Status of the CEPC e^+e^- accelerator

M.E. Biagini, INFN-LNF

Seminario INFN_ACC, 13/12/2024

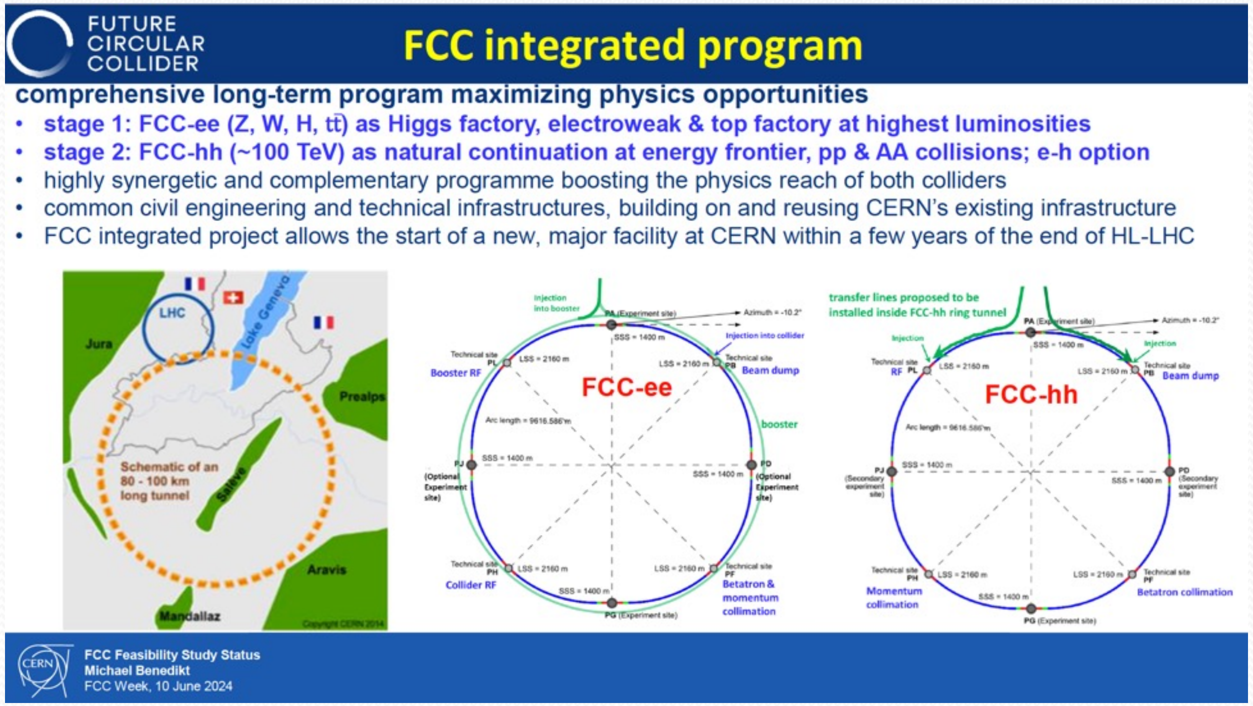
CEPC overview

- The Chinese Electron Positron Collider is a Higgs, Z, W, ttbar collider, "twin" of FCCee
- To probe new physics beyond SM:
  - Higgs-factory at *s*~ 240 GeV, above the ZH production threshold for ≥1 M Higgs;
  - Z pole at *s*~ 91 GeV for ~Tera Z;
  - WW pair at *s*~ 160 GeV and then ttbar pair production thresholds at *s*~ 360 GeV
- High luminosity 30 MW (SR power) with upgrade to 50 MW
- First proposed in 2012, an accelerator CDR was published in 2018, accelerator TDR in December 2023, detector TDR is planned for June 2025. An EDR phase is on-going
- Several sites considered, one almost certainly chosen but not to be disclosed (in progress)
- Operation start planned mid of 2030's (if approved beginning of 15^{th} 5-years plan)
- The project has been recently selected from the Chinese Academy of Science (CAS) as the 2^{nd} most important in China, to be submitted to the Central Government for approval in 2025-26
- Option to build a hadron collider SPPC in the same tunnel, after the e^+e^- data taking, is foreseen

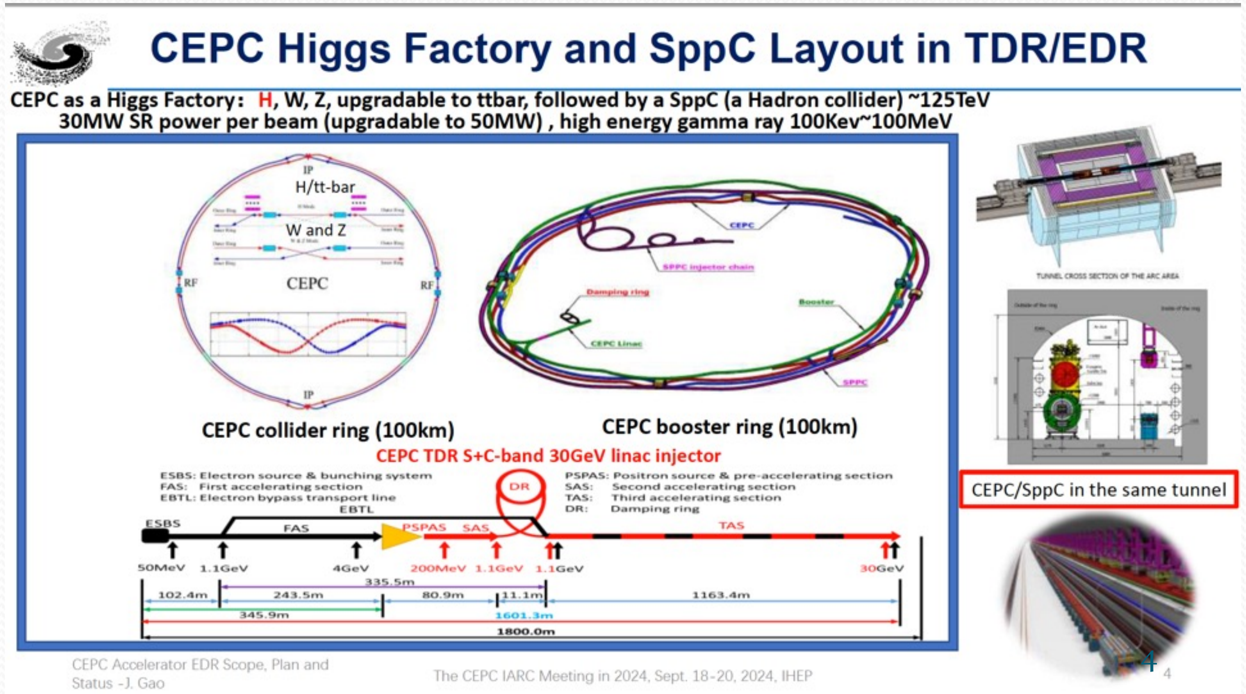
CEPC review committees

- CEPC progress has been monitored since the beginning, both from an International Accelerator Review Committee (IARC, meeting twice per year, chair M.E.B.) and an International Advisory Committee (IAC, meeting once per year, usually end of October, chair B. Foster)
- The TDR has been reviewed by a TDR-RC (June 2023, chair F. Zimmermann)
- The cost has been reviewed by a Cost Review Committee (September 2023, chair L. Rivkin)
- The EDR phase is being reviewed by and extended IARC-EDR (first meeting last September, chair M.E.B.)
- The detector is being reviewed by an International Detector Review Committee IDRC (first meeting last October, chair D. Bortoletto)

Super Higgs (Z,W,ttbar) Factories



~100 Km, 3 rings, underground tunnel, ramping booster, high synchrotron losses
Alignment is nightmare…



Need for some "green" solution to be able to sustain a very costly operation
Efforts are going on in both projects, more to be done

CEPC Operation Plan and Goals in TDR

Particle	$E_{c.m.}$ (GeV)	Years	SR Power (MW)	Lumi. per IP ($10^{34}cm^{-2}s^{-1}$)	Integrated Lumi. per year (ab^{-1}, 2 IPs)	Total Integrated L (ab^{-1}, 2 IPs)	Total no. of events
H*	240	10	50	8.3	2.2	21.6	4.3×10^6
			30	5	1.3	13	2.6×10^6
Z	91	2	50	192**	50	100	4.1×10^{12}
			30	115**	30	60	2.5×10^{12}
W	160	1	50	26.7	6.9	6.9	2.1×10^8
			30	16	4.2	4.2	1.3×10^8
$t\bar{t}$	360	5	50	0.8	0.2	1.0	0.6×10^6
			30	0.5	0.13	0.65	0.4×10^6

* Higgs is the top priority. The CEPC will commence its operation with a focus on Higgs.

** Detector solenoid field is 2 Tesla during Z operation, 3Tesla for all other energies.

*** Calculated using 3,600 hours per year for data collection.

Design challenges of such a complex accelerator system (applies to FCCee too)

- Beam parameter at IP
- Crab-waist collision
- IR design
- Solenoid compensation and ε_y growth
- Machine Detector Interface (MDI)
- IP orbit feedback and L tuning
- Low emittances
- Chromaticity and Non-Linearities
- DA & MA
- Errors handling → Optics/coupling
- High beam currents
- Lifetime
- Backgrounds in the IR
- Backgrounds in the rings
- Impedance → instabilities
- Ion-trapping/e^- cloud mitigation
- Fast injection (off/on/swap) & ramping
- Polarization (T and possibly L)

All are interconnected!

Technical challenges

- IR SC quadrupoles
- IR engineering (MDI)
- HOMs in IR
- Combined Function dipoles (B+S)
- SC RF
- High efficiency RF sources
- Reliable injector
- Plasma injector (option)
- Diagnostics & Controls
- Vacuum
- Collimators (NL?)
- Synchrotron losses (saw-tooth)
- Radiation hardness
- Alignment
- Installation
- Civil engineering

Other challenges…

- Money (construction & operation)
- Manpower (design, construction & operation)
- Time
- Availability of electronics/equipment in a few years, when required for mass production
- Accessibility → repairs in tunnel in case of failures
- Sustainability → green accelerator?
- …

