



CEPC: A Higgs Factory Collider

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On behalf of CEPC Accelerator Group
Seattle Snowmass Summer Meeting 2022

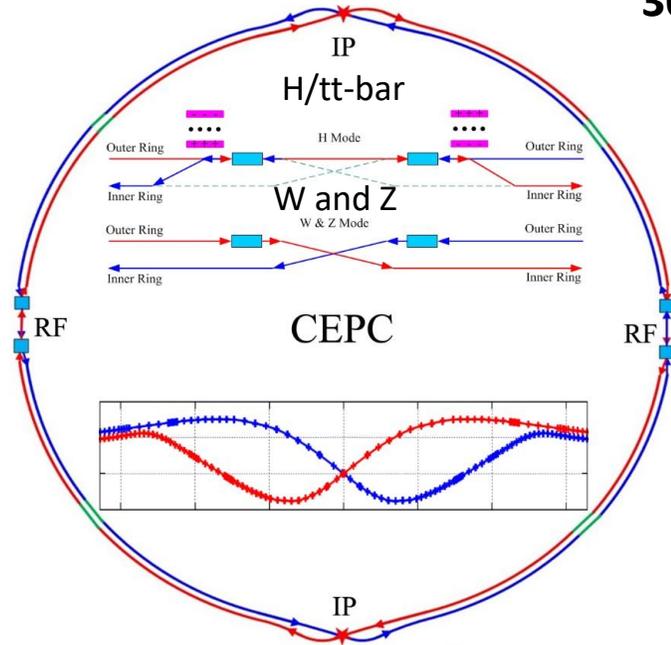
July 17-27, 2022, USA



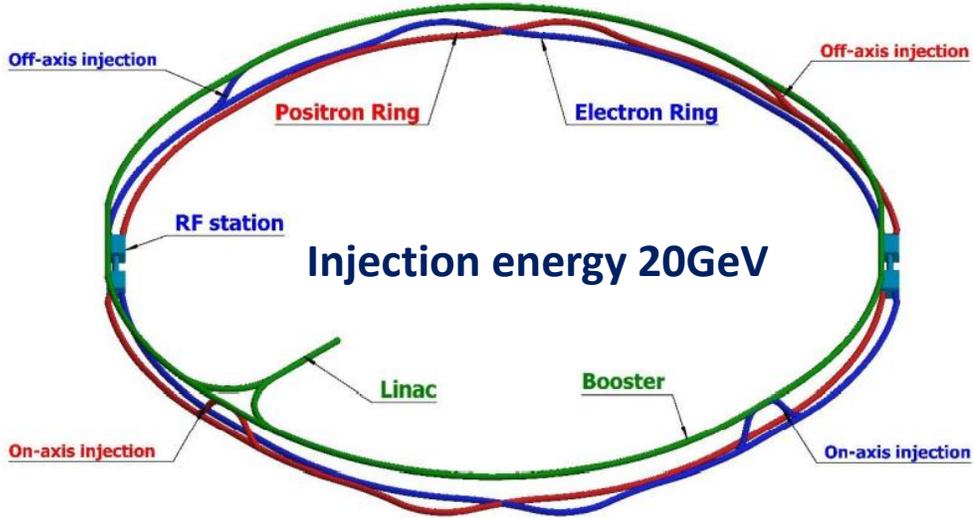
CEPC TDR Layout

CEPC as a Higgs Factory: **H**, **W**, **Z**, upgradable to **tt-bar**, followed by a SppC ~125TeV

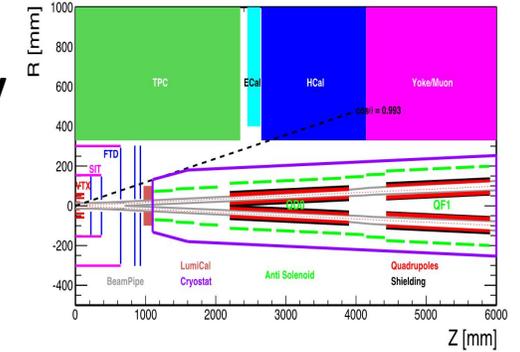
30MW SR power per beam (upgradable to 50MW)



CEPC collider ring (100km)

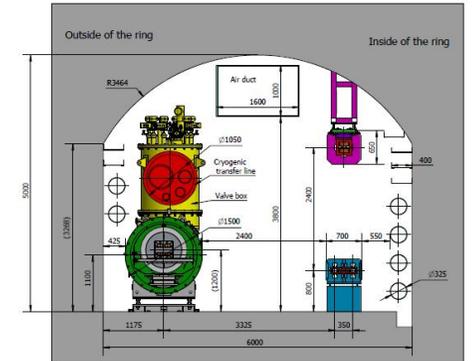


CEPC booster ring (100km)



