OPTICS DESIGN FOR CEPC DOUBLE RING SCHEME

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Abstract

CEPC is a future Circular Electron and Positron Collider proposed by China to mainly study the Higgs boson. Its baseline scheme is double ring scheme and alternative scheme is partial double ring scheme. This paper will present the optics design for the main ring of double ring scheme. CEPC will also work as W and Z factories. Compatible optics design for W and Z mode will be presented as well.

INTRODUCTION

CEPC is a future Circular Electron and Positron Collider proposed by China to mainly study the Higgs boson [1]. Its baseline scheme is double ring scheme and alternative scheme is partial double ring scheme [2]. The optics design for the main ring of double ring scheme will be presented in this paper. Fig. 1 show the schematic layout of CEPC double ring scheme. In the RF region, the RF cavities are shared by two ring. Thus each beam will be only filled in half ring.

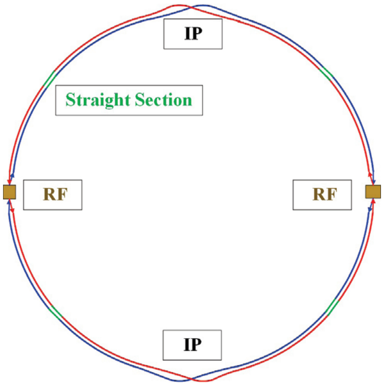

Figure 1: Layout of CEPC double ring scheme.

CEPC will also work as W and Z factories. The main issues for the compatible optics are common RF cavities and reasonable emittance.

The RF region layout for CEPC double ring scheme is shown in the Fig. 2. W and Z modes use the same cavities with H mode to save budget. But lower energy lead to a lower total RF voltage thus fewer cavities should be used in W and Z modes to lower the impedance [3]. To split the difference of cavity numbers in W and Z modes, half number of H cavities used in W and Z modes.

For the W mode, the emittance is got by scaling down the magnet strength with energy. For the Z mode, the emittance got by scaling down the magnet strength with energy will be too small thus two FODO cells in H mode are combined into one cell in Z mode to achieve an adequate emiitance.

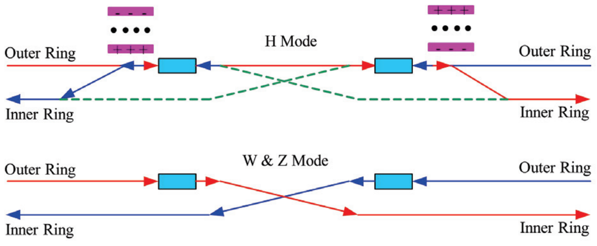

Figure 2: Layout of RF region.

The parameters list fulfilling these requirements shown in Table 1.

Table 1: Parameters for CEPC Double Ring Scheme [4]

	Higgs	W	Z
Number of IPs	2	2	2
Energy (GeV)	120	80	45.5
Circumference (km)	100	100	100
SR loss/turn (GeV)	1.67	0.33	0.034
Half crossing angle (mrad)	16.5	16.5	16.5
Piwinski angle	3.19	5.69	4.29
N_e/bunch (10^{11})	0.968	0.365	0.455
Bunch number	412	5534	21300
Beam current (mA)	19.2	97.1	465.8
SR power /beam (MW)	32	32	16.1
Bending radius (km)	11	11	11
Momentum compaction (10^{-5})	1.14	1.14	4.49
β_{IP} x/y (m)	0.171/0.002	0.171 /0.002	0.16/0.002
Emittance x/y (nm)	1.31/0.004	0.57/0.0017	1.48/0.0078
Transverse σ_{IP} (um)	15.0/0.089	9.9/0.059	15.4/0.125
ξ_x/ξ_y/IP	0.013/0.083	0.0055/0.062	0.008/0.054
RF Phase (degree)	128	126.9	165.3
V_{RF} (GV)	2.1	0.41	0.14
f_{RF} (MHz)	650	650	650
Nature σ_z (mm)	2.72	3.37	3.97
Total σ_z (mm)	2.9	3.4	4.0
HOM power/cavity (kw)	0.41(2cell)	0.36(2cell)	1.99(2cell)
Energy spread (%)	0.098	0.065	0.037
Energy acceptance (%)	1.5		
Energy acceptance by RF (%)	2.1	1.1	1.1
n_γ	0.26	0.15	0.12
Life time due to beamstrahlung_cal (minute)	52		
F (hour glass)	0.96	0.98	0.96
L_{max}/IP ($10^{34}cm^{-2}s^{-1}$)	3.13 (2.0)	5.15	11.9

OPTICS WORKING ON H MODE

Interaction Region

The interaction region was designed to provide local correction of chromaticity generated by the final doublet magnets and crab-waist collision. It consists of modular sections including the final transformer(FT), chromaticity correction for vertical plane(CCY), chromaticity correction for horizontal plane(CCX), crab-waist section(CW) and matching transformer(MT) [5–9]. Up to 3rd order chromaticity are

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corrected with pairs of main sextupoles, phase tuning and additional sextupoles respectively. All the 3rd and 4th resonance driving terms (RDT) due to sextupoles are almost cancelled [5, 8]. The tune shift due to finite length of main sextupoles is corrected with additional weak sextupoles [10].

