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MEASUREMENTS OF CROSS SECTION ASYMMETRY BY POLARIZED PHOTONS AND MODELS OF η° -MESON PHOTOPRODUCTION IN THE ENERGY RANGE E_{γ} =1-2 GEV

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Г.А.ВАРТАПЕТЯН, С.Е.ПИЛИПОСЯН

ИЗМЕРЕНИЯ АСИММЕТРИИ СЕЧЕНИЯ ПОЛЯРИЗОВАННЫМИ ФОТОНАМИ И МОДЕЛИ ФОТООБРАЗОВАНИЯ η°- МЕЗОНОВ В ОБЛАСТИ ЭНЕРГИИ E_{γ} =I-2 ГЭВ

Измерена асимметрия сечения Σ реакции $\gamma + p \to \eta^{\circ} + p$ при энергиях линейно-поляризованных фотонов I.39, I.53, I.8 Гэв и угле вылета η° -мезонов 46°, 57°, 73° в СЦИ. Полученные результаты для энергий E_{γ} = I.39, I.53 Гэв не согласуются с имеющимися предсказаниями изобарной модели. Угловая зависимость асимметрии при E_{γ} =I.8 Гэв не согласуется с предсказаниями модели комплексных моментов.

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MEASUREMENTS OF CROSS SECTION ASYMMETRY BY POLARIZED PHOTONS AND MODELS OF η^{o} -MESON PHOTOPRODUCTION IN THE ENERGY RANGE $E_{\gamma} = 1 - 2$ GEV

The cross section asymmetry Σ for reaction $\gamma + p \rightarrow \eta^{o} + p$ at the energies of linearly polarized photons 1.39, 1.53, 1.8 GeV and at the c.m.s. η^{o} -meson emission angles 46°, 57°, 73° is measured. The obtained results for E_{γ} = 1.39, 1.53 GeV disagree with the available isobar model predictions. Angular dependence of the asymmetry for E_{γ} = 1.8 GeV disagrees with predictions of the complex moment model.

Yerevan Physics Institute

Yerevan 1980

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MEASUREMENTS OF CROSS SECTION ASYMMETRY BY POLARIZED PHOTONS AND MODELS OF η° -MESON PHOTOPRODUCTION IN THE ENERGY RANGE E_{γ} =1-2 GEV

Yerevan 1980

Introduction

The η° -meson photoproduction on nucleons is so far studied much more worse than the π° -meson photoproduction, particularly in the resonance region from 1 to 2 GeV, where at present we dispose only of separate measurements of differential cross section of η° -meson photoproduction on protons (practically only for η° -meson forward production in the c.m.s.) [1-3]. There are no data available on η° -meson photo production on neutrons. Ref. 4 is the only work where the data on measurement of $R(\eta n/\eta p)$ on the deuterium nucleus for E_{γ} = 0.85 GeV (in the region of the S_{11} (1550) resonance) are given.

To determine both contributions of different resonances to the η° -meson photoproduction process [5,6] and the value of E_{γ} at which the complex moment model is already applicable to the η°-photoproduction [7], the data on polarization experiments are necessary.

We report here experimental results on the cross-section asymmetry of the reaction

$$\gamma + p \to \eta^{\circ} + p \tag{1}$$

with polarized photons in the resonance energy range [8,9] (Table 1). The only measurements of η°- photoproduction asymmetry were taken at 2.5, 3.0 GeV and $/ t / = 0.21 - 1.16\ (GeV/c)^2$ (Ref.10).

The recoil proton polarization in reaction (1) at $E_{\gamma} = 0.8 - 1.1$ GeV was measured by two groups of authors only [11,12]. The data of Ref. 12 are used in Ref. 6 as restrictions at fit of experimental data on process (1) within the limits of the isobar model.

To clearize the contribution of different resonances to the η° -meson photoproduction process the comparison of the obtained data with predictions of the isobar model would be useful. But unfortunately, in Ref. 6 , where a sufficiently good fit ($\chi^2/N = 0.98-1.3$) was achieved to the data on differential cross section of the process, the predictions for the observable polarization values Σ, P, T were not given. On this account a program was created by means of which the predictions σ_{tot}, $d\sigma/d\Omega^*, \Sigma, P, T$ in the whole angular and energy ($E_{\gamma} = 0.710-2.200$ GeV) range were obtained using the values of fitting parameters given in Ref. 6 .

