Jefferson Lab
Thomas Jefferson National Accelerator Facility

Calibration of a Mott Polarimeter

Valeria Ramírez Cruz
Carlos Hernández-García (Mentor)
R. Suleiman, J. Grames, P. Adderley, G. Palacios-Serrano

Thomas Jefferson National Accelerator Facility
Universidad Autónoma del Estado de Hidalgo

U.S. DEPARTMENT OF ENERGY | Office of Science

UAEH Universidad Autónoma del Estado de Hidalgo

01. Abstract

The Upgrade Injector Test Facility (UITF) at Jefferson Lab will employ a Mott polarimeter to measure the spin-polarization of a low energy (<200 keV) electron beam. A GaAs electron source provides longitudinally polarized electrons which are then rotated transversely by a Wien filter before scattering from thin (<100 nm) gold foils into a pair of detectors counting their rate. A scattering rate asymmetry calculated between the detectors is directly proportional to the spin polarization.

The purpose of this project is to calibrate the Mott polarimeter for each gold foil (called the effective Sherman function) to a well-known theoretical calculation when an electron scatters from an idealistic single gold atom.

02. Introduction to Mott scattering

When high energy electrons are scattered from a masive nucleus, the scattering cross-section gets modifed due to the spin-orbit interaction as follows:

$$\sigma(\theta) = \sigma_0(1 + \vec{P}\cdot\hat{n}S)$$

unpolarized cross-section (σ_0); polarization ($\vec{P}$); Sherman functions (S); $\hat{n} = \frac{\vec{k}\times\vec{k'}}{\|\vec{k}\times\vec{k'}\|}$

For both kinds of polarization (spin up or down), we could get:

$$\sigma_{dn}(\theta) = \sigma_0(1 - PS) \qquad \sigma_{up}(\theta) = \sigma_0(1 + PS)$$

