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

J. Gao

On behalf of CEPC Accelerator Group

Seventh Meeting of the CEPC-SppC International Advisory Committee

November 1, 2021, IHEP

Contents

Two CEPC IARC Meetings in 2021
(according to the recomendation from IAC in 2020)

The 2021 CEPC International Accelerator Review Committee

Review Report

May 19, 2021

Overview

The CEPC International Accelerator Review Committee was held remotely due to the Covid-19 pandemic on May 11th and 12th 2021. This is the second eeting. The Circular Electron Positron Collider（CEPC+SppC）Study Gr ently hosted by the Institute of High Energy Physics of the Chinese Ac Sciences, completed the conceptual design of the CEPC accelerator . As recommended by the CEPC International Advisory Committee (IA oup began the Technical Design Report phase for the CEPC accelerato , with a completion target year of 2022. Meanwhile an International or Review Committee (IARC) has been established to advise on rs related to CEPC accelerator design, the R&D program, the study achine-detector interface region, and the compatibility with an upgrad t-tbar energy region, as well as with a future SppC. The first IARC meeting to k place in Beijing during the CEPC international workshop on Nov. 18-21, 2019. The charge for the Committee from the CEPC(SppC) team is the following:

11 talks from CEPCaccelerator team

IARC chaired by Marica Biagini (INFN)

IARC Meeting, May 11-12, 2021

https://indico.ihep.ac.cn/event/14295/other-view?view=standard

2021 Second CEPC IARC Meeting

IARC Committee

October 20th, 2021

The Circular Electron Positron Collider (CEPC) a per Proton-Proton Collider (SppC) Study Group, currently hosted b Institute of High Energy Physics of the Chinese Academy of Scie ompleted the conceptual design of the CEPC accelerator in 2018. mmended by the CEPC International Advisory Committee (IAC) oup began the Technical Design Report (TDR) phase for the CEPC ator in 2019, with a completion target year of 2022. Meanwhile an ational Accelerator Review Committee (IARC) has been established ise on all matters related to CEPC accelerator design, the R&D n, the study of the machine-detector interface region, and the comp with an upgrade to the t-tbar energy region, as well as with a futu C.

The second EPC International Accelerator Review Committee was held remote to the Covid-19 pandemic on October 11th to 14th 2021. A total of 2 talks were presented on a variety of topics.

22 talksfrom CEPC accelerator team

IARC Meeting, Oct.11-14, 2021

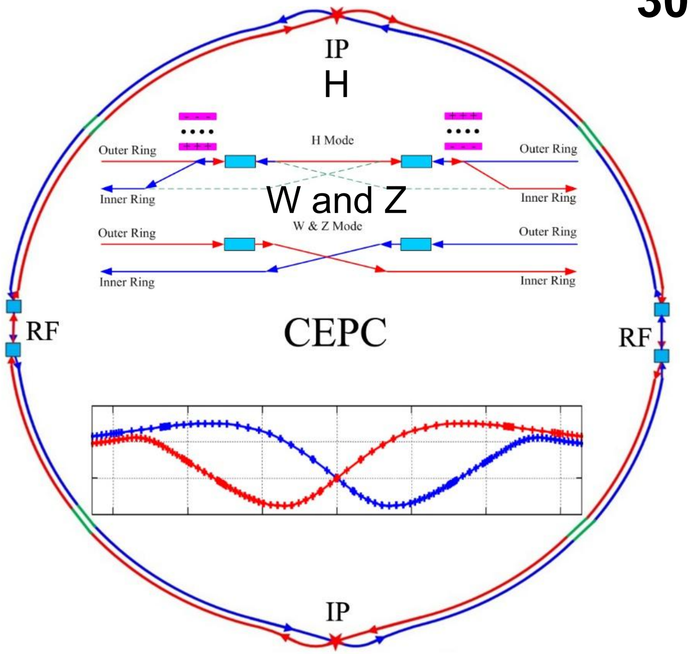
https://indico.ihep.ac.cn/event/15177/overview

CEPC Accelerator System Design and Optimizations inTDR

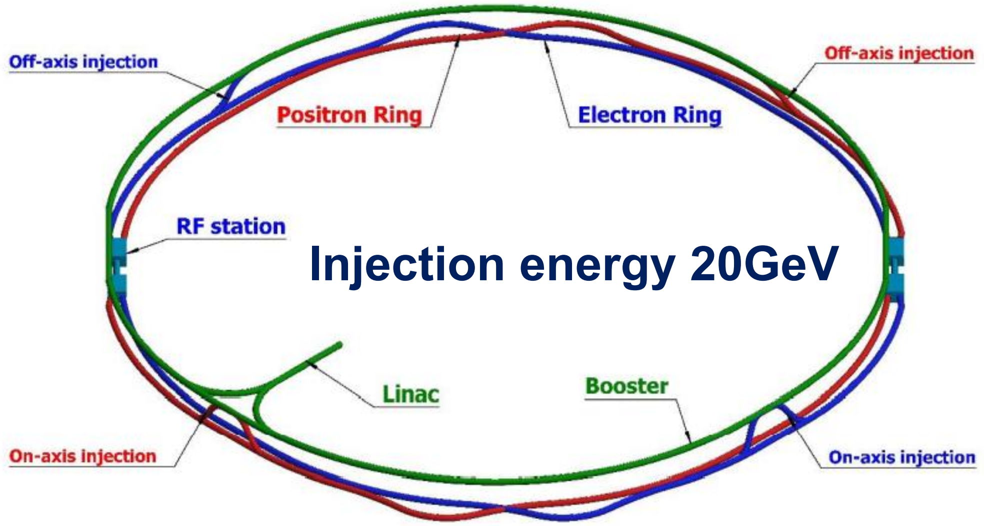
CEPC TDR Layout

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

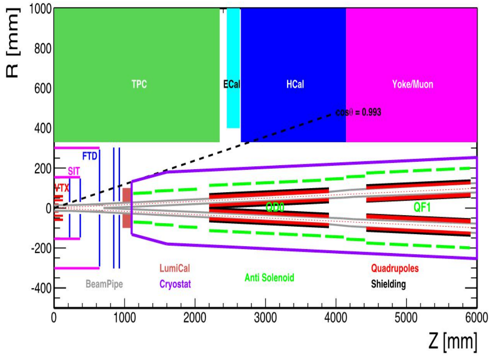
30MW SR power per beam (upgradale to 50MW)



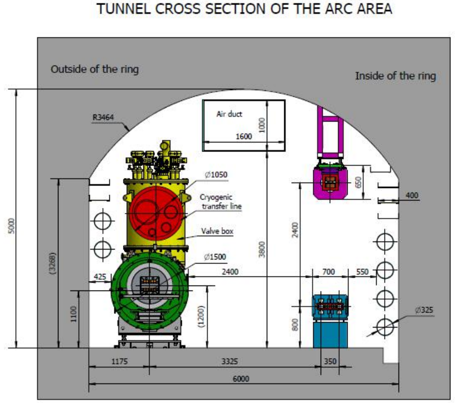
CEPC collider ring (100km)



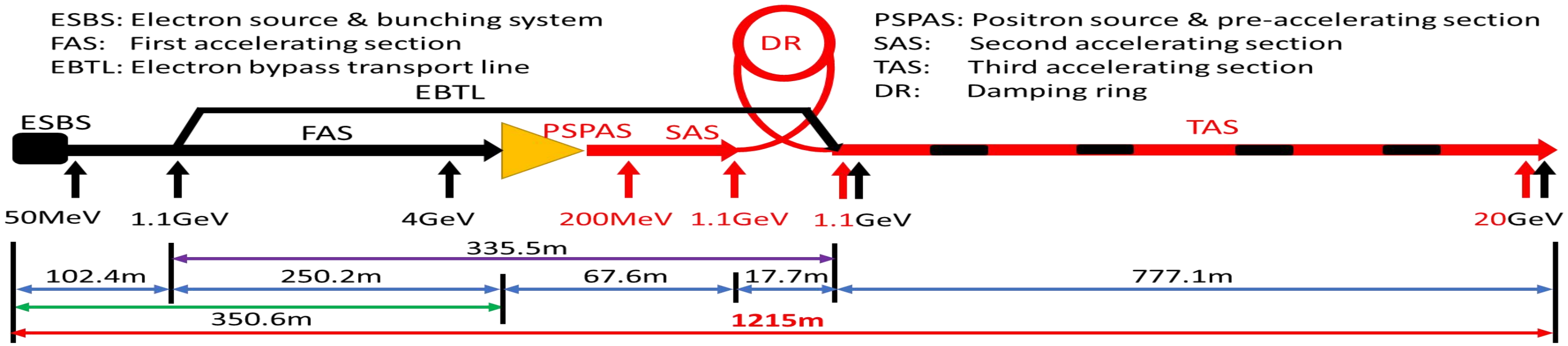
CEPC booster ring (100km)

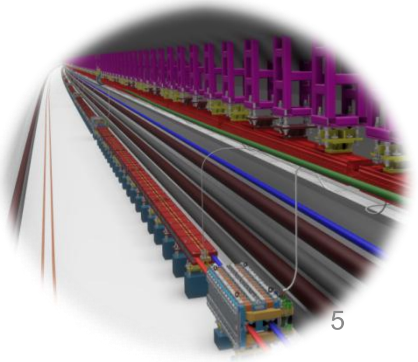


CEPC MDI



CEPC Civil Engineering





CEPC Linac injector of 20GeV

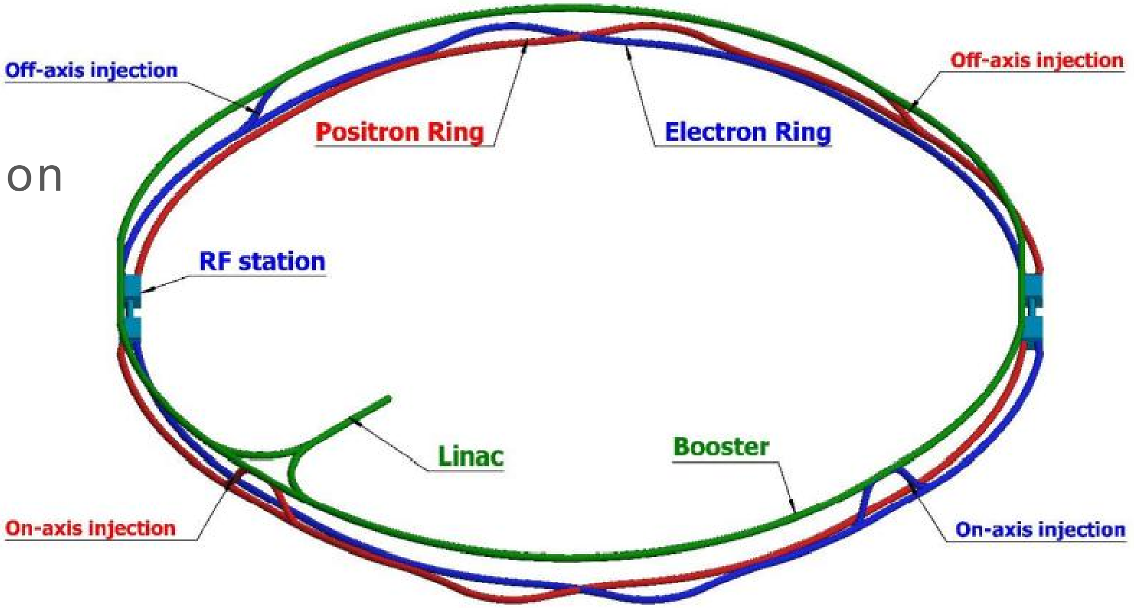
CEPC High Luminosity Parameters in TDR

	ttbar	Higgs	W	Z
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]	180	120	80	45.5
Energy loss per turn [GeV]	9.1	1.8	0.357	0.037
Piwinski angle	1.21	5.94	6.08	24.68
Bunch number	35	249	1297	11951
Bunch population [10^10]	20	14	13.5	14
Beam current [mA]	3.3	16.7	84.1	803.5
Momentum compaction [10^-5]	0.71	0.71	1.43	1.43
Beta functions at IP (bx/by) [m/mm]	1.04/2.7	0.33/1	0.21/1	0.13/0.9
Emittance (ex/ey) [nm/pm]	1.4/4.7	0.64/1.3	0.87/1.7	0.27/1.4
Beam size at IP (sigx/sigy) [um/nm]	39/113	15/36	13/42	6/35
Bunch length (SR/total) [mm]	2.2/2.9	2.3/3.9	2.5/4.9	2.5/8.7
Energy spread (SR/total) [%]	0.15/0.20	0.10/0.17	0.07/0.14	0.04/0.13
Energy acceptance (DA/RF) [%]	2.3/2.6	1.6/2.2	1.2/2.5	1.3/1.7
Beam-beam parameters (ksix/ksiy)	0.071/0.1	0.015/0.11	0.012/0.113	0.004/0.127
RF voltage [GV]	10	2.2	0.7	0.12
RF frequency [MHz]	650	650	650	650
HOM power per cavity (5/2/1cell)[kw]	0.4/0.2/0.1	1/0.4/0.2	-/1.8/0.9	-/-/5.8
Qx/Qy/Qs	0.12/0.22/0.078	0.12/0.22/0.049	0.12/0.22/	0.12/0.22/
Beam lifetime (bb/bs)[min]	81/23	39/18	60/717	80/182202
Beam lifetime [min]	18	12.3	55	80
Hour glass Factor	0.89	0.9	0.9	0.97
Luminosity per IP[1e34/cm^2/s]	**0.5**	**5.0**	**16**	**115**

Design Requirement of the CEPC Collider Ring (remind)

- SR power 30MW (50 MW upgradable), 100km, 2 IPs
- Crab waist collision
- Local chromaticity correction for the interaction region
- Non-interleaved sextupoles
- Correction of sawtooth orbit
- Shared cavities for two beam @ tt, Higgs
- Dual aperture dipole and quadrupole magnets
- Spin polarized beam @ Z (vertical polarization 5~10% with unsymetric wigglers)
- Asymmetric interaction region
- Compatible of $t\bar{t}$/H/W/Z modes
- Compatible with SPPC

Y.W. Wang

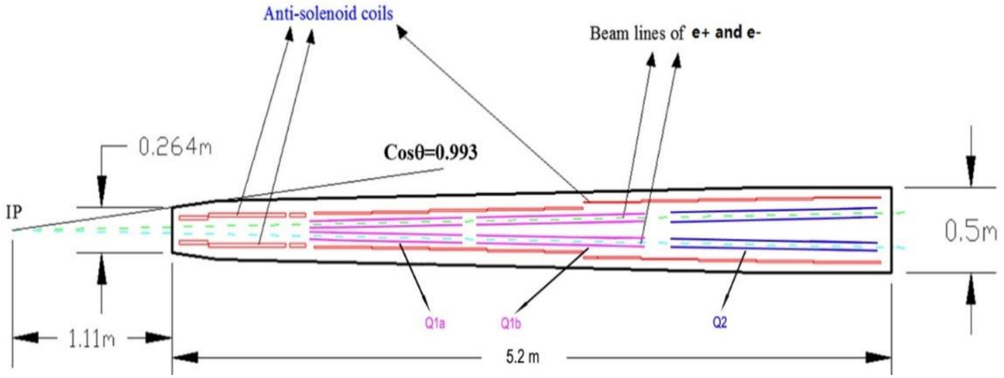


CEPC Collider Ring IR for all Energies

(tt-bar, Higgs, W and Z)

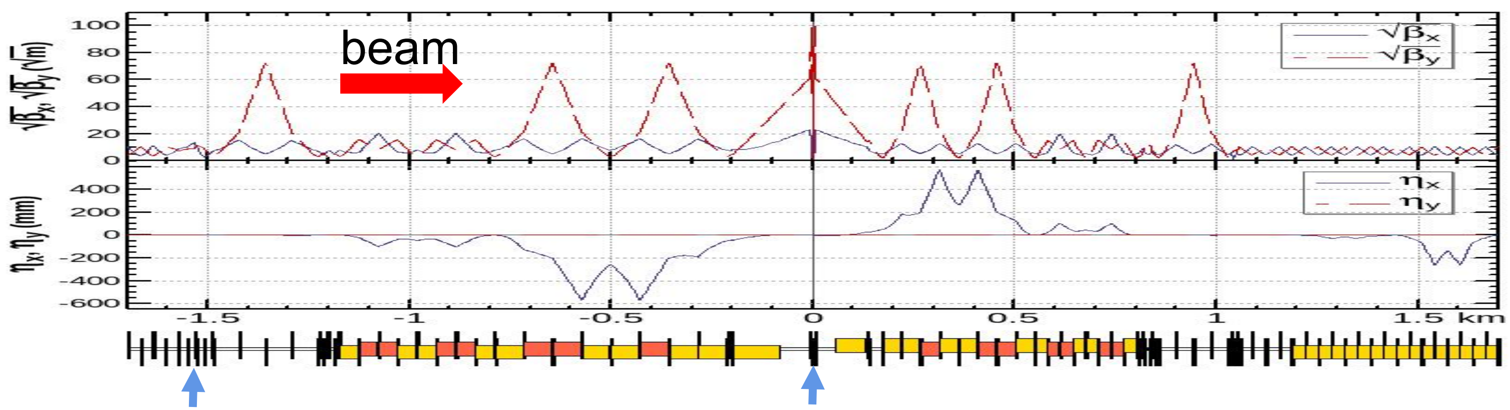
For the interaction region, the IP beta functions are refitted with the different combination of final doulets and the matching quadruples.

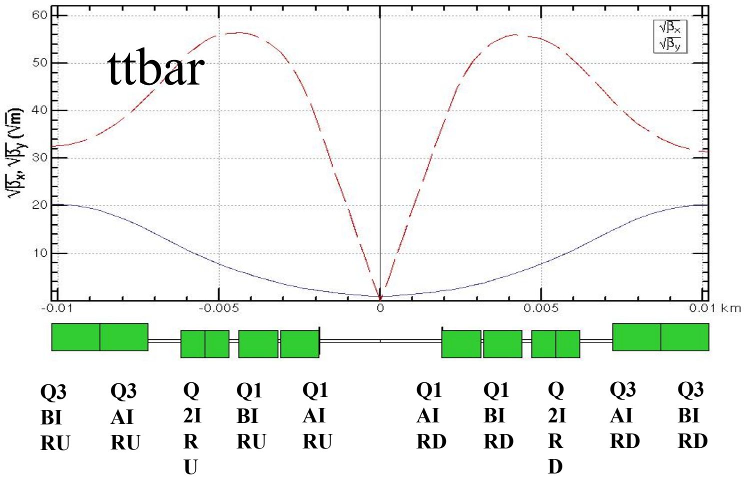
Y.W. Wang



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

Higgs: L*=1.9m, LQ1A=1.22m, LQ1B=1.22m, LQ2=1.5m, d=0.3m, GQ1A=142T/m, GQ1B=96T/m, GQ2=56T/m





CEPC Collider Ring ARC Regions for all Energies

(tt-bar, Higgs, W and Z) Y.W. Wang

Z and W modes need larger momentum compaction factor α_p and thus larger emittance εx, Qs

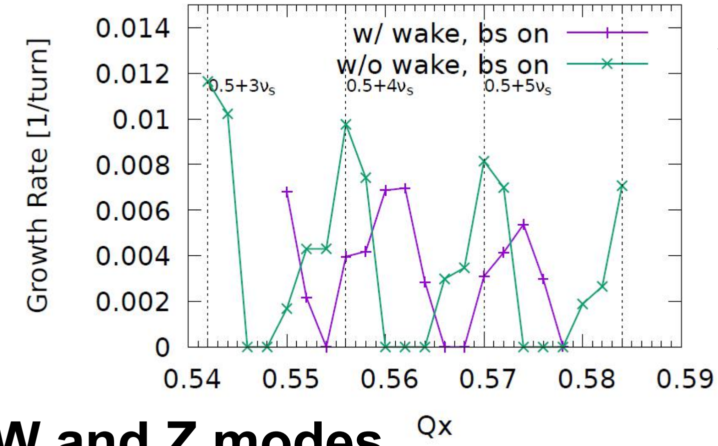
- To suppress the impedance induced instability at **Z mode**
- To increase stable tune area if considering beam-beam effect and impedance consistently at **W and Z modes**

Microwave instability

$$I_{th} = \frac{\sqrt{2\pi}\alpha_p \frac{E}{e} \sigma_{e0}^2 \sigma_l}{R \left| \frac{Z_{\parallel}}{n} \right|_{eff}}$$

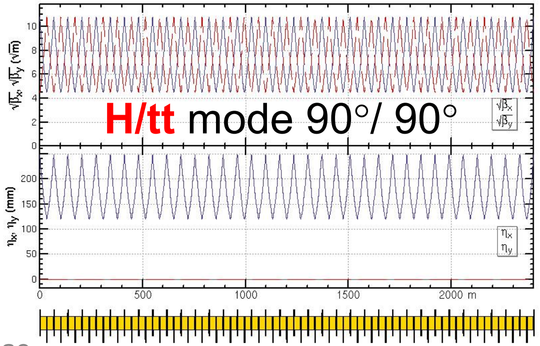
Na Wang,

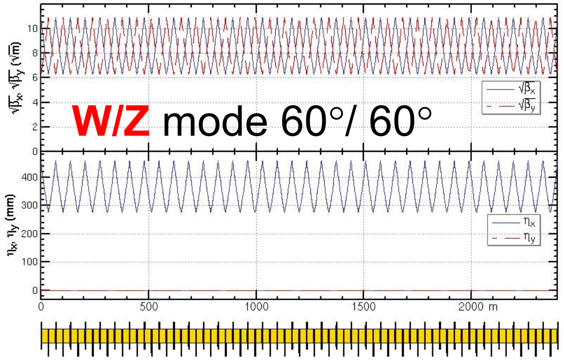
Stable tune area with both beam-beam and impedance (Z mode 90/90)



Yuan Zhang,

Phase advance reduced from 90° to 60° for W and Z modes

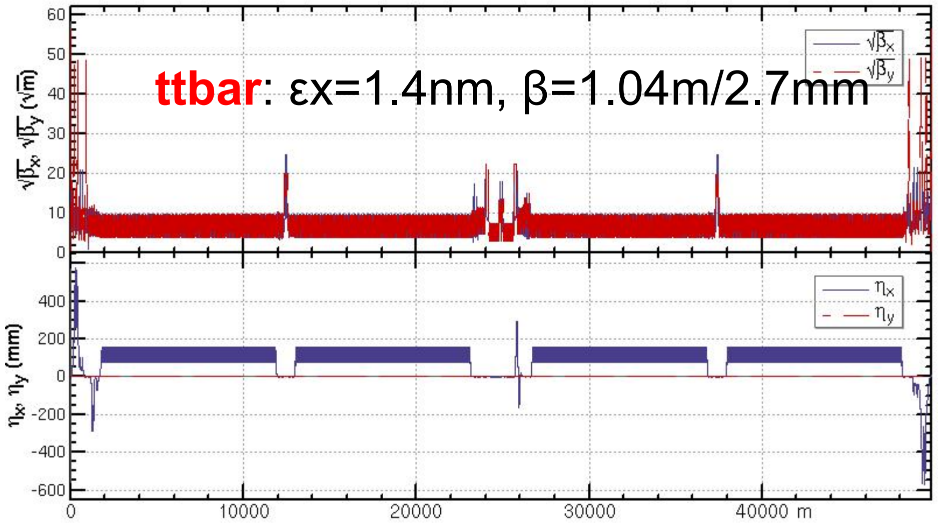


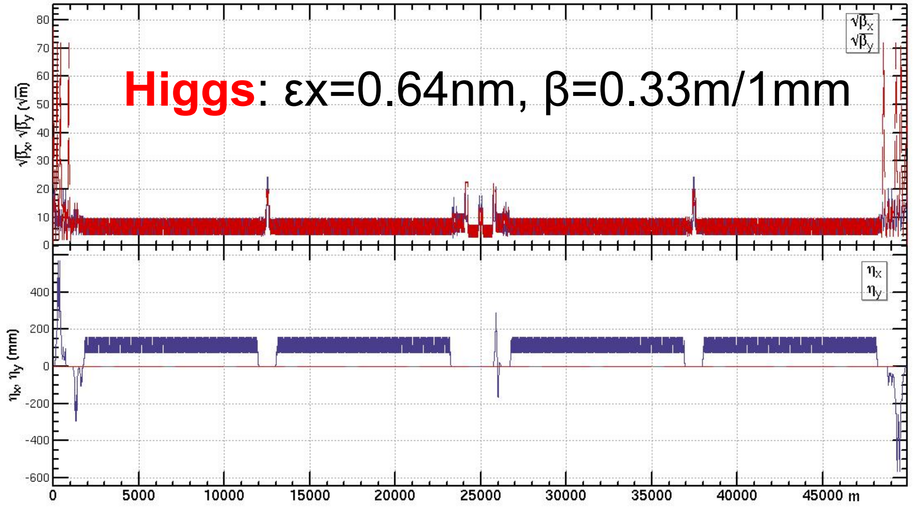


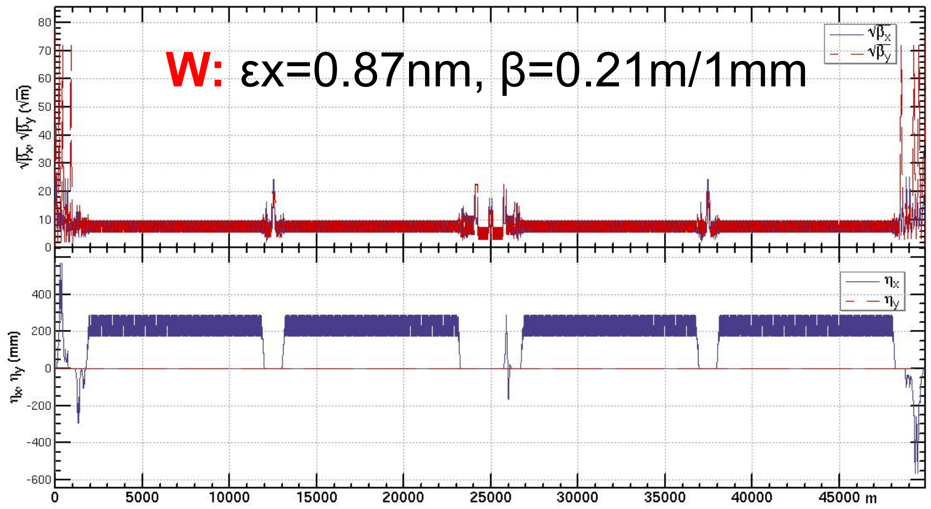
CEPC TDR Lattices of Half Ring for all Energies

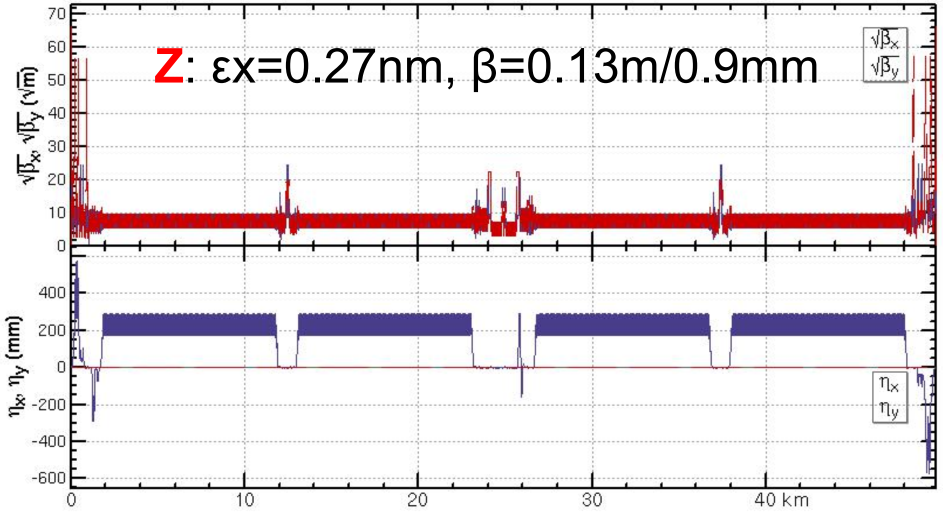
Y.W. Wang

(tt-bar, Higgs, W and Z)