Fig. 3 and 4 show the lattice design and geometry for interaction region, where the interaction point is located at the middle. An asymmetric lattice adopted to allow softer bends in the upstream of IP [11]. Reverse bending direction of last bends is applied to avoid synchrotron radiation hitting IP. For the upstream of IP, no bends in the last 100 m and the critical energy of synchrotron radiation is less than 60 keV within 150 m and 100 keV within 400 m. For the downstream of IP, no bends in the last 70 m and the critical energy is less than 120 keV within 120 m and 300 keV within 250 m. A preliminary study shows that the vertical emittance growth due to combination of solenoid & anti-solenoid field and crossing angle is less than 10% and acceptable.

Table 2: Parameters of the Interaction Region [12]

Parameters	**Unit**	**Value**
Distance from QD0 to IP L^*	m	2.2
Half crossing angle θ_c	mrad	16.5
Solenoid filed B_z	T	3.0
Gradient of QD0/QF1 $G_{\mathrm{QD0}}/G_{\mathrm{QF1}}$	T/m	150/100
Length of QD0/QF1 $G_{\mathrm{QD0}}/G_{\mathrm{QF1}}$	m	1.73/1.48
Distance of QD0 and QF1 d	m	0.5

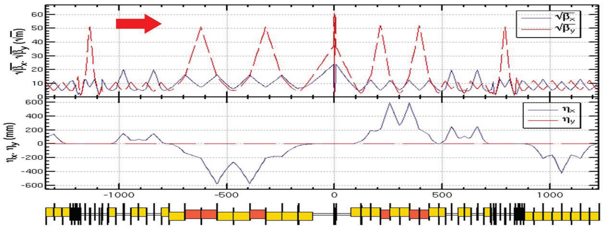

Figure 3: Lattice design for interaction region (red block are reserved dipoles with zero bending angle).

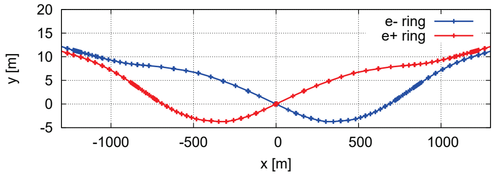

Figure 4: Geometry of interaction region.

Arc Region

For the Arc region, the FODO cell structure is chosen to provide a large filling factor. The 90/90 degrees phase advances and non-interleaved sextupole scheme [11] are selected due to its property of aberration cancellation: The tune shift is very small even with small emittance; In each 20 cells, all the 3rd and 4th resonance driving terms due to sextupoles cancelled, except small 4Qx, 2Qx+2Qy, 4Qy, 2Qx-2Qy [13]. The left aberration is mainly chromaticity which could be corrected with many families of arc sextupoles.

The dispersion suppressor at the ends of arc region was design with same FODO structure and re-matched quadrupoles. The way with half bending angle will change the geometry thus not adopted.

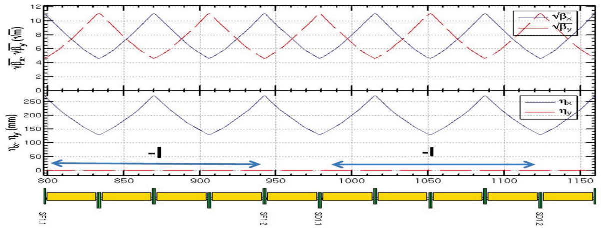

Figure 5: Lattice design for arc region of H mode.

RF Region

In the RF region, the RF cavities are shared by two ring. Each RF station is divided into two sections for bypassing half numbers of cavities in W and Z modes, see Fig. 2. An electrostatic separator combined with a dipole magnet to avoid bending of incoming beam [11], see Fig. 6. The gradient of the electrostatic separator is 1.8 MV/m and its total length 50 m. After the combined magnet, there is a drift as long as 75 m to make the two beam distance as large as 10 cm at the entrance of quadrupole. In order to limit the beta functions, two triplets are used. Then the beam is further separated with dipoles. The deviation of outgoing beam is 1.0 m for bypassing the cryo-modules whose radius is around 0.75 m.

