The Circular Collider Project in China:

from the Higgs Factory with CEPC to the Energy Frontier with SppC

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IHEP

INFIERI School edition at UAM, August 27, 2021

Contents

Introduction

Continious Efforts in Particle Physics

Research of Human Being

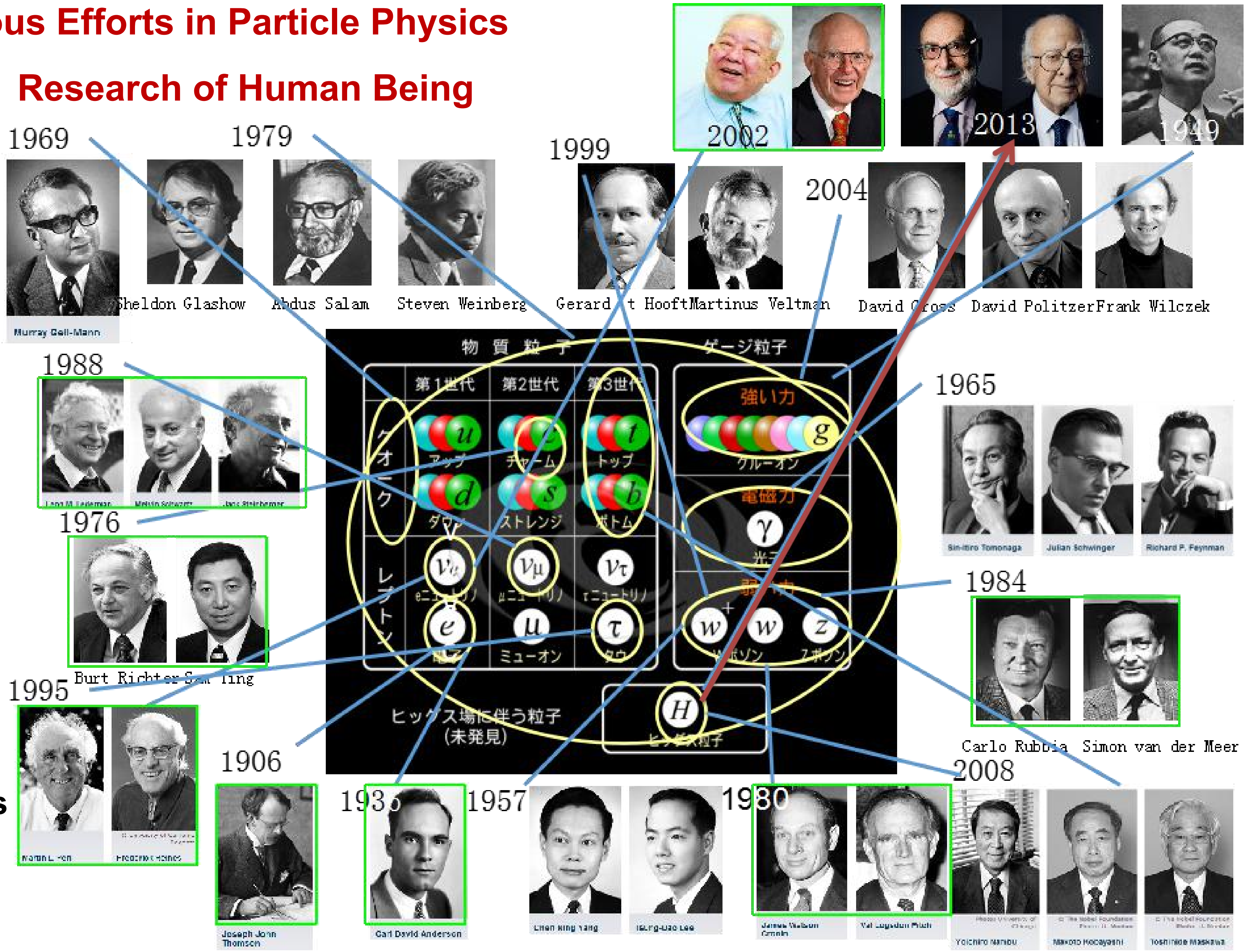
Nobel Prize distribution:

- **SM related**
  9 times
- **Particle discovery**
  8 times
- **Accelerator and detector related 3 times**

E.O. Lawrence (1932)

S. Van der Meer (1984)

G. Charpak(1992)



Higgs Boson was discovered on July 4, 2012 at LHC of CERN

Particle accelerators played a key role in particle discoveries and precise measurements

The CEPC-SppC Kick-off Meeting in Beijing

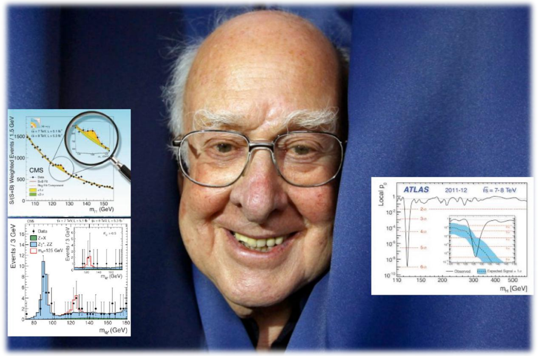
- The Chinese CEPC+ppPC Study Group kick-off meeting took place Sept. 13-14,2013 in Beijing
- Participation by over 120 physicists from 19 domestic institutes
- Domestic accelerator, theoretical and experimental physicists were organized
- International collaboration is open

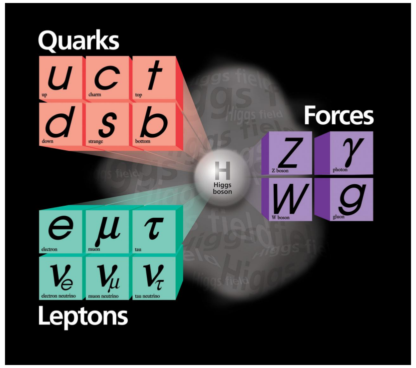
CEPC was firstly reported in the ICFA beam Dynamics Workshop, Accelerators for a Higgs Factory: Linear vs Circular Nov. 14-16, 2012, Fermi National Lab. USA

Organizingg Committee:

A。 Blondel, A. Chao, W. Chou, J. Gao, D. Schulte, K. Yokoya

CEPC-SppC was proposed by Chinese scientists in Sept. 2012 after Higgs Boson was discovered on July 4， 2012 at CERN



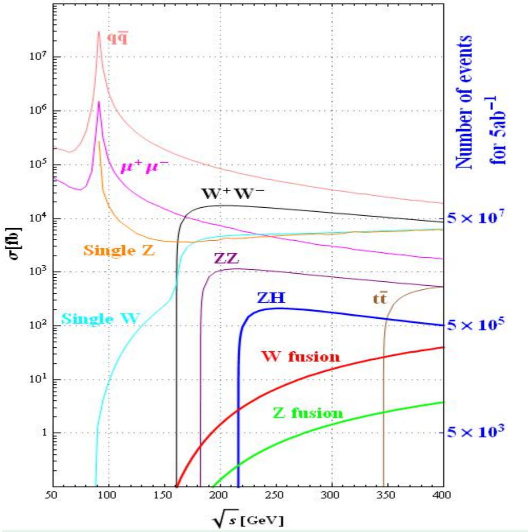


Physics Goals of CEPC-SppC

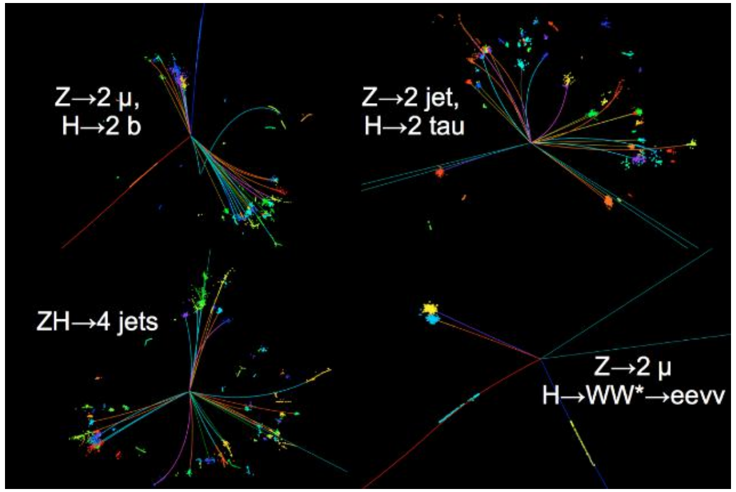
- Electron-positron collider (91, 160， 240, 360 GeV)
  - Higgs Factory（>10^6 Higgs）：
    - Precision study of Higgs(m_H, J^{PC}, couplings)， Similar & complementary to ILC
    - Looking for hints of new physics, DM...
  - Z & W factory（>10^{10} Z^0）：
    - precision test of SM
    - Rare decays ?
  - Flavor factory: b, c, t 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

Precision measurement + searches:
Complementary with each other !

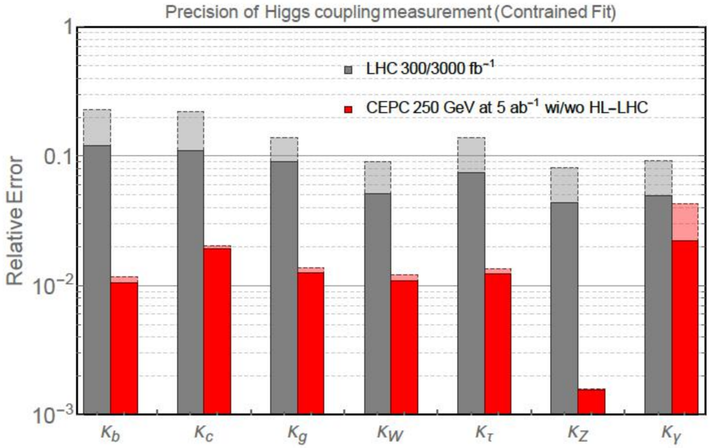
CEPC Physics Potentials



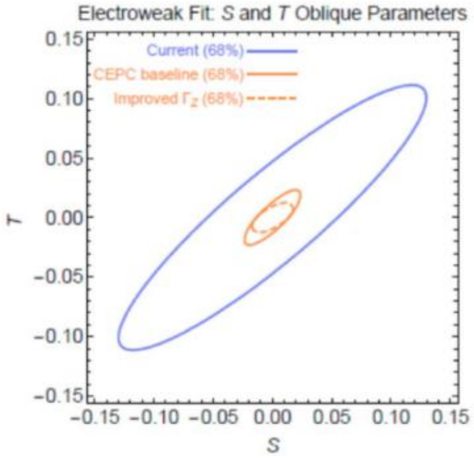
Cross sections for Major SM physics processes at the electron positron collider (without beam polarization)



Simulated Higgs signal with different decay final states at 250 GeV center of mass electron positron collisions, using PFA oriented detector design



Anticipated accuracy on Higgs properties at CEPC and at LHC/HL-LHC

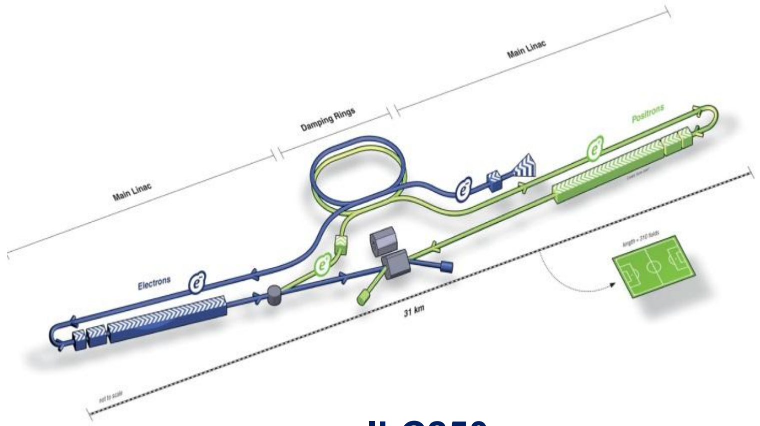


Anticipated electro-weak precision of the CEPC and comparison to current accuracy

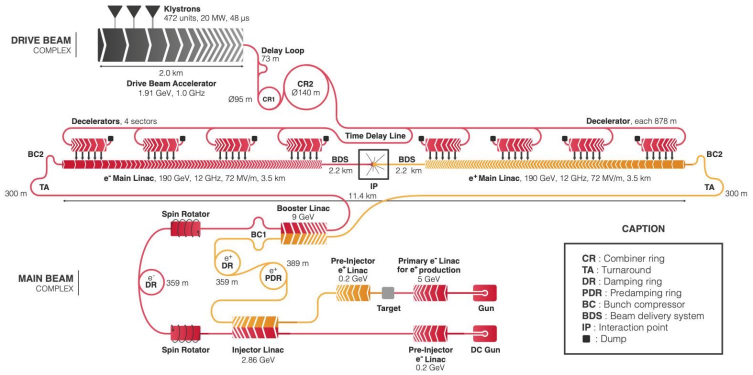
Proposals of Future HEP Large Facilities in the World

CEPC-SppC: FCC(ee,hh): LCC(ILC,CLIC)

1） Linear colliders：ILC-CLIC
from Higgs energy upto 3TeV



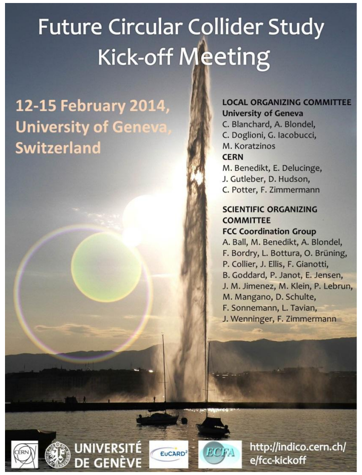
ILC250

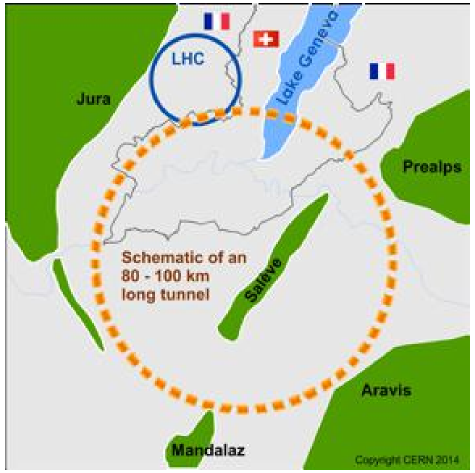


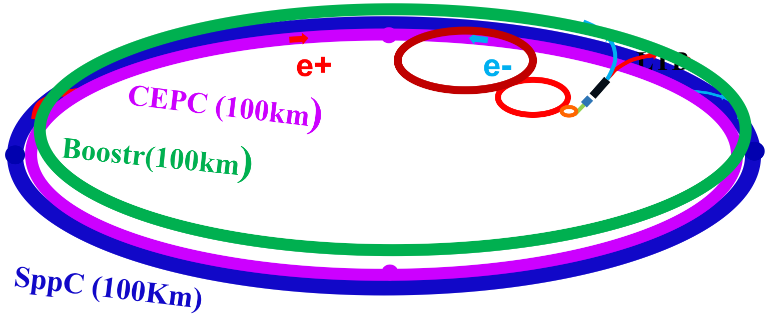
CLIC

2） Circular Colliders：

- CEPC-SppC kick-off meeting in Sept. 2013
- CERN FCC（ee,hh) kick-off meeting in Feb., 2014







CEPC-SppC

Maybe later to come...

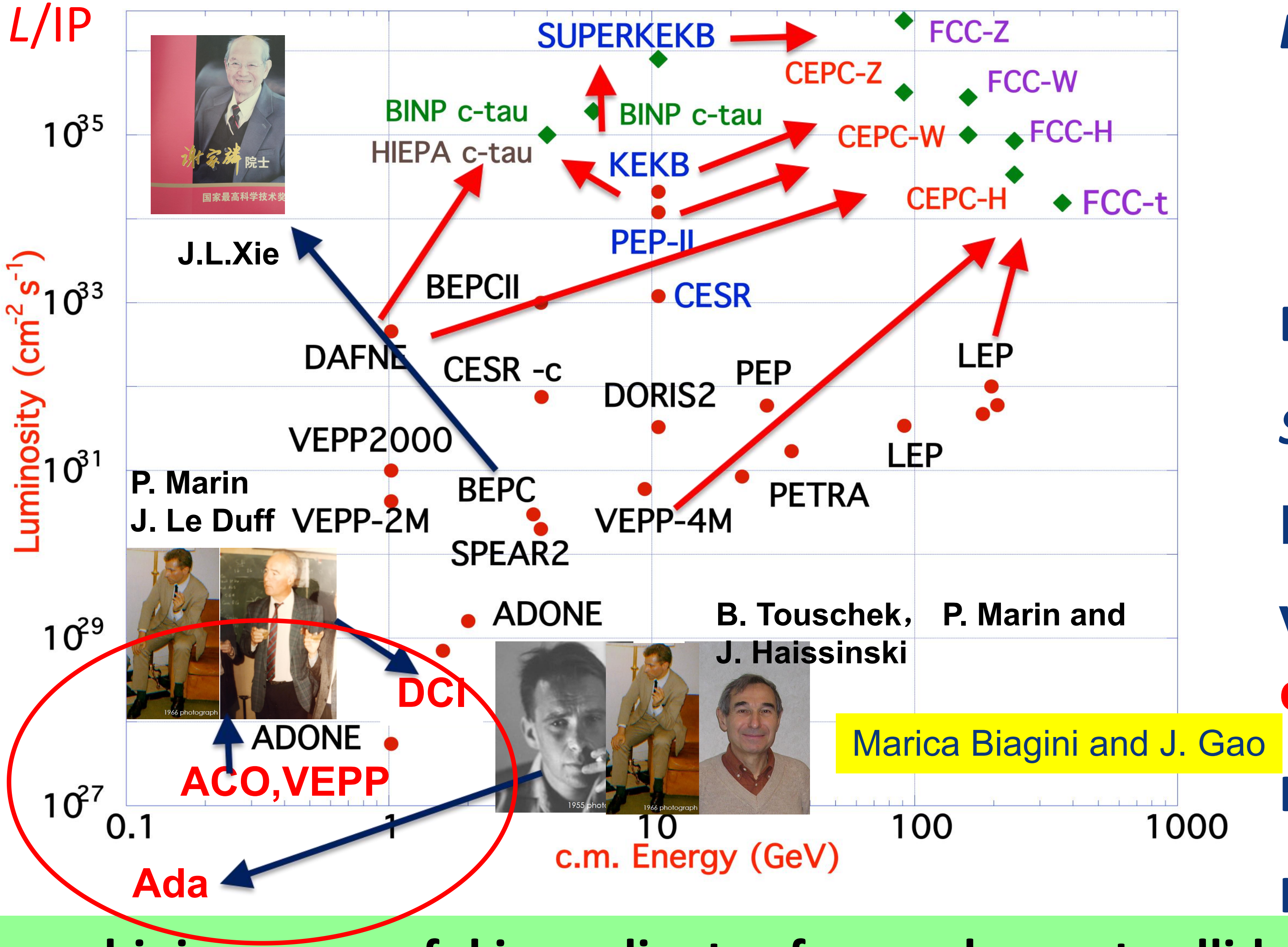
Muon collider

waiting for

Snowmass, P5

in 2022

Future circular lepton factories based on proven concepts and techniques from past colliders and light sources



B-factories: KEKB & PEP-II:
- double-ring lepton colliders,
- high beam currents,
- top-up injection

DAFNE: crab waist, double ring

Super B-factories, S-KEKB: low β_y*

LEP: high energy, SR effects

VEPP-4M, LEP: precision E calibration

KEKB: *e*$^+$ source

HERA, LEP, RHIC: spin gymnastics

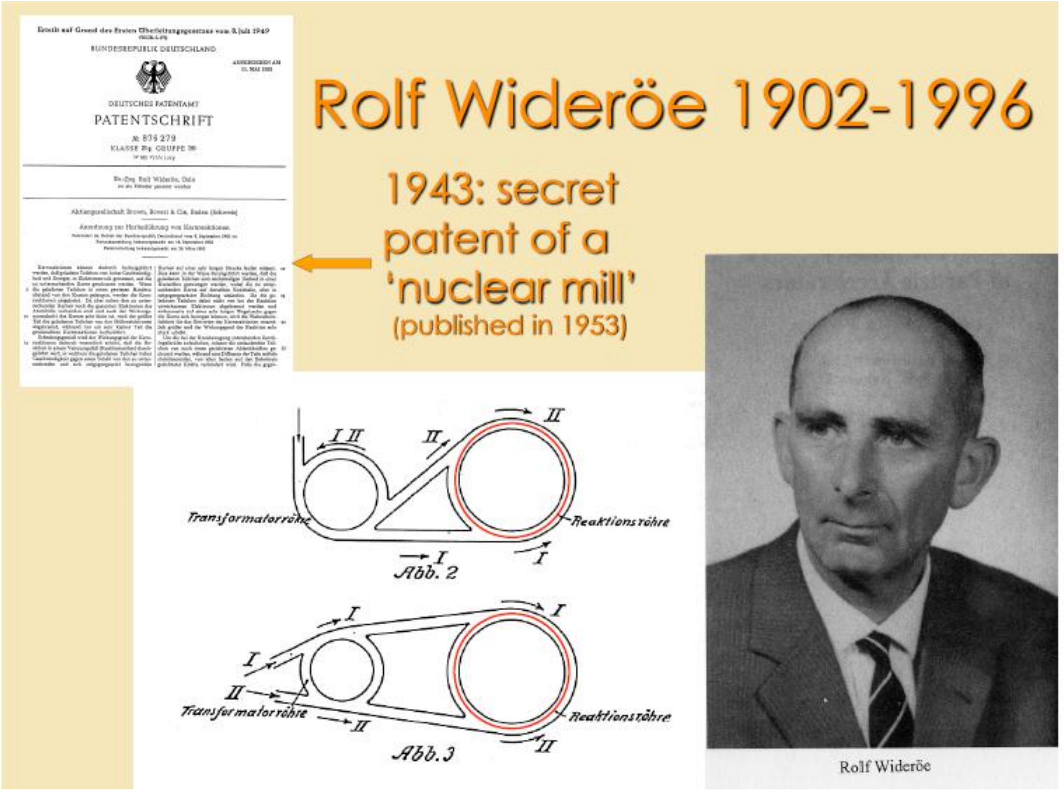
combining successful ingredients of several recent colliders → highest luminosities & energies

J. Haissinski, “A historical account of the first electron positron circular collider-Ada”

IHEP Seminar, Oct. 9, 2018 invited by Prof. Jie Gao

Historical Review of Storage Ring Collider

1rst Proposal (1943)



Rolf Videröe

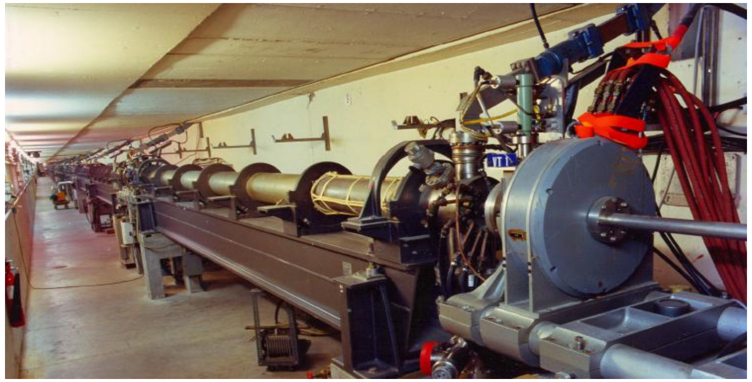
was a Norwegian engineer who had given some thoughts to the betatron principle while completing his training in Karlsruhe (1923).

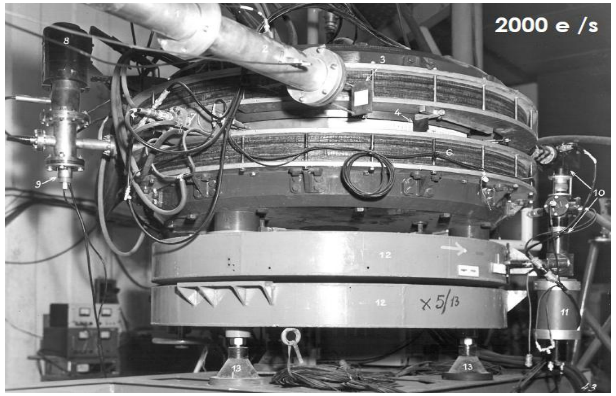
About his circular collider scheme, he wrote:

“...and this is when (1943) I had my idea. If it were possible to store the particles in rings for longer periods, and if these 'stored' particles were made to run in opposite directions, the result would be one opportunity for collision at each revolution...”

P. Marin

Historical Review-AdA (1962-1964)





Bruno Touschek

Main parameters of AdA

Parameter	Typical operation value	Units
Energy per beam	200	MeV
Circumference	4	m
Luminosity	$\sim 10^{25}$	$cm^{-2}\ s^{-1}$
Beam current, per beam	0.5	mA
Injector (linac) energy	500	MeV
Max field on the orbit	1.45	T
Field index (dB/B)/(dr/R)	0.54	
Vacuum pressure	1	nTorr
RF peak voltage	5.5	kV

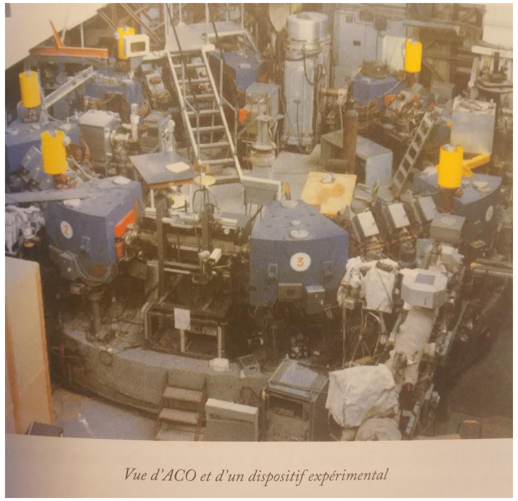
The event that launched the AdA project:

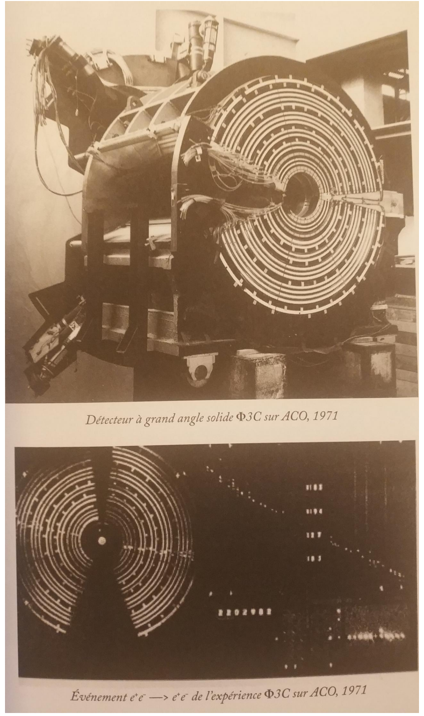
Bruno Touschek's seminar given in Frascati on March 7, 1960

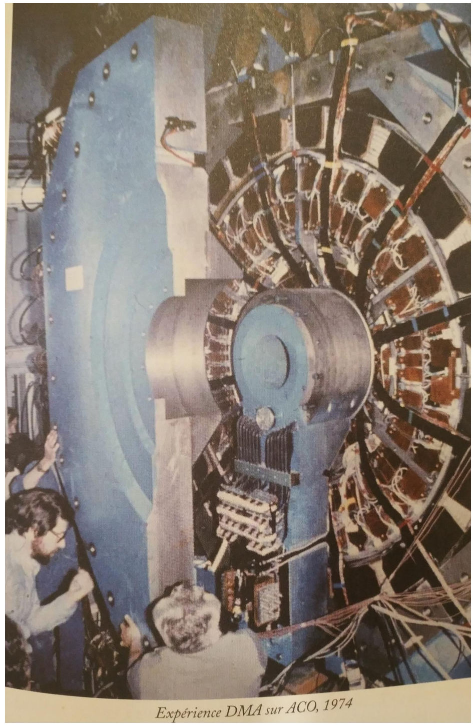
Touschek stressed that e+e- annihilations would be the pathway to new physics by providing a state of pure energy with well-defined quantum numbers (1^{--}).

He also pointed out that CPT invariance would garantee collisions between e- and e+.

Historical Review-ACO (1962-1975)







J. Le Duff

The first beam-beam tune shift limitation found in the world

The first diople magnet detector and antisolenoid

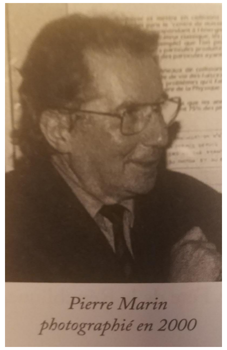
The first using sextupoles to correct chromaticity

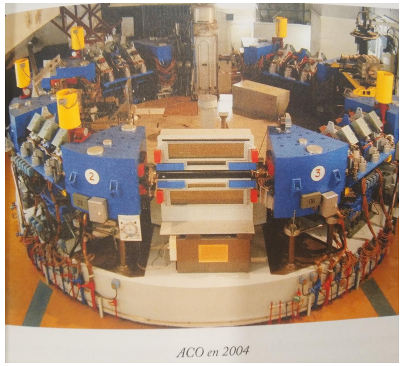
The first observation experimentally electron and positron polarisation

The first observation of bunch lengthening

....

P. Marin



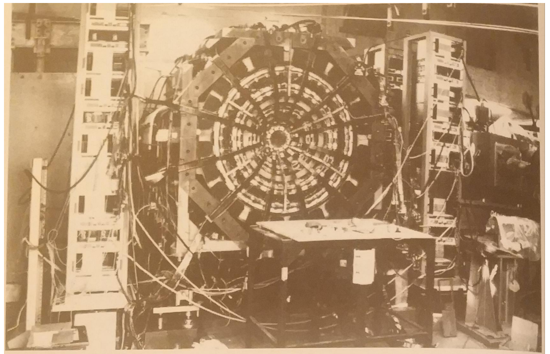


The book of P. Marin was published with the help of ACO Association after P. Marin passed away in 2003

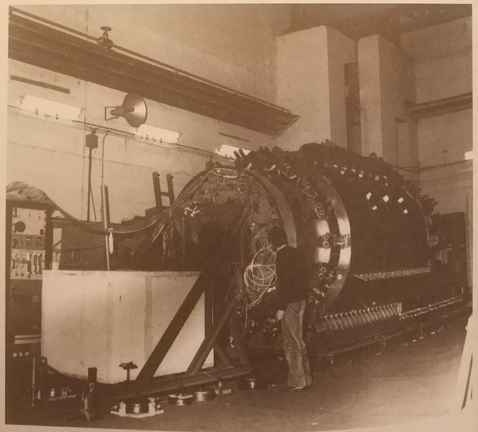
ACO as a museum in LAL, Orsay

Historical Review-DCI

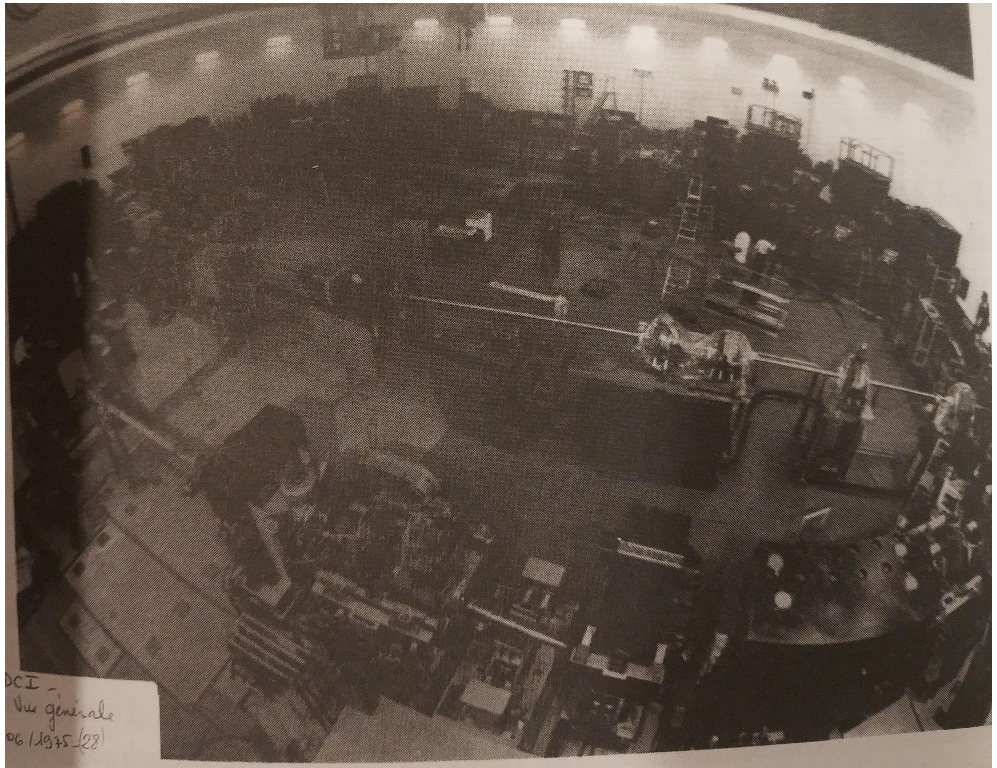
(1971-1985)



Appareillage DM1 avant son installation dans la section d'expériences du DCI, 1977



Assemblage du détecteur DM2 pour l'anneau de collisions DCI, 1978



Vue générale de DCI en 1975

The first two ring electron positron collider in the world

The first experiments on four beam collision
to compensate beam-beam effects

The first individual sextupoles to correct chromaticity

There are many two ring e+e- cirecular colliders afterwards: PEP-II, KEK B, BEPC-II, DAFNE, Super KEK B

....

From BEPC,BEPCII to CEPC

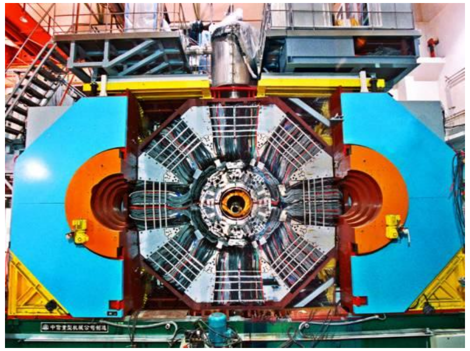
BEPC, the first collider in China, was completed in 1988 with luminosity $1\times10^{31}cm^{-2}s^{-1}$ @1.89GeV

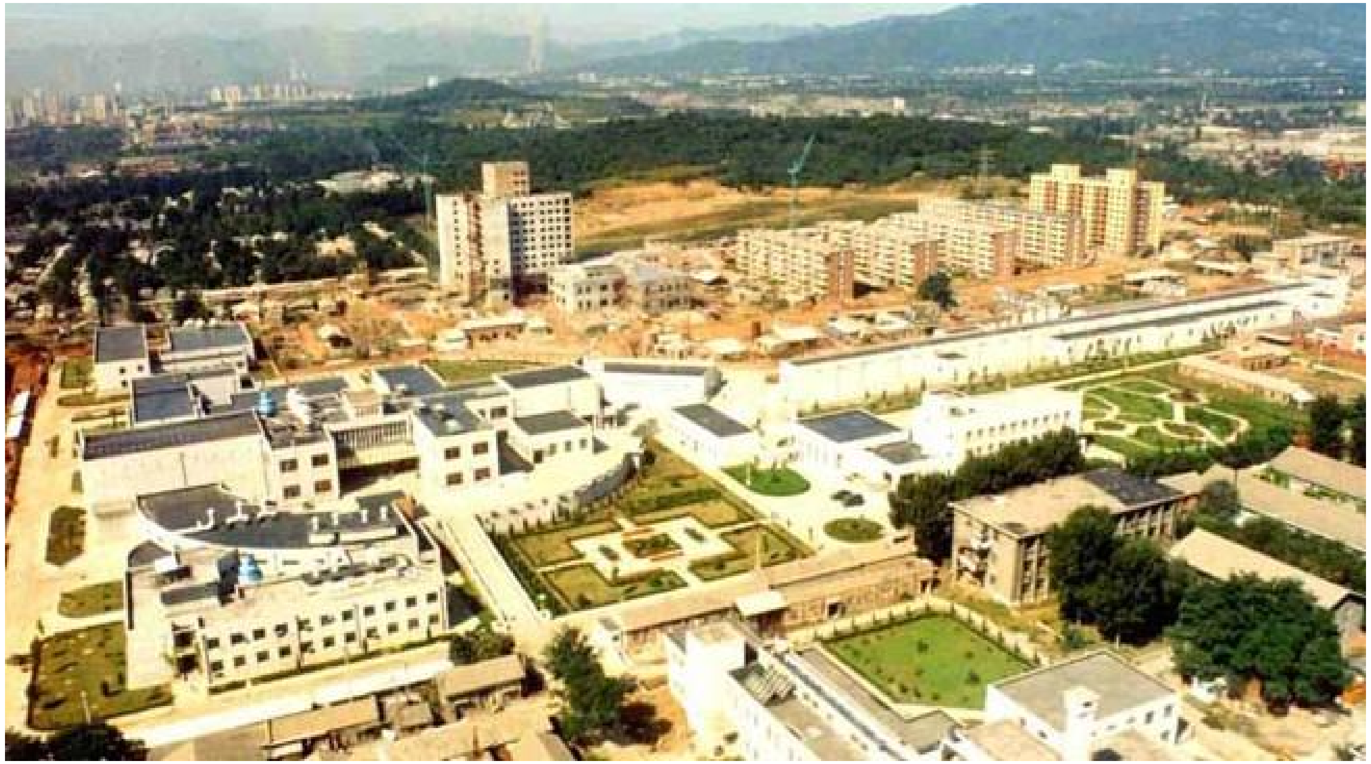
BEPC II was completed in 2009

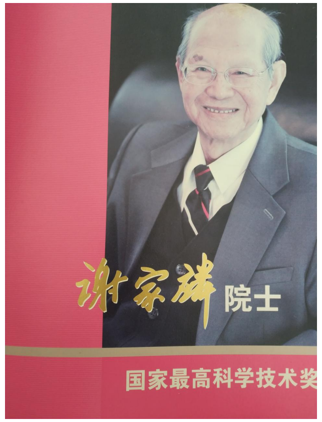
Luminosity reached on April 5, 2016: $10\times10^{32}cm^{-2}s^{-1}$ @1.89GeV

After BEPCII what is the next high energy collider?

Thanks to the discovery of Higgs at LHC@CERN in July 4, 2012, the answer is clear, CEPC!



