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AN ON-AXIS INJECTION DESIGN FOR CEPC

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Abstract

Considering the requirement on the dynamic aperture in the main collider, an on-axis injection method is needed for the Higgs energy at CEPC. A swap-out on-axis injection scheme using the booster as an accumulation ring is given in this paper. Some dynamical problems concerning the effectiveness of this injection scheme is also discussed.

INTRODUCTION

The CEPC is a circular e+e- collider with a 100-km circumference [1]. Its center-of-mass energy is 240 GeV, and it will serve as a Higgs factory at that collision energy. The design also allows operation at 160 GeV as a W factory and 91 GeV as a Z factory. The CEPC accelerator complex consists of a double-ring collider, a booster, a linac and several transport lines. The collider and booster are located in the same underground tunnel, while the linac is built at ground level. Electrons and positrons are generated and accelerated to 10 GeV in the collider, and then are injected into the booster ring. The beams are then accelerated to full-energy and injected into the collider. The geometry of the CEPC complex is shown in Fig. 1, and some key parameters of the booster and collider are shown in Table. 1.

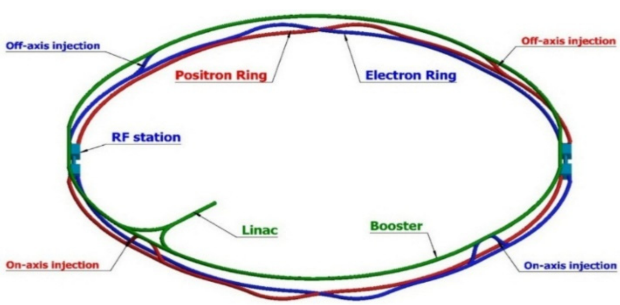

Figure 1: The geometry of the CEPC complex.

For the simplicity and robustness of the injection system, a conventional horizontal off-axis injection is chosen as the baseline design for Higgs, W, and Z mode. However, in the Higgs energy, when the errors and beam-beam effects are considered, the dynamic aperture in the collider may be not enough for an off-axis injection. To relax the requirements on dynamic aperture, an on-axis injection scheme, which is similar to the swap-out injection in HEPS [2], is proposed.

ON-AXIS INJECTION PROCESS

The idea of this on-axis injection is to use the booster as an accumulator ring, and inject the large bunch in the collider into the booster, not the other way around. Thus off-axis injection and bunch mergence are performed in the booster, whose dynamic aperture is large enough. A diagrammatic sketch of this injection process is shown in Fig. 2. In the injection, first fill the booster with small bunches whose bunch charge are 3% of the bunch charge in the collider. Ramp the booster up to 120 GeV, then several circulating bunches of the collider are injected back into the booster ring. After 4 damping times, the injected bunches will merge with the small bunches in the booster with the help of synchrotron radiation damping. Then the merged bunches will be injected back into the same buckets left empty from the last injection. This bunch exchange between the booster and collider ring can repeat until the booster is empty.

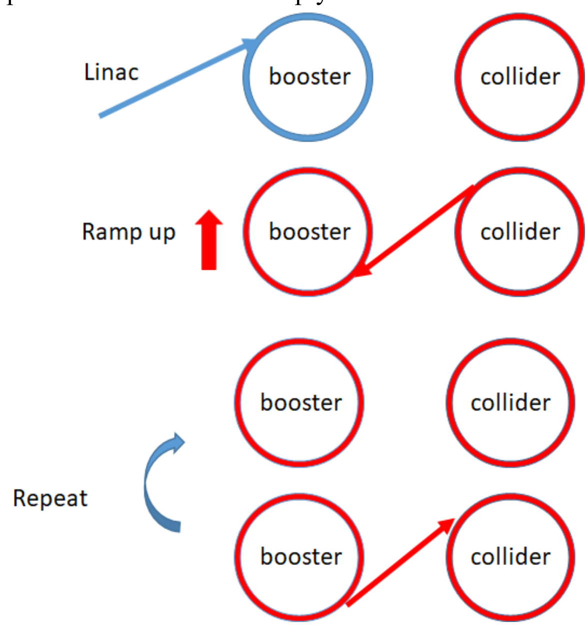

Figure 2: A sketch of the on-axis injection process.

