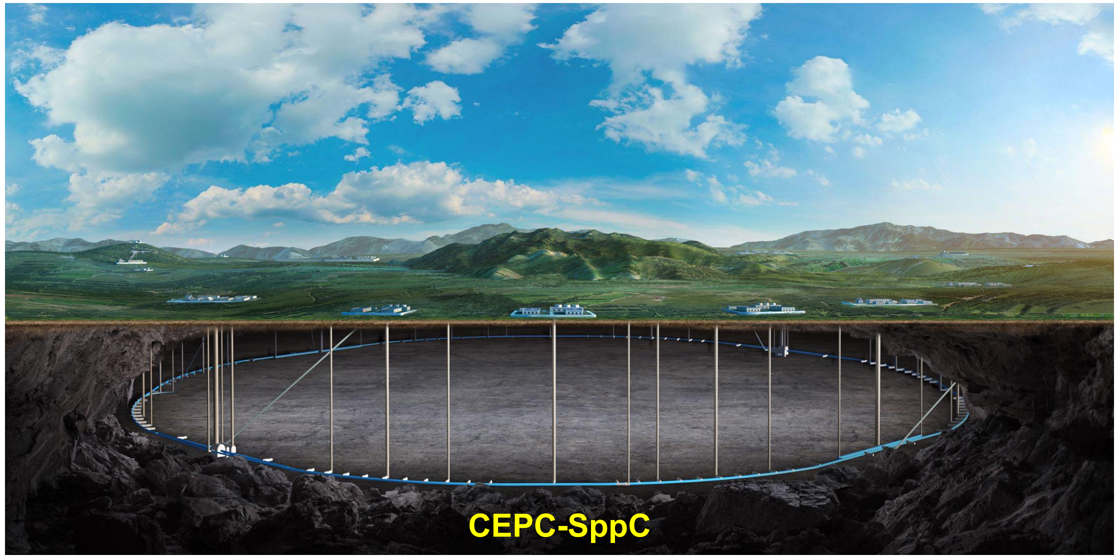
Status of CEPC and SppC

J. Gao

Institute of High Energy Physics

KAIST-KAIX Workshop for Future Particle Accelerators

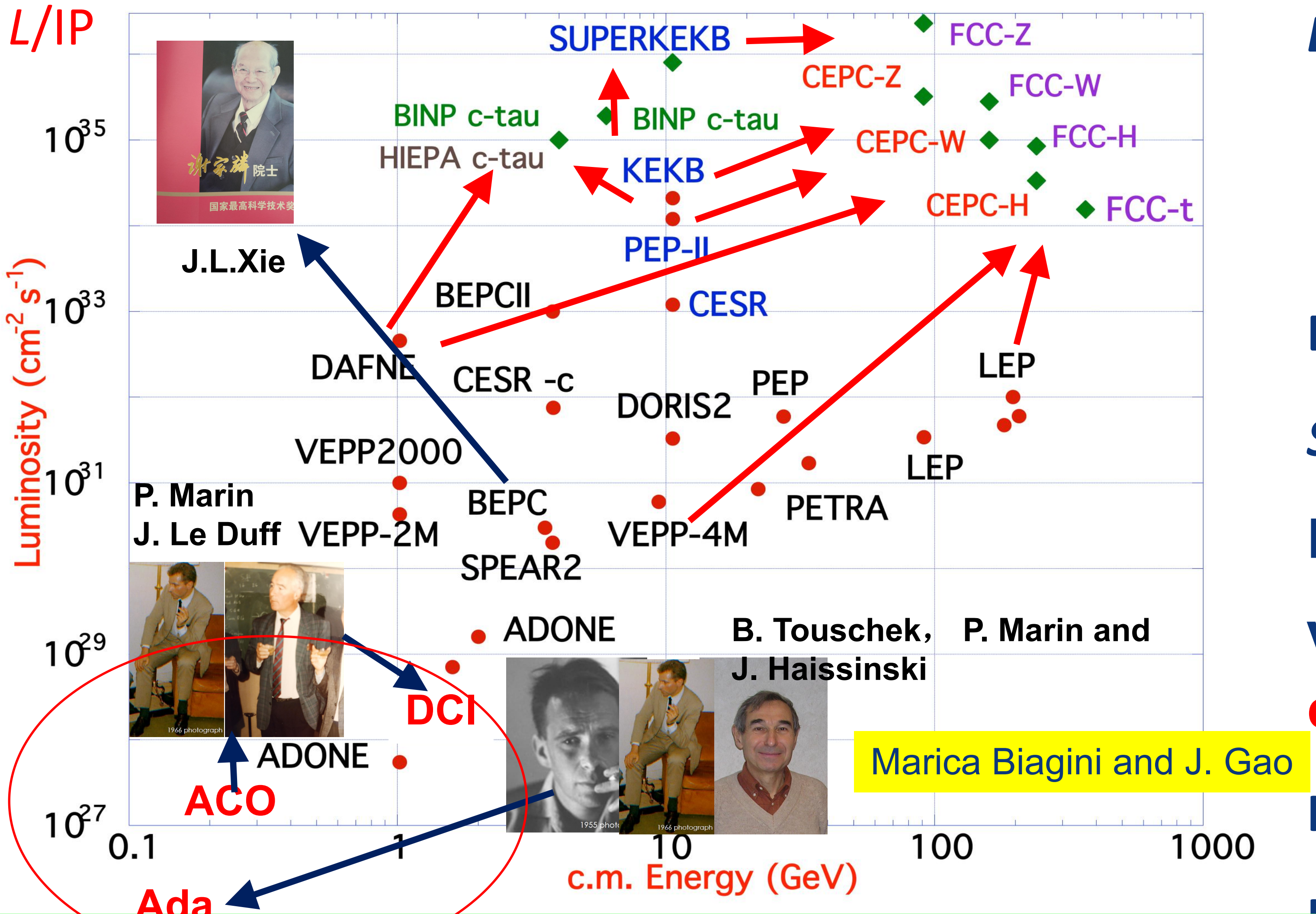
July 8-19, 2019, Daejeon, Korea



Outline

- Historical review of e+e- circular coliders
- Circular e+e- collider design principles
- CEPC status
- SppC status
- CEPC-SppC R&D
- CEPC-SppC siting and civil engineering
- Summary

Future circular lepton factories based on proven concepts and techniques from past colliders and light sources



B-factories: **KEKB & PEP-II:**
- **double-ring lepton colliders,**
- **high beam currents,**
- **top-up injection**

DAFNE: crab waist, double ring

Super B-factories, **S-KEKB: low β_y^***

LEP: high energy, SR effects

VEPP-4M, LEP: precision E calibration

KEKB: *e^+* source

HERA, LEP, RHIC: spin gymnastics

combining successful ingredients of several recent colliders → highest luminosities & energies

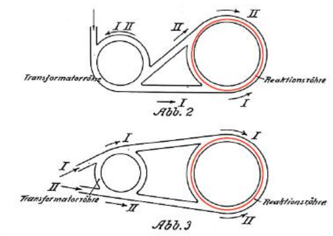
Historical Review-1 (Ada)

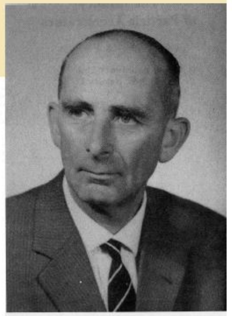
J. Haissinski, “A historical account of the first electron positron circular collider-Ada”

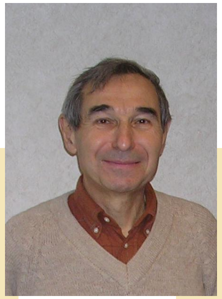
IHEP Seminar, Oct. 9, 2018

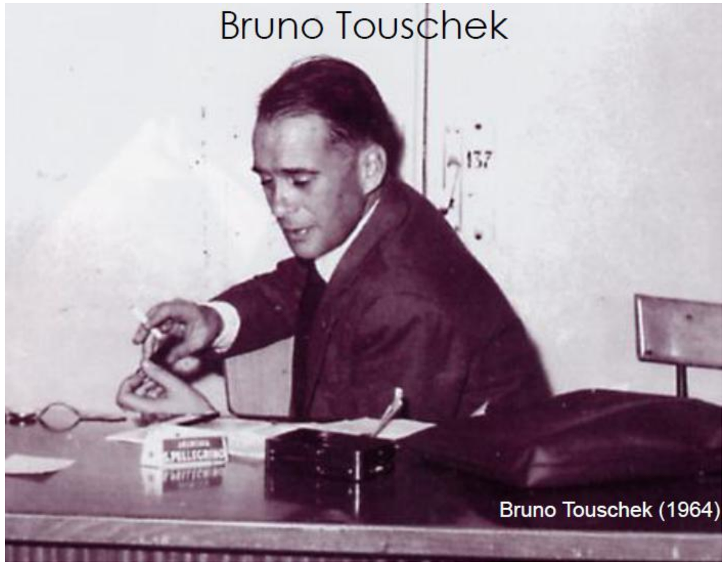
Rolf Wideröe 1902-1996

1943: secret patent of a ‘nuclear mill’ (published in 1953)




Rolf Wideröe





Bruno Touschek (1964)

p-p vs e-e- vs e+e- colliders

Each kind of colliders gives access to quite different physics:

- p-p New particle searches thanks to the high energy reach
- e-e- QED validity limits (electron size, photon propagator)
- e+e- annihilation Adjustable energy deposition in vacuum which allows one to study vacuum excitations → spin-1 boson searches and study.

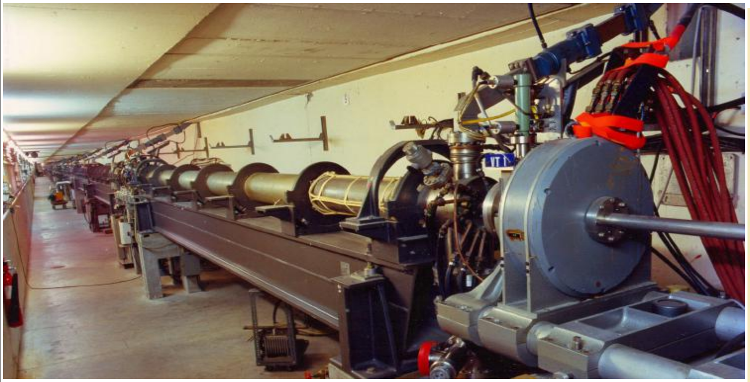
The technologies involved are quite different too

Main parameters of AdA

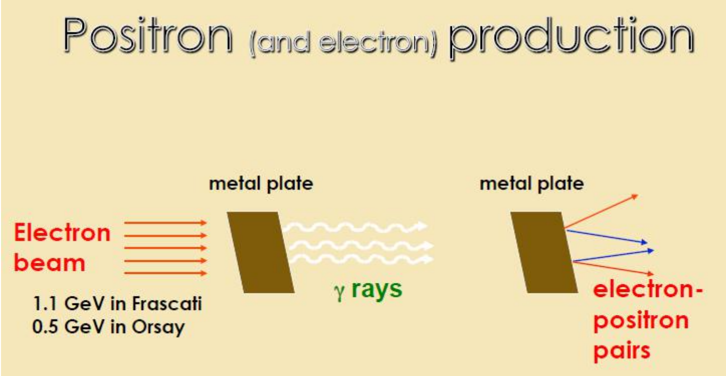
Parameter	Typical operation value	Units
Energy per beam	200	MeV
Circumference	4	m
Luminosity	$\sim 10^{25}$	$cm^{-2}\ s^{-1}$
Beam current, per beam	0.5	mA
Injector (linac) energy	500	MeV
Max field on the orbit	1.45	T
Field index (dB/B)/(dr/R)	0.54	
Vacuum pressure	1	nTorr
RF peak voltage	5.5	kV

Historical Review-2 (Ada) (1962-1964)

Touschek effect first found in Ada

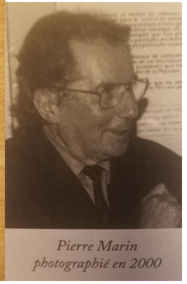


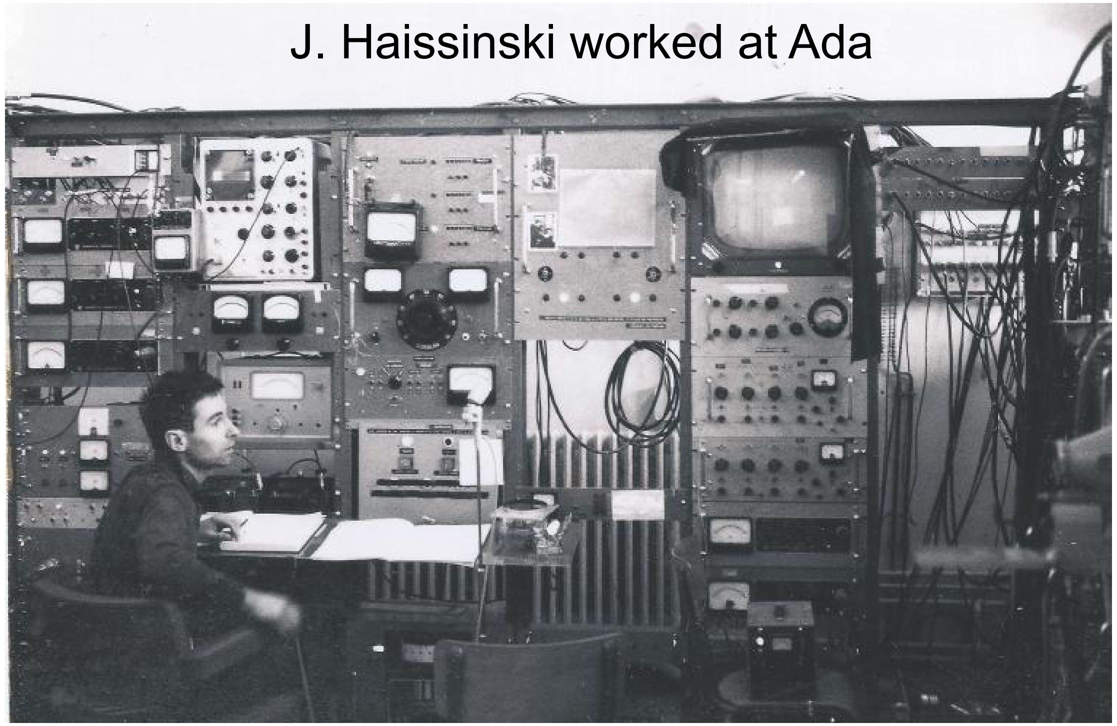
Linac at LAL/Orsay



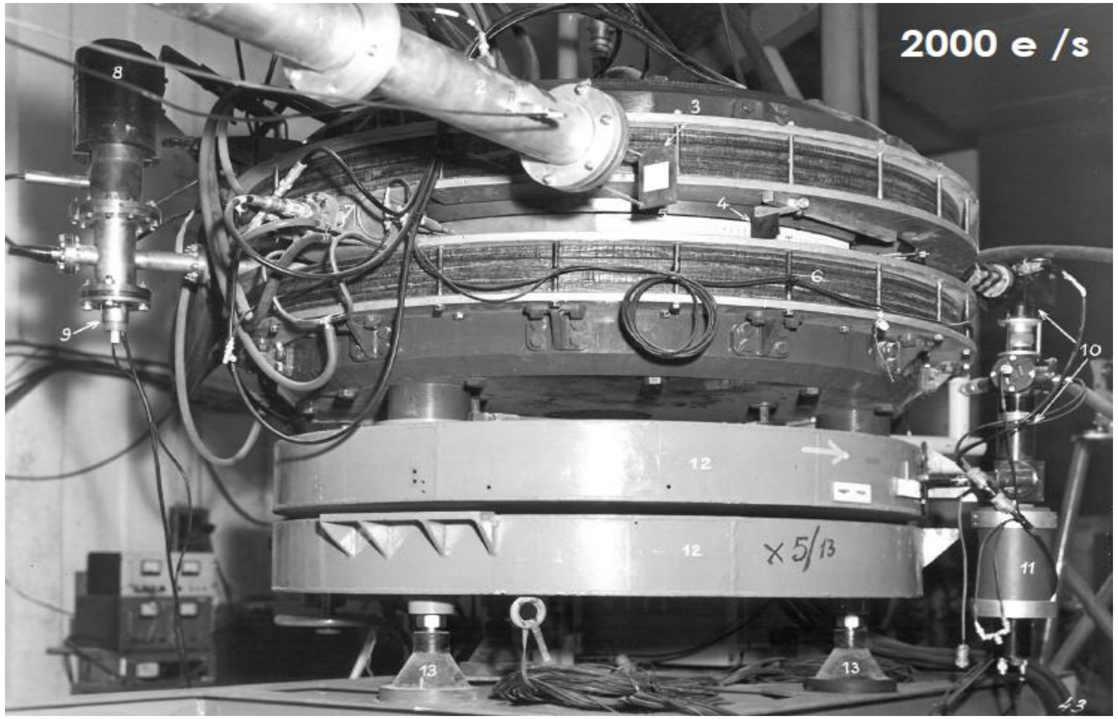
P. Marin and J. Haissinski

Book by P. Marin





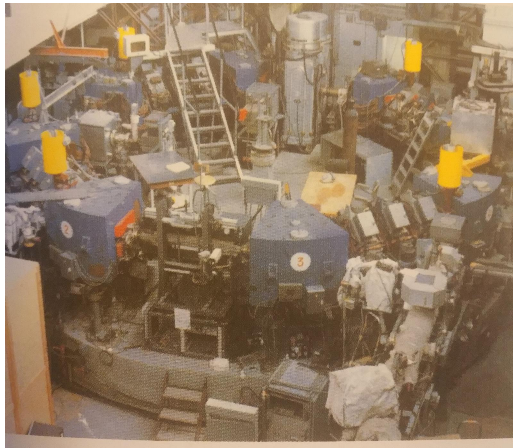
J. Haissinski worked at Ada



Ada at LAL

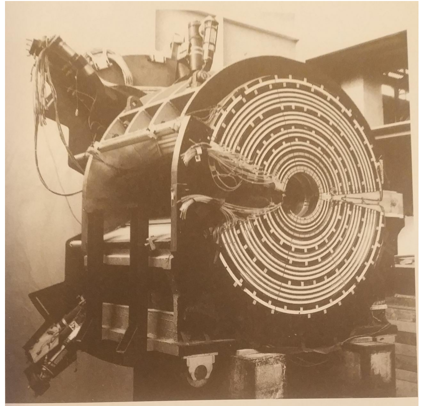
Historical Review-3 (ACO)

(1962-1975)

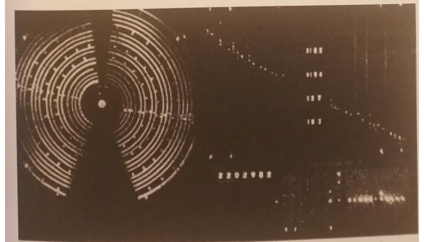


Vue d'ACO et d'un dispositif expérimental

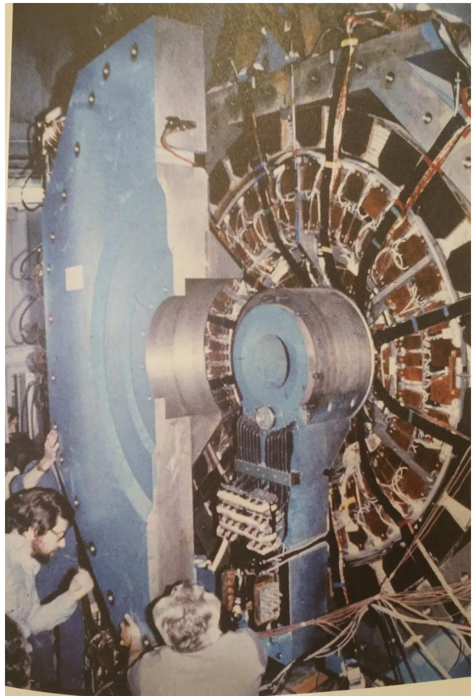
Devant le pupitre de la salle d'injection d'ACO quelques pionniers des anneaux de stockage en France



Détecteur à grand angle solide Φ3C sur ACO, 1971



Événement $e^+e^- \longrightarrow e^+e^-$ de l'expérience Φ3C sur ACO, 1971



Expérience DMA sur ACO, 1974

The first beam-beam tune shift limitation found in the world

The first diople magnet detector and antisolenoid

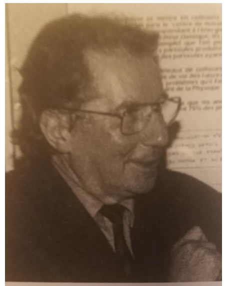
The first using sextupoles to correct chromaticity

The first observation experimentally electron and positron polarisation

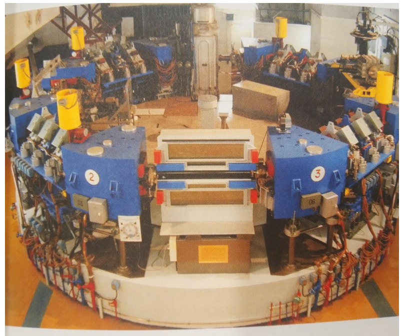
The first observation of bunch lengthening

....

P. Marin



Pierre Marin photographié en 2000



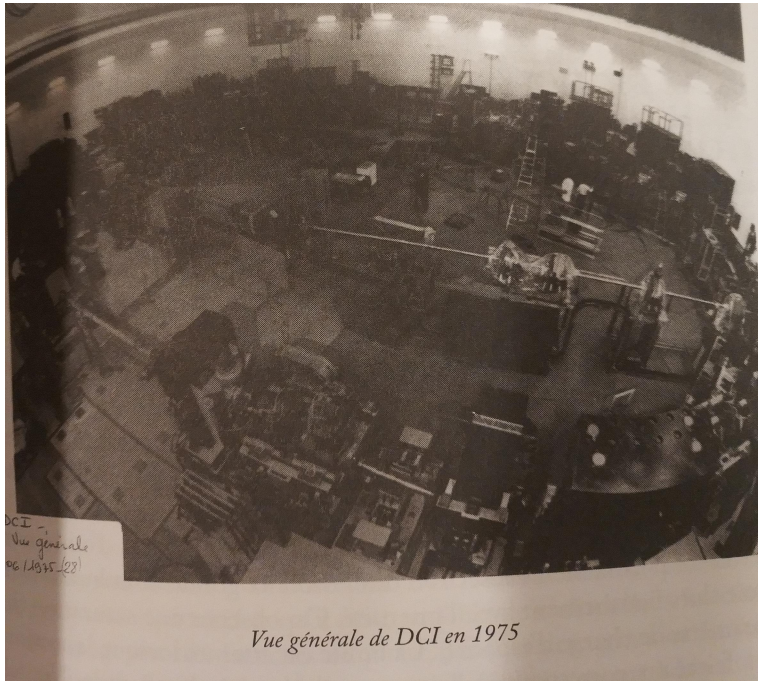
ACO en 2004

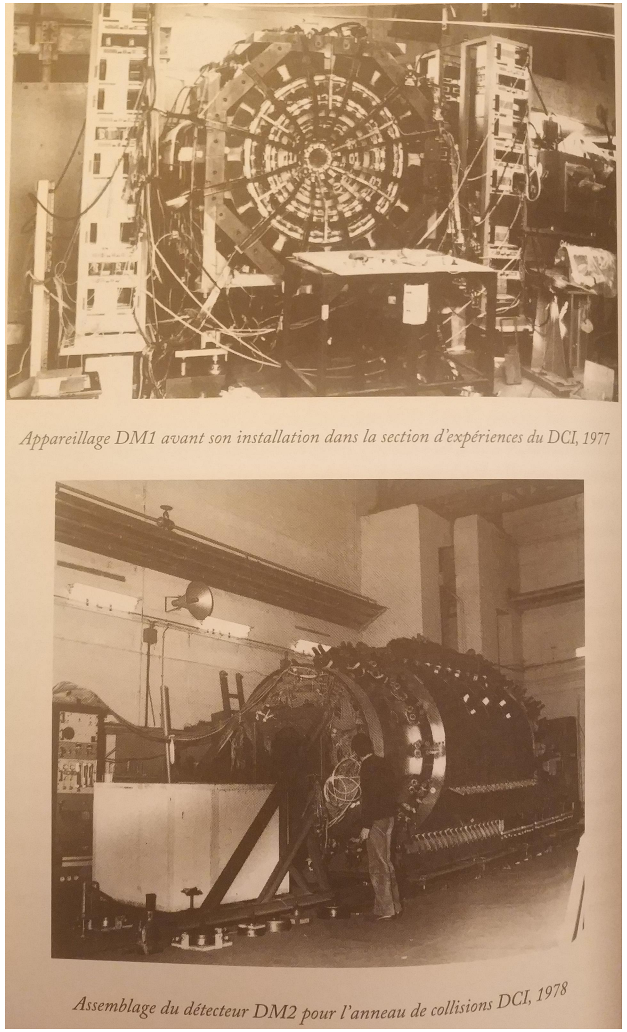
The book of P. Marin was published with the help of ACO Association after P. Marin passed away in 2003

ACO as a museum in LAL, Orsay

Historical Review-4 (CDI)

(1971-1985)





The first two ring electron positron collider in the world

The first experiments on four beam collision to compensate beam-beam effects

The first individual sextupoles to correct chromaticity

....

J. Gao from 1989-2005 at LAL, In2p3/CNRS, Orsay, France

2004 in the office of Prof. J. Haissinski, LAL, Orsay, France

Physics Goals of CEPC-SppC

- 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, t 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

Precision measurement + searches:
Complementary with each other !

