CEPC Accelerator Status and TDR Progress

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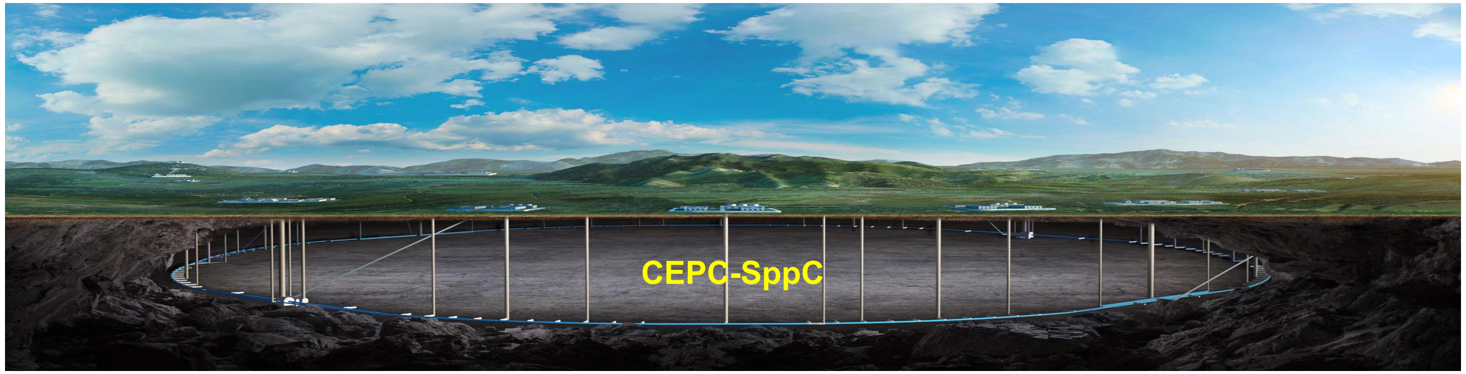
IHEP
On behalf of CEPC Group

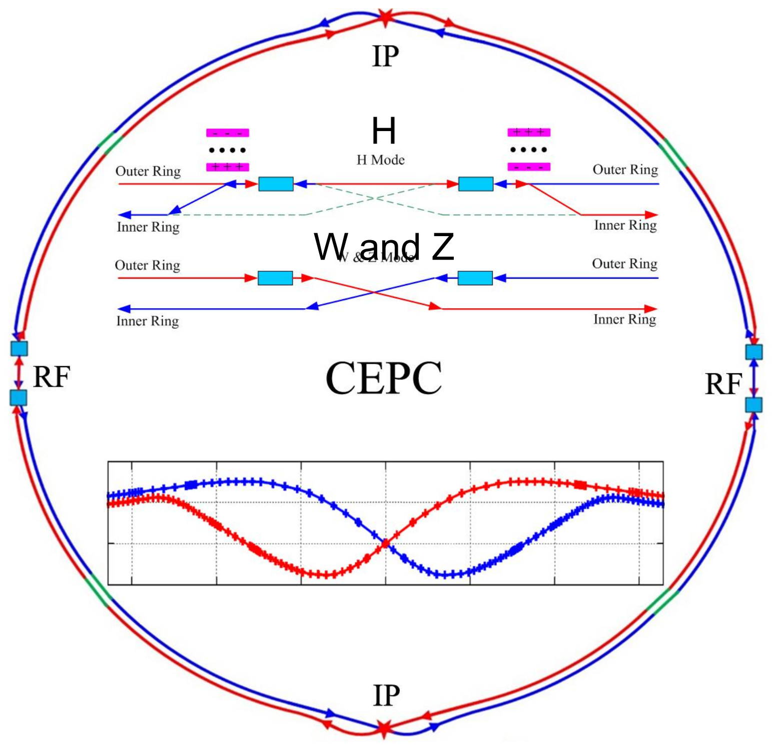


CEPC International Workshop 2020, Shanghai, China
Oct. 26-28，2020

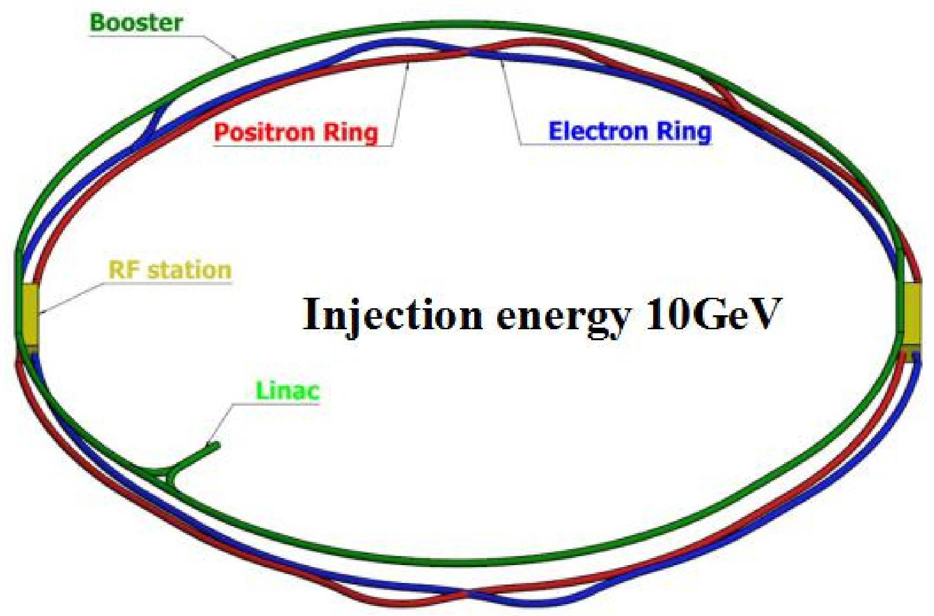
Contents

CEPC CDR Baseline Layout

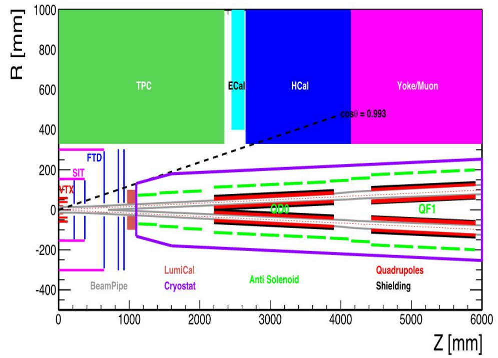
CEPC as a Higgs Factory： H, W, Z, followed by a SppC ~100TeV

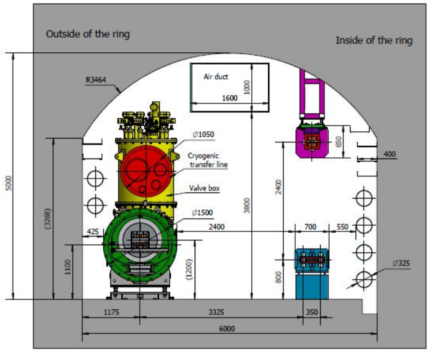


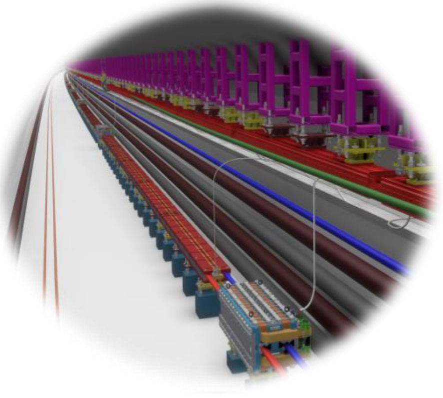
CEPC collider ring (100km)

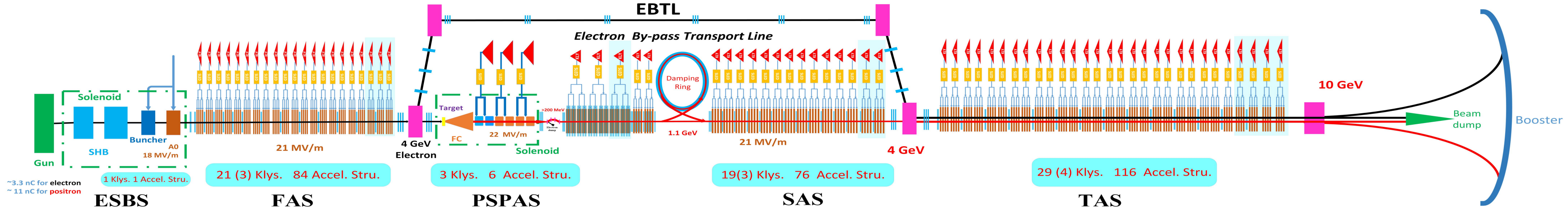


CEPC booster ring (100km)









CEPC Linac injector (1.2km, 10GeV)

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	
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**

CEPC CDR Lattice DA with Errors

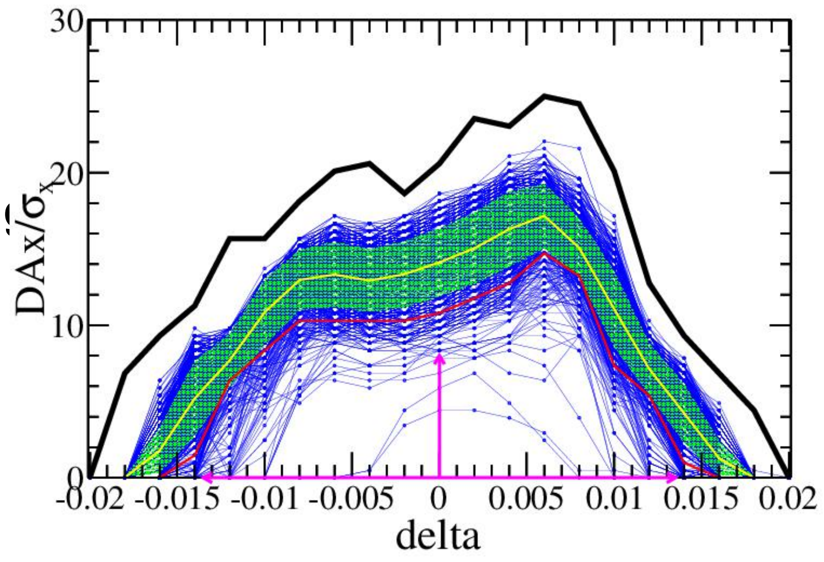
Achieved DA (with errors)@ Higgs: 10σx/21σy/0.00 (on momentum), 2σx/9σy/0.0135 (off momentum)

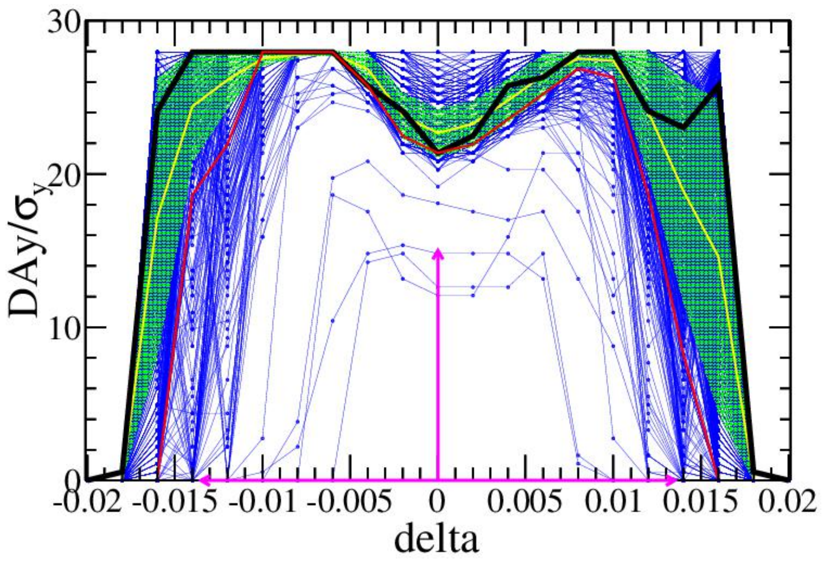
Design DA goal (with errors)@Higgs: 8σx/15σy/0.00 (on momentum), 1σx/1σy/0.0135 (off momentum)

Component	Δx (mm)	Δy (mm)	$\Delta\theta_z$ (mrad)	Field error
Dipole	0.10	0.10	0.1	0.01%
Arc Quadrupole	0.10	0.10	0.1	0.02%
IR Quadrupole	0.05	0.05	0.05	
Sextupole	0.10	0.10	0.1	

CDR lattice design with errors reached the DA design goal

Hi



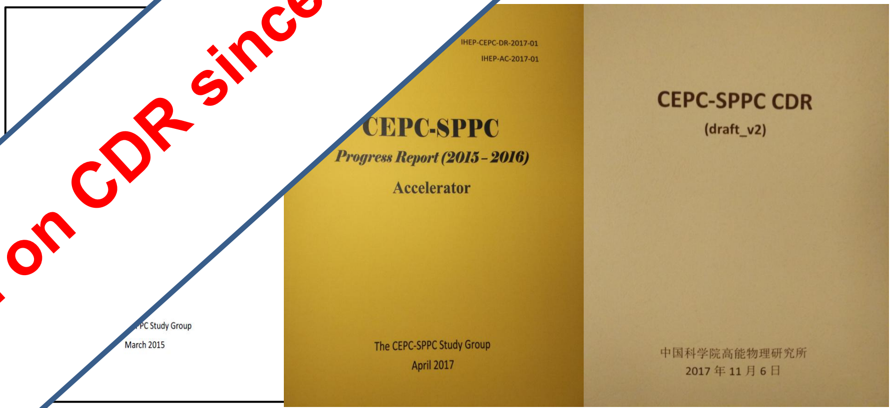


CEPC Accelerator from Pre-CDR … R towards TDR

CEPC accelerator CDR completed in June 2018 (to be … y 2018)

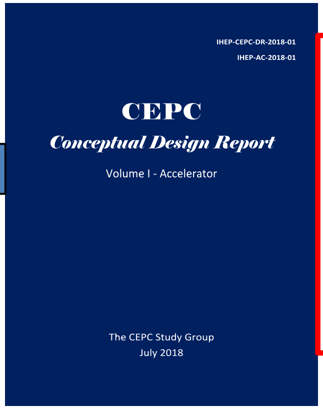
- – Executive Summary
- 1. Introduction
- 2. Machine Layout and Performance
- 3. Operation Scenarios
- 4. CEPC Collider
- 5. CEPC Booster
- 6. CEPC Linac
- 7. Systems Common to the CEPC Linac, Bo… and Collider
- 8. Super Proton Proton Collider
- 9. Conventional Facilities
- 10. Environment, Health and Saf…
- 11. R&D Program
- 12. Project Plan, Cost and S…
- – Appendix 1: CEPC …
- – Appendix 2: CEP… …ment List
- – Appendix 3: C… Requirement
- – Appendix … Double Ring
- – Append… Based on Plasma Wakefield Accelerator
- – App… …s a High Intensity γ-ray Source
- – A… …n for e-p, e-A and Heavy Ion Collision
- – … …tunities for Polarization in the CEPC
- – … …ernational Review Report

CEPC TDR R&D Started based on CDR since 2019



March 2015 | April 2017 | Draft CDR for Mini International Review in Nov. 2017

CEPC CDR Vol. I and II was publically released in Nov. 2018



CEPC Accelerator Submitted to European Strategy in 2019

1) CEPC accelerator: ArXiv: 1901.03169
2) CEPC Physics/Detector: 1901.03170

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

CEPC High Luminosity Parameter after CDR

	Higgs (high_lum.)	*Z (high_lum.)*
Number of IPs	2	2
Beam energy (GeV)	120	45.5
Circumference (km)	100	100
Synchrotron radiation loss/turn (GeV)	1.8	0.036
Crossing angle at IP (mrad)	16.5	16.5
Piwinski angle	4.87	18.0
Number of particles/bunch N_e (10^{10})	16.3	16.1
Bunch number (bunch spacing)	214 (0.7us)	10870 (27ns)
Beam current (mA)	16.8	841.0
Synchrotron radiation power /beam (MW)	30	**30**
Bending radius (km)	10.2	10.7
Momentum compact (10^{-5})	7.34	2.23
β function at IP β_x^* / β_y^* (m)	0.33/0.001	0.15/0.001
Emittance e_x/e_y (nm)	0.68/0.0014	0.52/0.0016
Beam size at IP σ_x/σ_y (μm)	15.0/0.037	8.8/0.04
Beam-beam parameters ξ_x/ξ_y	0.018/0.115	0.0048/0.129
RF voltage V_{RF} (GV)	2.27	0.13
RF frequency f_{RF} (MHz)	650	650
Natural bunch length σ_z (mm)	2.25	2.93
Bunch length σ_z (mm)	4.42	9.6
Energy spread (%)	0.19	0.12
Energy acceptance requirement (%)	1.7	1.4
Energy acceptance by RF (%)	2.5	1.5
Beamstruhlung lifetime /quantum lifetime (min)	41	-
Lifetime (hour)	0.35	1.8
Luminosity/IP L (10^{34}cm^{-2}s^{-1})	**5.0**	**101.1**

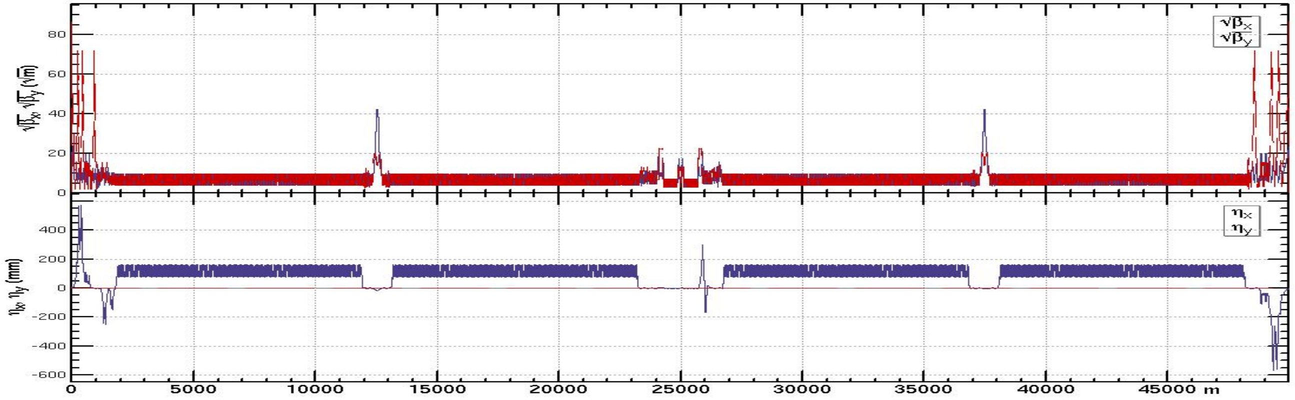
* High luminosity Z's lattice is same as Higgs CDR lattice. but high luminosity Higgs has a new lattice than that of CDR

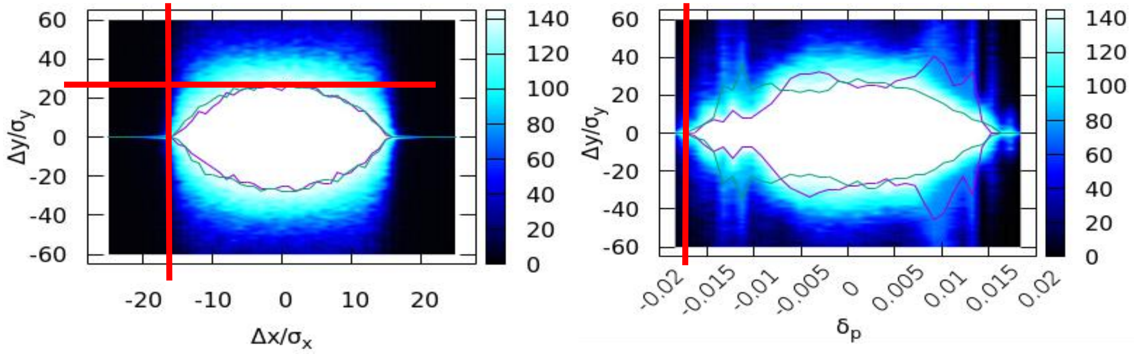
CEPC Higgs High Lumi Lattice and Dynamic Aperture Status

