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POLARIZATION TRANSFER IN THE $^{12}C(\vec{d},\vec{p})X$ REACTION FOR DEUTERON MOMENTA BETWEEN 5.8 AND 9.0 GeV/c

L.S.Azhgirey, A.P.Kobushkin[1]*, B.Kuehn, V.P.Ladygin, P.K.Manyakov, S.N.Nedev, L.Penchev*[2]*, C.F.Perdrisat*[3]*, N.M.Piskunov, V.Punjabi*[4]*, I.M.Sitnik, G.D.Stoletov, E.A.Strokovsky, A.I.Syamtomov*[1]

The polarization transfer coefficient of the $^{12}C(\vec{d},\vec{p})X$ reaction has been measured in the double scattering experiment using a vector polarized deuteron beam of the JINR Synchrophasotron and the spectrometer ALPHA. New data in 0—0.57 GeV/c internal momentum range of the deuteron wave function are presented.

The investigation has been performed at the Laboratory of High Energies, JINR.

Передача поляризации в реакции $^{12}C(\vec{d},\vec{p})X$ в области импульсов дейтрона между 5.8 и 9.0 ГэВ/с

Л.С.Ажгирей и др.

Измерен коэффициент передачи поляризации в эксперименте по двойному рассеянию в реакции $^{12}C(\vec{d},\vec{p})X$ на пучке поляризованных дейтронов синхрофазотрона ОИЯИ с помощью спектрометра АЛЬФА. Представлены новые данные в области внутренних импульсов в дейтроне 0—0.57 ГэВ/с.

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1. Introduction

The polarization observables of backward *dp* elastic scattering and the deuteron breakup reaction at the zero degree are quite precise tools for investigation of the deuteron structure. The measurements of the tensor analysing power T_{20} in the deuteron breakup reaction done at Dubna [1] and Saclay [2] showed large deviations from the theoretical values estimated in the framework of the non-relativistic and relativistic impulse approximation (NIA and RIA) with standard deuteron wave functions. The experimental

[1]Institute for Theoretical Physics, 252130 Kiev, Ukraine
[2]Institute for Nuclear Physics and Nuclear Energy, 1784 Sofia, Bulgaria
[3]College of William and Mary, Williamsburg, VA 23185 USA
[4]Norfolk State University, Norfolk, VA23504 USA

results obtained with the ALPHA set-up [1] show that T_{20} is negative up to $k \leq 0.8$ GeV/c. A similar result was obtained later with the ANOMALON set-up in Dubna [3], extending the range up to $k \leq 1$ GeV/c. Combined analysis of polarization transfer data from the deuteron to proton, κ_0, and T_{20} data, both obtained at Saclay [4] showed that no deuteron wave function (DWF) including *S*- and *D*-waves only, is suitable in the framework of the IA to describe these data [5]. First measurements of κ_0 in Dubna were performed with the ALPHA set-up [6,7] up to $k = 0.51$ GeV/c and later, with the ANOMALON set-up [8] up to $k = 0.55$.

Here we present results of new measurements of κ_0 obtained with the ALPHA set-up extending the range of *k*-values to 0,57 GeV/c.

2. Experiment

The polarization transfer coefficient κ is defined, in general, as

$$\kappa = \frac{p'_z}{p_z},$$

where p_z and p'_z are the vector polarization of the initial deuteron and secondary proton respectively. When the tensor polarization of the initial deuteron is equal to zero, as in the present experiment, κ becomes κ_0.

The spectrometer ALPHA (Fig.1) was adjusted as in our previous experiment [7], but a CH_2-target for the second scattering was used instead of CH. Previous measurements have shown that the analysing power is high enough at small angles to allow decreasing the rejection angle of the trigger system to select efficiently events with squared momentum transfer down to $-t = 0.01$ GeV^2. Also, the time of flight (TOF) system was upgraded from its original configuration [9].

The beam of vector polarized deuterons was provided by the POLARIS [10] source. The direction of polarization changed alternately from up to down burst by burst. The beam polarization was measured as described in Ref. [11] using data [12]; the absolute value of the vector polarization in both states was $|p_z| = 0.58 \pm 0.02$, and the tensor polarization was negligible $|p_{zz}| = 0.03 \pm 0.03$.

The deuteron beam intensity on the primary target, where the breakup reaction

$$\vec{d} + C \rightarrow \vec{p} + X$$

occurred, was $(0.5 - 10) \times 10^8$ particles per burst. The graphite target thickness was 2 cm when the deuteron momentum was 9 GeV/c, and 15 cm in the other cases.

