Asymmetry of the cross section of the reaction $\gamma n \to \pi^- p$ induced by linearly polarized photons with energies 0.8–1.75 GeV

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The asymmetry of the cross section Σ of the reaction $\gamma n \to \pi^- p$ induced by linearly polarized photons in the energy range 0.8–1.75 GeV and at c.m. angles of 45–90° is measured. The measurement results are consistent with the predictions of the existing phenomenological analyses.

Theoretical studies of new hadron models, which were motivated by the development of quantum chromodynamics,[1–4] have recently appeared in the literature. In these studies the role of gluon degrees of freedom in the nucleon-resonance spectroscopy has been discussed. In particular, Barnes and Close[4] used the bag model to estimate the constants of the radiative decay $N^* \to N\gamma$ for hermaphrodites, i.e., resonances having a structure of the type $qqq + g$. Using as an example the resonance $P_{11}(1.710)$, which is a possible low-lying candidate, it was shown that the radiative-decay constants and the isotopic properties of the radiative-decay amplitudes of these states may differ markedly from those predicted by "conventional" quark models.[5]

Blankleider and Walker[6] have developed a qualitatively different approach in determining the structure of the low-lying nucleon resonances. They showed by means of a potential approach that certain resonances such as $P_{11}(1.470)$, $D_{13}(1.520)$, $D_{15}(1.675)$, and $S_{31}(1.620)$ can be linked to the threshold effects associated with the creation of the system $[\pi + \Delta(1.232)]$ in the intermediate state.

A quantitative test of various theoretical predictions of the photoproduction processes $\gamma N \to \pi N$ requires that the radiation constants found from the partial-wave analyses of the experimental data be very accurate and reliable.

The current situation, however, is unsatisfactory on the whole, primarily for "weak" resonances, which have a relatively small radiation constant or an elastic modulus, and for neutral resonances with an isospin 1/2. This circumstance is attributable largely to a dearth of experimental data, particularly on the neutron-induced photoproduction of π mesons.

In this letter we present systematic data on the asymmetry of the cross section Σ for the reaction $\gamma n \to \pi^- p$ induced by linearly polarized photons at energies $E_\gamma = 0.85$–1.75 GeV and at angles[7] $\theta_\pi^{\text{c.m.}} = 45$–90°. The angular dependence of the asymmetry near the excitation energy of the $P_{11}(1.710)$ resonance is measured.

The experiment was carried out at the Erevan Physics Institute, using a linearly polarized photon beam with electron energies $E_e = 3.5$–4.5 GeV, a two-beam spectrometer, and a liquid deuterium target. The photon beam was monitored with a

Wilson γ detector and the parameters of the quasimonochromatic bremsstrahlung spectrum were controlled and measured with a nine-channel pair spectrometer.[8] The π^- mesons were detected by a magnetic spectrometer[8] with an angular acceptance of 3.5 msr and a momentum acceptance of 12%. The recoil protons were detected with a range spectrometer[7] with an angular acceptance of about 15 msr.

The energy and angular resolutions of the apparatus were (4–6)% and 1–2°, respectively, in the kinematic region studied. The background from the many-particle processes caused by the high-energy part of the bremsstrahlung spectrum was determined in the measurements with "disrupted" kinematics and with an amorphous emission spectrum. This background was estimated to be no greater than 5%. The asymmetry of the cross section was determined from the yields of the reaction, $N_\perp$ and $N_\parallel$, for photons polarized at right angles to the reaction plane and parallel to it:

$$\Sigma = \frac{1}{P_\gamma} \frac{N_\perp - N_\parallel}{N_\perp + N_\parallel},$$

where P_γ is the effective photon polarization in the range of 55 to 75%.

The results of determining the asymmetry of the cross section Σ for the reaction $\gamma n \to \pi^- p$ are shown in Fig. 1 as an energy dependence for the angles $\theta_\pi^{*\,\text{c.m.}} = 45$, 60, 75, and 90° and in Fig. 2 as an angular dependence at an energy $E_\gamma = 1.05$ GeV. The curves in Figs. 1 and 2 are the predictions of the phenomenological analyses of Refs.