With this on-axis injection scheme, the required horizontal dynamic aperture in the collider is reduced from 13σ_x to 8 σ_x. The number of exchanged bunches between the collider and booster every time is limited by the total current in the booster. With a 1mA booster current threshold, the time structure of the booster is shown in Fig 3. It is shown that the time needed for every on-axis injection is about 35s, which is less than the 47s required by the beam lifetime in the collider [1].

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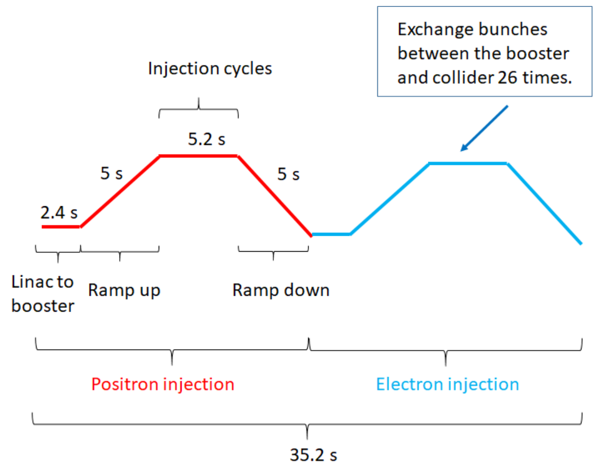

Figure 3: Time structure of the booster in on-axis injection.

Table 1: Some Key Parameters of CEPC

	Collider (Higgs energy)	Booster (Higgs energy)
Beam energy (GeV)	120	120
Circumference (km)	100	100
Bunch number	242	242
EBunch charge (nC)	24	0.72
Current (mA)	17.4	0.52
Emittance x/y (nm.rad)	1.21/0.0024	3.57/0.0178
Bunch length sz (mm)	4.4	2.8
Energy spread (%)	0.134	0.094
Damping time tx/ty/tz (ms)	46.5/46.5/23.5	52/52/26
Lifetime (hour)	0.43	/

SOME DISCUSSIONS

longitudinal Matching

In the on-axis injection scheme, the exchange bunches should be injected back to the right buckets of their own in the collider, so a longitudinal matching is needed. This problem is simplified by the same circumference of the booster and collider. Nevertheless, due to the different paths traveled by the injection beam and the circulating beam, a longitudinal deviation is introduced, as seen in Fig. 4. The length of the transport line is 261.2 meters, and the path difference between the injected beam and the circulating beam is only 0.011 meters, or 0.037 ns in time. This is equivalent to a 17 degree phase shift in the booster, and is in the stable region. This phase shift can be damped by synchrotron radiation. And if any longitudinal mismatch occurs, we could move the RF phase in the booster to fit this problem. An experiment at BEPC II shows that the 200ms injection time is enough for this purpose.

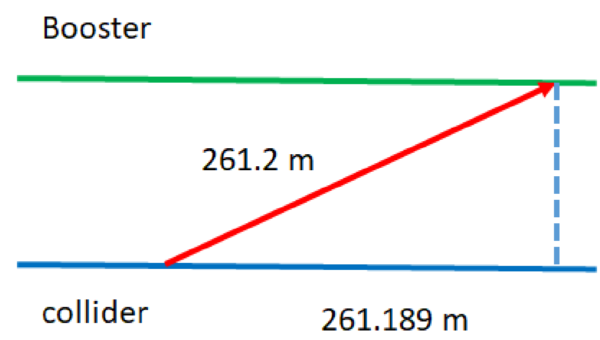

Figure 4: A sketch of the path length traveled by the injection beam and the circulating beam.

Beam Loading

Transient beam loading in the booster by the injection of large bunch and larger total beam current are considered [3]. With 7 large bunches (0.07mA) evenly distributed among the other small bunches. Max cavity voltage drop is 0.48 %. Max phase shift is 0.63 deg. With 13 large bunches in a very short bunch train. The maximum cavity voltage drop is 5.8%, and the maximum phase shift is 7.7 deg.

