Report on Accomplishment for the JSA/JLab Fellowship for the Period 06/01/2007 - 05/31/2008

Edwin Munivar
Advised by Dr. Barry L. Berman
The George Washington University
March 24, 2009

Abstract
This document reports on my research activities during the period between June 01/2007 and May 31/2008 based on the award received as part of the JSA/JLab Fellowship 2007. As part of the g13 CLAS run period (successfully finished on Summer 2007), my research has been mainly focused on monitoring, calibrating, and analyzing the g13 data.

1 Summer 2007

I was working as research assistant at JLab during the Summer of 2007. During that period, the second part of my experiment (g13b) was underway. g13b run with linearly polarized photons in an energy range from 0.8 to 2.3 GeV. A key part of the experiment was, precisely, to keep the coherent photon peak within a certain energy bin. By doing this, we could have certain of having a high degree of linear polarization in the photon beam meaning that the target would be really hit by linearly polarized photons. Therefore, one of my tasks consisted of performing a real time monitoring of the location of the coherent peak. In order to do that, I modified a couple of scripts that allowed me to have the coherent peak monitored 24 hours a day during the running period.

My main task however consisted of beginning the calibration of the CLAS Drift Chambers (DC) for both parts of the experiment: g13a (circular polarization) and g13b (linear polarization). The CLAS drift chambers consist of six independent sectors, each one containing three radial regions. Each region is a separate physical chamber composed of two superlayers. Each superlayer contains six layers of sense wires (summing a total of about 35000 wires). Therefore, the DC calibration is performed sector by sector, superlayer by superlayer independently (with one set of parameters for each superlayer), which means to have to deal with a total of 36 sets of parameters to just calibrate one run. The role played by the DC is essential in any CLAS experiment because DC not only reveals the path followed by the charged particles (tracking) but also it gives the momentum associated with those particles. The particle identification depends strongly on tracking and momentum. Therefore, the better the DC calibration is, the easier the identification and separation between pion-kaons and kaons-nucleons will be.
During this period I also had the opportunity of giving a talk in the 7th Latin American symposium on Nuclear Physics and Applications that took place in Cuzco, Peru from June 11 - June 16. The 20-minutes talk, titled “The g13 Experiment at Jefferson Lab: Strangeness Production on the Neutron in the Deuteron with Polarized Photons: $\vec{\gamma}n \rightarrow K^+\Sigma^-$”, was focused on giving a general description of the g13 experiment along with its possible contribution to the world-wide data and recent coupled-channels models. As part of the conference proceedings, I wrote a paper based on my talk which was published in October of last year [1] (the paper is included as appendix).

2 Fall 2007

The first half of this period was dedicated to continue the DC calibration and prepare the corresponding document and talk for the defense of my Ph.D proposal at the George Washington University. My topic thesis is based on the exclusive analysis for the reaction $\vec{\gamma}d \rightarrow K^+\Sigma^- (p)$, paying special attention to the determination of the beam asymmetry and the total cross section which will help to fill the current scarce experimental data for this channel. Having passed the defense and being considered for the Ph.D candidacy allowed me to begin in the second half of the Fall with the analysis of my reaction.

In October I attended the 2007 Annual Meeting of the Division of Nuclear Physics of the American Physical Society that took place in Newport News from October 10-13. This meeting provided to me with an excellent opportunity to improve my knowledge in topics closely related to my research.

By the end of December the DC calibration for the first part (g13a) was relatively finished with some minor adjustments for applying and the calibration for the second part was underway.

3 Spring 2008

The first part of the spring culminated with a decent DC calibration for both g13a and g13b allowing us to perform the first try of g13 data processing (known technically as pass0). Several problems found in the timing detectors made necessary a new round of calibration for all of the detectors.

In April I presented a talk in the hadronic physics session of the 2008 APS April Meeting and HEDP/HEDLA Meeting that took place in St. Louis, Missouri from April 11-15. The talk titled “Strangeness Polarization on the Neutron in the Deuteron with Polarized Photons: $\vec{\gamma}n \rightarrow K^+\Sigma^-$”, was aimed at giving a brief discussion about the g13 experiment and showing some preliminary results of my current (by that time) analysis. Thus, that meeting represented a timely opportunity to present some results to the nuclear physics community and get some feedback from experts in the topic.

The period covered by the Fellowship ended up with very good sets of DC calibration parameters which show residuals (the primary means of measuring the resolution of the drift chambers) with values equal or less than 200 microns (humbly speaking, this could represent the best DC calibration performed in CLAS ever). Figures 1, 2, and 3 display the time-lime histograms obtained in May 2008 for the residuals corresponding to superlayers.
Figure 1: DC residuals for superlayer 1, all sectors (time-line histogram obtained in May 2008).

