Asymmetry of the cross section of the photoproduction of η mesons by polarized photons in the resonant energy region

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We measured the asymmetry of the cross section of the reaction $\gamma+p\to\eta^0+P$ at linearly polarized photon energies 1.39, 1.53, and 1.78 GeV and at an η^0-meson emission angle 46° in the c.m.s. The results are compared with the calculated ones assuming contributions from different resonances.

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The photoproduction of η^0 mesons on nucleons has been much less studied than pion photoproduction reaction, especially in the resonant energy region 1–2 GeV, for which individual measurements of the differential cross sections have by now been performed.[1]

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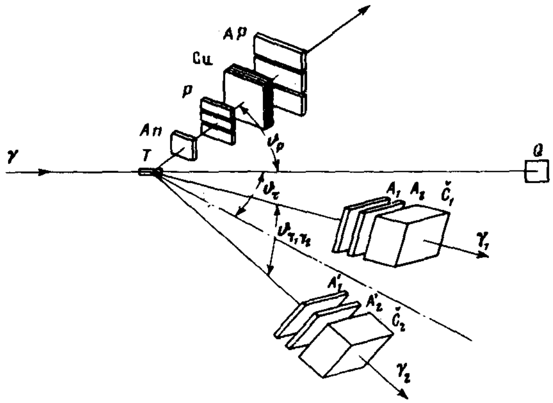

FIG. 1. Experimental setup: $\check{C}_1, \check{C}_2$—total-absorption Cerenkov counters; A_1, A_2, A_1', A_2'—scintillation counters for the identification of the γ photons; An, P, AP—range telescope; Cu—copper absorber, Q—quantameter.

To determine the contributions of the different resonances to the η^0-meson photoproduction process, polarization-experiment data are necessary.

We present here, for the first time, experimental results on the asymmetry of the cross section of the reaction

$$\gamma + P \rightarrow \eta^\circ + P \tag{1}$$

with polarized photons in the resonant energy region.[2]

The only measurements on the asymmetry of the photoproduction of η^0 mesons were made at energies 2.5 and 3.0 GeV and at $|t| = 0.21$–1.16 $(\mathrm{GeV}/c)^2$.[3]

The present experiment was performed on a beam of linearly polarized photons from a diamond single crystal at the energy 4.68 GeV of the electrons from the Erevan synchrotron.[4]

The asymmetry of the cross section of reaction (1) was measured at photon energies 1.39, 1.53, and 1.78 GeV and at an angle $\theta_{\eta_0}^{\mathrm{cms}} = 46°$. The η^0 mesons were registered by their decay into two γ photons (Fig. 1) with the aid of two total-absorption Cerenkov counters (2C).[5]

The recoil protons were registered with a range telescope that separated protons having a kinetic energy lower than a definite value $(T_p)_{\mathrm{max}}$. The energy

TABLE I.

E_γ, GeV	$\theta_{\eta^\circ}^{\mathrm{cms}}$	$-t$, $(\mathrm{GeV}/c)^2$	Σ	$d\sigma/d\Omega$ μb/sr
1.39 ± 0.05	46 ± 4°	0.25 ± 0.04	0.92 ± 0.16	0.335 ± 0.066
1.53 ± 0.055	46 ± 4°	0.29 ± 0.05	0.65 ± 0.11	0.331 ± 0.064
1.78 ± 0.06	46 ± 3°	0.35 ± 0.04	0.61 ± 0.19	0.206 ± 0.042

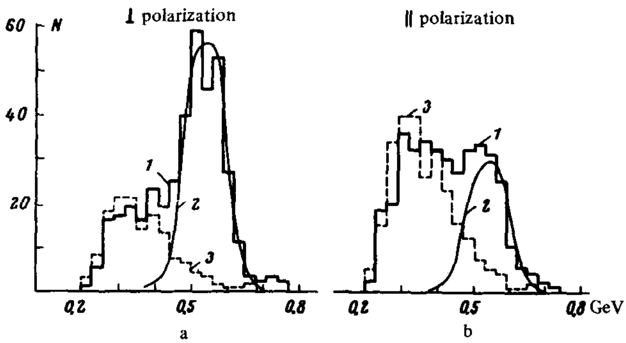

FIG. 2. Mass spectrum of the system of two γ photons at $E_\gamma = 1.53$ GeV: 1—experimental curve; 2—curve calculated by the Monte Carlo method for the reaction (1); 3—curve obtained with "disturbed kinematics".

resolution of the photons, according to Monte Carlo calculations, was on the average $\sigma_{E_\gamma} = 55$ MeV (Table I).

