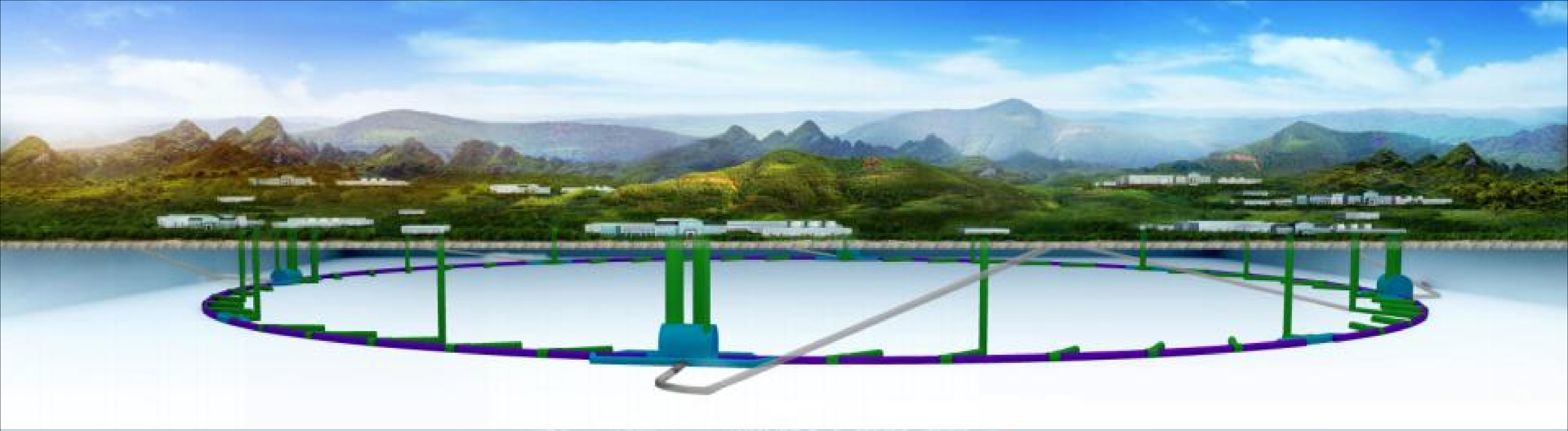


CEPC TDR Status and Perspectives

J. Gao

Institute of High Energy Physics

March 19, 2019, INP, Minsk, Belarus

Outline

- **CEPC CDR and TDR Status**
- **CEPC accelerator technology R&D towards TDR**
- **Summary**

CEPC Accelerator CDR and TDR Progress Status

CEPC Design –Higgs Parameters

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

CEPC Design – Z-pole Parameters

Parameter	Design Goal
Particles	e+, e-
Center of mass energy	2*45.5 GeV
Integrated luminosity (peak)	>10^34/cm^2s
No. of IPs	2
Polarization	**Z-pole polarization under study**

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

CEPC CDR Accelerator Chain and Systems

10 GeV

1) Injector

L=1.2km

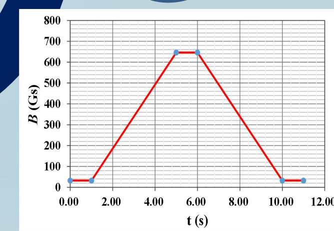
Electron

Positron

2) Booster

C=100km

Energy Ramp
10 ->45/120GeV



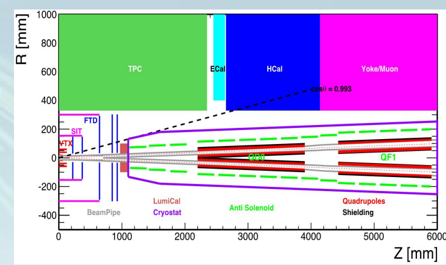
Booster Cycle (0.1 Hz)

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

3) Main Ring

C=100km
2IP

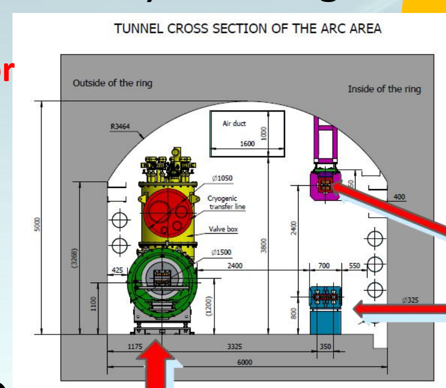
45/120 GeV



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.

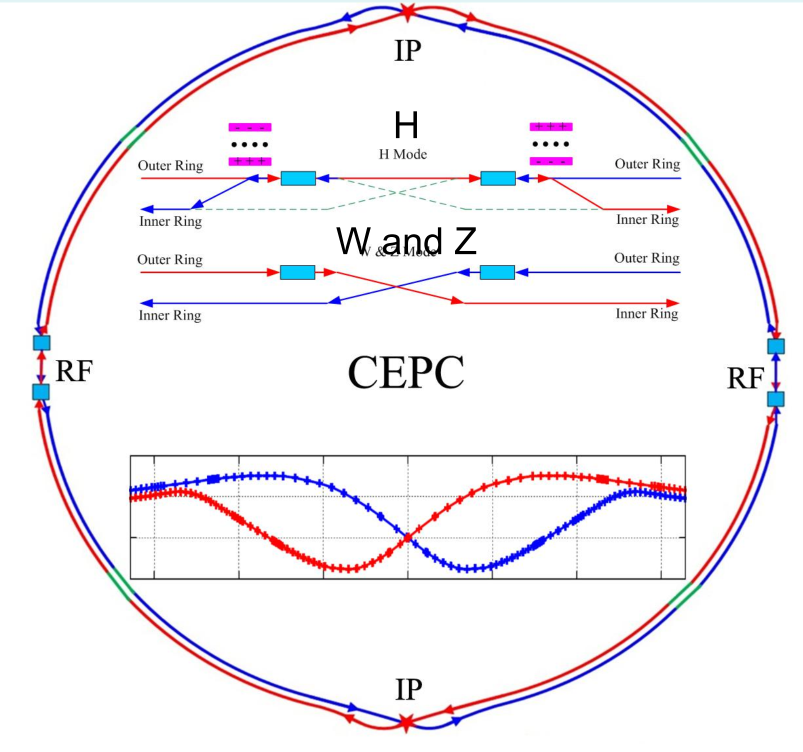


CEPC Booster

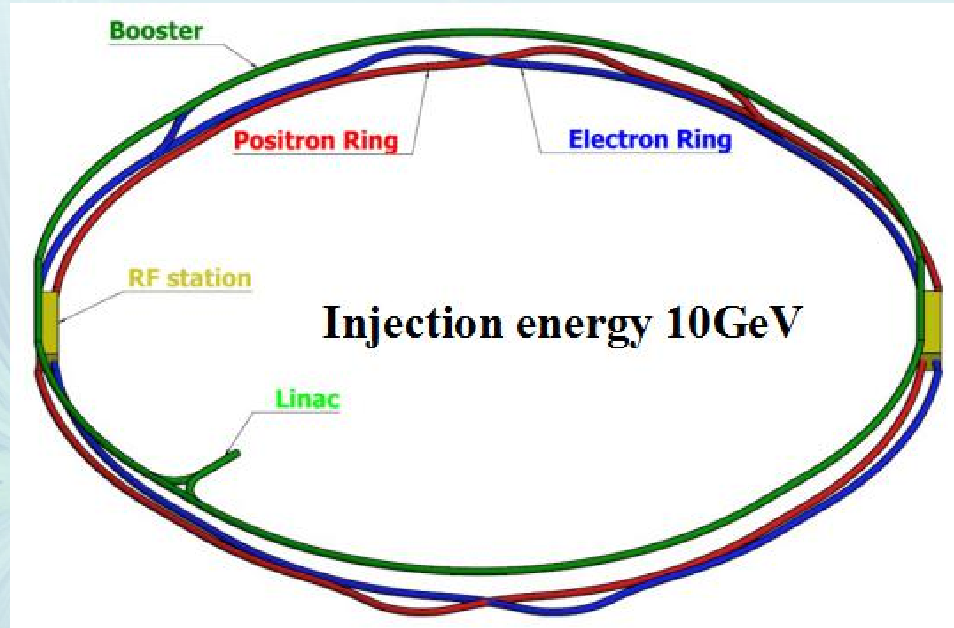
CEPC Collider

SppC

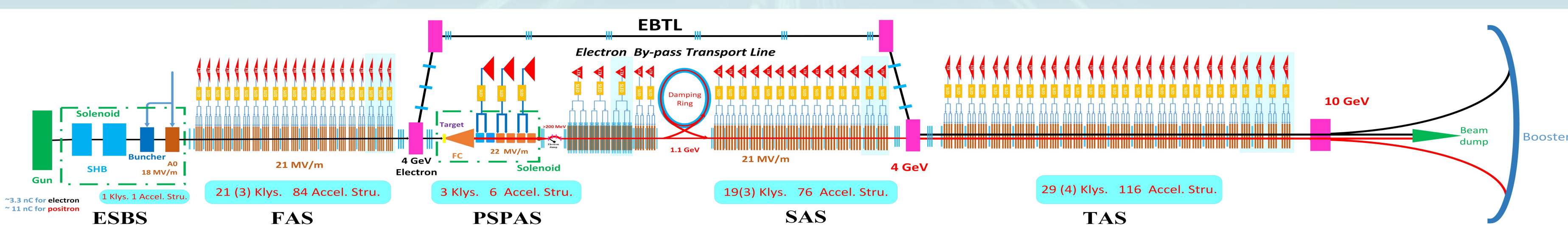
CEPC CDR Baseline Layout



CEPC collider ring (100km)



CEPC booster ring (100km)

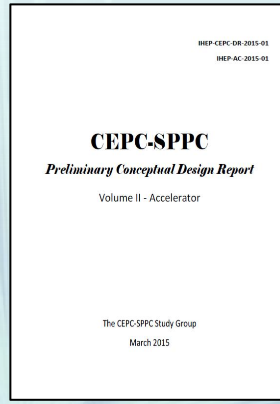


CEPC Linac injector (1.2km, 10GeV)

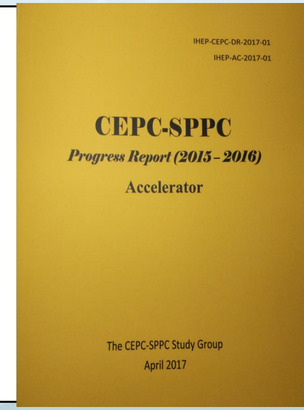
CEPC Accelerator CDR Completed

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

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



March 2015



April 2017

Draft CDR for Mini International Review in Nov. 2017

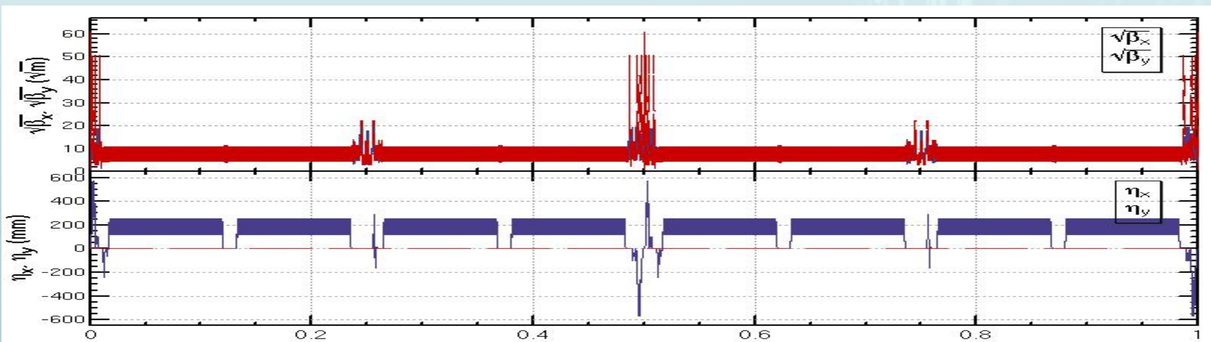
CDR Version for International Review June 2018, and formally relased on Sept. 2, 2018:arXiv：1809.00285, http://cepc.ihep.ac.cn/CDR_v6_201808.pdf

CEPC CDR Parameters

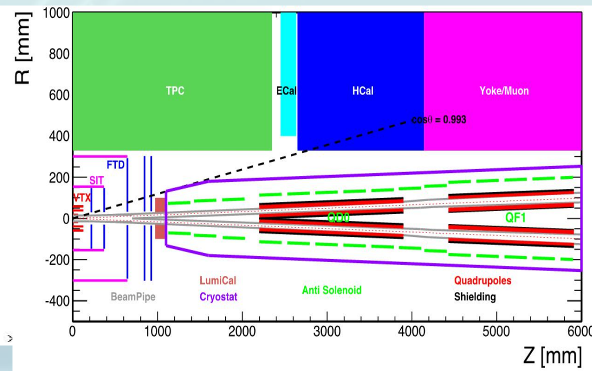
	Higgs	*W*	*Z (3T)*	*Z (2T)*
Number of IPs	2			
Beam energy (GeV)	**120**	**80**	**45.5**	
Circumference (km)	100			
Synchrotron radiation loss/turn (GeV)	1.73	0.34	0.036	
Crossing angle at IP (mrad)	16.5×2			
Piwinski angle	2.58	7.0	23.8	
Number of particles/bunch N_e (10^{10})	15.0	12.0	8.0	
Bunch number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

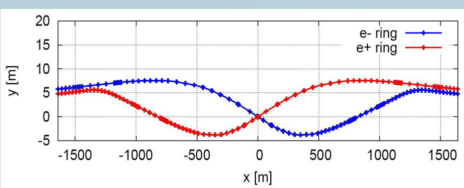
Lattice of the CEPC Collider Ring and MDI

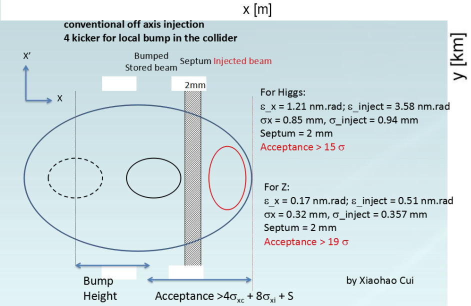
An optics fulfilling requirements of the parameters list, geometry, MDI, background and key hardware

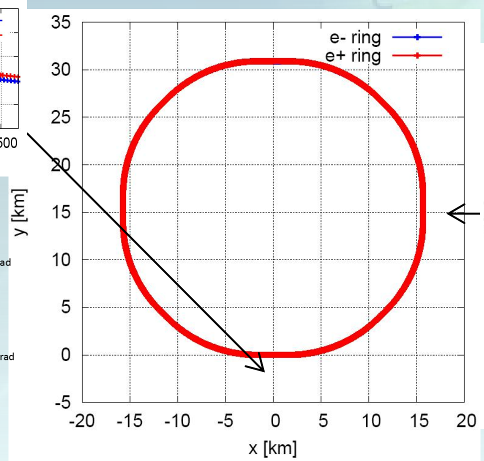


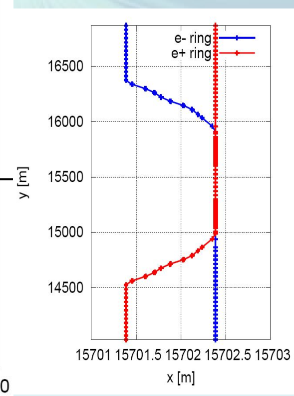
CEPC MDI











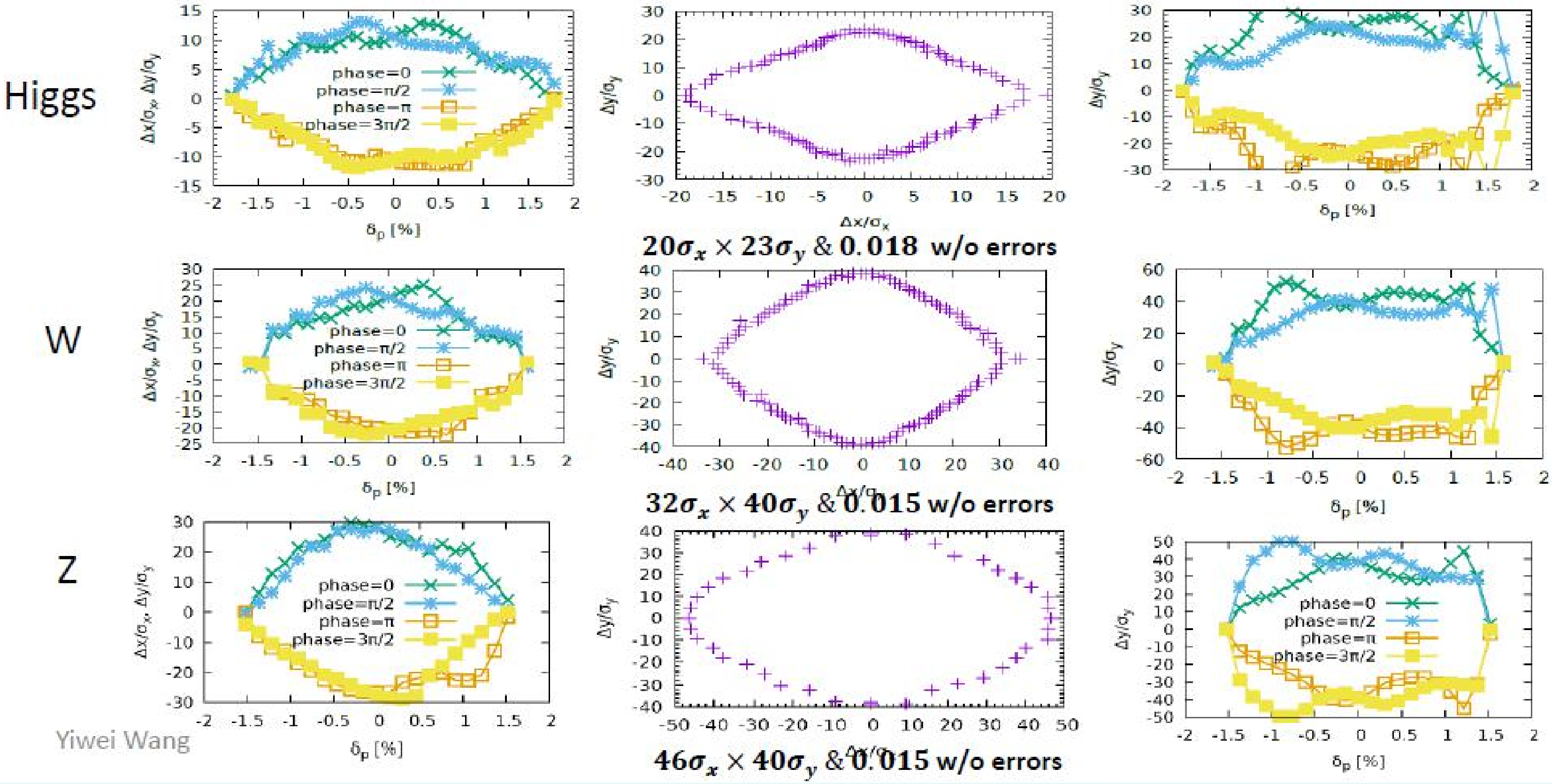
MDI parameters	Values
*L** (m)	2.2
Crossing angle (mrad)	33
Strength of QD0 (T/m)	150
Strength of detector solenoid (T)	3.0
Strength of anti-solenoid (T)	7.0

CEPC collider ring DA w/o errors

Dynamic aperture result (w/o errors)

by Y. ZHANG, et al

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



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

$32\sigma_x \times 40\sigma_y$ & 0.015 w/o errors

$46\sigma_x \times 40\sigma_y$ & 0.015 w/o errors

Yiwei Wang

Performance with magnets' errors

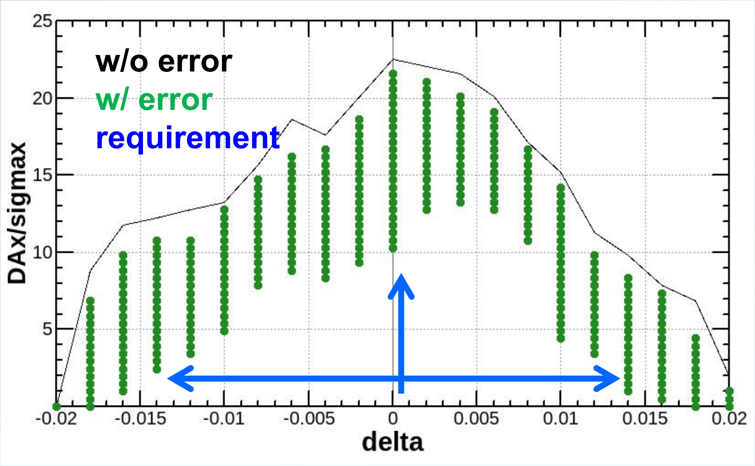
- Relaxed requirement of alignments and filed errors compared with CDR
- Stronger corrections made (Yuanyuan WEI's talk)

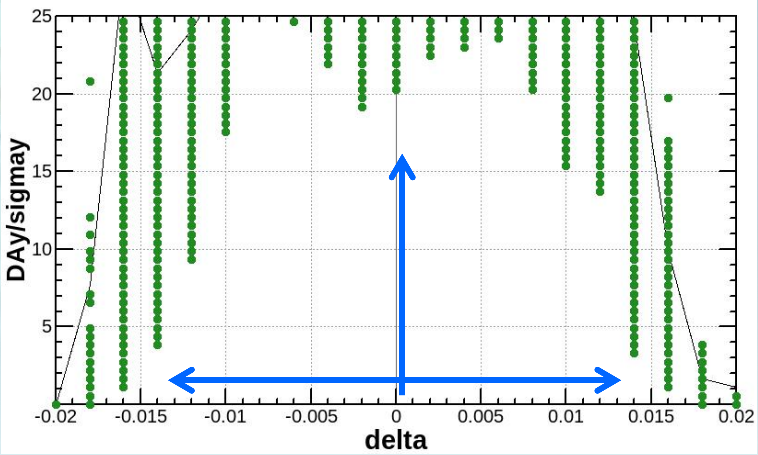
Component	Δx (um)	Δy (um)	$\Delta \theta_z$ (urad)
Arc quadrupole	100	100	100
IR Quadrupole (w/o FF)	50	50	50
Sextupole	100	100	100

Component	Field error
Dipole	0.01%
Arc quadrupole	0.02%

Performance with errors (cont.)

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





Requirement with on-axis injeciotn $8\sigma_x \times 15\sigma_y$ & 0.0135

CEPC Collider Ring SRF Parameters

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

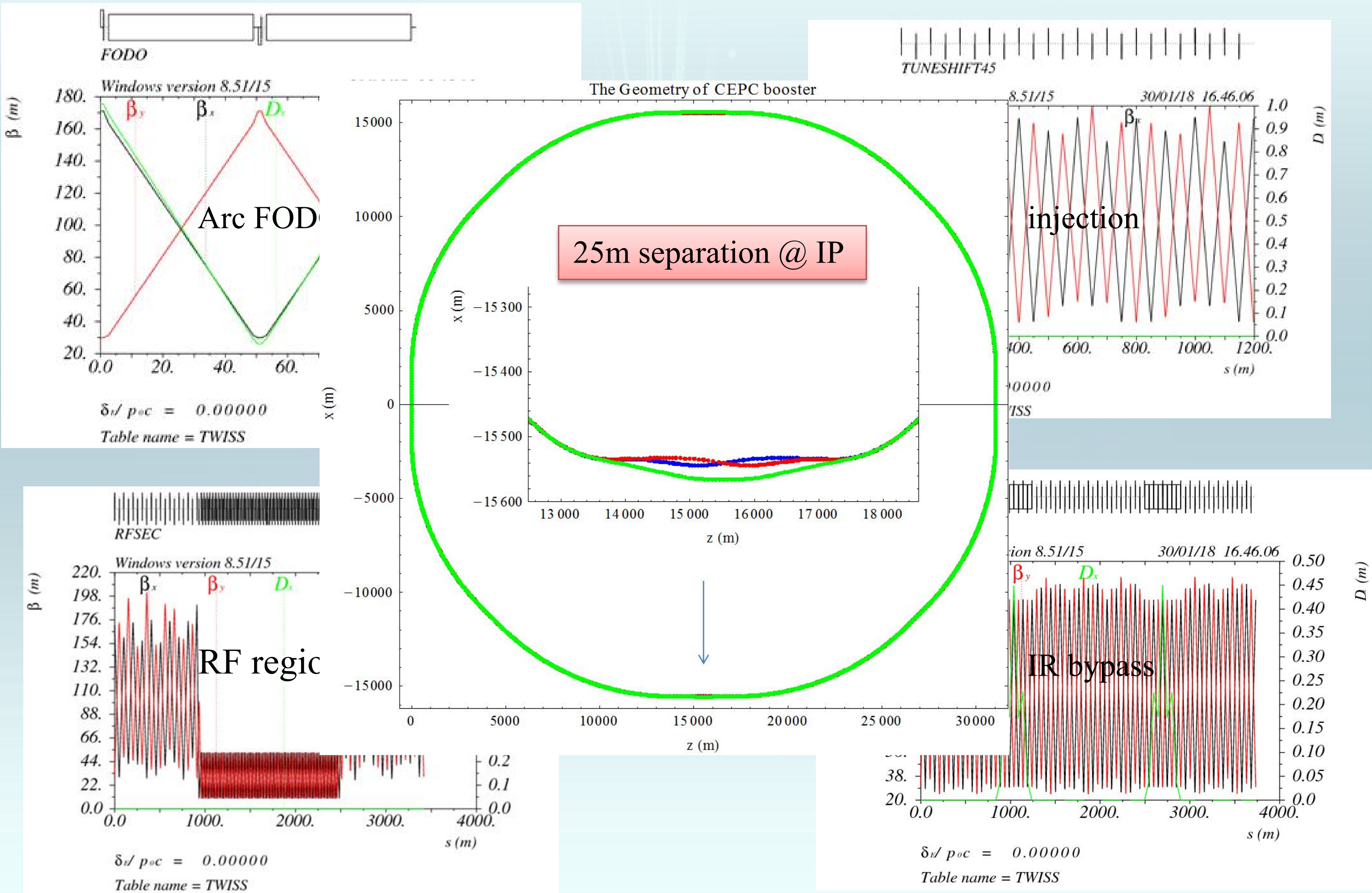
CEPC Booster parameters @ injection (10GeV)

		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

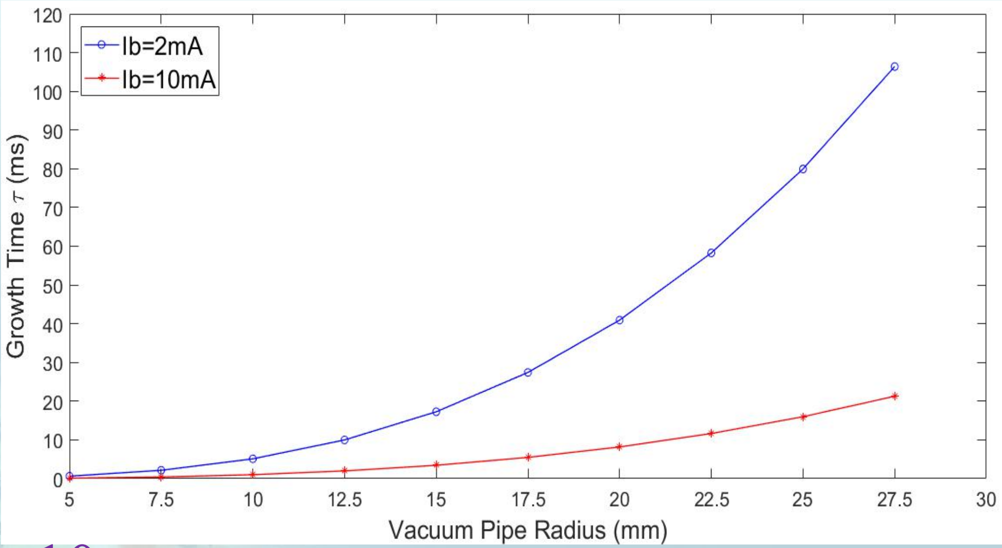
Dipole reproducibility requirement@10Gev

- Increase/decrease the strength of all the dipoles by the same amount.
- Decrease/increase the strength of quadrupoles & sextupoles → energy mismatch
- Evaluate the influence: working point, closed orbit, DA, energy acceptance
- Working point should not pass through the lower order resonance (<4)
- No shrink for dynamic aperture
- **Reproducibility requirement: ~0.02%**

	original	+0.01%	-0.01%	+0.05%	-0.05%
nux	263.20376	263.1367	263.271	262.868	263.5397
nuy	261.21034	261.1437	261.277	260.877	261.5437
Δx (um)	0	-54	54	-270	270
DA (%)	100	100	100	90	90

Booster multi bunch instability @10GeV

- Growth time << damping time (90ms)
- Feedback system is essential at 10 GeV



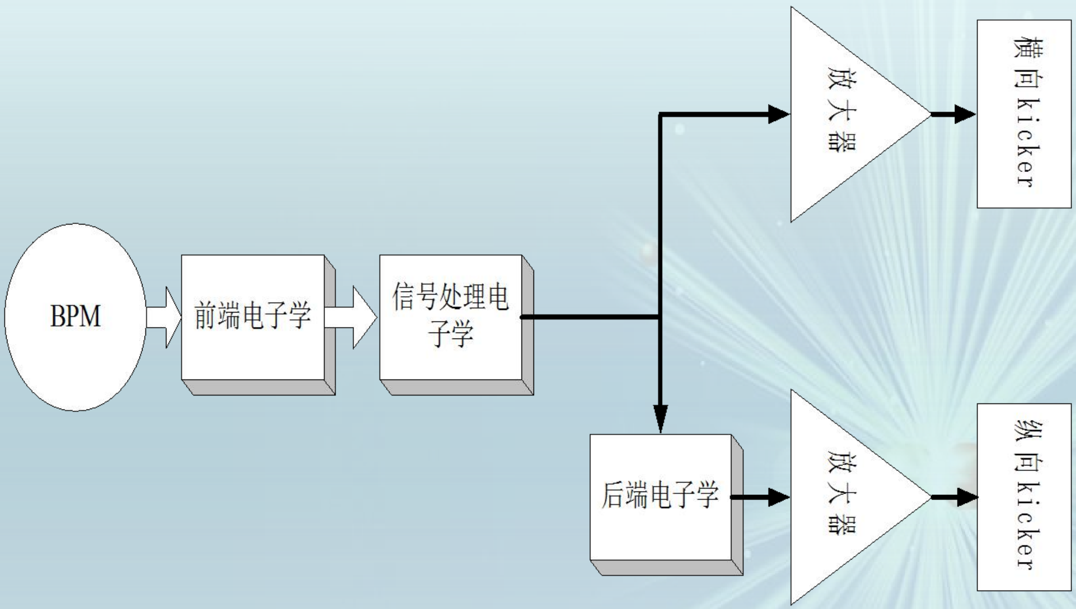
- Damping time of feedback: ~10 turns

CEPC Booster TESLA 9-cavity HOM CBI growth time

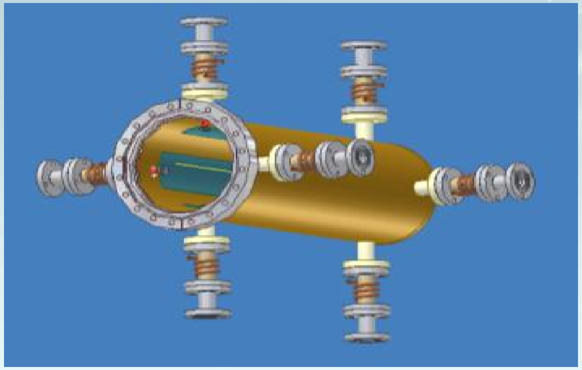
				H-injection	W-injection	Z-injection
TM011	2.45	156	5.9E4	149	29.6	11.3
TM012	3.845	44	2.4E5	82.7	16.4	6.3
TE111	1.739	4283	3.4E3	609	120.9	46.1
TM110	1.874	2293	5.0E4	77.4	15.4	5.9
TM111	2.577	4336	5.0E4	40.9	8.1	3.1
TE121	3.087	196	4.4E4	1028.4	204.1	77.8