Luminosity from Colliding Beams

- **For equally intense Gaussian beams**

Collision frequency

Particles in a bunch

$$L = f \frac{N_b{}^2}{4\pi\sigma_x\sigma_y} R$$

Geometrical factor:
- crossing angle
- hourglass effect

Transverse beam size (RMS)

- **Expressing luminosity in terms of our usual beam parameters**

$$L[\mathrm{cm}^{-2}\mathrm{s}^{-1}] = 2.17\times10^{34}(1+r)\xi_y \frac{E[\mathrm{GeV}]I[\mathrm{A}]}{\beta_y[\mathrm{cm}]}$$

In ACO it is found that ξ_y has a maximum value

where

$$\xi_y = \frac{r_e N_e \beta_y}{2\pi\sigma_y(\sigma_x + \sigma_y)}$$:

For exampe, for DCI at 800MeV $\xi_y = 0.024$

Analyical expression for the maximum value of $\xi_{y,max}$ is the keystone of a circular collider both for lepton and hadron one

$$\xi_y = \frac{r_e N_e \beta_y}{2\pi\sigma_y(\sigma_x + \sigma_y)}$$

Maximum Beam-beam tune shift analytical expressions for lepton and hadron circular colliders

For example: BEPCII@ 1.89GeV $\xi_y = 0.04$

For lepton collider:

$$\xi_{y,\max} = \frac{2845}{2\pi}\sqrt{\frac{T_0}{\tau_y \gamma N_{IP}}} \qquad \xi_{y,\max} = \frac{2845\gamma}{1}\sqrt{\frac{r_e}{6\pi R N_{IP}}}$$

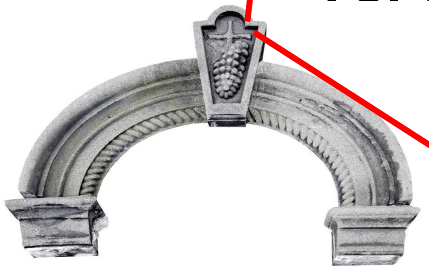
r_e is electron radius
γ is normalized energy
R is the dipole bending radius
N_{IP} is number of interaction points

$$\xi_{x,\max} = \sqrt{2}\xi_{y,\max}$$

J. Gao, **Nuclear Instruments and Methods in Physics Research A** 533 (2004) 270–274

J. Gao, Nuclear Instruments and Methods in Physics Research A 463 (2001) 50–61

For hadron collider:



Keystones

$$\xi_{\max} = \frac{2845\gamma}{f(x)}\sqrt{\frac{r_p}{6\pi R N_{IP}}}$$

where r_p is proton radius

$$f(x) = 1 - \frac{2}{\sqrt{2\pi}}\int_0^x \exp\left(-\frac{t^2}{2}\right)dt$$

$$x^2 = \frac{4f(x)}{\pi\xi_{\max}N_{IP}} = \frac{4f^2(x)}{2845\pi\gamma}\sqrt{\frac{6\pi R}{r_p N_{IP}}}$$

J. Gao, “Review of some important beam physics issues in electron positron collider designs”, **Modern Physics Letters A**, Vol. 30, No. 11 (2015) 1530006 (20 pages)

J. Gao, et al, "Analytical estimation of maximum beam-beam tune shifts for electron-positron and hadron circular colliders", Proceedings of ICFA Workshop on High Luminosity Circular e+e- Colliders – Higgs Factory, 2014

For example: SppC@ 75TeV $\xi_y = 0.0056$

Constraints for parameter choice

- Limit of Beam-beam tune shift

$$\xi_y = \frac{2845}{2\pi}\sqrt{\frac{U_0}{2\gamma E_0 N_{IP}}} \times F_l *$$

F_l: ξy enhancement by crab waist

J. Gao*

- Beam lifetime due to beamstrahlung

BS life time: 30 min

$$\frac{N_e}{\sigma_x \sigma_z} \le 0.1\eta \frac{\alpha}{3\gamma r_e^2}$$

1) V. Telnov, arXiv:1203.6563v, 29 March 2012
2) V. Telnov, HF2012, November 15, 2012

- Beamstrahlung energy spread

A=δ_0/δ_{BS} (A≥3)

- Beam currect limited by either radiation power or by HOM power per cavity

$$P_{HOM} = k(\sigma_z) e N_e * 2 I_b \le 2KW$$

*1) J. Gao, emittance growth and beam lifetime limitations due to beam-beam effects in e+e- storage rings, **Nucl. Instr. and methods A**533（2004）p. 270-274.

* 2) J. Gao, Review of some important beam physics issues in electron positron collider designs, **Modern Physics Letters A**, Vol. 30, No. 11 (2015) 1530006 (20 pages)

3) D. Wang, J. Gao, et al, Optimization parameter design of a circular e+e- Higgs factory, **Chinese Physcis C**, Vol. 40, No. 1 (2016) 017001-017007

4) D. Wang. J. Gao, eta al, Optimization parameter design of a circular e+e- collider with crab-waist, to be submitted to **Chinese Physcis C**

Basic theroy of dynamic aperture in circular accelerator-1

Linear Habiltonion +nonlinear perriodic kicks

$$H = \frac{p^2}{2} + \frac{K(s)}{2}x^2 + \frac{1}{m!B_0\rho}\frac{\partial^{m-1}B_z}{\partial x^{m-1}}x^m L\sum_{k=-\infty}^{\infty}\delta(s-kL)$$

Circular machine

A nonlinear multipole

Beam-beam effects, sextupoles,octupoles, wigglers, space charge effects...

$$B_z = B_0(1 + xb_1 + x^2b_2 + x^3b_3 + \cdots + x^{m-1}b_{m-1} + \cdots)$$

For one multipole $B_z = B_0 x^{m-1} b_{m-1}$ m≥3

$$\Psi = \int_0^s \frac{ds'}{\beta_x(s')} + \phi_0$$

$$J = \frac{\varepsilon_x}{2} = \frac{1}{2\beta_x(s)}\left(x^2 + \left(\beta_x(s)x' - \frac{\beta'_x x}{2}\right)^2\right)$$

$$H(J,\Psi) = \frac{J}{\beta_x(s)}.$$

$$\Psi_1 = \Psi + \frac{2\pi v}{L} - \int_0^s \frac{ds'}{\beta_x(s')}$$

$$J_1 = J$$

$$H_1 = \frac{2\pi v}{L}J_1.$$

$$I = \frac{x^2 B_y|_{x=0,y=0}}{2\rho^2 B_0} + \frac{1}{B_0\rho}\sum_{n=1}^{\infty}\frac{1}{n!}\frac{\partial^{n-1}B_y}{\partial x^{n-1}}\bigg|_{x=0,y=0}(x+iy)^n - (1+x/\rho)\left(1+\frac{\Delta P}{P_0} - \left(\bar{p}_x - \frac{eA_x}{P_0}\right)^2 - \left(\bar{p}_y - \frac{eA_y}{P_0}\right)^2\right)^{1/2} - \frac{e\Phi}{P_0}$$

Analytical treatment of dynamics aperture is the basestone to understand the performance of circular accelerators

$$x = \sqrt{2J_1\beta_x(s)}\cos\left(\Psi_1 - \frac{2\pi v}{L}s + \int_0^s \frac{ds'}{\beta_x(s')}\right).$$

$$\frac{dJ_1}{ds} = -\frac{\partial H_1}{\partial \Psi_1}$$

$$\frac{d\Psi_1}{ds} = \frac{\partial H_1}{\partial J_1}$$

$$\overline{J_1} = \overline{J_1}(\Psi_1, J_1)$$

$$\overline{\Psi_1} = \overline{\Psi_1}(\Psi_1, J_1)$$

$$\bar{I} = I + K_0\sin\theta$$

$$\bar{\theta} = \theta + \bar{I}$$

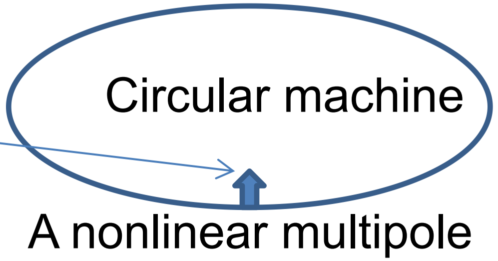
$|K_0| \le 1$ (0.97164) Analytical DA expressions

J. Gao, "Analytical estimation of the dynamic apertures of circular accelerators", **Nuclear Instruments and Methods in Physics Research A** 451 (2000) 545-557.

Basic theroy of dynamic aperture in circular accelerator-2

$$H = \frac{p^2}{2} + \frac{K(s)}{2}x^2 + \frac{1}{m!B_0\rho}\frac{\partial^{m-1}B_z}{\partial x^{m-1}}x^m L \sum_{k=-\infty}^{\infty}\delta(s-kL)$$

$$B_z = B_0(1 + xb_1 + x^2b_2 + x^3b_3 + \cdots + x^{m-1}b_{m-1} + \cdots)$$



Dynamic aperture analytical expressions are basestones for circular accelerators

For one multipole $B_z = B_0 x^{m-1} b_{m-1}$ m≥3

$$A_{\mathrm{dyna},2m} = \sqrt{2\beta_x(s)}\left(\frac{1}{m\beta_x^m(s(2m))}\right)^{\frac{1}{2(m-2)}}\left(\frac{\rho}{|b_{m-1}|L}\right)^{1/(m-2)}$$

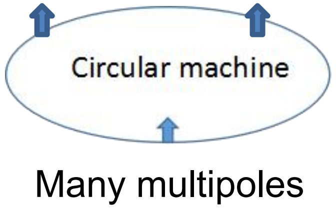
Standard Mapping
Chirikov Criterion

DA relation between X and Y $A_{\mathrm{dyna},2m,y} = \sqrt{\frac{\beta_x(s(2m))}{\beta_y(s(2m))}(A^2_{\mathrm{dyna},2m,x} - x^2)}$

Hénon and Heiles problem

For more independent multipoles

$$A_{\mathrm{dyna,total}} = \frac{1}{\sqrt{\sum_i \frac{1}{A^2_{\mathrm{dyna,sext},i}} + \sum_j \frac{1}{A^2_{\mathrm{dyna,oct},j}} + \sum_k \frac{1}{A^2_{\mathrm{dyna,deca},k}} + \cdots}}$$



J. Gao, "Analytical estimation of the dynamic apertures of circular accelerators", **Nuclear Instruments and Methods in Physics Research A** 451 (2000) 545-557.

CEPC Status

CEPC Accelerator Chain and Systems

10 GeV

1) Injector

L=1.2km

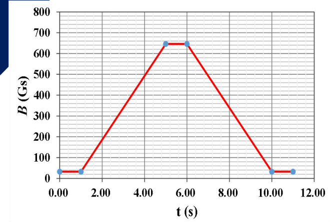
Electron

Positron

2) Booster

C=100km

Energy Ramp
10 ->45/120GeV



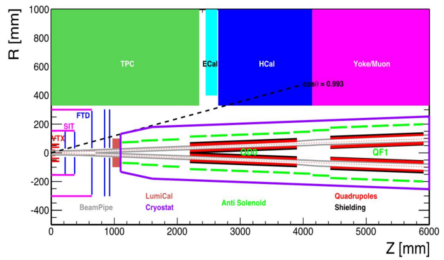
Booster Cycle (0.1 Hz)

Three rings in the same channel：
- **CEPC & booster**
- **SppC**

3) Main Ring

C=100km
2IP

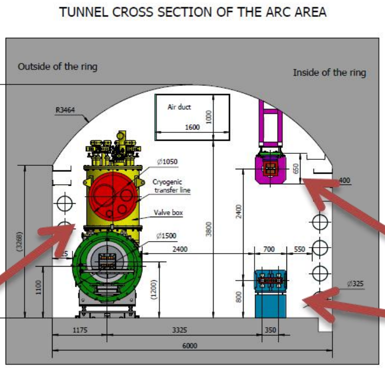
45/120 GeV



4) Detector Machine Interface (MDI)

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

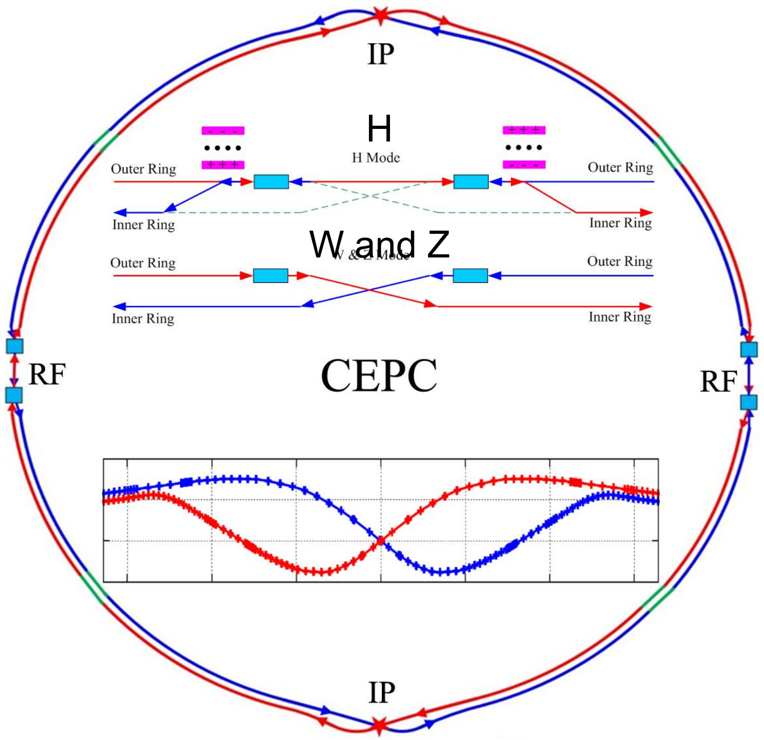
5) Civil Eng.



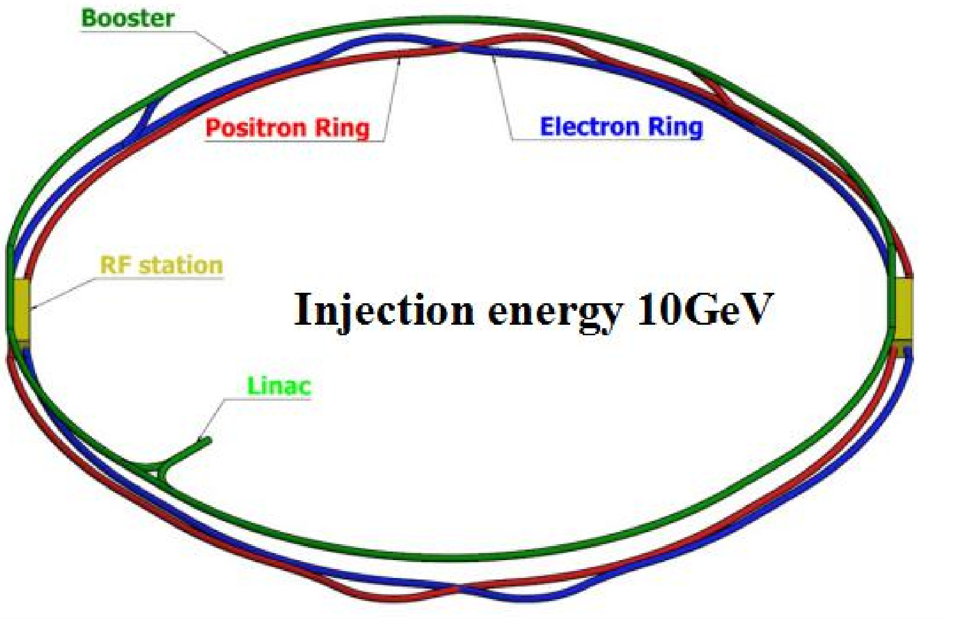
SppC

CEPC Booster
CEPC Collider

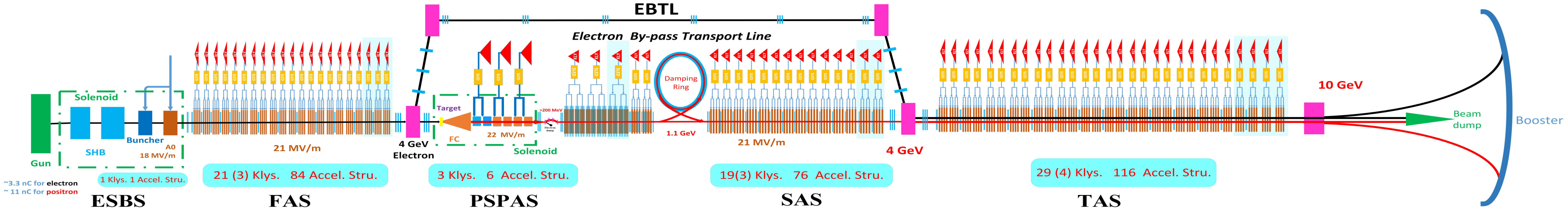
CEPC CDR Baseline Layout



CEPC collider ring (100km)



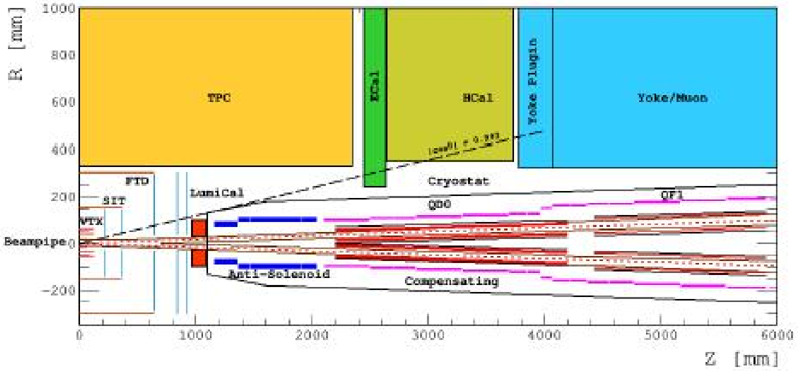
CEPC booster ring (100km)



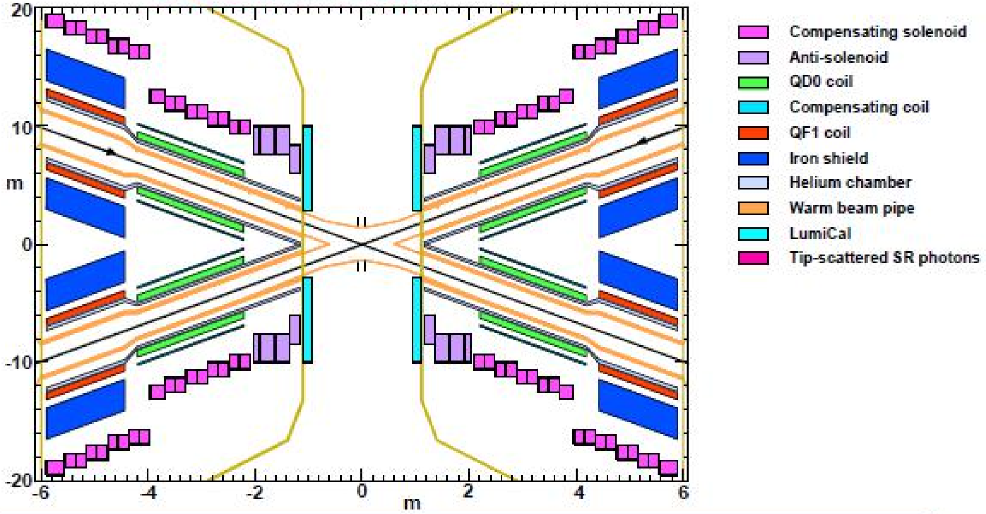
CEPC Linac injector (1.2km, 10GeV)

CEPC MDI Layout and Parameters

With Detector solenoid



Without Detector solenoid
~cryostat in detail



- 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.

- The Machine Detector Interface (MDI) of CEPC double ring scheme is about ±7m long from the IP
- The CEPC detector superconducting solenoid with 3T magnetic field and the length of 7.6m.

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 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**

CEPC New Parameters for Higgs

	tt	*Higgs*	*W*	*Z*（*3T*）	*Z*（*2T*）
Number of IPs	2				
Beam energy (GeV)	**175**	**120**	**80**	**45.5**	
Circumference (km)	100				
Synchrotron radiation loss/turn (GeV)	7.61	1.68	0.33	0.035	
Crossing angle at IP (mrad)	16.5×2				
Piwinski angle	0.91	3.78	8.5	27.7	
Number of particles/bunch N_e (10^{10})	24.15	17.0	12.0	8.0	
Bunch number (bunch spacing)	**34 (4.9μs)**	**218 (0.76μs)**	**1568 (0.20μs)**	**12000 (25ns+10%gap)**	
Beam current (mA)	3.95	17.8	90.4	461.0	
Synchrotron radiation power /beam (MW)	**30**	**30**	**30**	**16.5**	
Bending radius (km)	10.7				
Momentum compact (10^{-5})	0.91				
β function at IP β_x^* / β_y^* (m)	1.2/0.0037	**0.33/0.001**	**0.33/0.001**	**0.2/0.001**	
Emittance $\varepsilon_x/\varepsilon_y$ (nm)	2.24/0.0068	0.89/0.0018	0.395/0.0012	0.13/0.003	0.13/0.00115
Beam size at IP σ_x/σ_y (μm)	51.8/0.16	17.1/0.042	11.4/0.035	5.1/0.054	5.1/0.034
Beam-beam parameters ξ_x/ξ_y	0.077/0.105	0.024/0.113	0.012/0.1	0.004/0.053	0.004/0.085
RF voltage V_{RF} (GV)	8.93	2.4	0.43	0.082	
RF frequency f_{RF} (MHz) (harmonic)	650 (216816)				
Natural bunch length σ_z (mm)	2.54	2.2	2.98	2.42	
Bunch length σ_z (mm)	2.87	3.93	5.9	8.5	
HOM power/cavity (kw)	0.53 (5cell)	0.58 (2 cell)	0.77 (2 cell)	**1.94** (2 cell)	
Energy spread (%)	0.14	0.19	0.098	0.080	
Energy acceptance requirement (%)	**1.57**	**1.7**	**0.90**	**0.49**	
Energy acceptance by RF (%)	2.67	3.0	1.27	1.55	
Photon number due to beamstrahlung	0.19	0.104	0.050	0.023	
Beamstruhlung lifetime /quantum lifetime* (min)	~ 60	30/50	>400		
Lifetime (hour)	**0.7**	**0.22**	**1.2**	**3.2**	**2.0**
F (hour glass)	0.89	0.85	0.92	0.98	
Luminosity/IP *L* (10^{34}cm^{-2}s^{-1})	**0.38**	**5.2**	**14.5**	**23.6**	**37.7**

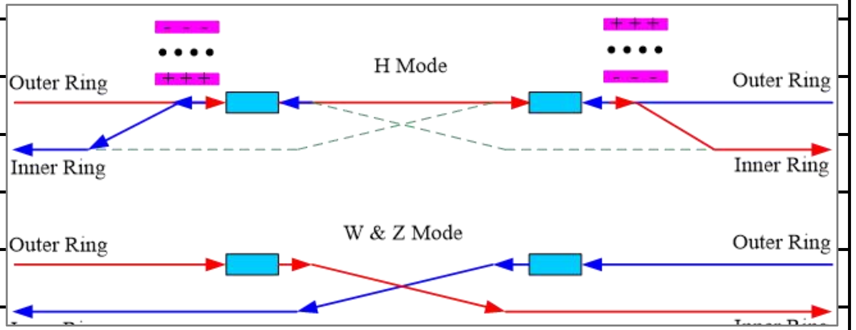
*include beam-beam simulation and real lattice

CEPC vs FCC-ee: Z (2T)

	CEPC-CDR	*CEPC-30MW*	*CEPC-38MW*	*FCC-ee*
Number of IPs	2	2	2	2
Energy (GeV)	45.5	**45.5**	**45.5**	45.6
Circumference (km)	100	100	100	100
SR loss/turn (GeV)	0.036	0.036	0.036	0.036
Half crossing angle (mrad)	16.5	16.5	16.5	15
Piwinski angle	23.8	27.9	33.0	28.5
N_e/bunch (10^{10})	8.0	12.0	15.0	17
Bunch number	12000	**14564 (20.6ns+10%gap)**	**15000**	16640
Beam current (mA)	461	839.9	1081.4	1390
SR power /beam (MW)	**16.5**	**30**	**38.6**	**50**
Bending radius (km)	10.7	10.7	10.7	10.76
Momentum compaction (10^{-5})	1.11	1.11	1.11	1.48
β_{IP} x/y (m)	0.2/0.001	**0.2/0.001**	**0.2/0.001**	0.15/0.0008
Emittance x/y (nm)	0.18/0.0016	0.18/0.0016	0.18/0.0016	0.27/0.001
Transverse σ_{IP} (um)	6.0/0.04	6.0/0.04	6.0/0.04	6.4/0.028
ξ_x/ξ_y/IP	0.004/0.079	0.004/0.093	0.004/0.098	0.004/0.133
V_{RF} (GV)	0.1	0.10	0.10	0.1
f_{RF} (MHz) (harmonic)	650	650	650	400
Nature bunch length σ_z (mm)	2.42	2.42	2.42	3.5
Bunch length σ_z (mm)	8.5	10.0	11.8	12.1
HOM power/cavity (kw)	1.94 (2cell)	**2.29 (1cell)**	**3.15 (1cell)**	?
Energy spread (%)	0.08	0.1	0.115	0.132
Energy acceptance (DA) (%)	1.5	**0.6**	**0.7**	1.3
Energy acceptance by RF (%)	1.7	1.7	1.7	1.9
Lifetime by rad. Bhabha scattering (hour)	2.9			1.13
Lifetime (hour)	2.5	**2.0**	1.8	1.0
L_{max}/IP ($10^{34}cm^{-2}s^{-1}$)	**32.1**	**74.5**	**101.6**	**230**