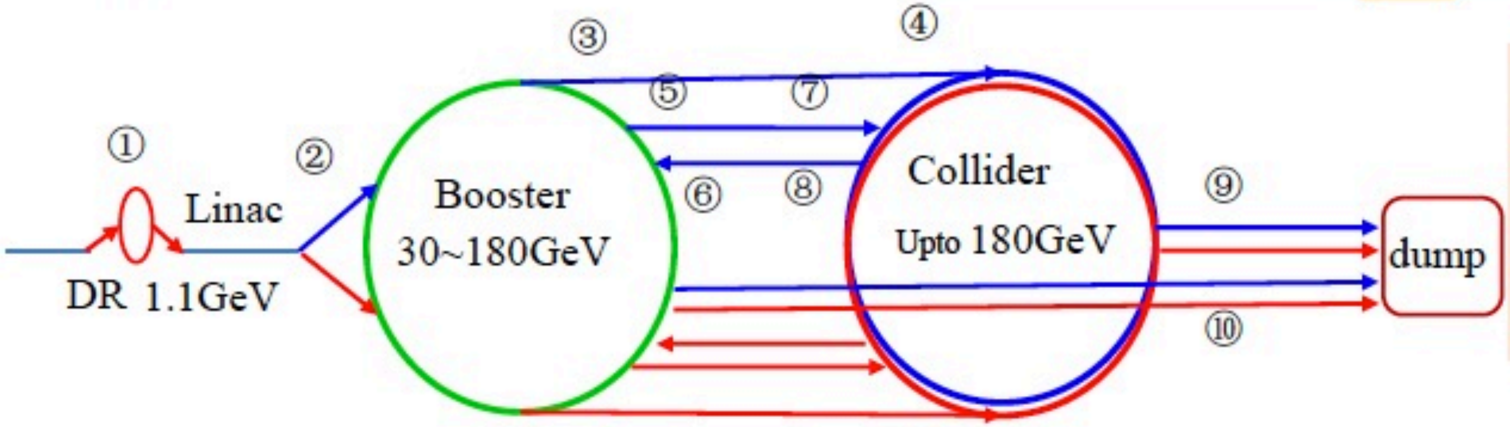
CEPC parameters and layout

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

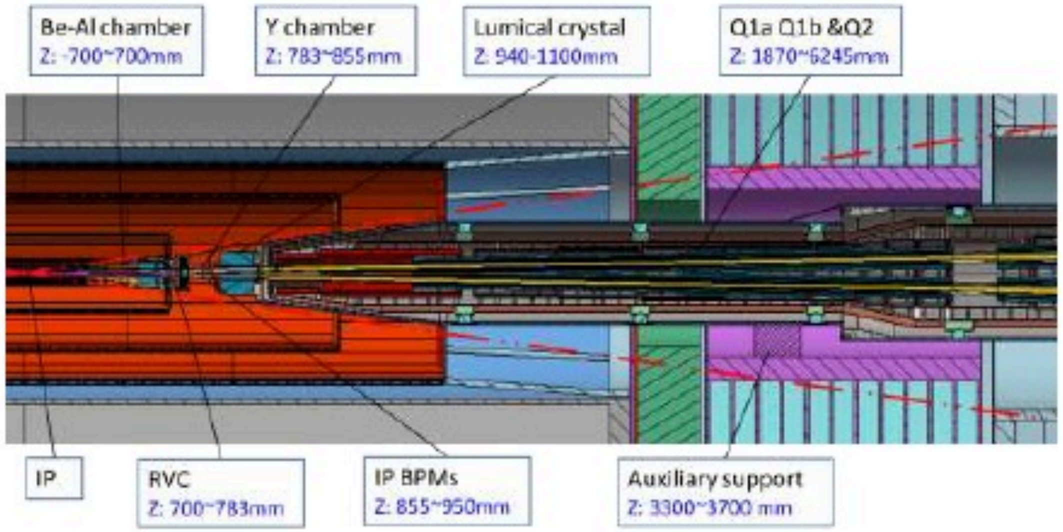


Running scenarios
Higgs 10 years
Z 2 years
W 1 year
ttbar 5 years

Machine Detector Interface

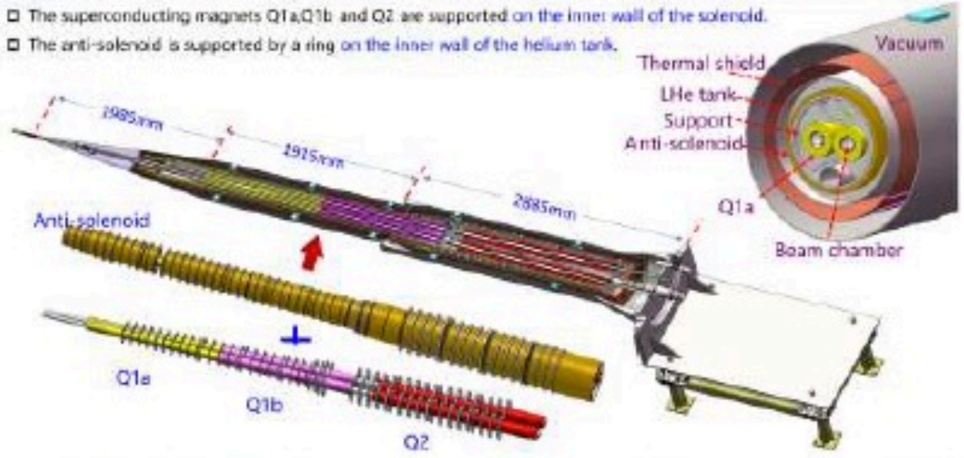
- MDI is a crucial part of the collider
- It is important to choose the right beam pipe material and geometry, evaluate correctly the beam losses and chamber heating, design supports able to minimize vibrations overall in the IR, at the same time satisfying the detector requirements for space
- Design of the SC quadrupoles and their correction coils is complicated
- In parallel, backgrounds and particle losses need to be carefully studied
- Luminosity performances will mostly depend on the IR design and engineering

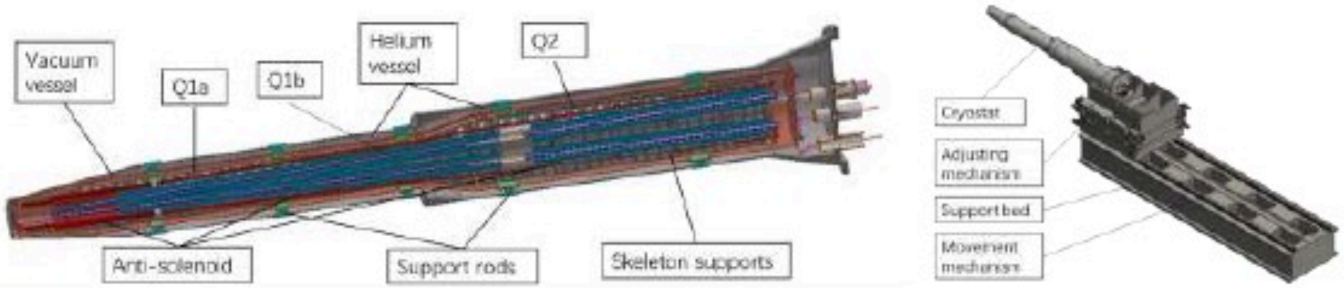
CEPC MDI Development in EDR



Structural Design of the SC Quadupole Cryostat and Support

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





CEPC SC Quadrupole Magnet Design with CCT Coil

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

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

- Geometry after TDR with modification updated
  - Accelerator Beam pipe changed to **Tungsten**
  - Coolant of central beampipe changed to Water
  - Cross-section is improved and more specific.

CEPC MDI in EDR

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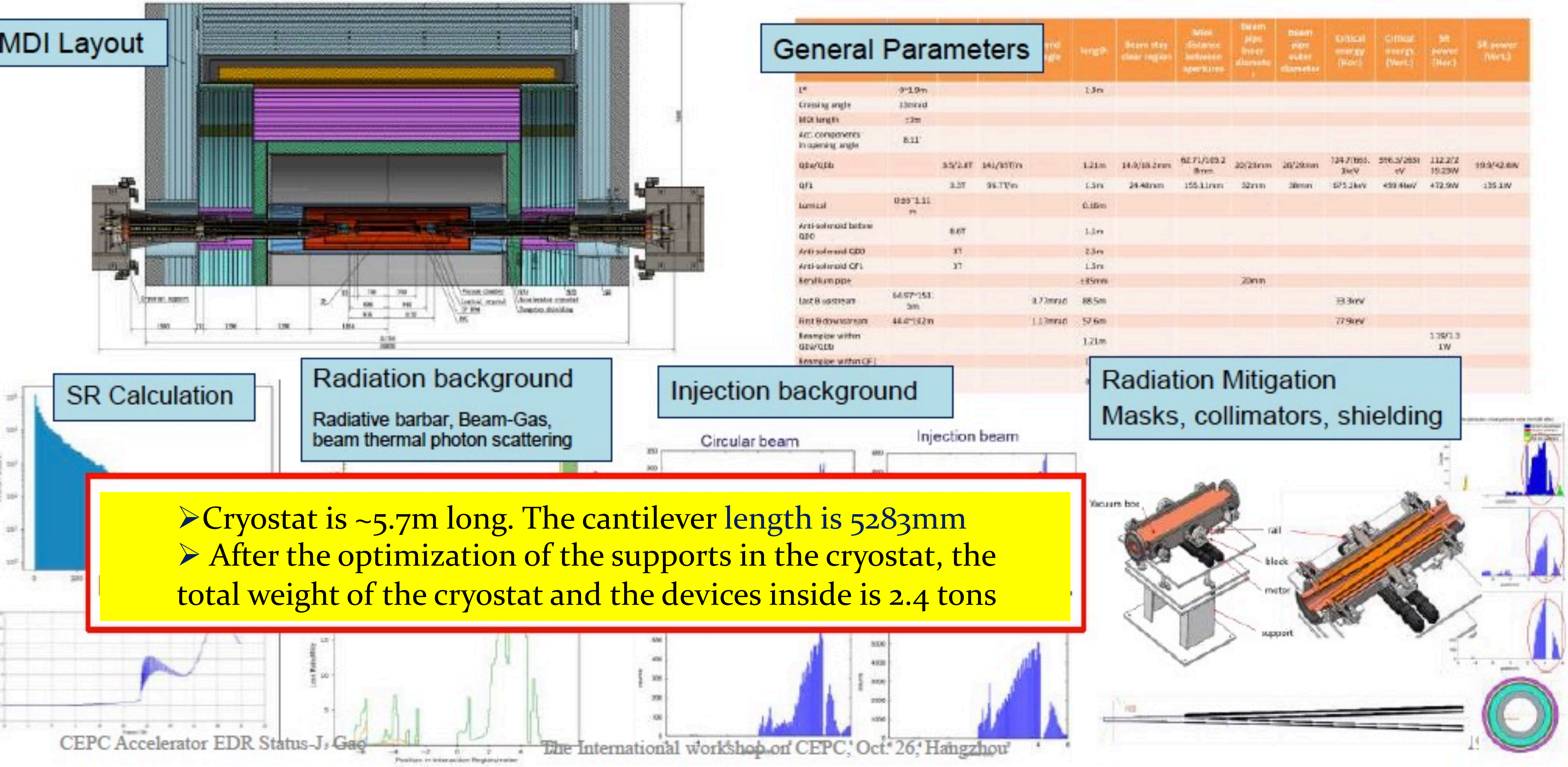
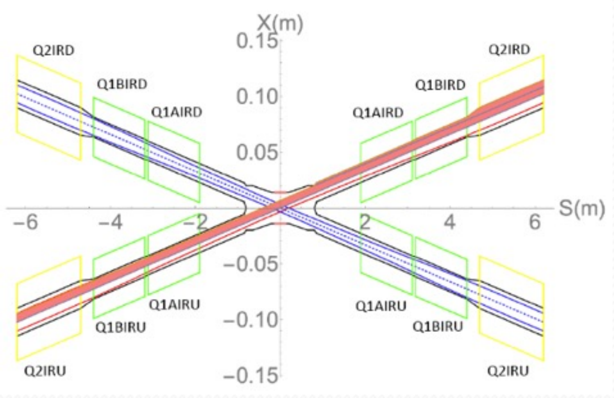
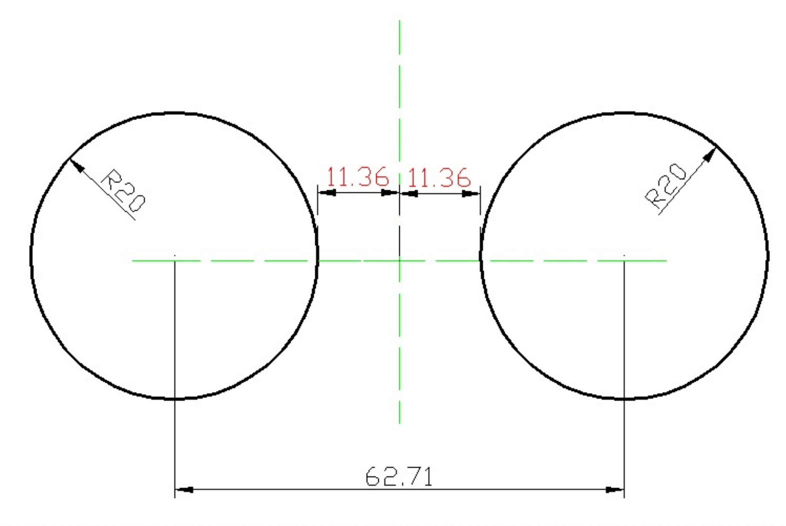


➢Cryostat is ~5.7m long. The cantilever length is 5283mm
➢ After the optimization of the supports in the cryostat, the total weight of the cryostat and the devices inside is 2.4 tons

SC IP quadrupoles

- Several options studied, for the SC IP quadrupoles, two preferred: iron-free CCT, Direct Winding CCT coil
- Q1 is particularly difficult:
  - High field gradient: 142.3T/m
  - Limited radial space in the magnet middle:
    R: [20mm, 31.36mm], **only 11.36 mm** available
  - Magnetic field crosstalk between two apertures
    High order field harmonics $\leq 3 \times 10^{-4}$
    Local dipole field: ≤300 Gs (Higgs)
    or ≤100 Gs (Z)





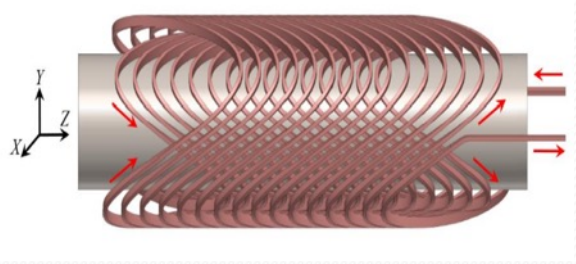
Direct winding CCT option (preferred)

- New design combining direct winding technology and CCT coils
- Divide the CCT coil into many layers
- **Wind CCT coil layer by layer using Direct winding machine**
- Adjacent layers of coils are separated by epoxy and insulation material
- Winding machine directly winds the coil based on theoretical position of each conductor

Advantages of Direct winding CCT coil:

➢**Accurate wire position** and high magnetic field precision
➢**No gap** between adjacent layers or coils
➢**Compact structure** for superconducting magnets with multiple coils
➢Coil self correction technology is used to solve magnetic field crosstalk
➢Pre-stress can be applied by wrapping fiberglass on the coil layers
➢Magnetic field harmonics can be corrected during the multi-layer winding process

Direct winding technology



CCT Coil

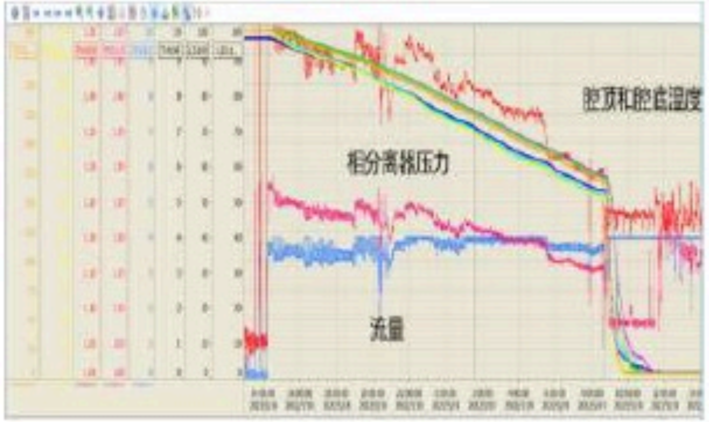
Generates magnetic field that varies longitudinally

