DETECTOR DEVELOPMENT AND CALIBRATION

CALIBRATION OF A PROTON POLARIMETER

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A proton focal plane polarimeter (FPP) has been constructed by a UVa–MIT–William & Mary collaboration. This polarimeter, along with the polarized electron beam at MIT-Bates, will be used to initiate a program of polarization measurements in coincidence electron scattering. The FPP will be installed in the One Hundred Inch Proton Spectrometer (OHIPS) at MIT-Bates. Beginning this year, we will commence a program of $(\vec{e},e'\vec{p})$ measurements on the proton, the deuteron, ^{4}He and complex nuclei. Physics issues to be addressed include the quadrupole amplitudes in the $N \rightarrow \Delta$ transition via the $p(\vec{e},e'\vec{p})\pi^0$ reaction (the question of "deformation" in the nucleon and Δ wavefunctions), the electromagnetic structure of the deuteron and helium, and sensitive tests of nucleon-nucleus dynamics in the $^{16}O(e,e'\vec{p})$ reaction.

The basic criteria that the device had to meet were 1) complete (0–2π) coverage in the azimuthal scattering angle for a position spread corresponding to a 10% momentum acceptance and scattering angles in the FPP up to 20°, 2) suitability for use with extended targets up to 10 cm in length, 3) resolution in scattering angle of $\leq 1°$, and 4) the ability to reject events with small ($<4°$) scattering angles in $\ll 1$ μs. The device is intended to operate over the full range of proton energies accessible at Bates: 100–800 MeV. The polarimeter consists of two scintillators for polarimeter trigger definition, and four multiwire proportional chambers, two before and two after a graphite scatterer (which can be from 0.5 to 30.5 cm thick). The optics of OHIPS, along with the use of extended targets, result in a fairly large and diverging beam at the entrance of the polarimeter. These characteristics, along with chamber separations large enough to provide adequate angular resolution, determined that the first two MWPCs be 70×36 cm^2 (X by Y) and the last two be 140×88 cm^2. The wire spacing in the chambers was chosen to be as large as possible consistent with the above criteria, resulting in 2-mm spacing in the front two chambers while 4-mm spacing was acceptable in the rear two chambers. This results in a total of 2200 wires (350 in each of the four X chambers, 180 in the first two Y chambers and 220 in the last two Y chambers).

The OHIPS FPP was calibrated at IUCF in a direct beam of polarized protons. Energies of 120, 150, 180 and 200 MeV were employed. At these energies, the $\vec{p}$-^{12}C analyzing power, measured at several laboratories,[1] is known to ±2%. This allowed a precise verification of the operation of the OHIPS FPP in a stand-alone mode decoupled from the influence of the OHIPS magnetic fields.

The FPP was installed in the QQSP area. A low-intensity ($\sim10^5$/s) polarized proton beam was obtained starting with the standard cyclotron beam by using a combination of a lead degrader, slits and collimators. The polarimeter was mounted on a hydraulic, wheeled table that allowed both up-down and left-right motions so that various regions could be illuminated.

The calibration run was extremely successful. We acquired all the required data at all the energies. Additional studies were made of the graphite thickness dependence of the analyzing power and the effect of mixing Freon in the wire chamber gas. The data at 200 MeV have been completely analyzed; we report those results here.

We compared the beam polarization as measured by the FPP and by the (previously calibrated) IUCF beamline polarimeters. When the beam polarization is reversed, the FPP physics asymmetry changes sign, allowing instrumental effects to be canceled. The magnitude of the beam polarization (at 200 MeV) as measured by the FPP compared to the IUCF beam polarimeters is: FPP/IUCF=0.976 ± 0.006. An even more significant result is our determination of the ratio of the spin-up to spin-down polarization. Here, an absolute asymmetry must be measured, i.e., instrumental effects do not cancel since each spin state is independently analyzed. This same ratio was also measured by a special IUCF low-energy polarimeter employing p+α elastic scattering. The ratio of spin-up/spin-down ratios from the two measurements is: FPP/IUCF=1.018 ± 0.011. Thus, the FPP's operation is consistent with design goals at the 2% level. Indeed, it is as good as can be expected. Figure 1 shows the asymmetry (=beam polarization×analyzing power) from our measurement compared to previous SIN[2] and LAMPF[3] data. Our data at this energy are