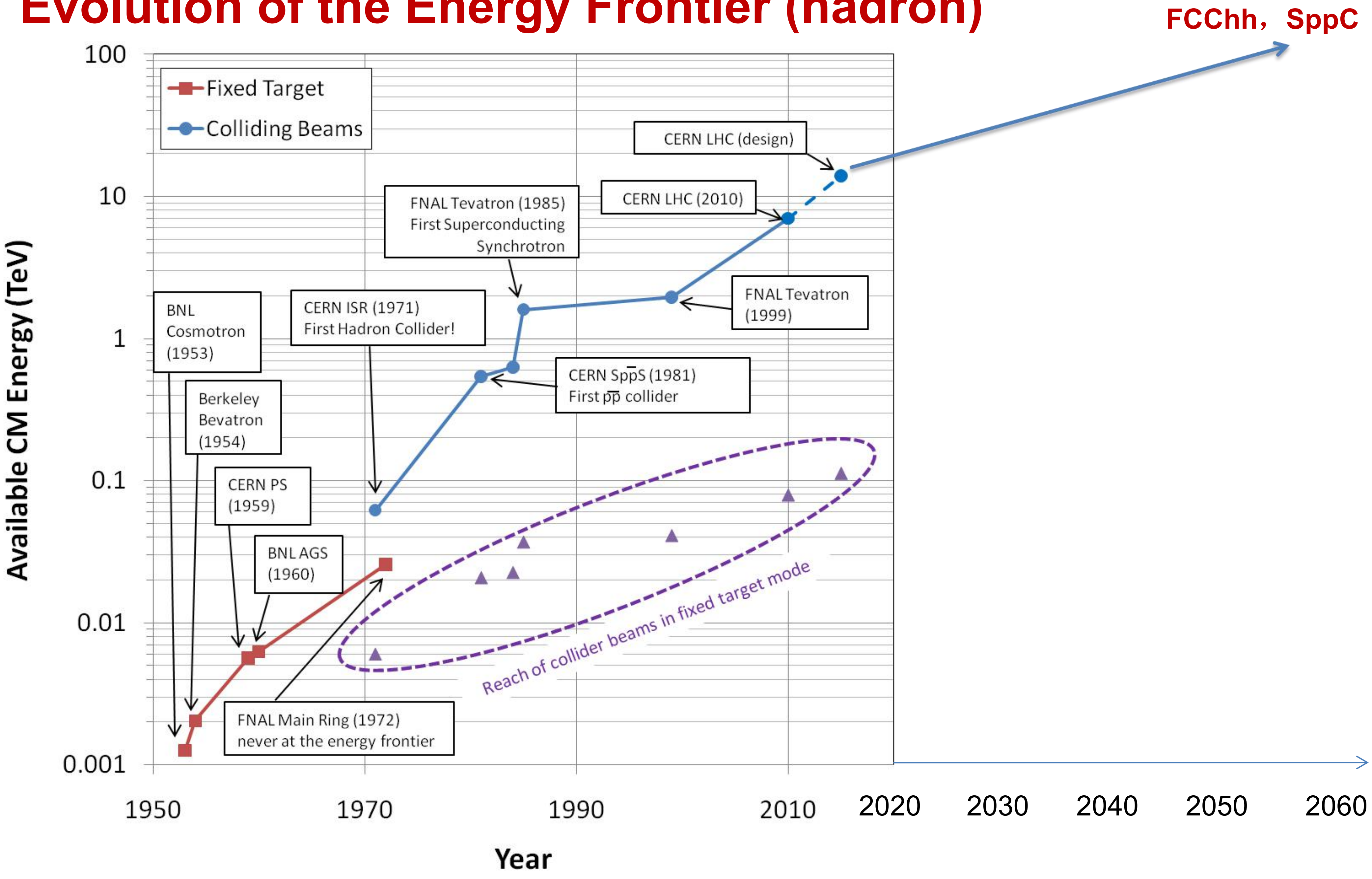




Prof. J. L. Xie

National Scientific and Technology Progress First Prize
for 2016 has been awarded to Prof. J. L. Xie on Jan 9, 2017

Evolution of the Energy Frontier (hadron)



Frank Zimmermann

updated by J. Gao

Past, planned but abandoned, operating & future hadron colliders

ISR (*p-p*) 1970-1983 0.03/0.03 TeV

SPS (*p-pbar*) 1981-1990 0.3/0.3 TeV

[CHEEP (*e*± *-p*) †1978 (?) 0.03/0.3 TeV]

[PEP (*e*± *-p*) †1981 (?) 0.015/0.3 TeV]

[TRISTAN (*e*± *-p*) †1983 (?) 0.03/0.3 TeV]

ISABELLE/CBA (p-p) †1983 0.4/0.4 TeV

Tevatron (*p-pbar*) 1987-2011 1/1 TeV?

HERA (*e*±↑ *-p*) 1991-2007 0.03/1 TeV?

UNK (*p-p*) †1992 (?) 3/3 TeV

SSC (*p-p*) †1993 20/20 TeV

RHIC (*p*↑*-p*↑ & *A-A*) 2000-2024? 0.3/0.3 TeV

LHC (*p-p* & *A-A*) 2009-2035? 3.5/3.5 & 7/7 TeV

SppC (pp, AA, ep) ~2055?- 100TeV

FCC(hh) (pp, AA, ep) ~2055?-100TeV

Luminosity from Colliding Beams in Storage Ring

- **For equally intense Gaussian beams**

$$L = f\,\frac{N_b^{\;2}}{4\pi\sigma_x\sigma_y}R$$

Collision frequency

Particles in a bunch

Geometrical factor:
- crossing angle
- hourglass effect

Transverse beam size (RMS)

- **Expressing luminosity in terms of our usual beam parameters**

$$L[\mathrm{cm}^{-2}\mathrm{s}^{-1}] = 2.17\times10^{34}(1+r)\xi_y\,\frac{E[\mathrm{GeV}]I[\mathrm{A}]}{\beta_y[\mathrm{cm}]}$$

where

$$\xi_y = \frac{r_e N_e \beta_y}{2\pi\sigma_y(\sigma_x+\sigma_y)}$$

In ACO it is found that ξ_y has a maximum value

For exampe, for DCI at 800MeV $\xi_y = 0.024$

Analyical expression for the maximum value of $\xi_{y,max}$ is the keystone of a circular collider both for lepton and hadron one

$$\xi_y = \frac{r_e N_e \beta_y}{2\pi\sigma_y(\sigma_x+\sigma_y)}$$

ximum Beam-beam Tune Shift Analytical Expressions for Lepton and Hadron Circular Colliders

For example: BEPCII@ 1.89GeV $\xi_{y,max} = 0.04$

For lepton collider:

$$\xi_{y,\ max} = \frac{2845}{2\pi}\sqrt{\frac{T_0}{\tau_y \gamma N_{IP}}} \qquad \xi_{y,max} = \frac{2845\gamma}{1}\sqrt{\frac{r_e}{6\pi R N_{IP}}}$$

r_e is electron radius

γ is normalized energy

R is the dipole bending radius

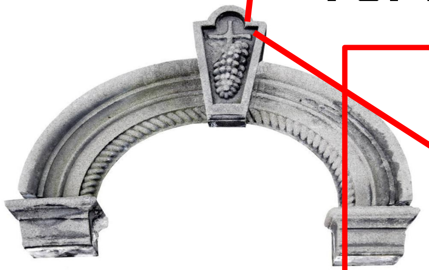
N_{IP} is number of interaction points

$$\xi_{x,\ max} = \sqrt{2}\xi_{y,\ max}$$

J. Gao, **Nuclear Instruments and Methods in Physics Research A** 533 (2004) 270–274

J. Gao, Nuclear Instruments and Methods in Physics Research A 463 (2001) 50–61

For hadron collider:



Keystones

$$\xi_{max} = \frac{2845\gamma}{f(x)}\sqrt{\frac{r_p}{6\pi R N_{IP}}}$$

where r_p is proton radius

$$f(x) = 1 - \frac{2}{\sqrt{2\pi}}\int_0^x \exp(-\frac{t^2}{2})dt$$

$$x^2 = \frac{4f(x)}{\pi\xi_{max}N_{IP}} = \frac{4f^2(x)}{2845\pi\gamma}\sqrt{\frac{6\pi R}{r_p N_{IP}}}$$

J. Gao, "Review of some important beam physics issues in electron positron collider designs", **Modern Physics Letters A**, Vol. 30, No. 11 (2015) 1530006 (20 pages)

J. Gao, et al, "Analytical estimation of maximum beam-beam tune shifts for electron-positron and hadron circular colliders", Proceedings of ICFA Workshop on High Luminosity Circular e+e- Colliders – Higgs Factory, 2014

For example: SppC@100km, 75TeV $\xi_{y,\ max} = 0.0056$

Constraints for CEPC Parameter Choice

- Limit of Beam-beam tune shift

$$\xi_y = \frac{2845}{2\pi}\sqrt{\frac{U_0}{2\gamma E_0 N_{IP}}} \times F_l *$$

F_l: ξy enhancement by crab waist

J. Gao*

- Beam lifetime due to beamstrahlung

BS life time: 30 min

$$\frac{N_e}{\sigma_x \sigma_z} \leq 0.1\eta \frac{\alpha}{3\gamma r_e^2}$$

1) V. Telnov, arXiv:1203.6563v, 29 March 2012
2) V. Telnov, HF2012, November 15, 2012

- Beamstrahlung energy spread

A=δ_0/δ_{BS} (A≥3)

- Beam currect limited by either radiation power or by HOM power per cavity

$$\mathrm{P}_{HOM} = \mathrm{k}(\sigma_z) e N_e * 2 I_b \leq 2 \sim 5KW$$

Or higher value depending on technology

- Tunnel length and beam synchrotron radiation power

L~100km, Prad.=30 (50)MW

*1) J. Gao, emittance growth and beam lifetime limitations due to beam-beam effects in e+e- storage rings, **Nucl. Instr. and methods A**533（2004）p. 270-274.

* 2) J. Gao, Review of some important beam physics issues in electron positron collider designs, **Modern Physics Letters A**, Vol. 30, No. 11 (2015) 1530006 (20 pages)

3) D. Wang, J. Gao, et al, Optimization parameter design of a circular e+e- Higgs factory, **Chinese Physcis C**， Vol. 40, No. 1 (2016) 017001-017007

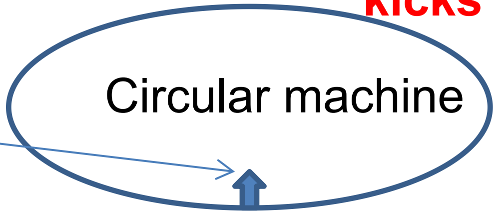
4) D. Wang. J. Gao, eta al, Optimization parameter design of a circular e+e- collider with crab-waist, to be submitted to **Chinese Physcis C**

Basic theory of dynamic aperture in circular accelerator

Linear Hamiltonion +nonlinear perriodic kicks

$$H=\frac{p^2}{2}+\frac{K(s)}{2}x^2+\frac{1}{m!B_0\rho}\frac{\partial^{m-1}B_z}{\partial x^{m-1}}x^m L\sum_{k=-\infty}^{\infty}\delta(s-kL)$$

$$B_z=B_0(1+xb_1+x^2b_2+x^3b_3+\cdots+x^{m-1}b_{m-1}+\cdots)$$



For one multipole $B_z=B_0x^{m-1}b_{m-1}$ m≥3

$$A_{\mathrm{dyna},2m}=\sqrt{2\beta_x(s)}\left(\frac{1}{m\beta_x^m(s(2m))}\right)^{\frac{1}{2(m-2)}}\left(\frac{\rho}{|b_{m-1}|L}\right)^{1/(m-2)}$$

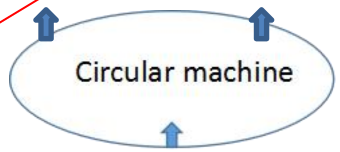
Standard Mapping
Chirikov Criterion

DA relation between X and Y $A_{\mathrm{dyna},2m,y}=\sqrt{\frac{\beta_x(s(2m))}{\beta_y(s(2m))}(A^2_{\mathrm{dyna},2m,x}-x^2)}$

Hénon and Heiles problem

For more independent multipoles

$$A_{\mathrm{dyna,total}}=\frac{1}{\sqrt{\sum_i\frac{1}{A^2_{\mathrm{dyna,sext},i}}+\sum_j\frac{1}{A^2_{\mathrm{dyna,oct},j}}+\sum_k\frac{1}{A^2_{\mathrm{dyna,deca},k}}+\cdots}}$$



Dynamic aperture in circular accelerators is one of the key limitation to the machine performance

Analytical expression of dynamic apertures

J. Gao, "Analytical estimation of the dynamic apertures of circular accelerators", **Nuclear Instruments and Methods in Physics Research A** 451 (2000) 545-557.

CEPC accelerator CDR

CEPC Design –Higgs Parameters

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

CEPC Design – Z-pole Parameters

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

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

CEPC CDR Accelerator Chain and Systems

10 GeV

1) Injector

L=1.2km

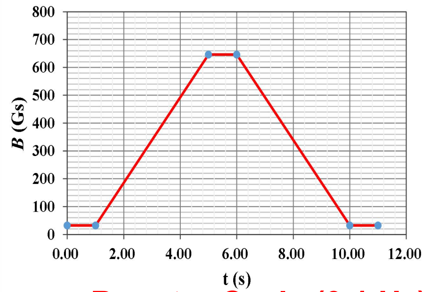
Electron

Positron

2) Booster

C=100km

Energy Ramp
10 ->45/120GeV



Booster Cycle (0.1 Hz)

Three rings in the sane channel:

- CEPC & booster
- SppC

3) Main Ring

C=100km

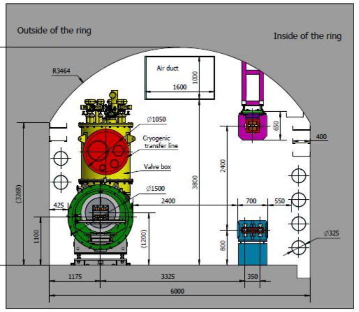
45/120 GeV

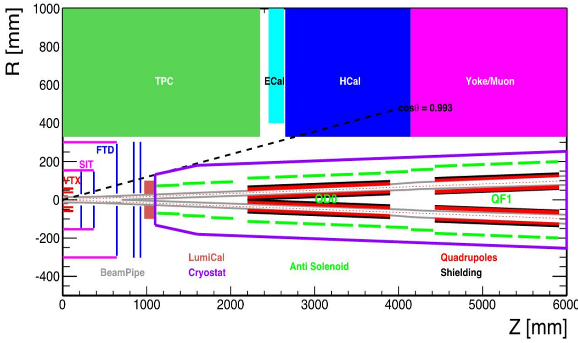
The key systems of CEPC:

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

5) Civil Eng.

TUNNEL CROSS SECTION OF THE ARC AREA

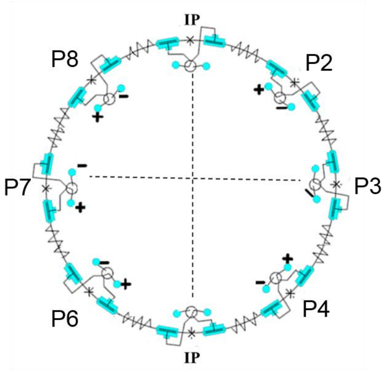




4) Detector Machine Interface (MDI)

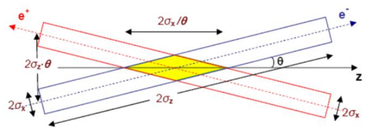
CEPC Four Options Evoluting towards CDR

CEPC Pre-CDR Scheme (head -on collision)

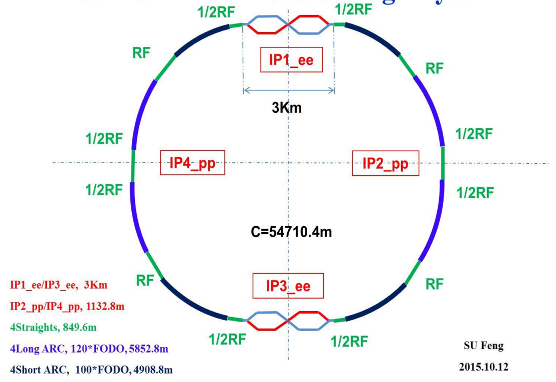


Since Oct 2012

Crab-waist collision in CEPC CDR

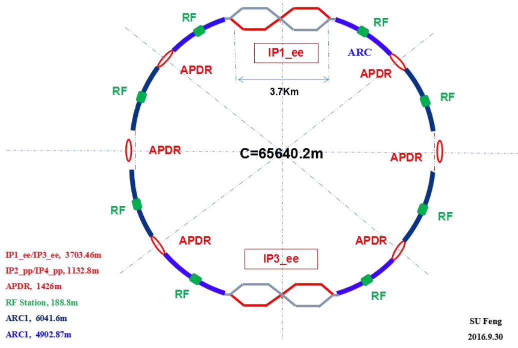


CEPC Partial Double Ring Layout



Since May 2015

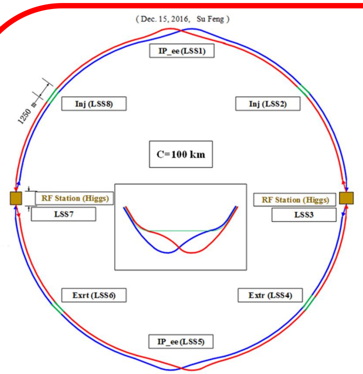
CEPC Advanced Partial Double Ring Option II



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

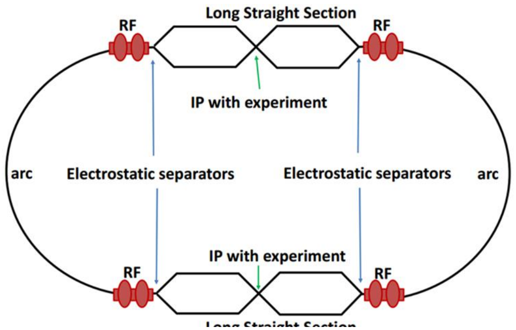


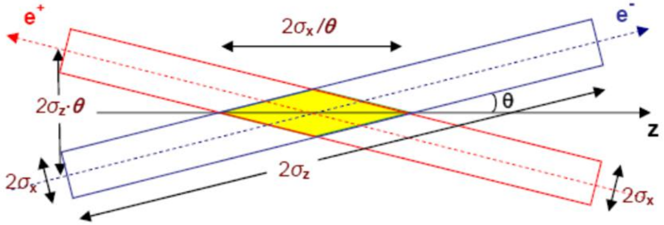
Since Nov 2016

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





MITIGATING PERFORMANCE LIMITATIONS OF SINGLE BEAM-PIPE CIRCULAR e^+e^- COLLIDERS

M. Koratzinos, University of Geneva, Switzerland and F. Zimmermann, CERN, Geneva, Switzerland.

Abstract

Renewed interest in circular e^+e^- colliders has spurred designs of single beam-pipe machines, like the CEPC in China, and double beam pipe ones, such as the FCC-ee effort at CERN. Single beam-pipe designs profit from lower costs but are limited by the number of bunches that can be accommodated in the machine. We analyse these performance limitations and propose a solution that can accommodate O(1000) bunches while keeping more than 90% of the ring with a single beam pipe.

SINGLE BEAM-PIPE LIMITATION

The CEPC collider [1] is a single beam-pipe e^+e^- collider with the main emphasis on 120 GeV per beam running with possible running at 45 and 80 GeV. Bunch separation is ensured by a pretzel scheme and the maximum number of bunches is limited to 50. This very small number of bunches for a modern Higgs factory introduces luminosity limitations at 120 GeV, and severe limitations at any eventual 45 GeV running.

A machine of the size of CEPC at 120 GeV ought to be designed to be operating at the beam-beam limit and not reach the beamstrahlung limit first. The best way to reach this goal is by keeping the bunch charge low and emittances as small as possible. A large momentum acceptance also helps. Another way (and the route chosen for the CEPC) is to keep the bunches as long as possible, but this gives rise to lower instability thresholds as well as to geometric luminosity loss. According to our calculations and with reasonable assumptions for the length of the FODO cell and phase advance, we arrive at an optimal number of bunches of around 120 at 120 GeV [2]. The accommodation of this number of bunches with the pretzel scheme would be more demanding.

For an eventual running at 45 GeV the limit of 50 bunches would be inadequate, as hundreds of bunches would be needed to explore the full potential of the machine [2].

THE 'BOWTIE' DESIGN

Without changing the basic design philosophy of the

apart transversely so that separate beam pipes and magnetic elements can be used to manipulate the electron and positron beams individually, and without any parasitic collisions. The length of the electrostatic separator section would be around 100 m on both sides of the straight section. Since now the beams travel in separate beam pipes, great flexibility about the choice of collision angle is ensured. The FCC-ee is pursuing a crab waist approach which gives excellent performance at low energies and where the crossing angle is 30 mrad.

Assuming a total length of the double beam pipe to be 2×2000m, and assuming that bunches within a train can be separated longitudinally by as little as 2 m (7 ns) then 2×1000 bunches for each species can be accommodated in the machine.

The ratio of single to double beam pipe would be ~4/52 or about 8%. Note that the cost increase would be much smaller than the above figure and actually the cost per luminosity unit would be greatly improved.

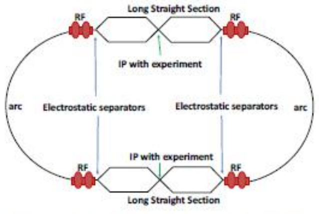


Figure 1: Schematic of the 'bowtie' idea (not to scale)

ELECTROSTATIC SEPARATORS

For illustration purposes we have chosen the LEP electrostatic separators [3]. These were 4 m long, 11 cm wide and the maximum operating voltage was 220 kV. Each separator produced a maximum deflection of 145

IHEP-AC-LC-Note2013-012

ILC-物理-2013-08

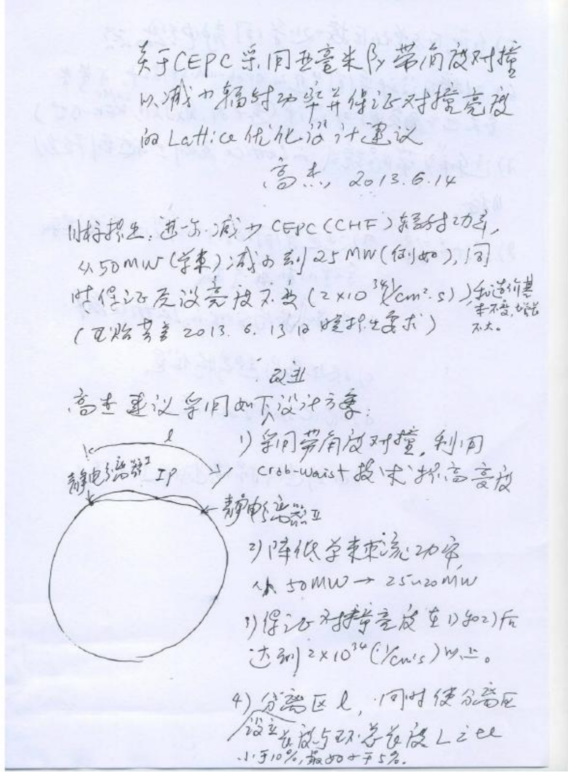
June 16th, 2013

关于CEPC采用亚毫米β_y带角度对撞以减少辐射功率并保证对撞亮度的Lattice优化设计建议

高杰

ILC Group, Accelerator Center

Institute of High Energy Physics (IHEP), Beijing



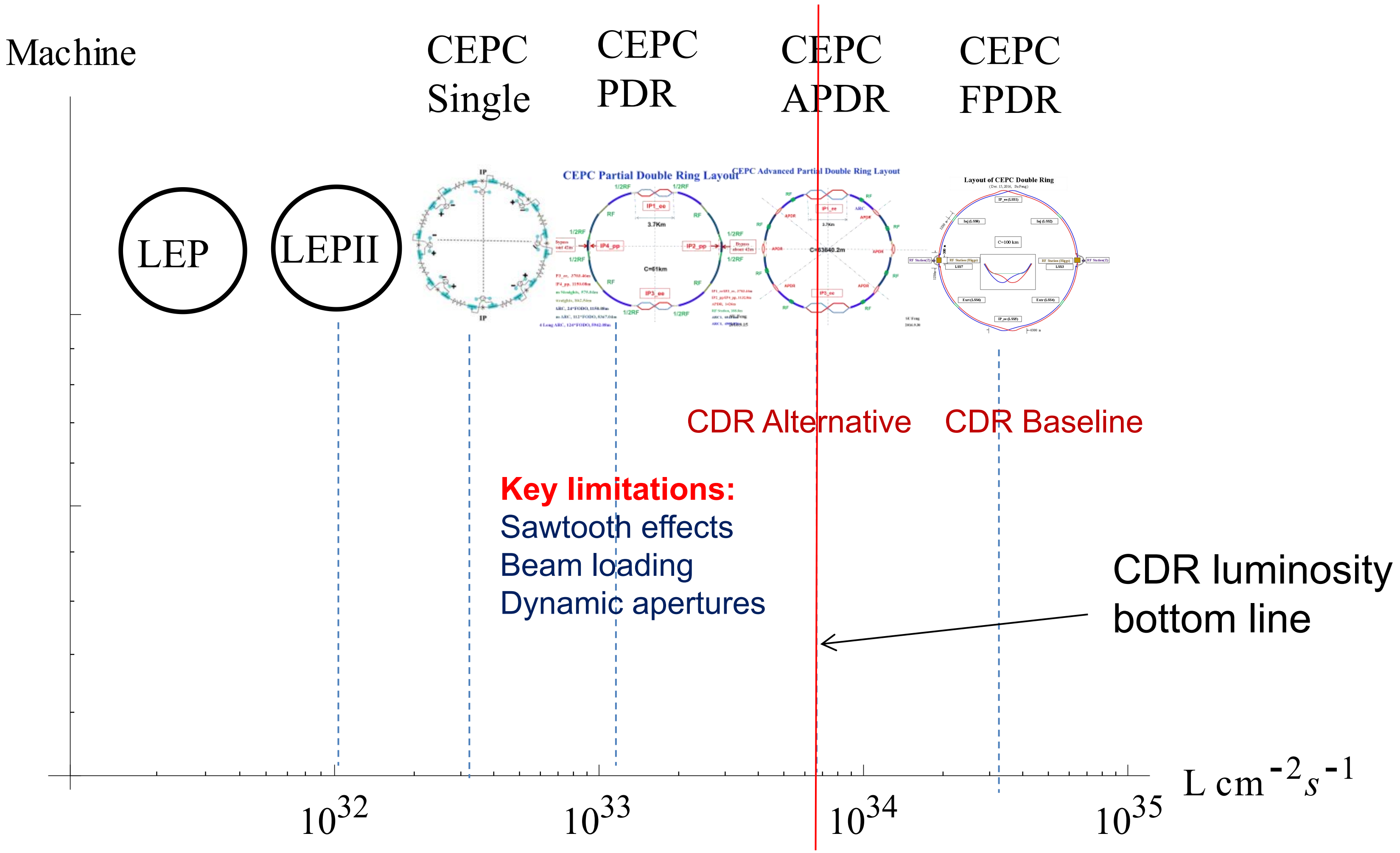
Partial Double Ring is the unique nature of CEPC and FCCee as a Higgs Factory

Partial Double Ring (PDR) was proposed independently at IHEP and CERN：

1）J. Gao, IHEP-AC-LC-Note 2013-012

2）M. Moratzinos and F. Zimmermann，2015 (IPAC 2015 M. Moratzinos and F. Zimmermann)

Collider Schemes vs Luminosity Potentials

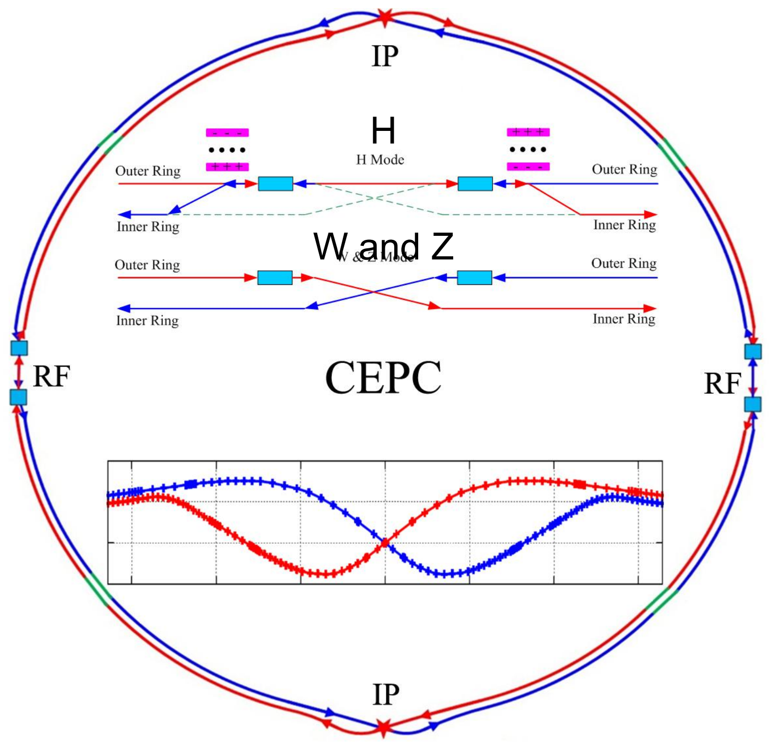


Luminosity H 10^32 <~2*10^34 >2~5*10^34 (cm^-2s^-1)

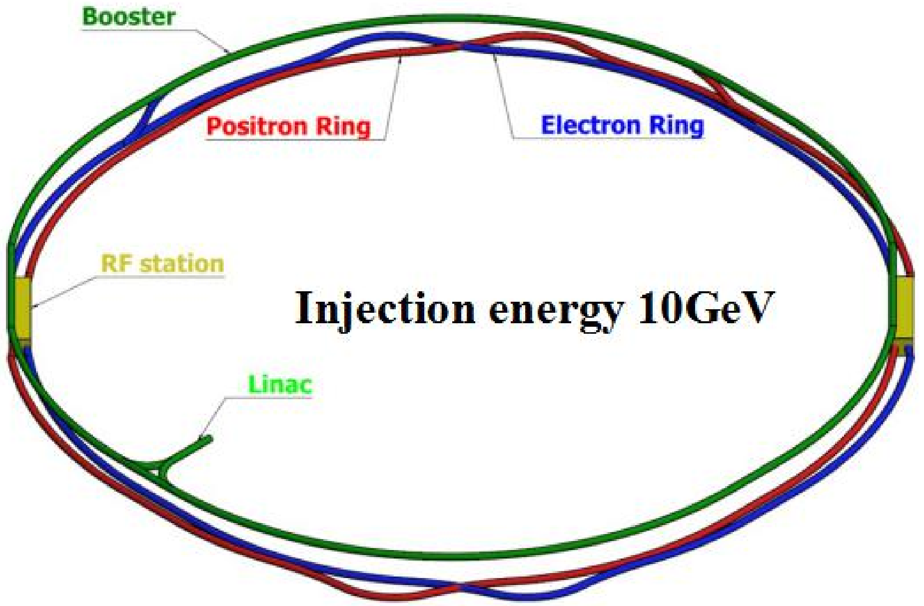
Luminosity Z 10^32 <~1*10^34 >10*10^34 (cm^-2s^-1)

CEPC CDR Baseline Layout

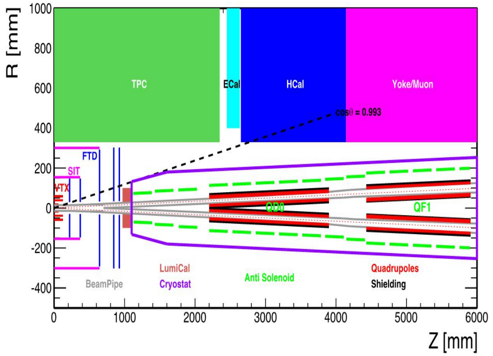
CEPC as a Higgs Factory： H, W, Z, followed by a SppC ~100TeV

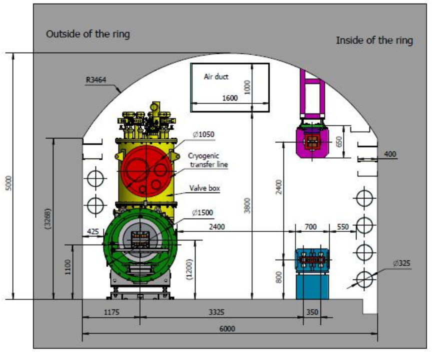


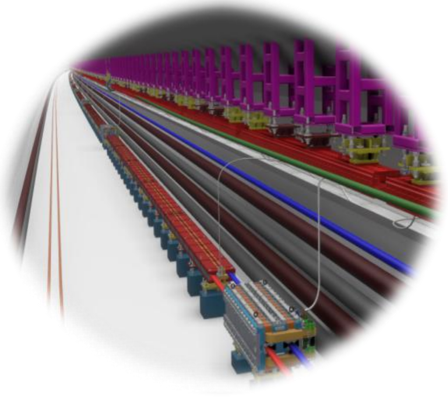
CEPC collider ring (100km)

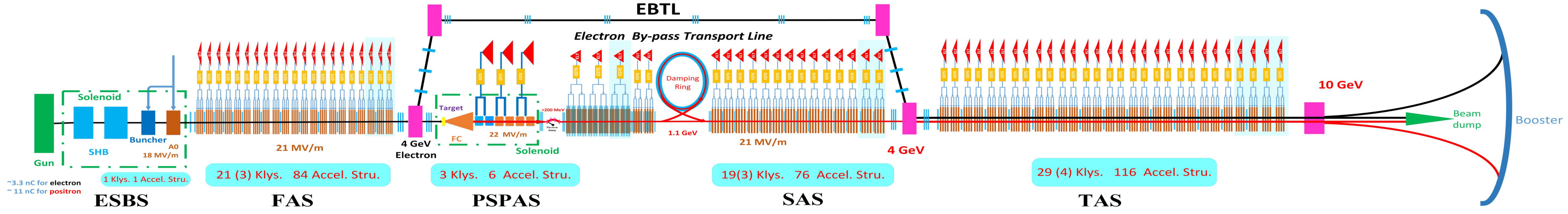


CEPC booster ring (100km)









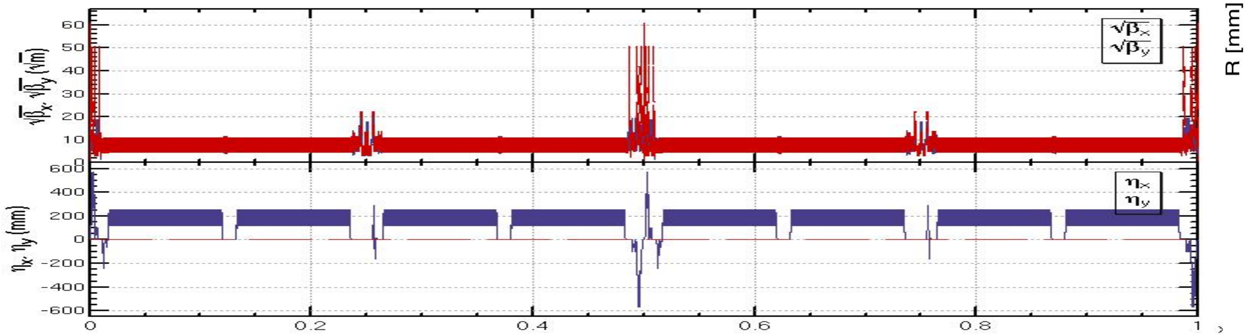
CEPC Linac injector (1.2km, 10GeV)

CEPC CDR Parameters

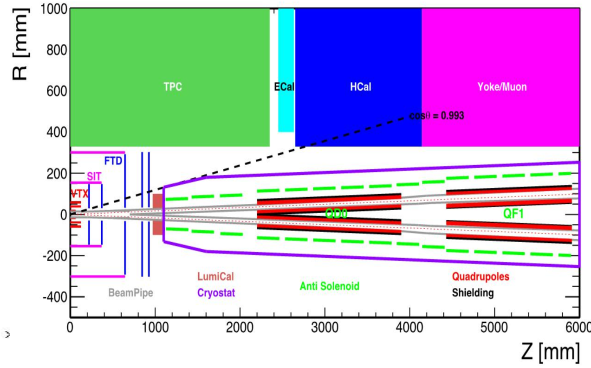
	Higgs	*W*	*Z (3T)*	*Z (2T)*
Number of IPs	2			
Beam energy (GeV)	**120**	**80**	**45.5**	
Circumference (km)	100			
Synchrotron radiation loss/turn (GeV)	1.73	0.34	0.036	
Crossing angle at IP (mrad)	16.5×2			
Piwinski angle	2.58	7.0	23.8	
Number of particles/bunch N_e (10^{10})	15.0	12.0	8.0	
Bunch number (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	
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**

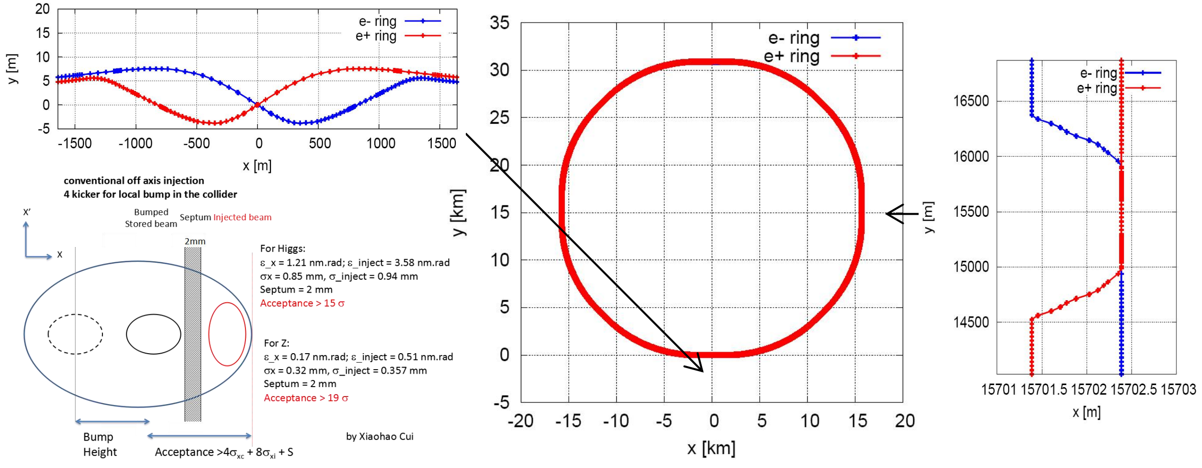
Lattice of the CEPC Collider Ring and MDI

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

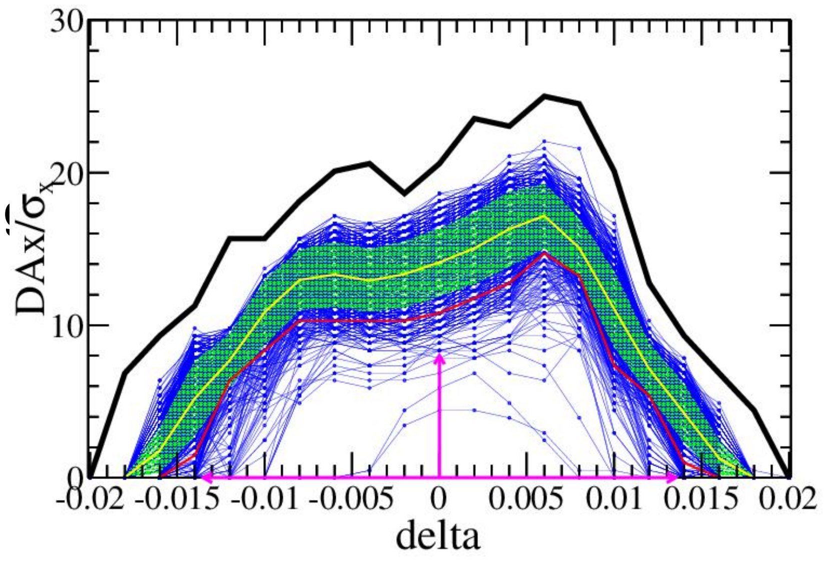
CEPC CDR Lattice DA with Errors

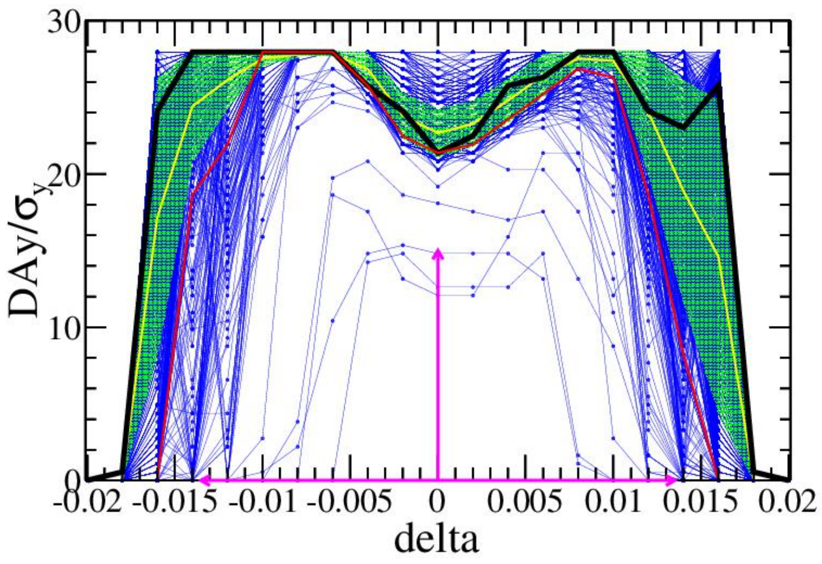
Achieved DA (with errors)@ Higgs: 10σx/21σy/0.00 (on momentum), 2σx/9σy/0.0135 (off momentum)

Design DA goal (with errors)@Higgs: 8σx/15σy/0.00 (on momentum), 1σx/1σy/0.0135 (off momentum)

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	

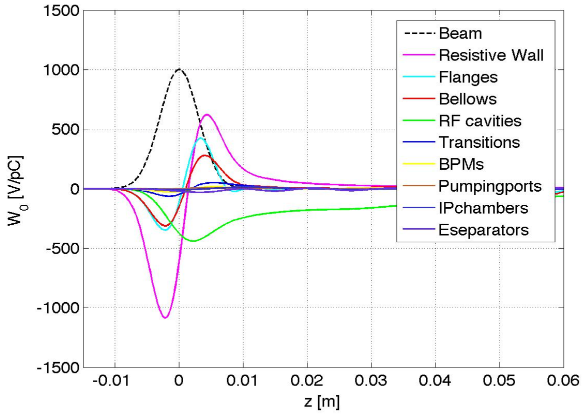
CDR lattice design with errors reached the DA design goal





CEPC Collider Ring Impedance Budget

Components	Number	$Z_{\|\|}/n$, mΩ	k_{loss}, V/pC	ky, kV/pC/m
Resistive wall	-	6.2	363.7	11.3
RF cavities	336	-1.4	315.3	0.41
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		**10.5**	**876.8**	**20.4**



