BATES SOUTH HALL RING COMMISSIONING FOR INTERNAL TARGET EXPERIMENTS *

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Abstract

In 2003, the installation and commissioning of the Bates Large Acceptance Spectrometer Toroid (BLAST) came in its final state. The South Hall Ring (SHR) commissioning has been dynamically integrated in this process to provide high quality electron beams under BLAST experimental conditions. The design goal of 80 mA stored high polarization beams is met routinely. Results of beam development for the BLAST commissioning runs in 2002 and 2003 are presented. New developments in beam diagnostic and spin manipulation are also presented.

INTRODUCTION

The commissioning of the BLAST spectrometer and the Internal Target (IT) physics program at Bates started in the spring of 2002 and continued through December. The commissioning resumed in April 2003, is nearing completion and the first measurement of physics asymmetry in e-p elastic scattering with polarized beam and polarized target is beginning. At 850 MeV, stored current of 140 mA peak is routinely achieved. The vacuum in the ring has continuously improved through synchrotron radiation, resulting in lifetimes of 50 minutes.

Longitudinal beam polarization at the IT is maintained with a Siberian snake spin rotator. For the first time, strong depolarization effects caused by non-linear spin resonance were observed and the vertical betatron tune was adjusted accordingly to avoid these resonance lines for maintaining full polarization. The high (~70%) polarization from the polarized source is then preserved during the lifetime of the beam. In collaboration with the University of Michigan, a spin flipper with a high flipping efficiency was installed and commissioned [1]. New developments of beam diagnostics, spin manipulation and polarized electron injector are presented.

SOUTH HALL RING

Figure 1 schematically shows the South Hall Ring with the BLAST IT area marked. On the opposite side of the BLAST area in the ring, a 180-degree Siberian snake fully preserves the longitudinal electron polarization at the IT region. A laser backscattering Compton polarimeter located upstream of the IT area measures beam polarization continuously [2]. An RF-driven spin flipper downstream of the IT area provides the capability for multiple reversal of the electron spin during each storage cycle. An atomic beam source (ABS) has been incorporated into the BLAST IT area for providing windowless high purity polarized hydrogen and deuterium targets for e-p and e-d nuclear scattering. The ABS system is now fully operational with the presence of the BLAST magnetic field. . These results were obtained with a 15 mm diameter and 40 cm long IT storage cell and with the presence of both the BLAST magnetic field and the ABS magnetic holding field. Two sets of slits are used to minimize beam halo and experimental backgrounds as indicated by the particle tracking wire chamber systems in BLAST. This beam optimization was further developed with signals from a set of 4 beam quality monitors (BQM) consisting of phototubes symmetrically positioned around the beam pipe immediately downstream of the IT area. A strong correlation was shown between this signal and the signal to noise ratio in the wirechambers.

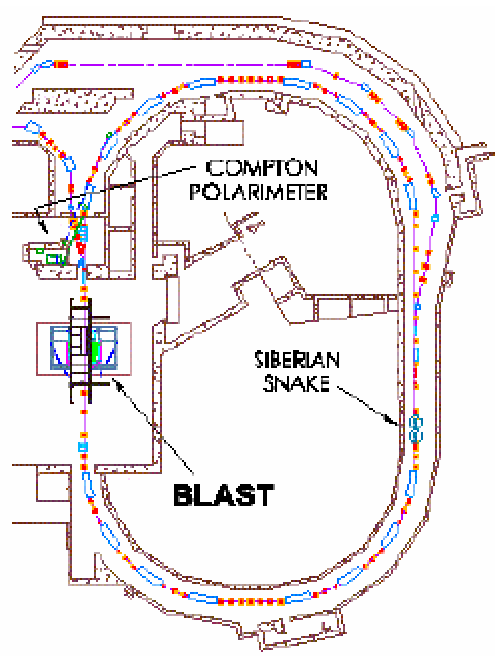

Figure 1: The Bates South Hall Ring with internal target area (BLAST)

BEAM CURRENT AND LIFETIME

The design goal of the BLAST experiments requires an average current of 80 mA and lifetimes longer than 30 minutes. These goals were met in the 2002 commissioning period. The peak stored current was 150 mA, with the snake magnets on and the target cell in.

The installation of the ABS at the IT area and a small aperture spin flipper in the fall of 2002 limited the maximum stored currents to below 100 mA. Ion trapping and possible multi-bunch instabilities intensified inferior vacuum conditions and deterioration of the ring impedance was considered as the primary causes of the lower stored currents for that period.

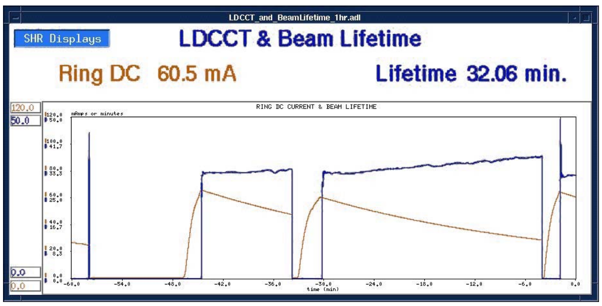

Figure 2: Typical fills for the experiment commissioning.

