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In this note we carry out dynamic aperture calcuations to understand the lifetime difference between the 2009 RHIC 100 GeV and 250 GeV polarized proton (p-p) runs. In these two runs the β^*s at the interatcion points (IPs) IP6 and IP8 are 0.7 m. We also compare the impacts of interaction region (IR) multipole errors with 2000 A and 5000 A triplet currents on the dynamic aperture.

1 Introduction

If we ingore the limits imposed by some of quadrupole power supplies in RHIC, the bare linear lattices with the same $\beta^* = 0.7$ m for the 100 GeV and 250 GeV runs should be same or very similar. The major difference in the lattices for 100 GeV and 250 GeV runs are the IR multipole errors. For 100 GeV p-p run, the main current bus of triplets is about 2000 A, while at 250 GeV p-p run, the current is about 5000 A.

The beam parameters at 100 GeV and 250 GeV runs are also different due to the different Lorentz factor γ . At 100 GeV, $\gamma = 107$ and at 250 GeV it is 266. If we assume the nomalized transverse emittance $\epsilon_n = 2.5$ mm.mrad, the ratio of the rms transverse beam sizes at 100 GeV and 250 GeV runs is 1.58:1. At IP6, the rms transverse beam size or 1 σ is 0.128 mm at 100 GeV or 0.081 mm at 250 GeV. And if we assume that the normalized full longitudinal beam area is 1.7 eV.s, the relative rms momentum spread $(\Delta p/p_0)_{rms}$ will be 2.828×10^{-4} at 100 GeV and 1.414×10^{-4} at 250 GeV.

In the following we will compare the calculated dynamic apertures for the Blue ring lattice in the 100 GeV and 250 GeV p-p runs. The inital off-momentum deviation is normally set to be $3 \times (\Delta p/p_0)_{rms}$ in the RHIC dynamic aperture study. Considering $(\Delta p/p_0)_{rms}$ is different at 100 GeV and 250 GeV, we calculate the dynamic apertures for particles with $(\Delta p/p_0) = 3 \times 2.828 \times 10^{-4}$ and $3 \times 1.414 \times 10^{-4}$ respectively. The proton bunch intensity is chosen to be 1.8×10^{11}. The beam-beam paramter is same for 100 GeV and 250 GeV p-p run.

To be fair, we use the same bare lattice of the 2009 RHIC 100 GeV run for the following dynamic aperture calculation and comparison. The only differences in the lattices at 100 GeV and 250 GeV runs are the IR multipole errors. For 100 GeV lattice, we install the IR multipole errors of 2000 A triplet current to the bare lattice. For 250 GeV lattice, we install the IR multipole errors of 5000 A instead. In the dynamic aperture calculation, the beam-beam is included. The first order chromaticities are corrected to (1,1). The tunes of zero amplitude particle without beam-beam are set to (28.685, 29.695).

2 Dynamic Aperture Comparison

2.1 Comparison in units of mm

Figure 1 shows the dynamic apertures in units of mm for 100 GeV and 250 GeV p-p run Blue ring lattices. In the following we only focus on the minimum dynamic aperture among the 5 phase angles. For particles with $(\Delta p/p_0) = 3 \times 2.828 \times 10^{-4}$, the dynamic apertures at 100 GeV and 250 GeV are 0.56 mm and 0.49 mm. For particles with $(\Delta p/p_0) = 3 \times 1.414 \times 10^{-4}$ particles, the dynamic apertures at 100 GeV and 250 GeV are 0.72 mm and 0.69 mm.

Therefore, for particles with $(\Delta p/p_0) = 3 \times 2.828 \times 10^{-4}$, the dynamic aperture is 12.5% smaller at 250 GeV than that at 100 GeV. And for particles with $(\Delta p/p_0) = 3 \times 1.414 \times 10^{-4}$, the dynamic aperture is 4.2% smaller at 250 GeV than that at 100 GeV. The difference in dynamic apertures for same $(\Delta p/p_0)$ particles is caused by the different IR multipole errors at100 GeV and 250 GeV runs.

2.2 Comparison in units of σ

Here we plots the above dynamic apertures in the units of σ in Figure 2. Note that 1 σ at 100 GeV is 0.128 mm at 100 GeV and 0.081 mm at 250 GeV.

For the same $(\Delta p/p_0) = 3 \times 2.828 \times 10^{-4}$, the dynamic apertures at 100 GeV and 250 GeV are 4.4 σ and 6.0 σ. For $(\Delta p/p_0) = 3 \times 1.414 \times 10^{-4}$ particles, the dynamic apertures at 100 GeV and 250 GeV are 5.6 σ and 8.5 σ.

The dynamic aperture in mm is 4.3% and 12.5% smaller at 250 GeV than that at 100 GeV for $(\Delta p/p_0) = 3 \times 2.828 \times 10^{-4}$ and $(\Delta p/p_0) = 3 \times 1.414 \times 10^{-4}$. However, in units of σ, the dynamic aperture at 250 GeV is 36.4% and 51.8% bigger than that at 100 GeV run for $(\Delta p/_0) = 3 \times 2.828 \times 10^{-4}$ and $(\Delta p/p_0) = 3 \times 1.414 \times 10^{-4}$.

