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TENSOR ANALYZING POWER T_{20} AND VECTOR TRANSFER COEFFICIENT K FOR THE $p+D \to (h, p) +X$ PROCESS

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In the framework of the covariant formalism on the basis of the relativistic deuteron wave function with one of the nucleons on mass-shell, the polarization characteristics of $p+D \to (h, p) +X$ process are considered. The tensor analyzing power T_{20} and vector polarization transfer coefficient K are calculated and their dependences on the deuteron wave function in the region of dynamic D-wave enhancement and momentum of incident proton are studied.

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

Тензорная анализирующая способность T_{20} и векторный коэффициент передачи поляризации К процесса $p +D \to (h,p) + X$

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В рамках ковариантного подхода в переменных светового конуса в импульсном приближении рассмотрены поляризационные характеристики процесса $p+ D \to (h, p)+X$. Вычислены импульсные зависимости тензорной анализирующей способности T_{20} и векторного коэффициента передачи поляризации К этого процесса. Исследована зависимость этих величин от выбора релятивистской волновой функции дейтрона в области динамического усиления D-волны и импульса налетающего протона.

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1. Introduction

The investigation of hadron-deuteron interactions at high energies yields independent information on the relativistic deuteron structure. Recent experimental data on momentum dependence of cross-section for the D-p fragmentation processes are given in Ref. [1-3]. Within

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the impulse approximation (IA) this data was analyzed, for example, in Ref.[4-6]. It was also shown that along the spectator mechanism that makes the main contribution to the cross-section, a noticeable one is made by the mechanism of pion enhancement due to the resonance Δ-isobar production.

However the analysis of the cross-section only is not sufficient to conclude unambiguously on the advantage of any relativistic approach to be used to describe both the deuteron itself and the processes involving it and does not allow, in particular, to consider unambiguously on the relative contribution of various mechanisms to the cross-section of the process (IA, pion enhancement, final state interactions, etc.).

The measurements of polarization characteristics — tensor analyzing power T_{20} and vector polarization transfer coefficient K of the D-p fragmentation process — allowed us to analyze this process more correctly theoretically. In particular, it was shown[5,6] that together with the scheme of deuteron wave function relativization, the relativistic description of the mechanism process themselves is of importance as well. The latter leads to the qualitative effect, i.e. the absence of zero of T_{20} in the region k = 0.3-0.5 (GeV/c).

Nevertheless, experiments[3,9,10] showed that theoretical IA calculations of T_{20} provide no description of experimental data. Therefore, it is concluded that T_{20} behaviour gives no direct information on the relativistic deuteron wave function (RDWF) structure in the core region wherein the D-wave is dynamically enhanced. Such a conclusion is proved, e.g., in Ref.[11], by the fact that the region of minimal T_{20} is filled by the contribution of pion enhancement mechanism.

The present paper offers experiments on measurements of tensor analyzing power T_{20} and vector polarization transfer coefficient K of the double inclusive process $p + D \to (h,\ p) + X$ by registrating a fast particle $h(\pi^+)$ scattered within a large angle ($\theta > 90°$) and backward scattered proton-spectator. In this case the contribution of the pion enhancement is kinematically suppressed. So one can hope to obtain direct information on the momentum distribution of nucleons in a deuteron and polarization RDWF in the region of dynamic D-wave enhancement ($k \approx 300$ MeV/c). In the framework of covariant formalism in the light-cone variables on the basis of the RDWF with one nucleon on mass-shell the dependences of T_{20} and K on the momentum of the incident proton are considered. It was shown, in particular, that the T_{20} dip is naturally filled due to the mass corrections that decrease with the energy increase. In this case both T_{20} and K tend to the asymptotic behaviour.

2. Tensor Analyzing Power T_{20} for the $p+\vec{D} \to (h, p)+X$ Process

The amplitude of the process considered in the IA is described by a diagram (Fig.1).