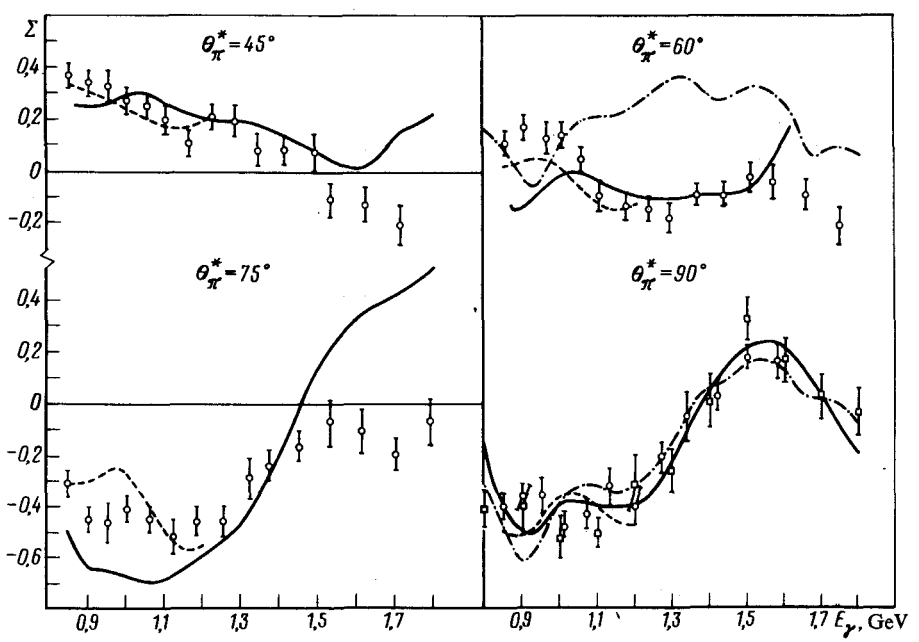

FIG. 1. Energy dependence of the asymmetry of the cross section Σ for the angles $\theta_\pi^{*\,\text{c.m.}} = 45$, 60, 75, and 90°. ○—The present study; □—the data of Ref. 12. The curves represent the results of phenomenological analyses. (···)—Ref. 9; (–)—Ref. 10; (- - - -)—Ref. 11.

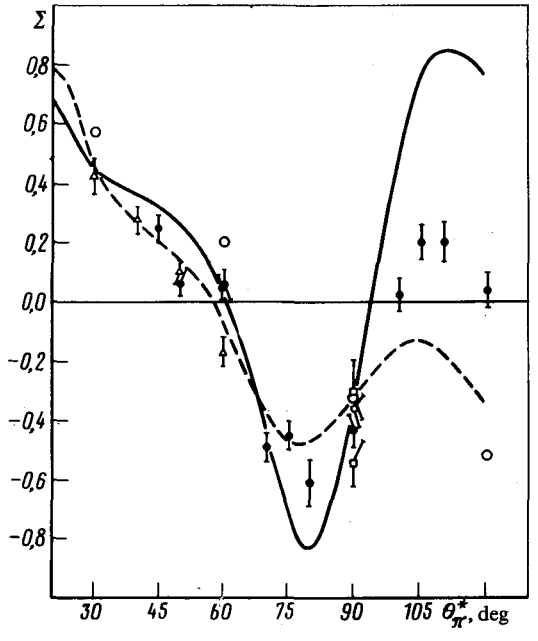

FIG. 2. Angular dependence of the asymmetry of the cross section Σ at $E_\gamma = 1.05$ GeV. ●—Our results; □—the results of Ref. 12; △—the results of Ref. 13; ○—the results of phenomenological analysis of Ref. 11. Curves—The results of phenomenological analysis: (···)—Ref. 9; (–)—Ref. 10.

9–11. As can be seen in Fig. 1, the predictions of the analyses are largely unsatisfactory, particularly in the region of the fourth πN resonance, with the exception of $\theta_\pi^{\text{c.m.}} = 90°$, where all analyses take into account the results of Ref. 12. This conclusion also pertains to the energy region near the excitation of the $P_{11}(1.710)$ resonance (Fig. 2), where the difference between the experimental data and the predictions of the phenomenological analyses is particularly large at angles $\theta_\pi^{\text{c.m.}} > 90°$.

The data on the asymmetry of the cross section Σ of the reaction $\gamma n \to \pi^- p$ thus show that predictions of the phenomenological analyses of the reaction $\gamma N \to \pi N$ are incorrect. These incorrect predictions qualitatively change the information obtained from these analyses on the constants of the radiative decay of nucleon resonances.

Since the results of this study comprise a large part of the polarization data on the reaction $\gamma n \to \pi^- p$ at $E_\gamma > 0.8$ GeV, the incorporation of these data and also the data of the most recent studies of the processes $\gamma N \to \pi N$ will greatly improve the accuracy of the predictions in the region of resonances with a mass $M_R > 1.6$ GeV.

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