Design of a precise 5 MeV Mott polarimeter operating at high average current

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Outline

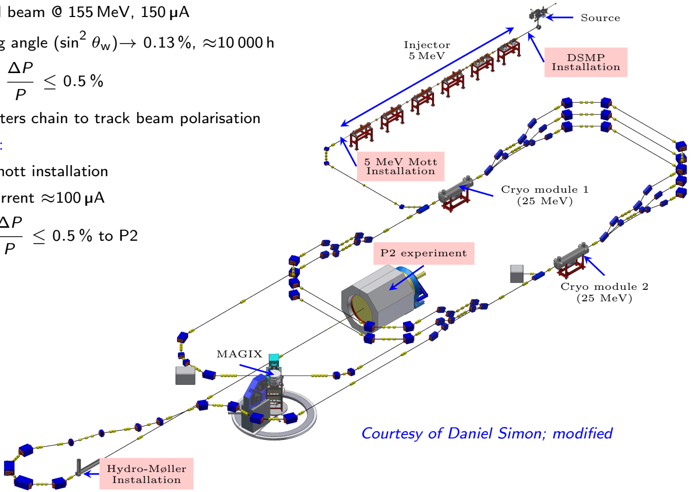
Introduction and motivation

P2 experiment:

- Polarised beam @ 155 MeV, 150 μA
- Weinberg angle ($\sin^2 \theta_w$) → 0.13 %, ≈10 000 h
- Requires $\frac{\Delta P}{P} \leq 0.5\,\%$
- Polarimeters chain to track beam polarisation

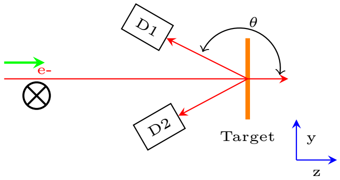
Project objective:

- 5 MeV mott installation
- Beam current ≈100 μA
- Deliver $\frac{\Delta P}{P} \leq 0.5\,\%$ to P2



Courtesy of Daniel Simon; modified

Essential theory

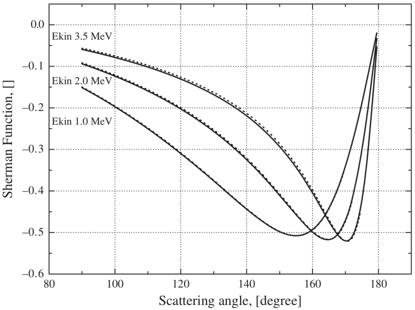


- Mott scattering for spin-polarization analysis
- Sherman function→ analyzing power of the target(Au)
  1. scattering angle(θ)
  2. beam energy(E)
  3. nuclear charge(Z)

- Experimental asymmetry

$$A_{exp} = \frac{R\uparrow - R\downarrow}{R\uparrow + R\downarrow} \qquad (1)$$

where, $R\uparrow$ and $R\downarrow$ are count rates for spin up and down



Tioukine et al., 2011

Essential theory

Three main factors that determine accuracy are:

1. accurate measurement of the asymmetry
2. determination of theoretical Sherman function for the single elastic scattering process
3. asymmetry extrapolation to zero target thickness

Steigerwald, 2001

Study of existing polarimeters

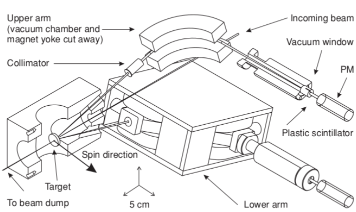


Figure 1: MAMI 3.5 MeV Mott polarimeter *Tioukine et al., 2011*

- Spectrometers for energy selection and background reduction.
- Backscattering angle 164°
- Beam current 1 nA-30 µA
- Uncertainity ≤1 %

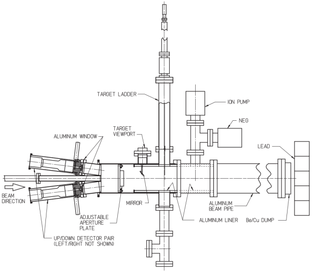


Figure 2: JLAB 5 MeV Mott polarimeter *Grames et al., 2020*

- Events associated with the beam dump are removed.
- Backscattering angle 172.6°
- Beam current 0.245 µA-4.3 µA
- Uncertainity ≤0.61 %

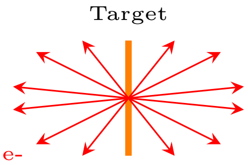
Energy spectra

- Simulations are done using BDSIM[1]. (EM_SS Physics list)
- Isotropic beam generation from target with corresponding normalised weight
- Weight from theoretical Mott scattering cross-section of unpolarised beam

$$I(\theta) = \left(\frac{Ze^2}{2mc^2}\right)^2 \frac{(1-\beta^2)(1-\beta^2 sin^2(\frac{\theta}{2}))}{\beta^4 sin^4(\frac{\theta}{2})} \tag{2}$$

