Chinese Physics C

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To cite this article: V. Vegna *et al* 2009 *Chinese Phys. C* **33** 1249

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CPC(HEP & NP), 2009, **33**(12): 1249—1253 **Chinese Physics C** Vol. 33, No. 12, Dec., 2009

Latest results from GRAAL collaboration*

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Abstract The GRAAL experimental set-up consists of a polarized and tagged photon beam that covers an energy range from a minimum of 600 MeV up to a maximum of 1500 MeV, of a liquid Hydrogen or Deuterium target and of the 4π Lagrange detector optimized for photon detection. It allows the study of pseudo-scalar and vector meson photoproduction on the nucleon in the energy range corresponding to the second and the third resonance regions. In the following, the Σ beam asymmetries in η and π^0 photoproduction on quasi-free nucleon are shown. Also single and double polarization observables in $K^+\Lambda$ photoproduction on free proton are shown; they are important to confirm the role of new or poorly known resonances in the 1900 MeV mass region.

Key words polarized photon, meson photoproduction, polarization observables

PACS 25.20.Lj, 13.60.Le, 13.88.+e

1 Introduction

Single and double polarization observables play a crucial role in the study of pseudo-scalar and vector meson photoproduction processes; their measurement allows the extraction of information on not-dominant terms of the production mechanisms, whose contribution is suppressed in total and differential cross-sections.

In order to perform polarization observables measurements, GRAAL experimental set-up consist of:

1) a fully linearly polarized and tagged photon beam, obtained by the Compton backscattering[1] of a laser light against the 6 GeV electrons circulating in the ESRF storage ring. The backscattered photon polarization can be easily rotated from the horizontal to the vertical direction with a half wave length placed plate in front of the laser;

2) a liquid Hydrogen or Deuterium target; if results on quasi free-proton in deuteron are in good

Received 7 August 2009
* Supported by ESRF as a host institution and to the members of the CRG support group
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agreement with results on free-proton in Hydrogen, then data on quasi-free neutron in deuteron could be used to infer results on the free neutron case;

3) the Lagrange detector[2]: it is optimized for the detection of photons with high energy resolution and neutrons with high detection efficiency and for the detection and identification of charged particles with good angular and TOF resolution.

During data taking the photon beam polarization direction is rotated each 20 minutes in order to collect the two different sets of data in the same experimental conditions. It allows an easy and absolutely efficiency independent extraction of the Σ beam asymmetry at fixed values of the incident photon energy E_γ and of the polar angle of the meson in the centre of mass frame $\theta^*_{\rm mes}$, from the fit of the azimuthal distribution of the following ratio:

$$\frac{\frac{N_{\rm V}}{K_{\rm V}}}{\frac{N_{\rm V}}{K_{\rm V}}+\frac{N_{\rm H}}{K_{\rm H}}}=\frac{1}{2}(1+P(E_\gamma)\Sigma(E_\gamma,\theta^*_{\rm mes})\cos(2\phi)),$$

where $N_{\rm V(H)}$ is the number of selected events with vertical (horizontal) polarization, $K_{\rm V(H)}$ is the photon flux corresponding to the vertical (horizontal) polarization , $P(E_\gamma)$ is the known beam polarization degree and ϕ is the azimuthal angle of the meson in the final state with respect to the horizontal direction.

By this procedure GRAAL has produced high quality asymmetries for different reactions; in particular, the latest results concern:

$$\gamma+{\rm n(p)}\rightarrow\eta+{\rm n(p)},$$

$$\gamma+{\rm n(p)}\rightarrow\pi^0+{\rm n(p)},$$

$$\gamma+{\rm p}\rightarrow{\rm K}^+\Lambda.$$

2 η and π⁰ photoproduction on quasi-free nucleon in Deuterium

Graal results[3, 4] show a very similiar distribution of the Σ beam asymmetry for the free proton in Hydrogen and for the quasi-free proton in Deuterium both for η (Fig. 1) and for π^0 photoproduction (Fig. 2).

Very few differences occur in the energy bins around 1 GeV and they can be ascribed to the Fermi motion. For this reason data on quasi-free neutron can be used to infer results for the free neutron case.

