WEAK-STRONG SIMULATION OF BEAM-BEAM EFFECTS IN SPPC

Lijiao Wang, Jingyu Tang, Institute of High Energy Physics, CAS, Beijing, China
Tanaji.Sen, Fermi National Accelerator Laboratory, Batavia, IL, US

Introduction

- The super proton proton collider (SPPC) is a 100km circular accelerator that aims to reach the luminosity of $1.01^{35} cm^{-2}s^{-1}$.
- the nominal beam beam parameter for each IP is 0.0075.
- There are 82 long-range interactions in each IR, the total interactions is 2 head-on interactions and 164 long-range interactions.

Table 1: SPPC norminal Parameters

parameter	value
Beam energy at collisions [TeV]	37.5
Number of bunches	10080
Bunch spacing [ns]	25
$\beta*$ [m]	0.75
Crossing angle[μrad]	110
Intensity [10^{11} p/bunch]	1.5
Norm. transv. emittance [μm]	2.4
Peak luminosity [10^{35} $cm^{-2}\cdot s^{-1}$]	1.01

Tune footprints and dynamic aperture

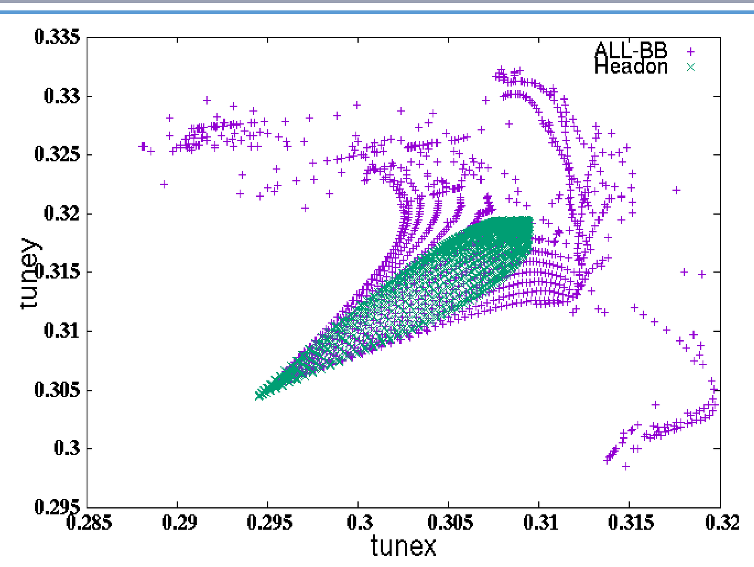


Figure1: Green points is the tune footprint of head-on interactions, violet points is the tune footprint with all of interactions.

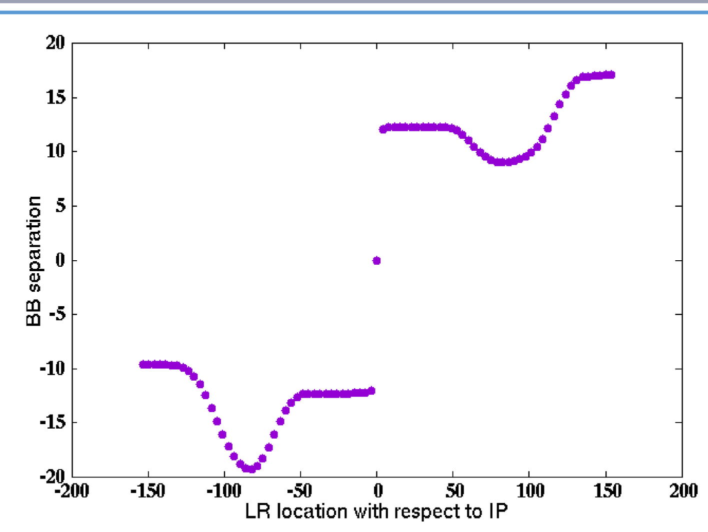
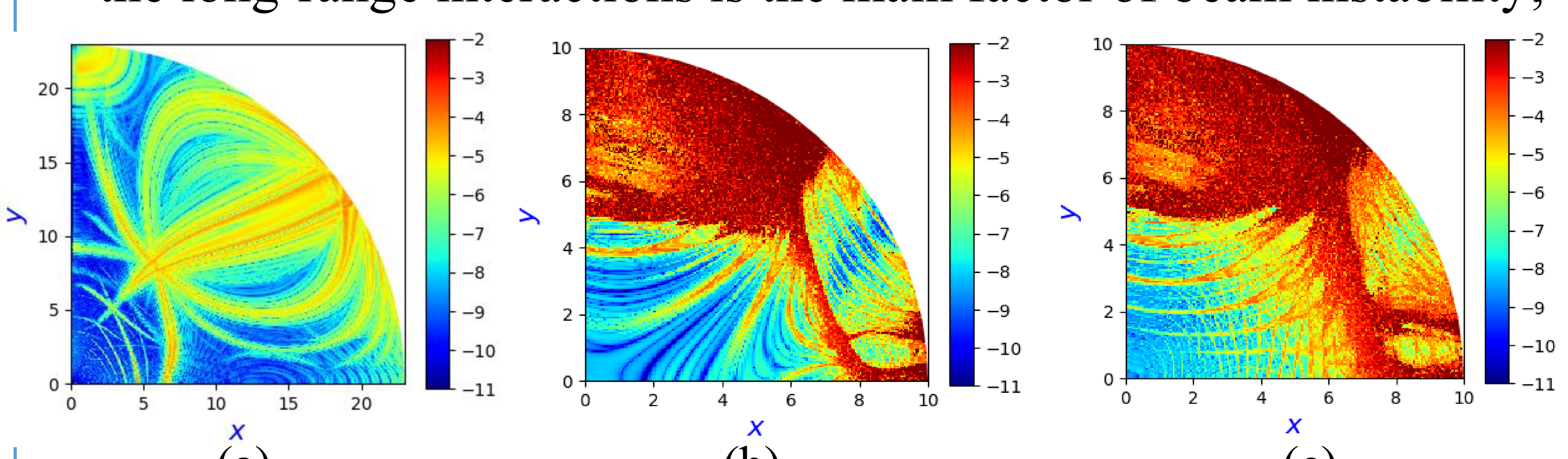


