Status in China

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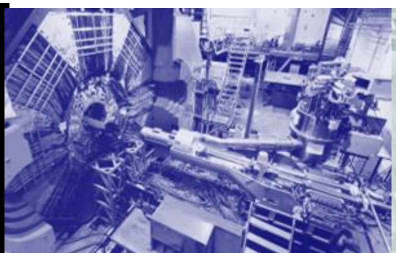
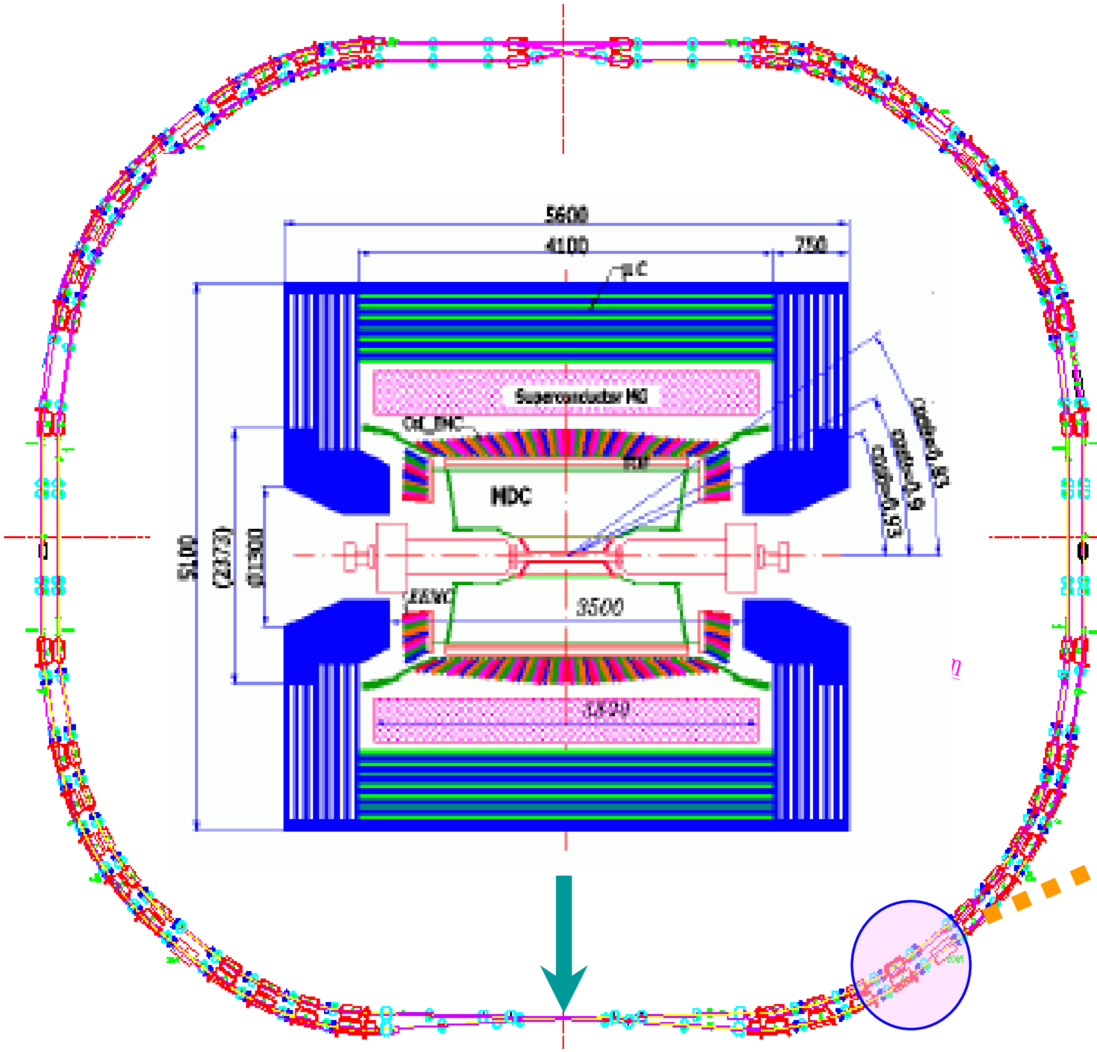
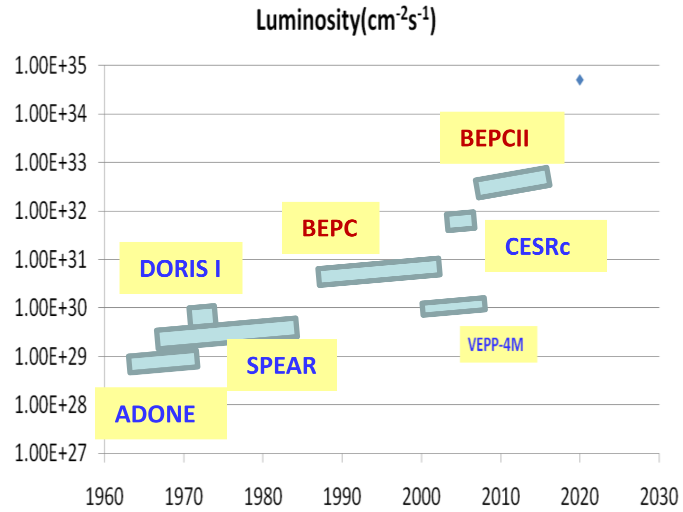
ALCW2018, May 28, 2018


From BEPC to BEPCII: 1984-2025





BEPCII/BESIII Upgrade: 2004-2008

Major Projects: Current and Future

		Current	Future
Accelerator-based	Precision frontier	BESIII	ILC, FCC ? CEPC ➔ SppC ?
		LHCb, Belle II、PANDA、COMET	
	Energy frontier	CMS、ATLAS	
Non-accelerator-based	Underground	Daya Bay	JUNO
		Jinping: PANDAx, CDEX	Exp. ?
	Surface	ARGO/ASγ	LHASSO
	Space	AMS	HERD ? XTP ?
		HXMT, Polar, DAMPE	

IHEP ILC Collaboration Since 2005

IHEP ILC R&D domain:

Since 2005 IHEP accelerator center has setup ILC collaboration group and since 2010 ILC group with administration nature has been established also, which guaranteed the smooth progress of China's participation of ILC international collaboration. The main R&D domais which IHEP participated are as following as shown in Fig. 3.

1) ILC250 GeV and ILC500 GeV parameter optimization design
3）ILC SC accelerator technologies
2) ILC ATF2 beam dynamics and hardwares
4）ILC damping ring design and technologies
5）ILC final focus optimization design and beam-beam effect study
6）ILC positron source target thermodynamics study and polarization source
7）ILC power source: Marx modulator

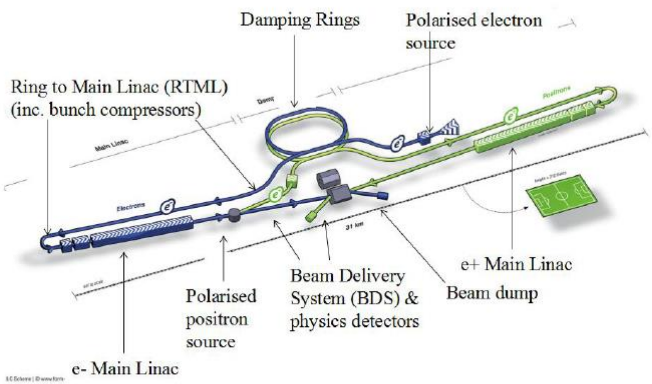


Fig. 3: IHEP ILC collaboration domains

Achievement of IHEP on ILC collaboration:

Since 2005 IHEP participated ILC ATF2 collaboration and fabricated all ATF2 beam line magnets, such as dipole and quadupoles, as shown in Fig. 4. In 2008, IHEP ILC group first demonstrated that on ATF2 the beam size has the potential to reach 20nm instead of 37nm, and due to this important result, ATF2 became a final focus facility not only for ILC but also for CLIC.

Fig. 4: ILC ATF2 beam line magnets

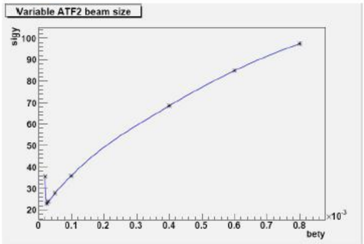


Fig. 5 AFT2 design and beam dynamics studies

Since 2005, IHEP ILC group started to make R&D on 1.3GHz superconducting cavities, from single cell to 9 cell, from fine grain to large grain niobium, from low loss shape, to TELSLA-like, and to TESLA cavities shapes, IHEP becomes the Institute which covers the whole range of the cavity types and materials, as shown in Fig. 5. In addition to cavity R&D, IHEP conducted ILC cryomodule study with both a 1.3GHz single 9cell cavity ILC Test Cryomoulde, including cacity, tunner, high power coupler, LLRF and cryostate, and 12m cryomodule cold mass industrialization for European X-XFEL project, as shown in Fig. 6 and 7. In the domain of 1.3GHz ILC rf power source R&D, IHEP ILC group made industrialization of high power L band Marx modulator and in collaborate with Institute of Electronics, CAS (IECAS), an ILC type 1.3GHz klystron of 10MW has been also constructed and tested by IECAS, as shown in Fig. 8. In the domain of ILC damping ring study, IHEP ILC group made a ILC damping design and made damping fast kicker, as shown in Fig. 9. As for ILC250GeV proposed in 2017, IHEP group made the optimization design for the accelerator parameters.

