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A diamond micro-strip electron detector for Compton polarimetry

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Summary. — A new Compton polarimeter was installed in Hall C at Jefferson Lab, with a goal of 1% systematic and 1% per hour statistical precision. The polarimeter was commissioned during the first run period of the Q_{weak} experiment. We discuss the milestones and preliminary results obtained from the Compton electron detector which shows that we have achieved our statistical goal and are well within reach of the systematic error goal.

PACS 29.27.Hj – Polarized beams.

1. – Introduction

The precise knowledge of electron beam polarization is crucial to parity-violating experiments such as the Q_{weak} experiment currently underway at Thomas Jefferson National Accelerator Facility (Jefferson Lab). A new Compton Polarimeter was recently installed and commissioned in Hall C for a non-invasive and continuous monitoring of beam polarization. It was successfully commissioned in Dec 2010. The Q_{weak} experiment is the first experiment to use the new Compton polarimeter.

2. – Description of the Compton polarimeter

The polarimeter consists of a magnetic chicane made of four identical dipole magnets which bend the nominal electron beam such that it can interact with polarized photons from a laser source (fig. 1). The effective laser power is $\sim 1\,\text{kW}$. This is achieved using a $10\,\text{W}$ continuous-wave laser locked to a low gain Fabry-Perot cavity. At the 3rd dipole, the Compton-scattered electrons are bent more compared to the un-scattered electrons. A set of diamond micro-strip detector [1] grown by chemical vapor deposition was placed before the fourth dipole to detect the Compton-scattered electrons. The backscattered photons are detected in a lead tungstate calorimeter placed below the 4th dipole. Some parameters of the Hall-C Compton are shown in table I.

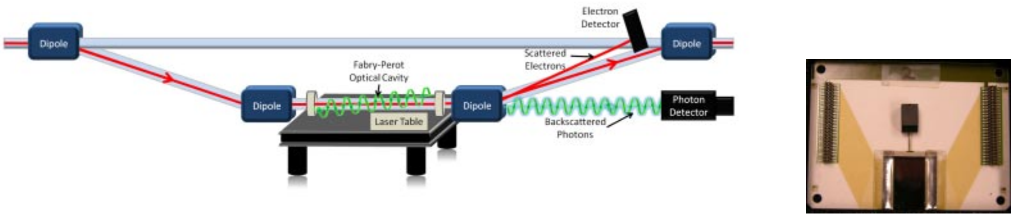

Fig. 1. – Compton polarimeter layout (left) and the diamond micro-strip detector (right).

The choice of diamond as the detector material was made due to its known property of radiation hardness. We have 4 planes of $21 \times 21 \times 0.5\,\text{mm}^3$ diamond plates, each of which have 96 strips of TiPtAu with a pitch of $200\,\mu$m. The diamond plates are mounted on alumina substrates. When a minimum ionizing particle passes through these diamond plates, they create electron-hole pairs which drift towards respective electrodes because of a bias voltage ($\sim 500\,\text{V}$). For each micro-strip the collected charge pulse is amplified, shaped and discriminated using custom electronic boards designed and built at the Tri-University Meson Facility (TRIUMF). These are the first diamond micro-strip detectors to be used as a tracking device in a nuclear and particle physics experiment.

3. – Asymmetry

When the polarized beam of electrons interacts with polarized photons, the electrons and photons with their spins aligned have a higher probability of scattering compared to that of anti-parallel spins. Thus the scattering has an asymmetry between the two helicity states.

The asymmetry can be determined as: $A = \frac{N_q^+ - N_q^-}{N_q^+ + N_q^-}$, where N_q^+ and N_q^- are the number of background subtracted positive and negative helicity events normalized by the net charge associated with these events. The background events are calculated by periodically turning off the laser. We have explicitly checked the asymmetry for laser off data and found it to be consistent with zero.

4. – Polarization

Based on the parameters of our polarimeter setup, the Compton edge for the calculated Compton asymmetry is fixed at 17.6 mm from the nominal beam. Each of the strips acts as an independent detector giving a measurement of asymmetry. The knowledge of strip number on the detector is translated into momentum of the scattered electrons

TABLE I. – *Table of relevant parameters for Hall-C Compton.*

Nominal beam energy	1.16 GeV
Laser wavelength	532 nm
Chicane bend angle	10.1 deg
Max. electron displacement	17.6 mm
Max. scattered photon energy	46 MeV

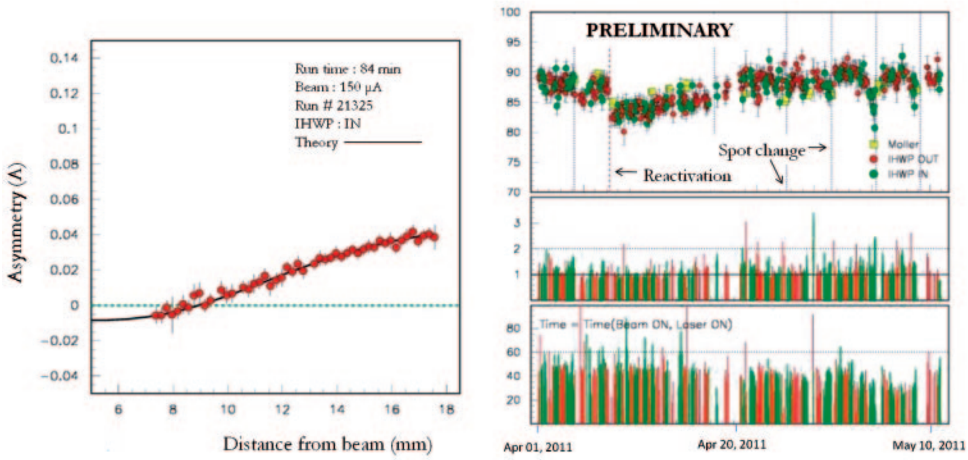

Fig. 2. – The measured Compton asymmetry (left). The measured polarization as a function of time (right, top). The dashed and dotted lines represent various events such as reactivation and change of spot in the photo-cathode of the polarized electron source. The error bars represent the statistical and preliminary systematic uncertainty added in quadrature. The value of the statistical uncertainty (right, middle) and the time interval of each data point (right, bottom) is also shown.

which in turn gives the measured asymmetry as a function of scattered electron momentum. Using the known laser polarization, the electron beam polarization is extracted by performing a two-parameter fit of the measured asymmetry with the well known shape of the theoretical Compton asymmetry as a function of electron momentum. The two parameters used are the electron beam polarization and a strip-pitch parameter to account for any geometrical mis-alignment of the detector with respect to beam. The Compton asymmetry as a function of distance from the nominal beam along with the fit to the theoretical calculation is shown in fig. 2 (left).

The experimental data were collected in runs which typically lasted an hour. The right top panel of fig. 2 shows the measured beam polarization over a 42 day period of the Q_{weak} experiment. The average beam current for the period covered in the plot was about $160\,\mu$A. Each data point represents an hour long run. We achieve 1% statistical error in less than an hour. The displayed errors show only a subset of systematic errors involved, and include contributions from the laser polarization, finite strip-width, absolute value of the magnetic field and the inter-plane variation of the extracted polarization, with the largest contribution due to laser polarization (0.4%). Additional sources of systematic errors are under investigation.

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