Development and Test of a 5 MeV Mott Polarimeter for Precision Measurement of Polarization for P2

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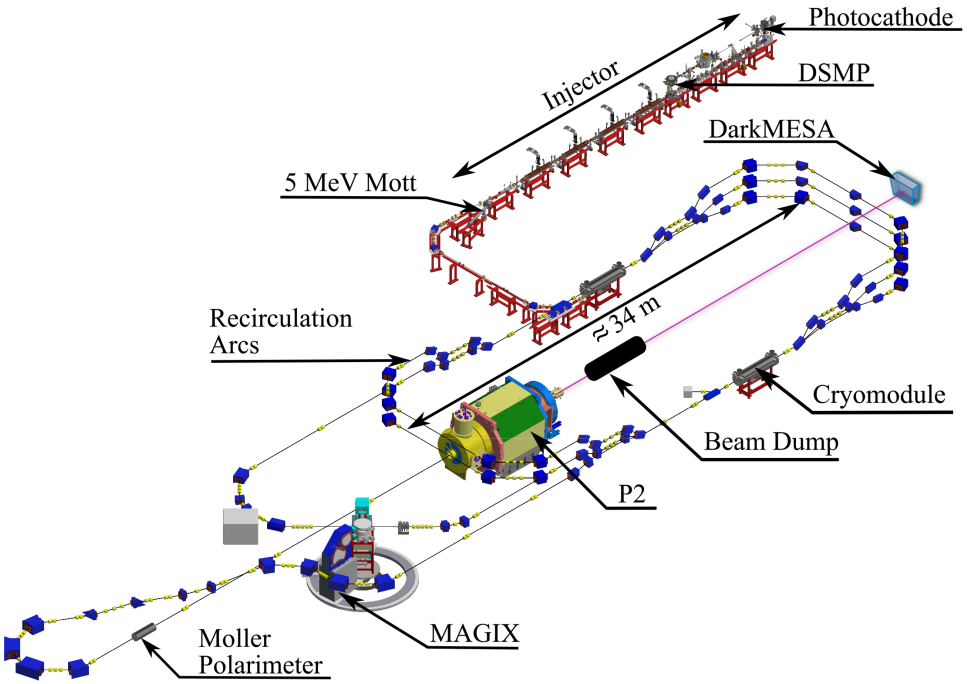
Outline

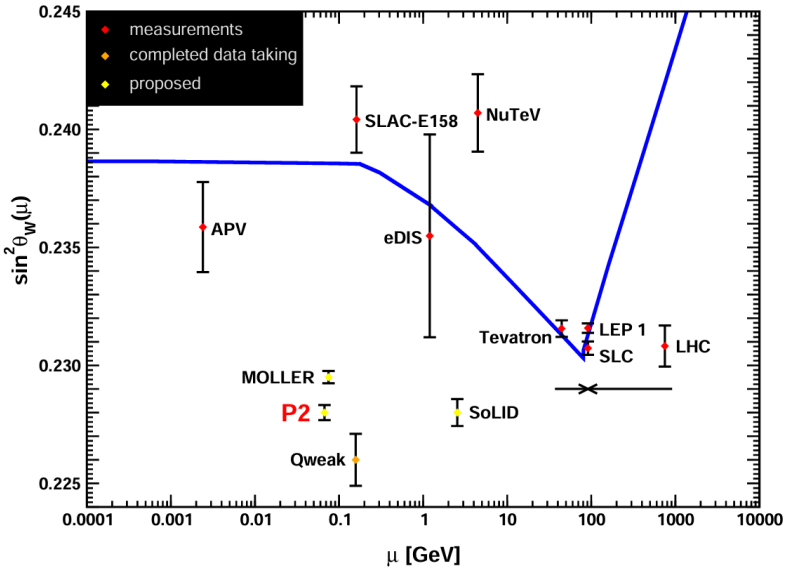
Overview of MESA

Mainz Energy-recovering Superconducting Accelerator (MESA)

- CW electron accelerator
- Operation frequency
  1.3 GHz
- Planned to operate in two modes:
- Extraction Beam mode(EB)
  Polarized beam
  155 MeV, 150 µA
  P2/DarkMESA
- Energy Recovery Linac mode (ERL)
  Unpolarized beam
  105 MeV, Stage I: 1 mA
  Stage II: 10 mA
  MAGIX
- Polarimetry chain for spin diagnostics

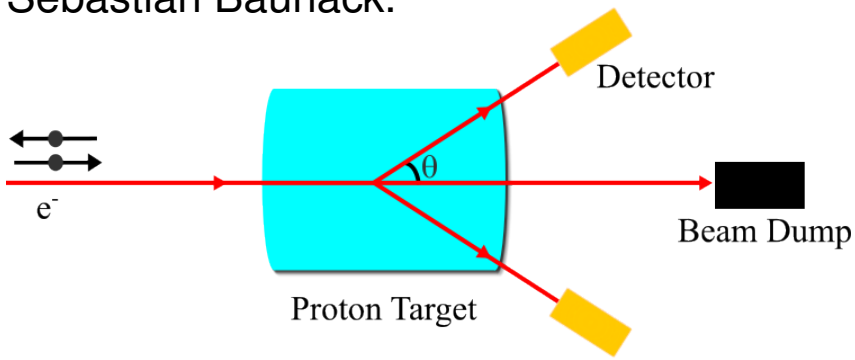


Motivation



D. Becker et al., 2018

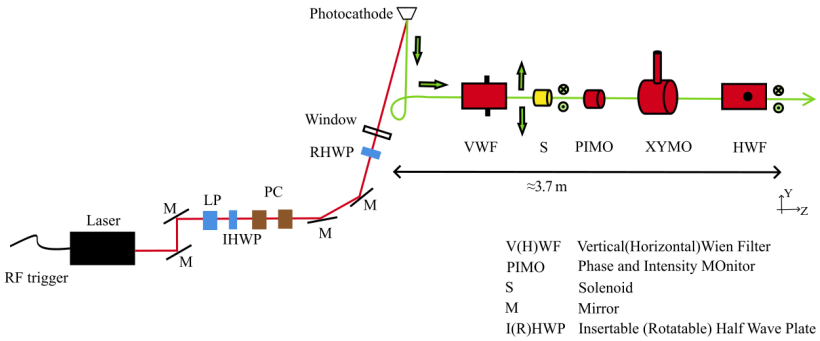
For more details on P2, please check out the talk "Experiments at MAMI/MESA by Sebastian Baunack."



