measured the ratios of cross sections for various polarization modes in the course of elastic *dp* scattering [$p_d = 3$ GeV/c, $\langle t\rangle = -0.143$ (GeV/c)^2], for which the analyzing power is known.[8] The most accurate estimate was found for the quantity

$$\Delta\rho = (\rho_{20}(+) - \rho_{20}(-)) = 0{,}45 \pm 0{,}06.$$

A calculation indicating the absence of a depolarization of the deuterons at the synchrophasotron[9] was confirmed experimentally in a vector polarization mode; the estimate here was 0.04 ± 0.02.

At $\theta = 0°$, T_{20} is related to the differential cross sections for the reaction (d,p) for aligned deuterons [$\sigma(\pm)$] and unaligned deuterons (σ) by

$$\sigma(\pm)/\sigma = 1 - \frac{1}{2}\rho_{20}(\pm)T_{20}\ . \tag{1}$$

The cross sections were measured in an experiment formulated in basically the same way as that described in Ref. 1. The data acquisition procedure consisted of a sequence of measurements, each in a momentum interval $|(p-p_0)/p|\leqslant 0.07$, with p_0 being varied from 4.4 to 6.6 GeV/c. The statistical base of each measurement was about 30 000 events. The greatest number of measurements, which were distributed uniformly over the duration of the entire session, was carried out at a momentum $p_0 = 5.7$ GeV/c (the region of the expected maximum of the effect) for a subsequent estimate of the beam polarization drift. Within the statistical errors, we found no such drift. In the course of an exposure we measured the intensity and the space-time characteristics of the deuteron beam and of the accelerator field at the time at which the beam was extracted. During the processing, the acceleration cycles were rejected, or necessary corrections were made, depending on the extent to which these parameters deviated from their nominal values.

Figure 1a shows ratios of the cross sections for various polarization modes. A joint fit of the ratios $\sigma(+)/\sigma$ and $\sigma(-)/\sigma$ reveals $\rho_{20}(-)/\rho_{20}(+) = -1.02 \pm 0.09$. To extract values of T_{20} (Fig. 1b), we used the combination $\sigma(+)/\sigma(-)$, which is the combination most sensitive to this quantity and which is related to T_{20} by [a reduction of Eq. (1)]

$$\ln(\sigma(+)/\sigma(-)) = -\frac{1}{2}\Delta\rho\, T_{20} \tag{2}$$

which holds within an error on the order of 10^{-3} [in the case $|\rho_{20}(-)| \approx |\rho_{20}(+)|$]. Only the statistical errors are shown in Fig. 1. The systematic error is dominated by the uncertainty in the value of $\Delta\rho$. Its effect on the data is shown in Fig. 1b in the following way. The solid line is a fifth-degree polynomial which approximates the data:

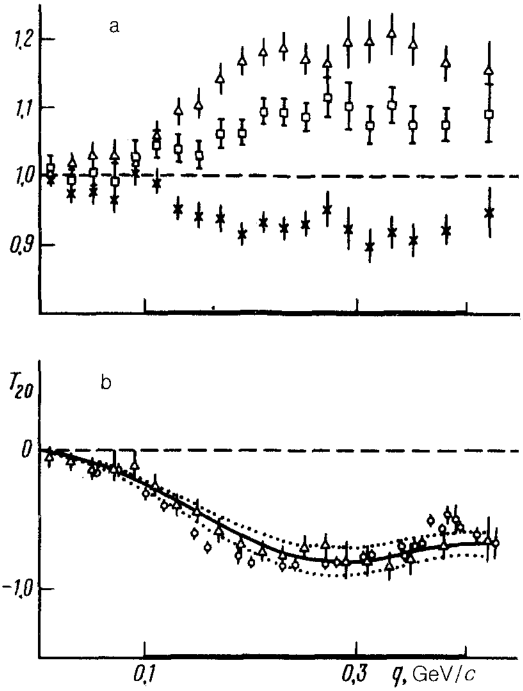

FIG. 1. a—The ratios (□) $\sigma(+)/\sigma$, (×) $\sigma(-)/\sigma$, and (△) $\sigma(+)/\sigma(-)$ versus the momentum of the proton in the rest frame of the deuteron; b—T_{20} for the reaction $^{12}C(d,p)$. △) data of present study; ○) Data of Ref. 12 (see the text proper for an explanation of the curves).

