RHIC POLARIZED PROTON NEW WORKING POINT COMMISSIONING*

M. BAI, R. TOMÁS, L. AHRENS, K. BROWN, A. DREES, C. J. GARDNER, J. W. GLENN, W. FISCHER, U. IRISO ARIZ, H. HUANG, Y. LUO, F. PILAT, W. W. MACKAY, G. MARR, C. MONTAG, V. PITISYN, T. ROSER, T. SATOGATA, S. TEPIKIAN, N. TSOUPAS, J. VAN ZEIJTS

Brookhaven National Laboratory, Upton, NY 11973, USA

The RHIC 2003 polarized proton run showed a limitation on the luminosity due to the beam-beam effect at a betatron tune working point of (0.225, 0.235). The integer parts of the horizontal and vertical betatron tunes are 28 and 29, respectively. The polarization transmission efficiency was also compromised because of the tight tune space due to the snake resonances. It was decided to explore the RHIC pp luminosity capability as well as the polarization capability with new working points during the RHIC pp 2004 Run. The working point (0.690, 0.685) at RHIC store energy of 100GeV/c was found to ameliorate the beam-beam effect and also improve the polarization transmission efficiency as well as polarization lifetime during store. This paper reports the commissioning efforts and results of the new working point commissioning during the latest RHIC polarized proton run.

1. Introduction

The Brookhaven Relativistic Heavy Ion Collider (RHIC) is designed to provide collisions of polarized proton beams with longitudinal polarization for two high luminosity detectors: PHENIX and STAR. It can also provide collisions with transversely polarized proton beam for the other two detectors: BRAHMS and PHOBOS. The nominal beta functions at the collision points of the STAR and PHENIX experiments are 1 m, and are 3 m at the other two experiments. During its first polarized proton run for physics data taking at an energy of $\sqrt{s} = 200$GeV in 2003, a strong beam-beam effect was observed. The large difference in beam lifetime for bunches colliding at 2, 3 and 4 experiments, respectively demonstrated that the beam-beam effect was the main contribution to the deterioration of beam lifetime during a store [1].

*This work is supported by us department of energy.

In a collider, the beam-beam effect comes from the Coulomb interaction between the two colliding beams [2,3]. For the same charge species, the beam-beam force behaves as a defocusing force near the center of the beam and then becomes highly non-linear at about one rms beam size. It causes not only the shift of the betatron tune of the beam as a whole but also increases the tune spread. For a proton-proton collider, the coherent betatron tune shifts downward while the tunes for the high amplitude particles are not affected much. The effect of beam-beam on the beam lifetime as well as luminosity lifetime is very sensitive to the working point.

A set of working point candidates were simulated and a subset of them were also studied carefully during the RHIC Au 2004 run at injection prior to the proton run [4]. Table. 1 lists the results of the working point studies. Here, $\nu_{x,y}$ are the tunes of the horizontal and vertical betatron oscillations.

Table 1. RHIC working point candidates

working point	ν_x	ν_y	available tune space with beam-beam	distance to a major snake resonance
RHIC design	0.19	0.18	0.008	0.01
RHIC operation	0.225	0.235	0.005	0.015
SPS operation	0.69	0.685	N/A	0.01
RHIC pp FY04	0.738	0.735	0.007	0.015

During the RHIC 2004 run, the working points in the two rings were located at either side of the $\nu_x = \nu_y$ resonance to avoid beam-beam driven resonances. The working point at the SPS operation tune could not be studied with Au beam at injection due to the strong 3^{rd} order resonance driven by the sextupole field component from persistant currents in the RHIC bending dipoles.

Another requirement on the RHIC working point is that it has to be in a region free of spin depolarizing resonances. The spin dynamics in a planar machine like RHIC is governed by the Thomas-BMT equation [5]. In a perfect accelerator, the spin vector precesses around the vertical direction $G\gamma$ times during one orbital revolution. Here, G is the anomalous gyromagnetic ratio. In a real machine, because of the errors and misalignments of magnets as well as the intrinsic betatron oscillations, the acceleration of polarized beam often encounters two types of spin depolarizing resonances [5]: imperfection at $G\gamma = nP$ and intrinsic spin resonances at $G\gamma = nP \pm Q_y$. Here, n is an integer and P is the accelerator super-periodicity. In RHIC, two Siberian helical snakes were installed in each ring to preserve the beam polarization [6]. However, it was discovered by simulation [5] and recently confirmed in RHIC [7] that a new type spin depolarizing resonance can also cause the beam polarization loss when the following condition is met.

$$\nu_s = m\nu_y + k. \tag{1}$$

Here ν_s is the spin precession tune, m and k are integers.