CEPC SRF cavities & power sources

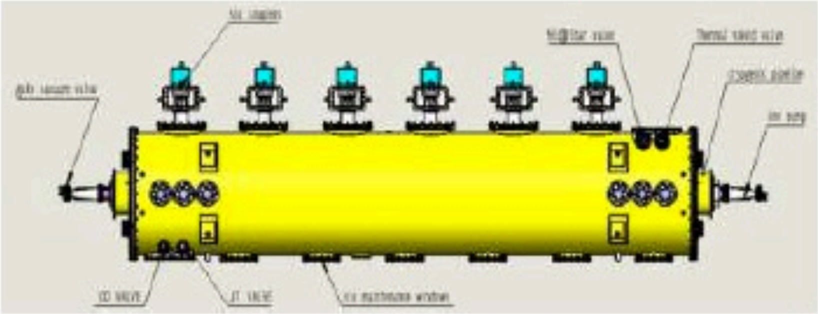
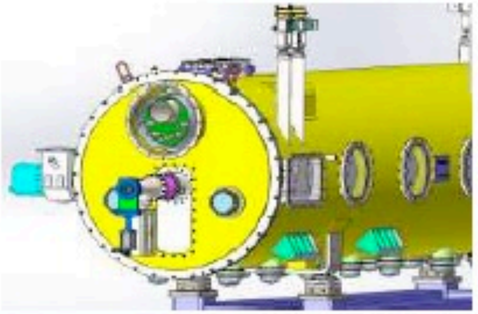
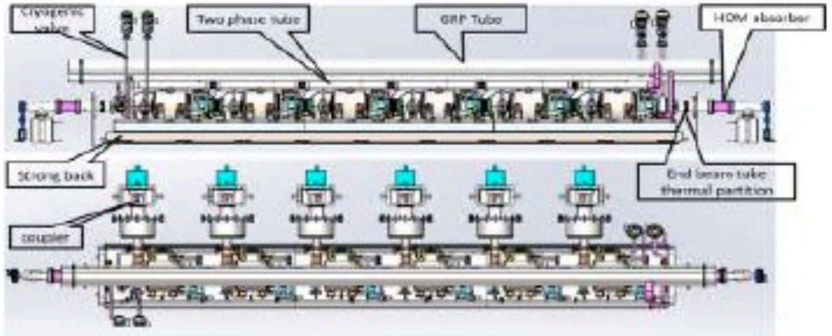
- More than 1000 cavities are needed, for booster (40%) and collider (60%)
- 1.3 GHz TESLA-like for the booster, built for DALS injector, 650 MHz for the collider, prototypes going-on on 2-cells cavity
- Significant results have been achieved on prototyping variable couplers, which are a key factor required for energy efficiency across the different collider modes
- New design of Cryo-Module (in series, not in parallel) → challenging but cost saving, strong collaboration between industry and institutions, test planned next year of a very large cold box of 18 kW @ 4.5 K
- High efficiency klystron → impressive result → recorded efficiency of 78.5% at CW 803 kW (aims at 90%!)
- Multi-beam klystron (MBK) and Energy Recovery MBK Klystrons tests by end 2024
- C-band pulsed klystron with 80 MW output power at 100 Hz repetition rate was designed and is ready for production

CEPC Accelerator SRF Development in EDR





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

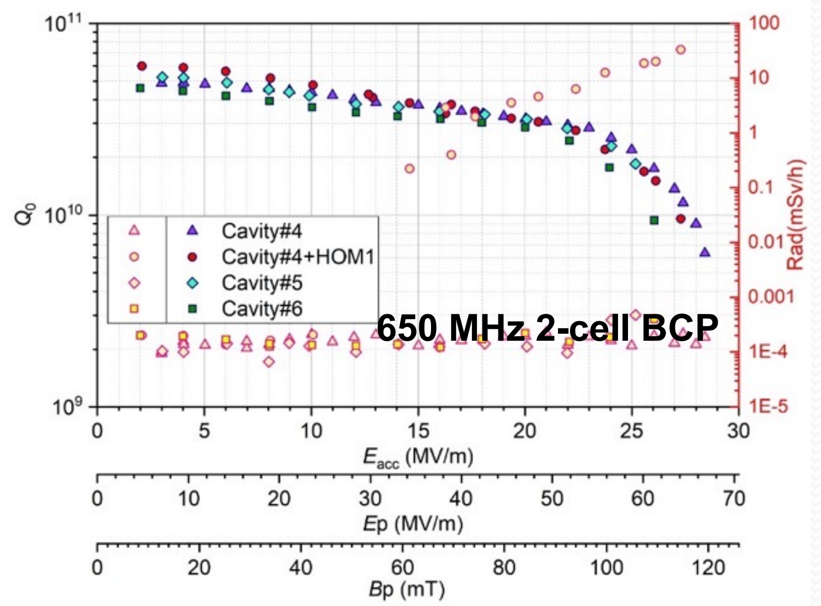
The collider Higgs mode for 30 MW SR power per beam will use 32 units of 11 m-long collider cryomodules will contain six 650 MHz 2-cell cavities, and therefore, a full size 650 MHz cryomodule will be developed in EDR

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

650 MHz 2-cell Cavity EDR R&D

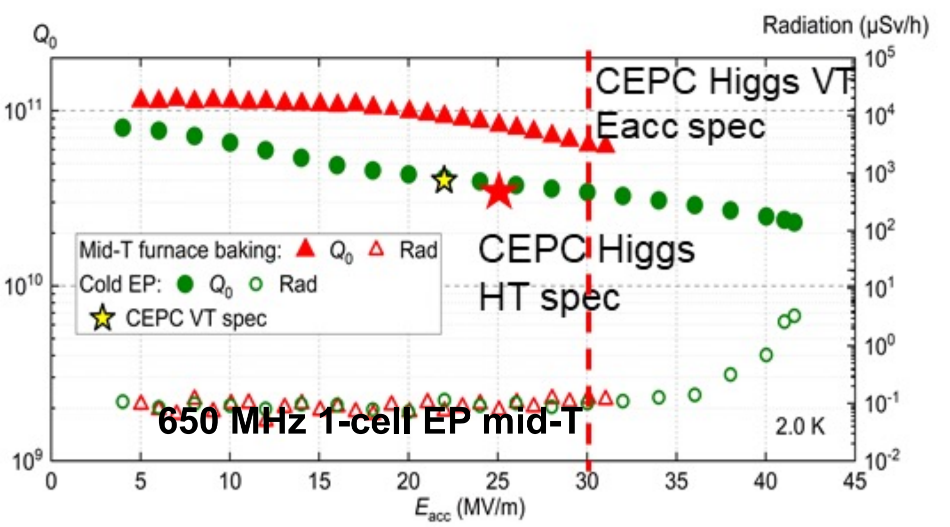
CEPC 650 MHz CM		EDR Specification
650 MHz 2-cell cavity vertical test	$E_{acc.max}$	**30 MV/m**
	Q_0	**3.6E10 @ 25 MV/m**
Module horizontal test acceptance	$E_{acc.max}$	28 MV/m
	Q_0	3.3E10 @ 25 MV/m
Module long term operation	$E_{acc.max}$	28 MV/m
	Q_0	3.0E10 @ 25 MV/m

20 % margin from vertical test to operation spec.



- **BCP dressed 2-cell VT**: 2E10 @ 25 MV/m, max ~ 26.5 MV/m
- **BCP 2-cell module test**: 2E10 @ 8 MV/m (coupler cooling limited?)
- **EP + mid-T 1-cell VT**: 8E10 @ 25 MV/m, max 31.5 MV/m
- **Apply 1-cell recipe to 2-cell**

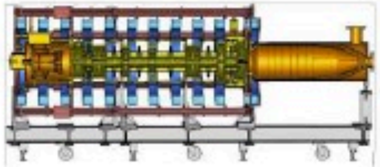
J. Zhai, CEPC EDR Review, Sep. 2024



CEPC Accelerator Development: Klystrons

Klystron R&D

Klystron No. 2
Efficiency 77%
(2021)



Klystron No. 1
Efficiency 65%
(2020)

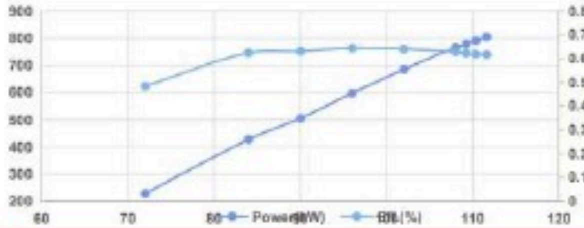
Pulsed RF Mode (30% duty factor, 60ms/5Hz)

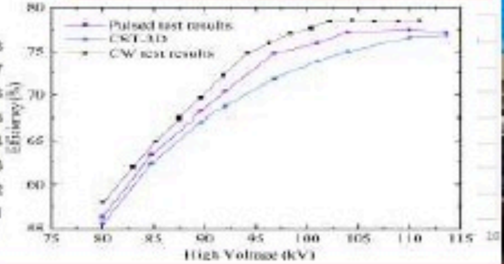
78.5%@803kW CW in 2024

Klystron No. 3 （MBK
Efficiency 80.5%

To be completed in 2024

High Voltage vs. Power&Efficency

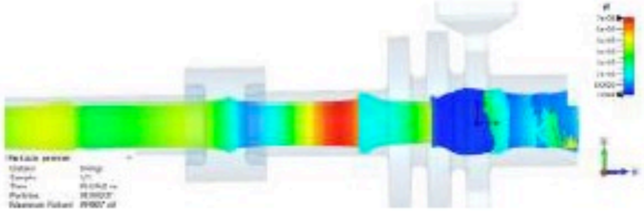


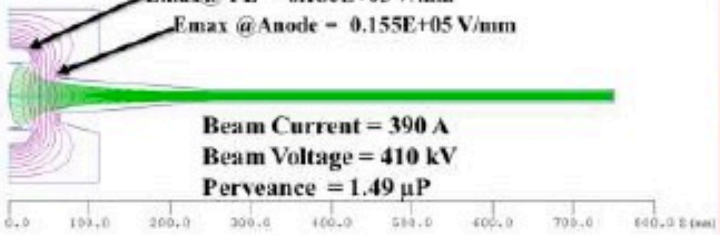


CEPC collider ring 650MHz klystron development in TDR phase

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

C band 5720MHz 80MW Klystron



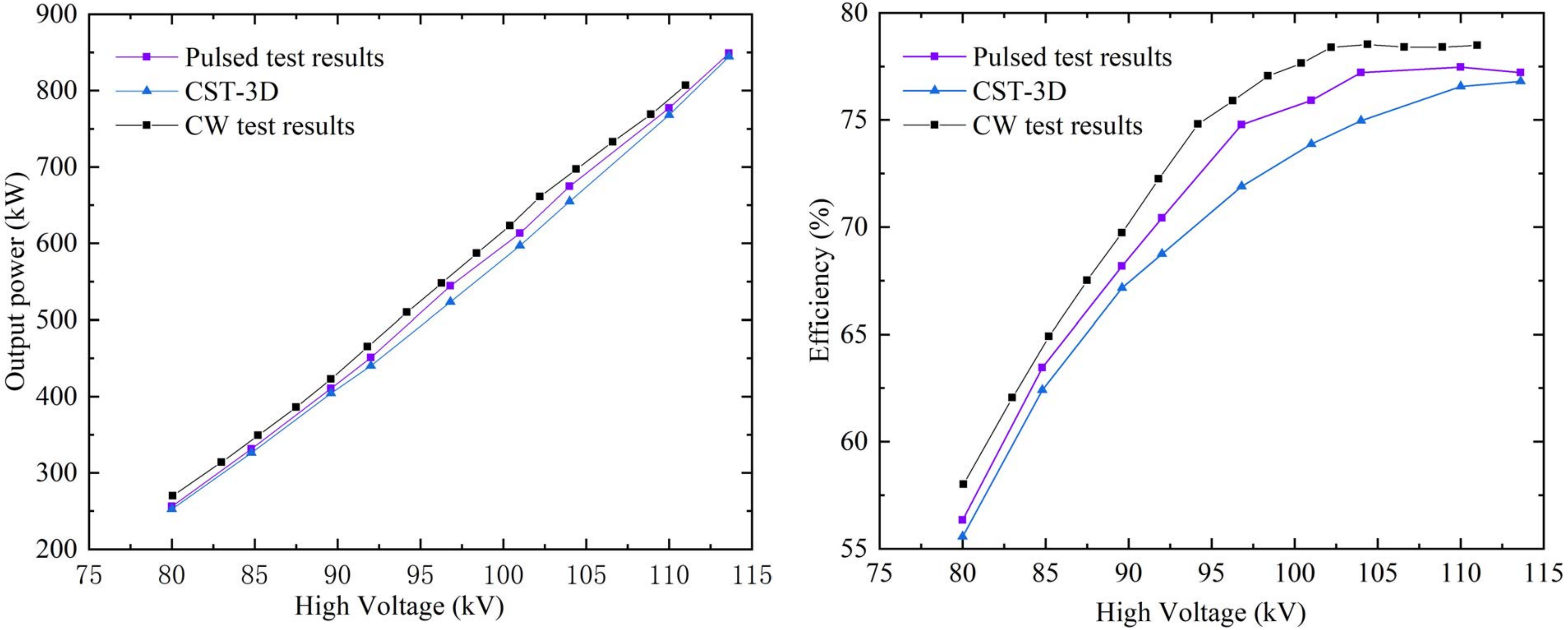


C band 5720MHz 80MW
Klystron design completed

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

650MHz/800kW CW klystron test results

Z. Zhou, CEPC EDR Review, Sep. 2024



FCCee Definition of alignment strategy

Alignment should comply the need of keeping errors to a minimum for machine performances

General constraints
- Access (installation, alignment, maintenance)
- Space
- Radiation level
- Thermal stability
- Stability of the tunnel floor, ground motion

Alignment is a real concern

Project constraints
- Cost
- Manpower available
- Operation / maintenance time

Alignment of a component inside a tunnel

Component & support design
- Impact of vibrations
- Eigen frequencies
- Rigidity of component & support
- Weight

Beam requirements
- Fiducialisation requirements
- Component assembly on girder
- Girder alignment in the tunnel
- Relative / absolute alignment requirements

Alignment methods & instrumentation available

- **Takes several years!!!**
- **Different methods and solutions needed according to the area**

Geodetic Metrology

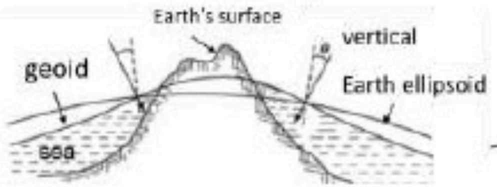
H. Mainaud Durand, FCCweek, June 2024

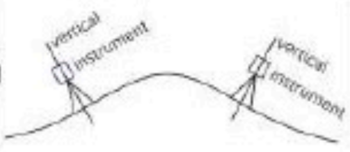
CEPC Alignment and Installation Plan in EDR

