POLARIZED ELECTRONS IN THE MIT-BATES SOUTH HALL RING

T. Zwart, T. Akdogan, K. Dow, M. Farkhondeh, W.A. Franklin, H. Kolster, E. Ihloff, K. Jacobs, J.B van der Laan, J.L. Matthews, S. Sirca, T. Smith, C.Tschalar, E. Tsentalovich, W. Turchinetz, J. Vriegg, F. Wang and V. Ziskin
MIT-Bates Linear Accelerator Center, Middleton, MA, 01949, USA
E.C. Booth, Boston University, Boston, MA 02215, USA
V.A. Anferov, B.B. Blinov, A.D. Krisch, W. Lorenzon, V.S. Morozov, C.C. Peters and K. Yonehara,
Spin Physics Center, University of Michigan, Ann Arbor, MI, 48109-1120, USA
Y.M.Shatunov, Budker Institute for Nuclear Physics, Novosibirsk, Russia
E. Six, Arizona State University, Tempe, AZ, 85287, USA

Abstract

The MIT-Bates facility is pursuing a vigorous spin physics program in its 1 GeV electron storage ring. The combination of polarized beams, polarized internal targets and a large acceptance spectrometer will allow world class measurements of important nuclear physics quantities including G^N_E and T_{20}. Toward this end we have constructed and installed a Siberian Snake to preserve longitudinal electron polarization at the internal target, a laser back-scattering Compton polarimeter to accurately measure the stored electron polarization and an RF coil for resonantly flipping the electron spin which will provide an important systematic check of all measured polarization dependent asymmetries. The status of the stored polarized beam and results from all these polarization handling devices are presented below.

1 SIBERIAN SNAKE

The MIT-Bates South Hall Ring (SHR) is shown in Fig. 1. The Bates Large Acceptance Spectrometer Toroid (BLAST), now under construction, surrounds the internal target and is located in the South Hall. On the far side of the ring, also indicated in Fig. 1, a Siberian Snake [1] [2] has been installed. This device serves to maintain longitudinal electron polarization at the internal target for electron energies up to 1.1 GeV. The optics of the Snake was designed by the Budker Institute of Nuclear Physics which also constructed the two superconducting solenoid magnets at the heart of the device. The optics of the entire Snake insertion is very similar to a space free of magnets and therefore the optical properties of the SHR are transparent to whether or not the Snake is powered on. This Snake scheme requires a longitudinal field integral of 10.5 Tm/GeV/c. The two 0.8 m superconducting solenoids therefore have peak fields in excess of 7 Tesla. The Snake has been installed, energized and tested with beam in the SHR in January of 2001. In all respects it performed to specifications. Fig. 2 shows the decay of the electron current at a beam energy of 669 MeV. The lifetime of 1000 s and peak current of 100 mA are more