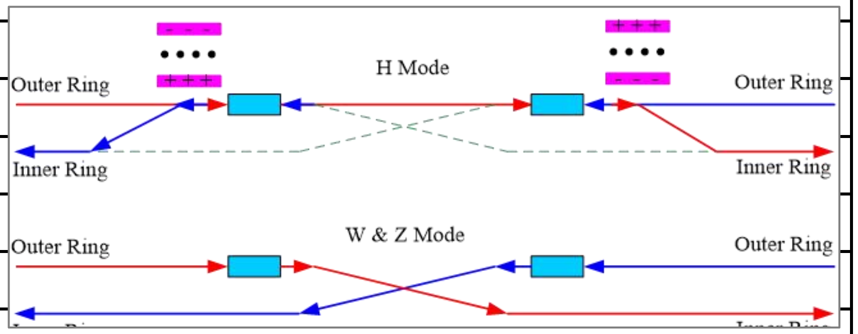
Longitudinal wake at the nominal σ_z = 3mm

Broadband impedance threshold:

Threshold	ttbar	Higgs	W	Z
$\|Z_L/n\|_{eff}$, mΩ	13.6	9.0	8.0	2.1
κ_y, kV/pC/m	81.2	61.6	69.0	38.7

CEPC Collider Ring SRF Parameters

New machine parameters 20190226 SRF parameters 20190301	CDR (2-cell)			HL-Z (new2) (1-cell)				HL-Z (2-cell)	Performance Limits & Risks
	H	W	Z	H	W	Z (a)	Z (b)	Z	
Luminosity / IP [10^{34} cm^{-2}s^{-1}]	2.93	10.1	**32.1**	2.93	10.1	**74.5**	**74.5**	**74.5**	
SR power / beam [MW]	30	30	16.5	30	30	30	30	30	
RF voltage [GV]	2.17	0.47	0.1	2.17	0.47	0.1	0.1	0.1	
Beam current / beam [mA]	17.4	87.7	460	17.4	87.7	838	838	838	
Bunch charge [nC]	24	19.2	12.8	24	19.2	19.2	19.2	19.2	
Bunch number / beam	242	1524	12000	242	1524	14564	14564	14564	
Bunch length [mm]	3.26	5.9	8.5	3.26	5.9	10	10	10	
Cavity number (650 MHz)	**240**	2 x 108	**2 x 60**	**240**	2 x 120	**2 x 120**	**2 x 60**	**2 x 120**	Smart by-pass could be a better approach than 1-cell.
Cell number / cavity	**2**	2	**2**	**1**	1	**1**	1	**2**	Common 1-cell for Z & H/W necessary or different cavity?
Idle cavities on line / ring	0	12	60	0	0	0	**60**	0	Z 2x60 symmetry detune parked half cavities for FM CBI
Cavity gradient [MV/m]	**20**	9.5	3.6	**40**	17	3.6	7.2	1.8	Current status: ~ 10 MV/m in storage ring. Field emission
Q_0 for long term operation	**1.5E10**	1.5E10	1.5E10	**3E10**	3E10	3E10	3E10	1.5E10	~ 1E9 in storage ring. Field emission. Magnetic shield
Input power / cavity [kW]	250	278	**275**	250	250	**250**	**500**	250	~ 300 kW in storage ring. Window events and damages
Klystron max power [kW]	800	800	800	800	800	800	**1400**	800	Klystron max power limit: 1200 kW? KLY # & $
Number of cavities / klystron	2	2	2	2	2	2	**2**	2	Avoid RF power source reconfiguration
HOM power / cavity [kW]	0.57	0.75	**1.94**	0.29	0.37	**2.28**	2.28	**4.57**	HOM coupler capacity (not HOM power per cavity) : 1 kW
Optimal Q_L	1.5E6	3.2E5	4.7E4	3.1E6	5.8E5	2.6E4	5.2E4	1.3E4	Coupler variation range, coupler kick to beam
Optimal detuning [kHz]	0.2	1.0	**17.8**	0.1	0.5	**32.3**	**16.1**	**64.6**	Fundamental mode coupled bunch instability
Wall loss / cavity @ 2 K [W]	25.6	5.9	0.9	25.6	4.8	0.2	0.9	0.2	Field emission will drastically increase the cryogenic load.
Total cavity wall loss [kW]	6.1	1.3	0.1	6.1	1.2	0.05	0.05	0.05	(cryogenic wall loss in two rings)



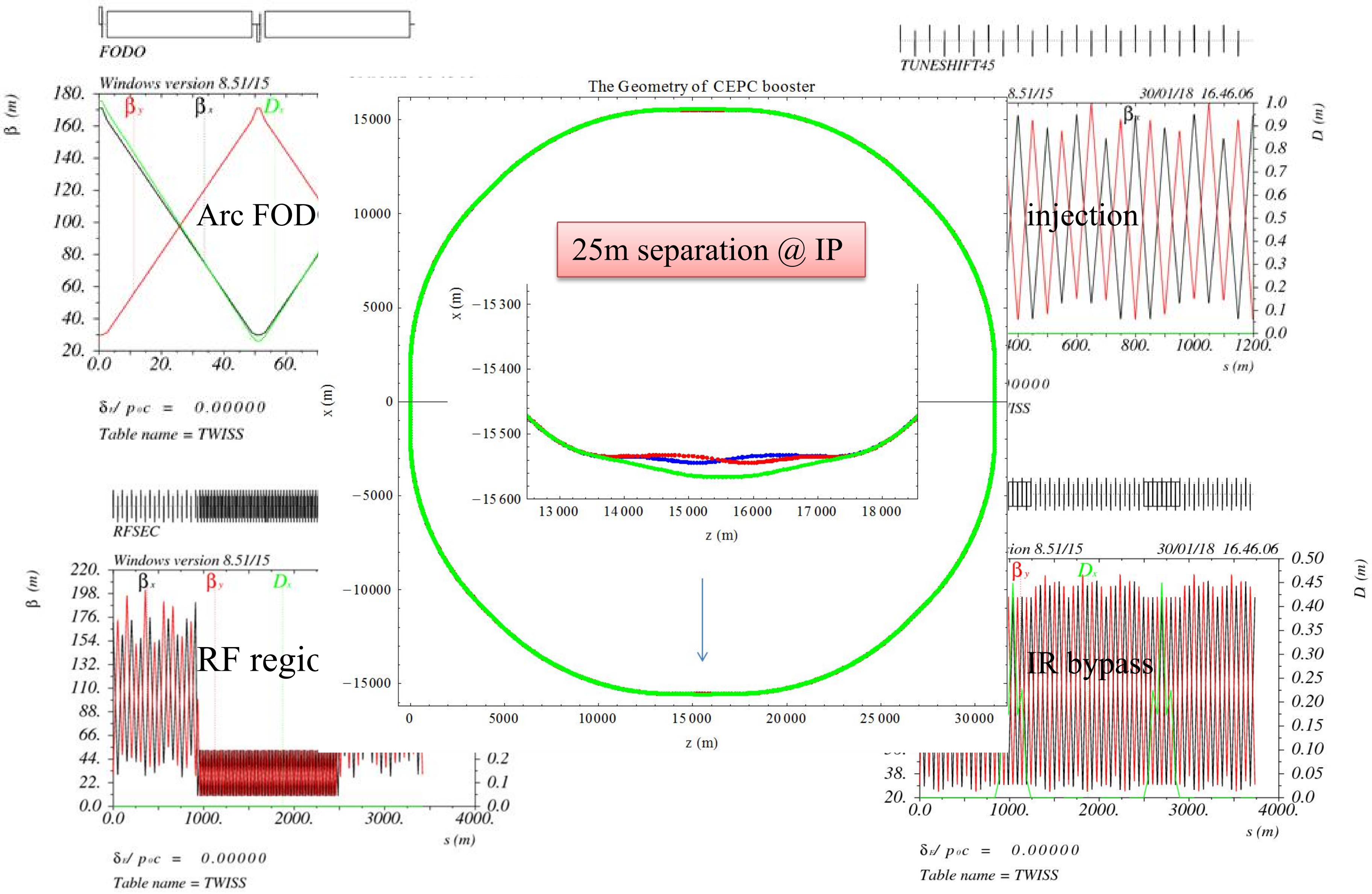
CEPC CDR Booster Parameters @ Injection (10GeV)

		H	*W*	*Z*
Beam energy	GeV	10		
Bunch number		242	1524	6000
Threshold of single bunch current	μA	25.7		
Threshold of beam current (limited by coupled bunch instability)	mA	127.5		
Bunch charge	nC	0.78	0.63	0.45
Single bunch current	μA	2.3	1.8	1.3
Beam current	mA	0.57	2.86	7.51
Energy spread	%	0.0078		
Synchrotron radiation loss/turn	keV	73.5		
Momentum compaction factor	10^{-5}	2.44		
Emittance	nm	0.025		
Natural chromaticity	H/V	-336/-333		
RF voltage	MV	62.7		
Betatron tune $\nu_x/\nu_y/\nu_s$		263.2/261.2/0.1		
RF energy acceptance	%	1.9		
Damping time	s	90.7		
Bunch length of linac beam	mm	1.0		
Energy spread of linac beam	%	0.16		
Emittance of linac beam	nm	40~120		

CEPC CDR Booster Parameters @ Extraction

		H		*W*	*Z*
		Off axis injection	On axis injection	Off axis injection	Off axis injection
Beam energy	GeV	120		80	45.5
Bunch number		242	235+7	1524	6000
Maximum bunch charge	nC	0.72	24.0	0.58	0.41
Maximum single bunch current	μA	2.1	70	1.7	1.2
Threshold of single bunch current	μA	300			
Threshold of beam current (limited by RF power)	mA	1.0		4.0	10.0
Beam current	mA	0.52	1.0	2.63	6.91
Injection duration for top-up (Both beams)	s	25.8	35.4	45.8	275.2
Injection interval for top-up	s	73.1		153.0	438.0
Current decay during injection interval		3%			
Energy spread	%	0.094		0.062	0.036
Synchrotron radiation loss/turn	GeV	1.52		0.3	0.032
Momentum compaction factor	10^{-5}	2.44			
Emittance	nm	3.57		1.59	0.51
Natural chromaticity	H/V	-336/-333			
Betatron tune ν_x/ν_y		263.2/261.2			
RF voltage	GV	1.97		0.585	0.287
Longitudinal tune		0.13		0.10	0.10
RF energy acceptance	%	1.0		1.2	1.8
Damping time	ms	52		177	963
Natural bunch length	mm	2.8		2.4	1.3
Injection duration from empty ring	h	0.17		0.25	2.2

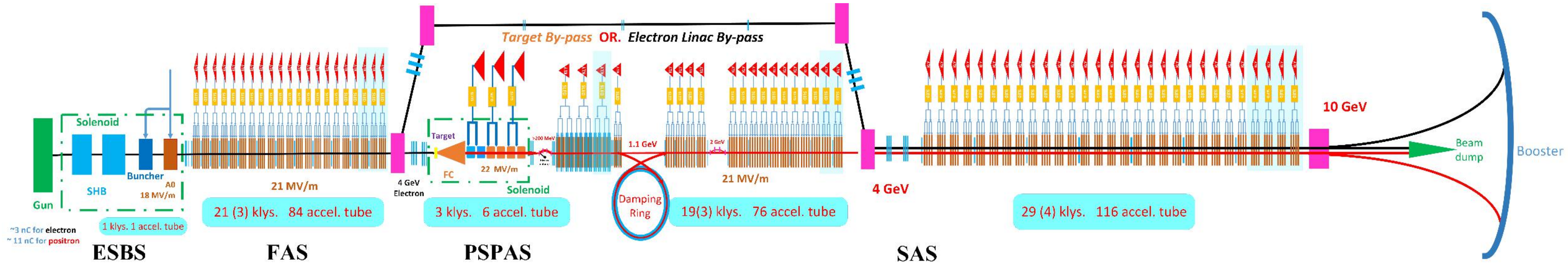
CEPC CDR Booster Optics & Geometry



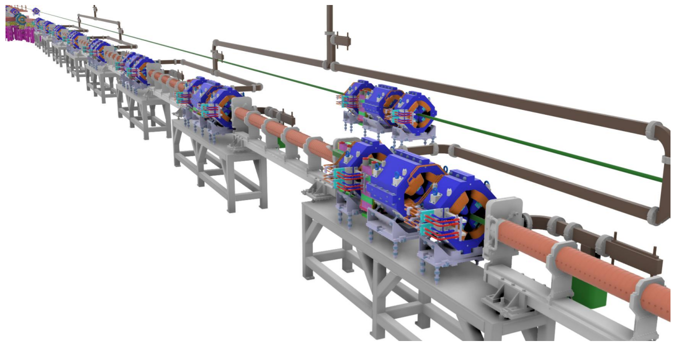
CEPC CDR Booster SRF Parameters

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 CDR Linac Injector



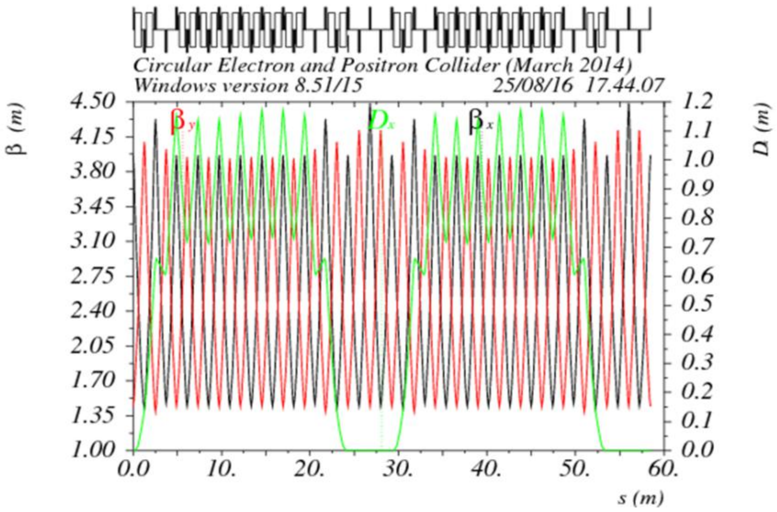
Parameter	Symbol	Unit	Baseline	Design reached
e^- /e^+ beam energy	E_{e-}/E_{e+}	GeV	**10**	**10**
Repetition rate	f_{rep}	Hz	**100**	**100**
e^- /e^+ bunch population	N_{e-}/N_{e+}		> 9.4×10^9	**1.9×10^{10} / 1.9×10^{10}**
		nC	**> 1.5**	**3.0**
Energy spread (e^- /e^+)	σ_e		**< 2×10^{-3}**	**1.5×10^{-3}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

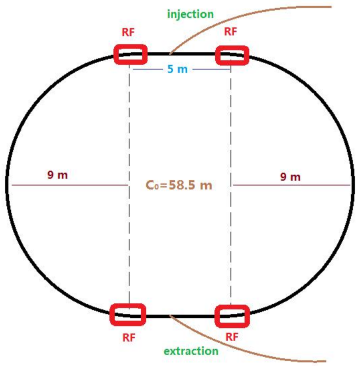


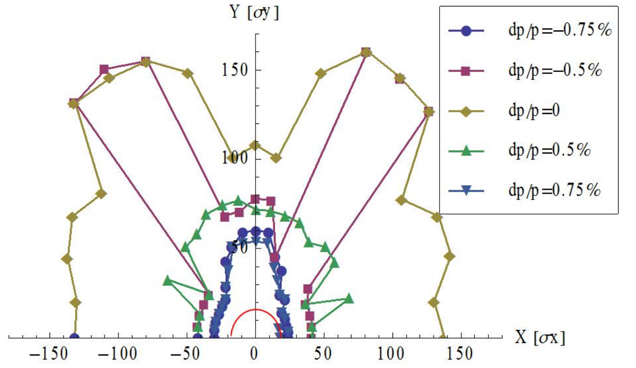
CEPC CDR Linac Injector Damping Ring

Parameters, lattice and layout

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







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

CEPC CDR Damping Ring Main RF Parameters

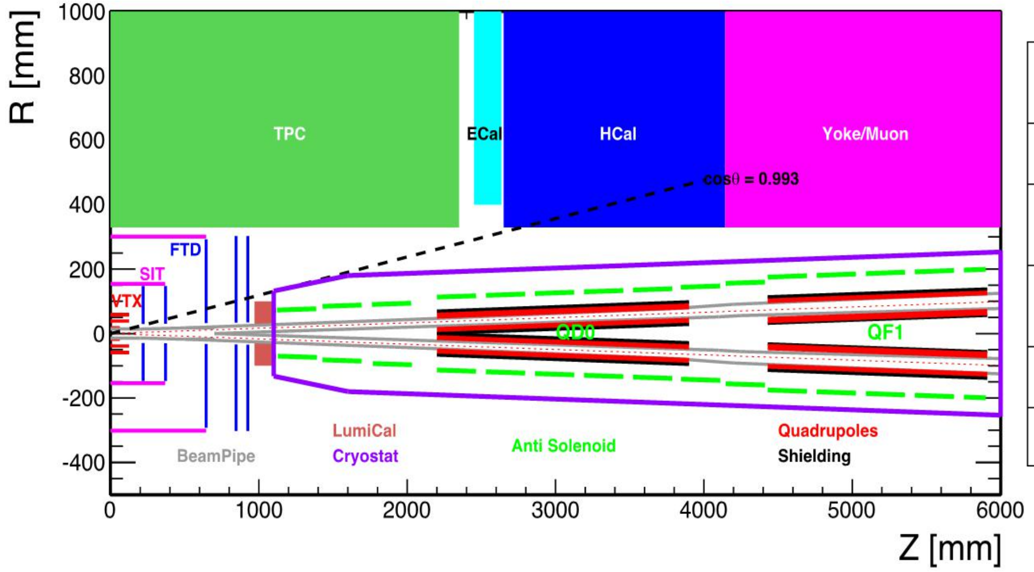
Circumference [m]	75.4
Beam energy [GeV]	1.1
SR loss/ turn [keV]	36.3
Revolution frequency [MHz]	3.98
SR power / beam [W]	433
Momentum compactor	7.82E-02
Beam current [mA]	11.9
Max Bunch charge [nC]	1.5
Number of bunches stored at a time	2
RF voltage [MV]	2.0
RF frequency [MHz]	650
Harmonic number	164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

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

Injection from Booster to Collider

Mode	Higgs		W		Z	
Injection Mode	Top-up	Full	Top-up	Full	Top-up	Full
Bunch number	242		1220		6000	
Bunch Charge (nC)	0.72	1	0.72	1	0.384	0.55
Beam Current (mA)	0.5227	0.726	2.63	3.67	6.91	10
Current threshold	1 mA		4 mA		10 mA	
Number of Cycles	1		1		2	
Current decay	3%		3%		3%	
Ramping Cycle (sec) (Up + Down）	10		6.6		3.8	
Filling time (sec) （e+， e-)	25.84		39.6		275.2	
Injection period (sec)	47		131		438	
Full Injection time	10 min		15 min		2.2 Hour (collide from 230mA	

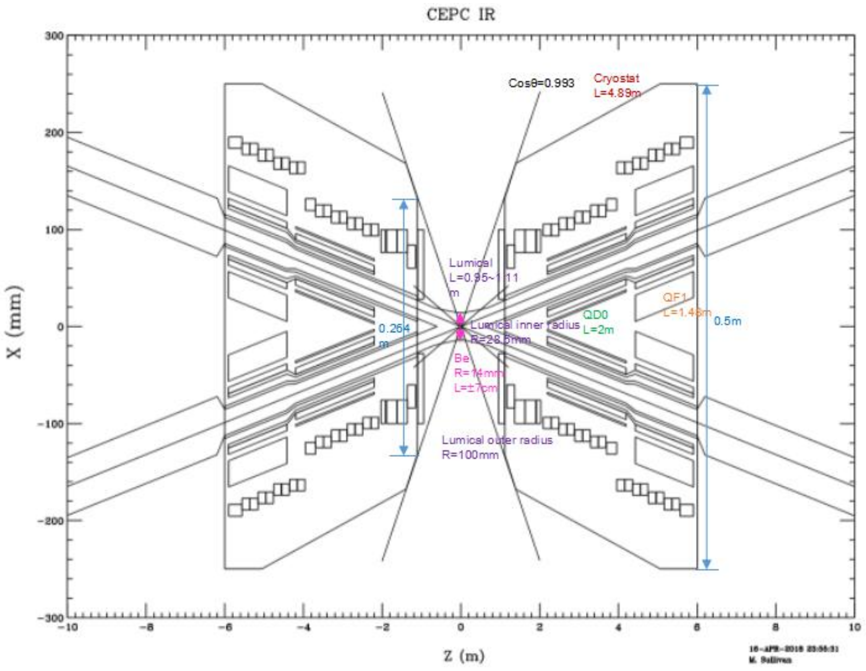
CEPC CDR MDI Layout and Parameters

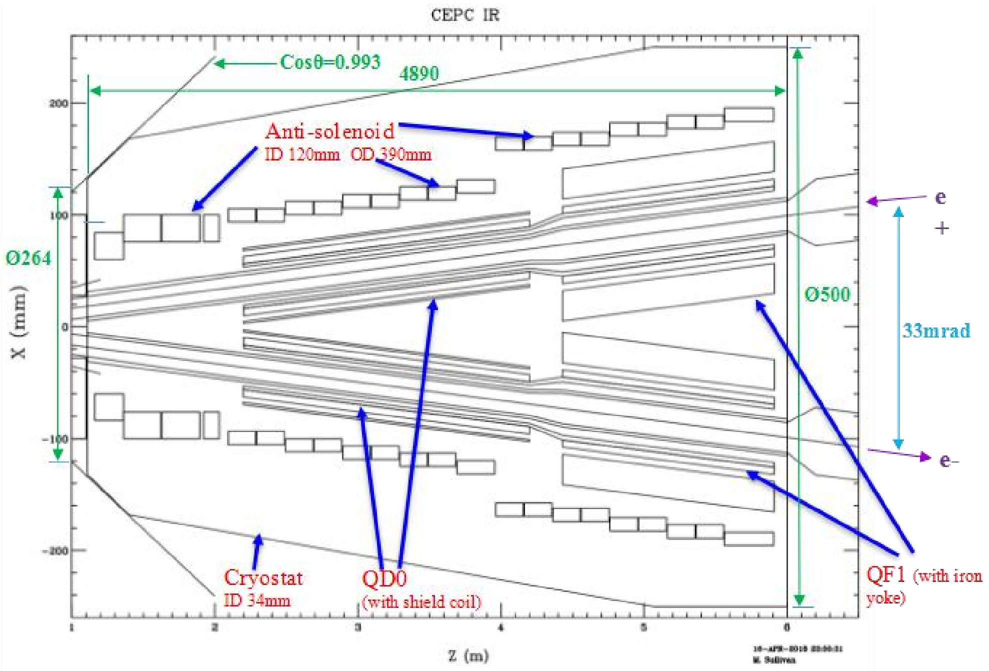


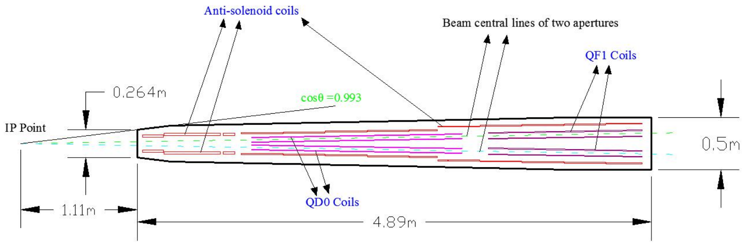
MDI parameters	Values
*L** (m)	2.2
Crossing angle (mrad)	33
Strength of QD0 (T/m)	150
Strength of detector solenoid (T)	3.0
Strength of anti-solenoid (T)	7.0

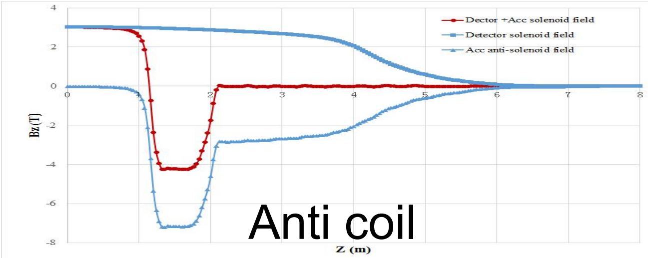
- The Machine Detector Interface of CEPC double ring scheme is about ±7m long from the IP.
- The CEPC detector superconducting solenoid with 3 T magnetic field and the length of 7.6m.
- The accelerator components inside the detector without shielding are within a conical space with an opening angle of 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 Final Focus Magnets & Cryostat

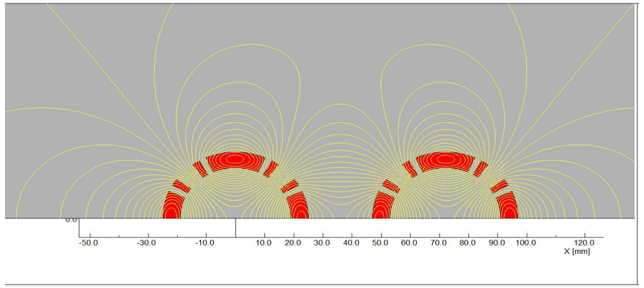


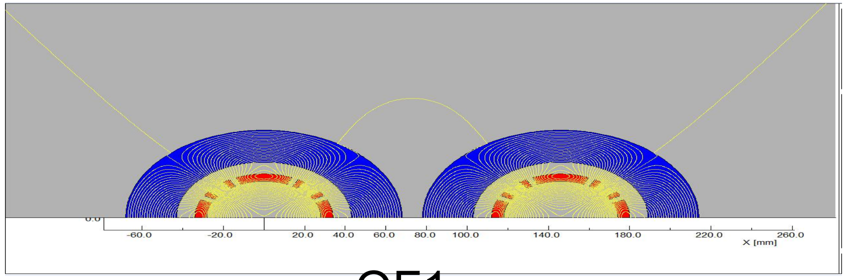






Anti coil


QD0


QF1

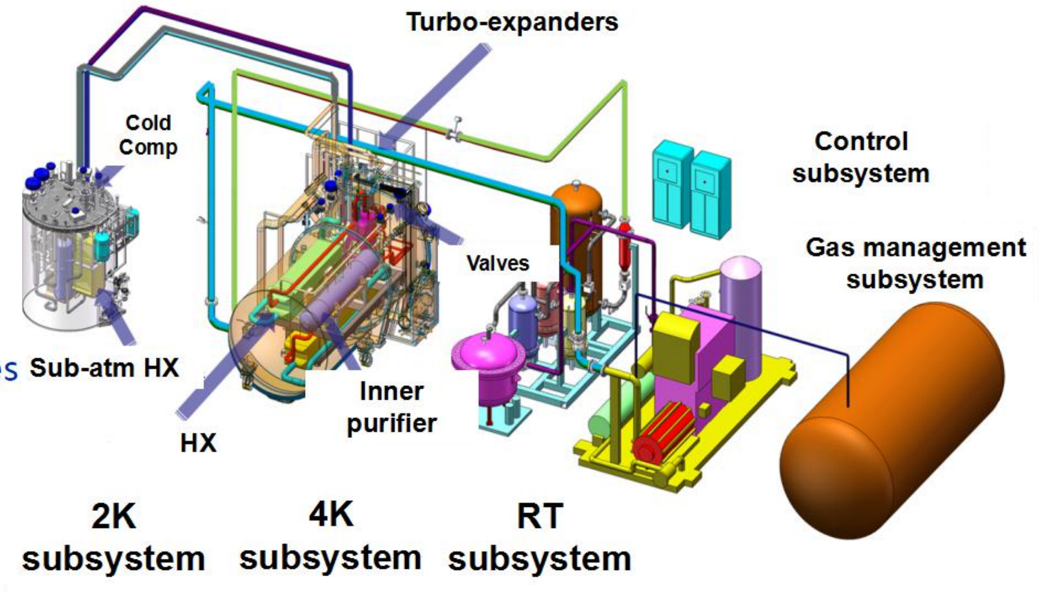
CEPC CDR Cryogenic System

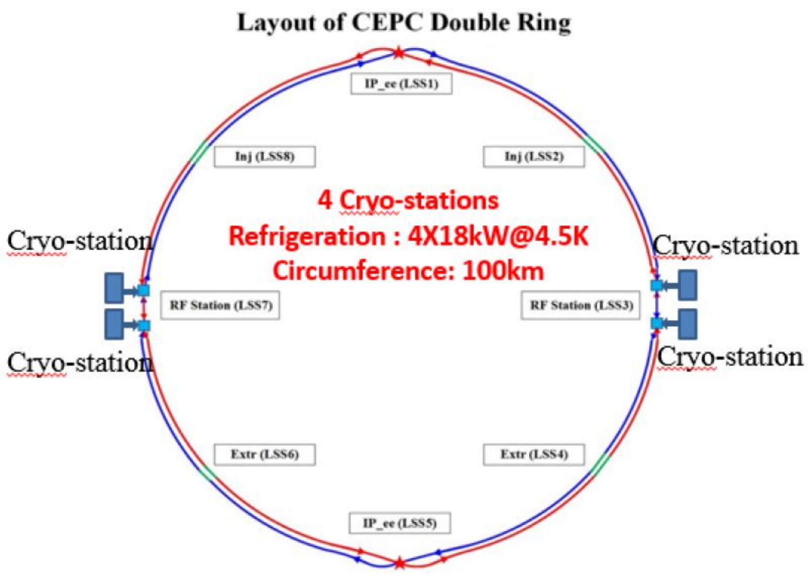
Booster ring:

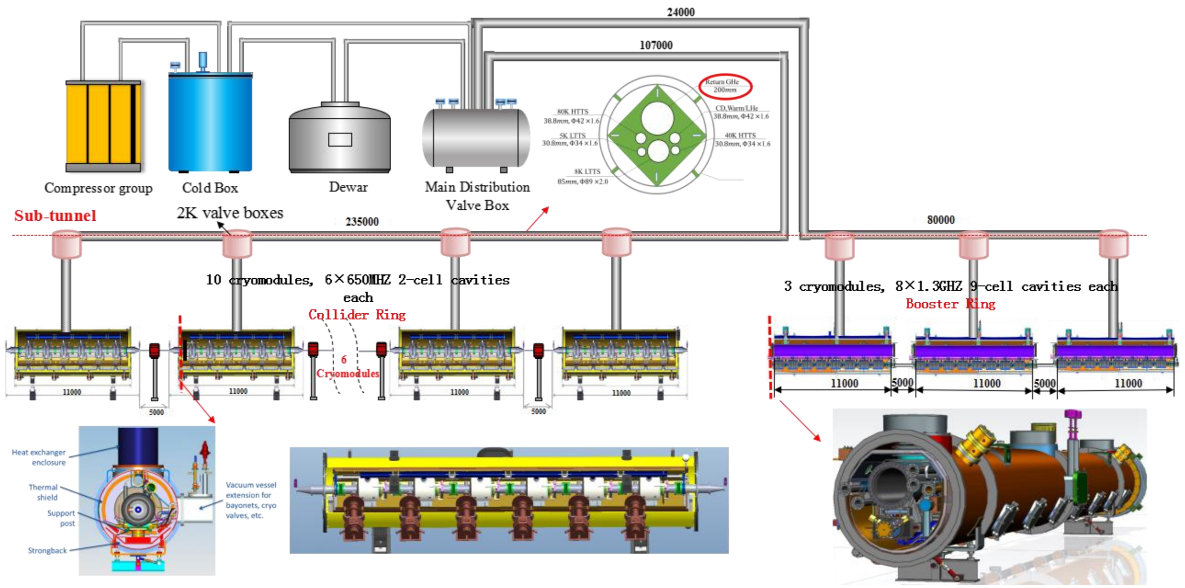
- 1.3 GHz 9-cell cavities, 96 cavities
- 12 cryomodules
- 3 cryomodules/each station
- Temperature: 2K/31mbar

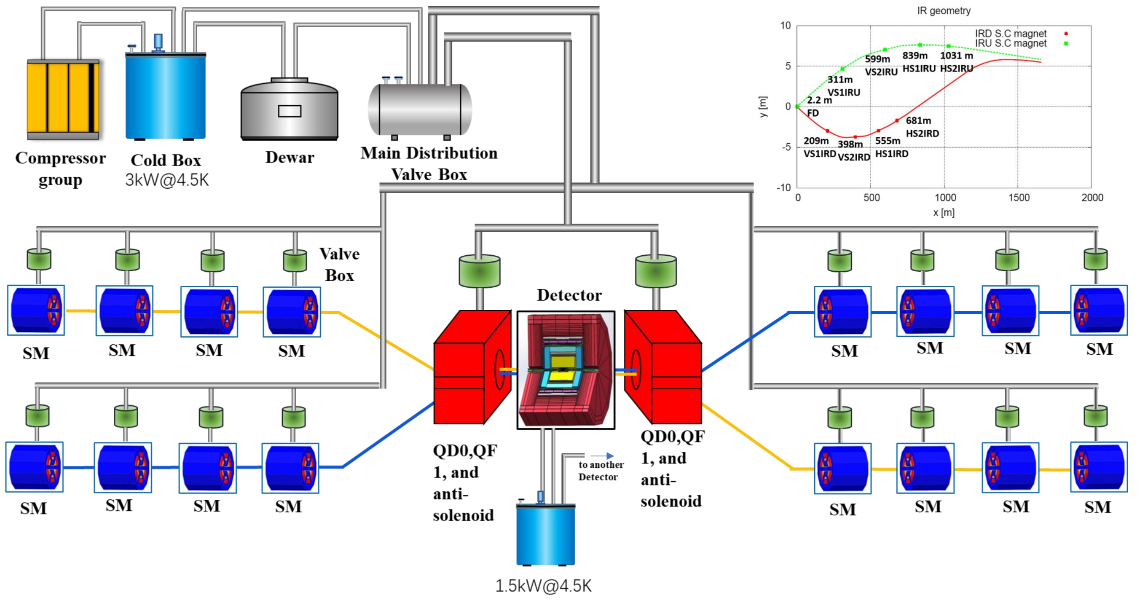
Collider ring:

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









CEPC CDR Power for Higgs and Z

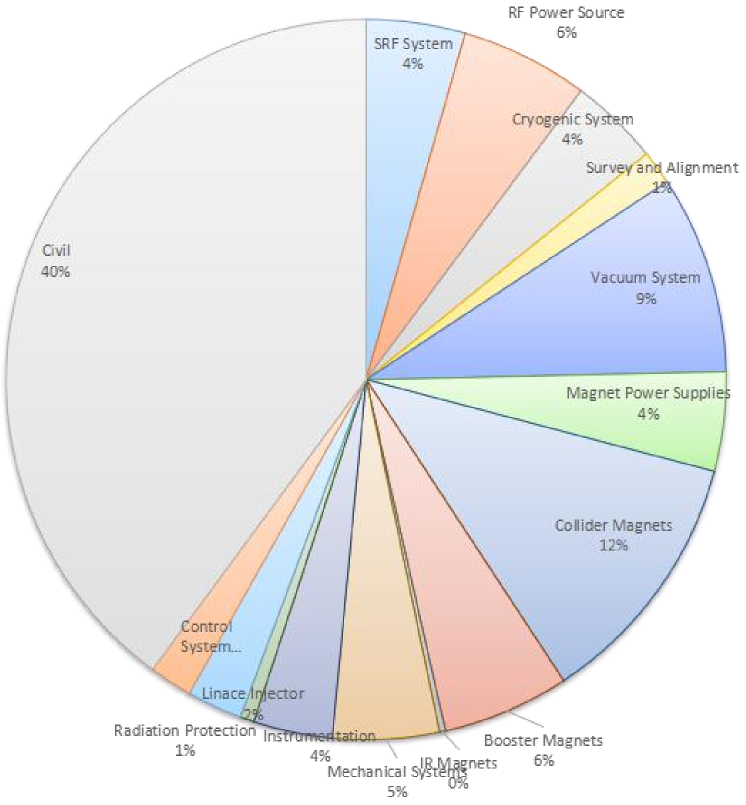
	System for Higgs (30MW)	Location and electrical demand(MW)						Total (MW)
		Ring	Booster	LINAC	BTL	IR	Surface building	
1	RF Power Source	103.8	0.15	5.8				109.75
2	Cryogenic System	11.62	0.68			1.72		14.02
3	Vacuum System	9.784	3.792	0.646				14.222
4	Magnet Power Supplies	47.21	11.62	1.75	1.06	0.26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

266MW

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

149MW

CEPC CDR Cost Breakdwon (no detector)



Total cost of CEPC: 5Billion USD

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

International Review of CEPC CDR

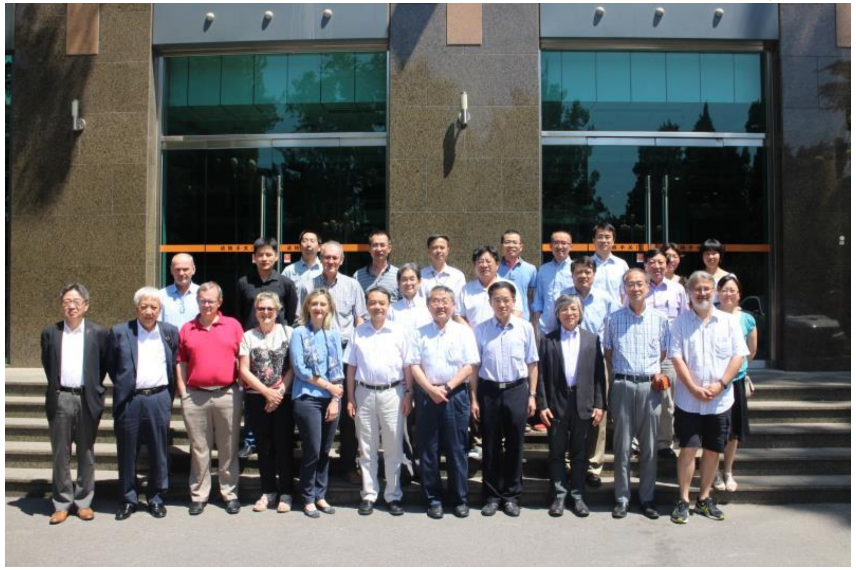
June 28 – 30, 2018, IHEP, Main Building, Room A415

Agenda

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

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

Saturday, June 30		
8:30-9:00 9:00-9:30 9:30-10:00 10:00-10:30	Chair: K. Oide Survey and alignment Mechanics Conventional facilities Site investigation	Xiaolong Wang Haijing Wang Guoping Lin 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/Tohoku 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.

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...

The Committee believes that the CDR has already reached a sufficient level of maturity to allow approval to proceed to a Technical Design Report.