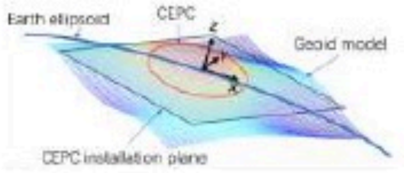
Alignment accuracy requirement

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





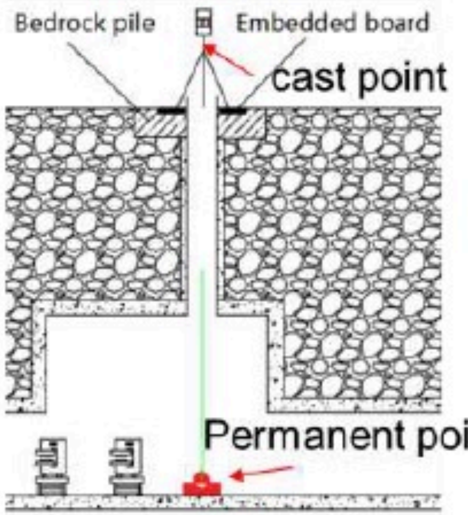


Component Pre-alignment

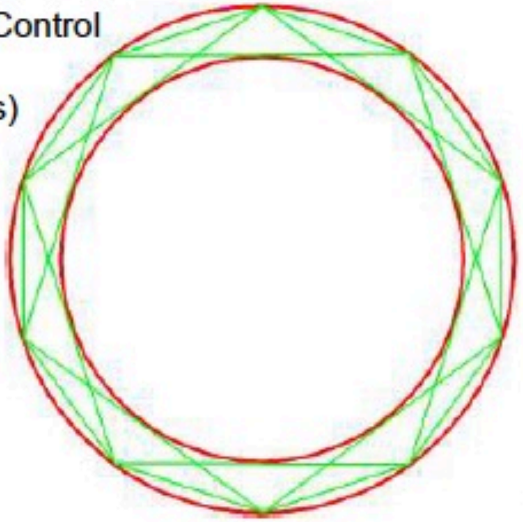
Wall Control Point

Ground Control Point

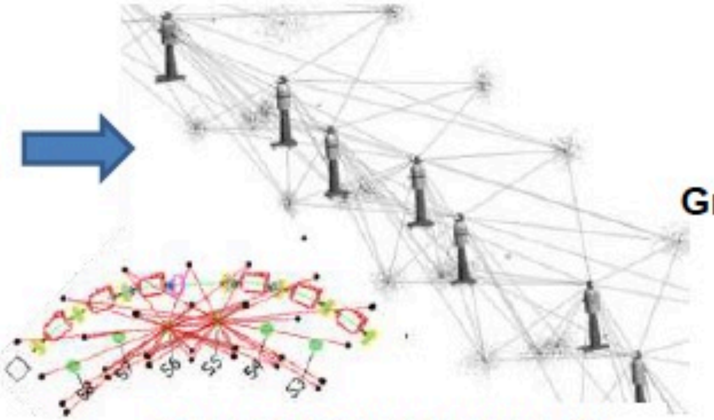
GPS receiver



Surface Control network (14Points)

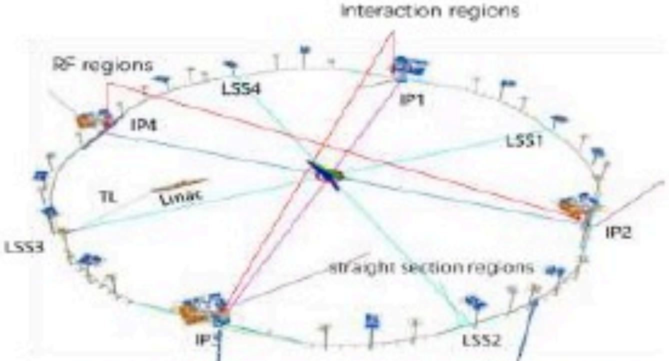


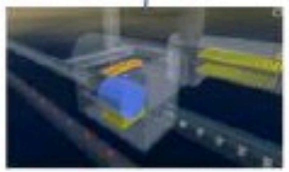
Backbone Control network
(short line:300m; long line:600m)



Tunnel Control network
(interval of 6 meters)

CEPC Installation Strategy Study in EDR

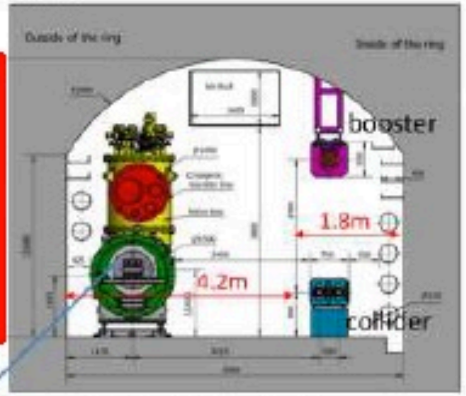




Detector

Ring

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



SPPC

Tunnel cross section

CEPC component list and quantities

Component	Collider Ring	Booster	Linac, DR, TL	Total
Dipole	13250	14866	135	28251
Quadrupole	4148	3458	714	8320
Sextupole	3176	100	72	3348
Corrector	7088	2436	275	9799
BPM 、 PR 、 DCCT 、 kicker	3544	2408	180	6132
Septum Magnet	68	32	2	102
Kicker	8	8	2	18
Cryomodule	32	12		44
Electrostatic separator	32			32
Collimator dump	36		8	44
Superconducting Magnets	4			4
Solenoid			37	37
Accelerating structure			577	577
Cavity			4	4
Electron Source			1	1
Positron Source			1	1
Detector	2			2
Total	31388	23320	2008	56716

Engineering Design towards an EDR

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

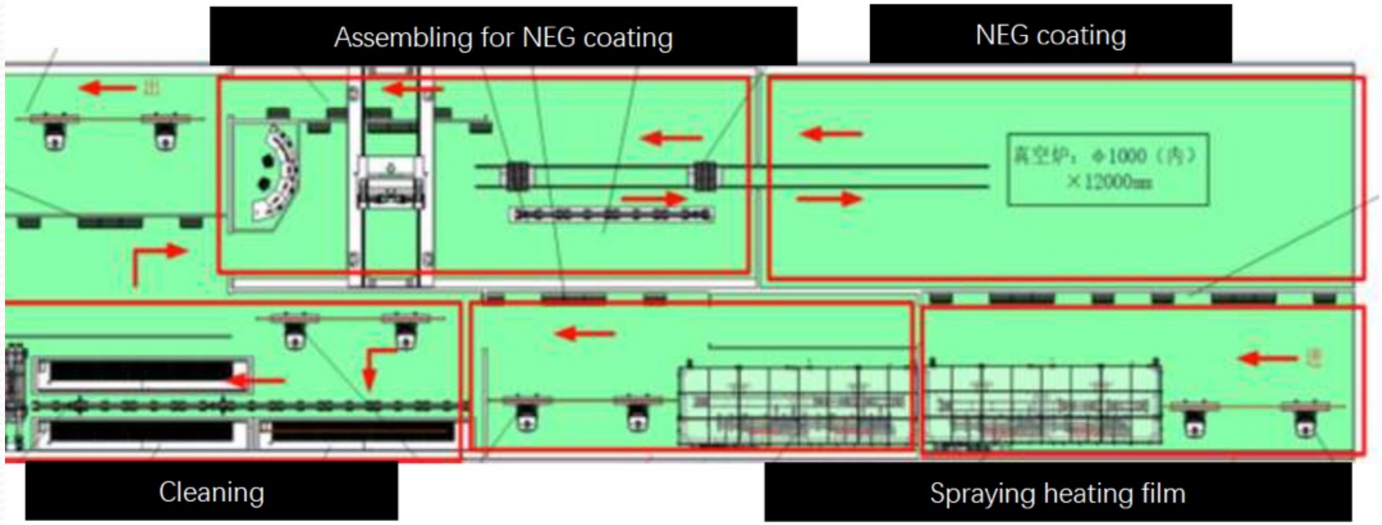
CEPC EDR Phase General Goal (2024-2027):

CEPC accelerator will enter the Engineering Design Report (EDR) phase (2024-2027); its also the preparation phase with the aim for CEPC proposal to the Chinese government ~2025 for approval.

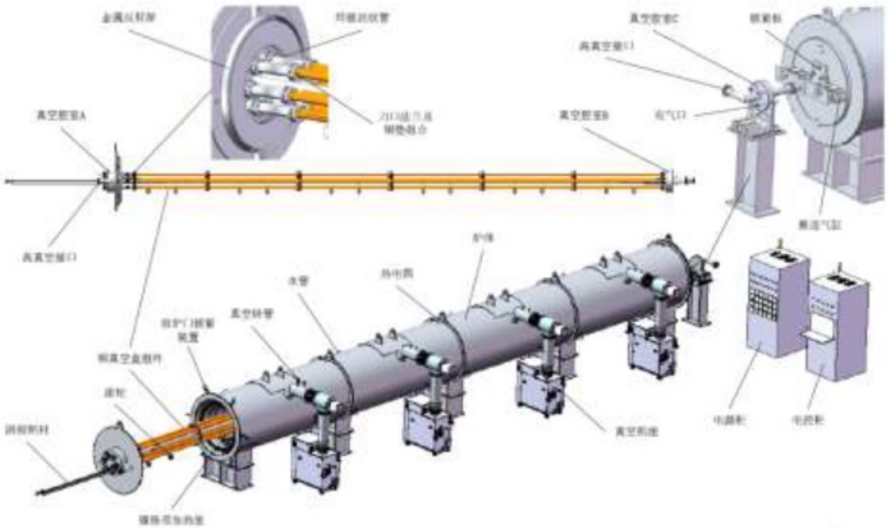
CEPC EDR includes accelerator and detector (TDRrd), 1st IDRC meeting last week
CEPC detector TDR reference design (rd) will be released by June 30, 2025

CEPC Accelerator EDR Phase goals, scope and the working plan (preliminary) of 35 WGs summarized in a documents of 20 pages reviewed by IARC in September 2024

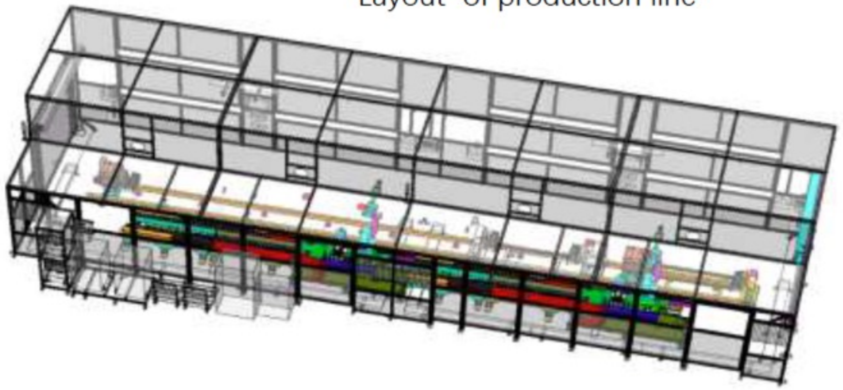
CEPC NEG Coated Vacuum Chamber (200km) Automatic Production Line in EDR



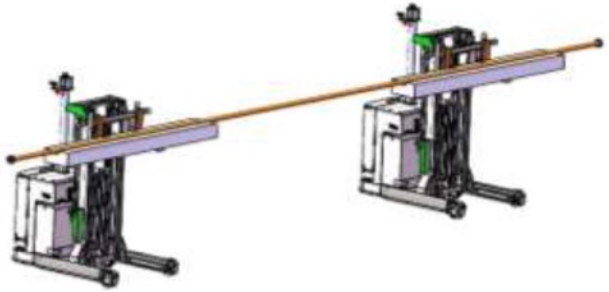
Layout of production line



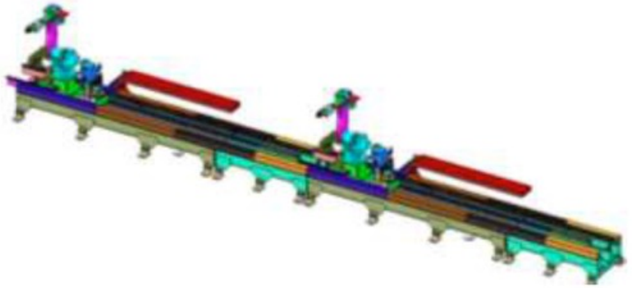
NEG coating facility by horizontal method



