Polarization of protons from the reaction $\gamma + p \to \pi^0 + p$ on a linearly polarized photon beam

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In the case when the photon-polarization vector is directed perpendicular (parallel) to the reaction plane, it becomes possible to measure three experimentally observable quantities[1]:

$$\Sigma = \frac{\mathrm{Re}H_2^{(-)}}{A^{(+)}}; \quad (1)$$

$$P_y^{\perp(\parallel)} = \frac{\mathrm{Im}H_1^{(+)} \pm \mathrm{Im}H_3^{(-)}}{A^{(+)} \pm \mathrm{Re}H_2^{(-)}} = \frac{P_y^{\circ} \pm T_y}{1 \pm \Sigma}; \quad (2)$$

(the plus and minus signs pertain respectively to perpendicular (⊥) and parallel (∥) polarization-vector directions).

If the angle between the photon polarization vector and the plane of the reaction is 45°, then we can obtain three components of the spatial polarization vector of the nucleon

$$P_x = \frac{\mathrm{Im}H_3^{(-)}}{A^{(+)}}; \quad (3)$$

$$P_y^{\circ} = \frac{\mathrm{Im}H_1^{(+)}}{A^{(+)}}; \quad (4)$$

$$P_z = \frac{\mathrm{Im}H_2^{(-)}}{A^{(+)}}, \quad (5)$$

where $H_i^{(\pm)}$ and $A^{(+)}$ are corresponding bilinear combinations of the helicity amplitudes,[1] p_y^0 is the polarization of the nucleon on an unpolarized photon beam, Σ and T_y are the asymmetries of the cross sections on the linearly-polarized photon beam and the polarized nucleon target, respectively.

Thus, measurements with linearly-polarized photons yield information on five bilinear combinations of the photoproduction amplitudes (out of the 10 needed for the complete experiment).

We present here, for the first time, experimental results of the measurement of the polarization of protons from the reaction $\gamma + p \to \pi^0 + p$ on linearly polarized 495-MeV photons with the polarization vector directed perpendicular and parallel to the plane of the reaction. The measurements were made at a pion c.m.s. emission angle $\theta_\pi = 105°$.

The experiment was performed with a beam of linearly-polarized photons obtained by coherent bremsstrahlung of electrons from the linear accelerator of our institute in single-crystal diamond.[2] The maximum energy of the photon spectrum was 1380 MeV. The energy resolution in the experiment was $\Delta E_\gamma = \pm 20$ MeV. The experiment was performed with two magnetic spectrometers,[3] in the focus of which the liquid-hydrogen target was located.

The polarization of the protons and the asymmetry Σ were measured with the aid of a telescope of spark chambers[4] mounted at the exit from one of the magnetic spectrometers. The presence of the second spectrometer made is possible to monitor during the course of the experiment the stability of the polarization of the photon beam and of the measured asymmetry, by observing the yield of the photoprotons from the reaction $\gamma + p \to \pi^0 + p$.[5]

In the experiments we performed three independent measurements of the proton polarization: 1) photon polarization vector directed perpendicular to the reaction plane, 2) polarization parallel to this plane, 3) coherent effect, and consequently no photon polarization. The third measurement is essential to take into account the contribution to the proton polarization from the background due to the incoherent bremsstrahlung and to the proton yield from the two-pion photo-production process.

$C_\perp$	$C^{\parallel}$	C°	$P_{y(\mathrm{eff})}$	$P^{\circ}_{y(\mathrm{meas})}$	Σ	$P_y^{\perp}$	$P_y^{\parallel}$	P_y°	T_y
0.493 ±0.014	0.218 ±0.011	0.866 ±0.009	0.791 ±0.012	−0.267 ±0.081	0.574 ±0.057	−0.48 ±0.29	0.30 ±0.52	−0.32 ±0.27	−0.45 ±0.35

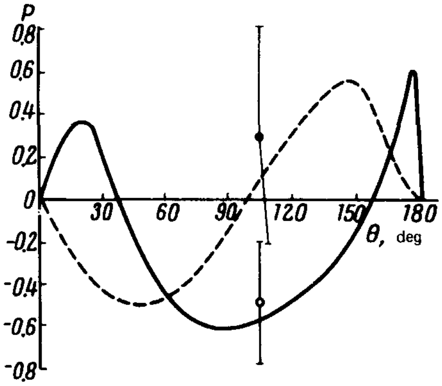

FIG. 1. Dashed lines—results of Walker's analysis,[7] ○—P_y, ●—P_y.

