Status of the 5 MeV Mott polarimeter at MESA

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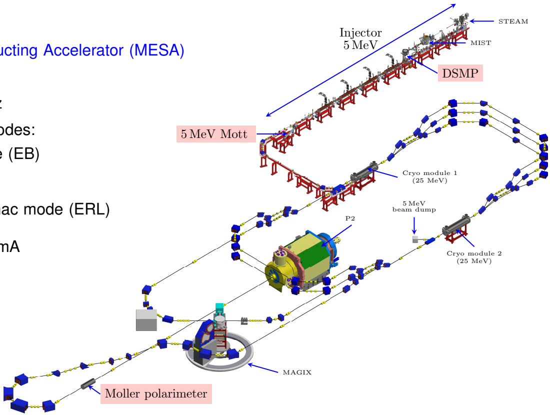
Outline

Introduction and motivation

Mainz Energy-recovering Superconducting Accelerator (MESA)

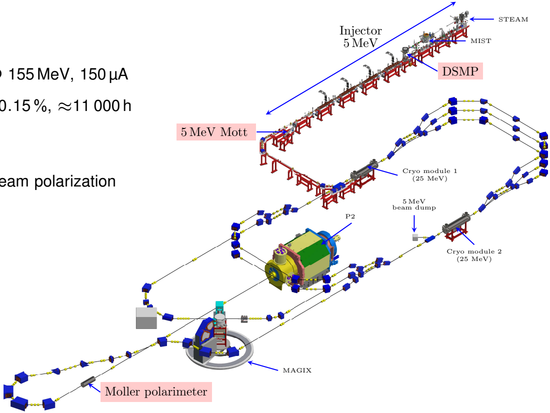
- CW electron accelerator
- Operation frequency 1.3 GHz
- Planned to operate in two modes:
  - External Beam mode (EB)
    Polarized beam
    155 MeV, 150 µA
  - Energy Recovery Linac mode (ERL)
    Unpolarized beam
    105 MeV, Stage I: 1 mA
    Stage II: 10 mA



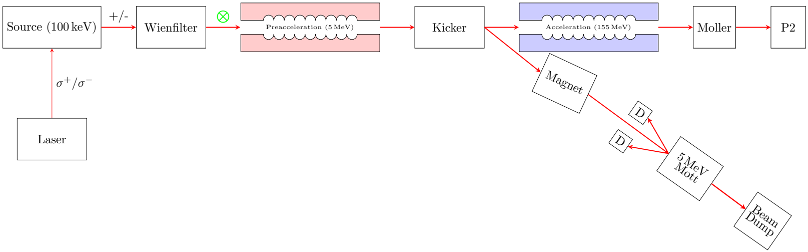
Introduction and motivation

P2 experiment:

- Polarised beam P $> 85\,\%$ @ 155 MeV, 150 µA
- Weinberg angle $(\sin^2\theta_W) \rightarrow 0.15\,\%$, $\approx$11 000 h
- Requires $\frac{\Delta P}{P} \leq 1\,\%$
- Polarimeters chain to track beam polarization



Overview of planned spin analyzing process



- Right/left circulary polarized light produces positive/negative helicity electron beam.
- Longitudinal spin is rotated into transverse plane and pre-accelerated to 5 MeV.
- Kicker offers possibility to operate on 100 %, 99 % and 1 % duty factor.
- This further opens possibility of operating Mott and Moller simultaneously.

Mott scattering

Mott cross section

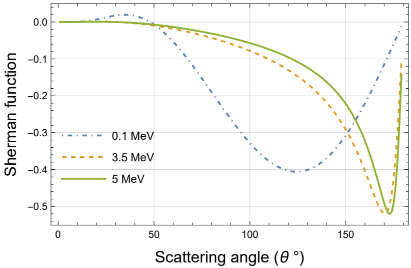
$$\sigma(\theta) = I(\theta)[1 + S(\theta)\vec{P} \cdot \hat{n}]$$

$S(\theta)$ = Sherman function/analysing power
$I(\theta)$ = unpolarised cross-section

- Asymmetric elastic scattering of spin polarised electrons in coulomb field

Theoretical corrections to Sherman function:

- Screening by atomic electrons
- Finite size correction
- Radiative corrections



Sherman function calculation for point nucleus of Au.

