Jefferson Lab
Thomas Jefferson National Accelerator Facility

U.S. DEPARTMENT OF ENERGY | Office of Science

Calibration of a Mott Polarimeter

Mexican Physical Society PROGRAM

JSA

UAEH
Universidad Autónoma del Estado de Hidalgo

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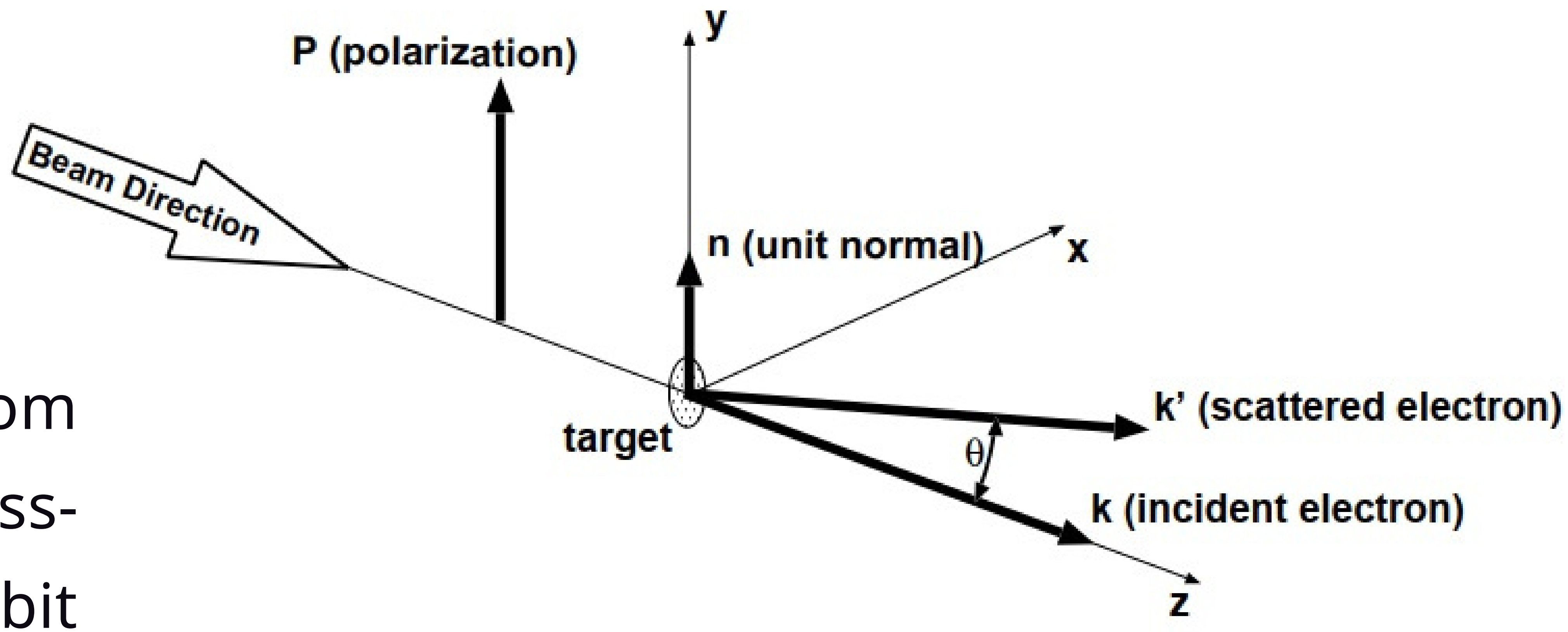
Introduction to Mott scattering



When energetic electrons are scattered from a massive nucleus, the scattering cross-section gets modified due to the spin-orbit interaction as follows:

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

unpolarized cross-section

polarization

$$\hat{n} = \frac{\vec{k}\times\vec{k'}}{\|\vec{k}\times\vec{k'}\|}$$

Sherman functions

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

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

We can measure the number of electrons scattered to the right or left

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

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

Asymmetry

$$\boxed{\epsilon = PS}$$

Considering flipping the polarization (**helicity)**

$$\boxed{\epsilon = \frac{1-r}{1+r}} \quad \text{with} \quad r = \sqrt{\frac{(N_+^l)(N_-^r)}{(N_-^l)(N_+^r)}}$$

The number of electrons that hit the target in a certain time, this is called the **rate:**

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

thickness of the target

beam current

target density

The target has lot of atoms instead of a single massive nucleus, this lead us to possible multiple scatterings, when this happens the value of the Sherman functions gets reduced

we have 1, 2 or more scatterings

ϵ gets reduced for targets with more atoms (thicker)

