# 5 MeV Mott Polarimeter for Rapid Precise Electron Beam Polarization Measurements*

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## 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; measured rates scale to 1 kHz/$\mu$A with a 1 $\mu$m thick gold target foil.

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, and creates the need for foil-thickness extrapolation or other calibration methods. [1] While statistical and systematic accuracy of order 1% has been achieved, low energy methods are slow and unsuited to rapid real-time monitoring of beam polarization. Low-energy Mott polarimeters tolerate nA beam currents which make beam position, angle, current, and spot size impossible to monitor simultaneously with polarization.

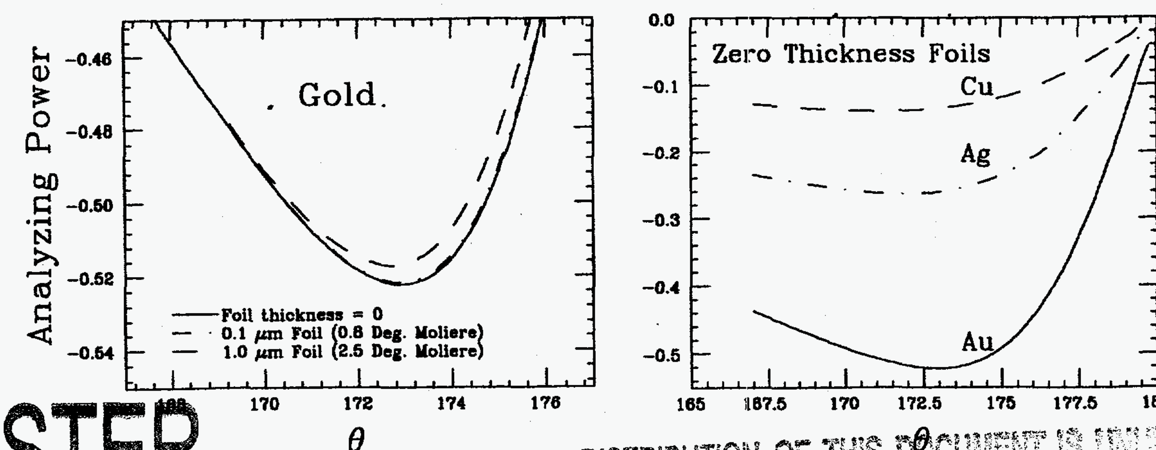




Figure 1. Calculated analyzing power for gold, copper and silver as a function of scattering angle at 5 MeV.

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There is little uncertainty in the calculated analyzing powers upon which the 5 MeV polarimeter design is based [2]. Figure 1 shows a calculation of Mott analyzing power for gold as a function of scattering angle at 5 MeV. The single-scattering analyzing power is a maximum (-0.52) at $\theta$=173° and is diluted 0.006 by multiple and plural scattering in a 1.0 $\mu$m thick foil. The small size of this effect makes calibration straightforward; foils of different Z (e.g. Cu and Ag) and identical Molière scattering distribution can be used to measure target foil analyzing power independent of beam polarization. The apparatus permits measurement of analyzing power over a modest range of scattering angles. Nuclear size effects at this energy are expected to be small. [3]

We have installed a prototype polarimeter in the 5 MeV section of the Jefferson Lab Injector. Figure 2 shows a side view drawing of the scattering chamber including placement of two of the four detectors at 173° to the beam line. This allows

