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ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ

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I.G.AZNAURIAN AND A.N.ZASLAVSKY

HIGH ENERGY CONTRIBUTIONS TO THE DISPERSION INTEGRALS, ISOTENSOR ELECTROMAGNETIC CURRENT,AND DATA ON $\pi^{\pm}$- PHOTOPRODUCTION FROM THE THRESHOLD UP TO 450 MEV

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Yerevan 1972

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E.G.AZNAURYAN, A.M.ZASLAVSKY

HIGH ENERGY CONTRIBUTIONS TO THE DISPERSION INTEGRALS, ISOTENSOR ELECTROMAGNETIC CURRENT AND DATA ON $\pi^{\pm}$ PHOTOPRODUCTION FROM THE THE THRESHOLD UP TO 450 MEV

The discrepancy between the dispersion relations (d.r.) and the experimental data on the reactions $\gamma n \to \pi^- p$ noted in some papers is removed taking into account the high energy contributions to the dispersion integrals. The experimental data on the $\pi^{\pm}$-photoproduction differential cross section from the threshold up to 450 MeV are described in dispersion approach. Some discrepancy at $E_\gamma = 350$ MeV and $\theta = 30^\circ$ still remains. It can be connected with the existence of the isotensor electromagnetic current. An estimate for the magnitude of isotensor electromagnetic current is obtained.

Yerevan Physical Institute
Yerevan 1972

1. Introduction

The experimental data /1-3/ on the differential cross sections of the reactions $\gamma n \rightleftarrows p\pi^-$ in the $\Delta(1236)$ resonance region are at present widely discussed from two points of view:

1) The well known solutions /4-6/ of the dispersion relations (d.r.) disagree with these data, and this discrepancy is attributed by different authors /7,8/ (see also /9/) to the violation of $\Delta I \leq 1$ rule for the electromagnetic interactions /10/.

2) In the $\Delta(1236)$ resonance region the data on the inverse reaction ($\pi^- p \to \gamma n$) do not coincide with those of direct reaction ($\gamma n \to \pi^- p$). This served as a reason for a consideration of a possible violation of T-invariance in the hadron electromagnetic current /7-9/.

We note, however, that the data /2,3/ on the direct reaction $\gamma n \to p\pi^-$ have been obtained in the impulse approximation from the experiments on the deuteron, and the discrepancy between the direct and inverse reactions is within the limits of one standard error. Therefore, the analysis was done on the assumption that no T-invariance violation in the reactions $\gamma n \rightleftarrows p\pi^-$ occurs.

The aim of this paper is to describe consecutively the experimental data on $\pi^- p \to \gamma n$ and $\gamma n \to p\pi^-$ reactions from the threshold up to 400-500 MeV in the framework of one-dimensional dispersion relations at fixed t.

It is shown that the discrepancy between the d.r. predictions and the experiment is connected mainly with the high energy contributions to the dispersion integrals. In particular, the experimental d ta on backward π^+ and π^- photoproduction at $E_\gamma \geqslant 350$ MeV bring to the necessity of taking into account these contributions and cannot be described by means of isotensor electromagnetic current.

The consideration of the high energy contributions allows to describe the experimental data on $\gamma p \rightarrow n\pi^+$ and $\gamma n \rightleftarrows p\pi^-$ in the energy interval from the threshold up to 400-450 MeV (see Figs. I-4). Some discrepancy remains at $\theta=90^\circ$ and $E_\gamma=350$ MeV. If the experimental data /2,3/ are correct, then this discrepancy leads to a lower estimate on the isotensor contribution $\sim$(7-IO) % of isovector resonance amplitude.

The consideration of high energy contributions also allows to describe the energy dependence of the π^+ and π^- photoproduction cross section difference in the Δ(I236) resonance region, the structure of which served as a basis for the introduction of isotensor electromagnetic current /7/.

2. Formulation of the Problem and the Method of Solution

Let us write the isotopic structure of the amplitude for π_β pion photoproduction on nucleons taking into account the isotensor electromagnetic current in the form:

$$H = H^{(+)}\delta_{\beta 3} + H^{(-)}\frac{1}{2}[\tau_\beta \tau_3] + H^{(0)}\tau_\beta + H^{(T)}\left(\tau_3\delta_{\beta 3} - \frac{1}{3}\tau_\beta\right), \qquad (I)$$

where

$$H^{(+)} = \frac{1}{3}\left(H^{\frac{1}{2}} + 2H^{\frac{3}{2}}\right), \qquad (2)$$
$$H^{(-)} = \frac{1}{3}\left(H^{\frac{1}{2}} + H^{\frac{3}{2}}\right)$$

are the isotopic even and isotopic odd isovector amplitudes, the amplitudes $H^{\frac{1}{2}}$ and $H^{\frac{3}{2}}$ correspond to the transition into a final state with $T=\frac{1}{2}$ and $\frac{3}{2}$, $H^{(0)}$ and $H^{(T)}$ are the isoscalar and isotensor amplitudes, respectively.

