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# USING OF POLARIZED TARGET IN BACKWARD ELASTIC *dp* SCATTERING*

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Effects due to the polarization of both colliding particles have been analysed in terms of four independent amplitudes which, in the general case, define the spin structure of the *dp* backward elastic scattering amplitude. It is shown, that spin correlation due to the transverse polarization of colliding particles has high sensitivity with respect to presumably existing *P*-wave in the deuteron. The experiments, needed to be performed for complete reconstruction of four independent amplitudes are discussed.

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

## Использование поляризованной мишени в *dp* упругом рассеянии назад

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В терминах четырех независимых амплитуд, определяющих в общем случае спиновую структуру амплитуды упругого *dp* рассеяния назад, рассмотрены поляризационные эффекты, возникающие в случае, когда обе сталкивающиеся частицы поляризованы. Показано, что спиновая корреляция, связанная с поперечной поляризацией сталкивающихся частиц, обладает высокой чувствительностью по отношению к возможному существованию *P*-волны в дейтроне. Обсуждаются возможные эксперименты, необходимые для полного восстановления четырех независимых амплитуд.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

## 1. Introduction

Studying of the short-range behaviour of the deuteron wave function (DWF) allows us:

to understand the role of such non-nucleonic degrees of freedom as quark or delta configurations;

to clarify the transition regime from pion-nucleon mode to possible manifistation of the non-nucleonic degrees of freedom;

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to check the different approaches of description of the relativistic bound states.

A direct reconstruction of the DWF from the measured quantities in the framework of the Impulse Approximation (IA) is possible in two types of reactions. They are deuteron electrodisintegration [1] $ed \to e + np$, and also $A(d,p)X$ and $p(d,p)d$ reactions [2,3].

The momentum distributions of fragments extracted from the data of the above experiments with electromagnetic and nuclear probes demonstrate, on the one hand, a substantial discrepancy with the predictions using standard DWF in the IA and, on the other hand, a good agreement with one another [4,5], which gives serious motivations to search for the explanation of the observed effects not only in deviation from the IA but also in nonadequate standard DWF. Even at the IA level the following questions arise:

the number of independent components of the DWF (two in nonrelativistic theory including $S$- and $D$-waves or four in relativistic theory including $S$-, $P$- and $D$-waves [6], or six in the spurion models [7]);

what is the argument of the DWF and furthermore the number of them (one as in standard models or two as in spurion approaches);

possible non-nucleonic degrees of freedom ($NN^*$, $\Delta\Delta$) of the deuteron.

To determine the behaviour of different components of the DWF, one needs to study polarization observables of the above reactions, because they are more sensitive to smaller terms than cross section. At the present time such data exist or are in progress only for nuclear probe reactions. Apart from cross sections, such observables as the tensor analyzing power $T_{20}$ and the polarization transfer coefficient from the deuteron to the proton $\kappa_t$ have been investigated for the reactions $A(d,p)X$ and $p(d,p)d$. Analysis of each of these reactions points out [8,9,10] no configuration consisting only of $S$- and $D$-waves are compatible with the data within the framework of the IA.

The existing set of data is insufficient to separate the deuteron structure from the reaction mechanism. So, measurements of new polarization observables are needed. They can be obtained using a polarized proton target for backward $dp$ elastic scattering (but not for the reaction $A(d,p)X$). The measurements of these observables are being planned now at Dubna.

## 2. Amplitude of the $d + p \to p + d$ ($\theta = 180°$) Process and General Analysis of the Polarization Effects

Backward $dp$ elastic scattering due to $P$-invariance and total helicity conservation can be described by only four independent complex amplitudes for the following transition $\lambda_d, \lambda_p \to \lambda'_d, \lambda'_p$,

$$F_{0+\to 0+} = g_2(s),$$

$$F_{++\to ++} = g_1(s) + g_4(s),$$

$$F_{-+\to -+} = g_1(s) - g_4(s),$$

$$F_{0+\to +-} = -\sqrt{2}\, g_3(s), \qquad (1)$$

where $g_1 - g_4$ are so named scalar amplitudes. Of course, all polarization effects can be described in terms of the scalar or helicity amplitudes.

In case of unpolarized target the differential cross section $\frac{d\sigma^{(T0)}}{d\Omega}$ depends only on the tensor polarization $P_{NN}$ of initial deuterons:

$$\frac{d\sigma^{(T0)}}{d\Omega} = \frac{d\sigma^{(00)}}{d\Omega}\left(1 + \frac{1}{2} P_{NN} C_{0,NN,0,0}\right),$$

$$N^{-1}\frac{d\sigma^{(00)}}{d\Omega} = 2|g_1(s)|^2 + |g_2(s)|^2 + 2|g_4(s)|^2,$$

$$C_{0,NN,0,0} N^{-1}\frac{d\sigma^{(00)}}{d\Omega} = -|g_1(s)|^2 + |g_3(s)|^2 - |g_4(s)|^2, \qquad (2)$$

where $\frac{d\sigma^{(00)}}{d\Omega}$ is the differential cross section for unpolarized initial particles, and $C_{0,NN,0,0}$ is the analyzing power due to tensor polarization of the initial deuteron. (Here we are following notations used in ref. [11].)

