Circular Electron Positron Collider

CEPC-SppC Accelerator Status

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Saint Petersburg University, Russia

Contents

- General background and status of CEPC
- CEPC/SppC design goals
- CEPC design options and design status
- CEPC/SppC international collaborations

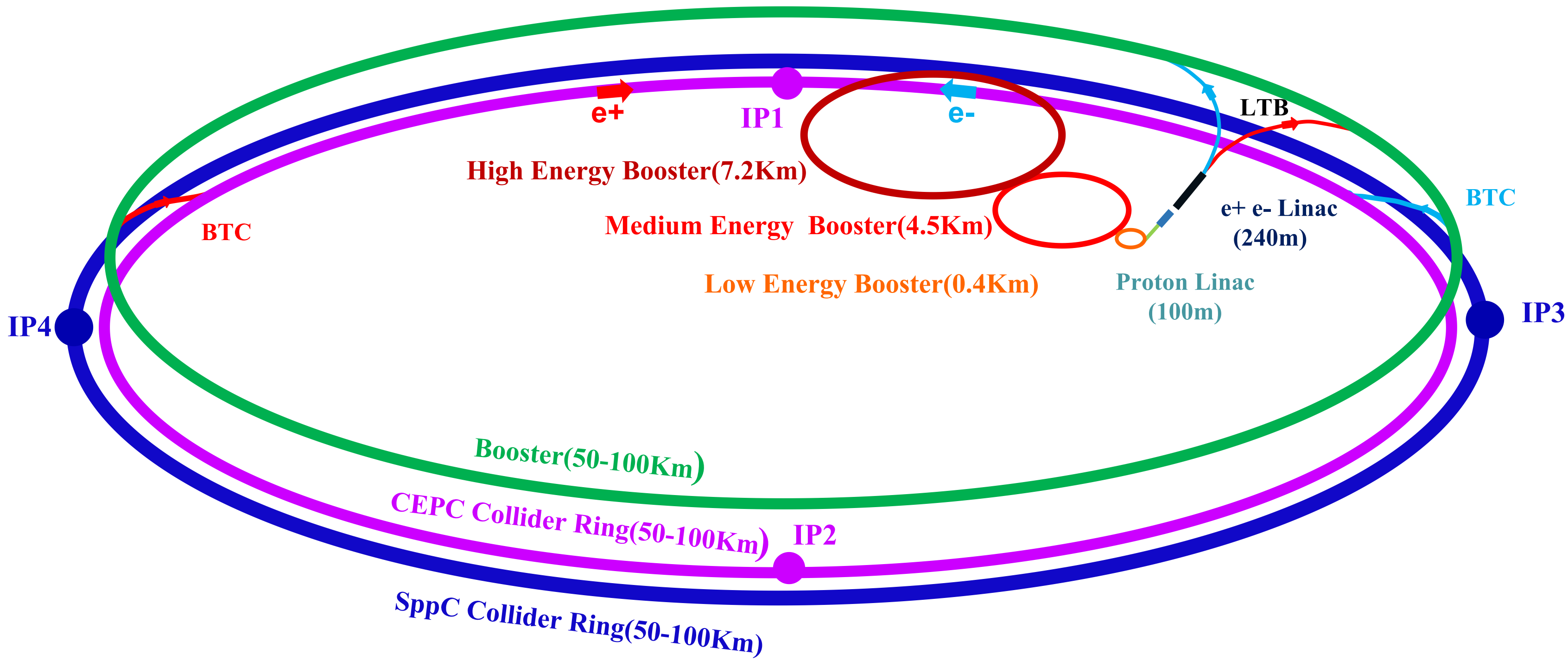
From BEPC to BEPCII

BEPC 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?

CEPC+SppC

- Thanks to the low mass Higgs, it is possible to build a Circular Higgs Factory (CEPC), followed by a proton collider (SppC) in the same tunnel



Important reminds

- CEPC-SppC is proposed in Sept. 2012, right after Higss discovery at CERN by LHC in July 2012

- "C" in CEPC doesn't stands for China, but "Circular" and mostly for high energy physics "Community". CEPC is of the Community, by the Community and for the Community

- ILC, CEPC, FCC(ee) are proposed tools to produce Higgs (+ others) through e+e- collision

- ILC, CEPC, FCC(ee) have many common technologies and task force overlapes

- The succeed of the community is the succeed of any of them

- In Oct. 30, 2015, Chinese government cleared next five year plan and beyond on science with the following statement: "Actively propose and lead the international science plans and big scientific projects (积极提出并牵头组织国际大科学计划和大科学工程) "

ICFA Statements

- ICFA meeting of Feb. 2014 at DESY, Hambourg, stated:

ICFA supports studies of energy frontier circular colliders and encourages global coordination

- ICFA meeting of July 2014 in Spain, stated:

… ICFA continues to encourage international studies of circular colliders, with an ultimate goal of proton-proton collisions at energies much higher than those of the LHC.

AsiaHEP/ACFA Statement on ILC + CEPC/SPPC

AsiaHEP and ACFA reassert their strong endorsement of the ILC, which is in a mature state of technical development. The aim of ILC is to explore physics beyond the Standard Model by unprecedented precision measurements of the Higgs boson and top quark, as well as searching for new particles which are difficult to discover at LHC. The Higgs studies at higher energies are especially important for measurement of WW fusion process, to fix the full Higgs decay width, and to measure the Higgs self-coupling. In continuation of decades of world-wide coordination, we encourage redoubled international efforts at this critical time to make the ILC a reality in Japan. The past few years have seen growing interest in a large radius circular collider, first focused as a "Higgs factory", and ultimately for proton-proton collisions at the high energy frontier. We encourage the effort lead by China in this direction, and look forward to the completion of the technical design in a timely manner.

