PHOTOPRODUCTION OF $\gamma p \rightarrow p\pi^0\eta$ AT ELSA IN BONN

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The study of nucleon resonances provides important information on many open questions in baryon spectroscopy. The key to any progress is the identification of the effective degrees of freedom leading to a qualitative understanding of strong QCD. The problem of *missing resonances* predicted by quark models is discussed on the basis of experimental results of the CB-ELSA experiment at the e^- accelerator ELSA in Bonn. Resonance production and even cascades of the type $N^{**}(\Delta^{**}) \rightarrow N^*(\Delta^*) \rightarrow p\pi^0\pi^0(p\pi^0\eta)$ are observed as well as $\eta\eta$ photoproduction off the proton. Indications for a Δ resonance around 1900 MeV are seen. The latter is particularly interesting if it had negative parity because a confirmation of this state would be in contradiction with constituent quark models[1,5]. Both, the quark models using one-gluon exchange and the quark model using instanton-induced forces as short-range residual quark-quark interaction predict the three states $\Delta_{5/2^-}(1930)$, $\Delta_{3/2^-}(1940)$ and $\Delta_{1/2^-}(1900)$ at masses in the 2100 MeV region.

1. Introduction

All current models describing the spectrum of baryon resonances predict a series of hitherto unobserved states. Their persistent non-observation would be a big problem for all models as they would fail to describe physical reality. There are at least two possible explanations which account for this open question. One is that these *missing resonances* do not exist if the 3 valence quarks of the nucleon are frozen into a quark-diquark substructure. This would reduce the number of effective degrees of freedom and, therefore, also the number of possible baryon states[2].

An alternative explanation is that those *missing resonances* have simply not been observed up to now. Almost all existing data result from πN elastic-scattering experiments and models focussing on baryon strong decays predict baryon states to be missing in πN elastic-scattering analyses

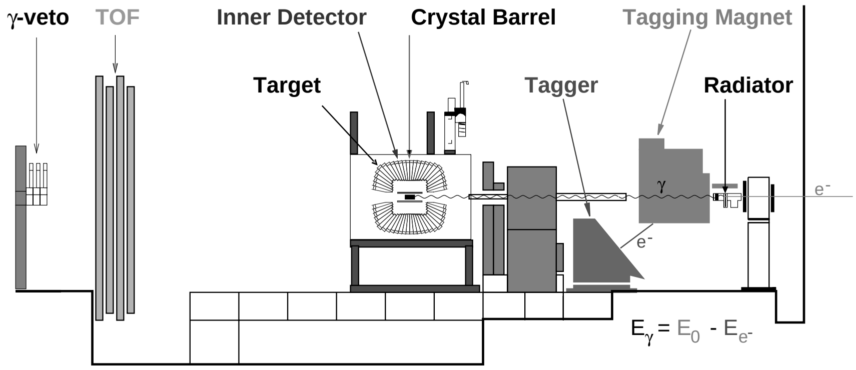

Figure 1. Start configuration for a first series of measurements

but to show up in electromagnetic production[3]. Those *resonances* should couple strongly to channels like $\Delta\pi$, for instance[4]. Thus, photoproduction experiments offer a large discovery potential.

2. The Crystal-Barrel Experiment at ELSA

The ELSA accelerator complex in Bonn provides electron beams up to energies of 3.5 GeV. A LINAC preaccelerates the particles which are then injected into an electron synchrotron. The latter provides electrons up to 1.6 GeV which are finally transferred to the stretcher ring ELSA[6].

