Sensitivity to polarization and quadrupolarization in elastic backward *pd* scattering at an energy in the region of 1 GeV

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The experimental data for the sensitivity of protons to polarization and of deuterons to quadrupolarization in elastic backward *pd* scattering at an energy $T > 1$ GeV are described by taking into account the interference of the amplitude of a single-nucleon exchange with the background amplitude.

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It is known (see, for example, Refs. 1 and 2) that the mechanism of single-nucleon exchange (SNE, Fig. 1) satisfactorily describes the magnitude of the cross section for inelastic backward *pd* scattering at an energy $T \gtrsim 1$ GeV and the shape of the peak for the angular distribution near 180°. The role of other mechanisms is important at lower energies.[3-5] Thus, at $T \approx 600$ MeV the mechanism with intermediate pion production[3,4] describes the structure in the energy dependence of the cross section, the sensitivity of the original protons to polarization $A_p(\theta)$ (Ref. 6) and the sensitivity of the original deuterons to quadrupolarization T_{20}.[7,8] The relative contribution of this mechanism is small at an energy $T \gtrsim 1$ GeV.

The results of recent polarization experiments,[6,7] which have confirmed the mechanism[3,4] at $T \sim 600$ MeV, contradict the SNE mechanism at $T \gtrsim 1$ GeV. A noticeably nonvanishing value of $A_p(\theta)$, which depends strongly on the scattering angle θ, was obtained in Ref. 6, whereas the SNE mechanism gives an $A_p(\theta)$ value which is identically equal to zero. The value of T_{20}, measured in Ref. 7 at $T = 1$ GeV and at angles close to 180°, turned out to be close to zero: $T_{20} = -0.009 \pm 0.030$, whereas the SNE mechanism gives a relatively large value $T_{20} = -0.74$.

We show in this paper that the aggregate of all the available data for polarization effects in elastic backward *pd* scattering at $T > 1$ GeV can be explained in terms of the interference of the SNE amplitude with the angle- and energy-independent background amplitude, which is a unit matrix of the spin assignments; moreover, an allowance for the background amplitude is consistent with the description of the cross

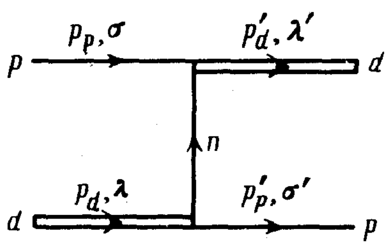

FIG. 1.

section.

We represent the *pd* scattering amplitude in the form

$$M_{\sigma\sigma'}^{\lambda\lambda'} = M_{\sigma\sigma'}^{\lambda\lambda'}(\mathrm{OHO}) + G\delta_{\lambda\lambda'}\delta_{\sigma\sigma'}, \qquad (1)$$

where the first term is the SNE amplitude, the second term is the background amplitude, G is a complex constant: $G = G' + iG''$, and λ,λ' and σ,σ' are the spin assignments of the deuteron and the nucleon. The background amplitude $G\delta_{\lambda\lambda'}\delta_{\sigma\sigma'}$ takes into account phenomenologically the contribution of all the mechanisms in addition to SNE (production of intermediate pions and isobars, rescattering of nucleons, etc.).

By calculating the SNE amplitude in nonrelativistic approximation and allowing for the relativistic kinematics, we can determine the expression for the cross section

$$\frac{d\sigma}{d\Omega} = \frac{m^4}{\pi^2 s}|\overline{M}|^2 \qquad (2)$$

$$|\overline{M}|^2 = G'^2 + G''^2 + G'\frac{(m^2-u)}{2m}(v^2(q) + w^2(q)P_2(z)) + \frac{3(m^2-u)^2}{16m^2}(v^2(q)+w^2(q))^2, \qquad (3)$$

where $s = (p_p + p_d)^2$, $u = (p_p - p_d')^2$, $q^2 = ((m_d+m)^2 - u)((m_d-m)^2 - u)/4m_d^2$ $P_2(z)$ is the Legendre polynomial, $z = (1 + {}^5/_4\cos\theta)\,/\,({}^5/_4 + \cos\theta)$, θ is the scattering angle in the c.m.s., and v and w are the S and D wave functions of the deuteron, which are normalized by the relation

$$\int_0^\infty (v^2(q) + w^2(q))q^2dq/(2\pi^2) = 1.$$

A calculation of the sensitivity of protons to polarization $A_p(\theta)$ gives the formula

$$A_p(\theta) = \frac{45G''(m^2-u)w^2(q)}{64m|M|^2}\,\frac{\left(\cos\theta + \frac{4}{5}\right)}{\left(\cos\theta+\frac{5}{4}\right)^2}\sin\theta, \qquad (4)$$

where $|\overline{M}|^2$ is defined by Eq. (3).

