RHIC BBLR MEASUREMENTS IN 2009 *

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Abstract

Long range beam-beam experiments were conducted during the Run 2009 in the Yellow and the Blue beams of the RHIC accelerator with DC wires. The effects of a long-range interaction with a DC wire on colliding and non-colliding bunches with the aid of beam losses, orbits, tunes were studied. Results from distance scans and an attempt to compensate a long-range interaction with a DC wire is presented.

INTRODUCTION

Two DC wires in the vertical plane were installed in the RHIC accelerator in 2006 (see Fig 1) with the aim of investigating long range (LR) beam-beam effects and a potential compensation.

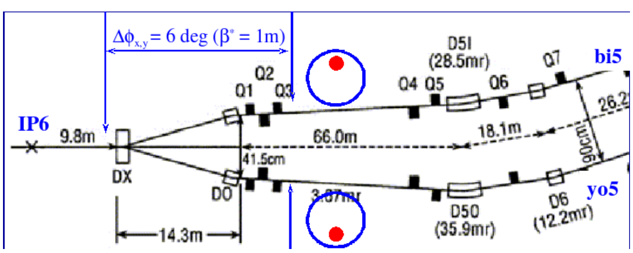

Figure 1: DC wire location with respect to IP6 in the RHIC rings. The top circle represents the Blue ring and the bottom circle represents the Yellow ring. The wires are vertical displaced above and below the Blue and Yellow beams respectively.

Extensive experiments were conducted focusing mainly on the effect of a wire on single ion beams from 2006-2009 [1, 2, 3]. A unique opportunity to compare the effect of the wire on colliding beams and compensation of a single LR beam-beam interaction were conducted in Run2009 with protons at 100 GeV. Due to aperture considerations for decreasing β^*, the Blue wire was removed during the shutdown after the Run2009 and the Yellow wire is foreseen to be removed in the near future. Therefore, these experiments serve as the final set of measurements for LR beam-beam with RHIC as a test bed. The relevant RHIC beam and lattice parameters are listed in Table 1 for the experiments in Run2009.

* This work was performed under the auspices of the US Department of Energy

Table 1: Relevant RHIC beam, lattice and wire parameters for experiments with proton beams.

quantity	unit	Blue	Yellow
beam energy E	GeV/n	100	
rigidity $(B\rho)$	Tm	831.8	
number of bunches	-	36	
# of colliding bunches	-	30	
max. wire current I_{max}	A	50	
curr ripple $\Delta I/I$ (at 50 A)	10^{-4}	< 1.7	
distance IP6 to wire center	m	40.92	
wire length L	m	2.5	
position range d	mm	0...65	-65...0
bunch intensity	10^{11}	1.7	1.7
norm. Emittance $\epsilon_{x,y}$	μrad	25,24	49,19
horizontal tune Q_x	...	28.691	28.232
vertical tune Q_y	...	29.688	29.692
chromaticites (ξ_x, ξ_y)	...	$(+2, +2)$	
β_x at wire location	m	556	1566
β_y at wire location	m	1607	576

BEAM MEASUREMENTS WITH COLLIDING BEAMS

A 36×36 bunch pattern with 6 non-colliding bunches where chosen to enable a comparison between the single beam and colliding beam simultaneously. After establishing collisions between the Blue and the Yellow ring with reasonable lifetime, two experiments was carried out:

- Position scan with a 50 A wire current to determine the onset of losses on colliding and non-colliding bunches
- Compensation of a single LR interaction via the DC wire with an equivalent current corresponding to 5 A.

Position Scan, 50 A

The position scan of the wire on each beam was performed with 50 A. The corresponding beam losses as a function of beam to wire separation is shown in Fig. 2. The beams collide at IP_6 and IP_8. The maximum beam losses were constrained to 100-150% for a very short period to avoid disrupting the beam quality significantly for subsequent measurements.

