DEUTERON SPIN OBSERVABLES FROM ELECTRON SCATTERING AT INTERMEDIATE ENERGIES

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THE BLAST COLLABORATION

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Double-polarization asymmetries have been measured for the $(\vec{e}, e'p)$ electrodisintegration from vector polarized deuterium over a range of four-momentum squared, Q^2 from 0.1 to 0.7 $(GeV/c)^2$, and a missing momentum range from 0 to 475 (MeV/c). Simultaneously, single polarization asymmetries have been measured from tensor polarized both in the elastic channel as well as in the $(e, e'p)$ reaction channel. These sets of polarization observables have been obtained with great statistical precision and low systematical errors. They are compared with theoretical calculations and provide a new way to test the ground state wave function and the electromagnetic currents that connect to the continuum np system.

1. Introduction

The deuteron is an ideal system for testing nuclear theory. Due to its simple structure reliable calculations can be performed in both nonrelativistic[1,2] and relativistic frameworks[3,4]. Such calculations use phenomenological nucleon-nucleon (NN) potentials, and the resulting ground-state wave function is dominated by the S-state, especially at low missing momentum p_M. Because of the tensor part of the NN interaction a D-state component is generated. The models predict that the S- and D-state components strongly depend on p_M and are sensitive to the repulsive core of the NN interaction at short distances[2]. Traditionally, the spin structure of the deuteron has been studied through measurements of the tensor analyzing power T_{20} in elastic electron-deuteron scattering[5], and more recently by electrodisintegration studies in the region of quasielastic scattering[6]. The cross section for the $^2\vec{H}(\vec{e}, e'p)n$ reaction, in which longitudinally polarized electrons are scattered from a polarized deuterium target, can be written as [22]

$$\sigma = \sigma_0\{1 + \sqrt{\frac{3}{2}}P_z A_d^V + \sqrt{\frac{1}{2}}P_{zz} A_d^T + h(A_e + \sqrt{\frac{3}{2}}P_z A_{ed}^V + \sqrt{\frac{1}{2}}P_{zz} A_{ed}^T)\} \quad (1)$$

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where σ_0 represents the unpolarized cross section, h the polarization of the electrons, and $P_z(P_{zz})$ the vector (tensor) polarization of the target. The beam analyzing power is denoted by A_e, with $A_d^{V/T}$ and $A_{ed}^{V/T}$ the vector and tensor analyzing powers and spin-correlation parameters, respectively.

The Bates Large Acceptance Spectrometer Toroid (BLAST) is a detector designed to measure spin observables from few-body nuclei. With BLAST the A_{ed}^V double-polarization asymmetries have been measured for the $(\vec{e}, e'p)$ electrodisintegration from vector polarized deuterium over a range of four-momentum squared, Q^2 from 0.1 to 0.7 $(GeV/c)^2$, and p_M values up to 475 (MeV/c). Simultaneously, single polarization asymmetries A_d^T have been measured from tensor polarized both in the elastic channel as well as in the $(e, e'p)$ reaction channel.

2. The BLAST Experiment

The MIT-Bates linear accelerator consists of a 500 MeV linac with recirculator to produce electrons with energies up to 1 GeV and polarizations of $\sim 70\%$. The BLAST experiment is situated on the South Hall Storage Ring. Injected currents of ~ 200 mA with lifetimes of ~ 25 minutes are typical. A Siberian snake maintains the longitudinal polarization of the stored electron beam and a Compton polarimeter is used to monitor the stored beam polarization.

The BLAST detector is based on an eight sector, toroidal magnet with a maximum field of ~ 3800 G. The detectors in the left and right, horizontal sectors nominally subtend $20°$–$80°$ in polar angle and $\pm 15°$ azimuthally. The detector is roughly symmetric with each sector containing: wire chambers for charged particle tracking, Čerenkov detectors for electron identification, and time of flight scintillators to measure the relative timing of scattered particles. The neutron detectors are somewhat asymmetric with the right sector having a greater thickness.

An atomic beam source is used to produce highly polarized targets of pure hydrogen or deuterium. Combinations of magnets and RF transition units populate and transport the desired spin states into a 15 mm diameter, 60 cm long, thin aluminium cylinder open at either end through which the electron beam passes. For deuterium, a target thickness of 6×10^{13} atoms/cm^2 with polarizations of 72% vector or 68% tensor are typical. A magnetic holding field of ~ 500 G defines the target spin angle. This is typically horizontal, at $32°$ into the left sector so an electron scattering to the left (right) corresponds to a momentum transfer roughly perpendicular (parallel) to the spin angle.

The data acquisition uses the CODA and trigger supervisor systems from TJLAB. This allows multiple triggers to be defined so data can be accumulated for elastic, quasi-elastic, inclusive, and production reactions at the same time. Data are collected reversing the beam helicity each fill and randomly cycling through the target spin states every five minutes.

3. Results

Fig. 1 shows preliminary results for the T_{20} and T_{21} single polarization asymmetries obtained from elastic *ed* scattering as a function of the momentum transfer Q. The two lowest points have been normalized to the latest parameterization of the deuteron form factors. Also shown is the world data on these observables as well as a number of different theoretical calculations. Unfolding of the deuteron from factors to include the new BLAST data is in progress.

