COMITATO NAZIONALE PER L'ENERGIA NUCLEARE
Laboratori Nazionali di Frascati

LNF-71/44
23 Agosto 1971

F. Carbonara, L. Fiore, G. Gialanella, E. Lodi-Rizzini, G. Mantovani, M. Napolitano, A. Piazza, A. Piazzoli, R. Rinzivillo, V. Rossi, G. Susinno and L. Votano : THE FORMATION OF $P_{11}(1470)$ RESONACE IN THE γ-n INTERACTION.

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F. Carbonara[(x)], L. Fiore[(x)], G. Gialanella[(x)], E. Lodi-Rizzini[(o)], G. Mantovani[(o)], M. Napolitano[(x)], A. Piazza, A. Piazzoli[(o)], R. Rinzivillo[(x)], V. Rossi[(+)], G. Susinno, L. Votano[(*)]: THE FORMATION OF $P_{11}(1470)$ RESONANCE IN THE γ-n INTERACTION.

The question whether the $P_{11}(1470)$ resonance can be photoproduced on nucleons has become of relevant interest in the last years because of its connection with the assignment of this resonance to an SU(3) multiplet and the related consequences on the quark model.

The P_{11} resonance has been established in many reactions induced by protons, pions and kaons both on proton and neutron[(1)].

If the P_{11} belongs to an SU(3) antidecuplet, it can be photoproduced on neutron only, because of the U-spin conservation[(2)].

Experimentally it seems that the P_{11} is not photoproduced on proton[(3)] and than an accurate investigation of the same reactions on neutron can contribute to its assignment to an SU(3) multiplet.

A further powerful way of testing the P_{11} assignment comes from the consideration that if the P_{11} belongs to $\overline{10}$ its decay in $\Delta + \pi$ is forbidden since $8 \otimes 10$ does not contain $\overline{10}$.

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Some previous experimental results[4], compared with theoretical calculation seemed to rull out the P_{11} photoexcitation on neutron.

In order to investigate the formation of the $P_{11}(1470)$ in pion photoproduction on neutron and its possible assignment to on SU3 antidecuplet, we report in this letter.

a) the results of an analysis on total and differential cross-sections of the reaction

(1) $$\gamma + n \rightarrow p + \pi^-$$

published in a previous letter;

b) the results of a fit to pion-nucleon effective mass distributions in the reactions

(2) $$\gamma n \rightarrow n\pi^+\pi^-$$

(3) $$\gamma p \rightarrow p\pi^+\pi^-$$

observed in the same experiment.

The complete experimental results of these reactions will be published elsewhere.

In Fig. 1 the total cross-section of the reaction (1) is shown. The superimposed curve is the total cross-section for the corresponding reaction on proton i.e. $\gamma + p \rightarrow n + \pi^+$.

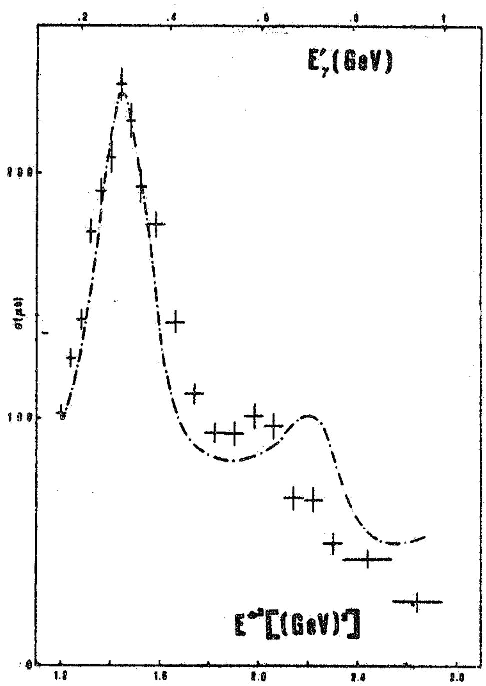

FIG. 1 - Total cross-section for the reaction $\gamma + n \rightarrow p + \pi^-$ as a function of E^{*2} (c.m. energy squared for the $\pi^- p$ system); + present work, - • - • - • - $\gamma + p \rightarrow n + \pi^+$ (ref. (5)).