Fig. 3 shows the evolution of the intensity between bunches with and without head-on collisions. The bunches with the head-on collisions have a more severe effect from the LR forces of the wire as expected.

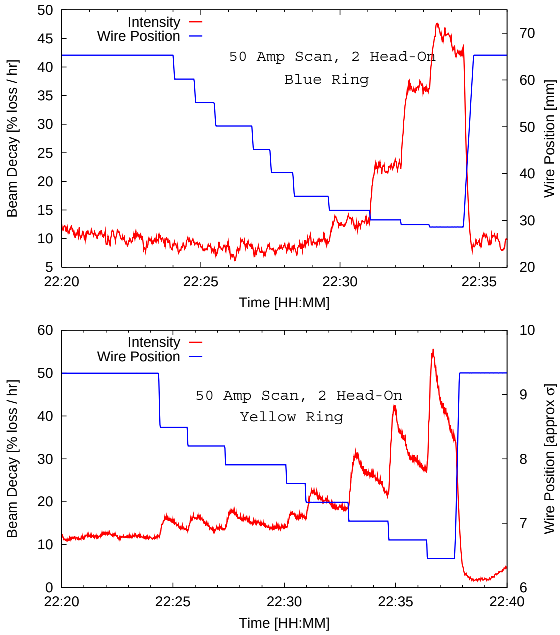

Figure 2: Position scan on the Blue (top) and Yellow (bottom) rings with a current of 50 A. Both beams collide at two IPs.

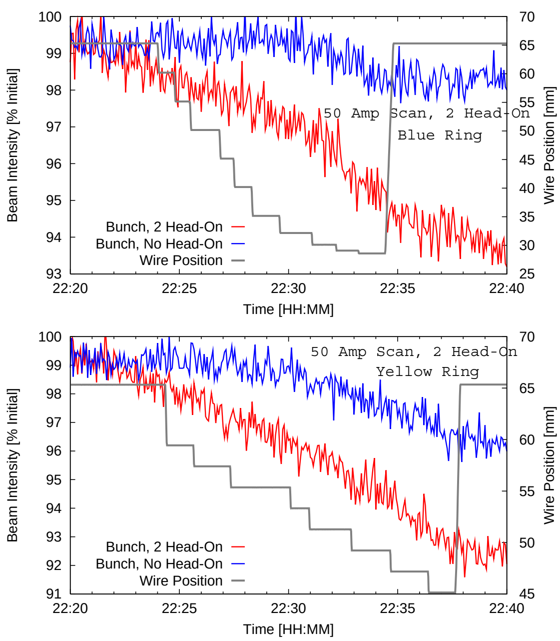

Figure 3: Single bunch intensities as a function of wire position for Blue (top) and Yellow (bottom) rings with a current of 50 A. Comparison between bunches with head-on and no head-on collision is shown.

Long range compensation

The bunch spacing and the interaction region geometry in RHIC does not inherently have LR beam-beam interactions. It is therefore, necessary to shift the collision point towards the DX magnet closest to the DC wires. This location enables for an artificially induced a LR interaction between the two beams and simultaneously allow for a minimum phase advance between the LR interaction and DC wires ($\sim 6°$). Additionally, this location has sufficient aperture for an orbit scan with the range of interest (3-10σ). Fig. 4 shows the trajectories of the Blue and Yellow rings with the LR interaction set at approximately 3.1σ.

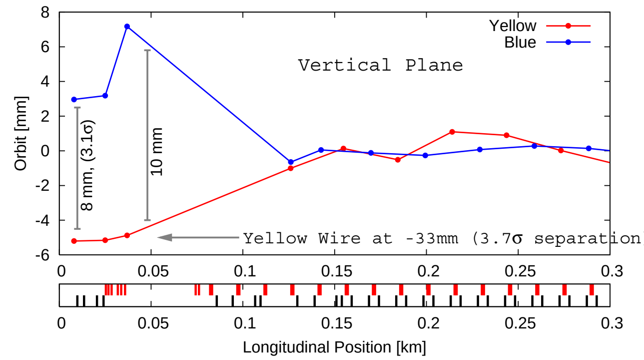

Figure 4: Orbits right of IP$_6$ for the Blue and the Yellow ring with the LR interaction setup near the DX magnet at approximately 3.1σ.

