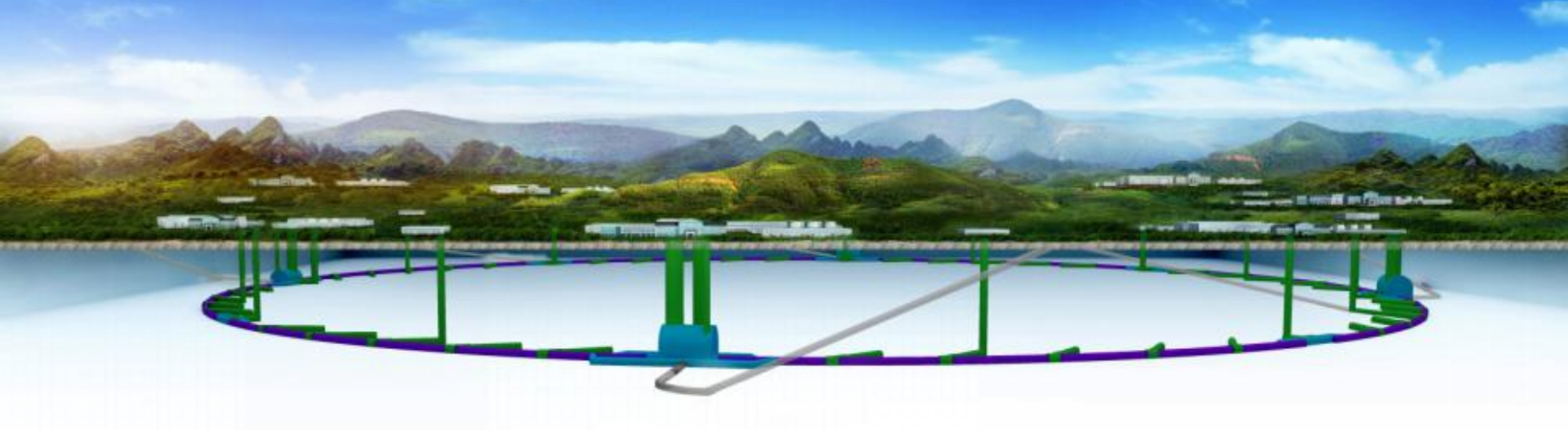


Introduction to CEPC

J. Gao

Institute of High Energy Physics

ASSCA2018

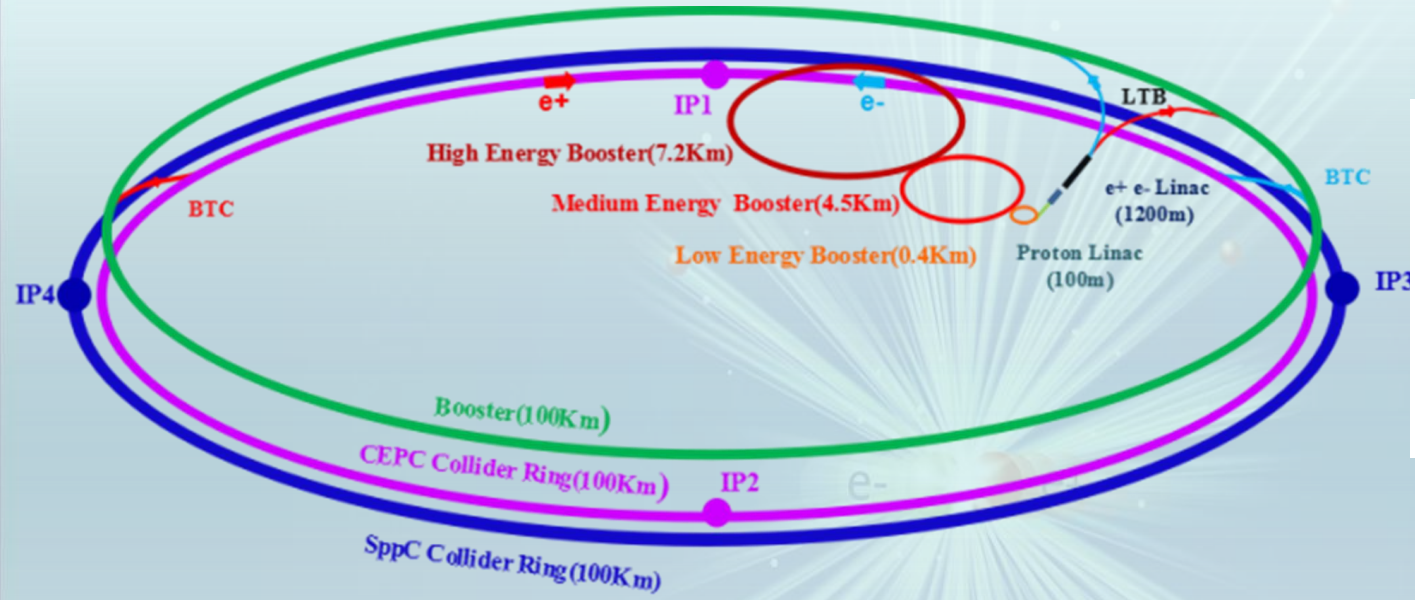
December 10-16, 2018, IHEP, Beijing, China

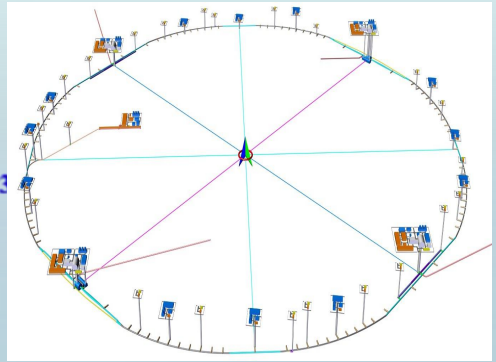
Outline

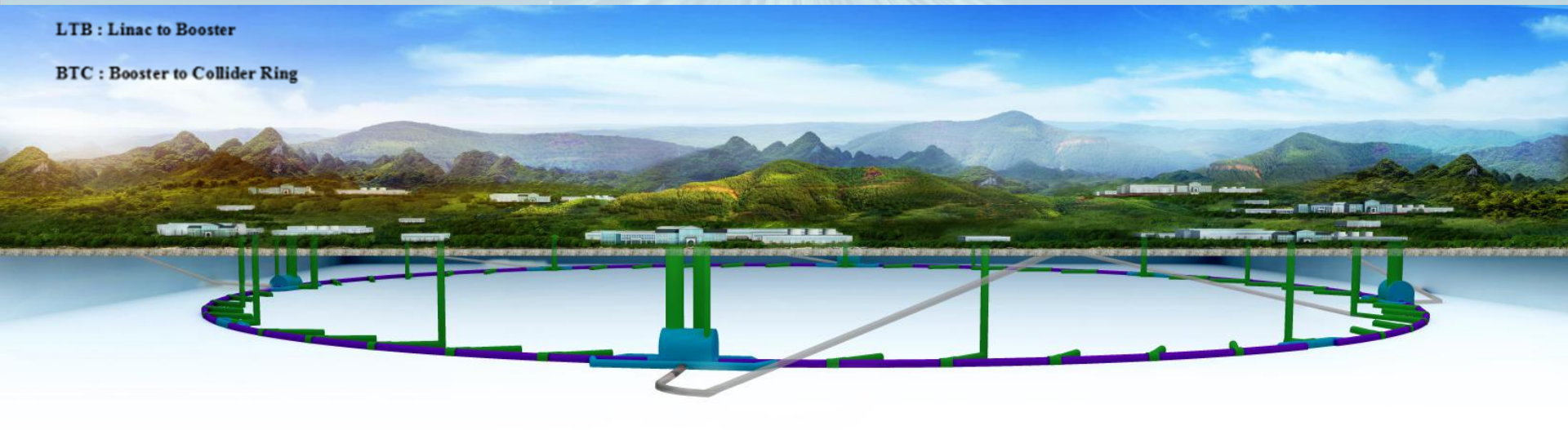
- CEPC CDR status, civil engineering, implementation, cost
- CEPC R&D toward TDR
- CEPC siting
- CEPC accelerator TDR international collaboration and with industries, and TDR management
- Summary

CEPC Accelerator CDR Status

CEPC as a Higgs Factory
(Z,W and followed by SppC)







CEPC-SppC Physics Goals in CDR (remind)

- **Electron-positron collider (91, 160， 240 GeV)**
  - **Higgs Factory（10^6 Higgs）:**
    - **Precision study of Higgs(m_H, J^{PC}, couplings)， Similar & complementary to ILC**
    - **Looking for hints of new physics**
  - **Z & W factory（10^{10} Z^0）:**
    - **precision test of SM**
    - **Rare decays ?**
  - **Flavor factory: b, c, τ and QCD studies**
- **Proton-proton collider(~100 TeV)**
  - **Directly search for new physics beyond SM**
  - **Precision test of SM**
    - **e.g., h^3 & h^4 couplings**

CEPC Design –Higgs Parameters

Parameter	Design Goal
Particles	e+, e-
Center of mass energy	2*120 GeV
Luminosity (peak)	>2*10^34/cm^2s
No. of IPs	2

CEPC Design – Z-pole Parameters

Parameter	Design Goal
Particles	e+, e-
Center of mass energy	2*45.5 GeV
Integrated luminosity (peak)	>10^34/cm^2s
No. of IPs	2
Polarization	to be considered in the second round of design

***Be noted that here the luminosities are the lowest reuiqrement to accomodate different collider schemes**

CEPC CDR Accelerator Chain and Systems

10 GeV

1) Injector

L=1.2km

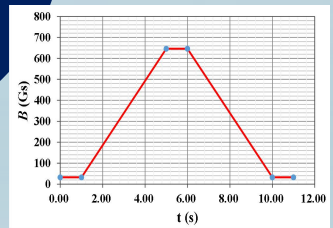
Electron

Positron

2) Booster

C=100km

Energy Ramp
10 ->45/120GeV



Booster Cycle (0.1 Hz)

Three rings in the sane channel：
- CEPC & booster
- SppC

3) Main Ring

C=100km
2IP

45/120 GeV

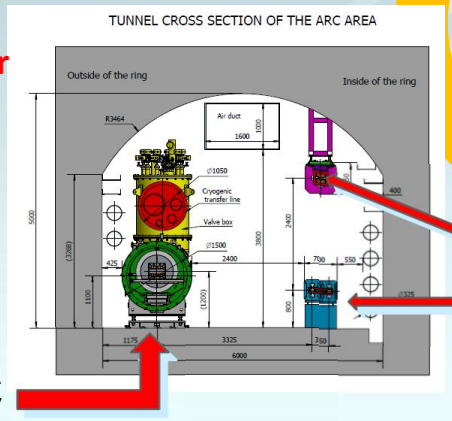
CEPC Booster

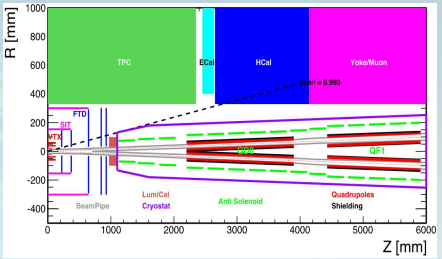
CEPC Collider

SppC

The key systems of CEPC:
1) Linac Injector
2) Booster
3) Collider ring
4) MDI
5) Civil Eng.

5) Civil Eng.

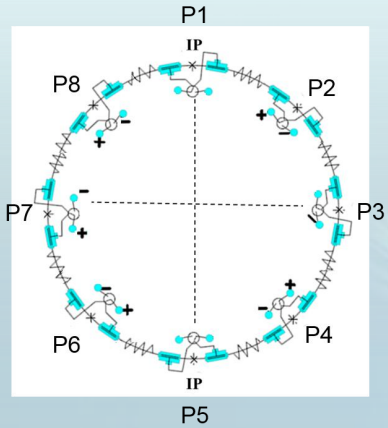




4) Detector Machine Interface (MDI)

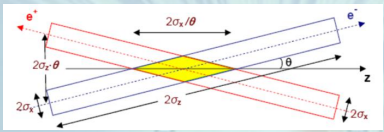
CEPC Four Options Evoluting towards CDR

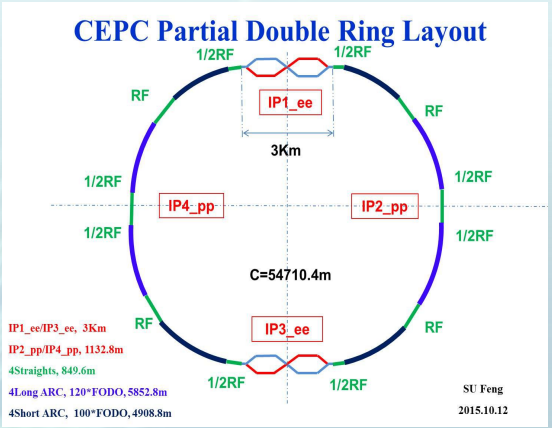
CEPC Pre-CDR Scheme (head -on collision)



Since Oct 2012

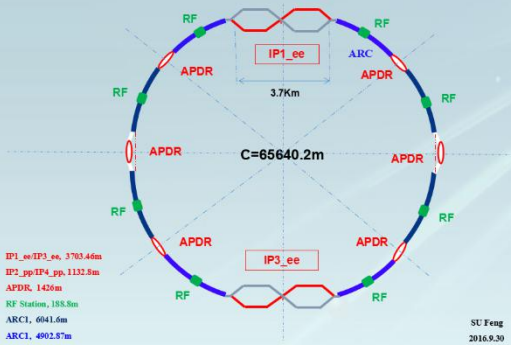
Crab-waist collision in CEPC CDR





Since May 2015

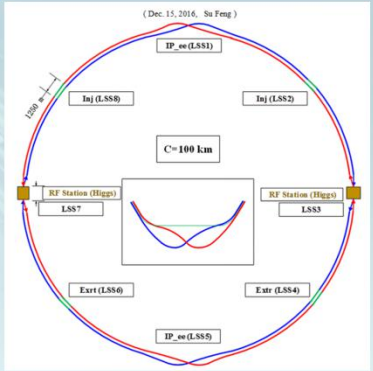
CEPC Advanced Partial Double Ring Option II



Since May 2016

CEPC Alternative Design

Lower cost and reaching the fundamental requirement for Higgs and Z luminosities, under the condition that sawtooth and beam loading effects be solved



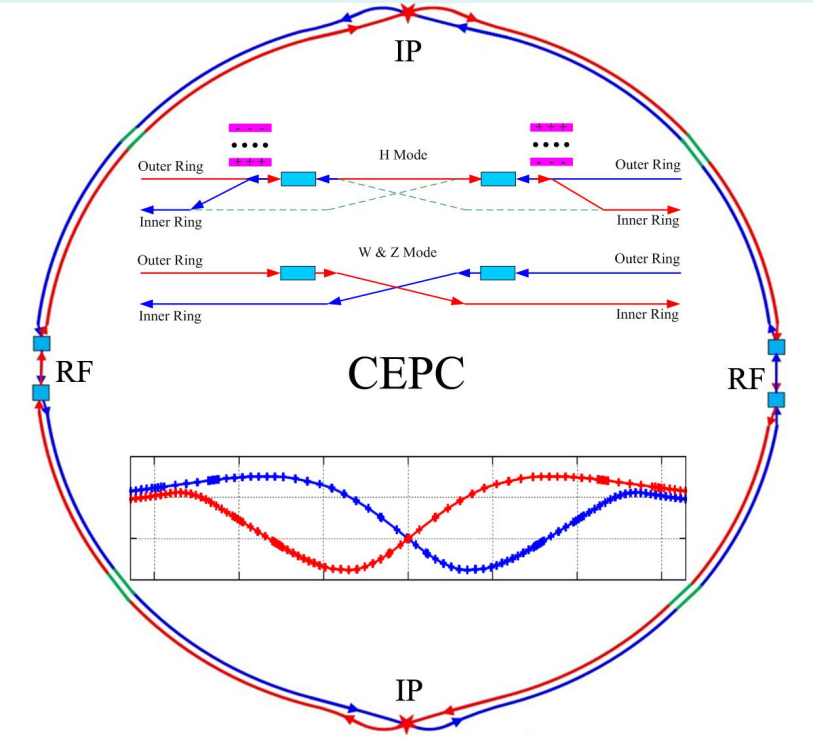
Since Nov 2016

CEPC Baseline Design

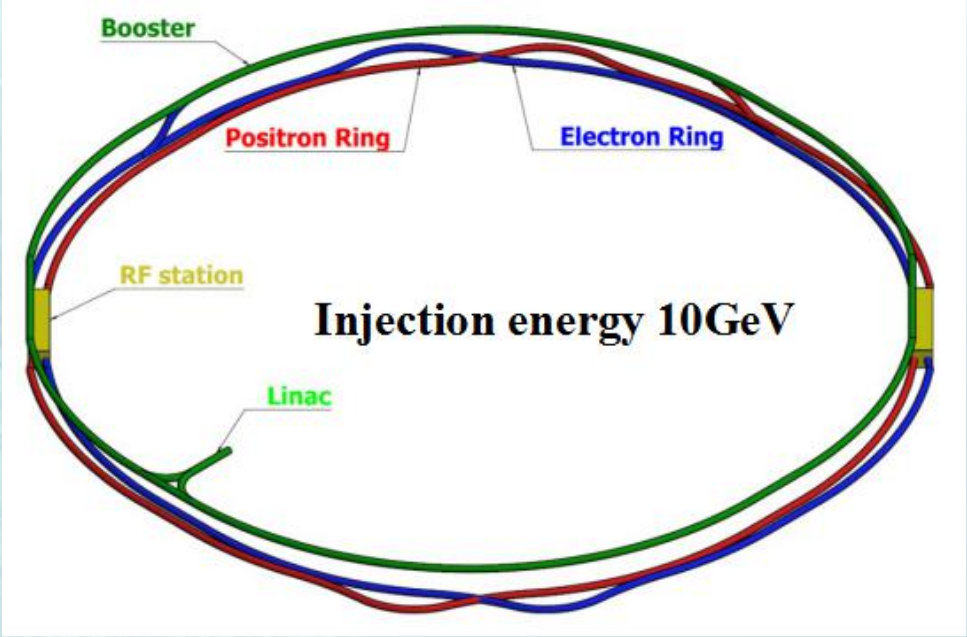
Better performance for Higgs and Z compared with alternative scheme, without bottle neck problems, but with higher cost 30MW synchrotron radiation power/beam

- CEPC 100km circumference was decided by CEPC SC based on the recommendation from IAC in Nov. 2016
- CEPC baseline and alternative options have been decided on Jan. 14, 2017

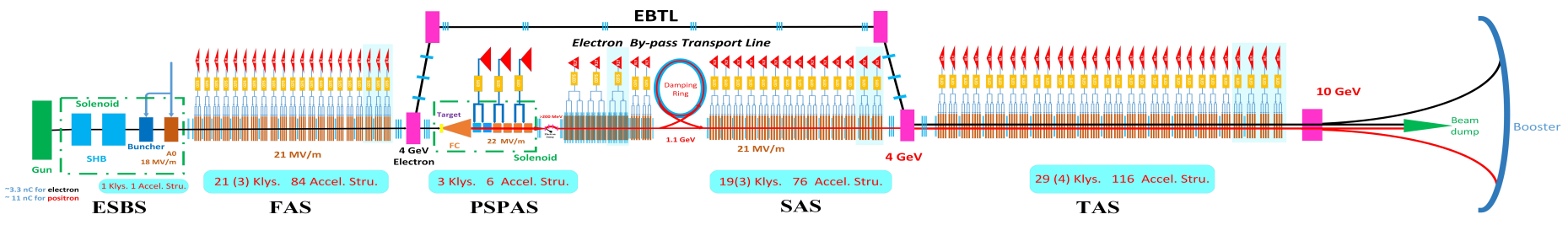
CEPC CDR Baseline Layout



CEPC collider ring (100km)

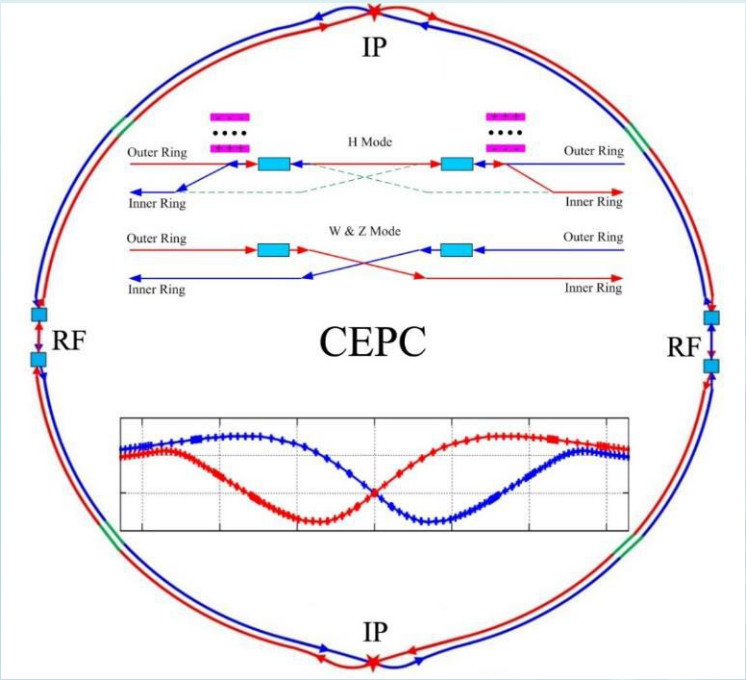


CEPC booster ring (100km)



CEPC Linac injector (1.2km, 10GeV)

CEPC Three Modes of Operation: Higgs, W, and Z



- **Higgs factory as first piority (fully partial double ring, with common SRF system for e+ and e- beams)**
- **W and Z factories are incorperated by beam swithyard (W and Z factories are double ring, with independent SRF system for e+ and e- beams)**
- **Higgs factory baseline SR per beam 30 MW to Minimize AC power**

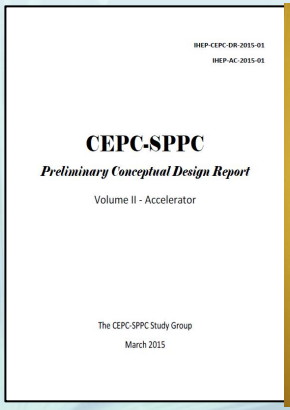
Economic CEPC baseline design as Higgs factory:

- W, Z factories incoperated with the same SRF system hardwares by using beam switchyard to change from Higgs factory and W, Z factories
- Synchrotron radiation power per beam at Higgs energy is set to 30MW to minimize AC power consumption

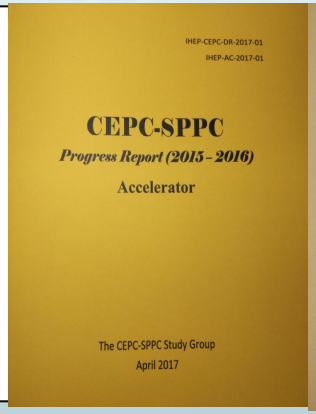
CEPC Accelerator CDR Completed

CEPC accelerator CDR completed and released on Sept. 2, 2018

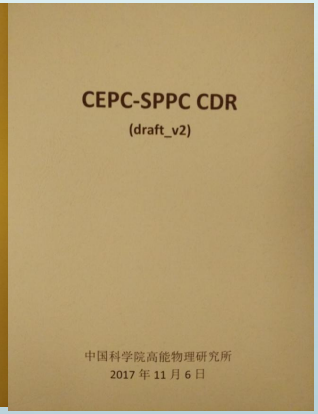
- Executive Summary
1. Introduction
2. Machine Layout and Performance
3. Operation Scenarios
4. CEPC Collider
5. CEPC Booster
6. CEPC Linac
7. Systems Common to the CEPC Linac, Booster and Collider
8. Super Proton Proton Collider
9. Conventional Facilities
10. Environment, Health and Safety
11. R&D Program
12. Project Plan, Cost and Schedule
- Appendix 1: CEPC Parameter List
- Appendix 2: CEPC Technical Component List
- Appendix 3: CEPC Electric Power Requirement
- Appendix 4: Advanced Partial Double Ring
- Appendix 5: CEPC Injector Based on Plasma Wakefield Accelerator
- Appendix 6: Operation as a High Intensity γ-ray Source
- Appendix 7: Operation for e-p, e-A and Heavy Ion Collision
- Appendix 8: Opportunities for Polarization in the CEPC
- Appendix 9: International Review Report



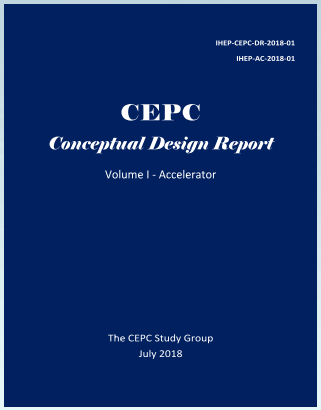
March 2015



April 2017



Draft CDR for Mini International Review in Nov. 2017



CDR Version for International Review June 2018, and formally relased on Sept. 2, 2018:arXiv：1809.00285, http://cepc.ihep.ac.cn/CDR_v6_201808.pdf

Mini-Review Workshop of CEPC-SPPC CDR (Nov. 4-5, 2017, IHEP)

CEPC-SPPC CDR Mini-review members

Name (alphabetical order)

Anton Bogomyakov	BINP	Russia
Brian Foster	Oxford U.	U.K.
Eugene Levichev	BINP	Russia
Kexin Liu（刘克新）	Peking U.	China
Ernie Malamud	Fermilab	USA
Kazuhito Ohmi	KEK	Japan
Katsunobu Oide	CERN / KEK	Switzerland
Carlo Pagani	U. of Milan / INFN	Italy
John Seeman	SLAC	USA
Sergey Sinyatkin	BINP	Russia
Mike Sullivan	SLAC	USA
Chuanxiang Tang（唐传祥）	Tsinghua U.	China
Lin Wang （王林）	USTC	China
Xiangqi Wang（王相綦）	USTC	China
Akira Yamamoto	KEK	Japan

Sunday, November 5

08:30 – 09:00	SRF	Jiyuan Zhai
09:00 – 09:30	RF power source	Zusheng Zhou
09:30 – 10:00	Cryogenic system	Shaopeng Li
10:00 – 10:30	Magnet	Fusan Chen
10:30 – 11:00	Coffee (30′)	

Informal Mini-Review of CEPC-SPPC CDR

November 4 – 5, 2017, IHEP, Main Building, Room A415

Agenda (draft v2. 09/14/2017)

Saturday, November 4

08:30 – 08:35	Welcome	Yifang Wang
08:35 – 09:10	Overview of beam dynamics	Chenghui Yu
09:10 – 09:40	Parameters	Dou Wang
09:40 – 10:10	Optics	Yiwei Wang
10:10 – 10:40	Dynamic aperture	Yuan Zhang
10:40 – 11:10	Coffee (30′)	
11:10 – 11:40	Beam-beam	Yuan Zhang
11:40 – 12:10	Instabilities	Na Wang
12:10 – 12:40	Machine-detector interface	Sha Bai
12:40 – 14:00	Lunch	
14:00 – 14:30	Injection and extraction	Xiaohao Cui
14:30 – 15:00	Booster	Tianjian Bian
15:00 – 15:30	Linac and sources	Cai Meng
15:30 – 16:00	Coffee (30′)	
16:00 – 16:30	Synchrotron radiation	Yadong Ding
16:30 – 17:00	Overview of SPPC	Jingyu Tang
17:00 – 17:30	SC magnet for SPPC	Qingjin Xu
17:30 – 18:30	Discussion	All
19:00	Dinner	

International Review of CEPC CDR
(June 28-30, 2018, IHEP)

International Review of CEPC CDR

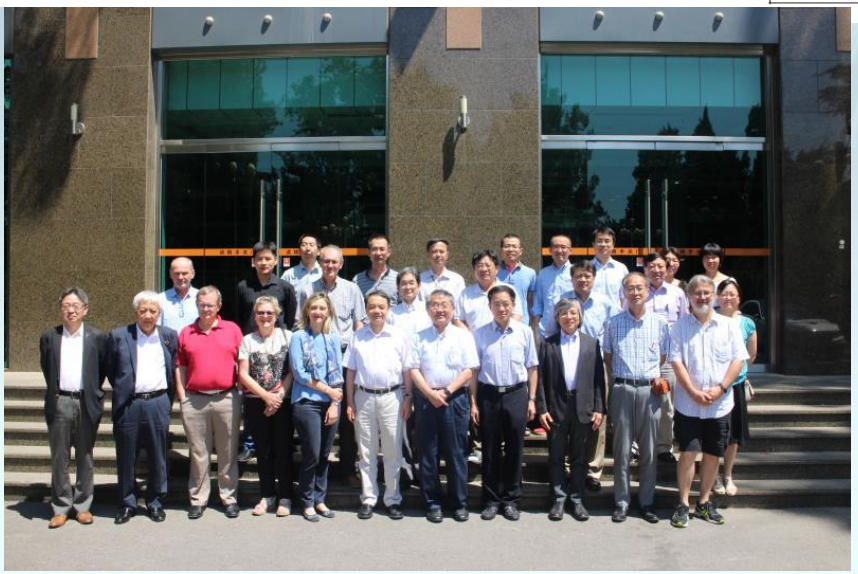
June 28 – 30, 2018, IHEP, Main Building, Room A415

Agenda

Thursday, June 28		
	Chair: K. Oide	
8:30-9:00	Committee Executive Session	
	Chair: Qing Qin	
9:00-9:05	Welcome	Yifang Wang
9:05-9:20	Overview of CEPC	Jie Gao
9:20-9:35	Overview of beam dynamics	Chenghui Yu
9:35-10:05	CEPC collider lattice design	Yiwei Wang
10:05-10:35	CEPC beam-beam and DA	Yuan Zhang
	Coffee break(30')	
	Chair: K. Oide	
11:05-11:35	Instabilities	Na Wang
11:35-12:05	Machine-detector interface	Sha Bai
12:05 – 14:00	Lunch break	
	Chair: K. Oide	
14:00-14:30	Booster	Dou Wang
14:30-15:00	Injection and extraction	Xiaohao Cui
15:30-16:00	Linac injector	Cai Meng
	Coffee break(30')	
16:30-18:30	Committee Executive Session	
19:00	Dinner of Committee	

	Chair: K. Oide	
8:30-9:00	SRF system	
9:00-9:30	RF power source	
9:30-10:00	Cryogenic system	
10:00-10:20	CEPC collider ring Magnet	
10:20-10:40	CEPC booster ring magnet	
	Coffee break(30')	
11:10-11:30	SC magnet for CEPC IR	
11:30-12:00	Power supplies	
12:00-12:30	Vacuum	
12:30 – 14:00		
	Chair: K. Oide	
14:00-14:30	Instrumentation	
14:30-15:00	Control	
15:00-15:30	Synchrotron radiation	
15:30-16:00	Radiation shielding	
	Coffee break(30')	
16:30-18:30	Committee Executive Sessi	
	Dinr	

Saturday, June 30		
	Chair: K. Oide	
8:30-9:00	Survey and alignment	Xiaolong Wang
9:00-9:30	Mechanics	Haijing Wang
9:30-10:00	Conventional facilities	Guoping Lin
10:00-10:30	Site investigation	Yu Xiao
	Coffee break (30')	
11:00-12:00	Discussion with CEPC team	
12:00 – 14:00	Lunch break	
14:00-16:00	Committee Executive Session	
	Coffee break (30')	
16:30-17:30	Close out	
	Banquet	



Review Committee Members:

Brian Foster	Oxford U./DESY
Eugene Levichev	BINP
Katsunobu Oide (chair)	CERN/KEK
Kazuro Furukawa	KEK
Manuela Boscolo	INFN
Marica Biagini	INFN
Masakazu Yoshioka	KEK/Tohoko University
Norihito Ohuchi	KEK
Paolo Pierini	ESS
Steinar Stapnes	CERN
Yoshihiro Funakoshi	KEK
Zhengtang Zhao (absent)	SINAP

International Review Report (draft) of CEPC CDR (June 28-30, 2018, IHEP)

International Review of the CEPC Conceptual Design Report
- Accelerator Design –

June 28 – 30, 2018
IHEP, Beijing

This is the review report of the accelerator part of the CEPC CDR. The review is done for the presentations based on the draft version of the CDR. Extensive discussions have been held between the review committee members and the CEPC team during the review meeting.

