The 2009 - 2010 JSA Graduate Student Fellowship Award greatly supported my physics research at Jefferson Lab. It enabled me to travel to several physics conferences to present my research and to learn from and interact with other physicists from around the world. With the help of the JSA fellowship I’m on track to finish my Rice University Ph.D. thesis, $K^{*0}(892)\Lambda$ & $K^+\Sigma^{*-}(1385)$ Photoproduction on the Neutron, in the spring of 2011.

Introduction

My research focuses on the measurement of the spectrum of excited nucleons ($N^*$) and their decays, an important part of the effort to understand the structure of the nucleon. 22 $N^*$ states are predicted to exist from SU(6) x O(3) symmetry models [1]. 14 of these predicted $N^*$ states have been conclusively observed, while observation of the remaining 8 excited states is critical. It is postulated that if two of the three quarks within the nucleon form a correlated di-quark pair that it will limit the spectrum of possible excited states [2]. Measuring the properties of the spectrum of $N^*$ states will provide valuable information on how the constituent quarks interact within the nucleon.

The missing $N^*$ resonances are difficult to identify unambiguously because they are wide, overlapping, and lie on top of a significant non-resonant background. Most of the current information on $N^*$ states comes from analyses of $\pi N$ channels. However, it has been predicted that the s-channel photoproduction of $K^{*0}(892)\Lambda$ and $K^+\Sigma^{*-}(1385)$ will couple non-negligibly to the decays of several of the excited $N^*$ states, including the well-established four-star $N(2190)G_{17}$ state [1]. It may be possible to extract some of the missing $N^*$ resonances from their decays to hyperon ($Y$) and $Y^*$ channels.

In this vein, the CLAS g13 experiment in Hall B at Jefferson Lab collected 50 billion events on deuterium using circularly and linearly polarized photon beams. The experiment ran between October 2006 and June 2007, with photon energies ranging between 1.1 and 2.65 GeV. A 40-cm-long liquid-deuterium target was used near the center of the CLAS detector. CLAS contains a six-fold symmetric torus magnet to bend charged particles through the drift chambers, time-of-flight scintillator paddles, and other detector components for event reconstruction across a wide angular acceptance [3]. I have performed my analysis on g13a, the circularly polarized photon portion of the experiment.
Figure 1: The $\gamma n \rightarrow p\pi^-$ cross sections from the CLAS g10 and g13a experiments prior to corrections due to final state interactions for a specific $E_\gamma$ bin. The g13a data is preliminary and a few things need to be investigated but the cross section matches the published g10 result fairly well at this stage.

**Research and Service Work**

With the support of the JSA fellowship I was able to make a lot of progress on my research, as well as perform service work for the CLAS collaboration. I have assisted the CLAS collaboration by taking shifts at the detector and by performing many different measurement and acceptance studies on the g13 dataset for the run group. I have calculated preliminary cross sections of not only the $\gamma n \rightarrow K^{*0}(892)\Lambda$ and $\gamma n \rightarrow K^{+}\Sigma^{*-}(1385)$ reactions, but of the $\gamma n \rightarrow p\pi^-$ calibration reaction as well. When finished I plan on publishing all of these data in physics journals.

In order to calculate cross sections it is imperative to take into account all of the different problems that may have occurred in measuring the physics events. This is done by running simulations of the detector to see how many of the events that occurred were lost. Events can be lost either due to the detectors not having a full $4\pi$ angular coverage or regions of the detector malfunctioning or performing inefficiently during the experiment.

I performed many different studies of these event acceptance effects, including kinematic fitting to determine momentum and beam energy corrections, trigger and detector efficiency studies to take into account inefficient regions of the detector, and fiducial cuts to remove areas of the detector with low acceptance. To test whether these effects have been handled correctly, I made a preliminary calculation of the $\gamma n \rightarrow p\pi^-$ cross section. As shown in Figure 1, it compares favorably to the previously published world data, although a few investigations still need to be made. These acceptance studies are reaction-independent and are being used by other members of the g13 experiment for their analyses as well.

