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EXPERIMENTAL STUDY OF COMPTON SCATTERING ON PROTON BY POLARIZED PHOTONS

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Նախատիպ ԵրՖԻ-1372(2)-92

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Կոմպտոնյան ցրումը պրոտոններով ուսումնասիրումը բևեռացված ֆոտոններով

Գծային բևեռացված ֆոտոնների Կոմպտոնյան ցրումը պրոտոններով ուսումնասիրվել է էներգիայի՝ 0.6 – 0.9 ԳէՎ և անկյունների՝ 90 – 120° տիրույթներում: Ստացված արդյունքները համեմատվում են համապատասխան տեսական հաշվարկների հետ:

Երևանի Ֆիզիկայի Ինստիտուտ

Երևան 1992

The Compton effect on a proton is a fundamental process for studying the γN interaction. This process was studied in detail in 1970-s [1-3] in view of the hadronic structure of high energy photons (Vector Dominance Model VDM) and also connected with the close similarity of the reaction to the elastic hadron-nucleon scattering (diffraction behavior, phenomenon of "dip" in the differential cross-section, etc...). According to Harari's predictions [4], this dip in the Compton effect cross-section as well as in the elastic scattering processes $\Pi^{\pm}p$, $K^{-}p$ and $\bar{p}p$ appears at $|t|\simeq 0,6$ $(GeV/c)^2$, but at lower energies of the primary photons $E_\gamma \leq 2$ GeV. In Compton scattering experiments at $E_\gamma = 5$ GeV the dip in $d\sigma/dt$ is absent [1]. For this reason it is necessary to study the Compton scattering at lower energies E_γ with the aim to check the VDM hypothesis, scattering amplitude properties, the dip phenomenon (the latter has been found near $E_\gamma =$ 0,7 GeV [5,10]). On the other hand, in the resonance energy range $E_\gamma = 0,5 \div 1,5$ Gev the Compton process is very suitable to study the properties of nucleon resonances for direct determination of coupling constants γNN^* which enter in the fourth order in the cross-section of this process [6÷8].

The results obtained up to now practically refer to the measurements of the differential cross-section of the Compton process. They should be complemented both by experimental data (including new observables connected with polarization measurements) and theoretical studies. At the Bonn 1990 symposium on high energy spin physics [9], Kroll described in detail one nonperturbative calculation based on diquarks as part of the proton. These calculations predict sizeable transverse polarization asymmetries in the Compton process $\gamma p \to \gamma p$.

In this work we present some results of the measurements of the cross-section asymmetry Σ for the Compton scattering on proton by linearly polarized photons in the energy range $E_\gamma = 0,55 \div 0,95$ GeV, at $\theta_\gamma^{CM} = 90^\circ$ and 120°, as well in the angular range $\theta_\gamma^{CM} =$ $85^\circ \div 120^\circ$ at the energy $E_\gamma = 0,75$ GeV. This energy range covers the second ΠN-resonance region. Here it seems possible to study Σ at $E_\gamma = 0,75$ GeV in the angular range that includes the dip in the differential cross-setion. According to the measurements of $d\sigma/dt$ carried out by two groups [5,10] at $E_\gamma = 0,7 \div 1,15$ GeV, a narrow structure in the dip region was revealed in [5], but did not confirmed in [10].

The experiment was carried out on the linearly polarized photon beam of the Yerevan Electron Synchrotron [11]. The identification of $\gamma p \to \gamma p$ and $\gamma p \to p \Pi^\circ$ reactions was realized by detecting a single γ-quantum in coincidence with the recoil proton.The photon detector includes a veto counter,a thin lead converter ($\simeq$ 1r.l.),two hodoscopes (H_x and H_y) and a lead glass shower counter.The protons were detected by magnetic spectrometer described elsewere [11]. The main difficulties in the study of the Compton scattering are due to the smallness of the cross-section in the investigated region ($d\sigma/d\Omega \simeq 0,03 \div 0,15$ Mkb/ster) and to the background of the Π°-meson photoproduction reaction $\gamma p \to p\Pi^\circ$ with the cross-section by two orders larger than that in the Compton process and with the practically same kinematical parameters.

