ЕФИ-ТФ-10(71)

I.G.AZNAURYAN, A.N.ZASLAVSKY

DISPERSION RELATIONS AND DATA ON THE REACTIONS $\gamma n \rightleftarrows p\pi^-$ IN THE $\Delta(1236)$ RESONANCE REGION

M-26

A b s t r a c t

It is shown that there is a discrepancy in the isovector photoproduction amplitude between the predictions of dispersion relations and the experimental data. This discrepancy cannot be removed by the introduction of an isotensor electromagnetic current. For the considered isotopic combination the result practically does not depend on the possible ambiguities in the solution of the dispersion relations.

I. Experiments on the measurement of the differential cross sections of the reactions $\gamma n \rightleftarrows p\pi^-$ in the Δ (I236) resonance region have been recently carried out /I,2/. The obtained data have been in disagreement with the predictions of dispersion relations /3,4/, and this discrepancy has been treated by some authors /5,6/ as an evidence for the presence of isotensor electromagnetic current ($\Delta T=2$) /7/. It has been asserted that the isotensor resonant amplitude is about (I0-40)% of the isovector resonant amplitude /5,6/.

We want to draw attention to the discrepancy existing between the predictions of dispersion relations (D.R.) and the experimental data in the large isovector photoproduction amplitude (see Fig.I). This discrepancy cannot be removed by the introduction of the isotensor amplitude. Therefore, the conclusion on the existence of an isotensor electromagnetic current is premature and requires further analysis.

We consider the sum of the differential cross sections of $\gamma p \to n\pi^+$ and $\gamma n \to p\pi^-$:

$$\Sigma = \frac{d\sigma}{d\omega}(\gamma p \to n\pi^+) + \frac{d\sigma}{d\omega}(\gamma n \to p\pi^-) \qquad (I)$$

to which, with a good accuracy, only the odd isotopic isovector amplitude $H^{(-)}$ gives contribution (hereafter we use the notations applied by C.G.L.N./8/).

The use D.R. for the amplitude $H^{(-)}$ has several advantages: a) the high energy contribution to D.R. for $H^{(-)}$ is strongly suppressed, b) the possible ambiguity in determining the multipoles $E_{0+}^{(-)}$, $M_{1-}^{(-)}$, $M_{1+}^{(-)}$ and $E_{1+}^{(-)}$ from the D.R. and the experimental data brings to an uncertainty not exceeding 7% in the final result at E_γ = 350MeV.

2. The isotopic structure of pion photoproduction amplitude has the form

$$H = H^{(+)}\delta_{\beta 3} + H^{(-)}\, {}^1/_2[\tau_\beta \tau_3] + H^{(0)}\tau_\beta + H^{(T)}(\tau_3\delta_{\beta 3} - {}^1/_3\tau_\beta) , \qquad (2)$$

where

$$H^{(+)} = {}^1/_3(H^{1/2} + 2H^{3/2}) , \quad H^{(-)} = {}^1/_3(H^{1/2} - H^{3/2}) \qquad (3)$$

are the isovector amplitudes, the amplitudes $H^{1/2}$ and $H^{3/2}$ correspond to the transitions to the final states with T = 1/2 and 3/2, $H^{(0)}$ and $H^{(T)}$ are the isoscalar and isotensor amplitudes, respectively.

The charged pions photoproduction amplitudes under consideration are of the form:

$$H\ (\gamma p \to n\pi^+) = \sqrt{2}\ [(H^{(0)} - {}^1/_3 H^{(T)}) + H^{(-)}] \ , \qquad (4)$$

$$H\ (\gamma n \to p\pi^-) = \sqrt{2}\ [(H^{(0)} - {}^1/_3 H^{(T)}) - H^{(-)}] \ . \qquad (5)$$

With a good accuracy, only the square of the isovector amplitude $H^{(-)}$ gives contribution to the sum of the charged pion differential cross sections (I):I = $4|H^{(-)}|^2$. The contribution of the isoscalar and isotensor amplitudes can only slightly raise the theoretical curves of Fig.I.

3.Let us describe the procedure how the result from D.R. for the invariant amplitudes A,B,C and D (notations of C.G.L.N /8/) is obtained. In the energy region up to 500 MeV we take into account only the contribution of the multipoles $E_{0+}^{(-)}$, $M_{1-}^{(-)}$, $M_{1+}^{3/2}$, $E_{1+}^{3/2}$ in dispersion integrals. The contributions of the other multipoles to the dispersion integrals can be neglected in this energy region, since, according to the unitary condition, these contributions are proportional to the corresponding small phases of πN- scattering. We have estimated the contribution of the region from 500 up to I200 MeV using the Walker analysis /9/. It appears that the influence of this region brings an uncertainty in the amplitudes $H^{(-)}$ of about (I-2)%. The contribution of the higher energies to the amplitudes $H^{(-)}$ is strongly suppressed. Note that for the amplitudes $H^{(+,0)}$, the contribution of the energy region higher than 500 MeV is significantly more essential.