An equivalent current (5 A) corresponding to a single LR interaction in RHIC was applied to the DC wire and a position scan was performed. Fig. 5 shows the tunes spectra measured using the beam transfer function with and without the LR compensation. No significant difference is visible except for a secondary peak in the vertical plane of the Blue ring.

The individual bunch intensities and beam loss rates were recorded during the position scan with the LR compensation. Fig. 6 shows the beam losses as a function of the wire position. In the Blue ring, the losses are always increasing as the wire approaches closer to the beam. Therefore, no evidence of compensation of the LR interaction from the Yellow beam is visible. However, in the Yellow ring, the beam lifetime when the beam to wire distance is approximately 3σ is improved (see Fig. 6). Consecutive retractions and restoration of the wire position to 3σ show similar improvement of the beam lifetime, therefore indicating a compensation of the effect of LR interaction by the DC wire.

The individual bunch intensities for bunches with and without LR interaction and simultaneous compensation is shown in Fig. 7. Note that all 36 bunches experience the effect of the DC wire, but only 30 bunches experience LR interactions. Therefore, only bunches with a LR interaction can have a compensation. In the Blue ring, the bunch intensity evolution is similar for bunches with and without LR compensation. Hence, only the effect from the wire is visible. The bunches with LR interaction and simultaneous compensation have reduced beam losses as compared to the bunches that only see the wire. This is consistent with the beam loss measurements (see Fig. 6).

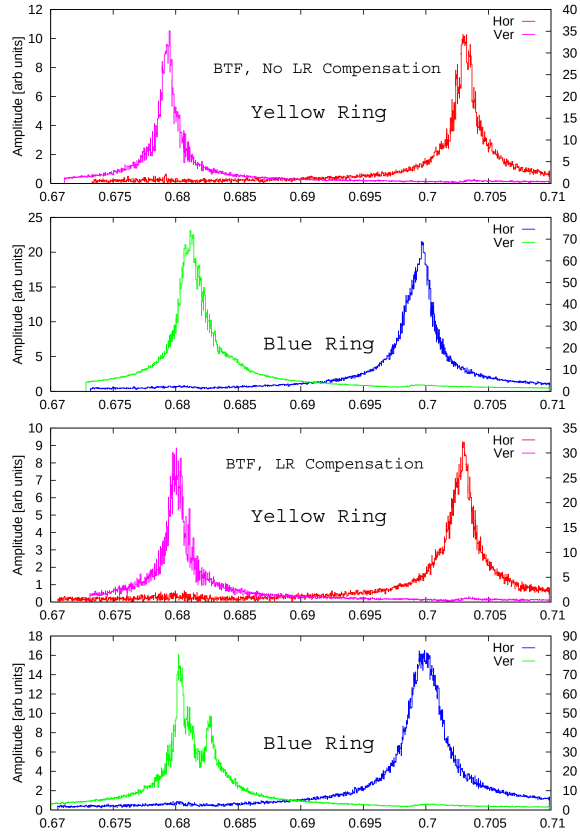

Figure 5: Beam transfer function measurement for single long-range interaction (top) and compensation (bottom) using a DC wire in the Blue and the Yellow ring.

CONCLUSIONS

Long range beam-beam experiments were conducted during the Run 2009 in the Yellow and the Blue beams of the RHIC accelerator with DC wires. The effects of a long-range interaction with a DC wire on colliding has observable effects as compared to non-colliding bunches. A single attempt to compensate long-range beam-beam interaction via a DC wire shows evidence of compensation using beam loss signals, but only in one ring.