CEPC Collider Ring SRF Parameters

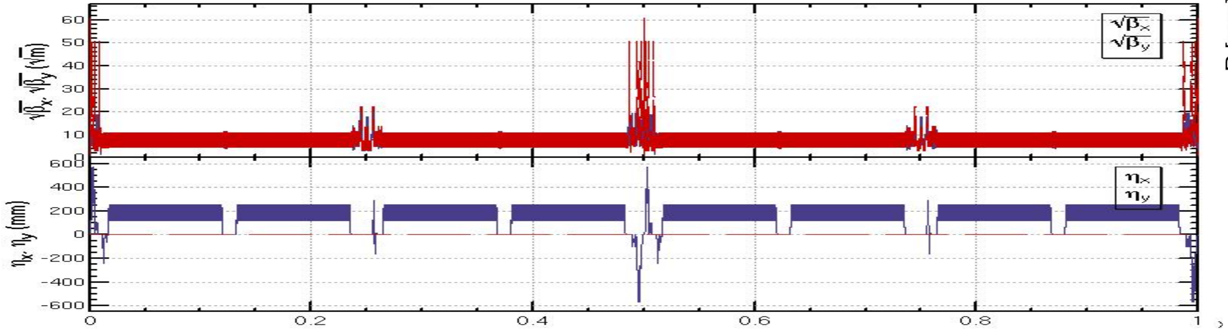
New machine parameters 20190226 SRF parameters 20190301	**CDR (2-cell)**			**HL-Z (new2) (1-cell)**				**HL-Z (2-cell)**	**Performance Limits & Risks**
	H	**W**	**Z**	**H**	**W**	**Z (a)**	**Z (b)**	**Z**	
Luminosity / IP [10^{34} cm^{-2}s^{-1}]	2.93	10.1	**32.1**	2.93	10.1	**74.5**	**74.5**	**74.5**	
SR power / beam [MW]	30	30	16.5	30	30	30	30	30	
RF voltage [GV]	2.17	0.47	0.1	2.17	0.47	0.1	0.1	0.1	
Beam current / beam [mA]	17.4	87.7	460	17.4	87.7	838	838	838	
Bunch charge [nC]	24	19.2	12.8	24	19.2	19.2	19.2	19.2	
Bunch number / beam	242	1524	12000	242	1524	14564	14564	14564	
Bunch length [mm]	3.26	5.9	8.5	3.26	5.9	10	10	10	
Cavity number (650 MHz)	**240**	2 x 108	**2 x 60**	**240**	2 x 120	**2 x 120**	**2 x 60**	**2 x 120**	Smart by-pass could be a better approach than 1-cell.
Cell number / cavity	**2**	2	**2**	**1**	1	**1**	1	**2**	Common 1-cell for Z & H/W necessary or different cavity?
Idle cavities on line / ring	0	12	60	0	0	0	**60**	0	Z 2x60 symmetry detune parked half cavities for FM CBI
Cavity gradient [MV/m]	**20**	9.5	3.6	**40**	17	3.6	7.2	1.8	Current status: ~ 10 MV/m in storage ring. Field emission
Q_0 for long term operation	**1.5E10**	1.5E10	1.5E10	**3E10**	3E10	3E10	3E10	1.5E10	~ 1E9 in storage ring. Field emission. Magnetic shield
Input power / cavity [kW]	250	278	**275**	250	250	**250**	**500**	250	~ 300 kW in storage ring. Window events and damages
Klystron max power [kW]	800	800	800	800	800	800	**1400**	800	Klystron max power limit: 1200 kW? KLY # & $
Number of cavities / klystron	2	2	2	2	2	2	**2**	2	Avoid RF power source reconfiguration
HOM power / cavity [kW]	0.57	0.75	**1.94**	0.29	0.37	**2.28**	2.28	**4.57**	HOM coupler capacity (not HOM power per cavity) : 1 kW
Optimal Q_L	1.5E6	3.2E5	4.7E4	3.1E6	5.8E5	2.6E4	5.2E4	1.3E4	Coupler variation range, coupler kick to beam
Optimal detuning [kHz]	0.2	1.0	**17.8**	0.1	0.5	**32.3**	**16.1**	**64.6**	Fundamental mode coupled bunch instability
Wall loss / cavity @ 2 K [W]	25.6	5.9	0.9	25.6	4.8	0.2	0.9	0.2	Field emission will drastically increase the cryogenic load.
Total cavity wall loss [kW]	6.1	1.3	0.1	6.1	1.2	0.05	0.05	0.05	(cryogenic wall loss in two rings)

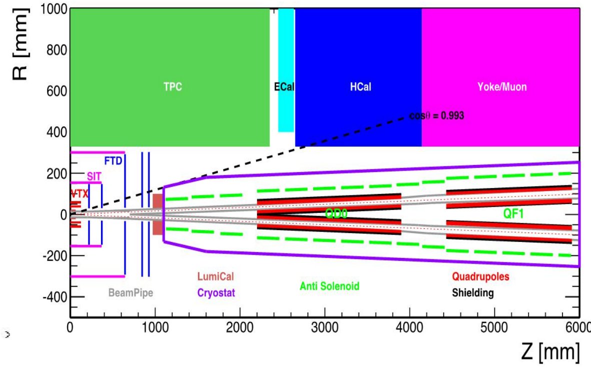


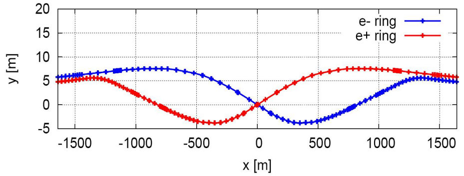
Lattice of the CEPC Collider Ring and MDI

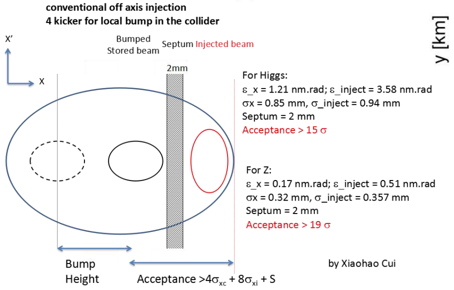
An optics fulfilling requirements of the parameters list, geometry, MDI, background and key hardware

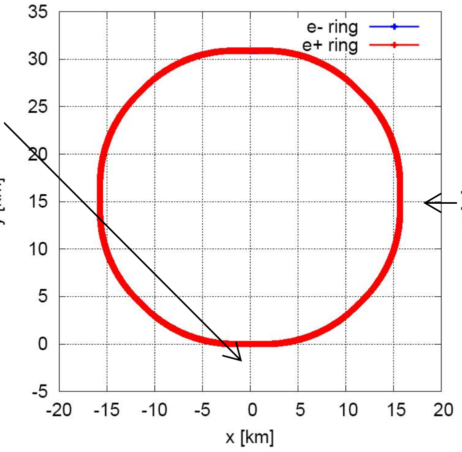
CEPC MDI

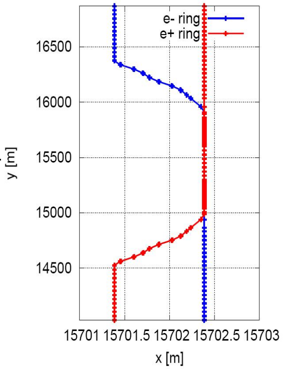












MDI parameters	Values
*L** (m)	2.2
Crossing angle (mrad)	33
Strength of QD0 (T/m)	150
Strength of detector solenoid (T)	3.0
Strength of anti-solenoid (T)	7.0

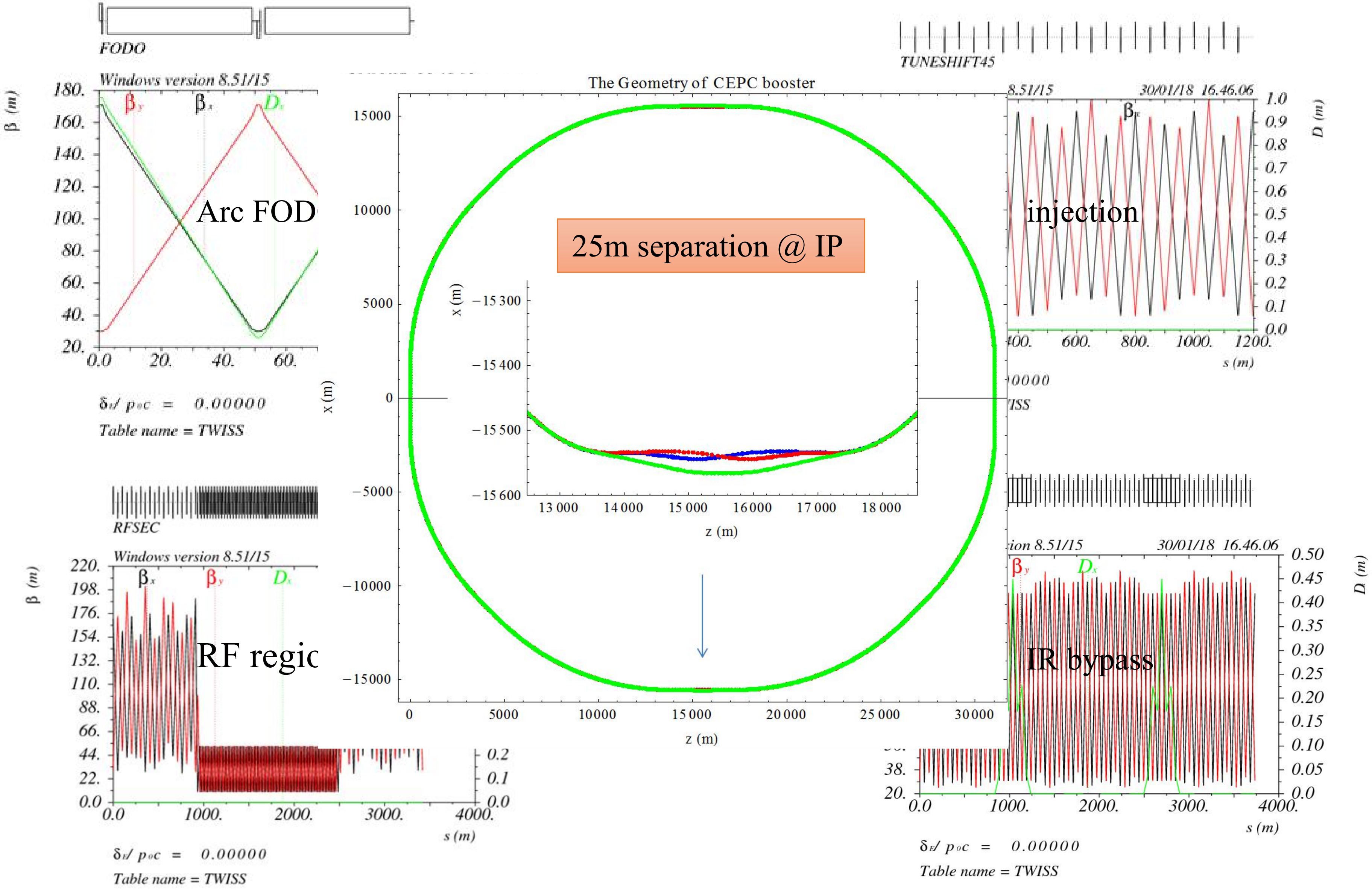
CEPC Booster Parameters @ Injection (10GeV)

		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

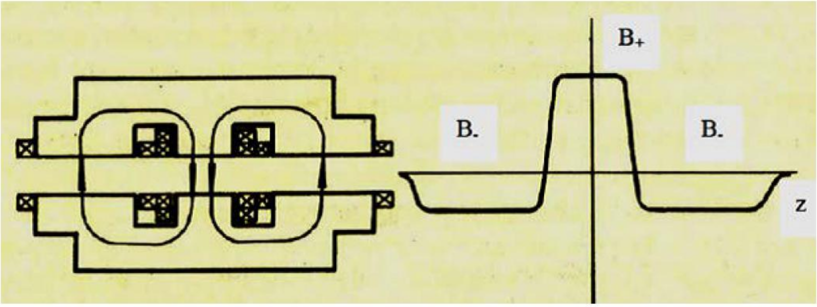
10 GeV injection	H	W	Z
Extraction beam energy [GeV]	120	80	45.5
Bunch number	242	1524	6000
Bunch charge [nC]	0.72	0.576	0.384
Beam current [mA]	0.52	**2.63**	**6.91**
Extraction RF voltage [GV]	1.97	0.585	0.287
Extraction bunch length [mm]	2.7	2.4	1.3
Cavity number in use (1.3 GHz TESLA 9-cell)	96	64	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 Self Polarization at Z-pole with Asymmetric Wigglers

- **Special wigglers to speed up self-polarization:**

N_w	B_+	L_+	B_-	L_-	$\frac{\tau_p}{\tau_p^w}$	u	$\frac{\Delta E_w}{\Delta E}$	$\frac{P_0^w}{P_0}$
10	0.6T	1m	0.15T	2m	13.4	0.34	3.2	0.99

u: Fraction of radiation energy loss enhancement. :Factor of beam energy spread enhancement.

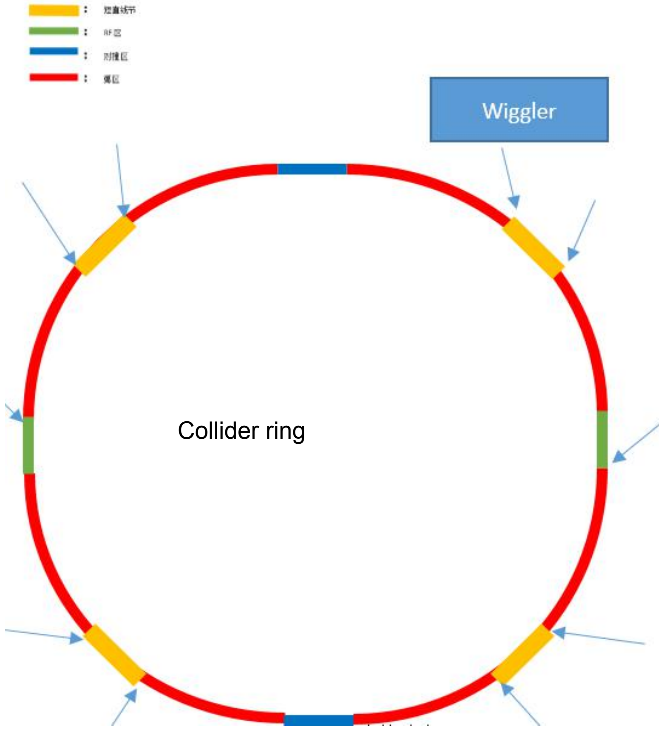


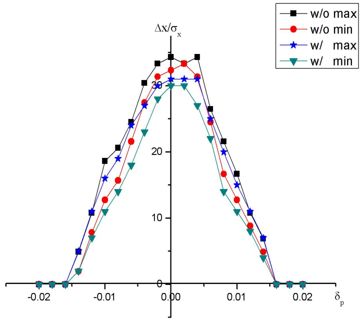
$$P(t) = P_0^w\left(1 - e^{\frac{-t}{\tau_p^w}}\right)$$

$$\tau_p^w = 19.6h,\ P(t) = 5\%,\ P_0^w = 0.913,$$

$$t = 1.10h$$

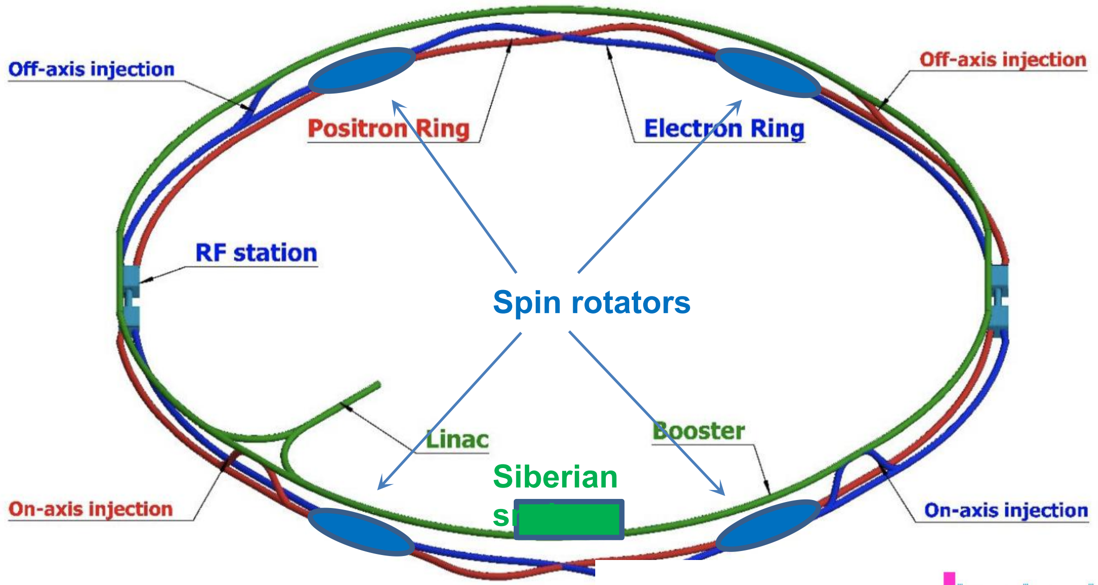
5% is enough for energy calibration.

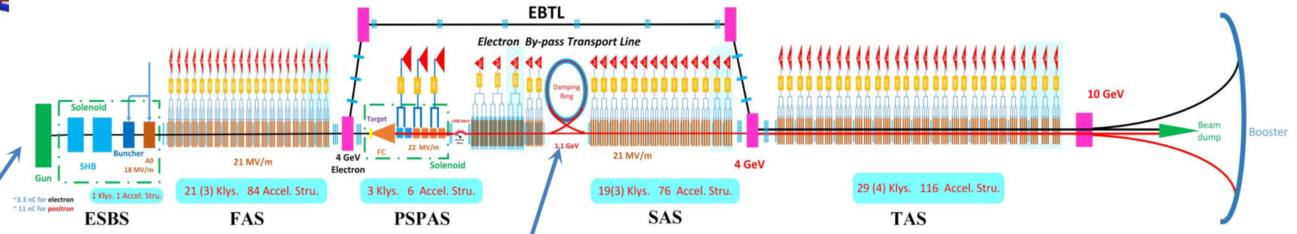




DA

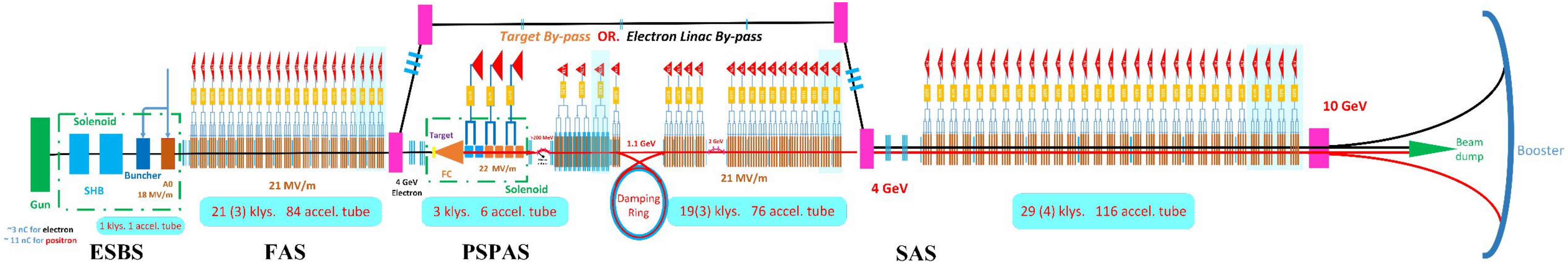
Beam Polarization Considerations at CEPC-Z





- **Minimal** inclusion of beam polarization @ Z-pole
  - Resonant Depolarization for energy calibration only
  - Dedicated polarization wigglers, rf depolarizer, polarimeter in the storage ring
- **Comprehensive** inclusion of beam polarization @ Z-pole
  - Resonant Depolarization for energy calibration **+ polarized e+e- colliding beams**
  - Dedicated polarization wigglers (not necessary), rf depolarizer, polarimeter in the storage ring
  - Polarized e- gun, low energy e+ damping/polarizing ring (optional)
  - Siberian snake in the booster
  - Spin rotators in the storage ring and the injector chain

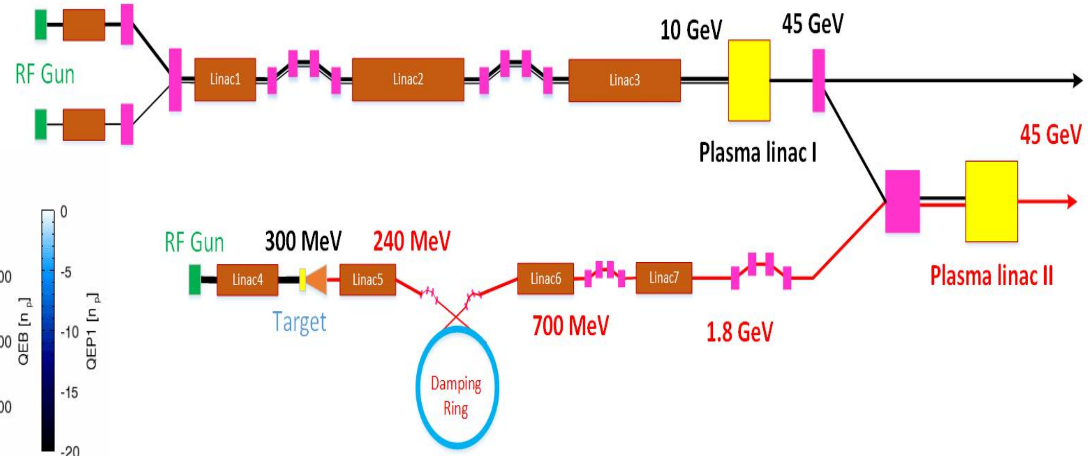
CEPC Linac Injector

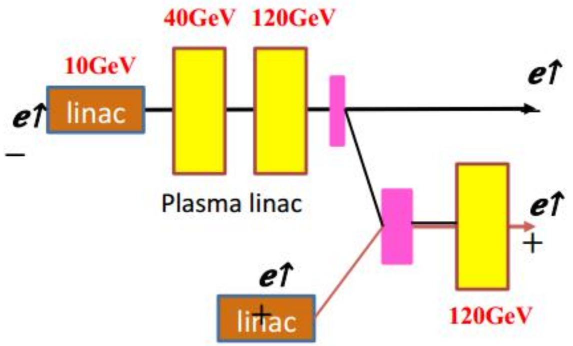


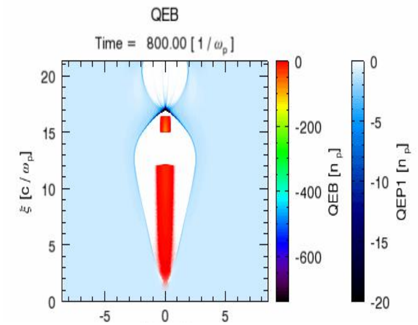
Parameter	Symbol	Unit	Baseline	**Design reached**
e^-/e^+ beam energy	E_{e-}/E_{e+}	GeV	**10**	**10**
Repetition rate	f_{rep}	Hz	**100**	**100**
e^-/e^+ bunch population	N_{e-}/N_{e+}		$> 9.4\times10^{9}$	**1.9×10^{10} / 1.9×10^{10}**
		nC	**> 1.5**	**3.0**
Energy spread (e^-/e^+)	σ_e		**$< 2\times10^{-3}$**	**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**

Experimental Verification Planfor CEPC Plasma Injector Scheme

A dedicated budget of 8Million has been alocated by IHEP

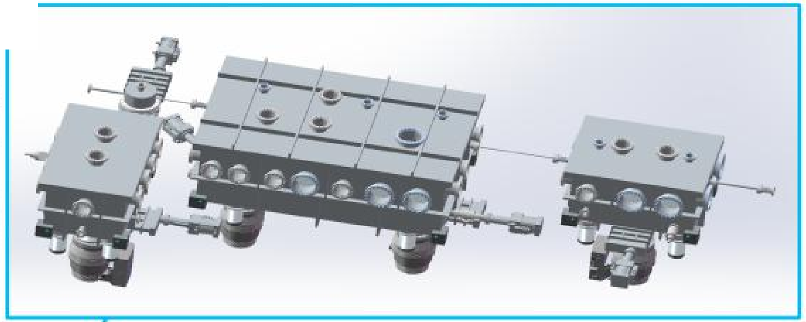


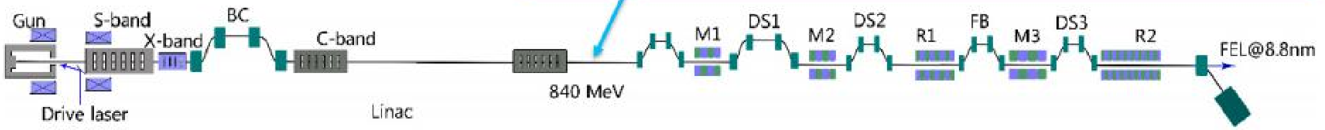




Plasma density $n_0(cm^{-3})$	5.15×10^{16}
Driver charge $Q_d(nC)$	6.47
Driver energy $E_d(GeV)$	10
Driver length $L_d(\mu m)$	285
Driver RMS size $\sigma_d(\mu m)$	10
Driver normalized emittance $\epsilon_{nd}(mm\ mrad)$	10
Trailor charge $Q_t(nC)$	1.25
Trailor energy $E_t(GeV)$	10
Trailor length $L_t(\mu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





- **Electron plasma acceleration will be tested in Shanghai's Soft XFEL Facility**
- **Positron plasma acceleration scheme will be tested at FACET-II at SLAC**

CEPC Power for Higgs and Z

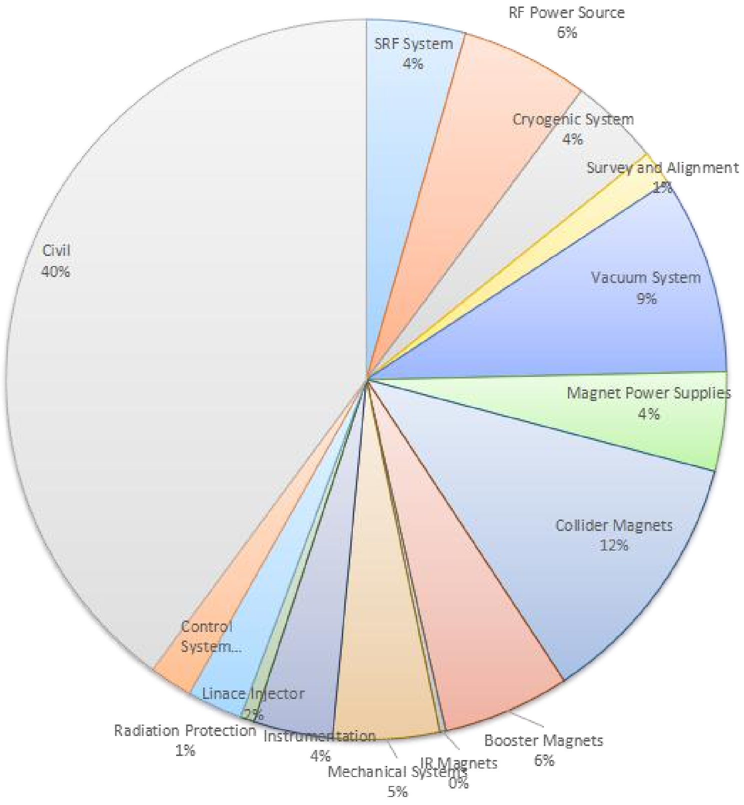
	System for Higgs (30MW)	Location and electrical demand(MW)						Total (MW)
		Ring	Booster	LINAC	BTL	IR	Surface building	
1	RF Power Source	103.8	0.15	5.8				109.75
2	Cryogenic System	11.62	0.68			1.72		14.02
3	Vacuum System	9.784	3.792	0.646				14.222
4	Magnet Power Supplies	47.21	11.62	1.75	1.06	0.26		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