Parameter design for transverse feedback

J. Yue



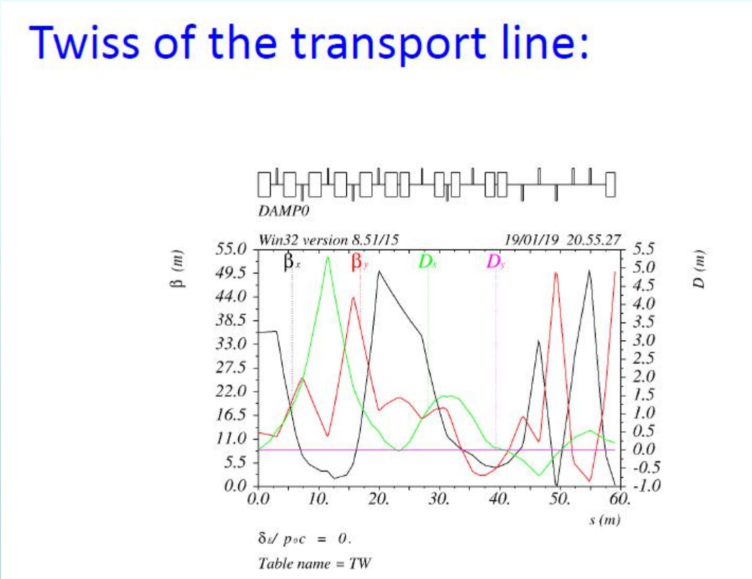
parameter	value
ν_x/ν_y	263.2/261.2
β(m)	120
E(GeV)	10
Growth time(ms)	3.1
T0(ms)	0.33
Bunch spacing(ns)	25
Bunch frequency(MHz)	40
Kicker impedance(kΩ)	160
Damping time(ms)	2
Vertical oscillatory amplitude (mm)	0.1



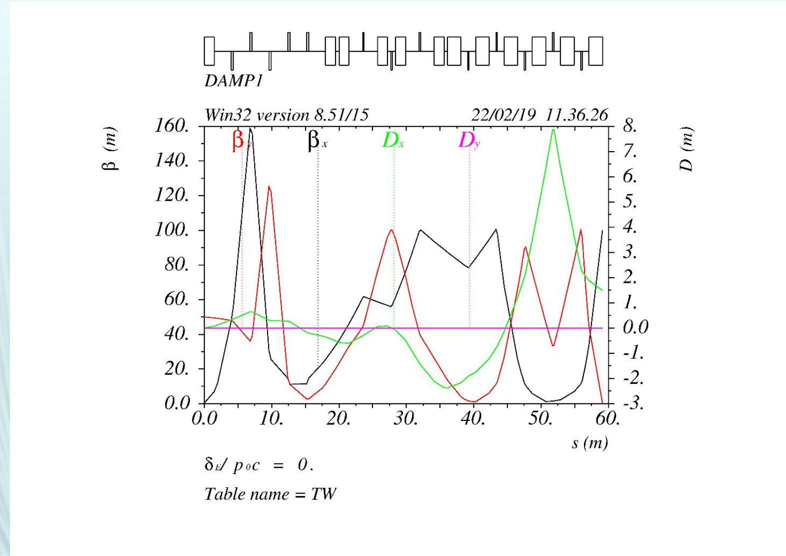
- L=450mm， R_S=160kΩ @40MHz

- 4-tap filter was considered
- With only one feedback, power for kicker too high
- Two feedback was considered, damping time for each: 4ms

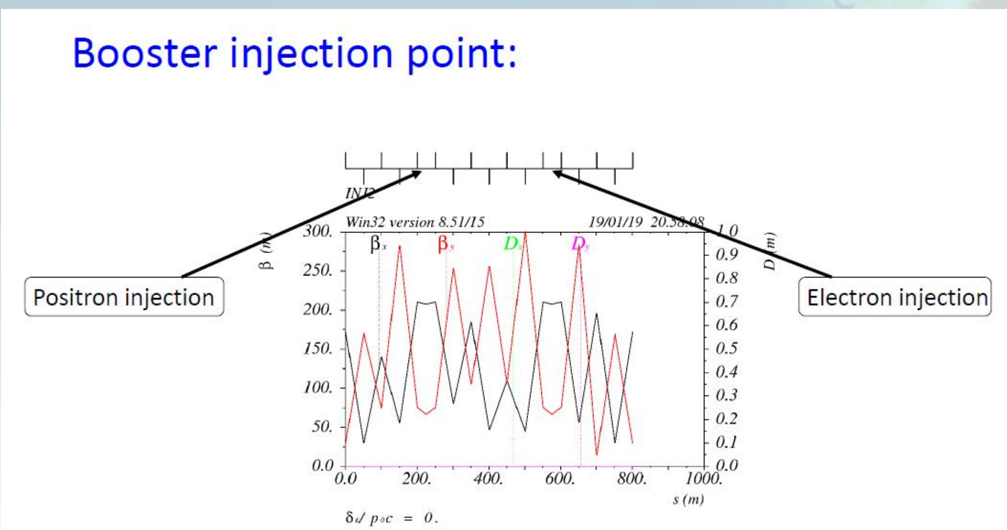
CEPC accelerator chain transport lines



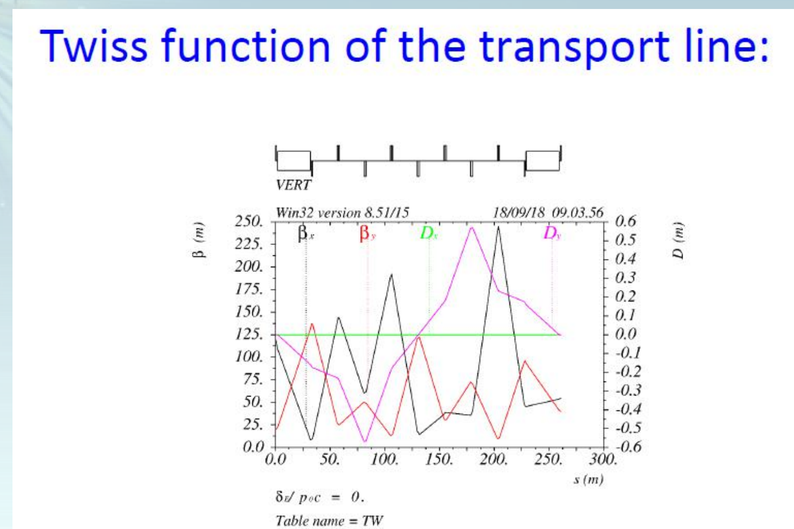
Injection from linac to damping ring



Injection from damping ring to linac



Injection from linac to Booster



Injection from booster to collider

Kickers and Septa (injection to and extraction from damping ring)

- Since there are two bunches in the ring, the rise time and fall time of the kickers should be less than the bunch spacing 100 ns.

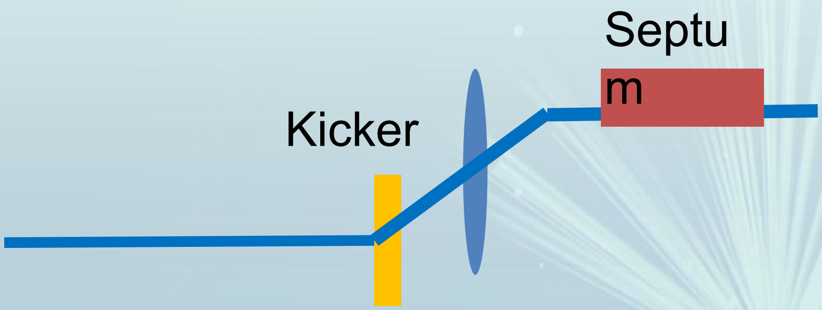
Compone nt	Number	Septum width	Length (m)	Deflection angle (mrad)	Field (T)	Beam-Stay-clear	
						H(mm)	V(mm)
Septum	2	10mm	2	100	0.18	60	60
Kicker	2		0.5	1.5	0.01	60	60

Injection to booster: kickers and septa

- One-turn on-axis injection due to the long damping time of the booster.
- The septum gives a horizontal deflection while the kickers give a vertical bending.

Component	Number	Septum width	Length (m)	Type	Deflection angle (mrad)	Field (T)	Beam-Stay-clear	
							H(mm)	V(mm)
Septum	2	10 mm	2	Lambertson	22	0.366	63	63
Kicker	8		0.3		0.25	0.028	40	40

Extraction kickers and septa from booster

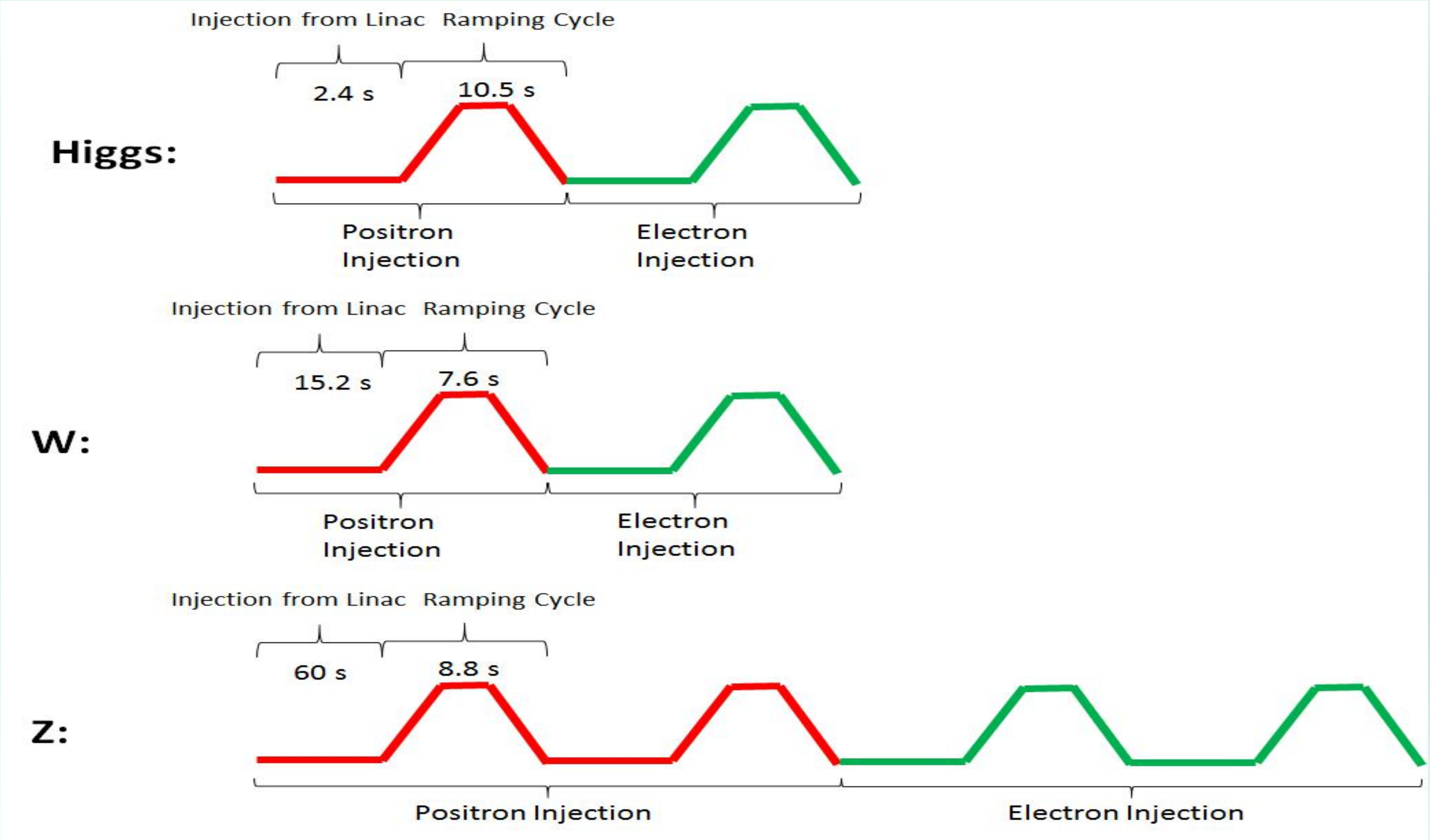


Component	Number	Septum width	Length (m)	Type	Deflection angle (mrad)	Field (T)	Beam-Stay-clear	
							H(mm)	V(mm)
Septum	2	10 mm	15	Lambertson	26	0.69	20	20
Kicker	4		0.7	0.1	0.06	40	40	4

Injection kickers and septa to collider ring

Component	Number	Septum width	Length (m)	Deflection angle (mrad)	Field (T)	Beam-Stay-clear	
						H(mm)	V(mm)
Septum	2	16mm	8.75	14	0.64	20	20
Septum	2	8mm	8.75	7	0.32	20	20
Septum	2	4mm	8.75	3.5	0.16	20	20
Septum	2	2mm	8.75	1.75	0.08	20	20
Kicker	8		0.7	0.1	0.06	20	20

Injection process



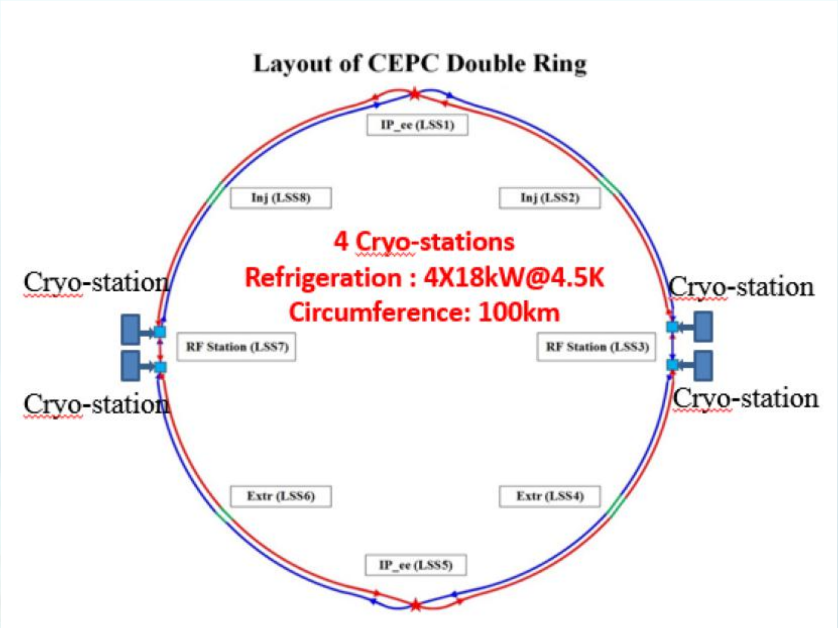
Injection parameters:

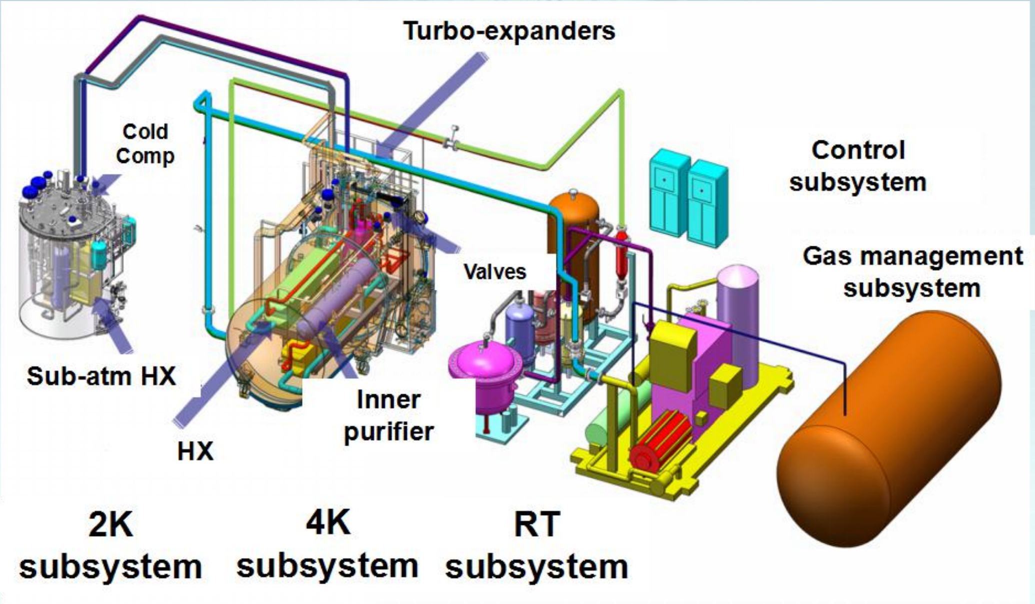
Mode	Higgs		W		Z	
Injection Mode	Top-up	Full	Top-up	Full	Top-up	Full
Bunch number in booster	242		1524		6000	
Beam Current (mA)	0.5227	0.726	2.63	3.67	6.91	10
Number of Cycles	1		1		2	
Ramping Cycle (sec) (Up + Down）	10		6.6		3.8	
Filling time (sec)（e+， e-)	25.84		39.6		275.2	
Injection period (sec)	47		131		438	

CEPC Cryogenic System

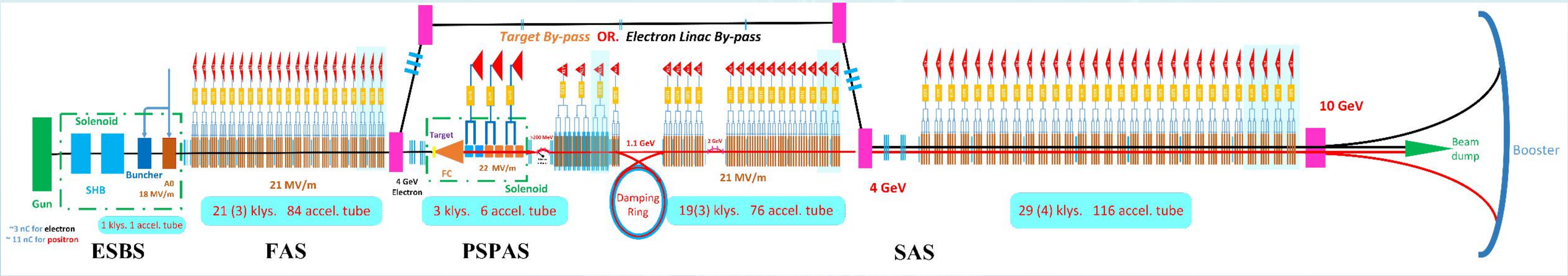
Booster ring:
- 1.3 GHz 9-cell cavities, 96 cavities
- 12 cryomodules
- 3 cryomodules/each station
- Temperature: 2K/31mbar

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





CEPC Linac Injector-1

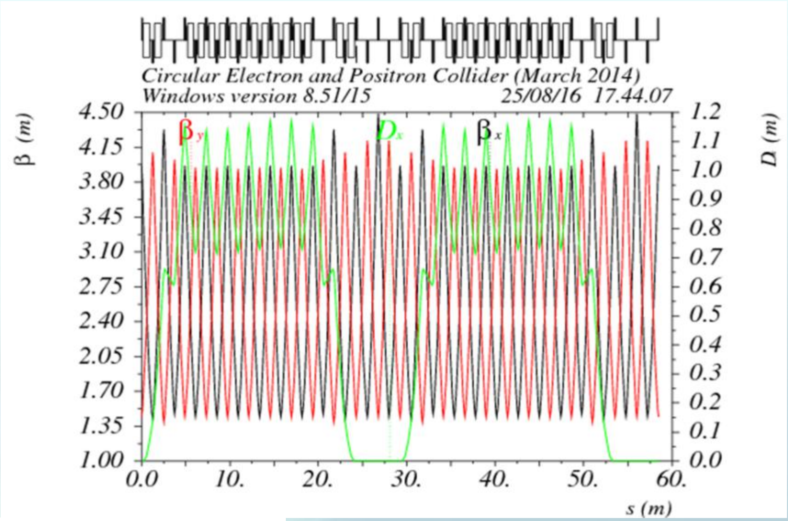


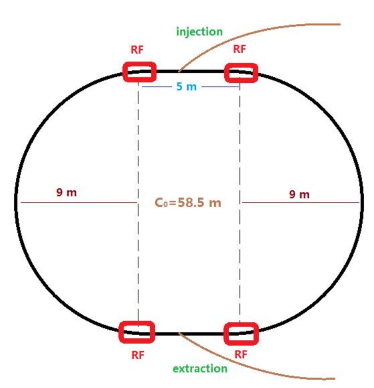
Parameter	Symbol	Unit	Baseline	Design reached
e^-/e^+ beam energy	E_{e-}/E_{e+}	GeV	**10**	**10**
Repetition rate	f_{rep}	Hz	**100**	**100**
e^-/e^+ bunch population	N_{e-}/N_{e+}		$> 9.4\times10^9$	**1.9×10^{10} / 1.9×10^{10}**
		nC	**> 1.5**	**3.0**
Energy spread (e^-/e^+)	σ_e		**$< 2\times10^{-3}$**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

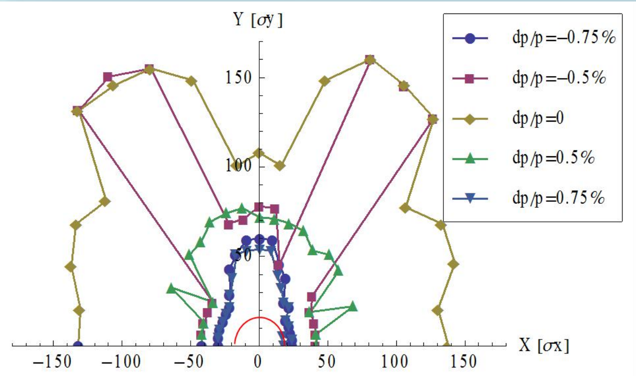
CEPC Linac Injector Damping Ring

Parameters, lattice and layout

Circumference [m]	75.4
Beam energy [GeV]	1.1
SR loss/ turn [keV]	36.3
Revolution frequency [MHz]	3.98
SR power / beam [W]	433
Momentum compactor	7.82E-02
Beam current [mA]	11.9
Max Bunch charge [nC]	1.5
Number of bunches stored at a time	2
RF voltage [MV]	2.0
RF frequency [MHz]	650
Harmonic number	164
RF energy acceptance [%]	0.95
Acc. Phase [deg]	88.96
Syn. Tune	0.012
Synchrotron oscillation period [us]	21.7
Longitudinal damping time [ms]	7.6
Longitudinal quantum lifetime [s]	177
Beam storage time [ms]	20.0







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

CEPC Damping Ring main RF parameters

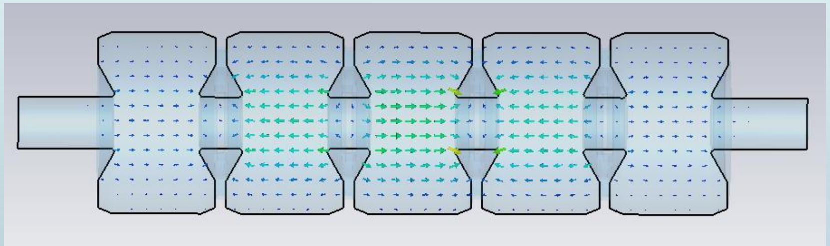
Circumference [m]	75.4
Beam energy [GeV]	1.1
SR loss/ turn [keV]	36.3
Revolution frequency [MHz]	3.98
SR power / beam [W]	433
Momentum compactor	7.82E-02
Beam current [mA]	11.9
Max Bunch charge [nC]	1.5
Number of bunches stored at a time	2
RF voltage [MV]	2.0
RF frequency [MHz]	650
Harmonic number	164
RF energy acceptance [%]	0.95
Acc. Phase [deg]	88.96
Syn. Tune	0.012
Synchrotron oscillation period [us]	21.7
Longitudinal damping time [ms]	7.6
Longitudinal quantum lifetime [s]	177
Beam storage time [ms]	20.0

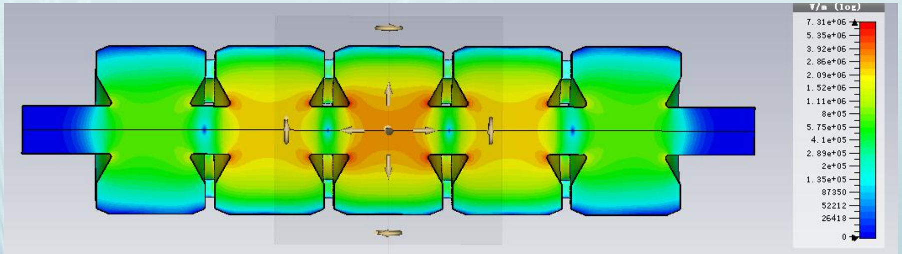
Cavity Type	NCRF
Number of cell/ cavity	5
Cavity effective length [m]	1.15
Cavity number	2
Input coupler/ cavity	1
Total klystron number	2
Cavity voltage [MV]	1.0
Cavity Acc. Gradient [MV/m]	0.87
Q0	33635
R/Q [Ohm]	1100
Beam power/ cavity [W]	216
Wall loss/ cavity [kW]	27.0
Input power/ cavity [kW]	27.2
Coupling Coefficient	1.01
Optimal Q_L	3.34E+04
Cavity bandwidth at optimal Q_L [kHz]	19
Detuning angle [deg]	-12.4
Cavity filling time [us]	16.3
Optimal detuning at optimal Q_L [kHz]	-2.14
Cavity stored energy [J]	0.22

CEPC Damping Ring NC cavity

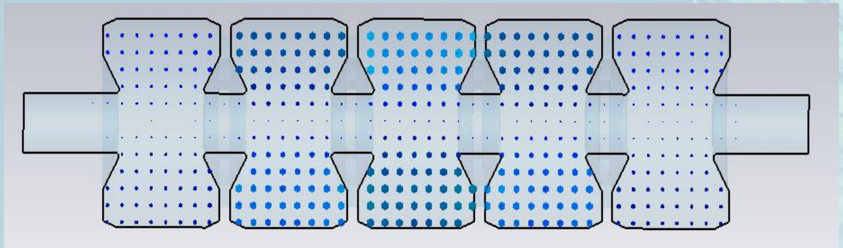
Fundamental mode: TM010

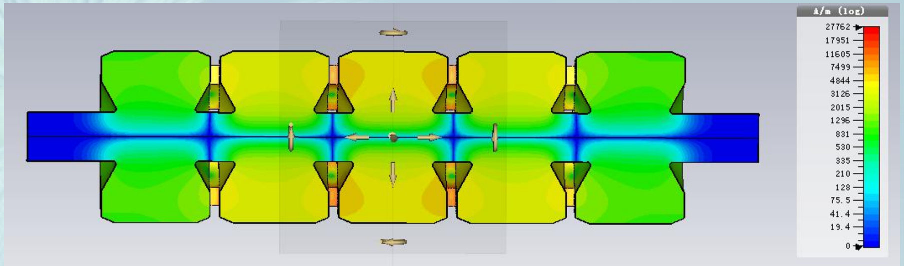
Electric Field：

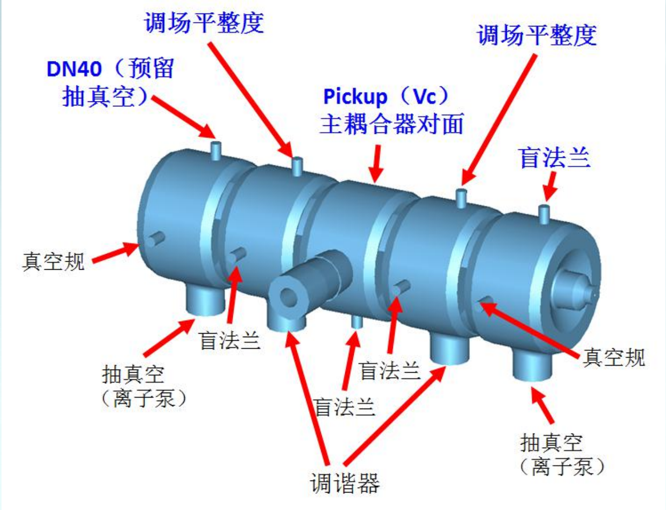


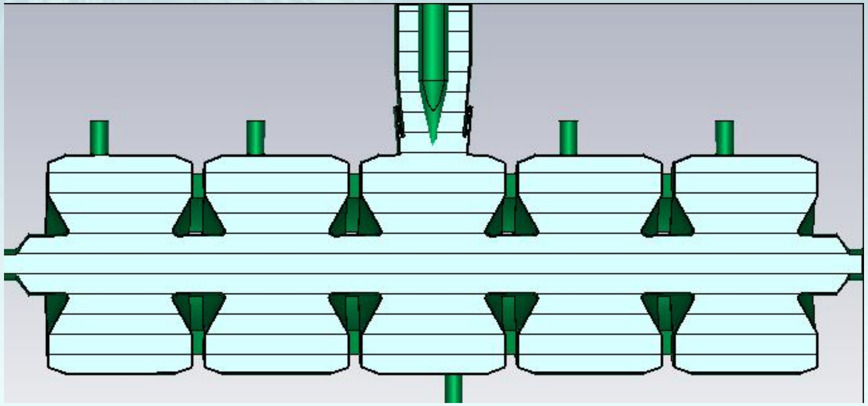


Magnetic Field：









Time structure for CEPC DR

Damping ring is needed for the positron beam.
The circumference for CEPC DR is 75.4 m.

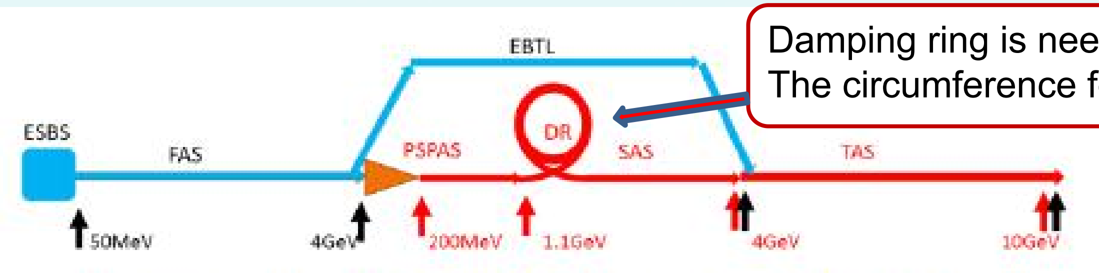
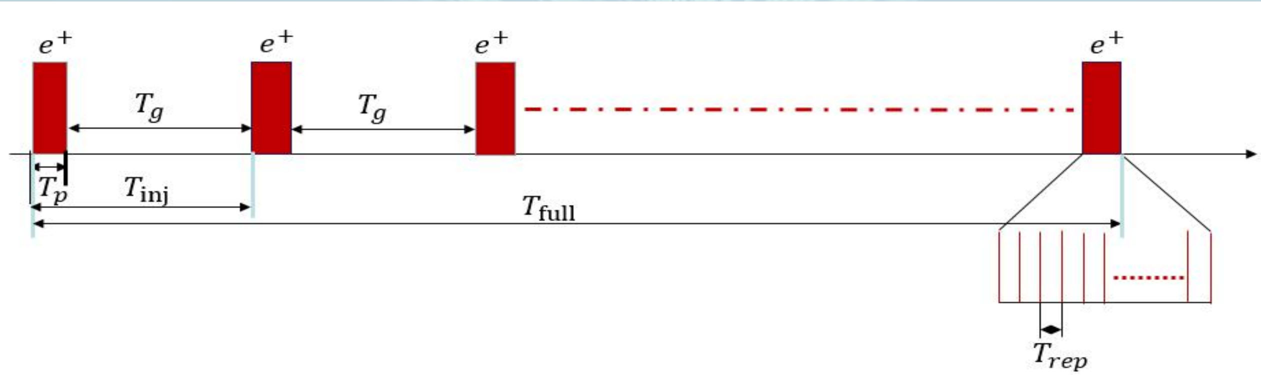


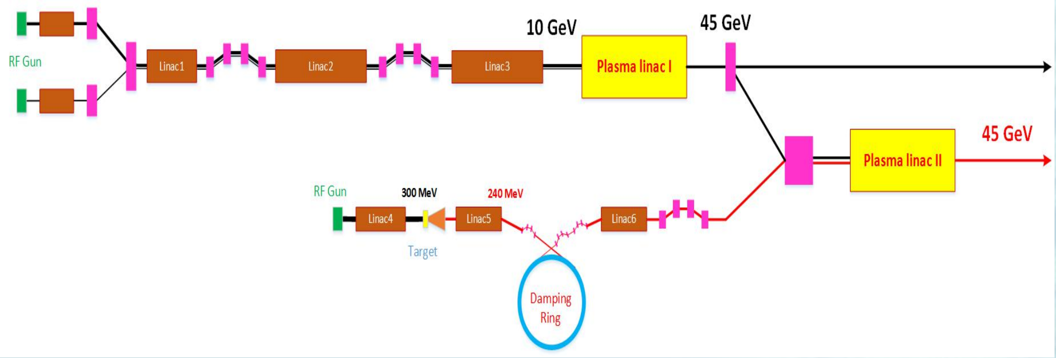
Figure 2: Sketch of CEPC Linac and damping ring.

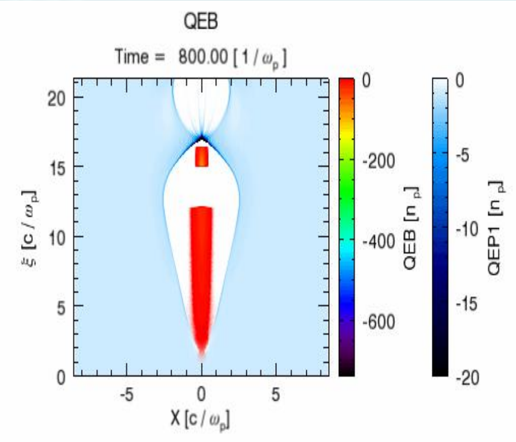
The injection beam structure of CEPC Linac is pulsed operation.



