BNL-94078-2011-CP

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Presented at the 2011 Particle Accelerator Conference (PAC'11)
New York, N.Y.
March 28 – April 1, 2011

Collider-Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy
Office of Science

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EVALUATING THE DYNAMIC APERTURE FOR THE NEW RHIC 250-GEV POLARIZED PROTON LATTICE*

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Abstract

To increase luminosity in the Relativistic Heavy Ion Collider's (RHIC's) polarized proton 250 GeV operations, we are considering reducing β^* to 0.65 m at the interaction points (IPs), and increasing bunch intensity. The new working point near the 2/3 integer will used on the ramp to preserve polarization. In addition, we plan to adjust the betatron-phase advances between IP6 and IP8 to (k+1/2)*π so to lower the dynamic beta-beat from the beam-beam interaction. The effects of all these changes will impact the dynamic aperture, and hence, it must be evaluated carefully. In this article, we present the results of tracking the dynamic aperture with the proposed lattices.

INTRODUCTION

In the previous 2009 polarized-proton 250 Gev operation, the β^*s at IP6 and IP8 were about 0.7 m at store [1]. To further increase the luminosity of the RHIC in this operational mode, we plan to reduce β* down to 0.65 m. Doing so requires having a large physical aperture in the interaction region.

In 2011 proton run, there will be up to three collision points, IP6, IP8, and IP2; in this simulation study, the β^* at IP6 and IP8 are all 0.65 m for the blue and yellow lattice, and the β^* at IP2 will be less than 3 m. The β^*s at all the other non-colliding IPs are 7.5 m. In tracking, the first-order chromaticity is set to 1.0 in the correction schemes for both the 2-family and 8-family chromaticity. The non-normalized rms transverse emittance is 15mm.mrad.

The longitudinal beam area is 0.17 eV·s, giving an rms beam momentum spread $dp/p_0 = 0.14\times10^{-3}$; the rms bunch-length is about 0.44 m. In the following study of the dynamic aperture, the initial off-momentum deviation δ is normally set to 0.0005, viz., close to the maximum energy-deviation of the RF bucket that is about 3.5 times the (dp/p_0) rms in the RHIC.

Table 1 lists the lattice and beam parameters in this study. The normal tunes shown in the table are tunes without collision. We included the errors in the interaction region's multipole field in the lattice models.

For blue- and yellow-lattice, the dynamic apertures are tracked along two tune lines in the tune diagram, the above and below diagram line, which means that the vertical tune Qy = Qx + 0.005 and Qy = Qx – 0.005, respectively. Qx is changed from 0.67 to 0.7. The integer tunes for the horizontal and vertical, respectively, are 28 and 29.

Table 1: Parameters Used for Dynamic Tracking

Parameters	Value
Bunch Intensity, N_b	$1.5\ 10^{11}$
Normalized Emittance	2.5 mm.mrad
β* at IP6 and IP 8	0.65 m
β* at IP2	3 m
β* at Other IPs	7.5 m
Chromaticity	(1,1)
RF Voltage	300 kV
Energy	250 GeV
Gamma	266
dp/p0	0.0005
Nominal Tune Blue Ring	(28.695,29.685)
Nominal Tune Yellow Ring	(28.695,29.685)
Qx (Scaned)	28.67-28.70
Qy (Scaned)	Qy = Qx +/- 0.005
IP Multipole Field	Included
Beam-Beam	Yes
Second Order Chromaticity	No Correction

Figure 1 shows the below and above tune lines that we scanned in tracking the dynamic aperture.

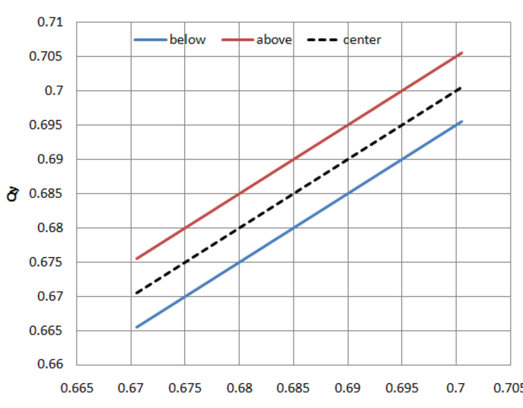

Figure 1: The Two Tune Lines Used in This Paper

SETUP FOR TRACKING THE DYNAMIC

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

We discuss in this paper, our tracking of the dynamic apertures for the tune range around the current pp working-point. The tracking was performed for 10^6 turns. We used the 6-D tracking code SimTrack [2].

The SimTrack code calculates the beam-beam interactions with the weak-strong model. To speed up the dynamic-aperture search, a binary searching method was used.

For each tune spot, the dynamic apertures are sought in five angles in the normalized coordinate frame. For comparison, in the following we show only the minimum dynamic apertures among these five angles. The dynamic apertures are given in unit of the design rms beam size that differs with particle energy, beta* and beam emittance. Emittance is normalized as 95% transverse emittance.

