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Hyperon Photoproduction

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Studies of systems with one or more strange quarks add to our understanding of fundamental two particle interactions by providing an opportunity to extend models developed for N-N, π−N, and γ-N (i.e. non-strange) interactions. This experiment will focus on the elementary photoproduction of the Λ, Σ^o, and Σ^+ using real photons. The goals of our proposed measurements are an improved knowledge of the strangeness photoproduction mechanism and of the nucleon-hyperon coupling constants. The CEBAF Large Acceptance Spectrometer (CLAS) will be used to study the three possible elementary strangeness-producing reactions on the proton:

$$\gamma + p \rightarrow K^+ + \Lambda \qquad (1)$$

$$\gamma + p \rightarrow K^+ + \Sigma^o \qquad (2)$$

$$\gamma + p \rightarrow K^o + \Sigma^+ \qquad (3)$$

The final state lambdas formed through Reaction (1) are known to be strongly polarized. The cause of this polarization may be partially due to elementary $s\bar{s}$ quark-pair production and partially due to final state interactions. The photoproduction of Λ-K and Σ-K pairs are reactions well suited to the study of polarization effects, since initial state interactions are absent. An advantage of using real photoproduction rather than electroproduction is that only four complex amplitudes need to be determined. Experimentally, real photoproduction is simpler also, because one fewer particle needs to be detected in the CLAS detector. Also, background problems should be less severe using the real photon beam.

The reaction $\gamma + p \rightarrow \Lambda + K^+$ has been studied since the late fifties, and received considerable experimental and theoretical attention in the 60's and early 70's. The differential cross section is moderately well established from threshold (at 911 MeV) up to 1.4 GeV, while the polarization of the Λ has been measured at only a few angles and energies, typically with large error bars. The Σ production data are very sparse. Only recently have calculations of strangeness photoproduction inspired directly by the quark model been undertaken. Instead, traditional calculations have been done using tree-level Feynman diagrams. Partly due to a lack of sufficient good data, the proper formulation of the interaction has remained uncertain, particularly regarding which non-Born term graphs are dominant. One consequence of this is that the basic coupling constants g_{KNL} and g_{KNS} extracted from photoproduction data are roughly a factor of two smaller than those obtained from hadronic data. Recent authors have attempted to understand the source of this difference but controversy exists. The theoretical situation is not at all settled.

Progress can be made in this field if better hyperon polarization data were available. Good Λ polarization data will sensitively discriminate among several existing calculations. Apart from better differential cross section data, hyperon polarization measurements would be the principal contribution of new experiments at CEBAF. In CLAS, we will look for the self-analyzing decay of the Λ into $\pi^- p$ in coincidence with the kaon which tags production of the Λ. Further in the future, with polarized hydrogen targets and polarized photon beams, experiments measuring a wide range of spin correlations in hyperon production reaction are possible.

The Λ and Σ hyperons are in the same spin-parity octet, and are related at the quark level by spin flips. Simultaneous measurements of all three channels will constrain the reaction mechanism to a high degree. No polarization information exists at all for Σ^o production, but because the Σ^o decays 100% via an M1 transition to the Λ, any measurement of the decay Λ polarization also measures the polarization of the Σ^o. The decay asymmetry for the Σ^+ is very large (a=-0.98), so its decay into $p\,\pi^o$ reveals information about the Σ^+ polarization.

The common experimental feature of the reactions discussed above is the need to filter out the copious non-strange events by identifying strangeness production. One can exploit the fact that the production and decays in the above reactions are all two-body interactions, so that one-to-one mapping between kinematic variables exists (for example between kaon angle and kaon momentum). Another useful kinematic feature in these measurements is the fact that neutral strange hyperons have a decay length of several centimeters. This allows the possibility of using the neutral "V" to signal the production of strange particles.