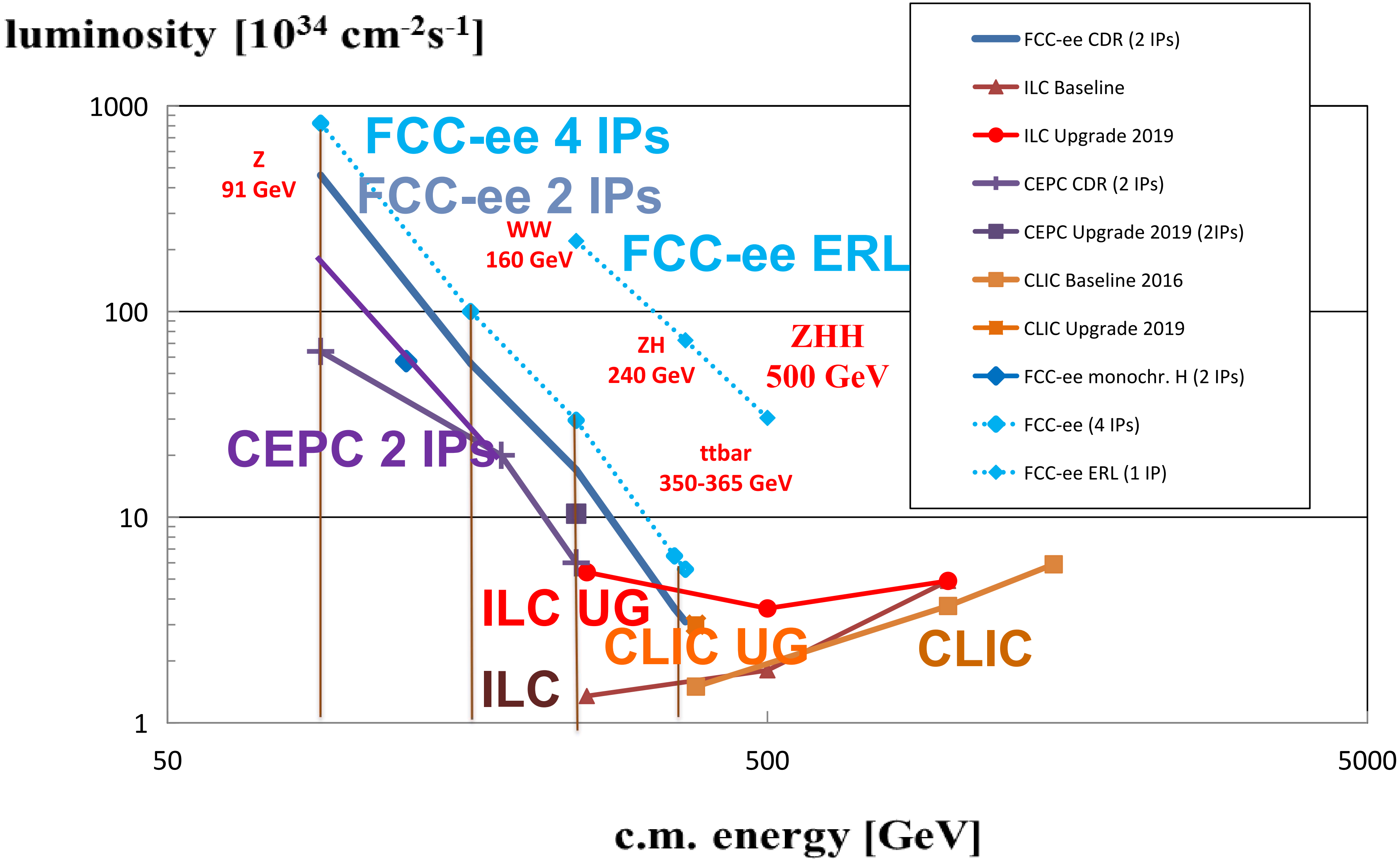
	System for Z	Location and electrical demand(MW)						Total (MW)
		Ring	Booster	LINAC	BTL	IR	Surface building	
1	RF Power Source	57.1	0.15	5.8				63.05
2	Cryogenic System	2.91	0.31			1.72		4.94
3	Vacuum System	9.784	3.792	0.646				14.222
4	Magnet Power Supplies	9.52	2.14	1.75	0.19	0.05		13.65
5	Instrumentation	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)



Total cost of CEPC: 5Billion USD



Benno List, Daniel Schulte, Dmitry Shatilov, Cheng Hui Yu, Vladimir Litvinenko, Thomas Roser

SppC

SppC Baseline Design

From Jan. 2017

- Baseline design
  - Tunnel circumference: 100 km
  - Dipole magnet field: 12 T, using full iron-based HTS technology
  - Center of Mass energy: >70 TeV
  - Injector chain: 2.1 TeV
  - Relatively lower luminosity for the first phase, higher for the second phase
- Energy upgrading phase
  - Dipole magnet field: 20 -24T, full iron-based HTS technology
  - Center of Mass energy: >125 TeV
  - Injector chain: 4.2 TeV (e.g., adding a high-energy booster ring in the main tunnel in the place of the electron ring and booster)
- Development of high-field superconducting magnet technology
  - Starting to develop required HTS magnet technology; before applicable iron-based HTS wire are available, models by YBCO and LTS wires can be used for specific studies (magnet structure, coil winding, stress, quench protection method etc.)

SPPC Parameter Choice and Comparation

CDR F. Su

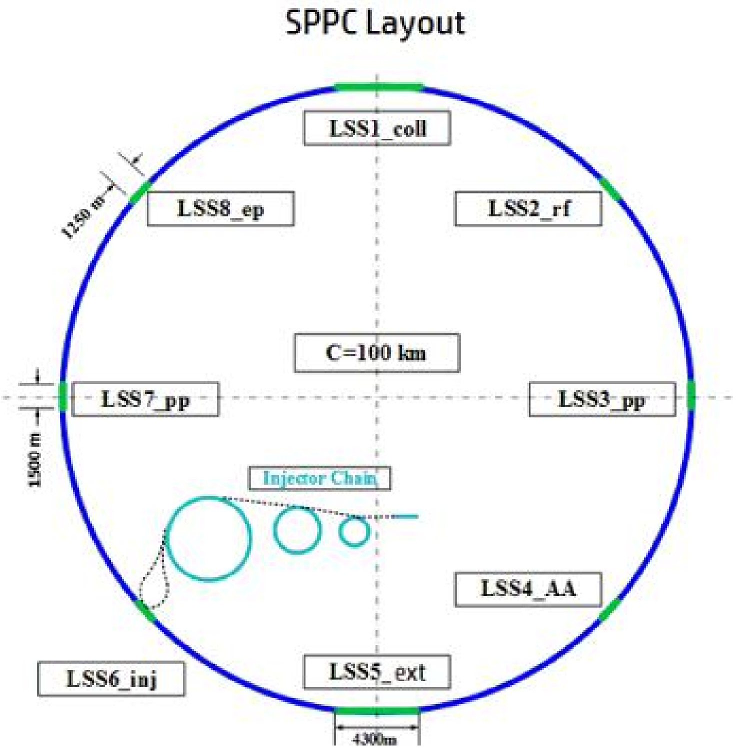
Table 2: SPPC Parameter list(2017.1)[4].6

	SPPC (Pre-CDR)	SPPC 61Km	SPPC 100Km	SPPC 100Km	SPPC 82Km	SPPC phase 1	SPPC phase 2
Main parameters and geometrical aspects							
c.m. Energy[E_0]/TeV	71.2	70	100.0	128.0	100.0	75.0	125.0-150.0
Circumference[C_0]/km	54.7	61.0	100.0	100.0	82.0	100.0	100.0
Dipole field[B]/T	20	19.88	16.02	19.98	19.74	12.00	20-24
Dipole curvature radius[ρ]/m	5928	5889.64	10676.1	10676.1	8441.6	10415.4	-
Bunch filling factor[f_2]	0.8	0.8	0.8	0.8	0.8	0.8	-
Arc filling factor[f_1]	0.79	0.78	0.78	0.78	0.78	0.78	-
Total dipole length [L_{Dipole}]/m	37246	37006	67080	67080	53040	65442	-
Arc length[L_{ARC}]/m	47146	47443	86000	86000	68000	83900	-
Straight section length[L_{ss}]/m	7554	13557	14000	14000	14000	16100	-
Physics performance and beam parameters							
Peak luminosity per IP[L]/ $cm^{-2}s^{-1}$	1.1×10^{35}	1.20×10^{35}	1.52×10^{35}	1.02×10^{36}	1.52×10^{35}	1.01×10^{35}	-
Beta function at collision[β^*]/m	0.75	0.85	0.99	0.22	1.06	0.71	-
Max beam-beam tune shift per IP[ξ_y]	0.006	0.0065	0.0068	0.0079	0.0073	0.0058	-
Number of IPs contribut to ΔQ	2	2	2	2	2	2	2
Max total beam-beam tune shift	0.012	0.0130	0.0136	0.0158	0.0146	0.0116	-
Circulating beam current[I_b]/A	1.0	1.024	1.024	1.024	1.024	0.768	-
Bunch separation[Δt]/ns	25	25	25	25	25	25	-
Number of bunches[n_b]	5835	6506	10667	10667	8747	10667	-
Bunch population[N_p] (10^{11})	2.0	2.0	2.0	2.0	2.0	1.5	-
Normalized RMS transverse emittance[ε]/μm	4.10	3.72	3.59	3.11	3.35	3.16	-
RMS IP spot size[σ^*]/μm	9.0	8.85	7.86	3.04	7.86	7.22	-
Beta at the 1st parasitic encounter[$\beta 1$]/m	19.5	18.67	16.26	69.35	15.31	22.03	-
RMS spot size at the 1st parasitic encounter[σ_1]/μm	45.9	43.13	33.10	56.19	31.03	41.76	-
RMS bunch length[σ_z]/mm	75.5	56.69	66.13	14.62	70.89	47.39	-
Full crossing angle[θ_c]/μrad	146	138.03	105.93	179.82	99.29	133.65	-
Reduction factor due to cross angle[F_{ca}]	0.8514	0.9257	0.9247	0.9283	0.9241	0.9265	-
Reduction factor due to hour glass effect[F_h]	0.9975	0.9989	0.9989	0.9989	0.9989	0.9989	-
Energy loss per turn[U_0]/MeV	2.10	1.98	4.55	12.23	5.76	1.48	-
Critical photon energy[E_c]/keV	2.73	2.61	4.20	8.81	5.32	1.82	-
SR power per ring[P_0]/MW	2.1	2.03	4.66	12.52	5.90	1.13	-
Transverse damping time [τ_x]/h	1.71	1.994	2.032	0.969	1.32	4.70	-
Longitudinal damping time [τ_ε]/h	0.85	0.997	1.016	0.4845	0.66	2.35	-

SPPC main parameters

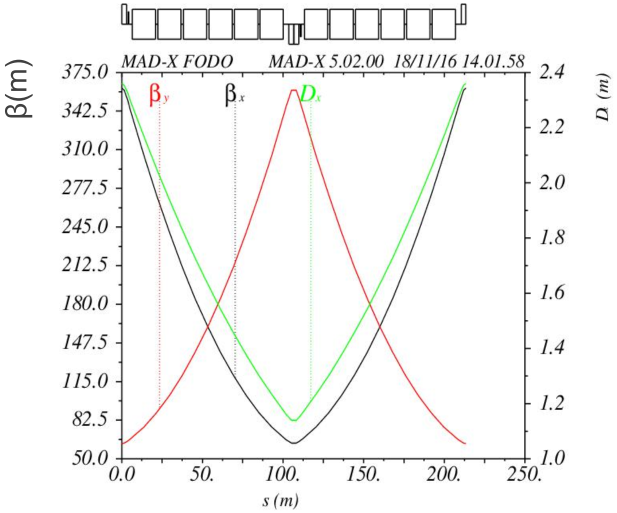
Parameter	Unit	Value		
		PreCDR	CDR	Ultimate
Circumference	km	54.4	100	100
C.M. energy	TeV	70.6	75	125-150
Dipole field	T	20	12	20-24
Injection energy	TeV	2.1	2.1	4.2
Number of IPs		2	2	2
Nominal luminosity per IP	$cm^{-2}s^{-1}$	1.2e35	1.0e35	-
Beta function at collision	m	0.75	0.75	-
Circulating beam current	A	1.0	0.7	-
Bunch separation	ns	25	25	-
Bunch population		2.0e11	1.5e11	-
SR power per beam	MW	2.1	1.1	-
SR heat load per aperture @arc	W/m	45	13	-

General Layout of SPPC



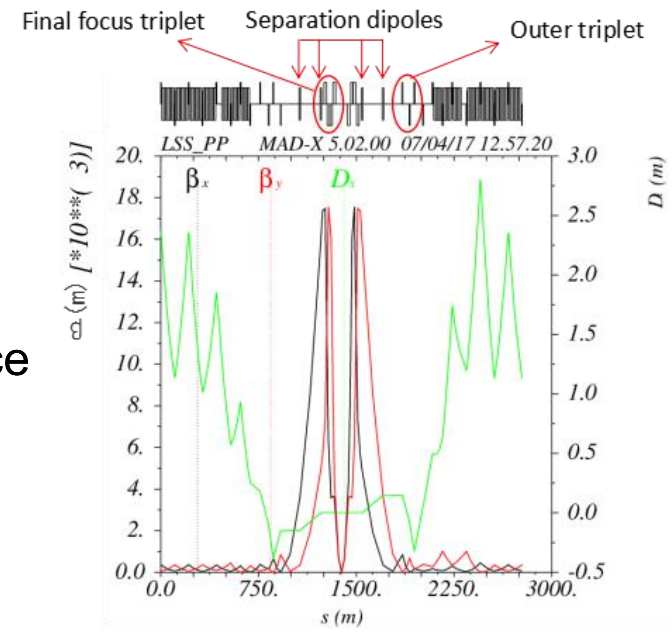
- Length of each section at present:
- 8 arcs, total length 83400 m
- 2 IPs for pp, 1500 m each
- 2 IRs for injection or RF, 1250 m each
- 2 IRs for ep or AA, 1250 m each
- 2 IRs for collimation(ee for CEPC ）, 4300 m each
- C = 100 km

SppC ARC lattice



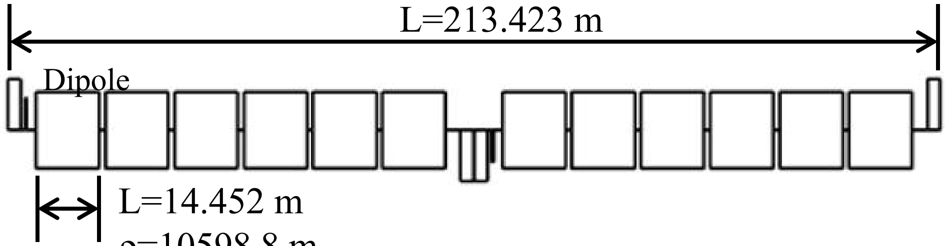
ARC FODO cell structure

SppC interaction region lattice



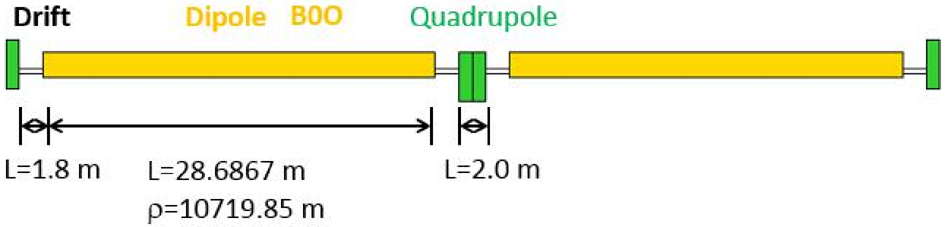
LSS_PP(beta*=0.75 m)

Tunnel compatibility requirement in ARC section



Equivalent radius of FODO cell : 13043.3 m

Structure of FODO cell in ARC of SPPC



Equivalent radius of FODO cell : 12812.5 m

Structure of FODO cell in ARC of CEPC

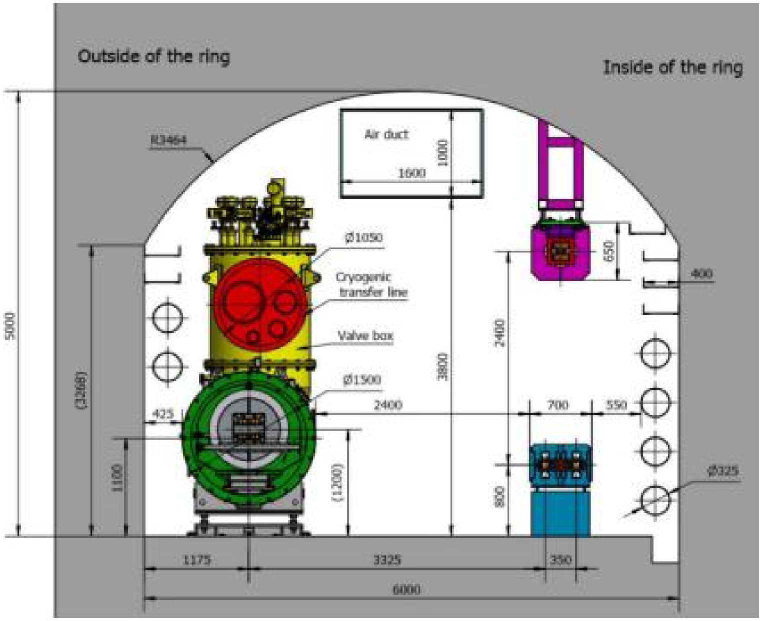
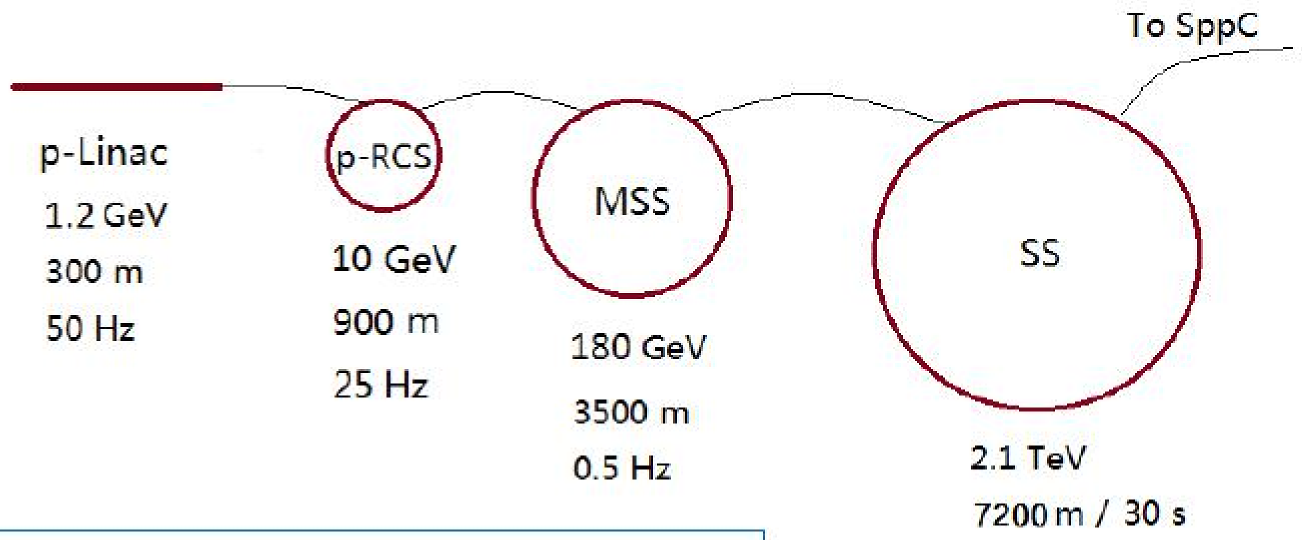


Figure 9.2.12: Inverted U-shape option in the Collider arc section

- SPPC is 3.325 m outside of the ring to the CEPC.
- For tunnel compatibility in ARC section, the equivalent radius of SPPC should be 3.325 m larger than that of CEPC.
- Restricted by the dipole magnet strength (12 T), the minimum equivalent radius of SPPC is about 13 km, which will be difficult to be further reduced.

SppC injector chain

(for proton beam)



p-Linac: proton superconducting linac

p-RCS: proton rapid cycling synchrotron

MSS: Medium-Stage Synchrotron

SS: Super Synchrotron

Ion beams have dedicated linac (I-Linac) and RCS (I-RCS)

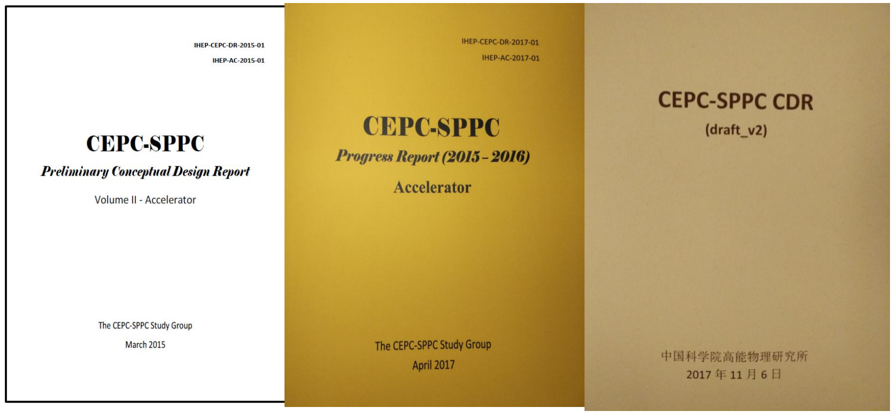
Major parameters for the injector chain

	Value	Unit		Value	Unit
p-Linac			MSS		
Energy	1.2	GeV	Energy	180	GeV
Average current	1.4	mA	Average current	20	uA
Length	~300	m	Circumference	3500	m
RF frequency	325/650	MHz	RF frequency	40	MHz
Repetition rate	50	Hz	Repetition rate	0.5	Hz
Beam power	1.6	MW	Beam power	3.7	MW
p-RCS			SS		
Energy	10	GeV	Energy	2.1	TeV
Average current	0.34	mA	Accum. protons	1.0E14	
Circumference	970	m	Circumference	7200	m
RF frequency	36-40	MHz	RF frequency	200	MHz
Repetition rate	25	Hz	Repetition period	30	s
Beam power	3.4	MW	Protons per bunch	1.5E11	
			Dipole field	8.3	T

CEPC Accelerator from Pre-CDR to CDR

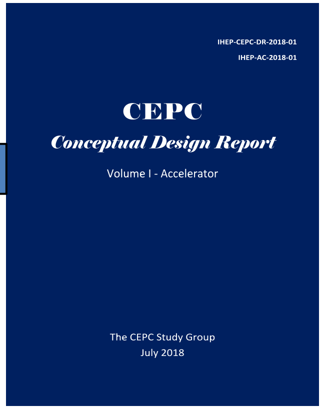
CEPC accelerator CDR completed in June 2018 (to be printed in July 2018)

- – 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

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: 1901.02170

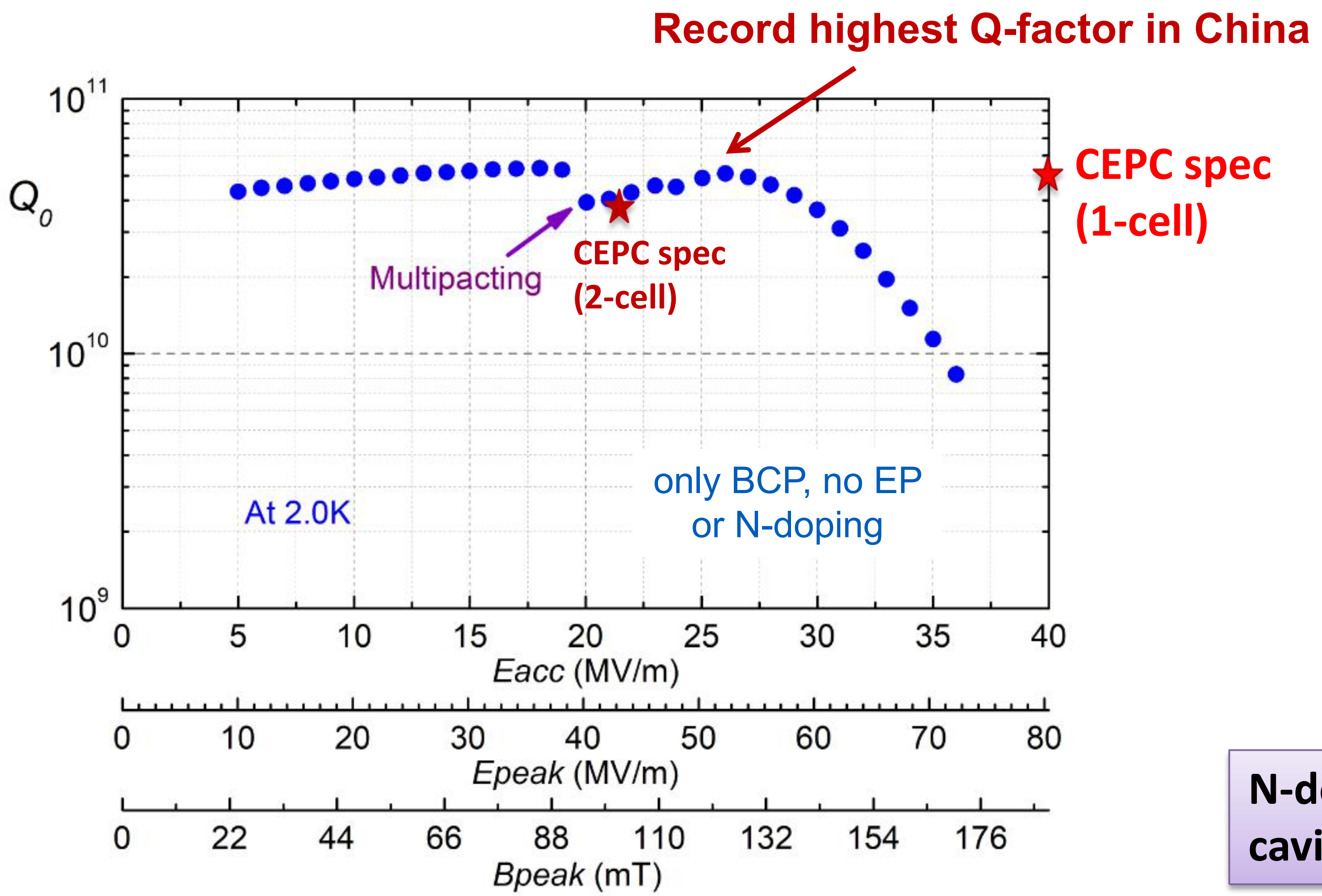
CDR Version for International Review June 2018
Formally relased on Sept. 2, 2018:arXiv：1809.00285
http://cepc.ihep.ac.cn/CDR_v6_201808.pdf

CEPC and SppC R&D

High Q and High Gradient R&D (650 MHz FG)

Accelerating gradient (Eacc) reach 36.0 MV/m，**Q = 5.1E10 @ Eacc = 26 MV/m。**

Next, increase the Q and Eacc through N-doping, EP, etc. Target: **5E10@42MV/m** for vertical test.