The expressions for the normal ($C_{0,N,N,0}$) and longitudinal ($C_{0,L,L,0}$) polarization transfer coefficients from the vector-polarized deuteron to the secondary proton are

$$C_{0,N,N,0} N^{-1}\frac{d\sigma^{(T0)}}{d\Omega} = 2\cdot \mathrm{Re}\left\{g_3(s)\cdot [g_1(s) + g_2(s) + g_4(s)]^*\right\},$$

$$C_{0,L,L,0} N^{-1}\frac{d\sigma^{(T0)}}{d\Omega} = 2\cdot\left\{|g_3(s)|^2 + \; + 2\mathrm{Re}[g_1(s)\cdot g_4(s)^*]\right\}. \qquad (3)$$

Discussed above polarization observables $T_{20}$ and $\kappa_t$ are connected with used in (2) and (3) as

$$T_{20} = -\sqrt{2}\, C_{0,NN,0,0}$$

$$\kappa_t = \frac{3}{2} C_{0,N,N,0} \, . \tag{4}$$

If the proton target is polarized, the differential cross section depends on mutual spin orientation of initial protons and deuterons

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma^{(T0)}}{d\Omega}\left[1 + \frac{3}{2}C_{N,N,0,0}(\mathbf{SP} - (\mathbf{nS})(\mathbf{nP}) + \frac{3}{2} C_{L,L,0,0}(\mathbf{nS})(\mathbf{nP})\right] . \tag{5}$$

From (5) one can see that the term $C_{N,N,0,0}(C_{L,L,0,0})$ is responsible for the asymmetry effect when spin orientations of both participants of the reaction are normal (longitudinal) to the direction of the initial deuteron 3-momentum.

In terms of scalar amplitudes the expressions for spin correlation parameters $C_{N,N,0,0}$ and $C_{L,L,0,0}$ are following:

$$C_{N,N,0,0} N^{-1} \frac{d\sigma^{(T0)}}{d\Omega} = -2\cdot \mathrm{Re}\left\{ g_3(s)\cdot [-g_1(s) - g_2(s) + g_4(s)]^* \right\} ,$$

$$C_{L,L,0,0} N^{-1} \frac{d\sigma^{(T0)}}{d\Omega} = -2\cdot\left\{ |g_3(s)|^2 - 2\mathrm{Re}[g_1(s)\cdot g_4(s)^*] \right\} . \tag{6}$$

In contrast to the differential cross section and $C_{0,NN,0,0}$, expressions for spin correlations and polarization transfer coefficients contain the interference contributions $\mathrm{Re}(g_i \cdot g_k^*)$, hence, these observables are particularly sensitive to the smallest terms.

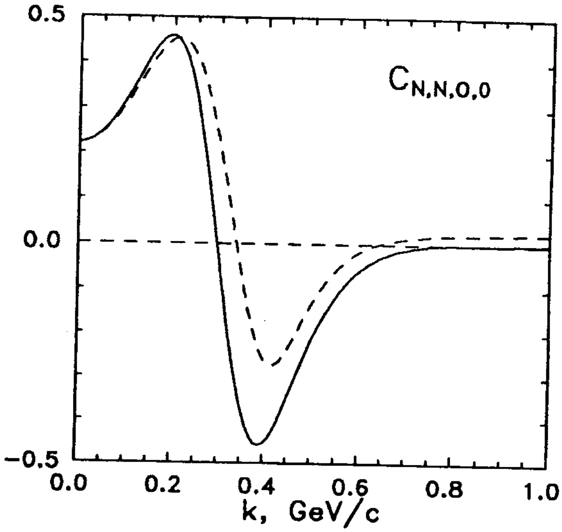
For realization of the complete experiment program it is necessary to obtain data for the polarization observables containing the $\mathrm{Im}(g_i \cdot g_k^*)$ contributions. Needed combinations appear only for triple correlations of vector polarizations:

$$\mathbf{S}_1 \times \mathbf{S}_2 \cdot \mathbf{S}_3 \, , \quad \mathbf{nS}_1 \cdot \mathbf{nS}_2 \times \mathbf{S}_3 \tag{7}$$

and so on, where $\mathbf{S}_i$ is the polarization vector of an $i$-particle. We would like to stress that polarization transfer measurements, in case all three particles have various combinations of parallel or antiparallel spins, do not provide needed information.

Within the IA (one nucleon exchange mechanism) with standard DWF only two amplitudes (real in this case) define all characteristics of the discussed reaction.

Spin correlation $C_{N,N,0,0}$ calculated for standard DWF [13] (solid line) and for DWF with additional $P$-wave components [6] (dashed line)




The various models of the deuteron with additional P-wave [6,12] components are compatible with the case, when the process is described by four independent (but real) amplitudes.

Calculations of $C_{N,N,0,0}$ performed for one of standard DWF [13] within the IA (Figure), demonstrate rather the scale of the effect than really expected behaviour, because, as it was mentioned above, this approach is not compatible with the results of experiments. One can see high sensitivity of $C_{N,N,0,0}$ to $P$-wave contribution.

More detailed consideration of all these question is given in [14].

## 3. Conclusions

Measurement of the spin correlation parameter $C_{N,N,0,0}$ is one of the most realizable polarization experiments for the $d + p \rightarrow p + d$ to date. These data (in addition to measured cross section [3], tensor analyzing power $T_{20}$ [8,10] and polarization transfer coefficient $\kappa_t$ [8]) could provide us to determine $g_1 - g_4$ amplitudes in the case they are real. Within IA it is possible to estimate a possible $P$-wave component in the deuteron.

To determine the imaginary parts of $g_1 - g_4$ amplitudes one needs to perform complicated transfer polarization experiments in case of both polarized initial particles. But if all three particles have various combinations of parallel or antiparallel spins, the measurements of these triple-order observables do not provide us information about imaginary parts of $g_1 - g_4$ amplitudes.

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