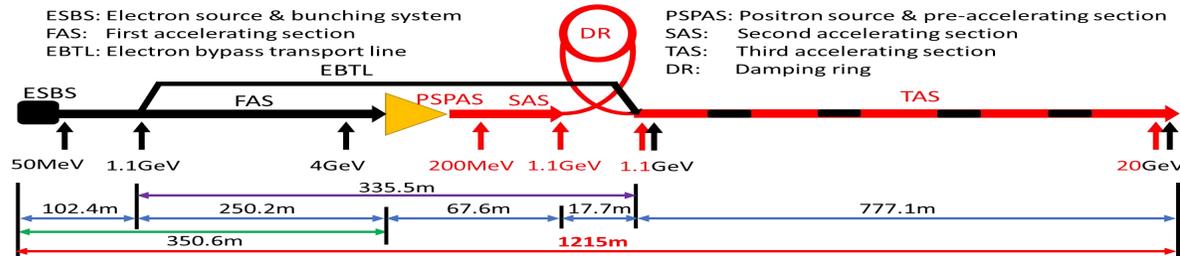
CEPC MDI

TUNNEL CROSS SECTION OF THE ARC AREA



CEPC Civil Engineering

CEPC TDR S+C-band 20GeV linac injector



CEPC TDR Parameters

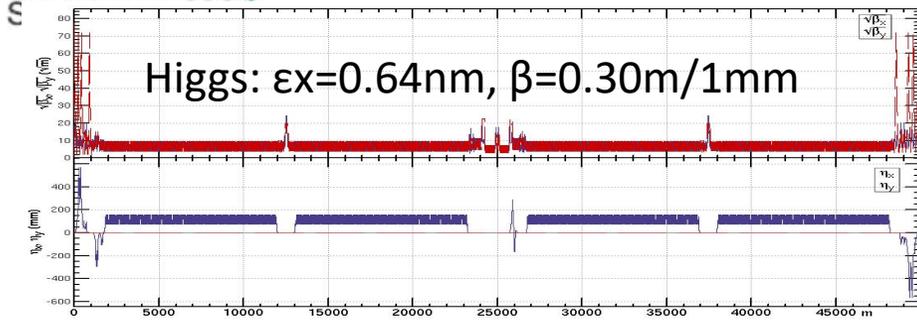
	Higgs	Z	W	ttbar
Number of IPs	2			
Circumference [km]	100.0			
SR power per beam [MW]	30			
Half crossing angle at IP [mrad]	16.5			
Bending radius [km]	10.7			
Energy [GeV]	120	45.5	80	180
Energy loss per turn [GeV]	1.8	0.037	0.357	9.1
Piwinski angle	5.94	24.68	6.08	1.21
Bunch number	268	11934	1297	35
Bunch spacing [ns]	591 (53% gap)	23 (18% gap)	257	4524 (53% gap)
Bunch population [10^{10}]	13	14	13.5	20
Beam current [mA]	16.7	803.5	84.1	3.3
Momentum compaction [10^{-5}]	0.71	1.43	1.43	0.71
Beta functions at IP (bx/by) [m/mm]	0.3/1	0.13/0.9	0.21/1	1.04/2.7
Emittance (ex/ey) [nm/pm]	0.64/1.3	0.27/1.4	0.87/1.7	1.4/4.7
Beam size at IP (sigx/sigy) [$\mu\text{m}/\text{nm}$]	14/36	6/35	13/42	39/113
Bunch length (natural/total) [mm]	2.3/4.1	2.5/8.7	2.5/4.9	2.2/2.9
Energy spread (natural/total) [%]	0.10/0.17	0.04/0.13	0.07/0.14	0.15/0.20
Energy acceptance (DA/RF) [%]	1.6/2.2	1.3/1.7	1.2/2.5	2.3/2.6
Beam-beam parameters (ksix/ksiy)	0.015/0.11	0.004/0.127	0.012/0.113	0.071/0.1
RF voltage [GV]	2.2	0.12	0.7	10
RF frequency [MHz]	650	650	650	650
Longitudinal tune Qs	0.049	0.035	0.062	0.078
Beam lifetime (bhabha/beamstrahlung)[min]	39/40	80/18000	60/700	81/23
Beam lifetime [min]	20	80	55	18
Hour glass Factor	0.9	0.97	0.9	0.89
Luminosity per IP [$1\text{e}34/\text{cm}^2/\text{s}$]	5.0	115	16	0.5



