CEPC Accelerator from TDR to EDR

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On behalf of the CEPC accelerator group

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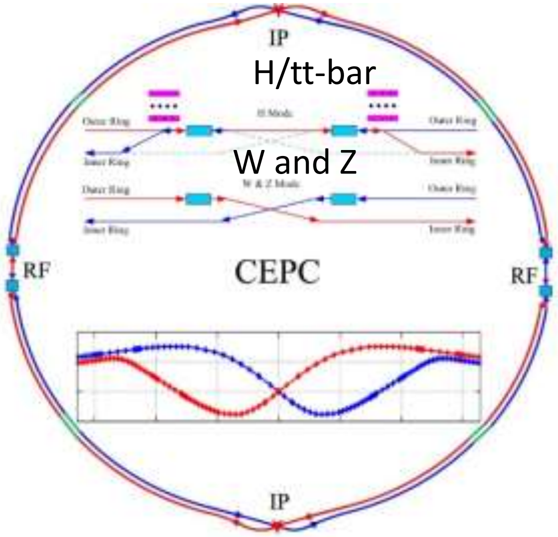
Contents

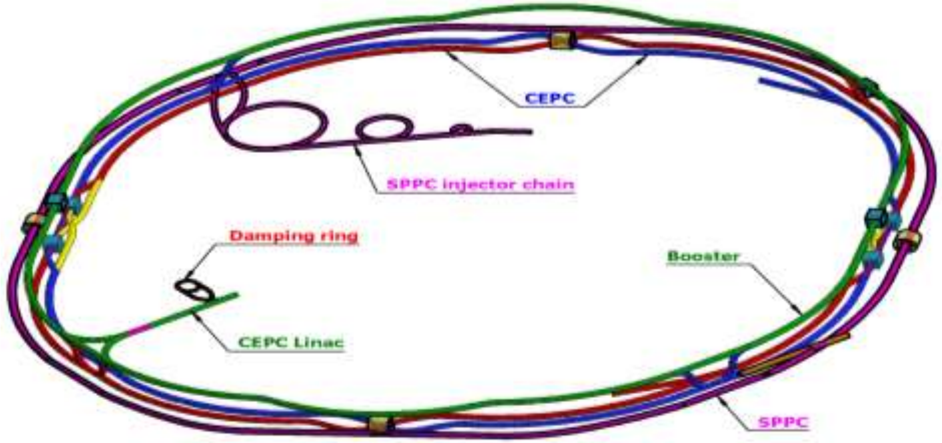
- Introduction
- CEPC accelerator system design and optimizations in TDR
- CEPC accelerator key hardware R&D progresses in TDR
- SppC compatibility with CEPC
- CEPC site selections and civil engineering
- CEPC EDR goals, plans and scope
- CEPC industrial preparation and international collaboration
- Summary

CEPC Higgs Factory and SppC in TDR

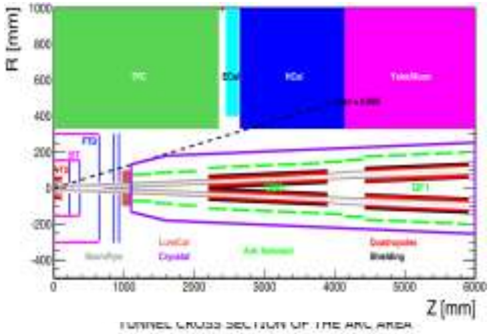
CEPC as a Higgs Factory： H, W, Z, upgradable to tt-bar, followed by a SppC (a Hadron collider) ~125TeV
30MW SR power per beam (upgradale to 50MW) , high energy gamma ray 100Kev~100MeV

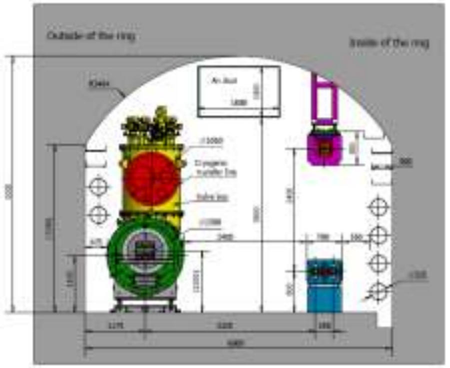


CEPC collider ring (100km)

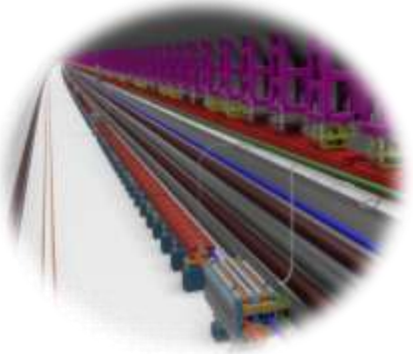


CEPC booster ring (100km)

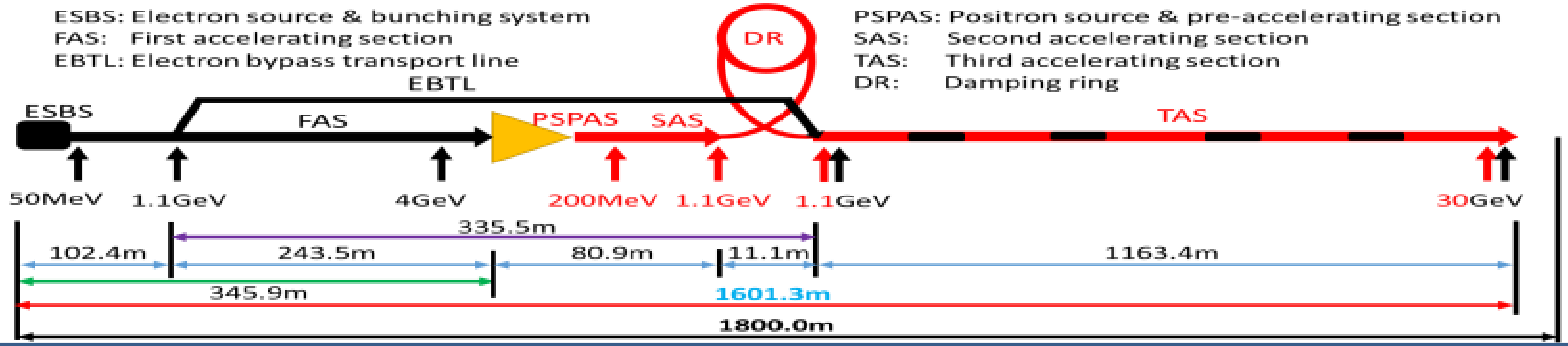




CEPC Civil Engineering



CEPC TDR S+C-band 30GeV linac injector



CEPC TDR Accelerator System Parameters

Linac

Parameter	Symbol	Unit	Baseline
Energy	E_{e-}/E_{e+}	GeV	**30**
Repetition rate	f_{rep}	Hz	100
Bunch number per pulse			1 or 2
Bunch charge		nC	1.5 (3)
Energy spread	σ_E		1.5×10^{-3}
Emittance	ε_r	nm	6.5

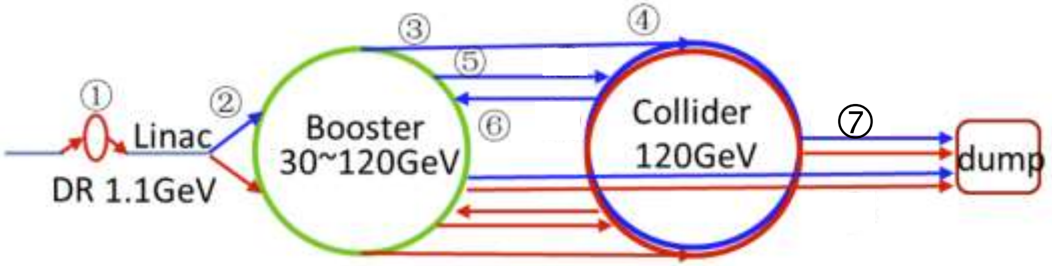
Booster

		tt	*H*		*W*	*Z*	
		Off axis injection	Off axis injection	On axis injection	Off axis injection	Off axis injection	
Circumfer.	km	**100**					
Injection energy	GeV	**30**					
Extraction energy	GeV	**180**	**120**		**80**	**45.5**	
Bunch number		35	268	261+7	1297	3978	5967
Maximum bunch charge	nC	0.99	0.7	20.3	0.73	0.8	0.81
Beam current	mA	0.11	0.94	0.98	2.85	9.5	14.4
SR power	MW	0.93	0.94	1.66	0.94	0.323	0.49
Emittance	nm	2.83	1.26		0.56	0.19	
RF frequency	GHz	1.3					
RF voltage	GV	9.7	2.17		0.87	0.46	
Full injection from empty	h	0.1	0.14	0.16	0.27	1.8	0.8

Collider

	Higgs	Z	W	$t\bar{t}$
Number of IPs	2			
Circumference (km)	**100.0**			
SR power per beam (MW)	**30**			
Energy (GeV)	**120**	**45.5**	**80**	**180**
Bunch number	268	11934	1297	35
Emittance $\varepsilon_x/\varepsilon_y$ (nm/pm)	0.64/1.3	0.27/1.4	0.87/1.7	1.4/4.7
Beam size at IP σ_x/σ_y (um/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
Beam-beam parameters ξ_x/ξ_y	0.015/0.11	0.004/0.127	0.012/0.113	0.071/0.1
RF frequency (MHz)	650			
Luminosity per IP (10^{34} cm^{-2} s^{-1})	**5.0**	**115**	**16**	**0.5**

Transport line

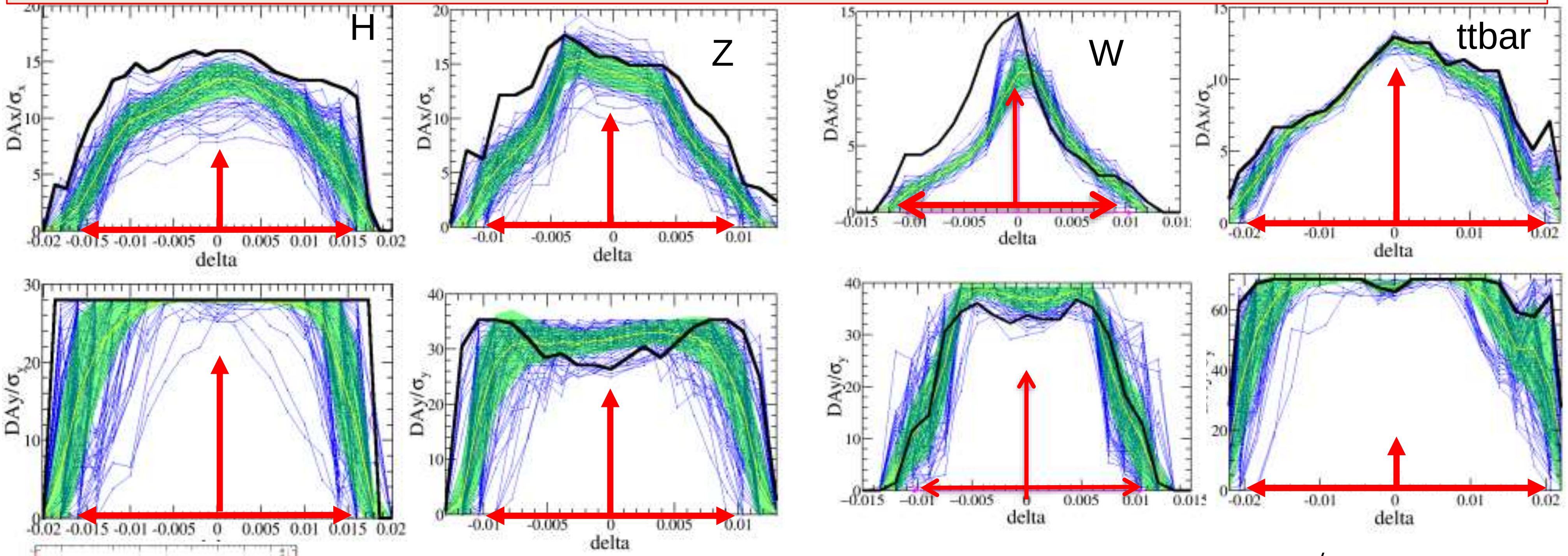


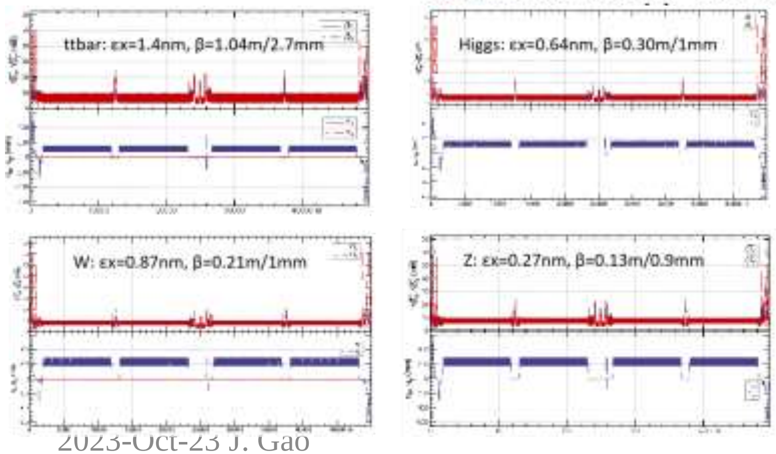
1. Injection/Extraction to the Damping ring (e^+)
2. Injection to the Booster ring from Linac (e^+/e^-)
3. Booster ring extraction system (e+/e-)
4. Collider off-axis injection system (e+/e-)
5. collider on-axis swap-out injection (e+/e-)
6. Collider swap-out extraction (e+/e-)
7. beam dump system (e+/e-)

CEPC Collider Ring Daynamic Apertures

Dynamic apertures with errors at Higss, W/Z and ttbar energies satisfy design goals

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



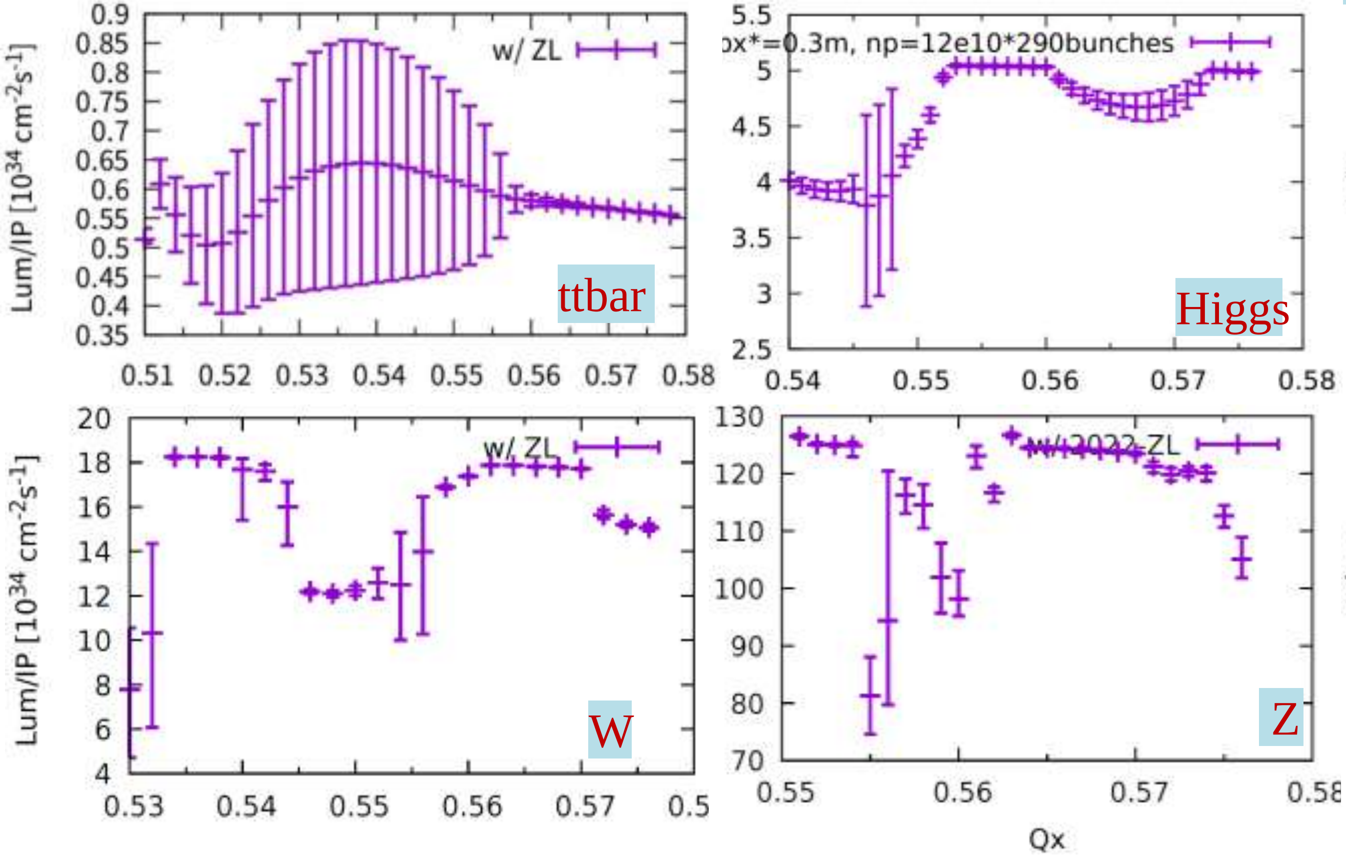


Component	Δx (mm)	Δy (mm)	$\Delta\theta_z$ (mrad)	Field error
Dipole	0.10	0.10	0.10	0.01%
Arc Quadrupole	0.10	0.10	0.10	0.02%
IR Quadrupole	0.10	0.10	0.10	0.02%
Sextupole	0.10*	0.10*	0.10	0.02%

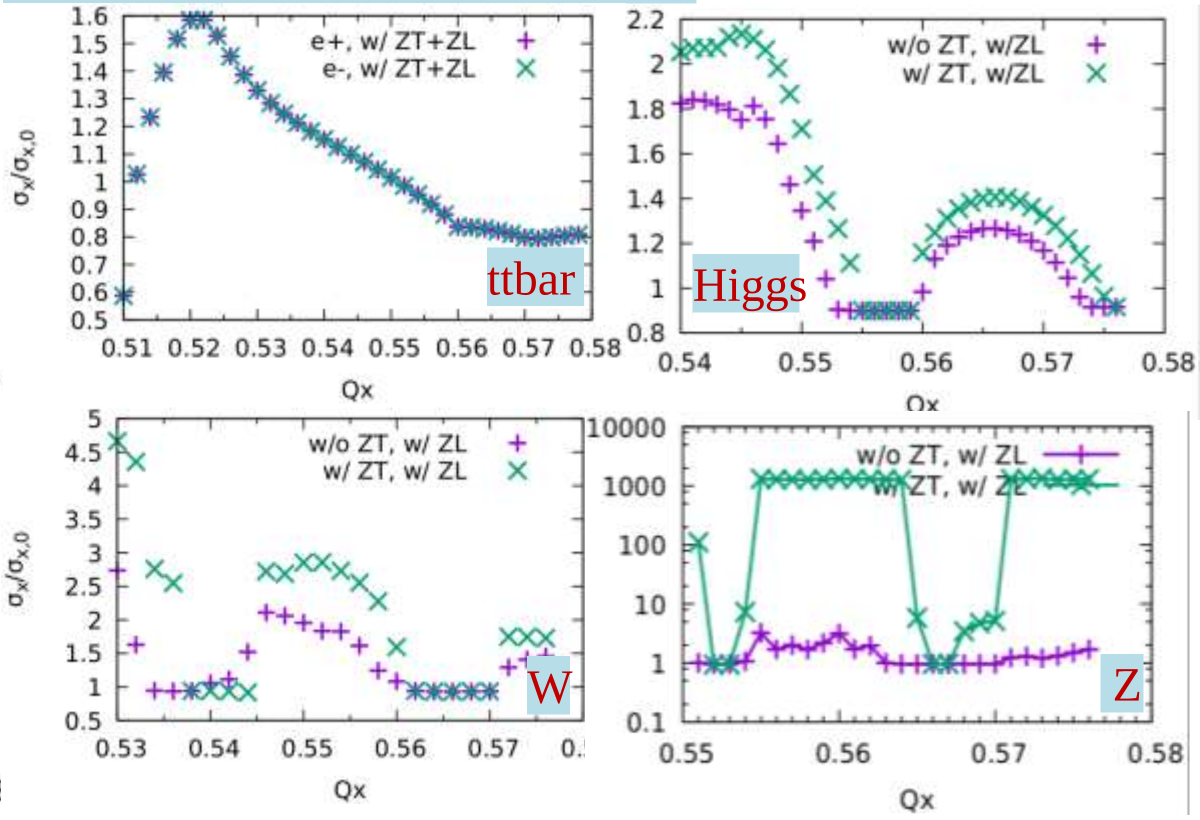
—w/o error
—mean value
—statistic errors
—seeds
—requirement

Studies of Beam-Beam Effects in CEPC

Luminosity simulations w/ZL



Transverse size simulations



Beam-beam simulation results are consistent with the TDR parameter tables.