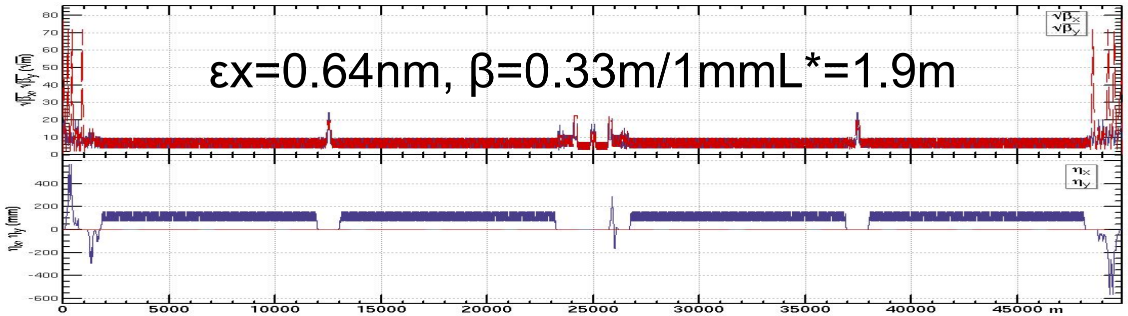






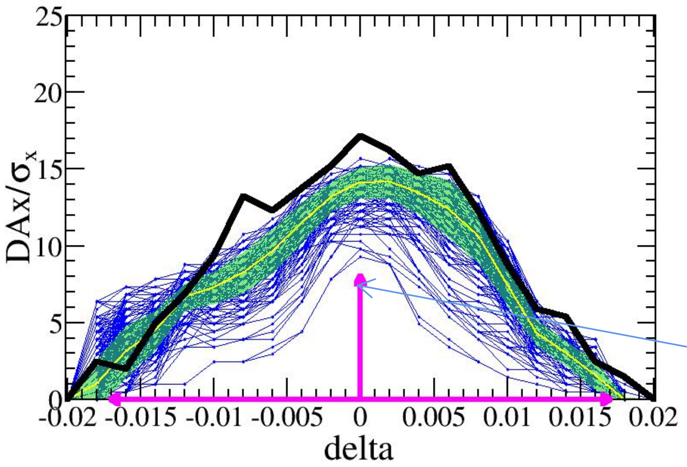
CEPC Collider Ring TDR Lattice Dynamic Aperture with Errors for Higgs

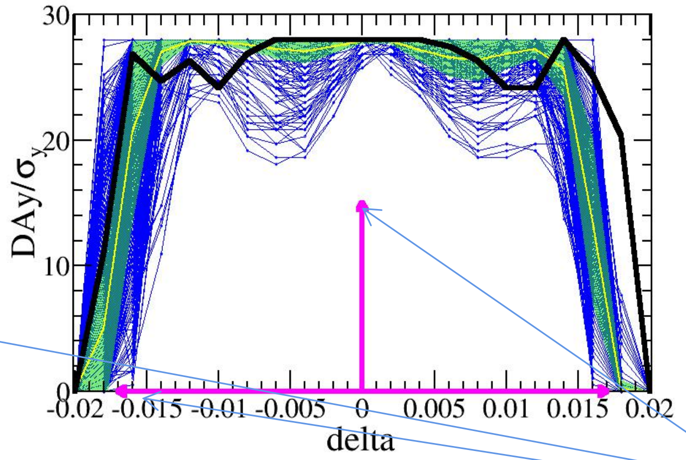
Y.W. Wang
B. Wang



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

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





—DA w/o error
—DA of each seed
—mean value
—statistic errors
—requirement

IR Quadrupole error of 0.05mm 75% of 1000 seed succeded;

DA design goal
$8\sigma_x \times 15\sigma_y$ & 0.017

Lattice version cepc.lat.diff.8713.346.2p used
The DA with erros of TDR lattice satisfiy the design goal

Component	Δx (mm)	Δy (mm)	$\Delta\theta_z$ (mrad)	Field error
IR Quadrupole	**0.1**	**0.1**	**0.01**	

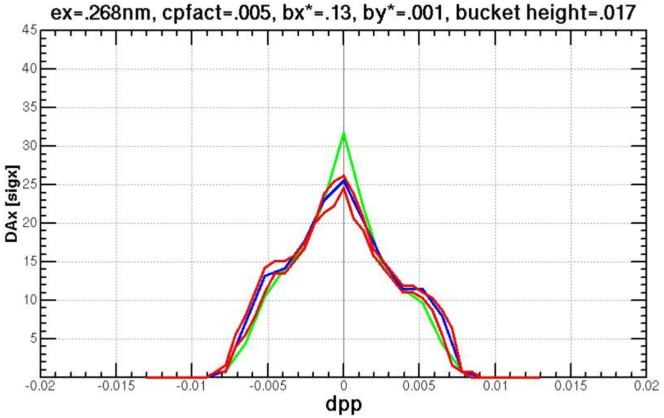
IR Quadrupole error of 0.1mm error 50% of 167 seeds succeded

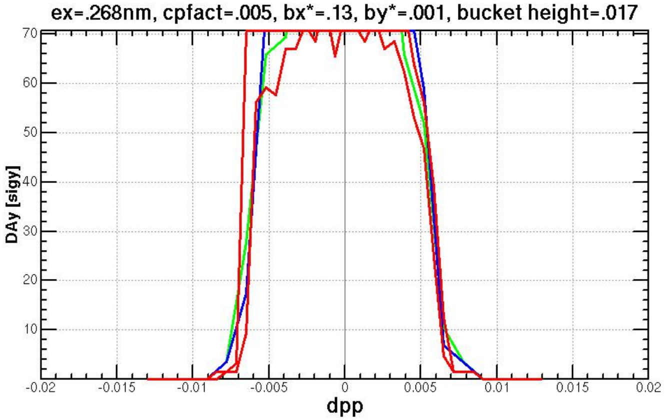
CEPC TDR Lattice Dynamic Apertures @ Z and ttbar

Y.W. Wang

DA requirement	ttbar	Higgs	W	Z
with on-axis injection	-	$7\sigma_x \times 15\sigma_y \times 1.7\%$	-	-
with off-axis injection	$13.9\sigma_x \times 20\sigma_y \times 2.3\%$	$14.4\sigma_x \times 15\sigma_y \times 1.7\%$	$10.5\sigma_x \times 9\sigma_y \times 1.2\%$	$11.8\sigma_x \times 9\sigma_y \times 1.3\%$

Z

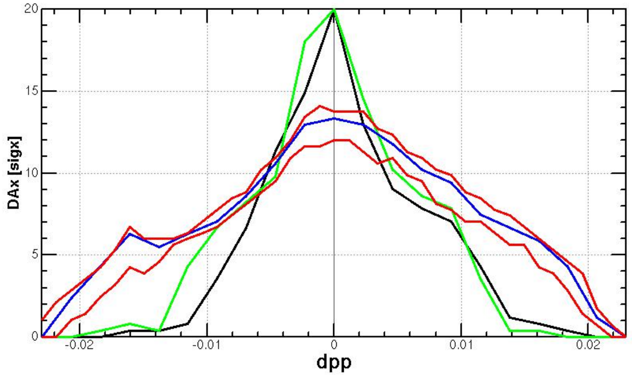


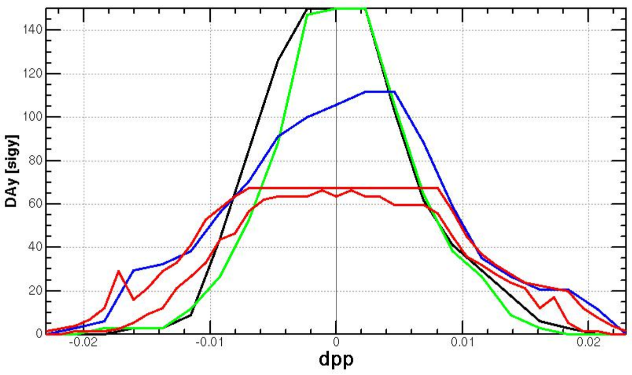


w/o RF
w/o rad
w/ damp
w/ damp+fluc (max, min)
turns for one transvers damping time
Initial phase=0

Erros will be added for ttbar, W and Z

ttbar





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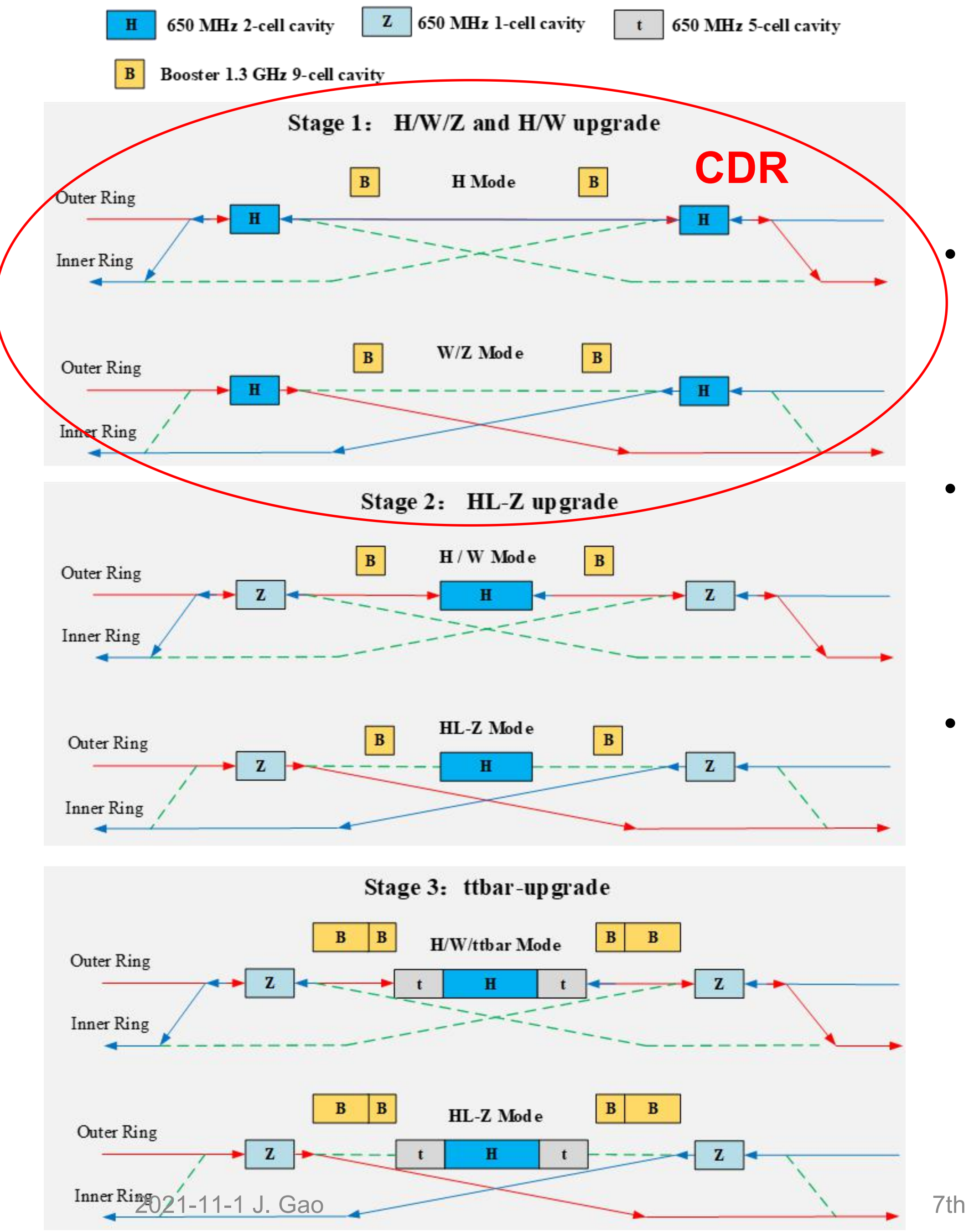


New RF Staging & By-pass Scheme for CEPC

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

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

CEPC Booster TDR parameters

D. Wang

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

Injection

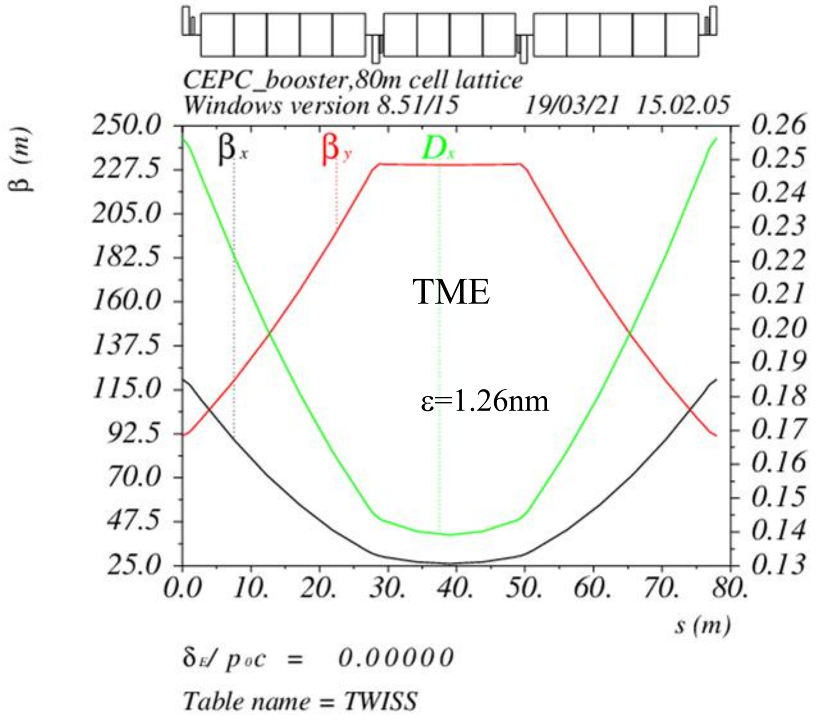
		tt	*H*	*W*	*Z*	
Beam energy	GeV	20				
Bunch number		37	240	1230	3840	5760
Threshold of single bunch current	μA	7.18	4.58	3.8		
Threshold of beam current (limited by coupled bunch instability)	mA	27				
Bunch charge	nC	1.07	0.78	0.81	0.89	0.92
Single bunch current	μA	3.2	2.3	2.4	2.7	2.78
Beam current	mA	0.12	0.56	2.99	10.3	16.0
Energy spread	%	0.016				
Synchrotron radiation loss/turn	MeV	1.3				
Momentum compaction factor	10^{-5}	1.12				
Emittance	nm	0.035				
Natural chromaticity	H/V	-372/-269				
RF voltage	MV	438.0	197.1	122.4		
Betatron tune ν_x/ν_y		321.23/117.18				
Longitudinal tune		0.13	0.087	0.069		
RF energy acceptance	%	5.4	3.6	2.8		
Damping time	s	10.4				
Bunch length of linac beam	mm	0.5				
Energy spread of linac beam	%	0.16				
Emittance of linac beam	nm	10				

*Diameter of beam pipe is 55mm for instability estimation.

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		37	240	233+7	1230	3840	5760
Maximum bunch charge	nC	0.96	0.7	23.2	0.73	0.8	0.83
Maximum single bunch current	μA	2.9	2.1	69.7	2.2	2.4	2.5
Threshold of single bunch current	μA	95	79				
Threshold of beam current (limited by RF system)	mA	0.3	1		4	10	16
Beam current	mA	0.11	0.51	0.99	2.69	9.2	14.4
Bunches per pulse of Linac		1	1		1	2	
Time for ramping up	s	7.3	4.5		2.7	1.6	
Injection duration for top-up (Both beams)	s	30. 0	23.3	32.8	39.3	134.7	128.2
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	9.3	2.05		0.59	0.284	
Longitudinal tune		0.13	0.087		0.069	0.069	
RF energy acceptance	%	1.34	1.31		1.6	2.6	
Damping time	ms	14.2	47.6		160.8	879	
Natural bunch length	mm	2.0	2.0		1.7	0.96	
Full injection from empty ring	h	0.1	0.14	0.16	0.27	1.8	0.8

CEPC Booster TDR Optics and DA with Errors

- 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

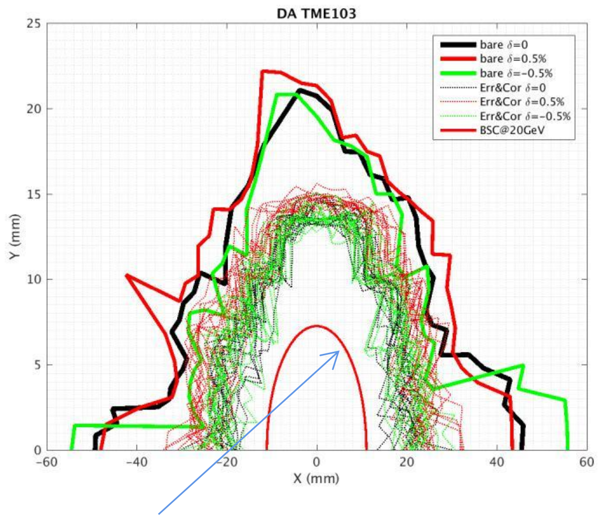


	Dipole	Quadrupole	Sextupole
Transverse shift X/Y (μm)	100	100	-
Longitudinal shift Z (μm)	100	150	-
Tilt about X/Y (mrad)	0.2	0.2	-
Tilt about Z (mrad)	0.1	0.2	-
Nominal field	1e-3	2e-4	3e-4

	Accuracy (m)	Tilt (mrad)	Gain	Offset w/ BBA(mm)
BPM(10Hz)	1e-7	10	5%	30e-3

- ➢ Orbit correction (COD)(100 Seeds)
  - Response matrix method(RM)
  - SVD method
- ➢ Optics correction(96 Seeds) (1/8 quadrupoles)
  - Response matrix method
  - LOCO code
  - Dispersion corrected

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



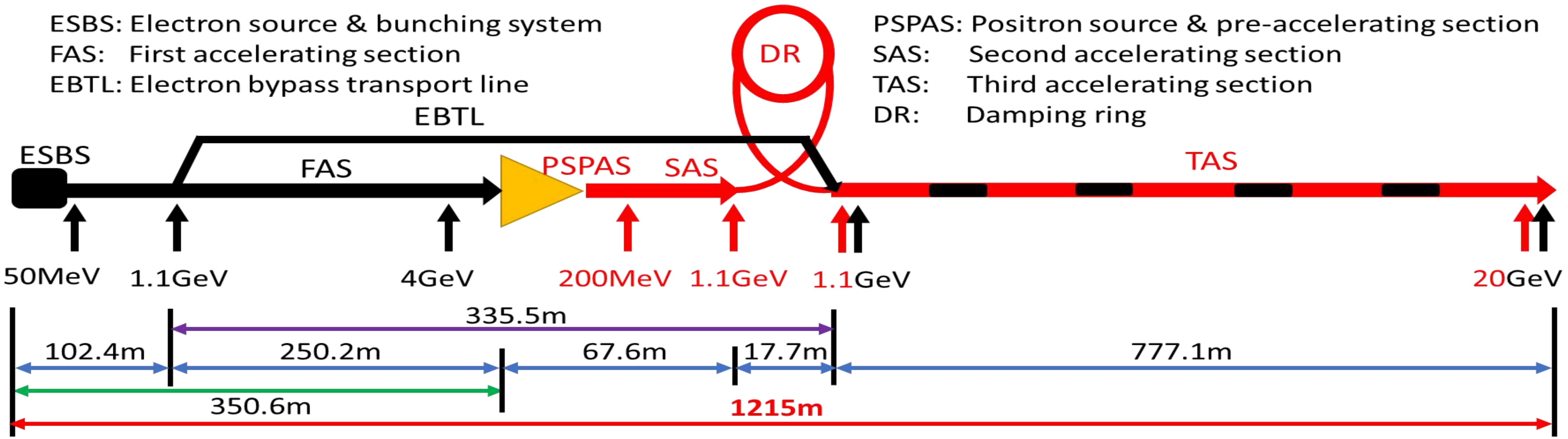
Booster DA design goal

Booster TME lattice DA with errors satisfies the design goal

CEPC 20GeV Linac for TDR

J.R. Zhang,
C. Meng

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



CEPC 20GeV Linac Parameters

J.R. Zhang
C. Meng

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

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

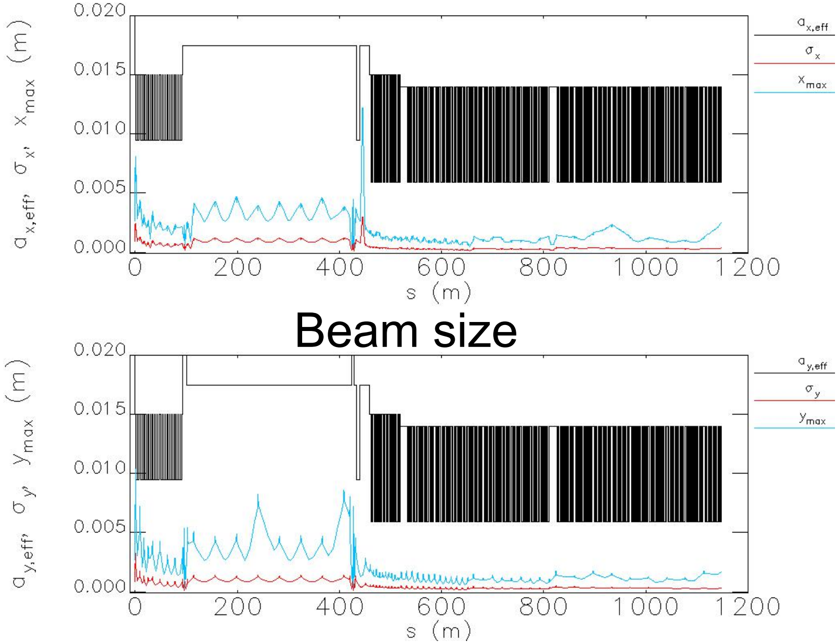
Parameter	Unit	S-band	C-band
Frequency	MHz	2860	5720
Length	m	3.1	1.8
Cavity mode		2π/3	3π/4
Aperture diameter	mm	20~24	11.8~16
Gradient	MV/m	21	45

CEPC 20GeV Electron Linac Design

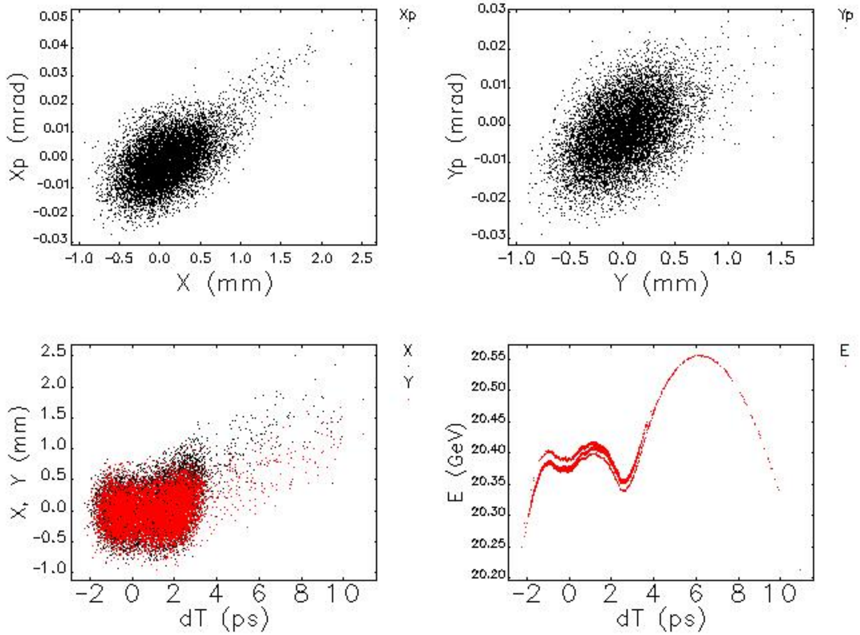
J.R. Zhang
C. Meng

- **Electron Linac**
  - 2.5nm@20GeV (W/o errors)
  - Electron linac emittance growth is less than in positron linac

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



Beam size



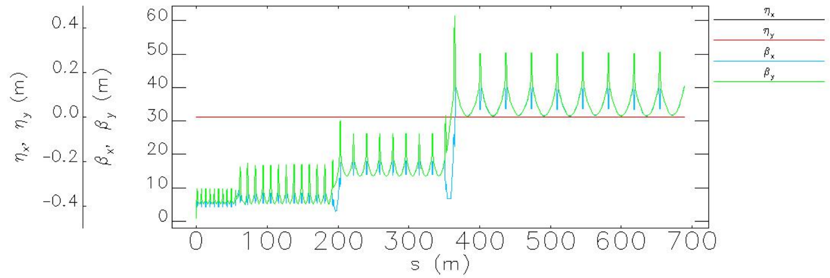
Distribution @ 20GeV

CEPC 20GeV Positron Linac Design

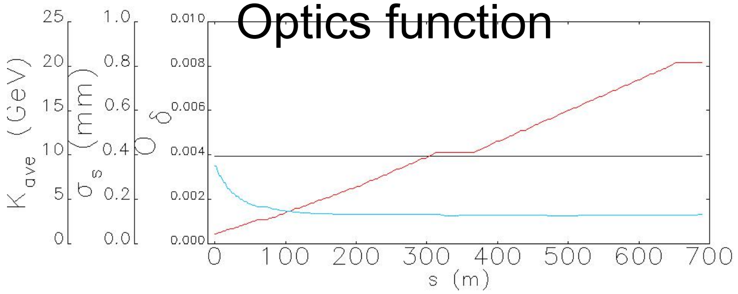
J.R. Zhang , C.Meng

- **Positron Linac**
- 5.9nm@20GeV (w erros)
- Goal 10nm@20GeV

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

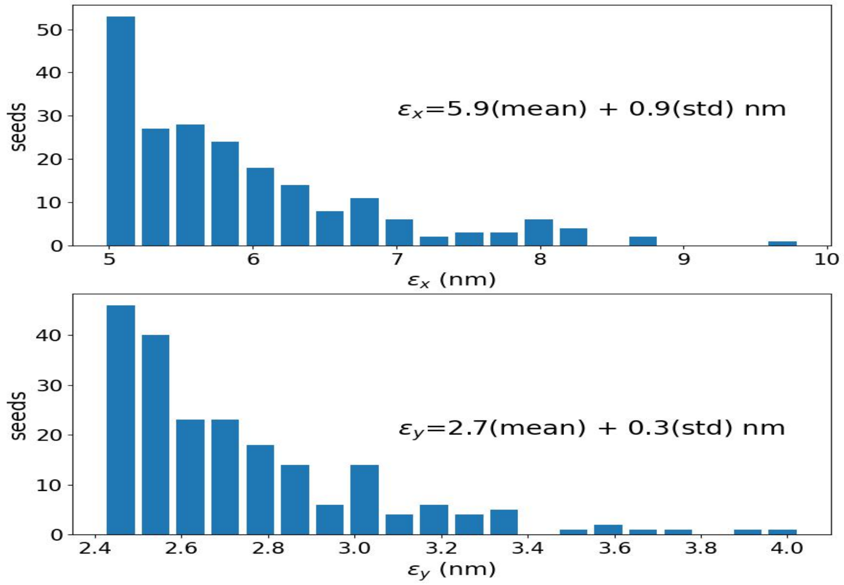


Optics function



Energy/bunch length/energy spread

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

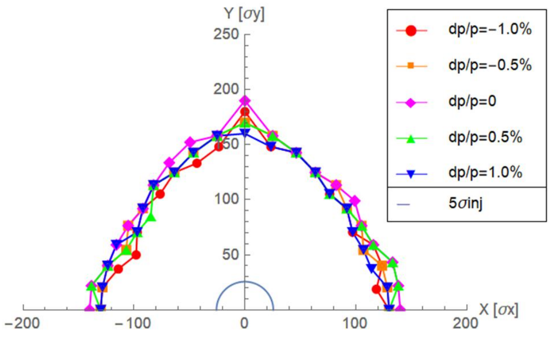


CEPC linac injector reached design goals taking into account of errors

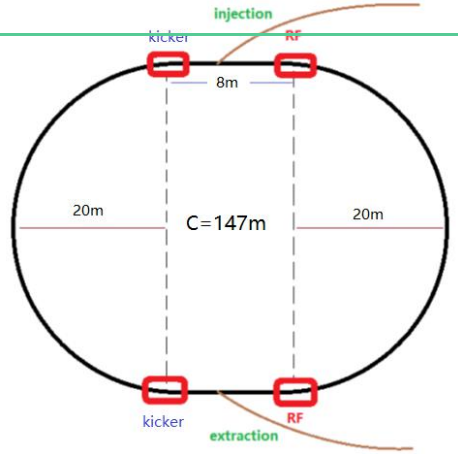
CEPC TDR Damping Ring Design

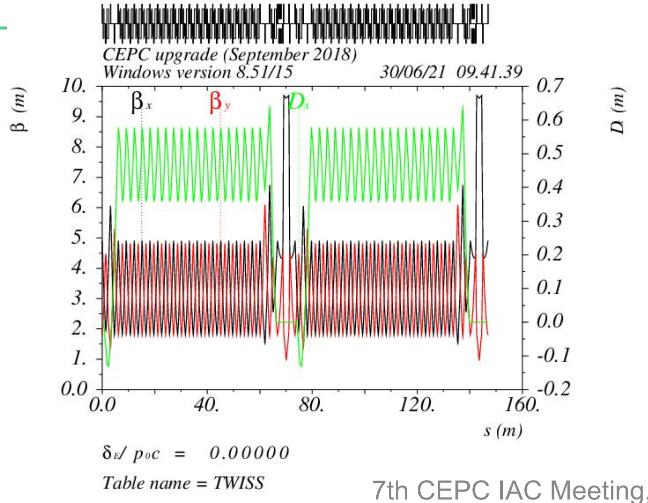
D. Wang

	CDR	TDR
Energy (GeV)	1.1	1.1
Inj. Emittance (mm·mrad)	2500	2500
Ext. emittance (mm·mrad)	530	<200
Storage time (ms)	20	20
Damping time (ms)	15	<13
Circumference (m)	75	~150



CEPC TDR damping ring reaches the design goal





	DR V3.0	
Energy (Gev)	1.1	
Circumference (m)	147	
Number of trains	2	
Number of bunches/trian	2	
Total current (mA)	12.4	
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	75/75
Momentum compaction	0.013	0.007485
Storage time (ms)	20	
δ_0 (%)	0.056	
ε_0 (mm.mrad)	94.4	56.7
injection σ_z (mm)	5	5
Extract σ_z (mm)	5.6	4.2
ε_{inj} (mm.mrad)	2500	2500
$\varepsilon_{ext\ x/y}$ (mm.mrad)	166/75	123/68
$\delta_{inj}/\delta_{ext}$ (%)	0.18 /0.056	0.18 /0.056
Energy acceptance by RF(%)	1.4	1.8
f_{RF} (MHz)	650	
V_{RF} (MV)	1.5	
Longitudinal tune	0.0299	0.0224

Total Impedance Budget @3mm@High Z

N. Wang,Y.D. Liu

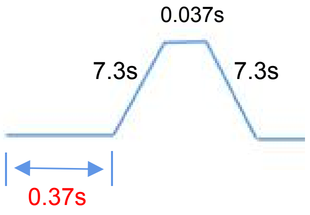
Components	Number	$Z_{\|\|}/n$, mΩ	k_{loss}, V/pC	ky, kV/pC/m
Resistive wall	-	6.2	363.7	11.3
RF cavities	240	-1.0	225.2	0.3
Flanges	20000	2.8	19.8	2.8
BPMs	1450	0.12	13.1	0.3
Bellows	12000	2.2	65.8	2.9
Pumping ports	5000	0.02	0.4	0.6
IP chambers	2	0.02	6.7	1.3
Electro-separators	22	0.2	41.2	0.2
Taper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

- No apparent showstoppers for ttbar, Higgs, W
- Main constraints for High-lumi Z include:
  - Longitudinal impedance will induce bunch lengthening and beam energy spread increase, as well as reduce the stable region of beam-beam interaction.
  - TMCI is OK considering bunch lengthening induced by longitudinal impedance.
  - Transverse resistive wall instability needs an efficient feedback damping time of ~3 turns
  - Ecloud needs an SEY of less than 1.2 or adding antechambers.
  - Emittance growth due to the beam ion effect are foreseen ⇒ feedback system is needed to damp this effect.
  - CBI due to HOMs needs to be further checked.