ACKNOWLEDGMENTS

We would like to thank the operations group for their help with beam setup. We would like to acknowledge valuable discussions and input from H -J. Kim, T. Sen, J. Qiang, A. Kabel, U. Dorda, J. P. -Koutchouk, F. Zimmermann.

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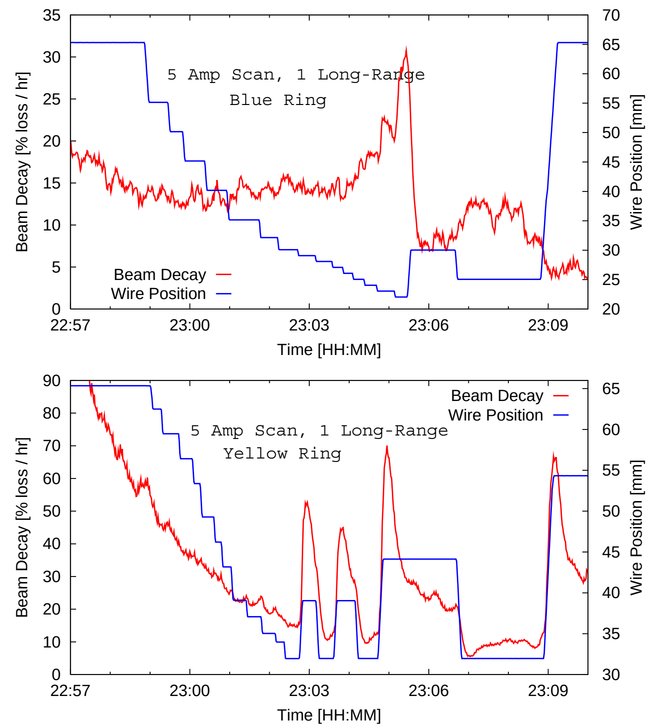

Figure 6: Beam loss comparison between bunches with single long-range and compared to the no long-range interactions as a function of the wire position for Blue (top) and Yellow (bottom) rings with a current of 5 A.

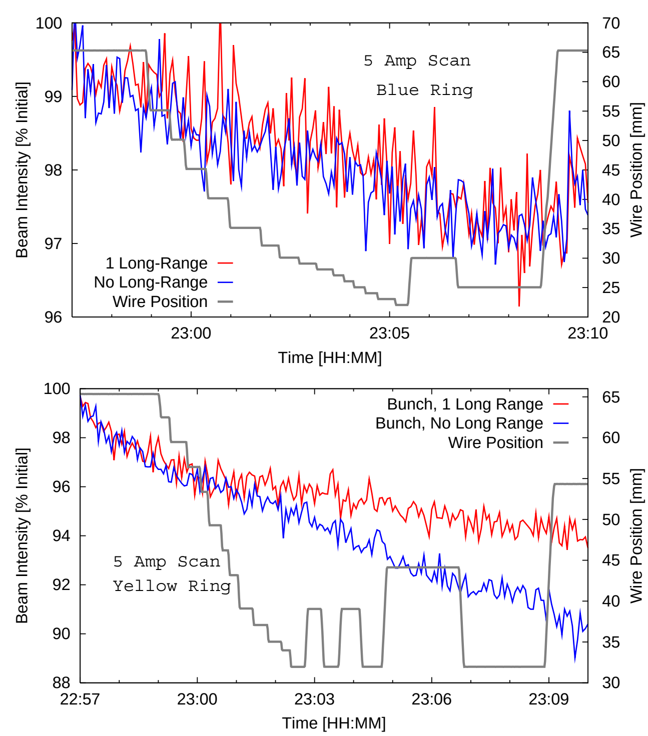

Figure 7: Beam intensity comparison between bunches with single long-range and compared to the no long-range interaction as a function of the wire position for Blue (top) and Yellow (bottom) rings with a current of 5 A.