CEPC Machine

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On behalf of CEPC Accelerator Team

Institute of High Energy Physics
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Higgs Hunting 2018, July 23-25, 2018,
Auditorium P.Lehmann & G.Charpak (LAL Orsay & LPNHE Paris), France

Contents

CEPC-SppC Physics Goals in CDR (remind)

- **Electron-positron collider (90, 160，250 GeV)**
  - Higgs Factory（10^6 Higgs）：
    - Precision study of Higgs(m_H, J^{PC}, couplings)，Similar & complementary to ILC
    - Looking for hints of new physics
  - Z & W factory（10^{10} Z^0）：
    - precision test of SM
    - Rare decays ?
  - Flavor factory: b, c, τ and QCD studies
- **Proton-proton collider(~100 TeV)**
  - Directly search for new physics beyond SM
  - Precision test of SM
    - e.g., h^3 & h^4 couplings

CEPC Design –Higgs Parameters

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

CEPC Design – Z-pole Parameters

Parameter	Design Goal
Particles	e+, e-
Center of mass energy	2*45.5 GeV
Integrated luminosity (peak)	>10^34/cm^2s
No. of IPs	2
Polarization	to be considered in the second round of design

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

CEPC-SPPC Timeline (preliminary and ideal)

CEPC

2015 | 2020 | 2025 | 2030 | 2035

Pre-studies (2013-2015)

R&D Engineering Design (2016-2022)

Construction (2022-2030)

Data taking (203-2040)

1st Milestone: Pre-CDR (by 2015) ;2nd Milestone: R&D funding from MOST (in Mid 2016);
3rd Milestone: CEPC CDR Progress Report (April 2017); 4th Milestone: CEPC CDR Report (publsih in July, 2018);5th Milestone: CEPC TDR Report and Proto R&D (by the end of 2021);6th Milestone: CEPC construction start (2022);

SPPC

2020 | 2030 | 2040

CDR and R&D (2014-2035)

Engineering Design (2035-2040)

Construction (2040-2045)

Data taking (2045-2060)

CEPC CDR Accelerator Chain and Systems

10 GeV

1) Injector

L=1.2km

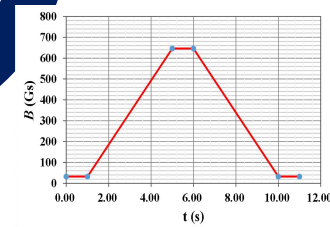
Electron

Positron

2) Booster

C=100km

Energy Ramp
10 ->45/120GeV



Booster Cycle (0.1 Hz)

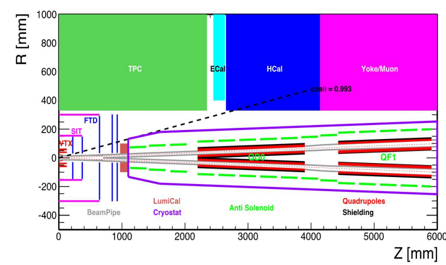
Three rings in the sane channel:

- CEPC & booster
- SppC

3) Main Ring

C=100km
2IP

45/120 GeV



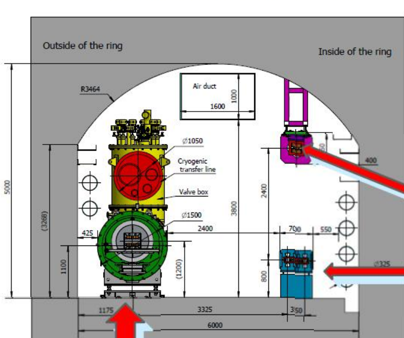
4) Detector Machine Interface (MDI)

The key systems of CEPC:

1) Linac Injector
2) Booster
3) Collider ring
4) MDI
5) Civil Eng.

5) Civil Eng.

TUNNEL CROSS SECTION OF THE ARC AREA



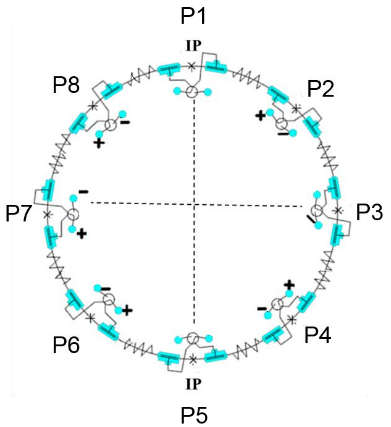
CEPC Booster

CEPC Collider

SppC

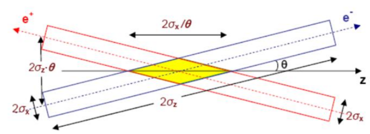
CEPC Four Options Evoluting towards CDR

CEPC Pre-CDR Scheme (head -on collision)

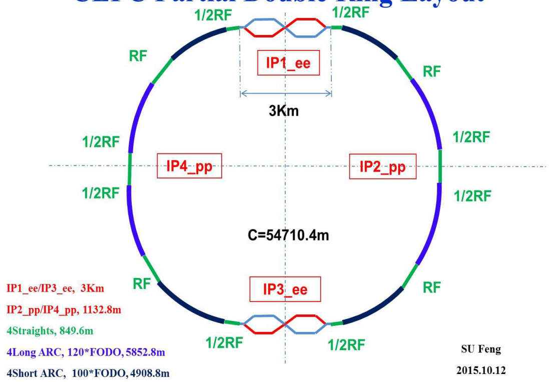


Since Oct 2012

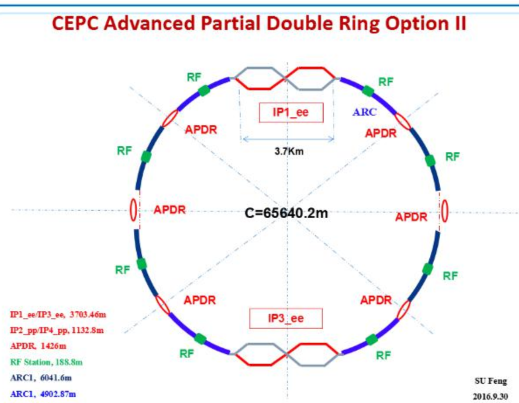
Crab-waist collision in CEPC CDR



CEPC Partial Double Ring Layout



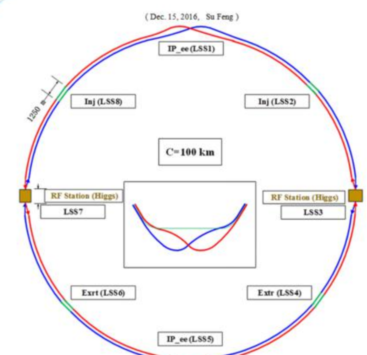
Since May 2015



Since May 2016

CEPC Alternative Design

Lower cost and reaching the fundamental requirement for Higgs and Z luminosities, under the condition that sawtooth and beam loading effects be solved



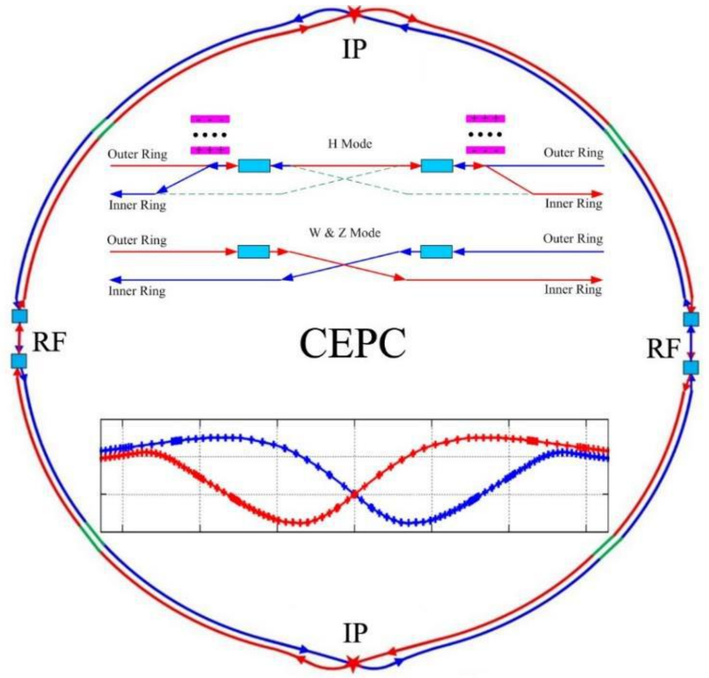
Since Nov 2016

CEPC Baseline Design

Better performance for Higgs and Z compared with alternative scheme, without bottle neck problems, but with higher cost 30MW synchrotron radiation power/beam

- **CEPC 100km circumference was decided by CEPC SC based on the recommendation from IAC in Nov. 2016**
- **CEPC baseline and alternative options have been decided on Jan. 14, 2017**