In order to make the comparison with the cross-section on free proton, we always refer to the squared c.m. energy E^{*2} of the $(p\,\pi^-)$ final state.

For convenience, the energy E'_γ is also quoted which is the photon energy necessary to get the same E^{*2} on a free nucleon.

The quite different behaviour in the region of the so called second resonance is evident.

We tried to interprete the peak at $E'_\gamma = 580$ MeV as due to the $D_{13}(1520)$ resonance shifted back because of the interference between the resonant and no-resonant amplitude, assumed as given by Born terms with electric coupling only.

Assuming a resonant amplitude of the Breight-Wigner type for the D_{13} multipoles (E_{2^-}, M_{2^-}) because of the interference, the cross section bump can be shifted back at most to $E_\gamma \approx 700$ MeV. Repeating the calculation with a resonant M_{1^-} multipole the amplitude needed to shift the bump back to 580 MeV agrees with the one found in the phenomenological fit.

This fact rapresents the first strong evidence for the formation of the P_{11} in γ- n interaction.

Further evidence for the P_{11} excitation is obtained in a phenomenological fit of the differential cross-sections extending from 400 to 1000 MeV and including some data on polarization[5] and asymmetry[6] in the reaction (1).

For the method used and the formalism adopted we refer to the paper by Walker[8].

In his work Walker adds to the gauge invariant Born terms with electric coupling only and to the resonant ones some background contributions varying very slowly with energy.

We assumed these contributions to be purely real and constant in the whole energy interval.

In table I our results for the resonant amplitudes and the added contributions are presented, together with the results of the fit by Walker for π^+ photoproduction.

The χ^2/(degree of freedom) of the fit was 1.4.

Fig. 2 shows our differential and total cross sections together with the fitted curves.

The polarization and asymmetry values obtained in our fit are presented in Fig. 3.

