Laboratori Nazionali di Frascati

LNF-69/68

P. Spillantini, V. Valente, M. Nigro and C. Oleari : MULTIPOLE ANALYSIS OF π^+ PHOTOPRODUCTION WITH LINERALY POLARIZED γ-RAYS AROUND THE FIRST RESONANCE (W = 1236 MeV)

Estratto da : Nuclear Phys. B13, 320 (1969).

8.A.8
8.B.5

Nuclear Physics B13 (1969) 320-328. North-Holland Publ. Comp., Amsterdam

MULTIPOLE ANALYSIS OF π^+ PHOTOPRODUCTION WITH LINEARLY POLARIZED γ-RAYS AROUND THE FIRST RESONANCE (W = 1236 MeV)

P. SPILLANTINI and V. VALENTE
Laboratori Nazionali di Frascati del CNEN, Frascati, Italy

and

M. NIGRO and C. OLEARI
Istituto Nazionale di Fisica Nucleare, Sezione di Padova, Padova, Italy

Received 29 May 1969

In photoproduction's analysis the usual comparison between the theoretical previsions and the experimental results does not give an unique or conclusive reply about the elementary amplitudes (multipoles) involved in that process. In fact if one tries to resolve the discrepancies between the theory and the experiments in terms of one of more elementary amplitudes, the choice of these is completely arbitrary, depending only on the refinement of the theoretical calculations (see for example ref. [1]). On the other way an iterative method, as that described and discussed in ref. [2], cannot improve accurately the validity of the zeroth-order approximations as the method is convergent only to solutions that fall very close to the starting point.

For these reasons the indeterminations of the theoretical previsions for the multipole amplitudes are somewhere very large (see ref. [1]) and also a statement on the sign of some amplitude is impossible (for example $\mathrm{Im}\, E^3_{1^+}$ at resonance).

It is our opinion that the experimental knowledge is sufficient to achieve, by means of a completely phenomenological approach, the whole set of the dominant amplitudes.

We present here the results of an analysis of this type, such results have to be regarded as preliminary for we have used only the experimental data concerning the photoproduction of π^+ by polarized γ-rays.

The total photoproduction amplitude has been expanded in multipole amplitudes taking in account multipole with $l \leq 1$, where l is the orbital angular momentum of the pion; states with $l > 1$ were included only in Born-approximation. From this hypothesis and from the Watson's theorem (for energies around the first resonance, W = 1236 MeV, we can assume the elasticity for all partial waves), taking as known the phase shifts of the pion-nucleon scattering (ref. [3]), we can write all the experimental quantities as functions of the four amplitudes E_{0^+}, M_{1^-}, E_{1^+}, M_{1^+}. Each of these amplitudes has the following isospin structure, for π^+ photoproduction

$$M_{l_J} = \frac{\sqrt{2}}{3}\left(3M_{l_J}^{(0)} + M_{l_J}^{(\frac{1}{2})} - M_{l_J}^{(\frac{3}{2})}\right) = \frac{\sqrt{2}}{3}\left(M_{l_J}^{(1)} - M_{l_J}^{(3)}\right), \tag{1}$$

in the usual notation.

So with the preceeding hypothesis we have to determine eight unknown amplitudes.

As experimental information we used the values of the asymmetry ratio $(A(\theta, E_\gamma))$ given in ref. [4] and the corresponding (i.e. at the same kinematical conditions) values of the unpolarized cross section. For the last quantity we used the results of a bi-dimensional fit on all the available experimental data (ref. [5]). In such way we obtained a total of 184 experimental points in the energy range $210 \leqslant E_\gamma \leqslant 430$ MeV, divided among 14 values of E_γ, with at least 10 points for each energy.

