5 MeV Mott Polarimeter at Jefferson Lab

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Polarized Sources, Targets, and Polarimetry 2013

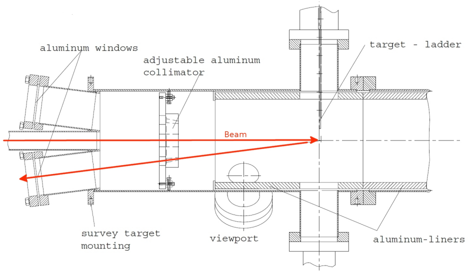
Outline

1. MeV Mott Overview
   - JLab MeV Mott Polarimeter
2. Current Upgrade
   - GEANT4 Modeling
   - Beam Dump Upgrade
3. Extra Slides

JLab MeV Mott Polarimeter

- Located in the injector
- Measures transverse polarization over the energy range of 3-5 MeV
- Largest arises from calculation of analyzing power

Polarimeter Specifications and Layout



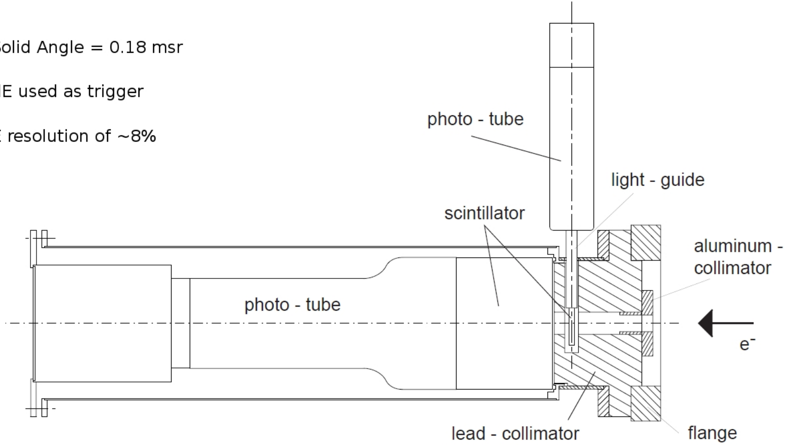
- Several Au, Ag, Cu, C targets with thickness from 0.01-5 μm
- Scattering angle of 172.9°

The Detectors

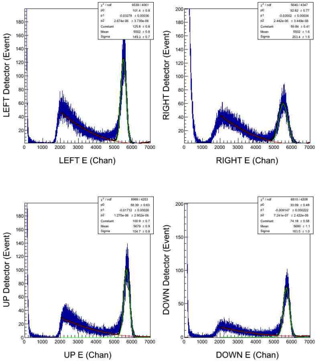
Solid Angle = 0.18 msr

dE used as trigger

E resolution of ~8%



Detector Specta



The long tails of the elastic peak present a problem since they also contain the physics signal we're looking for.

Measuring Asymmetries

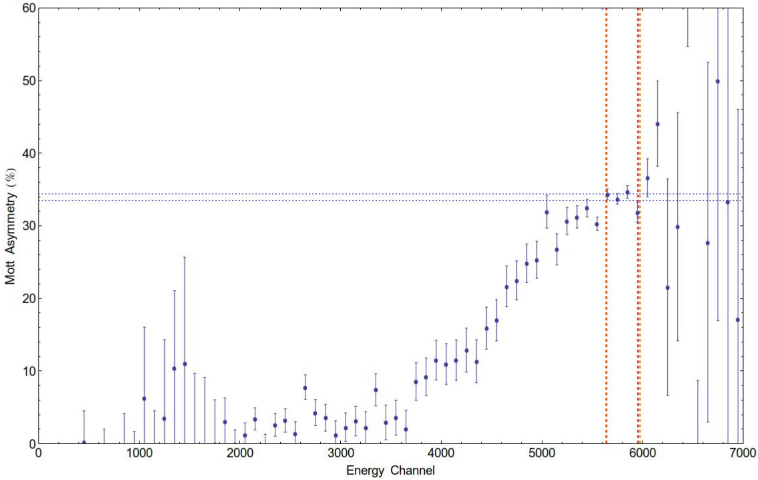
How we actually measure the polarization:

- Measure hits in each detector for one helicity state. Get $N_L^\uparrow$ and $N_R^\uparrow$.
- Flip helicity, repeat. Get $N_L^\downarrow$ and $N_R^\downarrow$.
- Calculate the *cross-ratio*, $r = \sqrt{\frac{N_L^\uparrow N_R^\downarrow}{N_L^\downarrow N_R^\uparrow}}$.
- Calculate asymmetry $A_{LR} = \frac{1-r}{1+r}$.
- Do the same for the vertical A_{UD}.

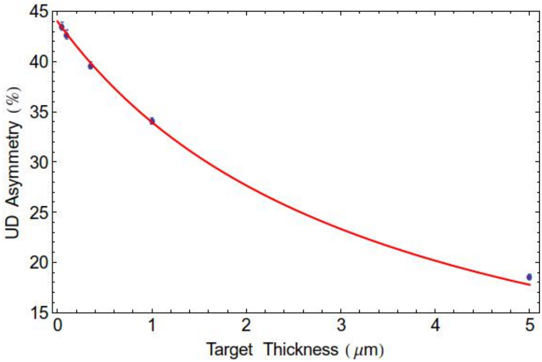
The polarization is

$$\mathbf{P} = \frac{1}{S_{eff}(\theta)} \left[A_{LR}\hat{\mathbf{y}} - A_{UD}\hat{\mathbf{x}} \right]$$

Asymmetry Vs. Energy



June 2012 Runs

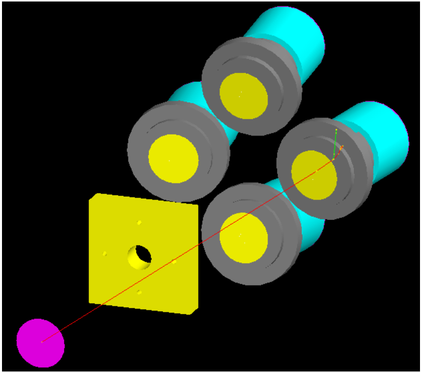


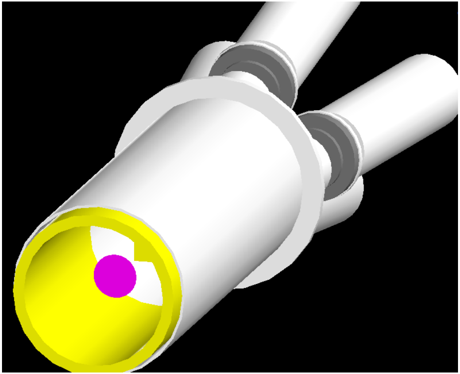
$S_{eff}(\theta_{sc}, 0) = 43.995\%$ and $\alpha = \frac{0.296}{\mu m}$ with $\chi^2 = 0.039$

Goals of Current Work

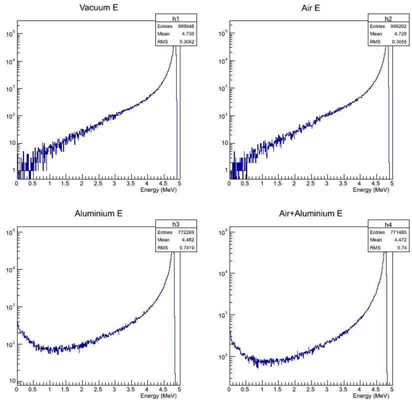
- Create full model of apparatus in GEANT4
- Gain a better understanding of the tail in the elastic spectrum we see
- Upgrade beam dump to reduce backscatter

Current Setup





Spectral Response to “Beamline” elements



New Plots forthcoming for each element and cumulative effect. (Due to long running times with Optical photons)