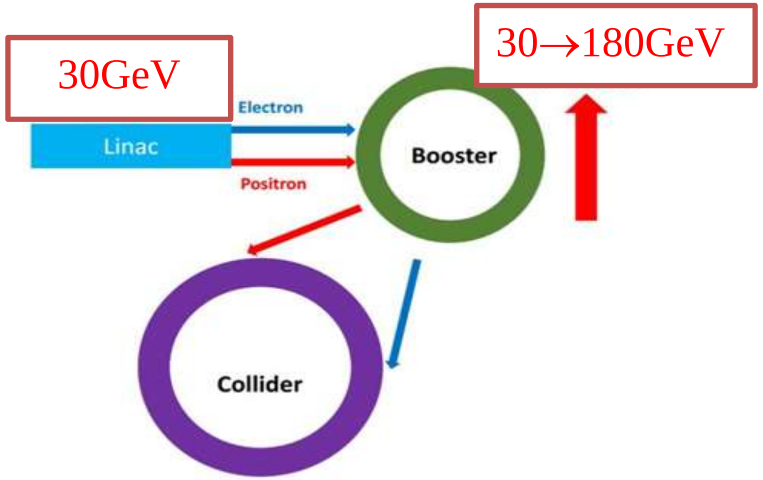
- **Luminosity & Lifetime is evaluated by strong-strong simulation**
- **X-Z instability is well suppressed even considering Potential Well Distortion**
- **Lifetime optimization with both beam-beam\lattice nonlinearity is done**

Parameters of CEPC Booster

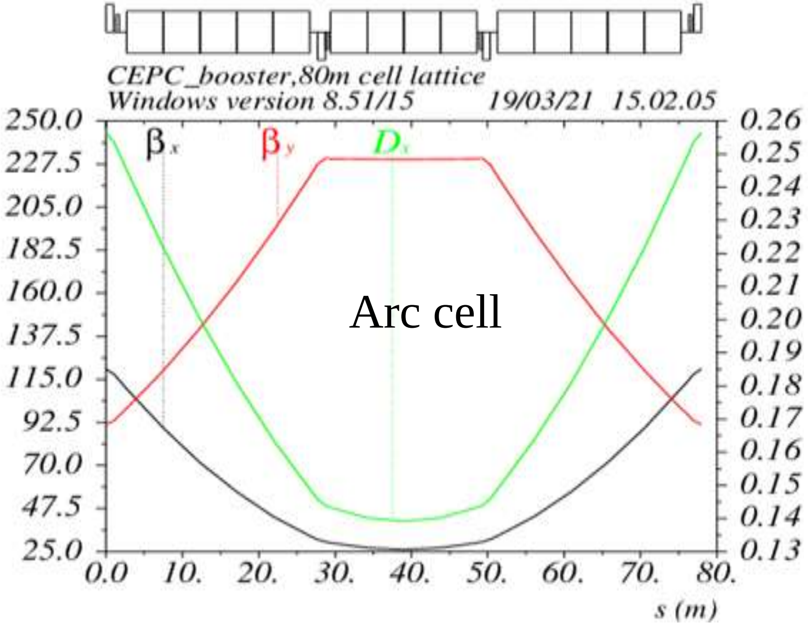
Injection		***tt***	***H***	***W***	***Z***	
Beam energy	GeV	30				
Bunch number		35	268	1297	3978	5967
Bunch charge	nC	1.1	0.78	0.81	0.87	0.9
Single bunch current	μA	3.4	2.3	2.4	2.65	2.69
Beam current	mA	0.12	0.62	3.1	10.5	16.0
Energy spread	%	0.025				
Synchrotron radiation loss/turn	MeV	6.5				
Momentum compaction factor	10^{-5}	1.12				
Emittance	nm	0.076				
Natural chromaticity	H/V	-372/-269				
RF voltage	MV	761.0	346.0	300.0		
Betatron tune ν_x/ν_y		321.23/117.18				
Longitudinal tune		0.14	0.0943	0.0879		
RF energy acceptance	%	5.7	3.8	3.6		
Damping time	s	3.1				
Bunch length of linac beam	mm	0.4				
Energy spread of linac beam	%	0.15				
Emittance of linac beam	nm	6.5				

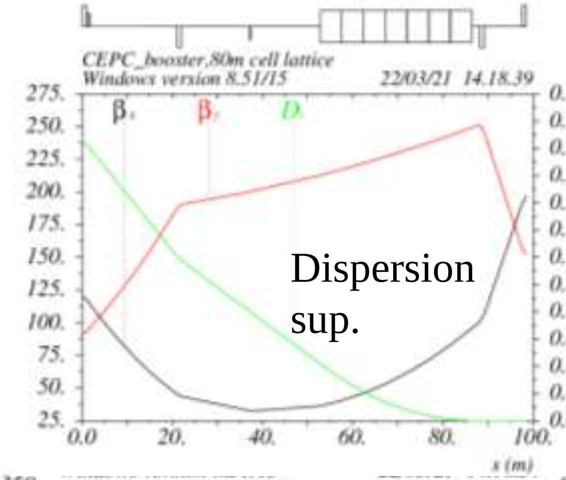
Extraction		***tt***	***H***		***W***	***Z***	
		Off axis injection	Off axis injection	On axis injection	Off axis injection	Off axis injection	
Beam energy	GeV	180	120		80	45.5	
Bunch number		35	268	261+7	1297	3978	5967
Maximum bunch charge	nC	0.99	0.7	20.3	0.73	0.8	0.81
Maximum single bunch current	μA	3.0	2.1	61.2	2.2	2.4	2.42
Beam current	mA	0.11	0.56	0.98	2.85	9.5	14.4
Bunches per pulse of Linac		1	1		1	2	
Time for ramping up	s	7.1	4.3		2.4	1.0	
Injection duration for top-up (Both beams)	s	29.2	23.1	31.8	38.1	132.4	
Current decay in Collider		3%					
Energy spread	%	0.15	0.099		0.066	0.037	
Synchrotron radiation loss/turn	GeV	8.45	1.69		0.33	0.034	
Emittance	nm	2.83	1.26		0.56	0.19	
Betatron tune ν_x/ν_y		321.27/117.19					
RF voltage	GV	9.7	2.17		0.87	0.46	
Longitudinal tune		0.14	0.0943		0.0879		
RF energy acceptance	%	1.78	1.59		2.6	3.4	
Damping time	ms	14.2	47.6		160.8	879	
Natural bunch length	mm	1.8	1.85		1.3	0.75	
Full injection from empty ring	h	0.1	0.14	0.16	0.27	1.8	0.8

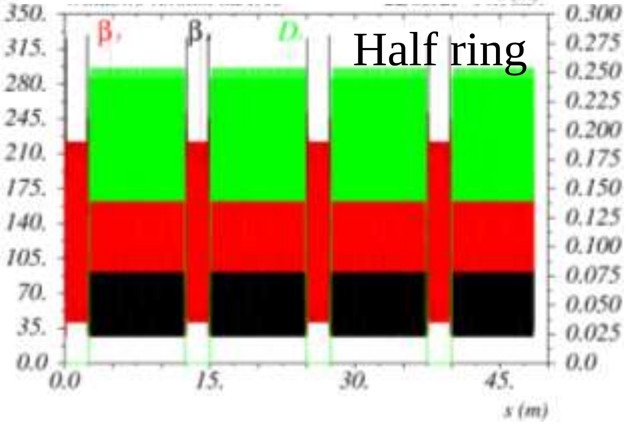
CEPC Booster Design

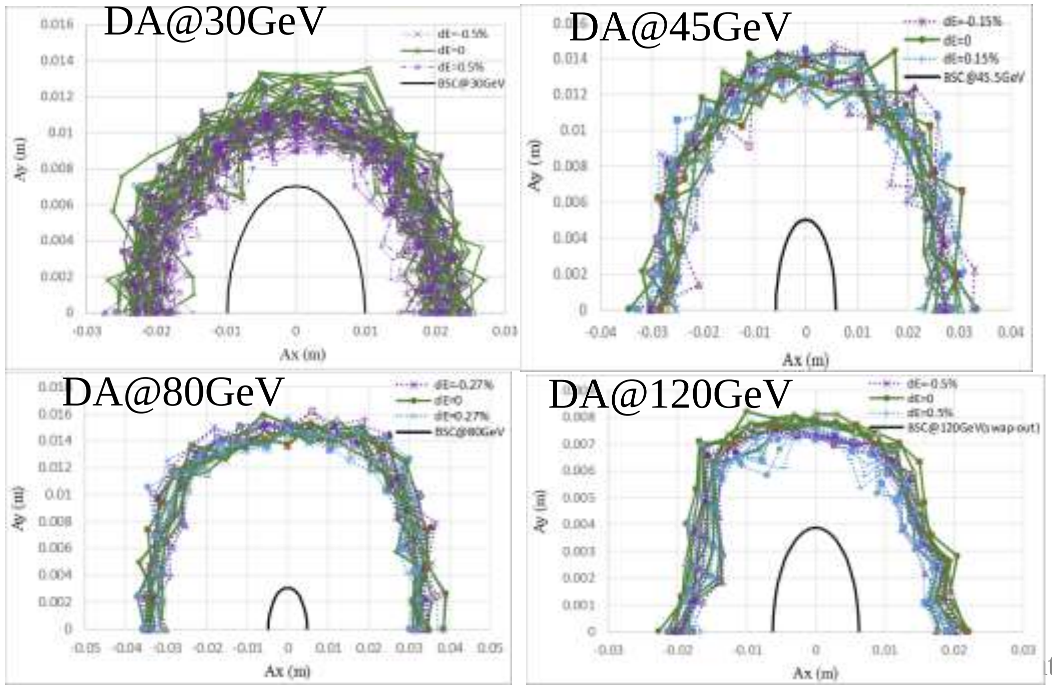


- TME like structure (cell length=78m)
- Interleave sextupole scheme
- Emittance@120GeV=1.26nm









- **30 GeV injection energy, Maximum extraction energy @ 180GeV**
- **Lattice design with TME structure, lower emittance than CDR**
- **Sufficient Dynamic Aperture for all energies with errors**

CEPC SRF System Design and Upgrade Plan

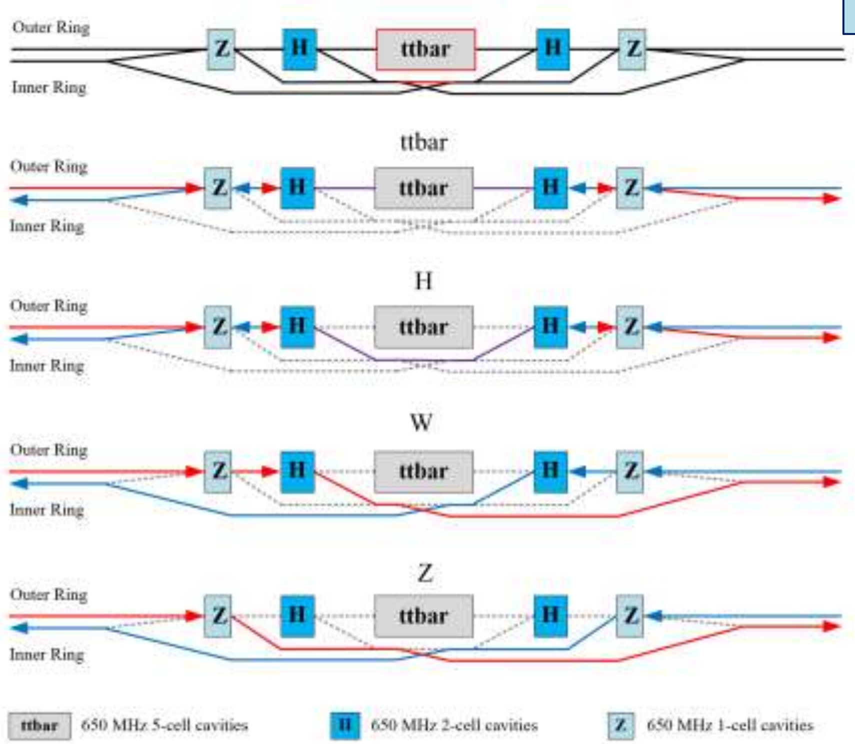
Collider 650MHz Parameters

30/50 MW SR power per beam for each mode. Higgs/ttbar shared cavities for the two rings. W/Z separate cavities. HL-Z cavities bypass.	ttbar 30/50 MW		Higgs 30/50 MW	W 30/50 MW	Z 30/50 MW
	New cavities	Higgs cavities			
Luminosity / IP [10^{34} cm^{-2}s^{-1}]	0.5 / 0.8		5 / 8.3	16 / 26.7	115 / 192
RF voltage [GV]	10 (6.1 + 3.9)		2.2	0.7	0.12 / 0.1
Beam current / beam [mA]	3.4 / 5.6		16.7 / 27.8	84 / 140	801 / 1345
Bunch charge [nC]	32		21	21.6	22.4 / 34.2
Bunch length [mm]	2.9		4.1	4.9	8.7 / 10.6
650 MHz cavity number	192	336	192/336	96 / 168 / ring	30 / 50 / ring
Cell number / cavity	5	2	2	2	1
Gradient [MV/m]	27.6	25.2	24.9 / 14.2	15.9 / 9.1	17.4 / 8.7
Q_0 @ 2 K at operating gradient	3E10	3E10	3E10	3E10	2E10
HOM power / cavity [kW]	0.4 / 0.66	0.16 / 0.26	0.4 / 0.67	0.93 / 1.54	2.9 / 6.2
Input power / cavity [kW]	188 / 315	71 / 118	313 / 298	313 / 298	1000
Optimal Q_L	1E7 / 6E6	9E6 / 5.4E6	1.6E6 / 9.5E5	8E5 / 2.7E5	1.5E5 / 3.8E4
Optimal detuning [kHz]	0.01 / 0.02	0.02 / 0.03	0.1 / 0.2	0.7 / 2	6.7 / 21.7
Cavity number / klystron	4 / 2	2	2	2	1
Klystron power [kW]	800	800	800	800	1200
Klystron number	48 / 96	168	96 / 168	96 / 168	60 / 100
Cavity number / cryomodule	4	6	6	6	1
Cryomodule number	48	56	32 / 56	32 / 56	60 / 100
Total cavity wall loss @ 2 K [kW]	12.1	7.1	3.9 / 2.3	1.6 / 0.9	0.45 / 0.2

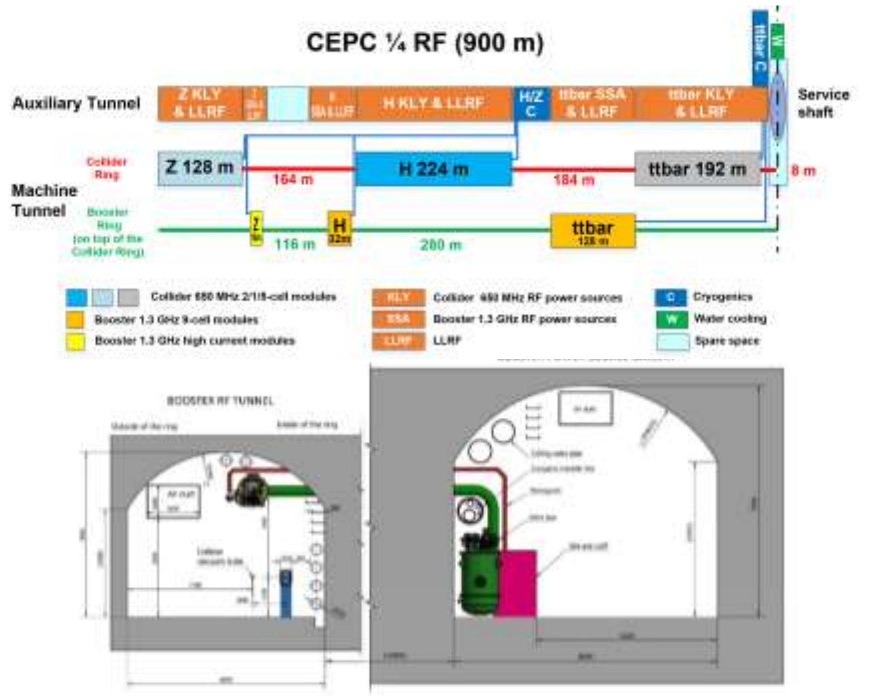
Booster 1.3GHz Parameters

30/50 MW Collider SR power per beam. 30 GeV injection. Higgs & ttbar half filled. Higgs on-axis injection with bunch swapping. Z injection from empty ring.	ttbar 30/50 MW		Higgs 30/50 MW	W 30/50 MW	Z 30/50 MW
	New cavities	Higgs cavities			
Extraction beam energy [GeV]	180		120	80	45.5
Extraction average SR power [MW]	0.05		0.5 / 0.67	0.02 / 0.04	0.05 / 0.1
Bunch charge [nC]	1.1		0.78 (20.3)	0.73	0.81
Beam current [mA]	0.12 / 0.19		0.63 (1) / 1 (1.4)	3.1 / 5.3	16 / 30
Injection RF voltage [GV]	0.761		0.346	0.3	0.3
Extraction RF voltage [GV]	9.7 (7.53 + 2.17)		2.17	0.87	0.46
Extraction bunch length [mm]	1.8		1.86	1.3	0.75
Cavity number (1.3 GHz 9-cell)	256	96	96	96	32
Module number (8 cavities / module)	32	12	12	12	4
Extraction gradient [MV/m]	28.3	21.8	21.8	8.7	13.8
Q_0 @ 2 K at operating gradient	2E10	3E10	3E10	3E10	3E10
Q_L	4E7	4E7	1.2E7	7.3E6 / 4.4E6	1.2E7 / 6.3E6
Cavity bandwidth [Hz]	33	33	110	178 / 296	111 / 208
Peak HOM power per cavity [W]	0.5 / 0.8		~ 75 / ~ 100	11.8 / 19.6	146 / 272
Average HOM power per cavity [W]	0.2 / 0.32		~ 10 / ~ 15	3.8 / 6.3	80 / 150
Input peak power per cavity [kW]	8.3 / 9.2	5.1 / 5.9	22 / 32	10.9 / 18.1	17 / 32
Input average power per cavity [kW]	0.3	0.2	6.5 / 9.2	0.3 / 0.5	2.5 / 4.5
SSA power [kW] (1 cavity / SSA)	10	10	25 / 30	25 / 30	25 / 40
Total cavity wall loss @ 2 K [kW]	0.36	0.05	0.5	0.02	0.08