1, 3, and 5. As can be seen, the residuals for superlayers 1 and 3 are all within the range -200 and 200 microns (except for some individual runs which currently are fixed already). Superlayer 5 shows some structures with peaks going up slightly above 200 microns. This can be explained as a consequence of DC gas level issues during the running period (already fixed too). The current status of all of the detectors in CLAS allows us to start a new round of pass0.

The analysis of my reaction is underway. Although the g13 data is not completely suitable to be analyzed yet, the current status of the data has allowed me to work on the particle identification and neutron detection. Currently I am refining the particle identification process and implementing an algorithm to determine efficiently the path described by the neutron involved in my reaction (neutron corrections). This step is very important to improve the reconstruction of the $\Sigma^-$. Figure 4 depicts the cuts employed to separate $K^+$ from $\pi^+$ and $p$. In my opinion, this momentum-dependent cut provides with a cleaner and more reliable signal for $K^+$ (same cuts are applied to separate $\pi^-$ from $K^-$). Figure 5 shows precisely how clean is the $K^+$ mass distribution after applying the momentum-dependent cut. A very preliminary $\Sigma^-$ mass distribution obtained without applying any neutron corrections is presented in Fig. 6. Although the distribution looks very thin, the peak seems to be shifted by about 50 MeV/c$^2$ respect to the nominal value. This shift is now attributed to an error in the cooking code. Overall, this preliminary analysis makes evident the feasibility of promising results based on g13 data.
Figure 2: DC residuals for superlayer 3, all sectors (time-line histogram obtained in May 2008).

Figure 3: DC residuals for superlayer 5, all sectors (time-line histogram obtained in May 2008).
Figure 4: Momentum-dependent cut to separate $K^+$ from $\pi^+$ and $p$. The cut defining potential good kaons is applied to be $|DTOF| < 1$ ns. Notice that this cut do not exclude a certain number of high-momentum pions.

Figure 5: Mass squared distribution for $K^+$ after applying the momentum-dependent cut above mentioned. The peak is off with respect to the nominal value by less than 5 MeV.
Figure 6: Mass distribution for $\Sigma^-$ as reconstructed from $\pi^-$ and $n$. The peak is about 50 MeV/c$^2$ off with respect to the nominal value. The reason for such a shift is now fully understood. A bug in the cooking code was causing to miss a very significant amount of neutrons.

References

The g13 Experiment at Jefferson Lab: 
Strangeness Production on the Neutron in the Deuteron with Polarized Photons: \( \vec{\gamma}n \rightarrow K\vec{Y} \)

E. Munevar*, B. L. Berman*, P. Nadel-Turoński*,†, and the CLAS Collaboration†

*The George Washington University, Washington, DC 20052
†Thomas Jefferson National Accelerator Facility, Newport News, Virginia 23606

Abstract. Strangeness has been shown to be important for the understanding of the so-called missing resonances. Due to the scarce experimental data in strangeness photoproduction on the neutron, phenomenological models such as coupled-channels analyses resort to certain approximations that do not allow getting either accuracy or agreement between different analyses when extracting resonance parameters. Thus, in order to obtain high-quality data on the neutron channels, a new experiment (designated g13), based on a liquid deuterium target and a polarized photon beam (both circular and linear polarization) covering from threshold to 2.3 GeV has been done at the Thomas Jefferson National Accelerator Facility. In this paper, a brief description of the g13 experiment is given.

Keywords: Kaon photoproduction, missing resonances, polarization observables

INTRODUCTION

The strong-interaction mechanism at the level of hadronic physics is still not well understood. Experimental measurements are well reproduced by quantum chromodynamics (QCD) at high energies, but its perturbative calculations diverge at intermediate energies. The difficulties in solving QCD in this intermediate-energy region makes it necessary for us to resort to phenomenological models.

Standard quark effective-potential models, in which the nucleon is represented by three degrees of freedom, predict a richer resonance spectrum than that measured experimentally [1, 2]. As opposed to this model, such a rich spectrum is not seen for the case of quark models with fewer degrees of freedom, such as those based on quark-diquark interactions inside the nucleon, the so-called diquark models [3]. Therefore, there is a set of excited states for the nucleon not yet found experimentally but predicted theoretically by the SU(6) symmetric constituent quark model; these hidden states are known as the “missing resonances.” Finding some of these states experimentally would confirm the validity of the quark-quark interaction model and, at the same time, would call into question the existence of strongly correlated quark pairs inside the nucleon. This is precisely the main goal of the g13 experiment: to search for missing resonances on the nucleon by using a polarized-photon beam and determining not only the cross section but also most of the polarization observables associated with the corresponding strange-particle reaction channels.
Most of the experimentally known resonances come from channels that include pions either in the initial state or in the final state of the reaction (the other known resonances are related to $\eta$ and $\omega$ production). The question is where to look for the missing resonances. Theoretical calculations have shown that missing resonances could be associated with resonances that couple weakly to pion channels and possibly strongly to photon channels [4]; this means that strangeness channels might be a good place to perform such a search. Specifically, the $K\Lambda$ and $K\Sigma$ photoproduction channels are the most important channels to look for these missing excited states of the nucleon. Recent theoretical analyses [5, 6] of the same CLAS polarization data on the proton [7] result in claims of evidence either for a $P_{13}$ or a $D_{13}$ resonance at 1900 MeV. Data for strangeness photoproduction on the neutron is needed to tell which theoretical analysis, if either, is correct.

