PHYSICS WITH A FOCAL PLANE PROTON POLARIMETER FOR HALL A AT CEBAF

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INTRODUCTION

A focal plane polarimeter intended for the CEBAF Hall A high resolution hadron spectrometer is under construction at Rutgers University and the College of William & Mary. Experiments with focal plane polarimeters are only now beginning at electron accelerators; they play a prominent role in the list of approved experiments for Hall A. Construction of the polarimeter is in progress; it is expected to be brought to CEBAF in spring 1995. Several coincidence ($e, e'\bar{p}$) and singles ($\gamma, \bar{p}$) measurements by the Hall A Collaboration are expected to start in 1996. In this paper we describe the polarimeter and the physics program planned for it.

THE POLARIMETER

Intermediate energy proton polarimeters are generally based on a nuclear scattering of the proton from a carbon analyzer. The spin orbit force introduces an azimuthal asymmetry, or ϕ dependence, into the scattering differential cross section. The scattering measurement is inclusive, with no determination made of the energy of the outgoing proton. The angle-averaged analyzing power of carbon in this situation ranges from about 0.5 near 200 MeV kinetic energy to about 0.1 for energies near 2 GeV. Polarimeters generally use wire chambers before and after the analyzer to determine the scattering angles.

The CEBAF Hall A polarimeter follows the usual techniques described above. It is unusual, however, in several respects, which are discussed below. The polarimeter is physically large, makes use of straw tube drift chambers and multiplexing electronics, and will be located at an electron accelerator.

The polarimeter system is shown in Figure 1. Four straw-tube chambers are used to track the proton trajectory into and out of a graphite block. The geometrical sizes of the chambers, up to 1.4 m $\times$ 2.8 m, have been set to accept 20° scatters from almost the entire analyzer block, including the effects of divergence of the beam envelope in the detector stack. To make the response of the detector identical in two orthogonal directions,

the straws are oriented along UV axes, at $\pm 45^\circ$ to the edges of the chamber. The straw diameter is slightly greater than 1 cm; each detector plane contains at least 176 straws, and is constructed so that the geometrical coverage is about 97%. These large sizes and the large numbers of wires in the chambers (~ 5500) influenced the choice of straw tubes over conventional wire chambers. Too, since the chambers are used in conjunction with a thick – up to 55 cm – carbon analyzer, multiple scattering in the chambers is not an important consideration. Position resolution of the chambers is expected to be about 150 – 200 μ . Monte Carlo simulations of the system indicate that tracking efficiency should be close to 100%, and false asymmetries less than 0.01 should be achievable at lower energies.

The design requirements for rate capability of the polarimeter arise from typical experiments in the physics program that measure the coincidence ($e,e'p$) reaction. Since coincidence rates can be small fractions of the singles rate in each detector arm, we require that the polarimeter have a 1 MHz singles rate capability. This leads to modest rates of 5 – 6 kHz in individual straws. However, individual wire readout was deemed to be prohibitively expensive.

The electronics design chosen uses readout boards developed at Rutgers University that amplify and discriminate the chamber signals, and multiplex the resulting logical signals. Given the needed rate capability, the boards were designed to multiplex 8 signals into an individual TDC channel. This is accomplished by using fixed width discriminator one-shots that vary across each set of eight channels from 35 to 70 ns, and fast logical ORs. Time digitization will use the multihit LeCroy 1877 TDC to measure both the leading edge of the pulse for drift time information, and the trailing edge for demultiplexing information.

The use of the polarimeter at CEBAF leads to calibration difficulties, as one lacks both a proton beam of known polarization and previously measured nuclear reactions. The calibration procedure at an electron accelerator uses elastic scattering of polarized electrons from an unpolarized hydrogen target. Insofar as the proton electric and magnetic form factors are known, this leads to protons of known polarization that can then be used to calibrate the polarimeter. This technique is discussed further below in the description of the G_E experiment. It is expected that the polarimeter will be calibrated and used for proton kinetic energies up to about 3 GeV.