The pion photoproduction amplitudes are of the following form:

$$H(\gamma p \to n\pi^+) = \sqrt{2}\left[\left(H^{(0)} - \frac{1}{3}H^{(T)}\right) + H^{(-)}\right], \tag{3a}$$

$$H(\gamma n \to p\pi^-) = \sqrt{2}\left[\left(H^{(0)} - \frac{1}{3}H^{(T)}\right) - H^{(-)}\right], \tag{3b}$$

$$H(\gamma p \to p\pi^0) = H^{(+)} + \left(H^{(0)} + \frac{2}{3}H^{(T)}\right), \tag{3c}$$

$$H(\gamma n \to n\pi^0) = H^{(+)} - \left(H^{(0)} + \frac{2}{3}H^{(T)}\right). \tag{3d}$$

The well known solutions of d.r. /4-6/ describe well the data on the reactions $\gamma p \to p\pi^0$ and $\gamma p \to n\pi^+$ and fail for the reactions $\gamma n \rightleftarrows p\pi^-$ /I-3/.

In /II/ it has been shown that this brings to a discrepancy between the d.r. predictions and the experiment for a large isovector photoproduction amplitude $H^{(-)}$, which with a good accuracy describes the sum of differential cross sections for the reactions $\gamma p \to n\pi^+$ and $\gamma n \to p\pi^-$ (Figs. I-4):

$$\Sigma \equiv \frac{d\sigma}{d\Omega}(\gamma p \to n\pi^+) + \frac{d\sigma}{d\Omega}(\gamma n \to p\pi^-) = 4|H^{(-)}|^2. \tag{4}$$

The account of isoscalar and isovector amplitudes can only somewhat raise the curves in Figs. I-4. The contribution of isoscalar amplitude $H^{(0)}$ to the sum of the cross sections Σ at large angles becomes noticeable at E_γ=420 MeV and higher energies. This contribution is taken into account for the curve shown in Fig. 4 and at θ=180 is (10-15) %.

From the figures is seen that at resonance (E_γ= 350 MeV) and higher energies there is a sharp discrepancy between the d.r. predictions at large angles and the experiment: the curves obtained by means of d.r. lie significantly higher than the experimental points.

It is convenient to carry out the analysis and the removal of discrepancy between d.r. and the experiment not by means of the reactions but by the isotopic amplitudes:

a) To remove the discrepancy in the isovector amplitude an analysis of the uncertainty in the d.r. solution for the amplitude $H^{(-)}$ has been carried out. It has been shown that the discrepancy between d.r. and the experiment is connected mainly with the high energy contributions to the dispersion integrals. It has been also shown that the change of the isovector resonance multipoles $M_{1+}^{(-)}$ and $E_{1+}^{(-)}$ connected with the introduction of an isotensor electromagnetic current cannot remove the main features of the discrepancy between d.r. and the experiment in the amplitude $H^{(-)}$.

b) The high energy contributions to the isoscalar amplitude $H^{(0)}$ allow to choose it in such a manner that no discrepancy between the predictions of d.r. and the data for the reaction $\gamma p \rightarrow n\pi^+$ would arise.

3. The Role of Isotensor Electromagnetic Current in the Removal of Discrepancy between D.R. and Experiment

We shall show that the introduction of isotensor resonant multipoles $M_{1+}^{(T)}$ and $E_{1+}^{(T)}$ cannot remove the main features of discrepancy between the d.r. predictions and experiment /I-3/.

The isotensor terms enter into the resonant multipoles, e.g. into M_{1+}, in the following way:

$$M_{1+}(\gamma p\to p\pi^{0}) = -\sqrt{2}\, M_{1+}(\gamma p\to n\pi^{+}) = \frac{2}{3}\left(M_{1+}^{\frac{3}{2}} + M_{1+}^{(T)}\right), \tag{5a}$$

$$M_{1+}(\gamma n\to n\pi^{0}) = \sqrt{2}\, M_{1+}(\gamma n\to p\pi^{-}) = \frac{2}{3}\left(M_{1+}^{\frac{3}{2}} - M_{1+}^{(T)}\right), \tag{5b}$$

$$M_{1+}^{(-)} = -\frac{1}{3} M_{1+}^{\frac{3}{2}} . \tag{5c}$$

The sums $M_{1+}^{\frac{3}{2}} + M_{1+}^{(T)}$ and $E_{1+}^{\frac{3}{2}} + E_{1+}^{(T)}$ are fixed by the data on the reaction $\gamma p\to p\pi^{0}$ having near the resonance a low background from the remained multipoles. Therefore any attempt to remove the discrepancy in Σ by the change of isovector multipoles $M_{1+}^{(-)}$ and $E_{1+}^{(-)}$ brings inevitably to the introduction of isotensor resonant multipoles.

The change of the multipoles $M_{1+}^{(-)}$ and $E_{1+}^{(-)}$ mainly affects the contribution of the imaginary part of $H^{(-)}$ in Σ, which is illustrated by the curves I in Figs 3 and 4. The influence of these multipoles on the contribution of the real part of $H^{(-)}$ in Σ through the dispersion integrals is less essential. Let us note that the contribution of the real part of $H^{(-)}$ in Σ increases slightly with decreasing the contribution of the imaginary part of $H^{(-)}$ in Σ due to the change of the multipoles $M_{1+}^{(-)}$ and $E_{1+}^{(-)}$.