On the other hand, in order to check the Donnachie assumptions [7] about applicability of the complex moment model to the η° -photoproduction process, beginning from $E_{\gamma} = 1.8$ GeV, the data obtained by us were compared with predictions within the limits of complex moment model. The behaviour of the cross-section asymmetry Σ for reaction (1) in terms of a square of four-dimensional momentum t obtained in Refs. 13-15 is practically unchanged with variation of energy E_γ. This fact makes it possible to compare our obtained data at $E_\gamma = 1.8$ GeV with theoretical predictions for $E_\gamma = 4$ GeV.

Experimental Layout and Measurement

This experiment was performed with a linearly polarized photon beam from a diamond single crystal using 4.7 GeV electrons of Yerevan synchrotron. The measurements were taken using a liquid-hydrogen target spaced at 34 m distance from the diamond. The target was a 5 x 10 cm^2 cylinder with a 10 x 10 mm^2 γ-quantum collimated beam passing through its axis.

η^0-mesons were identified by their two-gamma decay products with two total absorption Cerenkov counters ($2\check{C}$) [16]. Before each counter a lead collimator of 20 cm thickness and 10 x 15 cm^2 apertures was placed. The distance from the target centre to the collimator farther end was equal to 160 cm (Fig.1).

The recoil protons were detected by a range telescope which separated the protons with kinetic energy less than $(Tp)_{max}$. The proton shoulder consisted of the aperture counter brought into a coincidence with the proton hodoscope of three scintillation counters. Next came a copper absorber with a certain thickness necessary to stop the recoil protons having kinetic energy $Tp < (Tp)_{max}$. Next to the copper absorber were placed three scintillation counters brought into anticoincidence with the proton hodoscope to eliminate the $Tp > (Tp)_{max}$ protons and the background of high-energy charged particles. This separation of protons from reaction (1) results in reduction of the energy range captured by the detection system which provided a possibly high mean polarization of γ -quanta for reaction (1) [17]. Besides, in this case the contribution of background processes was suppressed.

In positions 4 and 5 (Table 1), due to increase of proton kinetic energy, the cross section of nuclear interactions of protons in the copper absorber material increased. For this reason in these positions directly after the proton hodoscope there were placed three threshold organic-glass Cerenkov counters that permitted to reduce the physical background from high-energy charged particles (mainly from $e^{\pm}$ and $\pi^{\pm}$) by 20 %. To eliminate the physical background from low-energy charged particles a 2 cm copper absorber was placed in front of the aperture counter.

During the measurements the data were fed on-line into the system computers (PDP-8/e, PDP-9) [18]. The accumulated information was transferred from the PDP-8/e computer to the "M-222" one for further processing [19].

The processing program analyzed the signals from two Cerenkov counters and from the system measuring the time interval (the time-amplitude transformer $\Delta T \rightarrow \Delta V$) between the proton telescope and $2\check{C}$.

Using a sufficiently simple detecting device (Fig.1) the physical background became large and the problem to separate the effect from the background arose at the data processing [20].

Measurements of the physical background were taken by two techniques:

1. By reducing the angle between the axes of two Č-counters of the γ -spectrometer (disturbance of a two-particle kinematics assuming that space distribution of background -quanta has the azimuthal symmetry) [3, 16].

2. By means of extreme counters of the proton hodoscope (Fig.1) simultaneously with statistics (assuming the spare distribution of background charged particles having the azimuthal symmetry) [20].

The contribution of the material of the liquid-hydrogen target vessel was also measured, whose value in the calculation region of true events of η° -mesons from reaction (1) obtained by Monte-Carlo method [17] made $\sim$ 2% from the liquid-hydrogen target contribution.[21]

The experimental results were processed by the effective mass method of two decayed γ -quanta as well as by two-dimensional distributions over E_{γ_1} and E_{γ_2} [20].

The Obtained Results and Phenomenological Analyses

The cross section asymmetry Σ was determined by the expression

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

where $N_{\perp}$ and $N_{\parallel}$ are normalized numbers of events for prinary photons polarized normal and parallel to the reaction plane, respectively, $P_\perp$ and $P_\parallel$ are the values of polarization in the both cases.

