THE MIT-BATES COMPTON POLARIMETER FOR THE SOUTH HALL RING *

W. A. FRANKLIN for the BLAST COLLABORATION

MIT-Bates Linear Accelerator Center,
P.O. Box 846,
Middleton, MA 01949, USA
E-mail: wafrankl@mit.edu

Storage ring experiments with polarized electrons require a nondestructive mechanism for measuring the beam polarization. During a series of experiments with 850 MeV polarized electrons at intensities up to 175 mA, the MIT-Bates Compton Polarimeter has provided precise beam polarization data on a continuous basis. An overview of its design is presented in this paper, emphasizing features developed for intense low-energy beams. The polarimeter has been combined with a dynamic spin flipper and other consistency checks to minimize systematic errors. Preliminary polarization results are shown and discussed.

MIT-Bates has an ongoing research program to study comprehensively nucleons and light nuclei at low momentum transfer ($Q^2 < 1$ GeV)[1]. In these experiments, intense beams of electrons at 850 MeV circulating in the South Hall Ring (SHR) are incident on a thin internal target of polarized hydrogen or deuterium produced by an atomic beam source[2]. The Bates Large Acceptance Spectrometer Toroid (BLAST) is used to measure double polarization asymmetries for several reactions. BLAST contains a symmetric set of detectors, subtending scattering angles from $20° < \theta_{lab} < 90°$ in the horizontal plane. The symmetry and large acceptance of the spectrometer permits the extraction of nucleon form factor ratios without independent measurements of the absolute beam or target polarization. Nevertheless, in order to maximize the electron beam polarization, a fast reliable polarimeter is essential

Compton polarimetry is a technique which utilizes the well understood spin dependence of the electromagnetic interaction. In the lab frame, low

*This work is supported by the U. S. Department of Energy under Cooperative Agreement BEFC294ER40818.

energy photons from a laser beam interacting with a highly energetic electron beam predominantly scatter in the direction defined by the electron momentum, *i.e.* backwards. Typically, the scattered photons receive a substantial energy boost allowing detection by a compact gamma ray detector. Varying the circular polarization of photons yields an asymmetry as a function of energy in the detected photon spectra which is dependent on the longitudinal polarization of the electron beam.

Compton polarimetry was initially established as a viable method of polarimety at multi-GeV energy machines[3]. Although the analyzing power for Compton scattering (A_{pol}) can be very large in this regime, it falls to a few percent for electron energies below 1 GeV. Additionally, in low-energy experiments, the maximum kinematically allowable energy for scattered photons (the Compton edge) is low compared to the maximum bremsstrahlung energy, making separation of the signal from background difficult. The typical SHR beam lifetime is approximately 30 minutes, necessitating optimization of the signal to achieve a statistically precise measurement for each ring fill.

The design of the MIT-Bates Compton Polarimeter was influenced heavily by the NIKHEF Compton polarimeter[4], the first device to operate in an electron storage ring at energies below 1 GeV. The Bates polarimeter is located upstream of the BLAST target to minimize bremsstrahlung background with a small correction made to account for spin precession between the polarimeter and the target. The apparatus includes a solid-state 5 Watts laser with an optical transport system designed to preserve polarization of 532 nm light. A set of remotely controllable mirrors permit the laser to intercept the electron beam at a crossing angle of less than 2 mrad. Scattered photons are detected with a pure CsI calorimeter chosen for its combination of energy and time resolution.

A number of provisions have been made in the experimental apparatus and data acquisition (DAQ) system to facilitate high-intensity operation. A movable lead collimator defines an azimuthally symmetric acceptance for the backscattered photons to minimize background from beam halo. The calorimeter is equipped with a photomultiplier tube and base engineered for linear operation at very high rates, although saturation does occur at the highest SHR intensities. To circumvent this problem, a set of variable thickness stainless steel absorbers was installed to attenuate the photon flux in a manner nearly independent of energy and insensitive to photon polarization. Typical photon rates in the calorimeter are of the order of 100 kHz necessitating a DAQ processor with high readout and sorting speed.

