中国科学院高能物理研究所
Institute of High Energy Physics
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CEPC Accelerator TDR Status Overview

J. Gao

On behalf of CEPC Accelerator Group

1st CEPC International Accelerator Review Committee Meeting in 2022

June 7, 2022, IHEP

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- **CEPC accelerator system optimization design in TDR**
  - Collider rings
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- **CEPC Accelerator System Key Hardware R&D Progresses in TDR**
  - SRF (platform, cavities, other components, cryomodules...)
  - 650MHz high power and high efficiency klystrons
  - Magnets in collider and booster rings (dipoles, quadrupoles and sextupoles)
  - Vacuum system
  - Electro-magnet seperator
  - Final focus SC quadrupoles, sextupoles in IR region
  - High field SC magnets for SppC
- **CEPC Siting, Civil Engineering, CEPC TDR Power Consumption**
- **CEPC Time Plan and Accelerator TDR Schedule**
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Feedbacks and Answers to CEPC IARC Reports from CEPC Accelerator Group

CEPC Accelerator Group Feedbacks (Answers) to CEPC IARC Report of Oct. 2021 was sent to IARC on May 1, 2022

2021 Second CEPC IARC Meeting

IARC Committee

The Circular E
Collider (SppC) S
ergy Physics of th
design of the CEP
ternational Adviso
Report (TDR) pha
get year of 2022. ... (IARC) has been established to advise on all matters related to CEPC accelerator design, the R&D program, the study of the machine-detector interface region, and the compatibility with an upgrade to the t-tbar energy region, as well as with a future SppC.

The second 2021 CEPC International Accelerator Review Committee was held remotely due to the Covid-19 pandemic on October 11th to 14th 2021.

A total of 22 talks were presented on a variety of topics.

The IARC meetings with questions, remarks suggestions from IARC members and the recommendations in the IARC Reports are extremely important and helpful in CEPC accelerator TDR development and beyond towards EDR.
We appreciate your helps and efforts very much!

Answers to 2021 Second CEPC IARC Meeting Report

General comments

The Committee congratulates the CEPC team for the work performed in the last months and presented at this meeting. In particular, the progress on the R&D of the hardware components looks very promising. The team has updated the table of parameters for the high-luminosity running, as well as the lattices and components for all accelerator systems: sources, Linac, Booster and Collider.

Recommendations

1. The Committee regrets that the talk on the civil engineering and auxiliary facilities
...hese topics are very
...ied before the end of

...lar Electron-Positron
...n XI, three talks on
...by three companies

...)

2. A clear alignment strategy was not presented, although a new instrument for alignment is being developed and was presented. Since there will be a total of about 310 km to align (Linac, Booster, two rings), the Committee suggests that a strategy be developed and presented at the next meeting;

A talk will be arranged in the next IARC meeting of June.

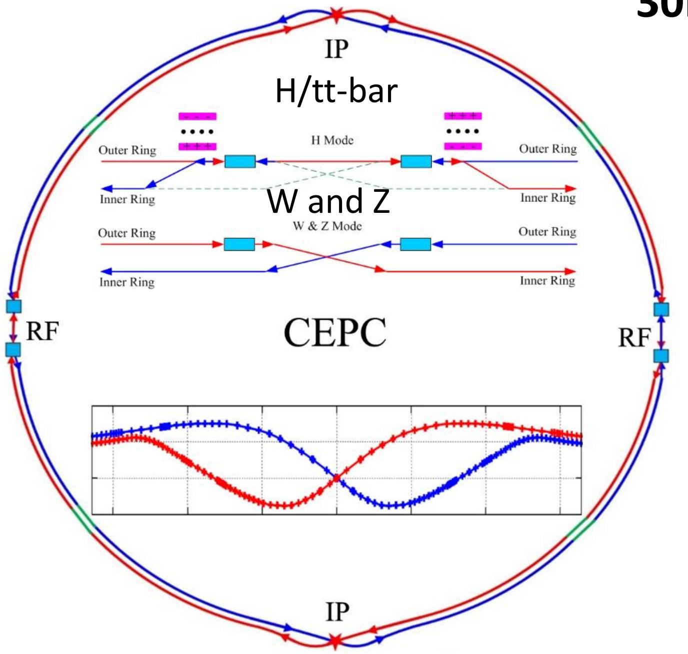
In the 2021 international workshop on the high energy Circular Electron-Positron Collider (CEPC) November 8-12, 2021, in Accelerator session XI, a talk on "CEPC Installation and allignment strategies and technologies" have been given by Xiaolong Wang (https://indico.ihep.ac.cn/event/14938/other-view?view=standard)

CEPC Accelerator System Design and Optimizations inTDR

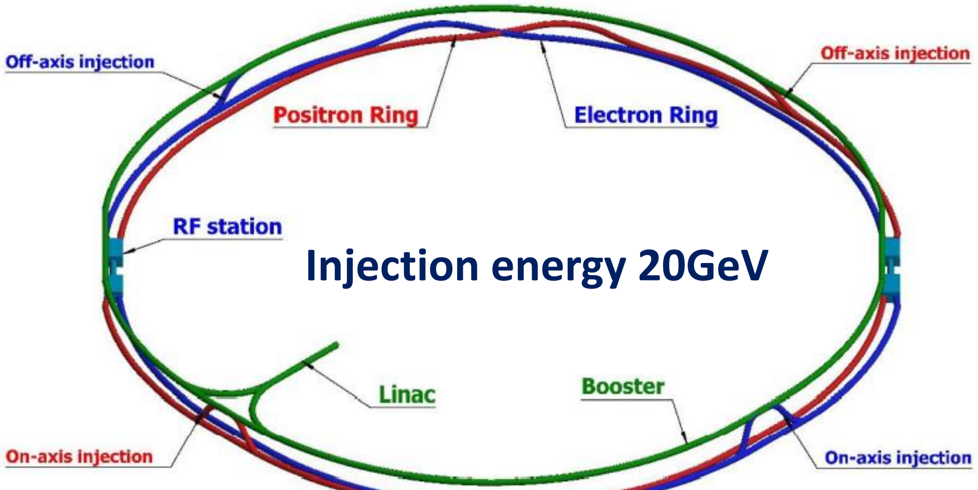
CEPC TDR Layout

CEPC as a Higgs Factory：H, W, Z, upgradable to tt-bar, followed by a SppC ~125TeV

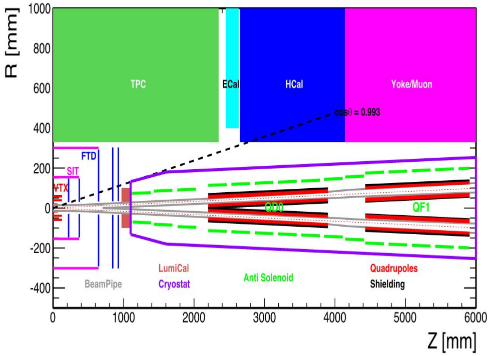
30MW SR power per beam (upgradale to 50MW)



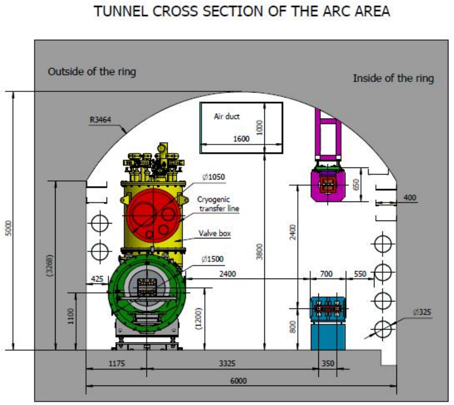
CEPC collider ring (100km)



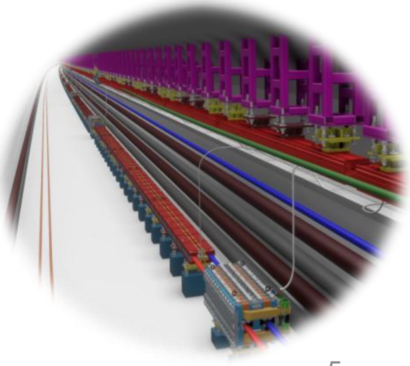
CEPC booster ring (100km)



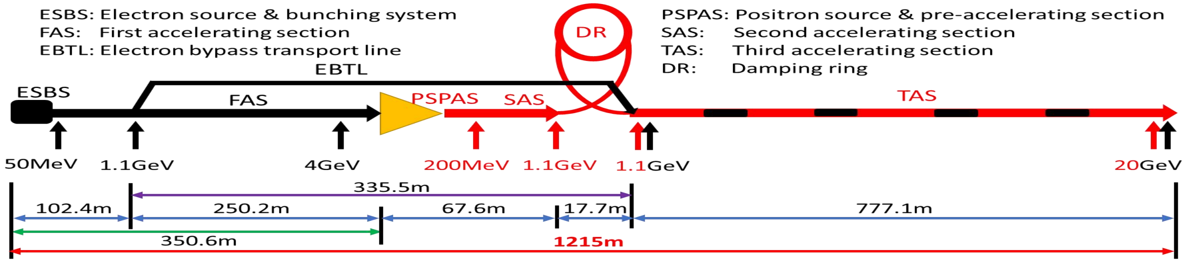
CEPC MDI



CEPC Civil Engineering



CEPC TDR S+C-band 20GeV linac injector



CEPC TDR Parameters

	Higgs	Z	W	ttbar
Number of IPs	2			
Circumference [km]	100.0			
SR power per beam [MW]	30			
Half crossing angle at IP [mrad]	16.5			
Bending radius [km]	10.7			
Energy [GeV]	120	45.5	80	180
Energy loss per turn [GeV]	1.8	0.037	0.357	9.1
Piwinski angle	5.94	24.68	6.08	1.21
Bunch number	268	11934	1297	35
Bunch spacing [ns]	591 (53% gap)	23 (18% gap)	257	4524 (53% gap)
Bunch population [10^10]	13	14	13.5	20
Beam current [mA]	16.7	803.5	84.1	3.3
Momentum compaction [10^-5]	0.71	1.43	1.43	0.71
Beta functions at IP (bx/by) [m/mm]	0.3/1	0.13/0.9	0.21/1	1.04/2.7
Emittance (ex/ey) [nm/pm]	0.64/1.3	0.27/1.4	0.87/1.7	1.4/4.7
Beam size at IP (sigx/sigy) [um/nm]	14/36	6/35	13/42	39/113
Bunch length (natural/total) [mm]	2.3/4.1	2.5/8.7	2.5/4.9	2.2/2.9
Energy spread (natural/total) [%]	0.10/0.17	0.04/0.13	0.07/0.14	0.15/0.20
Energy acceptance (DA/RF) [%]	1.6/2.2	1.3/1.7	1.2/2.5	2.3/2.6
Beam-beam parameters (ksix/ksiy)	0.015/0.11	0.004/0.127	0.012/0.113	0.071/0.1
RF voltage [GV]	2.2	0.12	0.7	10
RF frequency [MHz]	650	650	650	650
Longitudinal tune Qs	0.049	0.035	0.062	0.078
Beam lifetime (bhabha/beamstrahlung)[min]	39/40	80/18000	60/700	81/23
Beam lifetime [min]	20	80	55	18
Hour glass Factor	0.9	0.97	0.9	0.89
Luminosity per IP[1e34/cm^2/s]	5.0	115	16	0.5

CEPC TDR Parameters (upgrade)

	Higgs	W	Z	ttbar
Number of IPs	2			
Circumference [km]	100.0			
SR power per beam [MW]	50			
Half crossing angle at IP [mrad]	16.5			
Bending radius [km]	10.7			
Energy [GeV]	120	80	45.5	180
Energy loss per turn [GeV]	1.8	0.357	0.037	9.1
Piwinski angle	5.94	6.08	24.68	1.21
Bunch number	415	2162	19918	58
Bunch spacing [ns]	385	154	15(10% gap)	2640
Bunch population [10^{10}]	14	13.5	14	20
Beam current [mA]	27.8	140.2	1339.2	5.5
Momentum compaction [10^{-5}]	0.71	1.43	1.43	0.71
Phase advance of arc FODOs [degree]	90	60	60	90
Beta functions at IP (bx/by) [m/mm]	0.33/1	0.21/1	0.13/0.9	1.04/2.7
Emittance (ex/ey) [nm/pm]	0.64/1.3	0.87/1.7	0.27/1.4	1.4/4.7
Beam size at IP (sx/sy) [um/nm]	15/36	13/42	6/35	39/113
Bunch length (SR/total) [mm]	2.3/3.9	2.5/4.9	2.5/8.7	2.2/2.9
Energy spread (SR/total) [%]	0.10/0.17	0.07/0.14	0.04/0.13	0.15/0.20
Energy acceptance (DA/RF) [%]	1.7/2.2	1.2/2.5	1.3/1.7	2.3/2.6
Beam-beam parameters (xx/xy)	0.015/0.11	0.012/0.113	0.004/0.127	0.071/0.1
RF voltage [GV]	2.2 (2cell)	0.7 (2cell)	0.12 (1cell)	10 (5cell)
RF frequency [MHz]	650			
Beam lifetime [min]	20	55	80	18
Luminosity per IP[10^{34}/cm^2/s]	8.3	26.6	191.7	0.8

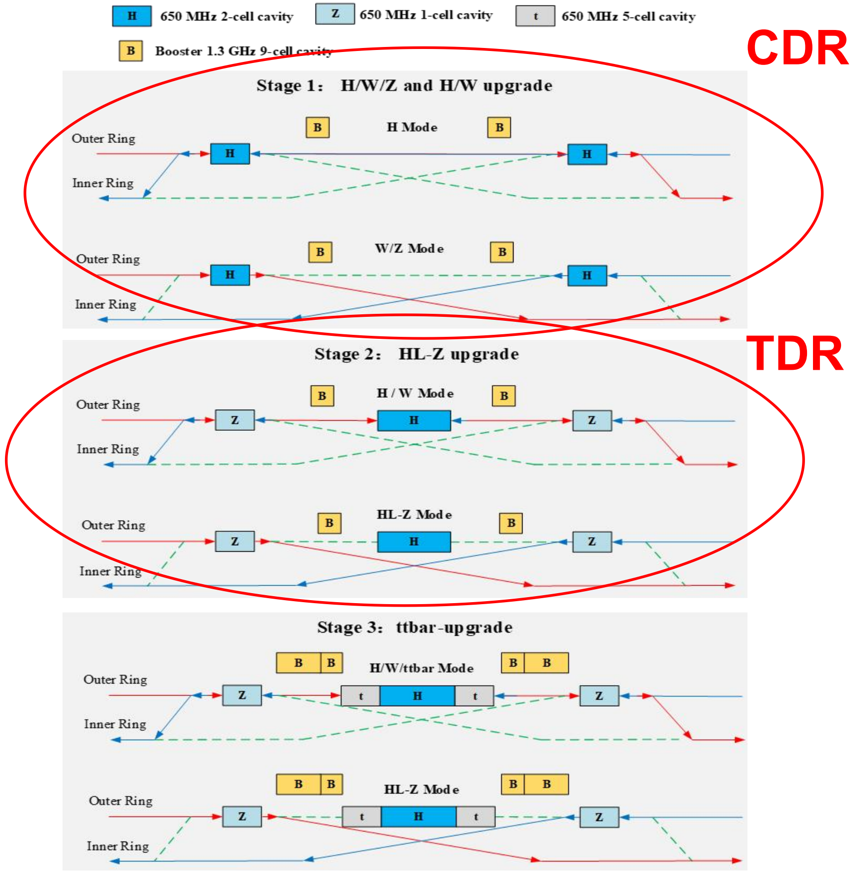
This parameter table is used by US Snowmass21 for CEPC physics performance potential evaluation

CEPC Accelerator white paper to Snowss21 arXiv:2203.09451

CEPC TDR RF Parameters (Collider Ring)

J.Y.Zhai

30 MW SR power per beam for each mode. ttbar and Higgs half fill with common cavities for two rings, W and Z with separate cavities for two rings.	ttbar		Higgs	W	Z bypass with 1-cell cavities
	additional 5-cell cavities	existing 2-cell cavities			
Luminosity / IP [10^{34} $cm^{-2}s^{-1}$]	0.5		5	16	115
RF voltage [GV]	10 (7.8 + 2.2)		2.2	0.7	0.12
Beam current / beam [mA]	3.3		16.7	84.1	803.5
Bunch charge [nC]	32		20.8	21.6	22.4
Bunch length [mm]	2.9		4.1	4.9	8.7
650 MHz cavity number	240	240	240	120/ring	30/ring
Cell number / cavity	5	2	2	2	1
Gradient [MV/m]	28.5	20	20	12.7	8.7
Q_0 @ 2 K at operating gradient (long term)	5E10	2E10			
HOM power / cavity [kW]	0.4	0.16	0.45	0.93	2.9
Input power / cavity [kW]	194	56	250	250	1000
Optimal Q_L	1E7	7E6	1.6E6	6.4E5	7.5E4
Optimal detuning [kHz]	0.01	0.02	0.1	0.9	13.3
Cavity number / klystron	4	12	2	2	1
Klystron power [kW]	1400	1400	800	800	1400
Klystron number	60	20	120	60	60
Cavity number / cryomodule	4	6			1
Cryomodule number	60	40			30
Total cavity wall loss @ 2 K [kW]	9.5	4.7		1.9	0.45

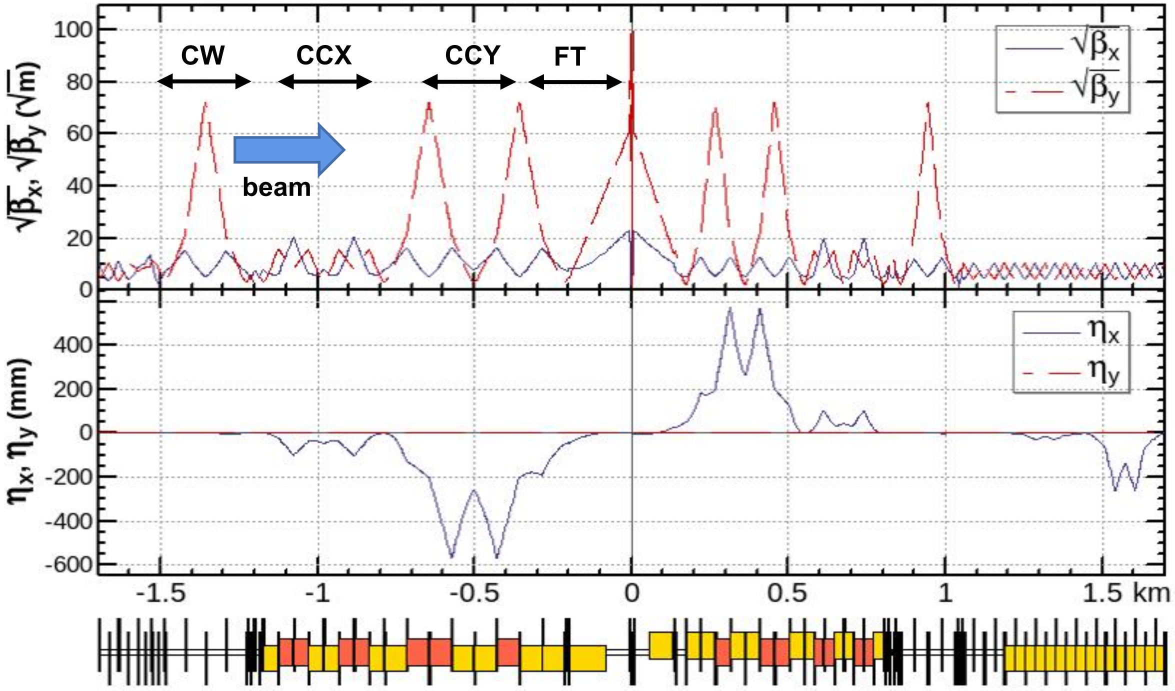


- RF staging and bypass. Seamless mode switching.
- Z lumi in Stage 1: 1/6 Lumi if CAV HOM < 1 kW.
- If start from Stage 2. W: 1/2 Lumi. Z: 1/12 Lumi.
- Transfer Higgs/ttbar RF power to high lumi Z.
- Klystron power and HOM handling capacity allow for 50 MW upgrade of ttbar, H, W. Add 30 cavities for Z 50 MW upgrade.

CEPC Collider Ring Interaction Region for Four Energies

Y.W. Wang

- For the interaction region, the IP beta functions are refitted with the different combination of final doulets and the matching quadruples.



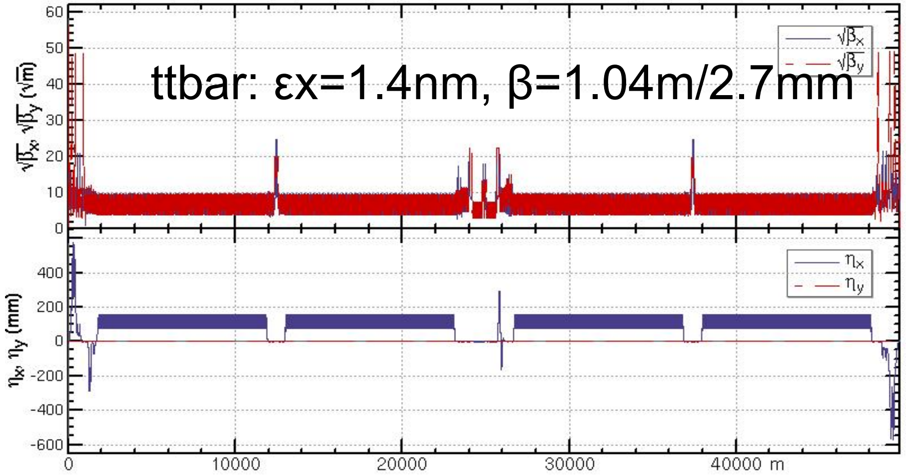
	QD	QF
Z	Q1A	Q1B
W/H	Q1A+Q1B	Q2
ttbar	Q1A+Q1B+Q2	add quad Q3A and Q3B

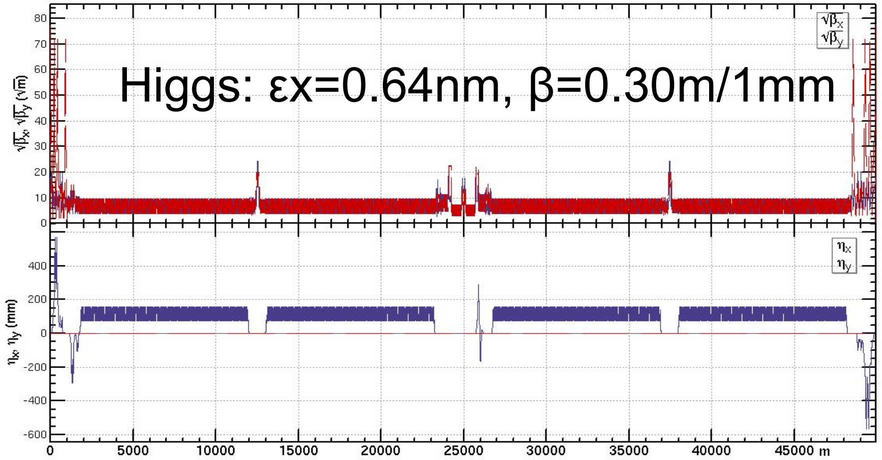
	L [m]	Strength [T/m]			
		ttbar	Higgs	W	Z
Q1AIRU	1.21	-141	-141	-94	-110
Q1BIRU	1.21	-59	-85	-56	+65
Q2IRU	1.5	-51	+95	+63	0
Q3AIRU	1.5	+40	0	0	+2
Q3BIRU	1.5	+40	0	0	+2
Q1AIRD	1.21	-142	-142	-95	-110
Q1BIRD	1.21	-64	-85	-57	+65
Q2IRD	1.5	-47	+96	+64	0
Q3AIRD	1.5	+40	0	0	+2
Q3BIRD	1.5	+40	0	0	+2

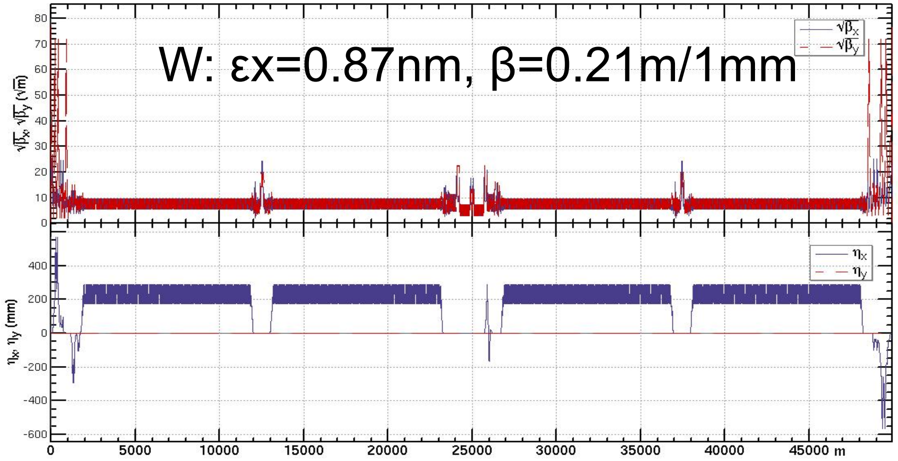
Strength of other modes doesn’t exceeded the one of Higgs mode.

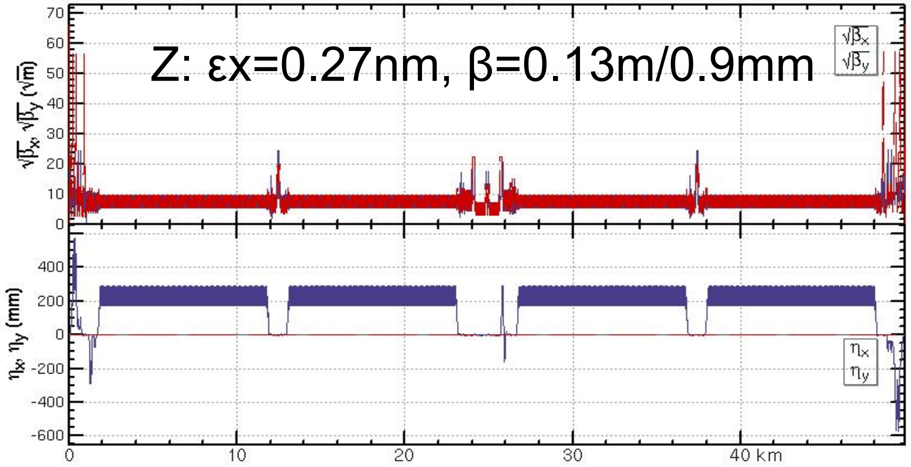
CEPC Collider Ring Lattice of Half Ring for Four Energies

Y.W. Wang









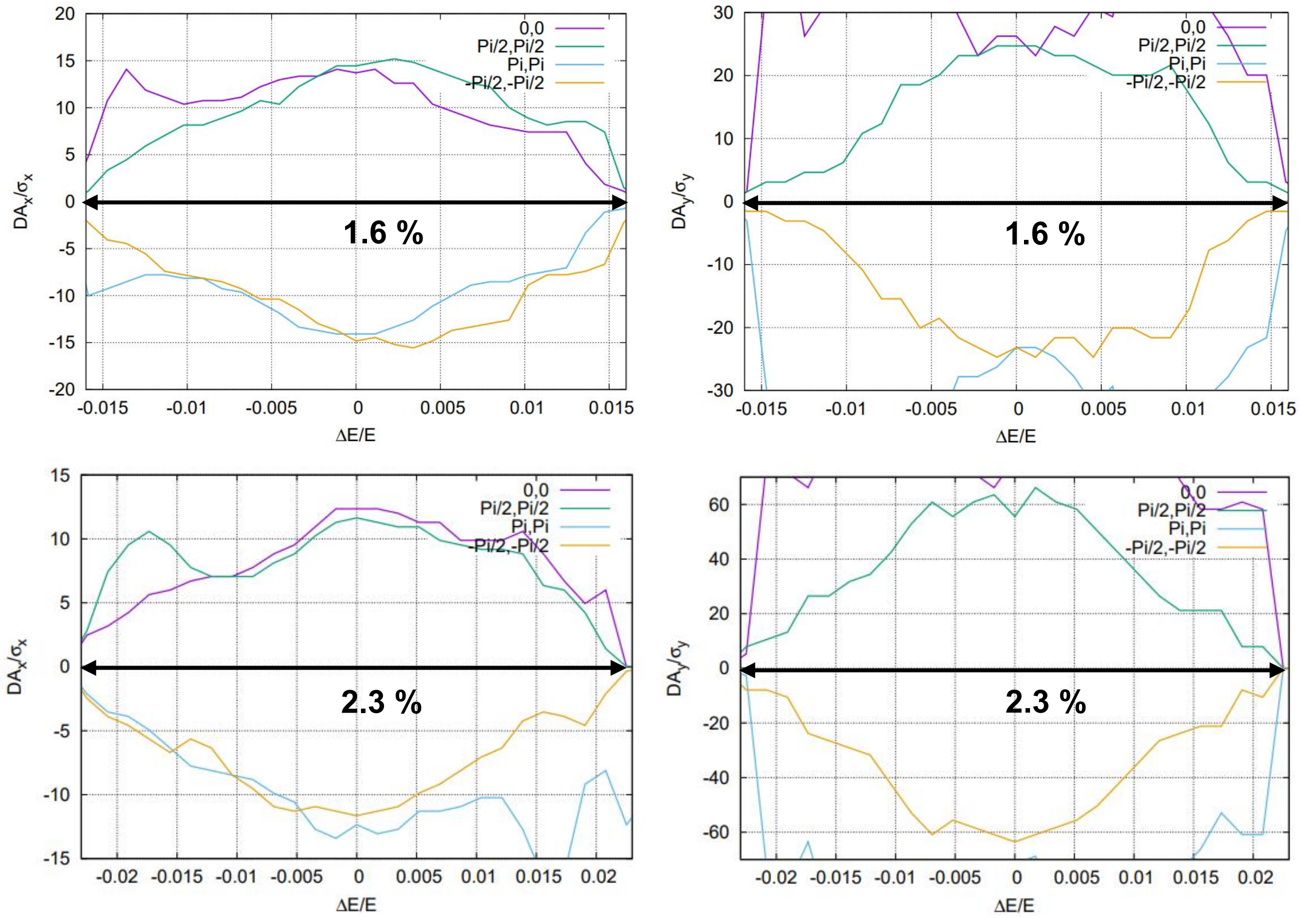
The new RF layout has not been implemented in these lattices.

