KAON ELECTROPRODUCTION AT LARGE FOUR-MOMENTUM TRANSFER

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Exclusive $H(e,e'K)Y$ data were taken in January, March and April of 2001 at the Jefferson Lab Hall A. The electrons and kaons were detected in coincidence in the hall's two High Resolution Spectrometers (HRS). The kaon arm of the pair had been specially outfitted with two aerogel Cerenkov threshold detectors, designed to separately provide pion and proton particle identification thus allowing kaon identification. Preliminary data show the cross section's dependence on the invariant mass, W , along with results of systematic studies. Ultimately the data will be used to perform a Rosenbluth Separation as well, separating the longitudinal from the transverse response functions.

1. Introduction

The electromagnetic production of kaons allows measurement of the structure of mesons containing a strange quark and was one of the motivations for building the Thomas Jefferson National Accelerator Facility. Jefferson Lab is able to measure strange quark electroproduction from threshold through the deep-inelastic hard scattering (DIS) region.

Experiment E98-108¹ was approved to measure kaon electroproduction over a broad kinematical range. The experiment separates the longitudinal, transverse, and longitudinal-transverse interference responses to the unpolarized cross section. One goal is to obtain a data set allowing the extrapolation in the Mandelstam variable t of the isolated longitudinal response to the kaon mass pole. Such a reaction would correspond to the scattering of an electron off of a free kaon. A second goal is to examine the behavior of transverse response in this kinematical region, which overlaps with both the resonance region and extends DIS region.

Figure 1. The online missing mass yield taken in March 2002 at $Q^2 = 1.9 \text{ (GeV/c)}^2$, $W' = 1.95 \text{ GeV}$ and $t = t_{\min}$.

The E98-108 collaboration collected data initially in January, March and April 2001 and finished running in March 2002. [Shown above in Fig. 1 is the online missing mass spectra from the March 2002 kinematics.] At a total of 30 kinematics points, the experiment measured the $H(e, e'K^+)Y$ cross section. Kinematics used momentum transfers of 1.90 and 2.35 (GeV/c)^2 and invariant masses between 1.8 and 2.2 GeV to measure the cross section as a function of ϵ (the photon longitudinal polarization), as well as measurements left and right of the direction of $\vec{q}$. Preliminary σ_L , σ_T , and σ_{LT} cross sections have been extracted from the data. The transverse cross section σ_T , and longitudinal-transverse interference cross section σ_{LT} is used to constrain the reaction mechanism. The behavior of the longitudinal cross section σ_L is mapped as a function of the Mandelstam variable t at fixed Q^2 . The kaon form factor is expected to be sensitivity to σ_L , albeit in a model dependent way. The data will allow the kaon electroproduction reaction mechanism to be determined and eventually allow the kaon form factor to be modelled as well.

The experiment required building two new aerogel Čerenkov radiation detectors with indices of refraction of 1.015 and 1.055 . The first detector,

due to the low index of refraction, required special handling of the delicate aerogel radiator. The first detector fired only on pions or lighter particles, but not on kaons or protons. The second aerogel was built primarily by the MIT group and fired on either kaons or protons but not pions. The use of two aerogels in anticoincidence is a novel PID idea. The response of the two new aerogels as a function of momenta has been studied in detail for protons, kaons and pions.

2. Present Status

Measurements of the $\gamma + p \rightarrow K^+ + Y$ and $e + p \rightarrow e' + K^+ + Y$ ($Y = \Lambda, \Sigma^0$) reactions are limited by short lifetimes ($c \cdot \tau_K = 370$ cm, $c \cdot \tau_\Lambda = 8$ cm), small production rates (an order of magnitude smaller than for pions) and high thresholds [$E_{th}(K\Lambda) = 911$ MeV, $E_{th}(K\Sigma^0) = 1.05$ GeV]. The unseparated cross sections are known with an accuracy of about 10%. Older, previous data from CEA, Cornell, and DESY provided an empirical fit to the unseparated cross section based on phase space, a simple monopole Q^2 -form factor, and an exponential drop with t . The past ten years have seen the first new data on electromagnetic kaon production.^{2,3}