The curves II in Fig. 3 illustrate the behaviour of the discrepancy between d.r. and experiment at E_{γ}= 350 MeV. It is seen that the chan of the multipoles $M_{1+}^{\frac{3}{2}}$ and $E_{1+}^{\frac{3}{2}}$, i.e. the introduction of the isotensor resonant multipoles cannot remove the main features of the discrepancy between d.r. predictions and experiment neither by the behaviour of the angular dependence nor by the magnitude at $E_\gamma \geqslant 350$ MeV and $\theta = 180^\circ$.

It is important to note that the contribution of the imaginary part of $H^{(-)}$ in Σ near the resonance is determined only by the resonant multipoles $M_{1+}^{(-)}$ and $E_{1+}^{(-)}$ and weakly depends on other multipoles. Therefore, with an accuracy up to the isotensor multipoles $M_{1+}^{(T)}$ and $E_{1+}^{(T)}$, this contribucion is fixed by the value of the differential cross section of the reaction $\gamma p \to p\pi^0$ and is independent of the uncertainties in the d.r. solution. The uncertainties in the d.r. solutions may affect the d.r. predictions for Σ only through the contribution of the real part of $H^{(-)}$ in Σ, i.e. it may change the background.

In the next section we shall describe the procedure of obtaining from d.r. the result for the contribution of the real part of $H^{(-)}$ in Σ and analyze the uncertainties which may be responsible for the discrepancy between the well known d.r. solutions and experiment /I-3/. We shall show that the ambiguity is mainly connected with the consideration of the high energy contributions to the dispersion integral.

3. The High Energy Contribution to the Dispersion Integrals

Let us write the d.r. for the photoproduction amplitude in the form

$$Re\,H(\nu,t) = R\left(\frac{1}{\nu_B-\nu} \pm \frac{1}{\nu_B+\nu}\right) + \frac{P}{\pi}\int_{\nu_{thresh}}^{\infty} Jm\,H(\nu',t)\left(\frac{1}{\nu'-\nu} \pm \frac{1}{\nu'+\nu}\right)d\nu', \tag{6}$$

$$\nu = E_\gamma - \nu_1,\quad \nu_1 = \frac{k\omega_q - \vec{k}\vec{q}}{2m} = -\frac{t-\mu^2}{4m},\quad \nu_B = -\nu_1,\quad \nu_{thresh} = \mu + \frac{\mu^2}{2m} - \nu_1$$

Here E_γ is the photon energy in lab. system, $\vec{K}$ and $\vec{q}$ are the photon and pion momenta in c.m., ω_q is the pion energy in this system, m and μ are the nucleon and pion masses, R is the residue of the amplitude in the Born poles at $\nu = \pm \nu_B$.

The sign (-) in d.r. corresponds to the amplitudes $A^{(-)}$, $B^{(-)}$, $\mathfrak{D}^{(-)}$ and $C^{(0)}$ (we used the notations of /I2/). This strogly depress the high energy contributions to the dispersion integrals for these amplitudes. For instance, the account of the contribution of the region from 500 MeV up to I GeV in d.r. by means of the Walker analysis /I3/ changes these amplitudes by less than I %.

The sign (+) in (6) corresponds to the amplitudes $C^{(-)}$, $A^{(0)}$, $B^{(0)}$ and $\mathfrak{D}^{(0)}$ and the high energy contributions to the dispersion integrals for these amplitudes may be essential.

Let us analyze the contributions of the various integration regions to the dispersion integrals for the amplitude $H^{(-)}$: from the threshold up to 500 MeV, from 500 MeV up to I GeV and higher than I GeV.

I) The Energy Region from the Threshold up to 500 MeV

In this region we take into account only the contribution of the multipoles $E_{0+}^{(-)}$, $M_{1-}^{(-)}$, $M_{1+}^{\frac{3}{2}}$, $E_{1+}^{\frac{3}{2}}$ to the dispersion integrals. In this energy region, the contribution of the remained multipoles can be neglected since, according to the unitarity condition, they are proportional to the corresponding small phases of πN-scattering. The error in determining the nonresonant multipoles $E_{0+}^{(-)}$ and $M_{1-}^{(-)}$ from d.r. and the existing experimental data does not exceed I00 % (see, for instance, /I4/). However, the change of the multipoles $E_{0+}^{(-)}$ and $M_{1-}^{(-)}$ within the limits of I00 % at $E_\gamma = 350$ MeV and $\theta = 180^\circ$ introduces an uncertainty into the final result not exceeding 3 % for each multipole and is less essential at $\theta < 180^{\circ}$.

For the resonant multipole $M_{1+}^{\frac{3}{2}}$ in the absence of an isotensor current one may take the CGLN solution /I2/ which describes well the experimental data on the reaction $\gamma p \to p\pi^{\circ}$ (having low background from other multipoles) and agree with all the d.r. solutions, e.g. with the solution of /4/. The phase of the multipole $M_{1+}^{\frac{3}{2}}$ is taken in the analytical form from /5/.