Kyoto, Janan, April, 2016

Physics of CEPC (SppC)

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

Precision measurement + searches:
Complementary with each other !

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

⇒ one million Higgs from 2 IPs in 10 years

CEPC Design – Z-pole Parameters

Parameter	Design Goal
Particles	e+, e-
Center of mass energy	2*45.5 GeV
Integrated luminosity (peak)	>1*10^34/cm^2s
No. of IPs	2
Polarization	Consider in the second round

CEPC Design – Guidelines

- Build an underground tunnel for a Higgs factory
- Use the same tunnel for a future *pp* collider:
  - The tunnel cross section should be big enough to accommodate an *e+e-* collider, a booster and a *pp* collider
  - The straight sections should be long enough to accommodate large detectors and complex collimation systems of a *pp* collider
  - It should allow to run both *e+e-* and *pp* experiments simultaneously
  - Within the budget limit, the tunnel circumference should be made as large as possible
- Keep options open for:
  - *e-p* and *e-A* colliders
  - Light source
  - XFEL

CEPC Design - PreCDR

- Tunnel circumference: ~54 km
- Tunnel size: 6.0 m (LEP tunnel: 3.6 m)
- 8 arcs and 8 straight sections: 4 straight for IPs and RF, another 4 for RF, injection and beam dump, etc.
- A 6 GeV linac on the surface (with the option for an FEL in the future)
- A full-energy 120 GeV Booster in the tunnel
- A 240 GeV e+e- Collider in the same tunnel underneath the Booster
- **A single beam pipe** for both e+ and e- beams (similar to LEP, CESR)
- Synchrotron radiation budget: 50 MW per beam
- Two SRF systems:
  - Booster: 1.3 GHz 9-cell cavity, similar to the ILC, XFEL, LCLS-II
    32 cryomodules, 256 cavities
  - Collider: 650 MHz 5-cell cavity, similar to the ADS, PIP-II
    96 cruomodules, 384 cavities

CEPC-SPPC Timeline (for discussion)

CEPC

2015 | 2020 | 2025 | 2030 | 2035

Pre-studies (2013-2015)	R&D Engineering Design (2016-2022)	Construction (2022-2030)	Data taking (2030-2040)

1st Milestone: Pre-CDR (by the end of 2014) ;2nd Milestone: R&D funding from MOST (in Mid 2016); 3rd Milestone: CEPC CDR Status Report (by the end of 2016); 4th Milestone: CEPC CDR Report (by the end of 2017);5th Milestone: CEPC TDR Report and Proto (by the end of 2022);6th Milestone: CEPC construction (by the end of 2030);

SPPC

2020 | 2030 | 2040

R&D and CDR (2014-2030)	Engineering Design (2030-2040)	Construction (2040-2050)	Data taking (2050)

Current Status of CEPC

- **Pre-CDR completed**
  - No show-stoppers
  - Technical challenges identified ➔ R&D issues
  - Preliminary cost estimate
- **R&D issues identified and funding request underway**
  - Seed money from IHEP available: 12 M RMB/3 years
  - MOST: ~ 80 M RMB / 5yr, 36M RMB has been proved in June 2016
  - Onters topical issue funds from NSFC, CAS and the Science and Technoogy Bureau of Beijing Municipal: ~9M RMB
  - **Working towards CDR, Accelerator by 2016 and Detector by 2017**
  - A working machine on paper solving the problems left by Pre-CDR
- **Site selections**
- **Internationalization & organization**

Main parameters for CEPC (Pre-CDR)

Parameter	Unit	Value	Parameter	Unit	Value
Beam energy [E]	GeV	120	**Circumference [C]**	m	54420
Number of IP[N_{IP}]		2	**SR loss/turn [U_0]**	GeV	3.11
Bunch number/beam[n_B]		50	**Bunch population [Ne]**		3.71E+11
SR power/beam [P]	MW	51.7	**Beam current [I]**	mA	16.6
Bending radius [ρ]	m	6094	**momentum compaction factor [α_p]**		3.39E-05
Revolution period [T_0]	s	1.82E-04	**Revolution frequency [f_0]**	Hz	5508.87
emittance (x/y)	nm	6.12/0.018	**β_{IP}(x/y)**	mm	800/1.2
Transverse size (x/y)	μm	69.97/0.15	**$\xi_{x,y}$/IP**		0.116/0.082
Beam length SR [$\sigma_{s.SR}$]	mm	2.17	**Beam length total [$\sigma_{s.tot}$]**	mm	2.53
Lifetime due to Beamstrahlung	min	80	**lifetime due to radiative Bhabha scattering [τ_L]**	min	52
RF voltage [V_{rf}]	GV	6.87	**RF frequency [f_{rf}]**	MHz	650
Harmonic number [h]		117900	**Synchrotron oscillation tune [ν_s]**		0.18
Energy acceptance RF [h]	%	5.98	**Damping partition number [J_ε]**		2
Energy spread SR [$\sigma_{\delta.SR}$]	%	0.13	**Energy spread BS [$\sigma_{\delta.BS}$]**	%	0.08
Energy spread total [$\sigma_{\delta.tot}$]	%	0.16	**n_γ**		0.23
Transverse damping time [n_x]	turns	78	**Longitudinal damping time [n_ε]**	turns	39
Hourglass factor	Fh	0.692	**Luminosity /IP[L]**	$cm^{-2}s^{-1}$	2.01E+34

