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Measurement of the beam asymmetry Σ in $\pi^0\eta$ production off the proton with the CBELSA/TAPS experiment*

The CBELSA/TAPS Collaboration

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Abstract. In photoproduction experiments, a large number of final states yielding various resonance contributions are accessible. To extract resonance parameters via partial-wave analysis not only the measurement of differential cross-sections is necessary, but also the determination of polarization observables. At the electron accelerator ELSA (Bonn) the coherent bremsstrahlung method was used to generate a linearly polarized photon beam. Using the CBELSA/TAPS detector setup, the beam asymmetry Σ in the reaction $\gamma p \to p\pi^0\eta$ was determined as a function of various masses and angles for photon energies between 970 MeV and 1650 MeV.

PACS. 13.60.-r Photon and charged-lepton interactions with hadrons – 13.60.Le Meson production – 13.88.+e Polarization in interactions and scattering

1 Introduction

The photoproduction of two-meson final states off the proton yields a great potential for gaining further insight in the field of baryons and their properties. Not only give photoproduction experiments a certain degree of independence from πN coupling strengths in the excitation of resonances [1], but also final states comprising two mesons give access to processes in which cascading resonance decays occur. Also, towards higher incoming photon energies, the cross-sections for double meson production exceed those for single mesons. Despite their general success in describing the baryon resonance spectrum, constituent quark models [2,3] pose certain problems, for example the prediction of the so-called *missing resonances*. Experimentally, the main key to a good understanding of the baryon spectrum is the measurement of a complete set of observables, one of which is the unpolarized cross-section. In the case of two-meson production, the other 14 observables [4] have to be determined in polarization experiments.

In case of a linearly polarized photon beam and unpolarized target, the cross-section for the photoproduction of two pseudoscalar mesons can be written in the form

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_0 \left(1 + \delta_l(\Sigma \cos 2\Phi + I^S \sin 2\Phi)\right), \quad (1)$$

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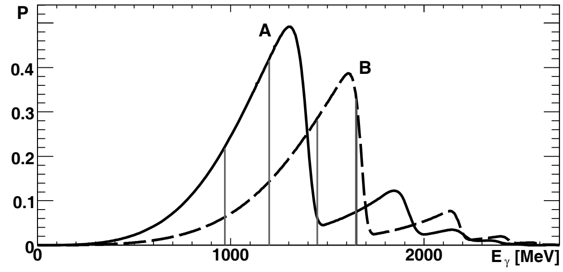

Fig. 1. Degree of linear polarization for the two different settings. The maximum degrees of polarization were 49.2% at $E_\gamma = 1300\,\mathrm{MeV}$ (A) and 38.7% at 1600 MeV (B), respectively (see [5] for details). Vertical lines indicate the energy ranges under consideration.

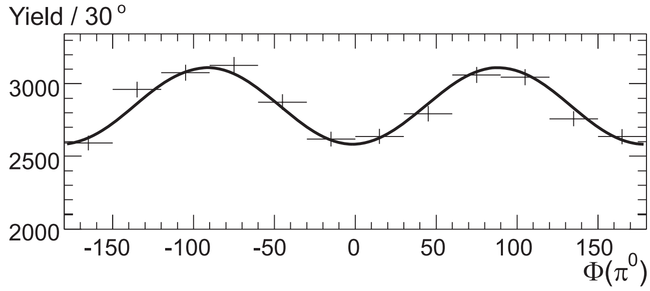

Fig. 2. Example of a measured Φ distribution as defined in eq. (1). Shown is the Φ distribution of the final state π^0 for all events in the energy range $E_\gamma = 1325 \pm 125\,\mathrm{MeV}$ (y-axis with suppressed-zero scale).

where $(\frac{d\sigma}{d\Omega})_0$ denotes the cross-section in case of an unpolarized photon beam, δ_l the degree of linear polarization of the photon beam, Σ and $\mathrm{I^S}$ the occurring polarization observables, and Φ the angle between the polarization plane and the normal to the reaction plane.

While the beam asymmetry Σ has been investigated in single meson production ([5] and references therein) as well as in double π^0 production experiments (up to incoming photon energies of 1500 MeV, [6] and references therein), no data at all has been published on the reaction

$$\gamma \mathrm{p} \to \mathrm{p}\pi^0\eta \tag{2}$$

as of yet.

2 Experimental setup

The data presented has been obtained with the CBELSA/TAPS experiment at the Bonn electron accelerator facility ELSA [7]. The experimental setup consists of an arrangement of two electromagnetic calorimeters, the Crystal Barrel detector [8] comprising 1290 CsI(Tl) crystals and the TAPS detector [9,10] in a forward-wall setup consisting of 528 $\mathrm{BaF_2}$ modules in combination with plastic scintillators for charge information. Together these calorimeters cover the polar angular range from 5° to 168° and the full azimuthal range. For further charged-particle identification a three-layer scintillating fiber detector [11] surrounds the liquid-hydrogen target [12].

