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5 MeV Mott Polarimeter Development at Jefferson Lab

J.S. Price*, B.M. Poelker*, C.K. Sinclair*, K.A. Assamagan†, L.S. Cardman*, J. Grames‡, J. Hansknecht*, D.J. Mack*, and P. Piot*

*Jefferson Lab,[1]
12000 Jefferson Avenue, Newport News, VA USA
†Hampton University, Hampton, VA USA
‡University of Illinois at Urbana-Champaign, IL USA

Abstract. Low energy (E_k=100 keV) Mott scattering polarimeters are ill-suited to support operations foreseen for the polarized electron injector at Jefferson Lab. One solution is to measure the polarization at 5 MeV where multiple and plural scattering are unimportant and precision beam monitoring is straightforward. The higher injector beam current offsets the lower cross-sections. Recent improvements in the CEBAF injector polarimeter scattering chamber have improved signal to noise.

INTRODUCTION

Low-energy ($E_k \leq$ 100keV) polarimeters using Mott scattering from high-Z foils have been used to measure electron beam polarization in a variety of applications. However, the large cross-section produces significant plural and multiple scattering in the thinnest of free-standing pure metal foils (40 nm thick) which reduces the effective analyzing power [1]. Mott scattering at higher energy has lower cross-section so μA beam currents can be tolerated which facilitates rapid real-time monitoring of beam polarization. Dilution of the analyzing power due to plural and multiple scattering from 0.1 μm thick gold foils is of order a few percent; this reduces sensitivity to target foil thickness. RF structure on μA beam currents in the CEBAF injector make beam position, angle, current, and spot size easy to monitor simultaneously with polarization thus allowing control of systematic uncertainties.

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DISCLAIMER

PROTOTYPE POLARIMETER

We have installed a prototype polarimeter in the 5 MeV section of the Jefferson Lab Injector. There is little uncertainty in the calculated single scattering analyzing powers upon which the polarimeter design is based [2]. Foils of different Z (e.g. Cu, Ag and Au) and identical Molière scattering distribution were used to make preliminary measurements of target foil analyzing power independent of beam polarization (Figure 1).

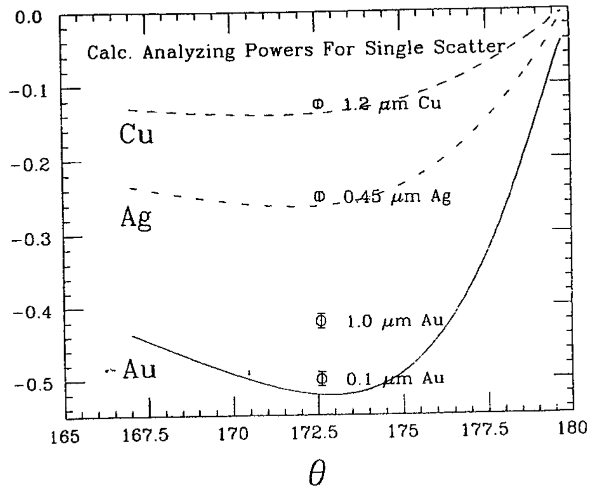

Figure 1. Calculated single-scatter analyzing power for Au, Ag and Cu as a function of scattering angle at 5 MeV (curves) and preliminary measured values (circles).

The 0.1 μm Au foil shows approximately 5% difference from the calculated maximum analyzing power (-0.52) at $\theta = 172.6$ °, however a 1.0 μm Au foil was -0.42. Nuclear size effects at this energy are expected to be of order a percent [3].

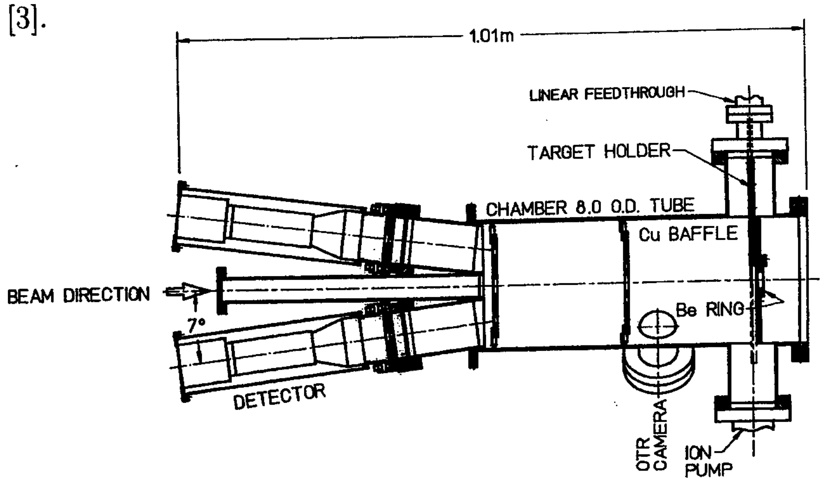

Figure 2. Prototype 5 MeV Mott polarimeter scattering chamber.

Figure 2 shows a side view drawing of the scattering chamber including placement of two of the four scintillation detectors at 173° to the beam line. These four detectors allow simultaneous measurement of the two components of polarization transverse to the beam momentum direction.