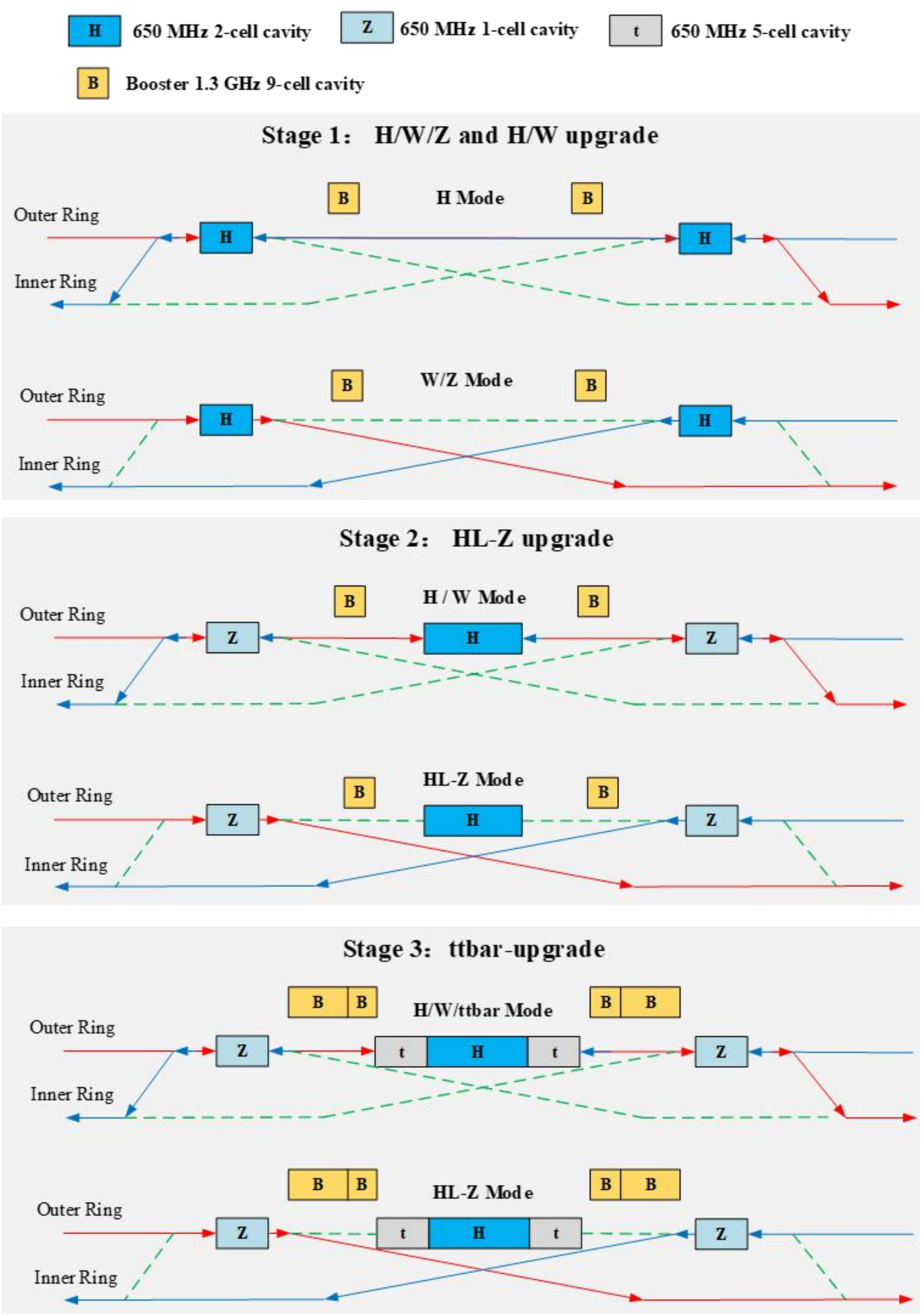
- Fit parameter list with luminosity of $5.2 \times 10^{34}/\mathrm{cm}^2/s$
  - Stronger optimization and stricter hardware requirement should be made to get enough dynamic aperture
- Optimization of the quadrupole radiation effect
  - Interaction region: longer QD0/QF1 (2m/1.48m => 3m/2m)
  - ARC region: longer quadrupoles (2m => 3m)
- Reduction of dynamic aperture requirement from injection
  - Straight section region: larger βx at injection point (600m => 1800m)
- Maximization of bend filling factor to minimize the synchrotron radiation loss per turn
  - ARC region: sextupoles in two rings changed from staggered to parallel; The left drifts are used for longer bend.
  - RF region: shorter phase tuning sections

Goal (w/ error): $8\sigma_x \times 15\sigma_y \times 1.7\%$

Achieved (w/o error): $16\sigma_x \times 28\sigma_y \times 1.8\%$







New RF Staging & By-pass Scheme for CEPC

- **Stage 1 (H/W run for 8 years):** Keep CDR RF layout for H(HL-H)/W and 50 MW upgrade. Common cavities for H. Separate cavities for W/Z. Z initial operation for energy calibration and could reach CDR luminosity. **Minimize phase 1 cost and hold Higgs priority**.
- **Stage 2 (HL-Z upgrade)**: Move Higgs cavities to center and add high current Z cavities. **By-pass low current H cavities**. International sharing (modules and RF sources): Collider + 130 MV 650 MHz high current cryomodules.
- **Stage 3 (ttbar upgrade):** add ttbar Collider and Booster cavities. International sharing (modules and RF sources): Collider + 7 GV 650 MHz 5-cell cavity. Booster + 6 GV 1.3 GHz 9-cell cavity. Both low current, high gradient and high Q, Nb_3Sn etc. 4.2 K?

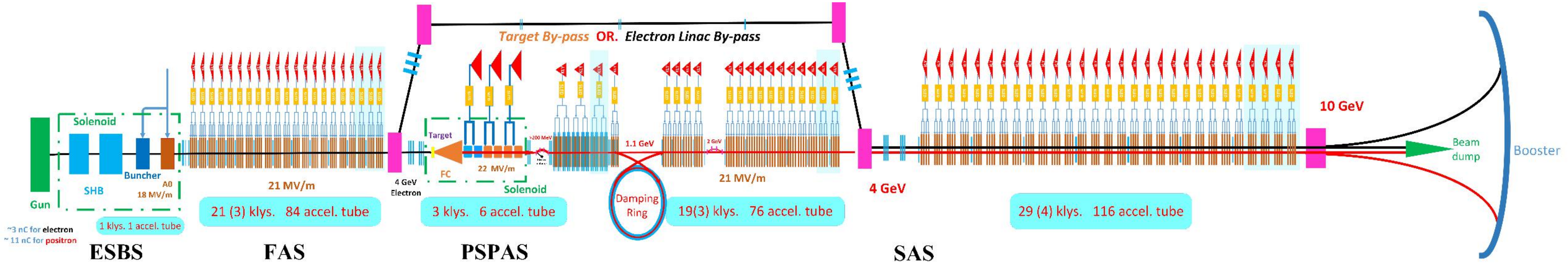
Unleash full potential of CEPC with flexible operation. **Seamless mode switching** with unrestricted performance at each energy until AC power limit. **Stepwise cost, technology and international involvement with low risk.**

CEPC SRF Parameter with By Pass Schemes

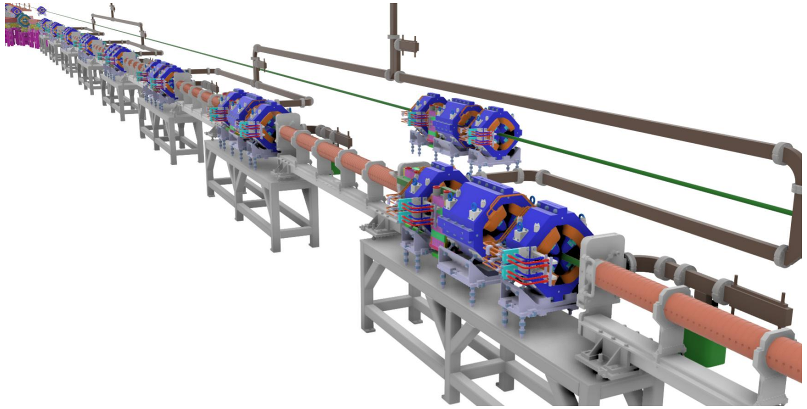
	BEPCII 500 MHz 4.2 K	**BEPC3** 500 MHz 4.2 K	**CEPC CDR H** 30 MW 3E34	**CEPC CDR Z** 16.5 MW 32E34	**CEPC 1-cell H** 30 MW 3E34	**CEPC TDR Z** 30 MW 100E34	**CEPC TDR H** 30 MW 3E34	**CEPC TDR W** 30 MW 10E34	**CEPC Ultimate Z 50 MW 167E34**
Beam current (mA)	400 (600)	900	2 x 17.4	460	2 x 17.4	**838**	2 x 17.4	2 x 87.7	1400
Cell number	1	1	2		1	1	2/1	2/1	1
Cavity number / ring	1	2	2 x 120	60	2 x 120	60	2x(90+60)	2x(90+60)	60
Eacc (MV/m)	6 (1.5 MV)	10 (2.5 MV)	**19.7**	3.6	**40**	**9.4**	**19.7**	4.2	9.4
Q_0 @ 4.2 K / 2 K	1E9	1E9	**1.5E10**	1.5E10	**3E10**	**1.5E10**	**1.5E10**	1.5E10	1.5E10
Total wall loss (kW)			6.1	0.1	6.1	0.35	6.1	0.27	0.35
Input power (kW)	110	150	250	275	250	**500**	250/125	250/125	**835**
Cavity# / klystron	1	1 SSA	2		2/1	1	2/1	2/1	1
Klystron power (kW)	250	150 SSA	800	800	800	800	800	800	1200
Total KLY number	2	4	120		60+120	120	90+120	90+120	120
HOM damper	Absorber	Absorber	Hook+ Absorber		Hook+ Absorber	Absorber	Hook+ Absorber	Hook+ Absorber	Absorber
HOM power (kW)	8*	20	0.6	1.9	0.23	2.4	0.46 / 0.23	**1.5** / 0.75	**4**

* Bunch length 15 mm, cavity cell HOM loss factor 0.1 V/pC, tapers 0.06 V/pC, absorbers 0.26 V/pC.

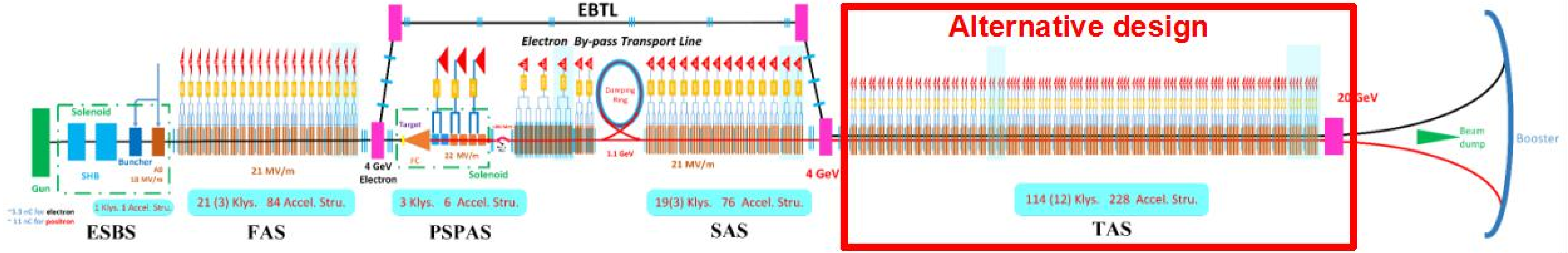
CEPC Linac Injector (CDR)



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+}		> 9.4×10^9	**1.9×10^{10} / 1.9×10^{10}**
		nC	**> 1.5**	**3.0**
Energy spread (e$^-$ /e$^+$)	σ_e		**< 2×10^{-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 20-GeV Linac Injector Alternative Scheme



- **Parameters**

S-band Accelerating structure

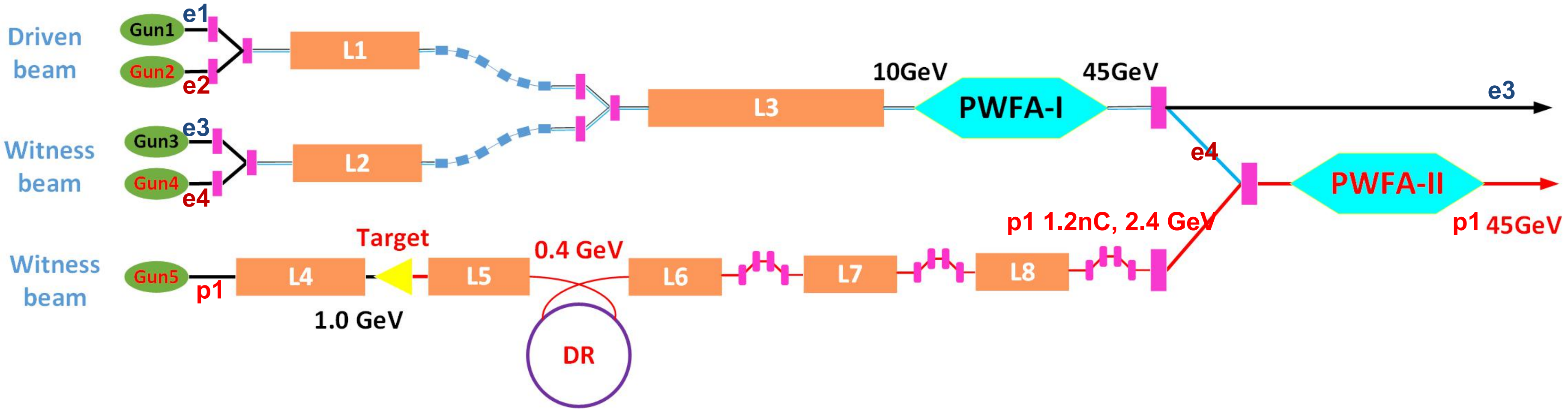
Parameter	Symbol	Unit	Baseline	Alternative
e^-/e^+ beam energy	E_{e-}/E_{e+}	GeV	10	20
Repetition rate	f_{rep}	Hz	100	100
Bunches/pulse			1	1
e^-/e^+ bunch population	$Ne-/Ne+$	nC	>1.5 (3)	>1.5 (3)
Energy spread (e^-/e^+)	σ_E		$<2\times10^{-3}$	$<2\times10^{-3}$
Emittance (e^-/e^+)	ε_r	nm	40	20

C-band Accelerating structure

C-band: 4GeV → 20GeV

Parameter	Unit	S-band	C-band
Frequency	MHz	2860	5720
Length	m	3.1	1.8
Cavity mode		2π/3	3π/4
Aperture diameter	mm	20~24	11.8~16
Gradient	MV/m	21	**45**

CEPC Plasma Injector Design

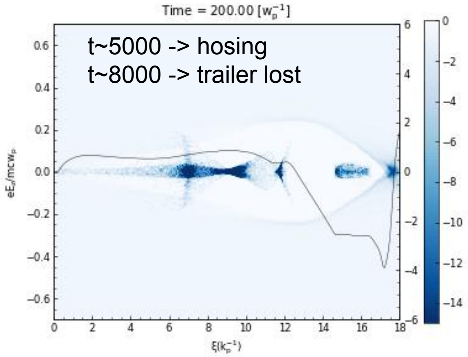


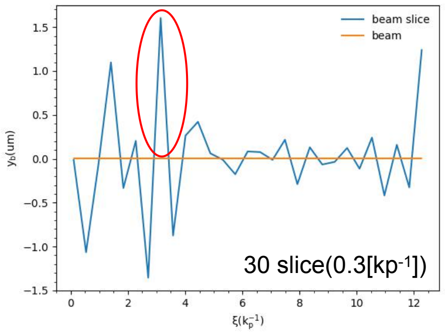
	e1/e3 Before PWFA-I	e3 After PWFA-I	e2/e4 Before PWFA-I	e4 After PWFA-I	p1 Before PWFA-II	p1 After PWFA-II	Booster Requirement
Energy (GeV)	10/10	45.5	10/10	45.5	2.4	45.5	45.5
Bunch Charge (nC)	5.8/0.84	1	15/4.5	>3	1.2	1	0.78
Bunch length (ps)	2/0.257	<1	3/0.7	<1	0.07	<1	<10
Energy Spread	~/0.2%	~1%	~/0.2%	1%	0.2%	~1%	0.2%
E_{normal} (μm rad)	<20*/<100	~100	<50*/<100	~100	<50	~100	<800
Bunch Size (μm)	3.87/8.65	<20	30/20	<20	20	<20	<2000

The plasma accelerator performance has been checked with the real linac beam quality, and it almost reached the design goal

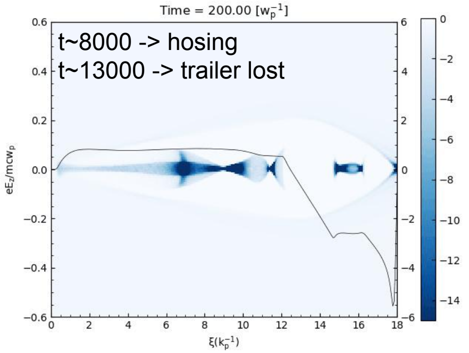
CEPC Plasma Injector Start to End Simulation

- Longitudinal shaping is well maintained → TR ☼
- Big slice jitter in PWFA acceleration → hosing → Transverse-Longitudinal coupling

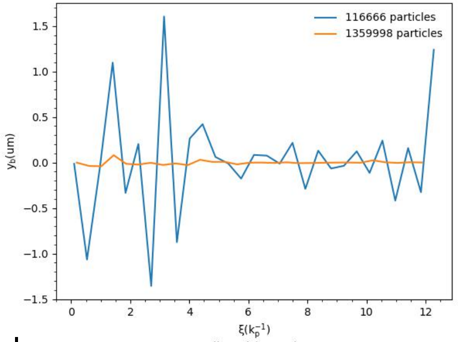


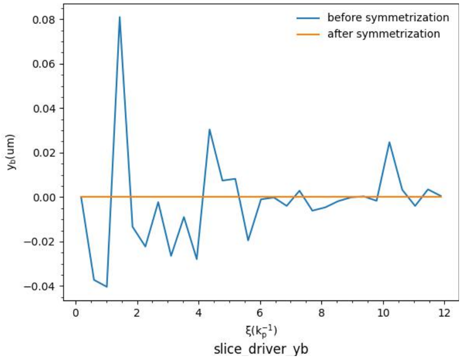


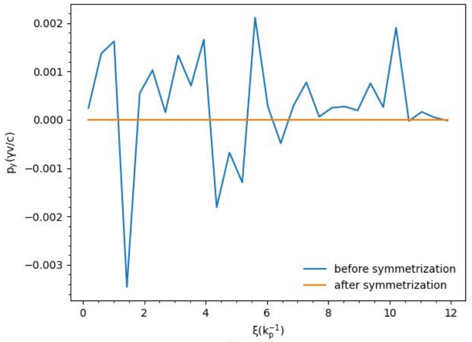
Driver initial beam centroid



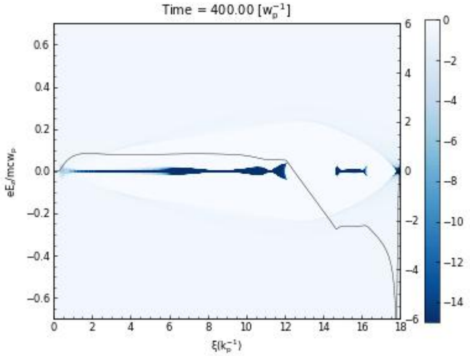
0.11m particles → 1.36m particles

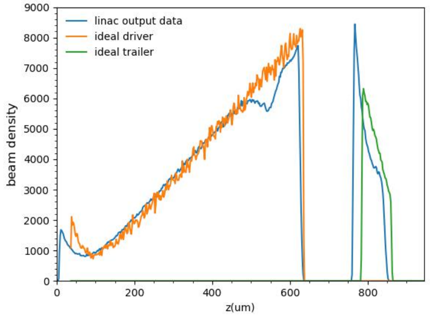


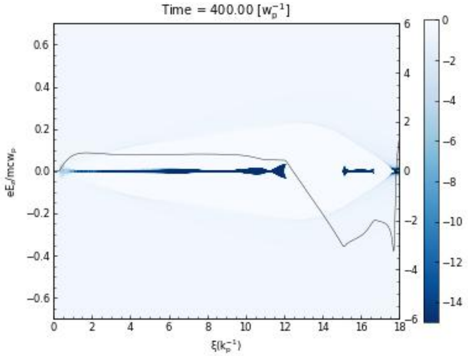


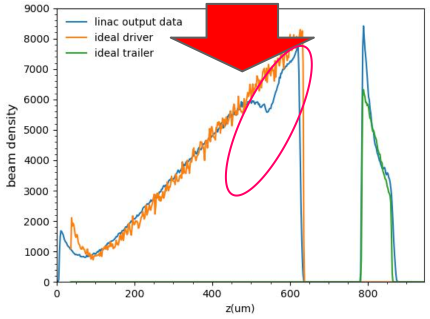


beam initial[x, y.px.py]~ [0,0,0,0]