The linearly polarized photons are produced via coherent bremsstrahlung of the initial 3.2 GeV electron beam delivered by ELSA off a diamond radiator. Electrons undergoing the bremsstrahl process are then momentum analyzed using a tagging spectrometer consisting of a dipole magnet and a scintillator-based detection system. For further details on the experimental setup, see [5].

For the given analysis, two datasets were considered. Figure 1 shows the degree of polarization as a function of the incident photon energy for two diamond radiator orientations, one yielding a maximum degree of polarization of 49.2% at $E_\gamma = 1300\,\mathrm{MeV}$ (A) and the other of 38.7% at 1600 MeV (B).

3 Data analysis

The two datasets were subdivided into three energy ranges, $E_\gamma = 1085 \pm 115\,\mathrm{MeV}$, $1325 \pm 125\,\mathrm{MeV}$, and $1550 \pm 100\,\mathrm{MeV}$ respectively, as indicated by the vertical lines in fig. 1. To guarantee a sufficiently high degree of polarization, the low-energy range consists solely of data taken with the polarization setting A, the high-energy range of data taken with setting B. For the intermediate energy range, both datasets were combined.

To enrich the final state given in (2), only events with five distinct detector hits, corresponding to four photons and the proton, were considered for further analysis. Only the two-photon decays of the final-state mesons were taken into account. To avoid systematic effects, in the further analysis the proton was treated as a missing particle and any four-particle combination was processed in order to ascertain a proton candidate.

After the application of cuts on the meson masses (invariant $\gamma\gamma$ masses) and the missing mass of any four-photon system as well as on the coplanarity of the meson system and the proton candidate, the data was subjected to a kinematic fit [13] imposing energy and momentum conservation. Only events were retained that exceeded a probability (CL) of 8% for the $\gamma\mathrm{p} \to \mathrm{p}\pi^0\gamma\gamma$ two-constraint hypothesis and of 6% for the $\gamma\mathrm{p} \to \mathrm{p}\pi^0\eta$ three-constraint hypothesis, respectively. In addition, events compatible with CL $> 1\%$ to the $\gamma\mathrm{p} \to \mathrm{p}\pi^0\pi^0$ hypothesis were rejected. The final event sample contains a total of 83964 events due to reaction (2) with a background contamination well below 2% as determined by extensive Monte Carlo simulations.

To extract the polarization observables according to eq. (1) a fit on the Φ distribution of the final-state particles was performed:

$$f(\Phi) = A + P(B\cos(2\Phi) + C\sin(2\Phi)) \tag{3}$$

with P being the the polarization determined for each event individually and later averaged for each fitted bin. Figure 2 shows an example of an according distribution. The effect of the beam asymmetry Σ is clearly visible in the distinct $\cos(2\Phi)$ modulation. The observable $\mathrm{I^S}$, which would result in a phase shift of the observed $\cos(2\Phi)$

