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DESIGN STUDY ON CEPC POSITRON DAMPING RING SYSTEM*

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Abstract

The primary purpose of CEPC damping ring is to reduce the transverse phase spaces of positron beam to suitably small value at the beginning of linac and hence reduce the beam loss in the booster. Before damping ring, an energy spread compression structure is designed to match the RF acceptance of damping ring. A longitudinal bunch length control is also necessary to meet the energy spread requirement in the linac by a bunch compressor system after the damping ring. Both designs for damping ring and energy/bunch compressors are discussed in this paper.

INTRODUCTION

So far, the whole CEPC system is composed of three parts: a linac, a booster, the collider ring [1]. The linac injector system is composed of a 10 GeV S-band linac with electron/positron source and a 1.1 GeV damping ring. The layout of CEPC accelerator chain is shown in Fig. 1.

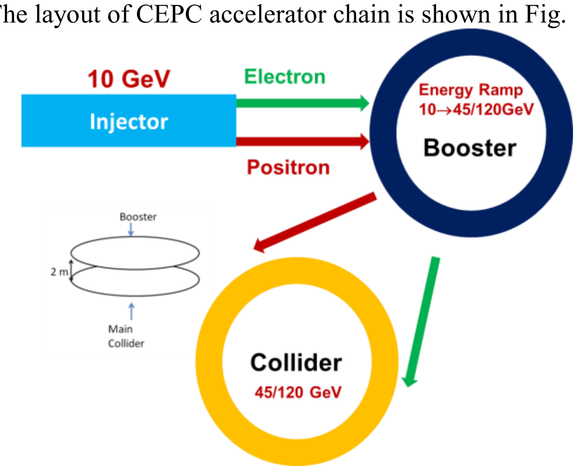

Figure 1: Sketch of CEPC accelerator chain.

The repetition rate of Linac is 100 Hz and one-bunch-per-pulse is considered. To achieve larger than 3 nC positron bunch, a 4 GeV primary electron beam with 10 nC hit tungsten target. The large transverse emittance of the positron beam emerging from the target is transformed to match pre-accelerating section with AMD flux concentrator. The captured positron beam will be pre-accelerated to 200 MeV. Each positron bunch is injected into damping ring every 10 ms and two bunches are stored in the ring so that the storage time for each bunch is 20 ms. The layout of CEPC Linac and damping ring is shown in Fig. 2.

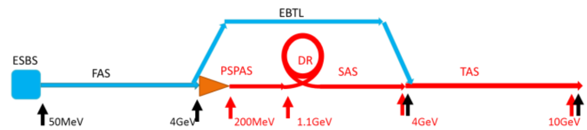

Figure 2: Sketch of CEPC Linac and damping ring.

DAMPING RING DESIGN

The energy of DR is 1.1 GeV and the circumference is 75.4 m. The DR has a racetrack shape and the arcs were designed with 60 degree FODO cell.

The injected emittance (normalized) for DR is 2500 mm·mrad and the injected energy spread is smaller than 0.2%. The positron beam will be stored in DR for 20 ms according to the 100 Hz repetition rate and two-bunch storage scheme. The extracted emittance is better to be smaller than one quarter of the injected emittance. Considering the issue of injection efficiency, the transverse acceptance of DR should be larger than five times of the injection beam size.

DR Parameter Design

The parameters of damping ring are calculated analytically based on the method in reference [2]. The layout of damping ring is shown in Fig. 3 and the main parameters are listed in Table 1.

