EPJ Web of Conferences **130**, 01008 (2016) DOI: 10.1051/epjconf/201613001008
MESON 2016

Recent result from the A2 collaboration at MAMI

Andreas Thomas[1,⋆]
for the A2 Collaboration

[1] *Institut für Kernphysik, Universität Mainz*

Abstract. The A2 Collaboration at the Mainz Microtron MAMI is measuring photon absorption cross section using circularly and linearly polarized photons up to energies of 1.6 GeV. The photons are produced in the 'Bremsstrahlungs' process, the energy is determined by a dedicated tagging system. The Crystal Ball-TAPS detector system with its high capability to cope with multi photon final states is used to acquire data with a variety of nonpolarized and spin polarized targets. Physical goals are the investigation of the nucleons excitation spectrum via single and double meson photoproduction and in addition a detailed determination of meson decays in precision experiments. We have started a program to measure double polarised Compton scattering to determine the nucleons scalar and spin polarisibilities. In this proceedings recent results from A2 collaboration are presented.

1 Experimental Apparatus

1.1 The A2 Photon Beam

The MAMI accelerator with its source of polarised electrons, based on the photoeffect on a strained GaAs crystal, routinely delivers polarised beam with a maximum energy of 1604 MeV and a degree of polarisation of approximately 85%. The last accelerator stage, MAMI C, is realized as a Harmonic Double Sided Microtron (HDSM). Details of the machine can be found in reference [1].
The A2-Glasgow-Mainz tagging facility [2] stands out due to its high photon intensity. The beam is derived from the production of Bremsstrahlung photons during the passage of the MAMI electron beam through a thin radiator. The resulting photons can be circularly polarised, with the application of a polarised electron beam, or linearly polarised, in the case of a crystalline radiator. The tagger focal plane is segmented into 352 scintillation detectors. Each counter can operate reliably to a rate of $\sim$1 MHz, giving a photon flux of $2.5 \cdot 10^5$ photons per MeV. Photons can be tagged in the momentum range from 4.7 to 93.0% of E_0.

1.2 The A2 Detector Setup

The central detector system consists of the Crystal Ball calorimeter combined with a barrel of scintillation counters for particle identification and two coaxial multiwire proportional counters for charged

⋆e-mail: thomand@uni-mainz.de

DOI: 10.1051/epjconf/201613001008

particle tracking. This central system provides position, energy and timing information for both charged and neutral particles in the region between 21° and 159° in the polar angle (θ) and over almost the full azimuthal (ϕ) range. At forward angles, less than 21°, reaction products are detected in the TAPS forward wall. The full, almost hermetic, detector system is shown schematically in Figure 1.

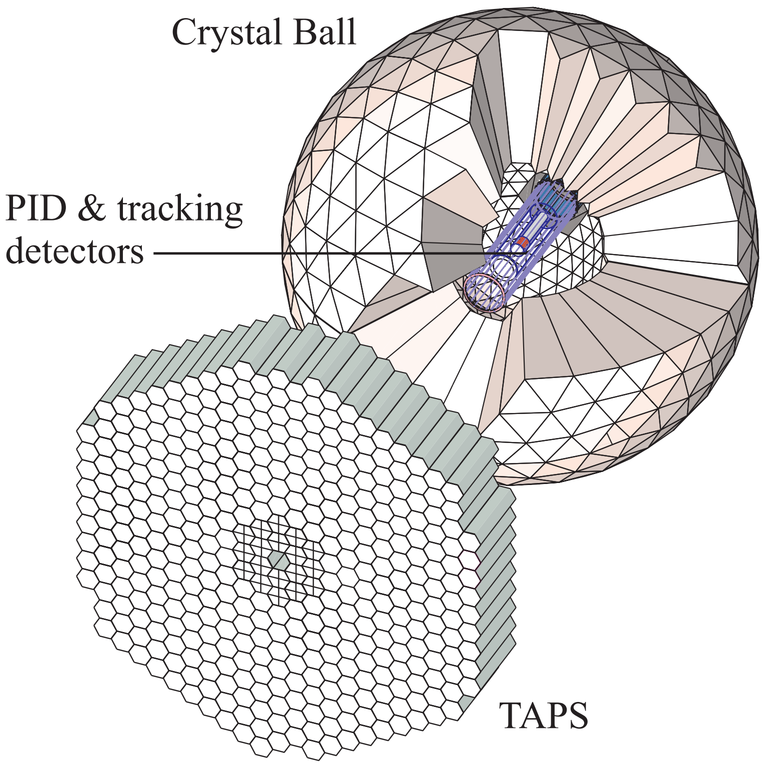


Figure 1. The A2 detector setup: The Crystal Ball calorimeter, with cut-away section showing the inner detectors, and the TAPS forward wall.