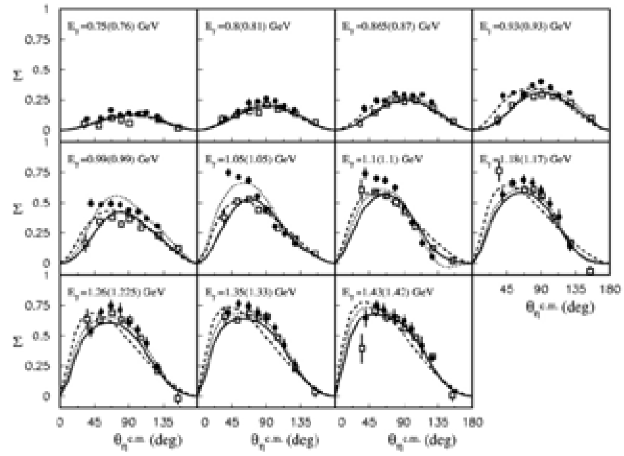

Fig. 1. Σ beam asymmetry results in η photoproduction on the proton[3]. Results on the quasi-free proton (empty squares) are compared with results on the free-proton (full circles). Data are compared with different theoretical models: MAID2001 for the free proton (dotted line) and MAID2001 (solid line) and the reggeized model (dashed line) for the quasi-free proton.

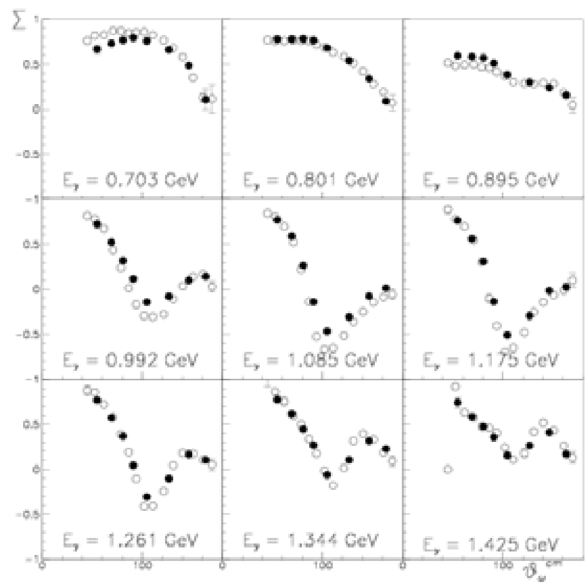

Fig. 2. Σ beam asymmetry results in π^0 photoproduction on the proton[4]. Results on the quasi-free proton (full circles) are compared with results obtained for the free-proton (empty circles).

The Σ beam asymmetries in η and π^0 photoproduction on the quasi-free neutron are shown in Fig. 3 and in Fig. 4 respectively.

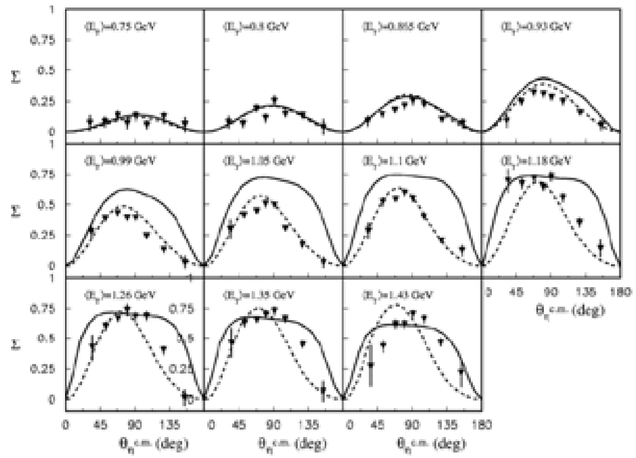

Fig. 3. Σ beam asymmetry results in η photoproduction on quasi-free neutron[3]. Data are compared with MAID2001 (solid line) and the reggeized model (dashed line).

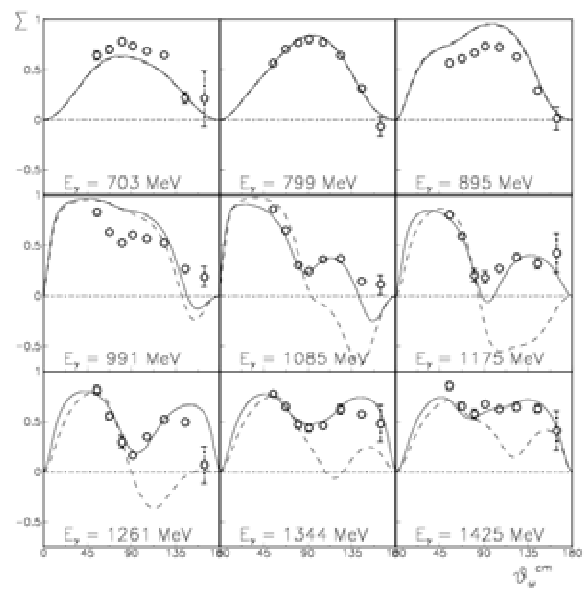

Fig. 4. Σ beam asymmetry results in π^0 photoproduction on quasi-free neutron[4]. The inclusion of GRAAL data in MAID database produced important differences between the MAID2007 (dashed line) and the modified MAID2007 (solid line) models.