The asymmetry error (Table 1) includes both the statistical ones of the values of $P_\perp$ and $P_\parallel$ as well as the errors ($\sim$ 10%) of the values of effective photon polarization ($P_\perp$ and $P_\parallel$).

Using the values of the experimental layout efficiency calculated by Monte-Carlo method, the yields of $N_\perp$ and $N_\parallel$ with account of contributions from the empty target, background processes *), conversion of γ -quanta due to η°-meson decay, inelastic interactions of recoil protons, differential cross sections for non-polarized photons (Table 1) were calculated. To estimate errors of differential cross sections the systematical errors were taken into account (the total mean-square systematical error was $\sim$ 16%) along with statistical ones.

Our values obtained for differential cross section of the

---

*) As far as the contribution of multiple background processes was measured in the experiment, then, by Monte-Carlo method only the contribution of the two-particle background reaction was calculated $\gamma + p \rightarrow \eta^\circ + \Delta^+(1232)$

with the following decay of Δ^+ resonence $\Delta^+(1232) \rightarrow \begin{cases} \pi^\circ + p \\ \pi^+ + n \end{cases}$

The cross section being equal to the process under investigation, the contribution of this process was 2-4% depending on kinematic position.

process under question agree with the References data [1-3] and with the isobar model predictions [6] within the error limits (Fig.2). We calculated also the energy dependence of a total cross section σ_{tot} of η° -photoproduction on the basis of Ref. 6 results. A satisfactory description of experimental data obtained as a result of ABBHHM collaboration [22] was observed (Fig.2).

In Fig.3 are given the predictions of the isobar model for energy dependence Σ at $\vartheta^{cm}_{\eta^{\circ}} = 45^{\circ}$ (the curves are denoted as in Ref. 6). In order to simplify the picture we do not give predictions of the type A solutions [6], since they describe the data on differential cross section ($\chi^2/N = 1.65$) worse and add nothing new for the cross section asymmetry Σ . It is obvious, that none of the solutions agree with the measured energy dependence of asymmetry Σ .

Predictions of the isobar model for angular dependence of asymmetry Σ at E_{γ} =1.4, 1.525, 1.8 GeV are given in Figs. 4,5,6, respectively.

For the energies E_{γ} = 1.4 and 1.525 GeV at η° -meson photoproduction forward in the c.m.s. either zero or negative asymmetry Σ is predicted. The experiment gives the value $\Sigma \approx +1$, i.e. in this energy range one can observe great disagreement of the theory with the experiment. Nevertheless, at E_{γ} = 1.8 GeV satisfactory agreement of the experimentally measured values of Σ with predictions of C2 -type solutions is observed.

It is of interest that the experimental dependence of Σ

on $\cos \vartheta_{\eta^*}^{cm}$ is almost unaltered in the energy range E_γ = 1.8-2.5 GeV (Fig.6).

It should be also noted that the angular dependence of the recoil proton polarization in reaction (1) at E_γ =900 MeV [11] is satisfactorily described by solutions B1, C2, B2 [6] (Fig.7).

Comparison of the obtained values of asymmetry Σ with theoretical predictions (Fig.8) from the complex moment model [13-15] shows that none of them describe the Σ behaviour at E_γ = 1.8 GeV in terms of $-t$, although not bad agreement of the values of Σ at E_γ = 3.0 GeV [10] with results of Ref. 15 is observed.

Our results do not confirm the Donnachie suggestion [7] about applicability of the complex moment model for η^* -photoproduction at so low energies as E_γ = 1.8 GeV, where exhibits a tendency to negative values as $-t$ increases.

This is apparently due to contributions of resonances F_{17}(1990), D_{13}(2040), G_{17}(2190), G_{19}(2200), H_{19}(2220). One may also assume that at E_γ =2.5 GeV mainly these S-channel resonances contribute to η^* -meson photoproduction process (Fig.6).

Conclusion

Although the authors of Ref. 6 , using the majority of well-known resonances with isospin I=1/2 and being care to avoid a multiple minima problem in the data fitting, achieved good fitting of data on differential cross section of process (1) and satisfactory agreement with the data on recoil proton polarization (Fig.7), yet their predictions are in strong disagreement with the measured values of asymmetry in the energy range E_γ = 1.35-1.55 GeV.