CEPC Collider Ring Dynamic Aperture Status @ Higgs and ttbar

Y.W. Wang

- Tracking to get DA **without errors**, with turns for one transvers damping time, with 4 initial phases
- DA optimized with 84 variables (64 arc sextupoles + 8 IR sextupoles + 4 multipoles + 8 phase advance)

Effects included in tracking
Synchrotron motion
Radiation loss in all magnets
Tapering
Crab waist sextupole
Maxwellian fringes
Kinematic terms
Finite length of sextupole



Higgs

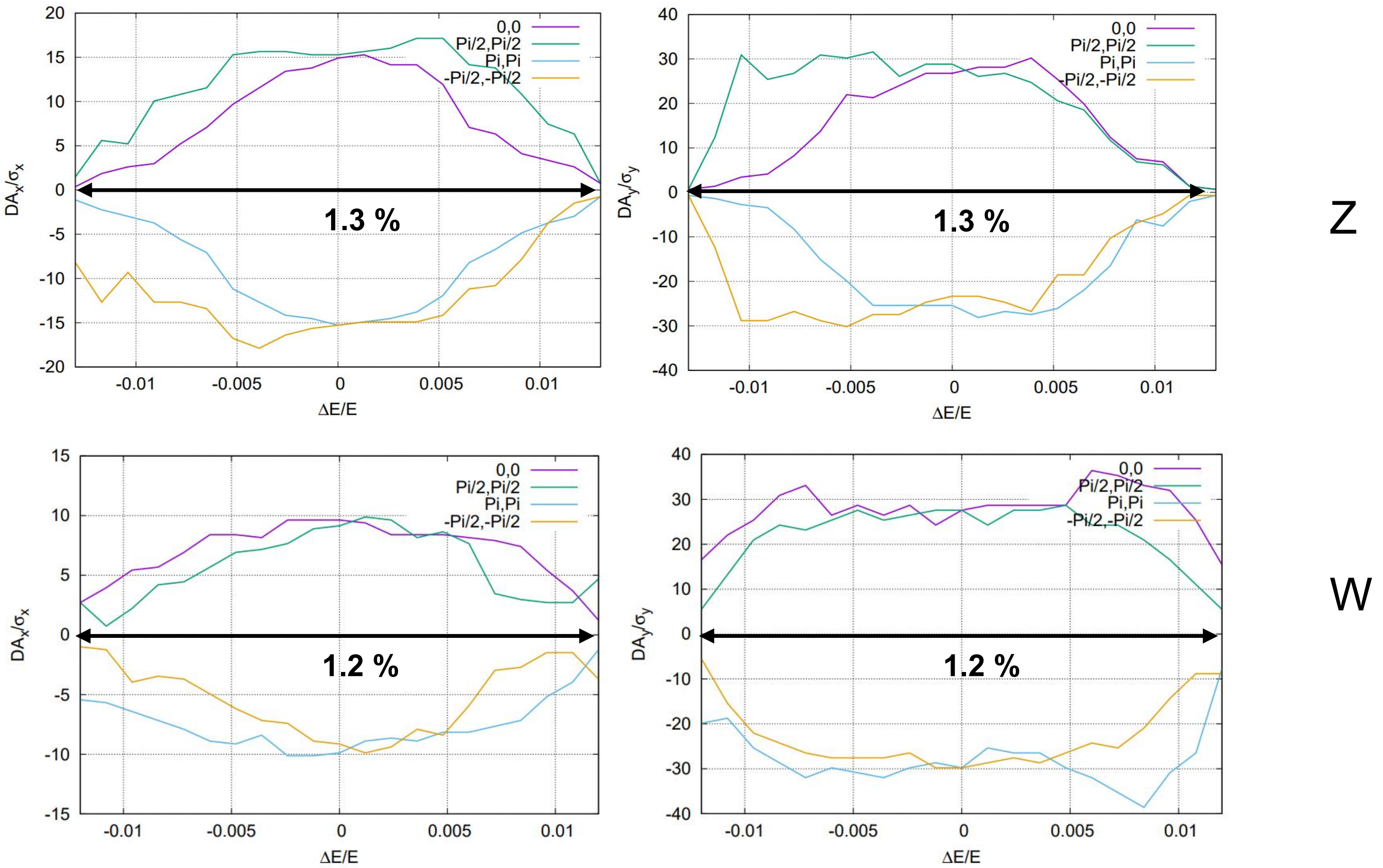
ttbar

CEPC Collider Ring Dynamic Aperture Status @ Z and W

Y.W. Wang

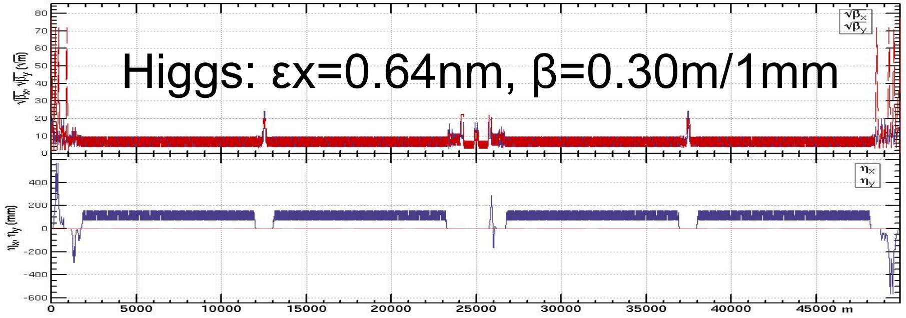
- Tracking to get DA **without errors**, with turns for one transvers damping time, with 4 initial phases
- DA optimized with 116 variables (96 arc sextupole families + 8 IR sextupoles + 4 multipoles + 8 phase advance)

Effects included in tracking
Synchrotron motion
Radiation loss in all magnets
Tapering
Crab waist sextupole
Maxwellian fringes
Kinematic terms
Finite length of sextupole



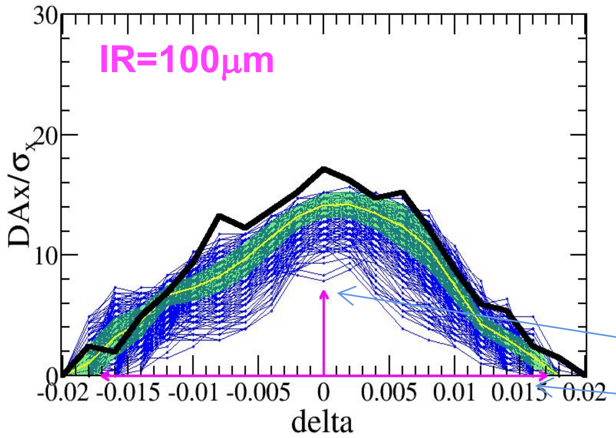
CEPC collider ring TDR lattice dynamic apertures with errors for Higgs energy

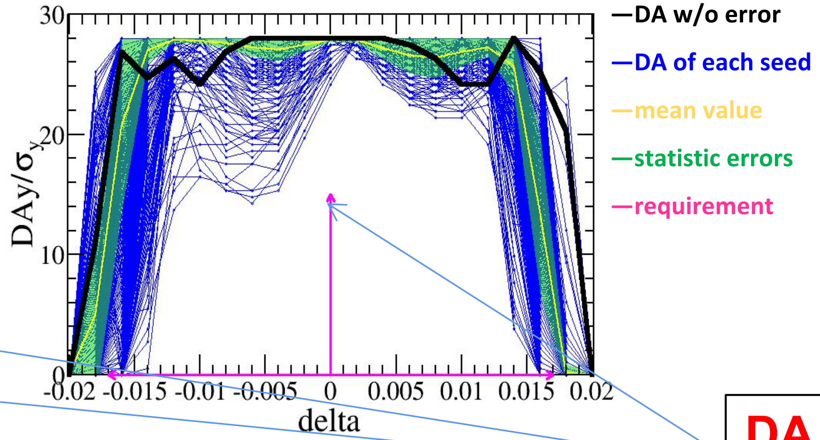
Yiwei Wang
Bin Wang



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

Effects included in tracking
Synchrotron motion
Radiation loss in all magnets
Tapering
Crab waist sextupole
Maxwellian fringes
Kinematic terms
Finite length of sextupole

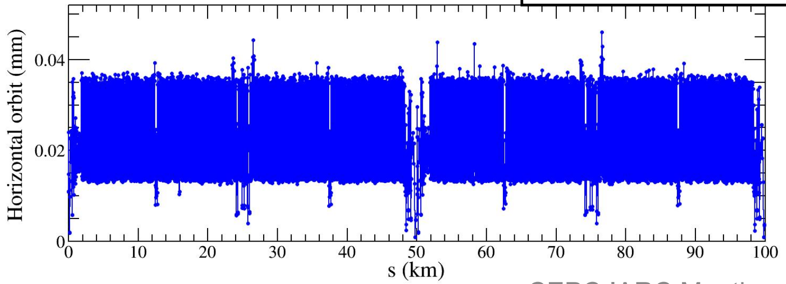


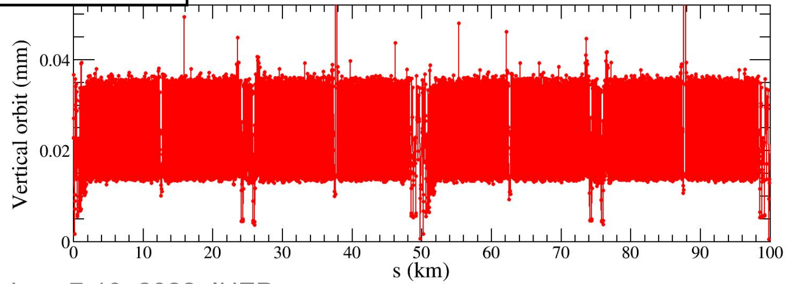


The DA with erros of TDR lattice satisfiy the design goal

DA design goal
$7\sigma_x \times 15\sigma_y \times 1.6\%$

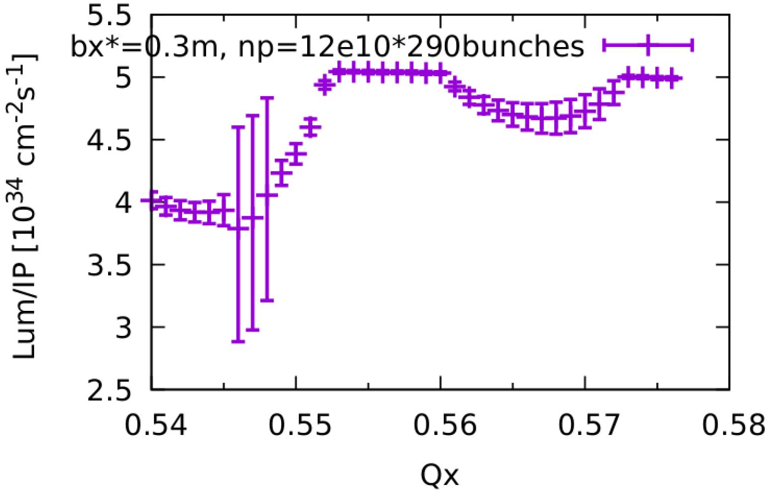
$RMS_{COD} < 0.05\ mm$

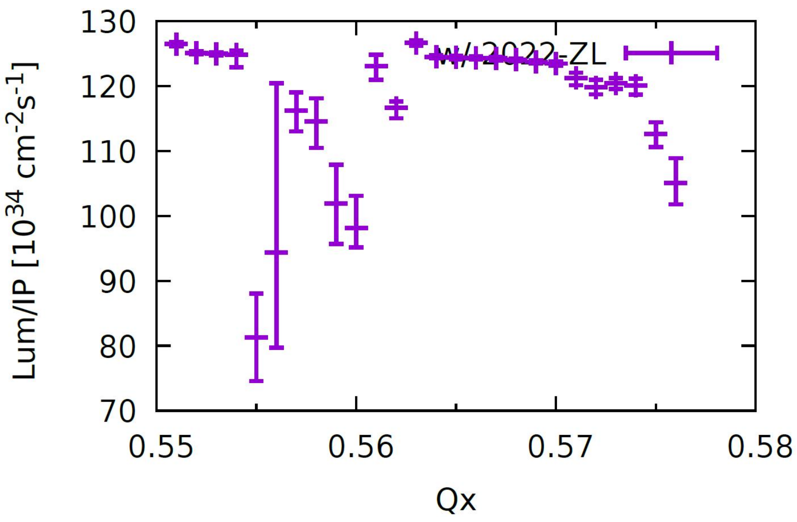


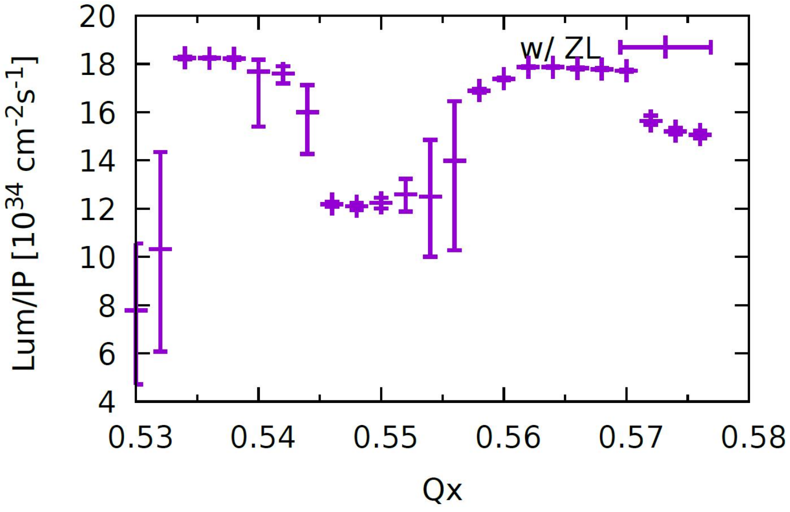


CEPC TDR Parameter Luminosity Check by Beam-beam Simulations

Y. Zhang







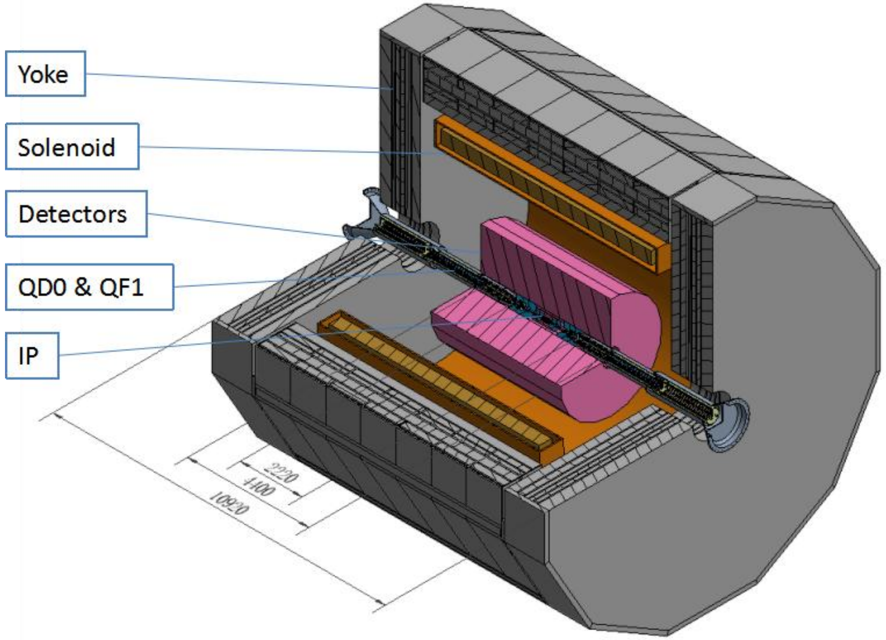
Higgs : 5*10^34/cm^2/s (BB Simulation)
Parameter table:5*10^34/cm^2/s

Z-pole : 125*10^34/cm^2/s (BB Simulation)
Parameter table:115*10^34/cm^2/s

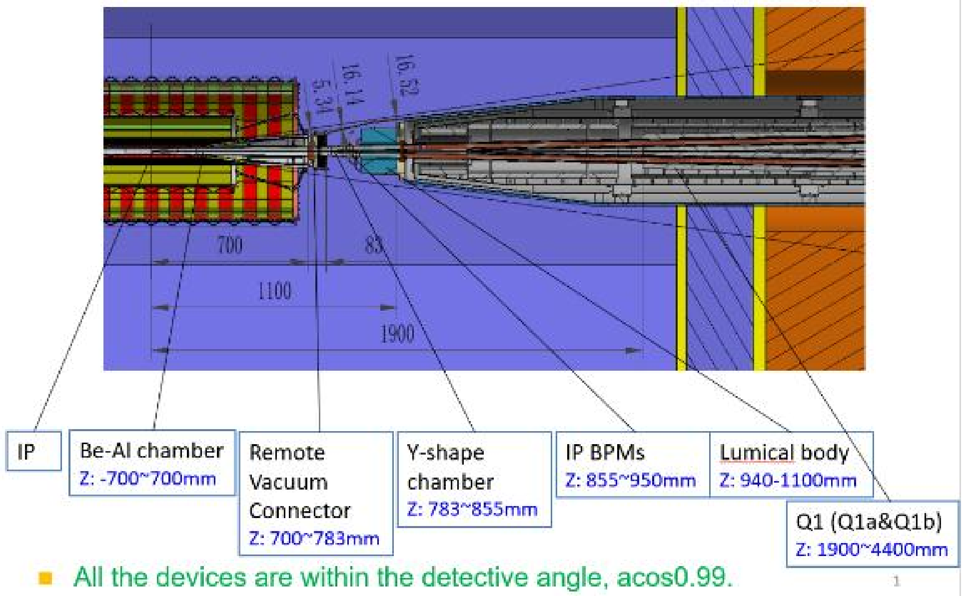
W-pole : 18*10^34/cm^2/s(BB Simulation)
Parameter table:16*10^34/cm^2/s

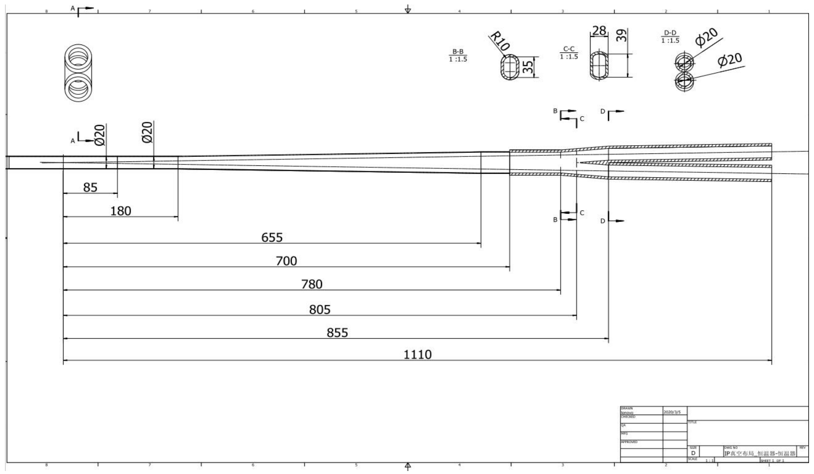
CEPC MDI TDR Study Progresses

S. Bai



- IR Superconducting magnet design
- IR beam pipe
- Synchrotron radiation
- Beam loss background
- Shielding
- Mechanical support
- Full detector simulation



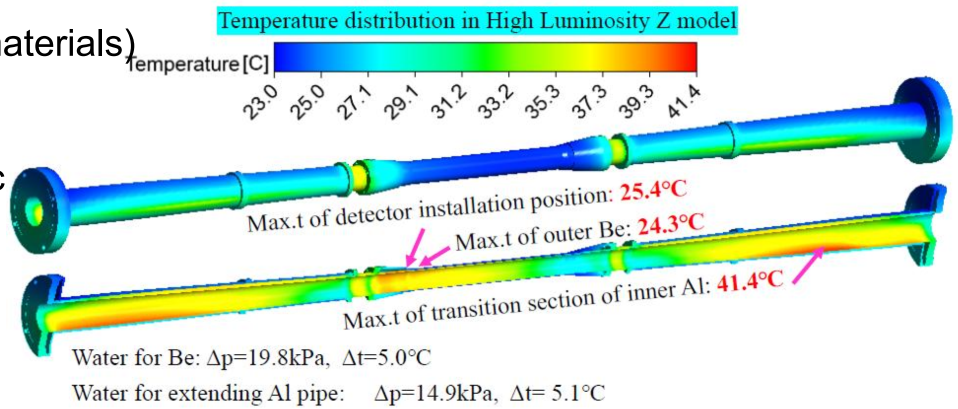


- ✓ HOM in IR region
- ✓ **results for MDI 20mm IP beam pipe diameter**
- ✓ Transition region: Racetrack (including materials)
- ✓ σ_z=5mm: Two beam in the IR
- ✓ Loss factor Trap in IR @k_trap: 0.032v/pc

P_{trap}: H/W/Z/tt:

24.0w/117.1w/1160.8w/6.67w

Temperature studies in IR beam pipe



CEPC TDR MDI Parameters

S. Bai

	range	Peak filed in coil	Central filed gradient	Bending angle	length	Beam stay clear region	Minimal distance between two aperture	Inner diameter	Outer diameter	Critical energy (Horizontal)	Critical energy (Vertical)	SR power (Horizontal)	SR power (Vertical)
L*	0~1.9m				1.9m								
Crossing angle	33mrad												
MDI length	±7m												
Detector requirement of accelerator components in opening angle	8.11°												
QDa/QDb		3.2/2.8T	141/84.7 T/m		1.21m	15.2/17.9mm	62.71/105.28mm	48mm	59mm	724.7/663.1keV	396.3/263keV	212.2/239.23W	99.9/42.8W
QF1		3.3T	94.8T/m		1.5m	24.14mm	155.11mm	56mm	69mm	675.2keV	499.4keV	472.9W	135.1W
Lumical	0.95~1.11m				0.16m			57mm	200mm				
Anti-solenoid before QD0		8.2T			1.1m			120mm	390mm				
Anti-solenoid QD0		3T			2.5m			120mm	390mm				
Anti-solenoid QF1		3T			1.5m			120mm	390mm				
Beryllium pipe					±120mm			20mm					
Last B upstream	64.97~153.5m			0.77mrad	88.5m					33.3keV			
First B downstream	44.4~102m			1.17mrad	57.6m					77.9keV			
Beampipe within QDa/QDb					1.21m							1.19/1.31 W	
Beampipe within QF1					1.5m							2.39W	
Beampipe between QD0/QF1					0.3m							26.5W	

CEPC Full Detector Simulation – detector impacts

S. Bai

Detector Impacts, Vertex : CDR→TDR(Scale)

	Higgs			Z		
	CDR	TDR-30	TDR-50	CDR	TDR-30	TDR-50
Hit Density($cm^{-2} \cdot BX^{-1}$)	2.3	2.3	2.3	0.63	0.63	0.63
TID($krad \cdot yr^{-1}$)	930	1490	2540	10.5	3150	5360
NIEL($n_{eq} \times 10^{12} \cdot cm^{-2} \cdot yr^{-1}$)	2.2	3,5	6.0	23.6	70.8	120.4

Detector Impacts, TPC : CDR→TDR(Scale)

	Higgs			Z		
	CDR	TDR-30	TDR-50	CDR	TDR-30	TDR-50
Hit Density($cm^{-2} \cdot BX^{-1}$)	2.59e-2	2.59e-2	2.59e-2	6.365e-3	6.365e-3	6.365e-3
TID($krad \cdot yr^{-1}$)	4.385	7.483	11.973	67.53	241.93	387.09
NIEL($n_{eq} \times 10^{12} \cdot cm^{-2} \cdot yr^{-1}$)	0.4519	0.7712	1.234	7.415	26.565	42.503

Detector Impacts, Ecal Barrel : CDR→TDR(Scale)

	Higgs			Z		
	CDR	TDR-30	TDR-50	CDR	TDR-30	TDR-50
Hit Density($cm^{-2} \cdot BX^{-1}$)	1.162e-3	1.162e-3	1.162e-3	2.714e-4	2.714e-4	2.714e-4
TID($krad \cdot yr^{-1}$)	0.319	0.544	0.871	5.505	19.722	31.555
NIEL($n_{eq} \times 10^{12} \cdot cm^{-2} \cdot yr^{-1}$)	0.1285	0.2193	0.3509	1.396	5.001	8.002

Detector Impacts, Ecal Endcup: CDR→TDR(Scale)

	Higgs			Z		
	CDR	TDR-30	TDR-50	CDR	TDR-30	TDR-50
Hit Density($cm^{-2} \cdot BX^{-1}$)	1.356e-3	1.356e-3	1.356e-3	2.335e-4	2.335e-4	2.335e-4
TID($krad \cdot yr^{-1}$)	0.2841	0.4848	0.7757	2.473	8.860	14.175
NIEL($n_{eq} \times 10^{12} \cdot cm^{-2} \cdot yr^{-1}$)	0.1248	0.2130	0.3408	1.069	3.830	6.128

Detector Impacts, HCal Barrel : CDR→TDR(Scale)

	Higgs			Z		
	CDR	TDR-30	TDR-50	CDR	TDR-30	TDR-50
Hit Density($cm^{-2} \cdot BX^{-1}$)	2.778e-5	2.778e-5	2.778e-5	1.1e-5	1.1e-5	1.1e-5
TID($krad \cdot yr^{-1}$)	7.603e-3	12.974e-3	20.76e-3	0.2529	0.906	1.450
NIEL($n_{eq} \times 10^{12} \cdot cm^{-2} \cdot yr^{-1}$)	0.0116	0.198	0.317	0.1627	0.5829	0.9326

Detector Impacts, HCal Endcup: CDR→TDR(Scale)

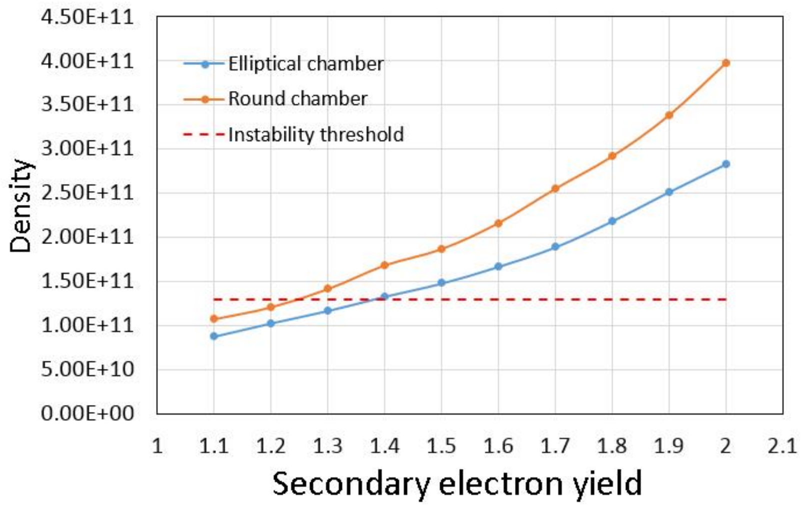
	Higgs			Z		
	CDR	TDR-30	TDR-50	CDR	TDR-30	TDR-50
Hit Density($cm^{-2} \cdot BX^{-1}$)	1.321e-3	1.321e-3	1.321e-3	2.732e-4	2.732e-4	2.732e-4
TID($krad \cdot yr^{-1}$)	0.284	0.485	0.775	4.589	16.44	26.31
NIEL($n_{eq} \times 10^{12} \cdot cm^{-2} \cdot yr^{-1}$)	0.159	0.271	0.434	1.108	3.97	6.351

CEPC TDR Collective Effects

N. Wang
Y.D. Liu

- No apparent show stoppers for ttbar, Higgs, W from collective instability point of view. The beam intensity of Z is restricted by the resistive wall instability and electron cloud effects.
  - Resistive wall instability ⇒ Tough requirement on feedback damping

	30 MW	50 MW
Instability growth time [ms]	1.9 (~6 turns)	1.1 (~3 turns)
Radiation damping [ms]	850	
Bunch by bunch feedback [ms]	1.0 (~3 turns)	0.5 (~1.5 turns)



30MW (SEY<1.2 for round chamber Realized by NEG coating)

Collective effects satisfy TDR requirments

Total impedance budget @3mm@ Z

Components	Number	$Z_{\|\|}/n$, mΩ	k_{loss}, V/pC	ky, kV/pC/m
Resistive wall	-	6.2	363.7	11.3
RF cavities	240	-1.0	225.2	0.3
Flanges	20000	2.8	19.8	2.8
BPMs	1450	0.12	13.1	0.3
Bellows	12000	2.2	65.8	2.9
Pumping ports	5000	0.02	0.4	0.6
IP chambers	2	0.02	6.7	1.3
Electro-separators	22	0.2	41.2	0.2
Taper transitions	164	0.8	50.9	0.5
Total		**11.4**	**786.8**	**20.2**

CEPC Booster TDR Parameters

D. Wang

- Injection energy: 10GeV → 20GeV
- Max energy: 120GeV → 180GeV
- Lower emittance ─ new lattice (TME)

Injection		*tt*	*H*	*W*	*Z*	
Beam energy	GeV	20				
Bunch number		35	268	1297	3978	5967
Threshold of single bunch current	μA	5.79	4.20	3.92		
Threshold of beam current (limited by coupled bunch instability)	mA	27				
Bunch charge	nC	1.1	0.78	0.81	0.87	0.9
Single bunch current	μA	3.4	2.3	2.4	2.65	2.69
Beam current	mA	0.12	0.62	3.1	10.5	16.0
Growth time (coupled bunch instability)	ms	1690	358	67	19.4	12.5
Energy spread	%	0.016				
Synchrotron radiation loss/turn	MeV	1.3				
Momentum compaction factor	10^{-5}	1.12				
Emittance	nm	0.035				
Natural chromaticity	H/V	-372/-269				
RF voltage	MV	531.0	230.2	200.0		
Betatron tune ν_x/ν_y		321.23/117.18				
Longitudinal tune		0.14	0.0943	0.0879		
RF energy acceptance	%	5.9	3.7	3.6		
Damping time	s	10.4				
Bunch length of linac beam	mm	0.5				
Energy spread of linac beam	%	0.16				
Emittance of linac beam	nm	10				

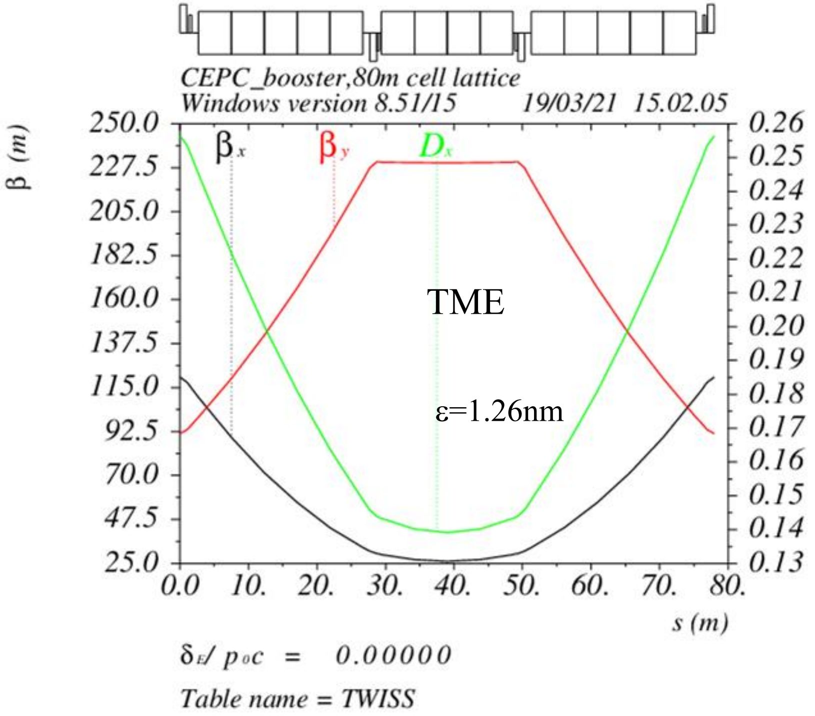
Extraction		*tt*	*H*		*W*	*Z*	
		Off axis injection	Off axis injection	On axis injection	Off axis injection	Off axis injection	
Beam energy	GeV	180	120		80	45.5	
Bunch number		35	268	261+7	1297	3978	5967
Maximum bunch charge	nC	0.99	0.7	20.3	0.73	0.8	0.81
Maximum single bunch current	μA	3.0	2.1	61.2	2.2	2.4	2.42
Threshold of single bunch current	μA	91.5	70		22.16	9.57	
Threshold of beam current (limited by RF system)	mA	0.3	1		4	16	
Beam current	mA	0.11	0.56	0.98	2.85	9.5	14.4
Growth time (coupled bunch instability)	ms	16611	2359	1215	297.8	49.5	31.6
Bunches per pulse of Linac		1	1		1	2	
Time for ramping up	s	7.3	4.5		2.7	1.6	
Injection duration for top-up (Both beams)	s	30. 0	23.3	32.8	39.4	139.0	
Injection interval for top-up	s	65	38		155	153.5	
Current decay during injection interval		3%					
Energy spread	%	0.15	0.099		0.066	0.037	
Synchrotron radiation loss/turn	GeV	8.45	1.69		0.33	0.034	
Momentum compaction factor	10^{-5}	1.12					
Emittance	nm	2.83	1.26		0.56	0.19	
Natural chromaticity	H/V	-372/-269					
Betatron tune ν_x/ν_y		321.27/117.19					
RF voltage	GV	9.7	2.17		0.87	0.46	
Longitudinal tune		0.14	0.0943		0.0879	0.0879	
RF energy acceptance	%	1.78	1.59		2.6	3.4	
Damping time	ms	14.2	47.6		160.8	879	
Natural bunch length	mm	1.8	1.85		1.3	0.75	
Full injection from empty ring	h	0.1	0.14	0.16	0.27	1.8	0.8

*Diameter of beam pipe is 55mm for re-injection with high single bunch current @120GeV.

