Tensor polarization in the *pd* backward scattering at intermediate energies

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The tensor polarization of deuterons in a *pd* backward scattering was calculated on the basis of a triangle diagram without free parameters. According to the experimental data, the tensor polarization turned out to be small at proton energies of 400–1000 MeV.

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The recently published results of measurements of the tensor polarization of deuterons as a result of elastic *pd* backward scattering showed that this value does not change with energy in the proton energy region $T_0 = 400$–1000 MeV and is very close to zero within the limits of measurement errors.[1] This experimental result sharply contradicts the predictions of the pole models[2] (see Fig. 1).

The triangle-diagram approximation[3,5] makes it possible to connect the amplitude of *pd* backward scattering with the amplitude of $pp \rightarrow d\pi$ reaction and to explain the experimental results.

The small tensor polarization in the triangle approximation was predicted earli-
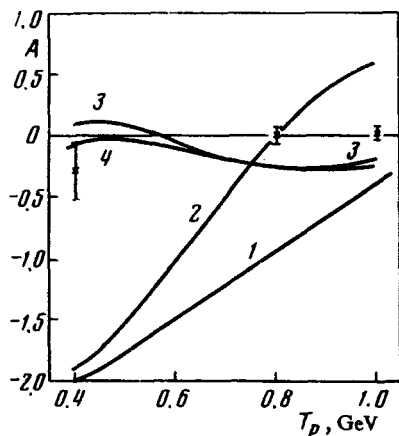
FIG. 1. Dependence of the tensor polarization A in the pd backward scattering on the energy T_0 of an incident proton. The experimental points were taken from Ref. 1. The theoretical curves are as follows: 1, pole model; 2, Kerman-Kisslinger isobaric model (curves 1 and 2 from Ref. 2); 3, triangle diagram for a Reid wave function with a "soft" core; 4, triangle diagram for a Reid wave function with a hard core.

er.[3] This assertion was qualitatively based on the fact that the polarization tensor of second order T_{ij} in the triangle diagram can be built only from the q_i vector—the relative nucleon pulse in a deuteron. In the integral over q the main contribution to the amplitude comes from the region of small values of q.[4,5] Therefore, the value $\langle q_i q_j \rangle$ must be small. This reason alone, however, is insufficient, since the momentum spectrum of the d wave of a deuteron function, which is considerable even in the calculation, is shifted in the direction of larger values of q as compared with the s-wave component. The main reason that $\langle q_i q_j \rangle$ is small at an energy of about 620 MeV is the fact that this is a threshold energy for formation of the Δ_{33} isobar in a nucleon-nucleon collision. We can easily see that $q = 0$ when the energy for a triangle mechanism is small, if the resonance width is disregarded. As shown below, an allowance for the width leads to small corrections.

Using the nonrelativistic deuteron wave function, we obtained the following expression in the triangle-diagram approximation, for the parameter A of the tensor polarization of deuterons in the pd backward scattering, which was determined in Refs. 1 and 2:

$$A = \frac{-(f_2|^2 + 2\sqrt{2}\,\mathrm{Re}(f_0^* f_2)}{|f_0|^2 + |f_2|^2}, \qquad (1)$$

where[5]

$$f_0 = \int_0^\infty \phi_0(r)\,e^{-\gamma r} j_1(\widetilde{p}r)(1 + \gamma r)\,dr. \qquad (2)$$

Here $\phi_0(r)$ is the radial part of the s wave of the deuteron function. The param-

eters y and $\bar{p}$ were determined in Ref. 7.

In the calculation of the cross section for pd scattering, the amplitude of the $pp \rightarrow d\pi$ reaction is usually replaced by its value for $q = 0$. In this approximation for the value f_2, which is determined by the d wave of a deuteron, we obtain an expression that differs from Eq. (2) because of the substitution of $\phi_0(r)$ for $\phi_s(r)$. We can see that the value of A, which is independent of energy, is $A = -0.8$. As mentioned above, however, this approximation for f_2 is too crude. To calculate f_2 more accurately, we must take into account the dependence of the amplitude $F^{pp \rightarrow d\pi}(T_0, q_z)$ on q_z—the longitudinal component of the Fermi momentum of nucleons in the target deuteron. To do this, we shall expand the amplitude F in a series in Legendre polynomials

$$F^{pp \rightarrow d\pi}(T_0, q_z) = \sum_{l=0}^{\infty} F_l(T_0, q) P_l(\cos\theta). \tag{3}$$

We represent the energy dependence of the amplitude $F^{pp \rightarrow d\pi}$ as a Breit-Wigner equation

$$F^{pp \rightarrow d\pi}(T_0, q_z) = F^{pp \rightarrow d\pi}(T_0) \; \frac{T_R - T_0 - \dfrac{i}{2}\Gamma}{T_R - T_0^*(q_z) - \dfrac{i}{2}\Gamma} . \tag{4}$$

The location of the maximum $T_R = 620$ MeV and the width $\Gamma = 300$ MeV were determined by fitting them to the experimental data for the cross sections of the $pp \rightarrow d\pi$ reaction. Using Eq. (3) we obtain the following expression for the f_2 amplitude:

$$f_2 = \sum_{L,l,l_1} B(L,l,l_1) \int_0^{\infty} e^{-\gamma r}(1+\gamma r) j_{l_1}(pr) \int_0^{\infty} \phi_2(q) j_L(qr) F_l \, q^2 \, dq \, dr. \tag{5}$$

The value $B(L,l,l_1)$ contains the well-known normalization factors and angular-momentum coefficients. We took into account in the calculations the relativistic kinematics and the q_z dependence of the $N \rightarrow N\pi$ vertex. The deuteron wave function was used in the form proposed by Reid[8] with two different parametrizations. We can see in Fig. 1 that the results of the calculations are in good agreement with the experimental data. We note that this result is consistent with the calculations of the vector polarization of deuterons in the pd backward scattering,[3,9] which showed that the contribution of the triangle diagram is dominant near the formation threshold of the Δ_{33} isobar. It seems that the tensor polarization at the formation threshold of the Δ_{33} isobar is small not only in the triangle diagrams but also in the mechanism with a rescattering of the isobar[6] (all these contributions to the backward scattering amplitude intersect each other to a great extent). The tensor polarization in the $pp \rightarrow d\pi$ reaction must also be small.

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