For each event we measured the momentum (p_p) of the recoil proton and its angles (θ_p, φ_p) as well as the coordinates of the scattered γ-quantum (X^M_γ, Y^M_γ) on the plane of hodoscopes. Assuming that this event corresponds to the Compton reaction $\gamma p \to \gamma p$, we calculated the possible coordinates of the γ-quantum X^{calc}_γ and Y^{calc}_γ using the single arm reconstruction parameters (p_p, θ_p, φ_p). Then we constructed distributions $X^M_\gamma - X^{cal}_\gamma(p_p, \theta_p)$ and $Y^M_\gamma - Y^{cal}_\gamma(\varphi)$. To determine the number of events corresponding to the Compton process (N^C), we took a peak part in the distribution $Y^M_\gamma - Y^{cal}_\gamma(\varphi)$ and subtracted the physical background from the $\gamma p \to p\Pi^\circ$ reaction under the Compton peak in the $X^M_\gamma - X^{cal}_\gamma(p_p, \theta_p)$ distribution. Fig. 1 illustrates this method in the case of kinematics:$E_\gamma = 0,6$ GeV, $\theta^{CM}_\gamma = 120^\circ$.The Compton peak width agrees well with the results of Monte-Carlo simulation, where the kinematical reconstruction accuracies were introduced ($\sigma_{\theta_p} = 3,5$ Mrad, $\sigma_{\varphi_p} = 4$ Mrad, $\sigma_{xtarget} = 0,3$ cm) The cross-section asymmetry Σ for the $\gamma p \to \gamma p$ reaction was determined by the formula:

$$\Sigma = \frac{d\sigma_\perp - d\sigma_\parallel}{d\sigma_\perp + d\sigma_\parallel} = \frac{1}{P_\gamma} \cdot \frac{N^C_\perp - N^C_\parallel}{N^C_\perp + N^C_\parallel} \text{, where}$$

$d\sigma_{\perp,\parallel}$ and $N^{c}_{\perp,\parallel}$ are the differential cross-sections and yields of the reaction in the case of the photons polarized in perpendicular and parallel to the reaction plane, and P_{γ} is the photon beam polarization (50 ÷ 70%).

The experimental results are presented in Table 1 and Figs.2(a, b,c). Fig. 2a shows the energy dependence of Σ at $\theta^{CM}_{\gamma} = 90^{\circ}$. The point at 300 MeV presents the result of the single measurement performed in 1968 at Frascati [12]. Experimental results are compared with the predictions of three analyses performed at INS – Tokyo [6÷8]. The first analysis based on the fixed – t dispersion relations in the second resonance region,where the imaginary part of the Compton scattering amplitudes can be estimated using the unitarity condition.The predictions of the analysis [6] as a whole agree satisfactorily with the experimental data up to E_{γ}=0,8 GeV. The second analysis [7] is based on the isobar model ,including three resonances (P_{11}(1470), D_{13}(1520), S_{11}(1535)) and the non-resonant background. The third analysis [8] is based also on the isobar model, including six resonances, with a large photocoupling for P_{33}(1600), and some phases for the resonances. Both analyses can not describe the experimental data satisfactorily in the full kinematic region, in particular noteceable discrepancies are observed for the third analysis above 0,7 GeV. Fig.2b shows the energy dependence of asymmetry Σ at $\theta^{CM}_{\gamma} = 120^{o}$, where the theoretical predictions are absent.

Fig.2c shows the t – dependence of Σ at E_{γ} = 0,75 GeV. At $|t|$= 0,5 – 0,6 $(GeV/c)^2$ the weak structure is seen in our data, which may have the same origin as the narrow structure observed in the cross – section data of Bonn [5] in the analogous kinematical conditions. The t – dependence of the asymmetry Σ has been measured at E_{γ}=3,5 GeV in the range $|t|$ = 0,1 – 0,7 $(GeV/c)^2$, and compared with the predictions of three models for the spin structure of the diffraction scattering: the 0^{+}– exchange, s – channel helicity conservation and spin independence [1]. These models predict the simple t – dependence of asymmetry Σ: in the case of 0^{+} – exchange $\Sigma = -0{,}35|t|$, in the case of s – channel helicity conservation $\Sigma = 0$ and in the case of spin independence $\Sigma = +0{,}35|t|$. We can compare these formulas with ou data,according to Harari's predictions.As it is seen from fig.2c the experimental results qualitatively agree with the spin –

independent model calculations. Unfortunately a more detailed analysis and comparison with models is not possible here.

The polarization data on cross-section asymmetry Σ together with the existing data on $d\sigma/d\Omega$ need to be analyzed in the framework of various phenomenological approaches to advance in the understanding of the Compton scattering mechanism on proton in the intermediate energy range.

Table 1.