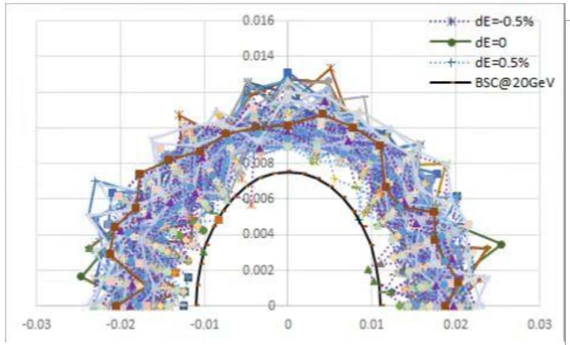
CEPC Booster TDR Optics and DA with Errors

D. Wang, D.H. Ji, C. H. Yu, Y. M. Peng..

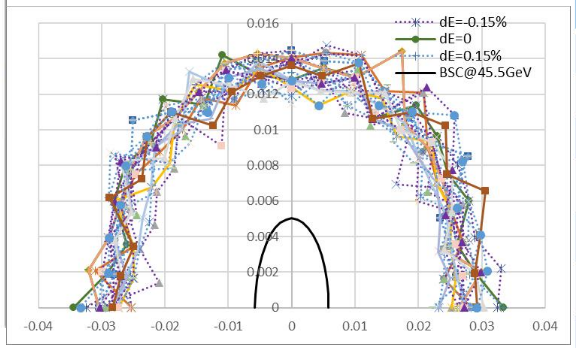
- TME like structure (cell length=80m)
- Overall idea: uniform distribution for the Q
- Combined magnet (B+S) scheme possible
- Interleave sextupole scheme
- Emittance@120GeV=1.26nm



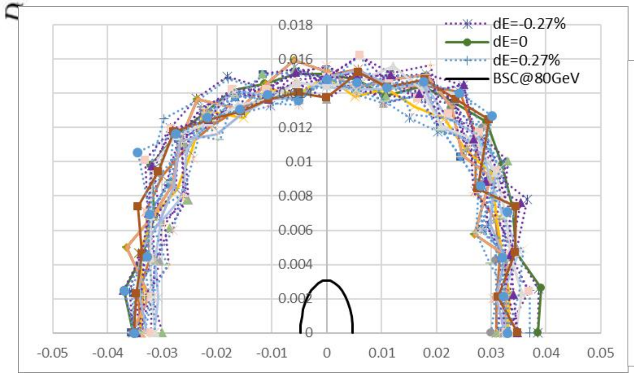
Dispersion sup.



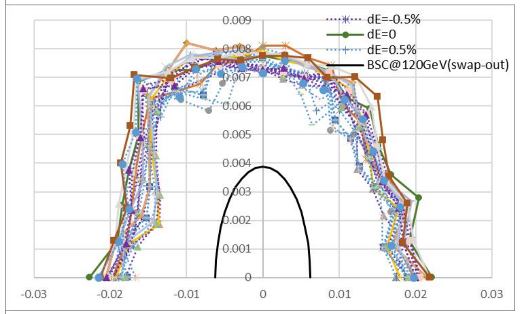
DA @20GeV



DA @45GeV

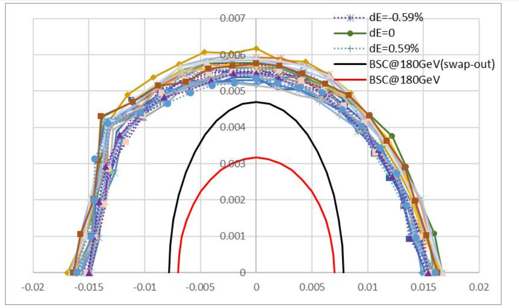


DA @80GeV



DA @120GeV

dipole	quadrupole	sextupole
B1/B0 ≤ 2×10^{-4}		
B2/B0 ≤ 3×10^{-4}	B2/B1 ≤ 3×10^{-4}	
B3/B0 ≤ 2×10^{-5}	B3/B1 ≤ 1×10^{-4}	B3/B2≤ 1×10^{-3}
B4/B0 ≤ 8×10^{-5}	B4/B1 ≤ 1×10^{-4}	B4/B2 ≤ 3×10^{-4}
B5/B0 ≤ 2×10^{-5}	B5/B1 ≤ 1×10^{-4}	B5/B2 ≤ 1×10^{-3}
B6/B0 ≤ 8×10^{-5}	B6/B1 ≤ 5×10^{-5}	B6/B2 ≤ 3×10^{-4}
B7/B0 ≤ 2×10^{-5}	B7/B1 ≤ 5×10^{-5}	B7/B2 ≤ 1×10^{-3}
B8/B0 ≤ 8×10^{-5}	B8/B1 ≤ 5×10^{-5}	B8/B2 ≤ 3×10^{-4}
B9/B0 ≤ 2×10^{-5}	B9/B1 ≤ 5×10^{-5}	B9/B2 ≤ 1×10^{-3}
B10/B0 ≤ 8×10^{-5}	B10/B1 ≤ 5×10^{-5}	B10/B2 ≤ 3×10^{-4}



DA @180GeV

TME DA with installation errors
and multipole errors satisfy design goals

CEPC TDR SRF Parameters (Booster Ring)

30 MW Collider SR power per beam for each mode. 20 GeV injection.	**ttbar**	**Higgs** off/on-axis	**W**	**Z** high current
Extraction beam energy [GeV]	180	120	80	45.5
Extraction average SR power [MW]	0.087	0.09	0.01	0.004
Bunch charge [nC]	0.96	0.7	0.73	0.83
Beam current [mA]	0.11	0.56/0.98	2.85	14.4
Injection RF voltage [GV]	0.438	0.197	0.122	0.122
Extraction RF voltage [GV]	9.7	2.17	0.87	0.46
Extraction bunch length [mm]	1.8	1.85	1.3	0.75
Cavity number (1.3 GHz 9-cell)	336	96	64	32
Extraction gradient [MV/m]	27.8	21.8	13.1	13.8
Q_0 @ 2 K at operating gradient (long term)	1E10			
Q_L	4E7	1E7		
Cavity bandwidth [Hz]	33	130		
Peak HOM power per cavity [W]	0.4	1.4/2.7	9.8	108.5
Input peak power per cavity [kW]	7.9	15.3/21.3	15	33
SSA peak power [kW] (one cavity per SSA)	10	25	25	40
Cryomodule number (8 cavities per module)	42	12	8	4

CDR Higgs energy:

J.Y. Zhai

-collider ring: 240 2cell 650MHz cavities
-booster: 96 1.3GHz 9cell cavities
-Nb consumption: 20 tons

For ttbar energy:

In addition to CDR Higgs energy, SRF cavity numbers have to be increased:
-collider ring:+350 5cell 650MHz cavities
-booster ring:+350 1.3GHz 9 cell cavities
-Additional Nb consumption:65 tons

For 30MW SR/beam Mode at Higgs energy, the cryogenic system need **32000liter Hellium**

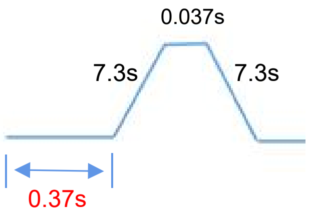
For 50MW/beam SR Mode:
at Higgs energy, the cryogenic system needs 42000liter Hellium; at ttbar energy **130000liter Hellium needed**

Refrigerators: 4*18kW@4.5K

CEPC Booster Ramping

Dou Wang, Xiaohao Cui

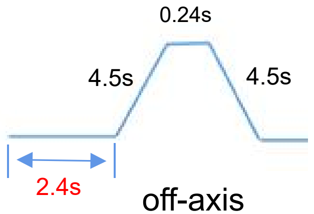
tt



1

0.37s+7.3s+0.037s+7.3s=15.0s

Higgs



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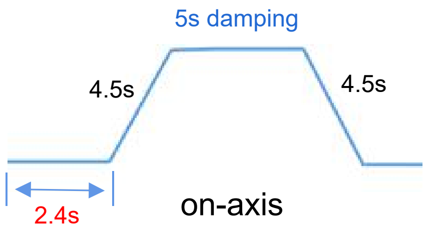
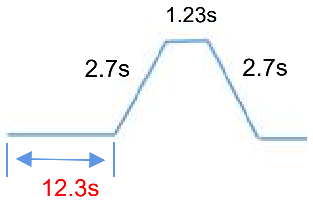


2.4s+4.5s+5.0s+4.5s=16.4s

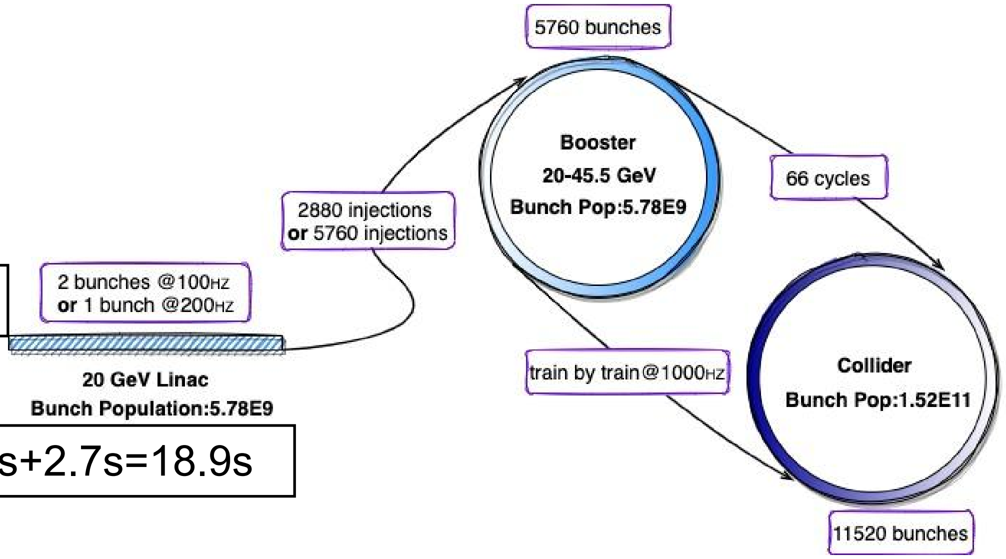
W



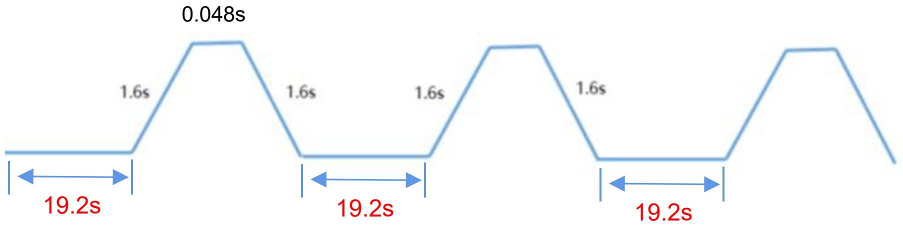
1

12.3s+2.7s+1.23s+2.7s=18.9s

Z mode injection (full injection)



Z



(19.2s+1.6s+0.048s+1.6s)*3=67.34s

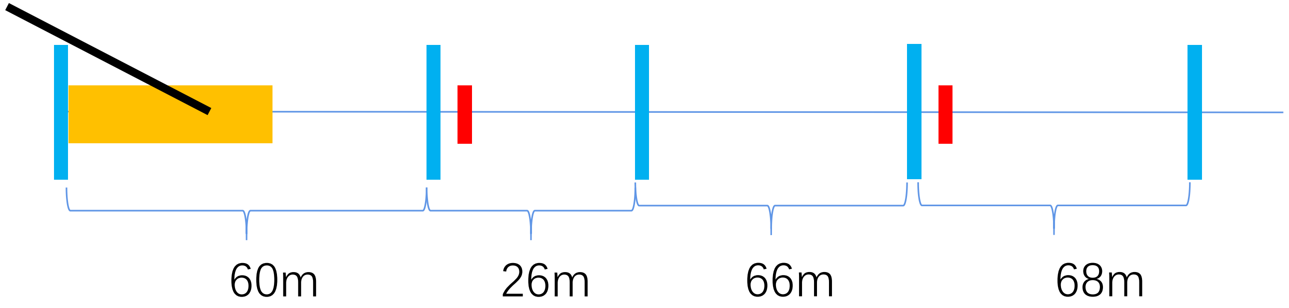
3

Extraction from Booster Collider Ring

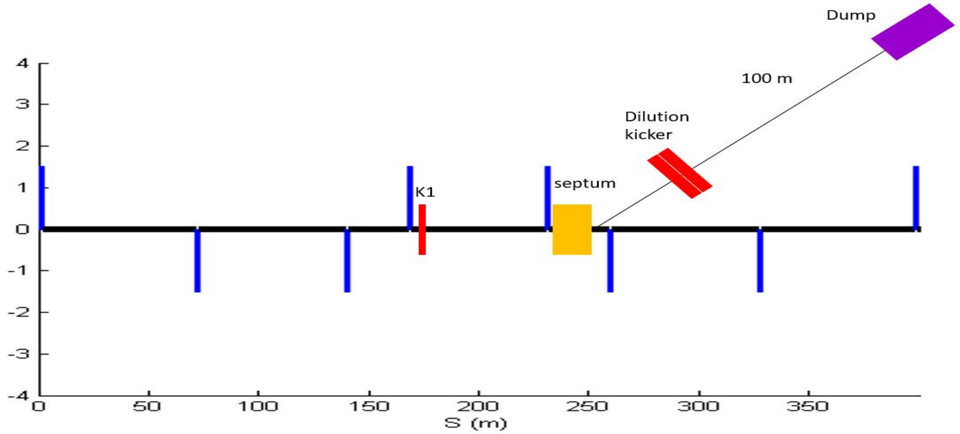
X.H. Cui

	tt	Higgs	W
Energy（GeV）	180	120	80
Bunch number	37	240	1230
Bunch seperation（us）	4.2	0.647	0.2677
Extraction scheme	bunch by bunch	bunch by bunch	bunch by bunch
Kicker frequency(Hz)	1000	1000	1000
Kicker pules duration (us)	<8.4	<1.29	<0.535
Kicker rise up/ fall down (us)	<4.2	<0.647	<0.2677
Timing delay(us)	4.2	0.647	0.2677
Extraction duration (s)	0.037	0.24	1.23

	Z
Energy（GeV）	45.5
Bunch number/train	80
Bunch separation（ns）	23.076
Number of trains	48
Train separation (us)	5.11
Extraction scheme	train by train
Kicker frequency(Hz)	1000
Flat top (us)	1.83
Kicker pules duration (us)	<12.05
Kicker rise up/ fall down (us)	<5.11
Timing delay(us)	6.94
Extraction duration (s)	0.048



From booster to collider



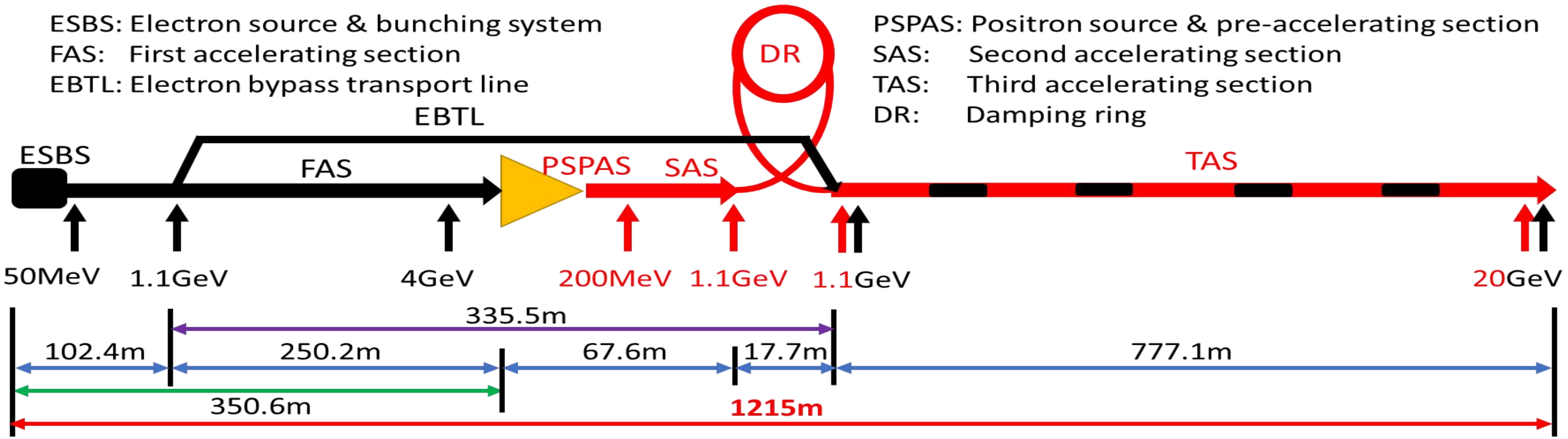
From colliderr to dump

Complete transport lines and timing from electron gun to damping ring, booster, collider ring till beam dump have been studied

CEPC 20GeV Linac for TDR

J.R. Zhang
C. Meng

- EBTL is in vertical plane with 1.2 m separation
  - Avoid interference with energy analyzing station, transport lines between the Linac and damping ring, waveguide and positron source
  - Reduce the tunnel width
- Accelerating structure
  - S-band: FAS/PSPAS/SAS
  - C-band: TAS



CEPC 20GeV Linac TDR Parameters

J.R. Zhang
C. Meng

- **Baseline scheme**
  - 20 GeV
    - Low magnetic field & large magnetic field range
    - C-band
      - Higher gradient → Shorter linac tunnel length
      - Small aperture & Strong wakefield
  - 10 nm
    - High luminosity
  - 100 Hz
    - Injection efficiency
    - High luminosity Z need faster injection process
      - 200 Hz
      - 100 Hz & two-bunch-per-pulse
      - 200 Hz & two-bunch-per-pulse (?)

Parameter	Symbol	Unit	Baseline
e^-/e^+ beam energy	E_{e-}/E_{e+}	GeV	20
Repetition rate	f_{rep}	Hz	100
e^-/e^+ bunch population	Ne-/Ne+	$\times 10^{10}$	0.94(1.88)
		nC	1.5 (3)
Energy spread (e^-/e^+)	σ_E		1.5×10^{-3}
Emittance (e^-/e^+)	$\varepsilon_{x,y}$	nm	10

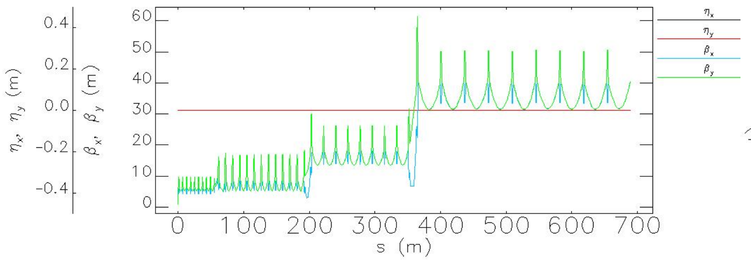
Parameter	Unit	S-band	C-band
Frequency	MHz	2860	5720
Length	m	3.1	1.8
Cavity mode		2π/3	3π/4
Aperture diameter	mm	20~24	11.8~16
Gradient	MV/m	21	45

CEPC 20GeV Positron Linac Design

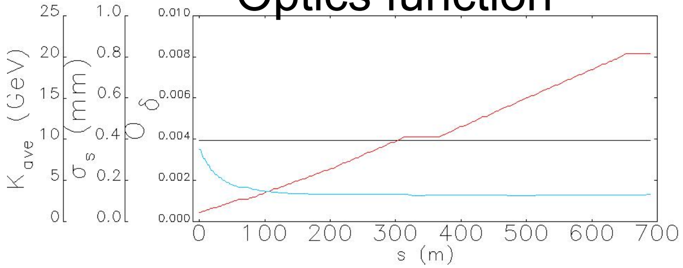
J.R. Zhang, C.Meng

- Positron Linac
  - Wakefield & CSR
  - Emittance(w/o error)
    - Growth: 5%
    - 5.2nm@20GeV

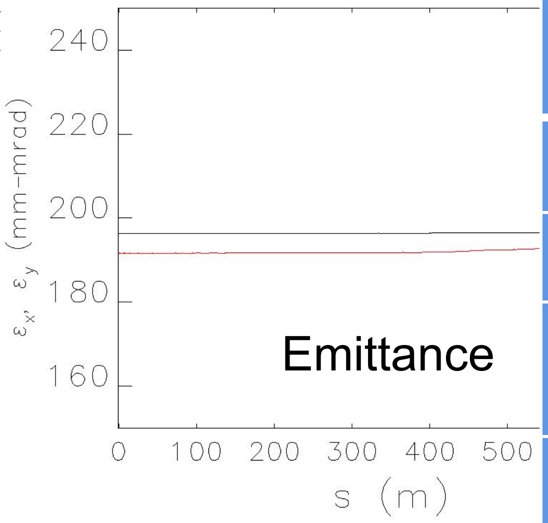
Parameter	Unit	Baseline	Electron	Positron
e^-/e^+ beam energy	GeV	20	20.38	20.37
Repetition rate	Hz	100	100	100
e^-/e^+ bunch population	$\times 10^{10}$	0.94(1.88)	1.88	1.88
	nC	1.5 (3)	3	3
Energy spread (e^-/e^+)		1.5×10^{-3}	1.3×10^{-3}	1.3×10^{-3}
Emittance (e^-/e^+)	nm	10	2.5	5.2



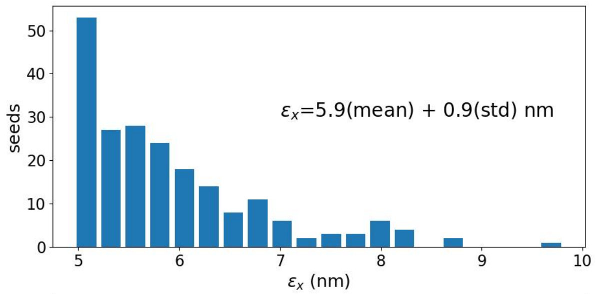
Optics function

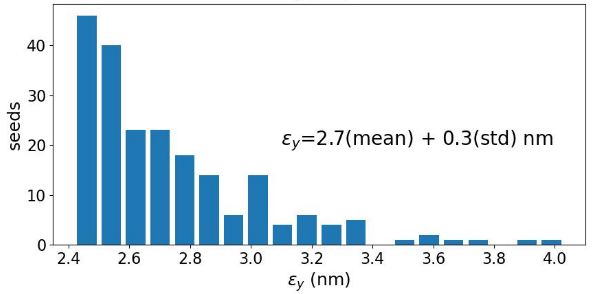


Energy/bunch length/energy spread



Error description	Unit	Value
Misalignment error	mm	0.1
Rotation error	mrad	0.2
Magnetic element field error	%	0.1
BPM uncertainty	μm	30





CEPC linac injector reached design goals taking into account of errors

CEPC SRF Cryogenic Systems in TDR

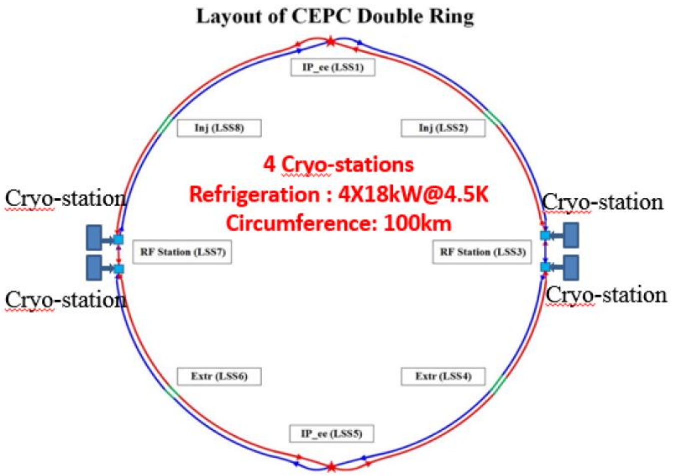
R. Ge
M. Li

Booster ring:

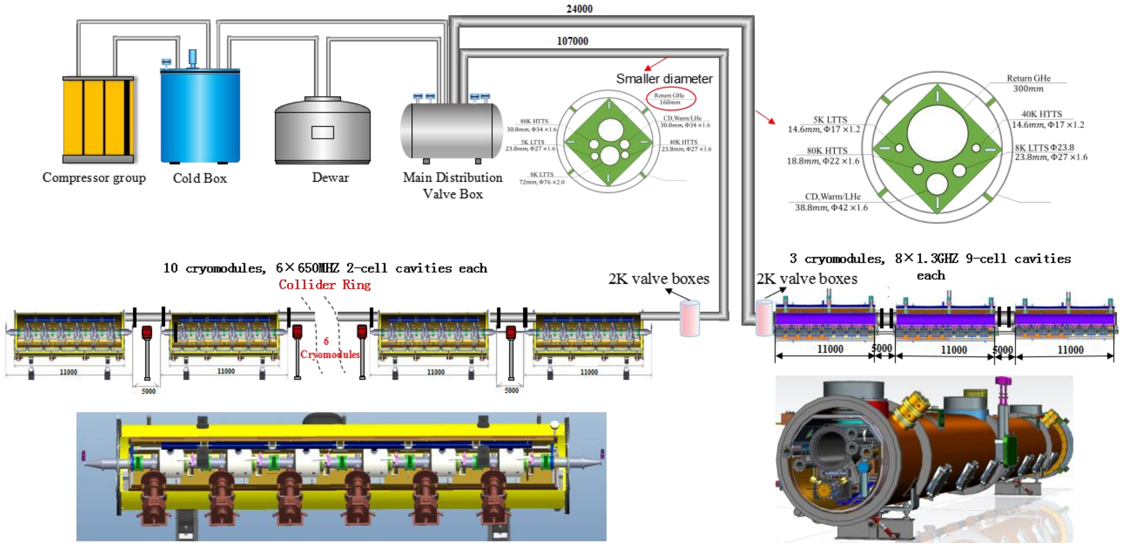
- 1.3 GHz 9-cell cavities, 96 cavities
- 12 cryomodules
- 3 cryomodules/each station
- Temperature: 2K/31mbar

Collider ring:

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



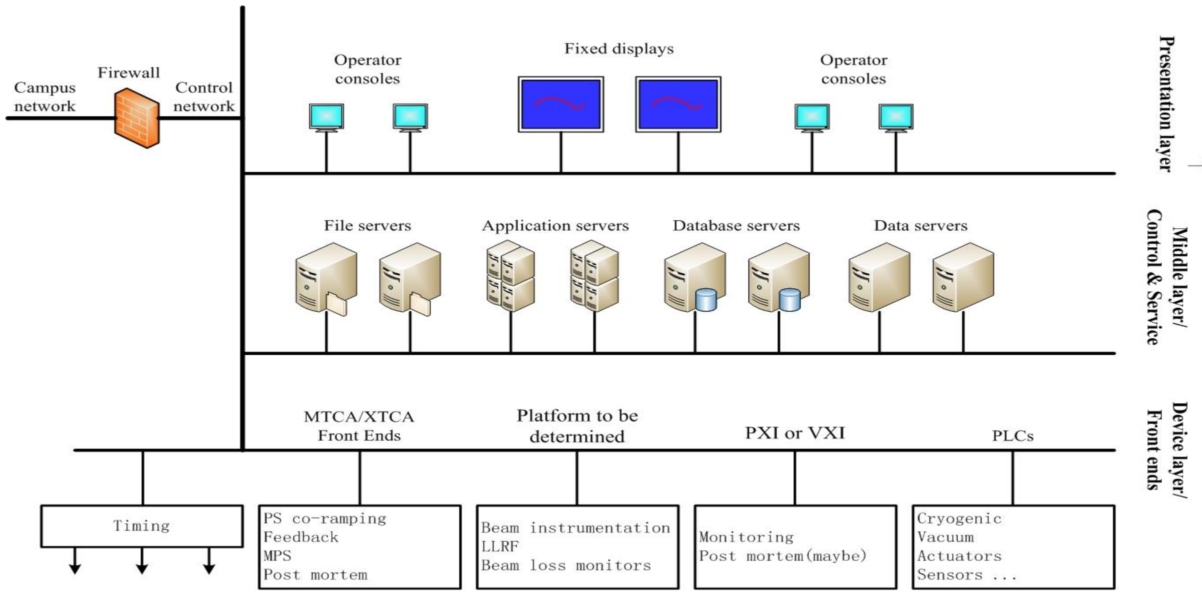
CEPC accelerator SRF cryogenic flow chart in TDR



For 30MW SR/beam Mode at Higgs energy, the cryogenic system need 32000liter Hellium

For 50MW/beam SR Mode:
at Higgs energy, the cryogenic system needs 42000liter Hellium; at ttbar energy 130000liter Hellium needed

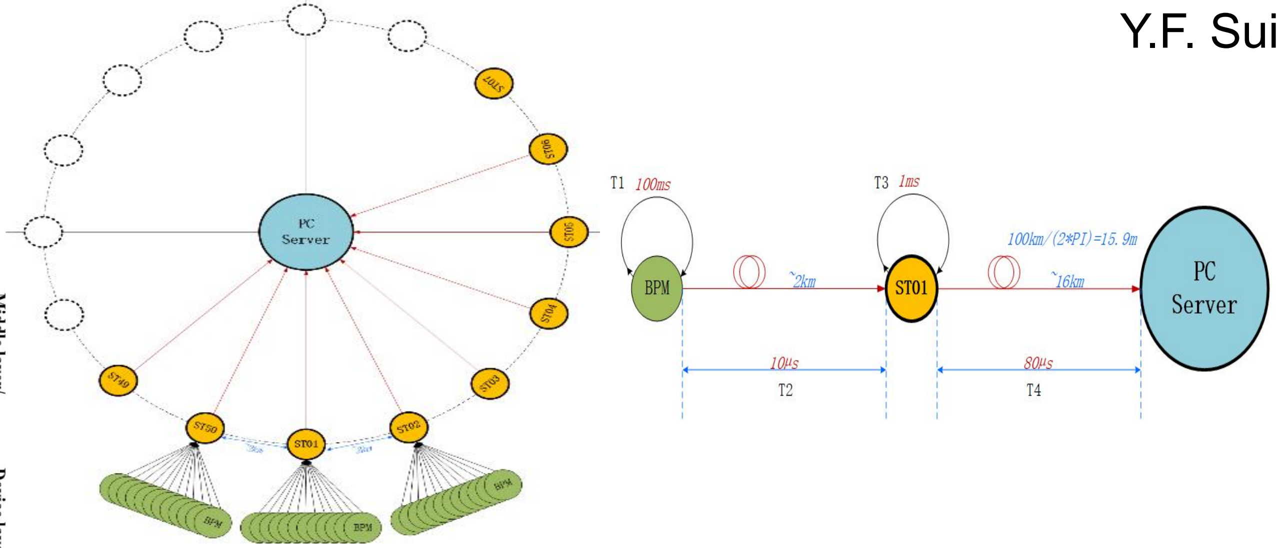
CEPC Control System and Beam Diagnostic System



Overall hardware architecture of the control system

Signal Time Delay Analysis of the COD Measurement (as an example for operation)

G. Li
Y.F. Sui

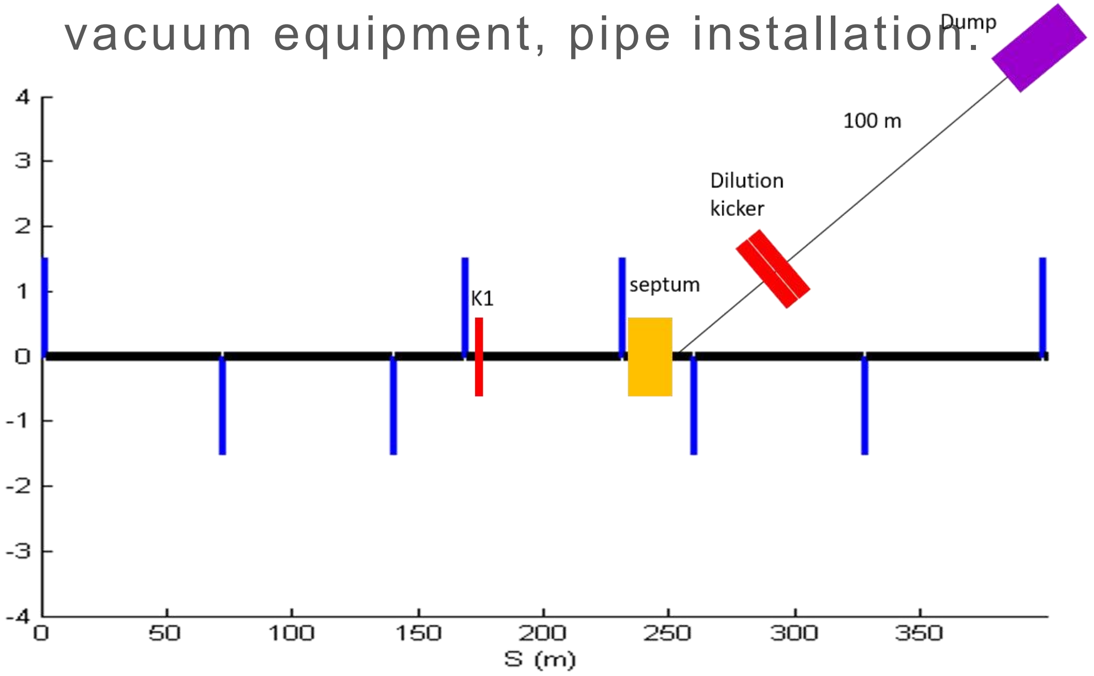


- 50 stations along the storage ring and connecting with PC sever station with the star topology fiber optic network.
- Consider the delay of whole system, the BPM COD measurement takes about 1s .

