# A MODEL FOR THE $\gamma N \to \pi\pi N$ REACTION*

J.A. GÓMEZ TEJEDOR AND E. OSET

Departamento de Física Teórica and IFIC
Centro Mixto Universidad de Valencia-CSIC
46100 Burjassot (Valencia), Spain

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We have studied the $\gamma N \to \pi\pi N$ reaction using a model which includes $N$, $\Delta(1232)$, $N^*(1440)$ and $N^*(1520)$ intermediate baryonic states and the $\rho$-meson as intermediate $\pi\pi$ resonance. The model reproduces fairly well experimental cross sections below $E_\gamma = 800$ MeV and invariant-mass distributions even at higher energies. One of the interesting findings of the study is that the $\gamma N \to N^*(1520) \to \Delta\pi$ process is very important and interferes strongly with the dominant $\Delta$-Kroll-Ruderman term to produce the experimental peak of the cross section.

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## 1. Introduction

The double pion photoproduction reactions on the proton have been extensively studied experimentally in the past ([1, 2, 3, 4]). New improvements in experimental techniques and facilities have reopened the study of these reactions at Mainz, with two experiments on the proton [5, 6].

Then, with this reaction becoming a target of new experimental study and interesting medium effects predicted for the $(\gamma, \pi^+\pi^-)$ reaction in nuclei [7], a thorough theoretical study of the $\gamma N \to \pi\pi N$ reaction is necessary. This task has been undertaken in Ref. [8].

## 2. The model

Our basic components are pions, nucleons and nucleonic resonances. We consider for the hadronic components $N$, $\Delta(1232)$, $N^*(1440)$ and $N^*(1520)$. The $N^*(1520)$ has a particularly large coupling to the photons and proves to

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be an important ingredient, mostly because its interference with the dominant component of the process, the $\gamma N \to \Delta\pi$ transition through the gauge $\Delta$-Kroll–Ruderman term. Higher resonances have a weaker coupling to photons and do not interfere with the dominant term, hence their contribution is small, at least for photon energies below 800 MeV, Mainz energies, where our model is meant to work.

The Feynman diagrams considered and detailed calculations can be found in Ref. [8].

## 3. Results

In Fig. 1 we show the total cross sections for the $\gamma p \to \pi^+\pi^- p$ isospin channel, as well as the contribution to the total cross section of diagrams with *nucleon*, $\Delta(1232)$, $N^*(1440)$, $N^*(1520)$ and $\rho(770)$ as intermediate states (in Ref. [8] we also showed results for the other isospin channels, as well as differential cross sections and invariant-mass distributions for the $\gamma p \to \pi^+\pi^- p$ channel). We show results up to $E_\gamma = 800$ MeV, where the new experiments at Mainz concentrate.

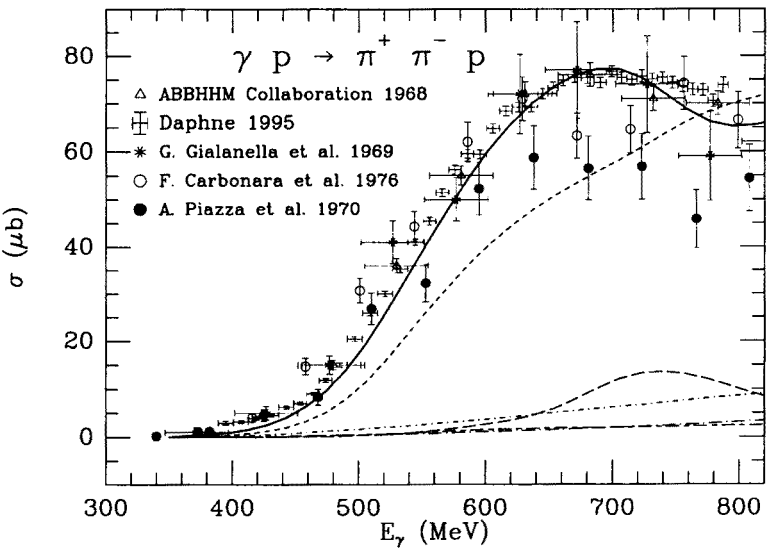


Fig. 1. Total cross section for the $\gamma p \to \pi^+\pi^- p$ reaction. Continuous line: total cross section. Short-dashed line: $\Delta(1232)$ contribution. Long-dashed line: $N^*(1520)$ contribution. Short-dash-dotted line: *nucleon* contribution. Long-dash-dotted line: $\rho$ contribution. Short-dash-long-dashed line: rest of the diagrams. Experimental data from Refs. [1–5].

The inclusion of the $N^*(1520)$ terms leads to an interference with the $\Delta$-Kroll-Ruderman terms which is responsible for the appearance of the maximum and a much better agreement with experiment. This interference occurs only between the $\Delta(1232)$-Kroll-Ruderman term and the $s$-wave part of the $N^*(1520)\Delta\pi$ contribution [8, 9].

## 4. Conclusions

We have constructed a model for the $\gamma N \to \pi\pi N$ reaction including *nucleons*, $\Delta(1232)$, $N^*(1440)$ and $N^*(1520)$ as intermediate baryonic states as well as $\rho$-meson intermediate states for the $\pi\pi$ system. Our model is rather complete, but still misses terms which become relevant from $E_\gamma =$ 800 MeV on. As in a previous model accounting for only a few of these diagrams [10] for the $\gamma p \to \pi^+\pi^- p$, we observe the dominance of the $\Delta$-Kroll-Ruderman and pion-pole terms but get an appreciable contribution from other terms. In particular we found the contribution of the $N^*(1520)$ resonance very important, and essential to produce the peak which is present in the experimental cross section around $E_\gamma = 680$ MeV.

Our model reproduces quite well the experimental results of Refs. [1, 5, 6] below $E_\gamma =$ 800 MeV for the $\gamma p \to \pi^+\pi^- p$ and $\gamma p \to \pi^0\pi^0 p$ isospin channels, but we have found some important discrepancies for the $\gamma p \to \pi^+\pi^0 n$ channel. For the isospin channels on the neutron we have found also some discrepancies with the old data of Refs. [1–5], but as we already mentioned in Ref. [8], these experiments should be improved.

Our model is also a starting point to generate exchange currents in nuclei. For instance, by producing one pion off-shell and attaching it to a nucleon line, we generate two body contributions to the $(\gamma, \pi)$ channel. Similarly, by producing the two pions off-shell and attaching them to two nucleons we generate three nucleon mechanisms which contribute to photon absorption in nuclei, and so on.

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