POLARIZED PROTON-LATTICE DYNAMIC APERTURE

Figure 2 plots the results from our tracking the dynamic aperture of the 2011 polarized proton 250-GeV blue lattice. Because there are two collision points in the blue- and yellow- rings, the actual tune will shift from the nominal one by about -0.015. The actual horizontal- and vertical- tunes will be around (28.68, and 29.67).

From Fig. 2, we first note that the tune on the lower line (green) in tune diagram, with Qy = Qx-0.005, has larger dynamic aperture around the actual horizontal working point, 28.68, than does the tune on the upper line (red) in this diagram.

The second and the more important issue, is that the tune on the lower line has larger flat range than does the upper line. Further, the tune on the lower line has a dynamic aperture that is 7~8 times the beam's size within the range from 0.67 to 0.686, which, according to previous experience, can be used for the 2011 polarity-proton 250 GeV operation.

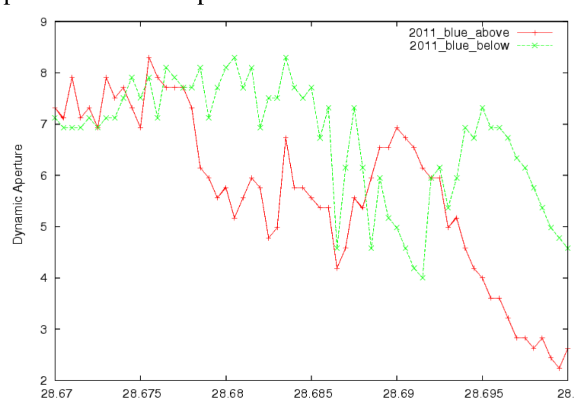

Figure 2: the Dynamic Aperture of the Blue Lattice.

Figure 3 shows results from tracking the dynamic aperture of the 2011 run 250 GeV polarized proton yellow lattice. From Fig. 3, we also find that the dynamic aperture along the tune from 0.67 to 0.685 on the lower line (green) is better than the dynamic aperture along the upper (red) line.

In this region, the dynamic aperture is greater than 6 times the rms beam's size, demonstrating that this yellow lattice also can be used.

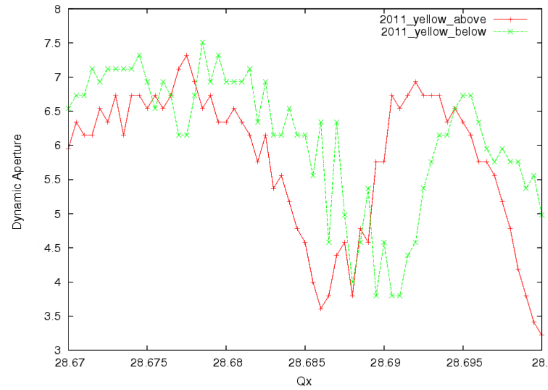

Figure 3: the Yellow Lattice's Dynamic Aperture.

Finally, according to the Figs.2 and 3, the nominal working point (28.695, 29.685) is validated by tracking, and will be used in 2011 RHIC polarized proton-run.

EXPLORING A NEW WORKING POINT FOR POLARIZED PROTONS

A new working point (28.19, 29.18) also was proposed for the energy ramp and store to maximize polarization transmission in the RHIC ring. To verify the viability of this new working point, we tracked the dynamic aperture around it, following the same tracking parameters as discussed earlier in this paper.

Fig. 4 is the dynamic aperture of the proposed new working point for yellow lattice. We see from it that the dynamic aperture for the tune on the lower line has less well-defined region vis-a-vis the comparable line depicted in Fig. 3. This will occasion a greater risk of beam loss.

Accordingly, based on our findings from tracking the dynamic aperture we rejected the usage of this new working point. .

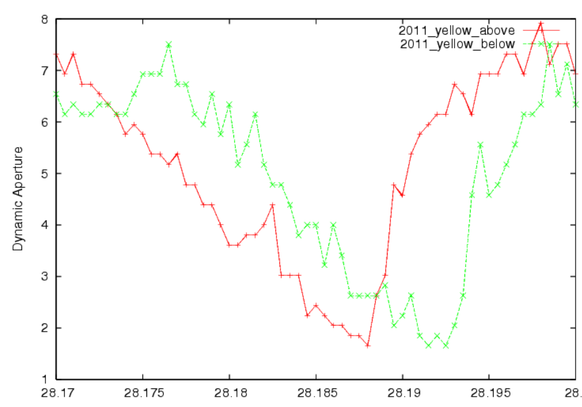

Figure 4: the Yellow Lattice's Dynamic Aperture with new Ramp Working Point.