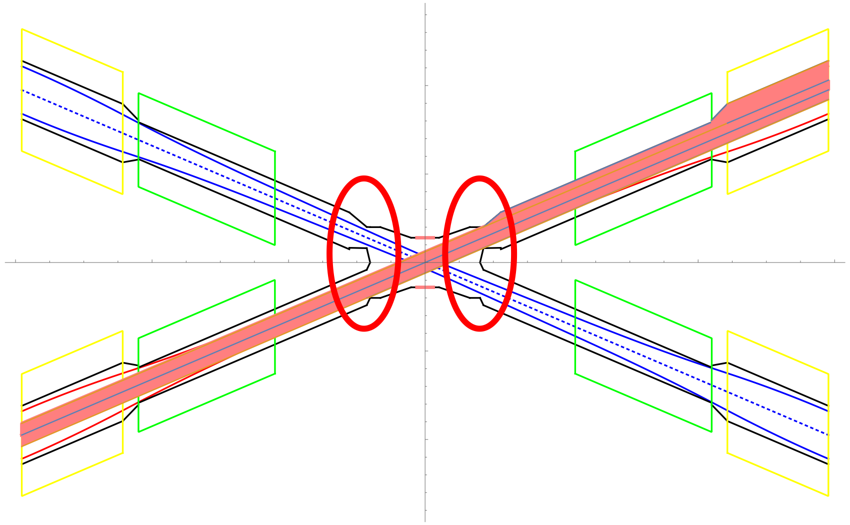




	Beam symmetrization	Change beam distance	Design
Δz(um)	126.7	149	149
Et(GeV)	40.6	42.80	45.5
Qt(nC)	0.9	0.7909	0.84

1kp^{-1}~52.52um

CEPC CDR MDI updated Design: Beam Pipe and Vacuum Chamber-1



- **Most important update:**
  asymmetric up & down stream beampipe apertures

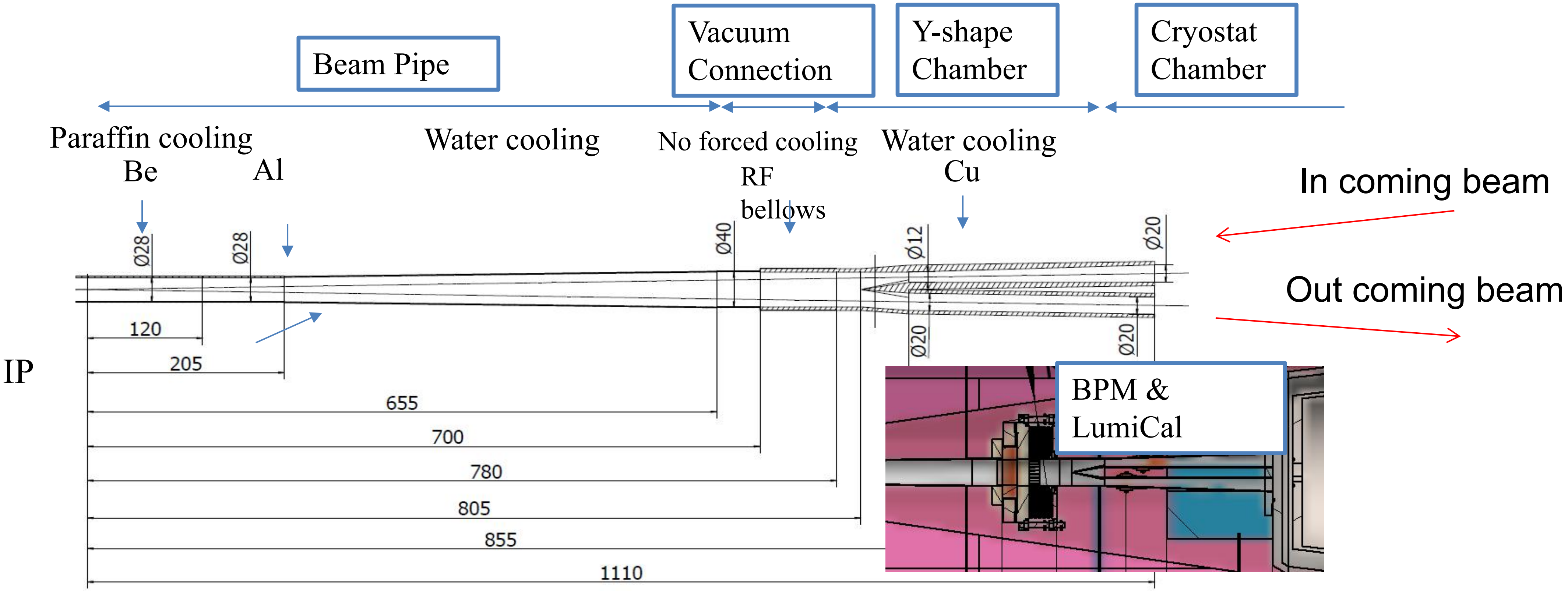
Feasibility confirmed by accelerator physics and mechanics design

↓

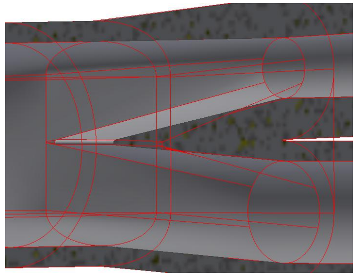
Guaranteed: no SR power deposition between **±0.855 m**

	Power Deposition	Average Power Density
0.855m~1.11m	36.53 W	39.79 W/cm^2
1.11m~2.2m	2.24 W	0.57 W/cm^2
QD0	4.34 W	0.6 W/cm^2
QD0~QF1	48.04 W	58.02 W/cm^2
QF1	4.56 W	0.86 W/cm^2

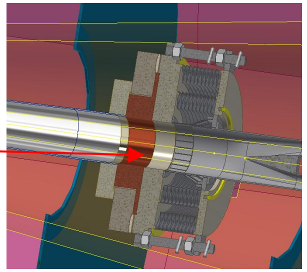
CEPC CDR MDI updated Design: Beam Pipe and Vacuum Chamber-2



Asymmetric design to prevent direct hitting of synchrotron radiation photons

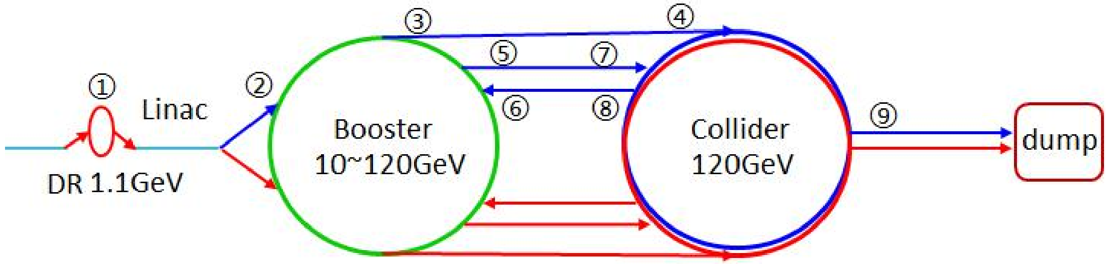


Remaining issue: difficult to dissipate the heat around the RF finger

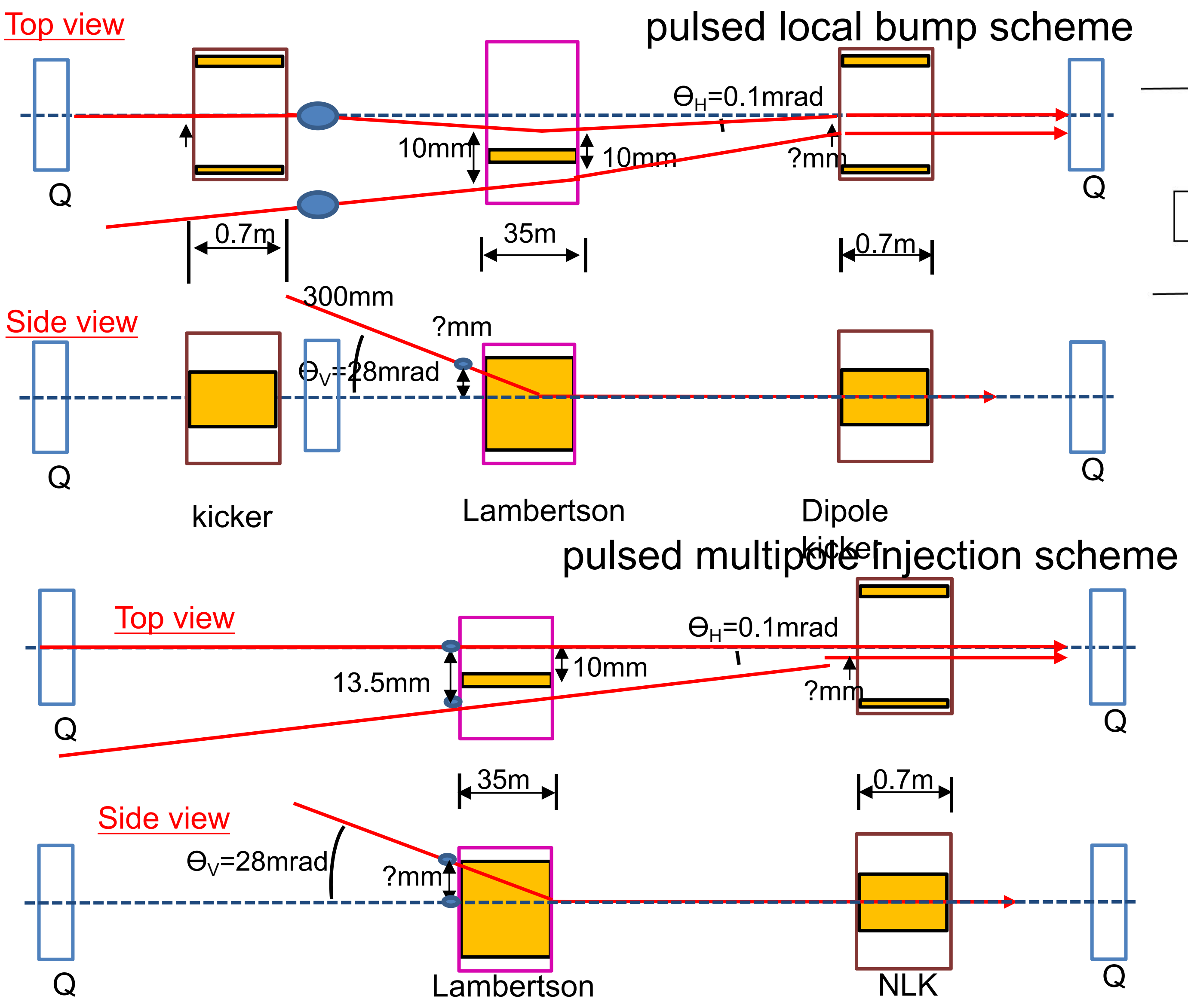


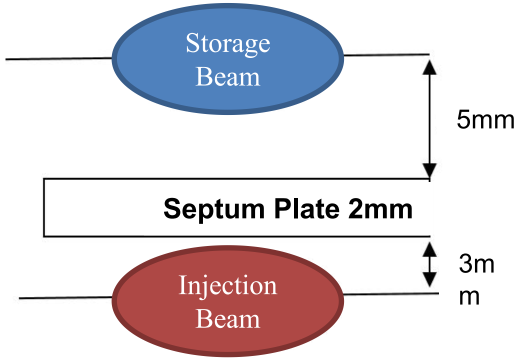
CEPC Injection and Extraction Systems

	Sub-system	Kicker Type	Kicker waveform	Septa Type
1	Damping ring inj./ext.	Slotted-pipe kicker	Half-sine/250ns	Horizontal LMS
2	Booster LE inj.	Strip-line kicker	Half-sine/50ns	Horizontal LMS
3	Booster ext. for CR off-axis inj.	Delay-line dipole kicker	Trapezoid /440-2420ns	Vertical LMS
4	Collider off-axis inj.	Delay-line NLK kicker	Trapezoid /440-2420ns	Vertical LMS
5	Booster ext. for CR on-axis inj.	Ferrite core dipole kicker	Half-sine/1360ns	Vertical LMS
6	Booster HE inj.	NLK or Pulsed sextupole	Half-sine/0.333ms	Vertical LMS
7	Collider swap out inj.	Ferrite core dipole kicker	Half-sine/1360ns	Vertical LMS
8	Collider swap out ext.	Ferrite core dipole kicker	Half-sine/1360ns	Vertical LMS
9	Collider beam dump	Delay-line dipole kicker	Trapezoid /440-2420ns	Vertical LMS
10	RF region beam separating	Delay-line dipole kicker	CW square / 165us,50%	Horizontal Copper septa

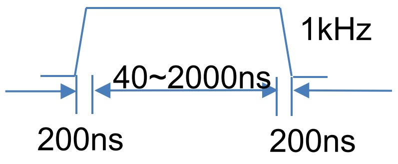


Collider Ring off-axis Injection





1. **Dipole kicker:** horizontal out-vacuum delay-line kicker+coating ceramic chamber+PFN-based solid-state pulser
2. **NLK kicker:** horizontal out-vacuum delay-line **NLK** kicker+coating ceramic chamber+PFN-based solid-state pulser
3. **Septa:** Vertical Lambertson magnet

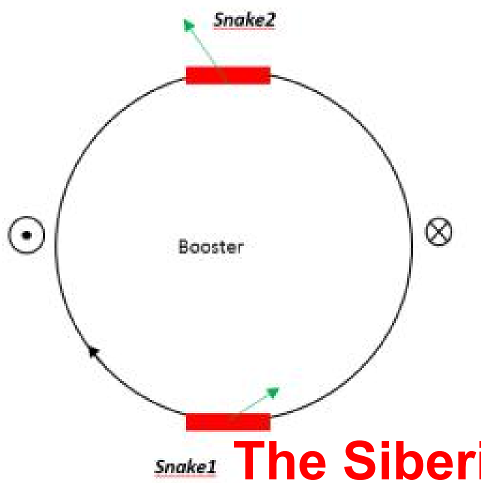


Siberian Snake in the Booster Ring for the Ramping of the Vertically Polarized Beam to the Z-pole Energy

● Snake configuration:

- $\eta_1 = \eta_4, \eta_2 = \eta_3.$
- $r_{h1} = -r_{h4}, r_{h2} = -r_{h3}.$
- $N_1 = N_4, N_2 = N_3$, where N_j is the number of periods in the jth helix.
- The magnetic field at the entrance of each helix is vertical ($\alpha_i = 0$).

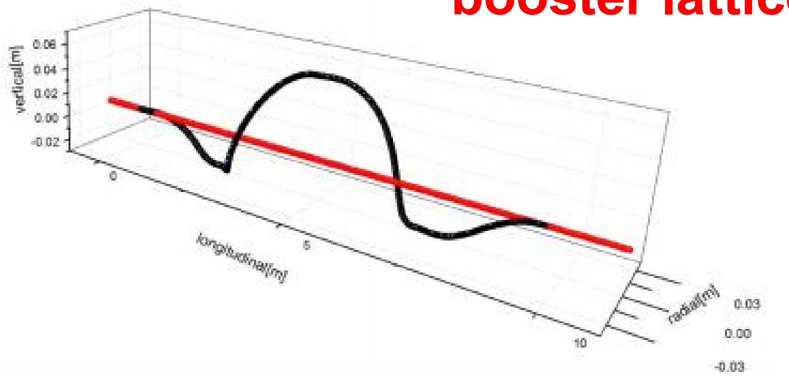
Here we choose η1=η2=η3=η4=1, N1=N2=N3=N4=1.



The Siberian Snake will be inserted into the booster lattice

● Preliminary parameters of Snake:

Helical Magnets				
#	length	Field helicity	Field orientation at entrance/exit	Field strength
1	2.4m	right-handed	vertical	1.01T
2	2.4m	right-handed	vertical	-3.26T
3	2.4m	right-handed	vertical	3.26T
4	2.4m	right-handed	vertical	-1.01T
Max. orbit excursion(hor/ver) (at 10GeV)				76mm/240mm
Radiation energy loss per turn in snakes U0[MeV] (at 10GeV/45.5GeV)				7.08/146.62



Orbital motion in Snake

CEPC Accelerator TDR R&D Priority, Plan and Test Facilities

Red Color means R&D issues have test facilities

1) CEPC 650MHz 800kW high efficiency klystron (80%) (at the end of 2021 complete the fabriation, finish test in 2022)

2) High precision booster dipole magnet (critical for booster operation) (Complete real size magnet model in 2021)

3) CEPC 650MHz SC accelerator system, including SC cavities and cryomules (Complete test cryomodule in 2022)

4) Collider dual aperture dipole magnets, dual aperture qudrupoles and sextupole magntes(Complete real size model in 2022)

5) Vacuum chamber system (Complete fabrication and costing test in 2022)

6) SC magnets including cryostate (Complete short test model in 2022)

7) MDI mechanic system (Remote vacuum connection be test in 2022)

8) Collimator (Complete model test in 2022)

9) Linac components (Complete key components test in 2022)

10) Civil engineering design (Reference implementation design complete in 2022)

11) Plasma injector (Complete electron accelerator test in 2022)

12) 18KW@4.5K cryoplant (Company)

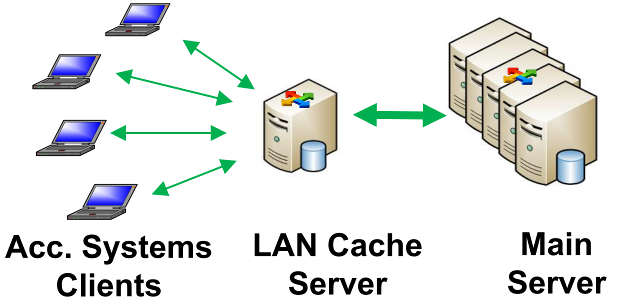
…

SppC technology R&D

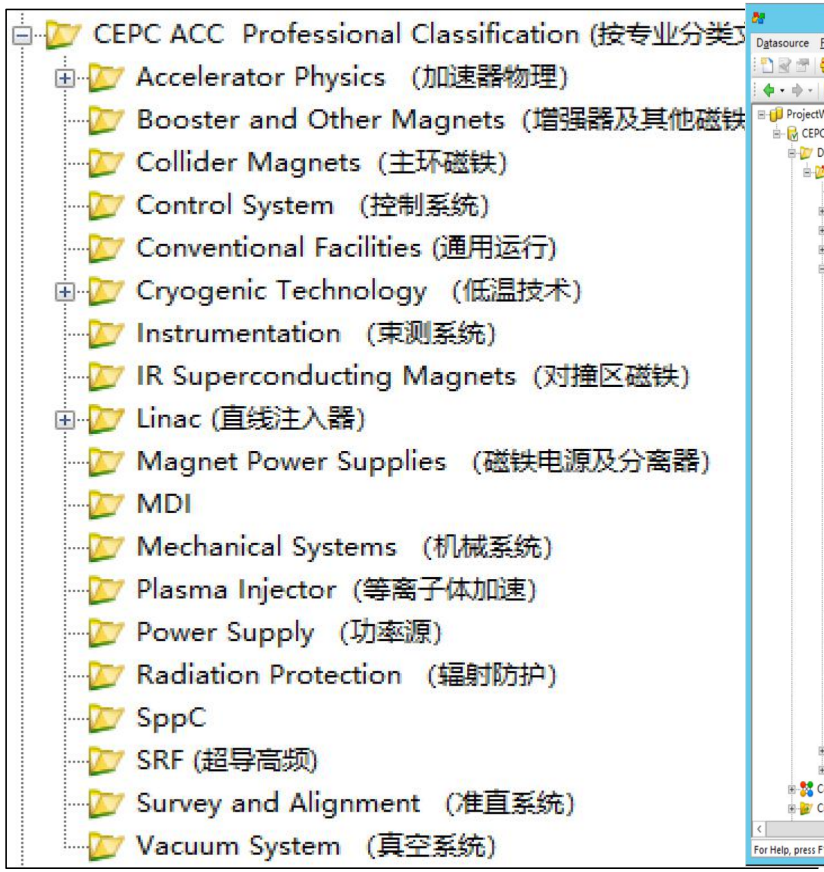
Ion based supercondcuting materials and high field magnets