The d.r. solutions for the $E_{1+}^{\frac{3}{2}}$ amplitude obtained by various authors /4,I5,I6/ differ between themselves in form of the $E_{1+}^{\frac{3}{2}}$ amplitude and in sign in the resonance region. From the data on the differential cross section and asmmetry in the reaction $\gamma p \to p\pi^{\circ}$ in Δ (I236) region, it may be concluded that in this region the $E_{1+}^{\frac{3}{2}}$ amplitude is small and cannot be more than (3-4) % of the $M_{1+}^{\frac{3}{2}}$ amplitude and has an opposite sign /I7/.

The curves shown in Figs I-4 correspond to the negative sign of $E_{1+}^{\frac{3}{2}}/M_{1+}^{\frac{3}{2}}$ at resonance and to the form $E_{1+}^{\frac{3}{2}}$ amplitude in accordance with the solution of /4/. The other d.r. solutions /I5,I6/ for $E_{1+}^{\frac{3}{2}}$, only raise the theoretical curves of Figs I-4 and enhance the existing discrepancy.

2) The Energy Region from 500 MeV up to I000 MeV

The contribution of this region to the dispersion integrals has been estimated with the help of the Walker analysis /I0/. At E_{γ}=350 MeV it introduces into the sum of the differential cross sections Σ an uncertainty of 2 and 3 % for θ=90° and θ= I80°, respectively, and practically no contribution is introduced at small angles.

There is, however, an ambiguity in determining the parameters of P_{11} (M = I435-I470 MeV, Γ= 200-400 MeV) resonance. Let us estimate the influence of this ambiguity on the theoretical results (curves I-4) by their maxima. For this purpose we assume that the P_{11} resonance appears only on neutron /I8/ in the amplitude and the total photoproduction cross section on neutron in the resonance region is only due to M_{1-} amplitude. Let us note that the contributions of all the multipoles to the total cross section are summed up. Then we obtain $M_{1-}^{(-)}(\sqrt{S} = 1435\ \text{MeV}) = \pm\ 0.0565\ (\text{GeV})^{-1}$. This value of $M_{1-}^{(-)}$ at P_{11} resonance obtained in estimating by the maximum, introduces into the theoretical predictions for Σ an uncertainty of 0.3, I.6, 2.4 and 3.0 μbarn at $\theta = 180^{\circ}$ and $E_{\gamma} = 200$, 280, 350 and 420 MeV, respectively, and practically does not change the predictions when $\theta \leqslant 90^{\circ}$.

Thus, the discrepancy between d.r. and experiment cannot be essentially connected with the ambiguity in determining the P_{11} (I470) parameters.

3) Region Higher than I000 MeV

As it was mentioned above, the contributions of the amplitudes $A^{(-)}$, $B^{(-)}$ and $D^{(-)}$ in this region are strongly suppressed by the kinematical factors. Only the contribution of the $C^{(-)}$ amplitude to the dispersion integrals at high energies may essentially influence the d.r. predictions at low energies.

The amplitude $C^{(-)}$ does not give for kinematical reason any contribution to the production at small angles; its contribution increases with angle. Thus, the change in the amplitude $C^{(-)}$, introduced by the high energy contributions has the same angular dependence as that of the discrepancy between the d.r. predictions and experiment (see Figs 3,4).

To clearify the energy dependence of this contribution let us rewrite the d.r. for the amplitude $C^{(-)}$, separating the high energy contribution:

$$Re\, C^{(-)}(\nu,t) = R\left(\frac{1}{\nu_B-\nu}+\frac{1}{\nu_B+\nu}\right)+\frac{P}{\pi}\int_{\nu_{nop}}^{1\,GeV} Im\, C^{(-)}(\nu,t)\left(\frac{1}{\nu'-\nu}+\frac{1}{\nu'+\nu}\right)d\nu' + \qquad (7)$$
$$+ f_c(t),$$

where $f_c(t)$ is the high energy integral which with a good accuracy at ν under consideration is a function of only t and is equal to

$$f_c(t) = \frac{2}{\pi}\int_{1\,GeV}^{\infty} Im\, C^{(-)}(\nu',t)\frac{d\nu'}{\nu'}\,. \qquad (8)$$

From the existing Regge analysis of the data at high energies, the function $f_c(t)$ is not determined unambiguously. Therefore, in our approach $f_c(t)$ serves as a free parameter which is chosen from the condition of agreement between the d.r. and experiment.

The high energy contributions to $Re\, C^{(-)}(\nu,t)$ do not depend on the energy ν and are fixed by the value of t. Choosing the necessary $f_c(t)$ at $E_\gamma=350$ and 420 MeV, we change the d.r. predictions at lower energies $E_\gamma=200$ and $E_\gamma=280$ MeV in a quite certain manner.

A good agreement between d.r. and experiment at $E_\gamma=350$ and 420 MeV and $\theta=180^0$ is achieved when

$$f_c(t) = -(0{,}25-0{,}30)\,(GeV)^{-2} \qquad (9)$$
$$t = -(0{,}25-0{,}34)(GeV)^2\,.$$

The values of $f_c(t)$ at smaller $|t|$ are chosen in such a way that the agreement between d.r. and experiment would not be violated at $E_\gamma=200$ and 280 MeV.