2.1. *The experimental setup of the detector*

Electrons extracted from ELSA hit a primary radiation target and produced Bremsstrahlung. The corresponding energy of the photons ($E_\gamma = E_0 - E_{e^-}$) was determined in a tagging system by the deflection of the electrons in a magnetic field. This detector provided a tagged beam in the photon energy range from 25 % up to 95 % of the incoming electron energy. The setup of the CB-ELSA detector used for a first series of experiments is shown in Fig. 1. The calorimeter (Crystal Barrel) consisting of 1380 CsI(Tl) crystals covering about 98 % of 4π solid angle is an ideal detector for photons. The photoproduction target in the center of the Crystal Barrel has a length of 5 cm and was filled with liquid hydrogen. It is surrounded by a scintillating fibre detector which was built to detect and trigger charged particles leaving the target. In addition, it provides an intersection point of a particle's trajectory with the detector and hence helps to identify clusters of charged particles in the barrel. Due to the *in-flight* character of the experiment, the general conception is to combine the calorimeter with suitable forward detectors. In the start configuration, the system was extended by Time-Of-Flight walls of the ELAN experiment previously carried out at ELSA in Bonn. The latter formed together with the tagging system and the inner detector the first-level trigger of the experiment. The second level then consisted of a fast cluster encoder which is able to determine the number of clusters in the barrel. Current measurements are carried out with the photon spectrometer TAPS in the forward direction. In order to make best use of its high granularity and of TAPS as a fast trigger, the Crystal Barrel was opened downstream, i.e. 3 forward crystal rings were removed.

3. Preliminary results of the reaction $\gamma\,p \;\rightarrow\; p\,\pi^0\,\eta$

Data has been taken since December 2000 with the whole apparatus fully operating. Measurements at three different ELSA energies have been performed: $E_0 = 1400$, 2600 and 3200 MeV. In the following, results on the reaction $\gamma\,p \;\rightarrow\; p\,\pi^0\,\eta$ are presented. It has to be pointed out that all distributions are neither efficiency corrected nor any flux normalisation has been carried out. However, the reconstruction efficiency is almost flat in $\cos\theta$ (of the proton in the center-of-mass system) and energy. Furthermore, no final tracking has been performed, therefore, improvements can be expected. Figure 2 (a) shows the total invariant mass for the $p\,\pi^0\,\eta$ final state. No structures are visible at first sight. Different mass regions are indicated and the corresponding $p\pi^0$ mass spectra given. Hints for baryon resonances decaying into $\Delta\eta$ now become visible. In the total mass region around 1700 MeV, no structure can be seen, Fig. 2 (b). However, a clear peak at the Δ mass can already be observed in the mass region around 1900 MeV, Fig. 2 (c). As a matter of fact, we expect a series of resonances in this mass region with positive as well as with negative parity. In principle, it would be very difficult to disentangle them. However, we expect a small angular momentum between the emitted meson (η meson) and the known intermediate state ($\Delta(1332)$ in this case) due to the centrifugal barrier such that it should be possible to excite certain resonances selectively. In the case of the reaction $\gamma\,p \;\rightarrow\; p\,\pi^0\,\eta$, this idea will help to answer the question whether there are negative-parity Δ states in this region. For orbital angular momenta $l = 0$ or 1, we should expect contributions from the $P_{31}(1910)$, $D_{33}(1940)$ and $F_{35}(1905)$. For higher $p\,\pi^0$ masses, further resonance intensity may be hidden in a structure around 1600 MeV, Fig. 2 (e). One has to