Fig. 5: ILC 1.3GHz 9-cell superconducting cavities

Fig: 6: IHEP ILC test cryomodule

Fig. 7: Euro-XFEL thermostat cryostate industrialization

Fig. 8: L band MarX Modulator and ILC 10MW klystron

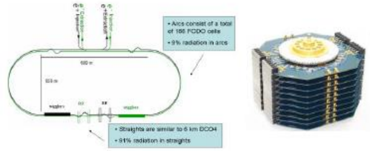
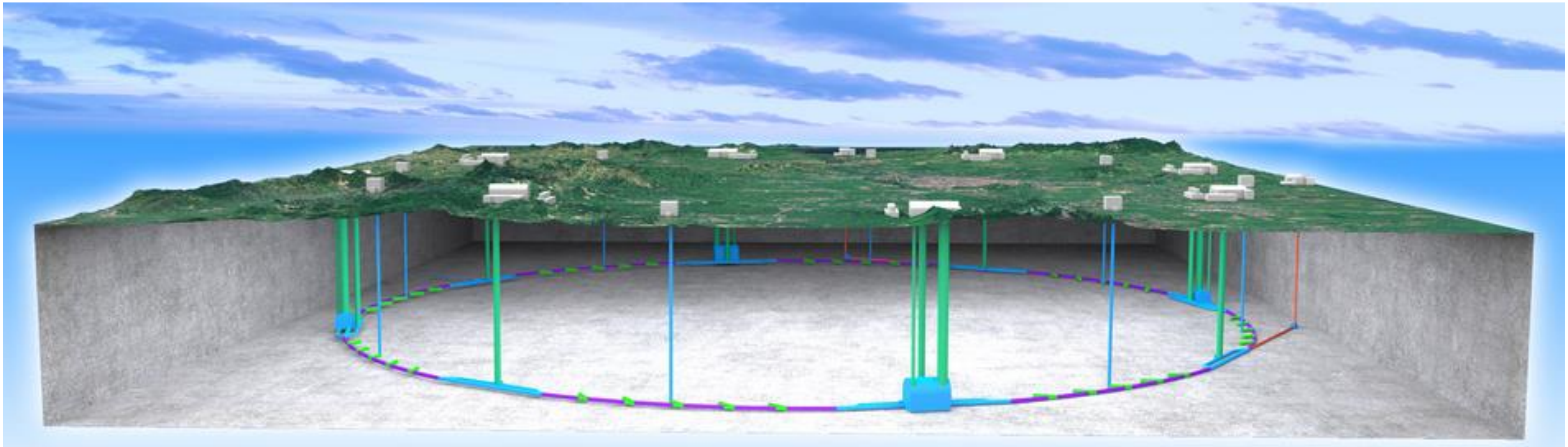


Fig. 9: ILC damping design and fast kiker

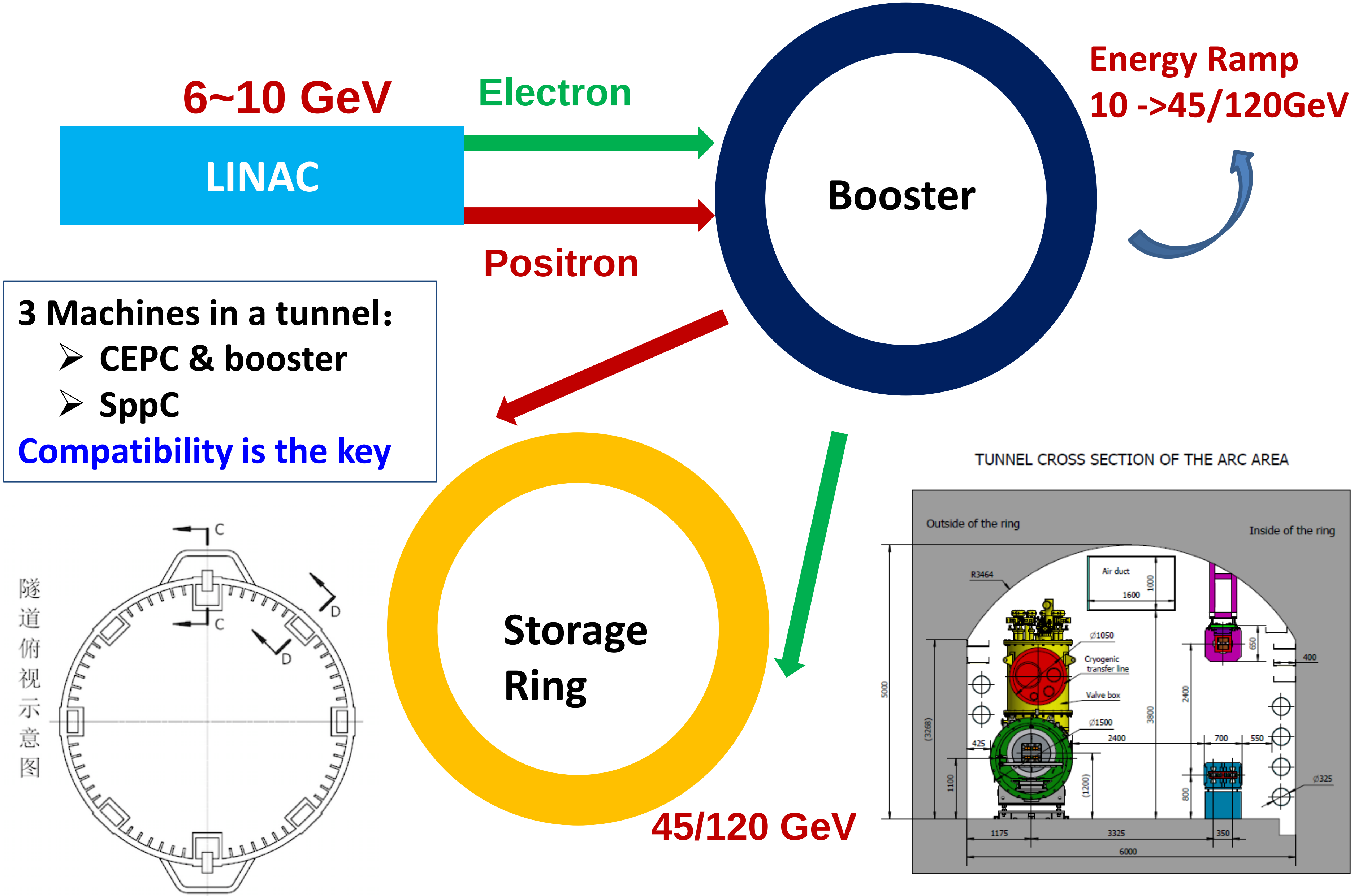
CEPC：A Higgs Factory

- Since 2005, we were discussing the next machine after BEPC/BEPCII
- Thanks to the low mass Higgs, there is the possibility to build a Higgs Factory: Circular e+e- Collider(CEPC)
  - Looking for Hints (from Higgs) ➔ direct searches
  - The tunnel will allow us to build pp, AA, ep colliders in the far future: Super proton-proton Collider(SppC)



The idea to build a circular Higgs factory followed by a proton machine, was discussed for the first time at the Higgs factory workshop in Oct. 2012

CEPC Accelerator Design



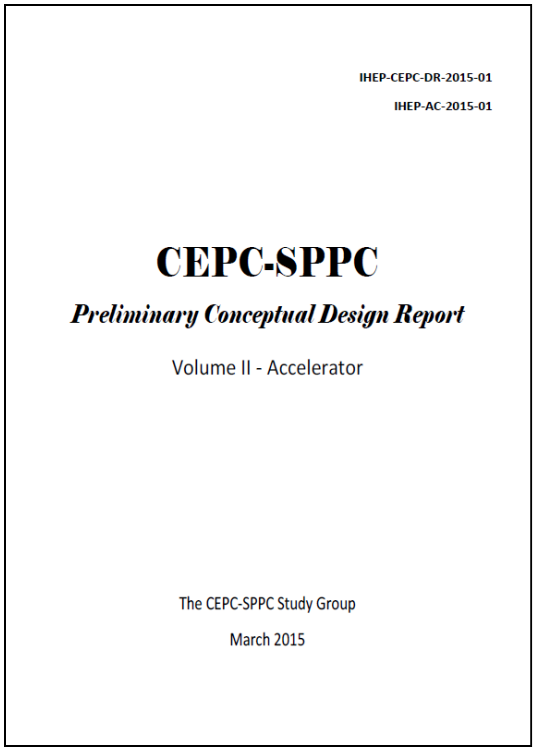
3 Machines in a tunnel:

- CEPC & booster
- SppC

Compatibility is the key

CEPC-SppC from Pre-CDR towards CDR

http://cepc.ihep.ac.cn



IHEP-CEPC-DR-2015-01
IHEP-AC-2015-01

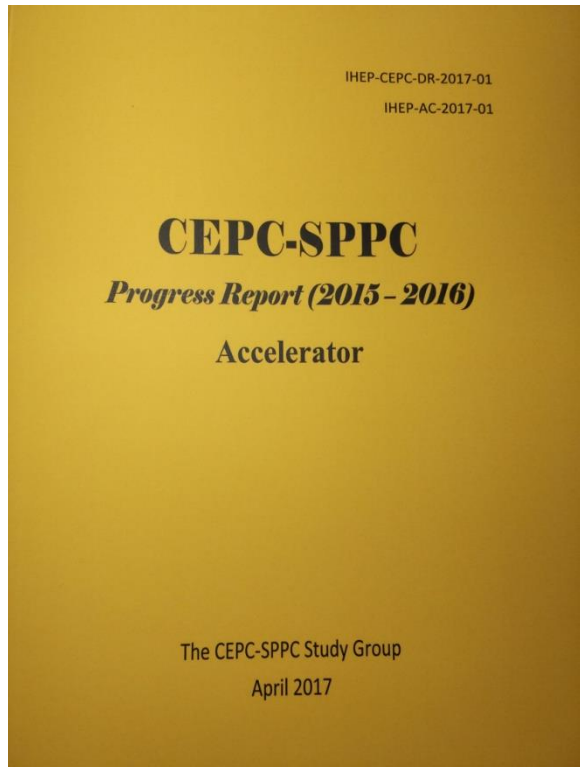
CEPC-SPPC

Preliminary Conceptual Design Report

Volume II - Accelerator

The CEPC-SPPC Study Group
March 2015

March 2015



IHEP-CEPC-DR-2017-01
IHEP-AC-2017-01

CEPC-SPPC

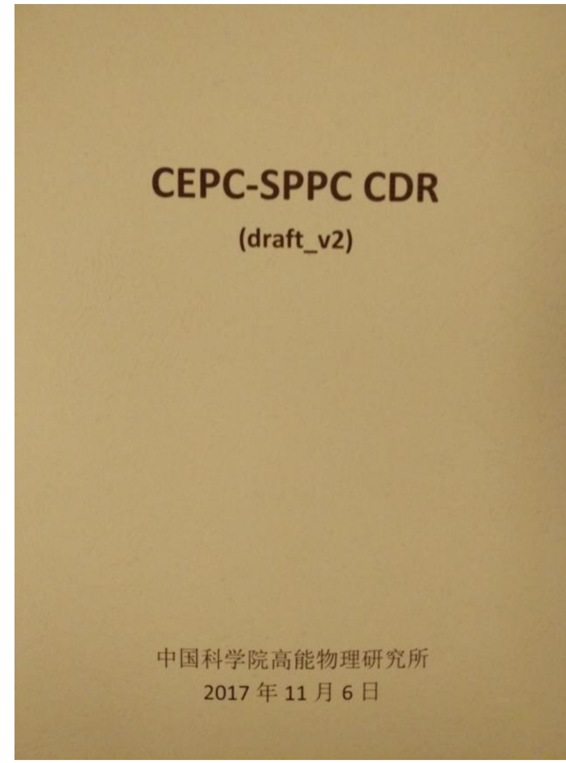
Progress Report (2015–2016)