	Higgs	W	Z-pole
Pulse length T_p [s]	12.9	19.8	137.6
Gap length T_g [s]	34.1	111.2	300.4
Injection period T_{inj} [s]	47	131	438
Injection repetition T_{rep} [ms]	10	10	10
Full injection time [min]	10	15	132

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





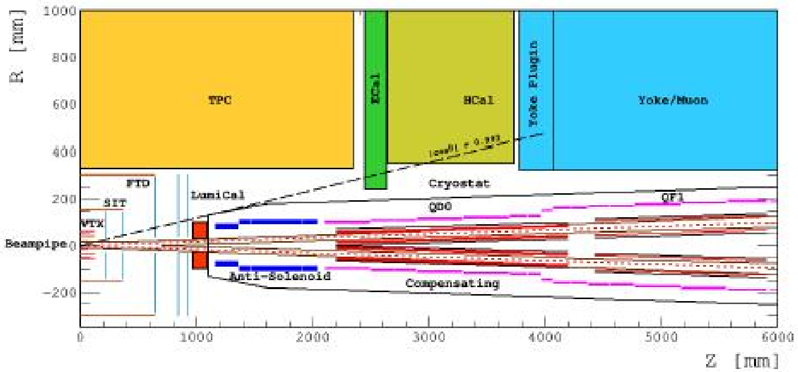
Plasma density $n_0(cm^{-3})$	5.15×10^{16}
Driver charge $Q_d(nC)$	6.47
Driver energy $E_d(GeV)$	10
Driver length $L_d(\mu m)$	285
Driver RMS size $\sigma_d(\mu m)$	10
Driver normalized emittance $\epsilon_{nd}(mm\ mrad)$	10
Trailor charge $Q_t(nC)$	1.25
Trailor energy $E_t(GeV)$	10
Trailor length $L_t(\mu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

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

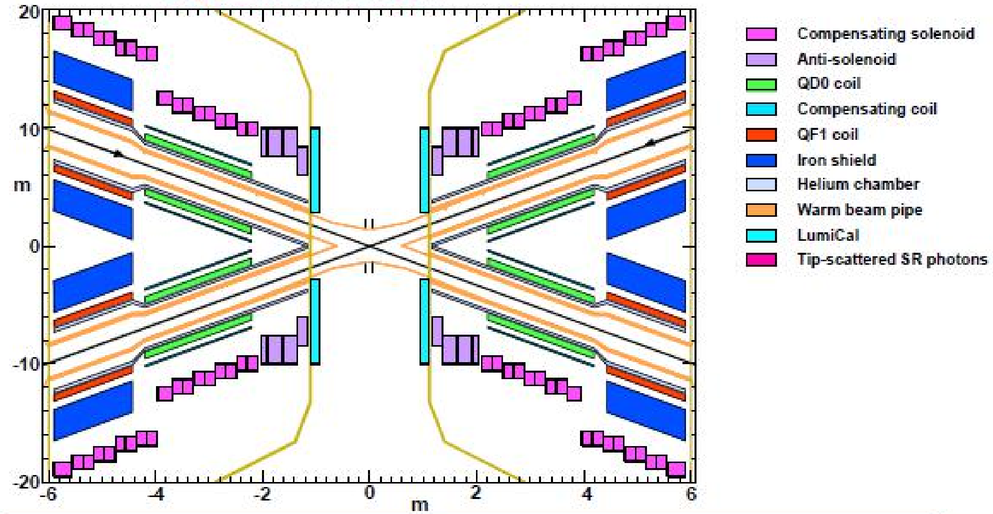
The simulations show that plasma scheme satisfies the CEPC booster requirement

CEPC 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 MDI Parameters

	SR power (Vertical)
L*	
Crossing an	
MDI length	
Detector requiremen opening ang	
QD0	292W
QF1	74W
Lumical	
Anti-solenoi before QD0	
Anti-solenoi	
Anti-solenoi	
Beryllium p	
Last B upstr	
First B dow	
Beampipe w QD0	
Beampipe w QF1	
Beampipe b QD0/QF1	

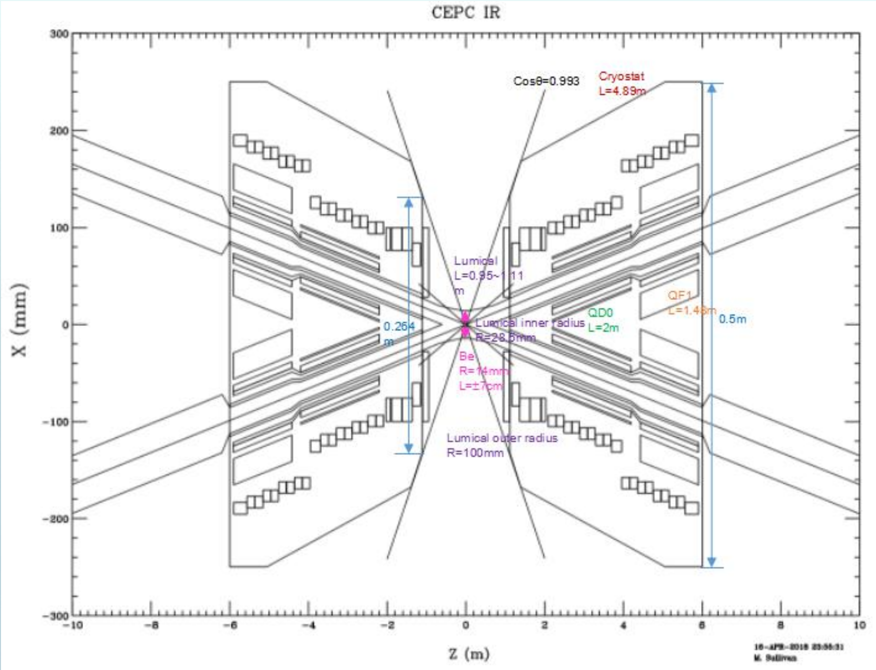
- The requirements of the Final Focus quadrupoles (QD0 and QF1) are based on the L* of 2.2 m, beam crossing angle of 33 mrad in the interaction region.

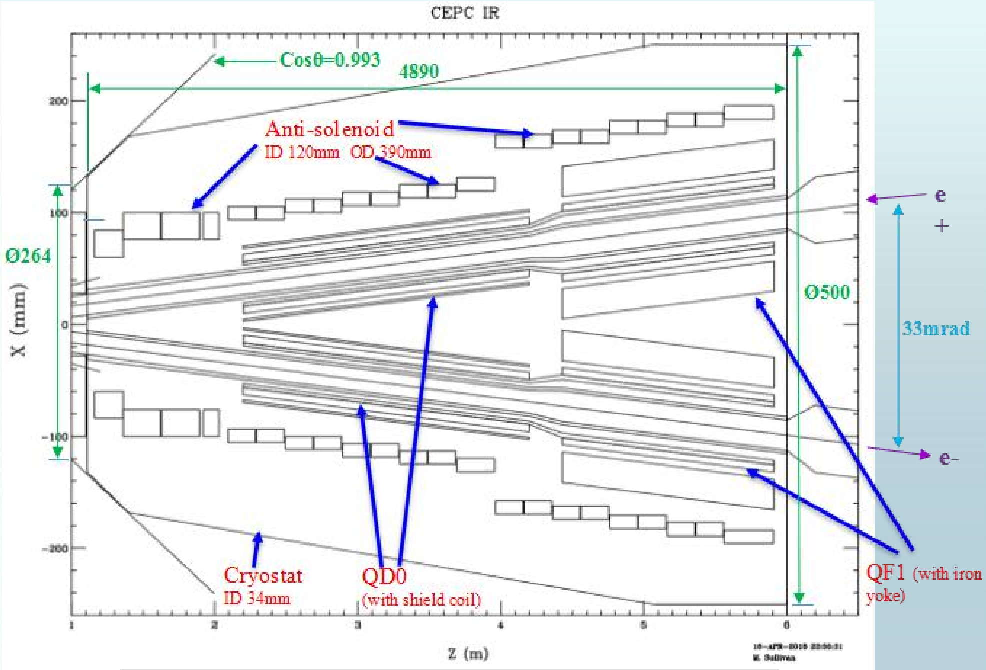
Table 1: Requirements of Interaction Region quadrupole magnets for Higgs

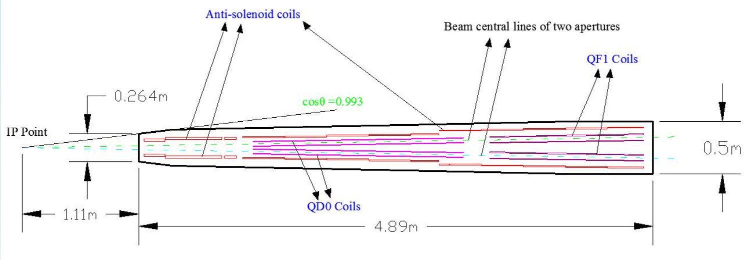
Magnet	Central field gradient (T/m)	Magnetic length (m)	Width of GFR (mm)	Minimal distance between two aperture beam lines (mm)
QD0	136	2.0	19.51	72.61
QF1	110	1.48	27.0	146.20

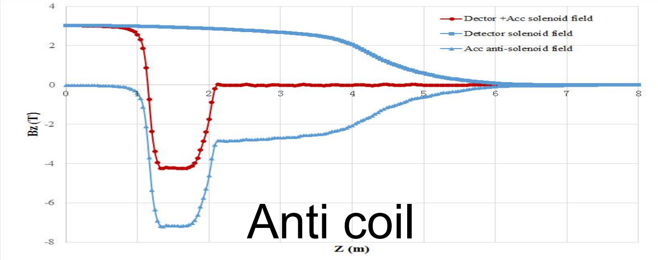
- QD0 and QF1 magnets are operated full inside the field of the Detector solenoid magnet with a central field of 3.0 T.
- To minimize the effect of the longitudinal detector solenoid field on the accelerator beam, anti-solenoids before QD0, outside QD0 and QF1, after QF1 are needed, so that the total integral longitudinal field generated by the detector solenoid and accelerator anti-solenoid is zero.

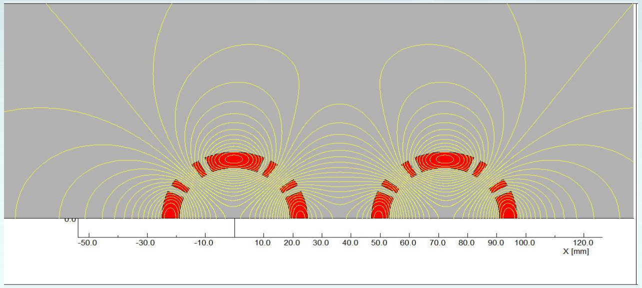
CEPC Final Focus Magnets & Cryostat

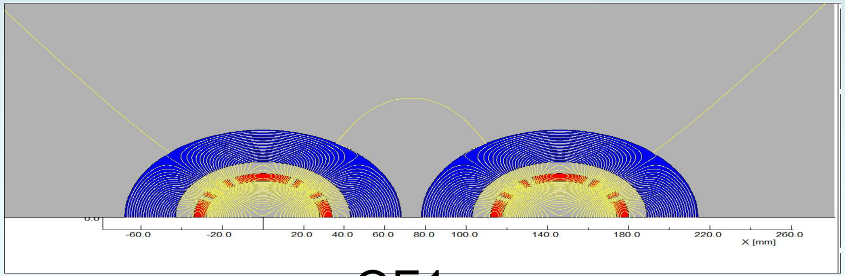









QD0


QF1

CEPC Longitudinal polarization of electrons (minimalist option)

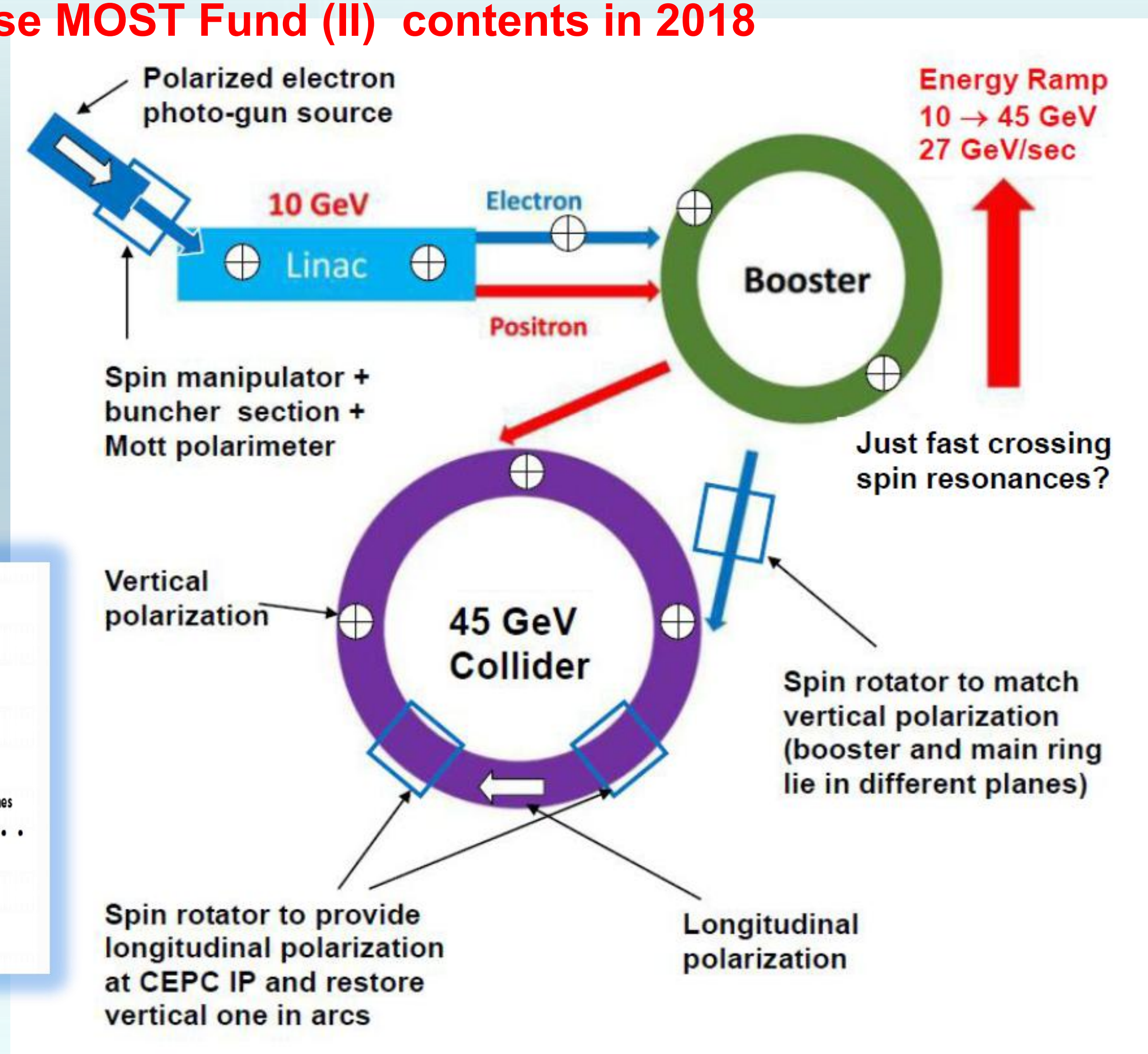
S. Nikitin

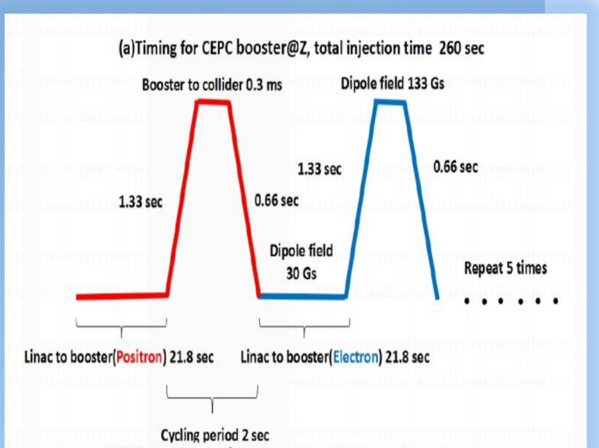
CEPC Chinese MOST Fund (II) contents in 2018

Electrons from gun source are longitudinally polarized. Spins are rotated to vertical plane in special transport section downstream of gun.Variants (CEBAF, NIKHEF):

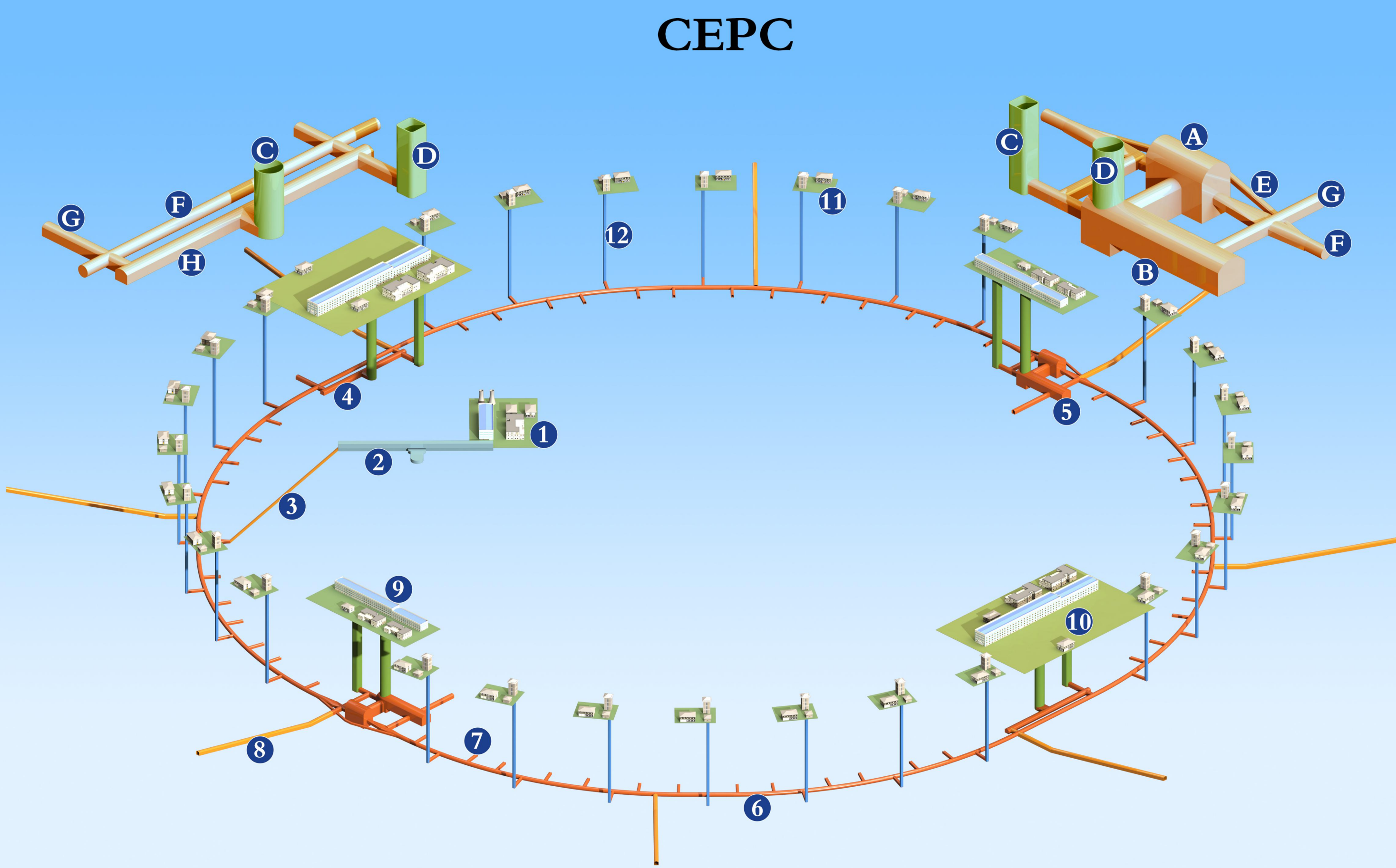
a) Wien's Filter

b) Z-manipulator includes two bends by E-field and solenoids between them.





CEPC Tunnel Design



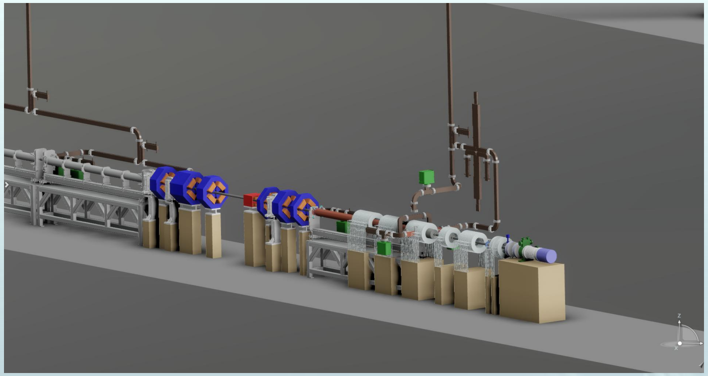
Accelerator Region Caverns:

1. Surface Buildings of Linac Segment
2. Linac Segment
3. Transfer Line
4. Tunnel Complex of RF Region
5. Detector Region Caverns
6. Main Ring Tunnel
7. Auxiliary Tunnel
8. Access Tunnel
9. Surface Buildings of Experiment Hall
10. Surface Buildings of RF Region
11. Surface Buildings of Shaft for Access and Cable
12. Shaft for Access and Cable

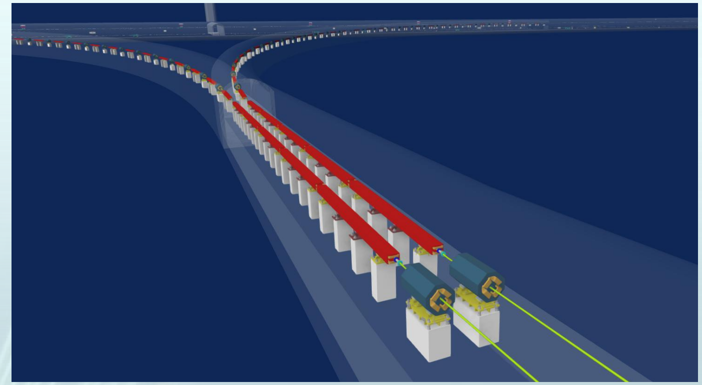
Detector Region Caverns:

A. Experiment Hall
B. Service Cavern
C. Transport Shaft
D. Shaft for Access, Cable and HVAC
E. Booster Bypass Tunnel
F. Main Ring Tunnel
G. Traffic Tunnel
H. Auxiliary Tunnel of RF Region

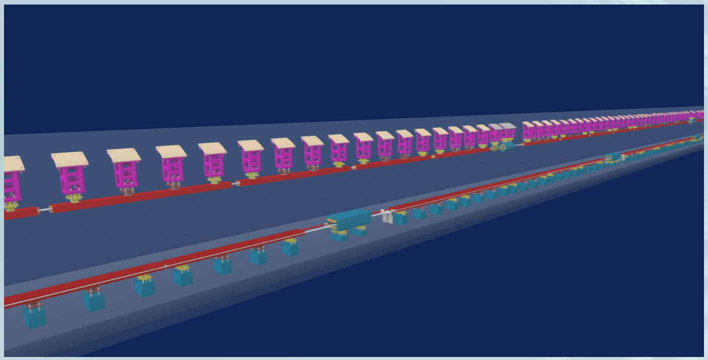
CEPC Civil Engineering



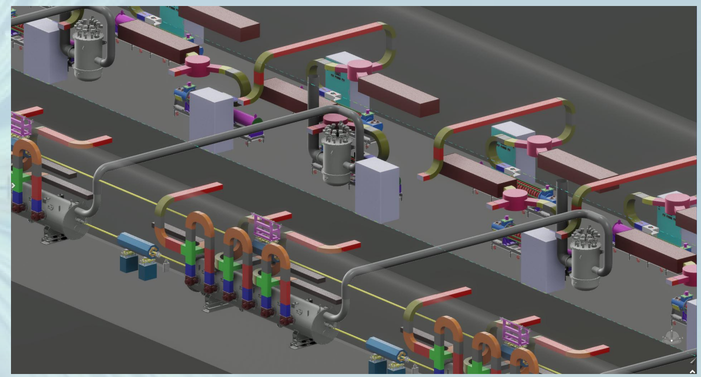
Electron source



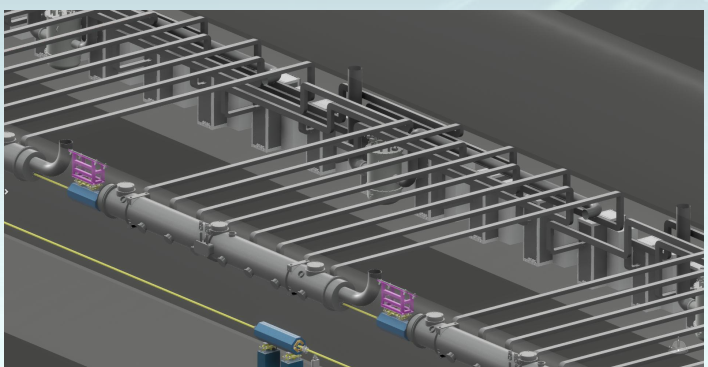
Linac to Booster



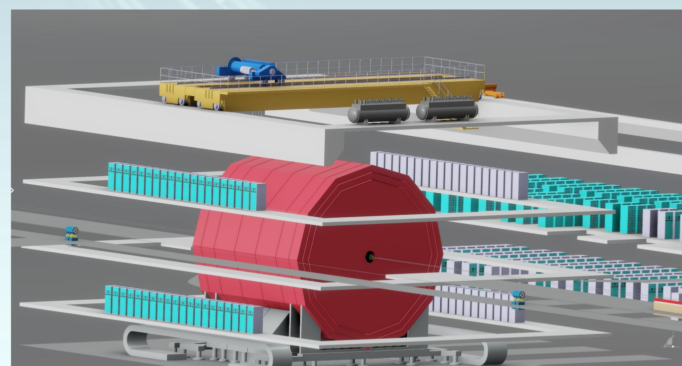
Booster and collider ring tunnel



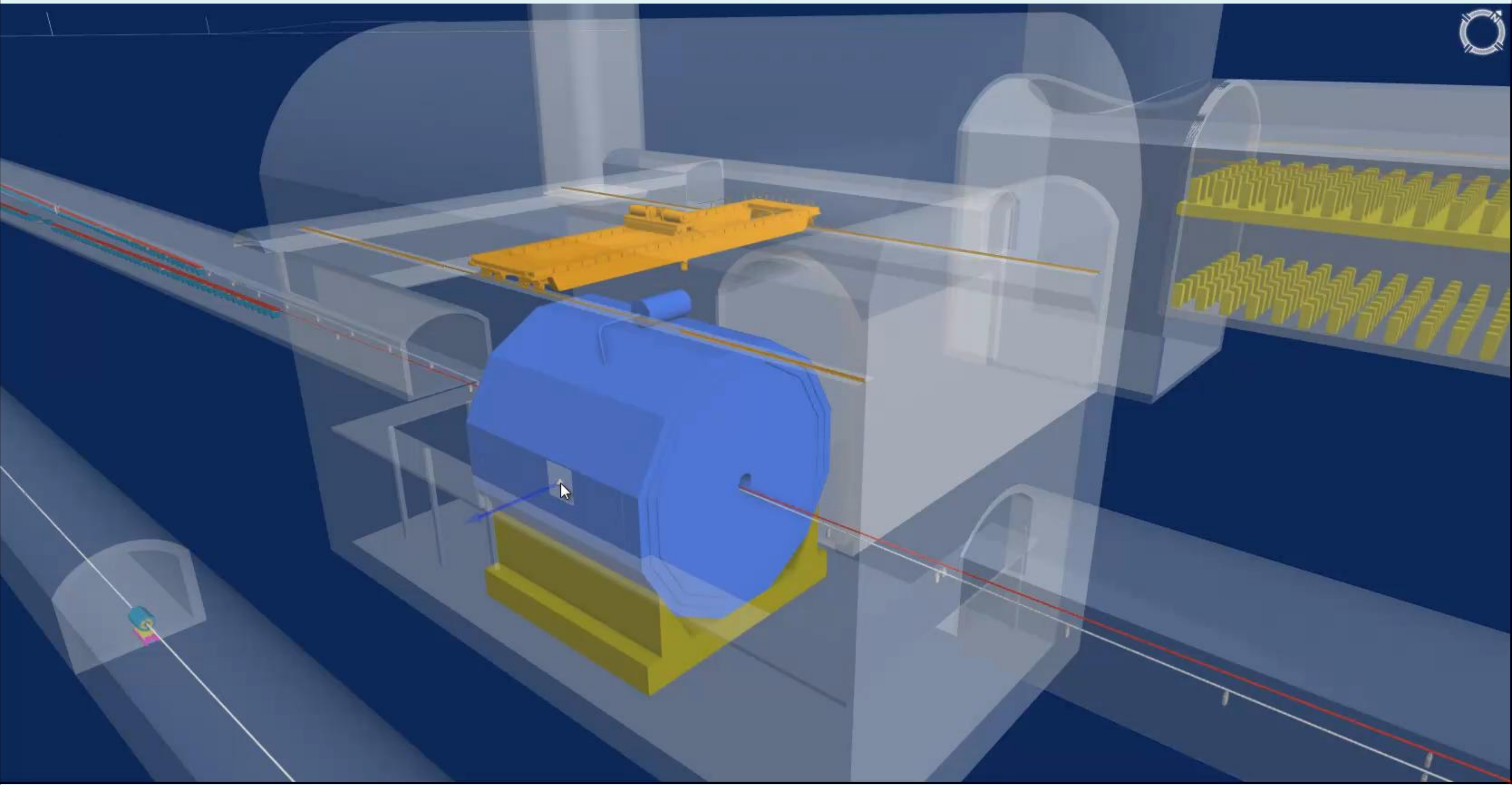
Collider ring SCRF



Booster SCRF



Detector hall



CEPC Power for Higgs and Z

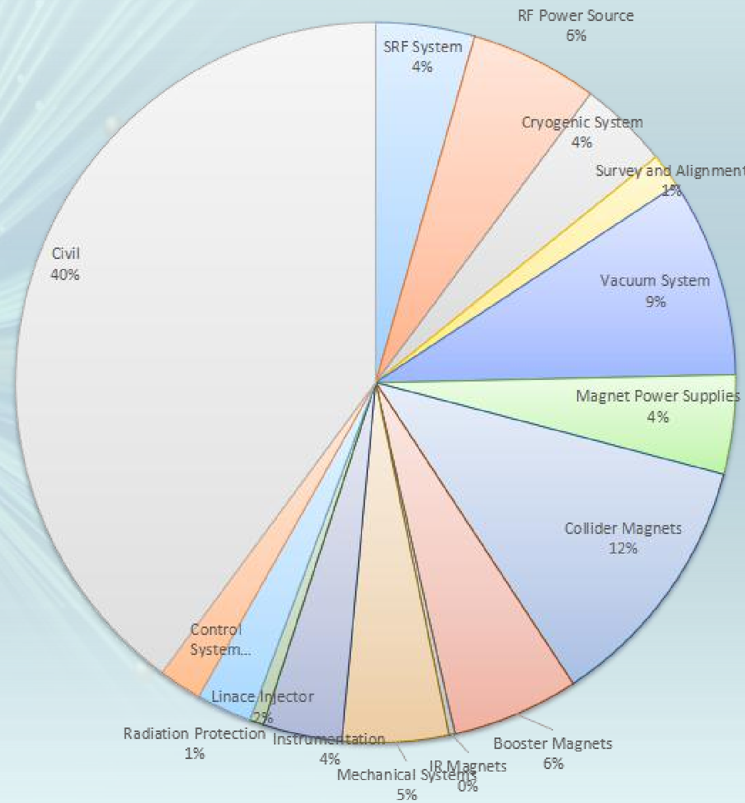
	System for Higgs (30MW)	Location and electrical demand(MW)						Total (MW)
		Ring	Booster	LINAC	BTL	IR	Surface building	
1	RF Power Source	103.8	0.15	5.8				109.75
2	Cryogenic System	11.62	0.68			1.72		14.02
3	Vacuum System	9.784	3.792	0.646				14.222
4	Magnet Power Supplies	47.21	11.62	1.75	1.06	0.26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

266MW

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

149MW

CEPC Cost Breakdwon (no detector)



Green CEPC

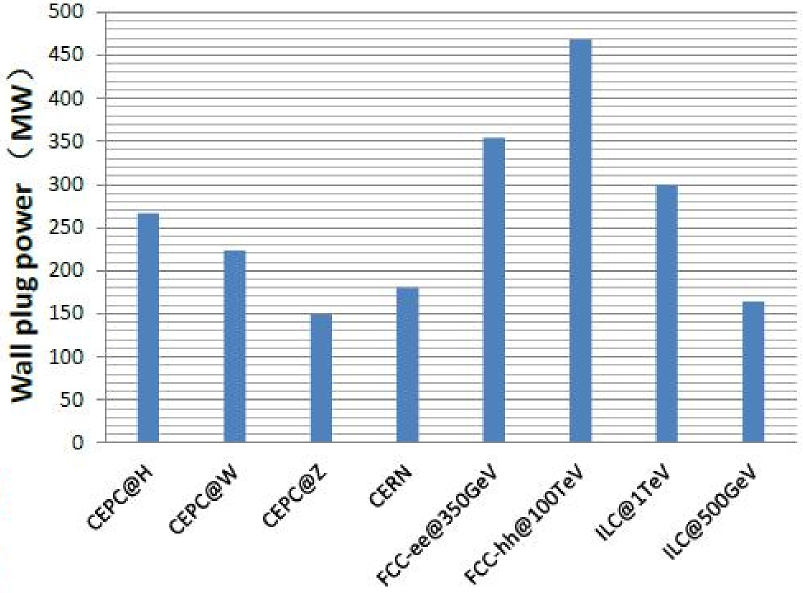
CEPC power consumption

CEPC CDR stage : 266MW (H)

	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

CEPC, CERN, FCC, ILC



CEPC TDR stage to reduce power consumption less than 266MW by green design

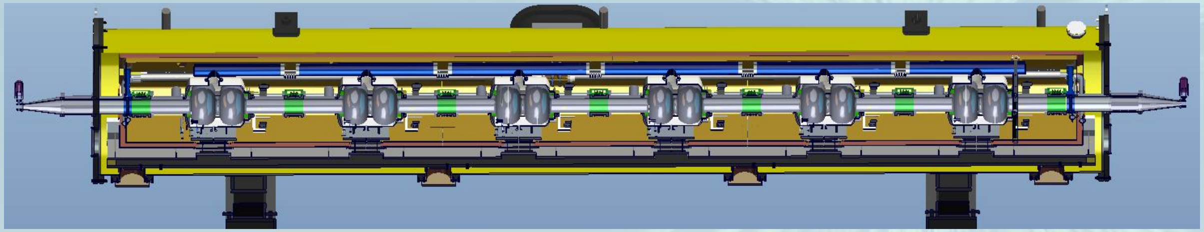
CEPC Accelerator Submitted to European Strategy:

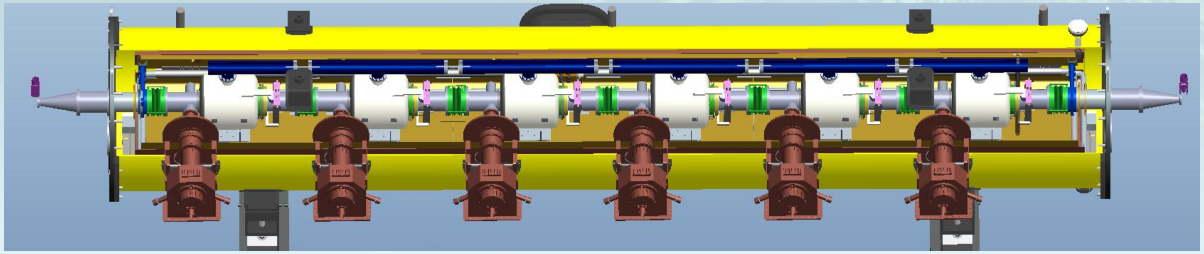
1) CEPC accelerator: ArXiv: 1901.03169
2) CEPC Physics/Detector: 1901.02170

CEPC Accelerator R&D towards TDR

CEPC 650 MHz Cavity Cryomodule

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

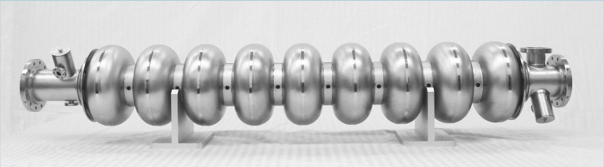




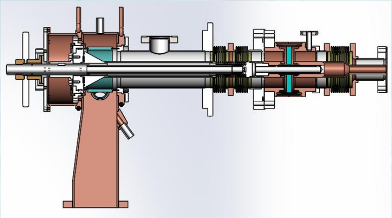
Overall length (flange to flange, m)	8.0
Diameter of vacuum vessel (m)	1.3
Beamline height from floor (m)	1.2
Cryo-system working temperature (K)	2
Number of cavities and tuners	6
Number of couplers	6
Number of RT HOM absorbers	2
Number of 200-POSTs	6
Static heat loads at 2 K (W)	5
Alignment x/y (cavities)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

1.3 GHz SRF Technology for CEPC Booster

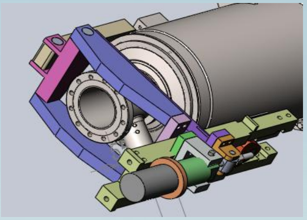
XFEL and LCLS-II type cryomodule, without SCQ. Technology R&D in synergy with Shanghai XFEL (SCLF). No big challenge.