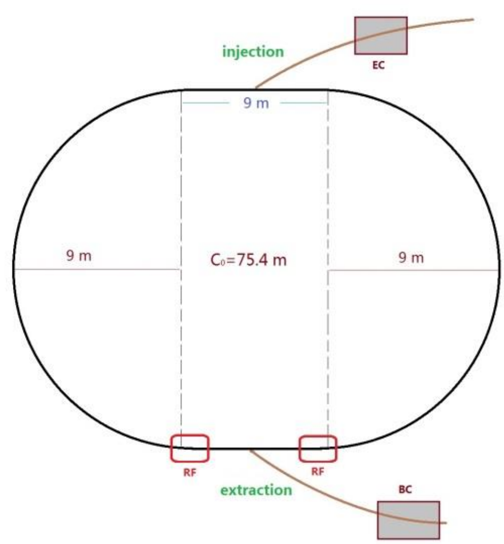

Figure 3: Layout of CEPC damping ring.

Table 1: Main Parameters of Damping Ring

	DR V2.0
Energy (Gev)	1.1
Circumference (m)	75.4
Bending radius (m)	3.6
Dipole strength B_0 (T)	1.03
U_0 (kev/turn)	36.3
Damping time x/y/z (ms)	15.2/15.2/7.6

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δ_0 (%)	0.05
ε_0 (mm.mrad)	376.7
injection σ_z (mm)	5
Extract σ_z (mm)	7.5
ε_{inj} (mm.mrad)	2500
$\varepsilon_{ext\ x/y}$ (mm.mrad)	530/180
δ_{inj} /δ_{ext} (%)	0.18 /0.05
Energy acceptance by RF(%)	1.0
f_{RF} (MHz)	650
V_{RF} (MV)	2.0

DR Optics Design

We chose 60°/60° FODO cell and interleave sextupole scheme for the arc. The emittance of the ring is 175 nm. The twiss parameters of DR are shown in Figs. 4-7.

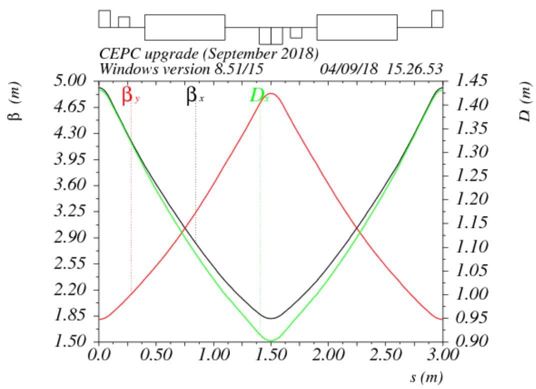

Figure 4: Twiss parameter for the arc FODO cell.

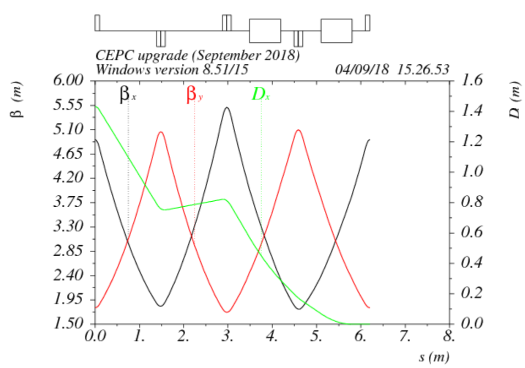

Figure 5: Twiss parameter for the dispersion suppressor.

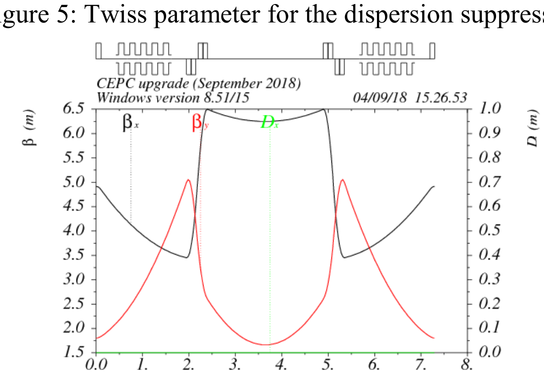

Figure 6: Twiss parameter for injection/extraction section.