Figure2: The BB separation of all LR interactions are normalised by its horizontal beam size in IR, X axis describe the different LR locations with respect to the IP.

- the DA is the same as the physical aperture of 23.6 σ with tracking with only the sextupoles and the head-on; Adding the long-range interactions reduces the DA to 5.5 σ;
- the long-range interactions is the main factor of beam instability;



(a) (b) (c)

Figure 2: FMA plots for 3 cases. (a): head-on and sextupole kick. (b): long-range and sextupole kick. (c): head-on, long-range and sextupole kick.

Tune scan studies

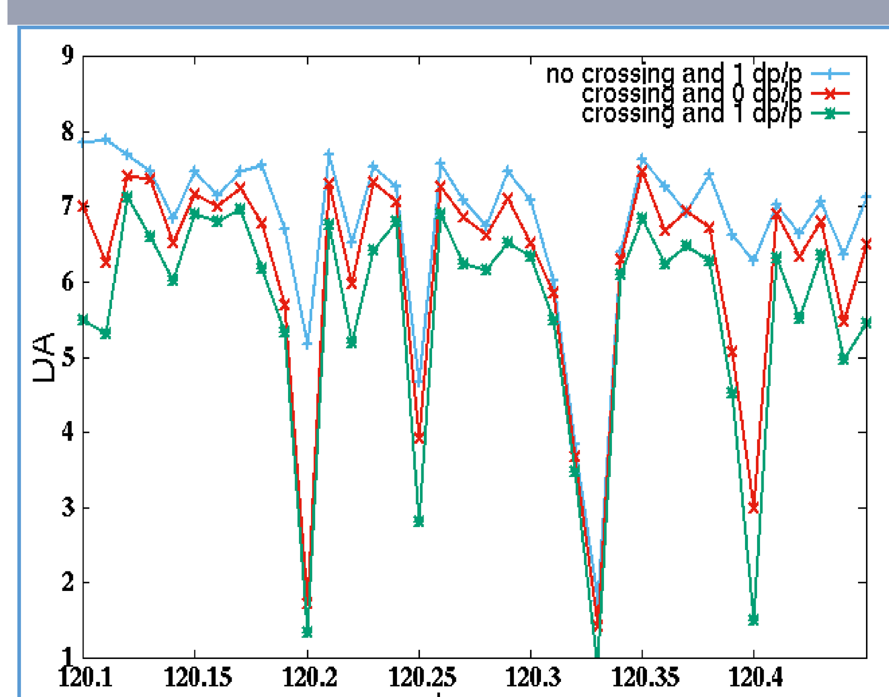


Figure 3: Average DA with different υx. υy= υx ± 0.01; red; with crossing angle and no momentum deviation; green: with crossing angle and 1 times rms momentum spread; blue: without crossing angle and 1 times rms momentum spread;

- The 3rd, 4th, 5th order sum resonances are excited even when the crossing angle is 0. Additional 10th and 9th sum resonances are excited in the presence of the crossing angles
- with non-zero momentum deviation, synchro-betatron resonances will be excited by the presence of the crossing angle, which can reduce the DA further.