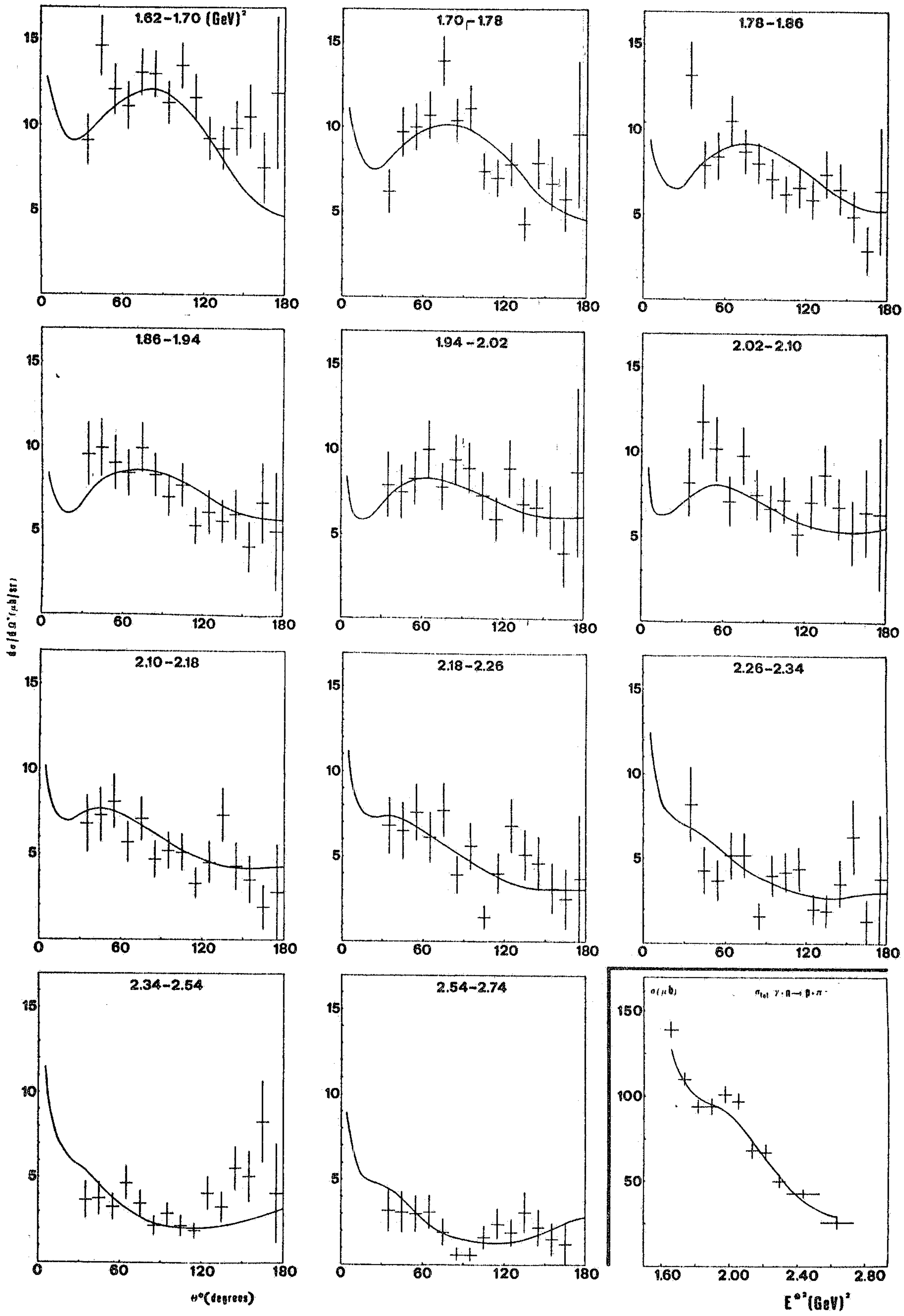

FIG. 2 - Differential cross-sections for eleven intervals of E^{*2} as a function of θ^{*}, the angle between the π^- and the incident photon in the $\pi^- p$ c. m. s. Total cross section for the same energy intervals is also reported. The superimposed curves are the result of the fit.

TABLE I

Resonant helicity element	Added contributions	Resonance	Energy W_o (GeV)	Width Γ_o (GeV)	Walker results for $A^+(W_o)$ ($\mu b^{1/2}$)	Our results for $A^-(W_o)$ ($\mu b^{1/2}$)
A_{1^+}		P_{33}	1.236	0.120	1.00	1.00 (Fixed to Walker value)
	ΔA_{1^+}					$-0.35^{+0.11}_{-0.05}$
B_{1^+}		P_{33}	1.236	0.120	-2.43	-2.43 (Fixed to Walker value)
	ΔB_{1^+}					$1.21^{+0.07}_{-0.07}$
A_{2^-}		D_{13}	1.519	0.102	-0.20	$-0.25^{+0.09}_{-0.09}$
	ΔA_{2^-}					$-0.36^{+0.07}_{-0.08}$
B_{2^-}		D_{13}	1.519	0.102	-1.32	$-0.15^{+0.09}_{-0.14}$
	ΔB_{2^-}					$0.96^{+0.02}_{-0.07}$
A_{0^+}		S_{11}	1.561	0.180	-0.65	$-0.36^{+0.16}_{-0.15}$
	ΔA_{0^+}					$0.71^{+0.11}_{-0.09}$
A_{1^-}		P_{11}	1.471	0.200	-0.25	$-1.06^{+0.08}_{-0.09}$
	ΔA_{1^-}					$0.55^{+0.10}_{-0.12}$