The $\gamma n \rightarrow K^{*0}(892)\Lambda$ and $\gamma n \rightarrow K^{+}\Sigma^{*-}(1385)$ reactions have many similarities so I have analyzed them in conjunction. The $K^{*0}(892)$ decays primarily to $K^{+}\pi^-$ and the $\Sigma^{*-}(1385)$ decays primarily to $\pi^-\Lambda$ so both of these reactions contain the same particles in the final state. The mass of the $\Lambda$ is calculated from its decay to $p\pi^-$ and is shown in Figure 2A. To select physics events...
corresponding to these reactions, this invariant mass is fit to a Gaussian and cut at $3\sigma$.

Since the neutrons are located within a deuteron target there is Fermi motion; the target neutron is not at rest. Therefore to select the events for my reactions, I placed a cut on the proton missing mass in $\gamma D \rightarrow K^+\pi^-\Lambda(p)$, as shown in Figure 2B. Additionally, a cut was placed requiring the momentum of the missing proton be less than 200 MeV/c, removing the majority of events in which one of the produced particles scattered against the spectator proton.

The invariant mass of the $K^{*0}(892)$ vs. that of the $\Sigma^{*-}(1385)$ is shown in Figure 3 to illustrate the signal overlap. Because these two reactions may interfere, this overlap region is cut away by fitting Breit-Wigners to the signals and cutting around the signal peaks such that 80% of the signal strength lies within the cuts. After the overlap cuts, the final $K^{*0}(892)$ and $\Sigma^{*-}(1385)$ signals are shown in Figure 4 for particular $E_\gamma$, $\cos(\theta)$ bins. These signals were fit to Breit-Wigners and are cut such that 80% of the signal strength is retained. Amongst the full range of $E_\gamma$ and $\cos(\theta)$ there are $\sim 31000$ $\Sigma^{*-}(1385)$ events and $\sim 4000$ $K^{*0}(892)$ events above background. Although preliminary cross sections have been calculated, I am not ready to show them yet as I am still performing critical systematic studies on my analysis.

**Travel and Presentations**

In the meantime, I presented my progress on my research at the CLAS Collaboration meetings in November of 2009 and June of 2010. I also presented my research to the international community in November at Hadron 2009 in Tallahassee, Florida, as well as at the April 2010 APS meeting in Washington, DC. I also published proceedings for my talk at the Hadron 2009 conference [4]. Additionally, I presented my research at my two job interview talks I had over the summer. They both went very well, and I have accepted a job offer from Carnegie Mellon University to be a post-doctoral research assistant after I finish my Ph.D.

I used the travel money awarded to me from the fellowship to travel to not only Hadron 2009 and the April 2010 APS meeting, but to the MENU 2010 conference in Williamsburg, VA as well. At these conferences, I was able to see many experts from around the world present and discuss many topics in nuclear physics. I was able to meet and discuss my work with numerous other
Figure 3: The $K^*(892)$ invariant mass from its $K^+\pi^-$ decay channel vs. the $\Sigma^*(1385)$ invariant mass from its $\Lambda\pi^-$ decay channel. Breit-Wigners are fit to the signals, and the cuts indicated by the black lines contain 80% of the signal strength.

Figure 4: (A) $K^*(892)$ and (B) $\Sigma^*(1385)$ signals after overlap cuts in particular $E_{\gamma}, \cos(\theta)$ bins. The signals are fit to Breit-Wigners, and the red lines are cuts which contain 80% of the signal. Overall there are $\sim 31000 \Sigma^*(1385)$ events and $\sim 4000 K^*(892)$ yield events above background.
scientists, including two theorists whom I have been working with to interpret my results. My nuclear physics knowledge base is much more well-rounded after attending these conferences, and I am very glad that I was able to attend them.

Summary

With the 2009 - 2010 JSA Graduate Student Fellowship Award I was able to make a lot of progress on furthering my career. I was able to attend three physics conferences and took that opportunity to network with other scientists and show them my research. I plan on finishing my PhD thesis, $K^*(892)\Lambda$ & $K^+\Sigma^-(1385)$ Photoproduction on the Neutron, at Rice University in the spring of 2011. I appreciate the opportunities that the JSA fellowship award granted, and I have tried to make the most of them.

References