SAWTOOTH EFFECT IN CEPC

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Abstract

CEPC is a circular electron and positron machine designed to study the properties of the Higgs boson. The beam energy for CEPC is thus chosen to be 120 GeV. At such a high energy, synchrotron radiation has pronounced effect on the beam behavior. In this paper, we will show the synchrotron radiation effect in the CEPC single ring design, namely, the closed orbit, linear optics and dynamic aperture.

INTRODUCTION

After the discovery of Higgs-like boson at CERN [1,2], many proposals have been raised to build a Higgs factory to explicitly study the properties of the particle. One of the most attractive proposals is the Circular Electron and Positron Collider (CEPC) project in China [3].

CEPC was first proposed to be a ring with a circumference of 50-70 km, which could be used as electron and positron collider at phase-I and could be upgraded to a Super proton-proton Collider (SppC) at phase-II. The designed beam energy for CEPC is 120 GeV, the main constraints in the design is the synchrotron radiation power, which should be limited to 50 MW, the target luminosity is on the order of 10^{34} cm^{-2}s^{-1}.

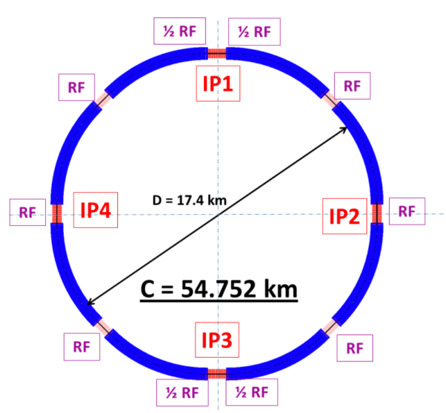

Figure 1: A schematic drawing of CEPC ring.

As beam energy is high, the synchrotron radiation effect is very strong in CEPC. In this paper, we will show the synchrotron radiation effect in the CEPC single ring design, namely, the energy saw-tooth and the effect on the closed orbit, linear optics and dynamic aperture. The layout of the single ring is shown in Fig. 1.

METHOD OF SIMULATING SAWTOOTH EFFECT

The single ring lattice [4,5], which is comprised of 60/60 degree FODO cells and was designed for the pretzel scheme is used to for our study. The code SAD [6] is used for the calculation of lattice and the tracking of dynamic aperture. The energy saw tooth effect is simulated by manually taper the strength of the bending magnets and quadrupoles, namely, each bending magnet can be defined as the bending angle and K0, where K0 represents the effect from the energy loss due to synchrotron radiation; quadrupoles and sextupoles are defined ad K1 and K2 each multiply a factor, this factor represents the effect from the energy loss due to synchrotron radiation.

The new definition of magnets and the simulation method is checked by comparing the results with the original lattice, with the new lattice turn synchrotron radiation off but the original lattice turn synchrotron radiation on. As the two have the same results (except for the energy variation along the beam line), as shown in Fig. 2, it is considered that the new definition of magnets and the simulation method is working.

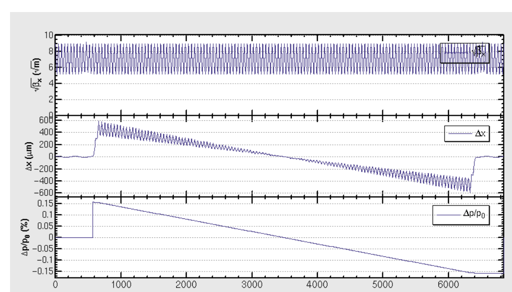

Figure 2: The beta function, closed orbit and energy saw tooth in one arc section of the ring. The maximum sawtooth orbit due to synchrotron radiation is ~ 6 mm, while the maximum energy spread is ~ 0.15%.

SAWTOOTH EFFECT ON THE CLOSED ORBIT

When we turn on the synchrotron radiation effect, the first thing to be checked will be the closed orbit of the electron and positron beam at the IP—-whether or not can they collide.

The closed orbit at IP3 after turn on synchrotron radiation effect is shown in Fig. 3.

We can see that the closed orbit at the IP can still merge, so the beams can collide even when the synchrotron radiation effect is on.

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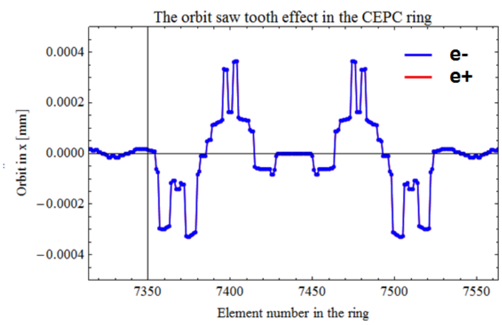

Figure 3: The beta function, closed orbit and energy saw tooth in one arc section of the ring. The maximum sawtooth orbit due to synchrotron radiation is ~ 6 mm, while the maximum energy spread is ~ 0.15%.

