中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

CEPC Accelerator EDR Status
-The path from EDR to start construction

J. Gao

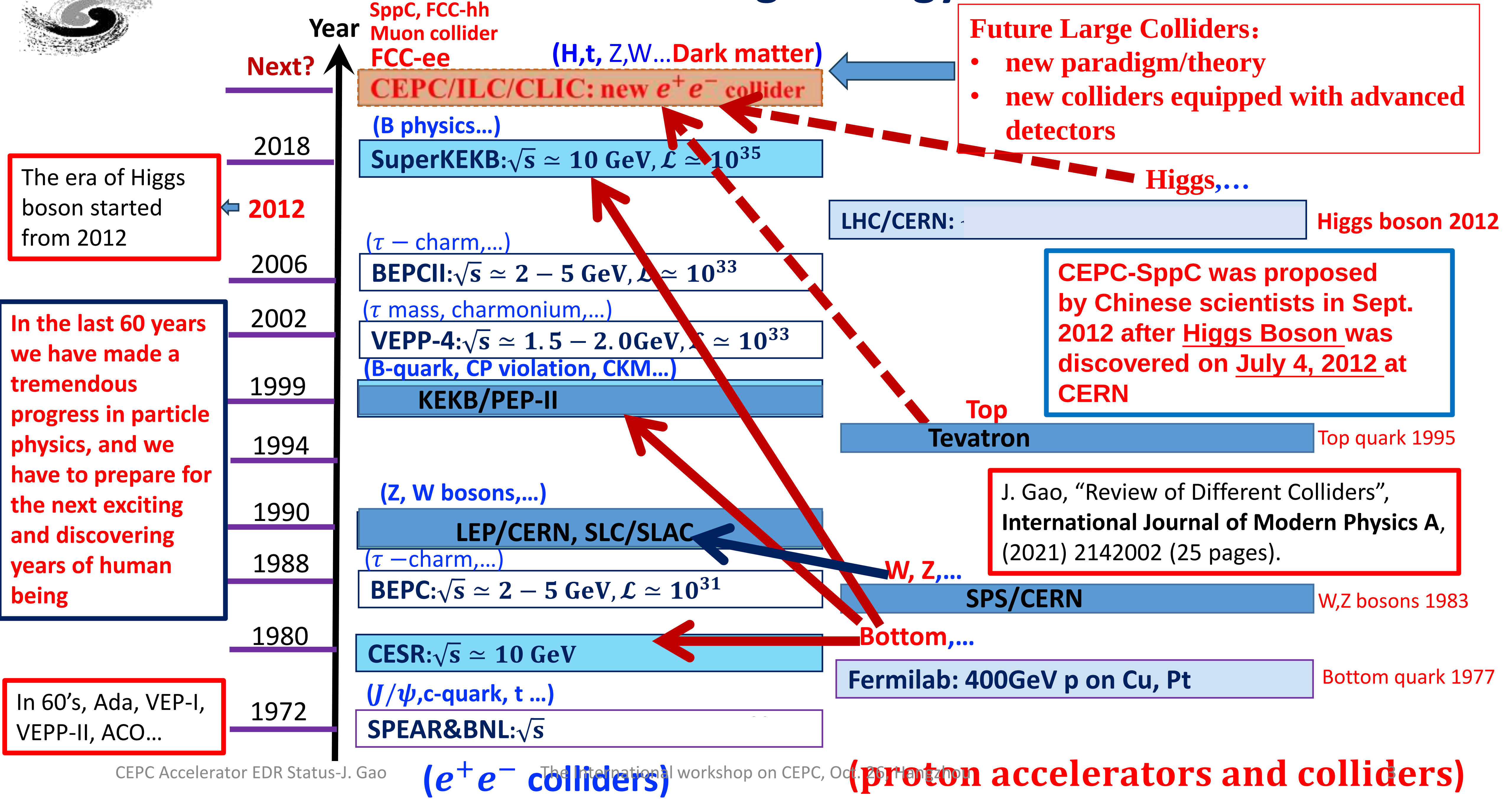
IHEP

On behalf of the CEPC-SppC accelerator team

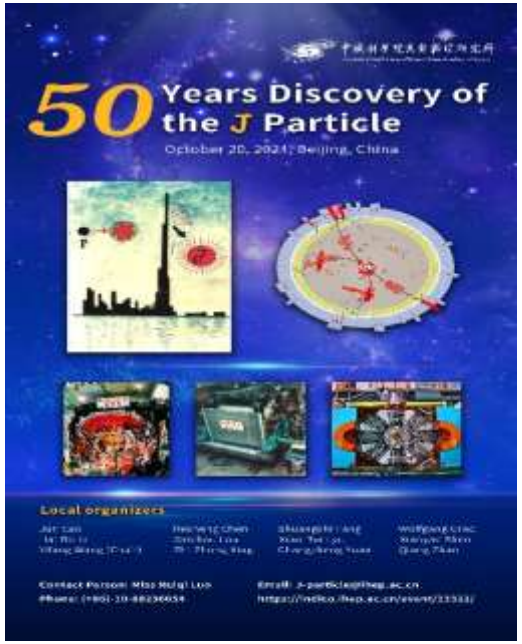
The International workshop on CEPC
Oct. 23-27, 2024, Hangzhou, China

Contents

A Brief Historical Recall: High Energy Colliders and Factories

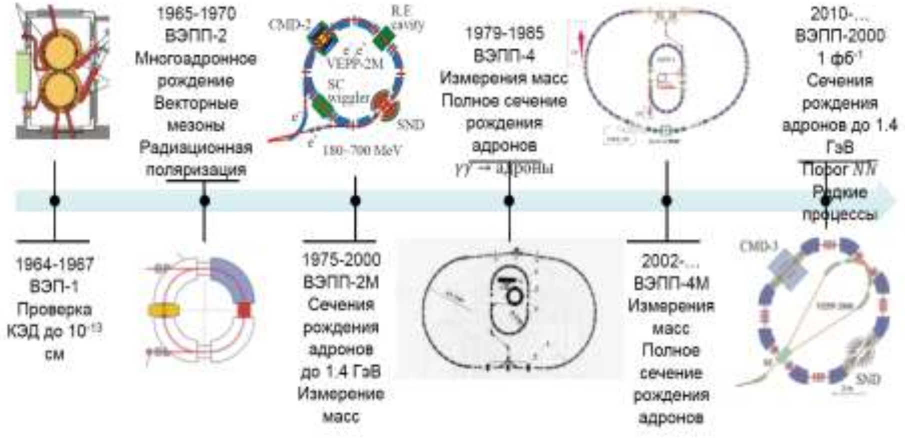


Recent Celebrations for HEP Worldwide



50 Years Discovery of the J Particle
Oct. 20, 2024, IHEP, China
https://indico.ihep.ac.cn/event/23322/timetable/

CERN's 70th anniversary
Oct. 1, 2024, CERN, Switzerland
https://indico.cern.ch/event/1373628/



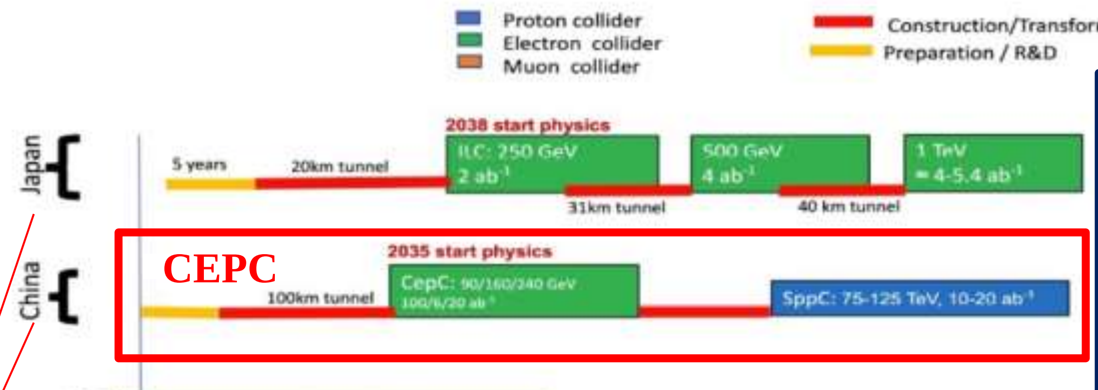
60 Years of Colliding Beams and 50 years of Electron Cooling in Budker INP
Oct. 1, 2024, BINP, Russia

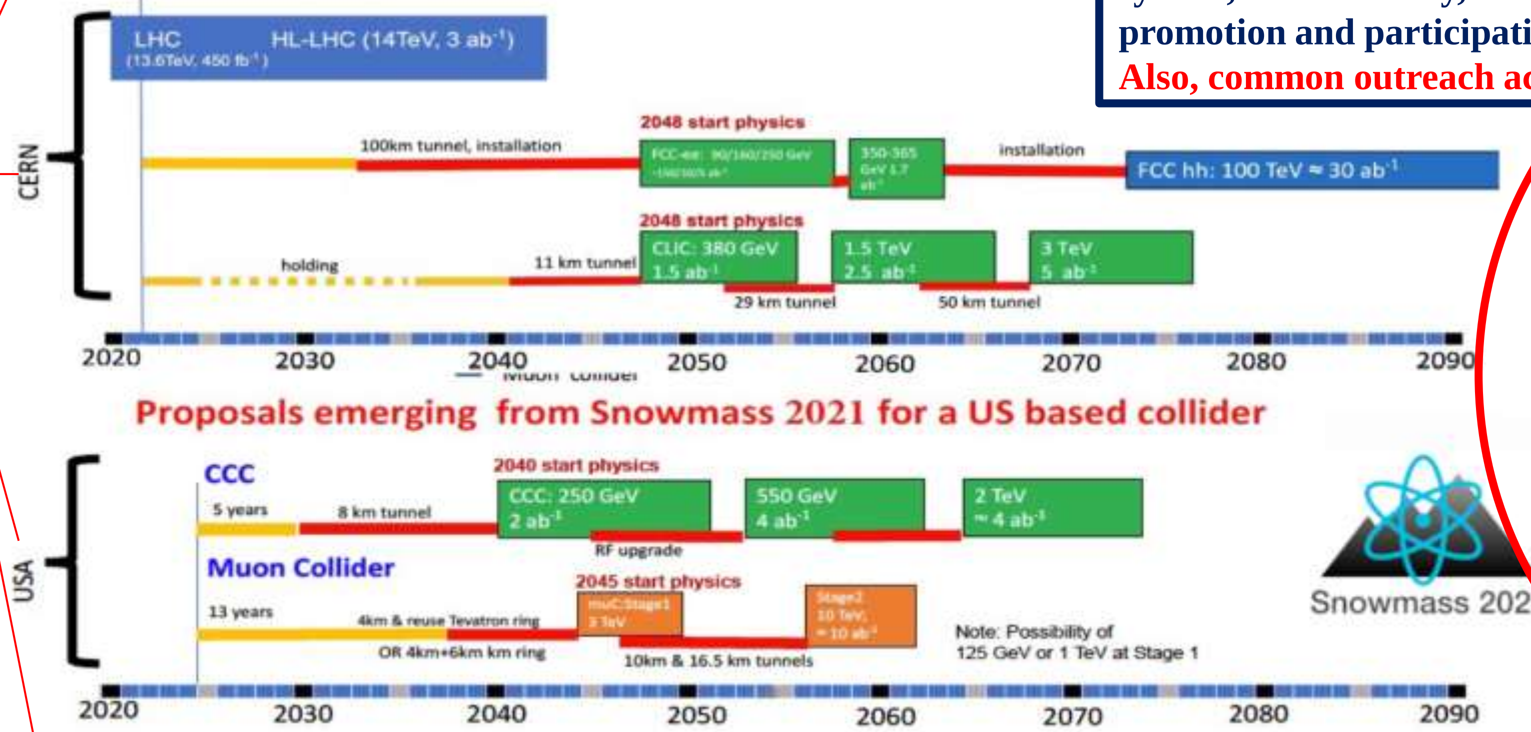
https://disk.yandex.ru/d/50mE_jBtlh5WVQ

It is important to look back for better looking and going forwards in future

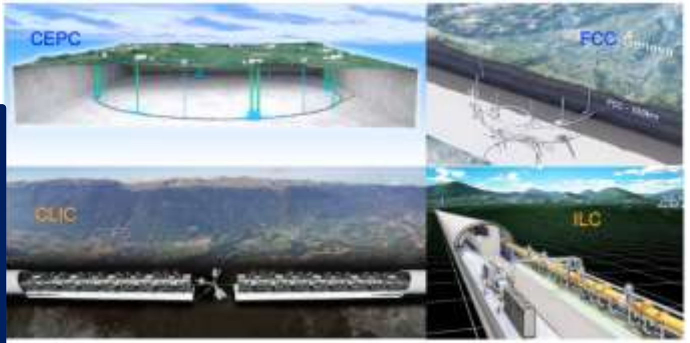
Worldwide High Energy Physics Goal
Timelines and Common Efforts towards Future

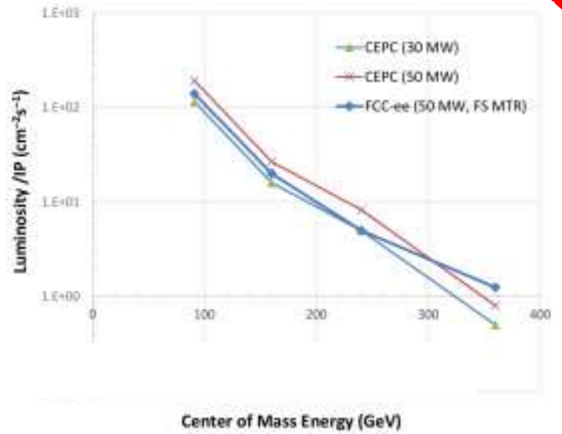
The common physics goals in complementary





Future large colliders have the common physics, accelerator and detector technologies:
SC accelerator technologies, positron source, damping ring, final focus, MDI, cryogenic system, sustainability, industrial promotion and participation.
Also, common outreach activities



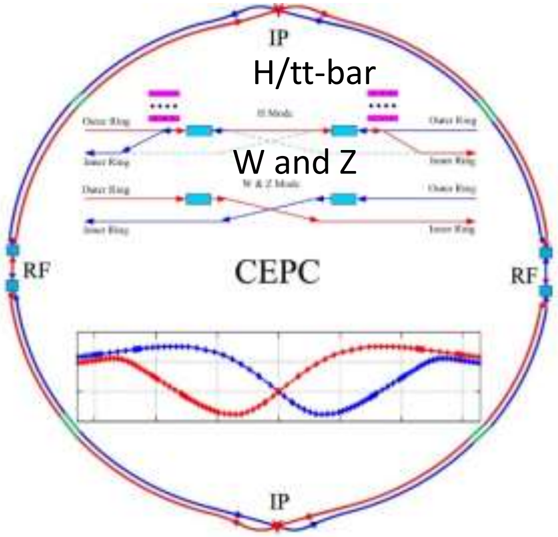


	Operation mode			
	H	Z	W	$t\bar{t}$
CEPC (TDR, 30 MW)	5	115	16	0.5
CEPC (TDR, 50 MW)	8.3	192	26.7	0.8
FCC-ee (FS MTR, 50 MW)	≥ 5.0	140	20	1.25

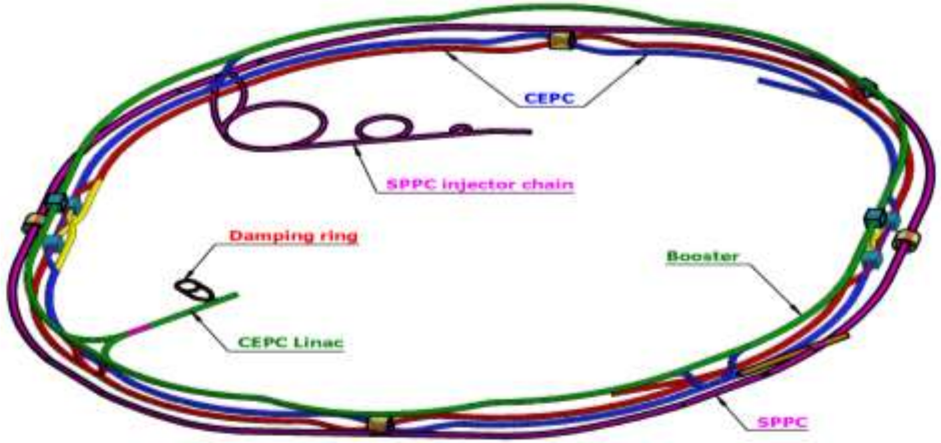
HALHF was proposed in 2023 as a Higgs factory based on plasma accelerator technology