$$F(q) = \sum_{n=1}^{5} A_n q^n, \quad A_n = (-1.24; -7.94; -99.3; 593; -754).$$

The points shown $F(q)\times(0.45\pm0.06)/0.45$, which are the best fit of the data in the case in which values of $\Delta\rho$ differing from those given above by the amount of the error are substituted into (2). Figure 2 shows values of T_{20} as a function of the "internal momentum" k, along with the distribution of nucleons in the deuteron, ψ_d^2, extracted from our data[2] on the $p(d,p)$ cross sections. The relationship between k and the momentum of the observed fragment and the relationship between ψ_d^2 and the cross section are given in Refs. 2 and 3. The solid lines show $\psi_d^2(d)$ and are calculated in the impulse approximation:

$$T_{20}(k) = \frac{w(k)}{\sqrt{2}}\,\frac{2\sqrt{2}u(k) - w(k)}{u^2(k) + w^2(k)} \qquad (3)$$

for the Paris NN potential. Here $u(k)$ and $w(k)$ are the s and d wave functions of the deuteron.

For all realistic NN potentials, $u(k)$ crosses zero at $k = k_1 < 0.4$ GeV/c. It follows from expression (3) that at $k < k_1$ the value $T_{20}^{\min} = -\sqrt{2}$ is necessarily reached. The fact that the measured value of T_{20} does not reach $-\sqrt{2}$ can be interpreted in the following ways: 1) $u(k)$ is positive everywhere (this behavior is allowed by the deu-

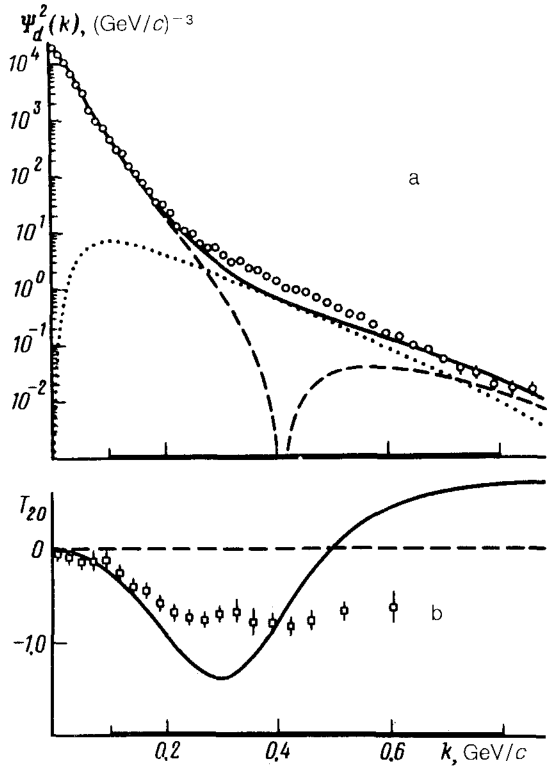

FIG. 2. a—Distribution of nucleons in the deuteron; b—T_{20} versus the "internal momentum." Solid lines) $\psi_d^2(k)$ and $T_{20}(k)$ for the Paris NN potential; dashed and dotted lines) $u^2(k)$ and $w^2(k)$, respectively.

teron model of Ref. 10, which assumes the existence of quark degrees of freedom, but which does not allow one to choose parameter values which lead to satisfactory descriptions of both sets of data shown in Fig. 2); 2) the behavior of T_{20} is not described by expression (3), because of, for example, a significant contribution of final-state-interaction effects (this possibility, however, contradicts the good agreement between our data and the data of Ref. 12, obtained at a substantially lower deuteron energy).

It can be asserted that our data agree qualitatively with the predictions of Ref. 11 (T_{20} is negative everywhere). We have not been able to find a model which would lead to a good quantitative agreement. Measurements of the coefficient of the polarization transfer from the deuteron to the fragment proton might help refine the question of whether a more appropriate model of the deuteron is required or whether the relationship between the observed cross sections and the wave function of the deuteron must be calculated more correctly.

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