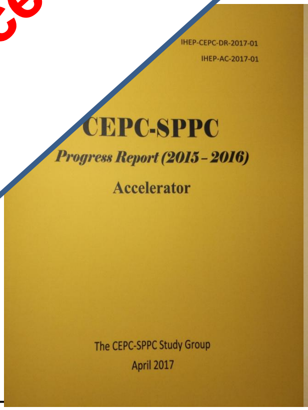
CEPC Accelerator from Pre-CDR … R towards TDR

CEPC accelerator CDR completed in June 2018 (to be … y 2018)

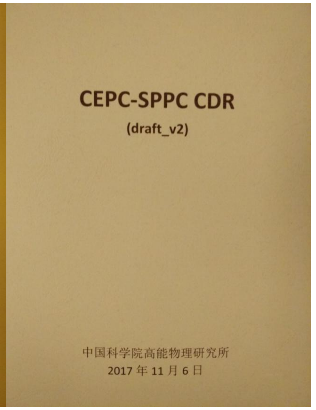
CEPC TDR R&D Started based on CDR since 2019

- – 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, Bo… and Collider
- 8. Super Proton Proton Collider
- 9. Conventional Facilities
- 10. Environment, Health and Saf…
- 11. R&D Program
- 12. Project Plan, Cost and S…
- – Appendix 1: CEPC …
- – Appendix 2: CE… …ent List
- – Appendix 3: … Requirement
- – Appendix … Double Ring
- – Append… Based on Plasma Wakefield Accelerator
- – App… …s a High Intensity γ-ray Source
- – A… …n for e-p, e-A and Heavy Ion Collision
- – … …tunities for Polarization in the CEPC
- … …ernational Review Report

March 2015

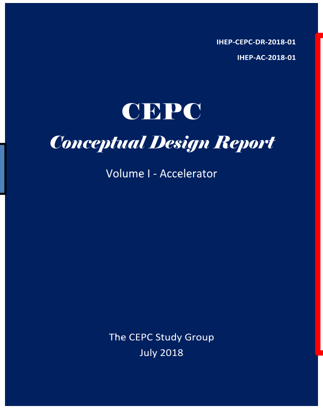


April 2017



Draft CDR for Mini International Review in Nov. 2017

CEPC CDR Vol. I and II was publically released in Nov. 2018



CEPC Accelerator Submitted to European Strategy in 2019

1) CEPC accelerator: ArXiv: 1901.03169
2) CEPC Physics/Detector: 1901.03170

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

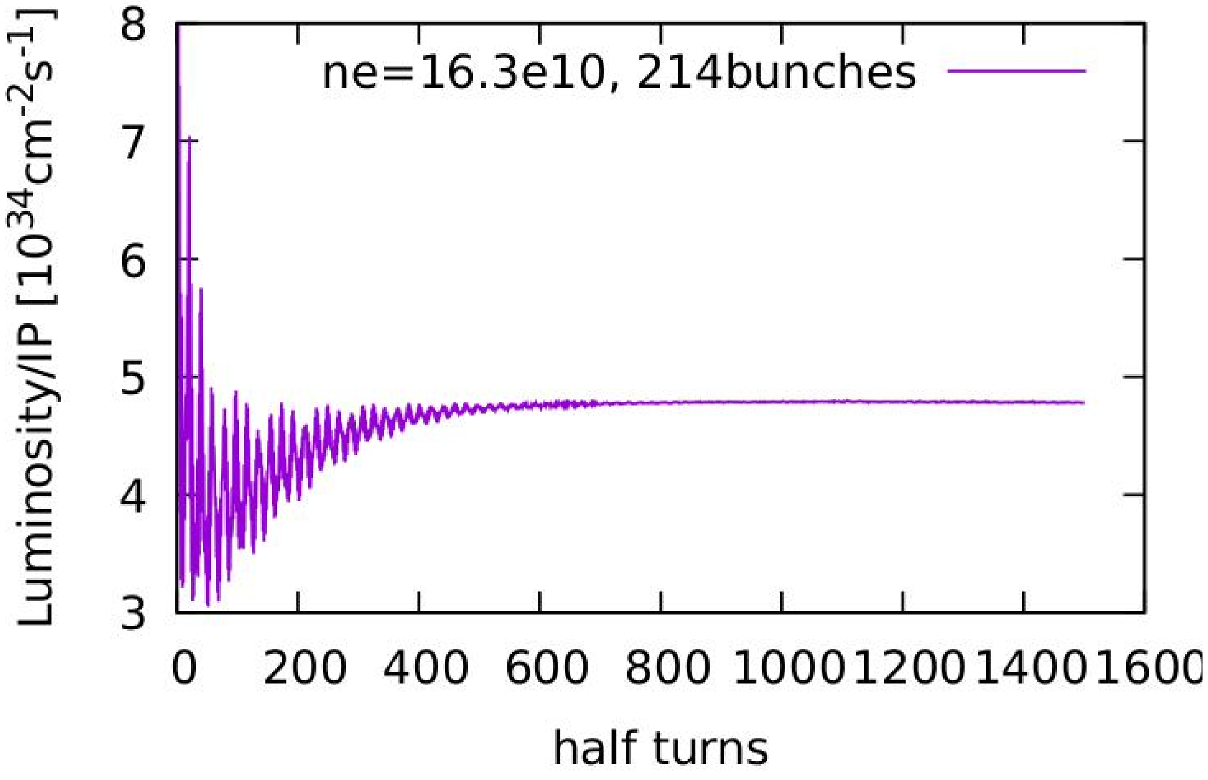
CEPC TDR Optimization Design

CEPC High Luminosity Parameters in TDR

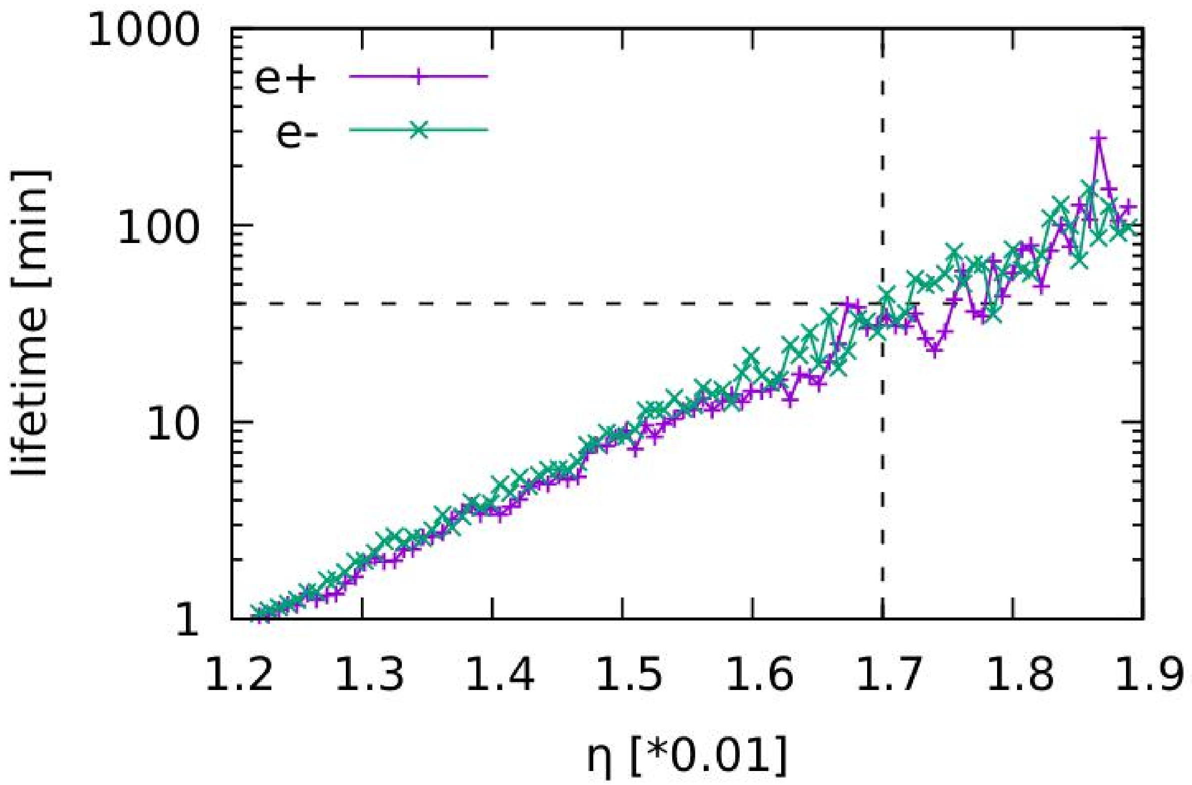
	ttbar	Higgs	W	Z
Number of Ips	2			
Circumference [km]	100.0			
SR power per beam [MW]	30			
Half crossing angle at IP [mrad]	16.5			
Bending radius [km]	10.7			
Energy [GeV]	180	120	80	45.5
Energy loss per turn [GeV]	9.1	1.8	0.357	0.037
Piwinski angle	1.21	5.94	6.08	24.68
Bunch number	35	249	1297	11951
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

Beam-Beam Simulations

Luminosity @ Qx=0.562

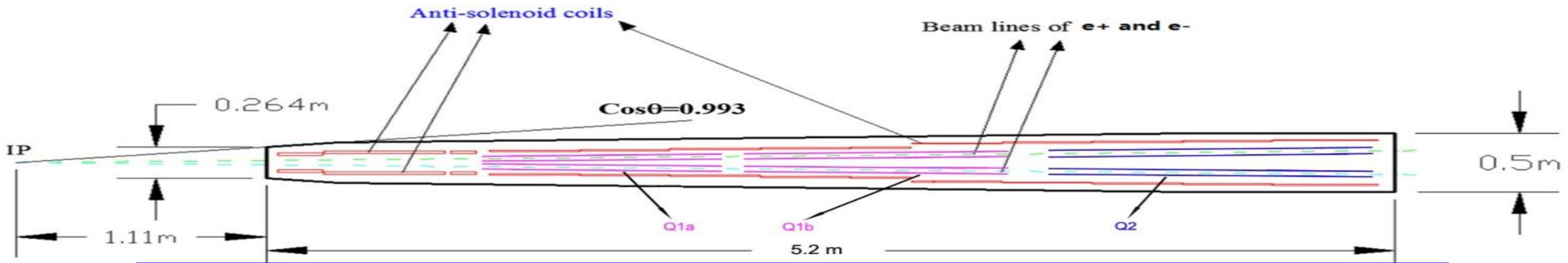


Beamstrahlung Lifetime



CEPC High Luminosity Scheme at Higgs Energy after CDR

- Motivation: make the lattice robust and provide good start point for DA
- The design of detectors won't be affected.
  - with lower emittance and smaller beam pipe aperture within the region of SCQ
  - with shorter anti-solenoid in front of QD0 without change the design of cryo-module



CDR scheme (Higgs)

- ✓ **L*=2.2m, θc=33mrad, βx*=0.36m, βy*=1.5mm, Emittance=1.2nm**
  - Strength requirements of anti-solenoids (peak field B_z~7.2T)
  - Two-in-one type SC quadrupole coils (Peak field 3.8T & 136T/m)

High luminosity scheme (Higgs)

- ✓ **L*=1.9m, θc=33mrad, βx*=0.33m, βy*=1.0mm, Emittance=0.68nm**
  - Strength requirements of anti-solenoids (peak field B_z~7.2T)
  - Two-in-one type SC quadrupole coils (Peak field 3.8T & 141T/m) with room temperature vacuum chamber & Iron yoke

Z mode: Q1a=Vertical focusing quadrupole, Q1b+Q2=Horizontal focusing quadrupole

W mode: Q1a+Q1b=Vertical focusing quadrupole, Q2=Horizontal focusing quadrupole

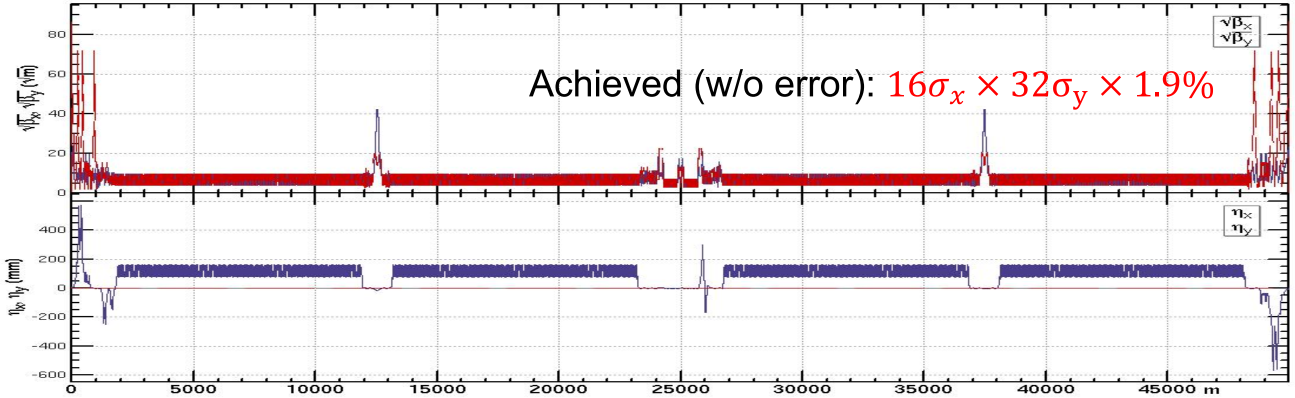
Higher than Higgs energy: Q1a+Q1b+Q2=Vertical focusing quadrupole

CEPC Higgs High Lumi Lattice and Dynamic Aperture Status

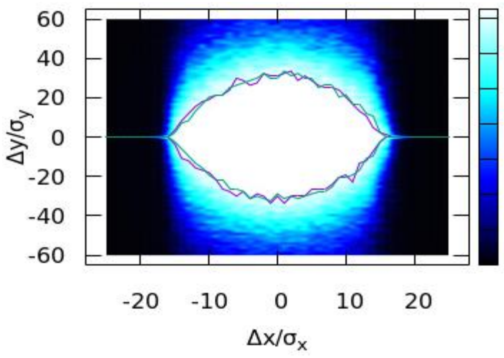
- Fit parameter list with luminosity of $5.2 \times 10^{34}/\mathrm{cm}^2/\mathrm{s}$
  - Stronger optimization and stricter hardware requirement should be made to get enough dynamic aperture
- Optimization of the quadrupole radiation effect
  - Interaction region: longer QD0/QF1 (2m/1.48m => 3m/2m)
  - ARC region: longer quadrupoles (2m => 3m)
- Reduction of dynamic aperture requirement from injection
  - Straight section region: larger βx at injection point (600m => 1800m)
- Maximization of bend filling factor to minimize the synchrotron radiation loss per turn
  - ARC region: sextupoles in two rings changed from staggered to parallel; The left drifts are used for longer bend.
  - RF region: shorter phase tuning sections

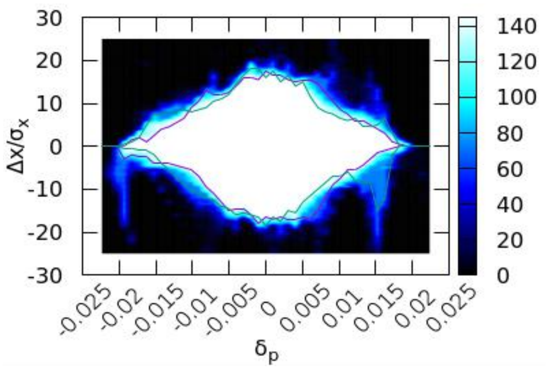
- With better correction of energy dependent aberration and shorter L* (without changing the front-end position of the final doublet cryo-module)

Goal (w/ error): $8\sigma_x \times 15\sigma_y \times 1.7\%$



Achieved (w/o error): $16\sigma_x \times 32\sigma_y \times 1.9\%$



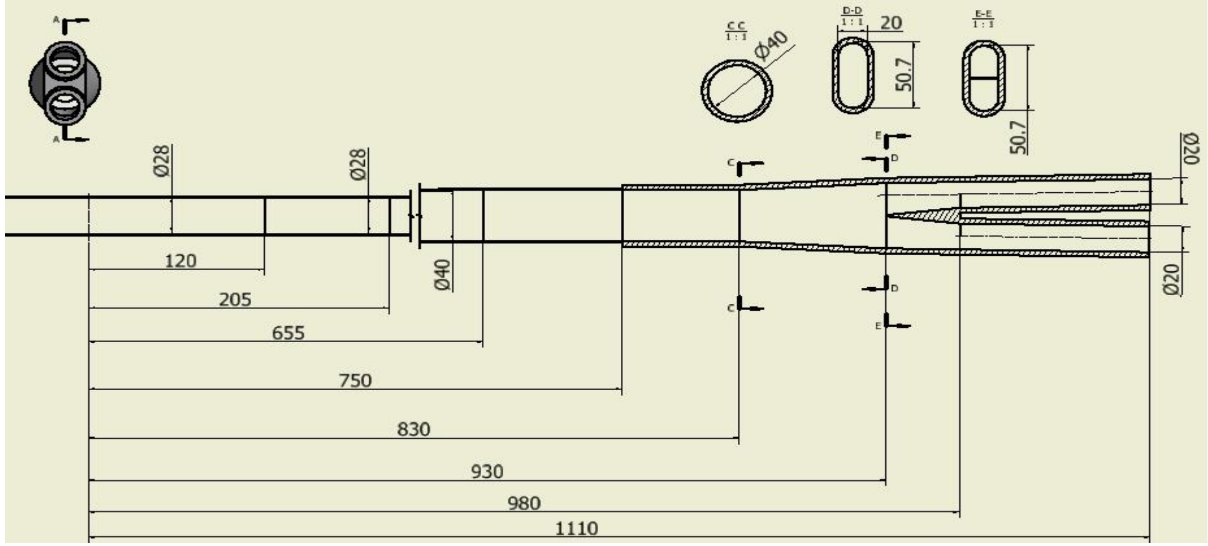


High Luminosity Scheme at Higgs energy

Change of IP chamber

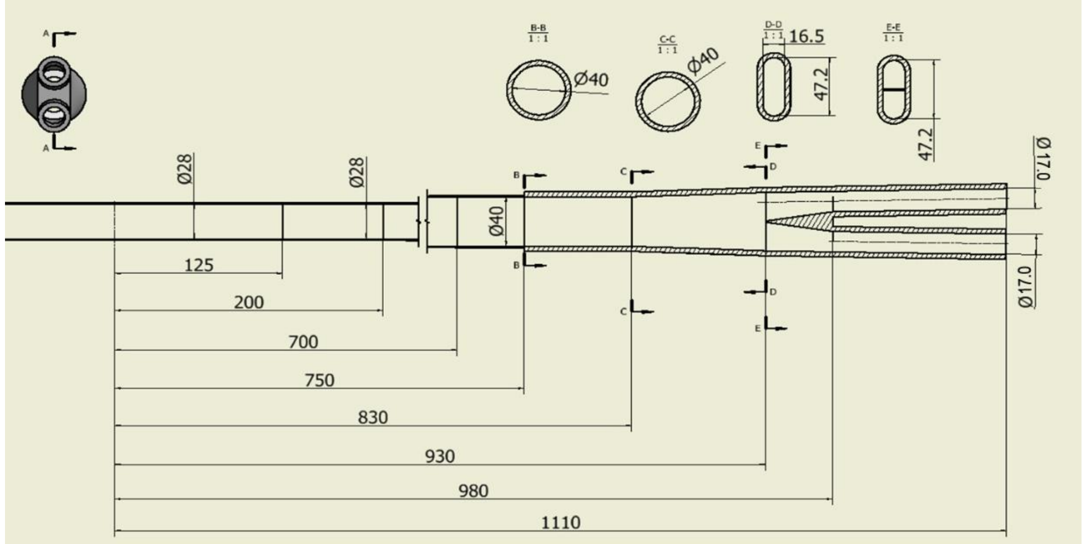
CDR

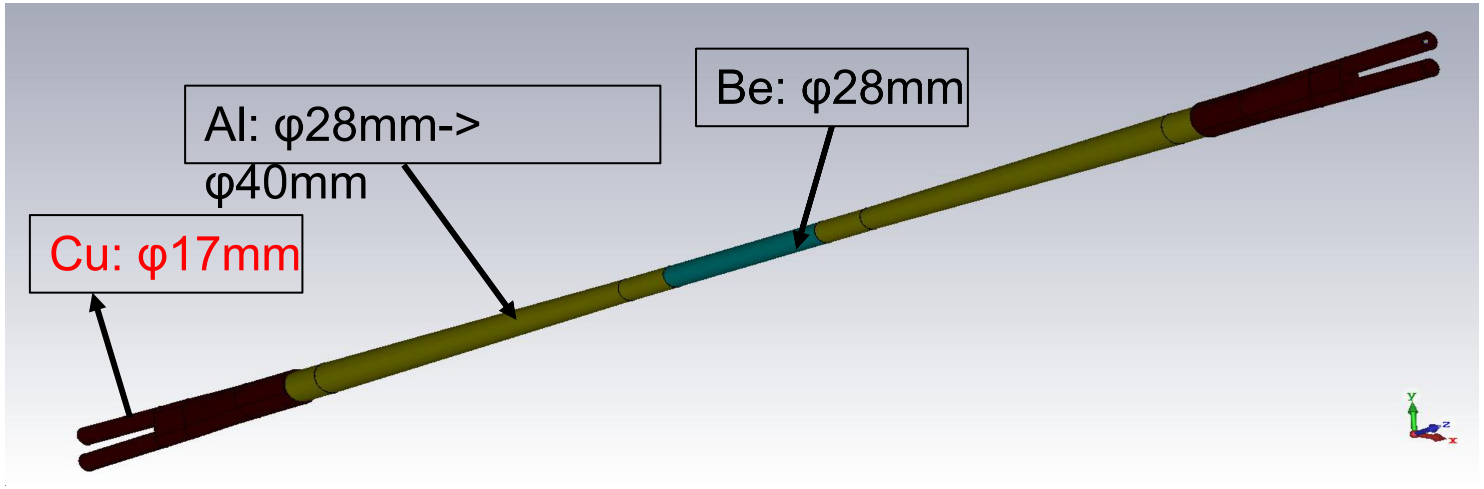
Be pipe: 28mm, SCQ Beam pipe:20mm



High luminosity

Be pipe: 28mm, Beam pipe:17mm





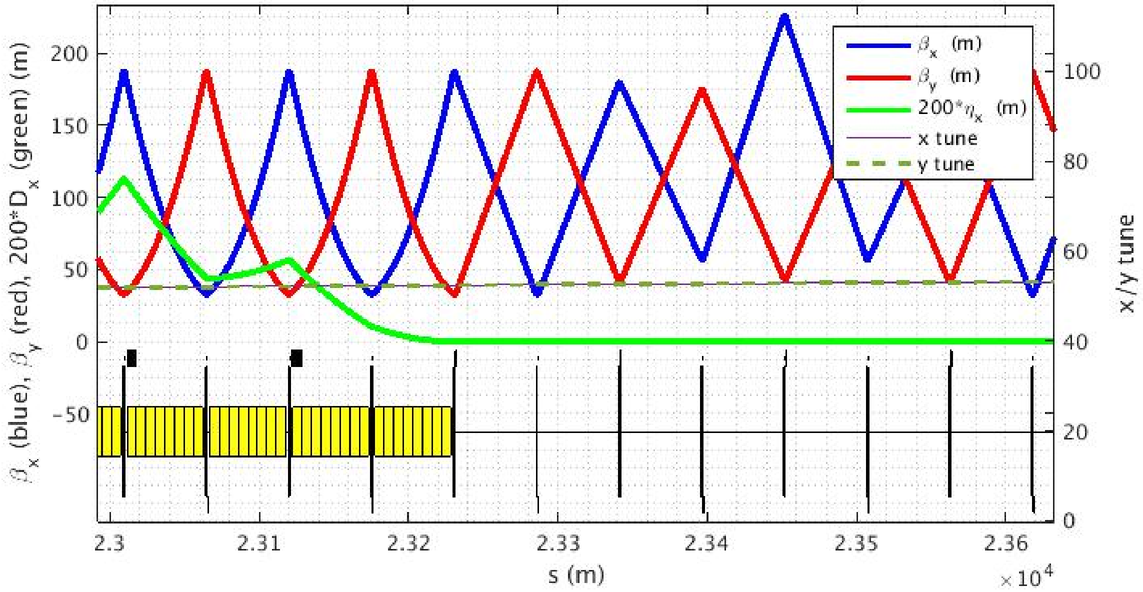
Booster New Parameters after CDR based on TME

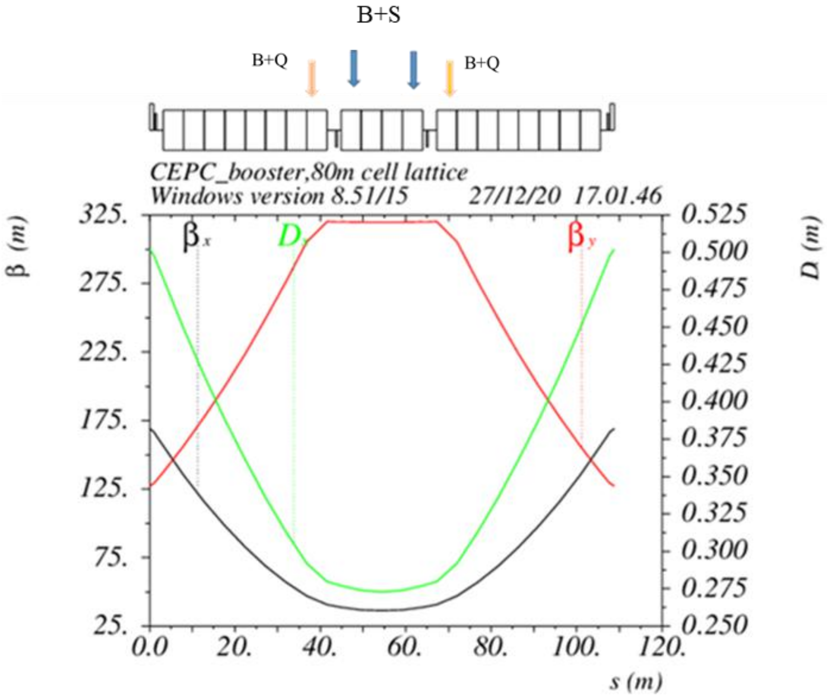
Injection		*tt*	*H*	*W*	*Z*
Beam energy	GeV	10			
Bunch number		37	214	1588	5750
Threshold of single bunch current	μA	6.82			
Threshold of beam current (limited by coupled bunch instability)	mA	44.6			
Bunch charge	nC	1.02	0.87	0.63	0.83
Single bunch current	μA	3.1	2.6	1.8	2.4
Beam current	mA	0.12	0.57	2.86	14.0
Energy spread	%	0.014			
Synchrotron radiation loss/turn	keV	79.5			
Momentum compaction factor	10^{-5}	2.21			
Emittance	nm	0.01			
Natural chromaticity	H/V	-271/-195			
RF voltage	MV	306.5	141.8	102.5	
Betatron tune ν_x/ν_y		230.23/87.18			
Longitudinal tune		0.216	0.147	0.125	
RF energy acceptance	%	4.5	3.1	2.6	
Damping time	s	36.3			
Bunch length of linac beam	mm	1.0			
Energy spread of linac beam	%	0.16			
Emittance of linac beam	nm	40			

Extraction		*tt*		*H*		*W*	*Z*
		Off axis injection	On 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	35+2	214	207+7	1588	5750
Maximum bunch charge	nC	0.92	30.7	0.78	26.1	0.58	0.75
Maximum single bunch current	μA	2.8	93.3	2.36	78.5	1.7	2.2
Threshold of single bunch current	μA	358.2		147.2			
Threshold of beam current (limited by RF power)	mA	0.3		1		4	13
Beam current	mA	0.105	0.29	0.51	1.0	2.69	12.6
Injection duration for top-up (Both beams)	s	31.7	32.6	24.3	30.8	51.9	150.2
Injection interval for top-up	s	65		38		153.0	153.5
Current decay during injection interval		3%					
Energy spread	%	0.25		0.168		0.112	0.064
Synchrotron radiation loss/turn	GeV	8.35		1.65		0.326	0.034
Momentum compaction factor	10^{-5}	2.21					
Emittance	nm	3.27		1.45		0.65	0.21
Natural chromaticity	H/V	-271/-195					
Betatron tune ν_x/ν_y		230.23/87.18					
RF voltage	GV	10.0		2.36		0.88	0.47
Longitudinal tune		0.216		0.147		0.125	0.125
RF energy acceptance	%	1.53		1.45		1.9	2.46
Damping time	ms	6.3		21.2		71.1	385.7
Natural bunch length	mm	4.1		3.88		3.15	1.8
Injection duration from empty ring	h	0.15		0.14		0.25	2.0

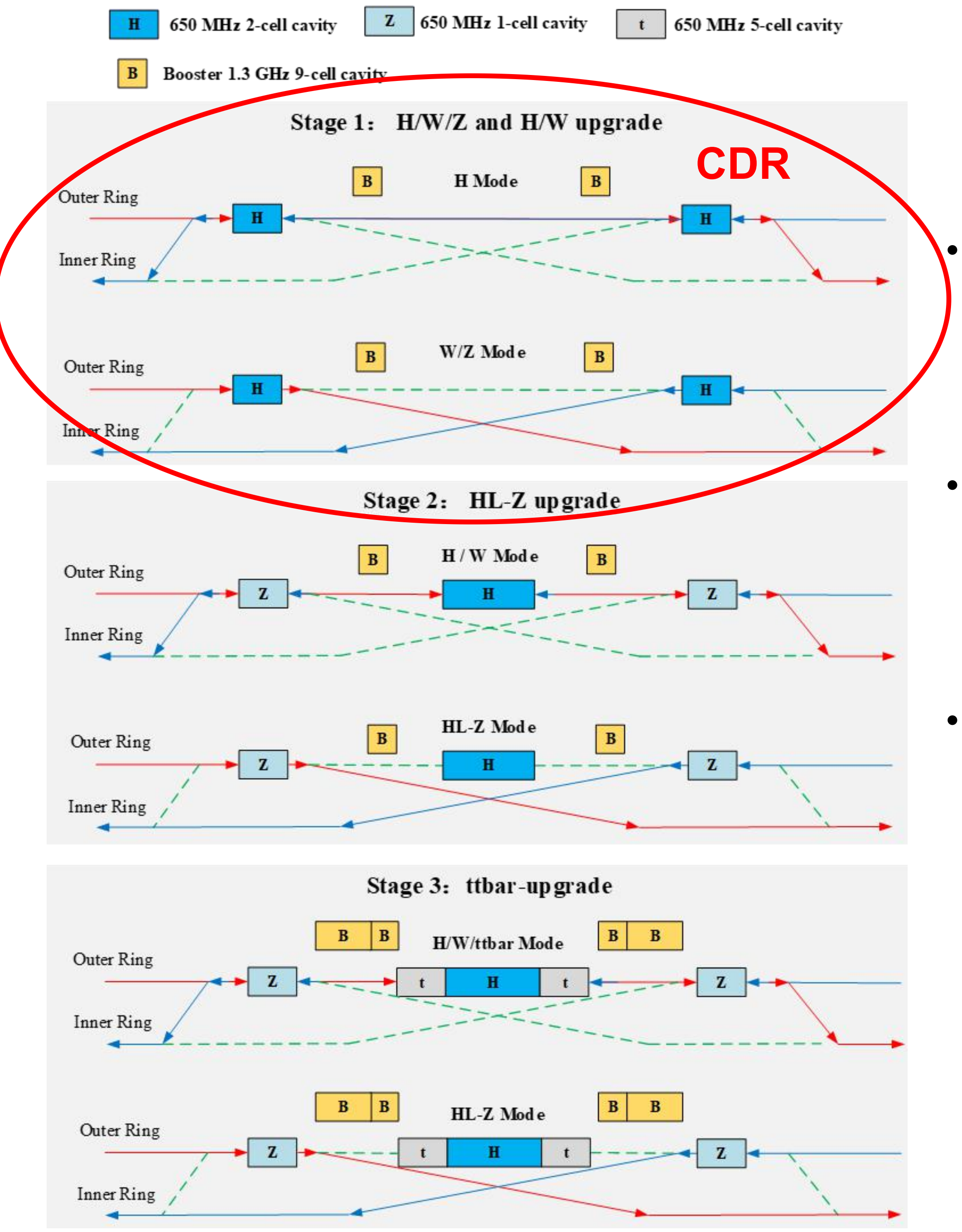
High Luminosity Scheme at Higgs Energy

Booster ring





- Standard TME cells with combined magnets are chosen for lower booster emittance to relax the DA requirement of collider ring.
- **1.4nm** is expected. (CDR: 3.6nm)



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.**

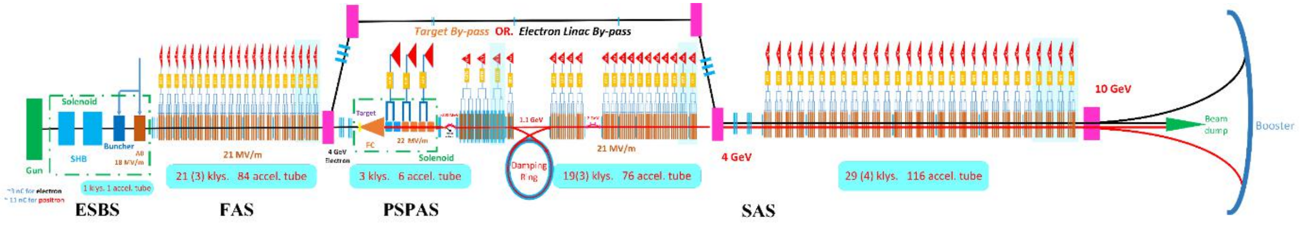
CEPC SRF Parameter with By Pass Schemes

	BEPCII 500 MHz 4.2 K	**BEPC3** 500 MHz 4.2 K	**CEPC CDR H** 30 MW 3E34	**CEPC CDR Z** 16.5 MW 32E34	**CEPC 1-cell H** 30 MW 3E34	**CEPC TDR Z** 30 MW 100E34	**CEPC TDR H** 30 MW 3E34	**CEPC TDR W** 30 MW 10E34	**CEPC Ultimate Z 50 MW 167E34**
Beam current (mA)	400 (600)	900	2 x 17.4	460	2 x 17.4	**838**	2 x 17.4	2 x 87.7	1400
Cell number	1	1	2		1	1	2/1	2/1	1
Cavity number / ring	1	2	2 x 120	60	2 x 120	60	2x(90+60)	2x(90+60)	60
Eacc (MV/m)	6 (1.5 MV)	10 (2.5 MV)	**19.7**	3.6	**40**	**9.4**	**19.7**	4.2	9.4
Q_0 @ 4.2 K / 2 K	1E9	1E9	**1.5E10**	1.5E10	**3E10**	**1.5E10**	**1.5E10**	1.5E10	1.5E10
Total wall loss (kW)			6.1	0.1	6.1	0.35	6.1	0.27	0.35
Input power (kW)	110	150	250	275	250	**500**	250/125	250/125	**835**
Cavity# / klystron	1	1 SSA	2		2/1	1	2/1	2/1	1
Klystron power (kW)	250	150 SSA	800	800	800	800	800	800	1200
Total KLY number	2	4	120		60+120	120	90+120	90+120	120
HOM damper	Absorber	Absorber	Hook+ Absorber		Hook+ Absorber	Absorber	Hook+ Absorber	Hook+ Absorber	Absorber
HOM power (kW)	8*	20	0.6	1.9	0.23	2.4	0.46 / 0.23	**1.5** / 0.75	**4**

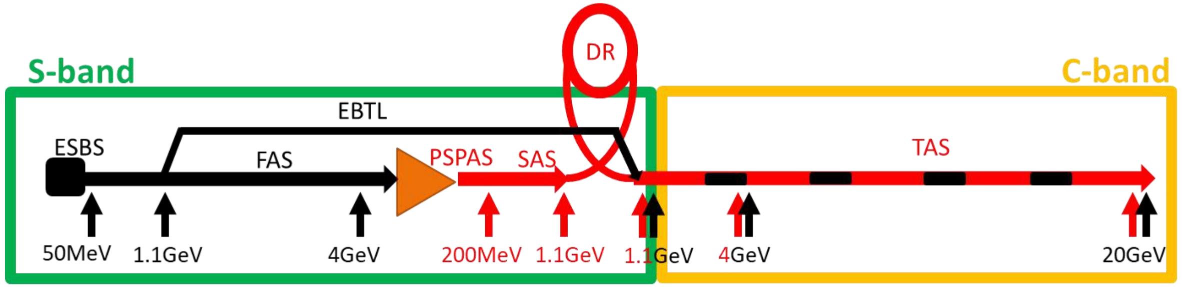
* Bunch length 15 mm, cavity cell HOM loss factor 0.1 V/pC, tapers 0.06 V/pC, absorbers 0.26 V/pC.

High Luminosity Scheme at Higgs Energy

LINAC



CDR Linac injector



TDR Linac injector

- In order to relax the DA requirement of booster the beam emittance of Linac should be controlled as **10 nm** with the damping ring of energy 1.1GeV. (CDR: 40nm)
- By-pass energy is reduced from 4GeV to 1.1GeV
- The extract energy the end of Linac is promoted for 10 to 20 GeV

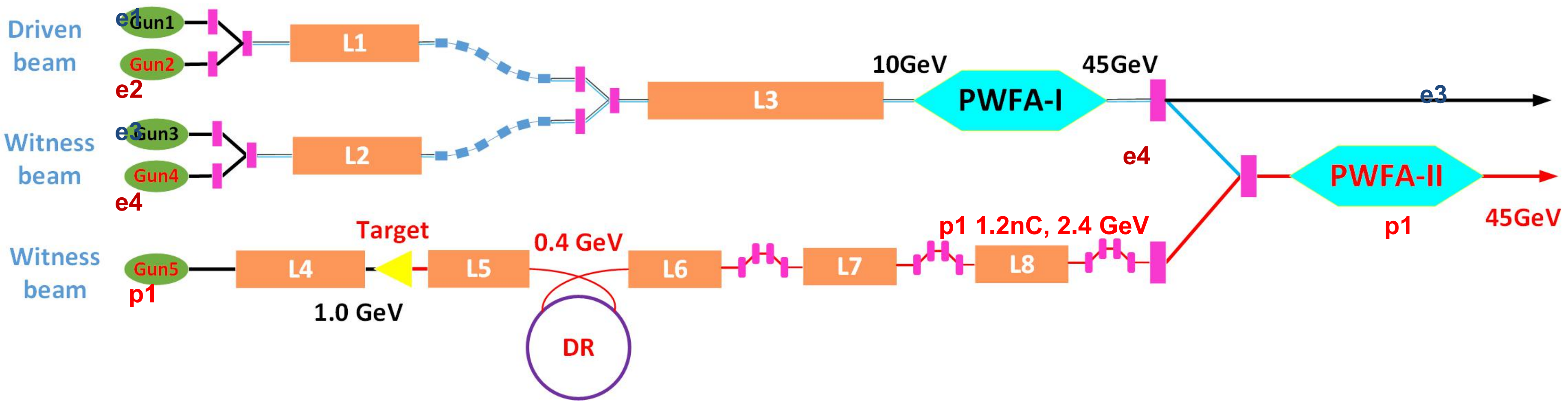
Parameter	Symbol	Unit	Designed
e^-/e^+ beam energy	E_{e-}/E_{e+}	GeV	**20**
Repetition rate	f_{rep}	Hz	**100**
e^-/e^+ bunch population	N_{e-}/N_{e+}		**$> 9.4\times10^9$ / $>9.4\times10^9$**
		nC	**> 1.5**
Energy spread (e^-/e^+)	σ_e		**$< 2\times10^{-3}$ / $< 2\times10^{-3}$**
Emittance (e^-/e^+)	ε_r	nm· rad	**10**
Bunch length (e^-/e^+)	σ_l	mm	**1 / 1**
e^- beam energy on Target		GeV	**1.1**
e^- bunch charge on Target		nC	**10**

CEPC Plasma Injector Design

The reason to increase the injection energy:

if injection energy is larger than 40 GeV, the booster dipole magnet can use normal iron material

with low price



	e1/e3 Before PWFA-I	e3 After PWFA-I	e2/e4 Before PWFA-I	e4 After PWFA-I	p1 Before PWFA-II	p1 After PWFA-II	Booster Requirement
Energy (GeV)	10/10	45.5	10/10	45.5	2.4	45.5	45.5
Bunch Charge (nC)	5.8/0.84	1	15/4.5	>3	1.2	1	0.78
Bunch length (ps)	2/0.257	<1	3/0.7	<1	0.07	<1	<10
Energy Spread	~/0.2%	~1%	~/0.2%	1%	0.2%	~1%	0.2%
E_{normal} (μm rad)	<20*/<100	~100	<50*/<100	~100	<50	~100	<800
Bunch Size (μm)	3.87/8.65	<20	30/20	<20	20	<20	<2000

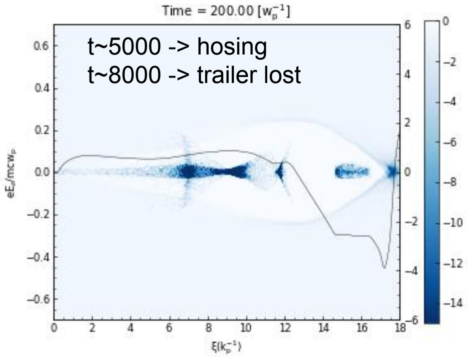
The plasma accelerator performance has been checked with the real linac beam quality, and it almost reached the design goal

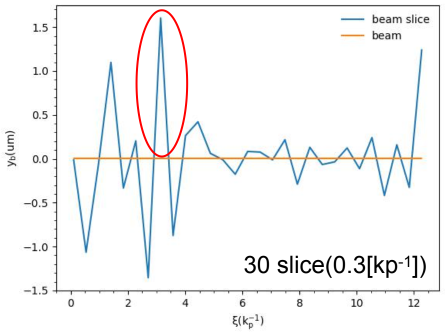
Requirment of Booster to Plasma Injector(@45.5GeV)

Parameter	Symbol	Unit	Requirement	Realized
e^- /e^+ beam energy	E_{e-}/E_{e+}	GeV	**45.5**	**45.3(-)/45.2(+)**
frequency	f_{rep}	Hz	**100**	**100**
e^- /e^+ bunch population	N_{e-}/N_{e+}	nC	**> 1.0**	**1.0(-)/1.0(+)**
Energy spread (e^- /e^+)	σ_e		**$< 2\times10^{-3}$**	**0.002(-)/0.0014(+)**
Emittance (e^- /e^+)	ε_r	nm· rad	**< 30**	**1.89(-)/1.0(+)**
Bunch length (e^- /e^+)	σ_l	mm	**< 3**	**0.3(-)/0.3(+)**
Switch time e^- /e^+		s	**< 20**	
Energy stability			**$< 2\times10^{-3}$**	
Longitudinal stability		mm	**< 2**	
Orbit stability		mm	**<5 (H) / 3 (V)**	
Failure rate		%	**< 1**	