CEPC Higgs Factory and SppC Layout in TDR/EDR

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

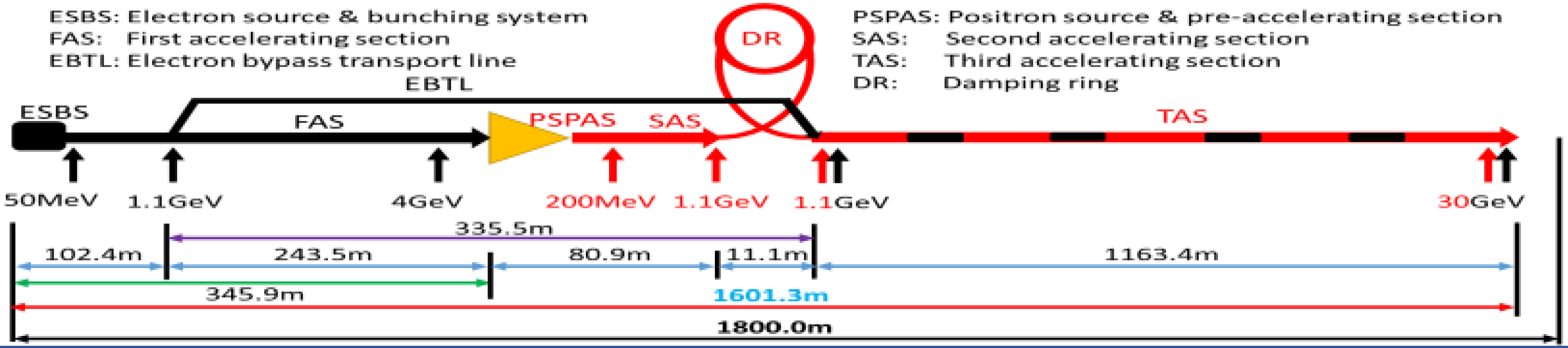


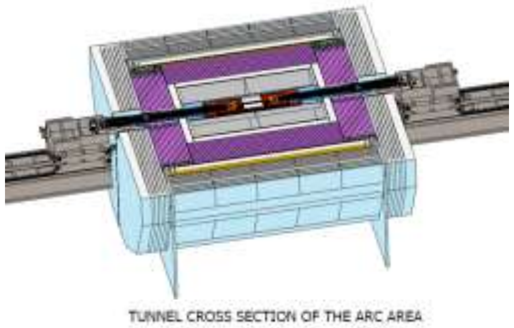
CEPC collider ring (100km)

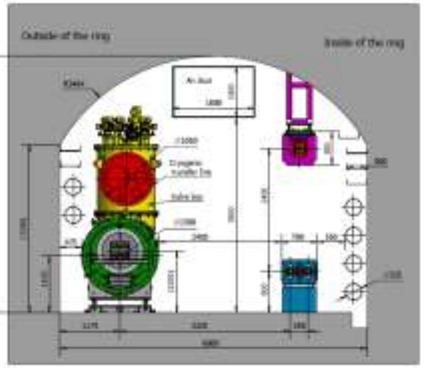


CEPC booster ring (100km)

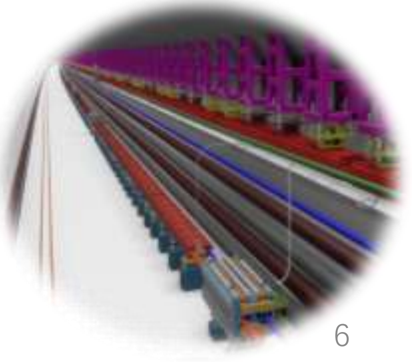
CEPC TDR S+C-band 30GeV linac injector







CEPC/SppC in the same tunnel



CEPC Accelerator System Parameters in TDR/EDR

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

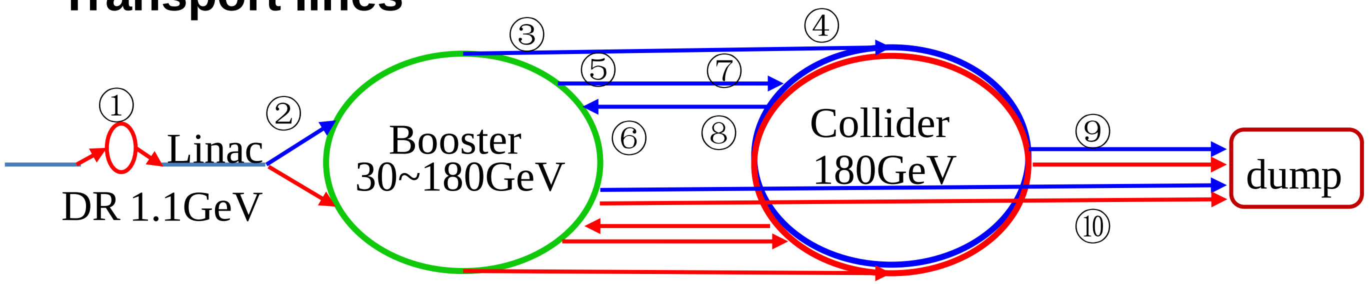
	Higgs	Z	W	$t\bar{t}$
Number of IPs	2			
Circumference (km)	**100.0**			
SR power per beam (MW)	**30**			
Energy (GeV)	**120**	**45.5**	**80**	**180**
Bunch number	268	11934	1297	35
Emittance $\varepsilon_x/\varepsilon_y$ (nm/pm)	0.64/1.3	0.27/1.4	0.87/1.7	1.4/4.7
Beam size at IP σ_x/σ_y (um/nm)	14/36	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**
Luminosity per IP (10^{34} cm^{-2} s^{-1}) From J. Gao's formula below	**5**	**115**	**12**	**0.59**

Running scenarios: Higgs 10 years, Z 2 years, W 1 year, ttbar 5 years

$$\text{Lmax}\,[cm^{-2}\ s^{-1}] = 0.158\times10^{34}\,\frac{(1+r)}{\beta_y[\text{mm}]}\sqrt{\frac{R[m]}{C_\gamma[mGeV^3]N_{IP}}}\left(P_b[\text{MW}]/E[GeV]^2\right)e^{\frac{\sqrt{\Phi_p}}{3.22}}\left(1+0.000505*\Phi_p^2\right)$$

(J. Gao's formula)

Transport lines



CEPC Technical Design Report (TDR) includes:
1) CEPC Accelerator TDR
2) CEPC Detector TDRrd (rd=reference design)
will be completed by June 2025

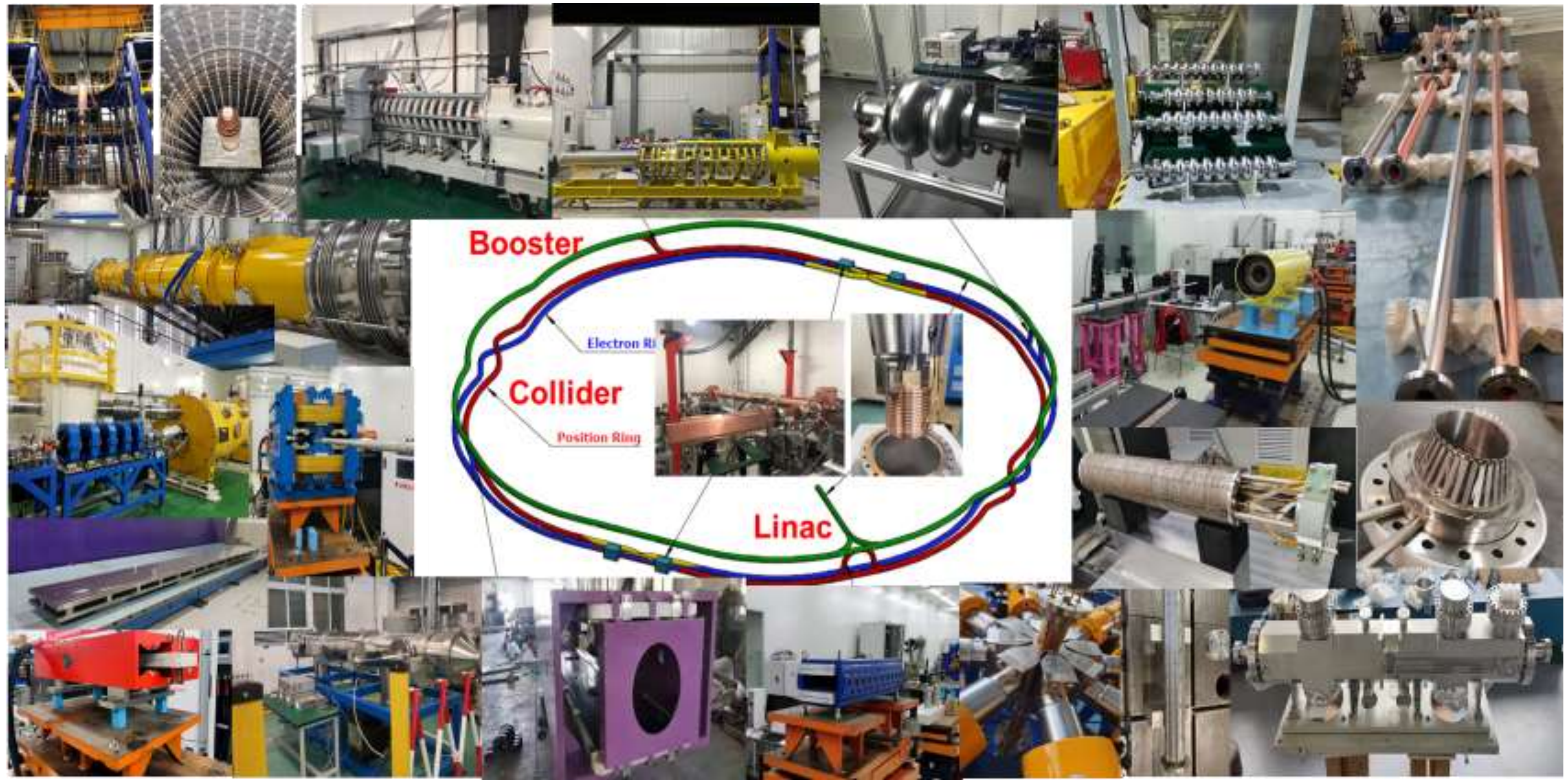
Power Consumption of CEPC @ Higgs

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

Various measures will be studied and implemented towards a green collider, as discussed in the Mini workshop of accelerator, Jan. 18-19, 2024, HKUST-IAS, Hong Kong
https://indico.cern.ch/event/1335278/timetable/?view=standard

CEPC Key Technology R&D Status in TDR

Specification Met ✓ Prototype Manufactured ✓



Accelerator	Fraction
✓ Magnets	27.3%
✓ Vacuum	18.3%
✓ RF power source	9.1%
✓ Mechanics	7.6%
✓ Magnet power supplies	7.0%
✓ SC RF	7.1%
✓ Cryogenics	6.5%
✓ Linac and sources	5.5%
✓ Instrumentation	5.3%
✓ Control	2.4%
✓ Survey and alignment	2.4%
✓ Radiation protection	1.0%
✓ SC magnets	0.4%
✓ Damping ring	0.2%

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

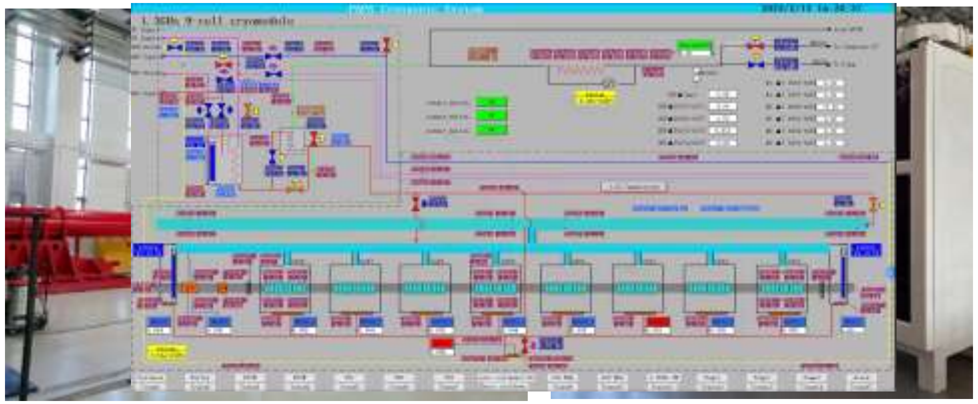
CEPC Booster 1.3 GHz 8 x 9-cell High Q Cryomodule

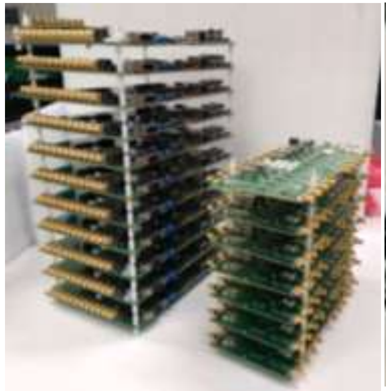
Parameters	SARI/China	CEPC Booster horizontal test results	CEPC Booster Higgs Spec	LCLS-II, SHINE Spec	LCLS-II-HE Spec
Average usable CW E_{acc} (MV/m)	29.1	23.1	21.8 MV/m	16 MV/m	20.8 MV/m
Average Q_0	4×10^{10}	3.4×10^{10}	3.0×10^{10}	2.7×10^{10}	2.7×10^{10}









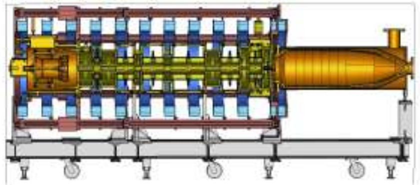



CEPC Accelerator Development: Klystrons

Klystron R&D

Klystron No. 1
Efficiency 65%
(2020)

Klystron No. 2
Efficiency 77%
(2021)



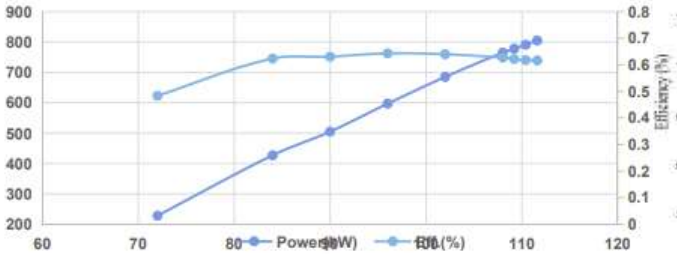
Klystron No. 3 （MBK
Efficiency 80.5%

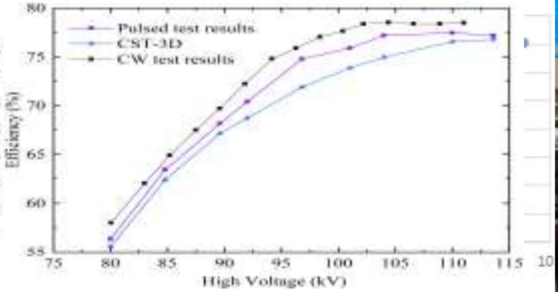
To be completed in 2024

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

78.5%@803kW CW in 2024

High Voltage vs. Power&Efficency

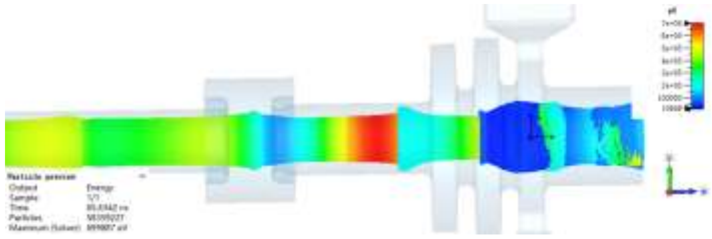


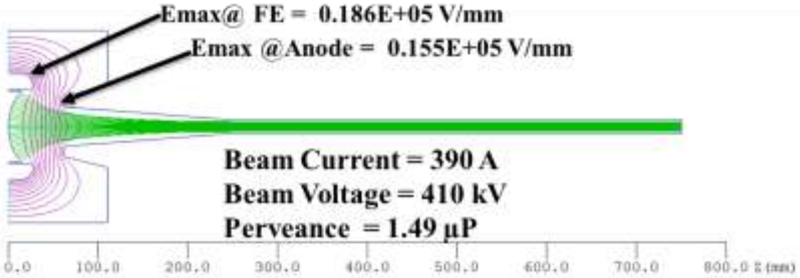


CEPC collider ring 650MHz klystron development in TDR phase

Parameters	Value
Frequency	5720 MHz
Output Power	80MW
Pulsed width	2.5us
Repetition rate	100Hz
Gain	54 dB
Efficiency	47%
$3dB$ bandwith	±5MHz
Beam voltage	420 kV
Beam current	403 A
Focusing field	0.28 T