DISPERSION PRIME CORRECTION

According to the reference [3], the spin-tune shift due to the horizontal dispersion angles in the snakes and rotators is

$$\delta Q_{sp} = \frac{G\gamma}{2\pi}\left(2\Delta D'_{sn} + \Delta D'_{rt_{ip6}} + \Delta D'_{rt_{ip8}}\right)\left(\frac{\Delta p}{p}\right)_{ave} \quad (1)$$

where $\left(\frac{\Delta p}{p}\right)$ is the beam's momentum shift, γ is a relativistic factor, G is a magnetic moment anomaly (G is 1.793 for proton), $\Delta D'_{sn} = D'_{sn9} - D'_{sn3}$, and $\Delta D'_{rt\_ip} = D'_{co\_rt\_left} - D'_{co\_rt\_right}$.

To reduce the spin-tune's spread during ramping from the injection energy to store energy 250 GeV, a lattice with D'_x correction also was proposed for the 2011 RHIC polarized-proton operation.

The dynamic aperture with the D'_x correction is tracked with some different quadrupole magnets. Table 2 lists their names and their strengths, given in units of mrads.

Table 2: Quadrupole and Strength for D'_x Correction

Blue Ring		**Yellow Ring**	
Quad.	Strength	Quad.	Strength
bi9-qf9	0.091678	yo8-qf8	0.098423
bi1-qf11	0.093543	yi10-qf9	0.089157
bi1-qd10	-0.096565	yi10-qd10	-0.096597
bo3-qf8	0.091784	yi10-qf11	0.093542
bi4-qf9	0.089192	yi11-qf9	0.089157
bi5-qf9	0.099057	yi3-qf9	0.09181
		yo4-qf8	0.09191

Fig.5 shows the dynamic aperture for the blue ring with the D'_x correction. Compared with Fig.2, there is no significant difference between them.

It also shows that the tune on the lower line (green) in tune diagram has larger dynamic aperture than the tune on the upper line (red) around the actual horizontal working point 28.68.

Furthermore, the tune on the lower line in the diagram, with the lattice with D'_x correction, also is seven- to eight-fold larger than the dynamic aperture of the rms beam size within the range from 0.67 to 0.685.

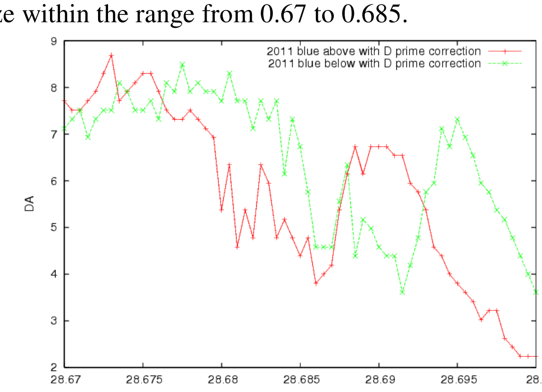

Figure 5: the Blue Lattice Dynamic Aperture with D'_x Correction

Fig. 6 shows that the dynamic aperture for yellow ring with D'_x correction. There is no significant difference between it and Fig 3.

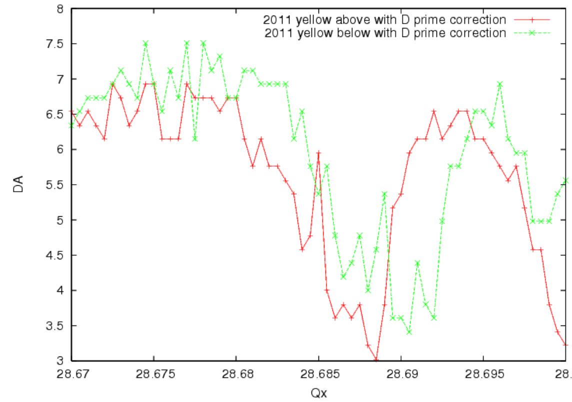

Figure 6: Tracking the Yellow Lattice Dynamic Aperture with D'_x Correction.

SUMMARY

We evaluated the dynamic apertures with the RHIC lattice for the 2011 polarized proton run. We checked them for the 250 GeV blue lattice with beta* = 0.65 m and yellow beta*= 0.65 m. We verified that the dynamic apertures of both lattices are acceptable; they will be used in 2011 RHIC run.

According to our findings in tracking the dynamic apertures, we discarded the proposal for a new working point so to assure sufficient safety margins for proton-beam loss.

Finally, our findings on the dynamic aperture of the lattice with the dispersion prime correction were very encouraging; hence, this lattice also will be tested in 2011 RHIC polarized-proton operation if sufficient machine time is available.

By reducing beta* to 0.65 m and with adding dispersion prime correction during ramping, we anticipate getting higher luminosity in the Relativistic Heavy Ion Collider (RHIC) 2011 polarized proton 250 GeV operations.

ACKNOWLEDGMENTS

The authors would like to thank Dr. Mei Bai for her helpful discussions.

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