CEBAF Mott Polarimeter Upgrade – Managing the Electron Beam

Samuel H. Rhodes (Lycoming College, Williamsport, PA 17701)

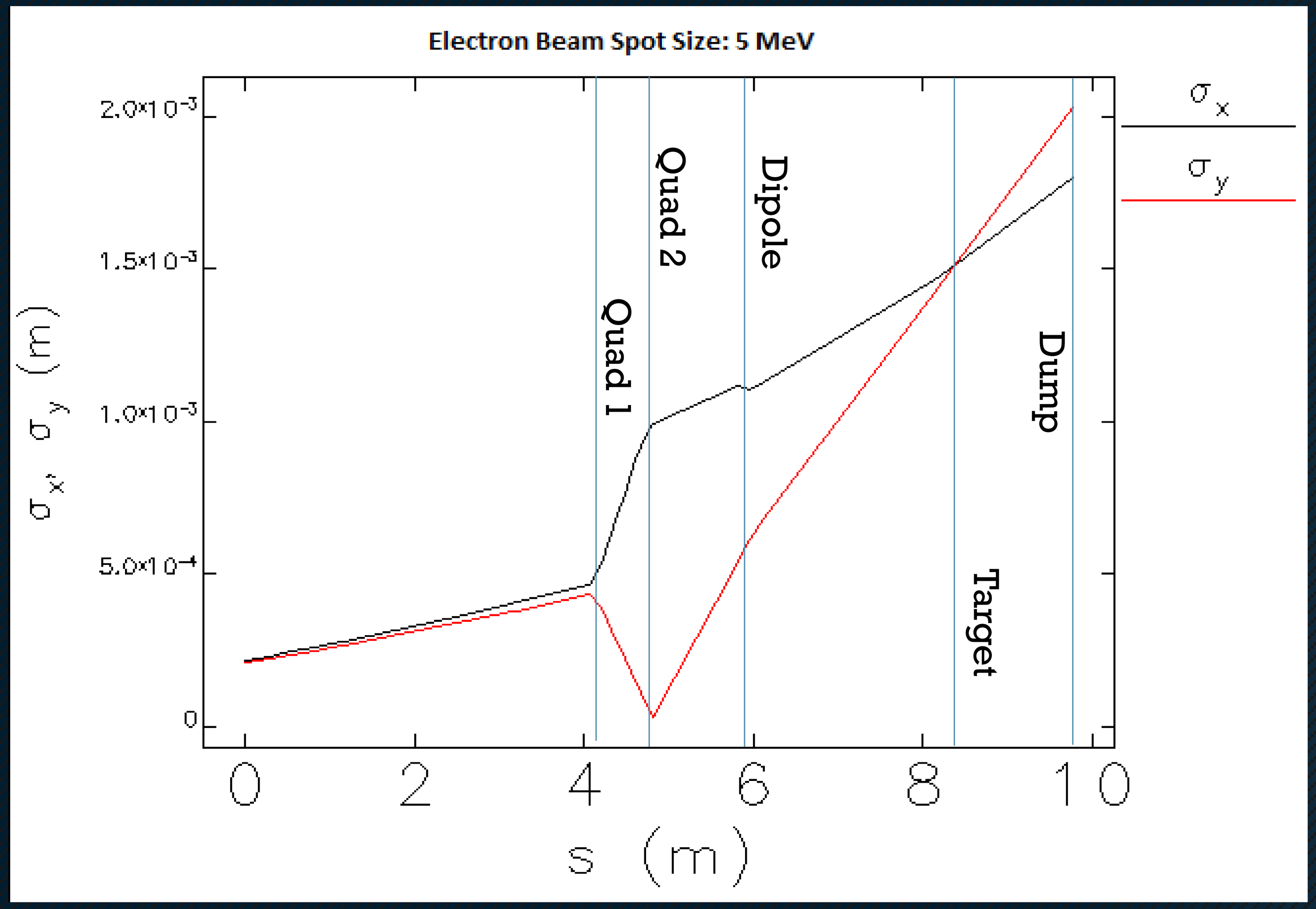
Mentor: Joe Grames (Thomas Jefferson National Accelerator Facility, Newport News, VA, 23606)

This material is based upon work supported by the National Science Foundation under grant No. 212049.