CEPC SRF Design for H,W, and Z

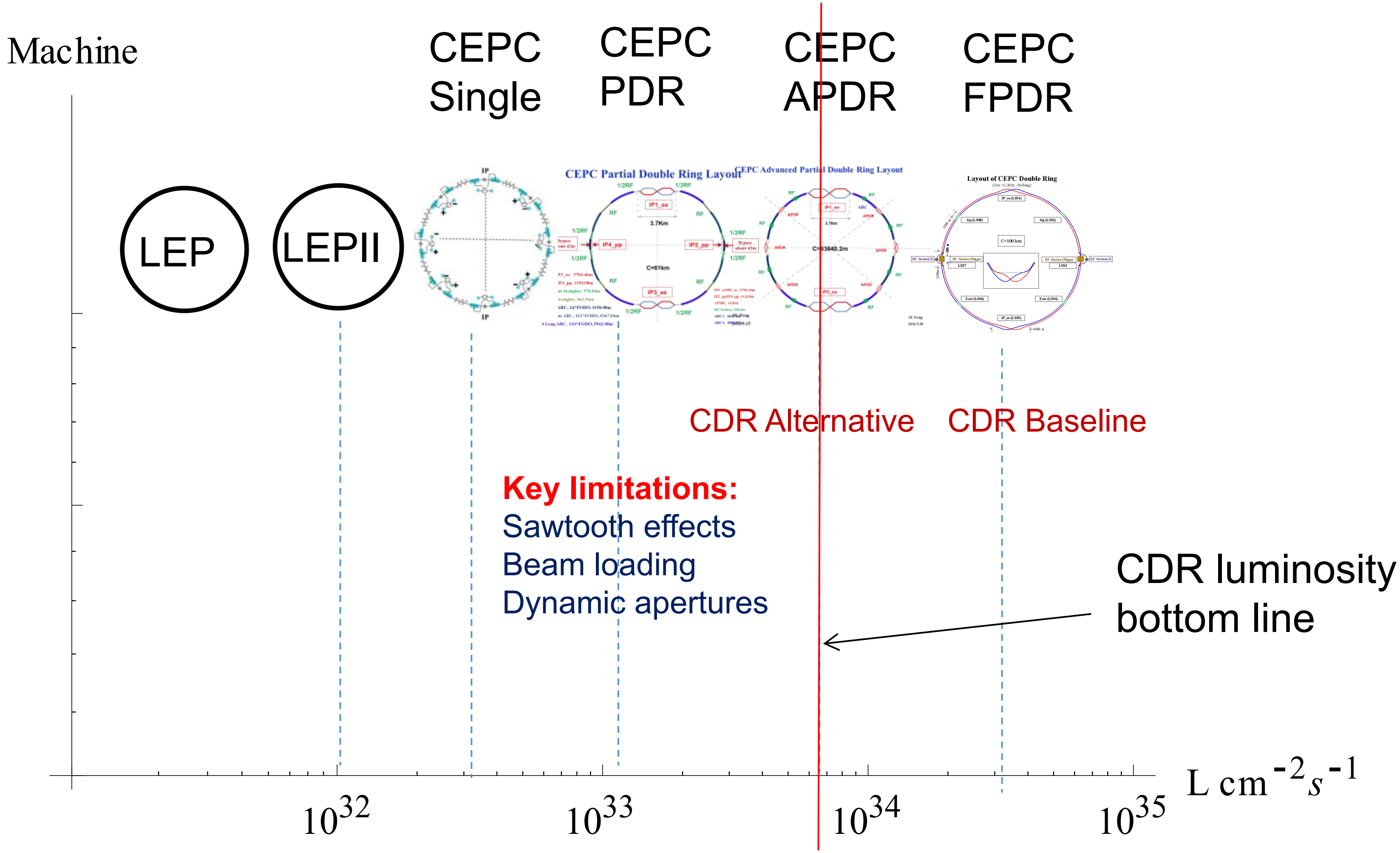


- Higgs factory as first piority (fully partial double ring, with common SRF system for e+ and e- beams)
- W and Z factories are incorperated by beam swithyard (W and Z factories are double ring, with independent SRF system for e+ and e- beams)
- Higgs factory baseline SR per beam 30 MW to Minimize AC power

Economic CEPC baseline design as Higgs factory:

- W, Z factories incoperated with the same SRF system hardwares by using beam switchyard to change from Higgs factory and W, Z factories
- Synchrotron radiation power per beam at Higgs energy is set to 30MW to minimize AC power consumption

Collider Schemes vs Luminosity Potentials



Luminosity H 10^32 (102GeV) <~2*10^34 >2~5*10^34 (cm^-2s^-1)

Luminosity Z 10^32 <~1*10^34 >10*10^34 (cm^-2s^-1)

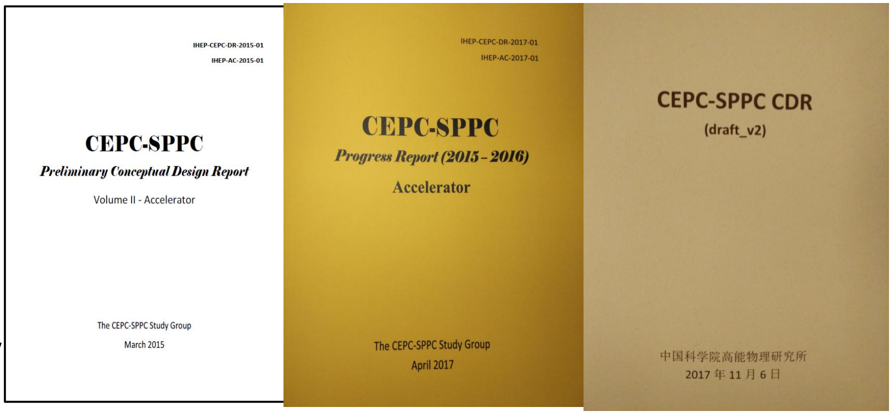
CEPC Accelerator from Pre-CDR to CDR

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

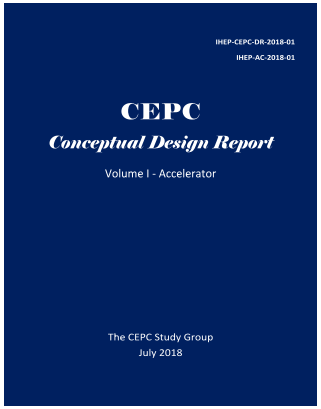
- **Executive Summary**

1. **Introduction**
2. **Machine Layout and Performance**
3. **Operation Scenarios**
4. **CEPC Collider**
5. **CEPC Booster**
6. **CEPC Linac**
7. **Systems Common to the CEPC Linac, Booster and Collider**
8. **Super Proton Proton Collider**
9. **Conventional Facilities**
10. **Environment, Health and Safety**
11. **R&D Program**
12. **Project Plan, Cost and Schedule**

- Appendix 1: CEPC Parameter List
- Appendix 2: CEPC Technical Component List
- Appendix 3: CEPC Electric Power Requirement
- Appendix 4: Advanced Partial Double Ring
- Appendix 5: CEPC Injector Based on Plasma Wakefield Accelerator
- Appendix 6: Operation as a High Intensity γ-ray Source
- Appendix 7: Operation for e-p, e-A and Heavy Ion Collision
- Appendix 8: Opportunities for Polarization in the CEPC
- Appendix 9: International Review Report



March 2015 | April 2017 | Draft CDR for Mini International Review in Nov. 2017



CDR Version for International Review June 2018

Mini-Review Workshop of CEPC-SPPC CDR (Nov. 4-5, 2017, IHEP)

CEPC-SPPC CDR Mini-review members

Name (alphabetical order)

Anton Bogomyakov	BINP	Russia
Brian Foster	Oxford U.	U.K.
Eugene Levichev	BINP	Russia
Kexin Liu（刘克新）	Peking U.	China
Ernie Malamud	Fermilab	USA
Kazuhito Ohmi	KEK	Japan
Katsunobu Oide	CERN / KEK	Switzerland
Carlo Pagani	U. of Milan / INFN	Italy
John Seeman	SLAC	USA
Sergey Sinyatkin	BINP	Russia
Mike Sullivan	SLAC	USA
Chuanxiang Tang（唐传祥）	Tsinghua U.	China
Lin Wang （王林）	USTC	China
Xiangqi Wang（王相綦）	USTC	China
Akira Yamamoto	KEK	Japan

Sunday, November 5		
08:30 – 09:00 09:00 – 09:30 09:30 – 10:00 10:00 – 10:30 10:30 – 11:00	SRF RF power source Cryogenic system Magnet Coffee (30')	Jiyuan Zhai Zusheng Zhou Shaopeng Li Fusan Chen

Informal Mini-Review of CEPC-SPPC CDR

November 4 – 5, 2017, IHEP, Main Building, Room A415

Agenda (draft v2. 09/14/2017)

Saturday, November 4		
08:30 – 08:35 08:35 – 09:10 09:10 – 09:40 09:40 – 10:10 10:10 – 10:40 10:40 – 11:10 11:10 – 11:40 11:40 – 12:10 12:10 – 12:40	Welcome Overview of beam dynamics Parameters Optics Dynamic aperture Coffee (30') Beam-beam Instabilities Machine-detector interface	Yifang Wang Chenghui Yu Dou Wang Yiwei Wang Yuan Zhang Yuan Zhang Na Wang Sha Bai
12:40 – 14:00	Lunch	
14:00 – 14:30 14:30 – 15:00 15:00 – 15:30 15:30 – 16:00 16:00 – 16:30 16:30 – 17:00 17:00 – 17:30 17:30 – 18:30	Injection and extraction Booster Linac and sources Coffee (30') Synchrotron radiation Overview of SPPC SC magnet for SPPC Discussion	Xiaohao Cui Tianjian Bian Cai Meng Yadong Ding Jingyu Tang Qingjin Xu All
19:00	Dinner	

International Review of CEPC CDR
(June 28-30, 2018, IHEP)

International Review of CEPC CDR

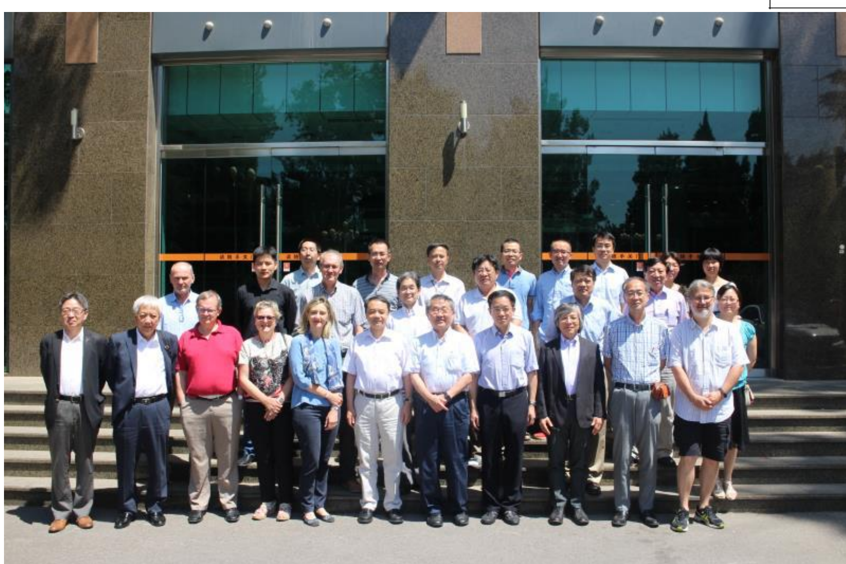
June 28 – 30, 2018, IHEP, Main Building, Room A415