To solve for the eight unknown multipoles we used a least square condition, i.e. we tried to minimize the function defined by

$$\chi^2 = \sum_i \left[\left(\frac{(\mathrm{d}\sigma^i/\mathrm{d}\Omega_{\mathrm{calc}}) - (\mathrm{d}\sigma^i/\mathrm{d}\Omega_{\mathrm{exp}})}{\epsilon_i}\right)^2 + \left(\frac{A^i_{\mathrm{calc}} - A^i_{\mathrm{exp}}}{\epsilon_i}\right)^2\right].$$

Here $(\mathrm{d}\sigma/\mathrm{d}\Omega)^i_{\mathrm{exp}}$ denotes the experimental cross section by unpolarized photons, and $(\mathrm{d}\sigma/\mathrm{d}\Omega)^i_{\mathrm{calc}}$ is the corresponding calculated quantity; $A^i_{\mathrm{exp(calc)}}$ are respectively the experimental and calculated asymmetry ratios [4]; ϵ_i denotes the experimental error. Summation is taken over the experimental points for each value of E_γ. The calculation was carried out by means of a statistical method. A Monte-Carlo computing program generates a random eight-components vector, calculates the quantities $(\mathrm{d}\sigma/\mathrm{d}\Omega)^i_{\mathrm{calc}}$ and A^i_{calc} and then, comparing with the experimental points, the χ^2 function. Only solutions whose χ^2 was less than a prefixed value were recordered;

Table 1

E_γ (MeV)	$\chi^2_{\max}/N$ points	$\chi^2_{\min}/N$ points
210	1.05	0.70
220	1.05	0.55
230	0.80	0.45
240	1.00	0.80
250	1.50	1.10
260	2.00	1.75
270	2.70	2.40
290	2.85	2.45
310	2.10	1.60
330	1.90	0.65
350	1.60	0.65
370	1.15	0.45
400	1.20	0.30
430	0.45	0.02

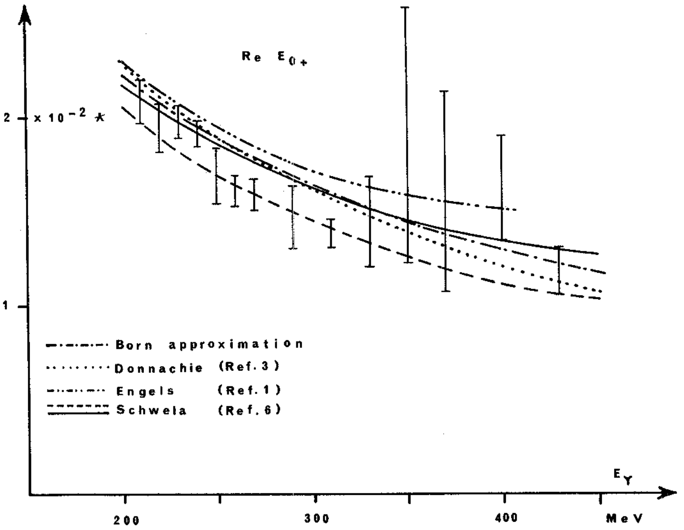

Fig. 1a. Experimental results for Re E_{0^+} versus E_γ.

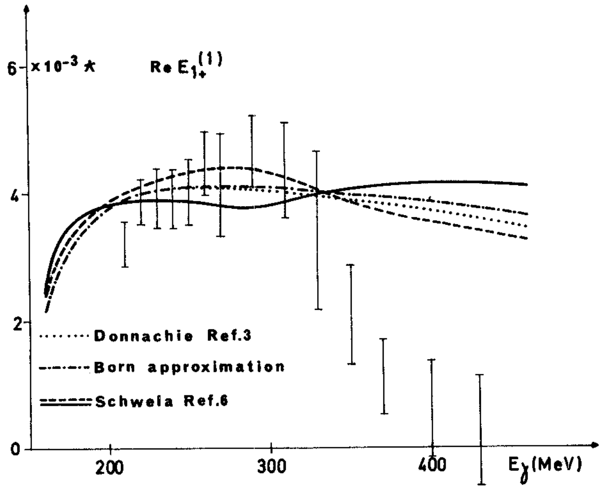

Fig. 1b. Experimental results for Re $E_{1^+}^{(1)}$ versus E_γ.

