Developments for the Deuteron EDM Search

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Work on the development of an experiment to search for an intrinsic electric dipole moment (EDM) on the deuteron using a storage ring was concentrated on the preparation of a proposal for the Brookhaven National Laboratory Program Advisory Committee and the beginning of development work on a deuteron polarimeter. At the beginning of 2004, the Deuteron EDM Collaboration was asked by Tom Kirk at Brookhaven to submit a proposal. The preparation for this consumed most of the next six months of effort. The collaboration decided for the sake of the proposal to freeze the design of the storage ring at a momentum of 0.7 GeV/c, and to use Yuri Orlov's lattice that provided for crossed electric and magnetic fields in each of the bending regions and four 8-m straight sections that would be used for injection, polarimetry, and optical manipulations aimed at increasing the polarization lifetime.

The Indiana contribution was to examine contributions to the systematic errors in the search from the measurements of the polarization of the circulating deuteron beam. The polarimeter design was based on the idea of slow extraction through Coulomb scattering on a thin target. In this scheme, a thin jet spreads the stored beam. The fringes of this beam hit a carbon annulus that is designed to be the limiting aperture for the storage ring as well as the target for the polarimeter. The carbon is thick, between 2 and 3 cm. On the basis of some elastic scattering measurements from the literature, the efficiency for getting a useful scattering event from this target is about 1%. With this target as the ring aperture where all beam is lost, this efficiency can be realized for all of the deuteron beam. With the deuteron momentum set to 0.7 GeV/c, the figure of merit of the polarimeter is best when the detectors are placed to intercept any charged particle at angles above about 35°. Using elastic scattering measurements at 70 MeV as a guide [1], the figure of merit peaks at about 40° and falls slowly at larger angles. A similar behavior is expected for the reactions channels with low Q-value.

The measurement plan for the EDM search is to balance the electric and magnetic fields in the storage ring so that the anomalous precession of the deuteron is almost cancelled. This allows a small ω_a that will be useful for defining the EDM signal. That signal is a vertical component to the vector polarization that bears the correct phase relationship to the anomalous precession. Other processes can also produce such a signal, so we developed an extended set of requirements for a real EDM signal. Besides the correct phase and period, we also required the correct behavior in a number of reversals common to polarization measurements, including flipping the sign of the polarization at either the ion source or in the spin precession magnets that transport the polarization to the storage ring, reversals in the direction of circulation of the beam in the ring, and reversal of the sign of the anomalous precession. In addition, the signal should be the same at different points around the ring, and its size should vary as $\omega_{edm} / \sqrt{\omega_a^2 + \omega_{edm}^2}$ when the anomalous precession frequency is changed.

A number of potential sources of systematic error were examined, beginning with the usual problems of geometrical misalignment or polarimeter rotation and residual vertical polarization in the beam from the spin precession system. Several issues peculiar to this search were explored. One was the left-right asymmetry induced by a small tensor polarization in the beam. In particular, there is the possibility that such a polarization can be induced during the measurement itself [2]. A particularly complicated class of errors arises through the non-commutativity of rotations. Small field errors in the ring can produce motions of the spin axis out of the ring plane that result, when combined with the remaining anomalous precession, in an

EDM-like signal. These errors are distinguishable from a real EDM signal because they behave differently whenever the sign or the magnitude of the anomalous precession is changed. Of all of these errors, the largest originated from a failure to cancel geometrical asymmetries. This enters in third order in a cross-ratio analysis. A summary of these analyses was included in the proposal.

The Brookhaven Program Advisory Committee found that the physics justification for the experiment was excellent and the conceptual design of the storage ring was thorough even if challenging to implement. They were concerned about the cost of the project, and did not recommend approval for this reason. The collaboration discussed this result and decided on two courses of action. There would be an investigation of ways to reduce the cost of ring construction, and a novel approach using a resonance between the anomalous precession frequence and synchrotron oscillations would be investigated. The goal would be to present this experiment to the PAC again in 2005.

During the summer of 2004, we started preparations for a series of measurements of the vector analyzing power of deuteron-induced reactions and scattering from a carbon target. This led us to build scintillator-NaI charged-particle telescopes to cover proton energies up to 200 MeV. The NaI detectors were already available at IUCF, having been purchased for the first generation of proton polarimeters in the cyclotron beam lines. We constructed matching scintillators 0.64-cm thick to provide an energy loss measurement for particle identification. The detectors were tested for energy and particle identification resolution using the 200-MeV proton beam scattered from a CH_2 target in the RERP-1 beam line. A sample spectrum for protons is

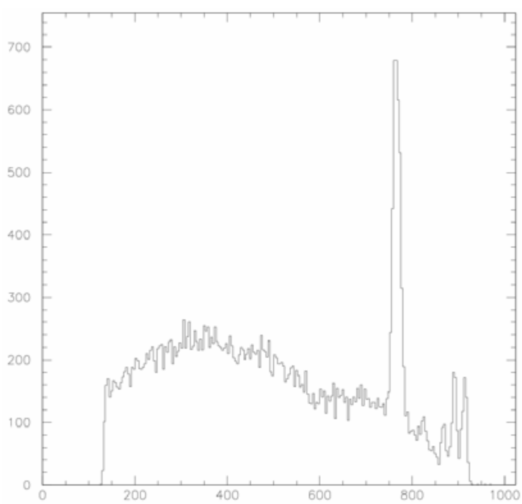

Figure 1: An energy spectrum for 200-MeV protons scattered at 24° from a CH_2 target. The large peak comes from p+p elastic scattering. Other peaks at higher energy are the ground and excited states of ^{12}C. The energy resolution is 2% FWHM.

shown in Fig. 1. The large peak is p+p scattering. The smaller peaks at the upper end of the spectrum come from the ground and first excited states of carbon. The energy resolution is roughly 2%, a value deemed adequate for these studies. The plan by the end of September, 2004, was to take these systems to the cyclotron at the KVI in Groningen and to make the analyzing power experiments there. These data will be used to develop a Monte Carlo simulation of the polarimeter and to examine how the design parameters can be varied to maximize the figure of merit.

1. S. Kato *et al.*, Nucl. Instrum. Methods A **238**, 453 (1985).
2. V.G. Baryshevski, arXiv:hep-ph/0109099, hep-ph/0201202.