CEPC Booster Ramping

Dou Wang, Xiaohao Cui

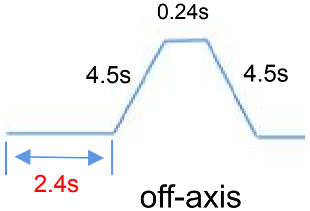
tt



1

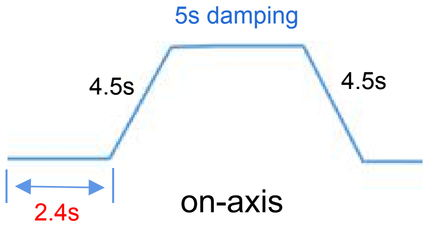
0.37s+7.3s+0.037s+7.3s=15.0s

Higgs



off-axis

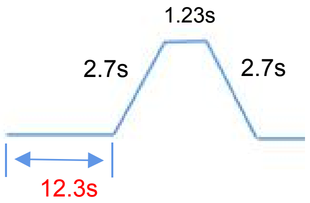
1



on-axis

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

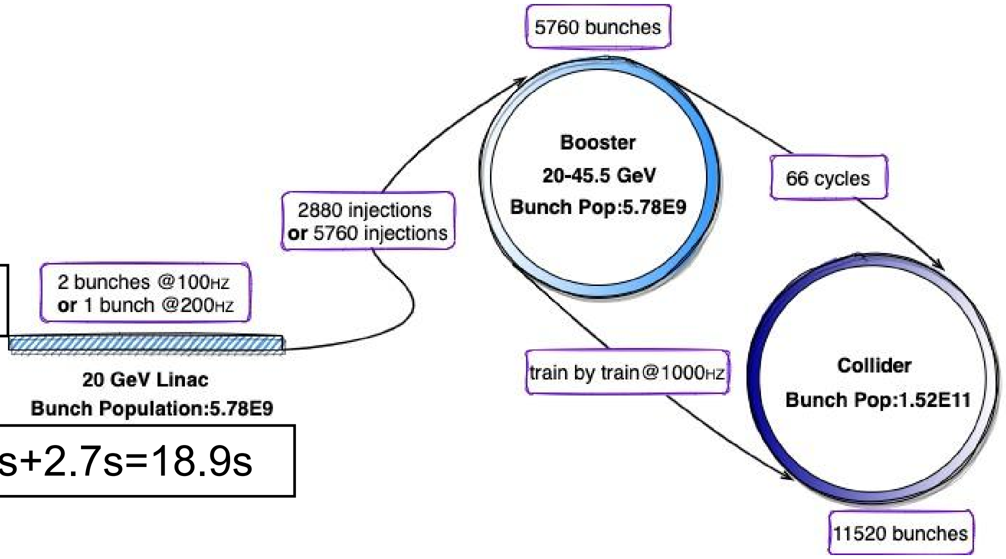
W



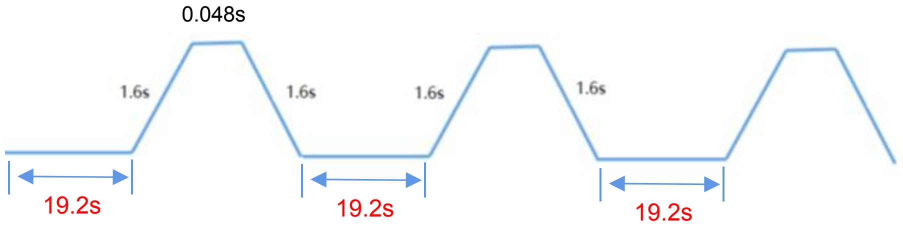
1

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

Z mode injection (full injection)



Z



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

3

Requirements of CEPC Accelerator Timing and Controle System

Gang Li, Ge Lei, X.H. Cui, D. Wang

- Choose 130MHz as clock beat $\rightarrow$ minimum time separation=7.69ns
- (FPGA clock &EVG/EVR transmission can be realized)
- Circumference of damping ring: $(L*1000*10^9/(3*10^8))/(1000/650)$=integer
- Length of transfer line between DR and Linac: （（N*150+75+104*2-8.3） $10^9/(3*10^8))/(1000/2860)$=integer 104m $\rightarrow$101.65m
- Circumference of collider/booster: $(L*1000*10^9/(3*10^8))/(1000/650)$=integer
- Length of transfer line between booster and collider: $(L*10^9/(3*10^8))/(1000/650)$=integer 252m or 246m

T.M. Xin

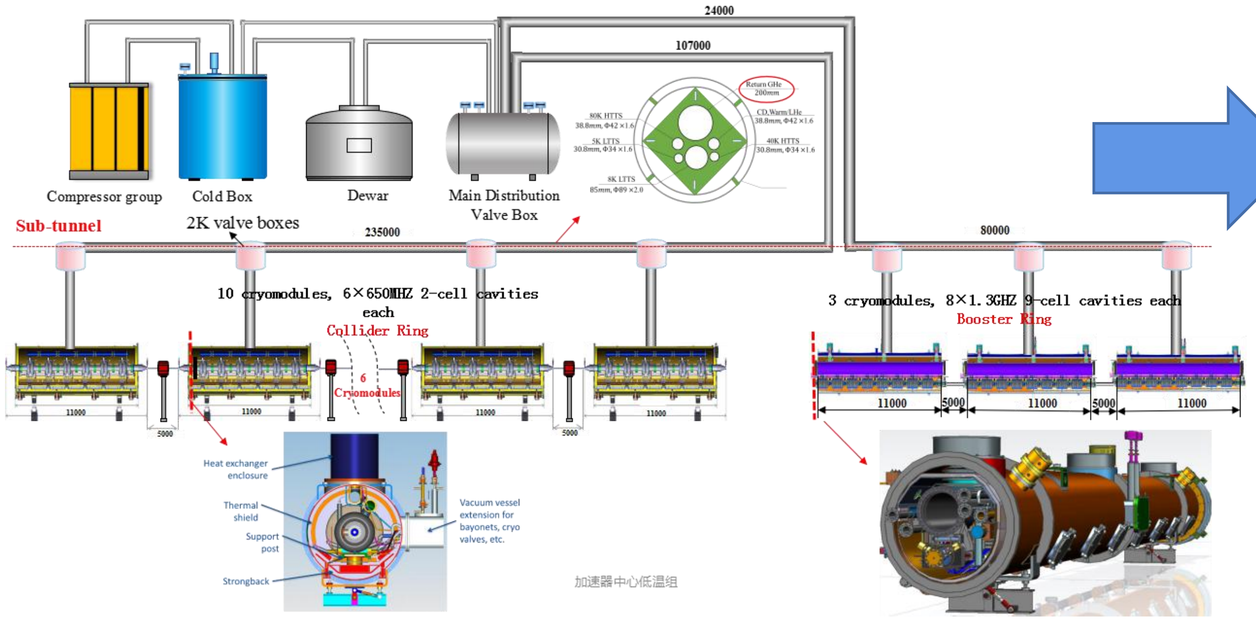
L-Band RF Gun electron source is under study

	Common frequency	Bunch separation	Luminosity @Z	Filling flexibility	Remark
1. Keep current Linac	13MHz	38.46ns	58%	No	
2. Cancel SHBs, use RF gun	130MHz	23.07ns	100%	No	
3. *f*(Linac):2860→2600MHz	130MHz	23.07ns	100%	No	
4. Cancel SHBs, use RF gun + uneven filling	130MHz	7.69ns,15.38ns,23.07ns…	100%	Yes	Upgradable to 50MW
5. New frequency for Linac and rings (hope)		20.00ns,21.54ns,23.07ns,24.62ns,26.15ns, 27.69ns	100%	Yes	

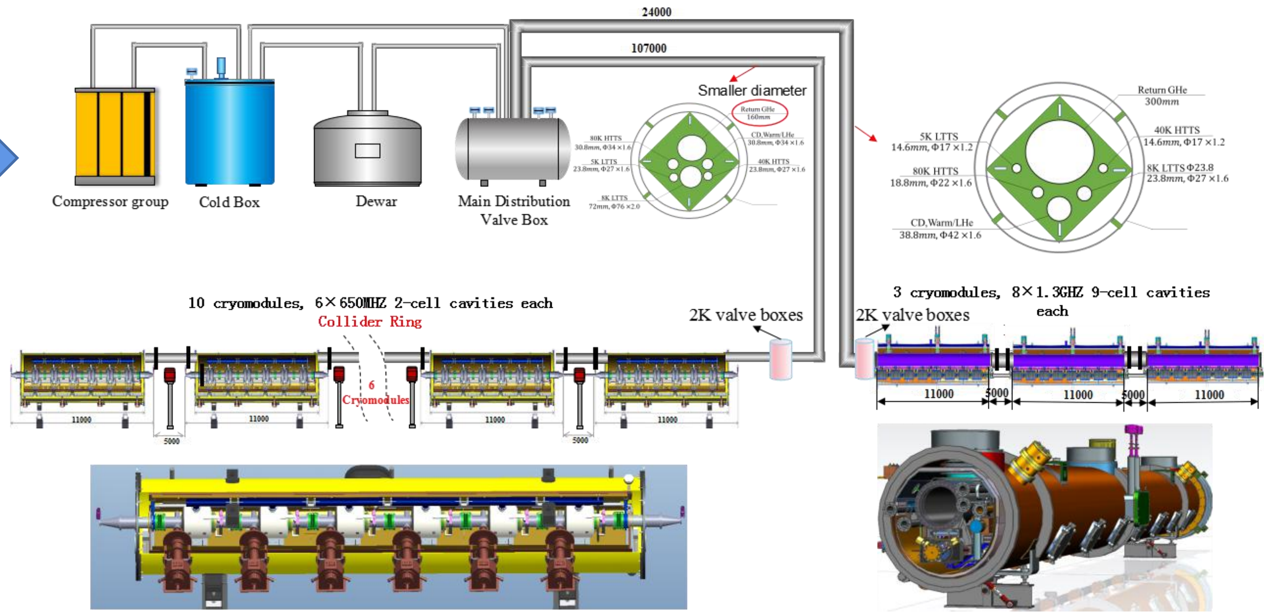
CEPC SRF Cryogenic Systems in TDR

R. Ge

CEPC accelerator SRF cryogenic flow chart in CDR



CEPC accelerator SRF cryogenic flow chart in TDR



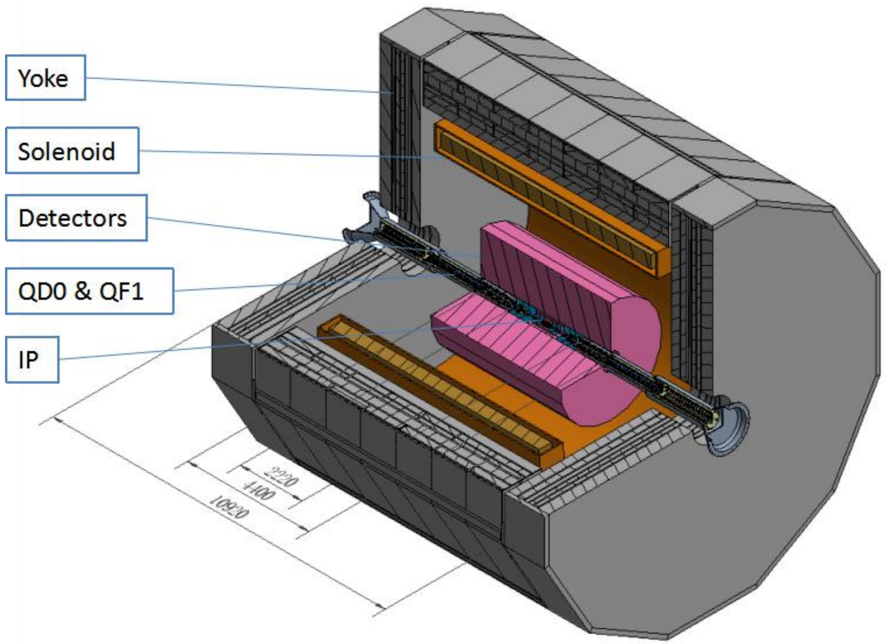
The length of SRF cyogenic tansfer lines is 2240m in CDR

The length of SRF cyogenic tansfer lines has been reduce from 2240m in CDR to 744m in TDR

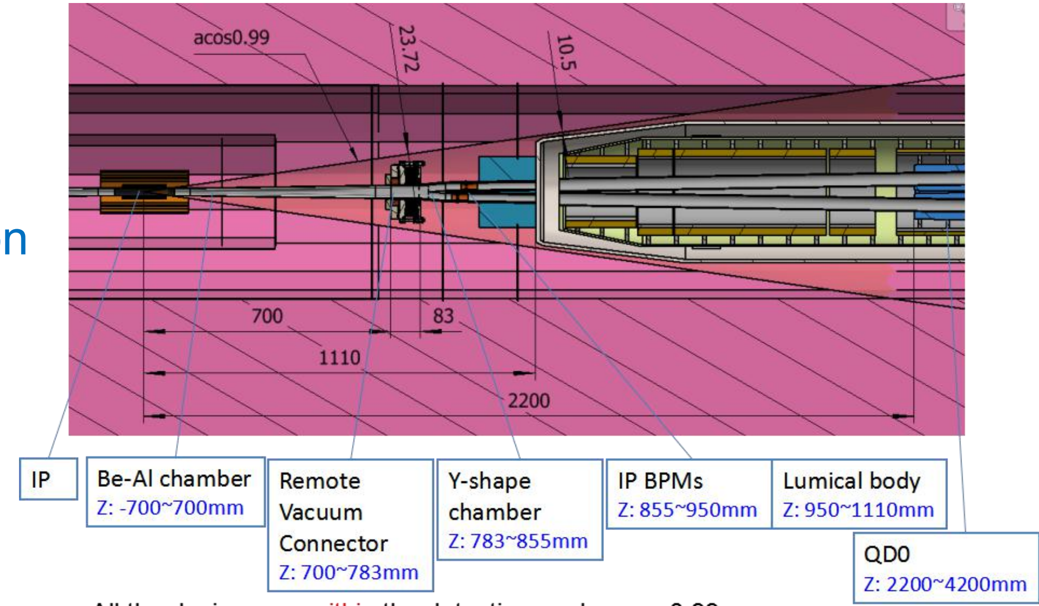
The length of SRF cyogenic tansfer lines is 744m in TDR

CEPC MDI Study Progresses

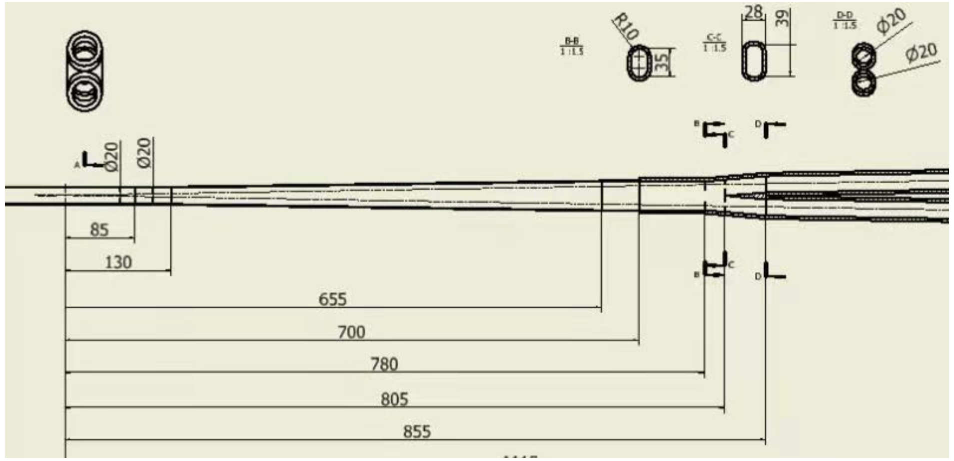
S. Bai, H.J. Shi



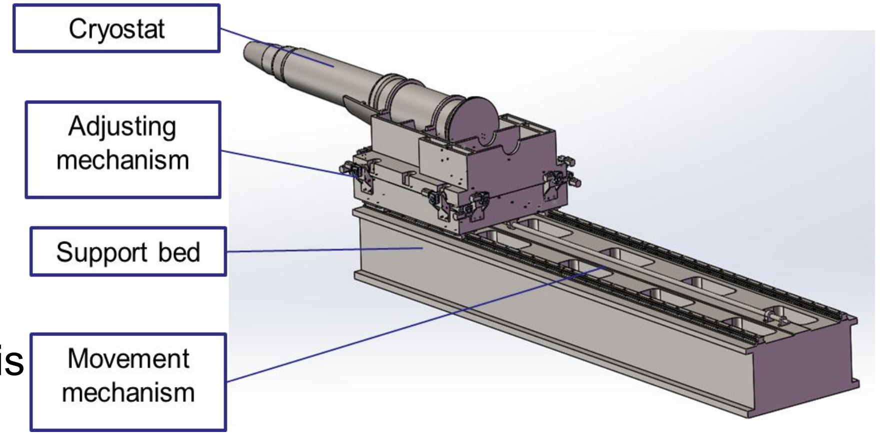
- IR Superconducting magnet design
- IR beam pipe
- Synchrotron radiation
- Beam loss background
- Shielding
- Mechanical support
- Full detector simulation



- All the devices are within the detective angle, acos0.99.

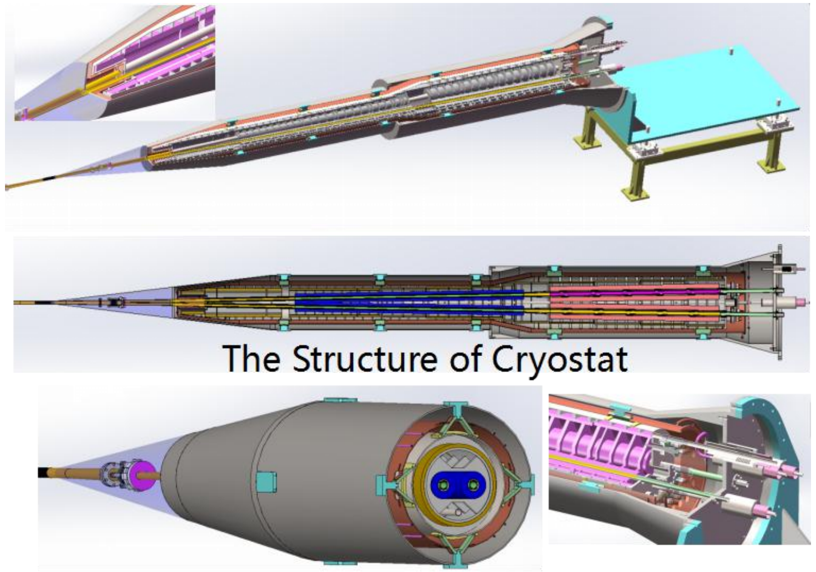


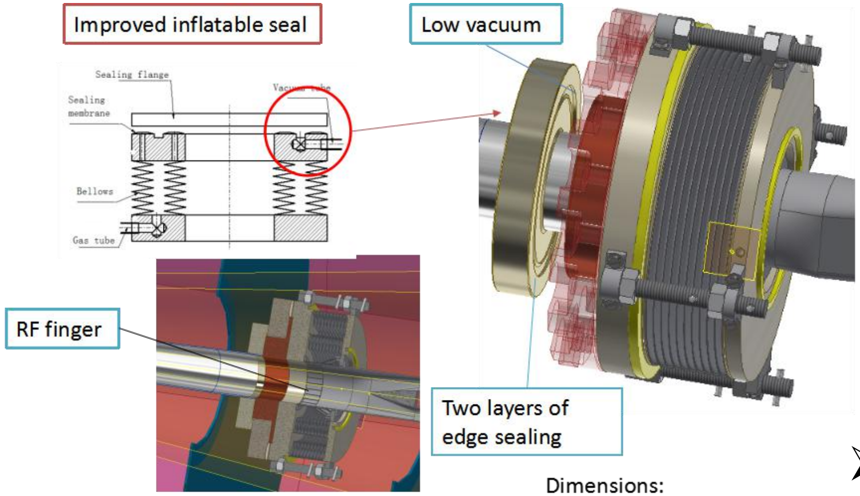
- Central beryllium pipe inner diameter changes from 28mm(CDR) to 20mm
- There is no SR photons hitting the central beam pipe in normal conditions.
- Single layer beam pipe with water cooling, SR heat load is not a problem.



CEPC MDI Study Issues

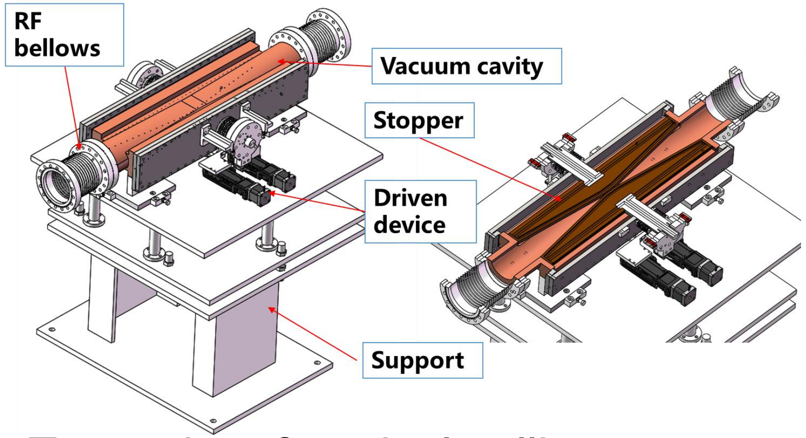
H.J. Wang





- Replace the sealing membranes by two layers of edge sealing.

Dimensions:
- Transversal: Max. ϕ174mm
- Longitudinal: ~83mm



➢ Two pairs of vertical collimators added, with which the beam loss background from RBB/BGB/BTH with multipole errors and beam-beam effects reduced 20%.4 collimators per IP per ring

Study issues (1):
- SC magnet support system
- Remote vacuum connector
- Collimators for background decreasing
- Beam loss failure
- Preliminary design on machine protection

Study issues (2):
- SR from last bending magnet upstream of IP
- Beam loss backgrounds
- Shielding
- Full Detector Simulations

CEPC MDI Q1a SC Magnet Optimization Design

Y.S. Zhu

- **Focused on reducing the magnet weight of Q1a.**

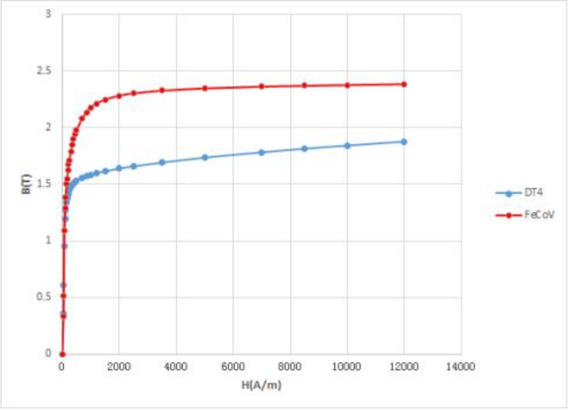
- Paths:

  1 Relax the dipole field requirement of crosstalk (<30Gs)

  2 Use special iron material (**FeCoV**)

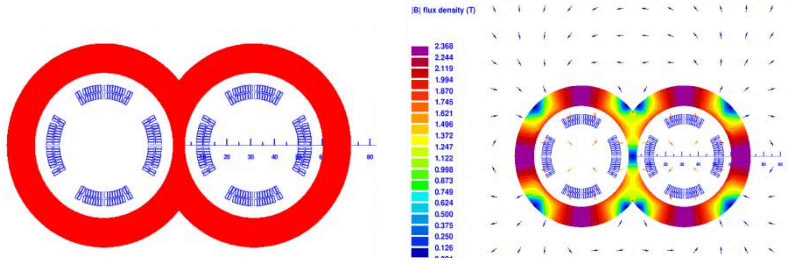
  Q1a baseline design: Two layer coils, Weight: 78.9Kg (55% of original value 143.6kg) , cross talk <30Gauss, field gradient: 141T/m.

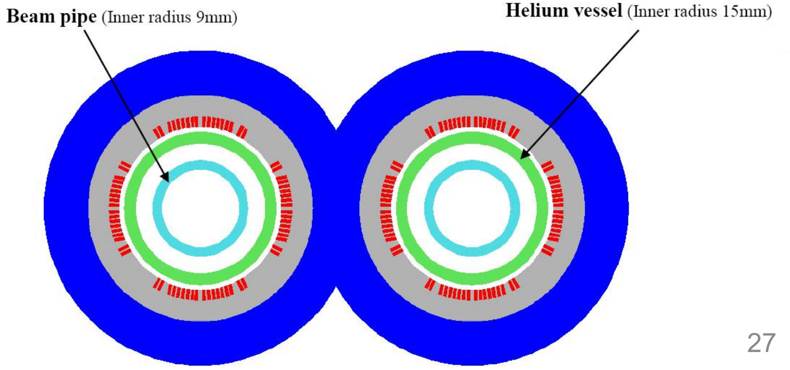
  Q1a alternative design: One layer coil,Weight: 60.2Kg (42% of original value) , cross talk <30Gauss, field gradient: 141T/m.