Aulenbacher et al., 2018

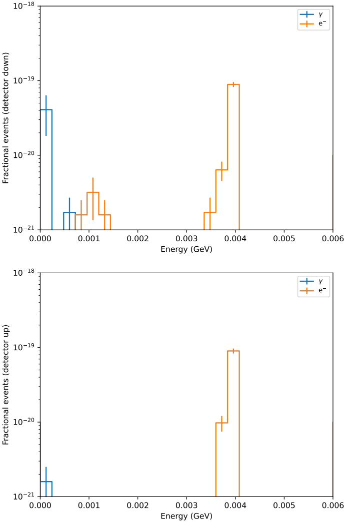
$$xp = sin(\phi)cos(\theta)$$
$$yp = sin(\phi)sin(\theta)$$
$$zp = cos(\phi)$$
$$\theta \rightarrow [0, \pi]$$
$$\phi \rightarrow [0, 2\pi]$$



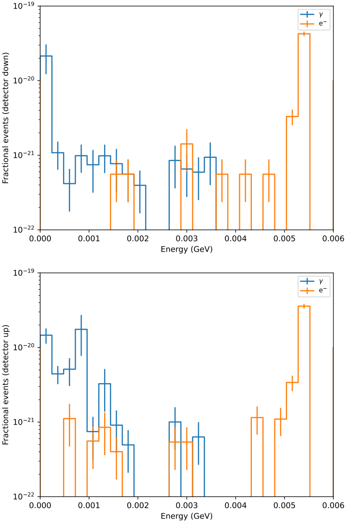
[1] L.J. Nevay et al., BDSIM: An Accelerator Tracking Code with Particle-Matter Interactions, Computer Physics Communications 252 107200 (2020).

Energy spectra

MAMI 3.5 MeV Mott



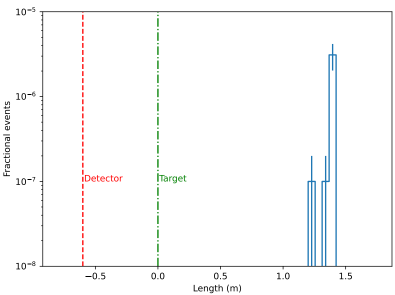
JLab 5 MeV Mott



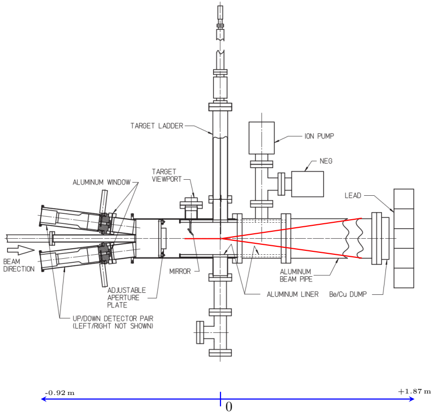
Primaries = 4 942 368

Interactions: Coulomb scattering, Bremsstrahlung, Electron ionisation

Longest photon trajectory



Primaries $= 1 \times 10^7$

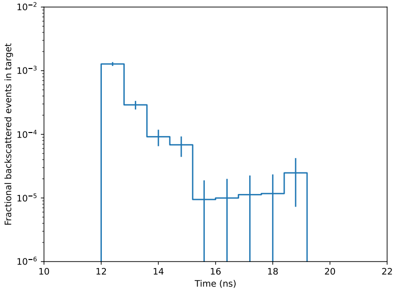


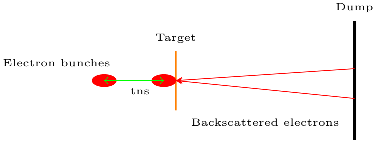
Reference beam ("Pencil beam")

Grames et al., 2020, adapted

Extension tube inner diameter ≈99 mm
Target thickness= 100 nm
Simulated geometry dimensions taken from `https://github.com/JLabMottGroup/MottG4`

Backscattered events from dump





Primaries $= 1 \times 10^6$

- Reference beam ("Pencil beam")
- Electron bunches repetation at target before/after backscattered events

Outlook and summary

Outlook

- Control of background to below 1 %
- Implement 5 MeV mott and set up appropriate detector system
- Calibration of polarimeter

Summary

- Mott scattering experiment to analyze polarization
- Experiment requires $\frac{\Delta P}{P} \leq 0.5\,\%$
- Geometry induced background study

Design parameters

- Kinetic energy 5 MeV
- Backscattering angle 173°
- Beam current $\approx$ 100 μA
- Cross-section $6.822 \times 10^{-26}\,\mathrm{cm}^2\,\mathrm{sr}^{-1}$
- Solid angle 0.23 msr
- FOM $\approx 5 \times 10^{-12}$ (for t = 100 nm)
- $t_{meas} = 22\,\mathrm{s}$ (for t = 100 nm)

First sample design to be simulated