中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

CEPC Accelerator : TDR + R&D Status

J. Gao

On behalf of CEPC Accelerator Group

8th Meeting of the CEPC-SppC International Advisory Committee

Oct. 31, 2022, IHEP

Contents

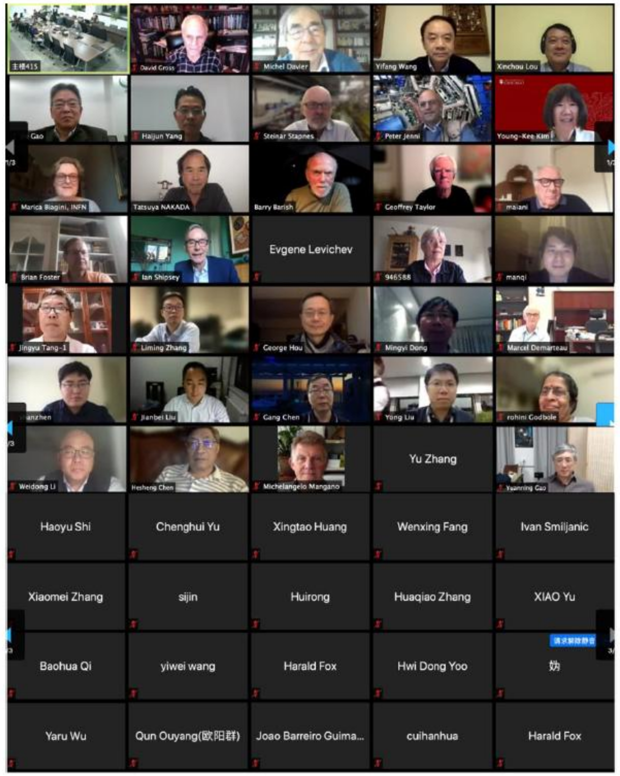
CEPC IAC2021

Nov. 1-5, 2021

Report:

The Sixth Meeting of
the CEPC-SppC International Advisory Committee

November 9, 2021



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

1. Overview

The seventh meeting of the CEPC-SppC International Advisory Committee took place virtually on November 1-3 and 5, 2021. The appendices to this report contain the charge for the meeting (Appendix A), the members of the IAC (Appendix B), and the agenda of the meeting (Appendix C). Due to different time zones, this meeting was much shorter than previous in-person meetings and missed informal exchanges of opinions. The IAC looks forward to in-person meetings with more detailed materials as soon as possible.

The IAC appreciates the implementation of the recommendations from the 2020 IAC meeting. The International Accelerator Review Committee (IARC) had its meetings virtually on May 11-12 and October 11-14, 2021 and its reports were available prior to this meeting. The IAC is grateful to the IARC for their detailed review of the progress in the accelerator design. Their reports were extremely valuable to the IAC.

The IAC is concerned about a new global reality and a recent reduction of the international community's involvement in the CEPC. The CEPC team's involvement in global scientific and technical activities will be critical to overcome some of these issues. It is important to position the CEPC project appropriately in particle-physics roadmaps as a fully international project. **The IAC recommends that the CEPC team increase its effort on generic worldwide accelerator and detector R&D and explore further collaboration with the CLIC, ILC, FCC-ee, and SuperKEKB groups for common effort in the accelerator and detector technical development.**

CEPC Accelerator IARC2022

June 7-10, 2022 (online)

The 2019 CEPC International Accelerator Review Committee

Review Report

December 6, 2019

The review mee
Circular Electro
Committee (IAR
(MDI) sessions

The IARC was p
TDR. The quali
even if not alre
luminosity perfo
improving the fo

The IARC is ple
would like to th
help and hospita

The 2021 CEPC International Accelerator Review Committee

Review Report

May 19, 2021

The CEPC Inter
due to the Covid
IARC meeting.

The Circular
currently hosted
Academy of Sc
accelerator in 2
Committee (IAC
CEPC accelerat
an International
to advise on all
the study of the

2021 Second CEPC IARC Meeting

IARC Committee

October 20th, 2021

The Circular Electron Positron Co
Collider (SppC) Study Group, curren
ergy Physics of the Chinese Academ
design of the CEPC accelerator in 20
ternational Advisory Committee (IAC
Report (TDR) phase for the CEPC ac
get year of 2022. Meanwhile an Inter
(IARC) has been established to advis
erator design, the R&D program, the
region, and the compatibility with an
well as with a future SppC.

The Committee congratulates the CE
last months and presented at this me
R&D of the hardware components lool
the table of parameters for the high-l
and components for all accelerator sy
lider.

2022 First CEPC IARC Meeting

IARC Committee

June 17th, 2022

The Circular Electron Positron Collider (CEPC) and Super Proton-Proton Collider (SppC) Study Group, currently hosted by the Institute of High Energy Physics of the Chinese Academy of Sciences, completed the conceptual design of the CEPC accelerator in 2018. As recommended by the CEPC International Advisory Committee (IAC), the group began the Technical Design Report (TDR) phase for the CEPC accelerator in 2019, with a completion tar-

A total of 24 talks were presented on a variety of topics.
The charges to CEPC IARC for this meeting are:

1. For the TDR, how are the accelerator design and the technology R&D progress towards the TDR completion at the end of 2022. Are there any important missing points in the accelerator design and optimization?
2. based on CEPC TDR design, the CEPC dedicated key technology R&D status and the technologies accumulated from the other IHEP responsible large-scale accelerator facilities, such as HEPS, could the CEPC accelerator group start the TDR editorial process and EDR preparation?
3. with the new progresses between CEPC and FCCee possible synergy and the continuing collaboration with SuperKEKB, are there more suggestions on the next steps of international collaborations?

Nov. 2019: https://indico.ihep.ac.cn/event/9960/

May, 2021: https://indico.ihep.ac.cn/event/14295

October, 2021: https://indico.ihep.ac.cn/event/15177

June, 2022: https://indico.ihep.ac.cn/event/16801/

All IARC reports (**2019-2022**) on IAC2022 Meeting Indico:
https://indico.ihep.ac.cn/event/17996/page/1415-materials

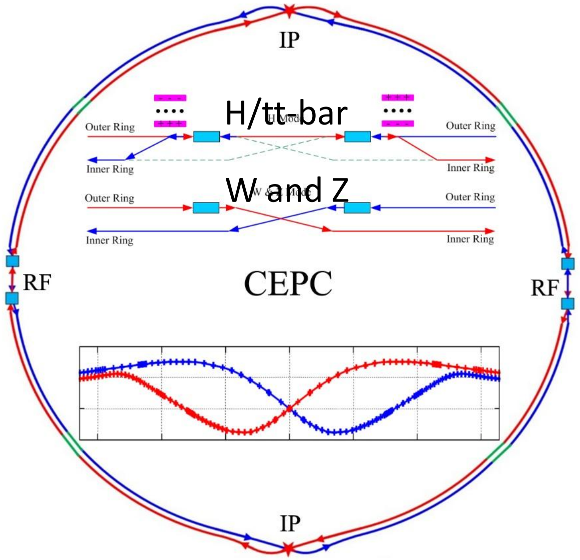
After the completeion of CEPC CDR in Nov. 2018, since the first CEPC IARC meeting in **2019**, there has been **toally 4 IARC meetings till 2022**, with each meeting a carefully written IARC report, which are very helpful for CEPC accelerator in TDR phase and beyond.

CEPC Accelerator System Design and Optimizations inTDR

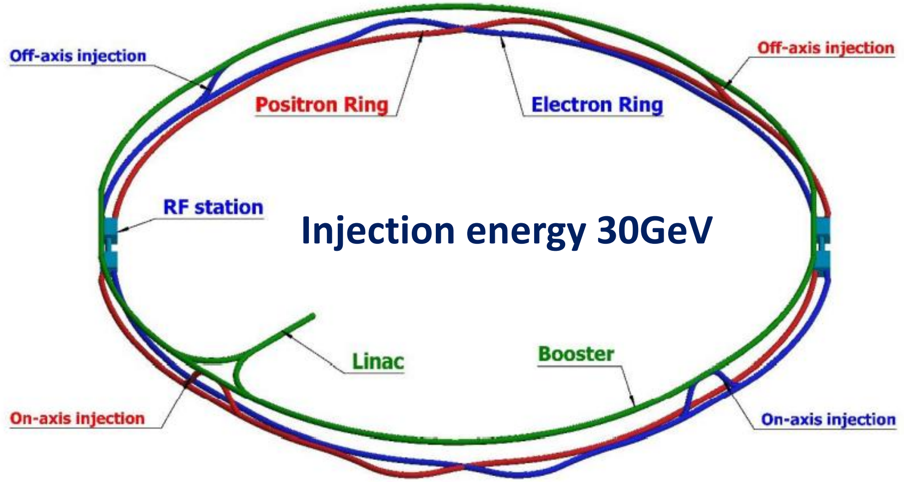
CEPC TDR Layout@30GeV Linac

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)

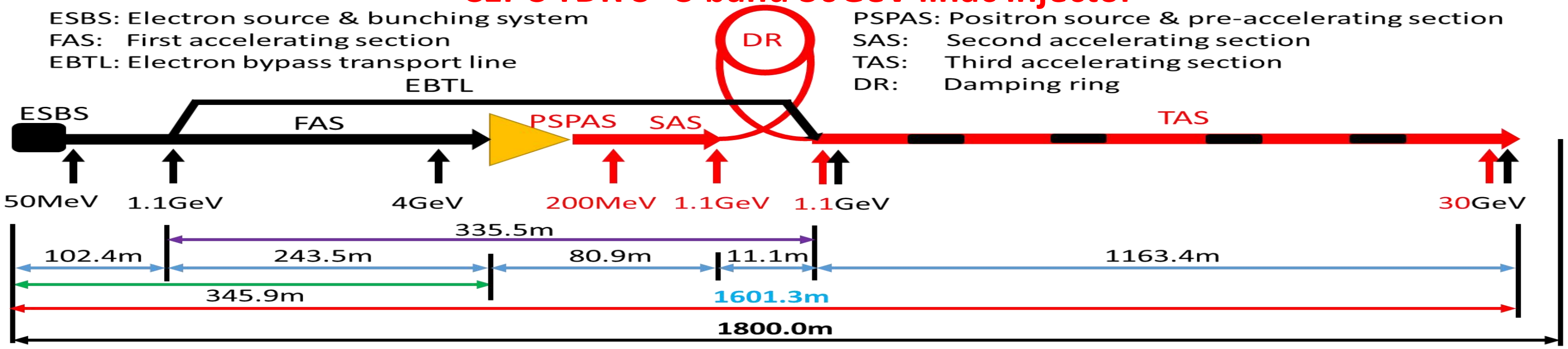


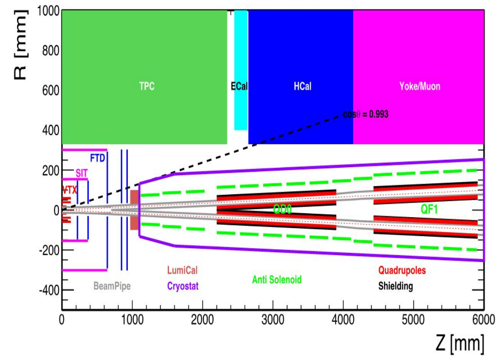
CEPC collider ring (100km)



CEPC booster ring (100km)

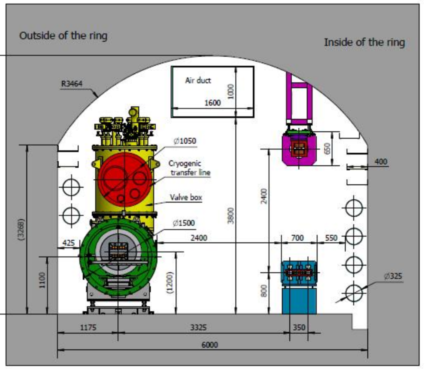
CEPC TDR S+C-band 30GeV linac injector

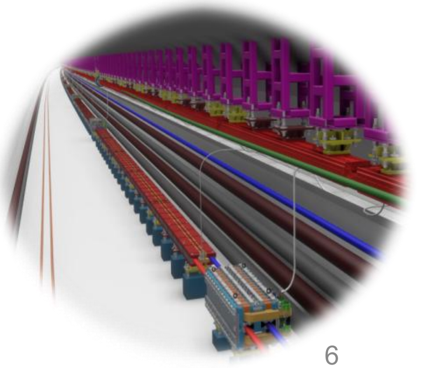




CEPC MDI

TUNNEL CROSS SECTION OF THE ARC AREA





CEPC Civil Engineering

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

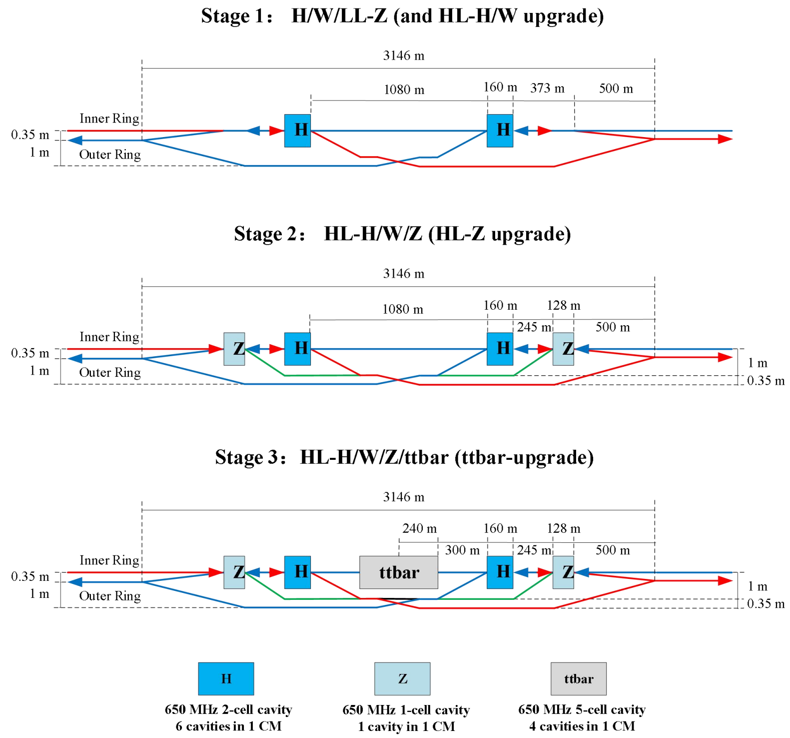
CEPC Accelerator white paper to Snowss21 arXiv:2203.09451

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** additional 5-cell cavities	**ttbar** existing 2-cell cavities	**Higgs**	**W**	**Z** bypass with 1-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

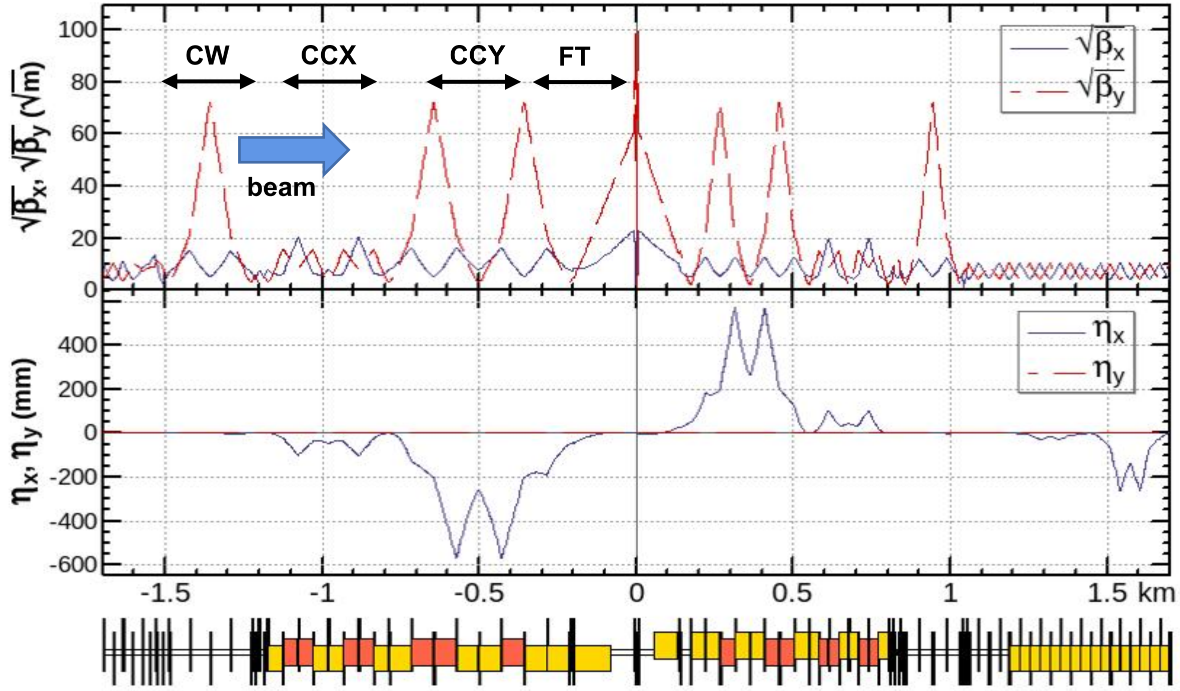
- Aiming for all-mode seamless switching in whole project lifecycle without hardware movement
- Highest luminosity in each energy. Maximize performance and flexibility for future circular electron positron collider



CEPC Collider Ring Interaction Region for Four Energies in TDR

Y.W. Wang

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



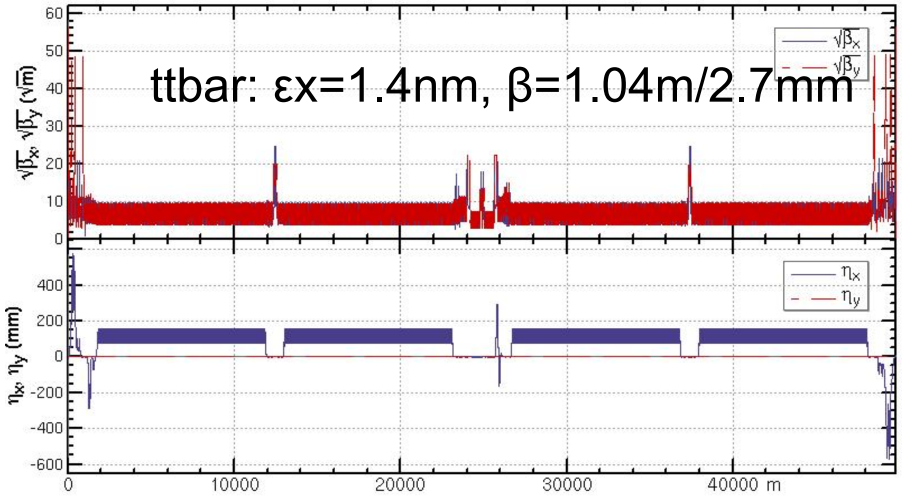
	QD	QF
Z	Q1A	Q1B
W/H	Q1A+Q1B	Q2
ttbar	Q1A+Q1B+Q2	add quad Q3A and Q3B

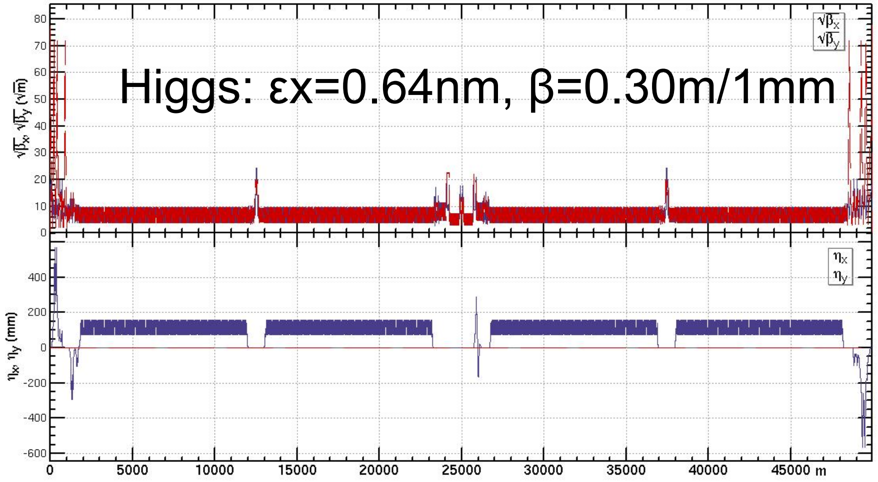
	L [m]	Strength [T/m]			
		ttbar	Higgs	W	Z
Q1AIRU	1.21	-141	-141	-94	-110
Q1BIRU	1.21	-59	-85	-56	+65
Q2IRU	1.5	-51	+95	+63	0
Q3AIRU	1.5	+40	0	0	+2
Q3BIRU	1.5	+40	0	0	+2
Q1AIRD	1.21	-142	-142	-95	-110
Q1BIRD	1.21	-64	-85	-57	+65
Q2IRD	1.5	-47	+96	+64	0
Q3AIRD	1.5	+40	0	0	+2
Q3BIRD	1.5	+40	0	0	+2

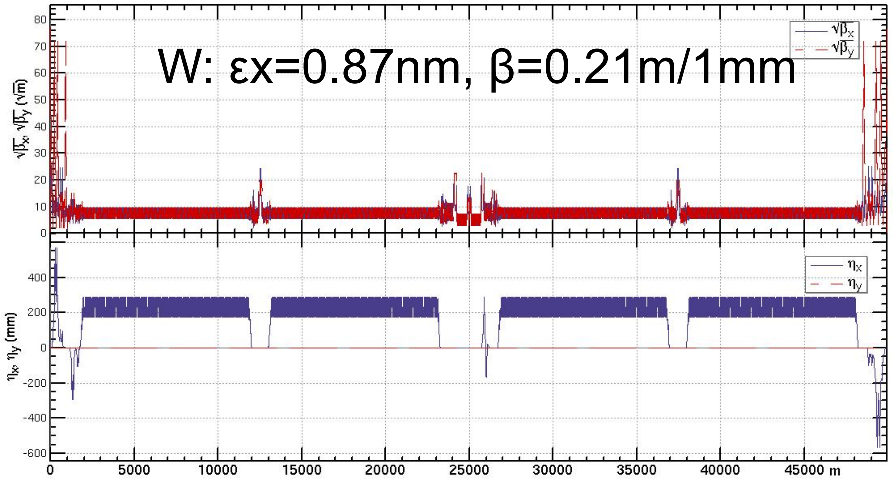
Strength of other modes doesn’t exceeded the one of Higgs mode.

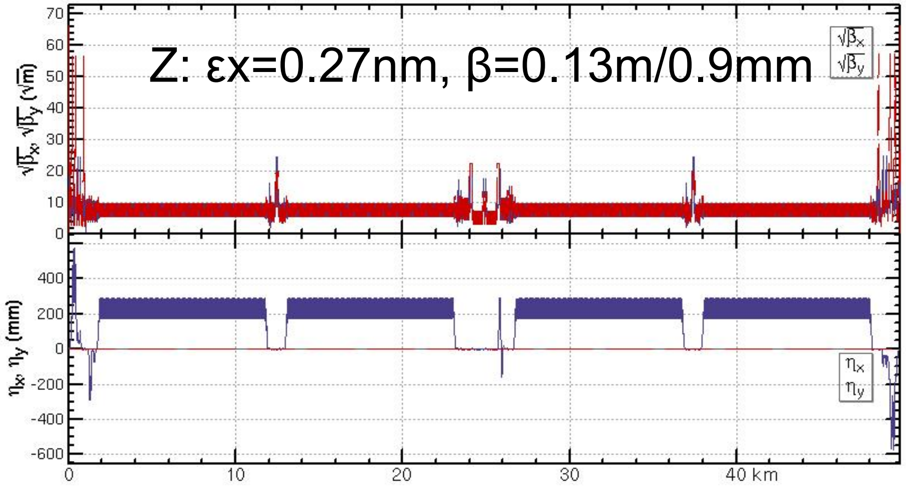
CEPC Collider Ring Lattice of Half Ring for Four Energy Operation Modes in TDR

Y.W. Wang







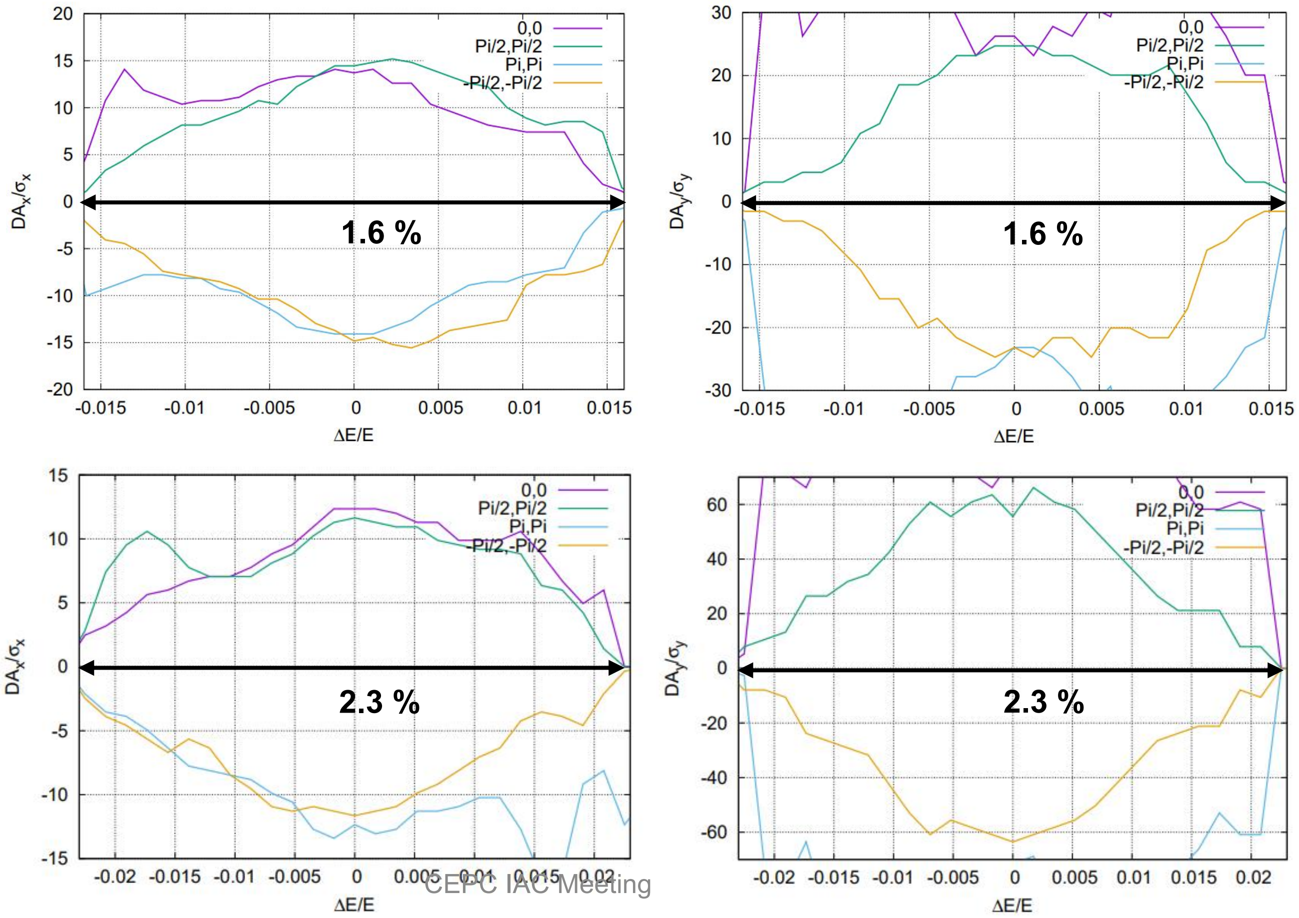


CEPC Collider Ring Dynamic Aperture Status @ Higgs and ttbar in TDR

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

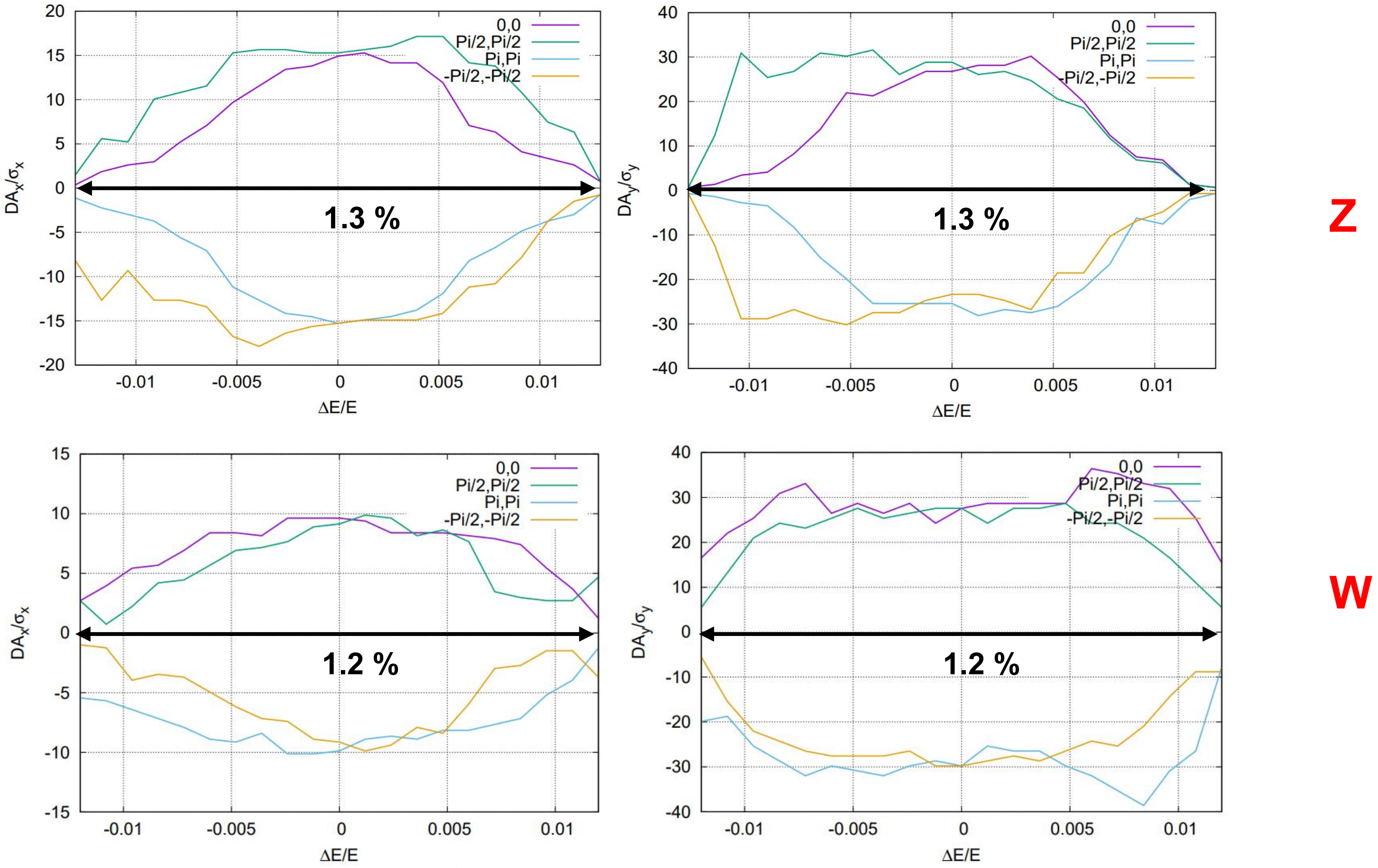
ttbar

CEPC Collider Ring Dynamic Aperture Status @ Z and W in TDR

Y.W. Wang

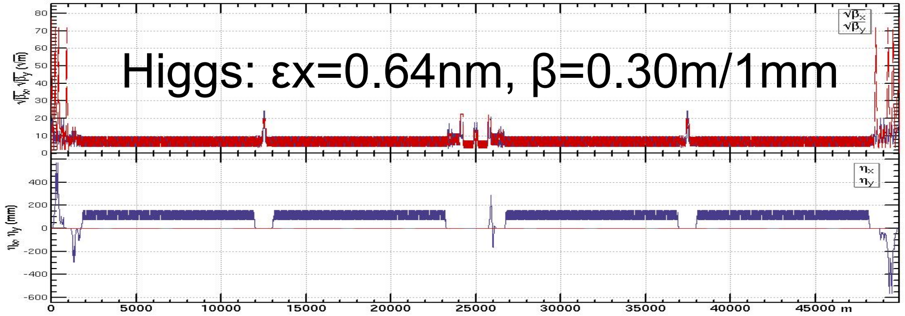
- Tracking to get DA **without errors**, with turns for one transvers damping time, with 4 initial phases
- DA optimized with 116 variables (96 arc sextupole families + 8 IR sextupoles + 4 multipoles + 8 phase advance)