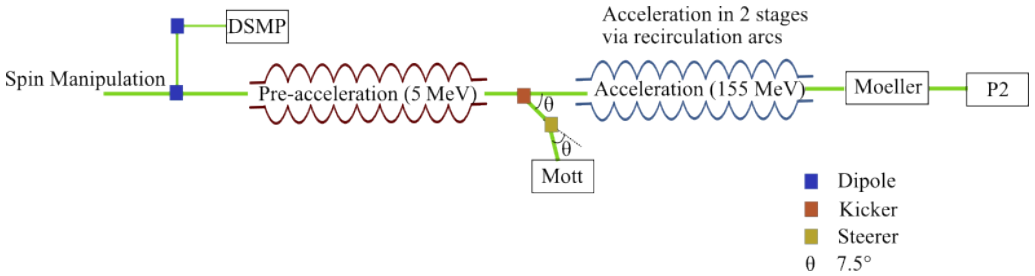
$$A^{PV} \equiv \frac{d\sigma^+ - d\sigma^-}{d\sigma^+ + d\sigma^-} \propto P(1 - 4sin^2\theta_w)$$

A^{PV} : Parity-violating Asymmetry
$d\sigma$: Differential cross-section for the elastic scattering of electrons with $\pm$ helicity off unpolarized protons
$sin^2\theta_W$: Weak-mixing Angle
P : Polarization of electrons

Spin Manipulation and Polarimetry



Spin Manipulation System



Schematic of Polarimetry at MESA.

- Right/left circularly polarized light produces positive/negative helicity electron beam
- Longitudinal spin rotated into the transverse plane, pre-accelerated to 5 MeV
- Kicker enables duty factors of 100%, 99%, and 1%
- Possibility to operate Mott and Moller simultaneously

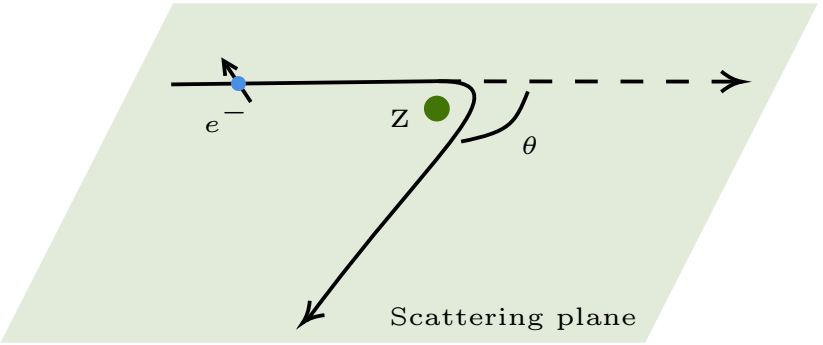
Mott Polarimetry

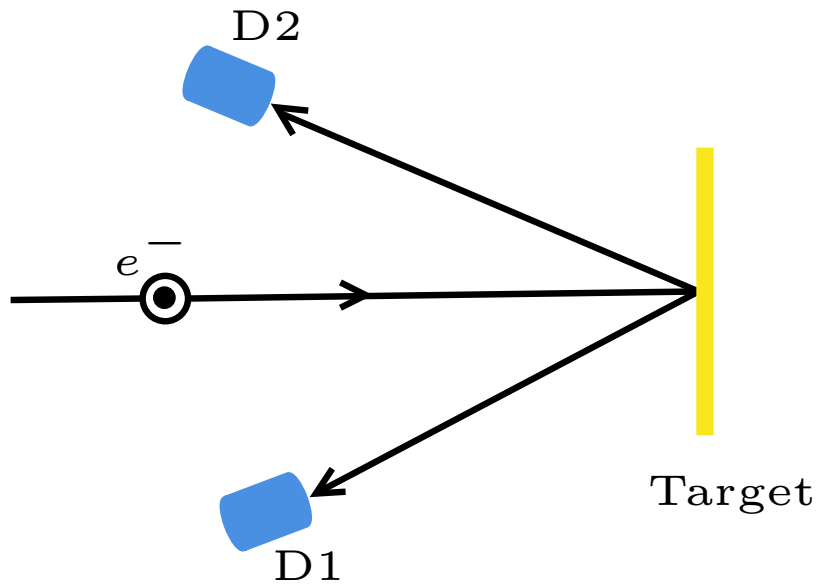
Mott cross section

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

$S(\theta)$ = Sherman function/analyzing power
$I(\theta)$ = unpolarized cross-section
$\hat{n}$ = unit vector perpendicular to the scattering plane

- Asymmetric elastic scattering of spin polarized electrons in coulomb field
- Experimental situation: A = P.S, A = Asymmetry, P = degree of beam polarization, S = Sherman function





