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

The Status of the CEPC Accelerator in EDR

J. Gao

IHEP

On behalf of CEPC-SppC team

16th FCPPN/L Workshop, July 21-25 , 2025
Shandong University, Qingdao, China,

Contents

- Introduction
- CEPC EDR planning and milestones
- CEPC accelerator EDR progress status
- CEPC EDR site investigation, implementation and construction plans
- CEPC technology industrial preparations and international collaborations
- Summary

A Brief Historical Recall: High Energy Colliders and Factories

The era of Higgs boson started from 2012， and we entered the BEST EPOCH of High Energy Physics

In the last 60 years we have made a tremendous progress in particle physics, and we have to prepare for the next exciting and discovering years of human being

In 60's, Ada, VEP-I, VEPP-II, ACO…

Year

Next?

2018

2012

2010

2006

2002

1999

1994

1990

1988

1980

1972

SppC, FCC-hh
Muon collider
FCC-ee
(H,t, Z,W…Dark matter)
CEPC/ILC/CLIC: new e^+e^- collider
(B physics…)
SuperKEKB: $\sqrt{s} \simeq 10\ \mathrm{GeV}, \mathcal{L} \simeq 10^{35}$
LHC: $\sqrt{s} \simeq 14\mathrm{TeV}, \mathcal{L} \simeq 10^{33}$
(τ − charm,…)
BEPCII: $\sqrt{s} \simeq 2-5\ \mathrm{GeV}, \mathcal{L} \simeq 10^{33}$
(τ mass, charmonium,…)
VEPP-4: $\sqrt{s} \simeq 1.5-2.0\mathrm{GeV}, \mathcal{L} \simeq 10^{33}$; DAFNE: $\sqrt{s}$ ~1GeV , $\mathcal{L} \simeq 10^{32}$
(B-quark, CP violation, CKM…)
KEKB/PEP-II
SSC: $\sqrt{s} \simeq 40\mathrm{TeV}, \mathcal{L} \simeq 10^{33}$ 1993 stopped
(Z, W bosons,…)
LEP/CERN, SLC/SLAC
(τ −charm,…)
BEPC: $\sqrt{s} \simeq 2-5\ \mathrm{GeV}, \mathcal{L} \simeq 10^{31}$
CESR: $\sqrt{s} \simeq 10\ \mathrm{GeV}$
(J/ψ,c-quark, t …)
SPEAR&BNL: $\sqrt{s}$

Future Large Colliders:
- new paradigm/theory
- new colliders equipped with advanced detectors

Higgs,…

LHC/CERN:

Higgs boson 2012

Crab-Waist in 2014 at DAFNE

CEPC-SppC was proposed by Chinese scientists in Sept. 2012 after Higgs Boson was discovered on July 4, 2012 at CERN

Top

Tevatron

Top quark 1995

HERA: ep

J. Gao, "Review of Different Colliders", **International Journal of Modern Physics A**, (2021) 2142002 (25 pages).

W, Z,…

SPS/CERN

W,Z bosons 1983

Bottom,…

PETRA: $\sqrt{s} \simeq 12\sim46.7$ GeV GeV

Gluon 1979

Fermilab: 400GeV p on Cu, Pt

Bottom quark 1977

(e^+e^- colliders)

(proton accelerators)

From BEPC, BEPCII, BEPCII-U to CEPC

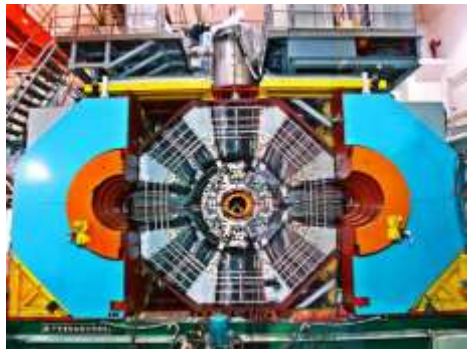
BEPC, the first collider in China, was completed in 1988 with luminosity $1\times10^{31}cm^{-2}s^{-1}$ @1.89GeV
BEPC II was completed in 2009
Luminosity reached on April 5, 2016: $10\times10^{32}cm^{-2}s^{-1}$ @1.89GeV

Precise tau mass measurement @BEPC

After BEPCII what is the next high energy collider?

Thanks to the discovery of Higgs at LHC@CERN in July 4, 2012, the answer is clear, CEPC!

J. Gao, "BEPCII and CEPC", Proceedings of eeFACT 2025, arXiv:2505.02401, https://doi.org/10.48550/arXiv.2505.02401



National Scientific and Technology Progress First Prize for 2016 has been awarded to Prof. J. L. Xie on Jan 9, 2017

IPAC (Asia) Top Prize Named with J.L. Xie

Prof. J. L. Xie

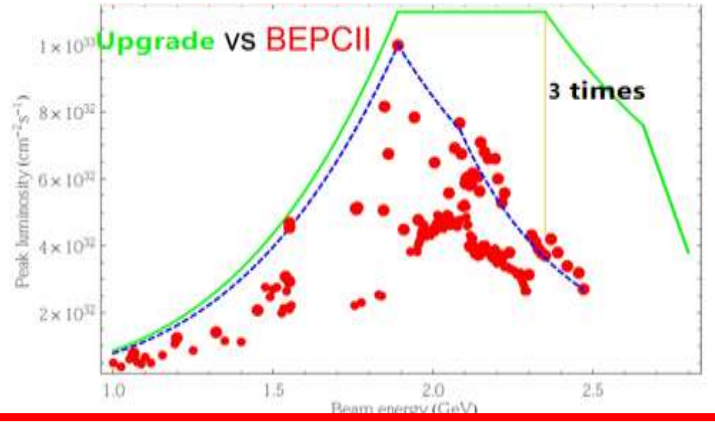
Prof. M. Davier visited IHEP in May, 1988, see his review article below

Michel Davier, Minghan Ye and China{France collaboration in high-energy Physics, International Journal of Modern Physics A Vol. 40, Nos. 13 & 14 (2025) 2545005 (9 pages) https://doi.org/10.1142/S0217751X25450058

Upgrade Project for BEPCII (BEPCII-U)

Key Technologies: Double beam power & Optics upgrade & Higher gradient of magnets

	BEPCII @ 2.35GeV	BEPCII-U @ 2.35GeV	BEPCII-U @ 2.8GeV
L $[10^{32}cm^{-2}s^{-1}]$	**3.5**	**11**	**3.7**
β_y^* [cm]	**1.5**	**1.35**	**3.0**
Beam current [mA]	400	900	450
SR Power [kW]	**110**	**250**	**250**
$\xi_{y,lum}$	0.029	0.033	0.043
Emittance [nmrad]	**147**	**152**	**200**
Couping [%]	**0.53**	**0.35**	**0.5**
Bucket Height	0.0069	0.011	0.009
$\sigma_{z,0}$ [cm]	1.54	1.07	1.4
σ_z [cm]	**1.69**	**1.22**	**1.6**
RF Voltage [MV]	**1.6**	**3.3**	**3.3**



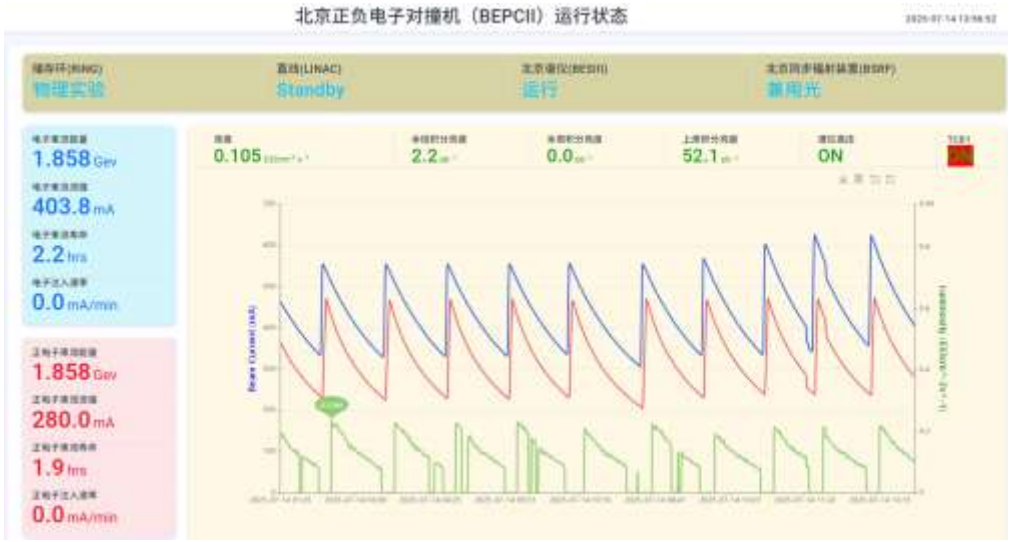
Tau-Charm physics studies on BEPCII-U

Physics predictions

$\Lambda_c\bar{\Lambda}_c$ $\Sigma_c\bar{\Sigma}_c$ $\Xi_c\bar{\Xi}_c$ $\Omega_c\bar{\Omega}_c$

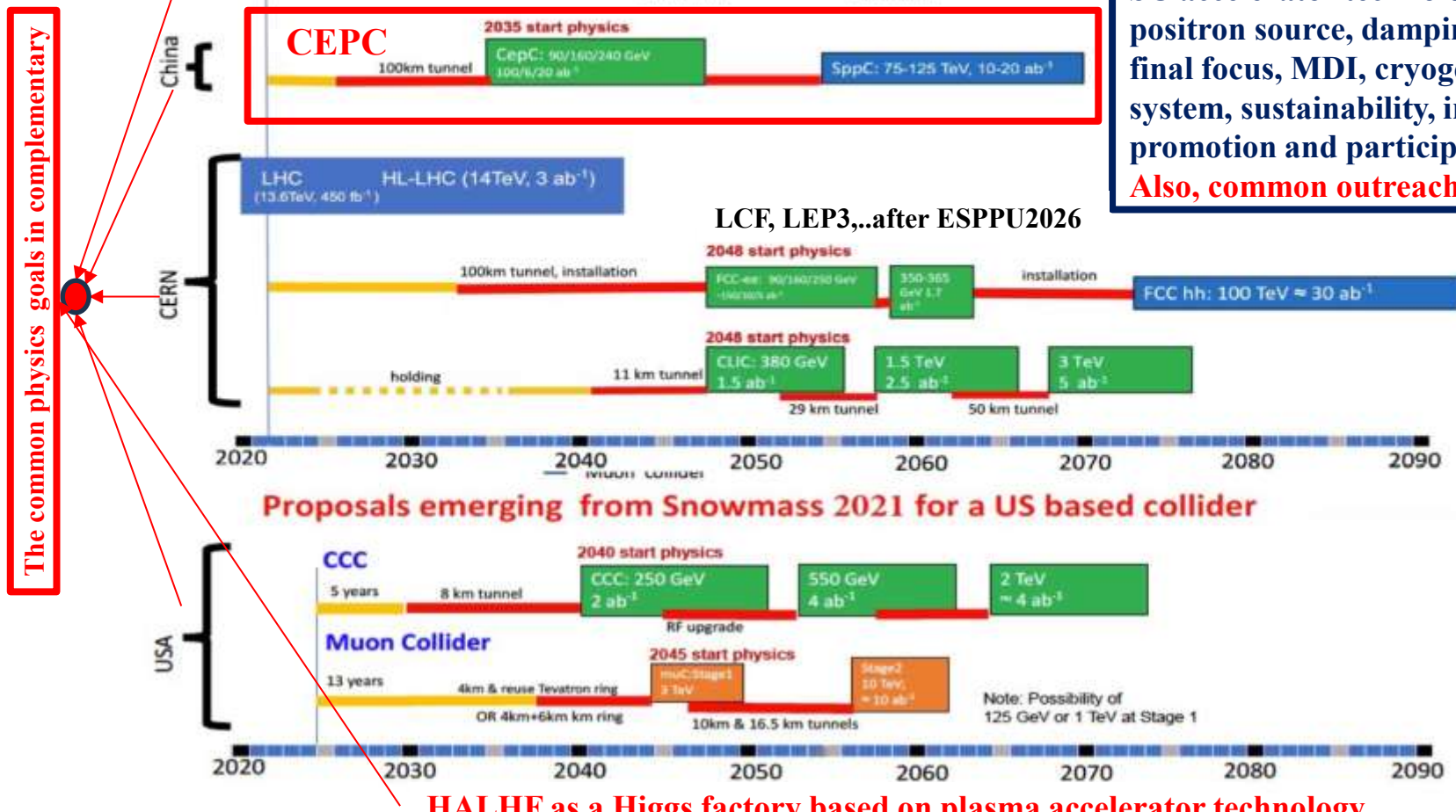
* KEDR new scan points positions are fixed at pQCD predictions
Expected total uncertainty is about 3 % (systematic uncertainty about 2.5%)

BEPCII-U in Commissioning

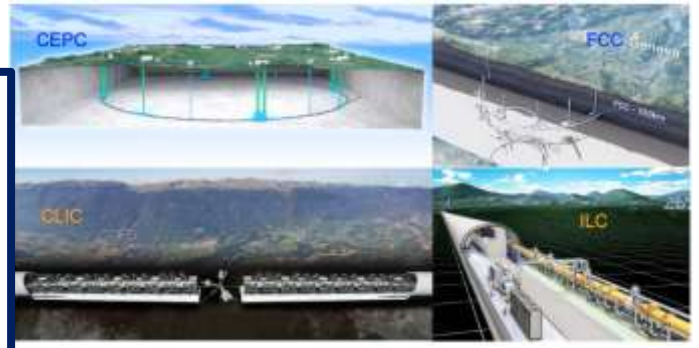


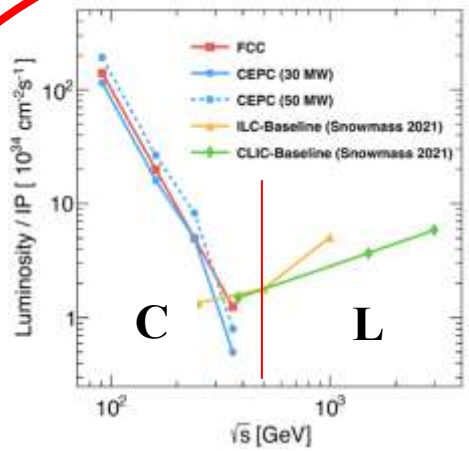
BEPCII-U started commissioning in March 2025

Worldwide High Energy Physics Frontier Goals Timelines and Common Efforts



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





The complementarity between circular and linear Higgs factories

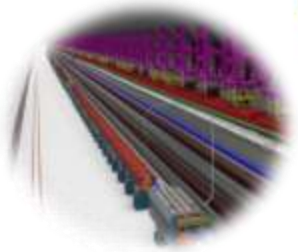
HALHF as a Higgs factory based on plasma accelerator technology

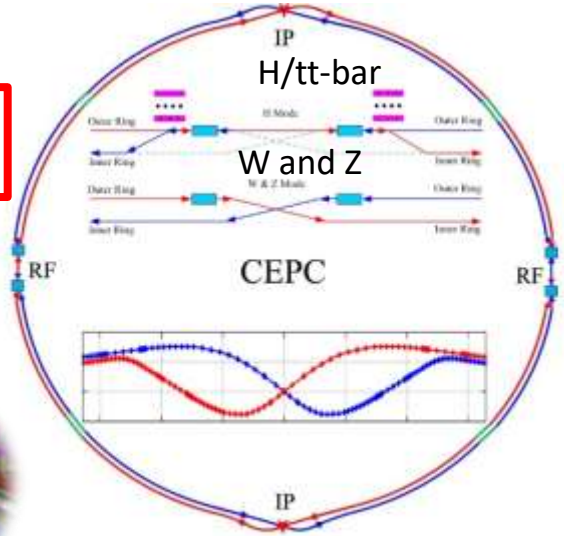
G. Arduini，et al, Future Colliders Comparative Evaluation - Working Group Report, ESPPU26, 2025,
https://indico.cern.ch/event/1439855/contributions/6542430/attachments/3076609/5444588/Future_Colliders_Comparative_Evaluation_WG_report.pdf

CEPC Higgs Factory and SppC Layout in TDR/EDR

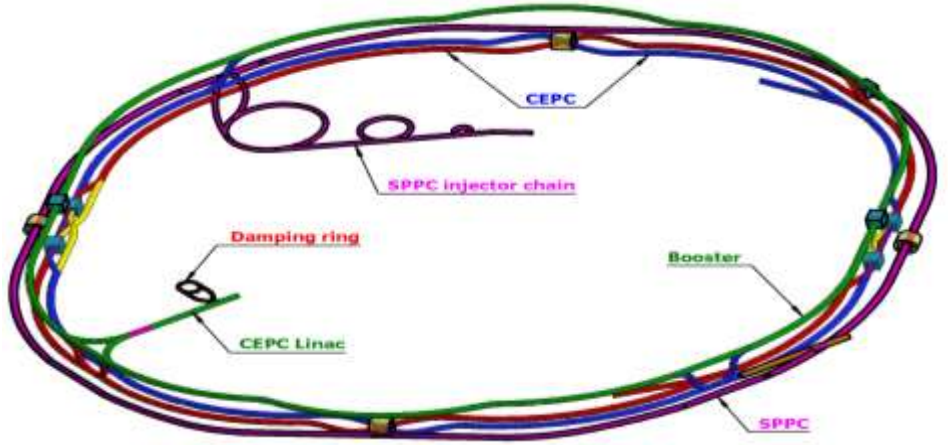
CEPC as a Higgs Factory： H, W, Z, upgradable to ttbar, followed by a SppC (a Hadron collider) ~125TeV
30MW SR power per beam (upgradable to 50MW) , high energy gamma ray 100Kev~100MeV