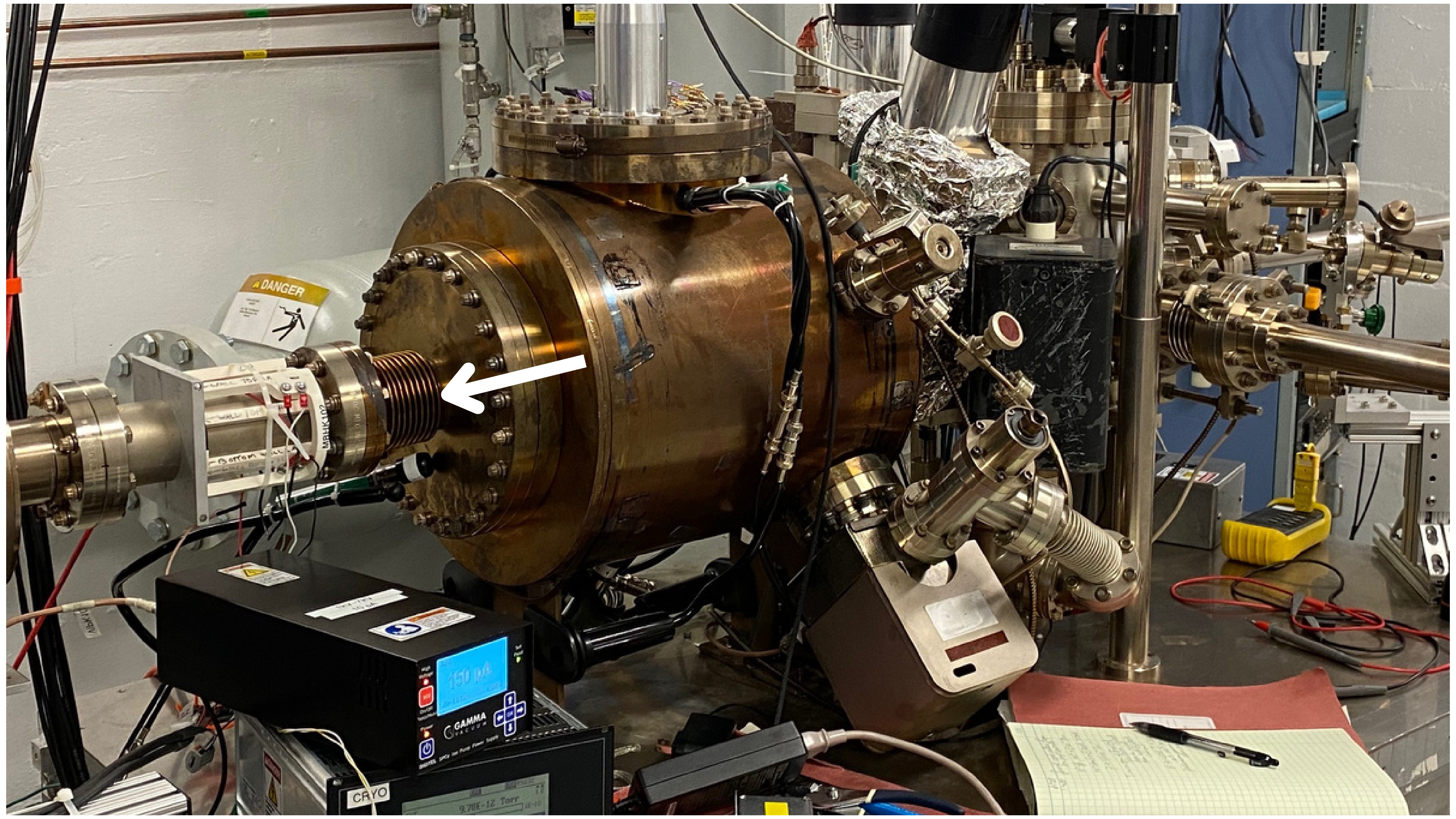
Objective

Calculate the polarization through the Sherman functions for this specific energy beam and through the asymmetries obtained from the experiment measuring the number of scattered electrons after having them hit gold foil targets of different thicknesses.

$$\boxed{\epsilon = PS}$$

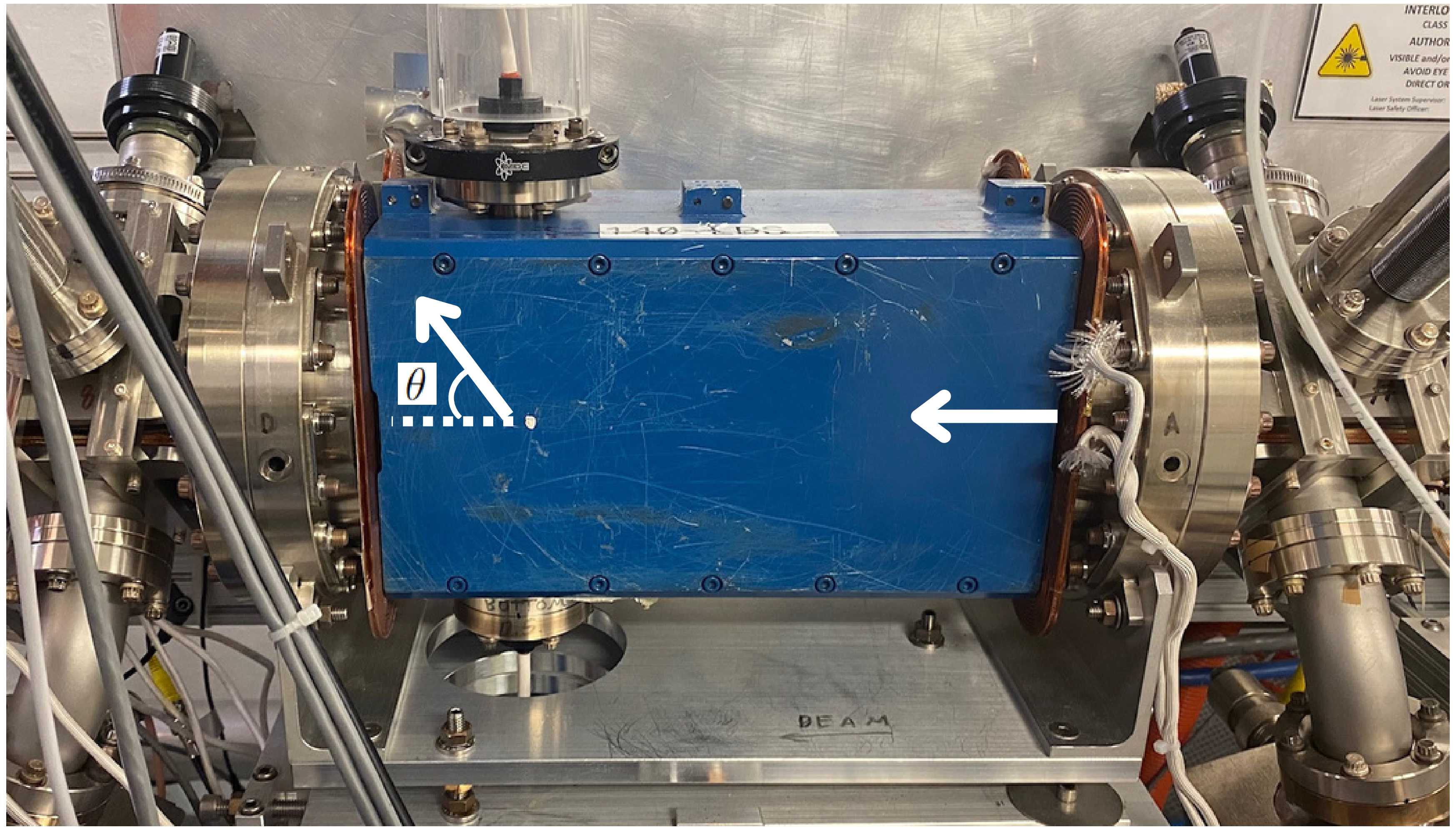
The experiment

Electron gun



Provides a polarized electron beam by illuminating a GaAs cathode with a circularly polarized laser and using high voltage to accelerate electrons to 180 keV