CEPC Machine Protection, Beam Abort and Dump System

X.H. Cui
G.Y. Tang

- A set of kicker magnets has been used to dilute the beam horizontally and vertically;
- The area of bunch distribution in front of dump is assumed to be 6cm x 6cm; These dimensions haven't been optimized yet.
- The length of transfer tunnel is about 100m; the diameter is about 2m, considering the vacuum equipment, pipe installation.



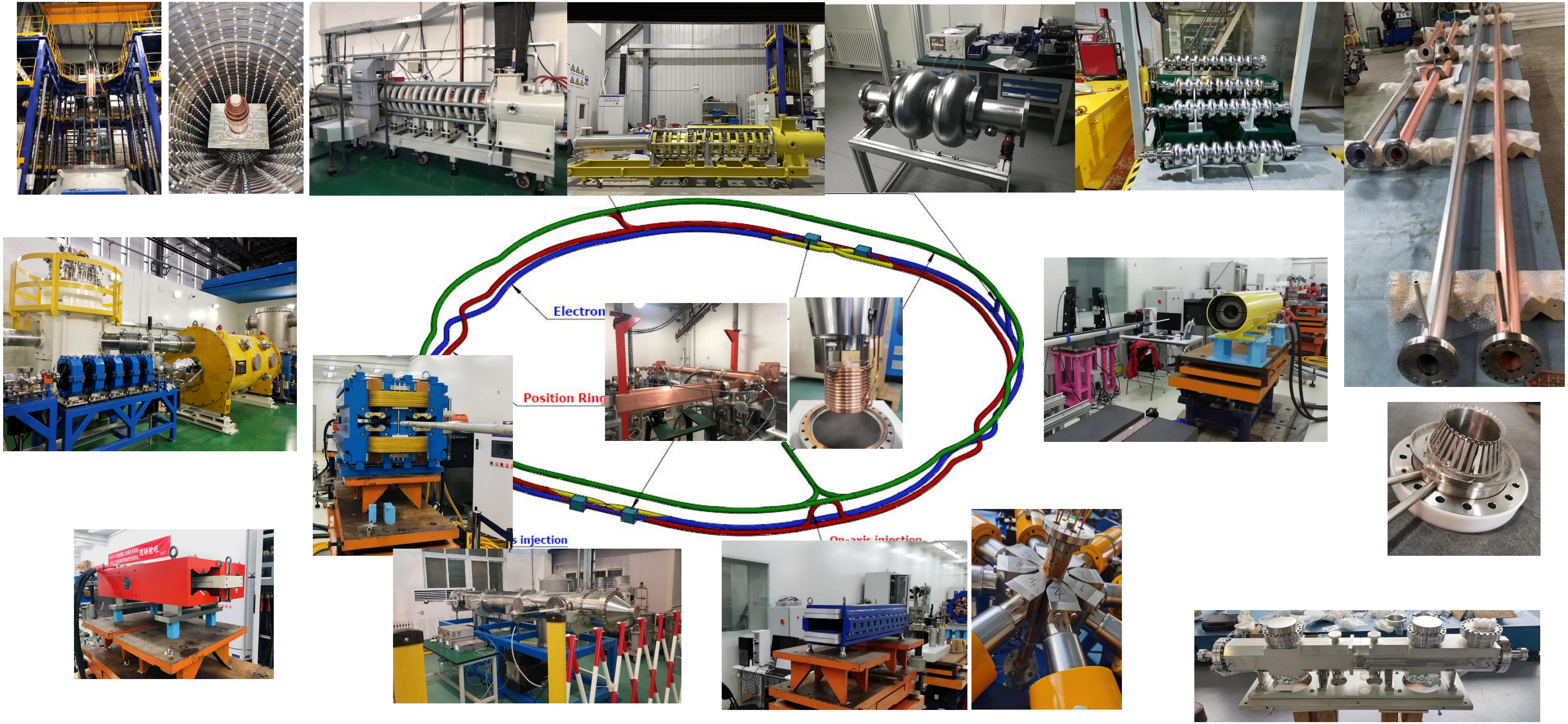
		Extraction kicker	Septum	Dilution kickers
Length (m)		2	20	10
Magnetic flux density (Gauss)	Z	281		40
	WW	494		
	Higgs	741	7000	
	ttbar	1110		

Beam dump graphite core (example) temperature rise

	Higgs	WW	Z	ttbar
Beam energy/GeV	120	80	45.5	182.5
Ne/bunch/10^{10}	14	13.5	14	20
Bunch number (50MW)	415	2162	19918	58
Max. temperature rise	510 ± 15℃	1020 ± 30℃	2620 ± 15℃	
Maximum temperature rise by one bunch	7.31 ± 0.03℃	5.38 ± 0.03℃	3.76 ± 0.02℃	10.08 ± 0.04℃

CEPC Accelerator System Key Hardware R&D Progresses in TDR

CEPC TDR R&D Status of Key Technologies



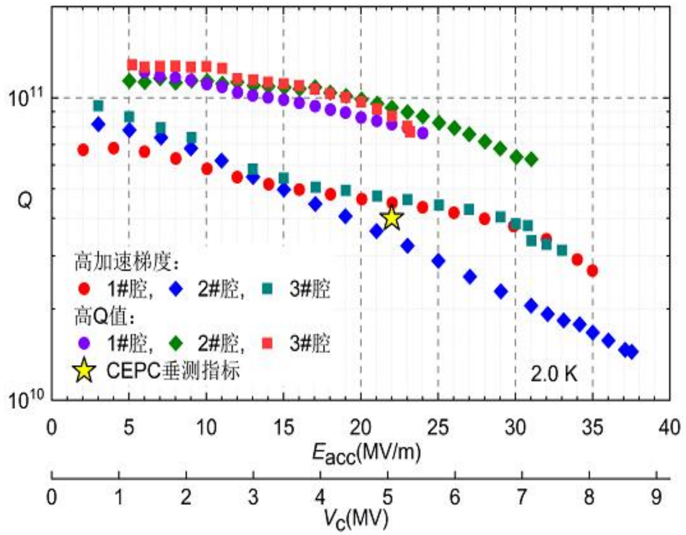
CEPC SRF Facilities and Componets

J.Y. Zhai, P. Sha

Mid-T (medium temperature furnace baked) cavities have higher gradient and Q than Nitrogen doped cavities with less EP process (1 vs 3)

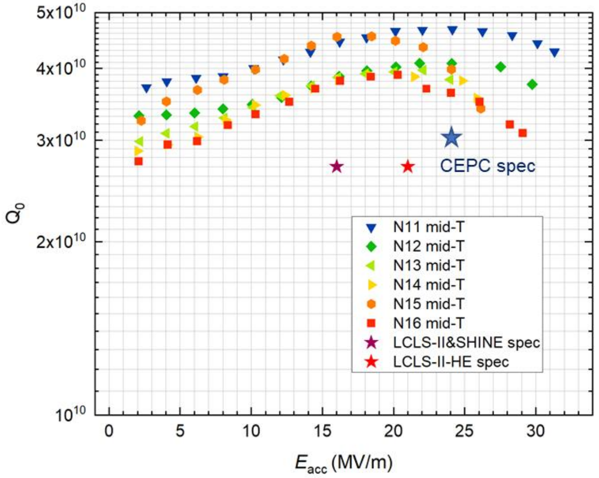
IHEP PAPS is in full operation since 2021

CEPC 650 MHz 1-cell Cavity

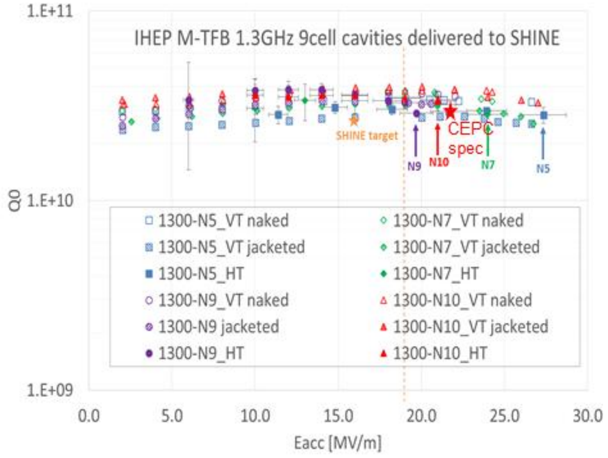


The 650Mhz 1-cell cavity's results (8E10@22MV/m, 1.5E10@37.5MV/m) have broken China's gradient record of low-frequency (<1 GHz) elliptical cavities. **World record Q** of 650 MHz cavity above 30 MV/m.

1.3 GHz High Q Mid-T Cavity Horizontal Test



Vertical Test (N11-16)

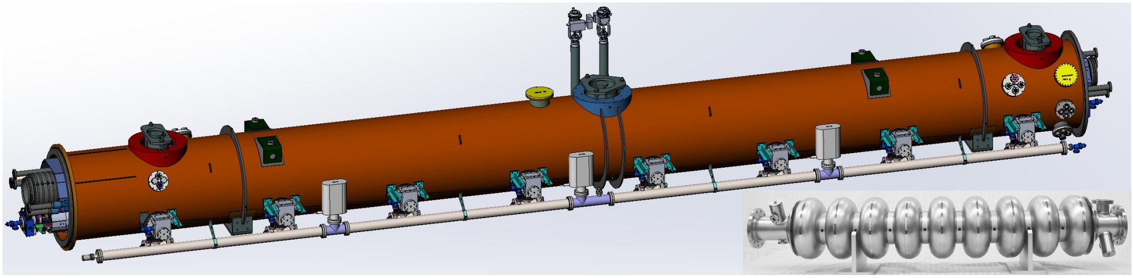


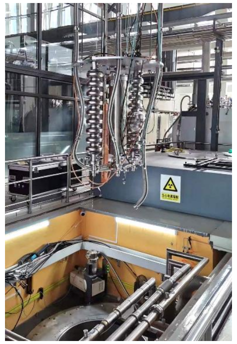
Horizontal Test (N5/7/9/10) (self excited loop mode)

1.3 GHz High Q Cryomodule (8x9-cell)

J.Y. Zhai

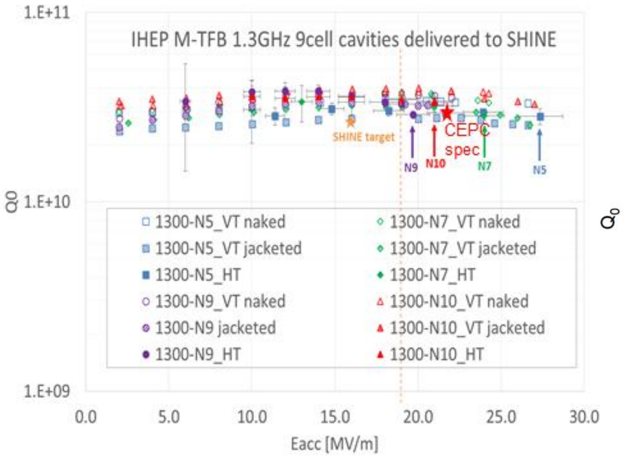
CEPC booster 1.3 GHz SRF R&D and industrialization in synergy with CW FEL projects.



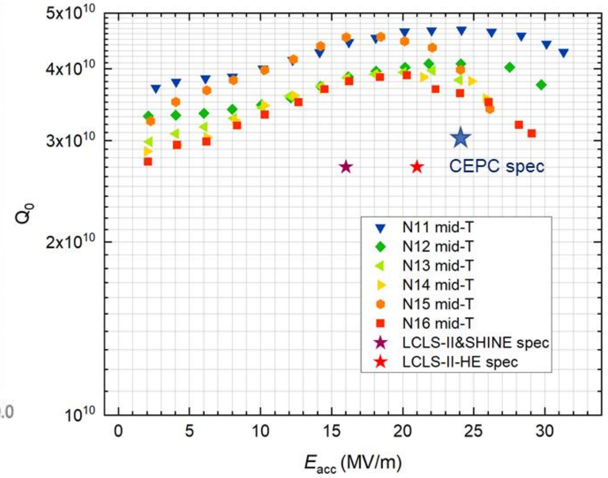


Mid-T (medium temperature furnace baked) cavities have higher gradient and Q than Nitrogen doped cavities with less EP process (1 vs 3)

- **Horizontal test of 4 mid-T 9-cell cavities:**
  avg. Q_0 3.5E10 @ 16 MV/m, 3.1E10 @ 21 MV/m
  avg. E_{acc} 24.6 MV/m, usable 22.6 MV/m (sporadic quench)
  horizontal test average performance better than LCLS-II
- **8 NEW mid-T 9-cell cavities for the 1.3 GHz module:**
  VT avg. Q_0 4.1E10 @ 16~21 MV/m, E_{acc} 27.7 MV/m
  vertical test average performance better than previous batch and LCLS-II-HE cavities.
  one cavity now horizontal testing with tuner in GDR mode



Horizontal Test (N5/7/9/10)
(self excited loop mode)



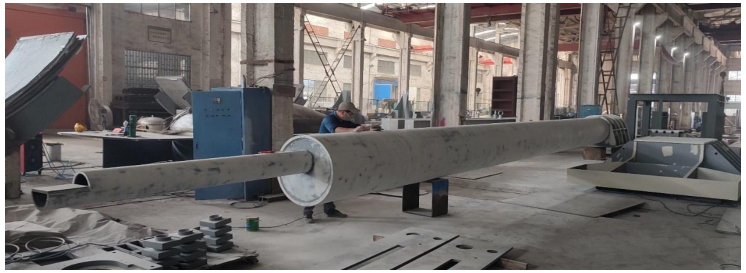
Vertical Test (N11-16)

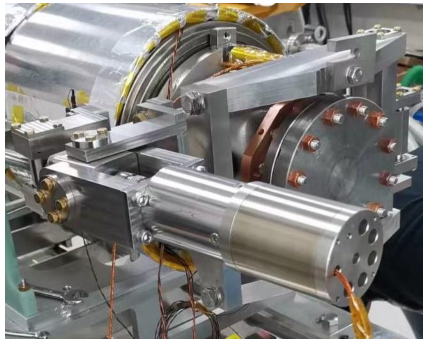
1.3 GHz High Q Cryomodule (8x9-cell)

J.Y. Zhai



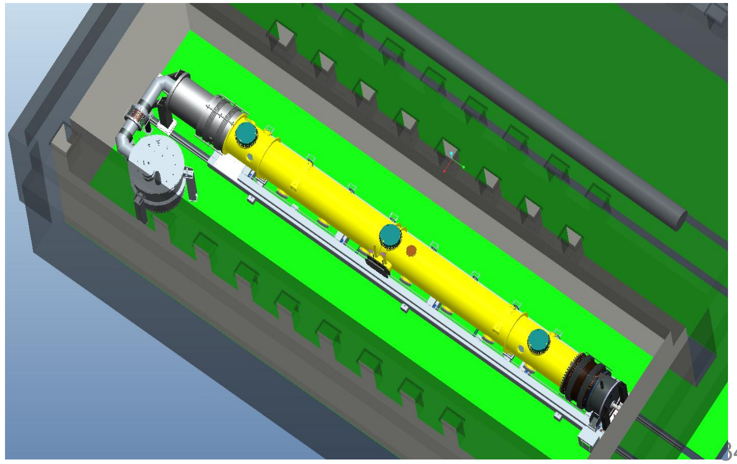






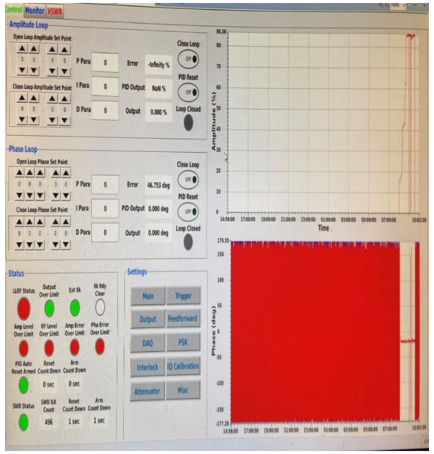


- **Vacuum vessel**, **upper cold mass**, **assembly tooling, SSAs** deliver to PAPS in June
- **8 cavities**, **input couplers**, **tuners** etc finish testing at PAPS in June
- **Superconducting magnet** test and degaussing, **BPM** calibration at IHEP in June
- **Module cart**, **feed-cap**, **end-cap**, **volve-box**, **LLRF system** ... in fabrication
- Cavity string and module assembly at PAPS in August-October, 2022
- Horizontal test in November, 2022

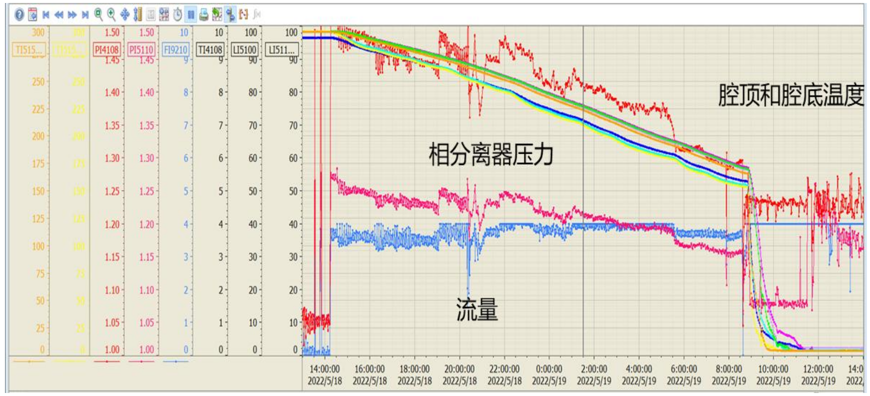


CEPC 650 MHz 2 x 2-cell Test Cryomodule

J.Y. Zhai



- **Module automatic cool-down experiment (first time in China)**
  - For more intelligent control of future CEPC cavity & cryogenic system
  - Designed and implemented automatic cool-down/warming-up procedure for SRF cavity cryomodule with Model Predict Control (MPC) method & Artificial Neural Network (ANN)
- **LLRF system commissioning and high power test**
  - Pended in May by local prevention policy. Hope to continue in mid June, 2022
- **DC photo-cathode gun voltage conditioning up to 400 kV**



1. 300 to 150 K: < 10 K/hr. Cavity top and bottom ΔT < 20 K
2. 150 to 4.5 K: Cavity surface > 1 K/min
3. 4.5 to 2 K

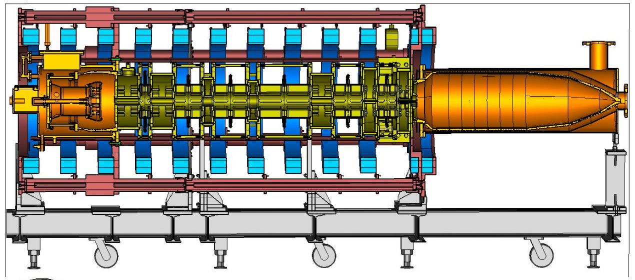
CEPC 650MHz High Efficiency Klystrons

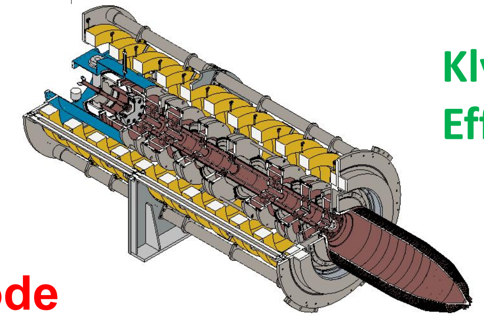
Z.S.Zhou

Klystron No. 1
Efficiency 65%
(2020)

Under test

Klystron No. 2
Efficiency 77%
(2021)

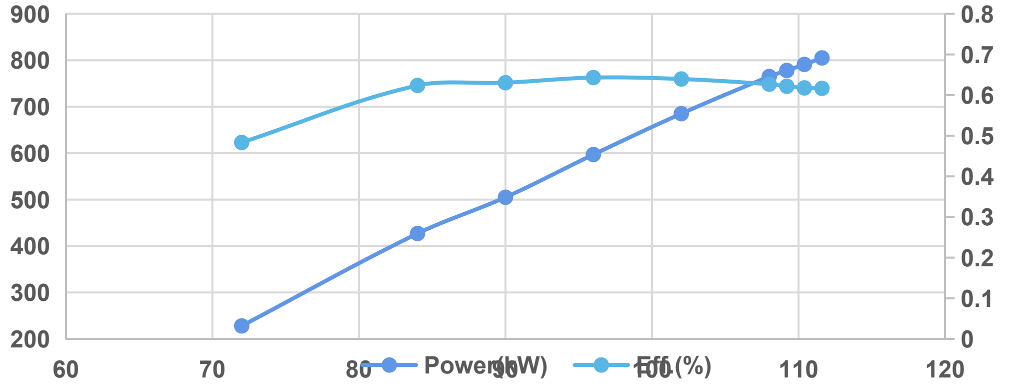




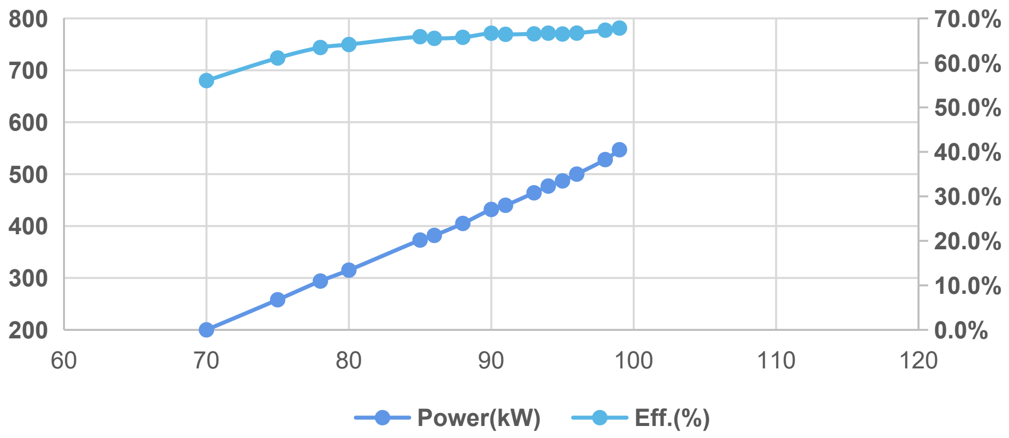
Klystron No. 3
Efficiency 80.5%
(2022)

2022年5月19日

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



CW RF Mode

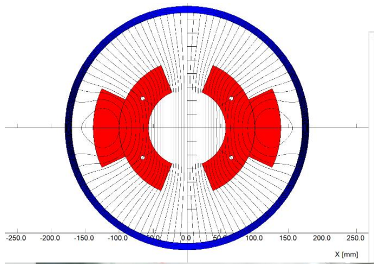


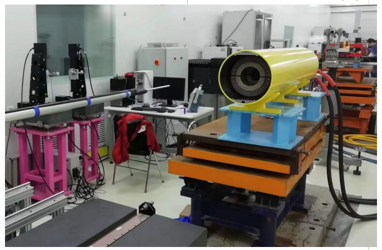
The test is still under way, with ~68% at 547kW

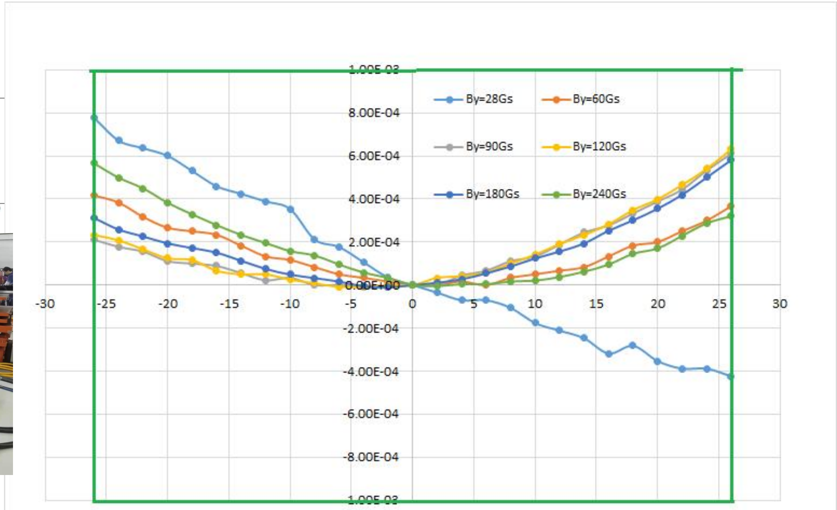
>70% at 800kW is expected

CEPC Full Size Booster Dipole Magnets

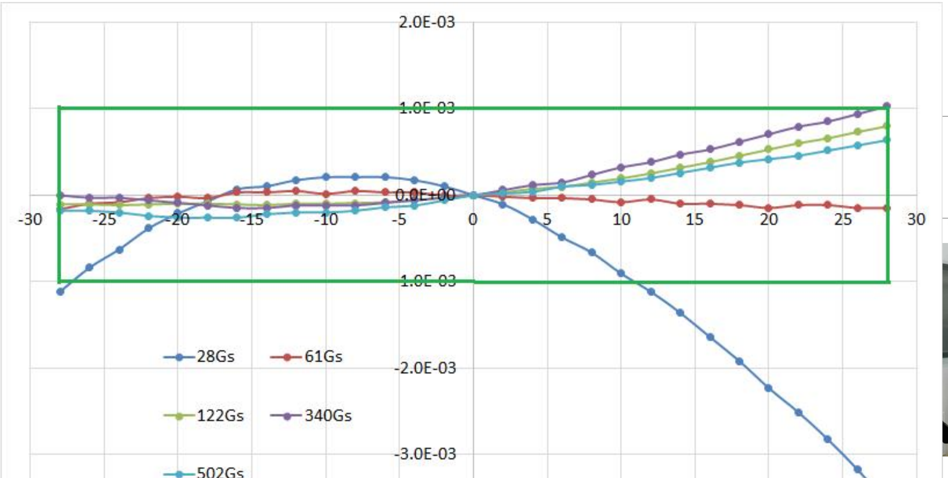
W. Kang

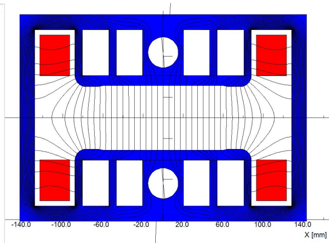




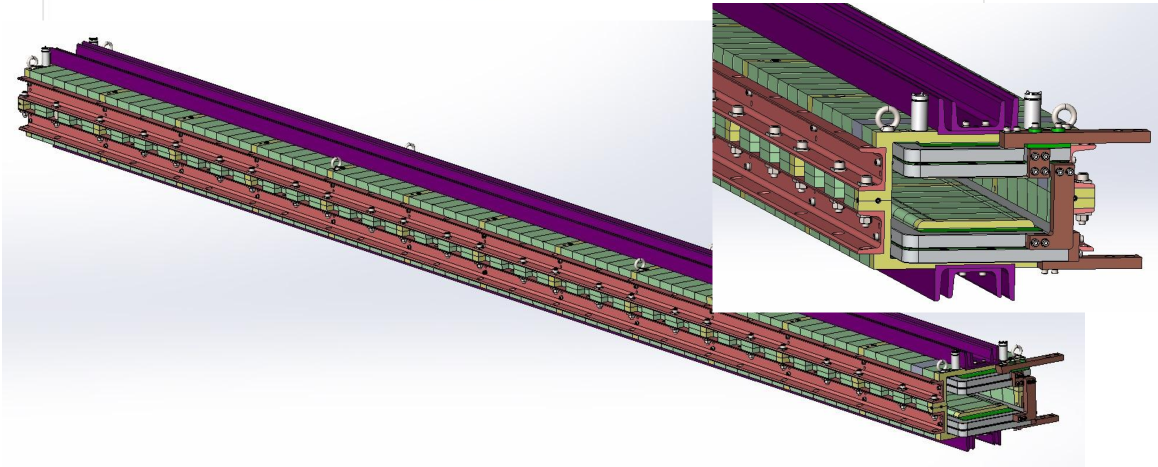


Works for 10GeV injection energy





Works for 20GeV injection energy (New baseline)

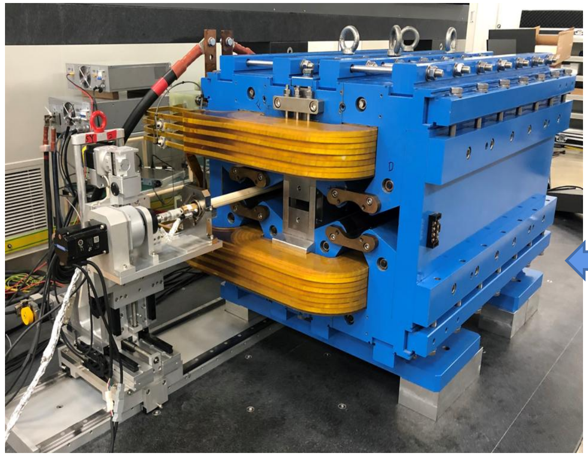


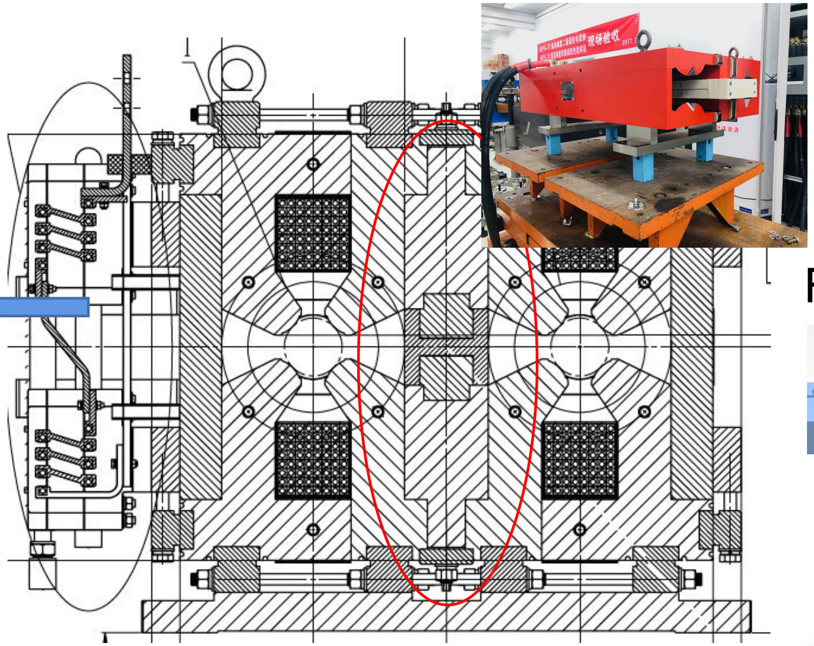
Two types of 4.7m long full size booster dipoles prototype fabrication in progress

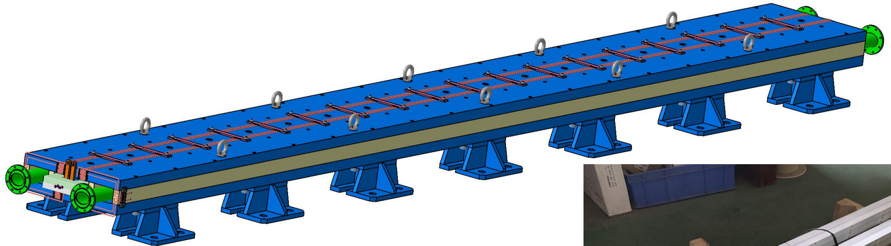
CEPC Collider Ring Magnets

M. Yang

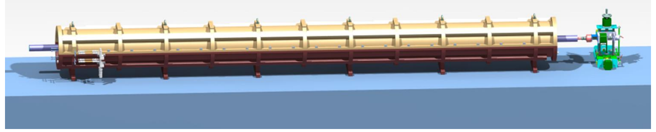
- Modification of the dual aperture quadrupole magnet

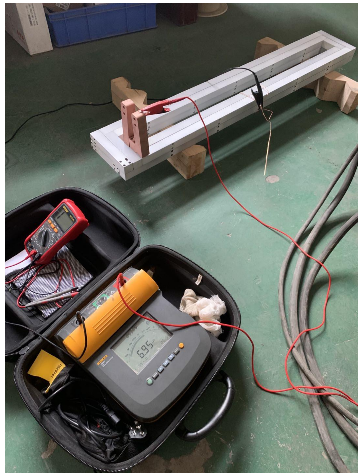




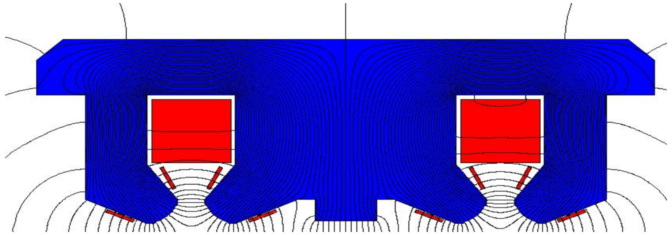


Full size dural aperture dipole

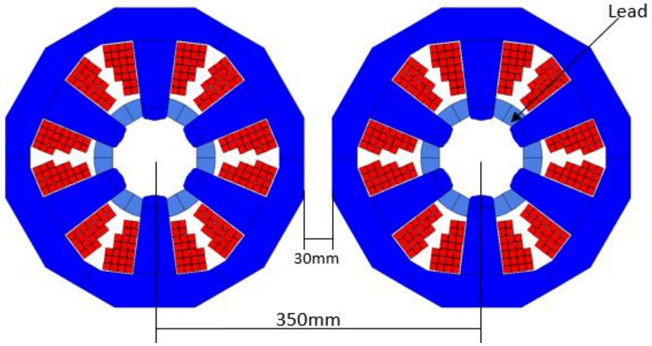


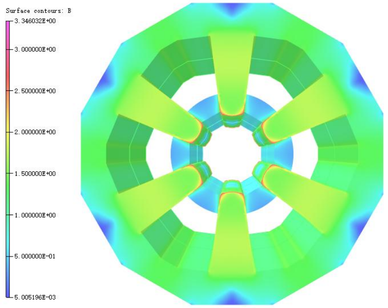


After iron modification with center shim, X0 shifts is lower, which is agreed with the simulation results.