2. Commissioning results

During the RHIC 2004 run, the RHIC working point at injection was set to (0.72,0.73) in the window of snake resonance at 0.7 and snake resonance at 0.75. The ramp was developed to accelerate the polarized proton beam with this working point. Two working points (0.738, 0.735) and (0.69, 0.685) were carefully studied at store. A tune swing from (0.73,0.72) to (0.69,0.685) was successfully implemented at store energy before the final beta squeeze [4]. Both working points yielded similar tolerance to the beam-beam effect. The luminosity lifetime with working point (0.745, 0.735) was also evaluated under the beam-beam limit with bunch intensity of 1.7×10^{11} protons. However, it was discovered that the beam polarization lifetime at this working point was significantly shorter than the polarization lifetime with (0.69,0.685) working point during a 5 hour store. The possible reason could be that the tunes of particles at high amplitudes are higher than the tune of the beam as a whole and hence closer to the snake resonance at 0.75. Careful studies will be required to confirm this. Fig. 1 shows the results of the beam lifetime as a function of beam betatron tune. The lower plot shows the proton loss rate as a function of the tunes.

3. Conclusion

Two new working points were investigated during the RHIC 2004 polarized proton run. Both of them showed an improved luminosity lifetime. However, due to the strong snake resonance at 0.75, the working point at (0.69,0.685) yields better polarization transmission efficiency and polarization lifetime at store.

4. Acknowledgement

The authors would like to thank the Operation Group of the C-A Department. The authors would also like to thank P. Cameron, K. Vetter, R. Michnoff and many others for their support during the polarized proton run.

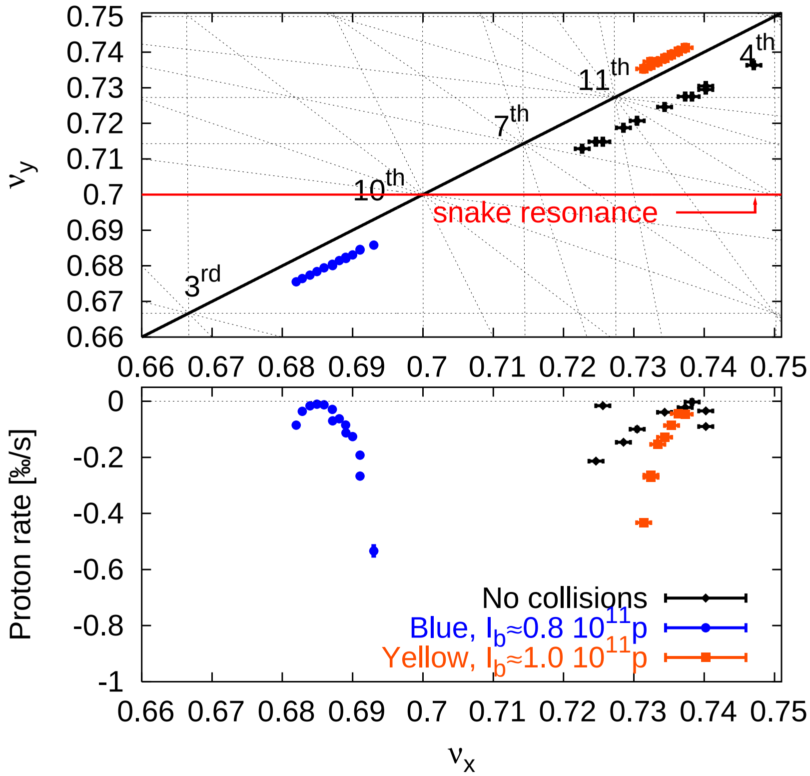

Figure 1. Scan of beam lifetime as a function of working point at store with beam in collision.

References

1. W. Fischer, et al; *Summery of Beam-beam Observation during Stores in RHIC Proceedings of Halo'03 and Beam-beam'03 Workshop* ***AIP Conference Proceedings****, 693 (2003).*
2. *H. Wiedemann;* Particle Accelerator *Springer* (2003)
3. Eberhard Keil; *Beam-Beam Dynamics CERN SL/94-78 (1994)*
4. *R. Tomas, et al;* Quest of New Working Point *Proceedings of EPAC04* (2004)
5. S. Y. Lee; *Spin Dynamics and Snakes in Synchrotrons World Scientific (1997).*
6. *RHIC Spin Design Manual (1998).*
7. *V. Ptitsyn, et al;* Snake Resonances Observed in RHIC *these proceedings*.