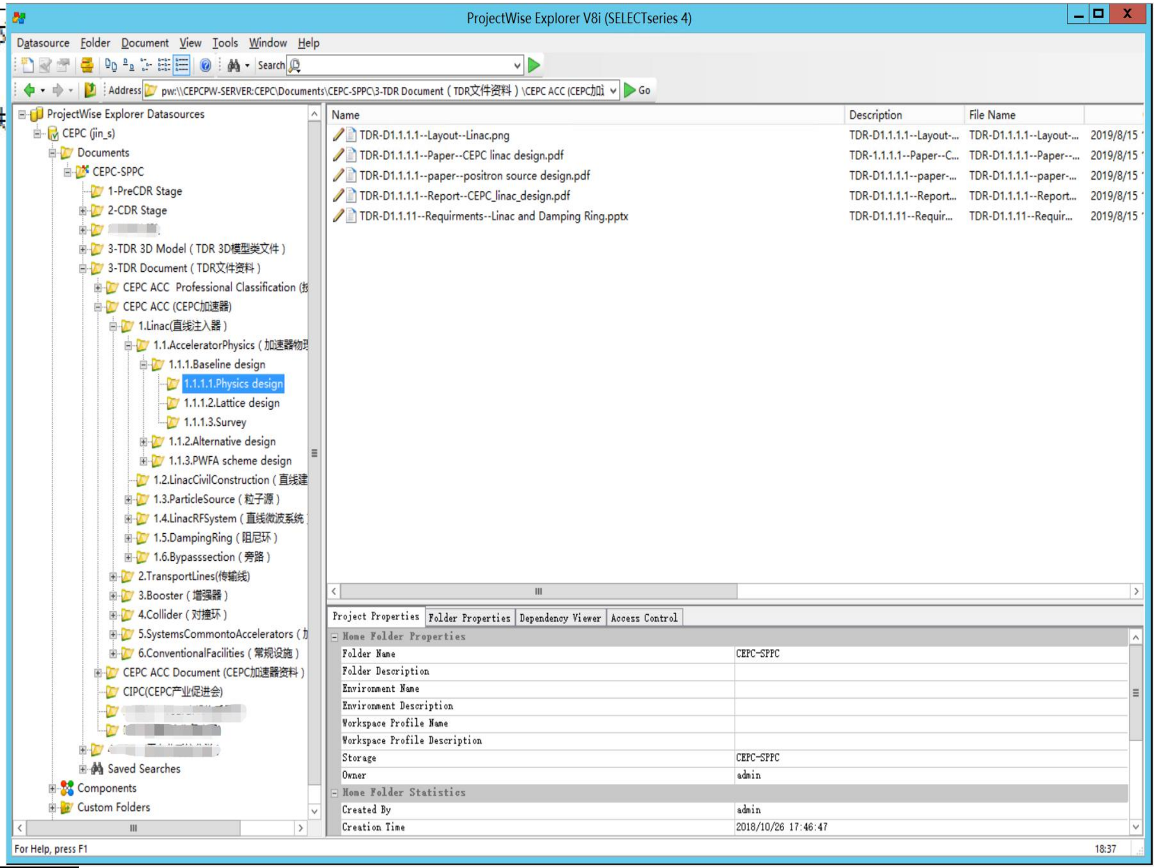
CEPC Accelerator Documents Management

- Documents management for CEPC accelerator based on a professional software--ProjectWise.



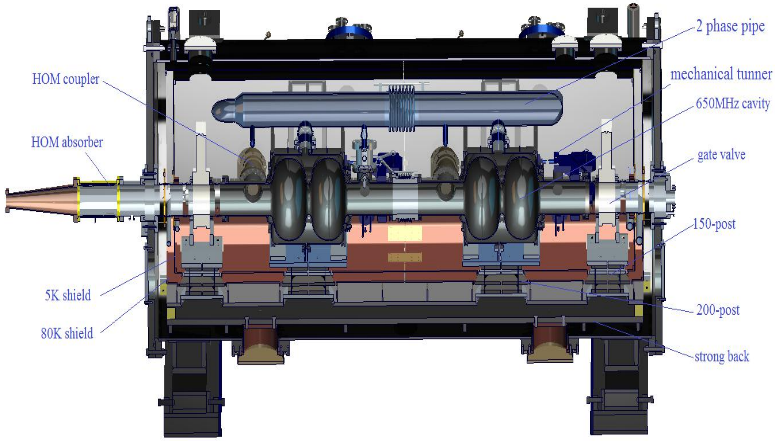
CEPC accelerator documents storage





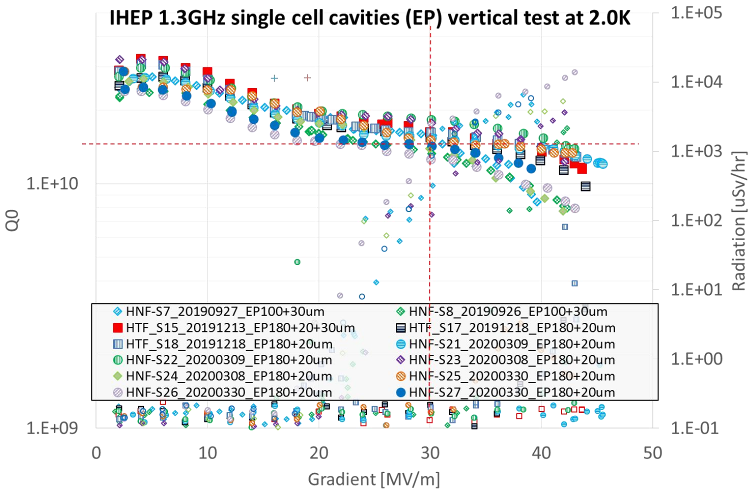
CEPC SCRF R&D Progresses

CEPC 2*2cell 650MHz cryomodule with beam test later

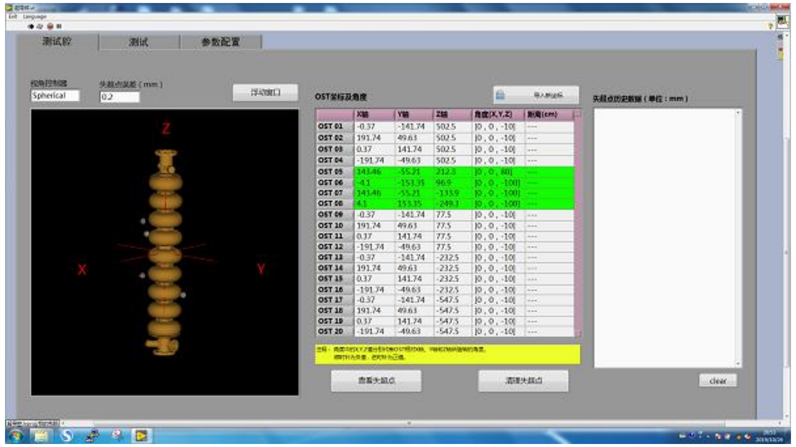


General superconducting cavity test cryomodule in IHEP New SC Lab

SC cavity vertical test temperature monitor system established

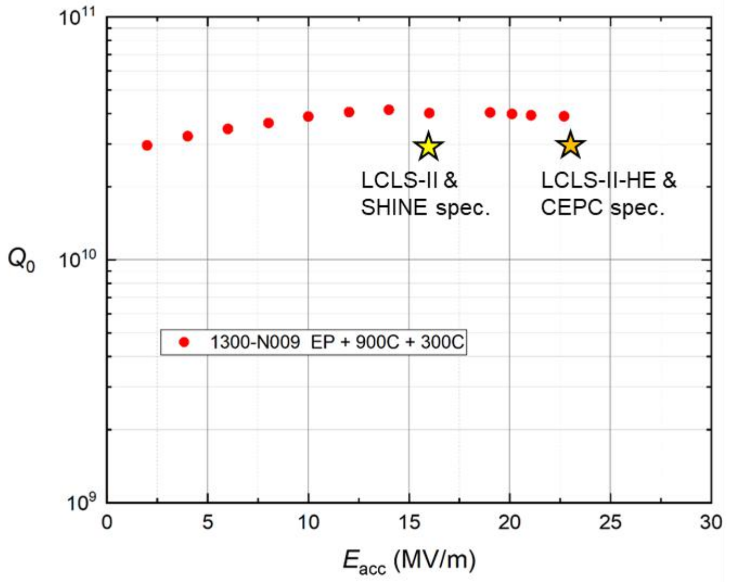


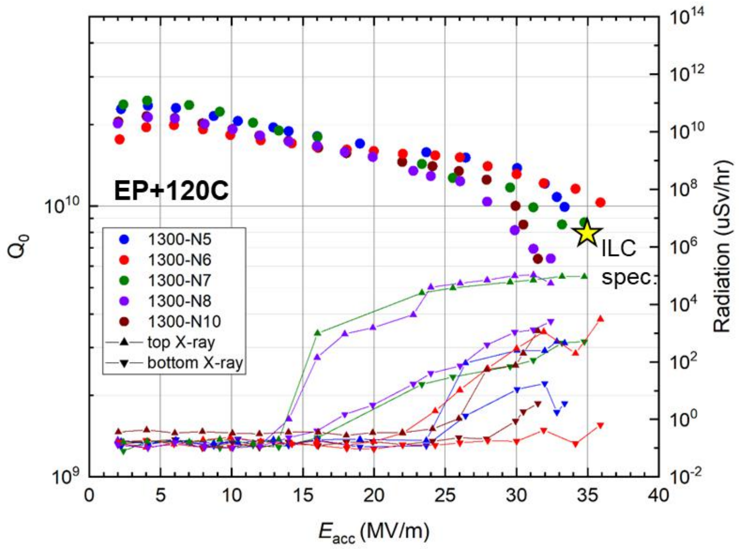
1.3GHz fine grain single cell:
1) 46MV/m
2) 43MV/m@Q0 1.3 $\times 10^{10}$

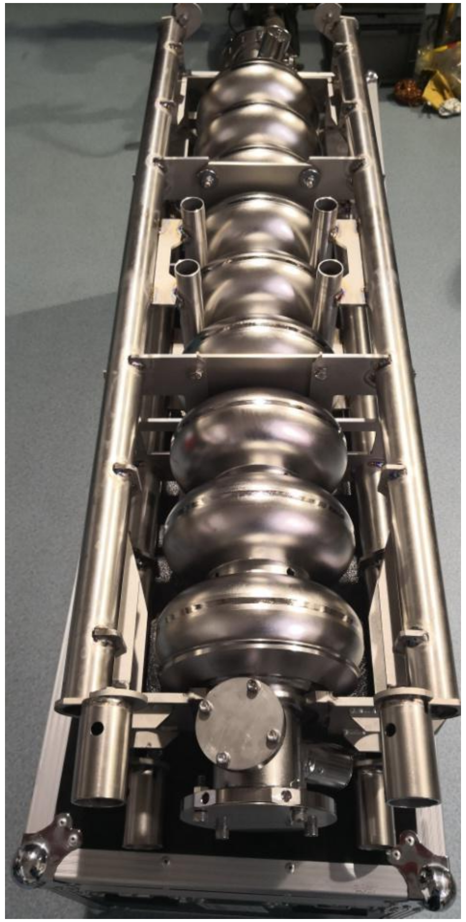


General superconducting cavity test cryomodule in IHEP New SC Lab

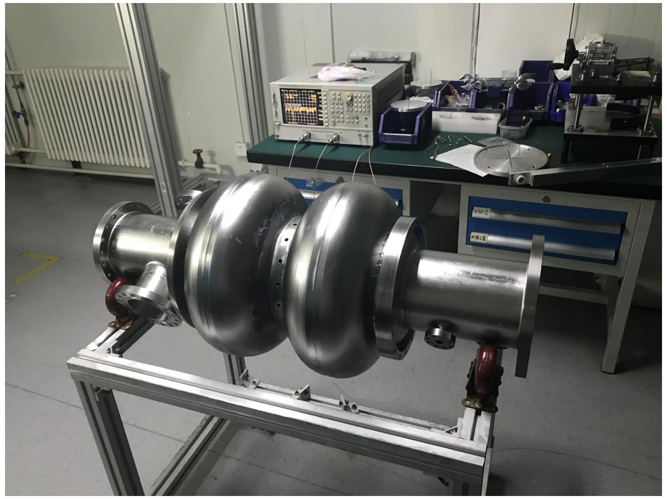
IHEP 650MHz 2cell and 1.3 GHz 9-cell Cavities



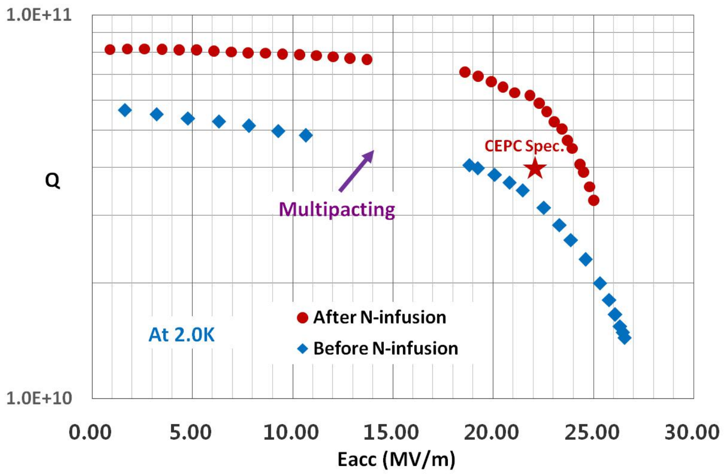




Booster 1.3GHz 9 cell cavity



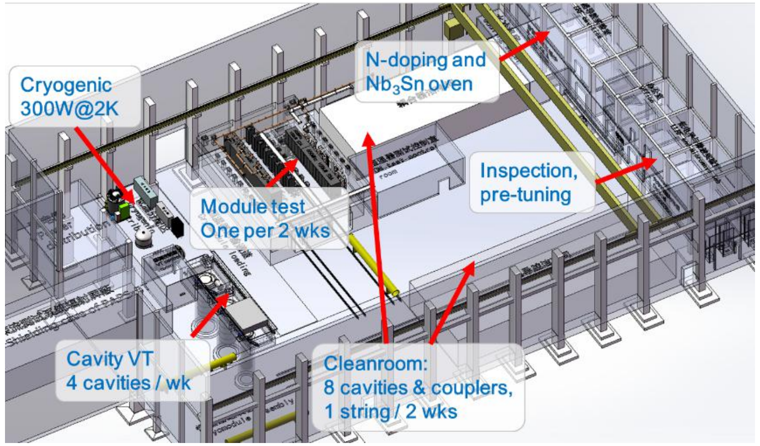
Collider ring 650Mhz 2 cell cavity

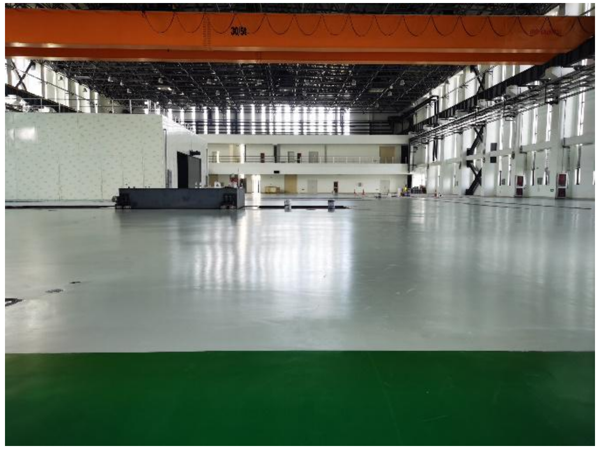


650 MHz 2-cell cavity reached **6E10@22MV/m** after N-infusion, which has exceeded CEPC Spec （**Q=4E10@Eacc=22MV/m**）.

IHEP New SC Lab under Construction (Status in Nov. 2019)

Facility: CEPC SCRF test facility (lab) is located in IHEP Huairong Area of 4500m^2





New SC Lab Design (4500m^2)

SC New Lab will be available in 2021

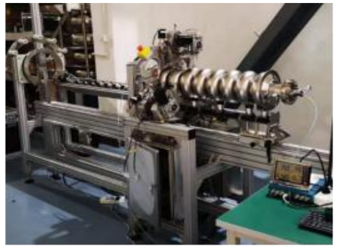
Crygenic system hall in Jan. 16, 2020

Vacuum furnace (doping & annealing)

Nb3Sn furnace

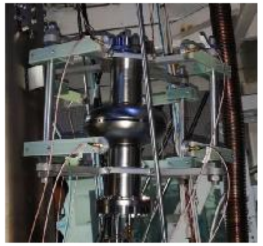
Nb/Cu sputtering device

Cavity inspection camera and grinder

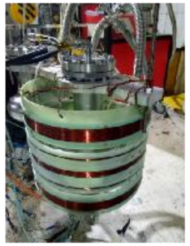


9-cell cavity pre-tuning machine

Temperature & X-ray mapping system



Second sound cavity quench detection system



Helmholtz coil for cavity vertical test

Vertical test dewars

Horizontal test cryostat

CEPC 650MHz High Efficiency Klystron Development

Facility: CEPC high power and high efficincy test facility (lab) is located in IHEP

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
- 2020 - 2021 ： Fabricate 2nd high efficiency klystron & test
- 2021 - 2022 ： Fabricate 3rd high efficiency klystron & test

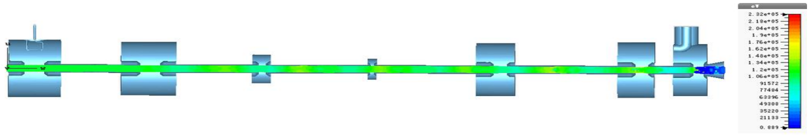
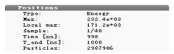
Parameters	Conventional efficiency	**High efficiency**
Centre frequency (MHz)	650+/-0.5	**650+/-0.5**
Output power (kW)	800	**800**
Beam voltage (kV)	80	**-**
Beam current (A)	16	**-**
Efficiency (%)	~ 65	**> 80**



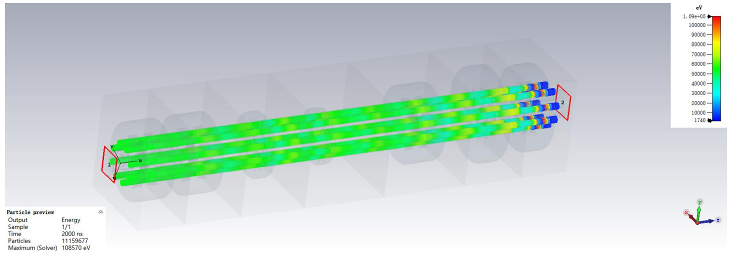
1st Klystron of 62% efficiency

On March 10， 2020， the first CEPC650Mhz klystron output power has reached pulsed power of 800kW (400kW CW due to test load limitation), efficiency 62% and band width>+-0.5Mhz.

