Strangeness Production at CLAS

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Abstract. The CLAS detector is a large acceptance spectrometer located at the electron accelerator at Thomas Jefferson National Accelerator Facility. Production of K^+ and K^* mesons along with associated hyperons were measured using the CLAS detector at electron beam energies of 2.4-4.4 GeV. In addition, polarization transfer from the electron helicity to the Λ hyperon was measured. These data are compared with theoretical models, where available, based on fits to older, less precise K^+ data. The new data for CLAS indicate that improvements in the models are necessary in order to interpret the results.

INTRODUCTION

Kaon electroproduction is complementary to pion electroproduction, and comparison of both reactions will be helpful to understand the role of various N^* resonances. Since s-quarks are not present as valence quarks within the nucleon, the reaction amplitudes depend on the wavefunction of $s\bar{s}$ quark pairs produced from the vacuum. Most models assume the $s\bar{s}$ are in a 3P_0 state. Polarization observables, which are easily measured because the Λ is self-analyzing, provide information about the state of the produced $s\bar{s}$ pair. This in turn can be used in theoretical models to improve our understanding of the reaction mechanism. We may also find that N^* resonances have different decay amplitudes into strange and non-strange channels. Unlike pion production, data for kaon production has been sparse, and the potential for finding "new" resonances is appealing.

In K^+ production, both t-channel and s-channel diagrams contribute. Because of the heavy mass of the s-quark, the t-channel contributes mostly at forward kaon angles. The N^* resonances contribute through the s-channel, and hence will be more visible at backward kaon angles. In addition, only N^* resonances can contribute to the Λ final state, whereas both N^* and Δ^* resonances contribute to the Σ^0 production. Because Λ and Σ^0 hyperons have the same valence quarks (uds) and nearly the same mass, they act as an isospin filter for s-channel production. A

FIGURE 1. Overall angular distribution of cross section to the Λ and Σ^0 final states.

comparison of the W -dependence for these two final states helps to untangle the role of N^* and Δ^* resonances in the reaction mechanism.

Other reactions with strange quarks, such as electroproduction of vector mesons like the K^* are also useful to understand the role of N^* resonances in the reaction mechanism. However, the higher threshold for K^* production (above $W = 2.0$ GeV) restricts this channel to resonances above the cluster of $L = 1$ resonances at about 1.7-1.9 GeV. This may be an advantage in a search for higher lying resonances which may be obscured by t-channel processes in other reaction channels [1].

EXPERIMENTAL SETUP

The CLAS detector is a novel design with a torroidal magnetic field. The nearly 4ft coverage is segmented into six sectors, each with three sets of drift chambers followed by plastic scintillators for time-of-flight measurement. At forward angles are Cerenkov detectors and electromagnetic calorimeters used in part for detection of the scattered electron. The CLAS detector has been described in detail elsewhere [2].

RESULTS AND DISCUSSION

Fig. 1 shows the angular distributions for kaon electroproduction to Λ and Σ final states. The data for the Λ exhibit a large increase as θ^* , the angle of the kaon relative to the virtual photon direction, becomes small ($\cos \theta \sim 1$) whereas for the Σ data tend to peak at central angles (near $\cos \theta^* = 0$). In addition, the ϕ -dependence of the cross sections is very different for these two

FIGURE 2. Angular distributions of cross sections for different bins in W . The Λ results are given by circles and the Σ results by squares. The curves are calculations for Λ (solid) and Σ (dashed).

final states at a given kaon angle. This difference is perhaps surprising when considering the Λ and Σ^0 are different only in the isospin configuration of the u - d quarks. (The δ effect on kinematics, but kinematics can not explain the differences seen in Fig. 1.) We note that constituent quark models [3] predict a larger coupling constant for t-channel processes for the Λ than for the Σ , which is consistent with the data in Fig. 1.

The unpolarized and interference cross sections for the *Lambda* (circles) and Σ (squares) production are shown in Fig. 2 as a function of $\cos \theta^*$. Also shown in this figure are curves from a hydrodynamic model by Mart and Bennhold [4] where the effective degrees of freedom are baryons and baryon resonances (s-channel) and mesons (t-channel), for the Λ and Σ channels. Although the calculations predict the general magnitude of the unpolarized cross sections ($\sigma_U = \sigma_T + \epsilon \sigma_L$ where T and L represent the transverse and longitudinal photon polarizations and ϵ is the standard kinematic variable), the interference cross sections for Λ production show structure not present in the solid curves. For Σ production, the interference structure functions are small, but again differ significantly from the predictions shown in the dashed curves. The calculations are based on phenomenological fits to previous data [5?] which had much larger error bars. Clearly, the new precise data from CLAS will force improvements in the theoretical models which in turn could lead to a more fundamental understanding of the production mechanism of strange quarks.

Both K and K^* mesons, with masses of 494 and 892 MeV respectively, contribute to the t-channel in the $H(e, e' K^+)$ reaction. As a result, any model of this reaction will necessarily predict the coupling constants for K^* production. By measuring the $H(e, e' K^{*0})$ reaction in addition to K^+ production, tighter constraints may be placed on theoretical models. Production of the neutral K^* has significant experimental advantages, because it decays almost immediately into K^+ and π^- . The large acceptance of CLAS provides the kinematic phase space necessary to measure K^{*0} production. Also, t-channel contributions are minimized due to the neutral charge, resulting in the prediction that s-channel nucleon resonances are the primary contributions. This reaction has a threshold just above $W = 2.0$ GeV, and so it may be sensitive to higher-energy N^* resonances. Known N^* resonances above 2 GeV are the $G_{17}(2190)$, $H_{19}(2220)$ and $G_{19}(2250)$. The W distribution of strength for K^{*0} production are shown in Fig. 3. We note that the acceptance

FIGURE 3. Relative yield (vertical axis) of K^* electroproduction as a function of W , after correction for the detector acceptance. The threshold for the $H(e, e' K^{*0}) \Sigma^+$ reaction is $W = 2.08$ GeV.

correction for the CLAS detector has only a small affect on the shape of the W -dependence. This suggests that the excess strength at 2.1-2.3 GeV is due to N^* resonance contributions, although it is not clear if the known (high-spin) resonances are contributing strongly here. Calculations are being developed using the same hadrodynamic model as used for K^+ production, and should provide evidence for the structure seen near threshold for K^{0*} production.

In conclusion, new precise data on strangeness production from CLAS is challenging theoretical models and will hopefully lead to a new understanding of the role of N^* resonances in electroproduction reactions.

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REFERENCES

1. Bennhold, C, "Kaon Photoproduction on the Nucleon", in *Strange Quarks in Hadrons, Nuclei and Nuclear Matter*, edited by K. H. Hicks, World Scientific, Singapore, 2000, pp. 64-73.
2. Brooks, W., *Nucl. Phys. A*, 664, 1077c (2000).
3. Capstick, S., and Roberts, W., *Phys. Rev. D*, 58, 1 (1998).
4. Mart, T., and Bennhold, C., *Phys. Rev. C*, 61,012201 (1999).
5. Bebek, C., *Phys. Rev. D*, 15, 3082 (1977).