Study of the $\gamma p \to n\pi^+$ reaction with polarized protons and photons at $E_\gamma = 340$ MeV

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A two-fold polarization experiment of the "beam-target" type is carried out for the first time for the reaction $\gamma p \to n\pi^+$ for $E_\gamma = 340$ MeV, and the three polarization parameters, Σ, T, and P are determined simultaneously.

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Multipole analyses of the available experimental data on the photoproduction of pions on nucleons in the region of photon energies $\leqslant 500$ MeV are characterized by ambiguity in the results and by their irregular energy behavior near the P_{33}-resonance peak (~ 340 MeV).[1,2] The reasons for these problems in the analyses are related to unreliable experimental data which contain systematic errors.

In this connection, there is an urgent need for new polarization experiments which on the one hand would extend the available data on the photoproduction process and, on the other hand, would assure internal consistency in the data.

In this article we give the results of the first two-fold polarization experiment of the "beam—target" type for the $\gamma p \to n\pi^+$ reaction at $E_\gamma = 340$ MeV. The use of a polarized proton target and a beam of linearly polarized photons at once provides information on three observables: Σ, the cross section asymmetry for linearly polarized photons; T, the asymmetry for polarized protons; and P, the recoil nucleon polarization. It is clear that in such an experiment the compatibility of all three polarization parameters will be assured.

The linearly polarized photon beam was obtained by the coherent bremsstrahlung of 1250-MeV electrons in a diamond monocrystal 300 μm thick; in the primary coherent maximum the photon polarization p_γ reached 60% for $E_\gamma = 340$ MeV. The polarized target provided for a proton polarization p_γ up to 70% in ethylene glycol with Cr^V structure at a temperature of 0.5 K in a magnetic field of 2.7 T.[3] Pions from the $\gamma p \to n\pi^+$ reaction were recorded at the magnetic spectrometer output by a telescope of scintillation counters and gas Cerenkov counter. Thus, pions produced on both free (polarized) protons and bound nuclear protons occurring in the target material were detected. Therefore, the total pion yield may be written as

$$C = C_0^U [1 - p_\gamma \Sigma \cos(2\phi) + p_y (T - p_\gamma P \cos(2\phi))] + C_0^N [1 - p_\gamma \Sigma_N \cos(2\phi)], \quad (1)$$

where C_0^U and C_0^N are respectively the pion yields from free protons and from nuclei

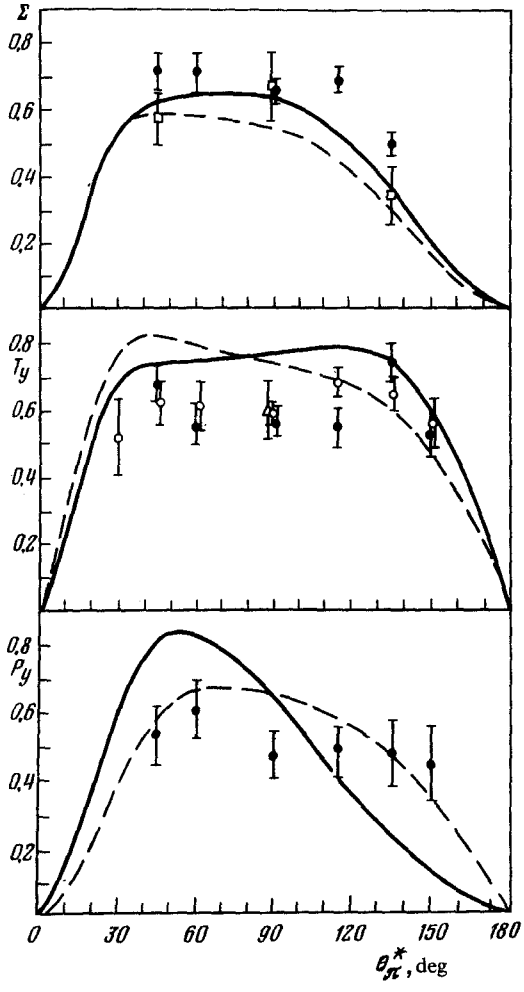

FIG. 1. Polarization data for the $\gamma p \to n\pi^+$ reaction at $E_\gamma = 340$ MeV: filled circles, our work; open circles, Ref. 6; squares, Ref. 7, and triangles, Ref. 8. Dashed curves are for theoretical predictions,[4] solid curves are predictions of the energy-independent analysis.[5]

for an unpolarized beam and target, p_γ is the polarization of the photon beam averaged over the energy resolution of the apparatus taking into account the intranuclear motion of nucleons, ϕ is the angle between the photon polarization vector and the reaction plane, and Σ_N is the reaction cross section asymmetry on intranuclear protons. The direction of the proton polarization vector is normal to the reaction plane.

In order to determine Σ, T, and P using Eq. (1), we measured the pion yields from the polarized targets: $C^{\uparrow}_{\perp}$, $C^{\uparrow}_{\parallel}$, $C^{\downarrow}_{\perp}$, and $C^{\downarrow}_{\parallel}$, and from the liquid hydrogen (unpolarized) targets: $C^{U}_{\perp}$ and $C^{U}_{\parallel}$ (the arrows denote the direction of the proton polarization vector relative to the normal to the reaction plane, and $\perp$ and $\parallel$ correspond to ϕ values of 90° and 0°).

As a result of the experiment we obtained values of Σ, T, and P for $E_\gamma = 340$ MeV and for pion production angles of 45°, 60°, 90°, 115°, 135°, and 150° in the center of mass system. The correction which was introduced for the contribution from pion pair production processes did not exceed 20% for T and 5% for Σ and P.

Figure 1 shows the results in comparison with the predictions of theory[4] and of an energy-independent multipole analysis,[5] and with other types of experimental data.[6-8] The discrepancy found with theoretical predictions should lead to an improvement in the values of the multipole photoproduction amplitude in the region of the P_{33}-resonance.

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