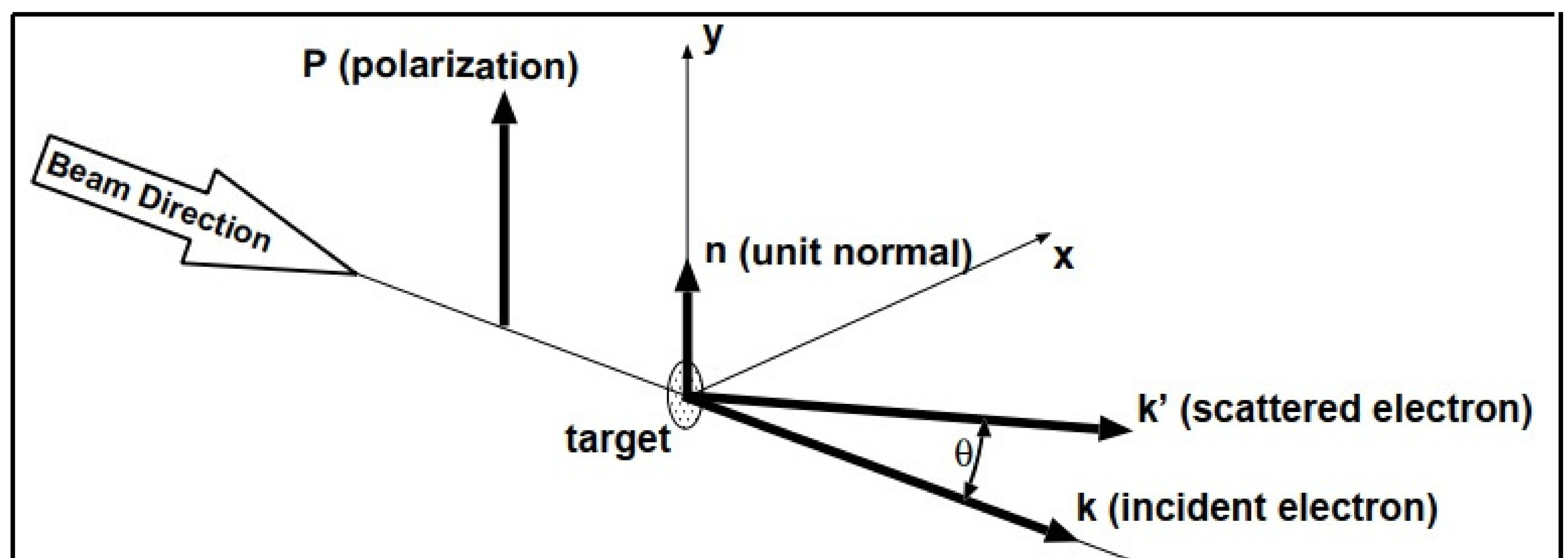

Fig 1. Diagram of the physics of Mott scattering

We can also measure the number of electrons scattered an angle θ to the right (N^r) or to the left (N^l)

$$N^r \propto (1+PS) \qquad N^l \propto (1-PS)$$

So it is possible to define the **asymmetry** as:

$$\epsilon = \frac{N^r - N^l}{N^r + N^l} \qquad \epsilon = PS$$

We can also calculte the asymmetry **considering the helicity**:

$$\epsilon = \frac{1-r}{1+r} \quad \text{with} \quad r = \sqrt{\frac{(N^l_+)(N^r_-)}{(N^l_-)(N^r_+)}}$$

In an experiment a target has a lot of atoms and its possible to measure the no. of electrons that hit the target in a certain time, this is called the **rate:**

$$R(\theta) = N/T = \sigma(\theta)L\rho(I/e^-)$$

beam current (I/e^-); thickness of the target (L); target density (ρ)

$\sigma(\theta)$ decreases → N decreases → ϵ gets reduced for targets with more atoms (thicker)

03. The experiment

The beamline

- Electron gun

Provides a polarized electron beam by shooting a photoemission GaAs cathode with a circulary polarized laser

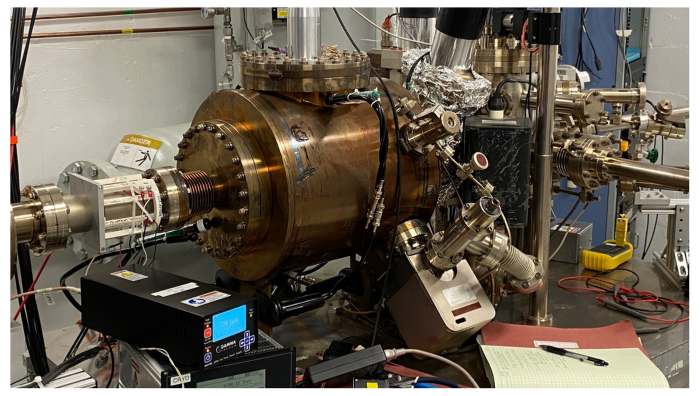

Fig 2. Electron gun

- Wien filter

It rotates the direction of the spin by using perpendicular electric and magnetic fields and this effect is governed by the BMT equation:

$$\theta = \frac{eL}{m_0 c\beta\gamma^2}B_x$$

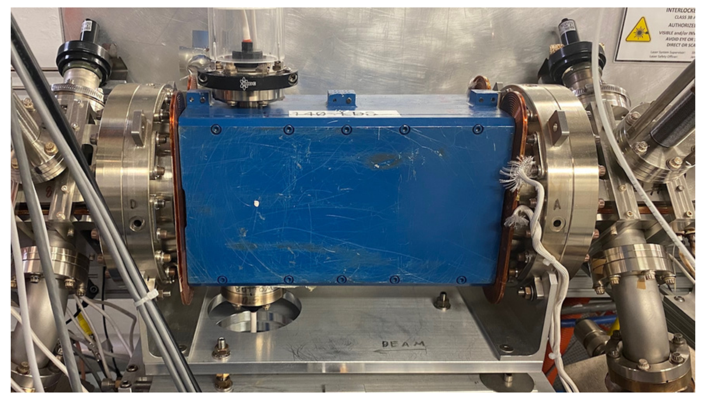

Fig 3. Wien filter after being mounted

The Mott polarimeter

Constists in the following elements

- Vacuum chamber
- Target ladder
- Detectors
- Beam dump

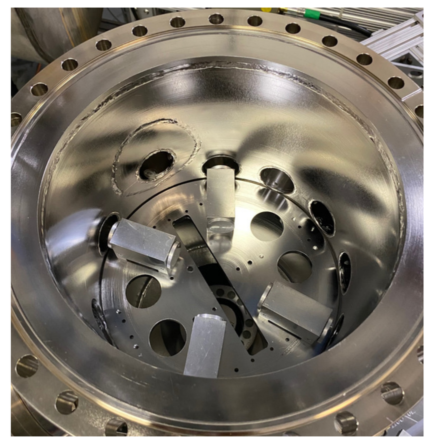

Fig 4. Vacuum chamber

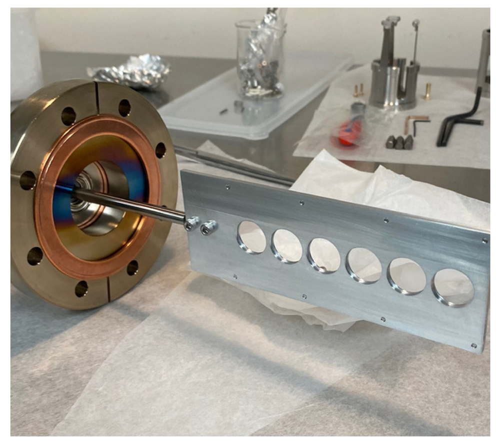

Fig 5. Target ladder

Fig 6. Gold foils

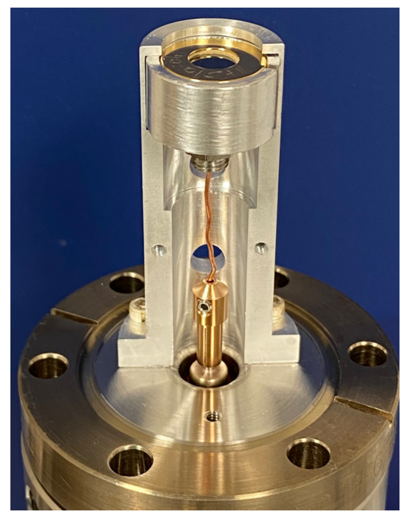

Fig 7. Detector

Fig 8. Beam dump

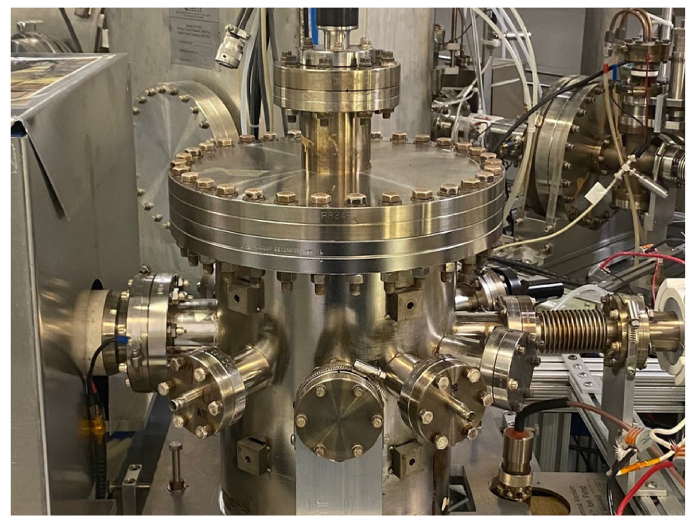

Fig 9. Mounted Mott polarimeter

04. Data Aquisition and results

By programming it is possible to filter and organize the data to select the electrons that will be used to calculate the asymmetry, once this is done the target thickness scan for the four golden foils is obtained.