General remarks

The Circular Electron-Positron Collider (CEPC) is a very ambitious and important project aimed at various physics at ZH (E_{beam} = 120 GeV), W± (80 GeV), and Z (46 GeV) production which would produce the highest luminosity ever achieved by a collider in the world. The Superconducting Proton-Proton Collider (SppC) is planned as the second stage of the project using the same collider tunnel to explore the energy frontier of elementary particle physics.

The Review Committee unanimously congratulates the CEPC team on the completion of the CDR, with remarkable successes in various aspects of the design. The progress since the pre-CDR has been a major step in the project, especially the full double-ring scheme, lattice design, and various beam dynamics with beam-beam effects and collective phenomena. The design work on each system has verified the basic feasibility of the project, including the superconducting RF, normal and superconducting magnets, cryogenic system, vacuum system, injectors with a booster synchrotron and a linac, instrumentation, control, safety, civil engineering, etc.

The Committee believes that the CDR has already reached a sufficient level of maturity to allow approval to proceed to a Technical Design Report. On the other hand, we think that this machine has more potential for further extensions, including:

(1) Experiments for ttbar production (E_{beam} ≈ 180 GeV);
(2) Even higher luminosity (~x10) at Z and W±;
(3) Higher beam current, up to 50 MW/beam synchrotron radiation loss;
(4) More interaction points;
(5) Polarized beams.

These extensions will be achievable if the machine preserves the possibility to implement these possibilities by relatively small investments, such as longer quadrupole magnets, a less compressed layout around the interaction point (IP) with shallower bends, and sufficient length for the RF section. Actually, such improvements may even reduce the operation costs. The committee encourages the CEPC team to explore and preserve these possibilities, since once CEPC is built, no second machine with the same scale is likely to be built in the world.

The Review Committee unanimously congratulates the CEPC team on the completion of the CDR, with remarkable successes in various aspects of the design. The progress since the pre-CDR has been a major step in the project...

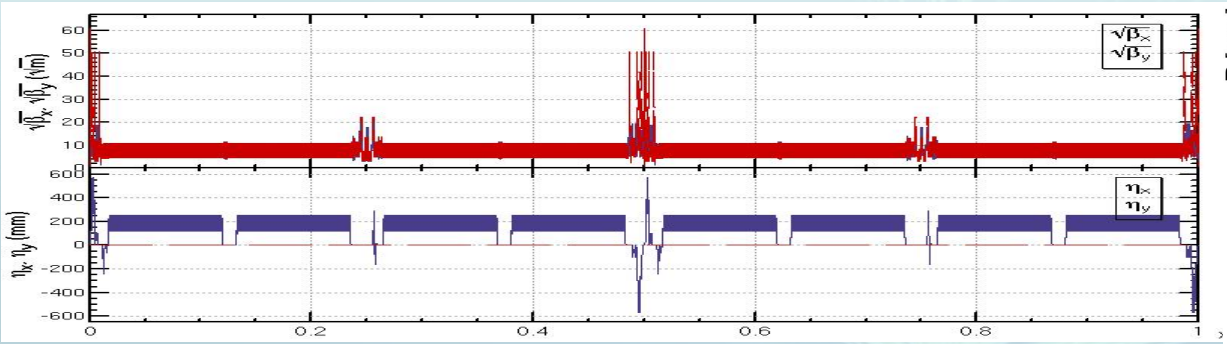
The Committee believes that the CDR has already reached a sufficient level of maturity to allow approval to proceed to a Technical Design Report.

CEPC CDR Parameters

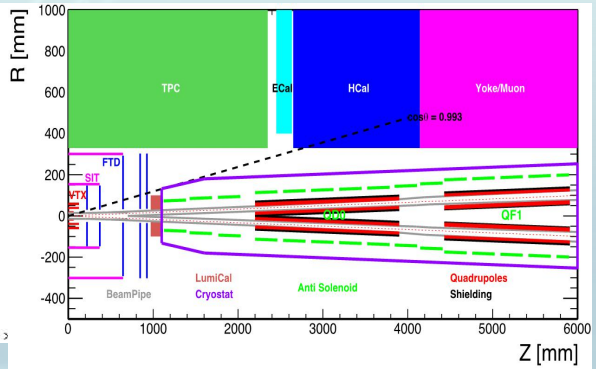
	Higgs	*W*	*Z（3T）*	*Z（2T）*
Number of IPs	2			
Beam energy (GeV)	**120**	**80**	**45.5**	
Circumference (km)	100			
Synchrotron radiation loss/turn (GeV)	1.73	0.34	0.036	
Crossing angle at IP (mrad)	16.5×2			
Piwinski angle	2.58	7.0	23.8	
Number of particles/bunch N_e (10^{10})	15.0	12.0	8.0	
Bunch number (bunch spacing)	**242 (0.68μs)**	**1524 (0.21μs)**	**12000 (25ns+10%gap)**	
Beam current (mA)	17.4	87.9	461.0	
Synchrotron radiation power /beam (MW)	**30**	**30**	**16.5**	
Bending radius (km)	10.7			
Momentum compact (10^{-5})	1.11			
β function at IP β_x^* / β_y^* (m)	**0.36/0.0015**	**0.36/0.0015**	**0.2/0.0015**	**0.2/0.001**
Emittance $\varepsilon_x/\varepsilon_y$ (nm)	1.21/0.0031	0.54/0.0016	0.18/0.004	0.18/0.0016
Beam size at IP σ_x/σ_y (μm)	20.9/0.068	13.9/0.049	6.0/0.078	6.0/0.04
Beam-beam parameters ξ_x/ξ_y	0.031/0.109	0.013/0.106	0.0041/0.056	0.0041/0.072
RF voltage V_{RF} (GV)	2.17	0.47	0.10	
RF frequency f_{RF} (MHz) (harmonic)	650 (216816)			
Natural bunch length σ_z (mm)	2.72	2.98	2.42	
Bunch length σ_z (mm)	3.26	5.9	8.5	
HOM power/cavity (2 cell) (kw)	0.54	0.75	**1.94**	
Natural energy spread (%)	0.1	0.066	0.038	
Energy acceptance requirement (%)	**1.35**	**0.4**	**0.23**	
Energy acceptance by RF (%)	2.06	1.47	1.7	
Photon number due to beamstrahlung	0.1	0.05	0.023	
Lifetime _simulation (min)	100			
Lifetime (hour)	**0.67**	**1.4**	**4.0**	**2.1**
F (hour glass)	0.89	0.94	0.99	
Luminosity/IP *L* (10^{34}cm^{-2}s^{-1})	**2.93**	**10.1**	**16.6**	**32.1**

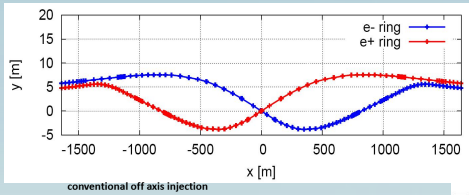
Lattice of the CEPC Collider Ring and MDI

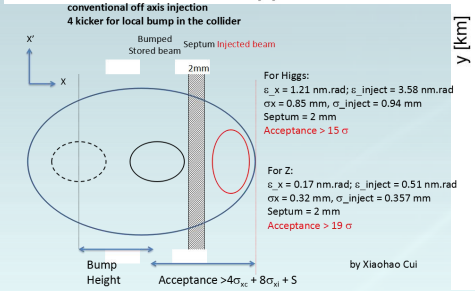
An optics fulfilling requirements of the parameters list, geometry, MDI, background and key hardware

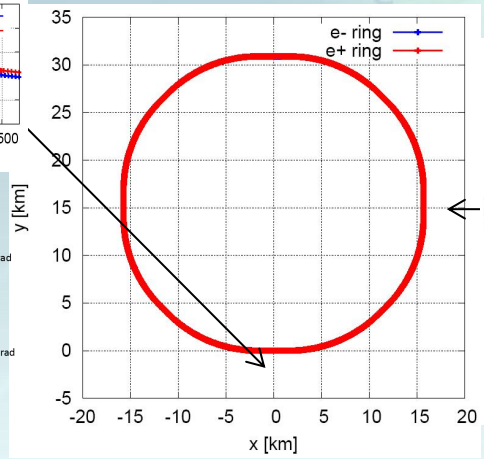


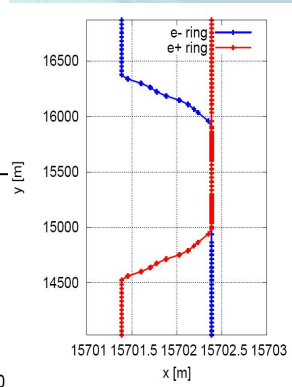
CEPC MDI









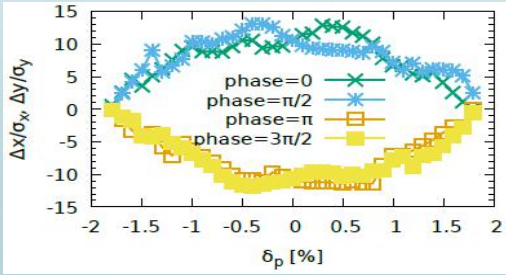


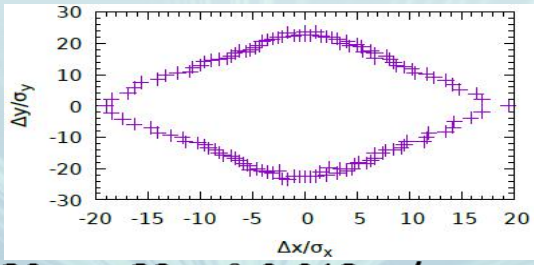
MDI parameters	Values
L^* (m)	2.2
Crossing angle (mrad)	33
Strength of QD0 (T/m)	150
Strength of detector solenoid (T)	3.0
Strength of anti-solenoid (T)	7.0

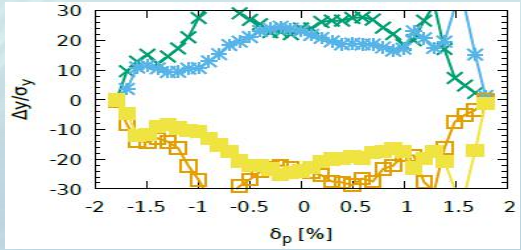
CEPC Collider Ring Dynamic Apertures (w/o errors)

Tracking in SAD w/ synchrotron radiation damping, fluctuation(100 samples), energy sawtooth and tapering, 145/475/2600 turns(H/W/Z, 2 damping times), 4 initial phases

Higgs

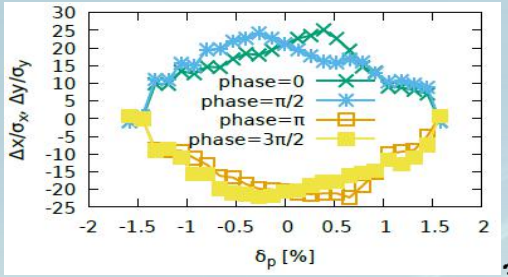


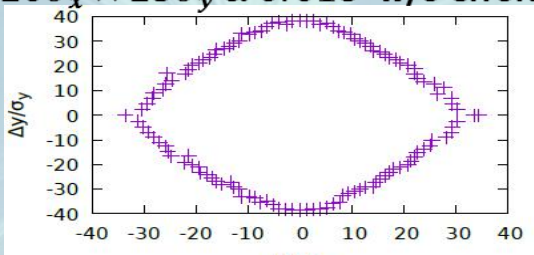


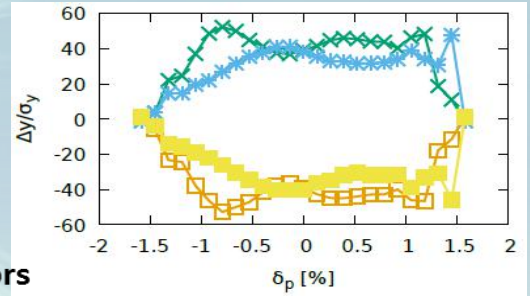


$20\sigma_x \times 23\sigma_y$ & 0.018 w/o errors

W

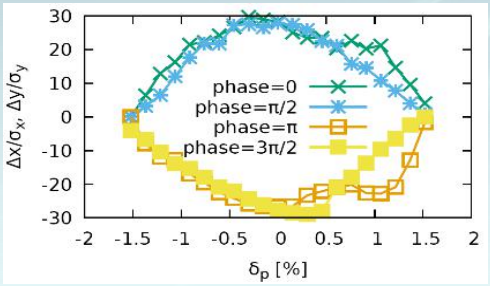


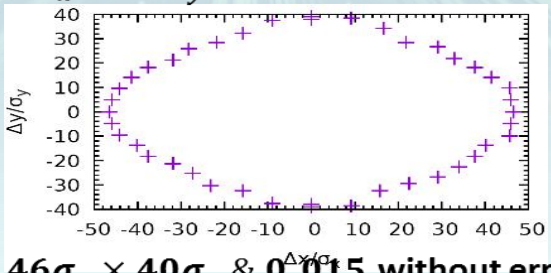


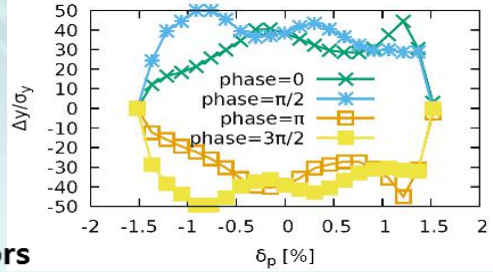


$32\sigma_x \times 40\sigma_y$ & 0.015 without errors

Z







$46\sigma_x \times 40\sigma_y$ & 0.015 without errors

CEPC Collider Ring SRF Parameters

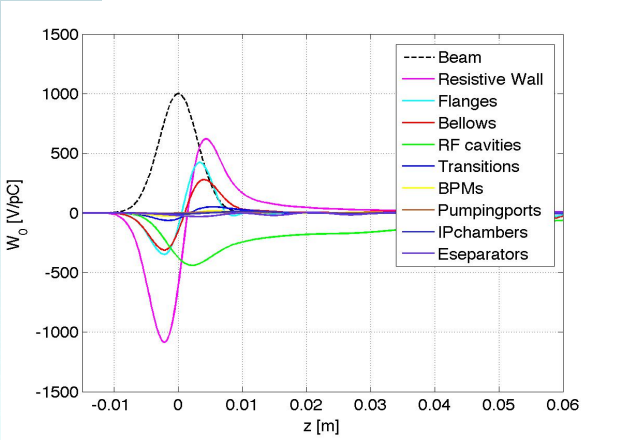
Collider parameters: 20180222	H	W	Z
SR power / beam [MW]	30	30	16.5
RF voltage [GV]	2.17	0.47	0.1
Beam current / beam [mA]	17.4	87.9	461
Bunch charge [nC]	24	24	12.8
Bunch number / beam	242	1220	12000
Bunch length [mm]	3.26	6.53	8.5
Cavity number (650 MHz 2-cell)	240	2 x 108	2 x 60
Cavity gradient [MV/m]	19.7	9.5	3.6
Input power / cavity [kW]	250	278	276
Klystron power [kW] (2 cavities / klystron)	800	800	800
HOM power / cavity [kW]	0.54	0.86	1.94
Optimal Q_L	1.5E6	3.2E5	4.7E4
Optimal detuning [kHz]	0.17	1.0	18.3
Total cavity wall loss @ 2 K [kW]	6.6	1.9	0.2

Kickers and Septums for collider injection

Component	Length (m)	Waveform	Deflection angle (mrad)	Field (T)	Beam-Stay-clear	
					H (mm)	V (mm)
Septum	8.75	DC	14	0.64	20	20
Septum	8.75	DC	7	0.32	20	20
Septum	8.75	DC	3.5	0.16	20	20
Septum	8.75	DC	1.75	0.08	20	20
Kicker	2	Half_sin	0.1	0.02	20	20

CEPC Collider Ring Impedance Budget

Components	Number	$Z_{\|\|}/n$, mΩ	k_{loss}, V/pC	ky, kV/pC/m
Resistive wall	-	6.2	363.7	11.3
RF cavities	336	-1.4	315.3	0.41
Flanges	20000	2.8	19.8	2.8
BPMs	1450	0.12	13.1	0.3
Bellows	12000	2.2	65.8	2.9
Pumping ports	5000	0.02	0.4	0.6
IP chambers	2	0.02	6.7	1.3
Electro-separators	22	0.2	41.2	0.2
Taper transitions	164	0.8	50.9	0.5
Total		**10.5**	**876.8**	**20.4**



Longitudinal wake at the nominal σ_z = 3mm

Broadband impedance threshold:

Threshold	ttbar	Higgs	W	Z
$\|Z_L/n\|_{eff}$, mΩ	13.6	9.0	8.0	2.1
κ_y, kV/pC/m	81.2	61.6	69.0	38.7

CEPC Collider Ring Collective Instabilities

- **The design single bunch intensity are all below the instability threshold.**
- **Transverse and longitudinal feedbacks are needed to damp the coupled bunch instabilities.**

CDR

Beam instability	ttbar	Higgs	W	Z
Bunch lengthening, σ_l/σ_{l0}	13%	20%	22%	73%
Beam energy spread increase, σ_e/σ_{e0}	~0	~0	2%	15%
CSR threshold $N_{bth,}$ nC	1565	622	201	38
Transverse impedance tune shift $\Delta\nu_{x,y}$	-0.02	-0.01	-0.006	-0.008
Transverse Mode Coupling N_{bth}, nC	207	93	37	16
Transverse resistive wall instability, ms	1986	298	39	11
Longitudinal RF HOMs CBI, ms	4.3E4	3.8E3	446	87
Transverse RF HOMs CBI, ms	1.2E4	1.7E3	352	85
Fast beam ion instability, ms	900	76	18	7

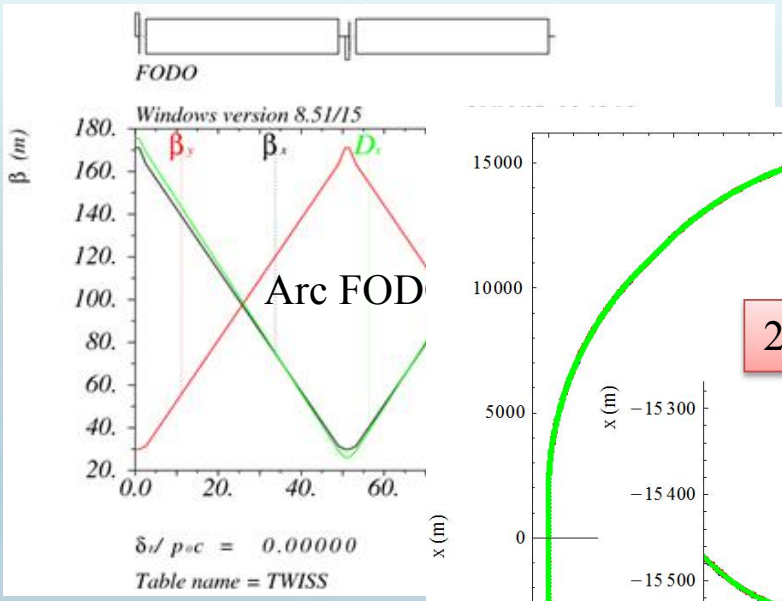
CEPC Booster parameters @ injection (10GeV)

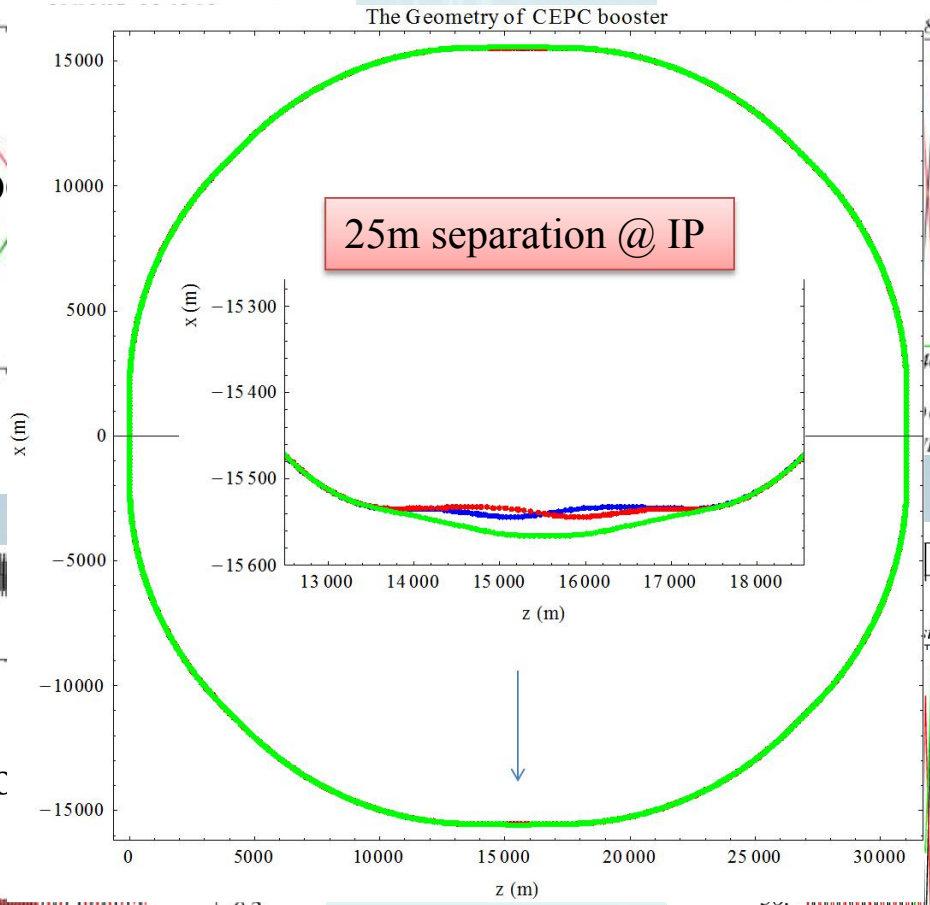
		H	*W*	*Z*
Beam energy	GeV	10		
Bunch number		242	1524	6000
Threshold of single bunch current	μA	25.7		
Threshold of beam current (limited by coupled bunch instability)	mA	127.5		
Bunch charge	nC	0.78	0.63	0.45
Single bunch current	μA	2.3	1.8	1.3
Beam current	mA	0.57	2.86	7.51
Energy spread	%	0.0078		
Synchrotron radiation loss/turn	keV	73.5		
Momentum compaction factor	10^{-5}	2.44		
Emittance	nm	0.025		
Natural chromaticity	H/V	-336/-333		
RF voltage	MV	62.7		
Betatron tune $\nu_x/\nu_y/\nu_s$		263.2/261.2/0.1		
RF energy acceptance	%	1.9		
Damping time	s	90.7		
Bunch length of linac beam	mm	1.0		
Energy spread of linac beam	%	0.16		
Emittance of linac beam	nm	40~120		

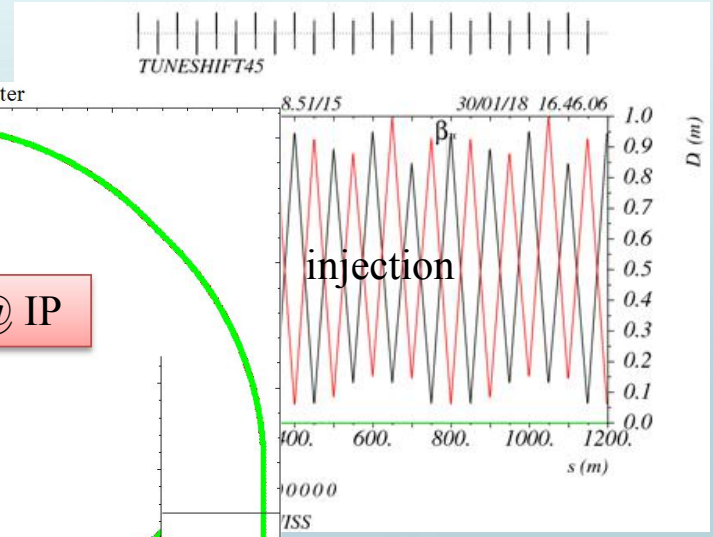
CEPC Booster parameters @ extraction

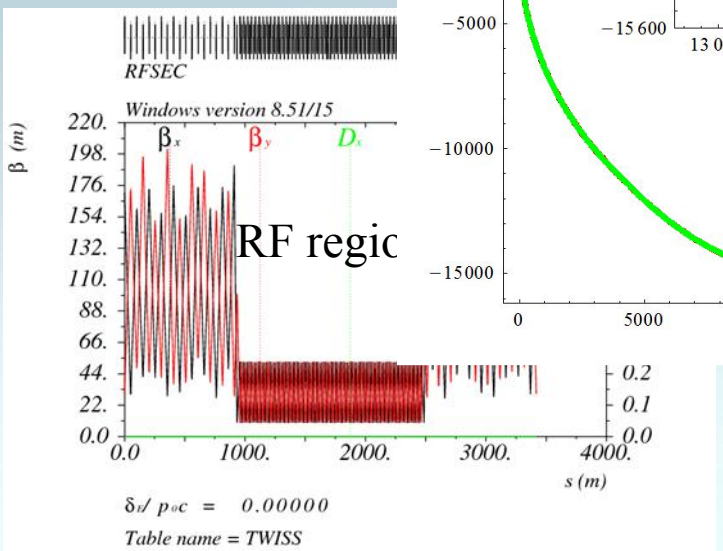
		H		*W*	*Z*
		Off axis injection	On axis injection	Off axis injection	Off axis injection
Beam energy	GeV	120		80	45.5
Bunch number		242	235+7	1524	6000
Maximum bunch charge	nC	0.72	24.0	0.58	0.41
Maximum single bunch current	μA	2.1	70	1.7	1.2
Threshold of single bunch current	μA	300			
Threshold of beam current (limited by RF power)	mA	1.0		4.0	10.0
Beam current	mA	0.52	1.0	2.63	6.91
Injection duration for top-up (Both beams)	s	25.8	35.4	45.8	275.2
Injection interval for top-up	s	73.1		153.0	438.0
Current decay during injection interval		3%			
Energy spread	%	0.094		0.062	0.036
Synchrotron radiation loss/turn	GeV	1.52		0.3	0.032
Momentum compaction factor	10^{-5}	2.44			
Emittance	nm	3.57		1.59	0.51
Natural chromaticity	H/V	-336/-333			
Betatron tune ν_x/ν_y		263.2/261.2			
RF voltage	GV	1.97		0.585	0.287
Longitudinal tune		0.13		0.10	0.10
RF energy acceptance	%	1.0		1.2	1.8
Damping time	ms	52		177	963
Natural bunch length	mm	2.8		2.4	1.3
Injection duration from empty ring	h	0.17		0.25	2.2

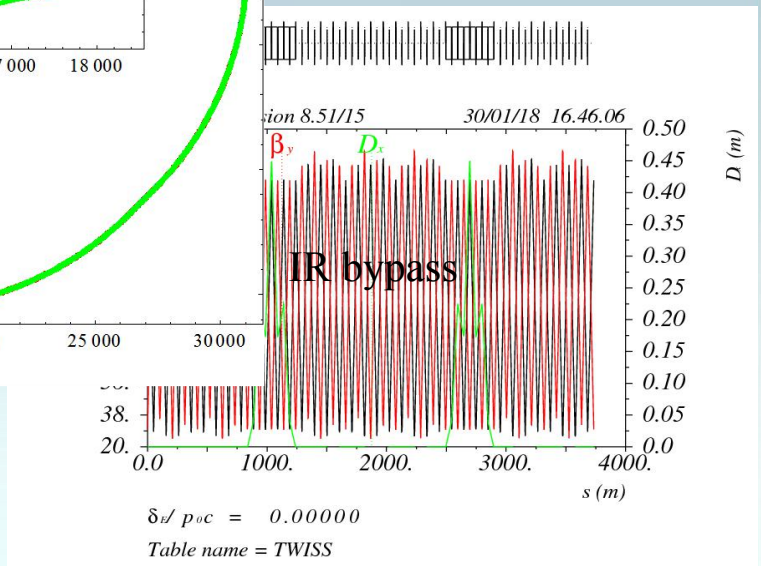
CEPC Booster Optics & Geometry











CEPC Booster SRF Parameters

10 GeV injection	H	W	Z
Extraction beam energy [GeV]	120	80	45.5
Bunch number	242	1524	6000
Bunch charge [nC]	0.72	0.576	0.384
Beam current [mA]	0.52	**2.63**	**6.91**
Extraction RF voltage [GV]	1.97	0.585	0.287
Extraction bunch length [mm]	2.7	2.4	1.3
Cavity number in use (1.3 GHz TESLA 9-cell)	96	64	32
Gradient [MV/m]	19.8	8.8	8.6
Q_L	1E7	6.5E6	1E7
Cavity bandwidth [Hz]	130	200	130
Beam peak power / cavity [kW]	8.3	12.3	6.9
Input peak power per cavity [kW] (with detuning)	18.2	12.4	7.1
Input average power per cavity [kW] (with detuning)	0.7	0.3	0.5
SSA peak power [kW] (one cavity per SSA)	25	**25**	**25**
HOM average power per cavity [W]	0.2	0.7	**4.1**
Q_0 @ 2 K at operating gradient (long term)	1E10	1E10	1E10
Total average cavity wall loss @ 2 K eq. [kW]	0.2	0.01	0.02

