Photoproduction of the $\Lambda^*(1520)$ Hyperon

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Abstract. The photoproduction of the $\Lambda^*(1520)$ on both the proton and neutron have been studied by using the CLAS eg3 run data set. The reactions are $\gamma d \to K^+\Lambda^*(n)$ and $\gamma d \to K^0\Lambda^*(p)$ with $\Lambda^* \to pK^-$. Preliminary total and differential cross sections have been extracted in the photon energy region $1.75 \text{GeV} < E_\gamma < 5.50 \text{GeV}$. This is the first time that the photoproduction of $\Lambda^*(1520)$ on the neutron is reported, and we will extend the results on the proton to higher energies than in previous studies.

Keywords: Hyperon, $\Lambda^*(1520)$, Photoproduction, Cross Section.


INTRODUCTION

There is renewed interest in strange baryon production in the nuclear physics community recently. There are several reasons for that. Some of the possible “missing” $N^*$ resonances are predicted to couple stronger to strange mesons and hyperons and thus decaying through strange channels. The searching for the pentaquark $\Theta^+$ has spurred the study of other strange baryons production mechanism. And there are new generation experiments with high luminosity making it possible to study those resonance states with small cross sections.

$\Lambda^*(1520)$, with a mass similar to that of the reported pentaquark $\Theta^+$ but opposite strangeness, is often the main background channel in those pentaquark searches. Yet its production mechanism is still poorly understood due to the lack of experimental data. There are only two photoproduction$^{1,2}$ and two electroproduction$^{3,4}$ measurements on the proton and no published data on the neutron. The measurements all suggest dominance of t-channel processes, but have $K^*$ exchange for the photoproduction and $K$ exchange for the electroproduction.

Several model predictions for total and differential cross sections are available. The photoproduction cross section on the neutron is predicted to be much smaller than on the proton$^5$. Measurement of cross section and decay angular distribution can provide constraints on model prediction and insights into the production mechanism.

EXPERIMENT

The eg3 data was collected in December of 2004 and January of 2005 in Hall B at Jlab. A 5.7655GeV electron beam was passed through a radiator and bent into a tagging system. The photon beam from the radiator with its energy ranging from $1.75 \text{GeV}$ to $5.50 \text{GeV}$ impinged upon a 40 cm long liquid deuterium target. Multi-particle final states were reconstructed in the CLAS detector. During the run period, about 4.2 billion physics events were collected.

DATA ANALYSIS

The data are calibrated and processed with the standard CLAS cooking software. Then a series of standard CLAS correction and cuts are applied with parameters tailored to the run. Charged particles are identified by their momenta and flight time.

For the proton channel, three final state charged particles $pK^+K^-$ are required. The dominant background is $p\pi^+\pi^-$, where the two pions are misidentified as kaons. The misidentification is cleared out by assuming the two kaons as
pions and cutting out when the missing mass is around the neutron mass. Then the exclusiveness is ensured by cutting at 3σ of the Gaussian peak around the deuteron missing mass \( M_{M_d}(p\pi K^-K^-) \). The resulting events still include another channel \( p\phi(1020) \) with \( \phi \rightarrow K^+K^- \) which was not cut out because it actually contributes to \( \Lambda^*(1520) \) production by interference.

For the neutron channel, four final state charged particles \( p\pi^+\pi^-K^- \) are required. To make sure the two pions are from \( K_s^0 \), a 3σ cut around the Gaussian peak of their invariant mass is applied. This cut effectively clears out the misidentification of \( \pi^- \) and \( K^- \) at the same time. The exclusiveness is ensured by cutting at 3σ of the Gaussian peak around the deuteron missing mass \( M_{M_d}(p\pi^+\pi^-K^-) \).

In both channels, the \( \Lambda^*(1520) \) resonance is clearly visible at the invariant mass \( M(pK^-) \) spectrum shown in Fig.1.