$\theta_\gamma^{cm} = 90 \pm 5°$											
E_γ(MeV)	500 ± 25	550	600	650	700	750	800	850	900	950	1000
t	0.242	0.25	0.32	0.35	0.39	0.43	0.47	0.51	0.56	0.6	0.64
Σ	-.16	-.06	0.11	0.19	0.28	0.18	0.17	-.03	-.03	0.03	-.08
σ_Σ	0.18	0.13	0.07	0.15	0.10	0.08	0.12	0.10	0.10	0.16	0.33
$\theta_\gamma^{cm} = 120 \pm 5°$											
E_γ(MeV)	500 ± 25	550	600	650	700	750	800	850	900	950	1000
t	0.363	0.42	0.48	0.53	0.59	0.65	0.71	0.77	0.83	0.89	0.96
Σ	-.17	-.35	-.28	-.03	-.01	0.04	0.14	-.14	-.05	0.07	-.24
σ_Σ	0.14	0.10	0.05	0.07	0.08	0.06	0.06	0.09	0.10	0.16	0.17
$E_\gamma = 750 \pm 50$ MeV											
θ_γ^{cm}	85 ±2.5°	90	95	100	105	110	115	120	125		
t	0.395	0.43	0.47	0.51	0.55	0.58	0.62	0.65	0.68		
Σ	0.36	0.18	0.10	0.27	-.01	0.14	0.15	0.04	-.08		
σ_Σ	0.19	0.08	0.12	0.06	0.06	0.06	0.09	0.06	0.06		

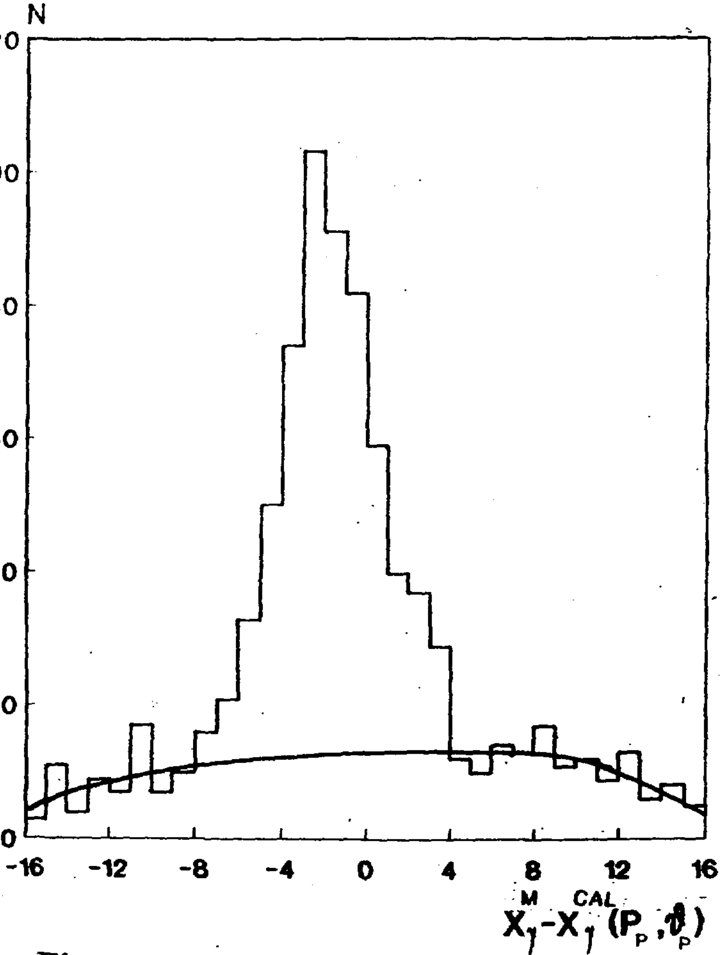
N
120
100
80
60
40
20
0
-16
-12
-8
-4
0
4
8
12
16
$X_\gamma^M - X_\gamma^{CAL}(P_p, \vartheta_p)$