CEPC has two detectors



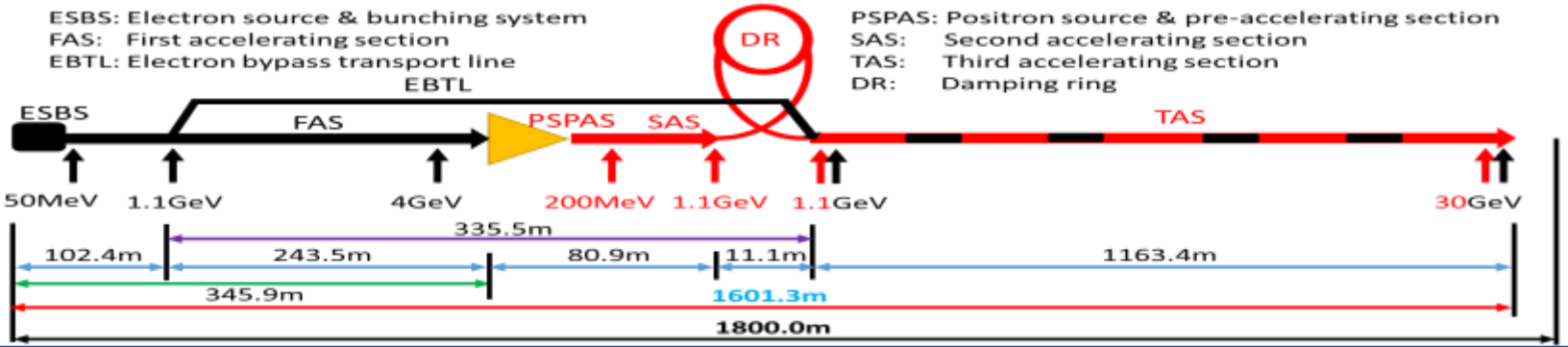


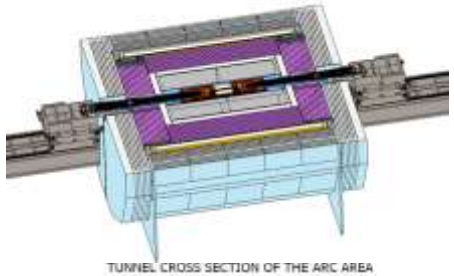
CEPC collider ring (100km)



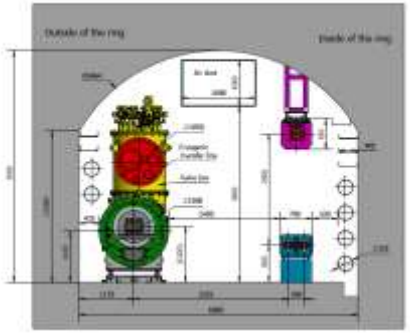
CEPC booster ring (100km)

CEPC TDR S+C-band 30GeV linac injector

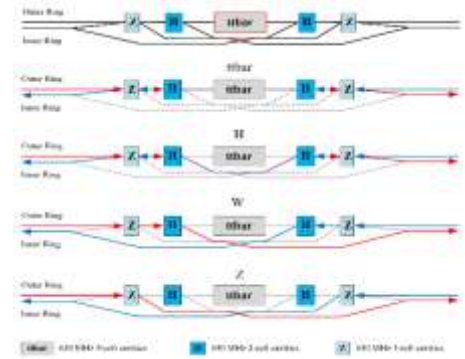




TUNNEL CROSS SECTION OF THE ARC AREA



CEPC/SppC in the same tunnel



Z,W, Higgs and ttbar energies

CEPC Physics Goals, Operation Plan and Goals in TDR/EDR

Operation mode		ZH	Z	W⁺W⁻	$t\bar{t}$
$\sqrt{s}$ [GeV]		~240	~91	~160	~360
Run Time [years]		10	2	1	5
30 MW	L / IP [$\times 10^{34}$ cm^{-2}s^{-1}]	**5.0**	**115**	**16**	**0.5**
	$\int L\,dt$ [ab^{-1}, 2 IPs]	13	60	4.2	0.65
	Event yields [2 IPs]	2.6×10^{6}	2.5×10^{12}	1.3×10^{8}	4×10^{5}
50 MW	L / IP [$\times 10^{34}$ cm^{-2}s^{-1}]	**8.3**	**192**	**26.7**	**0.8**
	$\int L\,dt$ [ab^{-1}, 2 IPs]	21.6	100	6.9	1
	Event yields [2 IPs]	4.3×10^{6}	4.1×10^{12}	2.1×10^{8}	6×10^{5}

* Higgs is the top priority for CEPC

** Detector solenoid field is 3 Tesla for all other energies.

CEPC physics white papers:

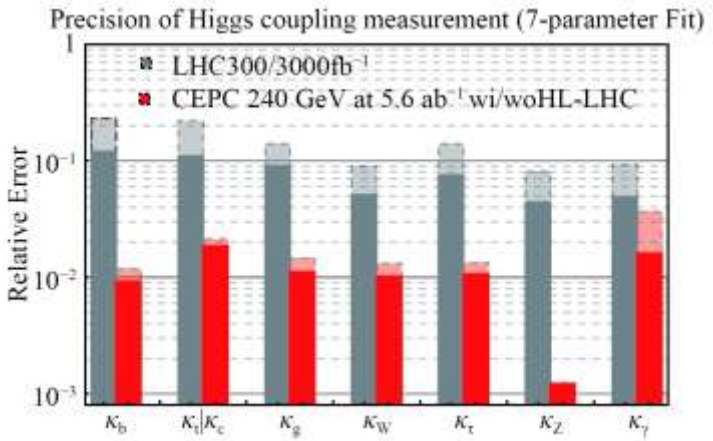
1: Higgs physics, Chinese Physics C Vol. 43, No. 4 (2019) 043002
https://arxiv.org/pdf/1810.09037

2: Flavor physics, https://arxiv.org/pdf/2412.19743 (2024)

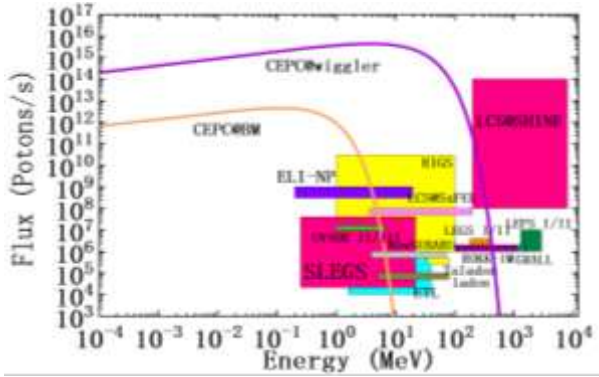
3: Electroweak physics, to be published

4: New Physics Search at the CEPC: a General Perspective
https://doi.org/10.48550/arXiv.2505.24810 （2025）

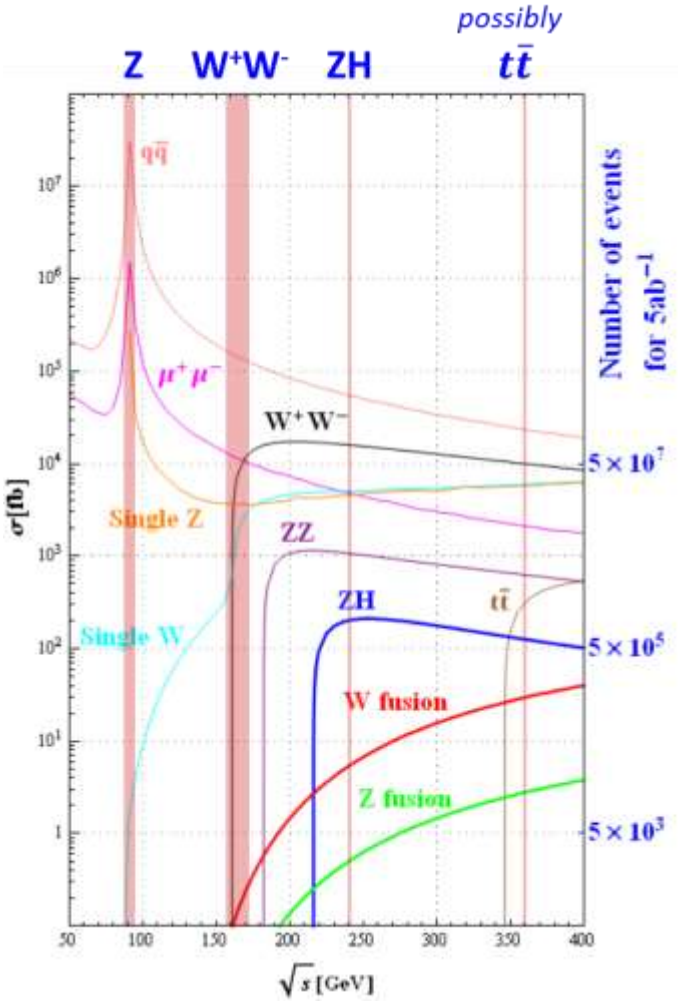
5: QCD, to be published



CEPC operation scenarios:
Higgs 10 years, Z-pole 2 years,
W 1 year, ttbar 5 years as upgrade



CEPC as high energy SR light source



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	99.955					
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)	99.955			
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

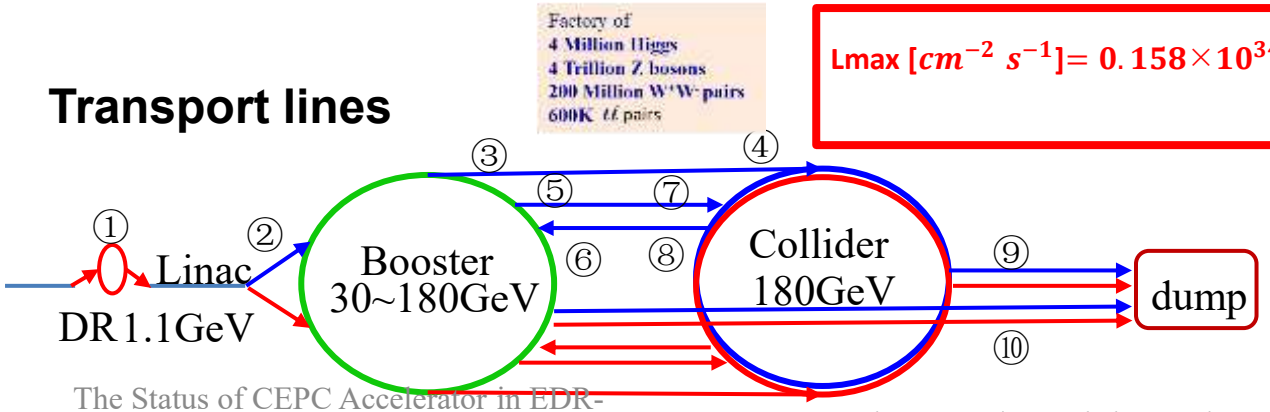
Running scenarios: Higgs 10 years, Z 2 years, W 1 year, ttbar 5 years

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

(J. Gao's formula)

for isomagnetic machine with crab-waist collision

Transport lines

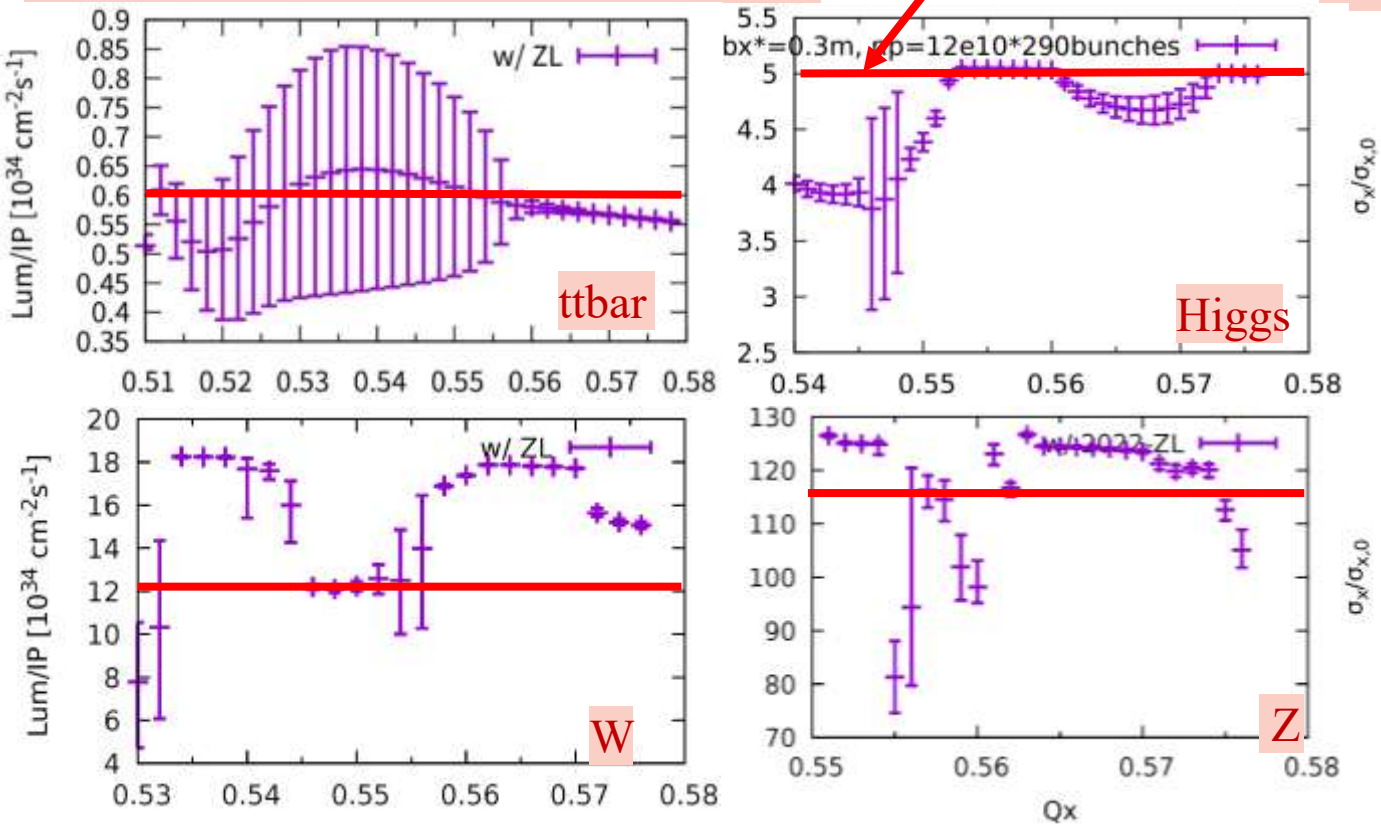


CEPC Technical Design Report (TDR) includes:
1) CEPC Accelerator TDR released on Dec. 25, 2023
2) CEPC Detector ref-TDR (reference design) has been completed and reviewed by IDRC in April 2025, and will be relased in 2025

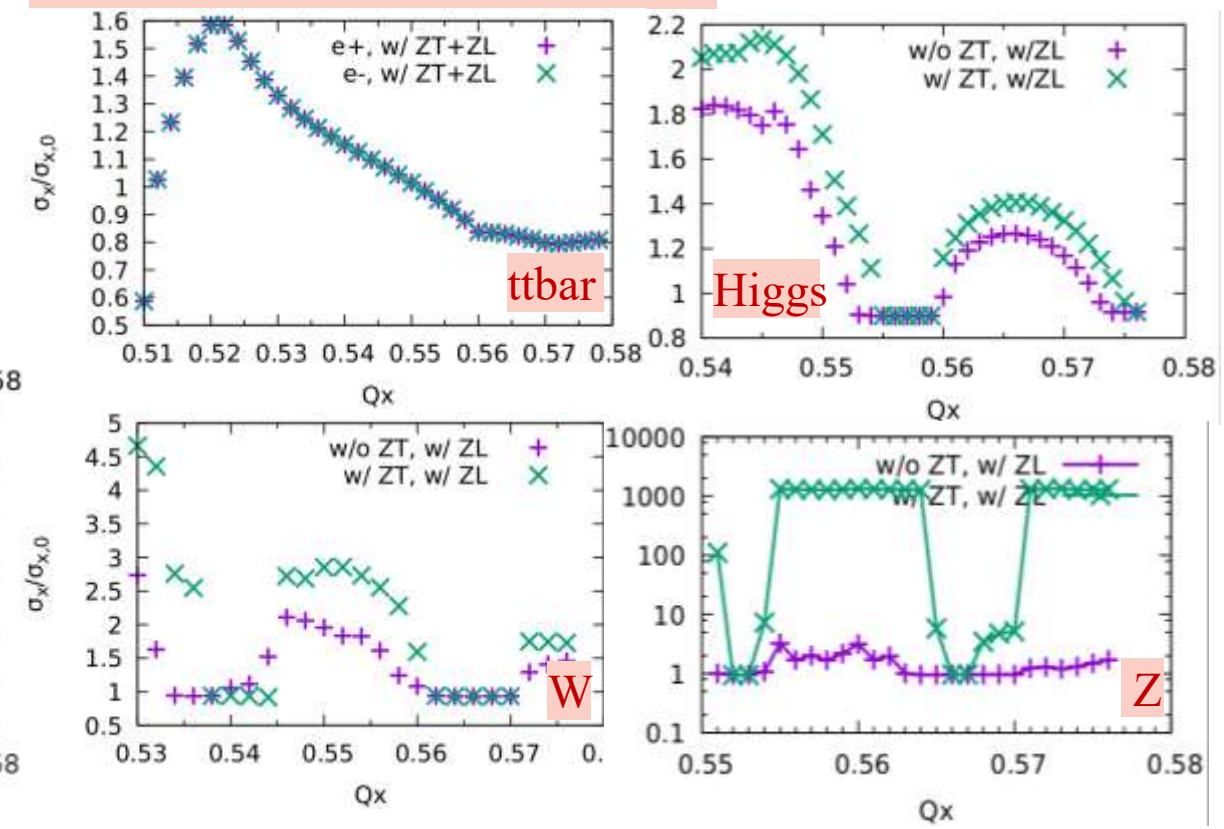
The Beam-Beam Effects and the Luminosities in CEPC