C band 5720MHz 80MW Klystron





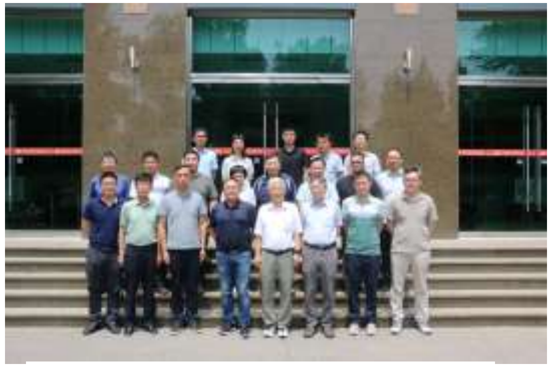
C band 5720MHz 80MW Klystron design completed

Technical assessment has been done on August 12, 2024, start construction Soon, to be completed on 2025

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, Hong Kong

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



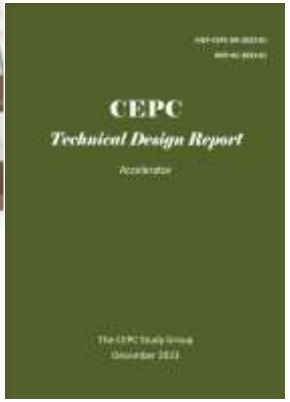
Domestic Civil Engineering
Cost Review, June 26, 2023, IHEP

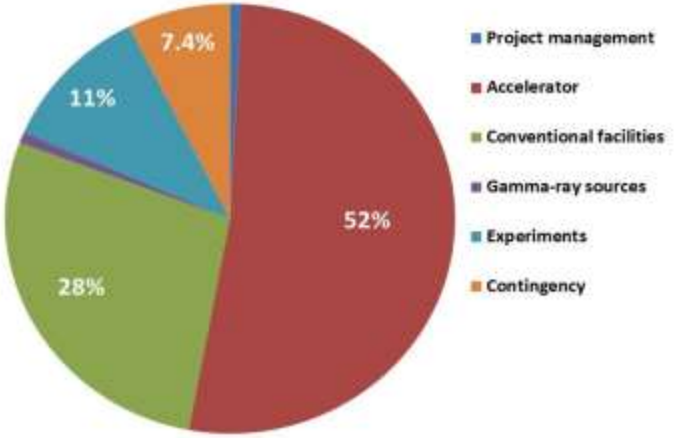
9th CEPC IAC 2023 Meeting
Oct. 30-31, 2023, IHEP

CEPC Accelerator TDR completion was announced during the ICFA Seminar from Nov. 28-Dec.1, 2023, DESY, Hamburg, Germany

Table 12.1.2: CEPC project cost breakdown. (Unit: 100,000,000 yuan)

Total	364	100%
Project management	3	0.8%
Accelerator	190	52%
Conventional facilities	101	28%
Gamma-ray beam lines	3	0.8%
Experiments	40	11%
Contingency (8%)	27	7.4%





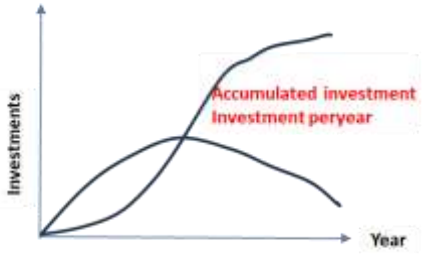
Distribution of CEPC Project total TDR cost of **36.4B RMB (~5.2USD)**

CEPC accelerator TDR has been completed and formally released on December 25, 2023:
http://english.ihep.cas.cn/nw/han/y23/202312/t20231229_654555.html
CEPC accelerator TDR has been published formally in Journal Radiation Detection Technology and Methods (RDTM) on June 3, 2024:
DOI: 10.1007/s41605-024-00463-y
https://doi.org/10.1007/s41605-024-00463-y

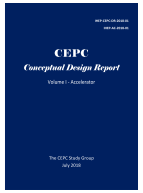
CEPC Milestones, Timeline and Human Resources

Year	2012	2013	2015	2017	2018	2023	2025	2027	2030	2035
Human resources			~50		~100	~200	~300	~500	~2800	~2500

Year	Accelerator human resource	Accumulated accelerator spending Billion RMB
2015	50	-
2018	100	-
2023	200	0.2
2025	300	0.3
2027	500	0.4
2031	2800	9
2035	2500	20



CEPC kickoff meeting in Sept. 2013



Proposal (2025) for CEPC entering 15th five year plan

2025

36.4B RMB
Total construction

CEPC detector reference design
Will be completed by June 2025

CEPC EDR site study and civil engineering design

2012.9	2013.9	2015.3	2017.4	2018.11	2023.12	2024 ~ 2027		~2035
CEPC proposed		Pre-CDR	Progress report	CDR	TDR	EDR	start of construction	Completion

CEPC Engineering Design Report (EDR) Goal

2012.9	2015.3	2018.11	2023.10	2025	2027	15th five year plan
CEPC proposed	Pre-CDR	CDR	TDR	CEPC Proposal CEPC Detector reference design	EDR	Start of construction

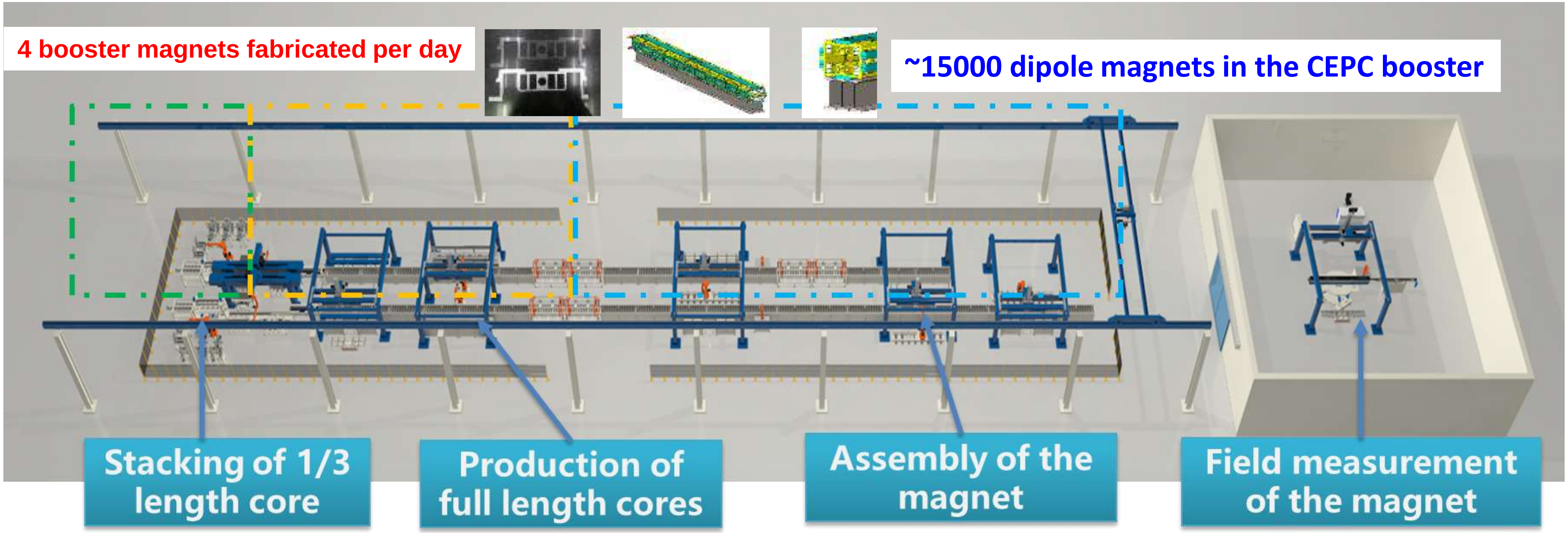
CEPC EDR Phase General Goal: 2024-2027

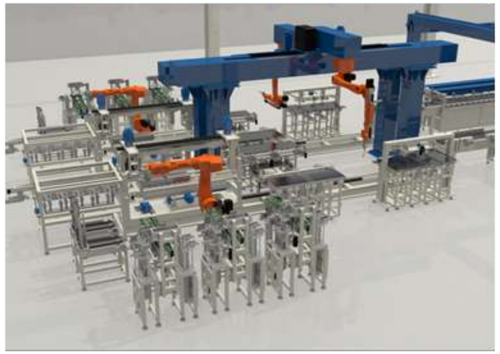
After completion CEPC accelerator TDR in 2023, CEPC accelerator will enter into the Engineering Design Report (EDR) phase (2024-2027), which is also the preparation phase with the aim for CEPC proposal to be presented to and selected by Chinese government around 2025 for the construction start during the "15th five year plan (2026-2030)" (for example, around 2027) and completion around 2035 (the end of the 16th five year plan).

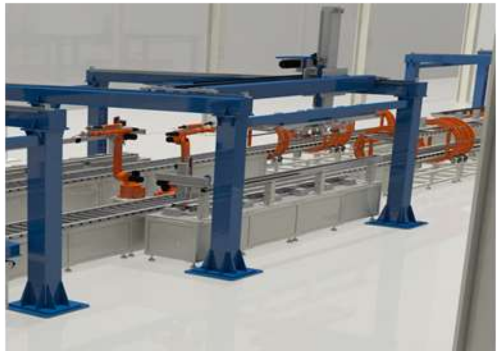
CEPC EDR includes accelerator and detector (TDRrd)
CEPC detector TDR reference design (rd) will be released by June 30, 2025

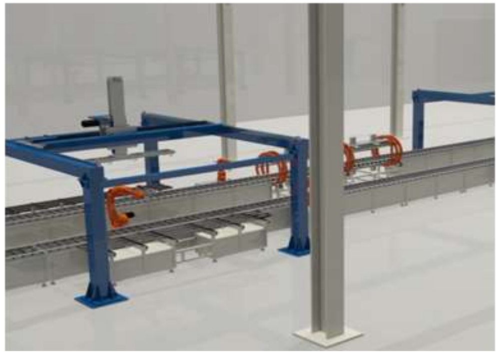
CEPC Accelerator EDR Phase goals, scope and the working plan (preliminary) of 35 WGs summarized in a documents of 33 pages to be reviewed by IARC in Spet. 18-20, 2024

CEPC Magnet Automatic Production Line in EDR



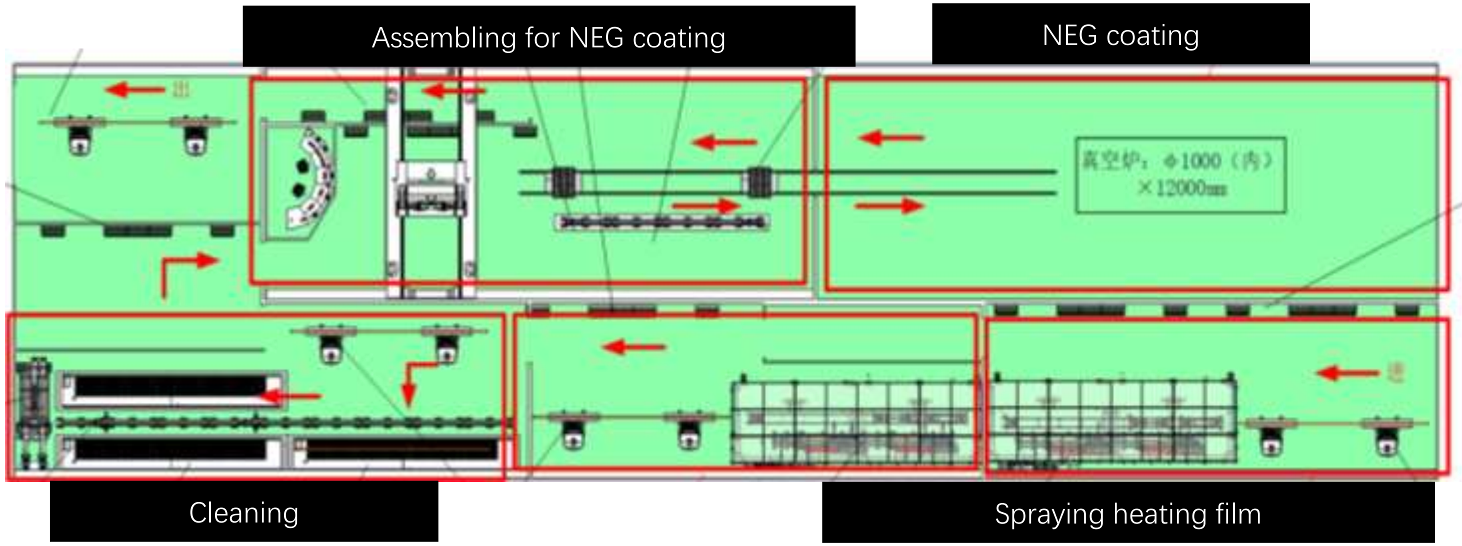




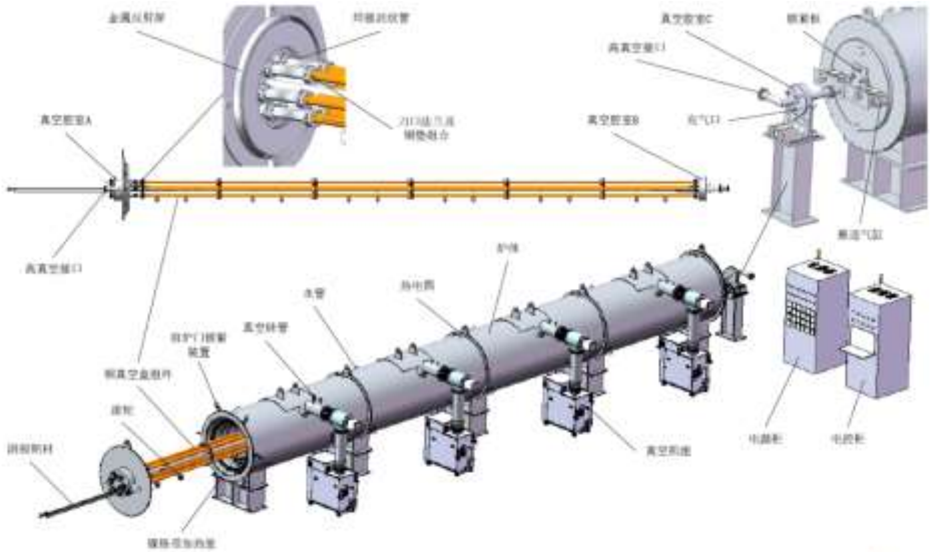


Plan： Technical design review has been done. To be completed in 2025

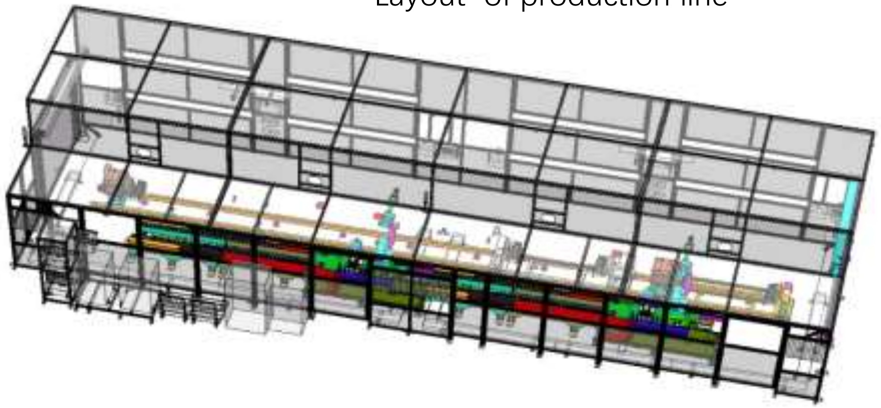
CEPC NEG Coated Vacuum Chamber (200km) Automatic Production Line in EDR