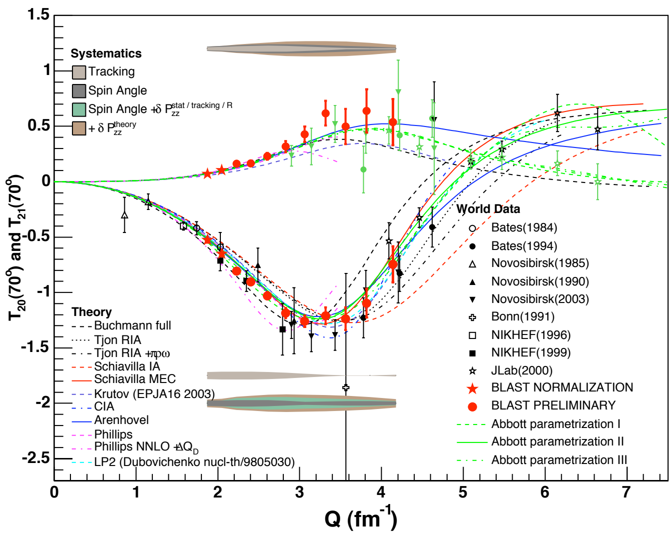

Figure 1. Preliminary results for the T_{20} and T_{21} single polarization asymmetries obtained from elastic *ed* scattering as a function of the momentum transfer Q

By studying quasi-elastic *ep* scattering from deuterium the D-state contribution and hence tensor force can be studied. In the Born approximation the tensor asymmetry for quasi-elastic scattering should be zero in the absence of D-state contributions. As seen in Fig. 2 for both perpendicular and parallel kinematics a significant asymmetry is seen as p_M increases indicating the onset of D-state contributions. Similar effects are seen in the vector asymmetries (see Fig. 3). At $p_M \leq$ 100 MeV/c, the theoretical results[1] for A_{ed}^V neither depend on the choice of the NN potentials nor on the models for the reaction mechanism. This shows that in this specific kinematic region the deuteron can be used as an effective neutron target. Thus, these data were normalized to the calculations and yielded an accurate determination of hP_z for our measurement of the charge form factor of the neutron (see M. Kohl, these proceedings). For increasing p_M, both the data and predictions for the asymmetry reverse sign. This reflects an increasing contribution from the D-state component in the ground-state wave function of the deuteron.

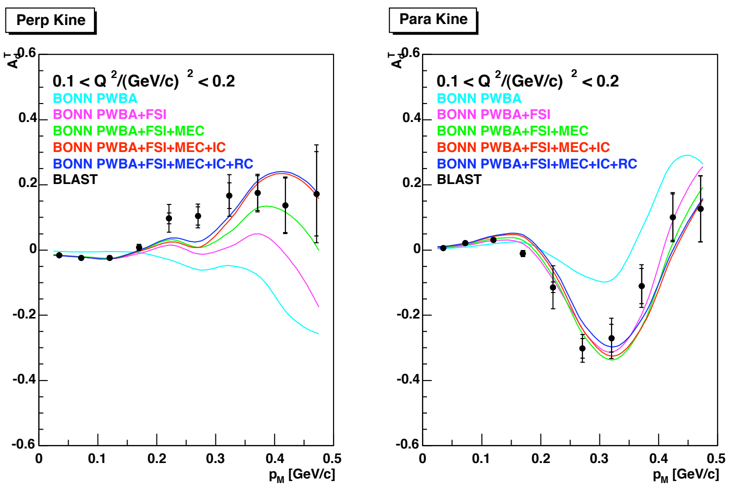

Figure 2. Tensor single spin asymmetry A_d^T as a function of p_M for the lowest Q^2 bin, 0.1 to 0.2 (GeV/c^2).

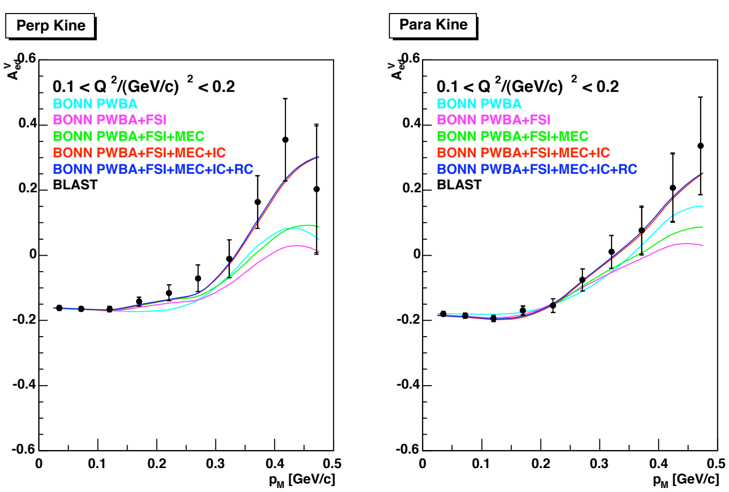

Figure 3. Vector double spin asymmetry A_{ed}^V as a function of p_M for the lowest Q^2 bin, 0.1 to 0.2 (GeV/c^2).

References

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