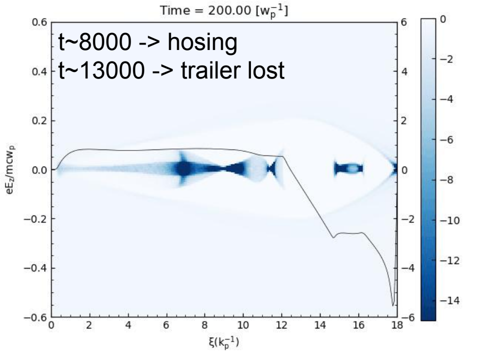
CEPC Plasma Injector Start to End Simulation

- ➢ Longitudinal shaping is well maintained → TR ☼
- Big slice jitter in PWFA acceleration → hosing → Transverse-Longitudinal coupling

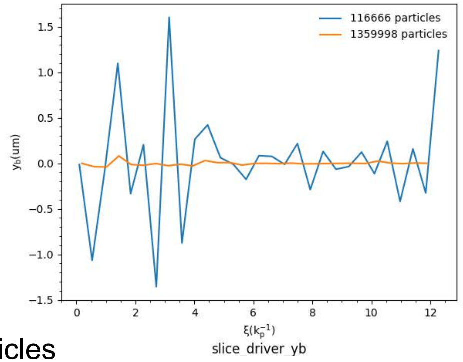


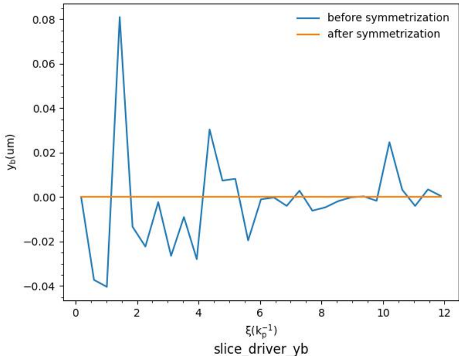


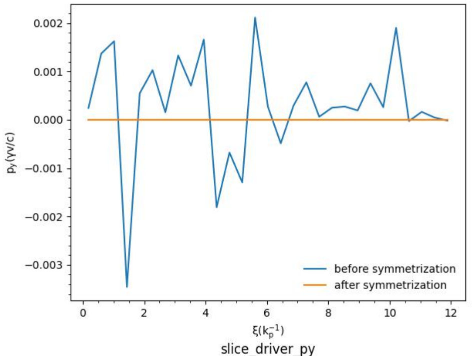
Driver initial beam centroid

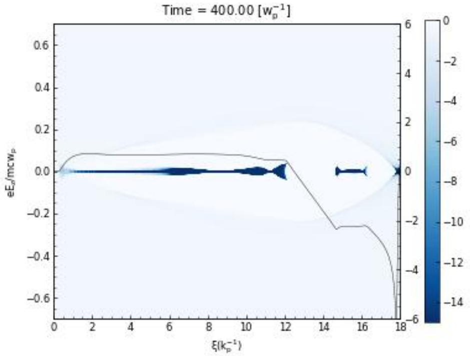


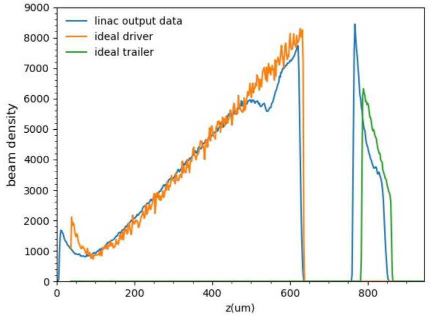
0.11m particles → 1.36m particles





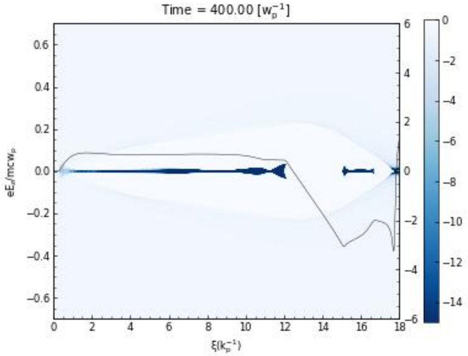


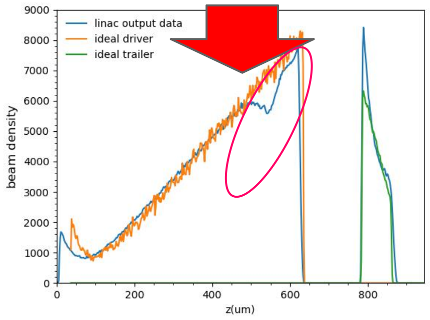




beam initial[x, y, px, py]~ [0,0,0,0]

	Beam symmetrization	Change beam distance	Design
Δz(um)	126.7	149	149
$Et(GeV)$	40.6	42.80	45.5
Qt(nC)	0.9	0.7909	0.84





1kp^{-1}~52.52um

CEPC TDR and R&D

CEPC Accelerator TDR R&D Priority and Plan

1) CEPC 650MHz 800kW high efficiency klystron (80%) (at the end of 2021 complete the fabriation, finish test in 2022)

2) High precision booster dipole magnet (critical for booster operation) (Complete real size magnet model in 2021)

3) CEPC 650MHz SC accelerator system, including SC cavities and cryomules (Complete test cryomodule in 2022)

4) Collider dual aperture dipole magnets, dual aperture qudrupoles and sextupole magntes(Complete real size model in 2022)

5) Vacuum chamber system (Complete fabrication and costing test in 2022)

6) SC magnets including cryostate (Complete short test model in 2022)

7) MDI mechanic system (Remote vacuum connection be test in 2022)

8) Collimator (Complete model test in 2022)

9) Linac components (Complete key components test in 2022)

10) Civil engineering design (Reference implementation design complete in 2022)

11) Plasma injector (Complete electron accelerator test in 2022)

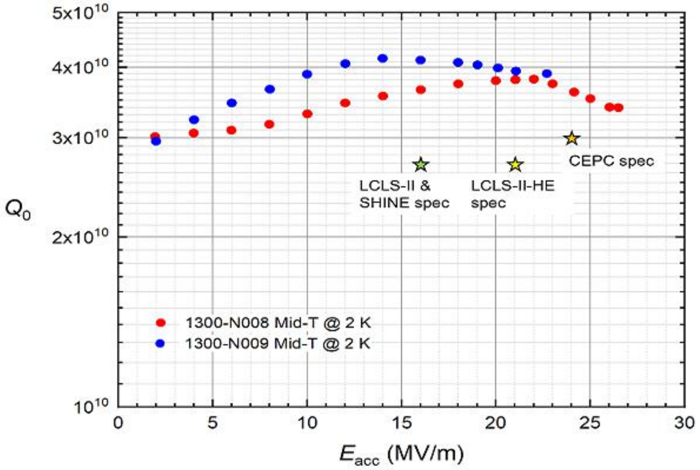
12) 18KW@4.5K cryoplant (Company)

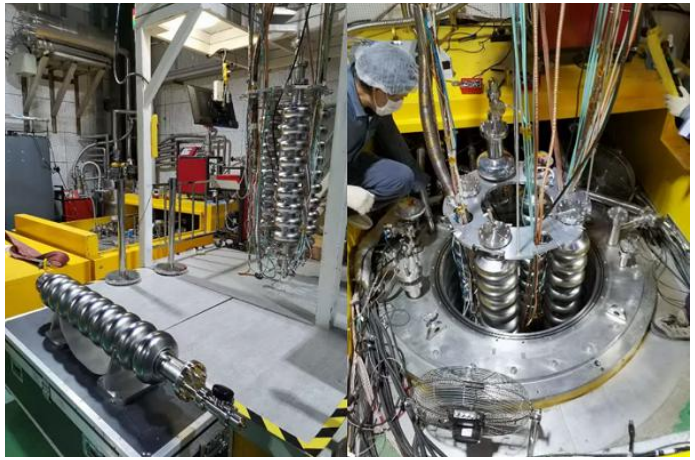
…

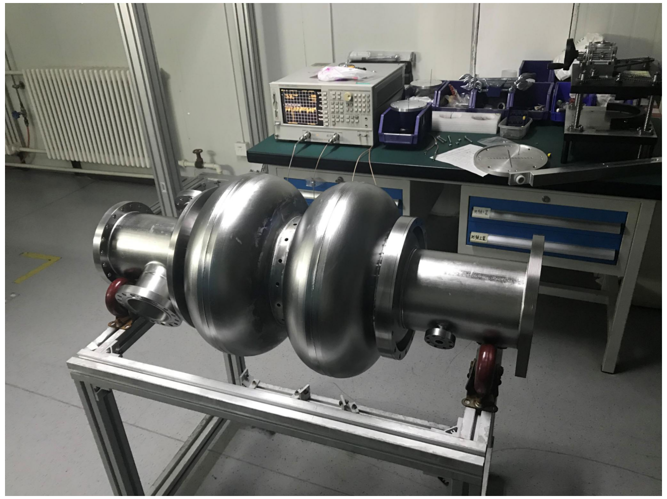
SppC technology R&D

Ion based supercondcuting materials and high field magnets

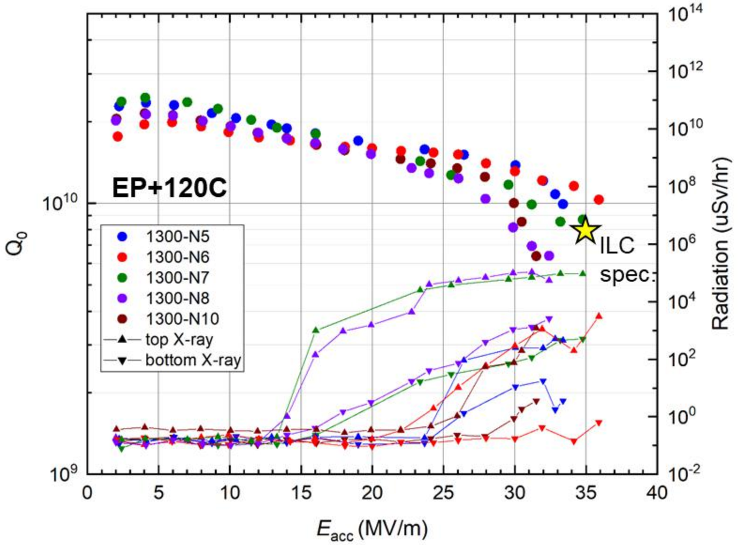
IHEP 650MHz 2cell and 1.3 GHz 9-cell Cavities



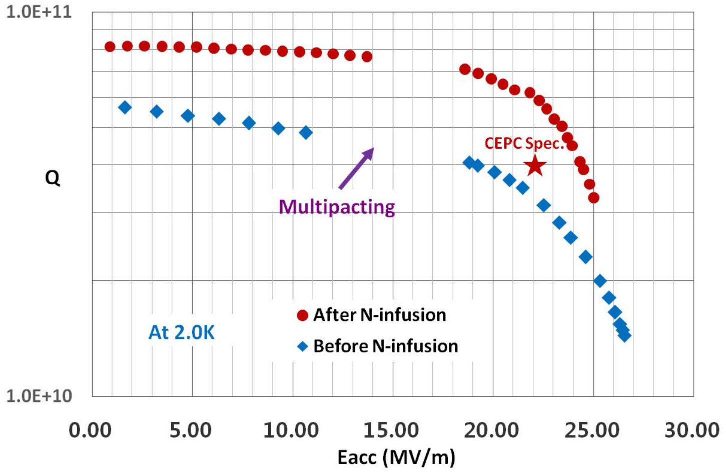




Collider ring 650Mhz 2 cell cavity



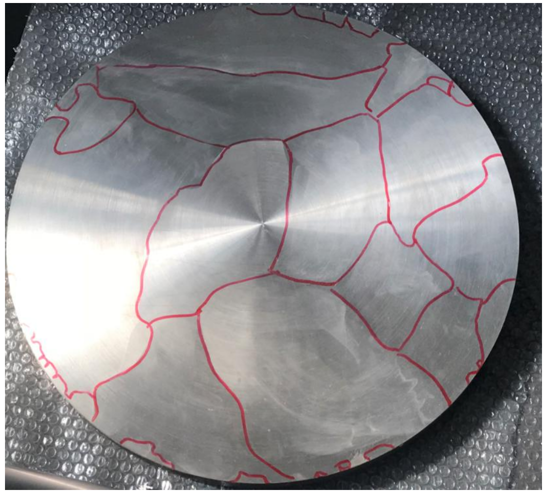
Booster 1.3GHz 9 cell cavity

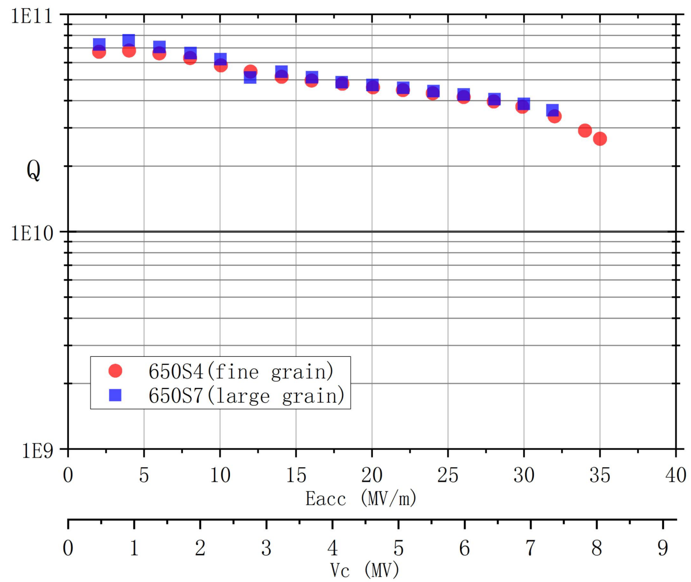


650 MHz 2-cell cavity reached **6E10@22MV/m** after N-infusion, which has exceeded CEPC Spec （**Q=4E10@Eacc=22MV/m**）.

650 MHz 1-Cell Cavity (Large Grain)

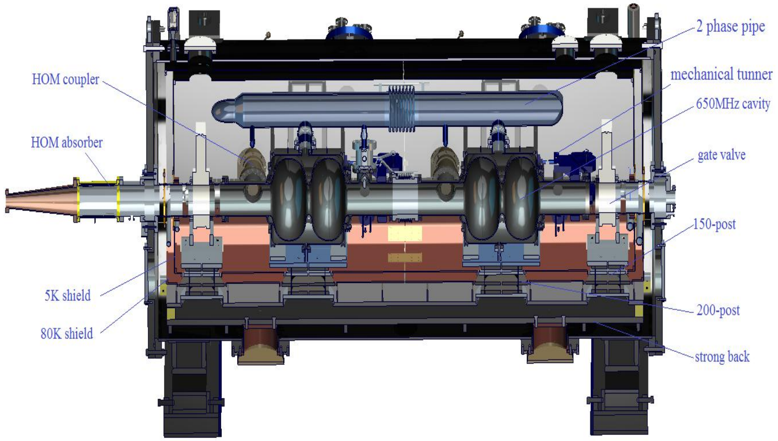
- 650 MHz 1-cell cavity (large grain) is favorable for HL-Z, which have higher Q and gradient than fine grain.
- Target of Vertical test: **5E10 @ 42MV/m at 2.0 K**.
- 650MHz 1-cell (large grain) cavity reaches: **2.7E10 @ 35MV/m at 2.0 K**





Large grain Nb sheets made by OTIC

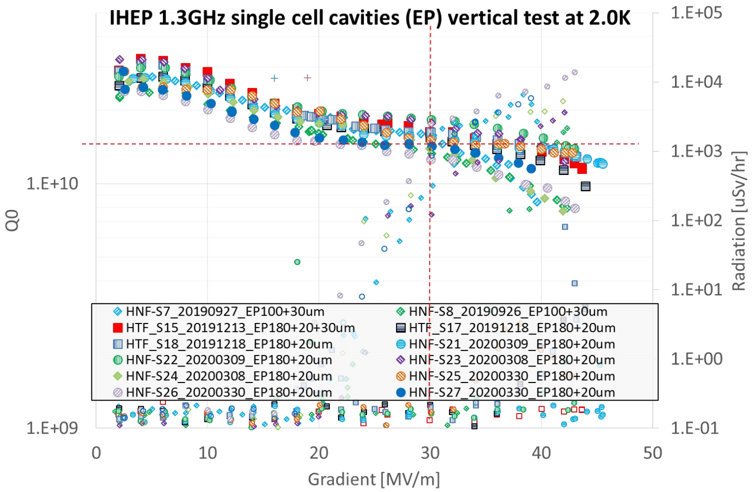
CEPC SCRF R&D Progresses



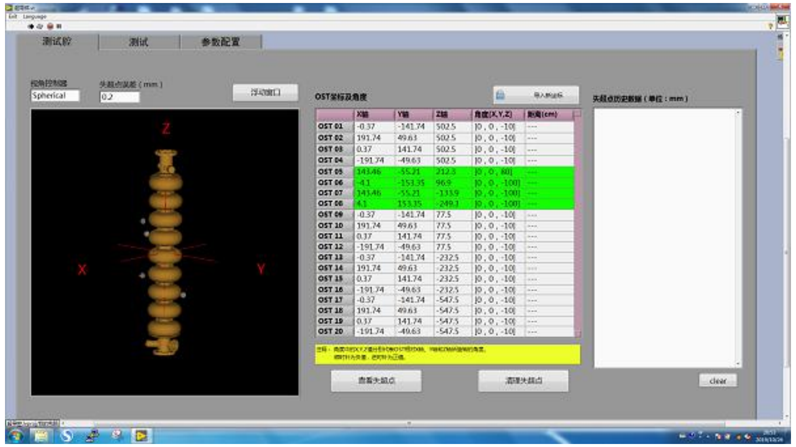
CEPC 2*2cell 650MHz cryomodule with beam test later

General superconducting cavity test cryomodule in IHEP New SC Lab

SC cavity vertical test temperature monitor system established

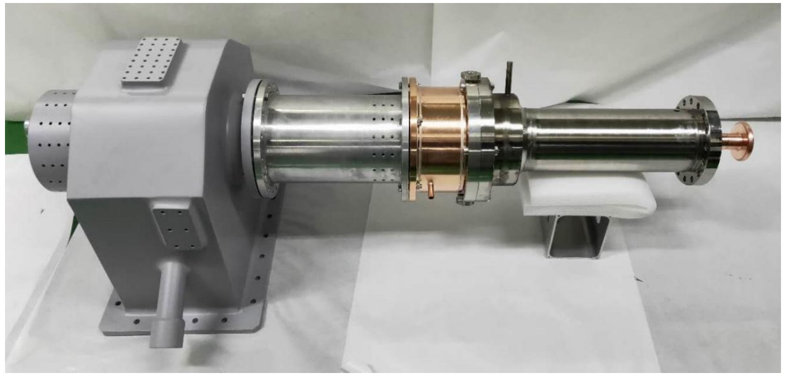


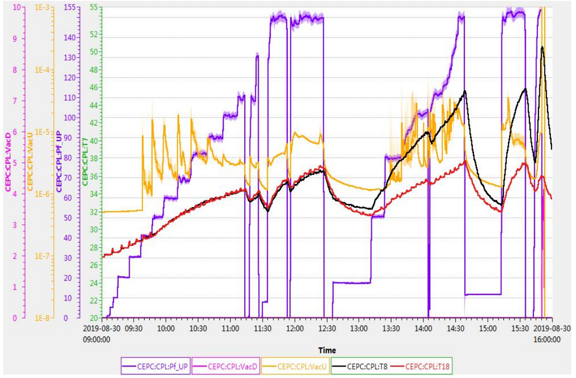
1.3GHz fine grain single cell:
1) 46MV/m
2) 43MV/m@Q0 1.3 $\times 10^{10}$



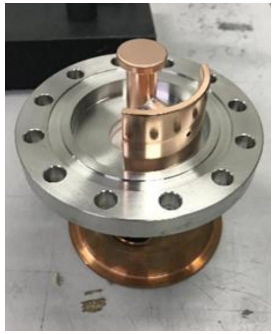
General superconducting cavity test cryomodule in IHEP New SC Lab

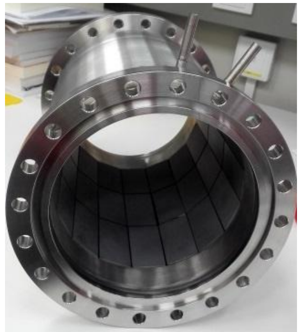
650 MHz High Power SRF Components





High power test of one 650 MHz fixed coupling input coupler reached 150 kW SW (corresponding to 400 kW TW at the window). Another coupler's window broke due to excess ceramic heating. New window and variable coupler in fabrication.





Four high power HOM couplers fabricated and low power tested. Three of them will mount on the 2-cell cavities. Vertical test soon with the cavity to verify the notch properties. High power test (1 kW) at cryogenic temperature planned.

Wideband high power HOM absorber with SiC+AlN material. 5 kW high power test planned.

IHEP New SC Lab (PAPS) in Operation (June 28， 2021)

Facility: CEPC SCRF test facility (lab) is located in IHEP Huairong Area of 4500m^2

New SC Lab Design (4500m^2)

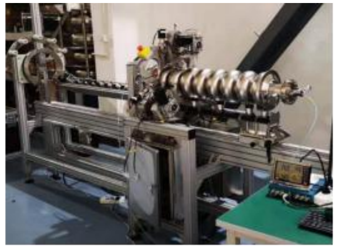
SC New Lab (PAPS) has been put to operation in June 2021

Vacuum furnace (doping & annealing)

Nb3Sn furnace

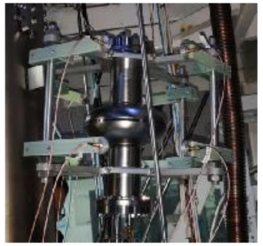
Nb/Cu sputtering device

Cavity inspection camera and grinder

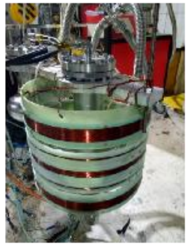


9-cell cavity pre-tuning machine

Temperature & X-ray mapping system



Second sound cavity quench detection system



Helmholtz coil for cavity vertical test

Vertical test dewars

Horizontal test cryostat

CEPC 650MHz High Efficiency Klystron Development

Facility: CEPC high power and high efficincy test facility (lab) is located in IHEP

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
- 2020 - 2021： Fabricate 2nd high efficiency klystron & test
- 2021 - 2022： Fabricate 3rd high efficiency klystron & test

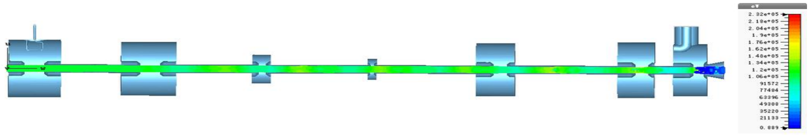
Parameters	Conventional efficiency	**High efficiency**
Centre frequency (MHz)	650+/-0.5	**650+/-0.5**
Output power (kW)	800	**800**
Beam voltage (kV)	80	**-**
Beam current (A)	16	**-**
Efficiency (%)	~ 65	**> 80**

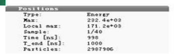


The first CEPC 650Mhz klystron output power has reached pulsed power of 800kW (700kW CW), efficiency 62% and band width>+-0.5Mhz.

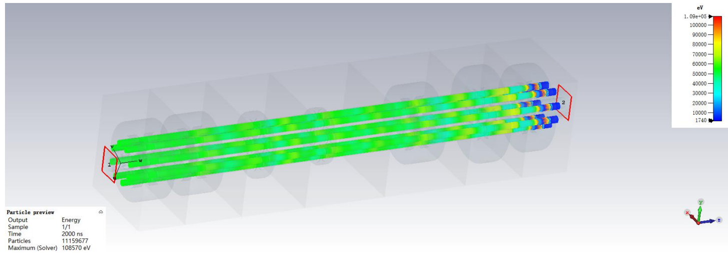
800kW Load

1st Klystron of 62% efficiency completed in 2020



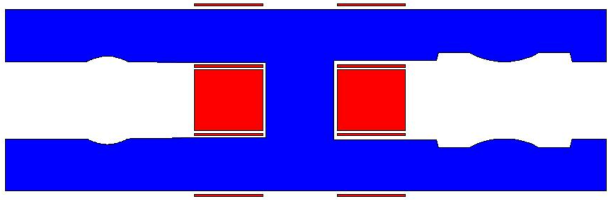


2nd Klystron of 77% efficiency to be completed in 2021

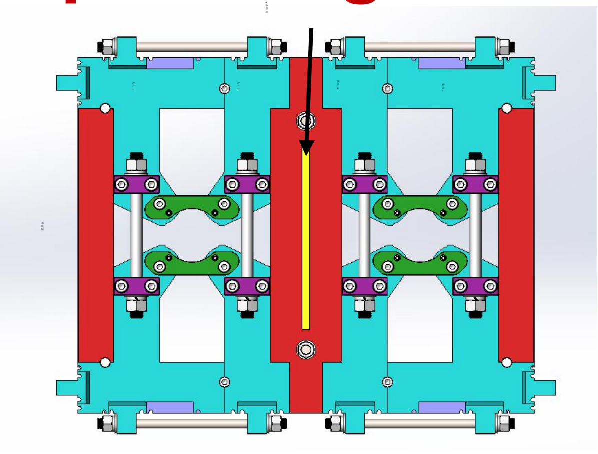


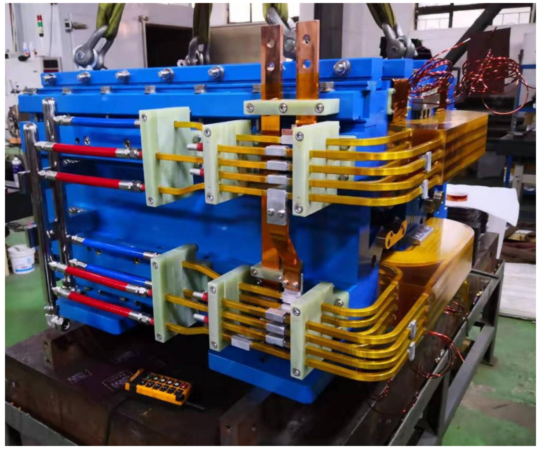
3nd Klystron: Multib-eam Klystron of 80.5% efficiency to be completed in 2022

CEPC Collider Ring dual Aperture Dipole, Quadrupole and Sextupole Magnets

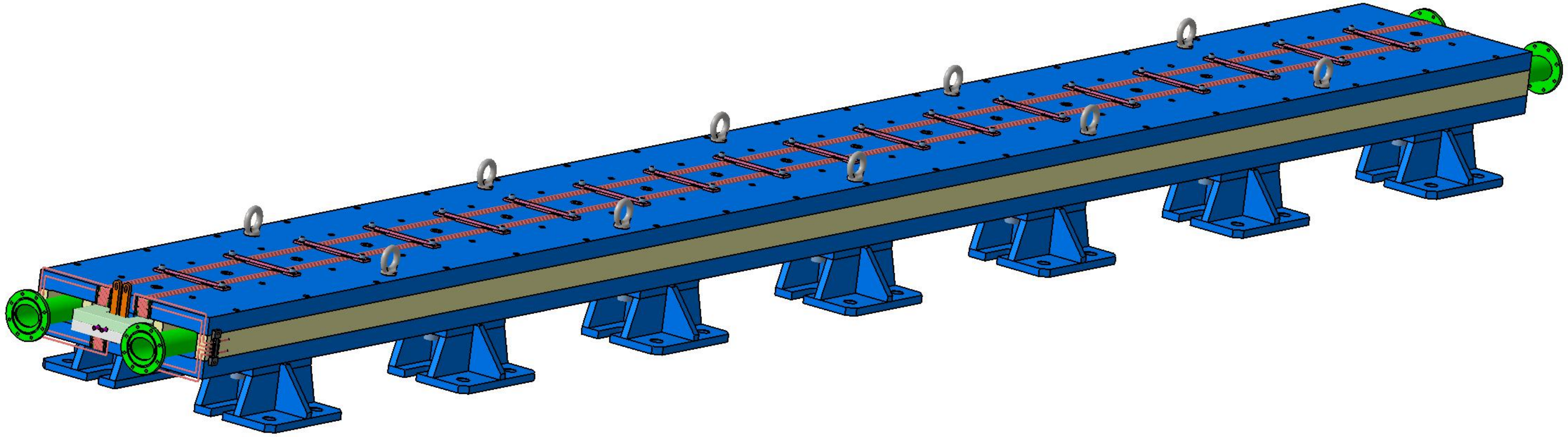


First dual aperture dipole test magnet of 1m long has been fnished in Nov, 2019, and the field mesurement shows that it





First dual aperture quadrupole magnet has been fnished in Nov, 2019. Field measurement showed aix shift for different energies and the new design has been made.

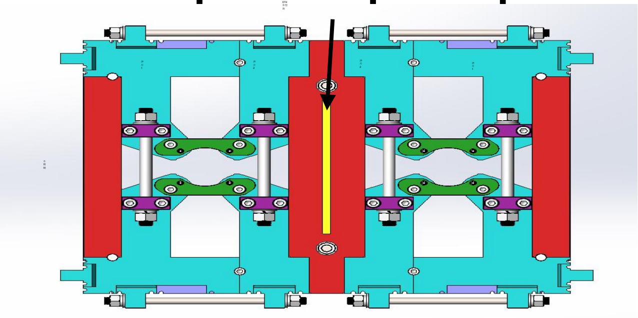


The mechanical design of a full size CEPC collider ring dual aperture dipole of 5.7m long has been designed and be starting fabrication at the end of 2021.

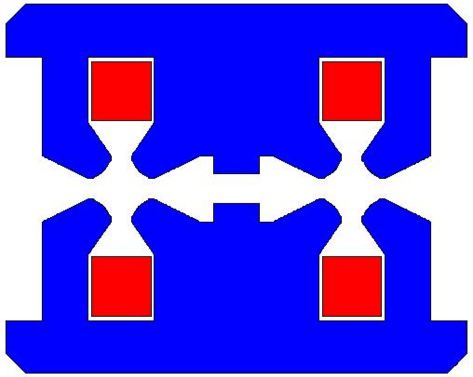
Facility: CEPC magnet test facility (lab) is located in IHEP Dongguan CSNS

CEPC Collider Ring Dual Aperture Quadropole and Sextupole Magnets

Dual aperture quadrupole

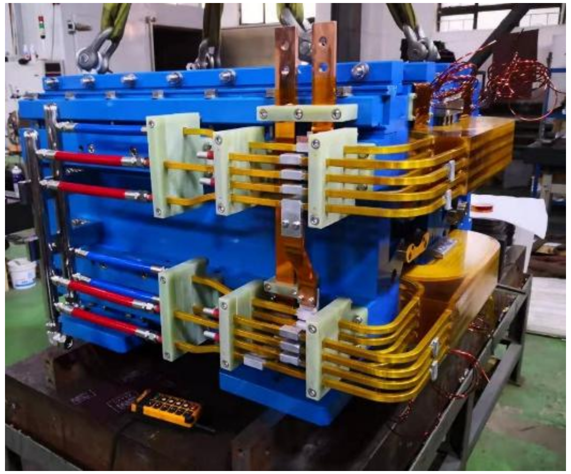


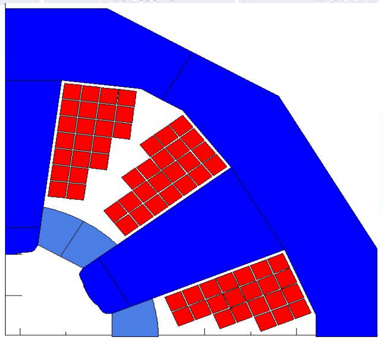
The first dual aperture quadrupole design with a 1m long prototype

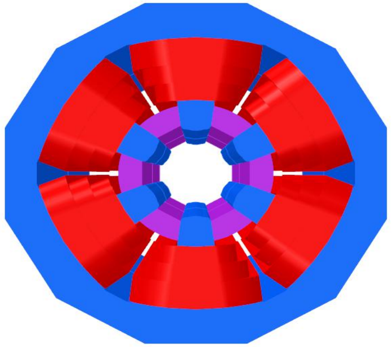


The new dual aperture quadrupole design reached the design goal

	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







Sextupole design is on going, the challenge is mechanical design with limited transverse

The first dual aperture quadrupole model has not matched the requirement with axis shift found. New design shows good results and satisfy the design goal (Axis shift problem solved!), and the first protptype model will be modified to test the new design in 2021.

CEPC Low Field Booster Dipole Magntes' Specifications and Challenges

	BST-63B
Quantity	16320
Minimum field (Gs)	28
Maximum field (Gs)	338
Gap (mm)	63
Magnetic Length (mm)	4700
Good field region (mm)	55
Field uniformity	0.1%
Field reproducibility	0.05%

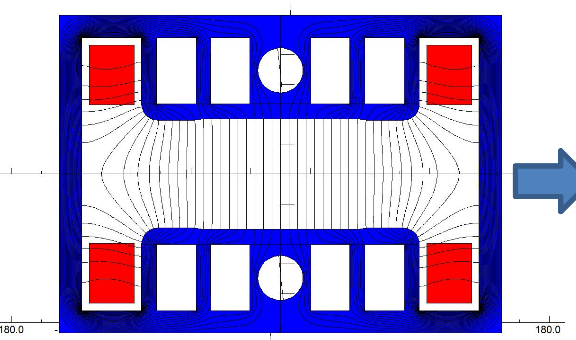
10GeV injection enegy from linac to 100Km booster

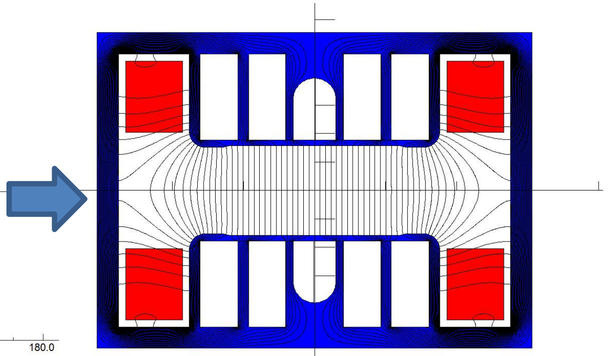
Challenges

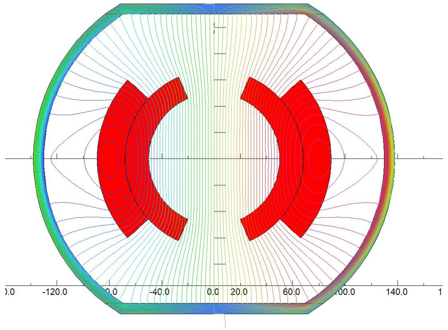
- Total length of the dipoles ~75km how to reduce cost
- Field error <29Gs*0.1%=0.029Gs how to design
- Field reproducibility<29Gs*0.05%=0.015Gs how to measure
- Magnet length ~4700mm how to fabricate

Booster High Precision Low Field Dipole Magnets

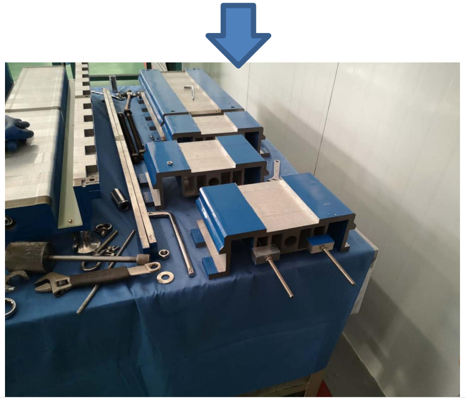
Two kinds of the dipole magnets with diluted iron cores and without iron core (CT) are proposed and designed

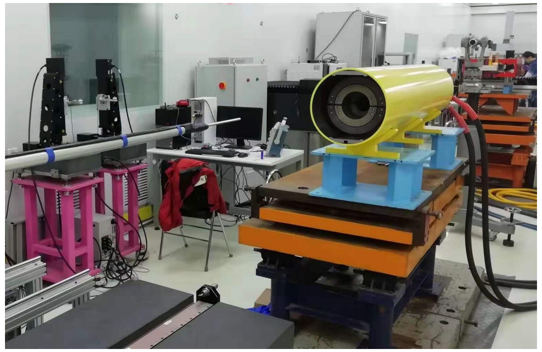


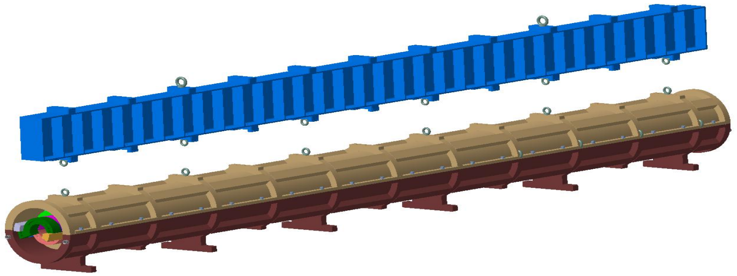


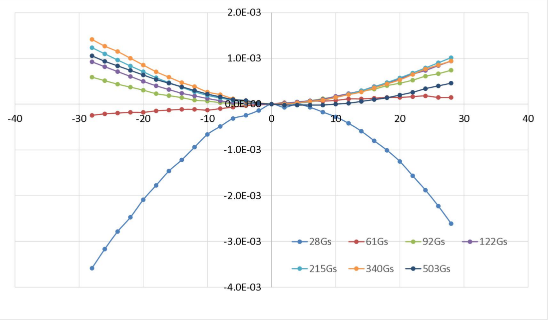


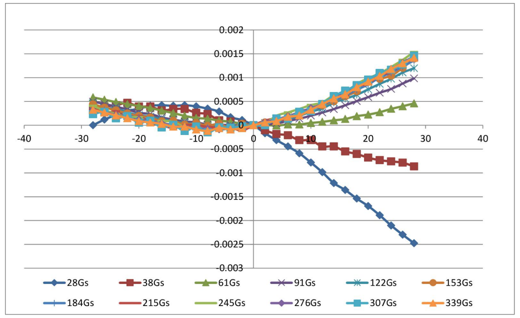
1m long CT test booster dipole magnet without iron core completed in Oct. 2019, and the test result shows that CT design reached the design goal.

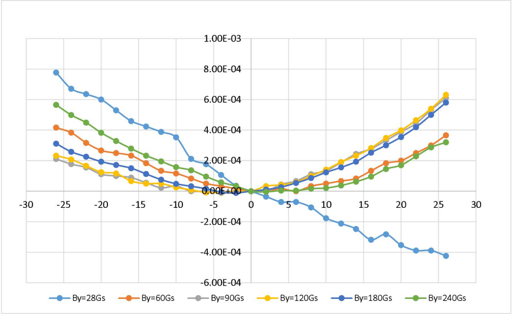












A full scale CT dipole magnet of 5.1m long will be completed at the end of 2021

If injection energy is larger than 20GeV, iron core magntes could be used, which is adoped in TDR.

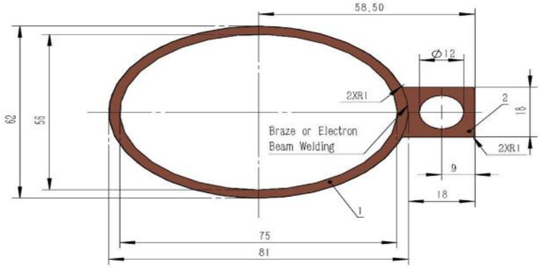
CEPC Vacuum System R&D

Facility: CEPC vaccum test facility (lab) is located in IHEP Dongguan CSNS

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.

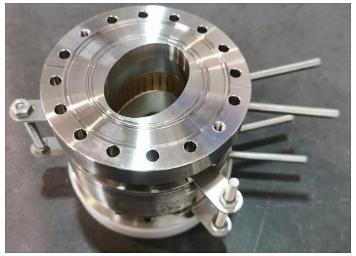
- The vacuum pressure is better than 2 x 10-10 Torr
- Total leakage rate is less than 2 x 10-10 torr.l /s.

