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# MEASUREMENT OF THE TENSOR ANALYZING POWER FOR THE $^{12}C(d,p)$ REACTION AT $P_d$=9.1 GeV/c AND ZERO ANGLE PROTON EMISSION

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We have reported some results of break-up experiments performed at the Dubna synchrophasotron. Relativistic deuterons, $^3He$ and $^4He$ were directed into hydrogen and/or nuclear targets, and the fragments were detected at a zero angle in the ALPHA spectrometer /1-3/ .

Information on the nucleon momentum distribution in light nuclei up to k = 1 GeV/c* was obtained, and a cross section enhancement in the hard momentum region k > 0.2 GeV/c was found in comparison with theoretical NN-potential model predictions (Paris-potential, etc.). This fact is supported by other similar deuteron fragmentation experiments at BERKELEY for lower energies and at Dubna /4/, where the proton is knocked out from the deuteron in a hard collision, light nuclei electrodisintegration reactions and the pd-backscattering process (see ref./2/ and references therein). The necessity of similar experiments with polarized deuterons is discussed, for example, in ref./13/ .

In the present paper we report the results of measurements of the tensor analyzing power for the $^{12}C(d,p)$ reaction with the proton emission angle $\theta_{lab} = 0.4°$ at a deuteron momentum, $p_d$ , of 9.1 GeV/c. Preliminary results have been presented at several conferences /2,5/.

In our case eq.(1) shows the $T_{20}$-dependence on the differential cross sections of aligned and unaligned deuteron fragmentation:

$$T_{20} = 2\,\frac{1-\vec{\sigma}/\sigma}{\rho_{20}}, \qquad (1)$$

where $\rho_{20}$ is the alignment of the primary beam given in eq.(2)

$$\rho_{20} = \frac{1}{\sqrt{2}}\,\frac{N_+ + N_- - 2N_0}{N_+ + N_- + N_0}, \qquad (2)$$

where $N_+$, $N_-$ and $N_0$ are the numbers of deuterons populating the magnetic substates $m_d$ = (+1, -1, 0)/7/.

*k is the relativistic internal momentum of the bound system of two particles (see ref./2/ ).

Several modes of polarized deuterons are emitted by the ion source POLARIS [8]. Only vector polarized deuterons are created in the POLARIS regime (I). Regime (II) gives a combination of vector and tensor polarizations. The table demonstrates how the polarization of consecutive beam cycles (the cycle duration is 400 ms) is changed in both ion source regimes.

*Table*

| POLARIS regime | consecutive accel. cycle | cross section | polarization (max. value) vector $\rho_{10}$ | polarization (max. value) tensor $\rho_{20}$ |
|---|---|---|---|---|
| (I) | 1 | $\sigma$ | 0 | 0 |
| | 2 | $\vec{\sigma}(+)$ | $+2/\sqrt{6}$ | 0 |
| | 3 | $\vec{\sigma}(-)$ | $-2/\sqrt{6}$ | 0 |
| (II) | 1 | $\sigma$ | 0 | 0 |
| | 2 | $\sigma(+)$ | $+1/\sqrt{6}$ | $+1/\sqrt{2}$ |
| | 3 | $\sigma(-)$ | $+1/\sqrt{6}$ | $-1/\sqrt{2}$ |

The averaged beam intensity reached $\sim 5\cdot 10^8$ particles per cycle and did not depend on the polarization mode.

The beam tensor and vector polarizations were estimated by measuring the elastic forward scattering reaction p(d,d)p at a beam momentum, $p_d$, of 3 GeV/c. The averaged transfer momentum squared depends on beam emittance, and the polarimeter acceptance amounts to $\langle -t\rangle = 0.143$ $(\mathrm{GeV/c})^2$. This calibration reaction was investigated by the SATURNE and ARGONNE groups [8]. The analyzing powers $A_y$ and $A_{yy}$ are known with a statistical uncertainty of 0.03. The beam polarization values of $\rho_{10}$ and $\rho_{20}$ are estimated using eqs.(3) and (4):

$$\rho_{10}(\pm) = \sqrt{\frac{2}{3}}\,\frac{1}{A_y}(\vec{\sigma}(\pm)/\sigma - 1), \tag{3}$$

$$\rho_{20}(\pm) = \frac{\sqrt{2}}{A_{yy}+A_y}(\sigma(\pm)/\sigma - 1). \tag{4}$$



