PROPOSED EXPERIMENT AT HERA TO MEASURE THE SPIN DEPENDENT STRUCTURE FUNCTIONS

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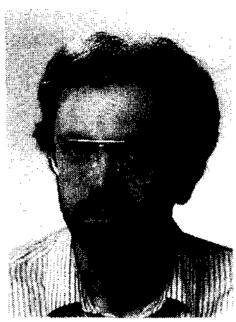

Abstract

A new proposed HERA experiment is presented that will allow a precise determination of the spin dependent structure functions of proton and neutron as well as a test of the Bjorken sum rule with an accuracy of 5–8%. It is intended to scatter the longitudinally polarised HERA electron beam off a polarised internal gas target of H and D or ^3He. By the use of a storage cell target densities above 10^{14} atoms/cm^2 and luminosities above $3.5 \cdot 10^{31}\text{cm}^{-2}\text{s}^{-1}$ can be achieved. High statistical precision can be obtained within short runs of about 3 weeks per target. Besides the measurement of the spin dependent structure functions $g_1(x)$ and $g_2(x)$ for proton and neutron, the novel structure function $b_1(x)$ can be measured by scattering unpolarised electrons off polarised deuterons.

Motivation

Recently, the European Muon Collaboration has measured the spin dependent structure function g_1 of the proton[1,2] and discovered a violation of the Ellis-Jaffe Sum Rule. This surprising result triggered a lot of theoretical discussions on its interpretation and the consequences for our understanding of the quark structure of the nucleon[3].

Unfortunately, the experimental results are not sufficient to disentangle how the quarks and gluons contribute to the spin of the nucleon. To clarify the situation we propose a new experiment to measure the the x-dependence of the spin structure functions $g_1(x)$ and $g_2(x)$ for the proton as well as for the neutron with high precision, which will be more than 6 times better than that of the EMC measurement. The data will allow an experimental check of the Bjorken Sum Rule[4]:

$$\int_0^1 [g_1^p(x) - g_1^n(x)]\, dx = \frac{1}{6} \left| \frac{g_A}{g_V} \right| + \text{QCD-correction} \qquad (1)$$

to 5–8%. A failure of this sum rule would cause big problems for our understanding of the parton model and of pertubative QCD[5]. In addition we want to verify (disprove) the EMC result on the Ellis-Jaffe sum rule[3]

$$\int_0^1 g_1^p(x)\, dx \neq 0.189\,. \qquad (2)$$

Measurements of hadronic asymmetries will allow us to separate the contributions of valence and sea quarks to the spin of the nucleon and the possible contributions of angular momenta of quarks to the spin of the nucleon[7].

Further options are measurements of the novel structure function $b_1^d(x)$ of deuterium which provide information on exotic components in nuclear matter[8].

The Concept of the Experiment

We intend to measure the spin structure functions by scattering polarised electrons off a polarised gas target at HERA. The experiment will be performed in the modified HERA east hall and can run simultaneously with the collider experiments H1 and ZEUS. Spin rotators will turn the transversally polarised HERA e^--beam into a longitudinally polarised one.

Polarised hydrogen and deuterium gas serves as proton and neutron target. Polarised ^3He is to a good approximation also a neutron target, as in ^3He the two protons couple to spin zero. In order to gain a luminosity as high as $L = 3.5 \cdot 10^{31} cm^{-2} sec^{-1}$ the new technique of a storage cell target will be used. The target cell is filled by a permanent gas flow from a source of polarised atoms. After several hundred wall bounces the atoms diffuse out of the cell through two exit tubes which have holes to let the e^--beam pass through. Densities above $\rho = 10^{13}$ atoms/cm^3 may be achieved by this method.

The influence of the target on the life time of the electron beam is negligible compared to the losses in the whole ring.

A target polarisation of up to 80% is achieved by Stern-Gerlach separation of atomic hydrogen and deuterium. ^3He is polarised by optically pumping with a polarised laser beam.

A high precision test of the Bjorken sum rule requires a measurement of both the longitudinal and the transversal asymmetries, since there is some mixing between the asymmetries and the structure functions:

$$\begin{aligned} A_{\parallel} &\sim A_1 + \eta A_2 \qquad & A_1 &\sim g_1 \\ A_{\perp} &\sim A_2 - \xi A_1 \qquad & A_2 &\sim g_1 + g_2 \\ &(\eta, \xi = \text{kinem. factors}) \end{aligned} \tag{3}$$

The different polarisation states are realized by a transversal resp. longitudinal guiding field of $B \simeq 0.3\ T$. This high magnetic field also suppresses depolarisation effects. The nuclear spin can be flipped within milliseconds by an HF-transition in the source. A periodical flip will minimize systematic errors in the experiment.

The major advantage of the gas target compared to our old EMC experiment is the fact that all target nucleons are polarisable compared to 3 out of 17 in the ammonium target used by EMC. With the same luminosity this corresponds to a gain of a factor of 32 in measuring time for the same statistical accuracy.

Detector Specifications

The detector will be a forward spectrometer with a dipole magnet of 1.5 Tm. A horizontal septum-plate in the middle of the magnet will protect the HERA-ring from the magnetic field. The angular acceptance is 40 $mrad < \Theta <$ 200 $mrad$. The kinematical range covered by the experiment is $0.02 < x < 0.8$ and $Q^2 > 1$ GeV^2. To suppress regions with high radiative corrections only events below $y < 0.85$ are accepted.

Angle and momentum of the scattered electron and of hadrons are measured by silicon-strip detectors, proportional- and drift-chambers. The resolution in x will be $\sim 2-6\%$ and in $Q^2 \sim 1-2\%$ depending on the kinematical region. A calorimeter wall serves as trigger device with a threshold of $E' > 5$ GeV. It provides an additional energy measurements of the scattered electrons and allows in conjunction with a TRD an electron – hadron separation with a π suppression of $> 10^4$.

Background

A full monte carlo simulation of the detector has been set up with the GEANT/GHEISHA program[9] to study the background and the resolution of the spectrometer. It was found that the pion-background can be suppressed by the TRD and the calorimeter to a negligible level. The background from the proton-beam can be suppressed by veto-counters as it comes back to front.

The MØller rate in the front detectors will be about 100 kHz and can be handled easily. The MØller electrons will not contribute to the trigger since their energy in our angular acceptance is a factor of 10 below the trigger threshold.

Synchrotron radiation has been calculated with a program of Pitzl[10]. As there is a long straight section in front of the target the amount of dipole radiation is small and can be shielded by collimators. The quadrupole radiation passes mainly through the beam hole in the target cell.

Radiative corrections can be precisely calculated[11]. Their size is below 30% in the kinematical range of the measurement. Most of the correction cancels as the radiative corrections for the two spin states are similar. Furthermore, part of the correction can be checked experimentally in the calorimeter.

Conclusion and Time Scale

The proposed experiment will provide fundamental information on the spin structure of the nucleon by the measurement of five different spin structure functions g_1^p, g_1^n, g_2^p, g_2^n, b_1^d with good precision. This includes a completely independent experimental check of the EMC-results for the proton and a test of the Bjorken sum rule with a precision of 5-8%. It promotes new experimental technologies, namely a *"polarised storage cell inside a polarised storage ring"*.

The full approval of the experiment has been delayed until the polarisation of the electron ring at HERA is experimentally proven (1990-91). The construction time of the spectrometer is about two years. Sufficient statistics is collected within one month of data taking for each target.

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