During the 2002 winter shutdown for ABS tests, the extraction septum magnets were removed to improve vacuum and impedance in that region. This resulted in a significant increase of maximum storage current from 150 mA to more than 200 mA. The maximum current was further increased to 300 mA by overcompensating the negative horizontal chromaticity. These high current results were obtained with the presence of the full magnetic fields of the Siberian snake and BLAST and the ABS holding field. An operational upper limit of 150 mA was put in effect to prevent damaging the synchrotron radiation monitor view ports from unprecedented radiation power for this ring and to provide practical long lifetimes for the present BLAST runs. Vacuum conditions are not yet optimal, but will improve gradually over time with more integrated charge in the ring. Typical ring filling cycle and beam lifetime are shown in figure 2.

BEAM POLARIZATION

The operating betatron tune was originally set to suppress vertical beam oscillations caused by ion trapping [1]. The Compton polarimeter beam polarization studies in 2002 revealed the presence of depolarization effects at high stored currents. Detailed study of polarization and betatron tunes indicated depolarization effects caused by non-linear spin resonances. The depolarization occurs only when beam current reaches a certain threshold that causes a significant enlargement of the beam size. A "safe" betatron tune operation zone is then chosen, to avoid both spin and betatron resonances. The margins in the resonant free area should be adequately large to accommodate both tune shifts and spreads in the operating current range. Under these conditions, full longitudinal polarization can then be maintained with the Siberian snake at currents well above 50 mA.

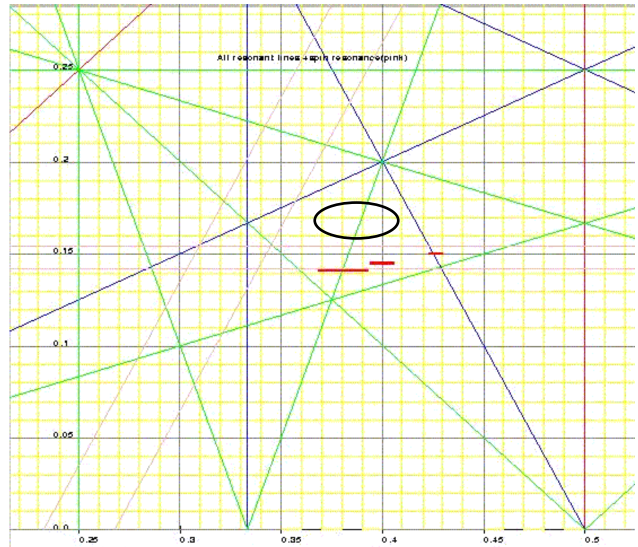

Figure 3: Tune diagram. The Oval area is the operating set point that maintains full polarization at high maximum currents and good lifetimes.

The resonances lines are defined by $3\nu_y + \nu_s = 0.5$, $3\nu_y + 2\nu_s = 0.5$ and $2\nu_x - \nu_y +/- \nu_s = 0.5$ respectively and are seen in Figure 3 below and left of the marked oval area. Our operating tune point is located between the betatron and spin resonance lines, the oval area in Figure 3. The indicated lines just below that area are the points where a drop in polarization was observed. Figure 4 shows the polarization for different vertical tune set points.

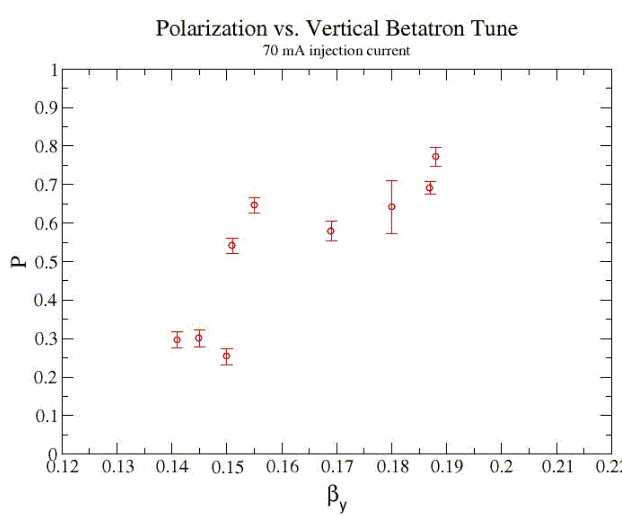

Figure 4: Measured beam polarization as a function of the vertical betatron tune.

Further study of non linear spin resonant and its effects on beam polarization is underway.