800kW Load

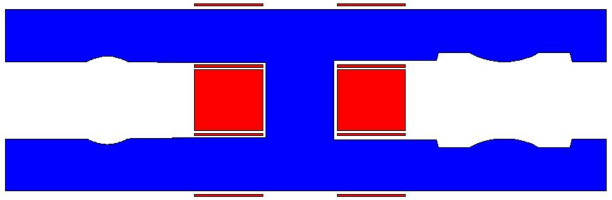



2nd Klystron of 77% efficiency

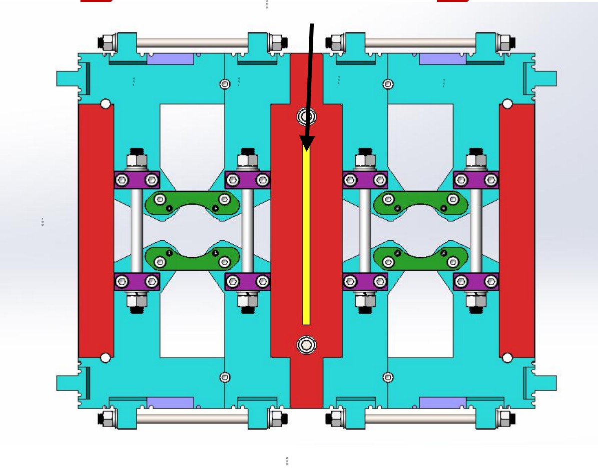


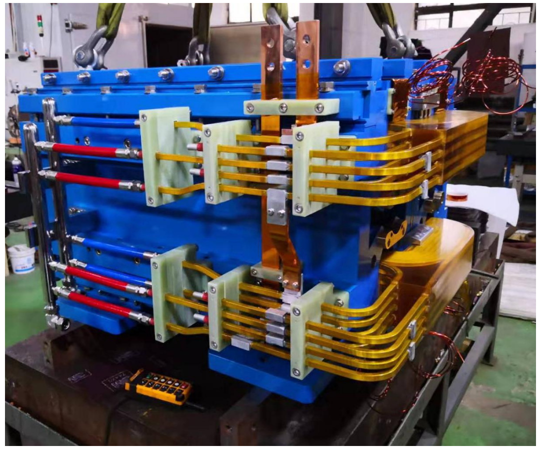
3nd Klystron of 80% efficiency

CEPC Collider Ring dual Aperture Dipole, Quadrupole and Sextupole Magnet Design Progress



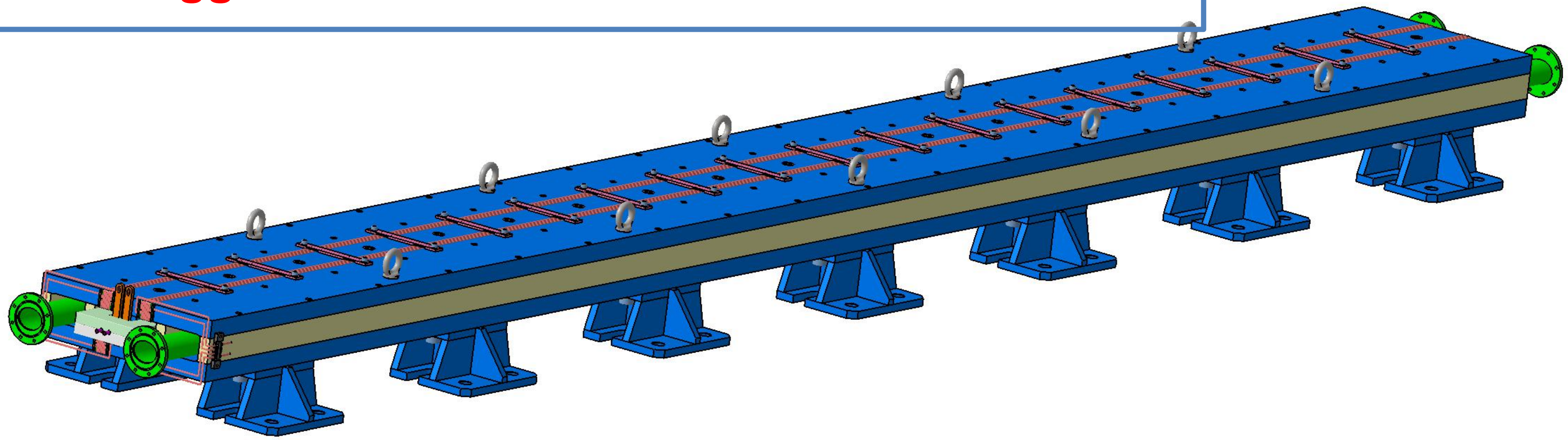
First dual aperture dipole test magnet of 1m long has been fnished in Nov, 2019





First dual aperture quadrupole magnet has been fnished in Nov, 2019

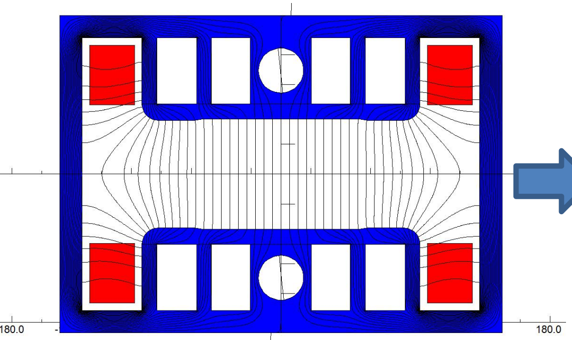
Facility: CEPC magnet test facility (lab) is located in IHEP Dongguan CSNS

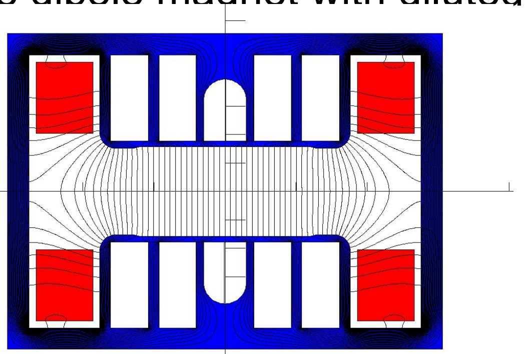


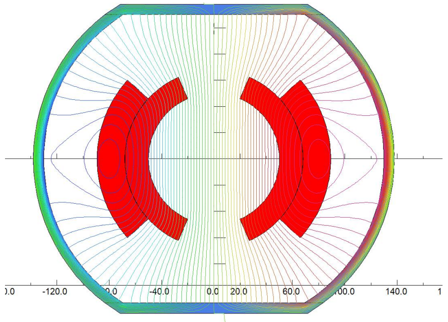
The mechanical design of a full size CEPC collider ring dual aperture dipole of 5.7m long has been designed and be fabricated at the end of 2020.

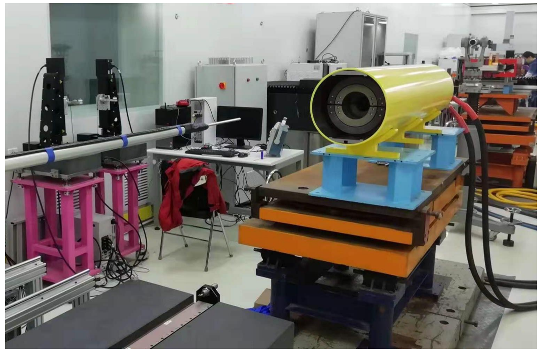
Booster High Precision Low Field Dipole Magnets

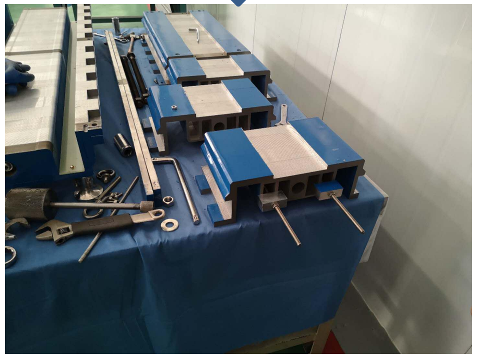
Two kinds of the dipole magnet with diluted iron cores and without iron core (CT) are proposed and designed

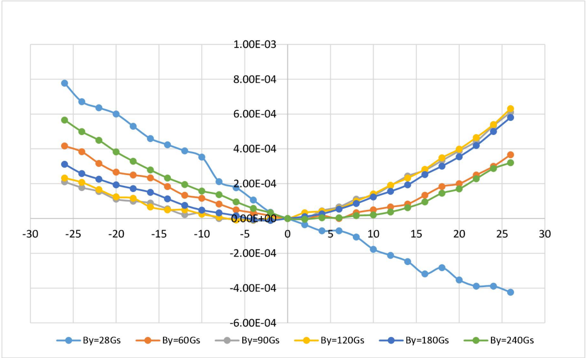






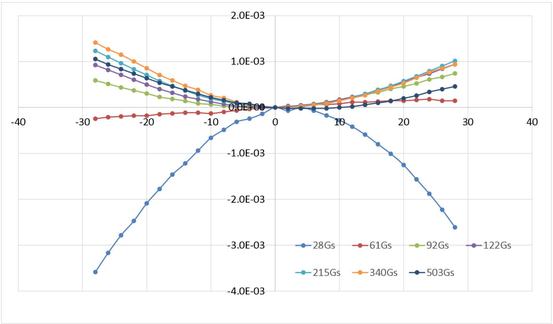




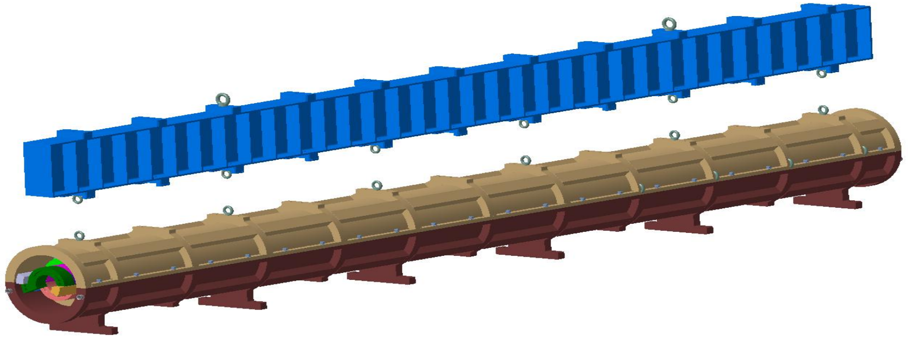


1m long CT test booster dipole magnet without iron core completed in Oct. 2019, and the test result shows that CT design reached the design goal.

The improved model is under test



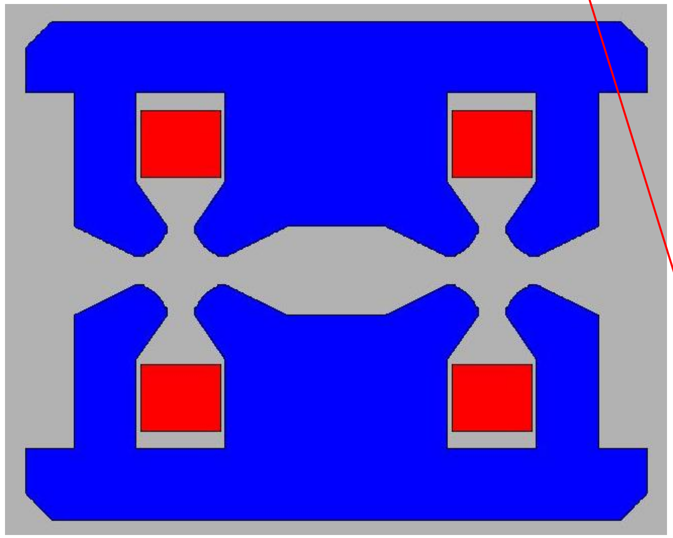
The first 1m long test booster dipole magnet with iron core, completed in Nov. 2019, and not yet reached design goal, improvement is under way



A full scale CT dipole magnet of 5.1m long is under design, and fabrication will be completed at te end of 2020

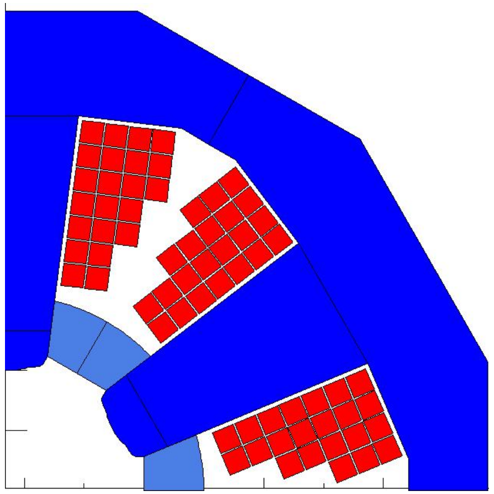
CEPC Collider Ring Quadropole and Sextupole Designs

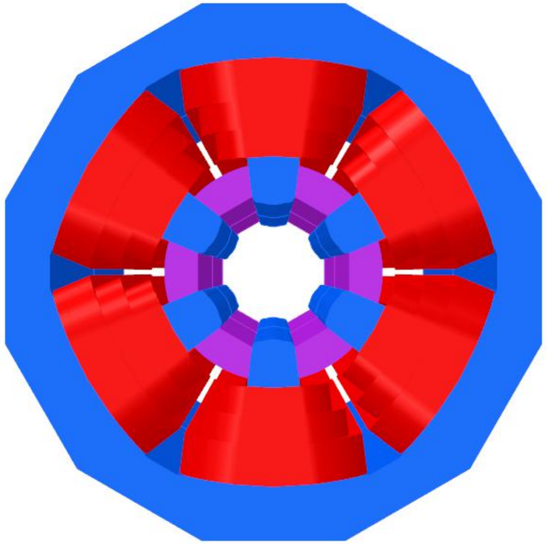
Dual aperture quadrupol



Using asymmetry poles or offset the cavity to reduce the b1 component.

- **Further physical optimization of the sextupole magnet.**
  - **Wedge-shaped magnetic poles are used to reduce magnetic pole saturation and improve excitation efficiency**
  - **Further optimization to the position of the lead block and the arrangement of coil wires to reserve space for magnet assembly.**
- **Mechanical design is in progress.**





Field harmonics

n	B_nL/B_3L
3	10000
9	1.0
15	-0.5
21	-0.1

Key R&D item

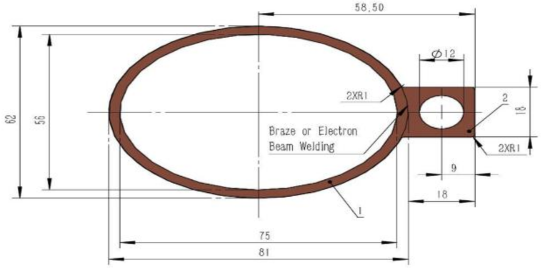
CEPC Vacuum System R&D

Facility: CEPC vaccum test facility (lab) is located in IHEP Dongguan CSNS

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.

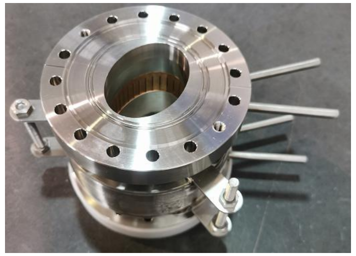
- The vacuum pressure is better than 2 x 10-10 Torr
- Total leakage rate is less than 2 x 10-10 torr.l /s.

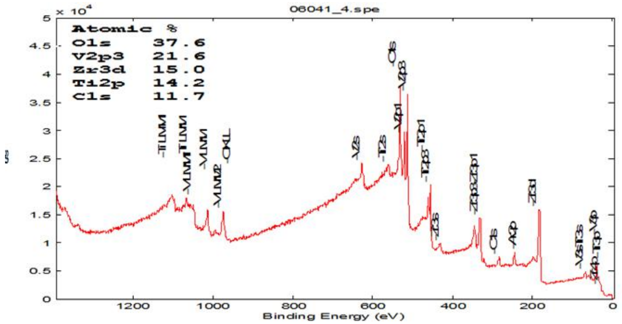
Positron ring

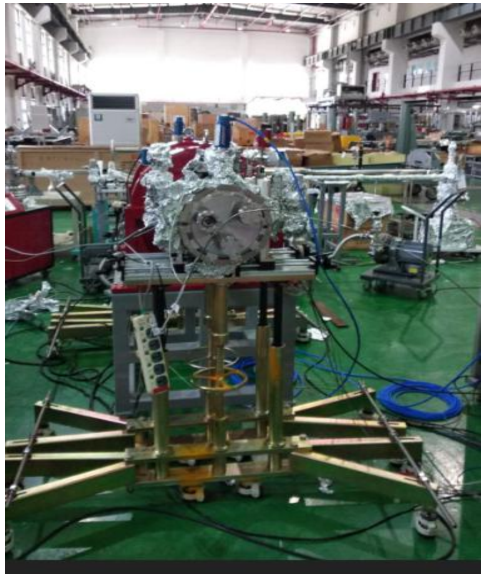


Copper vacuum chamber (Drawing) elliptic 75×56, thickness 3, length 6000)

Two 6m long vacuum chambers both for copper and aluminum







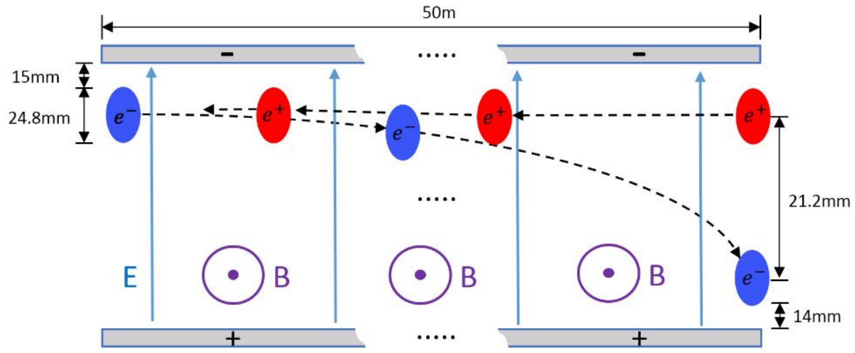
CEPC Electrostatic-Magnetic Deflector

The Electrostatic-Magnetic Deflector is a device consisting of perpendicular electric and magnetic fields.

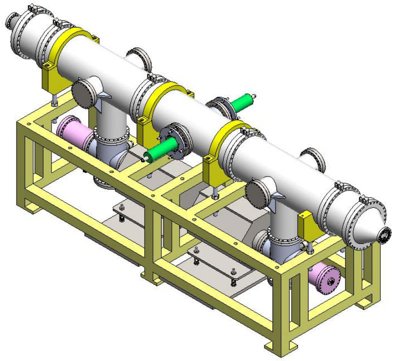
under fabrication

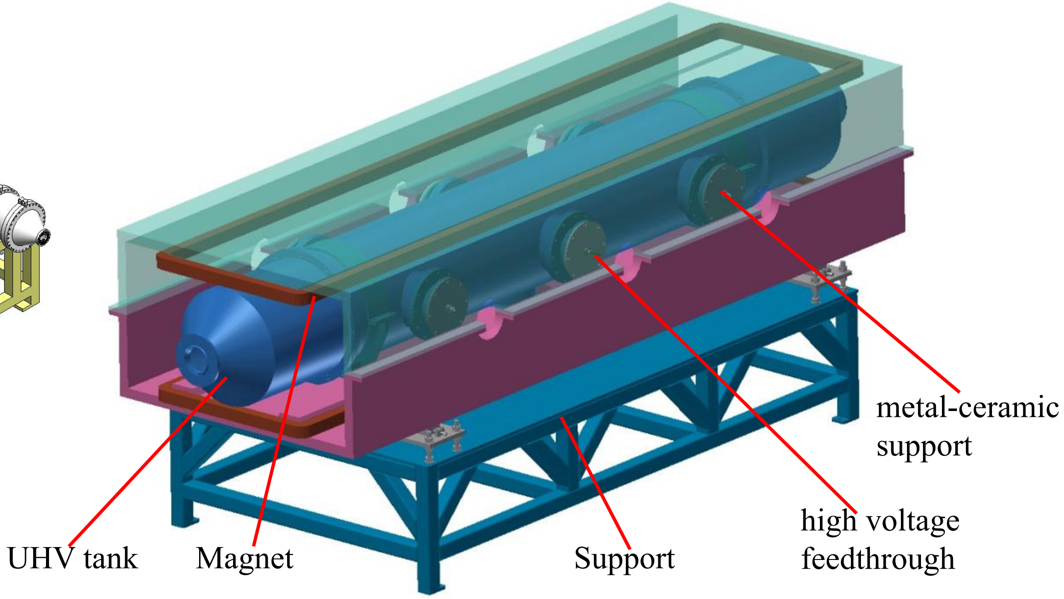
One set of Electrostatic-Magnetic Deflectors including 8 units, total 32 units will be need for CEPC.