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



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

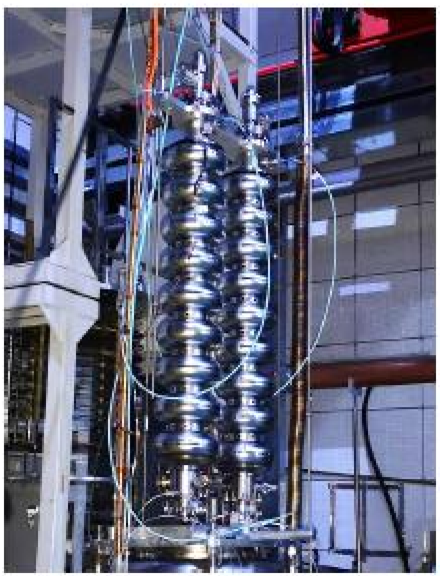


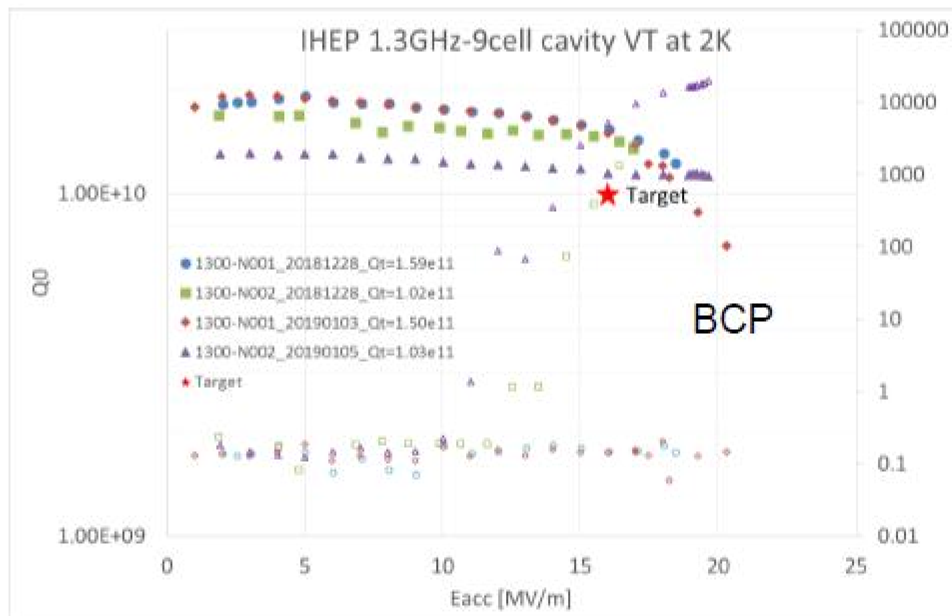
XFEL/LCLS-II type **end lever tuner**. Reliability. Large stiffness. Piezos abundance, radiation, overheating. Access ports for easy maintenance.

CEPC SRF hardware specifications

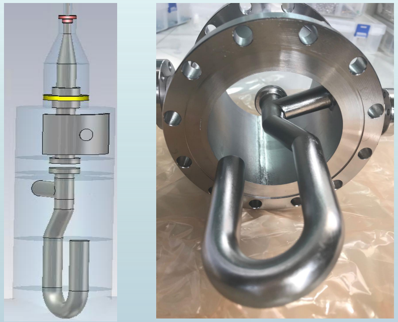
1.3 GHz TESLA 9-cell Cavities

- Prepare for mass production (SHINE project ~ 600 cavities)
- 10 (2+8) prototype cavities in fabrication at IHEP (BCP → EP → N-dope)
- 8 cavities dressing this year and install to cryomodule next year

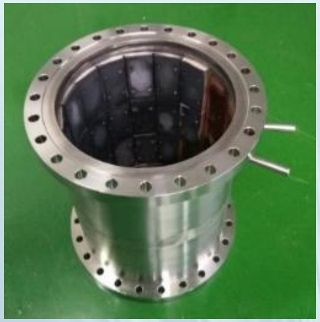




CEPC SRF Technology R&D

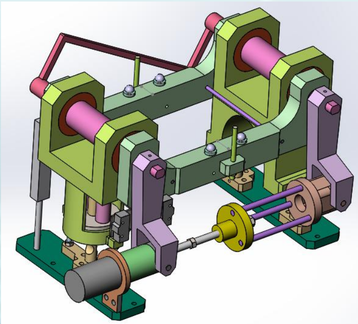


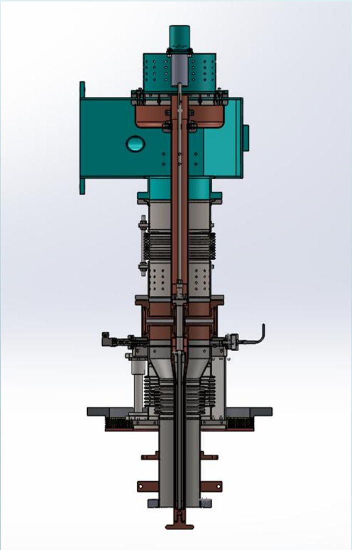
CEPC Collider HOM coupler （1 kW CW) by OTIC and HD



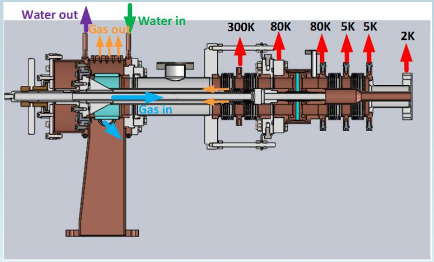
CEPC HOM absorber of SiC & AlN (5 kW CW)

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





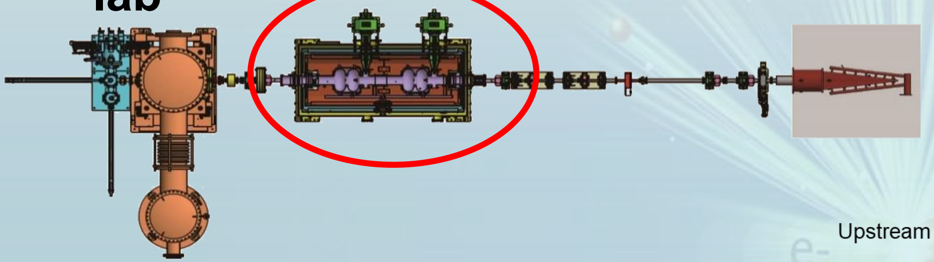
Tuner and input coupler (variable 300 kW CW) for CEPC 650 MHz cavity in fabrication

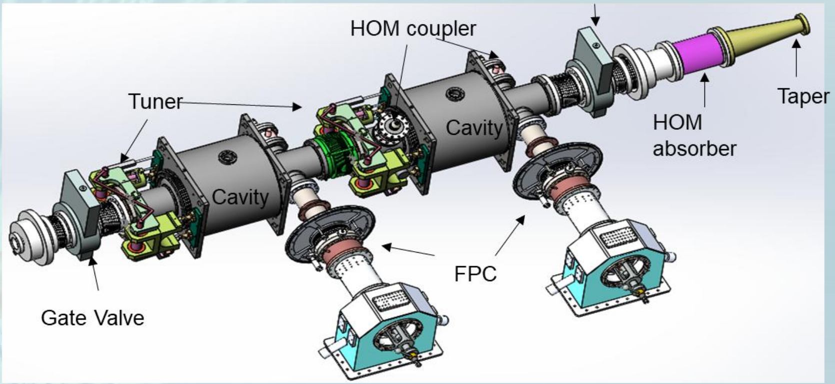


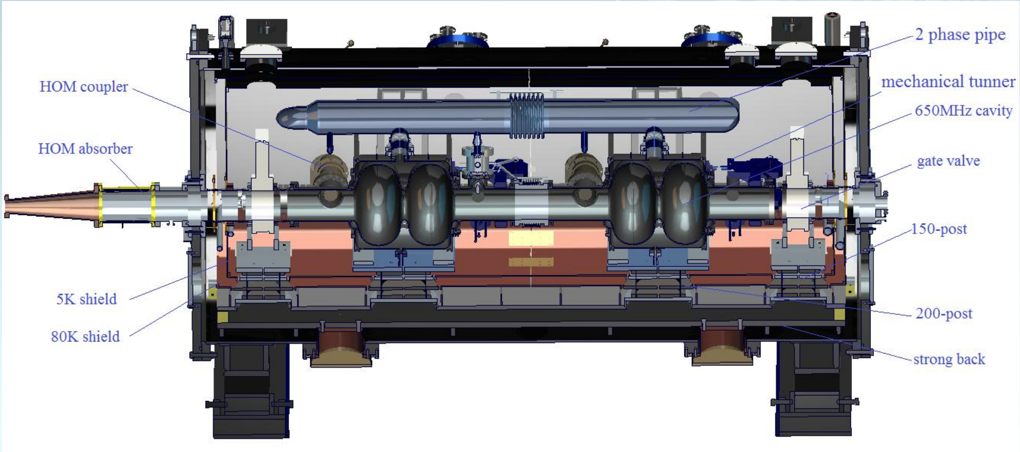
CEPC Booster 1.3 GHz variable double window coupler by HERT (in high power conditioning)

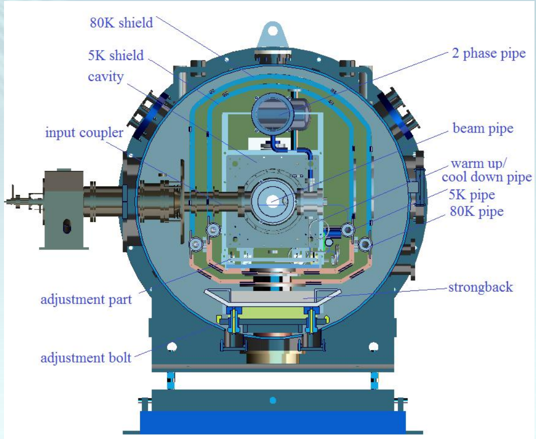
CEPC Collider Test Cryomodule

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



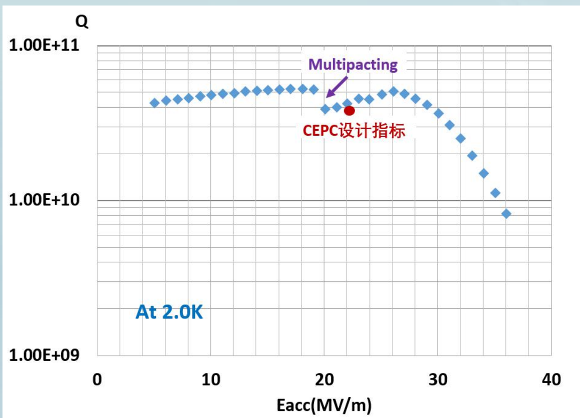




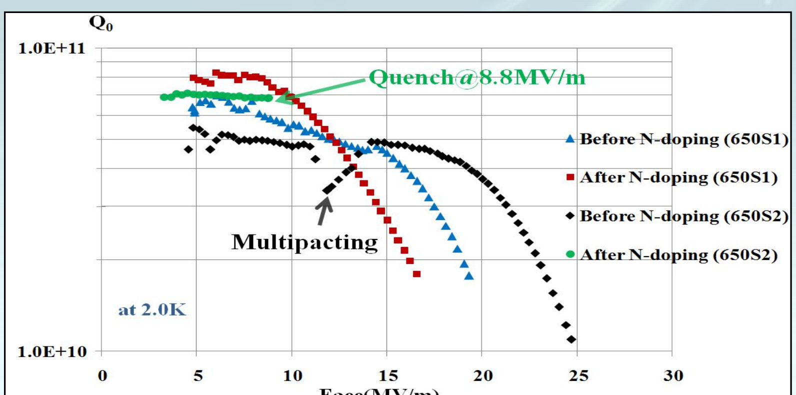


CEPC 650 MHz Cavity Development-1

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



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



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

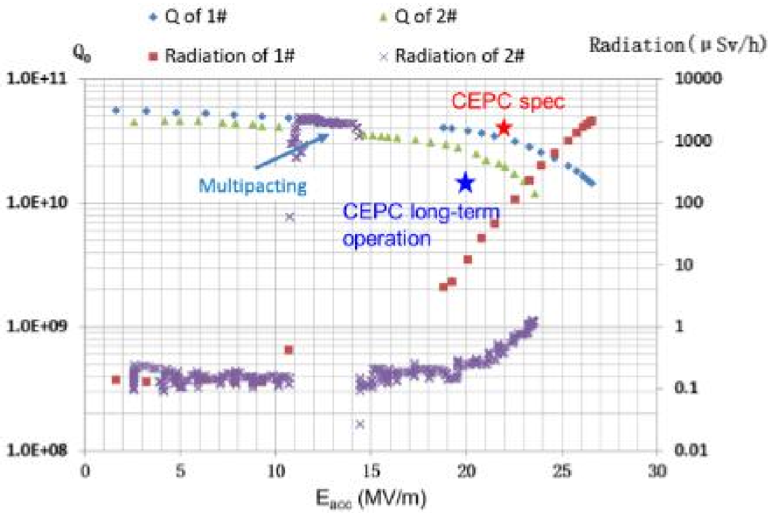
CEPC collider ring SRF R&D progress-2

CEPC SRF Technology R&D Status

CEPC 650 MHz 2-cell cavity by OTIC

CEPC 650 MHz 2-cell cavity by HERT

CEPC 650 MHz 5-cell cavity with waveguide HOM coupler by HERT



- 650 MHz 2-cell cavity (BCP without Nitrogen-doping) reached 3.2E10 @ 22 MV/m (**nearly reached CEPC collider cavity vertical test spec 4E10 @ 22 MV/m**)
- Nitrogen-doping and EP on 650 MHz cavity under investigation.
- EP facility under commissioning.

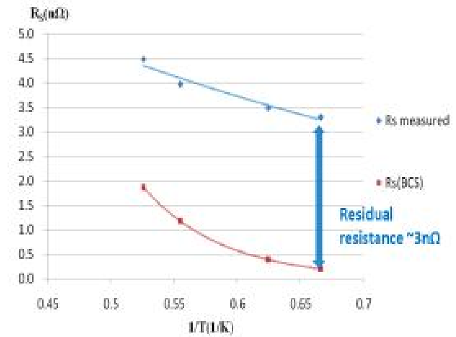
CEPC collider ring SRF R&D progress-3

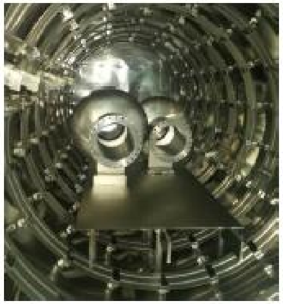
N-doping of 650 MHz 1-cell Cavity

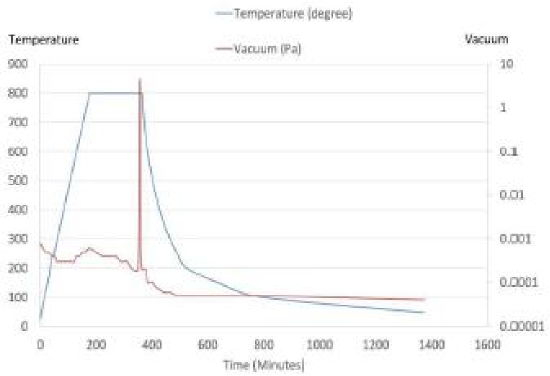
After N-doping of two 650 MHz single cell cavities, Q_0 increased obviously at low field for both cavities.

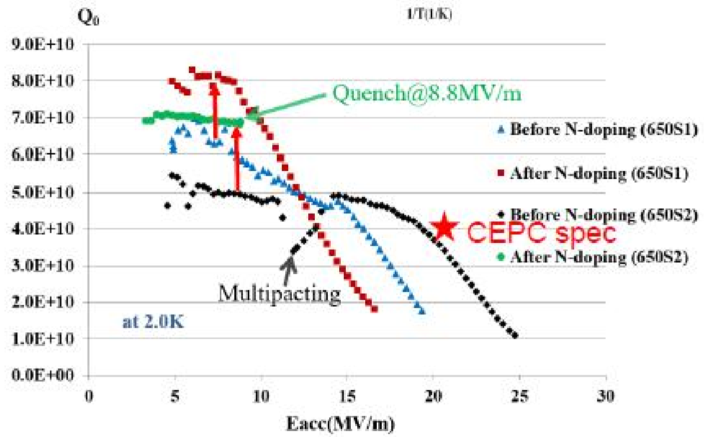
- 650S1: Q_0=7e10 @ Eacc=10 MV/m. But Q_0 decreased quickly at high field (>10 MV/m).
- 650S2: Quench at Q_0=6.9e10 @ Eacc=8.8 MV/m.

Flux gate and Helmholtz coil for demagnetization. EP facility necessary for the treatment.

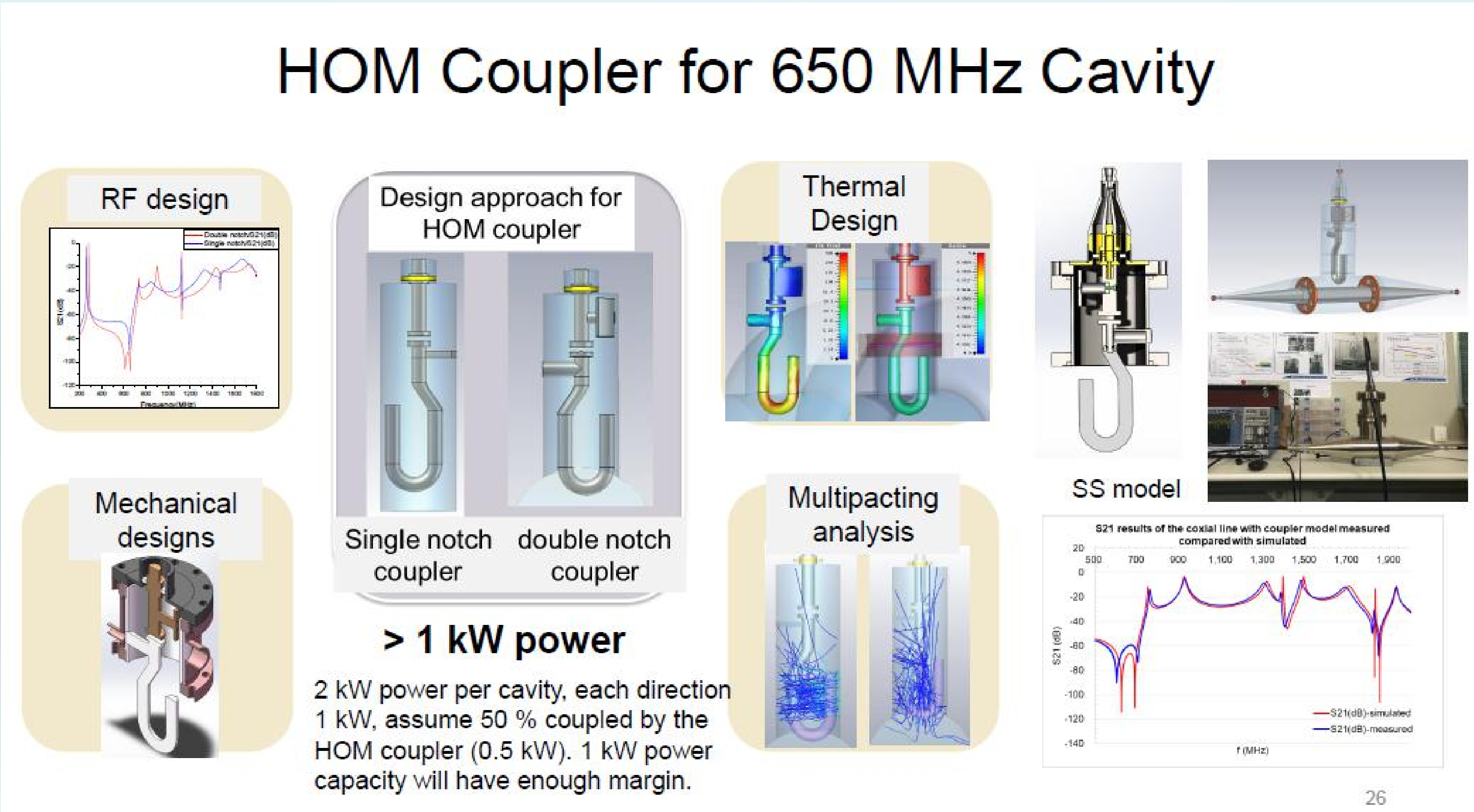






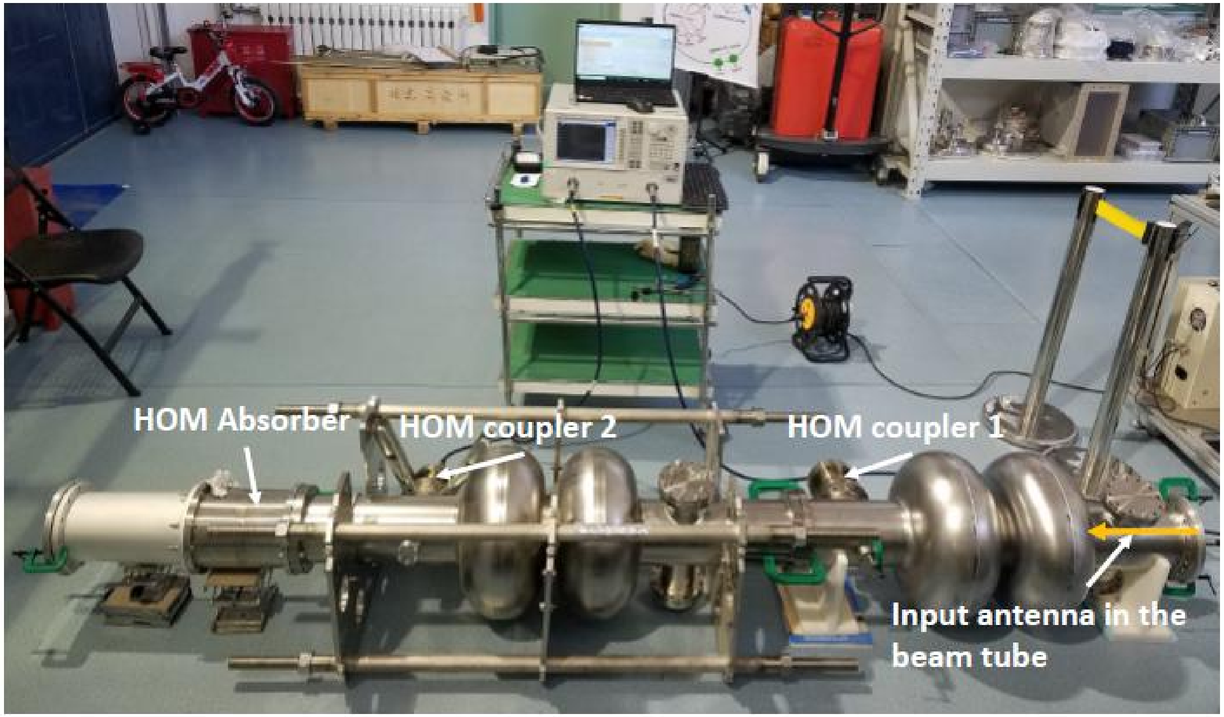


CEPC collider ring SRF R&D progress-4



CEPC collider ring SRF R&D progress-5

HOM Propagation through Two 2-cell Cavities



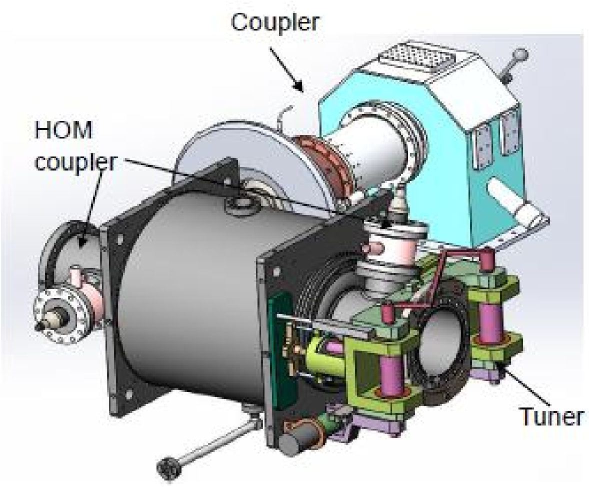
Transmission properties from input port to HOM1 port, HOM2 with matched load.

Transmission properties from input port to HOM2 port, HOM1 with matched load.

Plan to collaborate with Rostock University on the simulation technique.