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



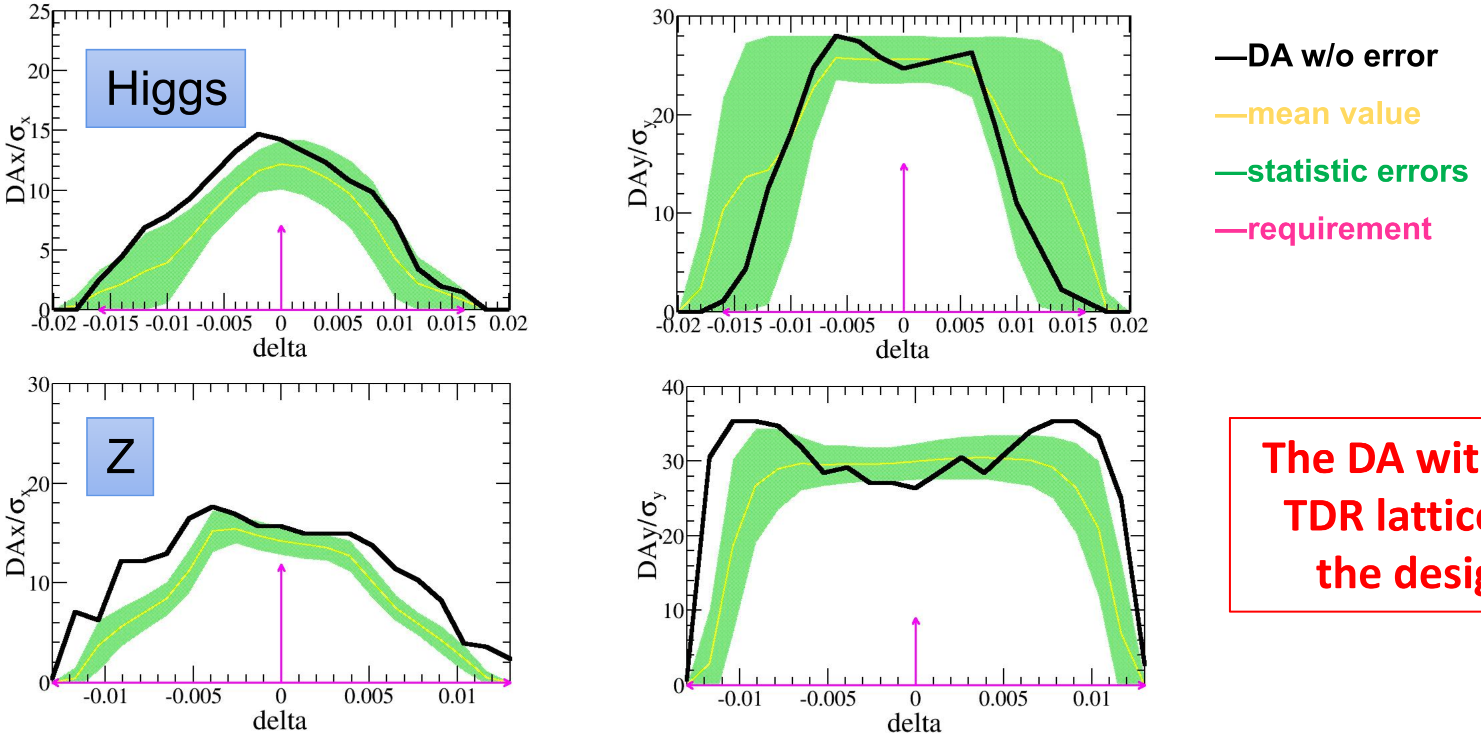
CEPC Collider Ring TDR Lattice Dynamic Apertures with Errors at Higgs and Z-pole Energies

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	0.02%
Sextupole	0.10*	0.10*	0.10	

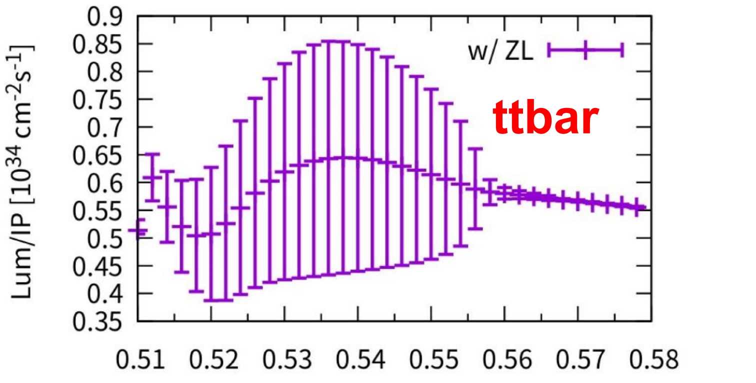
Effects included in tracking
Synchrotron motion
Radiation loss in all magnets
Tapering
Crab waist sextupole
Maxwellian fringes
Kinematic terms
Finite length of sextupole



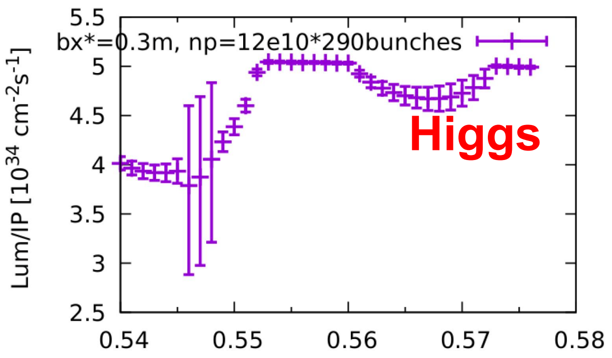
The DA with erros of TDR lattice satisfiy the design goal

CEPC TDR Parameter Luminosity Check by Beam-beam Simulations

Y. Zhang

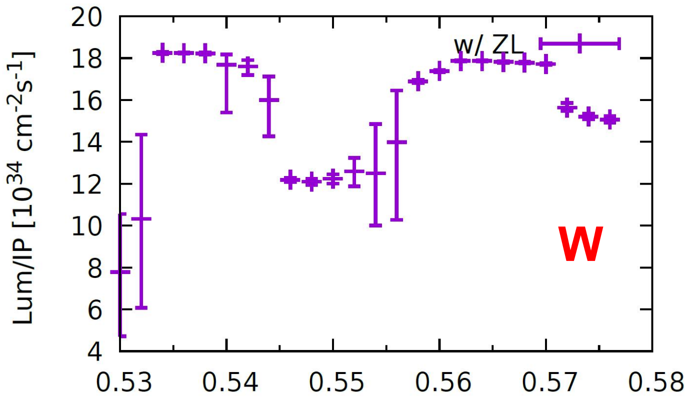


Ttbar: 0.55* 10^34/cm^2/s (BB Simulation)
Parameter table:0.5*10^34/cm^2/s

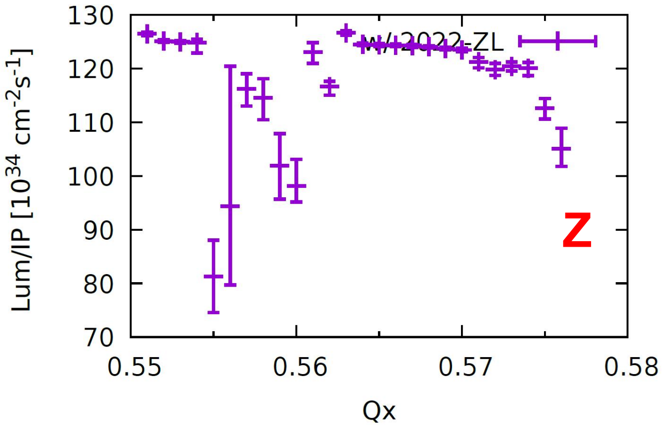


Higgs : 5*10^34/cm^2/s (BB Simulation)
Parameter table:5*10^34/cm^2/s

The beam-beam simulations results are consistent with the CEPC TDR parameter tables



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

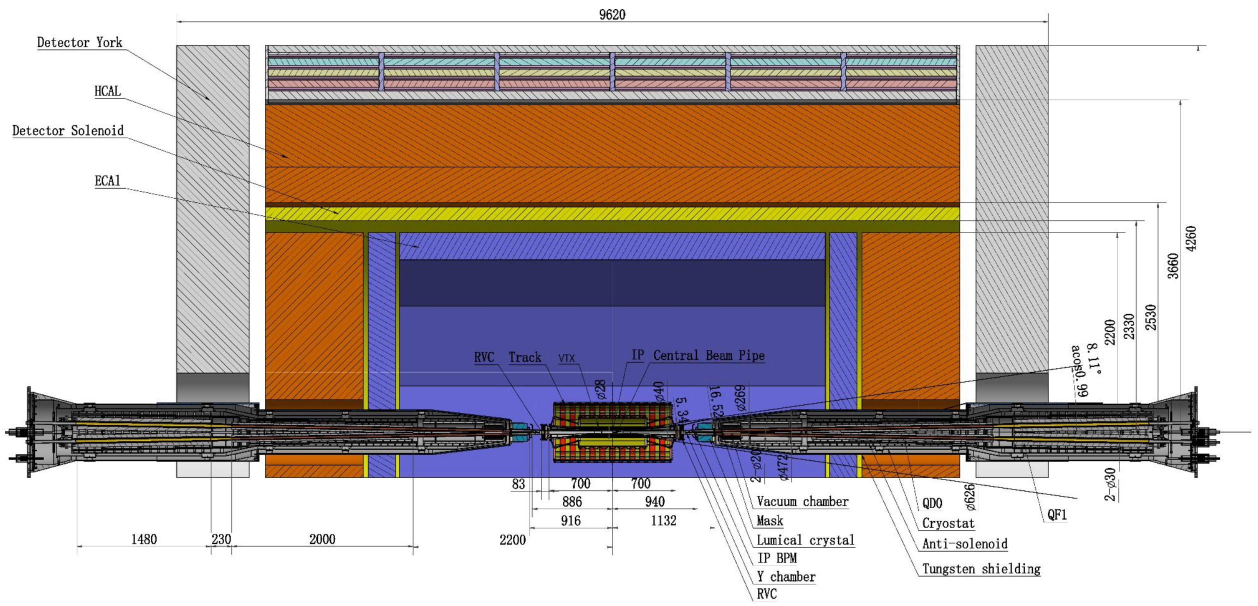


Z-pole : 125*10^34/cm^2/s (BB Simulation)
Parameter table:115*10^34/cm^2/s

CEPC MDI in TDR

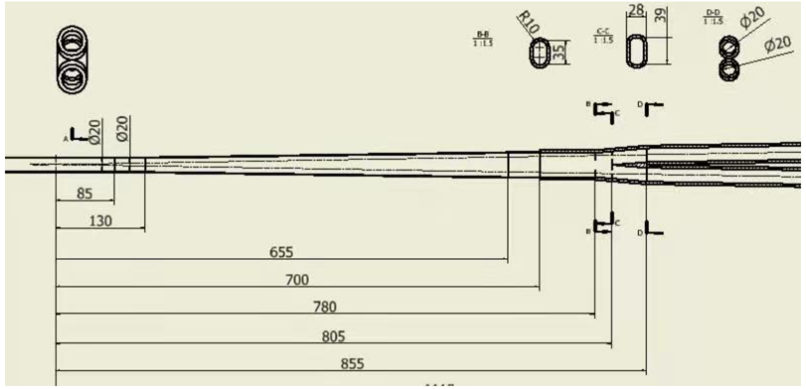
S. Bai

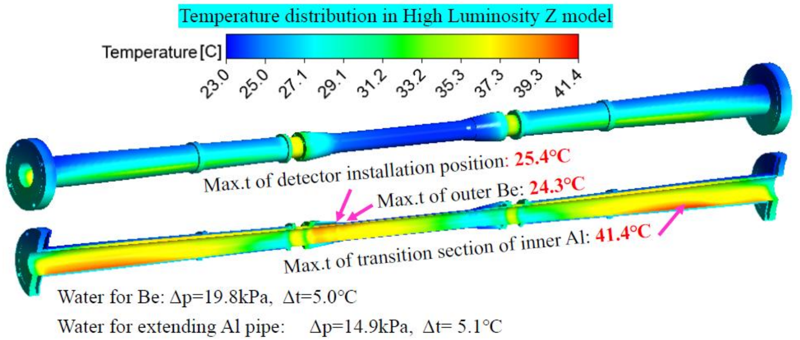
- IR Superconducting magnet design
- IR beam pipe
- Synchrotron radiation
- Beam loss background
- Shielding
- Mechanical support
- Full detector simulation



Central beryllium pipe inner diameter changes from 28mm(CDR) to 20mm

There is no SR photons hitting the central beam pipe in normal conditions.





L^*=1.9m, θ_c=33mrad, β_x^*=0.33m, β_y^*=1.0mm, Emittance=0.68nm

- Strength requirements of anti-solenoids (peak field B_z~7.2T)
- Two-in-one type SC quadrupole coils (Peak field 3.8T & 141T/m) with room temperature vacuum chamber & Iron yoke

CEPC TDR MDI Parameters

S. Bai

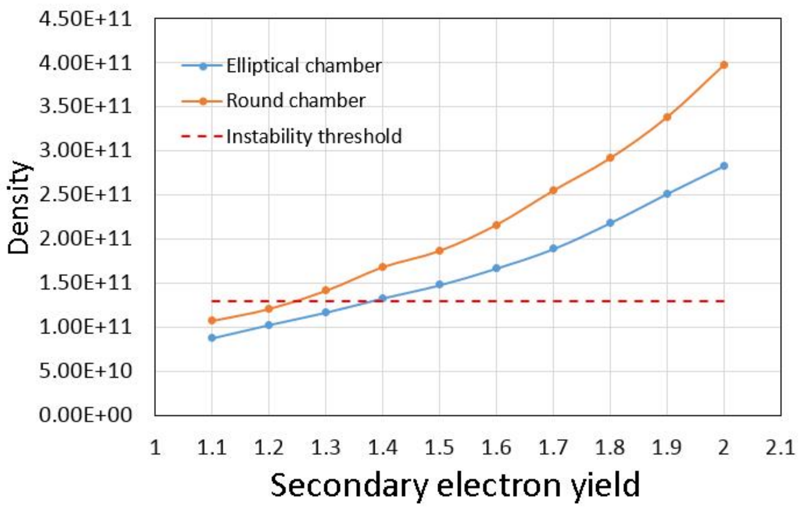
	range	Peak fieled in coil	Central fieled gradient	Bending angle	length	Beam stay clear region	Minimal distance between two aperture	Inner diameter of beam pipe	Outer diameter of beam pipe	Critical energy (Horizontal)	Critical energy (Vertical)	SR power (Horizontal)	SR power (Vertical)
L*	0~1.9m				1.9m								
Crossing angle	33mrad												
MDI length	±7m												
Detector requirement of accelerator components in opening angle	8.11˚												
QDa/QDb		3.5/2.8T	142/85T/m		1.21m	14.9/18.2mm	62.71/105.28mm	20/23mm	26/29mm	724.7/663.1keV	396.3/263keV	212.2/239.23W	99.9/42.8W
QF1		3.3T	96.7T/m		1.5m	24.48mm	155.11mm	32mm	38mm	675.2keV	499.4keV	472.9W	135.1W
Lumical	0.95~1.11m				0.16m								
Anti-solenoid before QD0		6.8T			1.1m								
Anti-solenoid QD0		3T			2.5m								
Anti-solenoid QF1		3T			1.5m								
Beryllium pipe					±85mm			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							1.19/1.31W	
Beampipe within QF1					1.5m							2.39W	
Beampipe between QD0/QF1					0.3m							26.5W	

CEPC Collective Effects in TDR

N. Wang
Y.D. Liu

- No apparent show stoppers for ttbar, Higgs, W from collective instability point of view for 50MW SR. The beam intensity of Z at 50MW SR is restricted by the resistive wall instability and electron cloud effects, but Z could work at 30MW SR. **Collective effects satisfy TDR requirments**
  - 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)

Total impedance budget @3mm@ Z

Components	Number	$Z_{||}/n$, mΩ	k_{loss}, V/pC	k_y, kV/pC/m
Resistive wall	-	6.7	425.6	13.8
RF cavities	60	0.5	101.2	0.5
Flanges	37714	5.2	37.3	5.2
BPMs	1808	0.04	9.5	0.2
Bellows	15949	2.9	87.4	3.9
Gate Valves	500	0.2	14.5	0.4
Pumping ports	5316	0.3	2.3	0.2
Collimators	16	0.04	23.4	0.6
IP chambers	2	0.004	0.3	0.05
Electro-separators	20	-0.1	34.5	0.1
Taper transitions	48	0.04	2.5	0.09
TDR Total		**15.8**	**738.5**	**25.0**
CDR Total		**11.4**	**786.8**	**20.2**

CEPC Booster TDR Parameters

D. Wang

- Injection energy: 10GeV → 20GeV → 30GeV
- Max energy: 120GeV → 180GeV
- Lower emittance — new lattice (TME)

		tt	*H*	*W*	*Z*	
Beam energy	GeV	30				
Bunch number		35	268	1297	3978	5967
Threshold of single bunch current	μA	8.68	6.3	5.8		
Threshold of beam current (limited by coupled bunch instability)	mA	97	106	100	93	96
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	2530	530	100	29.1	18.7
Energy spread	%	0.025				
Synchrotron radiation loss/turn	MeV	6.5				
Momentum compaction factor	10^{-5}	1.12				
Emittance	nm	0.076				
Natural chromaticity	H/V	-372/-269				
RF voltage	MV	761.0	346.0	300.0		
Betatron tune ν_x/ν_y		321.23/117.18				
Longitudinal tune		0.14	0.0943	0.0879		
RF energy acceptance	%	5.7	3.8	3.6		
Damping time	s	3.1				
Bunch length of linac beam	mm	0.4				
Energy spread of linac beam	%	0.15				
Emittance of linac beam	nm	6.5				

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	7.1	4.3		2.4	1.0	
Injection duration for top-up (Both beams)	s	29.2	23.1	31.8	38.1	132.4	
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

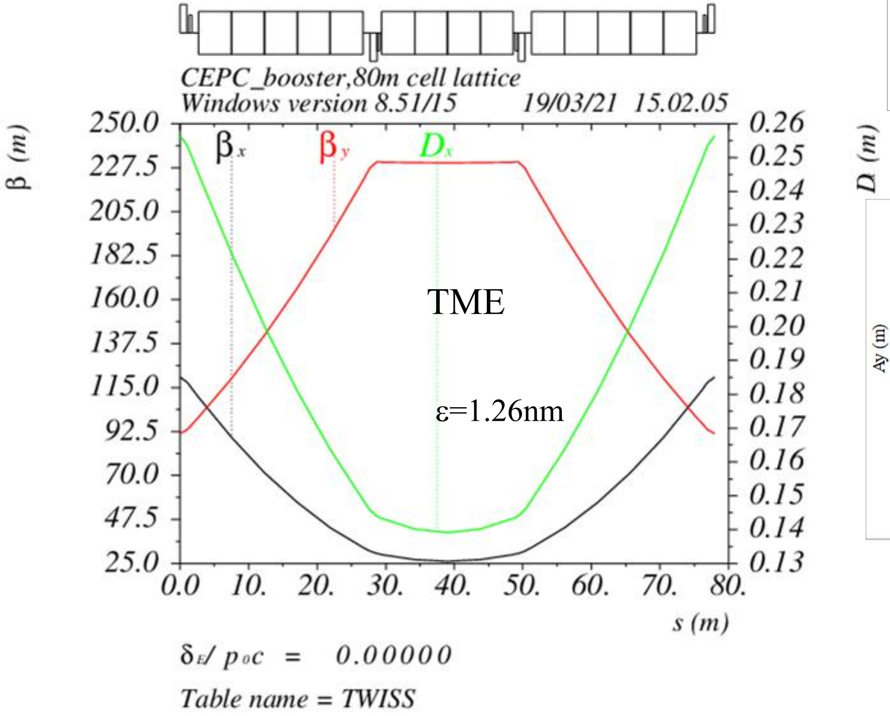
*Diameter of beam pipe is 55mm for re-injection with high single bunch current @120GeV.

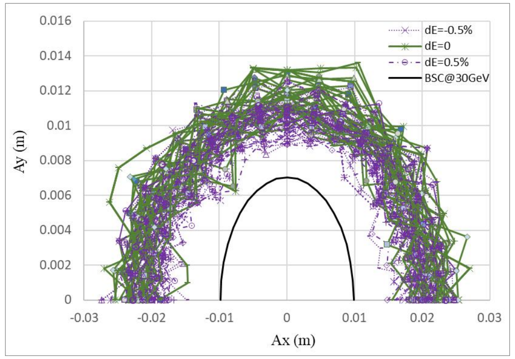
CEPC Booster TDR Optics and DA with Errors

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

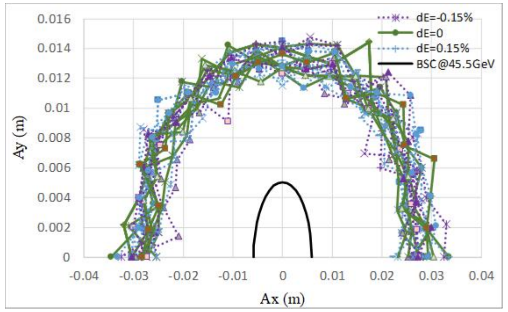
- TME like structure (cell length=80m)
- Overall idea: uniform distribution for the Q
- Combined magnet (B+S) scheme possible
- Interleave sextupole scheme
- Emittance@120GeV=1.26nm

Dispersion sup.

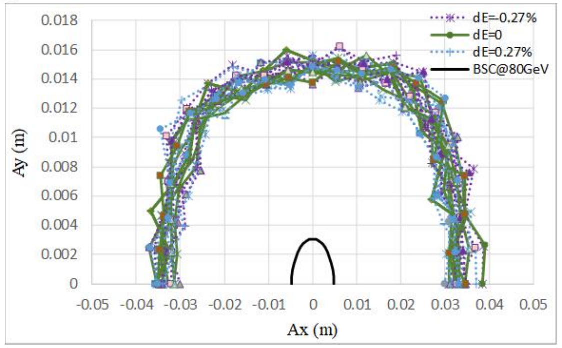




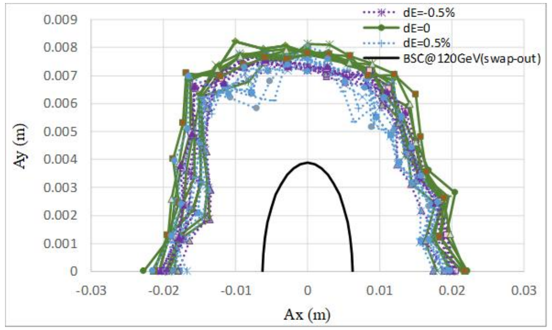
DA @30GeV



DA @45GeV

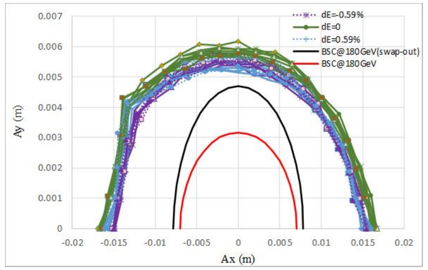


DA @80GeV



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

J.Y. Zhai

CDR Higgs energy:
-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**

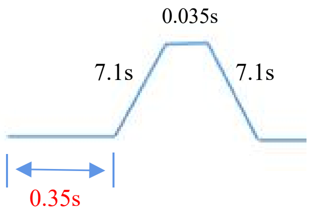
For 50MW/beam SR Mode:
at Higgs energy, the cryogenic system needs 42000liter Hellium; at ttbar energy **130000liter Hellium needed**

Refrigerators: 4*18kW@4.5K

CEPC Booster Ramping Scheme in TDR

Dou Wang, Xiaohao Cui

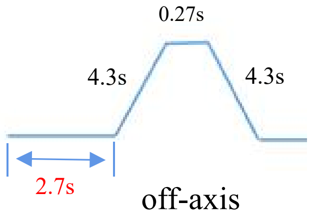
tt



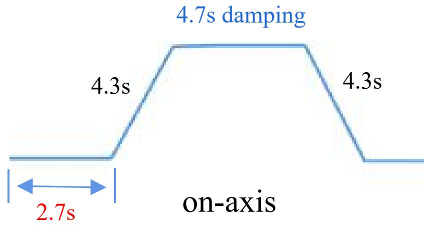
1 cycles/beam

0.35s+7.1s+0.035s+7.1s=14.6s

Higgs



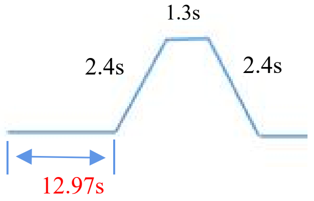
1 cycles/beam



2.7s+4.3s+4.7s+4.3s=16.0s

- **On-axis injection @ Higgs**
  - Step 1: Linac→booster (240 small bunches)
  - Step 2: Collider→booster (7 big bunches)
    off-axis injection
  - Step 3: Mix in booster
    (233 small bunches + 7 big bunches)
  - Step 4: Booster→collider (7 big bunches)
    on-axis injection
  - → Step 2
  - …

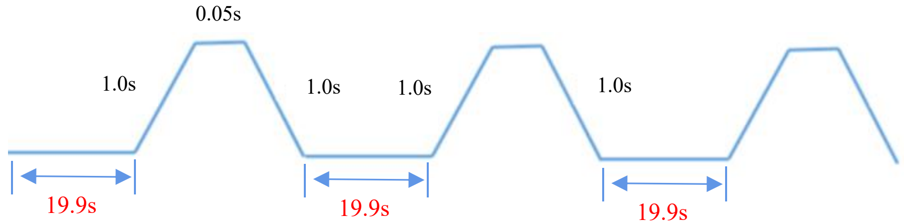
W



1 cycles/beam

12.97s+2.4s+1.3s+2.4s=19.1s

Z



(19.9s+1.0s+0.05s+1.0s)*3=65.9s

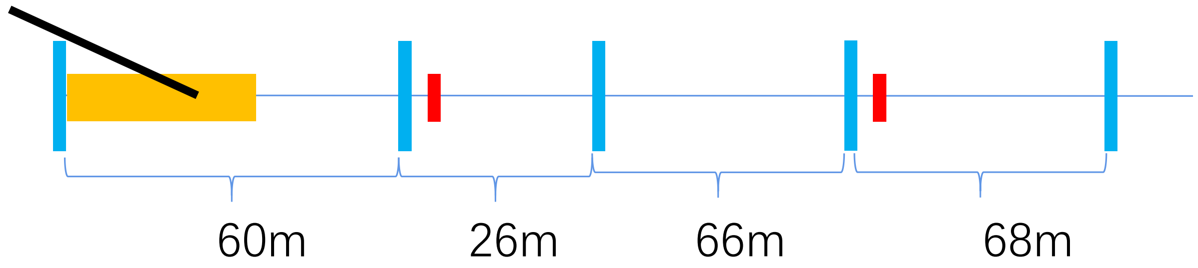
3 cycles/beam

Extraction from Booster Collider Ring in TDR

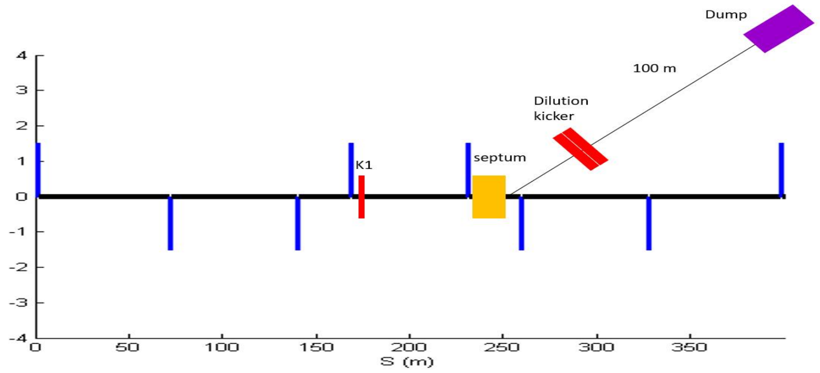
X.H. Cui

	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

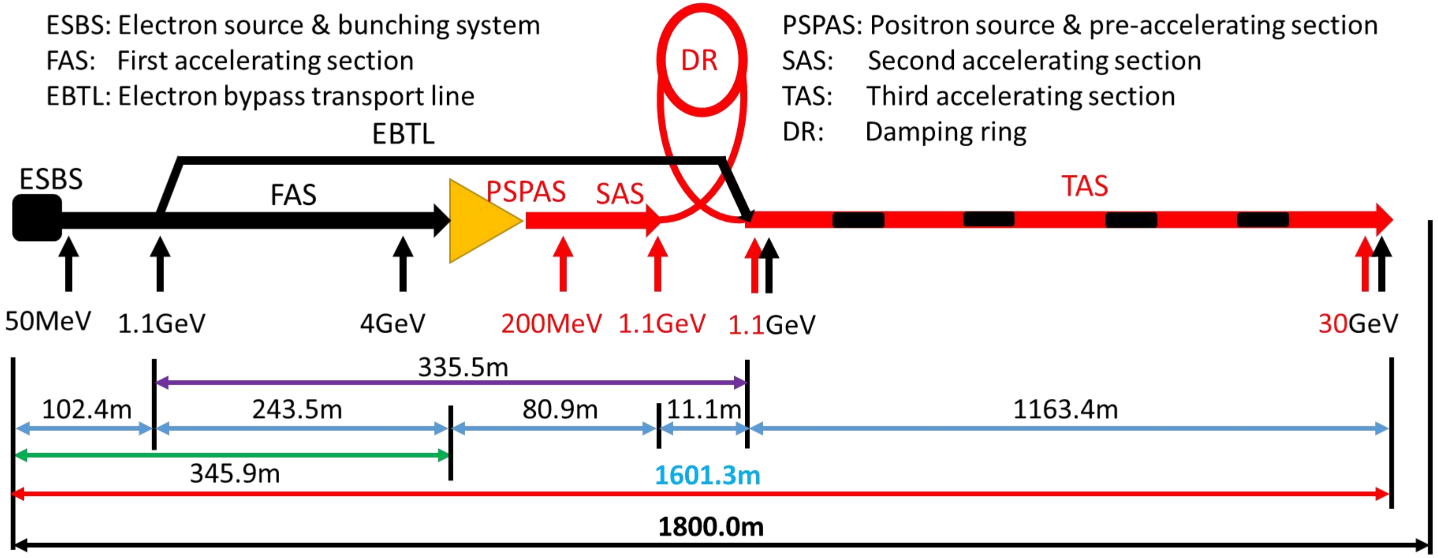
CEPC TDR Linac Injector of 30GeV

CEPC 20GeV Linac Injector design has also been completed

C. Meng

- 30GeV-Linac Scheme
  - C-band accelerating structure is used in TAS form 1.1GeV to 30GeV
  - S-band accelerating structure is used in FAS with energy of 4GeV and SAS with energy of 1.1 GeV
  - The bunch charge is 1.5nC and have the capability to reach 3nC both for electron and positron beam
- Electron Linac
  - ESBS+FAS+EBTL+TAS
- Positron Linac
  - ESBS+FAS+PSPAS+SAS+DR+TAS
- The Linac length is 1.6km and there is still 0.2km as reserved space, the Linac tunnel length is 1.8km
  - The circumference of the damping ring is about 0.15km

Parameter	Symbol	Unit	Baseline
Beam energy	E_{e-}/E_{e+}	GeV	30
Repetition rate	f_{rep}	Hz	100
Bunch population	Ne-/Ne+	$\times 10^{10}$	0.94
		nC	1.5
Energy spread	σ_E		1.5×10^{-3}
Emittance	ε_r	nm	6.5

