Report September 07

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Sept. 7 2020

During this week, the focus was given on making loss map using different lattice setups. In the following tests, apertures are added uniformly throughout the lattice with circular radius 25mm, as shown in figure 1. Then with initial unnormalized rms emittance 1 mm-mrad, a bunch with 10^{10} intensity modeled by $2 * 10^5$ macro particles is tracked for 3000 turns. For every 500 turns the newly lost particles are recorded, and their 6D coordinates and lost positions are made into histograms.

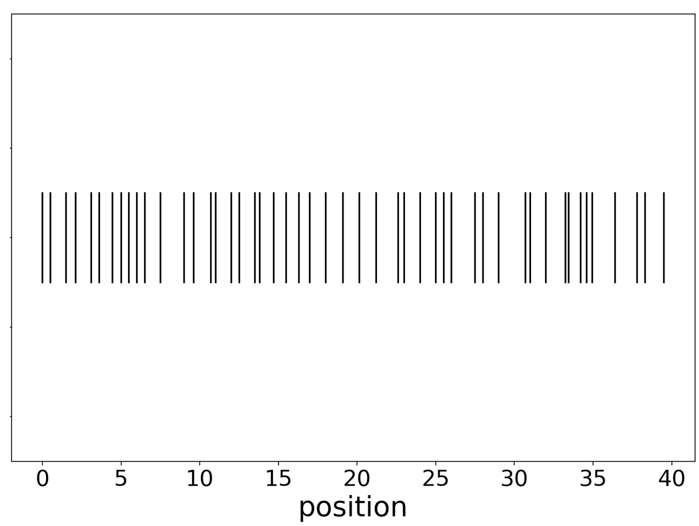
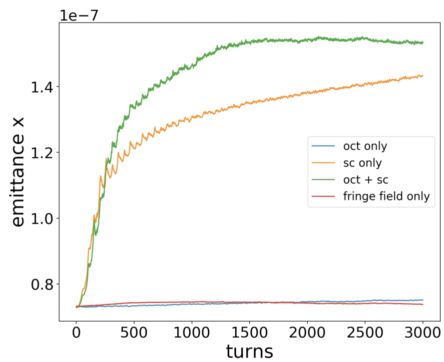
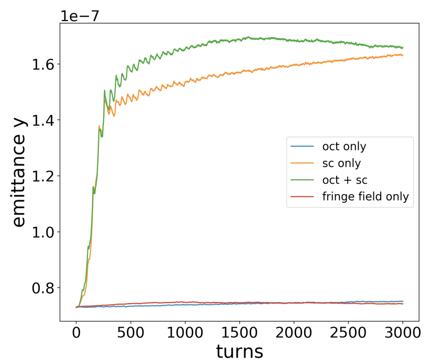


Figure 1: Uniformly distributed apertures in lattice

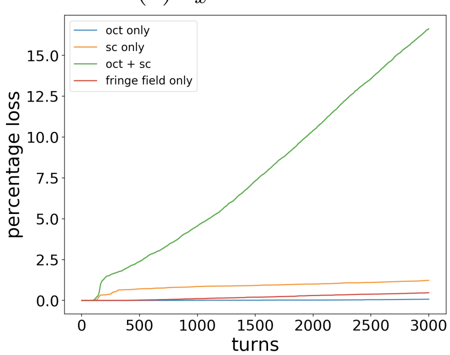
The lattice setups includes: 1. octupoles only 2. space charge effect only 3. octupoles with space charge effect 4. hard edge fringe effect only. The particle loss and emittance growth is plotted in figure 2:



(a) ϵ_x vs turns



(b) ϵ_y vs turns



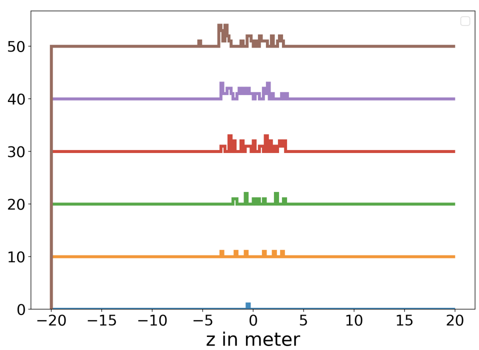
(c) % particle loss vs turns

Figure 2: Emittance and particle loss versus turns for different lattice setups

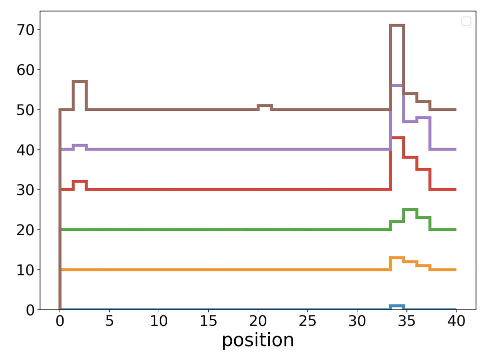
In figure 2, we see that for no space charge case, the octupole and hard edge fringe field alone will not cause large particle loss and emittance growth. For space charge alone, the particle loss increases in the first several hundred turns and then it reaches stable, and since the fringe particles gets removed by the apertures, the emittance increment rate gets smaller in the end. For space charge with octupoles case, since the octupoles create a small dynamic aperture, fringe particles that get moved outside dynamic aperture due to space charge effect becomes unstable and goes outside of physical aperture quickly. As the result, the emittance is stable, but we see a large particle loss rate.

1 Loss Histogram with Octupoles only

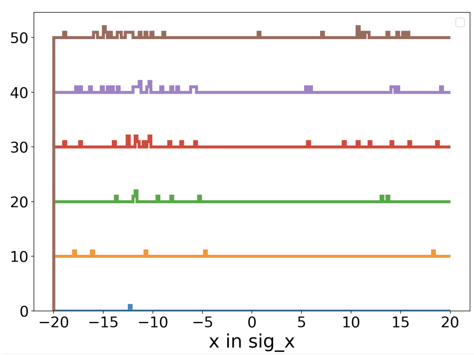
In this part, only octupoles with strength t = 0.4 is included in the lattice as extra source of nonlinearity (other than quads and dipoles), and in figure 3, the distribution of newly lost particles is plotted as histogram (mountain range plot) for every 500 turns. From bottom to top, the line represents newly lost particles in 0-500, 500-1000, ..., 2500-3000 turns.



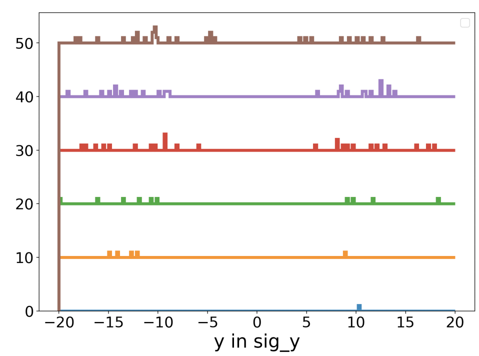
(a) lost particle distribution in z



(b) lost particle position distribution



(c) lost particle distribution in x



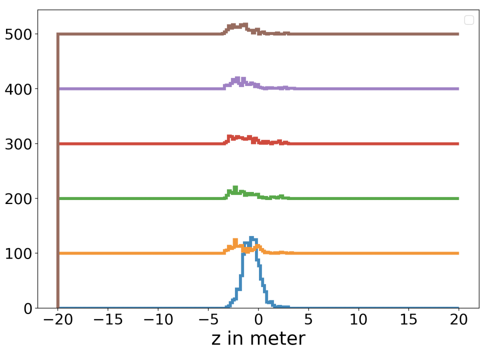
(d) lost particle distribution in y

Figure 3: Histogram of lost particles

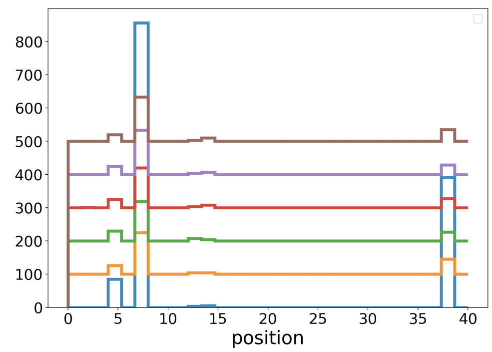
We find that with octupoles, the particle loss mainly happens in or close to the octupole region, which is 33 - 35 meters in this lattice we use according to figure 3(b), although the apertures are placed uniformly through the lattice as shown in figure 1.