Dural aperture F/D qudrupole design with trim coils





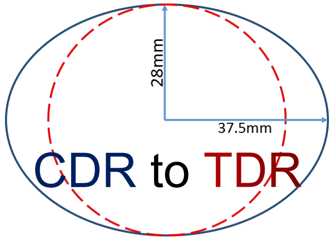
Sextupole design

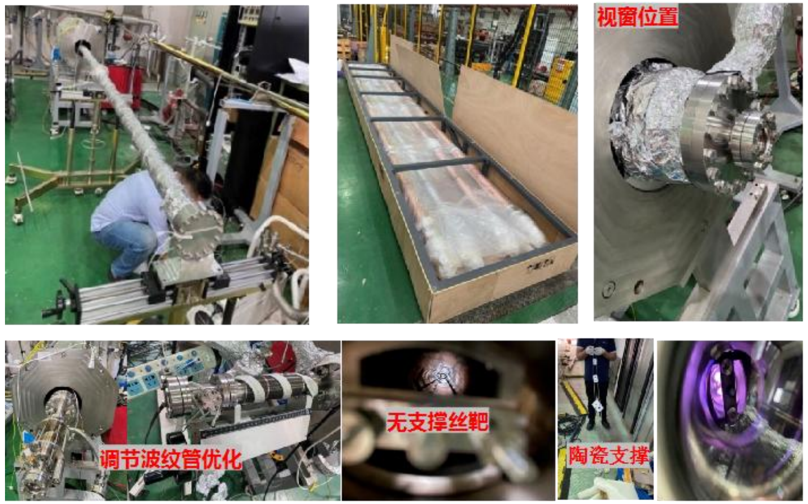
CEPC Vacuum System R&D

Y.S. Ma

New round pipe of Copper (3mm) with NEG coating (200nm) for collider ring in TDR

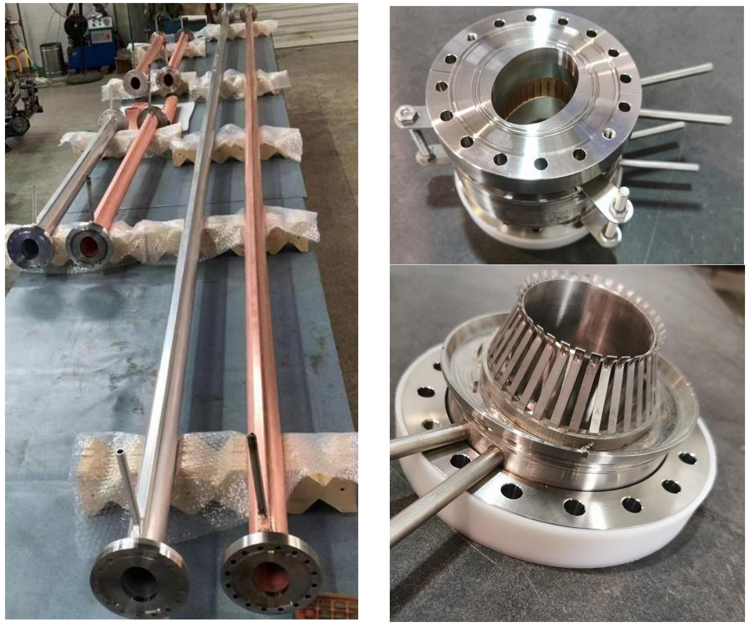
SEY<1.2





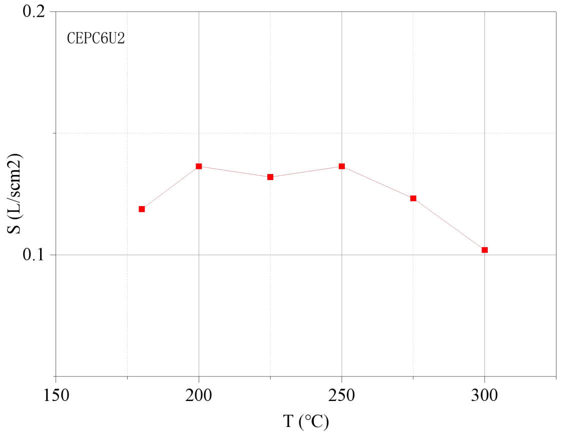
6 m vacuum pipe have been installed on the NEG coating setup

All metal gate valve different from VTA



Vacuum pipes and RF shielding bellows

Facility of pumping speed test have been finished in Dongguan



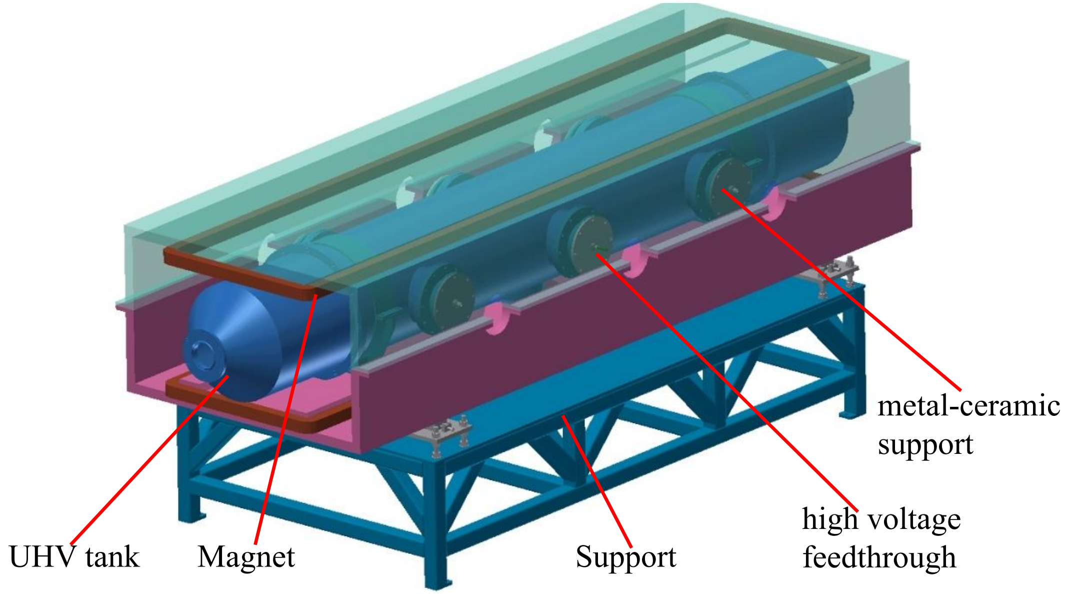
Pumping speed test of 2 meters long CEPC Cu pipe of NEG coating in IHEP

CEPC Electrostatic-Magnetic Deflector

B. Chen

- The Electrostatic-Magnetic Deflector is a device consisting of perpendicular electric and magnetic fields.
- One set of Electrostatic-Magnetic Deflectors including 8 units, total 32 units will be need for CEPC.

	Filed	Effective Length	Good field region	Stability
Electrostatic separator	2.0MV/m	4m	46mm x11mm	$5x10^{-4}$
Dipole	66.7Gauss	4m	46mm x11mm	$5x10^{-4}$



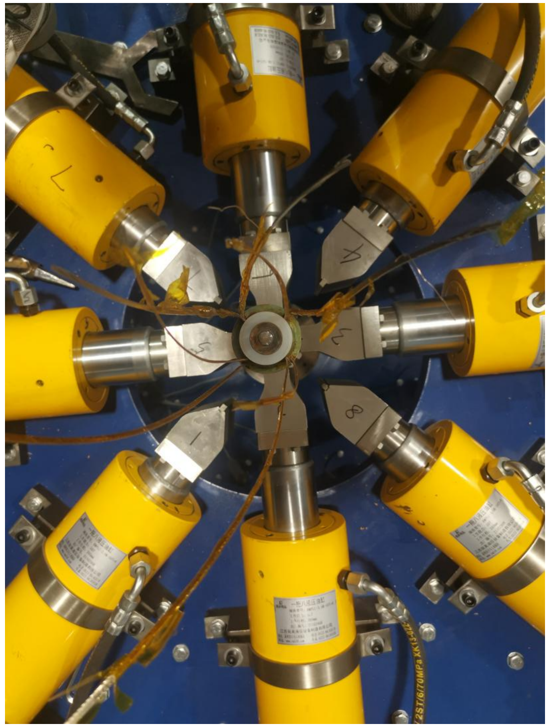
The high voltage of prototype test can reach ±90kV, which meets the requirements of Higgs Mode operation, the operating voltage of the electrostatic separator in Higgs Mode (120GeV) is ±75kV

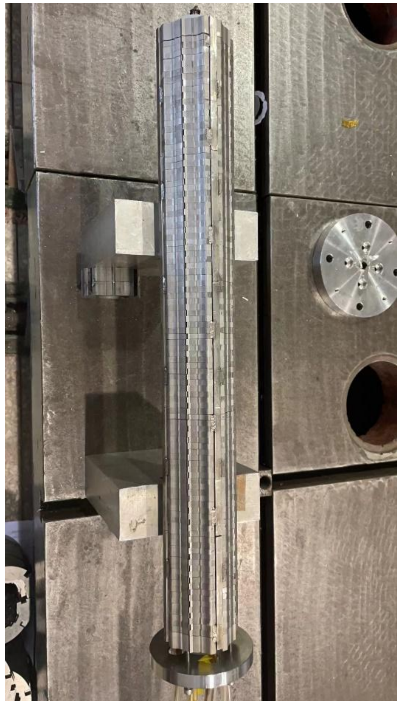
CEPC QD0 SC Magnet R&D (0.5m short model)

Magnet name	0.5m QD0 model magnet
Field gradient (T/m)	136
Magnetic length (m)	0.5
Coil turns per pole	21
Excitation current (A)	2070
Coil layers	2
Conductor	Rutherford Cable, width 3 mm, mid thickness 0.93 mm, keystone angle 1.9 deg, Cu:Sc=1.3, 12 strands
Stored energy (KJ) (Single aperture)	2.6
Inductance (H)	0.001
Peak field in coil (T)	3.4
Coil inner diameter (mm)	40
Coil outer diameter (mm)	53
Yoke outer diameter (mm)	108
X direction Lorentz force/octant (kN)	24.6
Y direction Lorentz force/octant (kN)	-23.7
Net weight (kg)	25

Y.S. Zhu

Fabrication of NbTi Rutherford cable is finished (12 strands). SC quadrupole coil winding machine, coil heating and curing system has been finished.



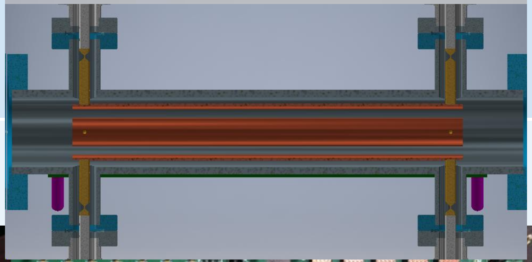


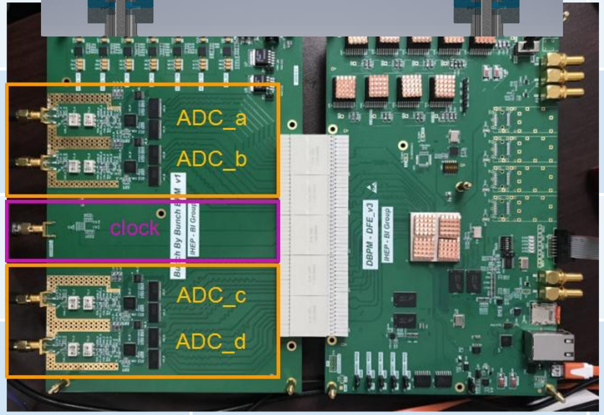
Fabrication of QD0 single aperture short model magnet (NbTi, 136T/m) will be completed in June, 2022, and a dual aperture SC quadrupole will be the next step

Status of CEPC Beam instrumentation R&D

Y.F. Sui

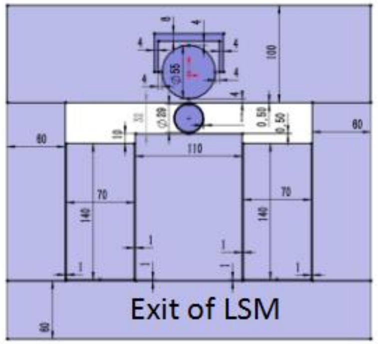
System	R&D Work supported by			Work to be done
	BEPCII	HEPS/HEPS TF	Funding	
BPM electronics	√	√	√	Radiation hardness Industrialization
Beam position monitor fabrication			√	detection;
Longitudinal feedback system	√			
Transverse feedback system	√			
Synchrotron radiation monitor				X-ray interferometer; Gas jet scanner……
BI at the interaction point			√	it
Bunch current monitor				&D based home- npany
Beam loss monitor			√	R&D;

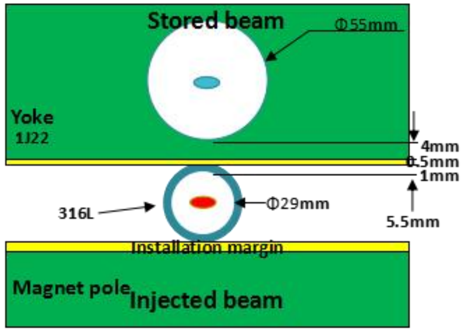


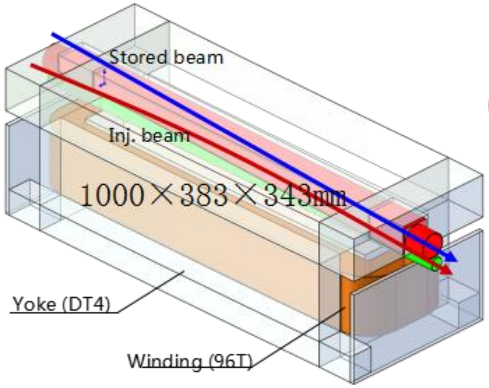


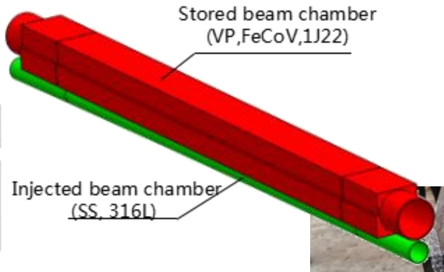
CEPC Inj.&Ext. Hardwares' R&D

J.H. Chen



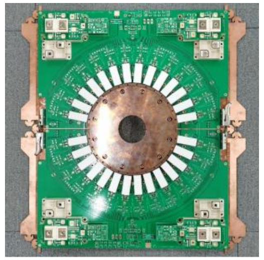


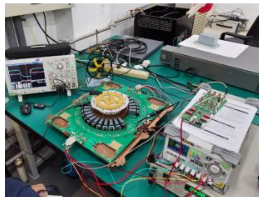




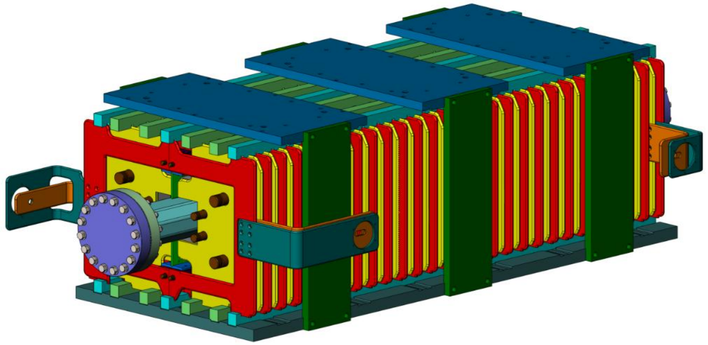
Lambertson magnet

Slotted-pipe kicker





250ns-fast kicker pulser

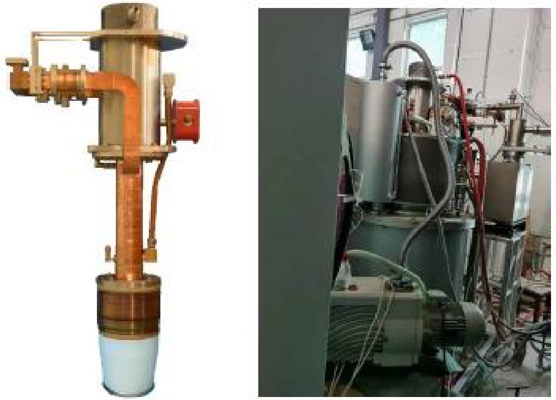


Delay-line dipole kicker

CEPC Technology Demonstration in Synergy with Other Projects

China company made 850kW@4K cryogenic plant installed in IHEP South Ligh Source test facility in Dongguan (May, 2022) (Next step is 10~18kw@4K)

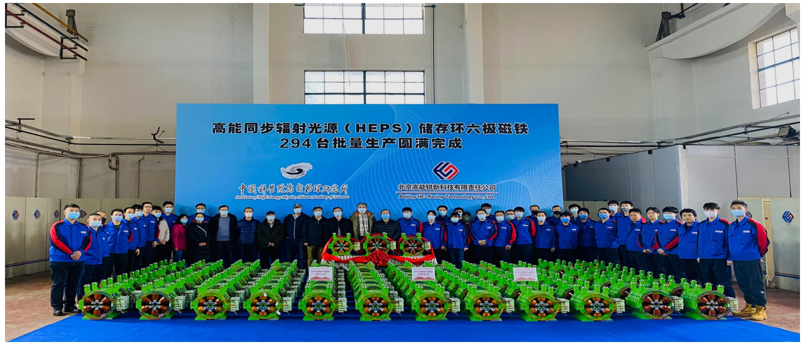
HEPS S-band Linac (May, 2022)



50MW 50Hz C-band klystron by Institute AIR of CAS for Shanghai Soft XFEL (Nov. 2021)

HEPS booster magnet unit (Jan. 2022)

HEPS power source for magnets magnets (June 2022)



HEPS storage ring sextupole magnets (Dec. 2021)

CEPC Plasma Injector 10 GeV → 25 GeV Pratically Feasible

D.Z. Li

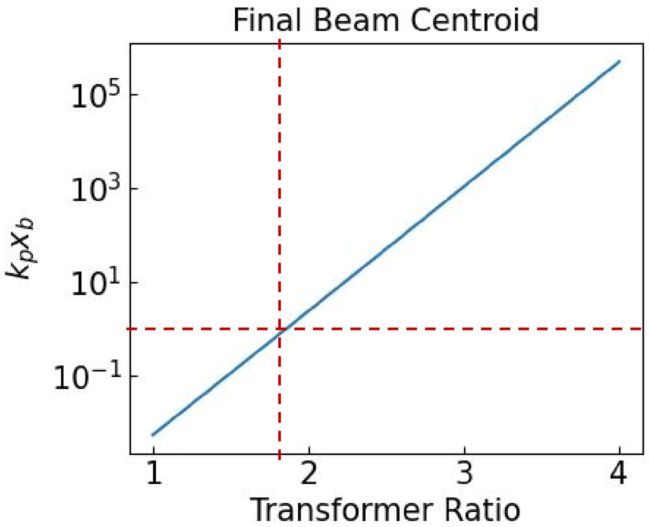
Theoretical analysis:

$$x_b \sim \frac{1.27\sigma_r}{\sqrt{1+1.67R}} \times 10^{-5} \times e^{1.3\left(\frac{\gamma_0}{2}\right)^{\frac{1}{6}} c^{\frac{1}{3}} c_b^{\frac{1}{3}} R^{\frac{1}{3}}\left(\sqrt{2}R+\frac{1}{\sqrt{2}}\right)^{\frac{2}{3}}}$$

The driver should be stable enough, if the beam centroid x_b is no more than $k_p{}^{-1}$. For a 10 GeV driver, let the beam size $k_p\sigma_r = 0.2$, $c = 0.7$, $c_b = 0.8$

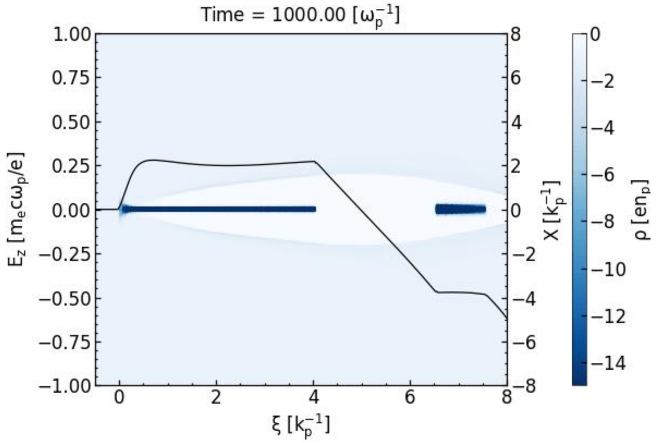
The transformer ratio R should be less than 1.8, which means:

10 GeV → 25 GeV CPI scheme ($R \sim 1.5$) should be safe.



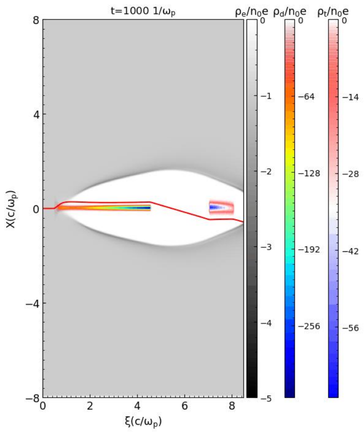
Simulation analysis for 10 GeV → 25 GeV CPI scheme

beam	Driver	Trailer
plasma density n_p	$0.5 \times 10^{16} cm^{-3}$	
Driver energy $E(GeV)$	10	10
Normalized emittance $\epsilon_n(mm\ mrad)$	20	100
Length(um)	300	77
(matched)Spot size(um)	3.87	8.65
Charge(nC)	4	1.24
Energy spread $\delta_E(\%)$	0	0
Beam distance(um)	184	

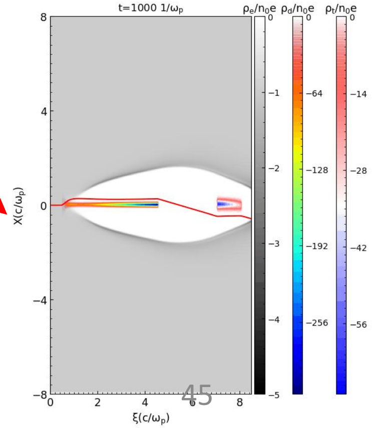


Acceleration process for idea case

Symmetry Ratio	Energy	Emittance (mm·mrad)	Bunch charge	rms Energy spread
100 (Ideal case)	25.02 GeV	100 / 100	1.36 nC	0.4%
97.5% (real case)	24.89 GeV	431 / 294	1.33 nC	0.62%



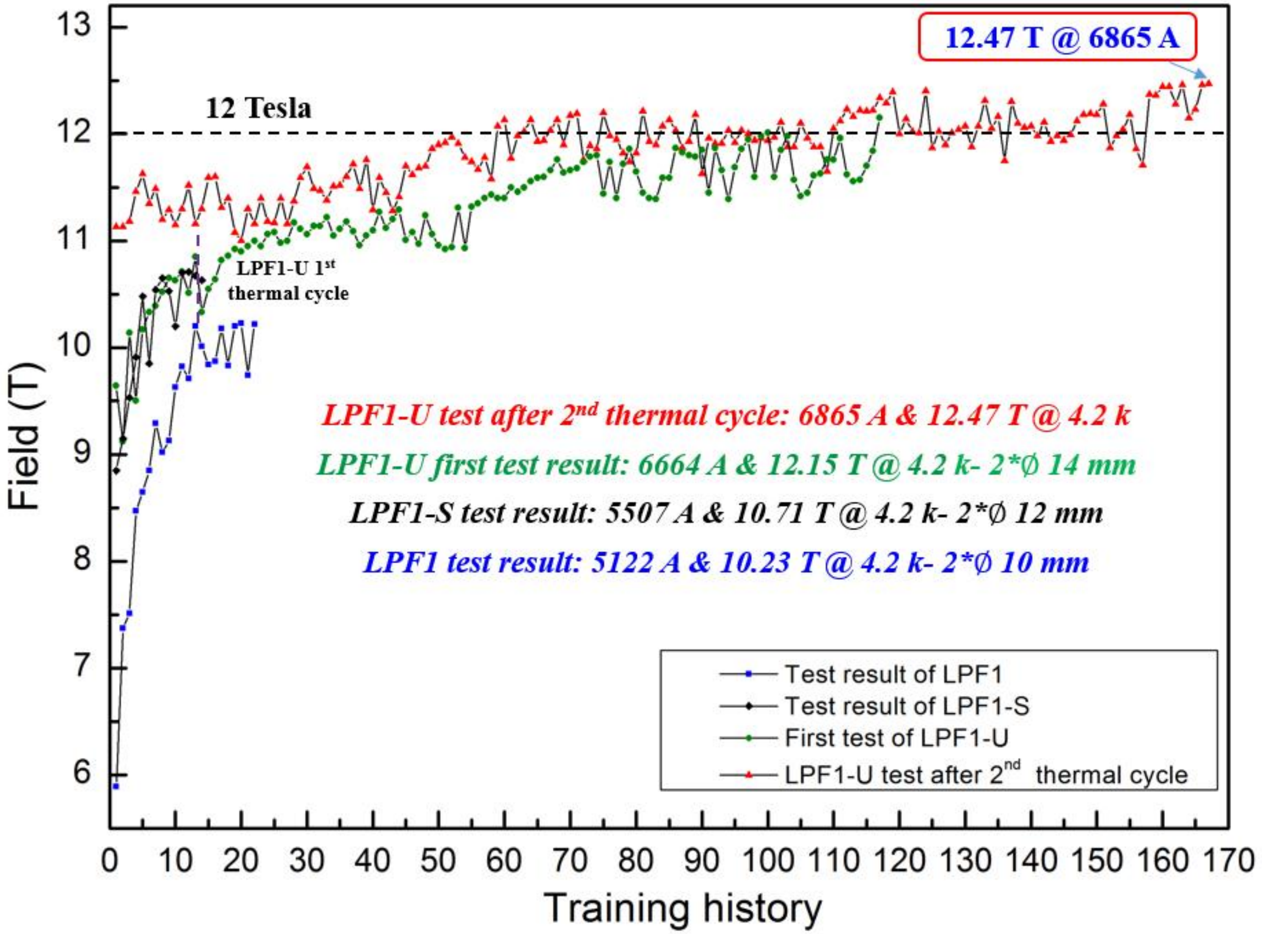
Error tolerance analysis shows the transverse and longitudinal offset thresholds is (-6μm, 6μm) and (-1.2μm, 1.35μm), which is acceptable to conventional linac accelerators.



Latest performance of LPF1-U (SppC)

Qingjin Xu

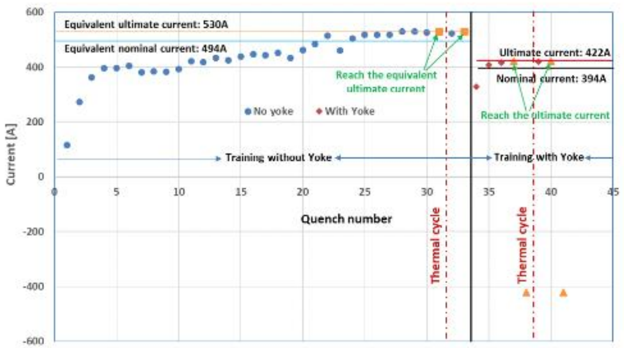
Picture of LPF1-U

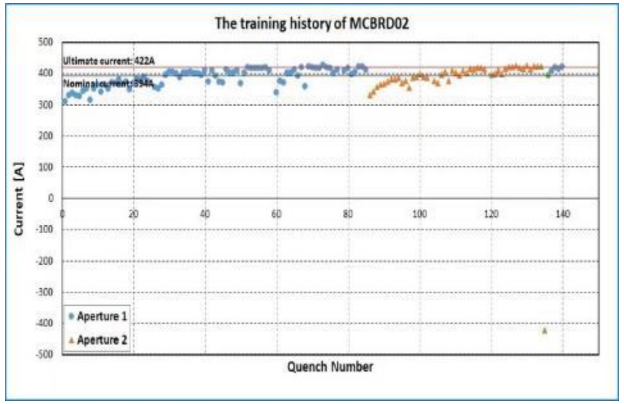


Dual aperture superconducting dipole achieves 12.47 T at 4.2 K
Entirely fabricated in China. The next step is reaching 16-19T field

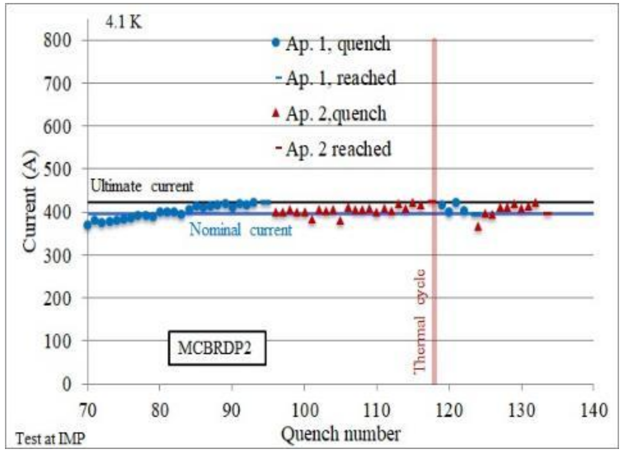
Development of CCT dipole magnets for HL-LHC by IHEP

Qingjin Xu





- The first set of CCT superconducting magnets MCBRD01 with satisfactory field strength and field quality, has been shipped to Europe in October, 2021.