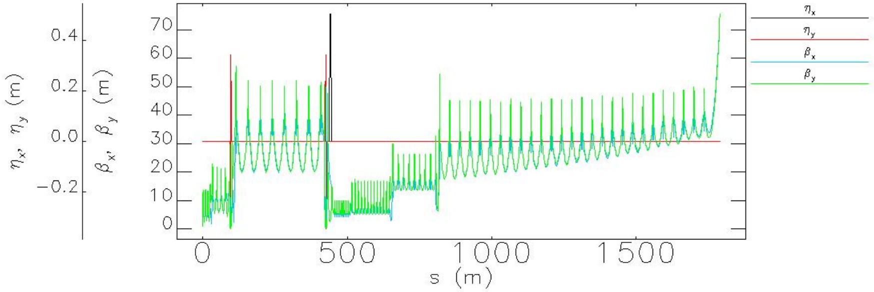


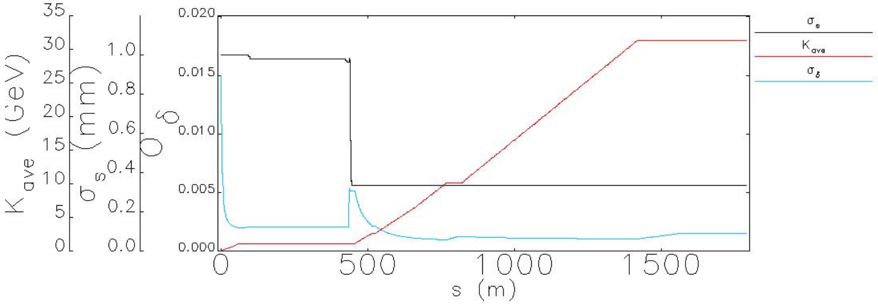
CEPC TDR Linac Injector Design (30GeV)

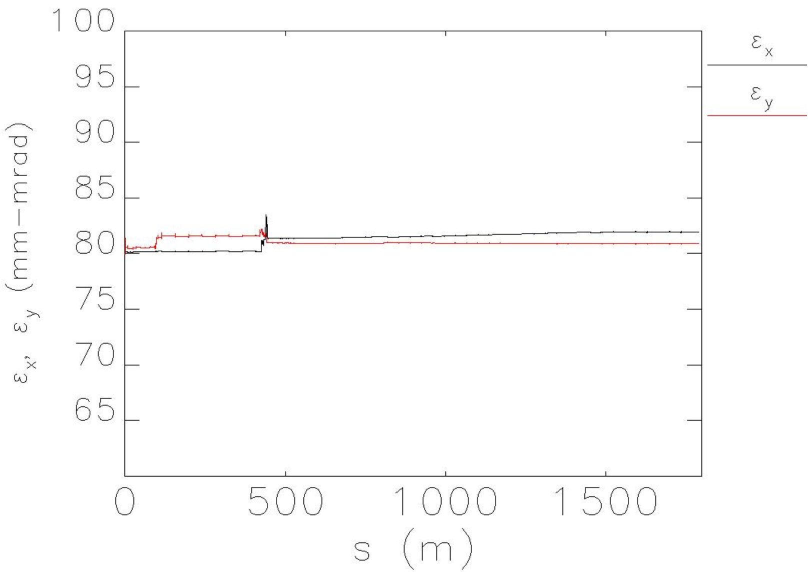
C. Meng

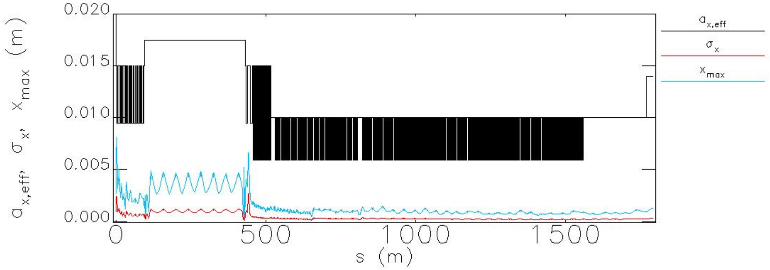
- Simulation results

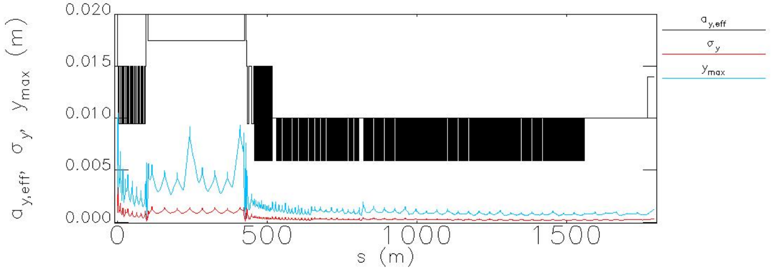
Parameter	Unit	Value	Simulated			
			Electron		Positron	
Beam energy	GeV	30	31.3	30.8	31.1	30.8
Repetition rate	Hz	100	/			
Bunch charge	nC	1.5	1.5	3.0	1.5	3.0
Energy spread		1.5×10^{-3}	1.4×10^{-3}	1.7×10^{-3}	1.4×10^{-3}	1.9×10^{-3}
Emittance	nm	6.5	1.4	1.5	3.3(H)/1.7(V)	3.5(H)/1.8(V)
Bunch length (RMS)	mm	/	0.4			







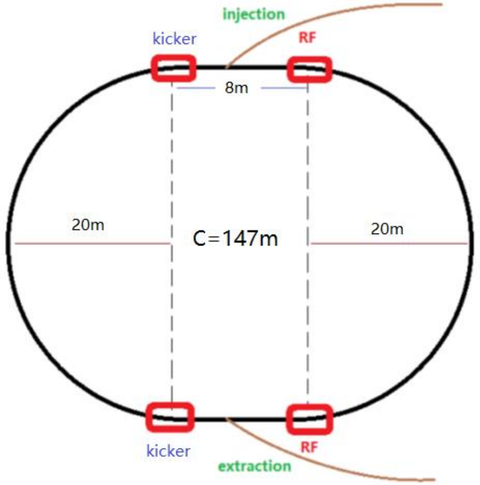


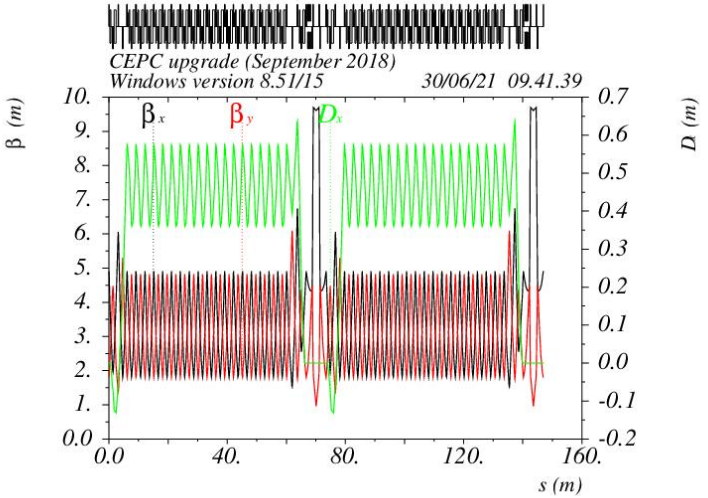


CEPC Positron DR TDR Parameters

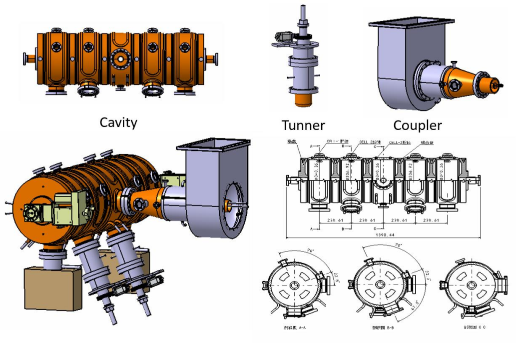
D. Wang, J.R. Zhang

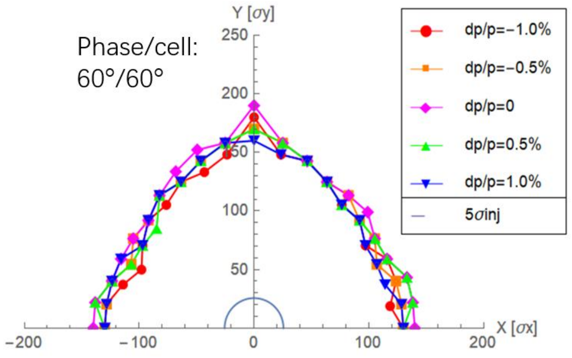
- Damping with **reversed bending magnet**
- 4 (max. 8)-bunch storage, storage time:20 (40) ms
- Emittance: 2500→ 166/75 (97/3) mm.mrad
- Flexibility for extr. emittance





RF Cavity Design

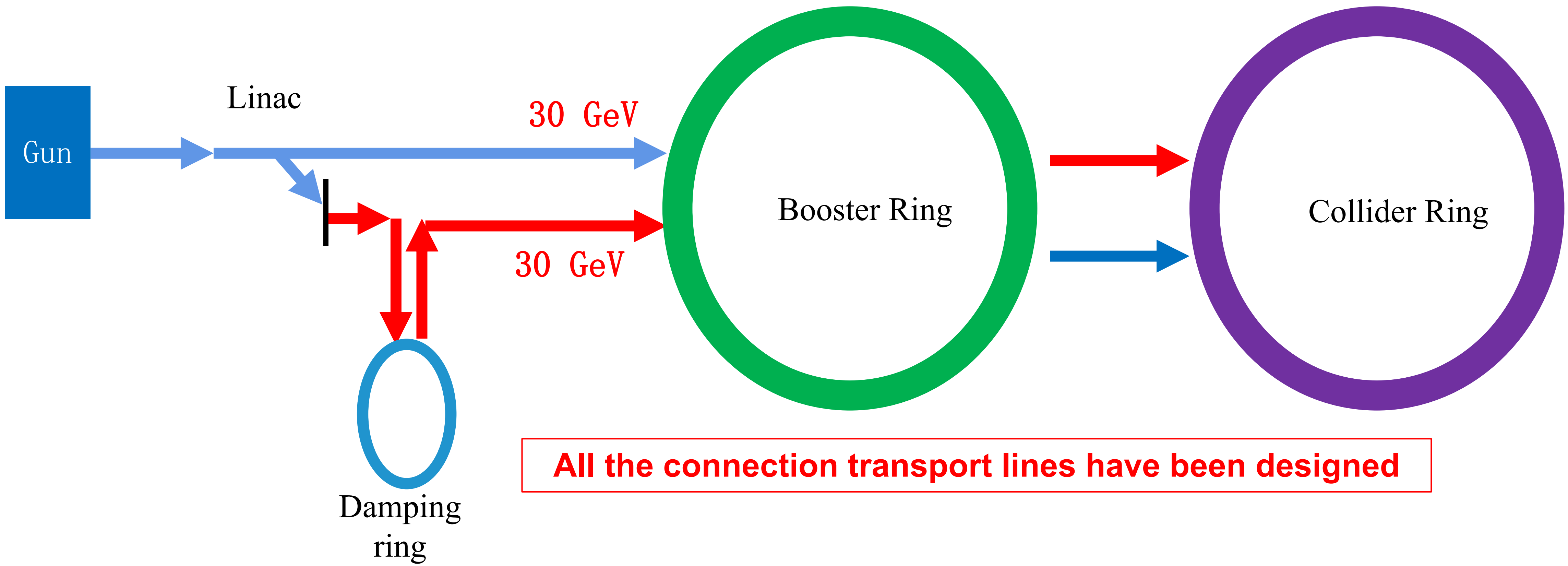




	DR V3.0
Energy (Gev)	1.1
Circumference (m)	147
Number of trains	2 (4)
Number of bunches/trian	2
Total current (mA)	12.4 (24.8)
Bending radius (m)	2.87
Dipole strength B_0 (T)	1.28
U_0 (kev/turn)	94.6
Damping time x/y/z (ms)	11.4/11.4/5.7
Phase/cell (degree)	60/60
Momentum compaction	0.013
Storage time (ms)	20 (40)
δ_0 (%)	0.056
ε_0 (mm.mrad)	94.4
injection σ_z (mm)	4.4
Extract σ_z (mm)	4.4
ε_{inj} (mm.mrad)	2500
$\varepsilon_{ext\ x/y}$ (mm.mrad)	166(97)/75(3)
$\delta_{inj}/\delta_{ext}$ (%)	0.18 /0.056
Energy acceptance by RF(%)	1.8
f_{RF} (MHz)	650
V_{RF} (MV)	2.5
Longitudinal tune	0.0387

CEPC Transport Lines in TDR

X.H. Cui



1. Injection and extraction from: Linac, damping ring, booster, and collider;

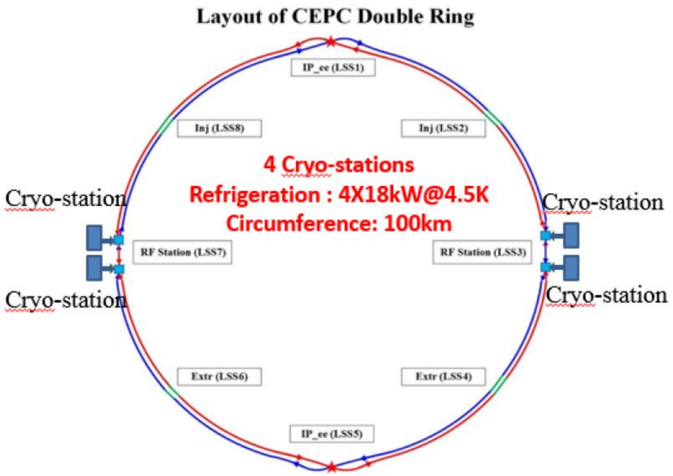
2. Energy: Higgs (120 GeV), W (80 GeV), Z (45.5 GeV), tt (180 GeV);

CEPC SRF Cryogenic Systems in TDR

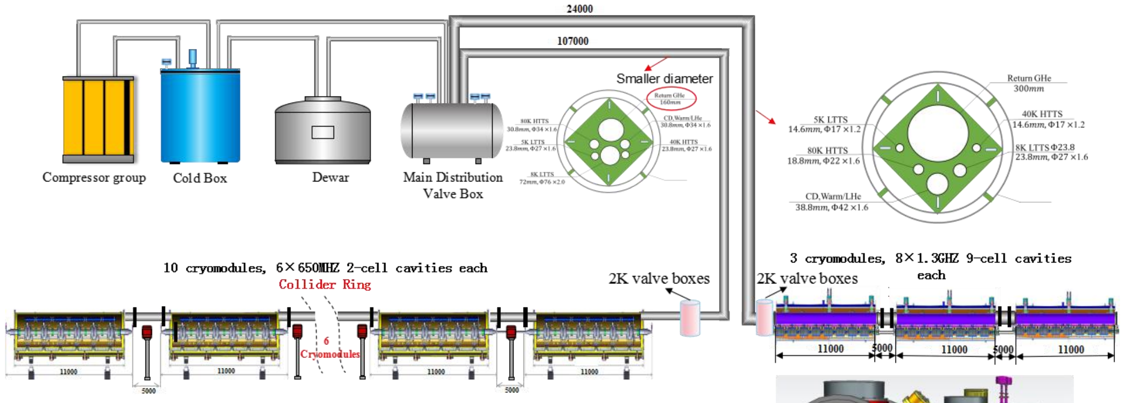
R. Ge
M. Li

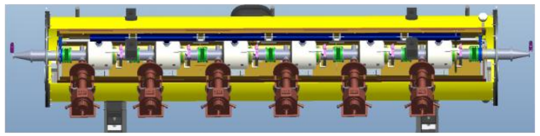
Booster ring:
- 1.3 GHz 9-cell cavities, 96 cavities
- 12 cryomodules
- 3 cryomodules/each station
- Temperature: 2K/31mbar

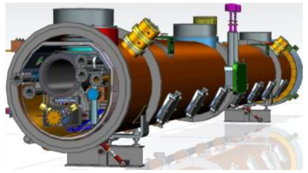
Collider ring:
- 650MHz 2-cell cavities, 336 cavities
- 56 cryomodules
- 14 cryomodules/each station
- Temperature: 2K/31mbar



CEPC accelerator SRF cryogenic flow chart in TDR







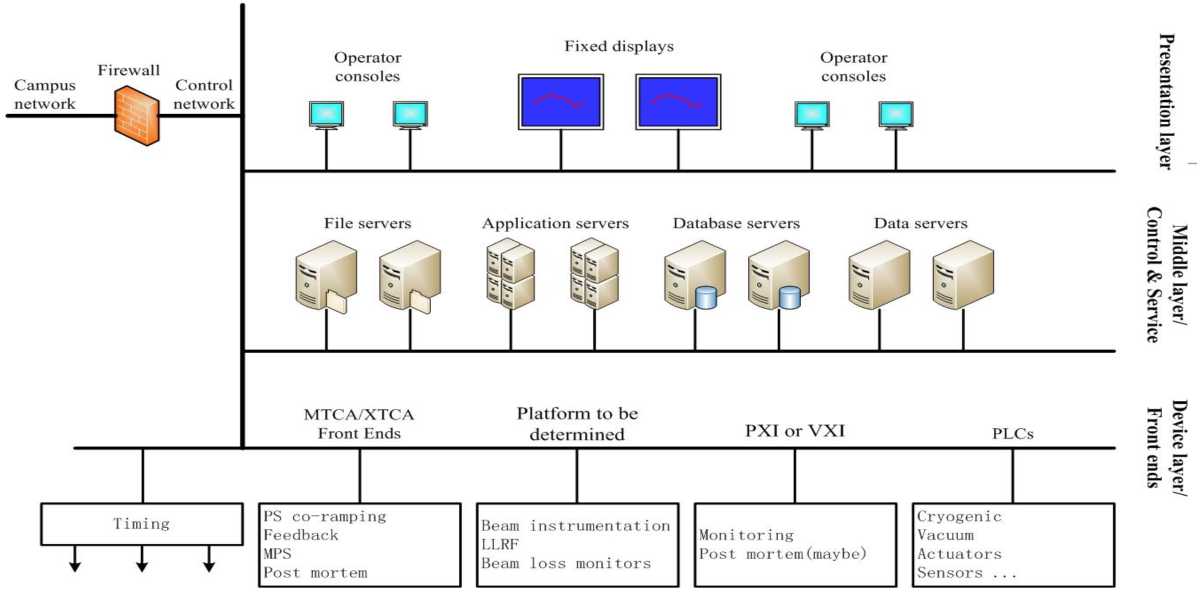
For 30MW SR/beam Mode at Higgs energy, the cryogenic system need 32000liter Hellium

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

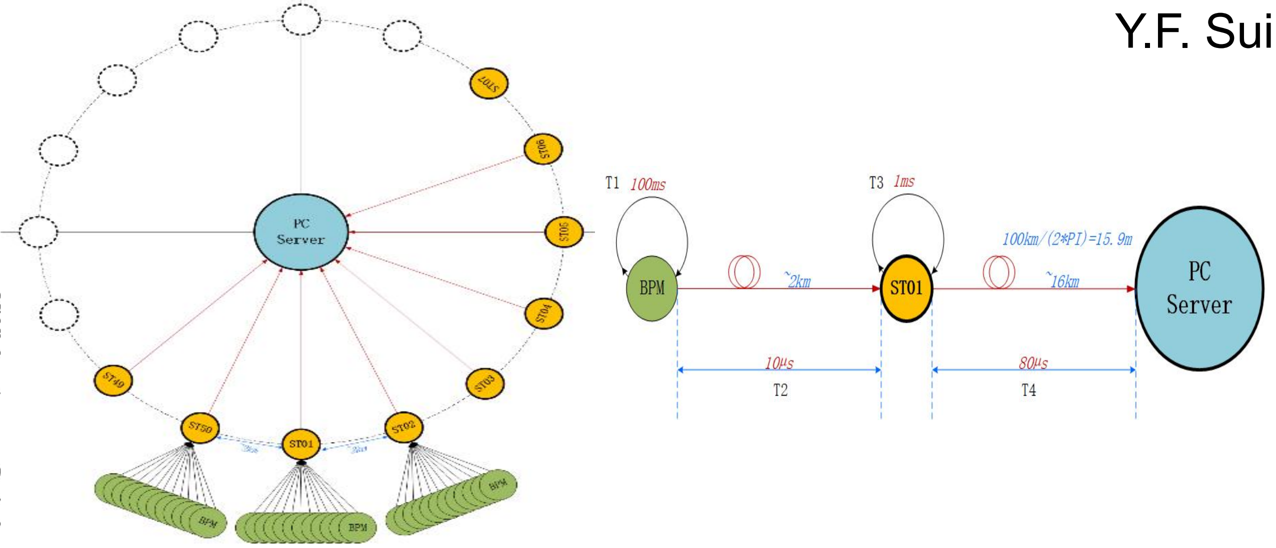
CEPC Control System and Beam Diagnostic System

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

G. Li
Y.F. Sui



Overall hardware architecture of the control system

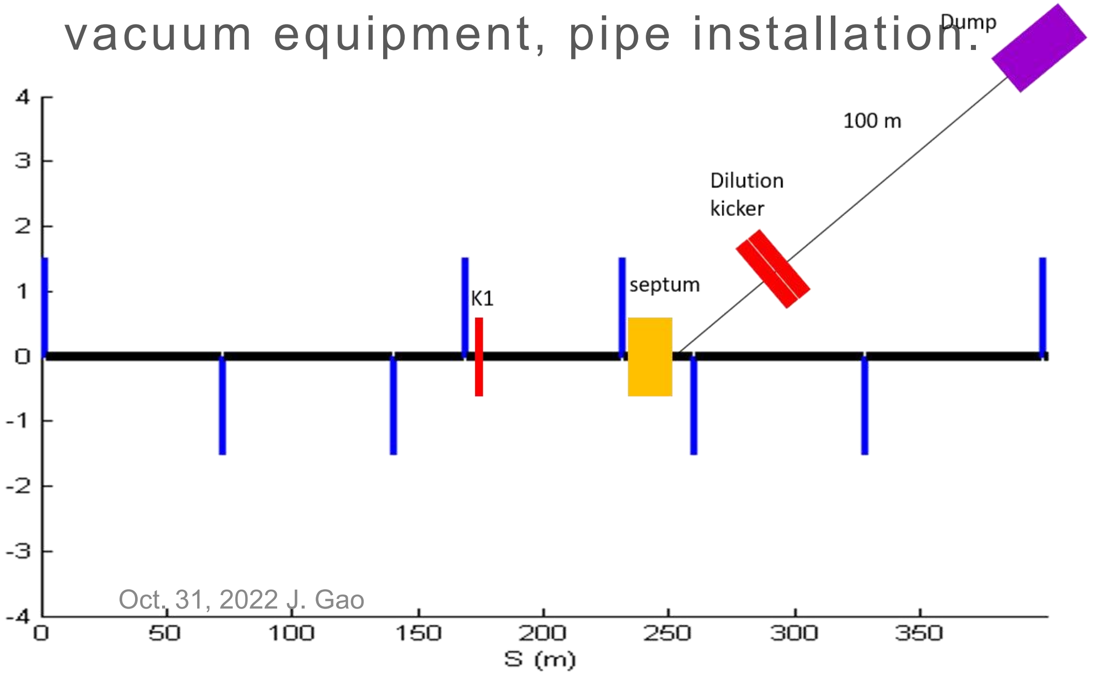


- 50 stations along the storage ring and connecting with PC sever station with the star topology fiber optic network.
- Consider the delay of whole system, the BPM COD measurement takes about 1s .

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.



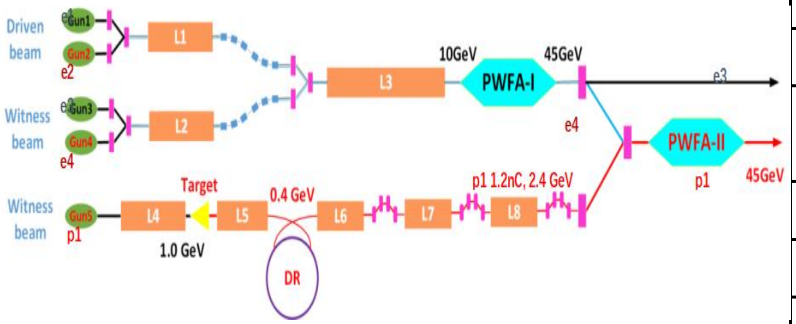
		Extraction kicker	Septum	Dilution kickers
Length (m)		2	20	10
Magnetic flux density (Gauss)	Z	281		40
	WW	494		
	Higgs	741	7000	
	ttbar	1110		

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℃

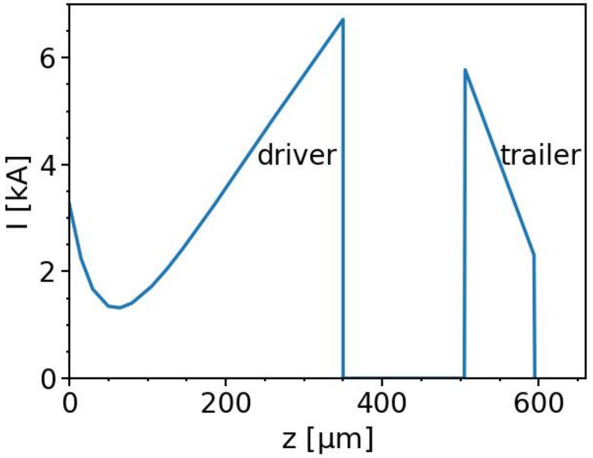
CEPC Plasma Injector 12 GeV → 30 GeV Pratically Feasible

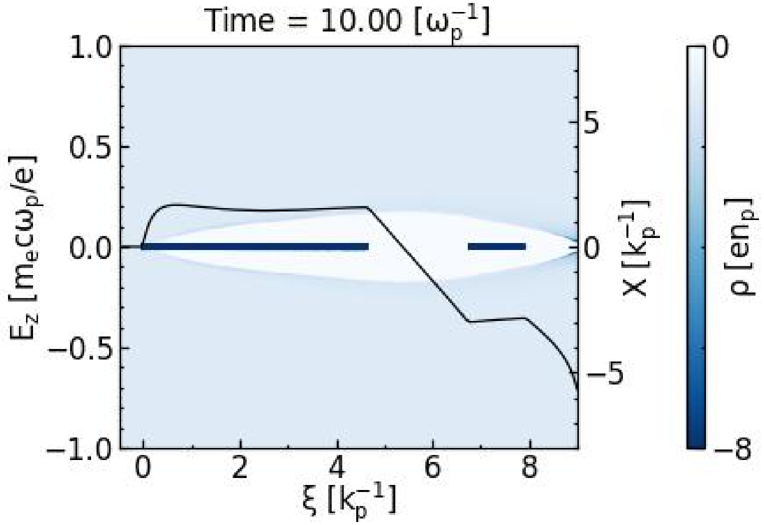
D.Z. Li, X.N. Wang

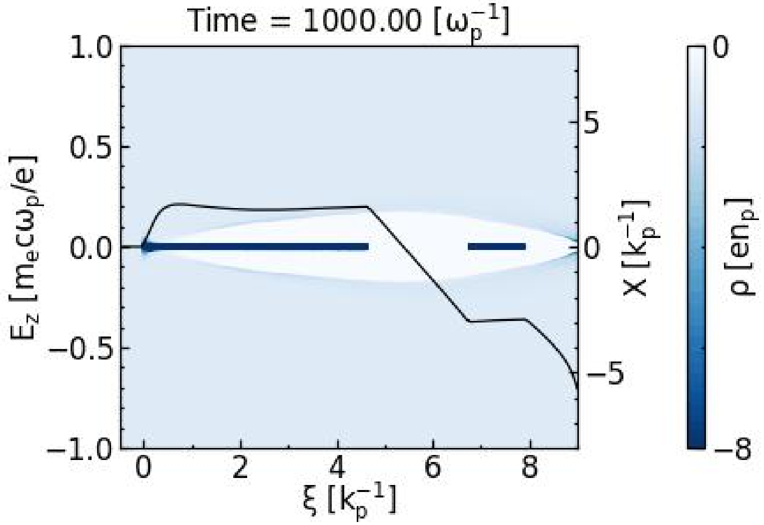


Parameters	Driver	Trailer
plasma density $n_p (\times 10^{16} cm^{-3})$	0.50334	
Driver energy E(GeV)	12	12
Normalized emittance ϵ_N (μm rad)	20	10
Length L (μm)	350	90
(matched) Spot size σ_r (μm)	3.72	2.63
Charge Q (nC)	4.0	1.2
Beam distance d (μm)	155	

Parameters	Trailer
Accelerating distance (m)	7.3 (97300 w_p^{-1})
Trailer energy $E(GeV)$	30
Normalized emittance $\epsilon_n(mm\ mrad)$	10
Charge(nC)	1.2
Energy spread δ_E(%)	0.58
R	1.8
Efficiency(%) (driver -> trailer)	55



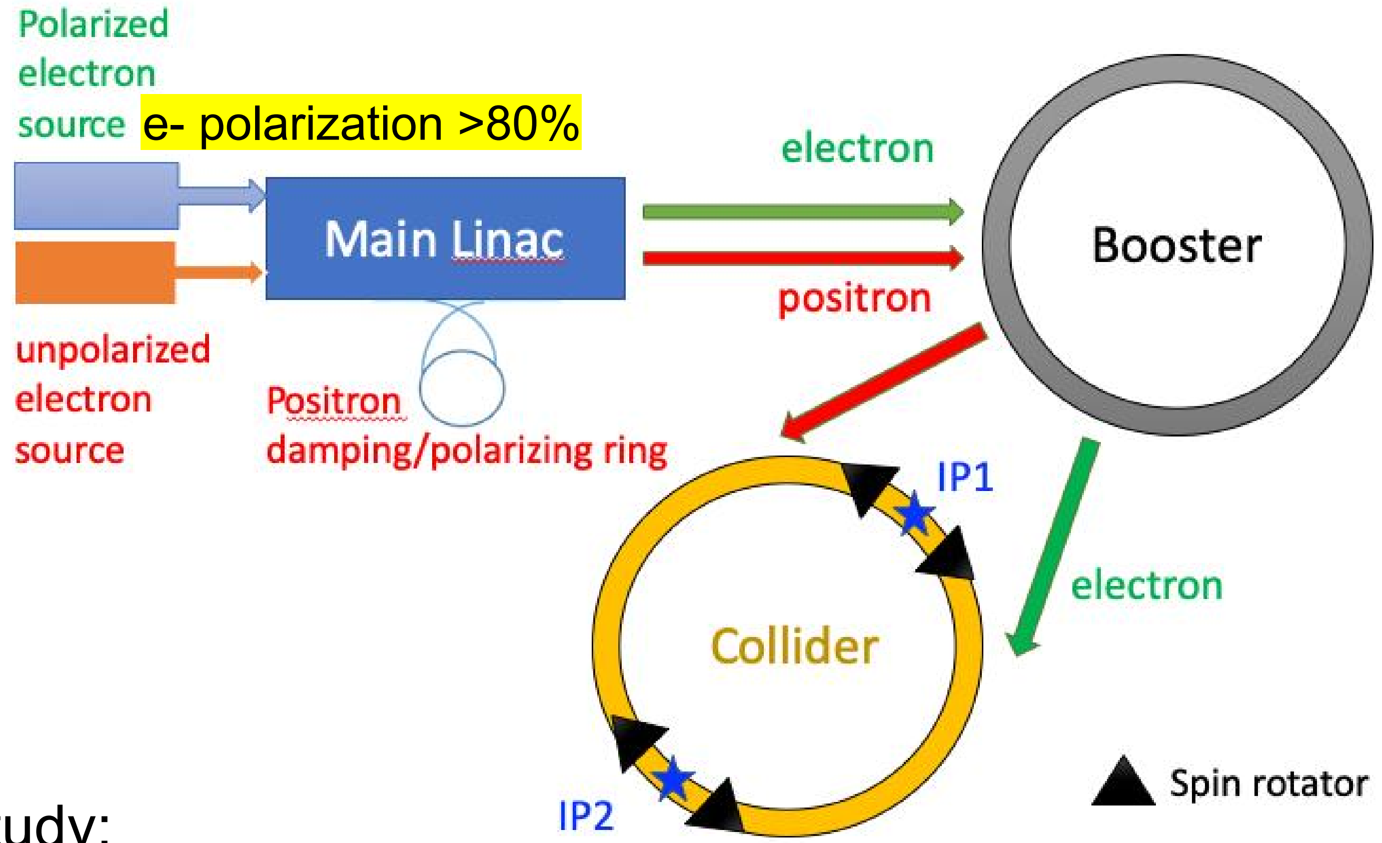




By Xiaoning Wang (2022, IHEP)

