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Baryon spectroscopy with the CB-ELSA detector at ELSA

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Abstract. The investigation of the excitation spectrum of baryons 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 recent experimental results of the CB-ELSA experiment at the e^- accelerator ELSA in Bonn. First hints for resonance production are given and cascades of the type $N^{**}(\Delta^{**}) \to N^*(\Delta^*) \to p\pi^0\pi^0(p\pi^0\eta)$ are observed. 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 almost all constituent quark models, (S. Capstick, N. Isgur, Phys. Rev. D **34**, 2809 (1986); U. Löhring *et al.*, Eur. Phys. J. A **10**, 309 (2001)) for instance. 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 2200 MeV region.

PACS. 25.20.-x Photonuclear reactions

1 Introduction

All current models describing the spectrum of baryon resonances predict a series of hitherto unobserved states. This feature would clearly be a big problem for all models as they would have failed to describe physical reality. There are at least two possible explanations which account for this open question. One is that these *missing resonances* have to exist if the 3 valence quarks of the nucleon are not frozen into a quark-diquark substructure. In fact, this would reduce the number of effective degrees of freedom and, therefore, also the number of possible baryon states [1].

An alternative explanation is that those *missing resonances* are really missing and have simply not been observed up to now because almost all existing data result from πN elastic-scattering experiments. As a matter of fact, some models focussing on baryon strong decays predict baryon states missing in πN elastic-scattering analyses but showing strong evidence in electromagnetic production [2]. Those *missing resonances* should couple strongly to channels like $\Delta\pi$, for instance [3]. Thus, photoproduction experiments offer a large discovery potential.

2 Experimental configuration

Electrons extracted from the stretcher accelerator (ELSA) hit a primary radiation target and produce Bremsstrahlung. The corresponding energy of the photons ($E_\gamma = E_0 - E_{e^-}$) is determined in a tagging system by the deflection of the electrons in a magnetic field. This detector provides a tagged beam in the photon energy range from 25% up to 92% of the incoming electron energy. The calorimeter (Crystal Barrel) consisting of 1380 CsI(Tl) crystals covers about 98% of 4π solid angle for reactions *at rest* and is an ideal detector for photons. The photoproduction target in the center of the Crystal Barrel has a length of 5 cm and is filled with liquid hydrogen. It is surrounded by a scintillating fibre detector which was built to detect and trigger charged particles leaving the target.

3 Study of baryon decay cascades

The CB-ELSA detector is the ideal instrument to study various multi-photon final states over the full dynamical range. It allows to identify highly excited baryon states up to 2.6 GeV/c^2 by observing cascades of high-mass states to the ground state via the emission of single pions and η-mesons. The 4π acceptance of the detector system in combination with a good spatial and energy resolution guarantees a large efficiency and selectivity of many neutral final states in photoproduction off the proton. Data presented below were taken at an ELSA energy of $E_0 = 3.2$ GeV.