Can be downloaded from

http://cepc.ihep.ac.cn/preCDR/volume.html

IHEP-CEPC-DR-2015-01

IHEP-EP-2015-01

IHEP-TH-2015-01

CEPC-SPPC

Preliminary Conceptual Design Report

Volume I - Physics & Detector

403 pages, 480 authors

The CEPC-SPPC Study Group

March 2015

IHEP-CEPC-DR-2015-01

IHEP-AC-2015-01

CEPC-SPPC

Preliminary Conceptual Design Report

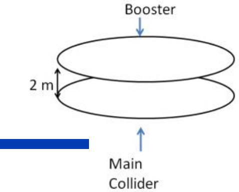
Volume II - Accelerator

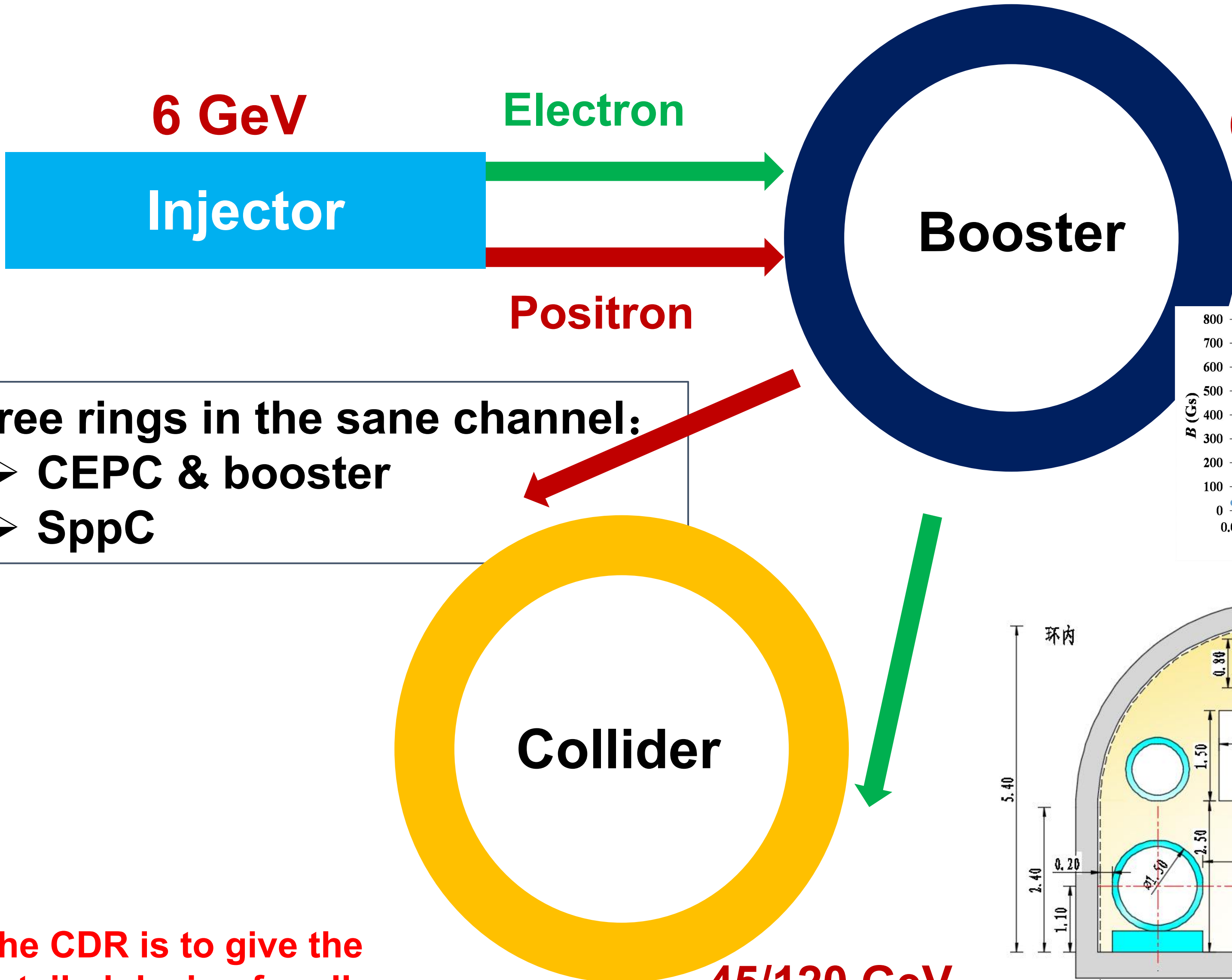
328 pages, 300 authors