Production line of NEG coating, spraying



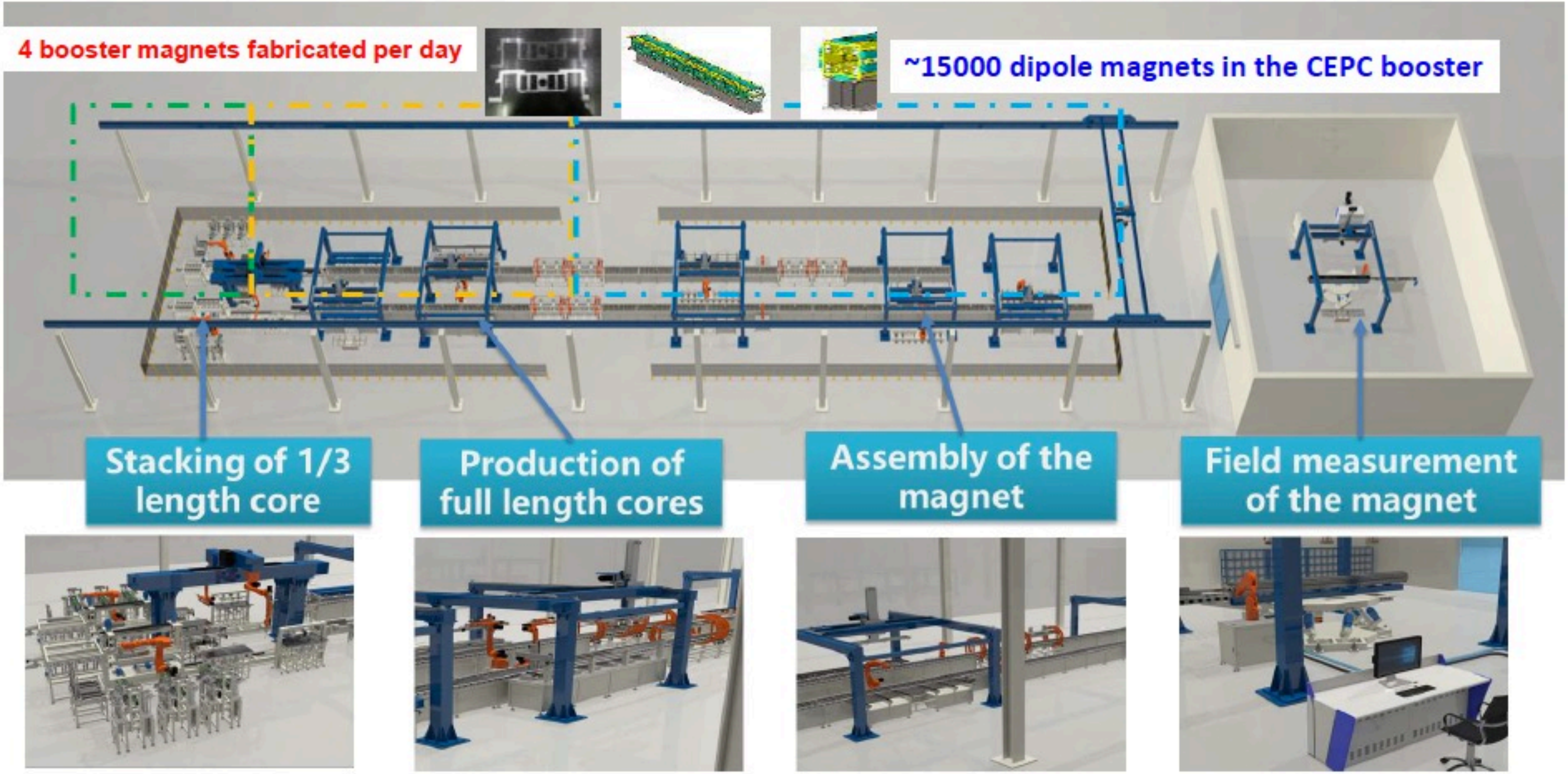
AGV(Automatic Guided Vehicle) transport



7-axis robot for assembling

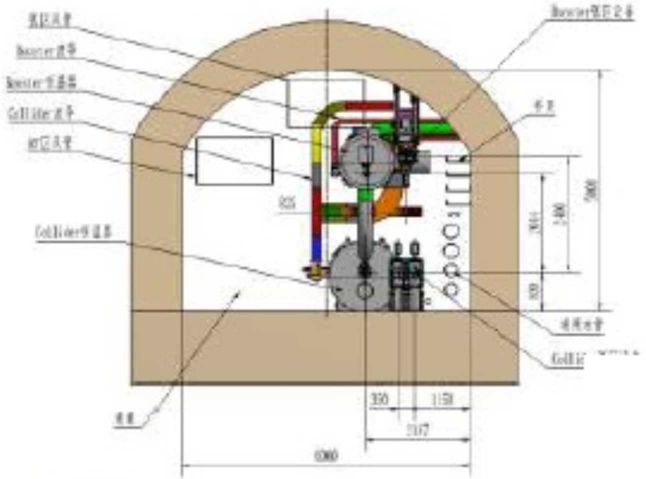
Plan： Technical design review has been done. To be completed in 2025

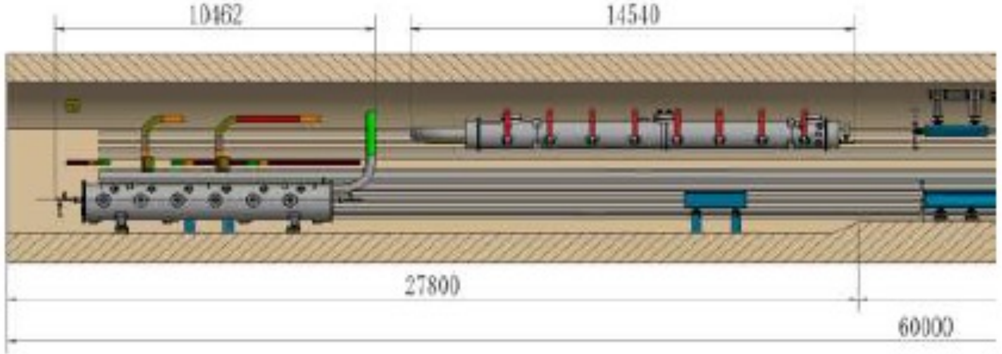
CEPC Magnet Automatic Production Line in EDR



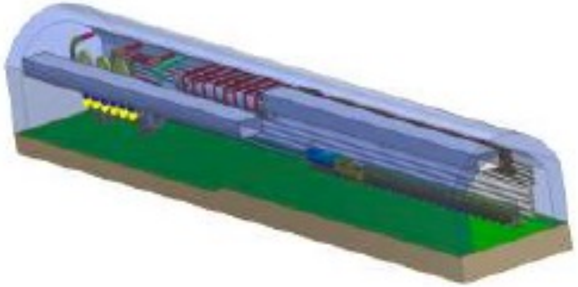
Plan： Technical design review has been done. To be completed in 2025

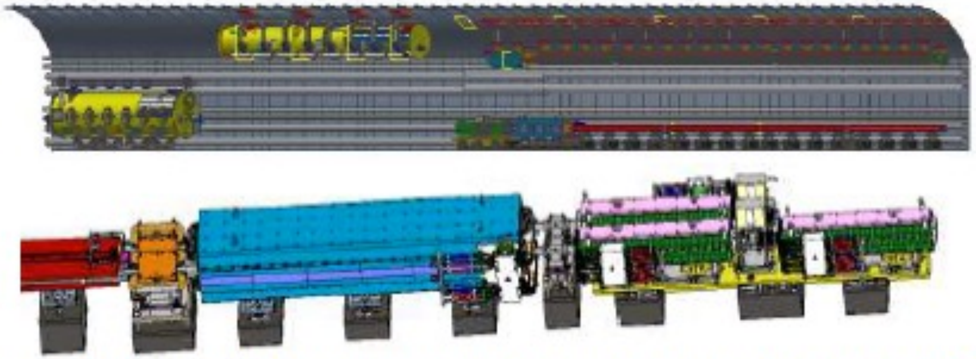
CEPC Tunnel Mockup for Installation in EDR

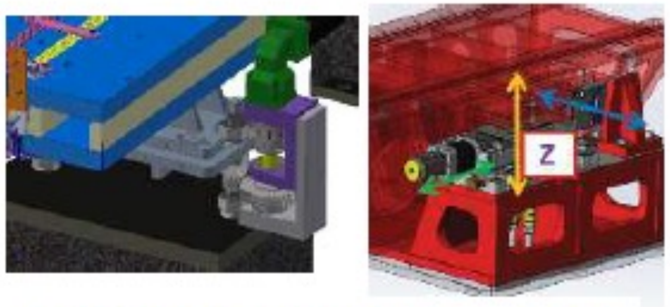




Booster magnets installation







Collider ring magnets supports

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

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

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

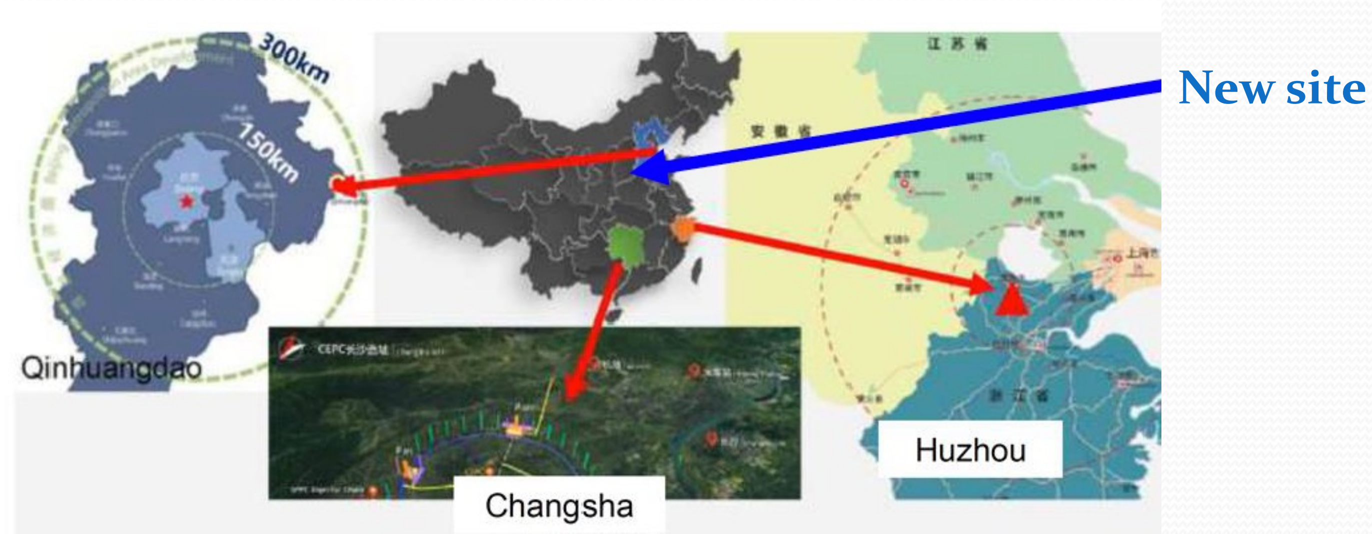
Power Consumption of CEPC @ Higgs

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

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

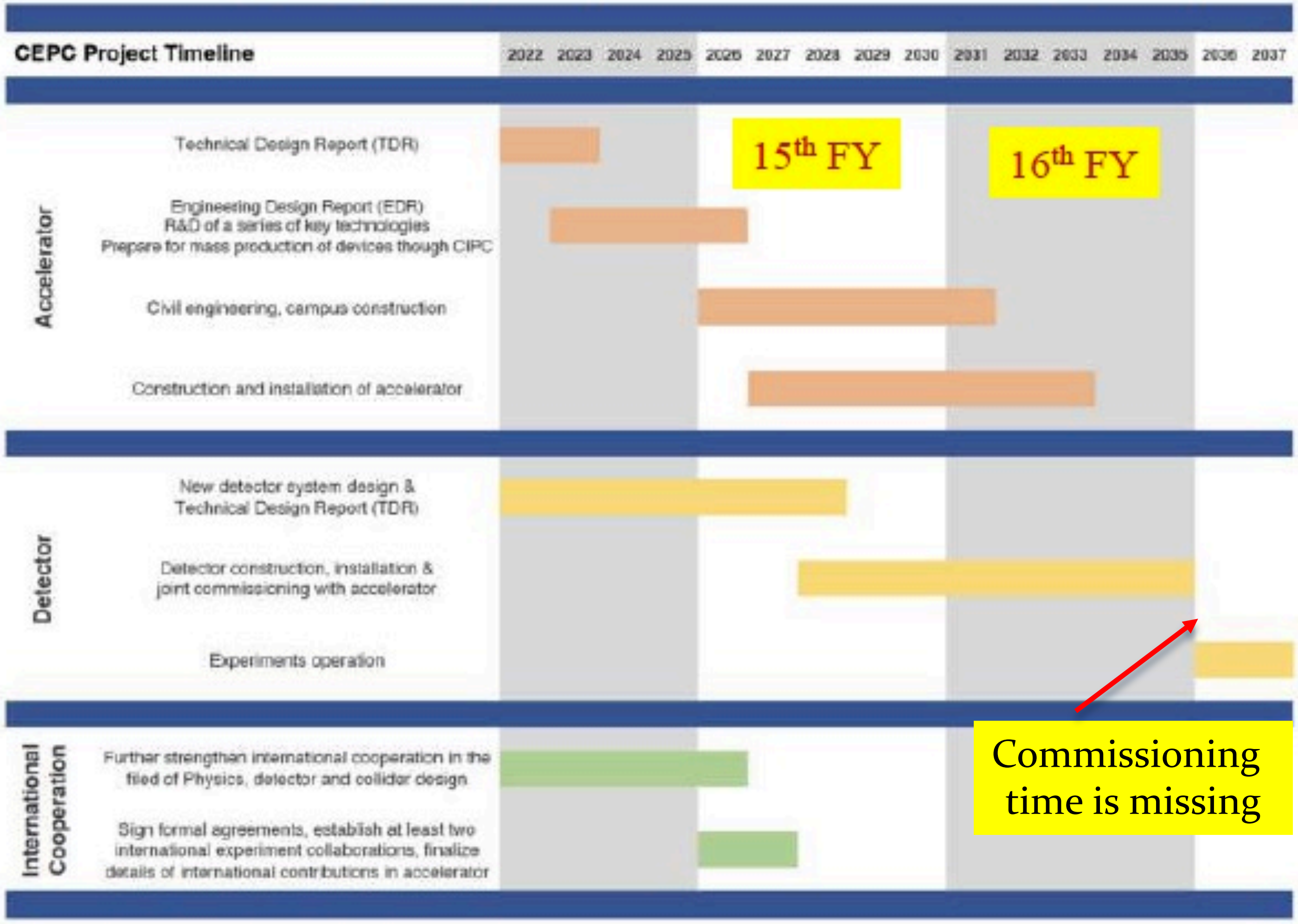
Site choice

- 3 “green-field” sites, all around China, close to big cities, were selected and their terrain and possible infrastructures studied
- The Province chosen should in principle contribute with a 30% of the cost of the machine
- Recently another province has offered a site and to fund a preliminary study. This is still in progress and its location is not to be disclosed now
- This very likely will be the final site (a new Physics Institute is being set-up nearby, director former IHEP Y. Wang)