	Filed	Effective Length	Good field region	Stability
Electrostatic separator	2.0MV/m	4m	46mm x 11mm	5×10^{-4}
Dipole	66.7Gauss	4m	46mm x 11mm	5×10^{-4}

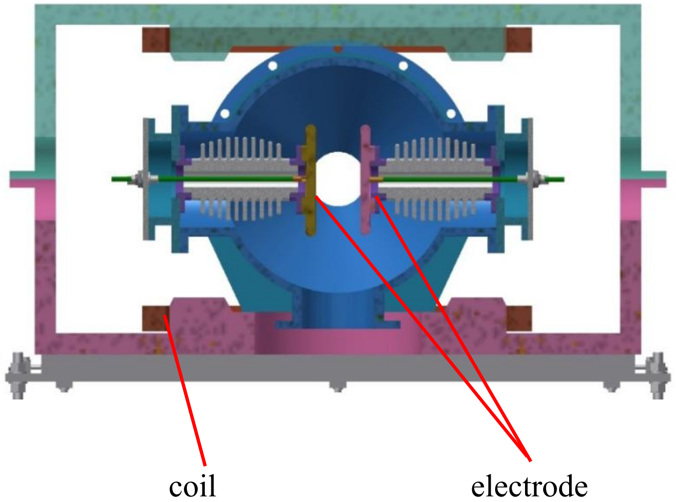


Schematic of Electrostatic-Magnetic Deflector





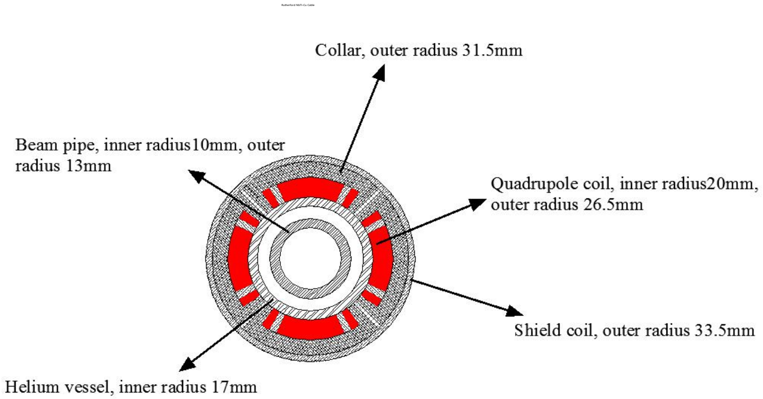
structure drawing of Electrostatic-Magnetic Deflector



CEPC IR Superconducting Magnets

Facility: CEPC IR SC magnet test facility (lab)

is located in Keye company joinly with IHEP

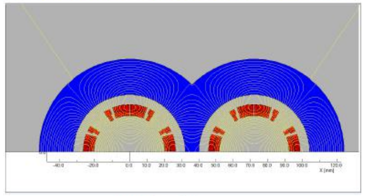


Room-temperature vacuum chamber with a clearance gap of 4 mm

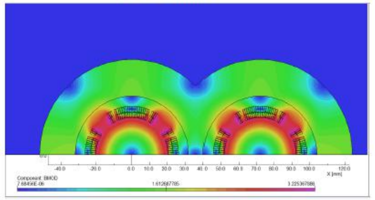
Magnet	Central field gradient (T/m)	Magnetic length (m)	Width of Beam stay clear (mm)	Min. distance between beams centre (mm)
QD0	136	2.0	19.51	72.61

Superconducting QD coils

- 2D field cross talk of QD0 two apertures near the IP side.



2D Flux lines

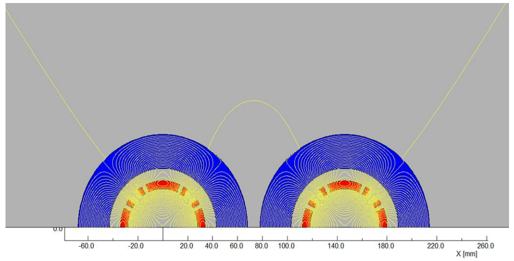


Bmod distribution

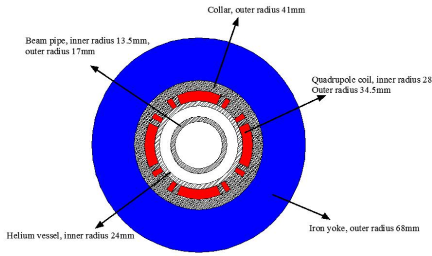
QF1 Integral field harmonics with shield coils ($\times 10^{-4}$)

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

Superconducting QF coils



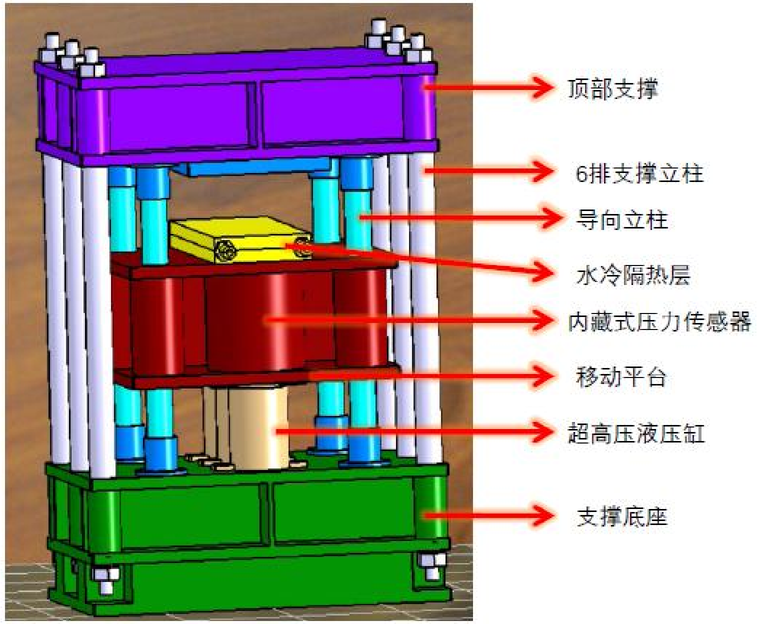
There is iron yoke around the quadrupole coil for QF1. Since the distance between the two apertures is larger enough and there is iron yoke, the field cross talk between two apertures of QF1 can be eliminated.



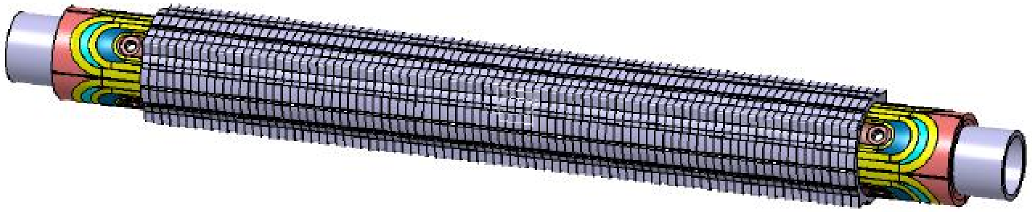
One of QF1 aperture (Peak field 3.8T)

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 MDI SC Quadrupole R&D

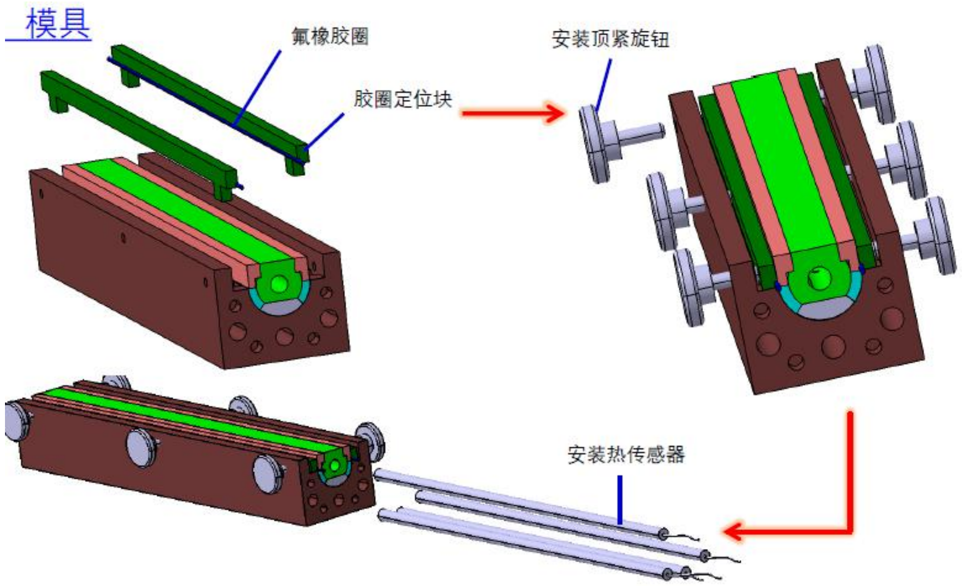


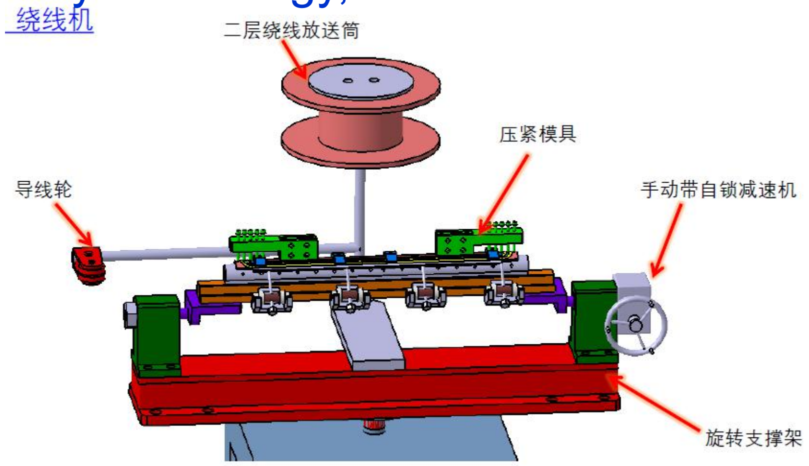
Superconducting quadrupole coil heating and curing system.



Field gradient 102T/m, coil bore diameter 38mm; The minimum distance between the center of the two apertures is 62.7mm

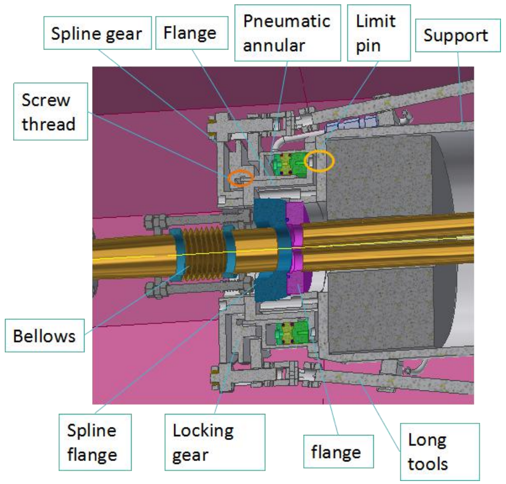
SC quadrupole mechanical design, coil winding technology, fabrication procedure study of quadrupole coil with small diameter, stress applying and monitoring, quadrupole magnet assembly technology, etc.



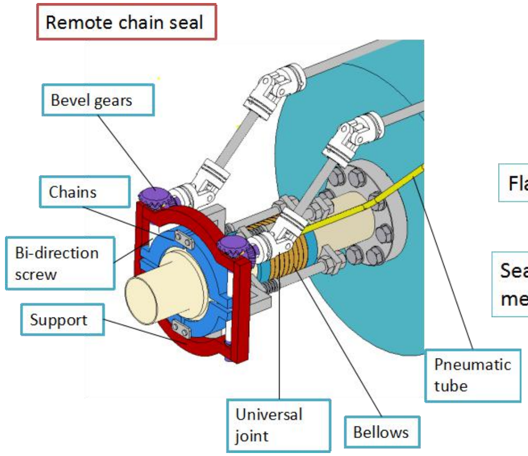


Progress of Remote Vacuum Connectors for MDI Beam Pipe

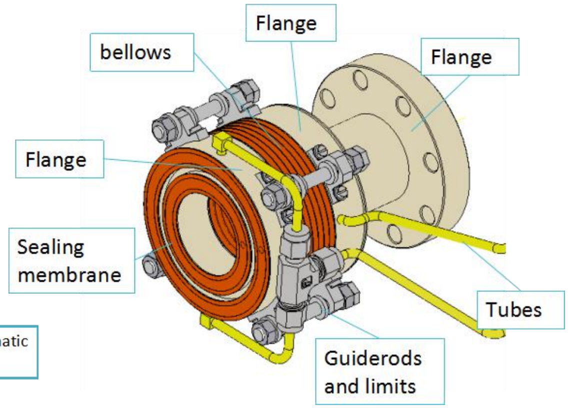
Sealing methods	Within detection angle	Leak rate estimation	Remarks
1-RVC	NO	★★★★★	Successful used in S-KEKB
2-Remote chain	Yes	★★	Eliminated
3-Inflatable seal*	Yes	★★★	Experience from CSNS
4-Improved inflatable seal	Yes		Mainly focused on



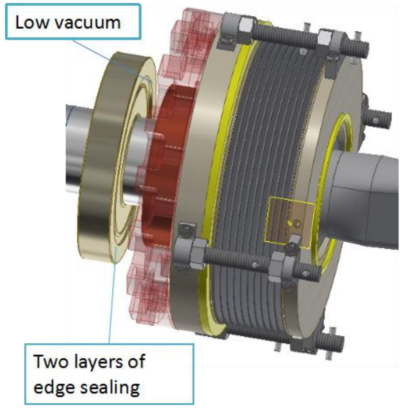
1



2



3



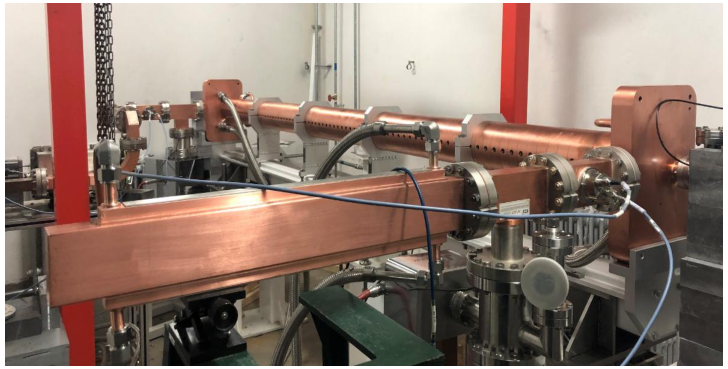
4

CEPC Linac and damping ring key technology R&D

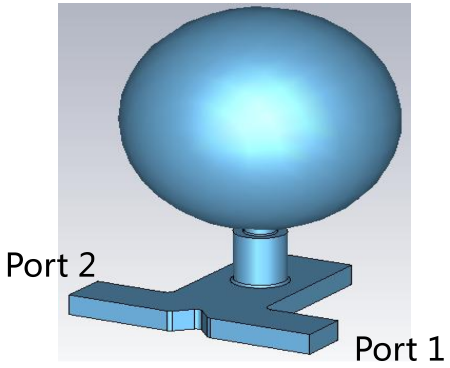
Facility: CEPC injection linac test facility (lab) is located in IHEP

Accelerating structure

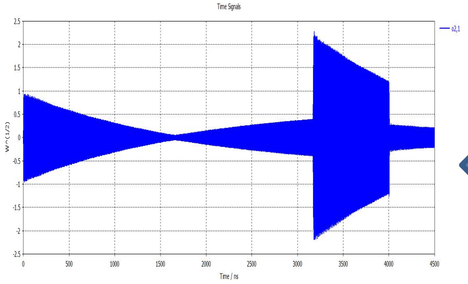
- The structure is 3 meters long with constant gradient design which work mode is 2π/3
- The high power test has finished and the gradiet is up to 33 MV/m



The acclelerating strucutre on high power test bench



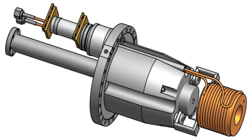
Simulation model



Simulated waveform

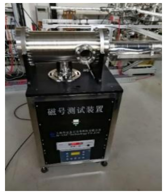
Pulse compressor:
Spherical cavity pulse compressor has devoloped
The TE_{113} mode is selected and the RF design is finished.
The Q value is about 140000
The Maximum Energy Multiplication Factor M=1.84.

Positron source R&D

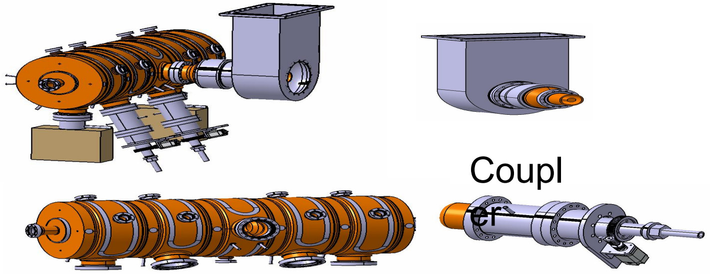


The mechanical design of FLUX concentrator

The finished FLUX concentrator



The test bench of the FLUX concentrator



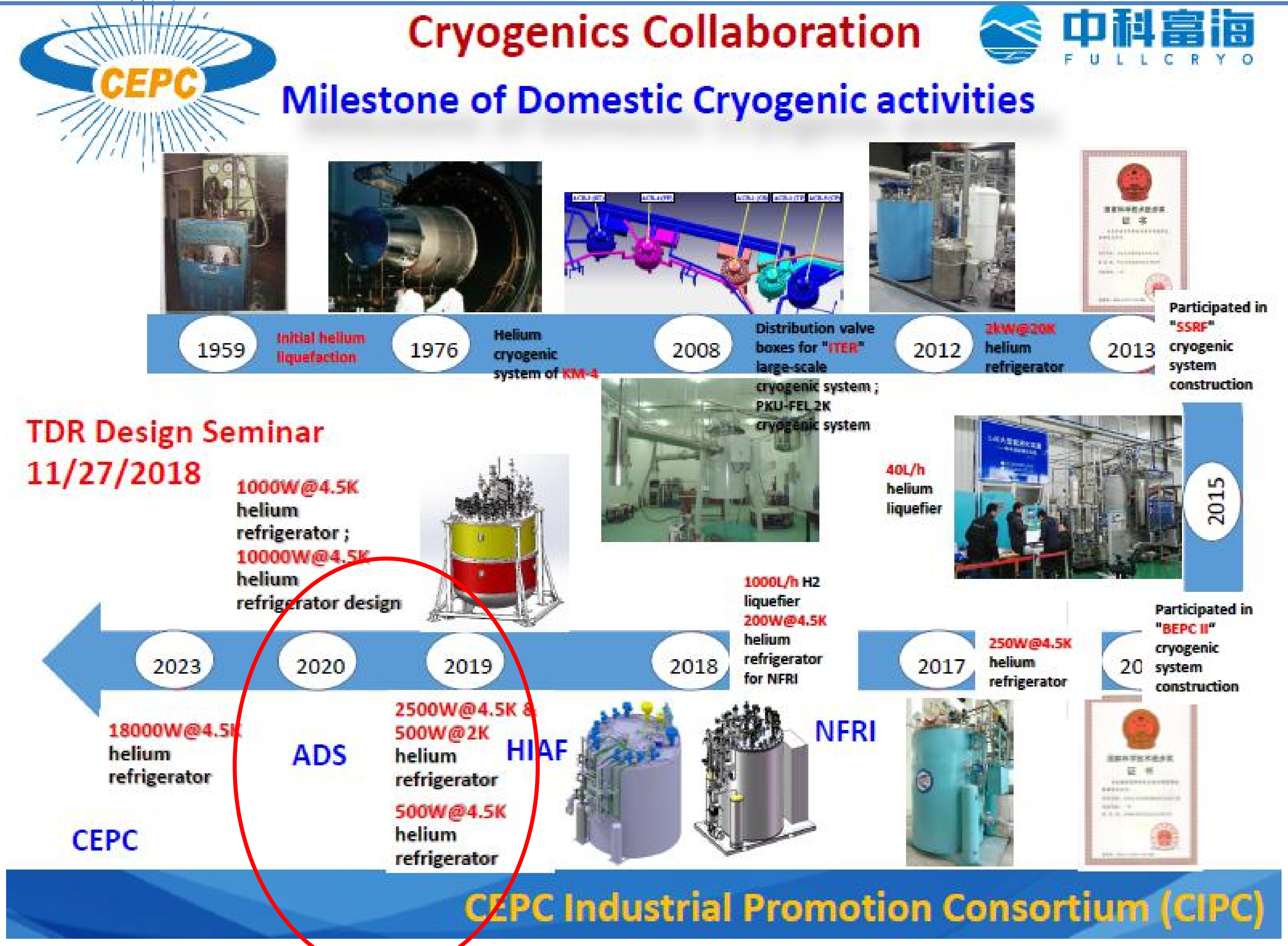
Damping ring 5cell Cavity

Tunner

Damping Ring 5 cell cavity: The The 1.1 GeV damping ring need the RF system provide 2 MV.Two 5 cell constant temperature cavities have recommended and the frequency is 650 MHz. According to the simulation, each cavity can provide 1.2 MV cavity voltage when the cavity consumption is 54 kw

CEPC 18kW@4.5K Cryogenic Plant R&D

Facility: CEPC18kW@4.5K cryogenic plant test facility (lab) is located in Full Cryo company



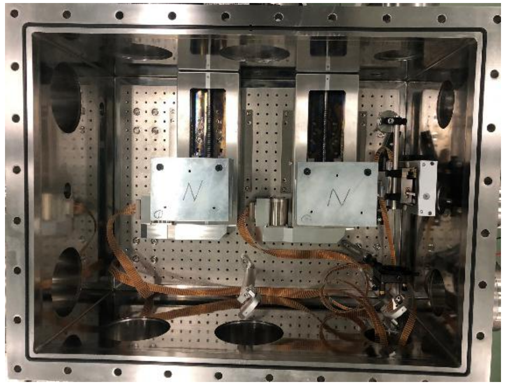
CEPC Plasma Injector Experimental Platform