The CEPC-SPPC Study Group

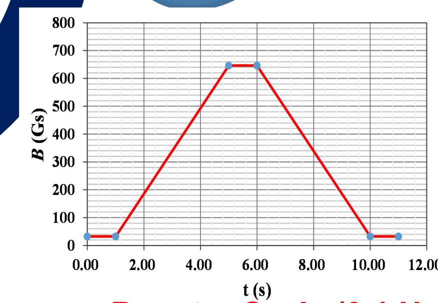
March 2015

CEPC Accelerator Chain

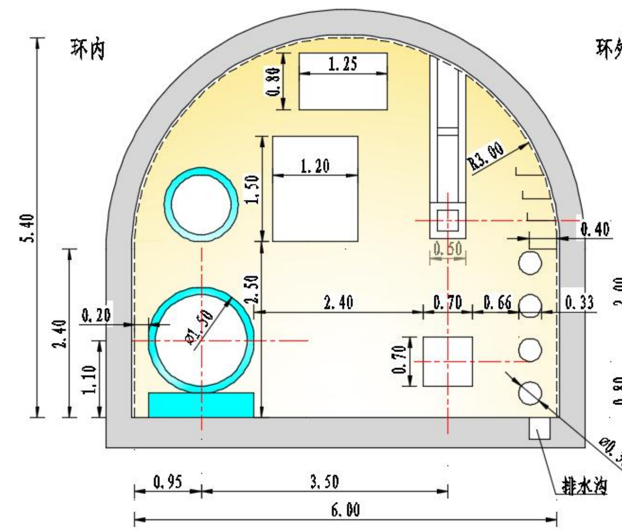




Three rings in the sane channel:
- **CEPC & booster**
- **SppC**



Booster Cycle (0.1 Hz)



The CDR is to give the detailed design for all systems

Main parameters for CEPC (Pre-CDR)

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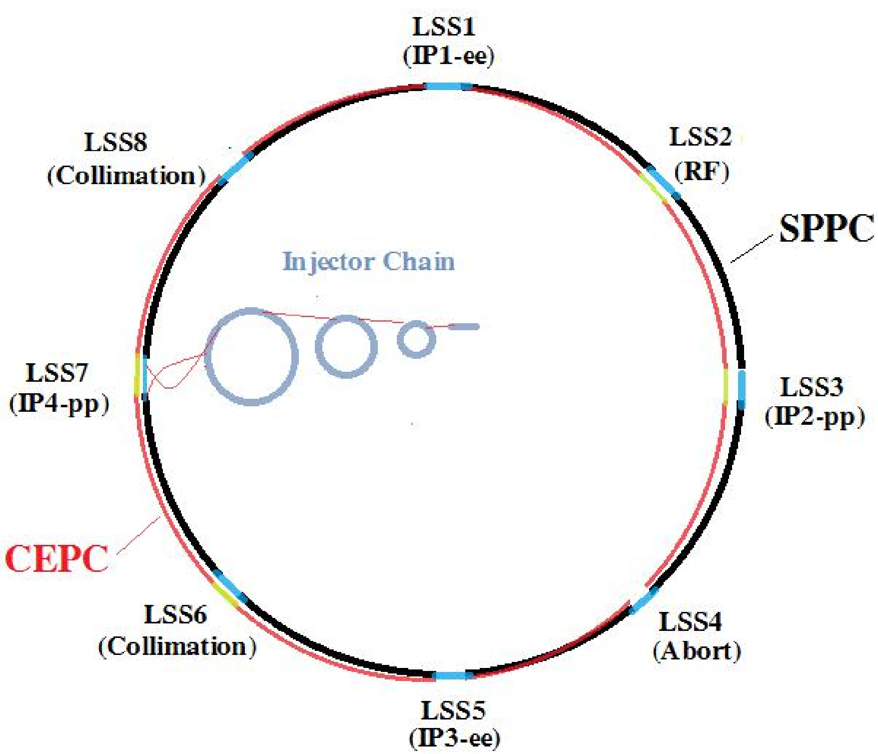
Hourglass factor	Fh	0.692	**Luminosity /IP[L]**	$cm^{-2}s^{-1}$	2.01E+34