CEPC Booster Kickers and Septums

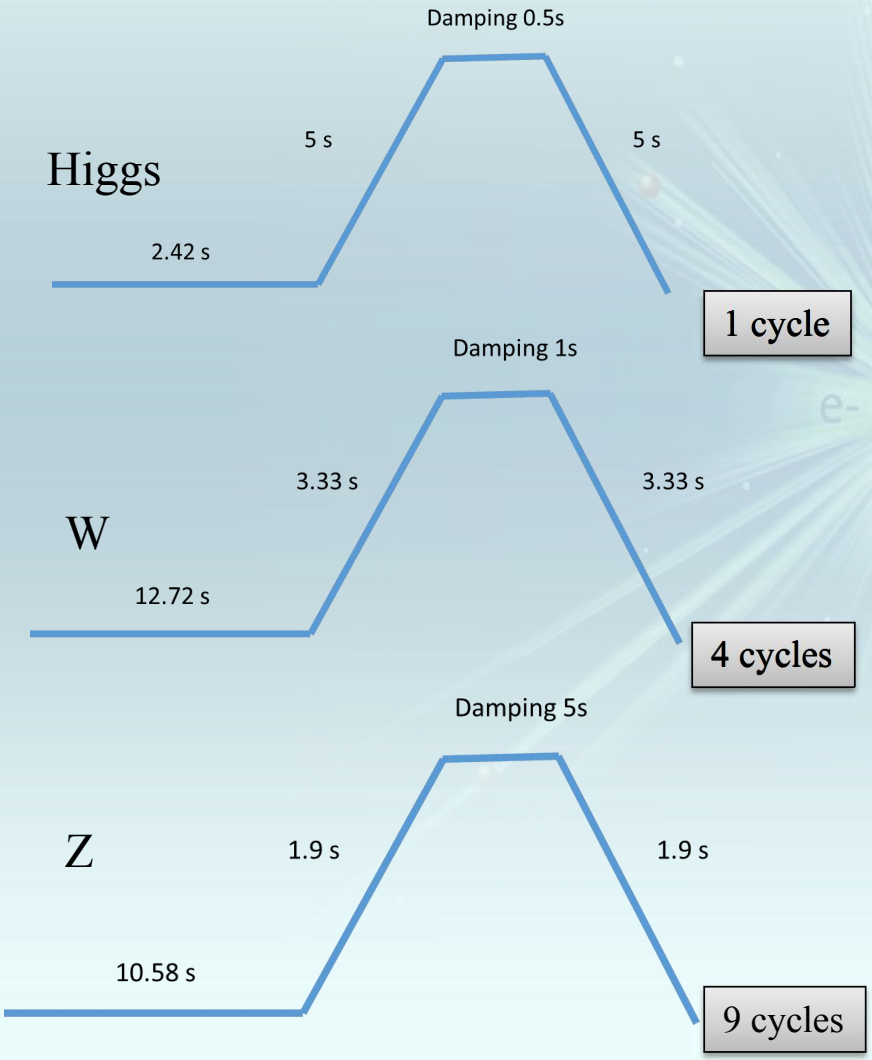
Booster Injection

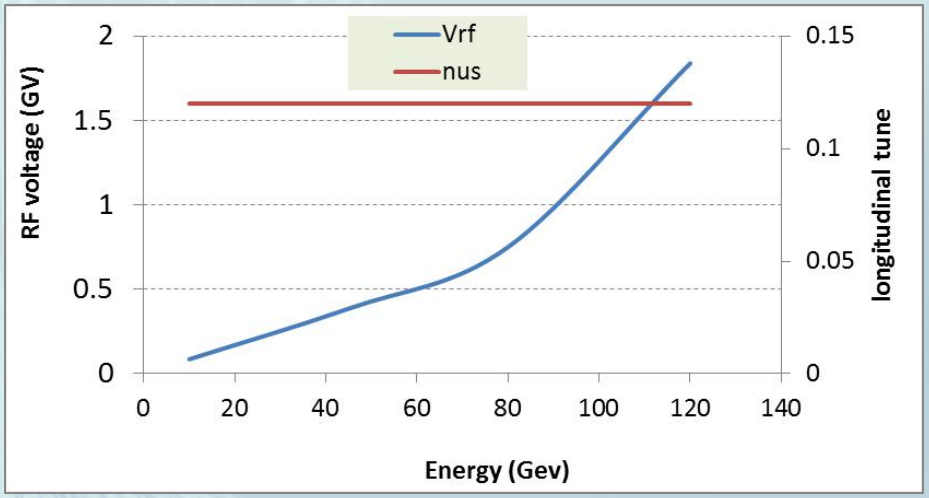
Component	Length (m)	Waveform	Deflection angle (mrad)	Field (T)	Beam-Stay-clear	
					H(mm)	V(mm)
Septum	2	DC	9.1	0.152	63	63
Kicker	0.5	Half_sin	0.5	0.034	63	63

Booster Extraction

Component	Length (m)	Waveform	Deflection angle (mrad)	Field (T)	Beam-Stay-clear	
					H(mm)	V(mm)
Septum	10	DC	10.4	0.41	20	20
Kicker	2	Half_sin	0.2	0.04	20	20

Booster Injection Time Structure





30Gauss @ 10GeV

Eddy current effect

- Transverse quantum lifetime@10GeV:
  1.65×10^8s (ε_{inj}=120nm)
- Beam loss due to lifetime << **1%**

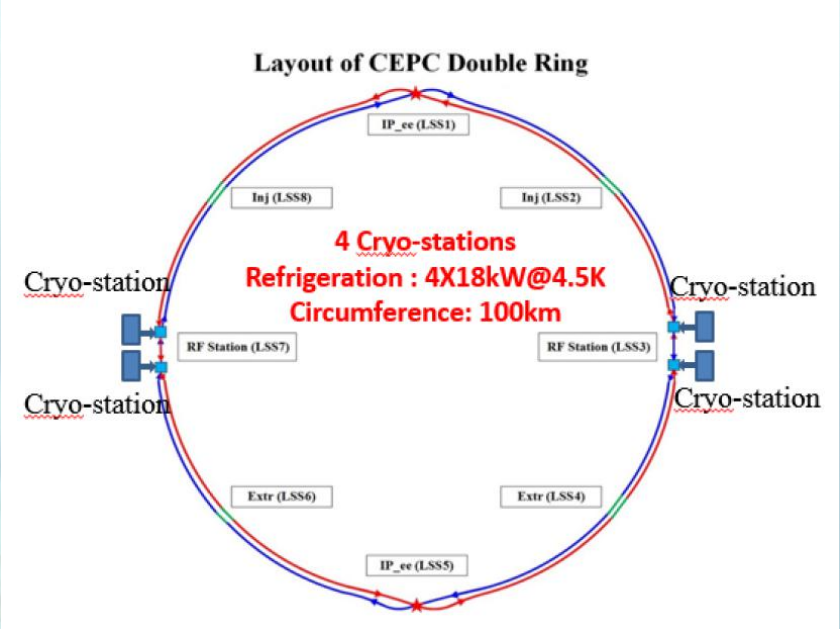
CEPC Cryogenic System

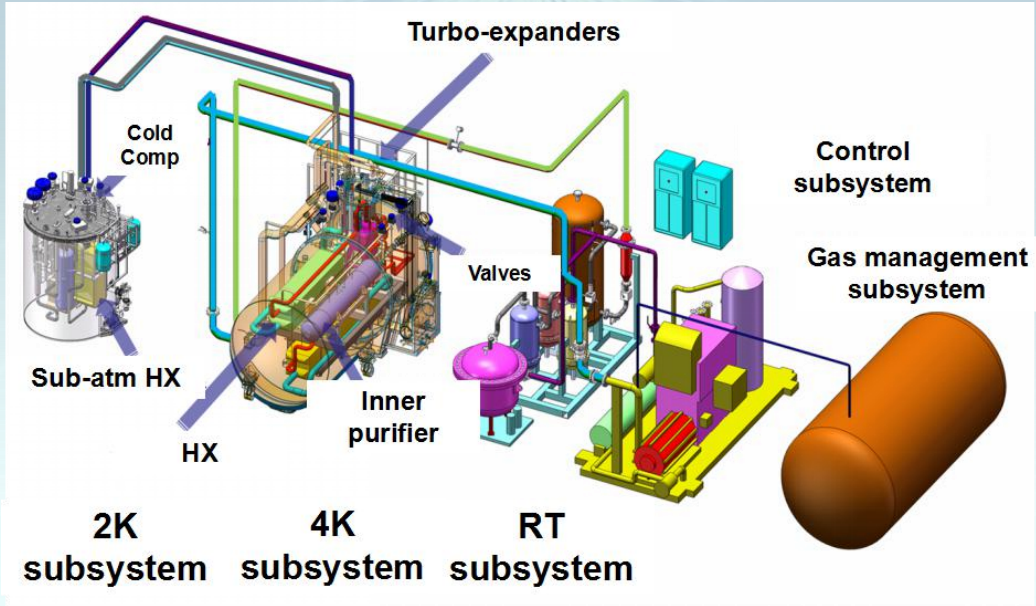
Booster ring:

- 1.3 GHz 9-cell cavities, 96 cavities
- 12 cryomodules
- 3 cryomodules/each station
- Temperature: 2K/31mbar

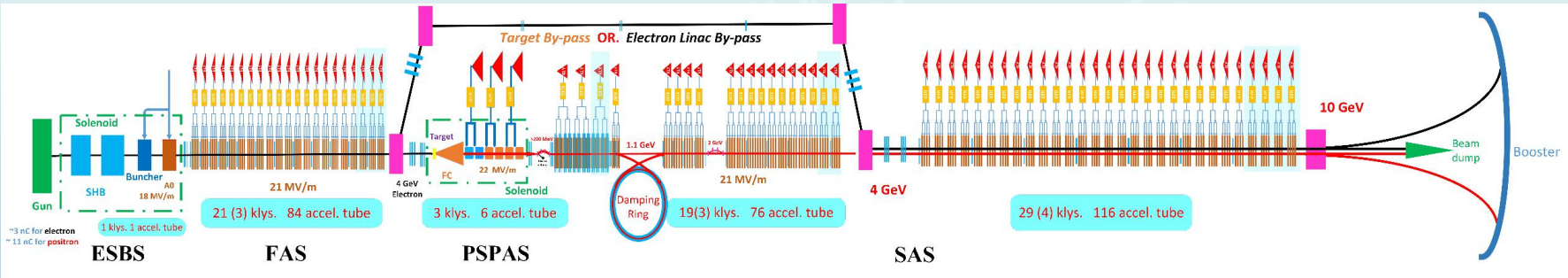
Collider ring:

- 650MHz 2-cell cavities, 336 cavities
- 56 cryomodules
- 14 cryomodules/each station
- Temperature: 2K/31mbar





CEPC Linac Injector-1

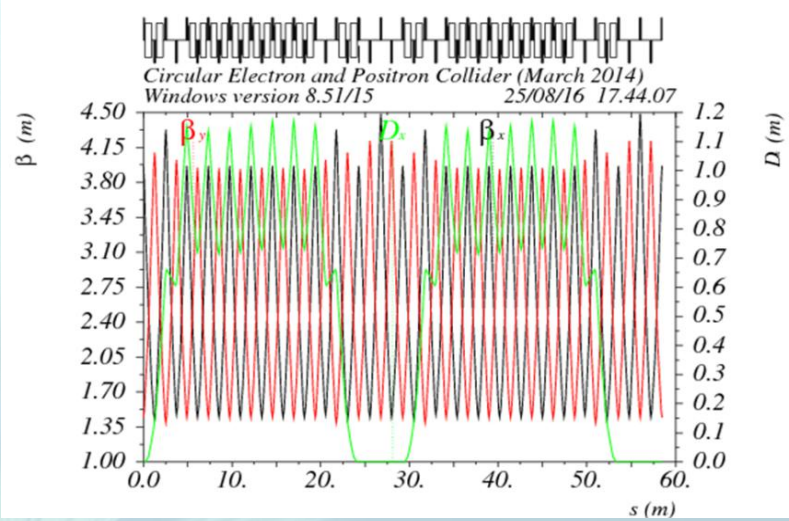


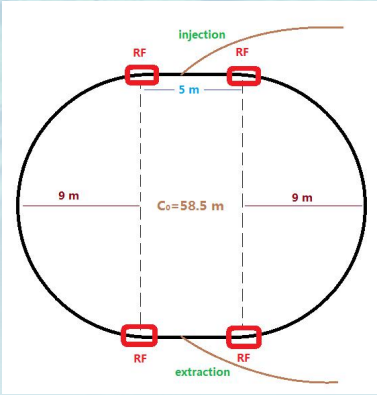
Parameter	Symbol	Unit	Baseline	Design reached
e^-/e^+ beam energy	E_{e-}/E_{e+}	GeV	10	10
Repetition rate	f_{rep}	Hz	100	100
e^-/e^+ bunch population	N_{e-}/N_{e+}		$> 9.4\times10^9$	1.9×10^{10} / 1.9×10^{10}
		nC	> 1.5	3.0
Energy spread (e^-/e^+)	σ_e		$< 2\times10^{-3}$	1.5×10^{-3} / 1.6×10^{-3}
Emittance (e^-/e^+)	ε_r	nm· rad	< 120	5 / 40 ~120
Bunch length (e^-/e^+)	σ_l	mm		1 / 1
e^- beam energy on Target		GeV	4	4
e^- bunch charge on Target		nC	10	10

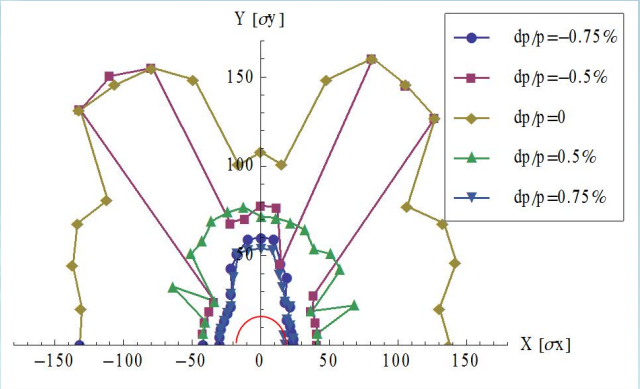
CEPC Linac Injector Damping Ring

Parameters, lattice and layout

DR V1.0	Unit	Value
Energy	GeV	1.1
Circumference	M	58.5
Repetition frequency	Hz	100
Bending radius	M	3.6
Dipole strength B_0	T	1.01
U_0	keV	35.8
Damping time x/y/z	Ms	12/12/6
δ_0	%	0.049
ε_0	mm.mrad	302
Nature σ_z	mm	7 (23ps)
Extract σ_z	mm	7 (23ps)
ε_{inj}	mm.mrad	2500
$\varepsilon_{ext\ x/y}$	mm.mrad	716/471
$\delta_{inj}/\delta_{ext}$	%	0.6/0.07
Energy acceptance by RF	%	1.0
f_{RF}	MHz	650
V_{RF}	MV	1.8



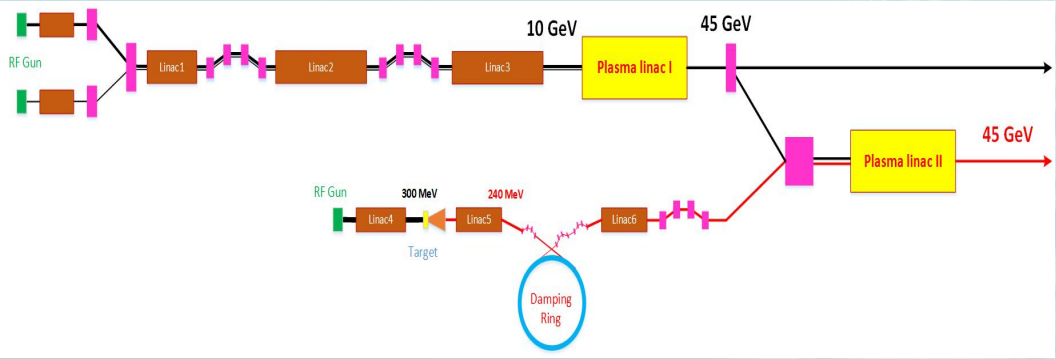


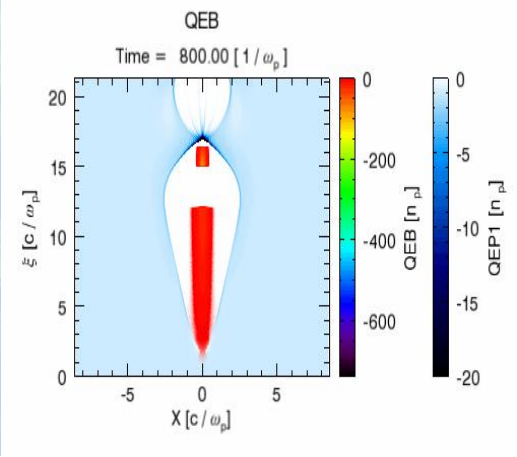


Kickers and Septums for damping ring

Component	Length (m)	Waveform	Deflection angle (mrad)	Field (T)	Beam-Stay-clear	
					H (m m)	V (m m)
Septum	2	DC	77	0.13	63	63
Kicker	0.5	Half_sin	0.2	0.0013	63	63

CEPC Linac Injector alternative: Plasma accelerator scheme up to 45GeV (single stage)~120GeV (cascade)





Plasma density $n_0(cm^{-3})$	5.15×10^{16}
Driver charge $Q_d(nC)$	6.47
Driver energy $E_d(GeV)$	10
Driver length $L_d(\mu m)$	285
Driver RMS size $\sigma_d(\mu m)$	10
Driver normalized emittance $\epsilon_{nd}(mm\ mrad)$	10
Trailor charge $Q_t(nC)$	1.25
Trailor energy $E_t(GeV)$	10
Trailor length $L_t(\mu m)$	35
Trailor RMS size $\sigma_t(\mu m)$	5
Trailor normalized emittance $\epsilon_{nt}(mm\ mrad)$	100

Trailor energy $E_t(GeV)$	45.5
Trailor normalized emittance $\epsilon_{nt}(mm\ mrad)$	98.9
TR	3.55
Energy spread $\delta_E(\%)$	0.7
Efficiency (driver -> trailor)	68.6%

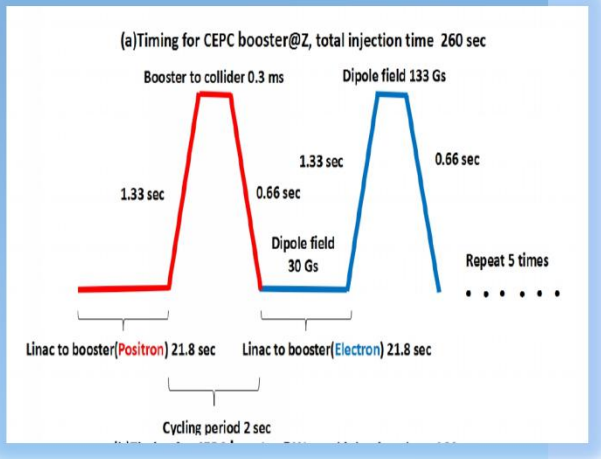
The simulations show that plasma scheme satisfies the CEPC booster requirement

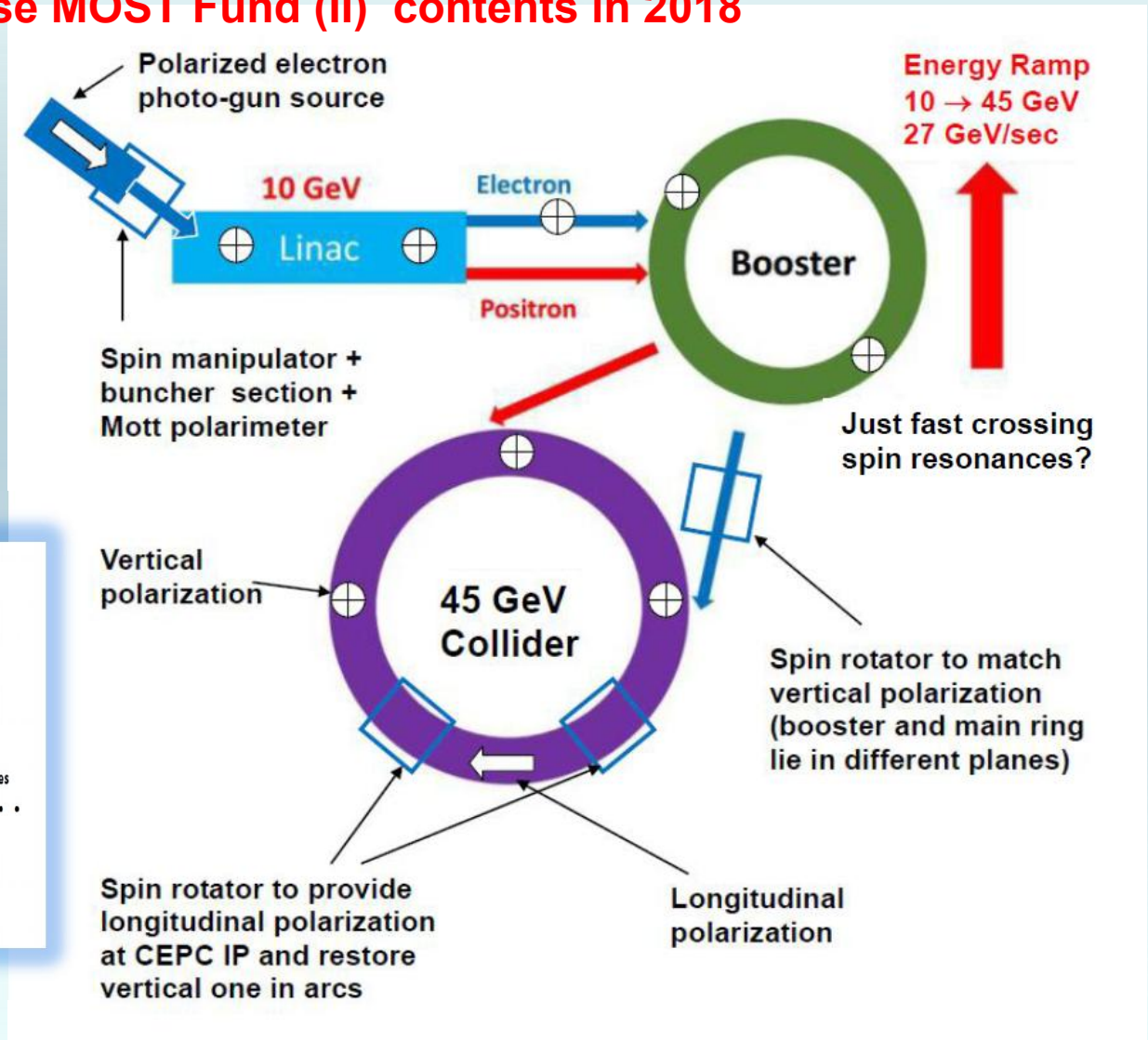
CEPC Longitudinal polarization of electrons

S. Nikitin (BINP)

CEPC Chinese MOST Fund (II) contents in 2018

Electrons from gun source are longitudinally polarized. Spins are rotated to vertical plane in special transport section downstream of gun.Variants (CEBAF, NIKHEF):
a) Wien's Filter
b) Z-manipulator includes two bends by E-field and solenoids between them.





Preliminary Study for CEPC Z-pole Polarization

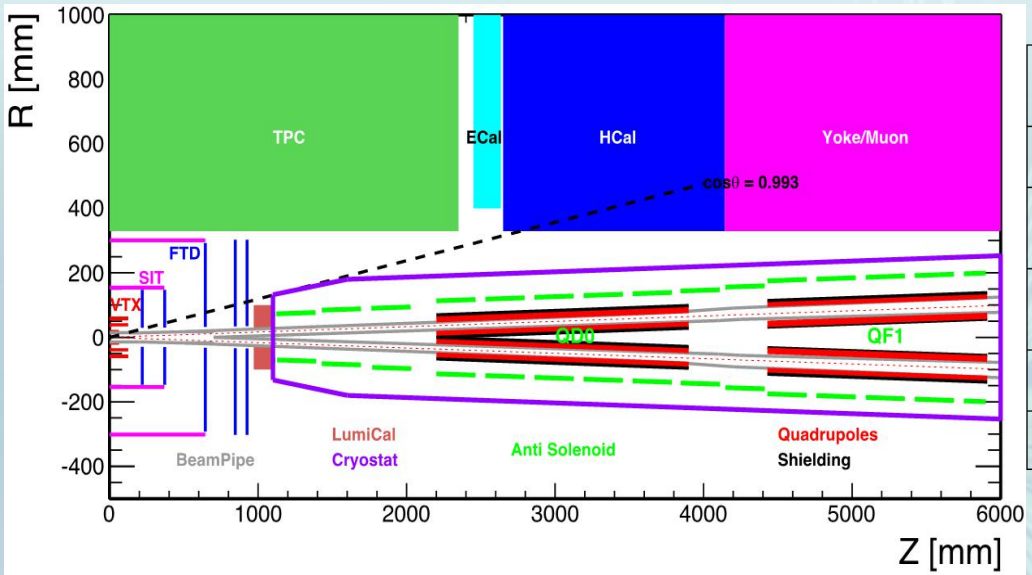
Table A8.3: Parameters for obtaining polarization at CEPC; * and ** indicate the cases with the use of special wigglers of $B_+ = 0.5$ T and $B_+ = 0.6$ T, respectively

E, GeV	$\lvert w_k \rvert$	G_{max}	ν_γ	τ_{rel}, hr	η, %	t_η, hr
45.602	10^{-3}	0.53	0.028	17.1*	10	3.93
45.602	10^{-3}	0.09	0.028	1.8**	6	2.28
79.978	.0005	0.32	0.040	4.8	10	2.14

A8.7: Summary

Particle polarization of at least 10% is needed to apply the resonant depolarization technique in precise measurement of the Z mass. Because of the excessively long time for radiative polarization, it becomes necessary to add to the Collider strong non-uniform wiggler magnets to speed up the polarization process. The wigglers cause a multiple increase in the spread of the spin precession frequency. This, in turn, leads to an intensification of the depolarizing effect of quantum fluctuations. The calculations of the depolarizing factor of vertical closed orbit distortions were performed taking into account the synchrotron modulation of the spin tune. Obtaining the required degree of polarization in CEPC at 45 and 80 GeV for an acceptable time is tentatively possible provided that the resonance spin harmonics of vertical closed orbit distortions are corrected to the levels indicated in the corresponding numerical examples. This conclusion is indirectly supported by similar estimates for LEP and their achieved polarization.

CEPC MDI Layout and Parameters



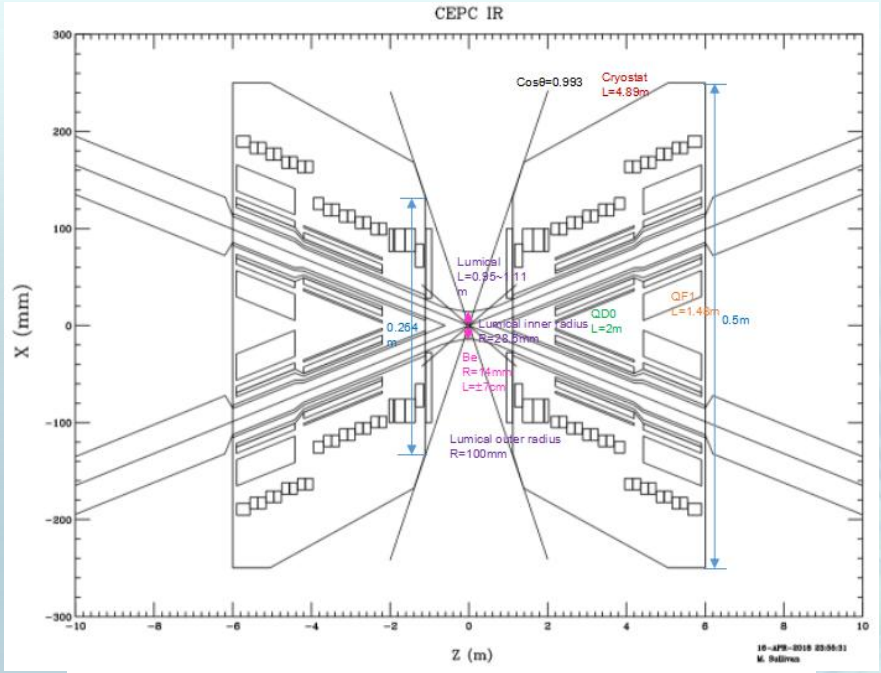
MDI parameters	Values
L^* (m)	2.2
Crossing angle (mrad)	33
Strength of QD0 (T/m)	150
Strength of detector solenoid (T)	3.0
Strength of anti-solenoid (T)	7.0

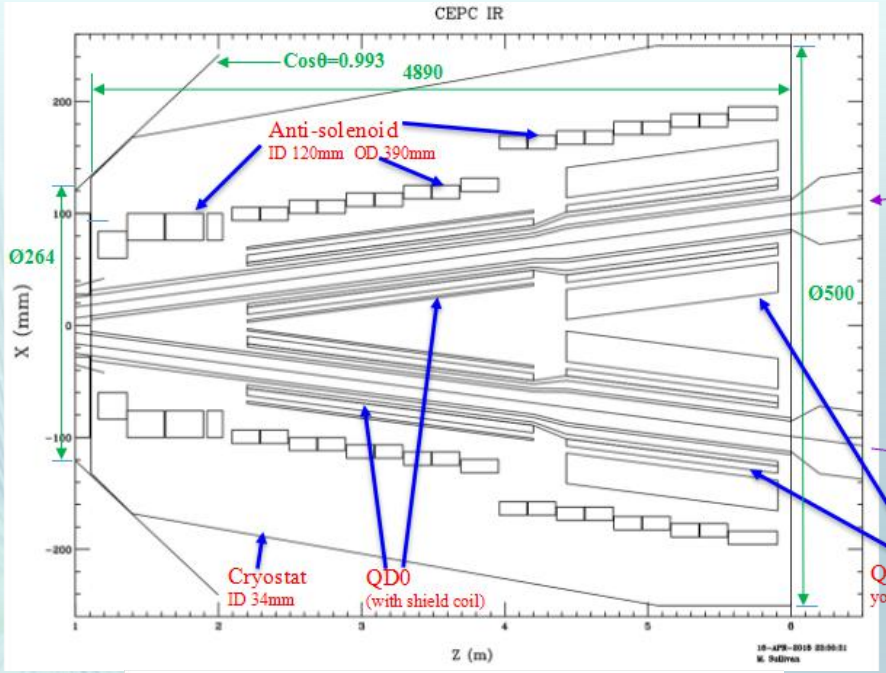
- The Machine Detector Interface of CEPC double ring scheme is about ±7m long from the IP.
- The CEPC detector superconducting solenoid with 3 T magnetic field and the length of 7.6m.
- The accelerator components inside the detector without shielding are within a conical space with an opening angle of cosθ=0.993.
- The e+e- beams collide at the IP with a horizontal angle of 33mrad and the final focusing length is 2.2m
- Lumical will be installed in longitudinal 0.95~1.11m, with inner radius 28.5mm and outer radius 100mm.