PHYSICS EXPERIMENTS

Two ($\vec{e},e'\vec{p}$) polarimetry experiments require a proton target. The proton electromagnetic form factors will be studied¹ in elastic scattering of polarized electrons. Spin transfer yields a longitudinal polarization that depends on the squared magnetic form factor, G_M^2 , and a transverse, in plane, polarization that depends on the product of electric and magnetic form factors, $G_E G_M$. The ratio of these spin components allows one to measure precisely the poorly known G_E relative to the well-known G_M without knowing the beam polarization or the carbon analyzing power. The experiment also serves to calibrate the focal plane polarimeter, provided the beam polarization is known, using the transverse spin component. In kinematics in which the Δ resonance is excited, response functions will be separated and subjected to a multipole analysis. The varying response functions allow accurate determination of the dominant $|M_{1+}|^2$ amplitude, the interference term

$\text{Re}(S_{1+}^* M_{1+})$ involving the quadrupole amplitude, and the influence of other resonant and nonresonant backgrounds.

Studies^{3,4,5} of $(e, e'p)$ are also planned on nuclei ranging from ^2H to ^{16}O . With unpolarized beam, the normal component of the polarization results solely from final state interactions. This should yield more precise information than simple cross section measurements about the reaction mechanism and nuclear wave functions, and allow improved tests of phenomena such as color transparency. The spin transfer with polarized beam depends, in the plane wave approximation, on known kinematic factors, the nuclear wave function, and the electromagnetic form factors of the proton. Spin transfer is generally insensitive to final state interactions. With the nuclear wave function and final state interactions constrained by cross section and induced polarization measurements, it is expected that the spin transfer data can provide the best restrictions on the modification of the proton electromagnetic form factors in the nucleus.

Studies^{6,7} of the (γ, p) reaction are planned on hydrogen and deuterium. These two experiments address the question of whether the scaling of the cross sections in these reactions is a real indication that quark/gluon degrees of freedom are dominant. The energy dependence of the cross section has been reproduced in both quark/gluon and meson/baryon models. The quark/gluon interpretation requires that the recoil proton polarization be zero, due to helicity conservation. The strong-interaction meson/baryon model essentially requires significant nonzero polarization due to final state interactions and the interference of baryon resonances with nonresonant contributions to the cross section.

1. C. F. Perdrisat, V. Punjabi, Mark Jones *et al.*, Electric Form Factor of the Proton by Recoil Polarization, CEBAF Proposal PR-93-027.
2. R. Lourie, S. Frullani *et al.*, High Precision Separation of Polarized Structure Functions in Electroproduction of the Δ and Roper Resonances, CEBAF Proposal PR-91-011.
3. J. M. Finn, P. Ulmer *et al.*, Polarization Transfer Measurements in the $D(\bar{e}, e'p)$ Reaction, CEBAF Proposal PR-89-028.
4. C. Glashauser, C. C. Chang, S. Nanda, J. W. van Orden *et al.*, Measurement of Recoil Polarization in the $^{16}\text{O}(\bar{e}, e'p)$ Reaction with 4 GeV Electrons, CEBAF Proposal PR-89-033.
5. A. Saha *et al.*, Study of Nuclear Medium Effects by Recoil Polarization up to High Momentum Transfers, CEBAF Proposal PR-91-006.
6. R. Gilman, R. J. Holt, Z.-E. Meziani *et al.*, Measurement of Proton Polarization in the $d(\gamma, p)n$ Reaction, CEBAF Proposal PR-89-019.
7. R. Gilman, R. J. Holt *et al.*, Measurement of Photoproton Polarization in the $H(\gamma, p)\pi^0$ Reaction, CEBAF Proposal PR-94-012.

Figure 1. The CEBAF Hall A focal plane polarimeter.

Figure 2. Expected results for the G_E experiment.

Figure 3. Expected results for the $\gamma d \rightarrow \bar{p} n$ experiment in two scenarios.