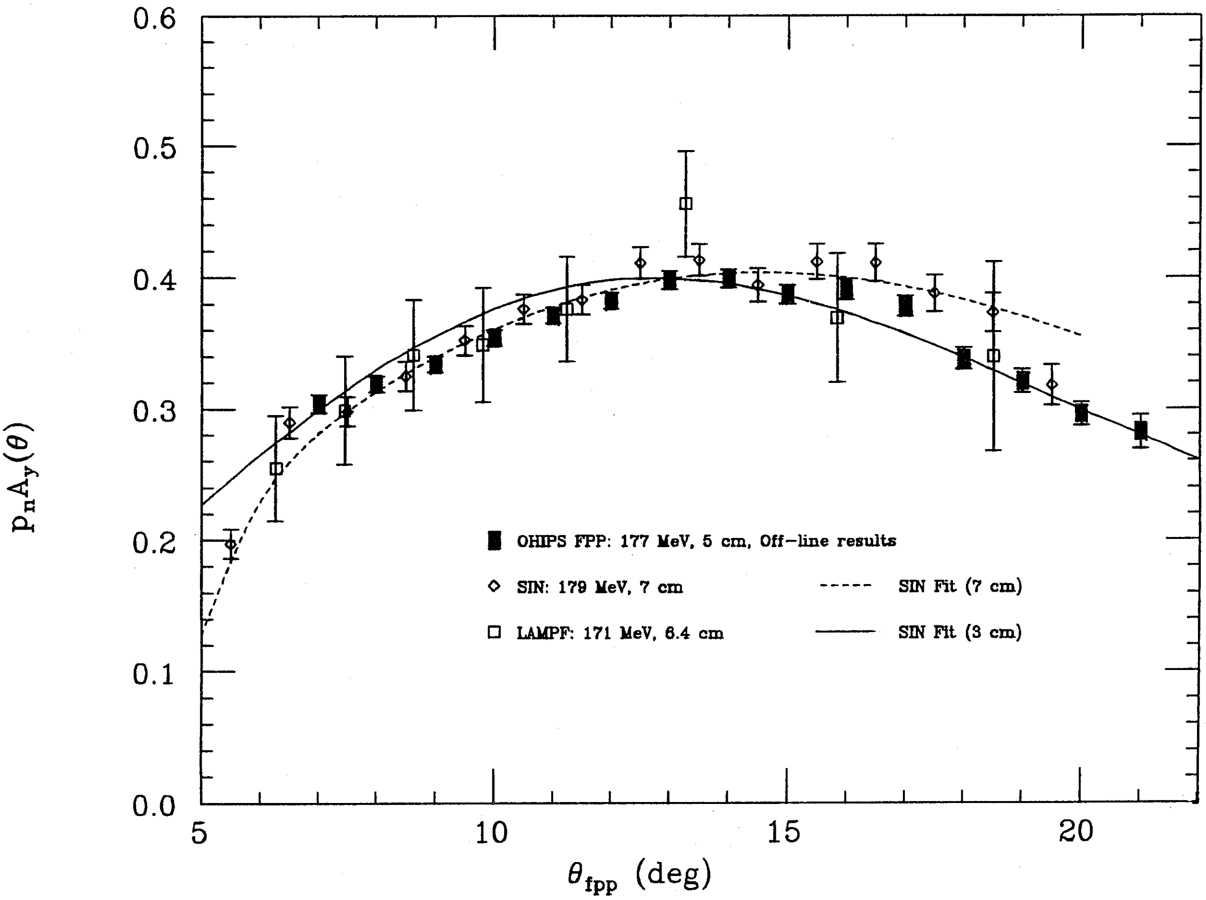

Figure 1. Asymmetry vs. scattering angle in the FPP. Solid rectangles: IUCF calibration of Bates FPP. Open diamonds: SIN. Open squares: LAMPF. The curves show two fits to the SIN data set.

not only consistent with the previous data but are of significantly greater precision. Data from the other energies are still under analysis although "spot checks" indicate that these data are comparable in quality to those obtained at 200 MeV.

Rejection of events with small angle scatterings is necessary in hardware since the vast majority of events (~90%) undergo only multiple Coulomb scattering in the graphite analyzer and, since they have zero analyzing power, are useless. We have constructed a hardware trigger system that, when presented with wire number data from the multiwire proportional chambers, can test the scattering angle within 180 ns.[4] The total time from the receipt of an event to the test result obviously depends on the chamber readout scheme; we are employing the PCOS III system from LeCroy so that the total decision time is 600 ns. This is significantly faster than previous implementations such as the 1.2 μs obtained using specially designed electronics at CERN[5] or the 8-μs test time using time-amplitude converters and drift chambers at LAMPF.[3]