Then

$$f_c(t) = -(0{,}15 - 0{,}20)(Gev)^{-2} \qquad (10)$$
$$|t| < 0{,}16\ (Gev)^2$$

The curves corresponding to these values of $f_c(t)$ are shown in Figs I-4. Thus, the consideration of the high energy contributions to the amplitude $C^{(-)}$ allows to describe the data at all energies from the threshold up to 450 MeV. The discrepancy can not be removed only at $E_\gamma = 350$ MeV and $\theta = 90^\circ$ where the curve in Fig. 3 cannot be lowered any more by means of the function $f_c(t)$ without violating the agreement with the experiment at $E_\gamma = 200$ and 280 MeV.

The remained discrepancy at $E_\gamma = 350$ MeV and $\theta = 90^\circ$ may be attributed to the isotensor current /IO/; the lower estimate of the isotensor contribution is $M^T_{1+}/M^{\frac{3}{2}}_{1+} \sim (7-10)\%$

The values $f_c(t)$ (9,IO) may be useful in analyzing the data at high energies.

The consideration of the high energy contributions to the amplitude $C^{(-)}$ allows to describe the sum (4) of the differential cross sections. However, the agreement between the theory and experiment then appeared to be violated in the reaction $\gamma p \to n\pi^+$ We shall show that these discrepancy may be removed with the help of the high energy contributions to the isoscalar amplitude $H^{(0)}$

4) The Contribution of High Energy to Isoscalar Amplitudes

As it was mentioned above, the high energy contributions may be essential only in the isoscalar amplitudes $A^{(0)}$, $B^{(0)}$, $\mathcal{D}^{(0)}$. But for reasonable values of $B^{(0)}$ and $\mathcal{D}^{(0)}$ at high energies, their high energy contributions to the differential cross section from the threshold up to 420 MeV are suppressed (the amplitudes $B^{(0)}$ and $D^{(0)}$ enter with a higher power [illegible]menta in comparison with the amplitude $A^{(0)}$). Therefore, only the high energy contribution to the amplitude $A^{(0)}$ may be essential. It is important to note that from the data on the ratio of π^+ and π^- differential cross sections at high energies (see Fig. 5) it follows unambiguously that the magnitude of the isoscalar amplitude at small $|t|$ is small and at $|t| \sim (0.3-0.5)$ $(GeV)^2$ is essential. Just these values of t correspond to the large angle production at $E_\gamma = 350$ and 420 MeV. Therefore, the high energy contribution to the amplitude $A^{(0)}$ has the necessary dependence on t which permits to describe the data on $\gamma p \to n\pi^+$ at energies from the threshold up to 420 MeV.

Thus, the consideration of the high energy contributions to the dispersion integrals permits to describe the data on the reactions $\gamma p \to n\pi^+$ and $\gamma n \rightleftarrows p\pi^-$.

Let us note that to obtain an agreement between the d.r. predictions and experiment for the reaction $\gamma p \to p\pi^0$ in /4/, it has been also taken into account the high energy contributions of the B and ω poles. In the resonance region (where the background is low) their contribution is insignificant and becomes essential near the threshold.

5) Conclusions

The high energy contributions to the dispersion integrals allow us to remove the discrepancy between the d.r. and experimental data on the reactions $\gamma n \rightleftarrows p\pi^-$ /I-3/ on the assumption that T-invariance is not violated and the data on the direct ($\gamma n \to p\pi^-$) /2,3/ and inverse ($\pi^- p \to n\gamma$) /I/ reactions coincide within the limits of the errors.

However, the experimental data on the reaction $\gamma n \to p\pi^-$ have been recently published by Fujii et al /19/. These data sharply disagree with the results of the measurement of inverse reaction $\pi^- p \to n\gamma$ /1/. If these results are correct, then the centre of the problem will be shifted from the question of the removal of the discrepancy between d.r. and experiment to the violation of T-invariance in the electromagnetic interactions of hadrons. In this case the phases of the multipoles in the photoproduction are arbitrary (not connected with the πN-scattering phases by the unitarity condition) and the application of d.r. becomes model dependent. For further analysis, new experiments on the reactions $\gamma n \rightleftarrows p\pi^-$ near the $\Delta(1236)$ resonance are necessary.

The available data on the reactions $\gamma p \to p\pi^0$, $\gamma n \to p\pi^-$, $\gamma p \to n\pi^+$ do not allow to establish the existence of the isotensor electromagnetic current /10/ with confidence. A reliable conclusion on the existence of an isotensor current in pion photoproduction may be done when new experimental data on the reaction $\gamma n \to n\pi^0$ in $\Delta(1236)$ resonance region will be appeared. The comparison of the differential cross sections of the reactions $\gamma p \to p\pi^0$ and $\gamma n \to n\pi^0$ in the resonance region will allow to solve this problem unambiguously.

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FIGURE CAPTIONS

Fig. I D.R. predictions for Σ and the experimental data at E_γ=200 MeV. The thick and thin curves are the d.r. predictions with and without taking into account the high energy contributions, respectively. The experimental data are taken from: ○ - /3/ and /20/; ● - /2I/ and /20/; □ -/22/ and /20/ ; x - /23/ and /20/; ▲ - /22/ and /24/.