Facilities: Shanghai S-XFEL facility for electron acceleration and FACETII at SLAC for positron

- Plasma experimental station: preliminary set up on Shanghai Soft XFEL facility

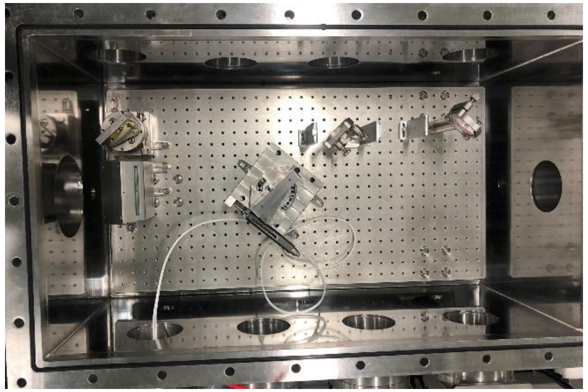
  Vacuum system: installation & testing

  - Light path
  - Beam diagnostic system



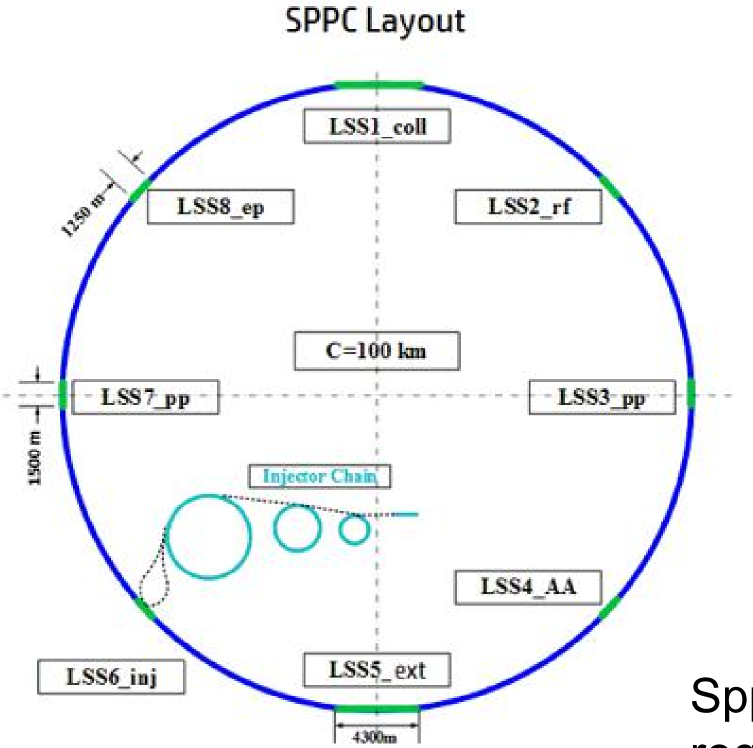
Beam test room

main room

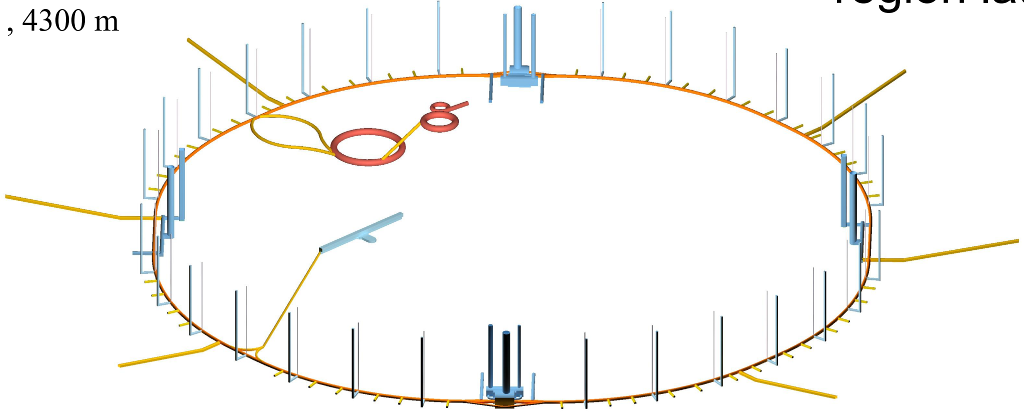


Laser compressor

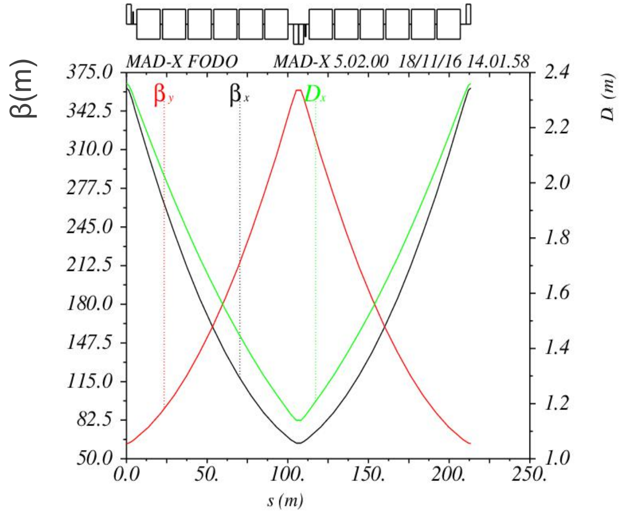
General Layout and Implementation of SppC



- Length of each section at present:
- 8 arcs, total length 83400 m
- 2 IPs for pp, 1500 m each
- 2 IRs for injection or RF, 1250 m each
- 2 IRs for ep or AA, 1250 m each
- 2 IRs for collimation(ee for CEPC ）, 4300 m each
- C = 100 km

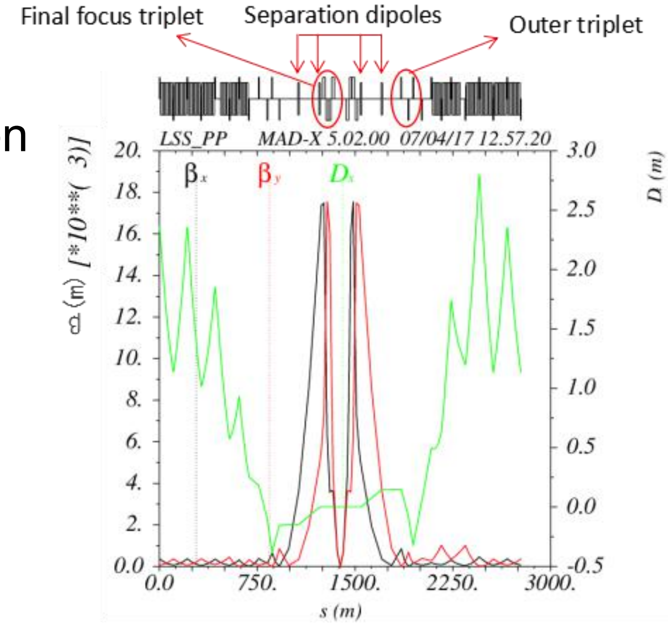


SppC ARC lattice



ARC FODO cell structure

SppC interaction region lattice



LSS_PP(beta*=0.75 m)

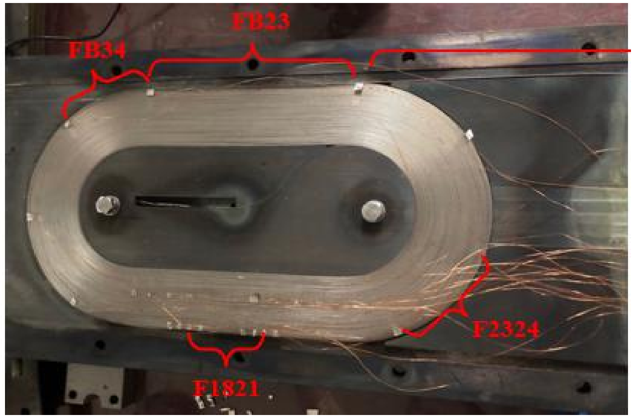
Status of the High Field Dipole Magnet R&D-2

Facility: SppC high field magnets test facility (lab) is located in IHEP of 240m^2

Test of the 1st IBS solenoid coil at 24 T and the 1st IBS racetrack coil at 10 T

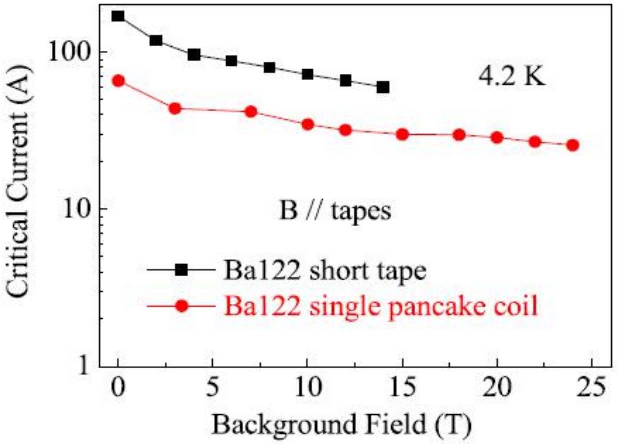
Table 2. Specification of single pancake coil

Parameter	Unit	Value
Inner diameter	mm	30
Outer diameter	mm	34.8
Height	mm	4.62
Thickness of stainless steel tape	mm	0.1
Turns		4.5
Total length of IBS wire	mm	450



Very good performance!

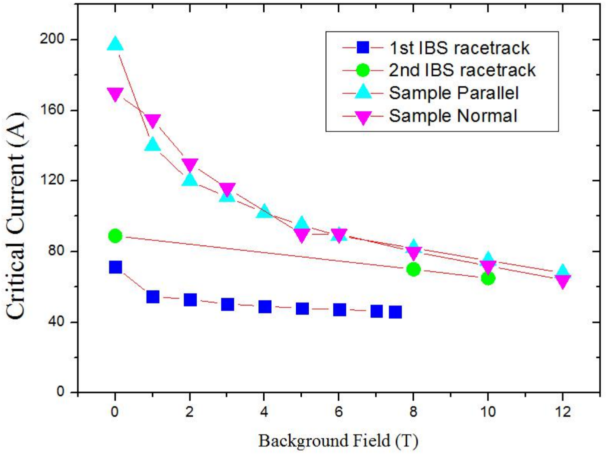
25T-HM, RT bore Φ38 mm



Supercond. Sci. Technol. 32 (2019) 04LT01

Demonstrating that IBS are very promising for high-field magnet applications

Critical Current w.r.t Background Field of IBS Racetracks

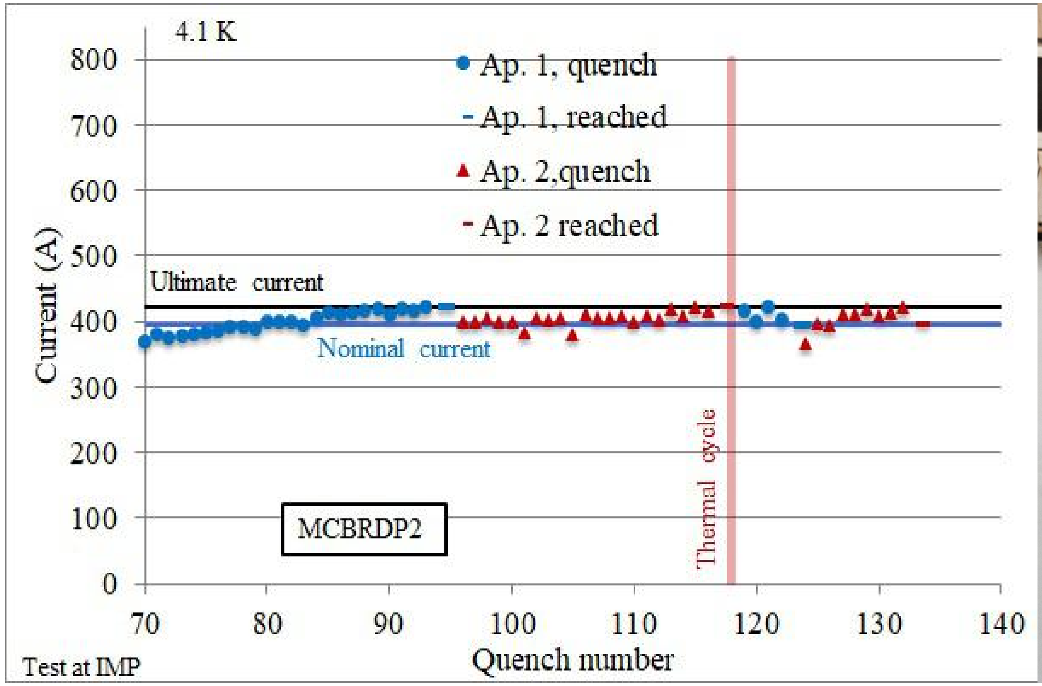


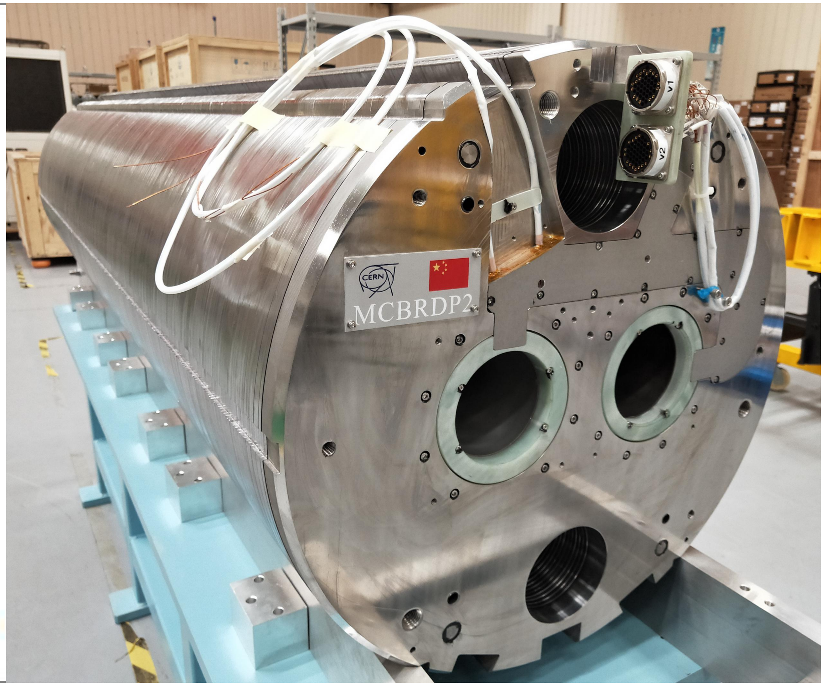
Supercond. Sci. Technol. 2020, in press

China-CERN HL-LHC CCT Project

China will provide 12+1 units CCT superconducting magnets for the HL-LHC project

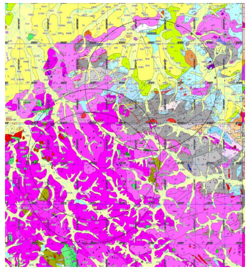
After more than 1 month test and training at 4.2K, both apertures reached the design current and ultimate current, and the field quality is within the limit.

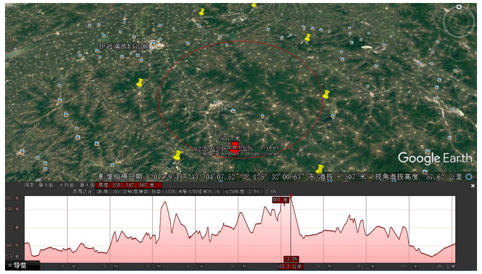




<u>The 1st prototype CCT magnethas been sent to CERN. A good start for the 12 units series production.</u>

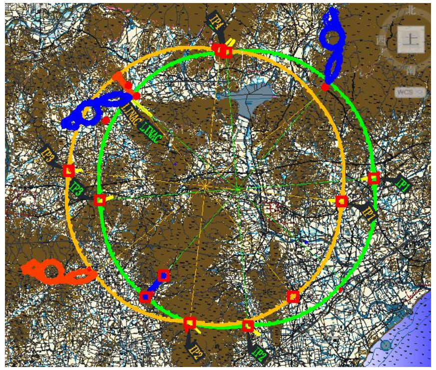
CEPC Site Selection Status





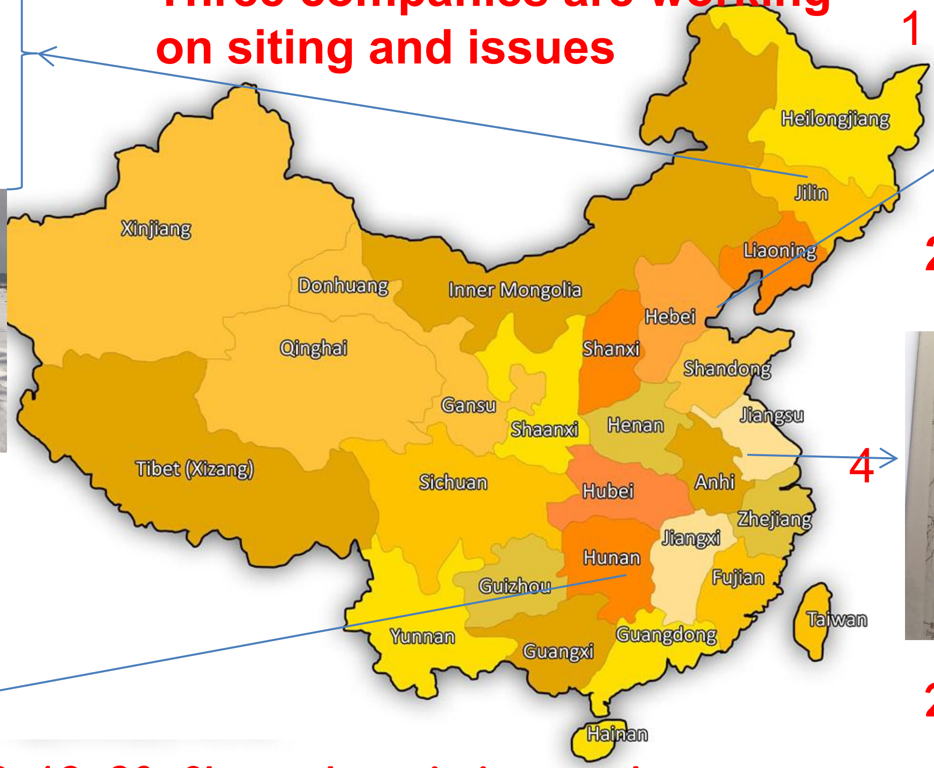
5

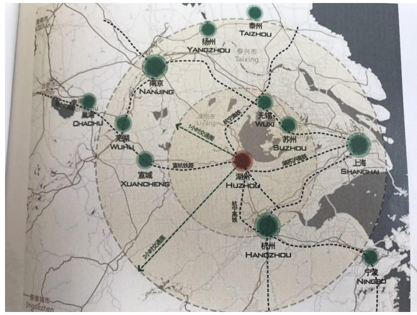
Three companies are working on siting and issues

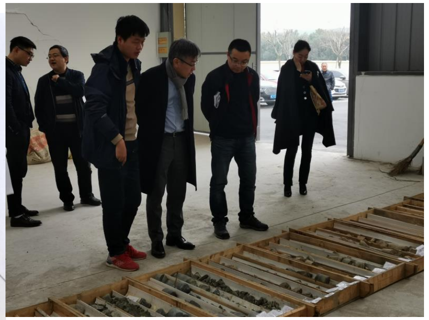


2020.9.14-18 Qinhuangdao updated

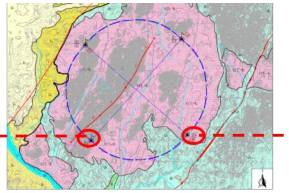
2019.12月8-11 and 2020.1.8-10 Chuangchun sitings update



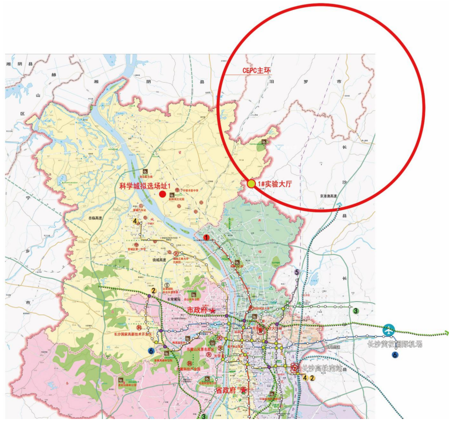




2019.12.16-17 Huzhou siting update



2019.08.19-20 Changsha siting update



1) Qinhuangdao, Hebei Province（Completed in 2014）

2) Huangling, Shanxi Province（Completed in 2017)