Results from J. Gao's formulae

- Luminosity simulations w/ZL



- Transverse size simulations

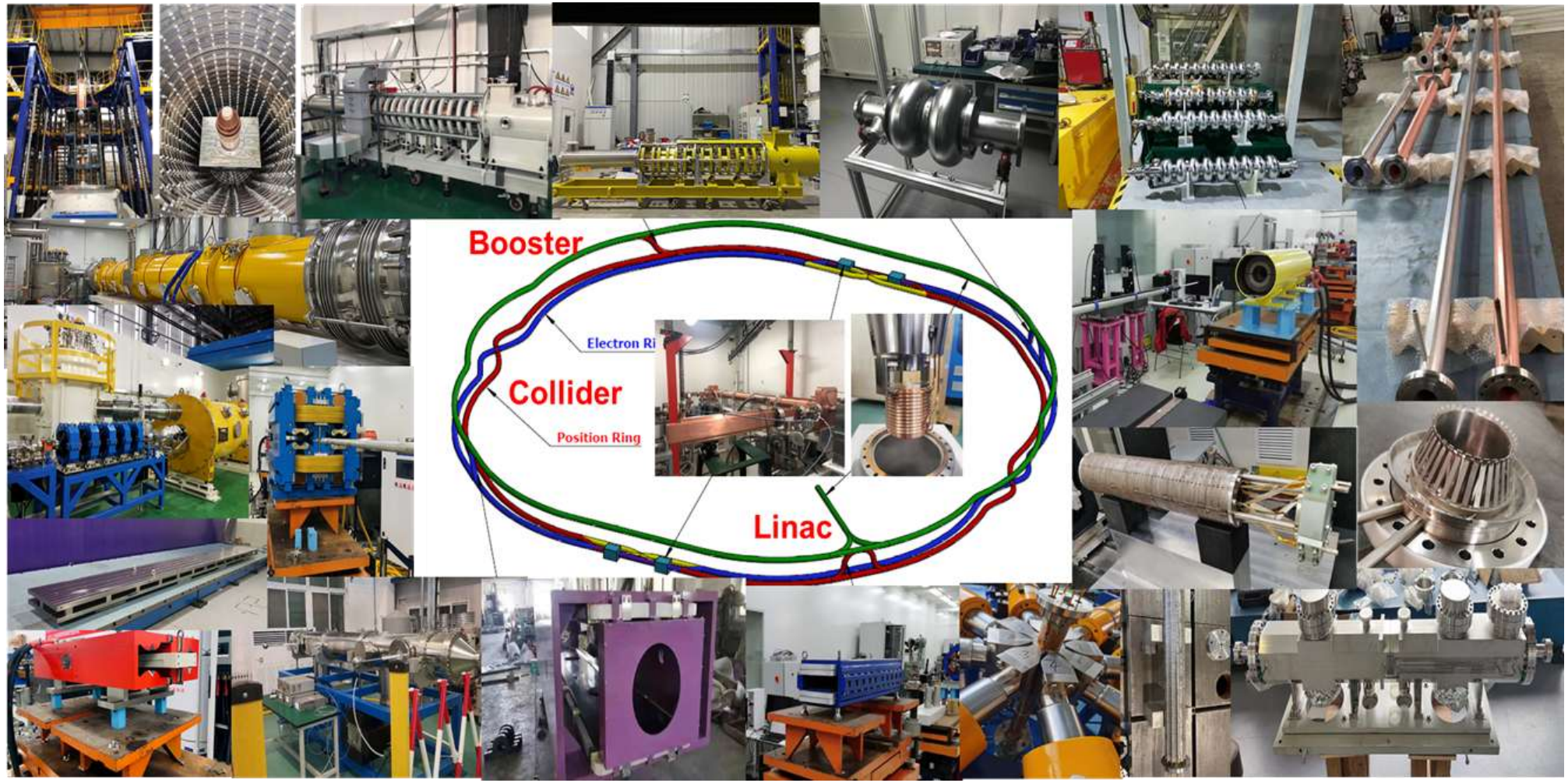


Above results from CEPC accelerator TDR: J. Gao, CEPC Technical Design Report: Accelerator. ***Radiat Detect Technol Methods (2024).*** https://doi.org/10.1007/s41605-024-00463-y

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

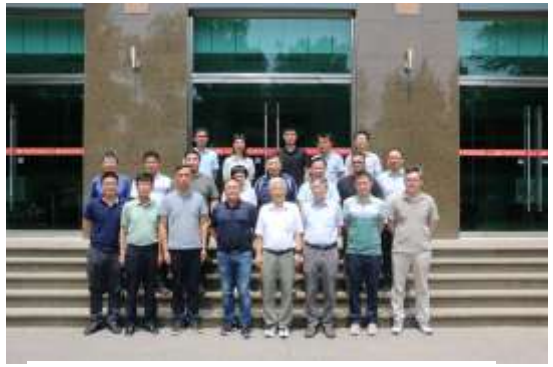
CEPC Accelerator TDR R&D Completed in 2023



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

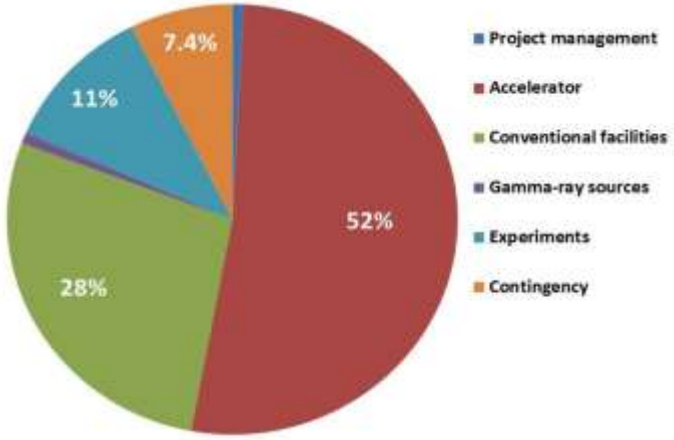


Domestic Civil Engineering
Cost Review, June 26, 2023, IHEP

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

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)**

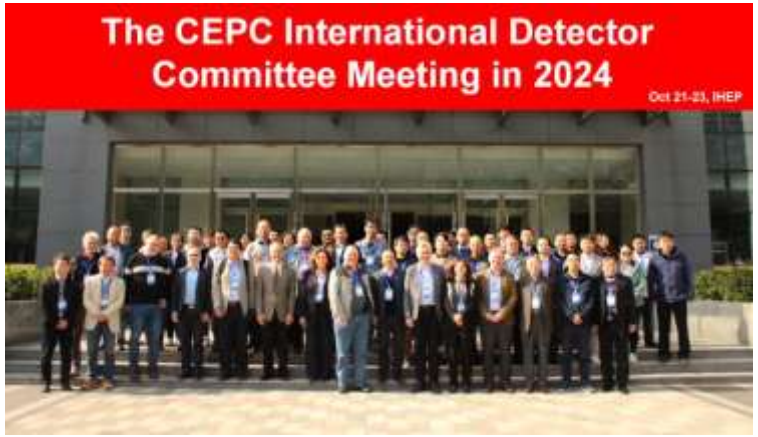
CEPC accelerator TDR has been completed and formally released on December 25, 2023:
http://english.ihep.cas.cn/nw/han/y23/202312/t20231229_654555.html
CEPC accelerator TDR has been published formally in Journal Radiation Detection Technology and Methods (RDTM) on June 3, 2024:
DOI: 10.1007/s41605-024-00463-y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

CEPC IARC, IDRC and IAC Meetings since EDR

CEPC IARC meeting was held from Sept. 18-20, 2024

https://indico.ihep.ac.cn/event/22311/

CEPC IARC meeting will be held from Sept. 16-19, 2025



The International Detector Review Committee (IDRC) held its inaugural meeting at IHEP, Oct 21-23, 2024, to review the status and plan of Ref-TDR.

https://indico.ihep.ac.cn/event/23265/

CEPC IAC meeting in 2024 was held from Oct. 29-30, 2024

https://indico.ihep.ac.cn/event/23450/timetable/

CEPC IAC meeting will be held from Nov. 20-21, 2025

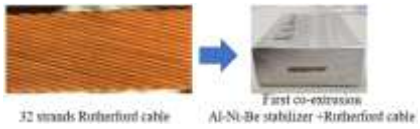
CEPC Detector Reference Design Report

CEPC IDRC meeting was held from April. 14-16, 2025

https://indico.ihep.ac.cn/event/25539

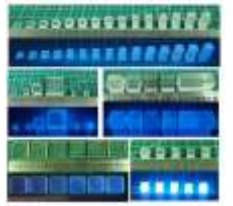
CEPC Detector Reference TDR Design

3T Magnet
(SC Solenoid)



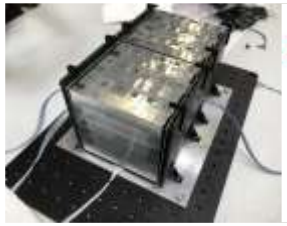
Yoke +
MU (PS+SiPM)

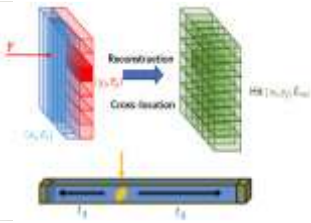
PFA HCAL
(Glass Scintillator)



$\gamma - \gamma$ separation for 5 GeV photons

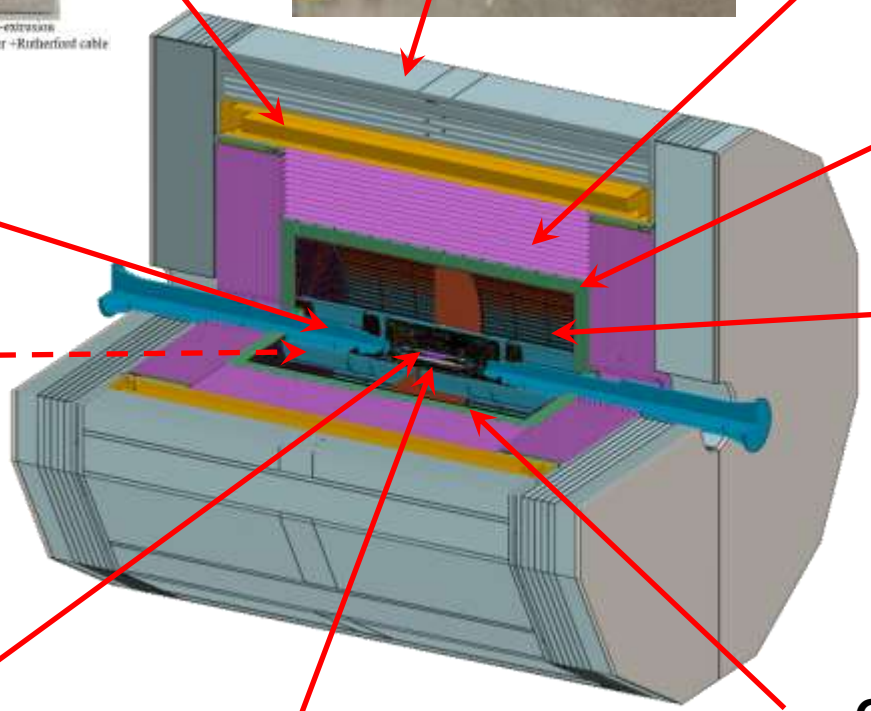
Crystal **PFA ECAL**
(Transverse bar)



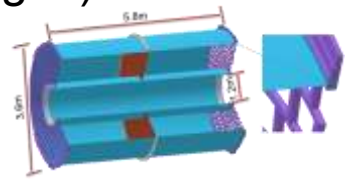


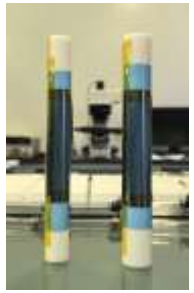
LumiCal
(SiDet + LYSO)

Potential
Endcap PID

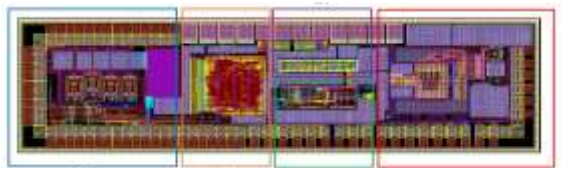


TPC
(Pixelated Micromegas)

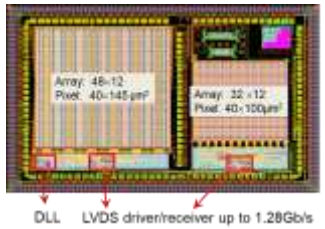




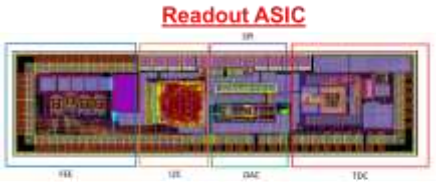
VTX
(MAPS SiPixel
+ Stitching + Bending)

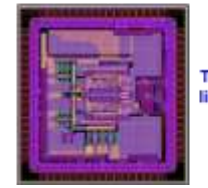


ITK
(MAPS SiPixel)



OTK
(AC-LGAD strip)





TDC delay line layout

CEPC Detector Reference Tchnical Design Report reviewed by IDRC in April 2025

Ref-TDR is based on this configuration

CEPC TDR-ref Detector Specifications

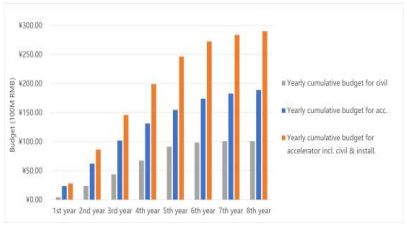
Sub-system	Key technology	Key Specifications
Vertex	6-layer CMOS SPD	$\sigma_{r\phi}$ ~ 3 μm, X/X_0 < 0.15% per layer
Tracking	CMOS SPD ITK, AC-LGAD SSD OTK, TPC + Vertex detector	$\sigma\left(\frac{1}{P_T}\right) \sim 2\times10^{-5} \oplus \frac{1\times10^{-3}}{P\times sin^{3/2}\theta}(GeV^{-1})$
Particle ID	dN/dx measurements by TPC Time of flight by AC-LGAD SSD	Relative uncertainty ~ 3% σ(t) ~ 30 ps
EM calorimeter	High granularity crystal bar PFA calorimeter	EM resolution ~ $3\%/\sqrt{E(GeV)}$ Effective granularity ~ 1×1×2 cm^3
Hadron calorimeter	Scintillation glass PFA hadron calorimeter	Support PFA jet reconstruction Single hadron $\sigma_E^{had} \sim 40\%/\sqrt{E(GeV)}$ Jet $\sigma_E^{jet} \sim 30\%/\sqrt{E(GeV)}$

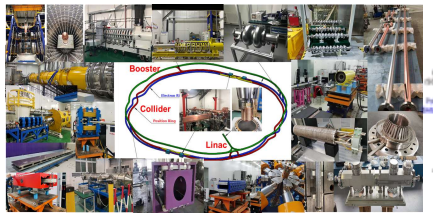
- Design of the CEPC detector evolves with the R&D progressing and our better understanding of the physics reach.
- The key specifications continue to be optimized.

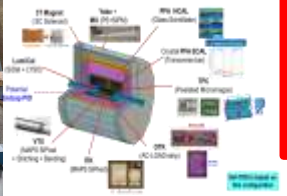
CEPC Milestones, Timeline and Human Resources

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







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

2025

36.4B RMB
Total construction

CEPC EDR site study and civil engineering design

2036-2037
CEPC commissioning

CEPC kickoff meeting in Sept. 2013

CEPC detector reference design completed in June 2025

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

J. Gao, "The Status of the CEPC Project in EDR", submitted to IJMPA , 2025, arXiv:2505.04663, https://doi.org/10.48550/arXiv.2505.04663

CEPC Key System EDR Progresses and Technical Reviews

CEPC Accelerator Key System EDR Progresses

-2025 March 20, CEPC booster magnet automatic fabrication line ready for construction
-2025 April 17, CEPC polarization cathode material and test facility ready for fabrication
-2025 April 25, CEPC vacuum chamber NEG coating automatic fabrication line ready for construction
-2025 April 28, 650MHz full size cryomodule ready for construction

CEPC Accelerator Key System EDR International Mini Reviews (Required by IARC)

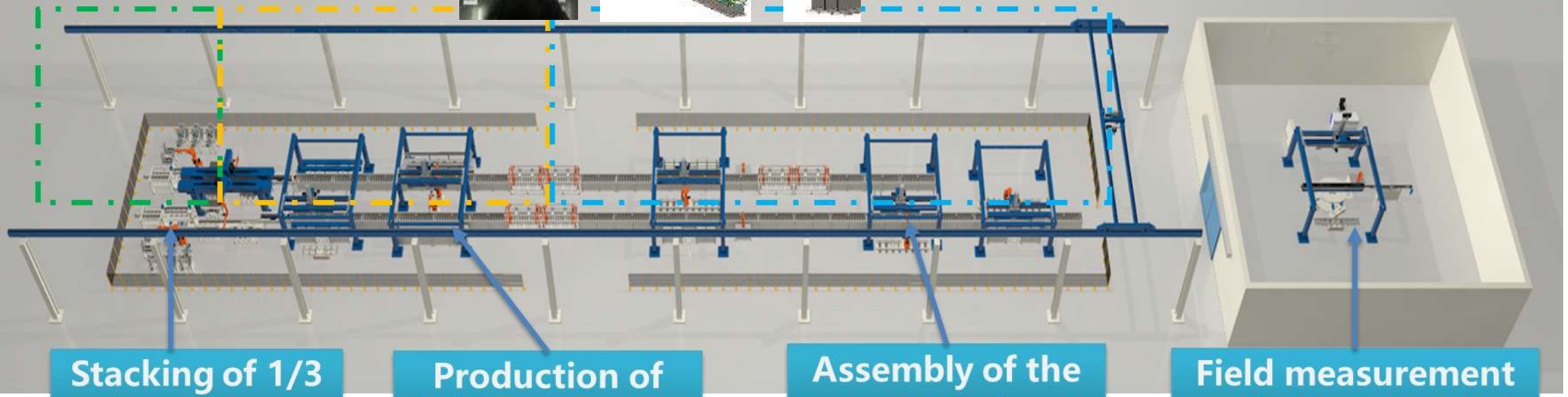
-2025 April 24, CEPC alignment and installation EDR international mini review
-2025 May 14,15, CEPC cryogenic system (+650MHz cryomodule) EDR international mini review
-2025 May 29, CEPC booster dipole and sextupole combined magnet EDR international mini review
-2025 June 9-10, CEPC MDI EDR international mini review
-2025 June 9-10, CEPC EDR site geological feasibility study review
-2025 July, CEPC vacuum chamber type EDR international mini review

J. Gao, "The Status of the CEPC Project in EDR", submitted to IJMPA , 2025, arXiv:2505.04663, https://doi.org/10.48550/arXiv.2505.04663