Polarized Beam Studies in CEPC

Z. Duan

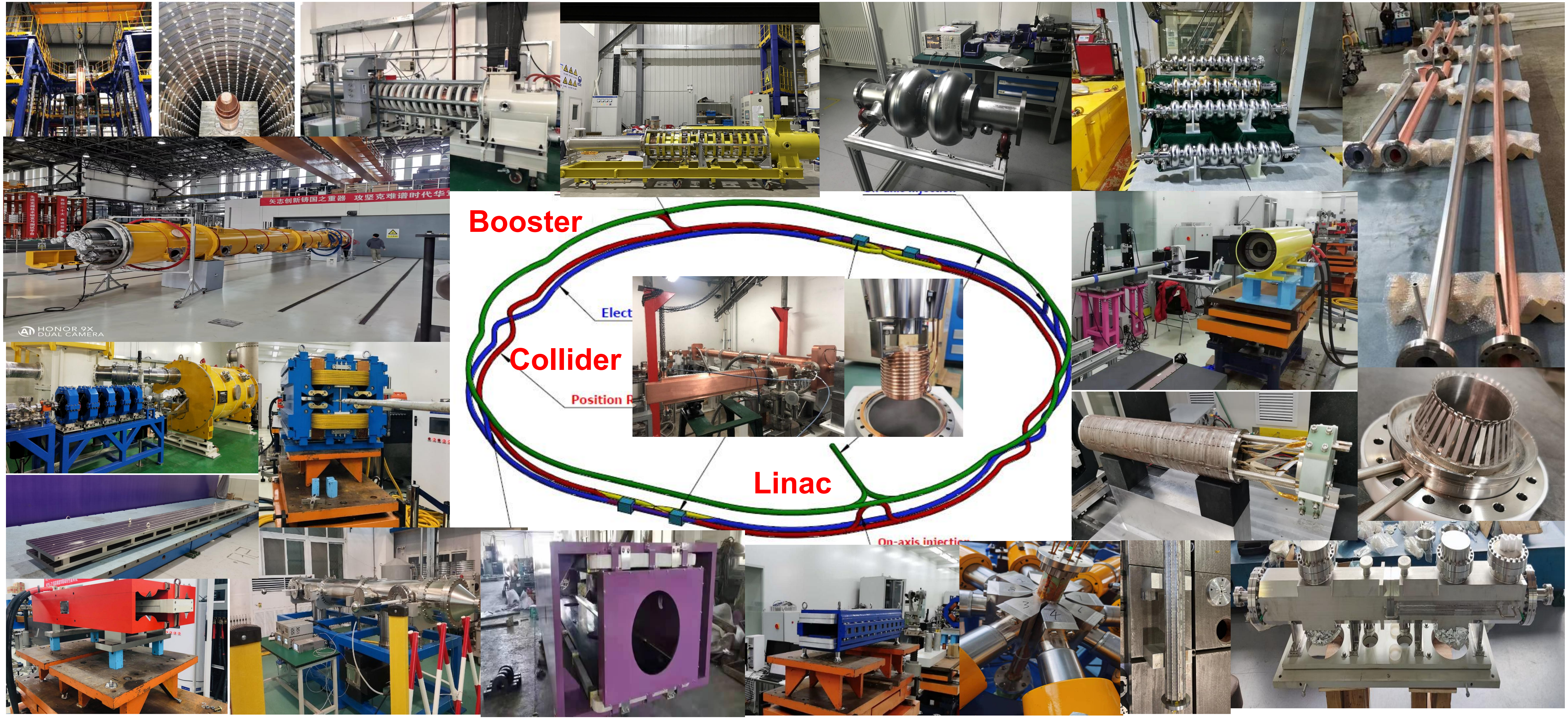


Key issues of study:

- Self polarization and energy calibriation in collider ring with transverse polarization
- Polarization beam injection, ramping in booster and collision with longitudinal polarization

CEPC Accelerator System Key Hardware R&D Progresses in TDR

CEPC TDR R&D Status of Key Technologies



CEPC SRF Facilities and Components

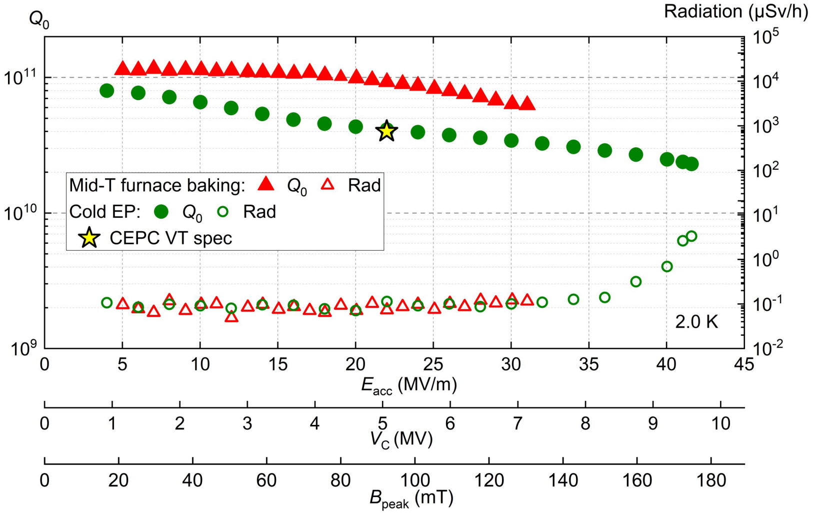
J.Y. Zhai, P. Sha




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



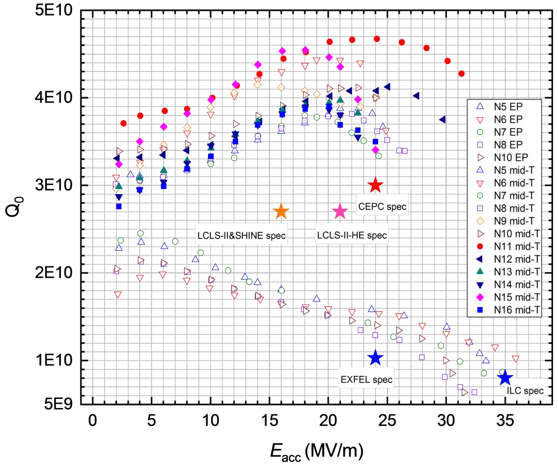
The 650Mhz 1-cell cavity's results (6.4E10@30MV/m, **2.3E10@41.6MV/m**)

.

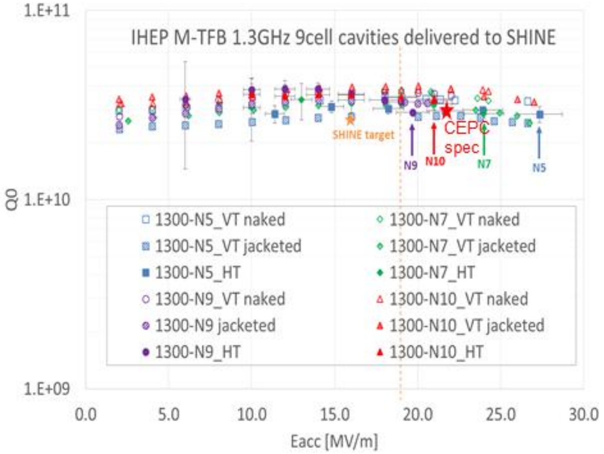
It is very promising to use 1-cell 650MHz cavity for Higgs, W, and Z modes with requirements:

3E10@40MV/m (horizontal)

1.3 GHz High Q Mid-T Cavity Horizontal Test



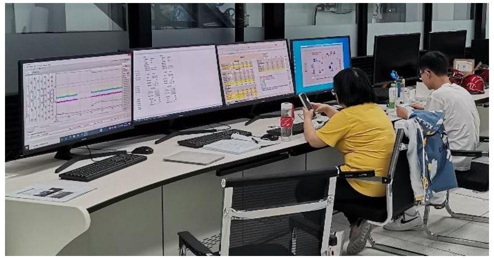
Mid-T 1.3 GHz 9-cell vertical test
avg.4.3E10@ 31 MV/m



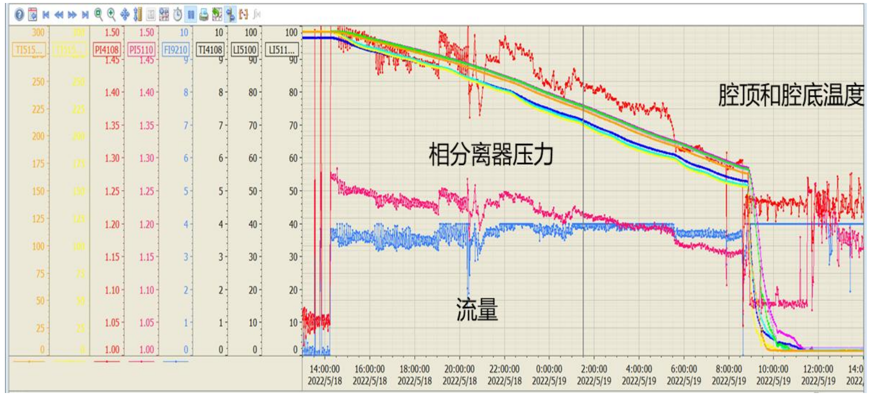
Mid-T 1.3 GHz 9-cell horizontal test (SEL)
3.1E10@21 MV/m, avg. 24.6 MV/m

CEPC 650 MHz 2 x 2-cell Test Cryomodule

J.Y. Zhai



- DC photo-cathode gun voltage conditioned up to 400 kV
- Cavity frequency, HOM coupler double notch filter, tuner, vacuum, cryogenics perform well
- Cavity magnetic field at 2 K < 2 mG (large beam pipe North to South)
- LLRF system commissioning and high power test ongoing
    - Optimizing the outer conductor helium gas cooling of the input coupler. Cavity early quench if with poor coupler cooling.

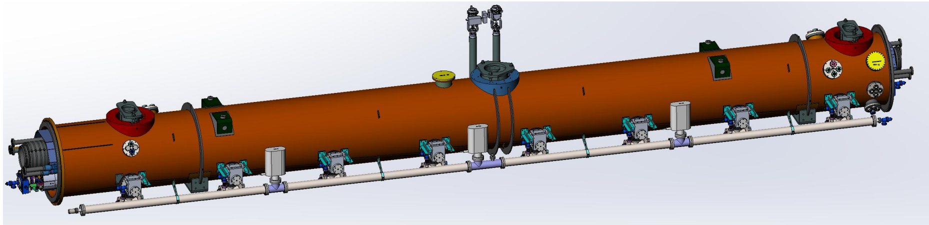


Module automatic cool-down experiment

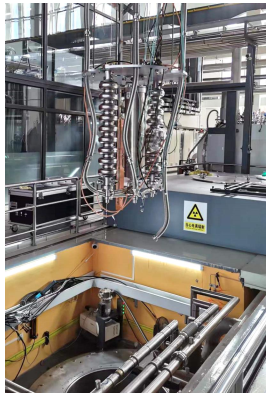
1. 300 to 150 K: < 10 K/hr. Cavity top and bottom ΔT < 20 K
2. 150 to 4.5 K: Cavity surface > 1 K/min
3. 4.5 to 2 K

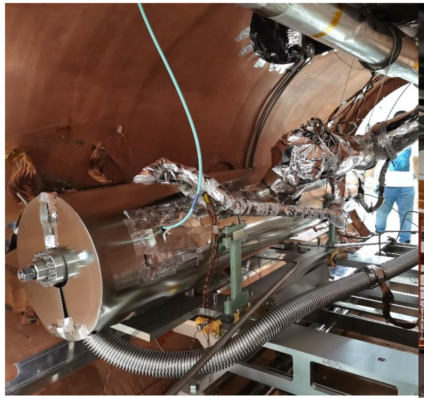
CEPC 1.3 GHz 8 x 9-cell High Q Cryomodule

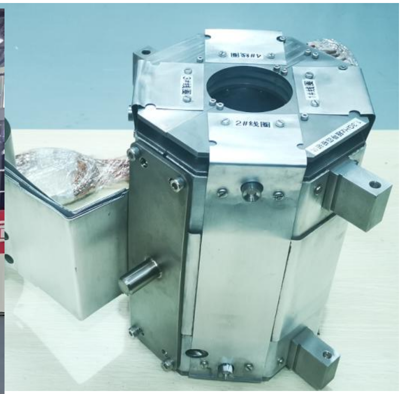
CEPC booster 1.3 GHz SRF R&D and industrialization in synergy with CW FEL projects. J.Y. Zhai

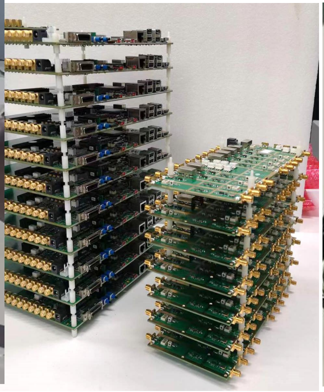


- 8 cavities, input couplers, tuners, SC magnet, BPM, cryostat, other components and tooling are near ready for module assembly
- Module cart, feed/end-cap, volve-box, SSAs, LLRF etc. will be ready soon for horizontal test in early 2023







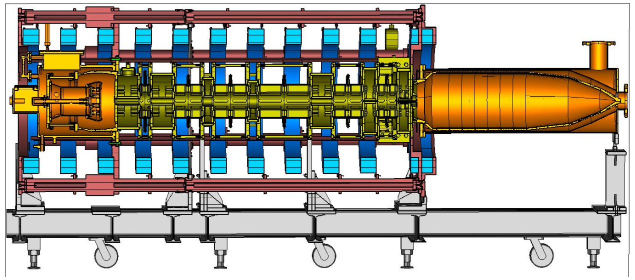


CEPC 650MHz High Efficiency Klystrons

Z.S.Zhou

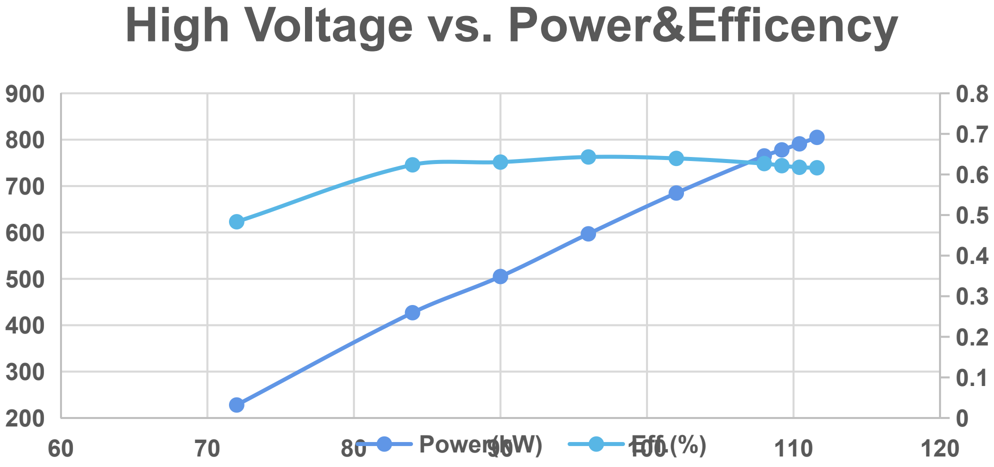
Klystron No. 1
Efficiency 65%
(2020)

Klystron No. 2
Efficiency 77%
(2021)



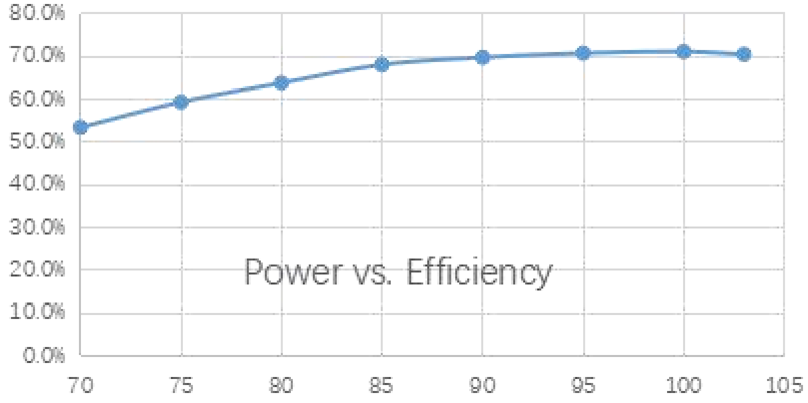
Klystron No. 3 （MBK)
Efficiency 80.5%
(under fabrication)

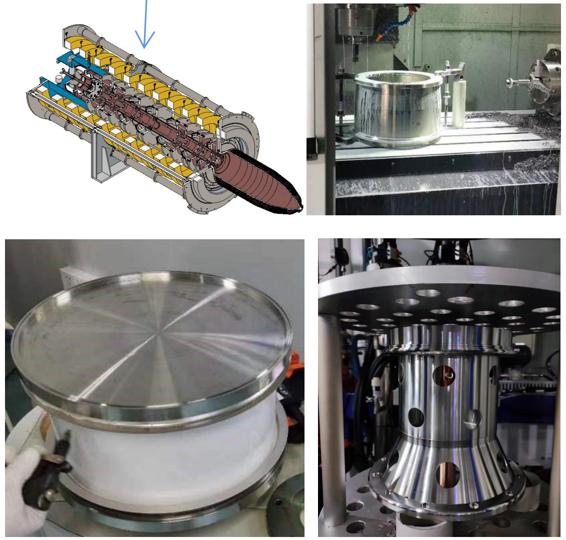
Pulsed RF Mode (30% duty factor, 60ms/5Hz)



2022

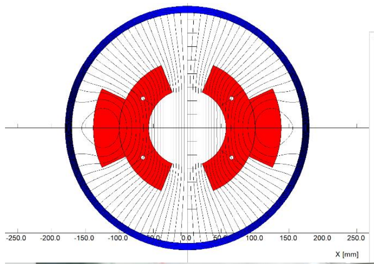
70.5% @ 630kW

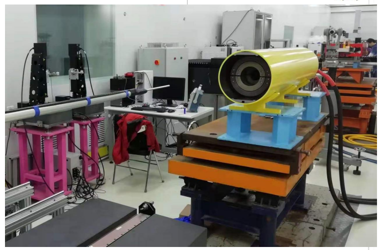


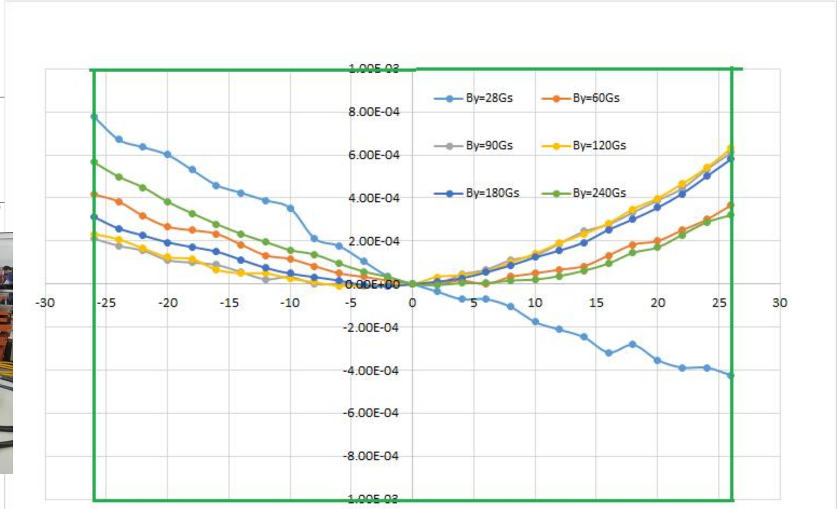


CEPC Full Size Booster Dipole Magnets

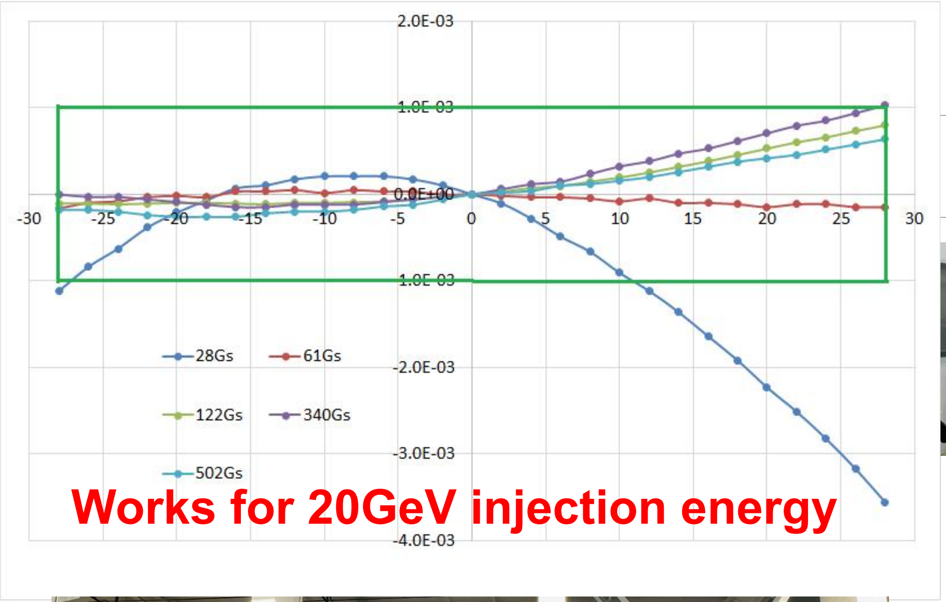
W. Kang



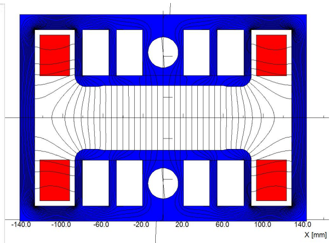




Works for 10GeV injection energy



Works for 20GeV injection energy



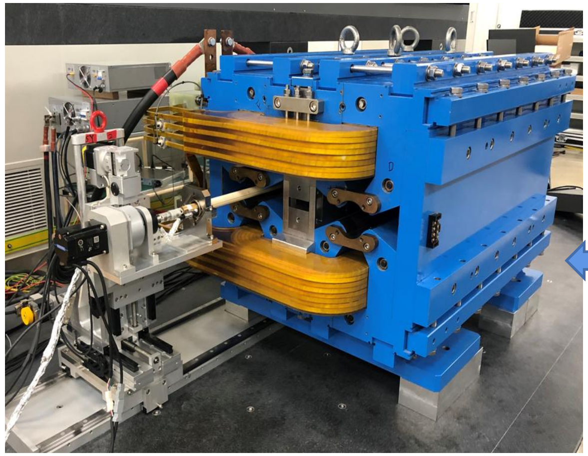
Oct. 20， 2022

Iron core type of 4.7m long full size booster dipoles prototype fabrication completed

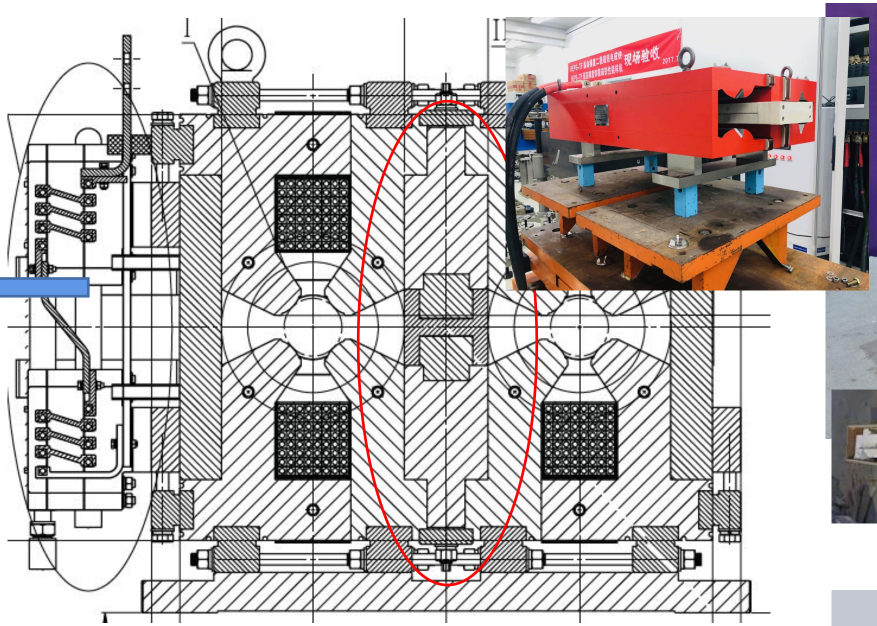
CEPC Collider Ring Magnets

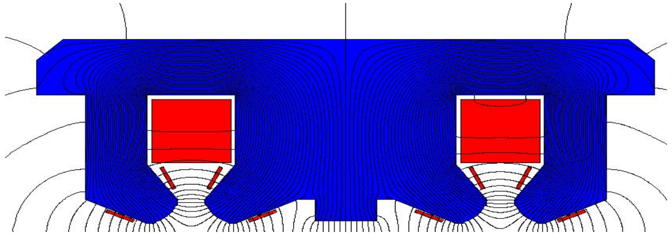
M. Yang

- Modification of the dual aperture quadrupole magnet

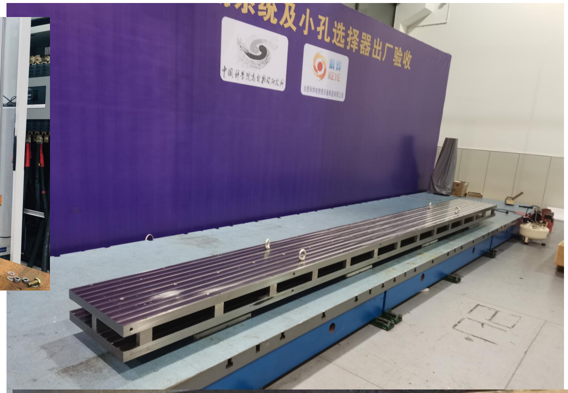


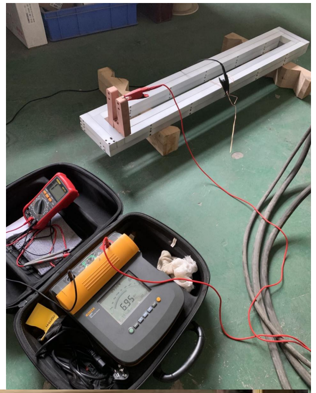
After iron modification with center shim, X0 shifts is lower, which is agreed with the simulation results.



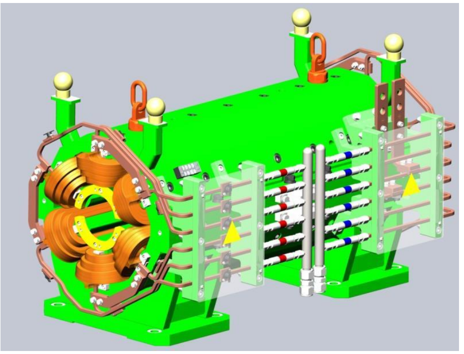


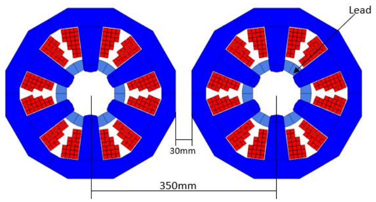
Dural aperture F/D qudrupole design with trim coils





Full size 5.67m dural aperture dipole



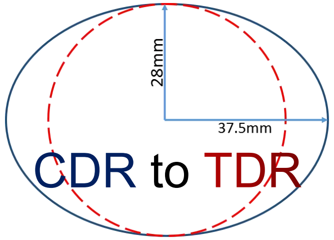


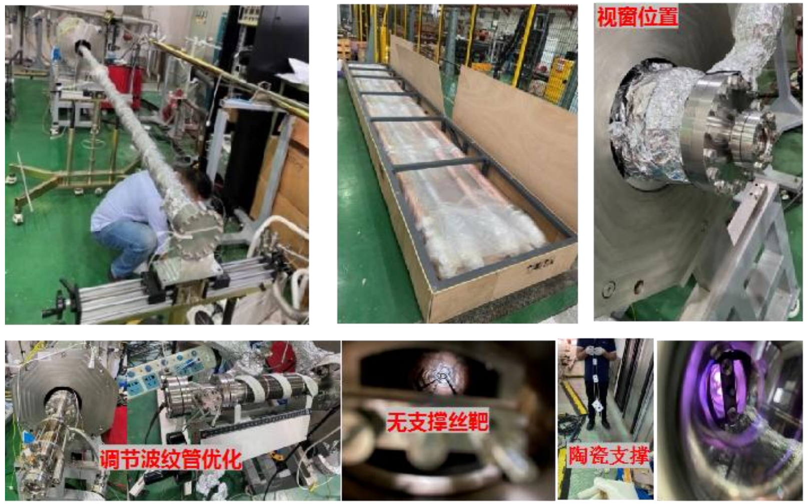
Sextupole design

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



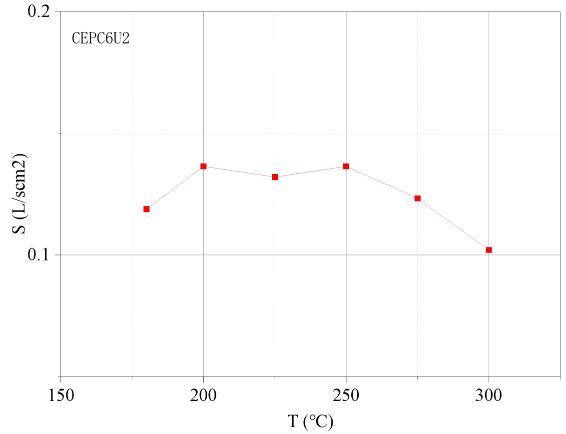


6 m vacuum pipe have been installed on the NEG coating setup

All metal gate valve different from VTA

Vacuum pipes and RF shielding bellows

Facility of pumping speed test have been finished in Dongguan



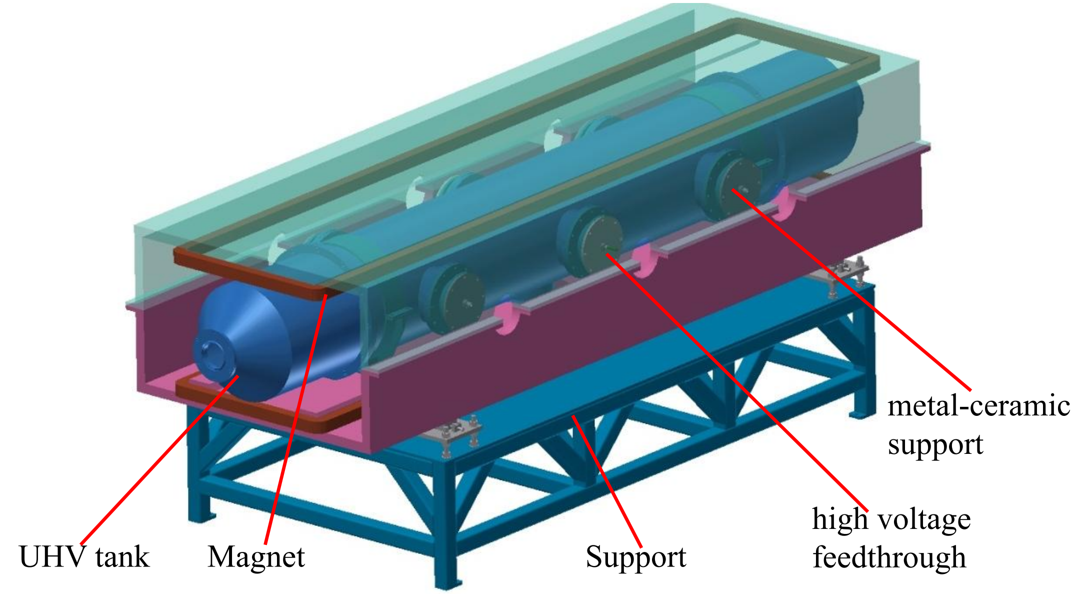
Pumping speed test of 2 meters long CEPC Cu pipe of NEG coating in IHEP

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



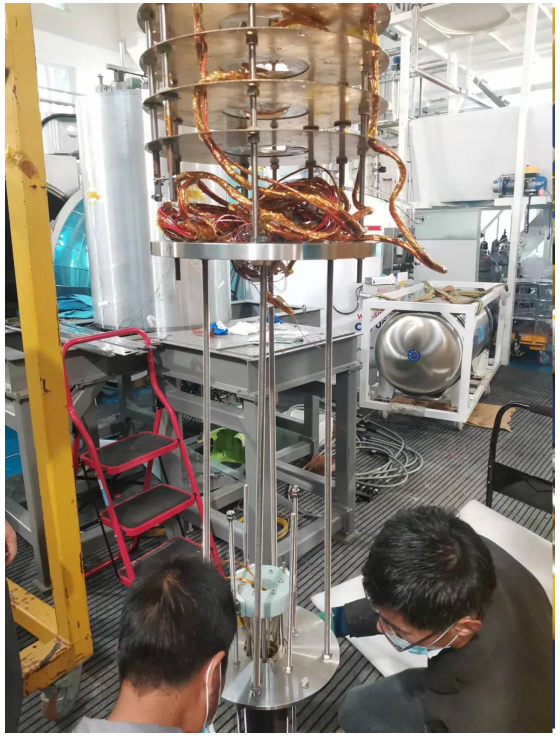
The high voltage of prototype test can reach ±90kV, which meets the requirements of Higgs Mode operation, the operating voltage of the electrostatic separator in Higgs Mode (120GeV) is ±75kV

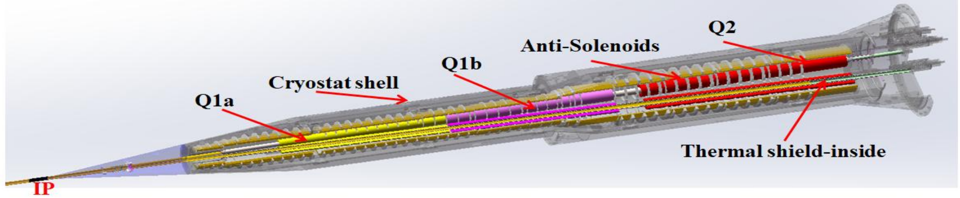
CEPC QD0 SC Magnet R&D (0.5m short model)

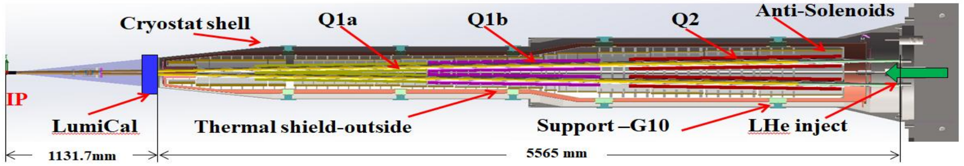
Magnet name	0.5m QD0 model magnet
Field gradient (T/m)	136
Magnetic length (m)	0.5
Coil turns per pole	21
Excitation current (A)	2070
Coil layers	2
Conductor	Rutherford Cable, width 3 mm, mid thickness 0.93 mm, keystone angle 1.9 deg, Cu:Sc=1.3, 12 strands
Stored energy (KJ) (Single aperture)	2.6
Inductance (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.