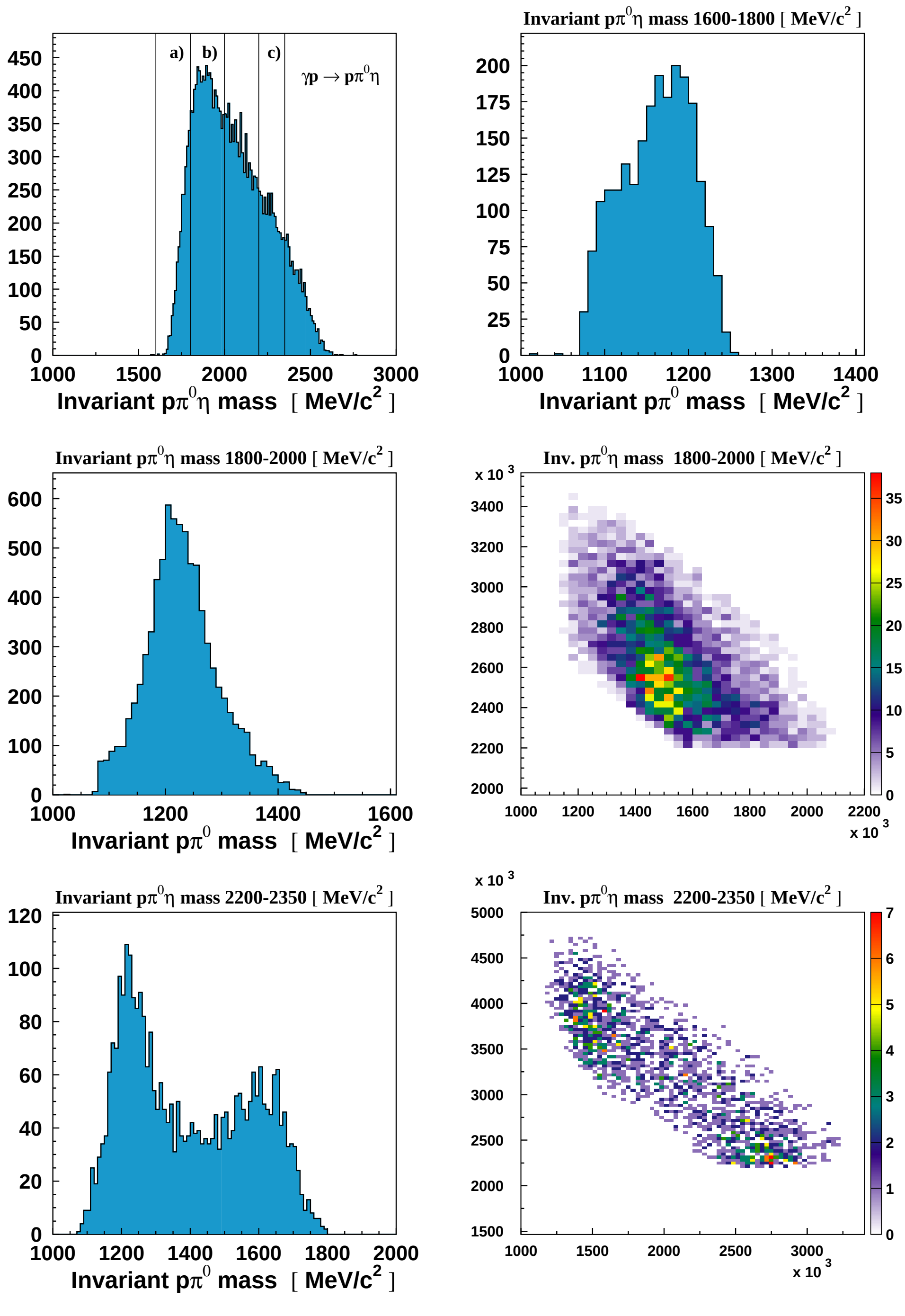

Figure 2. Different plots on the reaction $\gamma\,\mathrm{p} \;\rightarrow\; \mathrm{p}\,\pi^0\,\eta$. See text for details!

