Electroproduction of $K^{*0}$ mesons at CLAS

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The electroproduction of $K^{*0}$ mesons using the CLAS detector is described. Data for two electron beam energies, 4.056 and 4.247 GeV, were measured and the normalized yields are compared.

1. INTRODUCTION

Quark models predict baryon resonances [1] that have not yet been observed via strong interactions. These resonances could be detected via electro- and photoproduction of strange mesons. Of special interest are the nucleon resonances $N^*$ which some of them could couple strongly to $K\Lambda$ and $K\Sigma$ [2]. Moreover, higher mass nucleon resonances could favor decaying into $K^*\Sigma$, near threshold. Using a quark-pair creation model [2], a study of $N^* \rightarrow K^*Y$, where $Y$ is the hyperon, shows that most $K^*Y$ decay branching ratios are small due to the high thresholds of these channels. Only a few low-lying negative-parity states are predicted to be strongly coupled to $K^*\Sigma$ channels, e.g. $N(2070)$, $\Delta(2140)$, $\Delta(2145)$. In addition, vector meson production could be used to investigate below-threshold resonance couplings to $K^*Y$.

Experimental studies of neutral vector mesons used to concentrate on high energy regions that are dominated by the diffractive process and which could be accounted for by a soft Pomeron exchange model. Only recently, the study of non-diffractive mechanism in the vector meson production, near threshold, has become possible via resonance excitations. 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 doing experiments to study strange mesons electroproduction off the proton, $ep \rightarrow e'KY$,

$$ep \rightarrow e'K^+\Lambda \quad ep \rightarrow e'K^{+0}\Sigma \quad ep \rightarrow e'K^{*0}\Sigma^+ \quad (1)$$

Much work and publications have been done on the first two channels [3]. However, the third channel has barely been studied, because of its small cross section and the difficulty of detecting the $K^*$ decay. The availability of the high intensity electron facility and the Cebaf Large Acceptance Spectrometer (CLAS) in Hall B [4] at JLAB, and other facilities, has made it possible to study this channel and opened new avenues to search for “missing resonances”. Here, $K^{*0}$ electroproduction results are presented. Preliminary results of this reaction are also shown in the thesis of Ref. [5].

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2. THEORETICAL BACKGROUND

A theoretical model in which a quark model, with an effective Lagrangian, approach to vector meson production [6], near threshold, has been developed for \( K^{*0} \) production [7]. It is the first theoretical attempt 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 (i) uses two free parameters: the vector and tensor couplings for the quark-\( K^* \) interaction. They are the basic parameters in this model and are related to the \( K^*\Sigma N^* \) couplings that appear in the quark model symmetry limit, and (ii) adopted the SU(3)-flavor-blind assumption of non-perturbative QCD, which suggests the above two parameters should have values close to those used in the \( \omega \) and \( \rho \) meson photoproductions.

Our experimental data should play a role in tuning these parameters as well as testing and improving this model.

The production of \( K^* \) vector mesons is related to other strangeness productions, Eq. (1), as well as non-strange vector meson production. At the hadronic level, these reactions are related to each other since one reaction contains the meson production in the other one as the t-channel exchanged particle, and therefore constraining the range of available couplings. This allows \( K^* \) and \( K \) production to use the same observables, which are obtained from non-strange vector meson production, \( \rho \) and \( \omega \) in the resonance region [6].

At the quark level, both \( K \) and \( K^* \) productions involve the creation of \( s \bar{s} \) pair production, from the vacuum, in the SU(3) quark model. In this model, the \( s \) quark couples to the meson in the same way as the \( u \) and \( d \) quarks, assuming quarks have the same masses, i.e. assumption (ii) above.

3. EXPERIMENT

The \( K^{*0} \) electroproduction data were extracted from “e1b” dataset using the CLAS detector [4], at Jefferson Lab’s Hall B. CLAS consists of: (1) the main torus: six superconducting magnetic coils making regions, or “sectors”. Their toroidal magnetic field deflects charged particles toward or away from the beam line, while keeping the azimuthal angle unchanged, (2) a forward-angle electromagnetic calorimeter (EC): it is located in the forward region of each CLAS sector and covers up to 45° of the polar angle. It detects particles moving forward and distinguishes electrons from pions, (3) Cherenkov Counter (CC): covers the same angular range above. It is used along with the calorimeter to create a coincidence trigger, (4) three Drift Chambers (DC): located in each sector and they determine the trajectories of charged particles from which their momenta are reconstructed. They cover about 80% of the azimuthal angle and a polar range from 8° to 142°, and (5) Scintillator Counters (SC): an array of 288 scintillator counters where the charged particles times of flight and their energies are determined. They cover the same angular range as the DC.