CEPC Collider Ring TDR Lattice Design

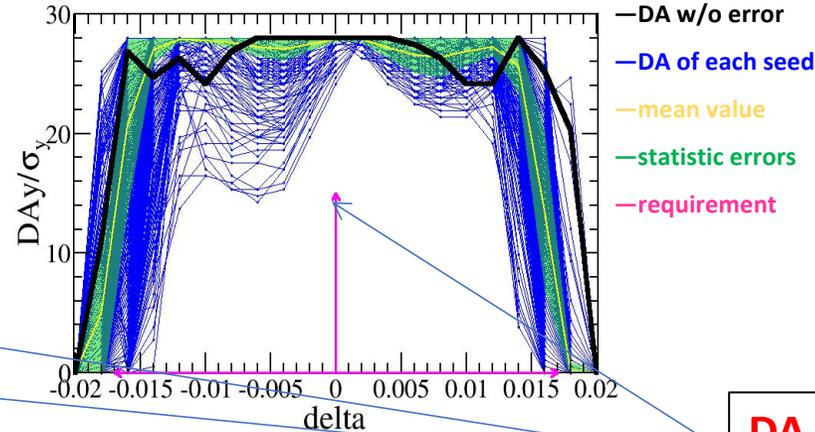
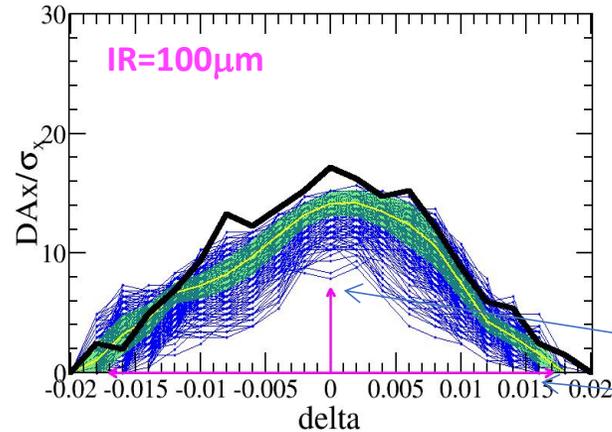
-dynamic apertures with errors

Accelerator design and challenges



Component	Δx (mm)	Δy (mm)	$\Delta\theta_z$ (mrad)	Field error
Dipole	0.10	0.10	0.10	0.01%
Arc Quadrupole	0.10	0.10	0.10	0.02%
IR Quadrupole	0.10	0.10	0.10	
Sextupole	0.10	0.10	0.10	

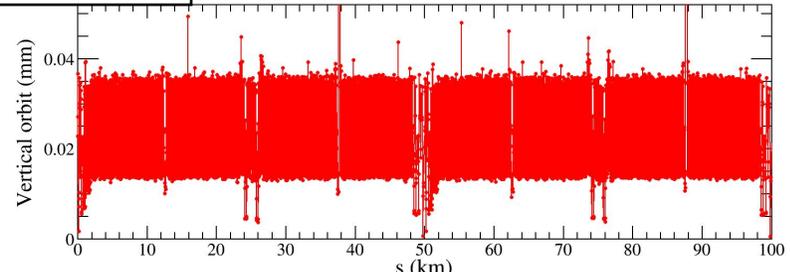
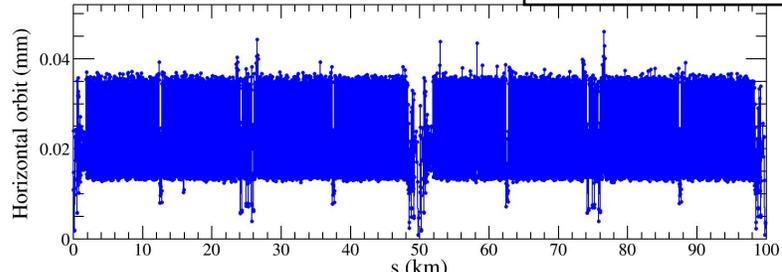
- Effects included in tracking
- Synchrotron motion
- Radiation loss in all magnets
- Tapering
- Crab waist sextupole
- Maxwellian fringes
- Kinematic terms
- Finite length of sextupole



The DA with errors of TDR lattice satisfy the design goal

DA design goal
 $7\sigma_x \times 15\sigma_y \times 1.6\%$

$RMS_{COD} < 0.05 \text{ mm}$





CEPC TDR R&D Status of Key Technologies

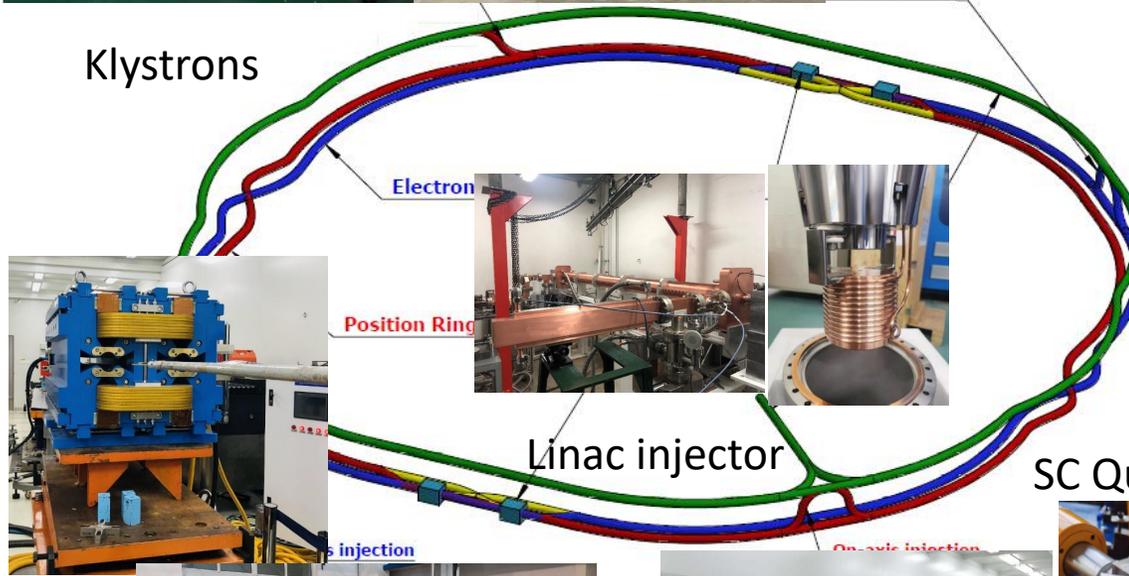


Klystrons

SC cavities



SRF technology



SC Quadrupole

Vacuum



Magnets



Kickers



CEPC TDR Power and Green CEPC

CEPC CDR Power for Higgs (SR 30MW/beam)

