Recent progress in N* physics from Kaon photoproduction experiments at CLAS

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Abstract. The N* programme at CLAS in Jefferson Lab is dedicated to the study of the spectrum of baryon resonances and the search for missing resonances. Recent developments in polarized beams and targets at CLAS have made it possible to measure many of the single and double polarization observables which are necessary to disentangle the contributing processes. In particular, CLAS is well on the way to making the first complete measurement on pseudoscalar meson production. The current status of the N* program is presented together with preliminary results from recently completed Kaon Photoproduction experiments.

1. Introduction
The photoabsorption cross section on the proton is shown in figure 1a. The evidence of resonant behaviour is clear from this 1D picture and constituent quark models, based on SU(6)×O(3) symmetry, do a good job of explaining such experimental results. However, the models overpredict the number of nucleon resonances, the so-called missing resonances, and it is clear that an extraction of amplitudes from several reaction channels will be required for the unambiguous determination of the baryon spectrum. In pseudo-scalar meson photoproduction, a complete measurement of the amplitudes is possible provided one measures with sufficient accuracy a minimum of seven polarization observables, in addition to differential cross sections [1]. This was proposed as early as 1975 and has been a holy grail of hadron physics for several decades. These observables include measurements with combinations of polarized beam, target and recoil, which pose a major experimental challenge and, until recently, have not been possible. However, at CLAS [2], with access to polarized photon beams and polarized targets, combined with the capability of capturing multi-particle final states over a large portion of 4π, we are in the process of making these measurements.

Circularly polarized photons have been available at JLab for many years, linearly polarized photons are now available at CLAS via coherent bremsstrahlung, longitudinal and transversely polarized proton targets (butanol) are available using FroST (Frozen Spin Target), and polarized neutrons are now available with the HDIcetarget. There is no recoil polarimetry, but for strange channels the recoiling hyperon is self-analysing, and thus the recoil polarization of the hyperon can be measured by measuring the angular distribution of the decay products in the CLAS spectrometer. It is, therefore possible to make the complete measurement on KY channels and to measure a range of single and double polarization observables on many other channels including single and double π production, η, η′ and ω.
Several running periods have been dedicated to this program in recent years, and the first results already published. For example, The First measurements of Beam-Recoil Observables $C_x$ and $C_y$ in Hyperon Photoproduction [3] was a notable early step and has been followed up by several more experiments with the aim of making the complete measurement. Some preliminary results from these and other recent N* experiments are show in the following sections. The results which are shown are mostly unpublished and preliminary, and are intended to illustrate the breadth of the programme and the quality of the data.

2. Recent measurements

2.1. Linearly polarized photons on the proton

The g8 experimental programme was the first at Jefferson Lab to use the new coherent bremsstrahlung facility, which produces a beam of photons with degree of linear polarization as high as 90%. Photons in the range 1.0 GeV - 2.1 GeV were incident on a LH$_2$ target to allow the measurement of the beam asymmetry $\Sigma$ for several channels including single and double $\pi$ production, $\eta$, $\eta'$ and $\omega$. For the hyperon channels it was also possible to measure recoil polarization $P$, Target Asymmetry $T$ and the beam-recoil observables $O_x$ and $O_z$. Figure 2 shows some of the results for the photon beam asymmetry $\Sigma$ for the reaction $\gamma p \rightarrow \pi^0 p$. These preliminary results demonstrate good agreement with previous data, and give an indication of the high statistics and extended coverage from the g8 experiment. Similar quality measurements have also been made on the $\pi^+ n$ channel.

Figure 3 shows preliminary results for of the beam-recoil double polarization observable $O_x$ for the reaction $\gamma p \rightarrow K^+ \Lambda$. The lines are from the RPR model of the Gent group using different resonance contributions. It is clear that this data will be a valuable ingredient for any future amplitude analysis. The observables $O_z$, $\Sigma$, $P$ and $T$ have also been measured, and the same observables have been measured for the reaction $\gamma p \rightarrow K^+ \Sigma^0$.

2.2. Linearly and circularly polarized photons on polarized proton target

The most recent experiments in the N* program have used FroST, the recently developed frozen spin target. All combinations of beam and target polarizations were been used over 2 running periods which were recently completed (fall 2010), so only some very preliminary results are
Some preliminary measurements of the beam asymmetry for $\pi^0p$. The blue line is from SAID. Analysis by M. Dugger, ASU.

Figure 2. Some preliminary measurements of the beam asymmetry for $\pi^0p$. The blue line is from SAID. Analysis by M. Dugger, ASU.

available. Figure 4 shows preliminary measurement of G and E, the beam - target observables for $\gamma p \rightarrow K^+\Lambda$. A large effort is now underway on the analysis of the FroST data, which will lead to many new measurements.

2.3. Linearly and circularly polarized photons on the neutron
In the g13 programme beams of circularly and linearly polarized photons were used together with a liquid Deuterium target to make measurements on the neutron. Figure 5 shows some representative, preliminary measurements of beam asymmetry $\Sigma$ for 2 hyperon channels: $\gamma n(p) \rightarrow K^0\Lambda$ and $\gamma n(p) \rightarrow K^+\Sigma^-$. For the $K^+\Sigma^-$ it is clear that the new measurements will extend the range of the small amount of world data on this channel. The $K^0\Lambda$ measurements will be the world’s first. The observables $O_x, O_z$ have been also measured for this channel, and for $K^0\Sigma^0$.

3. Status of N* program
In addition to several measurements of differential cross sections, several single and double polarization observables have been measured on many reaction channels. The analysis of the more recent measurements is still underway and over the next few years will provide vital constraints to the amplitude analyses which will be necessary for a full understanding of the baryon resonance spectrum. For single pion channels measurements have been made over a wide range of kinematics with very small error bars, and for the hyperon channels, many observables

Figure 2. Some preliminary measurements of the beam asymmetry for $\pi^0p$. The blue line is from SAID. Analysis by M. Dugger, ASU.
Figure 3. Preliminary measurement of the beam-recoil double polarization observable $O_x$ for $K^+\Lambda$ photoproduction on the proton. The lines are from the RPR model of the Gent group using different resonance contributions. Analysis by C. Paterson, Glasgow.

have been measured for the first time, or made with higher precision into previously unexplored kinematic regions. The data have been taken to produce the world’s first complete measurement in pseudoscalar meson production, and with the completion of FroST, all 16 observables will have been measured for $\gamma p \rightarrow K^+\Lambda$. Furthermore, in the near future the experiments with the HDIce target will provide polarized neutrons, and facilitate the first complete measurement on the neutron.

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Figure 4. Preliminary measurement of E, the beam - target observable for π+n photoproduction on the proton

Figure 5. Examples of the preliminary measurements of beam asymmetry for hyperon channels on the neutron. a) K⁺Σ⁻ at $E_γ \sim 2.3$ GeV. Analysis by E. Munevar, GWU. b) $K_0^sΛ$ at $E_γ \sim 2.1$ GeV. Analysis by N. Hassall, Glasgow. In both case there are measurements of this quality from threshold to 2.3 GeV. The first measurement of the $K_0^sΣ^0$ has also been made over the same photon energy range.

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