Agenda

Thursday, June 28		
	Chair: K. Oide	
8:30-9:00	Committee Executive Session	
	Chair: Qing Qin	
9:00-9:05	Welcome	Yifang Wang
9:05-9:20	Overview of CEPC	Jie Gao
9:20-9:35	Overview of beam dynamics	Chenghui Yu
9:35-10:05	CEPC collider lattice design	Yiwei Wang
10:05-10:35	CEPC beam-beam and DA	Yuan Zhang
	Coffee break(30')	
	Chair: K. Oide	
11:05-11:35	Instabilities	Na Wang
11:35-12:05	Machine-detector interface	Sha Bai
12:05 – 14:00	Lunch break	
	Chair: K. Oide	
14:00-14:30	Booster	Dou Wang
14:30-15:00	Injection and extraction	Xiaohao Cui
15:30-16:00	Linac injector	Cai Meng
	Coffee break(30')	
16:30-18:30	Committee Executive Session	
19:00	Dinner of Committee	

	Chair: K. Oide
8:30-9:00	SRF system
9:00-9:30	RF power source
9:30-10:00	Cryogenic system
10:00-10:20	CEPC collider ring Magnet
10:20-10:40	CEPC booster ring magnet
	Coffee break(30')
11:10-11:30	SC magnet for CEPC IR
11:30-12:00	Power supplies
12:00-12:30	Vacuum
12:30 – 14:00	
	Chair: K. Oide
14:00-14:30	Instrumentation
14:30-15:00	Control
15:00-15:30	Synchrotron radiation
15:30-16:00	Radiation shielding
	Coffee break(30')
16:30-18:30	Committee Executive Sessic
	Dinr

Saturday, June 30		
	Chair: K. Oide	
8:30-9:00	Survey and alignment	Xiaolong Wang
9:00-9:30	Mechanics	Haijing Wang
9:30-10:00	Conventional facilities	Guoping Lin
10:00-10:30	Site investigation	Yu Xiao
	Coffee break (30')	
11:00-12:00	Discussion with CEPC team	
12:00 – 14:00	Lunch break	
14:00-16:00	Committee Executive Session	
	Coffee break (30')	
16:30-17:30	Close out	
	Banquet	



Review Committee Members:

Brian Foster	Oxford U./DESY
Eugene Levichev	BINP
Katsunobu Oide (chair)	CERN/KEK
Kazuro Furukawa	KEK
Manuela Boscolo	INFN
Marica Biagini	INFN
Masakazu Yoshioka	KEK/Tohoko University
Norihito Ohuchi	KEK
Paolo Pierini	ESS
Steinar Stapnes	CERN
Yoshihiro Funakoshi	KEK
Zhengtang Zhao (absent)	SINAP

International Review Report (draft) of CEPC CDR (June 28-30, 2018, IHEP)

International Review of the CEPC Conceptual Design Report
- Accelerator Design –

June 28 – 30, 2018
IHEP, Beijing

This is the review report of the accelerator part of the CEPC CDR. The review is done for the presentations based on the draft version of the CDR. Extensive discussions have been held between the review committee members and the CEPC team during the review meeting.

General remarks

The Circular Electron-Positron Collider (CEPC) is a very ambitious and important project aimed at various physics at ZH (E_{beam} = 120 GeV), W± (80 GeV), and Z (46 GeV) production which would produce the highest luminosity ever achieved by a collider in the world. The Superconducting Proton-Proton Collider (SppC) is planned as the second stage of the project using the same collider tunnel to explore the energy frontier of elementary particle physics.

The Review Committee unanimously congratulates the CEPC team on the completion of the CDR, with remarkable successes in various aspects of the design. The progress since the pre-CDR has been a major step in the project, especially the full double-ring scheme, lattice design, and various beam dynamics with beam-beam effects and collective phenomena. The design work on each system has verified the basic feasibility of the project, including the superconducting RF, normal and superconducting magnets, cryogenic system, vacuum system, injectors with a booster synchrotron and a linac, instrumentation, control, safety, civil engineering, etc.

The Committee believes that the CDR has already reached a sufficient level of maturity to allow approval to proceed to a Technical Design Report. On the other hand, we think that this machine has more potential for further extensions, including:

(1) Experiments for ttbar production (E_{beam} ≈ 180 GeV);
(2) Even higher luminosity (~x10) at Z and W±;
(3) Higher beam current, up to 50 MW/beam synchrotron radiation loss;
(4) More interaction points;
(5) Polarized beams.

These extensions will be achievable if the machine preserves the possibility to implement these possibilities by relatively small investments, such as longer quadrupole magnets, a less compressed layout around the interaction point (IP) with shallower bends, and sufficient length for the RF section. Actually, such improvements may even reduce the operation costs. The committee encourages the CEPC team to explore and preserve these possibilities, since once CEPC is built, no second machine with the same scale is likely to be built in the world.

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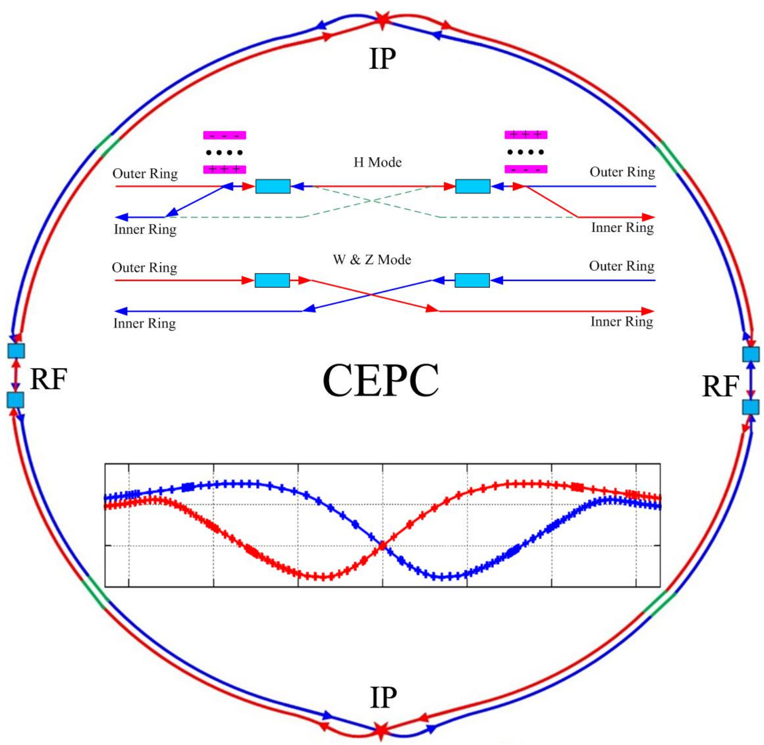
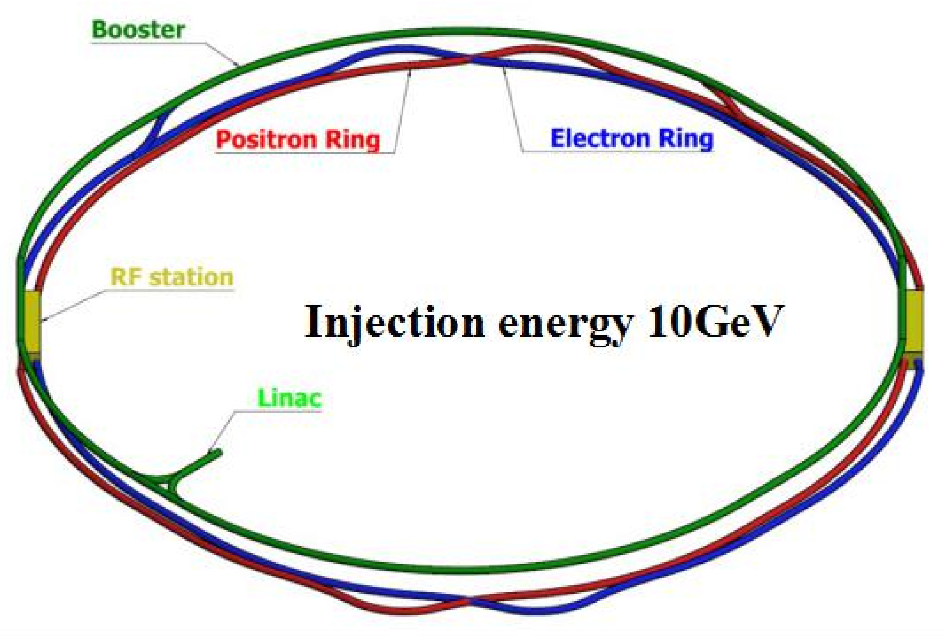
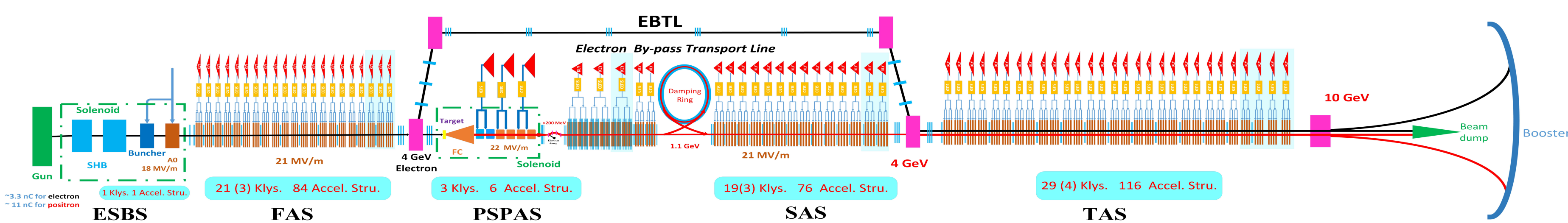
CEPC CDR Layout



CEPC collider ring (100km)



CEPC booster ring (100km)



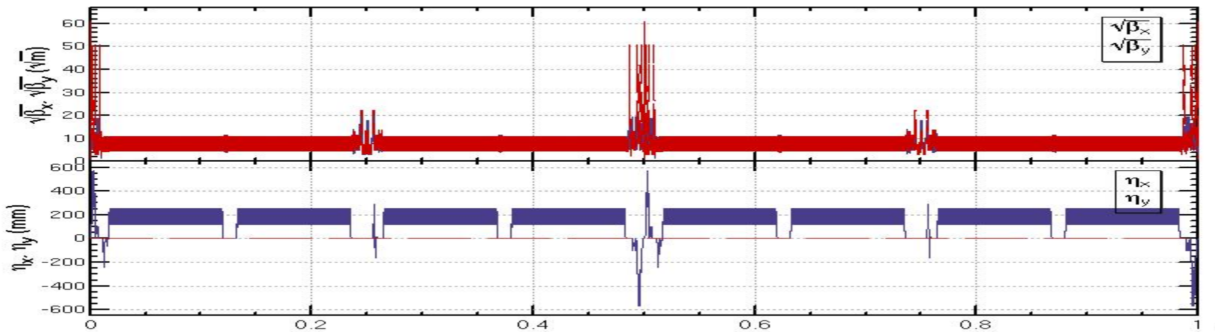
CEPC Linac injector (1.2km, 10GeV)