CEPC Planning, Schedule and Teams

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



CEPC team (domestic)

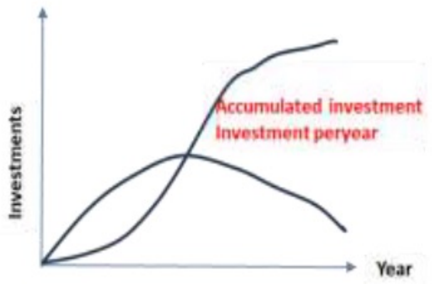
CEPC accelerator and detector/experiments/theory group is an highly **experienced** team with strong international collaboration experiences. It has demonstrated its **expertise** and **achievements** is the following related projects, both domestic and international ones, such as: **BEPC-BEPCII (BES-BESIII)，BFELP，CSNS，ADS，HEPS，LEP, LHC, LHCb, ILC, EXFEL, HL-LHC, BELLE, BELLE-II, CLEO, Daya Bay, JUNO, LHAASO, etc.**

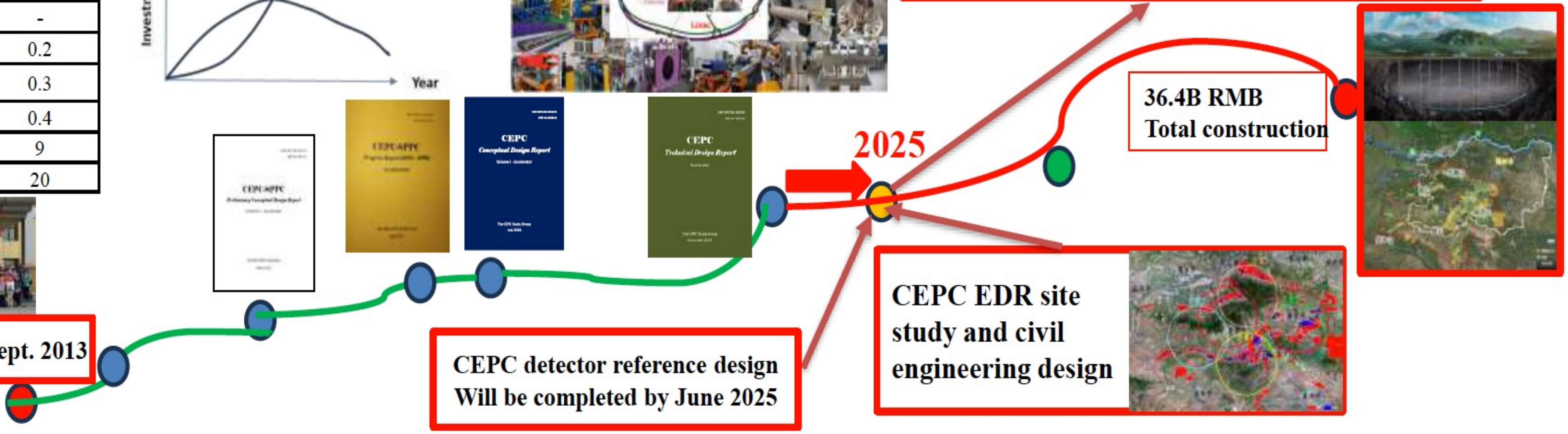
CEPC international partners and collaborators

CEPC 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

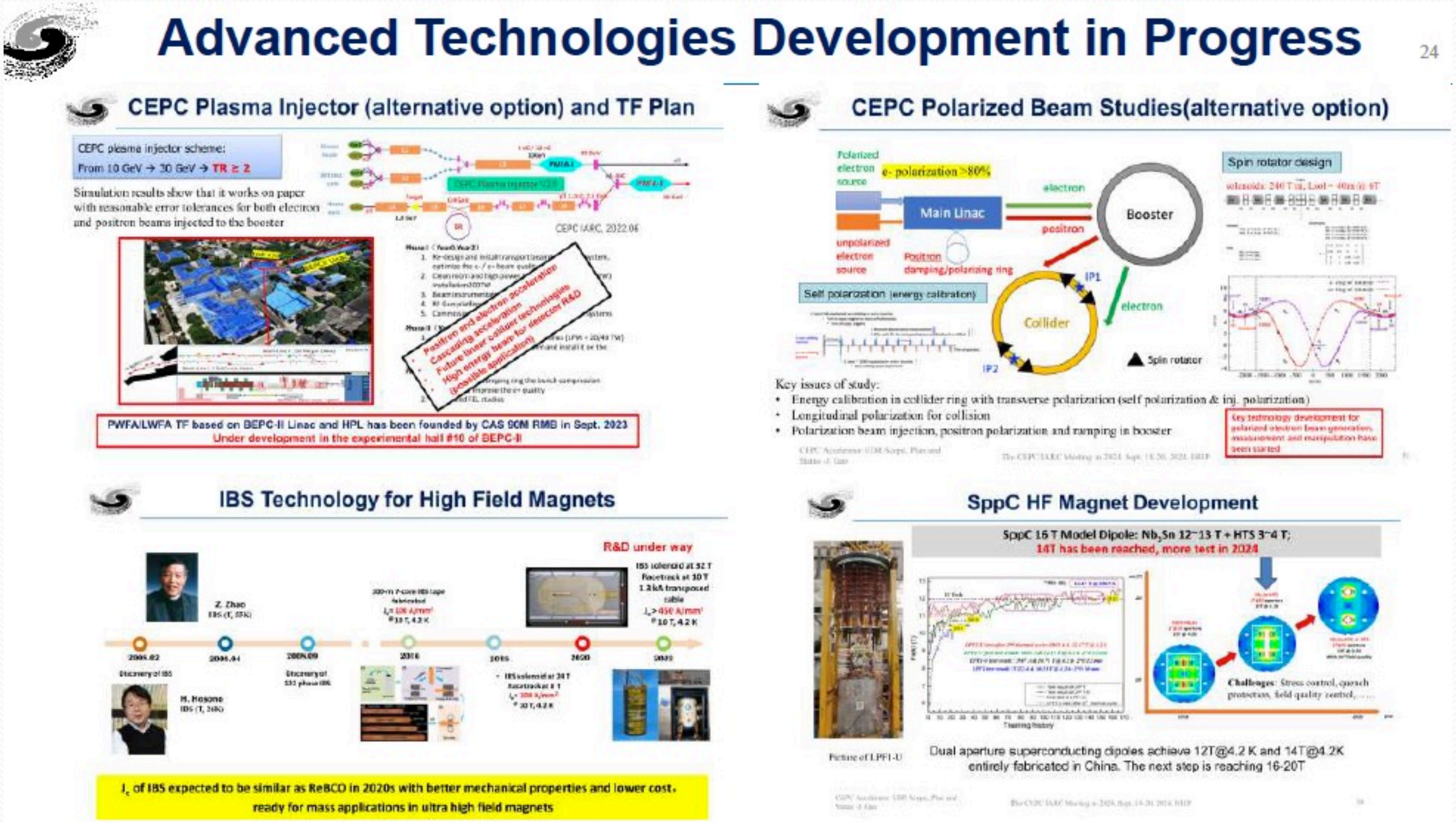
Year	Accelerator human resource	Accumulated accelerator spending Billion RMB
2015	50	-
2018	100	-
2023	200	0.2
2025	300	0.3
2027	500	0.4
2031	2800	9
2035	2500	20





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

Not strictly related to or a priority for CEPC



Detector

- Recently a review committee (IDRC) has been established also for the Detector
- Involvement of international partners is desired, but maybe difficult
- Several detector sub-systems have been studied in detail but there is no strawman design
- A detector solenoid can take up to 10 years to be built
- 2 detectors for 2 IPs?

TDR of a Reference Detector

- **The CEPC study group is in process to produce TDR of a reference detector (ref-TDR) by June 2025, aiming mainly for domestic endorsement**
- **CEPC will continue to seek for better technologies, and decide the final detectors within the CEPC international collaborations**

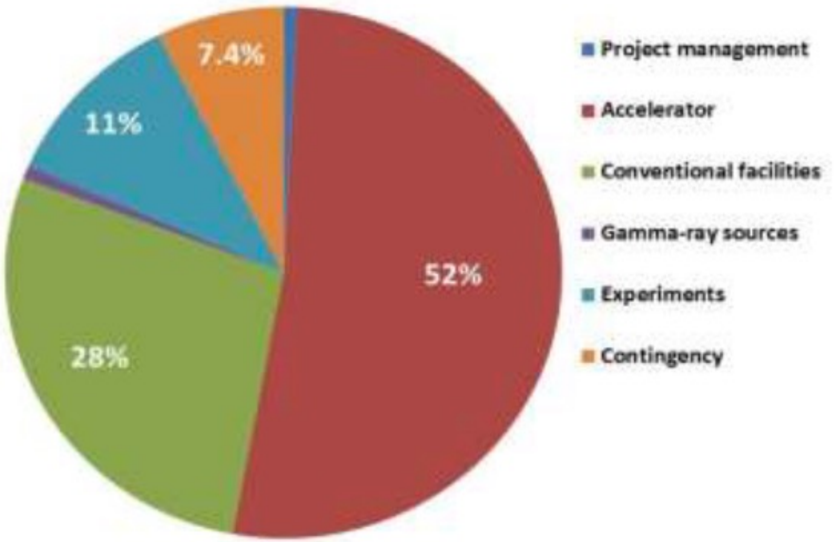
Date	Actions and/or Expectations
Jan 1, 2024	Start the process by comparing different technologies
Jun 30, 2024	Baseline technologies, general geometric configuration and key issues are decided
Oct 31, 2024	Discuss the ref-TDR at the CEPC workshop, report progresses to the CEPC IAC
Dec 31, 2024	The first draft of the ref-TDR is ready for internal reviews
Apr 15, 2025	international review
Jun 30, 2025	The ref-TDR for ready for public reviews
Oct 30, 2025	Submit the ref-TDR for publication

Cost

- An international committee has evaluated the cost estimate in September 2023
- For a Higgs factory of 30 MW SR power/beam, upgradable to 50 MW, cost is estimated at 36.4 B RMD (~5.2B USD), excluded civil engineering, detectors, operation and maintenance costs, personnel expenses
- Uncertainty 10% (probably too low), market uncertainties of material costs being the major factor
- Procurement strategy should be refined
- A detailed schedule and logistics plan should be developed

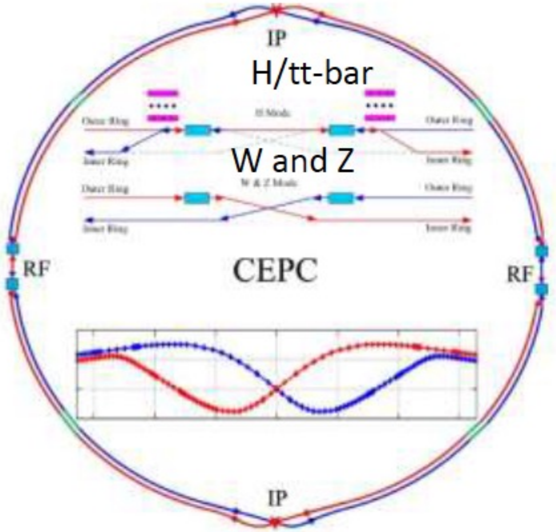
Table 12.1.2: CEPC project cost breakdown. (Unit: 100,000,000 yuan)

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%

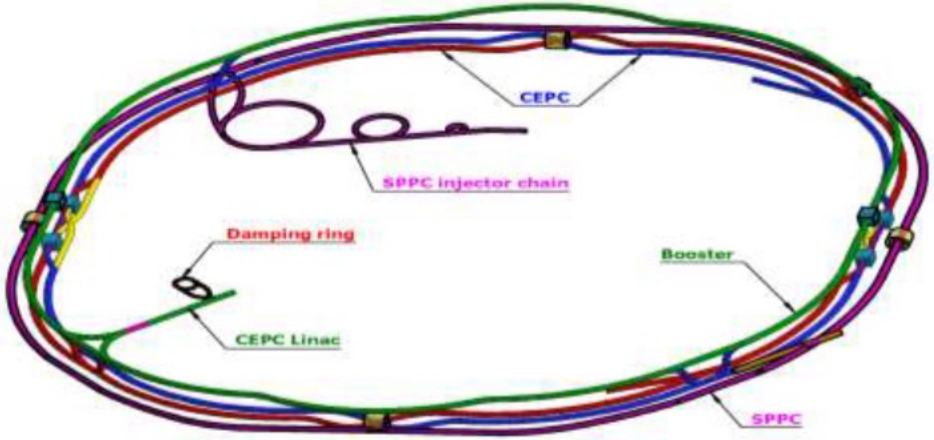


CEPC Higgs Factory and SppC Layout in TDR

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

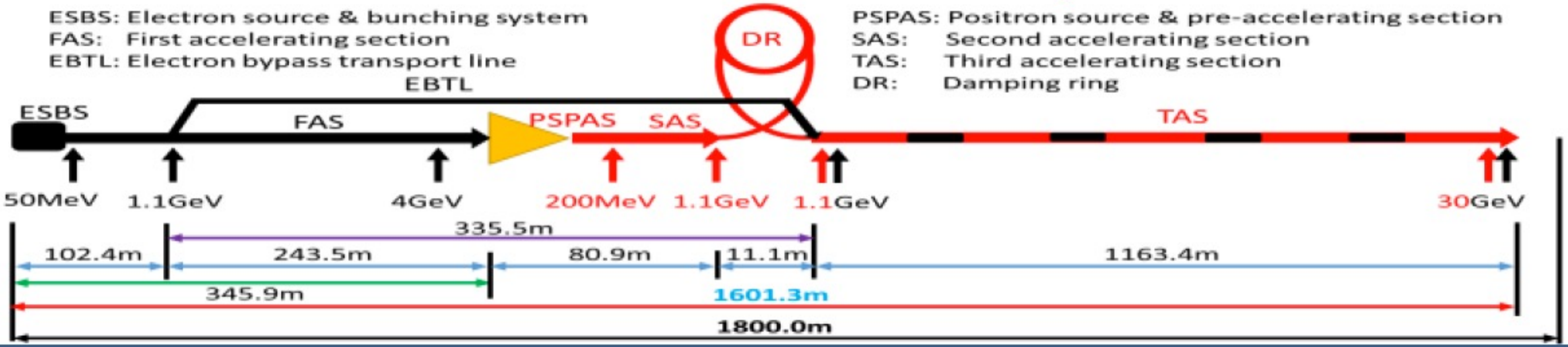


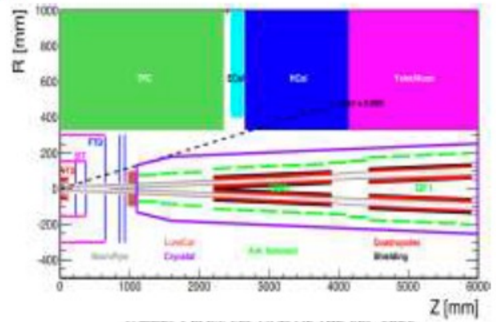
CEPC collider ring (100km)