Mott Polarimetry

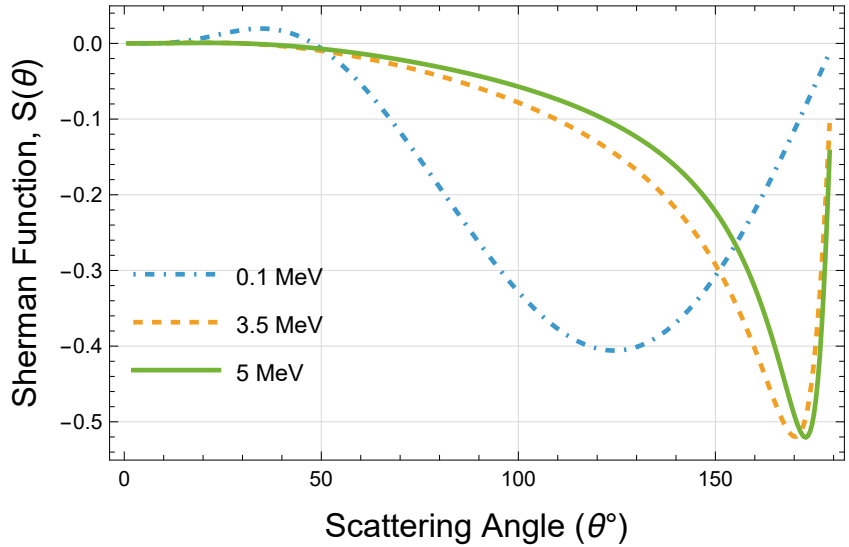
- keV Mott polarimeters for source optimisation
- Two MeV Mott polarimeters operational at MAMI(3.5 MeV) and JLAB(5 MeV)
- MeV Mott polarimeters for precision polarization measurements

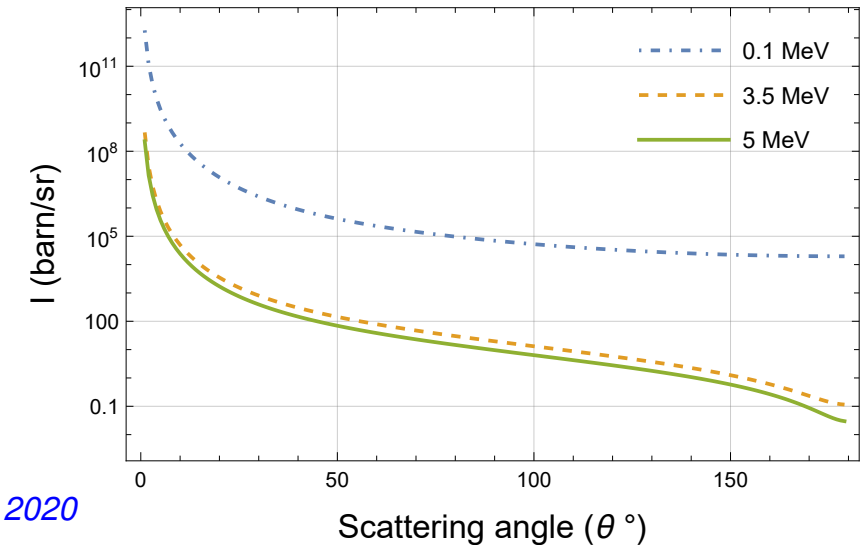
MeV energy Mott benefits

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

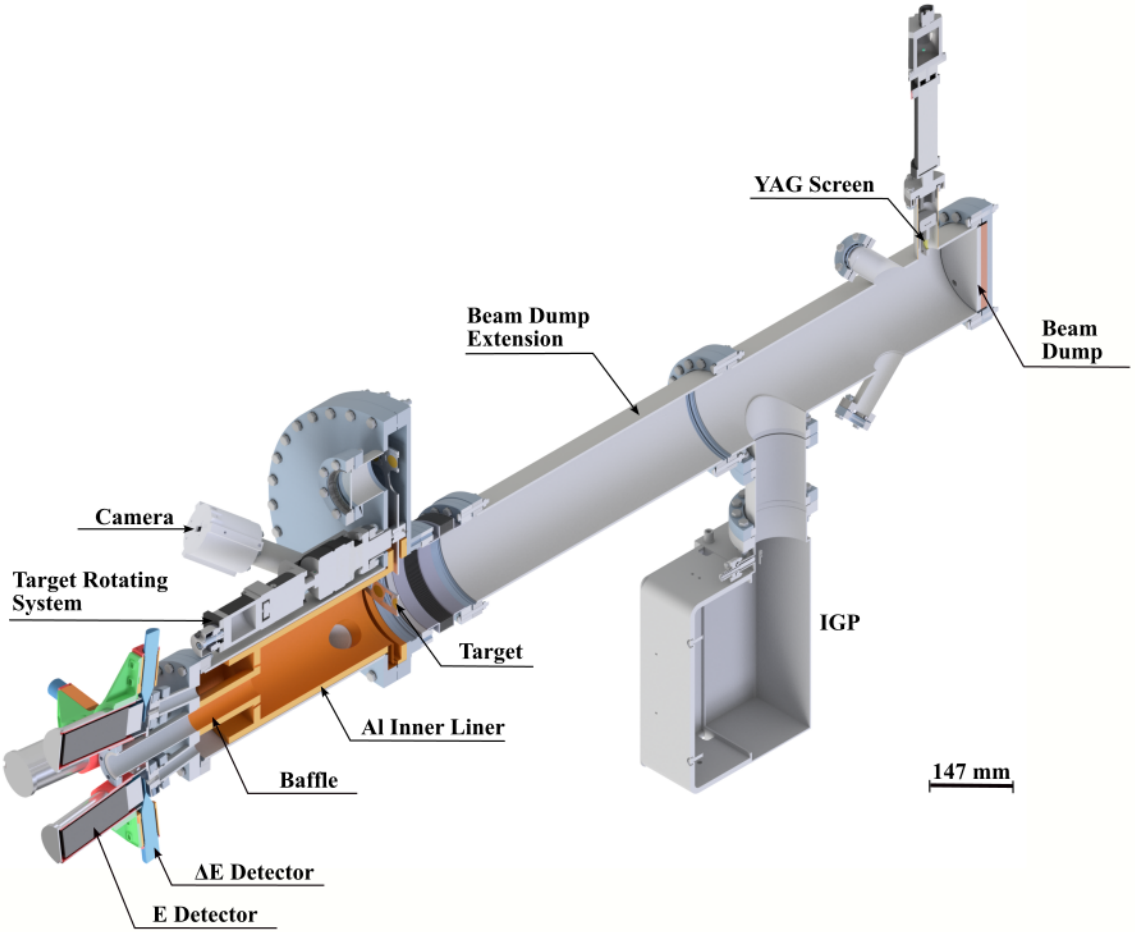
Contribution to the total uncertainty	Value
Theoretical Sherman function	0.50%
Target thickness extrapolation	0.25%
Systematic uncertainties	0.24%
Energy cut (0.10%)	
Laser polarization (0.10%)	
Scattering angle and beam energy (0.20%)	
Total	0.61%