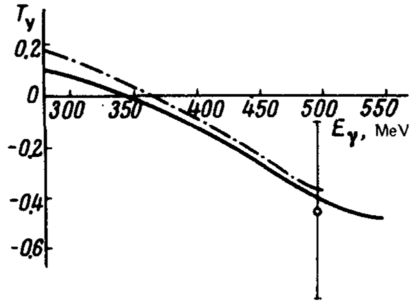

FIG. 2. Solid curve-results of Walker's analysis,[7] dash-dot line-results of Schwela's analysis.[8]

This measurement procedure has made it possible to separate the yields of the protons connected directly with coherent part of the photon spectrum. This yields the effective photon polarization $P_{\gamma(\mathrm{eff})}$ and the value of the proton polarization $P^{\perp(\parallel)}_{\mathrm{meas}}$ pertaining to the coherent spectrum, as well as the asymmetry parameter Σ.

The values of the proton polarization $P^{\perp(\parallel)}_{\gamma}$ for photons polarized perpendicular (parallel) to the plane of the reaction are obtained from the experimentally measured values $P^{\perp(\parallel)}_{\mathrm{meas}}$, $P_{\gamma(\mathrm{eff})}$, and Σ with the aid of the following relations:

$$P^{\perp}_{\mathrm{meas}} = \frac{(1+\Sigma)(1+P_{\gamma(\mathrm{eff})})P^{\perp}_{\gamma} + (1-\Sigma)(1-P_{\gamma(\mathrm{eff})})P^{\parallel}_{\gamma}}{(1+\Sigma)(1+P_{\gamma(\mathrm{eff})}) + (1-\Sigma)(1-P_{\gamma(\mathrm{eff})})};$$

$$P^{\parallel}_{\mathrm{meas}} = \frac{(1+\Sigma)(1-P_{\gamma(\mathrm{eff})})P^{\perp}_{y} + (1-\Sigma)(1+P_{\gamma(\mathrm{eff})})P^{\parallel}_{y}}{(1+\Sigma)(1-P_{\gamma(\mathrm{eff})}) + (1-\Sigma)(1+P_{\gamma(\mathrm{eff})})}. \quad (6)$$

From the values of $P^{\perp(\parallel)}_{y}$ and Eq. (3) we can obtain P^0_y and T_y.

To verify the experimental procedure, we carried out a control measurement of the polarization of the protons in the reaction $\gamma + p \to \pi^0 + p$ on unpolarized photons under the same kinematic conditions, with a bremsstrahlung spectrum with $E^{\max}_{\gamma} = 600$ MeV. The obtained polarization $P^0_{y(\mathrm{meas})} = -0.267 \pm 0.081$ is in good agreement with the value obtained with the aid of Eq. (2) and the previously measured data.[6]

$C^{\perp}$, $C^{\parallel}$, and C^0 are the relative yields of the protons for the corresponding directions of the photon polarization vector (the superscript 0 denotes the absence of the coherent effect). The errors given are statistical.

The results of the present paper are listed in the table. The relatively large errors in the measurements of $P^{\perp}_y$ and $P^{\parallel}_y$ are due to the small statistics and to the appreciable contribution of the incoherent background. At a small background, which is possible if thinner diamond crystals are used, these errors can be greatly decreased at the same statistics (1200 events of scattering by the polarization analyzer). Reasonable agreement is observed between the experimentally measured quantity, $P^0_{y(\mathrm{meas})}$, and the value P^0_y obtained from relation (2).

The results are shown in Figs. 1 and 2, where they are compared with the results of multipole analyses.[7,8]

The results are preliminary. Experiments are now under way aimed at obtaining information in a wide range of angles and energies, with much higher accuracy.

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[1]V.I. Nikiforov, Complete kinematic description of the $\gamma N \to \pi N$ reaction, Preprint KhFTI 72-41, Khar'kov, 1972.
[2]V.G. Gorbenko, Yu. V. Khebrovskiĭ, L. Ya. Kolesnikov, *et al.*, Yad. Fiz. 11, 1044 (1970) [Sov. J. Nuc. Phys. 11, 580 (1970)].
[3]N.G. Afanas'ev, V.A. Gol'dshteĭn, and S.V. Dementiĭ, Prib. Tekh. Éksp. No. 3, 30 (1968).
[4]A.I. Derebchinskiĭ, S.G. Tonapetyan, O.G. Konovalov, *et al.*, *ibid.* No. 6, 36 (1973).
[5]V.B. Ganenko, V.G. Gorbenko, Yu. V. Zhebrovskiĭ, *et al.*, ZhETF Pis. Red. 16, 459 (1972) [JETP Lett. 16, 325 (1972)].
[6]H. Wenzel and W. Pfeil, Photproduction Data Below 1.5 GeV, Bonn Univ. PIBI-168, February 1972.
[7]R.L. Walker, Phys. Rev. 182, 1729 (1970).
[8]D. Schwela, Preprint, Bonn Univ. PI12-86, 1970.