	System for Higgs (30MW)	Location and electrical demand(MW)						Total (MW)
		Ring	Booster	LINAC	BTL	IR	Surface building	
1	RF Power Source	103.8	0.15	5.8				109.75
2	Cryogenic System	11.62	0.68			1.72		14.02
3	Vacuum System	9.784	3.792	0.646				14.222
4	Magnet Power Supplies	47.21	11.62	1.75	1.06	0.26		61.9
5	Instrumentation	0.9	0.6	0.2				1.7
6	Radiation Protection	0.25		0.1				0.35
7	Control System	1	0.6	0.2	0.005	0.005		1.81
8	Experimental devices					4		4
9	Utilities	31.79	3.53	1.38	0.63	1.2		38.53
10	General services	7.2		0.2	0.15	0.2	12	19.75
	Total	213.554	20.972	10.276	1.845	7.385	12	266.032

Total TDR power at Higgs (SR 30MW/beam): **272MW**

where

Linac: **15.5MW**

Booster ring: **19.8MW**

Coolider ring: **214.664MW**

Total TDR power at upgrade Higgs (SR 50MW/beam): **344MW**

Energy Saving Consideration (Green CEPC)

Y. Xiao

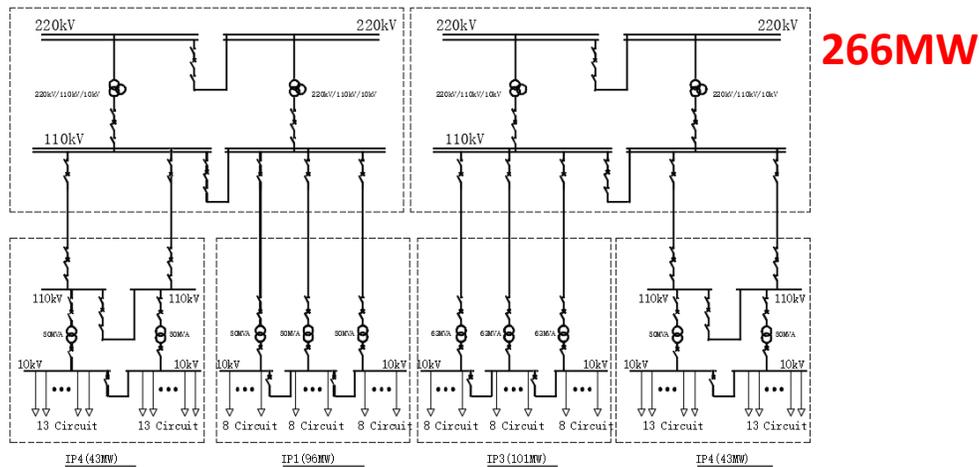
Reduce power consumption

- ⊗ Auxiliary facility should be **built near to the heat load center**.
- ⊗ **Minimize the operating pressure**.
- ⊗ Electric power consumption of auxiliary facility reaches **38.53 MW**. Using **high efficiency motor** and **variable frequency motor** will help to reduce energy consumption.
- ⊗ Adopting **high temperature chiller**, the cooling efficiency will increase by 2~3% for every 1°C increase of water outlet temperature.

Thermal energy recovery

Through heat recovery chiller, heat exchanger maximizes the heat absorbed by LCW as several heat sources.

- ⊗ Air conditioning heat source
- ⊗ Heating source in winter.(If possible, the heat supply could radiate to surrounding residential areas)
- ⊗ Other heat sources





CEPC TDR Parameters (upgrade)

