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

CEPC EDR Plan and Scope

Jie Gao

IHEP

9th Meeting of the CEPC-SppC International Advisory Committee
October 31, 2023, IHEP, Beijing

Contents

- Introduction
- CEPC Accelerator Design and Key Hardware R&D in TDR as Start of EDR
- CEPC EDR Goals, Plan and Scope
- CEPC Accelerator Human Resource Requirement for Construction
- CEPC Site Implementation in EDR and Construction Plans
- CEPC Industrial preparation and international collaboration in EDR
- Summary

CEPC Accelerator TDR Conditions to Start EDR

CEPC Engineering Design Report (EDR) phase will start from January 2024 based on CEPC accelerator Technical Design Report (TDR) in terms of:

a) CEPC accelerator TDR design (with required energy and luminosity goals and upgrade possibilities…)

b) CEPC accelerator key technologies in hands through TDR R&D (internationally reviewed)

c) CEPC accelerator TDR cost understood and internationally reviewed

d) Site selections and civil engineering design in TDR (three sites have been cost reviewed)

e) CEPC accelerator TDR team established

f) Industrial participation in TDR

g) International collaboration in TDR

h) …

CEPC Accelerator EDR General Goals towards Construction

CEPC Engineering Design Report (EDR) phase will end around 2027 when CEPC construction starts (hoped) by completing following key issues during EDR:

a) CEPC accelerator EDR design (complete and coherent with required goals and update possibilities…)

b) CEPC accelerator construction technologies in hands through EDR for industrialization and production in addition to international procurement and in kind contributions.

c) Site selection converges to one EDR construction site with site dependent geological and civil engineering design, and environment assessment…

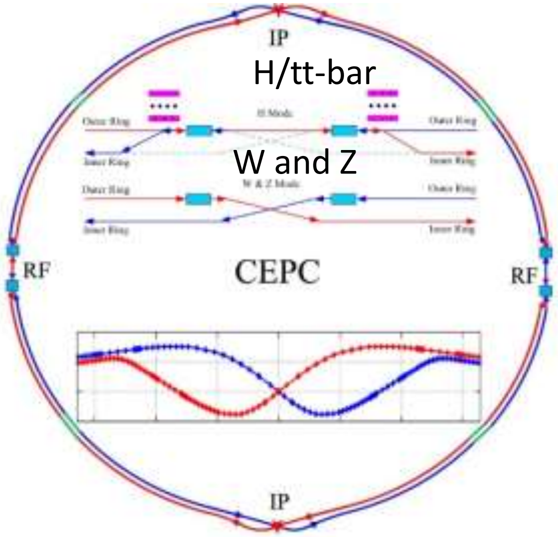
d) CEPC accelerator EDR team evolutes to the construction starting team with good understanding CEPC EDR cost, construction human resources, risks and risk mitigation measures

e) Industries prepared for staring the construction, such as magnets' automatic fabrication lines…

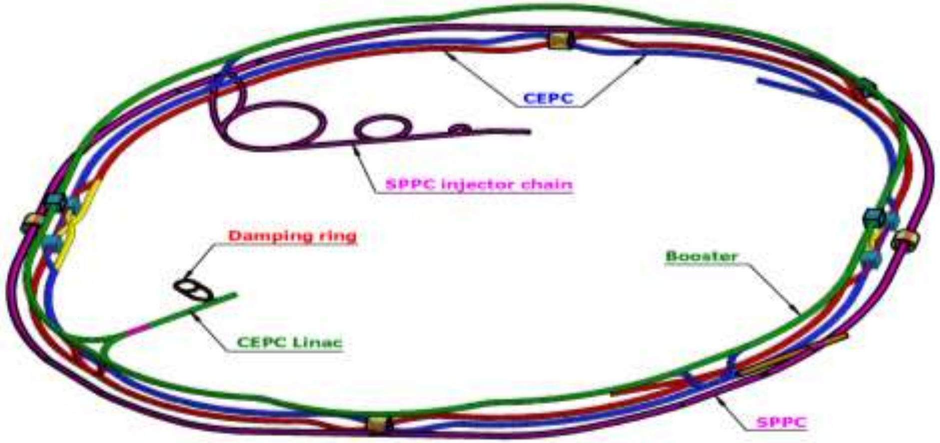
f) Complete the "CEPC PROPOSAL" around 2025 for the application to government for the CEPC be selected as construction project in the "15th five year plan" (2026-2030) and ready for construction.

CEPC Higgs Factory and SppC in TDR and EDR

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

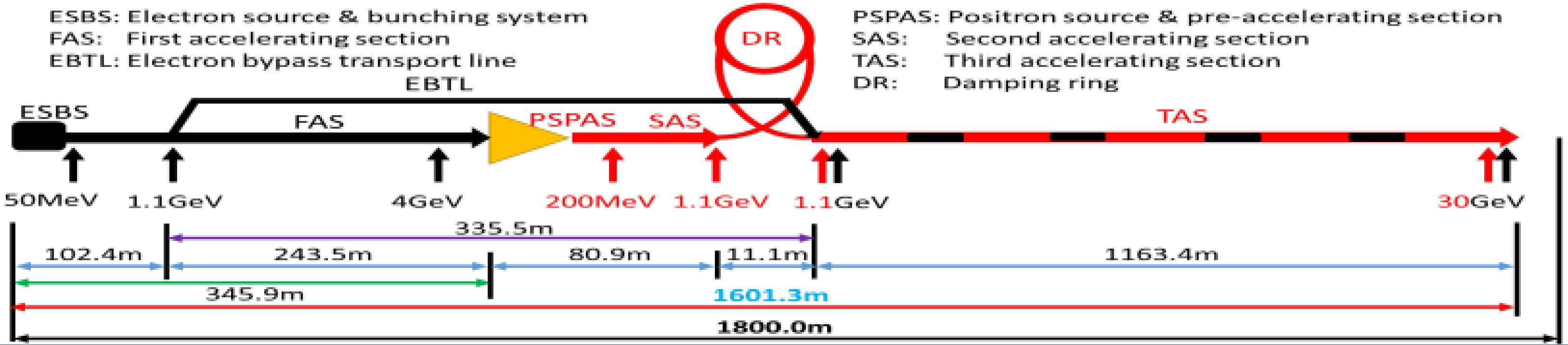


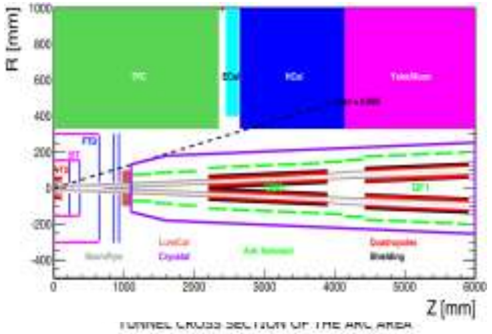
CEPC collider ring (100km)

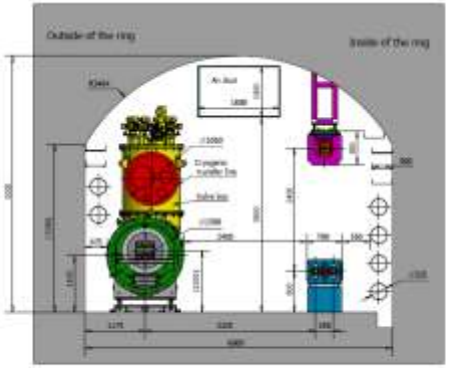


CEPC booster ring (100km)

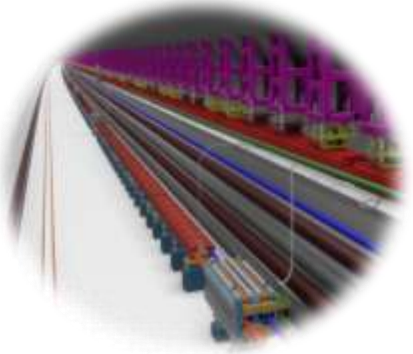
CEPC TDR S+C-band 30GeV linac injector







CEPC Civil Engineering



CEPC TDR (EDR) Accelerator System Parameters

Linac

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

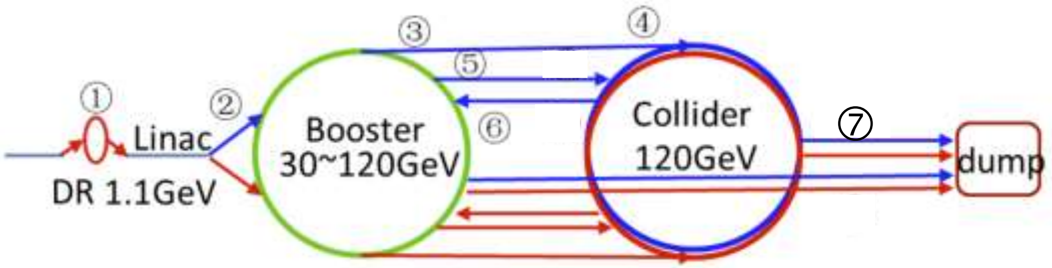
Booster

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

Collider

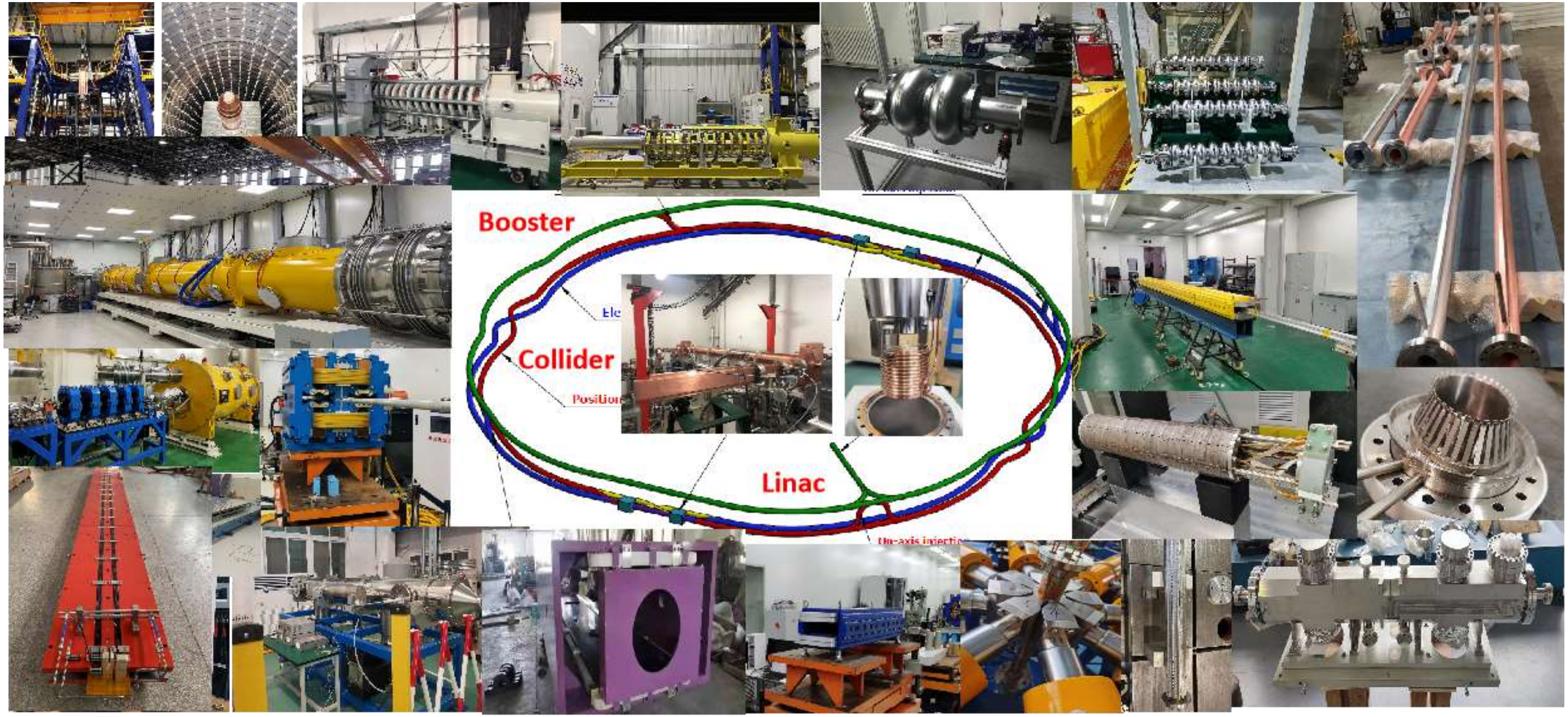
	Higgs	Z	W	$t\bar{t}$
Number of IPs	2			
Circumference (km)	**100.0**			
SR power per beam (MW)	**30**			
Energy (GeV)	**120**	**45.5**	**80**	**180**
Bunch number	268	11934	1297	35
Emittance $\varepsilon_x/\varepsilon_y$ (nm/pm)	0.64/1.3	0.27/1.4	0.87/1.7	1.4/4.7
Beam size at IP σ_x/σ_y (um/nm)	14/36	6/35	13/42	39/113
Bunch length (natural/total) (mm)	2.3/4.1	2.5/8.7	2.5/4.9	2.2/2.9
Beam-beam parameters ξ_x/ξ_y	0.015/0.11	0.004/0.127	0.012/0.113	0.071/0.1
RF frequency (MHz)	650			
Luminosity per IP (10^{34} cm^{-2} s^{-1})	**5.0**	**115**	**16**	**0.5**