Fig. 2 The same as that in Fig. I at E_γ= 280 MeV. ○ -/3/ and /25/; ●-/2/ and /25/; △ -/26/ and /25/.

Fig. 3 D.R. predictions for Σ and the experimental data at E_γ=350 MeV. The thick and thin curves are the d.r. predictions with and without taking into account the high energy contributions; the dotted curve (I) is the contribution of the imaginary part of $H^{(-)}$ in Σ ; the hatched-dotted curve illustrates the discrepancy between the d.r. and experiment. ○ -/3/ and /25/; X -/2/ and /25/; ● -/I/ and /25/.

Fig. 4 The same as that in Fig. 3 at E_γ=420 MeV. ● -/2/ and /28/; ○ -/27/ and /28/.

Fig. 5 The ratio of π^- and π^+ photoproduction cross sections at E_γ=3.4 GeV, E_γ=5 GeV. The experimental data are taken from: ● -/29/; ▲ -/30/; ○-/29/.

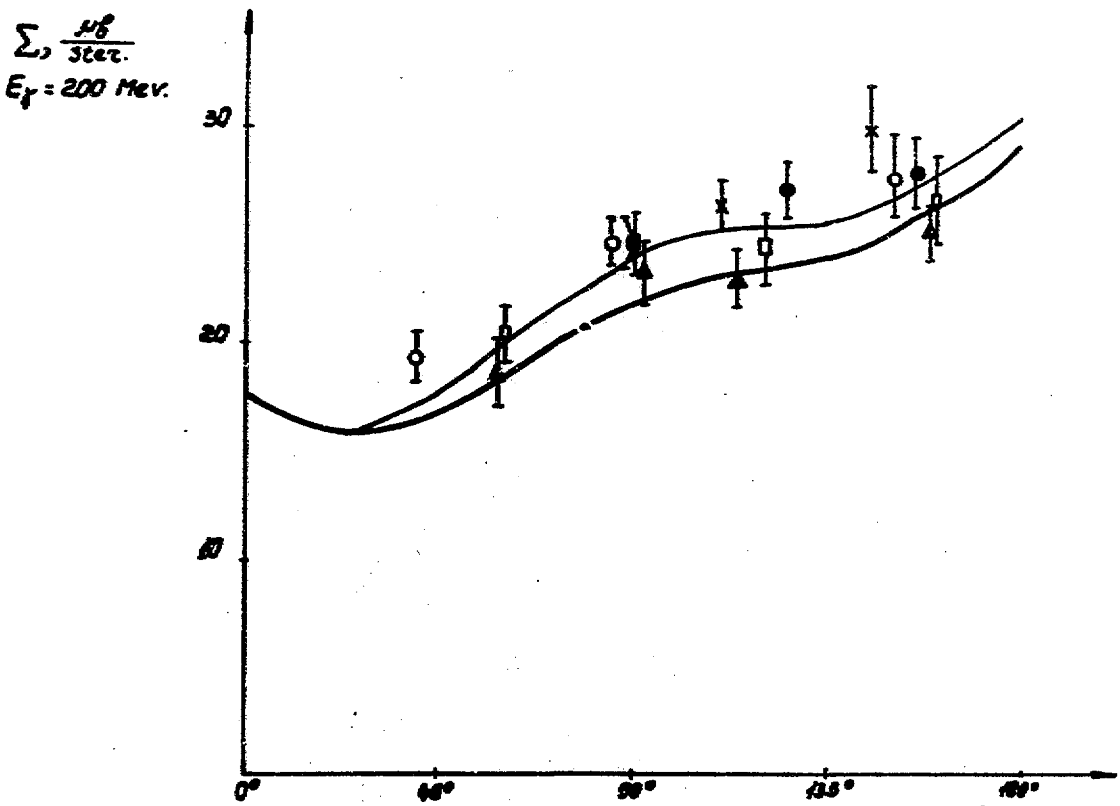
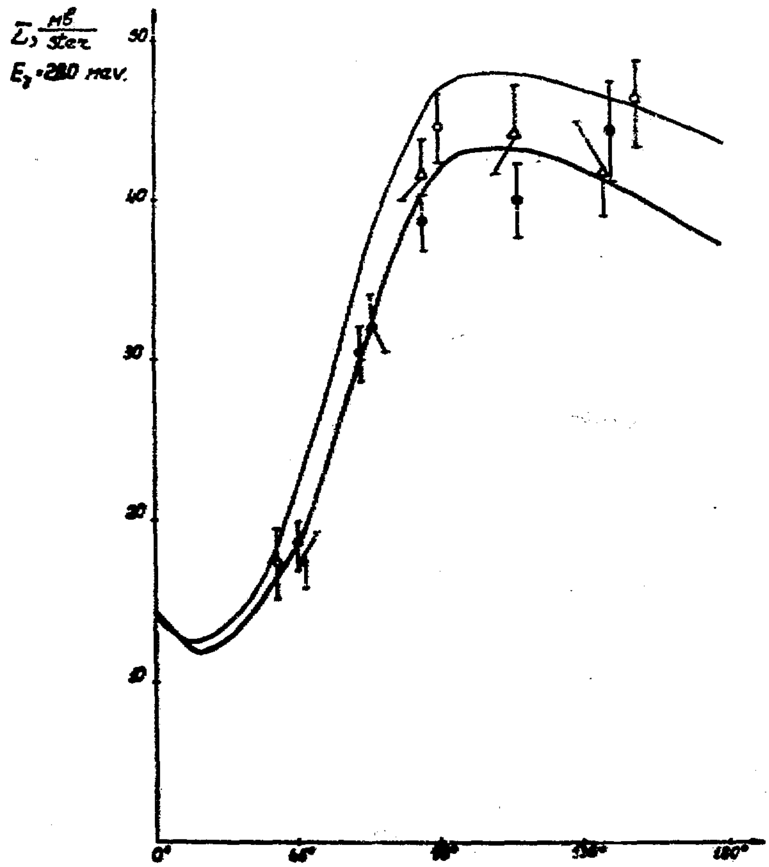