The outgoing protons from deuteron breakup at 0° were transported by a magnetic channel to the spectrometer ALPHA; it was tuned to transport particles with average

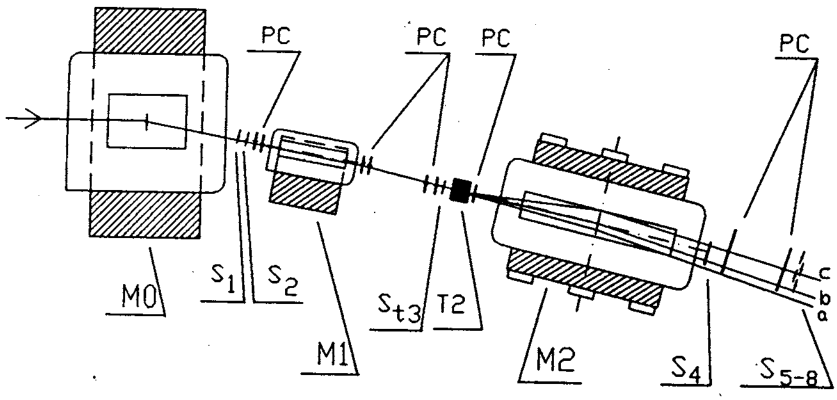

Fig.1. The spectrometer ALPHA in configuration for measurement of polarization transfer. T_{20}: second target, M_i : dipoles, S_i : scintillator counters, S_{ti} : counters of the TOF system, *PC*: proportional chambers. Line *a* is the unscattered beam direction, the region between lines *b* and *c* is the region of scattered events

momentum $p = 4.5$ GeV/c. The momentum and angular acceptances were respectively $\Delta p/p \simeq 3\%$ and $\Delta\Omega \simeq 10^{-4}$ sr.

The polarization of the secondary protons was obtained using the reaction

$$\vec{p} + CH_2 \rightarrow p + X$$

for this purpose. A 30 cm long CH_2 target was installed in the spectrometer area. The scintillation counters S_5–S_8 were positioned to create a trigger rejecting events with too small scattering angles. All dipoles bent particles to the right while left scattered events were detected. Such a geometry provides a correlation between momentum and scattering angle of events, when the tragger efficiency along $-t \simeq (p\,\theta)^2$ has a behaviour close to that of θ-function. Accumulations of events only in region of *t*, far from sharp behaviour of trigger efficiency, is an important condition to avoid systematic errors due to fluctuation of the initial beam parameters.

Because the momentum distribution of secondary protons was not narrow, a good separation of elastic and inelastic events required measuring the proton momentum both upstream and downstream from the CH_2 target with two dipoles and six proportional chambers. The distribution of the proton momentum p_1 before the second interaction is shown in Fig.2, and the difference of the momenta after (p_2) and before the interaction — in Fig.3.

A TOF system [9] with base length of 20 m, was used to separate the protons from deuterons produced in (d, d') reactions. The resolution of the TOF system was sufficient for complete separation of (d, d') and (d, p) processes.

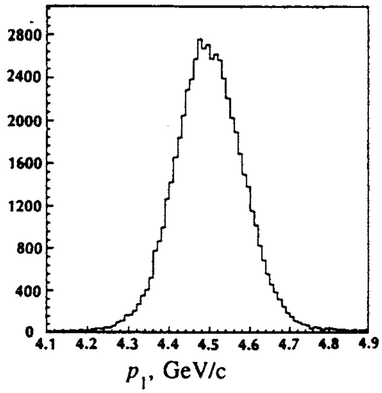

Fig.2. Distribution of proton momentum p_1 before second interaction

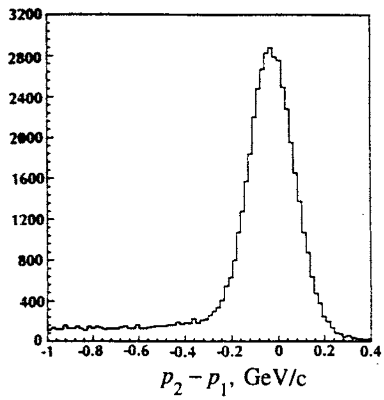

Fig.3. Distribution of the difference of the momenta before and after the second interaction