CEPC CDR Parameters

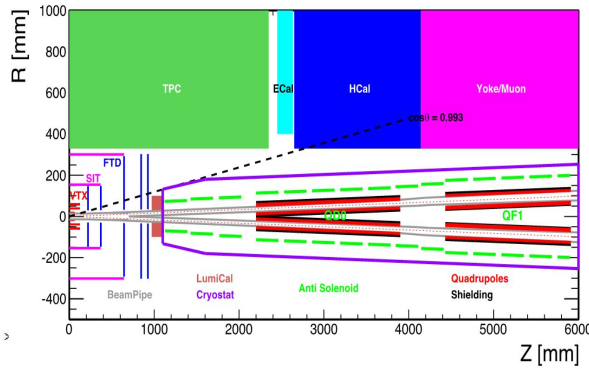
	Higgs	*W*	*Z (3T)*	*Z (2T)*
Number of IPs	2			
Beam energy (GeV)	**120**	**80**	**45.5**	
Circumference (km)	100			
Synchrotron radiation loss/turn (GeV)	1.73	0.34	0.036	
Crossing angle at IP (mrad)	16.5×2			
Piwinski angle	2.58	7.0	23.8	
Number of particles/bunch N_e (10^{10})	15.0	12.0	8.0	
Bunch number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

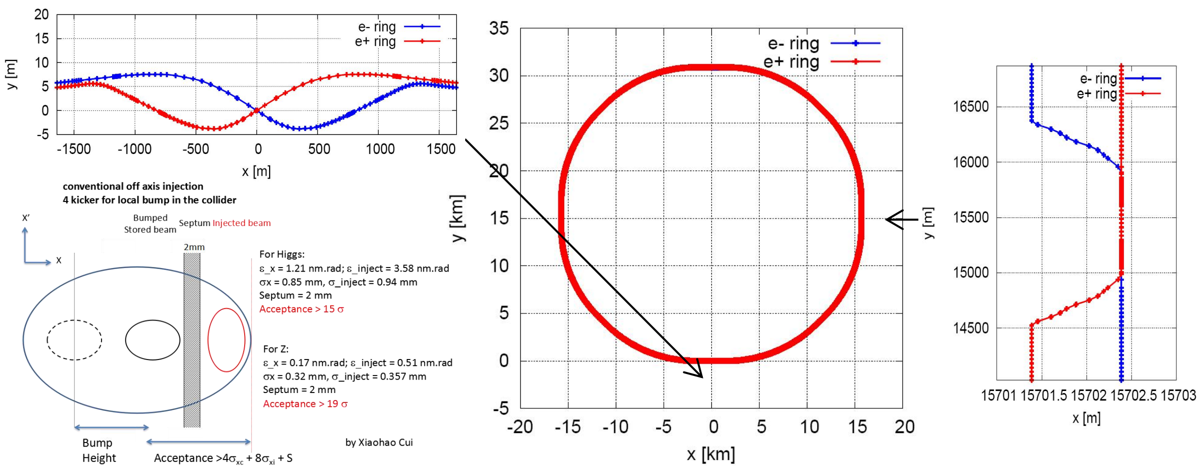
Lattice of the CEPC Collider Ring and MDI

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



CEPC MDI





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

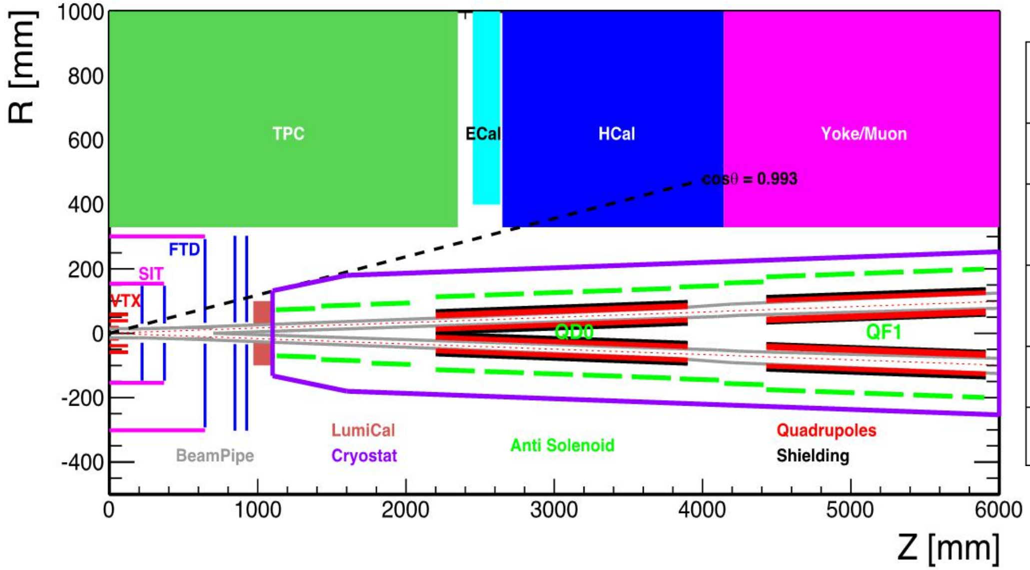
CEPC Collider Ring SRF Parameters

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

CEPC Booster SRF Parameters

10 GeV injection	H	W	Z
Extraction beam energy [GeV]	120	80	45.5
Bunch number	242	1524	6000
Bunch charge [nC]	0.72	0.576	0.384
Beam current [mA]	0.52	**2.63**	**6.91**
Extraction RF voltage [GV]	1.97	0.585	0.287
Extraction bunch length [mm]	2.7	2.4	1.3
Cavity number in use (1.3 GHz TESLA 9-cell)	96	64	32
Gradient [MV/m]	19.8	8.8	8.6
Q_L	1E7	6.5E6	1E7
Cavity bandwidth [Hz]	130	200	130
Beam peak power / cavity [kW]	8.3	12.3	6.9
Input peak power per cavity [kW] (with detuning)	18.2	12.4	7.1
Input average power per cavity [kW] (with detuning)	0.7	0.3	0.5
SSA peak power [kW] (one cavity per SSA)	25	**25**	**25**
HOM average power per cavity [W]	0.2	0.7	**4.1**
Q_0 @ 2 K at operating gradient (long term)	1E10	1E10	1E10
Total average cavity wall loss @ 2 K eq. [kW]	0.2	0.01	0.02

CEPC MDI Layout and Parameters



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

- The Machine Detector Interface of CEPC double ring scheme is about ±7m long from the IP.
- The CEPC detector superconducting solenoid with 3 T magnetic field and the length of 7.6m.
- The accelerator components inside the detector without shielding are within a conical space with an opening angle of cosθ=0.993.
- The e+e- beams collide at the IP with a horizontal angle of 33mrad and the final focusing length is 2.2m
- Lumical will be installed in longitudinal 0.95~1.11m, with inner radius 28.5mm and outer radius 100mm.

CEPC CDR Design Status

CEPC Collider Ring

Parameter	Symbol	Unit	Goal	Status
Beam Energy	E	GeV	120	**120**
Circumference	C	km	100	**100.006**
Emittance	$\varepsilon_{x/}\varepsilon_y$	nm·rad	1.21 / 0.0036	**1.208 / -**
Beta functions at IP	$\beta_{x/}\beta_y$	m	0.36 / 0.002	**0.36 / 0.002**
Energy acceptance	$\Delta P/P$	%	1.35	**1.8**
DA requirement	$DA_{x/}DA_y$	σ	13 / 12	**20 / 20 (w/o errors)**

* Z and W satisfies CDR requirement as well

CDR goal reached

CEPC Booster Design Status

Parameters	Design goals	Design results
Beam current (mA)	<0.8	0.54
Emittance in x (nm rad)	<3.6	3.1
Dynamic aperture for 0.5% off-momentum particles	>3σ	8.5σ
Energy acceptance	>1%	2.5%
Timing	Meet the top-up injection requirements	√

CDR goal reached

CEPC Linac Injector CDR Status

Parameter	Symbol	Unit	Goal	Status
e^- /e^+ beam energy	E_{e-}/E_{e+}	GeV	10	10/10
Repetition rate	f_{rep}	Hz	100	100
e^- /e^+ bunch population	$Ne-/Ne+$		$>6.25\times10^{9}$	$\sim1.875\times10^{10}$ $\sim1.875\times10^{10}$
	$Ne-/Ne+$	nC	>1.0	1.0/3.0*
Energy spread (e^- /e^+)	σ_E		$<2\times10^{-3}$	1.5×10^{-3} 1.4×10^{-3}
Emittance (e^- /e^+)		mm· mrad	<0.3	0.005/0.12**
e^- beam energy on Target		GeV	4	4
e^- bunch charge on Target		nC	10	10