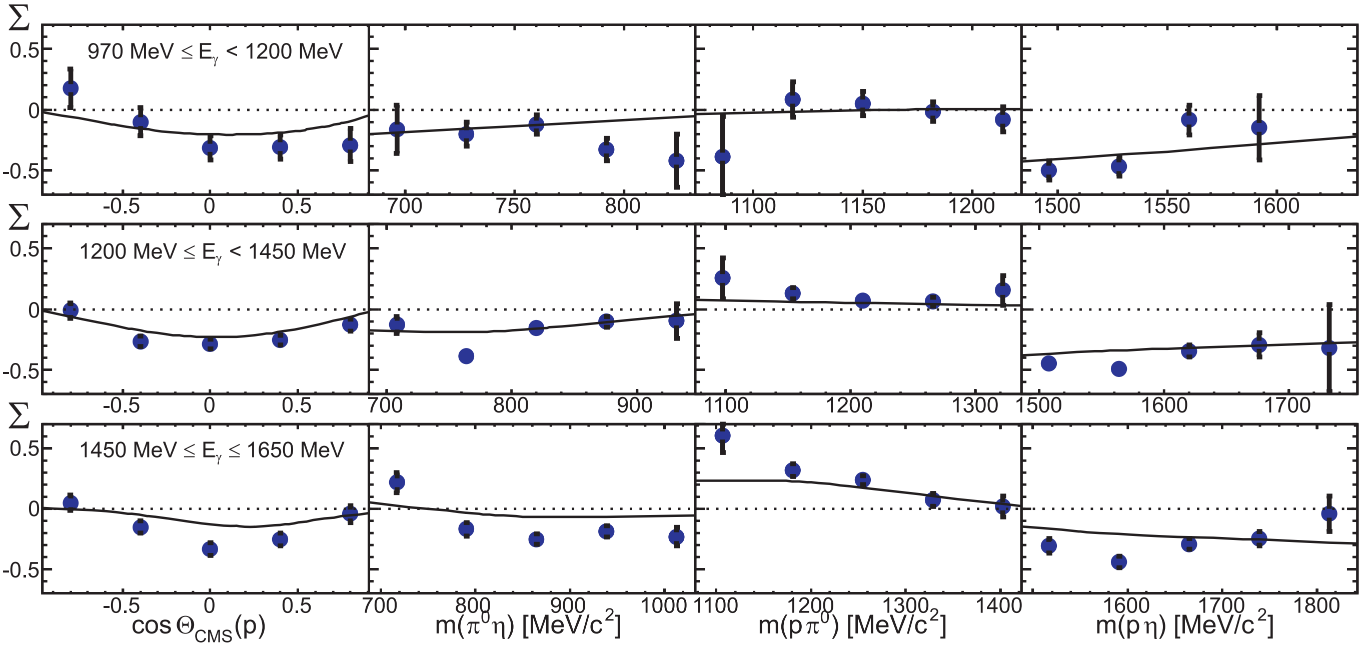

Fig. 3. Measured beam asymmetries Σ in the reaction $\gamma p \to p\pi^0\eta$. Top to bottom: incoming photon energy ranges 1085 ± 115 MeV, 1325 ± 125 MeV, 1550 ± 100 MeV. Left to right: beam asymmetries obtained from the Φ distribution of the proton as a function of $\cos\Theta_{\mathrm{CMS}}$ of the proton, as a function of the $\pi^0\eta$ invariant mass, from the Φ distribution of the η as a function of the $p\pi^0$ invariant mass, and from the Φ distribution of the π^0 as a function of the $p\eta$ invariant mass. Solid line: Bonn-Gatchina PWA prediction.

modulation was found to be at least an order of magnitude smaller than Σ and within its errors compatible with zero. Hence in the following only results on the beam asymmetry will be presented.

4 Results

Figure 3 shows the beam asymmetries Σ for the three energy ranges (top to bottom) $E_\gamma = 1085 \pm 115$ MeV, 1325 ± 125 MeV, and 1550 ± 100 MeV. Depicted are the beam asymmetries determined from the Φ distribution of (from left to right) the proton as a function of $\cos\Theta_{\mathrm{CMS}}$ and the $\pi^0\eta$ invariant mass along with the asymmetry extracted from the Φ distribution of the η-meson as a function of the $p\pi^0$ invariant mass, and of the π^0 as a function of the $p\eta$ invariant mass. Asymmetries up to the order of 50% can be clearly observed as well as distinct differences in the sign of the asymmetry derived from the Φ distributon of the η-meson and the proton and pion, respectively. An energy dependence, especially for the asymmetries as a function of the $p\pi^0$ invariant mass is also visible. The data are compared with a prediction of the Bonn-Gatchina partial-wave analysis (PWA) [14,15]. The solution shown has been determined from a PWA of the unpolarized CB-ELSA $\gamma p \to p\pi^0\eta$ data fitted in combination with additional datasets [16]. The data presented here were not incorporated. A general agreement between the data and the prediction is noticeable, tendencies and signs are widely reproduced, even though there is obviously room for improvement.

5 Summary and conclusions

The beam asymmetry Σ for the reaction $\gamma p \to p\pi^0\eta$ has been extracted from data taken with the CBELSA/TAPS experiment at ELSA for all final-state particles and as a function of various variables. A preliminary comparison with PWA predictions yields reasonable agreement. The influence of the polarization observable I^S has been found to be negligible.

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References

1. S. Capstick, W. Roberts, Phys. Rev. D **49**, 4570 (1994).
2. S. Capstick, W. Roberts, Prog. Part. Nucl. Phys. **45**, 241 (2000).
3. U. Löring *et al.*, Eur. Phys. J. A **10** 395; 447 (2001).
4. W. Roberts, T. Oed, Phys. Rev. C **71**, 055201 (2005).
5. D. Elsner *et al.*, Eur. Phys. J. A **33**, 147 (2007).
6. D. Moricciani *et al.*, Int. J. Mod. Phys. A **20**, 503 (2005).
7. W. Hillert, Eur. Phys. J. A **28**, 139 (2006).
8. E. Aker *et al.*, Nucl. Instrum. Methods A **321**, 69 (1992).
9. R. Nowotny, IEEE Trans. Nucl. Sci. **NS-38**, 379 (1991).
10. A.R. Gabler *et al.*, Nucl. Instrum. Methods A **346**, 168 (1994).
11. G. Suft *et al.*, Nucl. Instrum. Methods A **538**, 416 (2005).
12. B. Kopf, PhD Thesis, Dresden (2002).
13. H. van Pee *et al.*, Eur. Phys. J. A **31**, 61 (2007).
14. A.V. Anisovich *et al.*, Eur. Phys. J. A **24**, 111 (2005).
15. A.V. Anisovich *et al.*, Eur. Phys. J. A **34**, 243 (2007).
16. CB-ELSA Collaboration (I. Horn *et al.*), arXiv:0711.1138 [nucl-ex].