Figure 1(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

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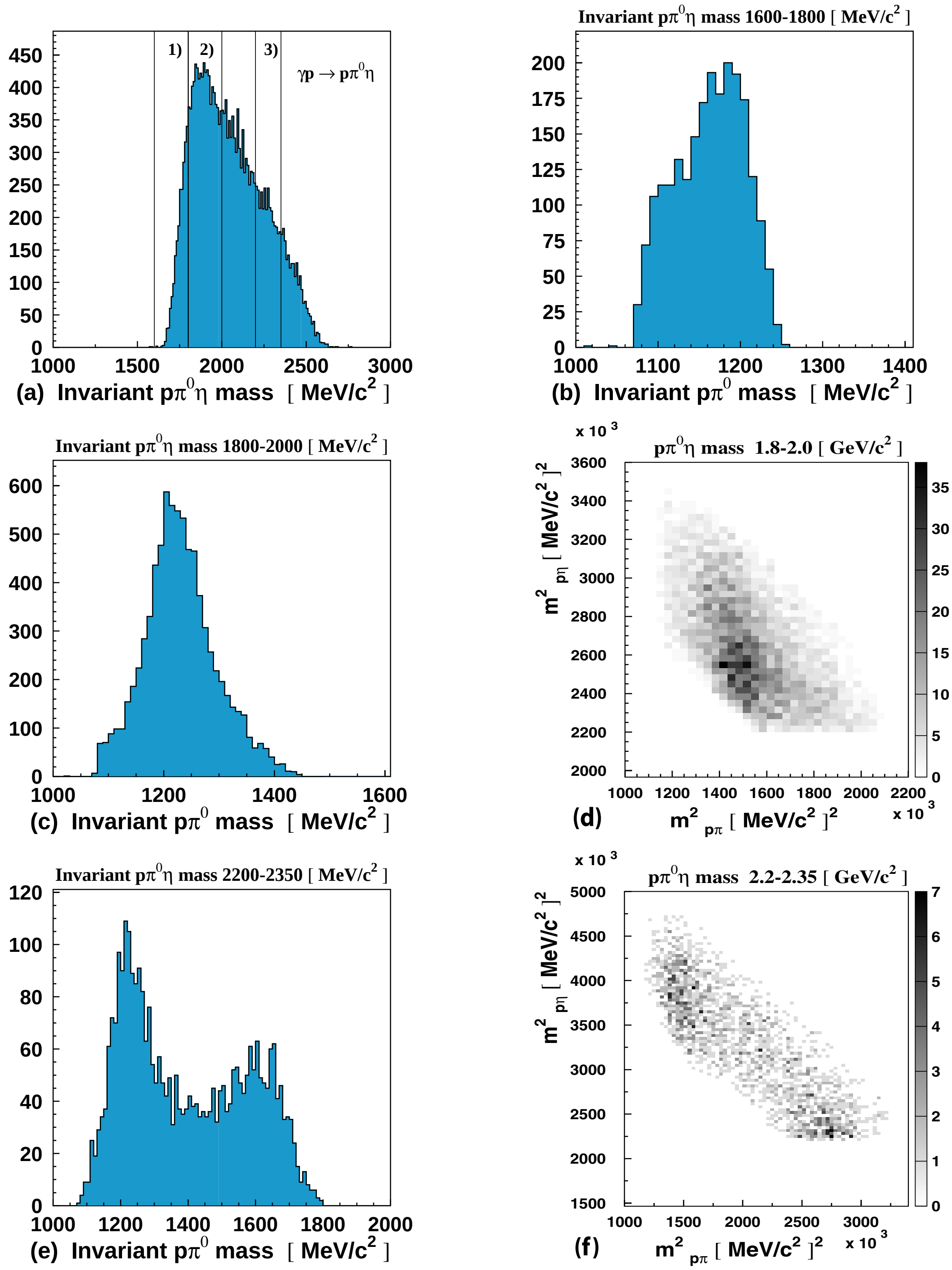

Fig. 1. Different plots on the reaction $\gamma\,\mathrm{p} \to \mathrm{p}\,\pi^0\,\eta$. (a) shows the total invariant $\mathrm{p}\pi^0\eta$ mass. In (b), (c), (e), the $\mathrm{p}\pi^0$ mass is plotted for the three different $\mathrm{p}\pi^0\eta$ mass regions indicated in (a). Clear evidence for the $\Delta(1232)$ can be observed and, thus, hints for resonances decaying via $\Delta\eta$ become obvious. (d) and (f) show the corresponding Dalitz plots for two different $\mathrm{p}\pi^0\eta$ mass regions. Resonance structures become even more transparent. All distributions are not efficiency corrected nor any photon 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.