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



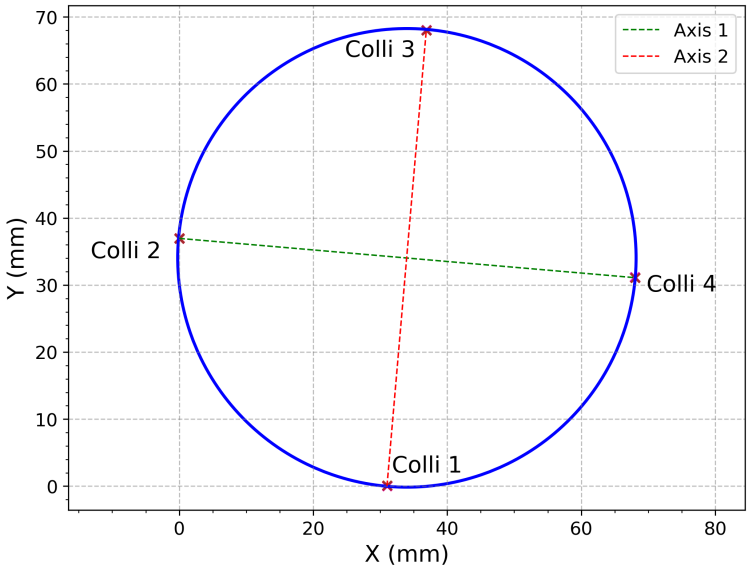


Design and Assembly of 5 MeV Mott polarimeter- Design

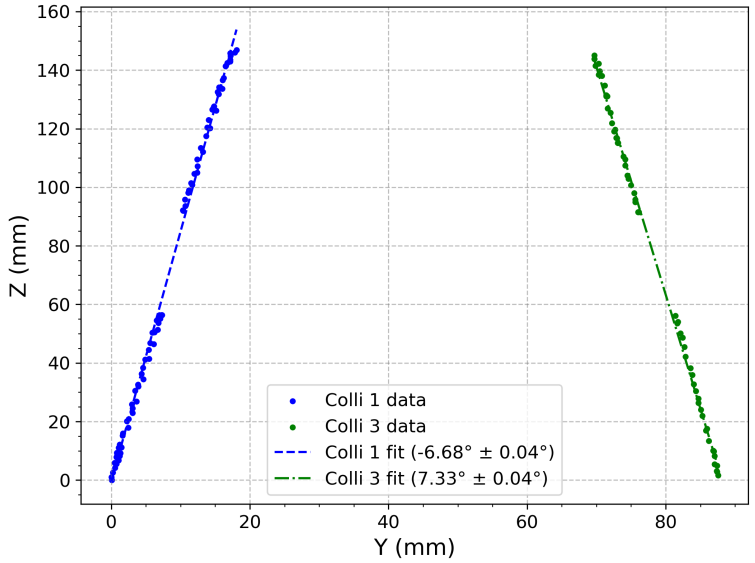


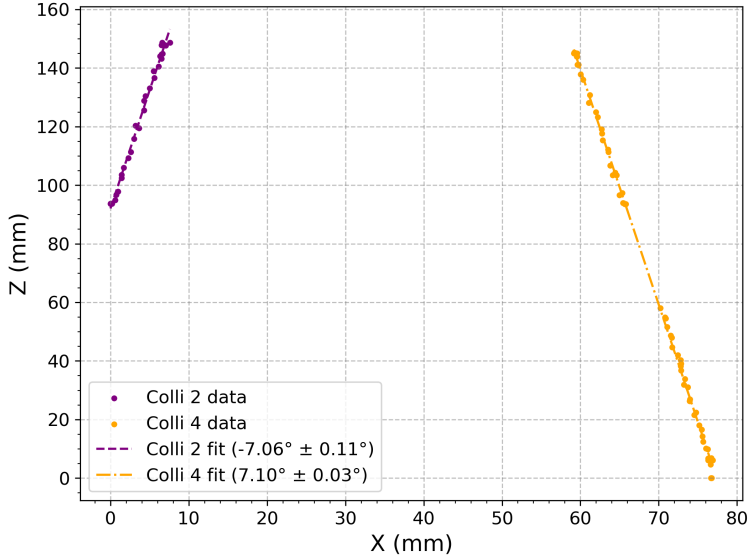
- Aluminium liner to reduce backscattering
- Baffle for solid angle collimation
- View screens for beam alignment
- Precise control of target ($< 100\,\mu m$)
- Aluminium window to seal the vacuum
- Can hold 20 targets