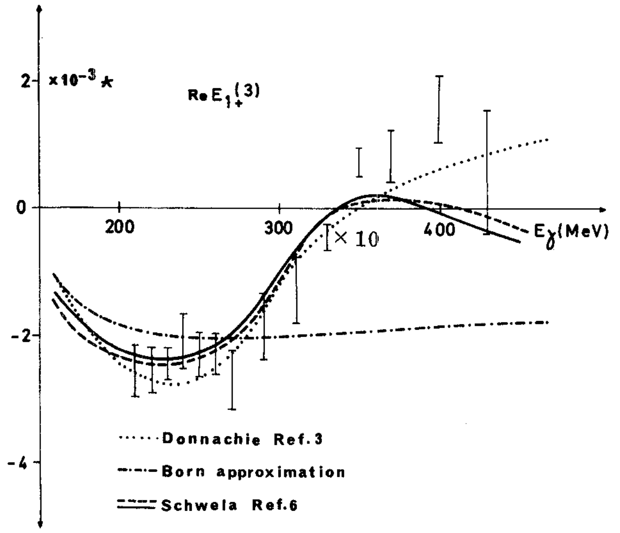

Fig. 1c. Experimental results for $\mathrm{Re}\,E_{1+}^{(3)}$ versus E_γ.

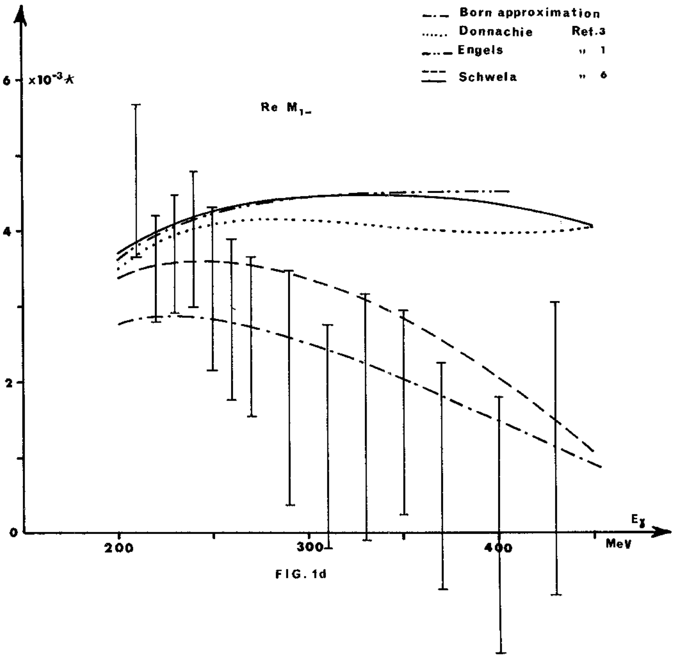

FIG. 1d

Fig. 1d. Experimental results for $\mathrm{Re}\,M_{1-}$ versus E_γ.

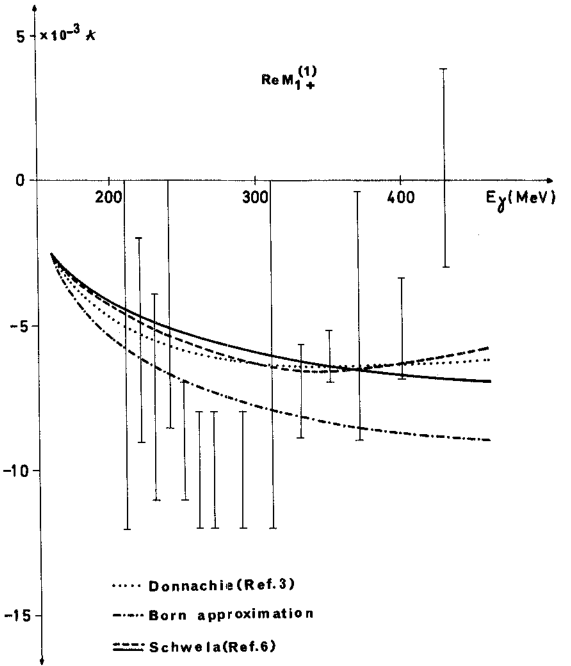

Fig. 1e. Experimental results for $\mathrm{Re}\,M_{1+}^{(1)}$ versus E_γ.

