Polarization parameters Σ, T, and P for the reaction $\gamma p \rightarrow p\pi^0$ in the energy interval 0.9–1.5 GeV at $\theta_{\pi^0}^{c.m.} = 120°$

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A doubly polarized beam-target experiment has been carried out on the reaction $\gamma p \rightarrow p\pi^0$ at $\theta_{\pi^0}^{c.m.} = 120°$. The three polarization parameters Σ, T, and P were measured simultaneously over the energy interval 0.9–1.5 GeV. The results are compared with the model-based predictions in the resonance region.

Study of reactions involving the single photoproduction of pions in collisions with nucleons in the energy region of the excitation of πN resonances can yield information on the properties of nucleon resonances according to various phenomenological analyses.[1,2] In particular, the electromagnetic coupling constants of these resonances can be determined in order to test the predictions of the quark model.[3] Data from polarization experiments are the most informative. Results obtained on polarization parameters are increased substantially in value if they are internally compatible, i.e., if they are obtained in a single experiment. The simultaneous use of a beam of linearly polarized γ rays and a polarized proton target makes it possible to obtain information on three observables simultaneously[4]: Σ, the asymmetry of the cross section for linearly polarized γ rays; T, the asymmetry of the cross section of a polarized proton target; and P, the polarization of the recoil nucleon. In the present letter we report the results of measurements of the parameters Σ, P, and T in a doubly polarized beam-target experiment for the photoproduction of π^0 mesons at an angle $\theta_{\pi^0}^{c.m.} = 120°$ in the center-of-mass frame and for γ energies $E_\gamma = 0.9$, 1.2, and 1.5 GeV. The literature reveals no corresponding experimental data.

The experiment was carried out in the 4.5-GeV beam of linearly polarized γ rays at the Erevan synchrotron by a method of coherent electron bremsstrahlung in a diamond single crystal.[5] The measurements were carried out in the polarized target of the Khar'kov Physicotechnical Institute.[6] As the working medium of the target we used 1,2-propylene glycol ($C_3H_8O_2$) with the HMBA-Cr^V complex. The polarization of the protons at a temperature of 0.5 K in a 2.7-T magnetic field reached 75%. The recoil protons were detected by a magnetic spectrometer,[7] in which the protons were separated from π^+ mesons by time of flight. To select the two-particle reaction, we connected the magnetic spectrometer in coincidence with a total-absorption Čerenkov counter,[8] which detected one γ ray from the decay of the π^0 meson. Because of the

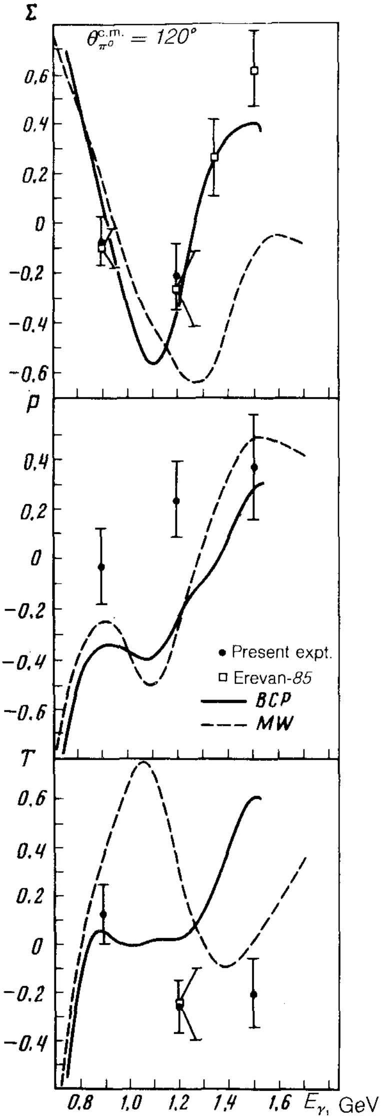

FIG. 1. Energy dependence of the polarization observables Σ, *P*, and *T*. ●—Results of the present study; □—results of Ref. 11.

complex chemical composition of the working medium of the target, photoproduction processes at nucleons bound in nuclei also contribute to the experimental yields. The total yield of the process can therefore be written[9]

$$C = C_0^f[1 - P_\gamma \Sigma \cos 2\Phi + P_y(T - P_\gamma P \cos 2\Phi)] + C_0^n[1 - \bar{P}_\gamma \Sigma_n \cos 2\Phi], \quad (1)$$

where C_0^f and C_0^n are the yields with unpolarized initial particles in collisions with free protons and with target nuclei, P_γ is the polarization of the γ rays, averaged over the energy range of the experimental apparatus, $\bar{P}_\gamma$ is the polarization of the γ rays when the intranuclear motion of nucleons is taken into account, P_y is the degree of polarization of the target protons, Σ_n is the asymmetry of the cross section for photonuclear processes in the linearly polarized γ beam, and Φ is the angle between the polarization vector of the γ rays and the reaction plane.

To determine the parameters Σ, T, and P from expression (1), we used a procedure similar to that of Ref. 10: a) We measured the yields for various combinations of the polarization directions of the γ rays [perpendicular ($\perp$) and parallel ($\|$) to the reaction plane; $\Phi = 90°$ and $0°$, respectively] and the polarization direction of the target [upward ($\uparrow$) and downward ($\downarrow$) with respect to the normal to the reaction plane], i.e., $C_\perp^\uparrow, C_\|^\uparrow, C_\perp^\downarrow, C_\|^\downarrow$. b) We carried out auxiliary measurements in a carbon (C) target and in a polyethylene (CH_2) target of equivalent thickness in order to evaluate the contributions of photonuclear reactions involving bound nuclei of the target nuclei, i.e., $C_\perp^C, C_\|^C$. c) We carried out background measurements in the empty and ^{3}He-filled part of the target for various polarization directions of the γ rays. As a result of the experiments, we obtained values of the parameters Σ, T, and P for $E_\gamma = 0.9$, 1.2, and 1.5 GeV and for the pion emission angle $\theta_{\pi^0} = 120°$ in the c.m. frame. The resolution of the experimental apparatus in terms of the γ energy and the pion emission angle in the c.m. frame are $\sigma_{E_j} \cong 60$ MeV and $\sigma_{\theta^*} \cong 0.7°$, respectively, on the average, according to the results of a Monte Carlo simulation.[9] The contribution from background processes involving pair production of pions was evaluated experimentally under conditions of a "violated" two-particle kinematics; this contribution was found to be less than[5] 6%.

The experimental results are shown in Fig. 1. The indicated errors include the statistical uncertainties in the measured yields and also the errors in the determination of the γ polarization ($\sim 10\%$) and the proton polarization ($\sim 10\%$). Also shown in this figure are the predictions of the phenomenological analyses of Metcalf and Walker,[1] based on an isobar model, and of Barbour *et al.*,[2] based on dispersion relations for a fixed momentum transfer. We see that the data on the asymmetry Σ agree qualitatively with the analysis curve of Ref. 1, but none of the analyses can give a satisfactory description of the experimental data on the parameters T and P. This discrepancy indicates a need for comprehensive phenomenological analyses also incorporating the new data.

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