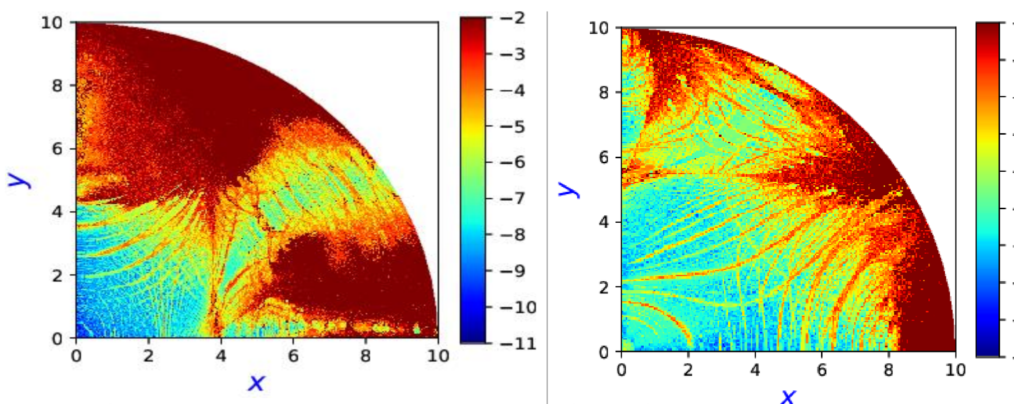


Figure4: Amplitude space FMA plot for nominal tune (left) and a better tune (right) of (0.27, 0.26).

- The tune scan reveals there are 4 tunes where the DA increases by 1.5σ to 7σ. The best tunes are (0.12, 0.13), (0.17, 0.19), (0.24, 0.26) and (0.27, 0.26).

crossing angle scan

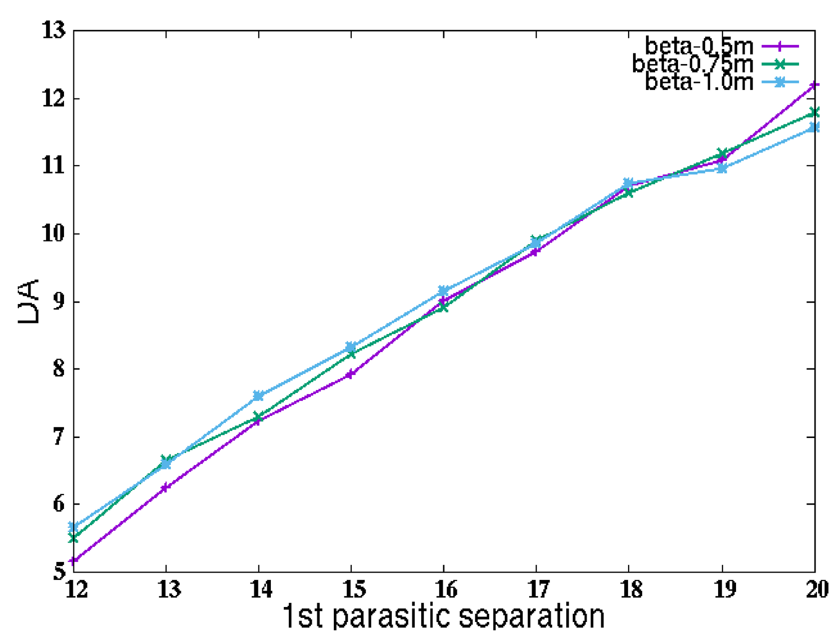


Figure 5: The DA for different β*(0.5m,0.75m,1.0m) with increasing 1st parasitic separation that is normalised by its horizontal beam size. The momentum deviation is 1 times rms momentum spread for all those cases.

- For different β*, to reach the DA goal of 12 σ, the initial separations need to be 20 σ;
- For each β *, there is a 6 σ improvement in the DA from 12 σ separation to 20 σ separation.
- the DA is independent on β * provided the scaled separation is constant.
- The smallest physical aperture from beam centre to beam pipe is 14 σ that is enough for the largest beam crossing angle with nominal beta* 0.75m. However, it will decrease to 9 σ with smallest β * 0.5m.