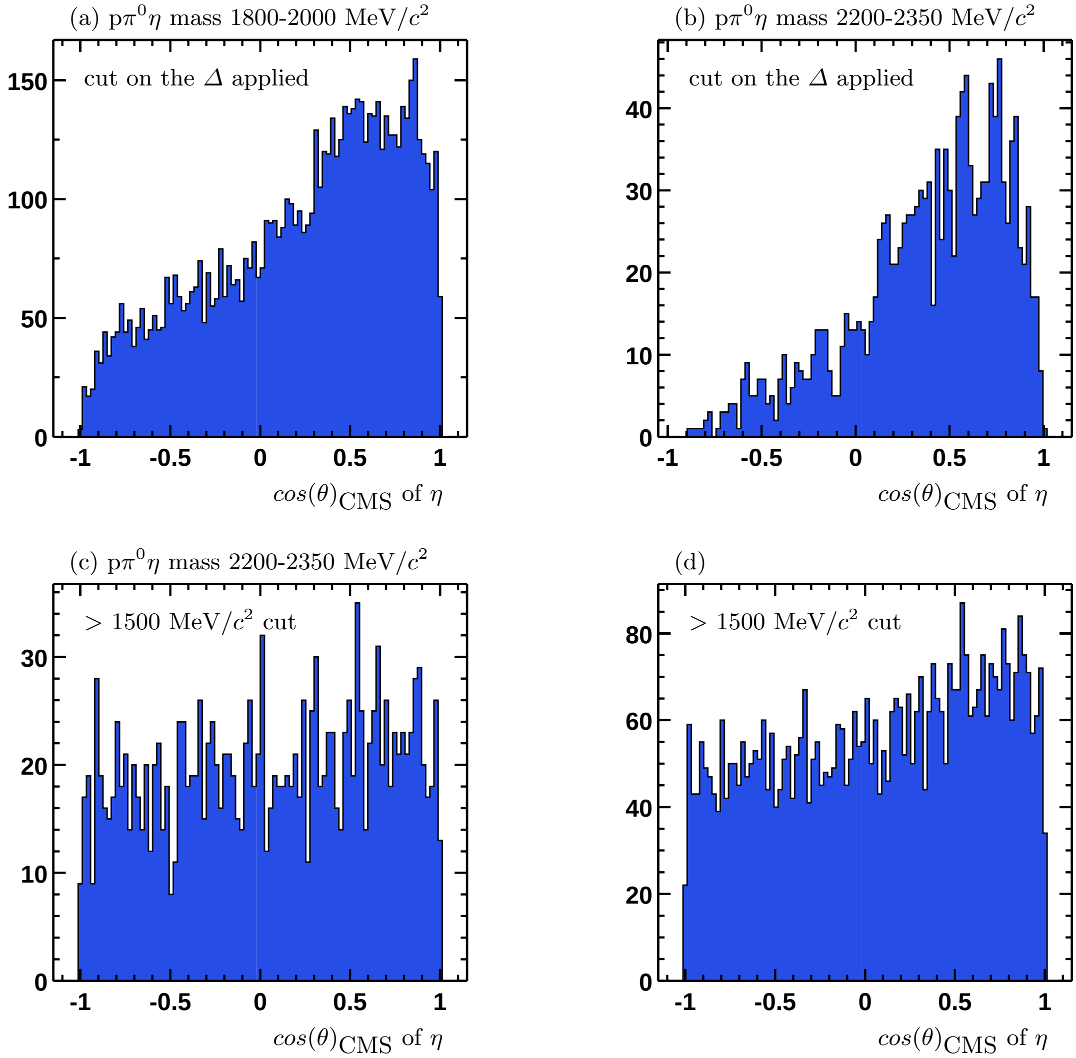

Fig. 2. $\cos(\theta)_{\text{CMS}}$ of the η-meson in the reaction $\gamma\,\text{p} \to \text{p}\,\pi^0\,\eta$. A flat angular distribution can be interpreted as the decay of S-wave resonances. The $\Delta(1232)$ above 2.2 GeV likely does not stem from resonances but is created via more complicated processes.

decaying into $\Delta\eta$ now become visible. In the total mass region around 1700 MeV, no structure can be seen. However, a clear peak at the Δ mass can already be observed in the mass region around 1900 MeV. 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 $\gamma\,\text{p} \to \text{p}\,\pi^0\,\eta$, this idea will help to answer the question whether there are negative-parity Δ states in this region. For higher $\text{p}\,\pi^0$ masses, further resonance intensity may be hidden in a structure around 1600 MeV. In fact, one has to be careful interpreting structures in the mass projections as those are often reflections of the corresponding Dalitz plots (fig. 1(d) and (f)).

More information is given by the CMS angular distributions of the η-meson for the same mass regions as indicated in fig. 1(a). These plots are given in fig. 2. A cut on the $\Delta(1232)$ in the $\text{p}\,\pi^0$ system is applied as well as on higher masses ($m(\text{p}\,\pi^0) > 1500$ MeV/c^2). The offset below the forward peak in fig. 2(a) and the flat angular distribution in 2(c) are likely to stem from resonant S-wave decays. On the other hand, the angular distribution in (b) 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.

References

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