Accelerator

The CEPC-SPPC Study Group
April 2017

April 2017

CEPCSppC baseline and alternative decision processe recorded



CEPC-SPPC CDR

(draft_v2)

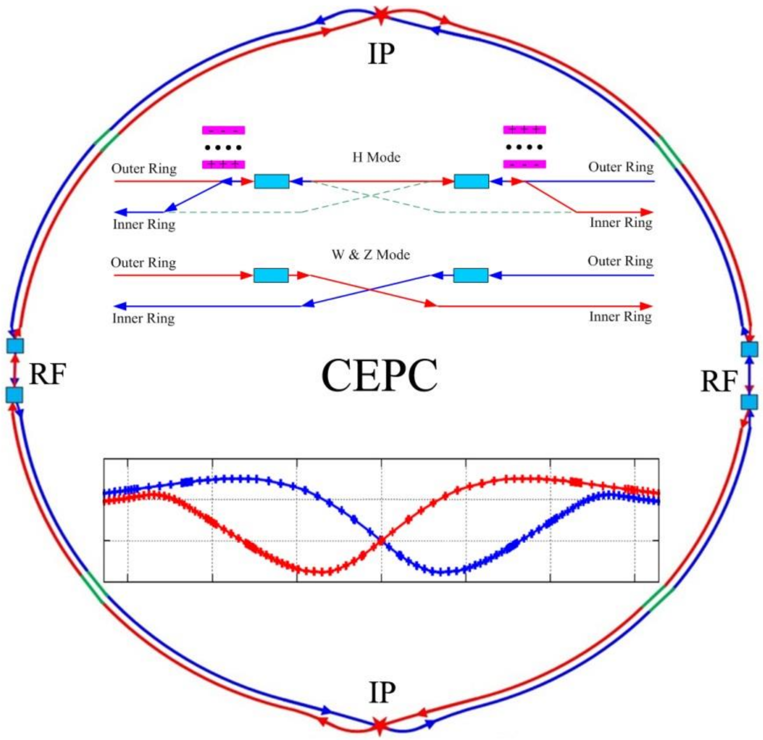
中国科学院高能物理研究所
2017 年 11 月 6 日

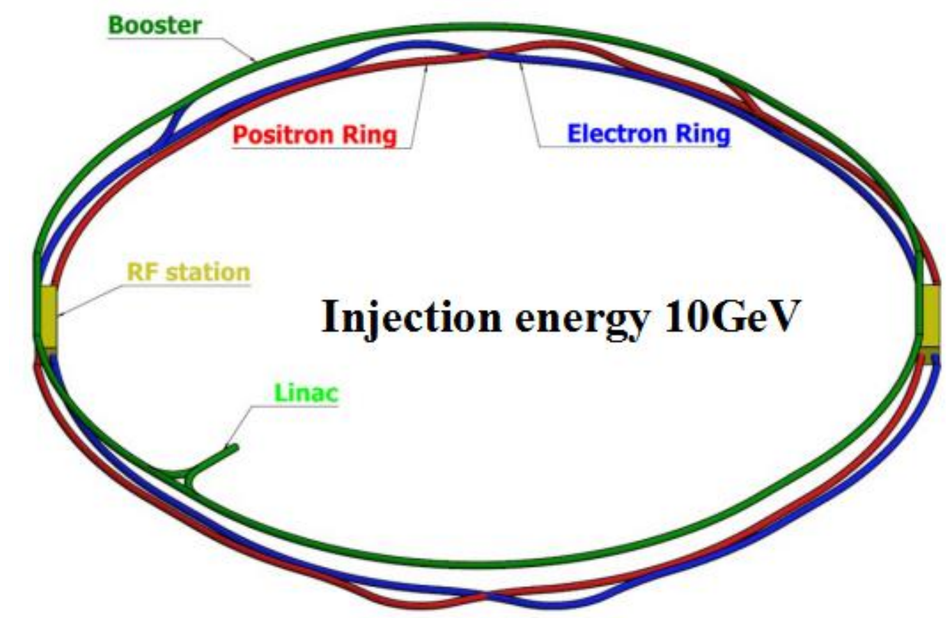
Nov 2017

CEPC-SppC CDR Preliminary Draft during CEPC-SppC Mini review

CEPC-SppC CDR will be available soon

CEPC CDR Basseline Layout

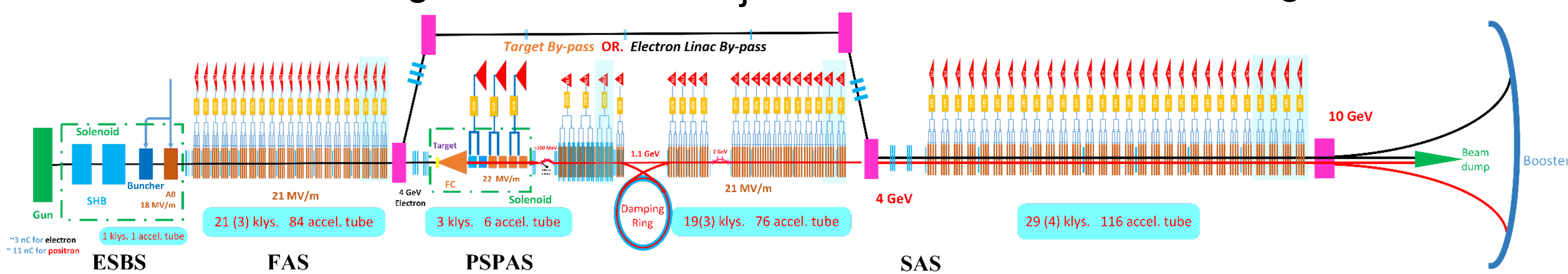




Collider ring

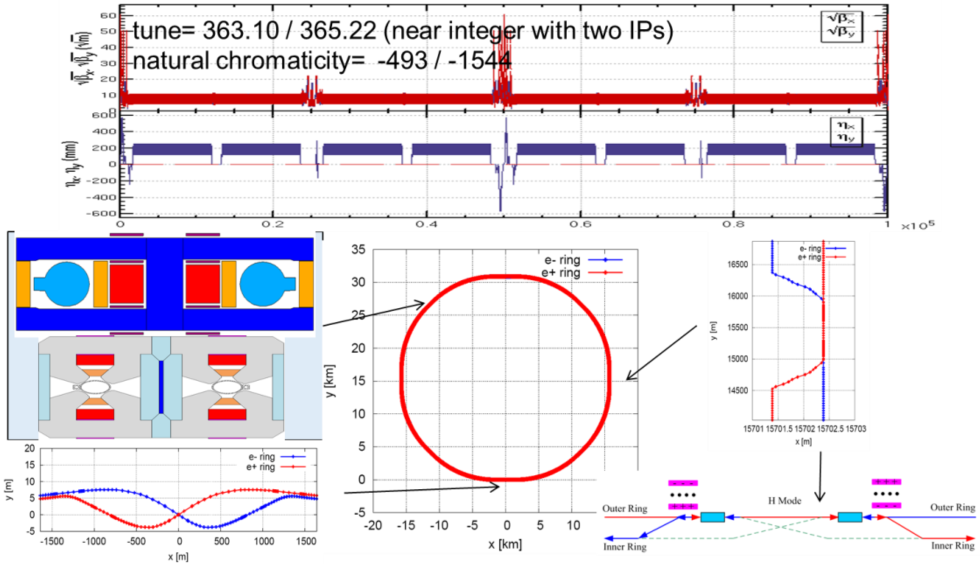
Linac injector

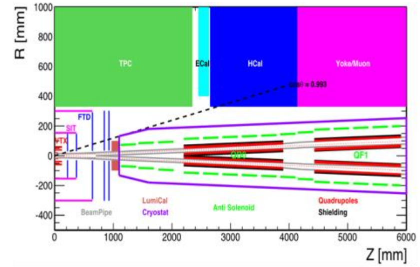
Booster ring

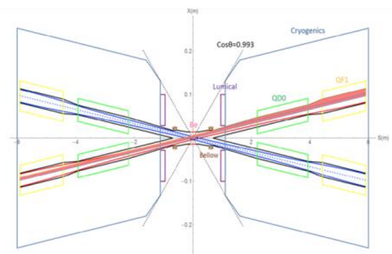


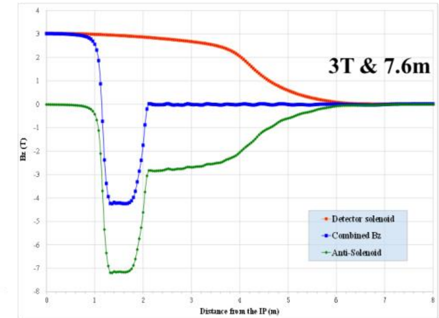
Baseline: 100 km, 30 MW; Upgradable to 50 MW, High Lumi Z
Try all means to cut cost down