For a more meaningful comparison, we should compare the dynamic apertures of particles with the same $3 \times (\Delta p/p_0)_{rms}$. The relative rms mometum spreads at 250 GeV and 100 GeV are 1.414×10^{-4} and 2.828×10^{-4} respectively. Therefore, we should compare the dynamic apertures with $(\Delta p/p_0) = 3 \times 2.828 \times 10^{-4}$ at 100 GeV to the dynamic apertures with $(\Delta p/p_0) = 3 \times 1.414 \times 10^{-4}$ at 250 GeV. By doing so, the dynamic aperture at 250 GeV is $(8.5 - 4.4)/4.4 = 93.2\%$ bigger than that at 100 GeV.

2.3 Effect of IR multipole errors on dynamic aperture

Here we calculate the impacts of IR multipole errors on the dynamic apertures at 100 GeV and 250 GeV. For comparison, we install the multipole IR errors of 5000 A current to the bare lattice of 100 GeV run. Note that in the real life it is not possible to do that since the current of triplets is about 2000 A in the 100 GeV p-p run.

Figure 3 shows the dynamic aperture with multipole IR errors of 2000 A and 5000 A triplet currents. The dynamic apertures with 5000 A errors is 3.8 σ and 5.2 σ for $(\Delta p/p0) = 3 \times 0.0002828$ and 3×0.0001414. Comparing to that with IR multipole errors of 2000 A, IR multipole errors of 5000 A reduce the dynamic aperture by 12.5% and 7% for particles with $(\Delta p/p0) = 3 \times 0.0002828$ and 3×0.0001414 particles.

3 Summary

We calculated the dynamic apertures for RHIC 100 GeV and 250 GeV run lattices with same $\beta^* = 0.7$ m. We found that the dynamic apertures in units of mm are 12.5% and 4.3% smaller at 250 GeV than those at 100 GeV for particles with $(\Delta p/p0) = 3 \times 0.0002828$ and 3×0.0001414 respectively. However, in units of σ, the dynamic apertures at 250 GeV are 36.4% and 51.7% bigger than those at 100 GeV. For particles with the same $3 \times (\Delta p/p_0)_{rms}$, the dynamic aperture at 250 GeV is almost twice of that at 100 GeV. We conclude that the lifetime difference for the 100 GeV and 250 GeV p-p runs with same $\beta^* = 0.7$ m lattices is mainly due to the fact that the relative rms momentum spread and rms transverse beam size are smaller than those at 100 GeV. If we install IR multipole errors of 5000 A triplet current to 100 GeV run, the dynamic apertures are reduced by 12.5% and 7% for particles with $(\Delta p/p0) = 3 \times 0.0002828$ and 3×0.0001414 particles, compared to that with IR multipole errors of 2000 A.

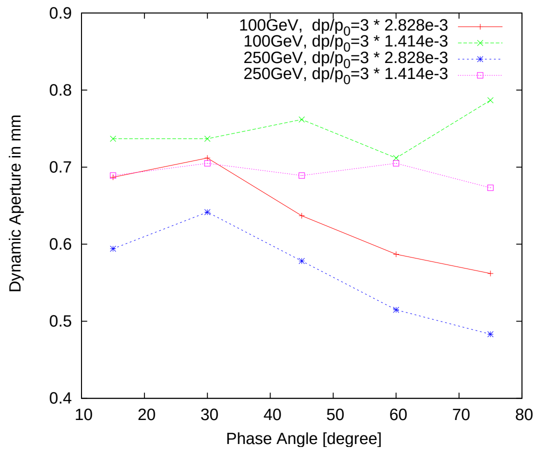

Figure 1: Dynamic apertures in units of mm for 100 GeV and 250 GeV p-p run Blue ring lattices.

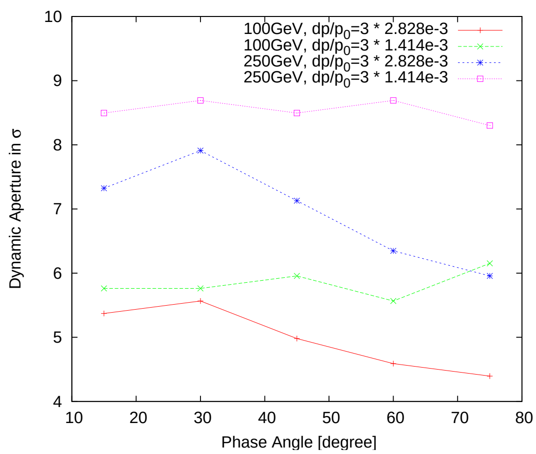

Figure 2: Dynamic apertures in units of σ for 100 GeV and 250 GeV p-p run Blue ring lattices.

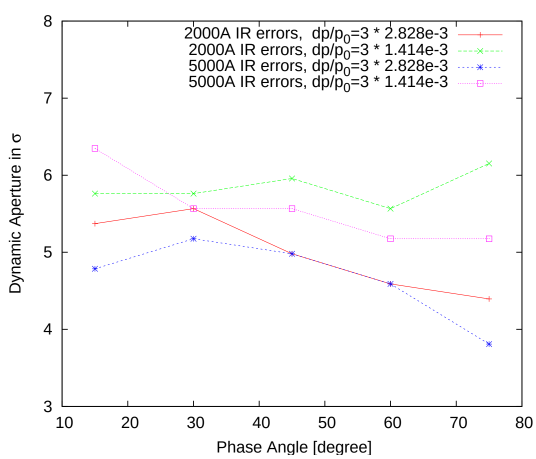

Figure 3: Dynamic apertures at 100 GeV with 2000 A and 5000 A IR multipole errors.