Transport line



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

CEPC Key Technology R&D+Costing in TDR



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

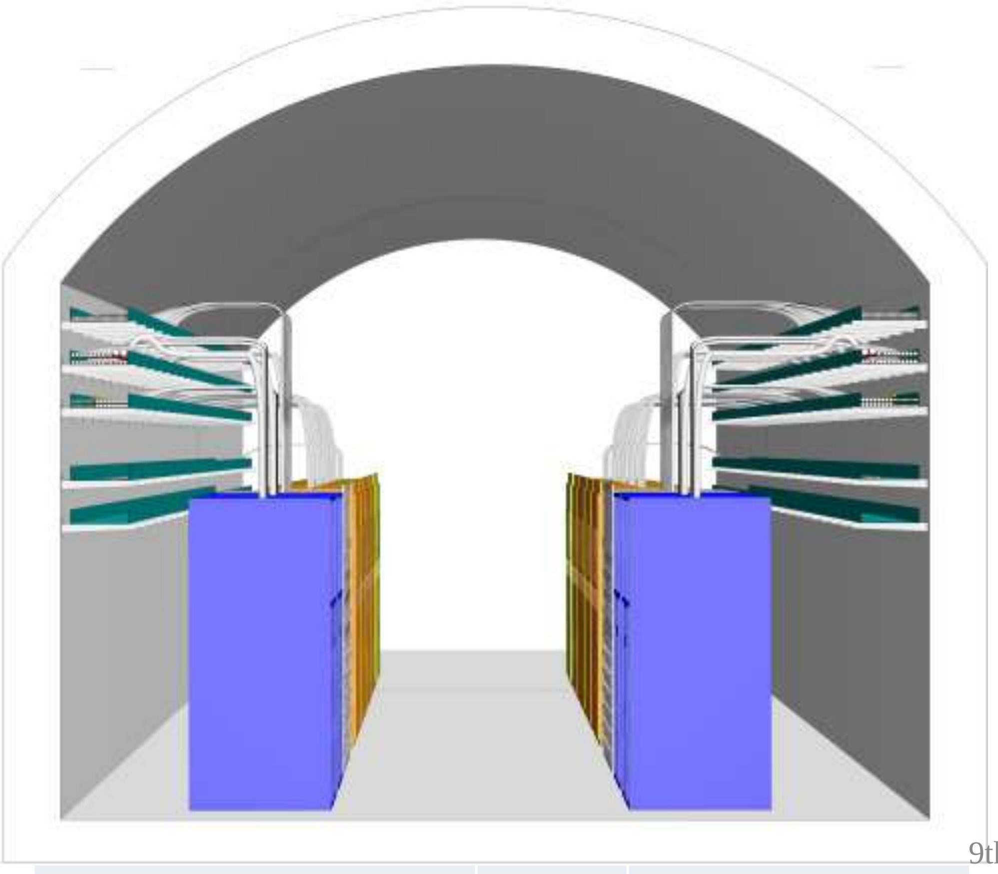
Power Consumption of CEPC - Higgs

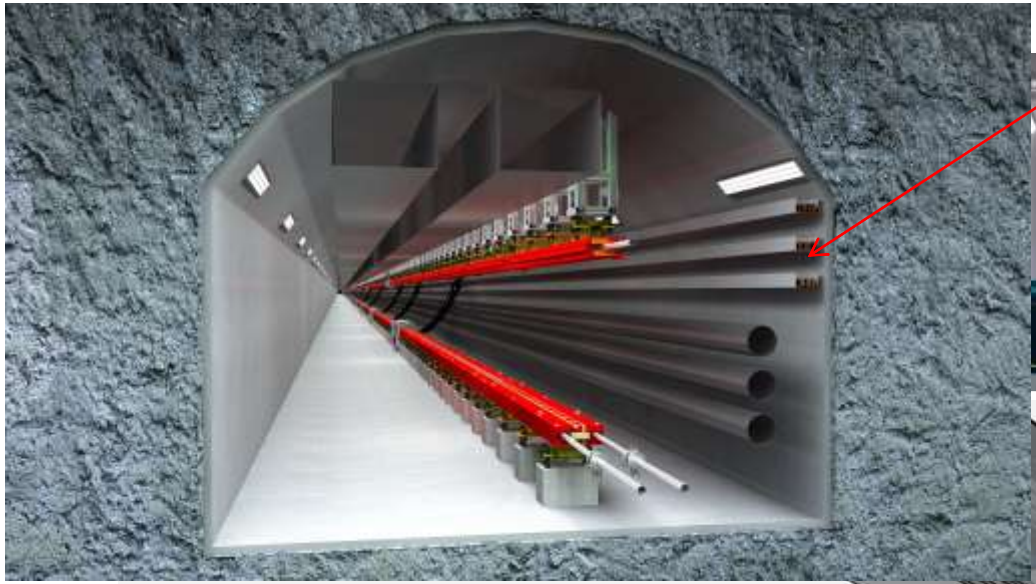
SN	System	Higgs 30MW							Higgs 50MW						
		Collider	Booster	Linac	BTL	IR	Surface building	Total	Collider	Booster	Linac	BTL	IR	Surface building	Total
1	RF Power Source	96.90	1.40	11.10				109.40	161.60	1.73	14.10				177.40
2	Crygenic system	9.72	1.71			0.14		11.57	9.17	1.77			0.14		11.08
3	Vacuum System	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**

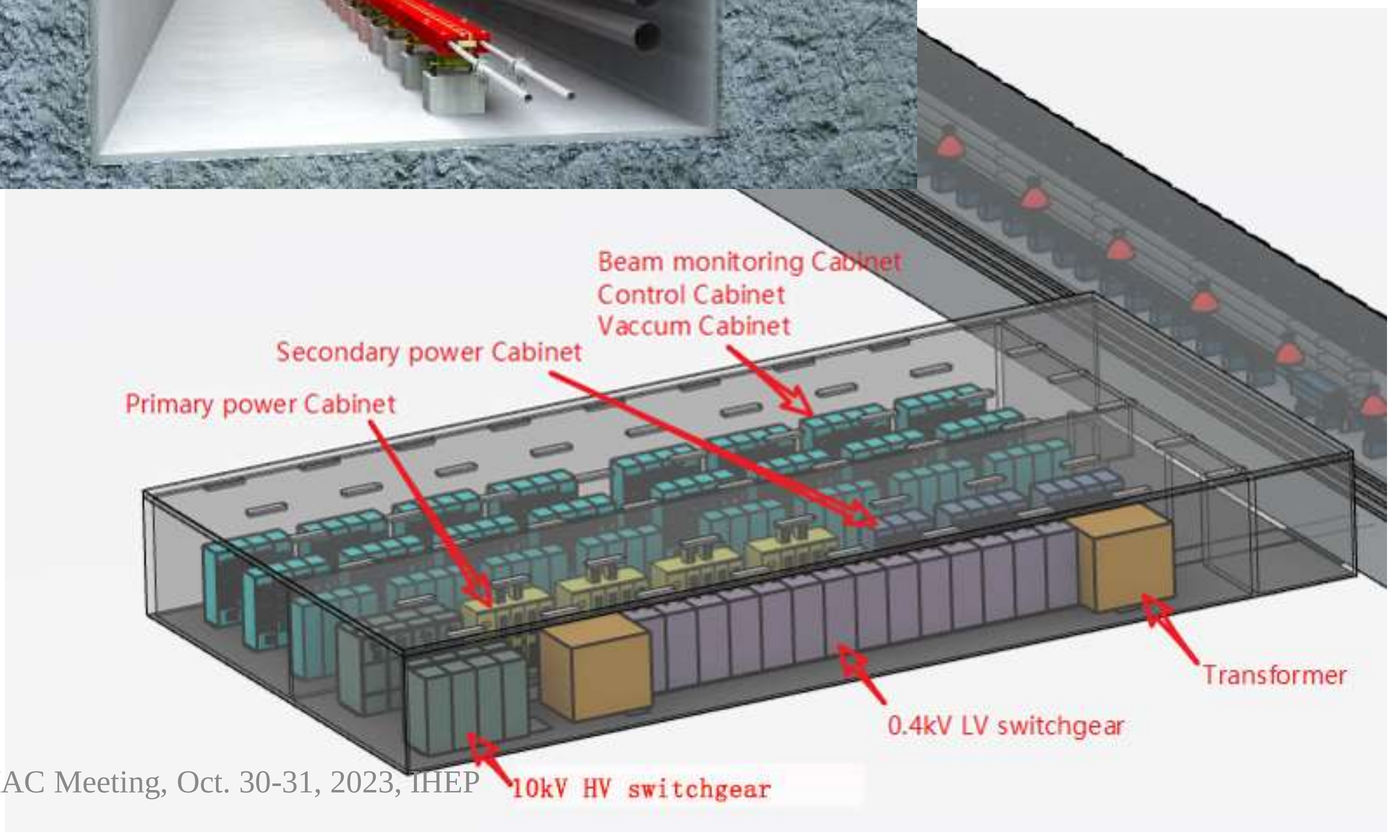
CEPC TDR Site Selections (three examples)

CEPC Conventional Facility and Civil Engineering

Electrical Equipment General Layout in Auxiliary

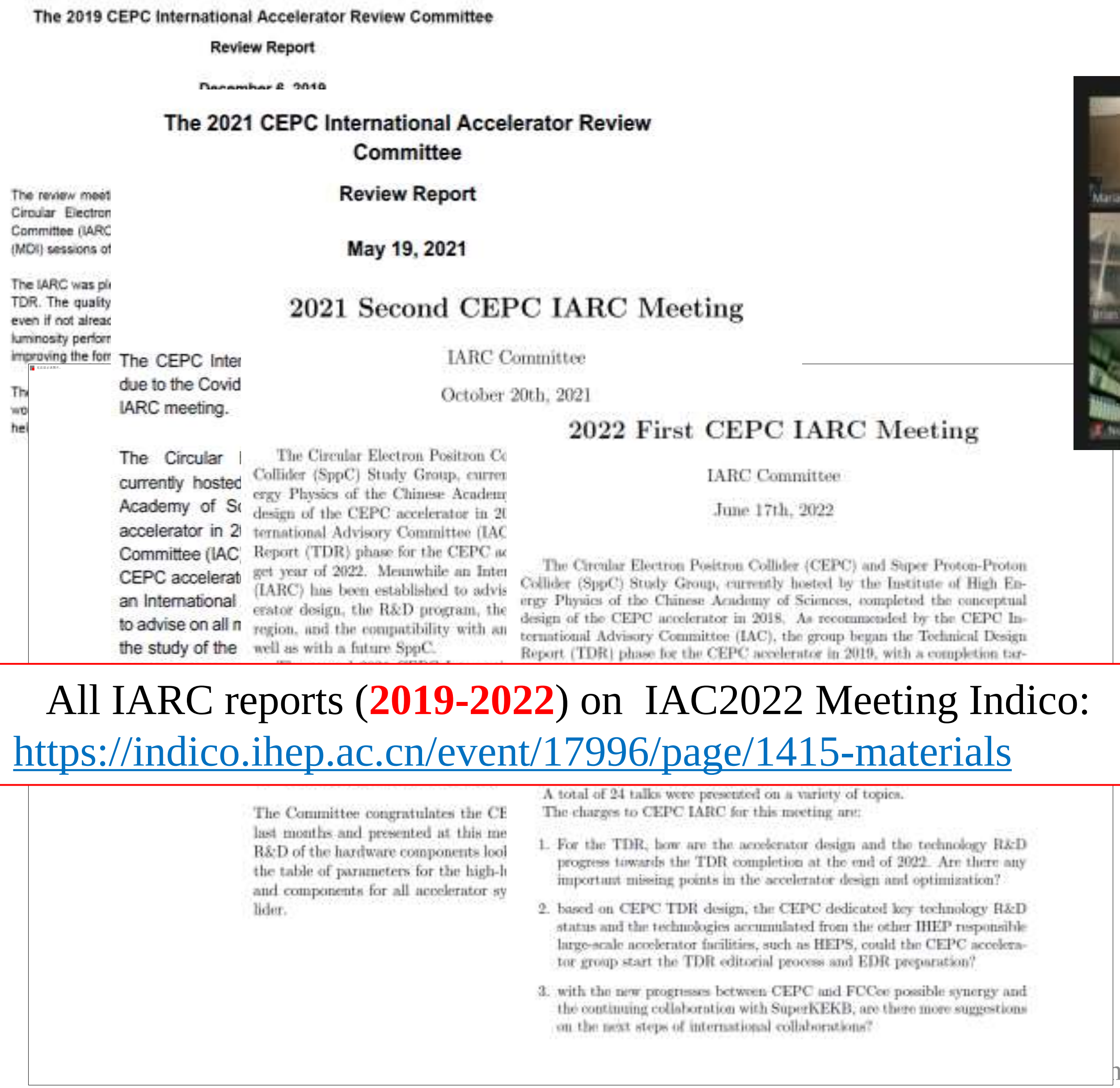






CEPC Accelerator IARC Meeting 2019-2022

International Accelerator Review Committee (IARC) under IAC


The 2019 CEPC International Accelerator Review Committee

Review Report

December 6, 2019

The 2021 CEPC International Accelerator Review Committee

Review Report

May 19, 2021

2021 Second CEPC IARC Meeting

IARC Committee

October 20th, 2021

2022 First CEPC IARC Meeting

IARC Committee

June 17th, 2022

The Circular Electron Positron Collider (CEPC) and Super Proton-Proton Collider (SppC) Study Group, currently hosted by the Institute of High Energy Physics of the Chinese Academy of Sciences, completed the conceptual design of the CEPC accelerator in 2018. As recommended by the CEPC International Advisory Committee (IAC), the group began the Technical Design Report (TDR) phase for the CEPC accelerator in 2019, with a completion tar-

A total of 24 talks were presented on a variety of topics.