Here q, p, k, r^h, r^p are momenta of the incident proton (p), deuteron (D), active nucleon (N), registered particle (h) and proton-spectator (p), respectively. The top block describes the amplitude of the $p+N \to h+X$ process, the bottom block describes the DNN vertex Γ_α with one nucleon on mass-shell. Under this approximation tensor analyzing power T_{20} of the $p+\vec{D} \to (h, p)+X$ reaction in the framework of the covariant formalism in the light-cone variables with the RDWF [12-14] is defined by the formula

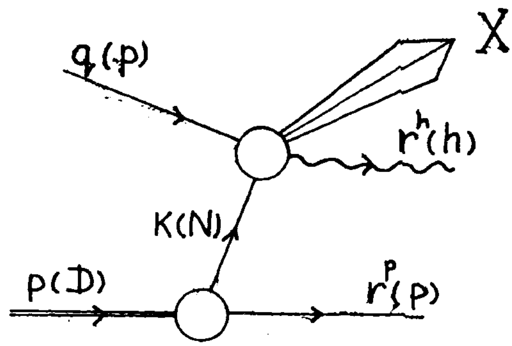

Fig.1. Amplitude of $p+D \to (h,p)+X$ process in the relativistic impulse approximation.

$$T_{20} = \frac{\sqrt{2}}{3}\, t_D^{hp} / \rho_D^{hp} . \qquad (1)$$

and

$$t_D^{hp} = \Phi_{zz}(x, k_\perp) \cdot S^{zz} \cdot \rho_N^h(x^h/x,\ r_\perp^h - x^h/x \cdot k_\perp) ,$$

$$\rho_D^{hp} = \Phi_{\alpha\beta}(x, k_\perp) \cdot \rho^{\alpha\beta} \cdot \rho_N^h(x^h/x,\ r_\perp^h - x^h/x \cdot k_\perp) .$$

Here $x^h = r_+^h/p_+$, $x = k_+/p_+$, $x^p = 1 - x$, $r_\perp^h$, $k_\perp$, $p_\perp^p$ are the fractions of the deuteron momentum and transverse momentum carried away by the particle h, active nucleon N, proton-spectator p, respectively; $S_{\alpha\beta}$ is a quadrupole part of the polarization deuteron density matrix ($S_{\alpha\beta} = S_{\beta\alpha}$, $S_{\alpha\alpha} = 0$, $p_\alpha S^{\alpha\beta} = 0$); $r_\pm = r_0 \pm r_3$; $\rho_{\alpha\beta} = -(g_{\alpha\beta} - p_\alpha p_\beta/M^2)/3$ is an unpolarized part of the polarization deuteron density matrix; M is a deuteron mass; ρ_N^h is the inclusive cross-section for the $p+D \to h+X$ process.

Tensor $\Phi_{\alpha\beta}$ is expressed via a vertex function Γ_α as follows:

$$\Phi_{\alpha\beta} = Sp\{(m+\hat{k})^{-1} \cdot \bar{\Gamma}_\alpha(k) \cdot (m+\hat{r}^p) \cdot \Gamma_\beta(k) \cdot (m+\hat{k})^{-1} \cdot (m+\hat{q})\} . \qquad (2)$$

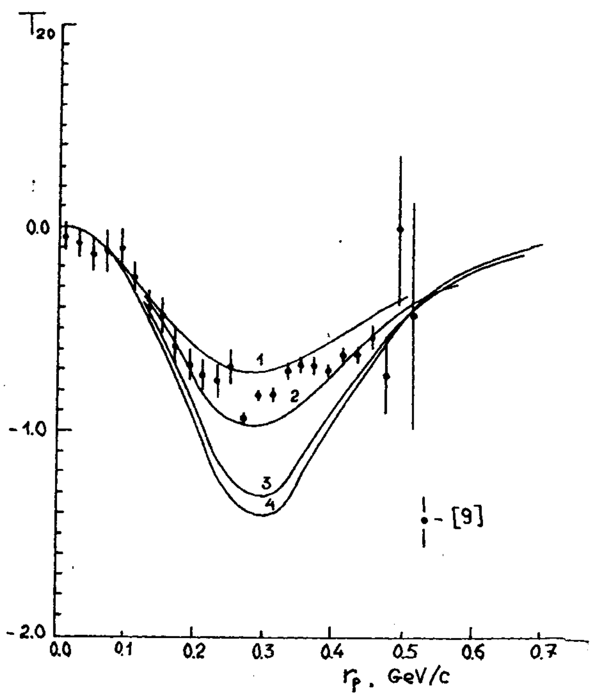

Fig.2. Tensor analyzing power T_{20} of the $p+\vec{D}\to(h,p)+X$ process in the relativistic impulse approximation.