CEPC Collider CDR Design





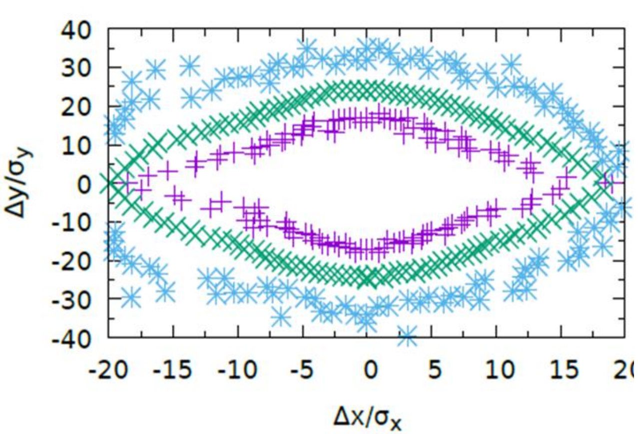


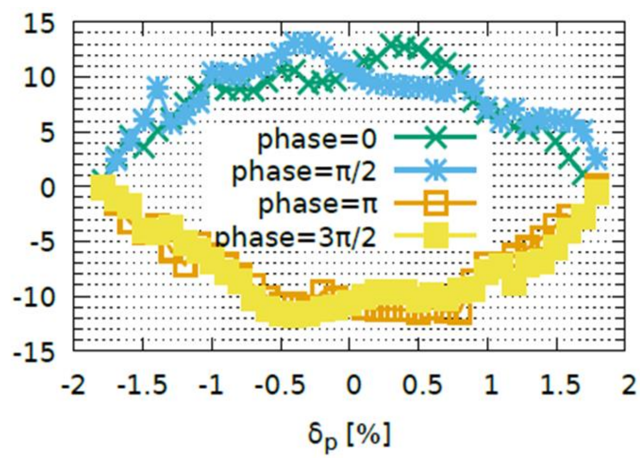


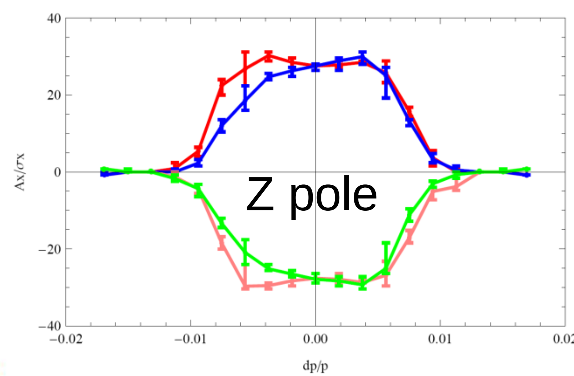
22 anti-Solenoid **sections with different inner coil diameters**

$\int B_z ds$ within 0~2.12m. Bz < 300Gauss away from 2.12m with local cancellation structure

The skew quadrupole coils are designed to make fine tuning of Bz over the QF&QD region instead of the mechanical rotation.







DAs of Higgs energy

DA of Z-Pole energy

Main 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	
Betatron tune ν_x/ν_y	363.10 / 365.22			
Synchrotron tune ν_s	0.065	0.0395	0.028	
HOM power/cavity (2 cell) (kw)	0.54	0.75	1.94	
Natural energy spread (%)	0.1	0.066	0.038	
Energy acceptance requirement (%)	1.35	0.4	0.23	
Energy acceptance by RF (%)	2.06	1.47	1.7	
Photon number due to beamstrahlung	0.29	0.35	0.55	
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

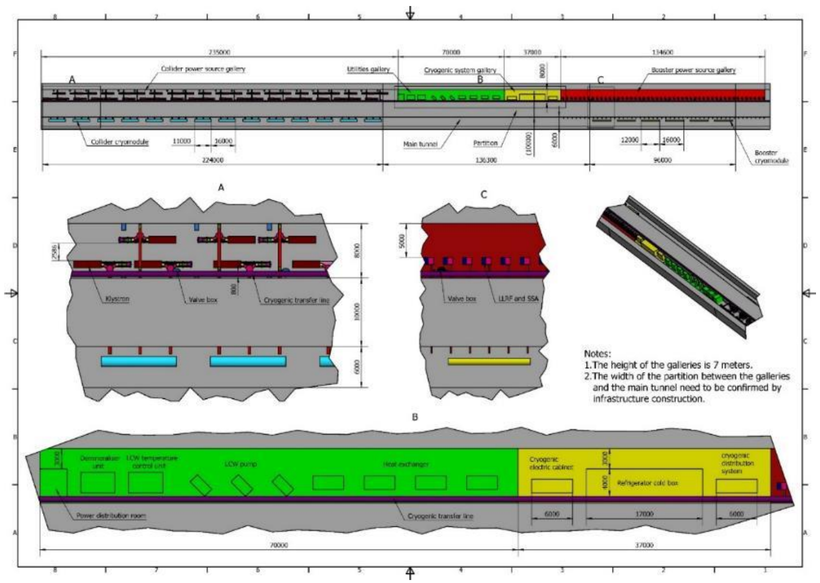
CEPC RF Layout

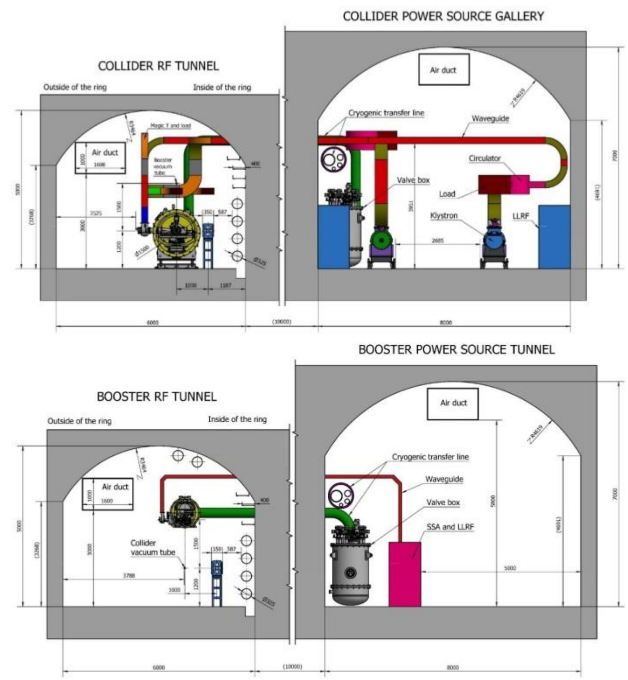
For 30 MW Higgs:

Collider: 240 650 MHz 2-cell cavities in 40 cryomodules (6 cav./ module).

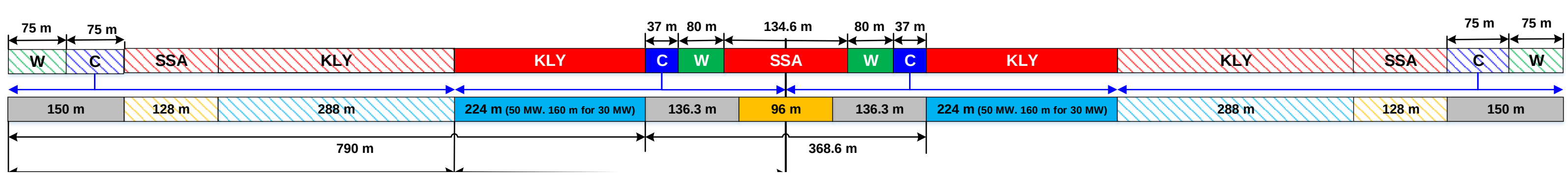
Booster: 96 1.3 GHz 9-cell cavities in 12 cryomodules (8 cav. / module).

For 50 MW Higgs: add 16 Collider modules.





RF Section A @ IP2 / LLS2 (length 1948.6 m)



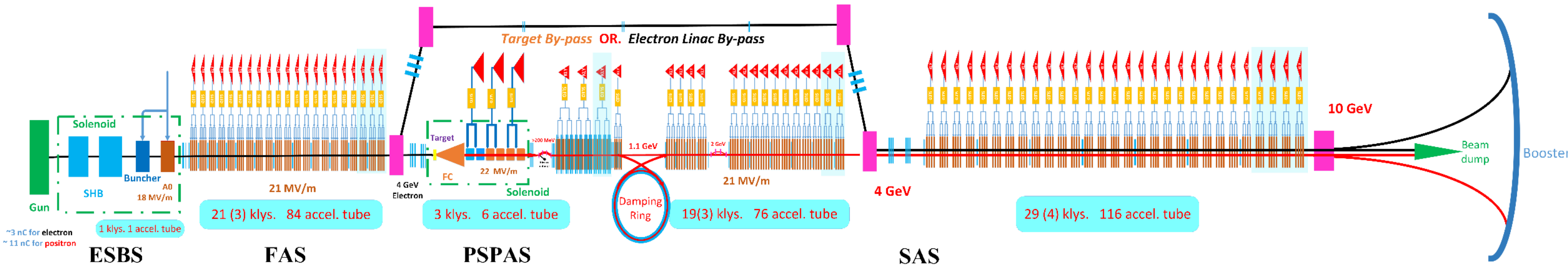
CEPC Collider Ring SRF Parameters

J. Y. Zhai

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

CEPC Linac Injector

C. Meng

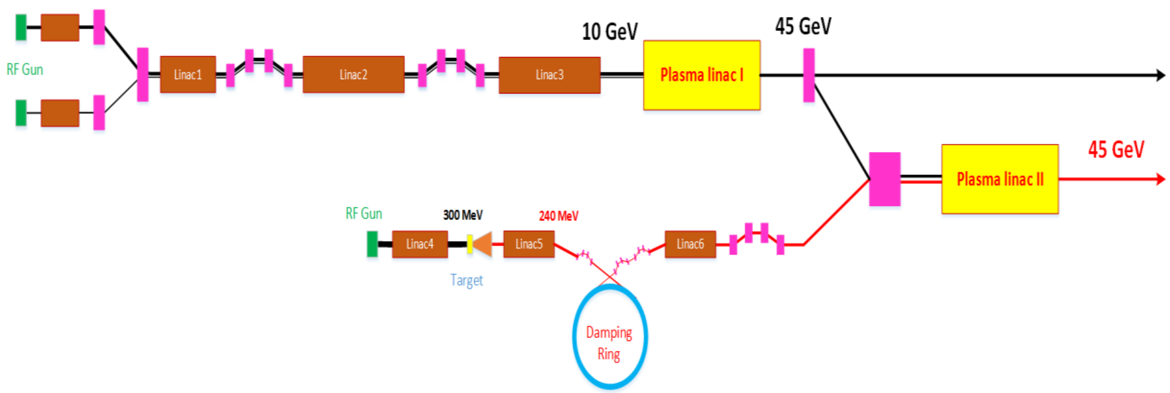


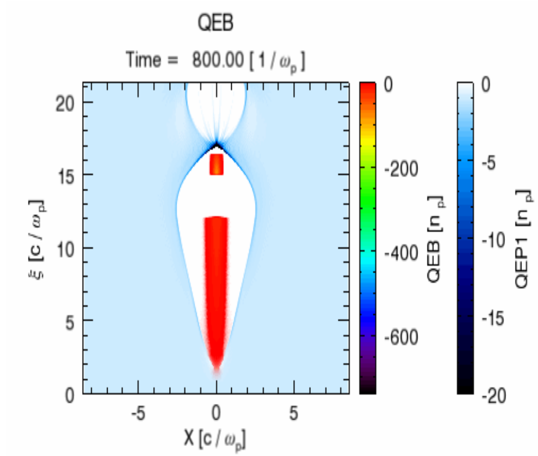
Parameter	Symbol	Unit	Baseline	**Design reached**
e^- /e^+ beam energy	E_{e-}/E_{e+}	GeV	**10**	**10**
Repetition rate	f_{rep}	Hz	**100**	**100**
e^- /e^+ bunch population	N_{e-}/N_{e+}		> 9.4×10^9	**1.9×10^{10} / 1.9×10^{10}**
		nC	**> 1.5**	**3.0**
Energy spread (e^- /e^+)	σ_e		**< 2×10^{-3}**	**1.5×10^{-3} / 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**

