THE K600 FOCAL PLANE POLARIMETER

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In 1989 the capability of performing complete sets of polarization transfer measurements at IUCF was achieved for the first time. This involved only minor upgrades of the K600 focal plane and focal plane polarimeter (FPP) hardware, but significant installation and calibration efforts on devices located in several other areas of the laboratory. These projects centered largely on the equipment and facilities necessary to be able to orient the polarization of the primary beam in an arbitrary direction, to measure precisely all three components of the beam polarization, and to have sufficient knowledge of the beamline optics to be able to determine the polarization at any subsequent point along the beam's path. Our goal was to develop a system flexible enough to supply proton beams of any desired polarization orientation to as many target areas as possible. Particular emphasis was given to the K600 spectrometer, the beam swinger area, and injection into the Cooler ring, as each of these programs has already demonstrated a need for in–plane (horizontally) polarized proton beams.

Descriptions of the primary components and physical arrangements of the K600 focal plane and focal plane polarimeter scintillator detectors and wire chambers are provided in Ref. 1. In addition to the equipment described therein, two horizontal drift chambers (HDC's) have since been installed directly behind (downstream) of the vertical drift chambers (VDC's) in the focal plane. Due to various technical problems with the HDC's, which provide y–axis or vertical trajectory information, we are currently in the process of replacing these with more standard MWPC's. By using two adjacent chambers with staggered wires, we will achieve an effective wire spacing of 1.0 mm. The large separation of the two sets of chambers (in excess of 20 cm for most particle trajectories) will provide extremely accurate vertical position and angle determinations.

In November 1989 we completed the first measurements on the K600 which required that the polarization vector of the incident proton beam lie in the (horizontal) scattering plane. Technical details and results from this experiment (E290) can be found elsewhere in this report.[2] Prior to the production running phase of this experiment, a series of calibration measurements was performed which utilized both of the superconducting spin precession solenoids (located just before and after the BL3 energy analysis magnet), the two permanently installed p+d polarimeters[3] associated with each solenoid, and an older proton polarimeter, based on p+^{12}C elastic scattering, that was temporarily positioned just downstream of the K600 scattering chamber. By systematically varying the two solenoid currents and detecting the vertical and sideways polarizations in each of the three polarimeters, it was possible to deduce both the conversion factors from solenoid current to precession angle for each solenoid, and the bend angle of the proton's trajectory in the energy analysis magnet (BM1 BL3) and in the QDDM (BM3 BL8). The locations of these elements are illustrated in Figure 1. Because some of these calibration schemes rely on the stability of the proton polarization orientation out of the main stage cyclotron, all measurements were repeated several times in relatively rapid succession, so that slow, time–dependent variations in the polarization direction and magnitude could be accomodated in the analysis. For example, data would be taken with a particular solenoid alternately off or energized to a certain value, from which one could interpolate the needed beam polarization parameters.