BH curve of DT4 and FeCoV

Iron yoke material: FeCoV; radius of the iron: 40.5mm





R&D plan:

First step, develop a 0.5m short single aperture SC quadrupole model (LTS NbTi, 136T/m) (started since 2020)

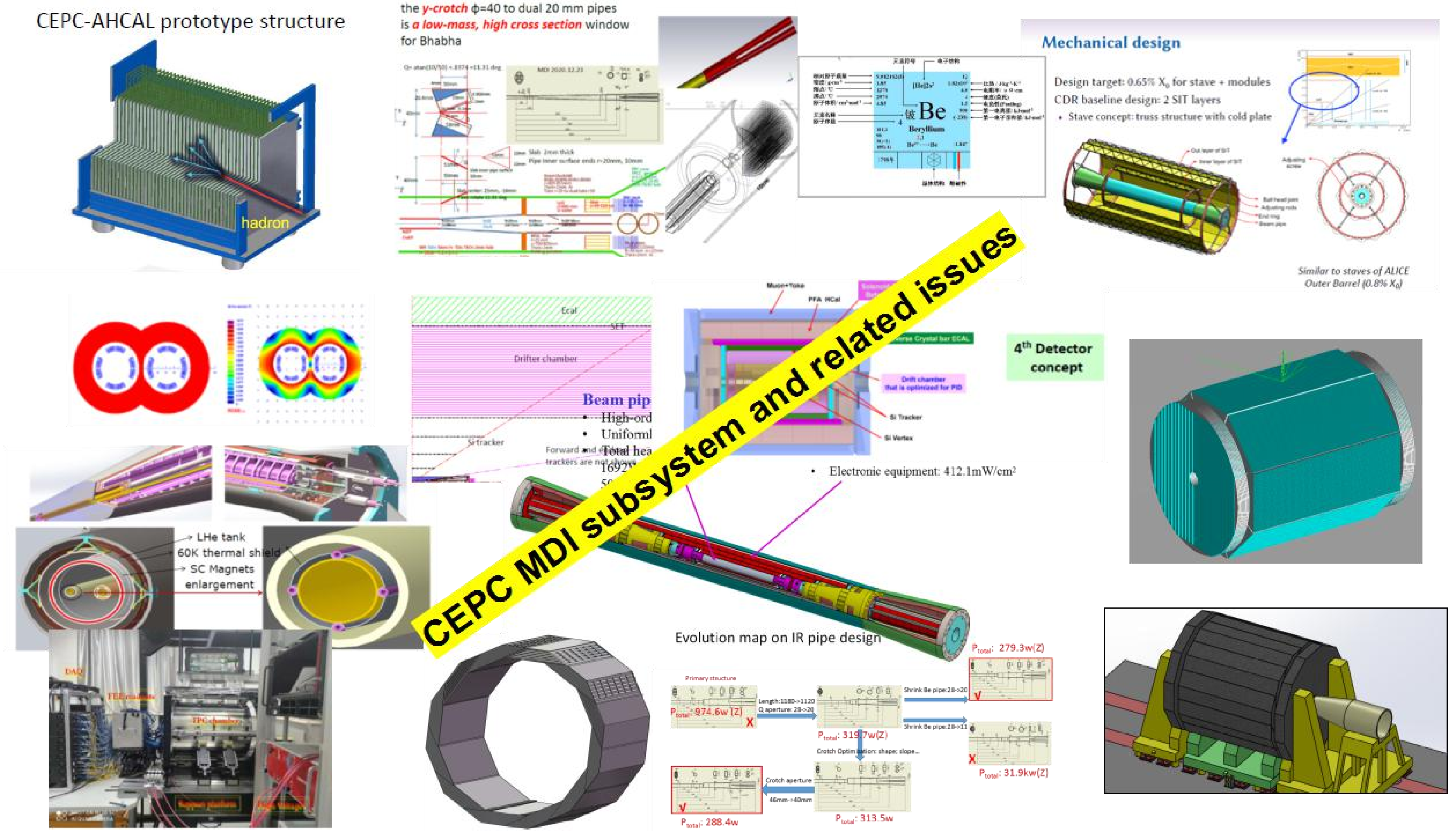
Second step, 0.5m double aperture SC quadrupole magnet

Third step, 1.2m double aperture SC quadrupole magnet

The 2021 Workshop on CEPC Detector & MDI Mechanical Design

(Oct. 22-23, 2021， IHEP/Donguan)

https://indico.ihep.ac.cn/event/14392/other-view?view=standard



Since the CEPC MDI workshop in August， 2020, there has been many important progresses which are reflected by the 20 talks

CEPC MDI Subsystem and Task Forces

H.Y. Shi, S. Bai

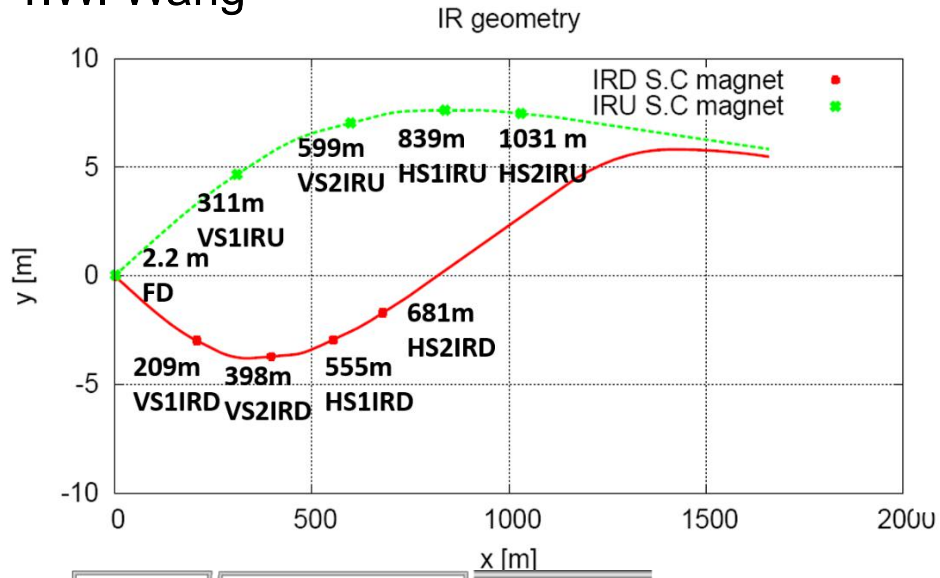
MDI__Accelerator	Person
IP Feedback	J.H. Yue/C.H. Yu/Y.W. Wang
BG Simulation	H.Y. Shi/S. Bai
LumiCal	Suen Hou/Ivanka/Phillipe
HOM absorber	Y.D. Liu/J.Y. Zhai
Vacuum Chamber	H.J. Wang
SR Masks	H.Y. Shi
QD0/QF1	Y.S. Zhu
Anti-Solenoid	Y.S. Zhu
Cryostats	M.F. Xu/T.X. Zhao
BPMs	Y.F. Sui
Instability&Impendance	Y.D. Liu/N. Wang
Cooling	Q. Ji/H.J. Wang
Shielding	H.Y. Shi/Z.J. Ma/S. Bai
Assembly&Supporting	H.J. Wang/Q. Ji
Alignment	X.L. Wang/Q. [illegible] Wang
Connecting System	H.J. Wan[illegible]
Vacuum pumps	Y.S. [illegible]
Last Bending Magnet	Y[illegible]ang
Collimators	[illegible]ai/H.J. Wang
Control	G. Li

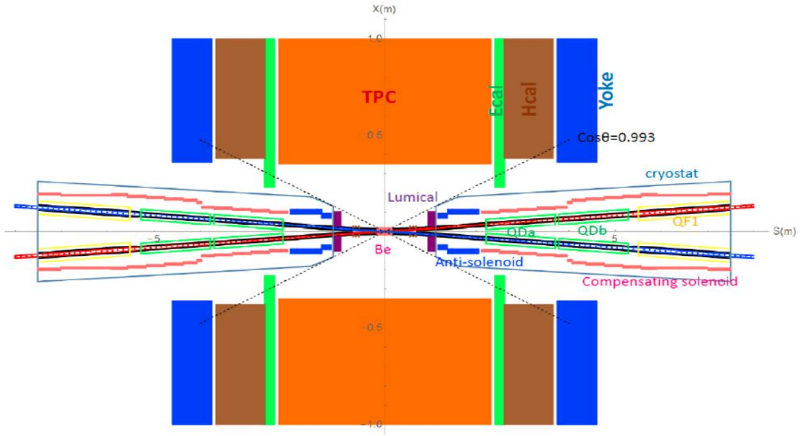
MDI__Detector	Person
Central Beam Pipe	Q. Ji
Vertex Detector	Z.J. Liang
LumiCal	Suen Hou/Ivanka/Phillipe
Silicon Tracke[illegible]	H. Fox
TPC	H.R. Qi
Hcal	Y. Liu
[illegible]	Y. Liu
[illegible]olenoid	F.P. Ning
Yoke	F.P. Ning
Muon Detector	X.L. Wang
Hall	Z.A. Zhu
BG Simulation&Shielding	H.Y. Shi
Software Geometry	C.D. Fu
Alignment&Assembly	Q. Ji/H.J. Wang/X.L. Wang
Electronics	W. Wei
Cryogenic	T.X. Zhao
Radiation Protection/dumps	Z.J. Ma
Collider ring/Booster	Y.W. Wang/D. Wang

MDI working group has been formed with regular meeting

CEPC IR Sextupoles and Cryogenic System

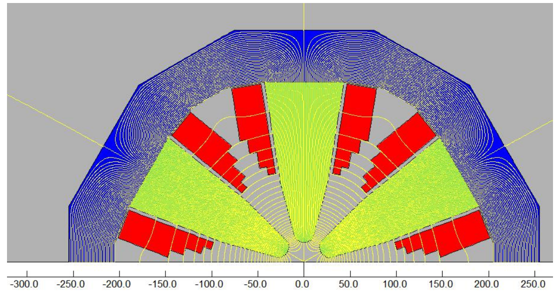
Y.W. Wang



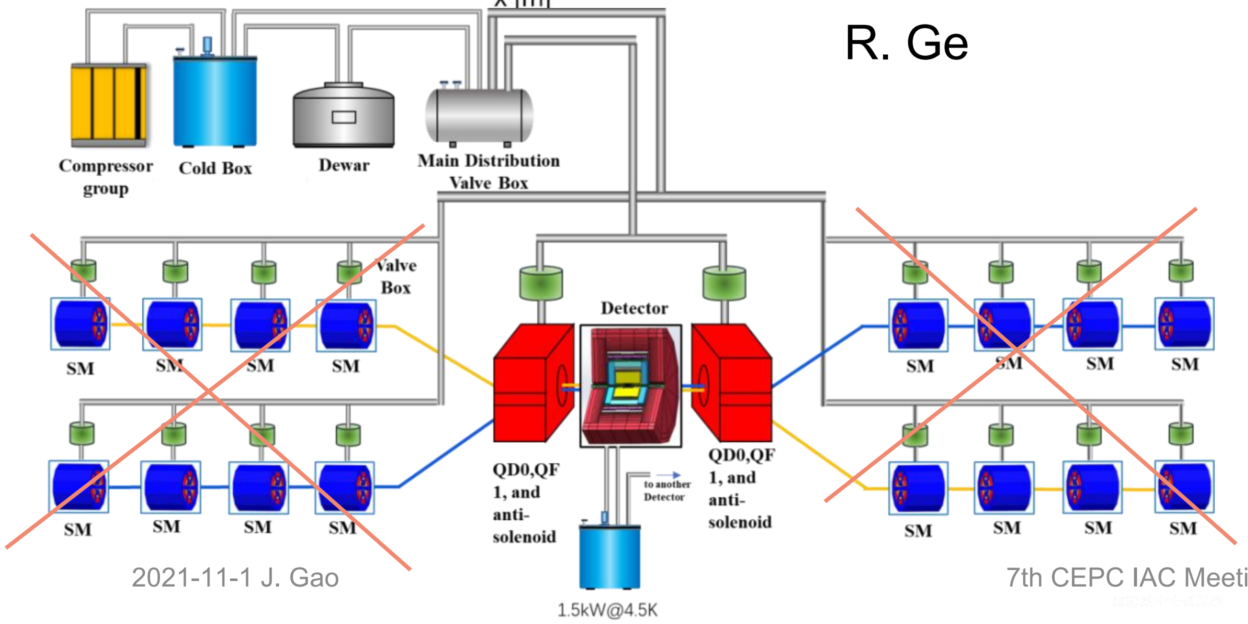


Schematic layout of QD0, QF1, and anti-solenoid

Y.S. Zhu



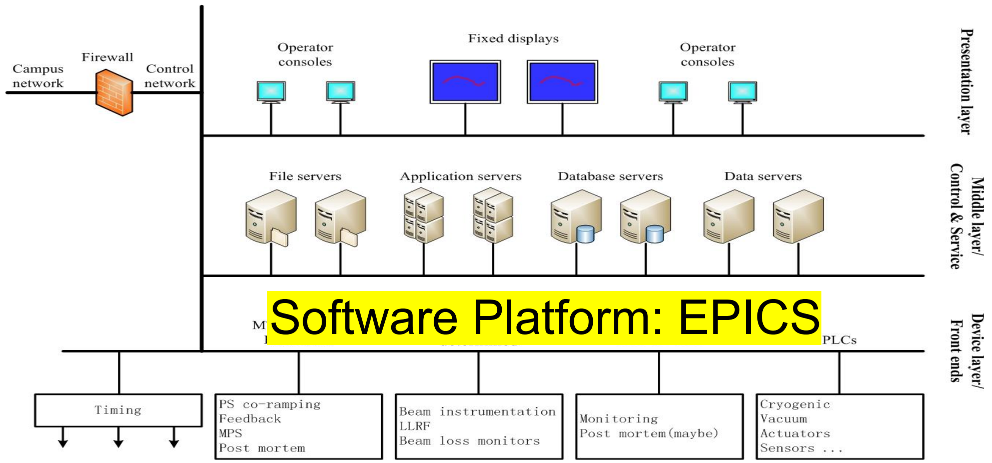
R. Ge



- ➢ The requirement for IR sextupole magnets is updated.
- ➢ The magnet bore and pole field is reduced.
- ➢ Conventional sextupole magnet technology can be used (FeCoV pole). Max strength 3886T/m^2 is achieved with bore aperture 42 mm. Max current < 200A.

IR sextupoles have been changed from SC magnets to normal conducting ones and cryogenic system for sextupoles can be eliminated.

CEPC Accelerator Control System



Overall hardware architecture of the control system

Potential challenges

- Data rate/traffic in the network(low latency switch)
- Travel time/response time(between GUI and IOCs/controlled devices)
- Faulty recovery(Distance between stations: dozens of km)
- Database and Management of the control system

G. Li

Global control

Control Platform

Center Control System: computers, servers, database, etc

Network System

Timing System

Post Mortem System

Machine Protection System

Video system

Local control

Power Supply Control System

Vacuum Control System

Temperature Monitoring System

Linac Control System

Integration of subsystems

LLRF, Cryogenic system, Injection/Extraction system etc.

Interface to other system

Detector, beamline and conventional facility

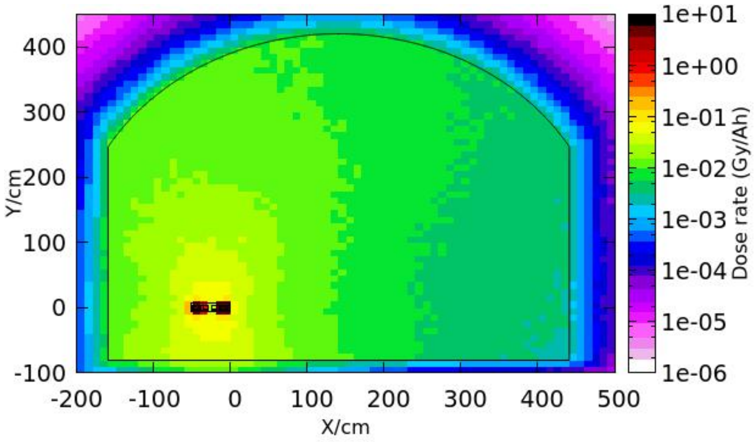
International collaborations are welcome

CEPC Radiological Impact Study

G.Y. Tang

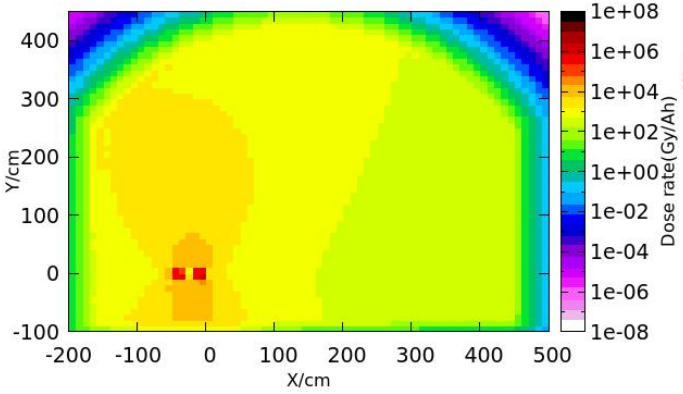
Impact factors	Characteristics
Synchrotron radiation	Radiation damage to magnet coil; Over heat load to ventilation system; Formation of ozone and nitrogen oxides in the air; Slightly activation to the material around;
Random beam loss	Cause secondary radiation inside the tunnel; Determine the bulk shielding thickness;
Hot spots	Collimation locations, collider/linac dumps, injection/extraction points;
Radiological impact on environment	Dose from stray radiation emitted during machine running Radionuclides in the cooling water, underground water, tunnel air, soil. Radioactivity analysis for the solid components and waste

The radiation data base is establishing for radiation protection and environment assesment

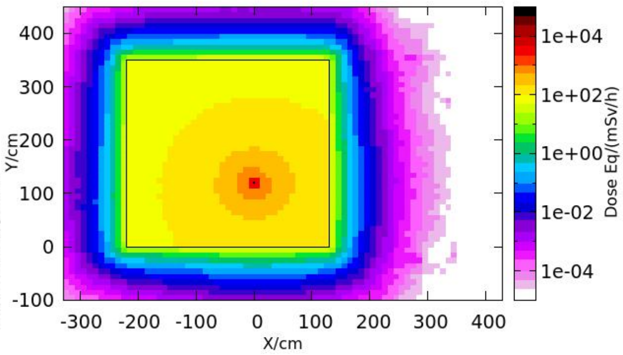


Prompt radiation dose caused by random beam loss

In collider ring tunnel, radiation caused by synchrotron is more serious than random beam loss



Prompt radiation dose caused by synchrotron radiation



Linac tunnel dose by beam loss of (Dose-eq: total, gamma, neutron)

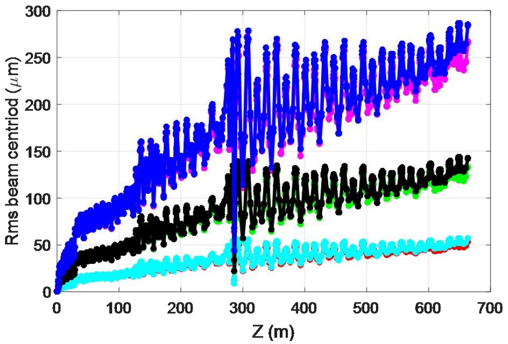
Preliminary Studies on CEPC Ground Motion

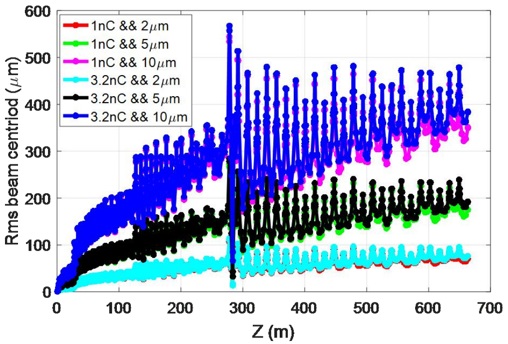
Y.W. Wang, C. Meng

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

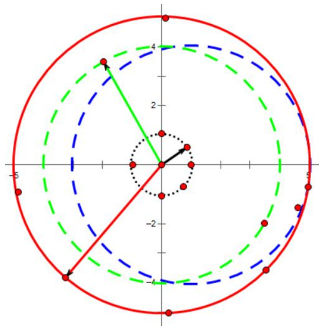
$$\frac{\Delta L}{L} \cong -\frac{(\Delta y/\sigma_y)^2}{4}$$

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

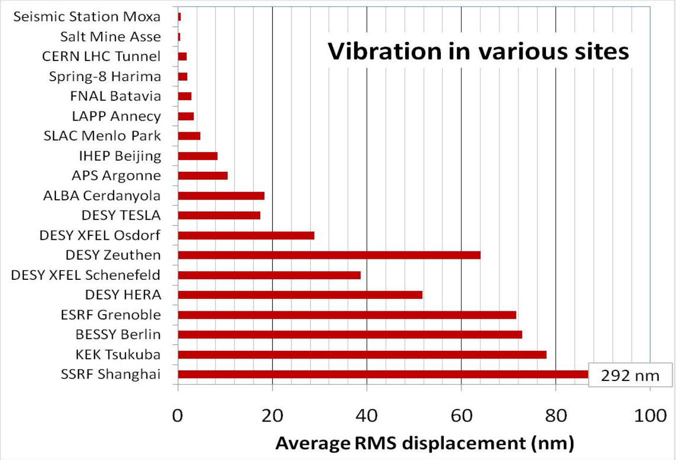


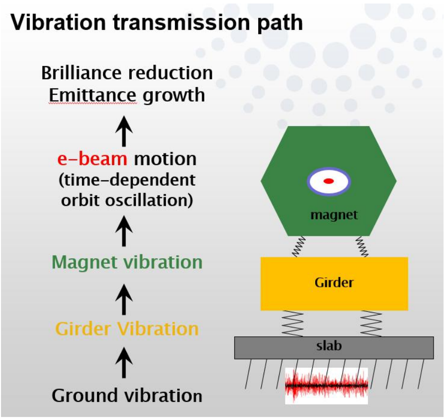


CEPC beam orbit variation in linac due to ground motion
With ground motion amplitude of 100nm, linac effective emittance increase 20%

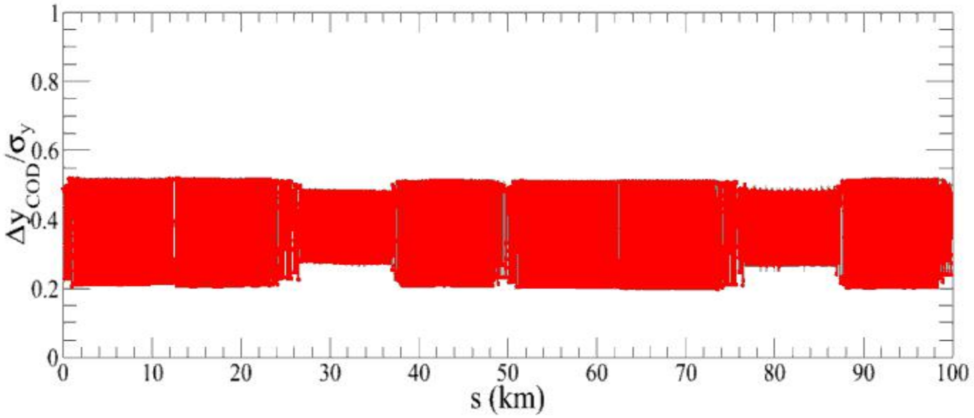


Effective emittance increase due to orbit variation





Ground vibration transmission to colliding beams



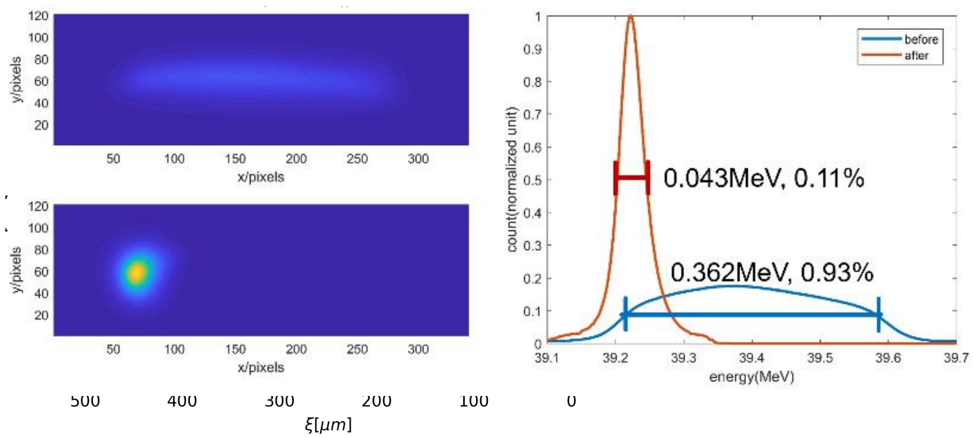
CEPC colliding beam orbit variation due to ground motion

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

CEPC Plasma Accelerator Injector (alternative)

W. Lu, D.Z. Li

Booster Requirement	
Energy (GeV)	45.5 (0.2%)
Bunch Charge (nC)	0.78
Bunch length(um)	<3000
Energy Spread(%)	0.2
ε_N(μm rad)	<800
Bunch Size(um)	<2000



Bunch energy spread1% to 0.1%, exp at Tsinghua U.

HTR e- acceleration

- Start-to-end simulation performed, CPI requirement to linac updated
- Without extra damping mechanism, the growth of hosing instability from statistical noise is acceptable when transformer ratio is 1-1.5
- There are other powerful damping mechanisms. HTR is still possible

PHYSICAL REVIEW LETTERS **127,** 174801 (2021)

Editors' Suggestion

Positron acceleration scheme made progress

High Efficiency Uniform Wakefield Acceleration of a Positron Beam Using Stable Asymmetric Mode in a Hollow Channel Plasma

Shiyu Zhou,[1] Jianfei Hua,[1] Weiming An,[2] Warren B. Mori,[3] Chan Joshi,[3] Jie Gao,[5] and Wei Lu[1,4,*]
[1]*Department of Engineering Physics, Tsinghua University, Beijing 100084, China*
[2]*Beijing Normal University, Beijing 100875, China*
[3]*University of California Los Angeles, Los Angeles, California 90095, USA*
[4]*Beijing Academy of Quantum Information Sciences, Beijing 100193, China*
[5]*Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, China*

e+ acceleration

- Asymmetry beam scheme is well accepted by PRL editor
- Experiments Plasma dechirper experiment got good results, energy spread from 1% to 0.1%
- Experiment on SXFEL is still ongoing. Dedicated TF for PWFA is crucial and under consideration

Dazhang Li, CPS, September 2019

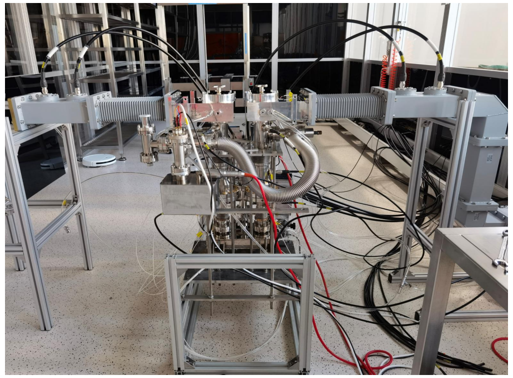
CEPC Accelerator System Key Hardware R&D Progresses in TDR

CEPC SRF Facilities and Componets

J.Y. Zhai, P. Sha

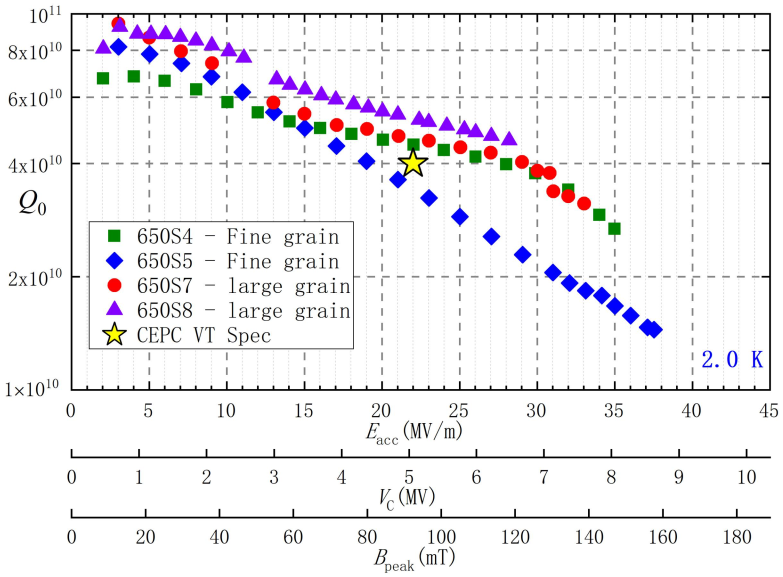






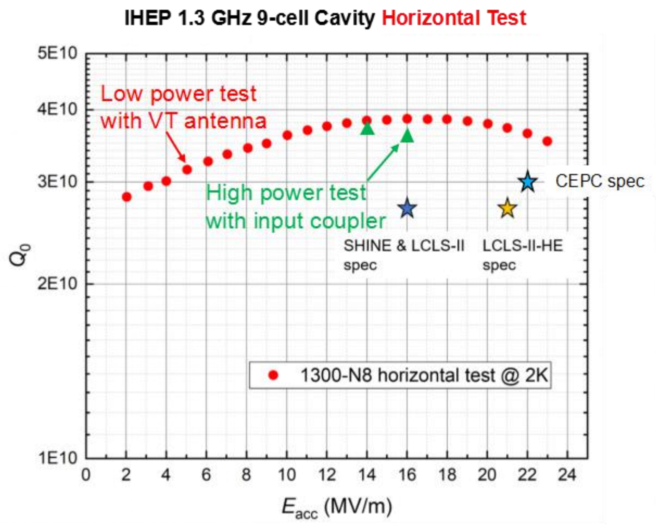
IHEP PAPS established in July 2021 Horizontal test stand, 1.3GHz 9cell cavities, and couplers...