The charges to CEPC IARC for this meeting are:

1. For the TDR, how are the accelerator design and the technology R&D progress towards the TDR completion at the end of 2022. Are there any important missing points in the accelerator design and optimization?
2. based on CEPC TDR design, the CEPC dedicated key technology R&D status and the technologies accumulated from the other IHEP responsible large-scale accelerator facilities, such as HEPS, could the CEPC accelerator group start the TDR editorial process and EDR preparation?
3. with the new progresses between CEPC and FCCee possible synergy and the continuing collaboration with SuperKEKB, are there more suggestions on the next steps of international collaborations?

The Committee congratulates the CE[...] last months and presented at this me[...] R&D of the hardware components loo[...] the table of parameters for the high-l[...] and components for all accelerator sy[...] lider.

All IARC reports (**2019-2022**) on IAC2022 Meeting Indico:
https://indico.ihep.ac.cn/event/17996/page/1415-materials

Nov. 2019: https://indico.ihep.ac.cn/event/9960/

May, 2021: https://indico.ihep.ac.cn/event/14295

October, 2021: https://indico.ihep.ac.cn/event/15177

June, 2022: https://indico.ihep.ac.cn/event/16801/

After the completeion of CEPC CDR in Nov. 2018, since the first CEPC IARC meeting in **2019**, there has been **toally 4 IARC meetings till 2022**, with each meeting a carefully written IARC report, which are very helpful for CEPC accelerator in TDR phase and beyond.

CEPC IAC Meeting 2022

https://indico.ihep.ac.cn/event/17996/

The Eighth Meeting of the CEPC-SppC International Advisory Committee

IAC Committee

B. Barish, M. Biagini, Yuan-Hann Chang, A. Cohen, M. Davier, M. Demarteau, B. Foster (Chair), R. Godbole, D. Gross, B. Heinemann, K. Jakobs, L. Linssen, L. Maiani, M. Mangano, T. Nakada, I. Shipsey, S. Stapnes, G. Taylor, A. Yamamoto, Hongwei Zhao

November 4th, 2022

1 Overview

The eighth meeting of the CEPC-SppC International Advisory Committee took place virtually on October 31, November 1,2 and 4, 2022. The appendices to this report contain the charge for the meeting (Appendix A), the members of the IAC (Appendix B), and the agenda of the meeting (Appendix C). Due to different time zones, this meeting was necessarily much shorter than previous in-person meetings and missed informal exchanges of opinions. The IAC considers it essential to have some form of person-to-person meetings with more detailed materials at its next meeting in 2023, even if such a meeting has to take place outside China.

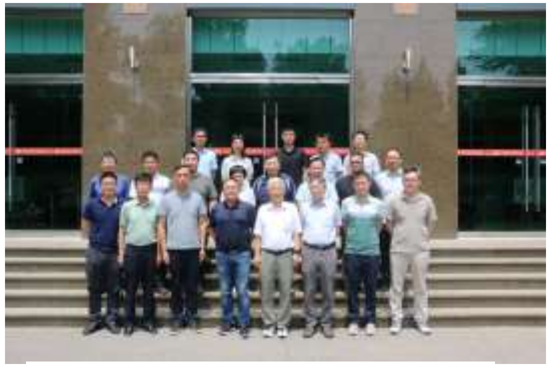
The IAC recommends that the project management presents a path to site selection, necessary for many aspects of the Engineering Design (ED) Phase, at the next IAC meeting.

According to the recommendation of IAC, CEPC Accelerator Engineering Design Report phase planning has been started.

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

CEPC Accelerator TDR Review
June 12-16, 2023

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



Domestic Civil Engineering
Cost Review, June 26, 2023

Accelerator Total	**189.8**	**100%**
Accelerator physics	0.8	0.42%
Collider	99.99	52.70%
Booster	41.13	21.68%
Linac and sources	18.3	9.64%
Damping ring	0.59	0.31%
Transport lines	1.57	0.83%
Common systems (cryogenic+protection +alignment)	16.63	8.76%
Installation (3%)	5.37	2.83%
Commissioning (3%)	5.37	2.83%

CEPC Total Cost	**368**	**100%**
Project management (1%)	3	0.82%
Accelerator	**190**	51.63%
Conventional facilities (Civil + General Utility)	103	27.99%
Gamma-ray beam lines	3	0.82%
Experiments	40	10.87%
Contingency (8%)	29	7.88%

CEPC TDR total cost: 36.8B RMB

CEPC Accelerator TDR International Review Report

Phase 1 CEPC TDR Review Report

CEPC TDR Technical Review Committee

15 July 2023

Chaired by Frank Zimmermann

1 Executive Summary

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

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

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

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

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

CEPC Accelerator TDR International Cost Review Report

CEPC Accelerator TDR Cost Review

Chaired by Loinid Rivkin

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

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

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

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

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

CEPC Engineering Design Report (EDR) Goal

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

CEPC EDR Phase General Goal: 2024-2027

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

CEPC Accelerator EDR Plan and Scope-1

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

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

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

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

CEPC Accelerator EDR Plan and Scope-2

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

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

(G) Complete the radiation, security, environment assessment studies and necessary documents –so called CEPC PROPOSAL, around 2025ready for the application to the central government to get the formal approval of construction in the “15th five year plan”

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

CEPC Accelerator EDR Plan and Scope-3

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

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

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

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

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

CEPC Accelerator EDR Plan and Scope-4

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

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

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

(Q) Risk assessment and risk management

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

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

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

CEPC Accelerator EDR Plan and Scope-5

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

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

(W) Refine the CEPC construction funding modes.

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

(Y) Complete "CEPC Proposal" around 2025 ready for application of final selection of the 15th 5-year plan, and complete EDR around 2027 before the construction.

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

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

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

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

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

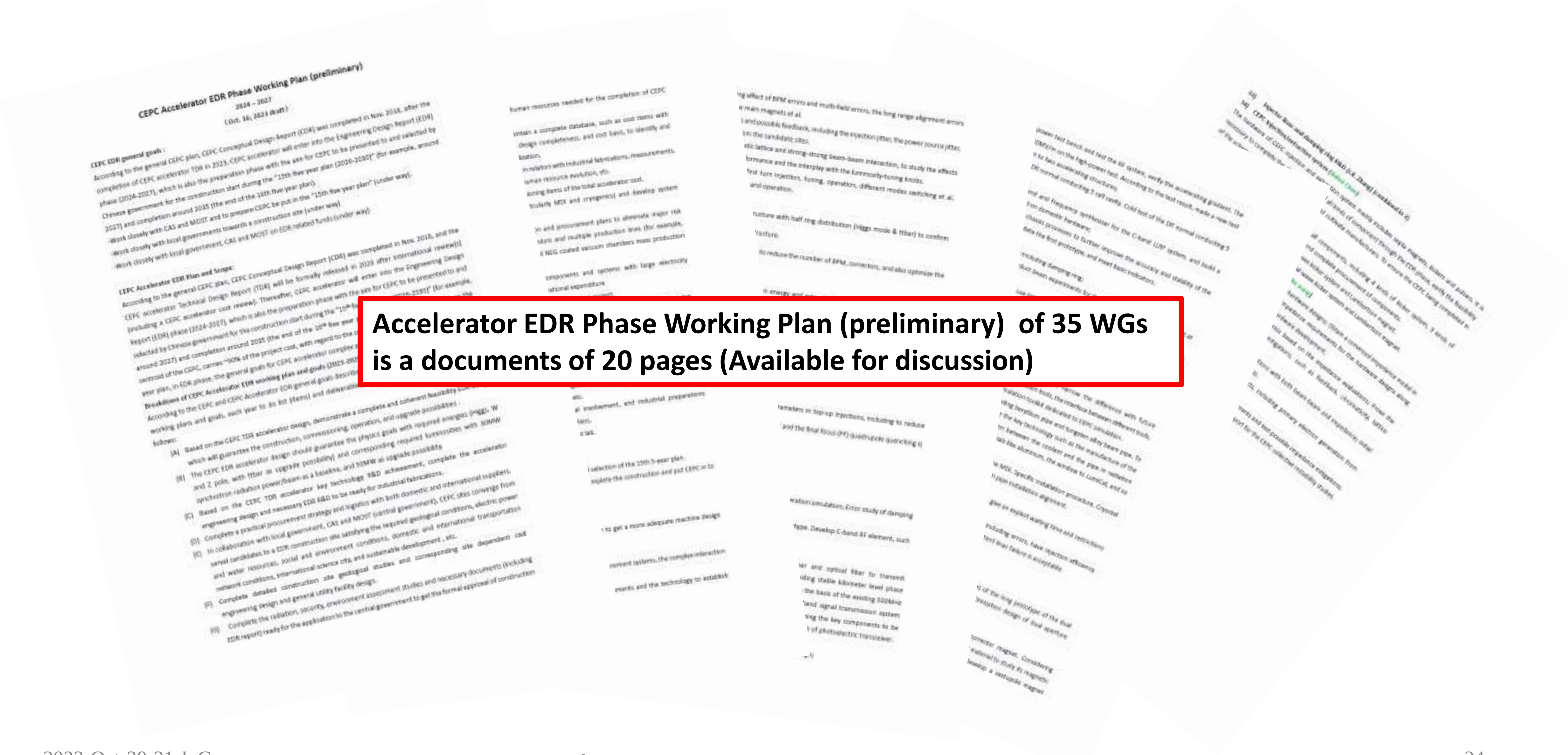
18) Control system (D.P. Jin, G. Li)
19) Conventional facilities (J.S. Huang)
20) Environment, health and safety issues (Guang Yi Tang and Zhongjian Ma)
21) Machine protection beam dump (Zhongjian Ma, X.H.Cui, and Yuting Wang)
22) CEPC high energy gamma ray beamlines (Y.W. Wang and Y.S. Huang)
23) Alignment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

The total CEPC EDR funding requirement (including site selection, civil engineering design, accelerator, detector, computing, management, etc. is about 1Billion RMB.

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

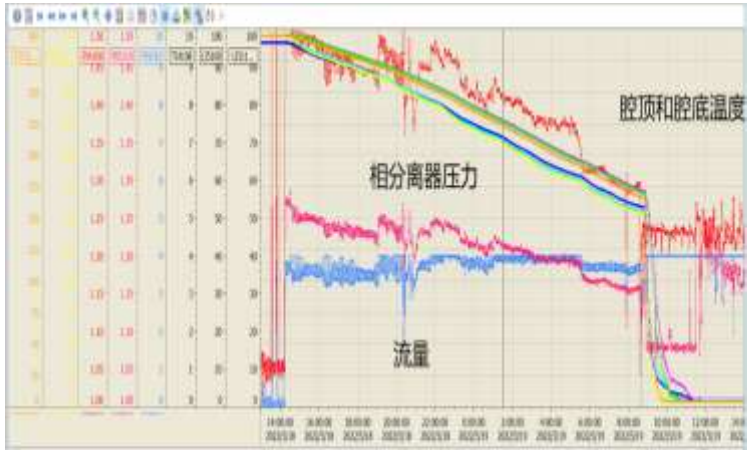
CEPC Accelerator EDR Phase Working Plan (preliminary) is a documents of 20 pages

CEPC EDR Goal, Plan and Scope

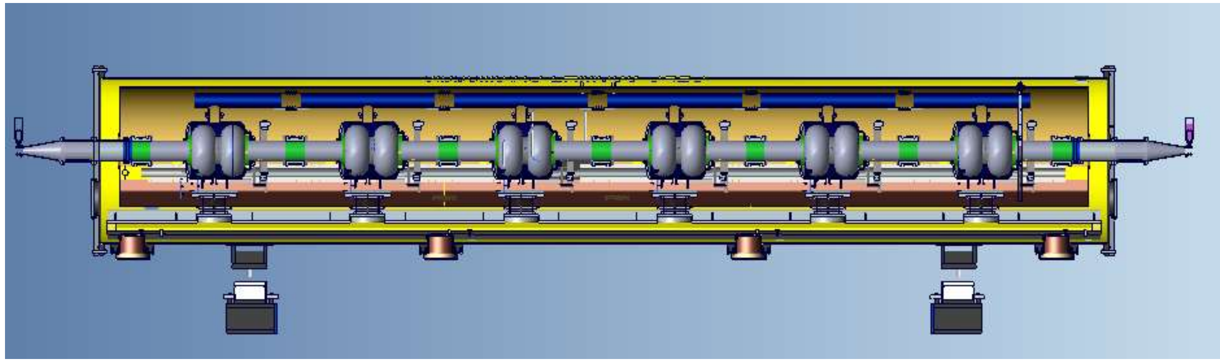


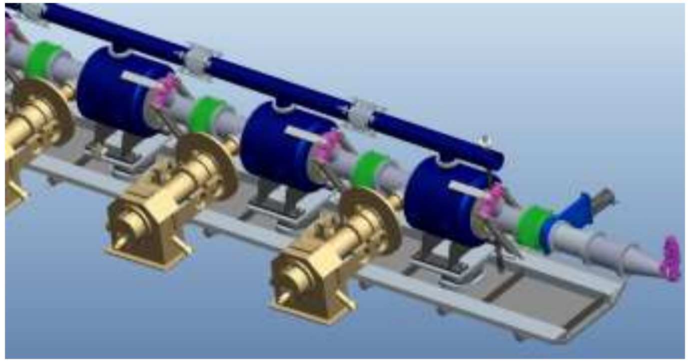
Accelerator EDR Phase Working Plan (preliminary) of 35 WGs is a documents of 20 pages (Available for discussion)

