PHOTOPRODUCTION OF π^0 AND η MESONS OFF PROTONS AT CB–ELSA *

OLIVIA BARTHOLOMY FOR THE CB–ELSA COLLABORATION

Helmholtz–Institut für Strahlen– und Kernphysik, Universität Bonn
Nußallee 14–16, 53115 Bonn, GERMANY
E-mail: bartholomy@hiskp.uni-bonn.de

Photoproduction of single neutral pseudoscalar mesons was investigated at the CB–ELSA experiment in Bonn. The main field of interest is the photoproduction of baryonic resonances in the intermediate state. The CB–ELSA experiment covers a rather large percentage of the solid angle, rendering it ideally suited for the observation of angular distributions. Data was taken for incident photon energies between 0.3 and 3.0 GeV, thus extending the region already investigated by other experiments as well in angular as in energy range.

1. Introduction

Photoproduction is a sensitive tool to study the properties of baryon resonances. Most of the properties of N and Δ states have been obtained in πN scattering. In γp, resonant states are excited in electromagnetic interaction, while they decay via strong interaction. Thus, we have access to hadronic and electromagnetic couplings of the resonances.

The often discussed problem of missing resonances (e. g. [1,2]) is an important topic at CB–ELSA. The investigation of photoproduction reactions yields a great discovery potential for some of these missing states. We are not limited to the channel πN, but have access to various final states, some of which are selective due to isospin conservation. The photoproduction of η mesons, e. g., selects contributions of N^* resonances in the intermediate state.

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2. Experiment

The data stem from the first experimental phase of the CB–ELSA experiment. An unpolarized photon beam was produced via scattering of a 1.4 GeV (or 3.2 GeV, respectively) electron beam delivered by the Electron Accelerator ELSA, having the $1/E_\gamma$ distribution typical for bremsstrahlung. The photons are then energy tagged by detecting the corresponding electrons in a magnetic dipole spectrometer. These photons hit a liquid hydrogen target in the center of the CB–ELSA detector, an electromagnetic calorimeter consisting of 1380 CsI crystals. If a reaction occurs, photons originating from the decay of produced neutral mesons are detected with high angular and energy resolution. The proton is detected as well and identified by an inner detector consisting of three layers of scintillating fibers. For the flux determination, a total absorption photon detector was placed further downstream.

3. Results

Results on $\gamma p \rightarrow p\pi^0$ and $\gamma p \rightarrow p\eta$ were obtained by detection of two photons for $\pi^0 \rightarrow 2\gamma$ and $\eta \rightarrow 2\gamma$ and by detection of six photons for $\eta \rightarrow 3\pi^0 \rightarrow 6\gamma$. The proton was either detected in the CB–ELSA detector and identified by the inner detector or, for low–energetic protons, taken from the hit in the inner detector alone.
A kinematic fit was applied to the measured values, with known event energy from the tagger and known four–vectors for the decay photons, while the proton was left unconstrained. Confidence–level cuts were applied on $> 10^{-4}$ for the two–photon, $> 10^{-2}$ for the six–photon case.

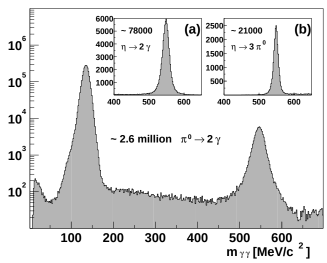

Figure 1. Invariant mass of two photons in three–particle final states, logarithmic scale, (a) 2γ mass, (b) 6γ mass, linear scale

A spectrum of invariant masses can be seen in Fig. 1. The two photon invariant mass is shown on a logarithmic scale. Insets (a) and (b) show the two– and the six–photon invariant mass in the η region. The background is of the order of magnitude of 10^{-3} underneath the π^0 and 10^{-2} beneath the η.

3.1. $\gamma p \rightarrow p\pi^0$

The angular distributions were calculated using the fitted data. In order to correct for efficiencies, a GEANT–

based simulation of the detector system was performed. The normalization was done with the help of the SAID analysis: For photon energies up to 1.3 GeV, the angular distributions were fitted to match the SAID prediction by applying a χ^2 fit, giving one factor for each energy bin. Above that energy, the flux was obtained by scaling the experimentally obtained photon flux with one constant scaling factor to get an agreement between SAID and our data at photon energies up to about 2 GeV.