A calculation of the sensitivity of deuterons to polarization $A_d(\theta)$ (which is equal to the value of $\mathscr{P}_y$ in Ref. 7) gives the expression which differs from Eq. (4) only in the sign. We, therefore, obtain

$$A_d(\theta) = -A_p(\theta). \qquad (5)$$

The relation (5) is the prediction of the model, which is based on the assumption that the background amplitude has a spin structure and which has no other uncertainties.

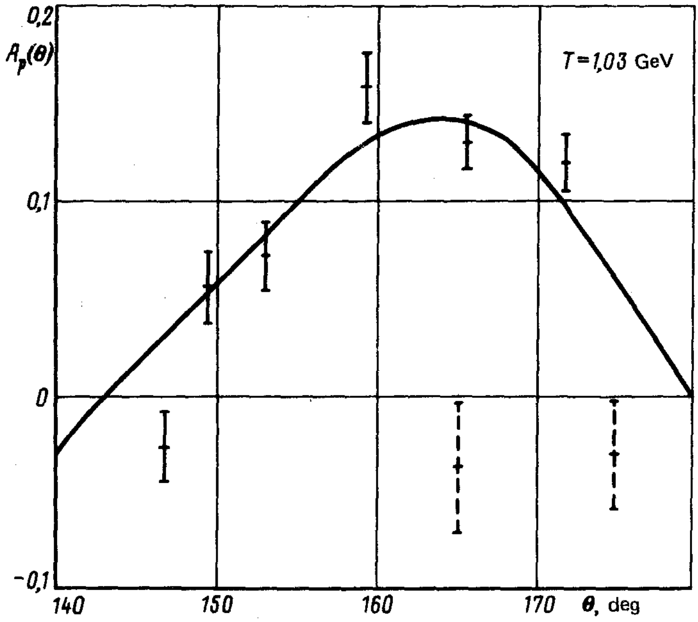
0,2
$A_p(\theta)$
T=1,03 GeV
0,1
0
-0,1
140
150
160
170
θ, deg

FIG. 2.

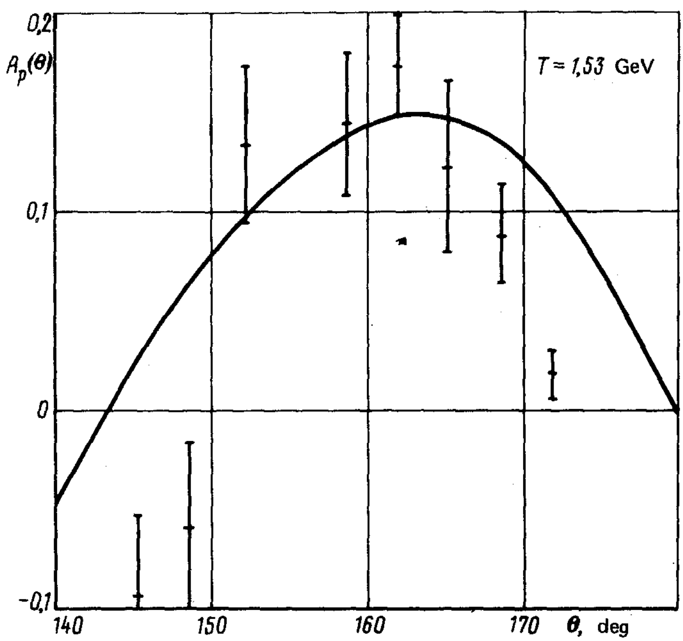
0,2
$A_p(\theta)$
T = 1,53 GeV
0,1
0
-0,1
140
150
160
170
θ, deg

FIG. 3.