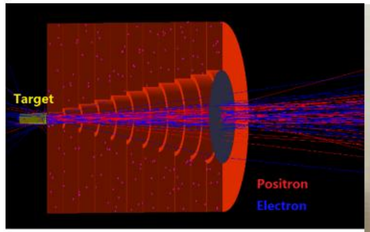


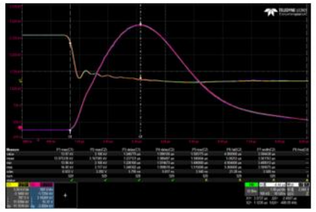
Fabrication of QD0 single aperture short model magnet (NbTi, 136T/m) has been completed in June, 2022, and will be tested in Nov. 2022 and a dual aperture SC quadrupole will be the next step

CPEC Linac Injector Key Technology R&D

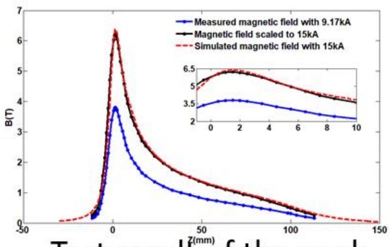
J. Zhang

- Flux concentrator for positron source
- S band pulse compressor
- High perform. S-band Acc. Struc.
- C-band Acc. Struc.

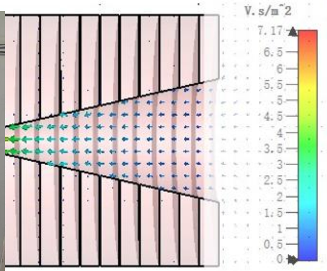




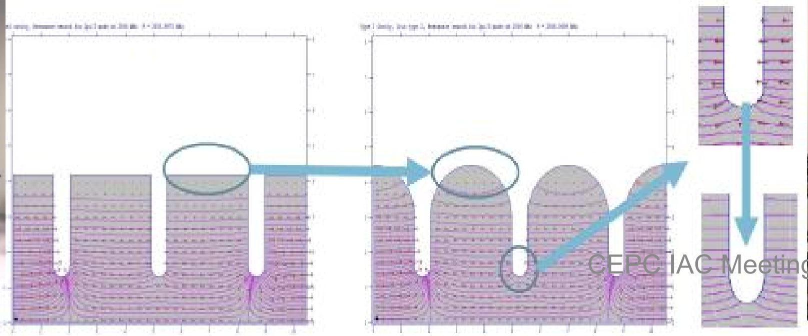
R&D of the solid state

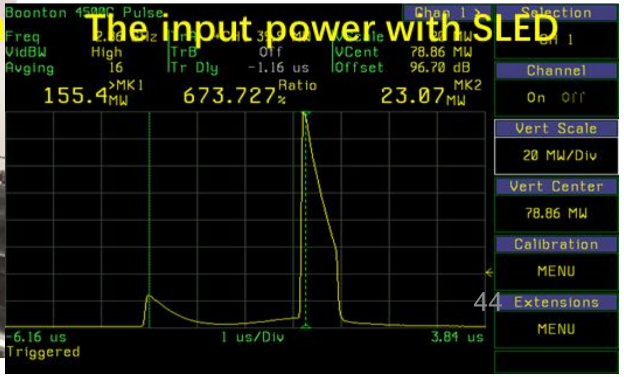


Test result of the peak



- pulsed magnetic field of 6 T to 0.5 T
- 15kA/15kV/50Hz solid state pulse source



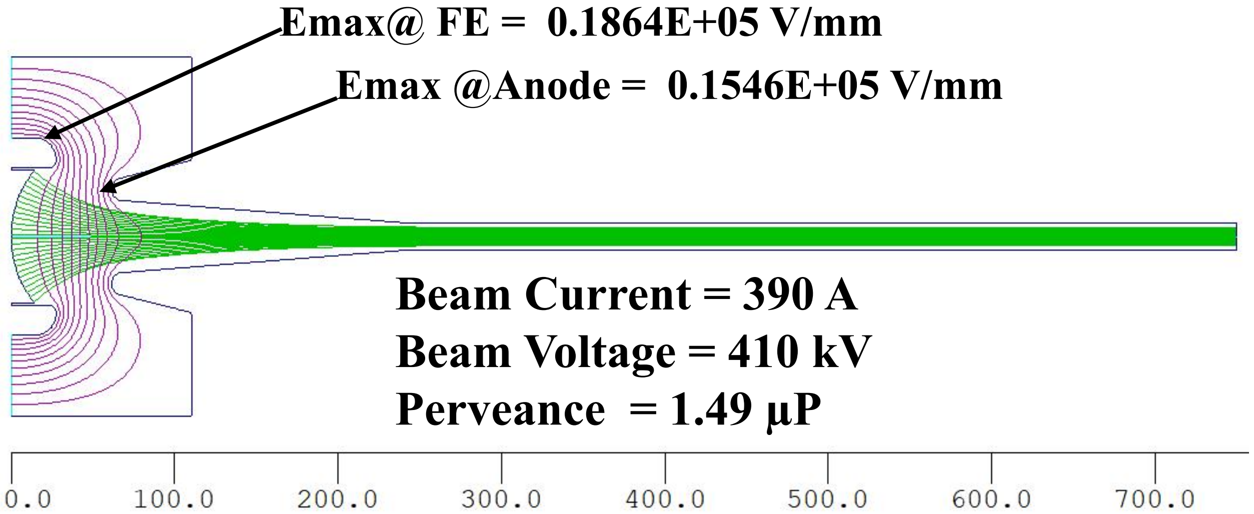


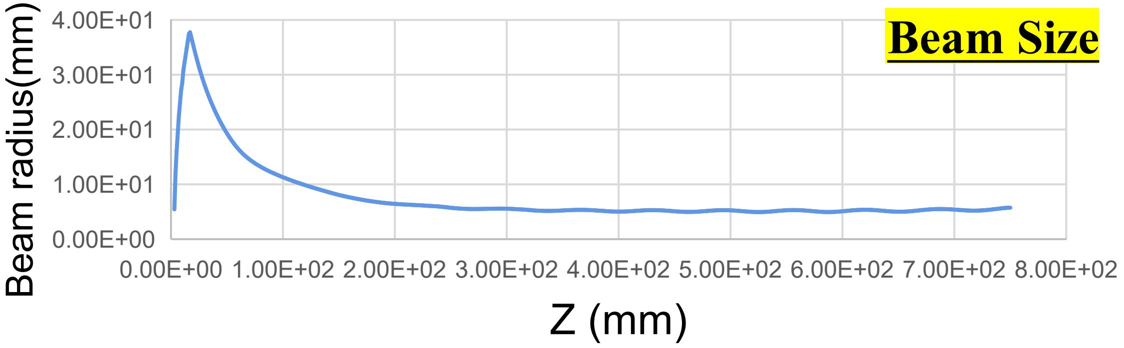
CEPC Linac Advanced Technology Development

J.R. Zhang

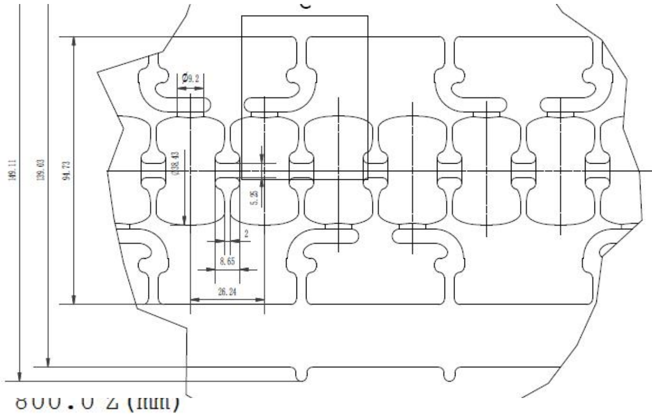
CEPC 80 MW C-Band(5720 MHz) Klystron Design

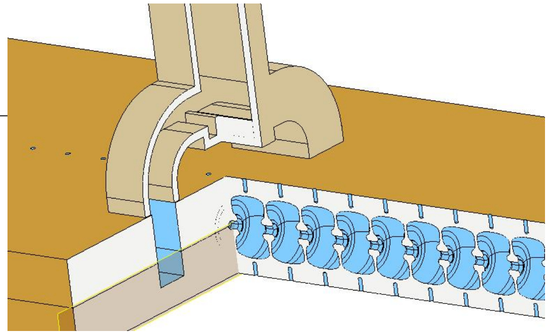
Z.S. Zhou

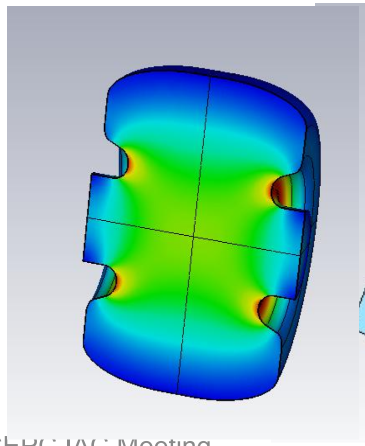


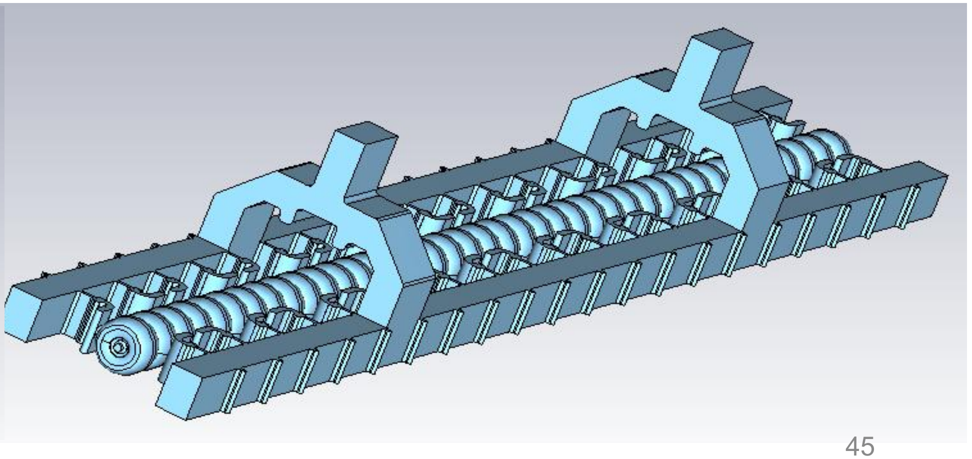


R&D on C3 C band accelerator technology as CEPC alternative C-band linac Eacc >70M/m





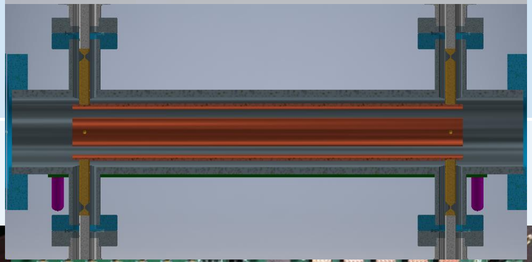


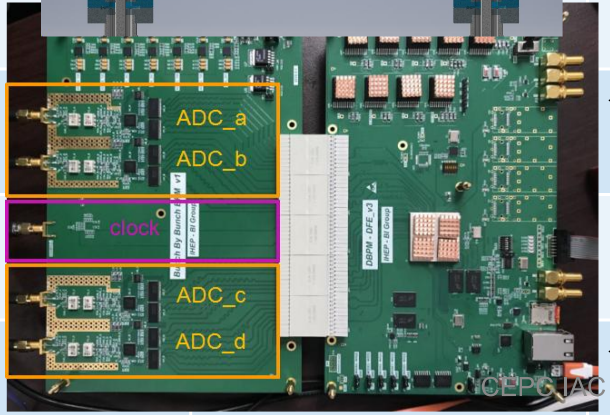


Status of CEPC Beam instrumentation R&D

Y.F. Sui

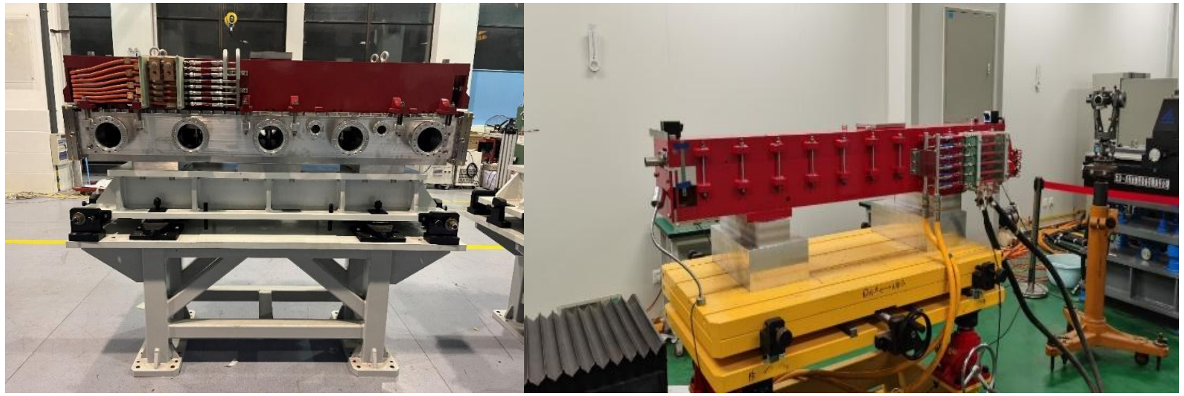
System	R&D Work supported by			Work to be done
	BEPCII	HEPS/HEPS TF	Funding	
BPM electronics	√	√	√	Radiation hardness Industrialization
Beam position monitor fabrication			√	detection;
Longitudinal feedback system	√			
Transverse feedback system	√			
Synchrotron radiation monitor				X-ray interferometer;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





CEPC Inj.&Ext. Hardwares' R&D

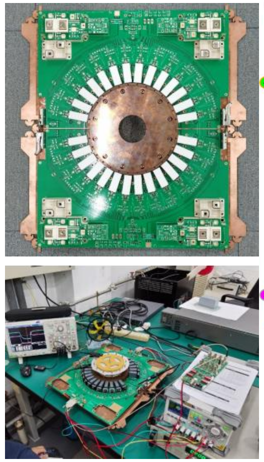
J.H. Chen

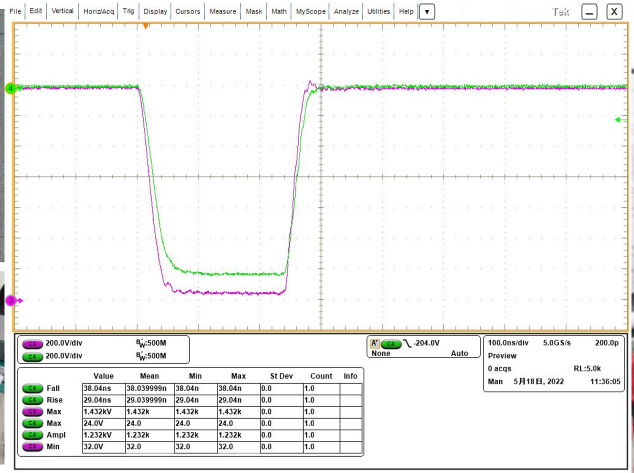


Lambertson magnets

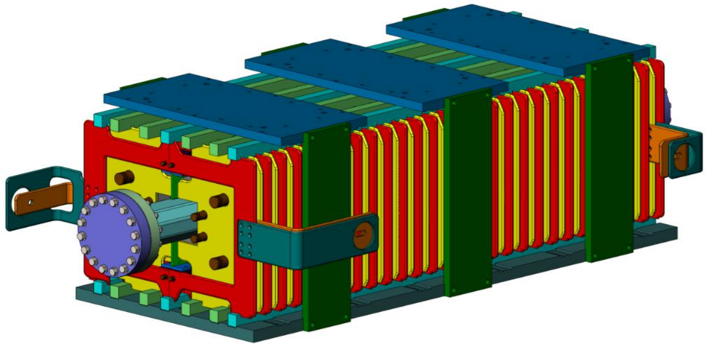
Slotted-pipe kicker

In synergy with HEPS project





250ns-fast kicker pulser

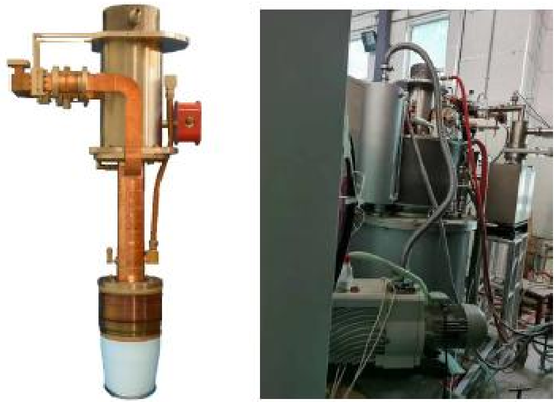


Delay-line dipole kicker

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)

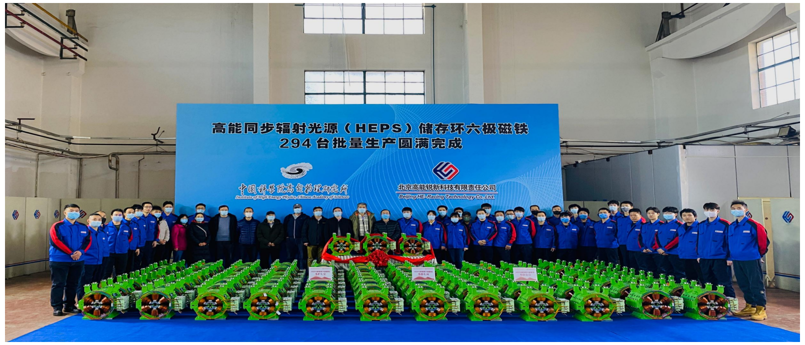
HEPS S-band Linac (May, 2022)



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 (June 2022)



HEPS storage ring sextupole magnets (Dec. 2021)

SppC Collider Parameters in TDR

-Parameter list (updated Feb. 2022)

Jingyu Tang
Haocheng Xu

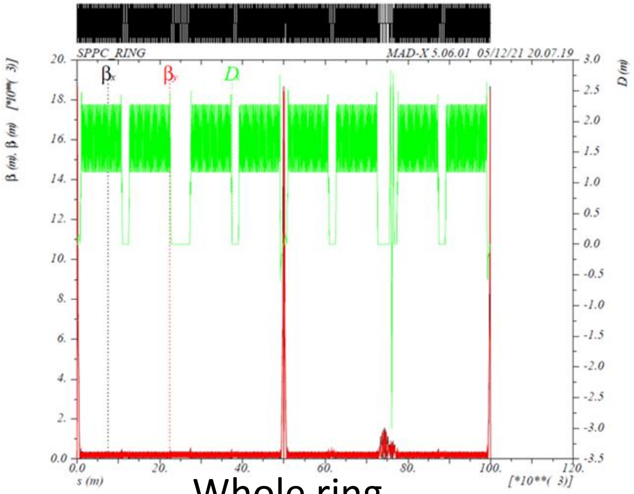
Main parameters		
Circumference	100	km
Beam energy	62.5	TeV
Lorentz gamma	66631	
Dipole field	20.00	T
Dipole curvature radius	10415.4	m
Arc filling factor	0.780	
Total dipole magnet length	65442.0	m
Arc length	83900	m
Total straight section length	16100	m
Energy gain factor in collider rings	19.53	
Injection 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

Ecm=125TeV with dipole field of 20T

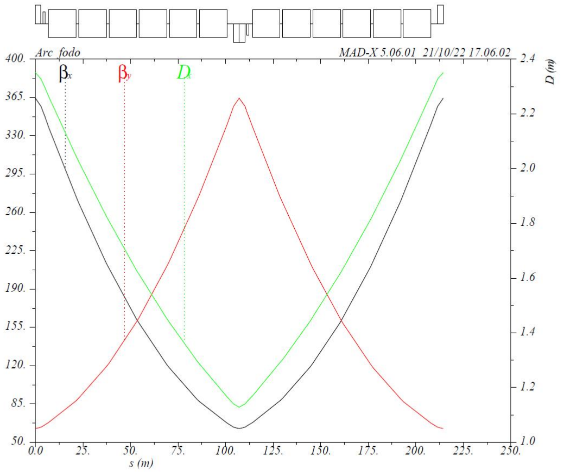
SppC Lattice Design@125TeV (20T) in TDR

Haocheng Xu
Yiwei Wang

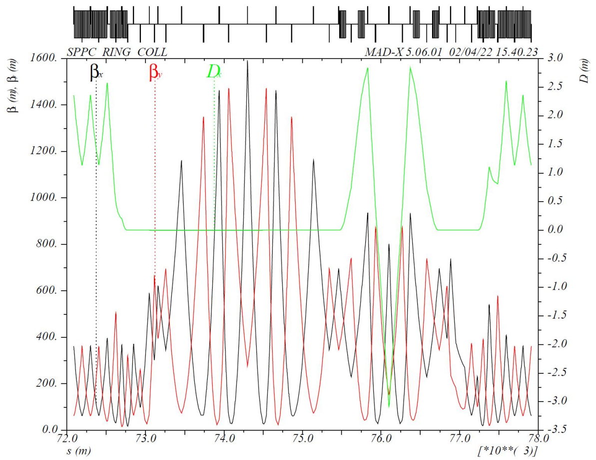
- Lattice of SPPC whole ring, Arc region, collimator section and IP region



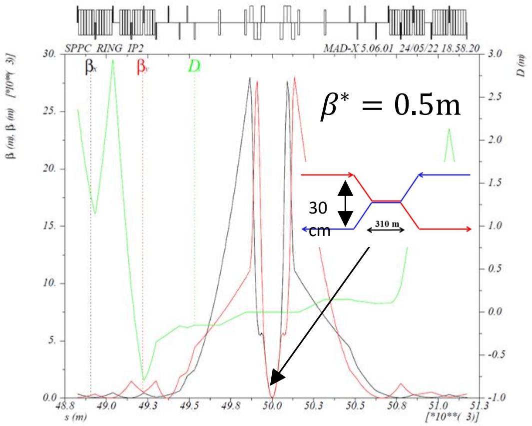
Whole ring



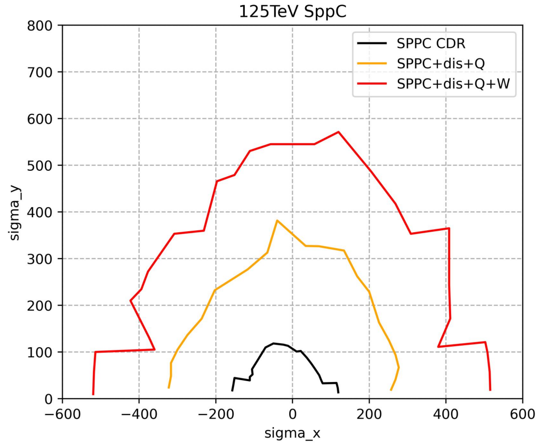
Arc cell

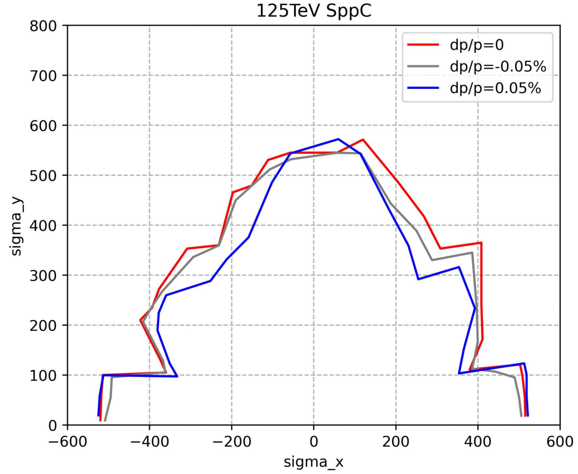


Collimation



IP



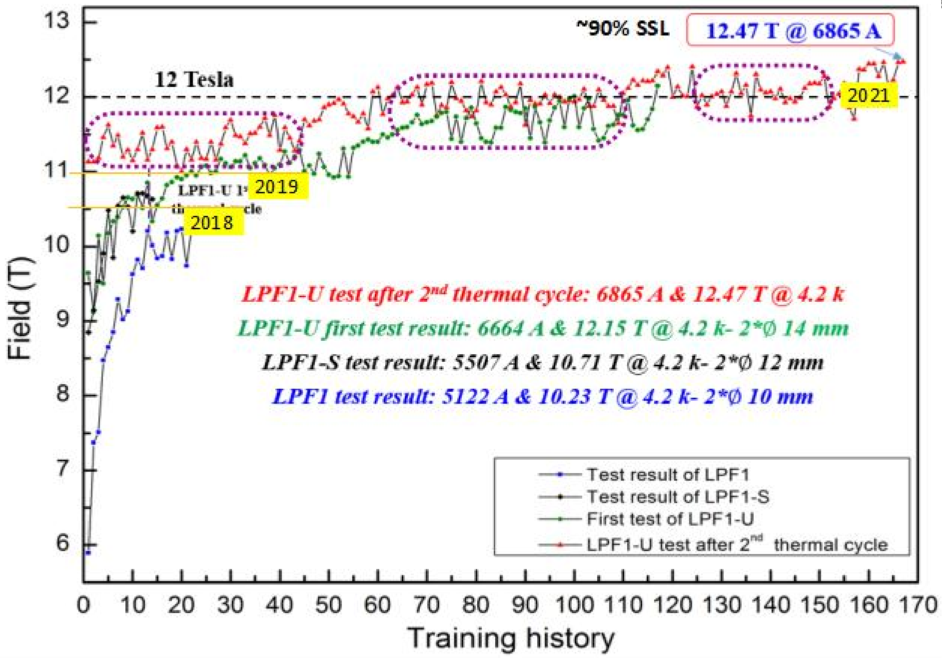


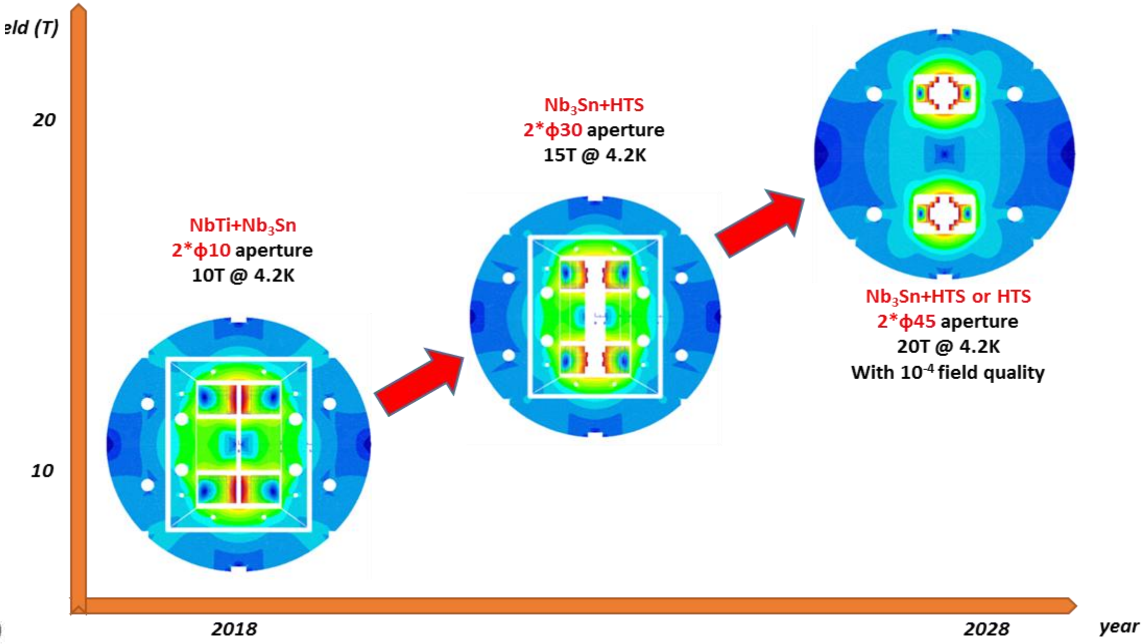
- Dynamic Aperture Optimization

Latest Performance of LPF1-U (SppC)