The Crystal Ball detector (CB) is a highly segmented 672-element NaI(Tl), self triggering photon spectrometer constructed at SLAC in the 1970's. Each element is a truncated triangular pyramid, 41 cm (15.7 radiation lengths) long. The Crystal Ball has an energy resolution of $\Delta E/E = 0.020 \cdot E[GeV]^{0.36}$ and angular resolutions of $\sigma_\theta = 2\ldots3°$ and $\sigma_\phi = \sigma_\theta/\sin\theta$ for electromagnetic showers. The TAPS forward wall is composed of 384 BaF_2 elements, each 25 cm in length (12 radiation lengths) and hexagonal in cross section, with a diameter of 59 mm. The front of every TAPS element is covered by a 5 mm thick plastic veto scintillator.

The tracks of charged particles emitted within the angular and momentum acceptance of the CB detector are reconstructed using two coaxial cylindrical multiwire proportional chambers (MWPCs) with cathode strip readout.

1.3 The A2 Targets

A variety of unpolarised and polarised targets can be implemented into the A2 setup. A standard liquid hydrogen or deuterium target is used for unpolarised and beam polarised experiments , another specially adopted liquid ^{3}Helium and ^{4}Helium target is available. In addition, solid nuclear targets are used in several experiments. For double polarisation measurements on polarised protons and deuterons a large horizontal ^{3}He/^{4}He dilution refrigerator was built in cooperation with the Joint Institute for Nuclear Research (JINR) Dubna. It has minimum limitations for the particle detection and fits into the central core of the inner Particle Identification Detector (PID). This was achieved by using the frozen spin technique with the new concept of placing a thin superconducting holding coil inside the polarisation refrigerator, longitudinal and transverse polarisations are possible. Highest nucleon polarisation in solid-state target materials is obtained by a microwave pumping process, known as 'Dynamic Nucleon Polarisation' (DNP). Several polarised proton and deuteron materials are available such as alcohols and deuterated alcohols (e.g. butanol C_4H_9OH), NH_3, ND_3 or ^{6}LiD. The most important criteria in the choice of material suitable for particle physics experiments are the degree of polarisation P and the ratio k of free polarisable nucleons to the total number of nucleons. Further requirements on polarised target materials are a short polarisation build-up time and a simple, reproducible target preparation. Another important consideration is, if the chemically bound background nuclei are spin-polarised or not, especially for our exsperiments at moderate enrgies. Taking all properties together, butanol and deuterated butanol are the best material for this experiment. For protons and deuterons we could achieve maximum polarisations in the order of $P = 80\%$ and an average polarisation of $P = 70\%$ in the frozen spin mode at 25mKelvin and spin relaxation times of more than 1000 hours. Figure 2 shows the Dubna-Mainz dilution cryostat with internal longitudinal superconducting coil.

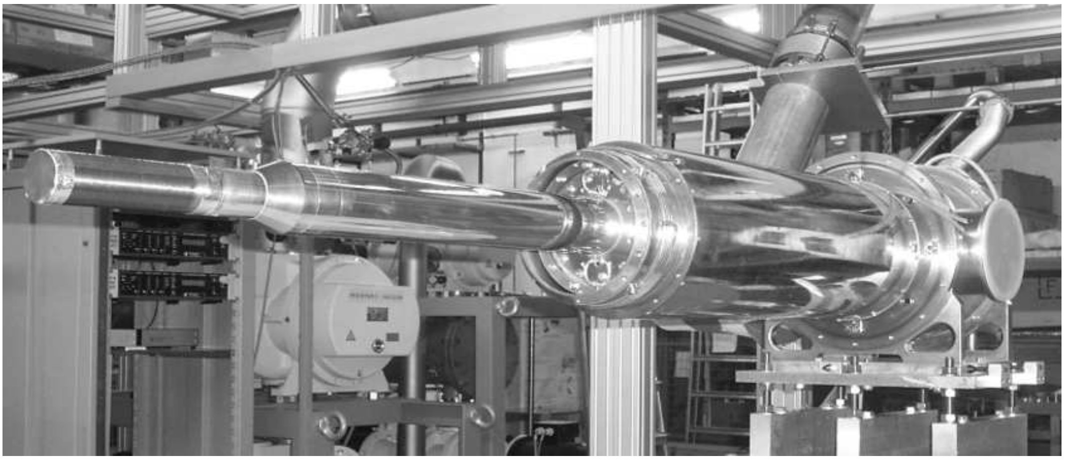


Figure 2. The Dubna-Mainz dilution cryostat with internal longitudinal superconducting coil.

2 Recent results

2.1 Unpolarised cross sections on protons and deuterons

Differential cross sections for the $\gamma p \rightarrow p\pi^0$ reaction have been measured up to the center-of-mass energy W = 1.9 GeV [3]. The new results, obtained with a fine energy and angular binning, increase the existing quantity of n π^0 photoproduction data by 47%. Owing to the unprecedented statistical accuracy and the full angular coverage, the results are sensitive to high partial-wave amplitudes. Figure 3 shows the high quality of the new data set.