A High Energy CEPC Injector Based on Plasma Wakefield Accelerator

W. Lu

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



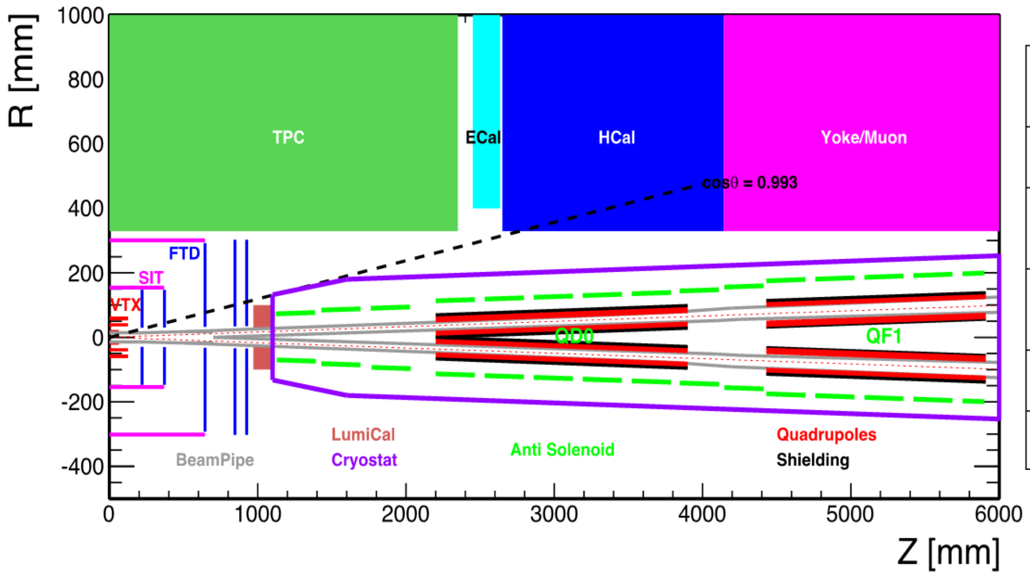


Plasma density $n_0(cm^{-3})$	5.15×10^{16}
Driver charge $Q_d(nC)$	6.47
Driver energy $E_d(GeV)$	10
Driver length $L_d(\mu m)$	285
Driver RMS size $\sigma_d(\mu m)$	10
Driver normalized emittance $\epsilon_{nd}(mm\ mrad)$	10
Trailor charge $Q_t(nC)$	1.25
Trailor energy $E_t(GeV)$	10
Trailor length $L_t(\mu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

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

CEPC MDI Layout

S. Bai
H.B. Zhu

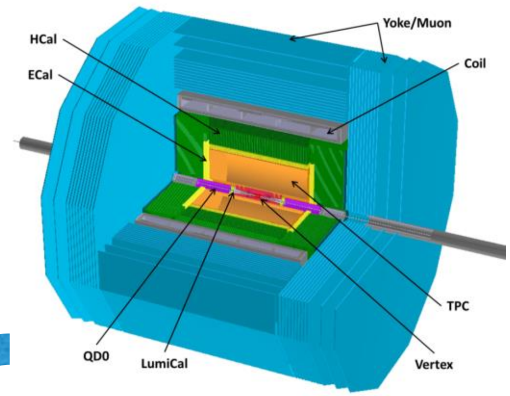


MDI parameters	Values
*L** (m)	2.2
Crossing angle (mrad)	33
Strength of QD0 (T/m)	150
Strength of detector solenoid (T)	3.0
Strength of anti-solenoid (T)	7.0

- 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.

CDR Conceptual Designs

Baseline detector for CDR
ILD-like
(similar to pre-CDR)



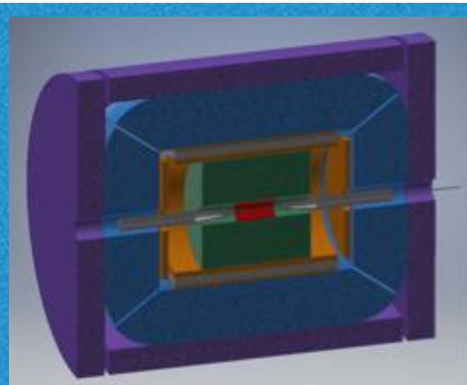
Impact parameter resolution
less than 5 μm

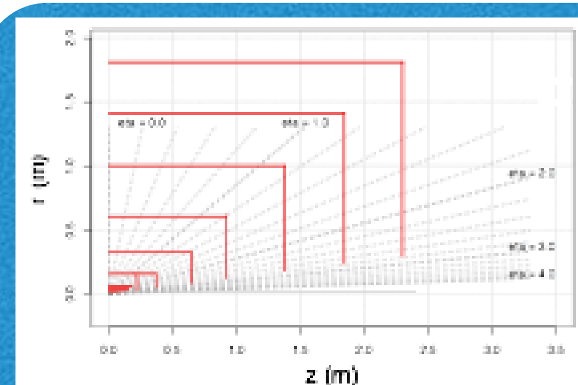
Tracking resolution
$\delta(1/P_t) \sim 2\times10^{-5}$ (GeV^{-1})

Jet energy resolution
$\sigma_E/E \sim 30\%/\sqrt{E}$

Two alternative detector concepts

Low magnetic field concept

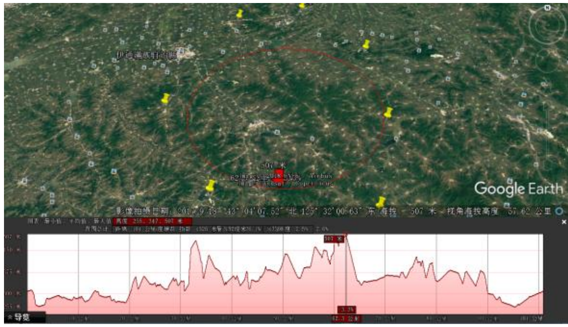




ull silico tracker concept

Final two detectors likely to be a mix and match of different options

CEPC Site Selections



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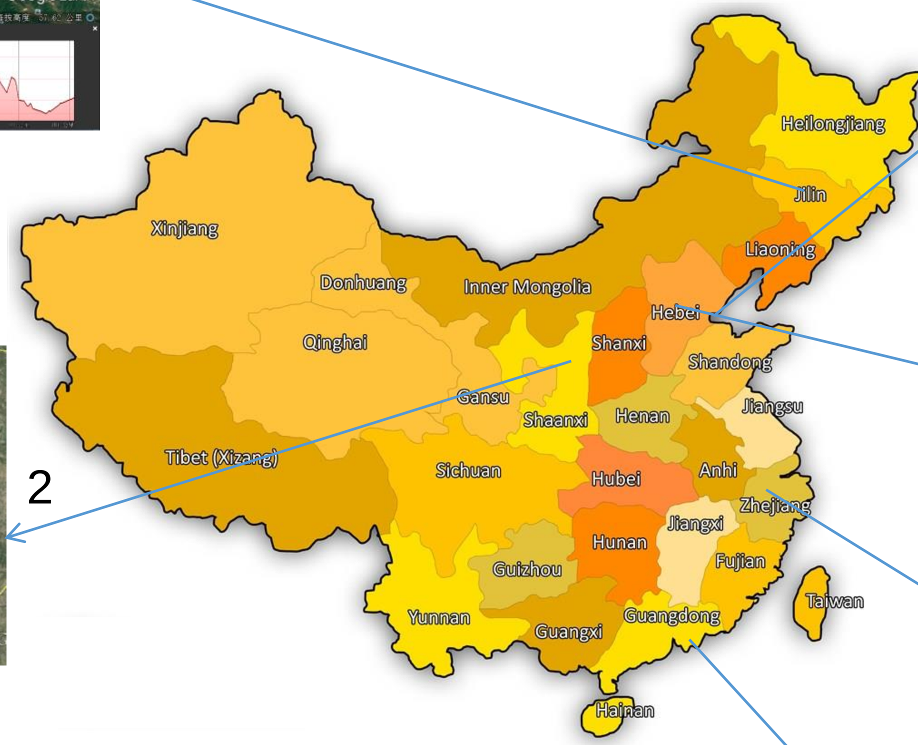

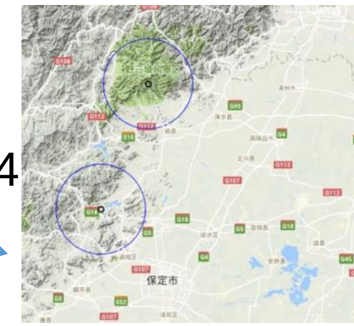

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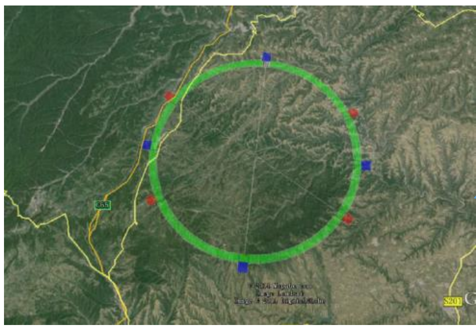

