A High Precision Mott Polarimeter at 5 MeV

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We report on the design and performance of a Mott polarimeter optimized for a nominal 5 MeV electron beam energy. Using beam with a 31.1875 MHz time structure from the electron injector of the 1497 MHz CEBAF accelerator, and incorporating time-of-flight in the electron detection, we can isolate those detected electrons that originate from the scattering foil. This background elimination results in exceptionally stable measured scattering asymmetries over a very broad range of beam conditions, beam currents, and foil thicknesses. In two separate measurements from two different photocathode electron sources, we have measured the scattering asymmetries produced by a ~ 86% transversely polarized electron beam incident on a range of gold foil thicknesses from 96 g/cm2 to 1.93 mg/cm2. The statistical uncertainty of each measurement is below 0.25%. We confirmed that within this statistical precision, the measured asymmetry was unaffected by +/- 2 mm shifts in the beam position on the target, and by beam current changes and deadtime effects over a wide range of beam currents. A detailed simulation of the complete polarimeter using GEANT4 has confirmed that double scattering in the target foil is the sole source of the measured asymmetry variation with foil thickness, and gives a result for the asymmetry versus foil thickness in excellent agreement with our measurements. Future measurements at different beam energies and with different Z foils will seek to bound uncertainties from small effects such as the nuclear size and radiative corrections. With a high precision measurement of the beam polarization using a different polarimeter, which is clearly possible at the CEBAF accelerator, simultaneous measurements with this polarimeter will allow a precision comparison with calculations of the Sherman function.

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Note: I have started writing on parts of this, and though I cannot write all of it on my own, I am very willing to be the “editor” to put together the final document from various contributions. Since I’m the only person without a day job, this may make some sense.

Content that must be included in the Mott polarimeter paper (not necessarily in correct order).

-1. Abstract (Sinclair)

1. Introduction (Sinclair)
2. The physical construction of the polarimeter (Sinclair, Grames)
   1. The scattering chamber, optimized for 5 MeV (i.e. 172.6o scattering angle)
   2. Internal collimation
   3. Target ladder and foils
   4. OTR viewport
   5. Beam dump, including long channel and dump magnet
   6. The detector packages (four ports)
   7. Shielding
   8. vacuum
3. Detector electronics, including TOF details (Sulieman)
4. The polarized source and injector (only basic descriptions, but including details relevant to polarization and its measurement) (Sinclair, Poelker)
   1. The gun, cathode, (including laser spot size at cathode and QE map?), and 130 kV operation (vs. original design at 100 kV?)
   2. Wien filters and solenoids
   3. The laser system, including details of 31.1875 (and 62.375) MHz operation and the IHWP
   4. Chopping, bunching, capture, and quarter cryomodule
   5. Beam monitoring and transport to polarimeter and spectrometer (including BPMs), and measured beam properties (emittance, E, dE, spot size at foil)
   6. Beam current measurements (F. cups, BCM)
5. Setup of polarization with Wien and solenoids, data collection, online analysis, and final offline analysis, including complete details of E counter spectra and TOF, event selection, etc. (Poelker, Sulieman, Moser)
6. Systematic studies (deadtime, PITA, IHWP, position change, sign of dump dipole, ultimate elimination of dump dipole, polarization stability measurements during run) (Sinclair, Grames)
7. Details of foils used and their thickness measurements by Lebow, FESEM, and singles rates (Stutzman, Mamun, Gay)
8. Experimental results – measured asymmetry versus measured foil thickness and hyperbolic fit to data (Moser)
9. GEANT4 model of the polarimeter and its performance, including generation of a fit to the data from first principles (McHugh)
10. Calculated Sherman function and its uncertainties, and comparison with model and experimental data (Roca-Maza, Sinclair)
11. Mention the spin dance and intercomparison of very different polarimeters (coupled with essentially zero polarization degradation in transport thru CEBAF) (Grames, Sinclair)
12. Summary and Conclusions (Grames, Sinclair, Gay)
13. Future plans (measurement with different Z foils, and at different energies, allowing some bounds to be placed on systematic uncertainties of the Sherman function calculations; precision polarimetry with a different polarimeter to allow extraction of the Sherman function from our results) (Sinclair, Poelker, Grames, Gay)