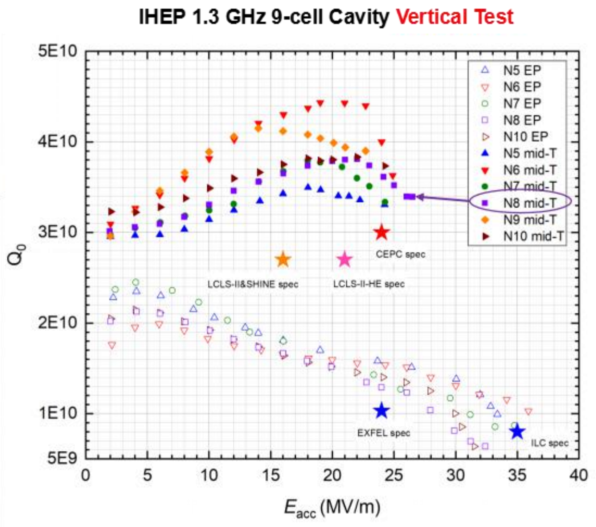
CEPC 650 MHz 1-cell Cavity



The 650Mhz 1-cell cavity's results (3.9E10@30MV/m, 1.5E10@37.5MV/m) have broken China's gradient record of low-frequency (<1 GHz) elliptical cavities. **World record Q** of 650 MHz cavity above 30 MV/m.

1.3 GHz High Q Mid-T Cavity Horizontal Test

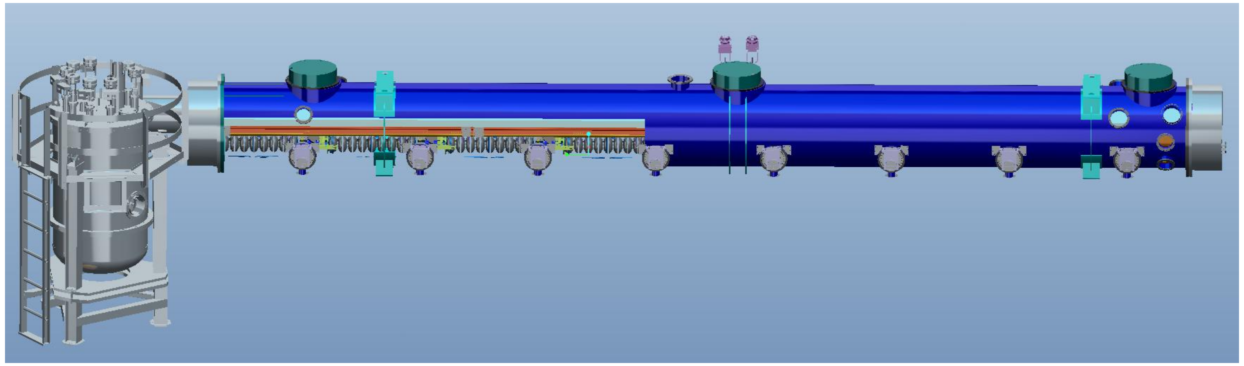




CEPC 650 MHz Test Cryomodule with Beam/ 1.3GHz High Q Cryomodule (8X9cell)

J.Y. Zhai

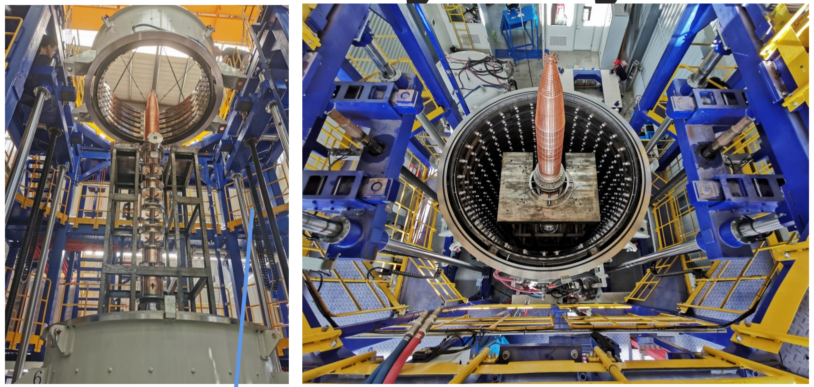
- Cavity string and module assembly in March to May 2021.
- Modul installation in beamline, 2 K cool down test and RT coupler conditioning in May to July. Horizontal and beam test soon.
- IR laser output to 116 W. Photo-cathode QE to 5 %. DC gun vacuum to 1.5E-10 Pa, voltage to 350 kV. Buncher cavity high power tested.



- 1.3 GHz 8x9-cell high Q cryomodule prototype
- Component fabrication in 2021 to mid 2022
- Assemble and horizontal test in 2022
- Ship to Dalian in 2023

CEPC 650MHz High Efficiency Klystrons

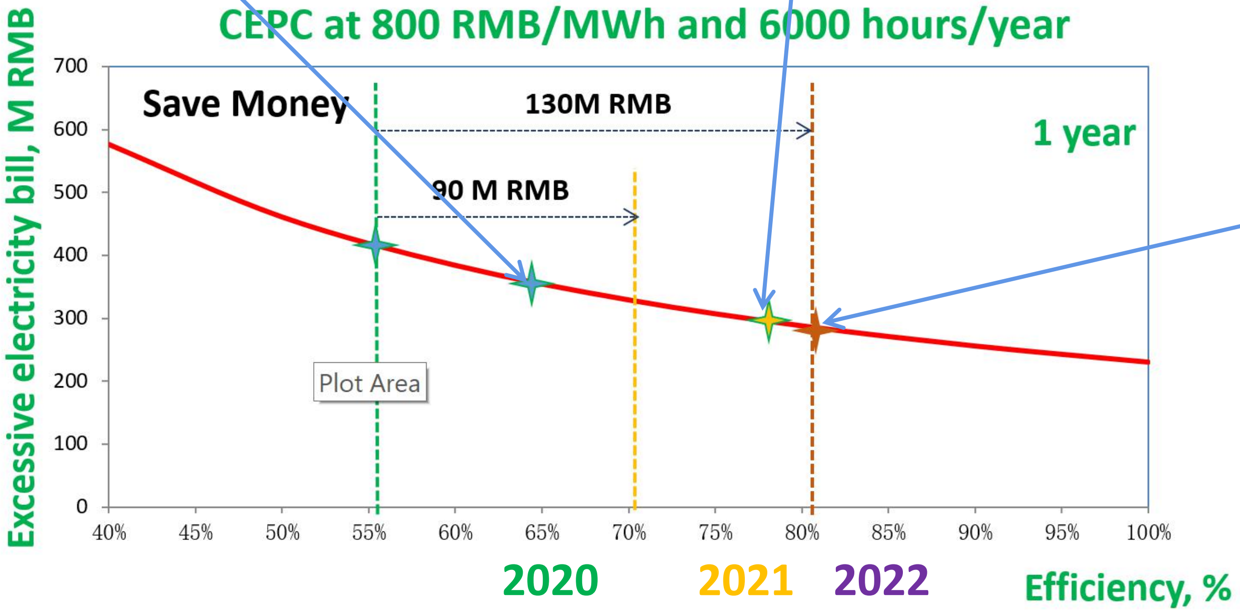
Z.S.Zhou

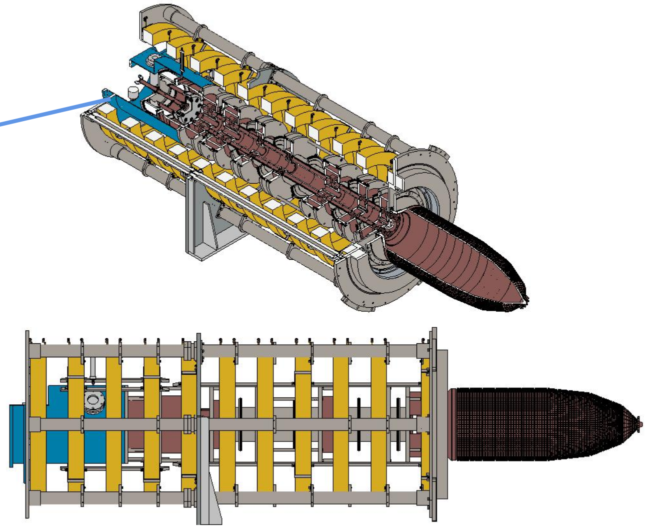


Klystron No. 2
Efficiency 77%
(2021)

Klystron No. 3
Efficiency 80.5%
(2022)

Klystron No. 1
Efficiency 65%
(2020)

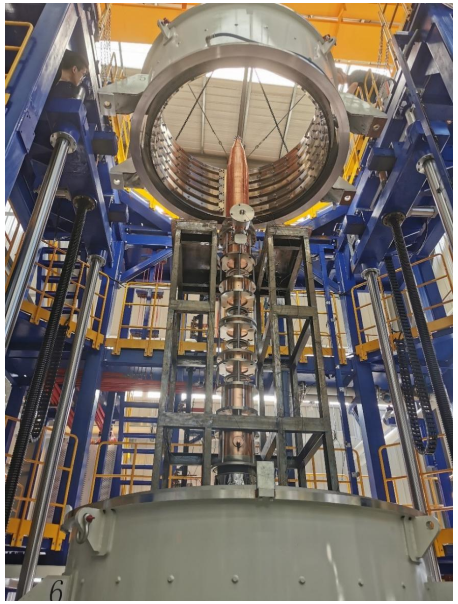


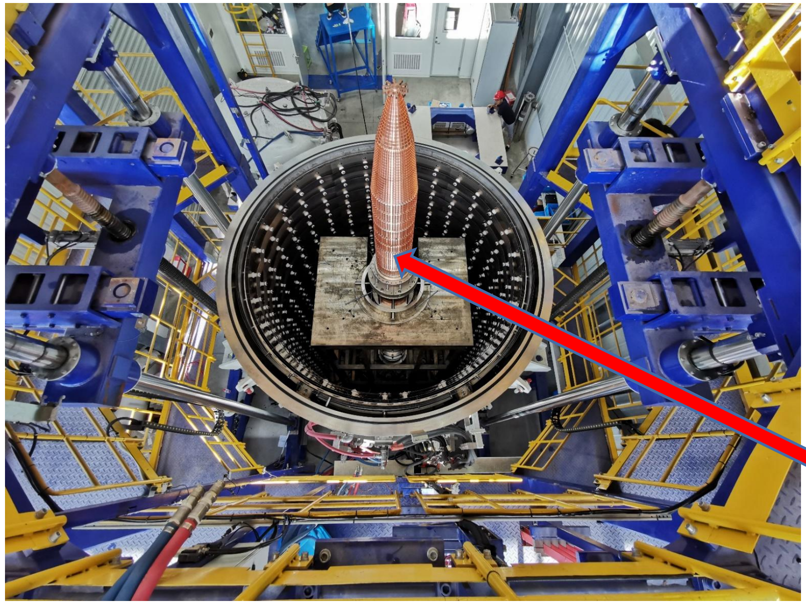


Efficiency impact on operation cost (Only considering operation efficiency of 650MHz klystrons)

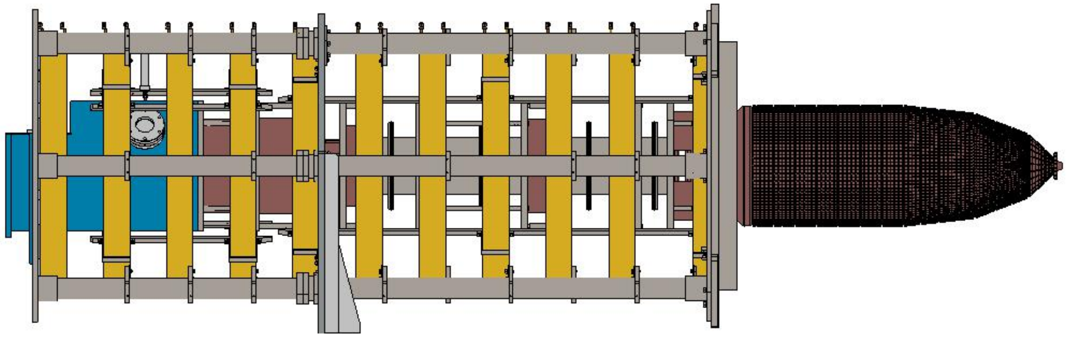
CEPC 650MHz High Efficiency Klystrons (2nd and 3rd)

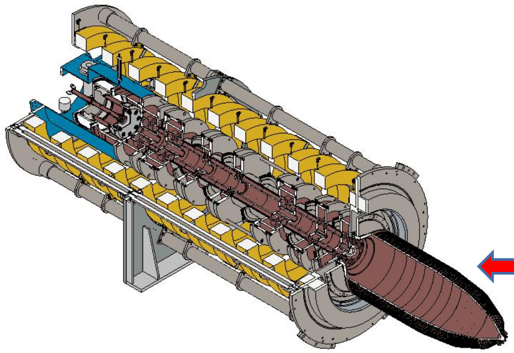
Z.S.Zhou





The 650MHz high voltage single beam klystron is fabricated under baking (77% efficiency) and test will start soon in PAPS

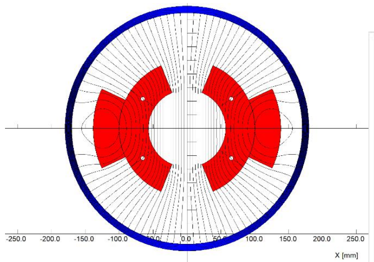


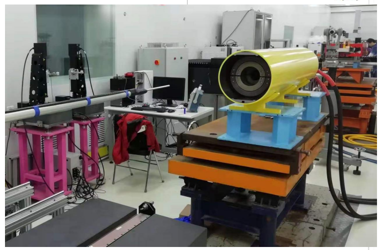


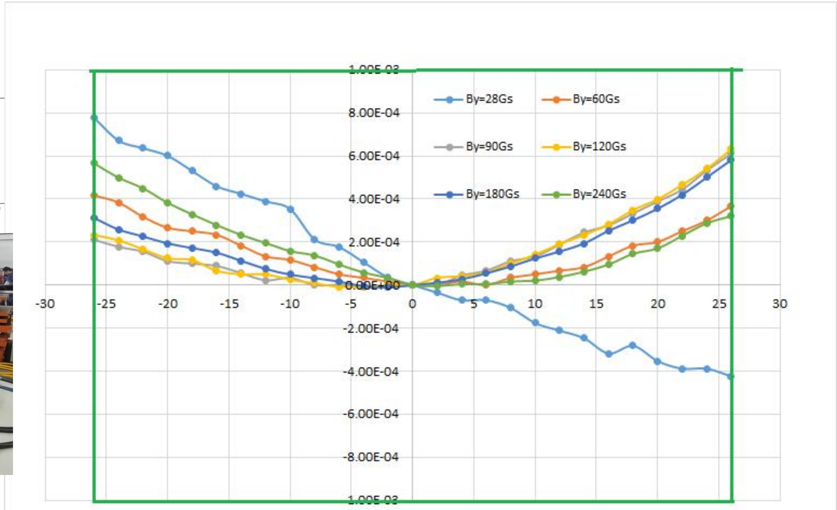
Klystron No. 3
Efficiency 80.5%
(2022)

CEPC Full Size Booster Dipole Magnets

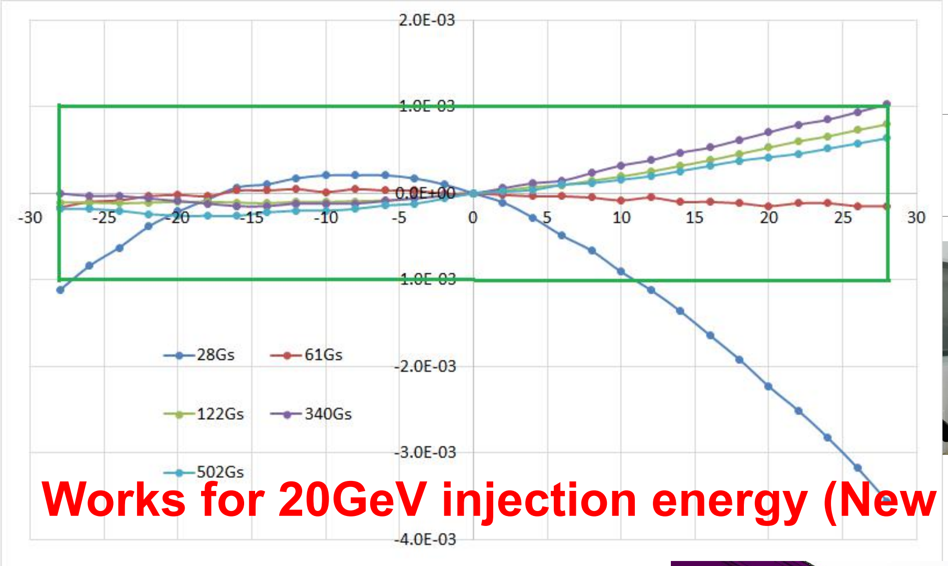
W. Kang



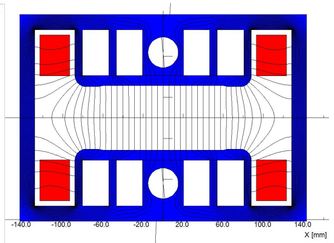


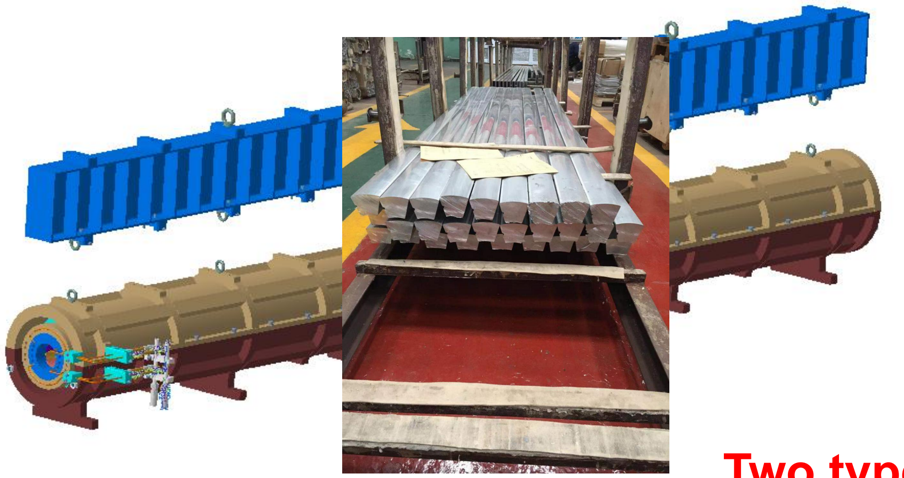


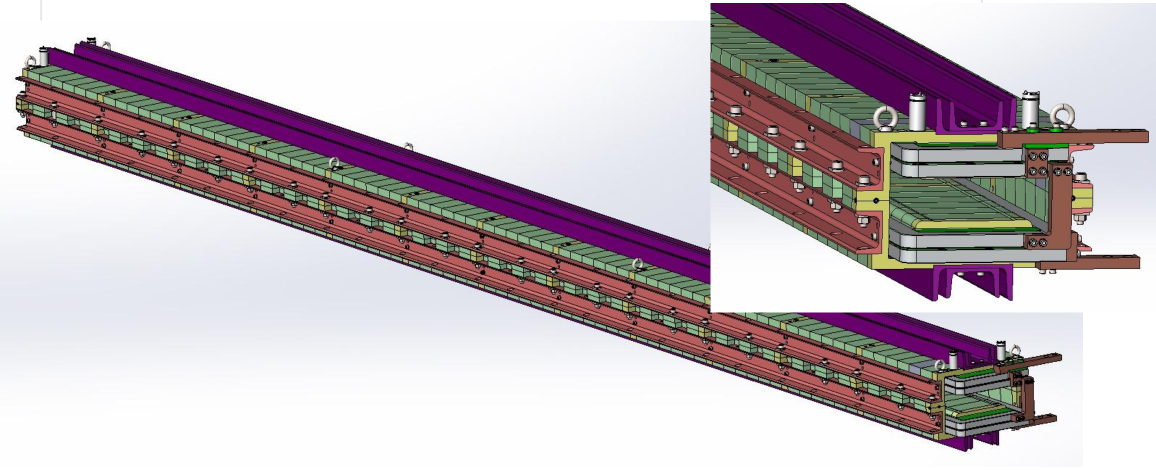
Works for 10GeV injection energy



Works for 20GeV injection energy (New baseline)





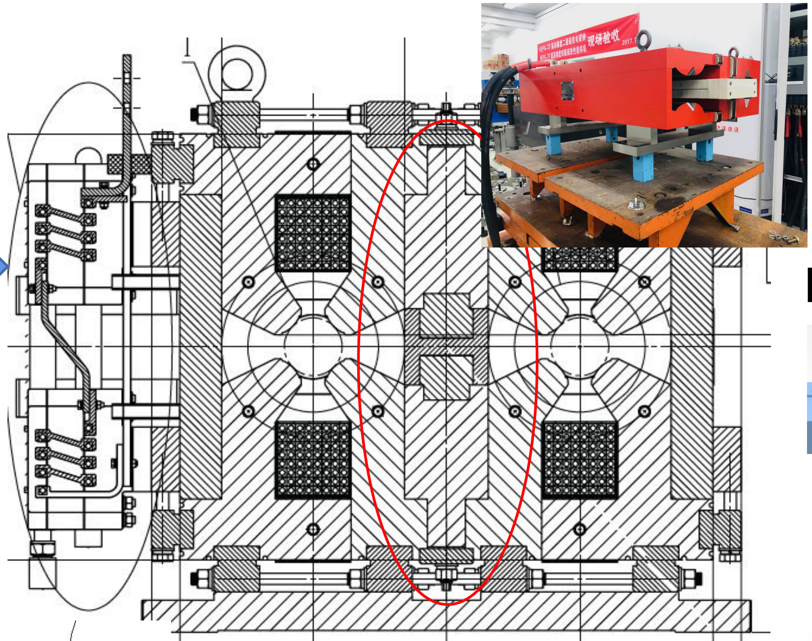


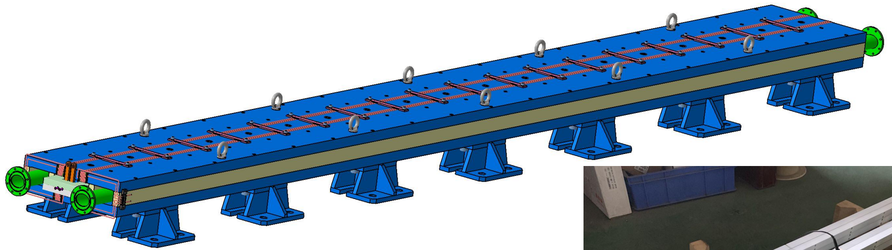
Two types of 5m long full size booster dipoles prototypes in progress

CEPC Collider Ring Magnets

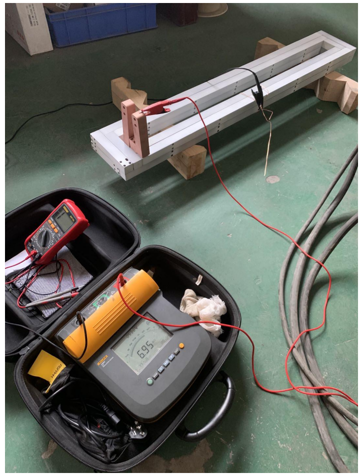
M. Yang

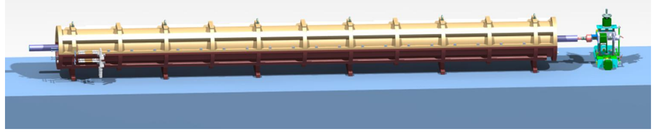
- Modification of the dual aperture quadrupole magnet

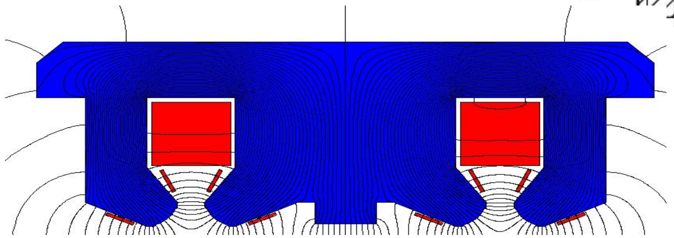




Full size dural aperture dipole

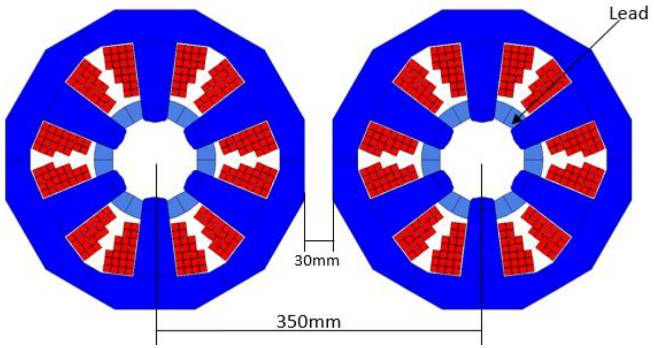


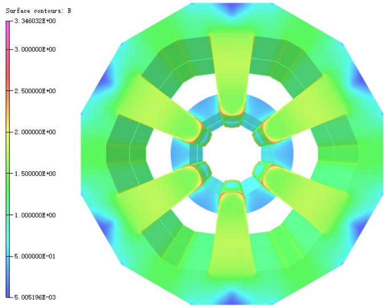




Dural aperture F/D qudrupole design with trim coils

Model experiment verification:
Axis shift problem solved in design





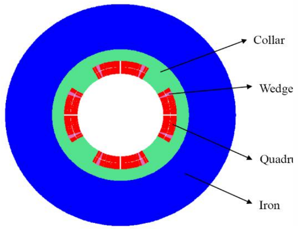
Sextupole design

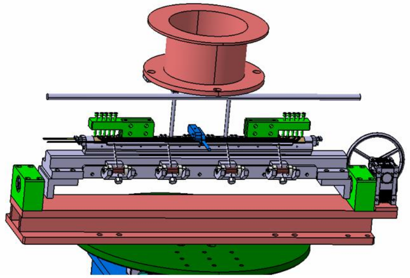
CEPC QD0 SC Magnet R&D (0.5m short model)

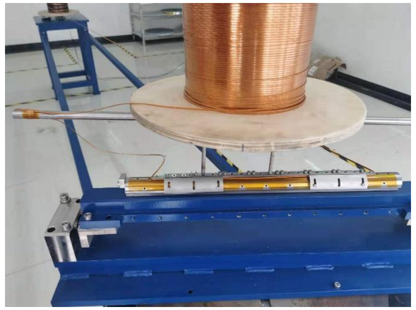
Magnet name	0.5m QD0 model magnet
Field gradient (T/m)	136
Magnetic length (m)	0.5
Coil turns per pole	21
Excitation current (A)	2070
Coil layers	2
Conductor	Rutherford Cable, width 3 mm, mid thickness 0.93 mm, keystone angle 1.9 deg, Cu:Sc=1.3, 12 strands
Stored energy (KJ) (Single aperture)	2.6
Inductance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

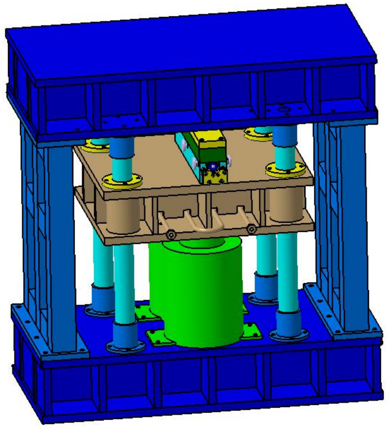
Fabrication of NbTi Rutherford cable is finished (12 strands). SC quadrupole coil winding machine, coil heating and curing system has been finished.