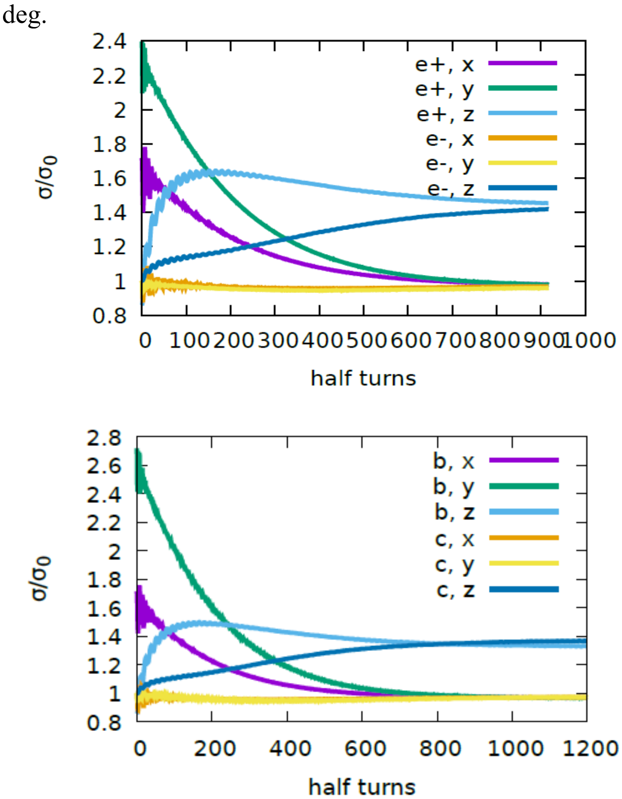

Figure 5: Simulation results without bunch condition difference (top) and with a 9 % σ_x horizontal offset, a 50 % σ_y vertical offset and 3% Intensity difference between colliding bunches.

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Flip-flop Instability

A beam-beam simulation is done for the bunch instability due to the absence of several bunches in the collider. The results are shown in Fig. 5. It shows that there is no flip-flop instability even with a transverse offset and 3% Intensity difference between the colliding beams.

Injection Efficiency

In the on-axis injection we need to transfer the whole bunch into the booster and back into the collider, it is needed and challenging to have a very high injection efficiency in this process. Some preliminary results on effect of the beam position and energy errors are shown in Fig. 6. More work are still needed when more error sources are included.

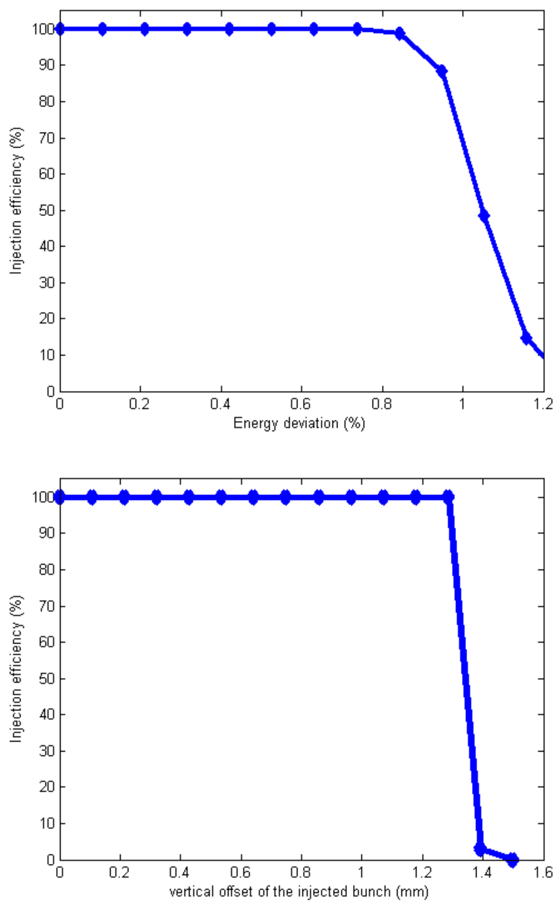

Figure 6: effect of the beam position errors (top) and energy deviation (bottom) on the injection efficiency.

CONCLUSION

An on-axis injection scheme for CEPC is shown in this paper. With this injection, the requirement on the horizontal dynamic aperture in the collider can be reduced significantly. Several problems concerning this injection are discussed. Efforts to improve the injection efficiency are needed in the future to make this on-axis injection a solid design.

REFERENCES

[1] The CEPC Study Group, "CEPC Conceptual Design Report", Volume I- Accelerator, IHEP-CEPC-DR-2018-01, IHEP-AC-2018-01, August 2018.

[2] Z. Duan, *et. al.*, "The Swap-out Injection Scheme For The High Energy Photon Source", in *Proc. IPAC'18.*

[3] J. Zhai, *et. al.*, "HOM Simulations and Damping Scheme for CEPC Cavities", in *Proc. IPAC'17.*