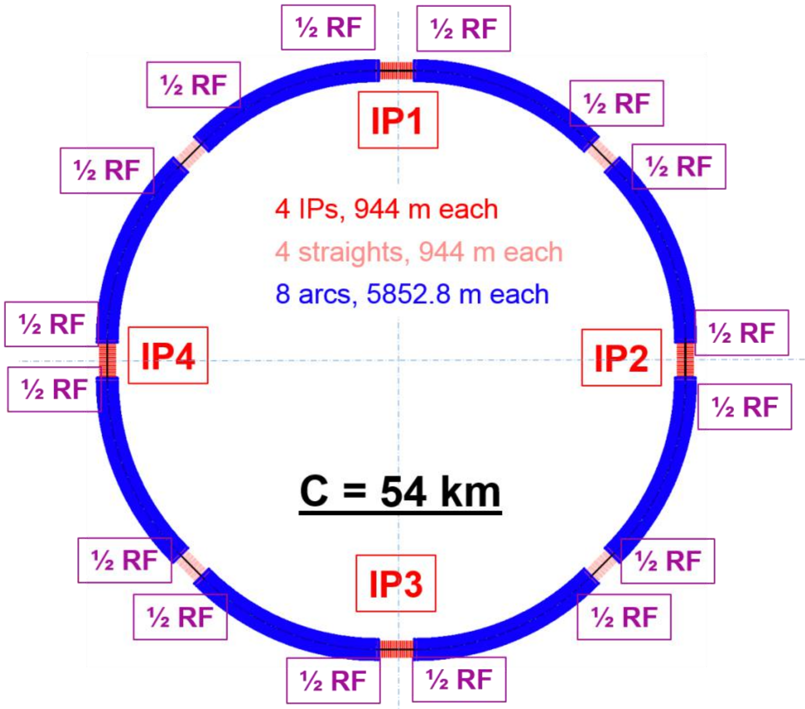
SppC General design

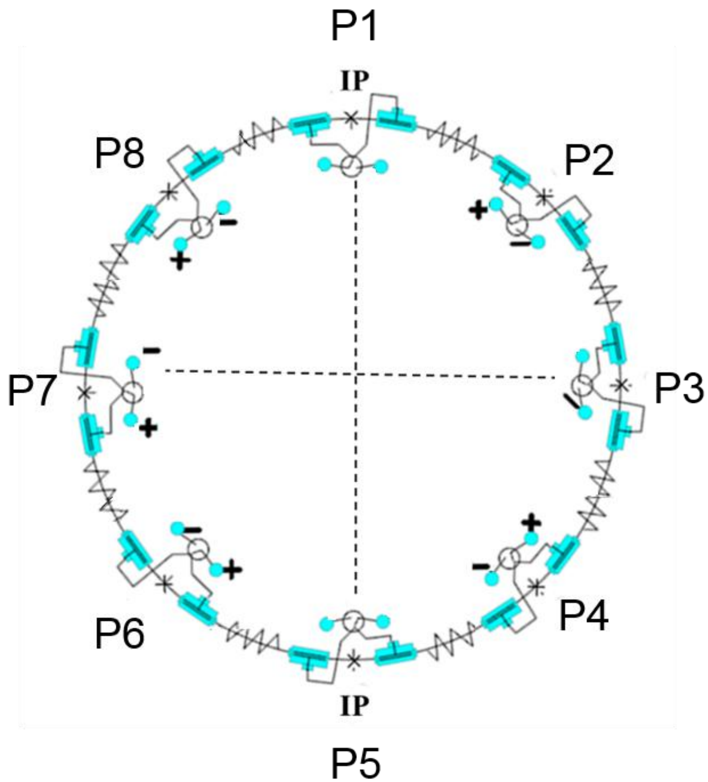


- 8 arcs (5.9 km) and long straight sections (850m*4+1038.4m*4)

Parameter	Value
Circumference	54.36 km
Beam energy	35.3 TeV
Dipole field	20 T
Injection energy	2.1 TeV
Number of IPs	2 (4)
Peak luminosity per IP	**1.2E+35 $cm^{-2}s^{-1}$**
Beta function at collision	0.75 m
Circulating beam current	1.0 A
Max beam-beam tune shift per IP	0.006
Bunch separation	25 ns
Bunch population	2.0E+11
SR heat load @arc dipole (per aperture)	56.9 W/m

CEPC Pretzel Scheme (Pre-CDR)





- 48 bunches / beam, 96 parasitic collision points (~ 500 m spacing)
- Horizontal separation, no off-center orbit in RF section
- One pair of electrostatic separators for each arc (green)
- One pair of electrostatic separators for P2, P3, P4, P6, P7, P8