CEPC collider ring SRF R&D progress-6

Tuners for 650 MHz Cavity

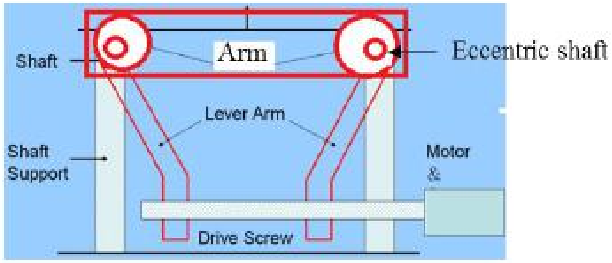


Cavity + Coupler + HOM Coupler + Tuner

Main parameters of tuner

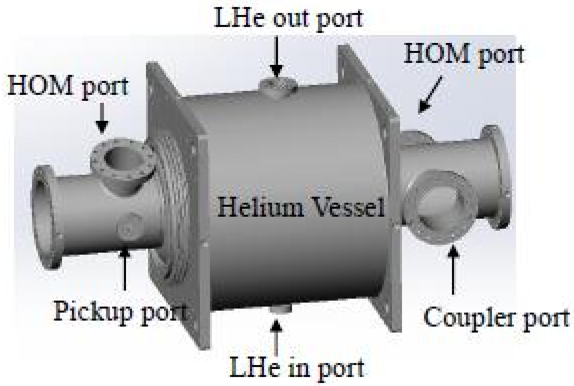
Parameters	Unit	Collider tuners
Tuning sensitivity	kHz / mm	310
Spring Constant	kN / mm	16
Operating Pressure	Torr	<5E-5
Operating lifetime	Year	20
Coarse (slow) tuner frequency range	kHz	340
Coarse tuner frequency resolution	Hz	< 20
Fine (fast) tuner frequency range	kHz	> 1.5
Fine tuner frequency resolution	Hz	3
Motor and Piezo temperature	K	5~10
Motor number		1
Piezo number		2

- Space tight due to the HOM coupler
- Improved from Saclay type tuner
- Cavity will be stretched

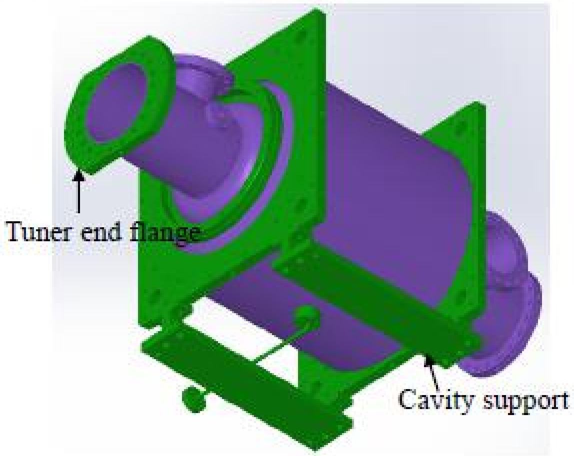


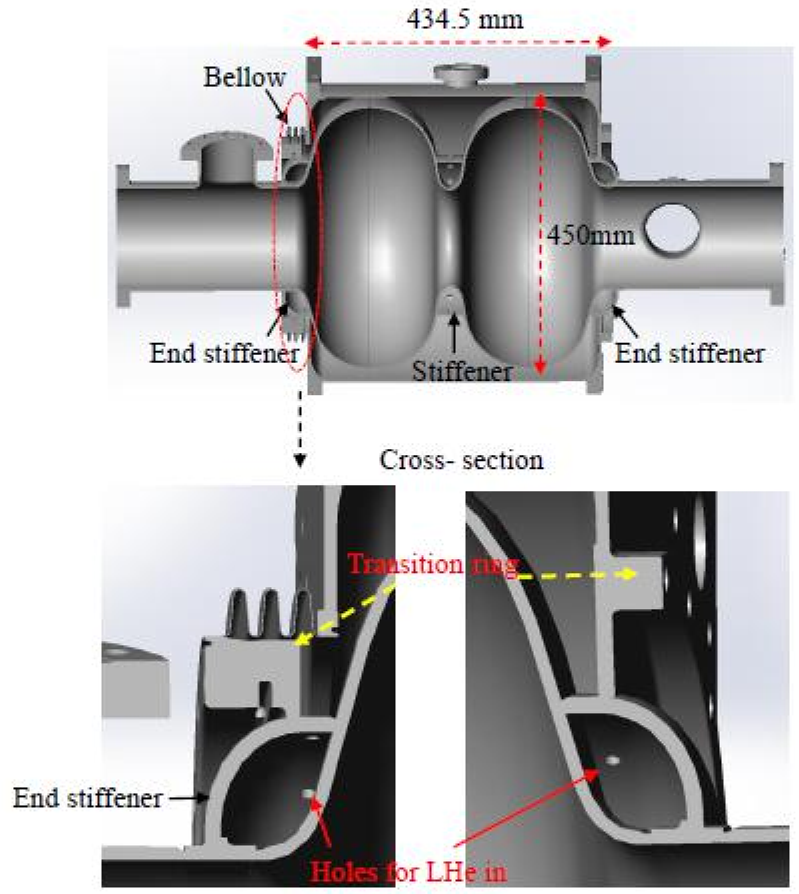
CEPC collider ring SRF R&D progress-7

Helium Vessel



650 MHz 2-cell cavity + Helium Vessel 3D module

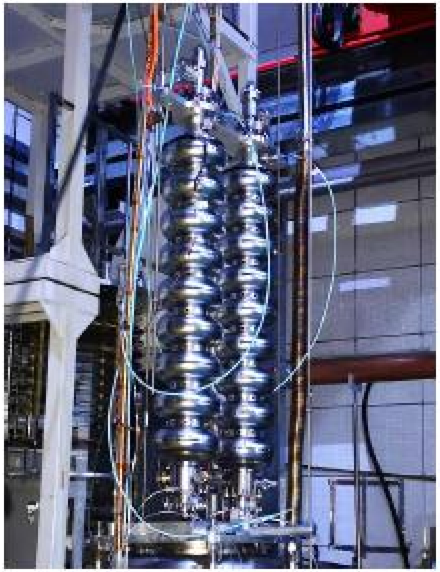


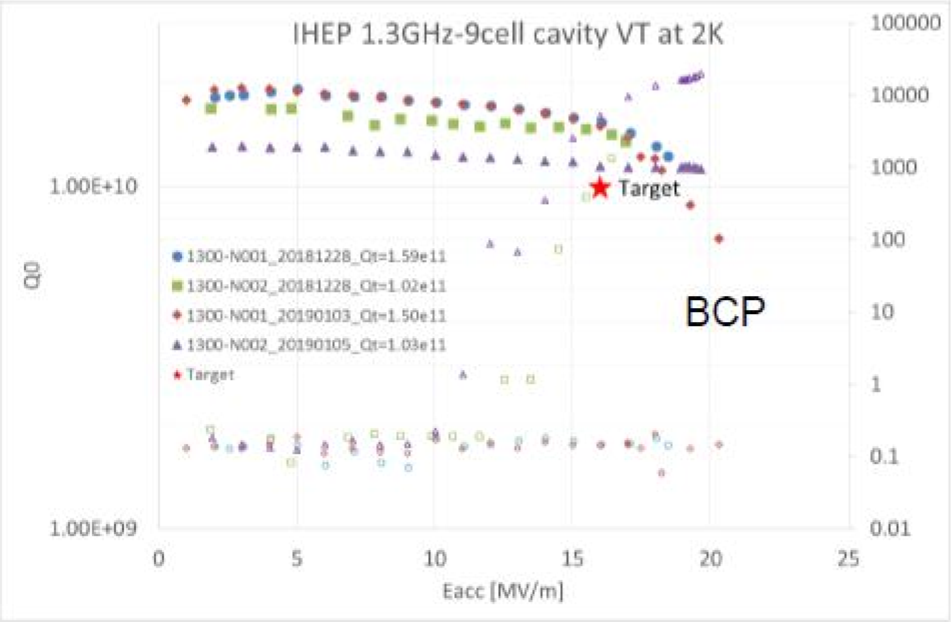


CEPC booster SRF R&D progress-1

1.3 GHz TESLA 9-cell Cavities

- Prepare for mass production (SHINE project ~ 600 cavities)
- 10 (2+8) prototype cavities in fabrication at IHEP (BCP → EP → N-dope)
- 8 cavities dressing this year and install to cryomodule next year

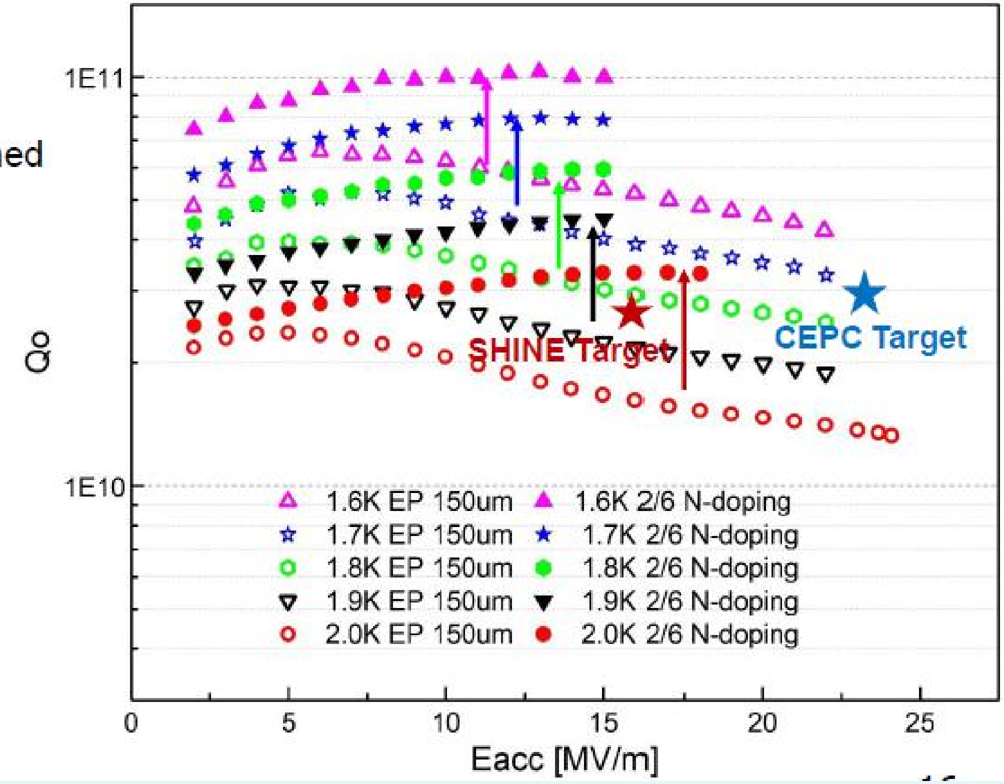




CEPC booster SRF R&D progress-2

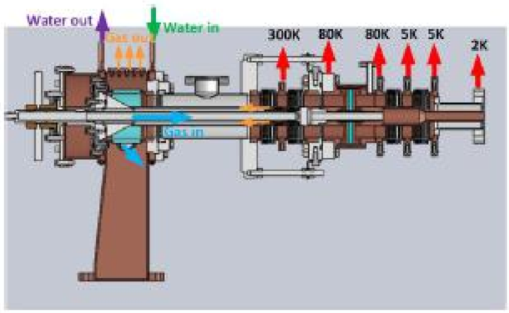
N-doping of 1.3 GHz 1-cell Cavity

- After N-doping, a 1.3 GHz 1-cell cavity reached 3.3E10 @ 18 MV/m, twice of baseline Q_0.
- Processing and vertical test at KEK.



CEPC booster SRF R&D progress-3

1.3 GHz Variable Coupler with Double Window

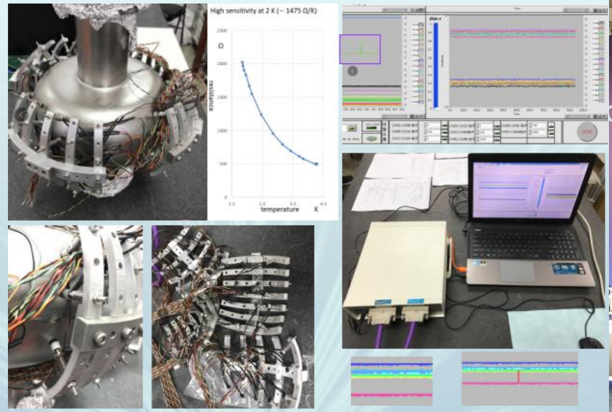


- Design for 70 kW CW power. Can be used for CEPC booster cavity (< 20 kW peak).
- High power conditioning in a resonance ring (up to 10 times of the 8 kW SSA power). Forward CW power 30 kW for 1 hour. Max power above 50 kW.

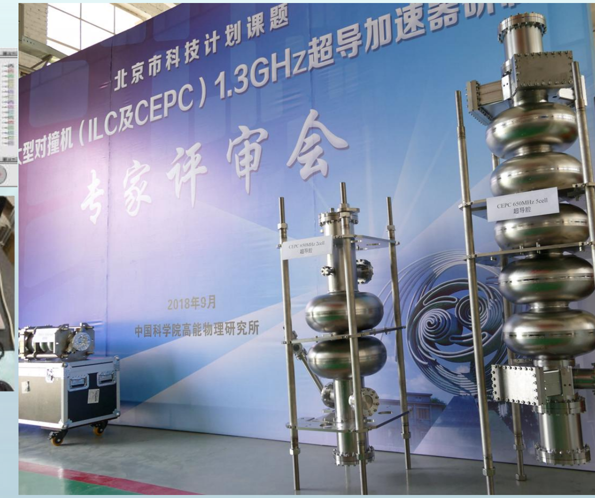
CEPC Key SCRF Technology Breakthrough

2018.9.12

Passing the examination



T-Mapping system



CEPC 650MHZ 2cell and 5 cell cavities

IHEP EP System

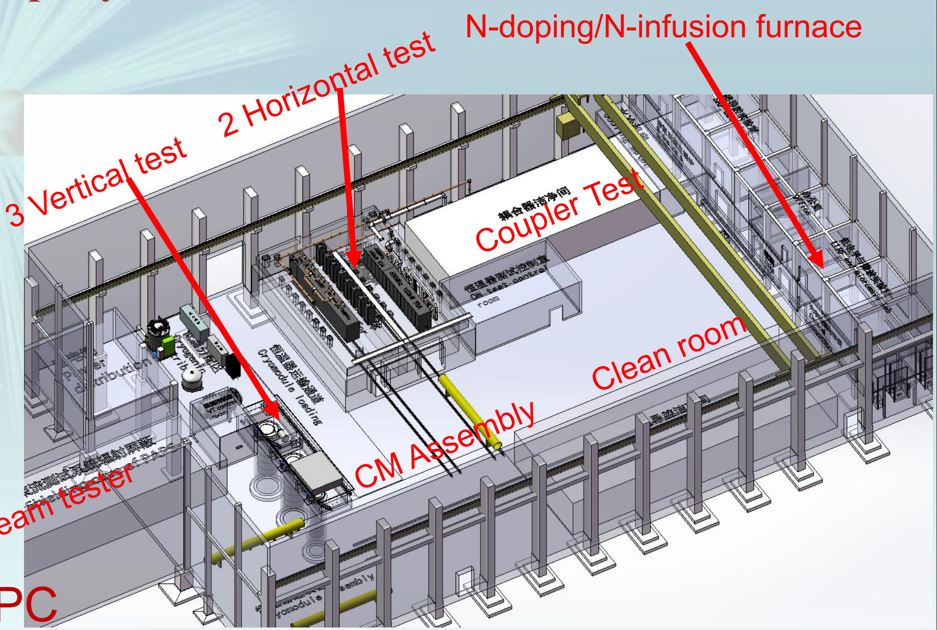
Cavity inner surface reparing system

IHEP New SRF Infrastructure

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

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

2018-09-23, KEK visitors (red)



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

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

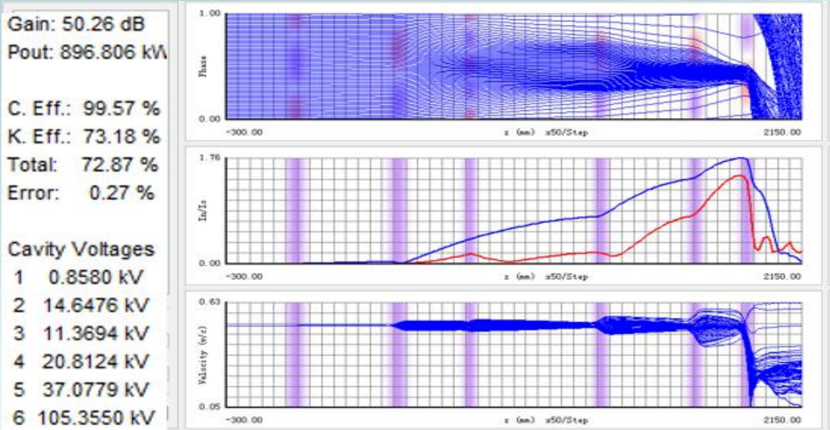
IHEP EP in commissioning at Ningxia

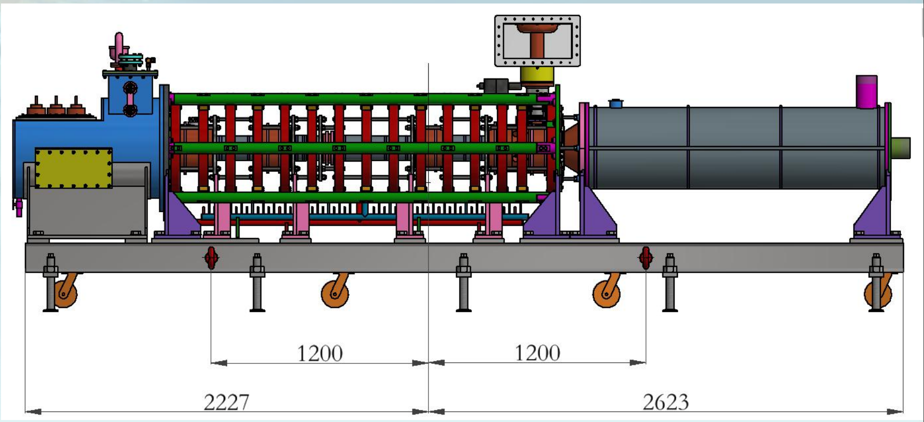
High Efficiency Klystron Development

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**





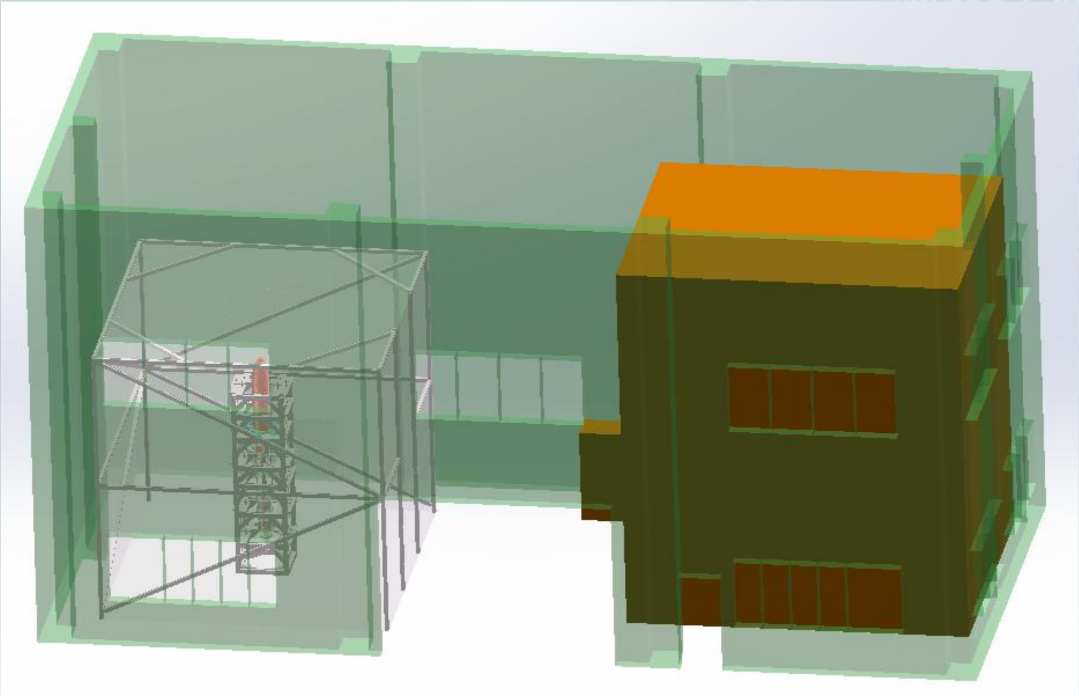
Mechanical design of conventional klystron

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

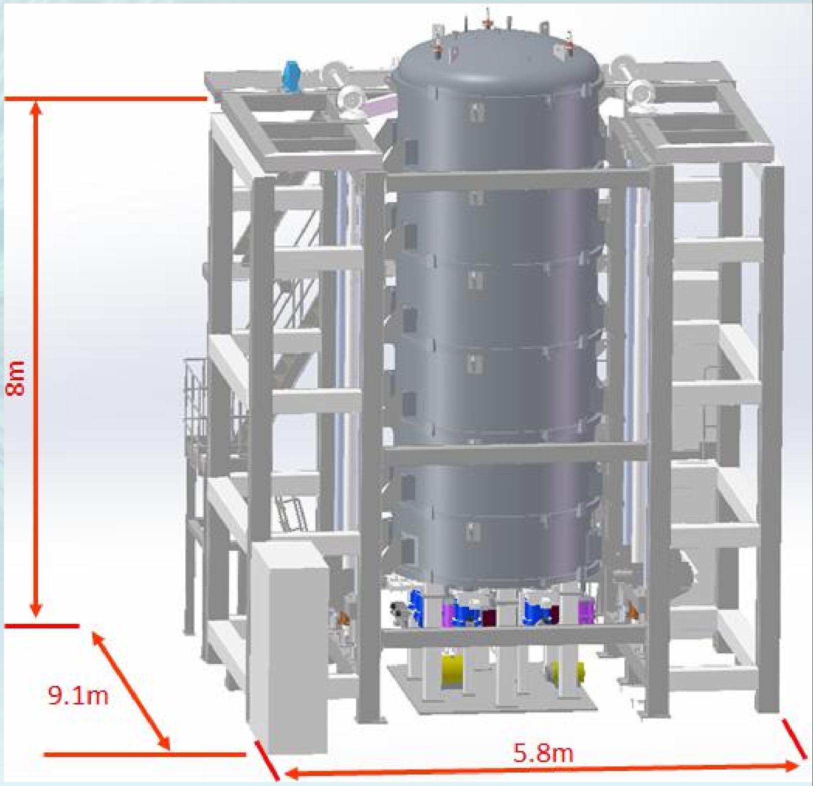
1

EP system commissioning in Ningxia

650MHz klystron mechanical assembly and manufacture facilities



Assembly workshop



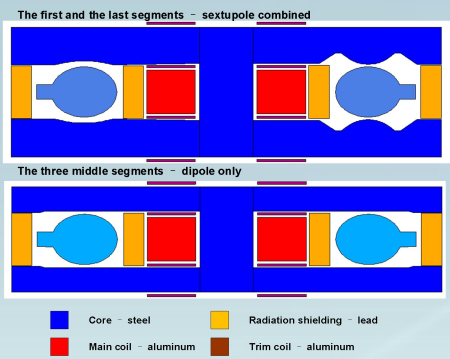
Baking furnace

CEPC Collider and Booster Ring Conventional Magnets

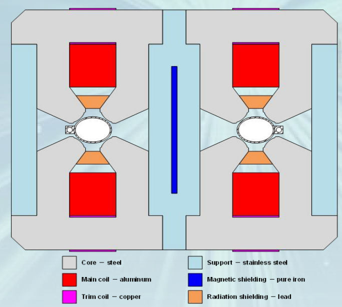
China Astronotics Department 508 Institute participates CEPC magnets mechanical designs

CEPC collider ring magnets

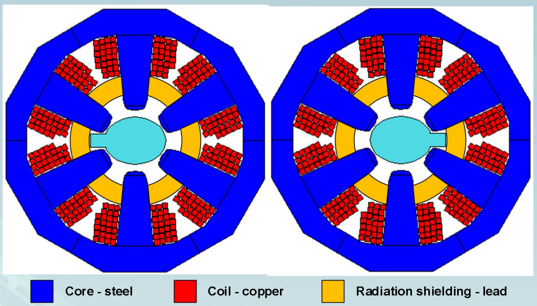
	Dipole	Quad.	Sext.	Corrector	Total
Dual aperture	2384	2392	-	-	13742
Single aperture	80*2+2	480*2+172	932*2	2904*2	
Total length [km]	71.5	5.9	1.0	2.5	80.8
Power [MW]	7.0	20.2	4.6	2.2	34



Dipole



Quadrupole

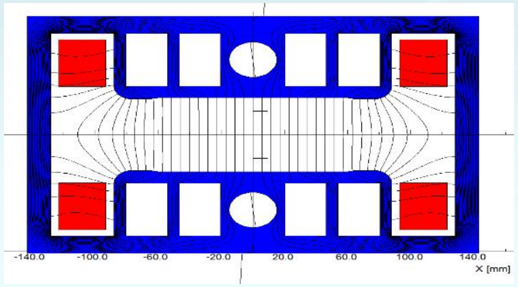


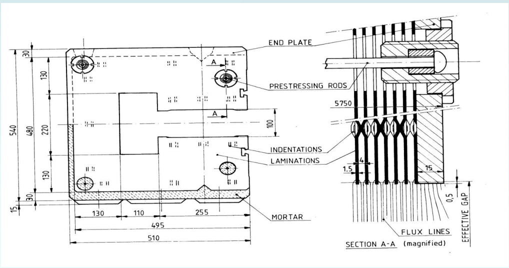
Sextupole

Booster ring low field magnets

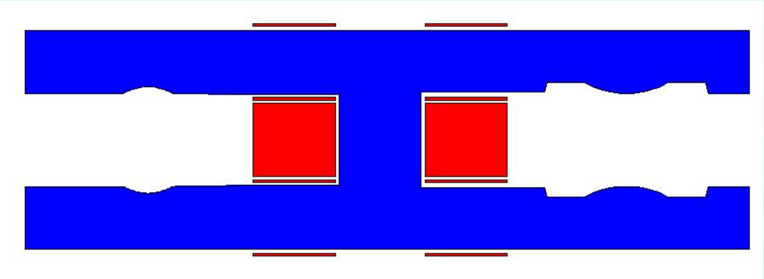
Quantity	16320
Magnetic length(m)	4.711
Max. strength(Gs)	338
Min. strength(Gs)	28
Gap height(mm)	63
GFR(mm)	55
Field uniformity	5E-4

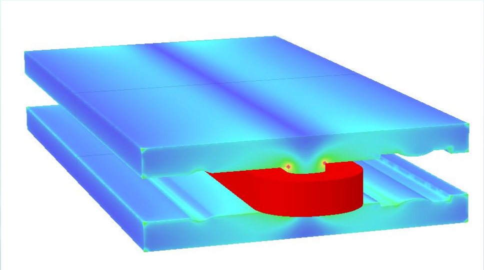
Dipole

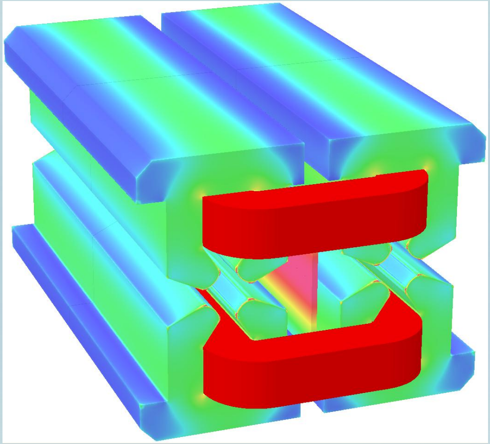


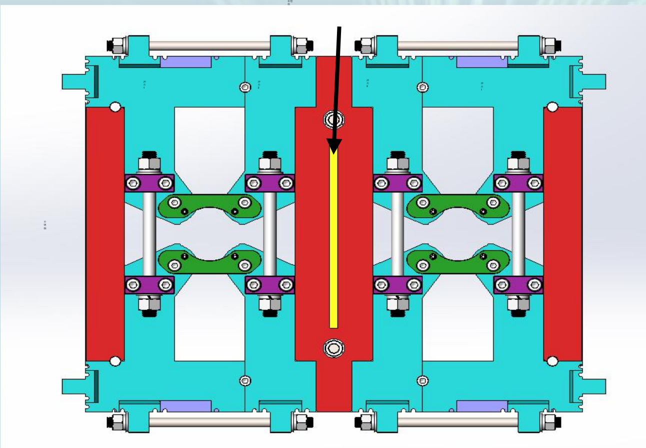


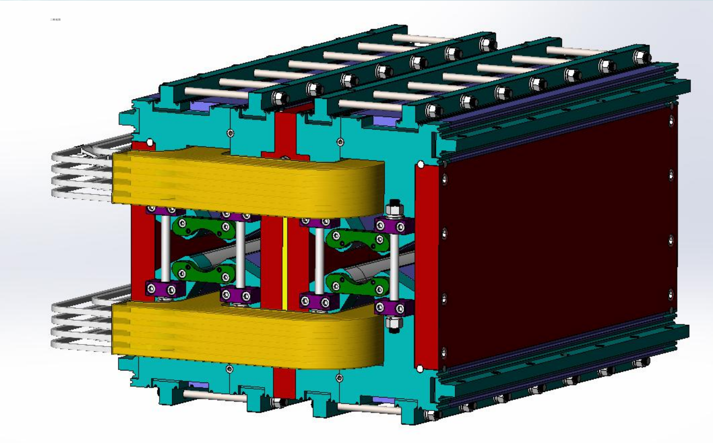
CEPC collider ring dual aperture dipole, quadrupole and sextupole magnet design progress

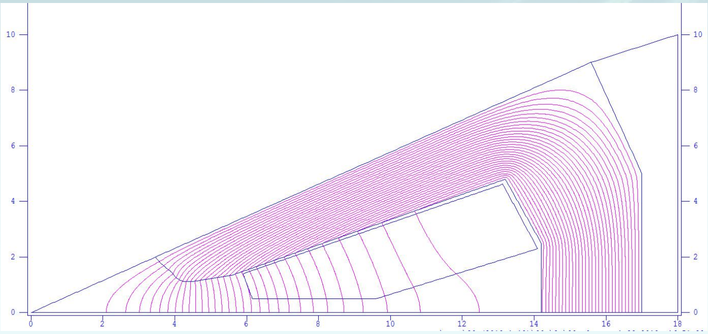


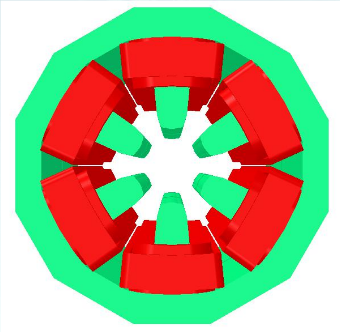


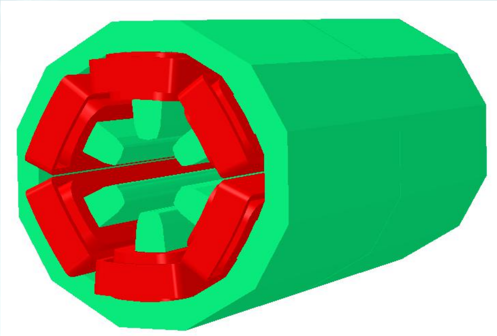






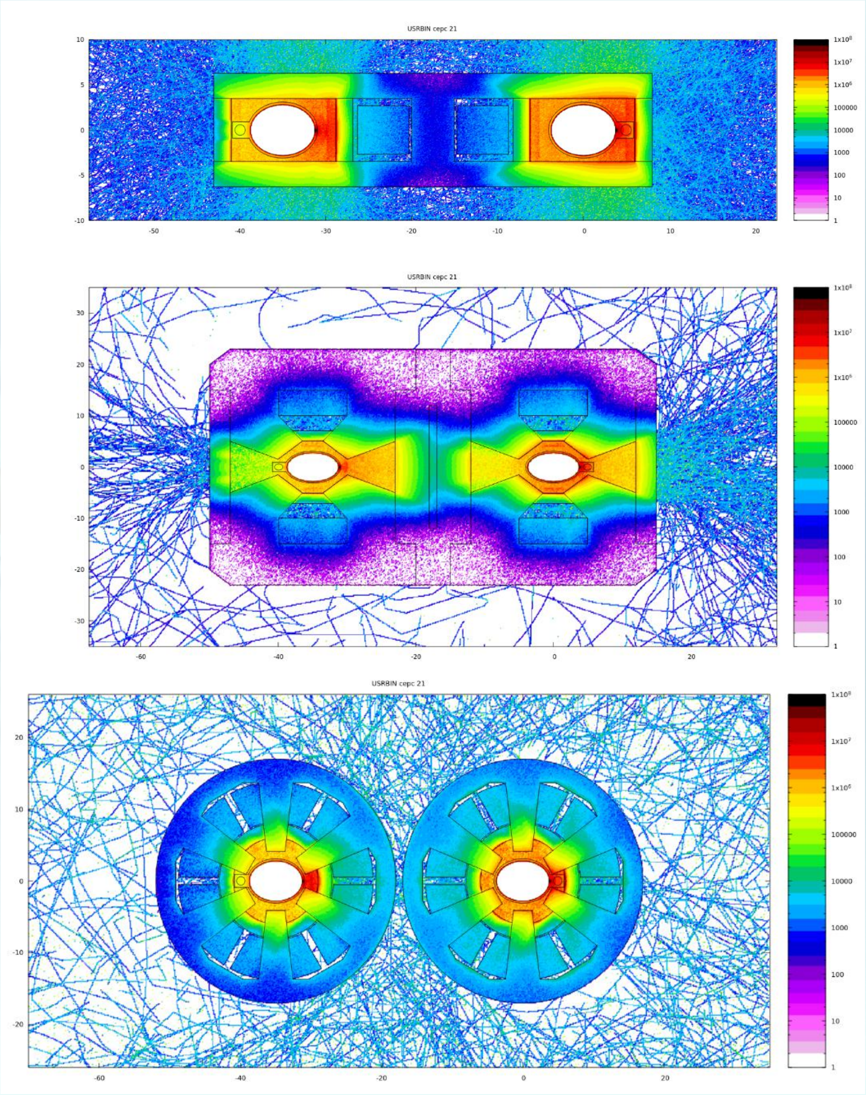






Magnets R&D:-SR Analysis

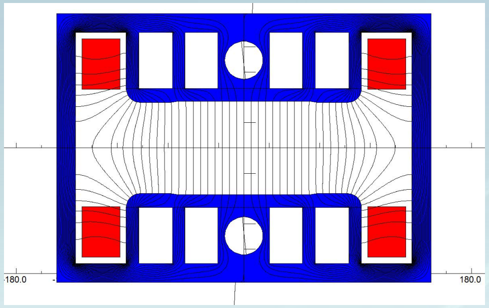
Total power 870 W/m			
Beam direction: left W/m		Beam direction: right W/m	
Al chamber	199	Al chamber	186
Cu chamber	308	Cu chamber	332
Dipole	186	Dipole	182
Lead A	60.6	Lead A	29.2
Lead B	33.5	Lead B	80.0
Lead C	46.8	Lead C	18.8
Lead D	14.3	Lead D	20.4
Quadrupole	279	Quadrupole	268
Lead A	37.8	Lead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

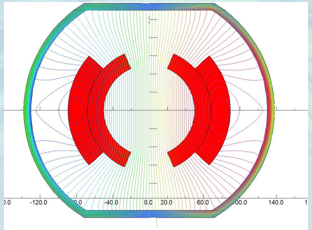
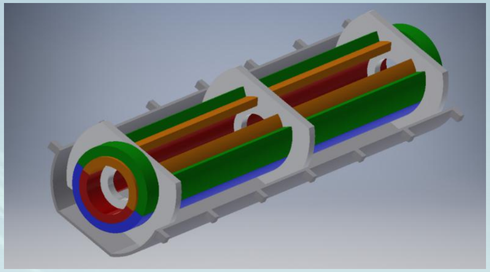
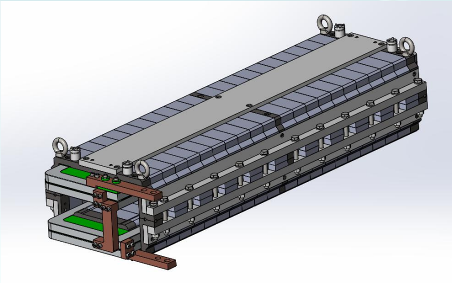
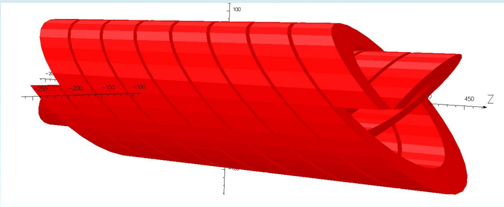