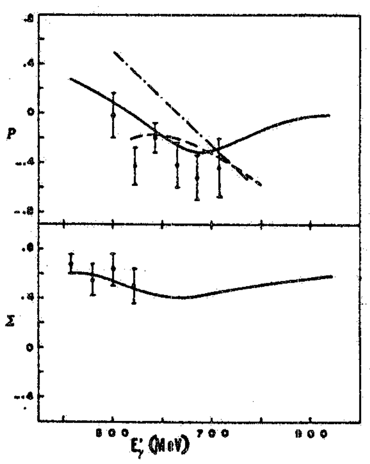

FIG. 3 - Polarization P and asymmetry Σ as obtained in our fit together with the experimental results of refs. (6) and (7) as a function of E'_γ (for the meaning of E'_γ see text).

The most impressive feature of this analysis is the strong depression of the D_{13} and the large contribution of the P_{11} with respect to π^+ photoproduction.

This fact argues for the asignment of the P_{11} to an SU(3) antidecuplet. If this is the case the decay of the P_{11} in $\Delta + \pi$ is forbidden. As a consequence the $\Delta(1236)$ production in the final state of the reaction (2) must be quite different from that in reaction (3), in which the channel $\Delta^{++}\pi^-$ is predominant in the energy region of the P_{11}.

We carried out a preliminary analysis of the production of $\Delta(1236)$ in the final state of the reactions (2) and (3) by fitting the two body effective mass distribution under the following simplifying assumptions:

i) In the reactions (2) and (3) the production of $\Delta(n\,\pi^-)$ and $\Delta(p\,\pi^+)$ is predominant with respect to that of $\Delta\,(n\,\pi^+)$ and $\Delta\,(p\,\pi^-)$, as suggested also by previous results in hydrogen[9];

ii) We neglect any interference effects between the different Δ charge states.

An energy dependent Breight-Wigner formula was used. The fitted parameter is the Δ percentage with respect to the phase-space contribution.

The results of the fit are reported in table II. Figs. 4 and 5 show the squared mass distributions and the fitted curves.

TABLE II

E^{*2} (GeV)^2	$\gamma n \to n\pi^-\pi^+$		$\gamma p \to p\pi^+\pi^-$	
	% Δ^-	χ^2/ν	% Δ^{++}	χ^2/ν
1.54 - 1.84	38 ± 7	1.2	38 ± 9	0.5
1.84 - 1.94	76 ± 7	0.9	73 ± 7	2.8
1.94 - 2.02	56 ± 10	0.7	86 ± 7	0.5
2.02 - 2.10	68 ± 10	1.1	89 ± 8	1.1
2.10 - 2.20	34 ± 11	1.5	77 ± 10	1.3
2.20 - 2.30	65 ± 11	0.9	59 ± 14	0.9
2.30 - 2.46	55 ± 12	0.8	72 ± 10	0.7
2.46 - 2.60	43 ± 40	1.7	46 ± 13	1.1