2 Loss Histogram with Space Charge only

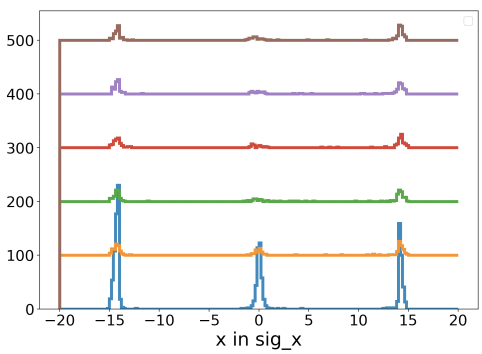
In this part space charge is introduced as the only source of nonlinearity, and the same histogram is made on lost particles in every 500 turns:



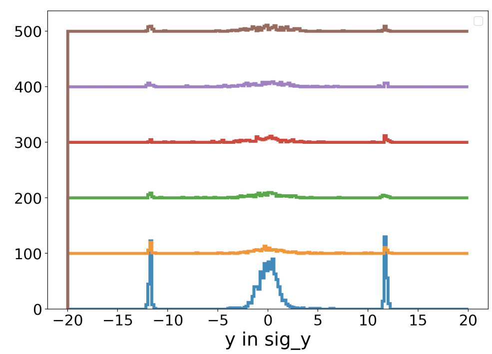
(a) lost particle distribution in z



(b) lost particle position distribution



(c) lost particle distribution in x



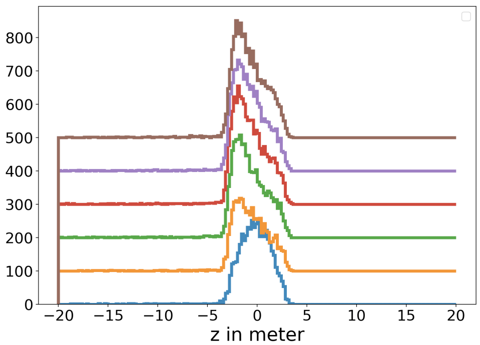
(d) lost particle distribution in y

Figure 4: Histogram of lost particles

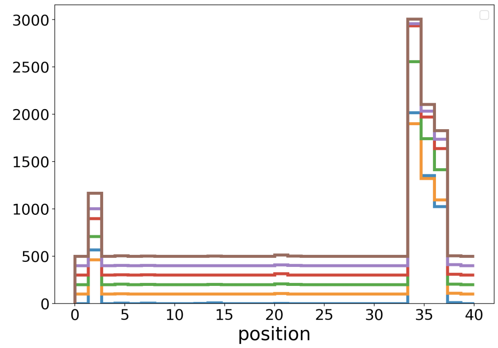
We see that without octupoles, the loss in or close to 33-35 m is much smaller.

3 Loss Histogram with Octupoles and Space Charge Effect

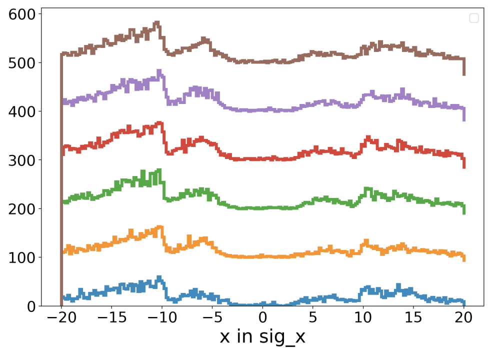
With both octupoles and space charge effect, we see the loss mainly happens at the octupole zone from 33 - 35 m again.