H.P. Geng

SPPC Layout

LSS1/5

1107m

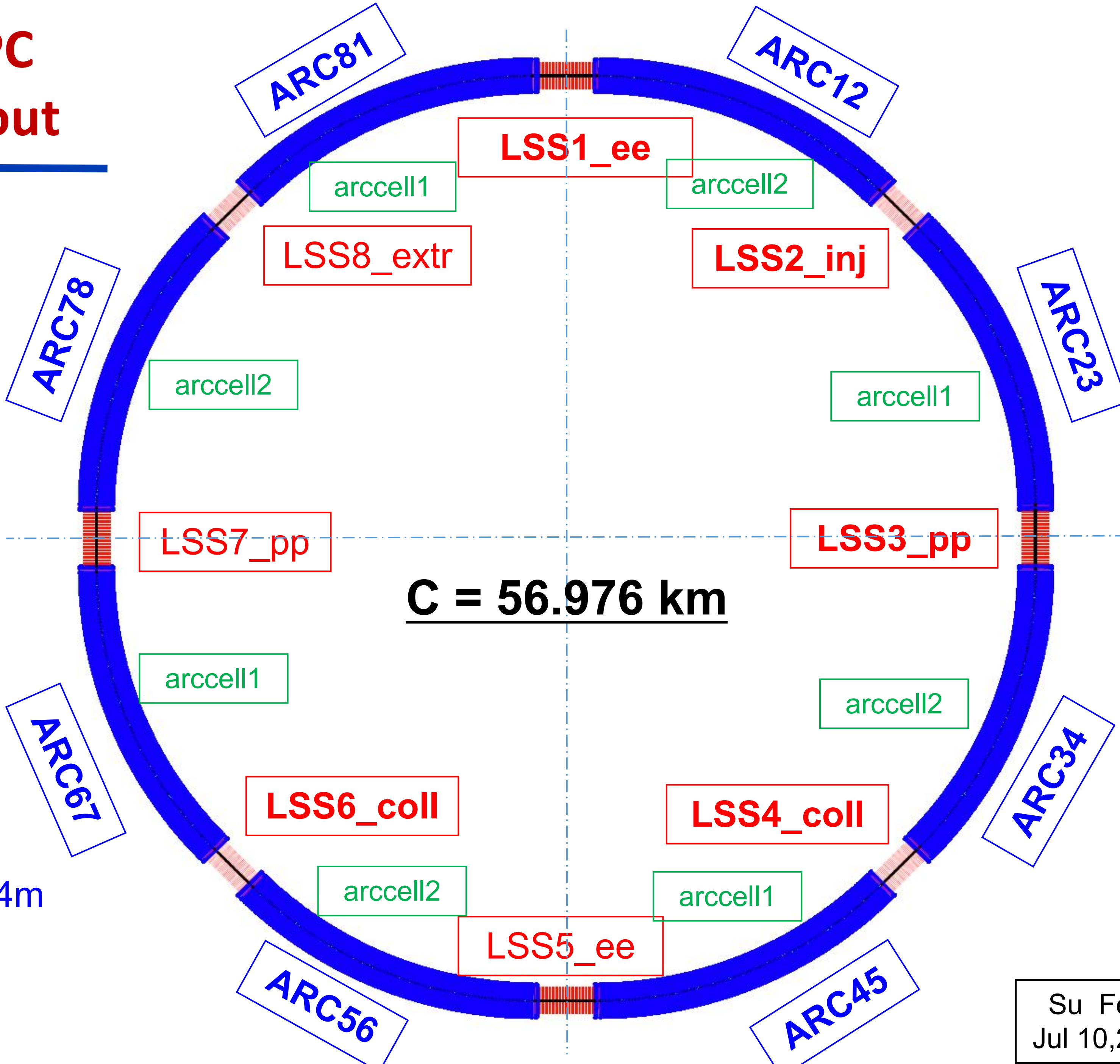
LSS2/4/6/8

959.4m

LSS3/7

1244m

ARC 6077.84m



Su Feng
Jul 10,2015

The main problems left in Pre-CDR

1) Z-pole luminosity could not be reached

2) AC power consumption is too high ~500MW

3) Pretzel design is very rigid, no flexibilty and stability, and with very small DA

4) Hugh HOM power in SC cavity 3.6kW/cavity

...

One has to move beyond CEPC Pre-CDR desin to a more realisitic and optimized design by exploring more possible options before making a choice for CDR

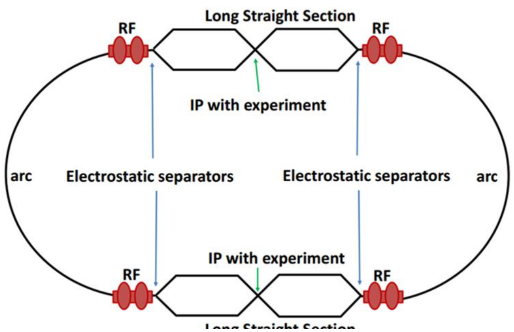
Difficulties of CEPC single ring scheme

	H		*Z*	
	Pre-CDR	***Low-HOM***		
Number of IPs	2	2	2	
Energy (GeV)	120	120	45.5	
Circumference (km)	54	54	54	
SR loss/turn (GeV)	3.1	3.1	0.062	
N_e/bunch (10^{11})	3.79	1.0	0.13	
Bunch number	50	187	4800	100
Beam current (mA)	16.6	16.6	55.5	1.1
SR power /beam (MW)	51.7	50	3.45	0.072
Bending radius (km)	6.1	6.1	6.1	
Momentum compaction (10^{-5})	3.4	3.4	3.4	
β_{IP} x/y (m)	0.8/0.0012	0.06/0.001	0.4/0.0012	
Emittance x/y (nm)	6.12/0.018	6.13/0.018	0.9/0.018	
Transverse σ_{IP} (um)	69.97/0.15	19.2/0.13	18.9/0.15	
ξ_x/IP	0.118	0.031	0.072	
ξ_y/IP	0.083	0.074	0.028	
V_{RF} (GV)	6.87	6.87	0.68	
f_{RF} (MHz)	650	650	650	
Nature σ_z (mm)	2.14	2.13	1.5	
Total σ_z (mm)	2.65	2.4	1.5	
HOM power/cavity (kw)	3.6	1.0	0.55	0.01
Energy spread (%)	0.13	0.13	0.05	
Energy acceptance (%)	2	1.5		
Energy acceptance by RF (%)	6	6.1	4.5	
n_γ	0.23	0.21	0.028	
Life time due to beamstrahlung_cal (minute)	47	46		
F (hour glass)	0.68	0.66	0.82	
L_{max}/IP ($10^{34}cm^{-2}s^{-1}$)	2.04	2.1	1.04	0.022

Main problems left in Pre-CDR

- Pretzel scheme is difficult in design, operation, fexibility and stability
- High AC power
- Booster with very low magnetic field (30 Gauss for 6GeV injection compared with 3 Gauss backgroud magnetic field in BEPCII tunnel) and small dynamic aperture
- Very low luminosity for Z with single ring
- Very small DA at 2% energy spread
- The clear criterion for reaching CDR requirement on DA with beam-beam effects and magnetic errors
- **What is the goal of CEPC CDR?**

In short, Pre-CDR is a "design" even not working on paper



IHEP-AC-LC-Note2013-012

ILC-物理-2013-08

June 16th, 2013

关于CEPC采用亚毫米βy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

关于CEPC采用亚毫米βy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

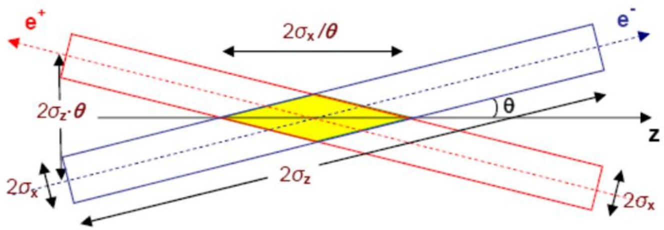
高杰，2013.6.14

目标提出：进一步减少CEPC（CHF）辐射功率，从50MW（原来）减少到25MW（例如），同时保证原设亮度不变（2×10^{34}/cm²·s）（而造价基本不变，增加不大。）（王贻芳所长2013.6.13日晚提出要求）

建议

高杰建议采用如下设计方案：

1）采用带角度对撞，利用crab-waist技术提高亮度
2）降低单束流功率，从50MW→25～20MW
3）保证对撞亮度在1）和2）后达到2×10^{34}（1/cm²s）以上。
4）分离区l，同时使分离区设立长度与环总长度L之比小于10%，最好小于5%。



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.