The best accuracy in regime (II) was achieved for the following parameter combination which does not depend on the vector part of eq.(4) providing $|\rho_{20}(+)| \simeq |\rho_{20}(-)|$:

$$\rho = \langle\rho\rangle \pm \epsilon = (\rho_{20}(+) - \rho_{20}(-)) = 0.45 \pm 0.06. \tag{5}$$

To verify the absence of depolarization effects in the synchrophasotron [9], the vector polarizations for two different acceleration modes were compared. In the first run the beam was continually accelerated up to 3 GeV/c, and in the second run the beam momentum reached 9.1 GeV/c and then the beam was decelerated to 3 GeV/c. The depolarization effect was found to be $0.04 \pm 0.02$.

The deuteron fragmentation was investigated with the ALPHA spectrometer. The statistics was collected for a series of measurements in the momentum intervals $|(p - p_0)/p| \leq 0.07$, where $p_0$ varied from 4.4 to 6.6 GeV/c. There were $\sim 3\cdot 10^4$ events in each run. A larger number of runs was performed at a momentum, $p_0$, of 5.7 GeV/c to estimate the drift of the beam polarization. The drift of the polarization was smaller than the statistical error level.

Figure 1a shows the ratios of the cross sections at different polarization states (+, −, 0) versus the proton momentum q in the deuteron rest frame.

The following ratio between plus and minus tensor polarizations was obtained in a complex fit for the cross section ratios $\sigma(+)/\sigma$ and $\sigma(-)/\sigma$:

$$\rho_{20}(-)/\rho_{20}(+) = (-1.02 \pm 0.09). \tag{6}$$

The ratio $\sigma(+)/\sigma(-)$ is the most sensitive one to extract $T_{20}$ as shown in fig.1a. Formula (1) can be reduced with a precision of $10^{-3}$ to approximate eq.(7):

$$\ln[\sigma(+)/\sigma(-)] = -\frac{1}{2}\rho T_{20}, \text{if } |\rho_{20}(-)| \simeq |\rho_{20}(+)|. \tag{7}$$

The measured values in fig.1 are presented only with statistical errors. A main contribution to the systematic error is made by an inaccuracy of the polarization value. Its effect is shown as follows. The solid line is a data fit by a fifth order polynomial:

$$F(q) = \sum_{n=1}^{5} A_n\cdot q^n, \quad A_n = (-1.24; -7.94; -99.3; 593; -754). \tag{8}$$