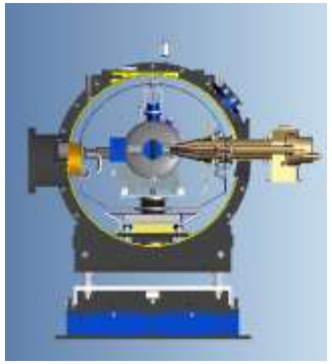
CEPC Accelerator Main EDR Development: SRF



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







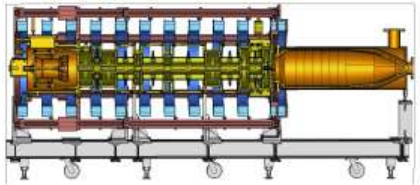
The collider Higgs mode for 30 MW SR power per beam will use 32 units of 11 m-long collider cryomodules will contain six 650 MHz 2-cell cavities, and therefore, a full size 650 MHz cryomodule will be developed in EDR

CEPC Accelerator Main EDR Development: Klystrons

Klystron R&D

Klystron No. 1
Efficiency 65%
(2020)

Klystron No. 2
Efficiency 77%
(2021)

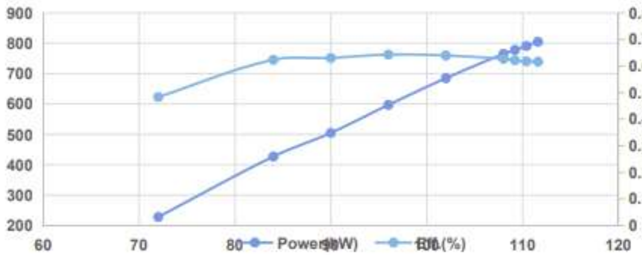


Klystron No. 3 （MBK
Efficiency 80.5%
(under fabrication)

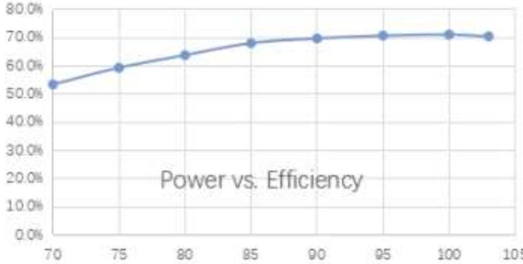
2022

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

High Voltage vs. Power&Efficency



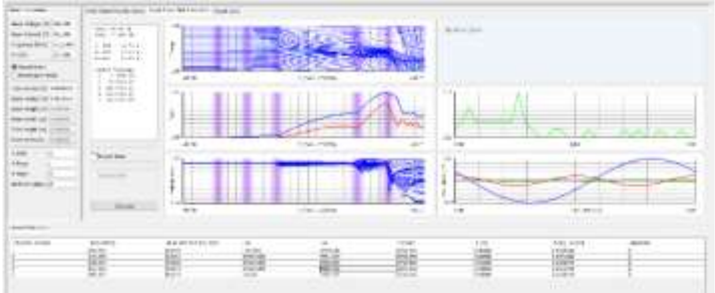
70.5% @ 630kW

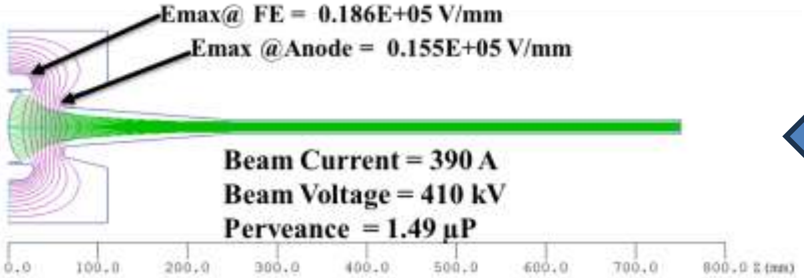


Parameters	Value
Frequency	5720 MHz
Output Power	80MW
Pulsed width	2.5us
Repetition rate	100Hz
Gain	54 dB
Efficiency	47%
$3dB$ bandwith	±5MHz
Beam voltage	420 kV
Beam current	403 A
Focusing field	0.28 T

CEPC collider ring 650MHz klystron development in TDR phase

C band 5720MHz 80MW Klystron



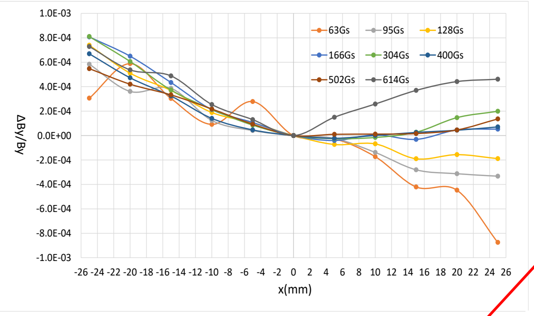


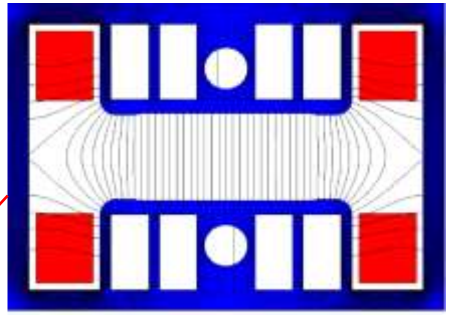
C band 5720MHz 80MW Klystron design progress

CEPC Accelerator Main EDR Development: booster magnet

Magnet name	BST-63B-Arc	BST-63B-Arc-SF	BST-63B-Arc-SD	BST-63B-IR
Quantity	10192	2017	2017	640
Aperture [mm]	63	63	63	63
Dipole Field [Gs] @180 GeV	564	564	564	549
Dipole Field [Gs] @120 GeV	376	376	376	366
Dipole Field [Gs] @30 GeV	95	95	95	93
Sextupole Field [T/m^2] @180 GeV	0	16.0388	19.1423	0
Sextupole Field [T/m^2] @120 GeV	0	10.6925	12.7615	0
Sextupole Field [T/m^2] @30 GeV	0	2.67315	3.19035	0
Magnetic length [mm]	4700	4700	4700	2350
GFR [mm]	±22.5	±22.5	±22.5	±22.5
Field errors	$\pm1\times10^{-3}$	$\pm1\times10^{-3}$	$\pm1\times10^{-3}$	$\pm1\times10^{-3}$

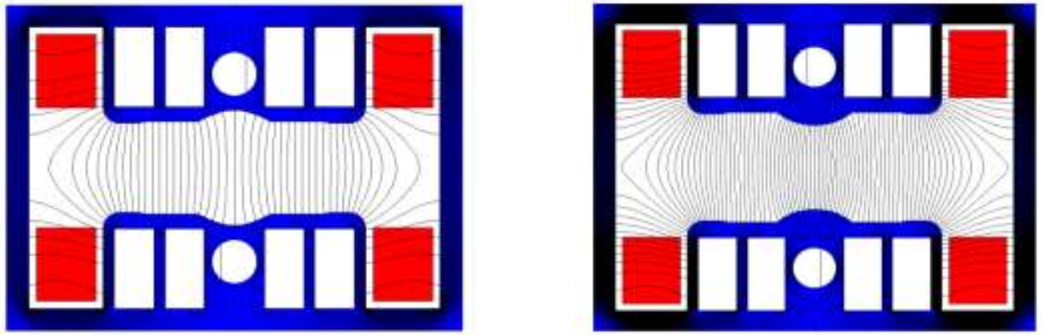
- Booster requires ~19k pieces of magnets (68km);
- Booster dipoles are required to work at the low field of 95 Gs (30GeV) with an error smaller than 1×10^{-3} ;
- Full length (4.7m) dipole was developed, and it meets the field specification;





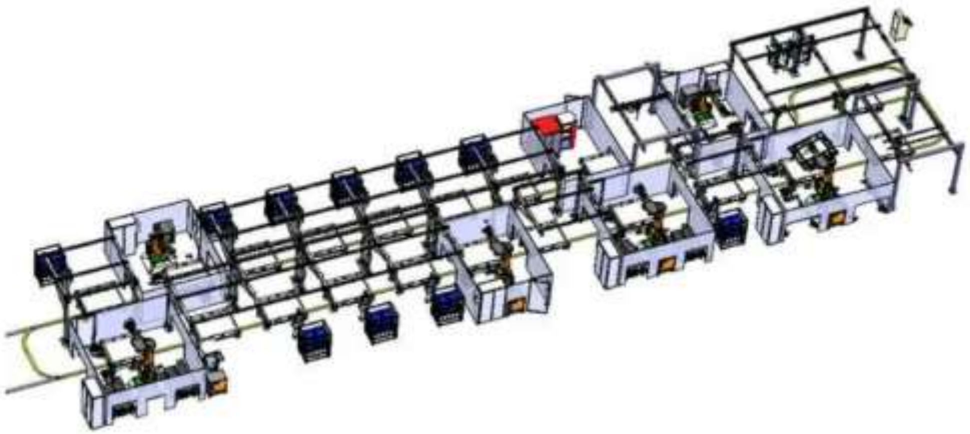
TDR booster dipole magnets: type I

In the TDR stage, the dipole magnets are grouped into three families. One family is the pure dipoles, while the other two families are the dipole sextupole combined magnets with the sextupole field of 10.69 T/m^2 and -12.76 T/m^2 at 120GeV.