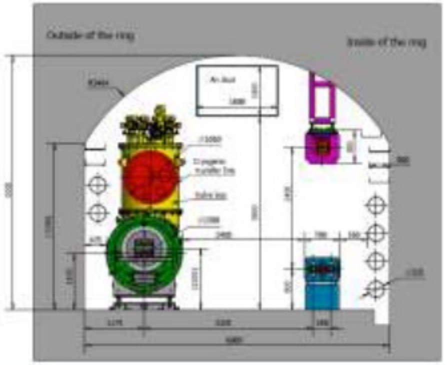


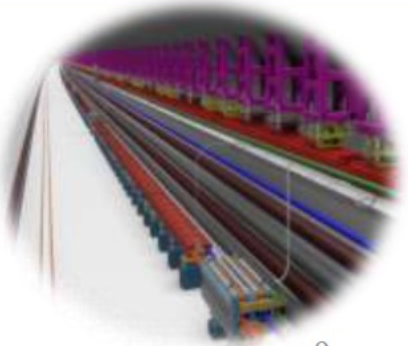
CEPC booster ring (100km)

CEPC TDR S+C-band 30GeV linac injector









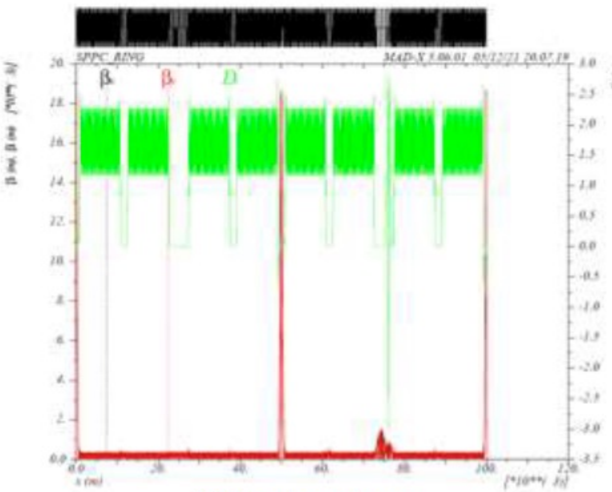
CEPC/SppC in the same tunnel

SppC Collider Parameters in TDR

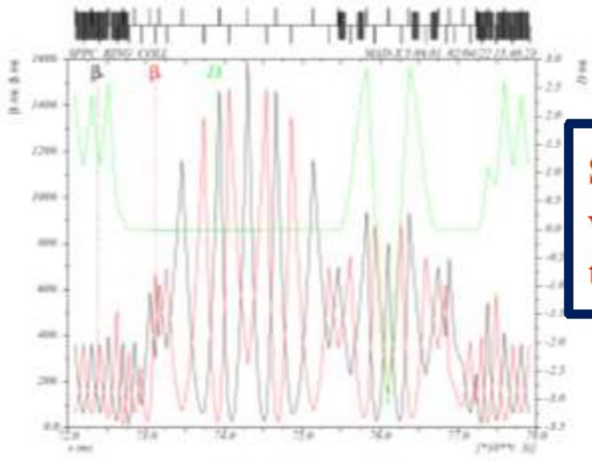
-Parameter list (updated Feb. 2022)

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

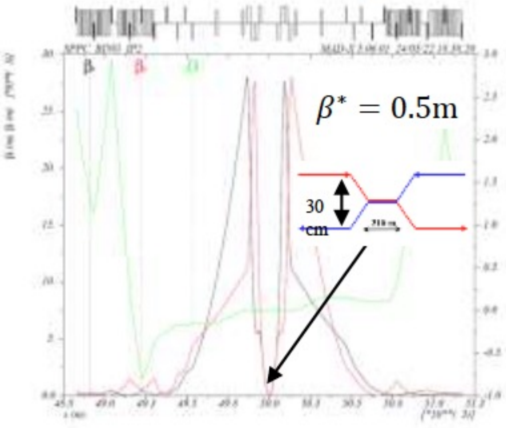
Lattice of SPPC



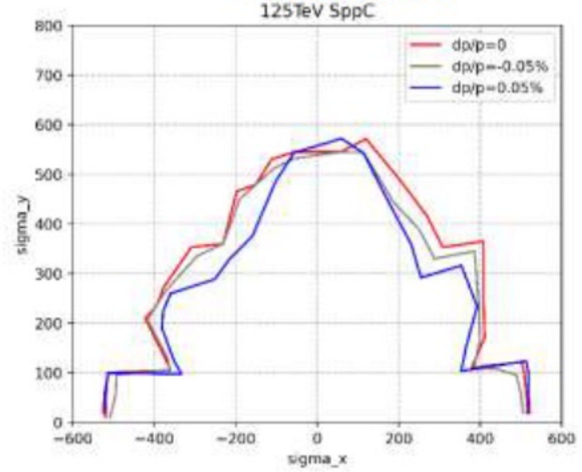
Whole ring



Collimation



IP



Dynamic Aperture

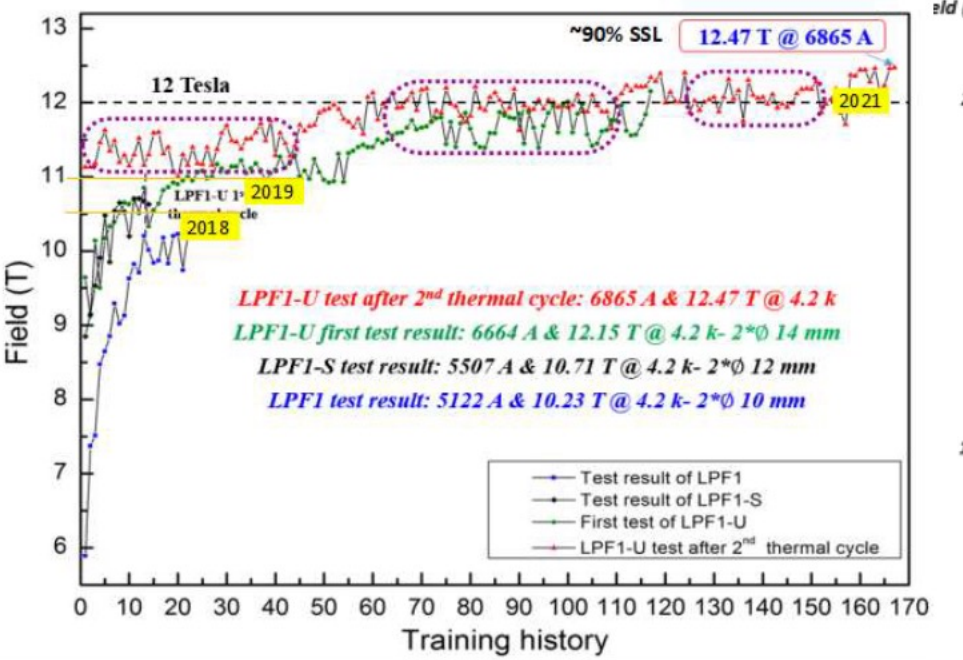
SppC is compatible with CEPC in the same tunnel

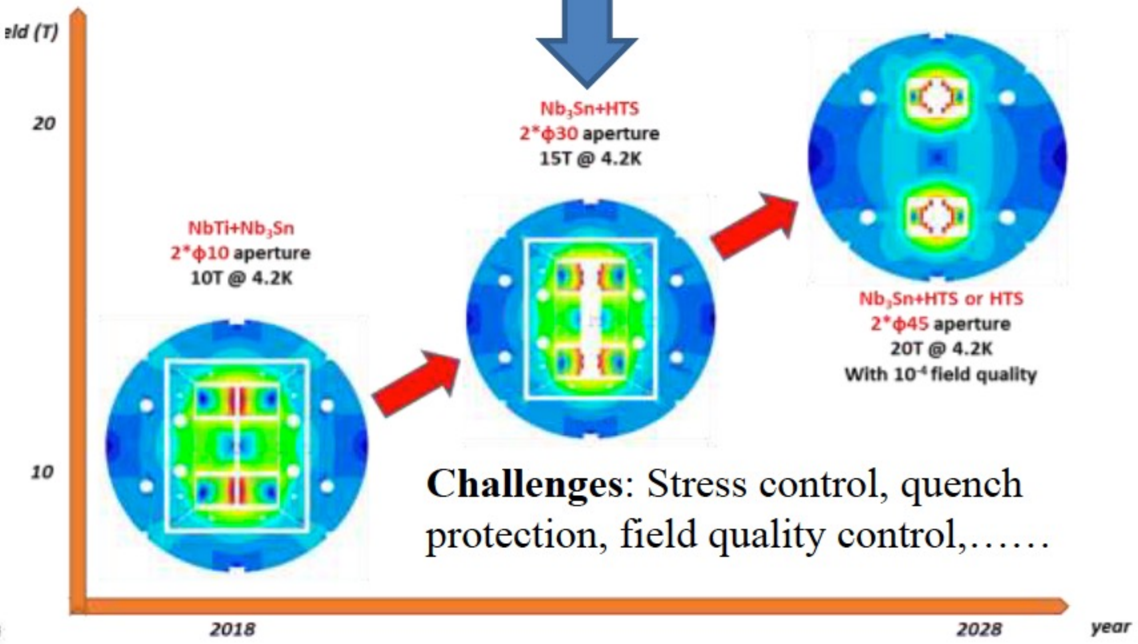
Ecm=125TeV with dipole field of 20T

SppC HF Magnet Development

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

Picture of LPF1-U





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

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

Force

- The accelerator team has made impressive progresses since the beginning of the project, acquiring knowledge and technical skills
- The team is increasing in size, and it seems adequate for the task
- Some of the technical sub-systems are very well developed and put CEPC as a leader in the field (ex. SC RF and high efficiency Klystrons, SC dipoles)
- Mass production is relatively easy in China
- The cost is relatively low (~1/3 FCCee)

Weakness

- Some topics still need a lot of R&D, particularly
  - engineering design of the IR,
  - SC IP quadrupoles,
  - alignment and installation procedure (and relative devices),…
- A "green" option looks unrealistic
- There is a lack of international involvement, necessary for the development of 1 (or 2) detector
- The detector(s) construction could be a bottle neck
- There are other Chinese competing projects

(Personal opinion)

Conclusions

- CEPC accelerator R&D is proceeding quickly, the design is completed and the approval from CAS (necessary for government approval) is sure thing
- The project will be presented to the government for approval in 25-26, with the aim to start building the machine soon after (8 years)
- The Engineering Design Report phase (basically R&D on all systems) is proceeding at high speed and probably will be finished before tunnel construction starts
- If approval comes by end of 2027, construction could be finished by 2035, data taking starting soon after

Thank you for your attention!