H/W/Z/ttbar bypass scheme



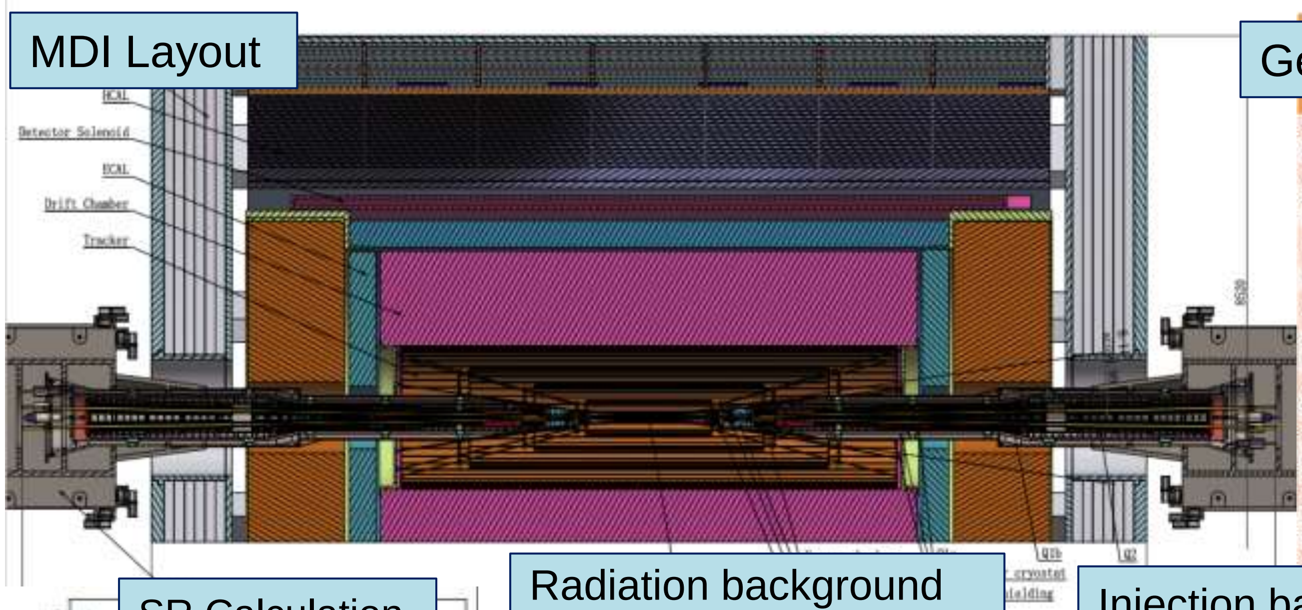
SRF power supply auxiliary tunnel



- CEPC TDR SRF layout and parameters are designed to meet physics requirements;
- RF system design optimized for Higgs 30/50 MW. Power and energy upgrade by adding cavities, RF power sources and cryogenic plants and other systems are compatible;
- Use dedicated high current 1-cell cavity for 10-50 MW Z. Solve the FM & HOM CBI problems.

CEPC MDI Design

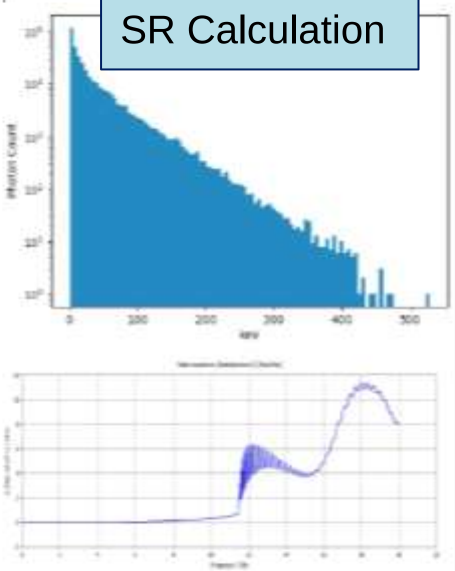
MDI Layout



General Parameters

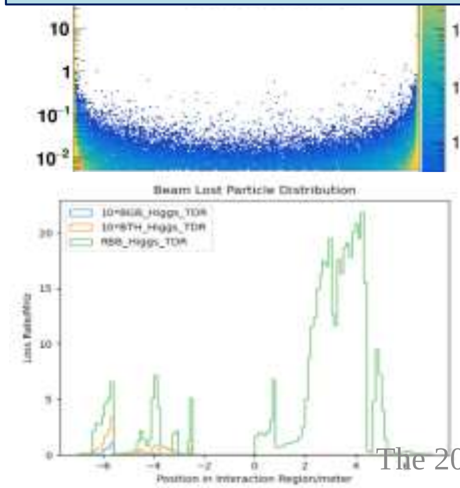
				end ngle	length	Beam stay clear region	Mini. distance between apertures	Beam pipe inner diameter	Beam pipe outer diameter	Critical energy (Hor.)	Critical energy (Vert.)	SR power (Hor.)	SR power (Vert.)
L*	0~1.9m				1.9m								
Crossing angle	33mrad												
MDI length	±7m												
Acc. components in opening angle	8.11°												
QDa/QDb		3.5/2.8T	142/85T/m		1.21m	14.9/18.2mm	62.71/105.28mm	20/23mm	26/29mm	724.7/663.1keV	396.3/263keV	212.2/239.23W	99.9/42.8W
QF1		3.3T	96.7T/m		1.5m	24.48mm	155.11mm	32mm	38mm	675.2keV	499.4keV	472.9W	135.1W
Lumical	0.65~1.11m				0.16m								
Anti-solenoid before QD0		8.6T			1.1m								
Anti-solenoid QD0		3T			2.5m								
Anti-solenoid QF1		3T			1.5m								
Beryllium pipe					±85mm			20mm					
Last B upstream	64.97~153.5m			0.77mrad	88.5m					33.3keV			
First B downstream	44.4~102m			1.17mrad	57.6m					77.9keV			
Beampipe within QDa/QDb					1.21m							1.19/1.31W	
Beampipe within QF1													

SR Calculation

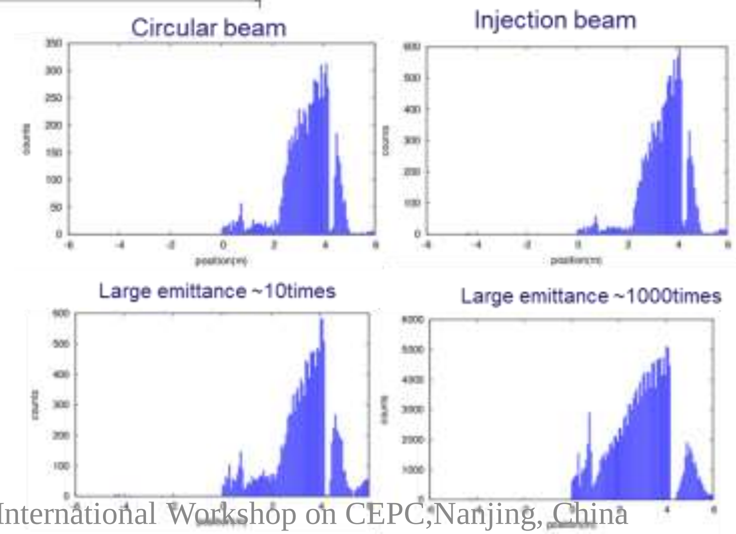


Radiation background

Radiative barbar, Beam-Gas, beam thermal photon scattering

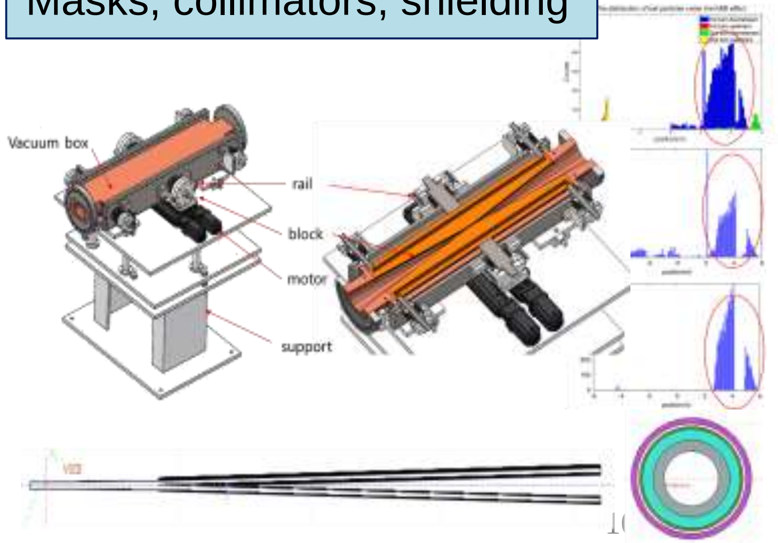


Injection background

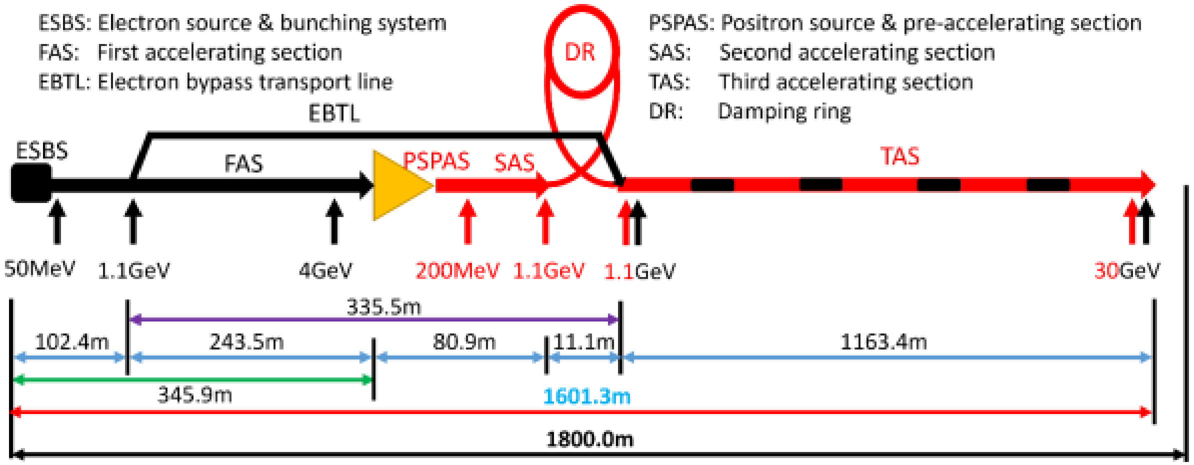


Radiation Mitigation

Masks, collimators, shielding

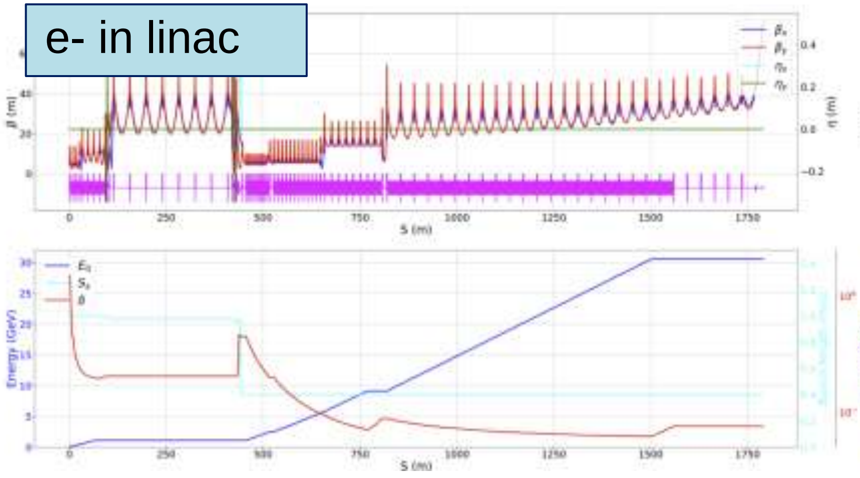


CEPC Electron and Positron Injection Linac Designs

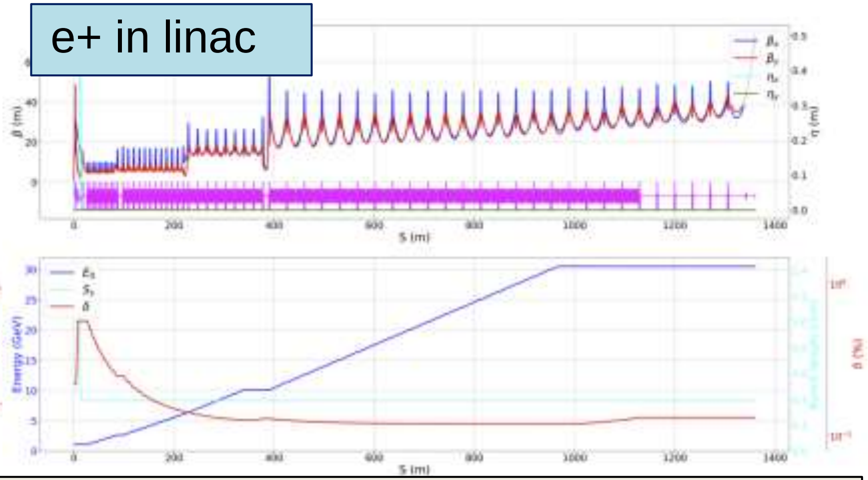


Parameter	Symbol	Unit	Design value
Energy	E	GeV	30
Repetition rate	f_{rep}	Hz	100
Number of bunches per pulse			1 or 2
Bunch charge		nC	1.5
Energy spread	σ_E		1.5×10^{-3}
Emittance	ε_r	nm	6.5
Electron energy at target		GeV	4
Electron bunch charge at target		nC	10
Tunnel length	L	m	1800