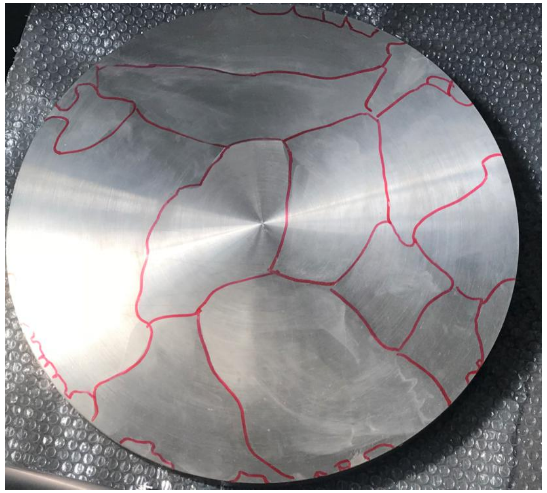
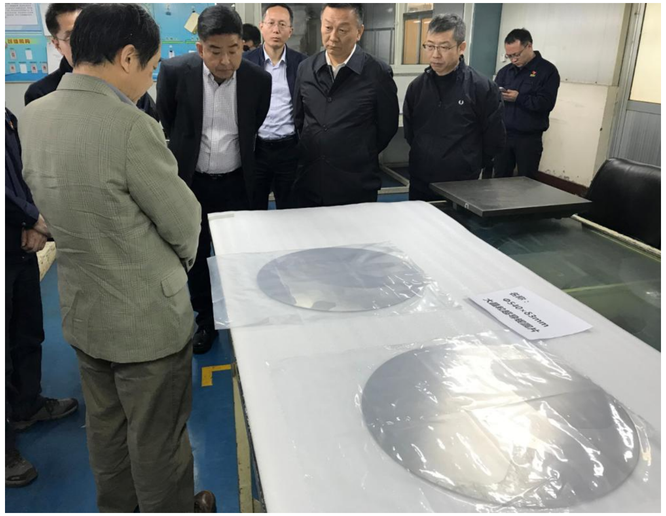


650 MHz 1-cell cavity

N-doping + EP will increase the 650 MHz cavity performance in near future

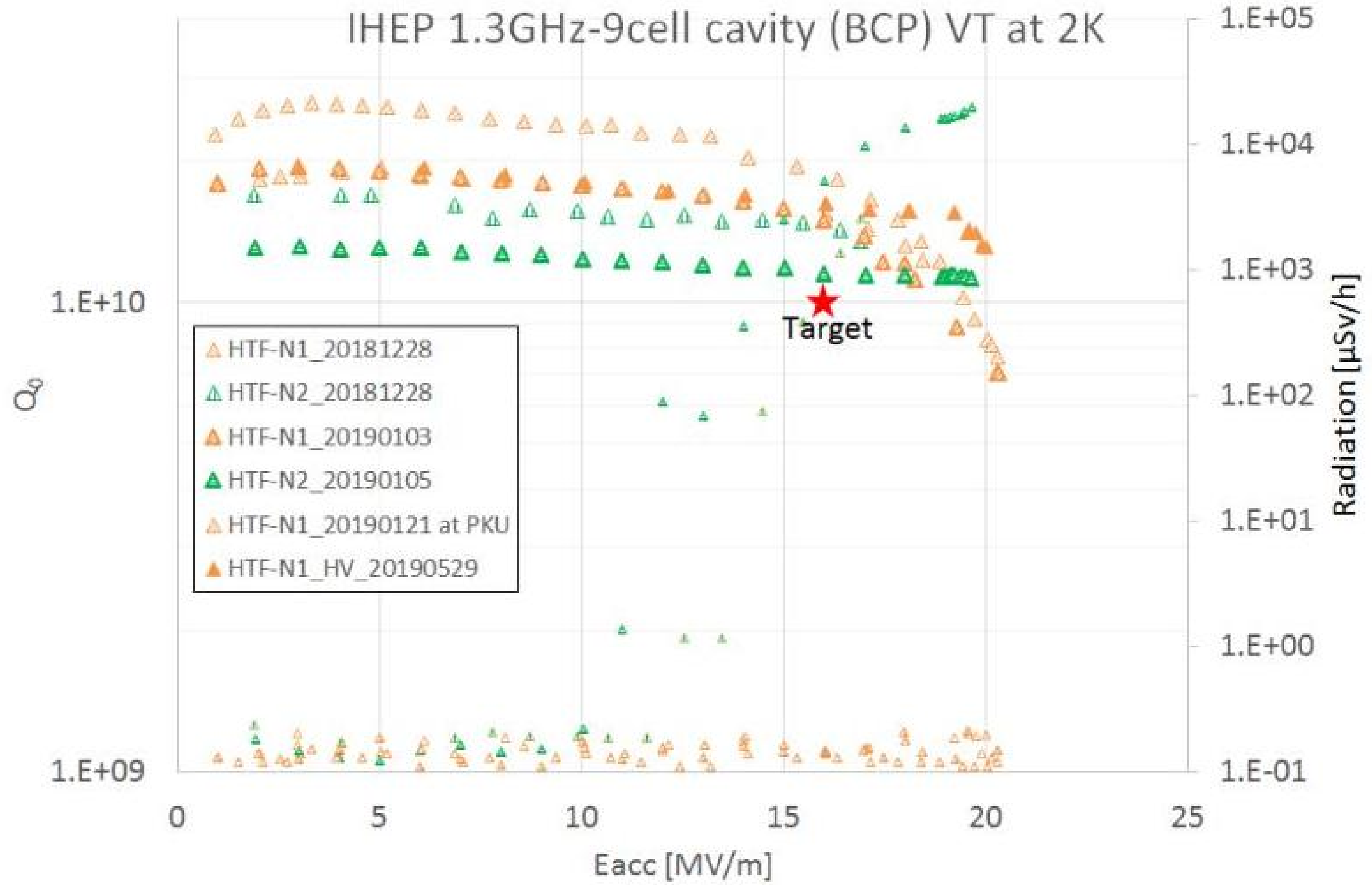
650 MHz 1-Cell Cavity (Large Grain)

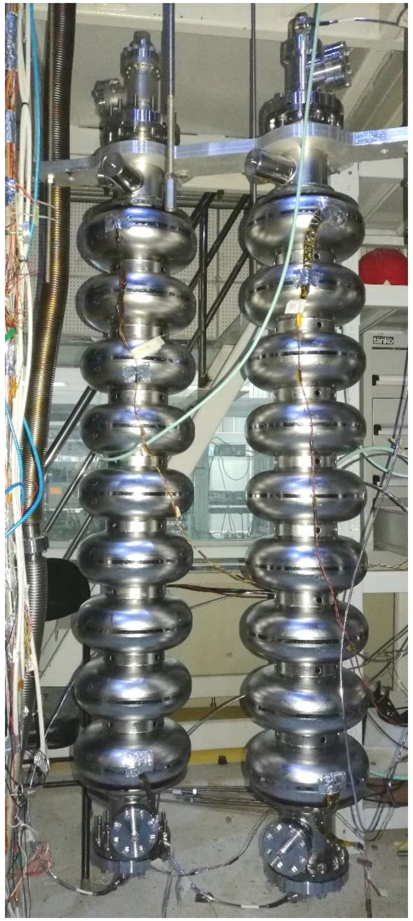
- 650 MHz 1-cell cavity (large grain) is favorable for HL-Z, which have higher Q and gradient than fine grain.
- Target of Vertical test: **5E10 @ 42MV/m at 2.0 K**.
- Four cavities are under fabrication now, which will be tested in the middle 2019.

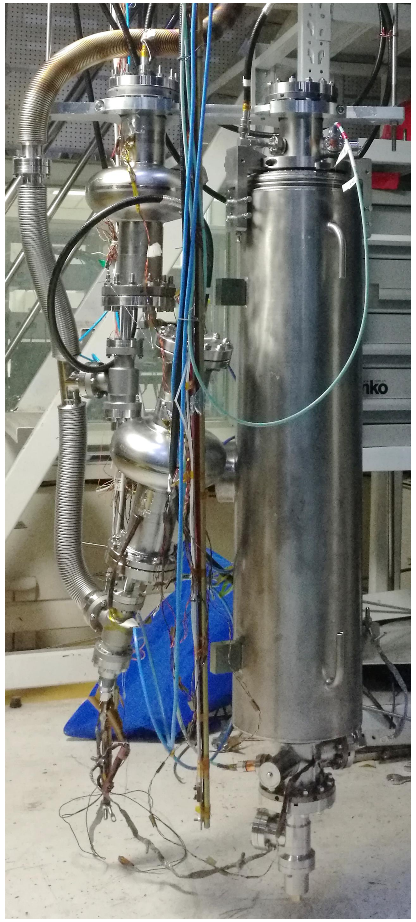




Large grain Nb sheets made by OTIC

IHEP SHINE 1.3 GHz 9-cell cavities (BCP)





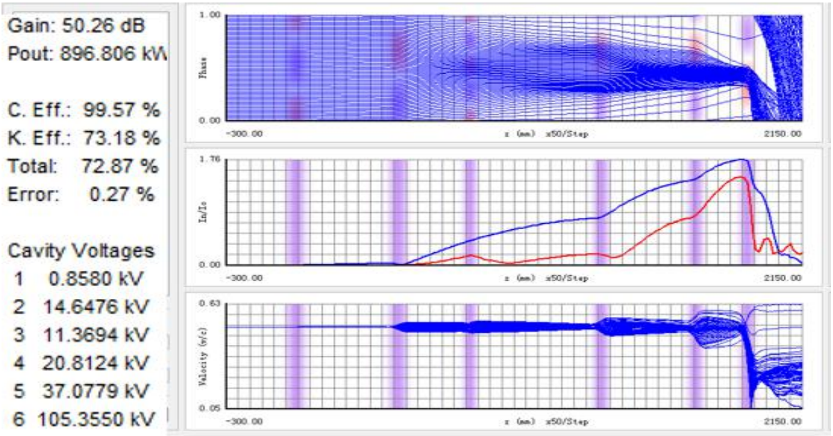


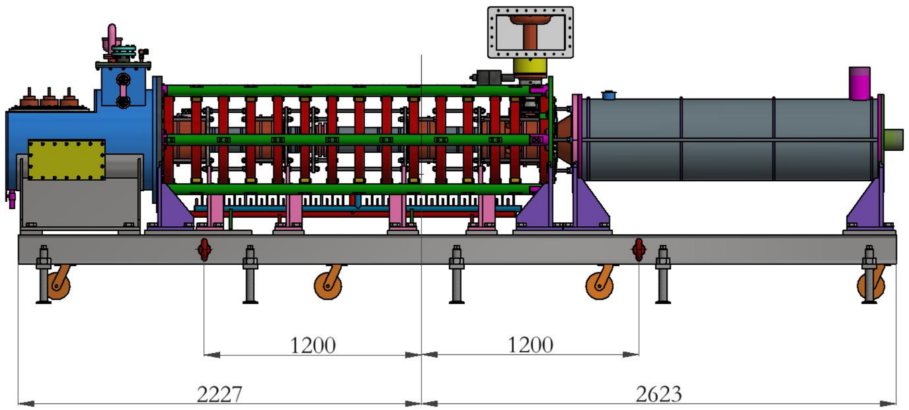
CEPC 650MHz High Efficiency Klystron Development

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

1st CEPC 650MHz Klystron Prototype Manufacture

① Components

Modulator anode

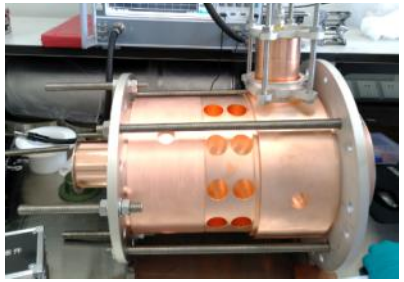
Focusing electrode

Cathode

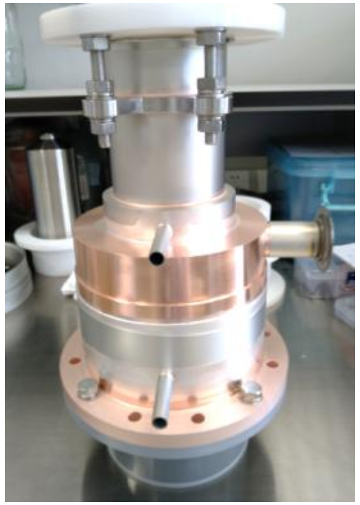
De-gassing facility

Input coupler

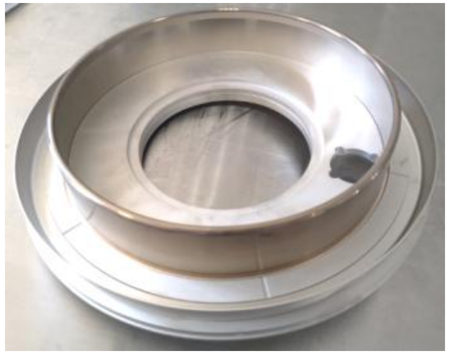
Pumping out pipe



Cavity



Output window



Gun support

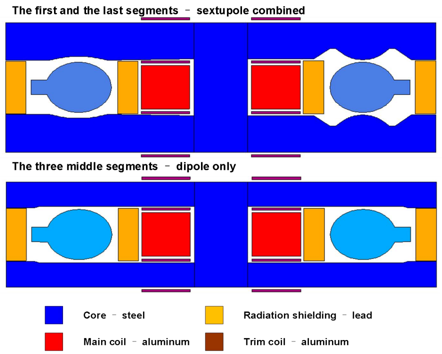
47

CEPC Collider and Booster Ring Conventional Magnets

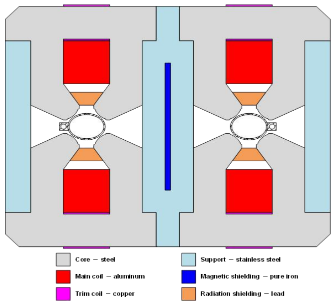
China Astronotics Department 508 Institute participates CEPC magnets mechanical designs

CEPC collider ring magnets

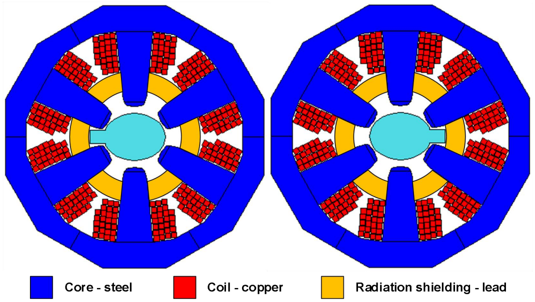
	Dipole	Quad.	Sext.	Corrector	Total
Dual aperture	2384	2392	-	-	13742
Single aperture	80*2+2	480*2+172	932*2	2904*2	
Total length [km]	71.5	5.9	1.0	2.5	80.8
Power [MW]	7.0	20.2	4.6	2.2	34



Dipole

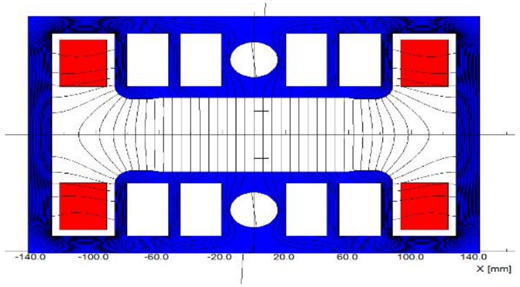


Quadrupole



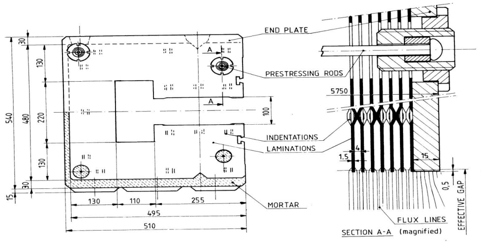
Sextupole

Dipole

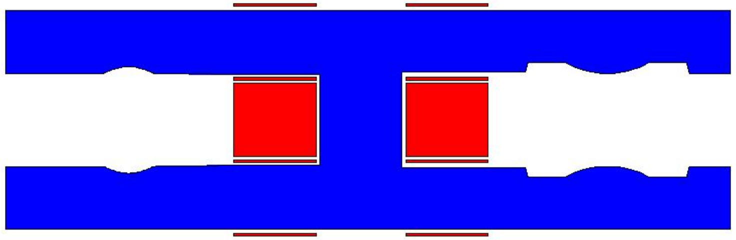


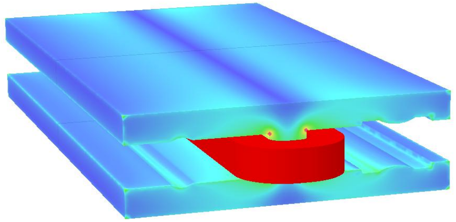
Booster ring low field magnets

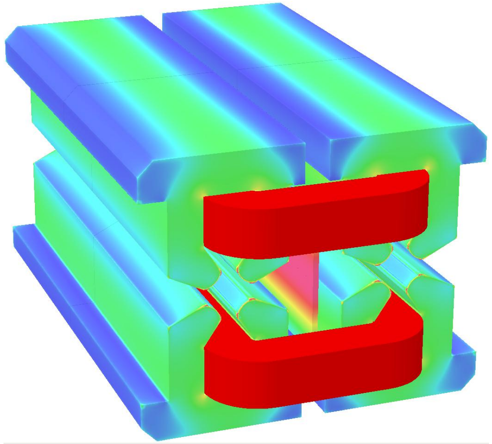
Quantity	16320
Magnetic length(m)	4.711
Max. strength(Gs)	338
Min. strength(Gs)	28
Gap height(mm)	63
GFR(mm)	55
Field uniformity	5E-4

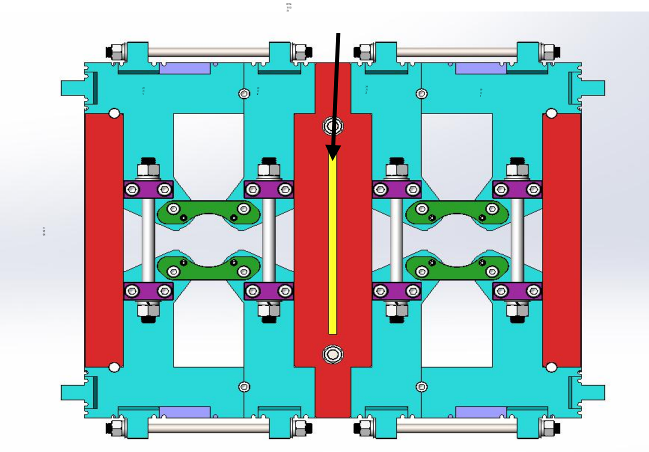


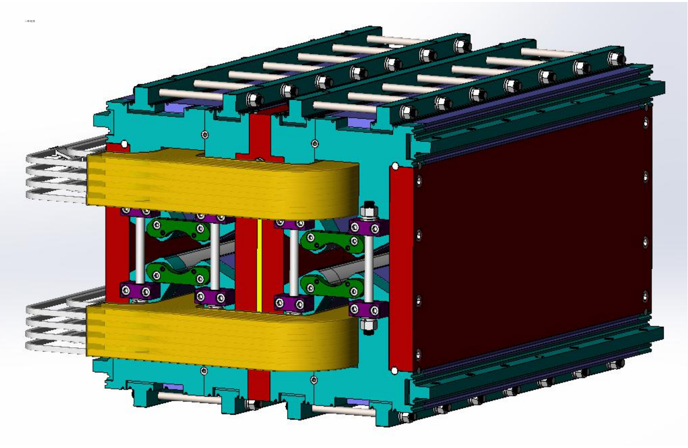
CEPC Collider Ring dual Aperture Dipole, Quadrupole and Sextupole Magnet Design Progress

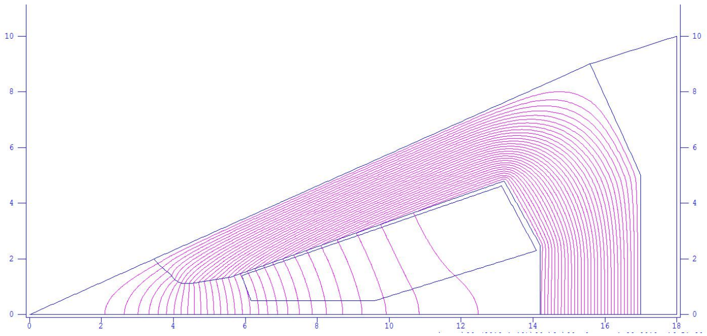


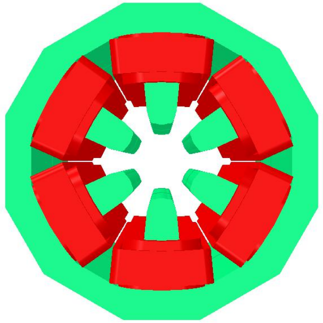


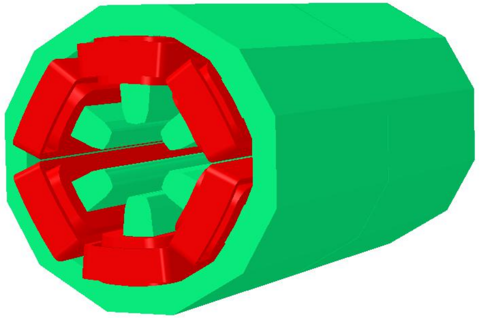










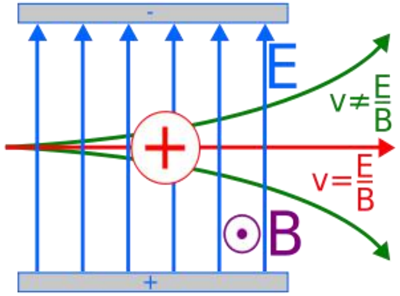


CEPC Collider Ring Electro-Magnet Separator

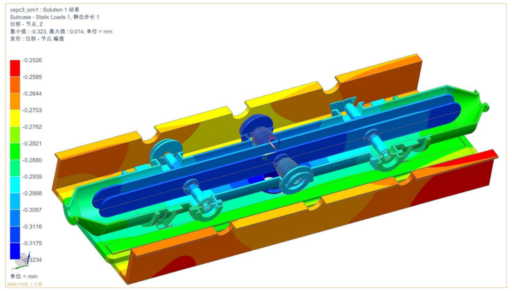
The **Electrostatic-Magnetic Deflector** is a device consisting of perpendicular **electric** and **magnetic** fields, just like **Wien filter**.