Qingjin Xu

Picture of LPF1-U

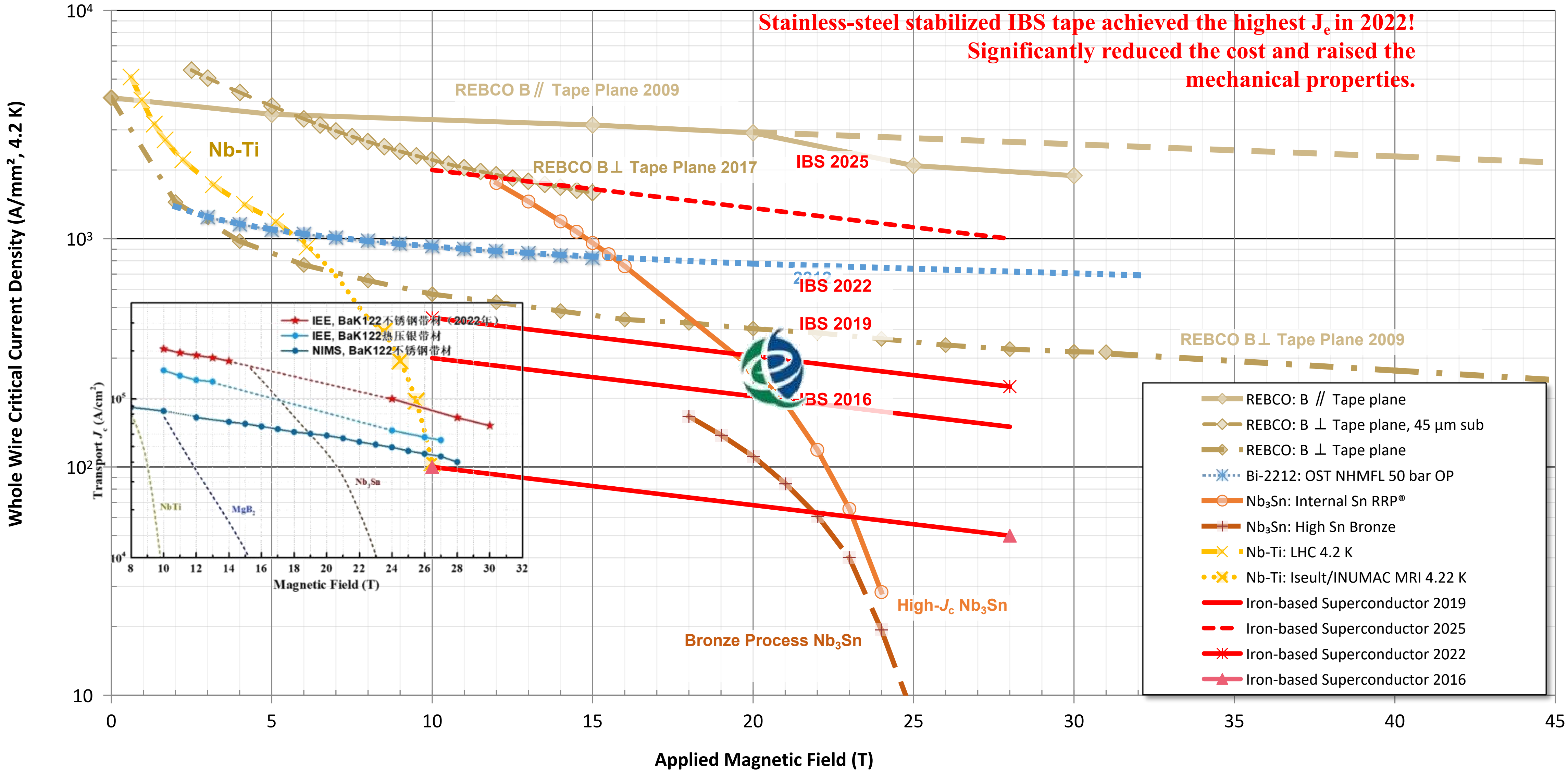




Dual aperture superconducting dipole achieves 12.47 T at 4.2 K
Entirely fabricated in China. The next step is reaching 16-19T field

IBS Technology: Status and Outlook

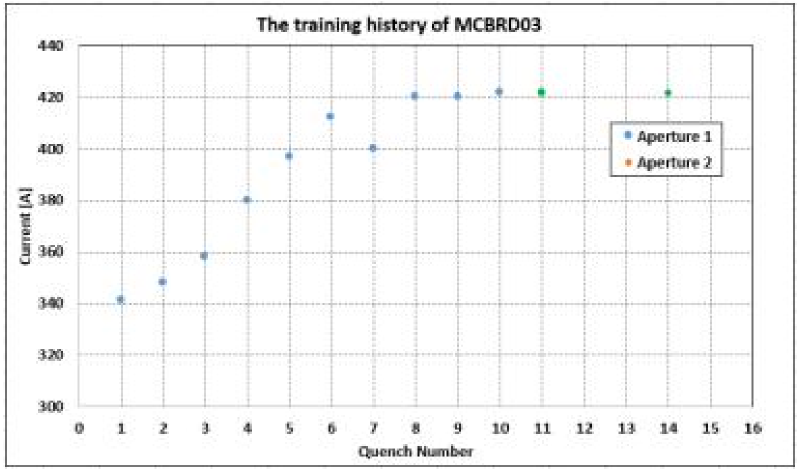
Qingjin Xu

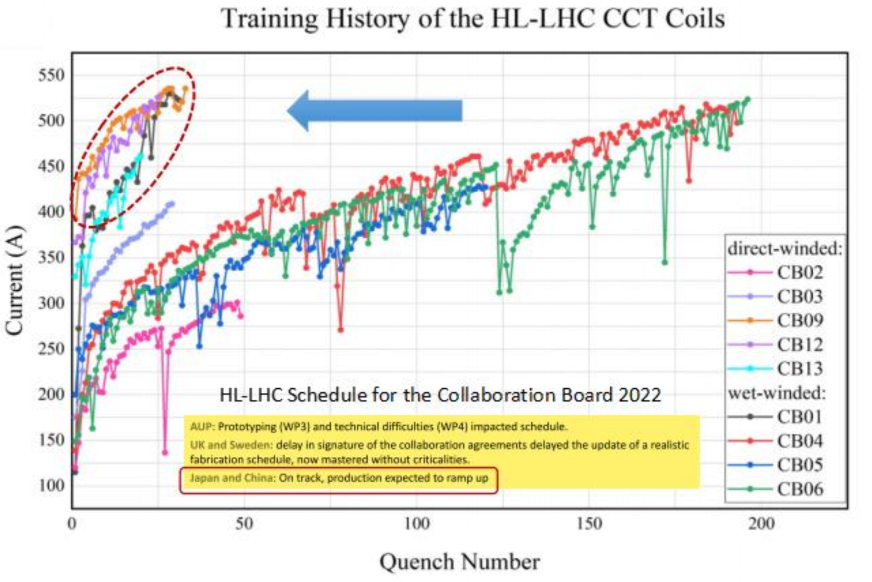


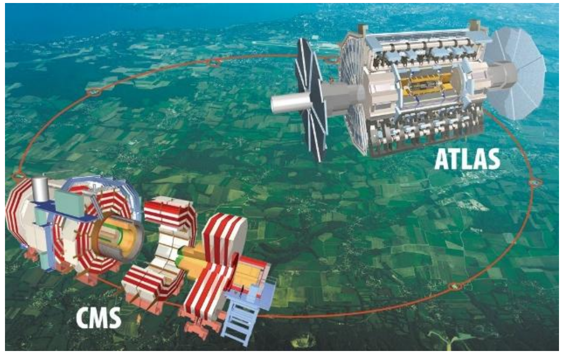
Development of CCT dipole magnets for HL-LHC by IHEP

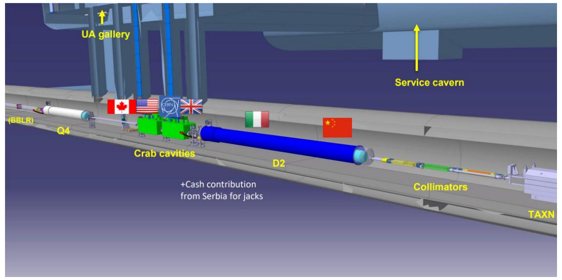
IHEP provides 13 units CCT twin-aperture dipole magnets for HL-LHC

Qingjin Xu





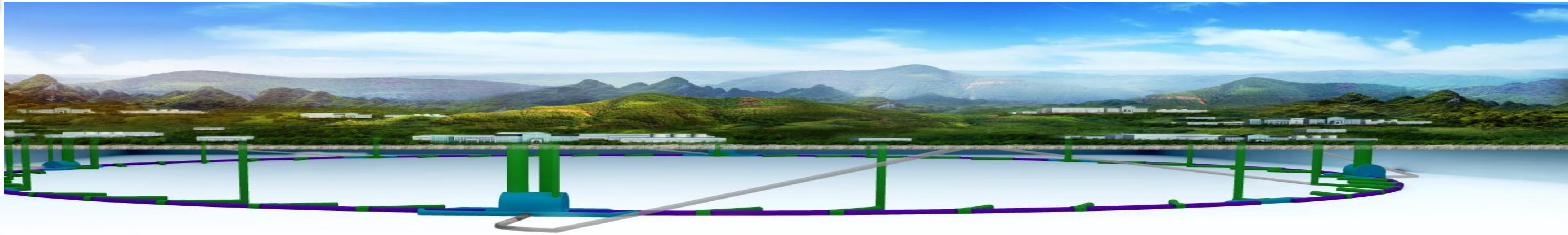


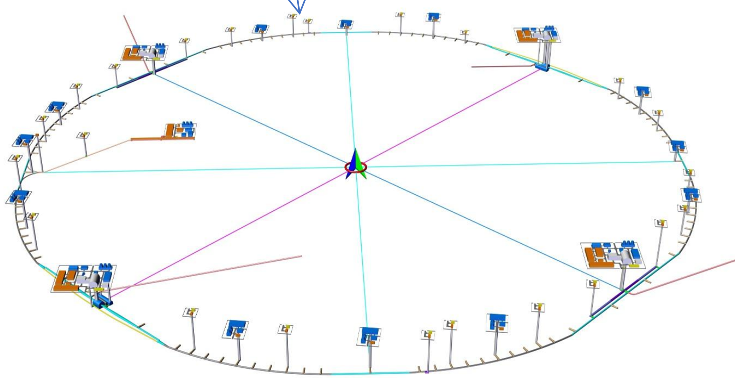


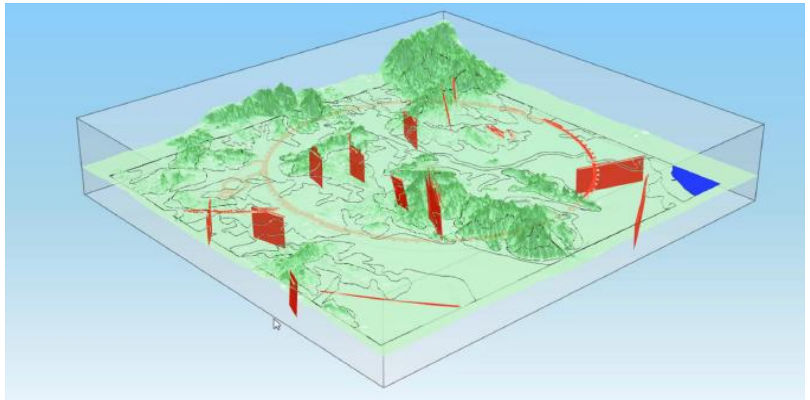
- AP1(CB12, 25 quenches 526A) reached ±422A after 11 quenches.
- AP2(CB09, 33 quenches 530A; after thermal cycle ＞500A) reached ±422A without any quenches.

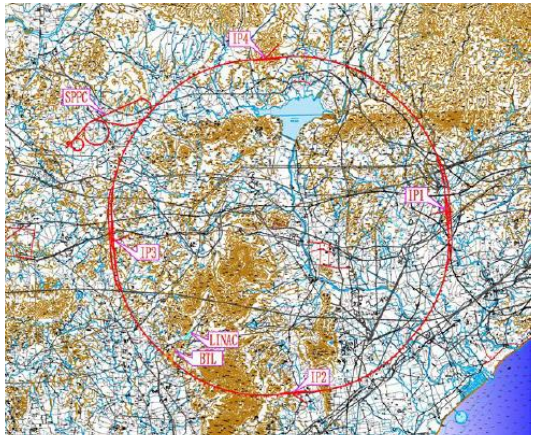
CEPC Siting, Civil Engineering, AC power consumptions,and Installation Strategy

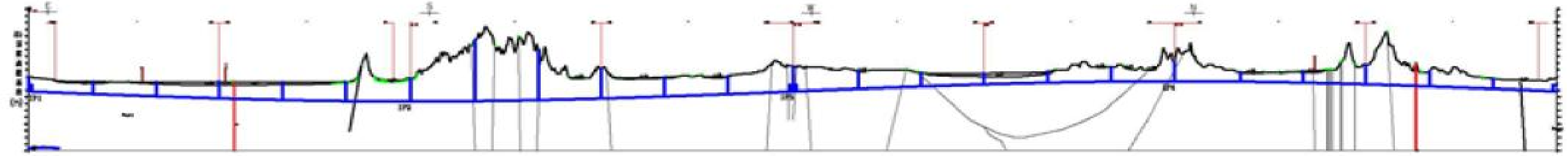
CEPC Siting and Civil Engineering (Qinhuangdao TDR site as an example)





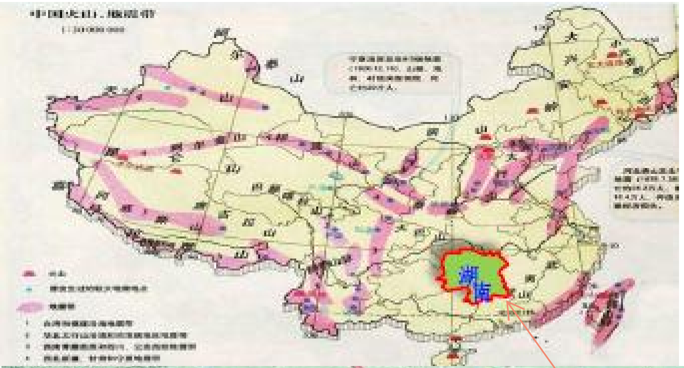


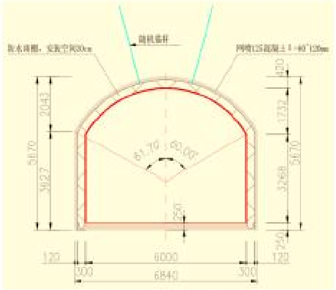




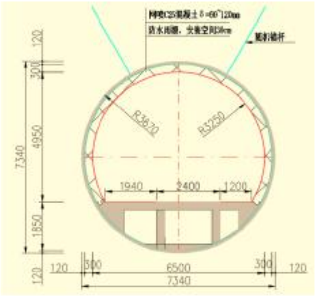
CEPC Siting, Civil Engineering (Changsha site as an example)

Very good geological condition

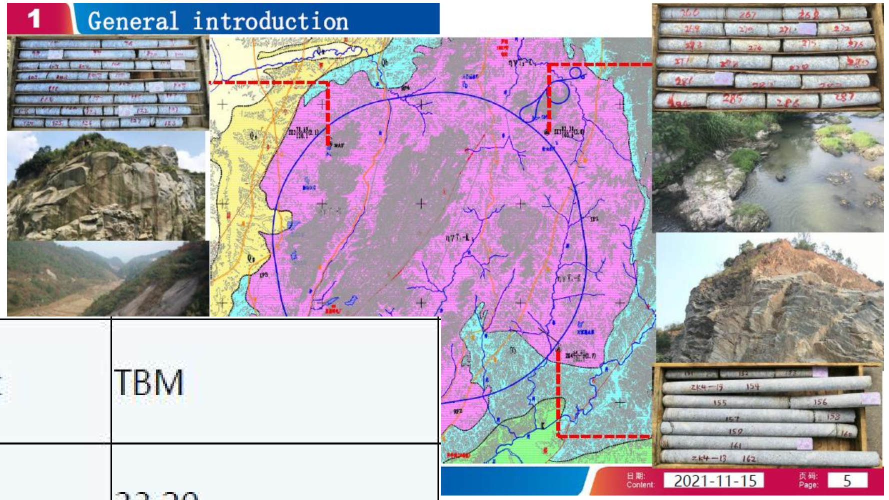


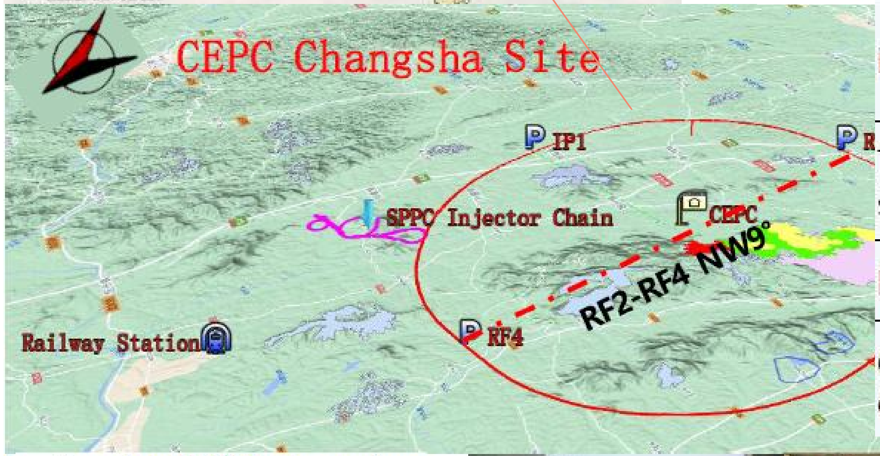


Drill-blast tunnel (6.0m×5.0m)

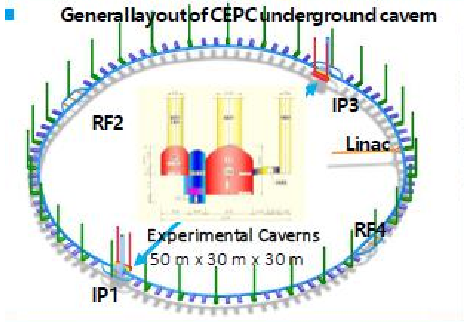


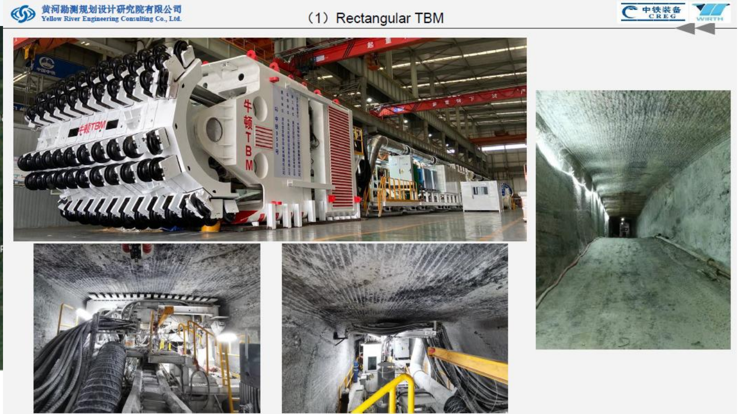
TBM tunnel （D6.5m）



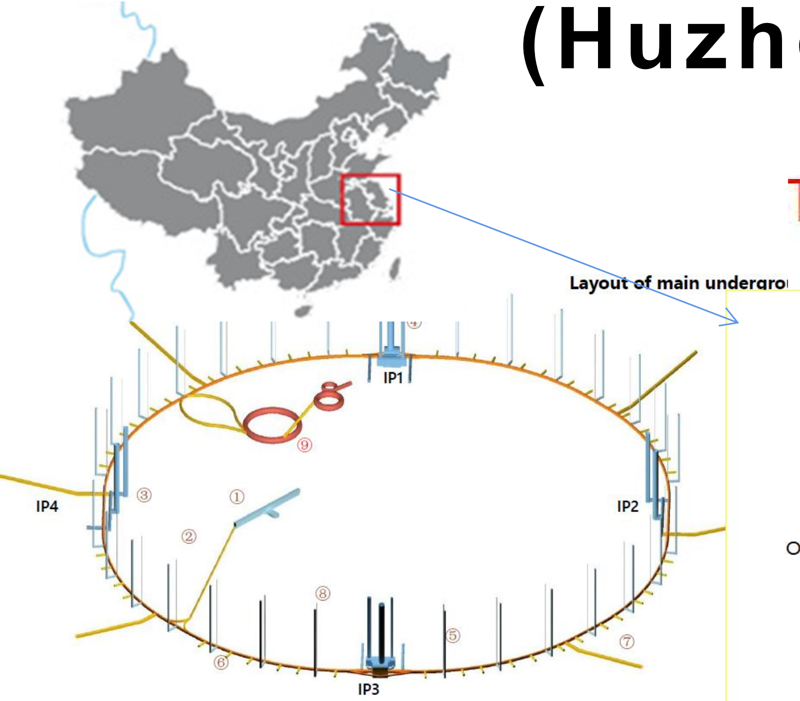


Item	Unit	Drill-blast	TBM
The clearance cross section	㎡	27.00	33.20
Excavation unit price	Yuan/m³	278.28	617.00
Construction duration	Month	50	52





CEPC Siting and Civil Engineering (Huzhou TDR site as an example)



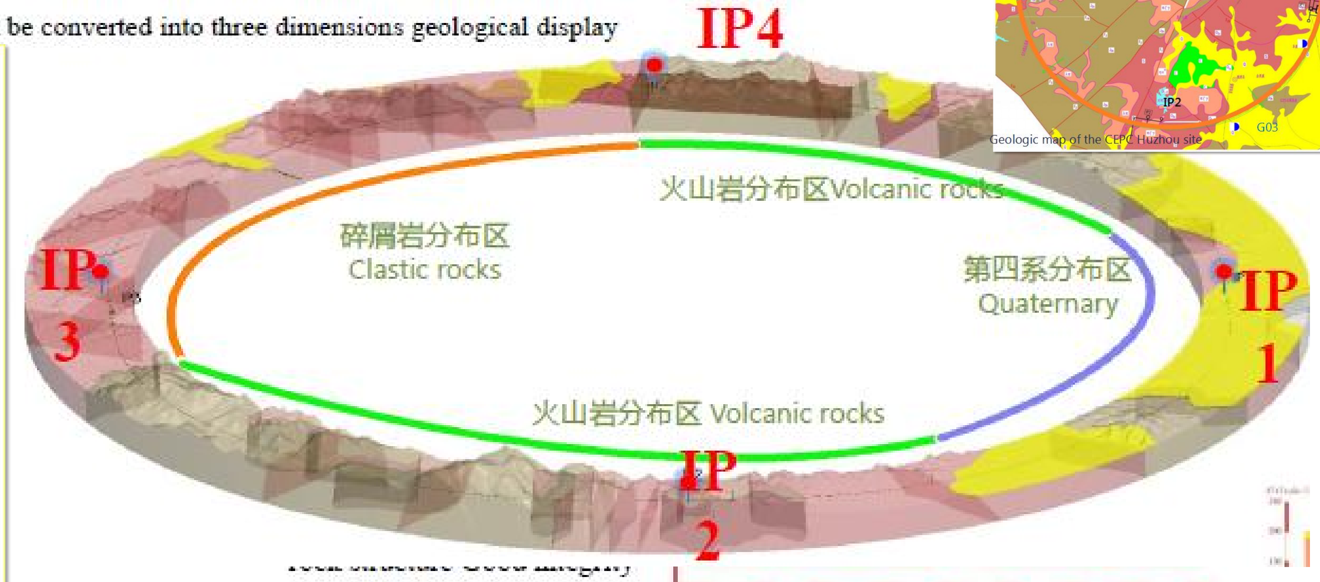
The minimum depth of the main ring is 70m

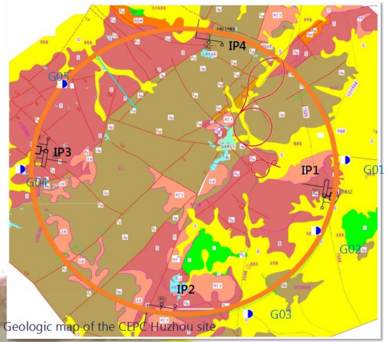
The geological work can be converted into three dimensions geological display

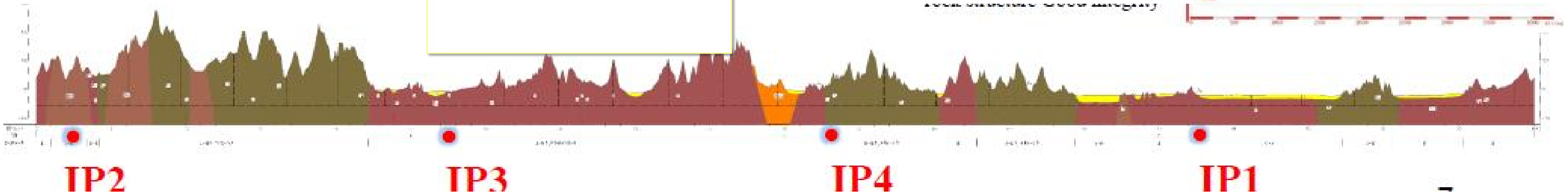
CEPC-SPPC 项目湖州场址TDR
第一阶段工程地质勘察主报告
工程编号：

CEPC TDR
On Engineering geological survey of the first stage
(Zhejiang Hu Zhou Site)

二〇一九年九月



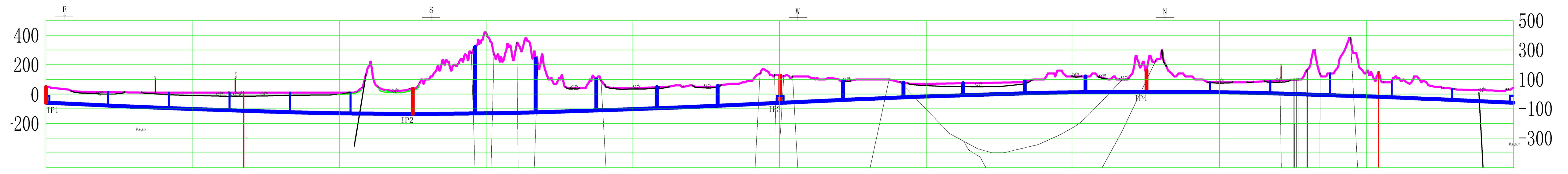




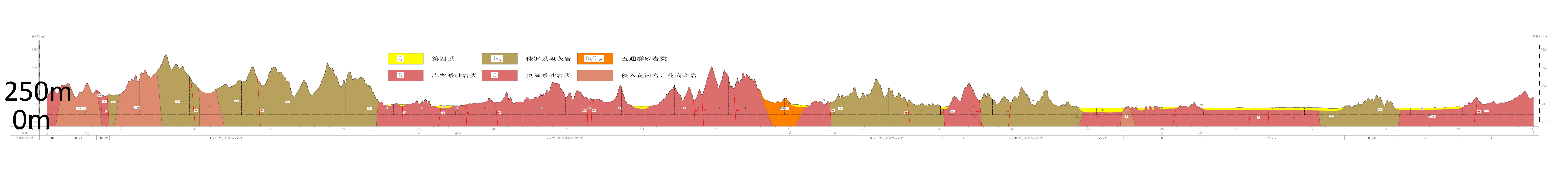
CEPC Sites Engineering Geologies in TDR

Qinhuangdao	Huzhou	Changsha

Qinhuangdao

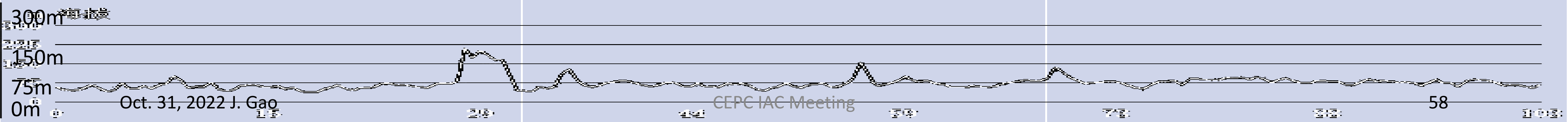


Huzhou

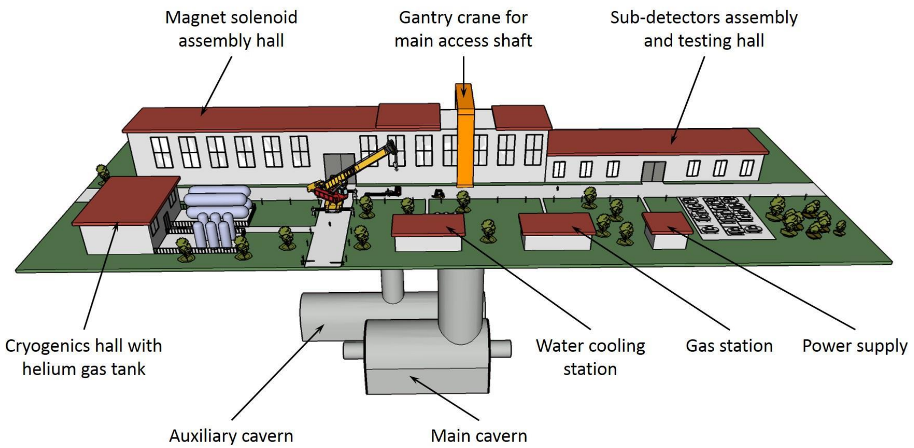


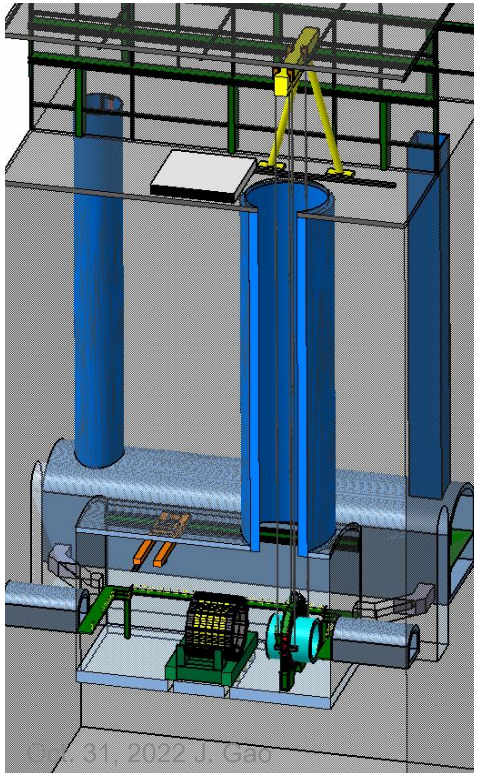
Changsha

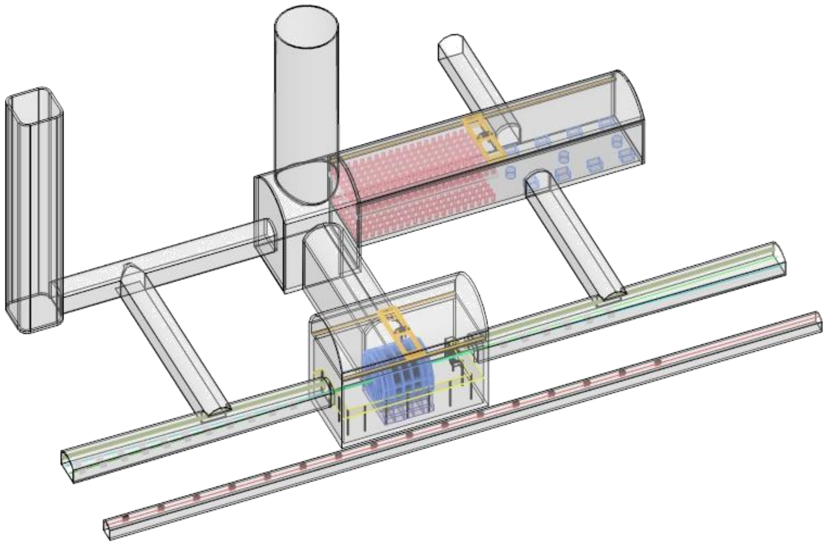
Shafts depths: 50m~106m



CEPC IR Region



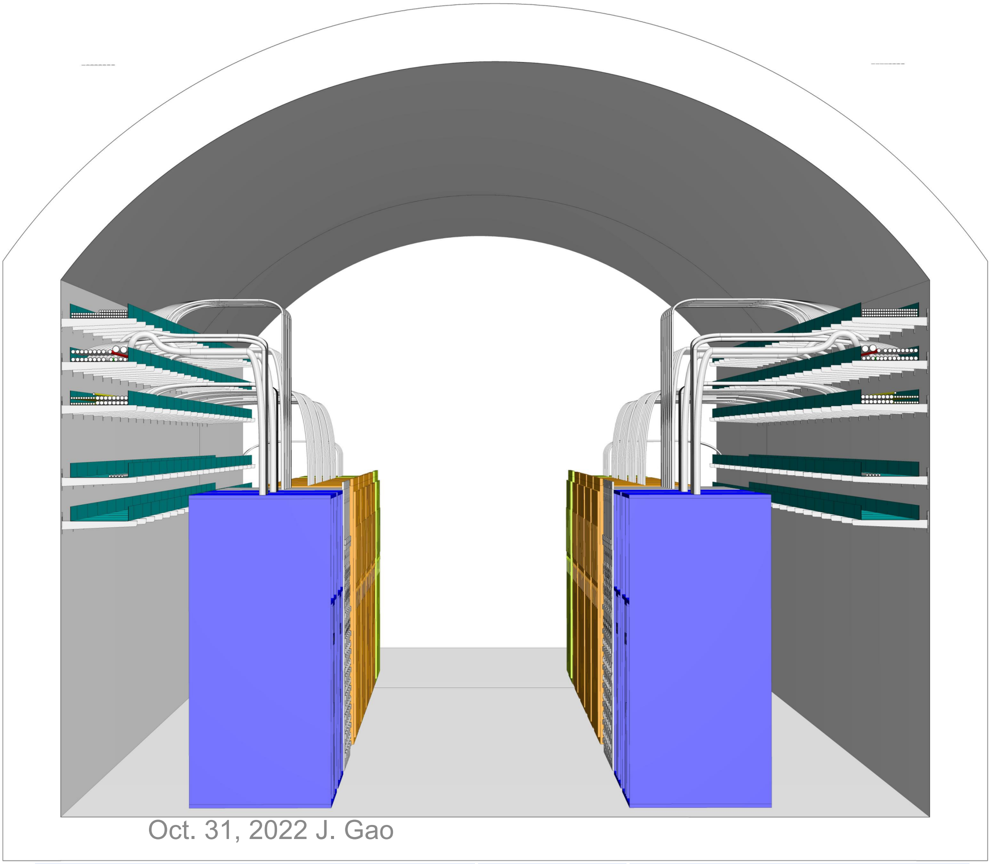




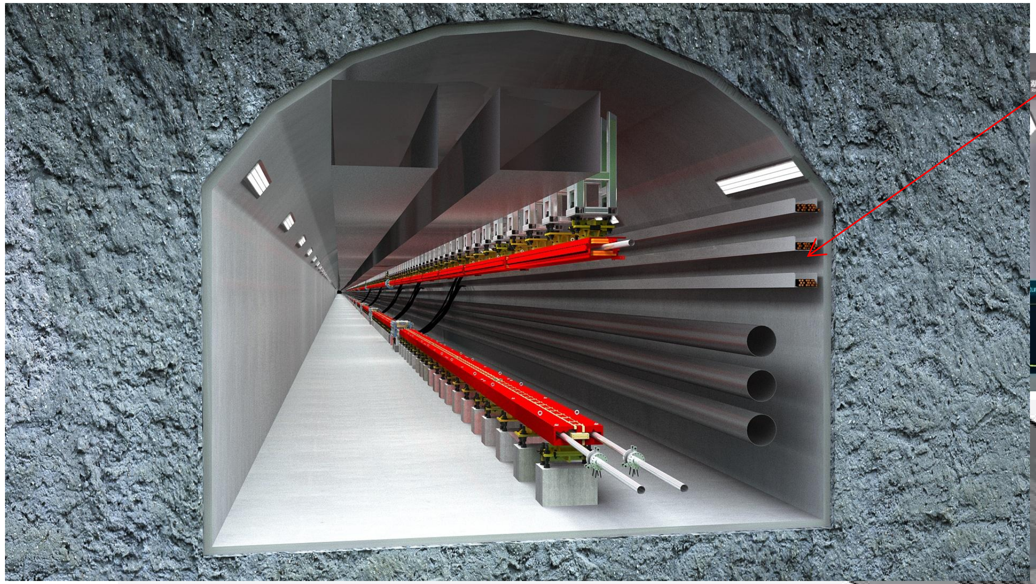
Name	L×W×H	Numb.
Experimental hall	39.4×20.4×31	×2
Axiliary hall	101.4×20×26.2	×2
Booster tunnel	1679×3.5×3.5	×4
Collider tunnel	1659.3x(6~11.4)x5	×4
Travel shaft	1200x7.5x7.5	×2
Connection, electric cable and ventilation shaft	70x10x10	×2

