Kaon Electroproduction

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Jefferson Lab will be uniquely well qualified to study strange quark electroproduction with the upgrade to a 12 GeV beam energy. The energy, combined with the CEBAF beam qualities (CW, high intensity, low emittance) will enable a quantitatively new type of physics to be done.

Specifically, JLab at 12 GeV is not JLab at 6 GeV revised. There is an opportunity to engage in qualitatively different physics, as opposed to recycling existing 6 GeV proposals to higher momentum transfers and energies. At 6 GeV, JLab has studied the onset of quark degrees of freedom. At 12 GeV, JLab will have access to quark nuclear physics in the non-perturbative region complementary to that of RHIC, HERMES and the proposed JHF. This kinematical region is approximately where factorization is expected to set in. Kaon electroproduction is expected to have a slightly higher threshold for factorization than pion electroproduction due to the increased strange quark mass.

Kinematically, with incident beam energies as high as 11 GeV and spectrometer angles as small as $5.5°$, Rosenbluth separations can be done for kaons up to $Q^2 = 12(GeV/c)^2$ and $W \gtrsim 2GeV$, allowing strangeness electroproduction responses to be determined over the region of W from threshold well into the deep inelastic region. Similarly, the t-dependence can be measured up to several GeV^2 (depending on the Q^2 and W).

Present Studies

In hadronic facilities such as RHIC, there is recognition of the rich physics information accessible via meson production. Topics as disparate as nucleon collective motion, parton rapidity, particle correlations and quark degrees of freedom are "tagged" via yields of $K^{\pm}$, K^0, $\bar{K^0}$. The hadronic reactions utilize the heavier strange quark mass (which results in $m_K > m_\pi$) to isolate short range, high momentum components of the multiparticle physics (medium modifications, the nuclear equation-of-state, or the presence of a quark-gluon plasma).

The 12 GeV beam energy upgrade will allow JLab to take advantage of complementary opportunities. In DIS using electron beams the quark spin, flavor, transversity and sea structure can be measured. Already studies of the requisite cross section factorization are proposed for pions at 6 GeV.

However in comparison to heavy ion collisions, electromagnetic production has several differences. In hadronic collisions at equivalent energy/nucleon, ratios of $R(\frac{K^+}{K^-}) \sim 1$ are observed as opposed to electromagnetic reactions where $R(\frac{K^+}{K^-}) < 0.01$. I.e., hadronic reactions probe the multi-particle nature of the nucleus being studied whereas in electromagnetic reactions, because of the weak interaction of the virtual photon the reaction probes a single nucleon. This has obvious advantages in measuring quark properties of the nucleons themselves (as opposed to the nucleus). Similarly, the K^+ probes the hadronic volume whereas due to the strong FSI, the K^- probes the hadronic surface.

At existing energies, kaons have been used to measure the electromagnetic structure of the kaon and hyperon as well as N^* decay via the kaon-hyperon channel), and the nuclear structure of hypernuclei. Studies of quark distributions have not typically used kaons.

Hard Scattering vs. Diffractive Production

At "high" W ($> 2.5GeV$, above the resonance region) and low x (implying low Q^2) the kinematics would be "diffractive" in the sense that the virtual photon first fluctuates to a virtual K^+K^- pair, with the K^- subsequently absorbed by the target baryon while the K^+ is knocked on shell. Here one would fix W and Q^2 and scan t. The diffractive cross section is characterized as having an amplitude $A \propto s^{J-1}$. For vector mesons, this implies the production is energy independent ($J - 1 = 0$) while for pseudoscaler mesons the amplitude drops as s^{-1}. Diffractive production has been studied in, e.g., high energy proton-proton scattering; at JLab it will form a competing process necessary to understand the production process. However, in electromagnetic production the virtual photon is not being "elastically" scattered via gluon exchange to put the kaon on the mass shell; there is quark transfer from the projectile to the target (the absorbtion of the virtual K^-). This means that the amplitude may not be as large at small t as in classic proton-proton diffractive scattering.