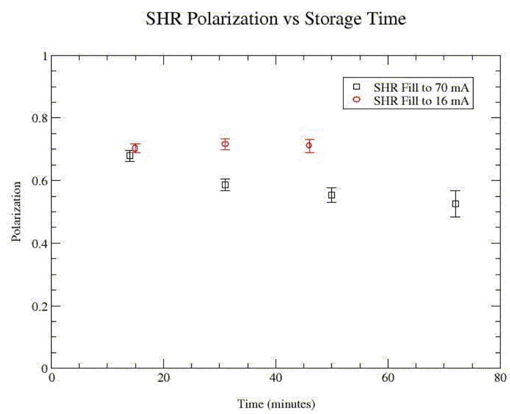

Figure 5: Polarization during a fill. A good tune working point ensures conservation of the polarization for a long enough time for the experiment (>~ 10 minutes)

BEAM DIAGNOSTIC AND SPIN FLIPPER IMPROVEMENTS

Tune measurement

An electrical betatron oscillation driver is used for measuring the beam tune on a 3 GHz spectrum analyzer. With this setup, at currents higher than about 80 mA, it becomes increasingly difficult to accurately measure the horizontal betatron tune. A frequency scanner in combination with an RF amplifier used on a ion clearer generates much better frequency response from the beam. The beam size is monitored by imaging synchrotron light on a CCD camera with framegrabber. Maximum changes in beam size of up to 100 µm were observed during a non-destructive frequency scan through the betatron resonance of the beam that has a 1 mm diameter. Work is in progress to develop a method for reproducible and routine measurements of the betatron tune.

Spin flipping

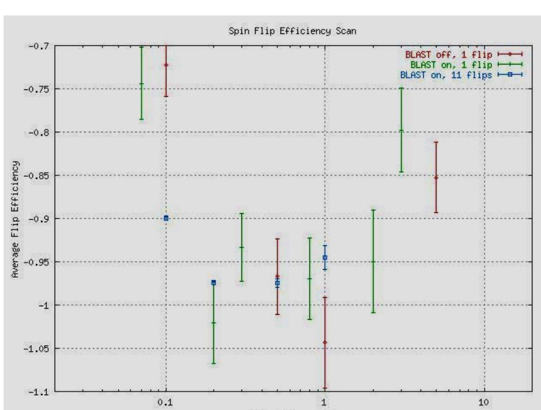

Figure 6: Polarization after a spin flip. Data are taken with and without the magnetic field from the BLAST toroid. The polarization of the data point with the smallest error bar was measured after 11 consecutive spin flips.

Spin flipping was demonstrated in the South Hall Ring in 2001 [1]. A new RF dipole with an impedance matched aperture has been built and tested. The spin direction can be reversed with an efficiency of greater than 99%. (Figure 5)

PRE-PREBUNCHER

The high stored currents in the ring are achieved by stacking multiple 1-2 mA pulses from the linac. However higher injection currents may have the advantages of both a shorter fill time and a higher stored peak current. This will particularly impact at low energies where high repetition rate injections are not be feasible .
The maximum available peak current from the polarized source is constrained by the effective Quantum Efficiency of the photocathode and the maximum laser power. When the maximum peak current from the source falls below the required peak current, the photocathode is heat cleaned and activated during which no beam is available .
The standard design of the S-band Bates linac with chopper - prebunch cavities combination has a capture efficiency of about 1/3 from the source to the linac. Any improvement in this capture efficiency leads to an increase in the duration between activations.
An additional prebunching cavity has been built and installed. PARMELA calculations show an increase of the capture efficiency from 33% to 58%. At present, 50% efficiency has been reached, as shown in Figure 8.

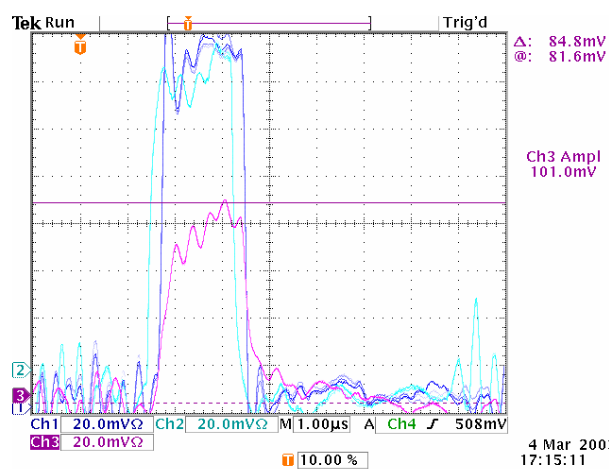

Figure 8: Peak currents at the polarized source, the chopper, and at the end of the linac. As seen there are no losses up to the chopper, and capture efficiency is 50%.

REFERENCES

[1] V.S. Morozov et al. PRST Ab 4, 104002 (2001)
[2] G.T. Zwart et al. IEEE Proc. PAC2001, 3597