Figure 2 shows the results of our calculation of the dependence of T_{20} of the process $p+\vec{D}\to(\pi^+, p)$ on the momentum of backward scattered proton-spectator with the registration of a fast π^+-meson ($r_{\pi^+} = 0.2$ GeV/c) at the angle of $\theta = 90°$. Curves 1, 2, 3 and 4 denote calculations using the RDWF [14] with the core for the momenta of the incident proton $q = 4.55$, 8.9, 20., 500. (GeV/c), respectively.

Figure 2 shows a noticeable dependence of T_{20} on the incident proton momentum, with the increase of q the value of T_{20} tending to the asymptotic behaviour. This is consistent with the results from Ref. [5] for $s = (p+q)^2 \to \infty$ with taking no account of mass terms resulting from $(m + \hat{q})$ in formula (2).

Note, that formula (1) under the IA for T_{20} coincides with T_{20} of the $p+\vec{D}\to p+X$ process. Therefore, it is natural to compare results of our calculations with experimental data on T_{20} [3,9]. Figure 2 shows experimental points [9] for comparison. Good agreement between the theoretical results and experimental data is observed.

Experimental verification of the predicted momentum dependence of T_{20} in the region of the dynamic D-wave enhancement is of interest. This may lead to the reconsideration of the role of the pion enhancement mechanism in this region.

3. Vector Polarization Transfer Coefficient for the $p+\vec{D} \to (h, \vec{p}) + X$ Process

Another characteristic that is able to give independent information on the polarization structure of the relativistic deuteron is the vector polarization transfer coefficient — K. It defines the value of polarization transfer from a vector-polarized deuteron to a registered polarized proton.

The K in the IA of the $p+\vec{D} \to (h, \vec{p}) + X$ process in the framework of the covariant formalism in the light-cone variables[12-14] is defined as follows:

$$K = V_D^{hp} / \rho_D^{hp}, \tag{3}$$

where

$$V_D^{hp} = \Phi^V_{\alpha\beta}(x, k_\perp) \cdot \rho_V^{\alpha\beta} \cdot \rho_N^h(x^h/x,\ r_\perp^h - k_\perp \cdot x^h/x).$$

Here $\rho^V_{\alpha\beta} = i\epsilon_{\alpha\beta\nu\lambda} \cdot s_D^\nu \cdot p^\lambda / 2M$ is the vector part of the polarization deuteron density matrix; s_D is four vector of the deuteron spin ($s_D^2 = -1$, $p_\alpha \cdot s_D^\alpha = 0$).

Tensor $\Phi^V_{\alpha\beta}$ as well as tensor $\Phi_{\alpha\beta}$ in (2) is expressed via the vertex function Γ_α with one nucleon on the mass-shell

$$\Phi^V_{\alpha\beta} = Sp\{(m+\hat{k})^{-1} \cdot \bar{\Gamma}_\alpha(k)\gamma_5 \cdot \hat{s}(m+\hat{r}^p) \cdot \Gamma_\beta(k) \cdot (m+\hat{k})^{-1} \cdot (m+\hat{q})\}. \tag{4}$$