ABSTRACT

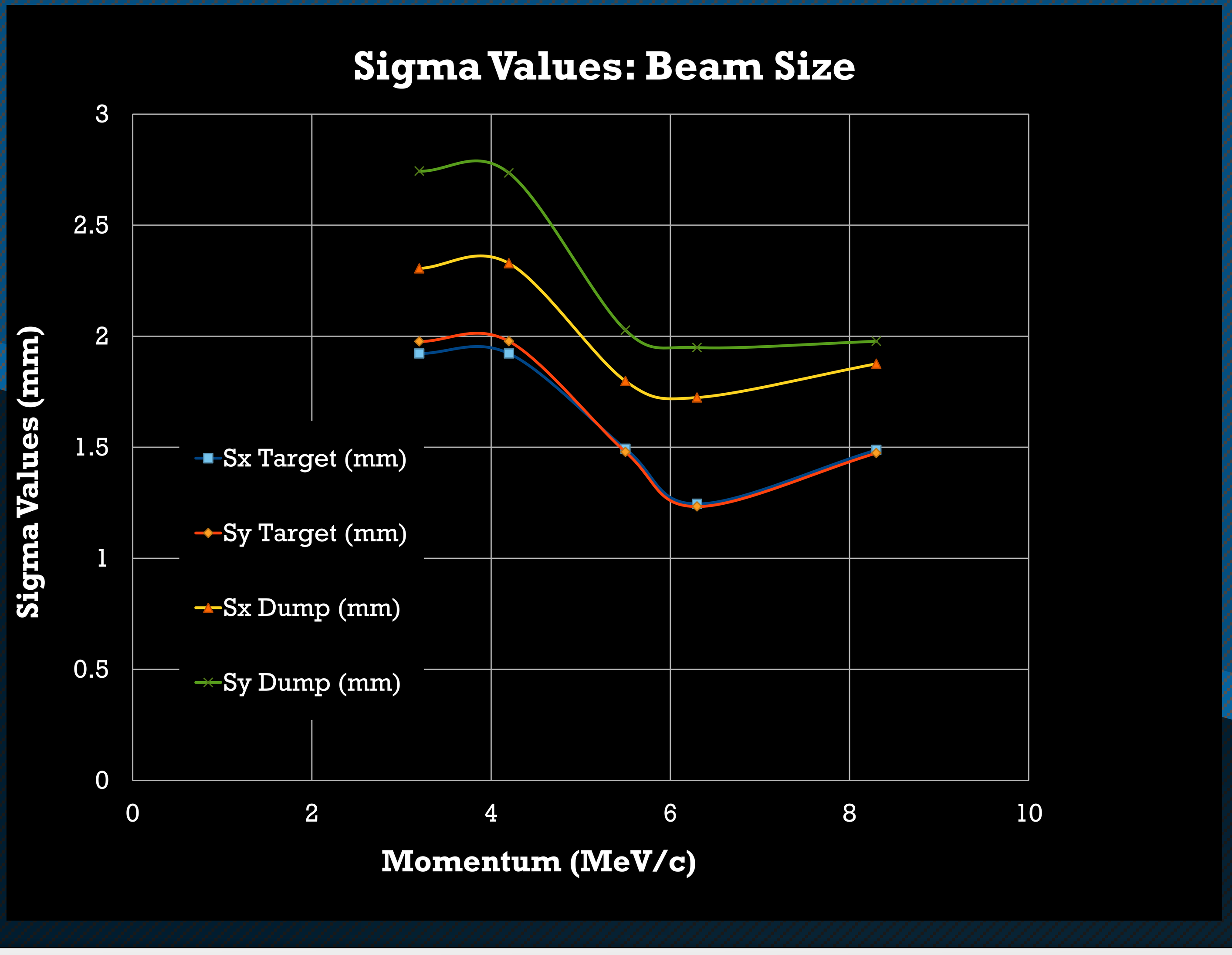
The Mott Polarimeter at Jefferson Lab has been going through an upgrade along with the rest of the CEBAF accelerator. In the process of upgrading the polarimeter, a new dump plate was desired. In preparation for the design of the dump plate a few things needed to be determined and those things were handled this summer. The first task was redirecting the beam and focusing it down the Mott line since it was being steered towards a different line for another experiment. The first task was done with the help of a particle tracking program called Elegant. The second task was using various programs to calculate the scattering angle due to multiple Coulomb scattering. In the process of calculating the scattering angle, a secondary task of validating a program called G4Beamline was attempted using theoretical calculations and other simulations as comparisons. The work done this summer will aid in the development of a new dump plate by providing data on the electron beams' power distribution on the dump plate which will then help the Mott group determine which configuration best reduces backscattering and manages beam power, hopefully enabling currents of more than 2 uA to be used over range of 3-8 MeV.