CEPC Magnet Automatic Production Line in EDR

4 booster magnets fabricated per day

~15000 dipole magnets in the CEPC booster

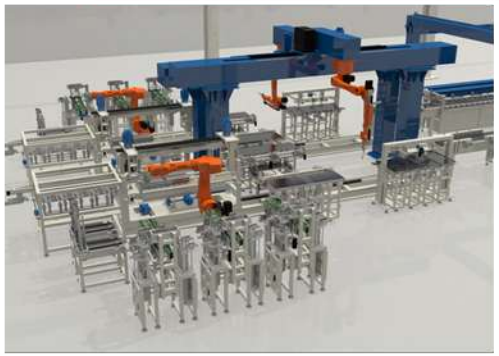


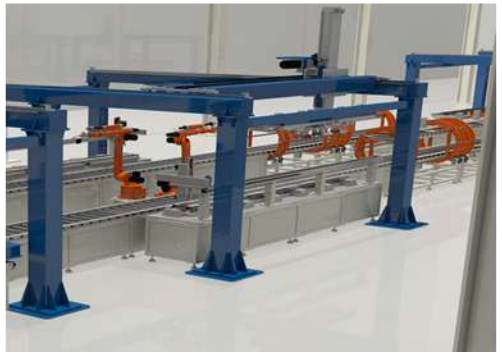
Stacking of 1/3 length core

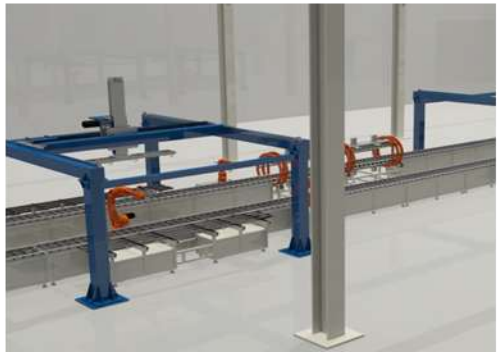
Production of full length cores

Assembly of the magnet

Field measurement of the magnet

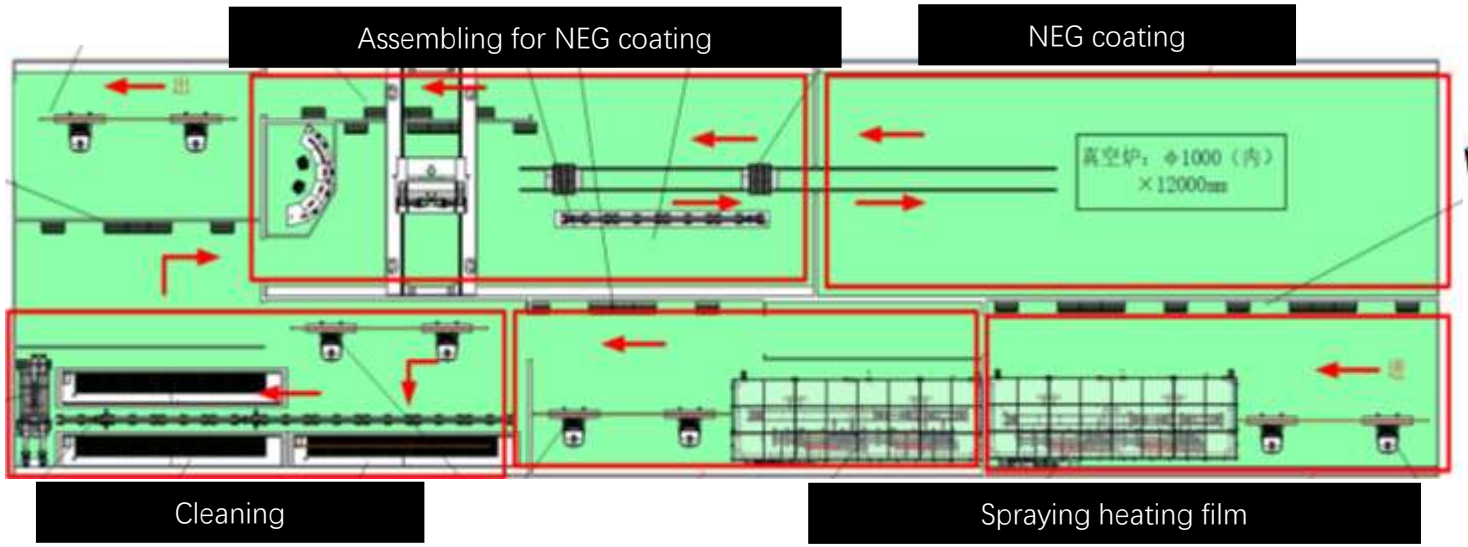


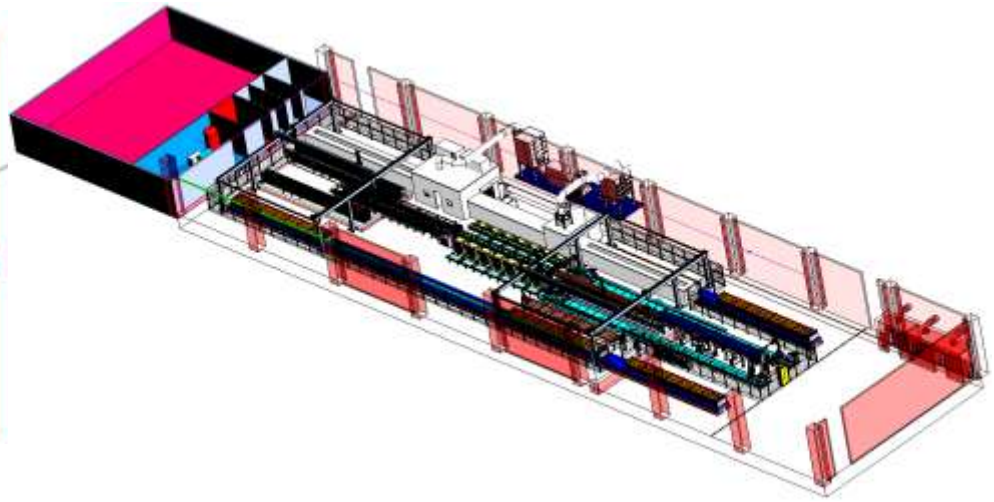




Status： construction started, to be completed in 2025

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



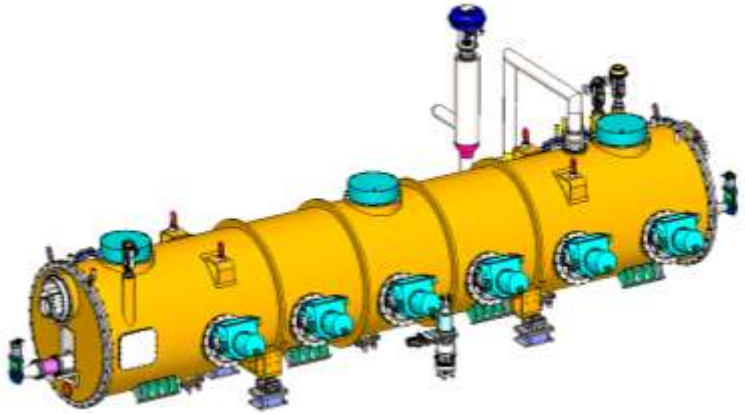


Layout of production line

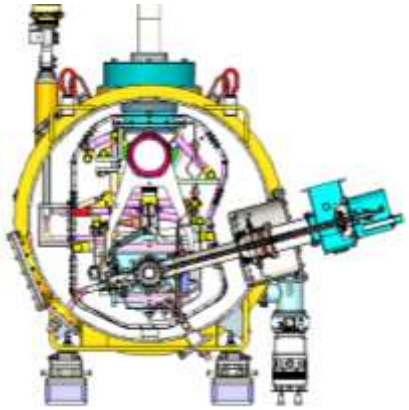
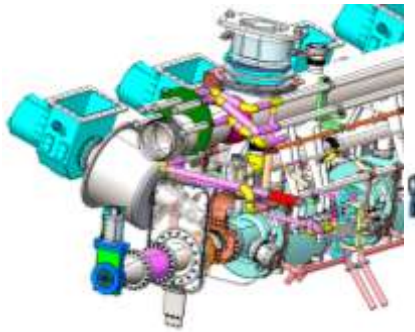
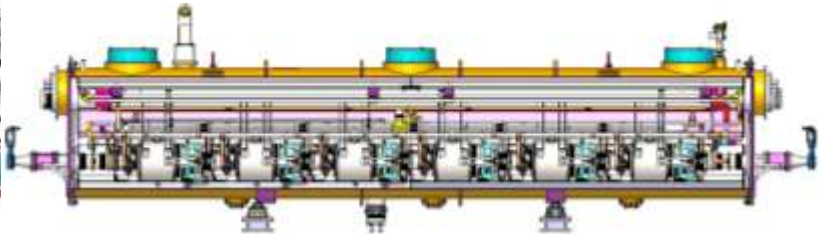
Status：construction started, to be completed in 2025

CEPC 650MHz 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

Status： construction started, to be completed in 2025

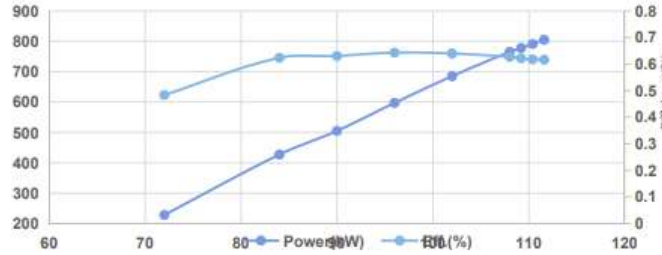
CEPC High Efficiency and High Power Klystrons

Klystron R&D

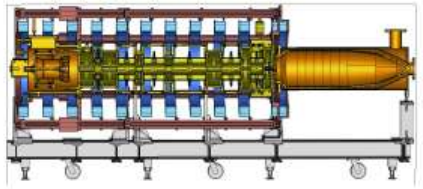
Klystron No. 1
Efficiency 65%
(2020)

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

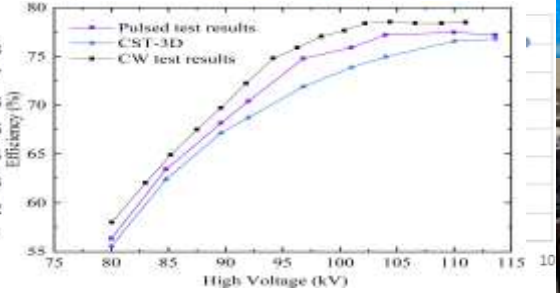
High Voltage vs. Power&Efficency



Klystron No. 2
Efficiency 77%
(2021)



78.5%@803kW CW in 2024



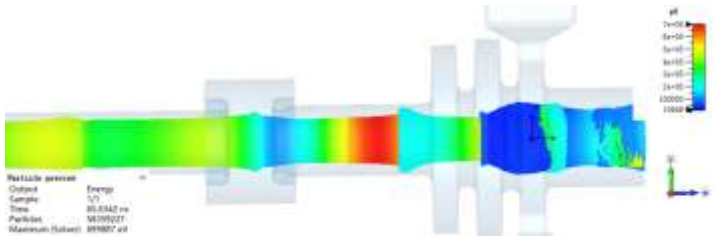
Klystron No. 3 （MBI
Efficiency 80.5%

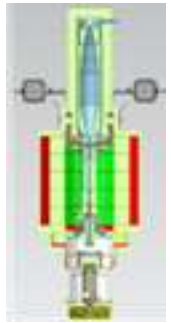
To be completed in 2025

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

CEPC collider ring 650MHz klystron development in TDR/EDR phase

C band 5720MHz 80MW Klystron



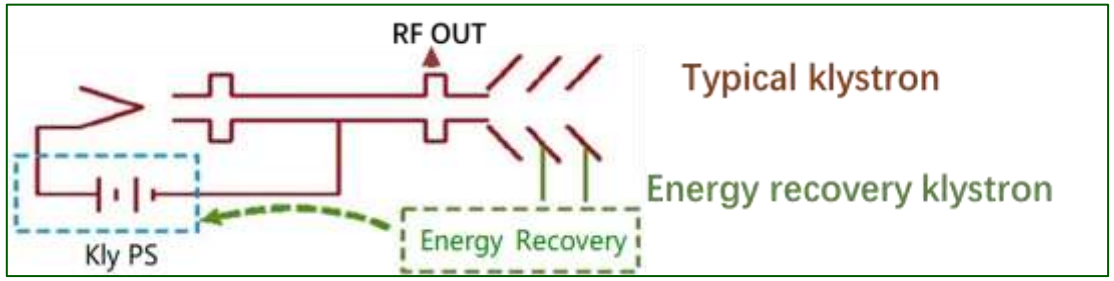


C band 5720MHz 80MW
Klystron design completed

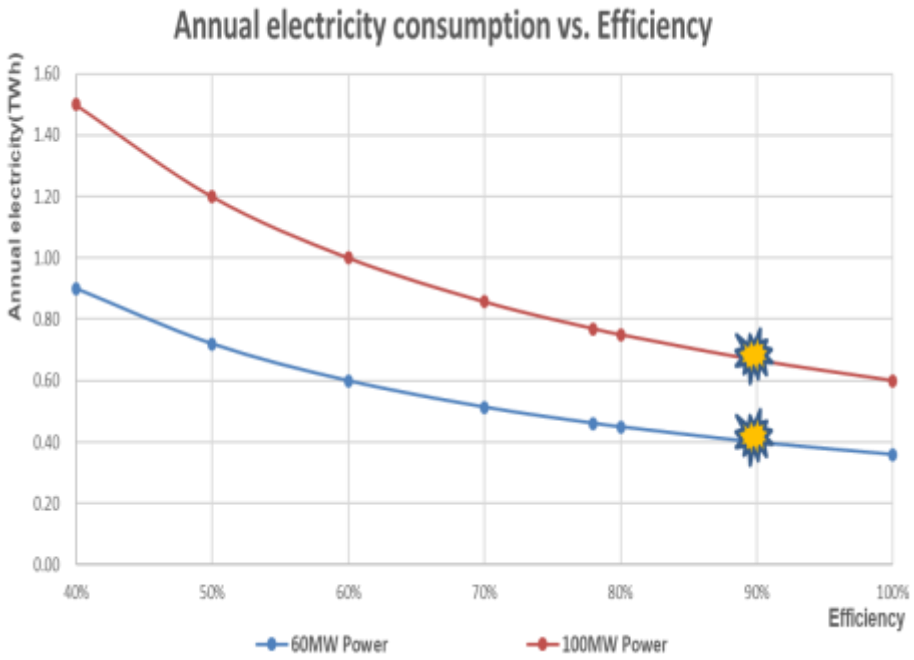
Technical assessment has been done on August 12, 2024, construction started , to be completed on 2025

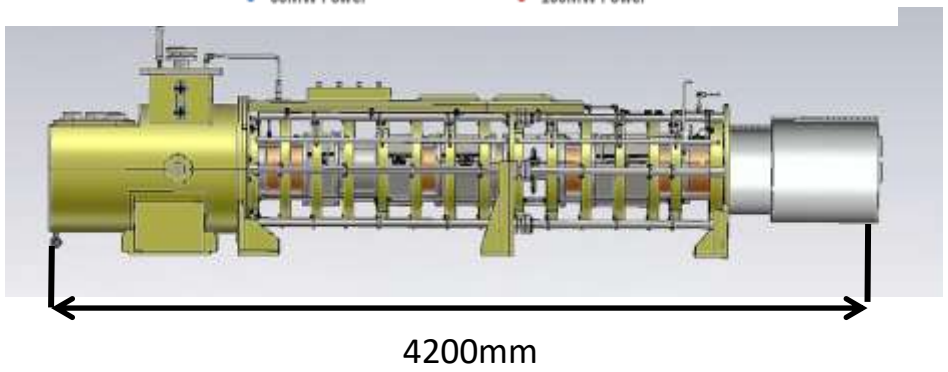
CEPC 650Mhz Energy Recovery Klystron Development

The 4th Klystron (Energy recovery, one stage)



Parameter	Value
Operating frequency	650 MHz
Beam Voltage	113 kV
Efficiency	77.5%
Output power	800 kW
Beam perveance	0.25 μP
Beam current	9.5A
Efficiency (one-stage depressed collector)	85%

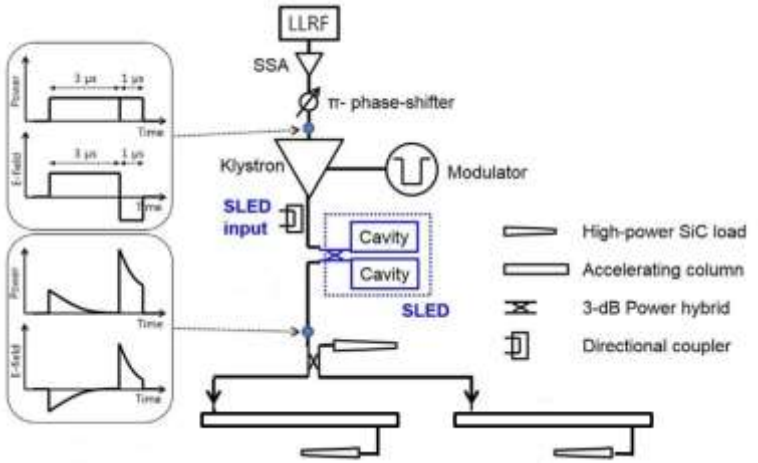


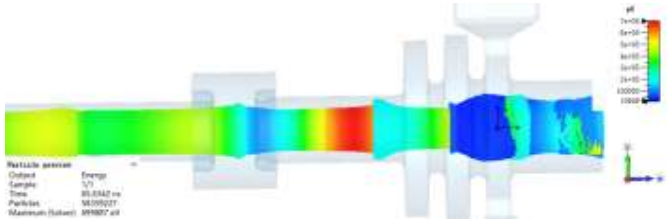


The 4th Klystron (Energy recovery, one stage) technical review has been done on July 8, 2025

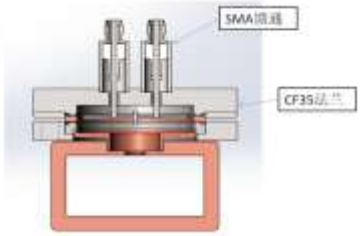
CEPC C-Band Linac Test Bench in EDR

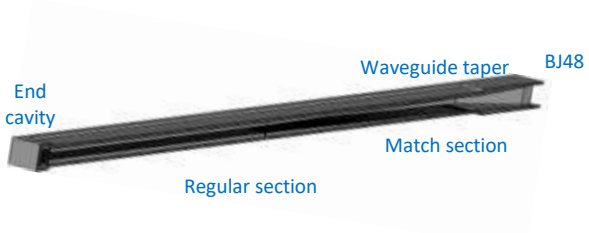
- CEPC EDR will establish the **C-band test bench** and test the components. With pulsed compressor, waveguides, directional couplers, loads, bend and straight waveguides, etc. **as a basic unit of CEPC C-band linac**
- The C-band test band is equipped with a CEPC 5720MHz 80MW power source
- The CEPC C-band test band will be completed in 2026

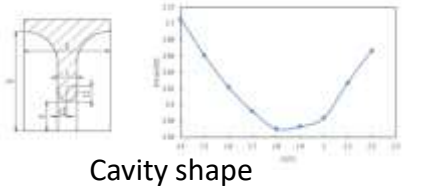




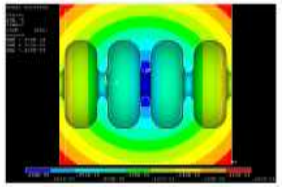
C band 5720MHz 80MW Klystron design completed, and fabrication will be completed in 2025