Long-range interaction compensation

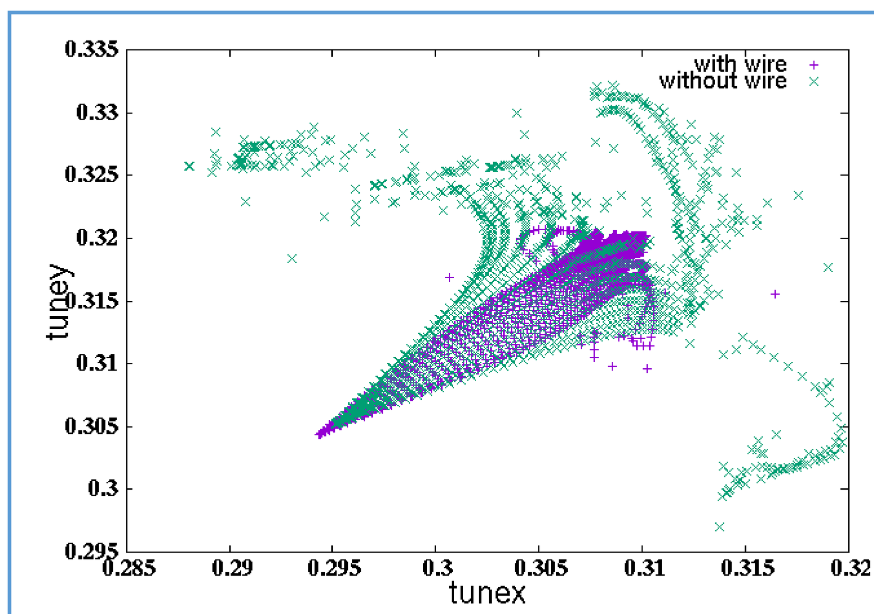


Figure 6: Tune footprint with wire compensation(violet point) and without compensation(green points)

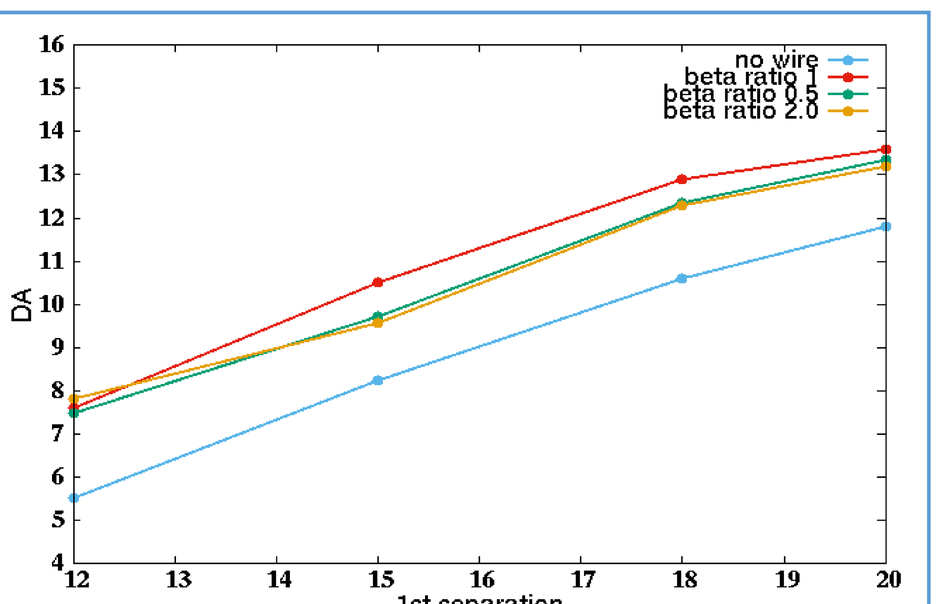


Figure 7: Dynamic aperture with increasing 1st parasitic separation that is normalised by its horizontal beam size for different beta ratios(1.0,0.5,2.0).

- the optimal location for the wires is at a phase advance of π from the long-range interactions and where βx/βy = 1.
- There's always 2σ increase over a large range of crossing angles.

CONCLUSION

- Long-range interaction is the main factor of limiting the particle stability and the DA in the SPPC baseline design is only 5.5σ.
- Tune scans showed the DA can be improved by ~1.5σ with careful choices of tunes.
- To reach the DA goal of 12σ, increasing the crossing angle or increasing β* are the most useful options.
- Using current wire at the phase advance in the crossing plane of nearly π will improve 2σ over a large range of crossing angles.

Email: wanglj@ihep.ac.cn