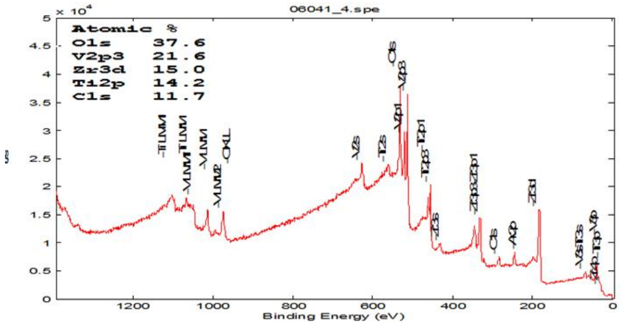
Positron ring

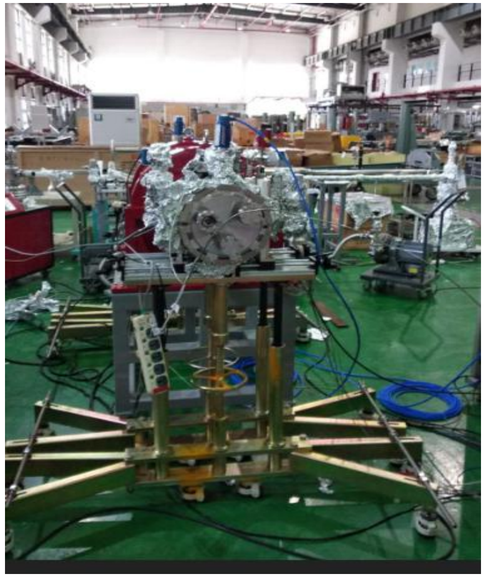


Copper vacuum chamber (Drawing) elliptic 75×56, thickness 3, length 6000)

Two 6m long vacuum chambers both for copper and aluminum







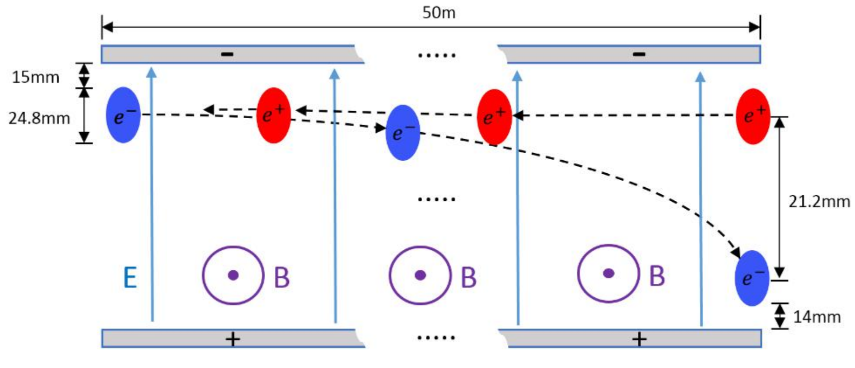
CEPC Electrostatic-Magnetic Deflector

The Electrostatic-Magnetic Deflector is a device consisting of perpendicular electric and magnetic fields.

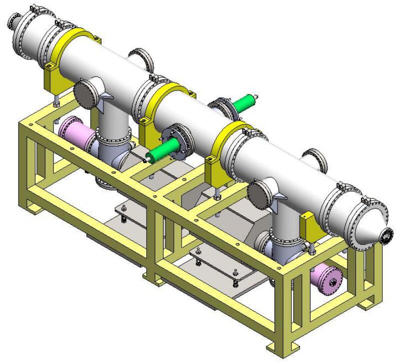
One set of Electrostatic-Magnetic Deflectors including 8 units, total 32 units will be need for CEPC.

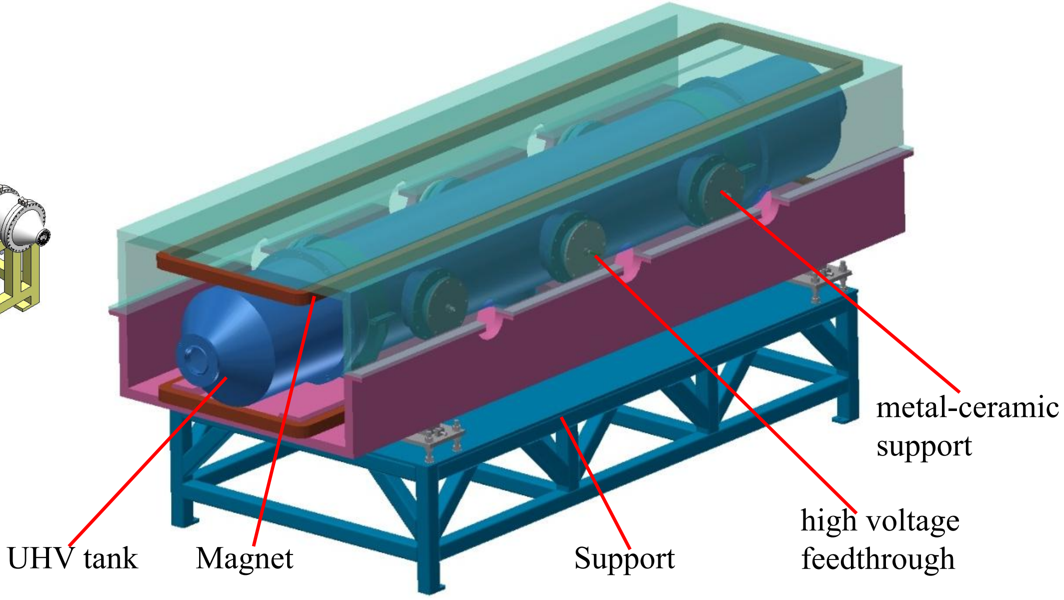
	Filed	Effective Length	Good field region	Stability
Electrostatic separator	2.0MV/m	4m	46mm x 11mm	5 x 10^{-4}
Dipole	66.7Gauss	4m	46mm x 11mm	5 x 10^{-4}

under fabrication

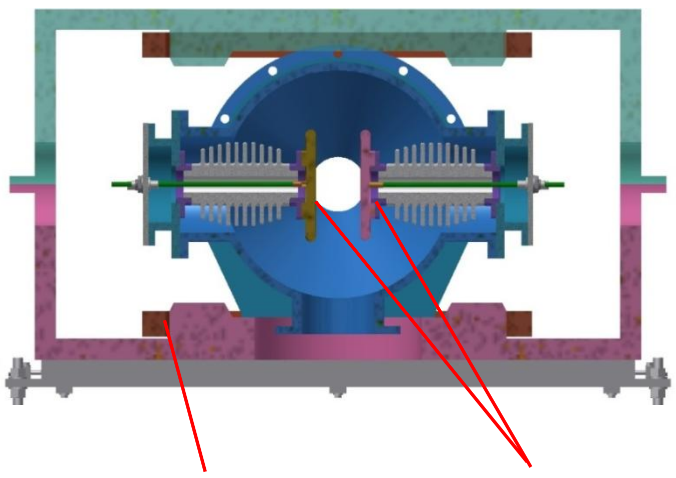


Schematic of Electrostatic-Magnetic Deflector





structure drawing of Electrostatic-Magnetic Deflector

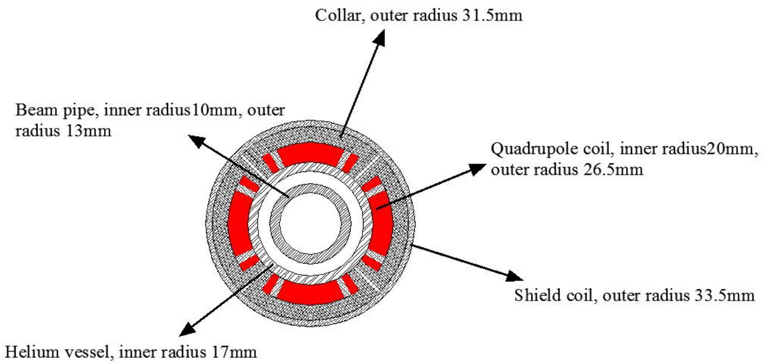


CEPC IR Superconducting Magnets (CDR)

Facility: CEPC IR SC magnet test facility (lab) is located in Keye company joinly with IHEP

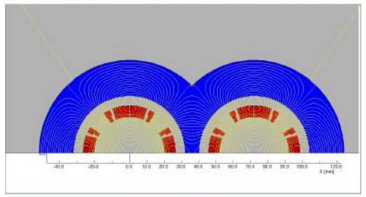
Superconducting QD coils

Superconducting QF coils

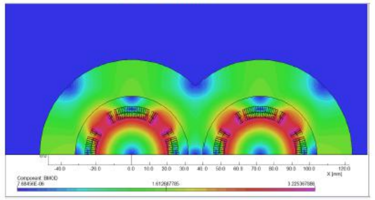


Room-temperature vacuum chamber with a clearance gap of 4 mm

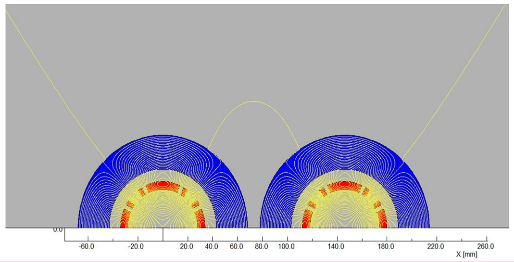
- 2D field cross talk of QD0 two apertures near the IP side.



2D Flux lines



Bmod distribution

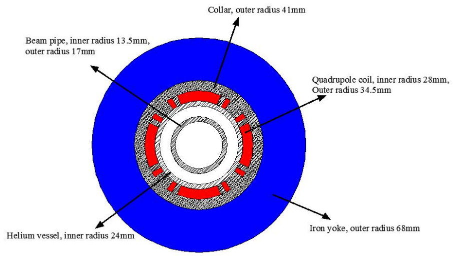


There is iron yoke around the quadrupole coil for QF1. Since the distance between the two apertures is larger enough and there is iron yoke, the field cross talk between two apertures of QF1 can be eliminated.

Magnet	Central field gradient (T/m)	Magnetic length (m)	Width of Beam stay clear (mm)	Min. distance between beams centre (mm)
QD0	136	2.0	19.51	72.61

QF1 Integral field harmonics with shield coils（$\times 10^{-4}$）

n	B_n/B_2@R=13.5mm
2	10000
6	1.08
10	-0.34
14	0.002

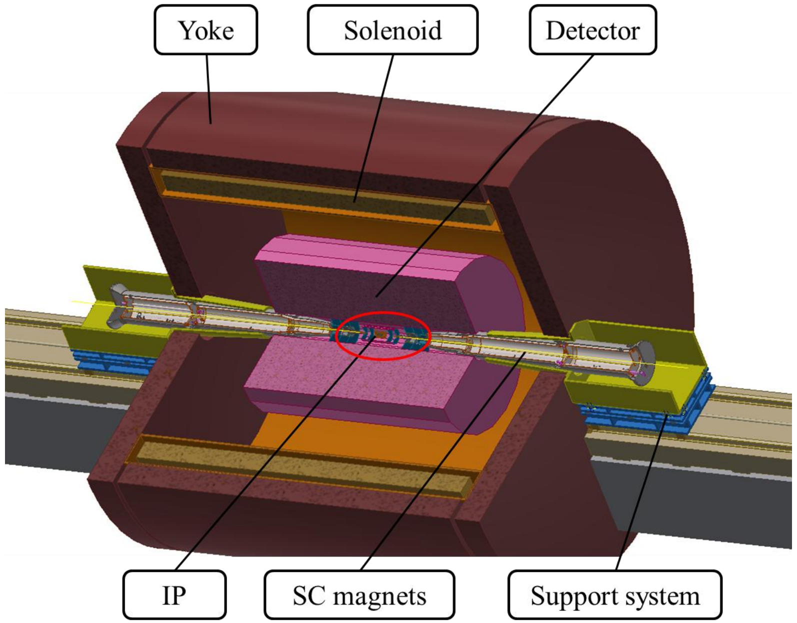


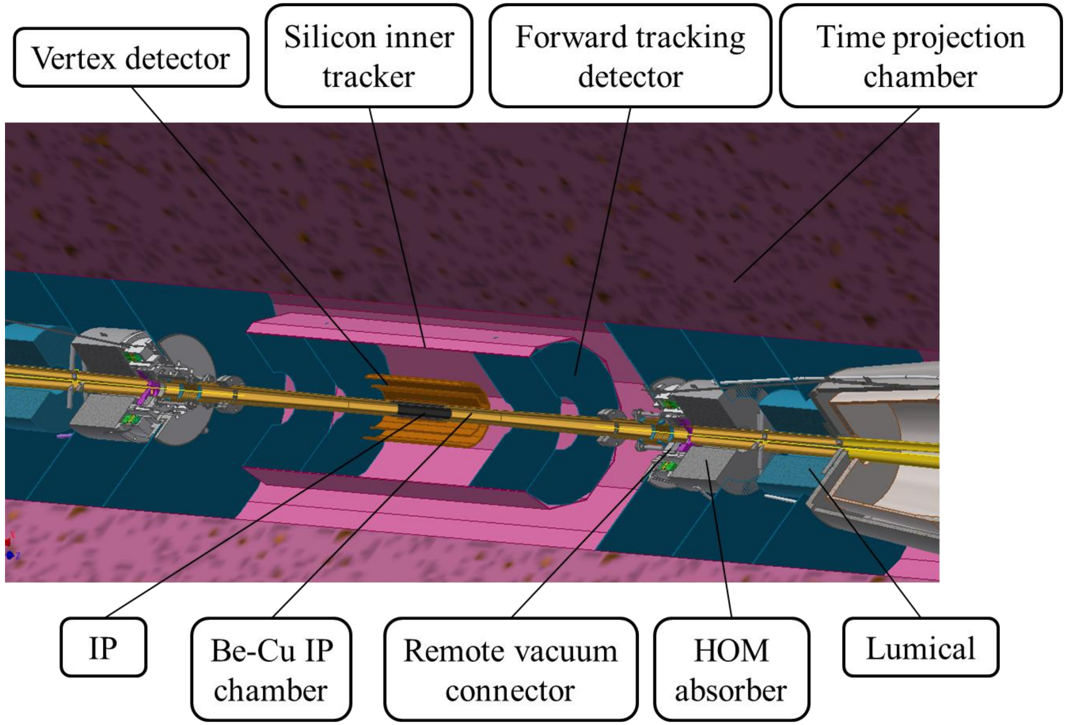
One of QF1 aperture (Peak field 3.8T)

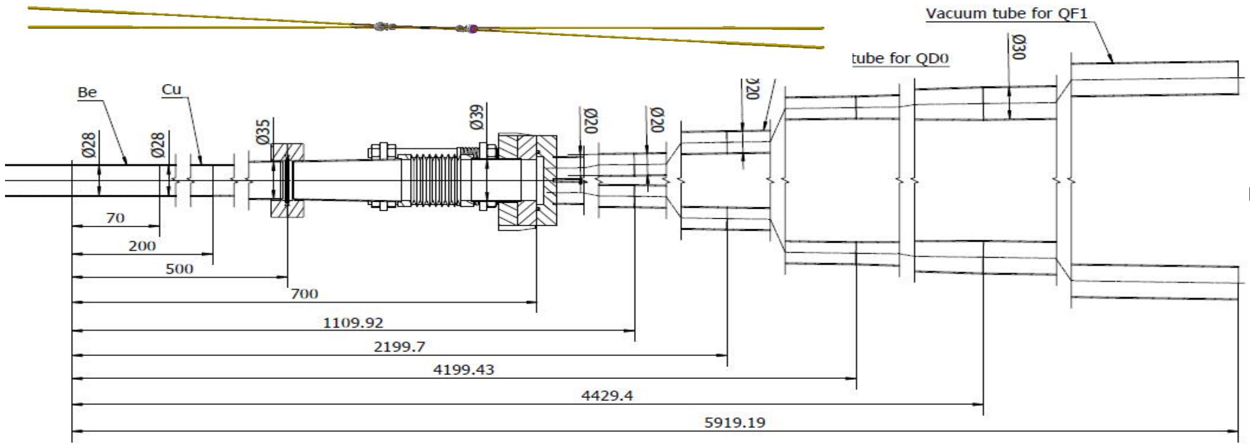
Magnet	Central field gradient (T/m)	Magnetic length (m)	Width of Beam stay clear (mm)	Min. distance between beams centre (mm)
QF1	110	1.48	27.0	146.20

High Luminosity Scheme at Higgs Energy

IR assembly







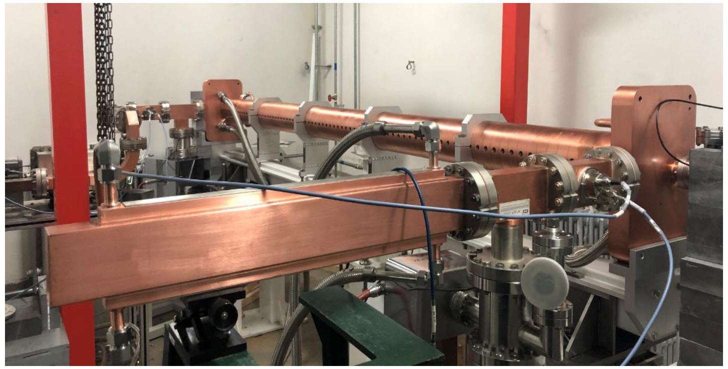
The installation design nearby the IP

CEPC Linac and damping ring key technology R&D

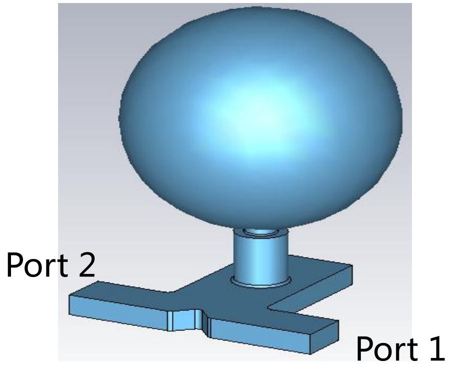
Facility: CEPC injection linac test facility (lab) is located in IHEP

Accelerating structure

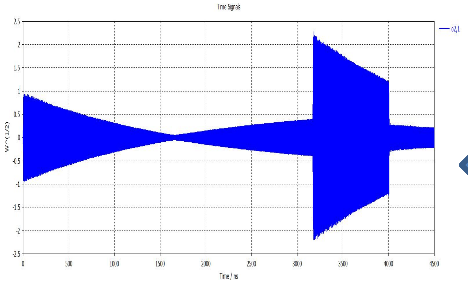
- The structure is 3 meters long with constant gradient design which work mode is $2\pi/3$
- The high power test has finished and the gradiet is up to 33 MV/m



The acclelerating strucutre on high power test bench



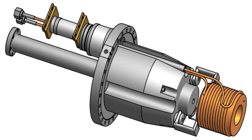
Simulation model



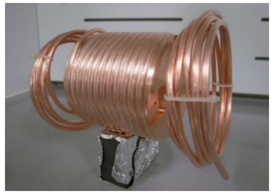
Simulated waveform

Pulse compressor:
Spherical cavity pulse compressor has devoloped
The TE_{113} mode is selected and the RF design is finished.
The Q value is about 140000
The Maximum Energy Multiplication Factor M=1.84.

Positron source R&D

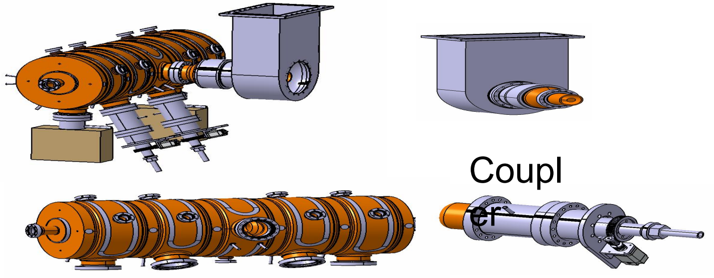


The mechanical design of FLUX concentrator



The finished FLUX concentrator

The test bench of the FLUX concentrator



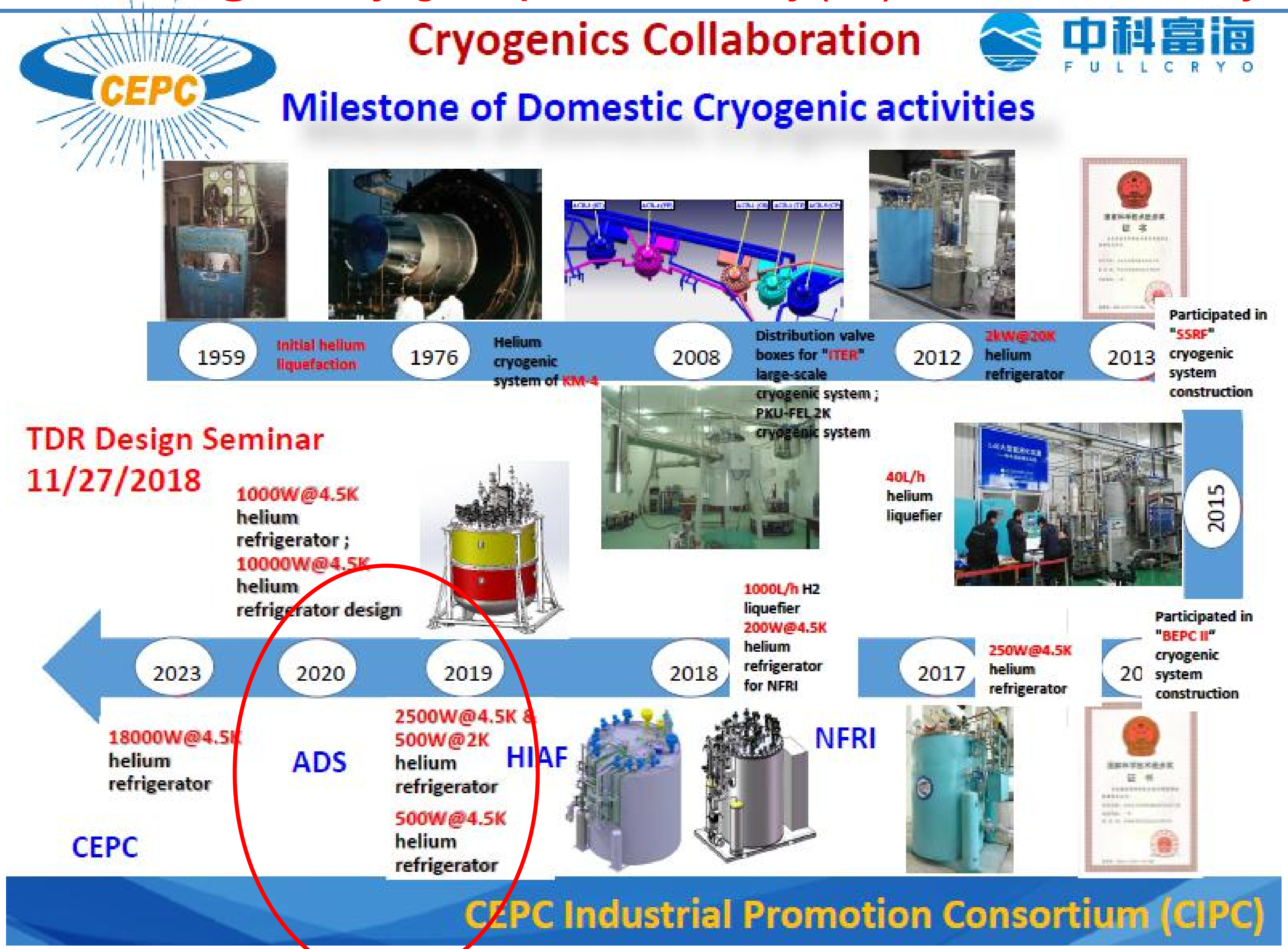
Damping ring 5cell Cavity

Tunner

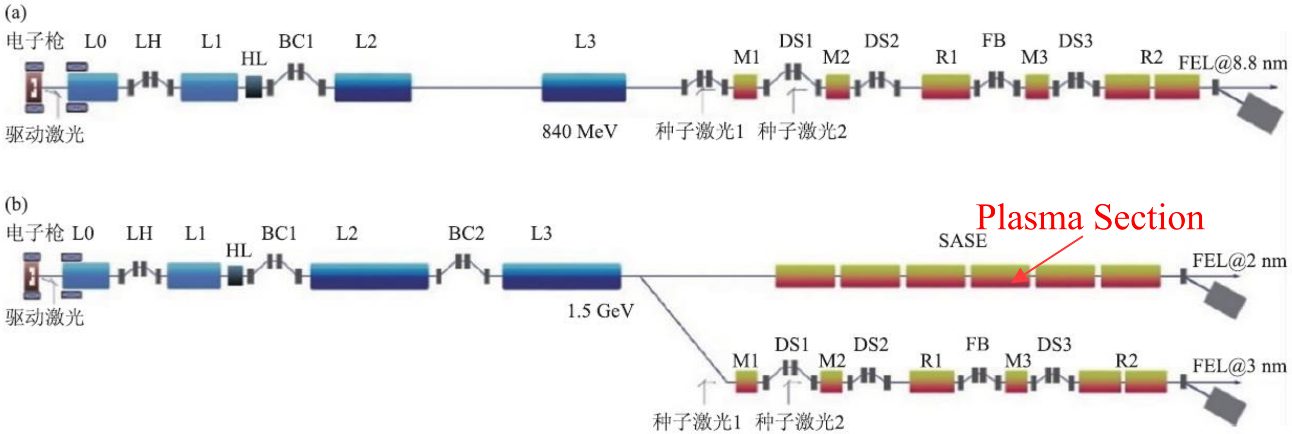
Damping Ring 5 cell cavity: The The 1.1 GeV damping ring need the RF system provide 2 MV.Two 5 cell constant temperature cavities have recommended and the frequency is 650 MHz. According to the simulation, each cavity can provide 1.2 MV cavity voltage when the cavity consumption is 54 kw

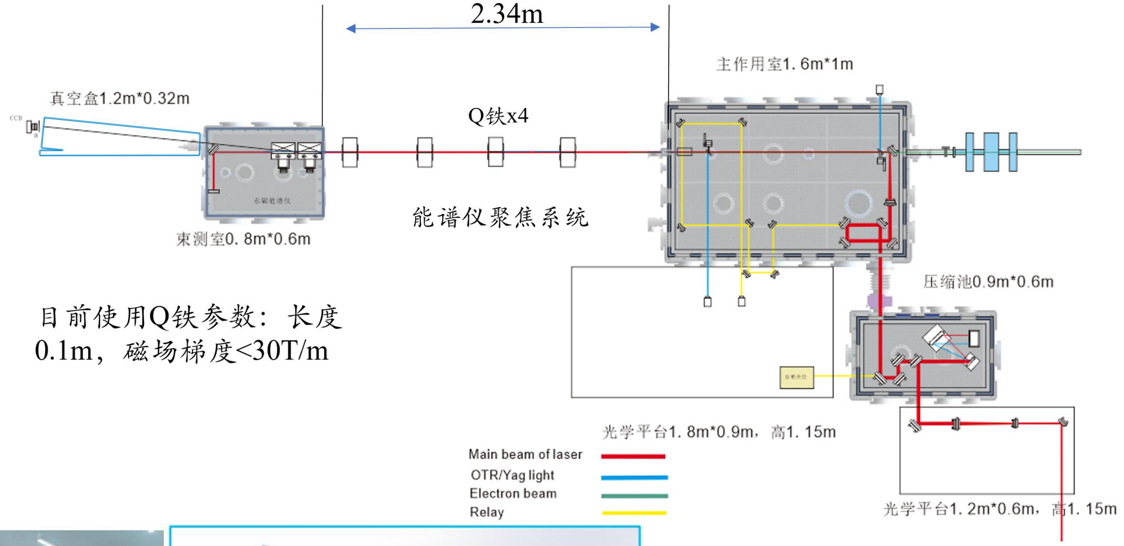
CEPC 18kW@4.5K Cryogenic Plant R&D

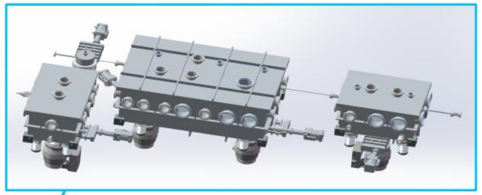
Facility: CEPC18kW@4.5K cryogenic plant test facility (lab) is located in Full Cryo company

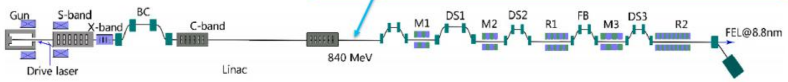


Plasma Dechirper & HTR Experiment Preparation@ SXFEL









Parameter	Value
Energy	0.8GeV
Charge	50pC
Emittance	0.8μm
Beam size	10μm
Peak current	2.4kA
Energy Chirp	~8MeV

Dechirper experiment schedule

- **First step:** Obtaining a stable positively-chirped beam with few percent energy spread
- **Second step:** Post-processing the beam using a passive dechirper

CEPC Plasma Injector Experimental Platform

Facilities: Shanghai S-XFEL facility for electron acceleration and FACETII at SLAC for positron

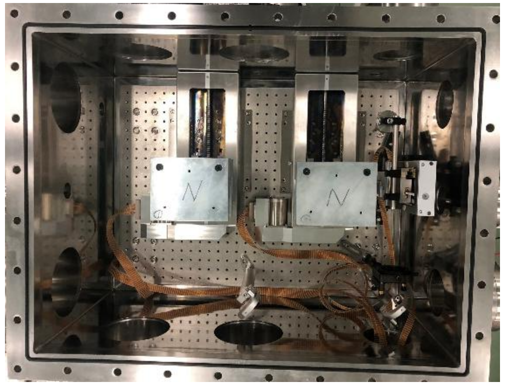
- Plasma experimental station: preliminary set up on Shanghai Soft XFEL facility

  Vacuum system: installation & testing

  - Light path
  - Beam diagnostic system

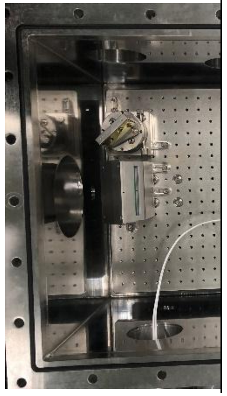
Two proposals have been sent to

SLAC FACET-II



Beam test room

main room



Laser compressor

Proposed experiments on FACET-II

SLAC National Accelerator Laboratory

FACET-II PROPOSAL

Date: Sep. 13th 2020

A. EXPERIMENT TITLE: Two Stage Cascaded High-Transformer-Ratio Plasma Wakefield Accelerator

B. PROPOSERS & REQUESTED FACILITY:

Principal Investigator:	Wei Lu, Mark Hogan, Chan Joshi, Jie Gao
Institution:	Tsinghua University, SLAC, IHEP
Contact Information:	weilu@tsinghua.edu.cn
Experiment Members:	Shiyu Zhou, Jianfei Hua, Dazhang Li
Collaborating Institutions:	
Funding Source (optional)	NSFC、DOE
Approximate Duration:	3-5years

SLAC National Accelerator Laboratory

FACET-II PROPOSAL

Date: Sep. 13th 2020

A. EXPERIMENT TITLE: Stable Mode in Hollow Channel

B. PROPOSERS & REQUESTED FACILITY:

Principal Investigator:	Wei Lu, Chan Joshi, Mark Hogan, Jie Gao
Institution:	Tsinghua/UCLA/SLAC/IHEP
Contact Information:	weilu@tsinghua.edu.cn
Experiment Members:	Shiyu Zhou, Jianfei Hua, Dazhang Li,
Collaborating Institutions:	
Funding Source (optional)	NSFC、DOE
Approximate Duration:	3 years

Hello Wei,

E-mail from Prof. Mark Hogan, head of plasma acc. group in SLAC

So good to hear from you! I very much agree that these are important ideas that can be very impactful for our field. I want to do everything we can to ensure that the proposals are highly reviewed and that we develop a plan that ensures the best chance of success.

Proposals will be reviewed tonight by SLAC group!!

SppC accelerator design and R&D

SppC Baseline Design

- **Baseline design**
  - Tunnel circumference: 100 km
  - Dipole magnet field: 12 T, using full iron-based HTS technology
  - Center of Mass energy: >70 TeV
  - Injector chain: 2.1 TeV
  - Relatively lower luminosity for the first phase, higher for the second phase
- **Energy upgrading phase**
  - Dipole magnet field: 20 -24T, full iron-based HTS technology
  - Center of Mass energy: >125 TeV
  - Injector chain: 4.2 TeV (e.g., adding a high-energy booster ring in the main tunnel in the place of the electron ring and booster)
- **Development of high-field superconducting magnet technology**
  - Starting to develop required HTS magnet technology; before applicable iron-based HTS wire are available, models by YBCO and LTS wires can be used for specific studies (magnet structure, coil winding, stress, quench protection method etc.)

SppC Parameter Choice and Comparation

CDR

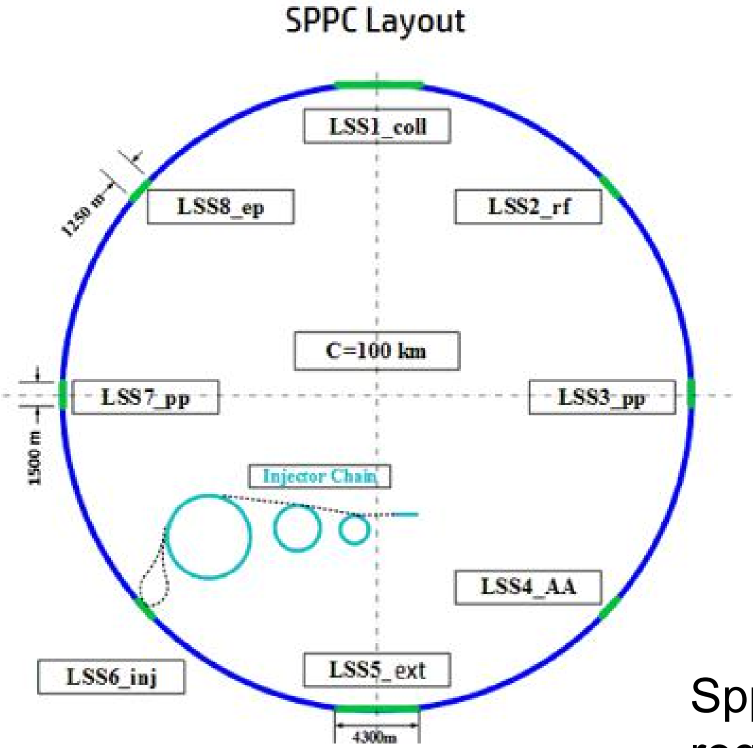
Table 2: SPPC Parameter list(2017.1)[4.6]

	SPPC (Pre-CDR)	SPPC 61Km	SPPC 100Km	SPPC 100Km	SPPC 82Km	SPPC phase 1
Main parameters and geometrical aspects						
c.m. Energy[E_0]/TeV	71.2	70	100.0	128.0	100.0	75.0
Circumference[C_0]/km	54.7	61.0	100.0	100.0	82.0	100.0
Dipole field[B]/T	20	19.88	16.02	19.98	19.74	12.00
Dipole curvature radius[ρ]/m	5928	5889.64	10676.1	10676.1	8441.6	10415.4
Bunch filling factor[f_2]	0.8	0.8	0.8	0.8	0.8	0.8
Arc filling factor[f_1]	0.79	0.78	0.78	0.78	0.78	0.78
Total dipole length [L_{Dipole}]/m	37246	37006	67080	67080	53040	65442
Arc length[L_{ARC}]/m	47146	47443	86000	86000	68000	83900
Straight section length[L_{ss}]/m	7554	13557	14000	14000	14000	16100
Physics performance and beam parameters						
Peak luminosity per IP[L]/ $cm^{-2}s^{-1}$	1.1×10^{35}	1.20×10^{35}	1.52×10^{35}	1.02×10^{36}	1.52×10^{35}	1.01×10^{35}
Beta function at collision[β^*]/m	0.75	0.85	0.99	0.22	1.06	0.71
Max beam-beam tune shift per IP[ξ_y]	0.006	0.0065	0.0068	0.0079	0.0073	0.0058
Number of IPs contribut to ΔQ	2	2	2	2	2	2
Max total beam-beam tune shift	0.012	0.0130	0.0136	0.0158	0.0146	0.0116
Circulating beam current[I_b]/A	1.0	1.024	1.024	1.024	1.024	0.768
Bunch separation[Δt]/ns	25	25	25	25	25	25
Number of bunches[n_b]	5835	6506	10667	10667	8747	10667
Bunch population[N_p] (10^{11})	2.0	2.0	2.0	2.0	2.0	1.5
Normalized RMS transverse emittance[ε]/μm	4.10	3.72	3.59	3.11	3.35	3.16
RMS IP spot size[σ^*]/μm	9.0	8.85	7.86	3.04	7.86	7.22
Beta at the 1st parasitic encounter[$\beta 1$]/m	19.5	18.67	16.26	69.35	15.31	22.03
RMS spot size at the 1st parasitic encounter[σ_1]/μm	45.9	43.13	33.10	56.19	31.03	41.76
RMS bunch length[σ_z]/mm	75.5	56.69	66.13	14.62	70.89	47.39
Full crossing angle[θ_c]/μrad	146	138.03	105.93	179.82	99.29	133.65
Reduction factor due to cross angle[F_{ca}]	0.8514	0.9257	0.9247	0.9283	0.9241	0.9265
Reduction factor due to hour glass effect[F_h]	0.9975	0.9989	0.9989	0.9989	0.9989	0.9989
Energy loss per turn[U_0]/MeV	2.10	1.98	4.55	12.23	5.76	1.48
Critical photon energy[E_c]/keV	2.73	2.61	4.20	8.81	5.32	1.82
SR power per ring[P_0]/MW	2.1	2.03	4.66	12.52	5.90	1.13
Transverse damping time [τ_x]/h	1.71	1.994	2.032	0.969	1.32	4.70
Longitudinal damping time [τ_ε]/h	0.85	0.997	1.016	0.4845	0.66	2.35

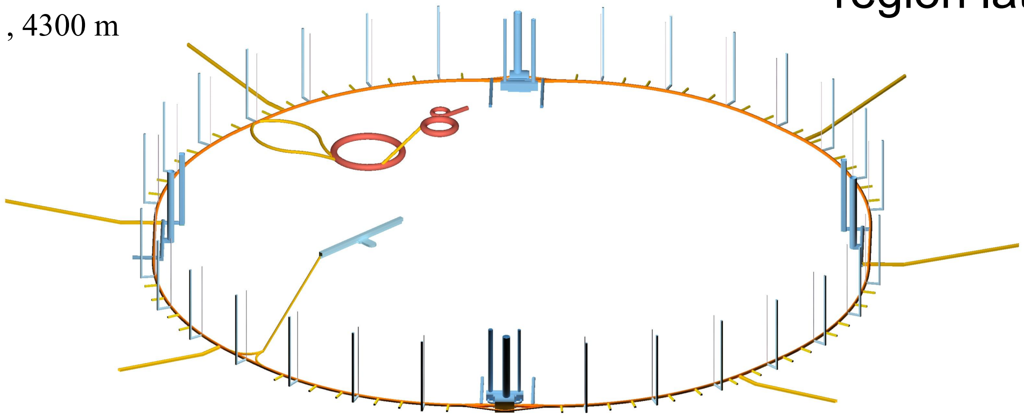
SppC Main Parameters

Parameter	Unit	Value		
		PreCDR	CDR	Ultimate
Circumference	km	54.4	100	100
C.M. energy	TeV	70.6	75	125-150
Dipole field	T	20	12	20-24
Injection energy	TeV	2.1	2.1	4.2
Number of IPs		2	2	2
Nominal luminosity per IP	$cm^{-2}s^{-1}$	1.2e35	1.0e35	-
Beta function at collision	m	0.75	0.75	-
Circulating beam current	A	1.0	0.7	-
Bunch separation	ns	25	25	-
Bunch population		2.0e11	1.5e11	-
SR power per beam	MW	2.1	1.1	-
SR heat load per aperture @arc	W/m	45	13	-

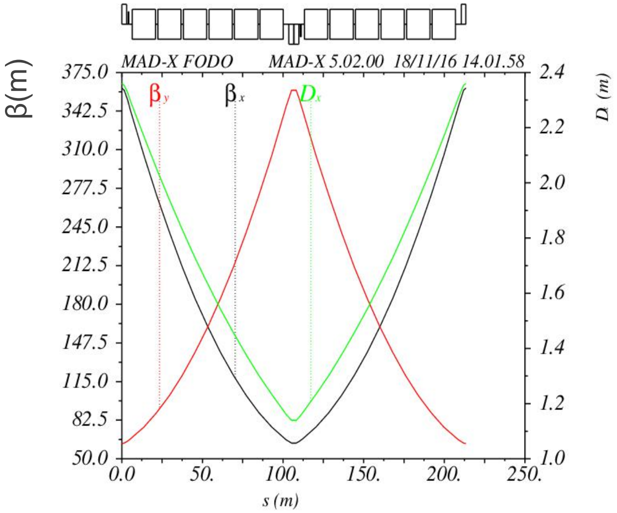
General Layout of SppC



- Length of each section at present:
- 8 arcs, total length 83400 m
- 2 IPs for pp, 1500 m each
- 2 IRs for injection or RF, 1250 m each
- 2 IRs for ep or AA, 1250 m each
- 2 IRs for collimation(ee for CEPC ）, 4300 m each
- C = 100 km

