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Polarization of secondary protons in the $\gamma+p\to\pi^0+p$ reaction at $E_\gamma=536$–640 MeV

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Measurements are reported of the polarization of protons from the $\gamma+p\to\pi^0+p$ reaction at photon energies of 540, 560, 585, 610, and 640 MeV at pion angle of emission of 90° in the center of mass system. The angular dependence of the proton polarization has been investigated for this reaction at a photon energy 600 MeV. The data obtained are compared with the results of the phenomenological analysis reported by Metcalf and Walker (Preprint CALT-68-425, 1974).

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Studies of the photoproduction of pions on nucleons play an important role in the systematics of resonances. The energy behavior of resonance multipoles, their relative contribution to observed quantities, and the parametrization of small phonon amplitudes combine into one of the important problems in the theoretical analysis of the photoproduction of pions on nucleons.

Several theoretical papers[1–5] have been published in recent years, where different methods (resonance model, dispersion relations, energy-independent multipole analyses, and so on) were used to calculate the partial amplitudes and their contributions to the different observed quantities. Comparison of experimental results with theoretical predictions may provide information on the degree of validity of any particular method. However, the amount of information available on polarization, which is one of the main characteristics involved in the study of the photoproduction of pions on nucleons, is currently quite inadequate. Despite the fact that the polarization of protons, especially in region II of πN resonances in the $\gamma+p\to\pi^0+p$ reaction was measured quite a long time ago, these measurements are neither systematic enough nor accurate enough to enable us to decide in favor of any particular theoretical approach.

In this paper we report the results of measurements of the polarization of protons emitted in the $\gamma+p\to\pi^0+p$ reaction at 90° in the center of mass system in the region of the π resonances, and the angular dependence of the polarization at $E_\gamma=600$ MeV.

1. ENERGY DEPENDENCE OF POLARIZATION AT 90° CM AT PHOTON ENERGIES BETWEEN 536 AND 640 MeV

The experiment was performed with the photon beam of the Khar'kov 2-GeV linear accelerator. The proton polarization was measured by a telescope consisting of optical spark chambers mounted at the exit from a magnetic spectrometer.[10] The telescope contained three four-gap spark chambers with aluminum electrodes, 0.15 mm thick (IK-4), and one 42-gap spark chamber with graphite electrodes (IK-42) of $350\times350\times7$ mm. The set of graphite electrodes of the IK-42 chamber was used as the polarization analyzer. The spark chambers IK-4, which were located in front of the IK-42, were used to determine the proton track direction prior to scattering in the graphite electrodes.

Since the focal line of the magnetic spectrometer passed through the first gap of the IK-42, this enabled us to determine the momentum of protons recorded on stereophotographs to an accuracy of better than 0.5%, and to assign it to the corresponding kinematic interval of the reaction under investigation. The total momentum range in the experiment was 7%.

The proton polarization was determined from the scattering asymmetry for a carbon target, using the maximum likelihood method. The analyzing power was taken from the paper of Peterson.[11] The following results were obtained for the polarization of protons from the $\gamma+p\to\pi^0+p$ reaction at 90° in the center of mass system:

$E_\gamma\pm\Delta E_\gamma$, MeV:	536 ± 10	560 ± 11	585 ± 12	610 ± 13	640 ± 28
$P\pm\Delta P$:	-0.48 ± 0.09	-0.54 ± 0.10	-0.59 ± 0.09	-0.72 ± 0.08	-0.74 ± 0.07

The uncertainties are statistical.

Figure 1 shows the experimental polarizations and the calculations of Metcalf and Walker[2] based on the resonance model. Satisfactory agreement is observed between the experimental energy dependence of polarization at 90° and the dependence predicted theoretically[2] in region II of the πN resonances.

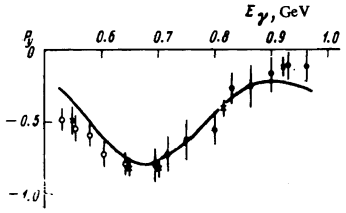

FIG. 1. Energy dependence of the polarization of protons from the $\gamma+p\to\pi^0+p$ reaction at $\theta_\pi=90°$ c.m.s.: —present results and our previously published results[8]; ×—results of Lundquist *et al.*[7]; solid curve—results of the Metcalf-Walker analysis.[2]

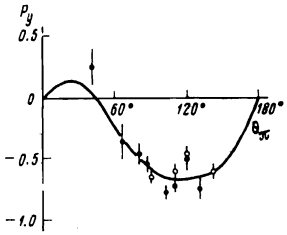

FIG. 2. Angular dependence of polarization at photon energy of 600 MeV: ○—present results; ●—results from the compilation of Genzel and Pfeil[12]; solid curve—results of Metcalf and Walker.[2]

It would be interesting to continue systematic measurements of the proton polarization at lower photon energies. This intermediate region between the $P_{33}(1236)$, $D_{13}(1520)$, and $S_{11}(1535)$ resonances is in need of detailed investigation, especially in view of the problem of the $P_{11}(1470)$ resonance whose contribution is difficult to take into account because of its large decay width. Unfortunately, such measurements are difficult to perform by the technique used in the present paper because the effectiveness of carbon as an analyzer for protons with energies below 100 MeV is inadequate.

2. ANGULAR DEPENDENCE OF POLARIZATION AT E_γ = 600 MeV

We have measured the polarization of protons from the $\gamma+p\to\pi^0+p$ reaction at $E_\gamma=600$ MeV in the angular range $\theta_\pi=90°-142°$ in the center of mass system. The results are listed below

θ_π (c.m.s.):	90°	110°	120°	142.5°
$P\pm\Delta P$:	−0.660±0.060	−0.605±0.058	−0.445±0.066	−0.595±0.059

The angle range in this experiment was ± 20'. The uncertainties indicated above are statistical

Figure 2 shows the proton polarization data at E_γ = 600 MeV, which are available at the present time. The curve is based on the phenomenological analysis of Metcalf and Walker.[2] It is clear that the theoretical curve is essentially in satisfactory agreement with the experimental angular dependence. However, the discrepancy in the angular range 100–120° may be an indication of a more complicated structure. The observed structure may be the result of an appreciable contribution of amplitudes with total angular momentum greater than 3/2 to the energy region under investigation. Systematic measurements of polarization at angles $\theta_\pi>90°$ c.m.s. in steps of not more than 10° and precision better than ± 0.06, using the same experimental technique, will, of course, be necessary before any final conclusions can be drawn. It follows that the conclusions drawn above from existing experimental data are only preliminary.

The angular dependence of the polarization of protons in the angular interval 90–142.5° at proton energies of 585 (P_1) and 615 (P_2) MeV are listed below:

θ_π (c.m.s.):	90°	110°	120°	142.5°
$P_1\pm\Delta P_1$:	−0.590±0.090	−0.528±0.085	−0.424±0.097	−0.624±0.078
$P_2\pm\Delta P_2$	−0.720±0.081	−0.664±0.084	−0.499±0.095	−0.523±0.092

where the uncertainties are statistical. These results were obtained by subdividing the energy range of the telescope into two intervals, namely, 585 ± 14 and 615 ± 15 MeV. It is readily seen that the character of the angular dependence of polarization at these two energies does not differ essentially from the angular dependence at $E_\gamma=600$ MeV in this angular range.

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