# Modeling and Instrumentation of a Beam Dump Compton Transmission Polarimeter

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**Abstract** At the Continuous Electron Beam Accelerator Facility (CEBAF) at Jefferson Laboratory, polarized electrons are generated and accelerated to 12 GeV to probe nuclear interactions. There are many ways to measure electron polarization, but an alternative novel idea is to use the beam dump of a Mott polarimeter which is installed along the beam line, making electrons interact with the beam dump and studying the radiation produced with a magnetized iron target. The transmission rate asymmetries are measured as a function of the beam helicity and the target magnetization. Simulations of the apparatus were also made with GEANT4, and the energy distribution of the electrons reaching the detector were simulated with and without the magnetized iron target. These simulations gives a more realistic idea of the interactions taking place in the beam dump and in the target.
We can now make a quick measurement of electron beam polarization without using the Mott, and without complicated Wien filter setups, which takes time to implement.

## I. INTRODUCTION

Electrons are polarized when their spin is oriented in a preferential direction. When spin polarized electrons stop in the material, the resultant Bremsstrahlung radiation possesses circular polarization proportional to the polarization of the electron beam. To evaluate the degree of circular polarization of Bremsstrahlung radiation in the form of x-rays can be passed through a magnetized iron target. If the spins of the electron beam are parallel or antiparallel to the magnetization, then there will be more or less x-rays able to penetrate. In this way the asymmetry is (see ref. [1]) as follows:

$$A = \frac{I_2^+/I_1^+ - I_2^-/I_1^-}{I_2^+/I_1^+ + I_2^-/I_1^-} \tag{1}$$

Where $I_1^{\pm}$ is the signal from the beam current monitor (BCM) and $I_2^{\pm}$ is the signal of the Compton detector. The asymmetry dependence on the Magnet current was measured as well as a function of the Beam current and the Spin angle. With this asymmetry, the polarization of the beam ($P_b$) can be written as:

$$P_b = \frac{A}{P_T \times (A.P.)} \tag{2}$$

Where $P_T$ is the polarization of the magnetized iron (approximately $\sim 8\%$ in this work) and A. P. is the analyzing power of the Compton Scattering in the target ($\sim 1.7\%$), (ref. [2]).

## II. COMPTON TRANSMISSION POLARIMETER

The apparatus was placed after the beam dump of the Mott polarimeter. It consists of a magnet of 15.24 cm long, and 10.16 cm diameter, with an iron cylinder core of 12.7 cm long and 2.5 cm diameter, ∼3,000 turns of copper wire (see ref. [3] and [4]). A photomultiplier tube (PMT) with a scintillator plastic of 7.62 cm diameter and 6.25 cm long is used to detect the x-rays, Lead bricks were used to shield the PMT from photons that hit the surrounding materials and scatter back to the PMT. Thus, PMT only record x-rays that passed through the iron target. The arrangement was aligned with the Mott dump, and the distances Beam Dump-Magnet and Magnet-Detector are about 5 mm (see figure 1).

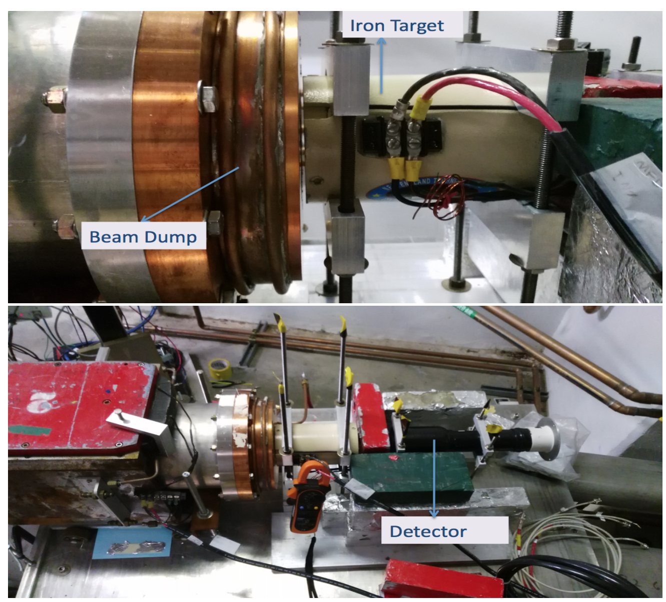


**FIG. 1:** Experimental apparatus: Mott Dump Polarimeter, with a magnetized target and a Photo Multiplier Tube as detector, covered with lead blocks.

The asymmetry showed in figure 2, remains constant at 2% for different values of the beam current for a magnet current of 1 A.

