PROCEEDINGS OF SCIENCE

CEPC Accelerator towards TDR

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In Nov. 2018, Circular Electron Positron Collider (CEPC) publically released Conceptual Design Report (CDR) and entered into Technical Design Report (TDR) phase, which included luminosity optimization, key technologies demonstration, such as magnets, SCRF cavities and accelerating unit, 650 MHz high efficiency klystron, vacuum system, linac injector RF components, electro-magntic seperator, SC magnets in Interaction region, etc. Parallely, CEPC siting and civil engineering designs are also in progress. It is aimed that CEPC TDR be completed by the end of 2022.

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1. Introduction

The discovery of the Higgs boson at CERN's Large Hadron Collider (LHC) on July 4, 2012 raised new opportunities for large-scale colliders. Due to the low mass of the Higgs boson, it is possible to produce it in the relatively clean environment by a circular electron−positron collider with reasonable luminosity, technology, cost and power consumption.

The Higgs boson is the cornerstone of the Standard Model (SM), yet is also related to many unknown mysteries: the large hierarchy between the weak scale and the Planck scale, the nature of the electroweak phase transition, the naturalness problem, the vacuum-stability problem and Dark matter issues, among others. Therefore, precise measurements of the Higgs boson serve as excellent probes of the fundamental physics principles underlying the SM and of exploration beyond the SM, and to build as soon as possible a Higgs factory is the most urgent requirement not only from high energy physics community world wide, but also from Science community as a whole.

In September 2012, Chinese scientists proposed a 240 GeV Circular Electron Positron Collider (CEPC), serving two large detectors for Higgs studies. The tunnel could also host a Super Proton Proton Collider (SPPC) co-existing with CEPC to reach energies beyond the LHC [1–4].

CEPC Preliminary Conceptual Design Report (Pre-CDR) [5] was published in March 2015, followed by a Progress Report in April 2017 [6, 7]. The Conceptual Design Report (CEPC Accelerator CDR) has been formally released in Nov, 2018 [8]. In May 2019, CEPC accelerator and physics/detector documents were submitted to European High Energy Physics Strategy workshop for world wide discussions [9].

2. CEPC CDR review

The CEPC Conceptual Design Report (CDR) baseline design is a 100 km fully partial double ring, as shown in Fig. 1 with the CDR parameters shown in Tab. 1.

3. CEPC TDR started

According to the recommendations from the CEPC International Advisory Committee (IAC), in 2019, CEPC accelerator formally entered into the phase of Technical Design Report (TDR), which is scheduled to be completed at the end of 2022 [12].

In the TDR phase, one needs to continue to make optimization design of parameters, both for Higgs and Z luminosities, taking into account the possiblity of ttbar option as well. The new Higgs energy parameter and new lattice of $\beta_y = 1$ mm could push Higgs luminisity to 5×10^{34} cm^{2}s^{-1}, and the dynamic aperture study is shown in Fig. 2.

As for Z-pole energy, to increase the luminosity up to 10^{36} cm^{2}s^{-1} is through increasing the colliding beam current, the new parameters for high luminosity for Z-pole energy by using single cell 650 MHz SC RF cavities instead of 2-cell ones as CDR is shown through SCRF cavity bapass scheme as shown in Fig. 3.