	Higgs	W	Z	ttbar
Number of IPs	2			
Circumference [km]	100.0			
SR power per beam [MW]	50			
Half crossing angle at IP [mrad]	16.5			
Bending radius [km]	10.7			
Energy [GeV]	120	80	45.5	180
Energy loss per turn [GeV]	1.8	0.357	0.037	9.1
Piwinski angle	5.94	6.08	24.68	1.21
Bunch number	415	2162	19918	58
Bunch spacing [ns]	385	154	15(10% gap)	2640
Bunch population [10^{10}]	14	13.5	14	20
Beam current [mA]	27.8	140.2	1339.2	5.5
Momentum compaction [10^{-5}]	0.71	1.43	1.43	0.71
Phase advance of arc FODOs [degree]	90	60	60	90
Beta functions at IP (bx/by) [m/mm]	0.33/1	0.21/1	0.13/0.9	1.04/2.7
Emittance (ex/ey) [nm/pm]	0.64/1.3	0.87/1.7	0.27/1.4	1.4/4.7
Beam size at IP (sx/sy) [$\mu\text{m}/\text{nm}$]	15/36	13/42	6/35	39/113
Bunch length (SR/total) [mm]	2.3/3.9	2.5/4.9	2.5/8.7	2.2/2.9
Energy spread (SR/total) [%]	0.10/0.17	0.07/0.14	0.04/0.13	0.15/0.20
Energy acceptance (DA/RF) [%]	1.7/2.2	1.2/2.5	1.3/1.7	2.3/2.6
Beam-beam parameters (xx/xy)	0.015/0.11	0.012/0.113	0.004/0.127	0.071/0.1
RF voltage [GV]	2.2 (2cell)	0.7 (2cell)	0.12 (1cell)	10 (5cell)
RF frequency [MHz]	650			
Beam lifetime [min]	20	55	80	18
Luminosity per IP [$10^{34}/\text{cm}^2/\text{s}$]	8.3	26.6	191.7	0.8

This parameter table is used by US Snowmass21 for CEPC physics performance potential evaluation

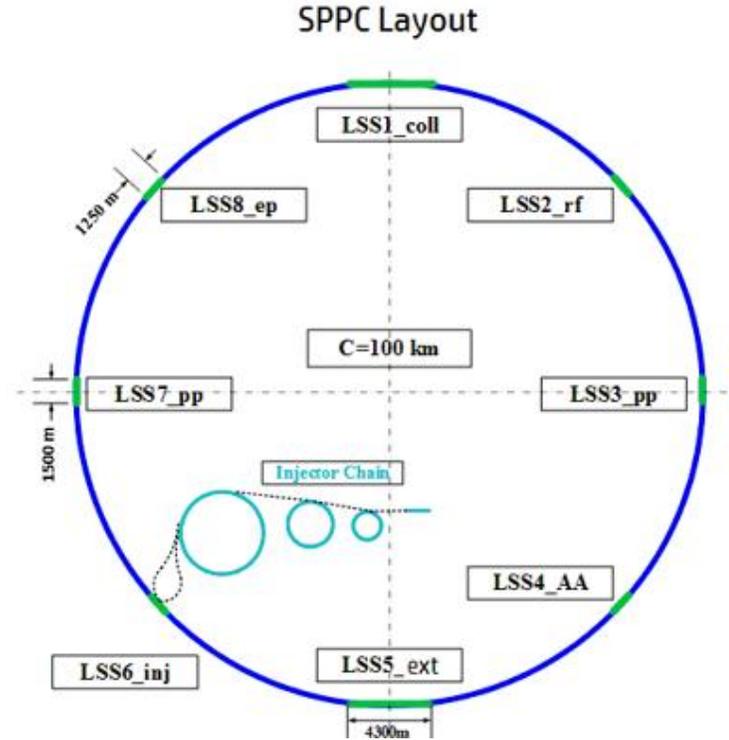
CEPC Accelerator white paper to AF03 Snowmass21 arXiv:2203.09451

Two steps of upgrades:

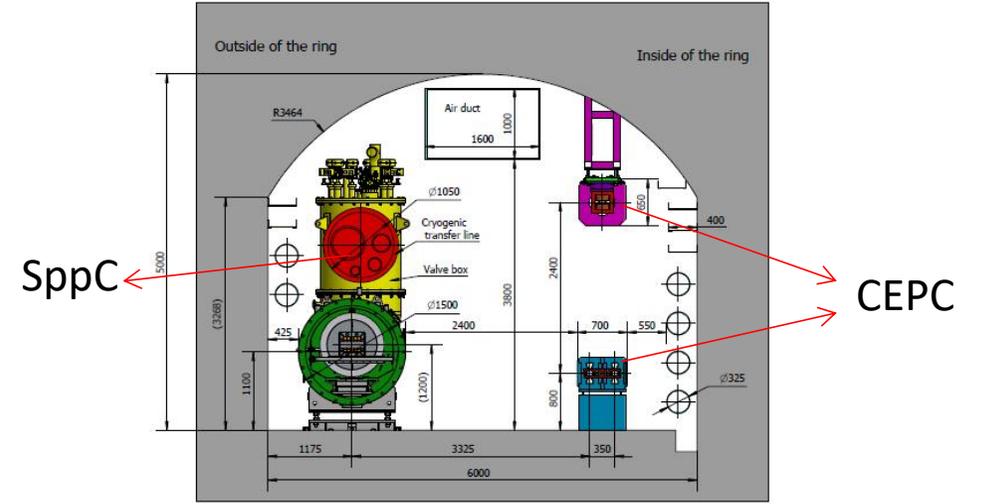
- By increasing SR power to **50MW/beam**
- By increasing energy to ttbar of **180GeV/beam**