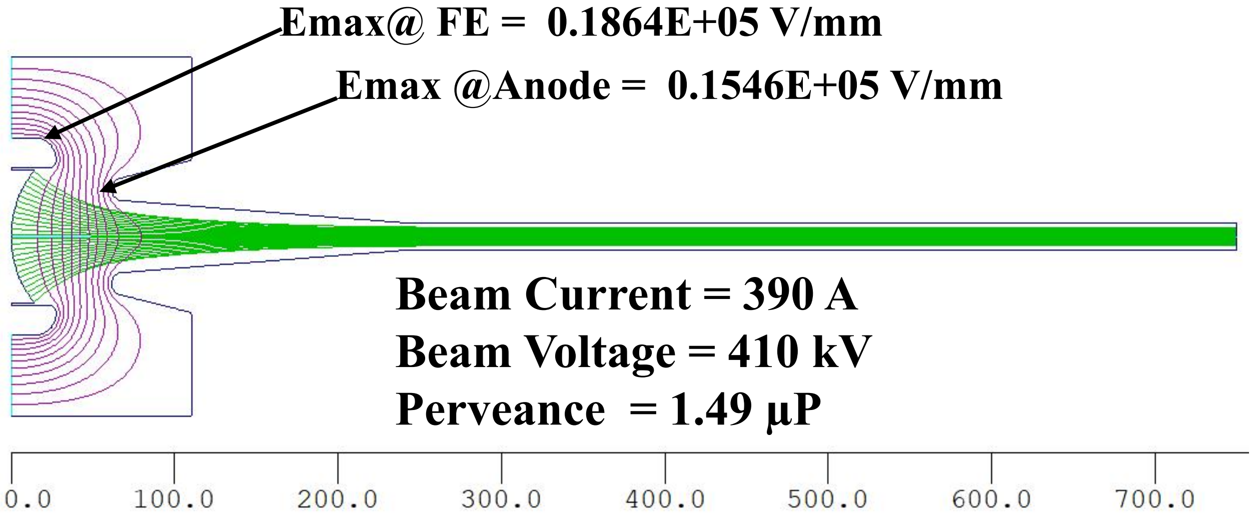
- The assembly of the 2nd set of HL-LHC CCT superconducting magnets has been finished in Jan, 2022, and now the magnet is tested at IMP

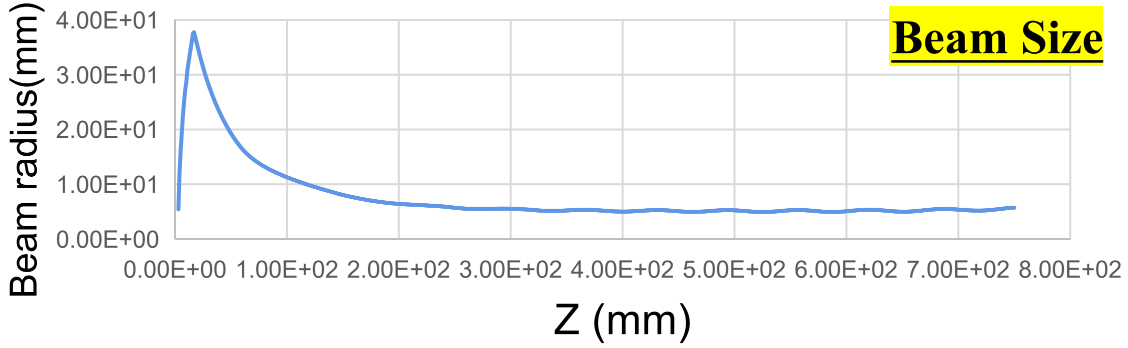
- Fabrication of a full size prototype magnet MCBRDP2 was completed in May, 2020. Both apertures reached the ultimate current.

CEPC Accelerator Advanced Technology Development

CEPC 80 MW C-Band(5720 MHz) Klystron Design

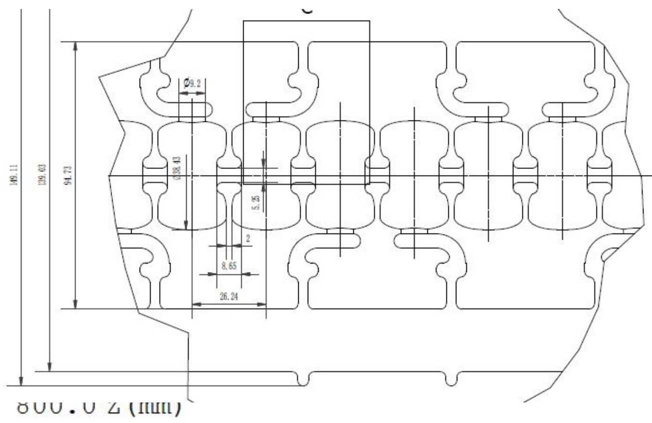
Z.S. Zhou

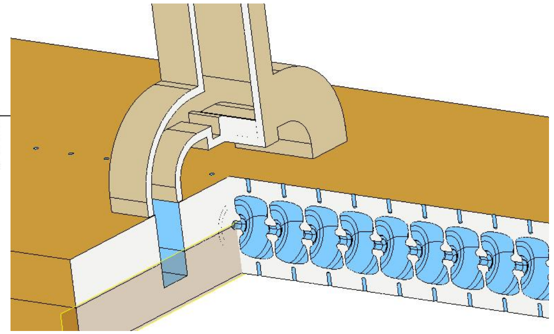


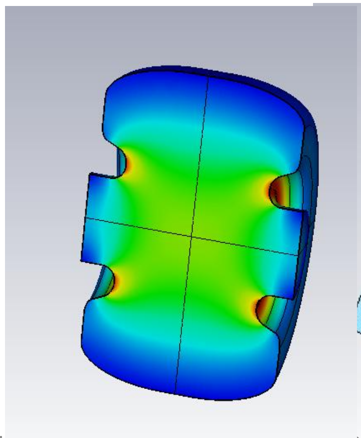


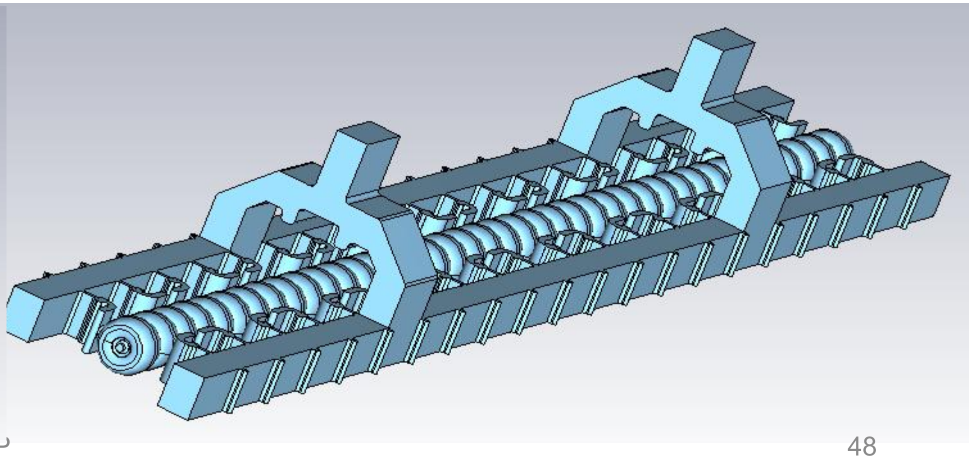
R&D on C3 C band accelerator technology as CEPC alternative C-band linac Eacc >70M/m

J.R. Zhang





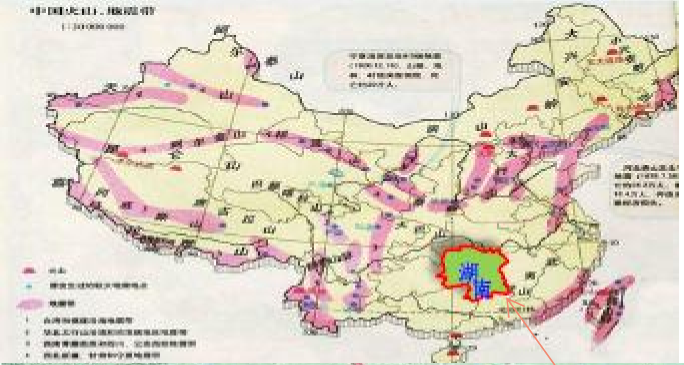


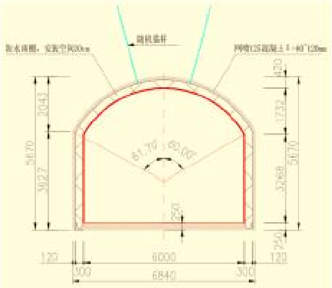


CEPC Siting, Civil Engineering, Installation Strategy

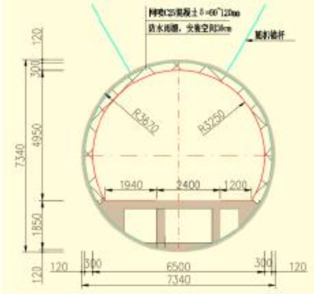
CEPC Siting, Civil Engineering (Changsha site as an example)

Very good geological condition

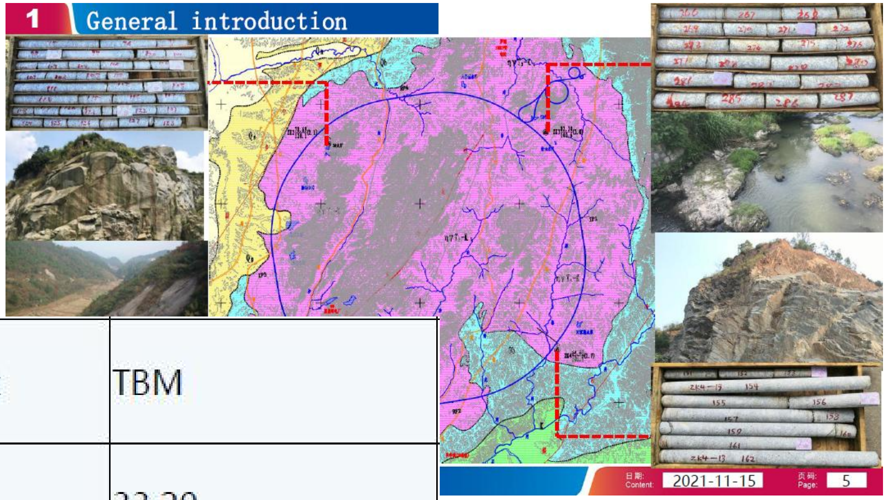


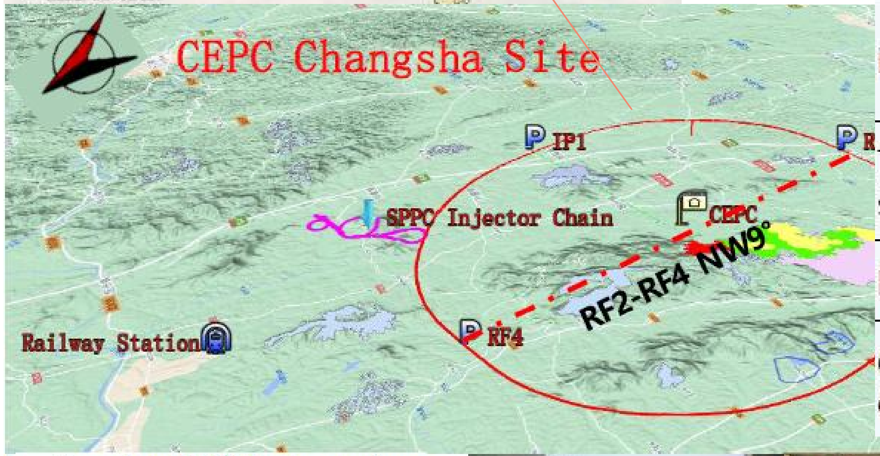


Drill-blast tunnel (6.0m×5.0m)

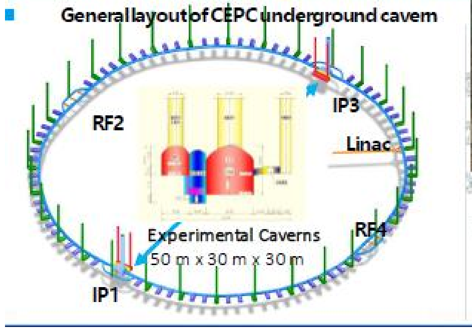


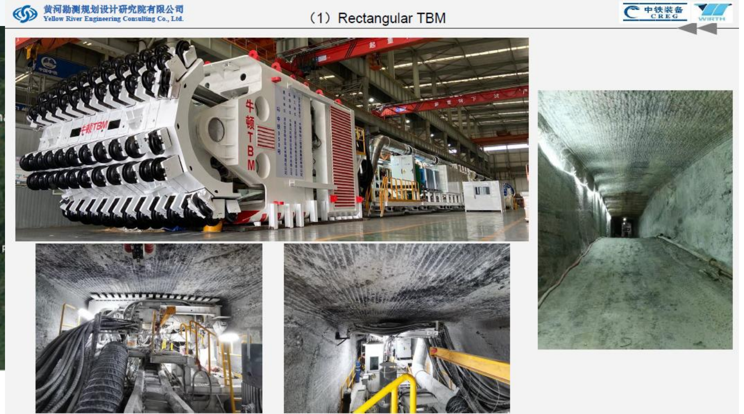
TBM tunnel (D6.5m)



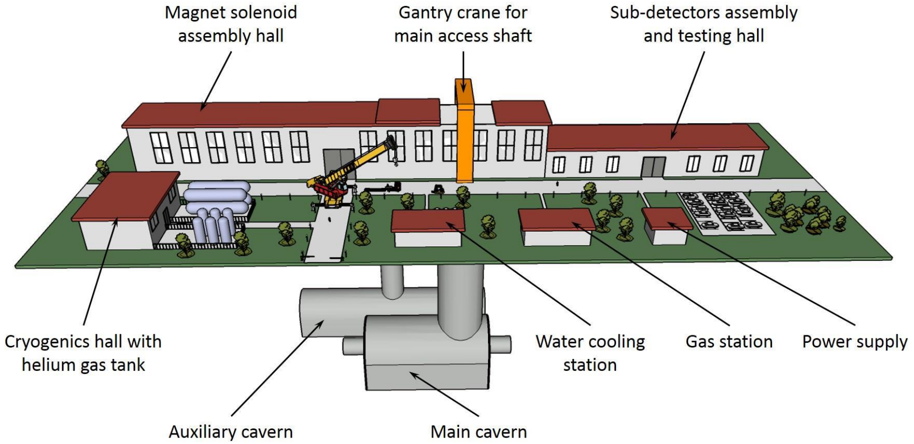


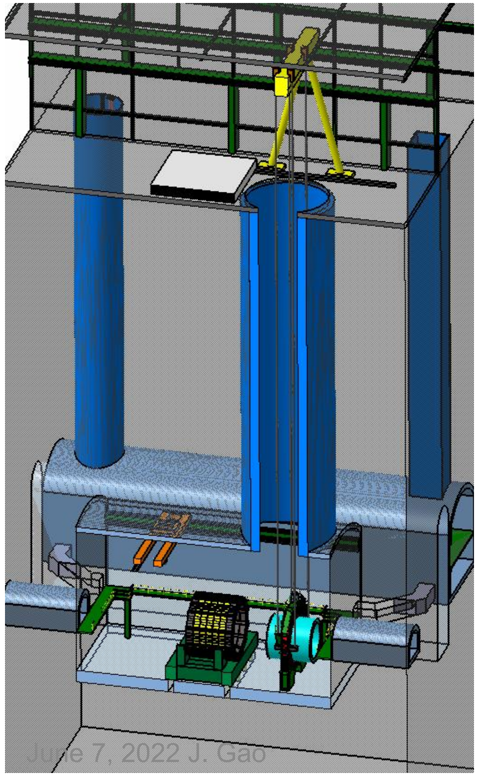
Item	Unit	Drill-blast	TBM
The clearance cross section	m²	27.00	33.20
Excavation unit price	Yuan/m³	278.28	617.00
Construction duration	Month	50	52

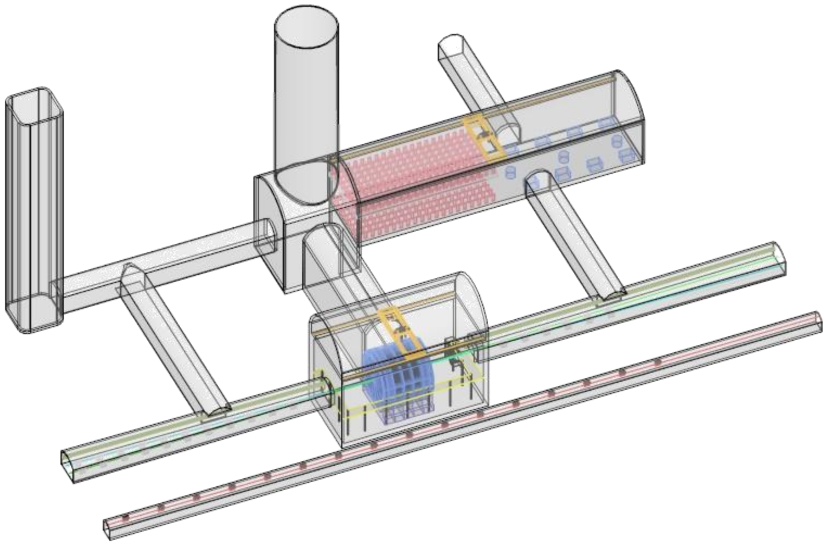




CEPC IR Region



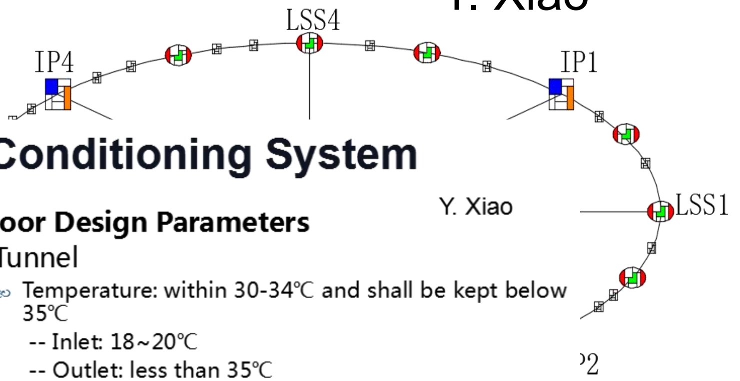




Name	L×W×H	Numb.
Experimental hall	39.4×20.4×31	×2
Axiliary hall	101.4×20×26.2	×2
Booster tunnel	1679×3.5×3.5	×4
Collider tunnel	1659.3x(6~11.4)x5	×4
Travel shaft	1200x7.5x7.5	×2
Connection, electric cable and ventilation shaft	70x10x10	×2

CEPC Auxiliary Facilities

Y. Xiao



Electric power demand

Total: 270.37MW (CDR)(upgrade 350MW)

	System for Higgs (30 MW /beam)	Location and Power Requiren			
		Collider	Booster	Linac	BTL
1	RF Power Source	103.8	0.15	5.8	
2	Cryogenic System	15.67	0.89		

Heating Ventilation Air Conditioning System

Y. Xiao

- **Estimated cooling loads of HVAC**
  - Ring tunnel: **6MW**
  - Service buildings: (200W/m²) 28MW
  - Total: **34MW**
- **Coolant for air conditioning: chilled water**
- **Heat source for heating system in winter**
  - Heat pump -- heat recover from cooling

- **Indoor Design Parameters**
  - Tunnel
    - Temperature: within 30-34℃ and shall be kept below 35℃
      - -- Inlet: 18~20℃
      - -- Outlet: less than 35℃
    - Relative humidity: 50% ~ 60%, and shall be lower than 65%
  - Experimental halls
    - emperature: about 26℃(summer), 20℃(winter)
    - elative humidity: 50% ~ 60%, and shall be lower han 65%.
  - ntrol room (or electronics)
    - emperature: about 20-25℃
    - elative humidity: 45% ~ 60%
  - ner service building
    - emperature: about 28℃(summer), 18℃(winter),
    - elative humidity: lower than 65%

1, IHEP 57

Cooling Wa

- **Key requirements and parameters**
  - **Total heat load : 212.186MW**
    - -- The heat load of 190.915MW dissipated by CEPC machin
    - -- The heat load of 21.945MW dissipated by the motors of
  - **Total flow rate of LCW: 30157 m³/h**
  - **Total flow rate of CTW: 40092 m³/h**
  - Cooling water temperature
    - -- **Cooling tower water temperature: ＜ 29℃**
    - (Base on wet-bulb air temperature of 27℃ ambient; machi
    - -- **LCW cooling water temperature: ＜ 32 ℃**
  - DW : Single DW unit can produce 3~5t/h deionized wa following standards.
    - -- Resistivity reach 18 MΩ·cm
    - -- Other parameters satisfy EW-1 requirements.
  - Water consumption : 14011m³/d (1.5% CTW)
  - Storage capacity of low-level radioactive wastewa

2021-11-01 J. Gao 7th CEPC IAC Meeting, Nov. 1, 20

Energy Saving Consideration (Green CEPC)

Y. Xiao

- **Reduce power consumption**
  - Auxiliary facility should be **built near to the heat load center.**
  - **Minimize the operating pressure.**
  - Electric power consumption of auxiliary facility reaches **38.53 MW**. Using **high efficiency motor** and **variable frequency motor** will help to reduce energy consumption.
  - Adopting **high temperature chiller**, the cooling efficiency will increase by 2~3% for every 1℃ increase of water outlet temperature.
- **Thermal energy recovery**

  Through heat recovery chiller, heat exchanger maximizes the heat absorbed by LCW as several heat sources.
  - Air conditioning heat source
  - Heating source in winter.(If possible, the heat supply could radiate to surrounding residential areas)
  - Other heat sources

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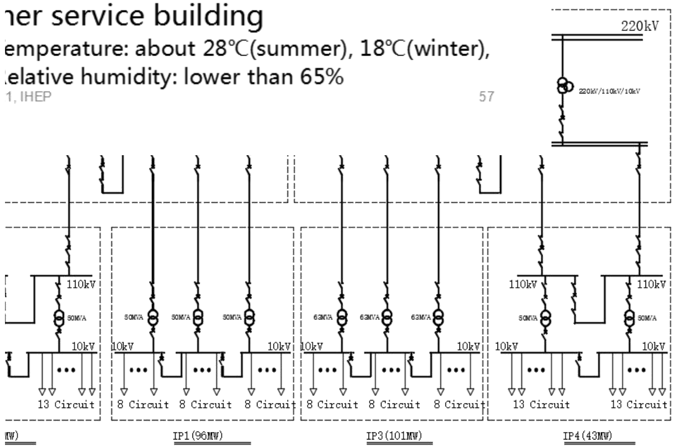
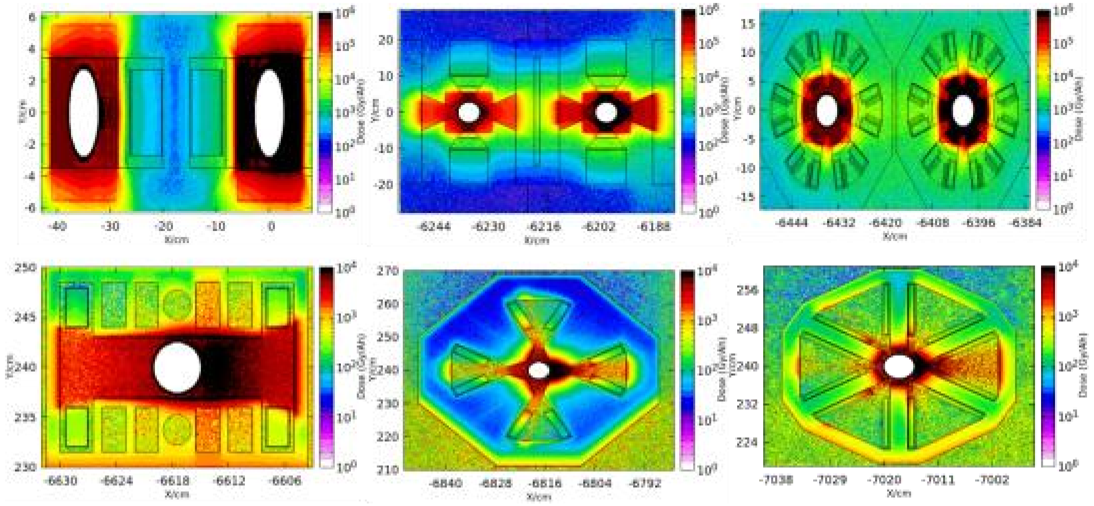


CEPC Site Rock Environment (Changsha example)

G.Y. Tang

- Average components of different kinds of rock are used for radiation calculation
- Simulate residual nuclei in:
  - Cooling water
  - Air in tunnel
  - Water outside tunnel
  - Rock



		Soil	Average components of 花岗岩、片麻岩、黄土、砂岩	Changsha site 长沙黑麋峰
density		1.6g/cm^3	1.2~3.3g/cm^3	~2.9g/cm^3
Major element (wt%)	C	1.0	---	---
	N	0.12	---	---
	O	34	30~70	48.3
	Na	0.50	0.1~2.9	2.4
	Mg	0.52	0.4~3.7	0.2
	Al	8.0	3.5~9.7	7.8
	Si	40	26~39	34
	P	---	0.02~0.16	0.06
	K	2.36	1.8~3.7	4.2
	Ca	2.26	0.2~4.8	1.0
	Ti	1.0	0.09~0.8	0.11
	Mn	0.24	0.02~0.12	0.02
	Fe	9.6	0.8~6.3	1.1

Radiation in the rock around the tunnel

		Half-life	Case 1		
			Specific activity/GB18871	Activity/GB18871	Stat. error (%)
Beam losses @Z-pole	Ar37	35d	4.45E-08	8.52E+01	0.697
	Cl36	3e5a	1.45E-11	2.77E-02	0.563
	S35	87d	9.35E-09	1.79E+00	6.826
	P33	25d	5.57E-09	1.07E+00	8.923
	P32	14d	1.44E-06	2.76E+03	5.557
	Si31	2.6h	6.82E-04	1.31E+05	0.123
	Na24	15h	3.26E-01	6.24E+06	0.113
	Na22	2.6y	7.20E-04	1.38E+03	1.322
	F18	1.8h	7.62E-04	1.46E+03	2.468
	O15	122s	1.34E-03	2.58E+01	0.694
	C14	5700y	3.47E-10	6.65E-02	1.337
	Be7	53d	2.09E-05	4.00E+02	1.632
	H3	12a	5.90E-09	1.13E+00	0.884

		Half-life	Case 1		
			Specific activity/GB18871	Activity/GB18871	Stat. error (%)
SR @ttbar	C14	5700a	1.5e-12	2.9e-4	99
	H3	12a	9.5e-11	1.8e-2	71

Radiation in the air of the tunnel

G.Y. Tang

		Half-life	Case 1			Case 2		
			Specific activity/GB18871	Activity/GB18871	Stat. error (%)	Specific activity/GB18871	Activity/GB18871	Stat. error (%)
Beam losses @Z-pole	O15	122s	2.7e-4	0.13	52	3.2e-4	0.15	17
	C14	5700a	7.7e-7	3.6	1	3.2e-7	1.5	0.5
	Be7	53d	1.1e-5	5.4	57	1.0e-5	4.8	27
	H3	12a	3.5e-9	1.7e-2	32	3.9e-9	1.8e-2	10
	P32	14d	---	---	---	1.9e-7	9.0	100
	P33	25d	1.9e-8	9.0e-2	100	3.8e-9	1.8e-2	100
	Cl36	3e5a	---	---	---	1.6e-14	7.7e-7	100
	Cl38	37m	---	---	---	7.e-5	3.6	61
	Ar37	35d	6.1e-9	0.29	59	1.4e-9	6.5e-2	38
	Ar41	2h	1.4e-3	0.65	12	5.4e-4	0.26	6
SR @ttbar	C14	5700a	6.5e-6	31	2	2.5e-6	11.7	3
	Ar41	2h	1.5e-2	7.2	20	3.3e-3	1.6	29

Radiation in the cooling water

		Half-life	Case 1			Case 2		
			Specific activity/GB18871	Activity/GB18871	Stat. error (%)	Specific activity/GB18871	Activity/GB18871	Stat. error (%)
Beam losses @Z-pole	O15	122s	2.44	2.76	10	2.37	2.67	3
	C14	5700a	3.5e-7	3.9e-3	23	3.4e-7	3.9e-3	9
	Be7	53d	1.3e-2	15.2	34	1.3e-2	14.4	12
	H3	12a	2.3e-6	2.6e-2	22	2.8e-6	3.2e-2	7
SR @ttbar	None							

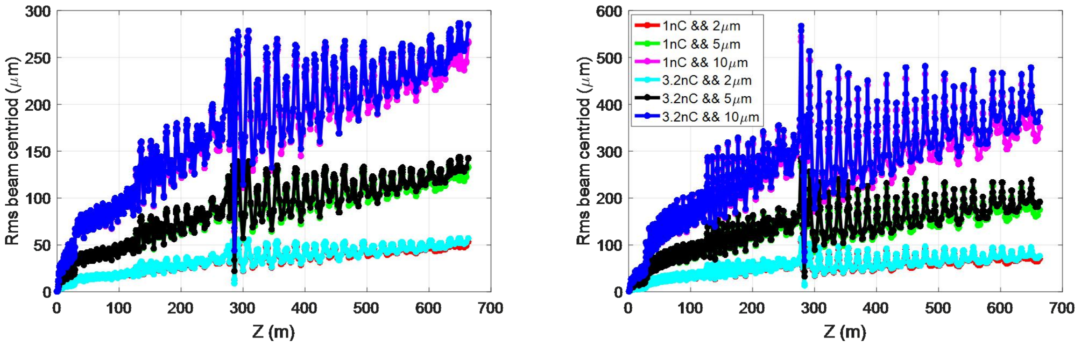
Preliminary Studies on CEPC Ground Motion

Y.W. Wang, C. Meng

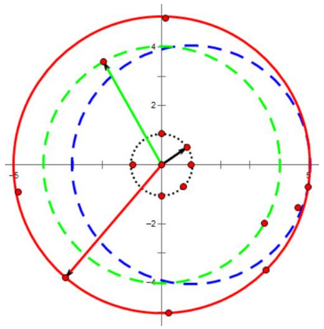
- Ground motion will increase cause beam orbit variation and also beam emittance

$$\frac{\Delta L}{L} \cong -\frac{(\Delta y/\sigma_y)^2}{4}$$

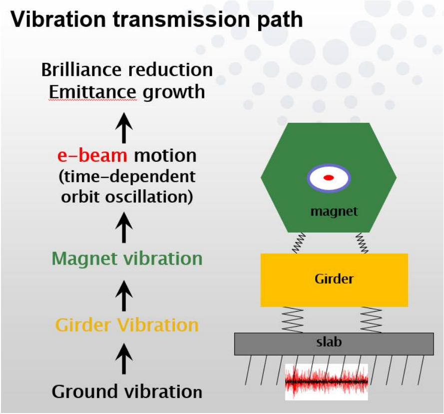
Amplitudes of ground motion (<100Hz) 4nm, 10nm, correspond to 1% or 6% Luminosity reduction