Nucleon resonances can be studied by using phenomenological models that extract resonance parameters, including mass, total width, and branching ratios. These models use Feynman diagrams to include contributions in the reaction from Born terms, from nucleon resonances, and from non-resonant corrections; the vertices of these diagrams are expressed in terms of parameters to be fitted to the experimental data. In the missing-resonance energy region (> 1.7 GeV) there are several open channels which make it necessary to implement in the models not only purely hadronic data, but also photoproduction data. The simultaneous inclusion of both meson-nucleon and photon-nucleon reactions in a single phenomenological model constitutes what is known as “coupled-channels analysis” [8, 9]. Recent calculations based on the coupled-channels approach have shown the absolute necessity of having experimental data for the strangeness photoproduction channels on the neutron [10]. Reliable results from coupled-channels analyses currently require data for the $\gamma n \rightarrow K^0\Lambda^0$, $\gamma n \rightarrow K^0\Sigma^0$, and $\gamma n \rightarrow K^+\Sigma^-$ reactions. These reactions therefore represent a very important input for coupled-channels analyses either for ultimately discovering unseen nucleon resonances or for ruling out their existence [11].

THE g13 EXPERIMENT

In order to search for missing resonances, we have proposed and carried out a new experiment [12] designed to produce strangeness data on the neutron using polarized photons with very high statistics. This experiment has finished its run recently at the Thomas Jefferson National Accelerator Facility, using the CLAS detector system together with the polarized tagged-photon beam in Hall B. The experiment (consisting of two parts and designated as g13) is intended to fulfill the conditions for experimental data required by the coupled-channels approaches: high-quality data with good kinematic coverage
and many experimental observables available for each reaction channel. Thus, the experiment makes use of a liquid deuterium target \( LD_2 \) and both circularly (g13a) and linearly (g13b) polarized photon beams with the measurement of kaons or their decay products (pions) and the decay products of the \( \Lambda \) and \( \Sigma \) (pions and nucleons) in the final state. The first part of the experiment used circularly polarized photons in the photon energy range up to 2.5 GeV, and was run in the Fall of 2006. The second part used linearly polarized photons ranging from 1.1 to 2.3 GeV, and was run in Spring-Summer 2007. The polarization observables obtained from both parts add up to seven: hyperon recoil polarization \( (P) \), beam \( (\Sigma) \) and target \( (T) \) asymmetries, and circular and linear polarization-transfer coefficients \( (Q_x, Q_y, O_x, \text{ and } O_z) \). Adding to these observables the unpolarized differential cross section \( (d\sigma/d\Omega) \), we obtain a total of eight observables (out of ten independent observables) for each channel. The two remaining observables require the use of a polarized target [12].

For g13a, Fig. 1 depicts the invariant mass of \( p\pi^- \) and \( \pi^+\pi^- \) pairs which show clearly the lambda and kaon peaks for the reaction \( \gamma n \to K^0\Lambda \). Plots are based on 15 million triggers with a 3-pass electron beam of 1.9 GeV and 84% polarization. We expect to have about \( 2 \times 10^5 \) exclusive \( K^0\Lambda \) events.

**FIGURE 1.** Invariant masses of \( p\pi^- \) and \( \pi^+\pi^- \). The top right plot shows a cut on the kaon mass between 0.485 and 0.510 GeV/c\(^2\). A cut on the mass of lambda \( 1.108 < m_\Lambda < 1.122 \) GeV/c\(^2\) is used in the bottom right plot. The data in the figures represent only a tiny fraction (< 0.1 %) of our total data.

As shown in Fig. 2, the quality of data in g13 can also be seen from the g13b run by looking at the coherent bremsstrahlung spectrum (left plot) and the azimuthal asymmetry.
(right plot) for events with only two particles in the final state (mainly, $\gamma n \rightarrow p \pi^-$).

**FIGURE 2.** The left plot represents the coherent spectrum with edges at 1.5 GeV (blue line) and 2.1 GeV (red line). The right plot shows the azimuthal asymmetry for events with only two particles back to back in the start counter for $1.3 < E_\gamma < 1.5$ GeV.

**CONCLUSIONS**

In g13 we obtained about 50 billion triggers. Out of these, about half a million correspond to good strangeness-production events divided roughly half and half between circular and linear polarization. As can be seen from the figures shown above, we have obtained a data set of high statistics and quality in the g13 experiment.

**ACKNOWLEDGMENTS**

This work was supported by the U.S. Department of Energy under Grant No. DE-FG02-95ER40901.

**REFERENCES**