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8.42 The Techniques of Proton Polarization Transfer Measurements at IUCF

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During the past year and a half, IUCF has been making measurements of the in-plane polarization transfer coefficients in 200-MeV proton elastic and inelastic scattering. These experiments required the preparation of a proton beam polarized in the horizontal plane with a spin axis that could be oriented in orthogonal directions. Figure 1 contains the major components involved in preparing the spin state of the beam and in measuring the resulting polarization components.

The atomic beam polarized ion source imposes a vertical quantization axis on the proton beam. Because an appropriate room-temperature solenoid was available, we chose to precess the spin axis into the horizontal plane in the beam line between the high voltage ion source terminal and the injector cyclotron where the beam energy is typically 600 keV. The proton spin will then precess several thousand times during acceleration in the injector and main stage cyclotrons. This large precession makes the spin direction sensitive to field settings in the cyclotron, a fact that we used to reorient the spin direction on target if changes were needed. This was typically done by changing the main stage dee voltage to produce a change in the number of turns. A high degree of polarization requires that the path through the cyclotrons be highly reproducible, and that at each extraction beam is removed from only one turn. By adjusting the turn pattern to have small radial oscillations, a larger turn separation at extraction was achieved, and no significant depolarization was measured. Because of field drifts, stability of the spin direction on target was often a problem. In the future, we intend to install two superconducting solenoids in the high energy beam line between the main stage cyclotron and the first high energy polarimeter shown in Fig. 1. The spin precession in the 42° energy analysis magnet is close to 90° for 200-MeV protons, so the two solenoids will be capable of delivering an arbitrarily directed proton spin to any target station.

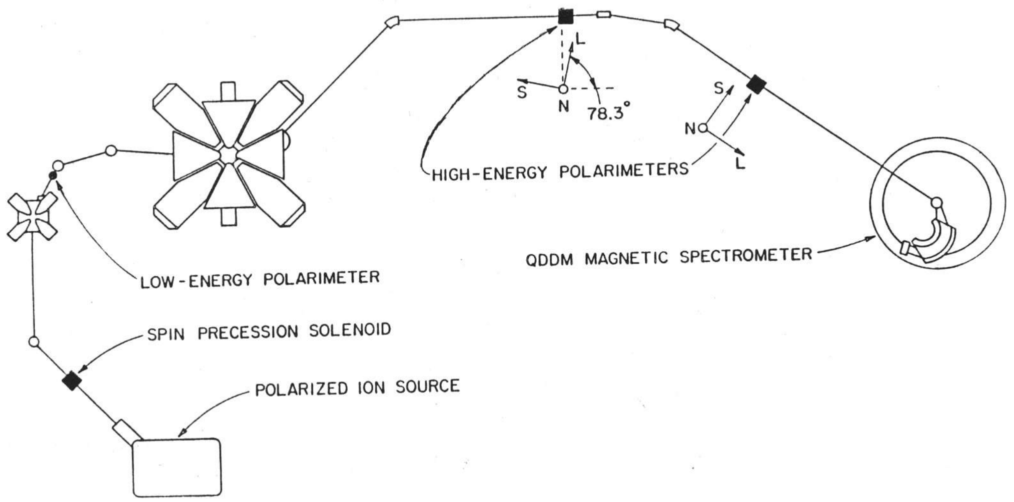

Figure 1: Map to scale of the beam line from the polarized ion source to the QDDM magnetic spectrometer. The components used to prepare and monitor the beam polarization are indicated.

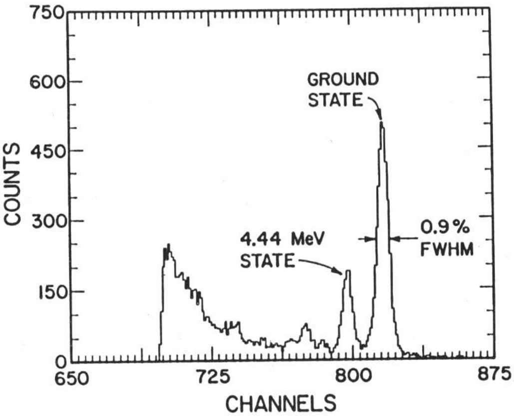

Fig. 2. Pulse height spectrum from the NaI(Tl) detectors mounted on the beam line polarimeters.

The beam polarization was monitored continuously by two polarimeters located in the beam line between the main stage cyclotron and the QDDM spectrometer target. Both polarimeters used self-supporting carbon foil targets with thicknesses between 50 and 800 $\mu g/cm^2$. Elastically scattered protons emerging at 20° were detected in 2"×6" cylindrical NaI(Tl) crystals. A spectrum is shown in Fig. 2. The resolution was typically less than 1% because of the large amount of light generated in the crystal and collimation of the scattered protons to track much narrower than the crystal diameter. The polarimeter analyzing power has been calibrated against double scattering measurements[1] and varies between 0.96 at 170 MeV and 0.81 at 200 MeV. The downstream polarimeter in Fig. 1 had two pairs of detectors for measuring the normal and sideways components of the beam polarization. The component which is longitudinal at the QDDM target is nearly sideways (see rotation diagram in Fig. 1) upstream of a 36° bend in the beam line. Another polarimeter located there had a pair of detectors for measuring the sideways component, thus completing the information on the polarization of the beam.

The focal plane of the QDDM magnetic spectrometer was instrumented with a helically-wound position-sensitive wire chamber, followed by two 1/4"-thick plastic scintillators that provided signals for particle identification. Immediately behind the second scintillator was a high-density graphite target 3.3 cm thick. Protons scattered from this target with vertical angles between 8° and 20° were detected by two telescopes mounted above and below the spectrometer median plane. The efficiency of the focal plane polarimeter (sum in upper and lower detectors) for elastic scattering was about 1.5%. The analyzing power depended on the quality of background rejection, proton energy, and the choice of the second telescope detector, and varied between 0.40 and 0.54. The large polarimeter efficiency and analyzing power permitted us to measure the elastic scattering spin rotation function with a precision typically less than 0.03.

The protons were bent through an angle of about 135° in the spectrometer dipole, making the sideways polarization component measured at the focal plane sensitive to both longitudinal and sideways polarization components at the target. For the measurement of spin rotation from a spin zero target, this information (along with freedom to adjust the beam polarization) is sufficient. For the more general case of inelastic scattering, a comparison of asymmetries measured with the spectrometer on either side of the beam line was needed to separate the effects of outgoing sideways and longitudinal polarization.

The measurements of spin rotation and polarization transfer are included in other contributions to this conference. This work was supported by the U.S. National Science Foundation.

References

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