Fig. 1



$\bar{\Sigma}, \frac{\mu b}{ster.}$
$E_\gamma = 280$ mev.
50
40
30
20
10
0°
45°
90°
135°
180°
θcm.

Fig. 2

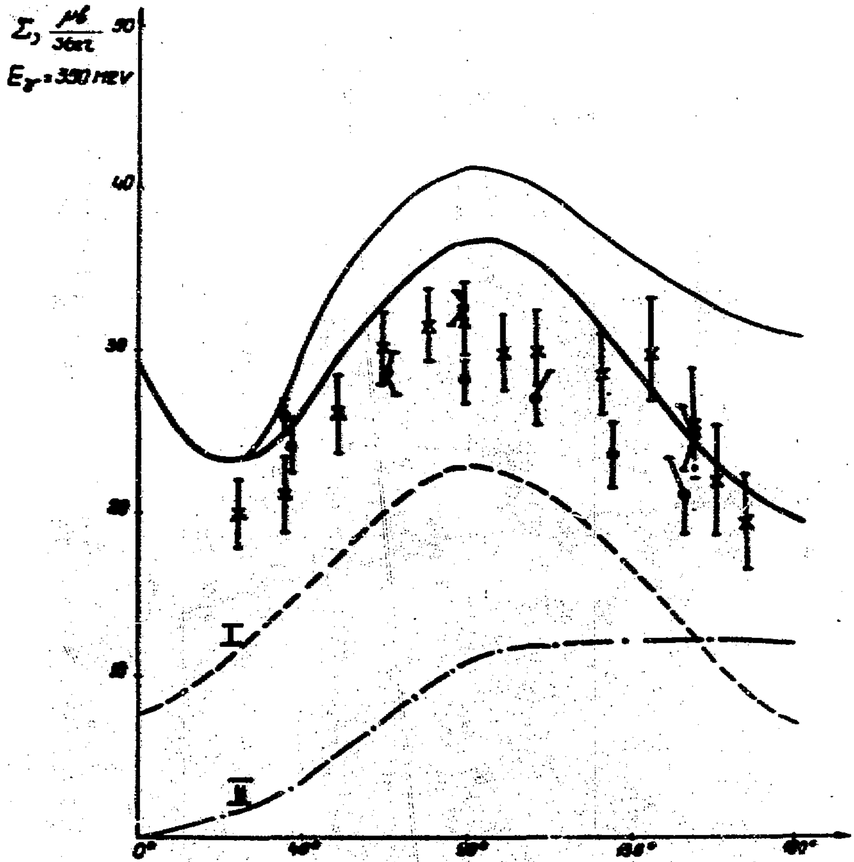
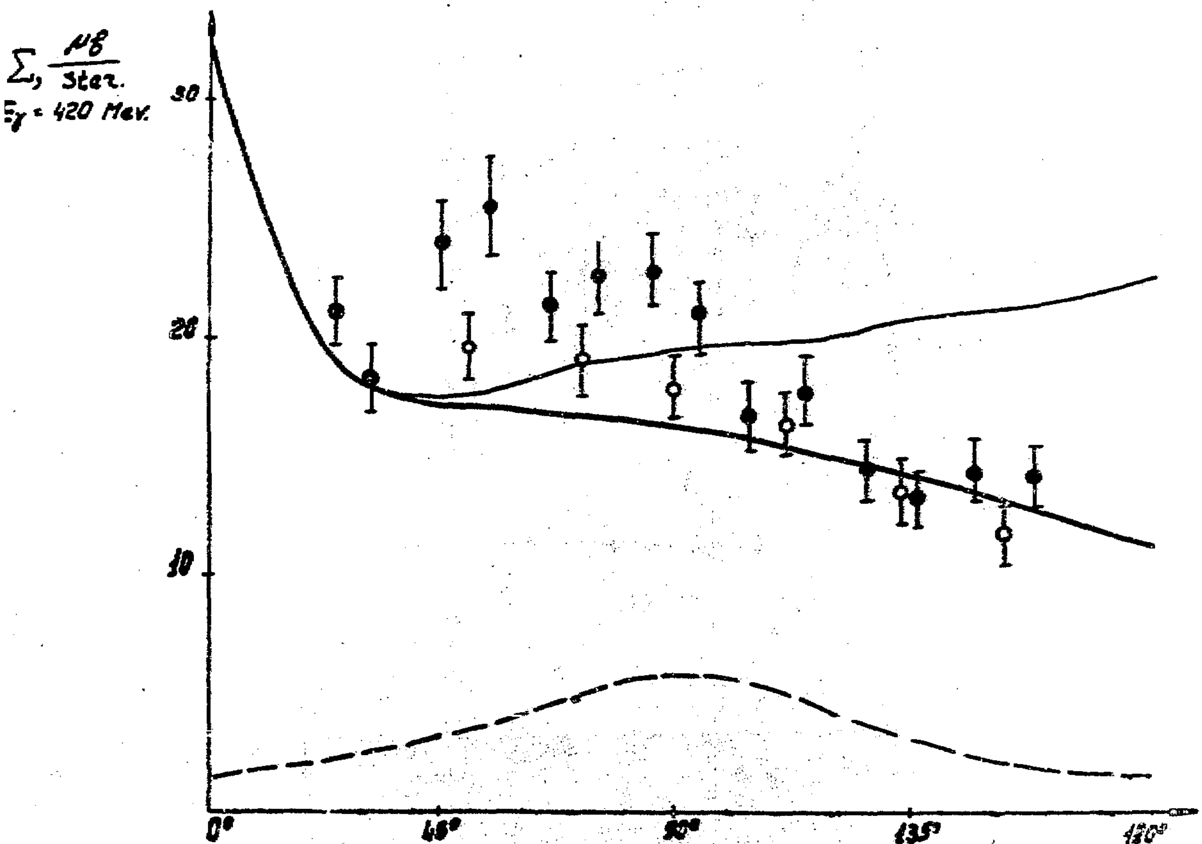