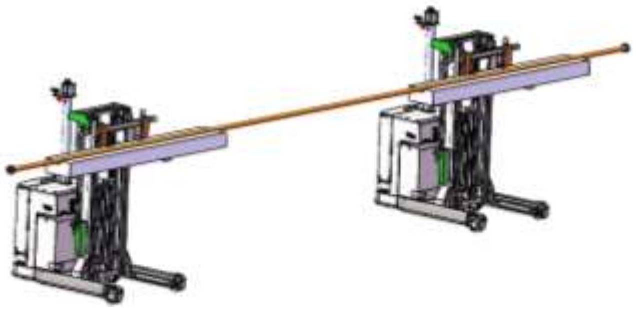
Layout of production line



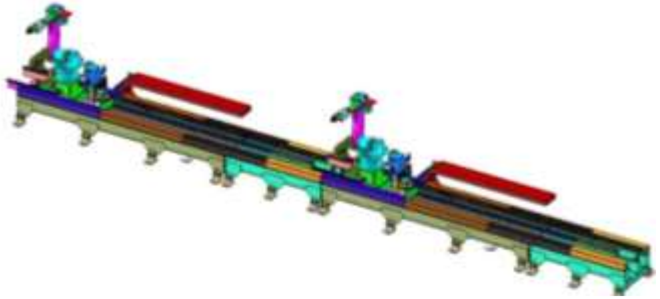
NEG coating facility by horizontal method



Production line of NEG coating, spraying



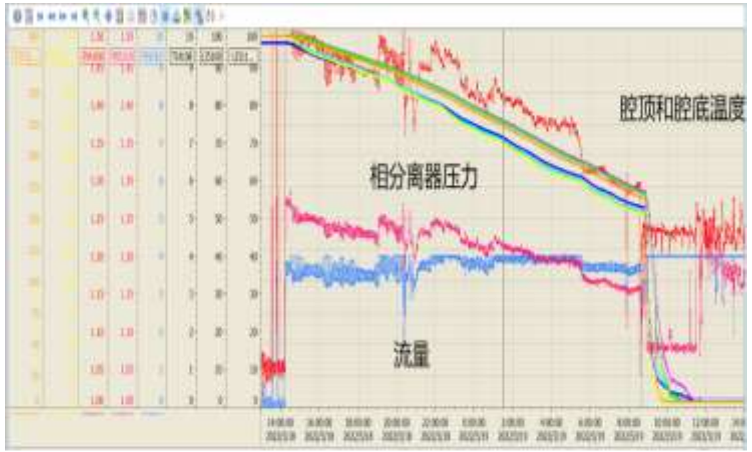
AGV(Automatic Guided Vehicle) transport



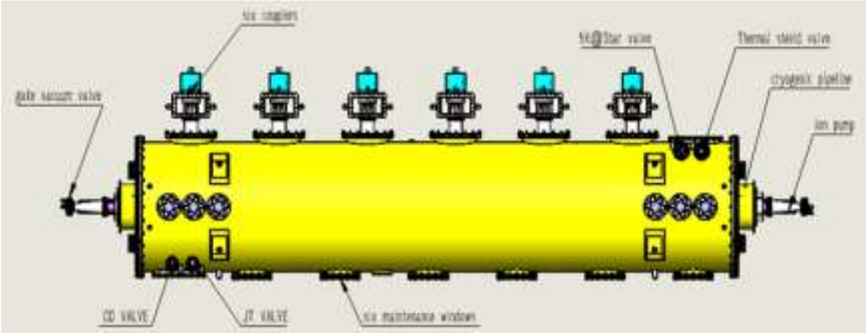
7-axis robot for assembling

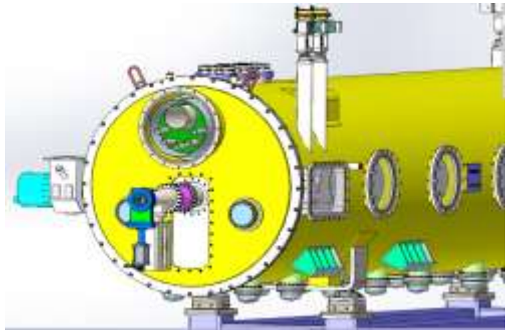
Plan： Technical design review has been done. To be completed in 2025

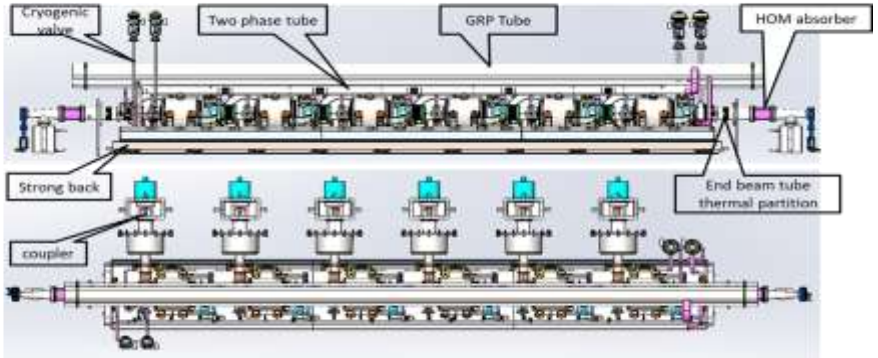
CEPC Accelerator SRF Development in EDR



CEPC collider ring 650MHz 2*cell short test module has been completed in TDR phase



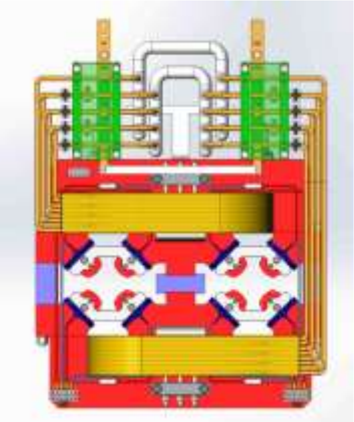


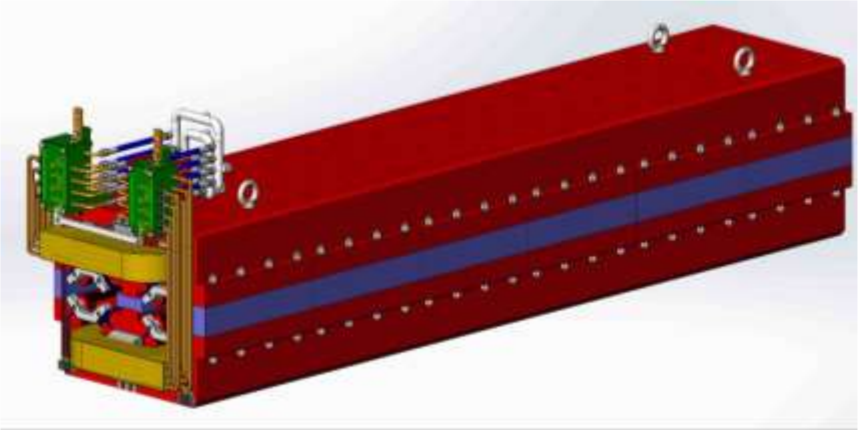


The collider Higgs mode for 30 MW SR power per beam will use 32 units of 11 m-long collider cryomodules will contain six 650 MHz 2-cell cavities, and therefore, a full size 650 MHz cryomodule will be developed in EDR

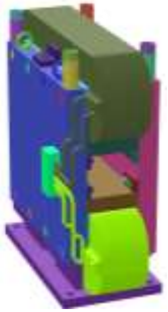
Plan： Technical design review has been done. To be completed in 2025

CEPC Collider Ring Magnets in EDR

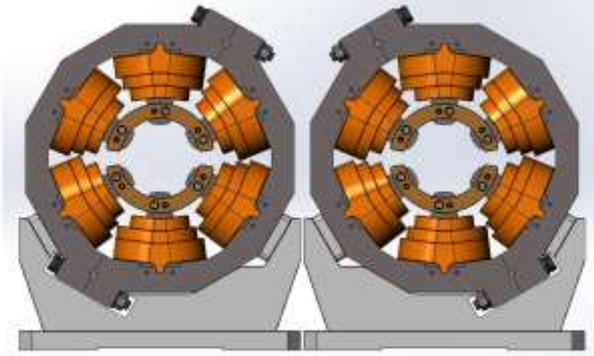


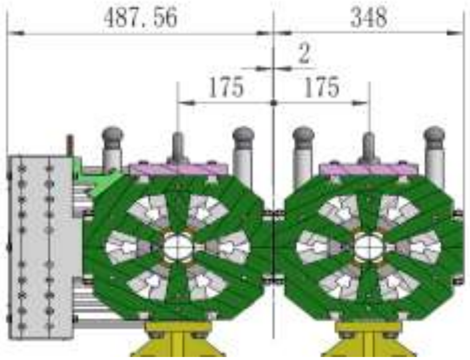


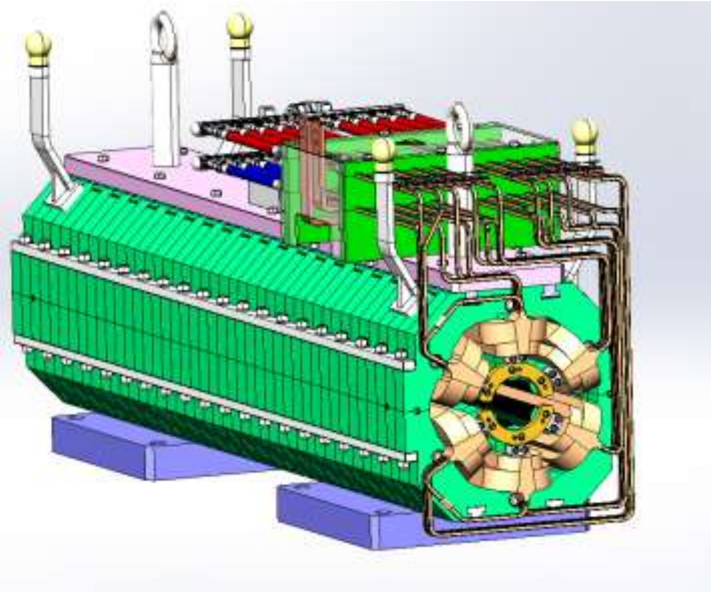
Dual aperture quadrupole: block iron core and new cooling and power line design in EDR



Correctors: mechanical design completed



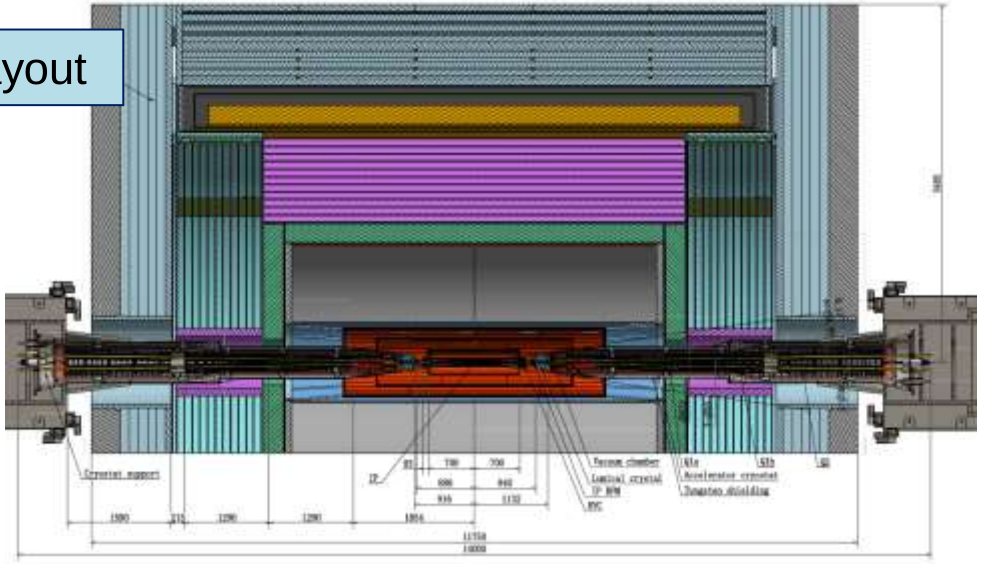




Sextupole magnets under design

CEPC MDI in EDR

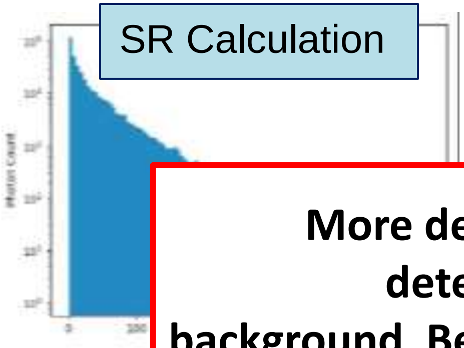
MDI Layout

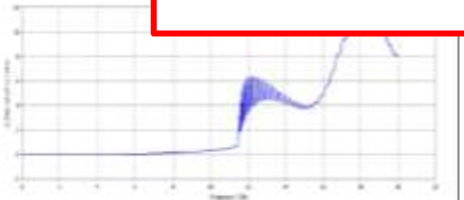


General Parameters

				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					[illegible]								

