Compton polarimetry for the MOLLER experiment at Jefferson Laboratory in a first of its kind of measurement

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Introduction

The Measurement of Lepton-Lepton Electroweak Reaction (MOLLER) experiment is designed to measure the parity-violating asymmetry in the scattering of longitudinally polarized electrons off unpolarized electrons. The experiment utilizes the upgraded 11 GeV beam in Hall A at Thomas Jefferson National Accelerator Facility (JLab), Virginia, USA, to achieve an overall high fractional accuracy of 2.4% [1]. Such a measurement would constitute more than a factor of five improvement in fractional precision over the only other measurement of the same quantity by the E158 experiment at SLAC [2] in 2005. The biggest contributor to the error budget of this high precision measurement is polarimetry. Here we discuss briefly the scientific considerations in the asymmetry data analysis of the Compton polarimeter in this experiment which has to deliver a precision of 0.4% in polarization [1].

Experimental Setup

The Compton polarimeter involves a magnetic chicane that turns the beam away from the main beamline [Fig. 1], a laser locked cavity where the beam electrons undergo Compton scattering with polarized green laser photons. These Compton scattered photons are backscattered into a photon detector and the corresponding electrons are detected in a state of the art diamond pixel based electron detector. Both the detectors will have different types of triggers to identify the true events including a coincidence mode. We plan to record the signals in the photon detector in integrating mode via Flash ADC. The electron detector readout will use a diamond detector that has preamplifiers built into it. It will generate LVDS that will be recorded in FPGA based readout boards. These FPGA based boards will be programmed to carry the logic to form the relevant triggers and readout the corresponding data.

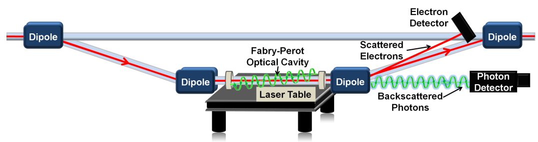

FIG. 1: Layout Compton Polarimeter Hall C JLab

Theoretical Framework

This polarimetry technique is based on a direct relativistic extension of the theoretical framework of the classical Compton effect in the Klein-Nishina formula for the differential cross section

$$\frac{d\sigma}{d\Omega} = r_0^2 \left(\frac{E'_\gamma}{E_\gamma}\right)^2 \left[\frac{E_\gamma}{E'_\gamma} + \frac{E'_\gamma}{E_\gamma} - 2\sin^2\theta\cos^2\phi\right] \tag{1}$$

where r_0 is the classical electron radius, E_γ and E'_γ are the incoming and scattered photon energies, θ is the scattering angle and ϕ is the azimuthal angle between the polarization vector of the photon and the plane of scattering. The term $\cos^2\phi$ captures the polarization dependence of the scattering cross-section. Due to this last term, the number of scattered electrons/photons vary between opposite polarization states. We then determine the polarization of the electron beam by analyzing the measured asymmetry in the scattering. The theoretical Compton asymmetry (A_0) for a given photon and electron energy is very precisely determined using well established QED calculation.

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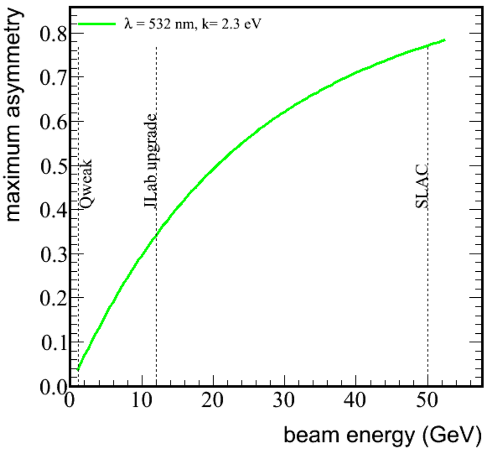

FIG. 2: Compton asymmetry with e-beam energy

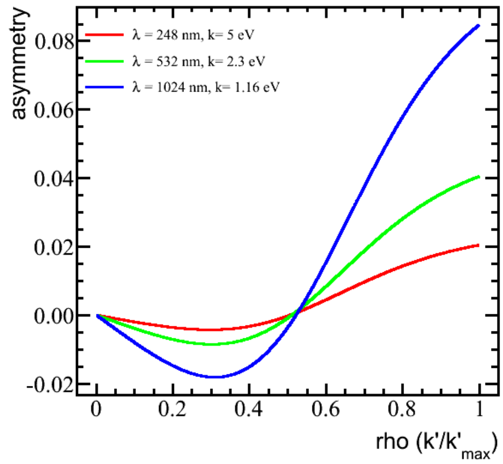

FIG. 3: Maximum asymmetry Vs laser energy

$$A_C = \frac{N^+ - N^-}{N^+ + N^-} \quad (2)$$

$$A_C = P_e P_\gamma A_0 \quad (3)$$

Preliminary and Proposed Work

The recently completed Q^P_{weak} experiment at Jefferson that attempted to measure the weak charge of proton[3] had the beam energy at 1.1 GeV leading to only a 6% asymmetry. The upgrade of JLab energy in the previous decade has in-effect increased the asymmetry close to 30% as shown in Fig. 2 for the same photon energy (green laser 2.3eV).

Fig. 4 shows the theoretically evaluated Compton yield against dummy electron detector strips. The initial few strips were turned off since in the real experiment due to beam proximity, it would have highest background. We have further shown the entire spectrum of the Compton asymmetry against the ratio of scattered photon energy in Fig. 3.

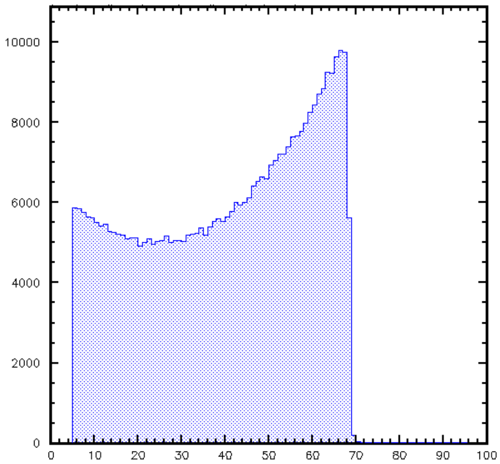

FIG. 4: Yield against detector strips

This study needs to continue to estimate several finer aspects of the polarimetry including the energy deposited on the detector, possible sources of false asymmetries, the various sources of systematic uncertainties in the measured asymmetry to ensure that we remain in the final error budget for polarization in the MOLLER experiment.

References

[1] Krishna Kumar et. at. Approved Jefferson Lab Experiment Moller. **E12-09-005**, year (2017).

[2] P. L. Anthony et al. [SLAC E158 Collaboration], Phys. Rev. Lett. 95, 081601 (2005) **95**, 081601 (2005).

[3] The Jefferson Lab Qweak Collaboration, Nature **557**, 207–211 (2018)