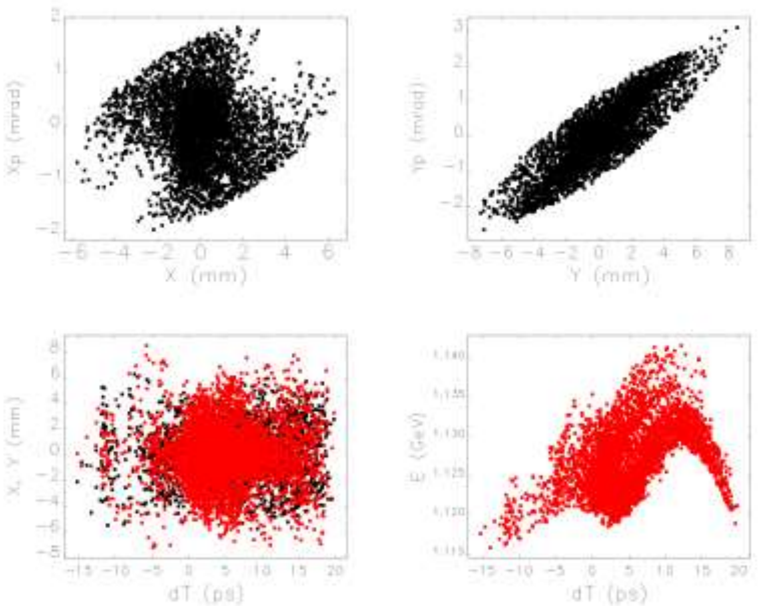
e- in linac



e+ in linac

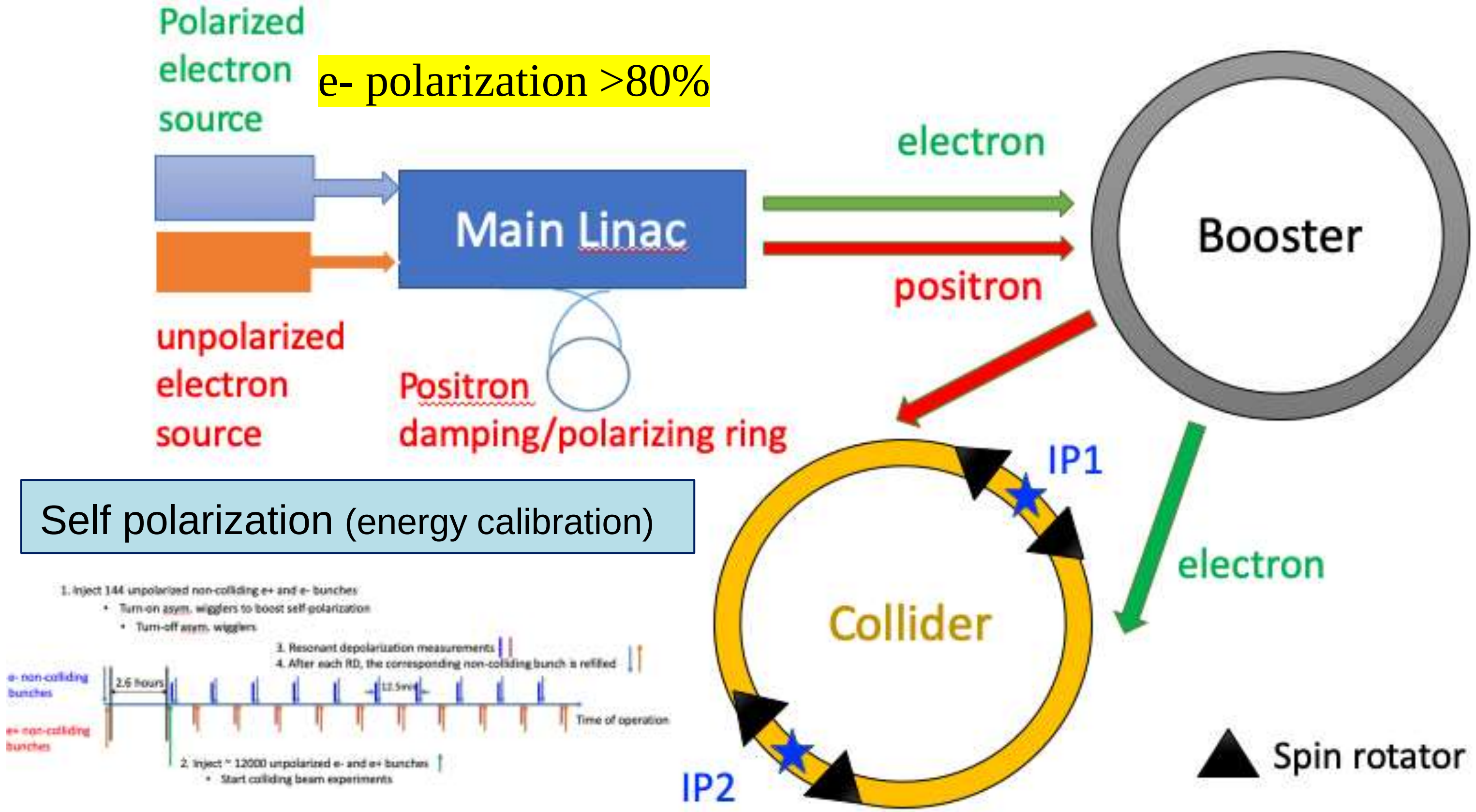


Phase space @ SAS exit



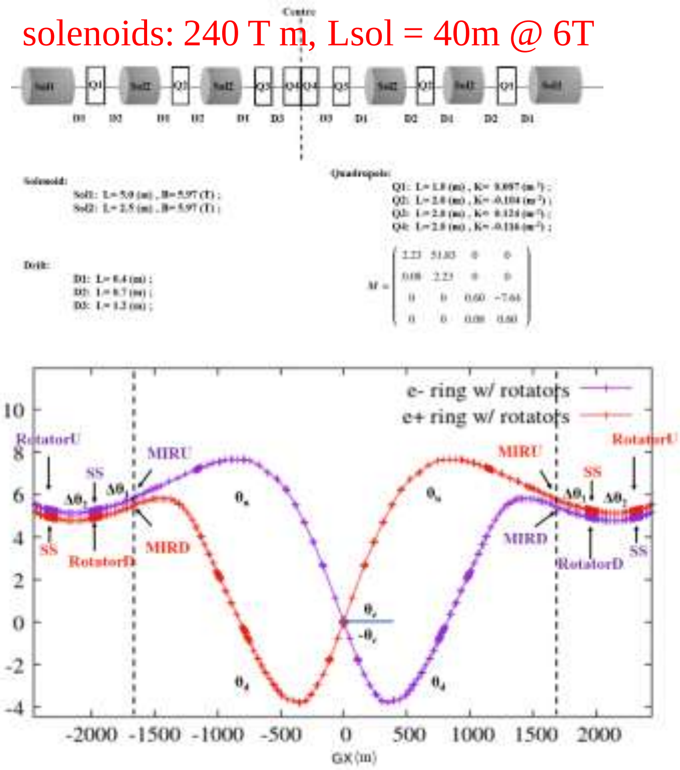
- **Linac energy increases to 30 GeV, with S+C band Accelerator;**
- **Start-to-end simulations were conducted for both electron/positron beams, with quality satisfying requirements.**

CEPC Polarized Beam Studies(alternative option)



Self polarization (energy calibration)

Spin rotator design



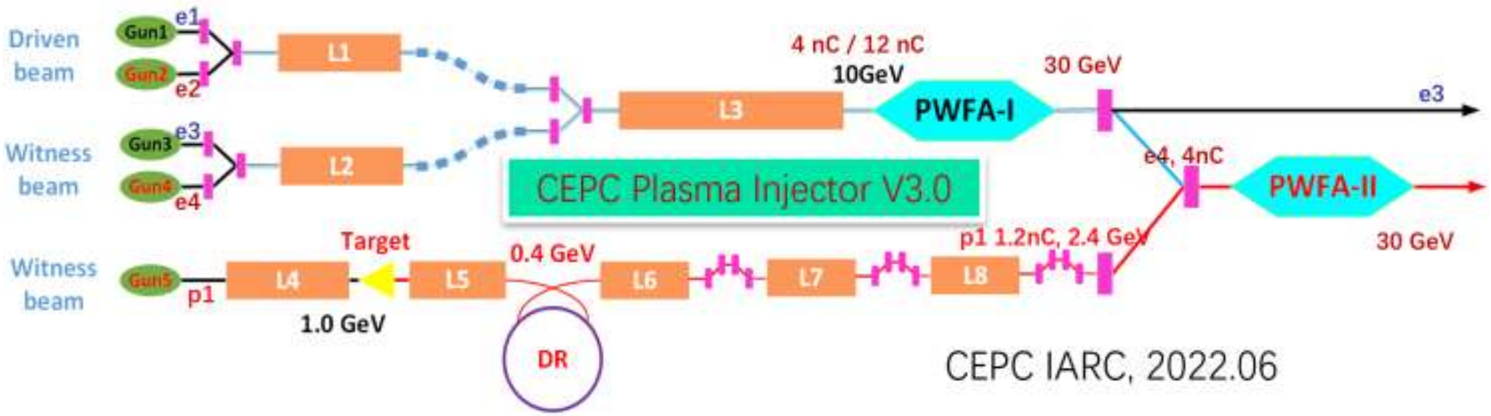
Key issues of study:

- Energy calibration in collider ring with transverse polarization (self polarization & inj. polarization)
- Longitudinal polarization for collision
- Polarization beam injection, positron polarization and ramping in booster

CEPC Plasma Injector (alternative option) and TF Plan

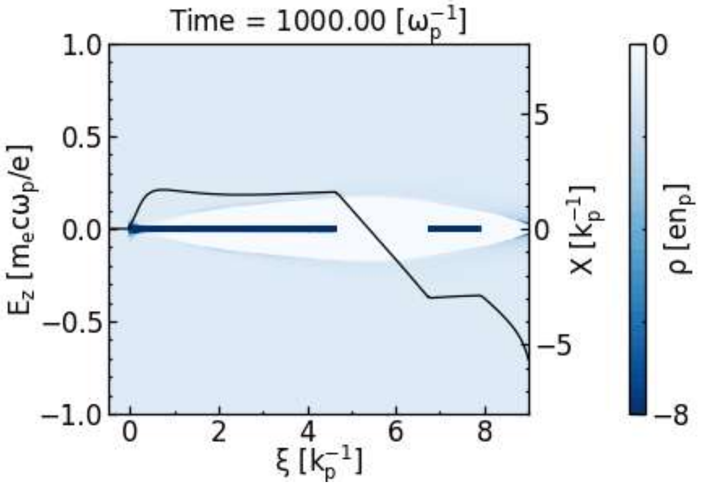
CEPC injector's baseline was changed:

10 GeV → 30 GeV → **TR ≥ 2**

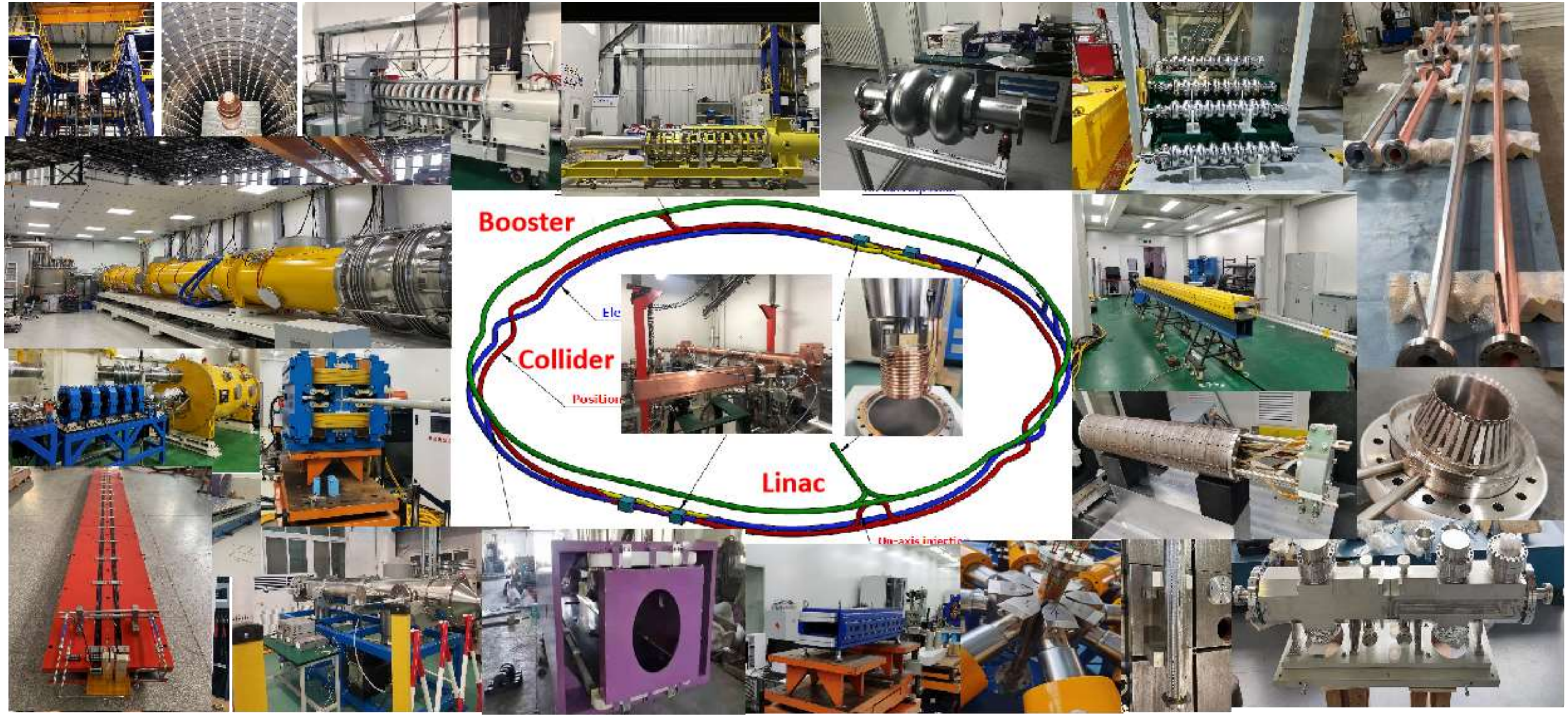


Parameters	Driver	Trailer
plasma density $n_p(\times 10^{16} cm^{-3})$	0.50334	
Driver energy E(GeV)	12	12
Normalized emittance ϵ_N ($\mu m\ rad$)	20	10
Length L (μm)	350	90
(matched) Spot size σ_r (μm)	3.72	2.63
Charge Q (nC)	4.0	1.2
Beam distance d (μm)	155	

Parameters	Trailer
Accelerating distance (m)	7.3 (97300 w_p^{-1})
Trailer energy $E(GeV)$	30
Normalized emittance $\epsilon_n(mm\ mrad)$	10
Charge(nC)	1.2
Energy spread δ_E(%)	0.58
R	1.8
Efficiency(%) (driver -> trailer)	55



CEPC Key Technology R&D



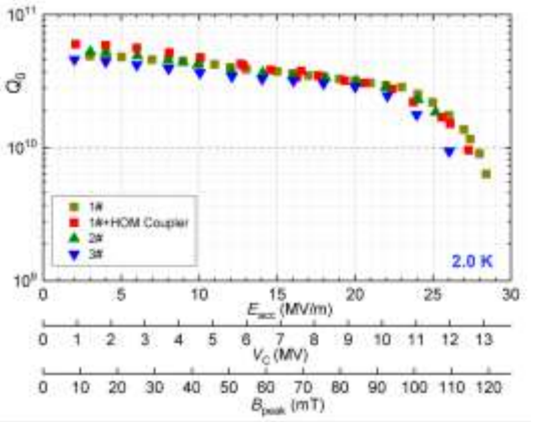
Key technology R&D spans all component lists in CEPC TDR

CEPC SRF Facilities and Components

Mid-T (medium temperature furnace baked) cavities have higher gradient and Q than Nitrogen doped cavities with **less EP process (1 vs 3)**

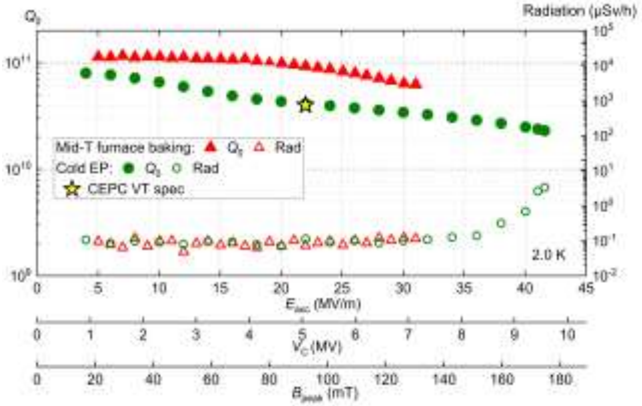
IHEP PAPS is in full operation since 2021

CEPC 650 MHz 2-cell Cavity



3E10@20MV/m.

CEPC 650 MHz 1-cell Cavity

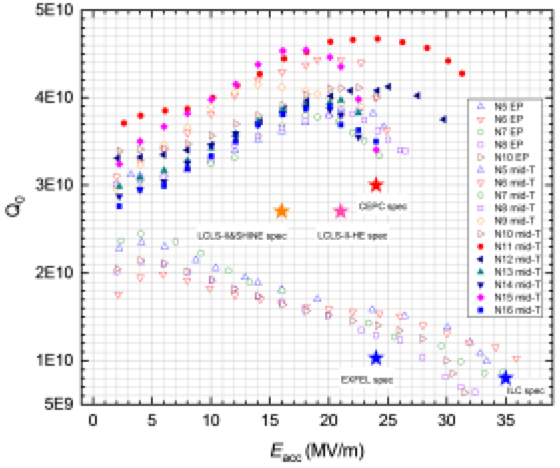


High G High Q 650 MHz 1-cell Cavity

EP treated: 2.3E10@41.6 MV/m@2 K

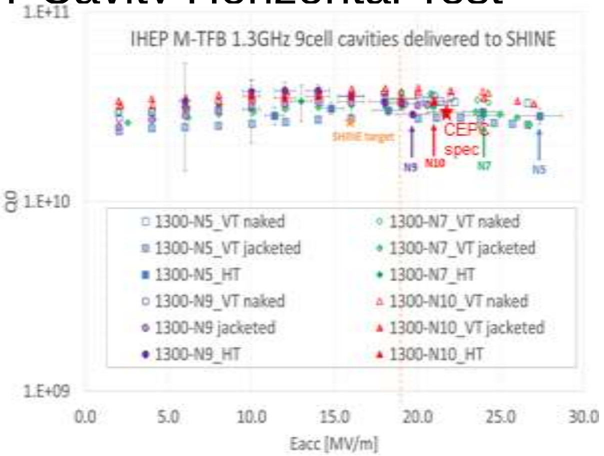
Mid-T treated: 6.3E10@31 MV/m@2 K

1.3 GHz High Q Mid-T Cavity Horizontal Test



Mid-T 1.3 GHz 9-cell vertical test

avg.4.3E10@ 31 MV/m



Mid-T 1.3 GHz 9-cell horizontal test (SEL)

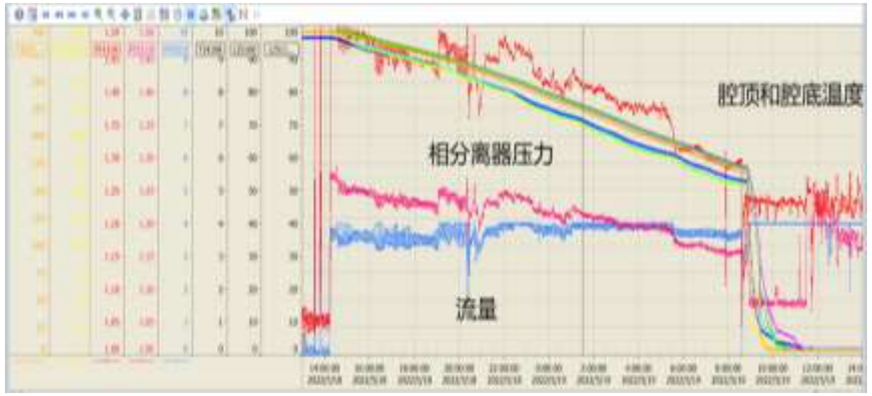
3.1E10@21 MV/m, avg. 24.6 MV/m

CEPC Collider 650 MHz 2 x 2-cell Test Cryomodule





- DC photo-cathode gun voltage conditioned up to 400 kV
- Cavity frequency, HOM coupler double notch filter, tuner, vacuum, cryogenics perform well
- Cavity magnetic field at 2 K < 2 mG (large beam pipe North to South)
- LLRF system commissioning and high power test ongoing
  - Optimizing the outer conductor helium gas cooling of the input coupler. Cavity early quench if with poor coupler cooling.



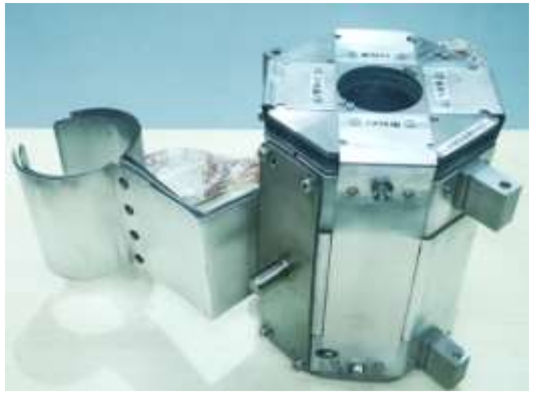
Module automatic cool-down experiment
1. 300 to 150 K: < 10 K/hr. Cavity top and bottom ΔT < 20 K
2. 150 to 4.5 K: Cavity surface > 1 K/min
3. 4.5 to 2 K

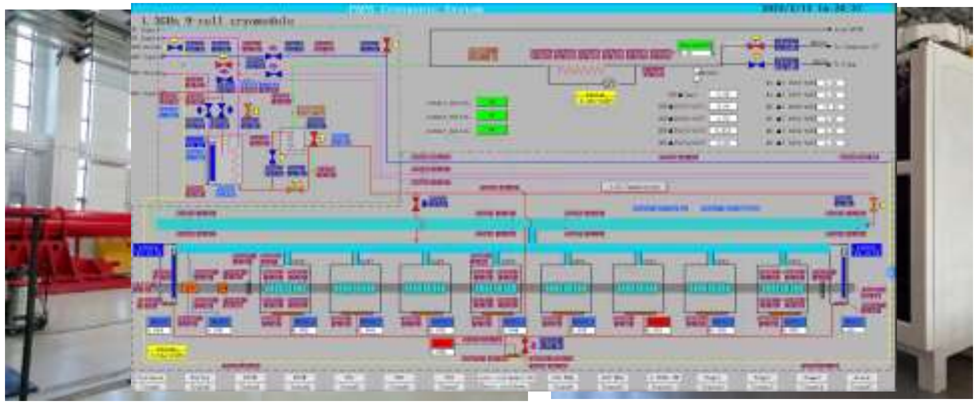
CEPC Booster 1.3 GHz 8 x 9-cell High Q Cryomodule

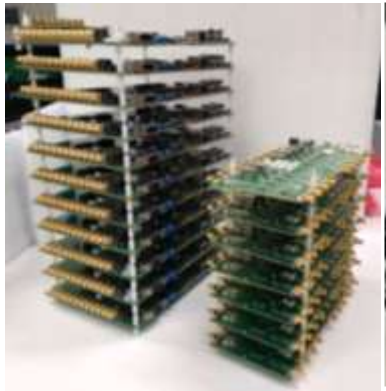
CEPC booster 1.3 GHz SRF R&D and industrialization in synergy with CW FEL projects.