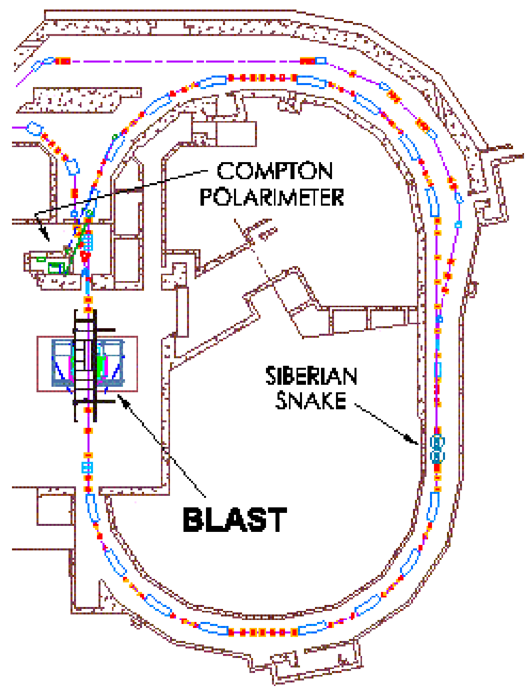


Figure 1: The MIT Bates South Hall Ring

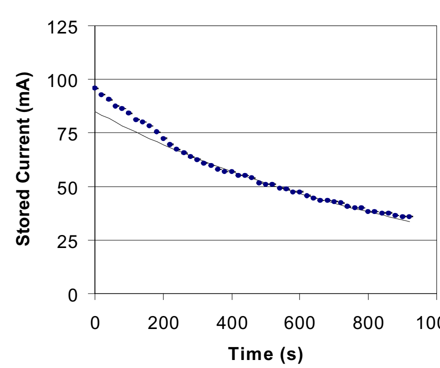
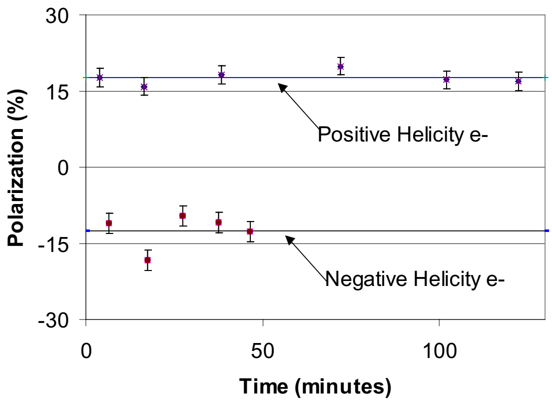


Figure 2: Stored electron current as a function of time. The Siberian Snake was on and the beam energy was 669 MeV for this measurement.



Figue 3: The measured polarization as a function of time the 669 MeV beam was stored in the SHR. The two data sets are for positive and negative helicity electrons.

than adequate for the luminosity requirements of the upcoming BLAST physics program. In addition the polarization lifetime was measured at this energy. The injected polarization was somewhat low for this run, because the spin transport into the ring was not optimized, P_e ~15%. Despite this, it is clear from Fig. 3 that the Snake served to preserve the polarization much longer than our ability to store the beam.

2 COMPTON POLARIMETER

These polarization measurements which demonstrated the performance of the Snake were made as part of the commissioning of the SHR laser back-scattering Compton polarimeter. The technique of laser back-scattering is well established at other facilities [3] [4]. However the energy of the SHR, ~1 GeV, presents some technical challenges for accurate measurements of the polarization. The chief difficulty is the small size of the analyzing power, ~2%, at its maximum.

We selected a Coherent 5W Verdi laser at 532 nm for the polarimeter. This laser has only half the power of readily available large frame ion lasers at 514 nm, but its superior amplitude and pointing stability have made it an excellent choice. Of the 5W of power available from the laser, greater than 3W was delivered to the interaction region. Laser on back-scatter rates of 4 kHz/mA/W were measured and therefore at typical currents of 50 mA and 3W laser power detector rates exceeded 600 kHz and calorimeter response and data acquisition dead time became the main obstacles to improved polarimeter performance.

At 669 MeV and 532 nm laser wavelength the Compton back-scattered photon spectrum is approximately flat up to the 16 MeV endpoint. A pure CsI crystal was selected for its fast resolving time, <100ns, and reasonable light output. We obtained ~1.5 MeV resolution at the 16 MeV Compton endpoint. The choice of polarimeter location upstream of the BLAST target (Fig. 1) was motivated by the desire to avoid the large Bremsstrahlung flux which will be produced in the internal target region.

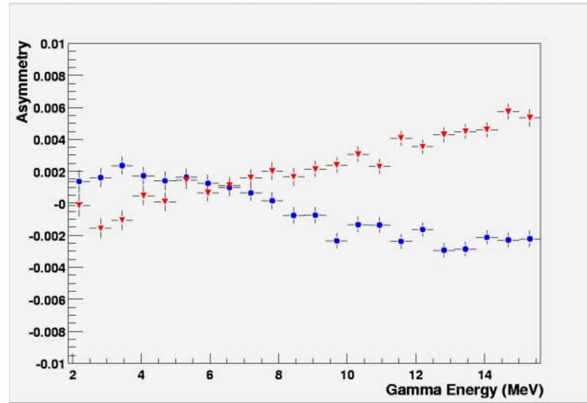


Figure 4: The measured Compton asymmetry for two opposing electron helicity sates injected into the SHR. Note the slightly positive offset in the crossing point at 6 MeV indicating a 10^{-3} false asymmetry.