3. Data Analysis

The number of protons scattered into direction (θ, φ) at the second target is given by:

$$N(\theta, \varphi, p_1) = N_0(1 + A(\theta, p_1)\, p'_z \cos\varphi), \tag{1}$$

where $A(\theta, p_1)$ is the target analysing power. Changing the sign of the polarization we obtain the asymmetry:

$$X = \frac{N_+ - N_-}{N_+ + N_-} = A(\theta, p_1)\, p'_z \cos\varphi. \tag{2}$$

Integrating over the φ acceptance of the spectrometer we have:

$$X = A(\theta, p_1)\, p_z \frac{p'_z}{p_z} = \kappa_0 B(\theta, p_1), \tag{3}$$

As is seen, if the scattered protons have a constant momentum p_1, the function B depends on the angle θ only, and not on the momentum of the primary deuterons. The different κ_{0i} for different initial deuteron momenta can be calculated as a proportionality coefficients between the asymmetry X_i and a single function B. They can be found by minimization of:

$$S = \sum_{i,j} [\kappa_{0i} B(t_j) - X_i(t_j)]^2, \tag{4}$$

where i indicates the different initial deuteron momenta and t_j — the different squared 4-momentum transfers defined as $|t_j| \approx (p_1 \theta_j)^2$.

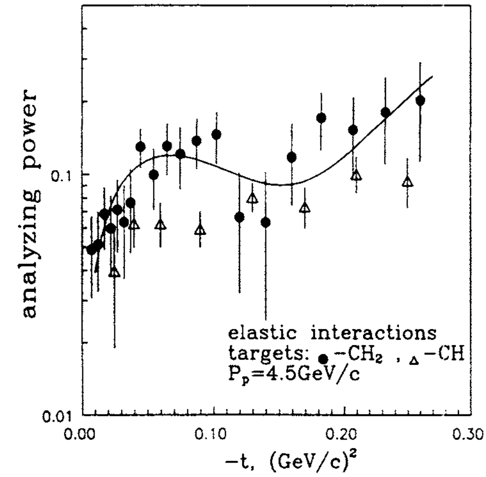

Fig.4. Analysing power of the elastic scattering at CH_2 and CH targets

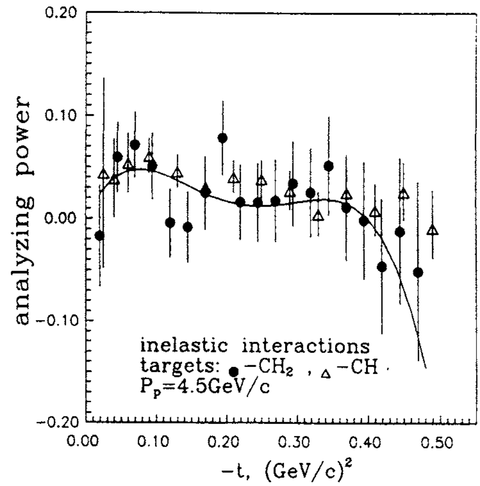

Fig.5. Analysing power of the inelastic scattering at CH_2 and CH targets

All events were divided into elastic ($|p_2 - p_1| < 0.25$) and inelastic ($p_2 - p_1 < -0.25$) groups. We used two fifth degree polynomials, with different coefficients — $B^{el}(t)$ for elastic and $B^{in}(t)$ for inelastic events. When the primary deuteron momentum is 9 GeV/c, the proton produced in the primary dC reaction carries half of deuteron momentum and has the same polarization as primary deuteron. The light cone variable k in this case is zero and $\kappa_{01} = 1$. The coefficients of the polynomials and the parameters κ_{0i} were found by minimization of the function (4) with fixed $\kappa_{01} = 1$. The error in κ_{01} due to the fit is included as a systematic error to the polarization transfer coefficients obtained in this experiment.

According to eq.(3), the analysing power of the CH_2 target can be obtained using the measured value of the primary beam polarization. The corresponding results for elastic and inelastic events are shown in Fig.4 and Fig.5 (full circles). The solid lines are calculated from the corresponding polynomials. In the same figures the analysing power of the CH target used in our previous experiment [7] is shown with triangles. It is seen that the analysing power for the inelastic scattering is similar for both CH and CH_2 targets, but the analysing power for the elastic scattering is higher for the CH_2 target.