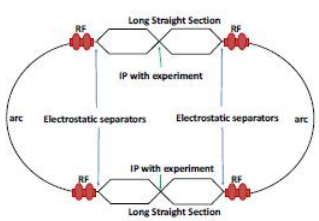


Figure 1: Schematic of the 'bowtie' idea (not to scale)

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

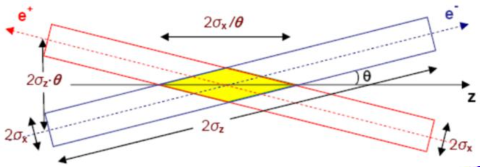
Partial Double Ring (DPR) was proposed independently at IHEP and CERN：

1）J. Gao, IHEP-AC-LC-Note 2013-012

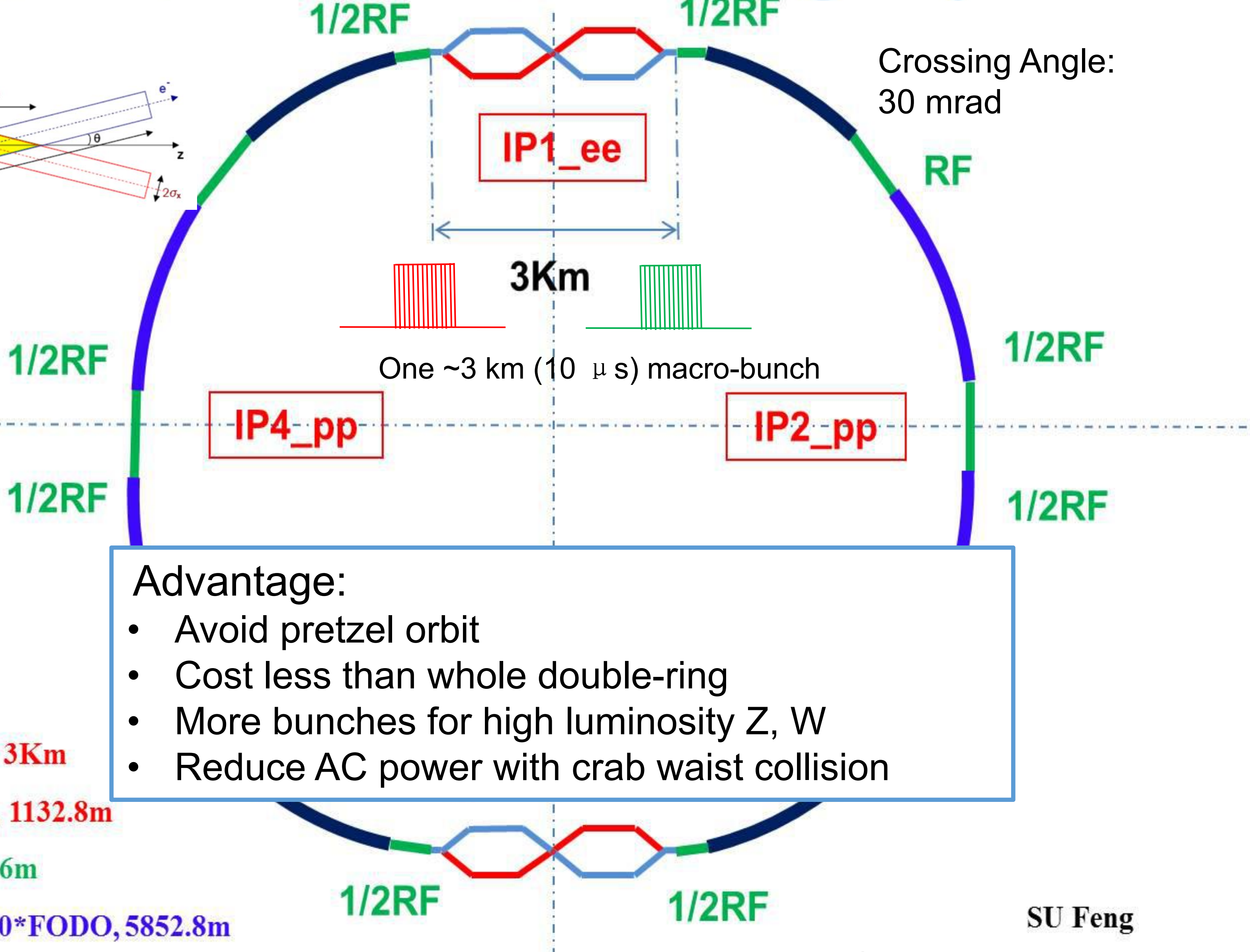
2）M. Moratzinos and F. Zimmermann，2015

(IPAC 2015 M. Moratzinos and F. Zimmermann)

CEPC Partial Double Ring Layout



Crossing Angle:
30 mrad



Advantage:
- Avoid pretzel orbit
- Cost less than whole double-ring
- More bunches for high luminosity Z, W
- Reduce AC power with crab waist collision