<table>
<tr><th>Parameters</th><th>Horizontal test results</th><th>CEPC Booster Higgs Spec</th><th>LCLS-II, SHINE Spec</th><th>LCLS-II-HE Spec</th></tr>
<tr><td>Average usable CW E_{acc} (MV/m)</td><td>23.1</td><td rowspan="2">3.0×10^{10} @ 21.8 MV/m</td><td rowspan="2">2.7×10^{10} @ 16 MV/m</td><td rowspan="2">2.7×10^{10} @ 20.8 MV/m</td></tr>
<tr><td>Average Q_0 @ 21.8 MV/m</td><td>3.4×10^{10}</td></tr>
</table>



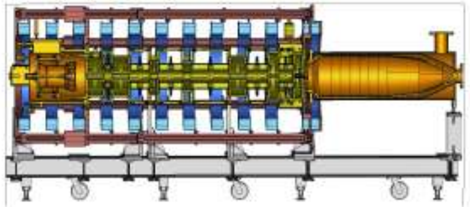



CEPC High Efficiency High Power Klystron Development and RF Power Distribution

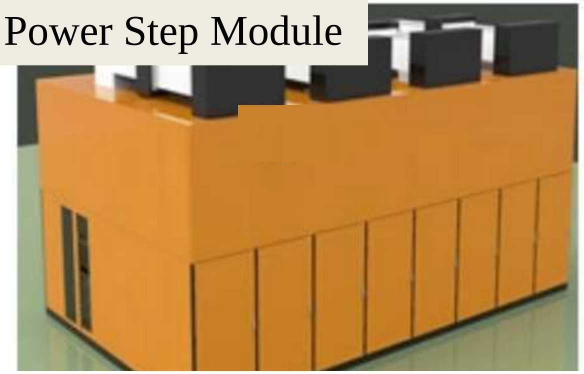
Klystron R&D

Klystron No. 1
Efficiency 65%
(2020)

Klystron No. 2
Efficiency 77%
(2021)



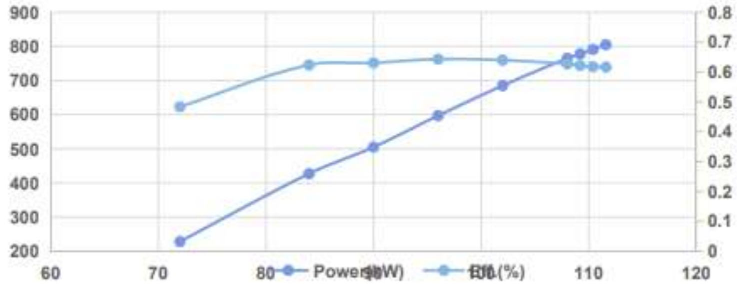
Power Step Module



Klystron No. 3 （MBK
Efficiency 80.5%
(under fabrication)

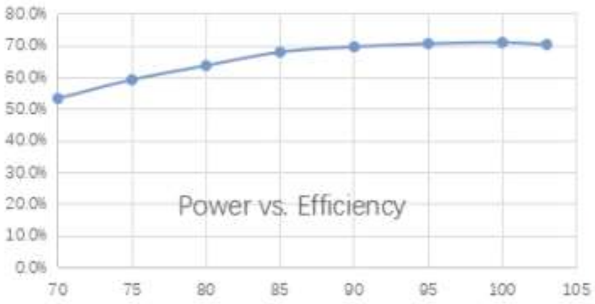
Pulsed RF Mode (30% duty factor, 60ms/5Hz)

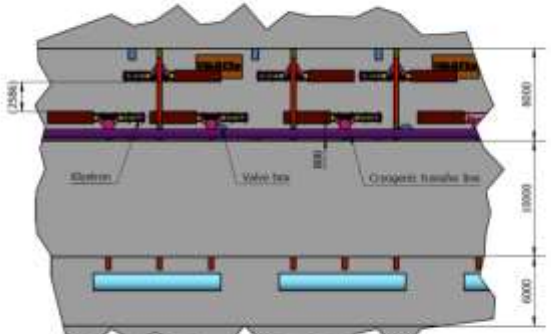
High Voltage vs. Power&Efficency

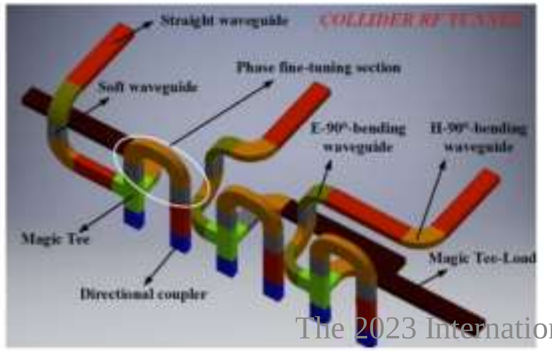


2022

70.5% @ 630kW



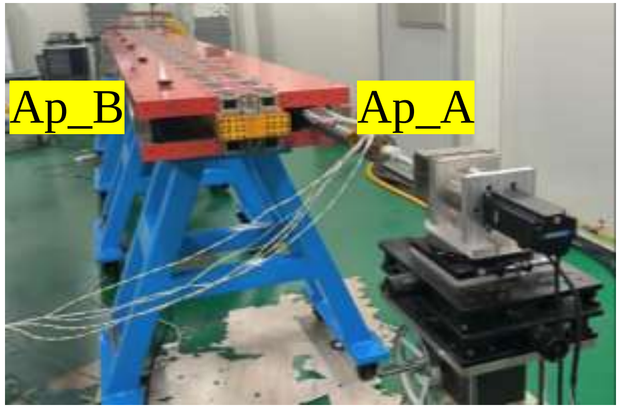




- Three prototypes of the 650MHz 800KW CW klystrons are developed. The efficiency reaches 70%
- PSM is developed with the industrial collaboration
- RF tunnel distribution was planed

CEPC Collider Ring Full-scale Dual-aperture Magnets

Full-length 5.67m Dual aperture dipole

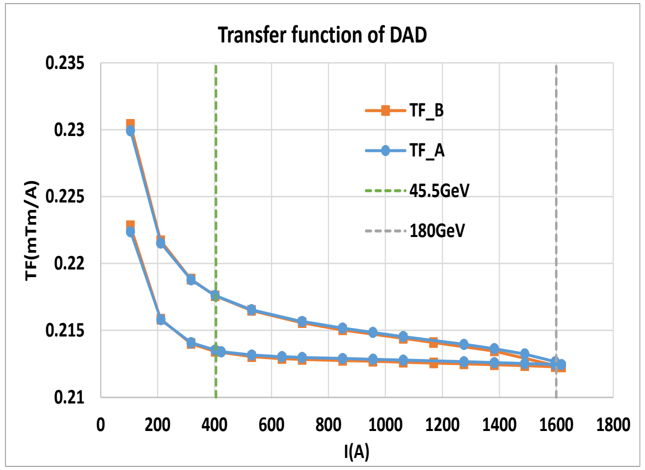


High harmonics @120GeV (units:1e-4)

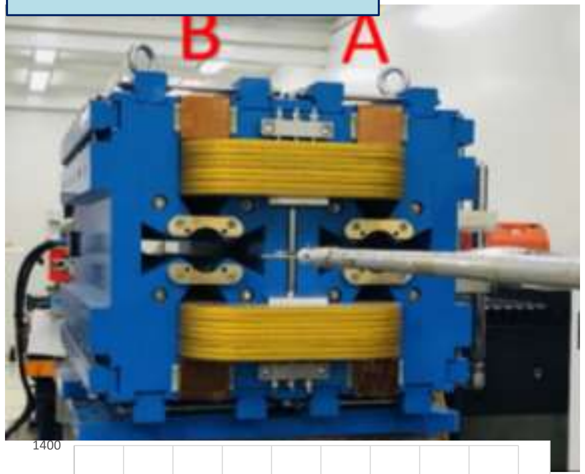
n	bn_A	bn_B
2	0	0
3	3.92	3.88
4	1.03	-1.22
5	0.47	0.54
6	0.08	-0.46

Two apertures differ <0.1%, transfer function in two apertures are consistent.

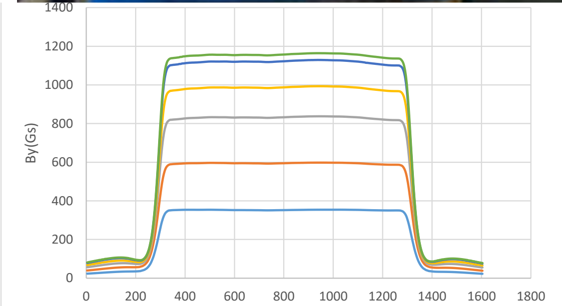
High harmonics are nearly the same at four energies and all less than 5 units, which can meet the requirements.

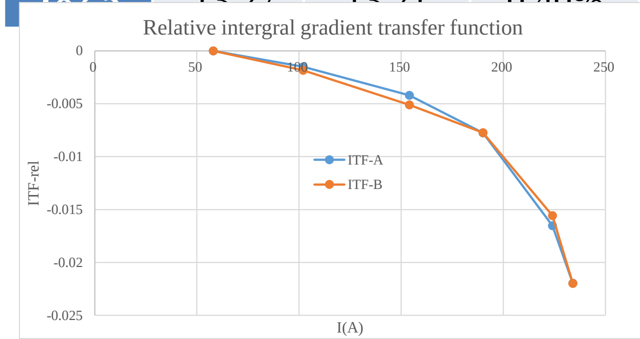


Dual aperture QUAD



E(GeV)	GL(T)-A	GL(T)-B	difference
45	-3.36	3.35	0.40%
80	-5.91	5.88	**0.59%**
120	-8.89	8.85	0.49%
148	-10.93	10.89	0.40%
175	-12.77	12.73	0.30%
182.5	13.27	13.21	0.40%

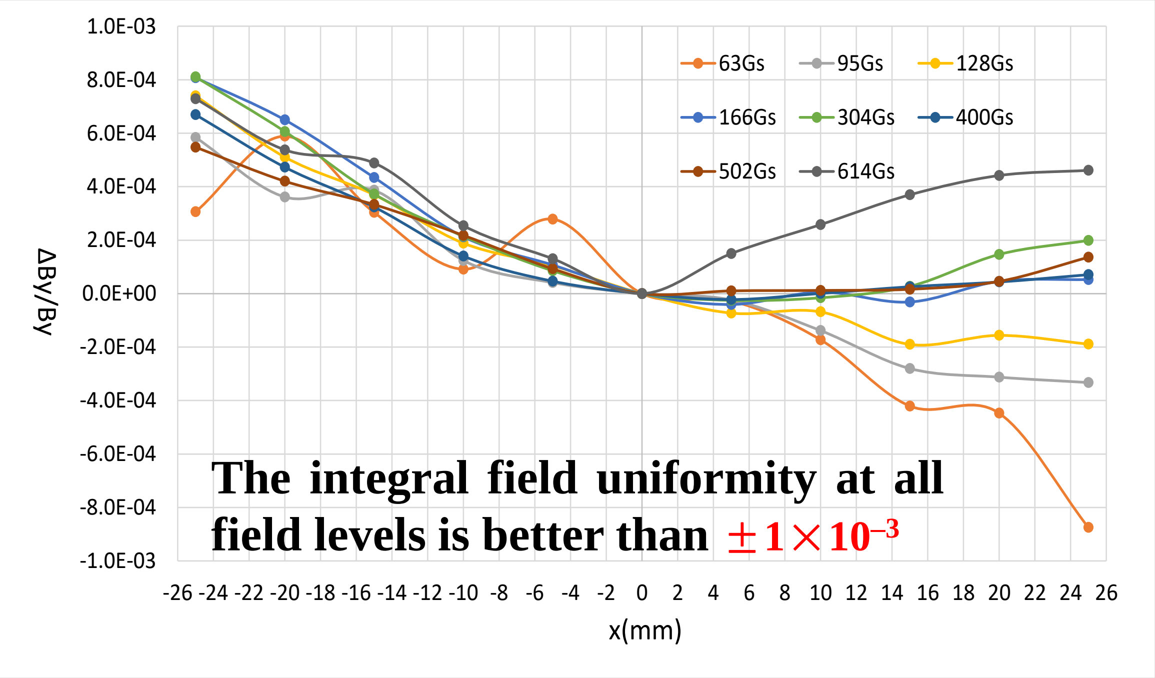




- **Large quantities of dual-aperture dipoles (69km) and quad. (10km) are required;**
- **Full length dual-aperture dipole and dual aperture QUAD (short length) have been fabricated, under test;**
- **Dipole/QUAD prototypes meet the requirements.**

CEPC Full-scale Weak Field Dipole for Booster

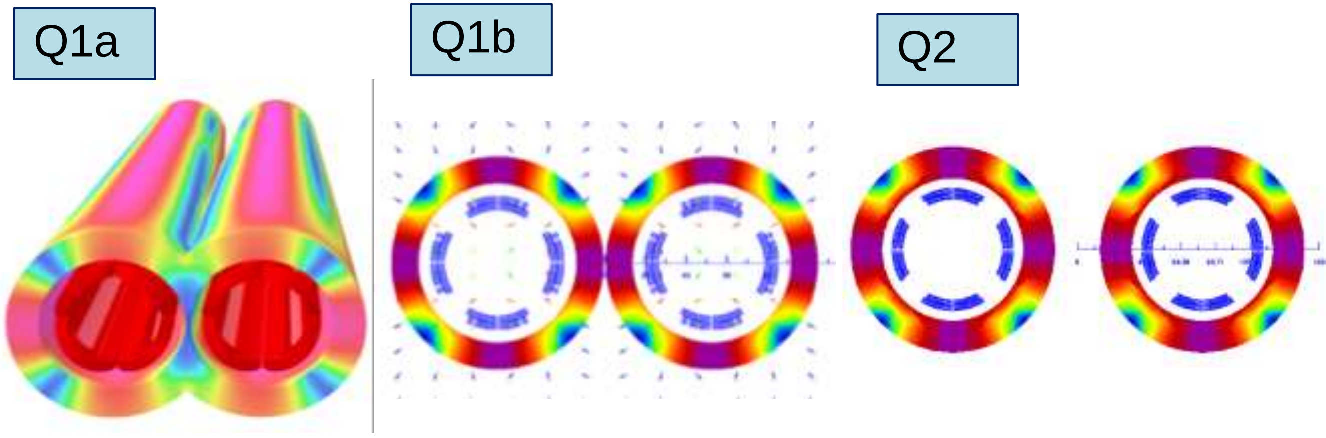
Magnet name	BST-63B-Arc	BST-63B-Arc-SF	BST-63B-Arc-SD	BST-63B-IR
Quantity	10192	2017	2017	640
Aperture [mm]	63	63	63	63
Dipole Field [Gs] @180 GeV	564	564	564	549
Dipole Field [Gs] @120 GeV	376	376	376	366
Dipole Field [Gs] @30 GeV	95	95	95	93
Sextupole Field [T/m^2] @180 GeV	0	16.0388	19.1423	0
Sextupole Field [T/m^2] @120 GeV	0	10.6925	12.7615	0
Sextupole Field [T/m^2] @30 GeV	0	2.67315	3.19035	0
Magnetic length [mm]	4700	4700	4700	2350
GFR [mm]	±22.5	±22.5	±22.5	±22.5
Field errors	$\pm 1\times10^{-3}$	$\pm 1\times10^{-3}$	$\pm 1\times10^{-3}$	$\pm 1\times10^{-3}$

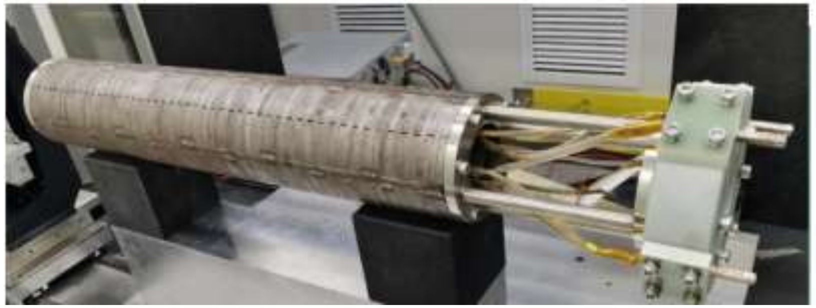


- Booster requires ~19k pieces of magnets (68km);
- Booster dipoles are required to work at the low field of 95 Gs (30GeV) with an error smaller than 1×10^{-3} ;
- Full length (4.7m) dipole was developed, and it meets the field specification;

CEPC Final Focus Superconducting Quadrupoles

SCQ Specifications	Q1a	Q1b	Q2	
Field gradient	142.3	85.4	96.7	T/m
Magnetic length	1210	1210	1500	mm
Reference radius	7.46	9.085	12.24	mm
Mini. distance between aperture center	62.71	105.28	155.11	mm
High order field harmonics	$\leq 5\times10^{-4}$	$\leq 5\times10^{-4}$	$\leq 5\times10^{-4}$	
Dipole field	≤3	≤3	≤3	mT





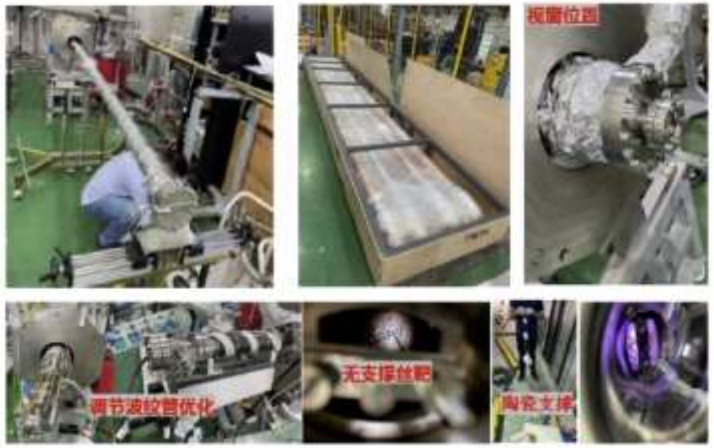
- CCT and Cos2θ type SCQs were modeled, and their fields were calculated; the CEPC specifications have been met;

- A 0.5-m single aperture SCQ using Cos2θ technology has been developed. The electro-magnet excitation test showed the highest current reached 2500A (176 T/m), which exceeds the CEPC requirement (142T/m)

CEPC Vacuum System

New round pipe of Copper (3mm) with NEG coating (200nm) for collider ring in TDR

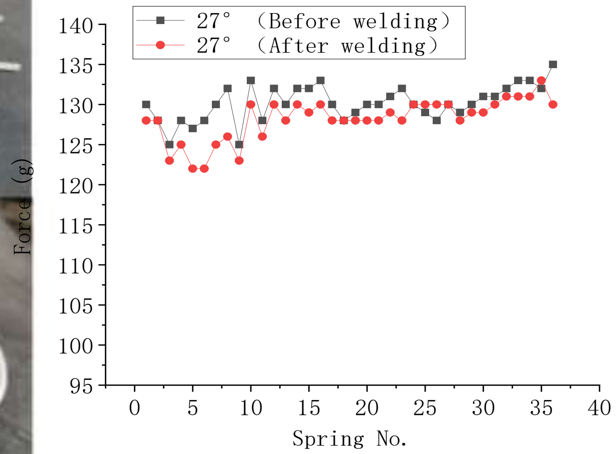
SEY<1.2



6 m vacuum pipe have been installed on the NEG coating setup

- ✓ 180℃/24h activation 4.5×10^{-10} Torr
- ✓ 200℃/24h activation 2.5×10^{-10} Torr

Vacuum pipes and RF shielding bellows



Vacuum chamber prototypes, copper & aluminum, with different shape/length were fabricated;

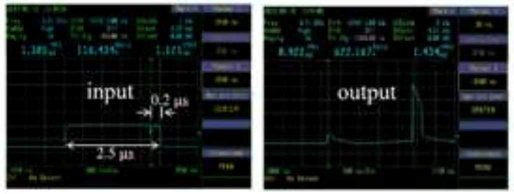
- NEG coating technology were developed;
- RF shielding bellow manufactured
- Vacuum technology applied and was tested at HEPS

Facility of pumping speed test have been finished in Dongguan

CEPC Linac Injector Key Technology R&D

- Flux concentrator for positron source
- RF pulse compressor
- High perform. S/C-band Acc. Struc.

