Asymmetry of the $\gamma n \to \pi^- p$ reaction cross section in the photon energy region 0.9–1.65 GeV

L. O. Abramyan, A. O. Agan'yants, F. V. Adamyan, G. G. Akopyan, G. V. Arustamyan, G. A. Vartapetyan, P. I. Galumyan, S. E. Piliposyan, and A. M. Sirunyan

(Submitted 15 October 1979)
Pis'ma Zh. Eksp. Teor. Fiz. **30**, No. 11, 735–738 (5 December 1979)

The asymmetry of the cross section for the $\gamma n \to \pi^- p$ reaction produced by a polarized photon beam in the energy region 0.9–1.65 GeV and π^--meson exit angles of 30–60° in cms was measured for the first time. The results of measurements are compared with the existing model predictions in the resonance region.

PACS numbers: 13.60.Kd

The experimental data from a neutron target are necessary to determine the isotopic structure of the π-photomeson production amplitude and to study the properties of baryon resonances in addition to investigation of the processes of production of π photomesons by protons. At present, systematic measurement have been made for the photon energy region above 0.8 GeV with respect to differential cross sections of the reaction of photoproduction of π mesons by neutrons, whereas the data for polarization are virtually nonexistent.

In this paper we present the results of measurements of the asymmetry of the reaction cross section for neutron-induced production of π^- photomesons on neutrons by polarized photons

$$\gamma + n \to \pi^- + p \qquad (1)$$

in the energy range $E_\gamma = 0.9$–1.65 GeV and π^--meson escape angles $\theta_\pi = 30$–$60°$ in cms. Similar data are nonexistent in the literature. The experiment was performed by using a beam of linearly polarized photons from a diamond single crystal at the electron energies of the Erevan 4.6-GeV synchrotron,[1] using a liquid-deuterium target. The π^- mesons were recorded by means of a magnetic spectrometer.[2] The recoil protons were recorded in coincidence with the π^- mesons by using a 12-module, time-of-flight spectrometer. The time-of-flight proton analysis was done in the flight path $L \approx 3.3$ m from the target to the spectrometer counters; moreover, the pulses from the π-meson arm were used as reference signals. The experiment was conducted "on-line" with the PDP-9 and M-222 computers.[3]

The kinematic reaction parameters were determined by modeling the experiment by using the Monte-Carlo method with allowance for the nuclear motion of nucleons in the deuterium target, which is defined by the Hewlton wave function.[4] The calculated resolution of the equipment with respect to photon energy and π^--meson escape angle in cms are shown in Table I.

To isolate the process under consideration against the background of the multiparticle reactions, we used the results of the time-of-flight analysis of the recoil protons. The contribution of the background processes was 8% on the average with respect to the effect. The results of the time-of-flight measurements and the angular distribution of the recoil protons were in agreement with the calculated data from the experimental simulation.

Table I

E_γ, GeV	θ_π^{cms}, deg	Σ	$d\sigma/d\Omega$ in cms (μb/sm)
0.9 ±0.028	40 ±1.0	0.38 ±0.065	4.1 ±0.46
1.05 ±0.030	30 ±0.8	0.43 ±0.065	4.1 ±0.45
1.05 ±0.032	40 ±1.0	0.28 ±0.045	3.9 ±0.42
1.05 ±0.037	50 ±1.5	0.10 ±0.040	3.5 ±0.38
1.05 ±0.042	60 ±2.0	−0.17 ±0.045	2.1 ±0.23
1.2 ±0.035	40 ±1.0	0.21 ±0.045	3.3 ±0.35
1.2 ±0.040	50 ±1.4	0.01 ±0.040	3.0 ±0.33
1.35 ±0.039	40 ±1.0	0.04 ±0.050	2.5 ±0.27
1.35 ±0.043	50 ±1.3	0.04 ±0.040	2.0 ±0.21
1.5 ±0.043	40 ±1.0	0.14 ±0.055	1.7 ±0.18
1.5 ±0.047	50 ±1.3	−0.17 ±0.060	1.1 ±0.12
1.65 ±0.047	40 ±0.9	−0.01 ±0.065	1.2 ±0.13