It is difficult to indicate unambiguously the cause of this disagreement, however, to our mind, it is possible to indicate the following moments:

1. In Ref. 6 they used not all known resonances in the energy range under question E_γ = 0.71-2.2 GeV, such as $D_{15}(1670)$, $D_{13}(1700)$, $F_{15}(2000)$, $D_{15}(2100)$, $G_{19}(2200)$, $H_{19}(2220)$ [23].
2. In the used model the authors [6], contrary to those of Ref. 5, introduced the resonance state phase and used it as a fitting parameter. Thus, from all the used resonances of this model only $S_{11}(1535)$ is a pure one, and for the rest 10 resonances the real part of the amplitude is not cancelled at $W=W_r$ (W_r is the resonance mass). Perhaps, this circumstance, though promoting a better fit of data on differential cross section, yet gives rise to the increase of the number of free parameters and, hence, leads to a multiple minima problem.
3. In solutions C1 the authors [6] used the so-called "stray" resonances P_{11} and P_{13} introduced by Donnachie [24] in order to explain the near-threshold anomaly in η^0-photoproduction. Although in solution C1 they obtained χ^2/N =0.98; the authors themselves consider this result speculative, since there are too many free parameters.

Introduction to the process of fit of resonances given in Point 1 would also result in increasing the number of free parameters.

Thus, in the given situation, when as proved by us[8], the high resonances with $J > 1/2$ contribute in reaction (1) any new measurements of the process under investigation would be extremely useful in order to clearize the role of different resonances in η°-photoproduction, especially the data in the energy range E_{γ} =0.71-2.5 GeV.

Table 1

Kinematical position	1	2	3	4	5
E_γ, GeV	I.39 ± 0.05	I.53 ± 0.055	I.78 ± 0.06	I.8 ± 0.08	I.8 ± 0.085
$\vartheta_{\eta^\circ}^{cm}$, degrees	46 ± 4	46 ± 4	46 ± 3	57 ± 4.3	73 ± 3.5
$-t$, $(GeV/c)^2$	0.25 ± 0.04	0.29 ± 0.05	0.35 ± 0.04	0.54 ± 0.09	0.8I ± 0.I0
T_p^L, MeV	I35 ± 24	I55 ± 25	I80 ± 27	285 ± 53	430 ± 64
ϑ_p^L, degrees	49 ± 3.5	5I ± 3.4	53 ± 3.8	48 ± 3.6	42 ± 3.4
Σ,	0.92 ± 0.I6	0.65±0.II	0.6I±0.I9	0.35±0.2	-0.08±0.I5
$\frac{d\sigma}{d\Omega^*}$, $\frac{barn}{sterad}$ *	0.I70±0.034	0.I67±0.033	0.I05±0.022	0.096±0.029	0.077±0.023

* In the given values of $d\sigma/d\Omega^*$ of the earlier published work [8] factor 2, which is a result of equivalence of two detected γ -quanta from η° -meson decay, was not taken into account.

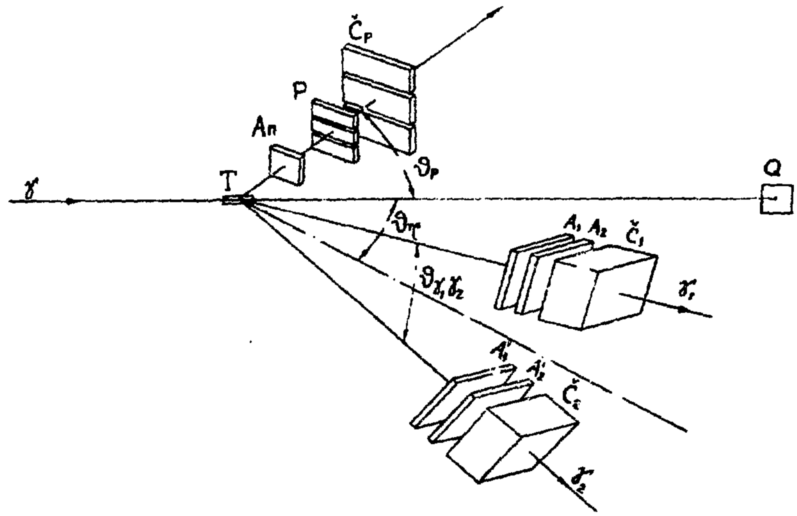
Č_P
P
An
T
γ
ϑ_P
Q
ϑ_π
A₁ A₂ Č₁
γ₁
ϑ_γ₁γ₂
A′₁ A′₂
Č₂
γ₂