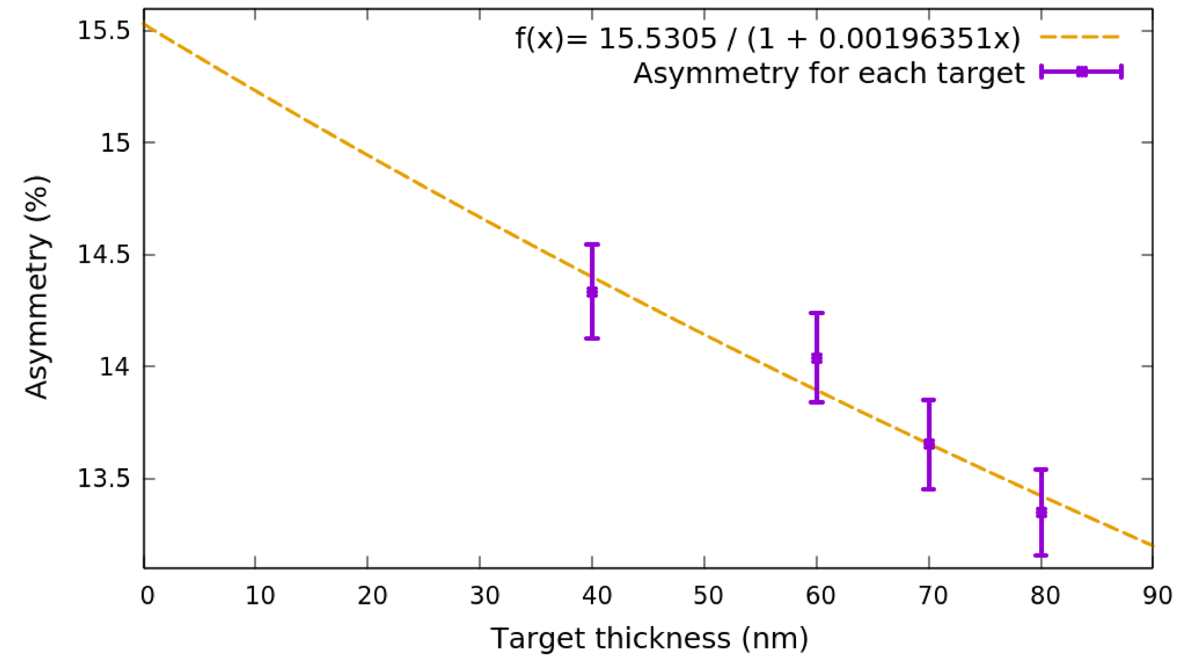

Fig 10. Target thickness scan (purple plot) with its correspondent fit (orange plot).

It can be seen that when the target thickness approaches zero the asymmetry will take a value of 15.5305 and with the Sherman functions for this beam energy (-0.426135) the polarization is obtained

$$P = 36.45\%$$

It is also interesting to notice how the asymmetry gets modified by varying the current applied to the solenoids with fields A and B. See Fig. 11.