Sherman function values will be taken from the existing precise theoretical calculations published.

Mott polarimetry

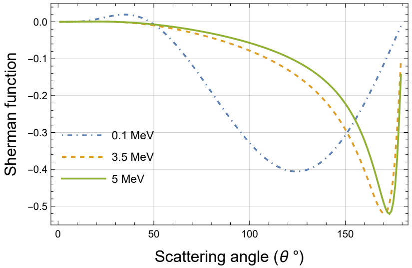
- keV Mott polarimeters are commonly used for source optimisation.
- Two existing Mott polarimeters operating at 3.5 MeV MAMI and 5 MeV JLAB
- Existing MeV mott polarimeters can be used for precision polarization measurements.

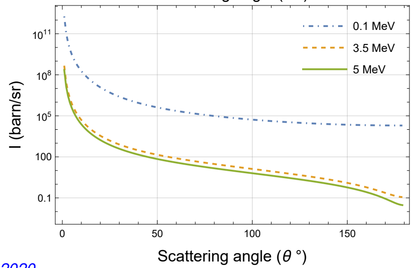
MeV energy mott benefits

- Larger analysing power
- Smaller cross section
- Free standing target

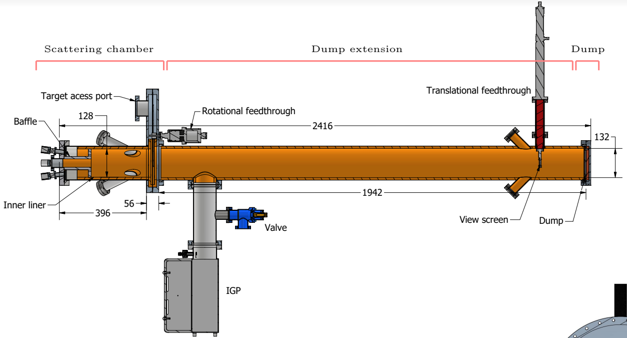
Contribution to the total uncertainty	Value
Theoretical Sherman function	0.50%
Target thickness extrapolation	0.25%
Systematic uncertainties	0.24%
Energy cut (0.10%)	
Laser polarization (0.10%)	
Scattering angle and beam energy (0.20%)	
Total	0.61%

Uncertainity budget of JLab 5 MeV polarimeter. *J. Grames et al., 2020*

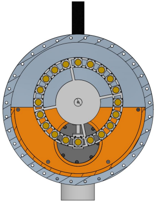




Design of the 5 MeV polarimeter set-up

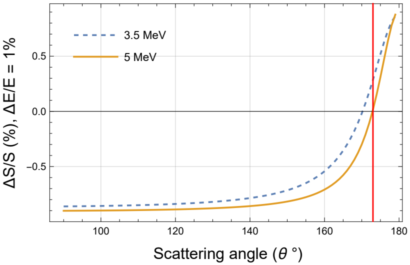


- Design was done based on understanding developed via computer simulation and the existing work.
- Beryllium disc to minimize the electron backscattering from the dump.
- Aluminium liner and aluminium dump extension pipe to reduce the backscattering.
- Baffle for the collimation of solid angle.
- Can hold 20 targets .
- View screens for beam alignment.
- View ports for targets and view screen alignment.

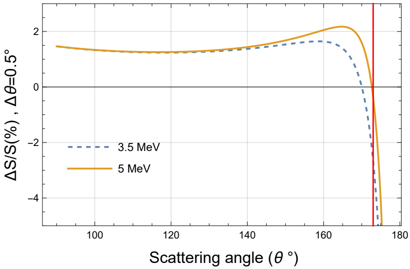


Section view of target system.