CEPC Power for Higgs and Z

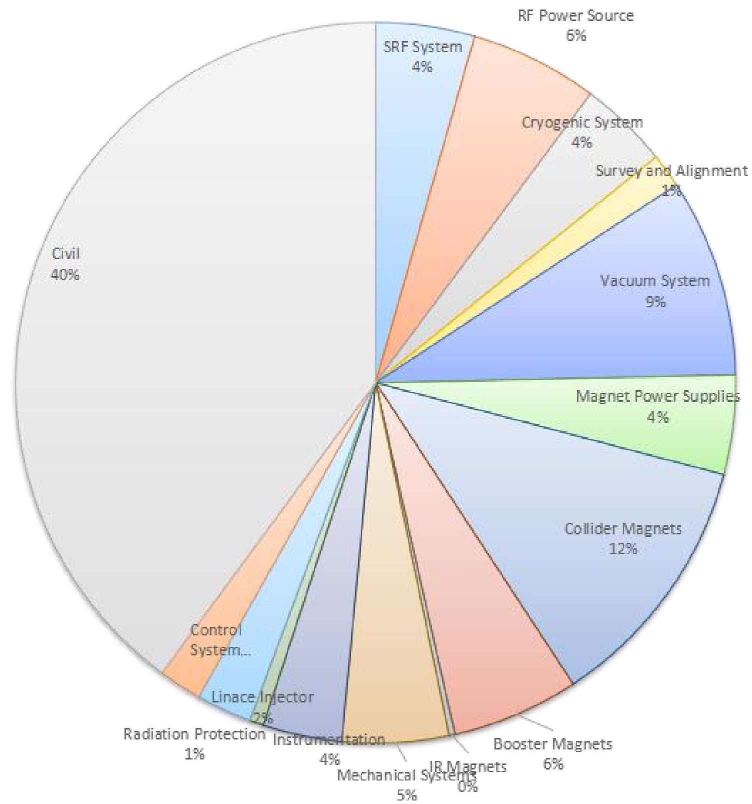
	System for Higgs (30MW)	Location and electrical demand(MW)						Total (MW)
		Ring	Booster	LINAC	BTL	IR	Surface building	
1	RF Power Source	103.8	0.15	5.8				109.75
2	Cryogenic System	11.62	0.68			1.72		14.02
3	Vacuum System	9.784	3.792	0.646				14.222
4	Magnet Power Supplies	47.21	11.62	1.75	1.06	0.26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

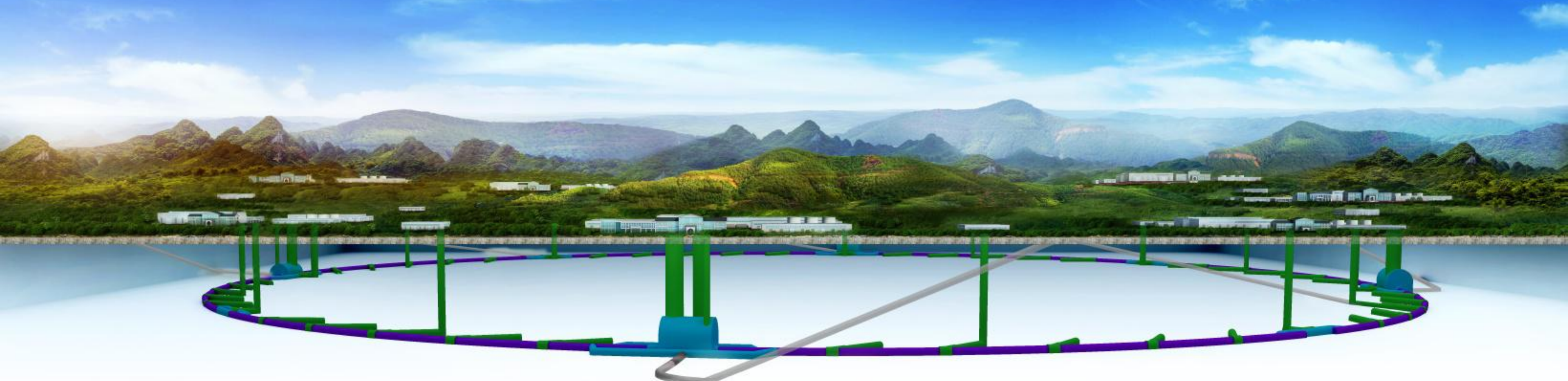
266MW

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

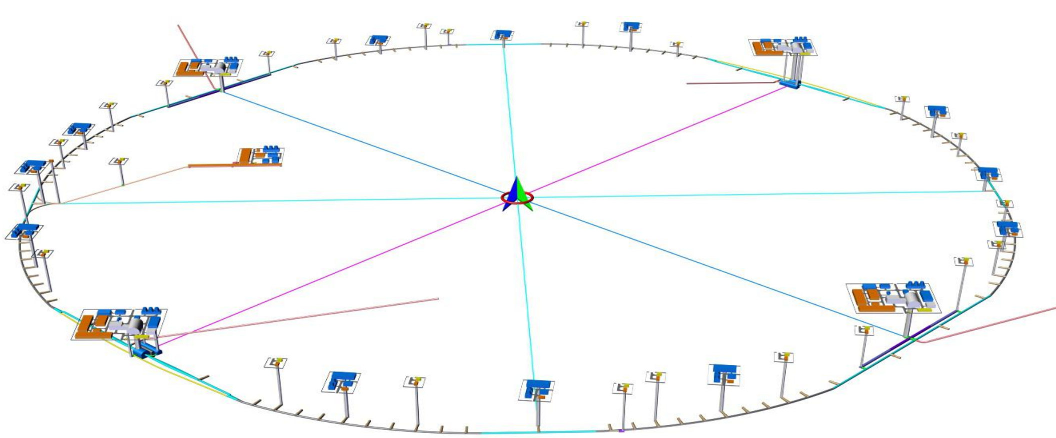
149MW

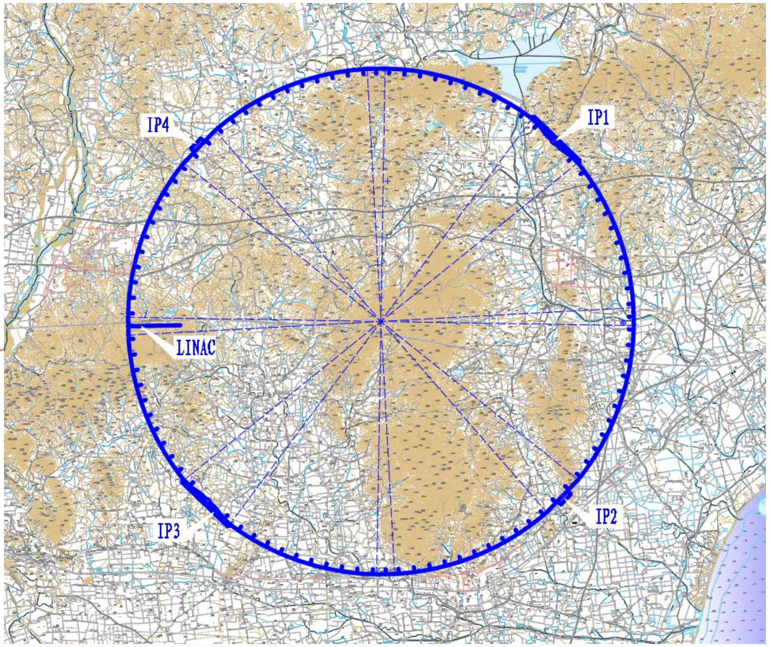
CEPC Cost Breakdwon (no detector)

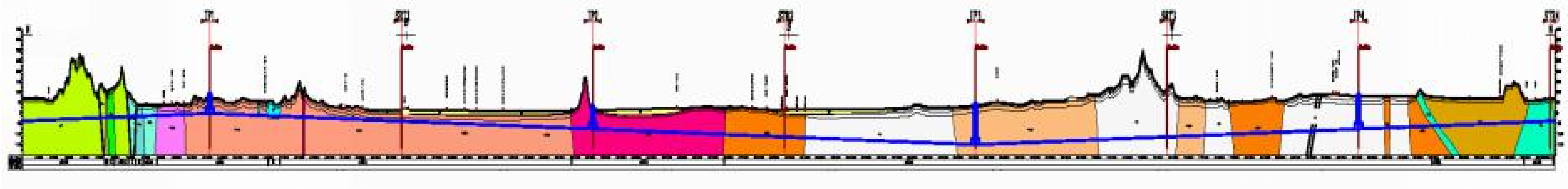




CEPC Civil Enginnering Design (Funing 100km, example)

