COMMISSIONING RHIC'S ELECTRON LENS *

X. Gu#, Z. Altinbas, M. Anerella, D. Bruno, M. Costanzo, W.C. Dawson, A.K. Drees, W. Fischer, B. M. Frak, D.M. Gassner, K. Hamdi, J. Hock, L.T. Hoff, A.K. Jain, J. Jamilkowski, R. Lambiase, Y. Luo, M. Mapes, A. Marone, C. Mi, R. Michnoff, T. Miller, M. Minty, C. Montag, S. Nemesure, W. Ng, D. Phillips, A.I. Pikin, S.R. Plate, P. J. Rosas, J. Sandberg, P. Sampson, L. Snydstrup, Y. Tan, R. Than, C.W. Theisen, P. Thieberger, J. Tuozzolo, P. Wanderer, and W. Zhang

Brookhaven National Laboratory, Upton, NY 11973

Abstract

In the 2013 RHIC polarized-proton run, it was found that the intensity of the RHIC bunch had reached a limit due to the head-on beam-beam interaction at intensity of $2x10^{11}$, as we expected from our simulations [1]. To overcome this limitation, we have planned to implement two electron lenses for beam-beam compensation. During and after the 2013 RHIC run, some e-lens systems were commissioned. The effect of the e-lens warm solenoids on the protons orbit was observed and corrected by orbit feedback. The blue electron-lens system was fully tested, except for the superconducting magnet; the electron beam was propagated from the gun to the collector, and most of the instrumentation for the blue e-lens was commissioned. The straightness of the superconducting solenoid #2 field was measured for the first time. The installation of the yellow e-lens system and two superconducting magnets are underway.

INTRODUCTION

Figure 1 schematically depicts the layout of the electron lens that was used during the 2013 run (A), and will be implemented for the upcoming 2014 run (B).

During the 2013 run, all e-lens warm magnets [2, 3] were ready and tested with proton beam; we placed the superconducting solenoid #1 on the yellow e-lens side and replaced the blue superconducting solenoid with a spare EBIS superconducting solenoid, which was operated at 3T. We tested the blue e-lens system with the electron beam.

For the 2014 run (Figure 1 B), the yellow e-lens system will also be available and the two e-lens systems will be ready for commissioning.

For commissioning the e-lens during the 2013 255 GeV polarized proton run, we first commissioned a new e-lens lattice [4]; then, we studied the effects of e-lens magnetic field on the proton beam with the e-lens warm solenoids. We found that when the currents from the warm solenoids were ramped up, there were some effects on the beam