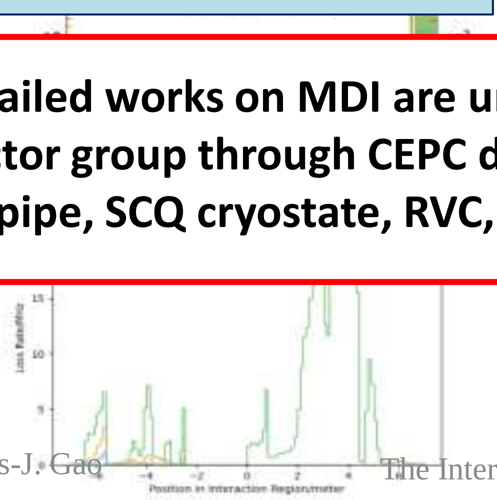
SR Calculation



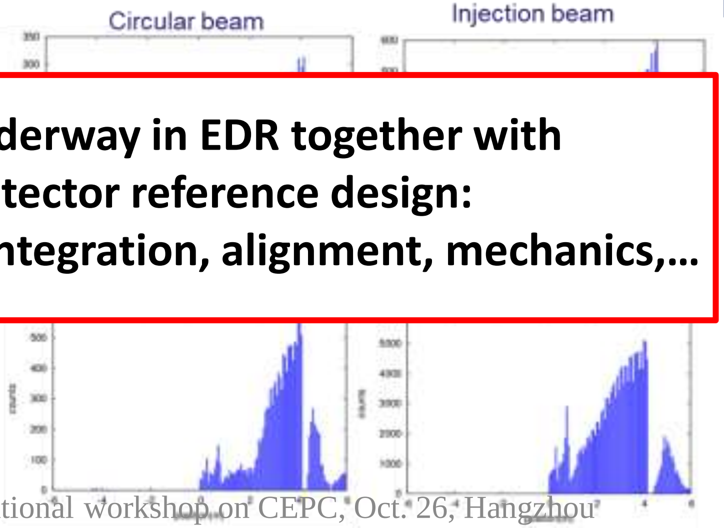


Radiation background

Radiative barbar, Beam-Gas, beam thermal photon scattering

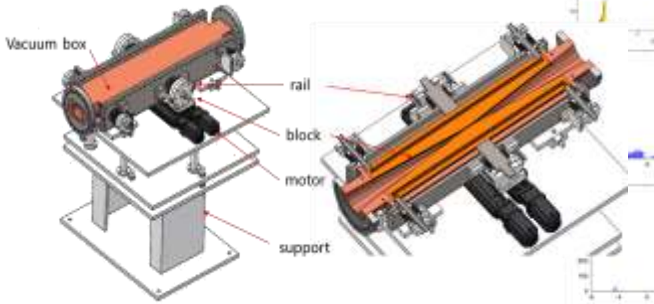


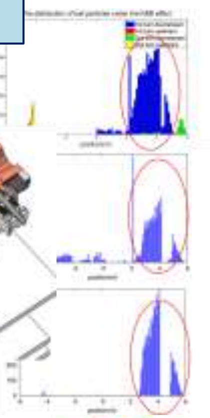
Injection background

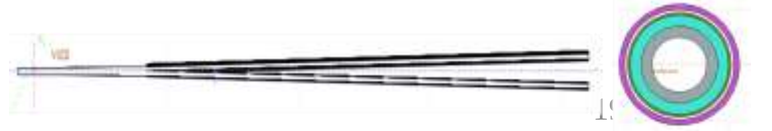


Radiation Mitigation

Masks, collimators, shielding

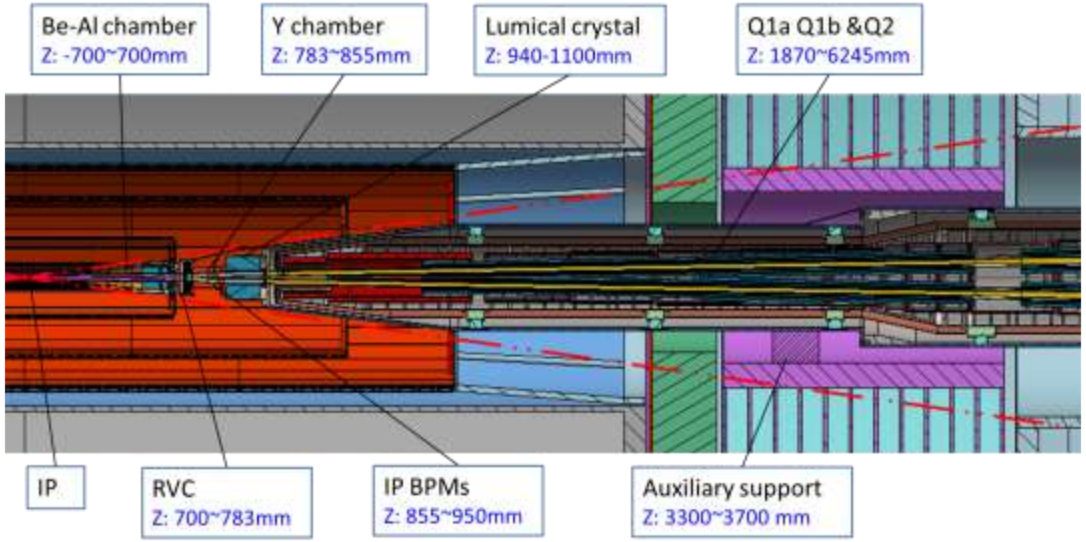






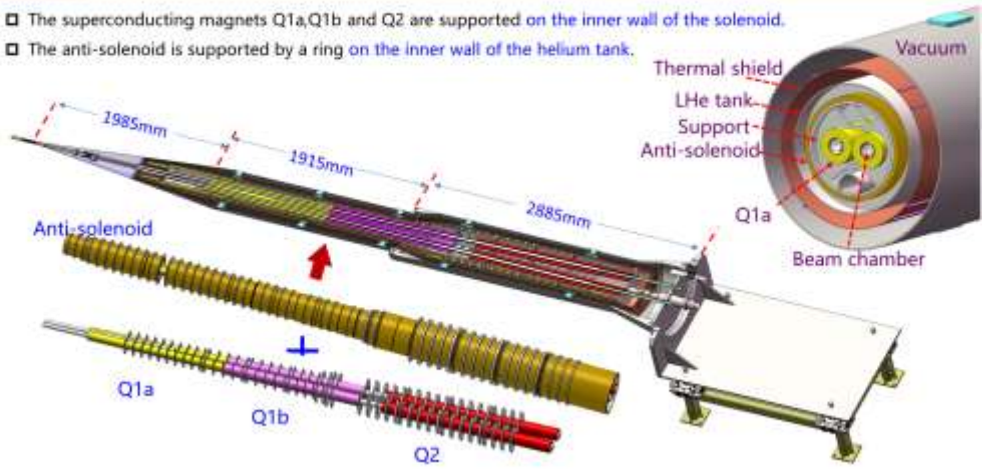
More detailed works on MDI are underway in EDR together with detector group through CEPC detector reference design: background, Be pipe, SCQ cryostate, RVC, integration, alignment, mechanics,…

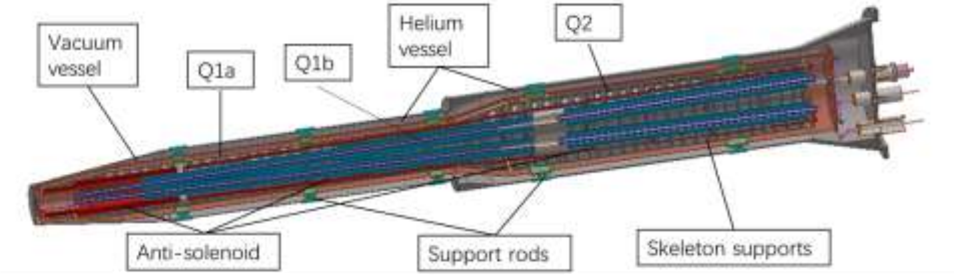
CEPC MDI Development in EDR

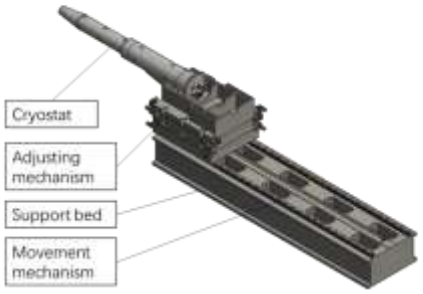


Structural Design of the SC Quadupole Cryostat and Support

- The superconducting magnets Q1a,Q1b and Q2 are supported on the inner wall of the solenoid.
- The anti-solenoid is supported by a ring on the inner wall of the helium tank.







CEPC SC Quadrupole Magnet Design with CCT Coil

Design parameters of Q1a, Q1b, Q2 magnet with CCT coil @ Higgs mode

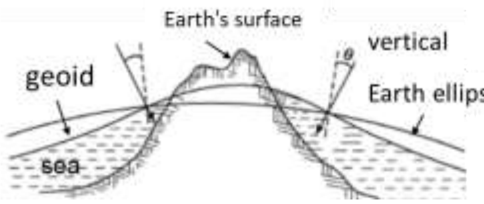
Magnet name	Q1a	Q1b	Q2
Field gradient (T/m)	142.3	85.4	96.7
Magnetic length (mm)	1.21	1.21	1.5
Excitation current (A)	780	650	770
Conductor (HTS or LTS)	0.8 or 0.7mm in diameter		
Maximum dipole field in aperture (Gs)	226	124	127
Stored energy (KJ)	16.7	15.2	22.9
Peak field in coil (T)	4.3	3.4	4.5
Integrated field harmonics	$<2\times10^{-4}$		
(Single aperture) Coil inner radius (mm)	20	26	31
(Single aperture) Coil outer diameter (mm)	30.5	39	44
Magnet mechanical length (m)	1.22	1.23	1.53
Net weight (kg)	25	32	43
Total weight of Q1a, Q1b, Q2 (kg)	100		
(For comparison, old net weight with iron option (kg))	Q1a: 93, Q1b:124, Q2: 235 Total weight of Q1a, Q1b, Q2: 452		

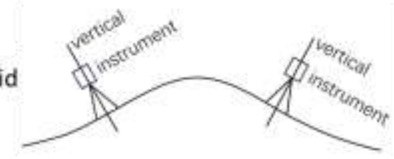
CEPC Alignment and Installation Plan in EDR

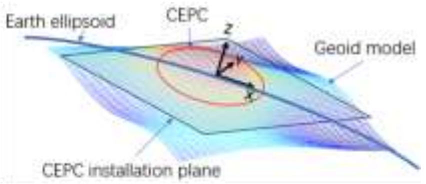
- Alignment accuracy requirement

Component	Δx (mm)	Δy (mm)	$\Delta\theta_z$ (mrad)
Dipole	0.10	0.10	0.10
Arc Quadrupole	0.10	0.10	0.10
IR Quadrupole	0.10	0.10	0.10
Sextupole	0.10*	0.10*	0.10

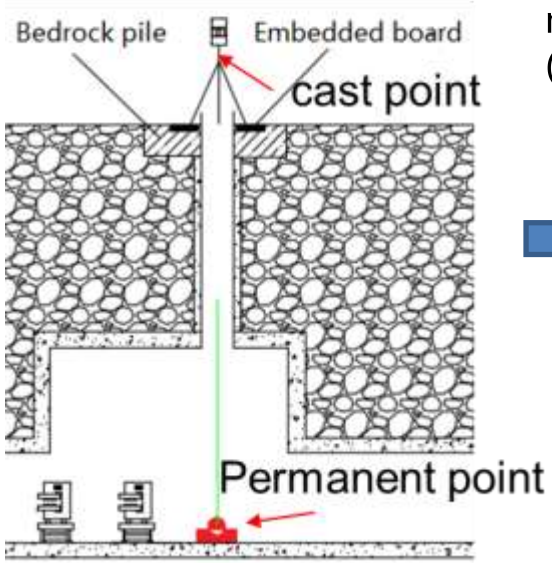
*implement beam-based alignment



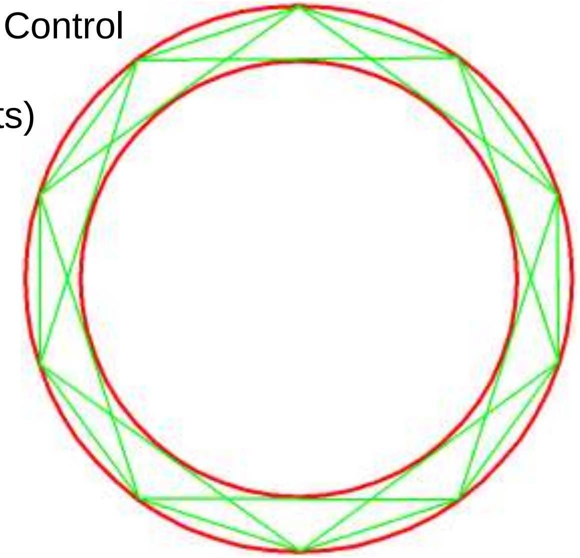




GPS receiver

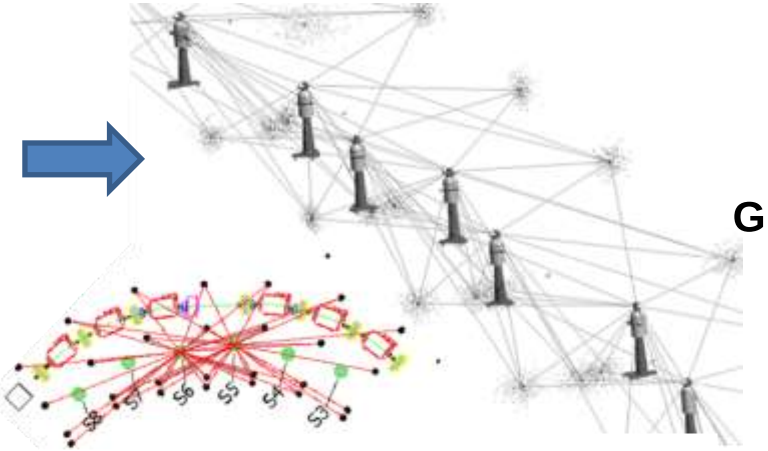


Surface Control network (14Points)



Backbone Control network
(short line:300m; long line 600m)

Component Pre-alignment

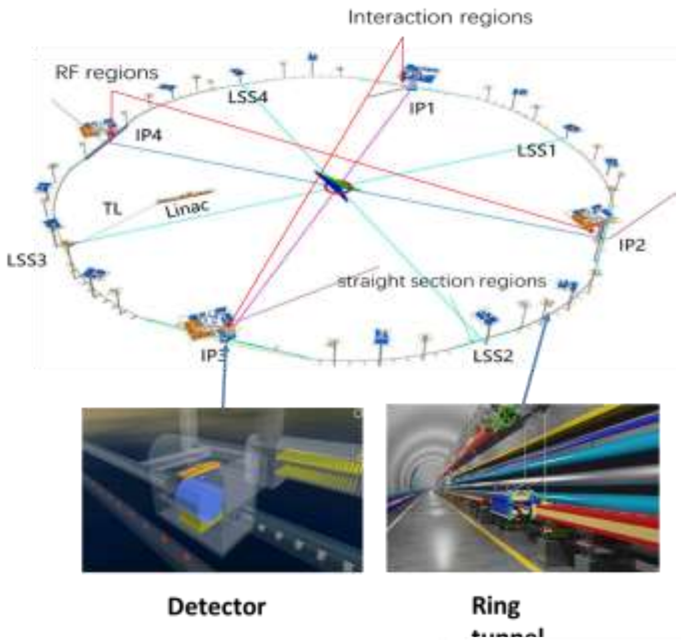


Tunnel Control network
(interval of 6 meters)

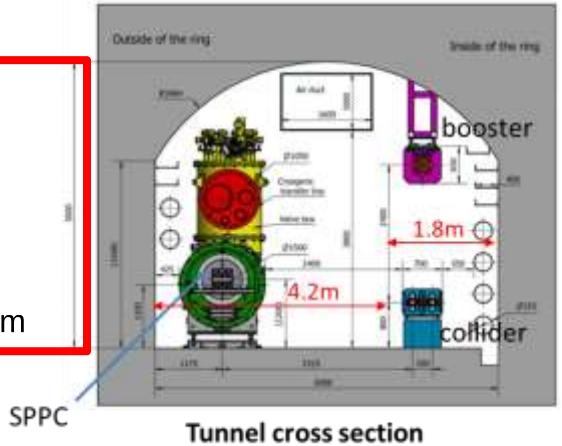
Wall Control Point

Ground Control Point

CEPC Installation Strategy Study in EDR



Linac: 1.6km
TL:1.5km
Circumference of ring tunnel:100km
Collider：100km
Booster：100km
Tunnel cross section：6X5m