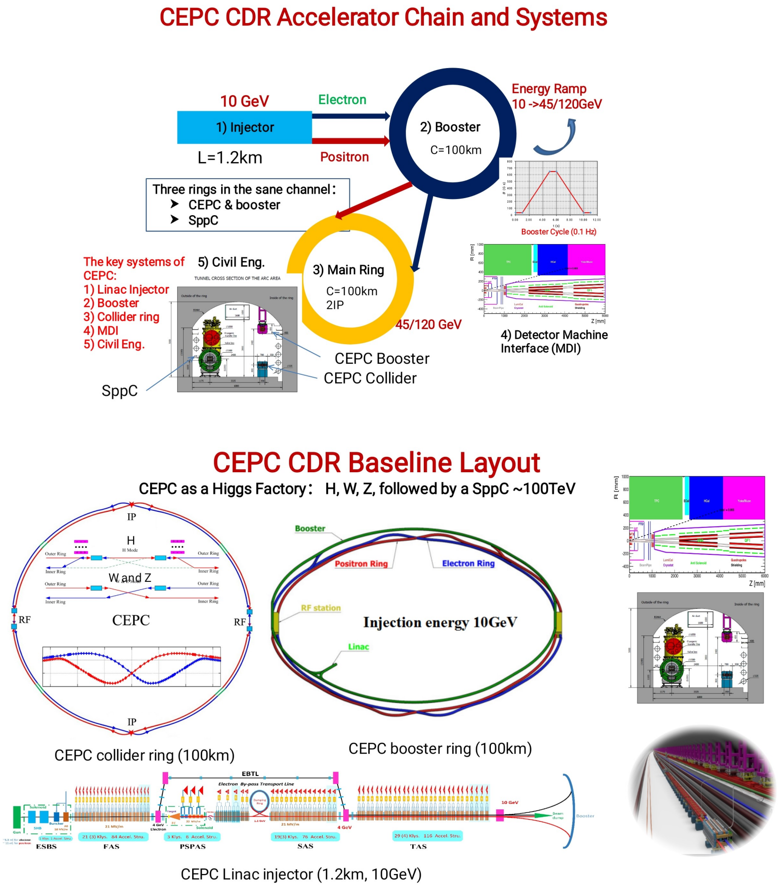


Figure 1: CEPC CDR baseline layout

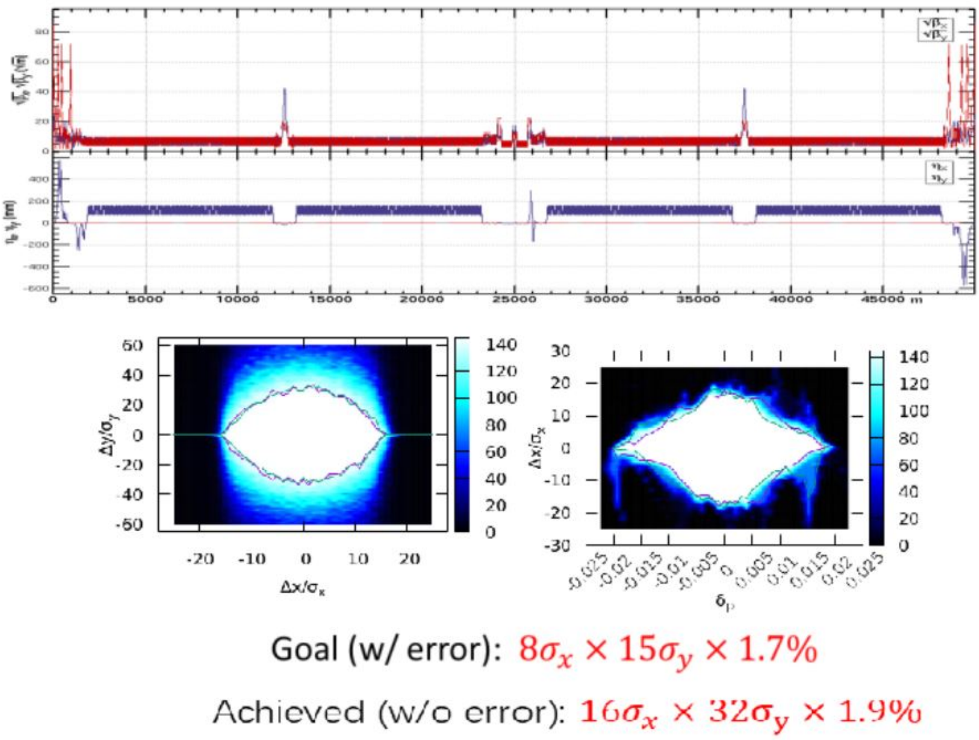


Figure 2: CEPC dynamic aperture of β_y =1 mm.

Table 1: CEPC CDR parameters.