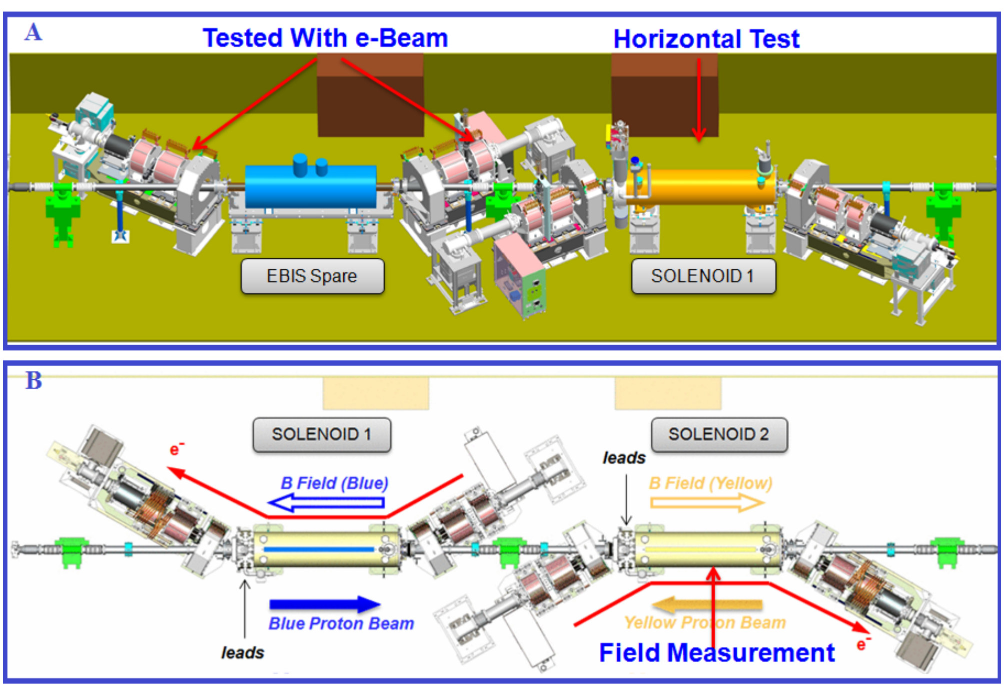

Figure 1: Schematic depictions of the layout of the electron lens during the 2013 run (upper) and the 2014 run (lower).

* Work supported by Brookhaven Science Associates, LLC under Contract No. DE-AC02-98CH10886 with the U.S. Department of Energy
#xgu@bnl.gov

vertical orbit; we can correct this distortion by beam feedback. There were no apparent effects on beam loss, or on the beam intensity, emittance, or luminosity.

We also tested some instrumentation and applications for single-bunch beam-beam compensation during the 2013 polarized-proton run. Two BPMs were commissioned for the proton beam and electron beam.

For commissioning the blue e-lens, we propagated the electron beam through a system with a 3T EBIS spare superconducting-magnet. The properties of the cathode and the profile of the beam were measured with both a pinhole scanner and a YAG screen. The beam profile has Gaussian distribution. The modulator was commissioned with the 80 kHz and the DC beam for 14 and 9.5 hours respectively.

To further investigate the e-lens system reliability and make it more robust, several scenarios of system failure also were undertaken, such as Machine Protection System failure.

MAGNET EFFECTS DURING PROTON STORE

During the 2013 polarized proton run, we tested the e-lens warm solenoids with a proton beam. According to our simulation [5], the orbit of the proton beam is affected by the e-lens warm solenoids, especially in the vertical plane.

Figure 2 shows the distortion of the proton beam during the ramp-up of the e-lens warm solenoids with the orbit feedback on.

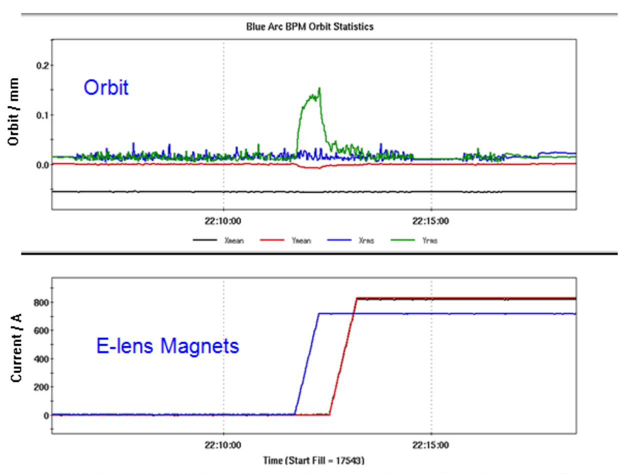

Figure 2: The vertical orbit rms with orbit feedback (top, in mm) and the warm magnet currents (bottom, in A).

The green (Yrms) trace in Figure 2, top, shows that the vertical beam rms position changes (~0.15mm) when the e-lens warm solenoid is ramped up even with the orbital feedback on, but recovered subsequently. A change in the orbit feedback parameters later reduced this effect. The effects on the horizontal plane were less.

Although e-lens warm magnets have some effects on the proton orbit, Figure 3, it is hard to discern any visible effects on RHIC luminosity.