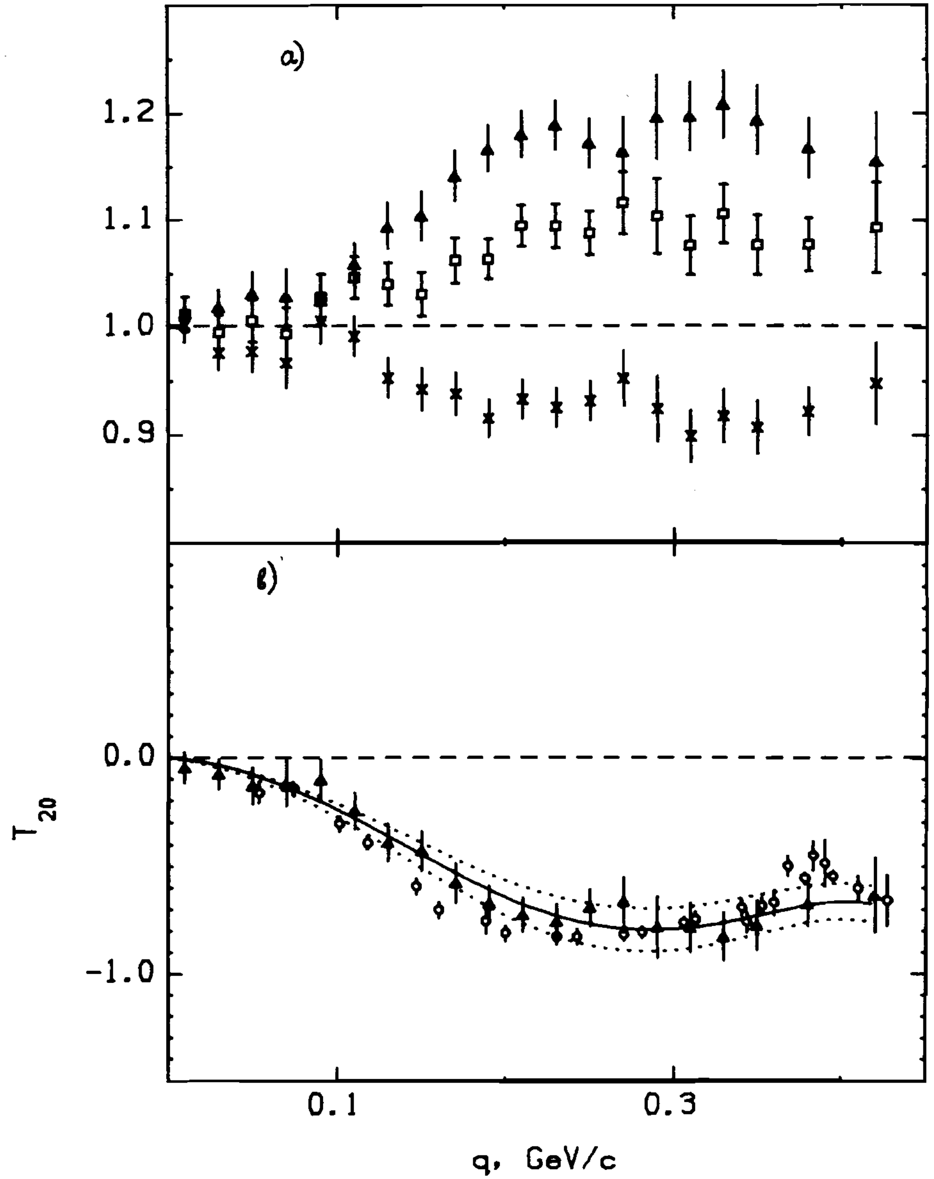


*Fig.1. a) The cross section ratios versus the proton momentum* **q** *in the deuteron rest frame;* □ - $\sigma(+)/\sigma$ , × - $\sigma(-)/\sigma$ , - $\sigma(+)/\sigma(-)$ . *b) The experimentally obtained tensor analyzing power* $T_{20}$ *of the* $^{12}C(d,p)$ *reaction versus* **q**; ▲ - *DUBNA (our data),* ○ - *SACLAY (ref.* /12/ *), solid and dotted lines - see the text.*