Let us discuss the contributions of the multipoles $E_{0+}^{(-)}$, $M_{1-}^{(-)}$, $M_{1+}^{3/2}$ and $E_{1+}^{3/2}$ to the dispersion integrals.

a) For the resonant multipole $M_{1+}^{3/2}$ we use the solution of C.G.L.N. This solution is in agreement with all the D.R. solutions, e.g. with the solution of Berends et al /4/.

The phase of the multipole $M_{1+}^{3/2}$ is taken in an analytical form from /3/.

b) The analysis of the data on the differential cross section and the assymetry in the reaction $\gamma p \to p\pi^0$ shows that the amplitude $E_{1+}^{3/2}$ in the resonance region is about (3-4)% of the amplitude $M_{1+}^{3/2}$ and has the same sign /I0/.

The various solutions of D.R. /4,II/ differ in sign of the amplitude $E_{1+}^{3/2}$ in the resonance region. The curve shown in Fig.I correspond to the positive sign of the ratio $E^{3/2}_{1+}/M^{3/2}_{1+}$ in the resonance. We have estimated the uncertainty arising from the other solutions and have found that it is about 5% at E_γ = 350MeV and lesser at lower energies.

c) The D.R. for the multipoles $E^{(-)}_{0+}$ and $M^{(-)}_{1-}$ have been solved by the method of successive approximations. In the first approximation the multipoles $E^{1/2,3/2}_{0+}$ and $M^{1/2,3/2}_{1-}$ were given by the Born terms and the dispersion integrals in which only the contribution $M^{3/2}_{1+}$ has been taken into account. In this approximation the real parts of $E^{1/2}_{0+}$ and $E^{3/2}_{0+}$, $M^{1/2}_{1-}$ and $M^{3/2}_{1-}$ have close magnitudes and opposite sign.

In the next approximation we have substituted these values for $E^{1/2,3/2}_{0+}$ and $M^{1/2,3/2}_{1-}$ in the dispersion integrals from the threshold up to 500MeV. Since the phases of the multipoles $E^{1/2}_{0+}$ and $E^{3/2}_{0+}$, $M^{1/2}_{1-}$ and $M^{3/2}_{1-}$, known from πN -scattering /I2/ are close in magnitudes and opposite in sign, then the corrections for $E^{(-)}_{0+}$ and $M^{(-)}_{1-}$ obtained in the second approximation appear to be insignificant: they are of the order of 2 and 6% for $E^{(-)}_{0+}$ and $M^{(-)}_{1-}$, respectively. Such a smallness of the corrections is an essential feature of the amplitude $H^{(-)}$ ($E^{(-)}_{0+}$ and $M^{(-)}_{1}$) ,while for the amplitudes $H^{(+,0)}$ this correction is larger.

The contribution of the energies from 500 up to I200 MeV to the dispersion integral has been estimated using the Walker analysis /9/, it introduces an 3% uncertainty in the differential cross section at E_γ = 350 MeV. Thus the isotopic combination $H^{(-)}$ considered by us is effectively determined by the Born term and the resonant amplitude $M^{3/2}_{1+}$ in the dispersion integral. The corrections connected with the multipoles $E^{(-)}_{0+}$, $M^{(-)}_{1-}$ and $E^{3/2}_{1+}$ are taken into account, and for this combination they appear to be insignificant.

The theoretical curve for the differential cross sections at E_γ=350MeV is shown in Fig.I and is in good agreement with /4/.

5. Let us discuss the obtained result. At E_γ = 200 and 280 MeV the experimental data are in good agreement with the theoretical predictions following from D.R. At E_γ = 350 MeV the D.R. predictions sharply diverge from the sum (I) of the experimental differential cross sections of the charged pion photoproduction at large angles.

There is a necessity to define more precisely the experimental data on the reaction $\gamma n \rightleftarrows p\pi^-$ in the resonance region. An additional study of this reaction in the region of Δ (I236) resonance is of great interest for the verification of the dispersion relations at fixed t. If further experiments confirm the data of the works /I,2/, then the contradiction discussed here will present a serious difficulty for the dispersion relation applied in the usual way of C.G.L.N. /8/. This contradiction may be related with the violation of T-invariance /5,6/, but this question requires further detail study.