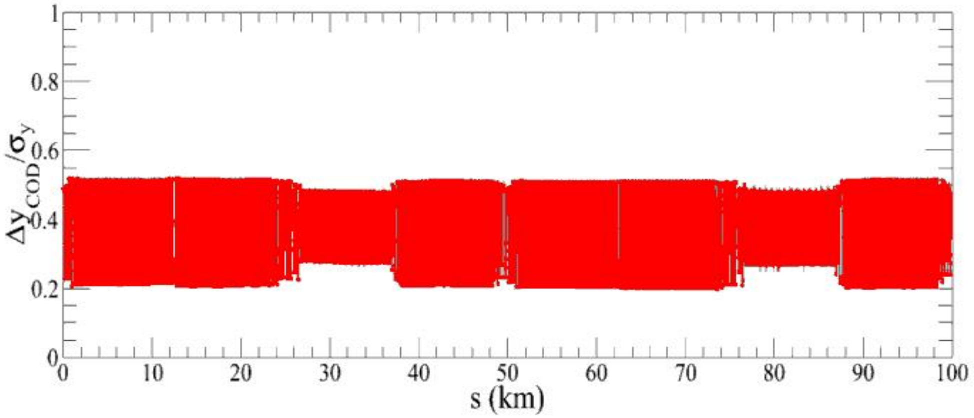
CEPC beam orbit variation in linac due to ground motion
With ground motion amplitude of 100nm, linac effective emittance increse 20%



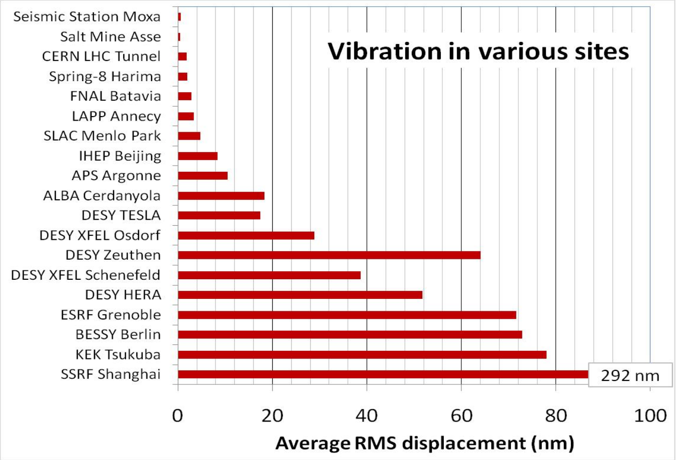
Effective emittance increase due to orbit variation



Ground vibration transmission to colliding beams



CEPC colliding beam orbit variation due to ground motion



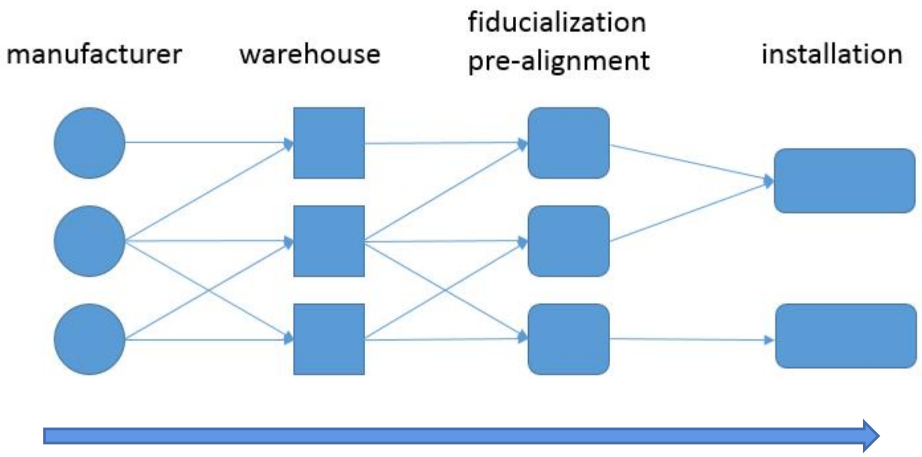
Ground vibration in different sites, LHC site is a good reference~3nm

CEPC Installation Strategy-1

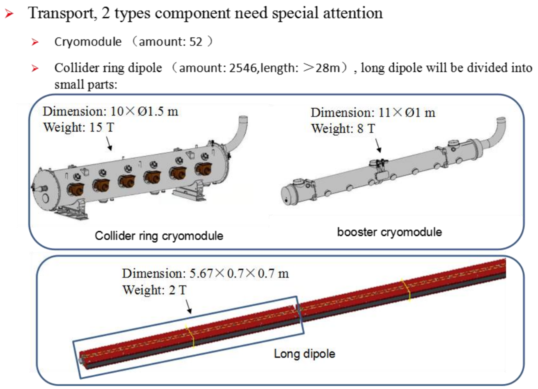
X.L. Wang

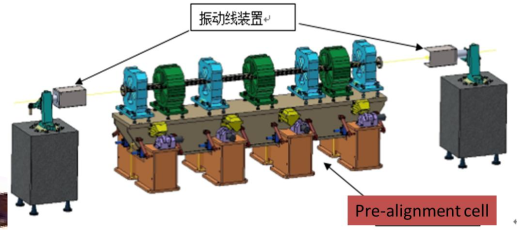
Installation and alignment scheme

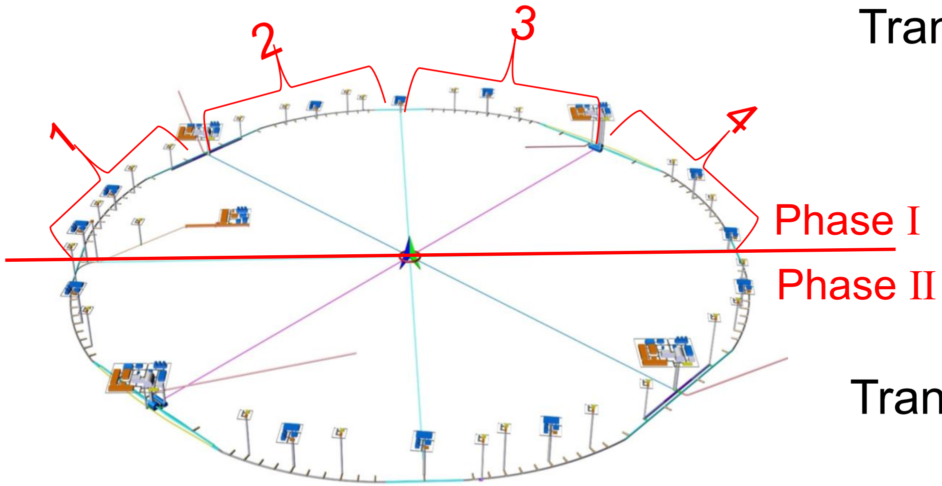
-Ring installation: phase Ⅰ, phase Ⅱ, each phase： half a ring

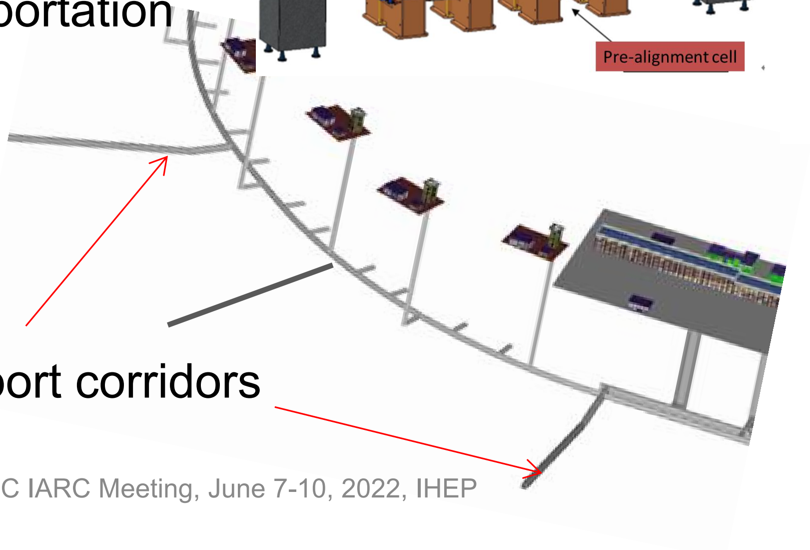


Transportation

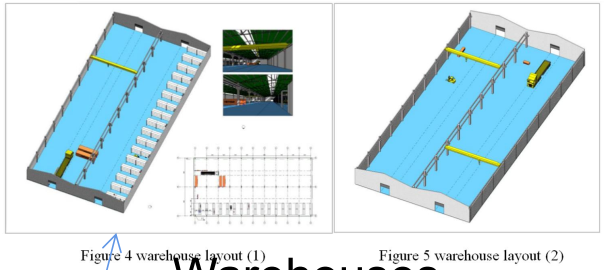




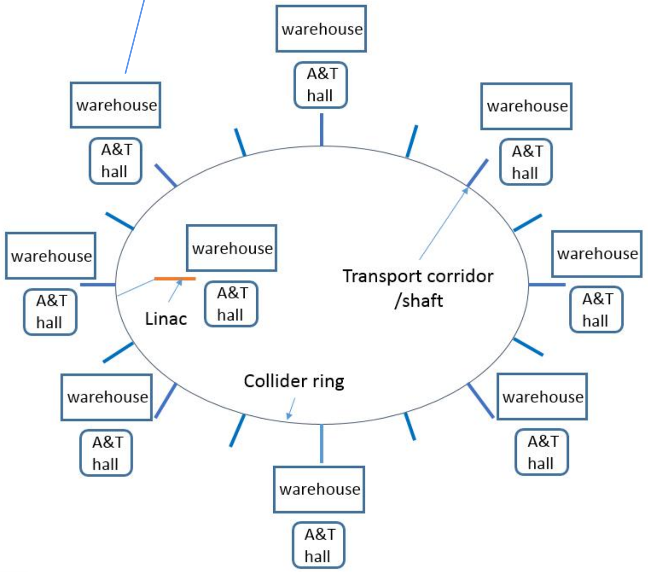


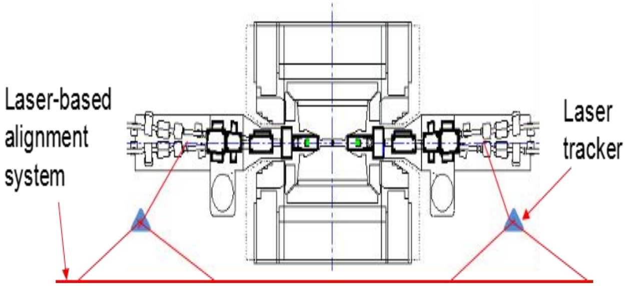


Transport corridors



Warehouses





CEPC Installation Strategy-2

X.L. Wang

Manpower and time arrangement of collider and booster ring installation and alignment

Phase	Group	Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
I	8	Network construction																																							
	16	Network measurement																																							
	16	Support setting out																																							
	16	Support installation																																							
	32+32	Ring installation																																							
II	8	Network construction																																							
	16	Network measurement																																							
	16	Support setting out																																							
	16	Support installation																																							
	32+32	Ring installation																																							

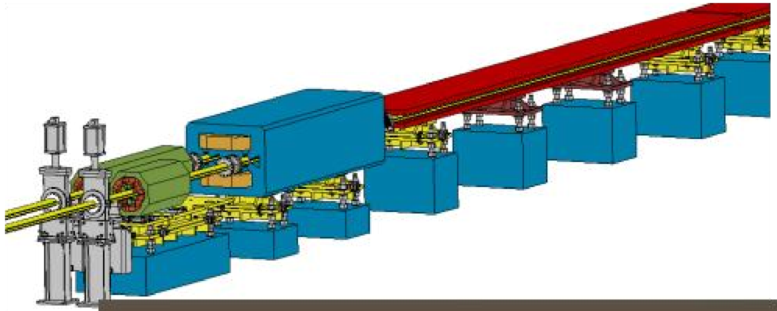
- The peak time Ⅰ, it needs 64 alignment groups and 56 installation groups.
- The Peak time Ⅱ, it needs 48 alignment groups and 48 installation groups.

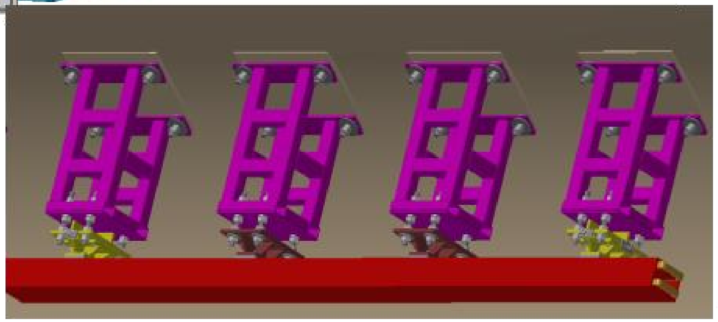
CEPC Accelerator Mechanical Supports and Installation Tools Inside the Tunnel

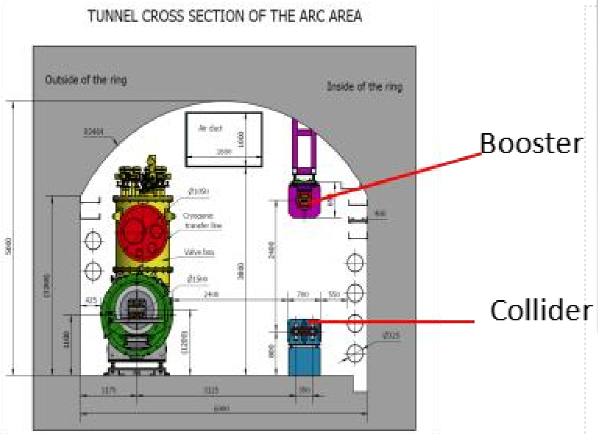
H.J. Wang

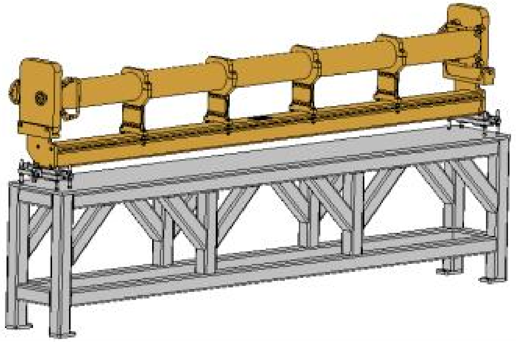
- Over 80% of the length is covered by magnets of about 138 types.

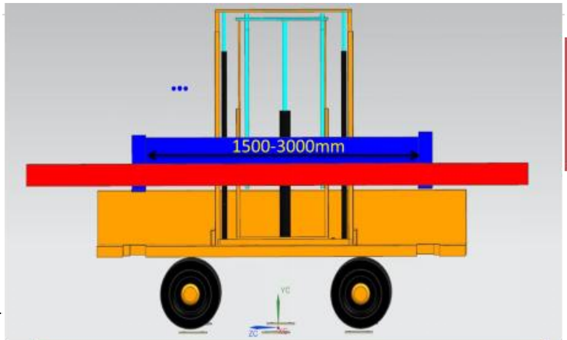
Adjustment Ranges of magnets			
X	≥±20 mm	Δθx	≥±10 mrad
Y	≥±30 mm	Δθy	≥±10 mrad
Z	≥±20 mm	Δθz	≥±10 mrad







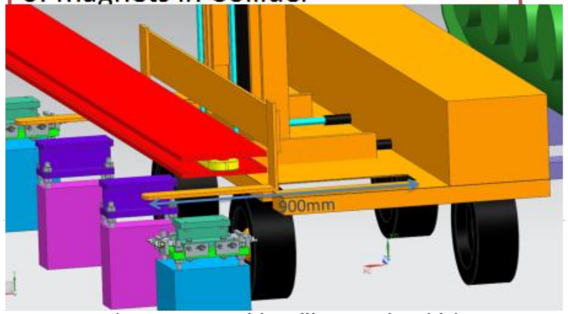


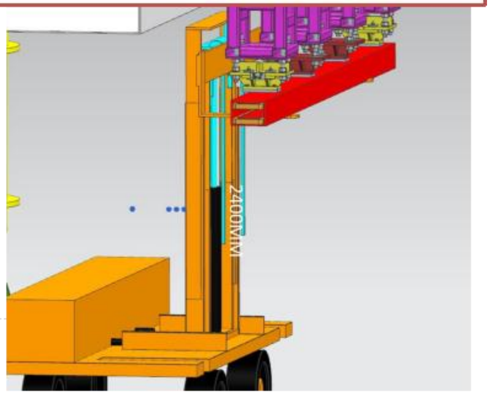


Flexible load support for "long" devices and "short" devices

Transportation and coarse location of magnets in Booster

Transportation and coarse location of magnets in Collider





* Cooperate with Beijing North Vehicle Group Corporation.

CEPC TDR Power (preliminary)

CEPC CDR 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 TDR Power for Higgs and Z

At Higgs energy (30MW) :
Collider ring power increment (MW): 9.81
Booster (MW):1
Linac (MW):10.4

Total power increment in TDR@Higgs:21.2

Total TDR power at Higgs: 266+15.8=**287MW**

At Z energy (SR/beam CDR16.5MW to TDR30MW):
Collider ring power increment (MW): 46.7
Booster (MW):2
Linac (MW):10.4
Total power increment in TDR@Z: 59.1

Total TDR power at Z: 149+59.1=**208MW**

- CEPC TDR power increase at Higgs energy compared with CDR is due to new lattices and linac increasing energy from 10GeV to 20 GeV
- CEPC TDR power increase at Z energy compared with CDR is due to new lattices and SR power/beam from CDR 16.5MW to TDR 30MW.

CEPC Cost Model Study in Relation with Collider Circumference

D. Wang, et al.

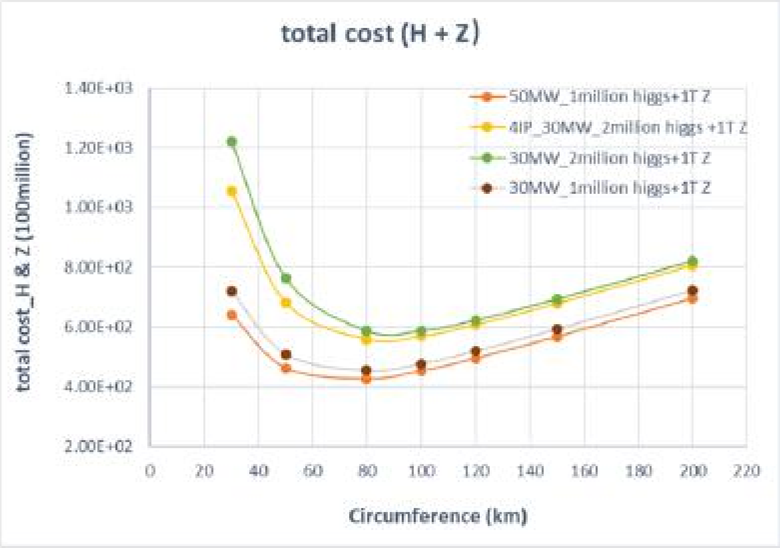
CEPC Cost Model Study and Circumference Optimization*

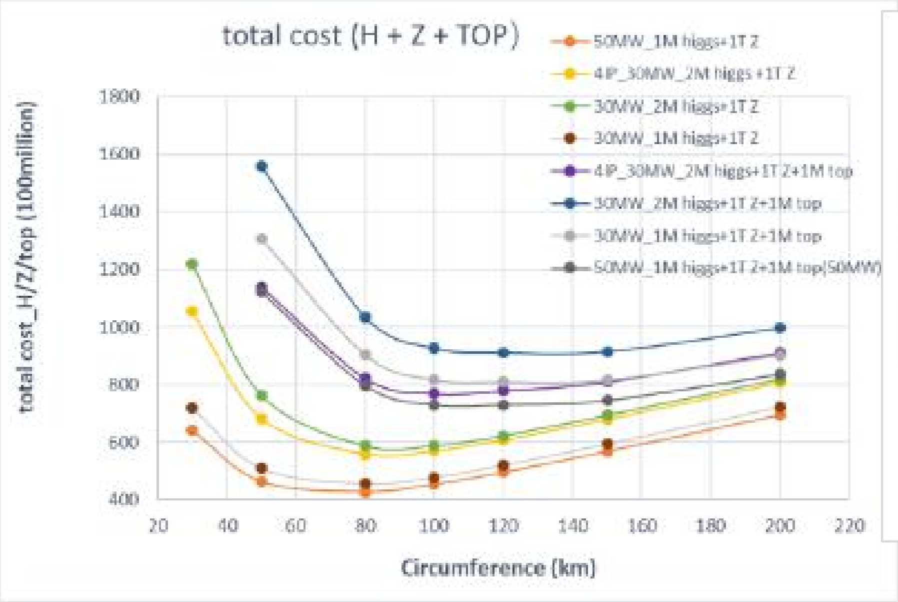
Dou Wang#, Jie Gao, Manqi Ruan, Yuhui Li, Haocheng Xu, Yudong Liu, Meng Li, Yuan Zhang, Yiwei Wang, Jiyuan Zhai, Zusheng Zhou

IHEP, Beijing, China

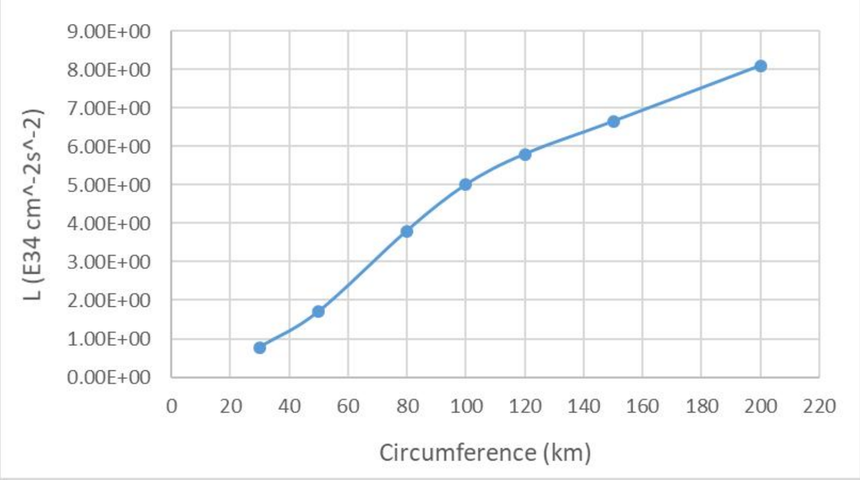
Abstract

An article has been submitted to NIM-A in 2022





Higgs luminosoty vs circumference



Global scientific goals (particle numers)/construction and operation costs shows that around 100km seems a very good choice

CEPC Time Plan and Accelerator TDR Schedule

CEPC Accelerator TDR Documentation Preparation and EDR Plans

TDR Contents (Draft)

0-Exectutive summary

Part I. TDR parameters and accelerator design
I-Collider lattice (Higgs, ttbar, , W, Z) design
II-Booster: Lattice design (Higgs, tt bar,W, Z)
III-Linac injector:
IV-Alternative plasma injector:
V-Global implementation:

Part II. CEPC Accelerator Key Technology
Fisibility R&D and Demonstration
I-Collider ring:
II-Booster ring;
III-Linac injector:
V-Global technologies:
VI-Facility development

Part III. CEPC TDR Cost and Power Comsumptions
Part. IV CEPC Siting and Civil Engingeering
Part V CEPC-SppC Compatibility
Part VI General Conclusion and Perspective for CEPC EDR Plan

TDR timeline:
TDR started to write after the first IARC reveiw in June 2022
TDR completes in Dec. 2022 (with IARC review, SC and IAC approval)

- **CEPC Accelerator EDR Phase Plan:Jan. 2023-Dec. 2025**

-CEPC site study converging to one or two with detailed feasibility studies (tunnel and infrastructures, environment)

-Engineering design of CEPC accelerator systems and components towards fabrication in an industrial way

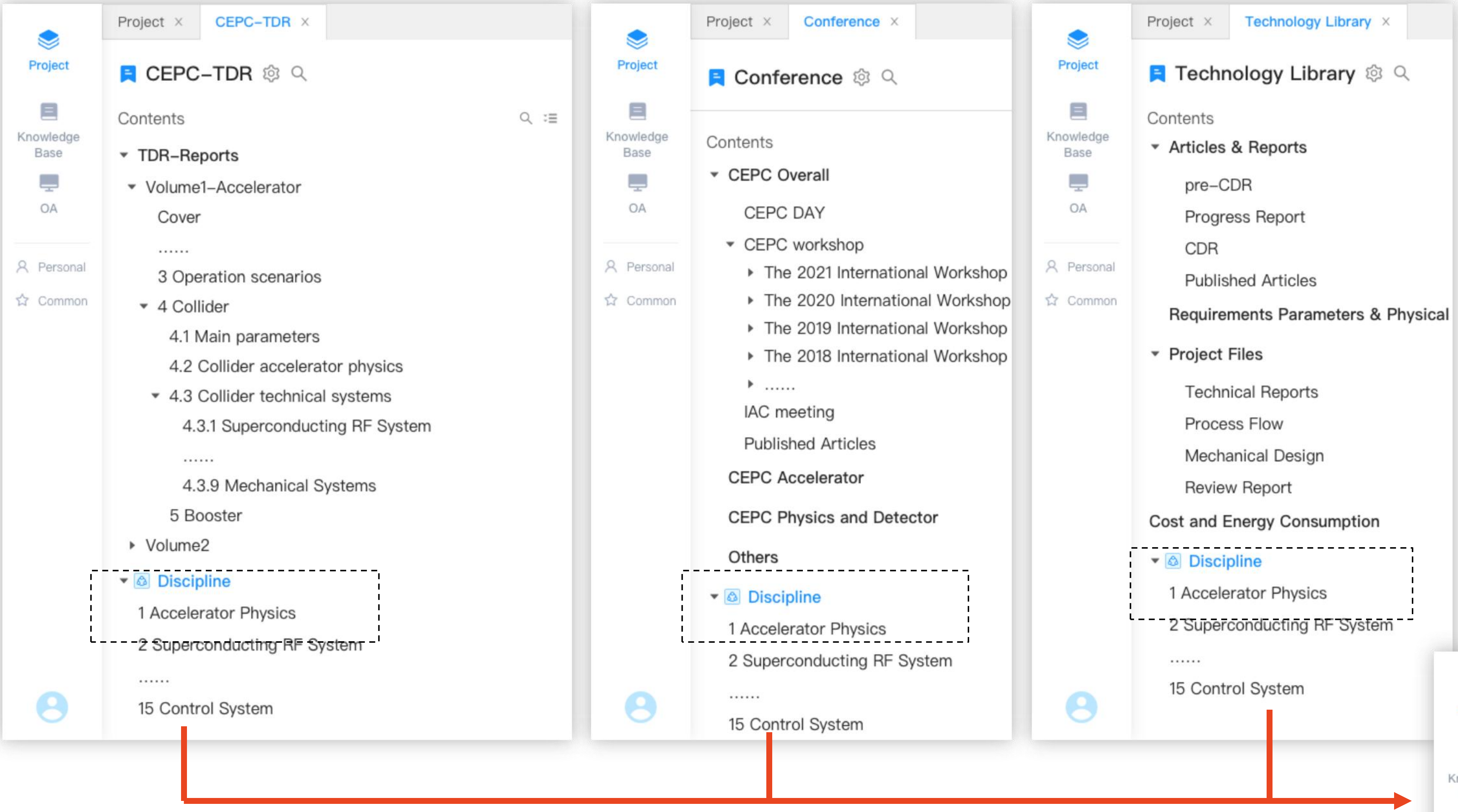
-Site dependent civil engineering design implementation preparation

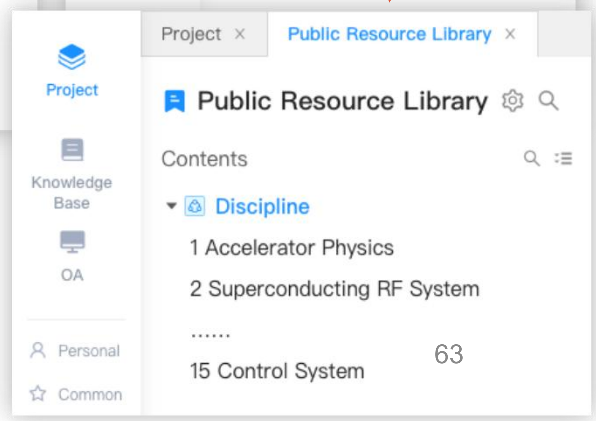
-Work closely with CAS and MOST to prepare CEPC be put in the “15th five year plan” (under way)

-EDR document completed for government’s approval of starting construction around 2026 (the starting of the “15th five year plan”)