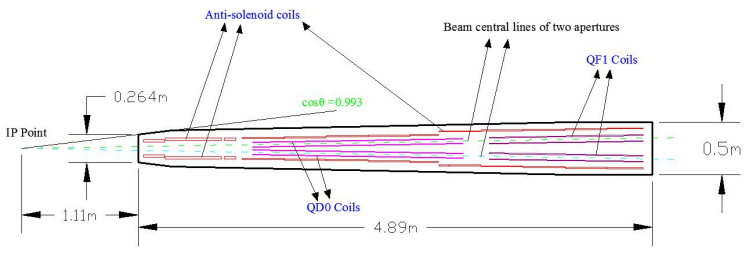
CEPC MDI Parameters

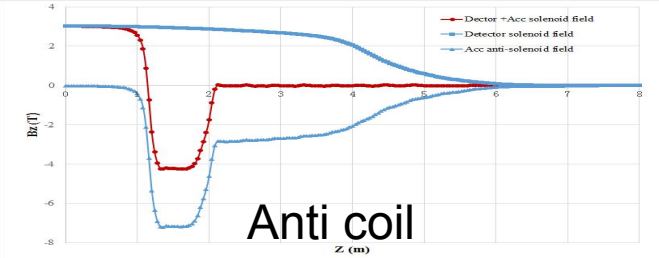
	range	Peak filed in coil	Central filed gradient	Bending angle	length	Beam stay clear region	Minimal distance between two aperture	Inner diameter	Outer diameter	Critical energy (Horizontal)	Critical energy (Vertical)	SR power (Horizontal)	SR power (Vertical)
L*	0~2.2m				2.2m								
Crossing angle	33mrad												
MDI length	±7m												
Detector requirement of opening angle	13.6°												
QD0		3.2T	136T/m		2m	19.51mm	72.61mm	40mm	53mm	1.3MeV	527keV	639W	292W
QF1		3.8T	110T/m		1.48m	26.85mm	146.2mm	56mm	69mm	1.6MeV	299keV	1568W	74W
Lumical	0.95~1.11m				0.16m			57mm	200mm				
Anti-solenoid before QD0		7.26 T			1.1m			120mm	390mm				
Anti-solenoid QD0		2.8T			2m			120mm	390mm				
Anti-solenoid QF1		1.8T			1.48m			120mm	390mm				
Beryllium pipe					±7cm			28mm					
Last B upstream	67.66~161.04m			1.1mrad	93.38m					45keV			
First B downstream	46.06~107.04m			1.54mrad	60.98m					97keV			
Beampipe within QD0					2m							2.9W	
Beampipe within QF1					1.48m							3.1W	
Beampipe between QD0/QF1					0.23m							36.2W	

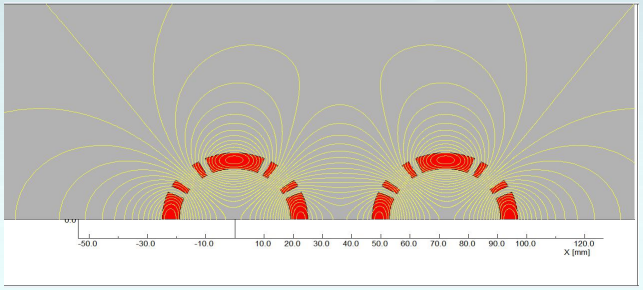
CEPC Final Focus Magnets & Cryostat



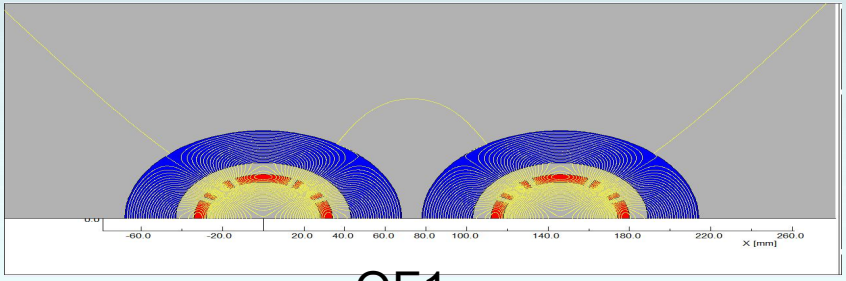




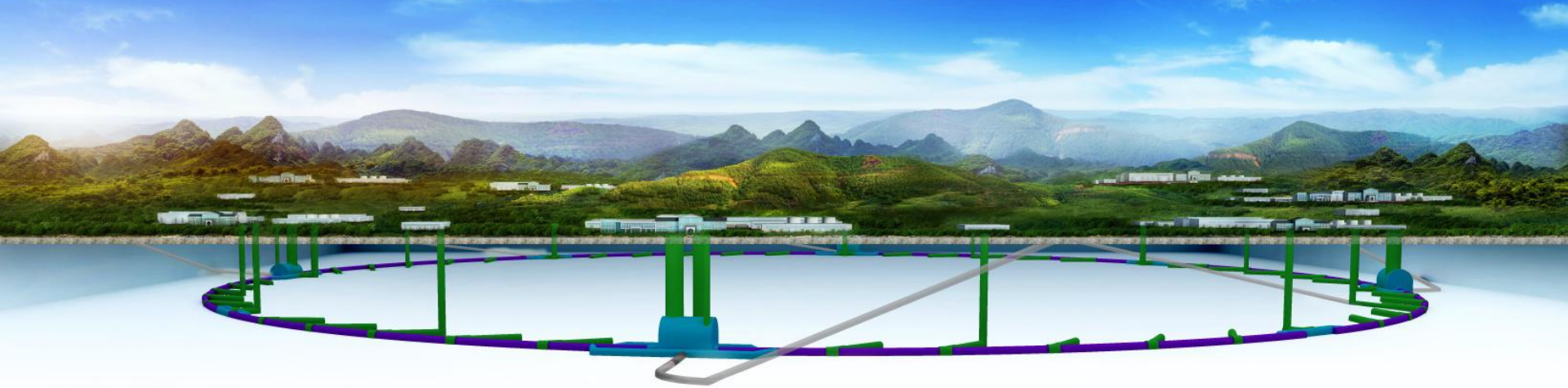




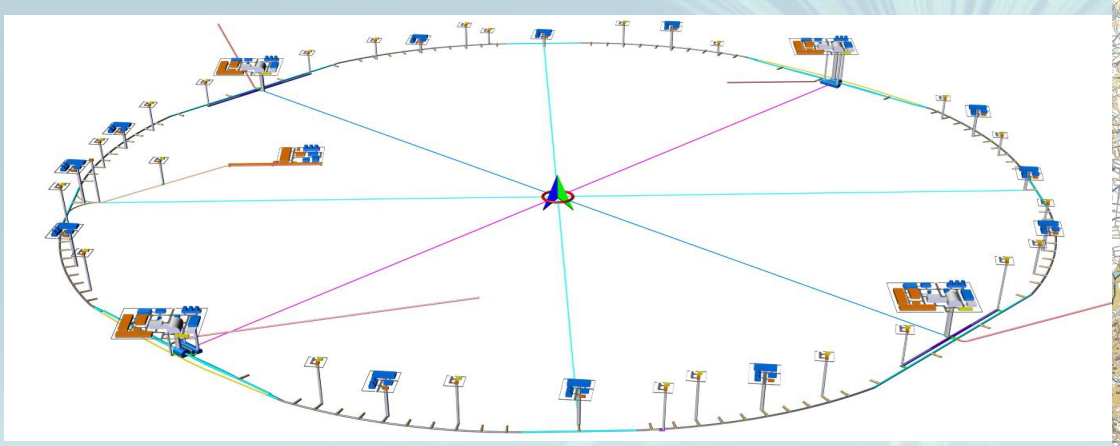
QD0

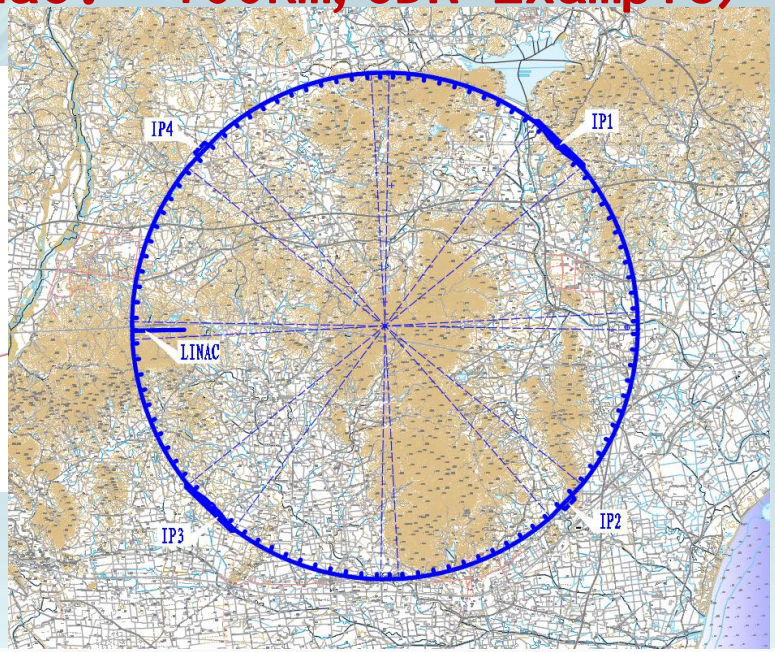


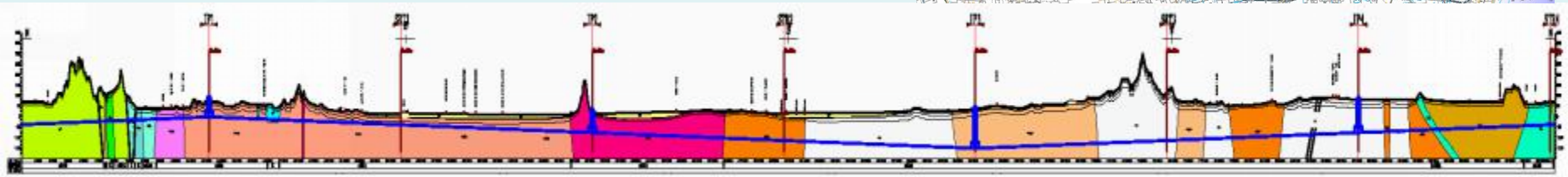
QF1



CEPC Civil Engineering (Qinhuangdao: 100km, CDR Example)

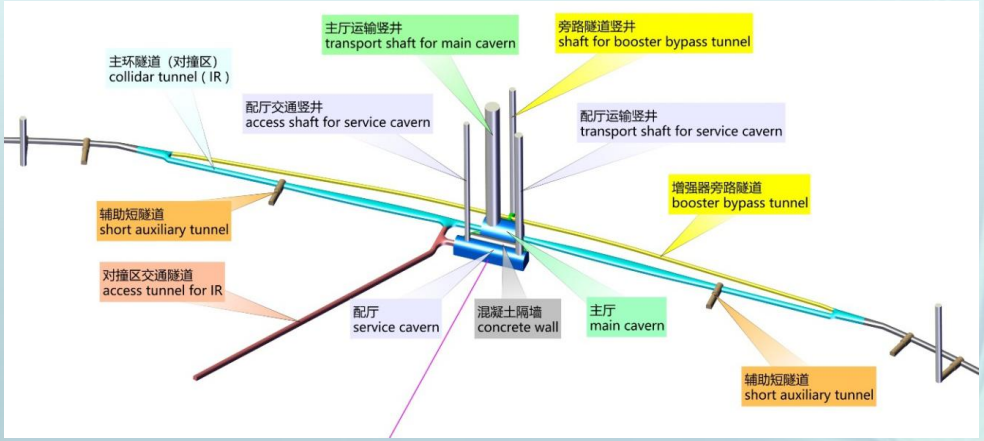




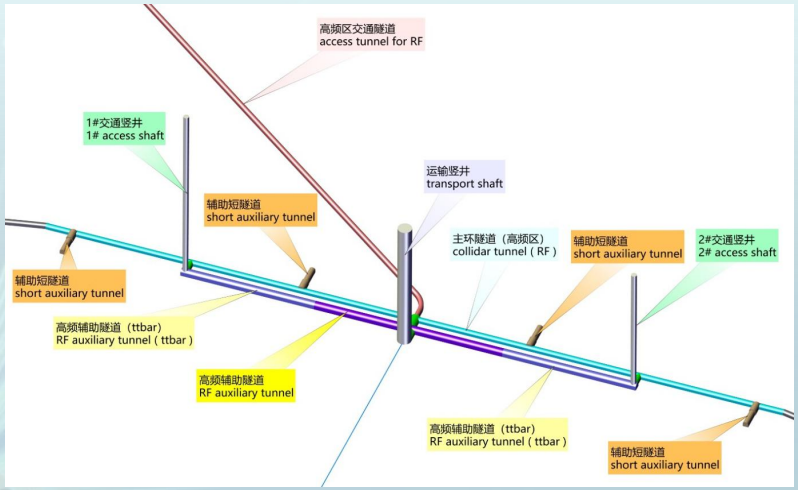


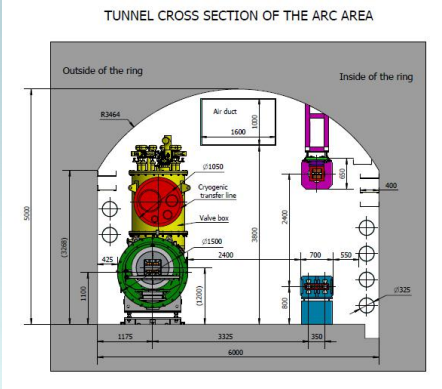
CEPC Tunnel Cross Sections, Detector and SCRF Regions

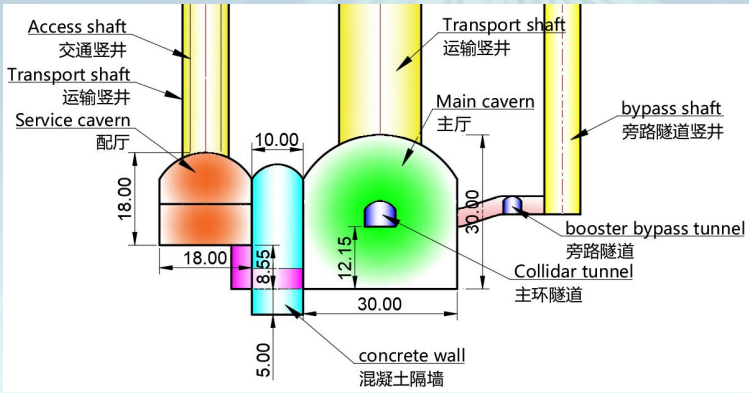
IP1 / IP3

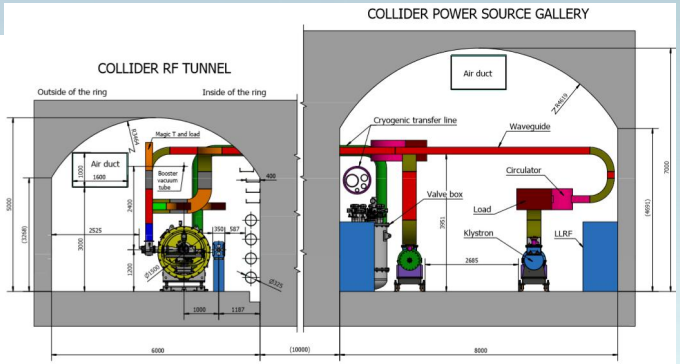


IP2 / IP4--SCRF region



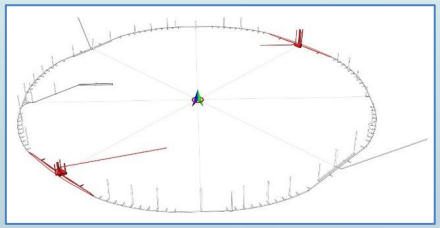


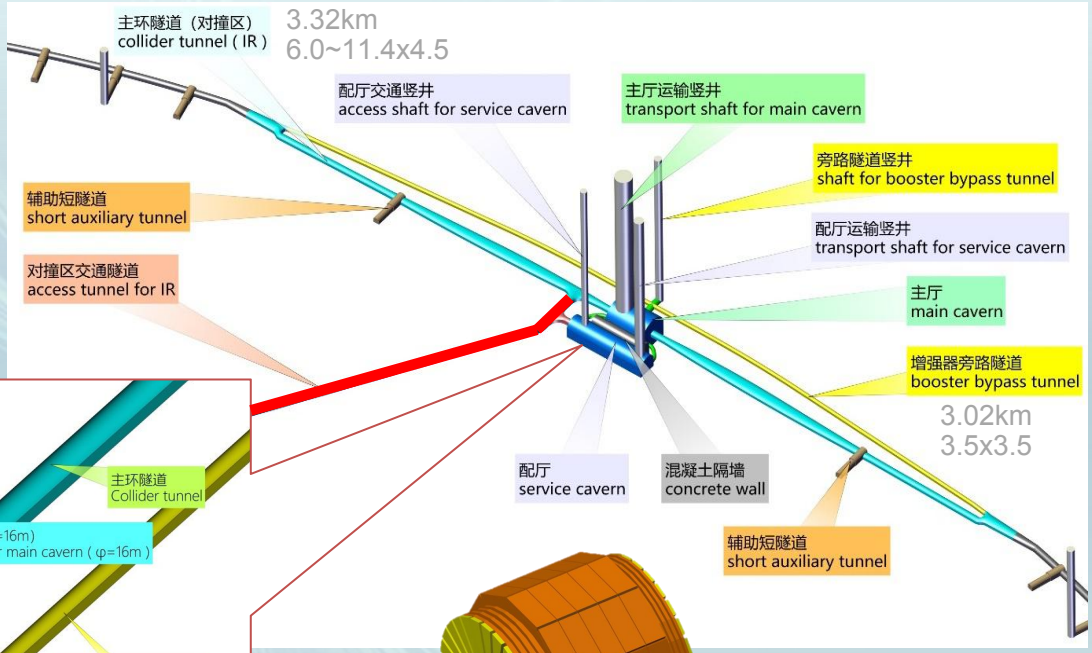


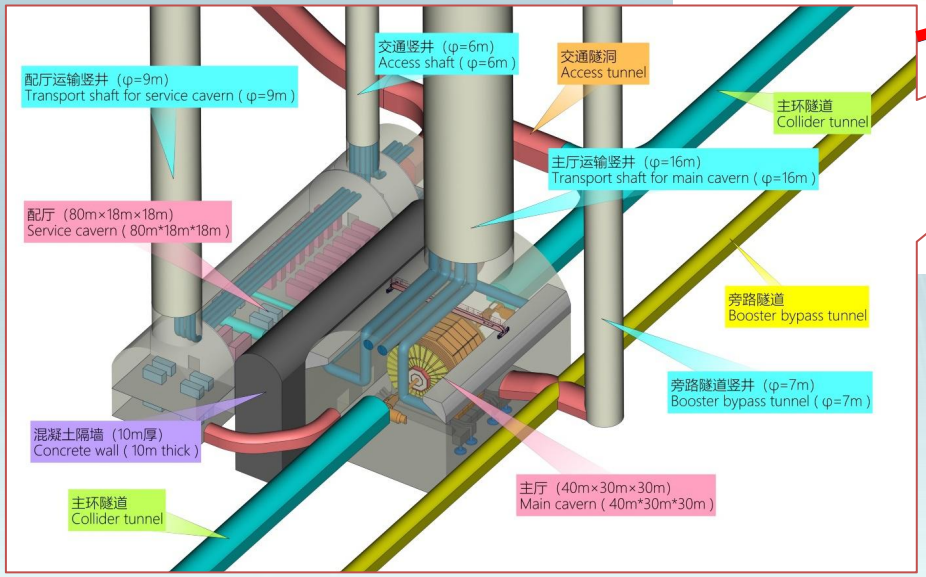


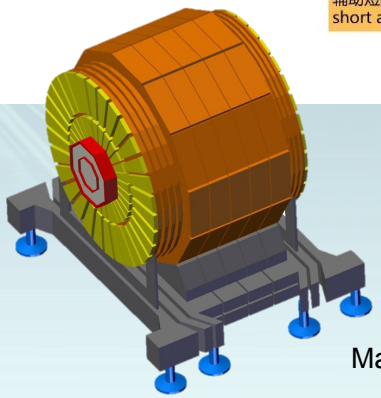
CEPC Tunnel in Detector Region

IP1 / IP3



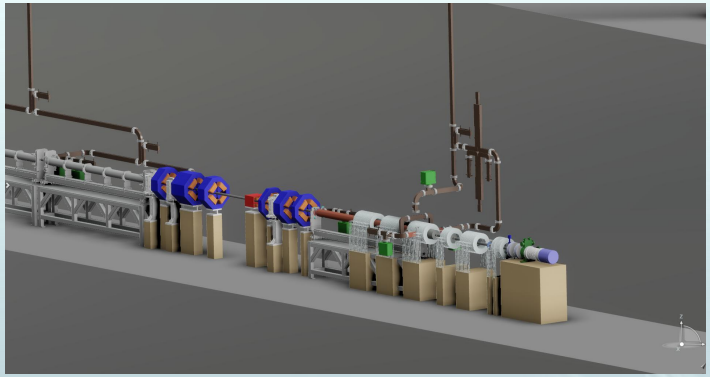




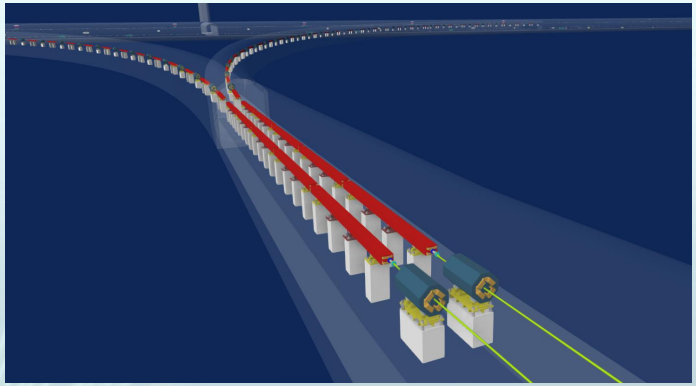


Main detector
主探测器

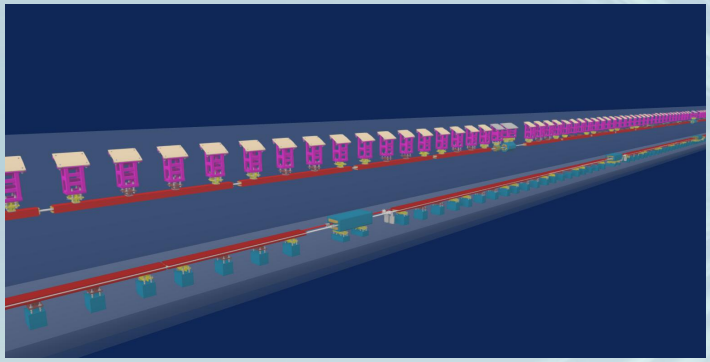
CEPC Civil Engineering



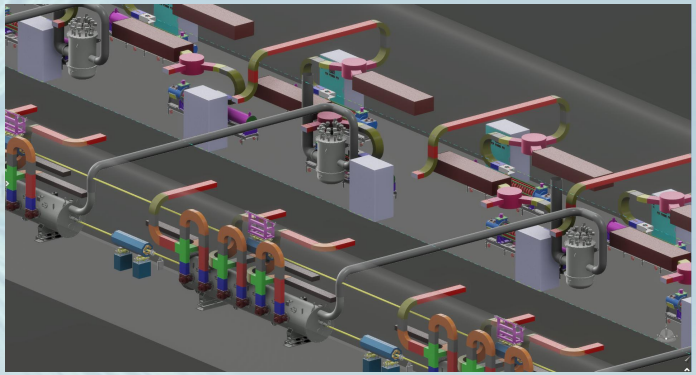
Electron source



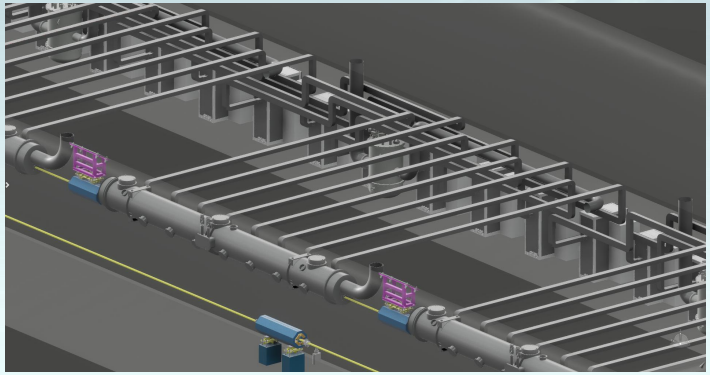
Linac to Booster



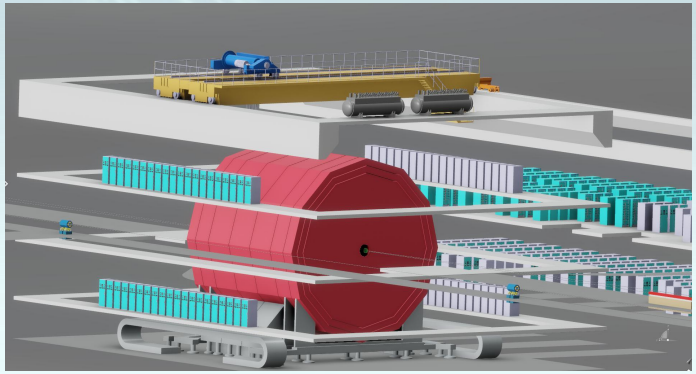
Booster and collider ring tunnel



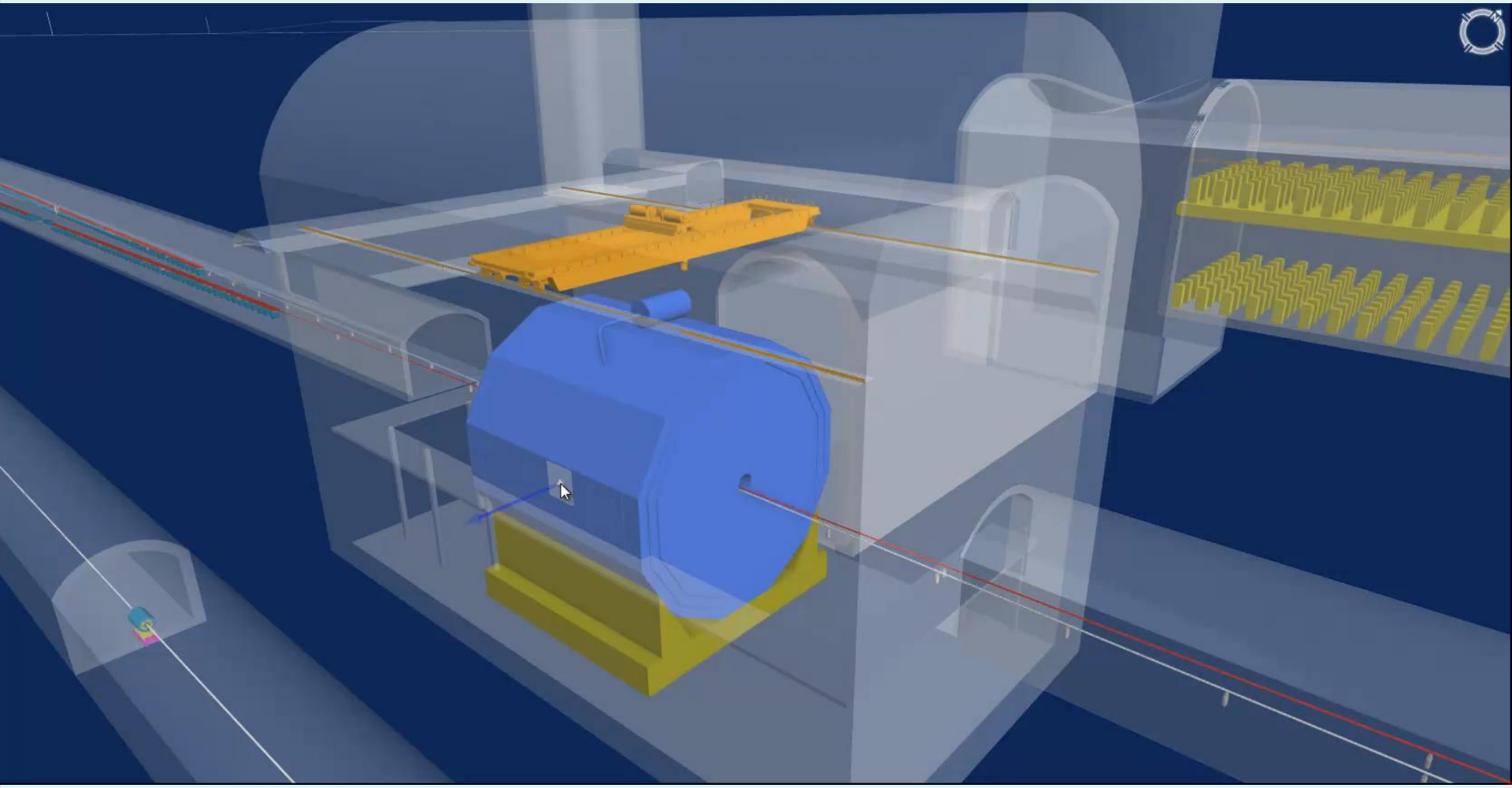
Collider ring SCRF



Booster SCRF



Detector hall



CEPC Power for Higgs and Z

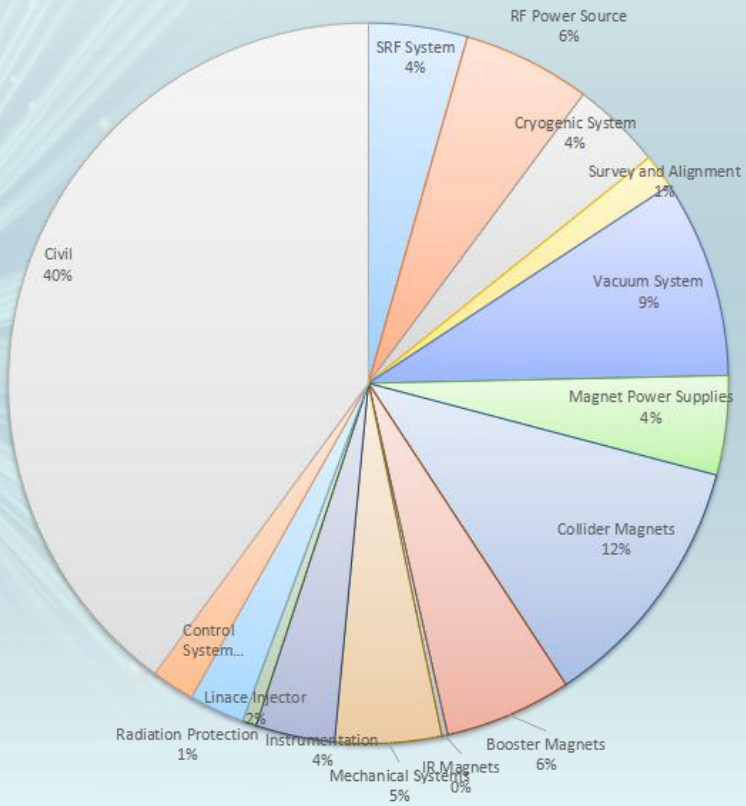
	System for Higgs (30MW)	Location and electrical demand(MW)						Total (MW)
		Ring	Booster	LINAC	BTL	IR	Surface building	
1	RF Power Source	103.8	0.15	5.8				109.75
2	Cryogenic System	11.62	0.68			1.72		14.02
3	Vacuum System	9.784	3.792	0.646				14.222
4	Magnet Power Supplies	47.21	11.62	1.75	1.06	0.26		61.9
5	Instrumentation	0.9	0.6	0.2				1.7
6	Radiation Protection	0.25		0.1				0.35
7	Control System	1	0.6	0.2	0.005	0.005		1.81
8	Experimental devices					4		4
9	Utilities	31.79	3.53	1.38	0.63	1.2		38.53
10	General services	7.2		0.2	0.15	0.2	12	19.75
	Total	213.554	20.972	10.276	1.845	7.385	12	266.032