The authors are much indebted to S.B.Gerasimov, L.I.Lapidus, S.H.Matinian, M.I.Podgoretsky, B.N.Valuev and especially V.I.Ogievetsky and L.D.Soloviev for helpful discussions, and want to thank G.R.Gulkanian for his help in carrying out numerical calculations on the computer.

Received by Publishing Department
on September I5, I97I

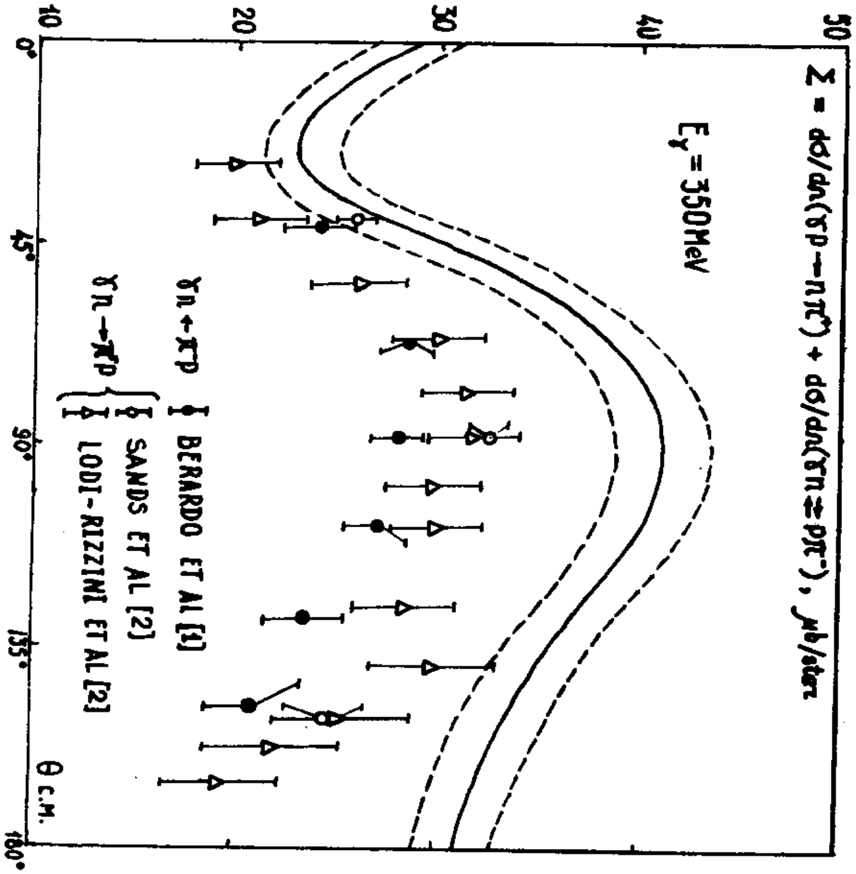

Fig. 1

Figure Caption

Fig.I. Predictions of dispersion relations for Σ and the experimental data: solid curves correspond to our calculations; dotted lines show the possible uncertainties of the calculations described in this work. The data on the reaction $\gamma p \to n\pi^+$ are taken from /13/. The theoretical curve at large angles is of (40-60)% higher than the experimental data.

References

I. P.A.Berardo et al., Phys.Rev.Letters, 26, 20I(I97I).

2. E.Lodi-Rizzini et al., Lettere Nuovo Cimento, 3, 697(I970); H.Sands et al., Phys.Rev., 95, 592(I954).

3. W.Schmidt, Z.f.Physik, I82, 76(I964).

4. F.A.Berends, A.Donnachie and D.L.Weaver, Nucl.Phys., B4, I(I967).

5. A.I.Sanda and G.Shaw, Phys.Rev.Letters, 24, I3I0(I970); Columbia preprint NYO-I932(2)-I68 (I970); Preprint DNPL/P 6I (I970).

6. P.A.Berardo et al., Phys.Rev.Letters, 26, 205(I97I).

7. V.G.Grishin, V.L.Lyuboshitz, V.I.Ogievetsky, and M.I.Podgoretsky, Yadernaya Fizika, 4, I26 (I966); N.Dombey and P.K.Kabir, Phys.Rev. Letters, I7, 730(I966).

8. G.F.Chew et al., Phys.Rev., I06, I345(I957).

9. K.L.Walker, Phys.Rev., I82, I729(I969).

I0. W.Schmidt and H.Wunder, Phys.Letters, 20, 54I(I96I).

II. P.Finkler, Preprint UCRL 7953-T (I964); W.Korth et al., Bonn preprint (I965).

I2. A.Donnachie et al., Phys.Letters, 26B, I6I(I968).

I3. D.Freytag, W.J.Schwille, R.J.Wedemeyer, Z.Physik, I86, I(I965).