4. Results

Results for κ_0 are given in the Table and are shown as triangles in Fig.6. The momenta of deuterons p_d and protons p_p are corrected for ionization losses in the first carbon target. The infinite momentum frame variable is defined [13,14,15] as:

$$\alpha = \frac{p_p + E_p}{p_d + E_d}, \quad M_{sf}^2 = \frac{m_p^2}{\alpha} + \frac{m_n^2}{1-\alpha},$$

$$k = \frac{\sqrt{\lambda(M_{sf}^2, m_p^2, m_p^2)}}{2M_{sf}}, \quad \lambda(a, b, c) = a^2 + b^2 + c^2 - 2ab - 2ac - 2bc,$$

where E_d, E_p are the energies of deuterons and protons, m_p and m_n are respectively the proton and neutron masses. The values of σ_k in the Table are r.m.s. for k, corresponding to the p_1-distribution (Fig.2) for each primary beam momenta.

The first point in Fig.6 is the calibration point with $\kappa = 1$, the second and the third (full triangles) are in a well-known region, the fourth point is at the highest value of k reached until now. It is seen from the figure that the polarization transfer coefficient is still negative at the highest k-value of 0.571 GeV/c. The reanalysed data of Cheung et al. [4,16] for *dp* breakup are plotted with open circles and our previous data [7] are shown as squares. The data of A.A.Nomofilov et al. [8] are shown as diamonds. The solid curve is from a calculation with Paris potential [17] in the frameworks of RIA [18]:

$$\kappa_0 = \frac{u^2(k) - w^2(k) - u(k)w(k)/\sqrt{2}}{u^2(k) + w^2(k)}. \tag{5}$$

One can see that both our new and previous data in the region $k \approx 0.55$ are in disagreement with data [8], performed in experimental conditions, close to our.

Both sets of data, obtained with the help of the ALPHA spectrometer are in good agreement with data [4,16] and with extrapolation based on parametrization [5] of both polarization transfer [4,16] and T_{20} [2] (dashed curev), obtained at Saclay at lower energies. That points out at energy independence of this polarization characteristics of the (d, p) reaction. So, deviation of data

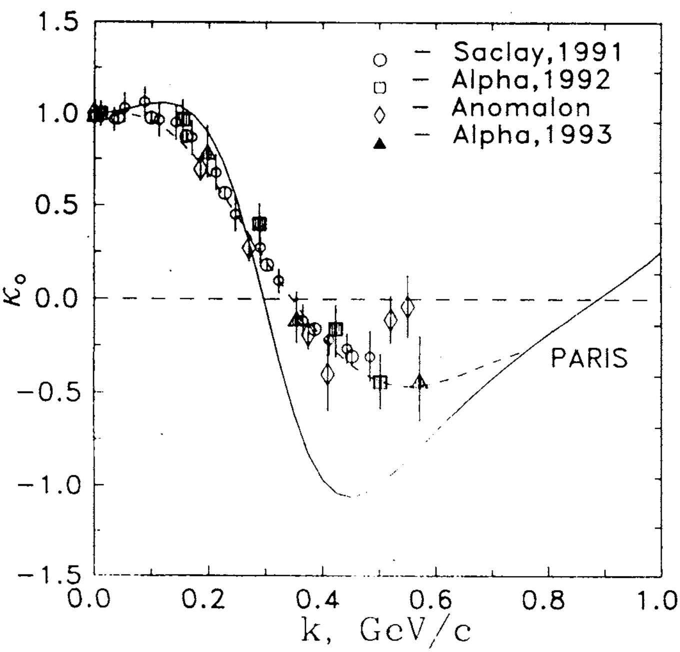

Fig.6. Polarization transfer coefficient κ_0 from vector polarized deuterons to protons in reaction on carbon

Table

	p_d (GeV/c)	p_p (GeV/c)	k (GeV/c)	σ_k (GeV/c)	κ_0	$\Delta\kappa$
1	8.989	4.503	0.002	0.008	1.00	0.07
2	7.374	4.470	0.198	0.016	0.79	0.14
3	6.575	4.489	0.354	0.022	− 0.10	0.14
4	5.785	4.462	0.571	0.037	− 0.43	0.23

from predictions, based on IA calculations with Paris potential (solid curve) demonstrates rather the deuterons structure peculiarity than contribution of additional to IA mechanisms of the reactions, such as considered in Ref. [19].

The achieved value of internal momentum of $k = 0.571$ GeV/c is still not large enough to estimate asymptotic behaviour of considered polarization characteristics and to make choice between models, predicting asymptotic value of κ_0 positive [20] or negative [21]. So, measurements at higher values of k are extremely important.

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