Figure 1

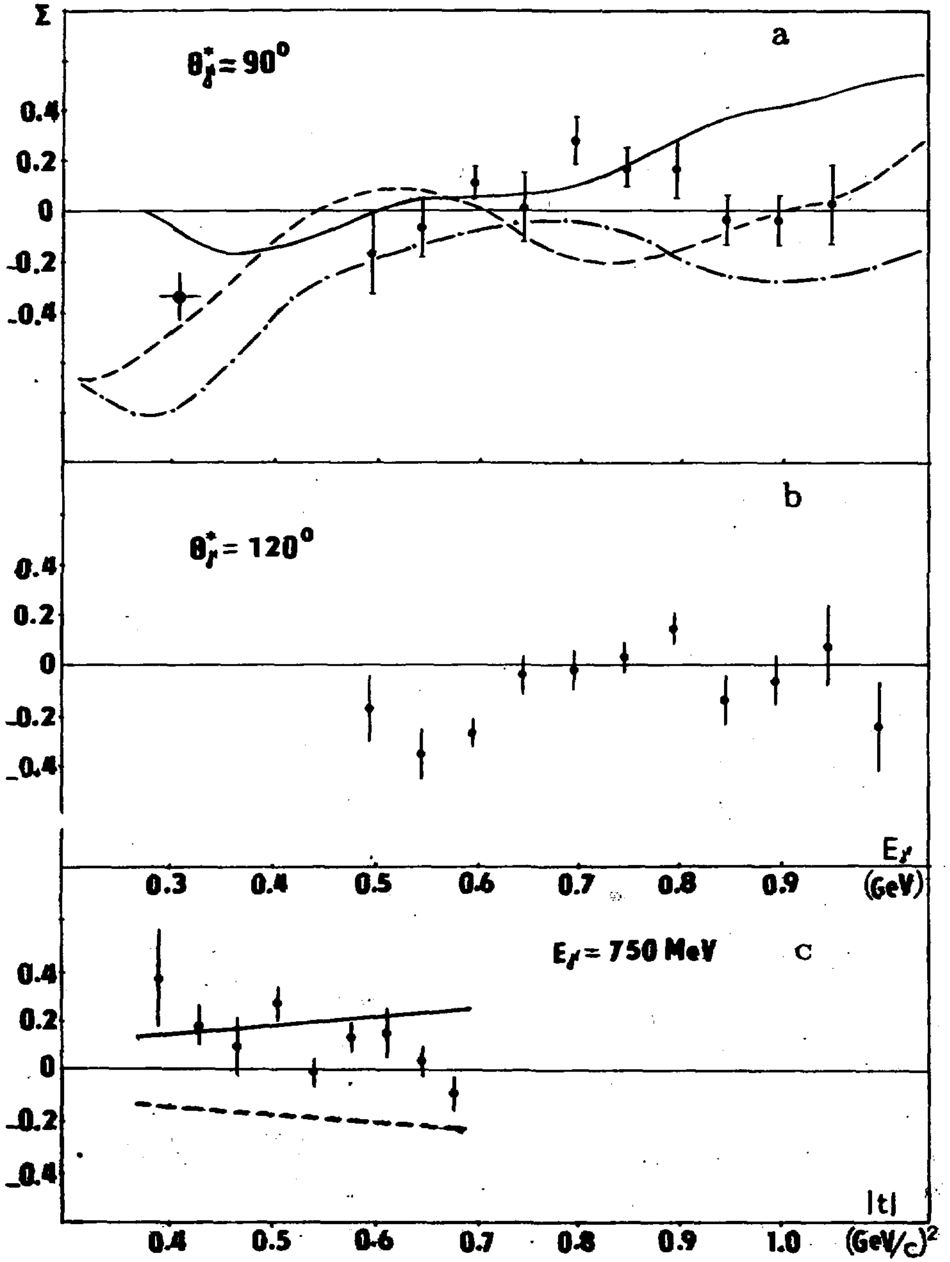
Σ
a
θ*γ = 90°
0.4
0.2
0
-0.2
-0.4
b
θ*γ = 120°
0.4
0.2
0
-0.2
-0.4
Eγ
0.3
0.4
0.5
0.6
0.7
0.8
0.9
(GeV)
Eγ = 750 MeV
c
0.4
0.2
0
-0.2
-0.4
|t|
0.4
0.5
0.6
0.7
0.8
0.9
1.0
(GeV/c)²

Figure 2

Figure Captions

Fig. 1 Distribution in $X_{\gamma}^{M}-X_{\gamma}^{cal}$ (p_p, ϑ_p) at E_{γ}= 0,6 GeV, θ_{γ}^{CM}= 120 . Horizontal polarization. The curve – polynomial fit of $\gamma p \to p\Pi$ background.

Fig. 2(a,b). Energy dependance of asymmetry Σ at θ_{γ} = 90 and 120 .Theoretical results: solid curve – prediction of the analysis [6],dashed – prediction of the analysis [7], dash-dotted – prediction of the analysis [8].

Fig,2c The |t|- dependence of asymmetry Σ at E_{γ}=0,75 GeV. Solid curve – prediction of the spin independent model, dashed prediction of the Ø exchange model.

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ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ КОМПТОНОВСКОГО РАССЕЯНИЯ НА ПРОТОНЕ ПОЛЯРИЗОВАННЫМИ ФОТОНАМИ

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