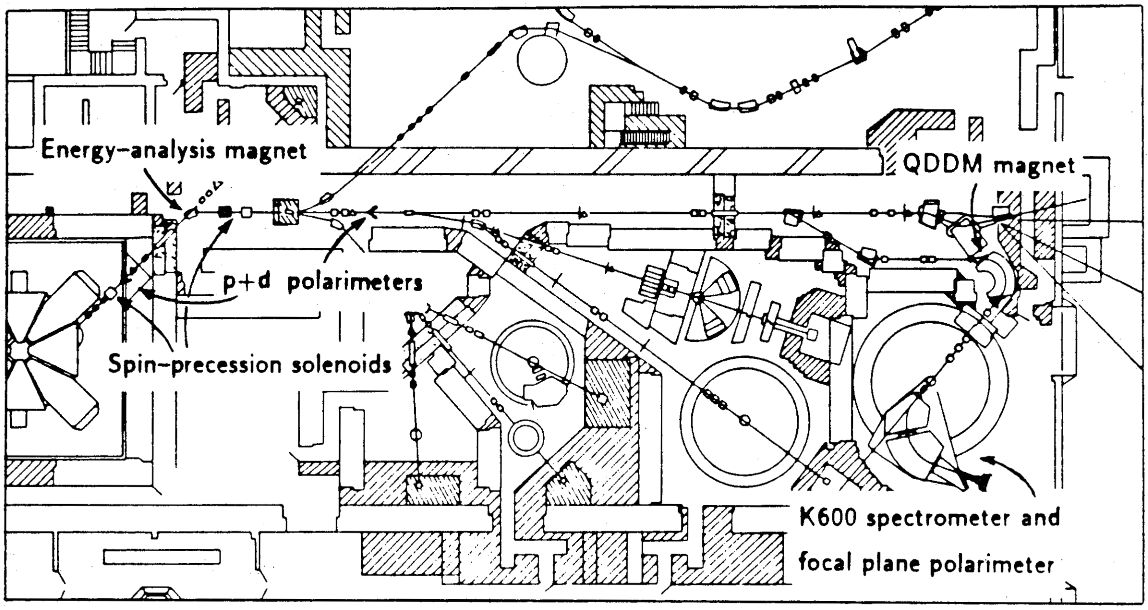

Figure 1. Schematic floor plan of the IUCF high energy beam lines, indicating the locations of the principal magnetic elements (dipoles and solenoids) that affect the orientation of the proton polarization vector, and the polarimeters used to measure the normal and sideways polarization components.

As a result of these procedures, the horizontal bend in the beam line between the two p+d polarimeters was found to be 44.8° ± 0.6°, which is consistent with the assumption that the beam undergoes a single 45° bend in the energy analysis magnet (BM1 BL3, see Fig. 1). Similarly, the net horizontal bend between the second (BL5) p+d polarimeter and the K600 beam line (BL8) had an average value of 130.4° ± 0.4°, also in agreement with the geometrically determined bend angle of 130° for the QDDM magnet system that serves as bending magnet 3 in beam line 8. Previous estimates that magnet currents of approximately 48.4 A would be required to produce 90° precession of a 200 MeV proton beam in the spin precession solenoids were also verified.

With these calibrations complete, we could reliably determine all components of the proton polarization at the K600 target based on the asymmetries measured in the two p+d polarimeters and the known currents in the two spin precession solenoids. To perform in-plane polarization transfer measurements, two additional pieces of information were required: a means of determining the bend angle of the scattered proton's trajectory within the K600 spectrometer, and an accurate determination of the effective analyzing power of the focal plane polarimeter for sideways polarization. Because the focal plane

x–chambers (VDC's) provide angular information, the first task reduced to a determination of the angle of the focal plane chambers with respect to the central ray at the entrance to the K600 spectrometer. This angle was deduced geometrically to be 77.9° ± 0.05° through two independent sets of measurements, which agreed with each other within their estimated uncertainties.

To determine the effective analyzing power of the focal plane polarimeter for the sideways polarization component, we again exploited some of the simplifying relationships[2] which exist among the reaction spin observables for $\frac{1}{2} + 0 \to \frac{1}{2} + 0$ spin configurations. In particular, if one investigates proton elastic scattering from 0^+ nuclei in kinematic regimes where the reaction analyzing power A_y is close to zero, then the effect of the nuclear scattering is to maintain the magnitude of the in–plane polarization but to rotate it by an angle β which is independent of the initial orientation. Thus, if one were to perform a series of measurements with a purely in–plane polarization vector lying at several different orientations, one would map out an up–down asymmetry in the focal plane that should vary sinusoidally with the angle of this orientation. More explicitly, if the polarization of the proton beam incident on the K600 target is expressed as

$$P_L = P_0 \cos\phi \tag{1}$$

$$P_S = P_0 \sin\phi \tag{2}$$

then for elastic scattering from a spin–0 target near $A_y = 0$, one would measure an up–down asymmetry in the focal plane polarimeter given by

$$\varepsilon_{FPP} = P_0 A_{FPP} \cos(\phi - \Phi) \ , \tag{3}$$

where A_{FPP} is the effective polarimeter analyzing power of interest, and Φ is a constant spin rotation due to contributions from both the nuclear scattering (β) and additional spin precession within the spectrometer magnet system. Note that these two parameters are completely decoupled, so that lack of precise knowledge of either β or the bend angle of the K600 do not affect the determination of A_{FPP}.

As part of experiment E290, A_{FPP} was calibrated using the above procedure at proton bombarding energies of approximately 200, 190, and 180 MeV on a ^{12}C target. In Figure 2 are shown the data at 190 MeV, which indicate a value of $A_{FPP} = 0.483 \pm 0.010$. This is in reasonable agreement with earlier measurements[4] of A_{FPP} for normal component polarization, though precise comparisons are difficult since much of the polarimeter software has been rewritten to incorporate more sophisticated trajectory and energy loss calculations. It is useful to point out that the same procedures were used to analyze the E290 production data as were used to determine A_{FPP}, and that the two data sets were taken at the same beam energy and with the same spectrometer angle calibration.

