PHOTOPRODUCTION OFF THE PROTON
AT CLAS

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We report here differential cross sections for the reaction \( \gamma p \rightarrow K^* \Sigma \) for the first time with high statistics. The measurements were done using the CEBAF Large Acceptance Spectrometer (CLAS) at Jefferson Lab. Data were taken at 3.115 GeV electron beam energy using tagged photons incident upon a liquid hydrogen target. In addition, our analysis provides information about nucleon resonances and their couplings to \( K^* \) decay. Our data will be used to test predictions of theoretical models of \( K^* \) production, and to provide constraints on the \( K^* \Sigma N \) coupling constant used in these models.

1. Introduction

Some Quark Models predict yet undetected baryon resonances [1]. These “missing” resonances have not been observed via strong interactions and could be observed via the photoproduction method. Of special interest are the nucleon resonances \( N^* \) which could couple strongly to \( K \Lambda \) and \( K \Sigma \) [2]. Moreover, higher mass nucleon resonances could favor decaying into \( K^* \Sigma \), near threshold. Vector meson electro- and photoproduction near threshold might provide good knowledge about these resonances, their internal structure, and their couplings to vector mesons. This has been the main motivation for studying strange mesons photoproduction off the proton, \( \gamma p \rightarrow KY \), where \( Y \) denotes the hyperon,

\[
\gamma p \rightarrow K^+ \Lambda, \quad \gamma p \rightarrow K^+ \Sigma^0, \quad \gamma p \rightarrow K^{*0} \Sigma^+. \tag{1}
\]

Analyses and results on the first two reactions have been published [3, 4]. However, the third channel has not been studied due to its small cross...
section and the difficulty of detecting kaons. The availability of the high intensity electron facility and the CEBAF Large Acceptance Spectrometer (CLAS), at Jefferson Lab, has made it possible to study this channel.

**Theoretical Model:** A theoretical quark model [5] has been developed to study nucleon resonances and to present quark model predictions for the $K^{*0}$ production. In addition to using common quark model parameters, this model uses two free parameters: the vector and tensor couplings, $a$ and $b$, for the quark-$K^*$ interaction. These are the basic parameters in the model and are related to the $K^*ΣN^*$ couplings that appear in the quark model symmetry limit. The SU(3)-flavor-blind assumption of non-perturbative QCD is adopted, which suggests the above two parameters should have values close to those used in the $ω$ and $ρ$ photoproduction. That is, the model predicts cross sections for the $K^{*0}$ production using couplings extracted from non-strange production. Our data will provide a good test of this model.

$K^*$ production is related to other strangeness production in Eq. (1). At the hadronic level, $(γ, K^*)$ and $(γ, K)$ are related to each other since one reaction contains meson production in the other process as the $t$-channel exchanged particle, and therefore constrains the range of available couplings. This allows both reactions to use the same observables. At the quark level, both reactions involve the creation of $s\bar{s}$ pair from the vacuum. Hence, these reactions are related also through the quark model.

### 2. Experiment and Analysis

The $K^{*0}$ photoproduction data were extracted from the “g1c” data set (4.5 billion triggers) using the CLAS detector [6], at Jefferson Lab’s Hall B. Data for our analysis were taken at 3.115 GeV electron beam energies.

The photon beam was produced in Hall B photon tagger [7], by directing the electron beam toward the tagger’s radiator where the beam strikes an Al foil creating bremsstrahlung photons. Each photon was tagged by measuring energies of the recoiling electrons in the tagger spectrometer, up to 95% of incident electron beam energy. The photon beam was then directed to hit the target at the heart of CLAS, through a pair of collimators which trim the beam halo. The target, a liquid hydrogen of length 17.85 cm, was surrounded by a start counter which provides prompt timing measurements once photons interact with the target. A coincidence between the tagger and the start counter provided the trigger. See Ref. [6] for details on CLAS spectrometer.
When the $\gamma$ strikes the $p$, in addition to $K^{*0}$ other background channels are produced from $K^+$ production,

$$\gamma p \to K^+\Sigma^0, \quad \gamma p \to K^+\Lambda/Y^*$$  \hspace{1cm} (2)

In this experiment, $K^{*0}$ decays to $K^+\pi^-$, while both ground states $\Sigma^0(1193)$ and $\Lambda(1116)$, in the background channels Eq. (2), decay (with 64% probability) to $\pi^-p$, and the $\Lambda(1520)$ decays (with 14% probability) into $\pi^-\Sigma^+$. In addition, we have other backgrounds, from higher excited states of $\Lambda$. Fig. (1) shows diagrams of the $K^{*0}$ (signal) and $\Lambda(1520)$ production.

![Figure 1. The reaction of interest (left) and a background channel, $\Lambda(1520)$, Eq. (2).](image)

The only detected particles are $K^+$ and $\pi^-$. The $K^{*0}$ meson is identified from its decay products, $K^+\pi^-$, while $\Sigma^+$ hyperon is reconstructed from the missing mass of $K^{*0}$. We have two major background contributions: (i) from misidentified $\pi^+$ as a $K^+$, and (ii) from the $K^+$ production, Eq. (2). Contributions from $\Sigma^0(1193)$ and $\Lambda(1116)$ hyperons were removed by applying a cut on the $K^+$ missing mass, $MM(K^+)$. To remove contributions from $Y^*$ states and the misidentified pions, and to identify $\Sigma^+$ as well as to extract the yields from it, we applied two cuts on $K^{*0}$ mass spectrum: a peak cut centered at 0.892 GeV (the $K^{*0}$ cut) and side-band cuts (the $Y^*$ cut) on either side of $K^{*0}$ peak. Using the peak cut, our signal (the $\Sigma^+$ yield) is reconstructed from the missing mass, $MM(K^+\pi^-)$, and is fit with a gaussian plus a polynomial fit to the background. On the other hand, using the side-band cut, the $Y^*$ physics background is calculated from the $MM(K^+\pi^-)$, obtaining another $\Sigma^+$ peak that is fit in the same way. From these fits we obtained two $\Sigma^+$ yields, one from $K^*$ cut and the other from $Y^*$ cut. By subtracting the latter from the former one we obtained the final $K^{*0}\Sigma^+$ yields. The measured yields were then normalized by the real photon flux and corrected for the CLAS detector acceptance (from Monte Carlo).
3. Results and conclusions

Fig. (2) shows the differential cross sections for the $K^*\gamma$ photoproduction. Although not shown in this figure, the cross sections are in good agreement with the theoretical model of Zhao [5], after a small modification of the $K^*$-quark vector and tensor coupling constants (see Section 1). More details will be presented in an upcoming paper. This suggests that the theoretical model of Zhao for vector meson production within the quark model has some predictive power.

At small angles, our data show the cross section is dominated by $t$-channel exchange except at the highest photon energy bin. At higher energies, the forward-peaking moves out of our detector acceptance, as CLAS can only measure the production angle up to $\cos(\Theta_{K^*}) < 0.9$ due to the beam-pipe hole through the center of CLAS.

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