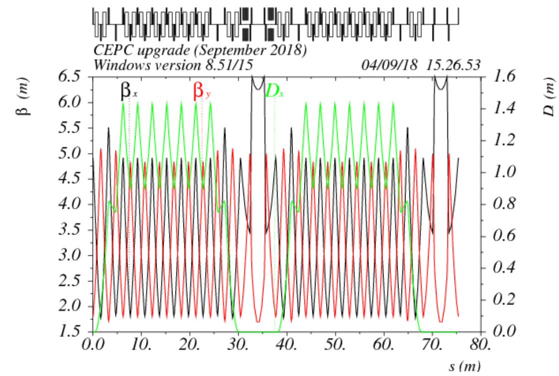

Figure 7: Twiss parameter for the whole ring.

Dynamic Aperture of DR

The chromaticity of the damping ring was corrected by two sextupole families. Then we tracked the DA of damping ring by 240000 turns (4 damping times) using SAD. The DA result is shown in Fig. 8. Since the DA is much larger than 5 times of injection beam size, the injection acceptance for the damping ring should be no problem.

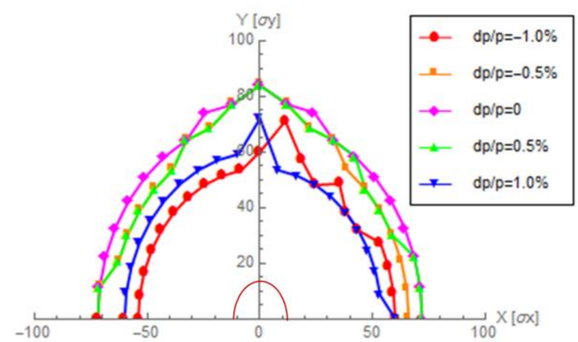

Figure 8: DA of damping ring (red line: 5 times of injection beam size).

ENERGY/BUNCH COMPRESSOR DESIGN

Before damping ring, the energy spread of the positron bunch should be reduced in order to match the RF acceptance of damping ring. After damping ring, longitudinal bunch length control must be provided to minimize energy spread in the linac. Reducing bunch length in the ring to the required value will need very high (~40 MV) RF voltage, so we add a bunch compressor system after the damping ring.

Consideration for EC/BC Design

Our design goal for energy compressor is to get small energy spread (<0.2%) at the entrance of damping ring and get short bunch length (<2mm) before re-injection to the linac. The design principle [2] is same for energy compression and bunch compression due to their inverse relationship. Meanwhile the compression ratio for EC/BC is better to be flexible. The basic structure of BC (EC) in our mind is shown in Fig. 9.

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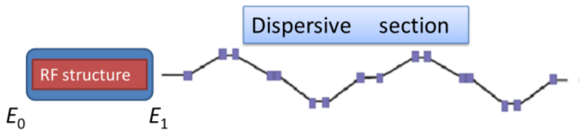

Figure 9: Principle sketch of bunch compressor.

Parameter Design for EC

The injection energy spread for energy compressor is 0.6% and injection bunch length is 1.5 mm. After the energy compressor, the energy spread should be smaller than 0.2% in order to be accepted by the damping ring RF system. The primary parameter designs for EC are listed in table 2. The relationships of injected energy spread and RF voltage with different extracted energy spread are shown in Figs. 10-11.

Table 2: Parameters of CEPC Energy Spread Compressor

	EC
E_0 (GeV)	1.1
δ_0 (%)	0.6
σ_{z0} (mm)	1.5
f_{RF} (MHz)	2860
V_{RF} (MV)	69.2
Length of acc. Structure (m)	3.0
ϕ_{RF} (degree)	89.9
R_{56} (m)	-0.833
E_f (GeV)	1.1
δ_f (%)	0.18
σ_{zf} (mm)	5

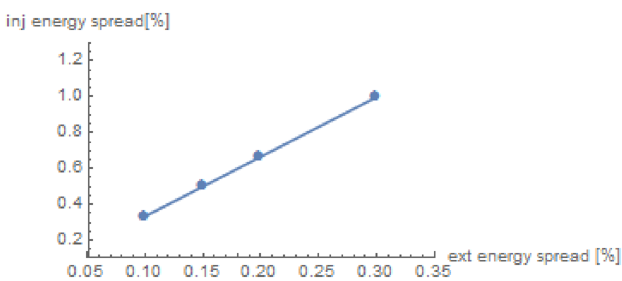

Figure 10: EC inj. energy spread vs. ext. energy spread.