Challenges: To maintain E/B ration in fringe field region

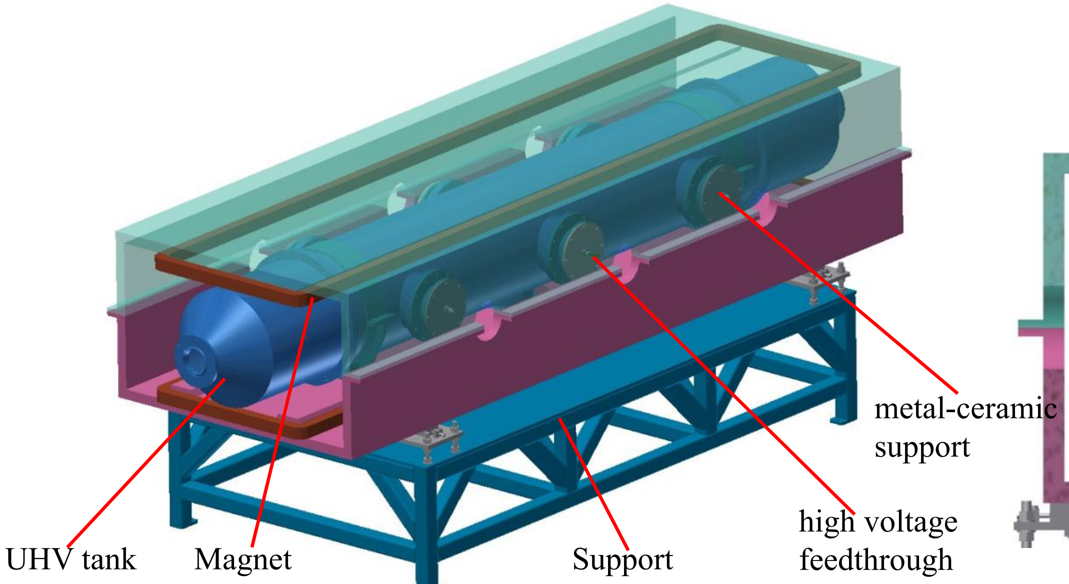
Reduce the impedance and loss factor of the separator



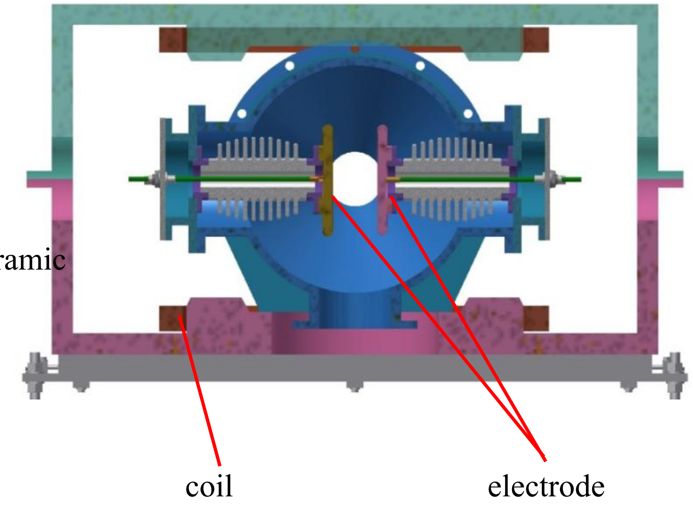
	Filed	Effective Length	Gap	Good field region	Stability
Electrostatic separator	2.0MV/m	4m	110mm	70mm x 30mm	5 x 10^{-4}
Dipole	66.7Gauss	4m	600mm	70mm x 30mm	5 x 10^{-4}



A Wien filter

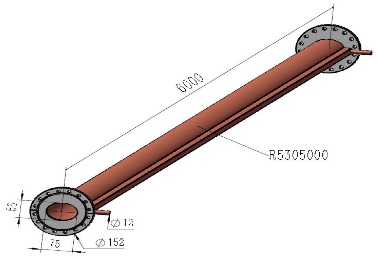


structure drawing of Electrostatic-Magnetic Deflector

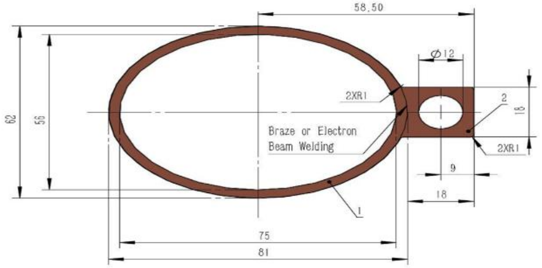


Vacuum System R&D

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

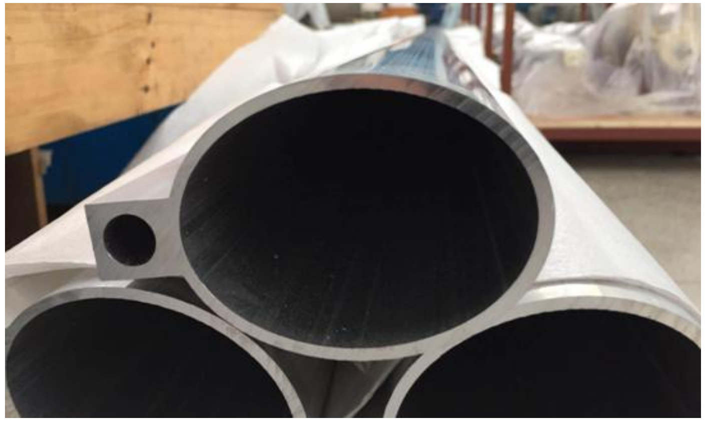


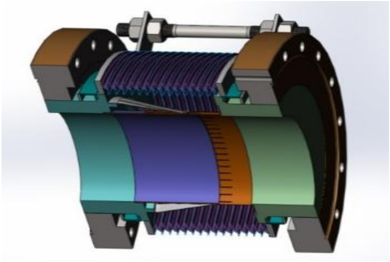
Positron ring

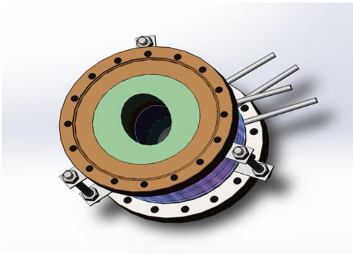


Copper vacuum chamber (Drawing)
(elliptic 75×56, thickness 3, length 6000)

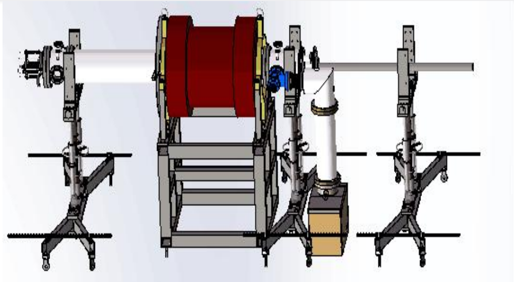
First test vacuum chamber

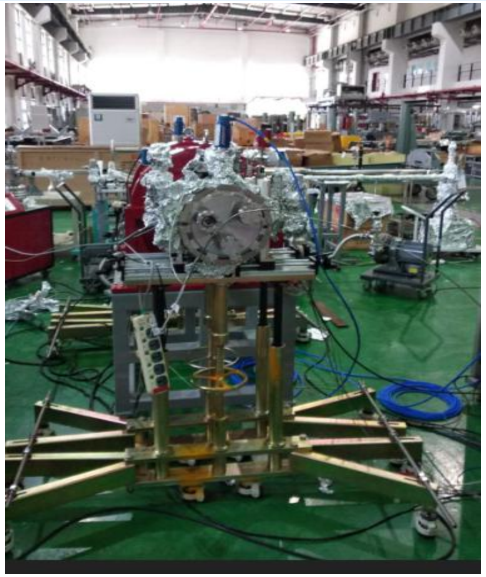






NEG coating suppresses electron multipacting and beam-induced pressure rises, as well as provides extra linear pumping. Direct Current Magnetron Sputtering systems for NEG coating was chosen.

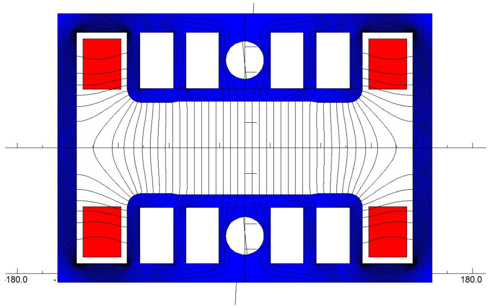


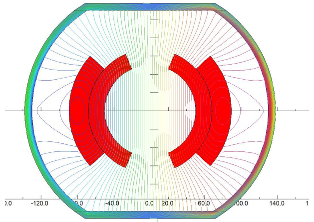
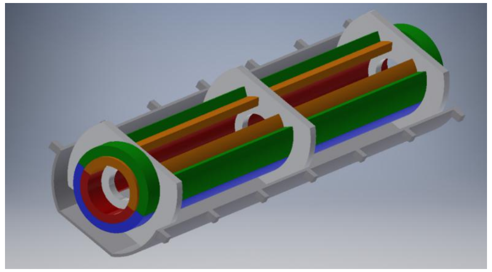
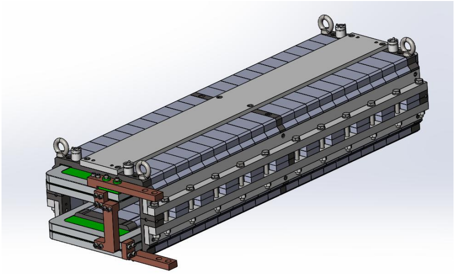
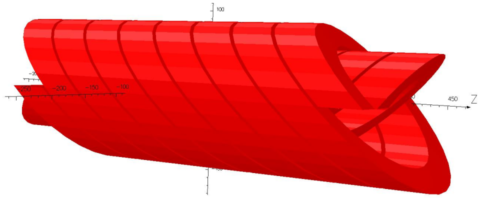
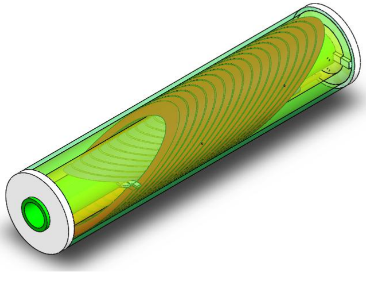


Booster High Precision Low Field Dipole Magnets

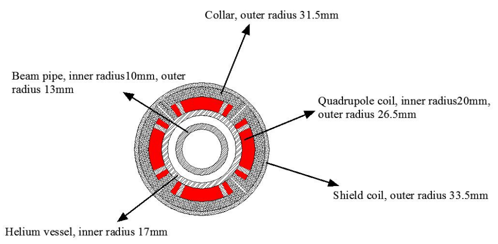
One kind of the dipole magnet with diluted iron cores is proposed and designed

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



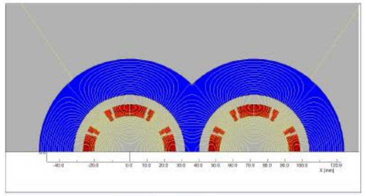






CEPC IR Superconducting Magnets

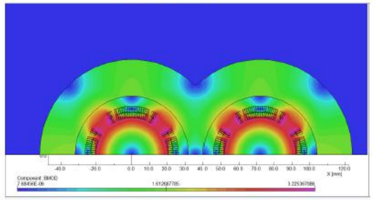


Superconducting QD coils

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

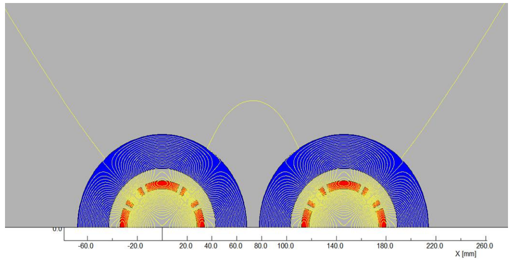


2D Flux lines



Bmod distribution

Superconducting QF coils



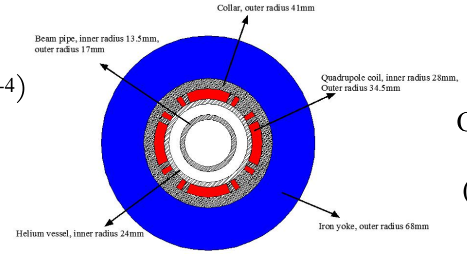
There is iron yoke around the quadrupole coil for QF1. Since the distance between the two apertures is larger enough and there is iron yoke, the field cross talk between two apertures of QF1 can be eliminated.

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

QF1 Integral field harmonics with shield coils （×10^{-4}）

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

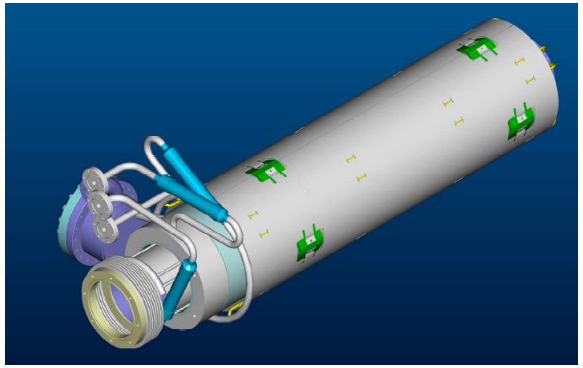


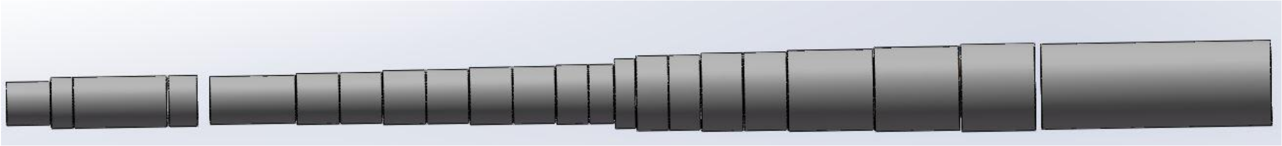
One of QF1 aperture (Peak field 3.8T)

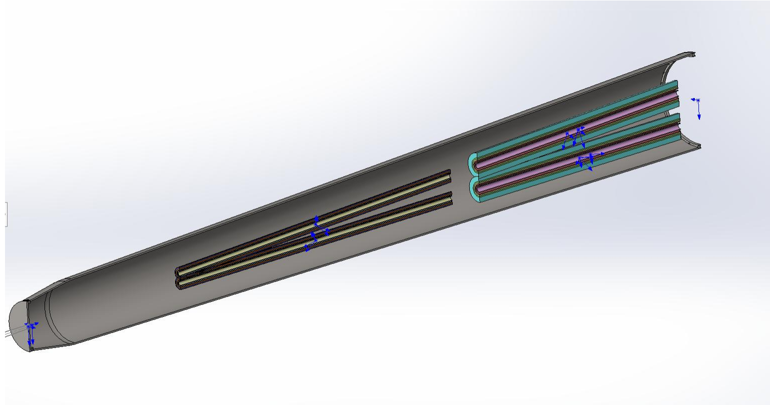
Magnet	Central field gradient (T/m)	Magnetic length (m)	Width of Beam stay clear (mm)	Min. distance between beams centre (mm)
QF1	110	1.48	27.0	146.20

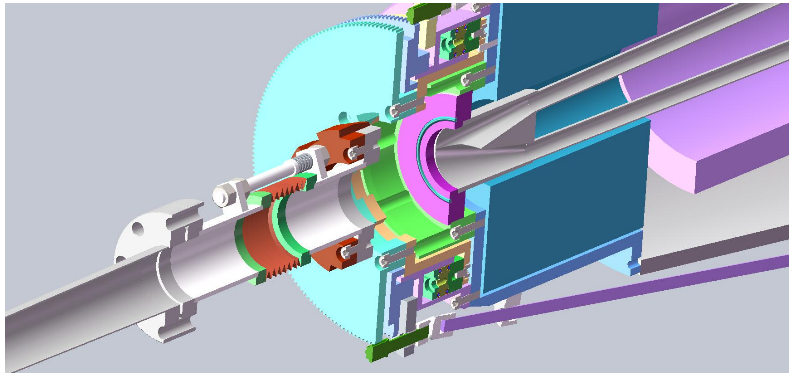
CEPC MDI SC Magnets and Mechanical Study

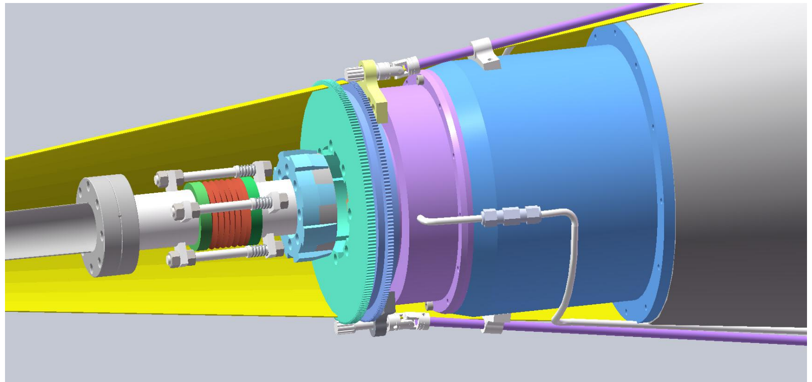
Huanghe Company,Huadong
-Shenyang Huiyu Company
participats in CEPC MDI mechanical
connection design
China Astronotics Department 508
Institute
participates in CEPC MDIsupporting
design

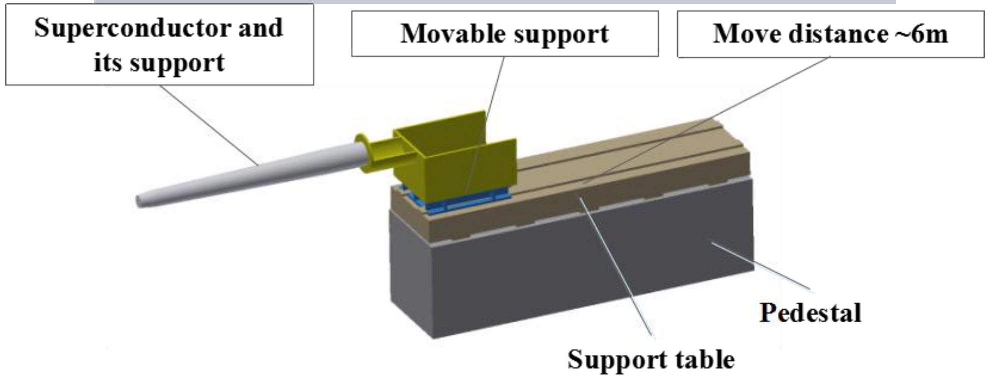












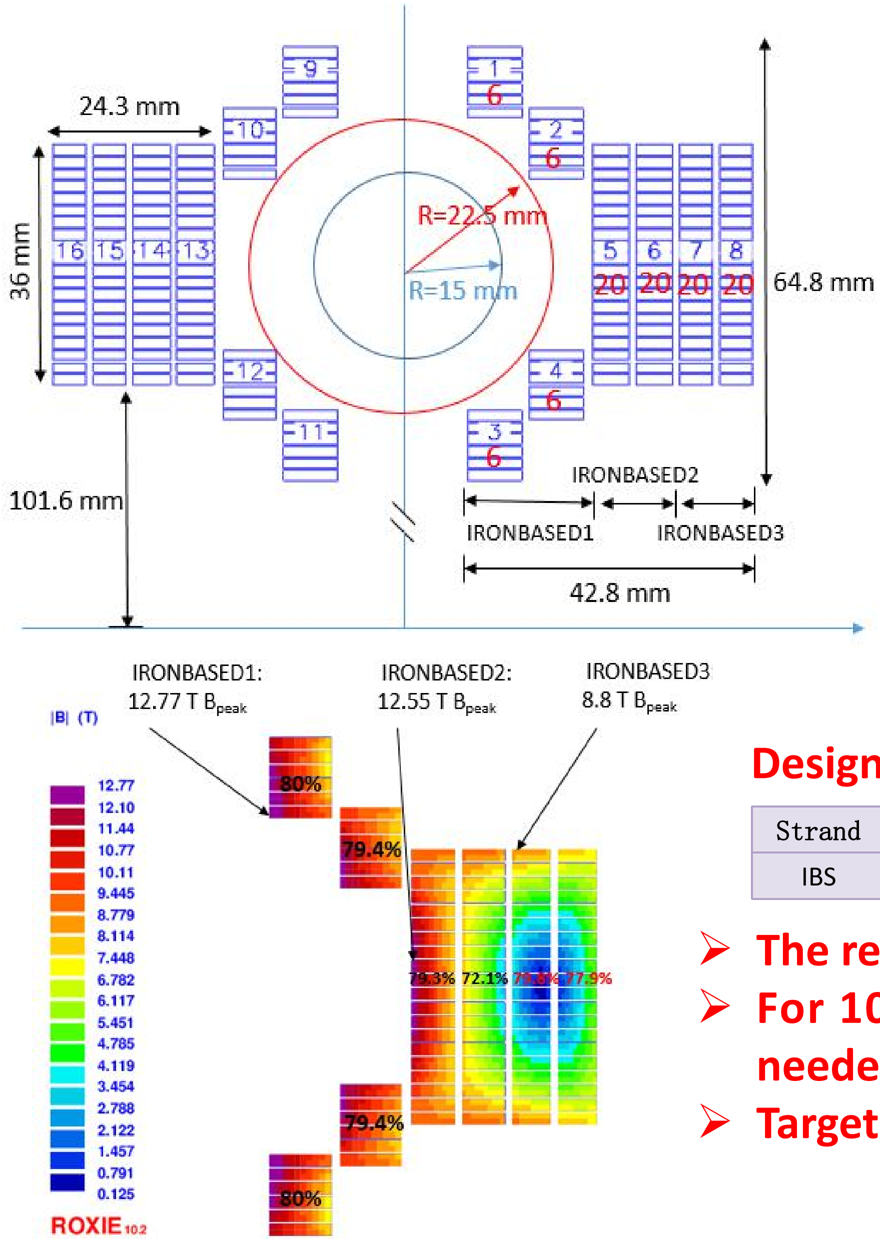
Schematic of support system of superconducting magnets

Domestic Collaboration on HTS for SppC SC Magnte

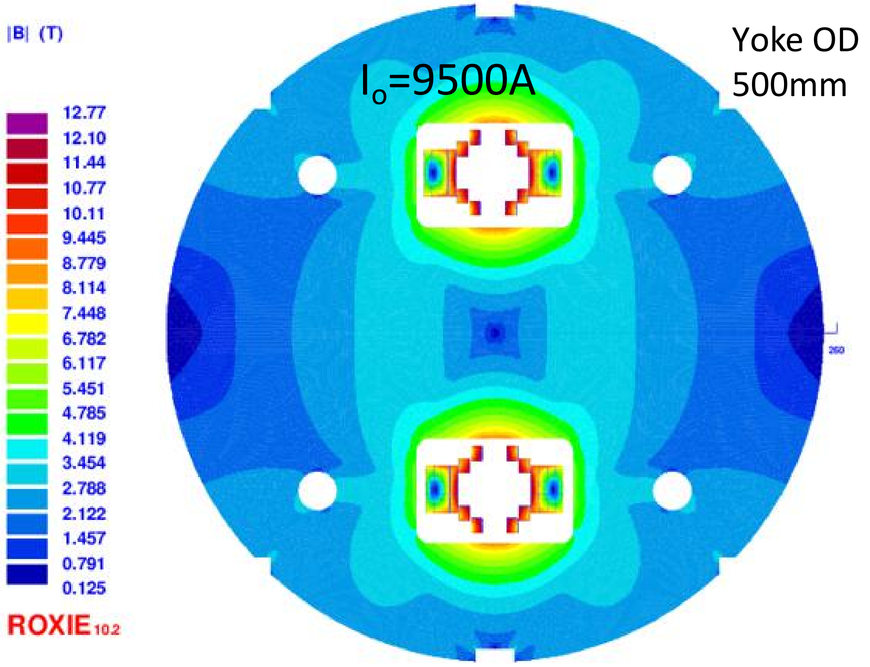
"Applied High Temperature Superconductor Collaboration" was established in Oct. 2016.

- **Goal:**
  1) To increase the J_c of **IBS** by 10 times, reduce the cost to **20 Rmb/kAm @ 12T & 4.2K**;
  2) To reduce the cost of **ReBCO and Bi-2212** conductors to 20 Rmb/kAm @ 12T & 4.2K;
  3) Realization and Industrialization of iron-based magnet and SRF technology.
- **Working groups:** 1) **Fundamental science** investigation; 2) **IBS** conductor R&D; 3) **ReBCO** conductor R&D; 4) **Bi-2212** conductor R&D; 5) **performance** evaluation; 6) **Magnet and SRF** technology.
- **Collaboration meetings**: every 3 months, to report the progress and discuss plan for next months.