Fabrication of QD0 short model magnet is in progress

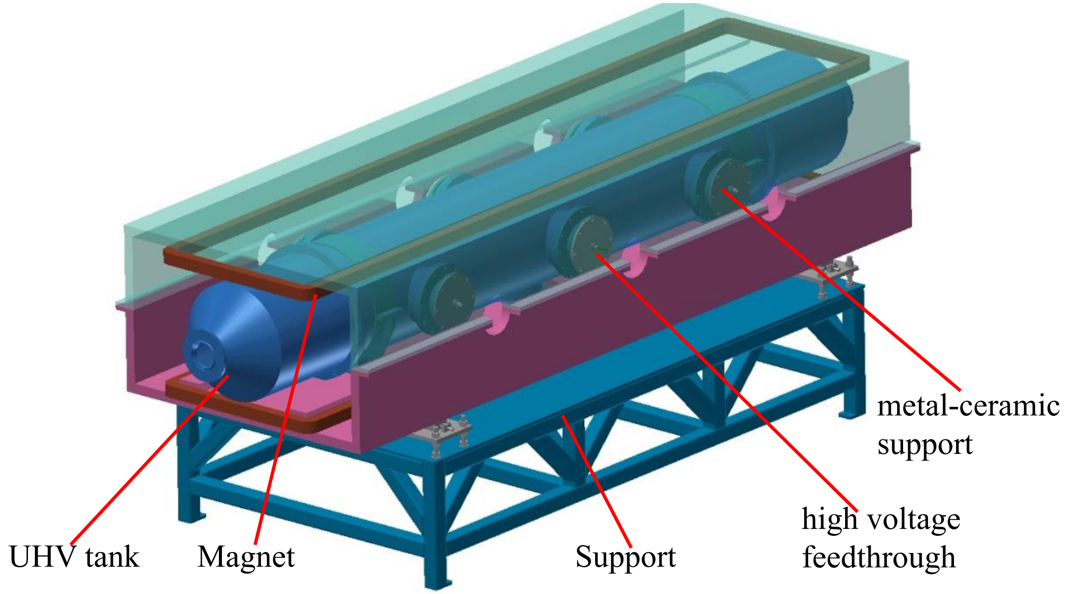


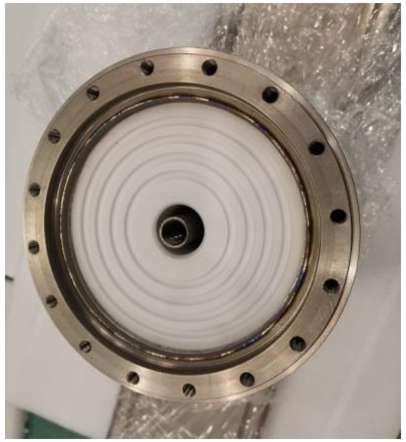
CEPC Electrostatic-Magnetic Deflector

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 x 11mm	5 x 10^{-4}
Dipole	66.7Gauss	4m	46mm x 11mm	5 x 10^{-4}



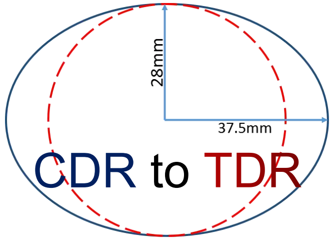


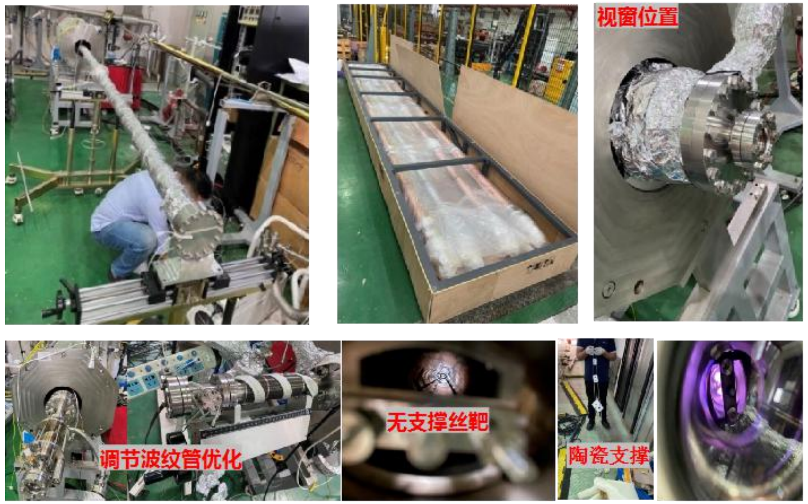
CEPC Vacuum System R&D

Y.S. Ma

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

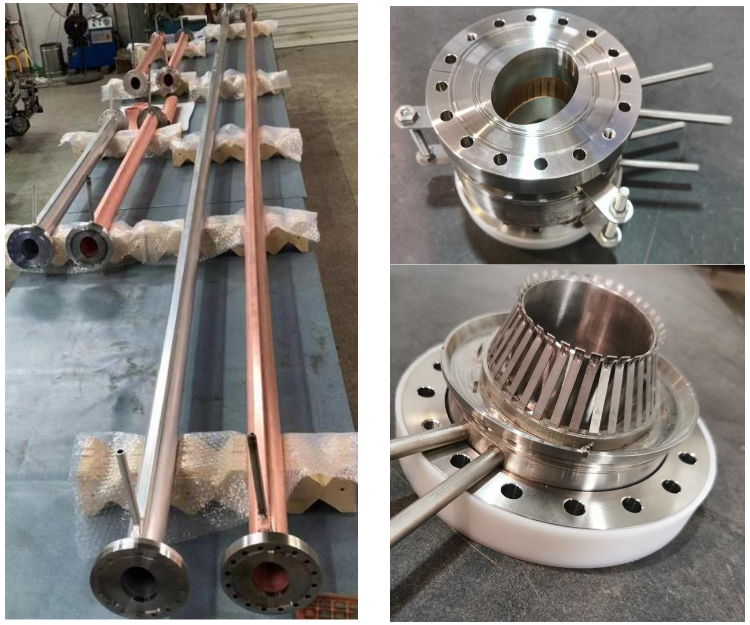
SEY<1.2





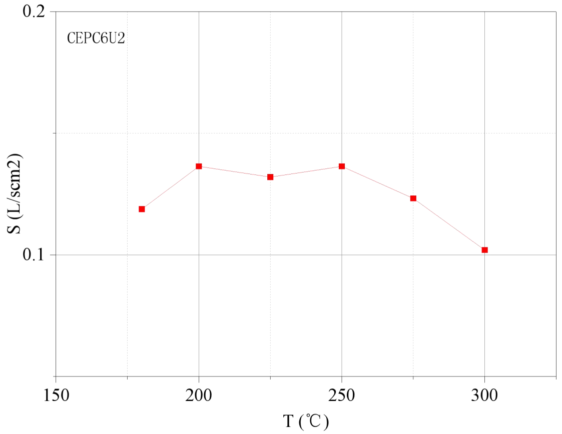
6 m vacuum pipe have been installed on the NEG coating setup

All metal gate valve different from VTA



Vacuum pipes and RF shielding bellows

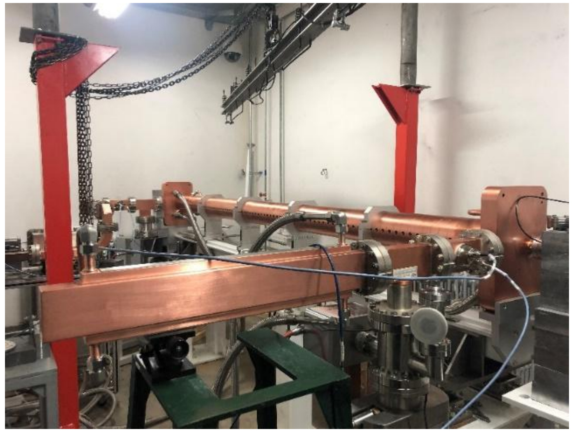
Facility of pumping speed test have been finished in Dongguan



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

CEPC Injector Hardwares' R&D

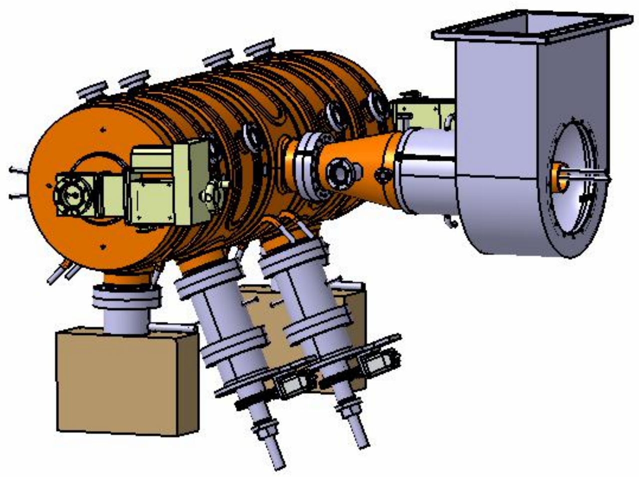
J.R. Zhang



S- band high power test bench
and CEPC S band structure
E=33 MV/m reached

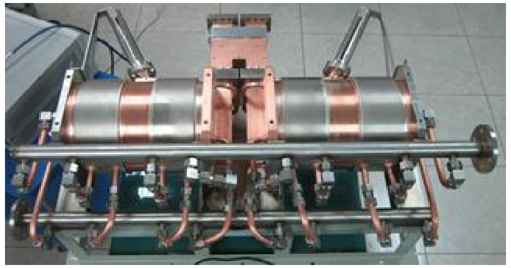
IHEP S band SLED：
Pulse length
4uS→0.8uS

Positron flux concentrator
ulsed magnetic field of
6.2 T reached



IDamping ring 650MHz
RF cavity design

IHEP C band acc. structure V1:
E=40MV/m, V2: E=45MV/m



IHEP C band SLED

Shanghai SXFEL C band
linac, Emax=41.7 MV/m

C band klystron design is starting

CEPC Main Types of Inj.&Ext. Hardwares

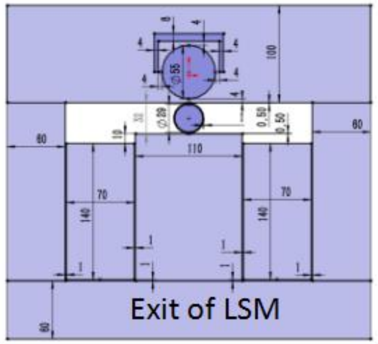
J.H. Chen

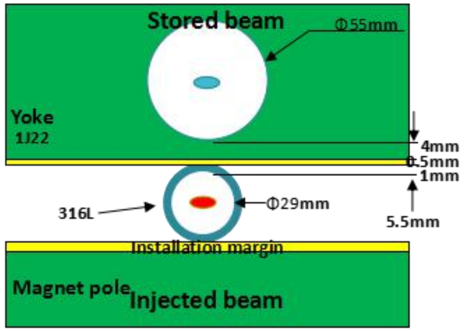
- One team is in charge of both HEPS and CEPC inj. & ext. system
- Some hardware R&D are overlapping

	Sub-system	Kicker Type	Kicker waveform	Septa Type	Thickness of septum
1	Damping ring inj./ext.	Slotted-pipe kicker	Half-sine/250ns	Horizontal LMS	ϕ22/3.5mm
2	Booster LE inj.	Strip-line kicker	Half-sine/50ns	Horizontal LMS	ϕ55/5.5mm
3	Booster ext. for CR off-axis inj.	Delay-line dipole kicker	Trapezoid /440-2420ns	Vertical LMS	Φ55/6mm
4	Collider off-axis inj.	Delay-line NLK kicker	Trapezoid /440-2420ns	Vertical LMS	Φ75x56/2mm
5	Booster ext. for CR on-axis inj.	Ferrite core dipole kicker	Half-sine/1360ns	Vertical LMS	Φ55/6mm
6	Booster HE inj.	NLK or Pulsed sextupole	Half-sine/0.333ms	Vertical LMS	Φ55/6mm
7	Collider swap out inj.	Ferrite core dipole kicker	Half-sine/1360ns	Vertical LMS	Φ75x56/6mm
8	Collider swap out ext.	Ferrite core dipole kicker	Half-sine/1360ns	Vertical LMS	Φ75x56/6mm
9	Collider beam dump	Delay-line dipole kicker	Trapezoid /440-2420ns	Vertical LMS	Φ75x56/6mm
10	RF region beam separating	Delay-line dipole kicker	CW square / 165us,50%	Horizontal Copper septa	Φ75x56/10mm

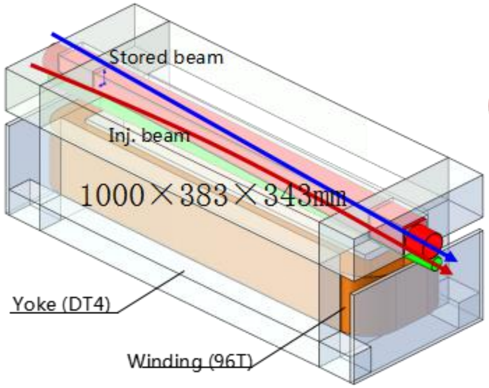
CEPC Inj.&Ext. Hardwares' R&D

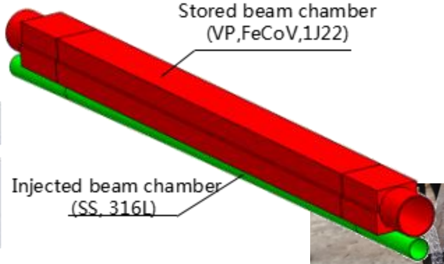
J.H. Chen



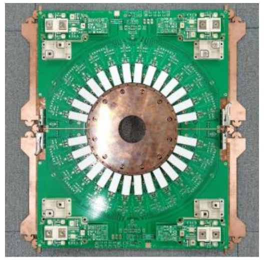


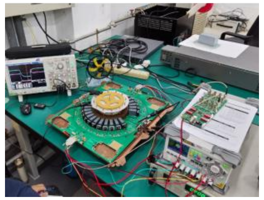
Slotted-pipe kicker



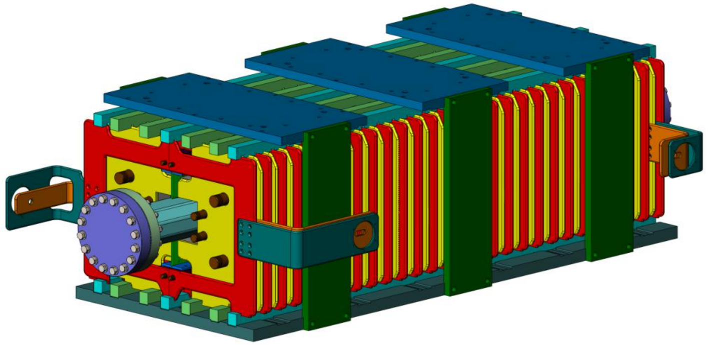


Lambertson magnet





250ns-fast kicker pulser

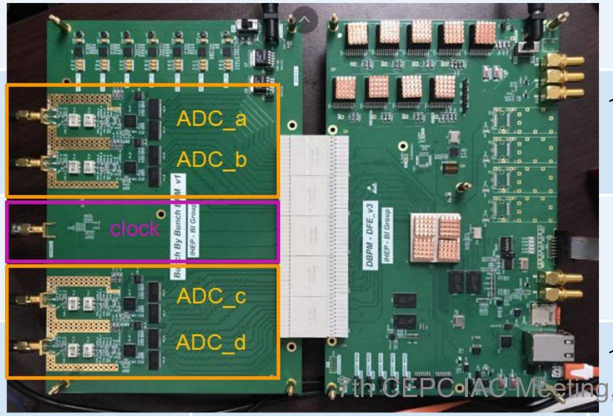


Delay-line dipole kicker

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 interfer Gas jet scann
BI at the interaction point			√	Special beam P
Bunch current monitor				BBB electronics R&D based home-developed and company
Beam loss monitor			√	beam loss detector R&D ; Industrialization



New Alignment Vision Instrument R&D

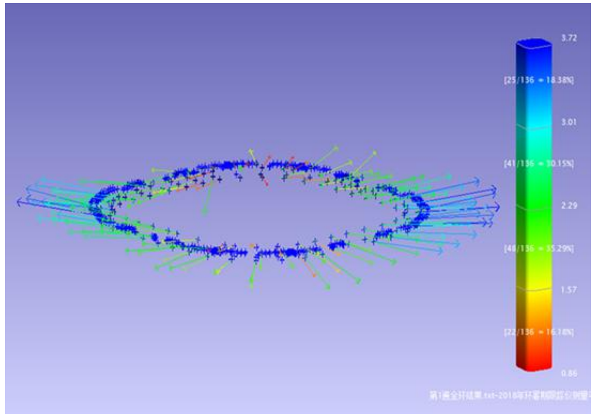
X.L. Wang

The new vision instrument can increase the efficiency by 4 times

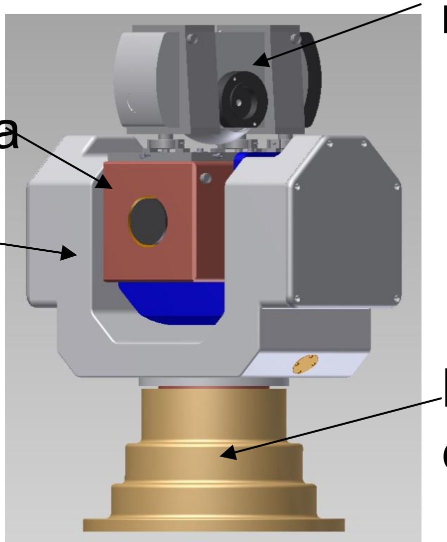
A new kind measurement instrument with three fuctions:

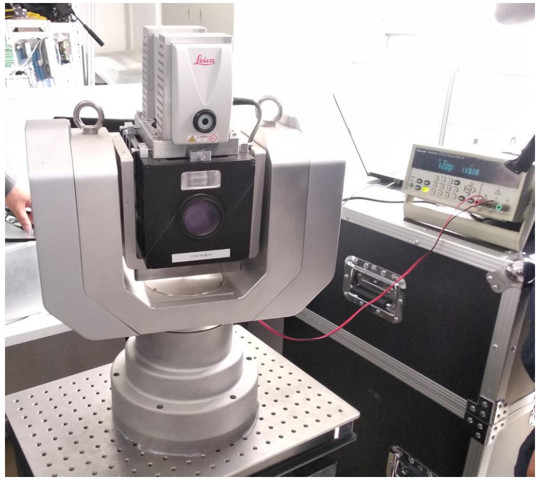
1) photogrammetry, 2) distance, 3) angle measurement functions

- Objective: high precision, high efficiency



Application test in RCS ring of CSNS measurement





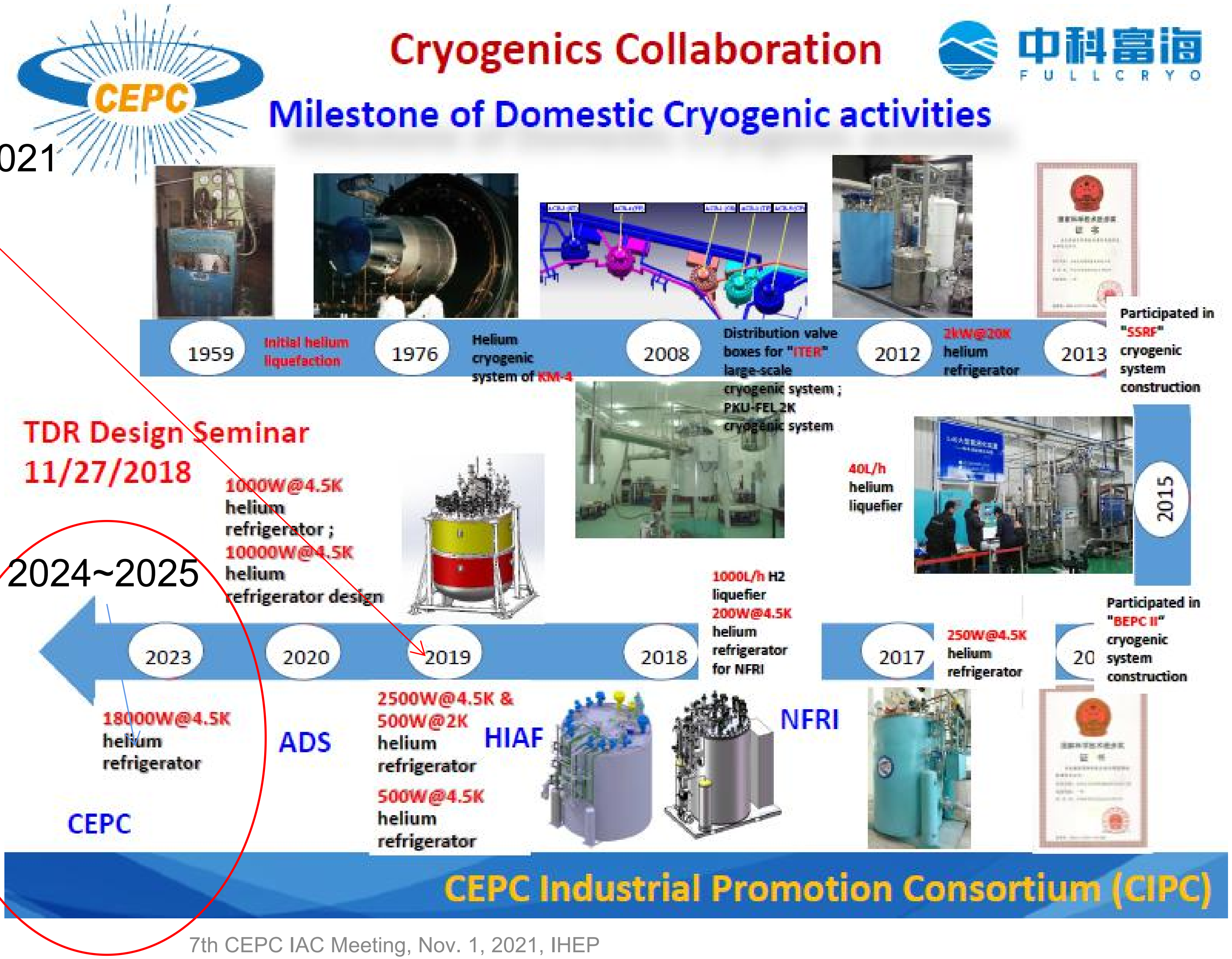
The completed vision instrument

Five-face target R&D

CEPC 18kW@4.5K Cryogenic Plant R&D

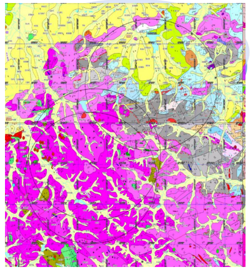
M. Li

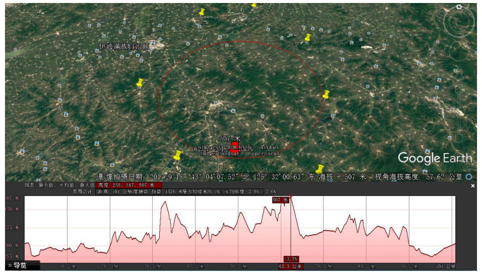
2.5kW@4.5K Cryogenic Plant successfully completed on April 7, 2021



CEPC Siting, Civil Engineering, Alignment and Installation Strategies

CEPC Siting Status

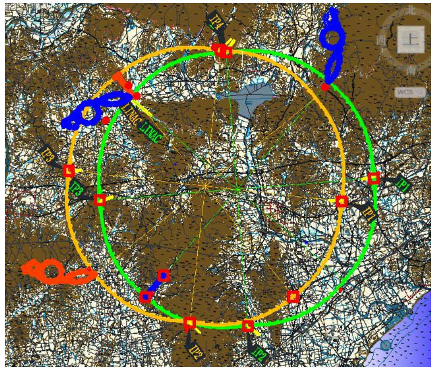




5

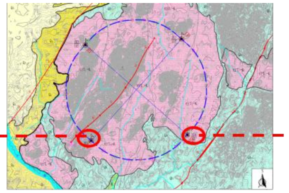
Three companies are working on siting and issues

1



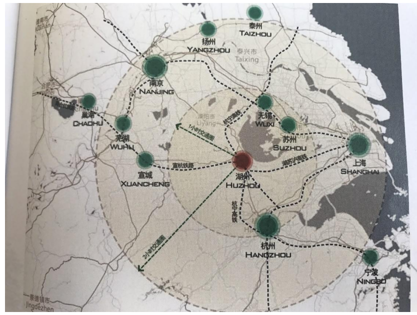
2019.12月8-11 and 2020.1.8-10 Chuangchun sitings update

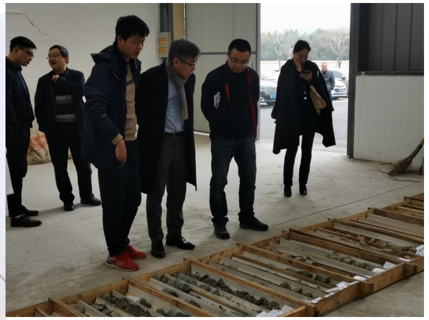
2020.9.14-18 Qinhuangdao updated



In 2021,Changsha site has some progress with local government starting a review process

4





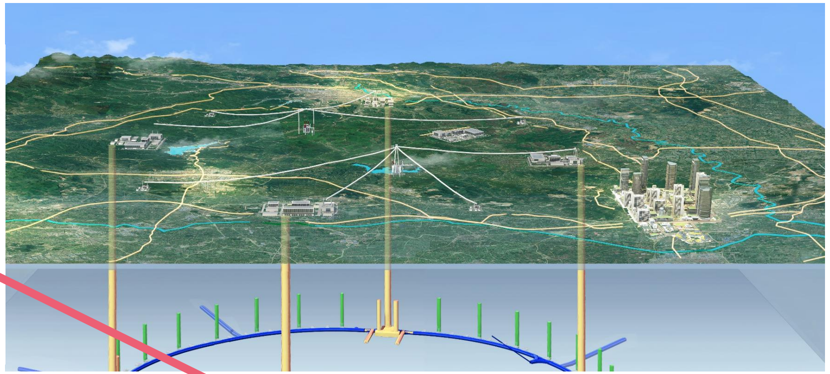
2019.12.16-17 Huzhou siting update

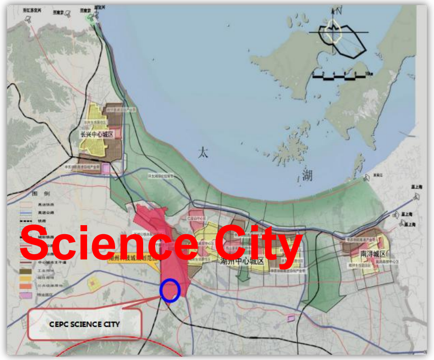
6

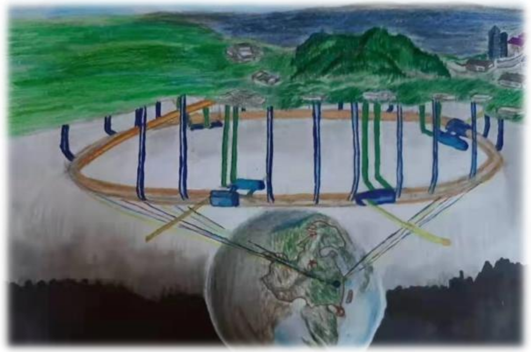
1) Qinhuangdao, Hebei Province (Completed in 2014)
2) Huangling, Shanxi Province (Completed in 2017)
3) Shenshan, Guangdong Province(Completed in 2016)
4) Huzhou, Zhejiang Province (Started in March 2018)
5) Chuangchun, Jilin Province (Started in May 2018)
6) Changsha, Hunan Province (Started in Dec.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