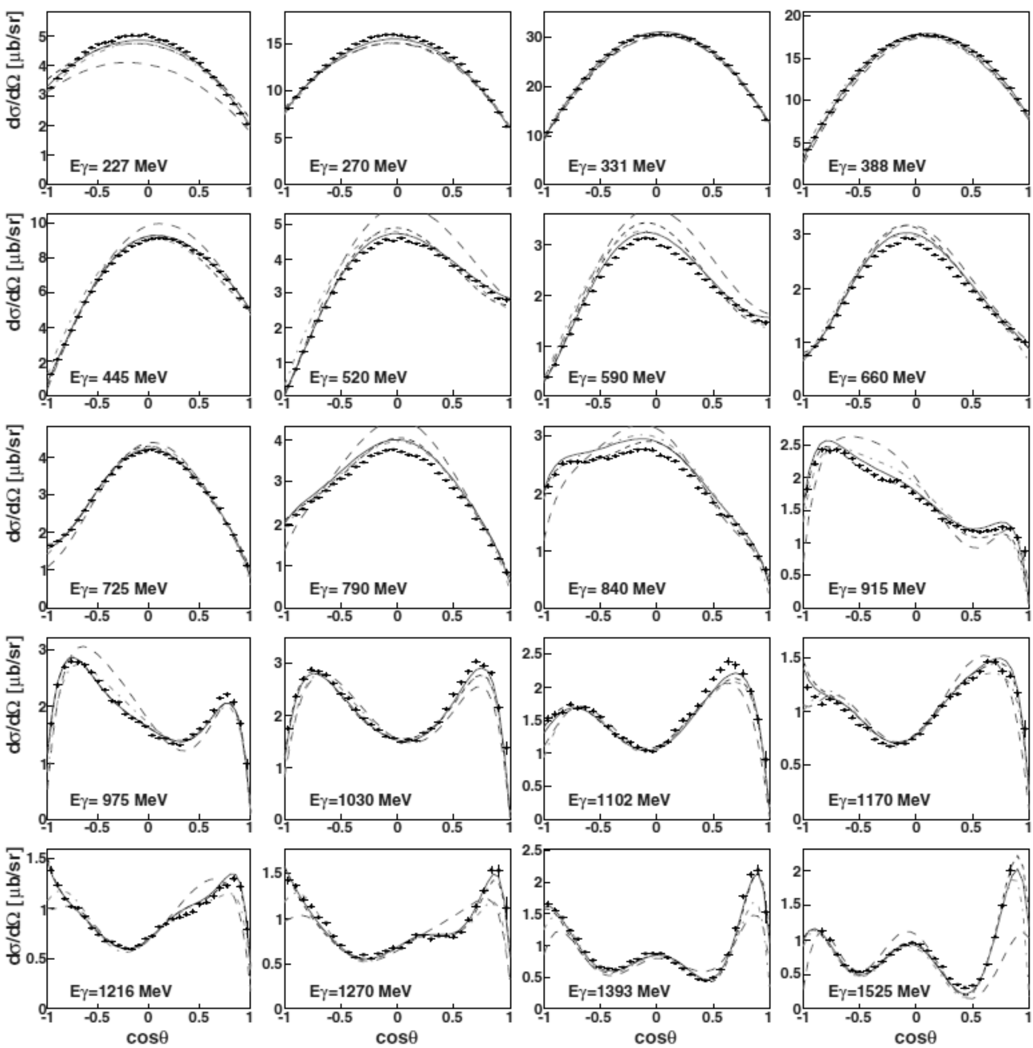
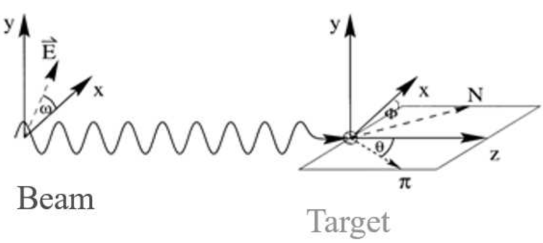


Figure 3. Selected results of the differential cross sections from the our work ([3] black points) with most recent partial wave analyses.

Another experiment was performed with an unpolarised liquid deuteron target for incident photon energies between 0.45 and 1.4 GeV [4]. Precise angular distributions have been measured for the first time for the photoproduction of π^0 mesons off neutrons bound in the deuteron. The effects from nuclear Fermi motion have been eliminated by a complete kinematic reconstruction of the final state.

2.2 Double polarized meson production

Since many years measurements to accomplish a complete set of polarisation observables in meson photoproduction were carried out. With the new quality of polarised beams and targets we could determine experimentally many of these observables in the recent experiments. The corresponding polarisation parameters are defined e.g. in ref [5]. Fig. 4 illustrates the geometrical orientation of the target and the corresponding photon beam polarisation.