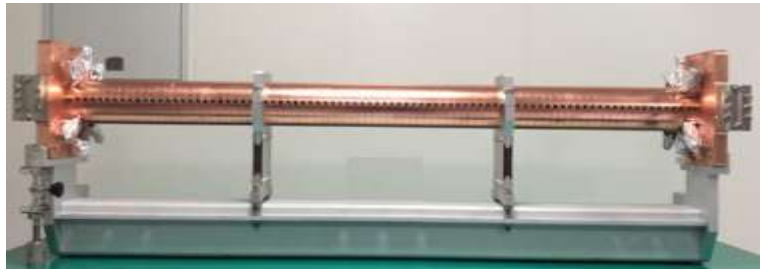


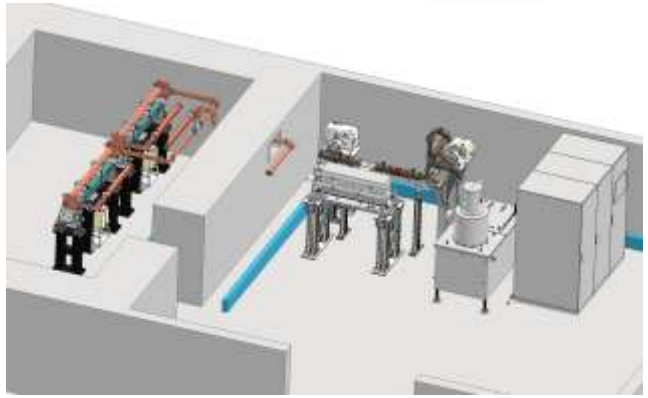


Cavity shape



The deformation caused by temperature variation

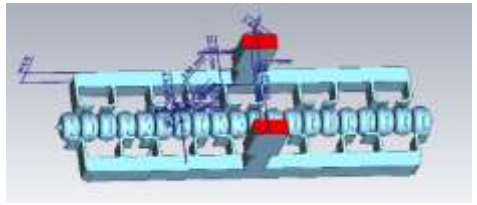


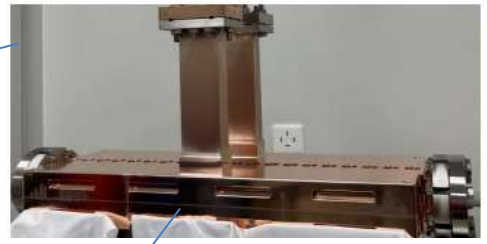


CEPC C-band linac test band will be completed in 2026

CEPC Cool Copper C-Band Linac Technology R&D

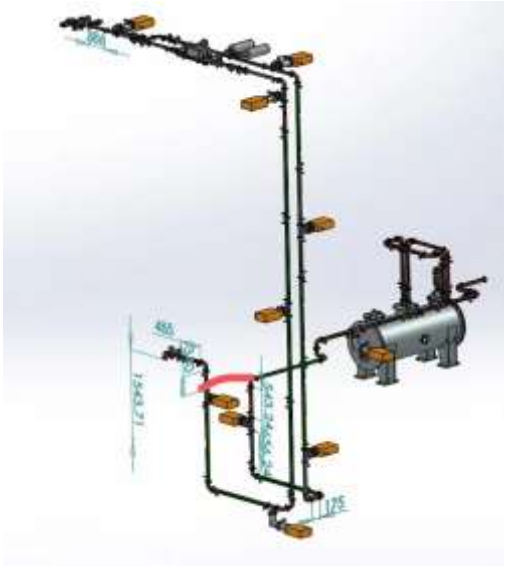
- CEPC is exploring the Cool Copper **C-band linac** technology (5712MHz is the test facility frequency)
- Two types of structures have been studied, type I and type II
- Type I has reached Eac 92.08MV/m, Q0 26162 with 20MW input (80MW input will reach Eac 199.2MV/m) (Iris diameter 5.25mm)
- Type II will reach 144MV/m with 80MW input (Iris diameter 10.49mm)



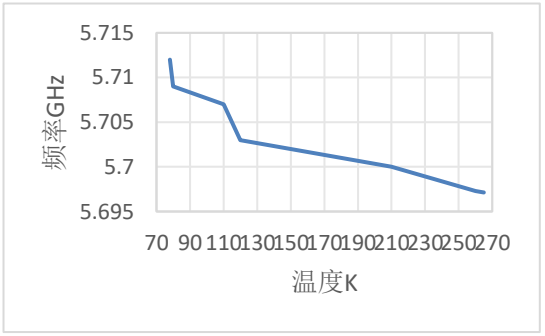


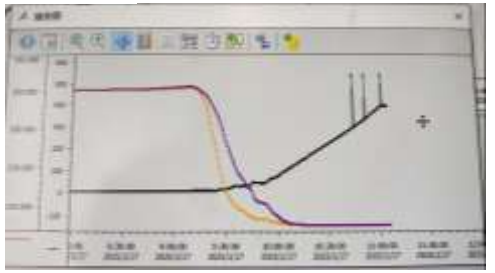
Type I: Aperture diameter 5mm, Length 0.5m

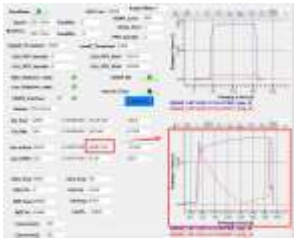
Parameters	Value
Fre (MHz)@77K	5712
Mode	Pi
Cavity numbers	20
Shunt impedance per meter(MΩ/m)@77K	303
E_s/E_0	2.42
Q_0@77K	31905

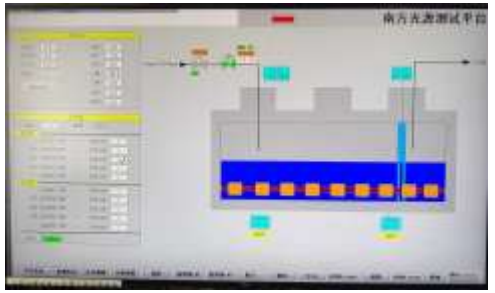


Type II: Aperture diameter 10mm, Length 1m



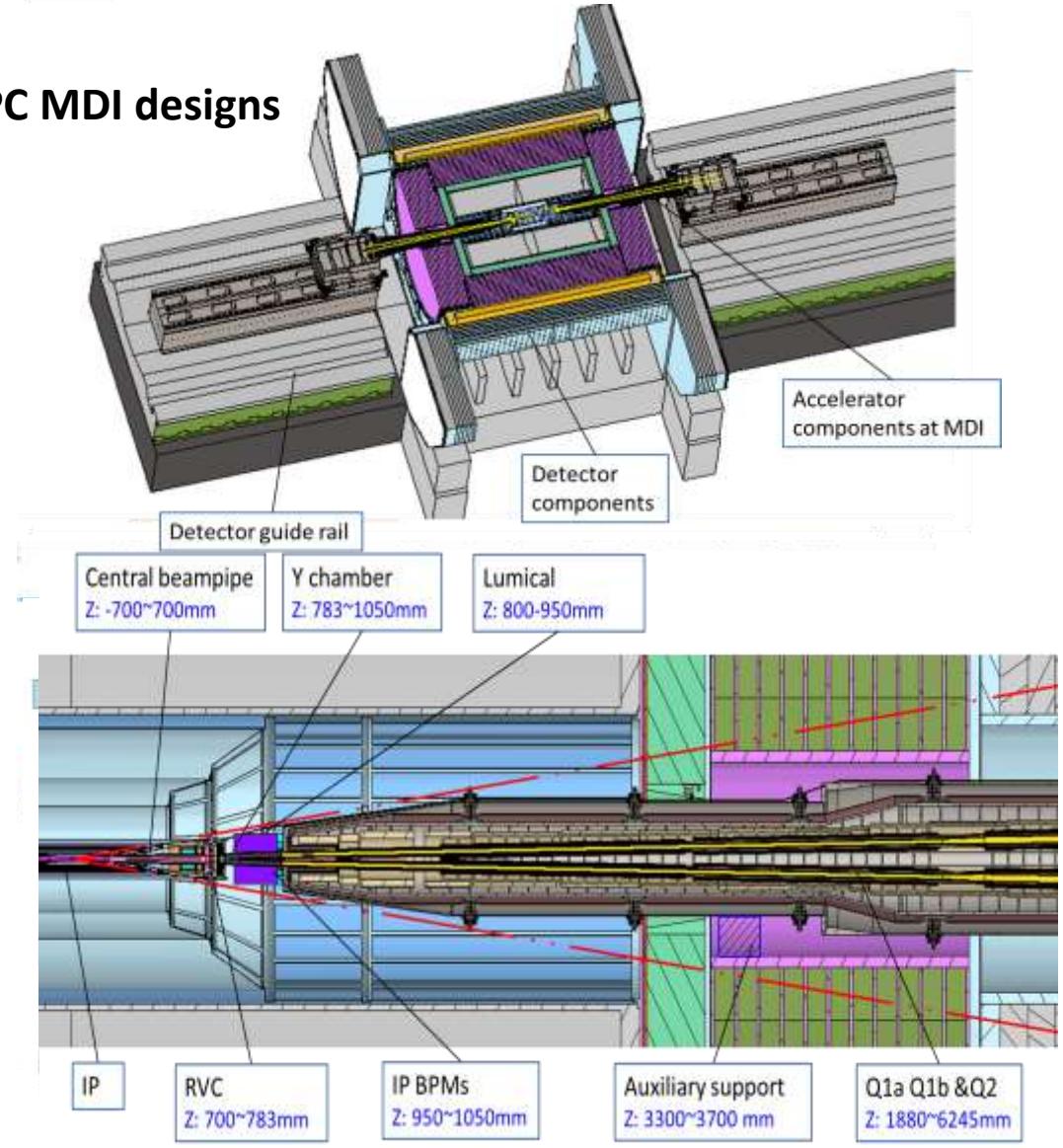






Other CEPC Accelerator EDR Activities

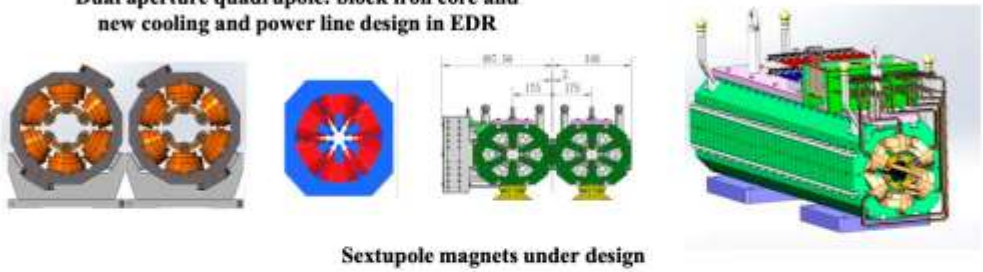
CEPC MDI designs



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



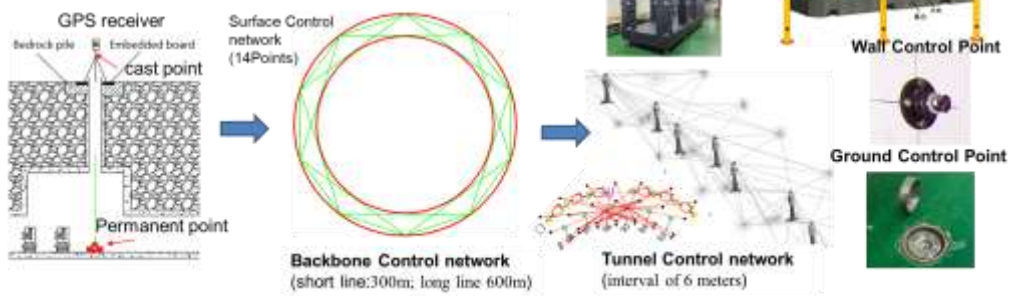
Sextupole magnets under design

CEPC Alignment and Installation Plan in EDR

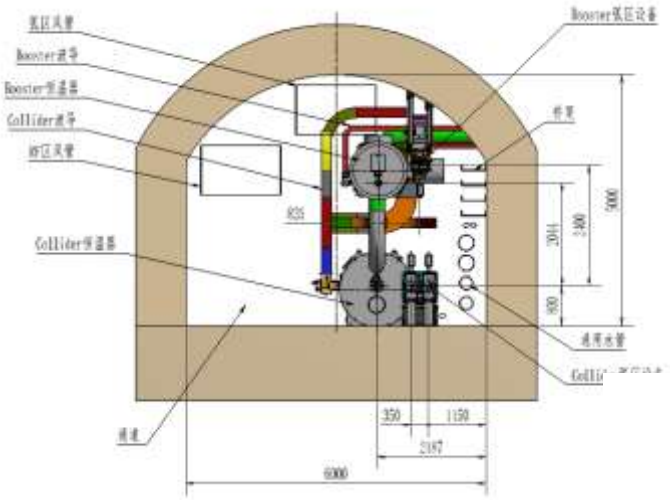
- Alignment accuracy requirement

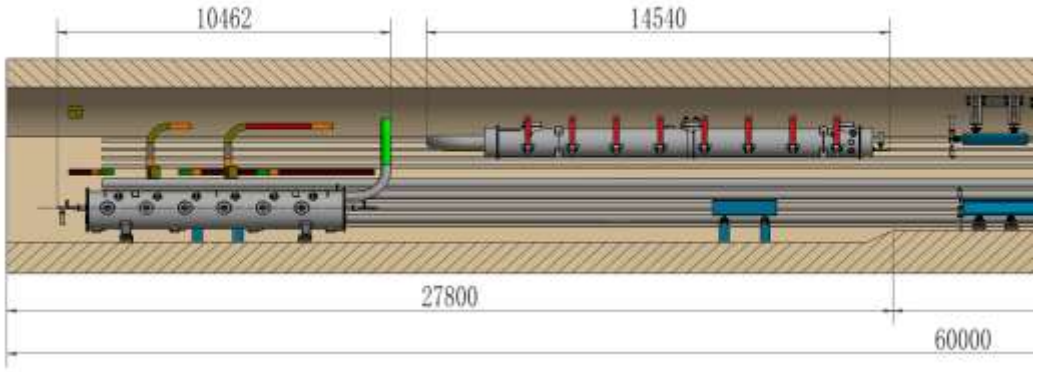
Component	Δx (mm)	Δy (mm)	Δθz (mrad)
Dipole	0.10	0.10	0.10
Arc Quadrupole	0.10	0.10	0.10
IR Quadrupole	0.10	0.10	0.10
Sextupole	0.10*	0.10*	0.10

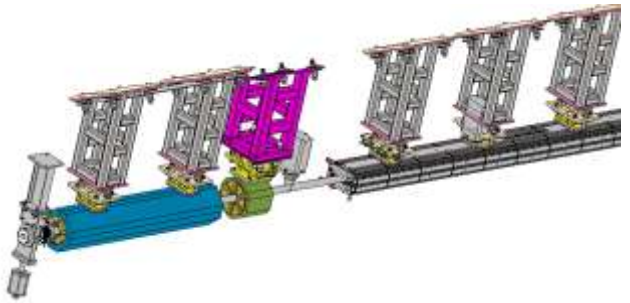
*implement beam-based alignment



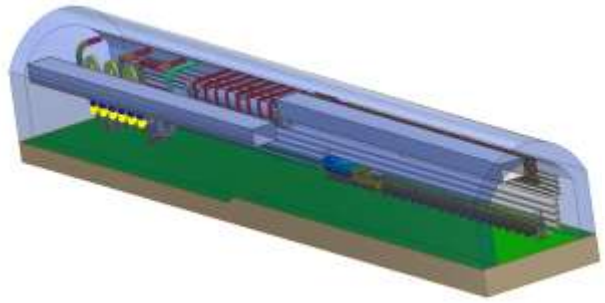
CEPC Tunnel Mockup for Installation in EDR

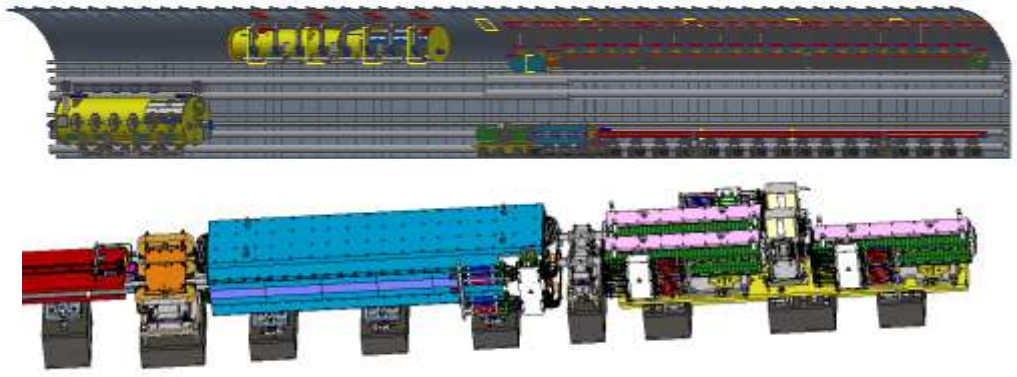


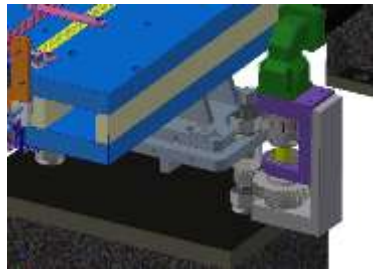


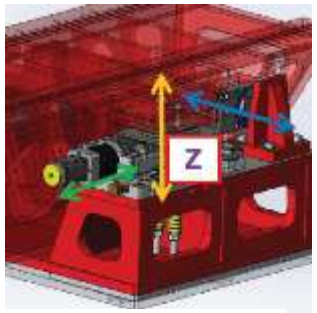


Booster magnets installation









Collider ring magnets supports

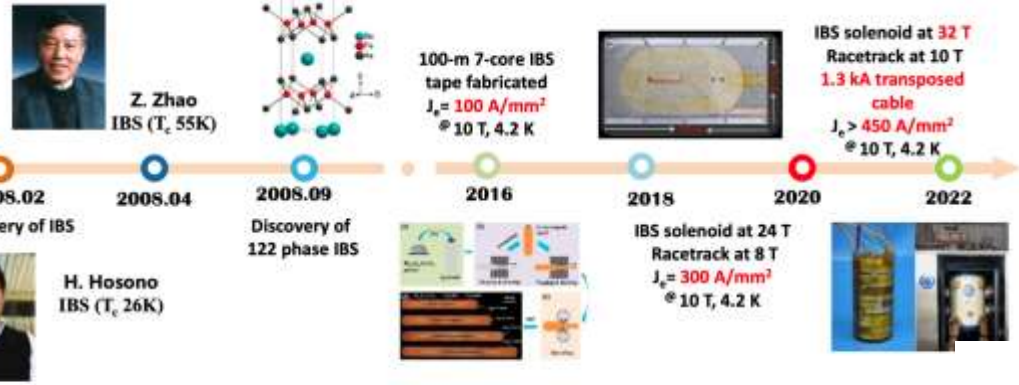
A 60 m long tunnel mockup, including parts of arc section and part of RF section