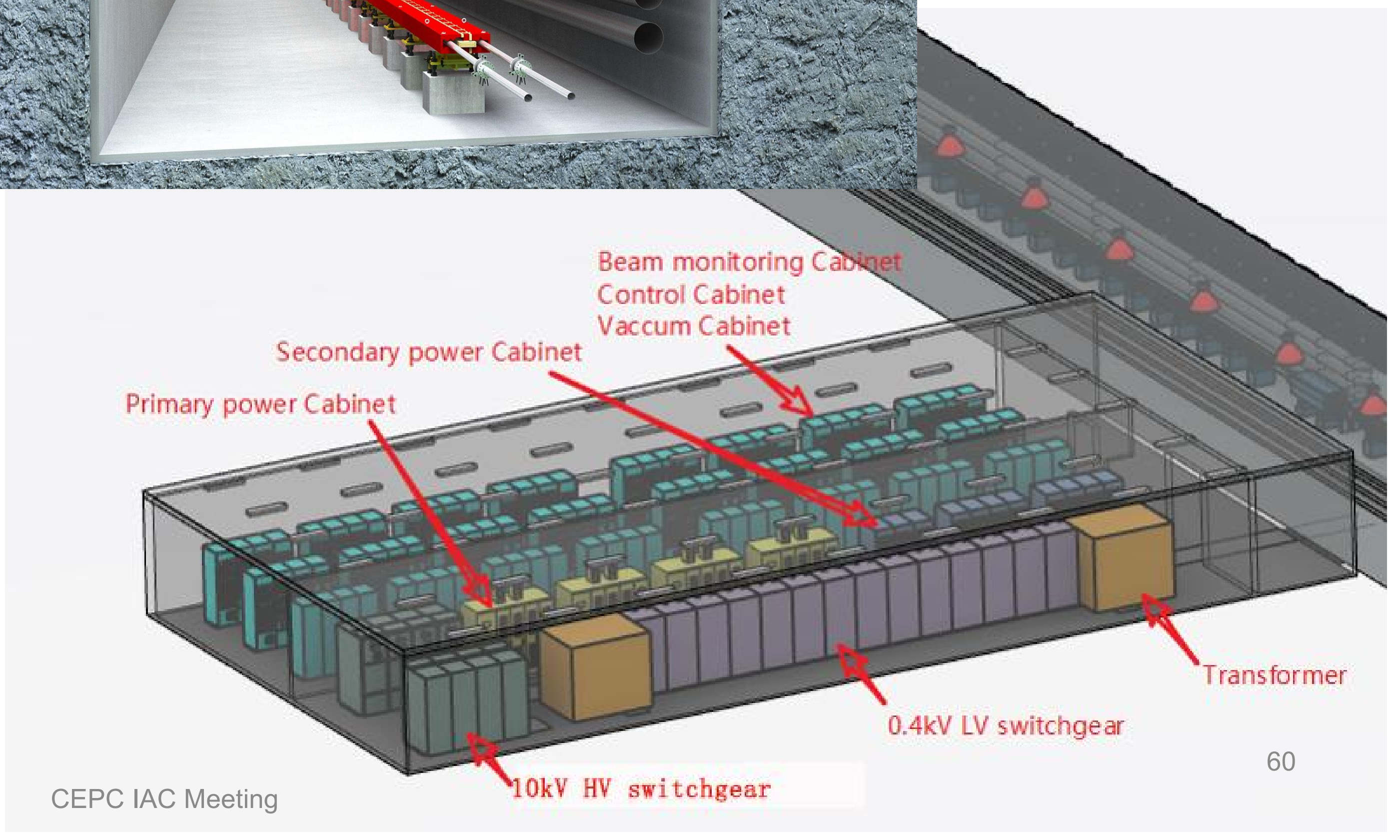
CEPC Conventional Facility and Civil Engineering

Electrical Equipment General Layout in Auxiliary



Cables installed!





CEPC TDR Power Consumption Breakdowns@Higgs with 30GeV injection Linac and 30MW SR/beam

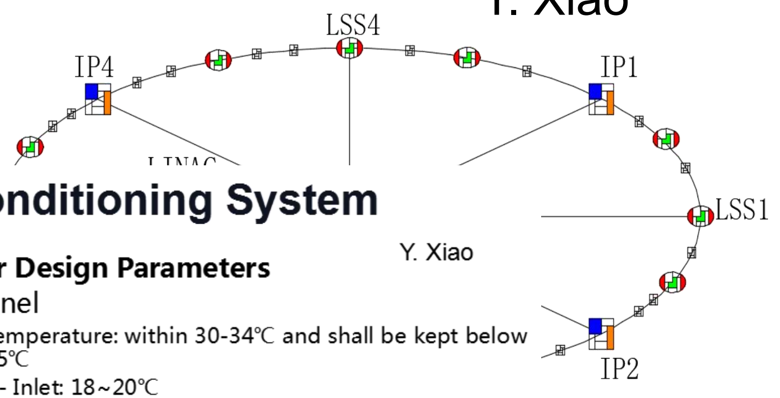
	Location and electrical demand(MW)						
	Ring	Booster	LINAC	BTL	IR	Surface building	TOTAL
RF Power Source	96.9	1.4	11.1				109.5
Cryogenic System	11.6	0.6	-		1.1		13.4
Vacuum System	1.0	3.8	1.8				6.5
Magnet Power Supplies	52.3	7.5	2.4	1.1	0.3		63.5
Instrumentation	1.3	0.7	0.2				2.2
Radiation Protection	0.3		0.1				0.4
Control System	1.0	0.6	0.2	0.0	0.0		1.8
Experimental devices					4.0		4.0
Utilities	31.8	3.5	2.0	0.6	1.2		39.1
General services	7.2		0.3	0.2	0.2	12.0	19.8
RF system			0.8				0.8
TOTAL	203.4	18.2	18.9	1.8	6.8	12.0	261.1

CEPC TDR Power Consumption Breakdowns@Higgs with 30GeV injection Linac and 50MW SR/beam

		Location and electrical demand(MW)						
		Ring	Booster	LINAC	BTL	IR	Surface building	TOTAL
1	RF Power Source	161.5	1.4	11.1				174.1
2	Cryogenic System	15.5	0.6	-		1.7		17.9
3	Vacuum System	1.0	3.8	1.8				6.5
4	Magnet Power Supplies	52.3	7.5	2.4	1.1	0.3		63.5
5	Instrumentation	1.3	0.7	0.2				2.2
6	Radiation Protection	0.3		0.1				0.4
7	Control System	1.0	0.6	0.2	0.0	0.0		1.8
8	Experimental devices					4.0		4.0
9	Utilities	42.4	3.5	2.0	0.6	1.2		49.7
10	General services	7.2		0.3	0.2	0.2	12.0	19.8
11	RF system			0.8				0.8
12	TOTAL	282.4	18.2	18.9	1.8	7.4	12.0	340.7

CEPC Auxiliary Facilities

Y. Xiao



Electric power demand

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

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

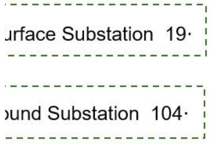
Heating Ventilation Air Conditioning System

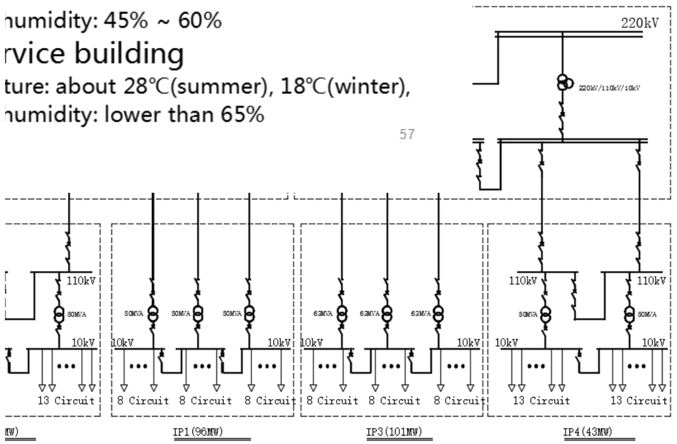
Y. Xiao

- **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**

- **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%
  - ...ental halls
    - ...ture: about 26℃(summer), 20℃(winter)
    - ...humidity: 50% ~ 60%, and shall be lower ...%.
  - ...oom (or electronics)
    - ...ture: about 20-25℃
    - ...humidity: 45% ~ 60%
  - ...rvice building
    - ...ture: about 28℃(summer), 18℃(winter),
    - ...humidity: lower than 65%

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...

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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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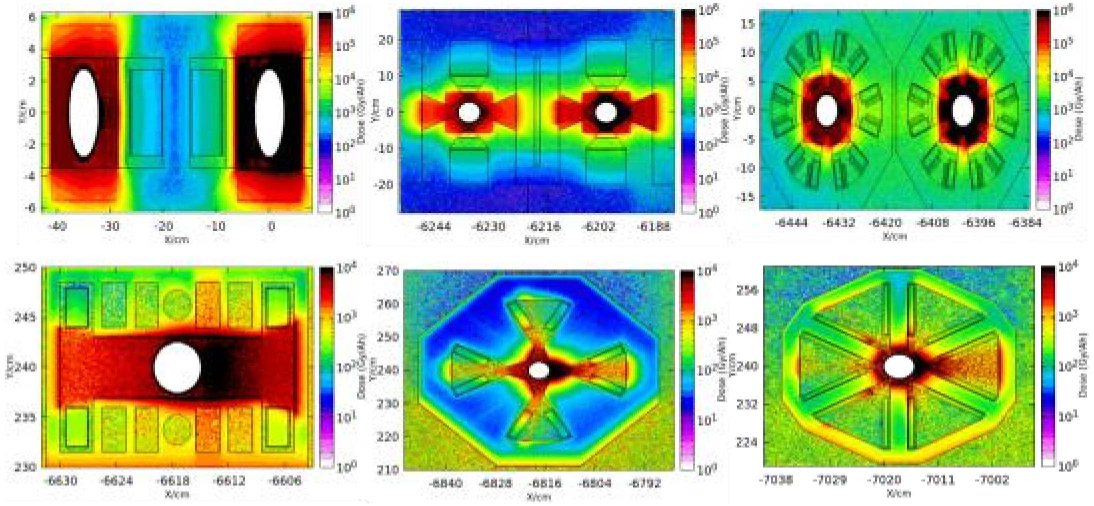
CEPC Site Rock Environment (Changsha example)

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	Case 1 Activity/GB18871	Case 1 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	Case 1 Activity/GB18871	Case 1 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 Specific activity/GB18871	Case 1 Activity/GB18871	Case 1 Stat. error (%)	Case 2 Specific activity/GB18871	Case 2 Activity/GB18871	Case 2 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 Specific activity/GB18871	Case 1 Activity/GB18871	Case 1 Stat. error (%)	Case 2 Specific activity/GB18871	Case 2 Activity/GB18871	Case 2 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							

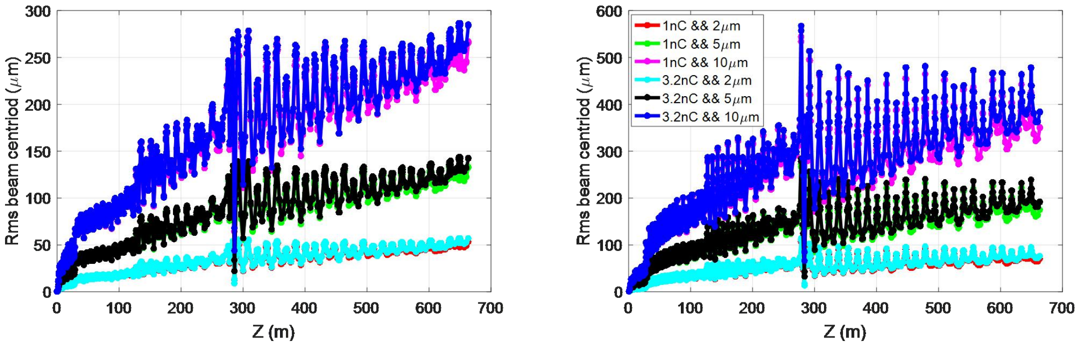
Preliminary Studies on CEPC Ground Motion

Y.W. Wang, C. Meng

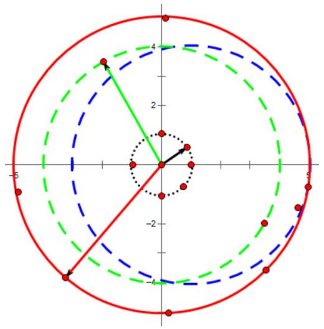
- Ground motion will increase cause beam orbit variation and also beam emittance

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

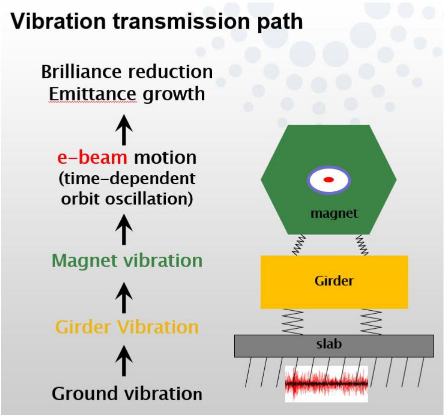
Amplitudes of ground motion (<100Hz) 4nm, 10nm, correspond to 1% or 6% Luminosity reduction



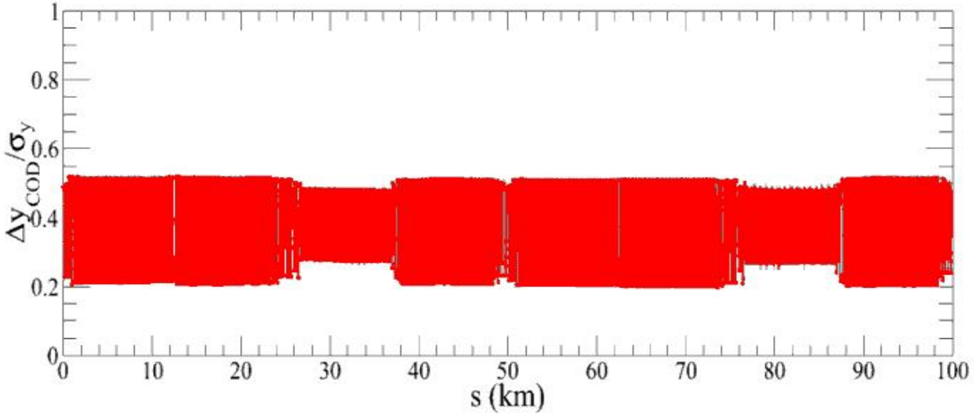
CEPC beam orbit variation in linac due to ground motion
With ground motion amplitude of 100nm, linac effective emittance increse 20%



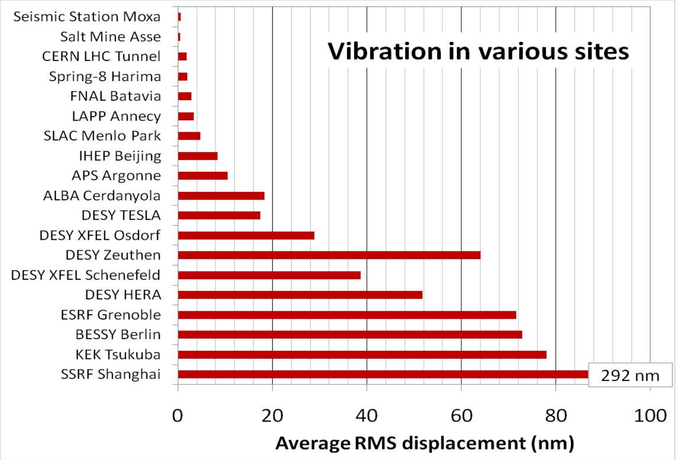
Effective emittance increase due to orbit variation



Ground vibration transmission to colliding beams



CEPC colliding beam orbit variation due to ground motion



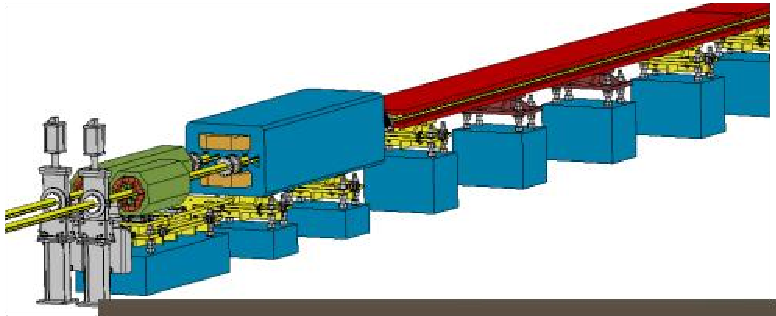
Ground vibration in different sites, LHC site is a good reference~3nm

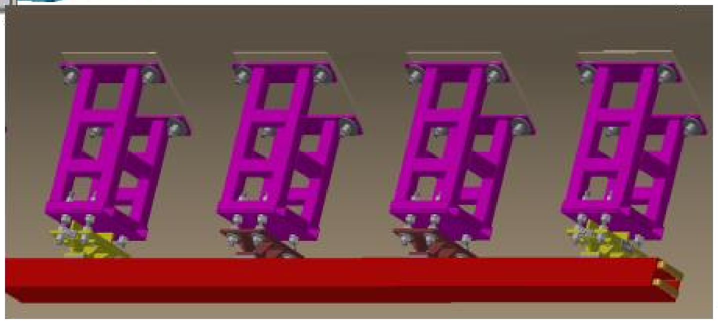
CEPC Accelerator Mechanical Supports and Installation Tools Inside the Tunnel

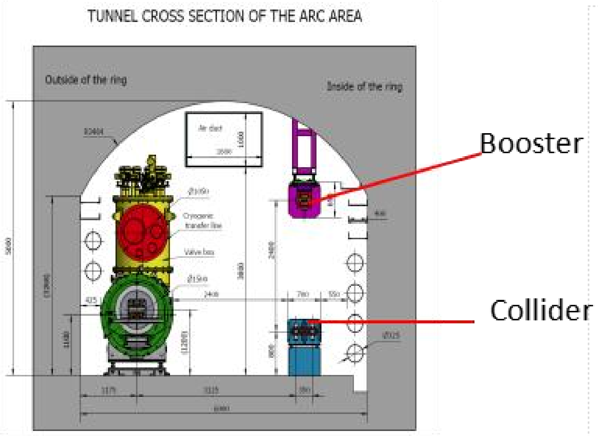
H.J. Wang

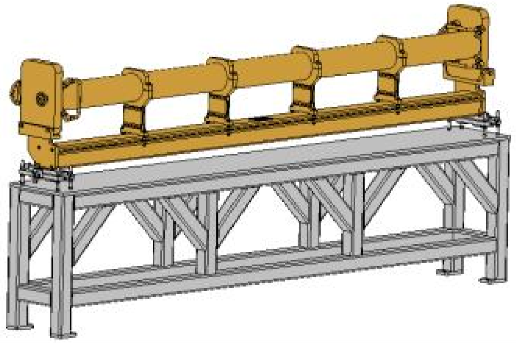
- Over 80% of the length is covered by magnets of about 138 types.

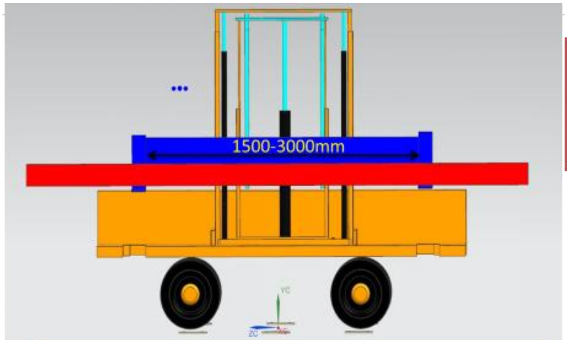
Adjustment Ranges of magnets			
X	≥±20 mm	Δθx	≥±10 mrad
Y	≥±30 mm	Δθy	≥±10 mrad
Z	≥±20 mm	Δθz	≥±10 mrad







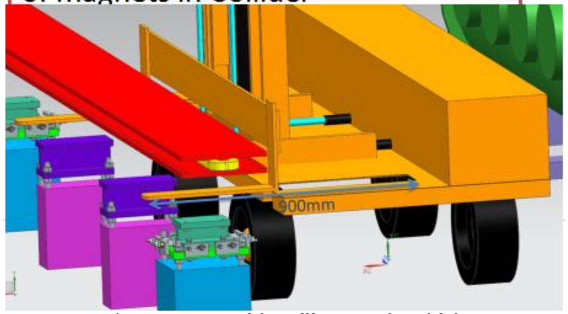


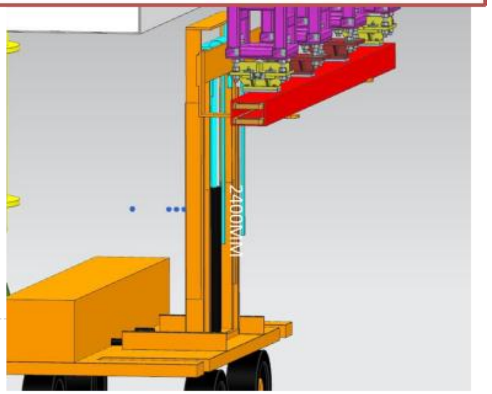


Flexible load support for "long" devices and "short" devices

Transportation and coarse location of magnets in Booster

Transportation and coarse location of magnets in Collider





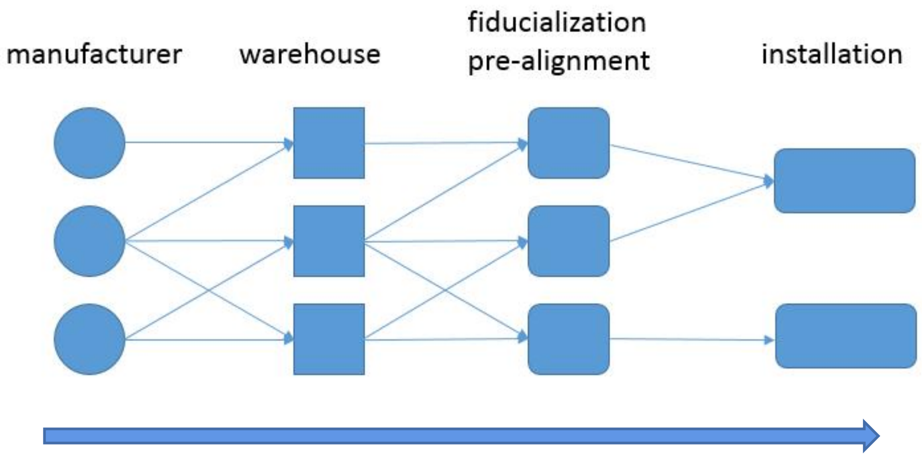
* Cooperate with Beijing North Vehicle Group Corporation.

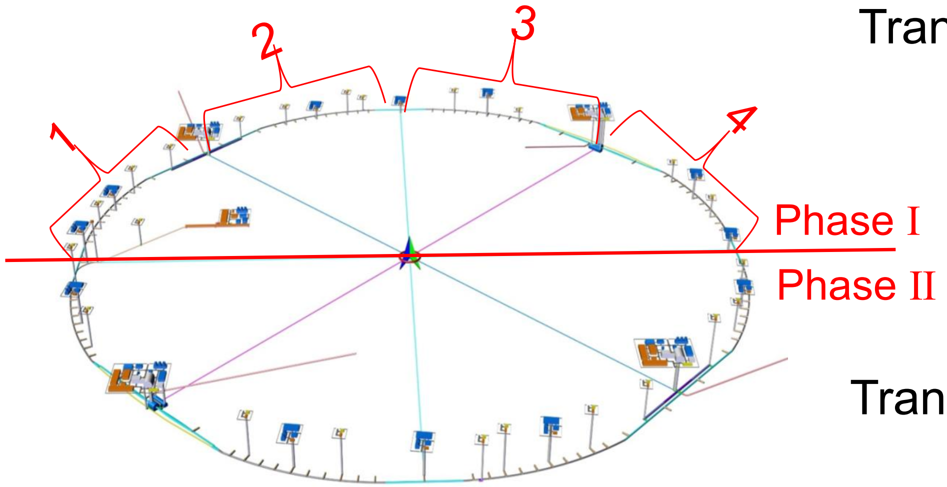
CEPC Installation Strategy-1

X.L. Wang

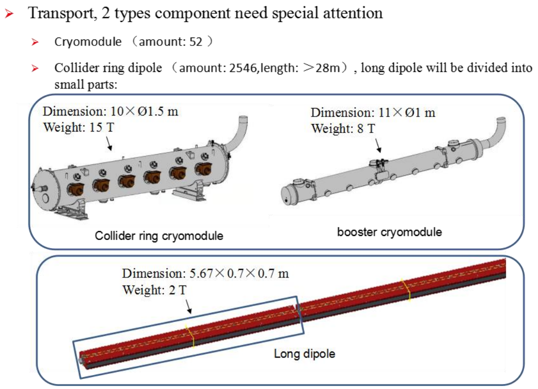
Installation and alignment scheme

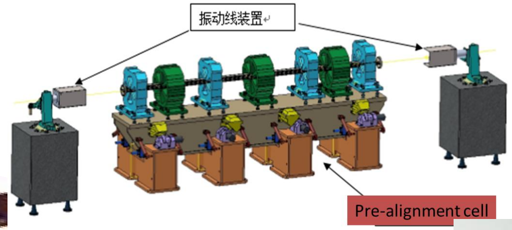
-Ring installation: phase Ⅰ, phase Ⅱ, each phase： half a ring

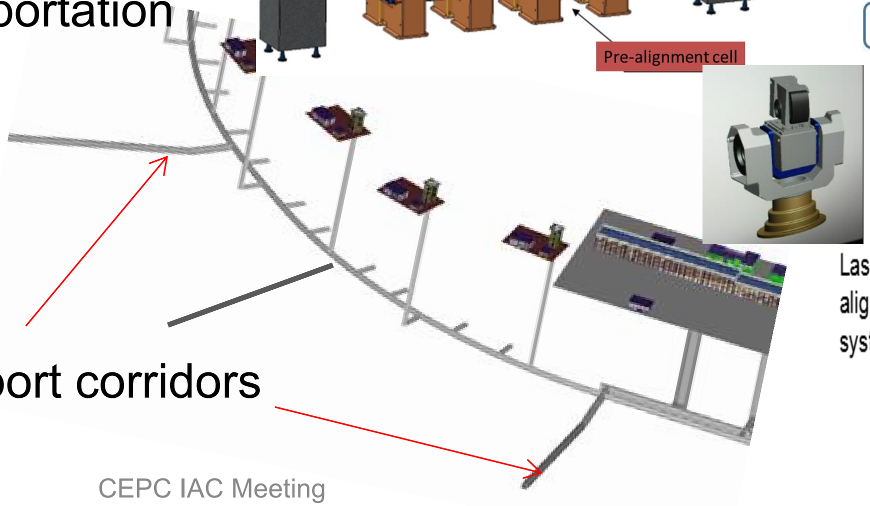




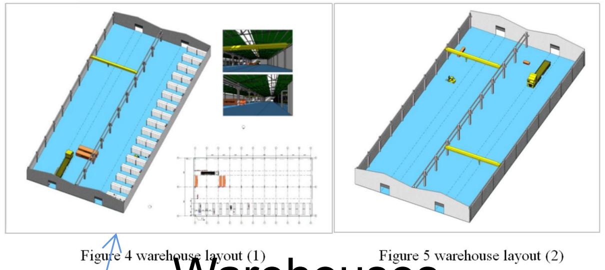
Transportation



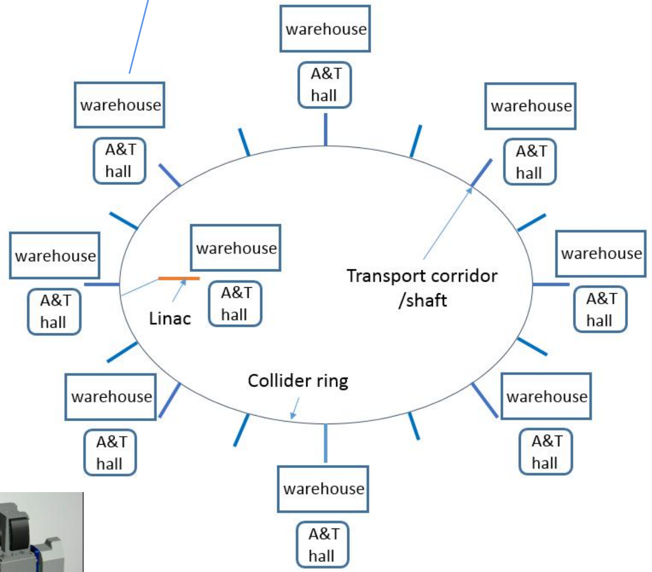


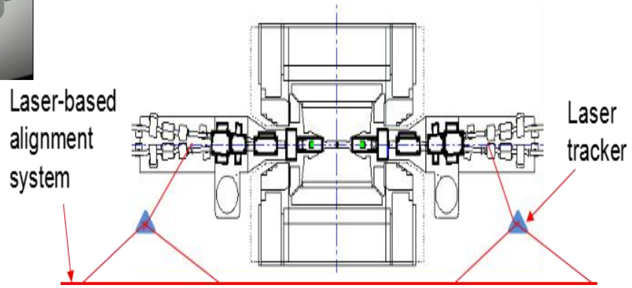


Transport corridors



Warehouses





CEPC Installation Strategy-2

X.L. Wang

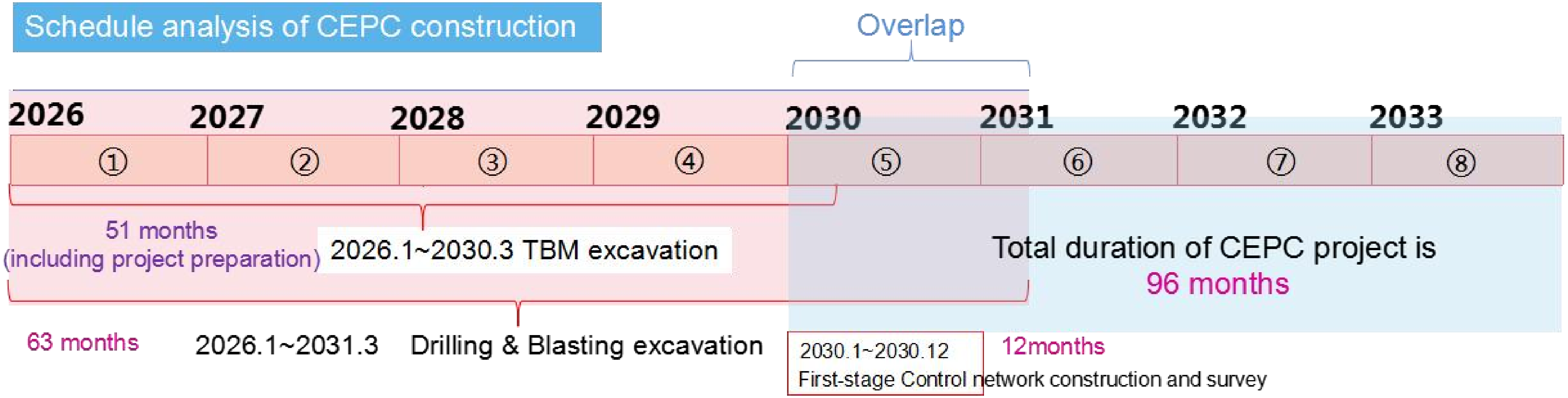
Manpower and time arrangement of collider and booster ring installation and alignment

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.