266MW

	System for Z	Location and electrical demand(MW)						Total (MW)
		Ring	Booster	LINAC	BTL	IR	Surface building	
1	RF Power Source	57.1	0.15	5.8				63.05
2	Cryogenic System	2.91	0.31			1.72		4.94
3	Vacuum System	9.784	3.792	0.646				14.222
4	Magnet Power Supplies	9.52	2.14	1.75	0.19	0.05		13.65
5	Instrumentation	0.9	0.6	0.2				1.7
6	Radiation Protection	0.25		0.1				0.35
7	Control System	1	0.6	0.2	0.005	0.005		1.81
8	Experimental devices					4		4
9	Utilities	19.95	2.22	1.38	0.55	1.2		25.3
10	General services	7.2		0.2	0.15	0.2	12	19.75
	Total	108.614	9.812	10.276	0.895	7.175	12	148.772

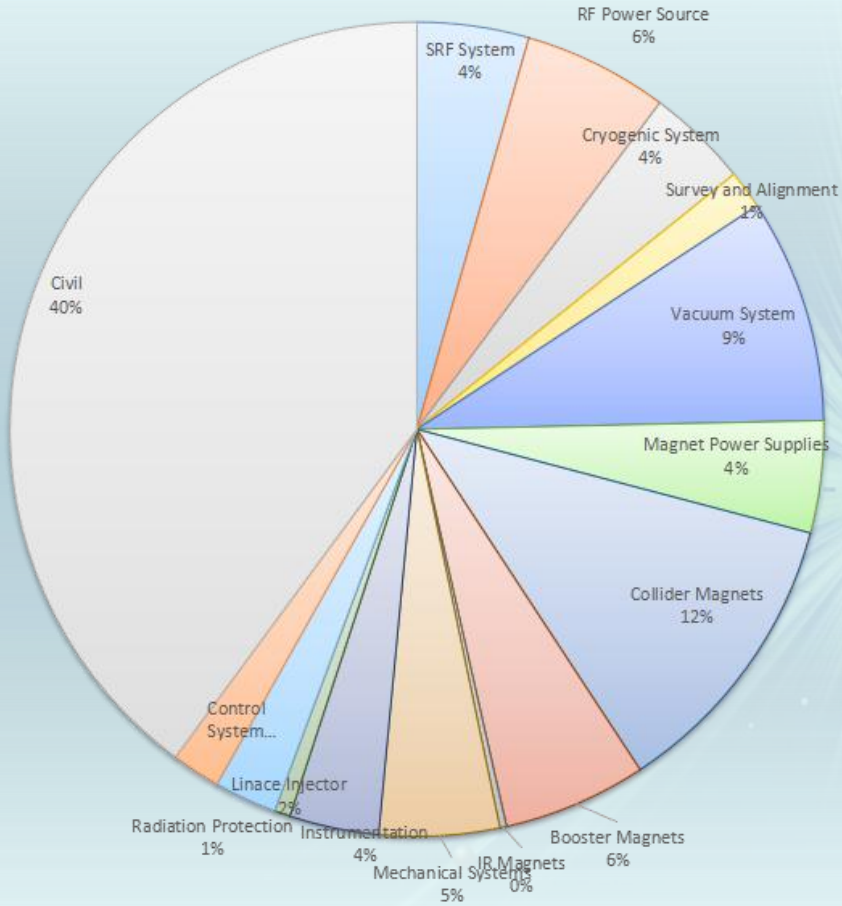
149MW

CEPC Cost Breakdwon (no detector)

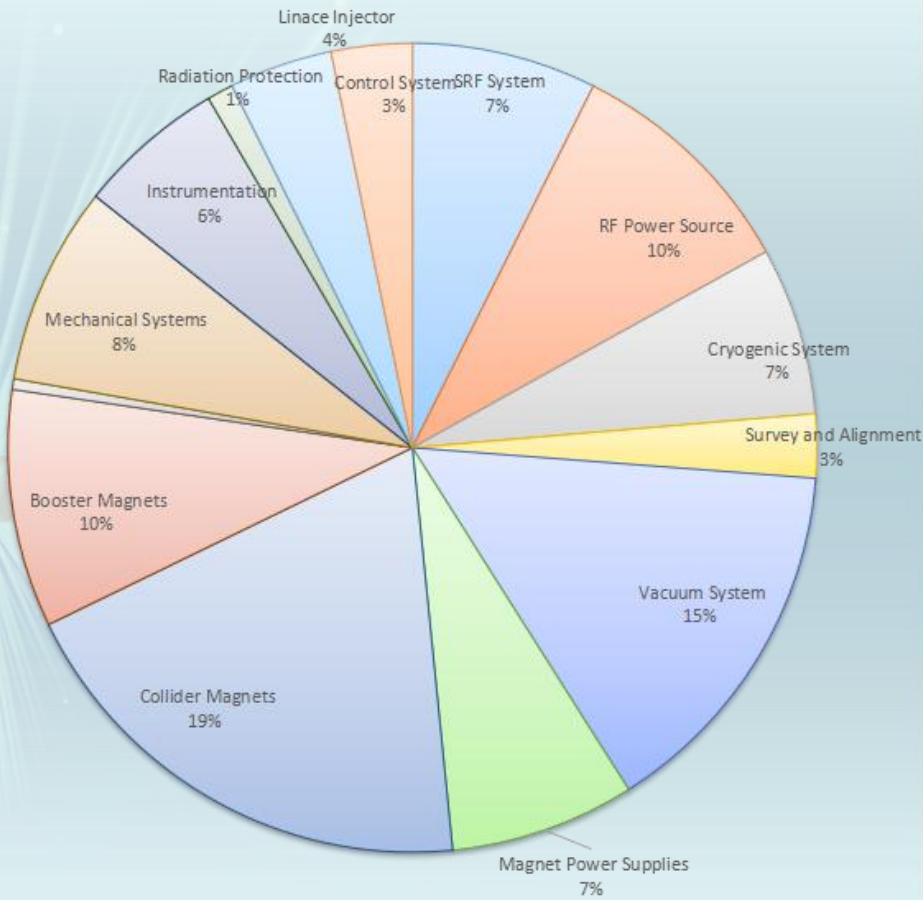


The total cost of CEPC~35Billion RMB~5Billion $ (Accelerator+2 Detectors+Civil+Contigence)

CEPC Cost Breakdown (no detectors)



Including civil cost



Without including civil cost

CEPC Accelerator R&D twowards TDR

CEPC TD Timeline

TDR from 2018-2022

CEPC

2015 | 2020 | 2025 | 2030 | 2035

- Pre-studies (2013-2015)
- R&D Engineering Design (2016-2022)
- Construction (2022-2030
- Data taking (203-2040)

1st Milestone: Pre-CDR (by 2015) ;2nd Milestone: R&D funding from MOST (in Mid 2016); 3rd Milestone: CEPC CDR Progress Report (April 2017); 4th Milestone: CEPC CDR Report (publsih in July, 2018);5th Milestone: CEPC TDR Report and Proto R&D (by the end of 2021);6th Milestone: CEPC construction start (2022);

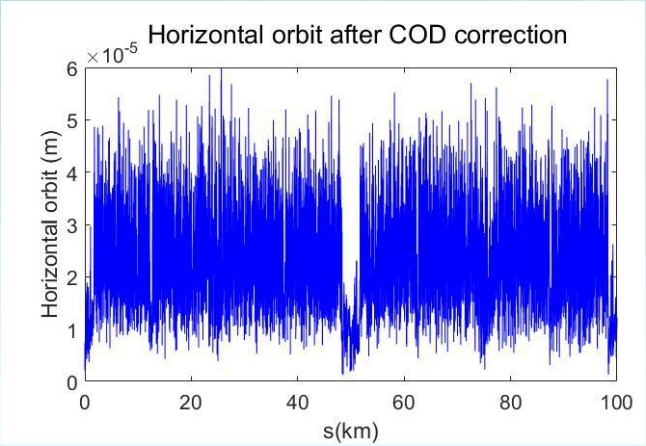
SPPC

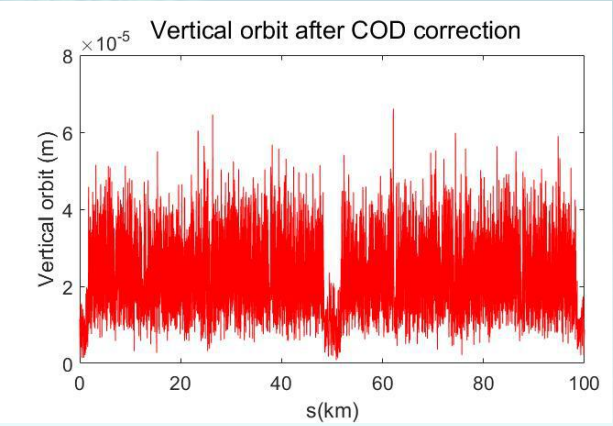
2020 | 2030 | 2040

- CDR and R&D (2014-2035)
- Engineering Design (2035-2040)
- Construction (2040-2045)
- Data taking (2045-2060)

CEPC Accelerator Optimization Design towards TDR

Refine all sub-systems, such as damping ring, booster, collider rings
Injection/extract physics and hardwares' design
Magnets and other hardwares' errors effects on DA, the advanced close orbit corrections method maintain DA reduction acceptable, keeping the tolerences requirments to reasonable values
All connecting transfer lines matching the collider accelerator chain requirements
Detector bakgroud reduction, beam-beam for long lifetime
Impedance studies including collimators
MDI SC magnets' optimazation design
Magnets' studies with H, W, and Z all modes
Upgrade possibility studies
....

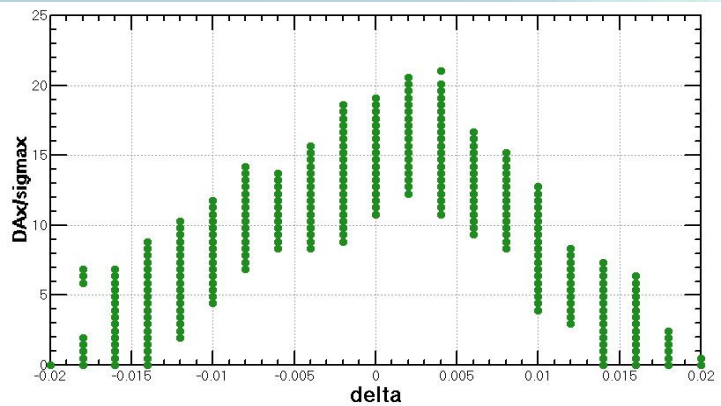


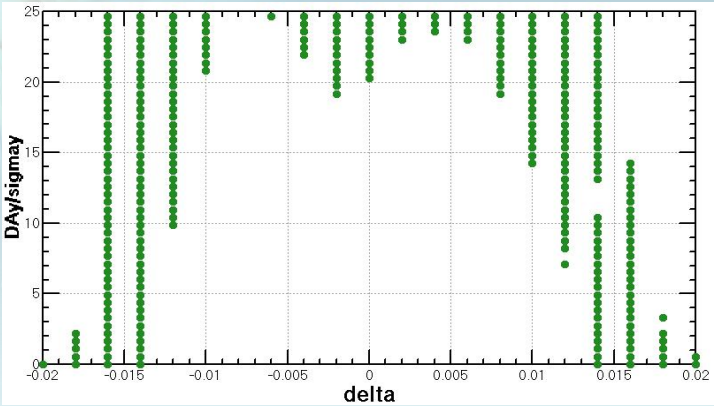


Close orbit corrections in x and y planes (0.1mm) with magnets' errors

CEPC Collider Ring Dynamic Apertures (w/ errors)

- Dynamic aperture result for **Higgs mode**
  - Tracking in SAD w/ radiation damping, fluctuation, energy sawtooth and tapering, 145 turns(2 damping times), initial phases=0
  - Totally around 800 random seeds used
  - Horizontal dynamic aperture decreased significantly with errors. But it still fulfils the dynamic aperture requirement of on-axis injection.



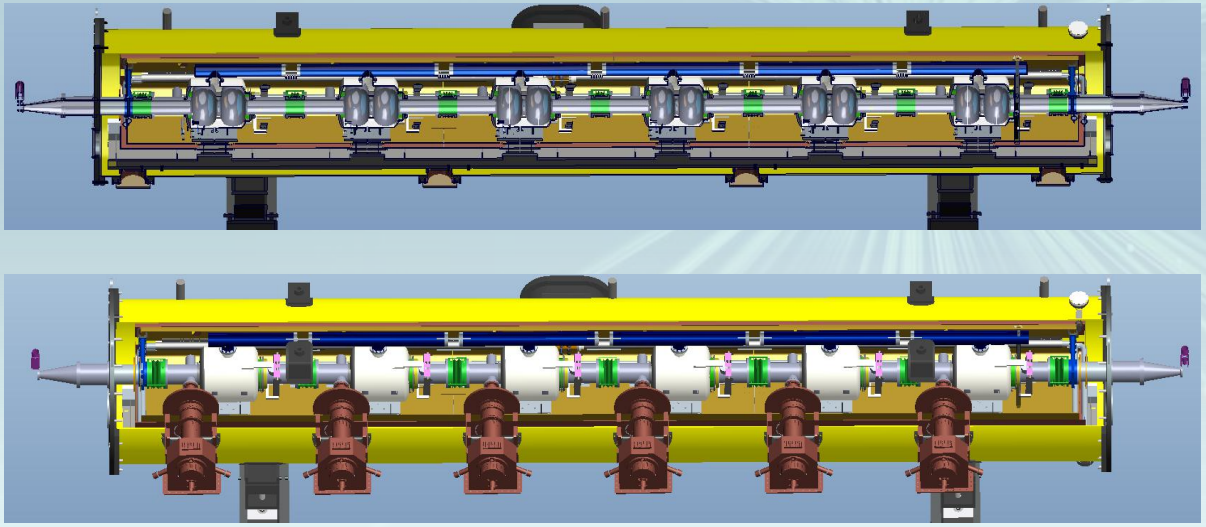


$20\sigma_x \times 23\sigma_y$ & 0.018 w/o errors

$11\sigma_x \times 19\sigma_y$ & 0.014 w/ errors

CEPC 650 MHz Cavity Cryomodule

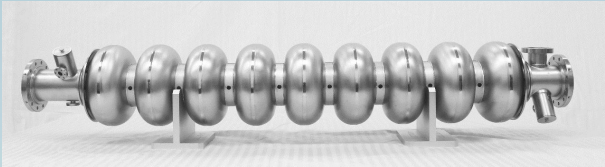
- Structure based on ADS cryomodule. High Q requirement drives new design features (fast cool down and magnetic hygiene).
- Fast cool down rate is supposed to be 10 K/min during 45 K to 4.5 K.
- Ambient magnetic field at cavity surface should be less than 5 mG. Magnetic shielding and demagnetization of parts and the whole module should be implemented for the magnetic hygiene control.



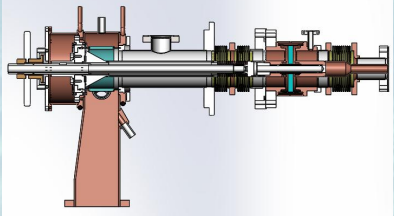
Overall length (flange to flange, m)	8.0
Diameter of vacuum vessel (m)	1.3
Beamline height from floor (m)	1.2
Cryo-system working temperature (K)	2
Number of cavities and tuners	6
Number of couplers	6
Number of RT HOM absorbers	2
Number of 200-POSTs	6
Static heat loads at 2 K (W)	5
Alignment x/y (cavities) (mm)	0.5
Alignment z (mm)	2

1.3 GHz SRF Technology for CEPC Booster

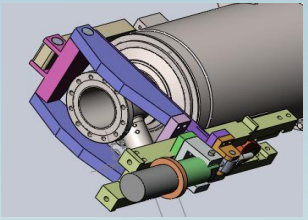
XFEL and LCLS-II type cryomodule, without SCQ. Technology R&D in synergy with Shanghai XFEL (SCLF). No big challenge.



TESLA cavity. Nitrogen-doped bulk niobium and operates at 2 K. $Q_0 > 3 \times 10^{10}$ at 24 MV/m for the vertical acceptance test. $Q_0 > 1 \times 10^{10}$ up to 20 MV/m for long term operation.



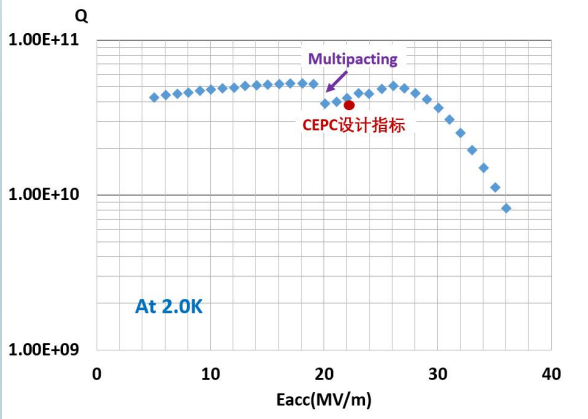
XFEL/ILC/LCLS-II or other type **variable power coupler**. Peak power 30 kW, average 4 kW, Q_{ext} 1E7-5E7, two windows.



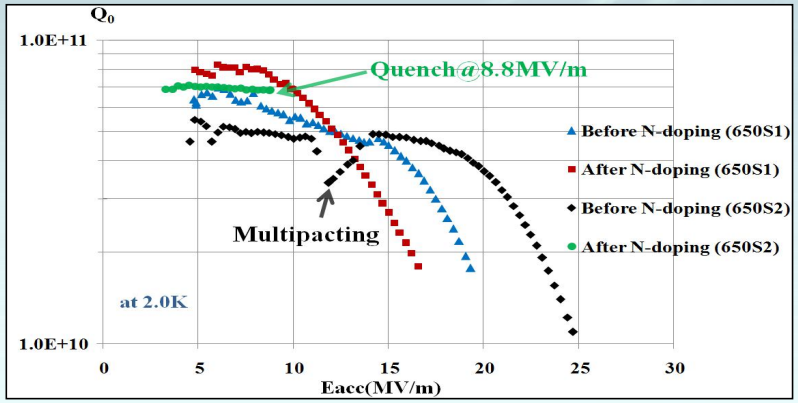
XFEL/LCLS-II type **end lever tuner**. Reliability. Large stiffness. Piezos abundance, radiation, overheating. Access ports for easy maintenance.

CEPC 650 MHz Cavity Development

- **Vertical test result: Q_0=5.1E10@26MV/m, which has reached the CEPC target (Q_0=4.0E10@22.0MV/m).**
- **Next, the CEPC target will be again improved by N-doping and EP, to increas Q_0 and to reduce further AC power**

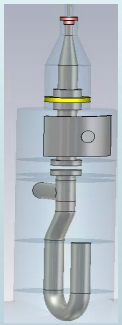


After N-doping, Q_0 increased obviously at low field for both 650MHz 1-cell cavities.

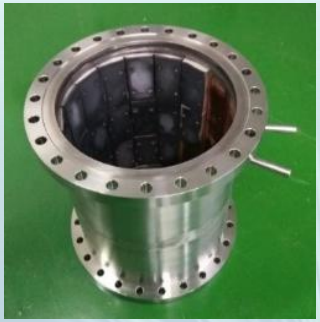


The civil construction of the EP facility is on going, and the commissioning will be at the end of 2018.

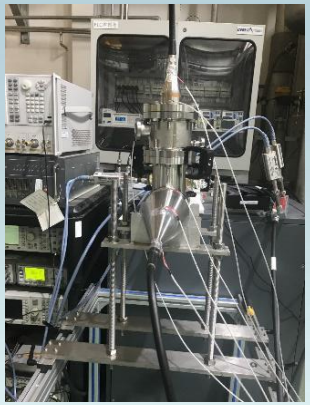
CEPC SRF Technology R&D



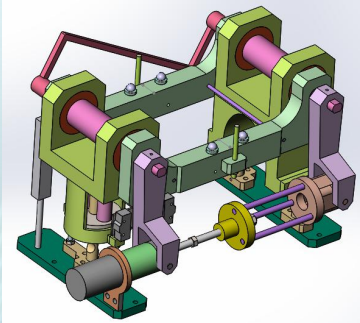
CEPC Collider HOM coupler (1 kW CW) by OTIC and HD

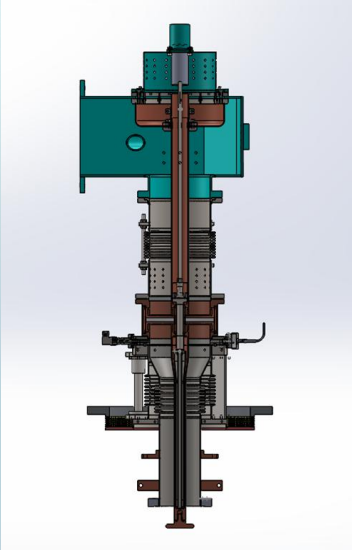


CEPC HOM absorber of SiC & AlN (5 kW CW)

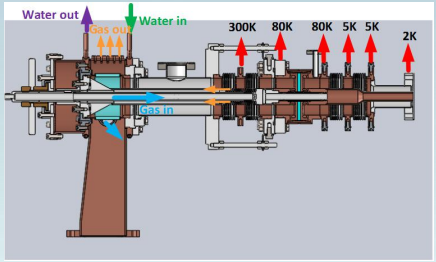


High power test of HOM coupler (left) and absorber (right) at room temperature. Up to 100 W transmitted power through the HOM coupler and 1 kW RF power absorbed by the HOM absorber.





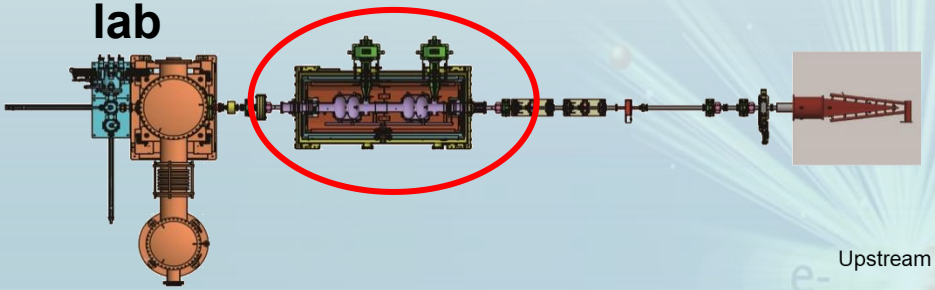
Tuner and input coupler (variable 300 kW CW) for CEPC 650 MHz cavity in fabrication

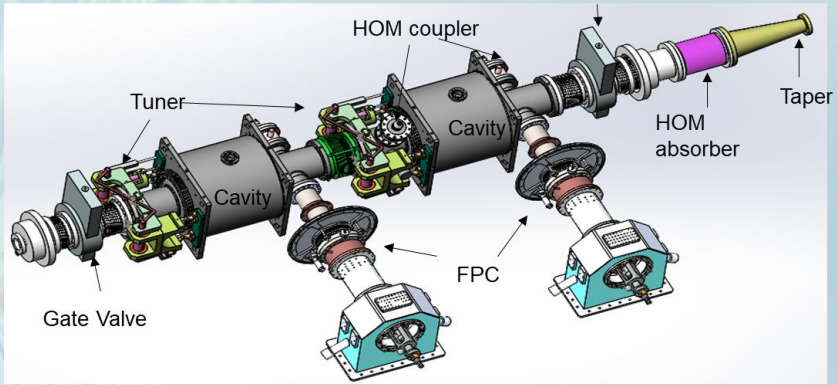


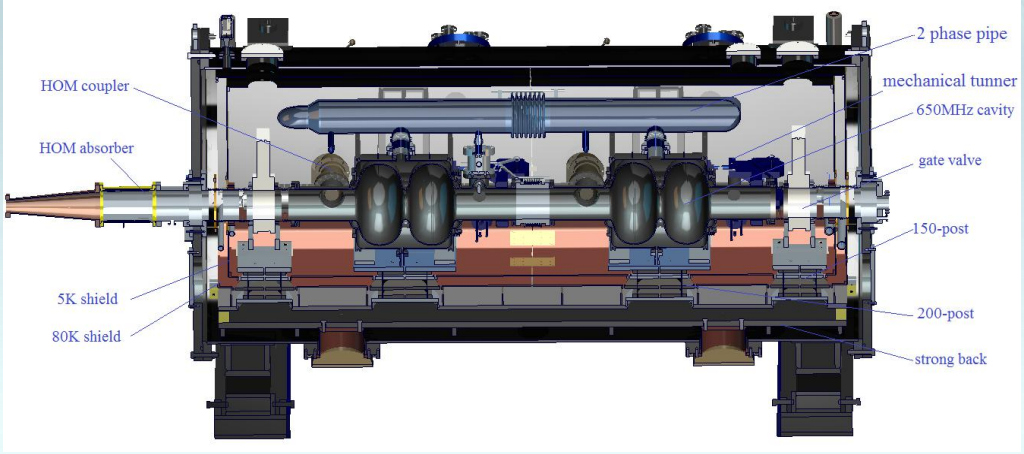
CEPC Booster 1.3 GHz variable double window coupler by HERT (in high power conditioning)

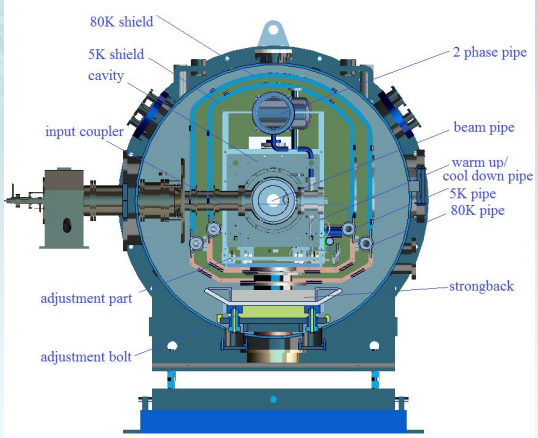
CEPC Collider Test Cryomodule

- **Cryomodule with two 650 MHz 2-cell cavities: in fabrication, assemble in 2019**
- **Beam test with DC photo cathode gun (CW 10 mA) in 2020 at new PAPS SRF lab**