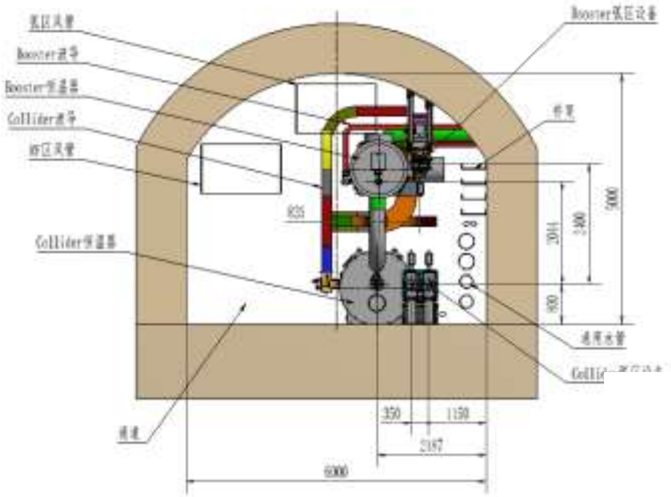


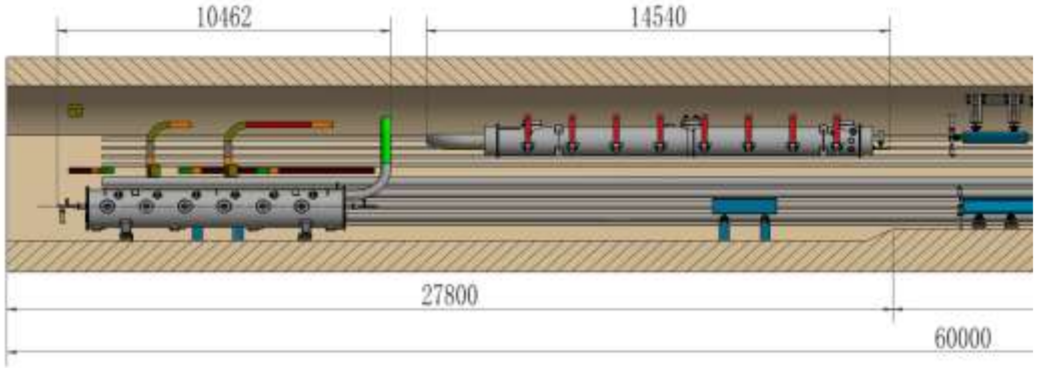
Tunnel cross section

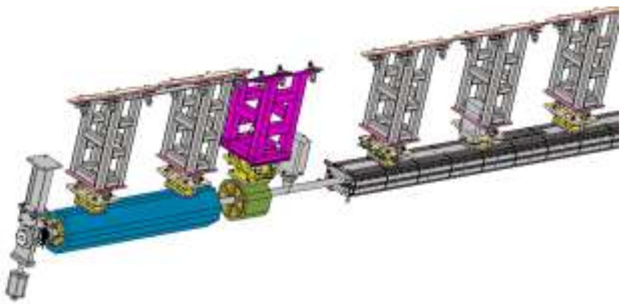
CEPC component list and quantities

Component	Collider Ring	Booster	Linac, DR, TL	Total
Dipole	16258	14866	135	31259
Quadrupole	4148	3458	714	8320
Sextupole	3176	100	72	3348
Corrector	7088	2436	275	9799
BPM 、 PR 、 DCCT 、 kicker	3544	2408	180	6132
Septum Magnet	68	32	2	102
Kicker	8	8	2	18
Cryomodule	32	12		44
Electrostatic separator	32			32
Collimator dump	36		8	44
Superconducting Magnets	4			4
Solenoid			37	37
Accelerating structure			577	577
Cavity			4	4
Electron Source			1	1
Positron Source			1	1
Detector	2			2
Total	34396	23320	2008	59724

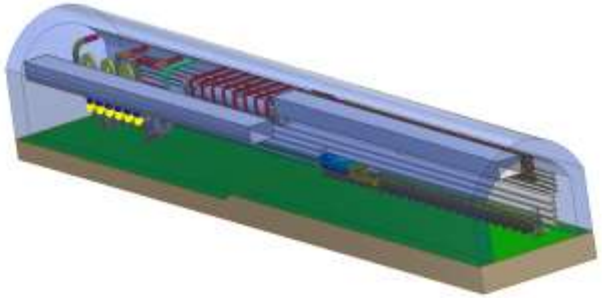
CEPC Tunnel Mockup for Installation in EDR

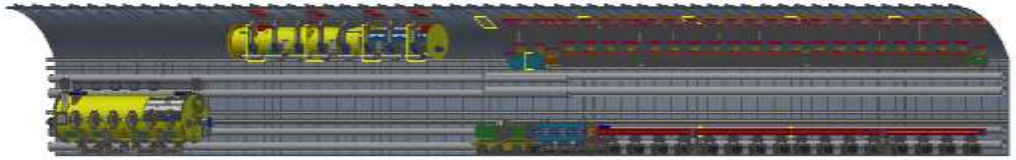


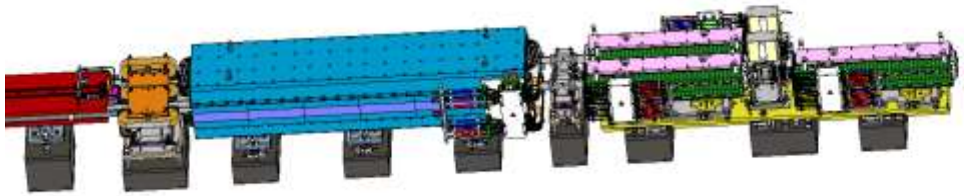


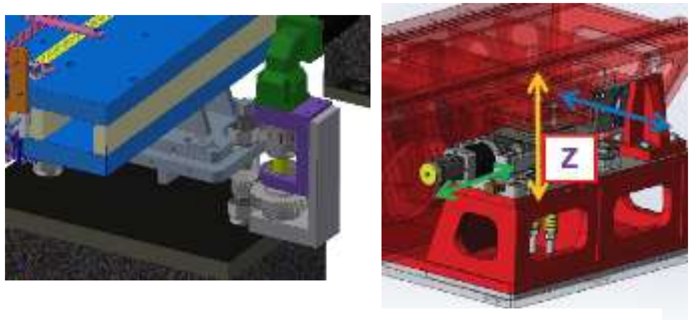


Booster magnets installation









Collider ring magnets supports

A 60 m long tunnel mockup, including parts of arc section and part of RF section

To demonstrate the inside tunnel alignment and installation, especially for booster installation on the roof of the tunnel

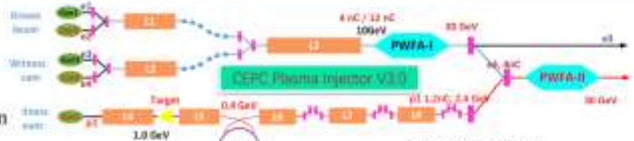
Plan： Technical design review has been done. To be completed in 2025

Advanced Technologies Development in Progress

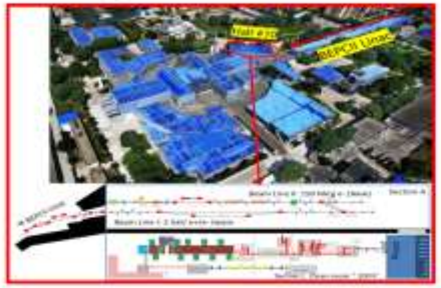
CEPC Plasma Injector (alternative option) and TF Plan

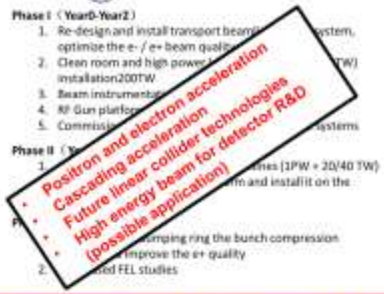
CEPC plasma injector scheme:
From 10 GeV → 30 GeV → TR ≥ 2

Simulation results show that it works on paper with reasonable error tolerances for both electron and positron beams injected to the booster



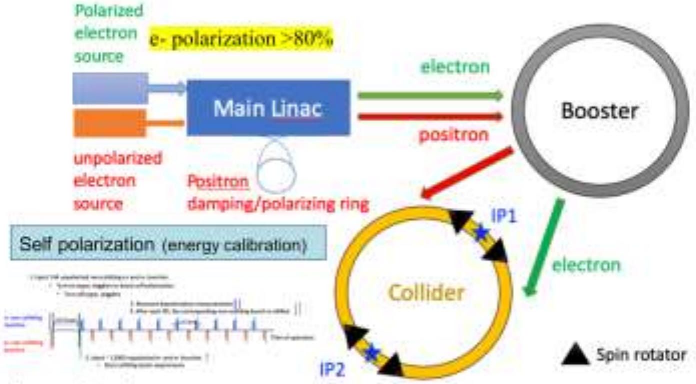
CEPC IARC, 2022.06

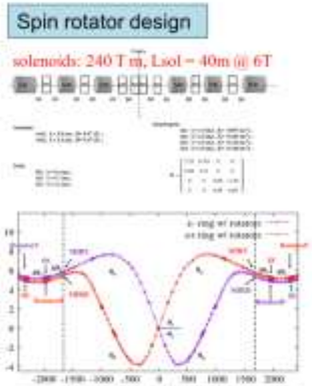




PWFA/LWFA TF based on BEPC-II Linac and HPL has been founded by CAS 90M RMB in Sept. 2023
Under development in the experimental hall #10 of BEPC-II

CEPC Polarized Beam Studies(alternative option)





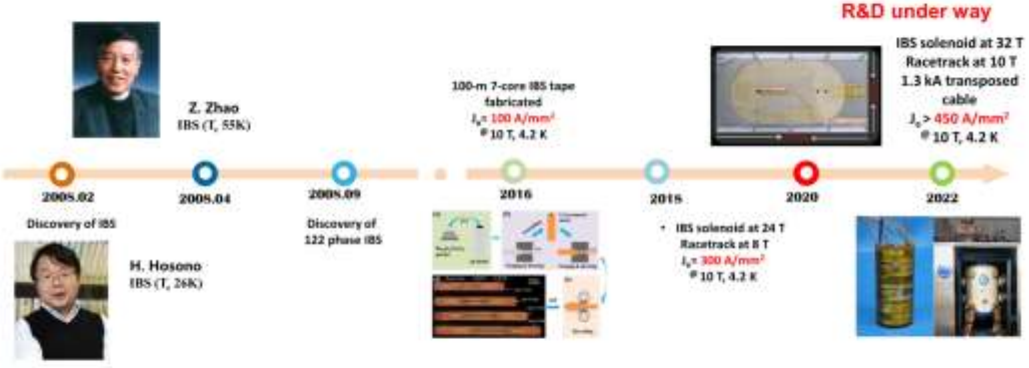
Key issues of study:

- 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

Key technology development for polarized electron beam generation, measurement and manipulation have been started

IBS Technology for High Field Magnets

R&D under way

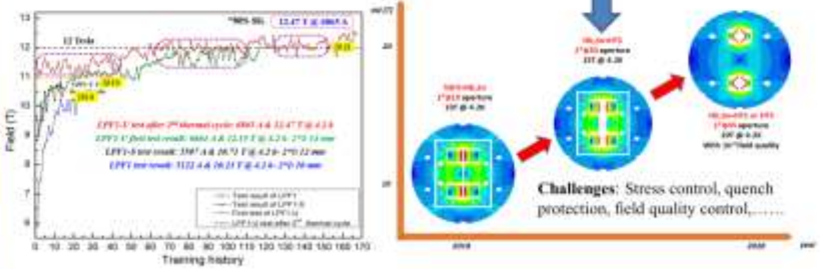


J_e of IBS expected to be similar as ReBCO in 2020s with better mechanical properties and lower cost，ready for mass applications in ultra high field magnets

SppC HF Magnet Development

SppC 16 T Model Dipole: Nb_3Sn 12~13 T + HTS 3~4 T;
14T has been reached, more test in 2024

Picture of LPF1-U



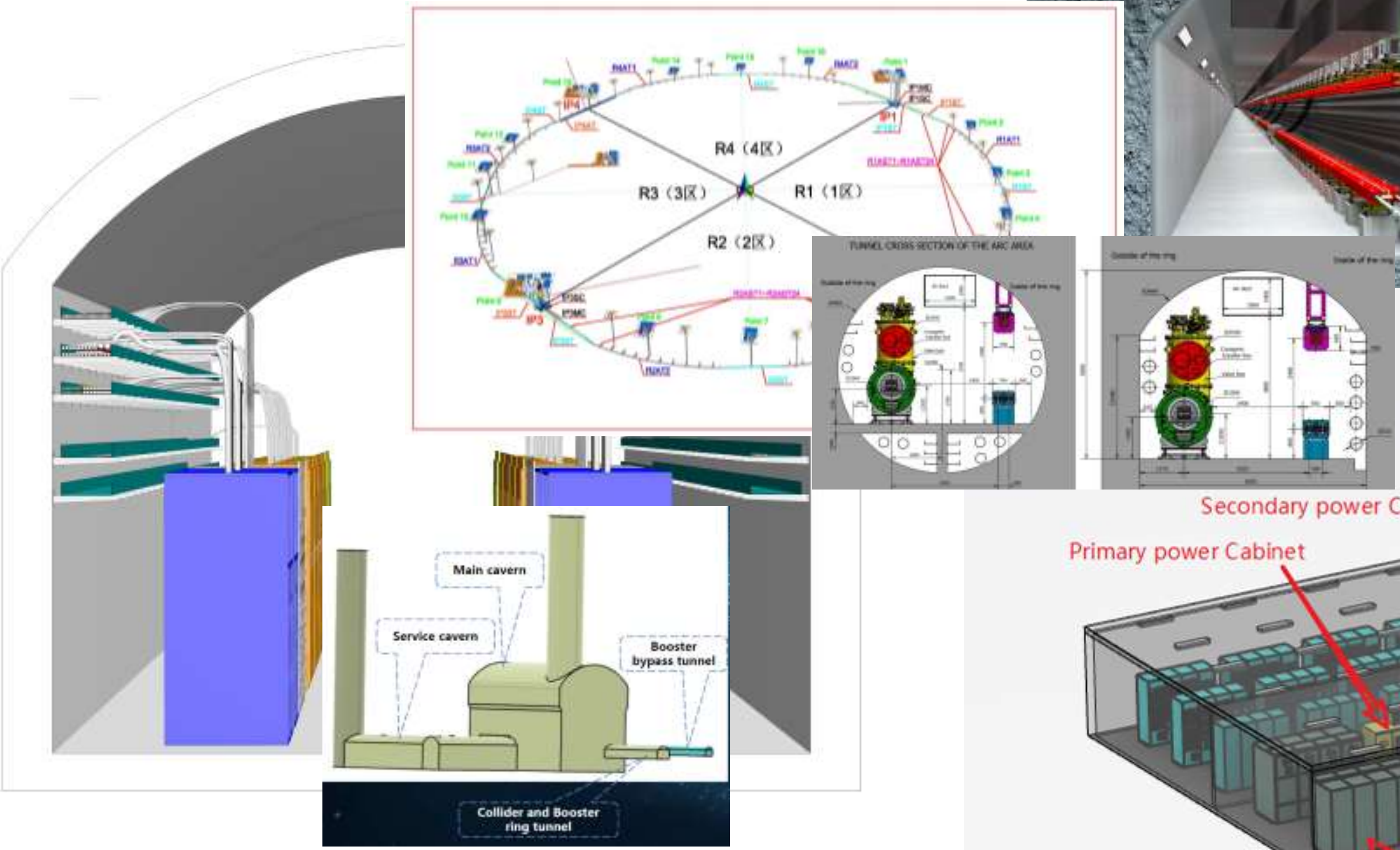
Challenges: Stress control, quench protection, field quality control,……

