Strangeness production in CLAS

Sergio Anefalos Pereira[1]
(for the CLAS collaboration)

Laboratori Nazionali di Frascati - Via E. Fermi,40 – I-00044 Frascati (Rome) Italy

Abstract. Quark models with approximate SU(6) $\otimes$ O(3) symmetry predict more states than have been found experimentally. This is often referred to as the "missing" resonance problem. A comprehensive study of electromagnetic strangeness production has been undertaken at Jefferson Lab using the CLAS detector, circularly and linear polarized photon beams and polarized hydrogen and deuterium targets, where many proton data has been published. Here we will focus on neutron photo-production, in particular, the unpolarized $\gamma n(p) \to K^+\Sigma^-(p)$ differential cross section.

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INTRODUCTION

A major goal of hadron physics is to study the structure of the nucleon and its excited states. In quark models the number of excited states is determined by the effective degrees of freedom, while their ordering and decay properties are related to the residual quark-quark interaction [1]. A different class of models uses interactions that give rise to a quark-diquark clustering within the baryon [2]. More states are provided by collective models of the baryon, like the algebraic approach [3], or flux-tube models [4], which are motivated by lattice QCD. So far, however, the experimentally observed number of states is still far lower than predicted, leading to the so-called "missing resonance" problem [5]. Mapping out the spectrum of excited states that decay into kaon-hyperon (KY) particles is crucial to provide a deeper insight into the underlying degrees of freedom of the nucleon and to discriminate among different models.

In addiction to this, for Y-photoproduction on the neutron one can take full advantage of the isospin symmetry of the triplet, putting significant constraints on the γKNY coupling constants [6]. By comparing bound and free proton results, using hydrogen and deuterium targets, final state interactions can be estimated and YN interactions can be studied.

JEFFERSON LAB AND THE CLAS DETECTOR

The CEBAF (Continuous Electron Beam Accelerator Facility) accelerator at Jefferson Lab is capable of delivering electrons with an energy range of 0.8-6.0 GeV, a current of 200μA and and beam polarization of $\sim$ 85%. It can simultaneously deliver beams

[1] sergio.pereira@lnf.infn.it

to 3 Halls. The CLAS (Cebaf Large Acceptance Spectrometer) [7] utilizes a non-uniform toroidal magnetic field generated by six superconducting coils which define six independent modules. The photon tagger can produce a tagged bremsstrahlung photon beam with 20-95% of the electron beam energy [8].

The targets can be longitudinally and transversely polarized with respect to the incident beam. Before 2010, the Hall-B polarized target has been used only in electron beam experiments due to the limited angular coverage in the forward direction imposed by the two 5 Tesla Helmholtz coils [9]. The FROzen Spin Target (butanol) with longitudinal and transverse polarization was designed to minimize this problem. In 2010, the FROST experiment finished a successful data-taking period with polarizations of $82-85\%$.

PHYSICS OBSERVABLES

As part of a comprehensive study of electromagnetic strangeness production at Jefferson Lab, a complete set of observables has been measured. In order to determine the transversity amplitudes in pseudoscalar meson photoproduction, without discrete ambiguities, four complex helicity amplitudes are necessary, at each energy and angle, resulting in 16 measured spin observables [10]. The differential cross section, $\sigma(\Theta)$, plus 3 single-spin observables, beam (Σ), target (T) and recoil polarization (P), are denoted as Type S measurements. In addition, there are 12 double-spin observables which can be classified into three types: beam-target (BT), beam-recoil (BR), and target-recoil (TR). All the above measurements have already been done and all 16 spin observables will be published soon for the first time.

So far, the CLAS collaboration has published results on $\sigma(\Theta)$, P and polarization transfer (C_x/C_z) for the reactions $\gamma p \to K^+\Lambda$ and $\gamma p \to K^+\Sigma^0$ [11, 12, 13]. New results have been published using the $g11$ unpolarized data set [14, 15]. Using the $g8b$ data taken with linearly polarized photon beams, results on Σ, T, O_x and O_z will be published soon [16]. The remaining BT and TR double-spin observables have already been measured by the $FROST$ experiment [17] with longitudinal and transverse polarized targets. The last part of $FROST$ data-taking has finished in August 2010 and data-processing has begun.

Concerning deuterium targets, Jefferson Lab has performed two experiments named $g10$ (unpolarized) and $g13$ (with circularly and linearly polarized beams). The first measured the $\gamma n \to K^+\Sigma^-$ cross sections and the second has several KY analysis ongoing.