2019.08.19-20 Changsha siting update

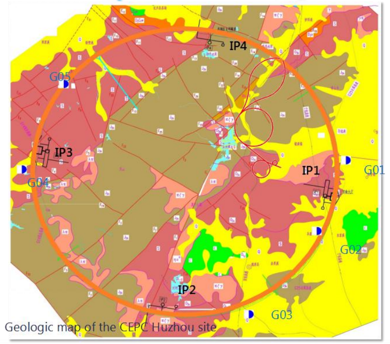
CEPC Siting and Civil Enegineering Progress

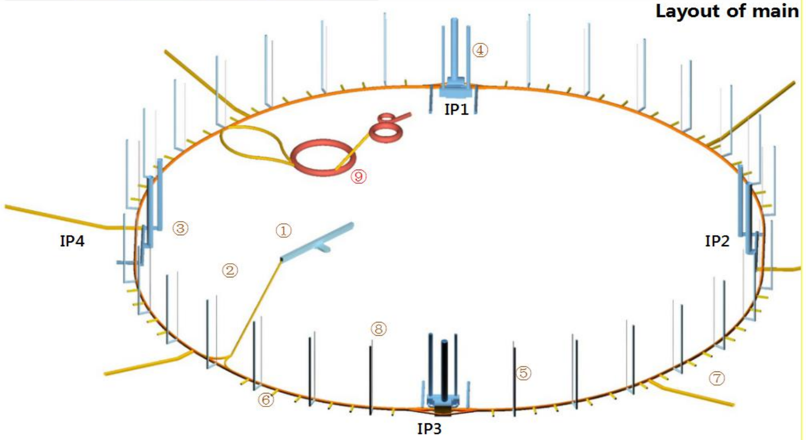




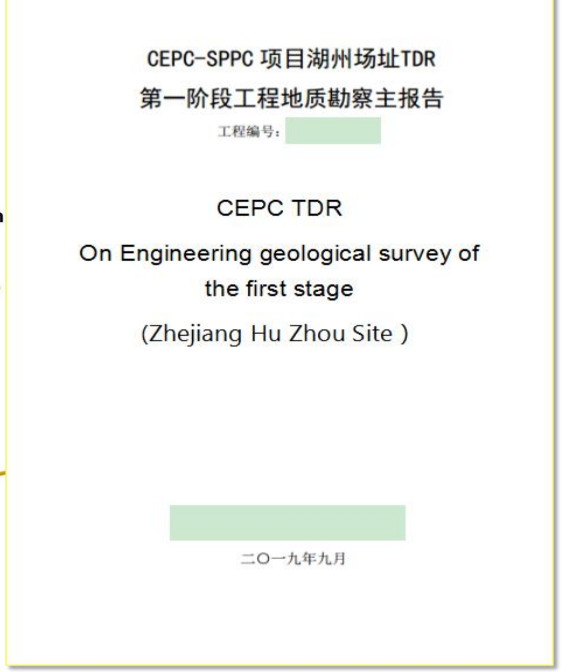


Huadong Company K. Huang





Huzhou site （example）



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

The work that has been done is as follows

- **CEPC report on site selection (Zhejiang Huzhou)**

Answer the questions-Why did CEPC choose huzhou

- **CEPC report on socio-economic assessment**

Answer the questions-Why did huzhou choose CEPC

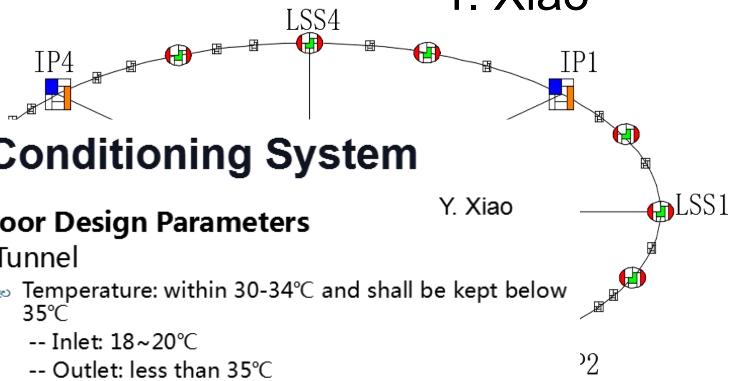
- **CEPC Technology Design Report on Civil engineering of the first stage**

- **CEPC report on science city concept plan**

Find a comfortable home for scientists

CEPC Auxiliary Facilities

Y. Xiao



Electric power demand

Total: 270.37MW

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

Heating Ventilation Air Conditioning System

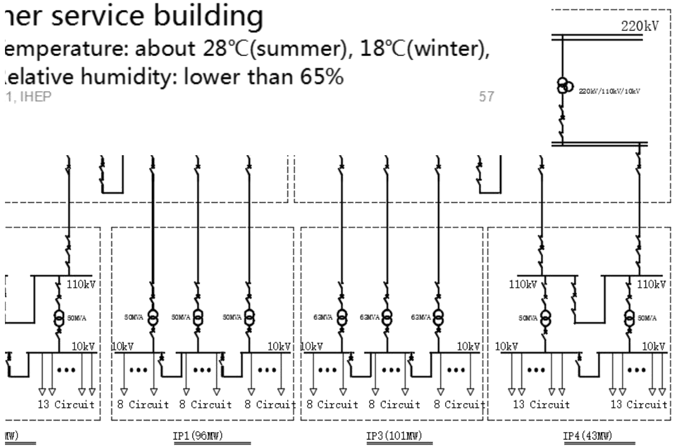
Y. Xiao

- **Estimated cooling loads of HVAC**
  - Ring tunnel: **6MW**
  - Service buildings: (200W/m²) 28MW

  Total: **34MW**
- **Coolant for air conditioning: chilled water**
- **Heat source for heating system in winter**
  - Heat pump -- heat recover from cooling

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

1, IHEP 57



Cooling Wa

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

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

Energy Saving Consideration (Green CEPC)

Y. Xiao

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

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

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

Civil Construction and Machine Installations

Huzhou site example

Huadong Company

Schedule analysis of CEPC construction

Overlap

2026 2027 2028 2029 2030 2031 2032 2033

① ② ③ ④ ⑤ ⑥ ⑦ ⑧

51 months (including project preparation) 2026.1~2030.3 TBM excavation

Total duration of CEPC project is 96 months

63 months 2026.1~2031.3 Drilling & Blasting excavation

2030.1~2030.12 First-stage Control network construction and survey 12months

2030.10~2031.9 Second-stage Control network construction and survey 12months

2031.1~2032.6 Support installation and alignment 18 months

2031.3~2032.8 Dipole magnets installation 18 months

26032.9~2033. Installation of other equipment 10 months

2033.7~ 2033.12 Overall alignment and commissioning 6 months

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

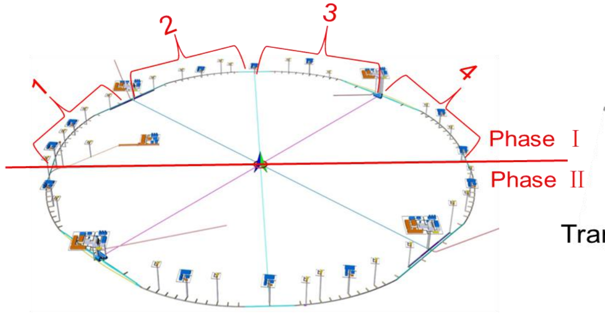
2.The total civil works period is 63 months.

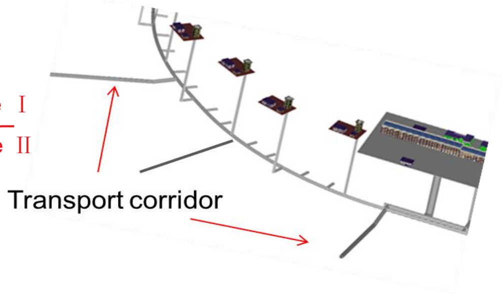
3.The total installation period of physical equipment is 48 months

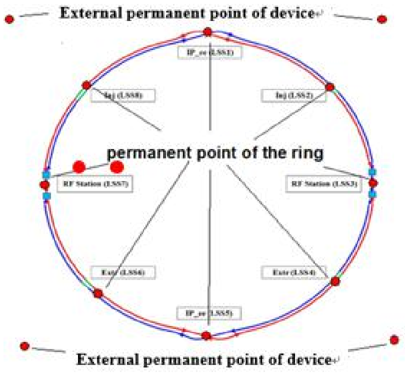
4. The Overlapping period of civil works and equipment installation is 15 months

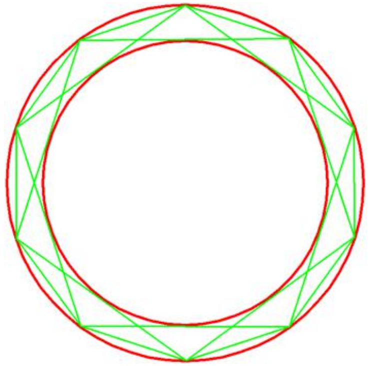
CEPC Installation and Alignment Strategies

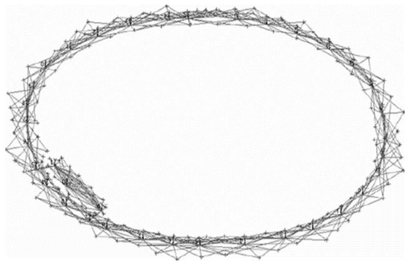
X.L. Wang



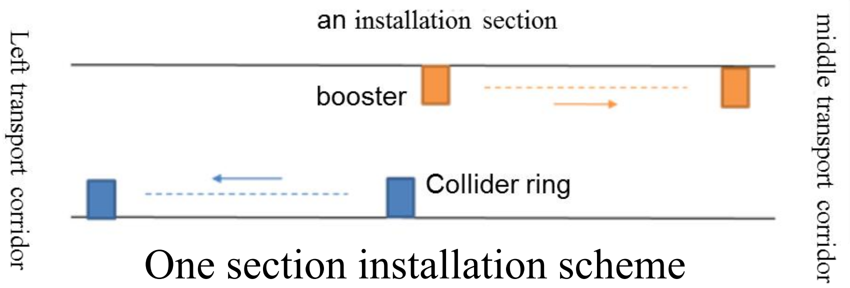








- CEPC civil construction will be divided into **two phases**, so the installation will follow it and include two phases
- In each phase the installation will be divided into **four sections** to be carried out in parallel

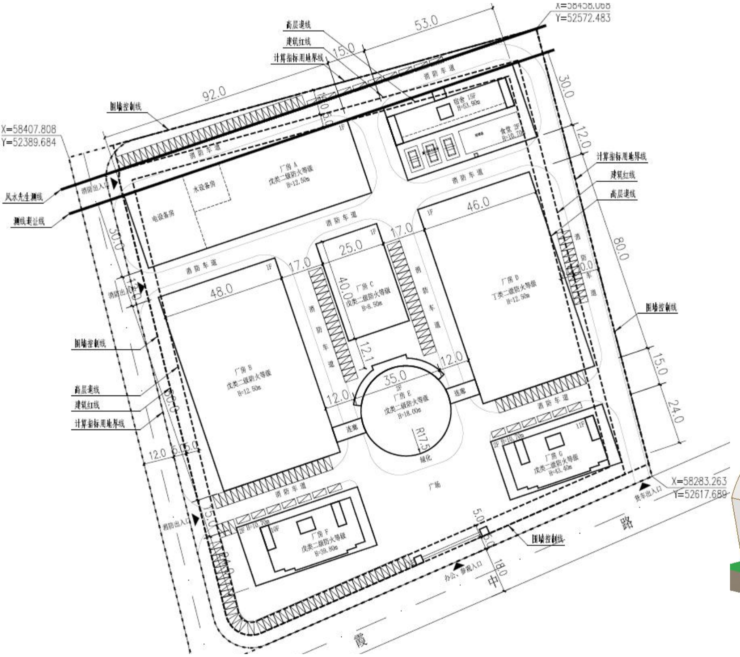


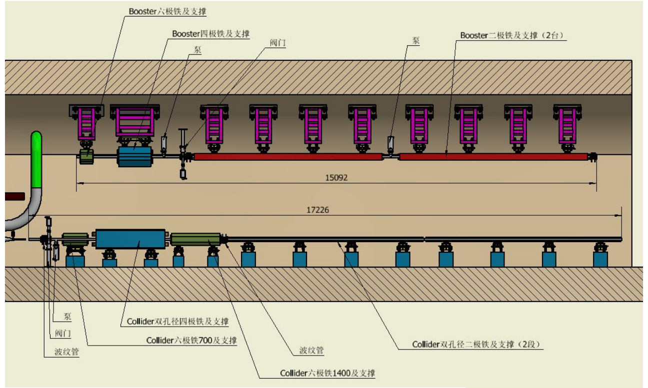
One section installation scheme

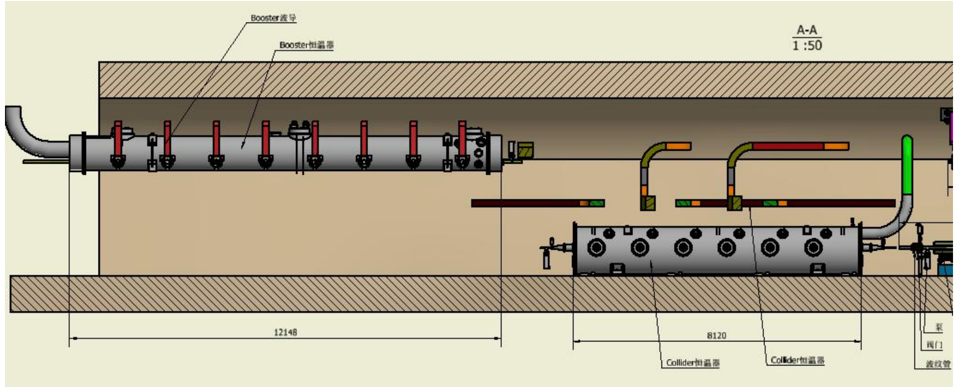
- 3 levels control network will be build to provide an unified location reference frame for CEPC alignment and control the error accumulation
- Component quantities：**41563**
- In the peak time, it will need **64** alignment groups and **56** installation groups
- Installation efficiency of each day has been estimated and the installation schedule has been made. According to the plan, the total installation time is **3 years and 8 months (44 months)**

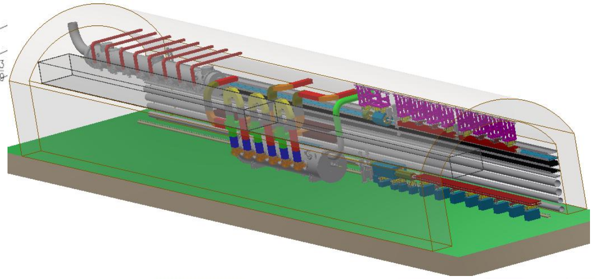
CEPC Tunnel Mockup Design

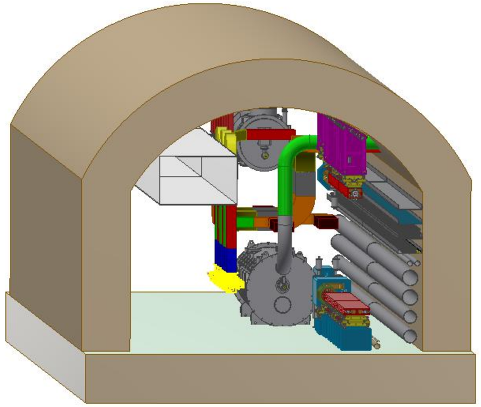
H.J. Wang

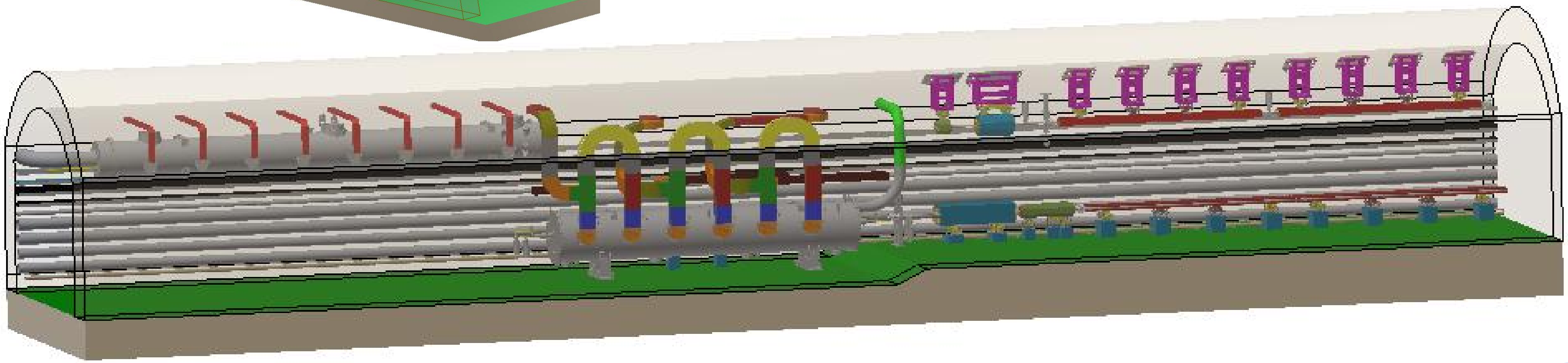








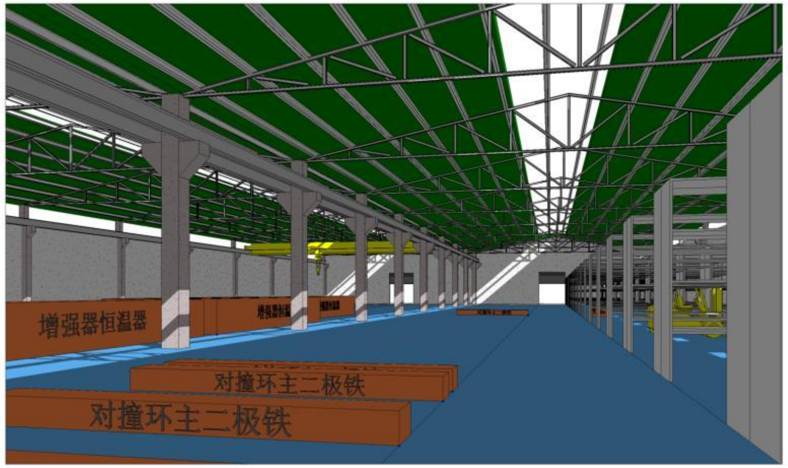


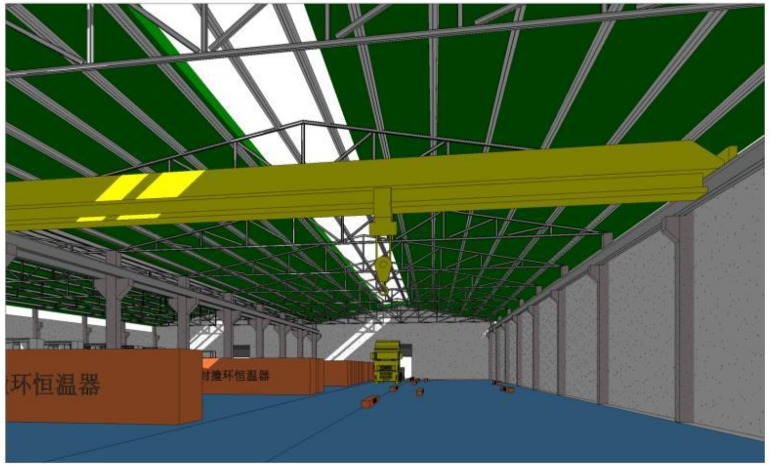


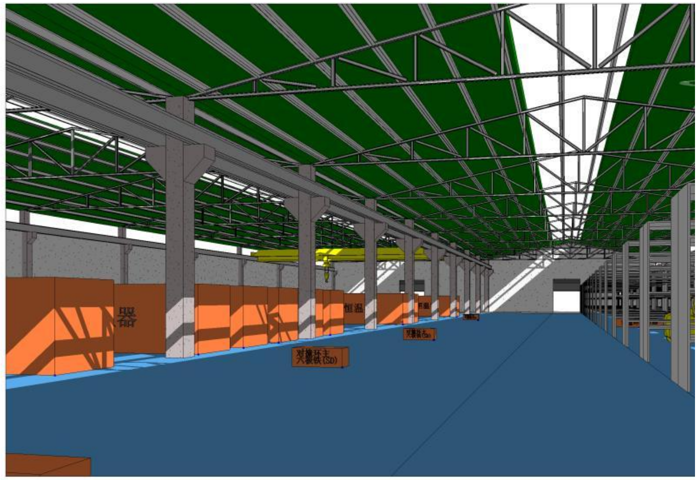
40 meters long

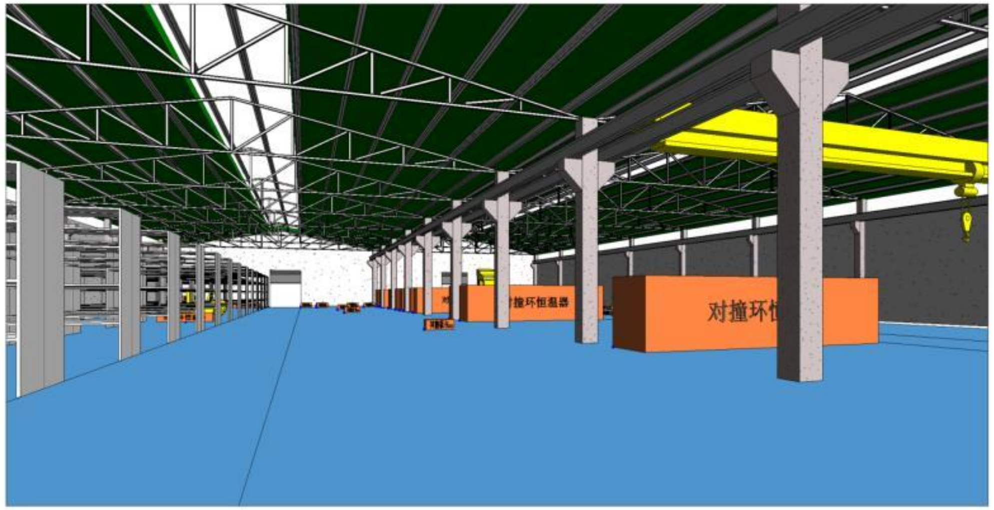
CEPC Component Stores for Installation Optimization

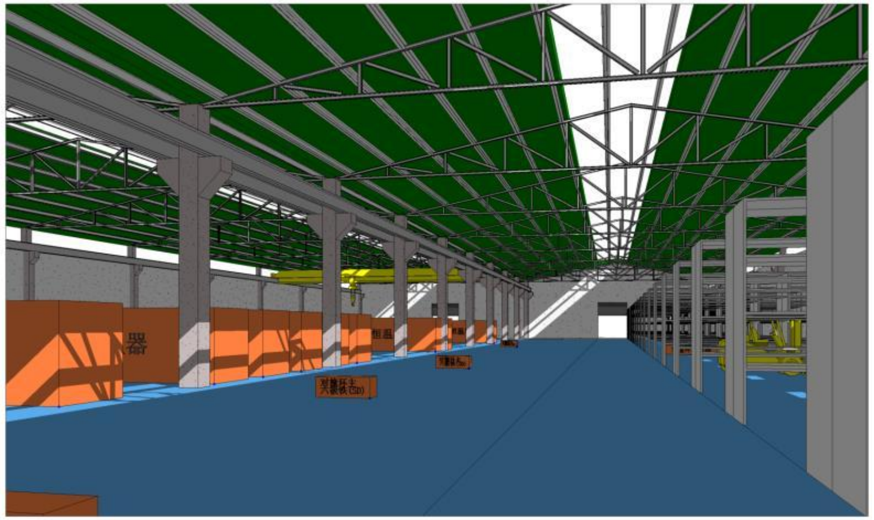
J.B. Wang





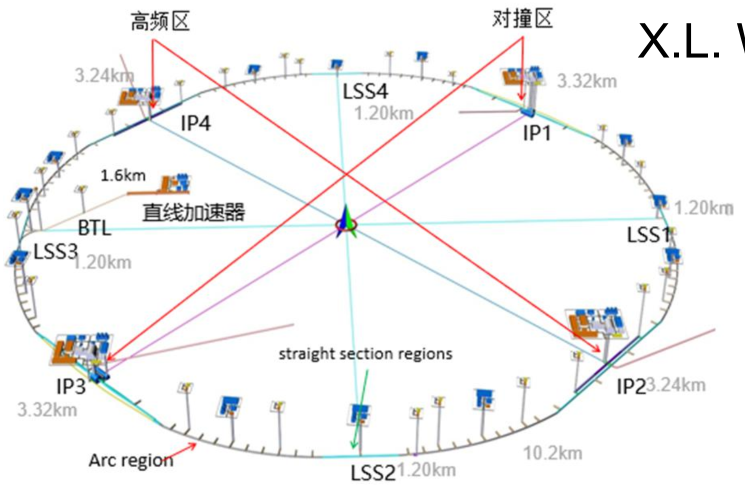






CEPC Accelerator Installation and Alignment

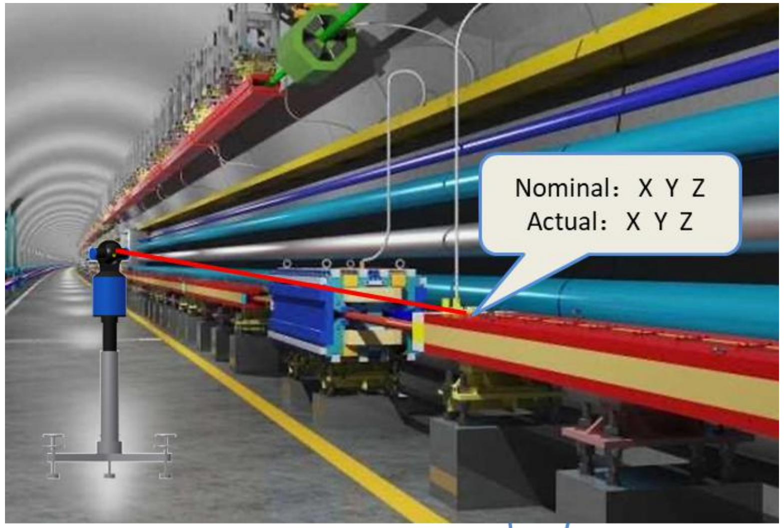
Component	Transversal/mm	Vertical/mm	Longitudinal/mm	Pitch /mrad	Yaw /mrad	Roll /mrad
Arc Dipole	0.1	0.1	0.1	0.1	0.1	0.1
Arc Quadrupole	0.1	0.1	0.1	0.1	0.1	0.1
Arc Sextupole	0.1	0.1	0.1	0.1	0.1	0.1
IR Quadrupole	0.05	0.05	0.05	0.05	0.05	0.05
IR SCQ	0.05	0.05	0.05	0.05	0.05	0.05
IR Sextupole	0.05	0.05	0.05	0.05	0.05	0.05



X.L. Wang

Workload of CEPC alignment

- Tunnel length 109.55km：100.034km main ring + 6.64kmIR booster tunnel + 1.21km Linac + 0.06km DR+ 1.07km BT + 2X0.268km BT
- Component quantities：41563～52155
- Use laser tracker 18259 X2=36518 stations.