Copper aperture plates 1 cm thick have been installed between the target foil and detectors. Four holes in each plate provide line of sight view to the target foil. The downstream portion not shown includes a long Al pipe which serves as a beam dump. A solenoid magnet focuses the scattered beam into a dipole field which deflects the electrons into a short Al dump angled at 40°. Chamber surfaces downstream of the foil are lined with high density polyethylene. The performance of the instrument as a polarimeter is directly related to the signal to noise. Recent efforts have reduced the number of inelastically scattered electrons; compare pulse height spectra in Figure 3. Encouraged by this progress, work continues on reducing background.

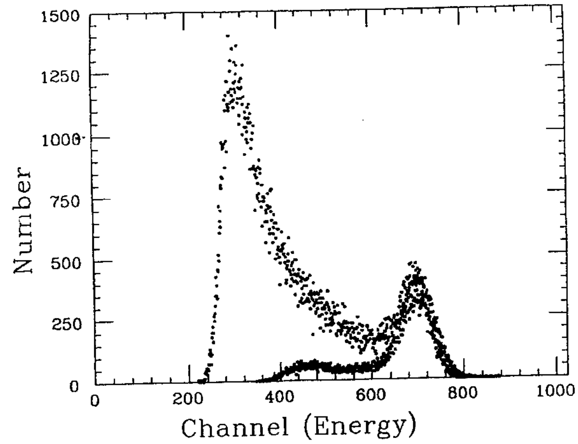

Figure 3. Typical PMT pulse height spectra for 1 μA beam on 0.1 μm Au foil shown before and after scattering chamber improvements.

The NE102a plastic scintillator detectors are equipped with 1 cm diameter apertures cut in 12 mm thick Al which subtend 1° in θ and about 5° in ϕ. Rate measurements with these 0.22 msr apertures give 130 Hz count rate with a 10 μA CW polarized beam on a 0.1 μm Au foil. This agrees with calculated expected rate allowing for the 0.20 mm thick Al vacuum window. Measurements with statistical uncertainty of order 1% can be made rapidly.

RF time structure is present so precision beam position, angle and current monitoring is straightforward. For example, a beam current monitor (BCM) is located 2 m upstream of the polarimeter; measurements of integrated charge can be made for different helicity states. A CCD camera focussed on the target foil can detect the visible radiation emitted as the electron beam passes through the foil. This optical transition radiation (OTR) monitor can easily resolve the profile of a mm diameter beam (see Figure 4). Helicity-correlated changes in spot size and position can be directly and simultaneously measured with polarization. This allows control of and correction for false asymmetries in the measurement due to beam spot changes. It is also a valuable diagnostic for polarized source performance.

Preliminary measurements of beam polarization as a function of beam current over a range 2 to 12 μA show insignificant rate dependence. Background and asymmetry vary little as a function of beam spot location within the central 0.4 diameter on the target foil.

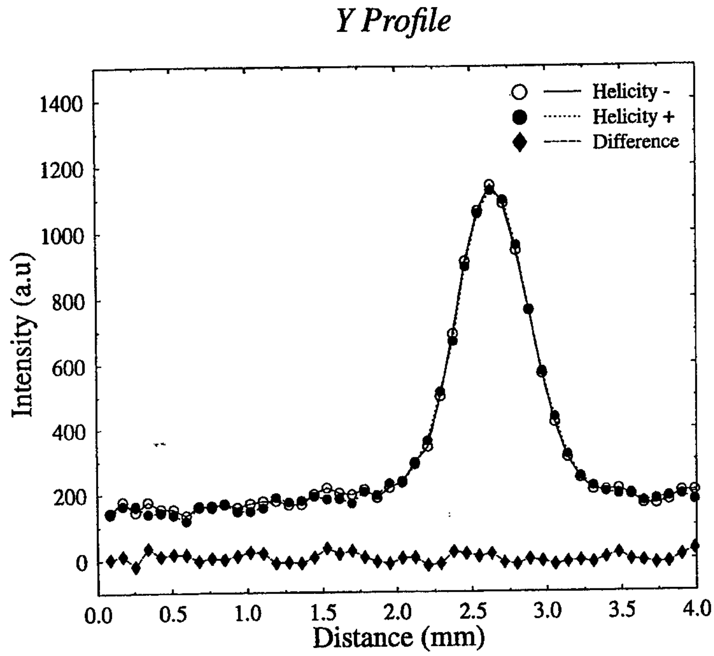

Figure 4. Helicity-correlated OTR beam profiles (summed channels vs y, 1 mm=16 ch) for 2.5 μA beam.

Polarimeter operation is controlled from the Machine Control Center via EPICS, CEBAF's accelerator control software. Accelerator operations personnel measured beam polarization during a recent five week period that required polarized electron delivery to more than one experimental hall. A video monitor presents operators with a real-time image of the beam spot on the target foil. Raw scaler rate, asymmetry, beam current and dead time can be monitored at one second intervals. Helicity-correlated pulse-height spectra for all four detectors are displayed automatically after each measurement period so that operators can evaluate data quality.

SUMMARY

Progress has been made on improving aspects of the prototype 5 MeV Mott polarimeter at Jefferson Lab. Although systematic studies are not complete, recent calibration efforts and operational experience indicate the instrument is performing well. Further chamber modifications and calibration runs are planned.

REFERENCES

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