Design and Assembly of 5 MeV Mott polarimeter- Baffle Survey

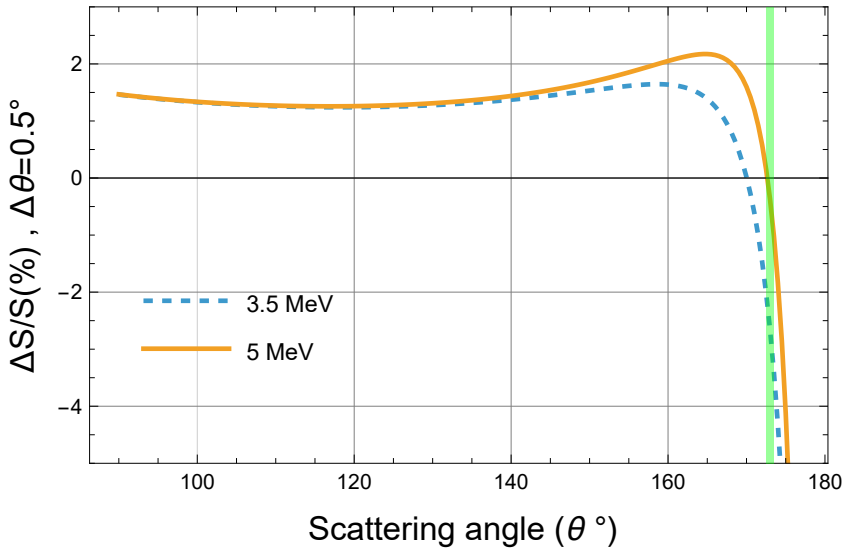


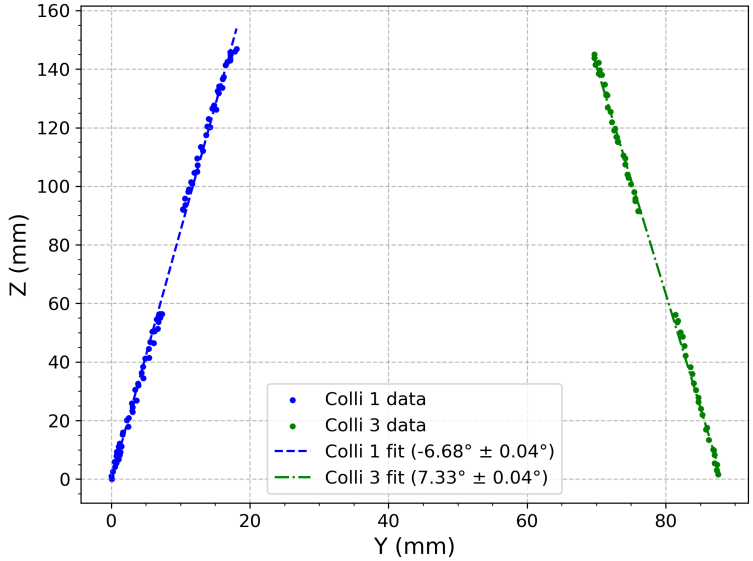
- Planes from collimators 1 & 3 and 2 & 4 oriented at 89.99°
- Deviation on ideal backscattering angle $< \pm 0.5°$



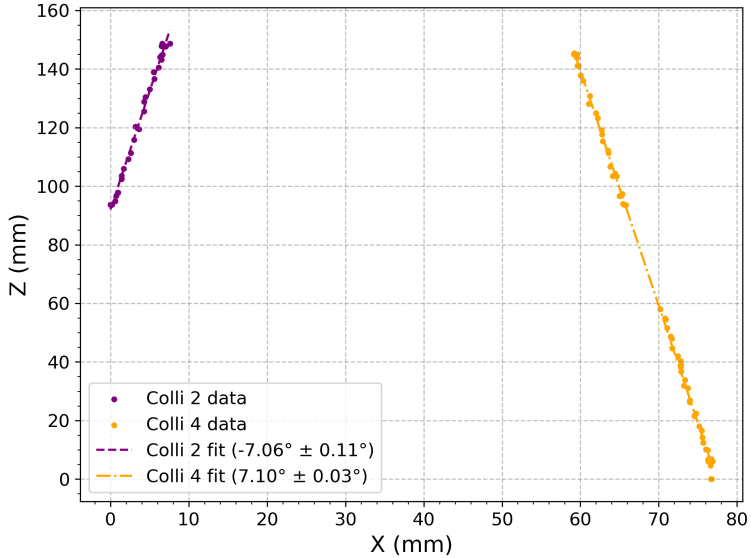


Design and Assembly of 5 MeV Mott polarimeter- Baffle Survey

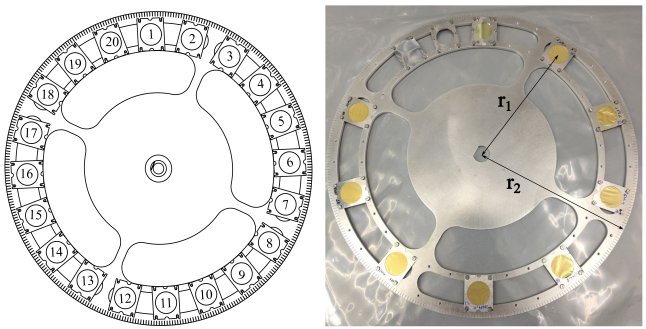




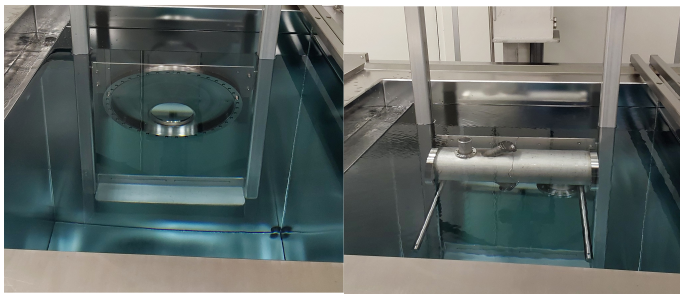
- Planes from collimators 1 & 3 and 2 & 4 oriented at 89.99°
- Deviation on ideal backscattering angle $< \pm 0.5°$
- Angular sensitivity to Sherman Function ≤ 1 %