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

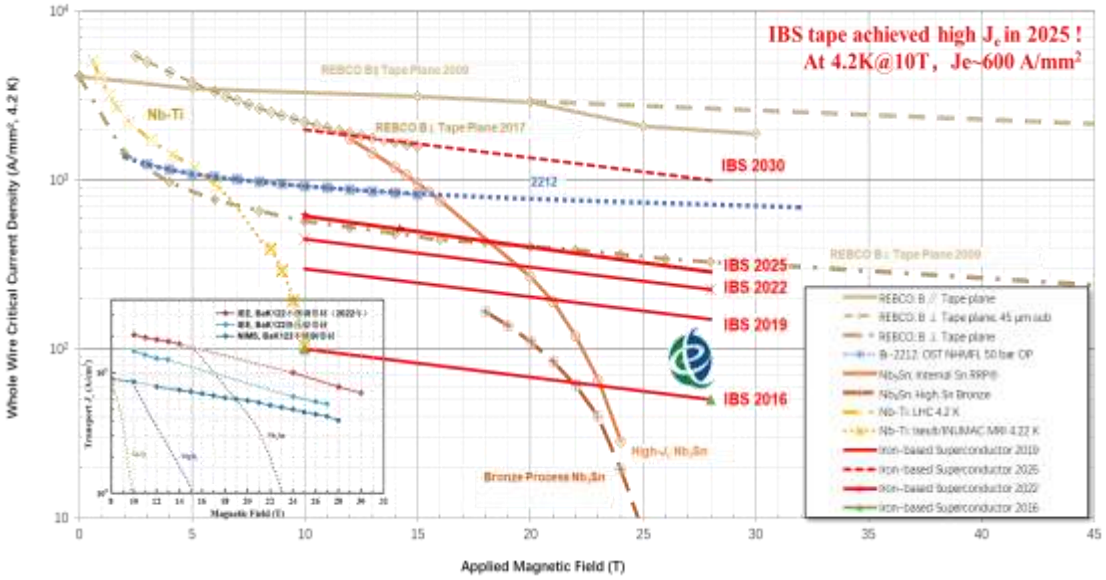
Plan：to be completed in 2026

Advanced Technologies Development in Progress

IBS Technology for High Field Magnets



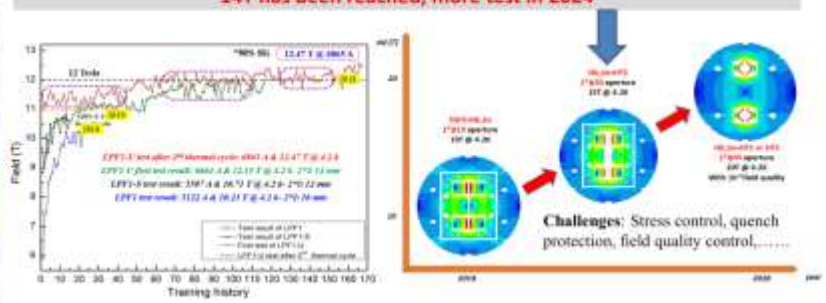
J_e of IBS expected to be similar as ReBCO in 5 years with better mechanical properties and lowe



SppC HF Magnet Development

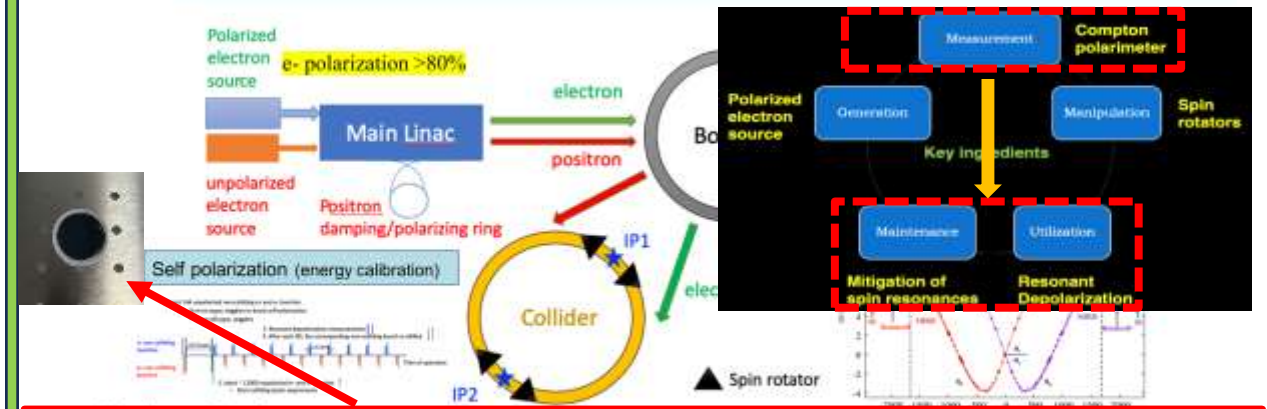
Picture of LPF1-U

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



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

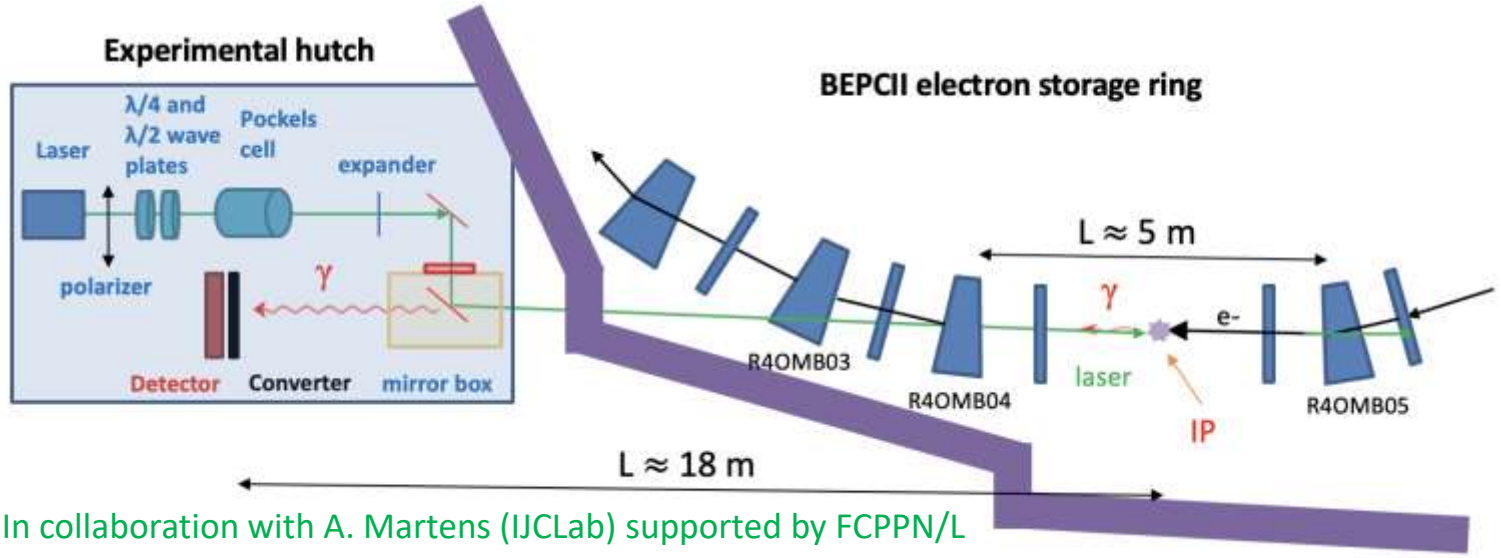
CEPC Polarized Beam Studies(alternative option)



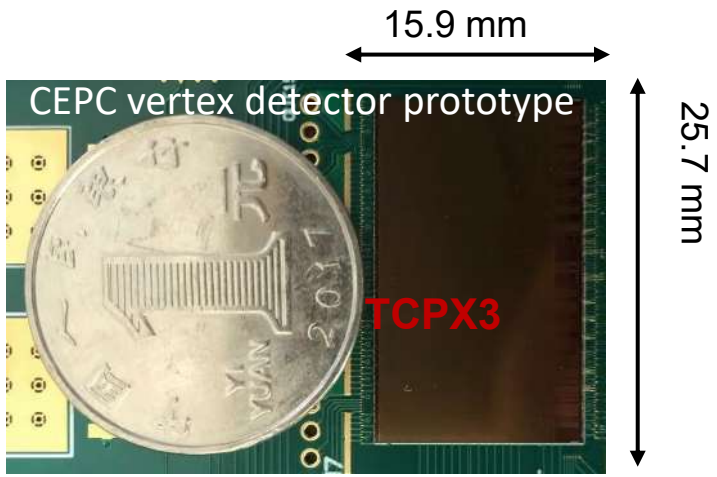
Polarized electron cathode chip (diameter ~5cm) has been fabricated in June 2025: Polarization of 85%, for 1ns laser (780nm) pulse length, several nC polarized electron charge will be obtained with the expected cathode lifetime ~6 months

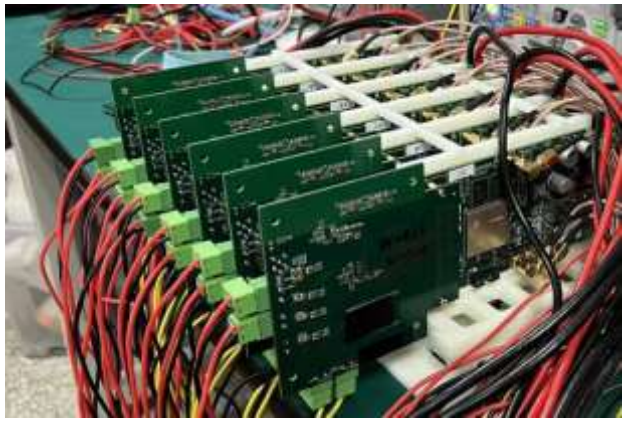
Compton Polarimeter at BEPCII-U (CEPC Polarization in Preparation Study)

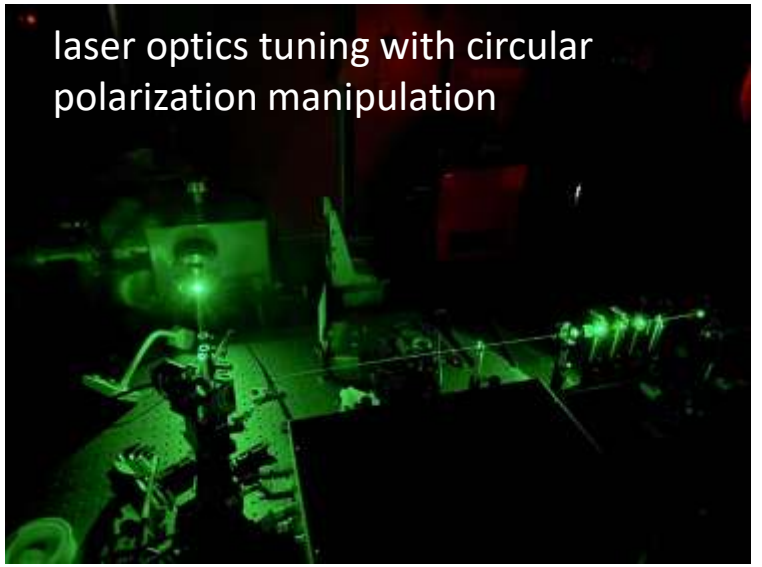
- A Compton polarimeter is now under commissioning at BEPCII-U
  - simulated performance: ~1% stats uncertainty within 20 second
  - Ready for tuning of laser-electron collision



In collaboration with A. Martens (IJCLab) supported by FCPPN/L





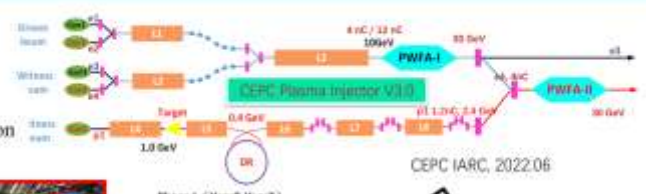


BEPCII-based PWFA Test Facility as Future Technologies

CEPC Plasma Injector (alternative option) and TF Plan

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

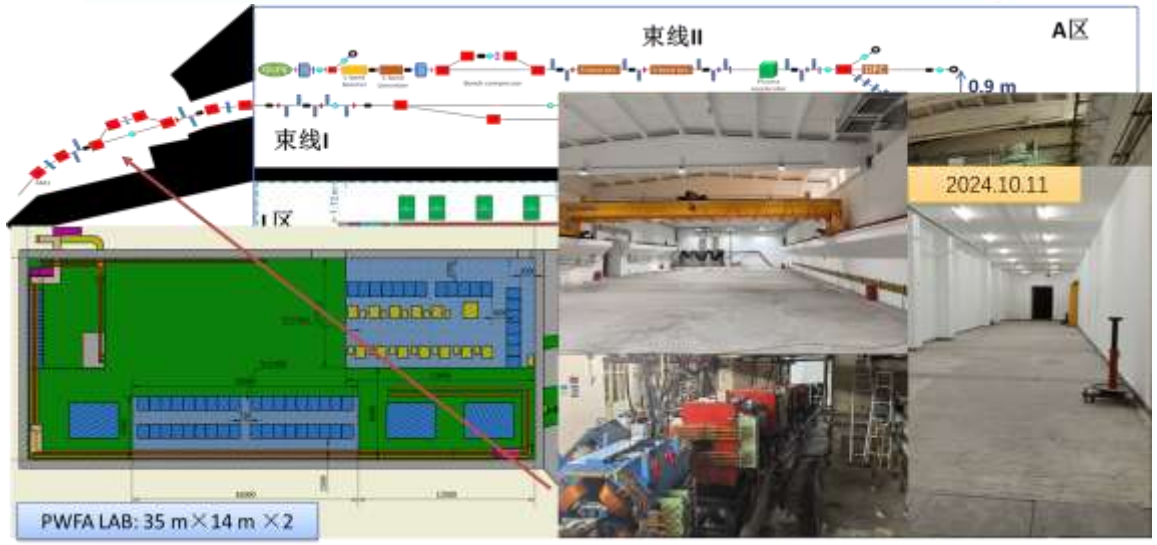
Simulation results show that it works on paper with reasonable error tolerances for both electron and positron beams injected to the booster



Phase I (Year0-Year2)
1. Re-design and install transport beamline, optimize the e- / e+ beam quality
2. Clean room and high power installation200TW
3. Beam instrumentation
4. RF Gun platform
5. Commissioning

Phase II
- Positron and electron acceleration
- Cascading acceleration
- Future linear collider technologies
- High energy beam for detector R&D
- (possible application)

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



- From 2023.09 to 2028.08
- Unique TF for e+ and cascaded PWFA

Beam quality → Beamline I

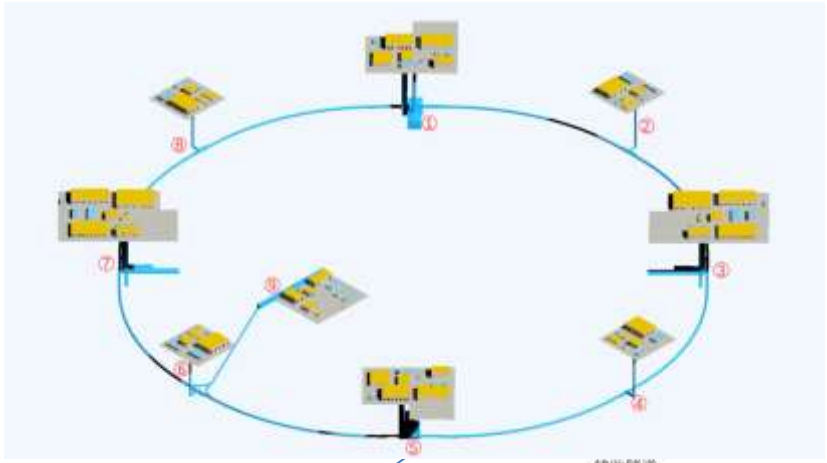
Parameters	Unit	BL-I e- (AM3)	BL-I e- (IP1)	BL-I e+ (AM3)	BL-I e+ (IP1)	BL-I e- (IP1, block)	BL-I e+ (IP1, block)
Energy	GeV	2	2	2	2	2	2
Charge	pC	2000	2000	100	100	9.4	0.2
bunch length	ps	10	1	10	1	~1	~1
Geo. emittance	mm-mrad	0.1/0.1	0.1/0.1	0.4/0.4	0.4/0.4	0.011/0.005	0.04/0.02
RMS beam size	μm	-	150/150	-	300/300	30/40	54/76

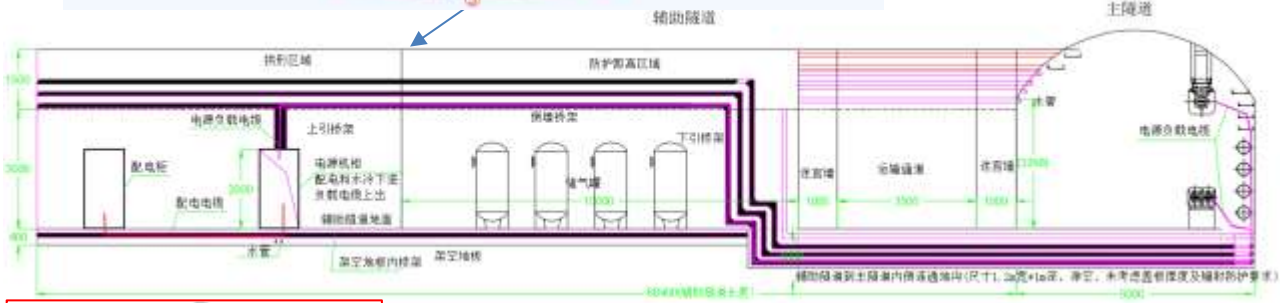
Goals: demonstration of acceleration of positron and electron beams with staging in next few years