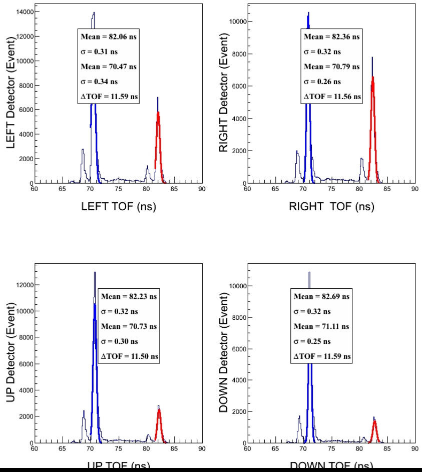
Collimator Competition

Plot Forthcoming. The basic result is that the aluminium collimator also filters events. From running without the Al vacuum window or air and rastering over the whole baffle collimator we see an additional reduction with the addition of the Al nose/collimator of almost 20%

Beam Dump

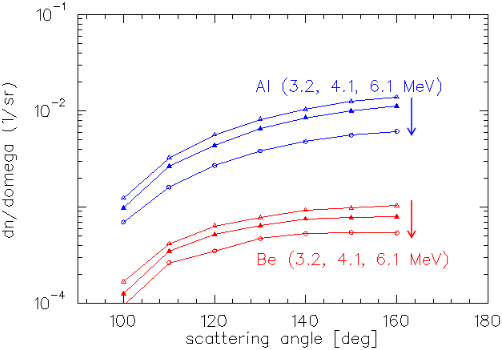
- Currently several inches of Aluminium in air
- Limits power (i.e. beam current)
- Large amount of backscatter makes it into the detectors

Backscatter Problem



On the 1 um foil 30% come from dump. More on thinner targets.

Beryllium Vs. Aluminium



Electron-Nucleus Scattering

Electron moves in the nuclear Coulomb field, $\mathbf{E} = \frac{Ze}{r^3}\mathbf{r}$. Magnetic field induced in electron's frame, $\mathbf{B} = -\frac{1}{c}\mathbf{v} \times \mathbf{E}$. Therefore

$$\mathbf{B} = \frac{Ze}{cr^3}\mathbf{r} \times \mathbf{v} = \frac{Ze}{mcr^3}\mathbf{L}$$

Magnetic field couples to the electron's spin $V_{so} = -\boldsymbol{\mu}_s \cdot \mathbf{B}$. Scattering potential :

$$V(r, \mathbf{L}, \mathbf{S}) = V_C(r) + V_{so}(r, \mathbf{L}, \mathbf{S}) = \frac{Ze}{r} + \frac{Ze^2}{2m^2c^2r^3}\mathbf{L} \cdot \mathbf{S}.$$

Sherman Function

The cross section is

$$\sigma(\theta) = I(\theta)\left[1 + S(\theta)\mathbf{P}\cdot\mathbf{n}\right]$$

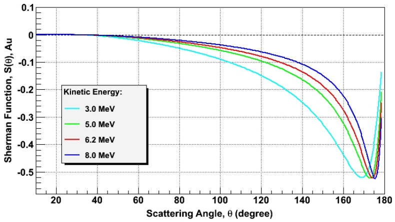
with $\mathbf{n} = \frac{\mathbf{k}\times\mathbf{k}'}{|\mathbf{k}\times\mathbf{k}'|}$. The spin-averaged cross section is

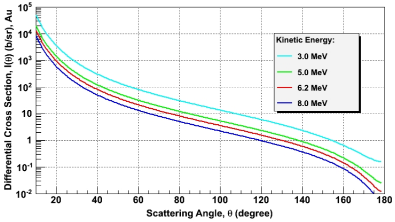
$$I(\theta) = |f(\theta)|^2 + |g(\theta)|^2$$

and $S(\theta)$ is the Sherman Function,

$$S(\theta) = i\frac{f(\theta)g^*(\theta) - f^*(\theta)g(\theta)}{I(\theta)}.$$

Sherman Function Corrections





$S(\theta)$ must account for

- Finite Nucleus. Adjust theoretical prediction.
- Multiple scattering. Shown as dependence on target thickness, d

$$S(\theta) \rightarrow S_{eff}(\theta, d) = \frac{S(\theta)}{1 + \alpha(\theta) d}.$$

Run on thinnest possible target.