Fig. 3



Σ, $\frac{\mu b}{\text{Ster.}}$
E_γ = 420 Mev.
30
20
10
0°
45°
90°
135°
180°
θcm.

Fig. 4

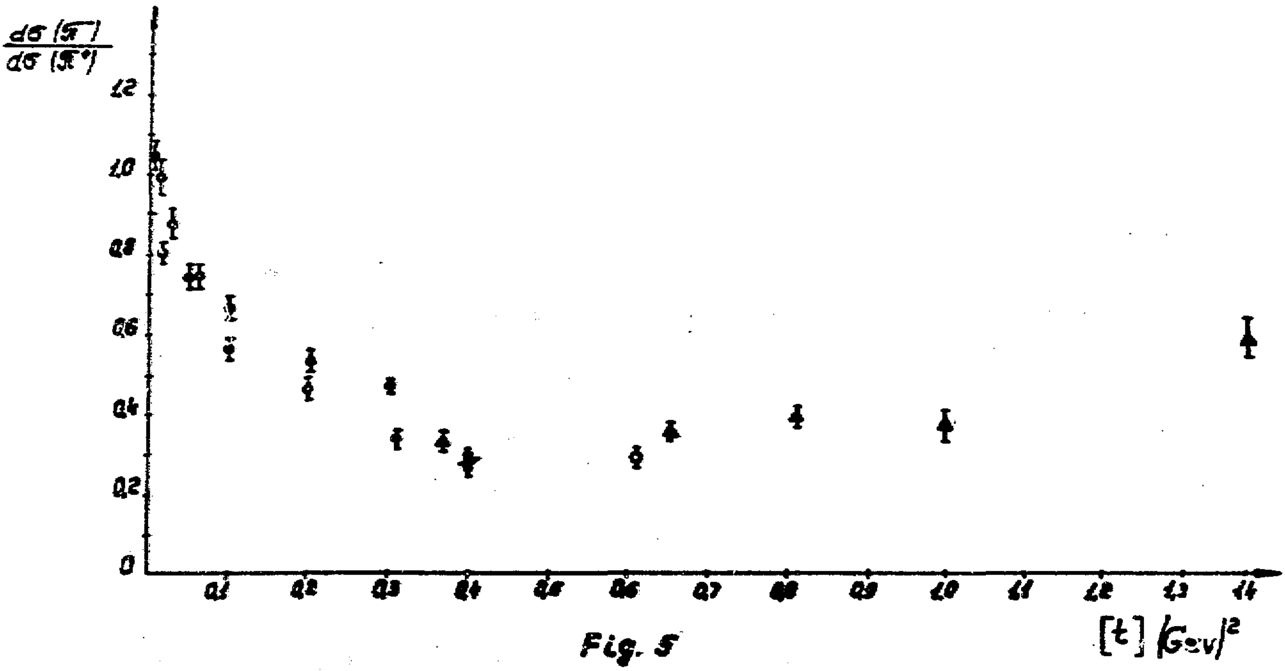

dσ (π⁻) / dσ (π⁺)
1,2
1,0
0,8
0,6
0,4
0,2
0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1,0
1,1
1,2
1,3
1,4
[t] (GeV)²

Fig. 5

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