Results on the neutron have not been completely interpreted and the comparison with results on quasi-free proton shows that there are different reaction contributions in the two cases. The effect is more evident if we look at the Σ beam asymmetry for fixed values of the polar angle $\theta^*_{\rm mes}$ as a function of the incident photon energy E_γ (Fig. 5 for η photoproduction and Fig. 6 for π^0 photoproduction).

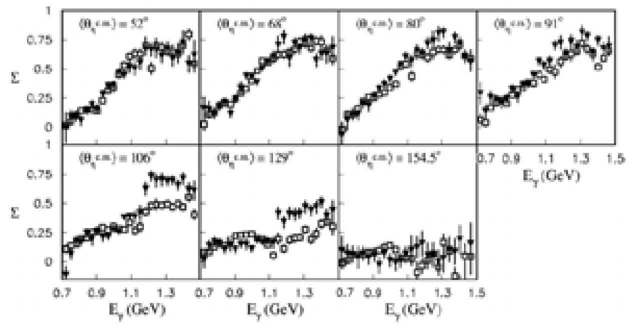

Fig. 5. Comparison between Σ beam asymmetry results in η photoproduction on quasi-free neutron (full triangles) and on quasi-free proton (empty squares)[3].

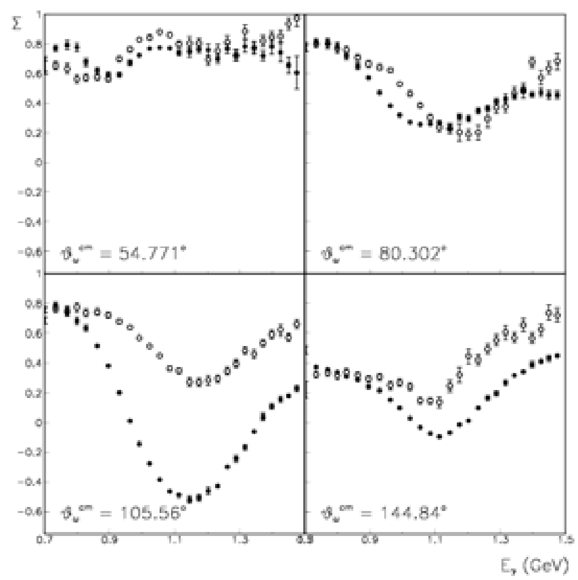

Fig. 6. Comparison between Σ beam asymmetry results in π^0 photoproduction on quasi-free neutron (empty circles) and on quasi-free proton (full circles)[4].

3 $K^+\Lambda$ photoproduction on free proton in hydrogen

$K^+\Lambda$ photoproduction is a clear example of the good performances of GRAAL detector in charged particle detection and discrimination. Due to the fact that the weak Λ decay is a self-analyzing reaction, it has been possible to perform single[5] and double[6] polarization observable measurements. GRAAL results on the Σ beam asymmetry (Fig. 7) and on the P_Λ recoil polarization (Fig. 8) confirmed the necessity to take into account the contribution of a new D_{13} state around 1900 MeV.