Civil Construction and Installation Timeline

Huadong Company

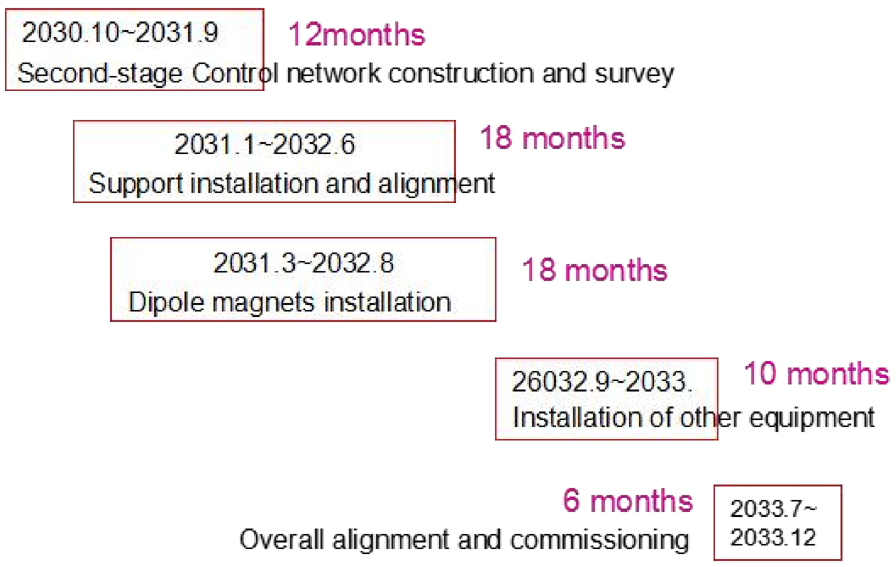


1.CEPC production Including civil works and installation of physical equipment. It will begin in 2026 and end in 2033, The total duration of CEPC project is 96 months.

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



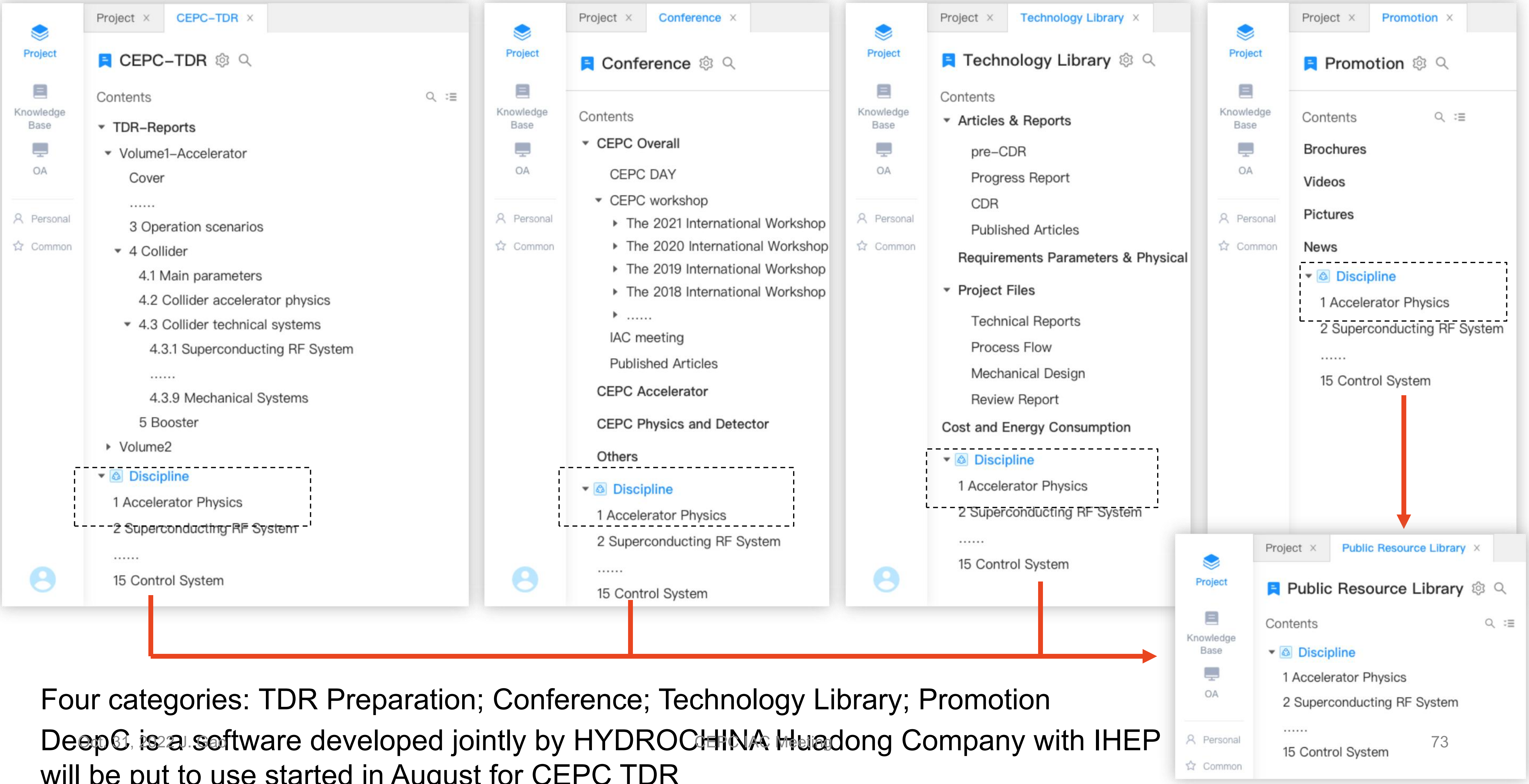
Accelerator TDR Documentation Schedule and EDR Plans and Timeline

CEPC Accelerator TDR Content Table

TDR written is underway, and to be finished at the end of 2022

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 Accelerator TDR Documentation Preparation and EDR Plans

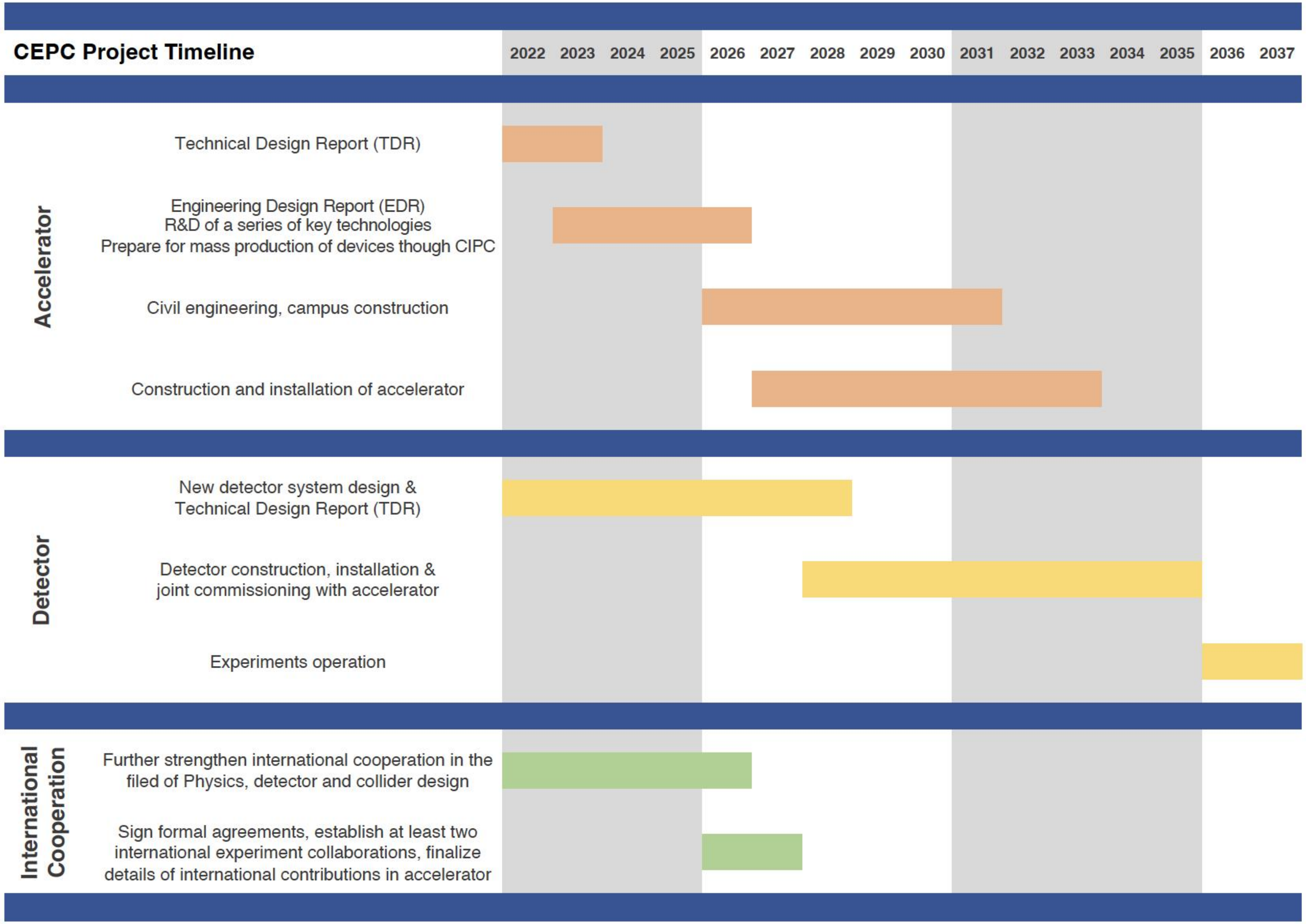
TDR timeline:

TDR started to write after the first IARC reveiw in June 2022
TDR completes document writing in Dec. 2022
TDR released in 2023 after international review

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 Timeline



CEPC International and Industrial Collaborations Conferences, Worhshops and Meetings

2021 IAC Report: Recommendations - Overview

Recommendation 1: The CEPC team increase its effort on generic worldwide accelerator and detector R&D and explore further collaboration with the CLIC, ILC, FCC-ee, and SuperKEKB groups for common effort in the accelerator and detector technical developme

Development:

- On May, 30 2022, Xinchou Lou gave an invited talk at **FCC** Week on "**Status of CEPC and possible synergies with FCC-ee developments**" https://indico.cern.ch/event/1064327/contributions/4891218/
- Since Feb. 2022, the extension Multi-National Partnership Project (**MNPP-01**) MoU of IHEP with **KEK Super B** is on going (ready for signatures).
- From Jan. 1, 2022, J. Gao has become **CERN Machine Advisory Committee (CMAC)** Member
- From May 25, 2022, J.Gao has been approved by TTC CB to be **TTC Executive Committee (EC)** member (TTC has a strong collaboration with ILC)
- Feb. 16, 2022, the 10th **IHEP-KEK collaboration** meeting on SCRF technologies Shinichiro Michizono and J. Gao have given talks on **ILC Accelerator Status** and **CEPC Accelerator**
- **TDR Status.** https://conference-indico.kek.jp/event/171/timetable/#20220216
- **Joint research works with FCC-ee and Super KEK B in 2022:**

  1) **FCC-ee** tuning working group, Y.W. Wang, B. Wang...; FCC-ee beam-beam efforts: Y. Zhang..
  2) **Super KEK B** beam beam working group, Y. Zhang...,
  3) **Superkek B** collaboration on simulations of injection efficiency and detector background of SuperKEKB, Dou Wang, Mei Li, Philip Bambade, J, Gao

CEPC Accelerator White Paper-AF3 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

Participated all the Snowmass21 series meetings:

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

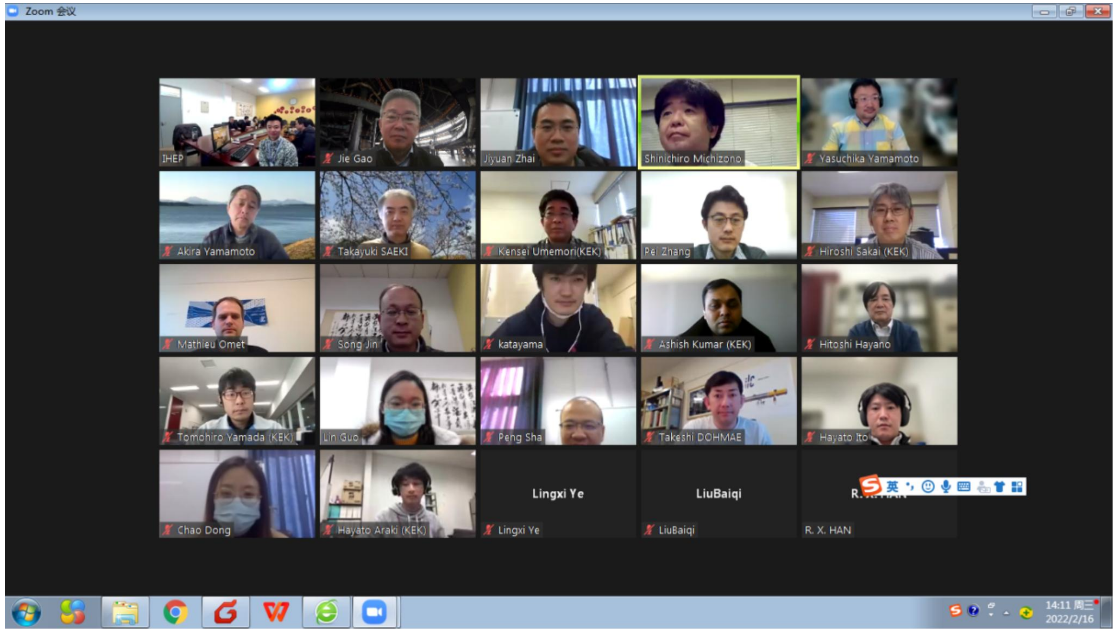
3) J. Gao, “CEPC: A Higgs Factory Collider”，**Seattle Snowmass Summer Meeting 2022-AF3, July 19, 2022, USA**

CEPC Collaborations with Industries

- CIPC, established in 2017, composed of ~ 70 high tech. enterprises, covers CIPC actively joins the Key technology R&D and **prepares for the mass production** for the CEPC construction.
- CEPC study group is **surveying main international suppliers. (See Dr. Song Jin's talk on Nov. 1)**
- CEPC strongly promote these relevant technology development (cost-benefit).

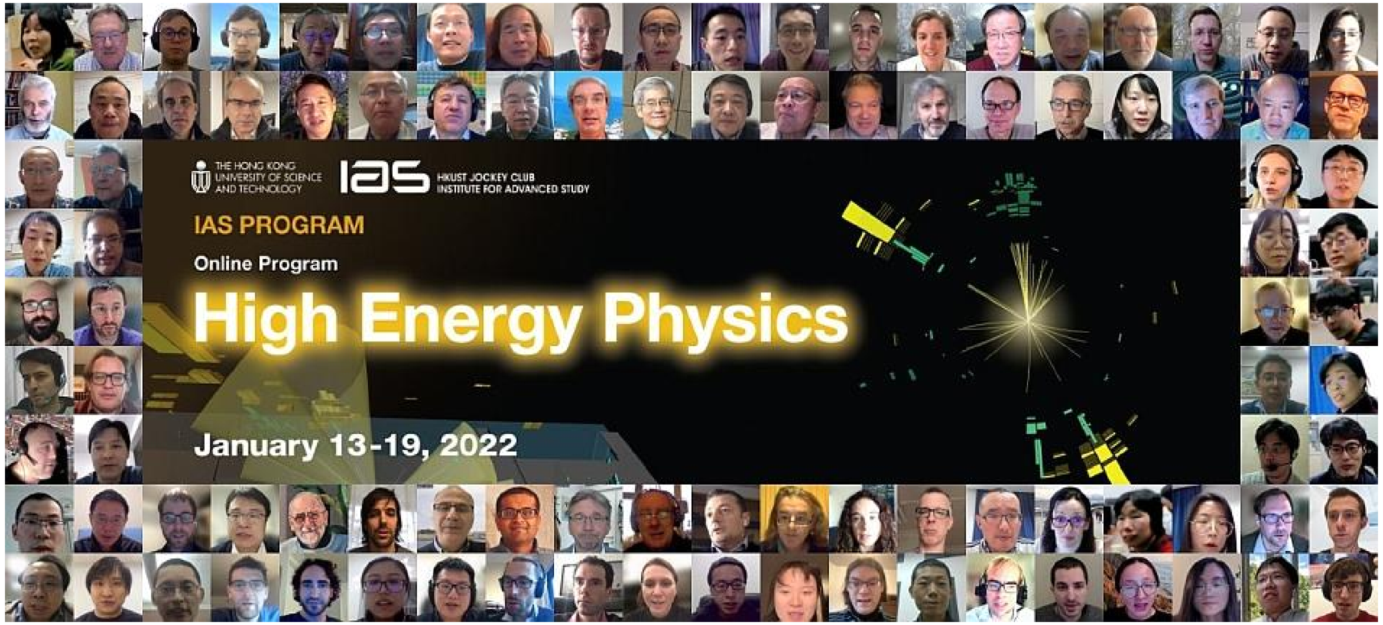
International Collaboration Meetings and Workshops

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 (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	CompMet / MDI / Perform. / CIPC
	17:30-20:00	Dinner		Dinner	Dinner
Evening	20:00-21:30	Plenary	Banquet		Plenary
	21:30-22:00	Coffee break		Special / Special / Special / Special	Coffee break
	22:00-23:30	Plenary			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 2022 International Workshop and CEPC IAC Meeting in 2022

The 2022international workshop on the high energy Circular Electron-Positron Collider (CEPC)

October 24-28，2022 (online) https://indico.ihep.ac.cn/event/17020/overview

Tentative Session Arrangement

		Monday 24th	Tuesday 25th	Wednesday 26th	Thursday 27th	Friday 28th
Morning	10:00 - 12:00	Higgs, Silicon, Accel., CIPC	Flavor, Calorim., Accel., CIPC	EW+tt, Gaseous, Accel., CIPC	QCD, PID+other, Accel., CIPC	Perform., Offline, Accel., MDI
	12:00-13:30	Lunch break	Lunch break	Lunch break	Lunch break	Lunch break
Afternoon	13:30-15:30	Higgs, Silicon, Accel., CIPC	Flavor, Calorim., Accel., CIPC	EW+tt, Gaseous, Accel., CIPC	BSM, TDAQ, Accel., CIPC	Perform., Offline, MDI
	15:30-16:00	Coffee break	Coffee break	Coffee break	Coffee break	Coffee break
	16:00-18:00	Higgs, Silicon, Accel., CIPC	Flavor, Calorim., Accel., CIPC	QCD, PID+other, Accel., CIPC	BSM, TDAQ, Accel., CIPC	Posters
	18:00-20:00	Dinner	Dinner	Dinner	Dinner	Dinner
Evening	20:00-21:30	Plenary		Posters		Plenary
	21:30-22:00	Coffee break				Coffee break
	22:00-23:30	Plenary				Plenary

There are 7 FCCee talks from CERN

KEK Super B
KEK TTC
INFN
IJCLab
PAL, Korea
Super Tau Charm, BINP
Tsinghua University (2)
Beijing University

Accelerator Parallel Session

67 Accelerator talks from around the world, **Asia, Europe**

CIPC Parallel Session on CEPC R&D

18 CIPC speakers in CEPC workshop

Summary

CEPC accelerator system optimization design based on TDR parameters considering also 50MW SR/beam and ttbar energy upgrade possibilities are completed

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 and SppC design progress well

CEPC siting, civil engeering, AC power consumptions, installation planning, international collaborations and CIPC collaborations are progressing well

CEPC TDR cost has no major change compared with CDR (to be reviewd)

Preparation for CEPC accelerator EDR phase 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 Key Technology R&D Status-1

Technology	Category	Quantity	Specification	R&D Status
650MHz 1 cell SRF cavity	Collider	240	Q= 3E10 @ 39.3 MV/m	Q= 2.3E10 @ 41.6 MV/m
650MHz 2 cell SRF cavity	Collider	240	Q= 4E10 @ 22 MV/m	Q= 6E10 @ 22 MV/m
1.3GHz SRF cavity	Booster	96	Q=3E10 @ 24 MV/m	Q= 4.3E10 @ 31 MV/m
650MHz high efficiency Klystron	Collider	120	Efficiency:75%; Power:800kW	Efficiency: ~70%; Power: 600kW
Electrostatic deflector	Collider	32	Electro field: 2.0MV/m； stability: 5 x 10-4； good field range: 46mm x 11mm	Prototype fulfill the specification
C-band RF cavity	Linac	292	45MV/m	2-m prototype engineered, waiting for high power test
Cool Copper RF cavity (C-band)	Linac	/	120MV/m	Physical design finished, in the manufacture process
Positron source FLUX concentrator	Linac	1	Center field>6T	Center field: 6.2T
Dual aperture dipole	Collider	2384	Field strength: 140Gs~560Gs, aperture:70mm; length: 28.7m in 5 segments； harmonic component <5×10-4； fields difference <0.5%	All specifications are satisfied in the 1-m prototype; full length prototype in manufacture
Dual aperture qudrupole	Collider	2392	Field gradient: 3.2~12.8T/m; length: 2m， aperture: 76mm； harmonic component <5×10-4； field difference<0.5%。	Preliminary measurement in the prototype shows prominent results, more test in process
Weak field dipole	Booster	16320	Field error <1E-3@60Gs	Prototype fulfills the specifications
Visual alignment device	All	11	Pixel position accuracy 5μm+5μm/m； angular accuracy: (h) 1.8”， (v) 2.2”；	Prototype manufactured, in test
Superconducting high field dipole magnet	SPPC	/	20T	12T

CEPC Key Technology R&D Status-2

Technology	Category	Quantity	Specification	R&D Status
2860MHz klystron	Linac	35	Power: 80MW Efficiency: 55%	Power: 65MW Efficiency: 42%
Advanced S-band cavity	Linac	111	30MV/m	HEPS production fulfill CEPC specifications
Single aperture Mag.	D(160)+Q(960)+S (1864)+Corr.(5808)	/	/	HEPS production fulfill CEPC specifications
BPM & electronics	All	~5000	Spatial resolution: 600nm response frequency:10Hz	Spatial resolution: 100nm response frequency:10Hz
Cryogenic machine	Collider/booster	4	18kW@4.5K	2.5kW@4.5K collaboration with CAS
kicker ceramic vacuum chamber and coating	transport line	/	75x56x5x1200mm	Prototype in manufacture
in-air delay-line dipole kicker & pulser	transport line	/	Trapezoid pulse width=440-2420ns,1kHz	Design completed
in-air delay-line nonlinear kicker & pulser	transport line	/	Trapezoid pulse width=440-2420ns,1kHz	Design completed

CEPC Key Technology R&D Status-3

Technology	Category	Quantity	Specification	R&D Status
strip-line kicker & fast pulser	transport line	/	pulse width<10ns, 20kV into 50Ω	HEPS devices fulfill specifications
slotted-pipe kicker & fast pulser	transport line	/	Trapezoid pulse width≤250ns	HEPS devices fulfill specifications
in-air Lambertson septa	transport line	/	septum thickness≤3.5mm	HEPS devices fulfill specifications
in-vacuum Lambertson septa	transport line	/	septum thickness≤2mm	HEPS devices fulfill specifications
Electric source	All	9294	Stability: 100-1000ppm； accuracy: 0.1%	HEPS devices fulfill specifications
Vacuum chamber &NEG coating	collider	~200km	Length: 6000mm; aperture: D56mm vacuum: 3×10^{-10} Torr NEG film H_2 pumping speed: 0.5 L/s·cm^2	Prototype fulfill specifications
Vacuum bellow	collider/booster	24000/12000	Force 125±25 g/finger；	HEPS devices fulfill specifications
Vacuum gate valves	All	1040	Leakage: 1×10^{-9} mbar·L/s @ 5000 times	Life time: 100

The CEPC key technology R$D are carried out with dedicated studies and in synergy with other projects, such as HEPS

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)

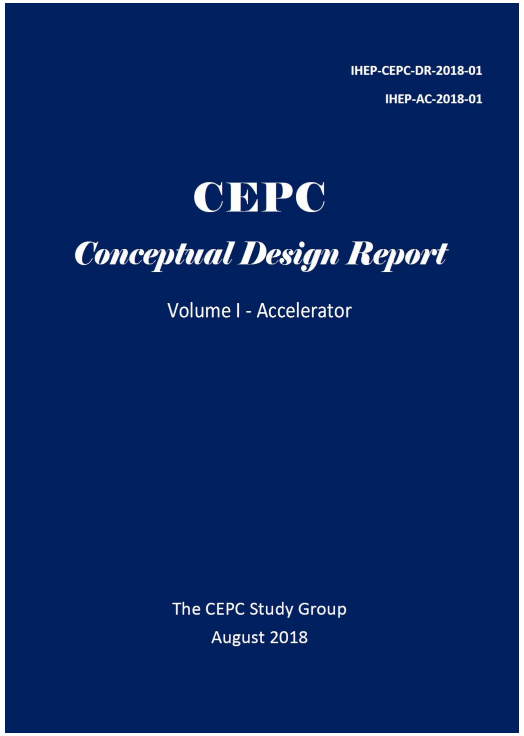
Peak Luminosity = $8.3\times 10^{34}cm^{-2}s^{-1}$

Ingetrated Luminosity = 15.4 ab^{-1}

Higgs annual luminosity =2.2 ab^{-1}

These parameters are used for Snowmass21

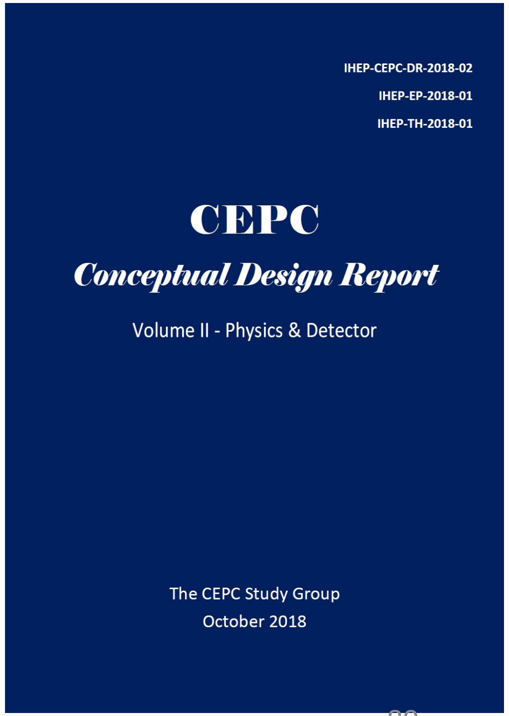
CEPC CDR Vol. I, Accelerator



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 Video (BIM design)
1) http://cepc.ihep.ac.cn/Qinhuang_Island.mp4
2) http://cepc.ihep.ac.cn/Huzhou.mp4
3) http://cepc.ihep.ac.cn/Changsha.mp4

CEPC CDR Vol. II, Physics/Detector



CEPC TDR Power Consumption Breakdowns@Z with 30GeV injection Linac and 30MW SR/beam

		Location and electrical demand(MW)						
		Ring	Booster	LINAC	BTL	IR	Surface building	TOTAL
1	RF Power Source	96.9	0.1	11.1				108.1
2	Cryogenic System	4.1	0.6	-		1.1		5.9
3	Vacuum System	1.0	3.8	1.8				6.5
4	Magnet Power Supplies	9.6	1.4	2.4	1.1	0.3		14.7
5	Instrumentation	1.3	0.7	0.2				2.2
6	Radiation Protection	0.3		0.1				0.4
7	Control System	1.0	0.6	0.2	0.0	0.0		1.8
8	Experimental devices					4.0		4.0
9	Utilities	28.1	3.5	2.0	0.6	1.2		35.5
10	General services	7.2		0.3	0.2	0.2	12.0	19.8
11	RF system			0.8				0.8
12	TOTAL	149.4	10.8	18.9	1.8	6.8	12.0	199.7

CEPC TDR Power Consumption Breakdowns@ttbar with 30GeV injection Linac and 50MW SR/beam

		Location and electrical demand(MW)						
		Ring	Booster	LINAC	BTL	IR	Surface building	TOTAL
1	RF Power Source	161.5	1.4	11.1				174.1
2	Cryogenic System	25.2	0.6	-		1.1		26.9
3	Vacuum System	2.0	3.8	1.8				7.6
4	Magnet Power Supplies	118.8	16.8	2.4	1.1	0.3		139.3
5	Instrumentation	1.3	0.7	0.2				2.2
6	Radiation Protection	0.3		0.1				0.4
7	Control System	1.0	0.6	0.2	0.0	0.0		1.8
8	Experimental devices					4.0		4.0
9	Utilities	44.7	3.5	2.0	0.6	1.2		52.0
10	General services	7.2		0.3	0.2	0.2	12.0	19.8
11	RF system			0.8				0.8
12	TOTAL	361.9	27.5	18.9	1.8	6.8	12.0	428.9

CEPC Project Timeline