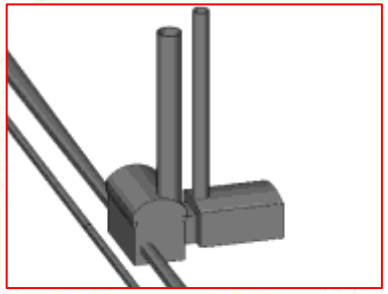
Dazhang Li, Wei Lu and Jie Gao, Research highlights on plasma-based acceleration at IHEP, AAPPS Bulletin (2025) 35:3, https://doi.org/10.1007/s43673-025-00143-z

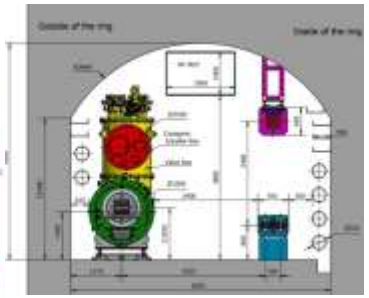
CEPC Civil Engineering and Conventional Facilities in EDR-1

CEPC general layout and auxiliary tunnel /500m along 100km

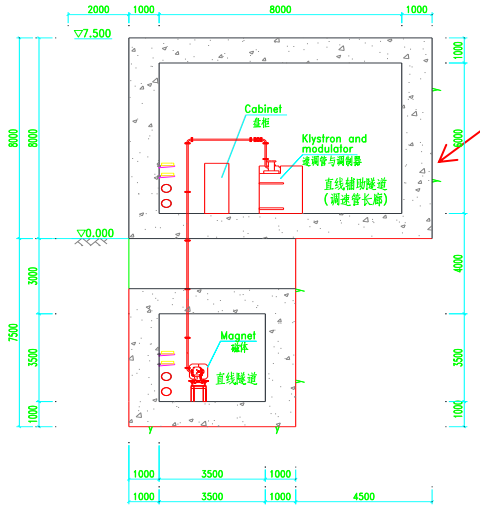


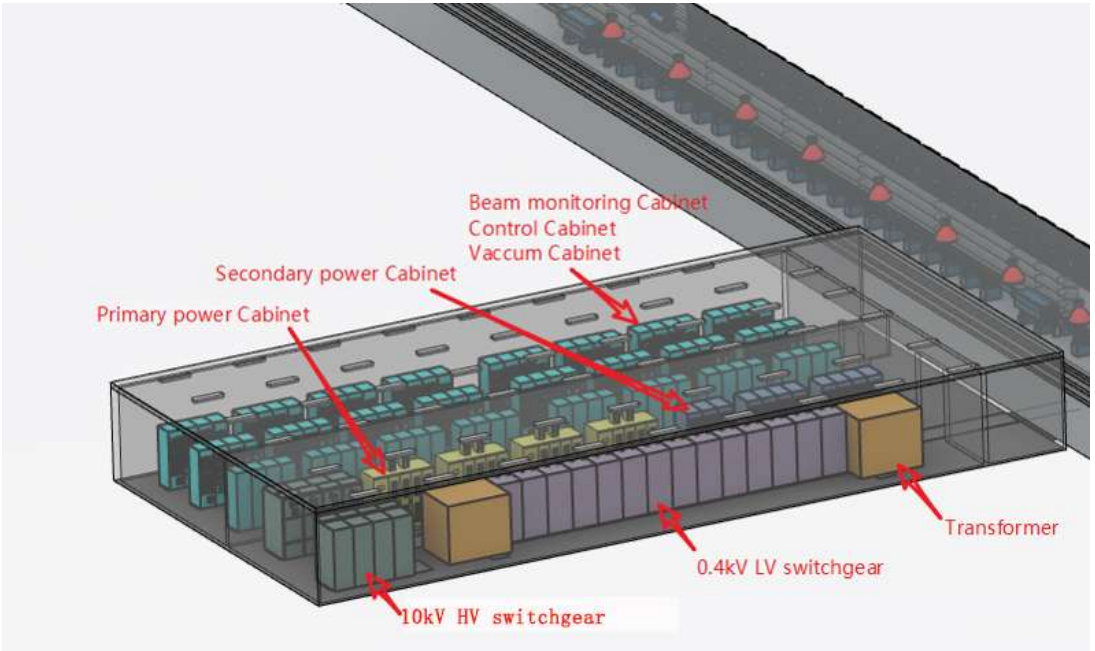






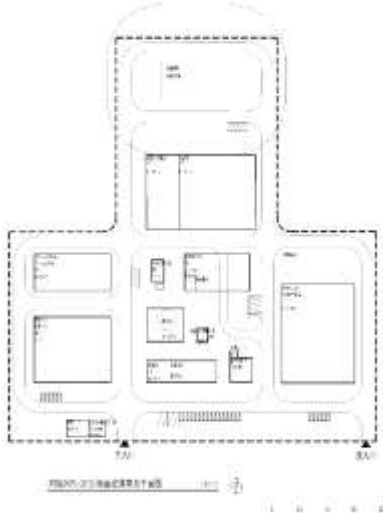
CEPC linac cross section



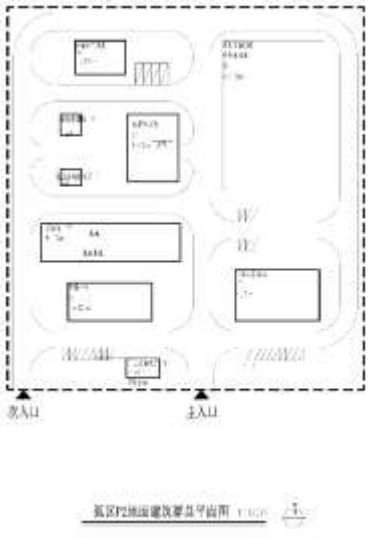


CEPC Civil Engineering and Conventional Facilities in EDR-2

CEPC general layout 100km

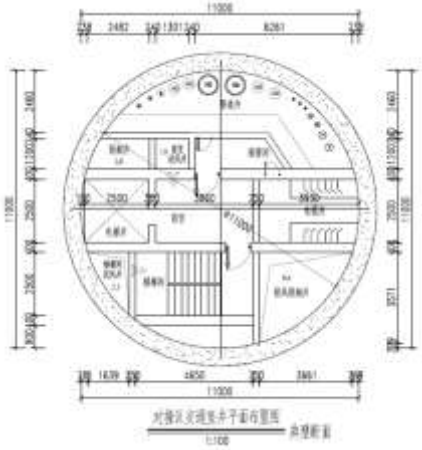


IP-1 surface building



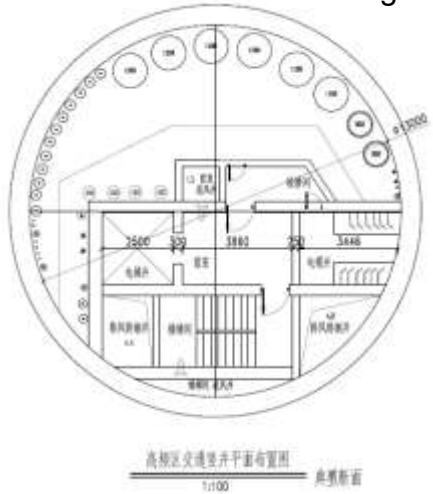
Arc shaft surface building

SRF shaft surface building



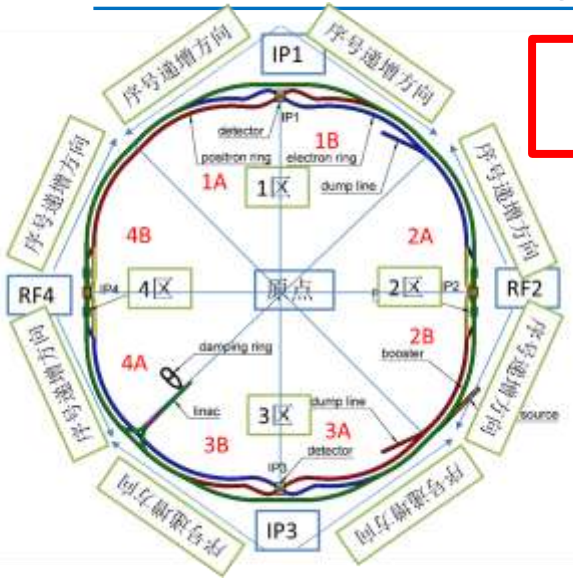
IP-1 auxiliary hall shaft

Arc shaft hall shaft



SRF shaft

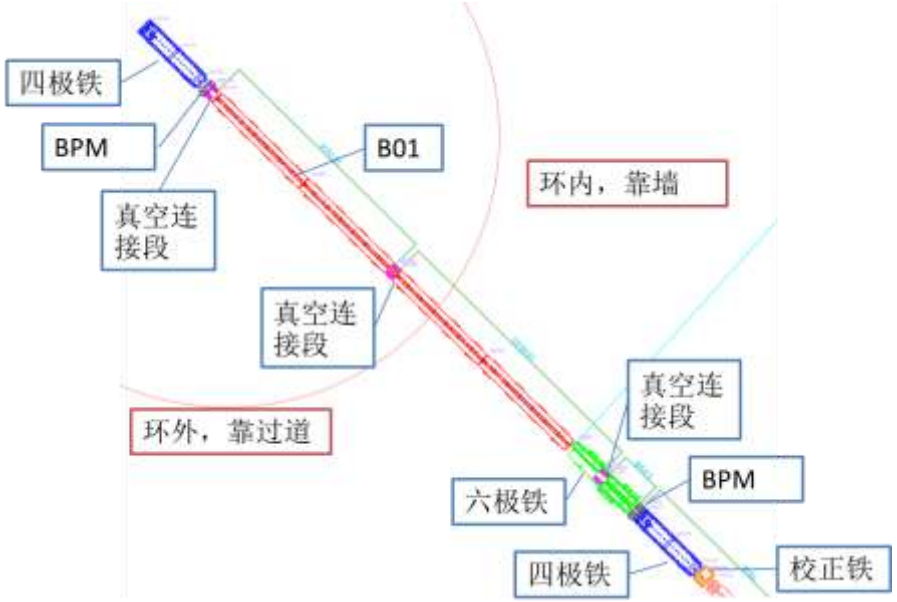
CEPC Accelerator EDR: Survey, Mechanical Design (2D/3D) Facility and component Naming System

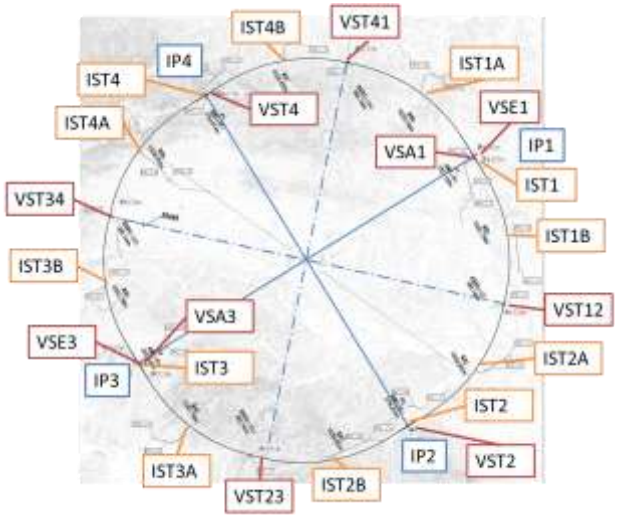


CEPC Facility components' naming sysem established

2D/3D linkage design for CEPC accelerator survey:

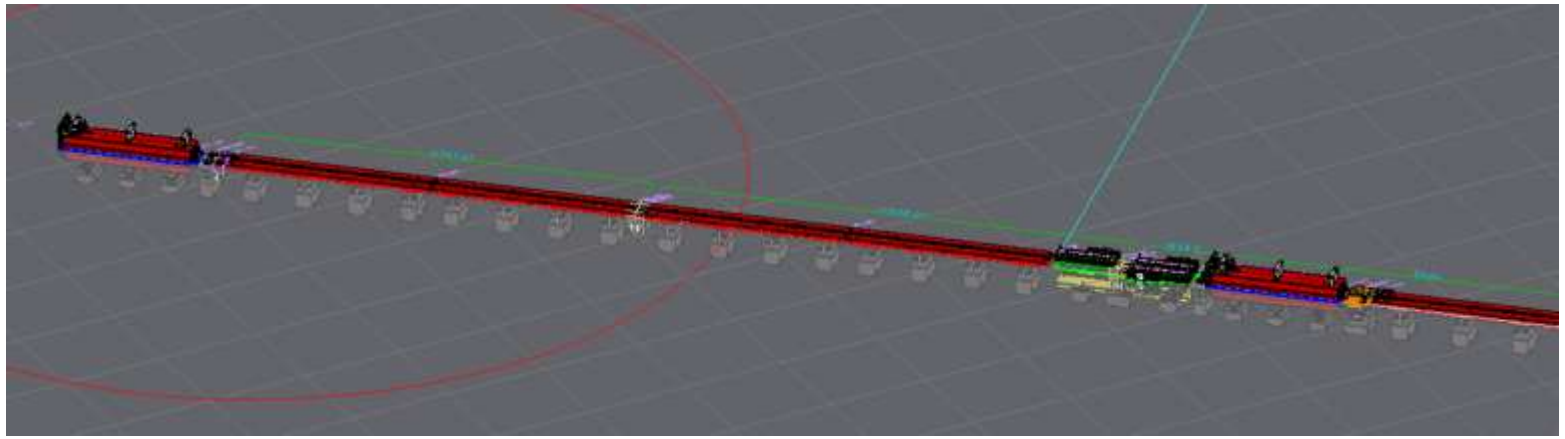
- If the 3D model is changed or replaced, the 2D model will be updated.
- If the 2D model is replaced or its location is changed, the 3D model will be updated.



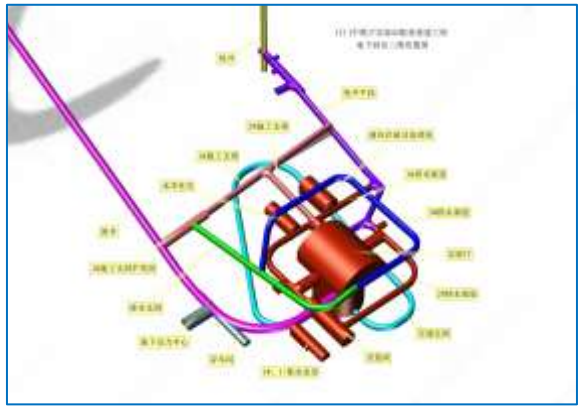


CEPC vertical shafts (10) and horizontal

Access tunnel distribution

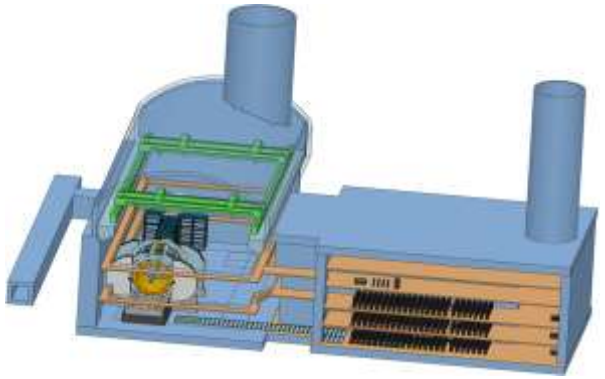


JUNO and CEPC in Synergy on Civil Engineering



JUNO will be put into operation in 2025

CEPC detector hall



JUNO detector hall:
56.25m×49m×27m
CEPC detector hall:
55.5m×31.5m×41.25m

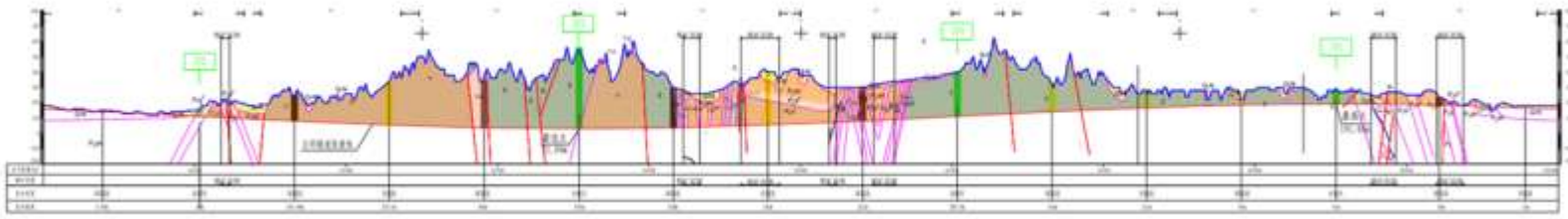
CEPC EDR Site Investigation

CEPC EDR site implementation plan

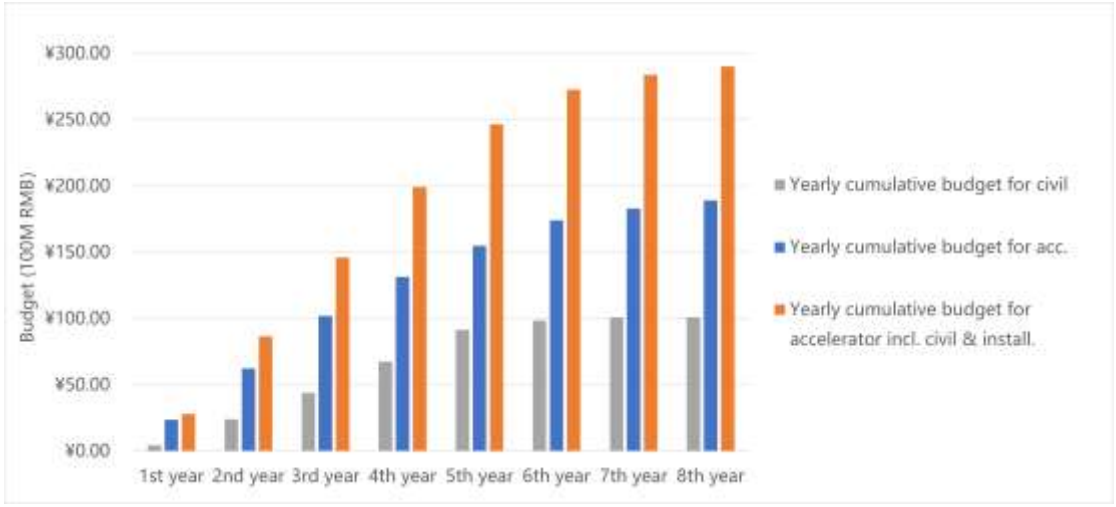
Design Stage	2024						2025						2026						2027					
	2	4	6	8	10	12	2	4	6	8	10	12	2	4	6	8	10	12	2	4	6	8	10	12
Preliminary Site Selection	Preliminary Site Selection																							
	Preliminary Site Selection Report																							
Feasibility Study (including Site Seletion & Project Proposal)				Site Selection																				
													Feasibility Study											
											Project Proposal													
Preliminary Design																								
Tender Design																								
Tender																								