SAWTOOTH EFFECT ON THE LATTICE

We first try to see the sawtooth effect on the lattice without Final Focus System. It is found that the sawtooth effect on the arc section is negligible, since neither the beta functions or the tunes are obviously changed.

Then we turn on the sawtooth effect for the lattice with FFS. It showed that the tunes changed from $\nu_x = .08, \nu_y = .22$ to $\nu_x = .03, \nu_y = .76$, and the beta functions at the IP changed from $\beta_x^* = 0.8$ m, $\beta_y^* = 3$ mm to $\beta_x^* = 0.05$ m, $\beta_y^* = 415$ mm. The beta functions before and after turning on the sawtooth effect are shown in Fig. 4 and Fig. 5.

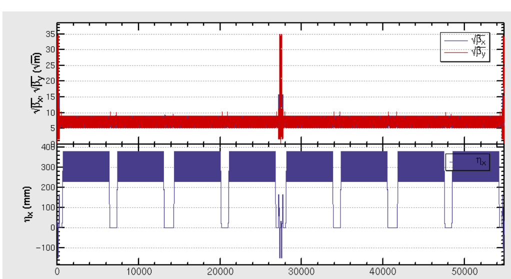

Figure 4: Beta functions and the dispersion function of the ring with final focus system before turn on the energy sawtooth effect.

The orbit along the ring due to the synchrotron radiation effect is shown in Fig. 6.

After turn on the synchrotron radiation effect, the whole lattice becomes unstable, thus there is no dynamic aperture. So we try to reduce the synchrotron radiation energy gradually, and try to see when the sawtooth effect could be effectively suppressed. We found that the lattice became stable when the synchrotron radiation energy per turn was reduced to one fifteenth of the nominal. And the dynamic aperture was checked after reducing the synchrotron radiation energy per turn was reduced to one twentieth of the nominal. It was found that, the dynamic aperture still was much smaller than the original one, especially for the off-momentum particles as shown in Fig. 7.

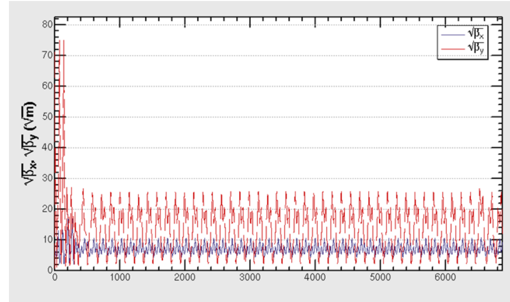

Figure 5: The sawtooth effect on the beta functions for 1/8th of the ring. The beta-beating is clearly shown. The β_y^* changed from 3 mm to 415 mm due to the strong energy sawtooth effect which comes from synchrotron radiation.

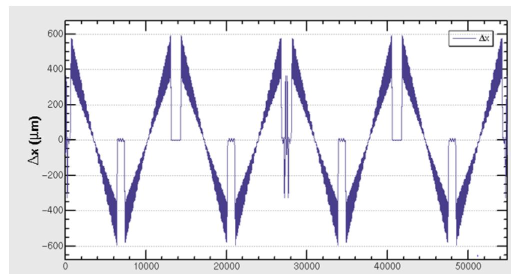

Figure 6: The saw tooth orbit along the ring due to the synchrotron radiation effect.

SUMMARY

In this paper, we have showed how the sawtooth effect in CEPC single ring. Unlike the double ring case, it is unlikely to taper the magnet strength to correct energy saw tooth effect due to the correlation of two beams. As it is shown, the sawtooth effect on the beam dynamics mainly comes from FFS, where the maximum beta functions and the maximum gradient of quadrupoles appear. It is showed in this paper that, the energy sawtooth has a fatal impact on the beam dynamics, even with reduced synchrotron radiation energy to one twentieth of the nominal. It implies that, it is impossible to conquer the sawtooth effect by simply increase the circumference. The ultimate solution will be the two

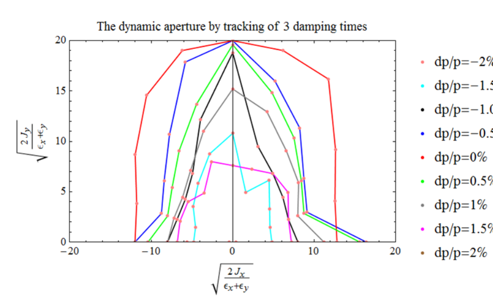

Figure 7: The dynamic aperture after reduce the synchrotron radiation energy per turn was reduced to one twentieth of the nominal.

ring scheme, which enables tapering the magnet strength to correct the sawtooth effect [7].

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