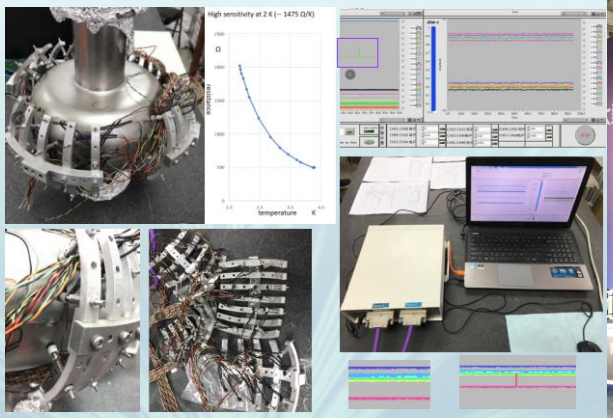




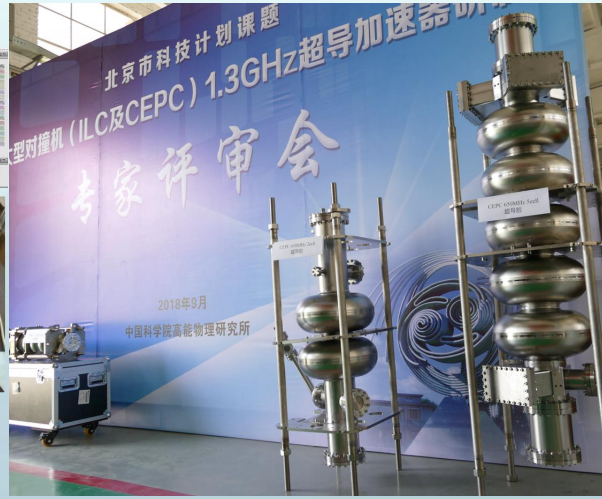
CEPC Key SCRF Technology Breakthrough

2018.9.12

Passing the examination



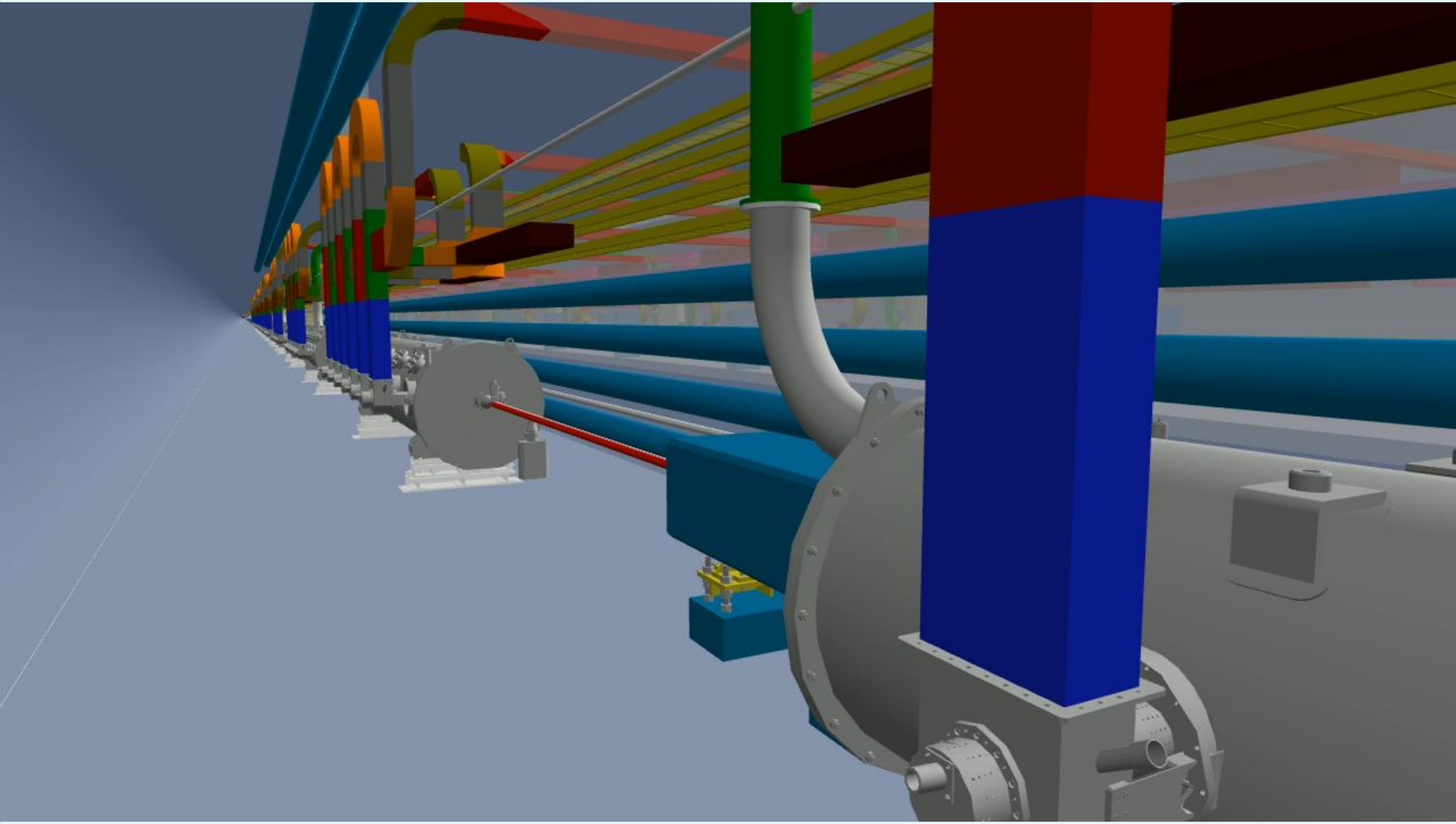
T-Mapping system

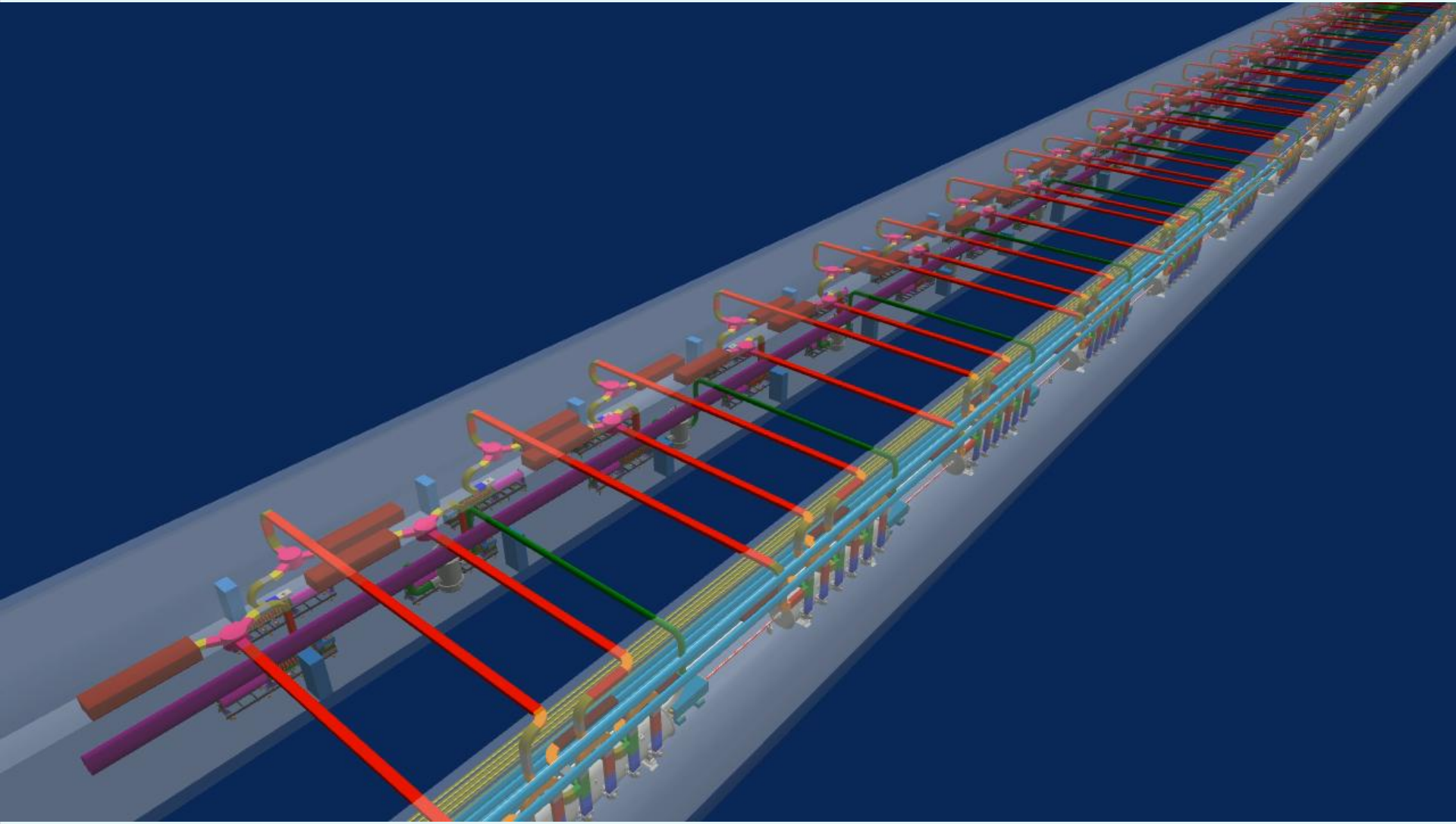


CEPC 650MHZ 2cell and 5 cell cavities

IHEP EP System

Cavity inner surface reparing system



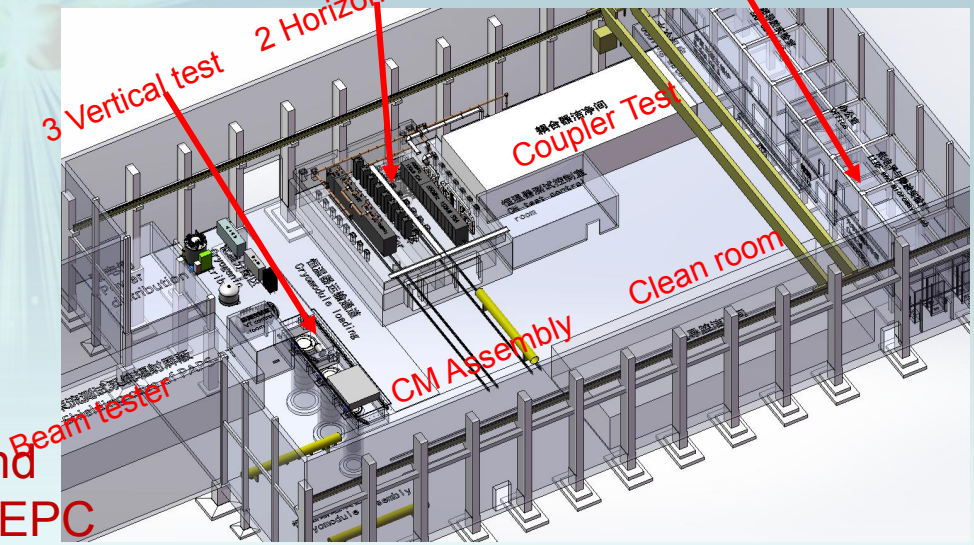


IHEP New SRF Infrastructure

- **4500 m² SRF lab in the Platform of Advanced Photon Source Technology R&D (PAPS), Huairou Science Park, Beijing.**
- **Mission to be World-leading SRF Lab for Superconducting Accelerator Projects and SRF Frontier R&D.**
- **Mass Production:**
  - **200 ~ 400 cavities & couplers test per year**
  - **20 cryomodules assembly and horizontal test per year.**
- **Construction : 2017 - 2020**

N-doping/N-infusion furnace

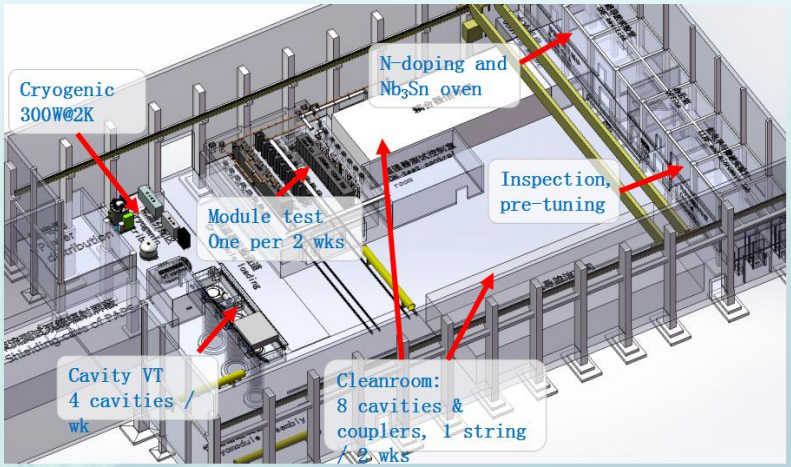
- ⇨ 3 VT dewars , 2 HT caves,
- ⇨ 500m2 Clean Room

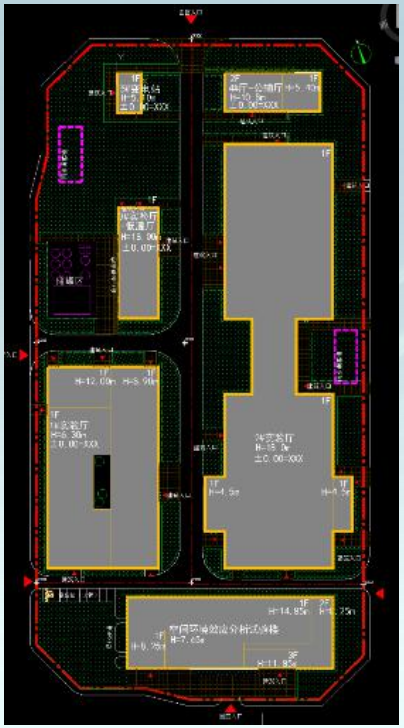


Shanghai city government decided to built Shanghai Coherent Light Facility(SCLF).

- 432 1.3 GHz cavities
- 54 Cryomodules
- IHEP plans to provide > 1/3 of cavities and cryomodules, an excellent exercise for CEPC

IHEP SCRF New Lab and Progress





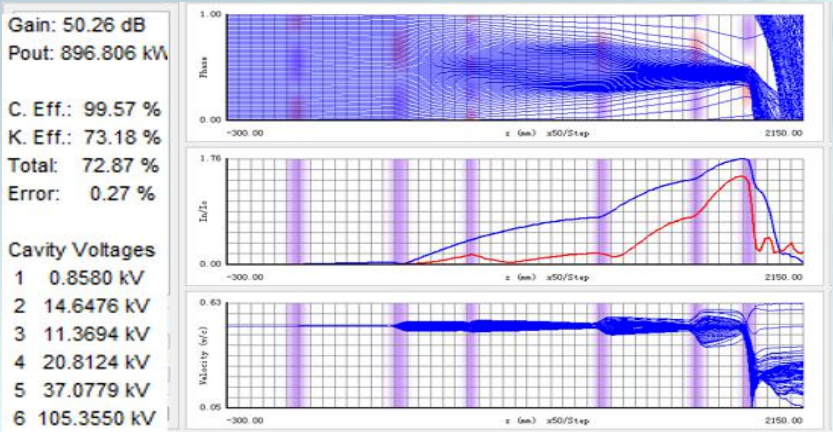
2018-09-23, KEK visitors (red)

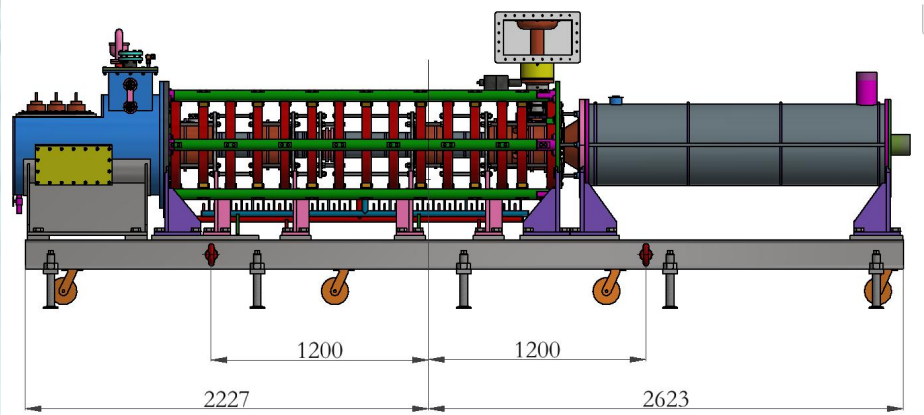
High Efficiency Klystron Development

Established "High efficiency klystron collaboration consortium", including IHEP & IE(Institute of Electronic) of CAS, and Kunshan Guoli Science and Tech.

- **2016 – 2018: Design conventional & high efficiency klystron**
- **2017 – 2018: Fabricate conventional klystron & test**
- **2018 - 2019 : Fabricate 1st high efficiency klystron & test**
- **2019 - 2020 : Fabricate 2nd high efficiency klystron & test**
- **2020 - 2021 : Fabricate 3rd high efficiency klystron & test**

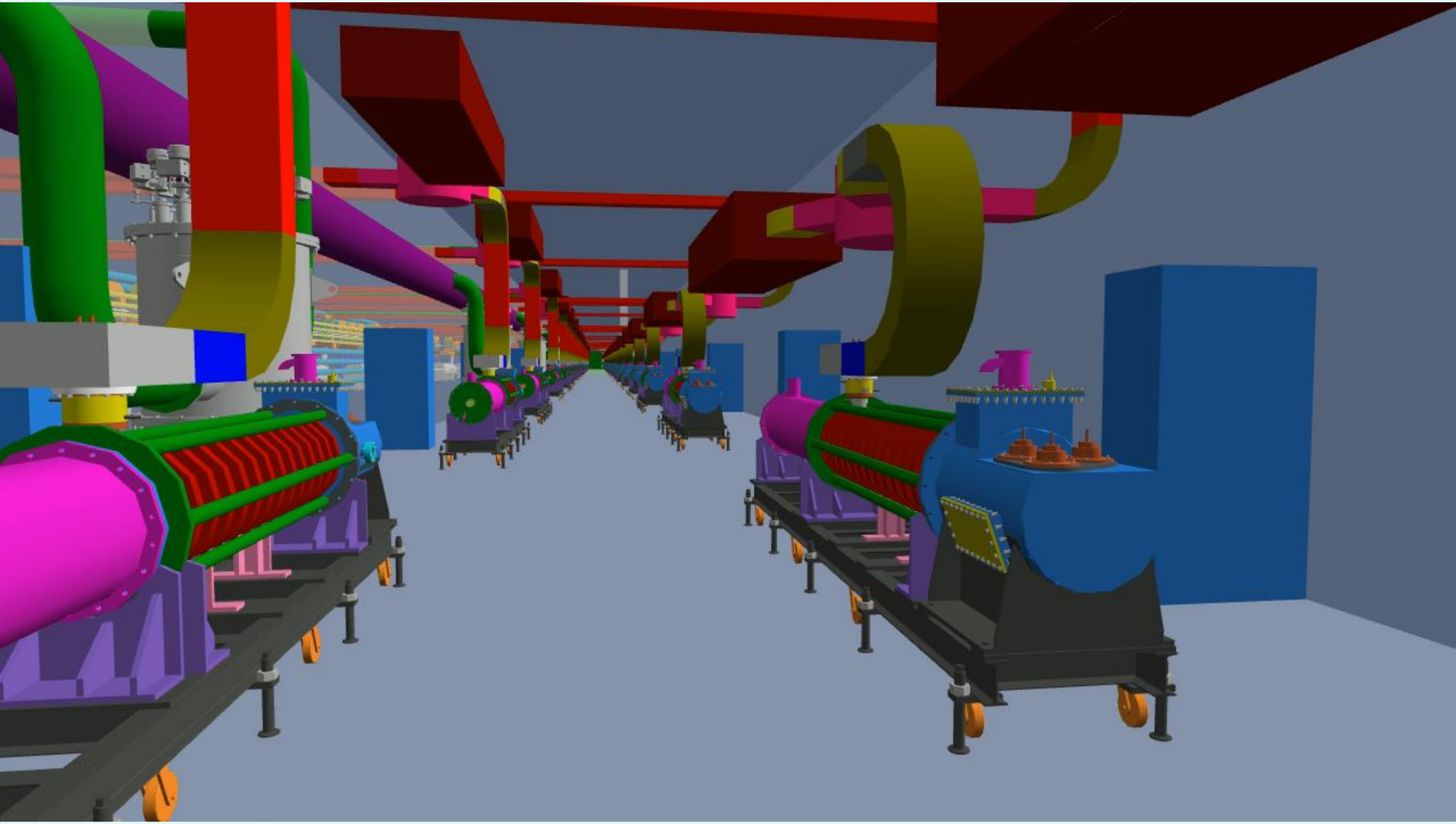
Parameters	Conventional efficiency	**High efficiency**
Centre frequency (MHz)	650+/-0.5	**650+/-0.5**
Output power (kW)	800	**800**
Beam voltage (kV)	80	**-**
Beam current (A)	16	**-**
Efficiency (%)	~ 65	**> 80**





Mechanical design of conventional klystron

⇨ 73%/68%/65% efficiencies for 1D/2D/3D

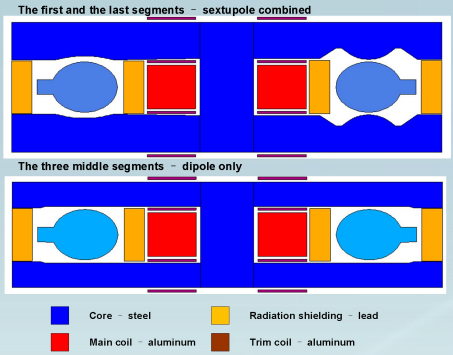


CEPC Collider and Booster Ring Conventional Magnets

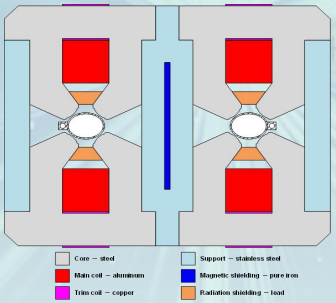
China Astronotics Department 508 Institute participates CEPC magnets mechanical designs

CEPC collider ring magnets

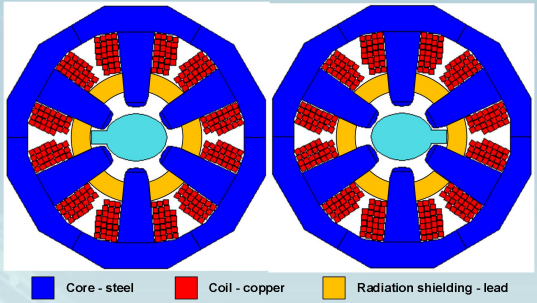
	Dipole	Quad.	Sext.	Corrector	Total
Dual aperture	2384	2392	-	-	13742
Single aperture	80*2+2	480*2+172	932*2	2904*2	
Total length [km]	71.5	5.9	1.0	2.5	80.8
Power [MW]	7.0	20.2	4.6	2.2	34



Dipole



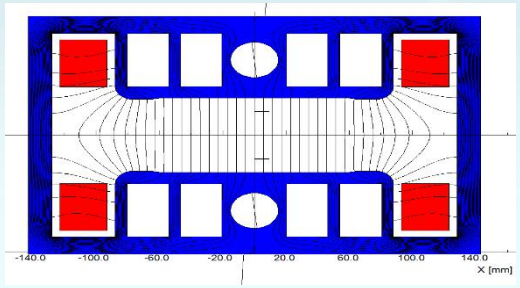
Quadrupole



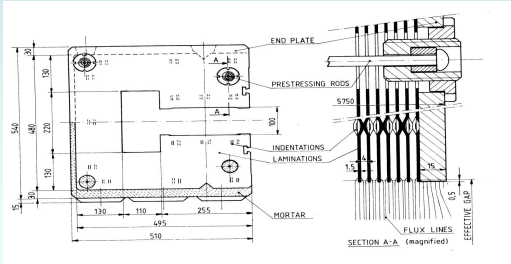
Sextupole

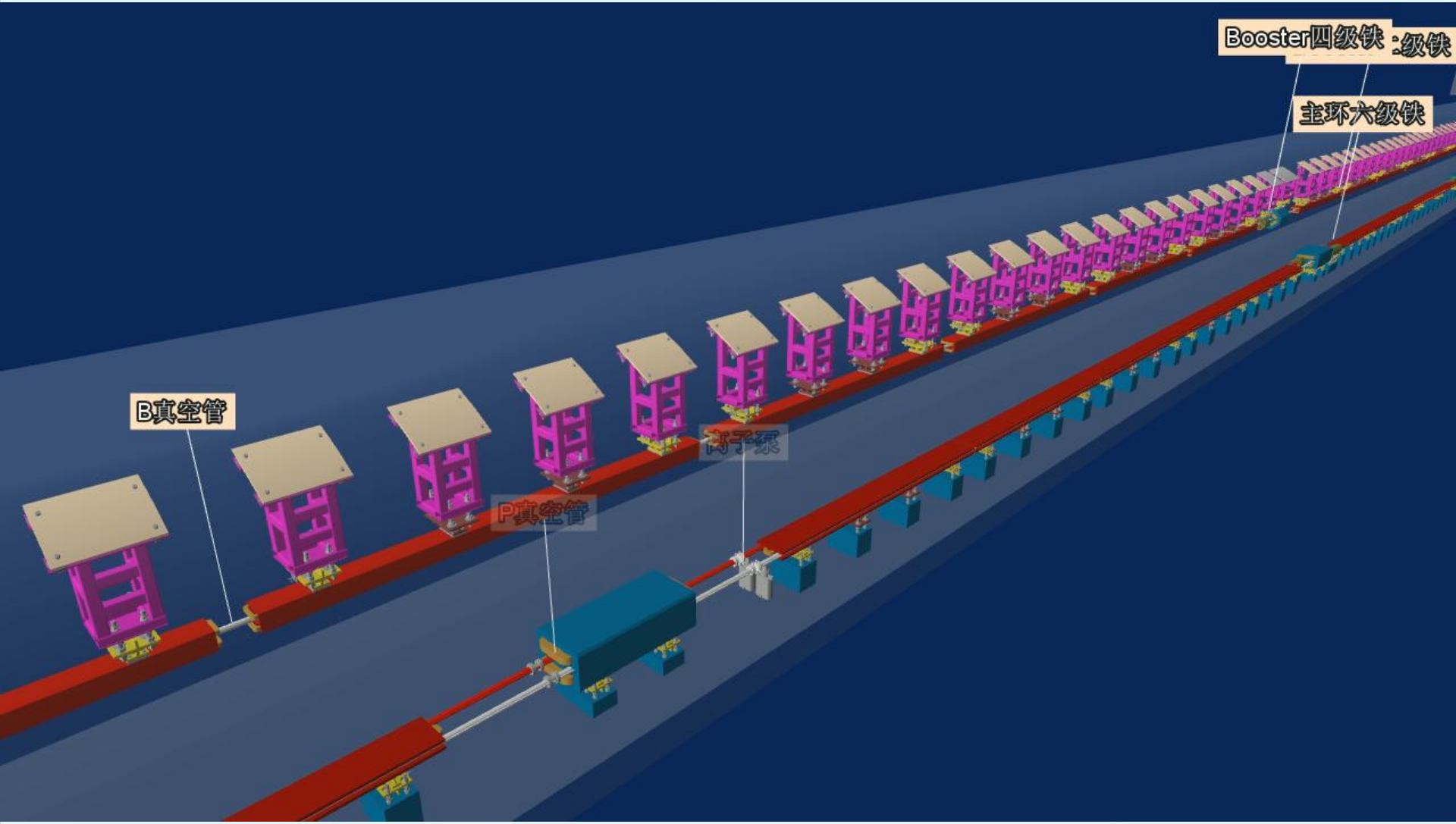
Booster ring low field magnets

Dipole



Quantity	16320
Magnetic length(m)	4.711
Max. strength(Gs)	338
Min. strength(Gs)	28
Gap height(mm)	63
GFR(mm)	55
Field uniformity	5E-4

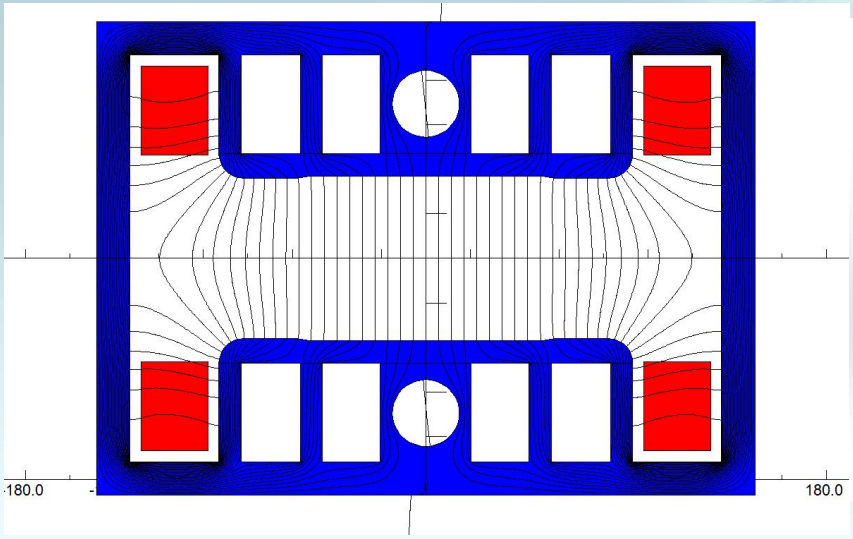


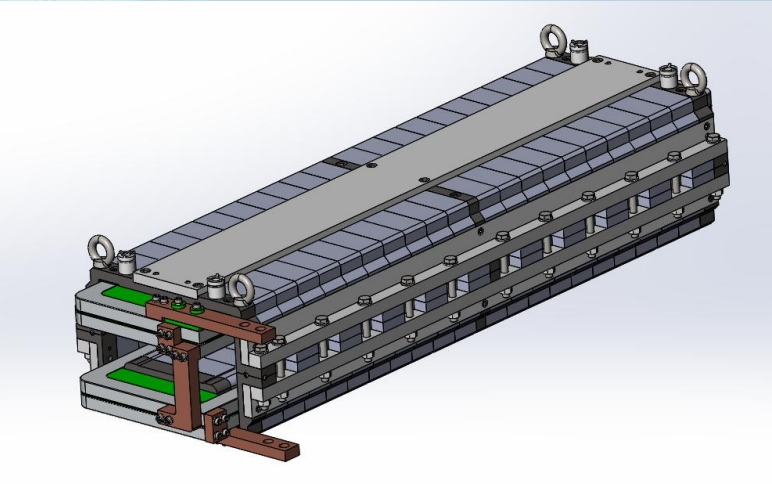

Booster四级铁
主环六级铁
B真空管
离子泵
P真空管

Booster high precision low field dipole magnets-1

One kind of the dipole magnet with diluted iron cores is proposed and designed.

- To reduce weight and cost of the magnet, the cores are diluted both in transversal and longitudinal directions.
- To decrease the influence of remnant field, the oriented low carbon silicon steel laminations with lower coercive force instead of non-oriented laminations will be used to stack the cores of the magnet.

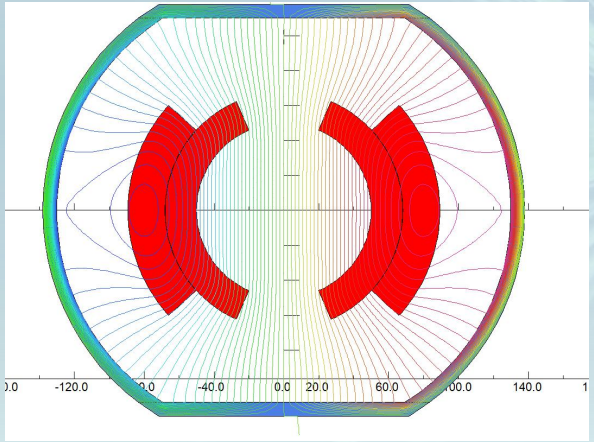


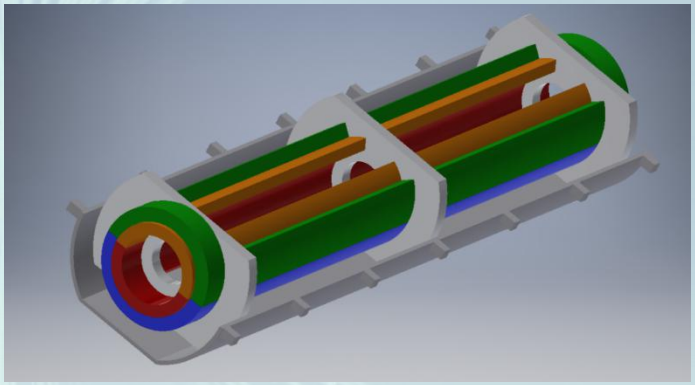


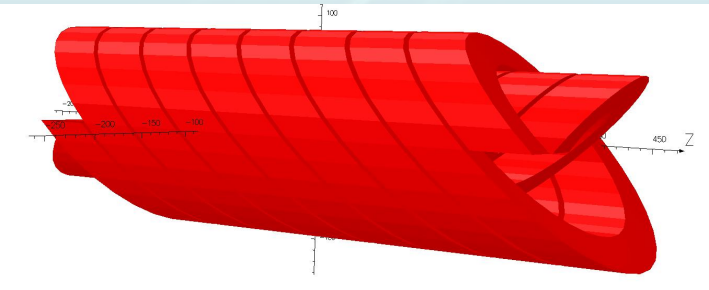
Booster high precision low field dipole magnets-2

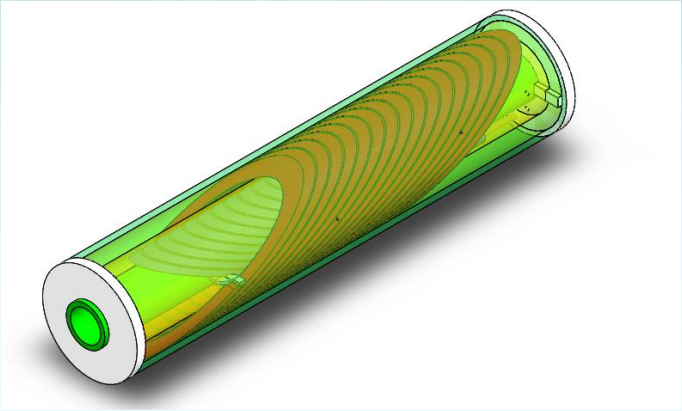
Two kinds of the dipole magnets without iron cores called Cos Theta (CT) and Canted Cos Theta (CCT) are proposed and designed.