The 12-T Fe-based Dipole Magnet



C. Wang, E. Kong (USTC), Q. Xu et al.



Design with expected J_e of IBS in 2025

Strand	diam.	cu/sc	RRR	Tref	Bref	Jc@ BrTr	dJc/dB
IBS	0. 802	1	200	4. 2	10	4000	111

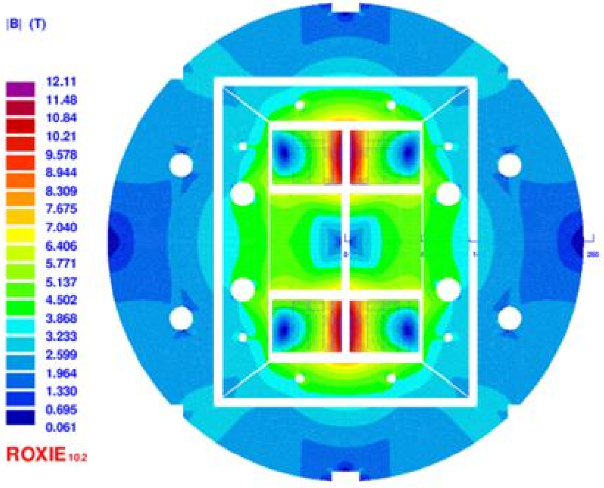
- The required length of the 0.8 mm IBS is 6.1 Km/m
- For 100-km SPPC accelerator, 3000 tons of IBS is needed
- Target cost of IBS: 20 RMB (~2.6 Eur) /kAm @12 T

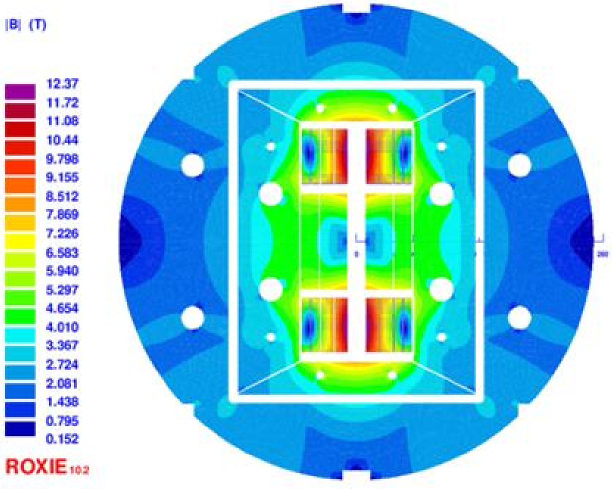
R&D of 12T twin-aperture dipole magnet

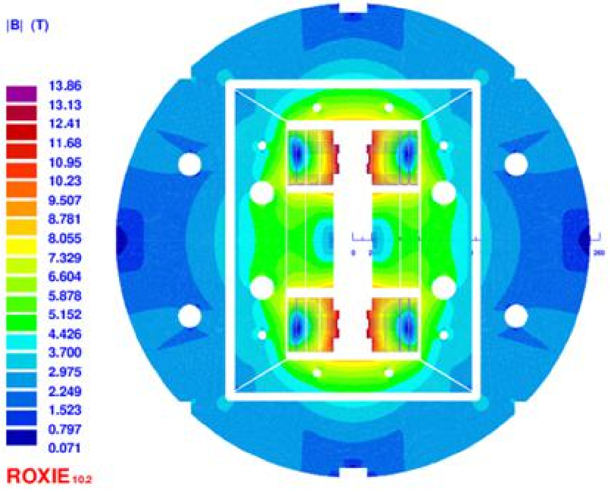
Operation load line at 12 T: ~80% at 4.2K

C. Wang, K. Zhang, Y. Wang, D. Cheng, E. Kong (USTC), Q. Xu et al.

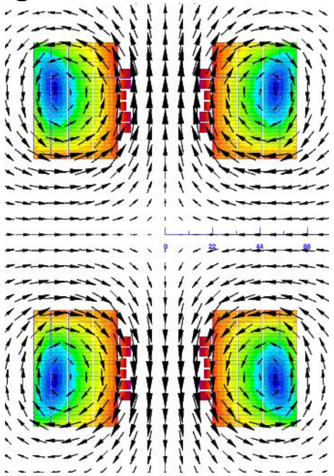
NbTi+Nb_3Sn, 2*ф10 → All Nb_3Sn, 2*ф20 aperture → Nb_3Sn+HTS, 2*ф30



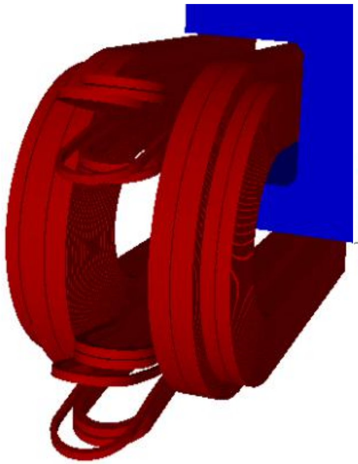




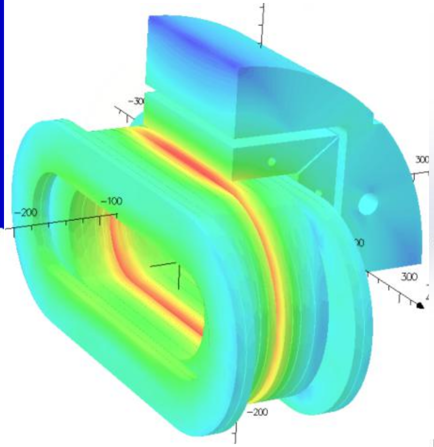
Magnetic flux distribution



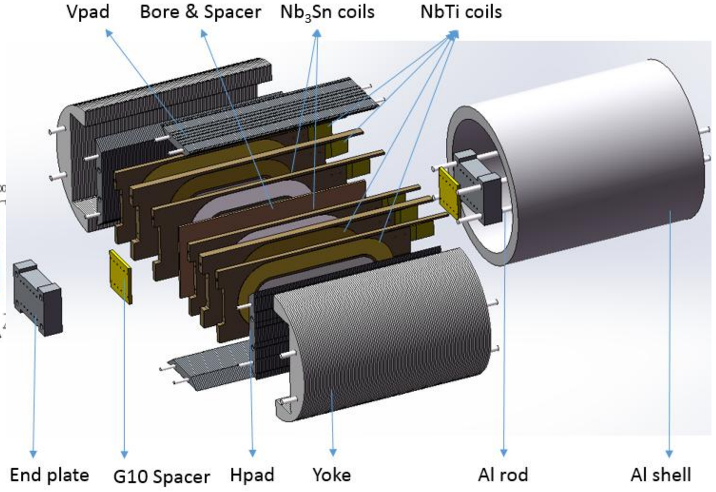
3d coil layout



3D magnetic field distribution



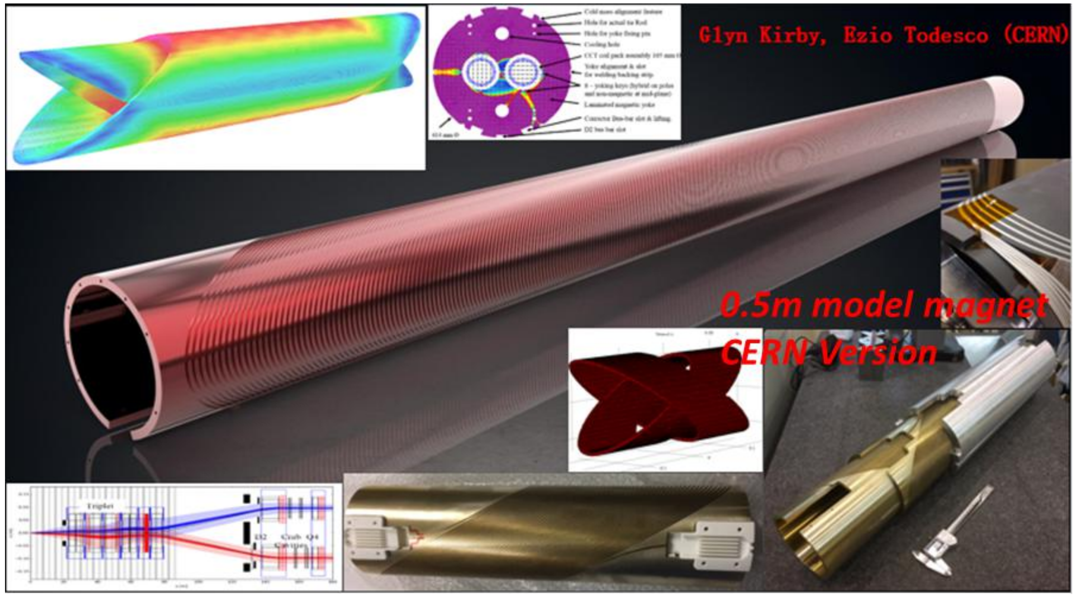
Components and assembly

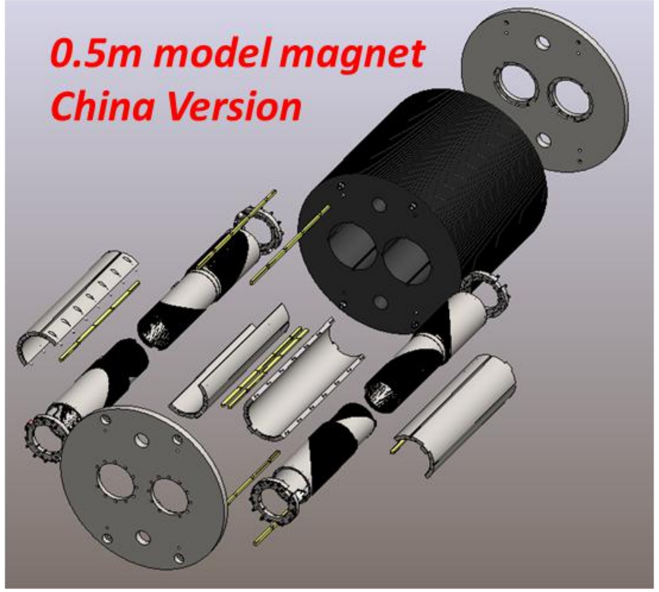


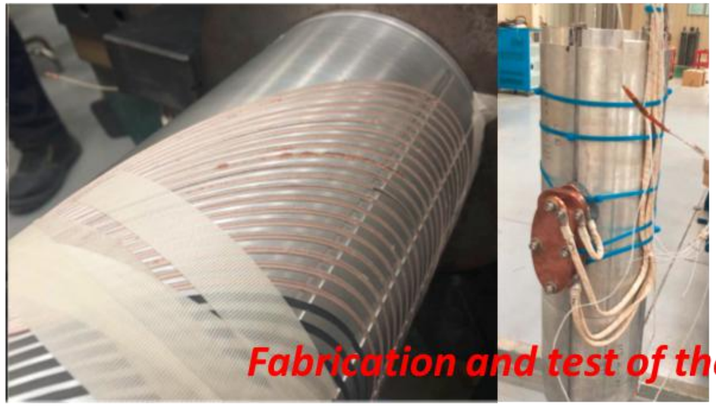
CERN & China Collaboration

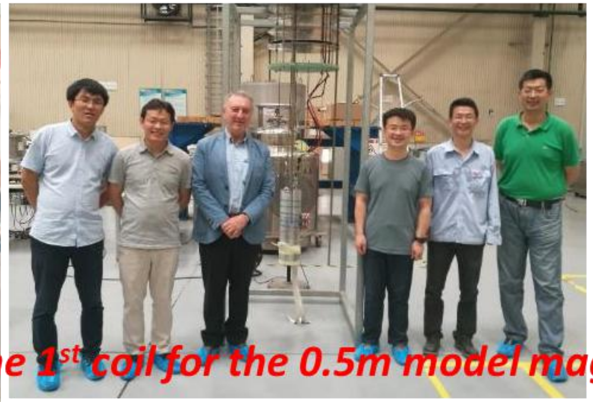
China will provide 12 units CCT corrector magnets for HL-LHC before 2022

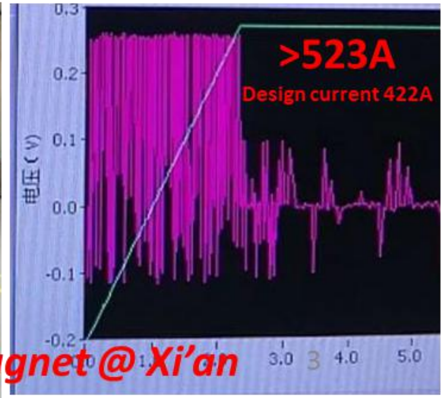
A 0.5m model and 2.2m prototype to be fabricated and tested by June 2019











Fabrication and test of the 1st coil for the 0.5m model magnet @ Xi'an

CEPC Industrial Promotion Consortium (CIPC) Collaboration Status

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

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

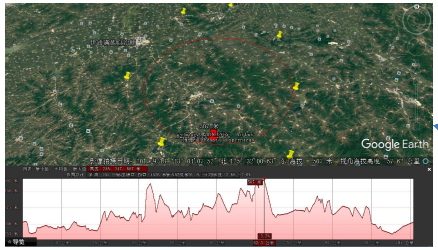
-Huadong Engineering Cooperation Company,on CEPC alignement and installation logistics...

CEPC-SppC Siting and Civil Engineering

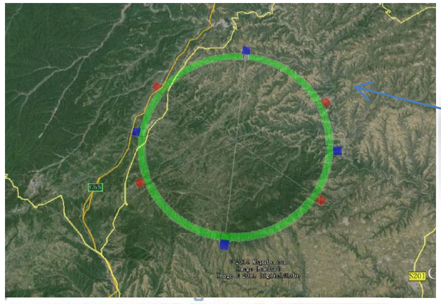
CEPC Site Selections

Huanghe Company particitated

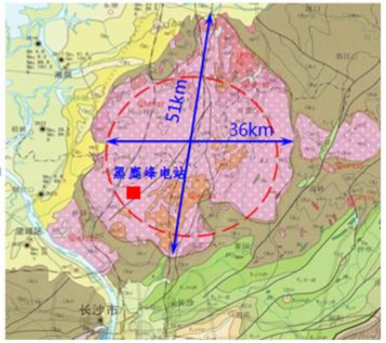
6

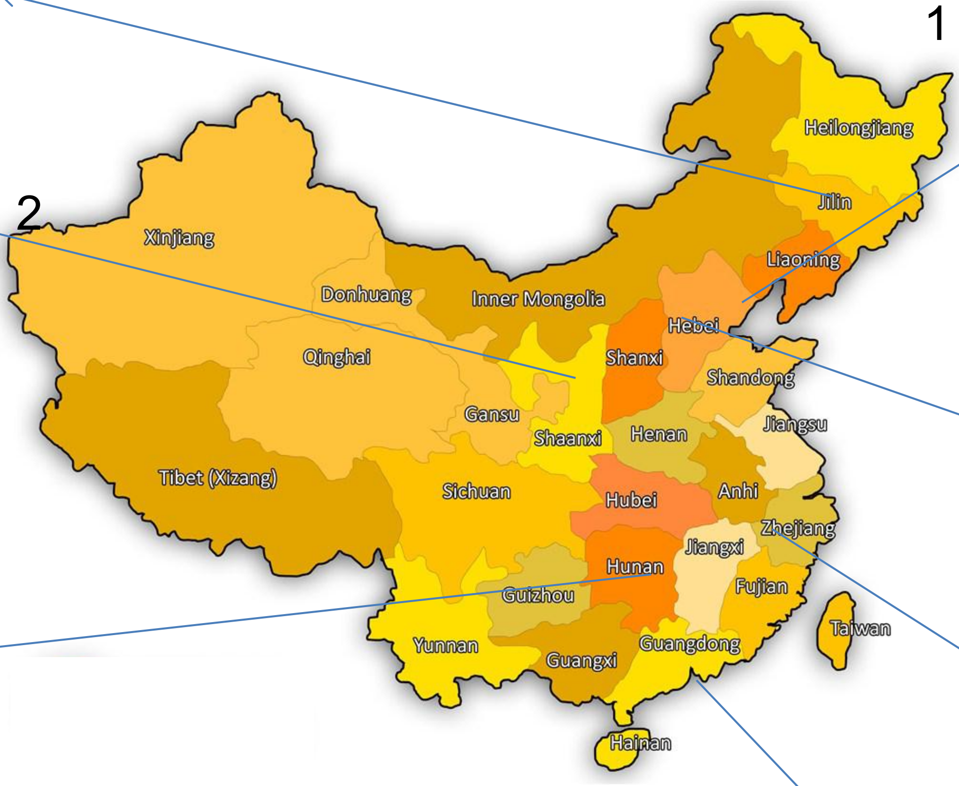


2



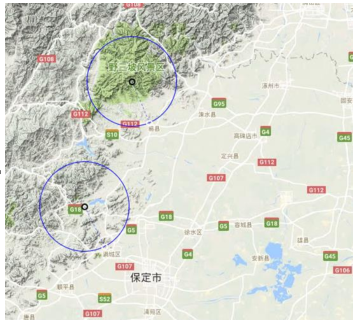
7



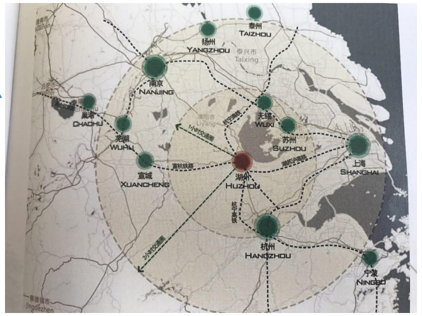


1

4



5



3

1) Qinhuangdao, Hebei Province（Completed in 2014）

2) Huangling, Shanxi Province（Completed in 2017)

3) Shenshan, Guangdong Province(Completed in 2016)

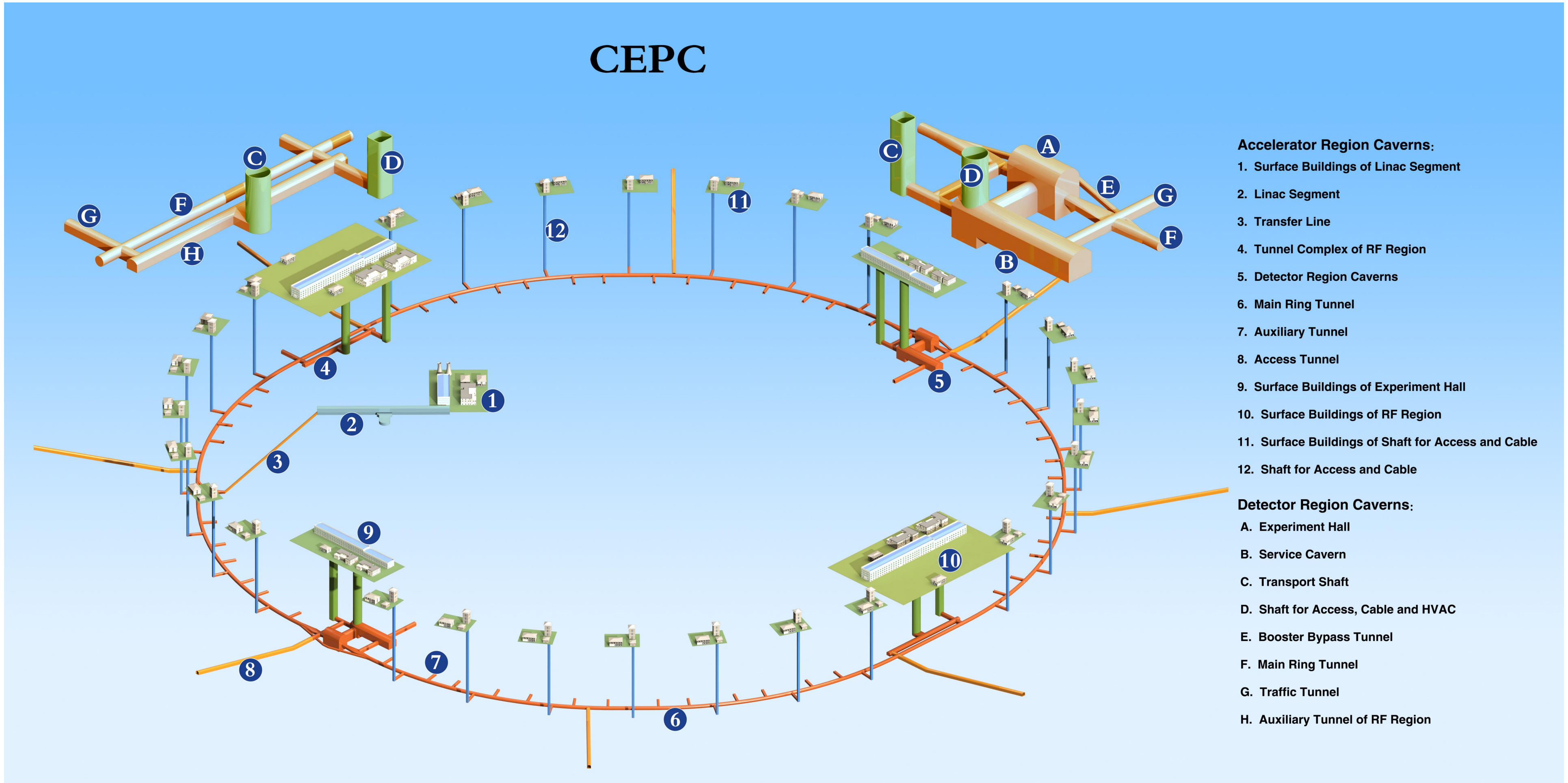
4) Baoding (Xiong an), Hebei Province (Started in August 2017)

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

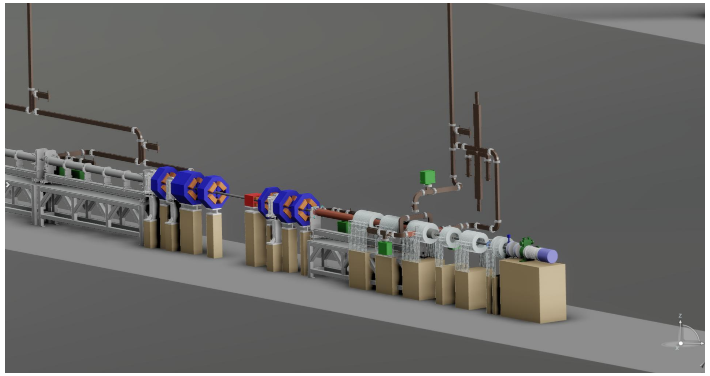
6) Chuangchun, Jilin Province (Started in May 2018)

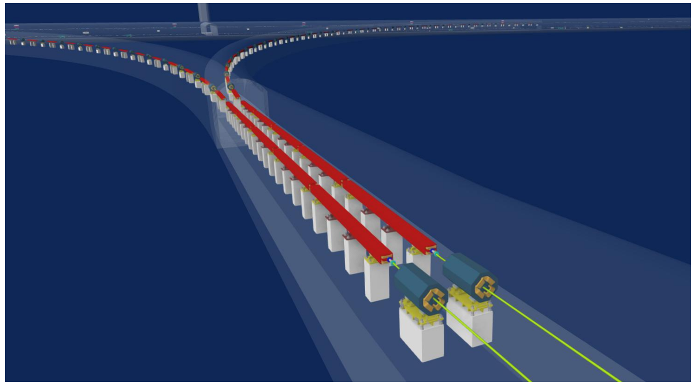
7) Changsha, Hunan Province (Started in Dec. 2018)