IHEP C-band SLED

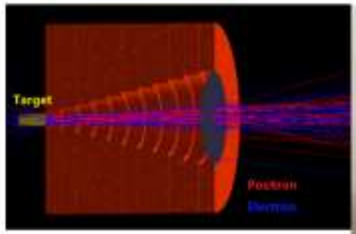


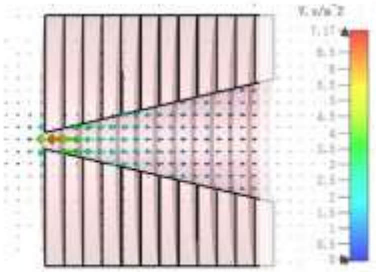
Test results of IHEP C-band SLED

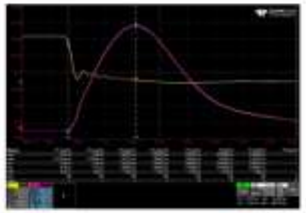
SACLA C-band SLED

IHEP C-band BOC

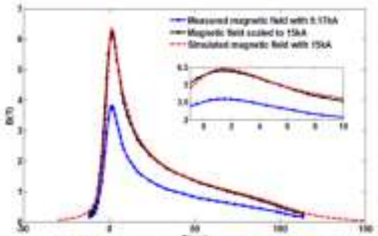
PSI BOC





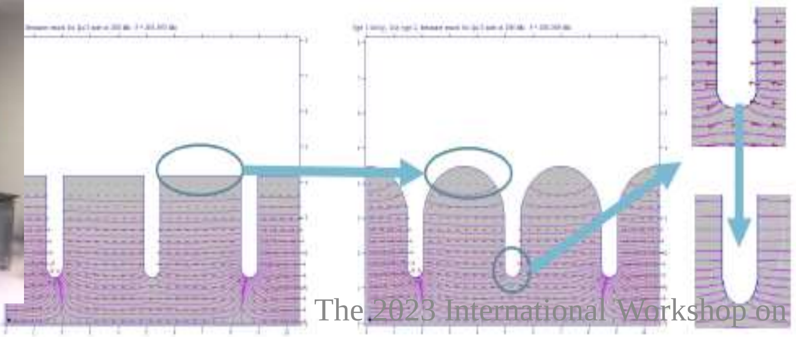


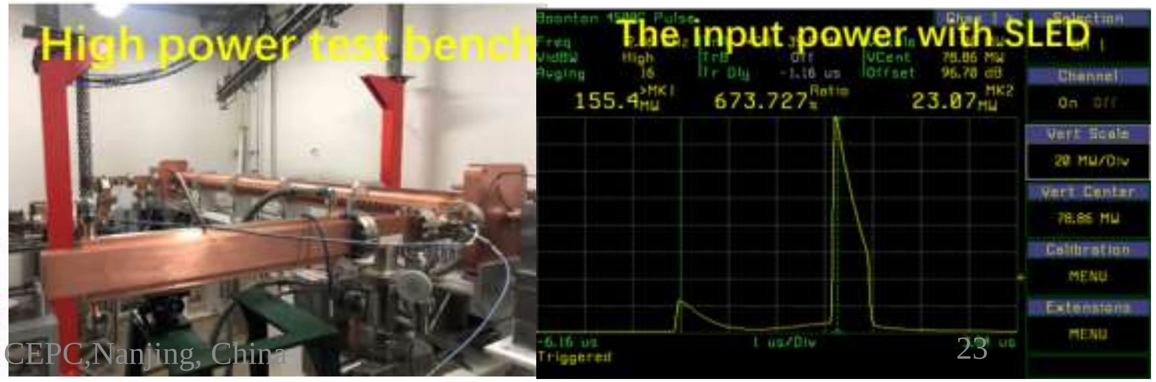
R&D of the solid state



Test result of the peak

- Positron pulsed magnetic field of 6 T to 0.5 T
- 15kA/15kV/50Hz solid state pulse source





Power Consumption of CEPC - Higgs

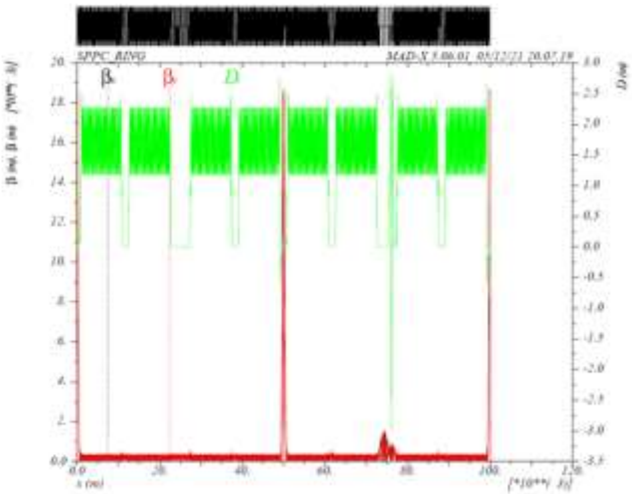
SN	System	Higgs 30MW							Higgs 50MW						
		Collider	Booster	Linac	BTL	IR	Surface building	Total	Collider	Booster	Linac	BTL	IR	Surface building	Total
1	RF Power Source	96.90	1.40	11.10				109.40	161.60	1.73	14.10				177.40
2	Crygenic system	9.72	1.71			0.14		11.57	9.17	1.77			0.14		11.08
3	Vacuum System	5.40	4.20	0.60				10.20	5.40	4.20	0.60				10.20
4	Magnet Power Supplies	44.50	9.80	2.50	1.10	0.30		58.20	44.50	9.80	2.50	1.10	0.30		58.20
5	Instrumentation	1.30	0.70	0.20				2.20	1.30	0.70	0.20				2.20
6	Radiation Protection	0.30		0.10				0.40	0.30		0.10				0.40
7	Control System	1.00	0.60	0.20				1.80	1.00	0.60	0.20				1.00
8	Experimental devices					4.00		4.00					4.00		4.00
9	Utilities	37.80	3.20	1.80	0.60	1.20		44.60	46.40	3.80	2.50	0.60	1.20		54.50
10	General services	7.20		0.30	0.20	0.20	12.00	19.90	7.20		0.30	0.20	0.20	12.00	19.90
	Total	204.12	21.61	16.80	1.90	5.84	12.00	262.27	276.87	22.60	20.50	1.90	5.84	12.00	339.71

SppC Collider Parameters in TDR

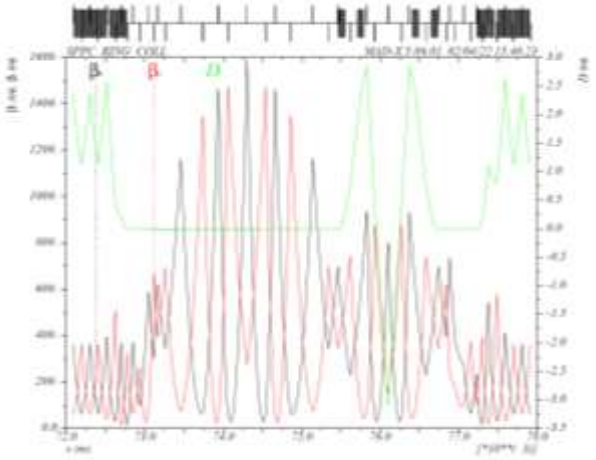
-Parameter list (updated Feb. 2022)

Main parameters		
Circumference	100	km
Beam energy	62.5	TeV
Lorentz gamma	66631	
Dipole field	20.00	T
Dipole curvature radius	10415.4	m
Arc filling factor	0.780	
Total dipole magnet length	65442.0	m
Arc length	83900	m
Total straight section length	16100	m
Energy gain factor in collider rings	19.53	
Injection energy	3.20	TeV
Number of IPs	2	
Revolution frequency	3.00	kHz
Revolution period	333.3	μs
Physics performance and beam parameters		
Initial luminosity per IP	4.3E+34	$cm^{-2}s^{-1}$
Beta function at initial collision	0.5	m
Circulating beam current	0.19	A
Nominal beam-beam tune shift limit pe	0.015	
Bunch separation	25	ns
Bunch filling factor	0.756	
Number of bunches	10080	
Bunch population	4.0E+10	
Accumulated particles per beam	4.0E+14	

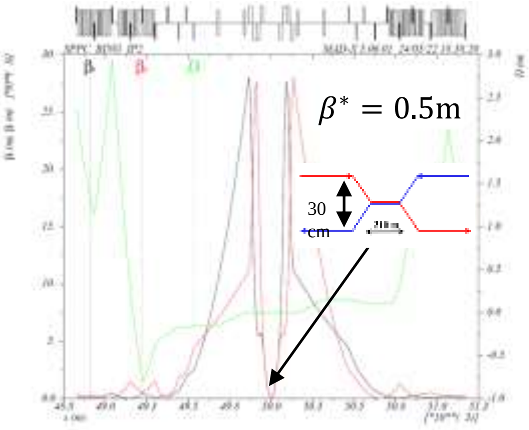
Lattice of SPPC



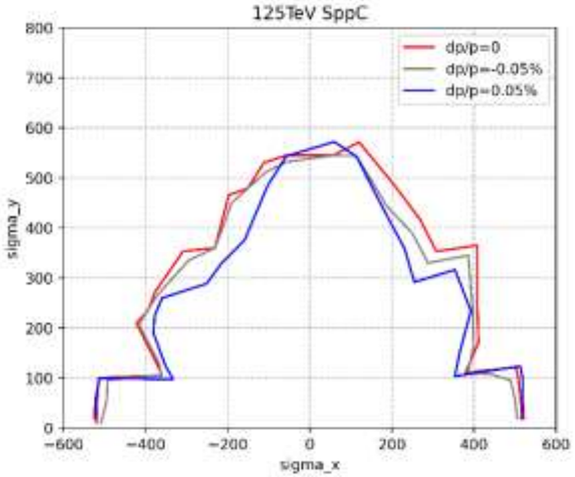
Whole ring



Collimation



IP



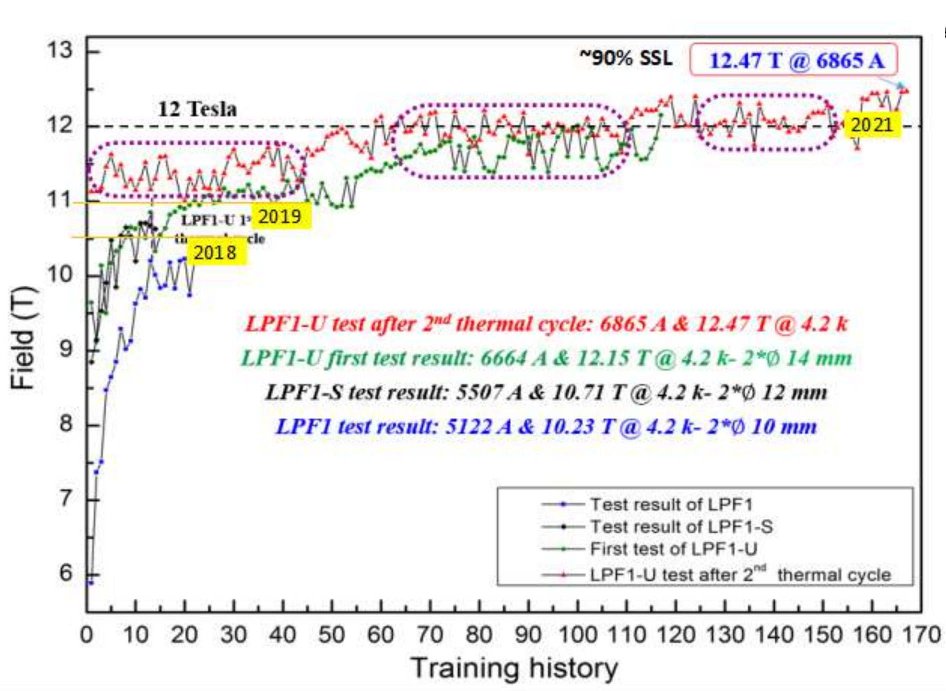
Dynamic Aperture

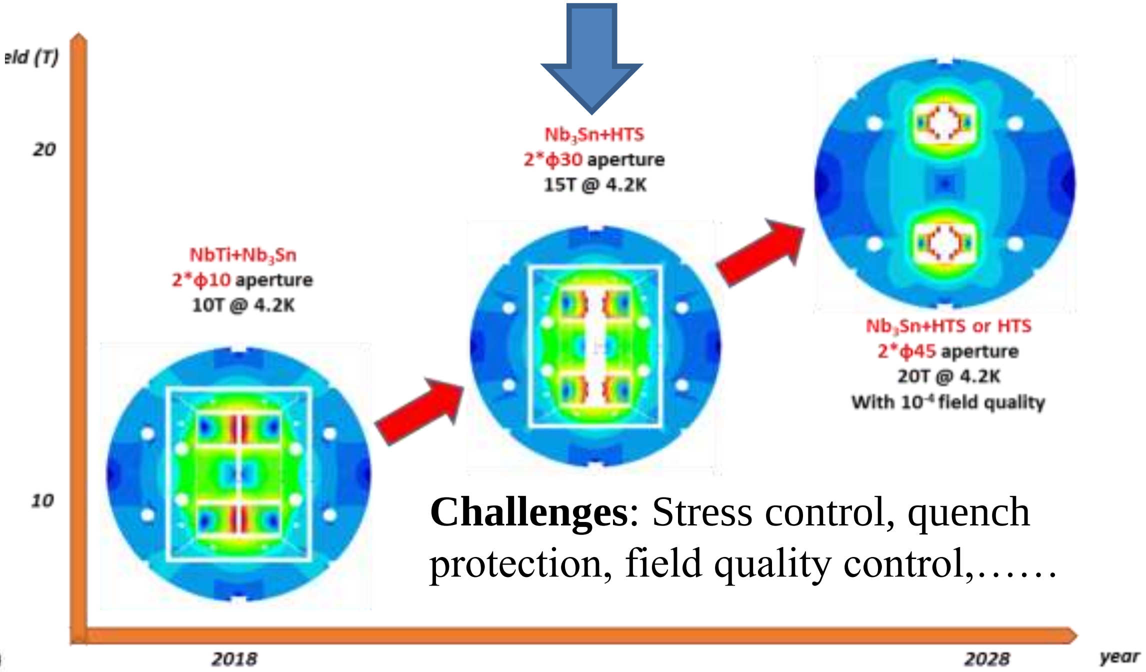
Ecm=125TeV with dipole field of 20T

Latest Performance of LPF1-U (SppC)