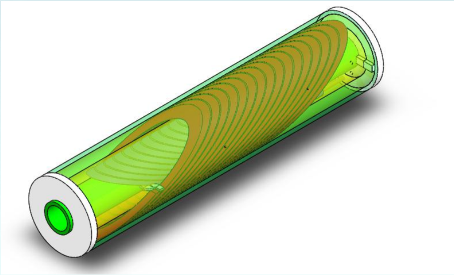
Booster high precision low field dipole magnets

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

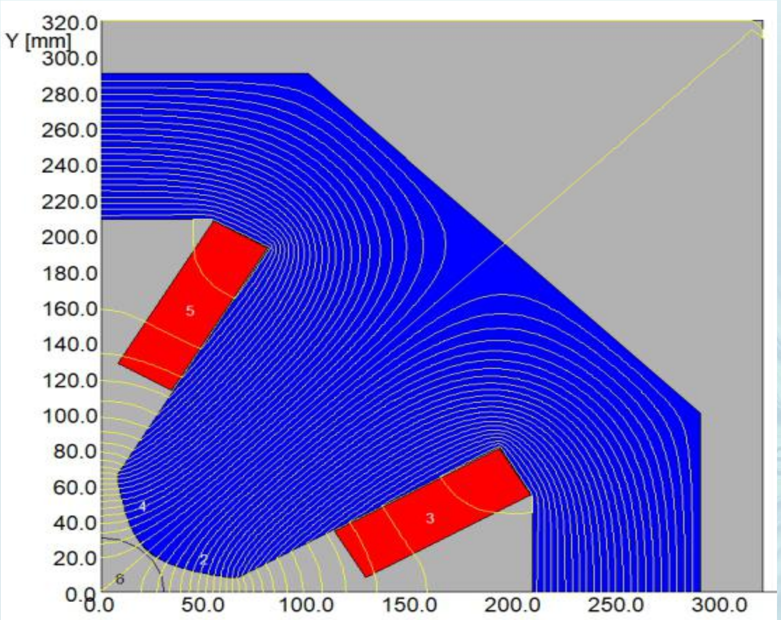
Two kinds of the dipole magnets without iron cores called Cos Theta (CT) and Canted Cos Theta (CCT) are proposed and designed

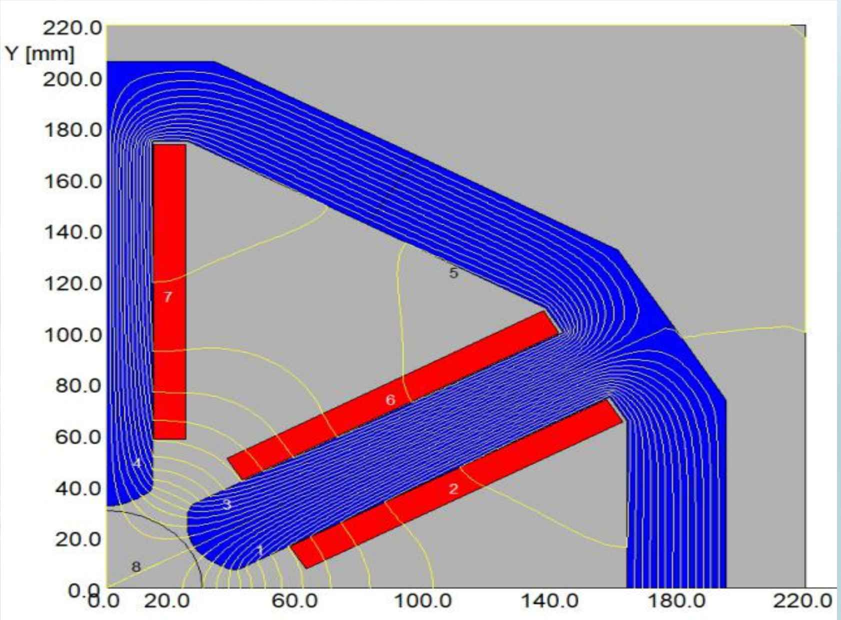




Booster quadrupole and sextupole designs



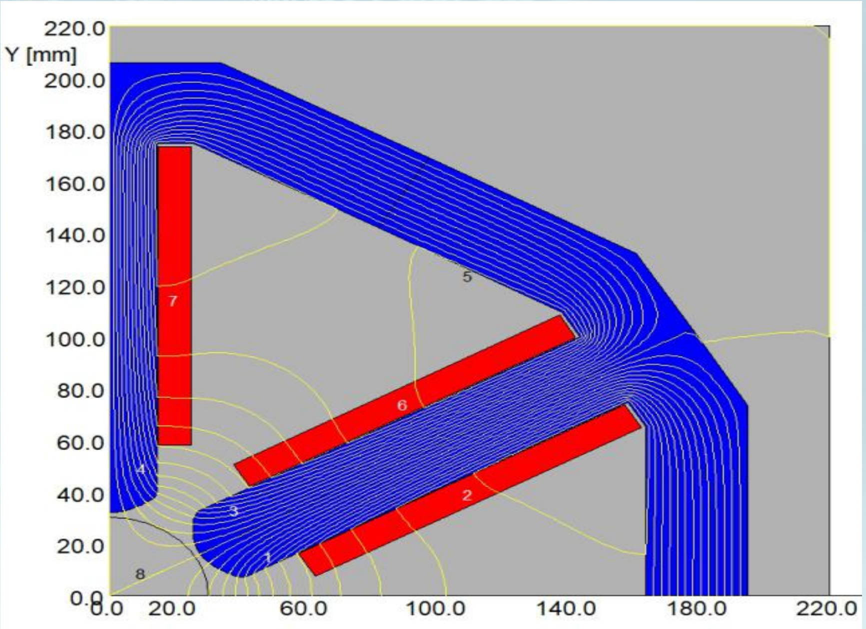


At Higgs energy: 120GeV
Quarople number: 2036
Maximum power(MW):12.26

At Higgs energy: 120GeV
Sextupole number: 448
Maximum power(kW: 270.61

Booster sextupole designs

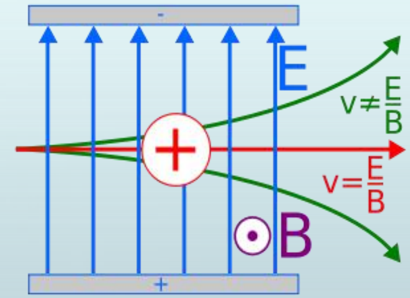
六极磁铁
对于SF与SD两种磁铁，由于磁场要求相差较大，故分为两种类型来进行磁铁的初步设计，选择空心铜导线，单层绕线，总体为上下二合一结构。两种类型的磁铁，极面设计相同，匝数及磁极与磁轭不同。



在最大引出能量为120GeV时，
磁铁数量 448
总最大功率(kW)　　270.61
导线质量(Ton)　　4.52
铁芯质量(Ton)　　76.38

CEPC Collider Ring Electro-Magnet Separator

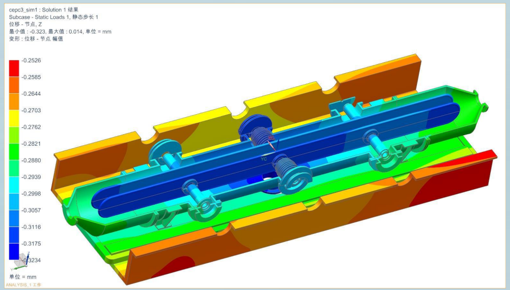
The **Electrostatic-Magnetic Deflector** is a device consisting of perpendicular **electric** and **magnetic** fields, just like **Wien filter**.



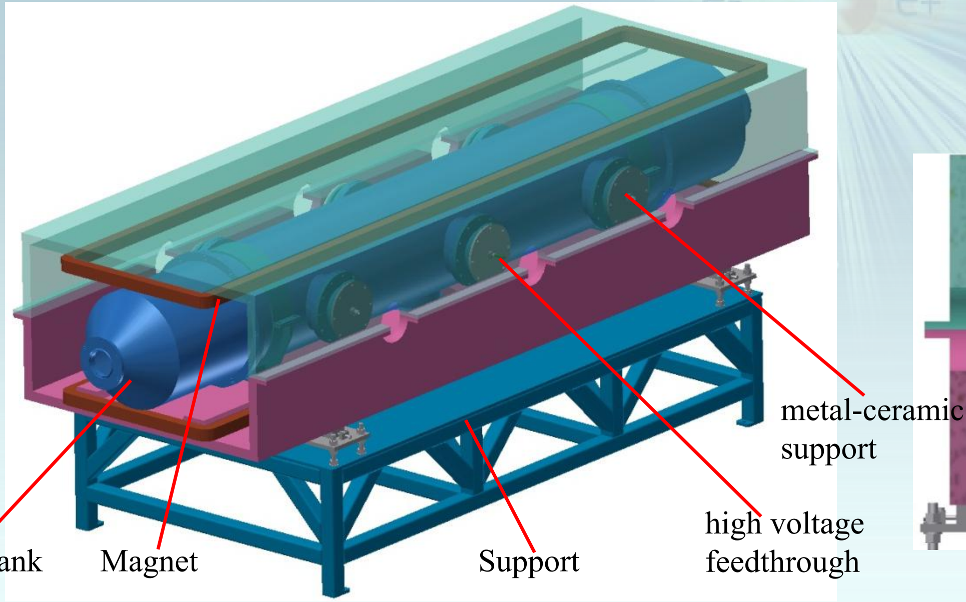
Challenges: To maintain E/B ration in fringe field region

Reduce the impedance and loss factor of the separator

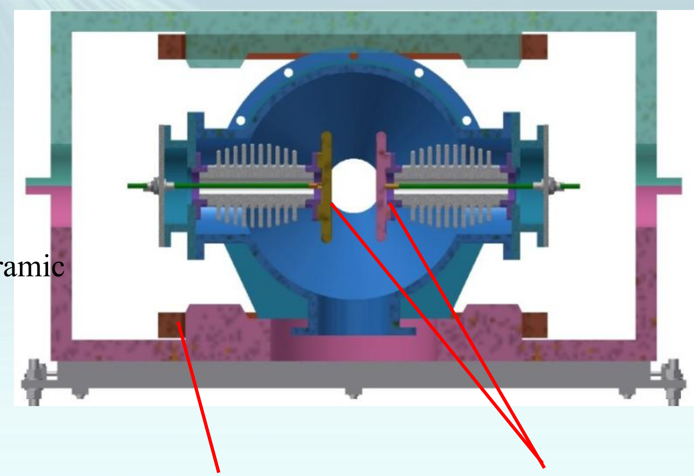
	Filed	Effective Length	Gap	Good field region	Stability
Electrostatic separator	2.0MV/m	4m	110mm	70mm x 30mm	5 x 10^{-4}
Dipole	66.7Gauss	4m	600mm	70mm x 30mm	5 x 10^{-4}



A Wien filter

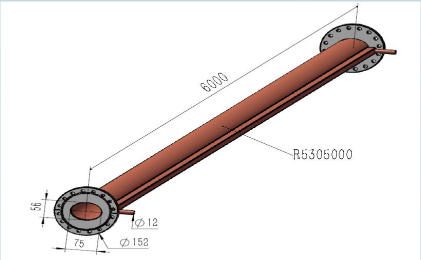


structure drawing of Electrostatic-Magnetic Deflector

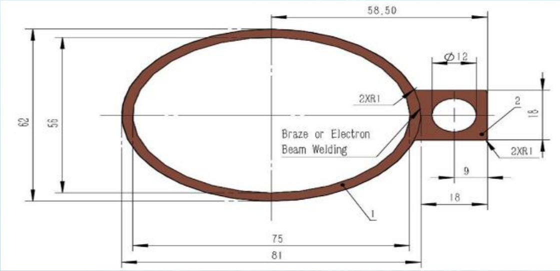


Vacuum System R&D

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

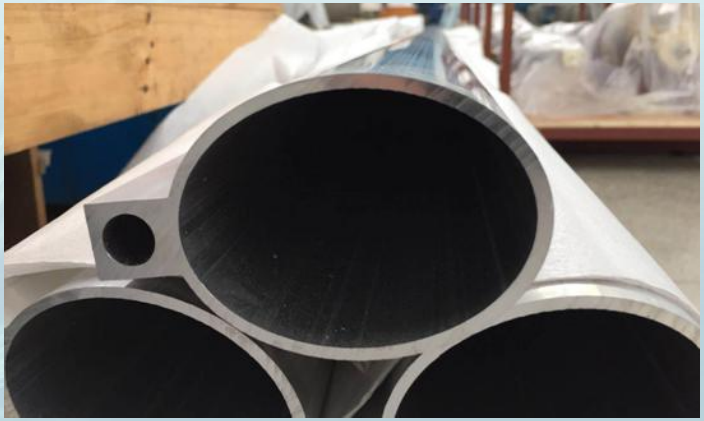


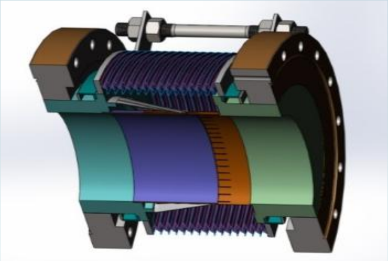
Positron ring

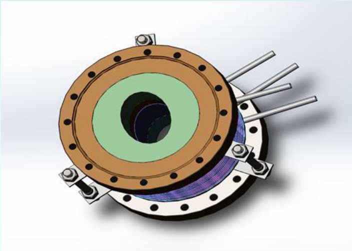


Copper vacuum chamber (Drawing)
(elliptic 75×56, thickness 3, length 6000)

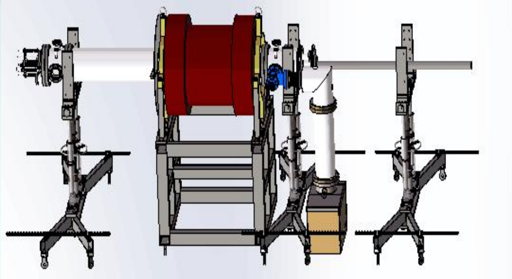
First test vacuum chamber

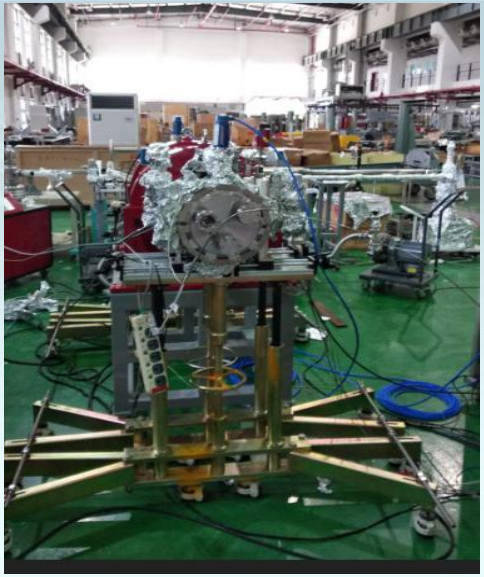




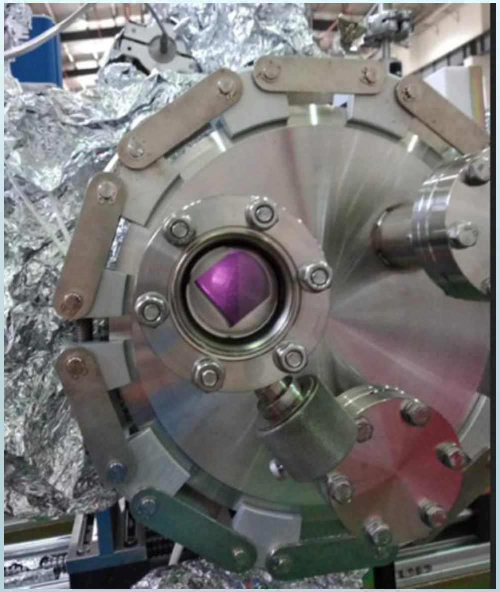


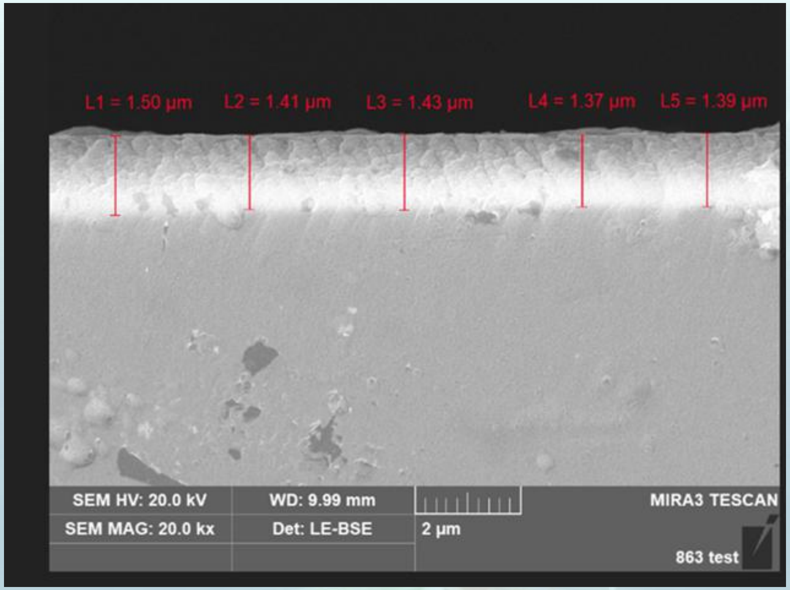
NEG coating suppresses electron multipacting and beam-induced pressure rises, as well as provides extra linear pumping. Direct Current Magnetron Sputtering systems for NEG coating was chosen.

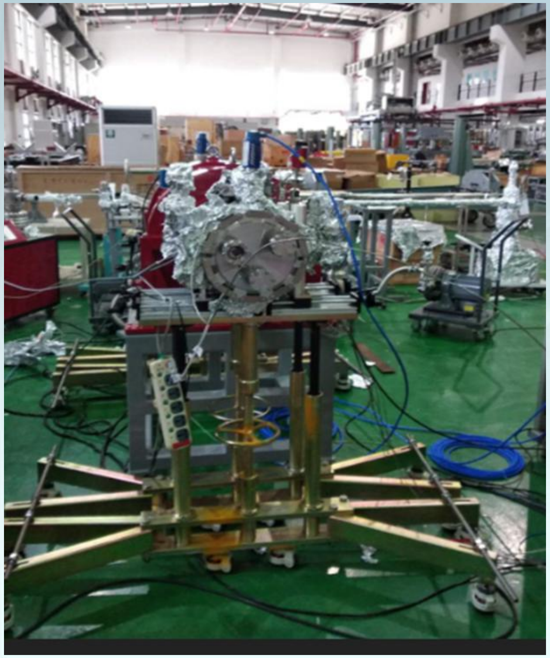


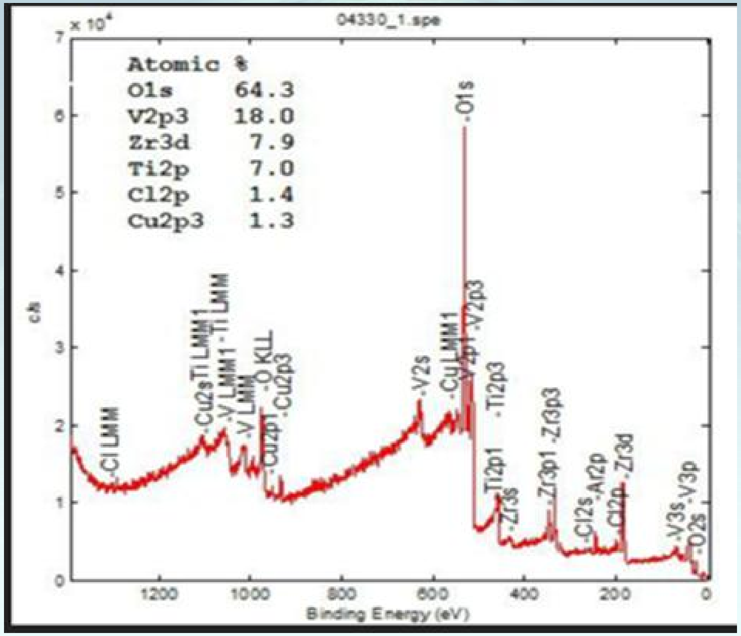


NEG coating



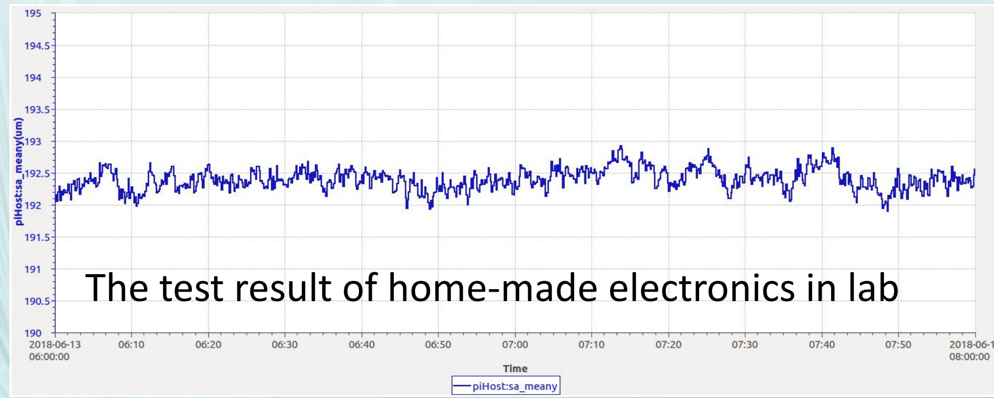




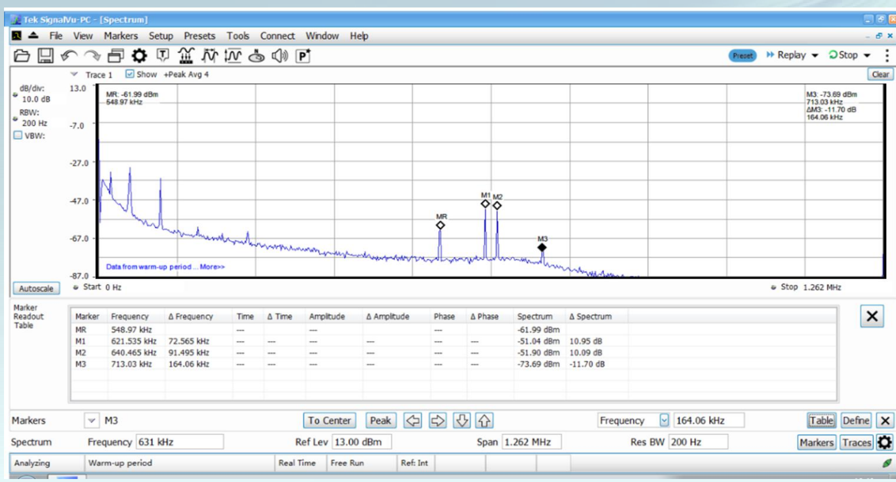


- **NEG coating suppresses electron multipacting (SEY < 1.2) and beam-induced pressure rises, as well as provides extra linear pumping.**
- **The setup of NEG coating has been built, and some experiments have been done.**
- **The thickness of the NEG films are about 1.4 µm.**
- **The proportion of Ti,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

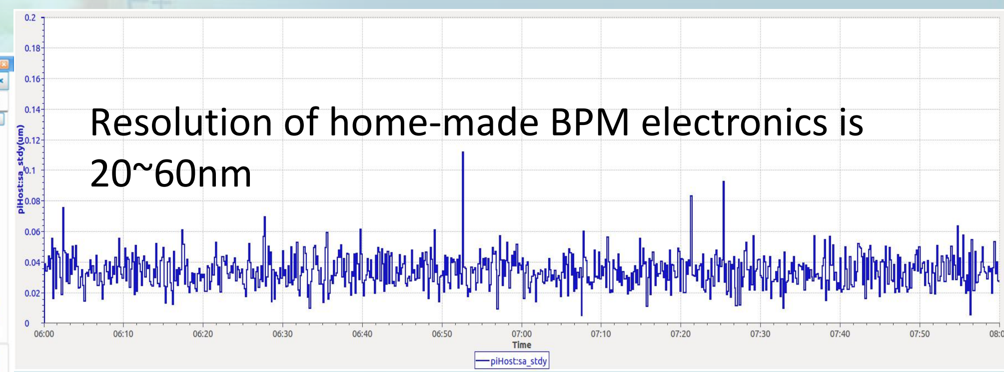
CEPC Beam instrumentation

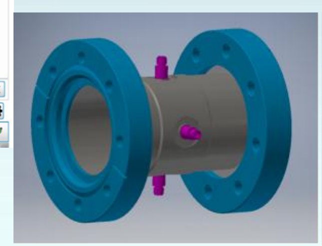


The electronics of beam position monitor

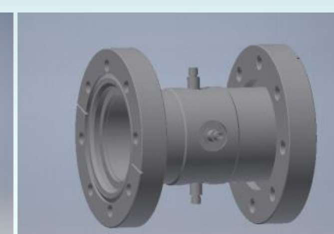


The result of DDD tune system

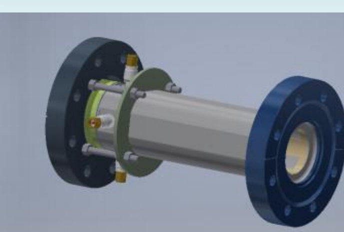




The BPM of storage ring



The BPM of Booster

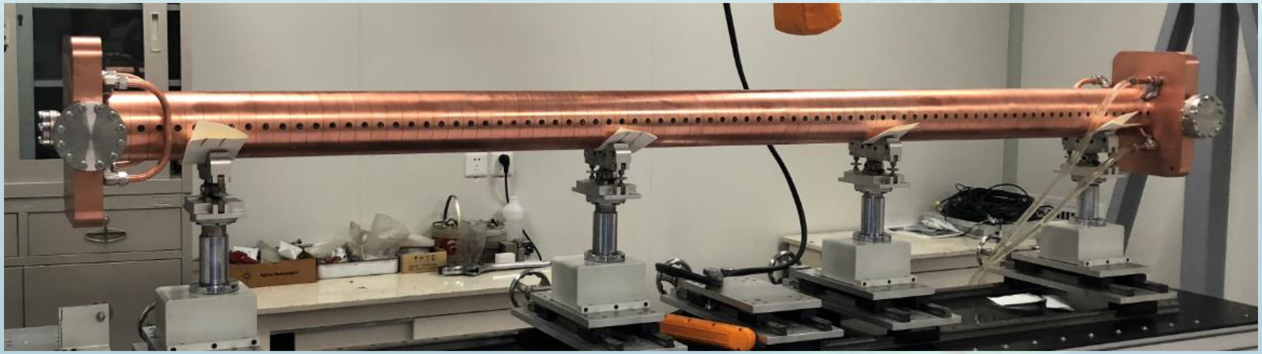


The BPM of Linac and BT

CEPC Linac Injector R&D

- S-band accelerating structure design

–Accelerating structure design



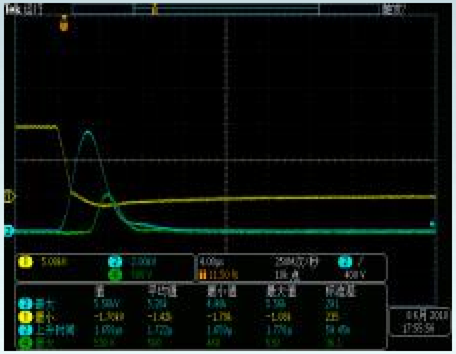
Accelerating structure under cold test

- Positron flux concentrator design

The mechanical design of FLUX concentrator

The finished FLUX concentrator

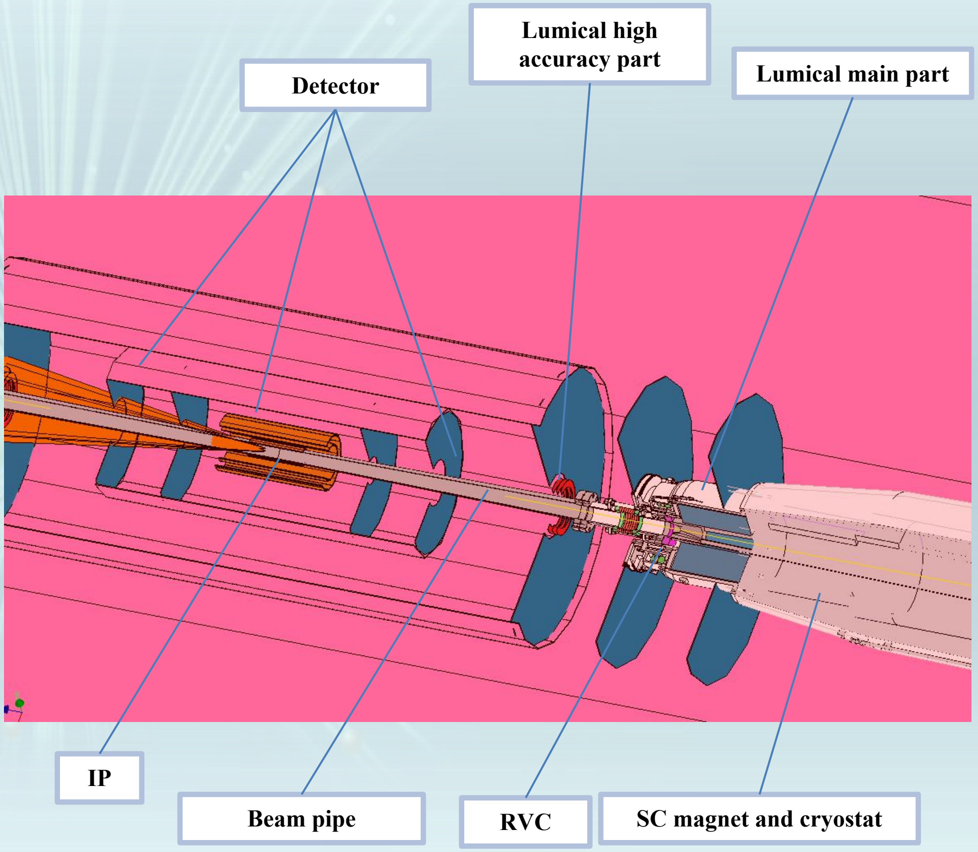
solid-state pulsed power generator



The output of 10kA measurement

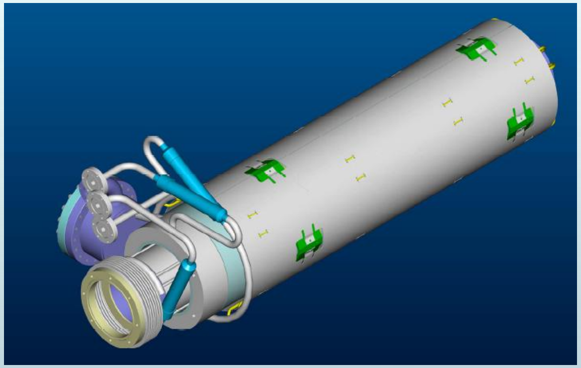
MDI RVC design

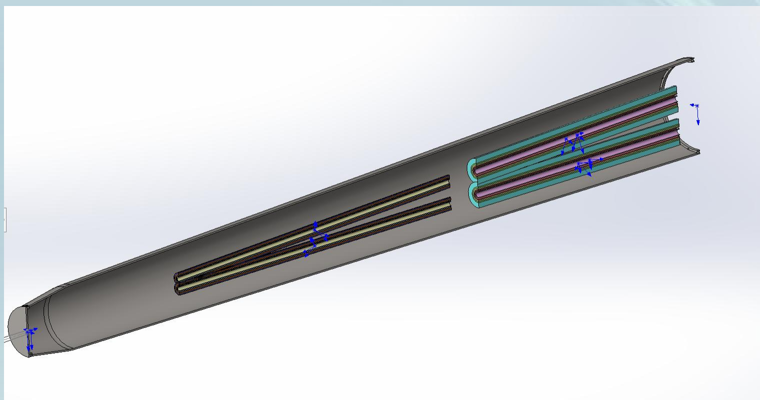
- CEPC MDI Lumical and accelerator components conflict in both position and alignment accuracy has been fixed: Lumical can be separated into 2 parts, one part with high precision installed and aligned with Be vacuum chamber, the other part ~50~100kg can be installed and aligned with cryostat. And can be calibrated with IP BPM(<1um, Be pipe installed with detector.
- Position conflict with HOM absorber， IP BPM should be solved.