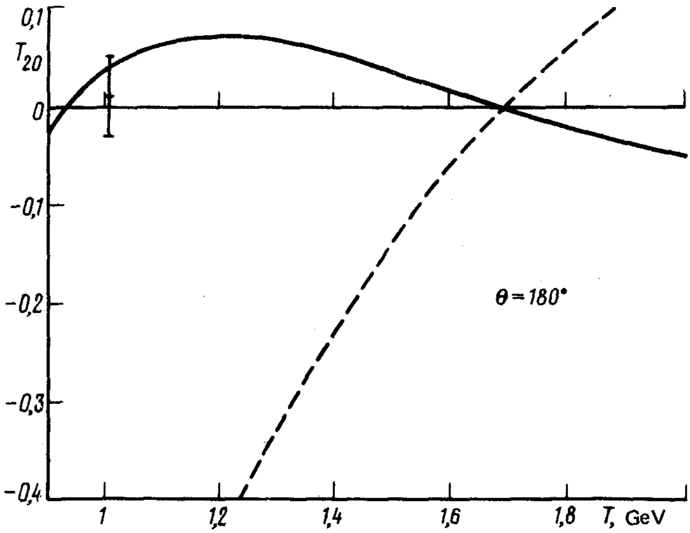

FIG. 4.

The T_{20} component of the tensor of the sensitivity of a deuteron to quadrupolarization for $\theta = 180°$ (see Ref. 9 for definition of T_{2m}) is

$$T_{20} = \frac{\sqrt{2}\,(m^2 - u)}{4m\,|\bar{M}|^2}\left(2\sqrt{2}\,v(q)\,w(q) - w^2(q)\right)\left[G' + \frac{3}{8}\,\frac{(m^2 - u)}{m}\left(v^2(q) + w^2(q)\right)\right]. \tag{6}$$

Figures 2 and 3 show the results of a calculation of $A_p(\theta)$ according to Eq. (4) at energies $T = 1.03$ GeV and $T = 1.53$ GeV, respectively, together with the experimental data[6] (solid lines). The calculations were carried out with use of the deuteron wave function in the Reid's model with a soft core in the parametrization.[10] The calculated curves are in qualitative agreement with the experimental data if the imaginary part of the background amplitude $G'' = -0.35$ GeV^2 is the same for both energies. We describe the maximum of the $A_p(\theta)$ function in the 160° region and the change of the sign in the interval between 140° and 150°, which is governed by the factor $(\cos\theta + 4/5)$ in Eq. (4).

The experimental data[7] for $A_d(\theta)$ are represented by the dashed lines in Fig. 2. These data indicate that the sign of $A_d(\theta)$ is opposite to that of $A_p(\theta)$, as follows from Eq. (5).

The quantity T_{20}, which was calculated within the framework of the SNE mechanism [i.e., for $G' = 0$ in Eq. (6)] is represented by the dashed line in Fig. 4 and the calculated value of T_{20} for $G' = -2$ GeV^{-2} is denoted by the solid line. The experimental point is taken from Ref. 7. The agreement of T_{20} with the experimental value is achieved because of a large compensation in the last factor in Eq. (6).

The contribution of the background amplitude $G = (-2 - i\,0.35)$ GeV^{-2}, which turned out to be the same order of magnitude as the SNE amplitude, to the scattering cross section was equal to 10-20% in the range of angles 170° to 180°, which does not exceed the uncertainties associated with the deuteron wave function at $q \sim 500$ MeV/c. This contribution is attributed to the reduction of the large values, which occurs at G' at which T_{20} is compensated. At the energy $T = 1.53$ GeV and $\theta = 180°$ the contribution of G''^2 to the cross section is 0.27 μb, the contribution of G'^2 is 8.35 μb and the contribution of the interference of the real part of the background with the SNE amplitude is -9.51 μb; the sum of these three components is -0.29 μb, the cross section, determined by the SNE amplitude without the background, is 7.58 μb and the cross section with allowance for the background is 7.29 μb. At smaller angles than 175° the contribution of the background amplitude to the cross section increases sharply and gives an incorrect absolute value and incorrect angular dependence of the cross section. The dependence of G on θ must therefore be taken into account in the calculation of the quantities $d\sigma/d\Omega$ and T_{20} in the region $\theta < 175°$, which are more sensitive to the angular dependence of the background amplitude than $A_p(\theta)$ and $A_d(\theta)$.

Thus, the experimental data obtained by us indicate that the proposed model is correct and that it should be further verified experimentally. The model can be verified by measuring the sensitivity of deuterons to polarization $A_d(\theta)$ in order to verify the relation $A_d(\theta) = -A_p(\theta)$. It would be useful to measure the energy dependence of T_{20} near 180° at $T > 1$ GeV. The value of T_{20} should remain close to zero in the interval 1-2 GeV (provided that the experimental value[7] for T_{20} at $T = 1$ GeV is correct). For a comprehensive investigation of the background amplitude over a broader range of angles, we must have data for the angular dependence of T_{2m} at different energies.

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