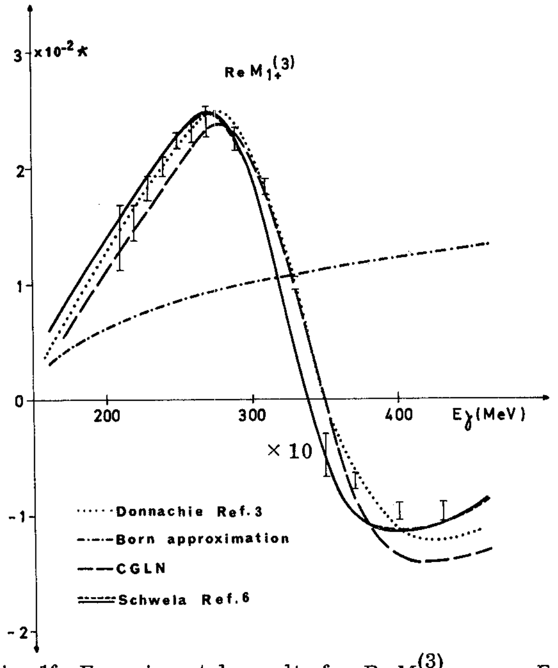

Fig. 1f. Experimental results for $\mathrm{Re}\,M_{1+}^{(3)}$ versus E_γ.

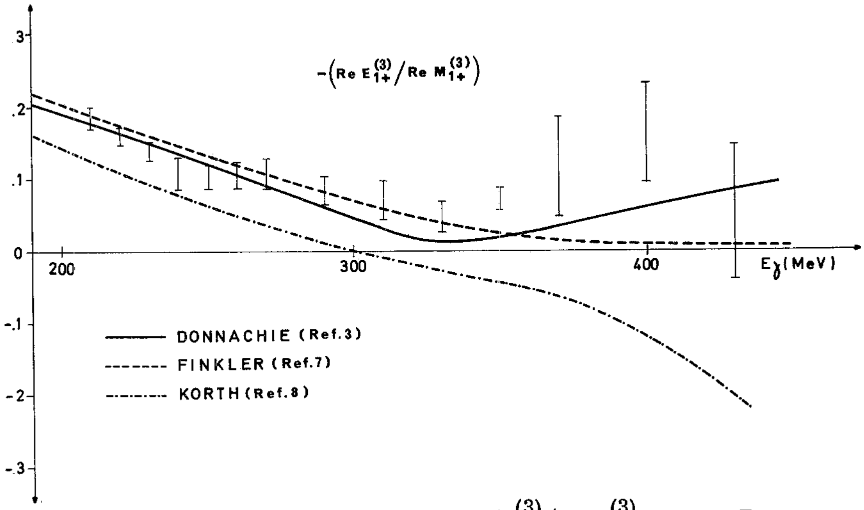

Fig. 2. Experimental results for $(\mathrm{Re}E_{1+}^{(3)}/\mathrm{Re}M_{1+}^{(3)})$ versus E_γ.

in these solutions, from the frequency distributions for each component, were determined the mean values and the accuracy (as standard error) of the multipoles.

The variability ranges of the multipoles were taken two or three times the maximum theoretical uncertainties [1].

In table 1 we give for each E_γ, the minimum and the maximum value of χ^2 (divided by the number of the experimental points) of the accepted solutions. The results are shown in figs. 1a-1f.