Since the process also occurs in pion production (the virtual photon fluctuates to a $\pi^+\pi^-$ pair followed by π^- absorbtion on the nucleon), diffraction can also be studied in the parallel process. Beam energies of 6 GeV and the Hall A septum magnets can be used to study the process with the Hall A HRS. Using $e_0 = 6GeV$, $e' \sim 3$, $p_K \sim 3$ and $\theta_e = \theta_K = 6°$, at $W = 2.5GeV$ and $Q^2 = 0.2GeV^2$ such a study for both π and K would take about 3 days to scan t from t_{min} as far as possible.

In hard scattering the idea is that the well known "handbag" diagram factorizes into two parts: a hard scattering containing the electromagnetic vertices and a soft scattering which contains the information on Generalized Parton Distributions (GPDs) which contain the quark distribution amplitudes. The quark wave functions then come from the GPDs, however the approach requires that factorization of the cross section holds (i.e., the independence of the quark distributions from the energy transferred, z). Determining the GPDs requires both factorization and quark wave functions having evolved to their asymptotic form.

Kinematically, the factorization should hold for "high" W ($> 2.5GeV$), Q^2 ($>$

$5 GeV^2$) and x (> 0.5). The longitudinal response is predicted to factorize before the transverse, in agreement with the vector-meson-dominance prediction that $R(\frac{L}{T}) \propto Q^2$. Information on quark transverse momentum distributions ("transversity") and angular momentum (spin content) can be determined on a flavor-by-flavor basis for the quarks. In the case of unpolarized vector mesons (i.e., ρ, ω, ϕ, and the J/ψ) such production is sensitive the unpolarized GPDs. However pseudoscaler mesons such as the π, η, and K are sensitive to the polarized GPDs allowing *e.g.*, the spin transversity to be determined on a flavor basis via pion and kaon hard scattering electroproduction. [DVCS is sensitive to both the unpolarized and polarized GPDs requiring more effort to disentangle the two.]

Other Possible Measurements

As discussed above, kaon electroproduction measurements including Rosenbluth separations of the responses can distinguish polarized nucleon structure information without the use of beam, target or recoil polarizations. As an experimental note, the measurements may still be easier than the performing Rosenbluth separations however. Inclusive measurements of $\vec{N}(\vec{e}, e'K^{\pm}$ enable better control of systematic uncertainties than Rosenbluth separations. Both will require better PID than at lower energies due to the decreasing usefullness of both TOF and threshold aerogel cerenkov for hadrons. Particularly inclusive measurements, where the missing mass spectrum cannot be used to determine the PID efficiency, will require redundancy.

Another topic of interest is the measurement of Σ^- to Σ^0 cross sections as a function of W. Present measurements, taken at different values of Q^2, suggest that the ratio increases with W, suggesting that t-channel (which gives a ratio $R = \frac{\Sigma^- + \Sigma^0}{\Sigma^0} = 3$ due to the isospin Clebsch-Gordon coefficients) may dominate over the s-channel (where $\Delta\Sigma$ coupling gives 1.5). Such measurements would require use of hydrogen and deuterium targets to separate the Σ^0 and Σ^- reactions. The implication is that the nuclear physics of the targets must also be dealt with.

In previous kaon measurements in Hall C, exclusive vector meson production has also been shown to be measureable. Specifically, using the Hall C experience with H(e,e'p)ω as a guide, the coherent production off light nuclei (D, ^{3,4}He) would allow extending the same measurements to look at the unpolarized GPDs. Such an approach would require separating the diffractive from the hard scattering, which would be more difficult for vector mesons (since the quantum numbers are degenerate for vector mesons and virtual photons). Extending beyond the ω might also require dedicated detectors such as a pair spectrometer to detect the decay of a neutral meson.