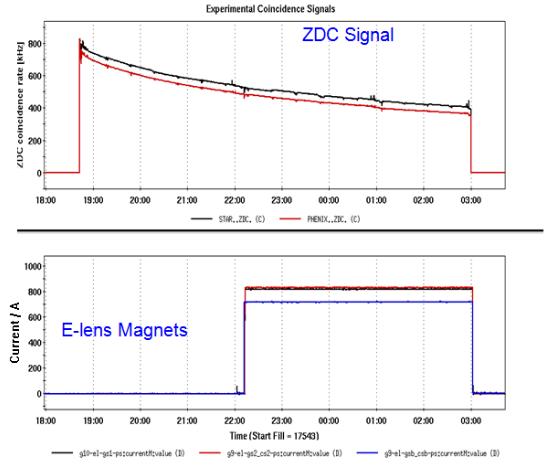

Figure 3: E-lens magnets current (bottom, in A) and luminosity (top).

ELECTRON BEAM COMMISSIONING

The blue e-lens system was fully commissioned with the help of the EBIS spare superconducting magnet, including the electron gun [6] and the collector. Figure 4 shows the perveance measurement of electron gun, which is 1.0×10^{-6} $AV^{-3/2}$.

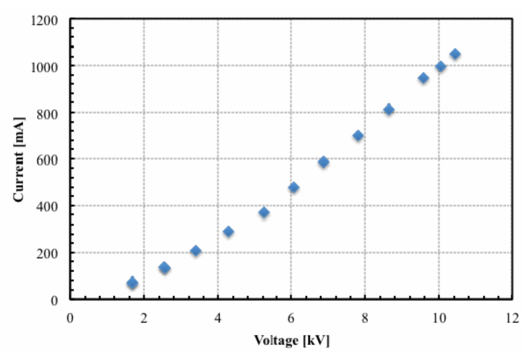

Figure 4: Perveance measurement of the electron gun.

We fully tested the electron beam running modes, and also demonstrated the system reliability. We ran the DC beam (1.256A) and the 80 kHz (parasitic) beam, respectively, for 9.5 hours and 14 hours; they were stopped intentionally for another test.

Figure 5 illustrates the 14 hour test of the 80 kHz electron beam. The bottom plot is the vacuum in the collector, which indicates that electron current was available in the collector; the upper plot, the anode voltage, denotes that the beam current was constant.

We also measured the electron beam profile with a YAG screen and a pinhole scanner [7]. Figure 6A shows the YAG profile for a 70 mA beam; Figure 6B shows the profile measured by the pinhole scanner for 1150 mA beam. The profile is Gaussian, with a small flat top, similar to the profile from the test bench [8, 9]. The total beam radius is 2.76 rms widths; the model yielded a value of 2.8.

ISBN 978-3-95450-138-0

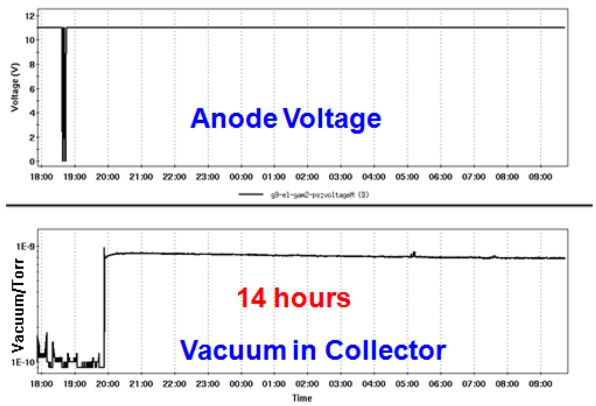

Figure 5: 80 kHz modulator test with more than a 1A beam.

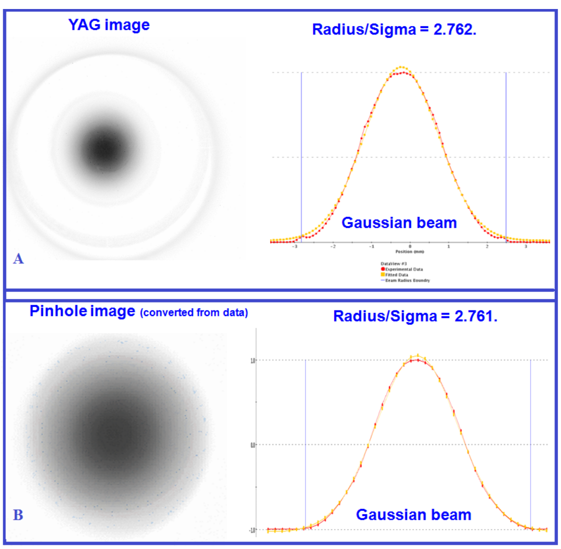

Figure 6: YAG screen (A) and pinhole (B) profile measurements of the electron beam.