From the obtained results we can achieve the following conclusions:

(i) the goodness of the solution decreases in the energy range 260-330 MeV; it is our opinion that such effect depends on the adopted hypothesis. In fact the interference terms between the imaginary parts of the multipoles with $l = 2$ and the resonant ones can become relevant in the region around the first pion-nucleon resonance. This indication is suggested also by the polynomial analysis reported in ref. [9];

(ii) the isospin components of E_{0^+} and M_{1^-} (i.e. $E_{0^+}^1$, $E_{0^+}^3$ and $M_{1^-}^1$, $M_{1^-}^3$) cannot be determined separately, while the combination (1) is well established. This reflects the circumstance that the examined quantities are not sensitive to the imaginary parts of these multipoles, also for the smallness of their phase shifts;

(iii) the mean values of the resonant amplitudes do not depend on the accuracy of the other multipole. For this we obtain a good determination of the ratio E_{33}/M_{33} (see fig. 2).

In figs. 3a-3d we compare some angular distributions of the π^+ cross section calculated from our multipoles with all the available experimental points. The impossibility of separating the isospin components of E_{0^+}, M_{1^-} multipoles prevents us to calculate the analogous cross section for π^0 production.

We think that the results of the present work demonstrate the possibility

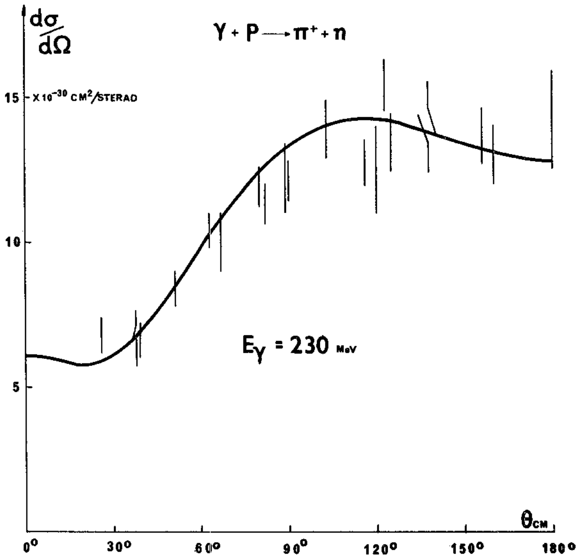

Fig. 3a. Experimental π^+ photoproduction cross section, all existing data at: $E_\gamma = 230$ MeV, compared with the cross section calculated from our multipoles.

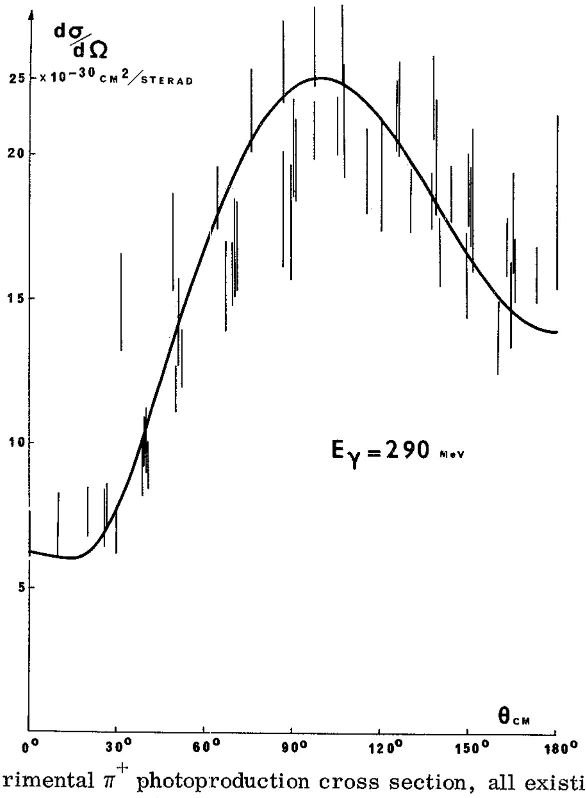

Fig. 3b. Experimental π^+ photoproduction cross section, all existing data at: $E_\gamma = 290$ MeV, compared with the cross section calculated from our multipoles.