CEPC Staging to SppC

General Layout of SppC

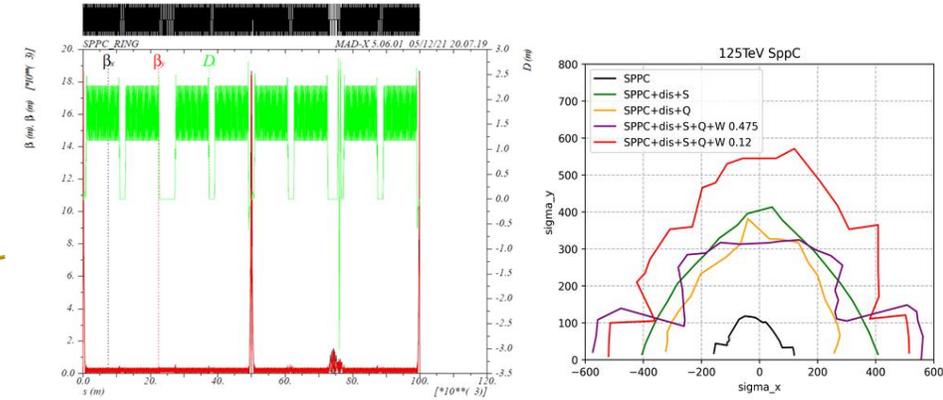
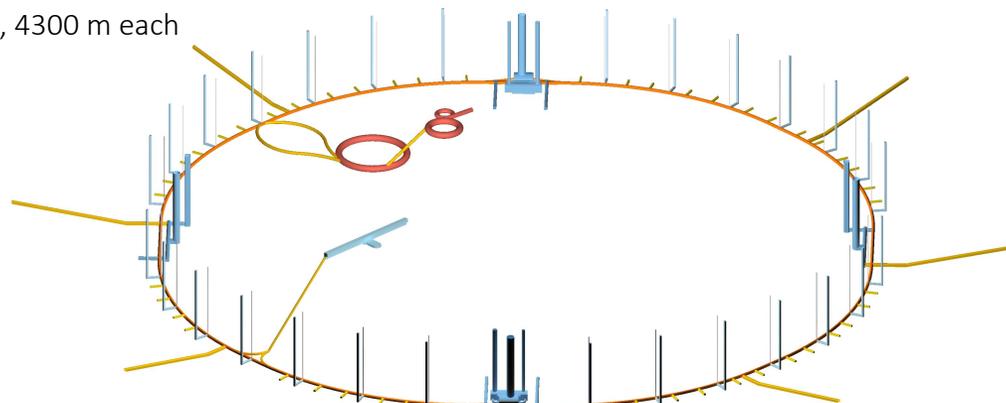


TUNNEL CROSS SECTION OF THE ARC AREA



- Length of each section at present:
- 8 arcs, total length 83400 m
- 2 IPs for pp, 1500 m each
- 2 IRs for injection or RF, 1250 m each
- 2 IRs for ep or AA, 1250 m each
- 2 IRs for collimation(ee for CEPC) , 4300 m each
- C = 100 km