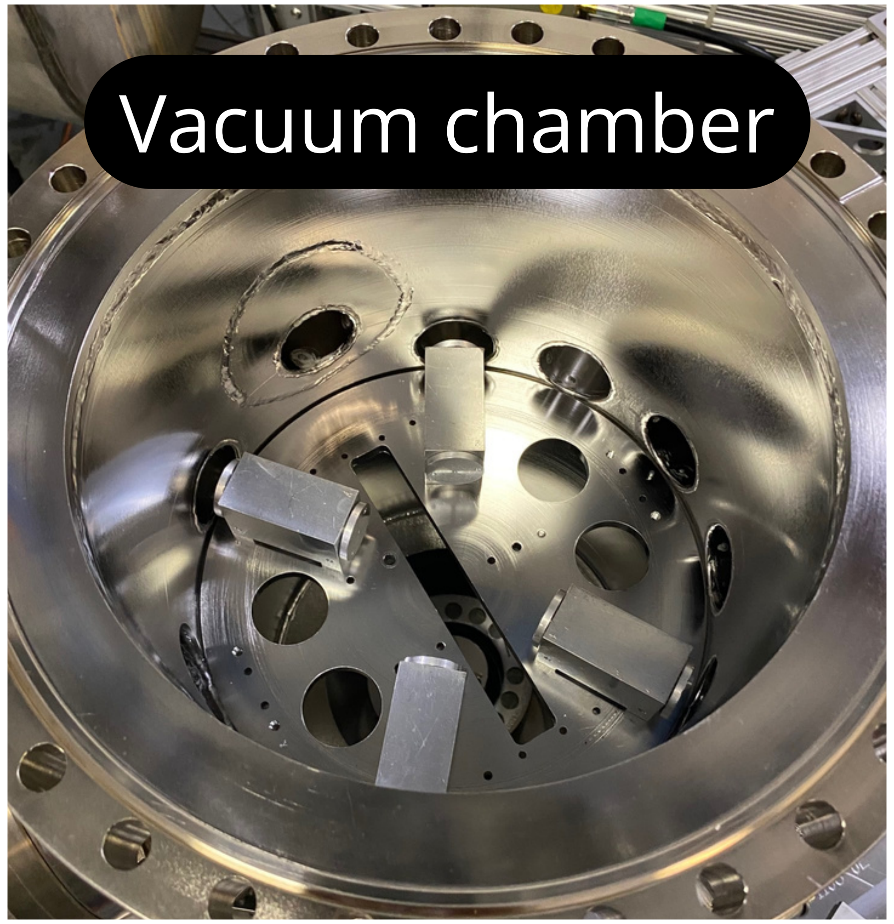
Wien Filter

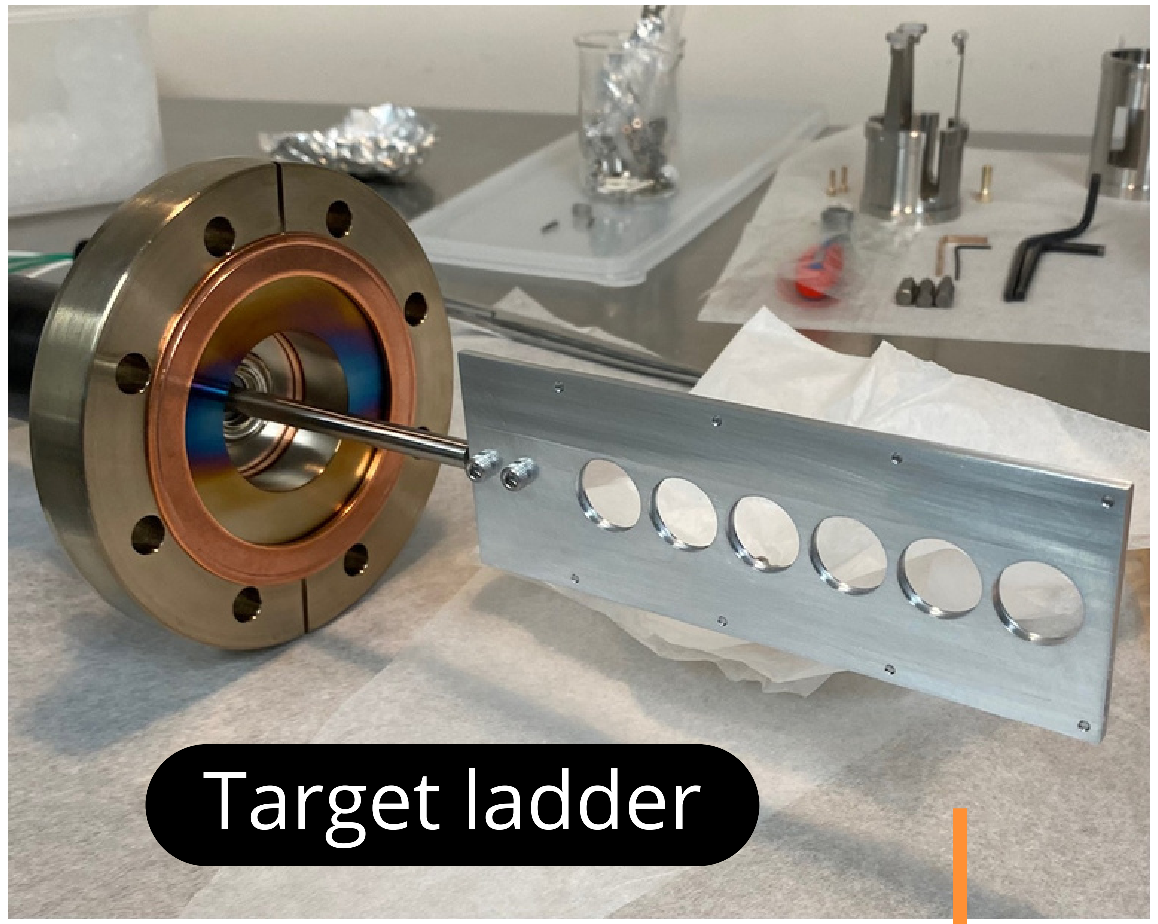


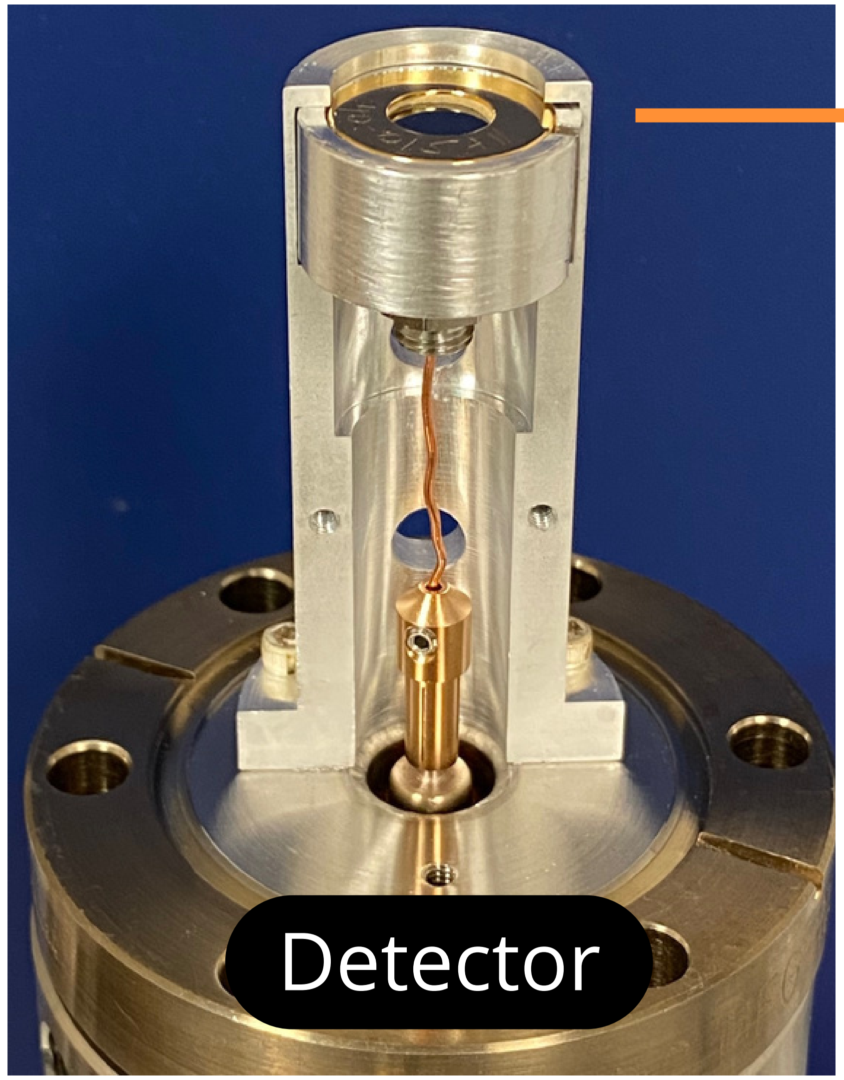
Rotates the direction of the spin by using perpendicular electric and