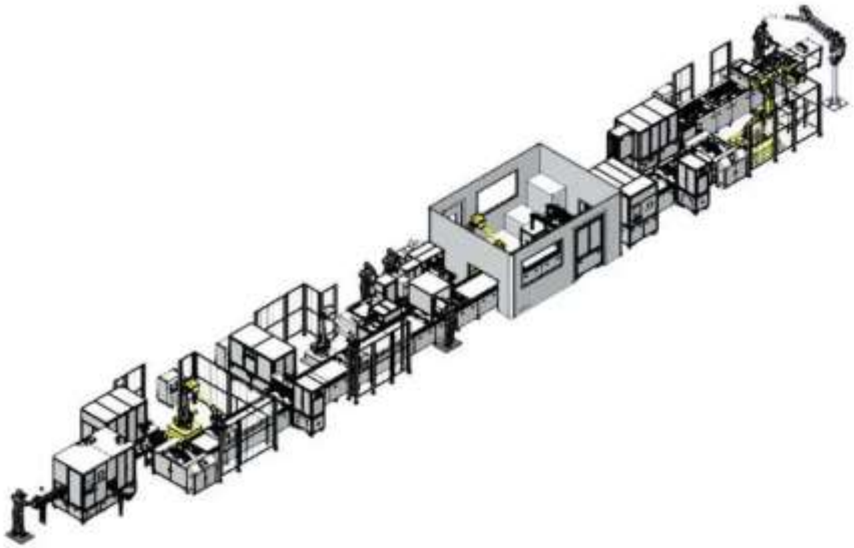


EDR booster dipole magnets with sextupoles: type II and III

CEPC Magnets' Automatic Production Lines in EDR



Conceptual design type-I

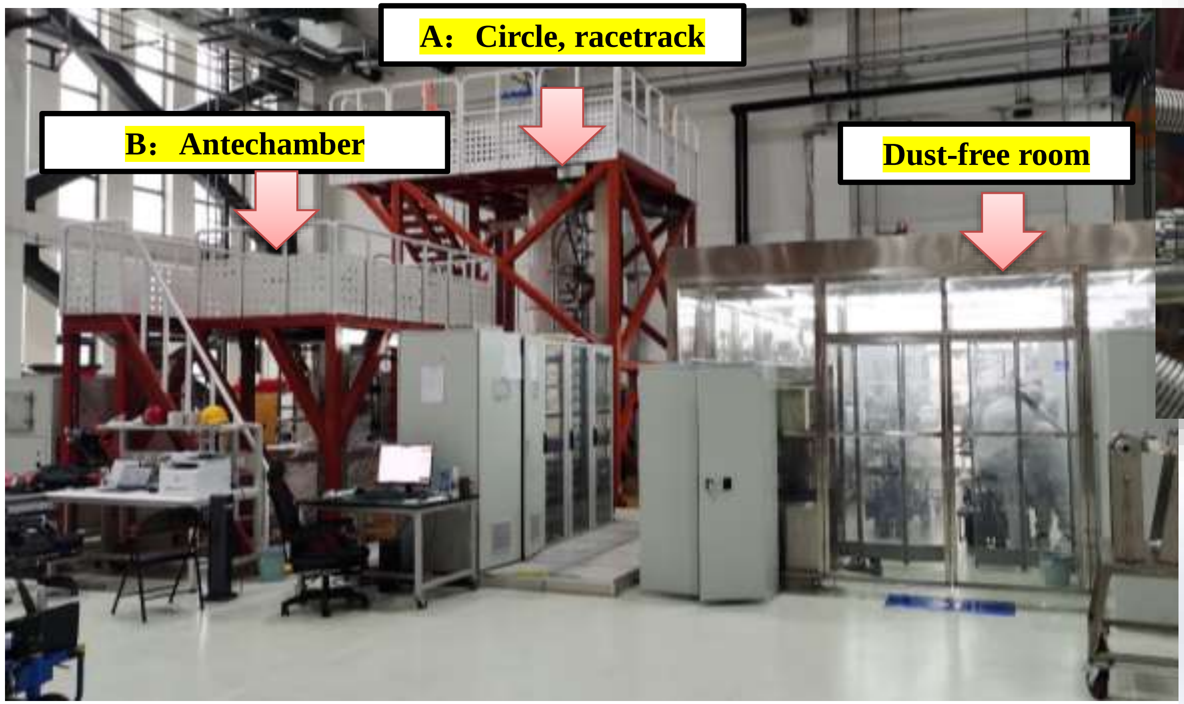


Conceptual design type-II

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

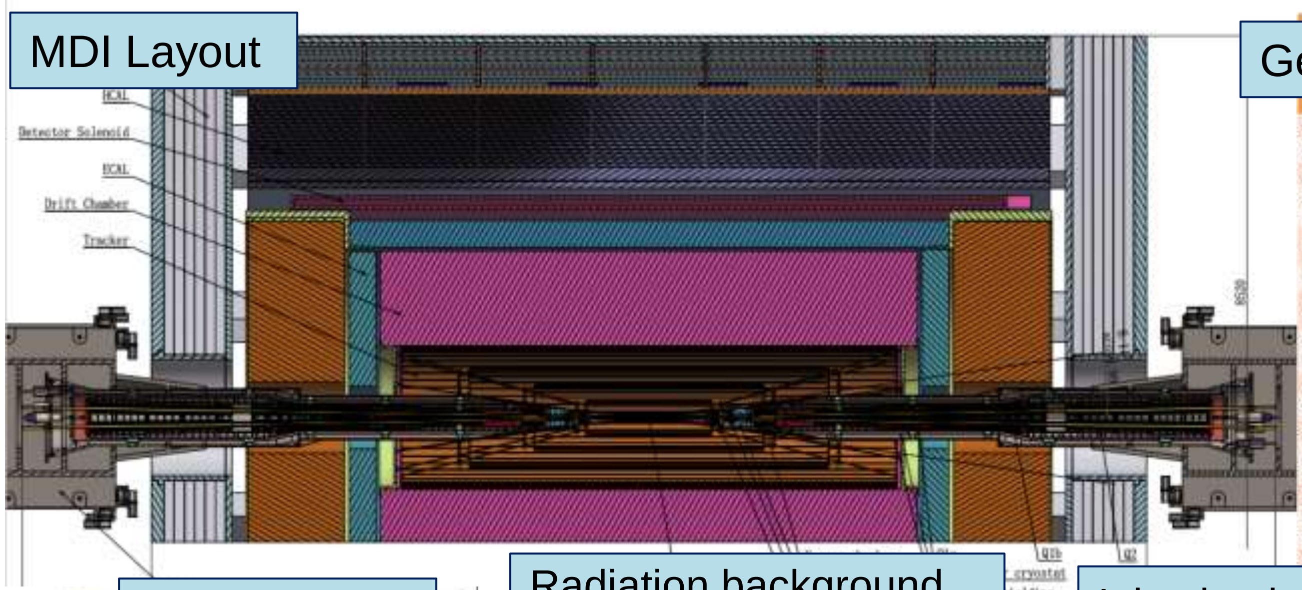
Massive Production Line of NEG Coating Vacuum Chambers in EDR

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

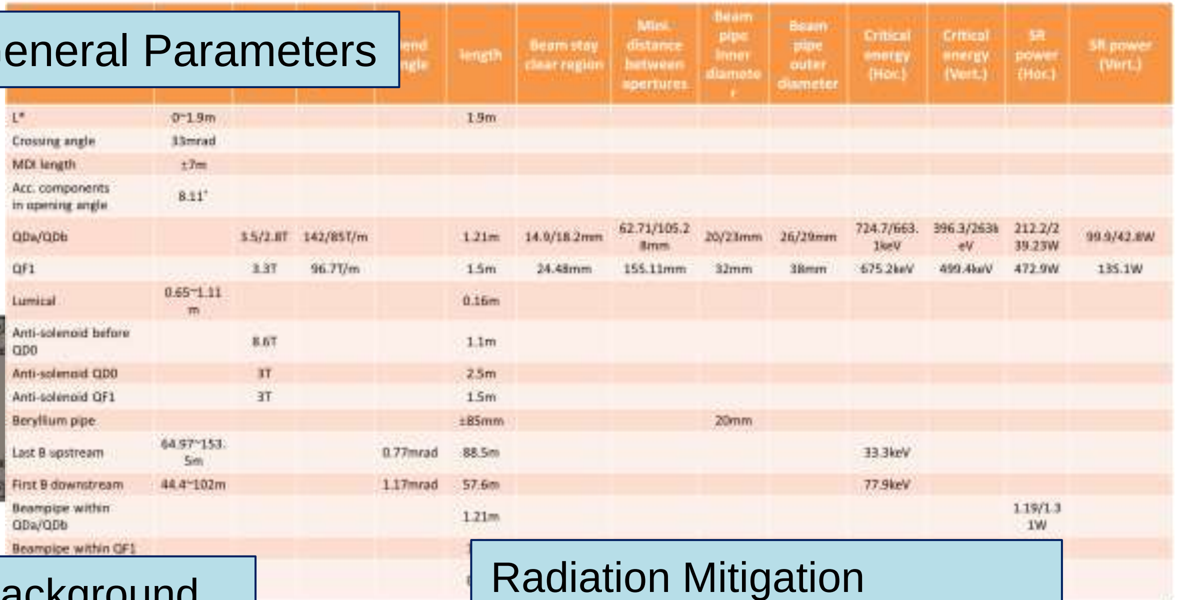


CEPC MDI in EDR

MDI Layout

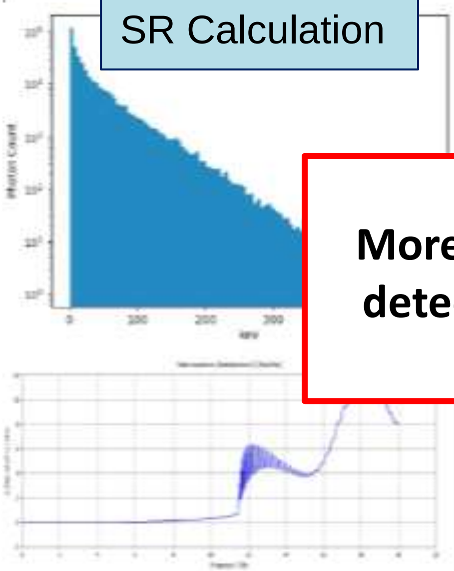


General Parameters



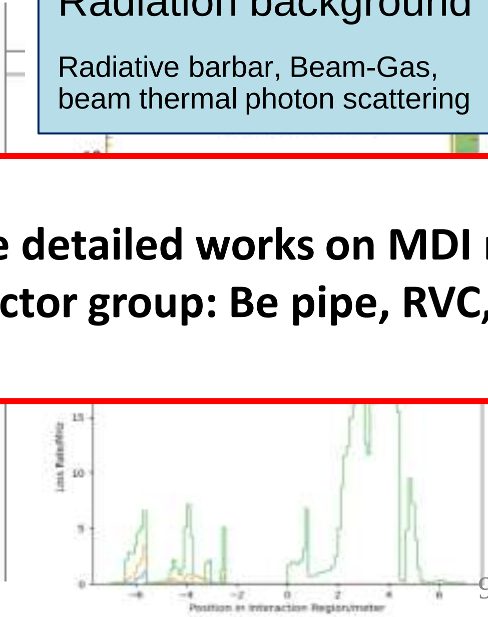
				end ngle	length	Beam stay clear region	Mini. distance between apertures	Beam pipe inner diameter	Beam pipe outer diameter	Critical energy (Hor.)	Critical energy (Vert.)	SR power (Hor.)	SR power (Vert.)
L*	0~1.9m				1.9m								
Crossing angle	33mrad												
MDI length	±7m												
Acc. components 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

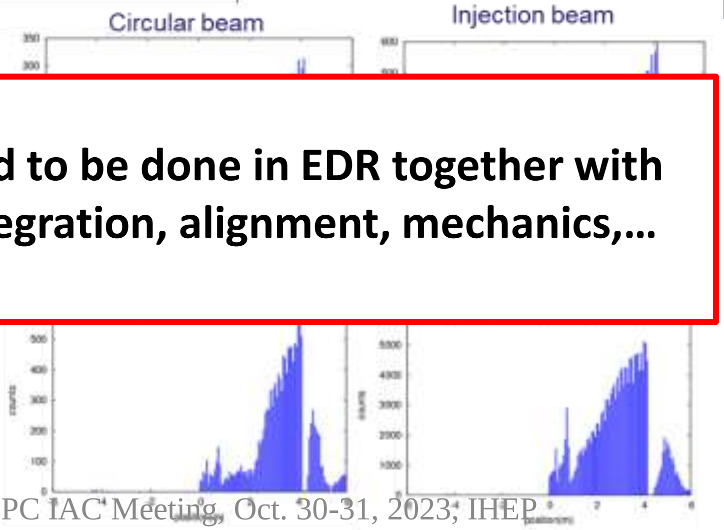


Radiation background

Radiative barbar, Beam-Gas, beam thermal photon scattering

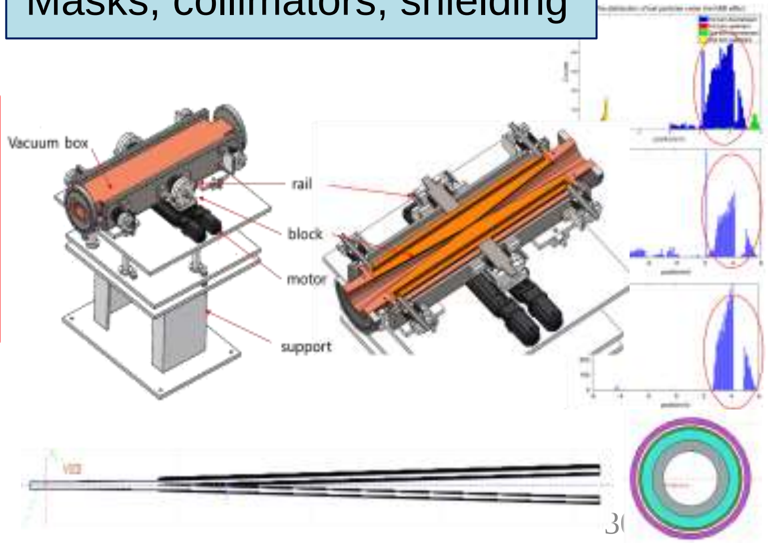


Injection background



Radiation Mitigation

Masks, collimators, shielding

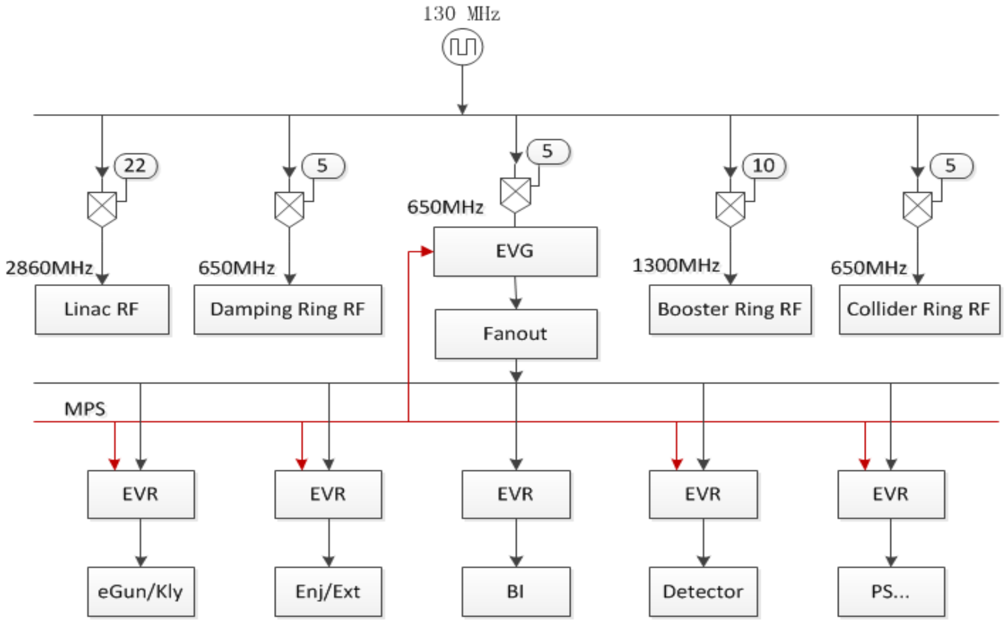


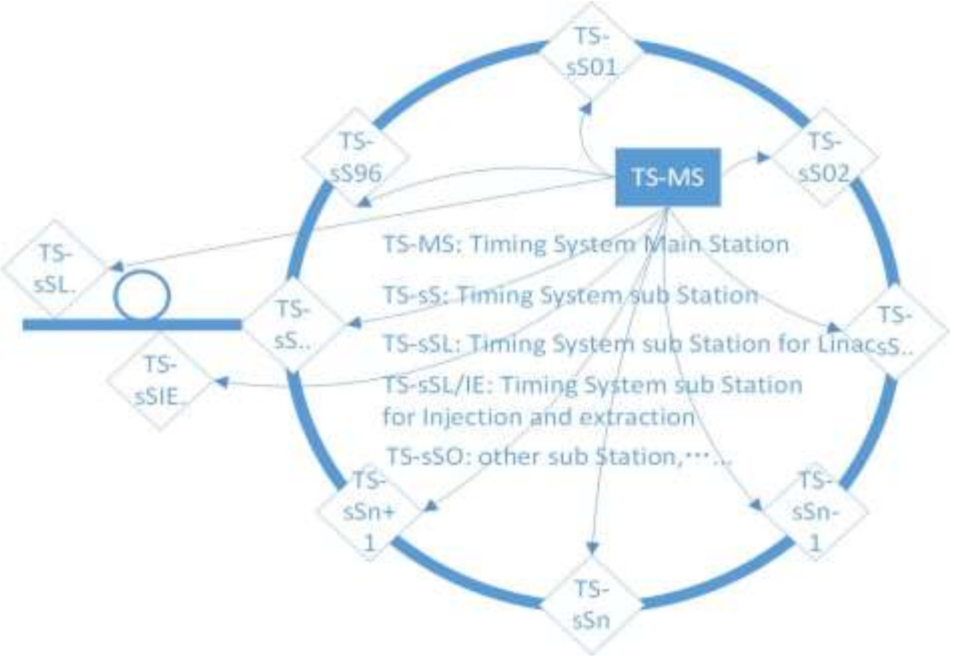
More detailed works on MDI need to be done in EDR together with detector group: Be pipe, RVC, integration, alignment, mechanics,…