To increase the excitation efficiency, the shielding cylinder with flatted top and bottom plates will be adopted for CT magnet. And a small canted angle will be used for CCT magnet.



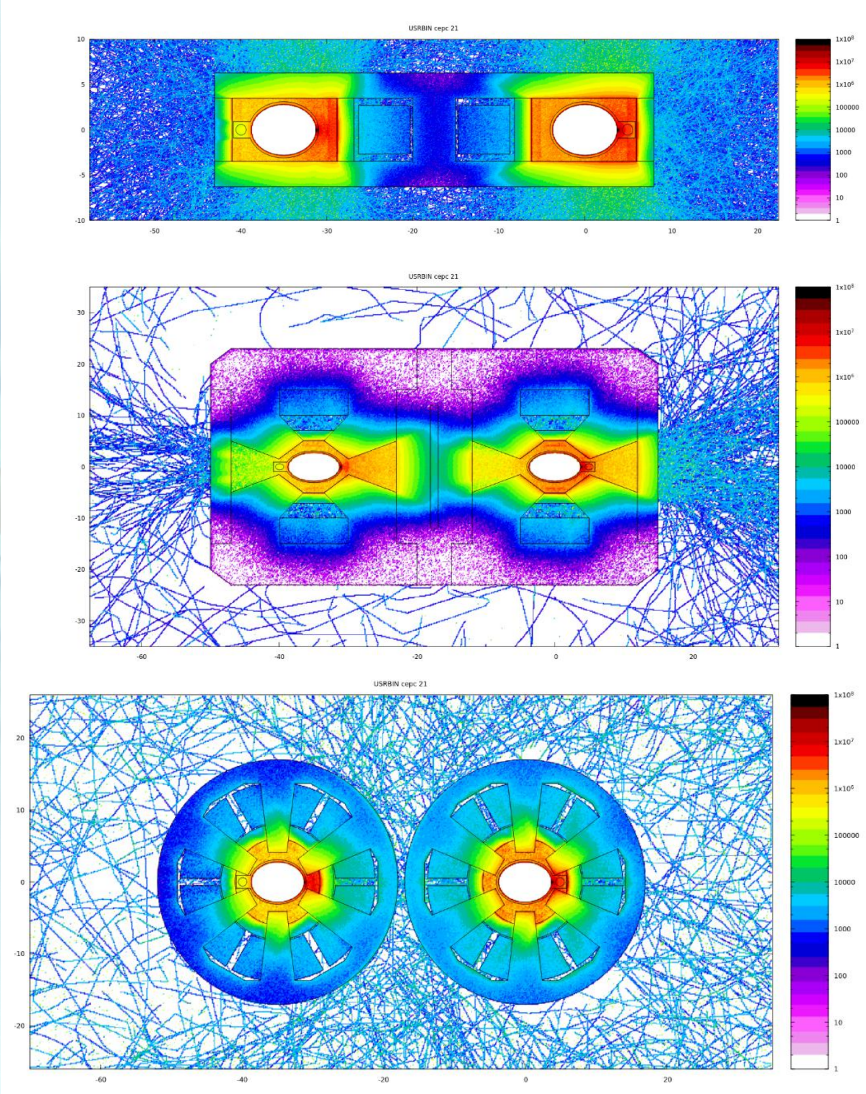






Magnets R&D:-SR Analysis

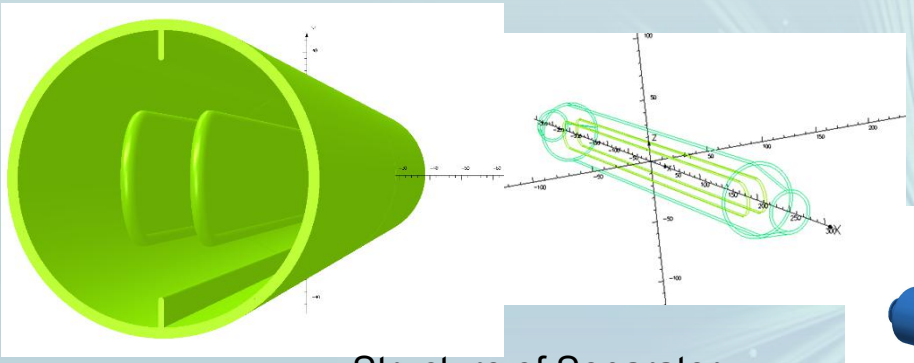
Total power 870 W/m			
Beam direction: left W/m		Beam direction: right W/m	
Al chamber	199	Al chamber	186
Cu chamber	308	Cu chamber	332
Dipole	186	Dipole	182
Lead A	60.6	Lead A	29.2
Lead B	33.5	Lead B	80.0
Lead C	46.8	Lead C	18.8
Lead D	14.3	Lead D	20.4
Quadrupole	279	Quadrupole	268
Lead A	37.8	Lead A	36.4
Lead B	18.1	Lead B	21.7
Sextupole	179	Sextupole	174
Lead A	95.1	Lead A	107
Lead B	60.3	Lead B	43.1



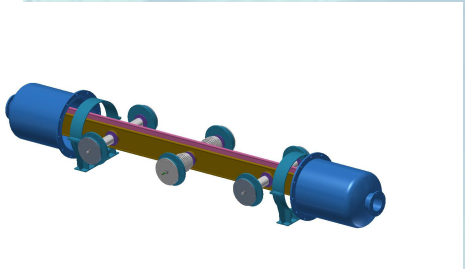
CEPC Collider Ring Electro-Magnet Separator

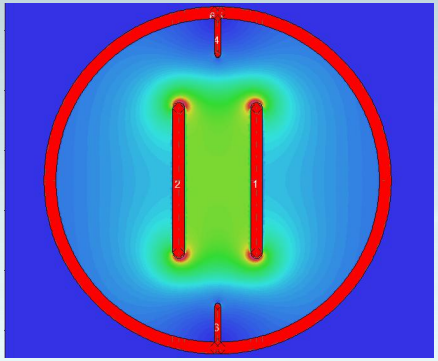
- **An electrostatic separator combined with a dipole magnet to avoid bending of incoming beam (Magnet group is responsible for the design of dipole magnet)**

	Filed	Effective Length [m]	Gap [cm]	Quantity
Electrostatic separator	2.25 MV/m	4	11	40
Dipole	75 Gauss	4	7	40

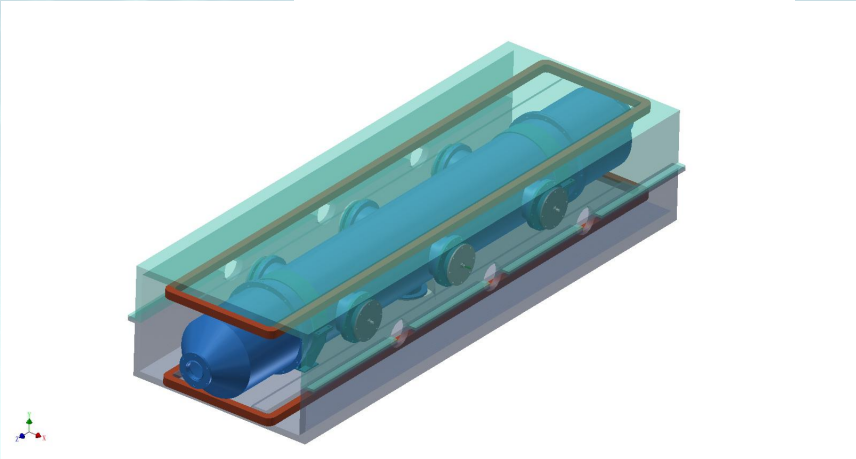


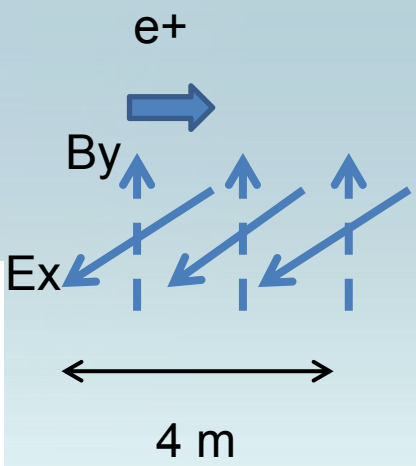
Structure of Separator





Field distribution

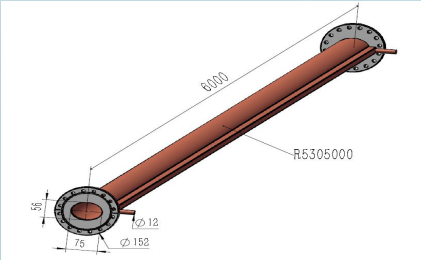




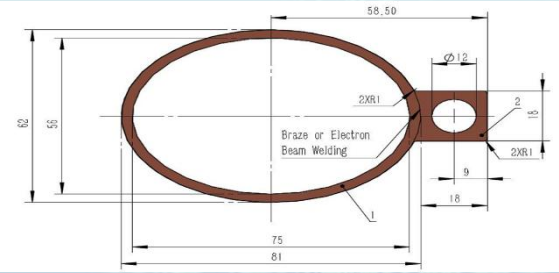
Zhongxin Heavy Industry participates in Elecletric-magnetic seperator design

Vacuum System R&D

- The vacuum pressure is better than 2 x 10-10 Torr
- Total leakage rate is less than 2 x 10-10 torr.l /s.

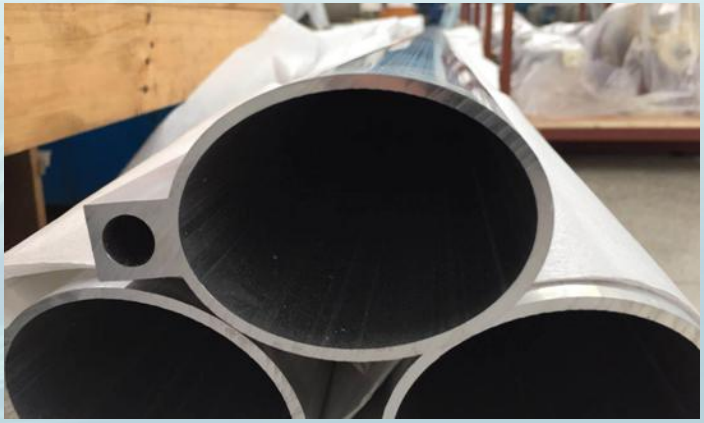


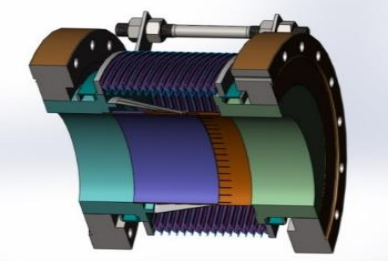
Positron ring

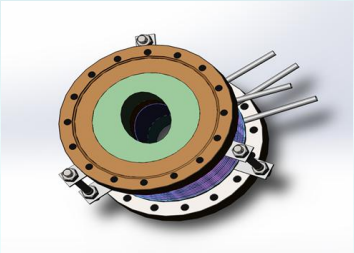


Copper vacuum chamber (Drawing) (elliptic 75×56, thickness 3, length 6000)

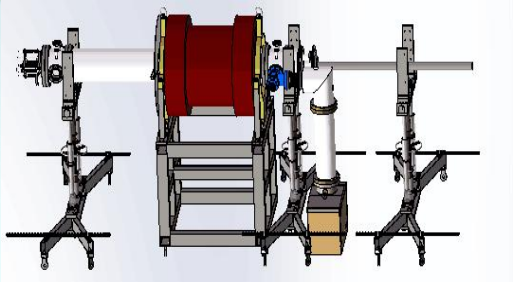
First test vacuum chamber

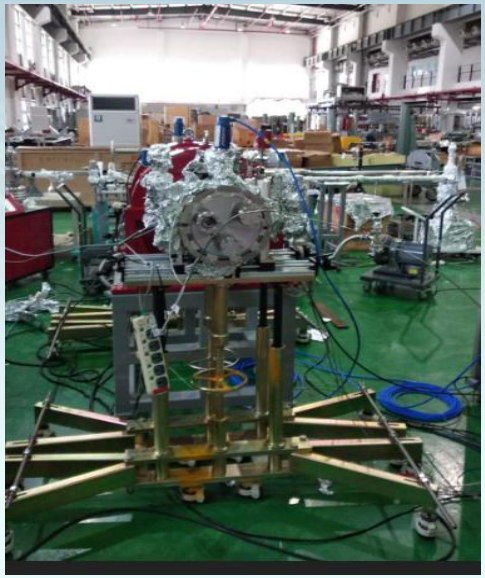




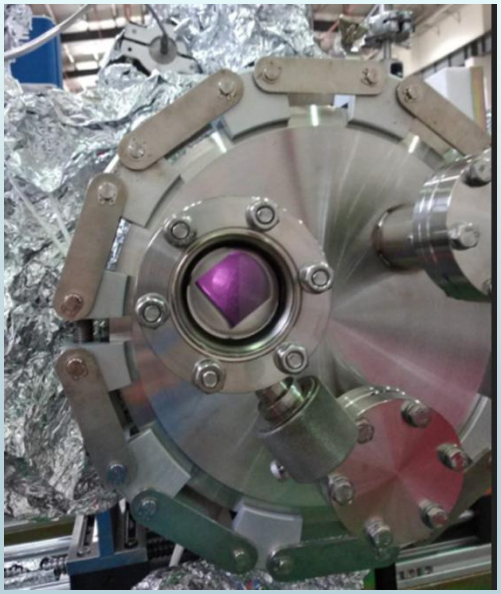


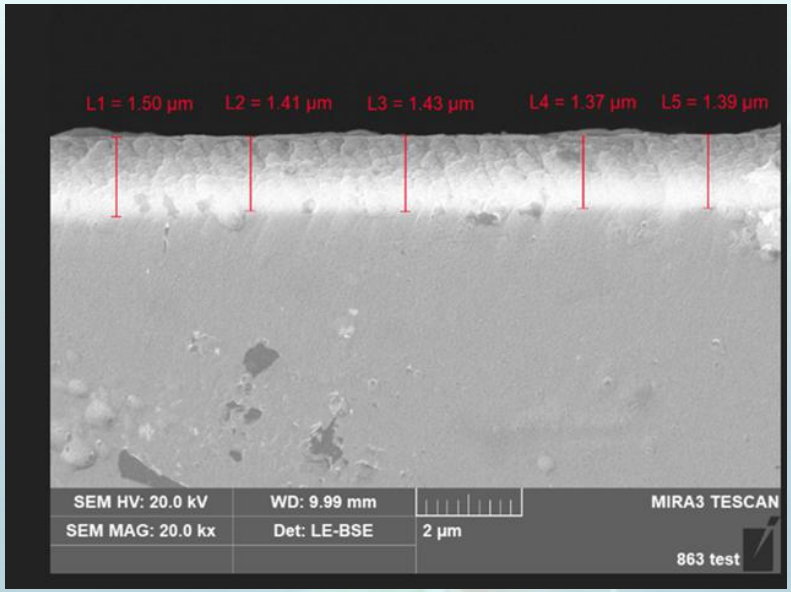
NEG coating suppresses electron multipacting and beam-induced pressure rises, as well as provides extra linear pumping. Direct Current Magnetron Sputtering systems for NEG coating was chosen.

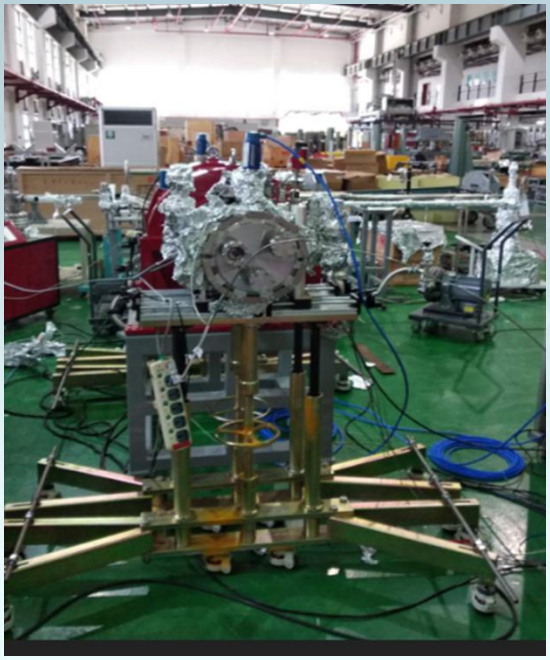


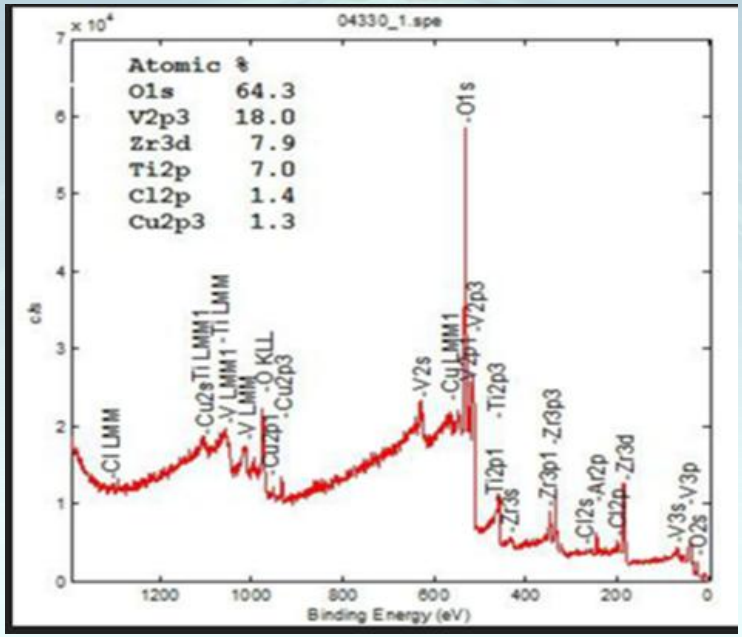


NEG coating







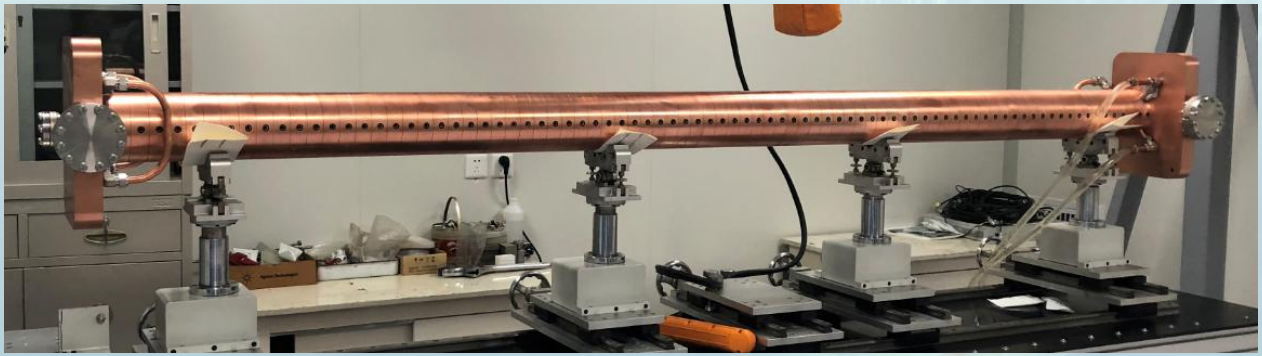


- NEG coating suppresses electron multipacting (SEY < 1.2) and beam-induced pressure rises, as well as provides extra linear pumping.
- The setup of NEG coating has been built, and some experiments have been done.
- The thickness of the NEG films are about 1.4 µm.
- The proportion of Ti, Zr and V is 1: 1.1 :2.5.
- The more tests will be done to improve the performance of

CEPC Linac Injector R&D

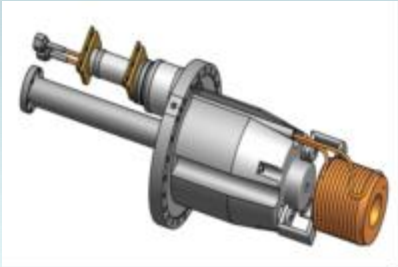
- S-band accelerating structure design

–Accelerating structure design



Accelerating structure under cold test

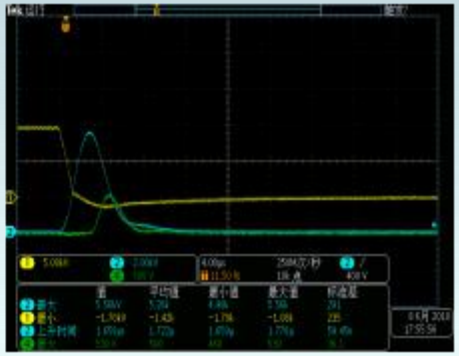
- Positron flux concentrator design



The mechanical design of FLUX concentrator

The finished FLUX concentrator

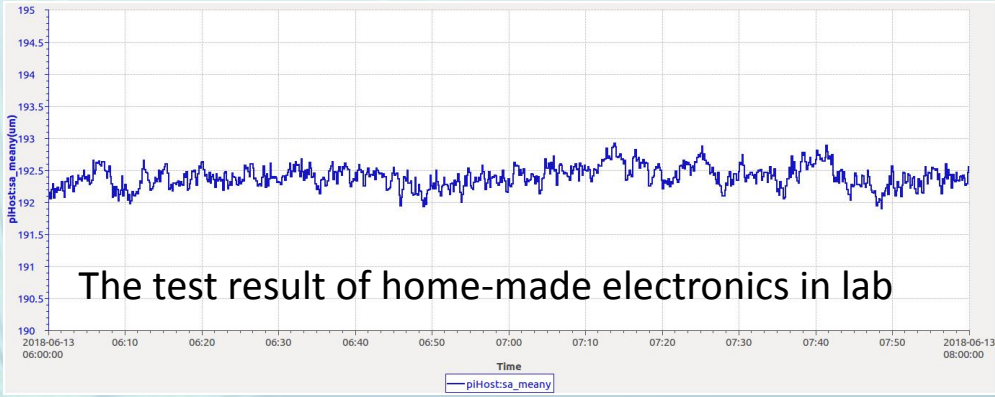
solid-state pulsed power generator



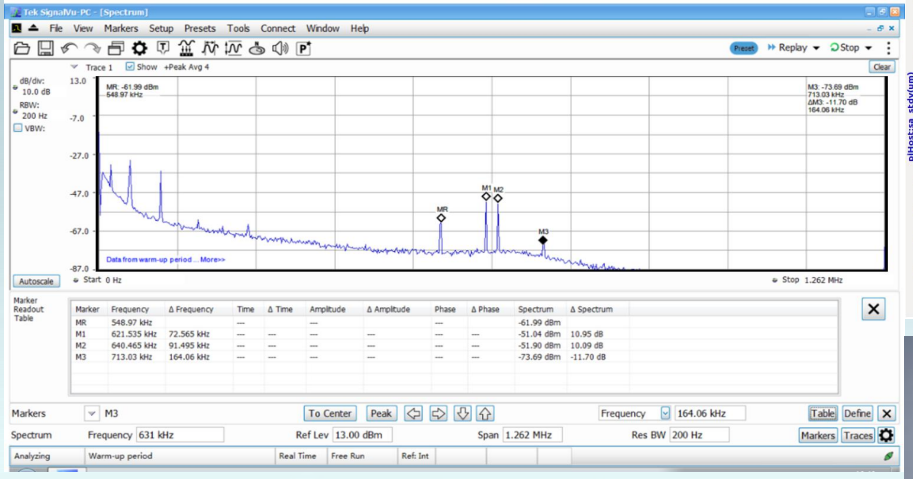
The output of 10kA measurement

CEPC Beam instrumentation

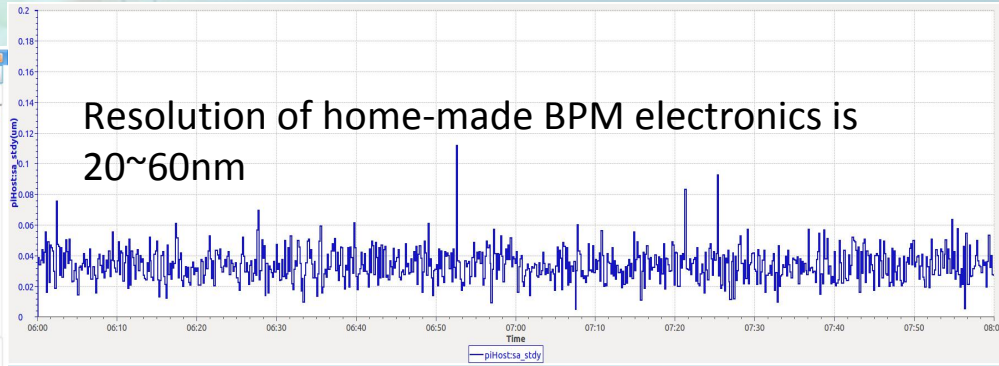
The electronics of beam position monitor



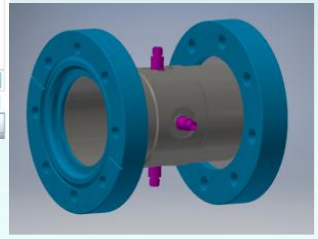
The test result of home-made electronics in lab



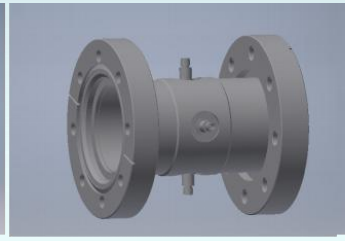
The result of DDD tune system



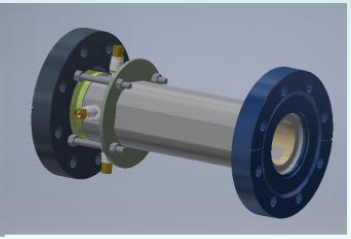
Resolution of home-made BPM electronics is 20~60nm



The BPM of storage ring

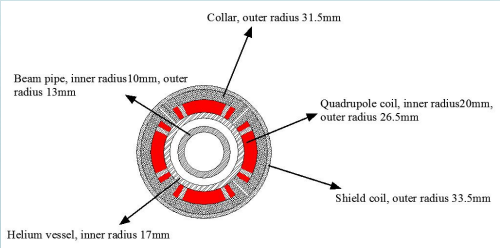


The BPM of Booster



The BPM of Linac and BT

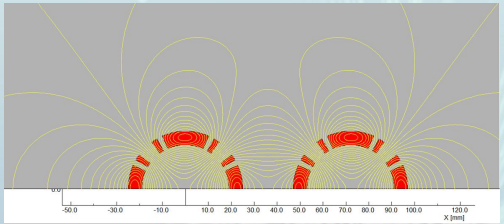
CEPC IR Superconducting magnets



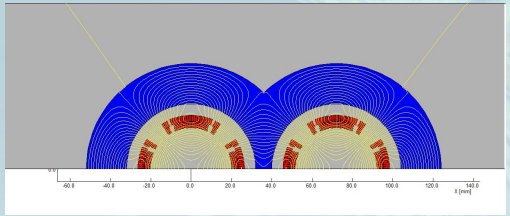
Room-temperature vacuum chamber with a clearance gap of 4 mm

Magnet	Central field gradient (T/m)	Magnetic length (m)	Width of Beam stay clear (mm)	Min. distance between beams centre (mm)
QD0	136	2.0	19.51	72.61

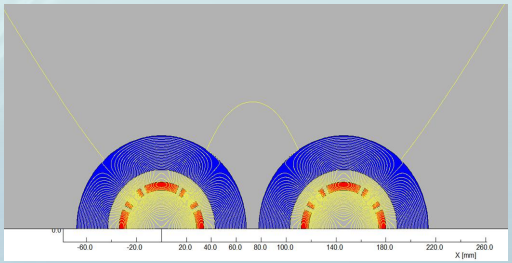
Superconducting QD coils



Iron option for QD0 is investigated.



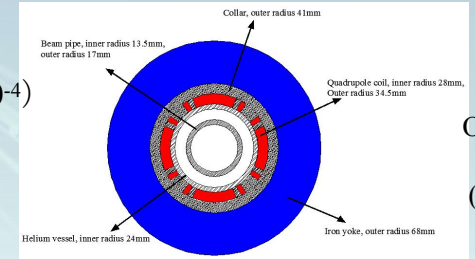
Superconducting QF coils



There is iron yoke around the quadrupole coil for QF1. Since the distance between the two apertures is larger enough and there is iron yoke, the field cross talk between two apertures of QF1 can be eliminated.