Рис. I

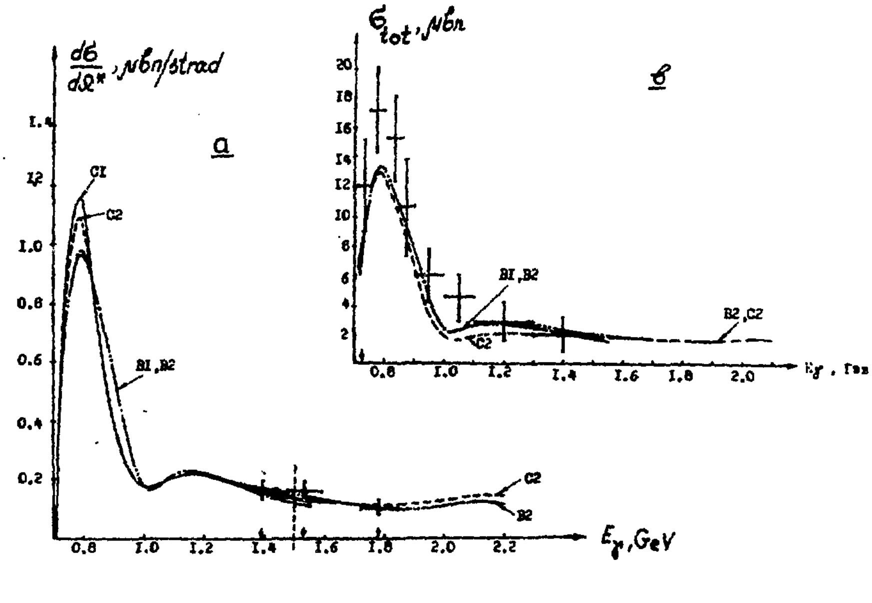
dσ/dΩ*, μbn/strad
a
C1
C2
B1,B2
B2
E_γ, GeV
σ_tot, μbn
в
B1,B2
B2,C2
C2

Рис. 2

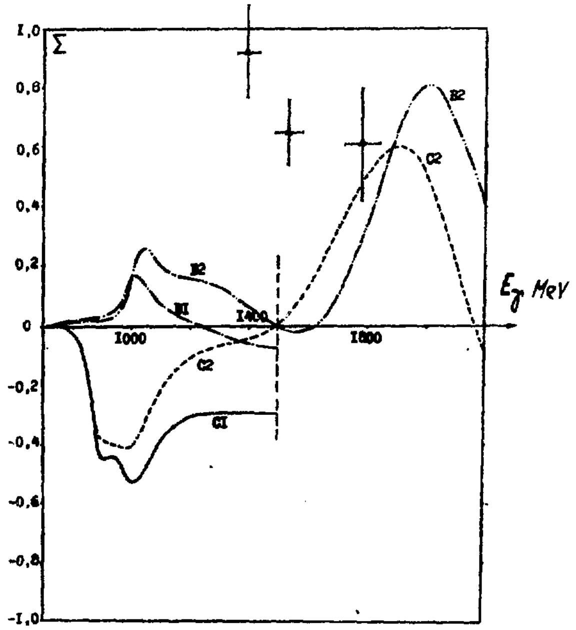
Σ
I,0
0,8
0,6
0,4
0,2
0
-0,2
-0,4
-0,6
-0,8
-I,0
I000
I400
I800
E_γ MeV
E2
EI
C2
CI