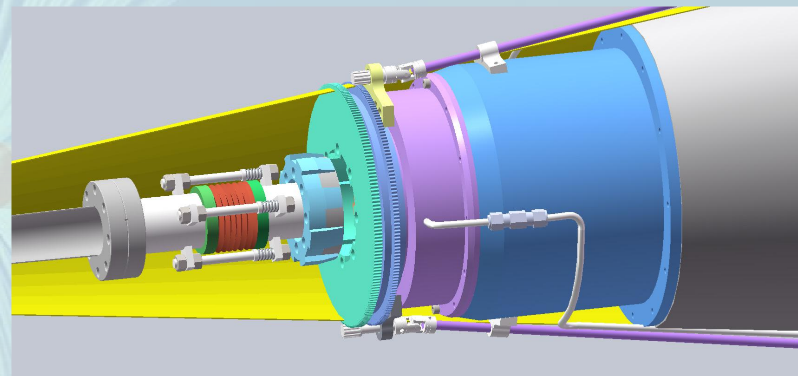


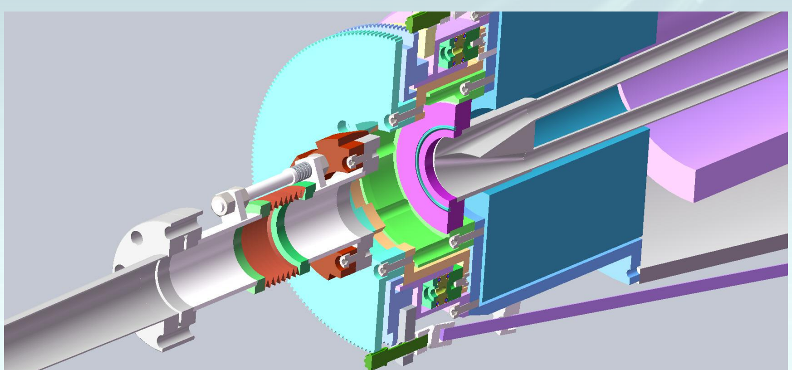
CEPC MDI SC Magnets and Mechanical Study

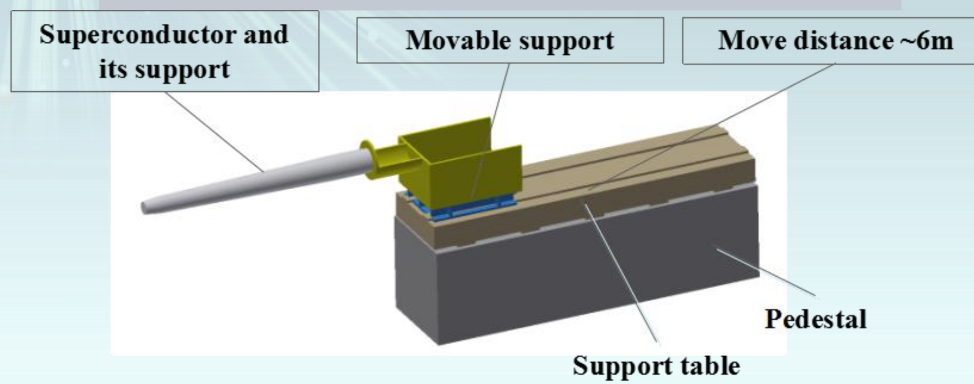
Huanghe Company,Huadong
-Shenyang Huiyu Company
participats in CEPC MDI mechanical connection design
China Astronotics Department 508 Institute
participates in CEPC MDIsupporting design







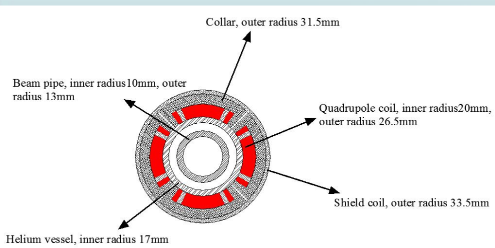




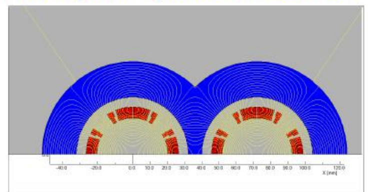
Schematic of support system of superconducting magnets

CEPC IR Superconducting magnets

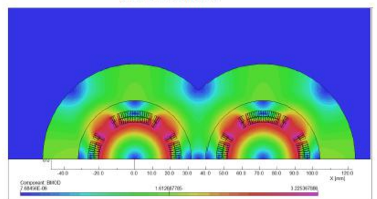
Superconducting QD coils



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

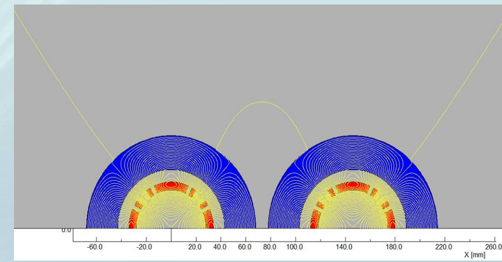


2D Flux lines



Bmod distribution

Superconducting QF coils



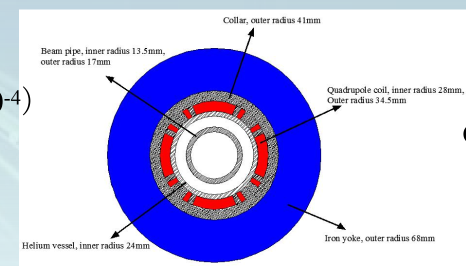
There is iron yoke around the quadrupole coil for QF1. Since the distance between the two apertures is larger enough and there is iron yoke, the field cross talk between two apertures of QF1 can be eliminated.

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



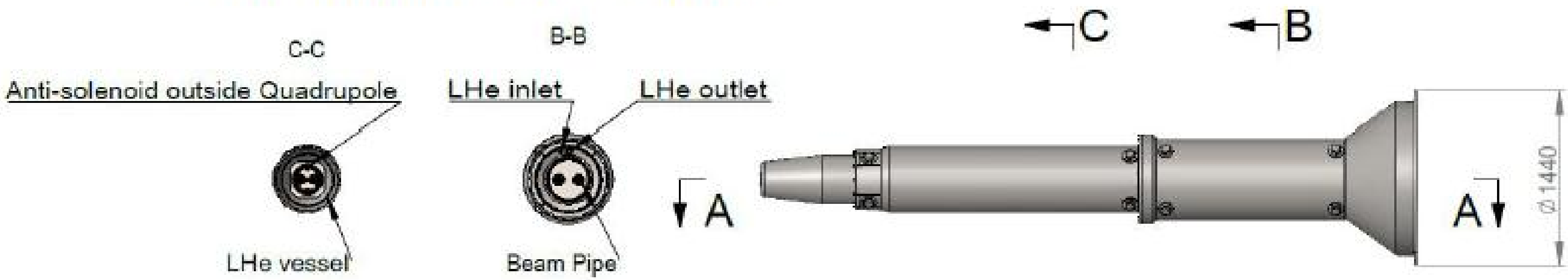
One of QF1 aperture (Peak field 3.8T)

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 IR Superconducting magnet cryostat design

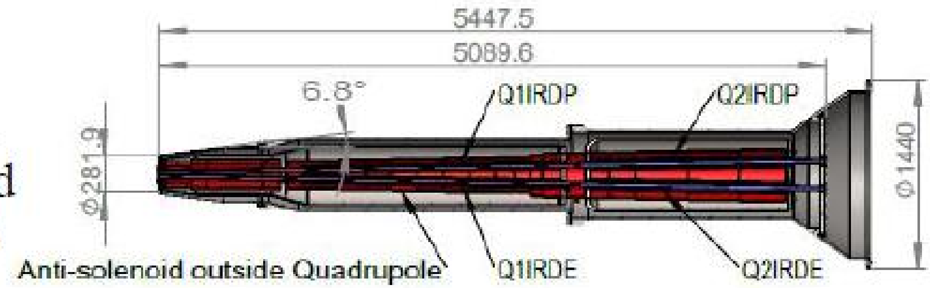
Design progress of magnet cryostat

The Structure of Cryostat

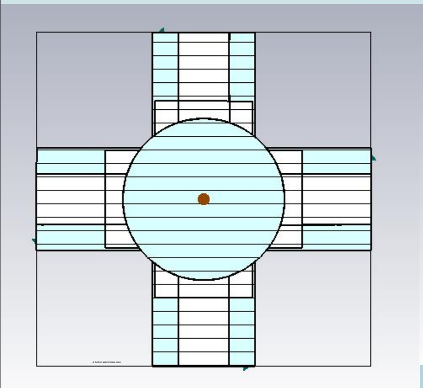


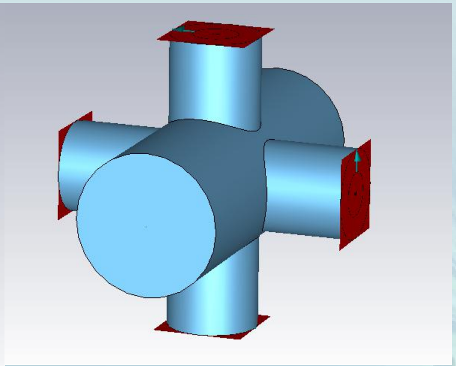
Magnet-cryostat design:

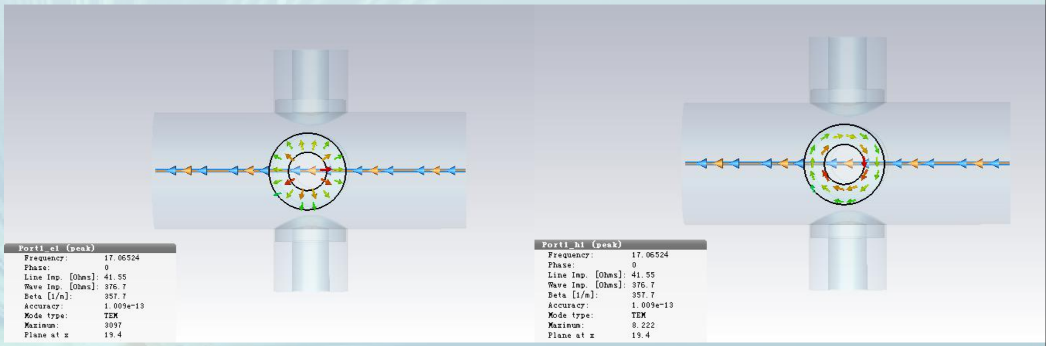
- superconducting magnets are assembled in the helium vessel.
- Two beam pipes at room temperature pass completely through the helium vessel at 4.2K.
- Self-centered supports are designed to make the magnet positions after cool-down to be the nominal positon for the beam operation.



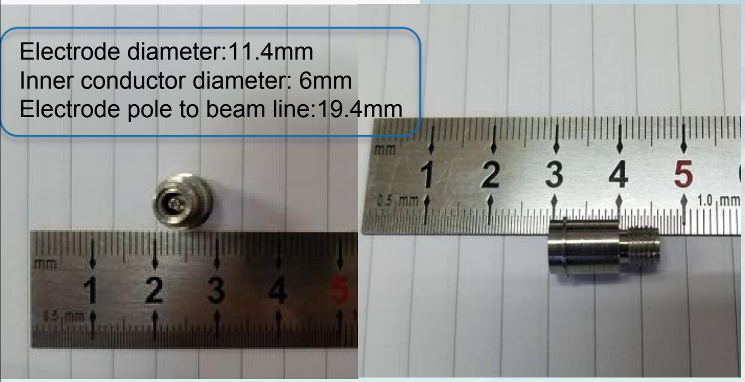
Four Button Electrodes IP BPM

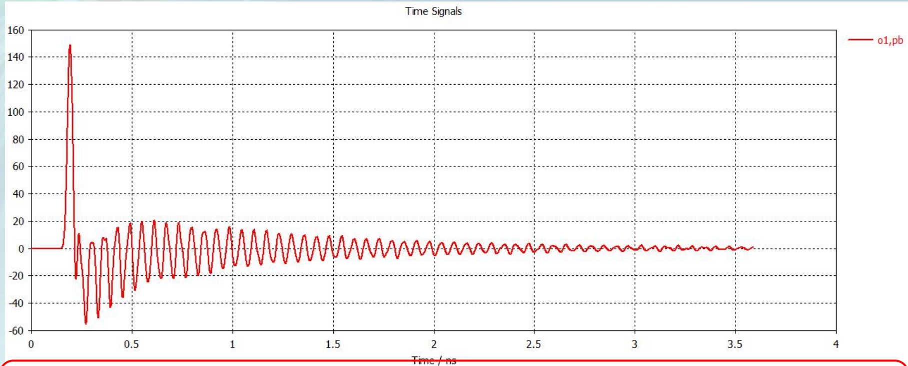






Electrode diameter:11.4mm
Inner conductor diameter: 6mm
Electrode pole to beam line:19.4mm



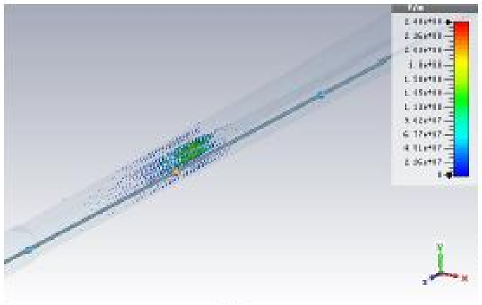


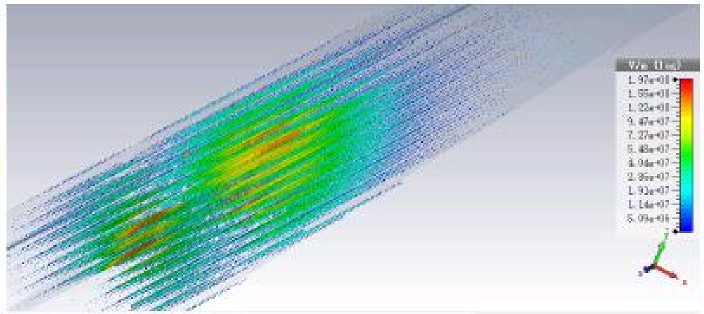
Due to the short bunch length, signal has many resonance hump, signal amplitude proportional to the bunch charge.

Size and signal intensity can be satisfied by CEPC MDI requirement.

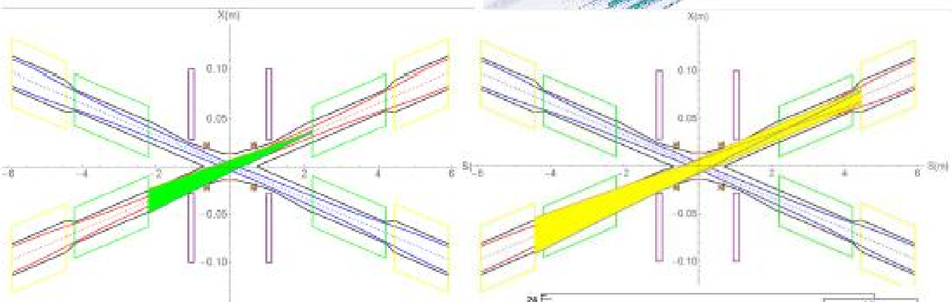
MDI HOM absorter

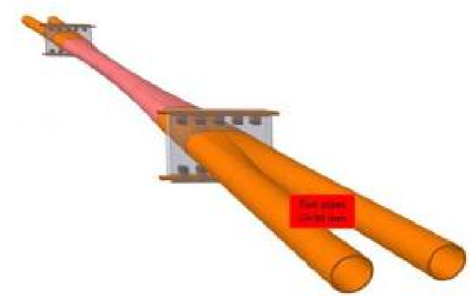
HOM absorber

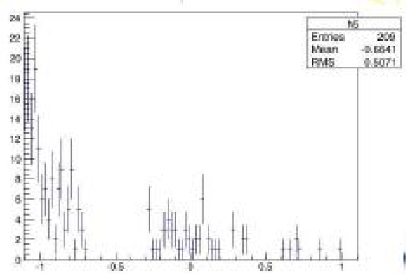




- TE mode, at crotch point (z~±700mm)
- Frenquency 3.2996GHz，Qe=1.42x10[12]
- This mode is trapped mode.
- HOM absorber is needed，water cooling system considered.
- With the high order mode of this TE mode, eg. 3.715GHz.





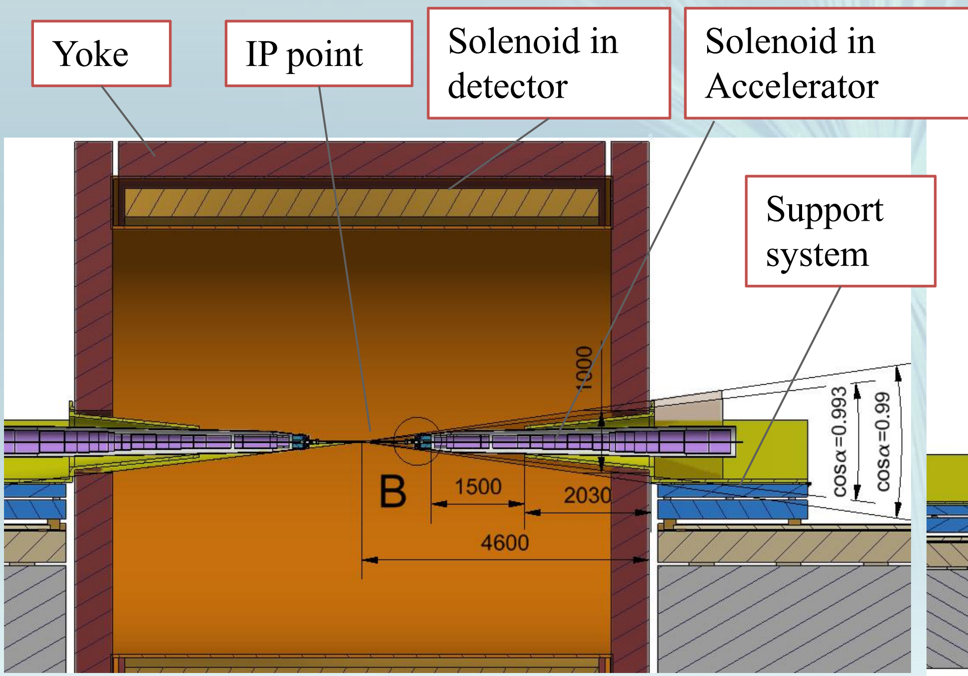


Synchrotron radiation from Final doublet magnets and reflection part from mask，HOM absorber radiation resistance requirements ?

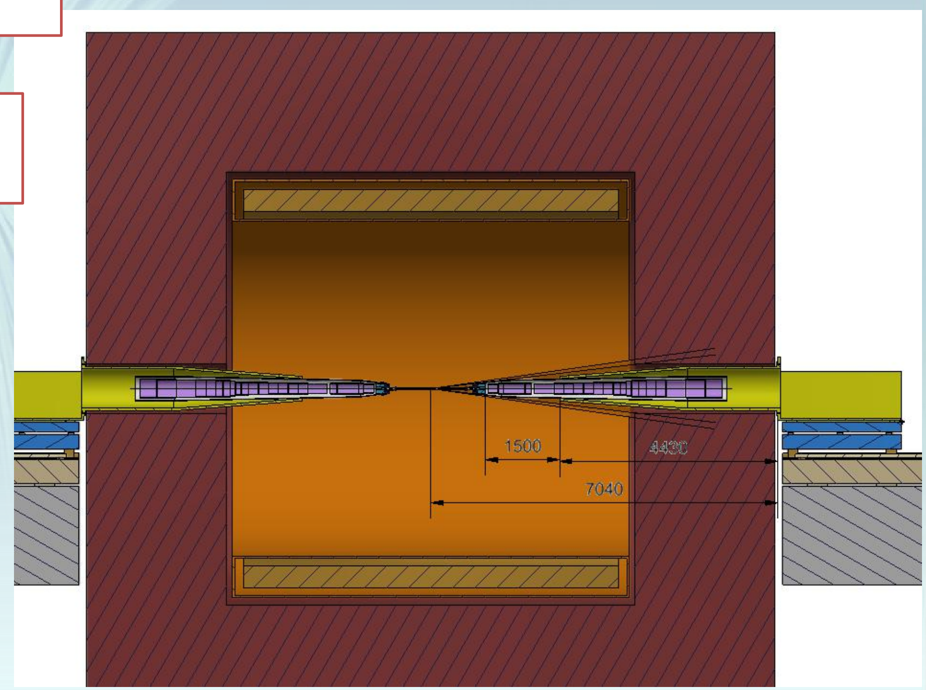
- HOM absorber design refer to FCC, under development
- Distance from IP is 70cm~90cm in crotch section，space conflict with RVC and IP BPM needs to be fixed.
- Impedance

能物理研究所
Chinese Academy of Sciences

Support System of MDI-1



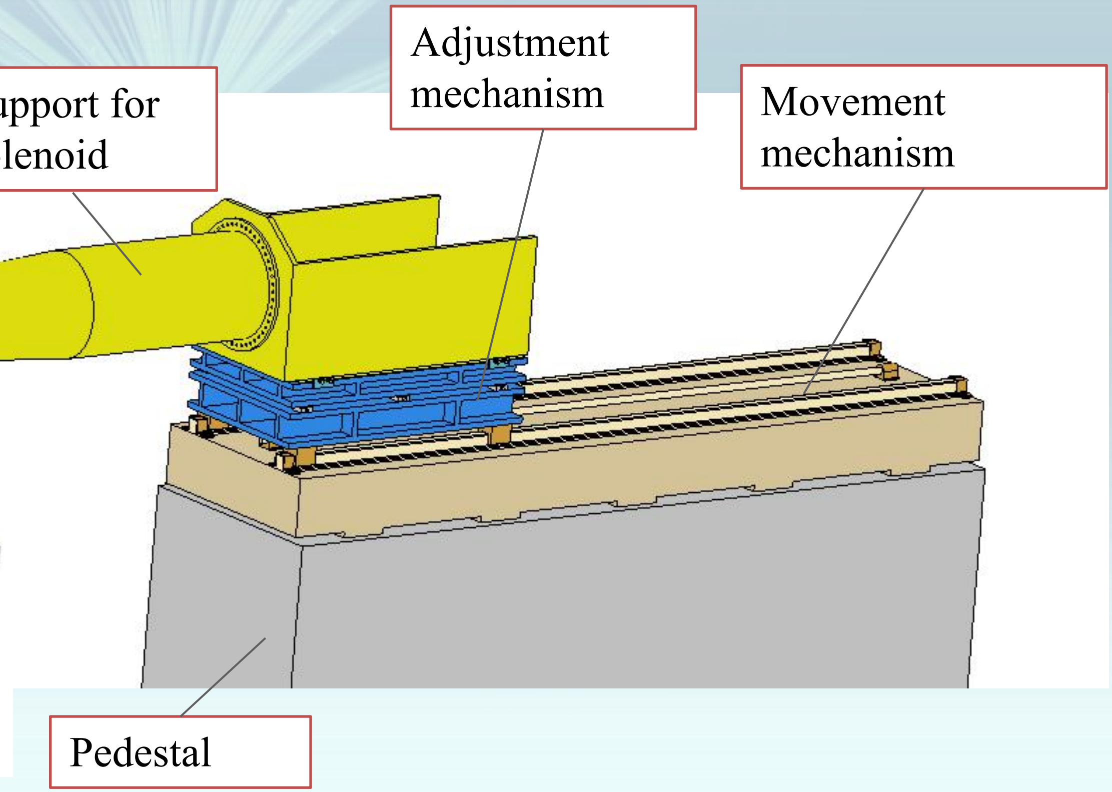
Scheme 1: small yoke

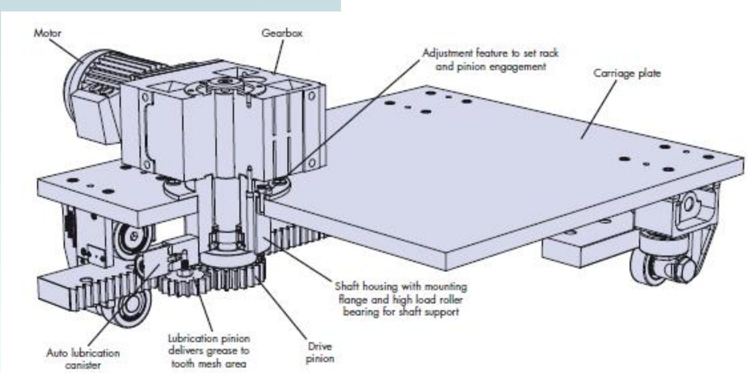


Scheme 1: big yoke

Support System of MDI-2

- **Adjustment mechanism: push-pull bolts for horizontal, wedge jacks for vertical.**
- **Movement mechanism: tracks & screw rod for baseline, tracks & pinions also under consideration.**

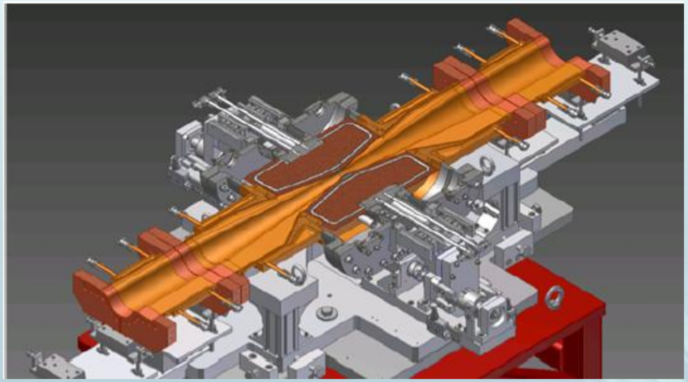




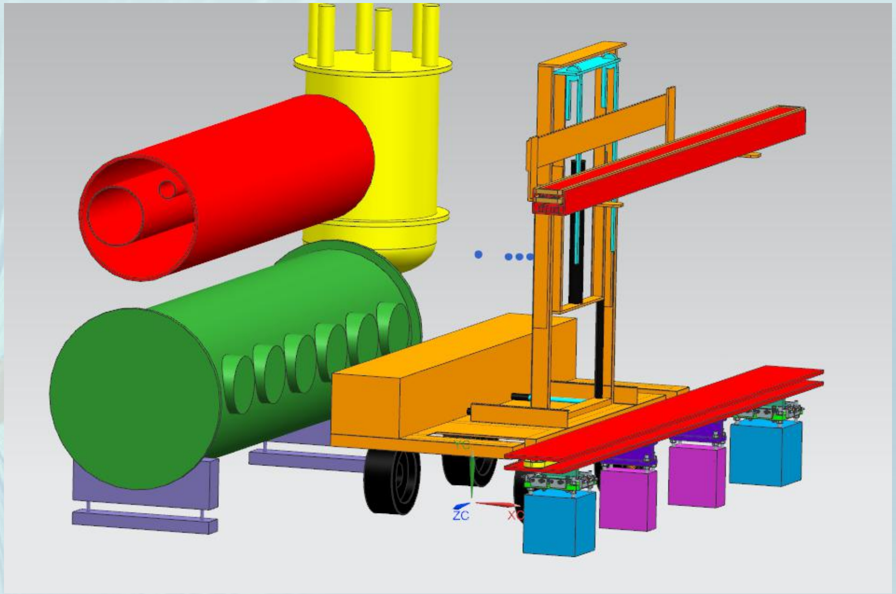
Tracks & pinions from HepcoMotion

CEPC Mechanical Studies

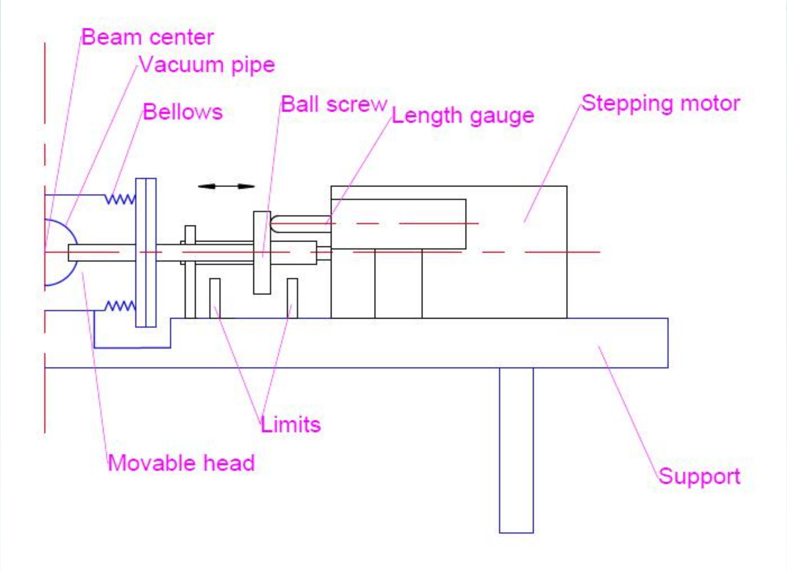
China Astronotics Department 508 Institute participates in CEPC movable collimators mechanical design



Collimator of SKEKB

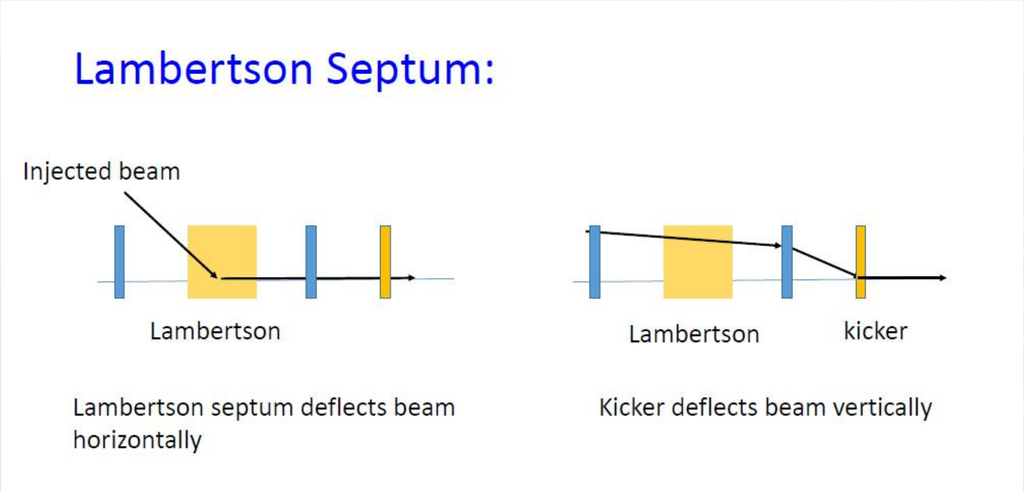


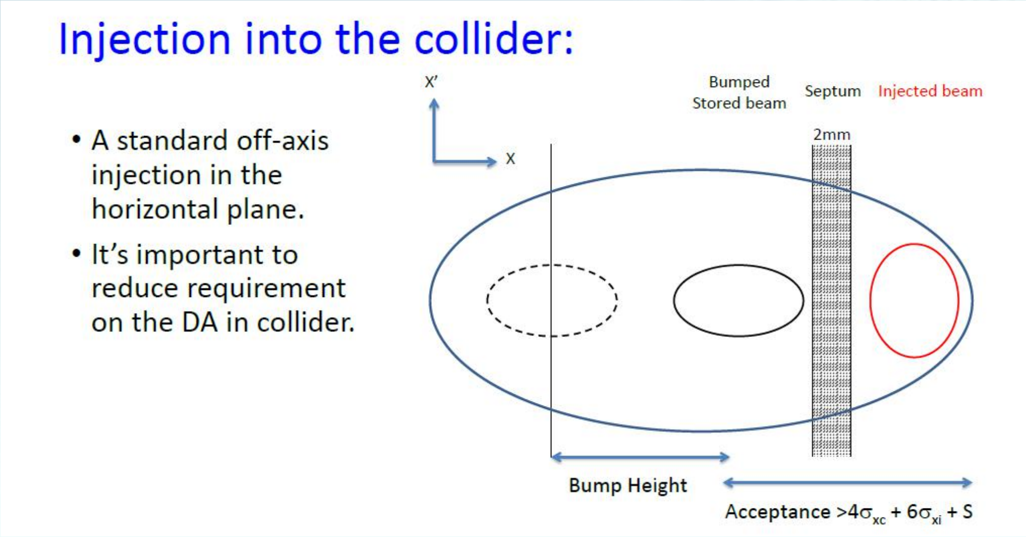
Schematic of transport vehicle of magnets