Backup slides

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Tatsuya Nakada	EPFL
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Gregor Kramberger	IJS
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Akira Yamamoto	KEK
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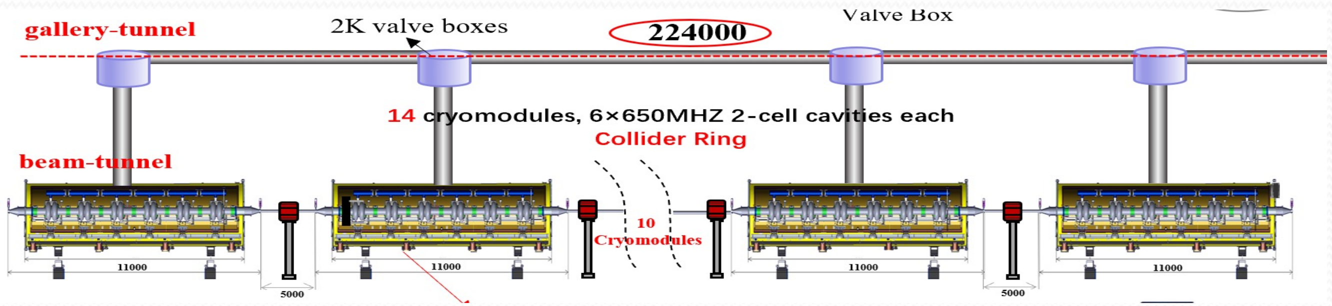
Colin Gay	UBC
Jim Brau	Oregon
Tommaso Tabarelli de Fatis	INFN Milano-Bicocca
Austin Ball	RAL
Roman Poeschl	IJCLab

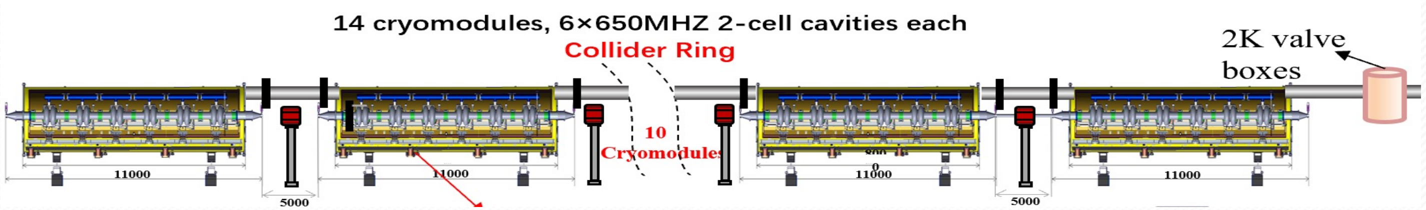
CEPC 650 MHz 6 x 2-cell Cryo-Module Design

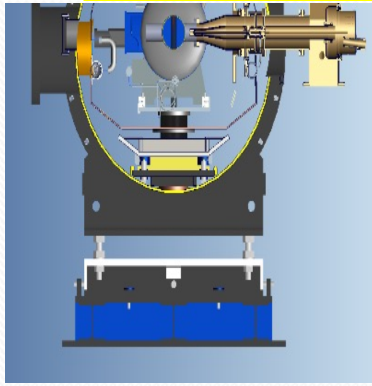
J. Zhai, CEPC EDR Review, Sep. 2024

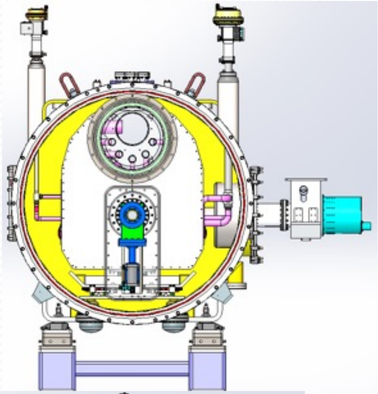
CDR

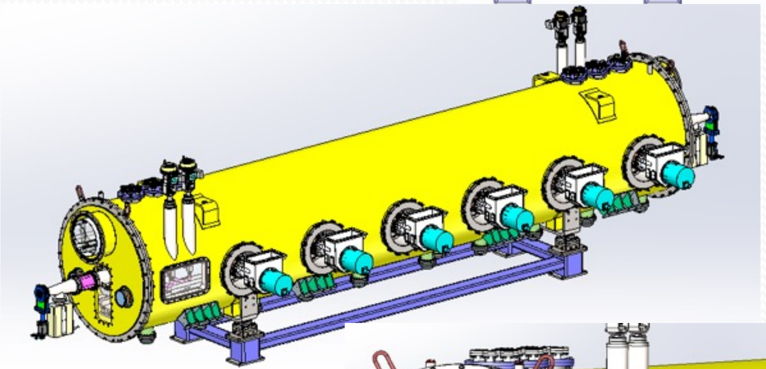


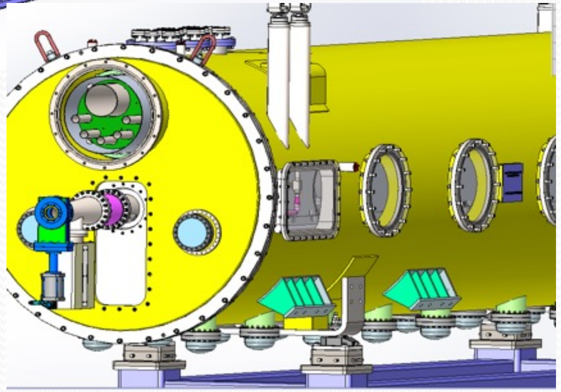
TDR











- Multi-channel cryogenic pipes inside the cryomodule
- Modified cavity strong-back support structure for better performance (based on ADS injector 325 MHz spoke module, CEPC 650 MHz 2x2-cell test module, PIP-II 650 MHz and CSNS-II 648 MHz module)
- Cryomodule combined with multi-channel cryogenic lines:
  - combines the features of cryomodule, valve box and cryogenic lines (under investigation)
  - shared vacuum, make full use of space, low cost
  - two 5 ~ 8 K Ø45 pipes for coupler, two 40 ~ 70 K Ø45 pipes for thermal shield, one 2 K Ø219 GRP, 3 Bara @ 5 K Ø45 pipe for supercritical supply

Multi-beam klystron fabrication

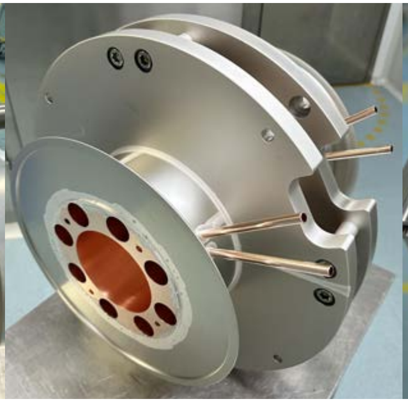
Z. Zhou, CEPC EDR Review, Sep. 2024

- MBK's cavity 3, 4, 5 and 6 have completed brazing, leak detection and tuning, while cavity 7 is still being processed and is expected to be completed this year
- Aims at 86% efficiency

The parameters of each cavities:

CAV. No.	2	3	4	5	6
Design Freq. (MHz)	651. 2	1296	1942. 5	670	671
Cold test before brazing (MHz)	651. 237	1303. 99	1936. 875	666. 9375	670. 3125
Cold test after brazing (MHz)	649. 375	1290. 5	1937. 4719	667. 21875	669. 7356
Cold test after tuning (MHz)	651. 1625	1295. 75	1942. 3249	669. 8125	670. 7325
Cold test after temperature and humidity correction (MHz)	651. 108	1295. 624	1941. 983	669. 819	670. 844
	18℃ RH% 45%	22℃ RH% 56%	21℃ RH% 52%	21. 5℃ RH% 47%	20℃ RH% 38%
	2023/2/17	2024/5/30	2024/7/23	2024/6/21	2024/5/6

CAV 3



CAV 4

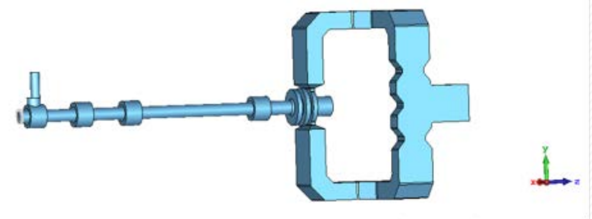
CAV 5

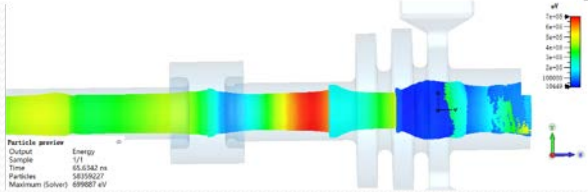
CAV 6

Design of a C-band 80 MW Klystron

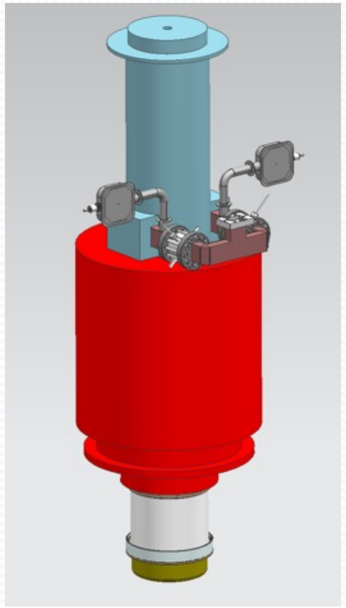
- Design review in May 2024 → reasonable and feasible, design results have achieved the expected goals

Parameters	Value	Cannon
Frequency	5720 MHz	5712MHz
Output Power	80MW	50MW
Repetition rate	100Hz	50Hz
Pulsed width	3us	3us
Efficiency	47%	42%
Beam voltage	420 kV	360kV
Beam current	403 A	320A





- Mechanical and process design review in August 2024 → design is feasible, meets technical specs, and has the conditions for production implementation → **enter the production stage**



Z. Zhou, CEPC EDR Review, Sep. 2024

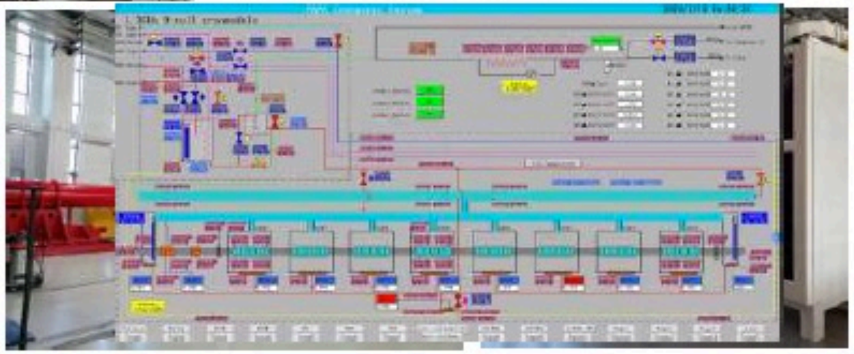
CEPC Booster 1.3 GHz 8 x 9-cell High Q Cryomodule

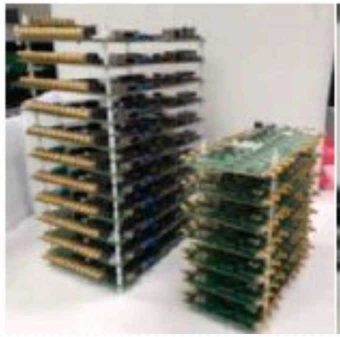
Parameters	SARI/China	CEPC Booster horizontal test results	CEPC Booster Higgs Spec	LCLS-II, SHINE Spec	LCLS-II-HE Spec
Average usable CW E_{acc} (MV/m)	29.1	23.1	21.8 MV/m	16 MV/m	20.8 MV/m
Average Q_0	4×10^{10}	3.4×10^{10}	3.0×10^{10}	2.7×10^{10}	2.7×10^{10}



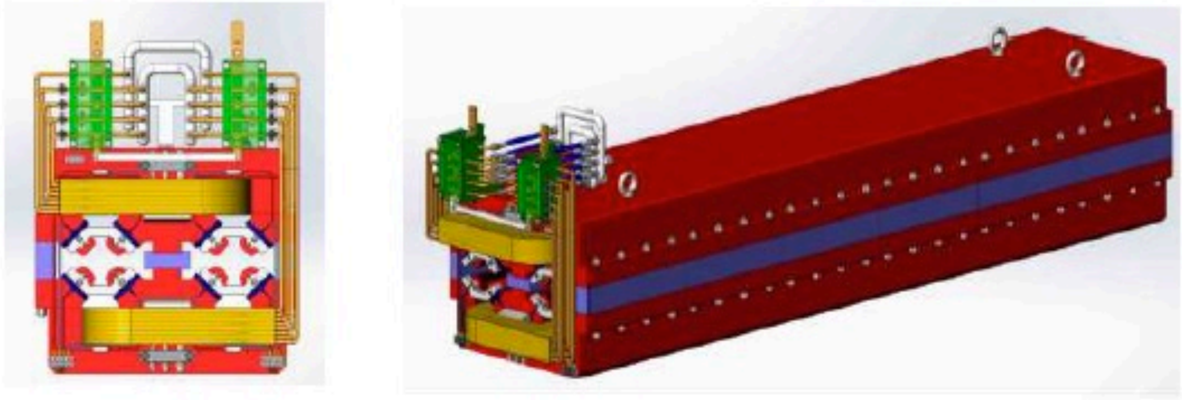






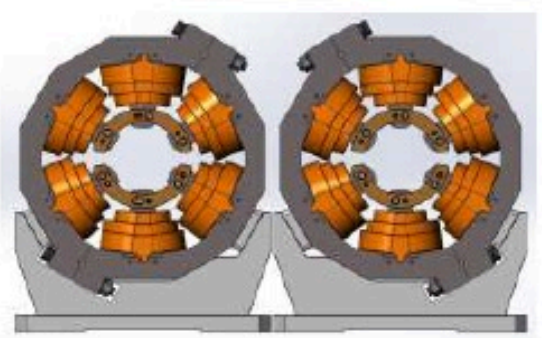


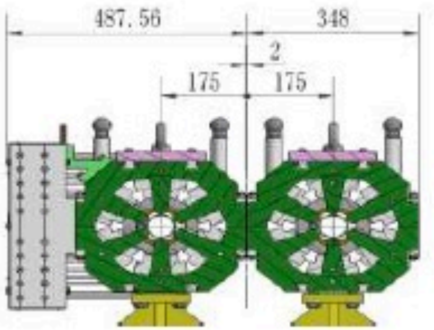

CEPC Collider Ring Magnets in EDR

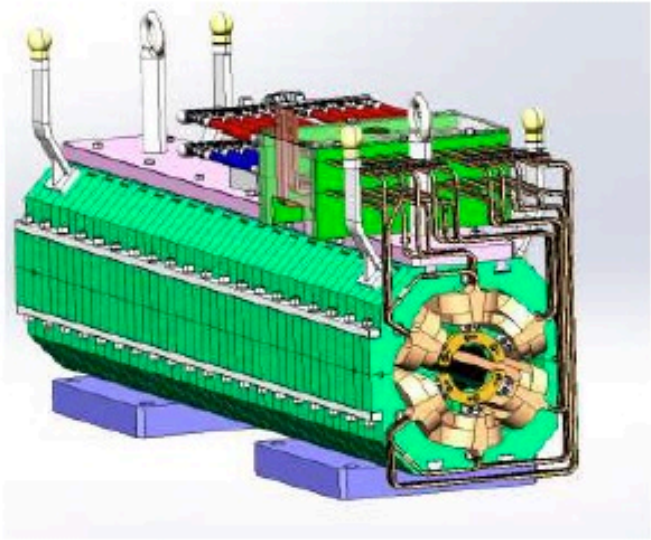


Correctors: mechanical design completed

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







Sextupole magnets under design