Fig. 4 shows a measured polarization asymmetry as a function of back-scattered photon energy for two opposing electron helicity states injected into the SHR. The clear reversal in the measured asymmetry is evident as is the expected zero crossing near 6 MeV. The polarization extracted from this asymmetry is only ~25%. This was due to two main factors, the use of a bulk rather than a strained GaAs photocathode and a mismatch between the orientation of the injected polarization and the closed spin orbit.

Given the small size of the analyzing power, care must be taken to eliminate or reduce as much as possible any helicity correlated electronic signals or unmeasured luminosity asymmetries which will produce a false polarization asymmetry. The offset in the vertical mirror symmetry of Fig. 4 shows that false asymmetries have been reduced to the 10^{-3} level, unfortunately still 20% of the measured asymmetry. Plans are underway to reduce these effects by at least one additional order of magnitude by eliminating spurious helicity correlations in the laser transport and in electronic cross talk.

3 SPIN FLIPPING

Once the Compton polarimeter had demonstrated a clear measured asymmetry it was pressed immediately into service to test the performance of a preliminary spin flipping device. Such a flipper will allow rapid reversals of the electron polarization which will provide important systematic checks of measured asymmetries in BLAST. This RF flipper was constructed by the University of Michigan's Spin Physics Center who have extensive experience with proton spin flippers at IUCF. [5]

The installation of a Siberian Snake in the SHR causes the electron polarization to precess about a stable spin direction, the "closed spin orbit" (more precisely "the invariant spin field") with a frequency, ν_s , equal to half the revolution frequency, in the case of the SHR,

$$\nu_{spin} = \frac{1}{2}\nu_{rev} = 788 \text{ kHz} \quad . \qquad (1)$$

By perturbing the spin motion with a small rotation at a frequency that ramps slowly across the spin resonance the polarization can be adiabatically reversed in a technique analogous to that used in Magnetic Resonance Imaging.

The Michigan group built an RF tank circuit and used an existing single turn coil located just downstream of the BLAST location (Fig. 1) to create an RF dipole field of rms amplitude 0.07 Tmm at 750 kHz. The ratio of the final to initial polarization, P_f/P_I, is given by the Froissart-Stora formula [6],

$$\frac{P_f}{P_i} = 2\exp\left(-\frac{(\pi\varepsilon f_c)^2}{\Delta f / \Delta t}\right) - 1 \quad , \qquad (2)$$

where ε is the strength of the resonance, directly proportional to the strength of the RF coil.

Fig. 5 shows the measured final polarization as a function of ramp time for a fixed frequency sweep between 786 and 788 kHz. The data is fit to equation 2, modified only by a decaying exponential which reflects other weaker depolarizing resonances encountered during the RF scan. The calculated spin flip efficiency is 84%. This work will soon be published by the Michigan group in greater detail. [7]

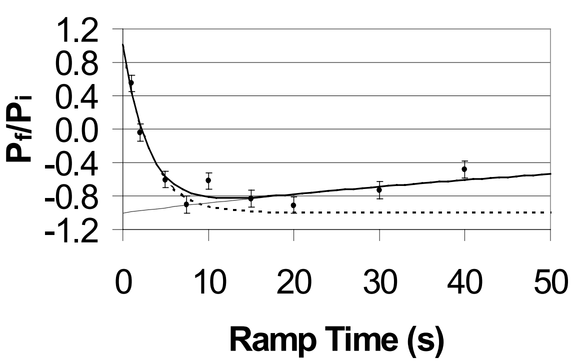


Figure 5: Shows the measured ratio of the final to initial polarization and a fit to the Froissart Stora Formula.

4 CONCLUSIONS

These successes with polarized beams in this SHR are promising for the BLAST physics program which is scheduled to begin in early 2002. At the electron source higher polarization cathodes, P ~70%, have been tested and will be used in upcoming runs. Improvements are also planned for the polarimeter data acquisition system to better reject pile-up at high rates.

In addition to preparing for BLAST physics, the behavior of polarized electrons in storage rings is interesting in its own right. A BNL group has recently proposed installing a resonant cavity polarimeter [8] and there is interest elsewhere in the accelerator community to pursue a measurement of the “kinetic polarization” which is best observed with a Siberian Snake at electron energies near 1 GeV. [9] This could provide an important test of the accuracy of spin tracking codes codes used at other laboratories.

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