GEANT4 Simulation of the Mott Polarimeter

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Introduction

The goal of this brief paper is to list for future reference the intended uses of the `GEANT4` simulation of the CEBAF MeV Mott Polarimeter. The simulation in question has been exclusively developed and run by myself and has already proven somewhat fruitful. The primary goals of the simulation are, in order of increasing importance (as I see it), as follows:

1. Accurately simulating the detector response to incoming electrons of appropriate energy. **Completed**
2. Determining all sources (i.e. what's it scattering off of) of backgrounds that may make it into our acceptance. **In Progress**
3. Incorporating the most accurate Mott scattering physics possible into `GEANT4` allowing us to determine numerically $S_{eff}(d, \theta)$ with some idea of the error bars. **In Progress**
4. Building a (mostly) complete model of the system that can be used in the future for benchmarking data against theory and which may assist in future design modifications. **In Progress**

Now I will briefly discuss the goals and the progress made towards them in more detail.

1 Detector Response

One of the issues facing the analysis of polarimeter data has been coming up with a model for explaining the shape of the elastic peak. The simulation has helped us see that the elastic peak shows a low energy tail largely because of bremsstrahlung photons being produced in the scintillator material which then escape (although a small number of electrons also scatter out of the material before losing all of their energy). This "energy tail" can be seen clearly in both real data and simulation in Figure 1.

Using simulation to identify the cause of this tail allows us to re-think the energy cuts we use on the data in a more systematic way. We will even be able to extract background dilution factors from simulation in the future and compare these to time-of-flight cuts as a method of background subtraction from simulations like this.

Work Remaining: Quantifying the agreement between simulation and data. More comparisons at different energies.

2 Background Sources

With the tools of `GEANT4` we will clearly be able to identify the source of each particle that makes it into our detectors. This provides a much more precise tool than time-of-flight for separating good, elastically-scattered electrons from the foil from all other sources. Moreover, with the inclusion of spin-physics (which is fully supported in `GEANT4`) the particles can be assigned a Mott asymmetry even when scattering from

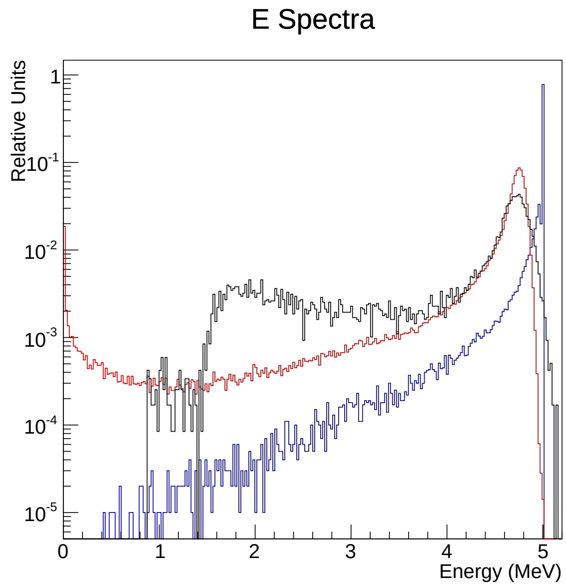

Figure 1: The data (**black**) compared with simulation of a full detector package with collimators, $E = 5$ MeV and $\delta E/E = 1\%$ (**red**) and a simulation of a naked scintillator with a mono-energetic 5 MeV beam (**blue**). The full simulation and data agree in the "energy tail" from 3.8 - 4.4 MeV.

other places than then target foil. The simulation would allow us to see what affect this asymmetry dilution has on our measurements.

Work Remaining: Building an accurate geometry for the beam dump, target ladder, OTR mirror etc.

3 Mott Scattering Physics

Once we have full theoretical support, `GEANT4` will allow us to examine multiple and plural Mott scattering in the target numerically by tracking the spin throughout the particle's path and at each scattering vertex. We can then vary the target thickness arbitrarily and perform comparisons to data. If we also proceed down a similar road as Michael Steigerwalt and calculate the probability of two scattering events and the associated asymmetry based on target thickness directly from the theory, we can further benchmark the theory and see at what thickness it begins to fail.

Work Remaining: Recieve good Mott scattering code from physics. Put it into our simulation. Possibly make it a publicly available physics package by sending it to the guys at CERN.

4 Future Uses

In any future re-designs of the Mott polarimeter or changes in the injector, the simulation could be used to help decide on things like target thickness or materials or new detector positions etc. The decision to move to beryllium in the dump plate was supported by work Joe and Sam did using G4beamline which is built upon the physics modelling of `GEANT4`.