Modeling and Instrumentation of a Beam Dump Compton Transmission Polarimeter

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Abstract

At CEBAF at Jefferson Lab, 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 the Mott polarimeter, making electrons interact with the beam dump and studying the radiation produced with a magnetized 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 target.

Introduction

Electrons are polarized when their spin is oriented in a preferential direction. When spin polarized electrons stop in 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, and therefore the electron beam, the 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 as follows:

$$A=\frac{I_2^+/I_1^+ - I_2^-/I_1^-}{I_2^+/I_1^+ + I_2^-/I_1^-} \quad \text{... (1)}$$

Where $I_1^{+/-}$ is the signal from beam current monitor (BCM) and $I_2^{+/-}$ 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:

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

Where P_T is the polarization of the magnetized iron and A.P. is the analyzing power of the Compton Scattering in the target (ref. [2]).

Compton Transmission Polarimeter

The apparatus was placed after the beam dump of the Mott polarimeter. It consists of a magnet 15.24 cm long (see ref. [3] and [4]), and 10.16 cm diameter, with an iron cylinder core 12.7 cm long and 2.5 cm diameter, wrapped with ~3,000 turns of copper wire. A photomultiplier tube (PMT) with a scintillator plastic 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, the PMT records only x-rays that passed through the iron target.

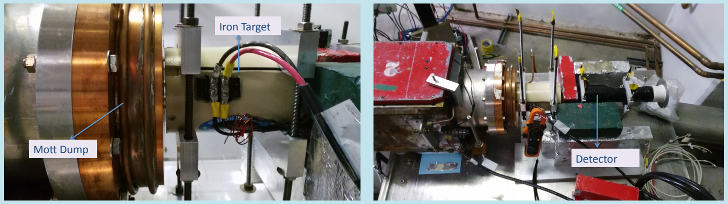

Fig. 1: Experimental arrangement aligned with the Mott dump.

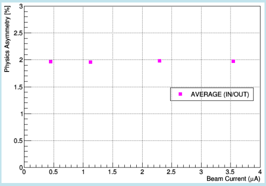

Fig. 2: Asymmetry remains constant at 2%, for different values of beam current (magnet current of 1 A).

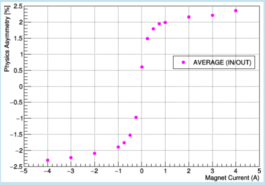

Fig. 3: Asymmetry as a function of the magnet current (beam current 2 μA).

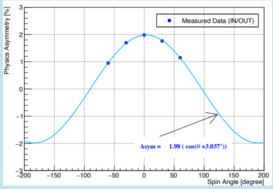

Fig. 4: Asymmetry as a function of the spin angle (magnet current of 1 A and beam current of 1.7 μA). The spin angle was changed using a Wien Filter.

Simulations

Simulations of the experiment were made with the GEANT4 program, to compare number of photons per μA 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.).

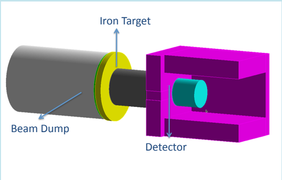

Fig. 5: Simulation of the apparatus In green and yellow are the berilium and copper components of the beam dump respectively. In gray the iron target is shown. The scintillator detector (blue cylinder) is placed inside a lead box (magenta blocks).

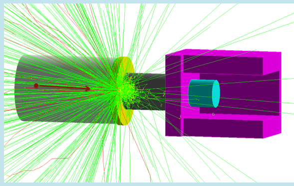

Fig. 6: 2,000 electron events, at 6.3 MeV (kinetic energy). Electrons hit the beam dump, radiation passes through the iron target, finally reaching the detector.

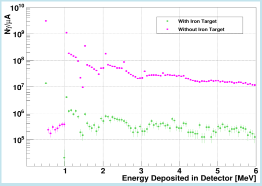

Fig. 7: Number of photons per μA as a function of the energy deposited in the detector with and without iron target.

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, and without complicated Wien filter setups, which takes time to implement.

References

[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** (2001)

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

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