Electron Beam Focusing at 5 MeV



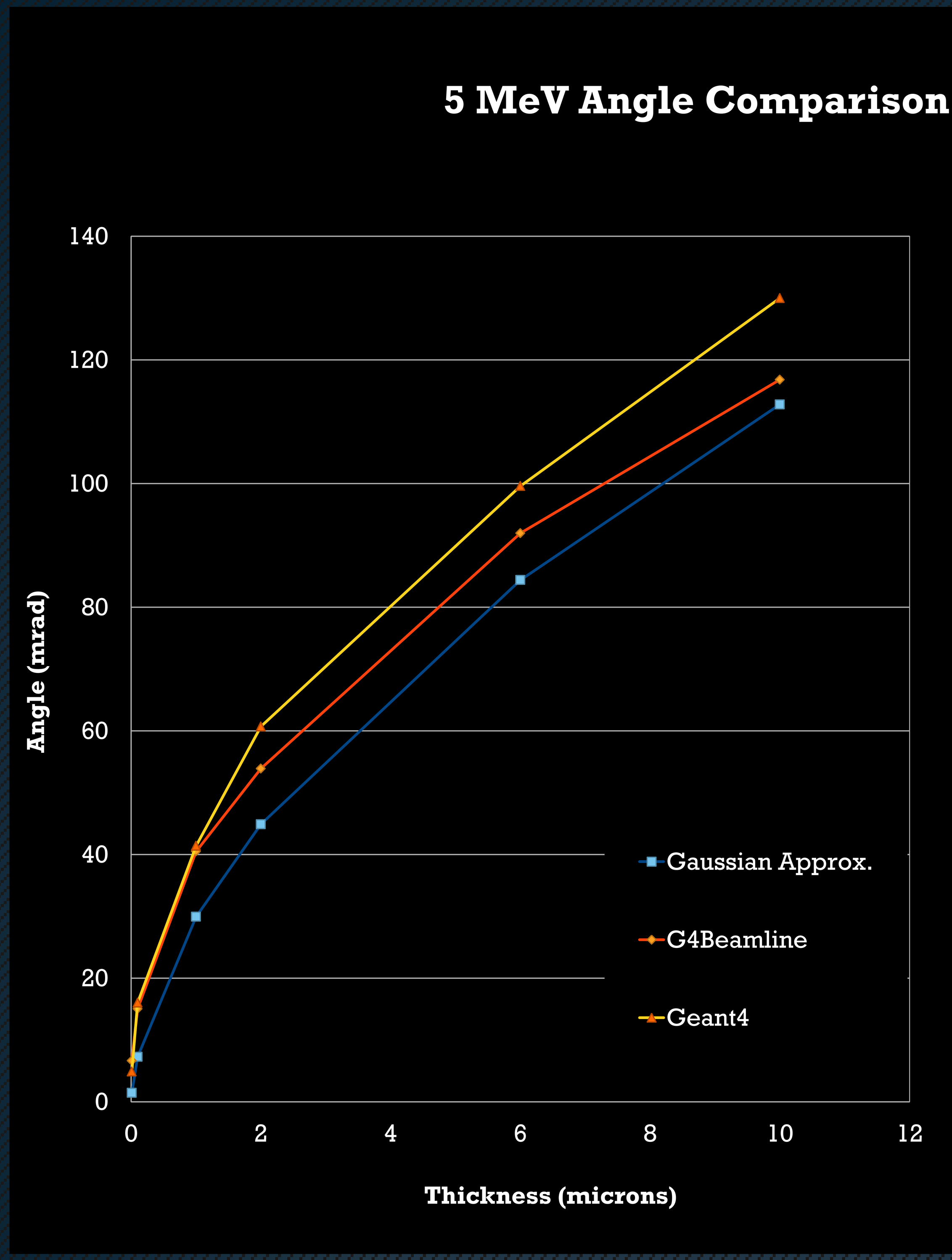
[Above] The beam size as a function of position; quad, target, and dump positions marked.