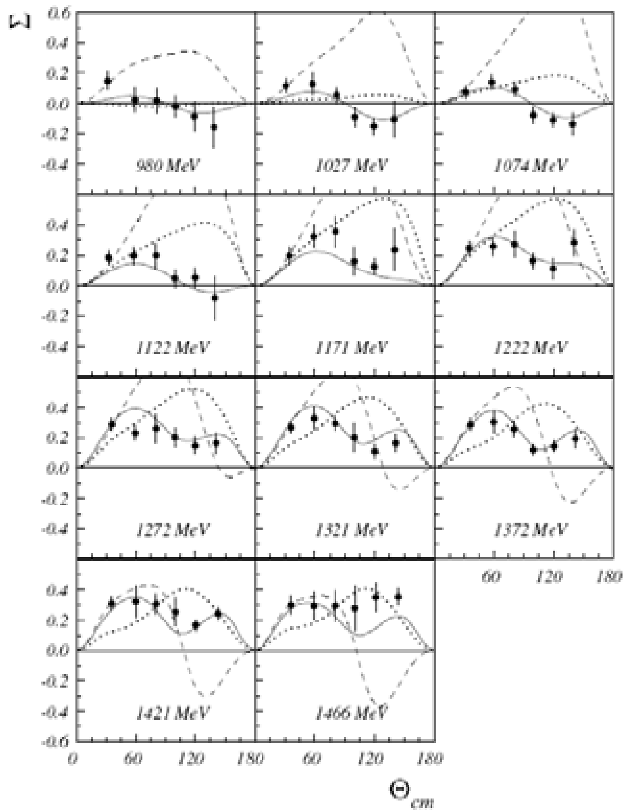

Fig. 7. GRAAL data[5] compared with different theoretical models: the Bonn coupled channel analysis (solid line), the Ghent Isobar (dotted line) and the Saclay-Argonne-Pittsburgh (dashed line) models.

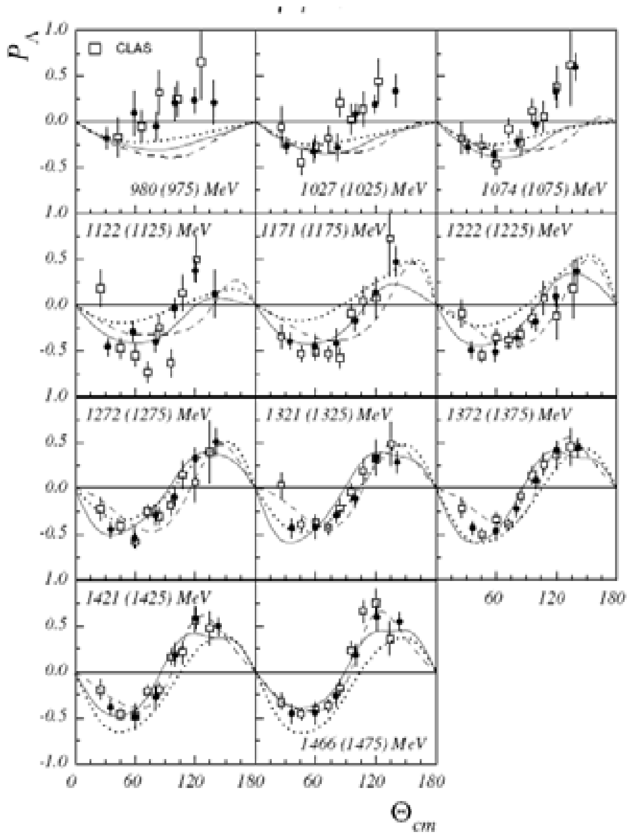

Fig. 8. GRAAL (full circles)[5] and CLAS (empty squares — energies in brackets) data compared with different theoretical models: the Bonn coupled channel analysis (solid line), the Ghent Isobar (dotted line) and the Saclay-Argonne-Pittsburgh (dashed line) models.