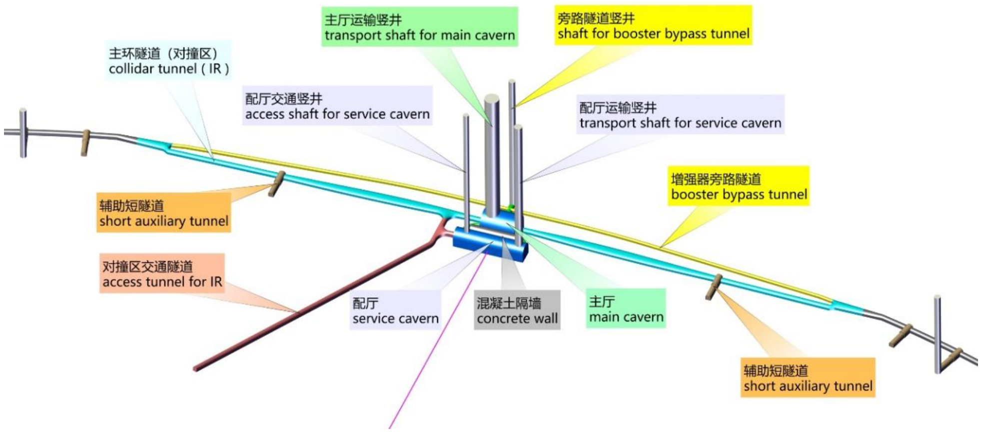




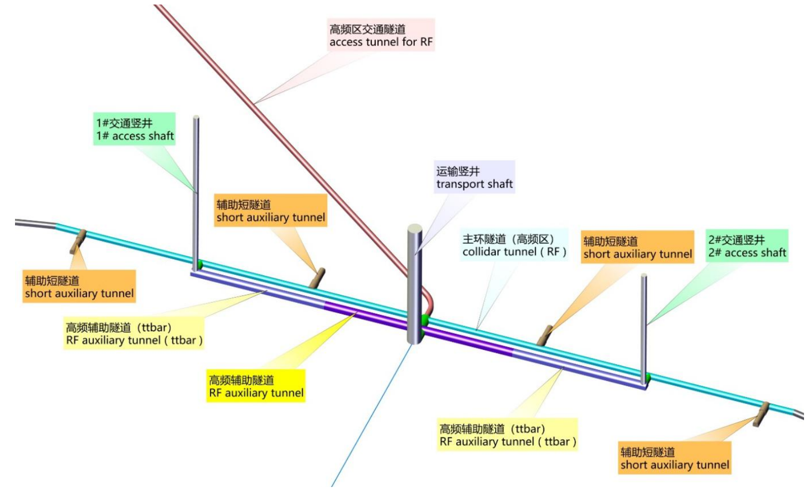


CEPC Tunnel Cross Sections, Detector and SCRF Regions

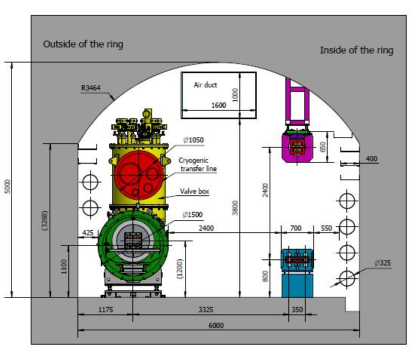
IP1 / IP3

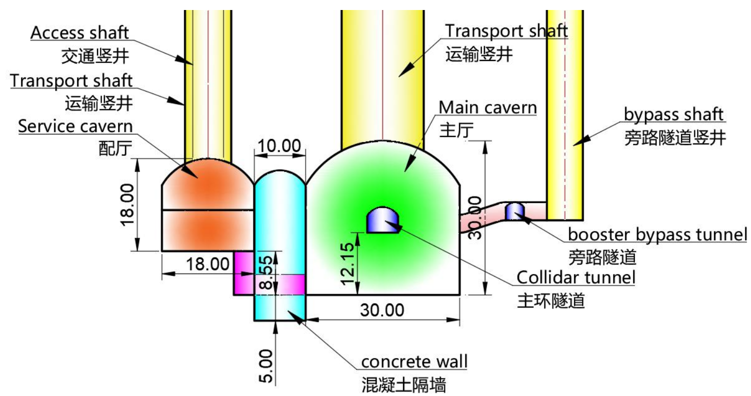


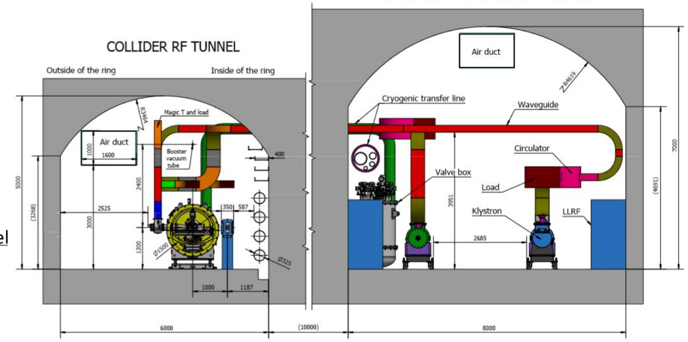
IP2 / IP4--SCRF region



TUNNEL CROSS SECTION OF THE ARC AREA

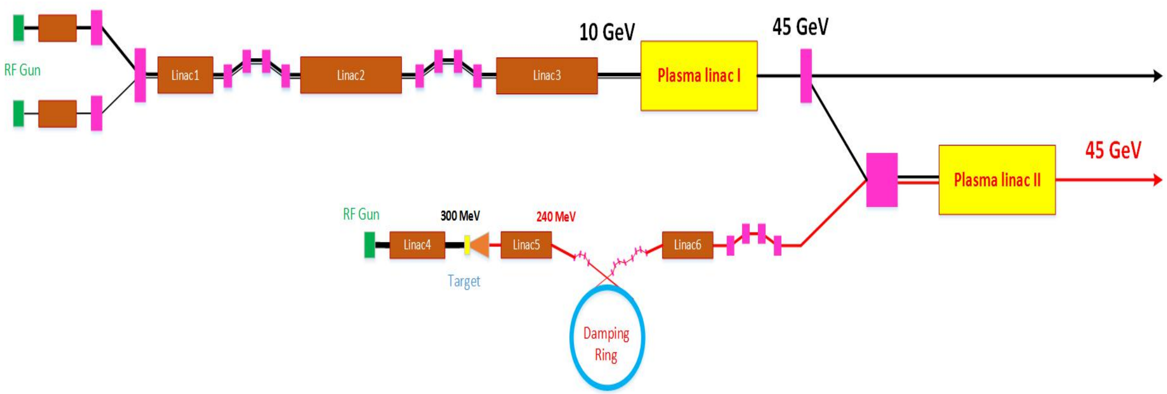


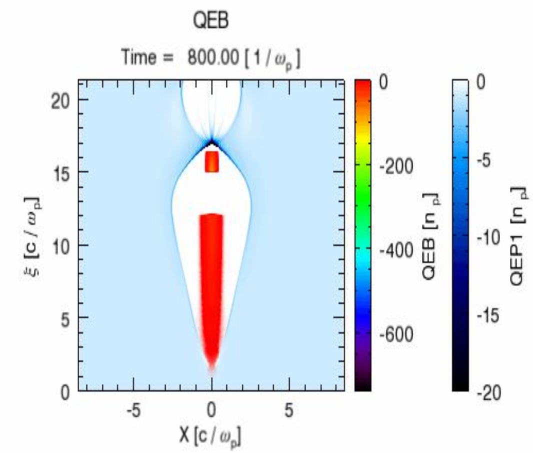




Alterniative solution (example): A High Energy CEPC Injector Based on Plasma Wakefield Accelerator

- Driver/trailer beam generation through Photo-injector
- HTR PWFA with good stability (single stage TR=3-4, Cascaded stage 6-12, high efficiency)
- Positron generation and acceleration in an electron beam driven PWFA using hollow plasma channel (TR=1)





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

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

CEPC Accelerator Key Component Designs and Technologies R&D

The CEPC keycomponents hardware have been designed and R&Ds have been planed and execued on the way

- **Polarized electron gun**
  - Super-lalce GaAs photocathode DC-Gun
- **High current positron source**
  - bunch charge of ~3nC,
  - 6Tesla Flux Concentrator peak magnetic field
- **SCRF system**
  - High Q cavity - Max operation Q_0 = 2E10 @ 2 K
  - High power coupler - 300kW（Variable）
- **High efficiency CW klystron**
  - Efficiency goal > 80%
- **Low field dipole magnet（booster）**
  - Lmag=5m, Bmin=30Gs, Errors <5E-4

- Vacuum system
  - ⇨ 6m long cooper chamber
  - ⇨ RF shielding bellows
- Electro-static separator
  - ⇨ Maximum operating field strength: 20kV/cm
  - ⇨ Maximum deflection: 145 urad
- Large scale cryogenics
  - ⇨ 12 kW @4.5K refrigerator, Oversized,
  - ⇨ Custom-made, Site integration
- HTS magnet
  - ⇨ Advanced HTS Cable R&D: > 10kA
  - ⇨ Advanced High Field HTS Magnet R&D: main field 12~12T

CEPC Funding

IHEP seed money

11 M CNY/3 years (2015-2017)

国家重点研发计划
项目预申报书

FY 2016

Ministry of Science and Technology
Requested 45M RMB; **36M RMB approved**

项目名称：	高能环形正负电子对撞机相关的物理和关键技术预研研究
所属专项：	大科学装置前沿研究
指南方向：	新一代粒子加速器和探测器关键技术和方法的预先研究
推荐单位：	教育部
申报单位：（公章）	清华大学

R&D Funding - NSFC

Increasing support for CEPC D+RDby NSFC
5 projects (2015); 7 projects(2016)

CEPC相关基金名称（2015-2016）	基金类型	负责人	承担单位
高精度气体径迹探测器及激光校正的研究 (2015)	重点基金	李玉兰/陈元柏	清华大学/高能物理研究所 Tsinghua IHEP
成像型电磁量能器关键技术研究(2016)	重点基金	刘树彬	中国科技大学 USTC
CEPC局部双环对撞区挡板系统设计及螺线管场补偿(2016)	面上基金	白莎	高能物理研究所
用于顶点探测器的高分辨、低功耗SOI像素芯片的若干关键问题的研究(2015)	面上基金	卢云鹏	高能物理研究所
基于粒子流算法的电磁量能器性能研究 (2016)	面上基金	王志刚	高能物理研究所
基于THGEM探测器的数字量能器的研究(2015)	面上基金	俞伯祥	高能物理研究所
高粒度量能器上的通用粒子流算法开发(2016)	面上基金	阮曼奇	高能物理研究所
正离子反馈连续抑制型气体探测器的实验研究(2016)	面上基金	祁辉荣	高能物理研究所
CEPC对撞区最终聚焦系统的设计研究(2015)	青年基金	王逗	高能物理研究所
利用耗尽型CPS提高顶点探测器空间分辨精度的研究 (2016)	青年基金	周扬	高能物理研究所
关于CEPC动力学孔径研究(2016)	青年基金	王毅伟	高能物理研究所

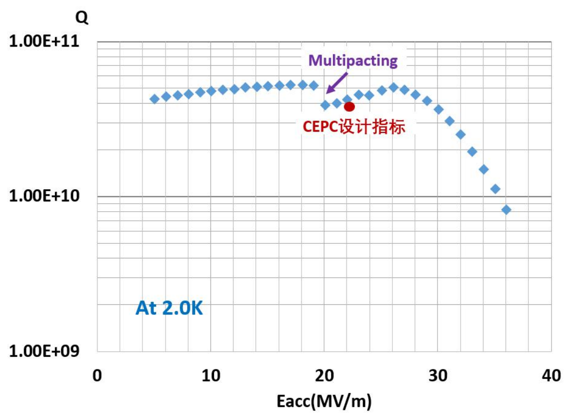
~60M CNY CAS-Beijing fund, talent program

year 2017 funding request (32M) to MOST approved

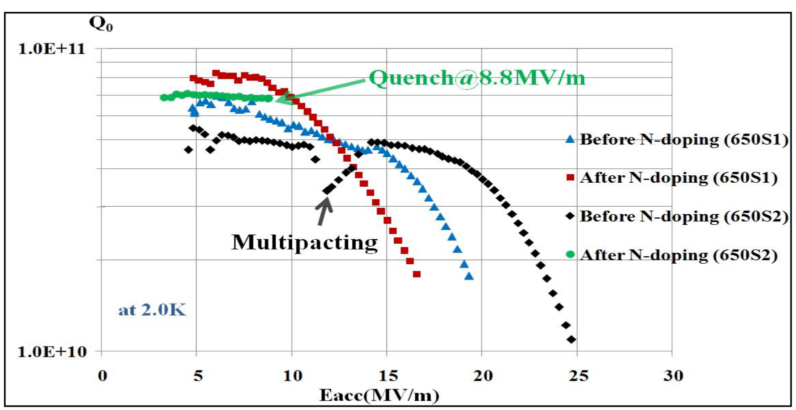
Basic funding needs for carrying out the CEPC design and the R&D should be met by end of 2018

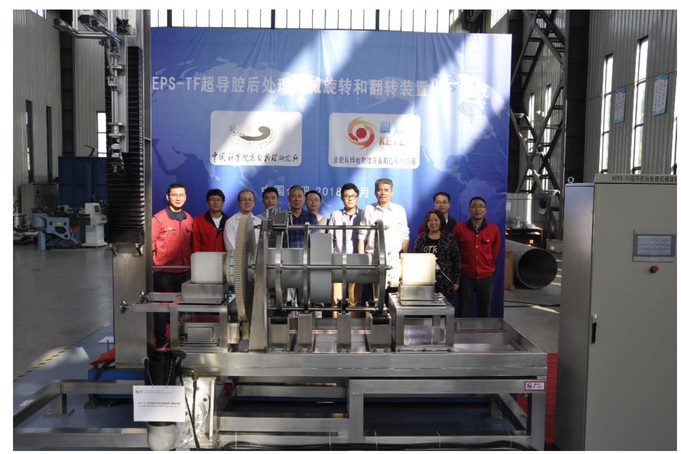
CEPC 650 MHz Cavity Development

- Vertical test result: Q_0=5.1E10@26MV/m， which is close to the CEPC target (Q_0=4.0E10@22.0MV/m).
- Next, the CEPC target will be achieved by N-doping and EP, etc.