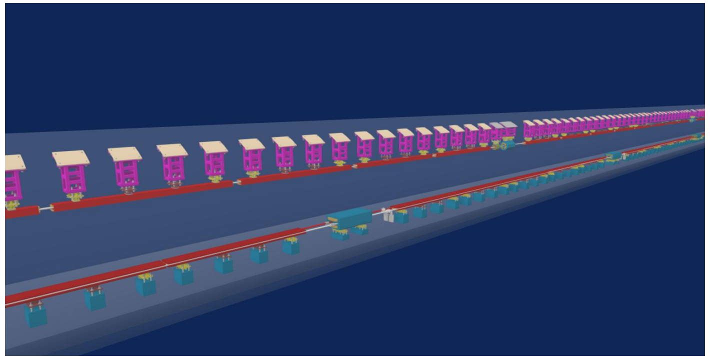
CEPC Tunnel Design

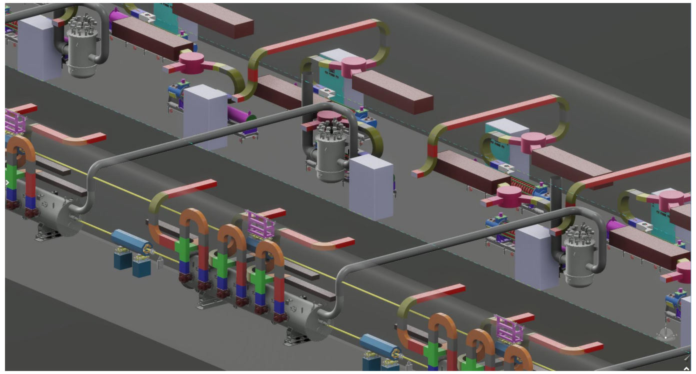


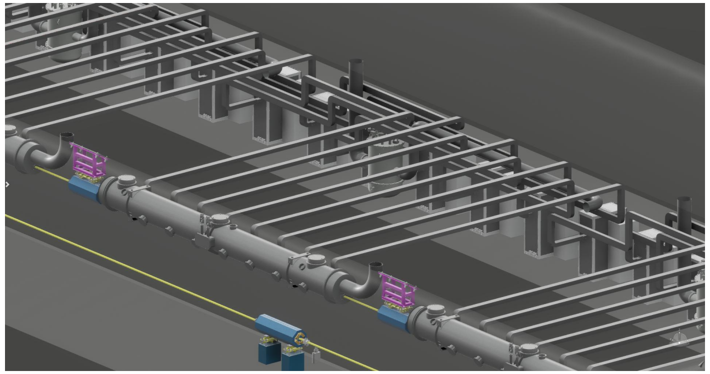
CEPC Civil Engineering

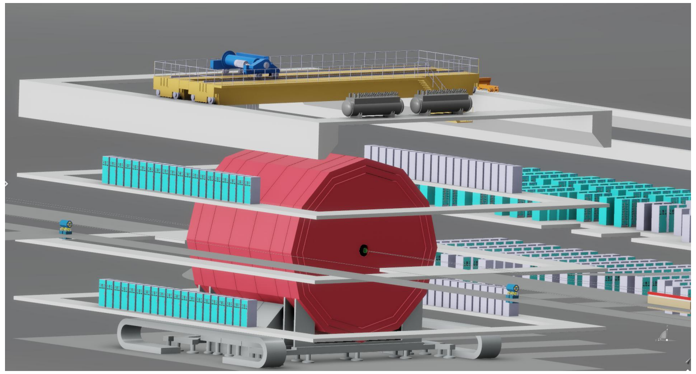

Electron source


Linac to Booster

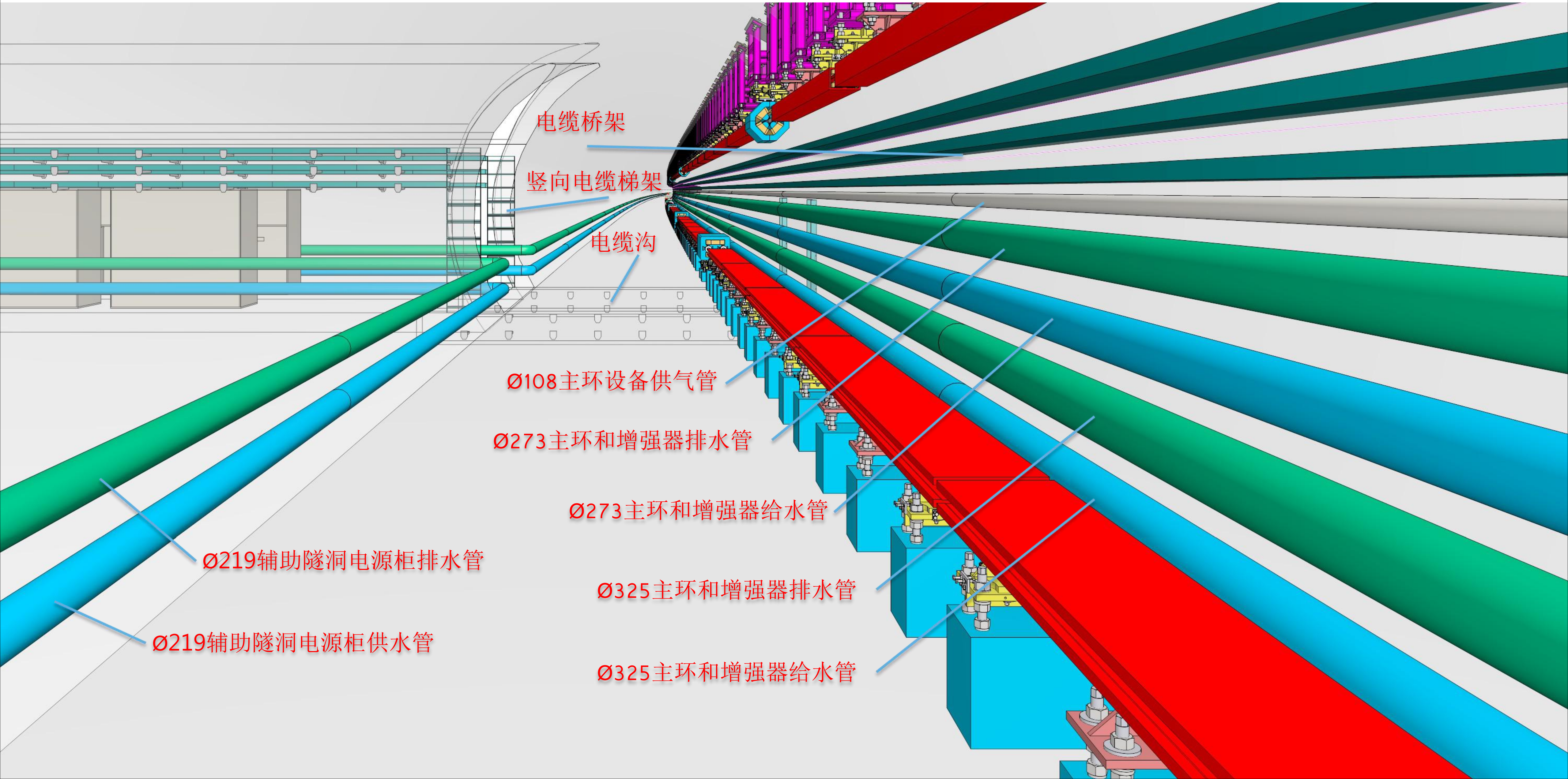

Booster and collider ring tunnel


Collider ring SCRF

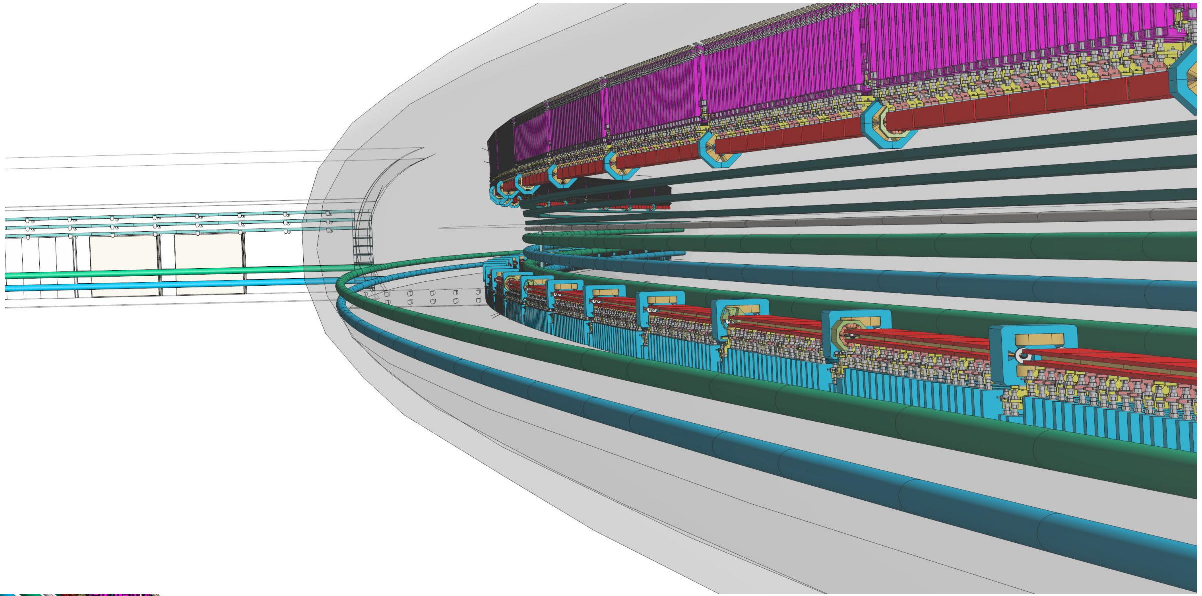

Booster SCRF

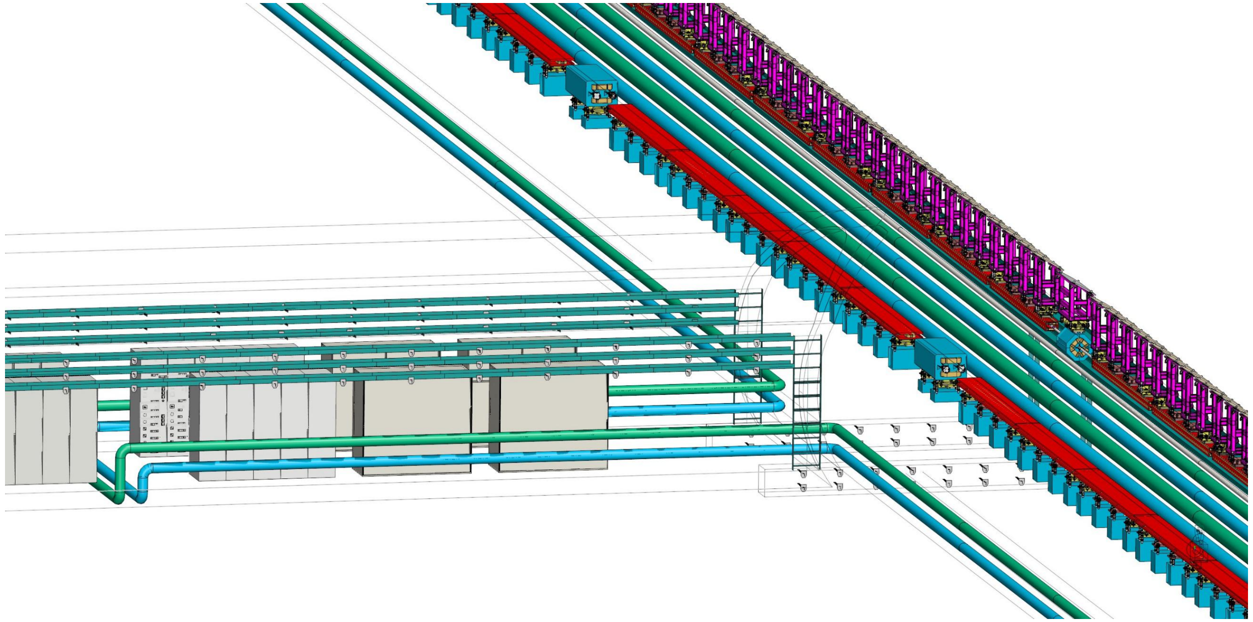

Detector hall

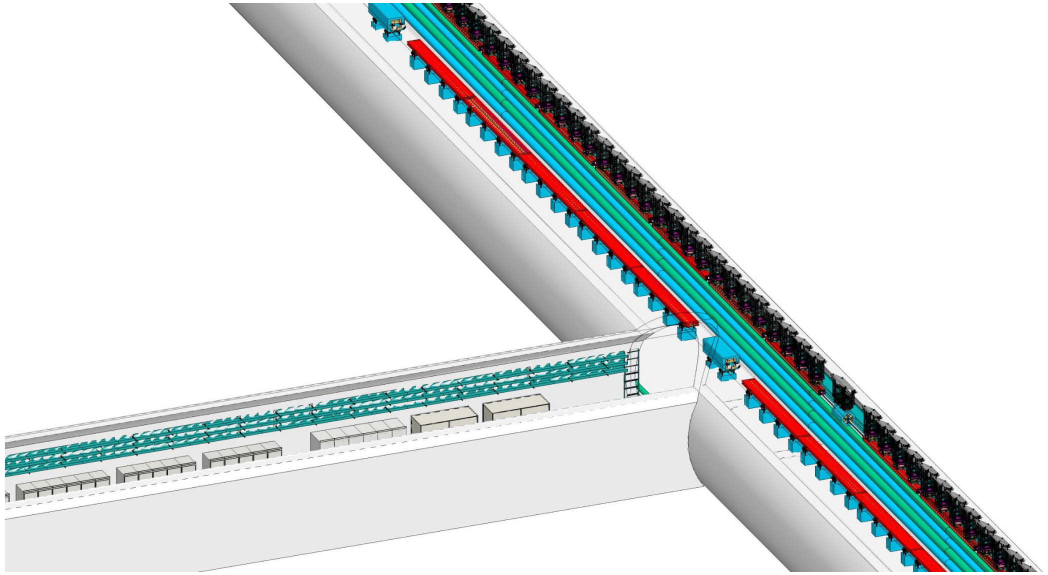
CEPC Main Tunnel and Auxiliary Tunnel-1



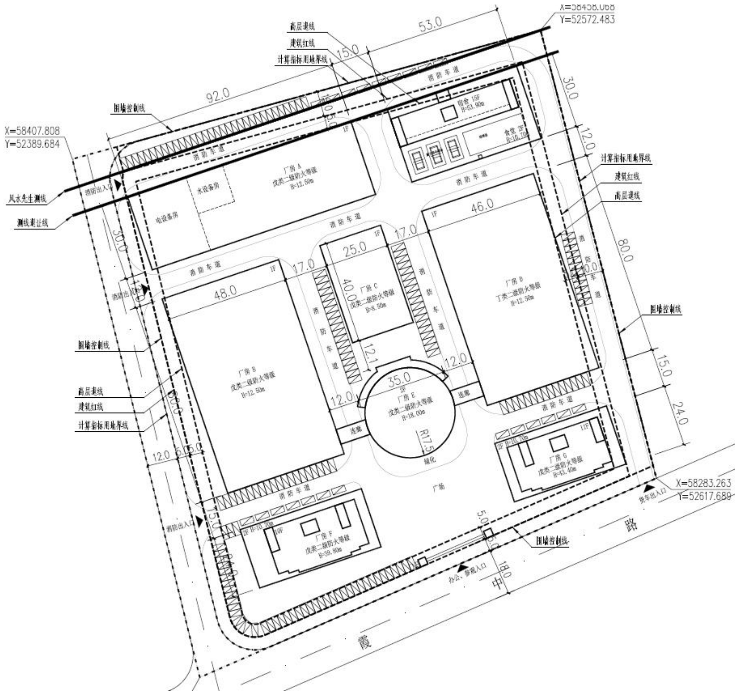
CEPC Main Tunnel and Auxiliary Tunnel-2

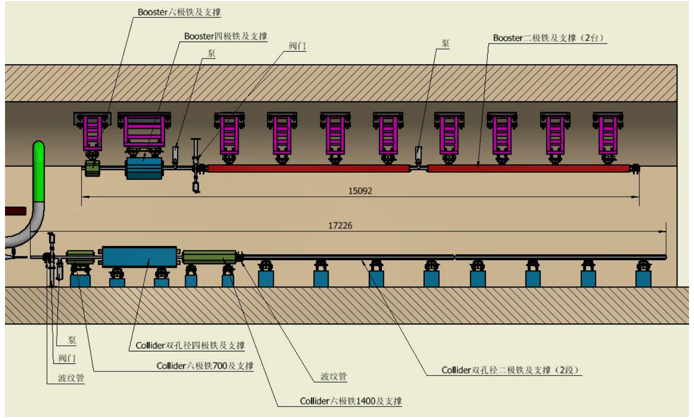


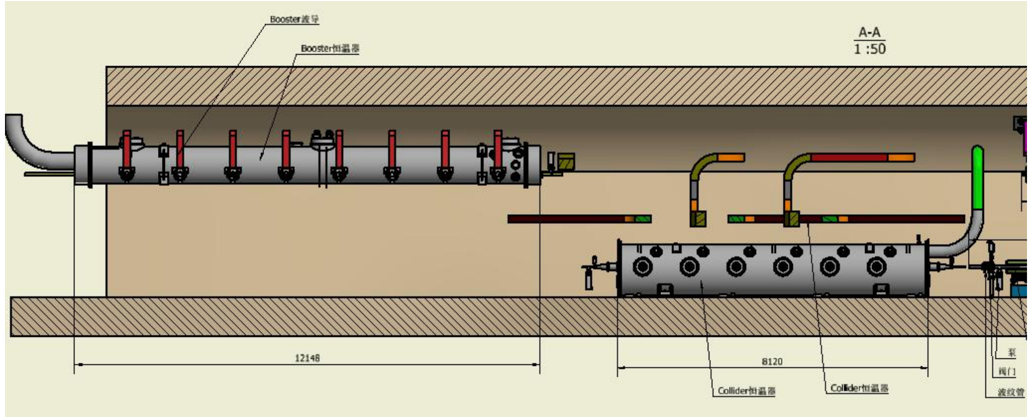


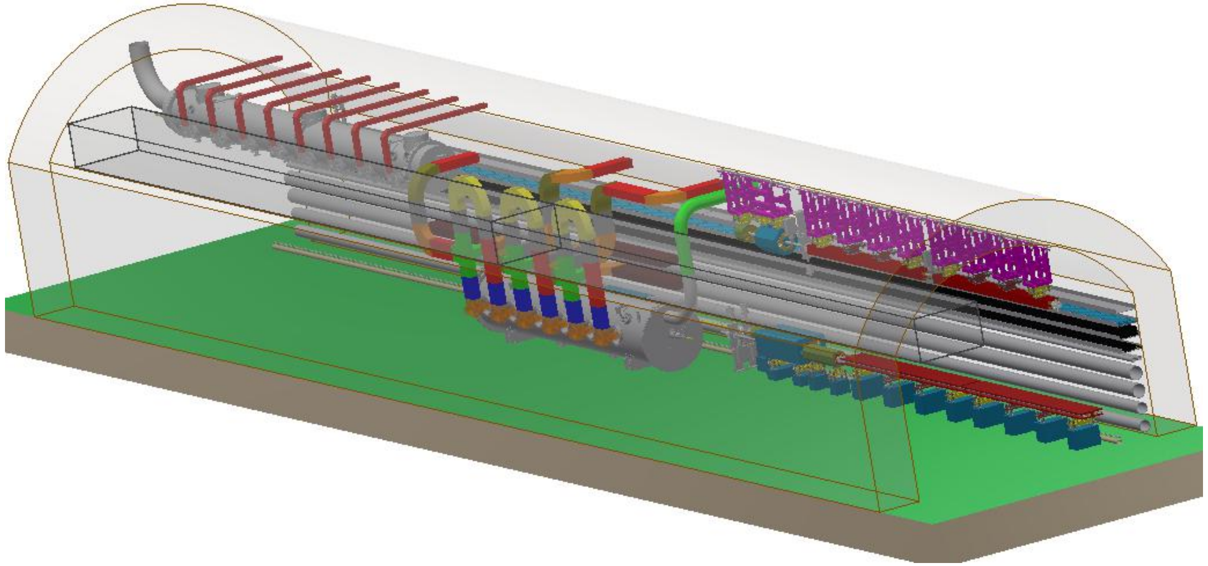


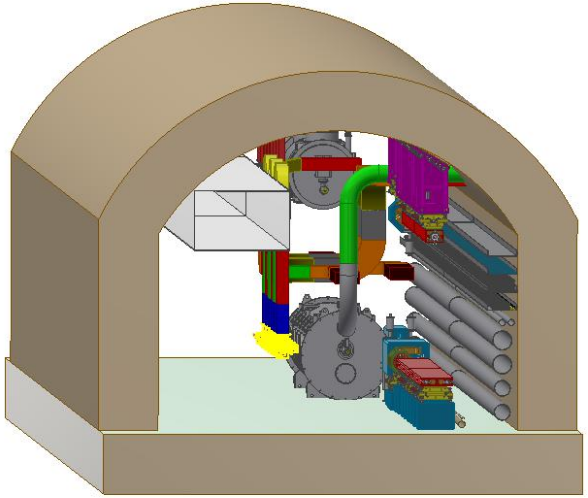
CEPC Mockup Tunnel Design (40m)



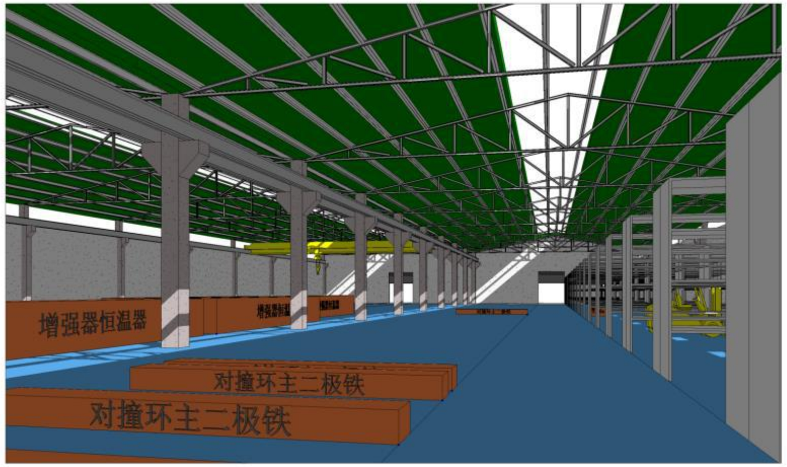


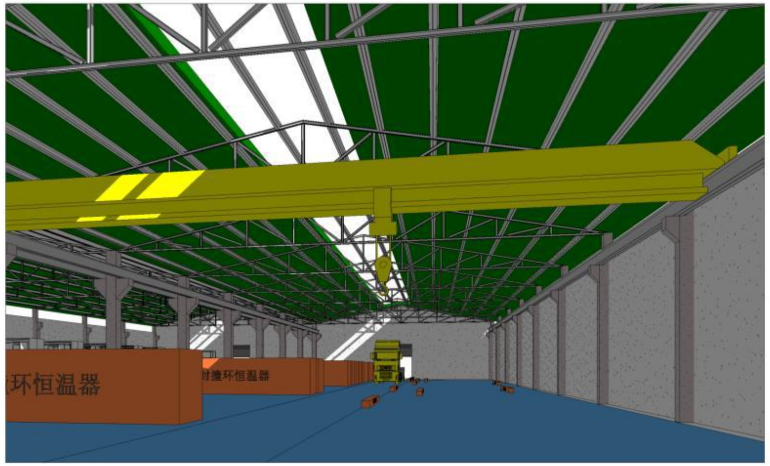


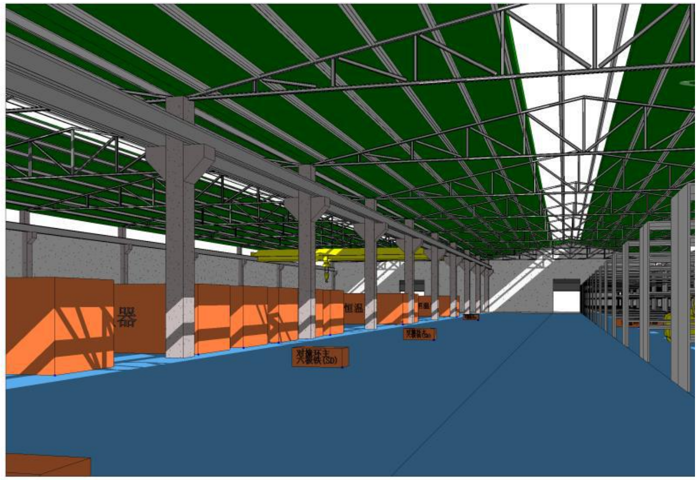


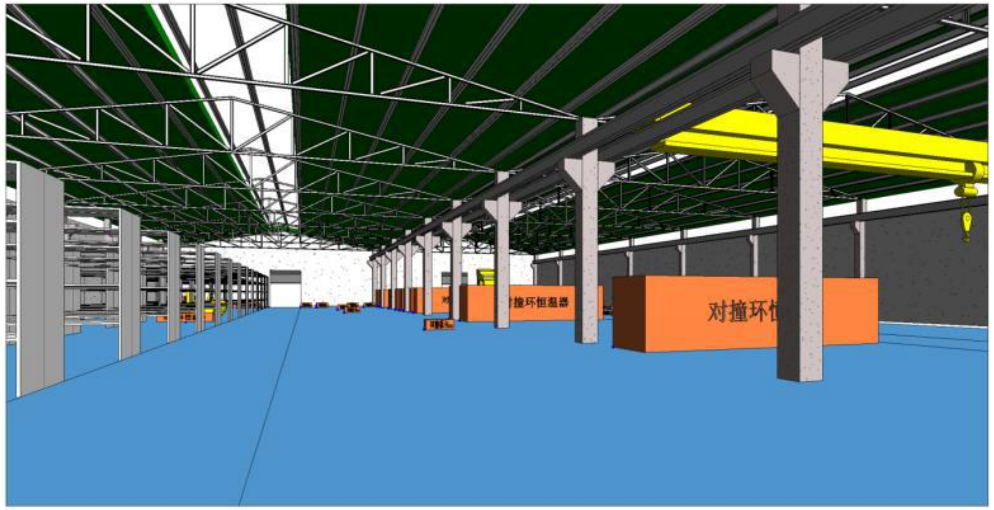


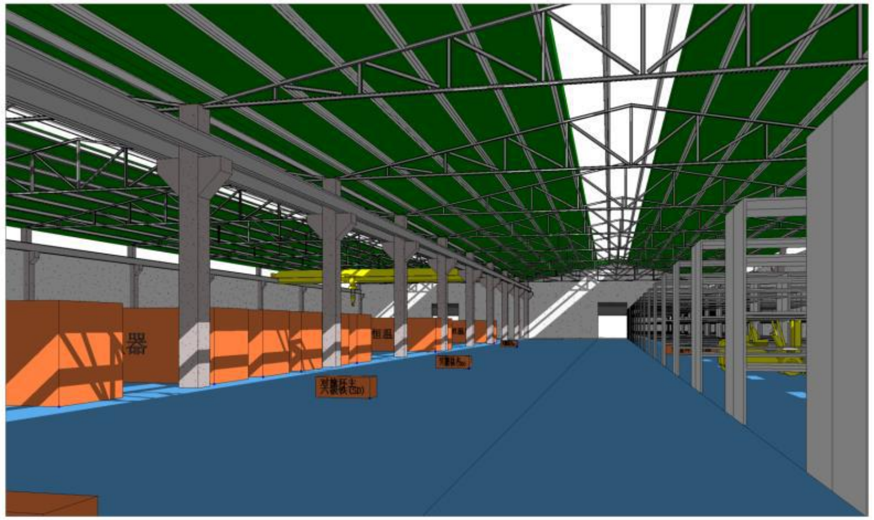
CEPC Component Stores for Installation



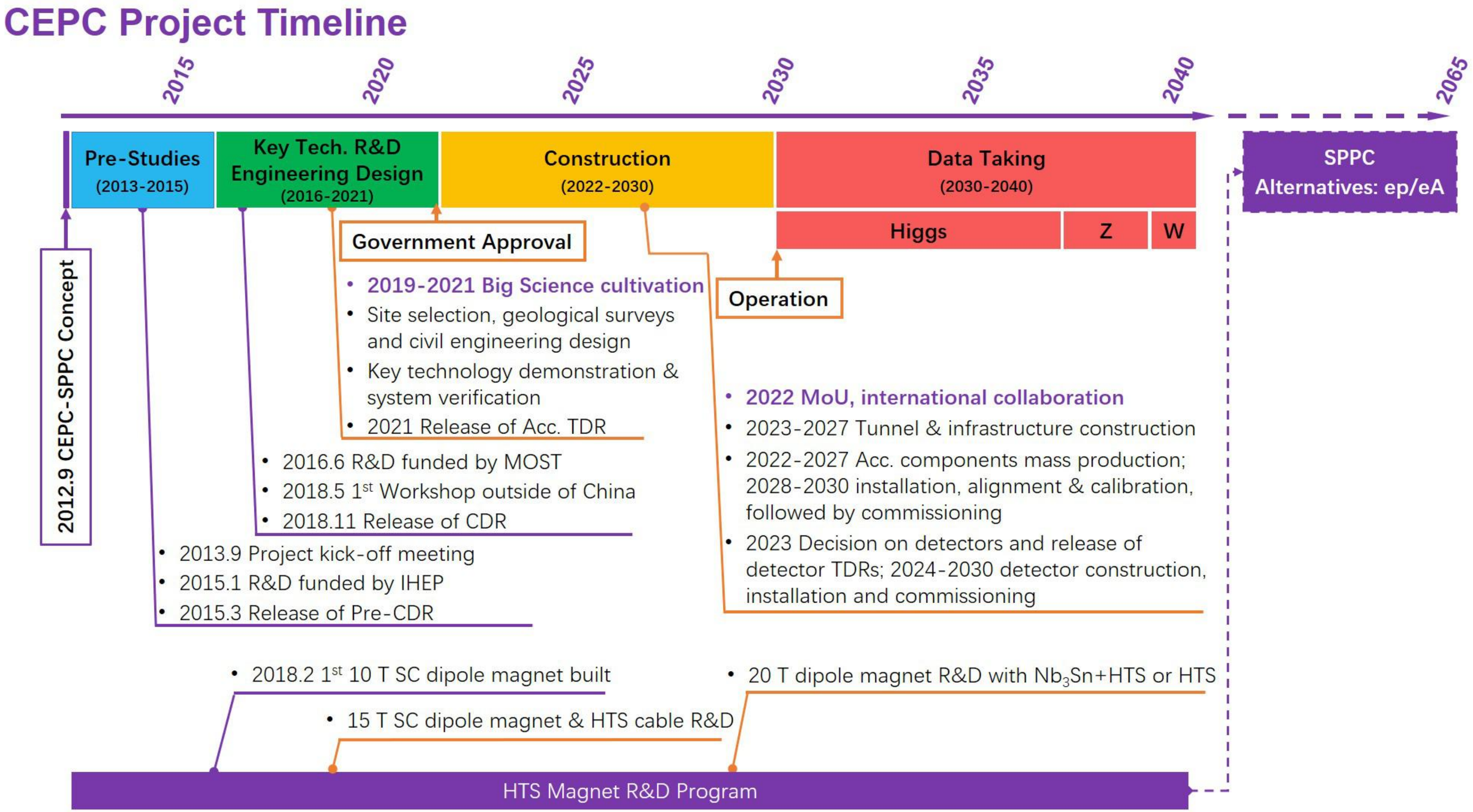








CEPC Timeline



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