In this analysis we took data at 4.056 and 4.247 GeV electron beam energies, with a liquid hydrogen target of length 5 cm. All data (430 and 610 million triggers, respectively) were taken in Feb. 1999. The toroidal coils current was 2250 A, corresponding to a magnetic field at 60% of the maximal field setting.

We binned the \( K^{*0} \) electroproduction data in the c.m. energy \( W \), from 2.1 to 2.5 GeV, and the 4-momentum transfer \( Q^2 \), from 0.75 to 1.5 \((\text{GeV/c})^2 \), which are determined.
entirely by the electron kinematics. Due to low statistics, the data were binned into large bins: (i) 100 MeV in W, (ii) integrated over the above broad range in $Q^2$, and (iii) integrated over the full angular range of $\theta$ and $\phi$.

Figure 1. Feynman diagrams of the reaction of interest (left) and one of the physics background channels, e.g. $\Lambda(1520)$ production, Eq. (2). The detected particles are $e'K^+\pi^-$. In addition to the reaction of interest, $ep \rightarrow e'K^0\Sigma^+$, where $K^0(892)$ decays immediately into two detected particles, $K^0 \rightarrow K^+\pi^-$, there are other physics background contributions, from $K^+$ production,

$$ep \rightarrow e'K^+\Lambda(1520)$$

$$ep \rightarrow e'K^+Y^*$$

where the $\Lambda(1520)$, Eq. (2), decays with 14% probability to $\Lambda(1520) \rightarrow \pi^-\Sigma^+$. That is, Eqs. (2) and (3) are background contributions to our final state, $K^+\pi^-\Sigma^+$. Eq. (3) represents physics background from other excited states of $\Lambda$ family, e.g. $\Lambda(1600)$, $\Lambda(1670)$, $\Lambda(1690)$. These resonances have 3- or 4-star ratings as well as several exited states above 1.8 GeV. Diagrams of the $K^0(892)$ production (signal) and the $\Lambda(1520)$ production are shown in Fig. (1).

The detected particles are $e$, $K^+$, and $\pi^-$, while $K^0$ and $\Sigma^+$ are undetected directly. The $K^0$ was identified from the invariant mass of the $K^+\pi^-$ system, which peaks at 0.892 GeV, while $\Sigma^+$, from which we obtained the yields, was identified by applying cuts on both $K^+$ mass and the missing mass of $K^0$, as explained below.

We have two major background sources: (i) from the $\pi^+\pi^-$ events, where the $\pi^+$ is misidentified as a $K^+$, and (ii) physics backgrounds from other channels, Eq. (3). To remove both background contributions and to identify $\Sigma^+$, we used the side-band technique and applied the following mass cuts on both $K^+$ and $K^0$ mass distributions: (1) a cut on the $K^+$ mass peak and a side-band cut, (2) two similar cuts on the $K^0$ invariant mass distribution. The side-band cuts on both $K^+$ and $K^0$ produce the pion background and the physics background, respectively. Combinations of the above four cuts produce two $\Sigma^+$ peaks shown in Fig. (2), (i) top ($K^0$ cut): cuts on both $K^+$ and $K^0$ peaks give the signal (upper/green), and (ii) bottom ($Y^*$ cut): $K^+$ peak along with the $K^0$ side-band cuts give the physics background contribution (lower/red). The other two combinations give the pion background shown, in yellow, under each peak. In particular, the background from $\Lambda(1520)$ production, Eq. (2), was removed by applying a cut on the $K^+$ missing mass.
4. RESULTS AND CONCLUSIONS

We subtracted the pion background events from each $\Sigma^+$ peak, Fig. (2), obtaining two yields, one from $K^*$ cut and the other from $Y^*$ cut. Subtracting the latter yields from the former one resulted in the final yields. The yields were then corrected for the CLAS detector acceptance and normalized by the virtual photon flux.

The measurements have been finished and analysis of the data is in progress. Preliminary values of the normalized yields are shown in Fig. (3) as a function of the center-of-mass energy $W$. Currently, these data are being compared with the theoretical model (not shown). Our preliminary results show disagreement between the two beam energies, and further work is needed. However, the disagreement could be due to: (i) broad $Q^2$ bin: a difference between the two $Q^2$ averages, at a particular $W$ value, due to our broad $Q^2$ bin, might have contributed to this disagreement, (ii) $\epsilon$ dependence: the virtual photon flux dependence on the polarization constant, $\epsilon$, which have different values for the two beam energies, might have contributed to this disagreement too, (iii) acceptance: the model from which we calculated the acceptances is still under improvements, Sec. 2. Improving the model and calculating the final cross sections are in progress.

I would like to thank Ken Hicks and Avto Tkabladze for their help in this project, and also to Stepan Stepanyan for valuable discussions.

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