THE GDH SUM RULE WITH NEARLY REAL PHOTONS AND THE G_1 PROTON STRUCTURE FUNCTION AT LOW MOMENTUM TRANSFER

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A measurement of the proton structure function g_1 for momentum transfer Q^2 in the range 0.01-0.5 GeV^2/c^2 is planned in Hall B at Jefferson Lab using the CEBAF Large Acceptance Spectrometer (CLAS). The CEBAF polarized electron beam with energy between 1 and 3.2 GeV will scatter off a polarized solid state target. The outgoing electrons will be detected down to a minimum angle of $\sim$5 degrees in CLAS thanks to a new gas Cherenkov counter designed to optimize the detection efficiency and pion rejection in the operating conditions of this experiment. The proton spin structure function g_1 will be measured from the threshold region to the resonance region and beyond. The expected results will add high precision information on the nucleon spin response in kinematics where tests of Chiral Perturbation Theory are possible, and provide the data for an improved understanding of hadronic spin processes in the confinement regime.

1. Physics Motivation

The study of hadronic structure with electromagnetic probes is deeply concerned with fundamental questions about the basic constituents of hadrons. In particular the spin structure of the nucleon which is one of the main topics in hadronic physics has been investigated for now more than three decades using lepton and photon beams. Measurements of the spin-dependent structure functions g_1 and g_2 have been performed at large Q^2 (Deep Inelastic Scattering region) at several facilities as SLAC, CERN, and DESY [1], providing information for the understanding of the nucleon structure in terms of the elementary constituents of QCD, i.e. quarks and gluons. On the contrary much less is known in the low momentum transfer region ($Q^2 < 1-2$ GeV^2), where non-perturbative phenomena like nucleon resonances start to play a dominant role.

At very low momentum transfer ($Q^2 < 0.05 - 0.1$ GeV^2), a new approach is given by Chiral Perturbation Theory (χPT) which provides an effective representation of the QCD Lagrangian based on hadronic degrees of freedom and can be considered as a fundamental theory in the low energy limit. χPT is nowadays a well developed theoretical tool capable of predicting the dynamics of hadronic processes in the strong binding regime and its test is important to identify the relevant degrees of freedom in this kinematic domain.

Recently, Chiral Perturbation Theory [2,3] calculations were used to extend the Gerasimov-Drell-Hearn Sum Rule to finite Q^2. Such calculations are expected to be valid up to a maximum Q^2 of the order of 0.05-0.1 GeV^2. To perform an accurate test of these predictions it is therefore necessary to reach Q^2 values below such limits.

These theoretical developments have renewed the interest in the very low momentum transfer region, providing motivation to pursue a high precision measurement of the GDH integral in this kinematical domain. This type of experiment has been planned in Hall B at Jefferson Lab using the CLAS detector and a polarized proton target [4]. In this contribution this experiment will be described, giving details of the experimental setup, analysis procedure, and expected accuracy.

2. Experimental Setup

A spin physics program with polarized beams and targets has been active for several years now at JLAB. In particular, beam-target asymmetries in inclusive electron scattering on the proton and deuteron have already been measured and results have been shown at this conference [5]. These measurements were performed using a NH_3/ND_3 solid state polarized target [6] and the CLAS detector [7]. CLAS is a magnetic spectrometer based on a six-coil torus magnet whose field is primarily oriented along the azimuthal direction. The particle detection system includes drift chambers for track reconstruction, scintillation counters for the time of flight measurement, Cherenkov counters for electron-pion discrimination, and electromagnetic calorimeters to identify electrons and neutrals. In the previous experiments the nucleon structure function g_1 was extracted from the measurement of the inclusive double polarization asymmetry for longitudinally polarized electron and nucleon, using a parameterization of the unpolarized structure function F_1, the longitudinal-transverse ratio R, and the spin structure function A_2. With the existing setup and this analysis procedure a

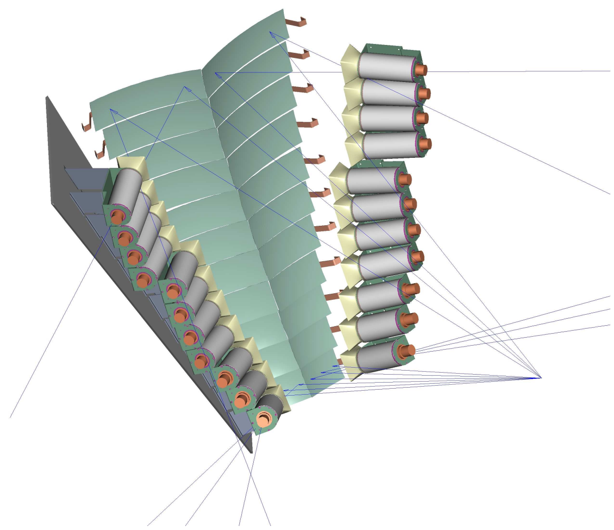

Figure 1. CAD view of the new Cherenkov detector. The spherical mirrors and the PMTs are shown. The line indicates hypothetical paths of the emitted light.

minimum Q^2 of 0.05 GeV^2 was reached.

