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PROSPECT FOR OBSERVATION OF POLARIZATION IN ELECTRON-DEUTERON ELASTIC
SCATTERING AT HIGH MOMENTUM TRANSFER

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A measurement of the charge and quadrupole form factors of the
deuteron would address the most fundamental questions in nuclear
physics: validity of perturbative QCD at relatively low momentum
transfer, effect of isoscalar meson-exchange currents, and the
deuteron structure at short range. Polarization methods will be
required in order to provide the separation of these form factors.
We propose that the high current of electrons in a storage ring be
employed in order to scatter electrons from a gaseous, tensor-
polarized, deuterium target.

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1. INTRODUCTION

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The prospect of isolating the charge and quadrupole form factors for the
deuteron has received much attention in the past few years. A separate
measurement of these form factors would provide an important constraint on
models¹ for the deuteron. An important question in electron-deuteron elastic
scattering is concerned with the location of the first zero in the charge form
factor. The exact location of the first zero, expected near $q \sim 4 \text{ fm}^{-1}$, is
sensitive² to the deuteron model as well as isoscalar meson exchange
currents. Unfortunately, the quadrupole form factor masks the location of a
minimum in the charge form factor, and thus the location cannot be determined
from the standard Rosenbluth separation technique of electron scattering.
However, a measurement of the tensor polarization t_{20} in electron-deuteron
scattering would permit the isolation of these form factors.

If perturbative QCD is valid for e-d scattering for $q \gtrsim 5 \text{ fm}^{-1}$ as suggested
by Brodsky and Chertok³ and, more recently by Carlson and Gross⁴, then one
might expect t_{20} to be negative rather than a positive value as predicted by
the conventional meson exchange model. Of course, the validity of pertur-
bative QCD at such low values of momentum transfer is a matter of current
debate⁵. Predictions for various models are shown in Fig. 1. The shaded
region in the figure represents the expected value for perturbative QCD, while
the curves depict predictions for the conventional models for the deuteron.
The two data points in the figure were determined⁶ with the use of a deuteron
tensor polarimeter in which the polarization of recoil deuterons from e-d
elastic scattering was measured.

Figure 1
The curves represent predictions² of t_{20} in e-d elastic scattering for various deuteron wave functions. The presence of isoscalar meson-exchange currents produce a significant impact on t_{20} for $q > 3 \text{ fm}^{-1}$. The prediction of perturbative QCD for $q > 5 \text{ fm}^{-1}$ represents a significant demarcation from that of the meson-exchange models of nuclei. The data points are from Ref. 6.

2. PROPOSED METHOD

It is clear from Fig. 1 that a measurement of t_{20} should be performed at the highest practical values of q^2 . For this reason, we are proposing that the experiment be performed with an internal polarized target in an electron storage ring. The principal advantage of this method is that high yields can be obtained owing to the high electron current (100 mA) and high energy (1-15 GeV) which are typical for electron storage rings. An example of the potential power of this method is illustrated in Fig. 2. Here, the curves

Figure 2
Event rates for expected measurements of t_{20} in e-d elastic scattering. The two points represent the rates encountered in the experiment of Ref. 6.

refer to the projected event rates for the PEP storage ring (SLAC) operating at electron energies of 5.0 and 14.5 GeV, two operating energies of the accelerator. This projection illustrates the possibility of performing a measurement of t_{20} in e-d elastic scattering for a momentum transfer of up to approximately 6 fm^{-1} , a very interesting region as emphasized in Fig. 1. The assumptions which enter into these rate estimates are the following: (i) $I_e = 100 \text{ mA}$ at $E_e = 14.5 \text{ GeV}$ and 25 mA at 5.0 GeV ; (ii) a target thickness of $10^{15} \text{ nuclei/cm}^2$; (iii) a detector solid angle which ranges between 3 and 15 msr depending on the kinematical region; and (iv) both the e^+ and e^- beams can be employed simultaneously. Note that an additional detector system would allow a simultaneous measurement of t_{21} and thereby permit an additional check on

the form factor measurements. The actual count rates which were obtained in the polarization experiment⁶ at the MIT-Bates Laboratory are shown in Fig. 2 for comparison purposes.

At present the greatest uncertainty in this novel proposal is the feasibility of supplying a tensor polarized deuterium gas target of up to 10^{15} nuclei/cm² in thickness. A study^{8,9} of existing techniques in the storage of polarized atomic beams and optical pumping techniques indicates that such a target should be practicable. For example, Wise and Haeberli¹⁰ expect to produce a polarized hydrogen target of 10^{14} nuclei/cm² with a conventional atomic beam source. Our proposal consists of employing an optical-pumping spin-exchange method in order to produce an order of magnitude more flux of polarized nuclei than that of conventional sources and thereby develop a target in the range of 10^{14} - 10^{15} nuclei/cm².

3. SUMMARY

A measurement of tensor polarization in electron-deuteron scattering at high momentum transfer appears to be plausible provided that a polarized gas target can be employed in an electron ring of high current and energy. This method should be applicable to a wide range of nuclear studies.

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