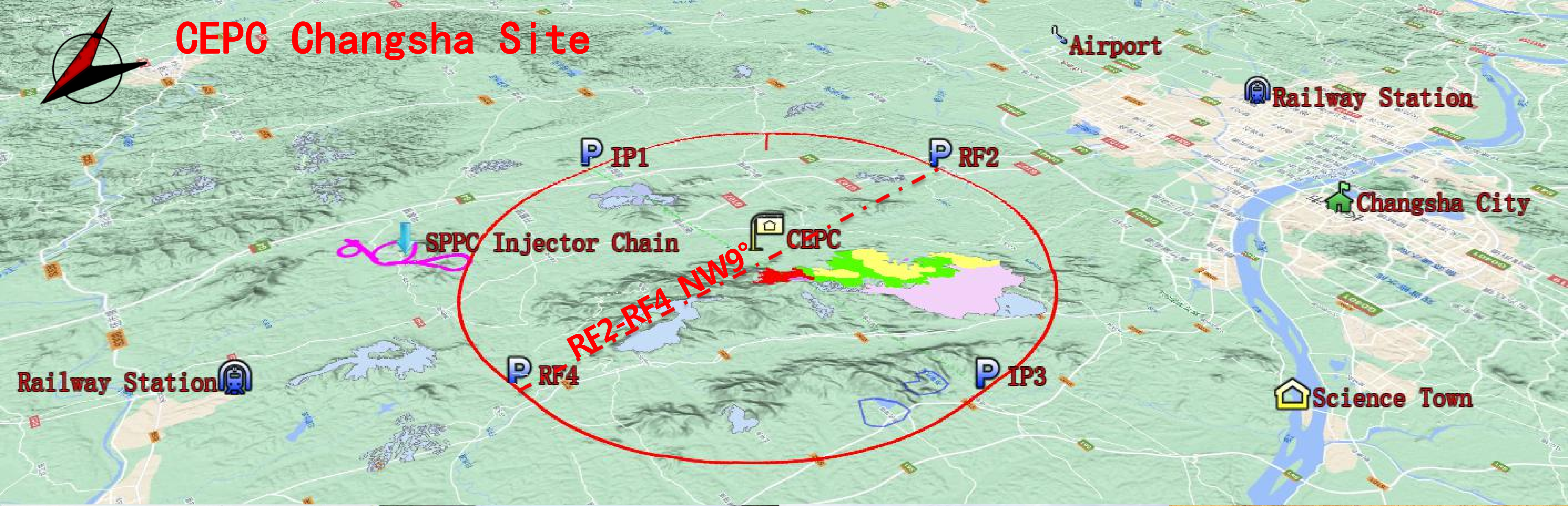
3) Shenshan, Guangdong Province(Completed in 2016)

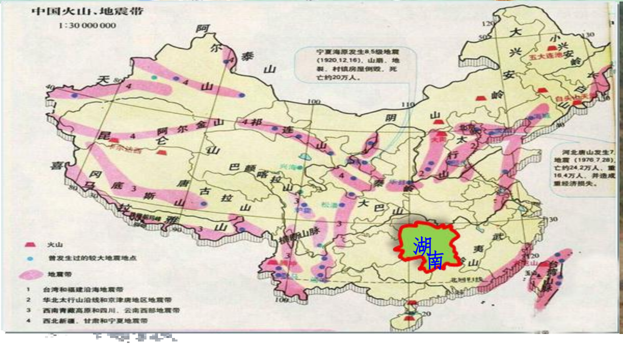
4) Huzhou, Zhejiang Province (Started in March 2018)

5) Chuangchun, Jilin Province (Started in May 2018)

6) Changsha, Hunan Province (Started in Dec. 2018)

The red color sites are more focused


CEPC Changsha Site
Airport
Railway Station
IP1
RF2
Changsha City
SPPC Injector Chain
CEPC
RF2-RF4 NW9°
RF4
IP3
Railway Station
Science Town


中国火山.地震带
1:30 000 000
湖南


151
152
153
2K4-13
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158
159
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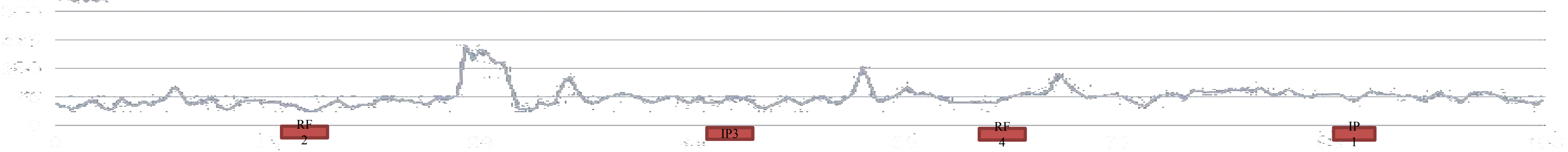
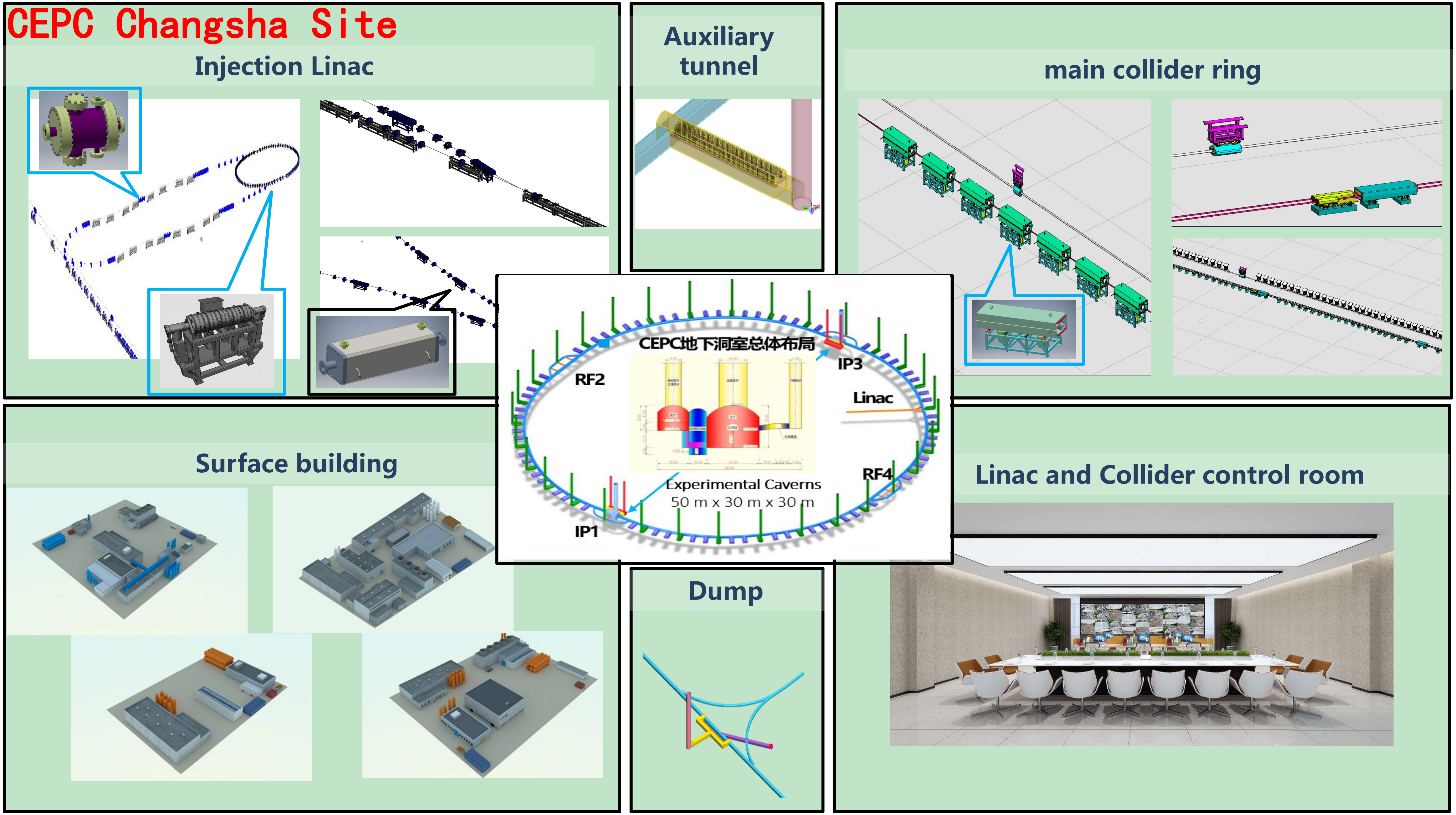
161
2K4-13
162


RF 2
IP3
RF 4
IP 1


CEPC Changsha Site
Injection Linac
Auxiliary tunnel
main collider ring
CEPC地下洞室总体布局
RF2
IP3
Linac
RF4
IP1
Experimental Caverns
50 m x 30 m x 30 m
Surface building
Linac and Collider control room
Dump

CEPC Industrial Promotion Consortium (CIPC) Collaboration Status

Established in Nov. 7 , 2017

Task forces for CEPC and SppC R&D: Institutions such as IHEP +CIPC (>70 companies)

Now:

-Huanghe Company, Huadong Engineering Cooperation Company, and Zhongnan Company on CEPC civil engineering design, site selection, implementation...

-Shenyang Huiyu Company on CEPC MDIRVC design

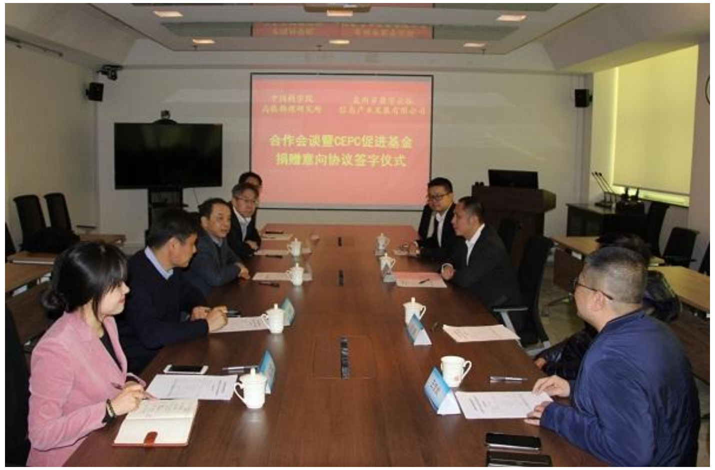
-Keye Compant on CEPC magntes desgins and SC Quadupole, DR cavity, detector hall...

-. Wuhan University: Alignmnent,

-Kuanshan Guoli on CEPC 650MHz high efficiency klystron

-Huadong Engineering Cooperation Company, on CEPC alignement and installation logistics...

-Beijing Pudaditai company: on Alignment and instatation



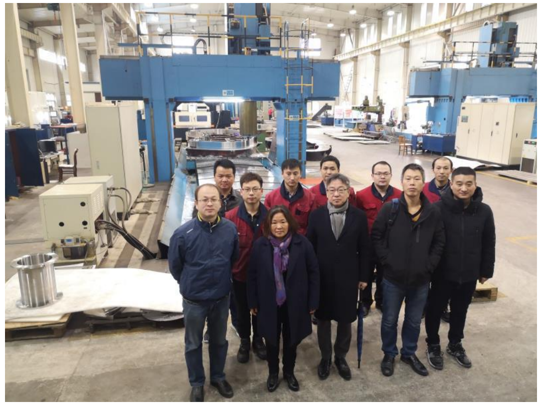
2020. 1. 2

Fujian Digital Valey on information signed CEPC Propmotion Fund Contribution with IHEP

2019. 12. 25-26, Nanchong,
Sichuan Jiutian Vacuum company

2020. 6. 5

Hefei Keye and Beijing Puda Ditai Company signed CEPC Propmotion Fund Contribution with IHEP



2019. 1218-19 visit Keye Company

CEPC-CIPC Collaboratios in CEPC R&D towards TDR

CEPC2020 Program Layout (Day-3)

	Monday (10/26)	Tuesday (10/27)	Wednesday (10/28)
	8:30 – 10:00 ACC, CIPC, HIGGS, Silicon	8:30 – 10:00 ACC, CIPC, BSM, CALO	8:30 – 10:00 Flavor, SOFT
	10:00 – 10:30 Break	10:00 – 10:30 Break	10:30 – 11:00 Break
	10:30 – 12:00 ACC, CIPC, Gas	10:30 – 12:00 ACC, CIPC, QCD, PERF	10:30 – 12:00 MDI, TDAQ
	12:00 – 14:00 Break	12:00 – 14:00 Break	12:00 – 14:00 Break
	14:00 – 16:00 ACC, CIPC, HIGGS, Silicon	14:00 – 16:00 ACC, CIPC, QCD, CALO	14:00 – 16:00 Flavor, TDAQ
	16:00 – 16:30 Break	16:00 – 16:30 Break	16:00 – 16:30 Break
	16:30 – 18:30 ACC, CIPC, SMEW, Gas	16:30 – 18:30 MDI, BSM, SOFT, PERF	16:30 – 18:30 SMEW, BSM
	18:30 – 20:00 Break	18:30 – 20:00 Break	
	20:00 – 23:00 Plenary-I	20:00 – 23:00 Plenary-II	20:00 – 23:00 Plenary-III
	23:00 – 1:00 AM HIGGS + SMEW	23:00 – 24:00 PERF (Discussion)	

40 speakers < 48 speakers

CEPC Accelerator Parallel Session

CIPC Parallel Session on CEPC R&D

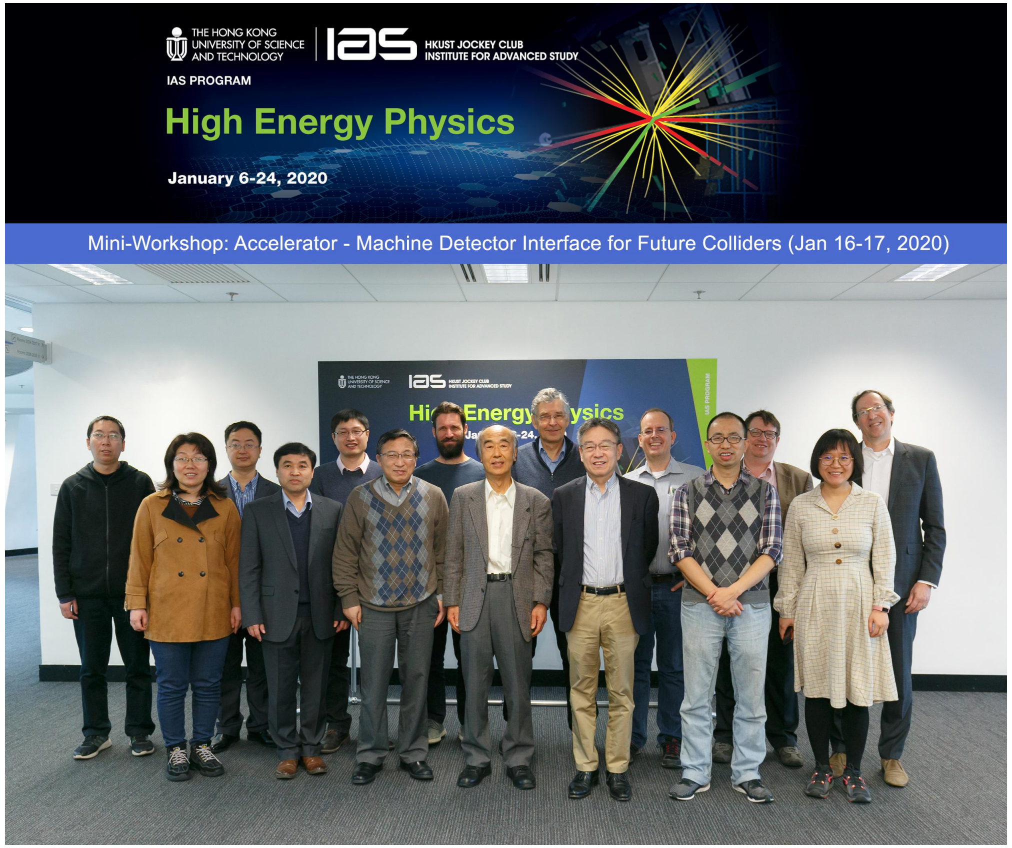
CEPC Conference, Oct. 26-28, 2020, Shanghai, China

https://weidijia.zoom.com.cn/j/62874286168

CEPC International Collaboration Meetings

IAS HEP ConferenceJan. 20-23, 2020 (Since 2015)

Mini-workshop: Accelerator - Machine Detector Interface (**MDI**) for Future Colliders
Dates: Jan 16-17, 2020



For 2021, HKIAS mini workshop on plasma accelerator physics an technologies Jan. 14-15, 2021) and HKIAS HEP conference (Jan. 18-21, 2021) will take place online.

CEPC submissions to Snowmass21

CEPC Input to the ESPP 2018

-Accelerator

CEPC Accelerator Study Group

LOI

Executive summary

The discovery of the Higgs boson at CERN's Large Hadron Collider (LHC) in July 2012 raised new opportunities for a large-scale accelerator. Due to the low mass of the Higgs, it is possible to produce it in the relatively clean environment of a circular electron–positron collider with reasonable luminosity, technology, cost and power consumption. The Higgs boson is a crucial cornerstone of the Standard Model (SM). It is at the center of some of its biggest mysteries, such as the large hierarchy between the weak scale and the Planck scale, the nature of the electroweak phase transition, and many other related questions. Precise measurements of the properties of the Higgs boson serve as excellent tests of the underlying fundamental physics principles of the SM, and they are instrumental in explorations beyond the SM. In September 2012, Chinese scientists proposed a 240 GeV *Circular Electron Positron Collider* (CEPC), serving two large detectors for Higgs studies. The tunnel for such a machine could also host a *Super Proton Proton Collider* (SPPC) to reach energies beyond the LHC.

The CEPC is a large international scientific project initiated and hosted by China. It was presented for the first time to the international community at the ICFA Workshop "*Accelerators for a Higgs Factory: Linear vs. Circular*" (HF2012) in November 2012 at Fermilab. A Preliminary Conceptual Design Report (Pre-CDR, the *White Report*)[1]was published in March 2015, followed by a Progress Report (the *Yellow Report*)[2] in April 2017, where CEPC accelerator baseline choice was made. The Conceptual Design Report (CEPC Accelerator CDR, the *Blue Report*) [3]has been completed in July 2018 by hundreds of scientists and engineers after international review from June 28-30, 2018 and formally released on Sept 2, 2018.

Including SppC and siting

CEPC -Accelerator Technologies to Snowmass2021 AF7

CEPC Accelerator Study Group

Executive summary

The discovery of the Higgs boson at CERN's Large Hadron Collider (LHC) in July 2012 raised new opportunities for a large-scale accelerator. Due to the low mass of the Higgs, it is possible to produce it in the relatively clean environment of a circular electron–positron collider with reasonable luminosity, technology, cost and power consumption. The Higgs boson is a crucial cornerstone of the Standard Model (SM). It is at the center of some of its biggest mysteries, such as the large hierarchy between the weak scale and the Planck scale, the nature of the electroweak phase transition, and many other related questions. Precise measurements of the properties of the Higgs boson serve as excellent tests of the underlying fundamental physics principles of the SM, and they are instrumental in explorations beyond the SM. In September 2012, Chinese scientists proposed a 240 GeV *Circular Electron Positron Collider* (CEPC), serving two large detectors for Higgs studies. The tunnel for such a machine could also host a *Super Proton Proton Collider* (SPPC) to reach energies beyond the LHC.
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Technologies

Collider Design
SCRF
Klystron
Linac+plasma
accelerator injector
Cost

Summary

- CEPC accelerator R&D efforts towards TDR progress well such as optimization design, klystron, SCRF, magnets, vacuum system, etc. with the aim to complet TDR at the end of **2022**
- **CEPC and SppC key technologies R&D have correspongding test facilities**
- **CIPC (> 70 companies) is an important task force for both CEPC and SppC in addition to institution and univerity ones...**
- **CEPC siting and civil engineering designs are in progress**
- **CEPC LOI and CEPC Technologies** for **AF** of Snowmass21 have been submitted online on June 29, 2020 at: https://www.snowmass21.org/docs/files/?dir=summaries/AF

Thanks go to CEPC-SppC team, CIPC and international partners and colleageus