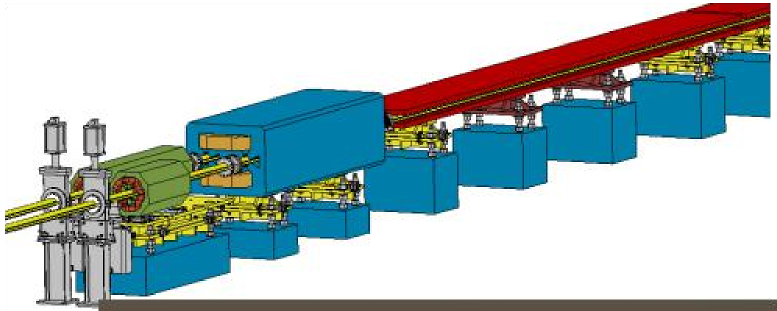
Ring tunnel

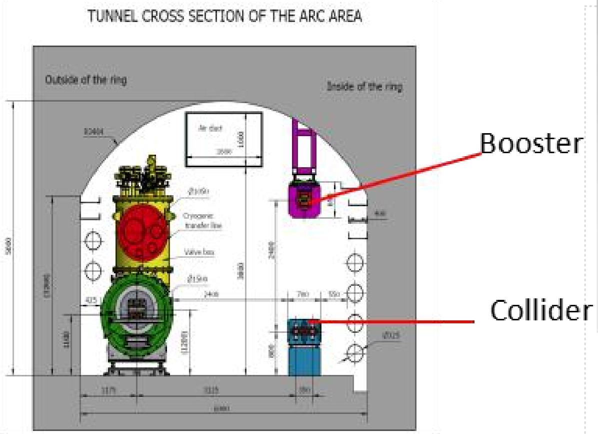
CEPC Accelerator Mechanical Supports and Installation Tools

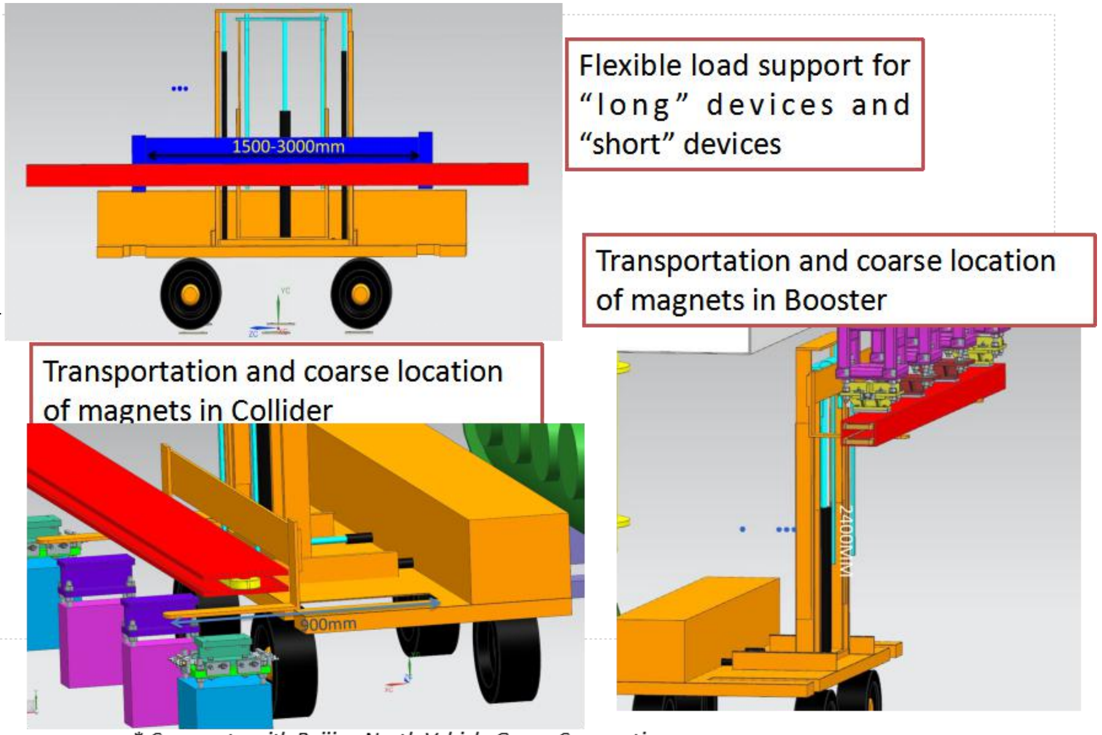
H.J. Wang

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

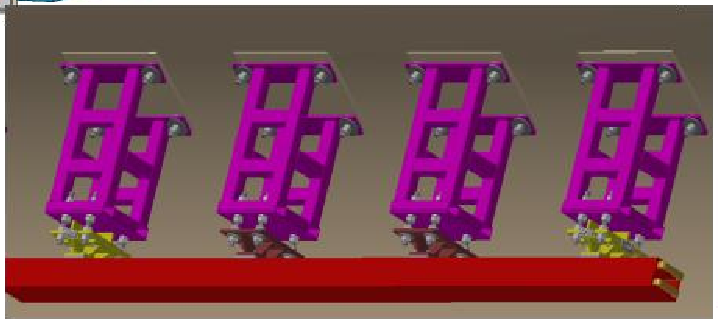
Adjustment Ranges of magnets			
X	≥±20 mm	Δθx	≥±10 mrad
Y	≥±30 mm	Δθy	≥±10 mrad
Z	≥±20 mm	Δθz	≥±10 mrad

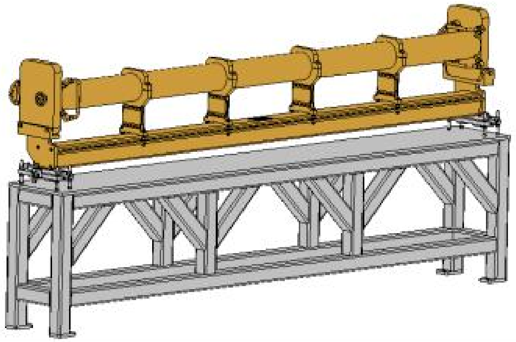






* Cooperate with Beijing North Vehicle Group Corporation.



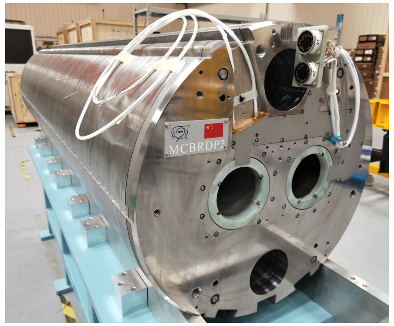


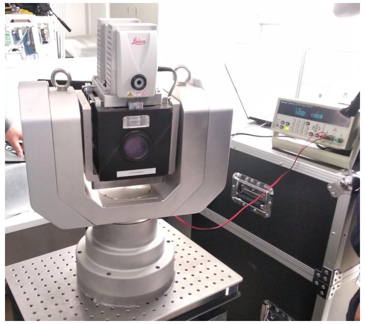
CEPC CIPC and International Collaborations

CEPC-CIPC Collaboration (part of CIPC members' logo)



CEPC 650MHz klystron at Kunshan Company

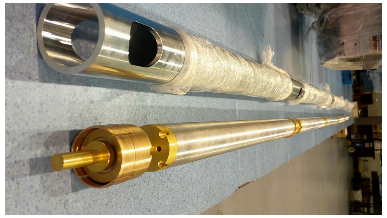




CERN LHC-HL CCT SC magnet

CEPC SC QD0 coil winding at KEYE Company

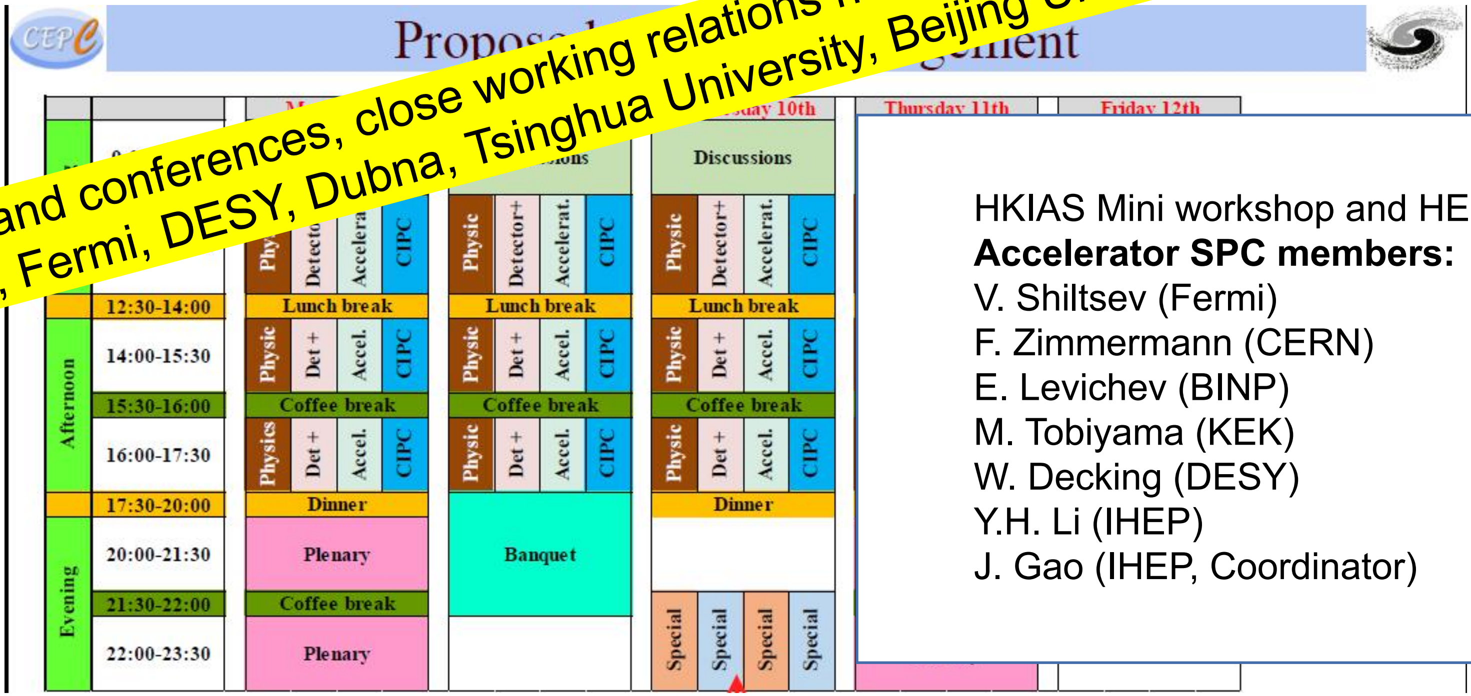
CEPC Detector SC coil winding tools at KEYE Company (Diameter ~7m)



CEPC long magnet measurement coil

International Meetings and Collaborations

- The 2021 International Workshop on the High Energy Circular Electron-Positron Collider (CEPC) will take place from November 8-12, 2021 (https://indico.ihep.ac.cn/event/14938/)(Online only)
- 2022 HKUST IAS Mini Workshop on Accelerator, “**Key beam physics and technologies issues for colliders**", Jan. 13-14, 2022 (Online only)
- 2022 HKUST IASHEP Conference (without parallel sessions), Jan. 17 ... only)



Through these workshops and conferences, close working relations have been kept with KEK, CERN, BINP, INFN, IJClab, Fermi, DESY, Dubna, Tsinghua University, Beijing University, etal...

HKIAS Mini workshop and HEP Conference
Accelerator SPC members:
V. Shiltsev (Fermi)
F. Zimmermann (CERN)
E. Levichev (BINP)
M. Tobiyama (KEK)
W. Decking (DESY)
Y.H. Li (IHEP)
J. Gao (IHEP, Coordinator)

CEPC submissions to Snowmass21

CEPC Input to the ESPP 2018

-Accelerator

CEPC Accelerator Study Group

Executive summary

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

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

CEPC -Accelerator Technologies to Snowmass2021 AF7

CEPC Accelerator Study Group

CEPC LOI to Snowmass21

Executive summary

The discovery of the Higgs boson at CERN's Large Hadron Collider (LHC) ... 2012 raised new opportunities for a large-scale accelerator. Due to the ... Higgs, it is possible to produce it in the relatively clean env... electron–positron collider with reasonable lumin... power consumption. The Higgs boson is a crucial cornerston... It is at the center of some of its biggest mysteries, such ... the weak scale and the Planck scale, the nature of the el... and many other related questions. Precise measure... Higgs boson serve as excellent tests of the underlying ... of the SM, and they are instrumental in explorations beyond the ... 2012, Chinese scientists proposed a 240 GeV *Circular Electron Positron* ... (CEPC), serving two large detectors for Higgs studies. The tunnel for such a machine could also host a *Super Proton Proton Collider* (SPPC) to reach energies beyond the LHC. The CEPC Preliminary Conceptual Design Report (Pre-CDR, the *White Report*)[1]was published in March 2015, followed by a Progress Report (the *Yellow Report*)[2] in April 2017, where CEPC accelerator baseline choice was made. The Conceptual Design Report (CEPC Accelerator CDR, the *Blue Report*) [3] has been publically realsed in Nov. 2018, and also submitted to European High Energy Strategy in May, 2019 [4].

CEPC Accelerator will continue to participate US Snowmass21 and P5 HEP scientific process and make contribution

LOI includes SppC and siting

Technologies

Collider Design
SCRF
Klystron
Linac+plasma
accelerator injector
Cost

CEPC Time Plan and Perspective for Accelerator TDR and EDR Plans

Perspective for Accelerator TDR and EDR Plans

- **CEPC Accelerator TDR completion time: Dec. 2022**
  - -Consistent TDR high luminosity parameter design as Higgs factory
  - -Key components with prototyping, techincal feasibility demonstrated, no technical show stopper
  - -Design and R&D technical documentation (Data, drawings, etc.)
  - -CEPC accelerator TDR document release in 2023

- **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

-EDR document completed for government's approval of starting construction in 2026 (the starting of the "15th five year plan")

-... (CEPC accelerator EDR phase plan needs more discussions)

Summary

- CEPC accelerator system optimization designs based on TDR high luminosity parameters is progressing and converging

- CEPC accelerator system key hardware R&D is progressing with the aim of finishing TDR at the end of 2022

- CEPC siting, civil engeering, auxiliary facilities, installation plan, international and CIPC collaborations are progressing

- More efforts are needed to the TDR completion goal at the end of 2022 and EDR preparation plan between 2023-2025 before the starting of CEPC construction has been birefly discussed

Acknowledgements

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

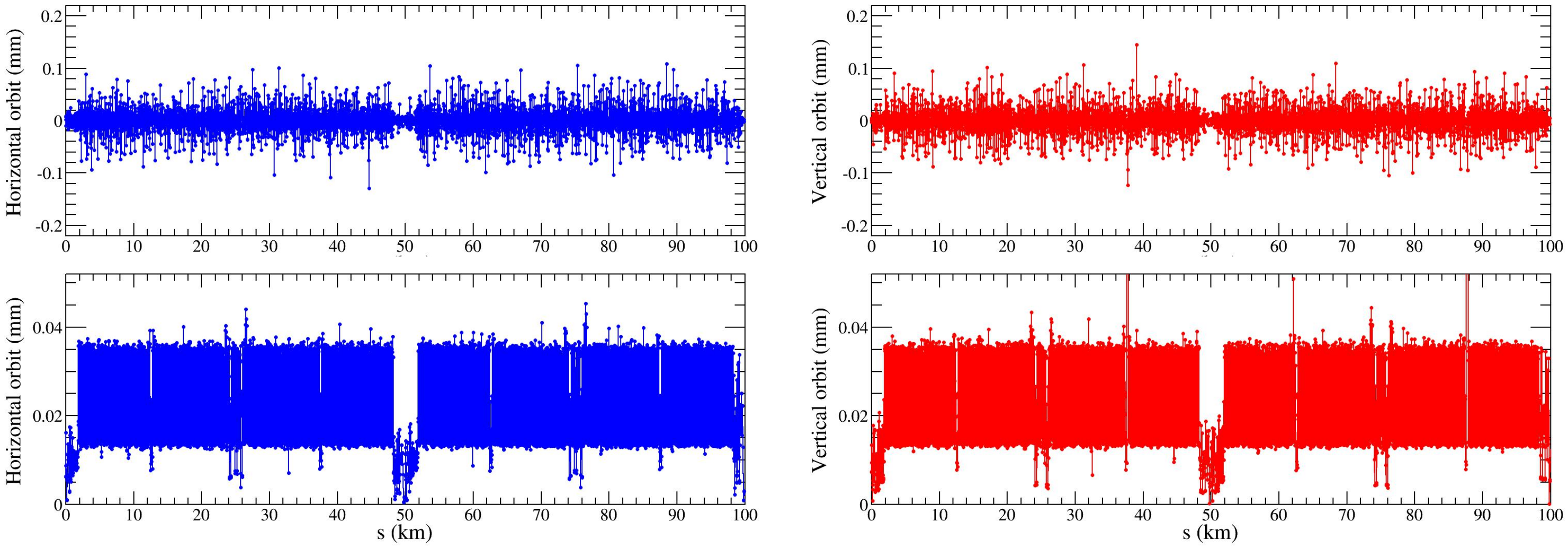
- Special thanks to CEPC SC, IAC and IARC's critical comments, suggestions and encouragement

Backup

CEPC Collider Ring COD Corrections

Y.W. Wang
B. Wang

- A new corrector setting is necessary for the more limited lattice.
- BPMs placed at quadrupoles (~1800, 4 per betatron wave) Horizontal correctors placed beside focusing quadrupoles (~1800)
- Vertical correctors placed beside defocusing quadrupoles (~1800)
- Orbit correction is applied using orbit response matrix and SVD method.



The close orbit correction and dispersion correction are finished, the passing rates and the correction effect are comparable to those for CDR lattice.

$\mathbf{RMS_{COD} < 0.05\ mm}$

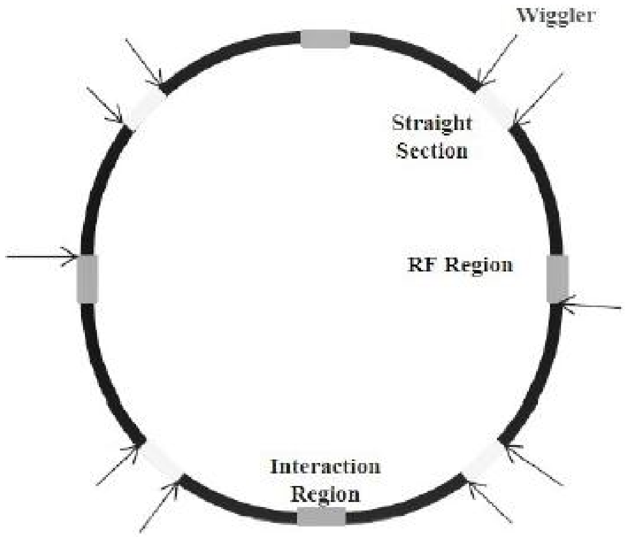
CEPC self-polarization at Z pole

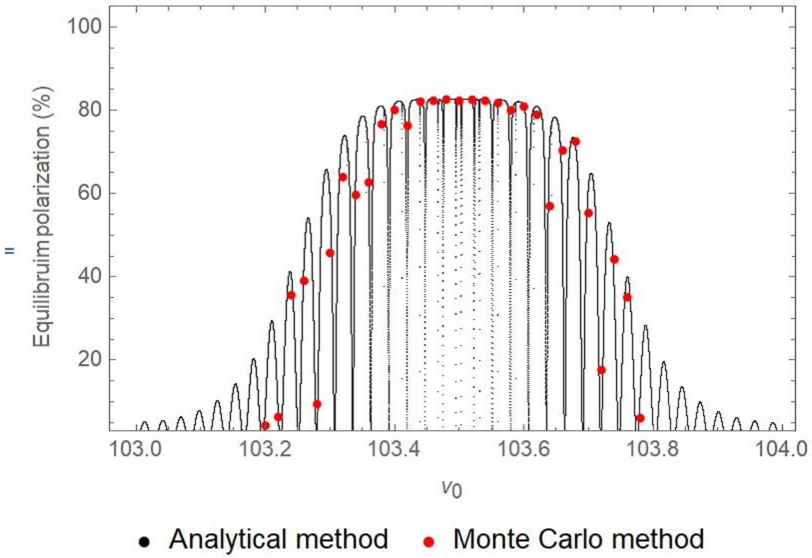
- Self-polarization with wigglers at Z pole：

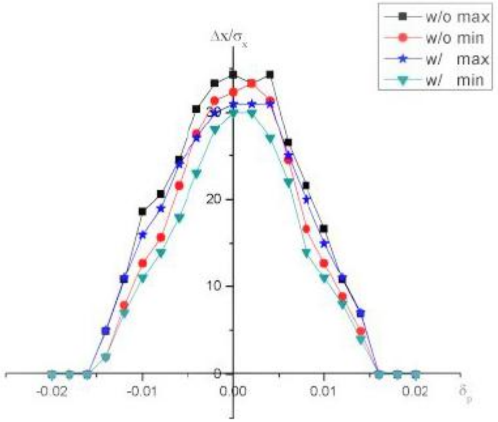
Z. Duan
W.H. Xia

  - 10 identical wigglers are inserted in the collider ring to speed up the self-polarization progress;
  - 5% transverse polarization can be obtained within 1.8 hours

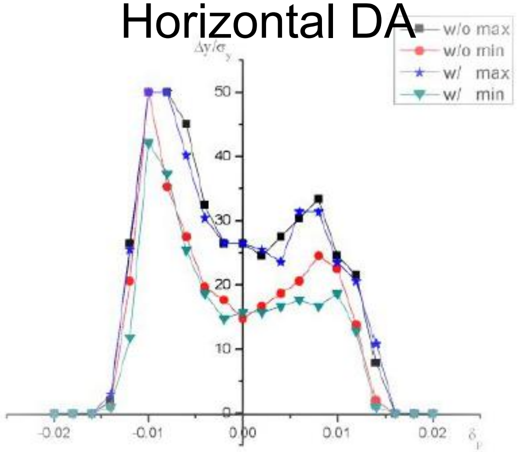
wigglers	B_+ [T]	L_+ [m]	B_- [T]	L_- [m]	U_0 [MeV]	$\Delta E/E$	τ_p [hours]	$\tau_{5\%}$ [hours]
w/	0.5	1	0.125	2	43.9	9.53×10^{-4}	32.3	1.80
w/o	-	-	-	-	36.1	3.76×10^{-4}	252.8	14.1







Horizontal DA

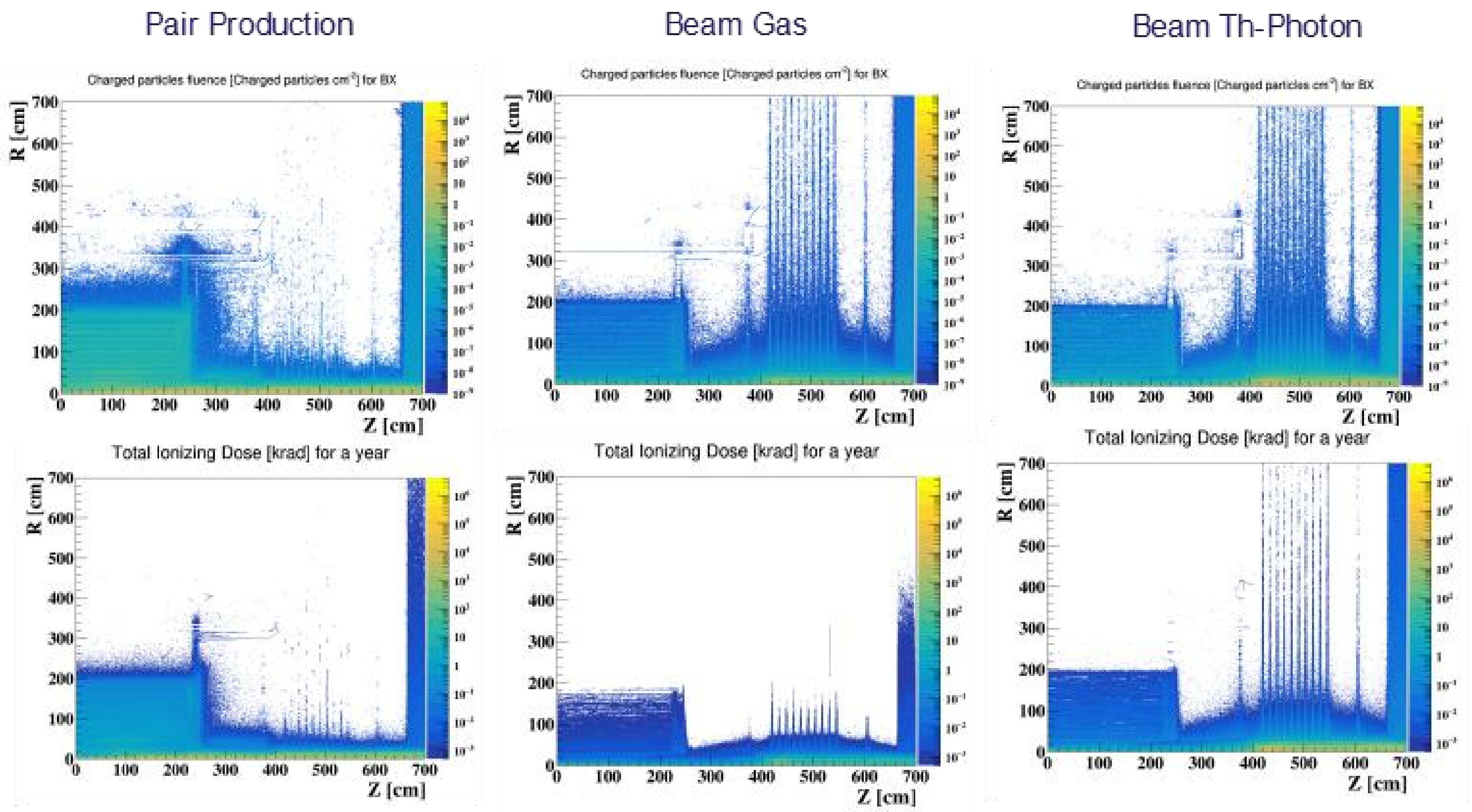


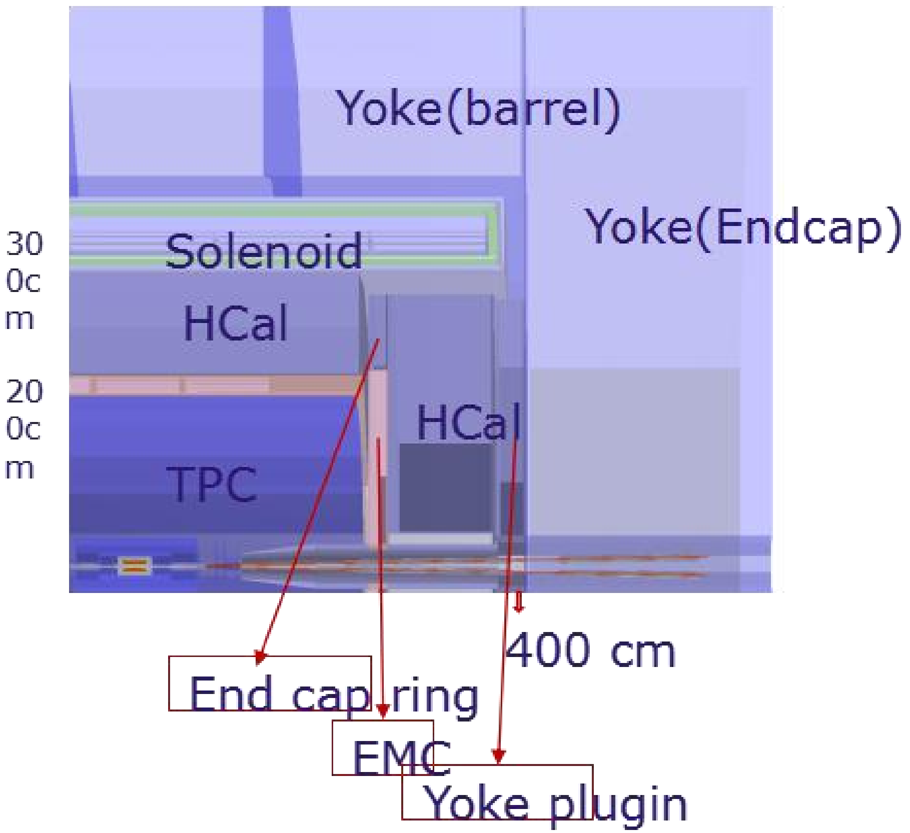
Vertical DA

DA is almost unaffected by the wigglers.

CEPC Full Detector Simulations

H.J. Shi





- The full detector simulation on Higgs Mode based on original CDR design & parameter has been performed
  - 28mm Be beam pipe
- The impact on detector due to bkg could reach EMC or more
- Pair Production contributes most, bth and bgb are at same level, lower than pair production

CEPC MDI Study Status

H.Y. Shi

Accelerator

IP Feedback	Not Covered
BG Simulation	Doing
LumiCal	Doing
HOM absorber	Considering
Vacuum Chamber	Done
SR Masks	Done
QD0/QF1	Doing
Anti-Solenoid	Doing
Cryostats	Doing
BPMs	Doing
Instability&Impendance	Done
Cooling	Done
Shielding	Doing
Assembly&Supporting	Doing
Alignment	Doing
Connecting System	?
Vacuum pumps	Doing
Last Bending Magnet	Done
Collimators	Doing

Detector

Central Beam Pipe	Done
Vertex Detector	Doing
LumiCal	Doing
Silicon Tracker	Doing
TPC	Doing
Hcal	Doing
Ecal	Doing
Solenoid	Doing, strength Fixed
Yoke	Doing
Muon Detector	Doing
Hall	?
BG Simulation&Shielding	Doing
Software Geometry	Done, check needed
Alignment&Assembly	Doing
Electronics	?
Cryogenic	?
Radiation Protection	Not Covered

CEPC Project Timeline