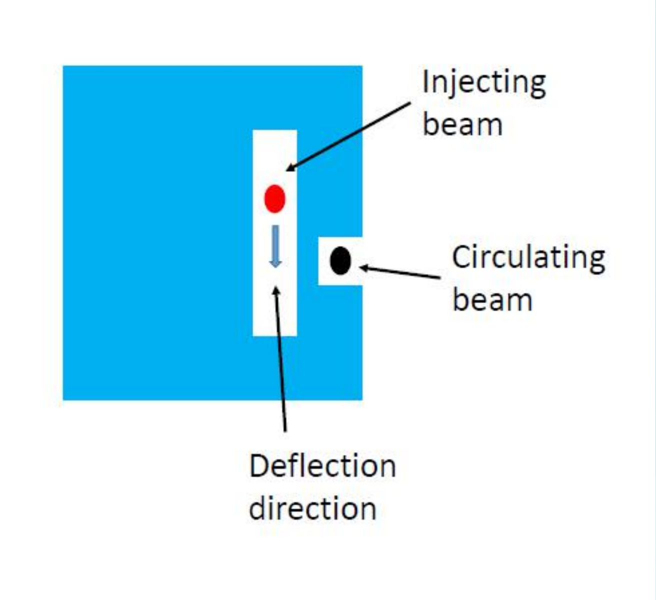


Schematic of movable collimators

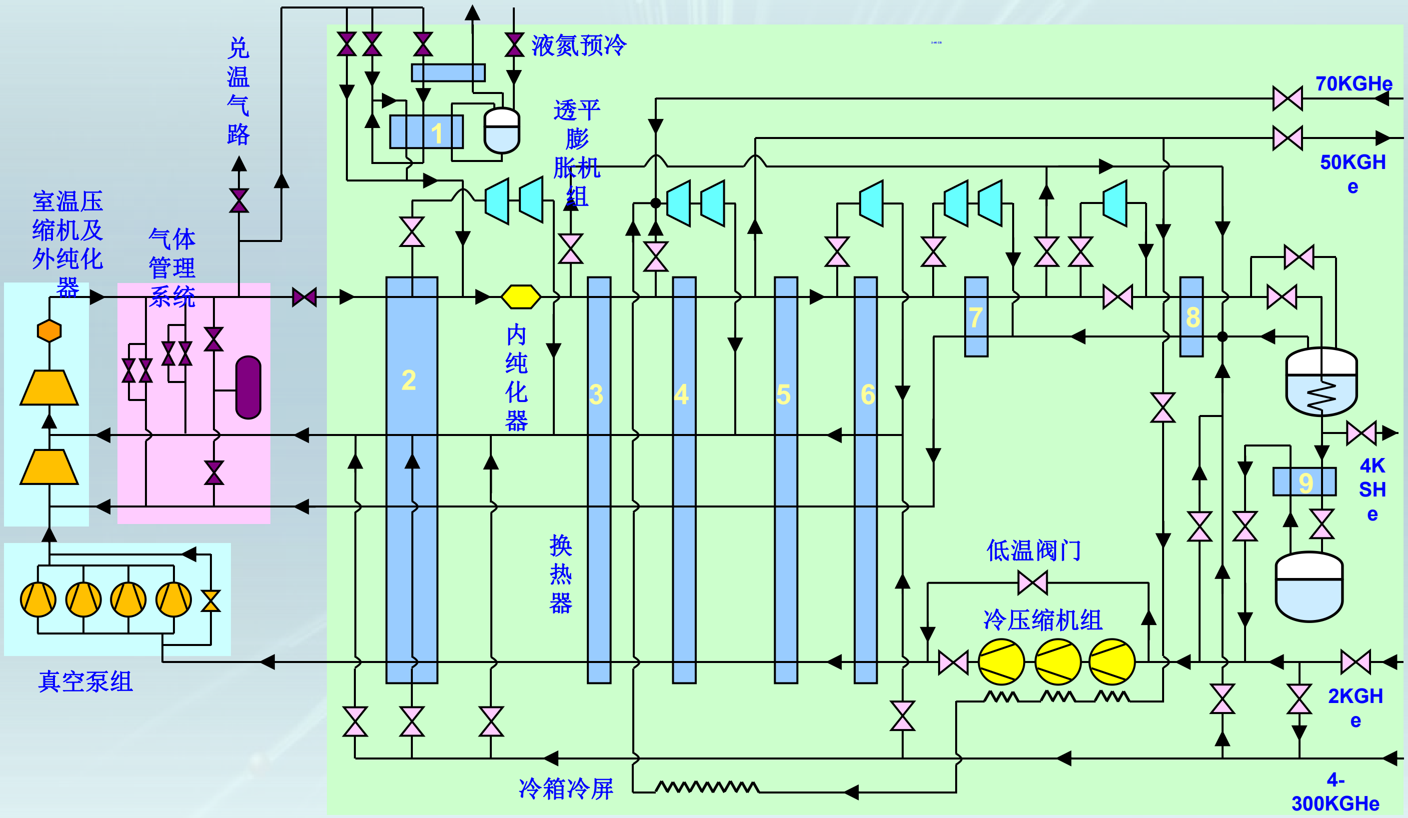
CEPC accelerator chain injection/extraction R&D







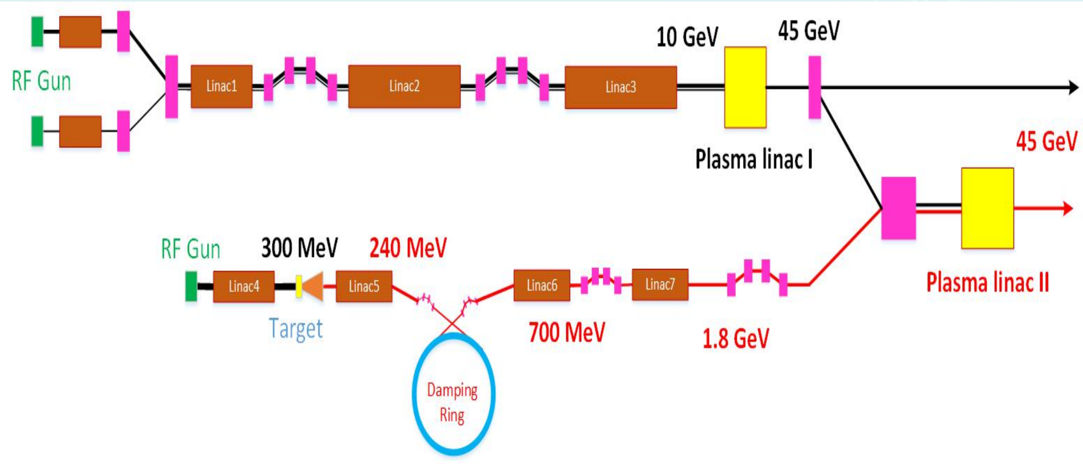
Future Work: from 10kW@4.5K cryosplant to 18kW@4.5K cryosplant

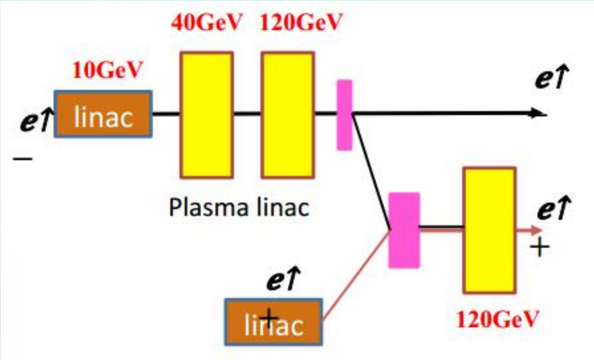


A first 20kW@4.5K cryosplant will be completed in five years from 2019 in China

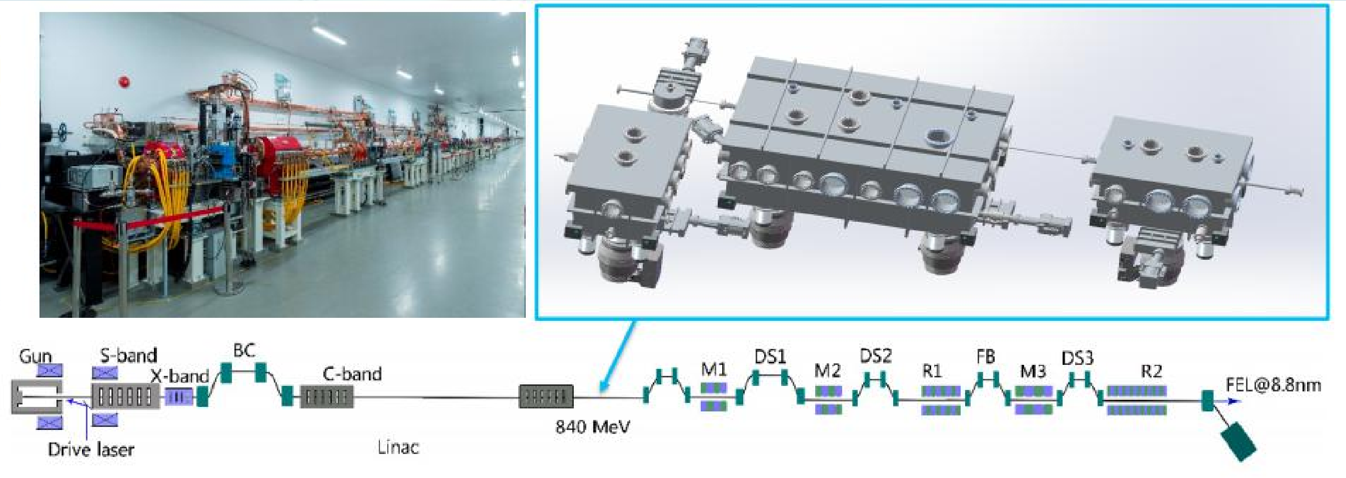
Experimental Verification Planfor CEPC Plasma Injector Scheme

A dedicated budget of 8Million has been alocated by IHEP





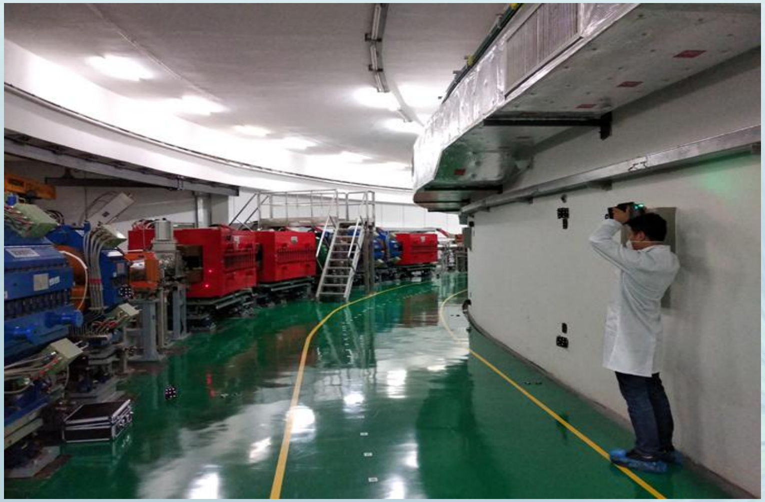
Electron (SXFEL-TF)	
Energy	840MeV
Energy spread(rms)	≤0.1%
Norm. Emittance(rms)	≤1.5mmmrad
Length(FWHM)	≤1ps
Charge	0.5nC
Repetition rate	10Hz



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

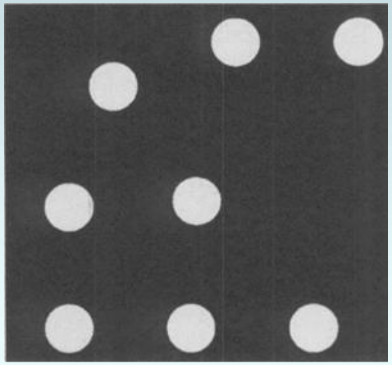
Alignment technologies

- **CEPC large scale, high precision and high efficiency**



- R&D on 3μm+3ppm camera、target and million capacity coded targets

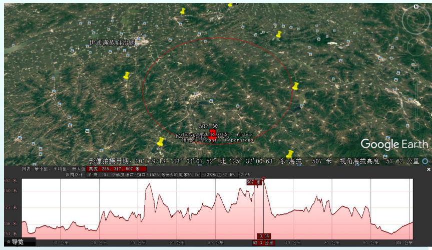
Target extraction
↓
Cross ratio invariance
↓
Model point extraction
↓
Affine transformation
↓
Recover code structure
↓
Coded value

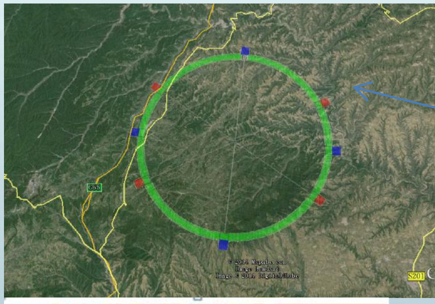


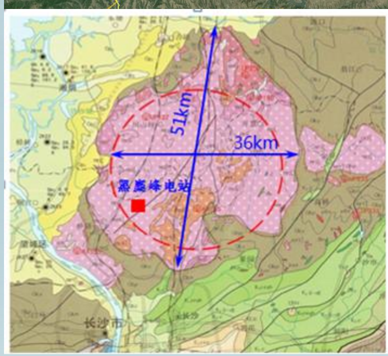
Coded target

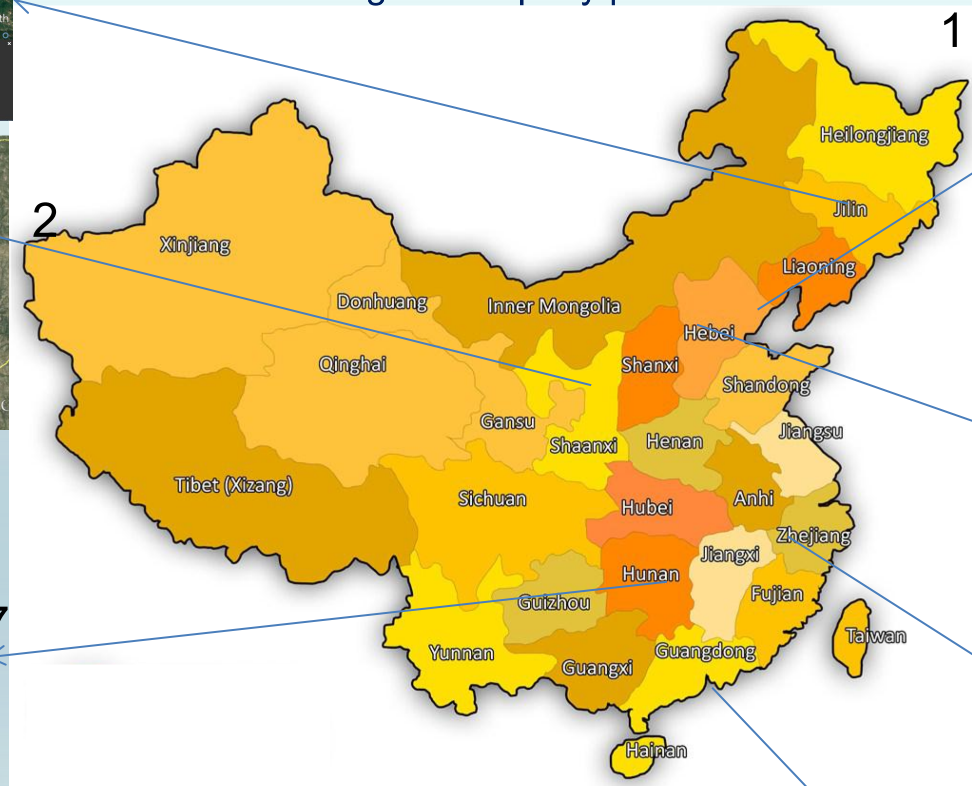
CEPC Site Selections

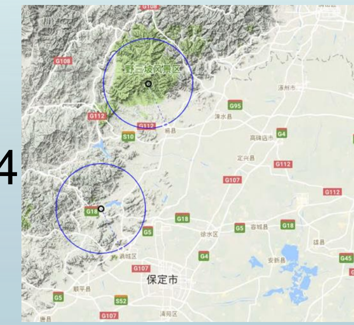
Huanghe Company particitated

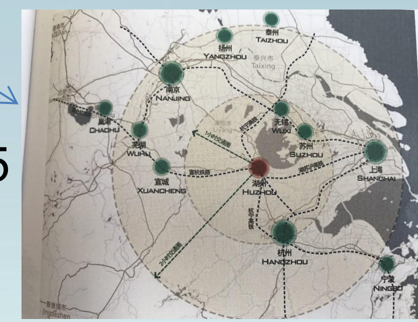












1) Qinhuangdao, Hebei Province（Completed in 2014）
2) Huangling, Shanxi Province（Completed in 2017)
3) Shenshan, Guangdong Province(Completed in 2016)
4) Baoding (Xiong an), Hebei Province (Started in August 2017)
5) Huzhou, Zhejiang Province (Started in March 2018)
6) Chuangchun, Jilin Province (Started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

CEPC Industrial Promotion Consortium (CIPC) Collaboration Status

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

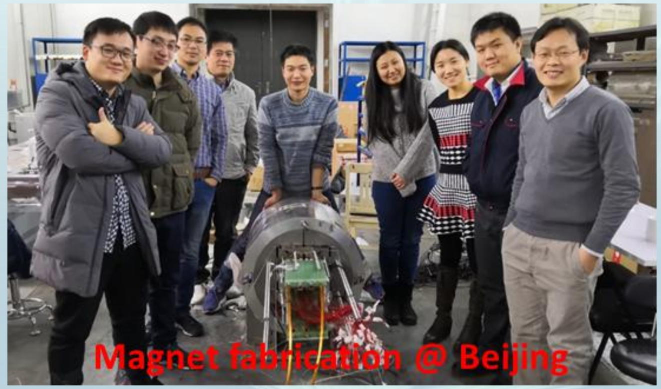
1) Superconduting materials (for cavity and for magnets)
2) Superconducting cavities
3) Cryomodules
4) Cryogenics
5) Klystrons
6) Vacuum technologies
7) Electronics
8) SRF
9) Power sources
10) Civil engineering
11) Precise machinary.....

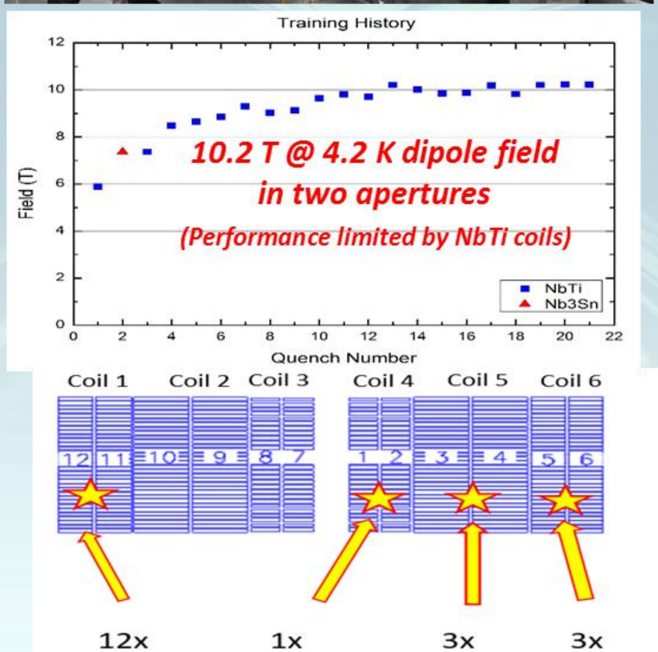
Now:
-Huanghe Company, Huadong Engineering Cooperation Company, on CEPC civil engineering design, site selection, implementation...
-Shenyang Huiyu Company on CEPC MDI mechanical connection design
-Zhongxin Heavy Industry on Elecletric-magnetic seperator design
-China Astronotics Department 508 Institute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

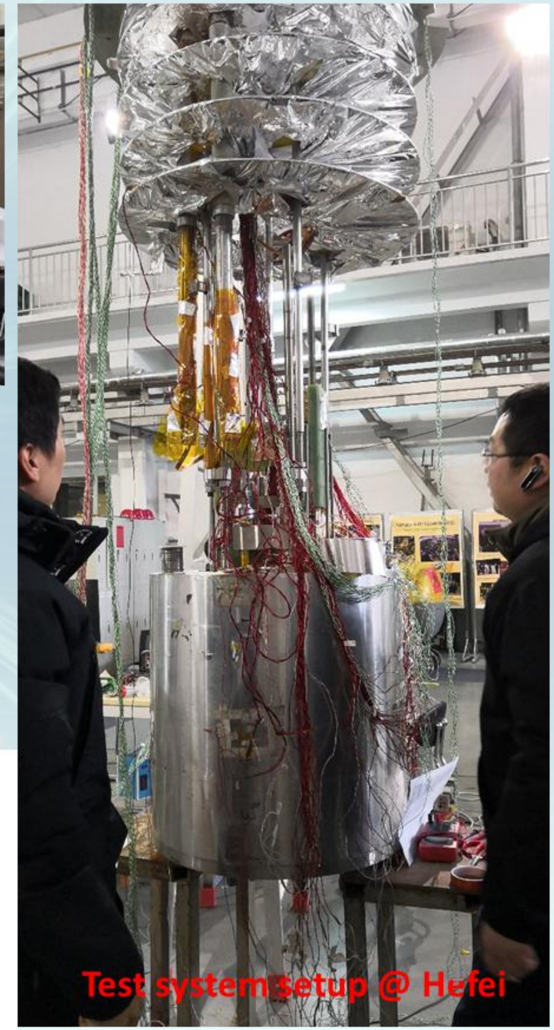
R&D of the 1st High Field Dipole Magnet in China

The 1[st] high field dipole magnet（NbTi+Nb_3Sn）in China successfully fabricated and tested in Feb 2018.

Reached 10.2T @ 4.2K dipole field in the two apertures.

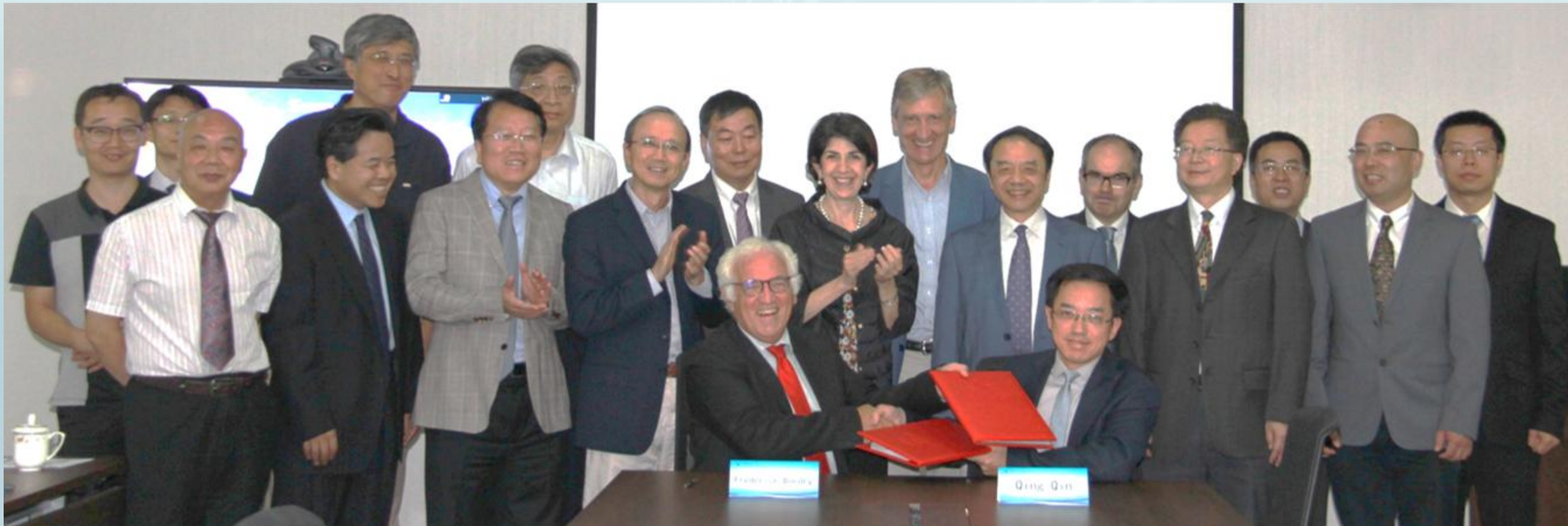




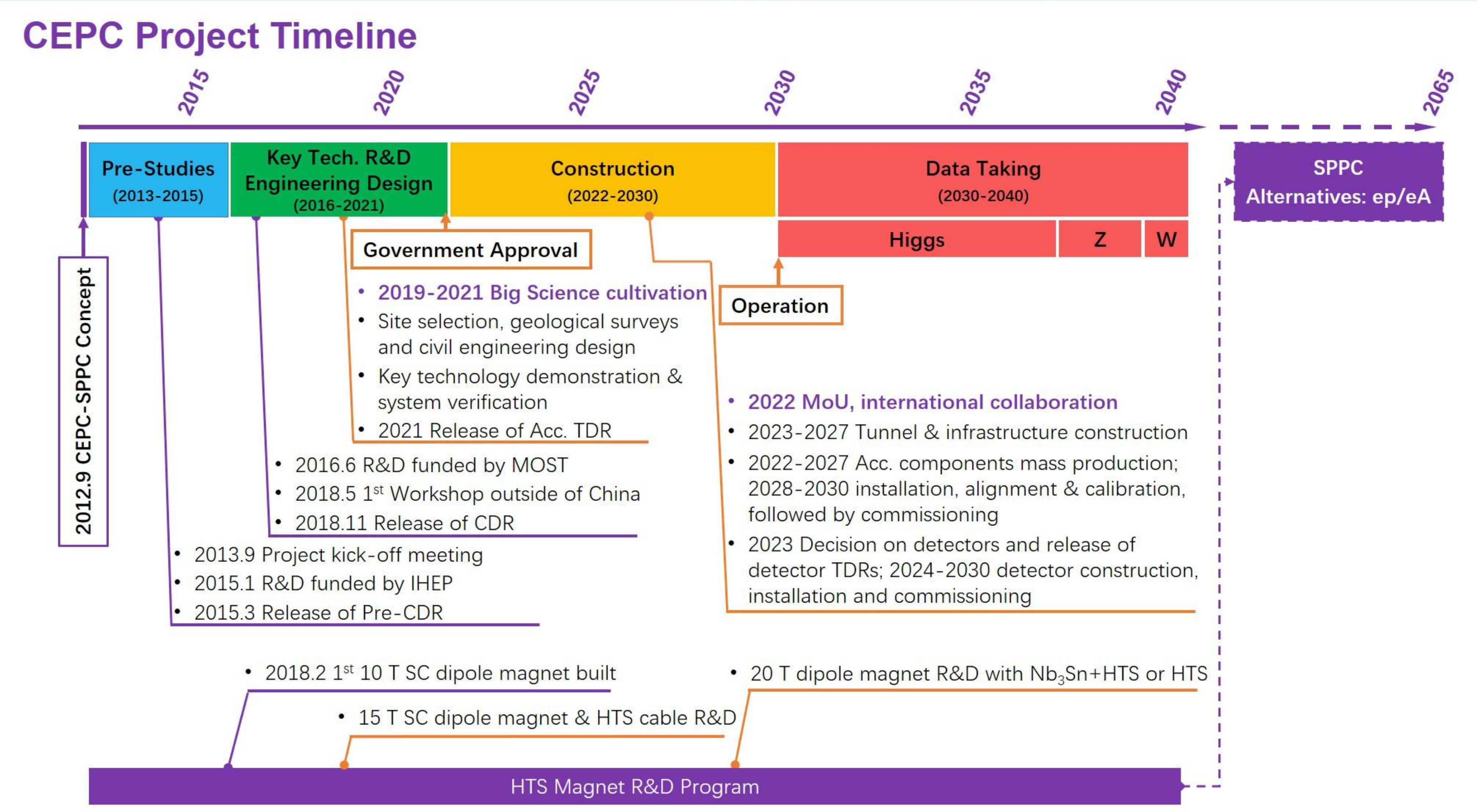


CERN & China Collaboration

MoU formally signed for CCT magnets in September 2018



CEPC timeline



CEPC New Parameters @Z

20190226	***Z（2T）- CDR*** W/O ante-chamber	***Z（2T）- new1*** W/O ante-chamber	***Z（2T）- new2*** W ante-chamber	***Z（2T）- new3*** W ante-chamber
Beam energy (GeV)	**45.5**			
Synchrotron radiation loss/turn (GeV)	0.036			
Crossing angle at IP (mrad)	16.5×2			
Piwinski angle	23.8	27.9	27.9	33.0
Number of particles/bunch N_e (10^{10})	8.0	12.0	12.0	15.0
Bunch number (bunch spacing)	**12000 (25ns+10%gap)**	**8570 (35ns+10%gap)**	**14564 (20.6ns+10%gap)**	**11682 (26ns+10%gap)**
Beam current (mA)	461.0	494.3	839.9	842.2
Synchrotron radiation power /beam (MW)	**16.5**	**17.7**	**30**	**30**
Bending radius (km)	10.7			
Momentum compact (10^{-5})	1.11			
β function at IP β_x^* / β_y^* (m)	**0.2/0.001**			
Emittance $\varepsilon_x/\varepsilon_y$ (nm)	0.18/0.0016			
Beam size at IP σ_x/σ_y (μm)	6.0/0.04			
Beam-beam parameters ξ_x/ξ_y	0.004/0.079	0.004/0.093	0.004/0.093	0.004/0.098
RF voltage V_{RF} (GV)	0.10			
RF frequency f_{RF} (MHz) (harmonic)	650 (216816)			
Natural bunch length σ_z (mm)	2.42			
Bunch length σ_z (mm)	8.5	10.0	10.0	11.8
HOM power/cavity (kw)	**1.94 (2cell)**	**1.35 (1cell)**	**2.29 (1cell)**	**2.45 (1cell)**
Energy spread (%)	0.080	0.1	0.1	0.115
Energy acceptance requirement (%)	**0.49**	**0.6**	**0.6**	**0.7**
Energy acceptance by RF (%)	1.7			
Photon number due to beamstrahlung	0.023	0.03	0.03	0.032
Lifetime (hour)	**2.5**	**2.0**	**2.0**	**1.8**
F (hour glass)	0.99	0.97	0.97	0.97
Luminosity/IP *L* ($10^{34}cm^{-2}s^{-1}$)	**32.1**	**43.9**	**74.5**	**79.2**

CEPC collider SCRF system optimization designs (preliminary)

D.J. Gong

CDR SCRF parameters	Higgs30	W	Z
Cavity material	N-doped bulk Nb	N-doped bulk Nb	N-doped bulk Nb
Cavity operating temperature [K]	2	2	2
Cell number / cavity	2	2	2
Cavity effective length [m]	0.46	0.46	0.46
R/Q [Ω]	213	213	213
Cavity operating voltage [MV]	9.0	4.4	1.7
Cavity operating gradient [MV/m]	19.7	9.5	3.6
Q_0 @ 2 K	1.5E+10	1.5E+10	1.5E+10
Input power / cavity [kW]	250	278	275
Cavity number / klystron	2	2	2
HOM power / cavity [kW]	0.57	0.75	1.94
Wall loss / cavity @ 2 K [W]	25.7	6.0	0.9
Total cavity wall loss @ 2 K [kW]	6.2	1.3	0.10
Optimal Q_L	1.5E+06	3.2E+05	4.7E+04
Cavity bandwidth at optimal Q_L [kHz]	0.4	2.0	13.7
Optimal detuning at optimal Q_L [kHz]	-0.2	-1.0	-17.8
Cavity time constant at optimal Q_L [μs]	752	157	23
Cavity stored energy [J]	94	22	3
Max cavity voltage drop	1.2%	0.7%	10%
Max phase shift [deg]	1.2	0.6	6.2

Single cell option	Higgs30	W	Z
Cavity material	LG Nb	LG Nb	LG Nb
Cavity operating temperature [K]	2	2	2
Cell number / cavity	1	1	1
Cavity effective length [m]	0.23	0.23	0.23
R/Q [Ω]	106	106	106
Cavity operating voltage [MV]	9.0	4.4	1.7
Cavity operating gradient [MV/m]	39.3	18.9	7.2
Q_0 @ 2 K	3.0E+10	3.0E+10	3.0E+10
Input power / cavity [kW]	250	278	275
Cavity number / klystron	2	2	2
HOM power / cavity [kW]	0.57	0.75	1.94
Wall loss / cavity @ 2 K [W]	25.7	6.0	0.9
Total cavity wall loss @ 2 K [kW]	6.2	1.3	0.10
Optimal Q_L	3.1E+06	6.4E+05	9.5E+04
Cavity bandwidth at optimal Q_L [kHz]	0.2	1.0	6.8
Optimal detuning at optimal Q_L [kHz]	-0.1	-0.5	-8.8
Cavity time constant at optimal Q_L [μs]	1511	315	47
Cavity stored energy [J]	189	44	6
Max cavity voltage drop	0.6%	0.4%	5%
Max phase shift [deg]	0.6	0.3	3.1

Summary

- CEPC Accelerator CDR has been completed and released with all systems reaching the CDR design goals with new ideas beyond CDR

- CEPC TDR optimization design has started, hardware design and key technologies' R&D progress well with financial funds towards TDR to be completed in 2022

- CEPC siting and engineering implementaion progress well

- CEPC executive plan from 2019-2030 has been made (preliminary)

- CEPC both accelerator and physics/detector have been submitted to European Strategies

- International collabotaion and collaboration with indusries progress well