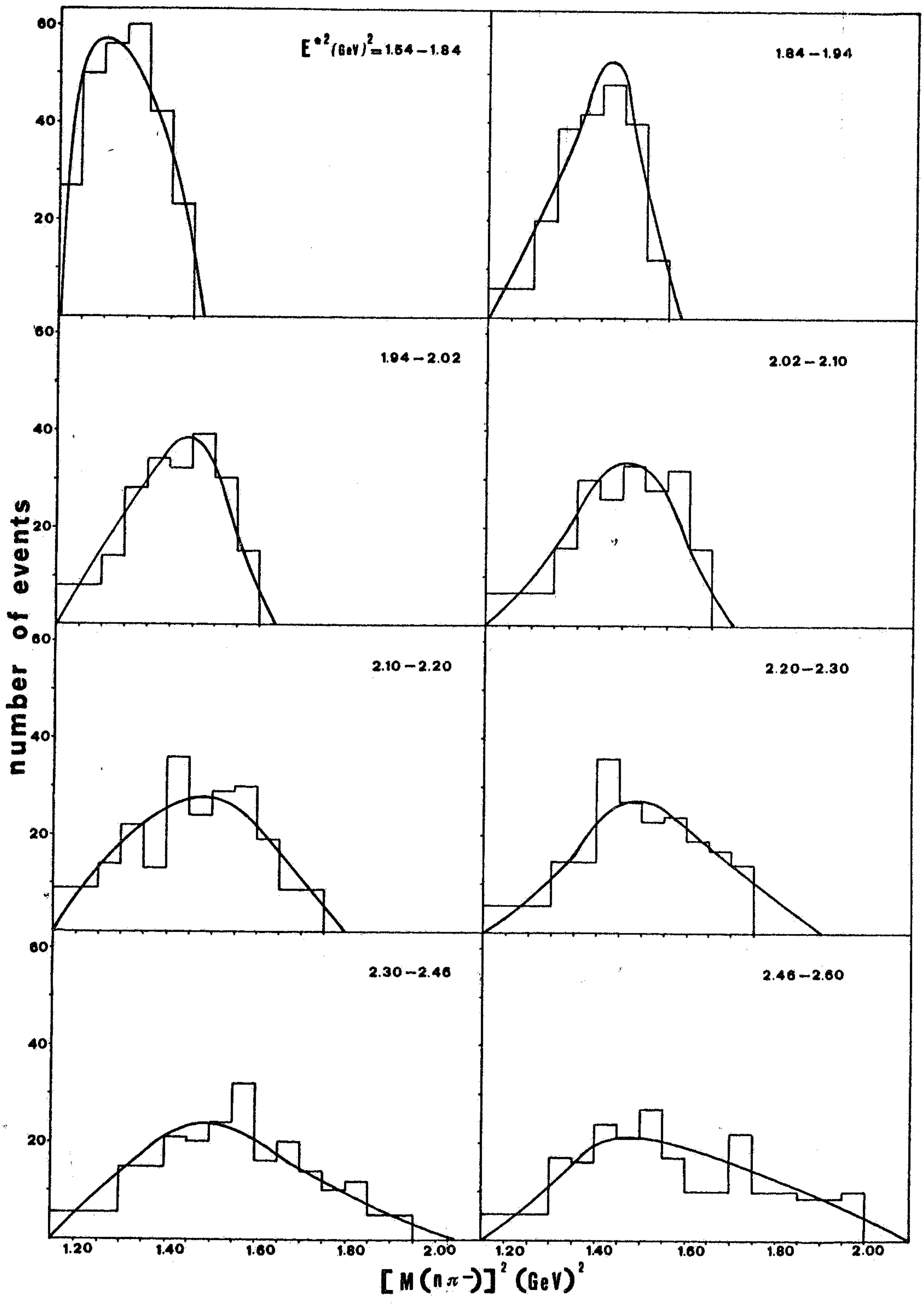

FIG. 4 - Squared effective mass distributions $n\pi^-$ in the reaction (2) for eight intervals of E^{*2} (c. m. energy squared for the $n\pi^-\pi^+$ system). The curves are the result of the fit.