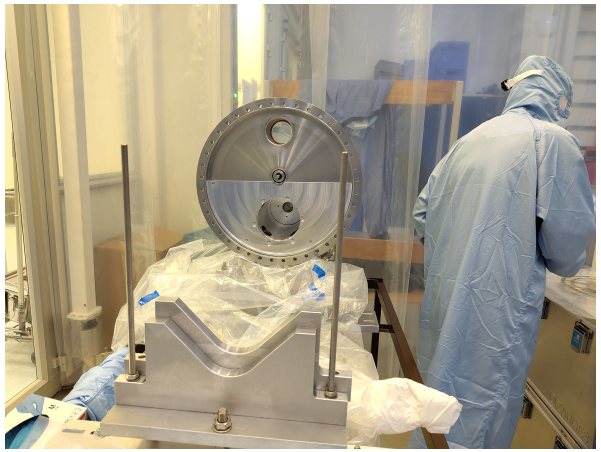
Design and Assembly of 5 MeV Mott polarimeter- Assembly



Rotating target holder. r1:124.1 mm, r2:145 mm



Rinsing of Mott parts after ultrasonic bath.

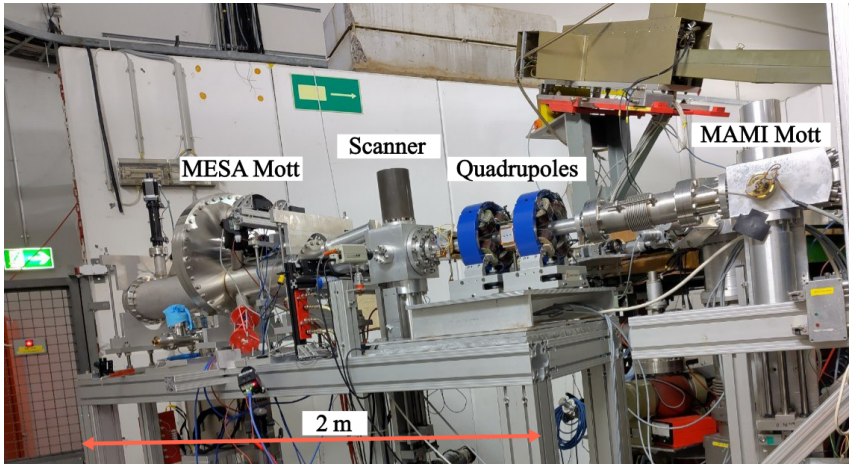


Assembly of Mott polarimeter under flowbox.

- Stainless steel parts cleaned in the ultrasonic bath in ISO 6 clean room
- Due to restrictions, alumnium parts cleaned in ultasonic bath under ambient conditions
- Aluminium parts wiped with isopropanol before everything was assembled under flowbox

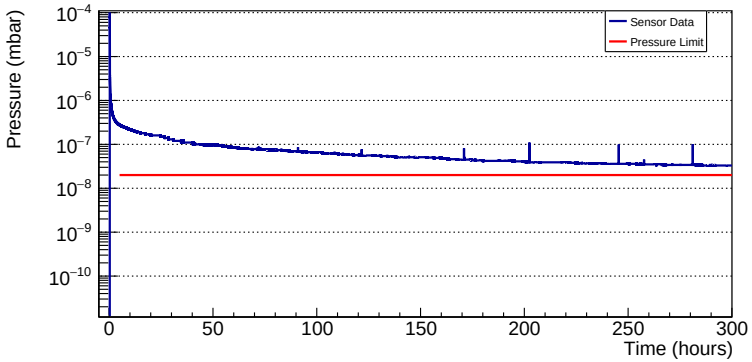
Design and Assembly of 5 MeV Mott polarimeter- Setup

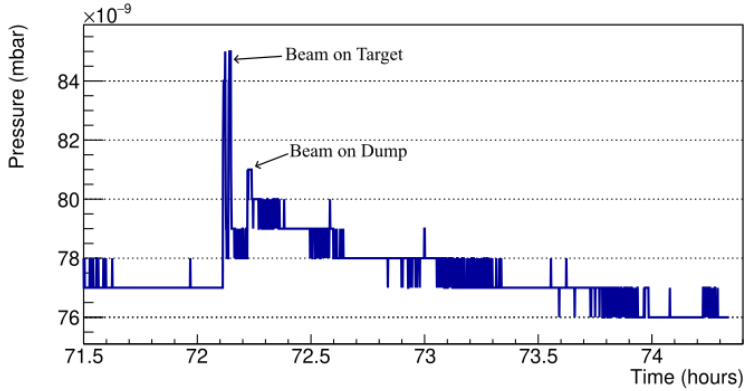
- MESA 5 MeV Mott assembly was transported and further assembled behind the MAMI 3.5 MeV Mott
- This gave us possibility to check polarization prehand.
- Setup was made compact due to space issues.