QF1 Integral field harmonics with shield coils （$\times 10^{-4}$）

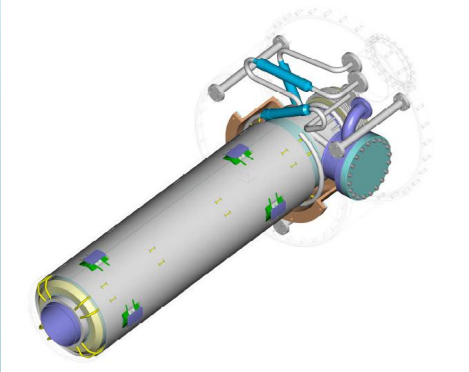
n	B_n/B_2@R=13.5mm
2	10000
6	1.08
10	-0.34
14	0.002

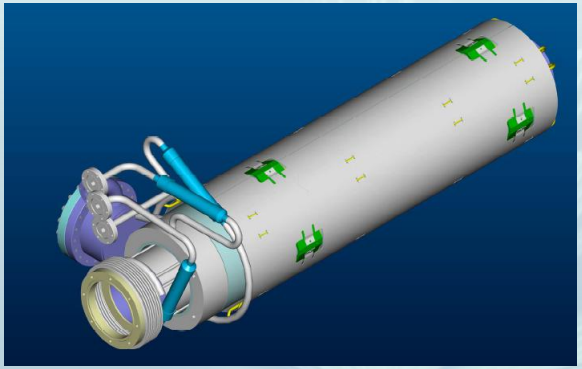


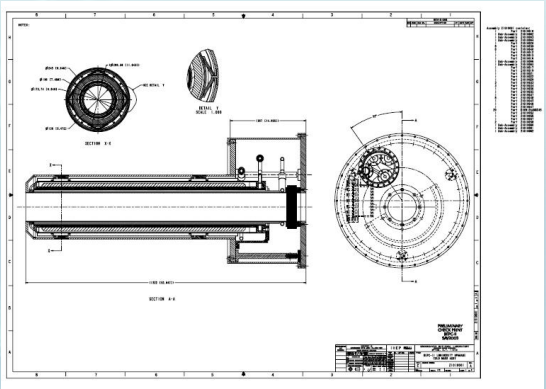
One of QF1 aperture (Peak field 3.8T)

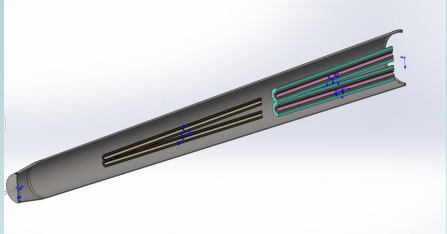
Magnet	Central field gradient (T/m)	Magnetic length (m)	Width of Beam stay clear (mm)	Min. distance between beams centre (mm)
QF1	110	1.48	27.0	146.20

CEPC IR Superconducting magnets mechanical design



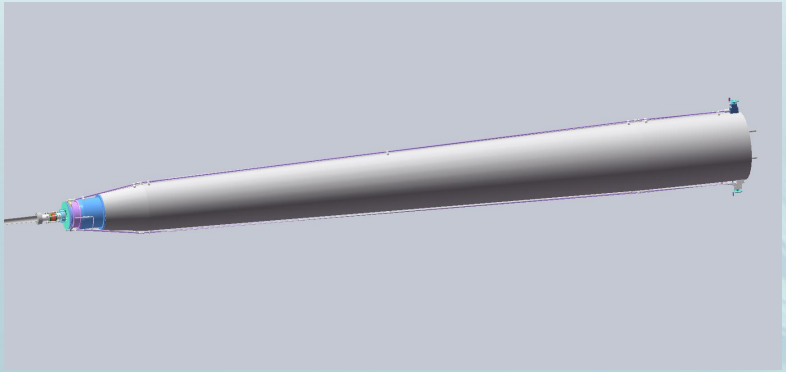


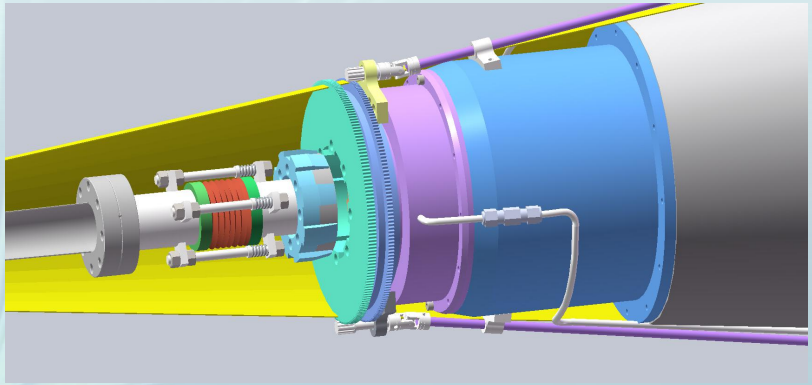


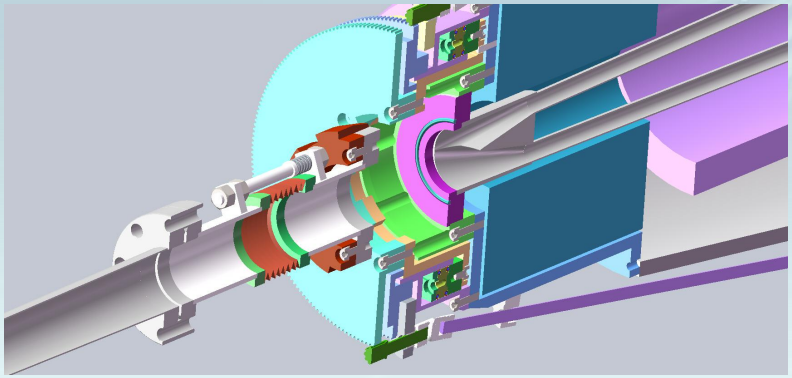


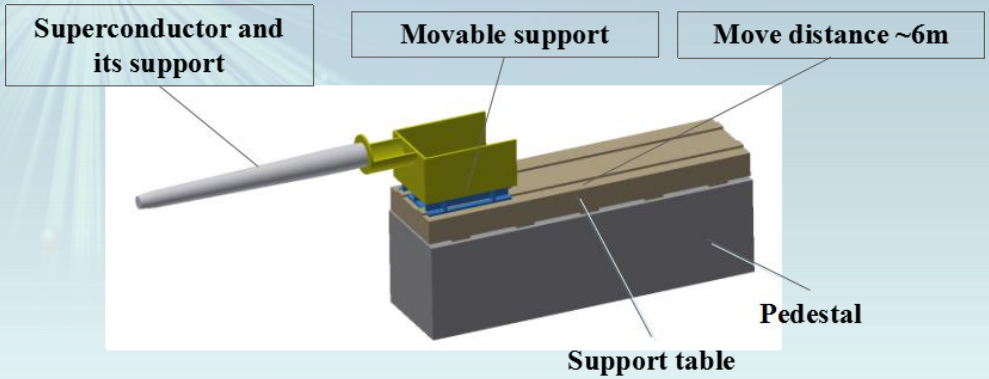
CEPC MDI Mechanical Study

Huanghe Company, Huadong -Shenyang Huiyu Company participats in CEPC MDI mechanical connection design
China Astronotics Department 508 Institute participates in CEPC MDIsupporting design





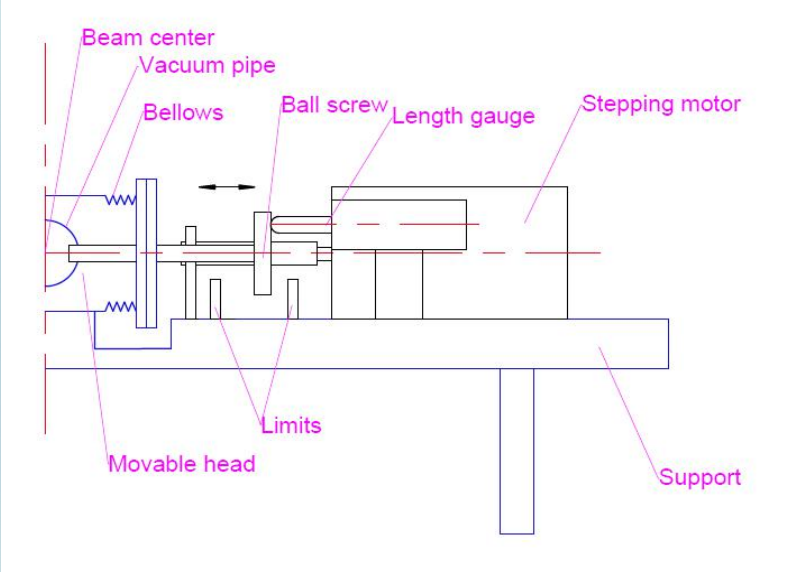




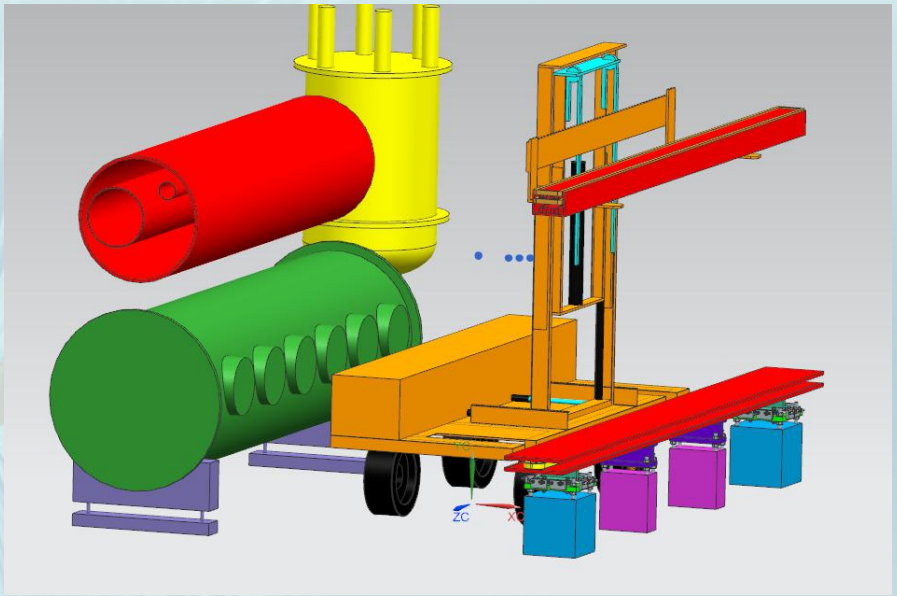
Schematic of support system of superconducting magnets

CEPC Mechanical Studies

China Astronotics Department
508 Institute
participates in CEPC movable
collimators mechanical design



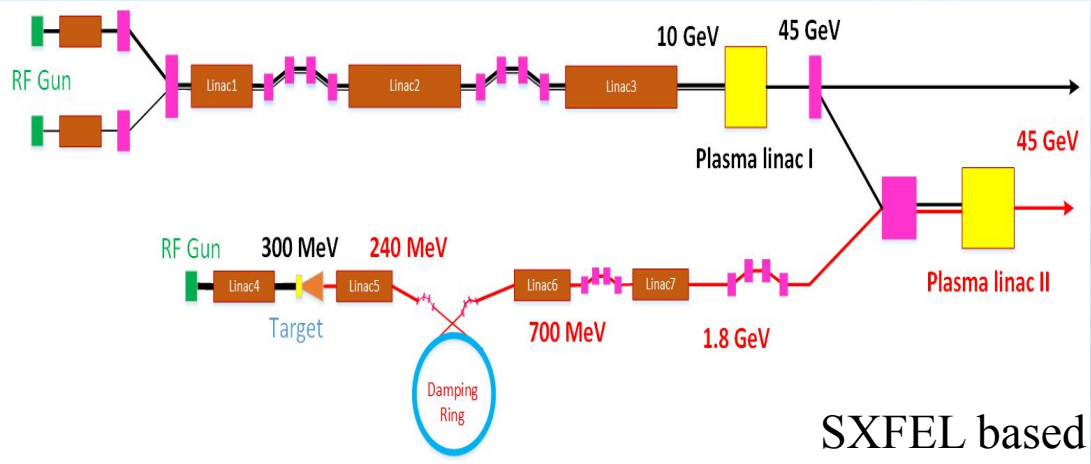
Schematic of movable collimators

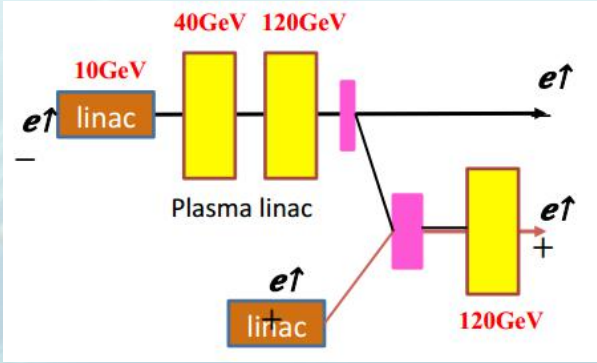


Schematic of transport vehicle of magnets

Experimental Verification Plan in SXFEL-TF for CEPC Plasma Injector Scheme

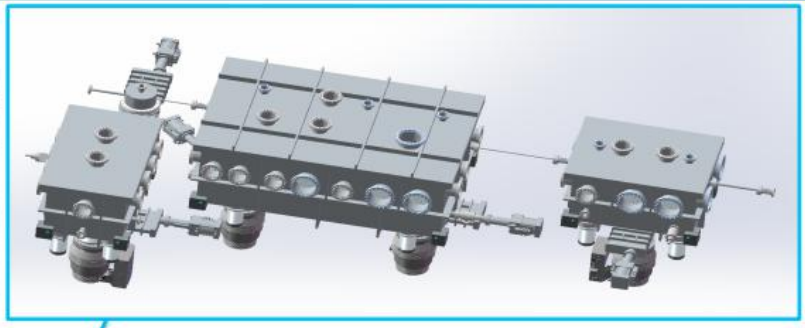
A dedicated budget of 10Million has been alocated by IHEP

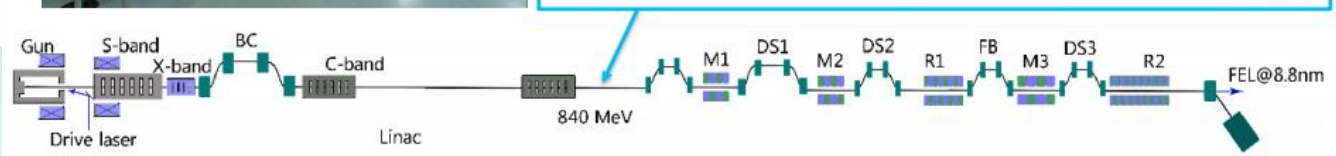




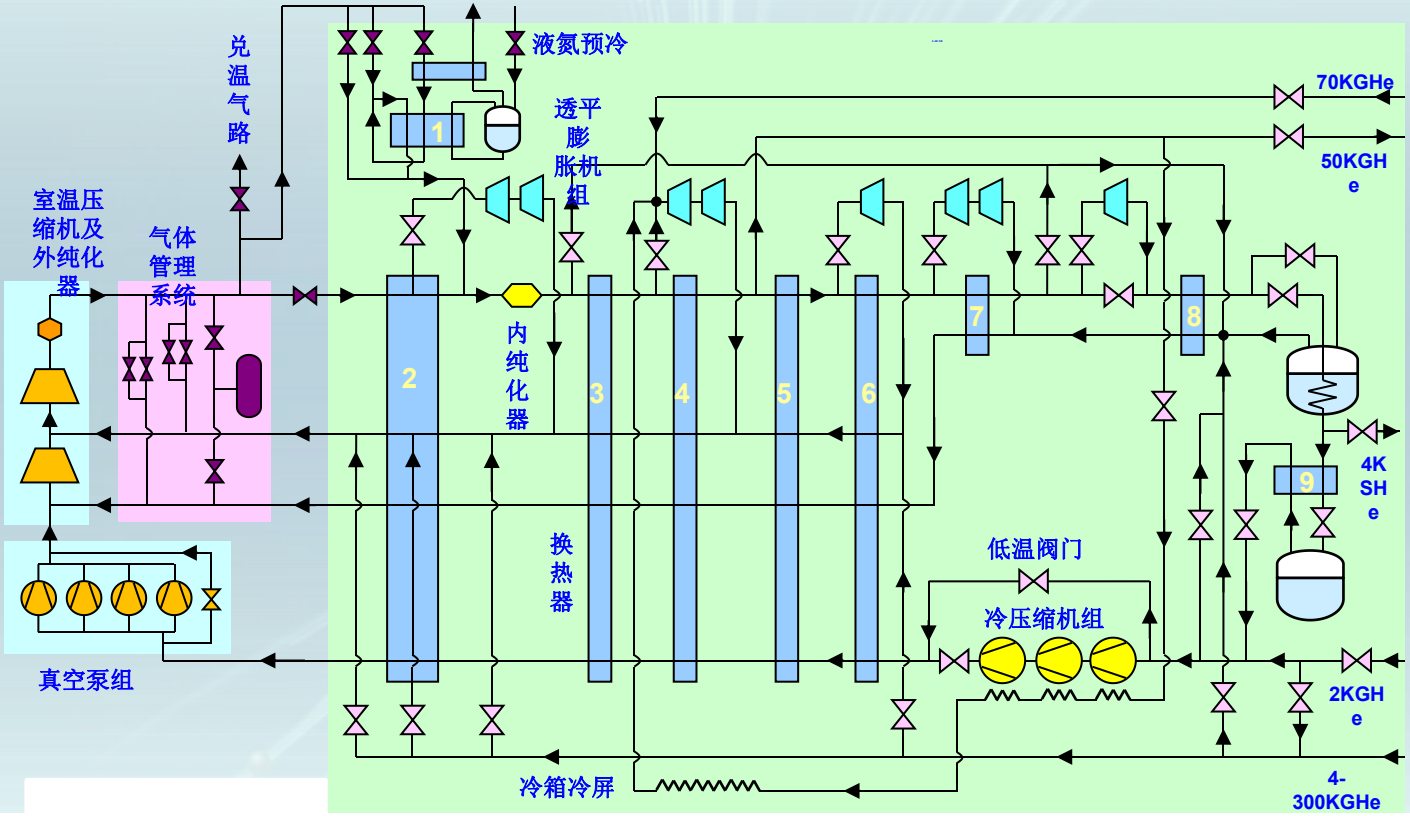
SXFEL based advanced accelerator research platform

Electron (SXFEL-TF)	
Energy	840MeV
Energy spread(rms)	≤0.1%
Norm. Emittance(rms)	≤1.5mmmrad
Length(FWHM)	≤1ps
Charge	0.5nC
Repetition rate	10Hz





Future Work: from 10kW@4.5K cryosplant to 18kW@4.5K cryosplant

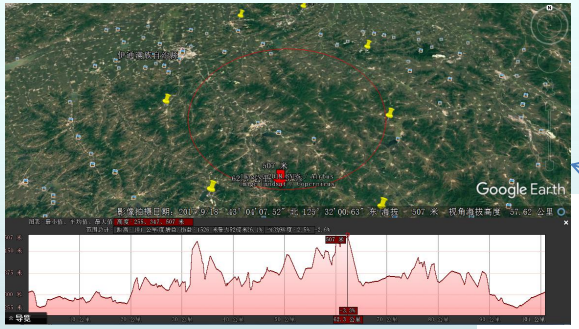


Proposed scheme for 10-12kW@4.5K Cryo-plants for CEPC, ADS, HIAF, etc.

CEPC siting

CEPC Site Selections

Huanghe Company particitated



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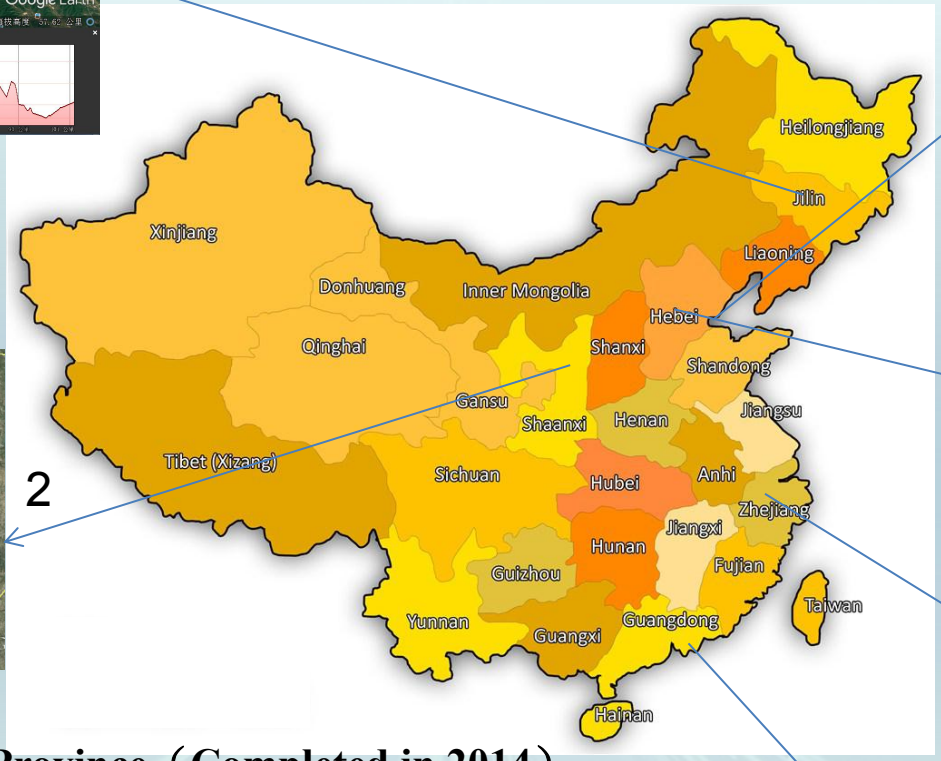
1



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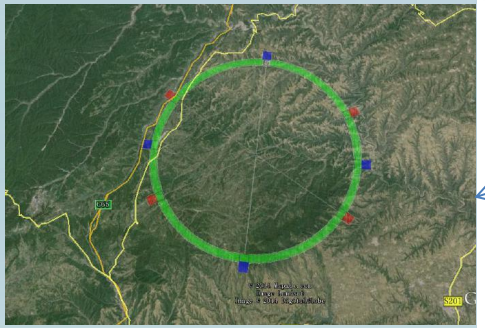

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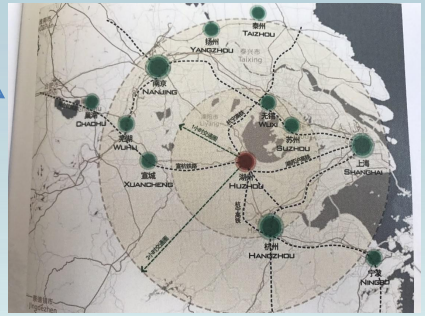
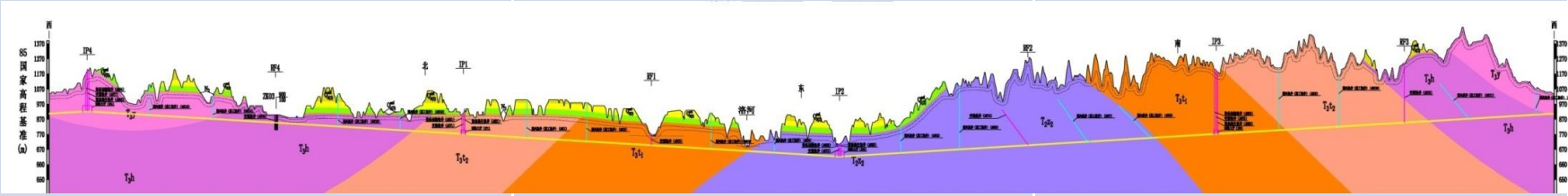
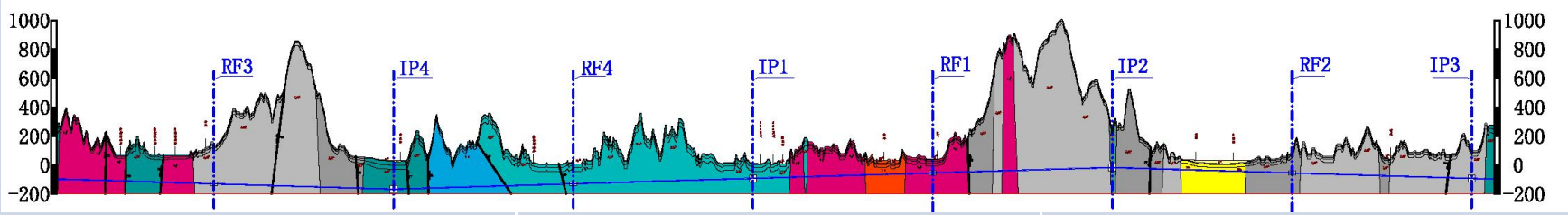
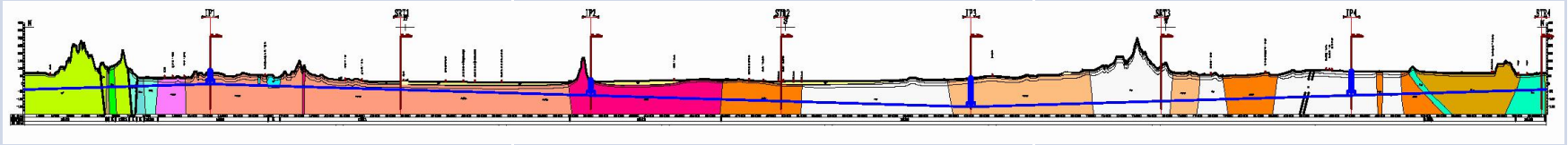


5

1) Qinhuangdao, Hebei Province（Completed in 2014）
2) Huangling, Shanxi Province（Completed in 2017)
3) Shenshan, Guangdong Province(Completed in 2016)
4) Baoding (Xiong an), Hebei Province (Started in August 2017)
5) Huzhou, Zhejiang Province (Started in March 2018)
6) Chuangchun, Jilin Province (Started in May 2018)

3

Item	Huangling	Shen-Shan	Funing
Project layout	Huangling（100km） 	Shen-Shan（100km） 	Funing（100km） 
Construction difficulty	Moderate	Relatively difficult	Relatively easy

CEPC accelerator TDR national, international collaboration, with industries (CIPC) and TDR management platform

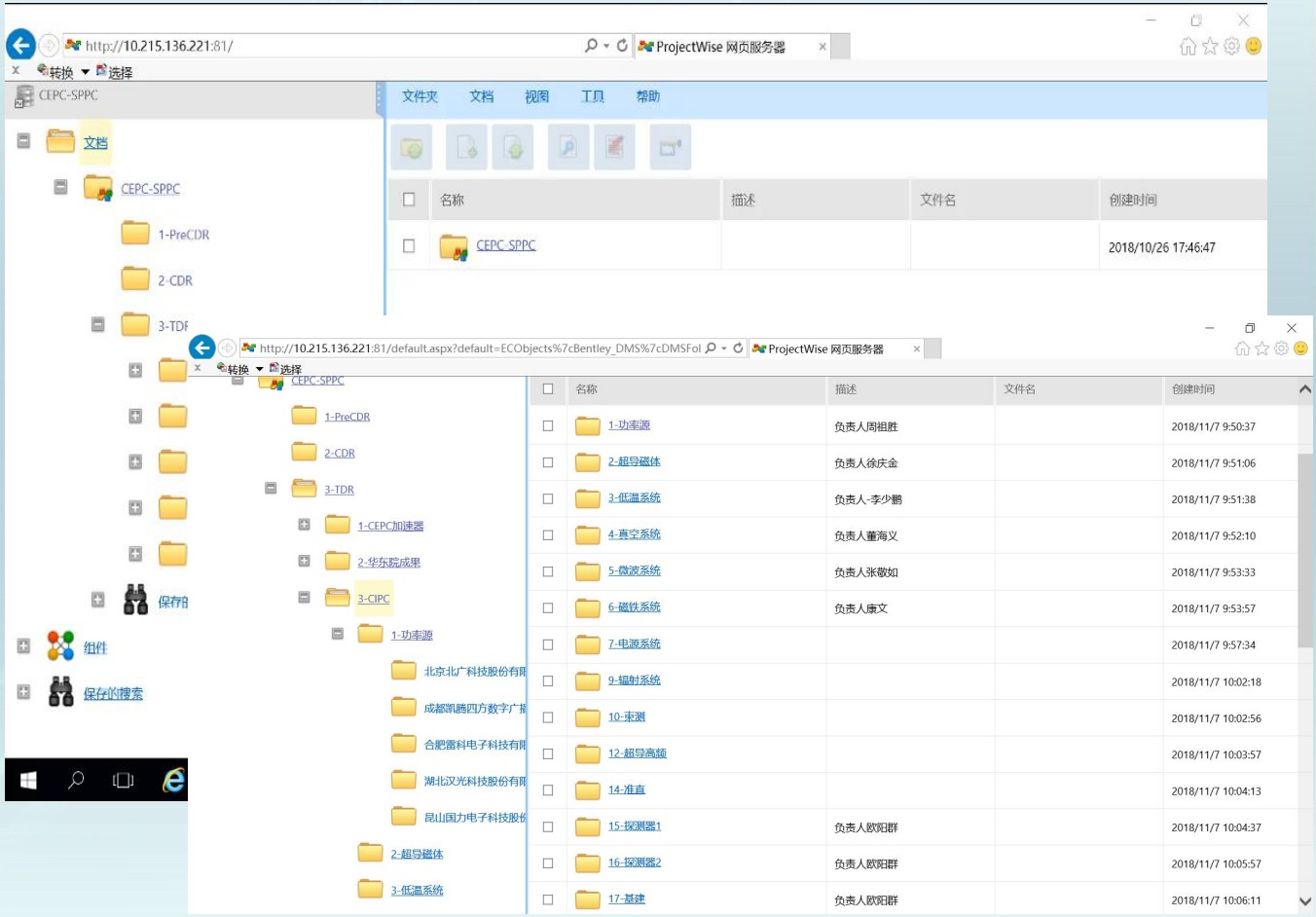
CEPC TDR Phase Accelerator Management System (Platform)

CEPC accelerator TDR national, international collaboration, and with industries (CIPC)

Established collaborative management system of CEPC, CIPC,IB Members and International Collaborators:

- ✓ **Among CEPC subsystems;**
- ✓ **CEPC-CIPC (industries)**
- ✓ **CEPC-IB members**
- ✓ **CEPC-International Collabrators**

Joint established with Huadong Engineering Coorpeation (华东勘探设计研究院有限公司）



CEPC Industrial Promotion Consortium (CIPC) Collaboration Status

1) Superconduting materials (for cavity and for magnets)
2) Superconductiong cavities
3) Cryomodules
4) Cryogenics
5) Klystrons
6) Vacuum technologies
7) Electronics
8) SRF
9) Power sources
10) Civil engineering
11) Precise machinary.....

Please attend the CIPC parallel session to learn more details! **Recommend**

Established in Nov. 7 , 2017
CIPC Annual Meeting, July 26 , 2018

Now:
-Huanghe Company, Huadong Engineering Cooperation Company, on CEPC civil engineering design, site selection, implementation...
-Shenyang Huiyu Company on CEPC MDI mechanical connection design
-Zhongxin Heavy Industry on Elecletric-magnetic seperator design
-China Astronotics Department 508 Institute on CEPC MDIsupporting design and CEPC magnets mechanical designs...
-Kuanshan Guoli on CEPC 650MHz high efficiency klystron
-Huadong Engineering Cooperation Company, on CEPC alignement and installation logistics...

CIPC Parallel Sessions (recommend)

Parallel session I: CIPC I - B410 Main building (16:00-18:00)

- Conveners: Mr. Gao, Jinlin

time	[id] title	presenter
16:00	[130] CEPC siting, civil engineering and implementation （秦皇岛）	XIAO（肖豫）, Yu
16:20	[131] CEPC civil engineering and E-management	黄可
16:40	[132] CEPC 650MHz/800kW Klystron	王少哲
17:00	[133] CEPC MDI assembly design	杨奇
17:20	[134] 508所关于CEPC相关设计与研究	何绍栋
17:40	[135] CEPC electrostatic-magnetic deflector	王智敏（副院长）

Parallel session III: CIPC III - B410, Main building (10:30-12:30)

- Conveners: Cai（蔡传兵）, Chuanbing

time	[id] title	presenter
10:30	[142] SC cavity production	何景山
10:50	[143] CEPC, 科学前沿中的技术挑战与发展机遇	戴旭文
11:10	[144] The Preparation for CEPC from Ningxia OTIC	赵红运
11:30	[145] 超导材料	宋建
11:50	[147] CEPC雄安	向亮

Summary

- CEPC Accelerator CDR has been completed and released with all systems reaching the CDR design goals with new ideas beyond CDR
- CEPC hardware design and key technologies' R&D progress well with financial funds towards TDR to be completed in 2022
- CEPC siting and engineering implementaion progress well
- CEPC TDR Phase Accelerator Management System (Platform) has been established
- International collabotaion and collaboration with indusries progress well
- Young generations played a key role during CEPC CDR and they are the key forces to realize the goals

Thank you for your attention

Thanks go to CEPC study group colleagues, CIPC member industries and international collaborators