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



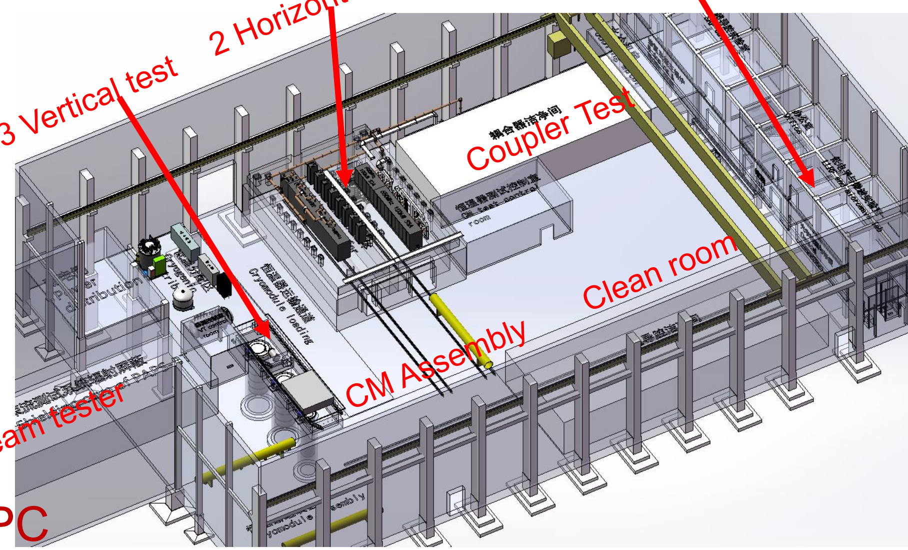


The civil construction of the EP facility is on going, and the commissioning will be on Sep-Oct 2018.

IHEP New SRF Infrastructure

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

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



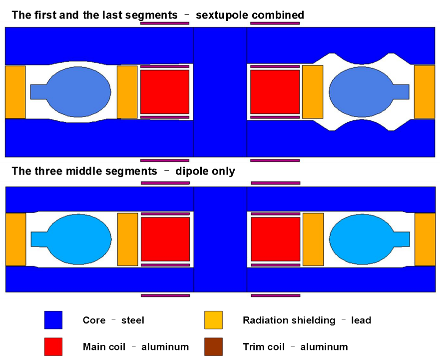
Shanghai city government decided to built Shanghai Coherent Light Facility(SCLF).

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

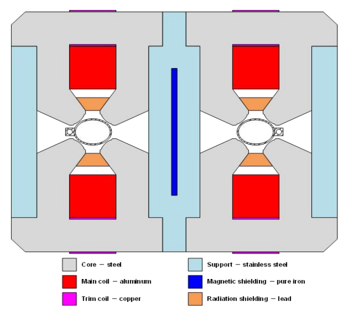
CEPC Collider and Booster Ring Conventional Magnets

CEPC collider ring magnets

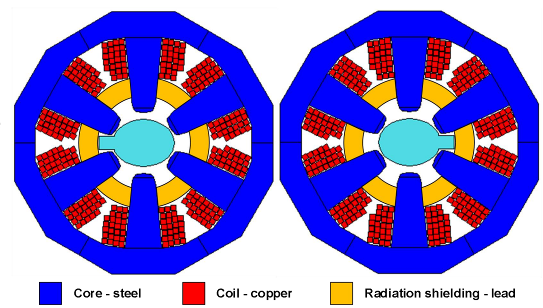
	Dipole	Quad.	Sext.	Corrector	Total
Dual aperture	2384	2392	-	-	13742
Single aperture	80*2+2	480*2+172	932*2	2904*2	
Total length [km]	71.5	5.9	1.0	2.5	80.8
Power [MW]	7.0	20.2	4.6	2.2	34



Dipole



Quadrupole

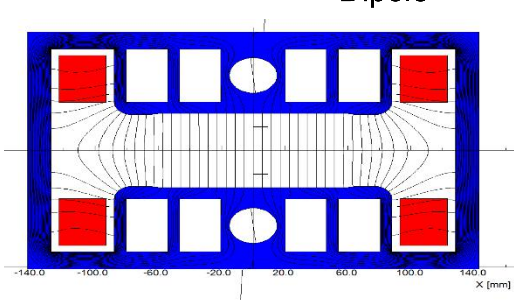


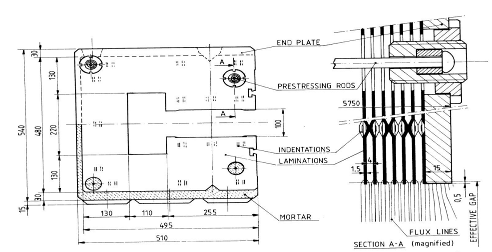
Sextupole

Booster ring low field magnets

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

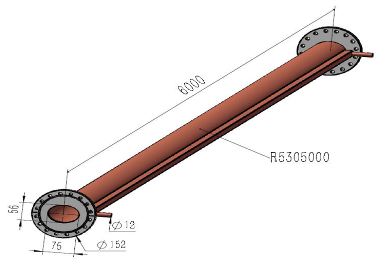
Dipole



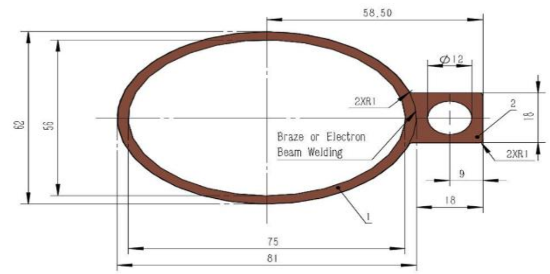


Vacuum System R&D

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

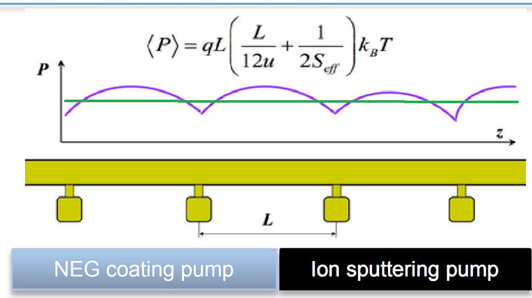


Positron ring



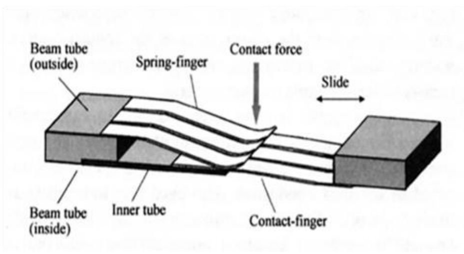
Copper vacuum chamber (Drawing) (elliptic 75×56, thickness 3, length 6000)

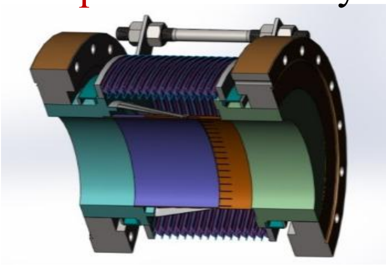
NEG coating suppresses electron multipacting and beam-induced pressure rises, as well as provides extra linear pumping. Direct Current Magnetron Sputtering systems for NEG coating was chosen.



- Function of the bellows module : allow thermal expansion of the chambers and for lateral, longitudinal and angular offsets due to tolerances and alignment,
- Providing a uniform chamber cross section to reduce the impedance seen by beam

- The Finger contact force of RF shielded bellow is 125±25 g/Finger.



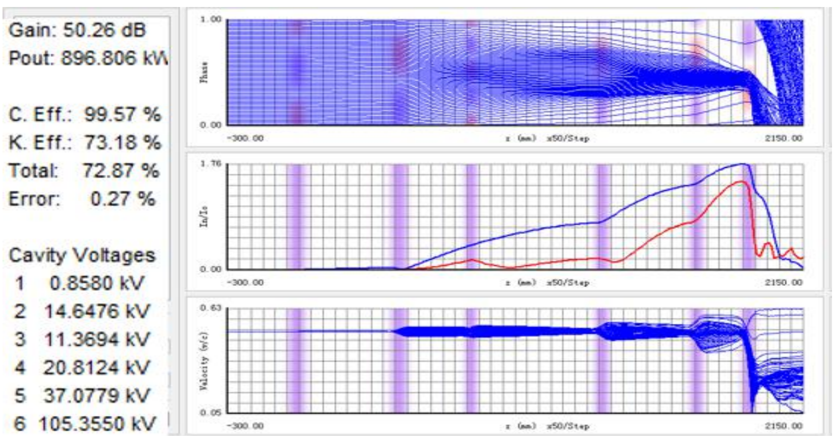


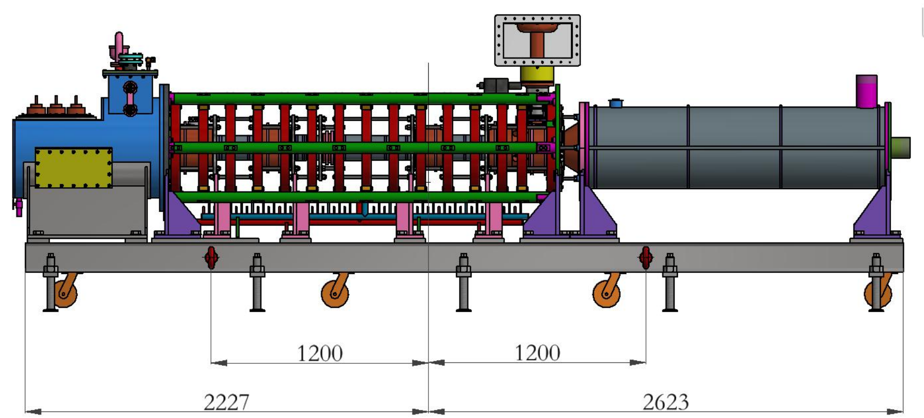
High Efficiency Klystron Development

Established "High efficiency klystron collaboration consortium", including IHEP & IE(Institute of Electronic) of CAS, and Kunshan Guoli Science and Tech.