5 MeV Mott test setup at MAMI.

Vacuum

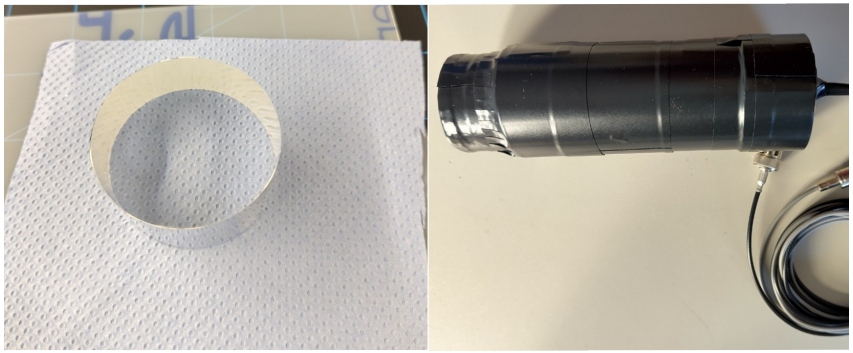




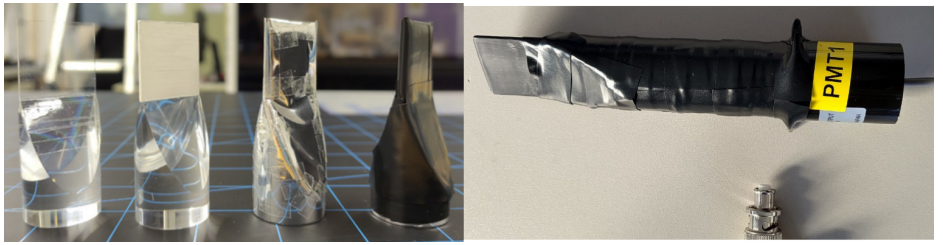
- Pumping speed of Ion Getter Pump (IGP) $150\,\mathrm{L\,s^{-1}}$
- Leak rate: $<1.7 \times 10^{-9}\,\mathrm{mbar\,L\,s^{-1}}$
- Pressure Bouncing due to outgassing
- Pressure limit reached about 2×10^{-8} mbar

- 100 nA electron beam on 2 µm target showed pressure rise of about 9 % compared to about 4 % on beam dump
- Scattering a beam into a larger surface area creates a larger beam-induced desorption of gas molecules