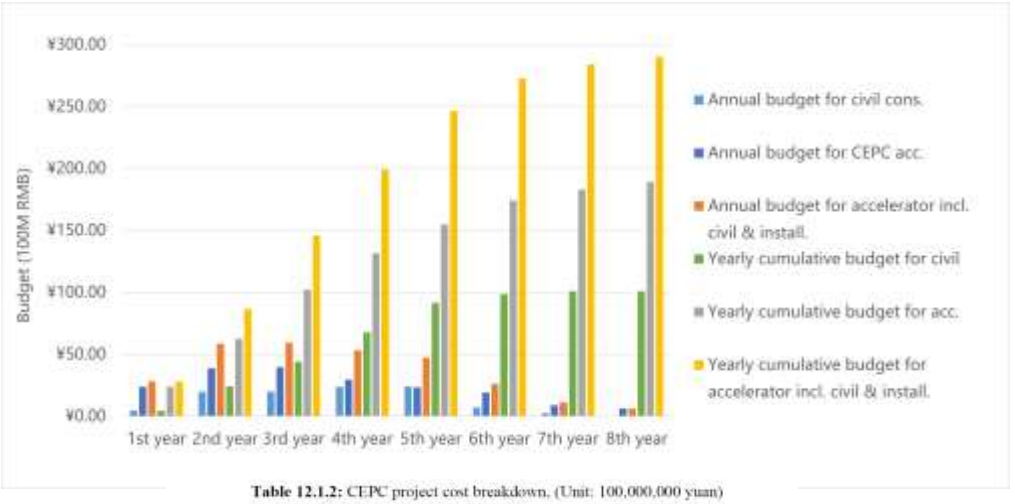
CEPC EDR site geological study has been started and the geological feasibility study will be completed in 2025

CEPC construction plan



CEPC Construction Investment Profiles





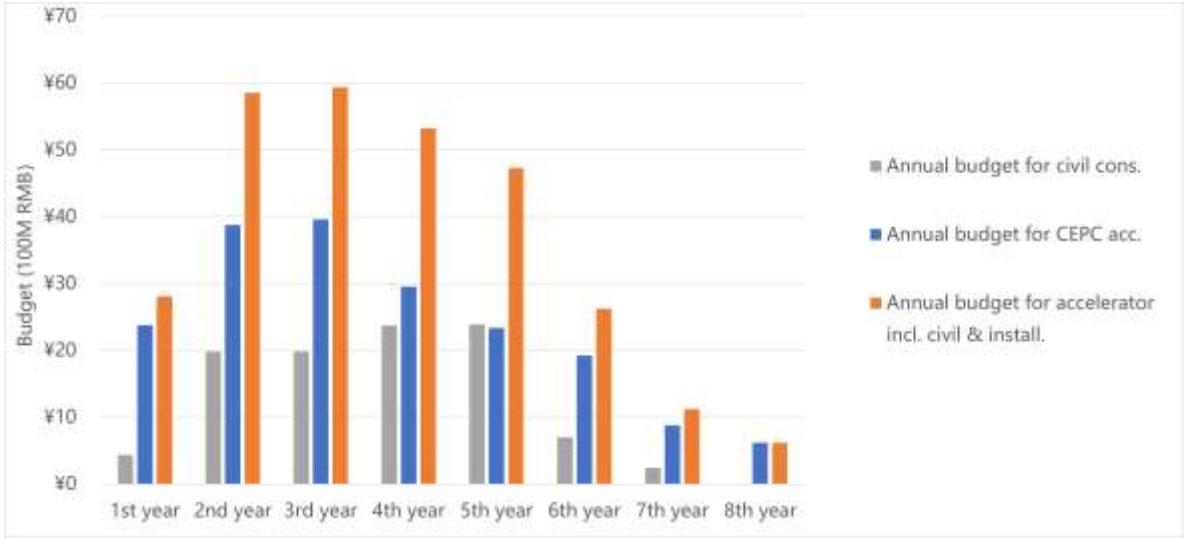
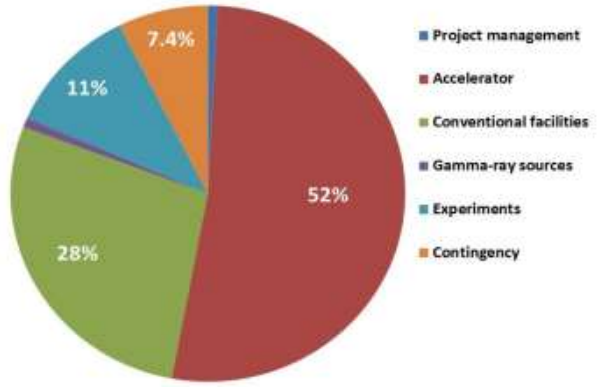


Table 12.1.2: CEPC project cost breakdown, (Unit: 100,000,000 yuan)

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)**

Green CEPC and Sustainability

- **SR power per beam: 30 MW** (CEPC-TDR p965)
  - Total electricity consumption: 262 MW
    - RF power (109 MW)
    - Magnet (58 MW)
    - Utilities (44 MW)
    - Cryogenics (11.6 MW)
    - Other auxiliary power combined (29 MW)

  } Need to improve these

- **SR power per beam: 50 MW** (CEPC-TDR p967)
  - Total electricity consumption: 340 MW
    - RF power (177 MW)
    - Magnet (58 MW)
    - Utilities (54 MW)
    - Cryogenics (11.1 MW)
    - Other auxiliary power combined (29 MW)

  } Need to improve these

Participated the 4th edition of the Sustainable High Energy Physics (HEP) workshop, May 12-15, 2025, with green CEPC and sustainability presentation and Panel discussions https://indico.global/event/4745/

On-going sustainability projects:

- High efficiency klystron:
  - 650 MHz
  - 80 MW C-band
- Permanent magnets for damping ring and transport lines
- High Q-factor SRF cryogenic-modules
- Recovery of waste heat (HEPS)
- Recovery and recycling of Helium
- Photovoltaic (PV) power generation systems (HEPS)

Prototypes have been developed addressing green collider technologies

Power efficiency, energy recycling, and clean energy generation are being addressed as comprehensive measures for sustainable operation

Publication: Dou Wang; Jie Gao; Yuhui Li; Jinshu Huang; Song Jin; Manqi Ruan; Mingshui Chen; Shanzhen Chen, "The carbon footprint and CO2 reduction optimization of CEPC", *RDMT*, https://doi.org/10.1007/s41605-025-00535-7 (2025).

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

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.

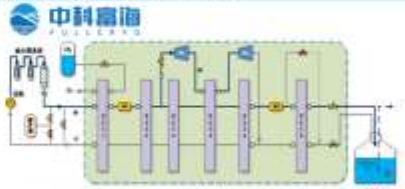
-The super large horizontal cold box with a length of 28m and a diameter of 4.2m achieves ultra-high vacuum and extremely low leakage.

-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.

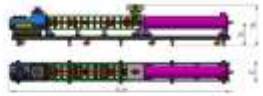


北京中科富海低温科技有限公司
Beijing Sinoscience Fullcryo Technology CO., Ltd. (CIPC member)

CEPC cryogenic system need four 14kW@4K cryogenic refrigerators
SppC needs 18kW@4.5K helium refrigerator as well

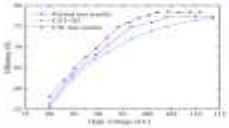
CEPC 650MHz 800kW CW High Efficiency Klystrons

国力研究院 GUOLI INSTITUTE (CIPC member)



Preliminary mechanical design for UHFKP8001

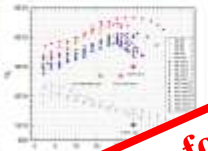
78.5%@803kW CW in August 18, 2024



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 3249MHz 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
2012 MHI
project
tons, 50% of the project
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
We had built the business relationship with many great customers such as DESY, MSU, Fermilab, IJLAB, INFN, STFC, CERN, TRIUMF, RI, ZANON, IHEP, IBS, RRCAT etc.

High RRR Nb sheet

High RRR Nb ingod

High RRR large grain Nb

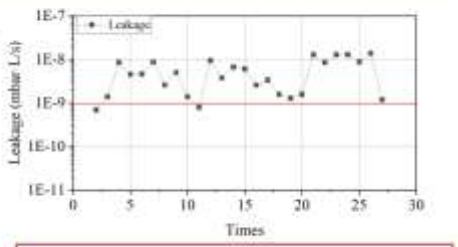
CEPC booster and colliders: 2GeV 1.3GHz and 650MHz SRF accelerators (Higgs); 10GeV 1.3GHz and 650MHz SRF accelerators (ttar)

The Key industries also for ILC and LCF in China

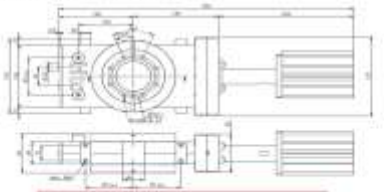
RF Shielding all Metal Gate Vacuum Valve

日揚科技

- 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 International Collaboration-1

CEPC attracts significant International participation and collaborations

CEPC 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

CEPC Detector Reference TDR report has been completed and reviewed by IDRC in April 14-16, 2025

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

CEPC International Collaboration-2

HKUST IAS23 HEP Conference, Feb. 14-16, 2023, Hong Kong

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

The 2025 HKUST IAS fundamental physics conference: Jan. 14-17, 2025, Hong Kong
https://indico.cern.ch/event/1454867/overview

CEPC Workshop EU Edition (Barcelona, Spain) June 16-19, 2025
https://indico.ifae.es/event/2054/overview

The 2026 HKUST IAS fundamental physics conference Jan. 12-16, 2026, Hong Kong

CEPC Workshop EU, April 7-10, 2026, Lisbon, Portugal

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

The 2025 international workshop on the high energy Circular Electron Positron Collider (CEPC) will be held from Nov. 6-10, 2025, Guangzhou, China
https://indico.ihep.ac.cn/event/25300/

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

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

FCPPNL, Qingdao, China, July 21-25, 2025
https://indico.ihep.ac.cn/event/25400/

CEPC in ESPPU 2026

Physics Preparatory Group

Karl Jakobs (chair)	**Xinchou Lou (IHEP)**
Gianluigi Arduini	Fabio Maltoni
Thomas Bergauer	Jocelyn Monroe
Tommaso Boccali	Hugh Montgomery
Anadi Canepa	Rogerio Rosenfeld
Cristinel Diaconu	Mike Seidel
Pilar Hernandez	Yuji Yamazaki
Gino Isidori	

CEPC-SppC participate actively in the 2026 update of the European Strategy for Particle Physics (ESPPU 26) with two input documents:

1) **The Circular Electron Positron Collider (CEPC)**
   An input to the European Strategy for Particle Physics - 2026 update
   Contact persons: **Jie Gao, Miao He, Dou Wang, and Jianchun Wang**

2) **High Performance and Cost Effective Superconducting Accelerator Magnet R&D at IHEP**
   Contact persons: **Chengtao Wang, Rui Kang, Chunyan Li, Yingzhe Wang, Juan Wang and Qingjin Xu**

Open Symposium on the European Strategy for Particle Physics
June 23-27, Venice, Italy
June 24
14:30 - 15:05 **Yifang Wang (IHEP Beijing)**
Status of CEPC in China
Sala Perla, Palazzo del Casinò

https://agenda.infn.it/event/44943/overview

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

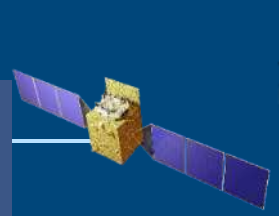
The total cost of the accelerator projects under construction:39B RMB more than CEPC cost of 36.4B RMB

Relevant accelerator human resources and industrial capabilities in China could be measured in relation with these massive investments

CEPC Host Lab IHEP and its Large Science Facilities

HERD (2027) on Chinese Space Station

HXMT
Insight Hard X-ray Modulation Telescope



GECAM
Gravitational wave EM Counterpart All-sky Monitor

Huairou Campus

HEPS High Energy Photon Source

YBJ (retired)
International Cosmic Ray Observatory

IHEP, Beijing Campus

BEPC Beijing Electron-Positron Collider

IHEP Plasma Accelerator Test Facility

Jinan Campus

HUNT, underwater in south China Sea

AliCPT
Ali CMB Polarization Telescope

LHAASO
Large High-Altitude Air Shower Observatory

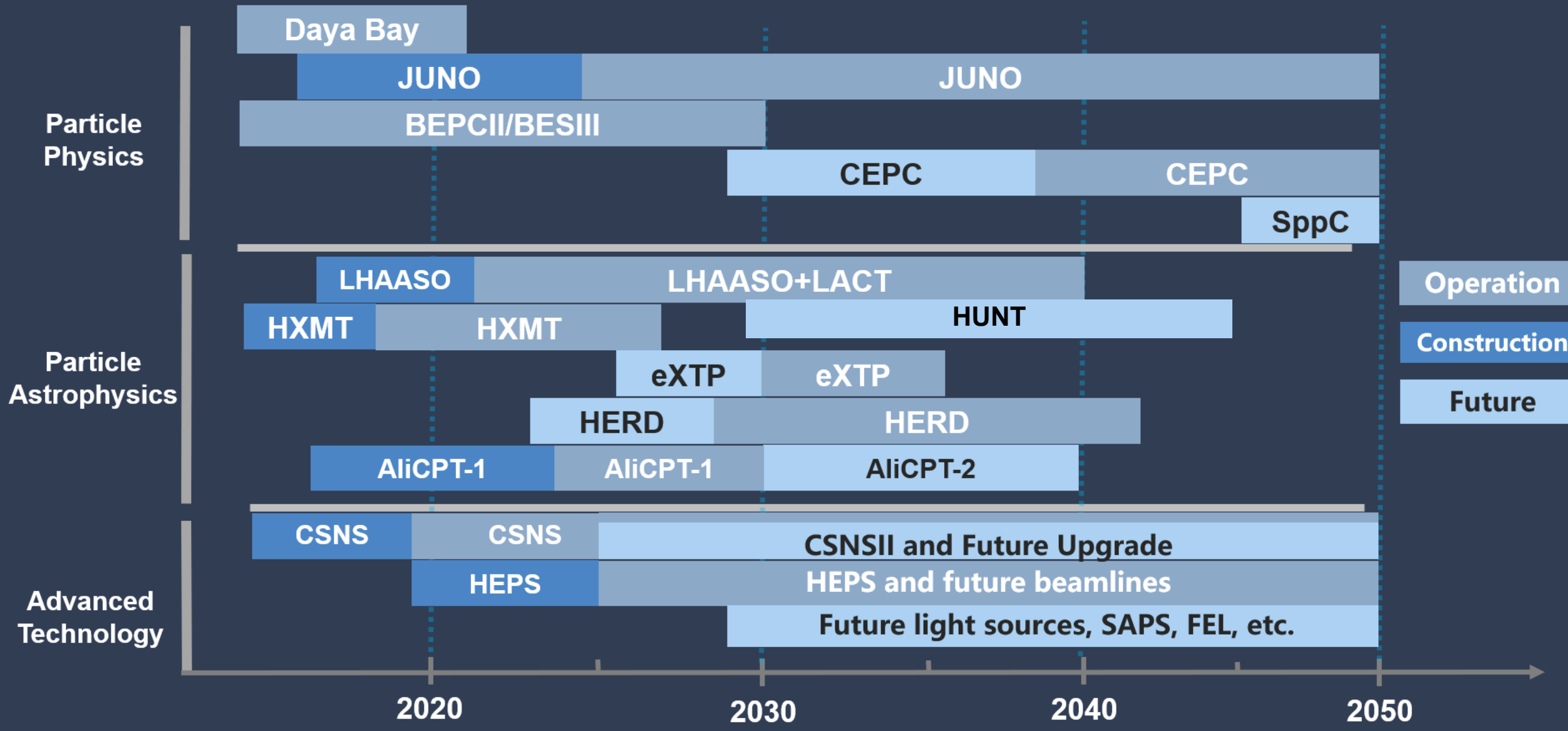
Daya Bay (retired)
Daya Bay reactor Neutrino Experiment

JUNO
Jiangmen Underground Neutrino Observatory

Dongguan Campus

CSNS China Spallation Neutron Source

Road Map of CEPC Host Lab: IHEP



CEPC Proposal Preparation (2025) and Beyond

CEPC/SppC inputs to EPPSU2026 have been submitted, and CEPC/SppC delegation will participate to the "Open Symposium on the European Strategy for Particle Physics", June 23-27, Venice, Italy

Concerning CEPC entering construction preparation phase 2026-2027, CEPC civil engineering design based on EDR site and geological conditions will be put to high priority with components' industrial mass production and installation preparations

CEPC accelerator overall survey, components' naming system, electronic management system (DeepC), BIM design, and AI applications in all CEPC systems, etc. have been started…

The CEPC Proposal (in Chinese) will be submit to China's "15th five-year-plan" process in 2025, and a draft has been completed in June 2025, about 1000 pages

Enhanced international/national collaborations and preparation for establishment of the construction team, long term personnel training, CEPC headquarter at EDR site will be put forward in close collaboration with local government

Recruitments information:
https://www.physicsworldjobs.com/job/22036/recruitment-of-overseas-high-level-talent/

Summary

- BEPCII@1.89GeV has reached luminosity of $1*10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ during routine operation. BEPCII-U@2.35GeV will reach luminosity of $1.1*10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$. BEPCII-U is under commissioning from March 2025.
- 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 (arXiv：2312.14363) 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 .
- **CEPC accelerator EDR including EDR site geological investigation and civil engineering design have progressed well with corresponding EDR funds and EDR human resources available**
- **CEPC detector reference design report has been reviewed by IDRC in April 2025.**
- **EDR site selection and geological feasibility studies have been started and completed in 2025.**
- Detailed preparation of **CEPC EDR** phase (**2024-2027**) before construction working plan and beyond have been established and executed 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 is an international project and international collaborations and participations are warmly welcome.**

Acknowledgements

Thanks go to BEPCII, BEPCII-U, HEPS and CEPC-SppC team's hard works, international and CIPC collaborations

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

Thanks for your attention