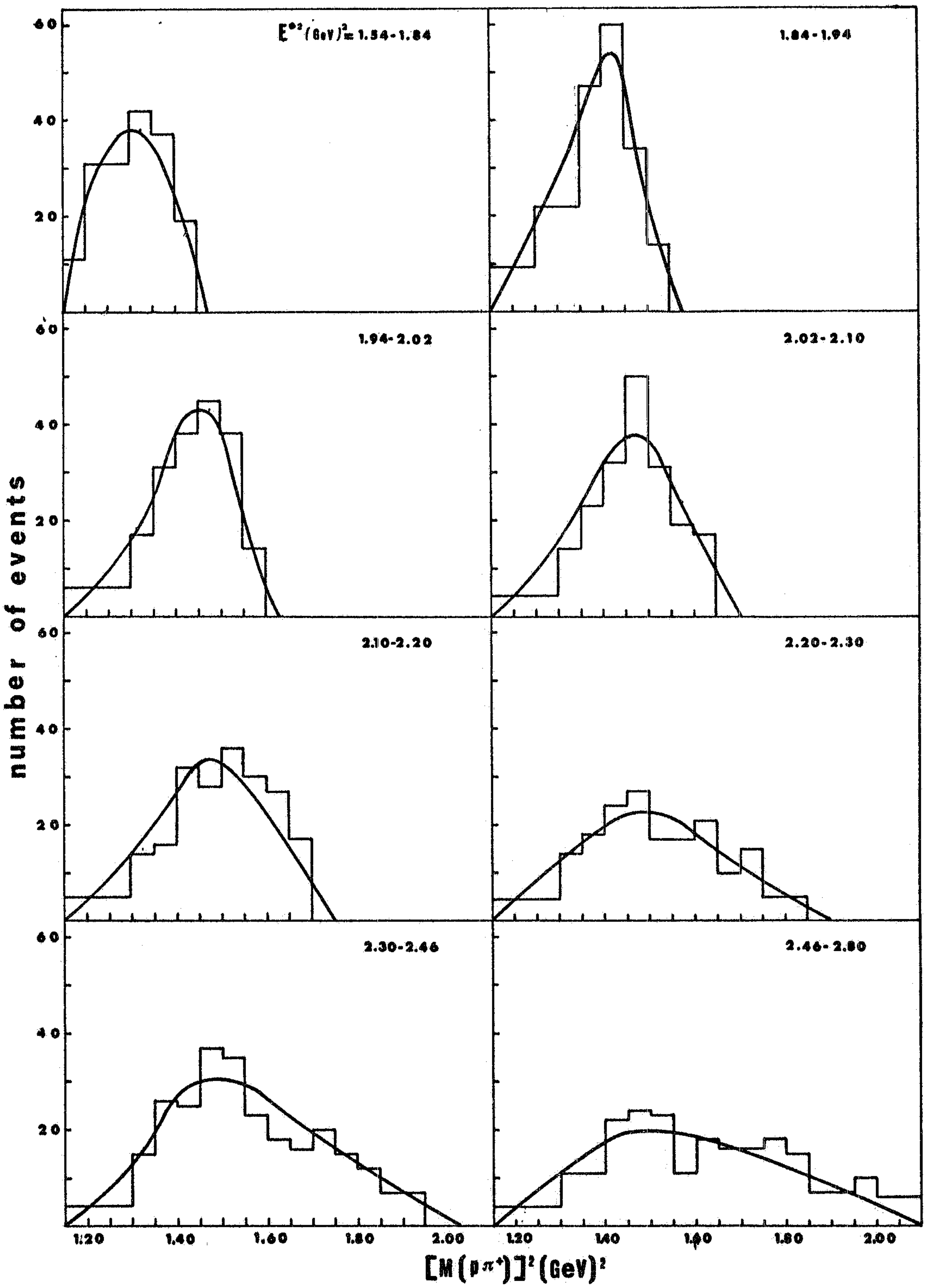

FIG. 5 - Squared effective mass distributions $p\pi^+$ in the reaction (6) for eight intervals of E^{*2} (c.m. energy squared for the $p\pi^+\pi^-$ system). The curves are the result of the fit.

As can be seen the percentage of Δ^- is significantly smaller than the Δ^{++} percentage in the P_{11} energy region ($550 \leq E'_\gamma \leq 700$ MeV).

We want to stress that the comparison between the reactions (2) and (3) is particularly meaningful, since the data for both reactions are obtained in the same experiment.

We conclude that:

a) The experimental results on the reaction (1) and the related analysis show that the $P_{11}(1470)$ is strongly photoexcited on neutron.

b) The result of the analysis of the effective mass distributions of reactions (2) and (3), although not a proof, is, however, indicative that the P_{11} does not decay in $\Delta + \pi$.

From a) and b), together with the experimental fact that in the photoproduction reactions on proton the P_{11} was not observed, we conclude that this resonance could be classified into an SU(3) antidecuplet.

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