To allow for the dependence of asymmetry on the deuteron effects, we carried out control measurements of the π^+-photomeson production by protons from a deuterium target and also by hydrogen at $E_\gamma = 1.35$ GeV and $\theta_\pi = 40°$ in cms. The obtained value

$$R = \frac{\Sigma(\gamma + d \to \pi^+ + n + n_s)}{\Sigma(\gamma + p \to \pi^+ + n)} = 0{,}94 \pm 0{,}2$$

together with the data obtained for much lower energies[5] confirm that the information on the asymmetry of the reaction cross section R [Eq. (1)] obtained from the data for deuterium is correct.

The obtained results for the asymmetry of cross section

$$\Sigma \equiv \frac{\sigma_\perp - \sigma_\parallel}{\sigma_\perp + \sigma_\parallel} = \frac{C_\perp - C_\parallel}{C_\perp + C_\parallel} \frac{1}{P_\gamma}$$

are shown in Table I. $C_\perp$ and $C_\parallel$ are the reaction yields for photons that are polarized perpendicularly and parallel to the meson production plane, respectively. The errors contained in the asymmetry include the statistical error in determining the values of $C_\perp$ and $C_\parallel$, and $\sim 10\%$ error for the effective photon polarization P_γ.

Using the values of $C_\perp$ and $C_\parallel$ and the simulation data, we calculate the differential cross sections of the reaction (1):

$$\frac{d\sigma}{d\Omega} = \frac{1}{2}\left(\frac{d\sigma_\perp}{d\Omega} + \frac{d\sigma_\parallel}{d\Omega}\right).$$

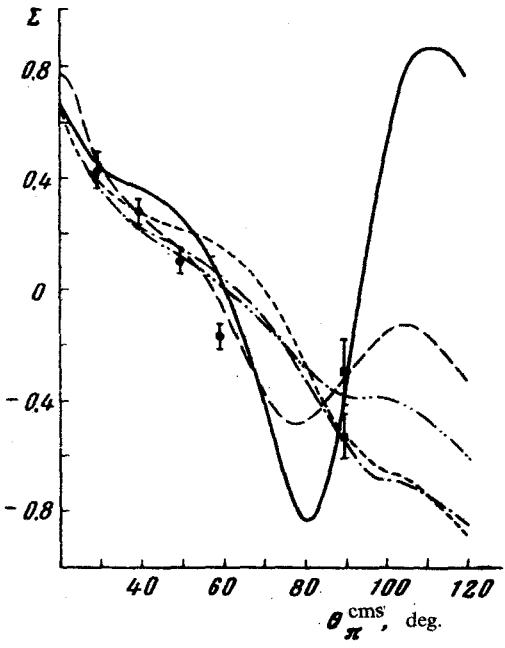

FIG. 1. Angular dependence of Σ in the reaction $\gamma n \to \pi^- p$ at $E_\gamma = 1.05$ GeV: ●, our experimental; □, Cambridge[8];—— Barbour *et al.*[11];— — —Metcalf and Walker[10]; (— — —, —·—·—, —··—), Moorhouse *et al.*[9]