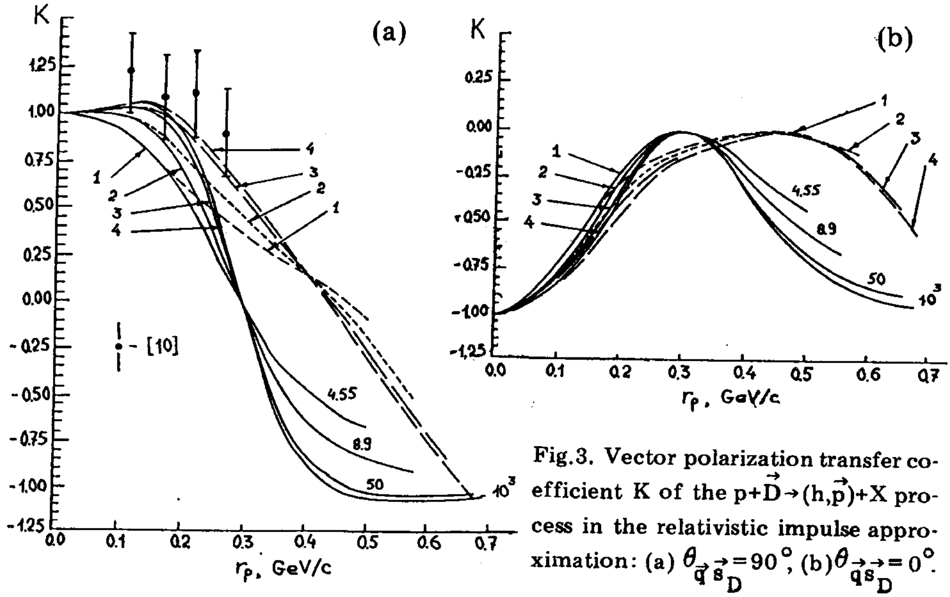

Fig.3. Vector polarization transfer coefficient K of the $p+\vec{D} \to (h,\vec{p})+X$ process in the relativistic impulse approximation: (a) $\theta_{\vec{q}\vec{s}_D} = 90°$, (b) $\theta_{\vec{q}\vec{s}_D} = 0°$.

The magnitude s is the four vector of the registered proton-spectator spin.

Figure 3(a) shows the results of our calculation of K for the $p+\vec{D} \to (\pi^+, \vec{p})+X$ process vs the momentum of the backward scattered proton-spectator ($\theta = 180°$) and the momentum of the fast π^+-meson, scattered at the angle of $\theta = 90°$. Curves 1, 2, 3 and 4 are calculations using the RDWF [14] with the core for momenta of the incident proton q= 4.55, 8.9, 20., 500. (GeV/c), respectively. The angle $\theta_{\vec{q}\,\vec{s}_D}$ between the incident proton momentum $\vec{q}$ and the vector of the deuteron spin $\vec{s}_D$ is 90°. Dashed lines 1, 2, 3, 4 are calculations using the RDWF [12] with no core. Fig.3(a) shows that the qualitative effect — the absence of zero in the S-wave of the RDWF is manifested in the displacement of K's zero into the region of $k > 0.3$ (GeV/c).

The dependence of K on the incident proton momentum q both for r^p more and less 300 (MeV/c) is clearly observed. With increasing q the curve of K tends to the asympotic behaviour. This agrees with the result [6] for K obtained under the IA for the $\vec{D} + {}^{12}C \to \vec{p} + X$ process in the $s = (p+q)^2 \to \infty$ limit. Figure 3(a) also shows experimental data [10] of K for this process.

The experimental points are seen to lie systematically upper than theoretical curves even for q = 500. (GeV/c).

Fig.3(b) shows the calculated results of K for the case of $\theta_{\vec{q}\,\vec{s}_D} = 0°$. Notation is the same as in Fig.3(a). With increasing q the flexure in the curve of K both for r^p less and more 0.3 (GeV/c) is observed and $K = 0$ for $r^p = 0.3$ (GeV/c). The calculation using the RDWF [12] without core, shows the displacement of the maximum of the dependence of K into the region of $k > 0.3$ (GeV/c).

4. Conclusion

Thus the obtained results show that tensor analyzing power T_{20} and vector polarization transfer coefficient K of the $p+D \to (h, p)+X$ process may yield important information on the polarization deuteron structure. A simultaneous experimental verification of the dependence of these magnitudes on the momentum of the incident proton in the region of the dynamic D-wave enhancement will allow us to determine the role of IA and pion enhancement mechanisms more exactly in the description of proposed process as well as a test of the developed relativistic approach.

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