Studies of Baryon Structure and Baryon Interactions at Thomas Jefferson National Accelerator Facility

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Introduction

The understanding of the structure of baryons and their interactions from Quantum Chromodynamics is one of the main objectives, and challenges, of contemporary nuclear physics. Of particular interest is the regime of confinement where the effective coupling constant is large and perturbative methods are not applicable to derive testable predictions. In this regime, models using effective degrees of freedom have been used to interpret experimental data and to gain insight in baryon properties and dynamics. The complexity of the strong interaction and the phenomenology involved in the models have left many open questions. The nature of the transition from hadronic to partonic degrees of freedom, the nature of the hyperon-nucleon interaction, and the understanding of nuclei in terms of quarks and gluons are some of the key problems that need to be addressed. In this talk I will discuss results of experiments with real photon beams on light nuclei from Jefferson Lab Hall B which have provided new insight into baryon structure and interactions over a broad non-perturbative distance range.

Transition from Hadronic to Partonic Degrees of Freedom

Hard photodisintegration of light nuclei has proved to be a useful tool to explore strong dynamics at intermediate energies. In this energy regime a separation of scales may be possible at specific kinematics, i.e. the elementary reaction mechanism is theoretically calculable while soft hadron structure is factored out and described phenomenologically. Studies of hard breakup of light nuclei initiated by real photons is interesting because on one hand, at $Q^2 = 0$ (GeV$/c)^2$ factorization has not been proved and the field has been driven primarily by experimental observations; on the other hand, observations of dimensional scaling in the invariant cross section provides an information about the onset of partonic dynamics in nuclei. Here we will present our new results for the differential cross section of two body breakup of ^{3}He [1] and for the beam-spin asymmetry of deuteron breakup [2].

We have observed for the first time dimensional scaling in an exclusive reaction initiated by a photon beam and involving an $A = 3$ nucleus. The scaling power of s^{-17} for $E_\gamma > 0.7$ GeV, is the highest quark-counting power-law dependence observed to date in leptoproduction. Our result indicates that QCD studies of nuclei are meaningful at energies as low as E_γ = 0.7 GeV and that the three-nucleon bound system may be an equally good laboratory for such studies as the deuteron.

Our results for the beam-spin asymmetry of deuteron photodisintegration cover photon energies from 1.1 GeV to 2.3 GeV and proton center-of-mass (c.m.) angles between 25° and 160° and have helped to significantly improve the theoretical modeling of the process. Comparison of our data with models indicates that separation of scales may be possible in this energy regime, but only at c.m. angle of 90°, where the momentum transfer to both nucleons is large. At other c.m. angles, non-perturbative quark-gluon dynamics contributes significantly and fully non-perturbative quark models are better suited to describe the reaction dynamics.

Hyperon-Nucleon Interaction

While considerable progress has been made in the past decades in the understanding of

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the nucleon-nucleon (NN) interaction, we are still far from a comprehensive understanding of the hyperon-nucleon(YN) and hyperon-hyperon (YY) potentials. These potentials are not only important for constructing a complete picture of the baryon-baryon interaction, but also for the understanding of hypernuclear matter and neutron stars. The best means to constrain the free parameters of the YN potentials is to perform phase-shift analysis of experimental YN scattering data. Since the quality of the existing YN scattering data is poor and their energy range is very limited, alternatives such as hypernuclear and hyperon production experiments have attracted significant interest.

Theoretical studies have suggested that experimental observables for hyperon production reactions can place stringent constraints on the free parameters of hyperon-nucleon potentials. We will present preliminary experimental results for the polarization observables Σ, P_y, O_x, O_z, C_x, and C_z for final-state interactions (FSI) in exclusive Λ photoproduction off the deuteron. This reaction allows to access the $\Lambda - n$ interaction via final-state rescattering of the hyperon (produced in a first step) off the neutron. The observables were obtained from data collected during the E06-103 (g13) experiment [3] with the CEBAF Large Acceptance Spectrometer (CLAS) in Hall B at Jefferson Lab. The g13 experiment ran with unpolarized deuteron target and circularly- and linearly-polarized photon beams with energies between 0.5 GeV and 2.5 GeV and collected about 5×10^{10} events with multiple charged particles in the final state. To select the reaction of interest, the kaon and the Λ decay products, a proton and a negative pion, were detected in CLAS. Missing-mass technique was used to further reduce the event sample. Final-state interaction events were selected by requesting that the reconstructed neutron has a momentum larger than 200 MeV/c. The large statistics of E06-103 provided statistically meaningful FSI event samples, which allow for the extraction of one- and two-fold differential single- and double-polarization observables. In this talk we will show preliminary results for a set of six observables for photon energies between 0.9 GeV and 2.3 GeV and for several kinematic variables in the $\Lambda - n$ center-of-mass frame. Comparison with theoretical calculations will also be discussed. Our results are the very first estimates of polarization observables for FSI in hyperon photoproduction and will be used to constrain the free parameters of hyperon-nucleon potentials.

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