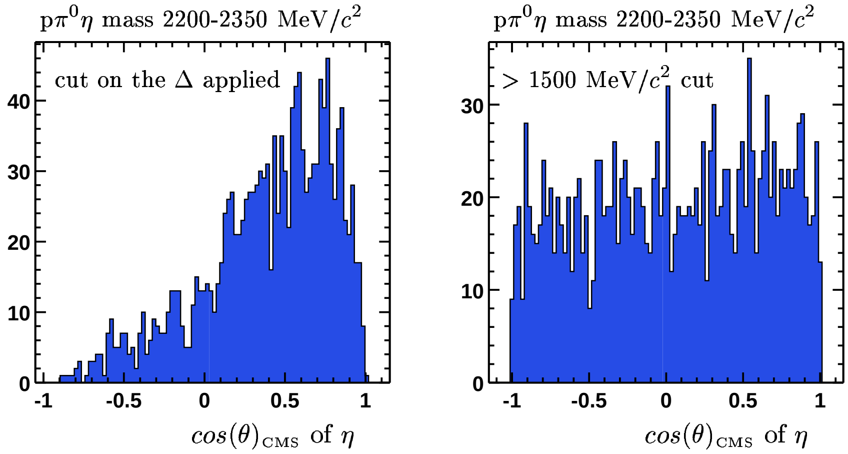

Figure 3. $cos(\theta)_{\mathrm{CMS}}$ **of** η **meson in the reaction** $\gamma\,\mathrm{p} \rightarrow \mathrm{p}\,\pi^0\,\eta$. ***A flat angular distribution can be interpreted as the decay of S-wave resonances. The*** $\Delta(1232)$ ***above 2.2 GeV in the total*** $p\pi^0\eta$ ***mass likely does not stem from resonances but is created via more complicated processes.***

be careful interpreting structures in the mass projections as those are often reflections of the corresponding Dalitz plots (Fig. 2 (d) and (f)).

More information is given by the CMS angular distributions of the η meson. For mass region (c) of Fig. 2 (a), a cut on the $\Delta(1232)$ in the $\mathrm{p}\,\pi^0$ system is applied as well as on higher masses ($m(\mathrm{p}\,\pi^0)$ > 1500 MeV/c^2), Fig. 3 (a) and (b), respectively. The flat angular distribution in Fig. 3 (b) is likely to stem from resonant S-wave decays. On the other hand, the angular distribution in Fig. (a) is strongly shifted into the forward direction. This indicates the direct production of $\Delta(1232)$ which will be due to other mechanisms than resonance production.

4. Acceptance correction and single π^0 photoproduction

The basis for a successful partial wave analysis is the proper determination of the detector acceptance. In Fig. 4, differential cross sections for the reaction $\gamma\,\mathrm{p} \rightarrow \mathrm{p}\,\pi^0$ are shown for an incoming photon energy from 400 MeV up to 1300 MeV. The solid line represents SAID model predictions for this reaction which are based on the well-measured data for $p\pi^0$. CB-ELSA data agree beautifully with the predictions indicating that the acceptance correction is understood.

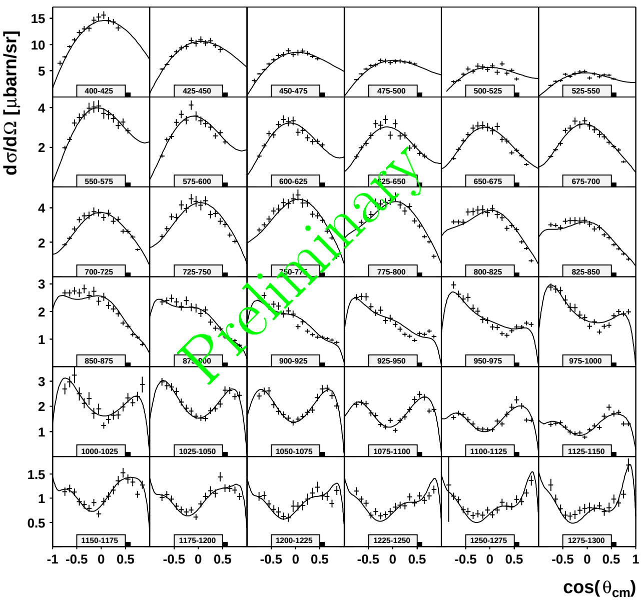

Figure 4. Differential cross sections for the reaction $\gamma\,\mathrm{p} \rightarrow \mathrm{p}\,\pi^0$. The range of the incoming photon energy in [MeV] is given at the bottom of each plot.

5. Conclusions

The photoproduction of neutral mesons off protons has been measured with the CB-ELSA as well as the CB/TAPS detector at ELSA. Events with multi-photon final states could be reconstructed with high efficiency. Strong indications for a Δ resonance at about 1900 MeV are given. A preliminary partial wave analysis is compatible with a negative parity of this state.

References

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