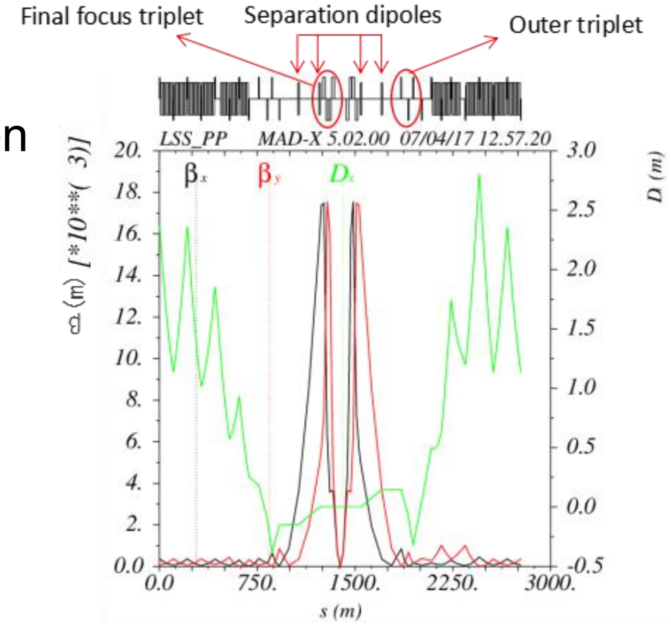


SppC ARC lattice



ARC FODO cell structure

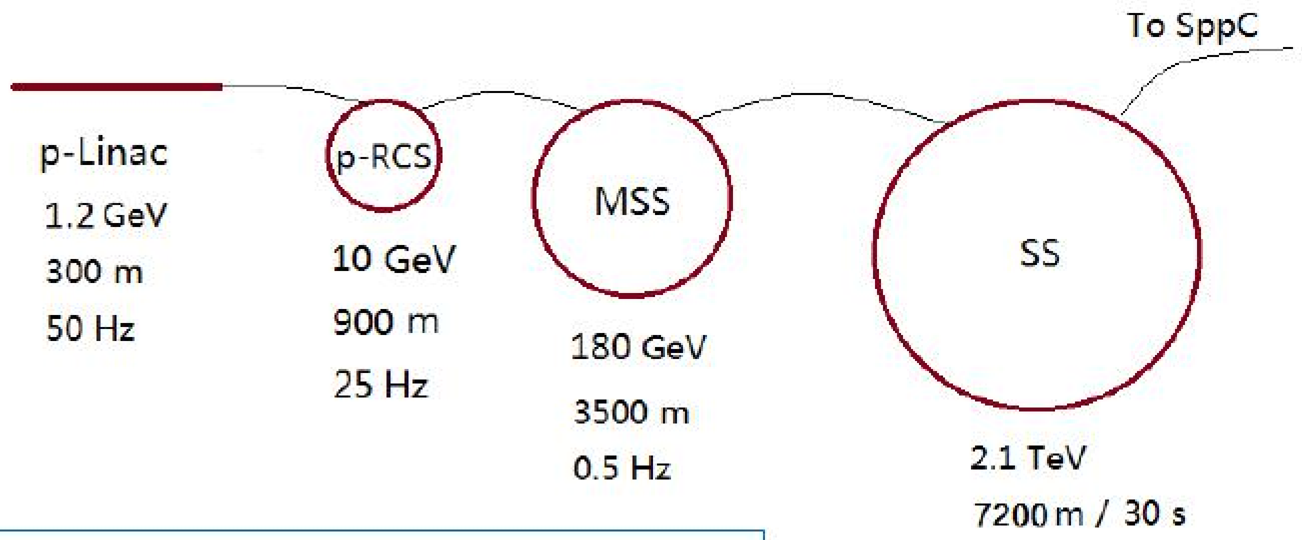
SppC interaction region lattice



LSS_PP(beta*=0.75 m)

SppC Injector Chain

(for proton beam)



p-Linac: proton superconducting linac

p-RCS: proton rapid cycling synchrotron

MSS: Medium-Stage Synchrotron

SS: Super Synchrotron

Ion beams have dedicated linac (I-Linac) and RCS (I-RCS)

Major Parameters for the SppC Injector Chain

	Value	Unit		Value	Unit
p-Linac			MSS		
Energy	1.2	GeV	Energy	180	GeV
Average current	1.4	mA	Average current	20	uA
Length	~300	m	Circumference	3500	m
RF frequency	325/650	MHz	RF frequency	40	MHz
Repetition rate	50	Hz	Repetition rate	0.5	Hz
Beam power	1.6	MW	Beam power	3.7	MW
p-RCS			SS		
Energy	10	GeV	Energy	2.1	TeV
Average current	0.34	mA	Accum. protons	1.0E14	
Circumference	970	m	Circumference	7200	m
RF frequency	36-40	MHz	RF frequency	200	MHz
Repetition rate	25	Hz	Repetition period	30	s
Beam power	3.4	MW	Protons per bunch	1.5E11	
			Dipole field	8.3	T

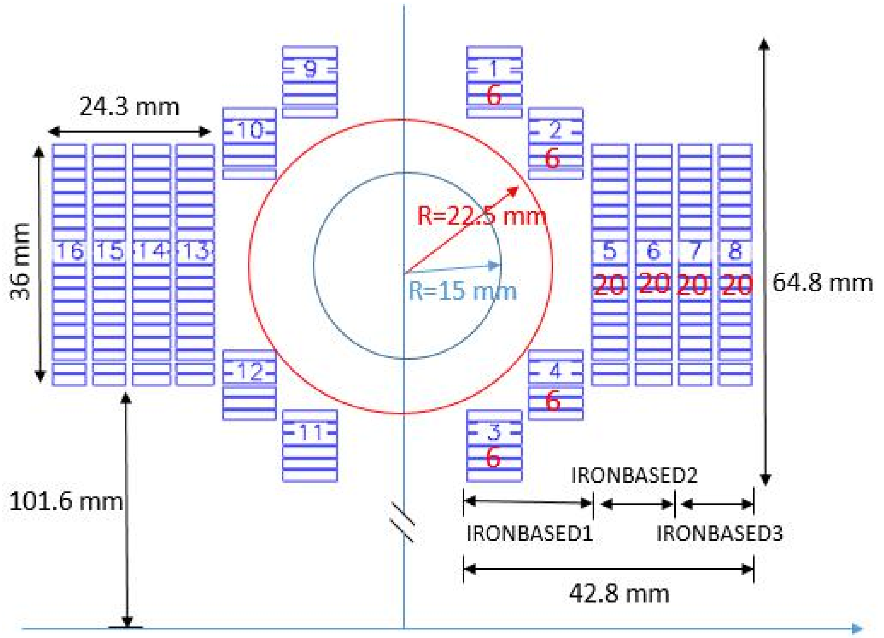
Domestic Collaboration on HTS for SppC SC Dipole Magnet

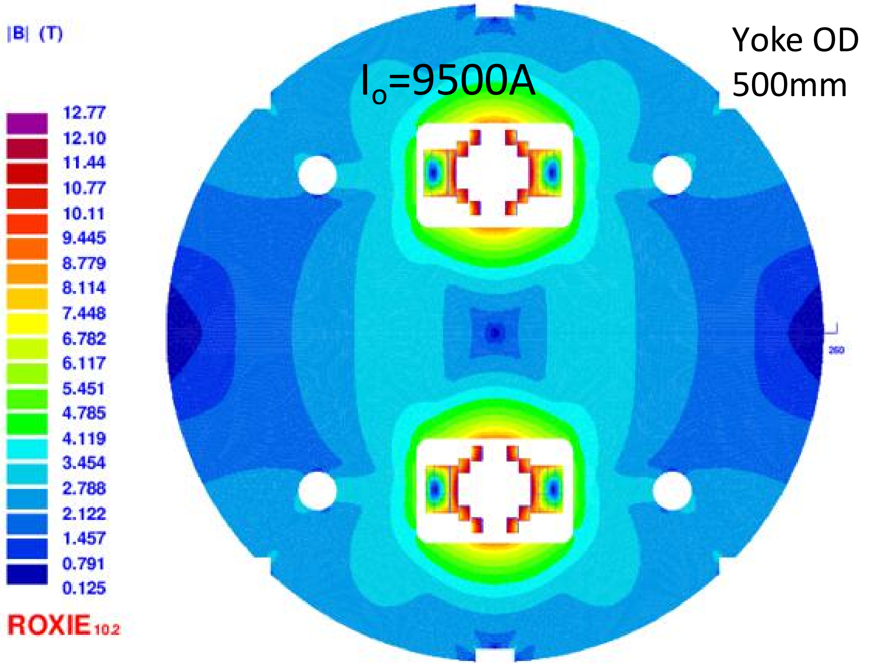
"Applied High Temperature Superconductor Collaboration" was established in Oct. 2016.

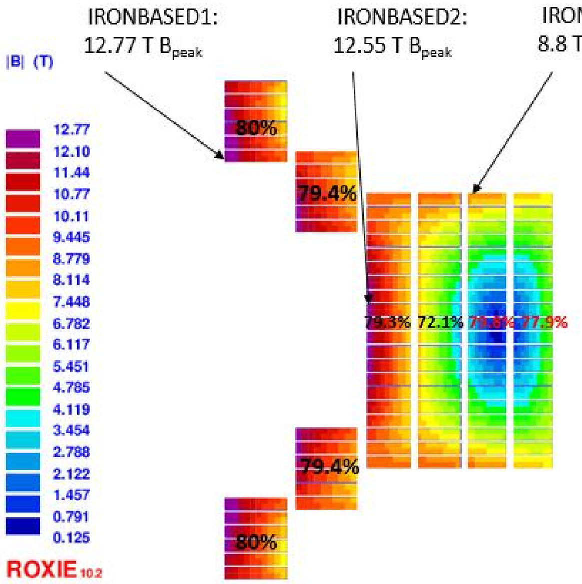
- **Goal:**
  1) To increase the J_c of **IBS** by 10 times, reduce the cost to **20 Rmb/kAm @ 12T & 4.2K**;
  2) To reduce the cost of **ReBCO and Bi-2212** conductors to 20 Rmb/kAm @ 12T & 4.2K;
  3) Realization and Industrialization of iron-based magnet and SRF technology.
- **Working groups:** 1) **Fundamental science** investigation; 2) **IBS** conductor R&D; 3) **ReBCO** conductor R&D; 4) **Bi-2212** conductor R&D; 5) **performance** evaluation; 6) **Magnet and SRF** technology.
- **Collaboration meetings**: every 3 months, to report the progress and discuss plan for next months.

The 12-T Fe-based Dipole Magnet

C. Wang, E. Kong (USTC), Q. Xu et al.







Design with expected J_e of IBS in 2025

Strand	diam.	cu/sc	RRR	Tref	Bref	Jc@ BrTr	dJc/dB
IBS	0.802	1	200	4.2	10	4000	111

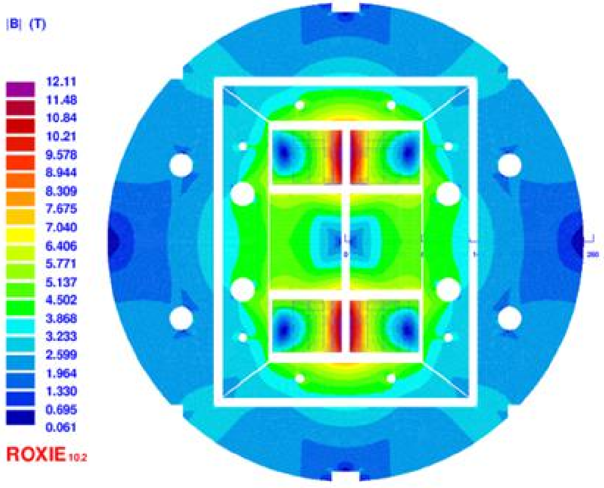
- The required length of the 0.8 mm IBS is 6.1 Km/m
- For 100-km SPPC accelerator, 3000 tons of IBS is needed
- Target cost of IBS: 20 RMB (~2.6 Eur) /kAm @12 T

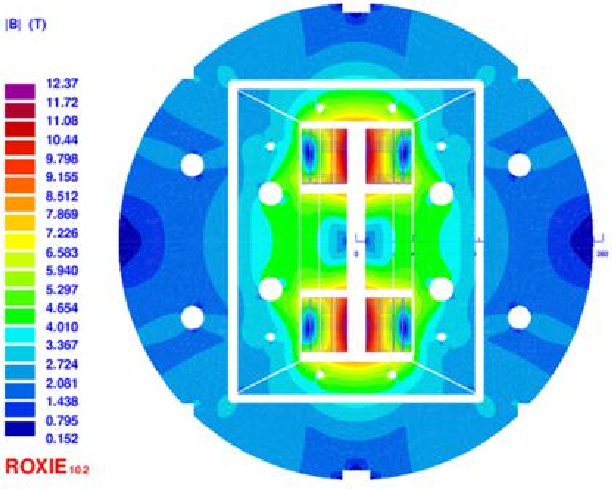
R&D of 12T Twin-Aperture Dipole Magnet

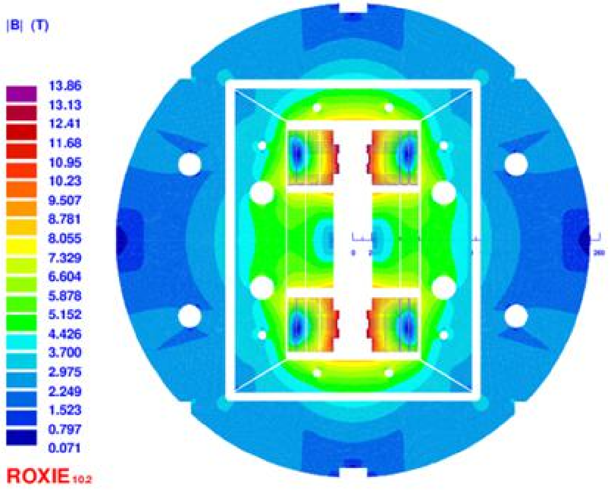
Operation load line at 12 T: ~80% at 4.2K

C. Wang, K. Zhang, Y. Wang, D. Cheng, E. Kong (USTC), Q. Xu et al.

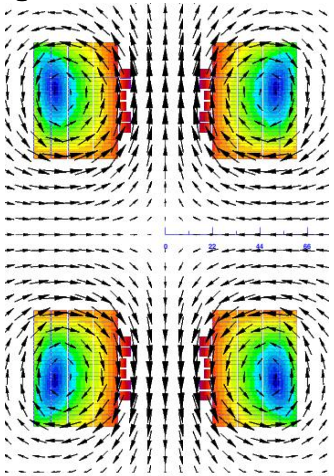
NbTi+Nb_3Sn, 2*ϕ10 → All Nb_3Sn, 2*ϕ20 aperture → Nb_3Sn+HTS, 2*ϕ30



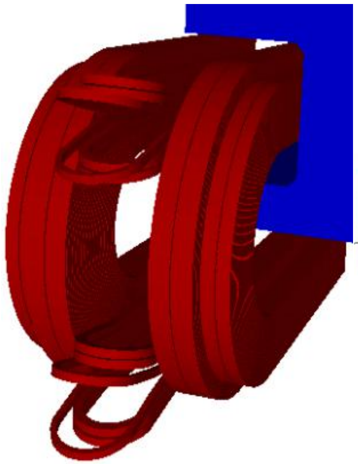




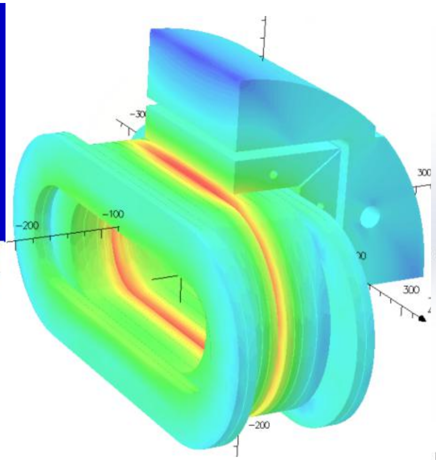
Magnetic flux distribution



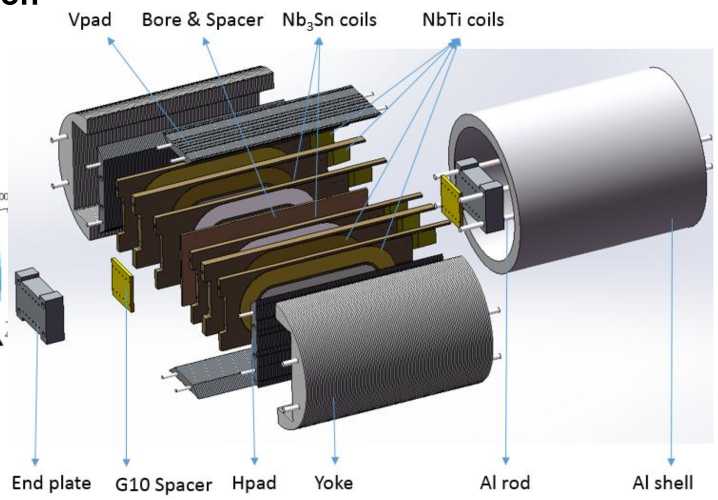
3d coil layout



3D magnetic field distribution



Components and assembly



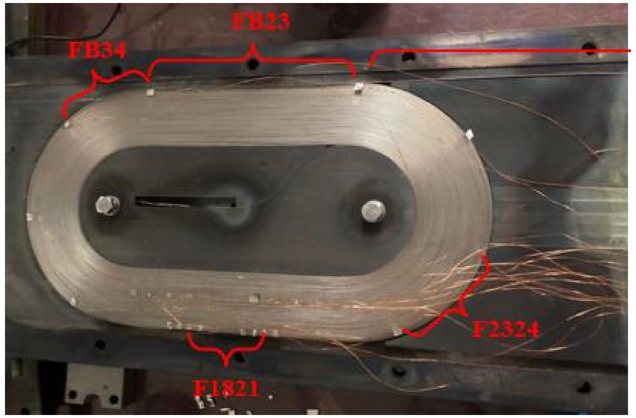
Status of the High Field Dipole Magnet R&D

Facility: SppC high field magnets test facility (lab) is located in IHEP of 240m^2

Test of the 1st IBS solenoid coil at 24 T and the 1st IBS racetrack coil at 10 T

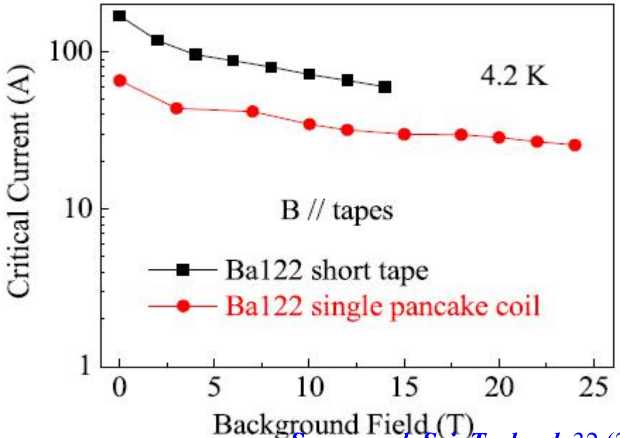
Table 2. Specification of single pancake coil

Parameter	Unit	Value
Inner diameter	mm	30
Outer diameter	mm	34.8
Height	mm	4.62
Thickness of stainless steel tape	mm	0.1
Turns		4.5
Total length of IBS wire	mm	450

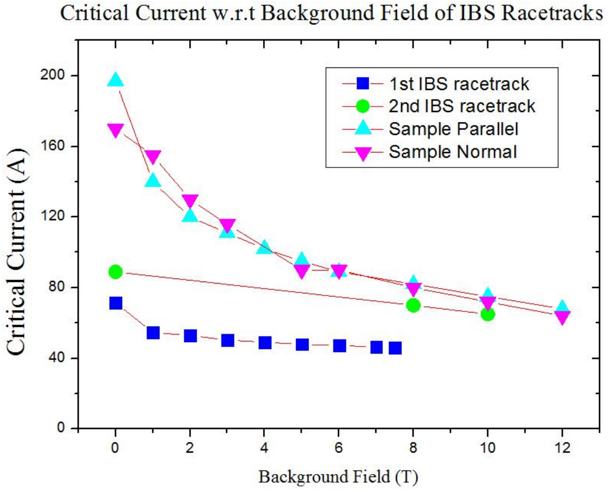


IHEP multi-material SC Dipole@4K reached 12T in June 2021

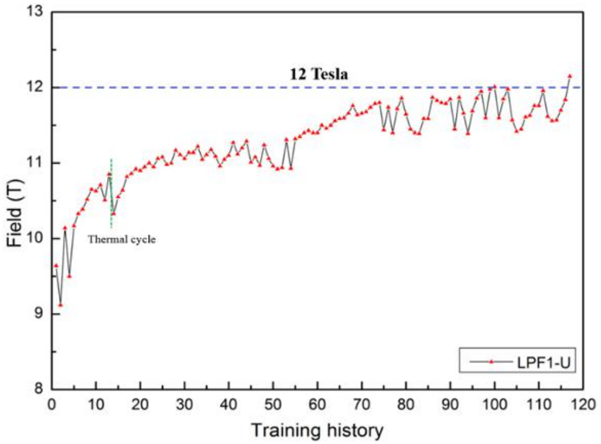
25T-HM, RT bore Φ38 mm



Supercond. Sci. Technol. 32 (2019) 04LT01

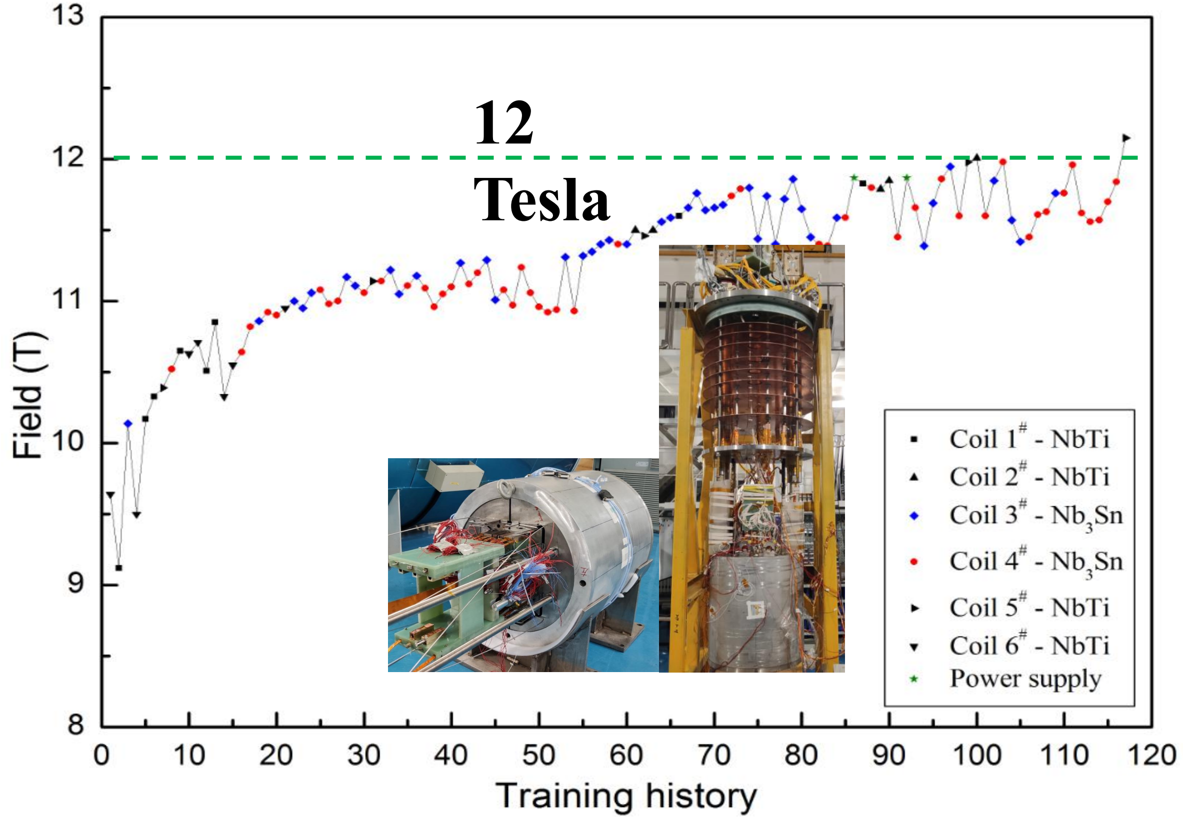


Supercond. Sci. Technol. 2020, in press

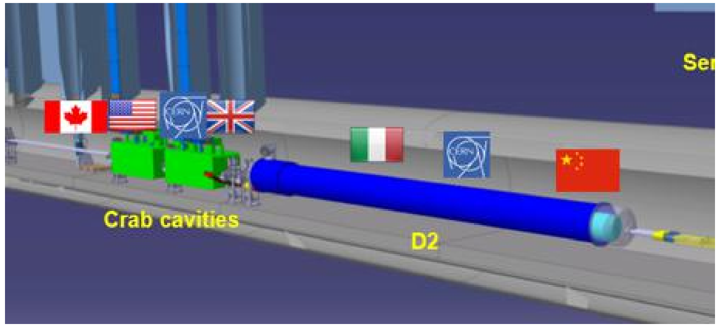


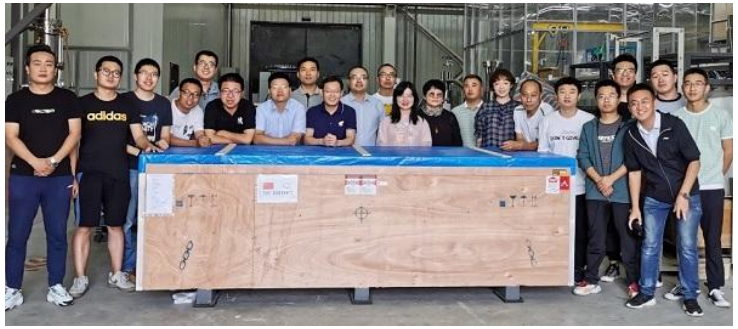
Advanced Accelerator SC Magnet R&D

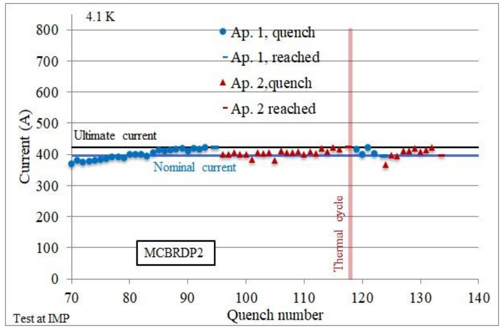
- The dual-aperture model dipole magnet reached 12 T at 4.2 K: common-coil configuration with 15-mm gap and Nb_3Sn+NbTi coils.
- Next step: 16 T model dipole with HTS+Nb_3Sn coils



The 1st full-length prototype magnet for LHC-HL CCT SC magnet from China: Performance test reached the design target. The 1st prototype CCT magnethas been sent to CERN. A good start for the 12 units series production.

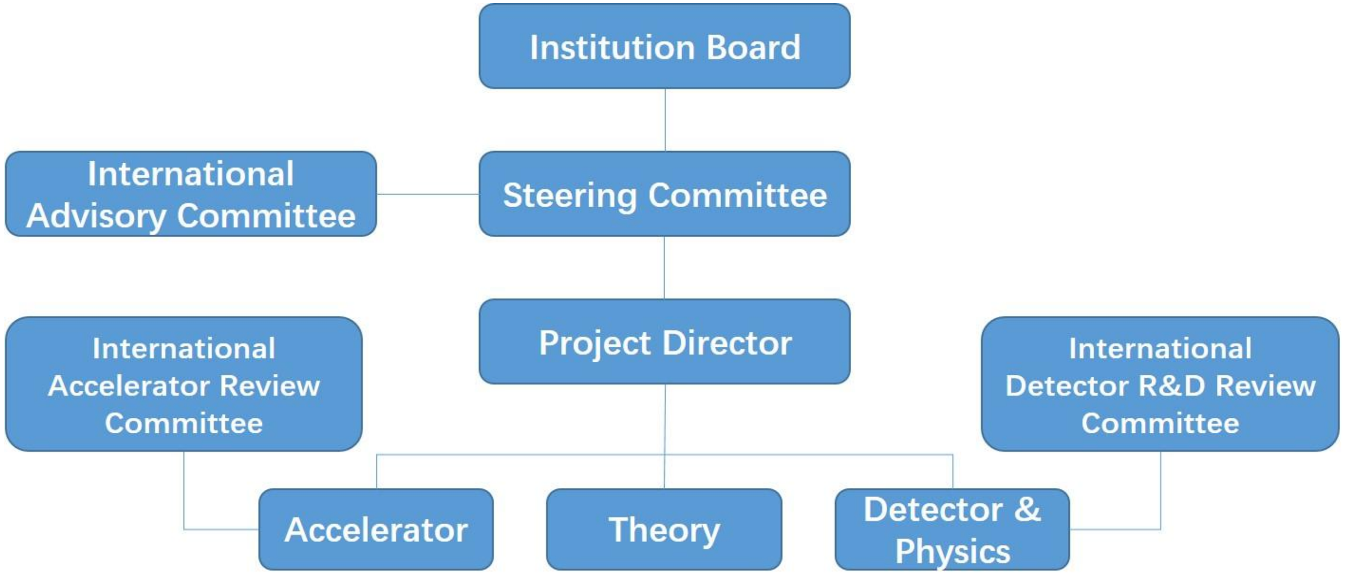






CEPC-SppC internation and CIPC collaborations

Organigram of CEPC



http://cepc.ihep.ac.cn/orga.html

IAC: Young-Kee Kim (Chair), University of Chicago

IARC: Marica Enrica Biagini (Chair), INFN

IDRC: Dave Newbold, UK, RAL (chair)

The first IAC meeting from Sept. 16-17, 2015

Institution Board		Yuanning Gao (PKU) Jie Gao (IHEP, Deputy)
Steering Committee		Yifang Wang (IHEP, Chair) Hongjian He (SJTU) Xinchou Lou (IHEP) Shan Jin (NJU) Haijun Yang (SJTU) Meng Wang (SDU) Nu Xu (IMP, CAS) Wei Lu (Tsinghua Univ) Jie Gao (IHEP) Yuanning Gao (PKU) Jianbei Liu (USTC) Qinghong Cao (PKU)
Project Director		Xinchou Lou (IHEP) Haijun Yang (SJTU, Deputy)
Working Group	Theory	Hongjian He (SJTU) Jianping Ma (ITP, CAS) Xiaogang He (SJTU)
	Accelerator	Jie Gao (IHEP) Jingyu Tang (SppC, IHEP) Chenghui Yu (IHEP) Yuhui Li (IHEP)
	Physics & Detector	Joao Guimaraes da Costa (IHEP) Jianchun Wang (IHEP) Jianbei Liu (USTC)

International Committees of CEPC

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Hesheng Chen, IHEP, Chinese Academy of Sciences

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Rohini Godbole, CHEP, Bangalore

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Peter Jenni, CERN & Albert-Ludwigs-University Freiburg

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Ivan Villa Alvarez, Spain, Santader

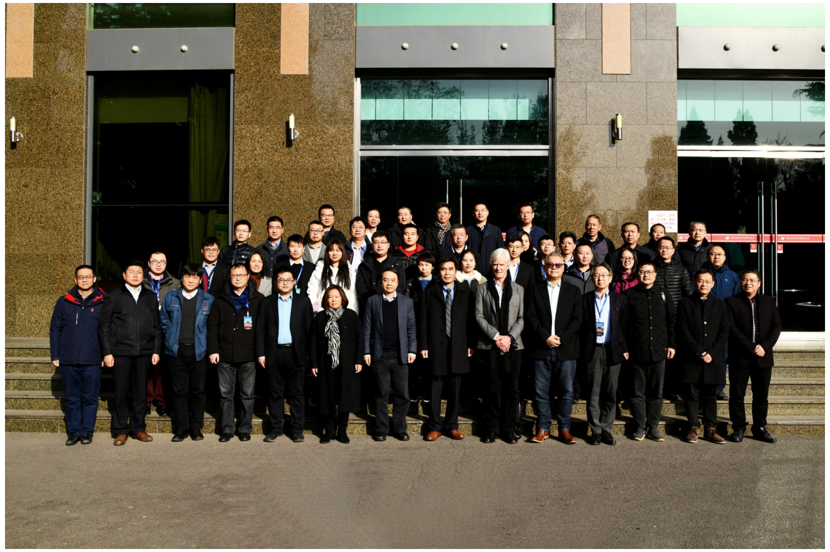
Hitoshi Yamamoto, Japan, Tohoku

http://cepc.ihep.ac.cn/orga.html

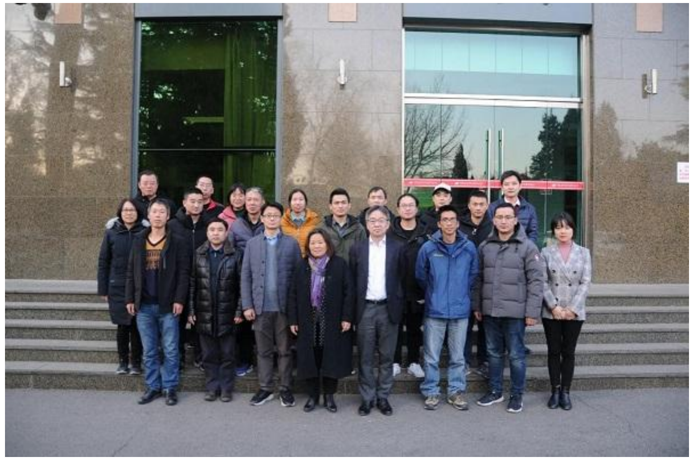
CEPC-CIPC Collaboration and CEPC Promption Fund (CPF)

CIPC established in Nov. 7 , 2017

CIPC Annual Meeting, July 26 , 2018

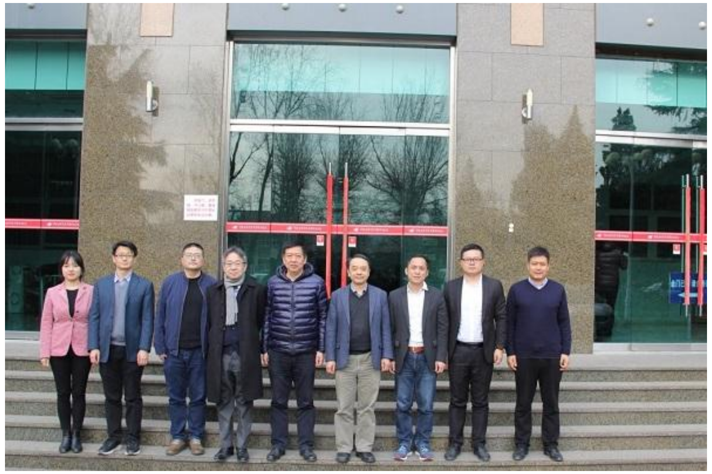


CEPC-CIPC Collavoration Meeting and CEPC Promotion Fund (CPF) First Meeting on Nov. 20, and 2019, IHEP



CEPC-Industry Collaboration Meeting Dec. 27 , 2019

CPF funding seed money of 500kUSD was from Yifang Wang on Nov. 17, 2019



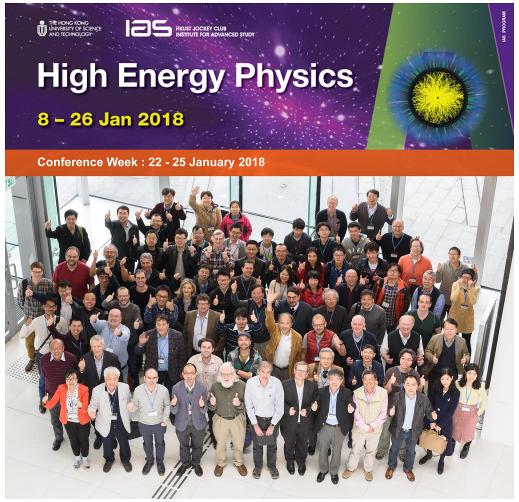
The first Industry contributed to CPF Jan. 2 , 2020

CEPC International Collaboration and International Meetings

More than 20 MoUs including CEPCcollaboration, such as KEK, BINP, JINR, ...

The first CEPC-SppC international Collaboration Workshop
Nov 6-8, 2017, IHEP, Bejing (2018, 2019)
http://indico.ihep.ac.cn/event/6618

The sencond CEPC-SppC international Collaboration Workshop
Nov 12-14, 2018, IHEP, Bejing
https://indico.ihep.ac.cn/event/7389/



IAS Higgh Energy Physics Workshop
(Since 2015 till now, every year
http://iasprogram.ust.hk/hep/2018

Workshop on the Circuar Electron Positron Collider-EU and US editions

May 24-26, 2018, Università degli Studi Roma Tre, Rome, Italy

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

2019 May Oxford,UK, 2019 Sept. Chicago,USA; 2020, May Marseille, France,
Catholic University, Washington DC, April 2020

CEPC Industrial Promotion Consortium (CIPC) Collaboration Status

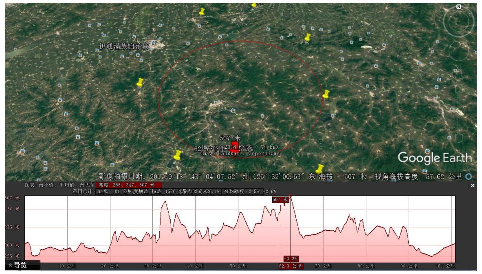
1) Superconduting materials (for cavity and for magnets)
2) Superconducting cavities
3) Cryomodules
4) Cryogenics
5) Klystrons
6) Vacuum technologies
7) Electronics
8) SRF
9) Power sources (650MHz Klystron)
10) Civil engineering
11) Precise machinary.....