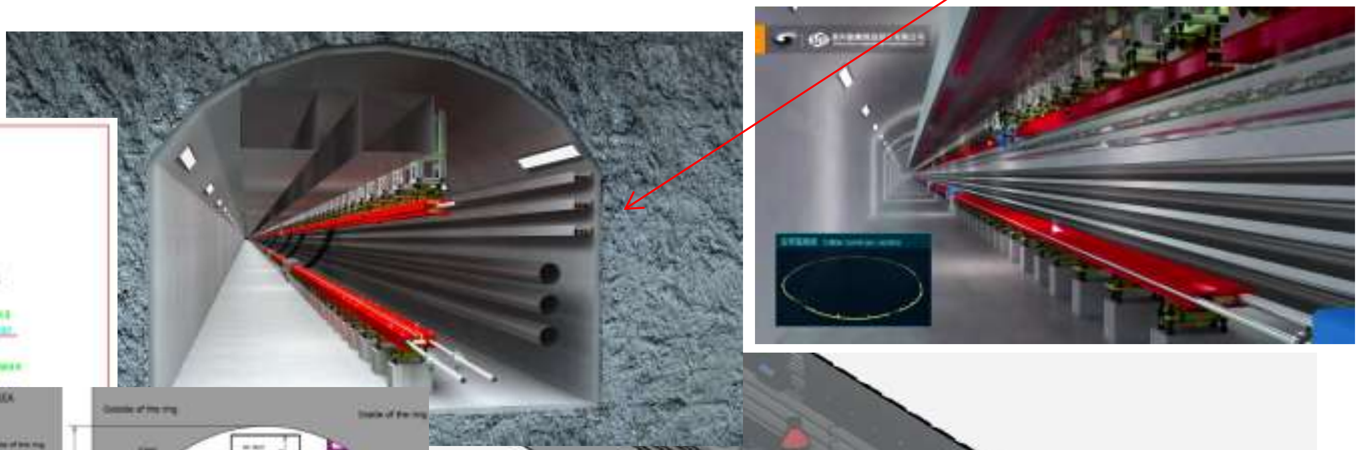
Dual aperture superconducting dipoles achieve 12T@4.2 K and 14T@4.2K entirely fabricated in China. The next step is reaching 16-20T

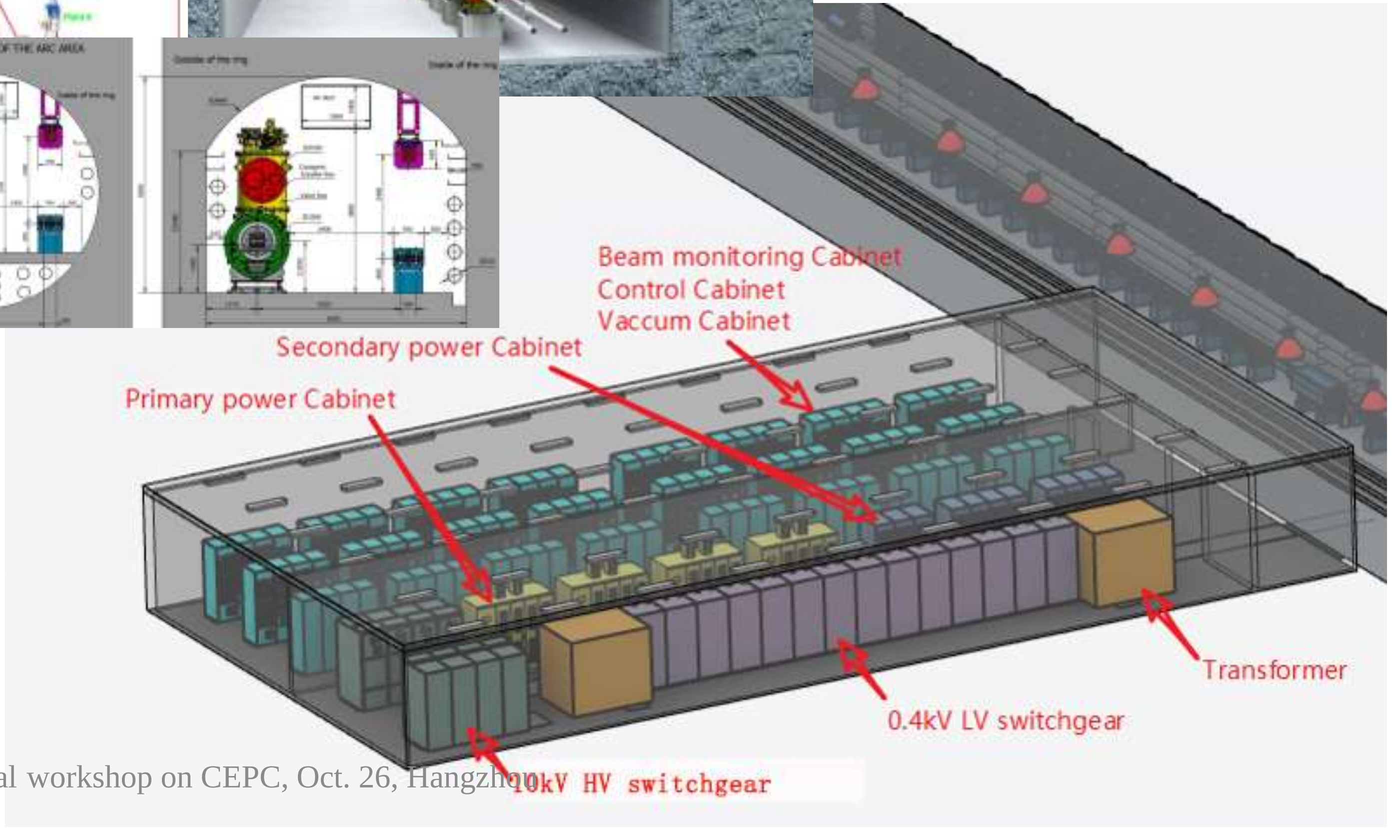
CEPC Conventional Facility and Civil Engineering in EDR

Cables installed!

Electrical Equipment General Layout in Auxiliary Tunnel/500m along 100km







CEPC Site Implementation and Construction Plans

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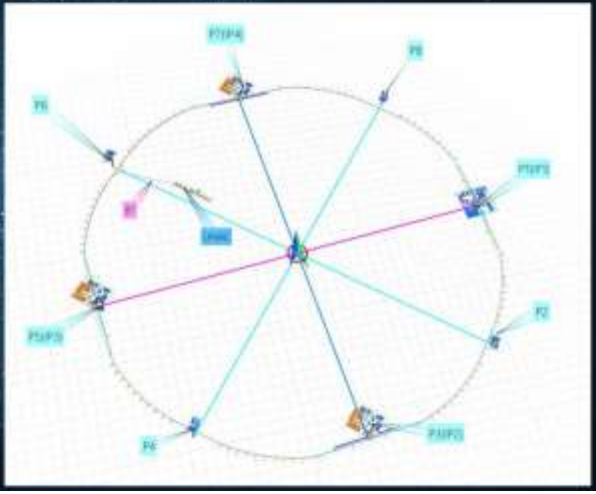
Yellow River Engineering Consulting Co., Ltd.

Layout of the Surface Structures



The surface structures are located close to shafts. These buildings house water cooling facilities, low-temperature facilities, ventilation systems, air compression systems, substations, etc.

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Layout of the Surface Structures

Area of surface structures （m²）

Surface Structure	P1（IP1）	P2	P3(IP2)	P4	P5（IP3）	P6	P7(IP4)	P8	LINAC	BT	Total	TDR	EDR-TDR
Control and duty rooms	1200	300	300	300	1200	300	300	300	400		4600	4600	0
Magnet powers source	100	100	100	100	100	100	100	100	200	200	1200	13900	-12700
High-frequency power source			6000				6000		9800		21800	16400	5400
110kV substation	2000		3000		2000		3000				10000	14000	-4000
10kV substation	1000	800	1000	800	1000	800	1000	800	600		7800	11200	-3400
HVAC system	1200	1000	1200	1000	1200	1000	1200	1000	1500	300	10600	14500	-3900
Cryogenic system（helium compression system）	2500		6000		2500		6000				17000	10000	7000
Cooling water system	3000	2500	3000	2500	3000	2500	3000	2500	1500	300	23800	29800	-6000
Experimental assembly and storage hall	1500	1000	1000	1000	1500	1000	1000	1000	500		9500	6000	3500
Transfer system	500	300	400	300	500	300	400	300	200	150	3350	3550	-200
Air compression system	300	300	300	300	300	300	300	300	300		2700	1350	1350
Electronic room	1000	300	300	300	1000	300	300	300	200	100	4100	6150	-2050
Data Center	600				600						1200	0	1200
Miscellaneous	500	500	500	500	500	500	500	500	300	100	4400	9000	-4600
Total	15400	7100	23100	7100	15400	7100	23100	7100	15500	1150	122050	140450	-18400

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General Layout Plan of IP1/IP3

Surface Structure	IP1/IP3 (m²)
Control and duty rooms	1200
Magnet powers source	100
High-frequency power source	
110kV substation	2000
10kV substation	1000
HVAC system	1200
Cryogenic system （helium compression system）	2500
Cooling water system	3000
Experimental assembly and storage hall	1500
Transfer system	500
Air compression system	300
Electronic room	1000
Data Center	600
Miscellaneous	500
Total	15400

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General Layout Plan of IP2/IP4

Surface Structure	IP2/IP4 (m²)
Control and duty rooms	300
Magnet powers source	100
High-frequency power source	6000
110kV substation	3000
10kV substation	1000
HVAC system	1200
Cryogenic system （helium compression system）	6000
Cooling water system	3000
Experimental assembly and storage hall	1000
Transfer system	400
Air compression system	300
Electronic room	300
Data Center	
Miscellaneous	500
Total	23100

CEPC Site Implementation and Construction Plans

CEPC site implementation plan in EDR

The EDR site selection and the site dependent civil engineering design works has been started.

CEPC construction plan

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 Promotion Consortium (CIPC, established in Nov. 2017)

Potential international collaborating suppliers worldwide

CIPC Parallel Sessions

There are 19 CIPC talks covering a wide spectrum of CEPC-SppC related accelerator technologies and industrial production capabilities in China

Nov. 23, 2024, Room 289

Nov. 24, 2024, Room 289

https://indico.ihep.ac.cn/event/22089/sessions/14178/#20241023

International Industrial Connection Sessions

Nov. 25, 2024, Room 289 **There are 12 international industrial talks covering a wide spectrum on detector technologies**

11:00	CAEN on Detector High Voltage	*Room 289*		11:00 - 11:15
	Design and Development of Thin-Walled Vacuum Chambers and High-Pressure Chambers for Applications in Physics Experiments (应用于物理实验的薄壁真空室和高气压室设计研制)	*Room 289*	*Yuntao Shen*	11:15 - 11:30
	SiPM readout ASIC from Microparity	*Room 289*	*Mr Wei Shen*	11:30 - 11:45
	Imdetek on Advanced Detector Material	*Room 289*		11:45 - 12:00
12:00	High Energy Physics and Medical Imaging (United-Imaging)	*Room 289*	*Mr Pengwei Xi*	12:00 - 12:15
	NCAP on Advanced Packaging Technology	*Room 289*		12:15 - 12:30

14:00	New Generation Software-defined Modular Instrument Platform	*Room 289*	*Likun Xie*	14:00 - 14:1
	Intelligent special power supply service provider from Fullde Electronics	*Room 289*	*Ms Qiuping Li*	14:15 - 14:3
	talk12 - TBD	*Room 289*		14:30 - 14:4
	Keysight for High-end Instruments for Precision Measurement	*Room 289*		14:45 - 15:00
15:00	NAT Europe on MicroTCA Crates & Standard (TBD)	*Room 289*		15:00 - 15:15
	SAMTEC on Advanced Interconnections & Sockets (TBD)	*Room 289*		15:15 - 15:30

https://indico.ihep.ac.cn/event/22089/sessions/14187/#20241025

CEPC Industrial Preparation

Large-scale Cryogenic Refrigeration & Liquefaction Equipment 中科富海 (CIPC member)

First 18kW@4.5K helium refrigerator fabricated in in China passes inspection

-It was developed by the Institute of TIPC,CAS, and integrated and manufactured by Fullcryo.

-The super large horizontal cold box with a length of 28m and a diameter of 4.2m achieves ultra-high vacuum and extremely low leakage.

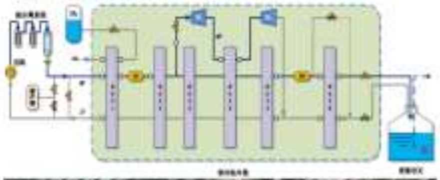
-The horizontal cold box at megawatt-level is the largest of its kind in China and even in the world.

-The horizontal cold box system has exceeded the set targets.

-On-site testing: 1. The airtightness test of each internal channel revealed a pressure drop of 0, surpassing the target value of 0.02 bar. 2. The overall leakage rate is 9.1×10^{-10} Pa.m³/s, surpassing the target value of 1×10^{-7} Pa.m³/s.

-Expected Goals: Achieving 3 operational mode adjustments: the cooling capacity ≥ 18kW@4.5K; the cooling capacity in the superfluid helium temperature range ≥4kW@2K.

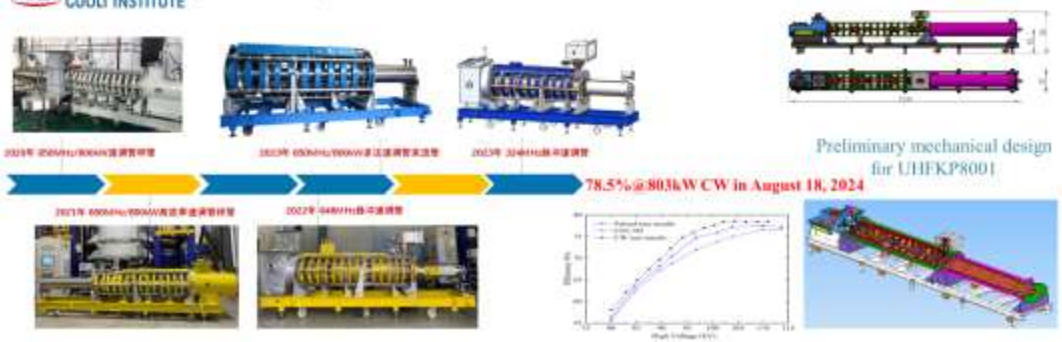
中科富海 FULLCRYO



北京中科富海低温科技有限公司
Beijing Sinoscience Fullcryo Technology CO., Ltd. (CIPC member)

CEPC 650MHz 800kW CW High Efficiency Klystrons

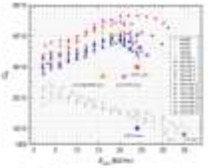
国力研究院 GUOLI INSTITUTE (CIPC member)



Kunshan National Research Institute has successively developed **650MHz/800KW klystron sample tubes, 650MHz/800KW high-efficiency klystron sample tubes, 648MHz pulse klystron tubes, 650MHz/800KW multi-injection klystron beam tubes**, and the latest 324MHz pulse klystron tubes Electro vacuum products for 50 years. Provide high power thyristor of GL1536A in batches for BEPCII in 2012.

HE-RACING Technology and OTIC on SRF Technologies (CIPC members)

高能锐新 (CIPC member)



1.3GHz cryomodule assembly

东方钽业 OTIC (CIPC member)

2011 DESY - XFEL
RRR300 Nb: 8 tons, 30% of the project
2012 Michigan State University - FRIB
RRR250 Nb: 8.5 tons, 70% of the project
2014 Fermilab - LCLS II
RRR300 Nb: 5 tons, 50% of the project
2017 INFN and STFC - ESS
RRR300 Nb: 12.5 tons, 100% of the project
2019 IBS - RISP, CERN - HL-LHC, Fermilab - PIP-II, Shanghai - SHINE
RRR300 niobium material procurement in progress

High RRR Nb sheet

High RRR Nb ingod

High RRR large grain Nb

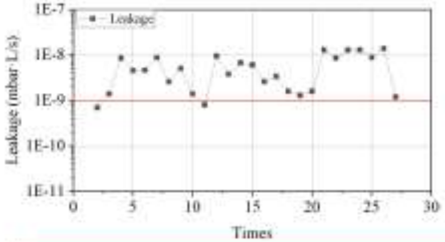
CEPC booster and colliders: 2GeV 1.3GHz and 650MHz SRF accelerators (Higgs); 10GeV 1.3GHz and 650MHz SRF accelerators (ttar)

We had built the business relationship with many great customers such as DESY, MSU, Fermilab, JLAB, INFN, STFC, CERN, TRIUMF, RI, ZANON, IHEP, IBS, RRCAT etc.