16 T Model Dipole: Nb_3Sn 12~13 T + HTS 3~4 T; ***To be tested in Sep-Dec 2023***

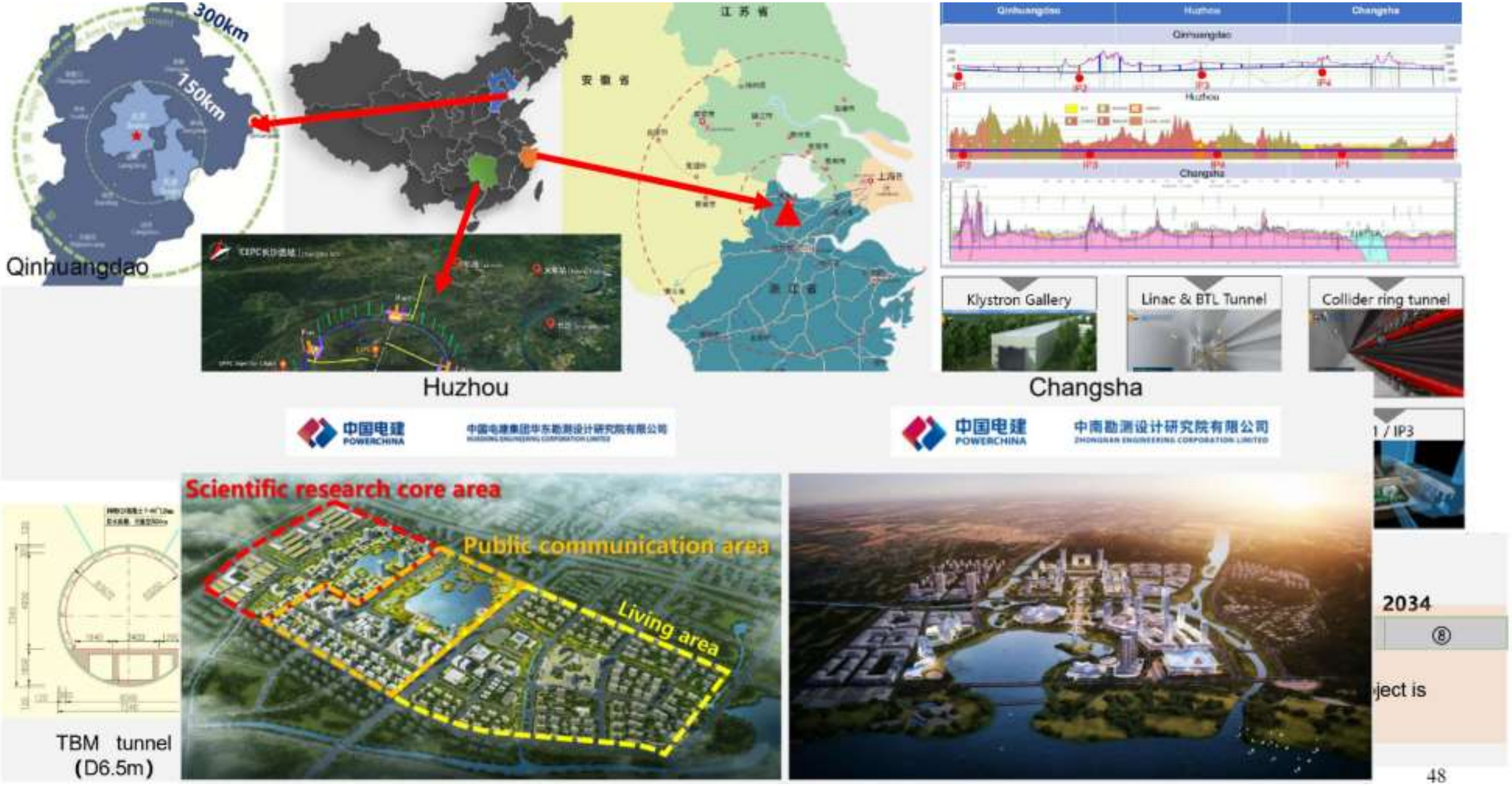
Picture of LPF1-U





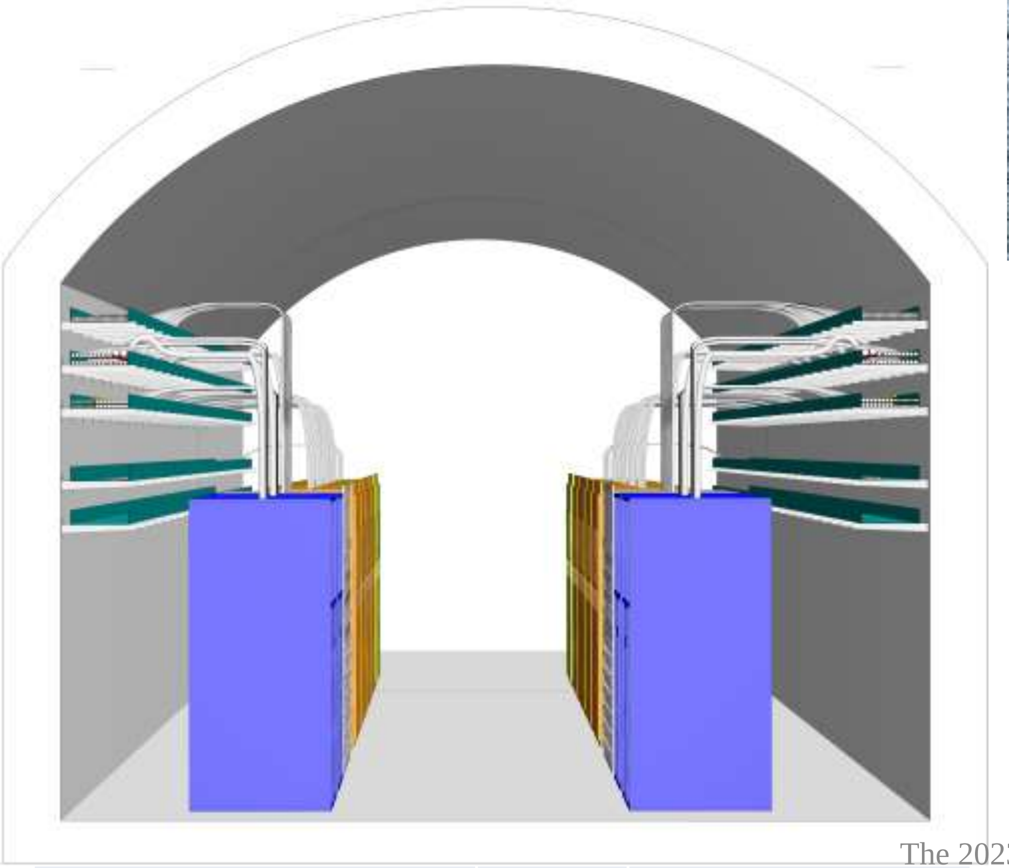
Dual aperture superconducting dipole achieves 12.47 T at 4.2 K
Entirely fabricated in China. The next step is reaching 16-20T

CEPC Site Selections (three examples)

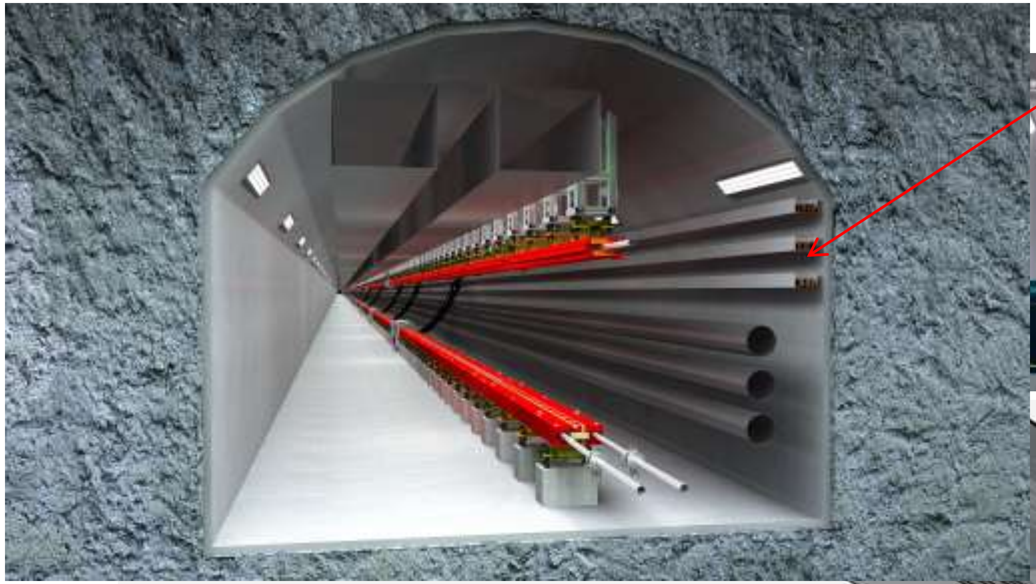


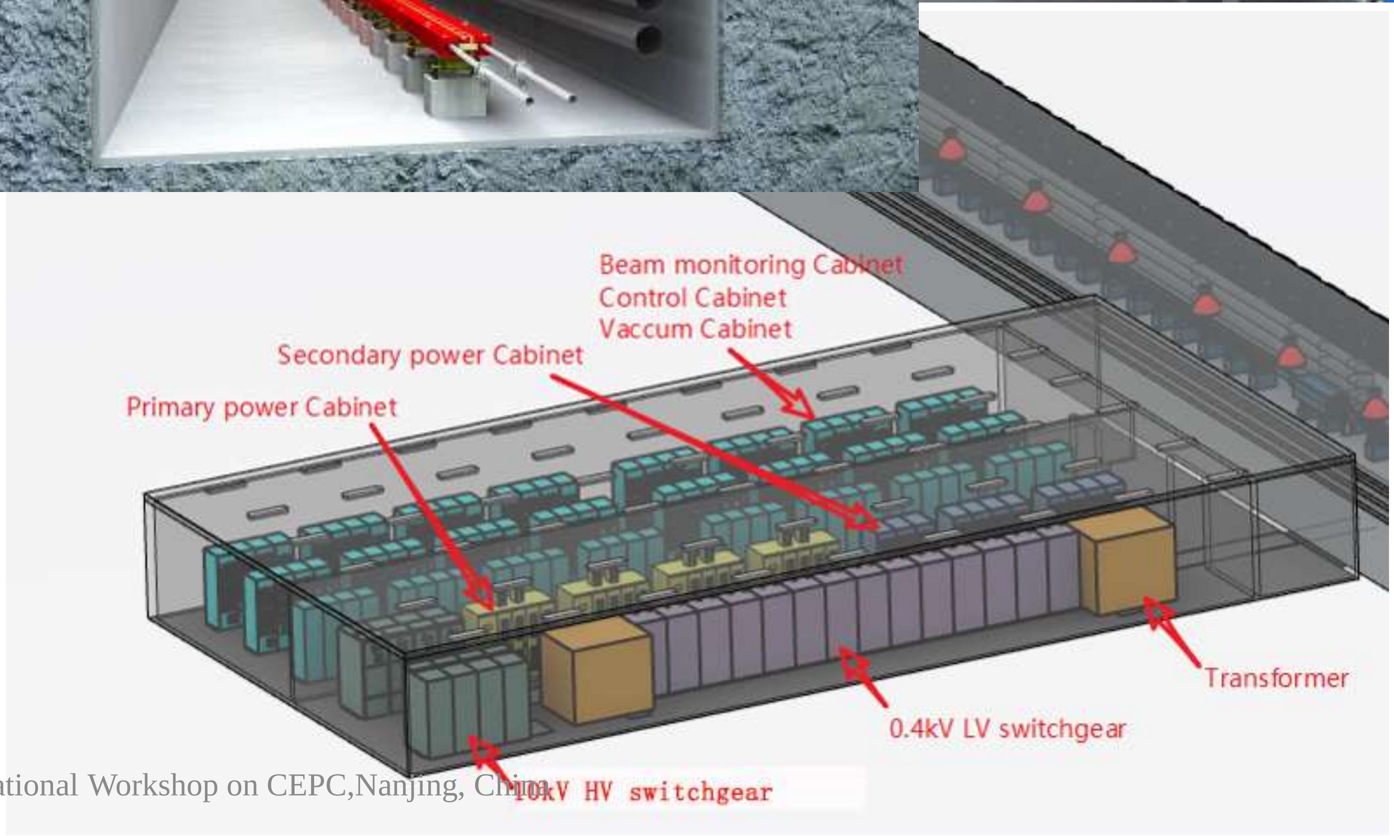
CEPC Conventional Facility and Civil Engineering

Electrical Equipment General Layout in Auxiliary



Cables installed!

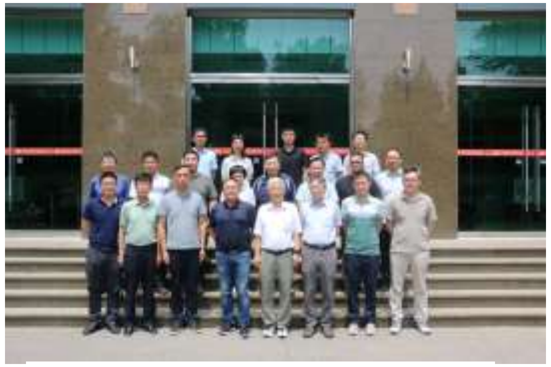




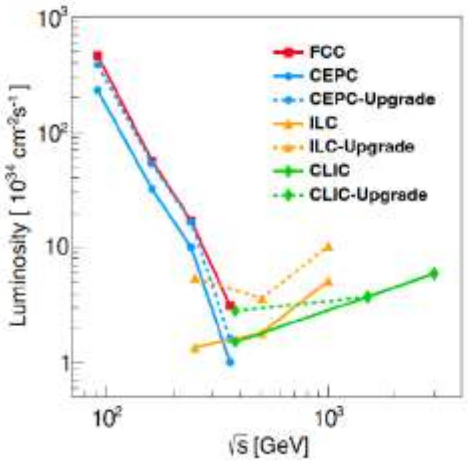
CEPC Accelerator International TDR Review and Cost Review June 12-16, and Sept. 11-15, 2023, in HKUST-IAS, Hong Kong

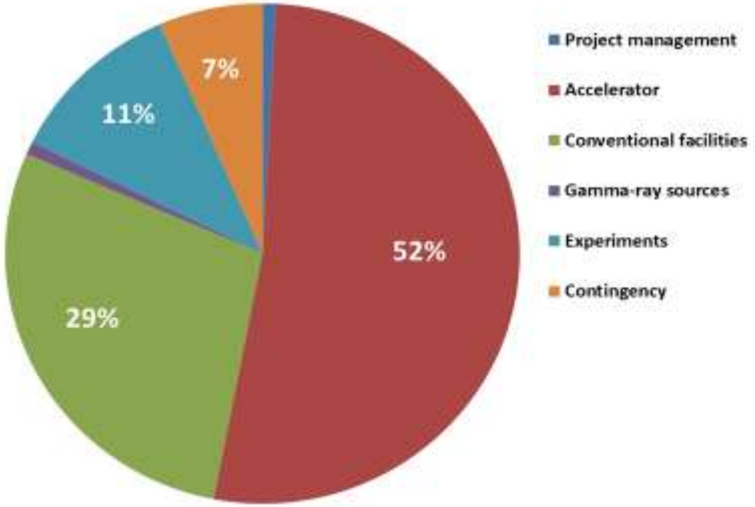
CEPC Accelerator TDR Review
June 12-16, 2023

CEPC Accelerator TDR Cost Review
Sept. 11-15, 2023



Domestic Civil Engineering
Cost Review, June 26, 2023





CEPC TDR cost distribution

CEPC accelerator TDR to be released formally soon in 2023

CEPC Accelerator TDR International Review Report

Phase 1 CEPC TDR Review Report

CEPC TDR Technical Review Committee

15 July 2023

Chaired by Frank Zimmermann

1 Executive Summary

Five years after the completion of the CDR, the draft TDR for the CEPC accelerator has been prepared. The TDR will be completed taking into account the feedback from this Committee. The key technologies for CEPC have been developed. Prototypes meeting or exceeding the specifications are available. The CEPC team is on track to launch an engineering-design effort. After a site has been selected, the construction of the CEPC could start in 2027 or 2028. The Committee endorses this plan.

The Committee wishes to congratulate the CEPC team on the excellent progress. The Committee is impressed by the amount and quality of the work performed and presented.

The next section provides answers to the different charge questions, the following sections contain comments and recommendations related to the individual presentations.

CEPC Accelerator International TDR Review was held June 12-16, 2023, in HKUST-IAS, Hong Kong

https://indico.ihep.ac.cn/event/19262/timetable/

CEPC Accelerator TDR International Cost Review Report

CEPC Accelerator TDR Cost Review

Chaired by Loinid Rivkin

The CEPC Accelerator TDR Cost Review committee examined the cost estimate of the TDR of accelerator systems for the first stage of the CEPC project operated as a Higgs factory with synchrotron radiation power up to 30 MW per beam (including all infrastructure that is not easily upgradeable and is already designed to operate up to the ttbar energy and at 50 MW). The cost estimate under review does not include the civil engineering, the detectors at the IPs with their technical services, and the central computing services.

In the opinion of the committee the cost estimate presented is sufficiently complete to form a proper basis for the next iteration that will be done during the EDR stage.

The responses to the Charge are set out below, followed by some general observations, and then some specific issues on which we have more to say.

CEPC Accelerator International TDR Cost Review was held Sept. 11-15, 2023, in HKUST-IAS, Hong Kong

https://indico.ihep.ac.cn/event/19262/timetable/

CEPC Engineering Design Report (EDR) Goal

2012.9	2015.3	2018.11	2023.10	2027	15th five year plan
CEPC proposed	Pre-CDR	CDR	TDR	EDR	Start of construction

CEPC EDR Phase General Goal: 2024-2027

After completion CEPC accelerator TDR in 2023, CEPC accelerator will enter into the Engineering Design Report (EDR) phase (2024-2027), which is also the preparation phase with the aim for CEPC to be presented to and selected by Chinese government for the construction start during the ”15th five year plan (2026-2030)” (for example, around 2027) and completion around 2035 (the end of the 16th five year plan).

CEPC Accelerator EDR Plan and Scope-1

(A) Based on the CEPC TDR accelerator design, demonstrate a complete and coherent feasibility EDR design, which will guarantee the construction, commissioning, operation, and upgrade possibilities .

(B) The CEPC EDR accelerator design should guarantee the physics goals with required energies (Higgs, W and Z pole, with ttbar as upgrade possibility) and corresponding required luminosities with 30MW synchrotron radiation power/beam as a baseline, and 50MW as upgrade possibility.

(C) Based on the CEPC TDR accelerator key technology R&D achievement, complete the accelerator engineering design and necessary EDR R&D to be ready for industrial fabrications.

(D) Complete a practical procurement strategy and logistics with both domestic and international suppliers.

CEPC Accelerator EDR Plan and Scope-2

(E) In collaboration with local government, CAS and MOST (central government), CEPC sites converge from serval candidates to a EDR construction site satisfying the required geological conditions, electric power and water resources, social and environment conditions, domestic and international transportation network conditions, international science city, and sustainable development , etc.

(F) Complete detailed construction site geological studies and corresponding site dependent civil engineering design and general utility facility design.

(G) Complete the radiation, security, environment assessment studies and necessary documents (including EDR report) ready for the application to the central government to get the formal approval of construction in the “15th five year plan”

(H) Make detailed analysis and preparation for the human resources needed for the completion of CEPC construction.

CEPC Accelerator EDR Plan and Scope-3

(I) In the Engineering Design Phase, create and maintain a complete database, such as cost items with information regarding technology maturity (TRL), design completeness, and cost basis, to identify and prioritize areas for R&D, prototyping and industrialization.

(J) Wort out a detailed construction time line and plan in relation with industrial fabrications, measurements, transportations, storage warehouses, installation, human resource evolution, etc.

(K) Workout details on 3% installation and 3% commissioning items of the total accelerator cost.

(L) Improve design maturity of several systems (particularly MDI and cryogenics) and develop system integration.

(M) Implement the risk-mitigation plan in the production and procurement plans to eliminate major risk during the mass production, providing multiple vendors and multiple production lines (for example, demonstrate automatic magnets production line and NEG coated vacuum chambers mass production facility).

CEPC Accelerator EDR Plan and Scope-4

(N) Consider re-optimizing the technical design of components and systems with large electricity consumption taking into account both capital and operational expenditure

(O) Define unambiguously what constitutes the end of the construction project.

(P) For labour-intensive, high-volume activities, in particular the components of the collider and booster, refine and review the production model to check the availability of in-house resources.

(Q) Risk assessment and risk management

(R) Based on TDR cost estimate, make an updated EDR cost estimate.

(S) Carefully consider the recommendations from CEPC accelerator TDR review and TDR cost review committees, IARC and IAC, etc.

(T) Continues efforts in green collider and sustainable development with energy saving technologies, wast heat reuse, energy recovery, and green energy utilization, etc.

CEPC Accelerator EDR Plan and Scope-5

(U) Establish more international collaborations, international involvement, and industrial preparations both from domestic and international companies and suppliers.

(V) Refine the CEPC management structure in relation with host lab.

(W) Refine the CEPC construction funding modes.