The DAQ system was locally developed and features an externally triggered 12-bit flash ADC with pulse sampling capability at 100 MHz for pulse-shape discrimination and pile-up rejection. The DAQ system is synchronized with the BLAST event stream and integrated with the BLAST analysis.

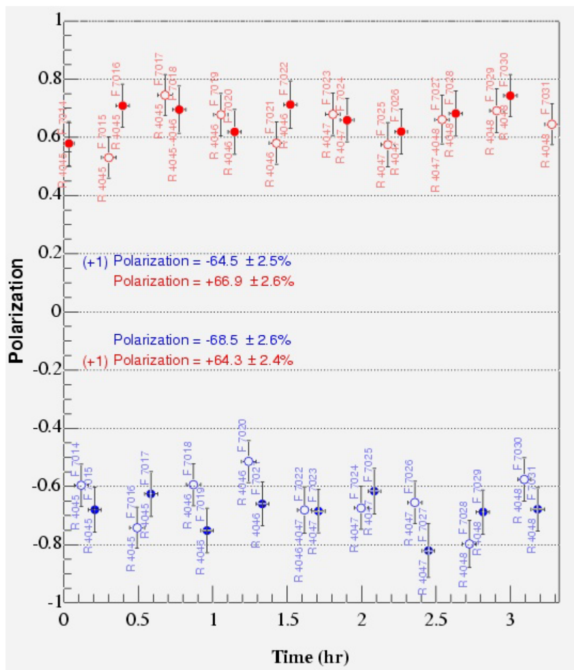

Figure 1. Preliminary polarization measurements in the SHR.

Data analysis involves conversion of raw ADC spectra to helicity-based asymmetries. The energy calibration of the calorimeter is monitored continuously by tracking the position of the ADC pedestal and the Compton edge. The analyzing power for the polarimeter has been calculated using a detailed GEANT simulation of the apparatus. The polarimeter provides results for each SHR storage cycle with a typical precision of $\Delta P \approx .04$ for a fifteen minute fill.

Figure 1 shows the extracted polarization as a function of time for a representative set of data over a period of a few hours. The direction of the beam polarization at injection is reversed on each time the SHR is filled. The beam polarization can also be adiabatically reversed while the beam is stored by ramping the driving frequency of a spin-flipping RF dipole[5] through a depolarizing resonance of the SHR. This highly efficient device is helpful in constraining instrumental asymmetries resulting from effects such as helicity-correlated steering effects in the laser transport system. In Fig. 1, dark circles represent measurements of the initial polarization in the SHR, while open circles denote measurements following operation of the spin flipper. The average SHR beam polarization in 2004 is 0.66 with the results displaying a gaussian profile.

Table 1. Estimated systematic uncertainties for the MIT-Bates Compton Polarimeter.

Systematic Uncertainty Contribution	ΔP
A_{pol}	0.03
Pile-up	0.01
Beam alignment and PITA	0.02
Laser circular polarization	0.01
Spin precession uncertainty	0.01
Total	0.04

Long term uncertainties in the beam polarization are dominated by systematic uncertainties in the polarimeter. Results have been compiled into a database for the BLAST experiment allowing a detailed look at systematic behavior of the device. Consistency checks including comparisons to low-energy polarization measurements in the polarized source and variation of the polarization angle upon injection into the SHR are also used to assess the overall accuracy of the instrument. Table 1 provides a preliminary estimate of the error contributions form various sources to the overall level of systematic uncertainty. Much of the uncertainty results from uncertainties in modeling the analyzing power of the device, a quantity which is still being improved. Overall systematic error control and calibration uncertainty meet the levels required for completion of the BLAST program.

References

1. C. Crawford, A. Maschinot, and V. Ziskin, in these proceedings.
2. E. Tsentalovich, in these proceedings.
3. D. Barber et. al., *Nucl. Instr. and Meth.* **A329**, 79 (1993).
4. I. Passchier et. al., *Nucl. Instr. and Meth.* **A414**, 446 (1998).
5. V. Morozov et. al., *Phys. Rev. ST Accel. Beams* **4** 104002 (2001).