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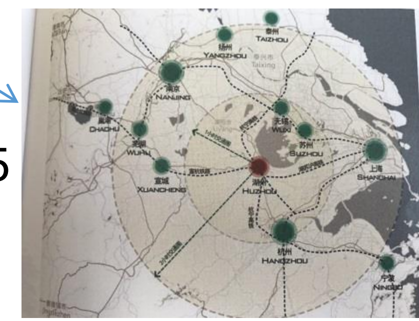
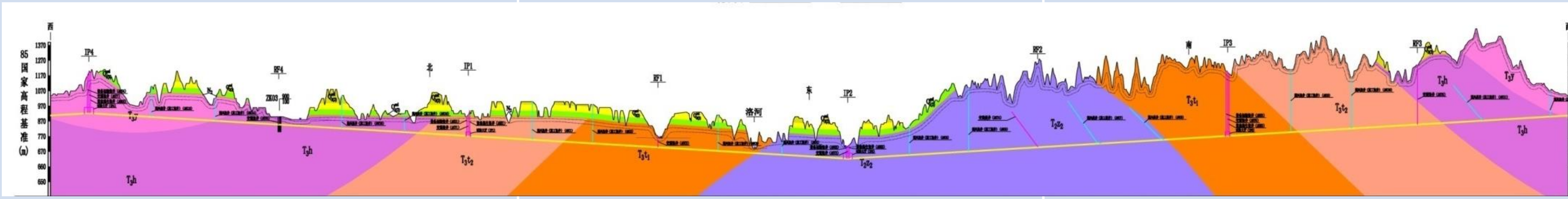
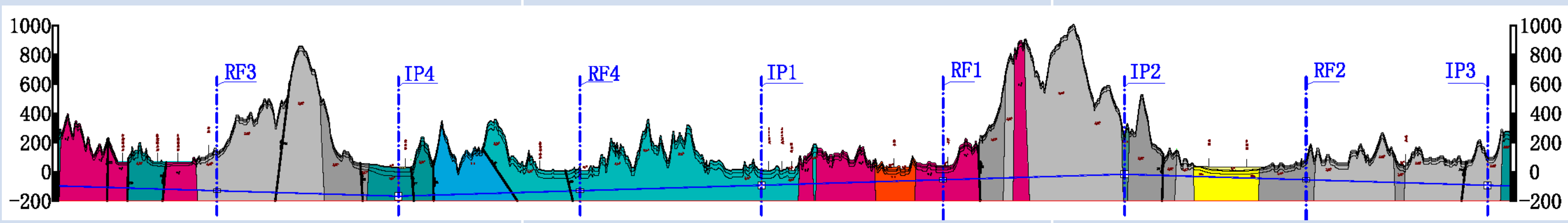


5

1) **Qinhuangdao, Hebei Province（Completed in 2014）**
2) **Huangling, Shanxi Province（Completed in 2017)**
3) **Shenshan, Guangdong Province(Completed in 2016)**
4) **Baoding (Xiong an), Hebei Province (Started in 2014)**
5) **Huzhou, Zhejiang Province (Started in March 2018)**
6) **Chuangchun, Jilin Province (Started in May 2018)**

3

<table>
<tr><th>Item</th><th>Huangling</th><th>Shen-Shan</th><th>Funing</th></tr>
<tr><td rowspan="6">Project layout</td><td colspan="3">Huangling（100km）</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">Shen-Shan（100km）</td></tr>
<tr><td colspan="3">
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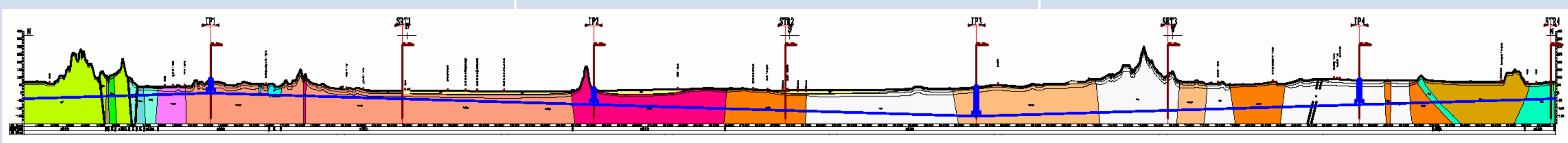
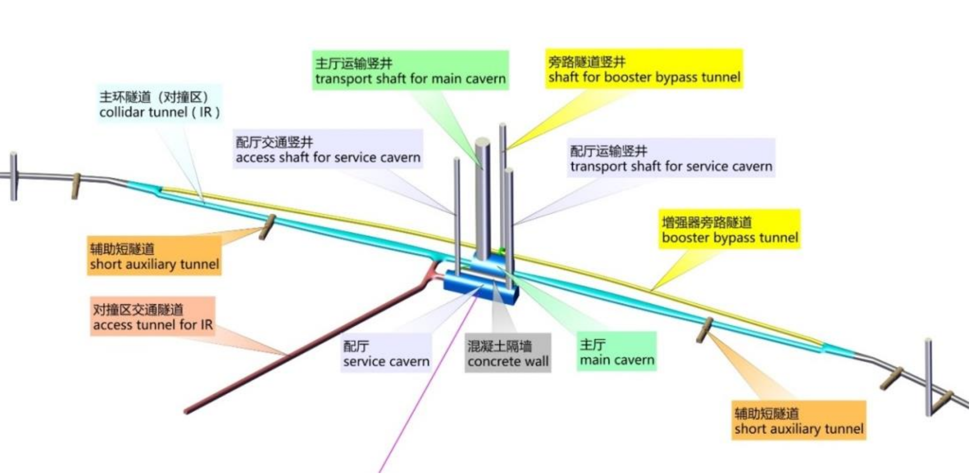
<tr><td colspan="3"></td></tr>
<tr><td>Construction difficulty</td><td>Moderate</td><td>Relatively difficult</td><td>Relatively easy</td></tr>
</table>

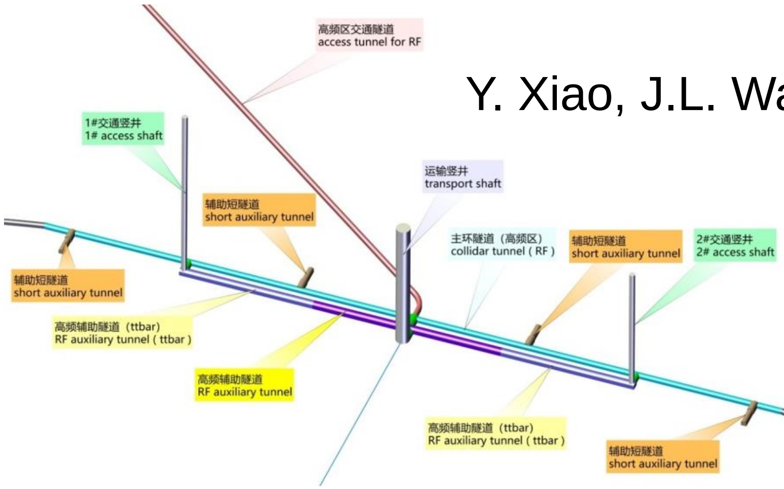
CEPC Tunnel Cross Sections, Detector and SCRF Regions