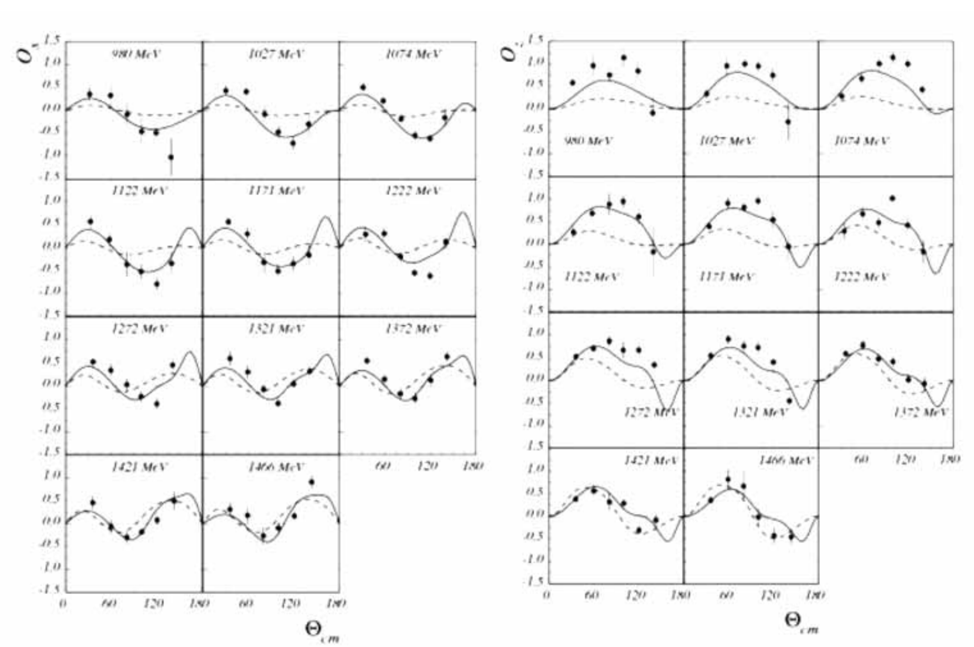

Fig. 9. GRAAL results for the beam-recoil polarization observables[5]. Data are compared with predictions of the Bonn-Gatchina (solid line) and the Regge-Plus-Resonance (dashed line) models.

Beam-recoil observables measurements for this reaction have been performed at GRAAL[6] (Fig. 9), with a linearly polarized photon beam, and at CLAS[7], with a circularly polarized photon beam. The two data-sets are in a very good agreement (Fig. 10) and they both confirm the necessity to introduce the contribution of the resonances P_{13} and/or D_{13} in the mass region of 1900 MeV. Moreover it is important to observe that we will need to measure only one additional double polarization observable in order to extract the four helicity amplitudes for $K^+\Lambda$ photoproduction on the proton.

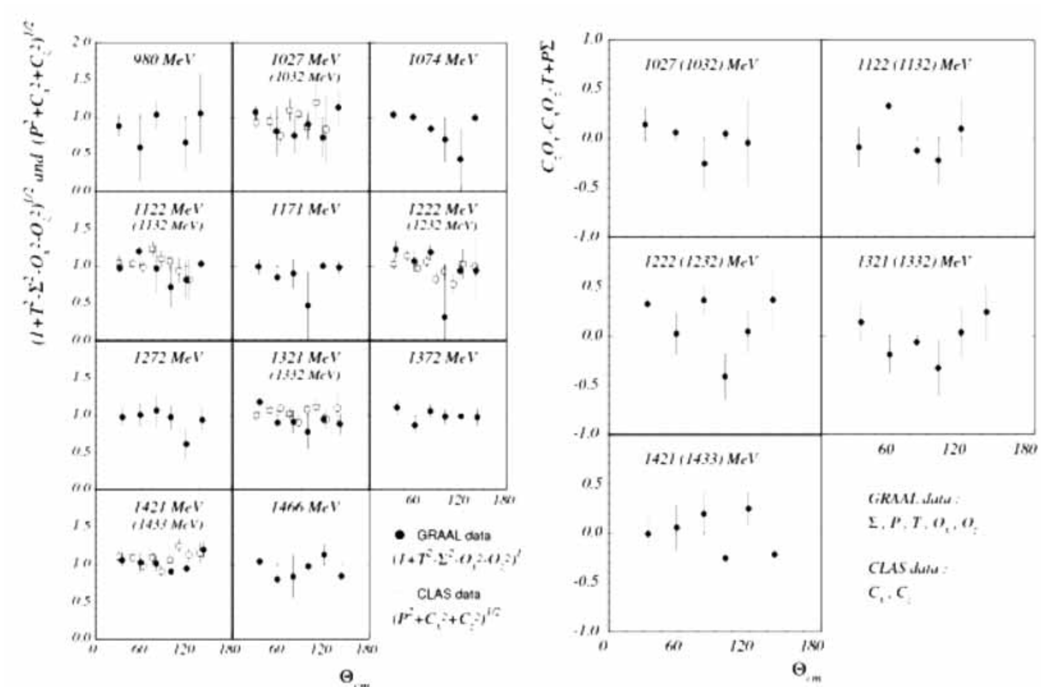

Fig. 10. Comparison between GRAAL[6] and CLAS results [7]. The two independent sets of data satisfy the expected relation for polarization observables.

4 Conclusions

Latest results from GRAAL collaboration have been shown. Results on the Σ beam asymmetry in η and π^0 photoproduction on the proton and on the neutron show different behaviour in certain energy and angular bins. It implies that resonant contributions are involved in different ways, depending on the nucleon we are investigating.

Results on single and double polarization observables in $K^+\Lambda$ photoproduction on the proton are also shown. They shaded a new light on the contribution of the missing $D_{13}(1900)$ resonance and of a new $P_{13}(1900)$ state.

We would like to thank L.Tiator, A.Fix and S.Kamalov for their contribution to the interpretation of GRAAL data.

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