magnetic fields. This effect is governed by the BMT equation:

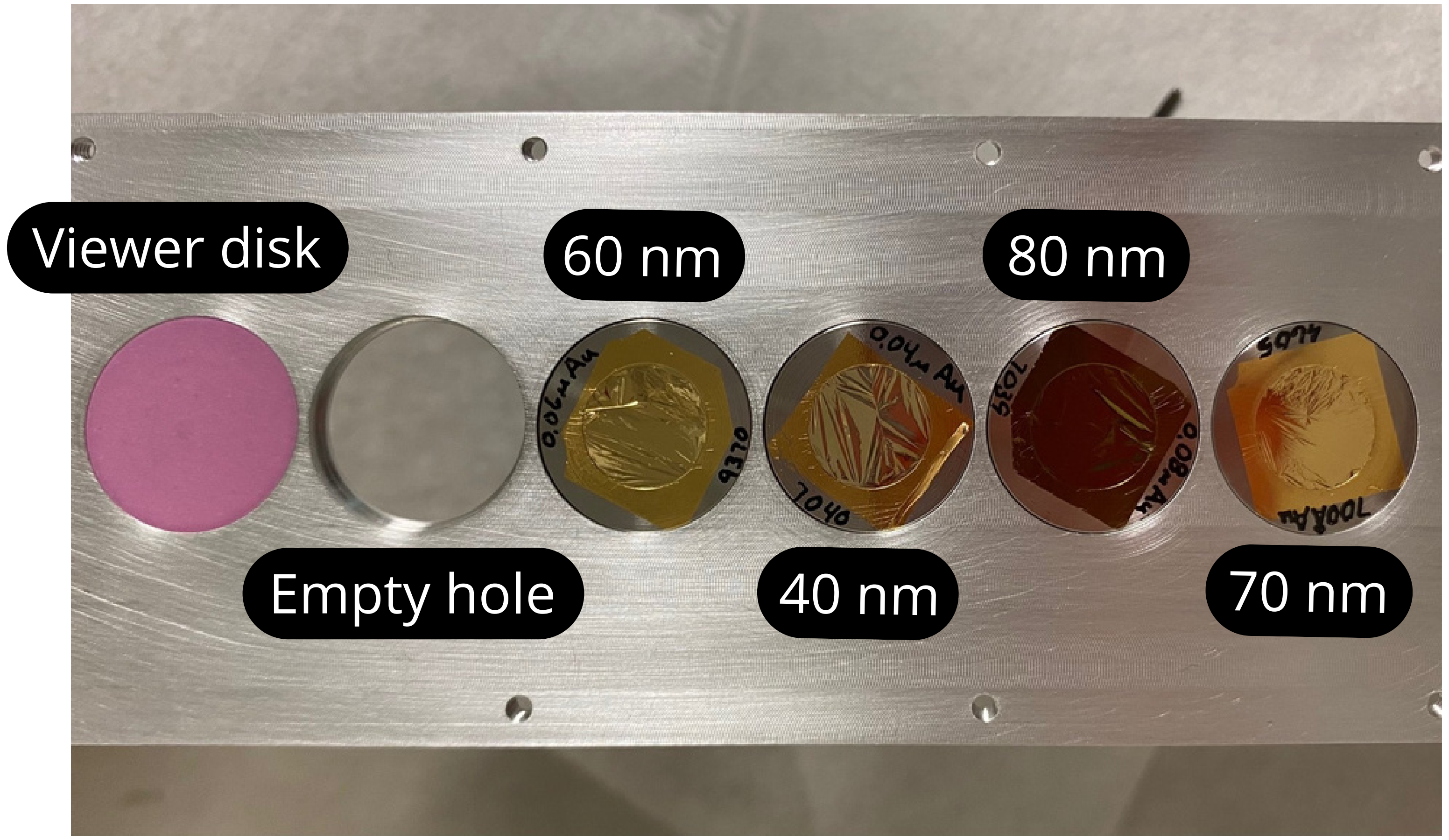
$$\frac{d\theta}{dt} = \frac{e}{m_0 c}\left[aB_x + \left(\frac{(1+a)\beta^2 - 1}{\beta}\right)E_y\right]$$