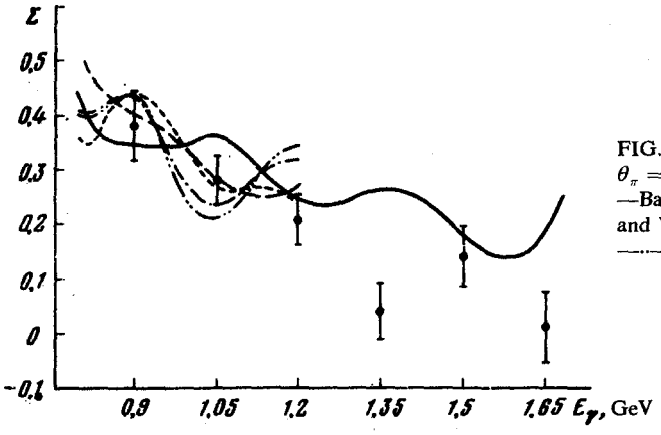

FIG. 2. Energy dependence of Σ at $\theta_\pi = 40°$ in cms: ●, our experiment,——Barbour *et al.*[11]; — — —Metcalf and Walker[10]; (— — —, ——, ——), Moorhouse *et al.*[9]

Our data for the differential cross sections, which allow for a possible systematic error of ~10%, [1)] are in agreement with those published earlier.[6,7]

Figure 1 shows the angular dependence of the asymmetry Σ in the reaction (1) at $E_\gamma = 1.05$ GeV, together with the Cambridge data[8] and the results of the analyses.[9-11] As seen in Fig. 1, all the theoretical curves satisfactorily describe the behavior of the experimental data points. A structure can be seen in the energy dependence of the asymmetry for the π-meson escape angles $\theta_\pi = 40$ and 50° in cms (Figs. 2 and 3); definitive conclusions concerning congruence of the experimental data with the results in Ref. 11 for $E_\gamma > 1.2$ GeV are difficult to draw in this case.

The obtained data indicate a need for conducting new analyses that would include our results for production of π^- photomesons by neutrons.

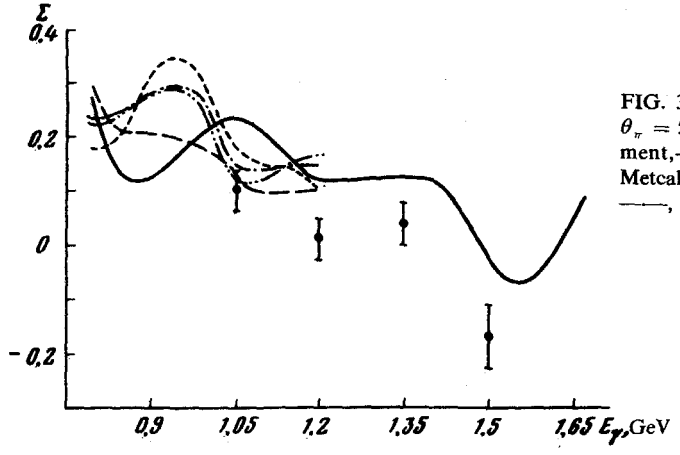

FIG. 3. Energy dependence of Σ at $\theta_\pi = 50°$ in cms: ●, this experiment,——Barbour *et al.*[11]——— Metcalf and Walker,[10] (——, ——, ——)—Moorhouse *et al.*[9]

[1])Statistical errors were 3–5%.

[1]L.O. Abramyan *et al.*, Phys. Lett. **48B**, 463 (1974).
[2]L.O. Abramyan *et al.*, *ibid.* **38B**, 544 (1972).
[3]A.T. Dadyan *et al.*, Nucl. Instr. and Meth. **129**, 193 (1975).
[4]D.H. White *et al.*, Phys. Rev. **120**, 614 (1960).
[5]V.B. Ganenko *et al.*, Yad. Fiz. **23**, 107 (1976) [Sov. J. Nucl. Phys. **23**, 56 (1976)].
[6]P. Joos, DESY-HERA, **70**, 1 (1970).
[7]P.E. Scheffler and P.L. Walden, Phys. Rev. **24**, 952 (1970).
[8]J. Alspector *et al.*, *ibid.* **28**, 1403 (1972).
[9]R.G. Moorhouse *et al.*, *ibid.* **D9**, 1 (1974).
[10]W.J. Metcalf and R.L. Walker, Nucl. Phys. **B76**, 253 (1974).
[11]J.M. Barbour *et al.*, *ibid.* **B141**, 253 (1978).