![Graphs](attachment:graphs.png)

**FIGURE 1.** Invariant mass distribution \( M(pK^-) \) for the (a) proton and (b) neutron channels.

**SIMULATION**

A simulation is performed to obtain the acceptance for those two channels. Nearly 10 million events are generated for each reaction with the FSGEN event generator which uses simple phase space distributions and contains Fermi-motion smearing. A constant t-slope \( \beta=2 \) is applied after several iterations and comparing to the t-slope for real cross sections of both channels. The generated events are processed by the standard CLAS simulation package GSIM to simulate the particle interaction with the detectors. Then particle track smearing and drift chamber wire efficiencies are implemented by the program GPP to mimic the actual CLAS resolution. The simulated raw data are cooked with the same version of the CLAS cooking software package as the eg3 data. Finally the reconstructed simulation events pass through same analysis procedure with same cuts applied in the real data. The acceptance is calculated by comparing the number of reconstructed events with the number of generated events.

**RESULTS**

**Kinematic Binning and Yield Extraction**

All of the events in data and simulation are binned by the photon energy \( E_\gamma \) and the kinematic variable \( t' = - (t-t_0) \). Bin widths vary to allow enough statistics in each bin for the yield extraction. The invariant mass \( M(pK^-) \) spectrum of every bin is fitted with a Breit-Wigner function convoluted with a Gaussian plus a polynomial background. Then the \( \Lambda^*(1520) \) yield is extracted by calculating the total signal minus the background.

**Differential Cross Section**

The resulting differential cross sections for the proton and neutron channels are shown for each energy bin in Fig. 2. They can all be well fitted by an exponential function of \( a e^{bt'} \). This indicates the dominance of t-channel processes and t slope \( \beta \) is determined from the fit. Note that the analysis is still in its early stage and the very preliminary results below only have statistical errors attached.
FIGURE 2. Differential cross sections of $\Lambda^*(1520)$ for the (a) proton and (b) neutron channels.

**Total Cross Section**

The total cross section is obtained by integrating the differential cross section over the whole range of $t$ for every energy bin. To compare our result to the available results, the $\Lambda^*(1520)$ total cross sections from Daresbary and CLAS g11 run (both on the proton) are shown together with our proton and neutron channel results in Fig. 3. Overall the proton result from eg3 data agrees with CLAS g11 result at lower energies and Daresbary result at higher energies. There's a potential structure around 4.3 GeV for eg3 data which still needs further investigation. The neutron result from eg3 data is the only one available up to now. It follows the similar trend of the proton channel and has similar magnitude. This is very different from what theory predicts.

FIGURE 3. Total cross sections of $\Lambda^*(1520)$. The circle is Daresbary result on the proton, the square is CLAS g11 on the proton, the star is CLAS eg3 result on the proton and the triangle is CLAS eg3 result on the neutron. The error is only statistical.
t-Slope

From the fitting of the differential cross sections, the t-slope is extracted and shown in Fig. 4. For the proton channel, the distributions of CLAS g11 and eg3 agree with each other. They are flat and centered around 2 at the energies above 2.5GeV, but rise sharply towards lower energies. The enhancement is due to the contribution from the $\phi$ interference. For the neutron channel, where there’s no interference, the t-slope is mostly flat over all energy range.

![Graph showing t-slope of \( \Lambda^*(1520) \) with data points and error bars. The square is CLAS g11 result on the proton, the star is CLAS eg3 result on the proton and the triangle is CLAS eg3 result on the neutron. The error is only statistical.]

**FIGURE 4.** t-slope of \( \Lambda^*(1520) \). The square is CLAS g11 on the proton, the star is CLAS eg3 result on the proton and the triangle is CLAS eg3 result on the neutron. The error is only statistical.

OUTLOOK

The \( \Lambda^*(1520) \) decay angle distribution will be examined to hopefully reveal some of its production mechanism. Systematic errors will be studied.

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REFERENCES

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