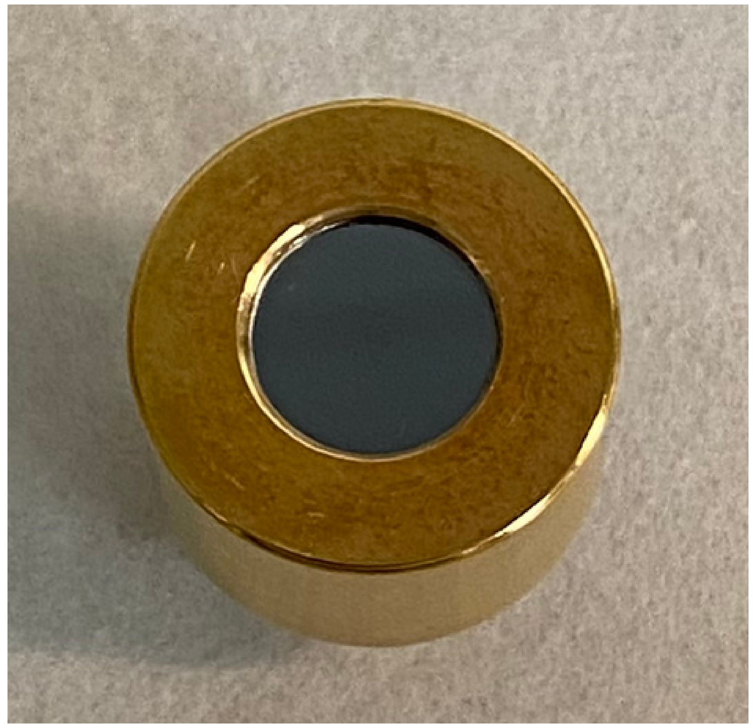
Mott polarimeter

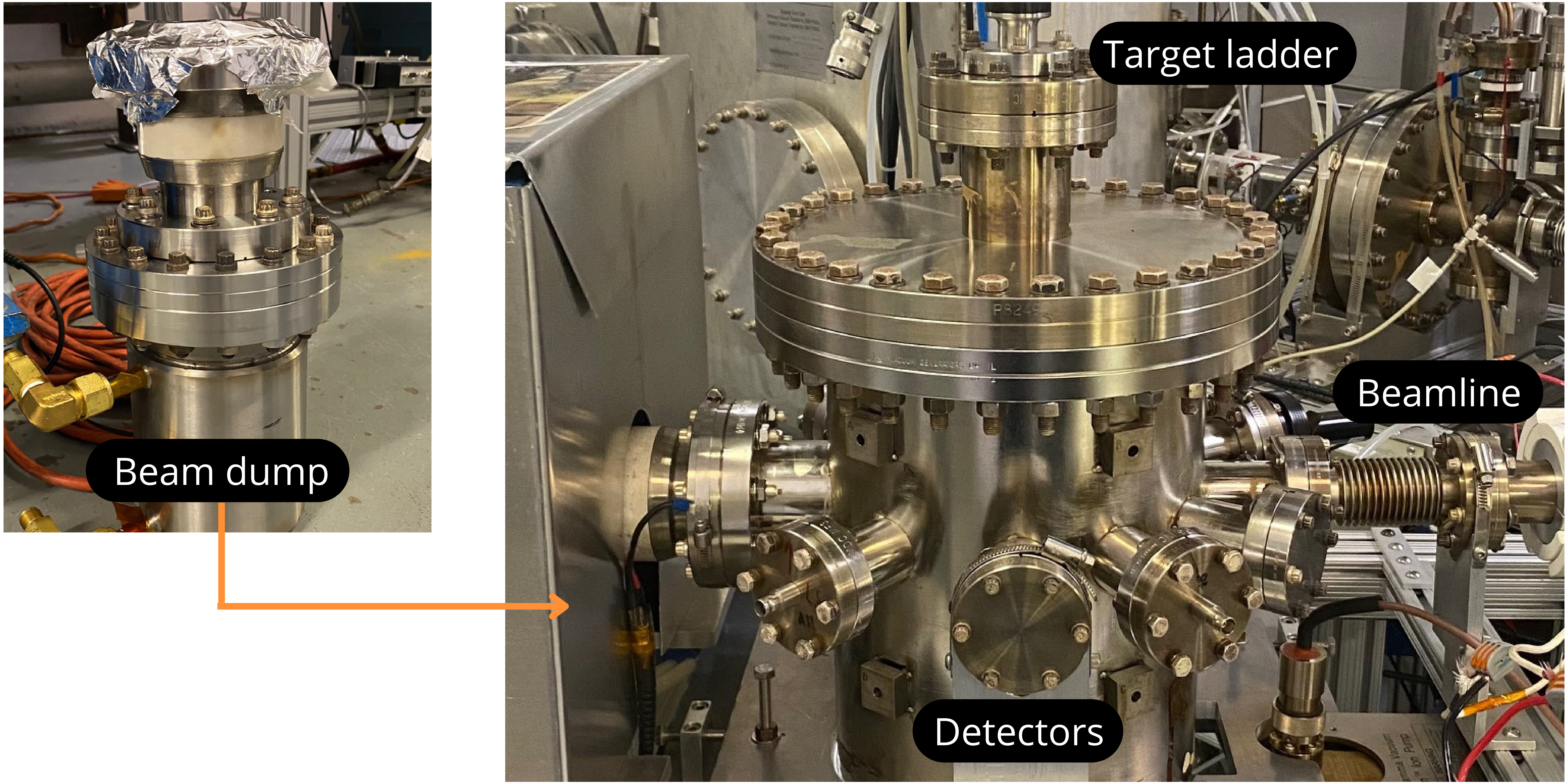











Beam dump
Target ladder
Beamline
Detectors

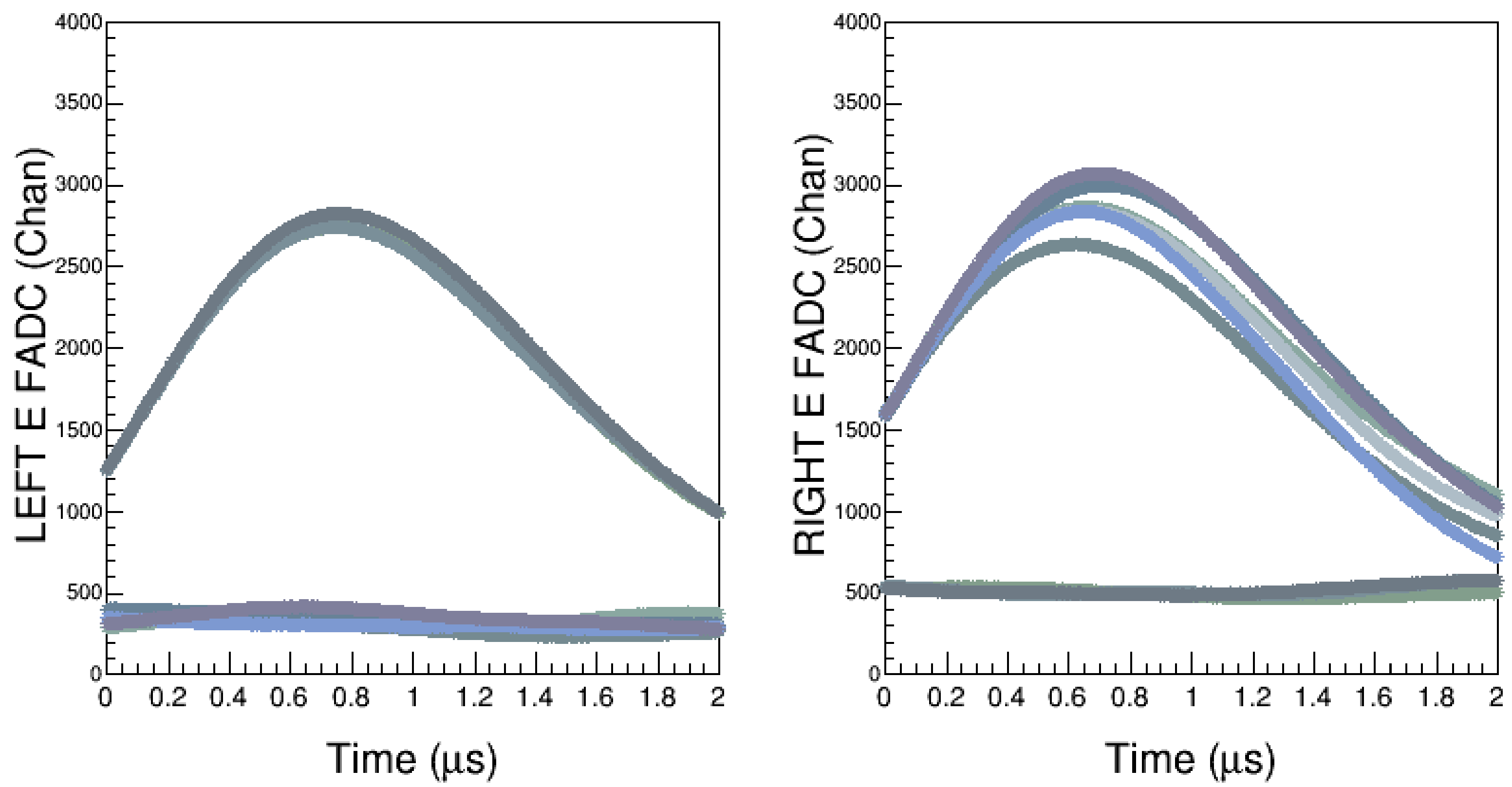
Data acquisition

The detectors measure 4 main things:

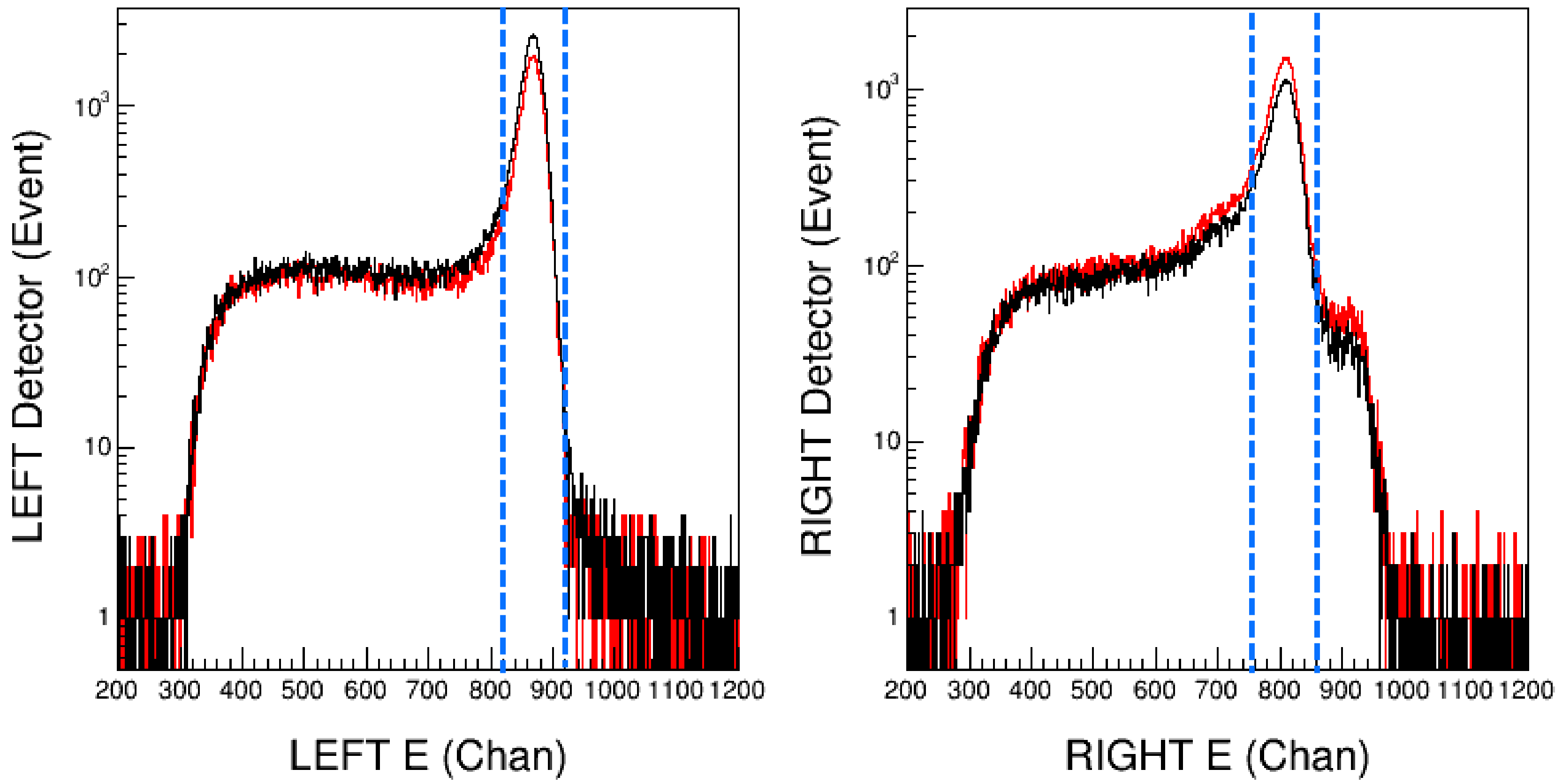
1. Value of the energy changing over time for the left and right detectors.
2. Logical sign: when to stop taking data.
3. Helicity: takes high and low values for 33 ms
4. T-Settle: shows the helicity transition (0.5 ms)

We will sum over the values of the energy to obtain **histograms** that organize the data.

energy
vs
no. of electrons



Energy of each electron over time for the target of 60 nm thickness.