CEPC Accelerator Control and Timing in EDR

- **The basic structure of Timing System**
  - Event system and RF transmission system
  - Event system: Trigger signal and Low frequency clock signal
  - RF transmission system: Transmit high stability RF signal

In EDR phase CEPC high precision timing and control technology will be developed





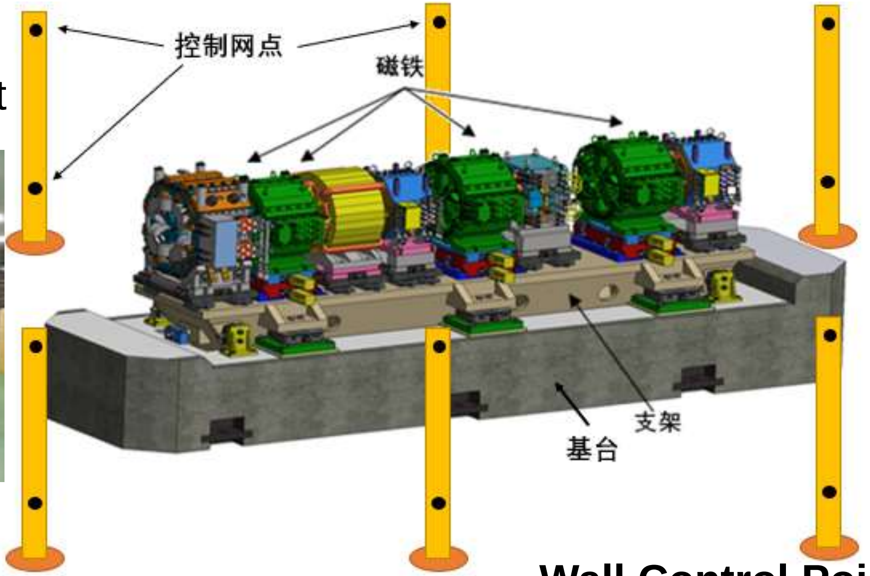
CEPC Alignment and Installation Plan in EDR

- Alignment accuracy requirement

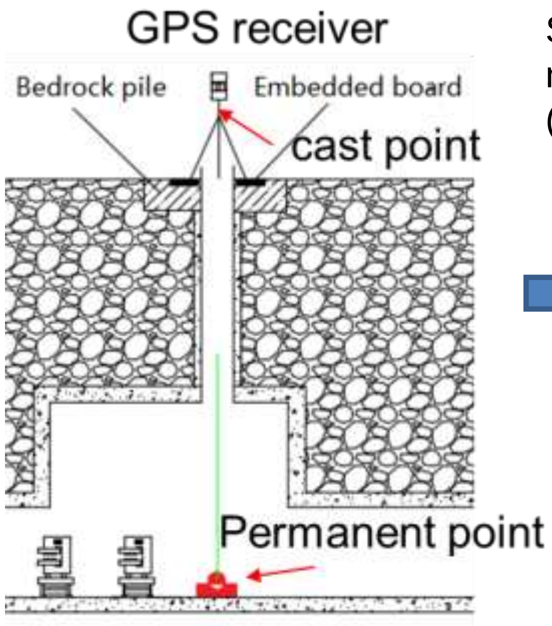
Component	Δx (mm)	Δy (mm)	$\Delta\theta_z$ (mrad)
Dipole	0.10	0.10	0.10
Arc Quadrupole	0.10	0.10	0.10
IR Quadrupole	0.10	0.10	0.10
Sextupole	0.10*	0.10*	0.10

*implement beam-based alignment

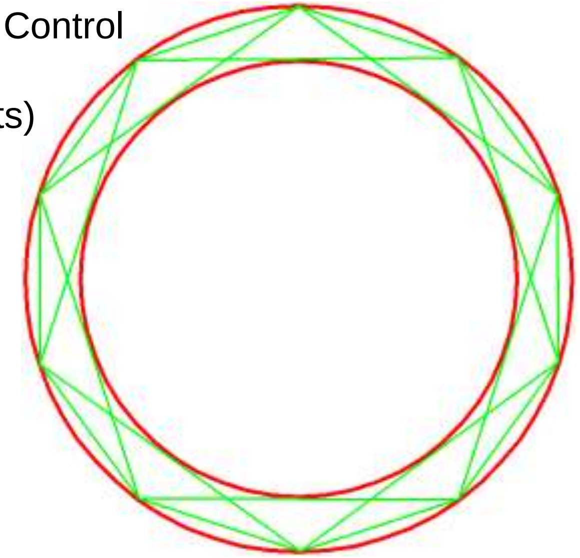
Component Pre-alignment



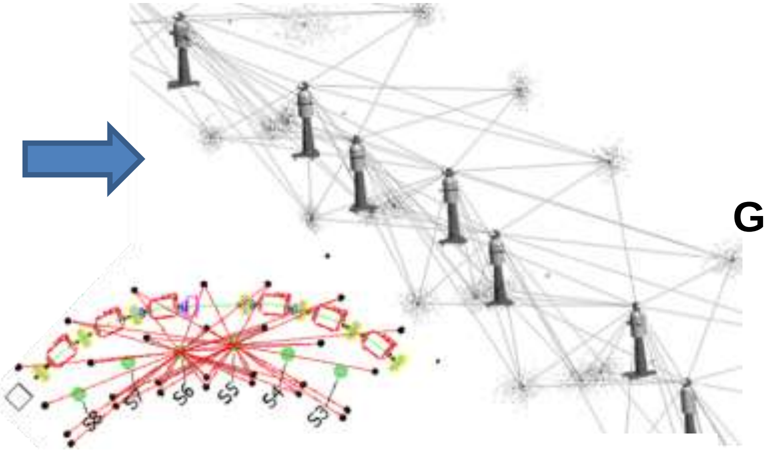
Wall Control Point



Surface Control network (14Points)



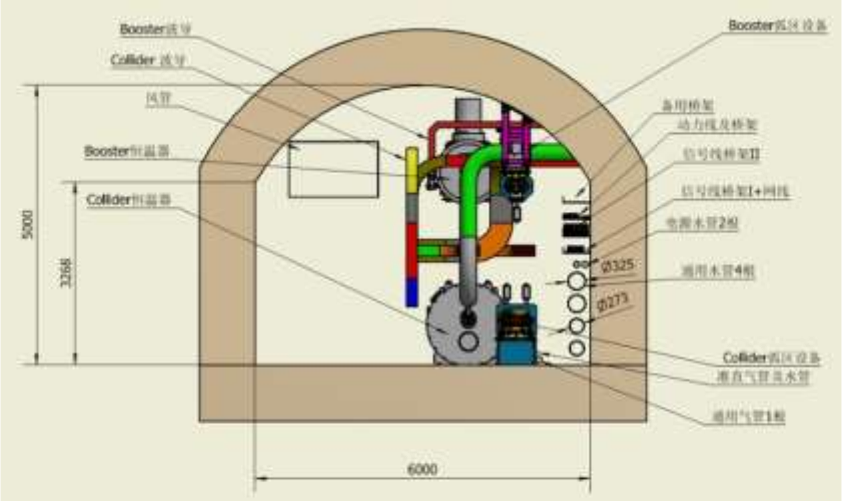
Backbone Control network
(short line:300m; long line 600m)

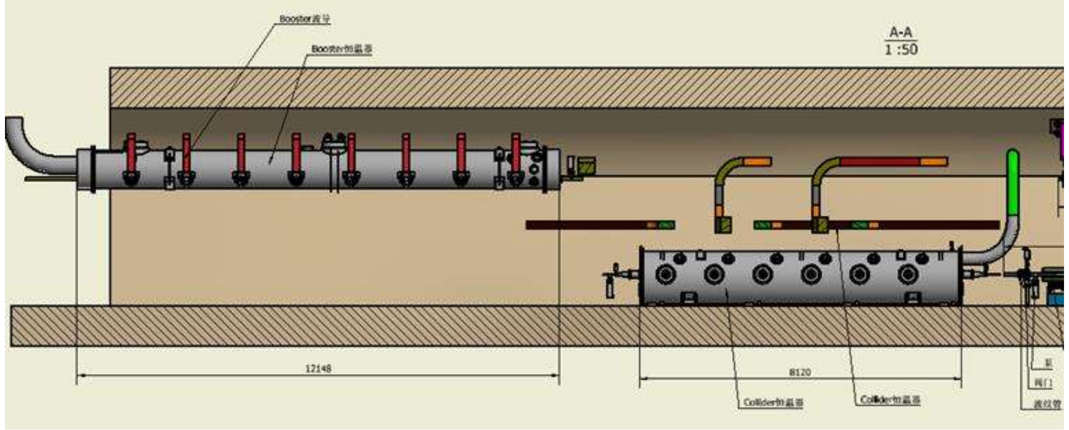


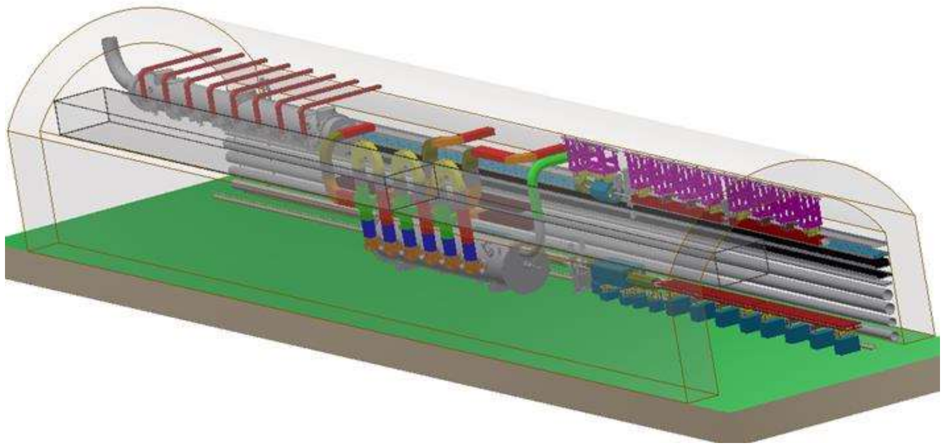
Tunnel Control network
(interval of 6 meters)

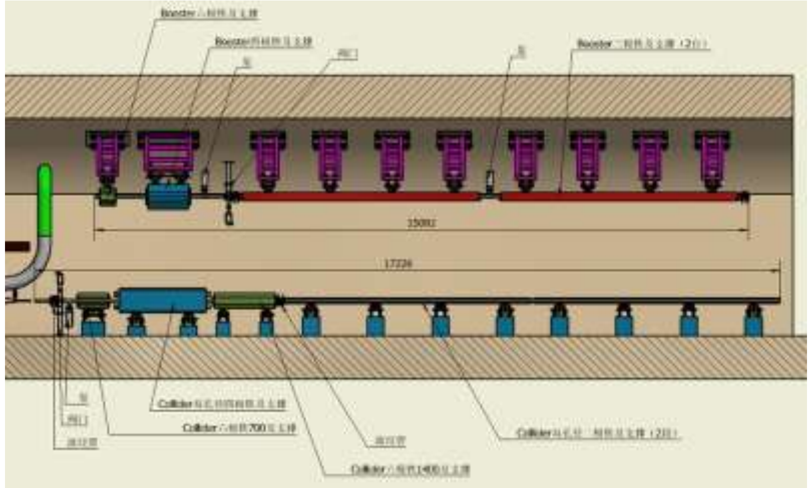
Ground Control Point

CEPC Tunnel Mockup for Installation in EDR (option)