SppC lattice design





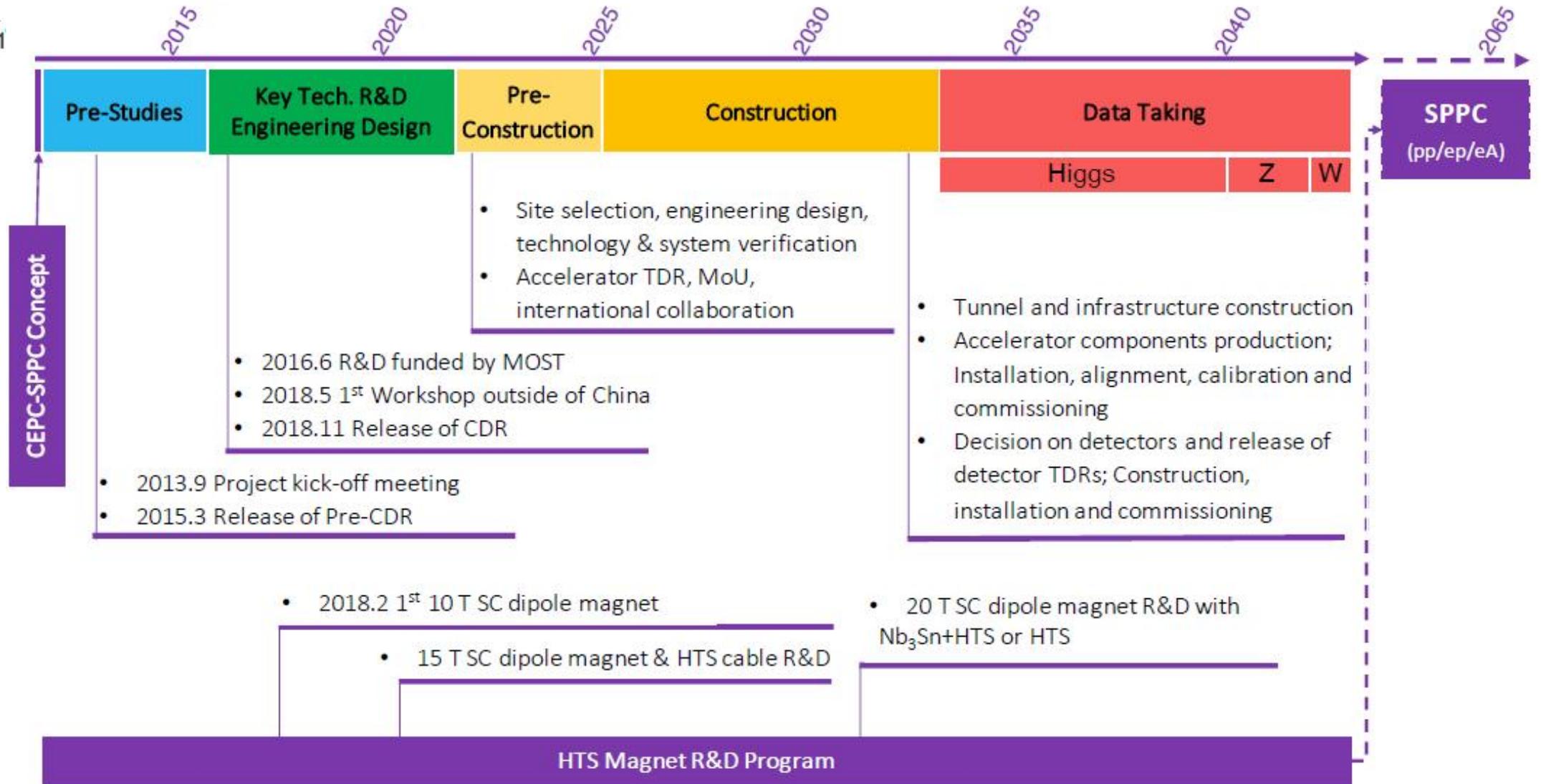
SppC Collider Parameters

(updated Feb. 2022)

Main parameters					
Circumference	100	km	Normalized rms transverse emittance	1.2	μm
Beam energy	62.5	TeV	Beam life time due to burn-off	8.1	hour
Lorentz gamma	66631		Turnaround time	2.3	hour
Dipole field	20.00	T	Total cycle time	10.4	hour
Dipole curvature radius	10415.4	m	Total / inelastic cross section	161	mbarn
Arc filling factor	0.780		Reduction factor in luminosity	0.81	
Total dipole magnet length	65442.0	m	Full crossing angle	73	μrad
Arc length	83900	m	rms bunch length	60	mm
Total straight section length	16100	m	rms IP spot size	3.0	μm
Energy gain factor in collider rings	19.53		Beta at the 1st parasitic encounter	28.625	m
Injection energy	3.20	TeV	rms spot size at the 1st parasitic encoun	22.7	μm
Number of IPs	2		Stored energy per beam	4.0	GJ
Revolution frequency	3.00	kHz	SR power per ring	2.2	MW
Revolution period	333.3	μs	SR heat load at arc per aperture	26.3	W/m
Physics performance and beam parameters					
Initial luminosity per IP	4.3E+34	$\text{cm}^{-2}\text{s}^{-1}$	Critical photon energy	8.4	keV
Beta function at initial collision	0.5	m	Energy loss per turn	11.40	MeV
Circulating beam current	0.19	A	Damping partition number	1	
Nominal beam-beam tune shift limit per	0.015		Damping partition number	1	
Bunch separation	25	ns	Damping partition number	2	
Bunch filling factor	0.756		Transverse emittance damping time	0.51	hour
Number of bunches	10080		Longitudinal emittance damping time	0.25	hour
Bunch population	4.0E+10				
Accumulated particles per beam	4.0E+14				



CEPC Project Timeline





CEPC Accelerator TDR Status and EDR Plans

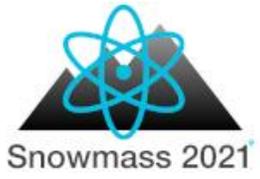
- **CEPC CDR relased in Nov. 2018**
- **CEPC Accelerator TDR completion time: Dec. 2022**
 - Consistent TDR high luminosity parameter design as Higgs factory
 - Key components with prototyping, techincal feasibility demonstrated, no technical show stopper
 - Design and R&D technical documentation (Data, drawings, etc.)
 - CEPC accelerator TDR document release in 2023
- **CEPC Accelerator EDR Phase Plan:Jan. 2023-Dec. 2025**
 - Engineering design of CEPC accelerator systems and components towards fabrication in an industrial way
 - CEPC site study converging to one or two with detailed feasibility studies (tunnel and infrastructures, environment)
 - Site dependent civil engineering design implementation preparation
 - EDR document completed for government’s approval of starting construction around 2026 (the starting of the “15th five year plan” of China)