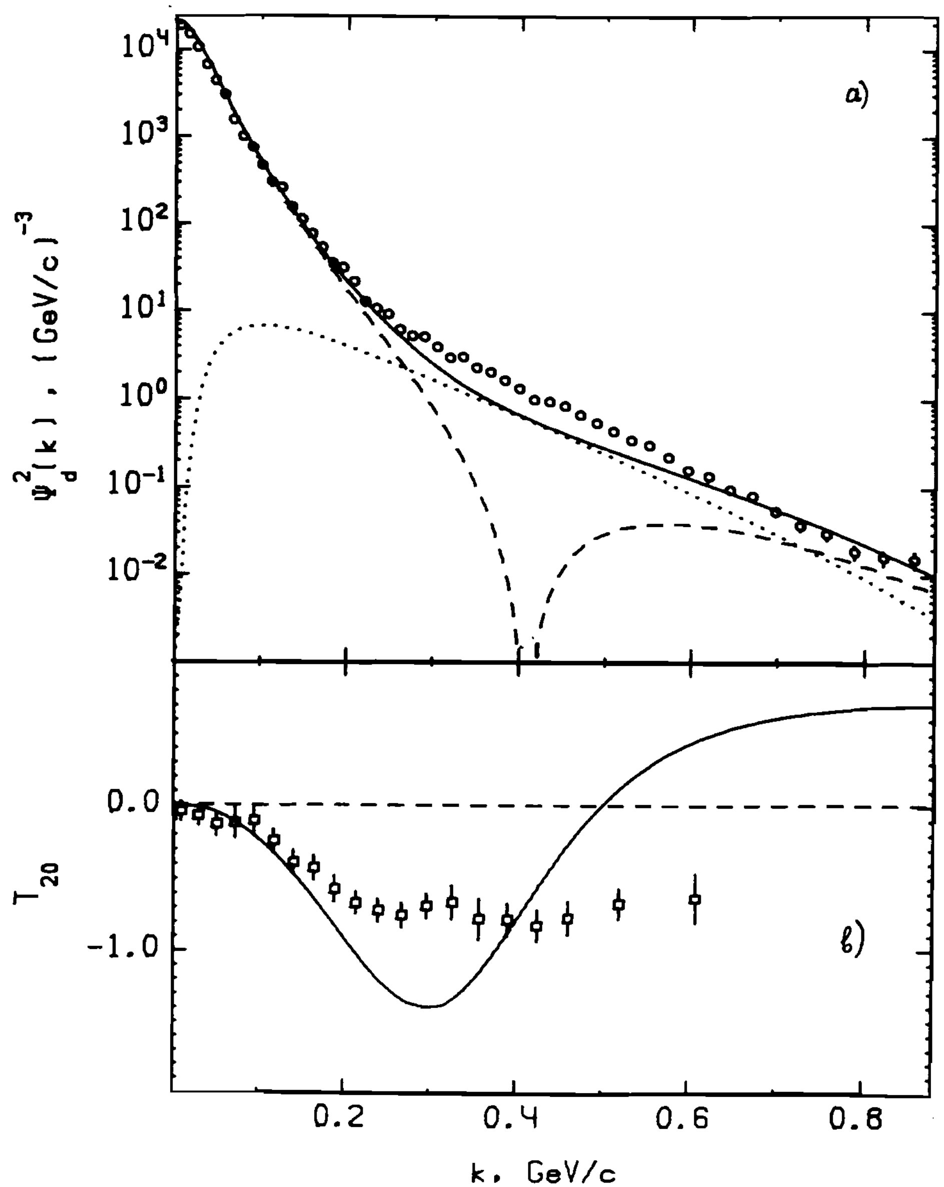


*Fig.2. a) The NMDD versus the interval momentum* **k**; *solid line -* $\psi_d^2(k)$, *dashed line -* $u^2(k)$ , *dotted line -* $w^2(k)$ , ○ - *DUBNA (our data). b) The tensor analyzing power* $T_{20}$ *versus* **k**; □ - *DUBNA (our data), solid line - impulse approximation for the Paris NN - potential.*

The polynomials

$$F_{\pm\epsilon}(q) = \frac{\langle\rho\rangle \pm \epsilon}{\langle\rho\rangle} F(q) \qquad (9)$$

are presented in fig.1b by the dotted lines and give the best fit of the data if the value of $\langle\rho\rangle \pm\epsilon$ is used in eq.(7) instead of $\langle\rho\rangle$.

The analyzing power $T_{20}$ and the nucleon momentum distribution in the deuteron extracted from our data on the p(d,p) reaction [2] versus the internal momentum k are shown in fig.2. The expressions for the connection of the momenta k and q and $\psi_d^2(k)$ as a function of the differential cross section are given in detail in refs. [2,3]. The solid lines represent the NMDD and $T_{20}(k)$ in the impulse approximation:

$$T_{20}(k) = \frac{1}{2} w(k) \frac{2\sqrt{2}u(k) - w(k)}{u^2(k) + w^2(k)} \qquad (10)$$

calculated with the Paris NN-potential. Here u(k) and w(k) are the S and D waves of the radial part of the deuteron wave function $\psi_d^2(k)$.

In realistic NN-potentials u(k) crosses zero at $k = k_1 < 0.4$ GeV/c. From eq.(10) it follows that the analyzing power reaches a theoretical minimum $T_{20} = -\sqrt{2}$ for $k < k_1$. The experimentally obtained $T_{20}$ does not reach this minimum. This fact can be interpreted by the following hypotheses:

- The wave function u(k) has a positive value over the whole momentum range. Such a behaviour is allowed by the deuteron model with quark degrees of freedom [10]. But it is impossible to describe satisfactorily the differential cross section and the tensor analyzing power together using this model.

- The $T_{20}$-dependence is not in agreement with the compilation using eq.(10). This means that final state interactions and so an can be important. However, the unimportance of the final state interaction is supported by the coincidence between our data and the break-up data from SACLAY [12] at essentially lower energy.

A qualitative agreement has been found between our data and the theoretical predictions of ref. [11], where $T_{20}$ is lower than zero over the whole momentum range. More detailed information to create a more adequate deuteron model or/and to calculate more exactly the dependence between the measured cross section and the deuteron wave function can be obtained by an experiment measuring spin trasnfer from the deuteron to the proton-fragment in the deuteron break-up reaction.



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