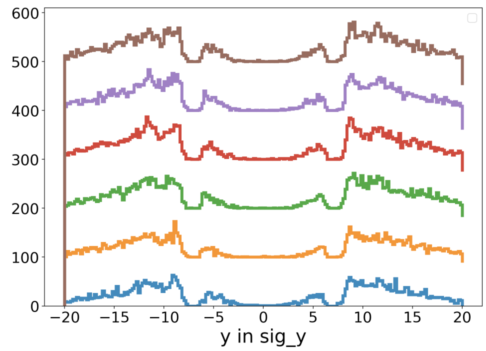
(a) lost particle distribution in z



(b) lost particle position distribution



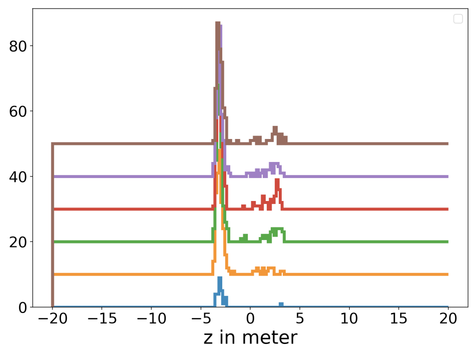
(c) lost particle distribution in x



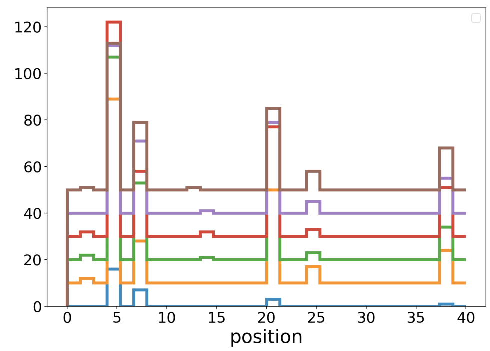
(d) lost particle distribution in y

Figure 5: Histogram of lost particles

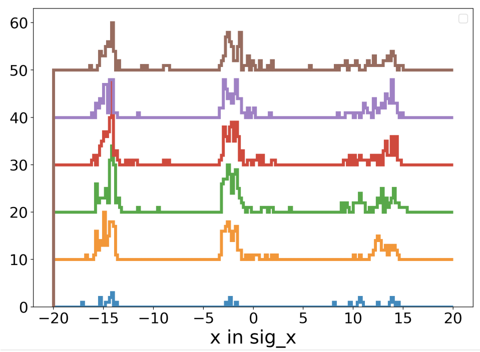
4 Loss Histogram wth Hard Edge Fringe Field only



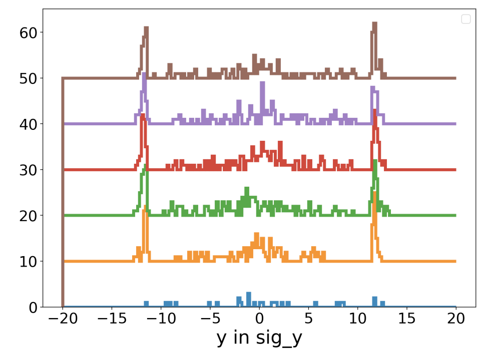
(a) lost particle distribution in z



(b) lost particle position distribution



(c) lost particle distribution in x



(d) lost particle distribution in y

Figure 6: Histogram of lost particles

5 Conclusion and Next Step

Previously in the test with space charge only, we see an increasing emittance and claim that it is not what we expect. However now with more apertures added uniformly in the lattice, we are able to capture more fringe particle loss so that the emittance growth is much smaller. We also see that the particle loss is small.

However, with both space charge effect and octupoles the particle loss is still very large. It seems the main issue is that the dynamic aperture of octupoles we used is to small for the bunch to be stable with even 10^{10} space charge effect, so the bunch keeps expanding and particles keep losing. Also, in figure 3 there are some patterns I am not sure how to explain like in 5(c) more particles are lost with negative x than positive x, and in 5(a) more particles are lost with negative z. This could be explained by the dispersion but I am not sure.

I am thinking that if nonlinear lens will provide us with larger dynamic aperture and more stable beam under SC effect. I have mostly finished coding the nonlinear lens in pyORBIT but I still have some details to confirm with Dr. Chad Mitchell since I basically finishes the code under procedure in his report. Once I finish it could we do some checks to make sure if the nonlinear lens code works as expected, and then use it to see if we get a more stable bunch with SC?