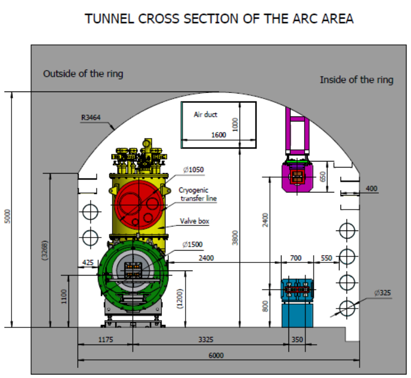
IP1 / IP3

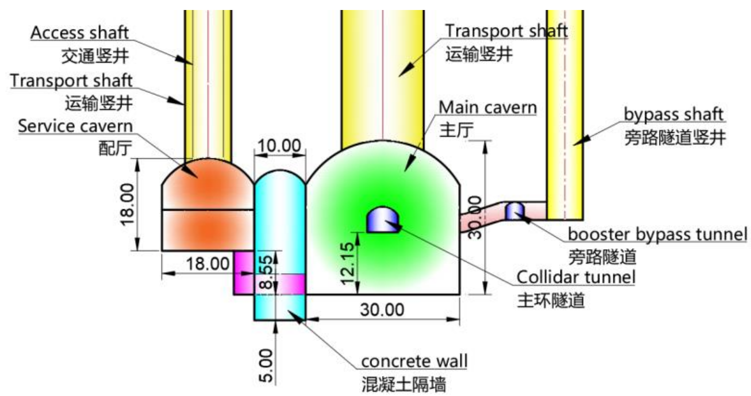


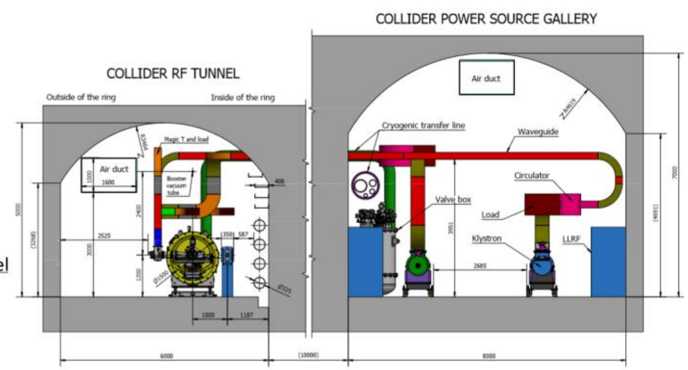
IP2 / IP4--SCRF region

Y. Xiao, J.L. Wang





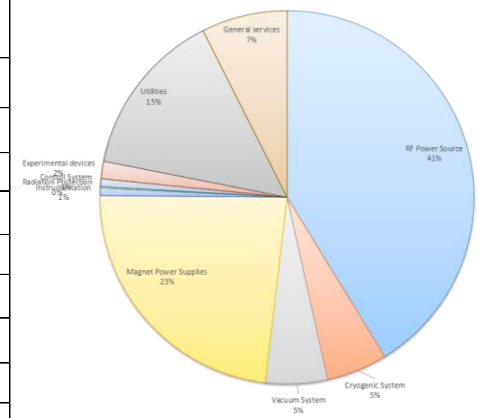




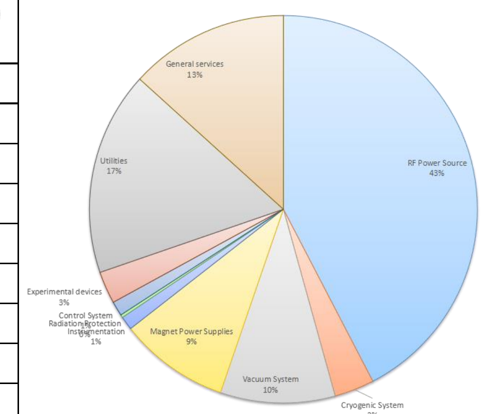
CEPC Power for Higgs and Z

S. Jin

	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



	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



CEPC Funding in China

HEP seed money

11 M RMB/3 years (2015-2017)

R&D Funding - NSFC

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

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

IHEP

国家重点研发计划
项目预申报书

Funding from the MOST

36 M in 2016

31 M in 2018

所属专项： 大科学装置前沿研究

指南方向： 新一代粒子加速器和探测器关键技术和方法的预先研究

推荐单位： 教育部

申报单位：（公章） 清华大学

40M RMB CAS talent program

100M RMB CAS fund for HTc

500M RMB Beijing city for light source

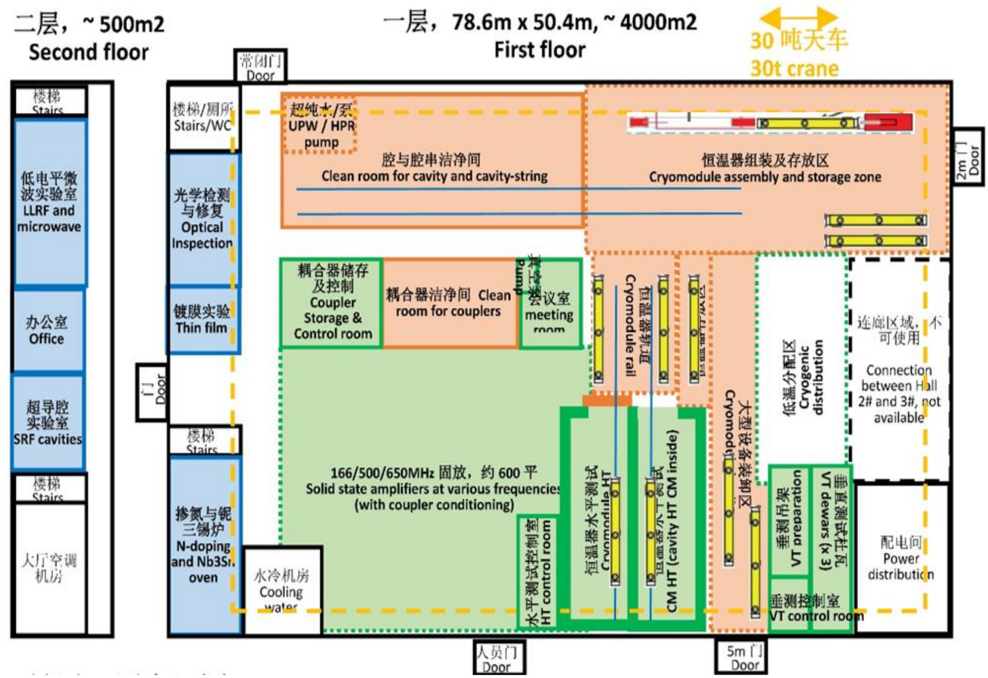
~100M RMB other agencies

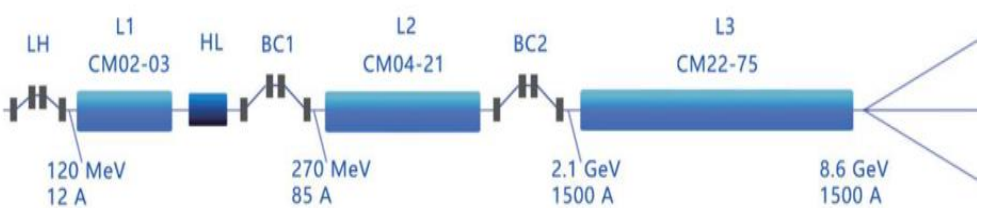
Funding needed for CEPC design and R&D are mostly satisfied

SRF Cavities

- Key components for CEPC and other accelerators
- A new SRF testing facility is under construction, thanks to Beijing city government
- Shanghai city government decided to built Shanghai Coherent Light Facility(SCLF).
  - 432 1.3 GHz cavities
  - 54 Cryomodules
- IHEP plans to provide > 1/3 of cavities and cryomodules, an excellent exercise for us.

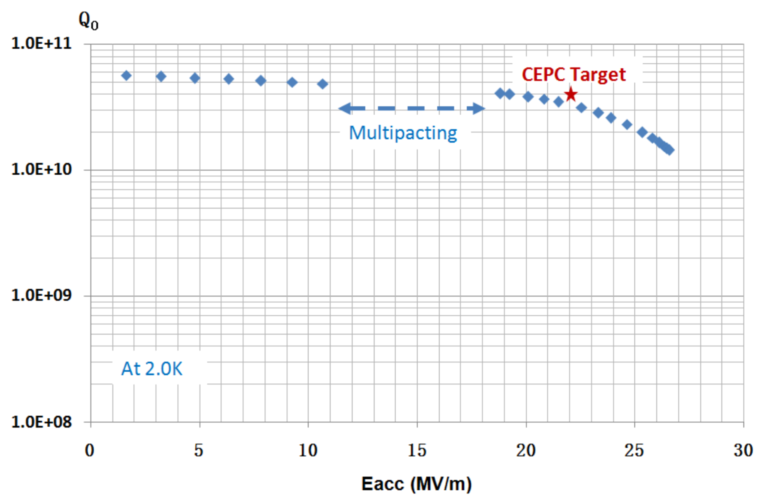
New SRF test facility under construction

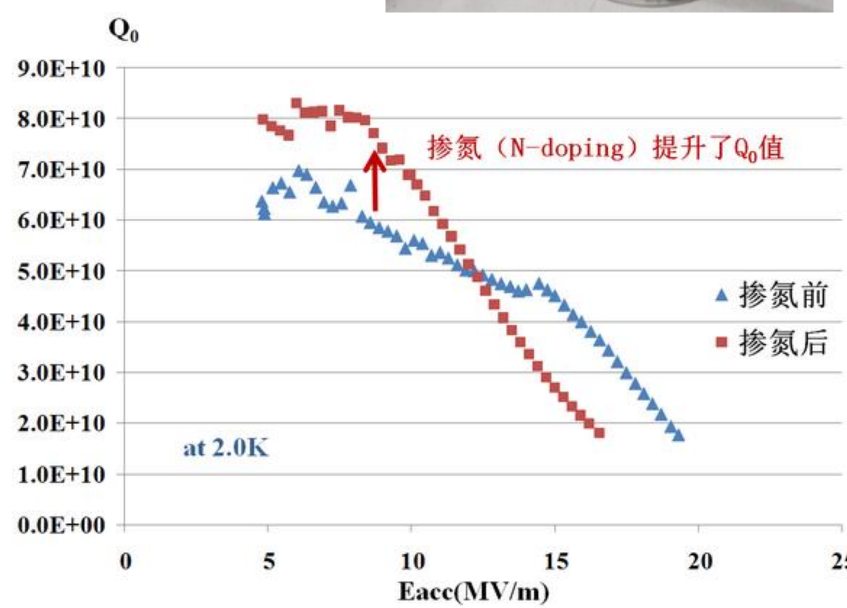




R&D results

- A CEPC 650MHz 1-cell cavity completed the vertical test.
- A CEPC 650MHz 2-cell cavity completed, to be test soon
- EP facility is under construction(ADS funding), ready this summer
- Two CEPC 650MHz 1-cell cavities tried N-doping, Q_0 increase is seen.

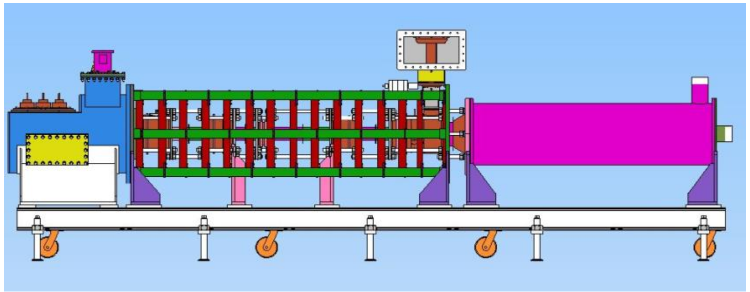


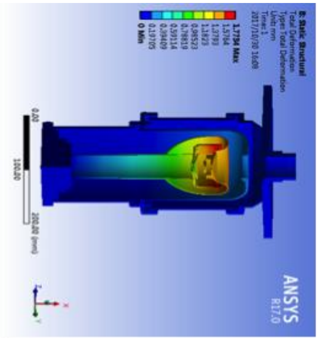


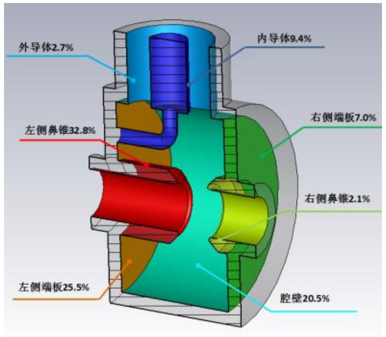
Vertical test result: Q_0=4.0E10@19.2MV/m，which is close to the target