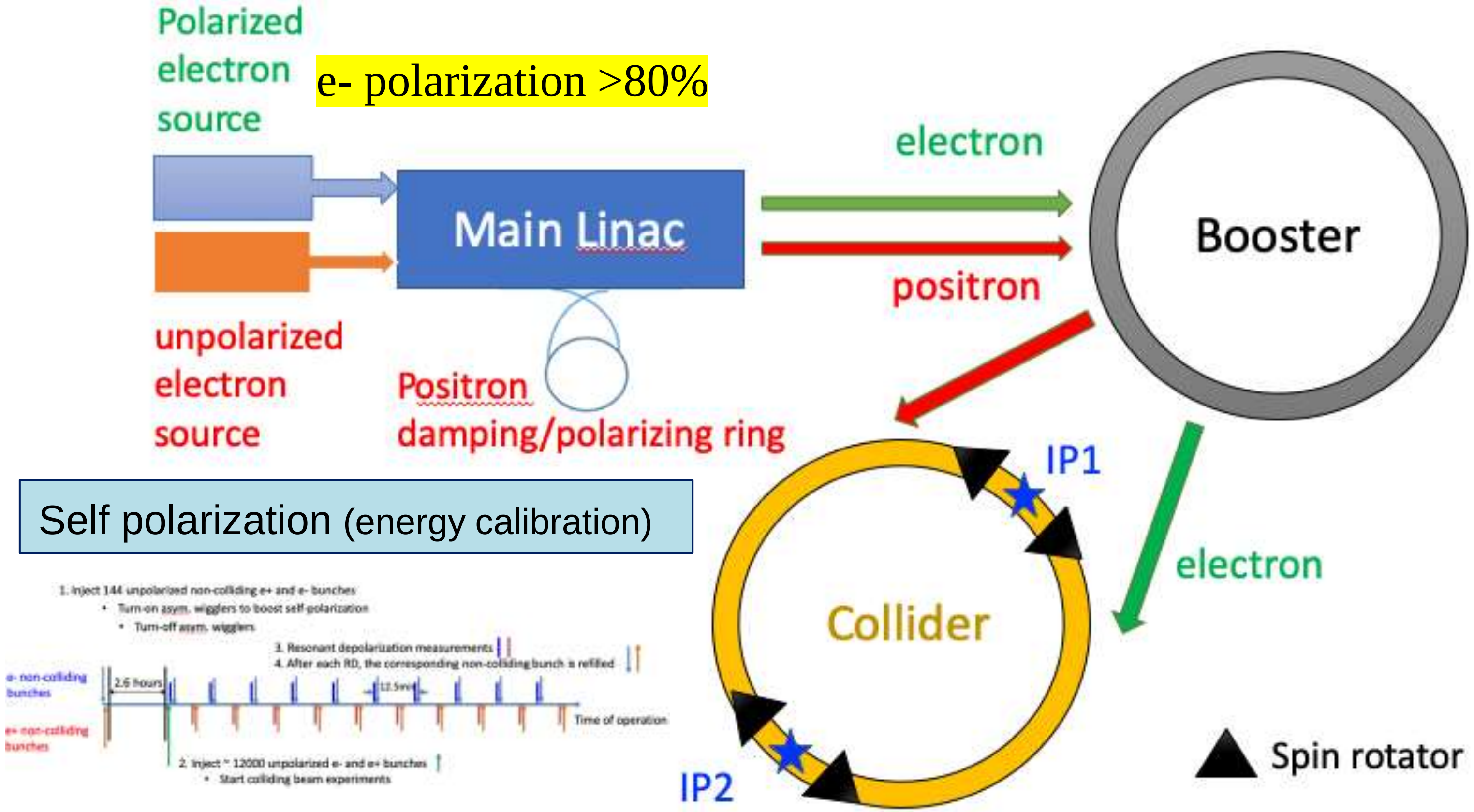






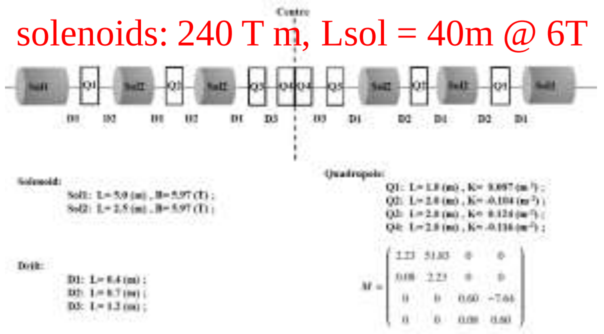
To demonstrate the inside tunnel alignment and installation, especially for booster installation on the roof of the tunnel

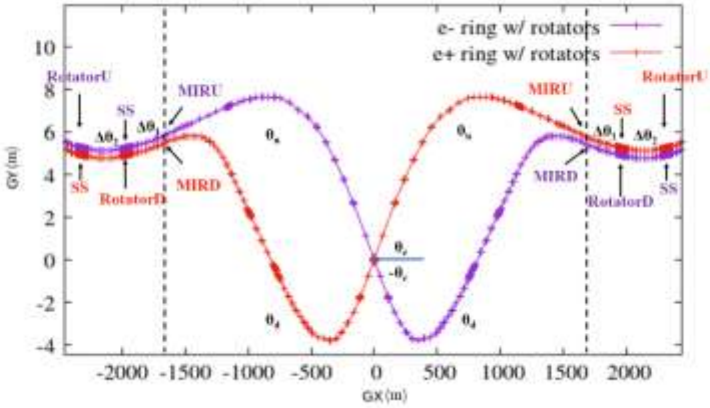
CEPC Polarized Beam Studies(alternative option)



Spin rotator design

solenoids: 240 T m, Lsol = 40m @ 6T





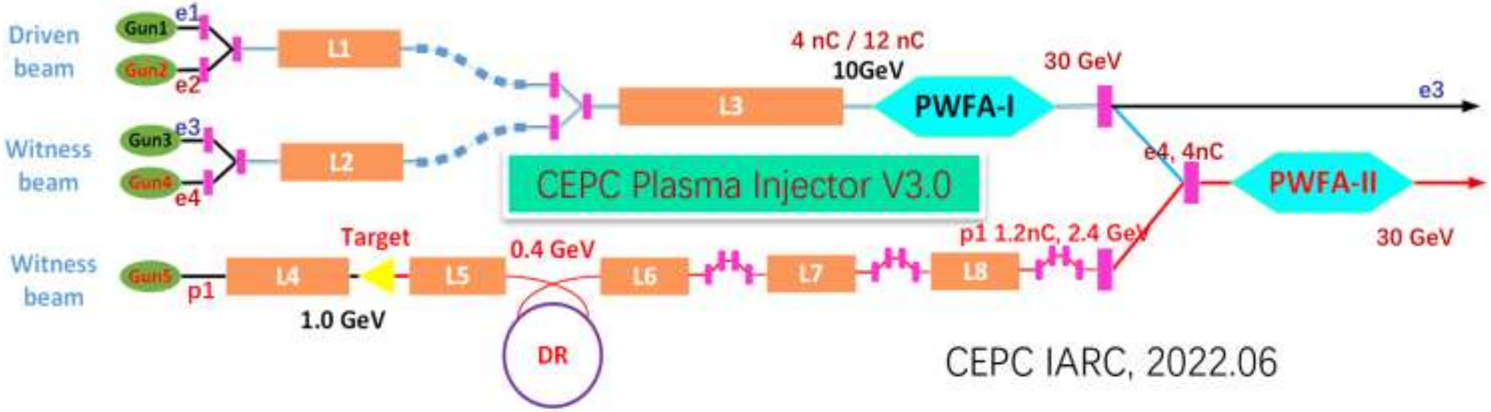
Key issues of study:

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

CEPC Plasma Injector (alternative option) in EDR

CEPC injector's baseline was changed:

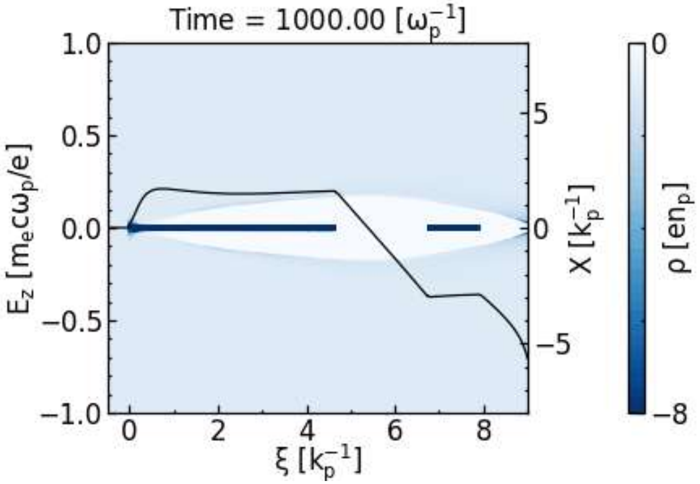
10 GeV → 30 GeV → **TR ≥ 2**



A test facility is under construction at IHEP based BEPCII injector started from Oct. 2023

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

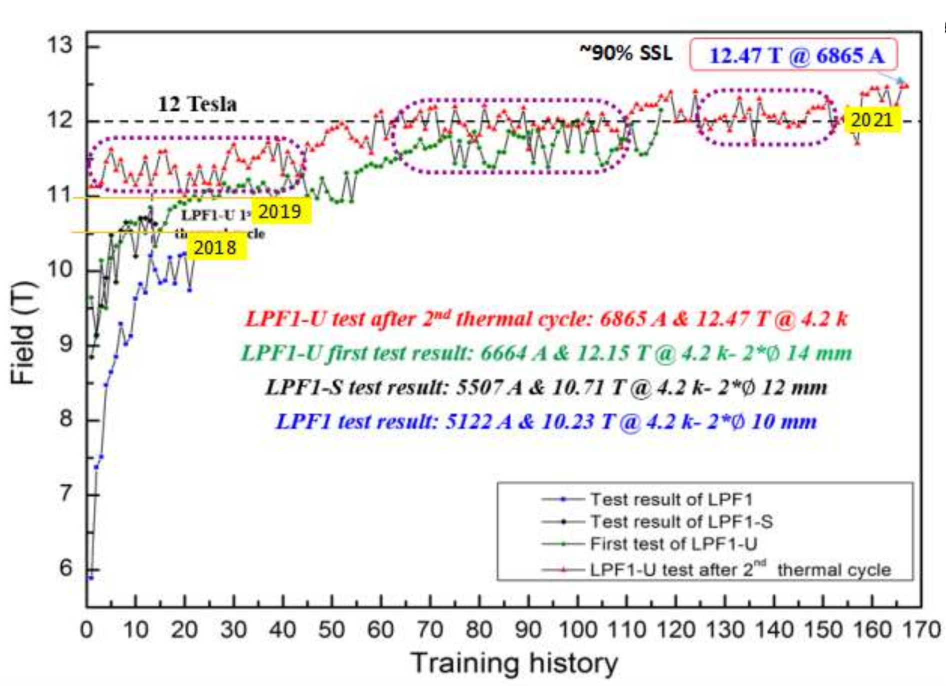
Parameters	Trailer
Accelerating distance (m)	7.3 (97300 w_p^{-1})
Trailer energy $E(GeV)$	30
Normalized emittance $\epsilon_n(mm\ mrad)$	10
Charge(nC)	1.2
Energy spread δ_E(%)	0.58
R	1.8
Efficiency(%) (driver -> trailer)	55

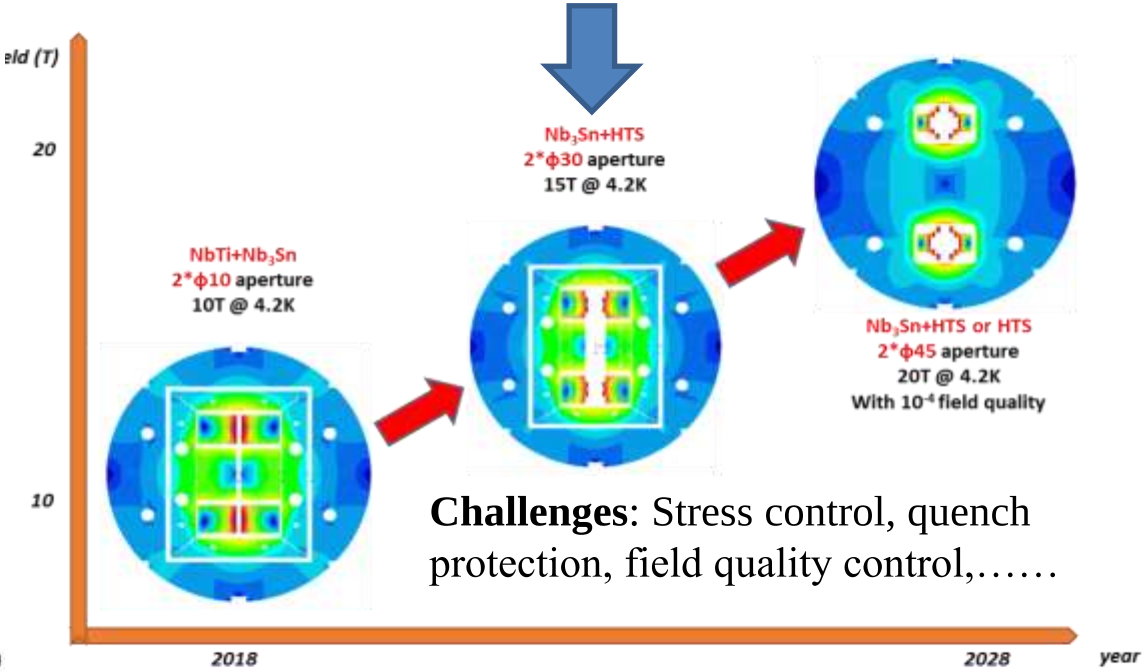


SppC HF Magnet Development

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

Picture of LPF1-U





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

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

CEPC Human Resource Requirement during Construction

Accelerator Total	189.8	100%
Accelerator physics	0.8	0.42%
Collider	99.99	52.70%
Booster	41.13	21.68%
Linac and sources	18.3	9.64%
Damping ring	0.59	0.31%
Transport lines	1.57	0.83%
Common systems (cryogenic+protection +alignment)	16.63	8.76%
Installation (3%)	5.37	2.83%
Commissioning (3%)	5.37	2.83%

CEPC Total Cost	368	100 %
Project management (1%)	3	0.82 %
Accelerator	**190**	51.63 %
Conventional facilities (Civil + General Utility)	103	27.99 %
Gamma-ray beam lines	3	0.82 %
Experiments	40	10.87 %
Contingency (8%)	29	7.88 %

CEPC TDR total cost: 36.8B RMB
CEPC TDR accelerator cost: 19B RMB
CEPC construction period accelerator peak personel number: ~2800, including detectors
The total personel (peak):~3000

CEPC human resource needed:

- HEPS model:
  HEPS accelerator total cost: **1.9B RMB** (not include civil engineering and utility costs), and the total personnel number: ~280