CEPC Accelerator TDR Electronic Documentation System-DeepC Development

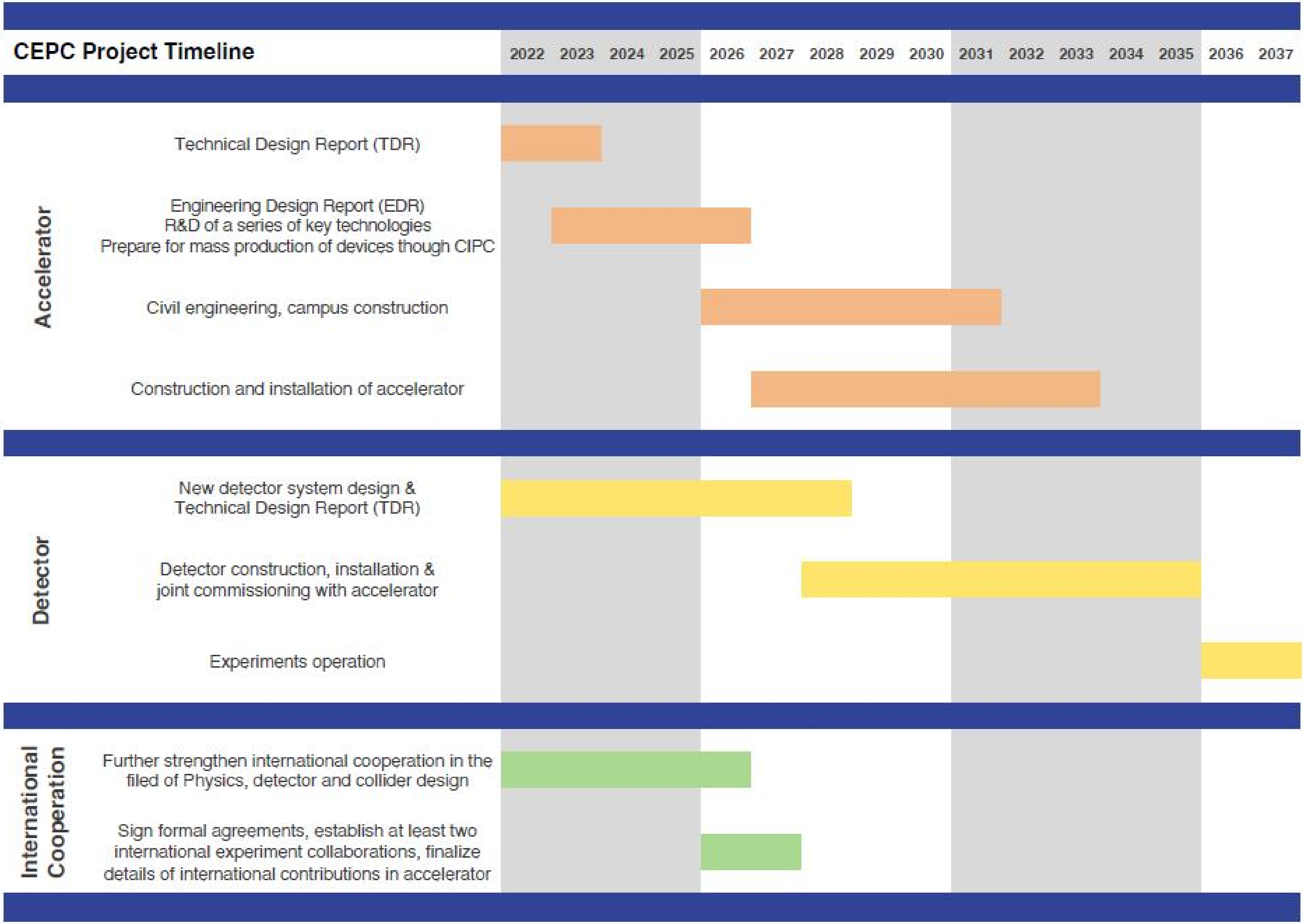
HYDROCHINA Huadong Company with IHEP





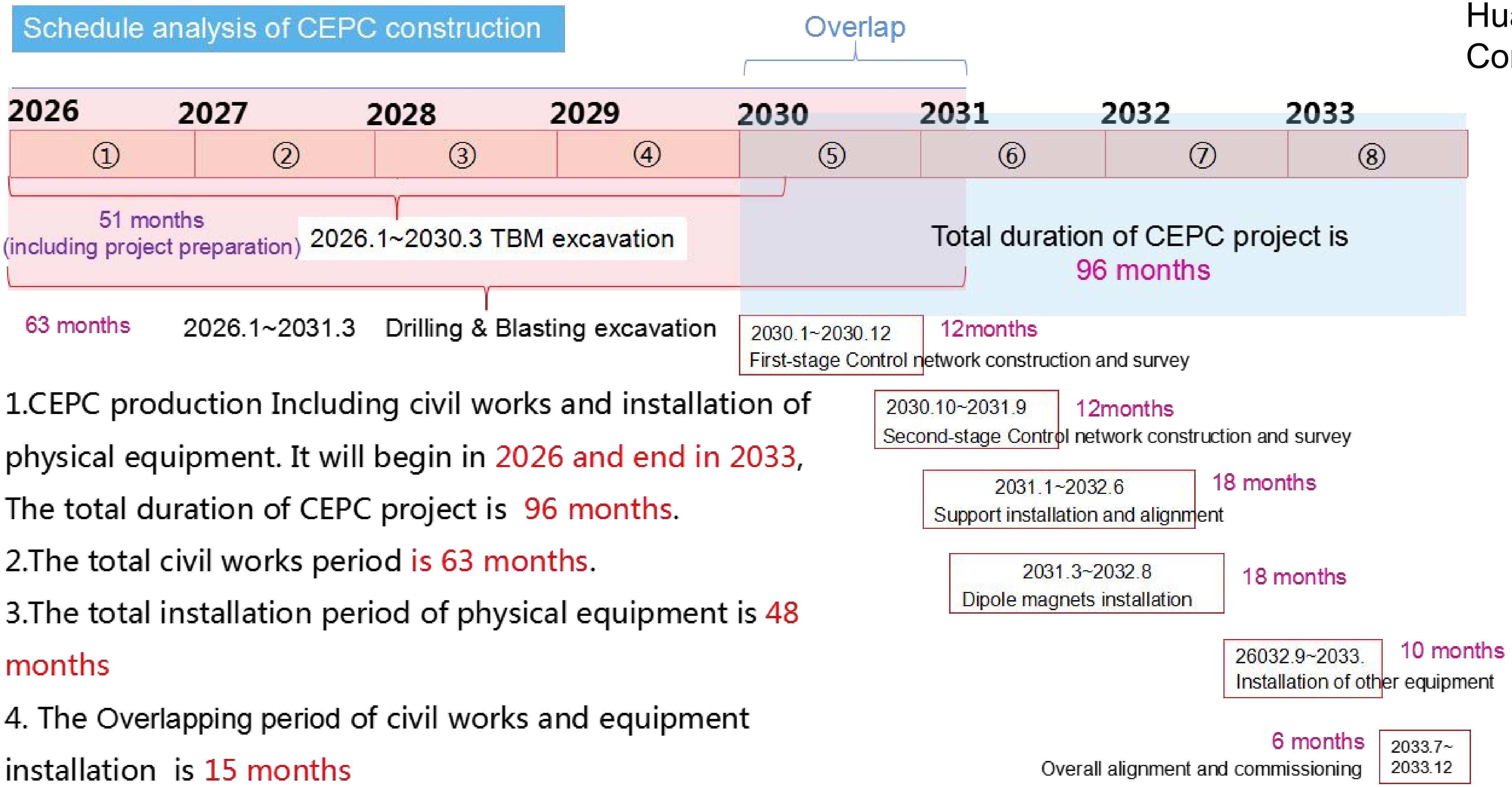
Four categories: TDR Preparation; Conference; Technology Library; Promotion

DeepC is a software developed jointly by HYDROCHINA Huadong Company with IHEP will be put to use started in August for CEPC TDR


CEPC Project Timeline
2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037
Accelerator
Technical Design Report (TDR)
Engineering Design Report (EDR)
R&D of a series of key technologies
Prepare for mass production of devices though CIPC
Civil engineering, campus construction
Construction and installation of accelerator
Detector
New detector system design &
Technical Design Report (TDR)
Detector construction, installation &
joint commissioning with accelerator
Experiments operation
International Cooperation
Further strengthen international cooperation in the
filed of Physics, detector and collider design
Sign formal agreements, establish at least two
international experiment collaborations, finalize
details of international contributions in accelerator

Civil Construction and Installation Timeline

Huadong Company



1.CEPC production Including civil works and installation of physical equipment. It will begin in 2026 and end in 2033, The total duration of CEPC project is 96 months.

2.The total civil works period is 63 months.

3.The total installation period of physical equipment is 48 months

4. The Overlapping period of civil works and equipment installation is 15 months

CEPC International Collaborations

CEPC International Collaborations

Possible synergies with FCCee

Dear Xinchou,

Thank you for message.

We would like to invite you to give a 20 minute presentation in the plenary session on Monday, 30 May, from 17h40 to 18h00 with the title **"Status of CEPC and possible synergies with FCC-ee developments"**

Please confirm your availability and register for the conference.

Best regards,

Michael

Collaboration with KEK on Super KEK B

The extension Multi-National Partnership Project (MNPP-01) MoU of IHEP with KEK Super B is on going. (Thanks to the support from Prof. M. Tobiyama)

Under MNPP-01 more than 10 CEPC accelerator specialists have visited KEK and workded on KEK Super KEK B collaborations

Report of the 19th Annual Meeting of the CERN Machine Advisory Committee

LHC Performance Workshop, January 24-27, 2022

The members: Ralph Assmann (DESY), Mei Bai (SLAC), Jie Gao (IHEP), Tadashi Koseki (KEK), Valerie Lebedev (JINR), Sergei Nagaitsev (FNAL), Mike Seidel (PSI, chair), and Pierre Vedrine (CEA).

ICFA Statement Regarding Higgs Factory Development and the ILC

https://icfa.hep.net/wp-content/uploads/ICFA_Statement_April2022_Final.pdf

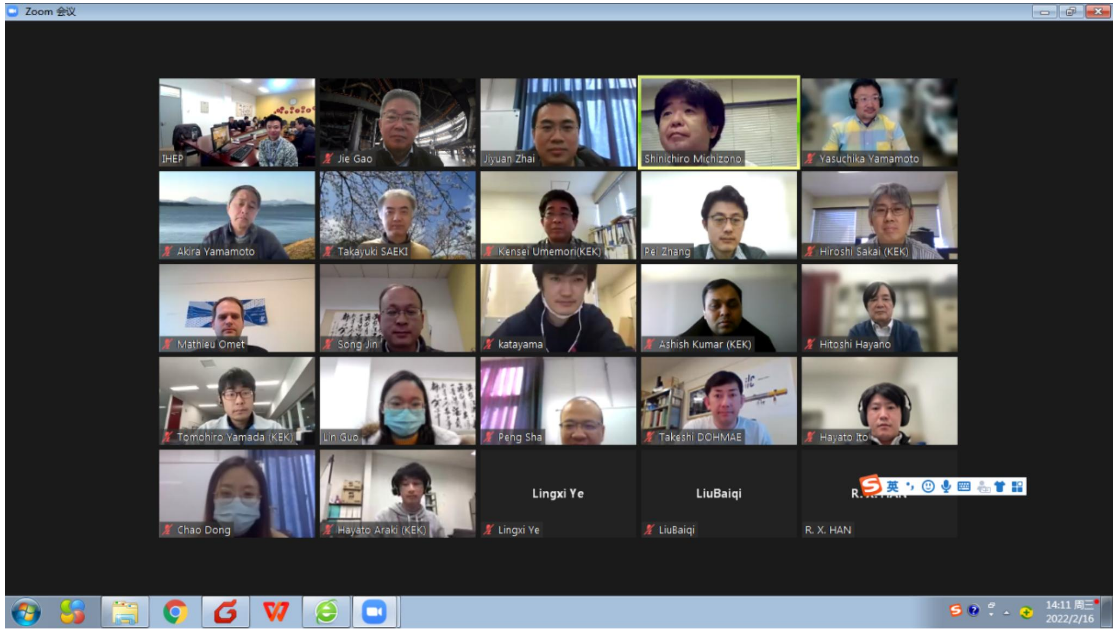
Various design studies based on different technologies are in progress, including both circular colliders (FCC-ee and CEPC) and linear colliders (ILC and CLIC). ICFA follows with great attention the development of Higgs Factory proposals worldwide and recognizes the importance of advancing such concepts.

Since Jan. 1, 2022, J. Gao has become CERN Machine Advisory Committee Member

Since May 25, 2022, J.Gao has been approved by TTC CB to be TTC EC member

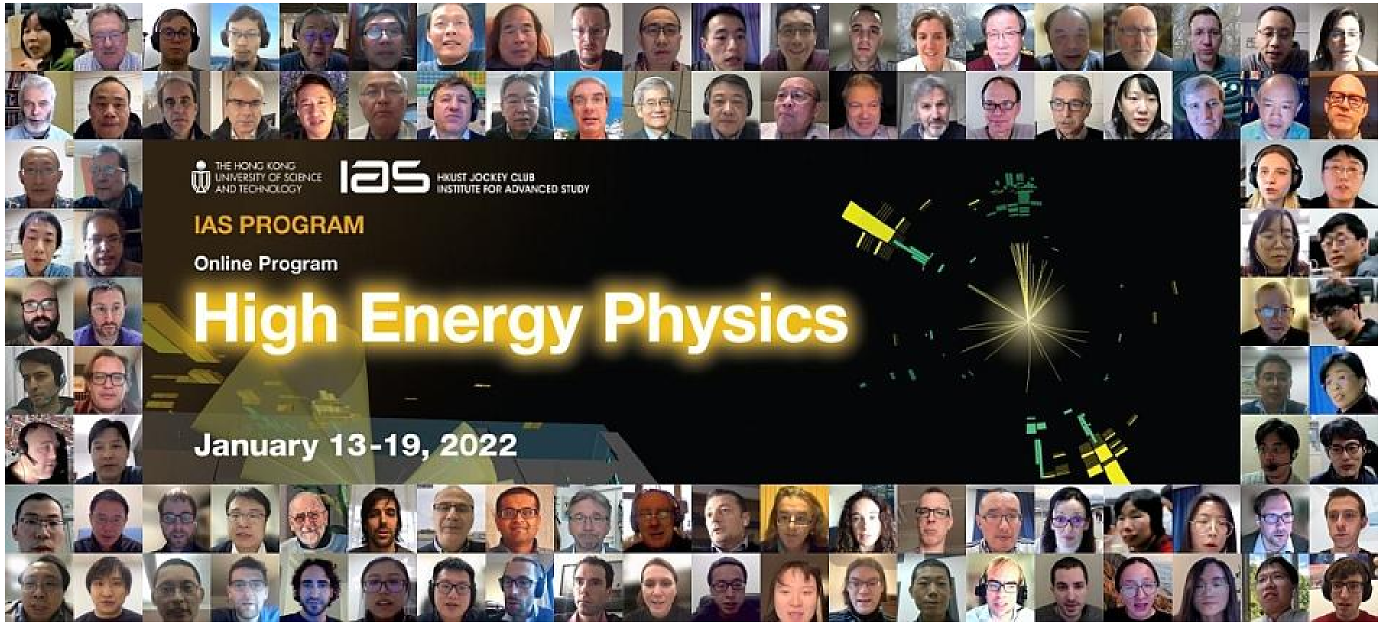
International Collaboration Meetings and Workshops

On Feb. 16, 2022, the 10th IHEP-KEK SRF Technology Collaboration Meeting was held online, more than 30 participants joined the meeting. J..Gao and Shinichiro Michizono co-chaired the meeting.



https://conference-indico.kek.jp/event/171/timetable/#20220216

HKIAS Mini workshop, **January 13-14, 2022,** on : Accelerator Physics — Key Beam Physics and Technologies Issues for Colliders. 41 talks from Asia, Europe and USA.
HKIAS 22 HEP Conference (ILC,CLIC,C3,FCC, CEPC, Muon Collider..) **January 17-19, 2022**



https://indico.cern.ch/event/1096427/timetable/#20220113.detailed

CEPC 2021 International Workshop and CEPC IAC Meeting in 2021

The 2021 international workshop on the high energy Circular Electron-Positron Collider (CEPC)

November 8-12, 2021, Nanjing (online) https://indico.ihep.ac.cn/event/14938/other-view?view=standard

		Monday 8th	Tuesday 9th	Wednesday 10th	Thursday 11th
Morning	9:00-10:30	Discussions	Discussions	Discussions	Discussions
	10:30 - 12:30	Higgs / Silicon / Accel. / CIPC	EW / Calor. / Accel. / CIPC	BSM / TDAQ / Accel. / CIPC	Flavor / Software / Perform. / CIPC
	12:30-14:00	Lunch break	Lunch break	Lunch break	Lunch break
Afternoon	14:00-15:30	Higgs / Silicon / Accel. / CIPC	EW / GasDet / Accel. / CIPC	BSM / TDAQ / Accel. / CIPC	Flavor / MDI / Accel. / CIPC
	15:30-16:00	Coffee break	Coffee break	Coffee break	Coffee break
	16:00-17:30	Higgs / Calor. / Accel. / CIPC	QCD / GasDet / Accel. / CIPC	QCD / Soft / Accel. / CIPC	CompMe / MDI / Perform. / CIPC
	17:30-20:00	Dinner		Dinner	Dinner
Evening	20:00-21:30	Plenary	Banquet		Plenary
	21:30-22:00	Coffee break			Coffee break
	22:00-23:30	Plenary		Special / Special / Special / Special	Plenary

Accelerator Parallel Session

52 Accelerator talks from around the world, **Asia, Europe and US**

CIPC Parallel Session on CEPC R&D

25 CIPC speakers in CEPC workshop

CEPC IAC Meeting in Nov. 2021

https://indico.ihep.ac.cn/event/15229/

Report:

The Seventh Meeting of the CEPC-SppC International Advisory Committee

November 9, 2021

CEPC Accelerator White Paper submissions to Snowmass21

Snowmass2021 White Paper AF3- CEPC

CEPC Accelerator Study Group[1]

1. Design Overview

1.1 Introduction and status

The discovery of the Higgs boson at CERN's Large Hadron Collider (LHC) in July 2012 raised new opportunities for large-scale accelerators. The Higgs boson is the heart of the Standard Model (SM), and is at the center of many biggest mysteries, such as the large hierarchy between the weak scale and the Planck scale, the nature of the electroweak phase transition, the original of mass, the nature of dark matter, the stability of vacuum, etc. and many other related questions. Precise measurements of the properties of the Higgs boson serve as probes of the underlying fundamental physics principles of the SM and beyond. Due to the modest Higgs boson mass of 125 GeV, it is possible to produce it in the relatively clean environment of a circular electron–positron collider with high luminosity, new technologies, low cost, and reduced power consumption. In September 2012, Chinese scientists proposed a 240 GeV *Circular Electron Positron Collider* (CEPC), serving two large detectors for Higgs studies and other topics as shown in Fig. 1. The ~100 km tunnel for such a machine could also host a *Super Proton Proton Collider* (SPPC) to reach energies well beyond the LHC.

The CEPC is a large international scientific project initiated and to be hosted by China. It was presented for the first time to the international community at the ICFA Workshop *"Accelerators for a Higgs Factory: Linear vs. Circular"* (HF2012) in November 2012 at Fermilab. A Preliminary Conceptual Design Report (Pre-CDR, the White Report)[1] was published in March 2015, followed by a Progress Report (the Yellow Report)[2] in April 2017, in which the CEPC accelerator baseline choice was made. The Conceptual Design Report (CEPC Accelerator CDR, *the Blue Report*) [3] has been completed in July 2018 by hundreds of scientists and engineers after an international review from June 28-30, 2018 and was formally released in Nov. 2018. In May 2019, CEPC accelerator document was submitted to European High Energy Physics Strategy workshop for worldwide discussions [4]. After the CEPC CDR, CEPC accelerator entered the phase of Technical Design Report (TDR) endorsed by CEPC International Advisory Committee (IAC). In TDR phase, CEPC optimization design with higher performance compared with CDR and the key technologies such as 650MHz high power and high efficiency klystron, high quality SRF accelerator technology, high precision magnets for booster and collider rings, vacuum system, MDI, etc. have been carried out, and the CEPC accelerator TDR will be completed at

[1] Correspondance: J. Gao, Institute of High Energy Physics, CAS, China
Email: gaoj@ihep.ac.cn

CEPC Accelerator white paper to Snowmass21, arXiv:2203.09451
Snowmass21 series meetings and document submissions

1)J. Gao,Circular Electron Positron Collider (CEPC), Snowmass21 Agora meeting, Jan. 19, 2022.

2）J.Gao, "CEPC 50MW upgrade parameters",Snowmass21 AF ITF Meeting , Feb. 10， 2022

Summary

- CEPC accelerator system optimization design based on TDR parametersc considering also 50MW and tt bar energy upgrade possibilities are converging

- CEPC accelerator key hardware R&D made important progresses with the aim of finishing TDR at the end of 2022

- SppC high field magnet R&D progress well

- CEPC siting, civil engeering, installation planning, international collaborations and CIPC collaborations are progressing well

- Preparation for EDR and beyond (15th five year plan) is underway

Acknowledgements

- Thanks go to CEPC-SppC accelerator team's hardworks, international and CIPC collaborations

- Special thanks to CEPC SC, IAC and IARC's critical comments, suggestions and encouragement

Backup Slides

CEPC CDR-Higgs

Peak Luminosity = $3\times 10^{34}cm^{-2}s^{-1}$

Ingetrated Luminosity = 5.6 ab^{-1}

Higgs annual luminosity =0.8 ab^{-1}

CEPC TDR-Higgs

Peak Luminosity = $5\times 10^{34}cm^{-2}s^{-1}$

Ingetrated Luminosity = 9.3 ab^{-1}

Higgs annual luminosity =1.3 ab^{-1}

CEPC TDR-Higgs (upgrade)

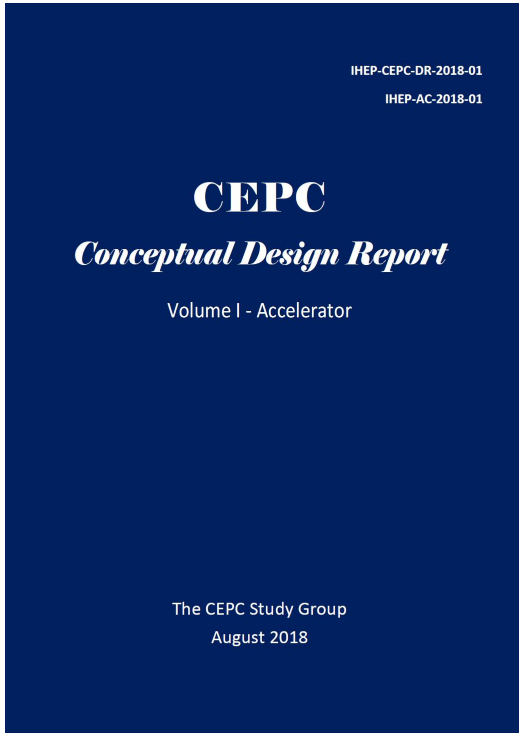
Peak Luminosity = $8.3\times 10^{34}cm^{-2}s^{-1}$

Ingetrated Luminosity = 15.4 ab^{-1}

Higgs annual luminosity =2.2 ab^{-1}

These parameters are used for Snowmass21

CEPC CDR Vol. I, Accelerator



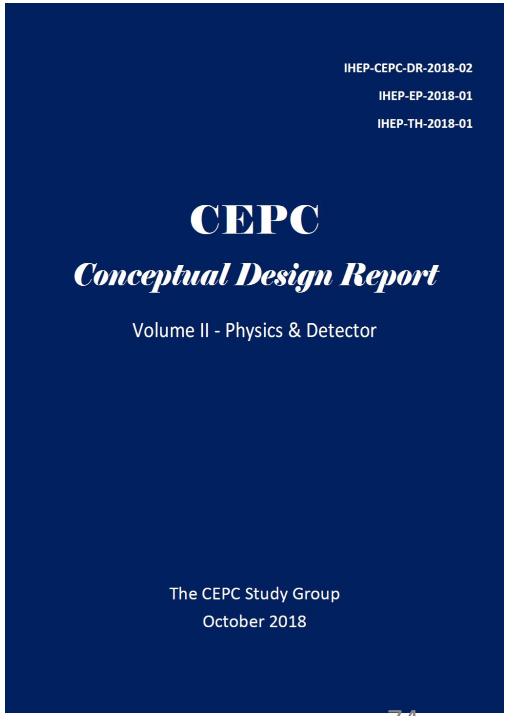
CEPC Accelerator Snowmass 21 AF White Paper

1) CEPC Accelerator white paper to Snowmass21, arXiv:2203.09451

2) CEPC CDR Vol. I, Accelerator ,http://cepc.ihep.ac.cn/CEPC_CDR_Vol1_Accelerator.pdf

3) CEPC CDR Vol. II, Physics and Detector, http://cepc.ihep.ac.cn/CEPC_CDR_Vol2_Physics-Detector.pdf

CEPC CDR Vol. II, Physics/Detector



SppC Collider Accelerator Physics
-Parameter list (updated Feb. 2022)

Jingyu Tang
Haocheng Xu

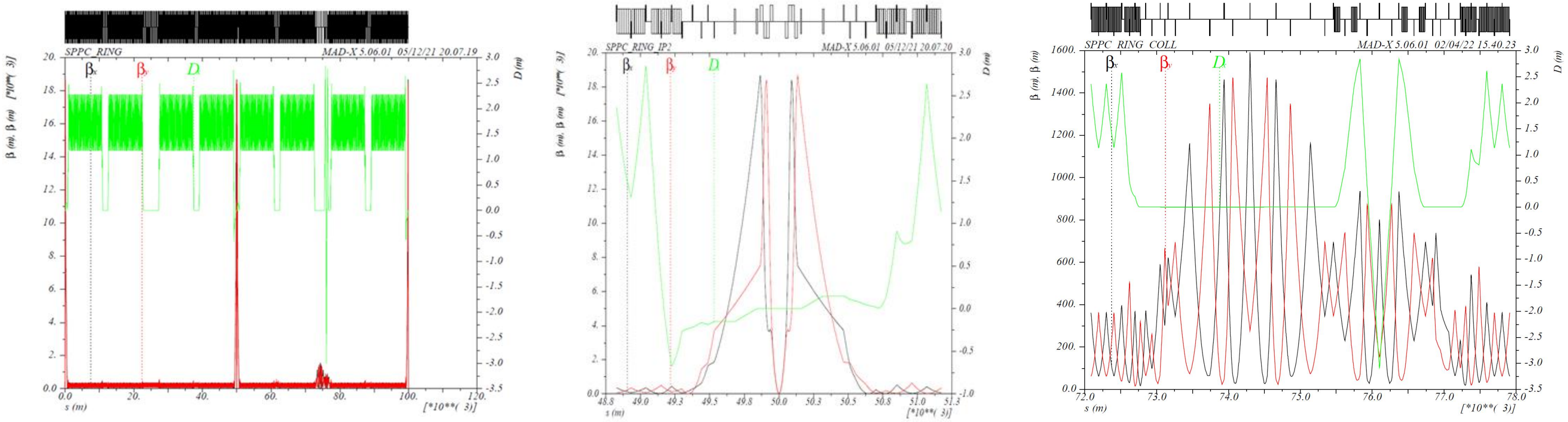
Main parameters		
Circumference	100	km
Beam energy	62.5	TeV
Lorentz gamma	66631	
Dipole field	20.00	T
Dipole curvature radius	10415.4	m
Arc filling factor	0.780	
Total dipole magnet length	65442.0	m
Arc length	83900	m
Total straight section length	16100	m
Energy gain factor in collider rings	19.53	
Injection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

Normalized rms transverse emittance	1.2	μm
Beam life time due to burn-off	8.1	hour
Turnaround time	2.3	hour
Total cycle time	10.4	hour
Total / inelastic cross section	161	mbarn
Reduction factor in luminosity	0.81	
Full crossing angle	73	μrad
rms bunch length	60	mm
rms IP spot size	3.0	μm
Beta at the 1st parasitic encounter	28.625	m
rms spot size at the 1st parasitic encoun	22.7	μm
Stored energy per beam	4.0	GJ
SR power per ring	2.2	MW
SR heat load at arc per aperture	26.3	W/m
Critical photon energy	8.4	keV
Energy loss per turn	11.40	MeV
Damping partition number	1	
Damping partition number	1	
Damping partition number	2	
Transverse emittance damping time	0.51	hour
Longitudinal emittance damping time	0.25	hour

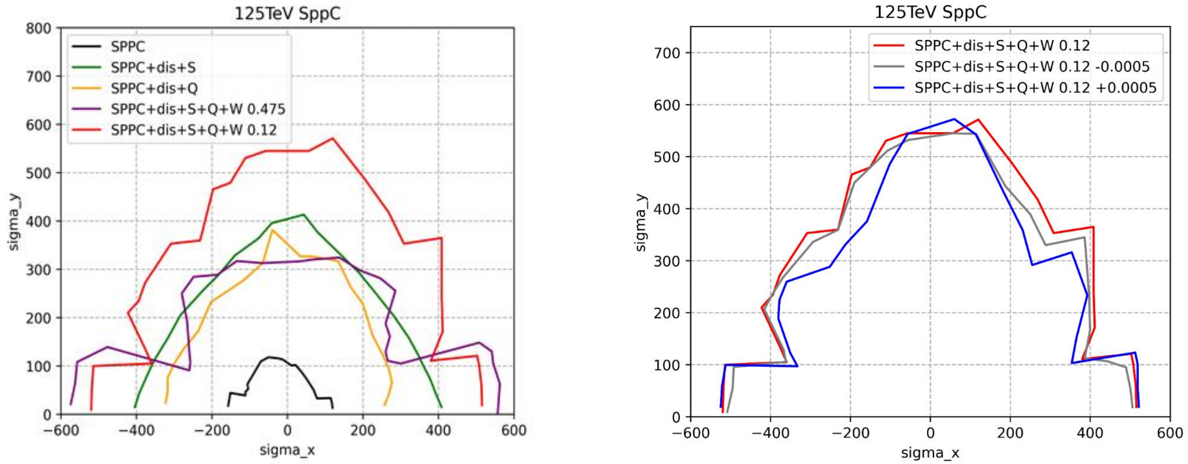
SppC Lattice Design

Haocheng Xu
Yiwei Wang

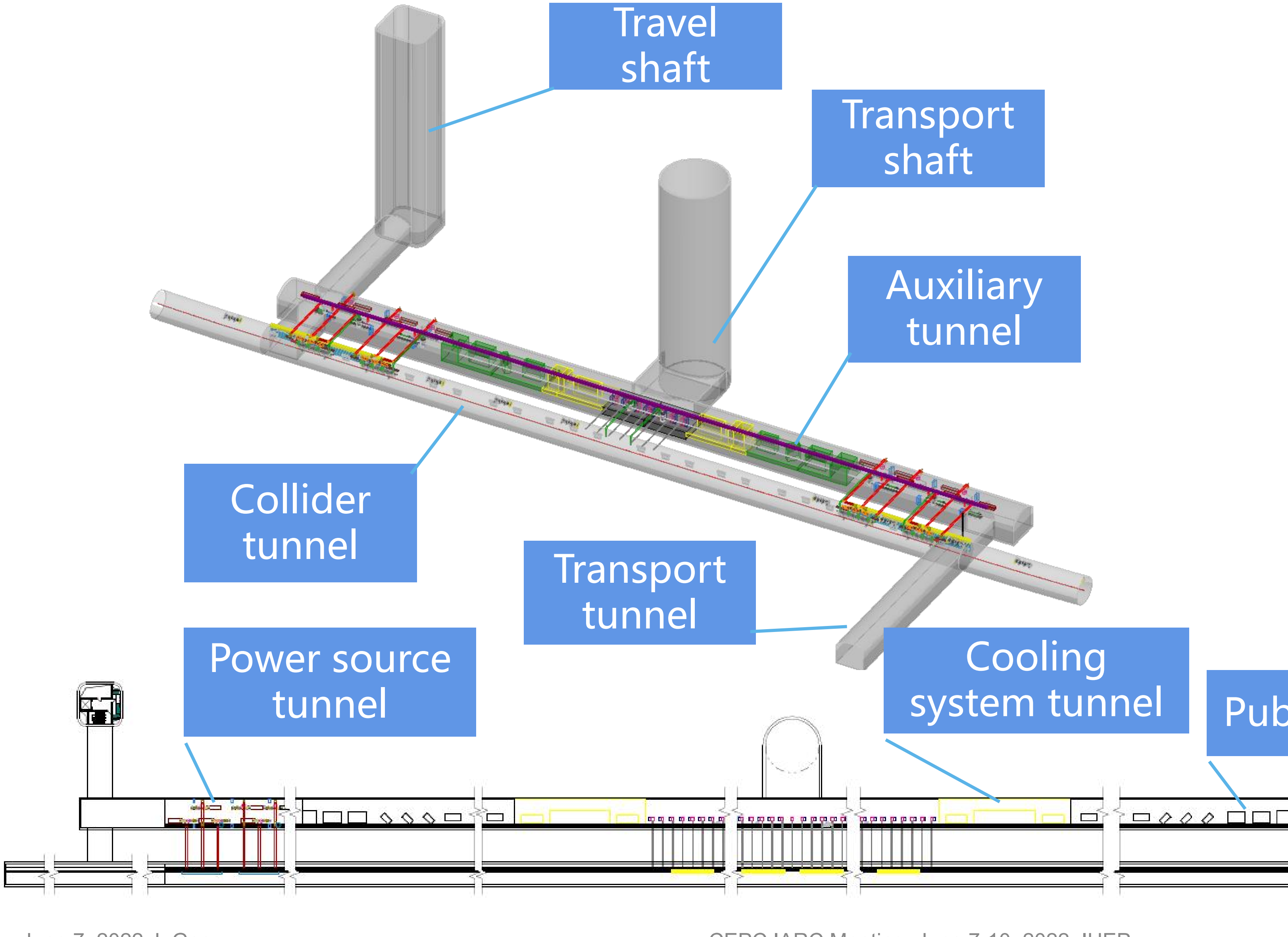
- Lattice of SPPC ring, IP and collimator section



- Dynamic Aperture Optimization



CEPC SCRF Region



Name	L×W×H	Numb.
SCRF auxiliary tunnel	1950×8×7	×2
SCRF collider tunnel	3500×6×5	×2
Transport shaft	15×70	×2
Travel, electric cable, ventilation tunnel	70×10×10	×2
SCRF transport tunnel	1200×88×7.5	×2

CEPC Conventional Facility and Civil Engineering

Cables installed!

Electrical Equipment General Layout in Auxiliary