- 2016 – 2018： Design conventional & high efficiency klystron
- 2017 – 2018： Fabricate conventional klystron & test
- 2018 - 2019： Fabricate 1st high efficiency klystron & test
- 2019 - 2020： Fabricate 2nd high efficiency klystron & test
- 2020 - 2021： Fabricate 3rd high efficiency klystron & test

Parameters	Conventional efficiency	**High efficiency**
Centre frequency (MHz)	650+/-0.5	**650+/-0.5**
Output power (kW)	800	**800**
Beam voltage (kV)	80	**-**
Beam current (A)	16	**-**
Efficiency (%)	~ 65	**> 80**

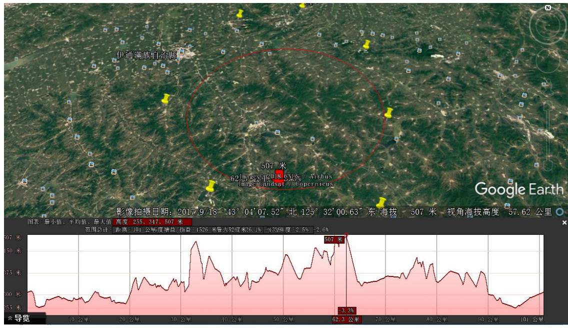




Mechanical design of conventional klystron

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

CEPC Site Selections



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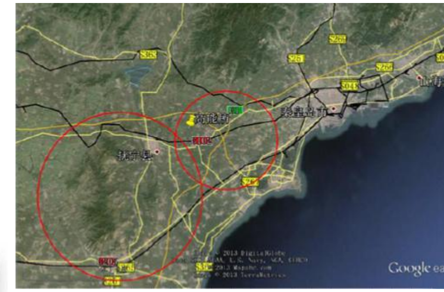
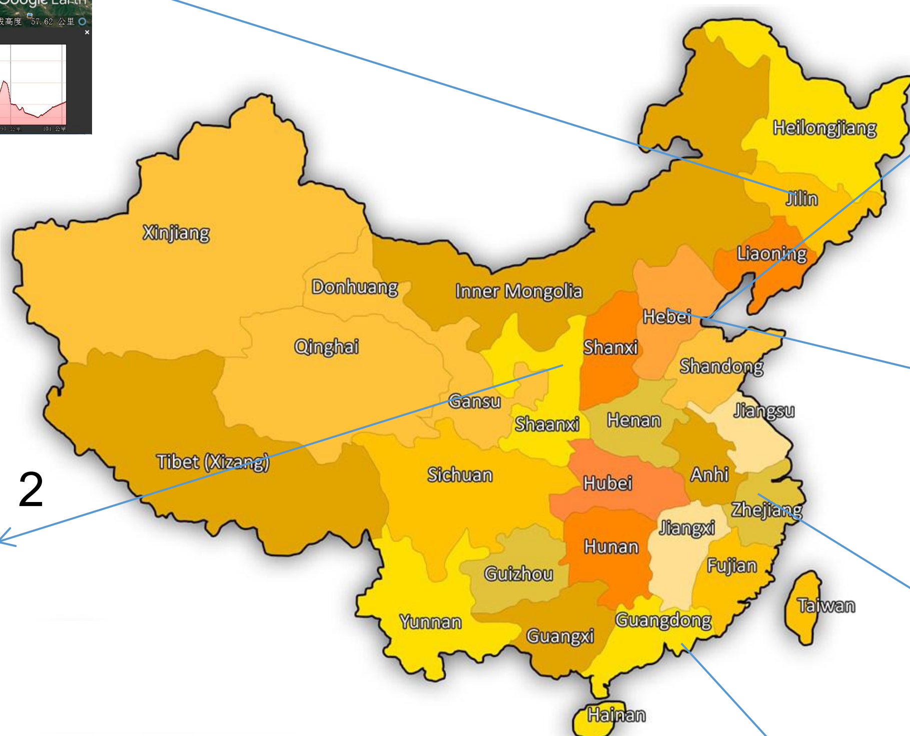
1





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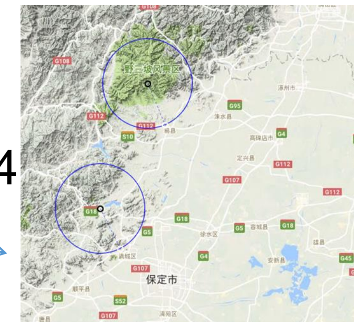

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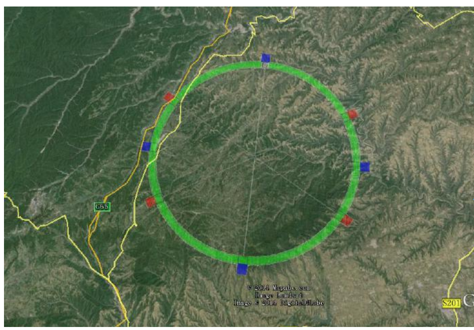

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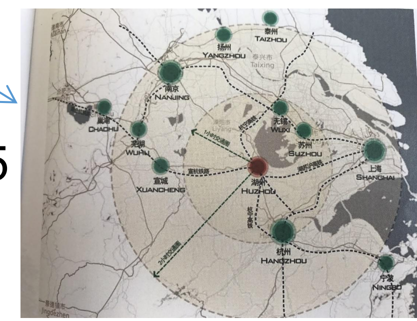


1) Qinhuangdao, Hebei Province（Completed in 2014）

2) Huangling, Shanxi Province（Completed in 2017)

3) Shenshan, Guangdong Province(Completed in 2016)

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

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

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

3

CEPC Industrial Promotion Consortium (CIPC)

Established in Nov. 7 , 2017

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

More than 50 companies joined in first phase of CIPC,
and more will join later....

CEPC International Collaboration Status-1

International collaboration experts in the CEPC study team:

- ✓ All accelerator subsystem working groups have established data base of potential international collaboration experts

- ✓ All accelerator subsystems have at least one international collaboration expert in the subsystem working groups

International collaboration with major international labs:

- ✓ IHEP-BINP (Russia) MoU (Jan 2016) (on CEPC collider lattice design, Z-pole polariztion)

- ✓ IHEP-KEK (Japan) MoU (Sept 2017) (on all systems of Super KEK B accelerators, good reference)

- ✓ IHEP-MEPhI (Russia) (Nov 2017) (CEPC SCRF)

- ✓ IHEP-IEF (University of Rostock, Rostock, Germany) (Jan 2018) (CEPC SCRF)

- ✓ IHEP-Jlab (USA) MoU update is considered (CEPC-SppC-ep)

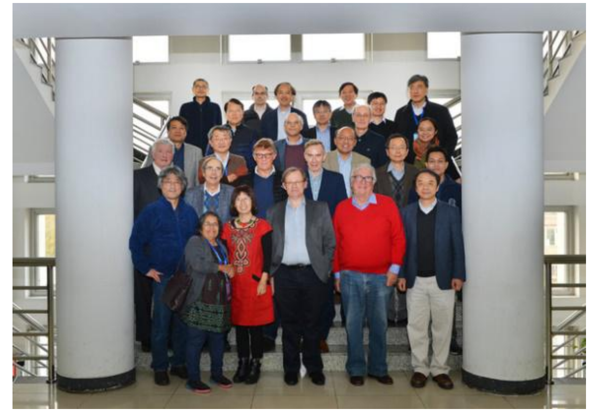
- ✓ With CERN and Dubna high level collaboration will progress

More than 20 MoU in general

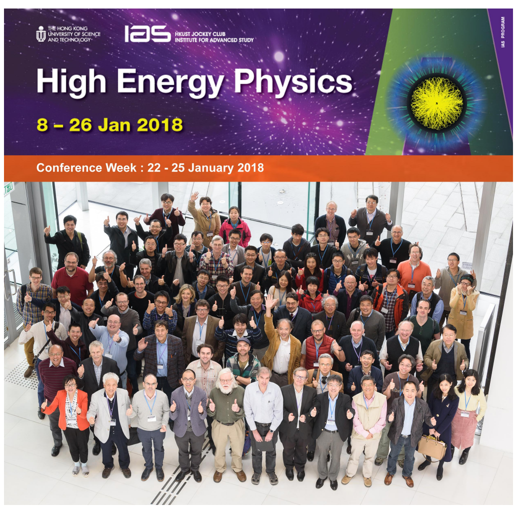
CEPC International Collaboration Status-2

The first CEPC-SppC international Collaboration Workshop
Nov 6-8, 2017, IHEP, Bejing

http://indico.ihep.ac.cn/event/6618



The the third CEPC-SppC International Advisory Committee Meeting, Nov 8-9, 2017, Beijing



IAS Higgh Energy Physics Workshop
(Since 2015)

http://iasprogram.ust.hk/hep/2018

Workshop on the Circuar Electron Positron Collider-EU edition
May 24-26, 2018, Università degli Studi Roma Tre, Rome, Italy

https://agenda.infn.it/conferenceDisplay.py?ovw=True&confId=14816

Conclusions

- **The study path from CEPC Pre-CDE to CEPC CDR baseline and alternative choice has been overviewed**

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

- **CEPC hardware design and key technologies' R&D plan are ready for full TDR phase**

Thanks go to

CEPC accelerator team and international collaborators

Thank you for your attention