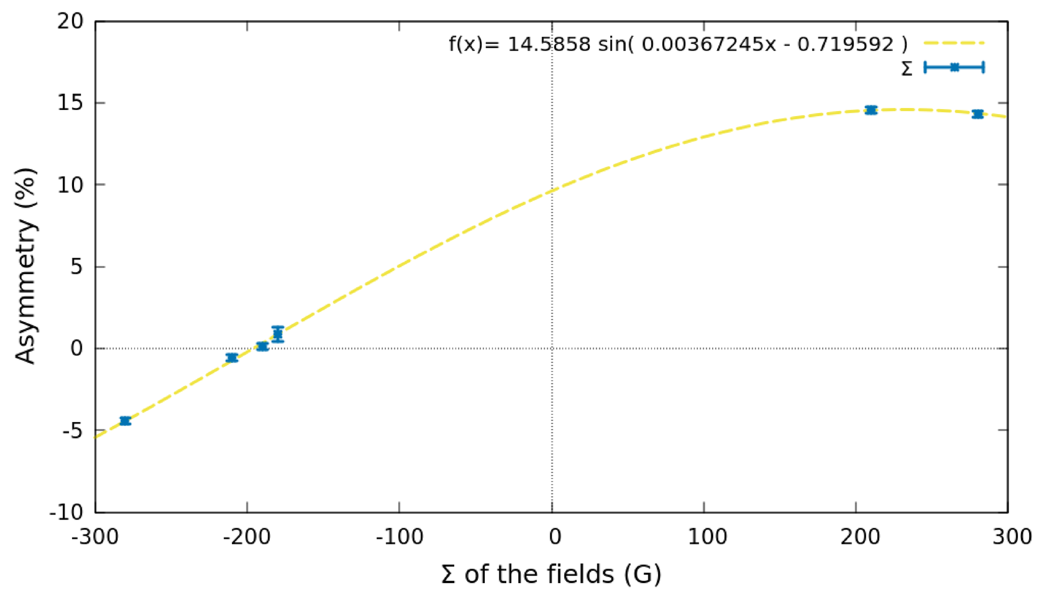

Fig 11. Change of asymmetry as the factor (A - B) of the fields in the solenoids change for the target foil of 40 nm thickness. The sinusoidal fit can be seen with the yellow dashed line

Finally, the voltage applied to the Wien filter was varied to see how the asymmetry changes. See Fig. 12.

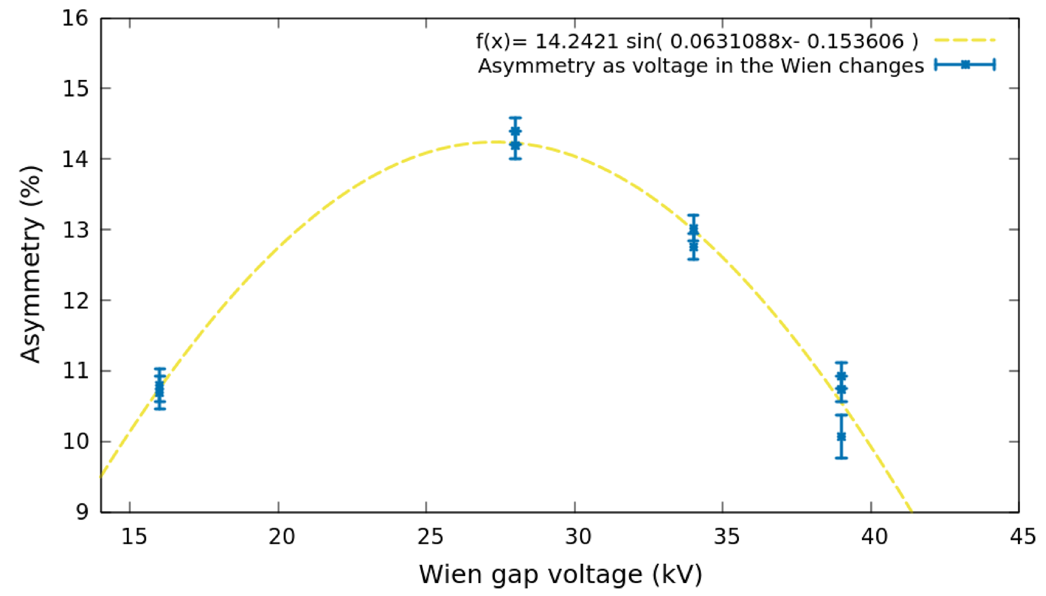

Fig 12. Change of asymmetry as the voltage applied to the Wien filter changes for the target foil of 40 nm thickness. The sinusoidal fit can be seen with the yellow dashed line.

05. Conclusions

- It is important to filter the data: which electrons will be used in the final measurement.
- Detectors measure more electrons of one type than another depending on their helicity.
- Thicker foils have smaller values of asymmetry, due to multiple scattering.
- The polarization has a value of ~ 36%, it is congruent with values normally found in the literature.
- The asymmetry changes when the solenoids current and voltage of the Wien filter is modified

Aknowledgments

Special thanks to Dr. Carlos Hernández García, as well as the injectors group, since I had the opportunity to learn from them.

I also thank the Mexican community of particle accelerators (CMAP) for making this experience fundamental in my academic development.