CIPC established in Nov. 7 , 2017
CIPC (>70 companies)

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

Site selection, civil engineering and timeline

CEPC Site Selection Status

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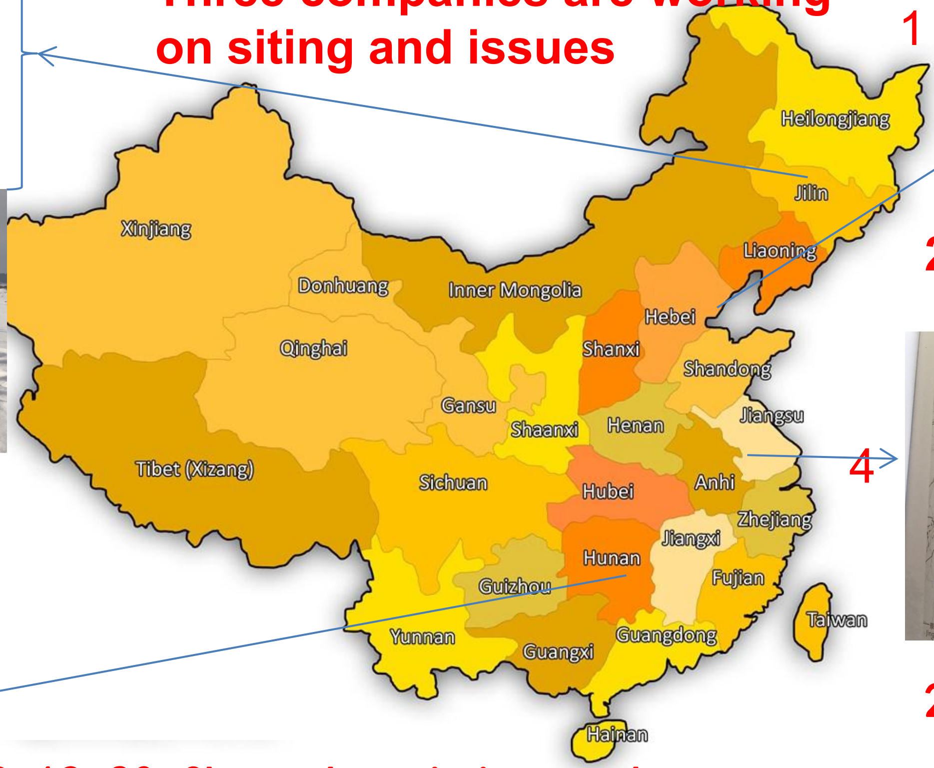
Three companies are working on siting and issues



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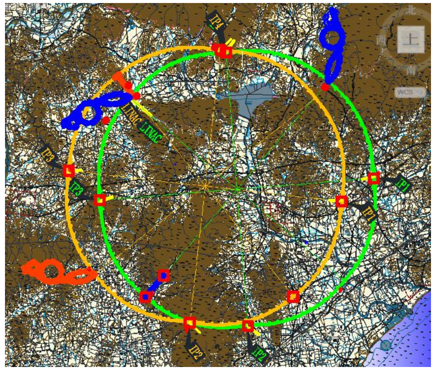
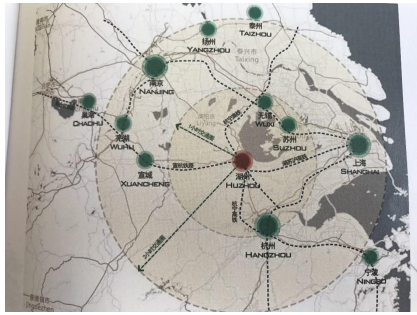
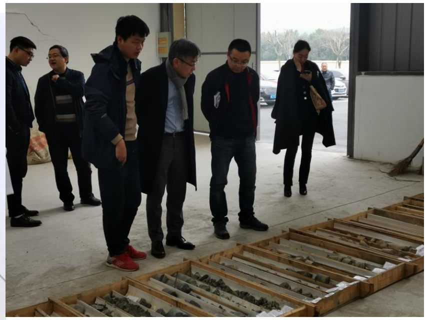


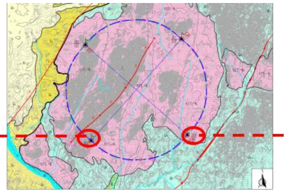
2020.9.14-18 Qinhuangdao updated


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

4

2019.12.16-17 Huzhou siting update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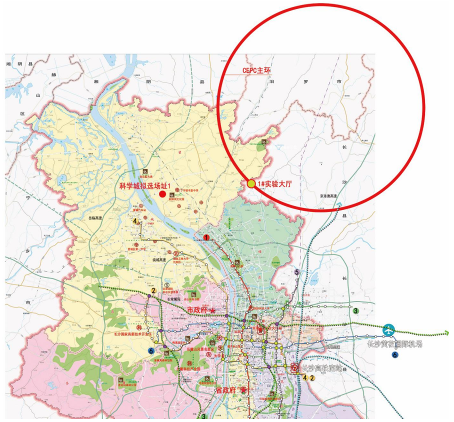
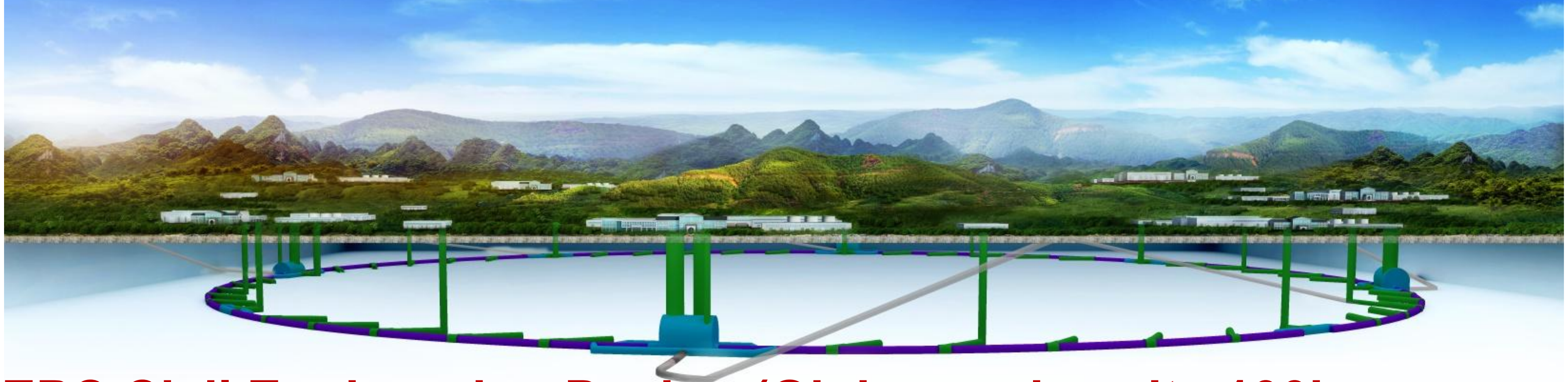
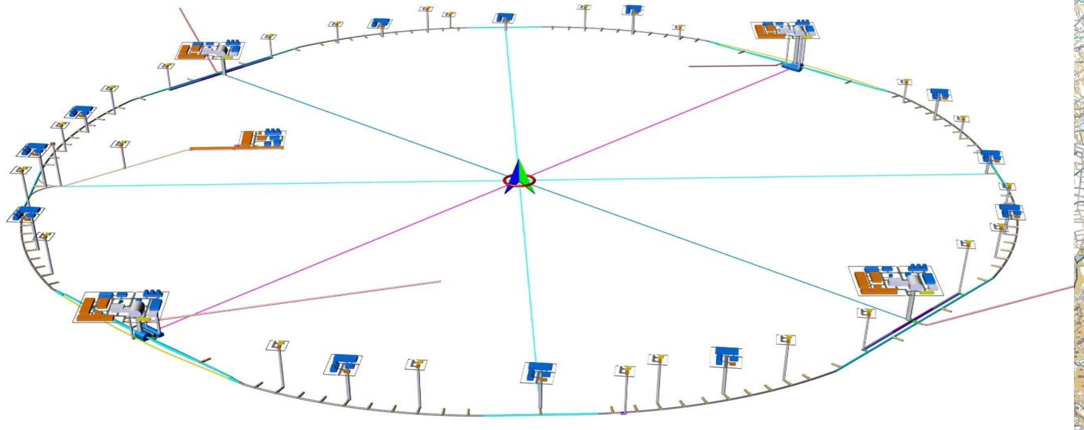
2019.08.19-20 Changsha siting update

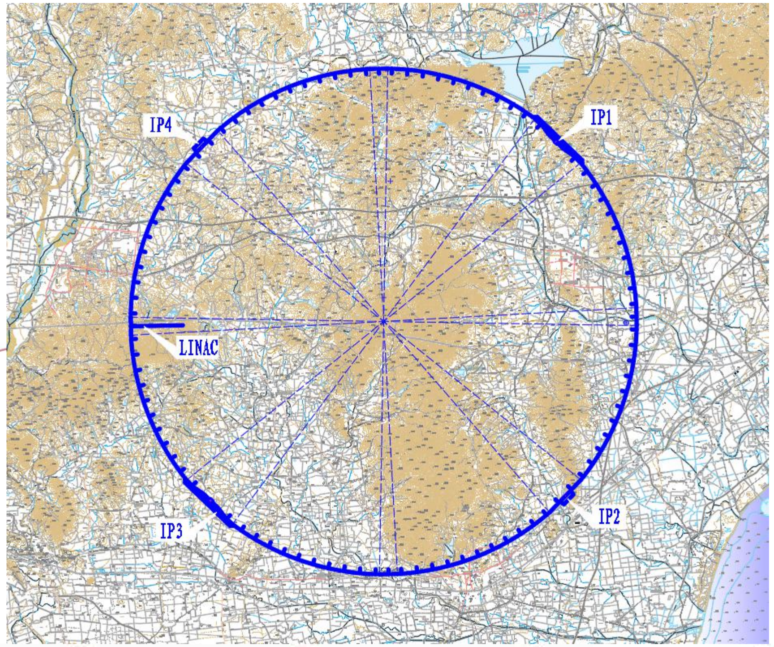


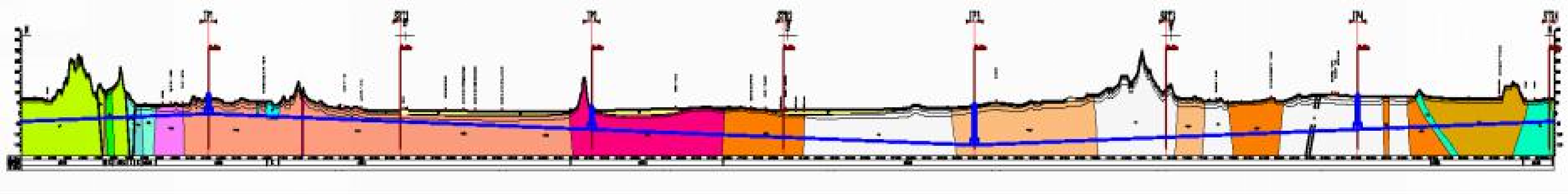

1) Qinhuangdao, Hebei Province（Completed in 2014）
2) Huangling, Shanxi Province（Completed in 2017)
3) Shenshan, Guangdong Province(Completed in 2016)
4) Huzhou, Zhejiang Province (Started in March 2018)
5) Chuangchun, Jilin Province (Started in May 2018)
6) Changsha, Hunan Province (Started in Dec. 2018)



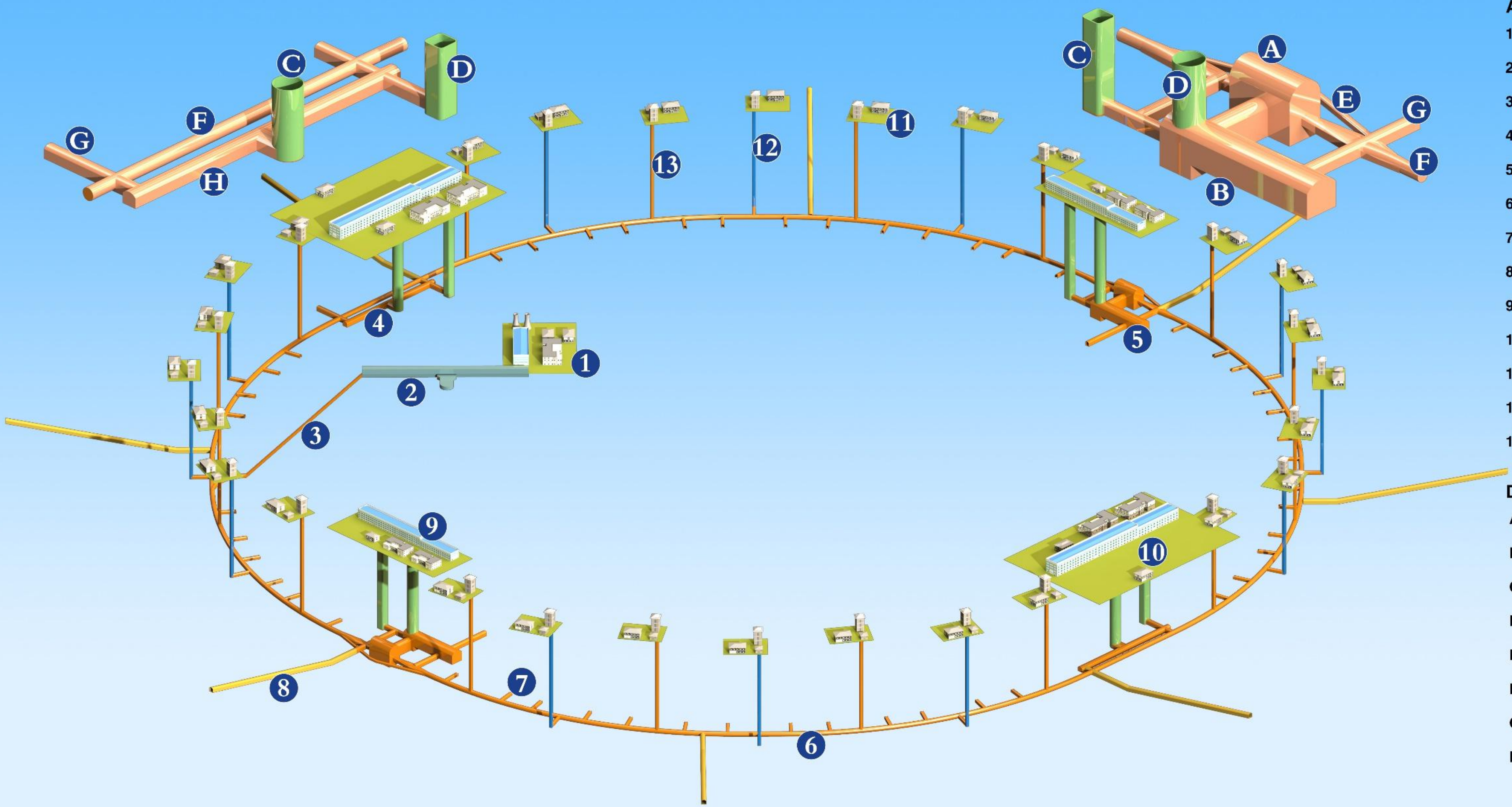
CEPC Civil Enginnering Design (Qinhuangdao site 100km, example)







CEPC



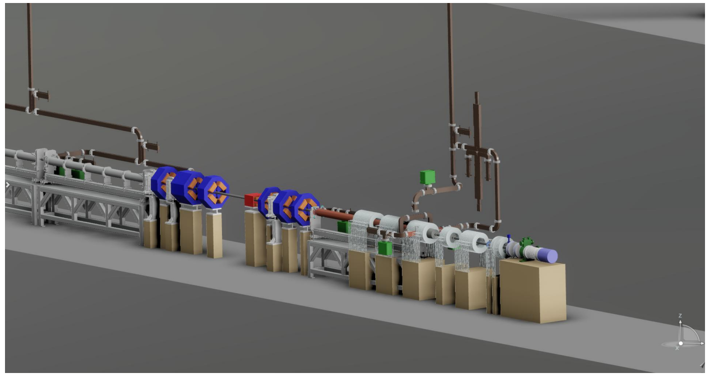
Accelerator Region Caverns:

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

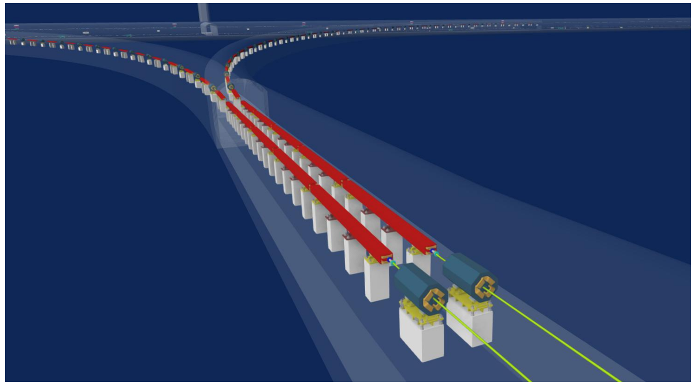
Detector Region Caverns:

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

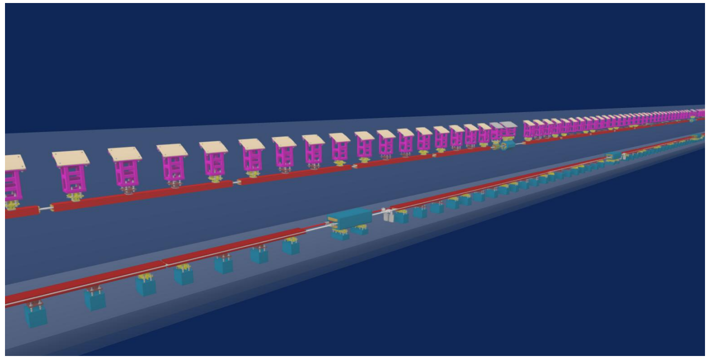
CEPC Civil Engineering



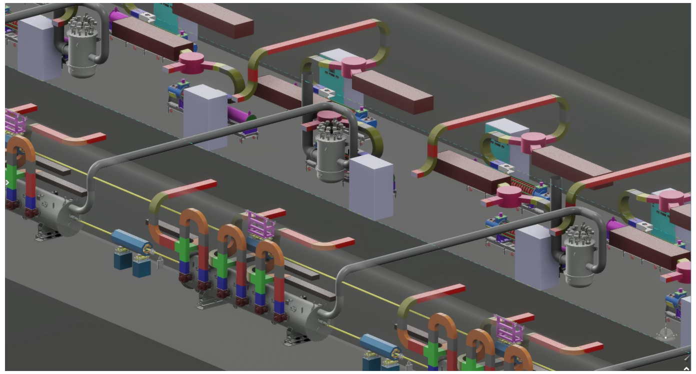
Electron source



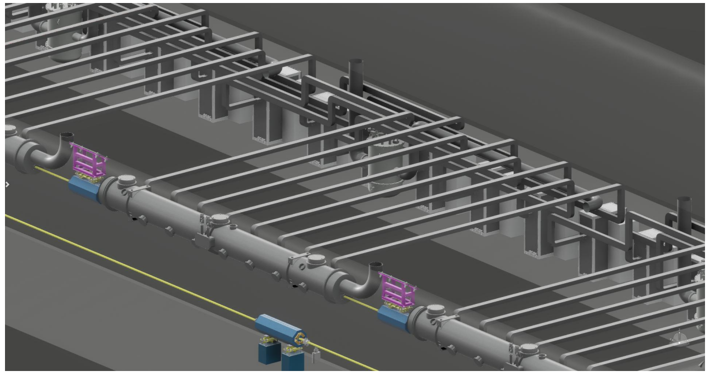
Linac to Booster



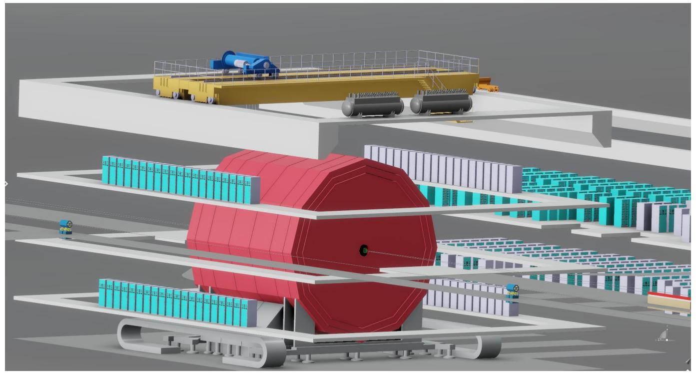
Booster and collider ring tunnel



Collider ring SCRF



Booster SCRF

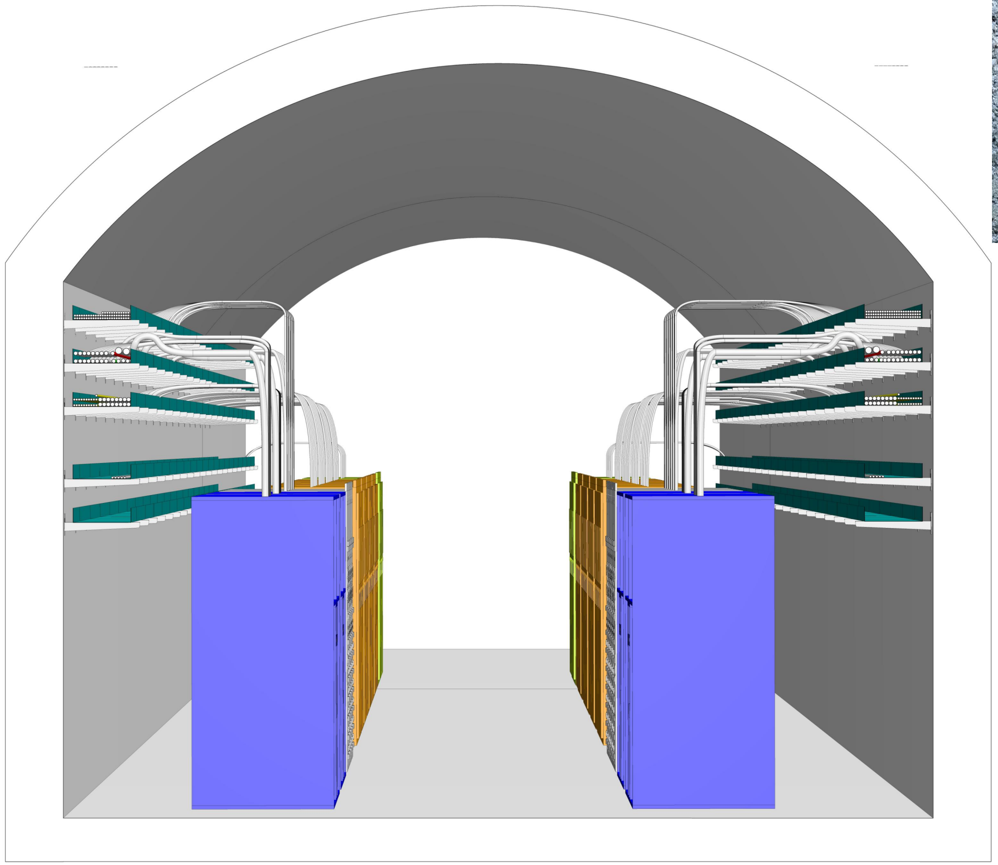


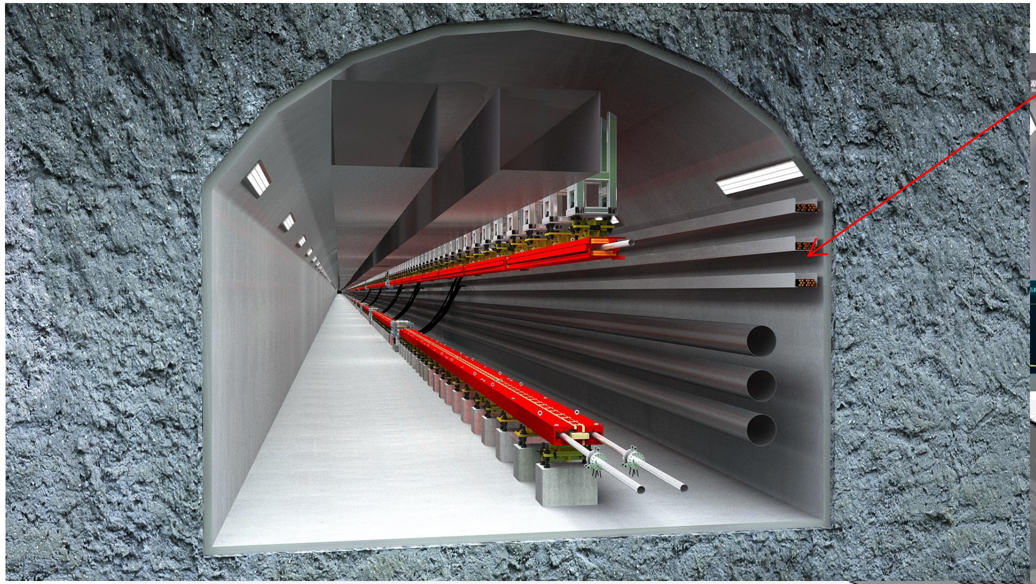
Detector hall

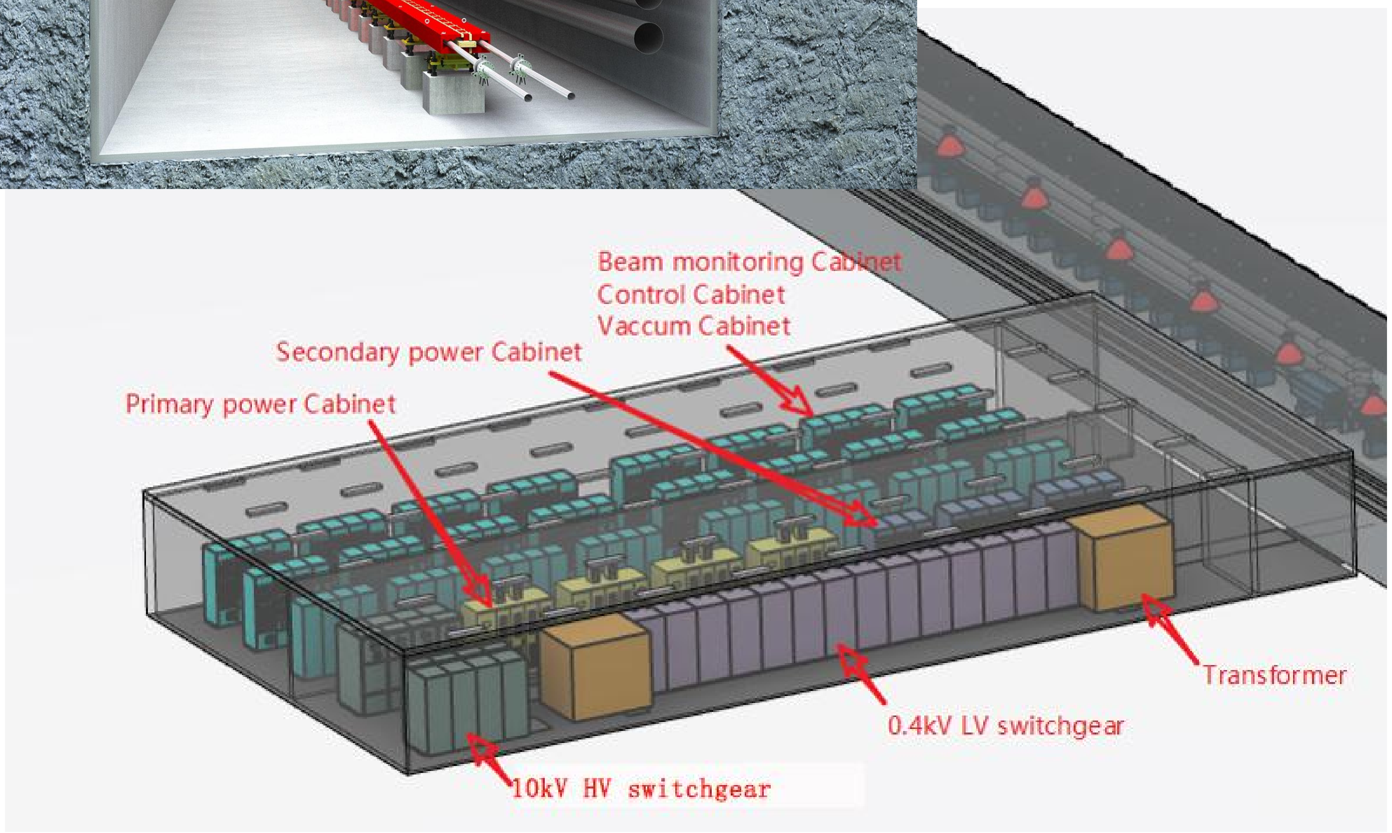
CEPC Conventional Facility and Civil Engineering

Cables installed!

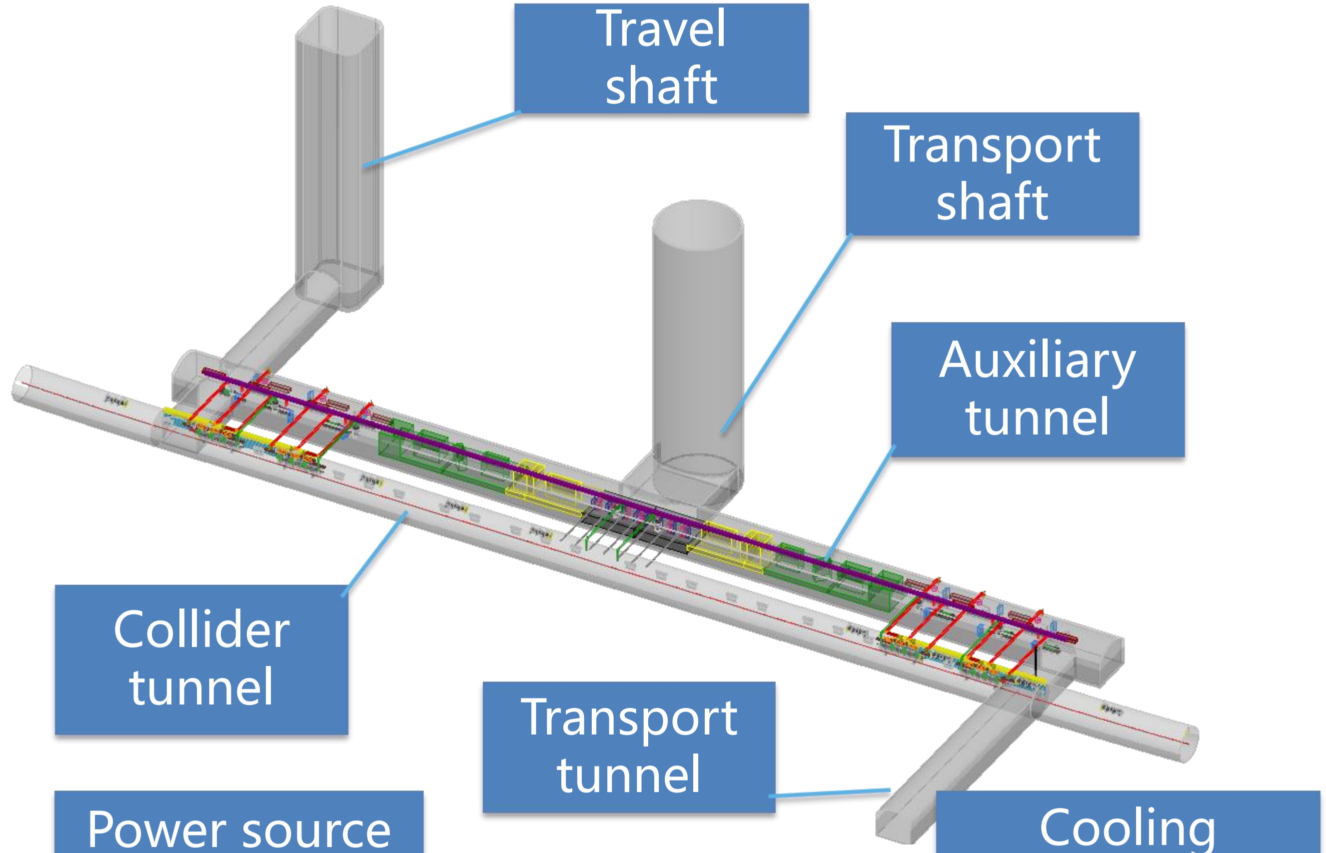
Electrical Equipment General Layout in Auxiliary

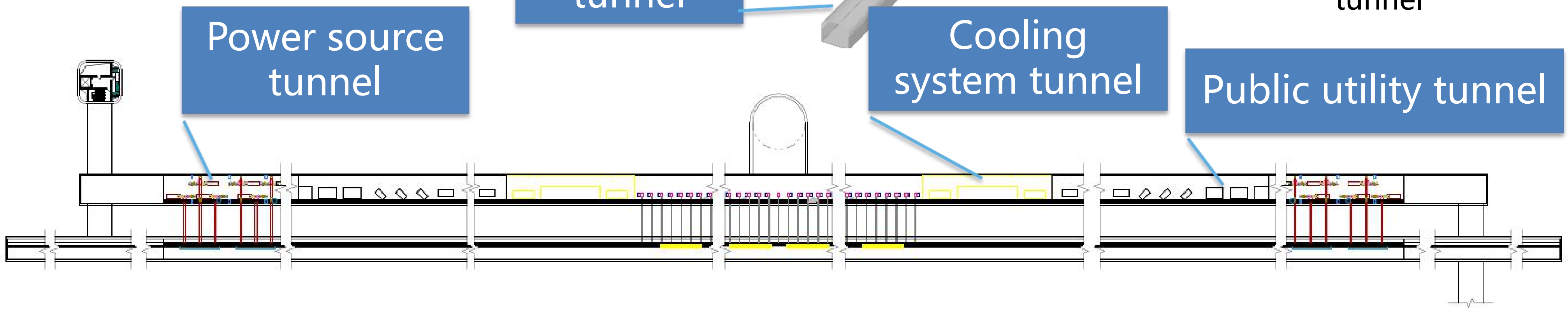






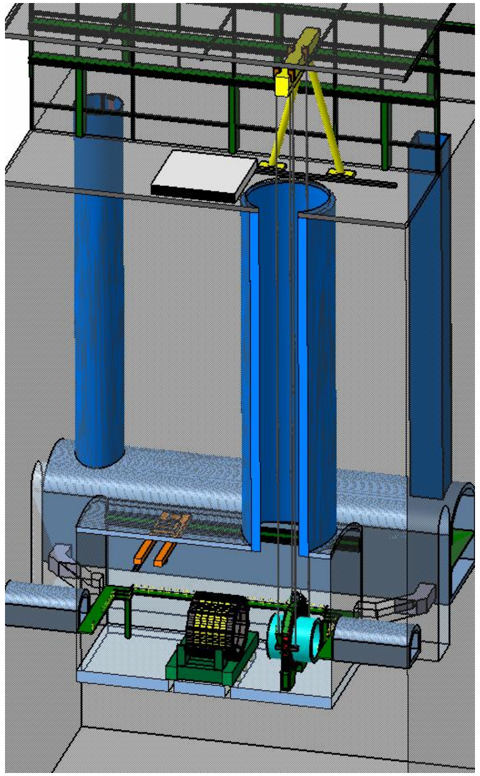
CEPC SCRF Region

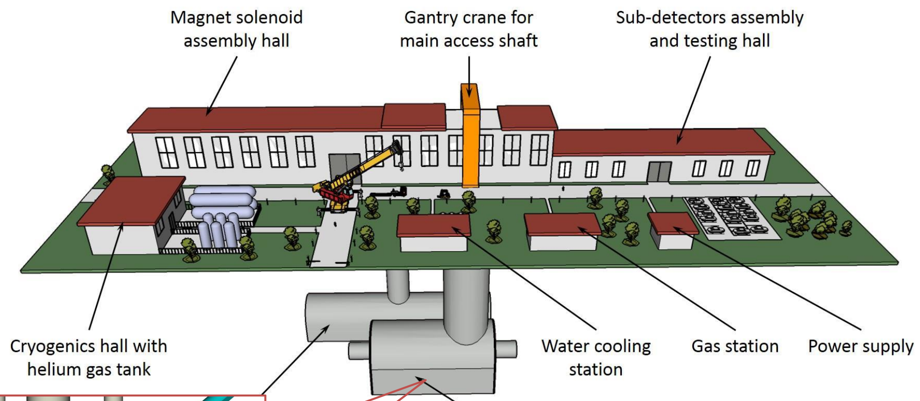


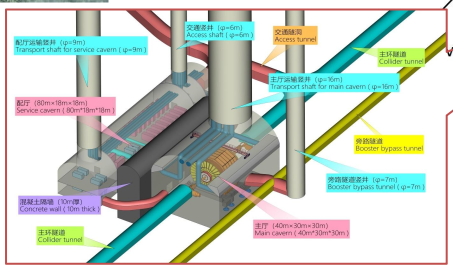


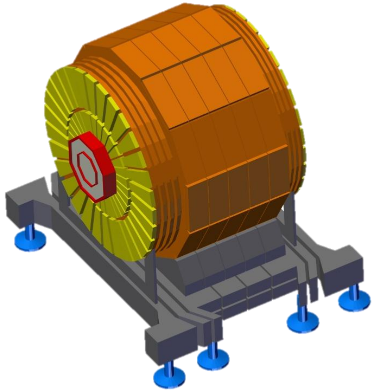
SCRF auxiliary tunnel	1950×8×7	×2
SCRF collider tunnel	3500×6×5	×2
Transport shaft	15×70	×2
Travel, electric cable, ventilation tunnel	70×10×10	×2
SCRF transport tunnel	1200×88×7.5	×2

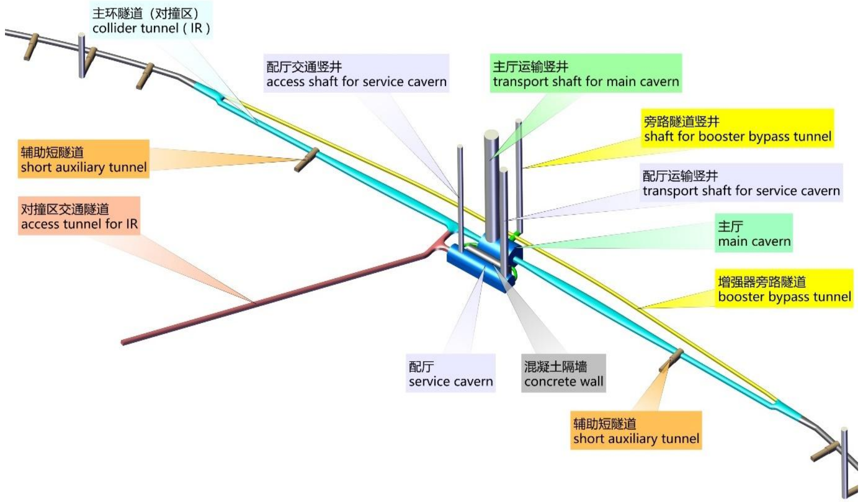
CEPC IR Region





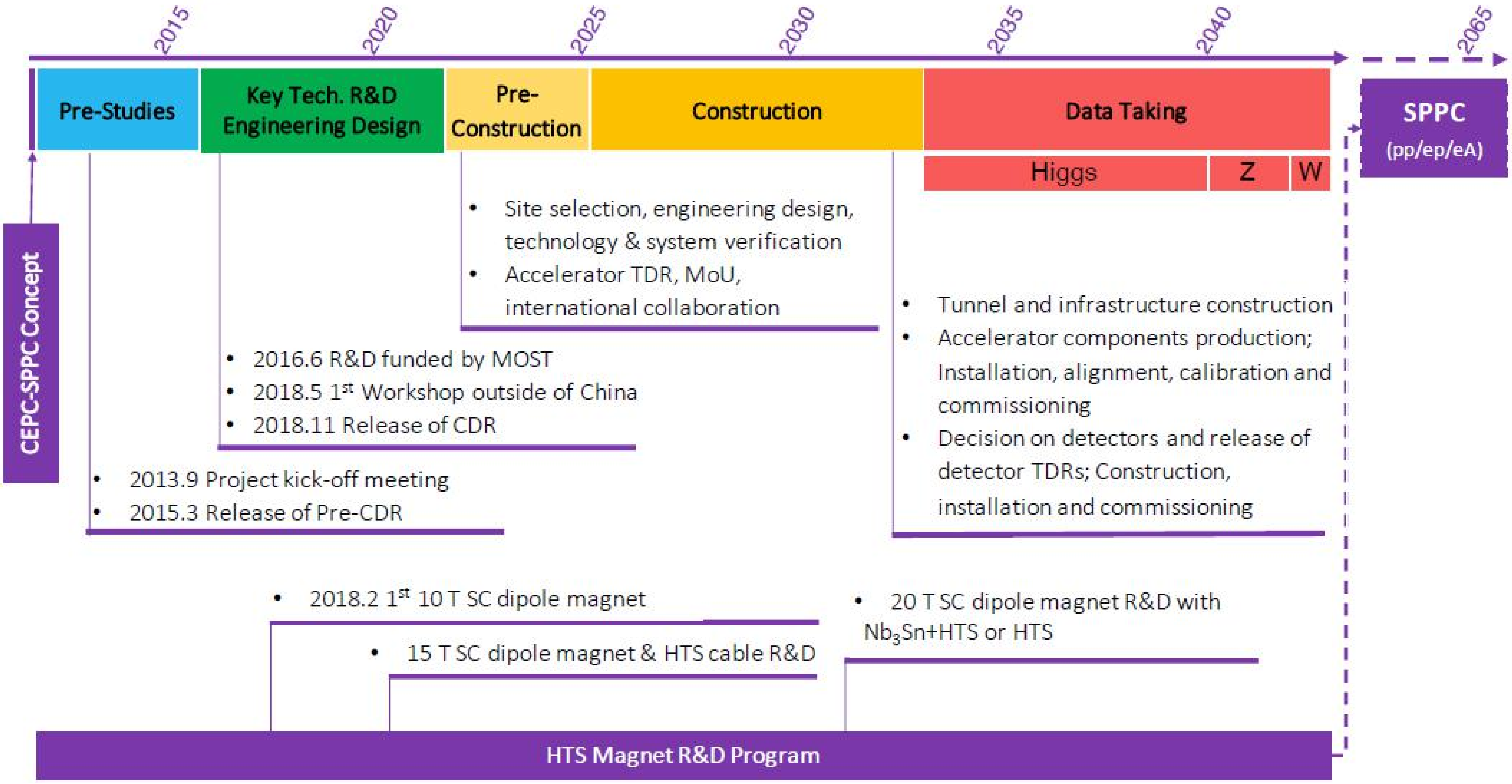






Experimental hall	39.4×20.4×31	×2
Axiliary hall	101.4×20×26.2	×2
Booster tunnel	1679×3.5×3.5	×4
Collider tunnel	1659.3x(6~11.4)x5	×4
Travel shaft	1200x7.5x7.5	×2
Connection, electric cable and ventilation shaft	70x10x10	×2

CEPC Project Timeline



CEPC and SppC submissions to Snowmass21

CEPC Input to the ESPP 2018

-Accelerator

LOI

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 China. It was presented for the first time to the international community at the ICFA Workshop "*Accelerators for a Higgs Factory: Linear vs. Circular*" (HF2012) in November 2012 at Fermilab. A Preliminary Conceptual Design Report (Pre-CDR, the *White Report*)[1]was published in March 2015, followed by a Progress Report (the *Yellow Report*)[2] in April 2017, 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.

Including SppC and siting

CEPC -Accelerator Technologies to Snowmass2021 AF7

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 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].

Technologies

Collider Design
SCRF
Klystron
Linac+plasma
accelerator injector
Cost

Summary

- CEPC as a Higgs Factory has been proposed in Sept. 2012 after the Higss Boson was found in July 2012 at LHC of CERN

- CEPC CDR has been completed in Nov.2018 and accelerator TDR will be completed at the end of 2022 before three years of Engineering Design Report (EDR) phase before eventual starting of the construction.

- CEPC international, institutional and industrial collaborations with CIPC (> 70 companies) progress well.

- CEPC siting and civil engineering designs are in progress

- CEPC and SppC LOIs have been submitted to European HEP Strategy and Snowmass21 of USA

- CEPC is proposed open for high energy physics community world wide

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