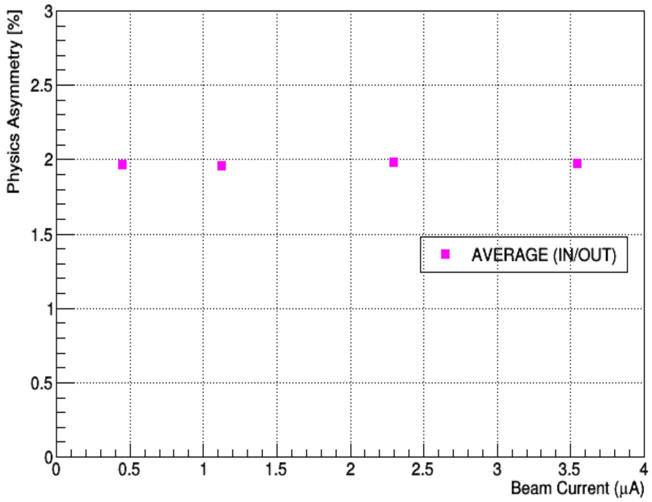


**FIG. 2:** Asymmetry remains constant at 2% for different values of the beam current (magnet current of 1 A).

In figure 3 the beam current was fixed at 2 $\mu$A, the asymmetry was measured as a function of the magnet current.

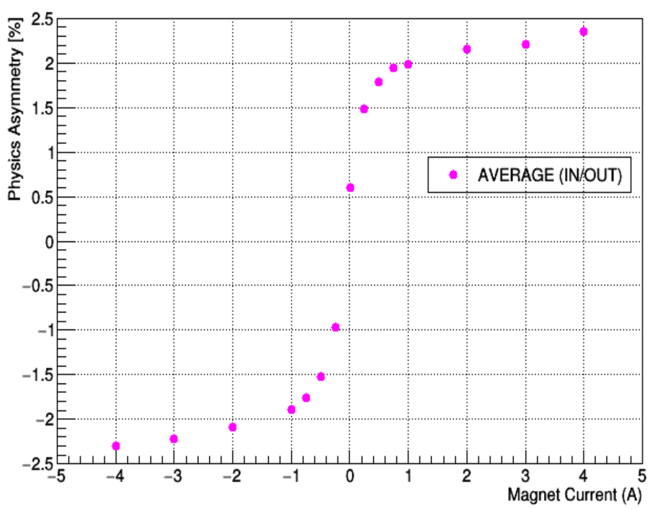


**FIG. 3:** Asymmetry as a function of the magnet current (beam current 2$\mu$A).

Finally with a magnet current of 1 A and beam current of 1.7 $\mu$A, the asymmetry was measured as a function of the spin angle. Figure 4 shows a maximum at 2%. The spin angle was changed using a Wien Filter.

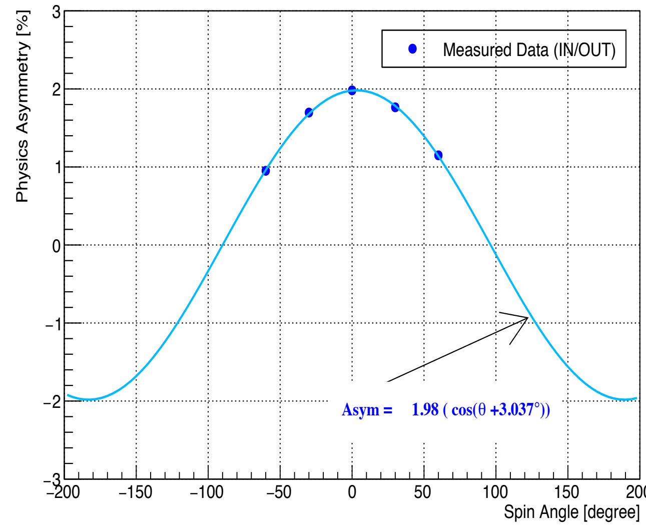


**FIG. 4:** Asymmetry as a function of the spin angle (magnet current of 1 A and beam current of 1.7 $\mu$A). The spin angle was changed using a Wien Filter.

## III. SIMULATION

Simulations of the experiment were made with the GEANT4 program (object oriented in C++), a toolkit which simulates the passage of particles through matter, to compare number of Photons per $\mu$A as a function of the energy deposited in the detector, with and without iron target. Later these results can be used to calculate the analyzing power (A. P.). In figure 5 the simulations shows the geometry of the arrangement.