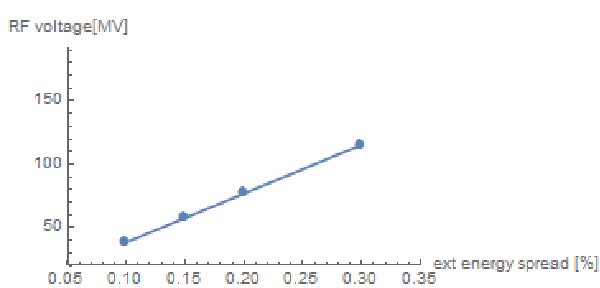

Figure 11: EC RF voltage vs. ext. energy spread.

Parameter Design for BC

The injection bunch length for bunch compressor is 7.5 mm, and the injection energy spread is 0.05%. After the bunch compressor, the beam energy should keep almost 1.1 GeV and the bunch length should be smaller than 2 mm in order to be accelerated in the linac. While the process of bunch compressing is at the cost of enlarging the beam energy spread at the exit of bunch compressor. The primary parameter designs for BC are listed in table 3. The relationships of extracted energy spread and RF voltage with different extracted bunch length are shown in Figs. 12-13.

Table 3: Parameters of CEPC Bunch Compressor

	BC
E_0 (GeV)	1.1
δ_0 (%)	0.05
σ_{z0} (mm)	7.5
f_{RF} (MHz)	2860
V_{RF} (MV)	41.2
Length of acc. Structure (m)	2.0
ϕ_{RF} (degree)	89.9
R_{56} (m)	-1.4
E_f (GeV)	1.1
δ_f (%)	0.54
σ_{zf} (mm)	0.7

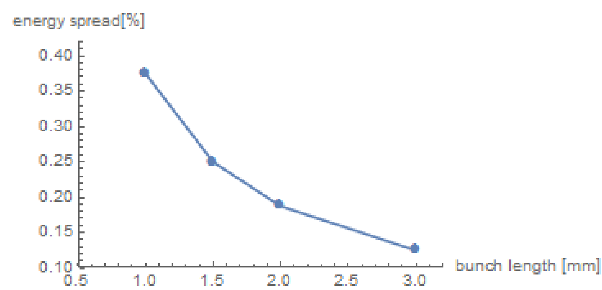

Figure 12: BC ext. energy spread vs. ext. bunch length.

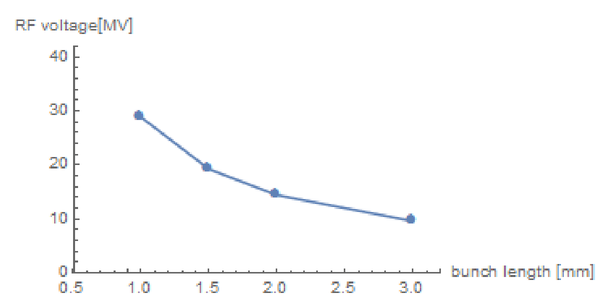

Figure 13: BC RF voltage vs. ext. bunch length.

SUMMARY

The purpose of CEPC damping ring is to reduce the transverse emittance of positron beam. Primary DR design has been finished. DA can fulfil the requirement for injection. Before and after damping ring, an energy compression system and a bunch compression system is needed to adjust energy spread and bunch length. Primary parameter design for EC and BC has been given. The detail optics design and beam dynamics study is underway.

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

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