Set-up accuracy



Sensitivity of Sherman function to energy.



Sensitivity of Sherman function to angle.

- For E = 5 MeV and $\Delta E/E = 1\,\%$, sherman function changes by 0.02 % at maximum.
- Energy spread can be measured using Dipole magnet.

- At 172.5° Sherman function changes by 0.25 %
- At 173.5° Sherman function changes by 1 %

Statistical accuracy

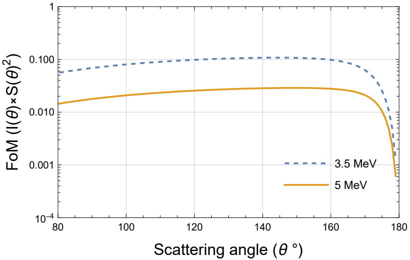
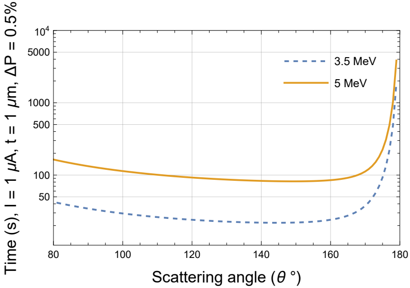


Figure of Merit (FoM) for corresponding angles.

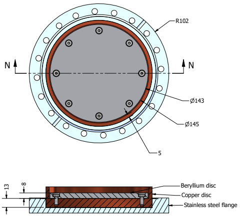


Measurement time required for corresponding angles.

- Statistical efficiency of a polarimeter is defined as FoM.
- FoM is larger for lower energy but can be adapted for beam currents that will be used for 5 MeV Mott.

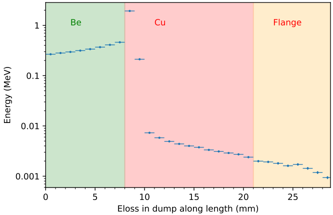
- Since FoM is larger for lower energy, therefore time required for the measurement is larger for higher energy.
- This can be adapted for the beam currents that will be used as well.

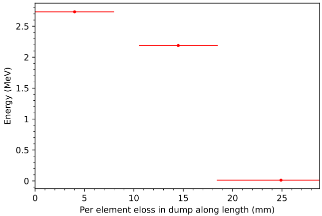
Design of beam dump



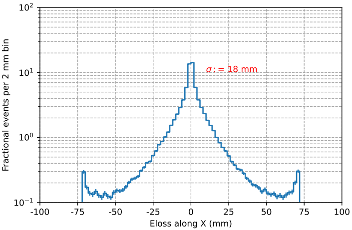
Design of the beam dump. Dimensions are in mm.

- Bdsim simulation with uniform beam of 5 MeV KE.
- 8 mm Be and 13 mm Cu for optimal background reduction.
- Stainless steel vacuum blind flange for vacuum sealing.



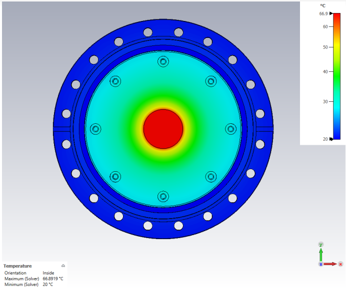


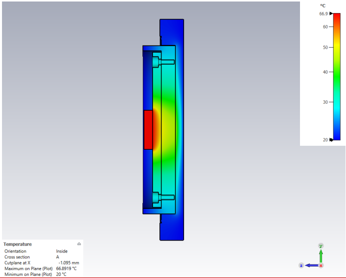
CST thermal simulation of Dump



Bdsim simulation for Eloss along X.