In order to cover the lower Q^2 region and test chiral predictions a new experiment was proposed and approved in January 2003. This experiment aims at a direct measurement of the inclusive spin dependent cross section with longitudinally polarized beam on a longitudinally polarized proton target for $Q^2 = 0.01 - 0.5$ GeV^2. The extended kinematics will be covered by installing a new Cherenkov Counter in one of the CLAS sectors. This new component was specifically designed to detect the scattered electrons at the very low angles (4-6 degrees) that are necessary to reach such low Q^2, while maintaining a very high electron detection efficiency (of the order of 0.999) and a high pion rejection (of the order of 10^{-3}). Figure 1 shows a CAD view of the new detector that is presently under construction. It consists of two sets of spherical mirrors that will focus the Cherenkov light emitted by the incoming electrons onto 5" PMTs located on the two sides. The mirrors will cover 20 degrees in the azimuthal direction around the mid-plane of the CLAS sector and $\sim$ 45 degrees in the polar direction. The mirror geometry was optimized performing detailed simulations of the light propagation. C_4F_{10} will be used as radiator providing electron/pion discrimination up to momenta of 2.5 GeV. After accounting for the gas absorption, the mirror reflectivity and the PMT quantum efficiency, an

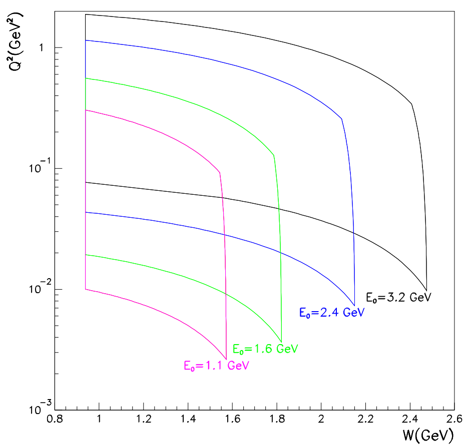

Figure 2. Kinematical coverage of the new experiment.

average number of photoelectrons greater than 40 was estimated.

Presently the design of the detector is fully established and the mirrors are already under construction.

3. Projected Results and Conclusions

The kinematical coverage of the new experiment is shown in Figure 2. Four different beam energies between 1.1 and 3.2 GeV will be used to have a full coverage of the resonance region in the proposed Q^2 domain. Counting rates were estimated based on a parameterization of the proton structure functions [8]. In the assigned beam time of 20 days the expected statistical accuracy of the generalized GDH and Γ_1 integrals, defined as

$$I_{GDH}(Q^2) = \frac{16\pi^2\alpha}{Q^2} \int_0^{x_{th}} g_1(x, Q^2)dx$$
$$\Gamma_1(Q^2) = \int_0^{x_{th}} g_1(x, Q^2)dx,$$

is shown by the error bars of Figure 3. The gray bands indicate the expected systematic uncertainty which includes effects related to modeling of A_2, extrapolation into the unmeasured kinematic region, luminosity and efficiency, and radiative corrections.

This new experiment is presently expected to take data in 2006. The high precision of the measurement will allow us to put stringent constraints

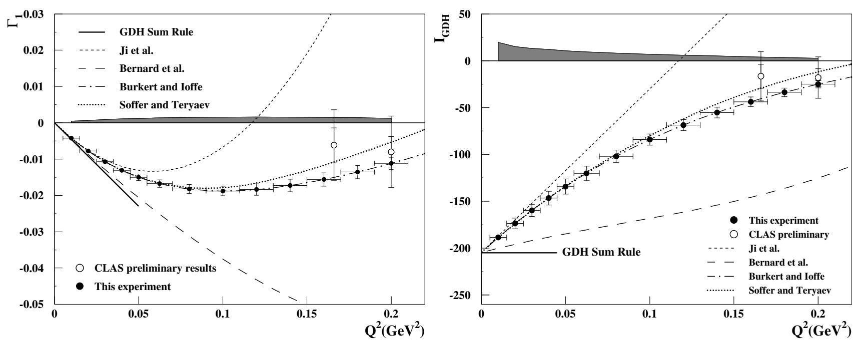

Figure 3. Projected results for the I_{GDH} and Γ_1 integrals. Full points are the expected results from the proposed experiment with statistical errors only. The open circle are the CLAS published results [9]. The dark grey band shows the estimated systematic error with our proposed method. Chiral perturbation theory calculations of Ref. [2] and [3] are shown by short-dashed and long-dashed lines, while the model predictions from Burkert and Ioffe [10] and Soffer and Teryaev [11] are indicated by the dashed-dotted and dotted lines.

on different approaches in Chiral Perturbation Theory at small Q^2, as well as to test phenomenological models aimed at describing the entire Q^2 range.

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