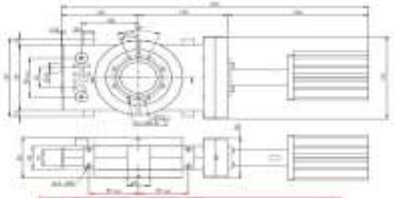
RF Shielding all Metal Gate Vacuum Valve

日揚科技 HTC

- Two prototypes of RF shielding All metal gate valve have been developed, and the leakage of one of them have been tested.
- The delivery inspection leakage test results for two valves, conducted by the manufacturer, were found to be < 1×10^{9} mbar ·L/s (30 times open and closed).
- The difference of leakage by IHEP & manufacture will be checked and retested in next.



- Tested by IHEP
- Expectation leakage < 1×10^{-9} mbar ·L/s



CEPC needs ~1700 all metal valves

CEPC in Synergy with other Accelerator Projects in China

Project name	Machine type	Location	Cost (B RMB）	Completion time
CEPC	Higgs factory Upto ttar energy	Led by IHEP, China	**36.4 (where accelerator 19)**	Around 2035 (starting time around 2027)
BEPCII-U	e+e-collider 2.8GeV/beam	IHEP (Beijing)	**0.15**	2025
HEPS	4th generation light source of 6GeV	IHEP (Huanrou)	**5**	2025
SAPS	4th generation light source of 3.5GeV	IHEP (Dongguan)	**3**	2031 (in R&D, to be approved)
HALF	4th generation light source of 2.2GeV	USTC (Hefei)	**2.8**	2028
SHINE	Hard XFEL of 8GeV	Shanghai-Tech Univ., SARI and SIOM of CAS (Shanghai)	**10**	2027
S3XFEL	S3XFEL of 2.5GeV	Shenzhen IASF	**11.4**	2031
DALS	FEL of 1GeV	Dalian DICP	**-**	(in R&D, to be approved,)
HIAF	High Intensity heavy ion Accelerator Facility	IMP, Huizhou	**2.8**	2025
CIADS	Nuclear waste transmutation	IMP, Huizhou	**4**	2027
CSNS-II	Spallation Neutron source proton injector of 300MeV	IHEP, Dongguan	**2.9**	2029

The total cost of the accelerator projects under construction:39B RMB more than CEPC cost of 36.4B RMB

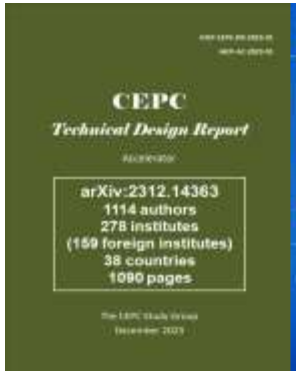
CEPC International Collaboration-1

CEPC attracts significant International participation and collaborations

Accelerator TDR report: 1114 authors from 278 institutes (including 159 International Institutes, 38 countries) Published in **Radiation Detection Technology and Methods (RDTM)** on June 3, 2024:

DOI: 10.1007/s41605-024-00463-y

https://doi.org/10.1007/s41605-024-00463-y



- More than 20 MoUs have been signed with international institutions and universities
- CEPC International Workshop since 2014
- EU-US versions of CEPC WS since 2018
- Annual working month at HKUST-IAS (mini workshops and HEP conference) since 2015

CEPC International Collaboration-2

HKIAS23 HEP Conference, Feb. 14-16, 2023
https://indico.cern.ch/event/1215937/

The 2024 HKUST IAS Mini workshop and conference were held from Jan. 18-19, and Jan. 22-25, 2024, respectively.
https://indico.cern.ch/event/1335278/timetable/?view=standard

Joint Workshop to Commemorate the MOU Between Korea University (KU) and the Institute of High Energy Physics (IHEP)，
Oct. 14-15,2024, Korea Uiniversity, Korea
https://indico.korea.ac.kr/event/104/

The 2025 HKUST IAS HEP conference: Jan. 13-17, 2025.

CEPC Workshop EU Edition (Barcelona, Spain), May 5-8, 2024

The 2023 International Workshop on Circular Electron Positron Collider, EUEdition,University of Edinburgh, July 3-6, 2023
https://indico.ph.ed.ac.uk/event/259/overview

The 2024 international workshop on the high energy Circular Electron Positron Collider (CEPC) are held from Oct. 23-27, 2024, Hangzhou, China
https://indico.ihep.ac.cn/event/22089/

The 2023 international workshop on the high energy Circular Electron Positron Collider (CEPC)
https://indico.ihep.ac.cn/event/19316/

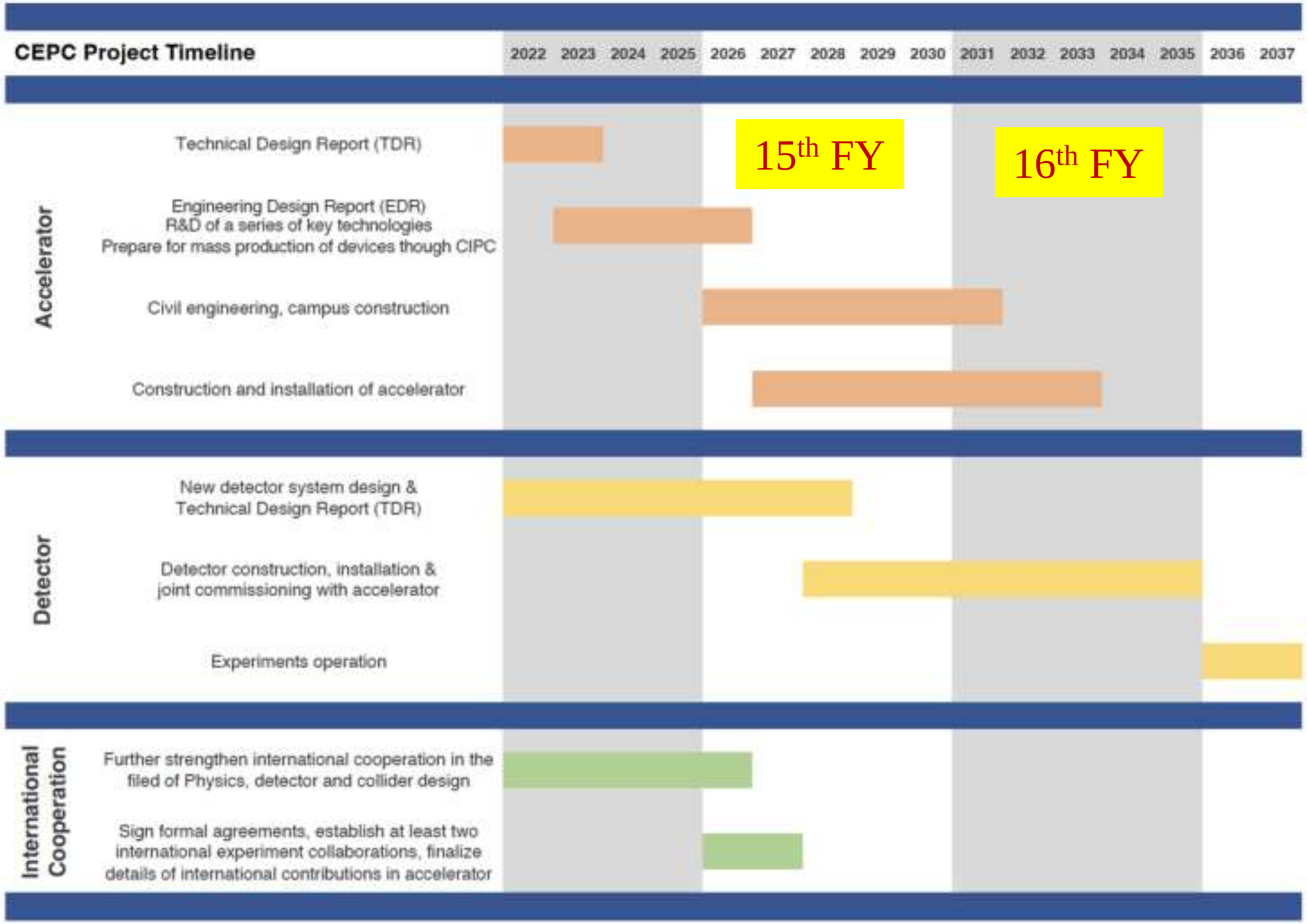
Professor Peter Higgs passed away on **April 8, 2024**. We miss him.

The 2024 international workshop of CEPC, EU-Edition were held in Marseille, France, April 8-11, 2024.
https://indico.in2p3.fr/event/20053/overview

FCPPNL, Bordeaux, France, June 10-14, 2024
https://indico.in2p3.fr/event/20434/overview

CEPC Planning, Schedule and Teams

TDR (2023), EDR(2027), start of construction (~2027)



CEPC team (domestic)

CEPC accelerator and detector/experiments/theory group is an highly **experienced** team with strong international collaboration experiences. It has demonstrated its **expertise** and **achievements** is the following related projects, both domestic and international ones, such as:

BEPC-BEPCII (BES-BESIII)， BFELP， CSNS， ADS， HEPS， LEP, LHC, LHCb, ILC, EXFEL, HL-LHC, BELLE, BELLE-II, CLEO, Daya Bay, JUNO, LHAASO, etc.

CEPC international partners and collaborators

CEPC IARC EDR Review-2024 (Sept. 18-20)

Meeting of the CEPC International Accelerator Review Committee
September 18-20, 2024, IHEP, Beijing

Charge

Charge

The CEPC Study Group, hosted by the Institute of High Energy Physics (IHEP), has been working on the design and development of a forefront e^+e^- collider as a Higgs factory that can extend to energies corresponding to the Z, WW and the top quark pairs, with the upgrade potential to a high energy pp collider. The CEPC represents a grand plan proposed, studied, and to be constructed by Chinese scientists in close collaboration with international partners. The CEPC Accelerator Technical Design Report was released in December, 2023, which documents the design, the outcomes of the R&D of key technologies, the technical systems, and the cost estimate of the e^+e^- collider.

Report

First CEPC IARC EDR Review Report

CEPC IARC EDR Review Committee

11 October 2024

The CEPC Study Group, hosted by the Institute of High Energy Physics (IHEP), has been working on the design and development of a forefront e^+e^- collider as a Higgs factory that can extend to energies corresponding to the Z, WW and top-quark-pair production, with the upgrade potential to a high-energy pp collider. The CEPC represents a grand plan proposed, studied, and to be constructed by Chinese scientists in close collaboration with international partners. The CEPC Accelerator Technical Design Report, which documents the design, the outcomes of the R&D of key technologies, the technical systems, and the cost estimate of the e^+e^- collider, was released in December, 2023. Going beyond the TDR and preparing CEPC for construction, which may begin in 2027-8, the CEPC Study Group has initialized the Engineering Design Study which will be documented in a formal report (EDR). In 2025, a CEPC proposal will be submitted to Chinese government aiming for CEPC be included into the 15th five year plan. The International Accelerator Review Committee (IARC), chaired by Dr. Maria Enrica Biagini (INFN, Frascati) has been asked to conduct the first review on the development of the CEPC accelerator technical systems within the context of the EDR study. The Committee is specifically asked to review and comment on the following aspects:

Agenda

Totally, there are 18 talks

Sep 18th 2024	Beijing time	CET time	Talk time	Speaker	Title
Wednesday	9:00	3:00	5'	Yifang Wang	Welcome
	9:05	3:05	25'	Xinchou Lou	CEPC general status
	9:30	3:30	30'	Jie Gao	CEPC accelerator EDR general scope, plan and status
	10:00	4:00	30'	Coffee break	
	10:30	4:30	30'	IARC preparation meeting (closed)	
	11:00	5:00	30'	Wen Kang/Mei Yang	CEPC Magnets (both collider & booster)
	11:30	5:30	30'	Cai Meng/Jingru Zhan	CEPC Linac EDR plan and status
	12:00	6:00	30'	Dou Wang	CEPC booster and damping ring (DR) EDR plan and status
	12:30	6:30	90'	Lunch	
	14:00	8:00	30'	Yiwei Wang	CEPC collider ring beam dynamics EDR plan and status
	14:30	8:30	30'	Sha Bai	CEPC MDI EDR plan and status
	15:00	9:00	30'	Haijing Wang	CEPC Interaction Region engineering design status
	15:30	9:30	30'	Coffee break	
	16:00	10:00	30'	Guangyi Tang	Radiation in the tunnel and its mitigation for CEPC EDR
	16:30	10:30	60'	IARC discussion and Q/A with CEPC accelerator speakers	
	17:30	11:30	30'	IARC members	Closed session
Sep 19th 2024	9:00	3:00	30'	Yingshun Zhu	CEPC SC quadrupoles development plan in EDR and status
Thursday	9:30	3:30	30'	Haijing Wang	CEPC Mechanical system EDR plan and status
	10:00	4:00	30'	Yongsheng Ma	CEPC Vacuum system EDR plan and status
	10:30	4:30	30'	Coffee break	
	11:00	5:00	90'	IARC discussion and Q/A with CEPC accelerator speakers (partly closed if	
	12:30	6:30	90'	Lunch	
	14:00	8:00	30'	Jiyuan Zhai/Peng Sha	CEPC SRF (both collider & booster) EDR plan and status
	14:30	8:30	30'	Rui Ge/Mei Li	CEPC cryogenic system EDR plan and status
	15:00	9:00	30'	Zusheng Zhou	CEPC RF power sources and power distribution EDR plan and
	15:30	9:30	30'	Coffee break	
	16:00	10:00	60'	IARC discussion and Q/A with CEPC accelerator speakers	
	17:30	11:30	60'	IARC members	Closed session
	18:30		180'	Banquet	
Sep 20th 2024	9:00	3:00	30'	Xiaolong Wang	CEPC alignment and installation EDR plan and status
Friday	9:30	3:30	30'	Yanfeng Sui	CEPC accelerator instrumentation EDR plan and status
	10:00	4:00	30'	Yuhui Li	CEPC sustainable development issues
	10:30	4:30	30'	Coffee break	
	11:00	5:00	60'	IARC discussion and Q/A with CEPC accelerator speakers (partly closed if	
	12:30	6:00	90'	Lunch	
	14:00	8:00		Adjourn and visit to HEPS facility	
Sep ** 2024	14:30	8:30	150'	IARC members	Closed session for document editing and final reading
(TBD)	17:00	11:00	60'	ALL	Report presentation to CEPC Team
	17:30	11:30			Adjourn

Visiting PAPS and HEPS's commission 40mA stored beam

Summary

- The CEPC TDR optimizations designs with high luminosity (**30MW and 50MW**) operations for all four energies (**Higgs, W/Z and ttbar**) satisfy the CEPC scientific goals.
- CEPC accelerator **TDR international review and cost review** were held from **June 12-16, 2023 and Sept. 11-15, 2023**, respectively, and endorsed by **IAC meeting** held from **Oct. 30-31, 2023**. **CEPC Accelerator TDR has be released formally on December 25, 2023 and published in Journal Radiation Detection Technology and Methods (RDTM) on June 3, 2024:** DOI: 10.1007/s41605-024-00463-y https://doi.org/10.1007/s41605-024-00463-y
- EDR site selection and site dependent engineering design have already been started
- Detailed preparation of **CEPC EDR** phase (**2024-2027**) before construction working plan and beyond have been established with the aim for **CEPC proposal** to be presented to and selected by Chinese government around **2025** for the construction start during the "**15th five year plan** **(2026-2030)"** (for example, around **2027**) and completion around **2035**.
- **CEPC Accelerator EDR have progressed well with corresponding EDR budgets and EDR human resources, and has been reviewed by IARC in Sept. 18-20, 2024 at IHEP.**
- **A beam driven PWFA experimental program** has been initialized and started at IHEP to address the cascade and e+ accelerations aiming on future plasma injector for CEPC and future linear colliders.
- **International collaboration and participation are warmly welcome.**

Acknowledgements

Thanks go to CEPC-SppC accelerator team’s hard works, international and CIPC collaborations

Special thanks to CEPC IB, SC, IAC, IARC and TDR review (+cost) committee’s critical advices, suggestions and supports

Thanks for your attention