Number of electrons with positive (red plot) and negative helicity (black plot) with a certain energy for the target of 60 nm thickness

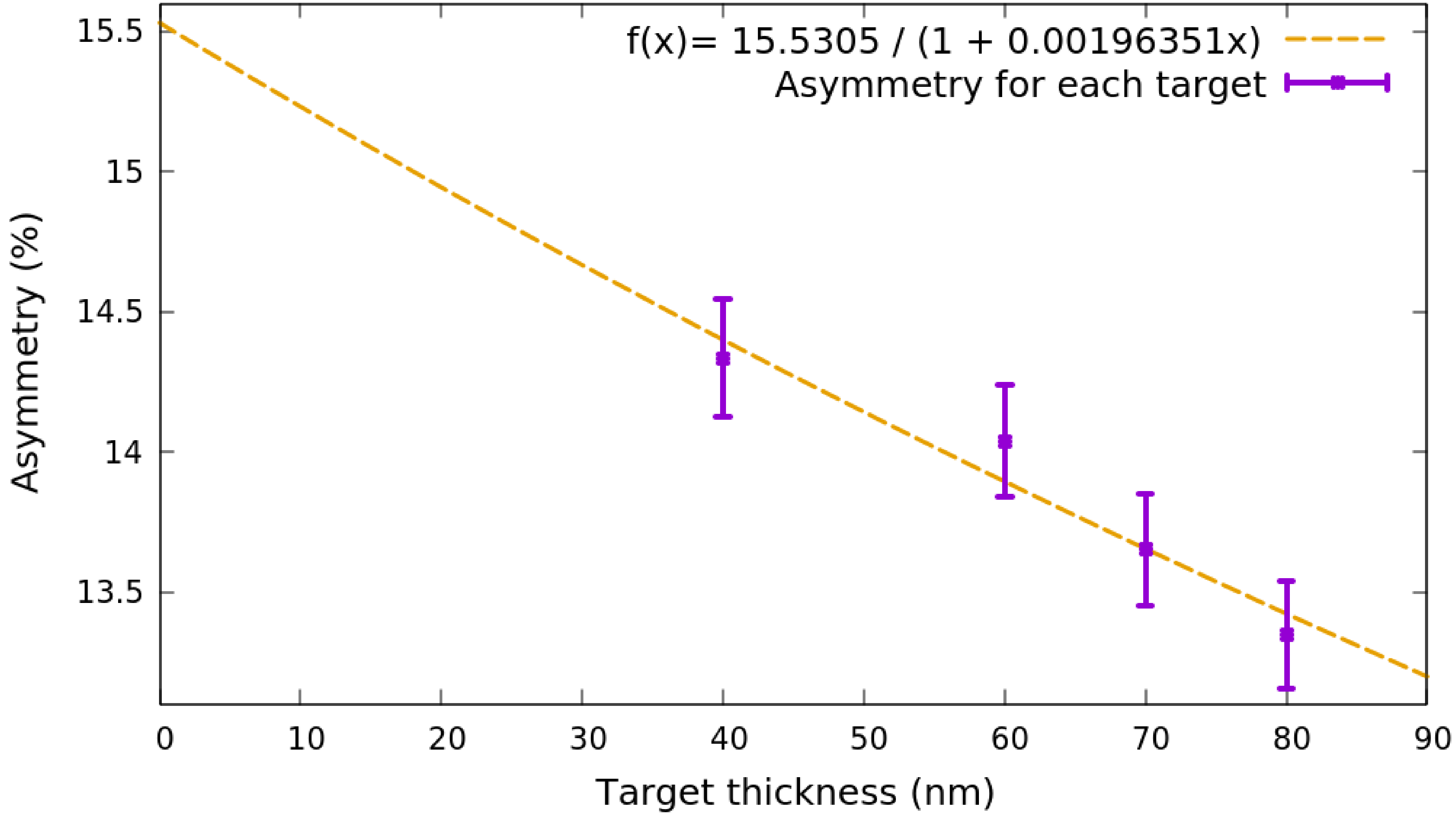
Measuring asymmetry and polarization

With the selected electrons for each one of the target foils a **target thickness scan** is obtained.

A fit of the following form is applied:

$$f(x) = \frac{a}{1 + bx}$$

$$a = 15.5305$$
$$b = 0.00196351$$



$$\boxed{\epsilon_0 = P S_0}$$

$$S_0 = -0.4261$$

$$\boxed{P = \frac{a}{S_0} = 36.45\%}$$

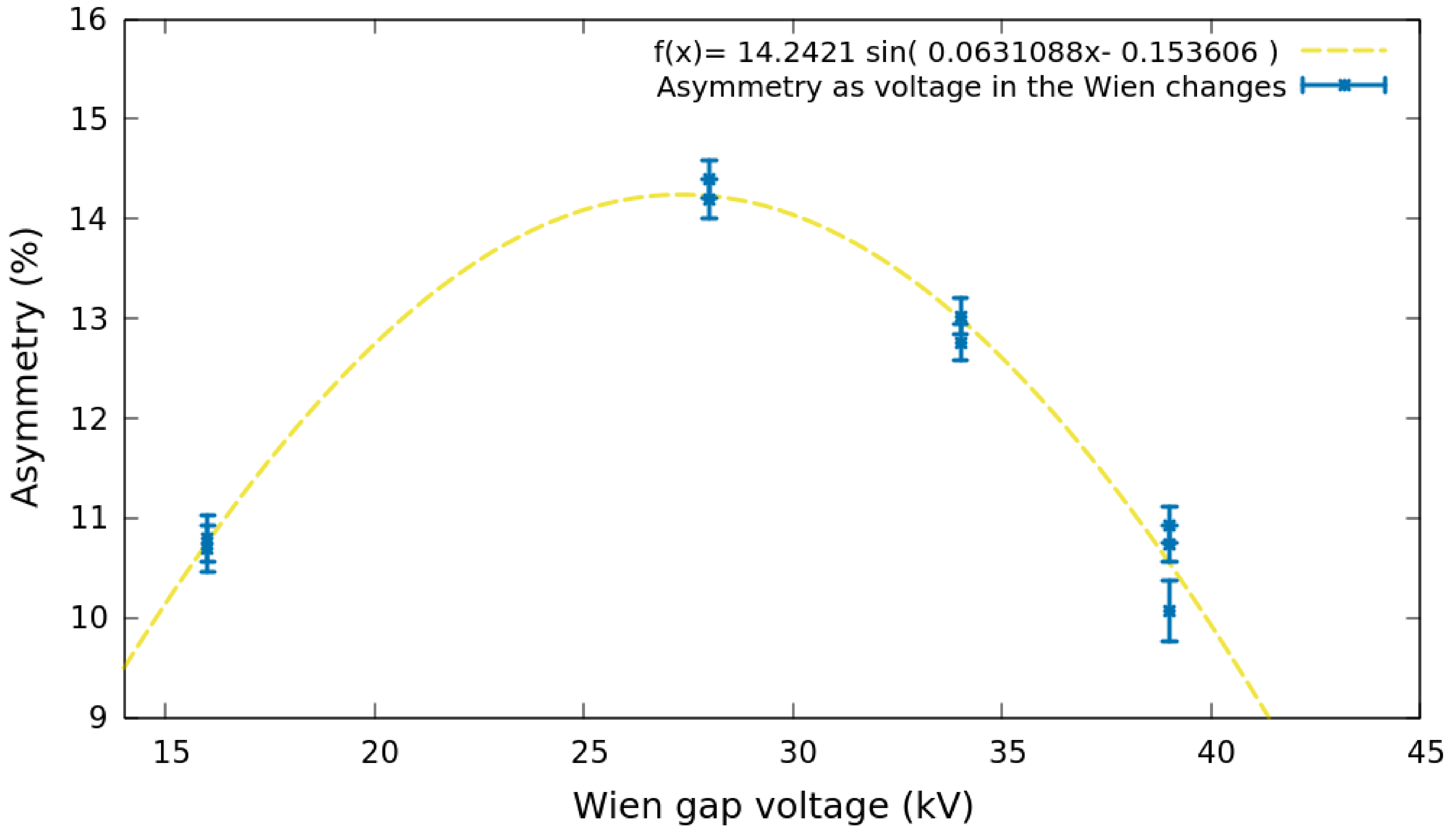
Asymmetry and voltage applied to the Wien filter