Our method employs a simple two-level system that utilizes two LeCroy ECLine modules: the 2378 Arithmetic Logic Unit (ALU) and the 2372 programmable Memory Lookup Unit (MLU). The ALUs are used to generate wire number differences which are then presented as addresses to the MLU. The programming of the MLU essentially implements a pattern recognition algorithm. The MLU then produces a single output bit that indicates whether or not the given wire difference pattern corresponds to a scattering angle greater than a predetermined minimum. The performance of the system can be seen in Fig. 2 which displays the angular distribution observed in the FPP with and without the small-angle system activated. One can see the two orders of magnitude enhancement in the proportion of large angle events using this system. The angular distribution is also in good agreement with previous measurements.[2]

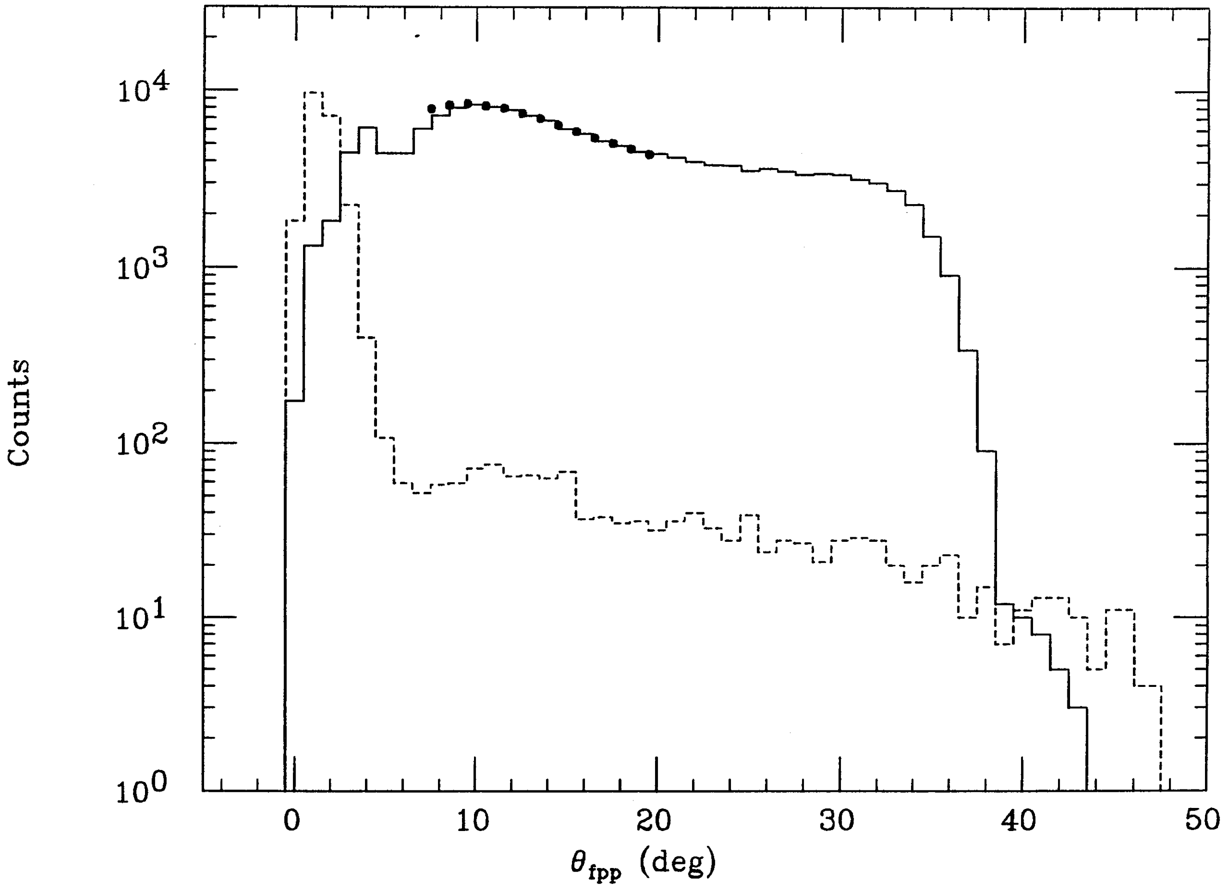

Figure 2. Angular distribution observed in the FPP. Solid (dashed) histogram is with (without) the small-angle rejection hardware activated. The dots represent the angular distribution from Ref. 2.

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2. E. Aprile-Giboni, *et al.*, Nucl. Inst. Meth. **215**, 147 (1983).
3. R.D. Ransome, *et al.*, Nucl. Inst. Meth. **201**, 309 (1982).
4. R.W. Lourie, S.P. Van Verst, J.H. Mitchell, D.H. Barkhuff and T.P. Welch, Nucl. Inst. Meth. **A306**, 83 (1991).
5. D. Aebischer, *et al.*, Nucl. Inst. Meth. **99**, 405 (1972); **117**, 131 (1974).