Abstract

The $\gamma n \to \pi^- p$ and $\gamma p \to \pi^+ n$ reactions are essential probes of the transition from meson-nucleon degrees of freedom to quark-gluon degrees of freedom in exclusive processes. The cross sections of these processes are also advantageous, for investigation of the oscillatory behavior around the quark counting prediction, since they decrease relatively slower with energy compared with other photon-induced processes. Moreover, these photoreactions in nuclei can probe the QCD nuclear filtering effects. We propose to perform singles $\gamma p \to \pi^+ n$ measurement from hydrogen, and coincidence $\gamma n \to \pi^- p$ differential cross section measurement at the quasifree kinematics from deuterium and ^{12}C for photon energies between 2.25 GeV to 5.8 GeV at a center-of-mass angle of 90°. The proposed measurement will be carried out in Hall A using a 50 μA electron beam impinging on a 6% copper radiator, a liquid hydrogen, a liquid deuterium and a solid ^{12}C target, and the two Hall A HRS spectrometers. Nuclear transparency of the $\gamma n \to \pi^- p$ process from ^{12}C will be tested, in conjunction with exploring the nuclear dependence of rather mysterious oscillations with energy that previous experiments have indicated. The various nuclear and perturbative QCD approaches, ranging from Glauber theory, to quark-counting, to Sudakov-corrected independent scattering, make dramatically different predictions for the experimental outcomes.

I. INTRODUCTION

Exclusive processes are essential to studies of transitions from the non-perturbative to perturbative regime of QCD. The differential cross sections for many exclusive reactions [1] at high energy and large momentum transfer appear to obey the quark counting rule [2]. The quark counting rule was originally obtained based on dimensional analysis of typical renormalizable theories. The same rule was later obtained in a short-distance perturbative QCD approach by Brodsky and Lepage [3]. Despite many successes, a model-independent test of the approach, called the hadron helicity conservation rule, tends not to agree with data in the similar energy and momentum region. The presence of helicity-violating amplitudes indicates that the short-distance expansion cannot be the whole story. In addition some of the cross-section data can also be explained in terms of non-perturbative calculations [4].

In recent years, a renewed trend has been observed in deuteron photo-disintegration experiments at SLAC and JLab [5] - [7]. Onset of the scaling behavior has been observed in deuteron photo-disintegration [7] at a surprisingly low momentum transfer of 1.0 (GeV/c)^2 to the nucleon. However, a polarization measurement on deuteron photo-disintegration [8], recently carried out in Hall A at JLab, shows disagreement with hadron helicity conservation in the same kinematic region where the quark counting behavior is apparently observed. These paradoxes make it essential to understand the exact mechanism governing the early onset of scaling behavior.

Moreover, it is important to look closely at claims of agreement between the differential cross section data and the quark counting prediction. Historically, the elastic proton-proton (pp) scattering at high energy and large momentum transfer has played a very important role.