Beam / Target	γ_{unpol}	P_γ^{lin} $\left(0, \frac{\pi}{2}\right)$	P_γ^{lin} $\left(+\frac{\pi}{4}, -\frac{\pi}{4}\right)$	P_γ^{circ}
P_{unpol}	$\left(\frac{d\sigma}{d\Omega}\right)$	$\Sigma(\theta)$	-	-
P_x	-	-	$H(\theta)$	$F(\theta)$
P_y	$T(\theta)$	$P(\theta)$	-	-
P_z	-	-	$G(\theta)$	$E(\theta)$

Figure 4. Polarisation observables in single meson production.

2.2.1 Transverse polarisation observables T and F

The reaction $\gamma p \rightarrow p\pi^0$ was studied at laboratory photon energies from 425 to 1445 MeV with a transversely polarized target and a longitudinally polarized beam [6]. The beam-target asymmetry F was measured for the first time and new high precision data for the target asymmetry T were obtained. In addition, the first data on target and beam-target asymmetries for the $\gamma p \rightarrow p\eta\pi^0$ reaction at photon energies from 1050 up to 1450 MeV were published [7].

2.2.2 Threshold π^0 photoproduction

Polarisation-dependent differential cross sections associated with the target asymmetry T have been measured in a dedicated experiment for the reaction $\gamma p \rightarrow p\pi^0$ with transverse target polarisation from threshold to photon energies of 190MeV [8]. These results have been used in combination with our previous measurements of the unpolarised cross section and the beam asymmetry for a model-independent extraction of S-and P-wave multipoles in the π^0-threshold region, which includes for the first time a direct determination of the imaginary part of the E_{0+}multipole.

2.2.3 Longitudinal polarisation observables E and G

A set of data for the longitudinal polarisation observable E and G were taken in the last year at the A2 facility and is under analysis. We could show in that experiments that a simultaneous measurement of both observables is possible by impinging with a longitudinaly polarised electron beam on a diamond radiatior. First preliminary results have been shown on this conference.

2.3 Double polarized Compton scattering

Beside the meson production program we have started with the experimental determination of double polarised Compton scattering. Since the cross section is two orders of magnitude smaller compared to pion-production and in addtion the final state requires an open trigger the experiment is very challenging. Our first results are published in [9].

The spin polarizabilities of the nucleon describe how the spin of the nucleon responds to an incident polarized photon. The most model-independent way to extract the nucleon spin polarizabilities is through polarized Compton scattering. Double-polarized Compton scattering asymmetries on the proton were measured in the $\Delta(1232)$ region using circularly polarized incident photons and a transversely polarized proton target. Fits to asymmetry data were performed using a dispersion model calculation and a baryon chiral perturbation theory calculation, and a separation of all four proton spin polarizabilities in the multipole basis was achieved. Our program to measure the Compton observables will be continued in the next years with other beam and target polarisations, which will lead finally to a more precise determination of the nucleons scalar and spin polarisibilities.

Acknowledgement

The authors wish to acknowledge the excellent support of the accelerator group and operators of MAMI. This work was supported by the Deutsche Forschungsgemeinschaft (SFB1044), the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" programme (Hadron Physics, Contract No. RII3- CT-2004-506078), Schweizerischer Nationalfonds (Contract Nos. 200020-156983, 132799, 121781, 117601, 113511), the UK Science and Technology Facilities Council (STFC 57071/1, 50727/1), the US Department of Energy (Offices of Science and Nuclear Physics, Award Nos. DE-FG02-99- ER41110, DE-FG02-88ER40415, DE-FG02-01-ER41194), and National Science Foundation (Grant Nos. PHY-1039130, IIA-1358175), INFN (Italy), and NSERC (Canada). We thank the undergraduate students of Mount Allison University and The George Washington University for their assistance.

References

[1] A. Jankowiak, Eur. Phys. J. A **28**, s01, 149 (2006)
[2] J.C. McGeorge *et al.*, Eur. Phys. J. A **37**, 129 (2008)
[3] P.Adlarson *et al.*, Phys. Rev. C **92**, 024617 (2015)
[4] M.Dieterle *et al.*, Phys. Rev. Lett. **112**, 142001 (2014)
[5] I.S.Barker *et al.*, Nucl. Phys. B **95**, 347 (1975)
[6] J.R.Annand *et al.*, Phys. Rev. C **93**, 055209 (2016)
[7] J.R.Annand *et al.*, Phys. Rev. C **91**, 055208 (2015)
[8] S.Schumann *et al.*, Phys. Lett. B **750**, 252 (2015)
[9] P.P.Martel *et al.*, Phys. Rev. Lett. **91**, 112501 (2015)