Spin Measurements in Photoreactions in Hall A

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Abstract

Spin and cross section measurements of photoreactions with 6+ GeV study reaction mechanisms, helicity conservation, scaling violations, and nonforward parton distributions. Much of the work can be done with existing Hall A equipment. A linear polarized photon facility is needed for Σ asymmetry measurements, and fully undertaking this physics program in Hall A also requires a single higher-momentum spectrometer.

1 Introduction

At beam energies above a few GeV and four momentum transfers $-t > 1$ (GeV/c)^2, cross sections [1] for several exclusive photoreactions demonstrate the approximate validity of the constituent counting rules (CCR). These rules can be derived from pQCD [2], but this explanation is not generally accepted [3]. No polarization data exist at high $-t$.

More precise measurements, now possible at Jefferson Lab, can determine the power law scaling of the cross sections systematically as a function of angle. Polarization measurements allow testing of a related prediction of helicity conservation. The induced polarization P and the polarization transfer C_x measure the imaginary and real parts of the helicity violating interference. If hadron helicity violation measures orbital angular momentum [4], these data relate to the nucleon spin problem. Spin measurements also help determine the reaction mechanism, as they are sensitive to small reaction amplitudes.

Calculations are available in many models. Nonforward parton distributions (NFPD) [5], describe how to remove a quark from the nucleon, allowing the photoquark reaction to be calculated. Calculations are available for Compton scattering [6], and are underway for meson production

[7]. Vector meson photoproduction measures the *spin-independent* NFPD, whereas pseudoscalar meson photoproduction measures the *spin-dependent* NFPD. Several reactions are needed to determine the NFPD, and to investigate the structure of the nucleon in a way complementary to that of deep inelastic scattering. Other calculations have been done recently in pQCD, the diquark model, in the exclusive limit of a quark-parton model calculation of inclusive meson photoproduction from a struck quark, and in Regge theory [8].

2 Experiments

E89-012 (R. Holt *et al.*) preliminary data [9] for deuteron photodisintegration show the validity of the CCR at 90°_{cm} for $E_\gamma \sim 1$ to 4 GeV. E96-003 (R. Holt *et al.*) extends data to $\sim$ 6 GeV, while E89-019 (Gilman, Holt, Meziani *et al.*) measures proton polarizations to $E_\gamma = 2.4$ GeV; P tests helicity conservation and is sensitive to resonance contributions. The energy upgrade allows polarization measurements at higher energies, using the Σ asymmetry, which involved linearly polarized photons polarized in and perpendicular to the reaction plane. Σ is also sensitive to resonance contributions.

Coherent Bremsstrahlung from a crystal radiator yields linearly polarized photons. A chicane, planned for Hall A, reduces backgrounds. Higher energy beam is needed, as the coherent Bremsstrahlung peak is usually put at $\sim$2/3 of the end point energy. A photon polarimeter is also needed. Due to spectrometer acceptance, one need not collimate out incoherent Bremsstrahlung in Hall A, as is desirable with an open 4π detector, such as CLAS. Being far from the end point, however, a neutron detector and a kinematically complete measurement are needed for efficient background rejection in deuteron photodisintegration.

E94-012 (Gilman, Holt *et al.*) measures $\vec{\gamma} p \to \vec{p}\pi^0$, covering 45 to 120° in the center of mass for beam energies up to 4 GeV, and 90° at 5 GeV. Uncertainties are 5 % for cross sections, and < 0.05 for spin observables. This channel was chosen as a first, experimentally simple test measurement. As the energy increases to 6+ GeV, increasing ep elastic backgrounds make a chicane and / or a π^0 detector necessary, and the angle range is limited by the maximum spectrometer momenta.

The FPP has measured protons up to 1.8 GeV kinetic energy in the G_E^p experiment, $\vec{e}p \rightarrow e'\vec{p}$, E93-027 (Perdrisat, Punjabi, Jones *et al.*). It needs to be calibrated for higher energy with a continuation of this experiment. A 10 % measurement for 4 GeV/c protons, using $E_e = 7$ GeV and $Q^2 = 6$ GeV^2, needs about 1 month beam time. At 4 GeV/c, spin precession is about 360° for a 45° bend angle. For higher momenta, it would be good to have instead a spectrometer with a bend angle not too close to either 22.5 or 45°. Polarimeter improvements are also possible - in particular alternate analyzers may allow a larger figure of merit.

Proposal E98-106 (Liang, Gilman, Afanasev *et al.*) measures $\vec{\gamma}p \rightarrow K^+\vec{\Lambda}^0$ for $E_\gamma = 3$ to 6 GeV and $\theta_{cm} = 50$ to 130°. Typical uncertainties are 5 - 10% for cross sections, and 0.05 - 0.10 for spin observables.

As the Λ^0 spin is largely carried by the s quark, $K^+\Lambda^0$ photoproduction provides a cleaner test of polarization transfer at the quark level then π^0 production. Spin effects should be larger and more reliably calculated. Also, production involving the $s\bar{s}$ sea of the nucleon is of more interest than that involving the light quark sea, but determining this contribution will require a thorough understanding of the reaction mechanism.

The Λ decay in its rest frame is self-analyzing, with a distribution $\sim 1 + 0.64P\cos\theta$. There is no decrease in figure of merit with energy, as occurs with the proton polarimeter. However, as $E_\gamma \rightarrow 8+$ GeV, we need a 4 GeV/c spectrometer plus a 7 - 8 GeV/c spectrometer for the forward angle particle. The Σ asymmetry remains important in understanding the reaction mechanism at high t, and requires higher energy beam.

3 Conclusions

Spin and cross section measurements for photoreactions with 6 - 12 GeV beam are promising. We expect to be able to study the reaction mechanisms, test the assumption of helicity conservation, determine scaling (CCR) violations, and investigate the nonforward parton distributions. Much of the work can be done with existing Hall A equipment. A linear polarized photon facility is needed to allow measurements of the Σ asymmetry, which will ultimately be important in understanding these reactions.

Fully undertaking this physics program in Hall A requires the addition of a higher-momentum spectrometer.

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