Рис. 3

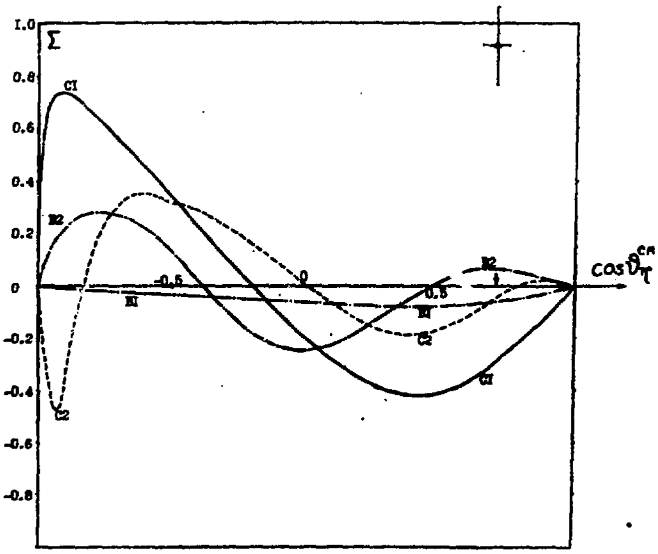
Σ
I.0
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
$\cos\vartheta_\eta^{cm}$
CI
E2
EI
C2