	Higgs	W	Z(3T)	Z(2T)
Number of IPs	2			
Beam energy (GeV)	120	80	45.5	
Circumference (km)	100			
Synchrotron radiation loss/turn (GeV)	1.73	0.34	0.036	
Crossing angle at IP (mrad)	16.5×2			
Piwinski angle	2.58	7.0	23.8	
Number of particles/bunch N_e (10^{10})	15.0	12.0	8.0	
Bunch number (bunch spacing)	242 (0.68μs)	1524 (0.21μs)	12000 (25ns+10%gap)	
Beam current (mA)	17.4	87.9	461.0	
Synchrotron radiation power /beam (MW)	30	30	16.5	
Bending radius (km)	10.7			
Momentum compact (10^{-5})	1.11			
β function at IP $\beta_x^\star$ /$\beta_y^\star$(m)	0.36/0.0015	0.36/0.0015	0.2/0.0015	0.2/0.001
Emittance ϵ_x/ϵ_y(nm)	1.21/0.0031	0.54/0.0016	0.18/0.004	0.18/0.0016
Beam size at IP $\sigma_x/\sigma_y(\mu$m)	20.9/0.068	13.9/0.049	6.0/0.078	6.0/0.04
Beam-beam parameters ξ_x/ξ_y	0.031/0.109	0.013/0.106	0.0041/0.056	0.0041/0.072
RF voltage V_{RF} (GV)	2.17	0.47	0.10	
RF frequency f_{RF} (MHz) (harmonic)	650(216816)			
Natural bunch length σ_z (mm)	2.72	2.98	2.42	
Bunch length σ_z (mm)	3.26	5.9	8.5	
HOM power/cavity (2 cell) (kw)	0.54	0.75	1.94	
Natural energy spread (%)	0.1	0.066	0.038	
Energy acceptance requirement (%)	1.35	0.4	0.23	
Energy acceptance by RF (%)	2.06	1.47	1.7	
Photon number due to beamstrahlung	0.1	0.05	0.023	
Lifetime simulation (min)	100		-	
Lifetime (hour)	0.67	1.4	4.0	2.1
F (hour glass)	0.89	0.94	0.99	
Luminosity/IP $L(10^{34}\text{cm}^{-2}\text{s}^{-1})$	2.93	10.1	16.6	32.1

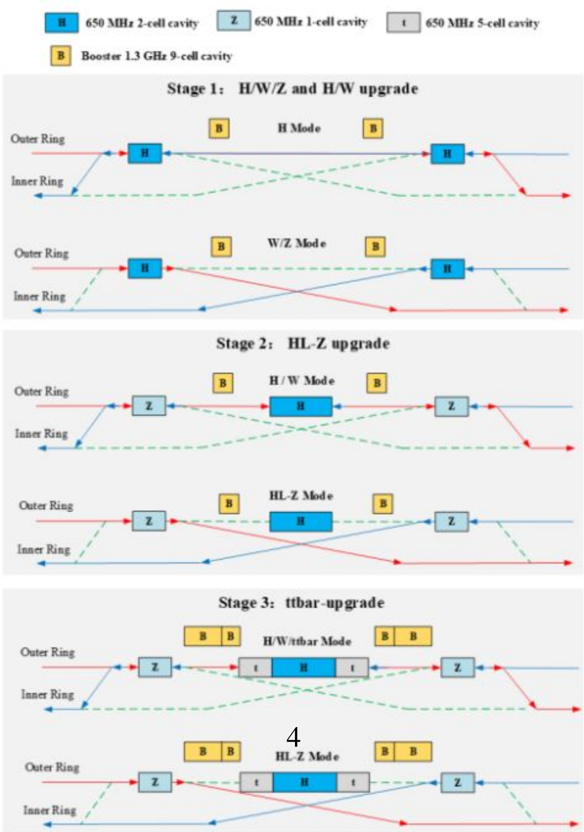
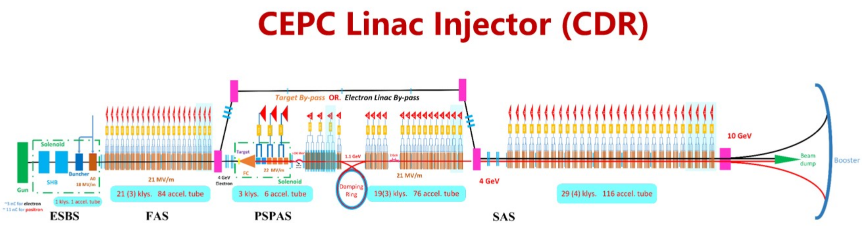


Figure 3: CEPC SCRF bypass schemes for different energies.