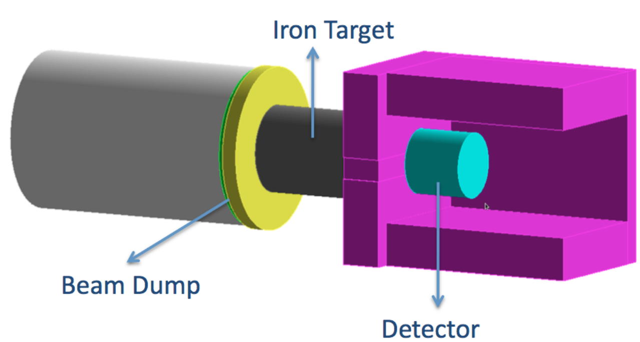


**FIG. 5:** Simulation of the geometry in GEANT4. In green and yellow are the Berilium and Copper components of the beam dump respectively. In gray the target is showed. The scintillator detector (blue cylinder) is placed inside a lead box (magenta blocks).

Figure 6 shows a 2,000 electron events, at 6.3 MeV. Electrons hit the beam dump, radiation passes through the iron target, finally reaching the detector.

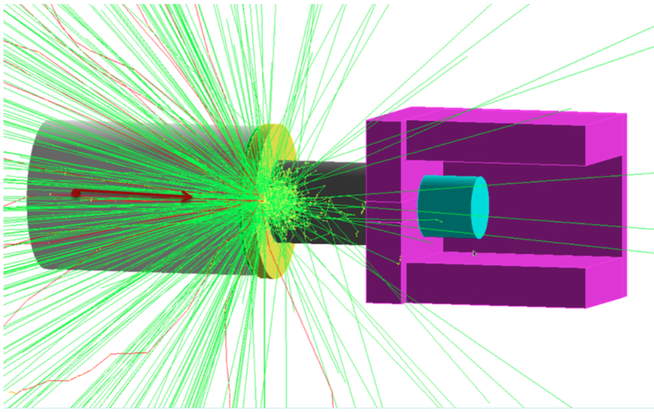

**FIG. 6:** Simulation of events: 2,000 electrons at 6.3 MeV (kinetic energy). Electrons hit the beam dump, radiation passes through the iron target, finally reaches the detector.

Figure 7 shows the number of photons per $\mu$A as a function of the energy deposited in the detector with and without the iron target A higher amount of electrons are detected without the magnet (magenta distribution) than for the case with the magnet (green distribution).

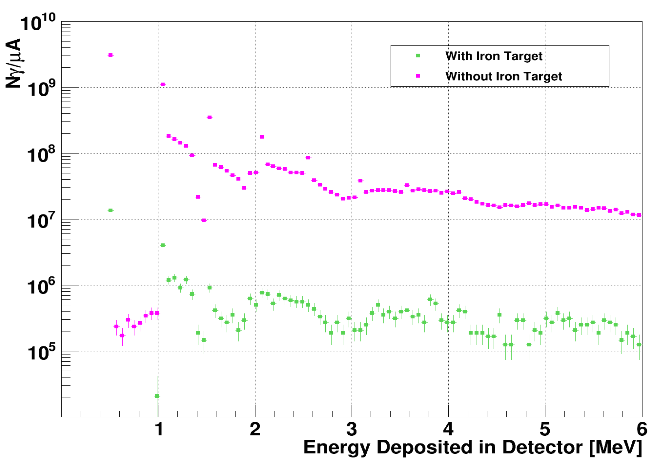


**FIG. 7:** Number of photons per $\mu$A as a function of the energy deposited in the detector with and without the iron target.

## IV. CONCLUSION

The goal of the experiment was to obtain the A. P. of the Compton Scattering in the target by using the known beam polarization of 88% (as measured by a Mott polarimeter), assuming $P_T$ ~8% and from beam based measurements of the Asymmetry of ~2%, the A. P. is found to be ~28%.

We can now make a quick measurement of electron beam polarization without using the Mott polarimeter, and without complicated Wien filter setups, which takes time to implement.

## V. ACKNOWLEDGMENTS

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[1] R. Barday, et al: *Compton transmission polarimeter for a very precise polarization measurement within a wide range of electron currents*, *J. Phys.: Conf. Ser.* **298** 012022 (2011)

[2] D. Abbott, et. al. *Production of Highly Polarized Positrons Using Polarized Electrons at MeV Energies*, PEPPo Collaboration, Phys. Rev. Lett. **116**, 214801 (2016)

[3] T. Zwart, et al: *Polarized electrons at Bates: Source to storage ring*, AIP Conference Proceedings **588**, 343 (2001)

[4] T. Zwart, et al: *Transmission Polarimetry at MIT Bates*, AIP Conference Proceedings **675**, 1011 (2003)