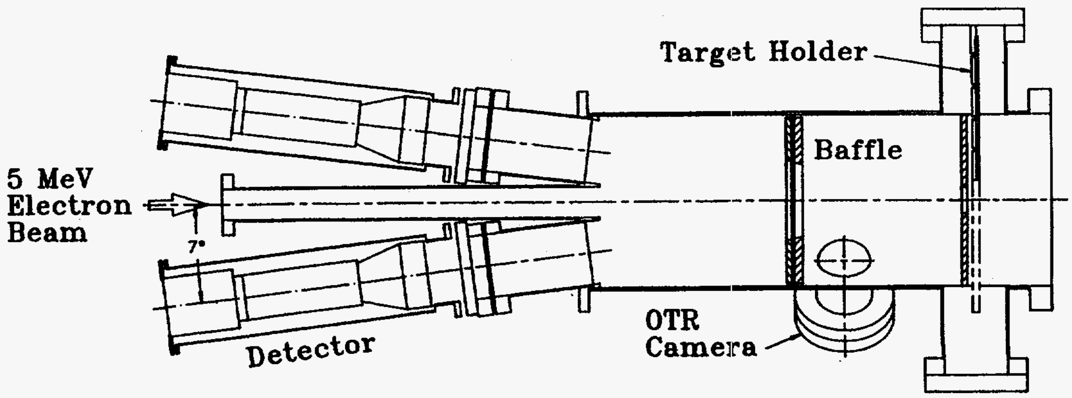


Figure 2. Prototype 5 MeV Mott polarimeter scattering chamber.

simultaneous measurement of the two components of polarization transverse to the beam momentum direction. The performance of the instrument as a polarimeter is directly related to the signal to noise. Recent efforts are aimed at reducing the number of inelastically scattered electrons from reaching the detectors. 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 the Al wall. Also, critical areas of the chamber are lined with high density polyethylene and detector apertures have been installed to further reduce the number of inelastics. Our measurements show that we see an unambiguous elastic peak, and that the above measures help suppress background; work continues on reducing background. The NE102a plastic scintillator detectors are equipped with slits cut in 12 mm thick Al; each slit subtends 1° in $\theta$ and 40° in $\phi$. Measurements with these 0.97 msr apertures scale to an expected 10 kHz signal rate from a 10 $\mu$A CW polarized beam on a 1 $\mu$m Au foil. Measurements with statistical uncertainty of order 1% can be made very 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; measurement of integrated charge can be measured 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 3). 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.

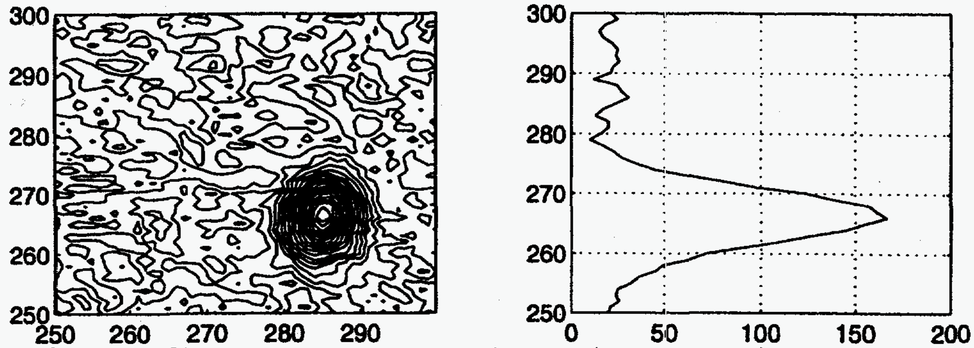


Figure 3. OTR profile and summed channels vs y (1 mm=8 ch) for 2.5 $\mu$A beam.

Typical pulse height spectra obtained with a multi-channel analyzer on signal pulses from the detector photo-multipliers are shown in Figure 4. The elastic peak integrated rate (background subtracted) scales linearly with beam current and foil thickness and agrees with calculated values for the expected rate.

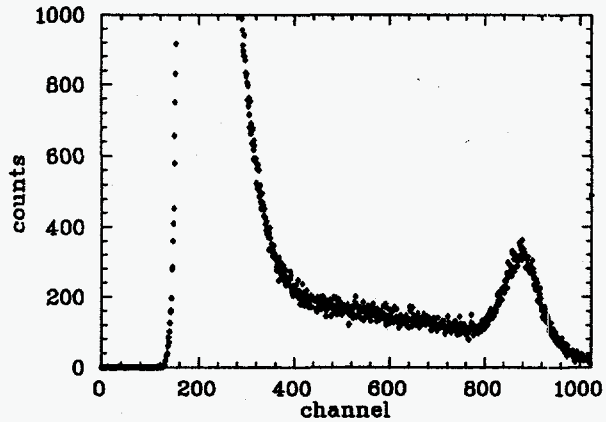


Figure 4. Typical PMT pulse height spectra for 1 $\mu$A beam on 0.1 $\mu$m Au foil.


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