CEPC Maturity Evaluation

Design Maturity	Maturity Criteria #1 (Design Maturity)	Maturity Criteria #2 (R&D Maturity)
0	No end-to-end design concept prepared	Concept proposed, but no systematic design requirements and/or parameters available.
1	No end-to-end design concept prepared	Concept proposed, proof-of-principle R&D underway
2	End-to-end preliminary design concept under development	Ongoing R&D to address fundamental physics/technical issues.
3	End-to-end preliminary design concept available	Sub-system operating parameters established based on preliminary design concepts for novel/critical sub-systems
4	End-to-end integrated design concept under development	Preliminary design concepts with operating parameters established for all sub-systems. Sub-system design R&D underway.
5	End-to-end integrated design concept available. Enables end-to-end performance evaluation.	Sub-system preliminary designs exist. Sub-system design R&D continues.
6	End-to-end performance evaluation complete. Reference (pre-CDR level) Design Report under development.	Sub-system performance risk assessment complete.
7	Reference Design available. Sub-system parameters and high potential alternatives documented.	Sub-system detailed design and performance R&D for highest risk sub-systems underway.
8	Conceptual Design Report in preparation.	Sub-system specifications with validated operating parameters established. High risk sub-system R&D underway.
9	Conceptual Design Report and detailed cost estimate available.	High risk sub-system R&D ongoing. Risk mitigation strategy for sub-system performance established.
10	Ready for Construction Proposal. Detailed Engineering Design being developed.	Performance Optimization R&D underway.

Following the table CEPC ranks:

- Design maturity 9
- R&D maturity 9

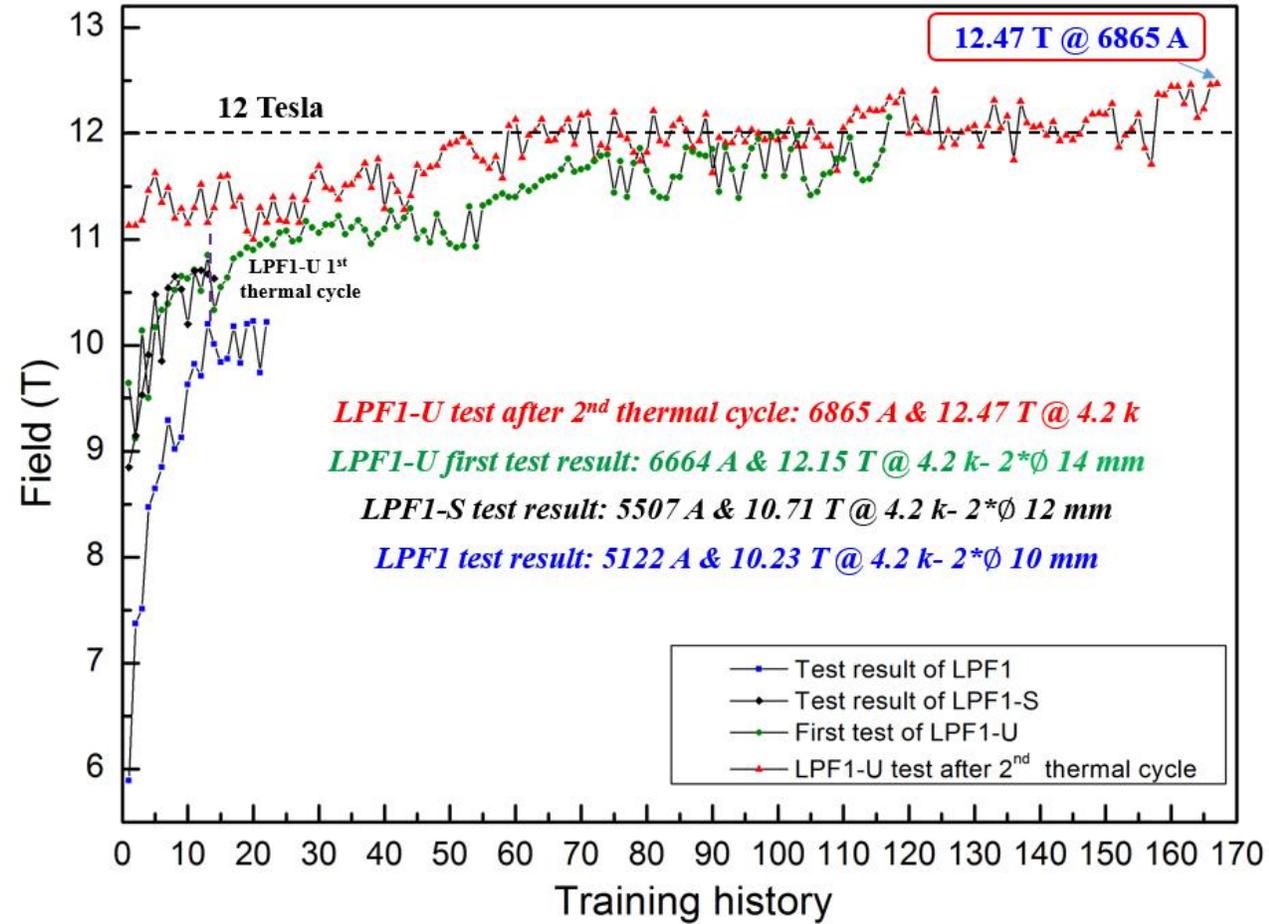


Thanks

Latest performance of LPF1-U (SppC)



Picture of LPF1-U



Dual aperture superconducting dipole achieves 12.47 T at 4.2 K
 Entirely fabricated in China. The next step is reaching 16-20T field