However the current situation for kaon electroproduction remains less satisfactory, both from the experimental and theoretical point of view. Jefferson Lab experiment E93-108³ was the first actual Rosenbluth separation, and demonstrated that the longitudinal response is large (approximately three-quarters the size of the transverse response) at $t = t_{min}$ or $\theta_{cm} = 0$. That experiment also demonstrated that Jefferson Lab is well suited for such precision separations, with the small emittance of the beam, the good particle identification of the detectors, and the accuracy of the spectrometers for cross section measurements.

In kaon electroproduction, the mass pole is in the unphysical region where $t > 0$. The only unambiguous data on the kaon form factor is from high-energy scattering of kaon beams from atomic electrons.⁴ Due to the inverse kinematics, the measurements were limited to low 4-momentum transfers ($.02 < Q^2 < .12$ (GeV/c)²). The measurements were able to determine the kaon charge radius by looking at the slope of the cross section with respect to Q^2 .

3. Experimental Setup

The experiment took place in Hall A at the Thomas Jefferson National Accelerator Facility's CEBAF accelerator. The standard equipment in Hall

Figure 2. The longitudinal (upper) and transverse (lower) response function at $Q^2 = 2.35 \text{ GeV/c}^2$ for $\Pi(e,e'K^+)$ as a function of the invariant 4-momentum, t .

A has been described elsewhere.⁵ Electron beams of energies upto 5.7 GeV were incident on liquid hydrogen targets of nominal 4 cm and 15 cm lengths. Electrons and kaons were detected in coincidence in the two magnetically symmetric high resolution spectrometers (HRS). The HRS spectrometers were outfitted with special particle identification: on the electron side there were a gas Čerenkov counter and a lead glass calorimeter to veto π^- mesons, while on the hadron side two different aerogel Čerenkov counters were used to separately veto pions and protons.

The pions were vetoed in the A1 aerogel which has a refractive index of 1.015 by requiring that the detector A1 not fire. Protons were vetoed in the A2 aerogel which has a refractive index of 1.055 by requiring that the detector did fire.

4. Experiment Status

The doctoral students analyzing the data (Marius Coman of Florida International University) is presently focussing on the systematic analysis (acceptance, normalizations, efficiencies and calibrations). For example, target "boiling" corrections are typically 4–6%, while VDC efficiency cor-

rections (both for the detector firing all four planes and for reconstructing one unique track) typically total 20%. The wire chamber efficiency, electronic and computer deadtimes, and cut efficiencies have been determined. Radiative corrections have been done using the MCEEP simulation code; a comparison to the SIMC simulation code is underway.

5. Preliminary Results

Figure 3. Shown are ratios of the longitudinal to transverse responses as a function of Q^2 from the previous E93-018 and from this experiment.

Preliminary separated longitudinal and transverse response function results as a result of the invariant 4-momentum transfer t are shown in Fig. 3. The upper panel shows the Hall A data at $Q^2=2.35$ (GeV/c)² while the lower curve shows the transverse response function. The error bars will decrease by a factor of 2–3 when the analysis is final.

The response functions were previously measured at lower Q^2 in Hall C by experiment E93-018. Plotted in Fig. 5 is the ratio of the longitudinal to the transverse response function from E93-018 and a point at the higher Q^2 of this experiment.

References

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- 3 *Longitudinal and Transverse Cross Sections in the $^1\text{H}(e,e'K^+)\Lambda$ Reaction*, G.Niculescu, et. al., *Phys. Rev. Lett.* 81, 1805 (1998).
- 4 *A Measurement of the Kaon Charge Radius* S.R.Amendolia et. al., *Phys. Lett. B* 178 435 (1986).
- 5 See, e.g., <http://hallaweb.jlab.org> and *Nucl. Instr. and Meth.* in preparation.