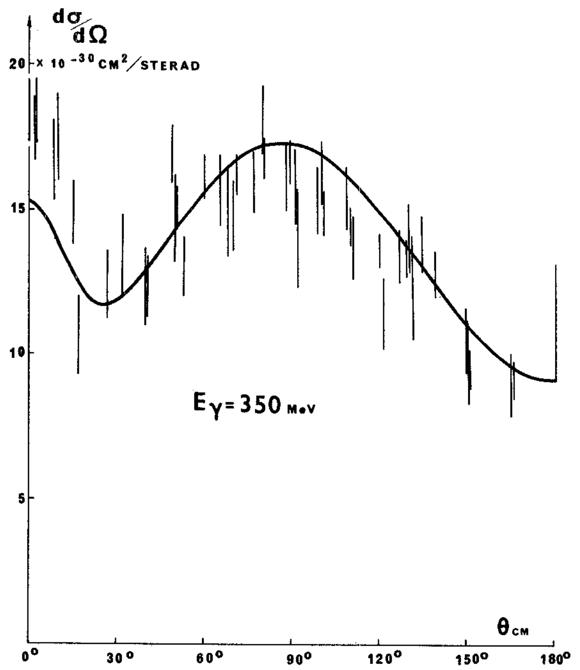

Fig. 3c. Experimental π^+ photoproduction cross section, all existing data at: $E_\gamma = 350$ MeV, compared with the cross section calculated from our multipoles.

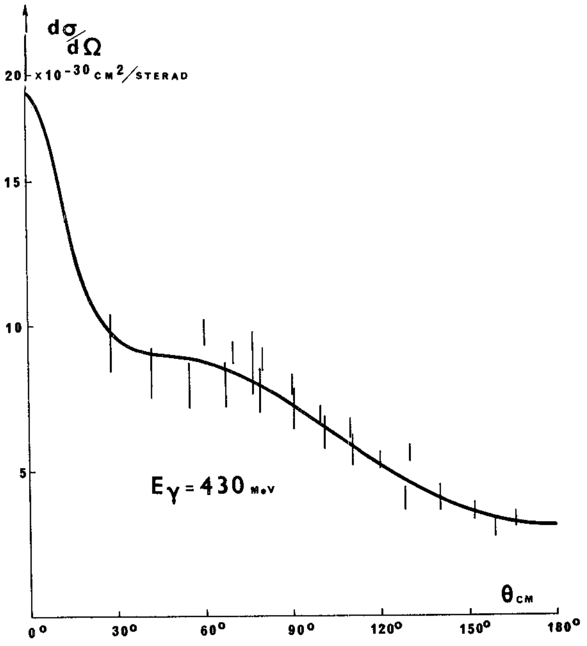

Fig. 3d. Experimental π^+ photoproduction cross section, all existing data at: $E_\gamma = 430$ MeV, compared with the cross section calculated from our multipoles.

of a completely phenomenological determination of the elementary amplitudes in photoproduction.

The inclusion in such analysis of the π^0 experimental informations (cross section, asymmetry, recoil polarization) will enable us to evaluate uniquely all the isospin components of the multipoles; besides we can try to evaluate also the multipoles with $l = 2$.

REFERENCES

[1] J. Engels, M. Müllensiefen and W. Schmidt, SLAC-PUB-415 (1968); submitted to Phys. Rev.
[2] T. Wennstrom, Nucl. Phys. B5 (1968) 235.
[3] F. A. Berends, A. Donnachie and D. L. Weaver, Nucl. Phys. B4 (1968) 1.
[4] M. Grilli, P. Spillantini, F. Soso, M. Nigro, E. Schiavuta and V. Valente, Nuovo Cimento 54A (1968) 877.
[5] P. Spillantini and V. Valente, LNF-Internal report, in press.
[6] D. Schewela, Thesis, Bonn University.
[7] P. Finkler, UCRL-7953-T (1964).
[8] W. Korth, H. Rollnik, D. Schwela and R. Weizel, Z. Physik 202 (1967) 452.
[9] M. Grilli, P. Spillantini, V. Valente, M. Nigro and E. Schiavuta, submitted to Nuovo Cimento for publication.