High Efficiency Klystrons

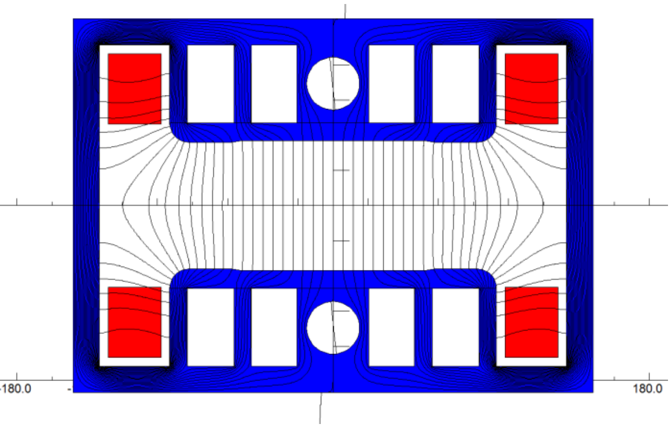
- Goal: CW Power > 800 kW, Efficiency > 80%, Lifetime > 100 k hrs
- A collaboration with the institute of electronics of CAS, and Kunshan Guoli
- Design of the first klystron with an efficiency of 65% has completed. Manufacturing contract signed. Available this year.
- Design of the second higher efficiency (70%) klystron will be finished soon. Production next year.
- Based on the test results, the high efficiency klystron (80%) will be built in 2020-2021

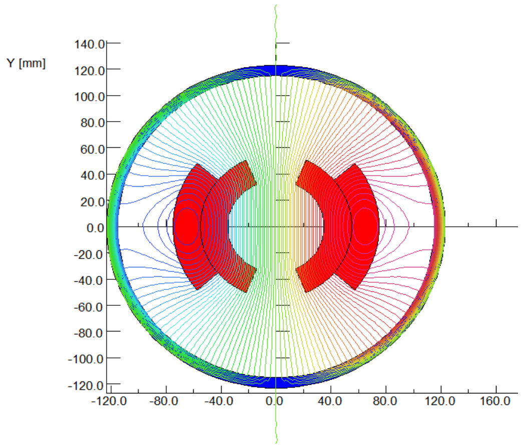




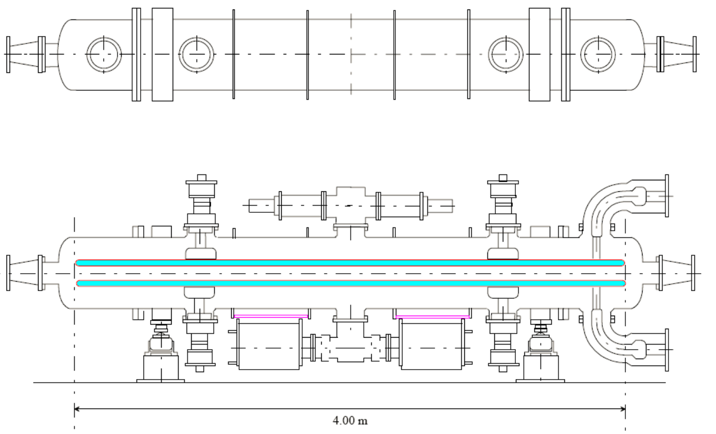


Other prototypes

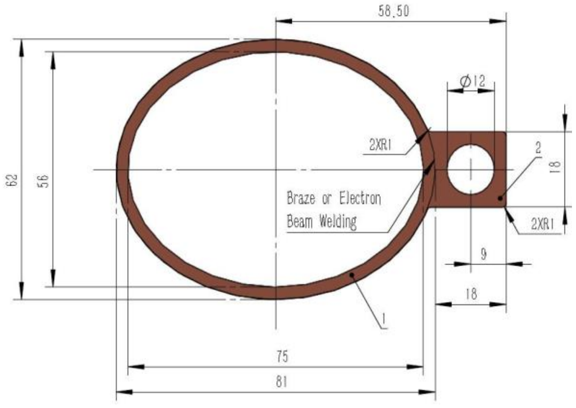


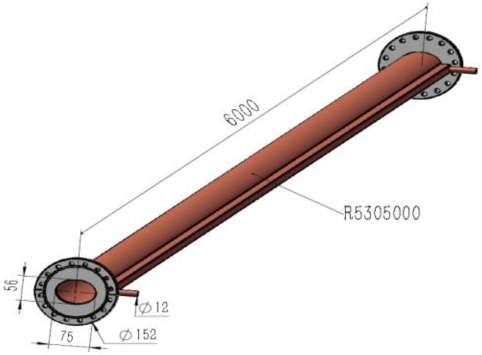


High precision, low field dipole magnet

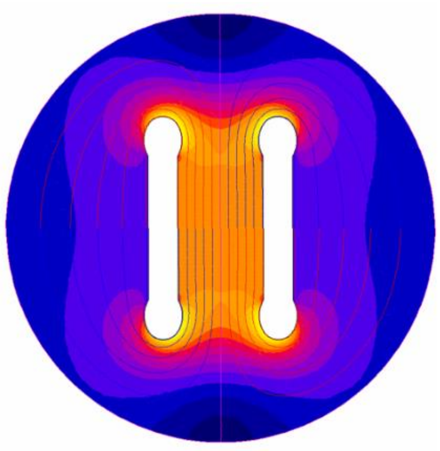


Electrostatic separator





6m long vacuum pipes(Al & Cu)



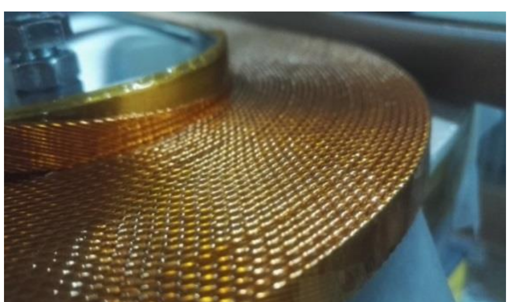
High Field Magnet based on HTC Cable ?

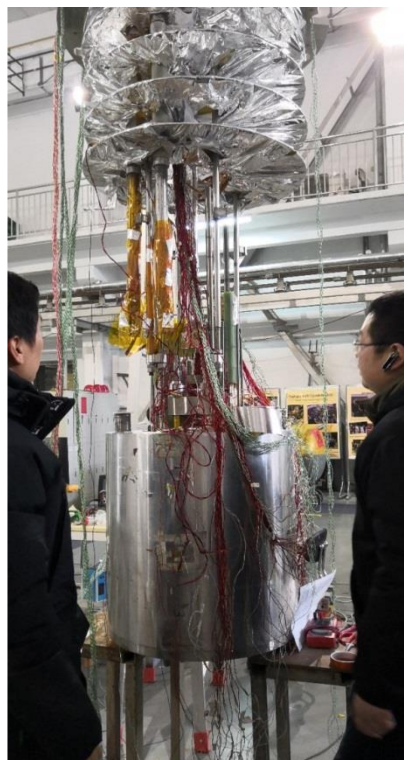
- Huge impact if HTC cable can be used for 10-20T magnets
  - Huge cost reduction
  - Huge applications in other area and industry
- Fe-based HTC cable
  - Advantages: metal, easy to process; isotropic; cheap in principle
  - Good start at CAS
    - World highest Tc Fe-based materials
    - World first ~ 115 m Fe-based SC cables: 12000 A/cm^2 @ 10 T
- A collaboration on “HTC SC materials” established
  - IOP, USTC, IOEE, SC cable companies
  - Two approaches:
    - Fe-based HTC cables
    - ReBCO & Bi-2212
- A workshop in Hong Kong this Jan. Next one in KEK

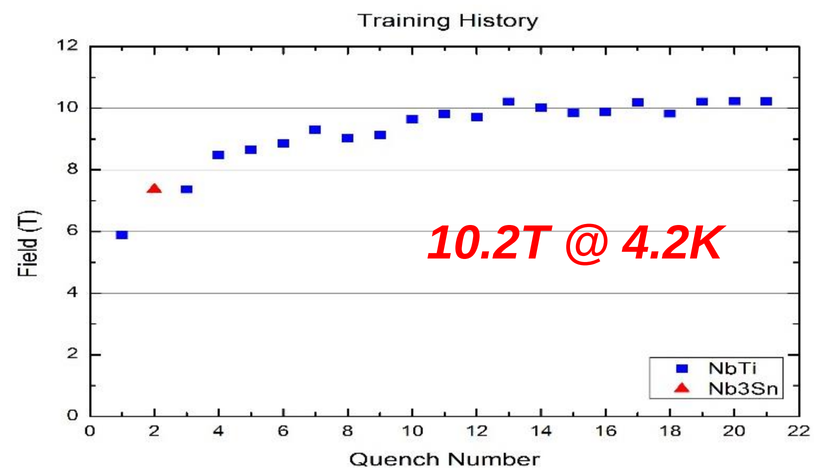
High Field Magnet R&D

- CCT magnet for LHC
- exercise of the Dipole magnet

$NbTi+Nb_3Sn$, 2*ф10 aperture → **All Nb_3Sn, 2*ф20 aperture** → **Nb_3Sn+HTS, 2*ф30 aperture** → **All HTS**







First ($NbTi+Nb_3Sn$) test successful

International Collaboration

- Limited international participation for the CDR
  - Not in any roadmap
  - No funding support
- Hopefully it will be included in the roadmap of Europe, Japan and the US
- International advisory board: A lot of suggestions
- MOUs signed with many institutions
- Welcome recommendation/suggestions

Workshop on the Circuar Electron Positron Collider-EU edition

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

1/3 international participation

CEPC-SppC Industrial Promotion Consortium (CIPC)

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

Established in Nov. 7 , 2017

More than 40 companies joined in first phase of CIPC，
and more will join later....

CEPC Schedule (ideal)

design issues
R&D items
preCDR

design, funding
R&D program
Intl. collabration
site study

seek approval, site decision
construction during 14th 5-year plan
commissioning

Latest Politics

- Science & Technology is strongly supported by this government ➔ also a "requirement" to local governments (difference seen at Beijing & Shanghai since 2016)
- No difficulty to find local support for the site
- State Council announced in March "Implementation method to support China-initiated large international science projects and plans"
  - Matter, Universe, life science, earth, energy, …
  - Goal:
    - up to 2020, 3-5 preparatory projects; 1-2 construction projects
    - up to 2035, 6-10 preparatory projects; ? construction projects
  - Possible competitors: ~ 50 ideas collected, Fusion reactor, space program, brain program, Investigation of the Qinghai Tibet Plateau, CEPC, …
- We are working with the MOST to be included in the roadmap planning, project selection, etc.

Thanks