CEPC CDR 10GeV linac injector and parameters are shown in Fig. 4.



Parameter	Symbol	Unit	Baseline	**Design reached**
e^-/e^+ beam energy	E_{e-}/E_{e+}	GeV	**10**	**10**
Repetition rate	f_{rep}	Hz	**100**	**100**
e^-/e^+ bunch population	N_{e-}/N_{e+}		$> 9.4\times10^9$	**1.9×10^{10} / 1.9×10^{10}**
		nC	**> 1.5**	**3.0**
Energy spread (e^-/e^+)	σ_e		**$< 2\times10^{-3}$**	**1.5×10^{-3} / 1.6×10^{-3}**
Emittance (e^-/e^+)	ε_r	nm· rad	**< 120**	**5 / 40 ~120**
Bunch length (e^-/e^+)	σ_l	mm		**1 / 1**
e^- beam energy on Target		GeV	4	**4**
e^- bunch charge on Target		nC	10	**10**

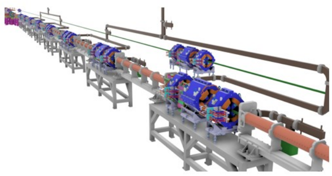


Figure 4: CEPC linac injector layout and parameters.

In CEPC CDR, injector linac energy was chosen to be 10 GeV, and the booster dipole starting magnetic field strength is 28 Gauss, which is very for dipole magnet fabrication. As backups for higher booster injection energies, two options have been studied, one is to increase linac exit energy to 20 GeV by adding a C-band linac after S-band linac, another is to use a plasma accelerator after 10 GeV Linac to boost the injector energy to 45 GeV.

4. CEPC TDR R&D progress status

CEPC TDR are mainly focused on key hardware technology R&D based on CDR to make the technology available and ready for industrialization before the starting of the project, and since TDR started, many progresses have been made [10, 11].

The new S-band accelerating structure has been fabricated and high power tested with accelerating gradient of 20 MV/m, which satisfies the CEPC CDR design goal.

The R&D on high precision booster dipoles are carried out by two types of designs, one is with iron core and another is without iron core. The dipole without iron core has reached the design precision.

The CEPC main collider rings employ dual aperture dipoles and quadrupoles and 1 meter test models are made. CEPC booster uses 1.3 GHz SC accelerator system with cryomodules similar to those used in ILC composed of 9-cell TESLA type SC cavities. CEPC collider ring uses 650 MHz SC accelerator system with cryomodules composed by 2-cell SC cavities in CDR or single cavities in TDR studies. For CDR 650 MHz accelerator R&D, a test cryomodule of two 2-cell cavities have been constructed, 1.3 GHz 9-cell cavity and 650 Mhz 2-cell cavity have reached operating goals. As for CEPC SC accelerator system test experiment with beam and cryomodule assembly, IHEP has developped a new 4500 m^2 supercondcuting technology laboratory which will be put into operation in 2021. CEPC 650 MHz CW 800 kW klystron efficiency goal is larger than 80%. As a first 650 MHz high power CW klystron, a single beam test klystron of 800 kW with efficiency of 65% was designed, facbricated and tested, and the output power has reached pulsed power of 800 kW (400 kW CW due to test load limitation), efficiency 62% and band width±0.5 MHz. As for CEPC 800 kW CW kystron of 80% efficiency, a single beam and a multi beam klystron (MBK) have been designed and the efficiency of 77% and 80.7% have been achieved by 3D simulation which will be tested in 2021 and 2022, respectively.

CEPC civil engineering design is composed of tunnel system design and components' numerical installation design. Numerical modelling design techniques (BIM) have been used .

5. CEPC site selection

Deciding where to site the CEPC-SppC involves numerous considerations, technical and social environment factors. So far six sites have been considered, among them, three sites, Qinhuangdao, Huzhou, and Changsha, three BIM design of CEPC videos have been done [12].

6. Summary

In this talk we give a brief review of the CEPC TDR R&D progresses. CEPC TDR will be completed at the end of 2022.

7. Acknowledgements

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