In the straight section for cryo-modules, small average beta functions is favourite for the reason of reducing the multi-bunch instability caused by RF cavities. Thus phase advance of 90/90 degree is choosen and quadrupoles distance of 14 m which allowed a cryo-module is choosen.

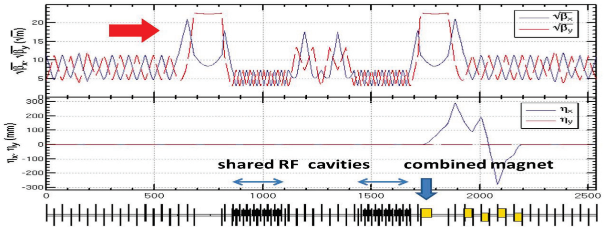

Figure 6: Lattice design for RF region of H mode.

Whole Ring

Fig. 7 shows the lattice design for whole ring of H mode.

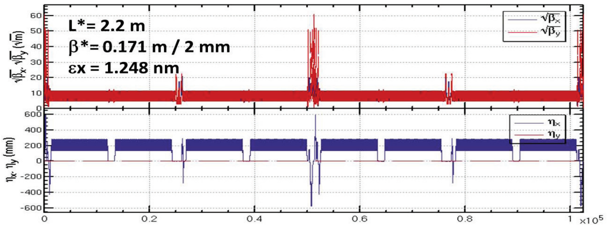

Figure 7: Lattice design for whole ring of H mode.

OPTICS WORKING ON W MODE

The interaction region is simply scaling down with energy from H to W mode as the same interaction point parameters. The Arc Region is also simply scaling down with energy from H to W mode. The RF Region is the same with Z mode which will be discussed in next section.

OPTICS WORKING ON Z MODE

Interaction Region

The interaction region is got by scaling down with energy from H and rematching the matching section for the slightly different β_x^*.

Arc Region

The horizontal emittance is given by

$$\epsilon_x = F\frac{C_q\gamma^2}{J_x}\theta^3 \tag{1}$$

where C_q is an constant, F depends on the structure of the cell, J_x usually equals to 1, γ is Lorentz factor and θ is the bending angle per cell. To achieve an adequate emittance from H to Z mode, two FODO cells are combined into one cell in the arc region. Fig. 8 shows the lattice design for arc cell of Z mode. The de-focusing quadrupole in H mode are turned off and focusing quadrupoles in the middle of two cells change sign.

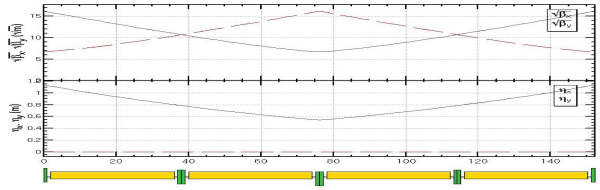

Figure 8: Lattice design for arc cell of Z mode.

RF Region

In the RF region, half numbers of cavities in H mode bypassed to fulfill the RF requirement mentioned and allow bunches filled in whole ring. Fig. 9 shows the lattice design for RF region of Z mode.

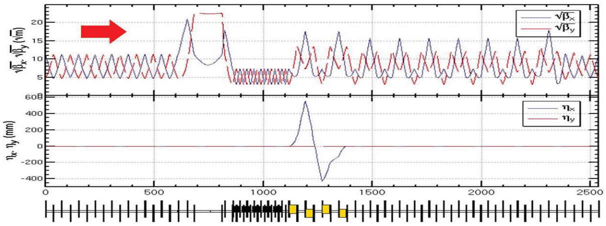

Figure 9: Lattice design for RF region of Z mode.

Whole Ring

Fig. 10 shows the lattice design for whole ring of Z mode. The emittance of the designed value almost achieved and some margin left.

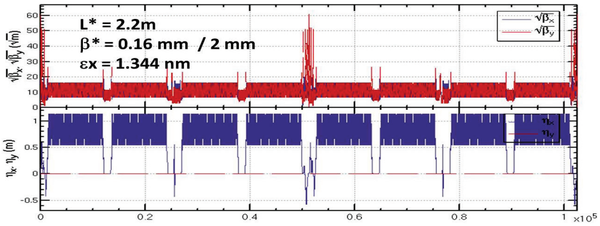

Figure 10: Lattice design for whole ring of Z mode.

SUMMARY

For the CEPC double ring scheme, optics for main ring with compatible modes of H, W & Z are designed. The design fulfills requirements of the design parameters, geometry, photon background and key hardware. The lattice is ready for dynamic aperture study, further MDI study and key hardware design. The dynamic aperture study is undergoing.

ACKNOWLEDGEMENT

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