(X) Obtain the necessary EDR plan and scope related fundings.

(Y) Complete EDR and necessary documentations ready for final selection of the 15th 5-year plan.

(Z) With aim of start the construction around 2027~2028 and complete the construction and put CEPC in to commissioning around 2035.

According to the CEPC EDR general goal and CEPC Accelerator EDR plan and scope (**A to Z**) described above CEPC accelerator key subsystems working plans and goals (2024 - 2027), each year to do list (items) and deliverables, milestones, etc. are briefly described in the breakdown 35 WGs as follows:

Breakdown of CEPC Accelerator EDR working plan and goals for WGs (2024-2027)-1

1) CEPC Collider ring (Yiwei Wang)
2) Booster ring (D. Wang)
3) Linac (+damping ring) (C. Meng, J.R. Zhang, D. Wang)
4) MDI (S. Bai)
5) Connection transport lines and timing (X.H. Cui)
6) Collider magnets (M. Yang)
7) Booster magnets (W. Kang)
8) Magnet power sources (B. Chen)
9) Electrostatic-magnet separator (B. Chen)
10) SC quadrupoles (Y.S. Zhu)
11) SRF system for collider ring (J. Y. Zhai, P. Sha)
12) SRF system for booster ring (J.Y. Zhai, P. Sha)
13) Cryogenic system (R. Ge and Mei Li)
14) RF power sources and power distribution (collider, booster and linac) (Z.S. Zhou)
15) Instrumentation and feedbacks (Y.F. Sui and Y.H. Yue)
16) Mechanical system (H.J. Wang and Minxian Li)
17) Vacuum system (Y.S. Ma)

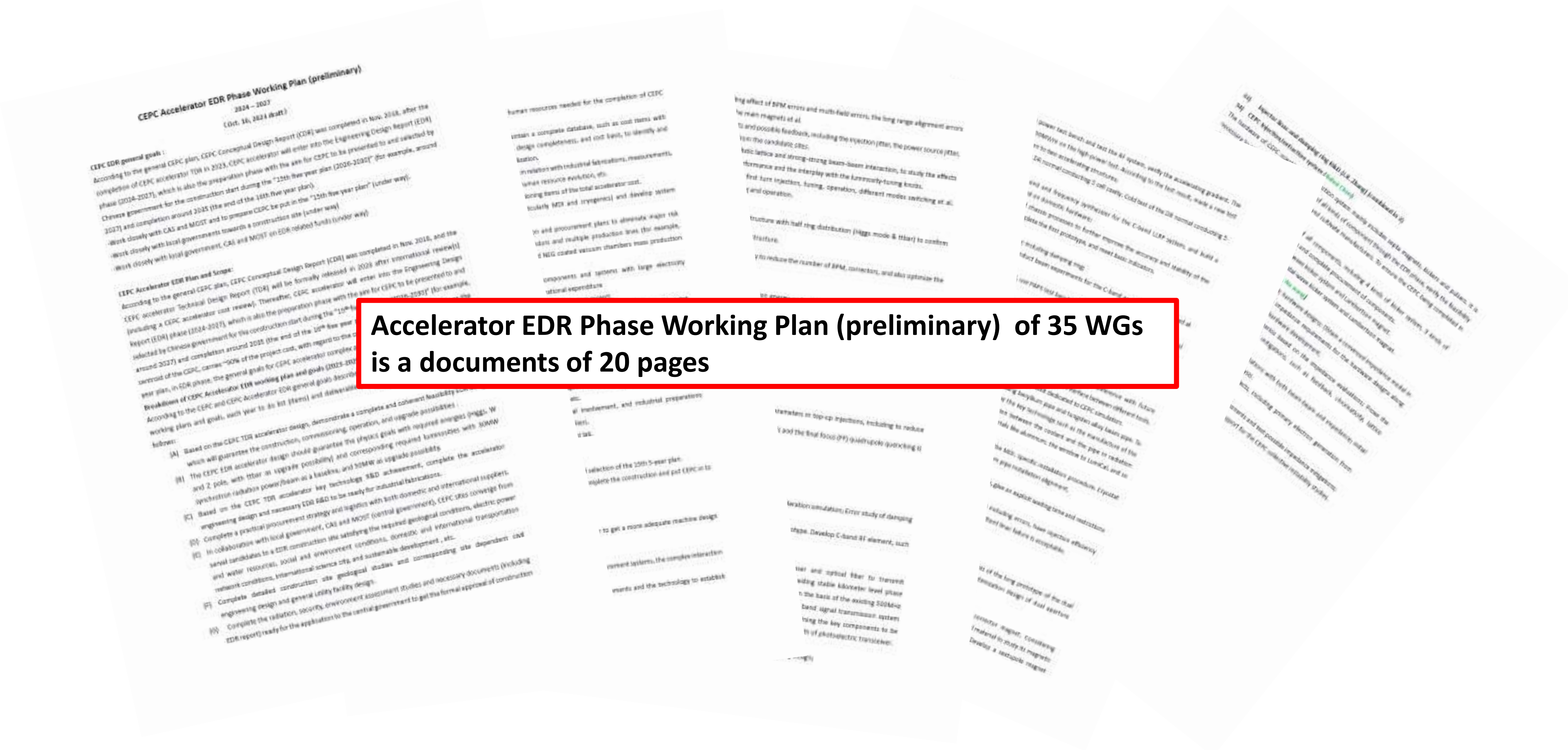
Breakdown of CEPC Accelerator EDR working plan and goals for WGs (2024-2027)-2

18) Control system (D.P. Jin, G. Li)
19) Conventional facilities (J.S. Huang)
20) Environment, health and safety issues (Guang Yi Tang and Zhongjian Ma)
21) Machine protection beam dump (Zhongjian Ma, X.H.Cui, and Yuting Wang)
22) CEPC high energy gamma ray beamlines (Y.W. Wang and Y.S. Huang)
23) Alignment and installation (X. L. Wang)
24) Beam driven plasma injector for CEPC (D.Z. Li)
25) CEPC polarization design (Z. Duan)
26) SppC design and compatibility with CEPC (Jingyu Tang and Y.W. Wang)
27) SppC high field magnet (Q.J. Xu)
28) CEPC electronic documentation system (K. Huang and S. Jin)
29) CEPC site selection and civil engineering design in Qinhuangdao and Chuangchun (Y. Xiao)
30) CEPC site selection and civil engineering design in Changsha (Yangjiang Pan and Zhiji Li)
31) CEPC site selection and civil engineering design in Huzhou (K. Huang)
32) CEPC domestic and international industry preparations (S. Jin)
33) Injector linac and damping ring R&D (J.R. Zhang) (combined in 3)
34) CEPC Injection/extraction system (Jinhui Chen)
35) Collective effects and impedance (Na wang, Yudong Liu)

Accelerator EDR Phase Working Plan (preliminary) of 35 WGs is a documents of 20 pages

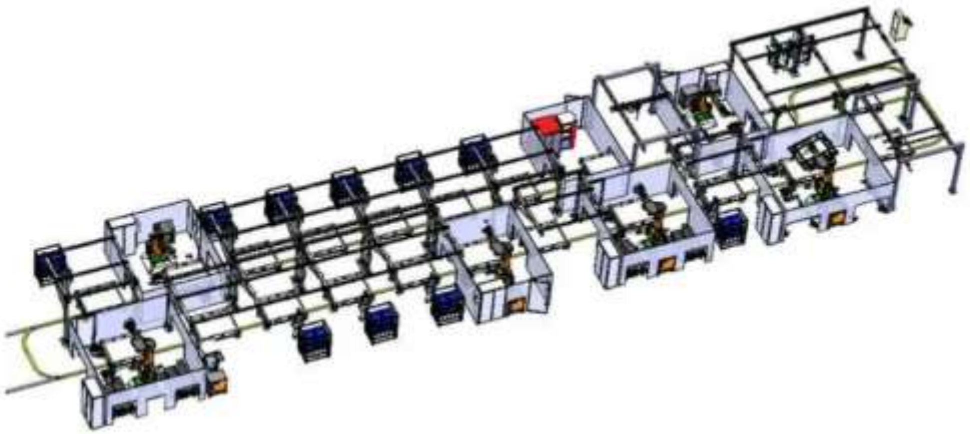
CEPC Accelerator EDR Phase Working Plan (preliminary) is a documents of 20 pages

CEPC EDR Goal, Plan and Scope

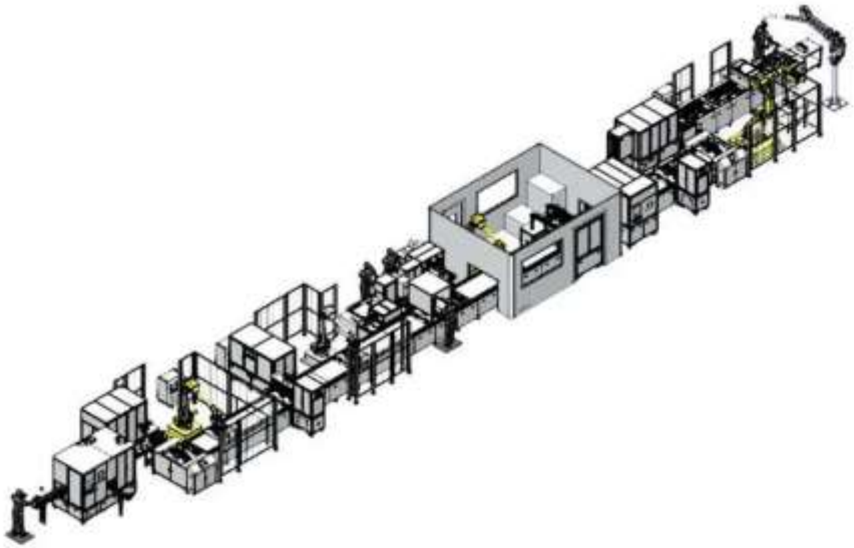


Accelerator EDR Phase Working Plan (preliminary) of 35 WGs is a documents of 20 pages

Automatic Production Lines of the CEPC Magnets in EDR



Conceptual design type-I

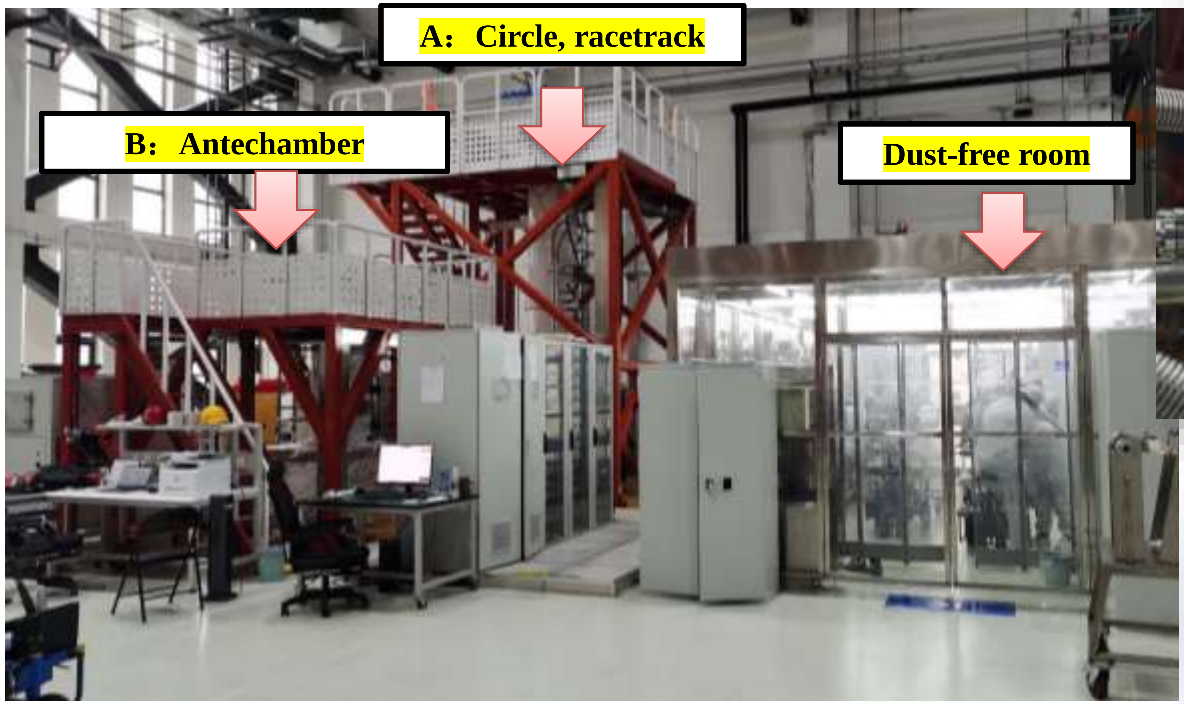


Conceptual design type-II

To reduce the fabrication cost of the magnets of CEPC, automatic magnet production lines will be demonstrated in EDR and used during construction

Massive Production Line of NEG Coating Vacuum Chambers in EDR

- The coating device A: Vacuum chambers are connected in parallel to 6 groups, each group of vacuum chambers length should be lower than 3.5m, outer diameter is about 0.47m;
- The coating device B: Antechamber are connected in parallel to 4 groups, each group of vacuum chambers length should be lower than 1.5m, due to its discharge difficulty.
- Two setups of NEG coating have been built for vacuum pipes of HEPS at IHEP Lab. And a lot of test vacuum pipes have been coated, which shows that NEG film has good adhesion and thickness distribution.
- In EDR phase a dedicated CEPC NEG coated vacuum chamber production line is planned

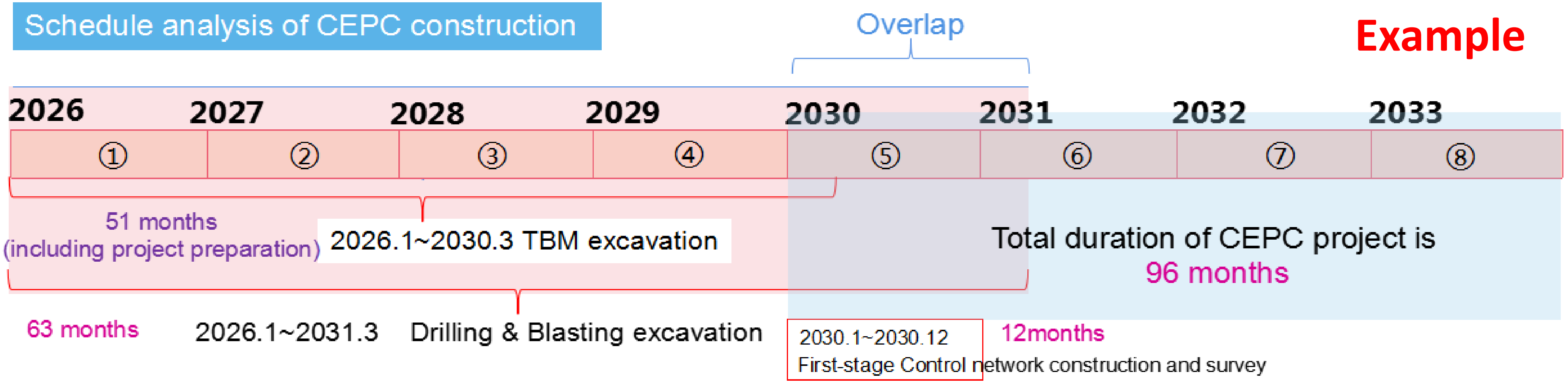


CEPC Accelerator Construction Timeline

2023: Accelerator TDR; 2027: EDR; Start construction upon approval

Schedule analysis of CEPC construction

Example

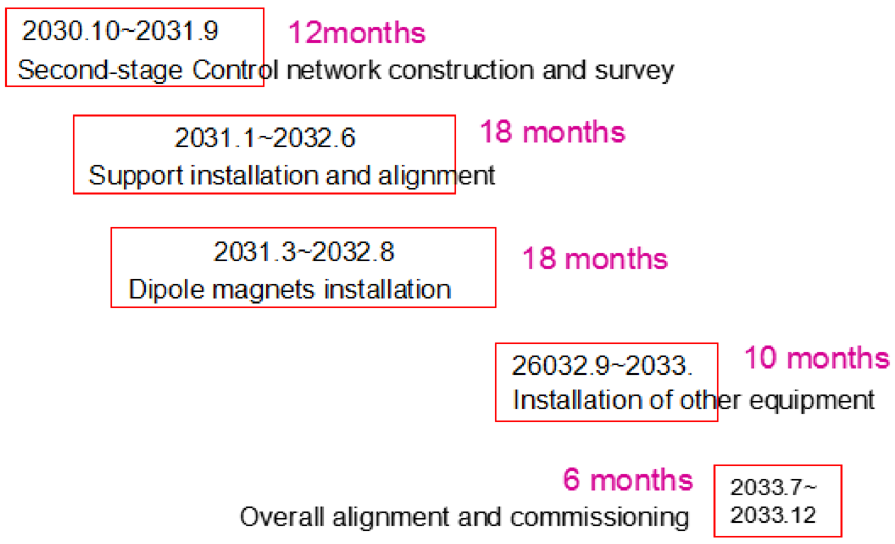


1.CEPC production Including civil works and installation of physical equipment. It will begin in 2026 and end in 2033, The total duration of CEPC project is 96 months.

2.The total civil works period is 63 months.

3.The total installation period of physical equipment is 48 months

4. The Overlapping period of civil works and equipment installation is 15 months



Participating and Potential Collaborating Companies in China (CIPC) and Worldwide

	System
1	Magnet
2	Power supplier
3	Vacuum
4	Mechanics
5	RF Power
6	SRF/ RF
7	Cryogenics
8	Instrumentation
9	Control
10	Survey and alignment
11	Radiation protection
12	e-e+Sources

CEPC Industrial Promototion Consortium (CIPC, established in Nov. 2017)

Potential international collaborating suppliers worldwide

CEPC International Collaborations

HKIAS23 HEP Conference
Feb. 14-16, 2023

https://indico.cern.ch/event/1215937/

The 2023 International Workshop on Circular Electron Positron Collider, EU-Edition,University of Edinburgh, July 3-6, 2023

https://indico.ph.ed.ac.uk/event/259/overview

The 2024 HKUST IAS Mini workshop and conference will be held from Jan. 18-9, and Jan. 22-25, 2024, respectively.

The 2024 international workshop of CEPC, EU-Edition Is planned to be held in Marseille, France

Summary

- The CEPC TDR parameter and design optimizations with high luminosity (30MW and 50MW) operations, for all four energies (Higgs, W/Z and ttbar) have been studied. The results demonstrate that the physics design satisfies the scientific goals.
- A comprehensive key technology R&D program has been carried out in TDR with CEPC key technplogies in hands ready for industrialization preparation in EDR.
- CEPC accelerator TDR international review and cost review were held from June 12-16, 2023 and Sept. 11-15, 2023, respectively, and will be released formally soon in 2023.
- Detailed preparation of CEPC accelerator EDR phase (2024-2027) before construction working plan and beyond have been established (preliminary), with the aim of starting the construction in "15th five-year-plan" (2026-2030) .
- International collaboration and participation are warmly welcome.

Thanks