PHOTOPRODUCTION ON NEUTRONS

Cross section data of hyperon photoproduction on neutrons are very scarce. Recently, CLAS has measured the $\gamma d \to \Sigma^- K^+(p)$ differential cross section [18]. The differential cross sections for fixed photon energy as a function of $cos(\Theta)$ of the kaon in the KY center-of-mass frame are shown in Figure 1. The error bars represent the total error (statistical plus systematic). At a photon energy of ~ 1.8 GeV, a clear forward peak starts to appear and becomes more prominent as the photon energy increases. This behavior, which is typically attributed to contributions from t-channel mechanisms, is

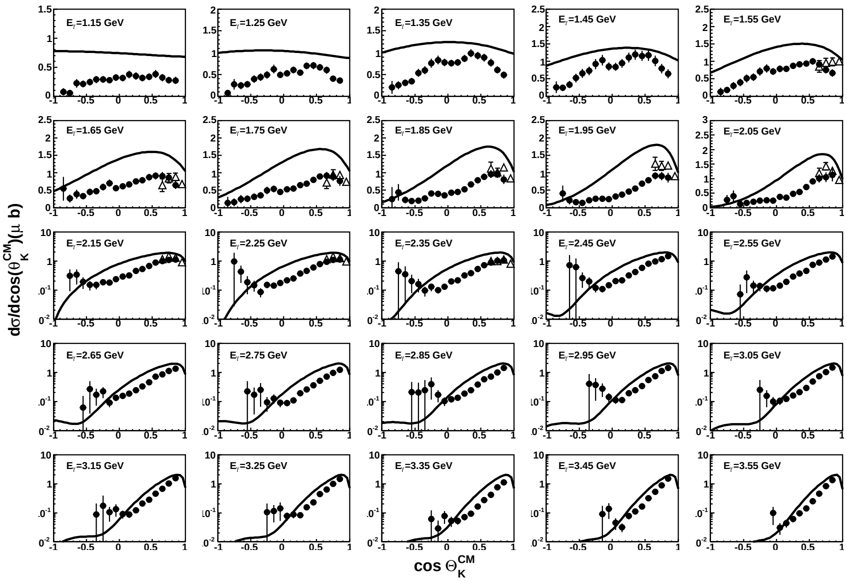

FIGURE 1. Differential cross sections for the reaction $\gamma n(p) \to K^+\Sigma^-(p)$ obtained by CLAS [18] (black circles). The error bars represent the total (statistical plus systematic) uncertainty. Data from LEPS [19] (empty triangles) and Regge-3 model prediction [20] (solid curve) are also shown.

not observed at lower energies, where the dominant contributions appear to be from *s*-channel mechanisms. Above $\sim$2.1 GeV there are indications of a possible backward peak, which might suggest the presence of *u*-channel mechanisms.

The few LEPS data [19] available for energies 1.5–2.4 GeV and at forward angles are also shown in Fig. 1. They are in good agreement with CLAS results within the total uncertainties. Also shown in Figure 1 are the theoretical results of a Regge-based calculation (Regge-3 model) [20].

In Figure 2 preliminary beam asymmetries for the $K^0\Lambda$, $K^0\Sigma$ and $K^+\Sigma^-$ channels on neutron are shown. For the channels $K^0\Lambda$(left) and $K^0\Sigma$(central) for the photon energy bin of Eγ=1.5GeV CLAS data (black circles) are compared with the MAID model [21] with different resonance contributions. There is no agreement between CLAS data and model predictions in the $K^0\Lambda$ channel, confirming the importance of CLAS data to constrain theoretical models. For the channel $K^+\Sigma^-$(right) for the photon energy bin of Eγ=2.3GeV CLAS data (open circles and red squares) are compared with LEPS results [19]. Within the error bars, there is a reasonable agreement between CLAS and LEPS data in the three bins in $cos(\Theta)$ where they can be compared.

New neutron data will be available soon from the *g*13 experiment with circularly and linearly photon beams and a deuterium target.

CONCLUSIONS

CLAS detector at CEBAF provides very precise measurements in a broad kinematic range in *KY* photoproduction offering kinematic and analysis advantages in N* physics. CLAS has already published *KY* results on proton and new beam-recoil (O_x, O_z) will

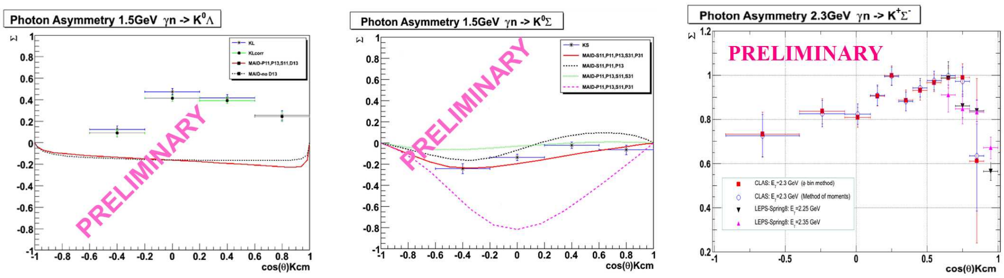

FIGURE 2. Preliminary beam asymmetries for the $K^0\Lambda$(left), $K^0\Sigma$(center) and $K^+\Sigma^-$(right) channels on neutron. For the channels $K^0\Lambda$ and $K^0\Sigma$ for the photon energy bin of Eγ=1.5GeV CLAS data (black circles) are compared with the MAID model [21] with different resonance contributions. For the channel $K^+\Sigma^-$ for the photon energy bin of Eγ=2.3GeV CLAS data (open circles and red squares) are compared with LEPS results (triangles) [19].

be published soon. The remaining beam-target (G, E) and target-recoil (L_x, L_z) results are in the analysis pipeline with FROST. Cross sections results of $\gamma n \to K^+\Sigma^-$ channel in a wide photon energy and angular range has been obtained with CLAS with $g10$ experiment for the first time and more results with polarized photon beam are coming out soon.

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