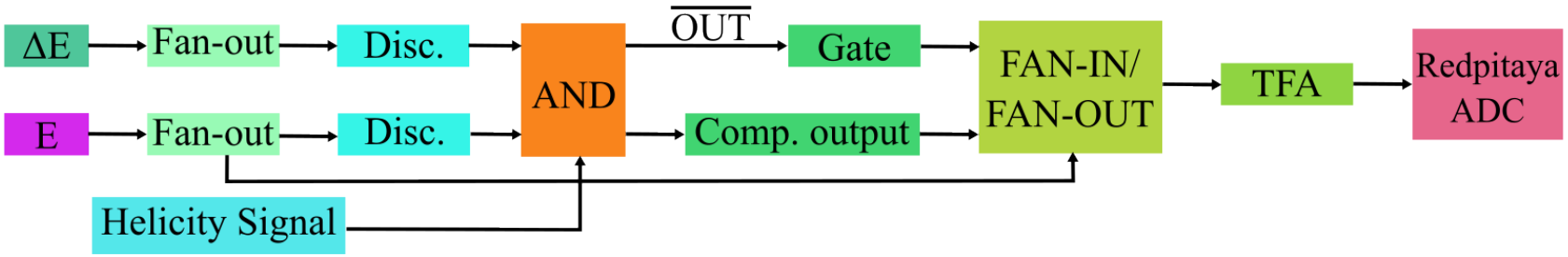
Detectors



- Scintillator size:30 mmx46 mm

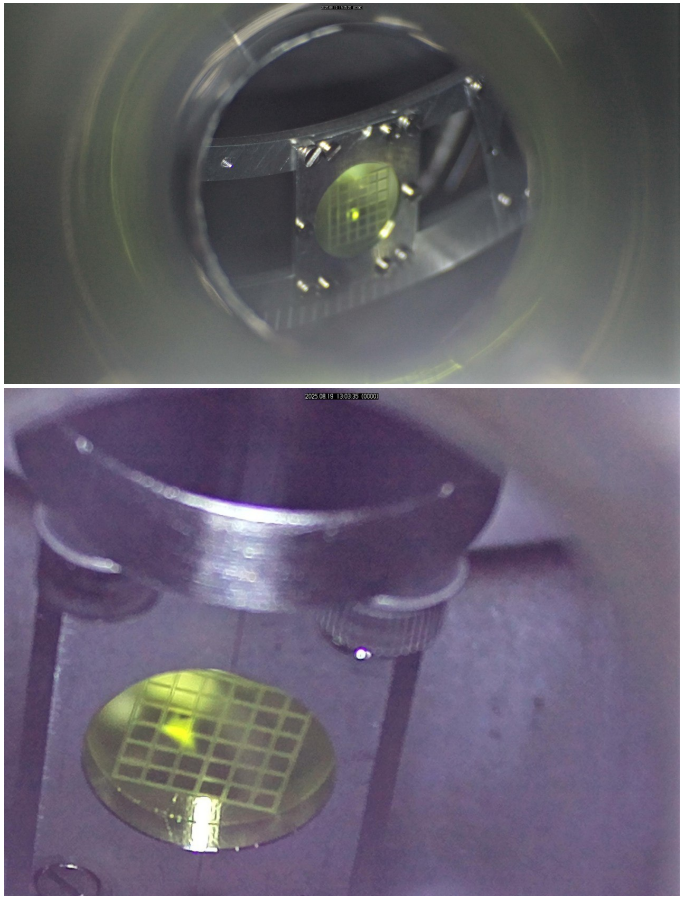


- Scintillator size:1 mmx25 mmx25 mm

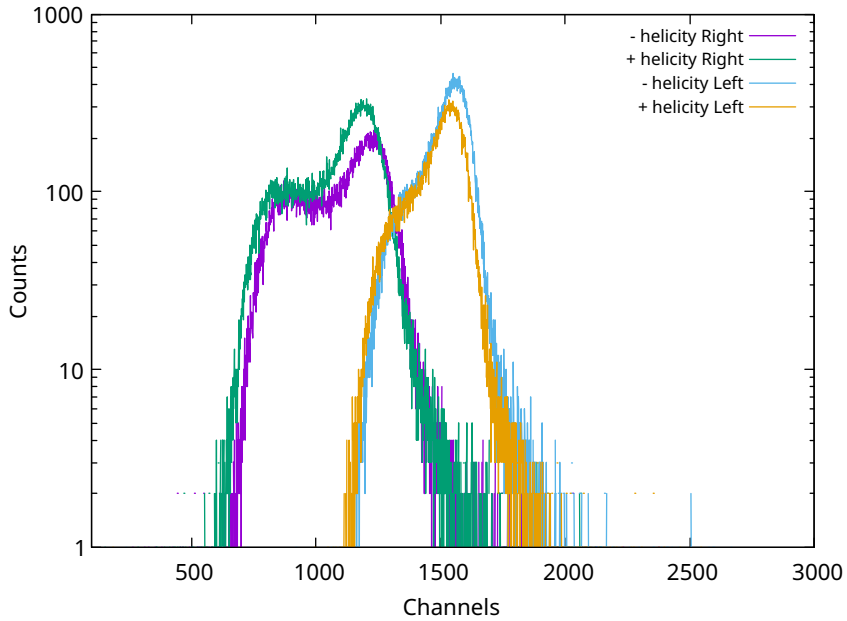


Gated energy spectrum for Mott events.

Mott Beam Run

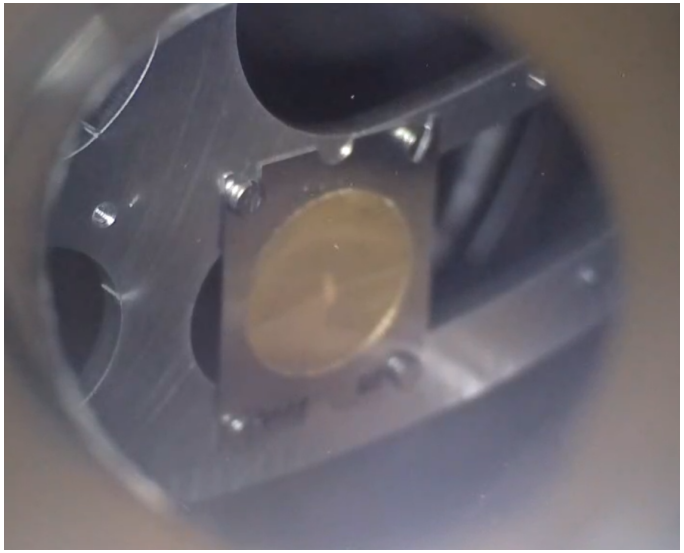


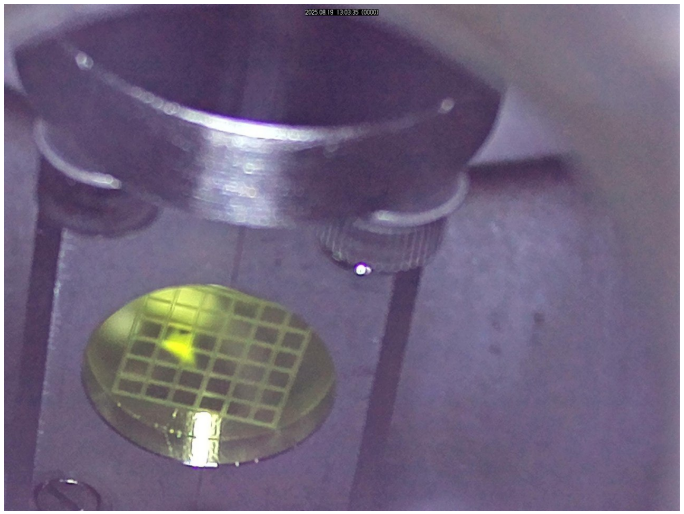
Beam aligned on YAG screens at target and near beam dump locations

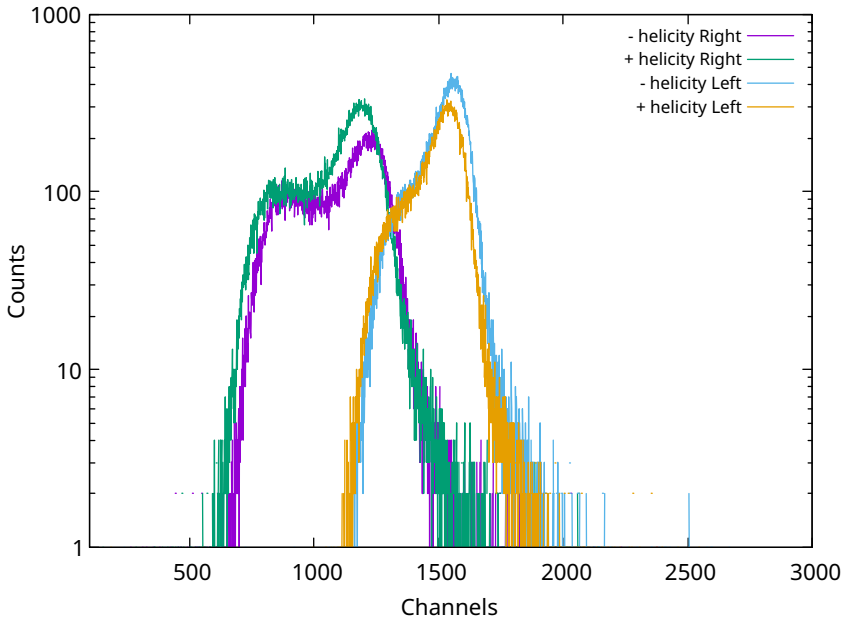


- Asymmetry observed for 2 µm gold target and 1 µA beam current

Mott Beam Run







- Asymmetry observed for 2 µm gold target and 1 µA beam current
- At 14 µA beam current, both OTR and beam-induced stress observed on 2 µm target

Outlook and Summary

- Design of the state-of-the-art 5 MeV Mott polarimeter completed
- Test setup with necessary electronics built and installed at MAMI
- Preliminary Mott measurements show asymmetry dilution due to backscattering
- Geant4 simulations needed to further understand the system
- Comprehensive study planned after installation at MESA with extended beam dump

Thank you!