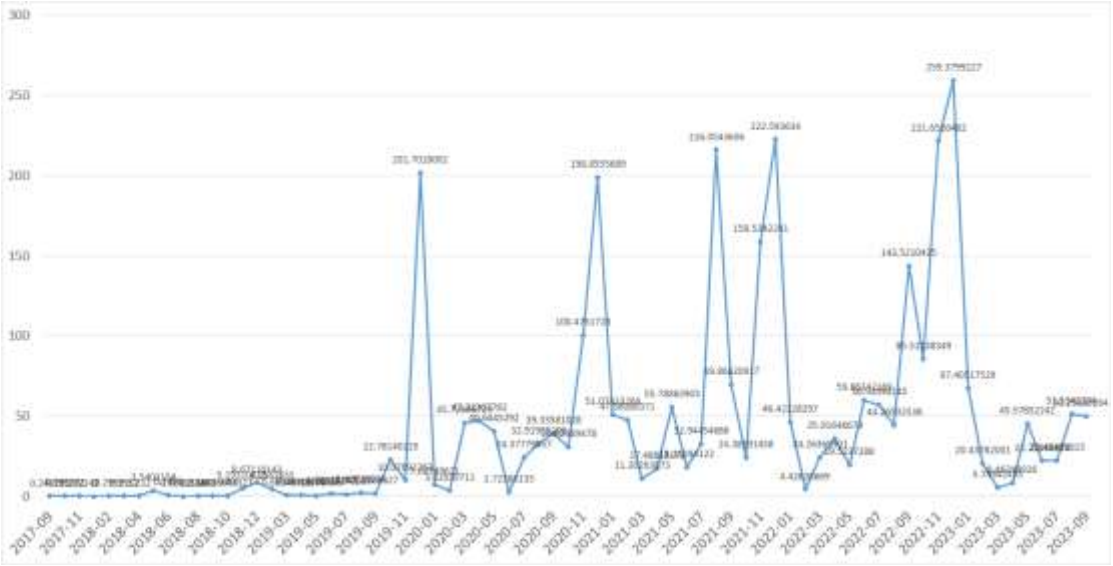
HEPS: 6.78M RMB/person which agrees with the rule of thumb of accelerator project: 1M USD/person

According to CEPC accelerator total cost:19B RMB, and the total personnel number: ~2800

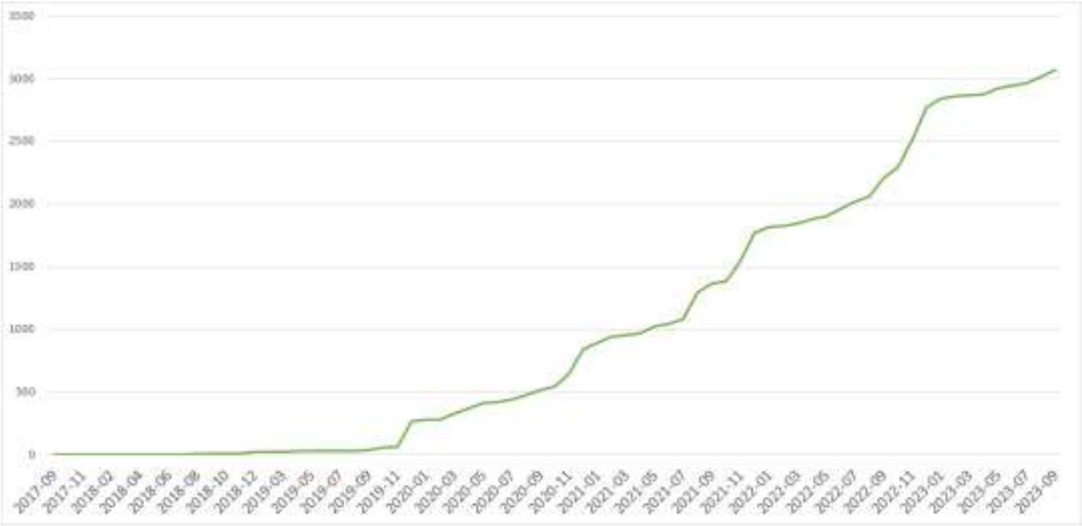
The personnel number evolution with construction time could be studied by taking HEPS spending profile as an example.

HEPS Spending Profiles (as reference)

Million RMB/month



Million RMB/month



HEPS spending profiles will be used as an example to study CEPC spending profile and personnel number evolution and the total personnel number

ILC Pre-Lab Human Resource Requirement
(as a reference)

Proposal for the ILC Preparatory Laboratory (Pre-lab)

International Linear Collider
International Development Team

1 June 2021

Table 2: List of estimated material costs and human resource requirements for deliverables of the technical preparation activities, where ILCU is defined in the text. (Resources for the infrastructure needed for deliverables are not included.)

Domains	Material cost [MILCU]	Human resources [FTE-yr]
Main Linacs (ML) and SRF	41.25	285
Electron Source	2.60	6
Positron Source	5.85	15
Damping Ring (DR)	2.50	30
Beam Delivery System	2.20	16
Dump	3.20	12
Total	57.60	364

arXiv:2106.00602v1 [physics.acc-ph] 1 Jun 2021

Table 3: Estimated human resource requirements for engineering design and documentation.

Item	Human resources [FTE-yr]
Accelerator/Engineering design and integration	75
Sources	35
Damping Ring (DR)	30
Beam transfer system from DR to ML	25
Main Linacs (ML)	60
Beam Delivery System	25
Total	250

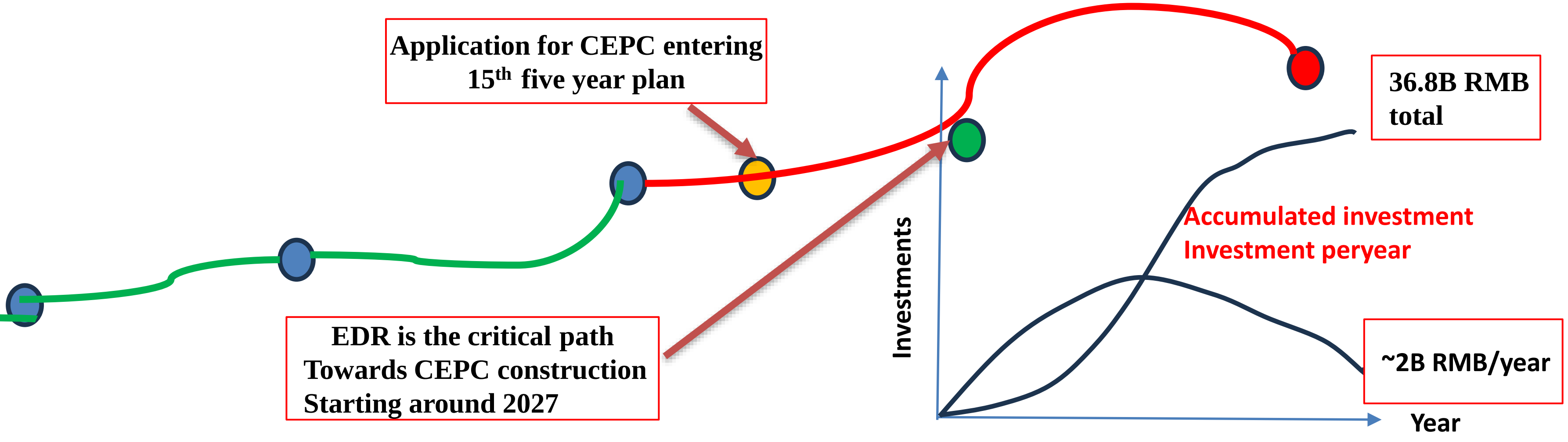
Table 4: Estimated civil engineering cost and human resources requirement.

Item	Cost [MILCU]	Human resources [FTE-yr]
Site surveys	22	70
Detailed designs	43	

CEPC Evolution Milestones with Human Resources

Year	2015	2018	2023	2025	2027	2030	2035
Human resource FTE	~50	~100	~200	~300	~500	~2800	~2500

Year	Accelerator human resource	Accumulated 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



2012.9 CEPC proposed

2015.3 Pre-CDR

2018.11 CDR

2023.10 TDR

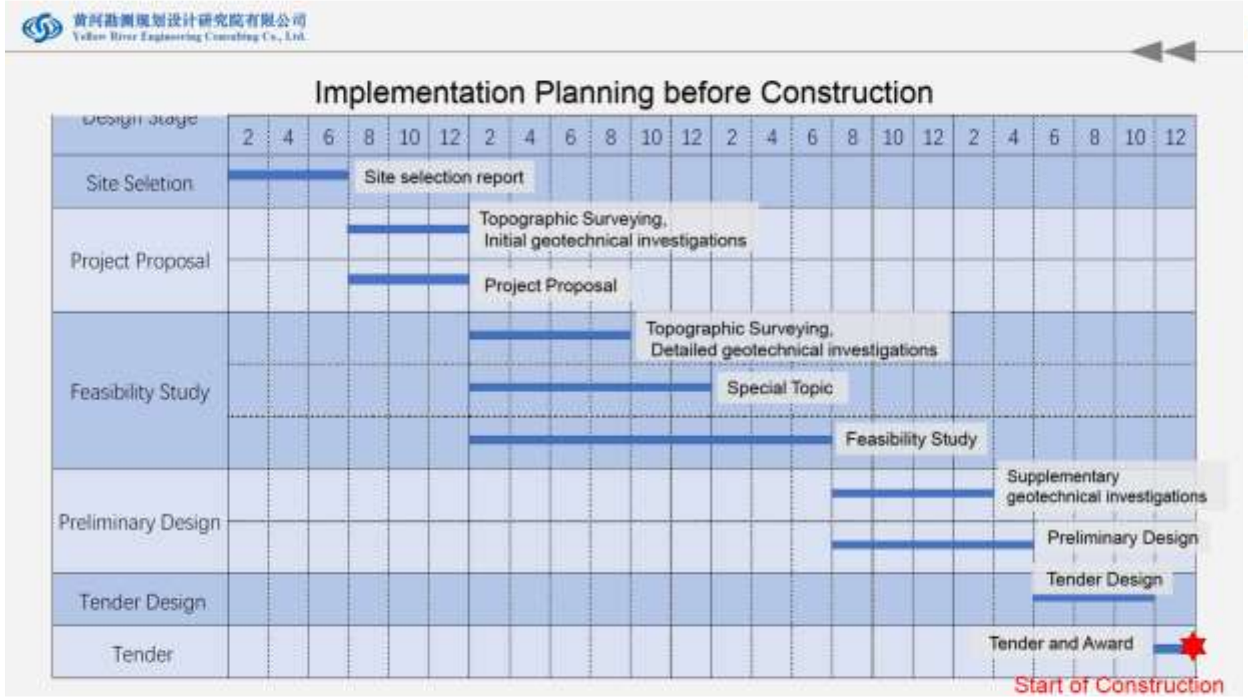
2024 ~ EDR

2027 start of construction

~2035 Completion

CEPC Site Implementation and Construction Plans

CEPC site implementation plan in EDR



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 Promototion Consortium (CIPC, established in Nov. 2017)

Potential international collaborating suppliers worldwide

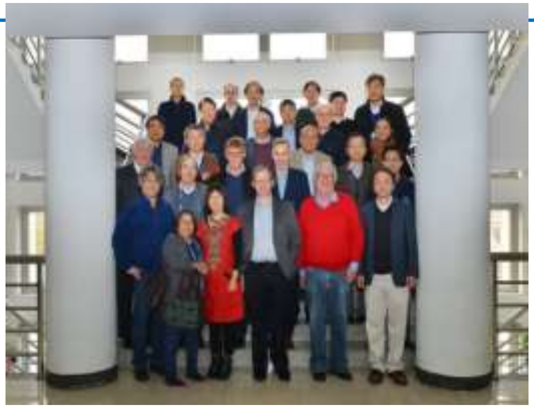
CEPC International Collaboration -1

The first CEPC-SppC international Collaboration Workshop
Nov 6-8, 2017, IHEP, Bejing

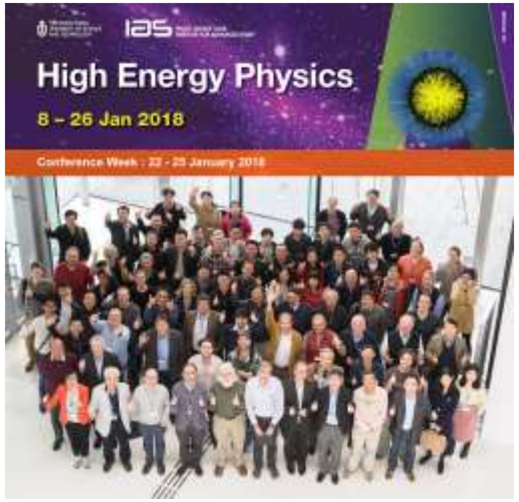
http://indico.ihep.ac.cn/event/6618

Workshop on the Circuar Electron Positron Collider-EU edition
May 24-26, 2018, Università degli Studi Roma Tre, Rome, Italy

https://agenda.infn.it/conferenceDisplay.py?ovw=True&confId=14816



3rd CEPC IAC, Nov 8-9, 2017,
IHEP, Beijing



IAS Higgh Energy Physics Workshop
(Since 2015)

http://iasprogram.ust.hk/hep/2018

CEPC Workshop-EU , 2019 Sep 2019, Oxford,UK

https://agenda.infn.it/conferenceDisplay.py?ovw=True&confId=14816

CEPC Workshop, EU-Eidition, 3-6 July 2023, Edinburg, UK

CEPC Workshop, 22-23 April 2020, USA

https://indico.cern.ch/event/863751/

More than 20 MoUs have been signed with international institutions and universities

CEPC International Collaboration-2

HKIAS23 HEP Conference
Feb. 14-16, 2023

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

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

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

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

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

Summary

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

Acknowledgements

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

Special thanks to CEPC, IAC, IARC and TDR review (cost) committee's critical comments, suggestions and encouragement

Thanks