The measurements were made in conjunction with a computer system that received and analyzed the signals from the two Cerenkov counters, and with a system that measured the time interval of registration between the range telescope and the $2\check{C}$ system. Next, using the kinematic and the calibration data, a data-reduction program calculated the effective mass of the system of the two photons and plotted the mass spectrum with allowance for the histogram of the time intervals and for the presence of random coincidences between the two $\check{C}$ counters and the range telescope (Fig. 2).

To determine the physical background in the effective-mass spectrum, measurements were made under "disturbed kinematics" (the angle between the two $\check{C}$ counters was decreased)[5] (Fig. 2).

The obtained values of the asymmetry

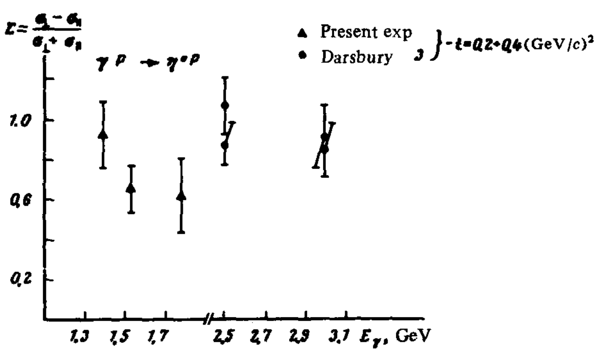

FIG. 3. Energy dependence of the asymmetry of the cross section of the reaction $\gamma + P \rightarrow \eta^0 + P$ at $|t| = 0.2$—0.4 $(\text{GeV}/c)^2$.

$$\Sigma = \frac{\sigma_{\perp} - \sigma_{\parallel}}{\sigma_{\perp} + \sigma_{\parallel}} = \frac{1}{P_{\gamma}} \frac{C_{\perp} - C_{\parallel}}{C_{\perp} + C_{\parallel}} \quad (2)$$

are listed in Table I, where $C_{\perp}$ ($C_{\parallel}$) are the η^0-meson yields in the investigated reactions for perpendicular (parallel) polarization of the photons, respectively. The asymmetry-measurement errors include both statistical errors as well as the ~10% error in the effective polarization of the photons $\tilde{P}_{\gamma}$.

Using the values of the experimental-setup efficiency, calculated by the Monte Carlo method, the yields $C_{\perp}$ and $C_{\parallel}$ with allowance for the contribution from the empty target, the background processes, the conversion of the γ photons from the decay of the η^0 mesons, the inelastic interactions of the recoil protons, as well as the contribution from the protons from reaction (1), satisfying the condition $T_p > (T_p)_{max}$, we calculated the differential cross sections for the unpolarized protons (Table I).[4] In the estimate of the error in the differential cross sections we took into account, besides the statistical errors, also the systematic errors (the combined rms systematic error was 16%). The obtained cross sections agree satisfactorily, within the limits of errors, with the published data.[1]

From the experimental data, and also from a phenomenological analyses of[6] and,[7] it follows that the dominant resonances in the investigated region are $S_{11}(1535)$, $S_{11}(1700)$, and $P_{11}(1750)$. In this case, the asymmetry of the reaction (1) should be equal to zero. Our results indicate that the photoproduction of η^0 mesons at an energy close to 1.4 GeV cannot be attributed solely to contributions of the resonances $S_{11}(1700)$ and $P_{11}(1750)$, and that it is necessary to take into account the contributions of resonances with spin $J > 1/2$.

At a photon energy $E_{\gamma} = 1.39$ GeV, excitation of the resonance $P_{13}(1860)$ is expected.[6,7] Donnachie proposes[6] that excitation of the state P_{13} is realized mainly by the magnetic dipole transition M_{1+}, and that $M_{1+} \approx M_{1-}$, where M_{1-} corresponds to the excitation of the $P_{11}(1750)$ resonance. In the case of the resonances $P_{11}(1750)$ and $P_{13}(1860)$, with allowance for $M_{1+} \approx M_{1-}$, one expects a value $\Sigma = 1$. If we assume in addition a contribution of $S_{11}(1700)$ with an electric transition E_{0+},[6] then we obtain, under the condition $E_{0+}/M_{1+} = 0.5$, the value $\Sigma = 0.9$, which agrees with our result (Fig. 3). For a final determination of the different resonances in the η^0-photoproduction process in the energy region investigated by us it is necessary to carry out a complete phenomenological analysis. At $E_{\gamma} = 1.78$ GeV, one expects a description of the process (1) with the aid of the model of complex angular momenta.[8] An experimental study of the angular dependence of the asymmetry would make it possible to verify this assumption.

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