[Below] The size of the beam as a function of momentum at the target, and it's size at the dump plate.



Conclusion #1: Smallest possible circular beam sizes are larger for lower momenta due to initial conditions. As it stands, on average, the smallest circular beam size attainable is ~1.5mm.

Multiple Scattering



[Above] Foils used in polarimeter. Usually gold, silver, or copper. Range in thickness from .01 µm to about 10 µm. [Left] Scattering angle as a function of thickness for the three methods of calculating angle.

Computing Scattering Angle

Method 1: Gaussian Approximation by *Lynch and Dahl*,

$$\theta_{RMS} = \sqrt{\frac{\chi_c^2}{1+F^2}\left(\frac{1+\upsilon}{\upsilon}\ln(1+\upsilon)-1\right)} \quad (1)$$

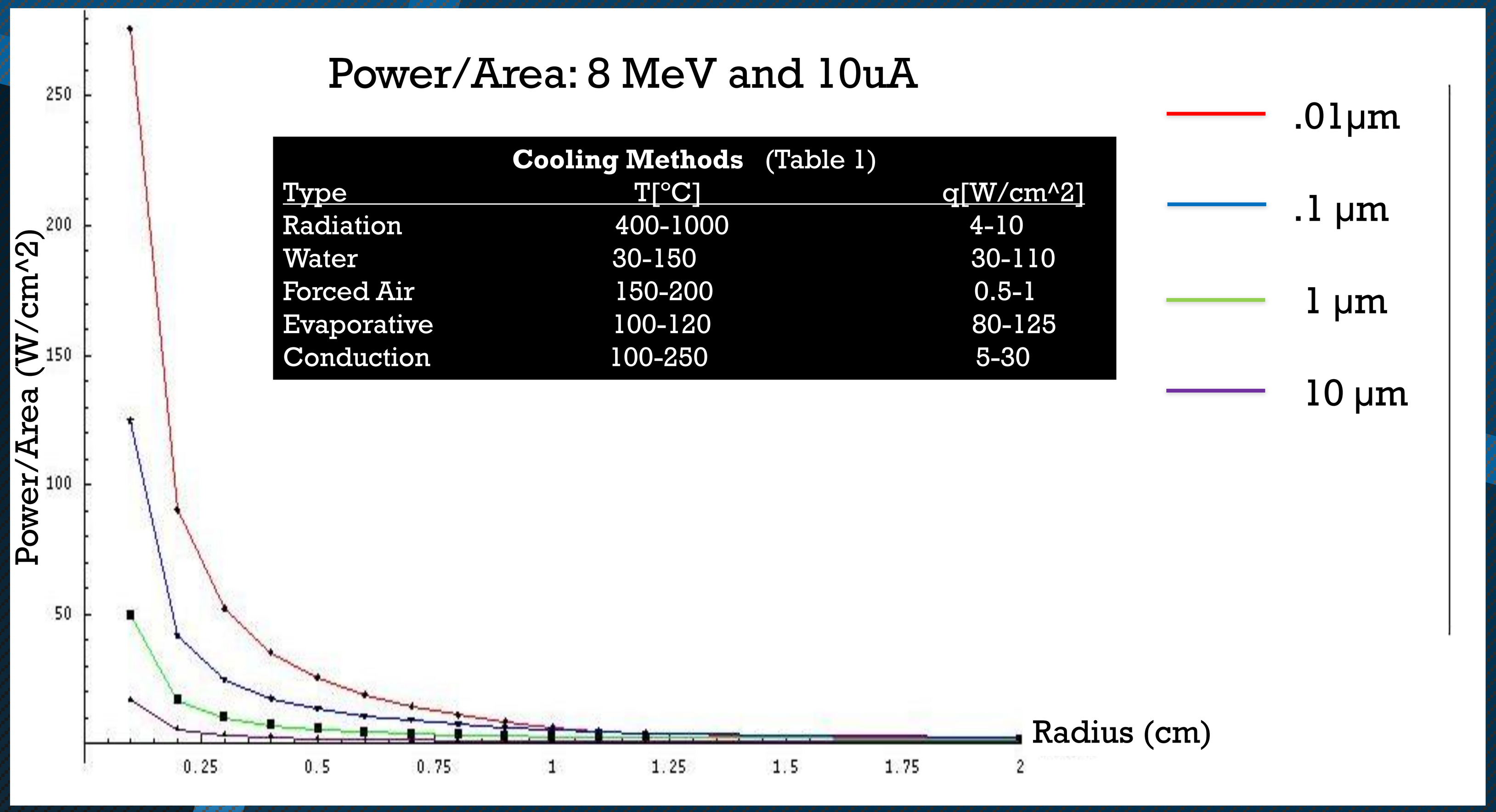
Aside: F is the fraction of the distribution taken into account (90-99.5%). X_c is the characteristic angle. $v = 0.5\Omega/(1-F)$, where $\Omega=(\chi_c / \chi_a)^2$, where χ_a is the screening angle.

Method 2: *G4Beamline* simulation. Uses standard Geant4 physics lists. The angle was found by taking the RMS of a histogram of arctan(Px/Pz) .

Method 3: Geant4 Monte Carlo simulation. Angle is the RMS of the histogram of arctan(Px/Pz).

Conclusion: #2 *G4Beamline* and *Geant4* are in agreement for the most part. Due to time constraints, unequal numbers of runs were done in *Geant4* than *G4Beamline*. The Gaussian Approximation is fairly close to the simulations.

Power Distribution on Dump



Cooling Methods (Table 1)

Type	T[°C]	q[W/cm^2]
Radiation	400-1000	4-10
Water	30-150	30-110
Forced Air	150-200	0.5-1
Evaporative	100-120	80-125
Conduction	100-250	5-30

After scattering through the target foil, the beam disperses and it's power is distributed on the dump plate in higher and lower concentrations depending on the target thickness. [Above] The power per unit area is displayed above. The points represent power distributions in a ring with outer radius at the labeled point and inner radius at the point before, e.g. point 2 has an outer radius of 2 and inner radius of 1.

Conclusion #3: One the most dangerous instances at the dump is when a large amount of power is hitting in a small area, as would be the case at 8MeV, since the energy in the beam is higher and the scattering angles are smaller. In the plot above, it is shown that with very thin targets the amount of power distributed per area is very large in towards the center of the dump. This would suggest that very thin targets above a few microamps would require active cooling via conduction and water cooling.

References
Table[1]- Reference Data for Radio Engineers, H.W. Sams Pub. (1970)
Equation[1]- *Applications for multiple Coulomb scattering*, Gerald R. Lynch and Orin I. Dahl (1990)