Рис. 4

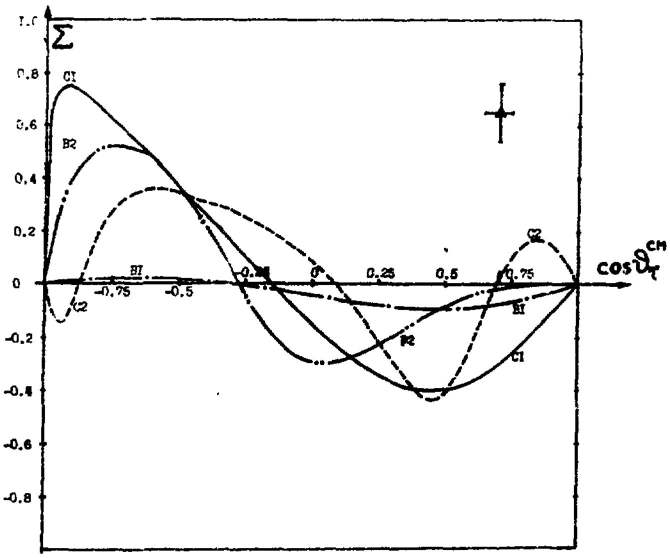

Рис. 5

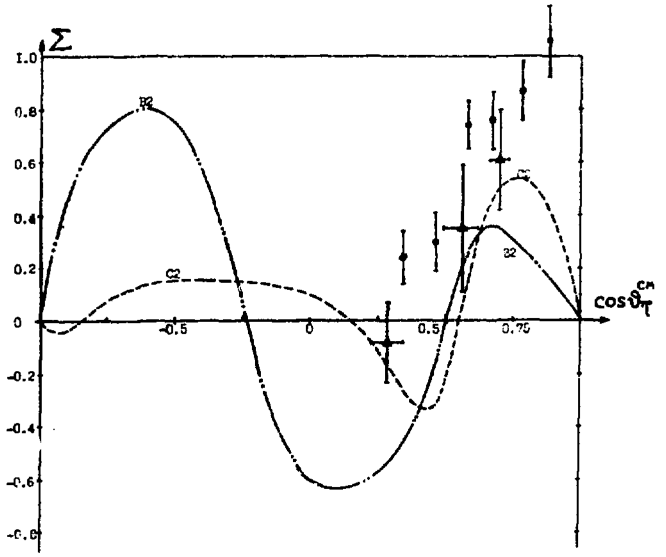

Рис. 6

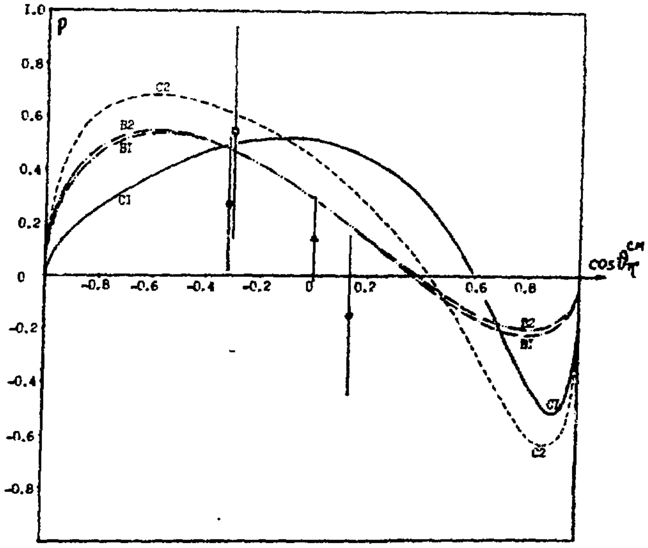

Рис. 7

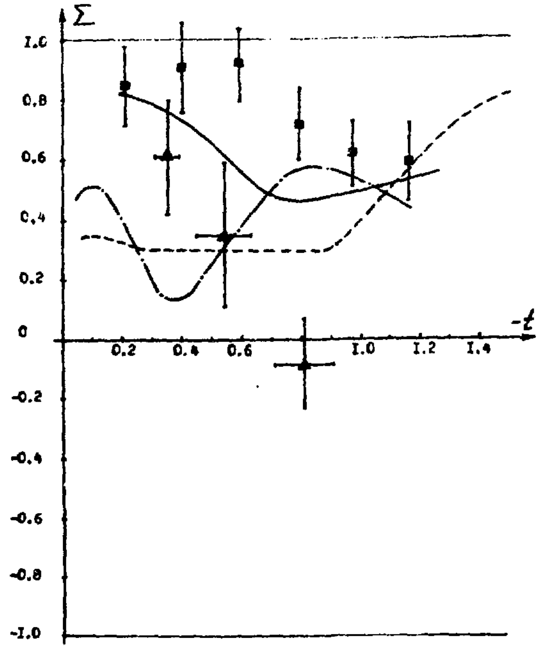

Рис. 8

FIGURE CAPTIONS

Fig.1 Experimental layout: $\check{C}_1$, $\check{C}_2$ - total absorption Cerenkov counters; A_1, A_2, A_1', A_2' - scintillation counters for identification of γ -quanta; An, P, AP -range telescope; Cu - copper absorber; Q - quantometer.

Fig 2 Predictions of isobar model [6] for reaction

$$\gamma + p \rightarrow \eta^\circ + p$$

a Energy dependence of differential cross section at $\vartheta_{\eta^\circ}^{cm} = 45^\circ$. Experimental points - results of this work.

b Energy dependence of total cross section. Experimental points - results of Ref. 22 .

Fig.3 Predictions of isobar model [6] for energy dependence of cross-section asymmetry Σ of reaction $\gamma + p \rightarrow \eta^\circ + p$ at $\vartheta_{\eta^\circ}^{cm} = 45^\circ$. Experimental points: ▲ - results of this work.

Fig.4 Predictions of isobar model [6] for angular dependence of cross-section asymmetry Σ of reaction $\gamma + p \rightarrow \eta^\circ + p$ at $E_\gamma = 1.4$ GeV. Experimental point - result of this work.

Fig.5 Predictions of isobar model [6] for angular dependence of cross-section asymmetry Σ of reaction $\gamma + p \rightarrow \eta^\circ + p$ at $E_\gamma = 1.525$ GeV. Experimental point - result of this work.

Fig.6 Predictions of isobar model [6] for angular dependence of cross-section asymmetry Σ of reaction $\gamma + p \rightarrow \eta^{\circ} + p$ at E_{γ} =1.8 GeV. Experimental points: ▲ - results of this work at E_{γ} =1.8 GeV; ● - results of Ref. 10 at E_{γ} ≈ 2.5 GeV.

Fig.7 Predictions of isobar model [6] for angular dependence of recoil proton polarization from reaction $\gamma + p \rightarrow \eta^{\circ} + p$ at E_{γ} =0.9 GeV. Experimental points: ● , ☐ -results of Ref. 11 , ▲ -result of Ref. 12 .

Fig.8 Cross-section asymmetry Σ of reaction $\gamma + p \rightarrow \eta^{\circ} + p$ as a function of $-t$. Theoretical curves are taken from the works: dotted line - Ref. 13 , dashed-dotted line - Ref. 14 , solid line - Ref. 15 . Experimental points: ▲ -results of this work at E_{γ} =1.8 GeV, ■ - results of Ref. 10 at E_{γ} =3.0 GeV.

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ИЗМЕРЕНИЯ АСИММЕТРИИ СЕЧЕНИЯ ПОЛЯРИЗОВАННЫМИ ФОТОНАМИ И МОДЕЛИ ФОТООБРАЗОВАНИЯ η°-МЕЗОНОВ В ОБЛАСТИ ЭНЕРГИИ $E_{\gamma} = 1-2$ ГЭВ

(на английском языке)

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