The figure shows how the asymmetry factor gets modified as the voltage applied to the Wien filter increase in a target foil of 40 nm

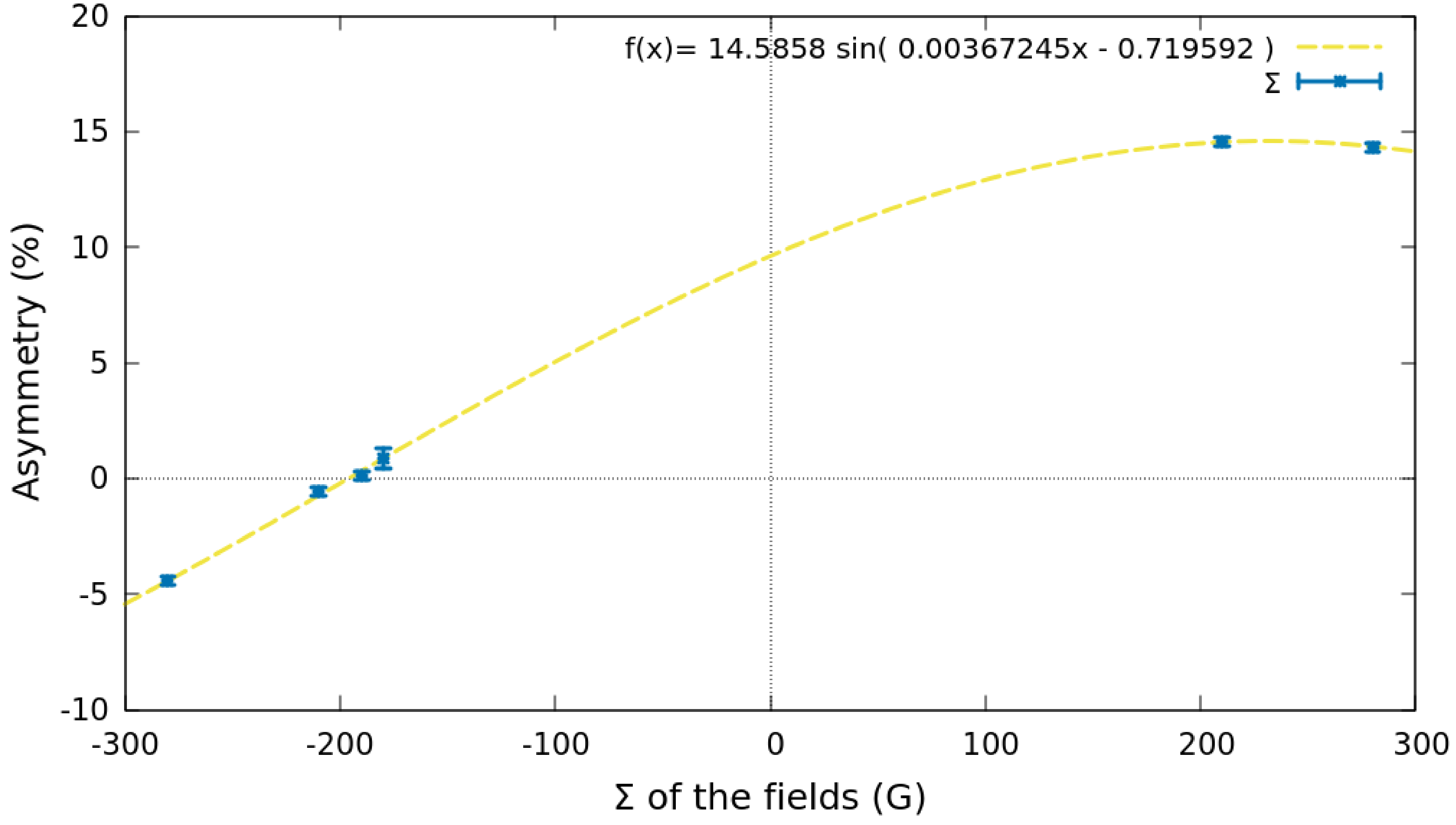
A sinusoidal fit was performed as the yellow dashed line shows:

$$f(x) = a\sin(bx + c)$$

$$a = 14.2421$$
$$b = 0.0631088$$
$$c = -0.153606$$



Asymmetry and current applied to the solenoids



The beamline contains two solenoids with fields A and B for focusing and directing the electron beam.

We can observe how the asymmetry changes as the factor (A + B) changes for the target foil of 40 nm.

A sinusoidal fit was performed as the yellow dashed line shows:

$$f(x) = a \sin(bx + c) \quad \begin{cases} a = 14.5858 \\ b = 0.00367245 \\ c = -0.719592 \end{cases}$$

Conclusions

It is important to select the data, to know which electrons will be used in the final measurement.

The detectors will find more scattered electrons of one type than another depending on their helicity

Thicker foils have smaller values of asymmetry, the electrons get scattered multiple times.

The polarization has a value of $\sim$ 36%, which is congruent with the values normally found in the literature.

The asymmetry changes when the solenoids current and the voltage of the Wien filter is modified.