For the next year, further development of the K600 spin transfer system will continue to be centered largely on equipment external to the polarimeter itself, which is essentially complete. Data taken at either very small scattering angles ($\theta_{lab} < 16°$) or on the right side of the beam presently require that the beam be stopped on a Faraday cup mounted

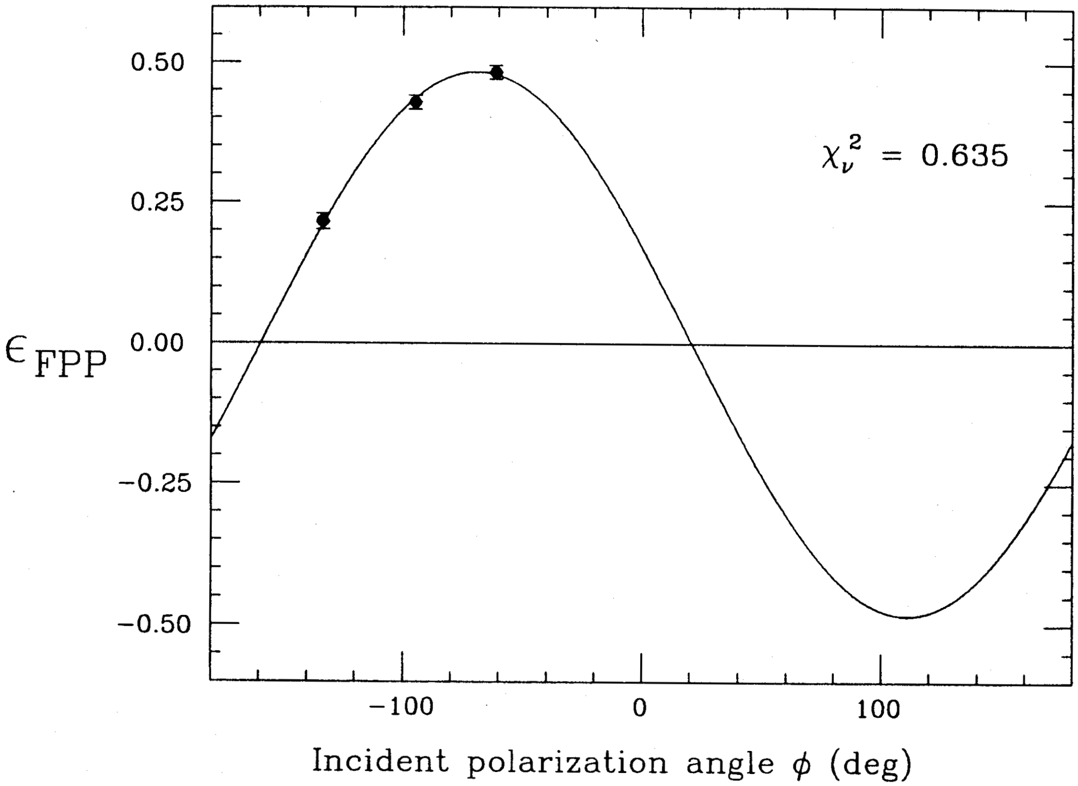

Figure 2. The up–down asymmetry measured in the K600 focal plane polarimeter, normalized by the magnitude of the incident polarization, plotted versus the angle of the incident polarization, as defined in equations 1 and 2 in the text. The data correspond to proton elastic scattering from a ^{12}C target at 188.9 MeV near the zero–crossing of the analyzing power at 24.85°.

within the K600 scattering chamber. The shielding on this cup is sufficiently poor that the room background generated limits operation of the focal plane polarimeter to a few nanoamperes of beam current. We are investigating several schemes for reducing this background radiation, either through use of a septum magnet to allow for transport to an external beam dump at significantly smaller scattering angles, or through extensive shielding of an internal Faraday cup that would be mounted downstream of the present scattering chamber.

1. S.W. Wissink *et al.*, IUCF Scientific and Technical Report, May 1988 – April 1989, p. 204.
2. S.W. Wissink *et al.*, *"Precise Determinations of Proton Analyzing Powers for 180–200 MeV Elastic Scattering on ^{12}C and ^{4}He"*, IUCF Scientific and Technical Report, May 1989 – April 1990.
3. A.K. Opper *et al.*, IUCF Scientific and Technical Report, May 1988 – April 1989, p. 89.
4. E.J. Stephenson *et al.*, IUCF Scientific and Technical Report, May 1988 – April 1989, p. 94.