E-LENS SUPERCONDUCTING MAGNETS

Two e-lens superconducting magnets were also tested. A horizontal test was done for both solenoid #1 and #2. With only 2 quenches, solenoid 1 reached 5 T. Solenoid #2 reached about 5.5 T. Both magnets have reached 6 T in a vertical test, and are expected to reach 6 T in the cryostat with further training quenches.

Figure 7 shows our measurements for the field straightness test at 2.83 T for solenoid #2, which was obtained at Brookhaven National Laboratory's Superconducting Magnet Department via magnetic needle [10]. The measurement was taken only with main coil and without fringe coil, anti-fringe coil, and correctors.

The green line in Figure7 is the field measurement and the red line is the measured deviation from a straight line. The blue line is the computed deviation after the application of five correctors.

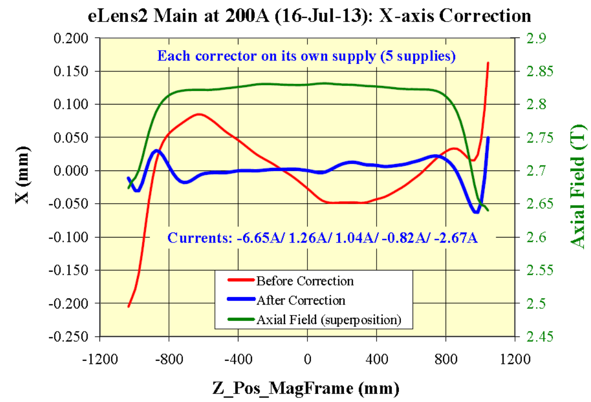

Figure 7: Measurement of the superconducting magnet field straightness in the horizontal plane.

As the blue line in Figure 7 shows, the straightness specification of ±50 µm is satisfied in X plane from about -900 mm to 900 mm without correctors. The uncorrected straightness deviation is even less in the Y (vertical) plane.

ACKNOWLEDGMENTS

The authors would like to acknowledge the help of the instrumentation group, vacuum group and controls group. The authors are also grateful to the valuable discussions with the FNAL TEL staff, in particular with V. Shiltsev, A. Valishev, and G. Stancari.

REFERENCES

[1] Y. Luo et al., "6-D weak-strong simulation of head-on beam-beam compensation in the Relativistic Heavy Ion Collider," Phys. Rev. ST Accel. Beams 15 (2012) 051004.

[2] W. Fischer et al., "Status of head-on beam-beam compensation in RHIC," Proc. of the ICFA Mini-Workshop on Beam-Beam Effects in Hadron Colliders (BB3013), CERN (2013).

[3] X. Gu et al., "Designing a Beam Transport System for RHIC's Electron Lens," PAC'11, New York, TUP208 (2011).

[4] V.H. Ranjbar et al., "RHIC Polarized Proton Operation for 2013," IPAC2013, Shanghai, China, p. 1544 (2013).

[5] X. Gu et al., "The Effects of The RHIC e-lenses Magnetic Structure Layout on The Proton Beam Trajectory," PAC'11, New York, USA TUP207.

[6] A. Pikin et al., PAC'11, New York, THP100, p. 2309 (2011).

[7] D. M. Gassner et al., "RHIC Electron Lens Test Bench Diagnostics," DIPAC'11, Hamburg, Germany, MOPD04.

[8] X. Gu et al., TUPHO01, NA-:PAC'13.

[9] T. Miller et al., "Electron-Lens Test Stand Instrumentation Progress," IBIC12, Tsukuba, Japan, THCB01 (2012).

[10] C. Crawford et al, Proc. Of PAC'99, New York, USA, pp. 3321-3323.