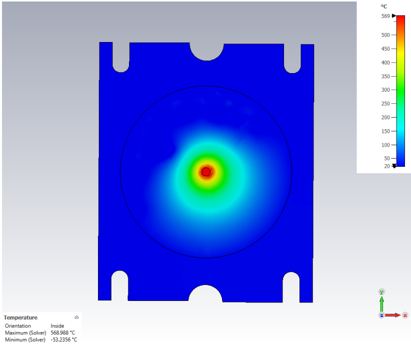
- Simulation of beam through a 100 nm target into the dump
- CST thermal simulation
- 36 mm diameter, 750 W uniform source
- Background vacuum



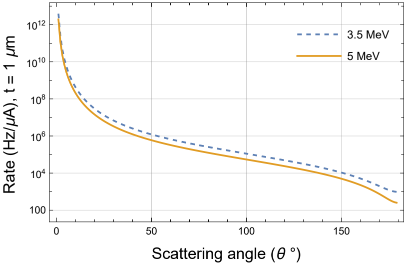


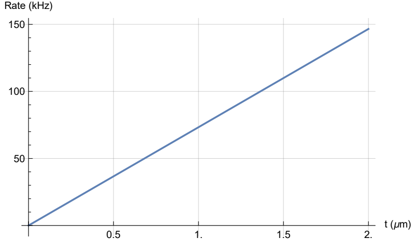
CST thermal simulation of Target

- 2 µm thick gold target, 1 mm thick aluminium holder
- 1 mm diameter, 1 W uniform source
- Background vacuum
- Accuracy needs to be improved.



Detector set-up

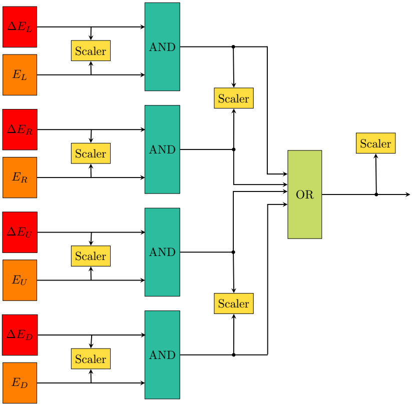




Total scattering rate for I = 150 μA, E = 5 MeV, $\Delta\Omega$ = 0.23 mSr

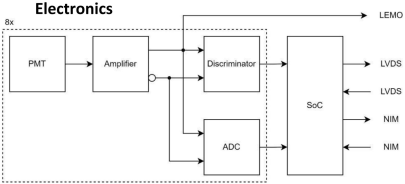
- Total scattering rate expected for up-down/left-right detector with target 2 μm is ≈150 kHz at 150 μA (without background).
- However, for 3.5 MeV it is slightly higher due to energy dependence.

Detector set-up



Detector logic

- Detector logic same as JLab.
- Coincidence technique to remove the photons background.
- Energy cuts for removal of inelastic events.
- Expected rate $\gtrsim$300 kHz (with background)
- SoC for readout



Courtesy of I. Beltschikow. Meeting 20.06.2023

Outlook and summary

Outlook

- Fabricate parts
- Conducting mechanical assessment

Summary

- Mott scattering experiment to analyze polarization.
- Design of the 5 MeV Mott in final stage.
- Experiment requires $\frac{\Delta P}{P} \leq 1\,\%$
- Next step is to implement the design.

Thank you!

Acknowledgements

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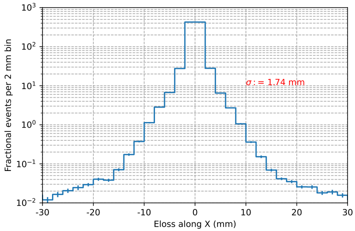
CST thermal simulation of 1 kW Dump with focused beam



Bdsim simulation for Eloss along X.

- CST thermal simulation
- 3.5 mm diameter, 1 kW uniform source
- Background vacuum
- Flange temperature less than 30 °C.