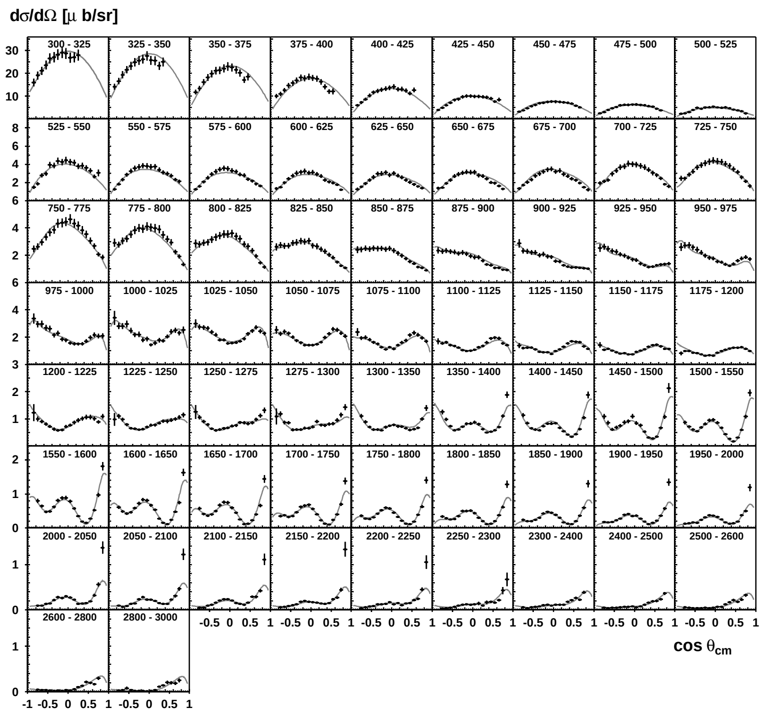

Figure 2. Differential cross sections $d\sigma/d\Omega$ of $\gamma p \to p\pi^0$ (E_γ binned), ■: CB–ELSA, solid line: PWA result

The distributions in Fig. 2[3] match well with the predicted values from the SAID analysis, reflecting the good understanding of our detector response. The data can be described well in a partial wave analysis[4]. The result is shown together with the experimental results.

3.2. $\gamma p \to p\eta$

The photoproduction of η mesons was investigated in its two different neutral, most common decay channels, 2γ and $3\pi^0$. The obtained cross sections match with a branching ratio of $\Gamma_{\eta\to 3\pi^0}/\Gamma_{\eta\to 2\gamma} = 0.825 \pm 0.001 \pm 0.005$, which is in excellent agreement with the values stated by the PDG[5]. This again reflects the good description of the detector and enables us to add the statistics from both channels.

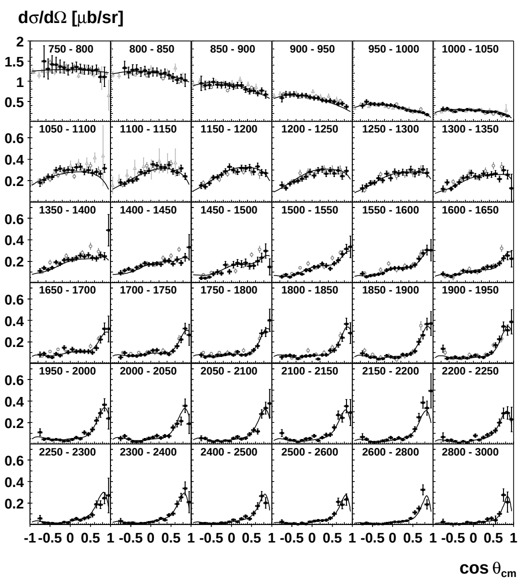

Figure 3. Differential cross section $d\sigma/d\Omega$ for $\gamma p \to p\eta$ (E_γ binned), ■: CB–ELSA, other symbols: data from TAPS, GRAAL, CLAS, solid line: PWA result

The data shown in Fig. 3[7] is in excellent agreement with previously published data from TAPS[8], GRAAL[9], and CLAS[10]. It extends the known region as well in photon energies as in angular range.

The resulting fit from a partial wave analysis is shown as well. Evidence is found for two new resonances, $D_{15}(2070)$ and $P_{13}(2200)$.

A symmetry observed in the results of this partial wave analysis is that the resonances $S_{11}(1535)$, $P_{13}(1720)$, and $D_{15}(2070)$ couple strongly to $N\eta$. In a harmonic–oscillator model, one could assign $L = 1, 2, 3$ and $S = 1/2$ to these states, coupling to $J = L - S$, giving the measured quantum numbers $J^P = 1/2^-, 3/2^+, 5/2^-$.

References

1. S. Capstick, W. Roberts, Phys. Rev. **D 49** (1994) 4570.
2. U. Löhring et al., Eur. Phys. J **A 10** (2001) 309.
3. O. Bartholomy et al., in preparation.
4. A. Anisovich et al., Proceedings NSTAR 2004.
5. K. Hagiwara et al., Phys. Rev. **D 66** (2002) 1.
6. R. A. Arndt et al., http://gwdac.phys.gwu.edu/.
7. V. Credé et al., in preparation.
8. B. Krusche et al., Phys. Rev. Lett. **74** (1995) 3736.
9. F. Renard et al., Phys. Lett. **B 528** (2002) 215.
10. M. Dugger et al., Phys. Rev. Lett. **89** 2002 222002.