IP1_ee/IP3_ee, 3Km

IP2_pp/IP4_pp, 1132.8m

4Straights, 849.6m

4Long ARC, 120*FODO, 5852.8m

4Short ARC, 100*FODO, 4908.8m

SU Feng

2015.10.12

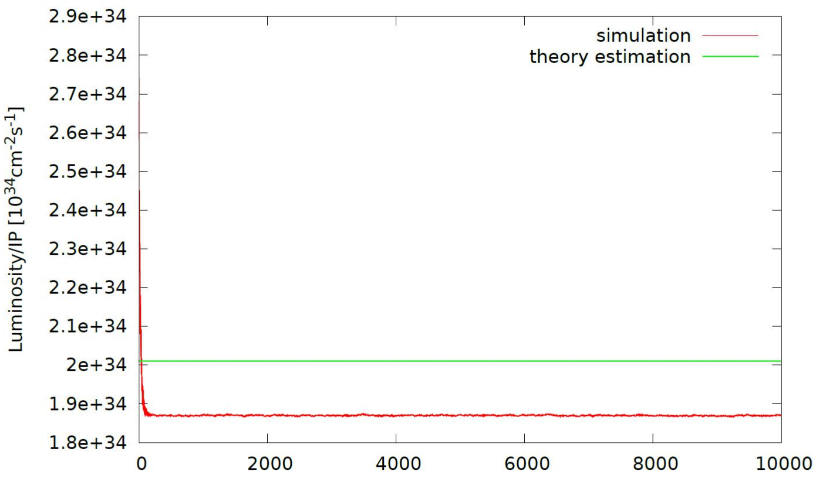
Parameter for CEPC partial double ring

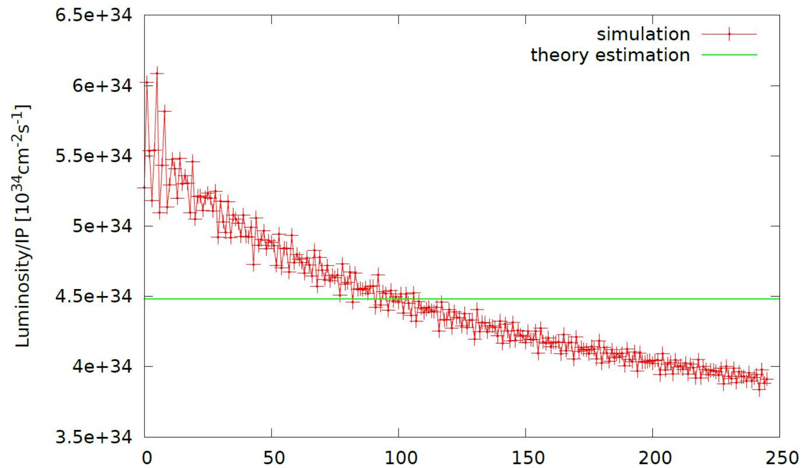
（wangdou20160918）

	Pre-CDR	*H-high lumi.*	*H-low power*	*W*	*Z*
Number of IPs	2	2	2	2	2
Energy (GeV)	120	120	120	80	45.5
Circumference (km)	54	61	61	61	61
SR loss/turn (GeV)	3.1	2.96	2.96	0.58	0.061
Half crossing angle (mrad)	0	15	15	15	15
Piwinski angle	0	1.88	1.84	5.2	6.4
N_e/bunch (10^{11})	3.79	2.0	1.98	1.16	0.78
Bunch number	50	107	70	400	1100
Beam current (mA)	16.6	16.9	11.0	36.5	67.6
SR power /beam (MW)	51.7	50	32.5	21.3	4.1
Bending radius (km)	6.1	6.2	6.2	6.2	6.2
Momentum compaction (10^{-5})	3.4	1.48	1.48	1.44	2.9
β_{IP} x/y (m)	0.8/0.0012	0.272/0.0013	0.275 /0.0013	0.1/0.001	0.1/0.001
Emittance x/y (nm)	6.12/0.018	2.05/0.0062	2.05 /0.0062	0.93/0.0078	0.88/0.008
Transverse σ_{IP} (um)	69.97/0.15	23.7/0.09	23.7/0.09	9.7/0.088	9.4/0.089
ξ_x/IP	0.118	0.041	0.042	0.013	0.01
ξ_y/IP	0.083	0.11	0.11	0.073	0.072
V_{RF} (GV)	6.87	**3.48**	**3.51**	**0.74**	**0.11**
f_{RF} (MHz)	650	650	650	650	650
Nature σ_z (mm)	2.14	**2.7**	**2.7**	**2.95**	**3.78**
Total σ_z (mm)	2.65	2.95	2.9	3.35	4.0
HOM power/cavity (kw)	3.6	0.74	0.48	0.88	0.99
Energy spread (%)	0.13	0.13	0.13	0.087	0.05
Energy acceptance (%)	2	2	2		
Energy acceptance by RF (%)	6	**2.3**	**2.4**	**1.7**	**1.2**
n_γ	0.23	0.35	0.34	0.49	0.34
Life time due to beamstrahlung_cal (minute)	47	37	37		
F (hour glass)	0.68	0.82	0.82	0.92	0.93
L_{max}/IP ($10^{34}cm^{-2}s^{-1}$)	2.04	3.1	2.01	4.3	4.48

Beam-Beam simulation check of H-low power and Z-pole parameter lists

(Y. Zhang)





H-low power:
Theory L: 2*10^34/cm^2s
Beam-beam: 1.9*10^34/cm^2s

Z-pole:
Theory L: 4.48*10^34/cm^2s
Beam-beam: 4*10^34/cm^2s

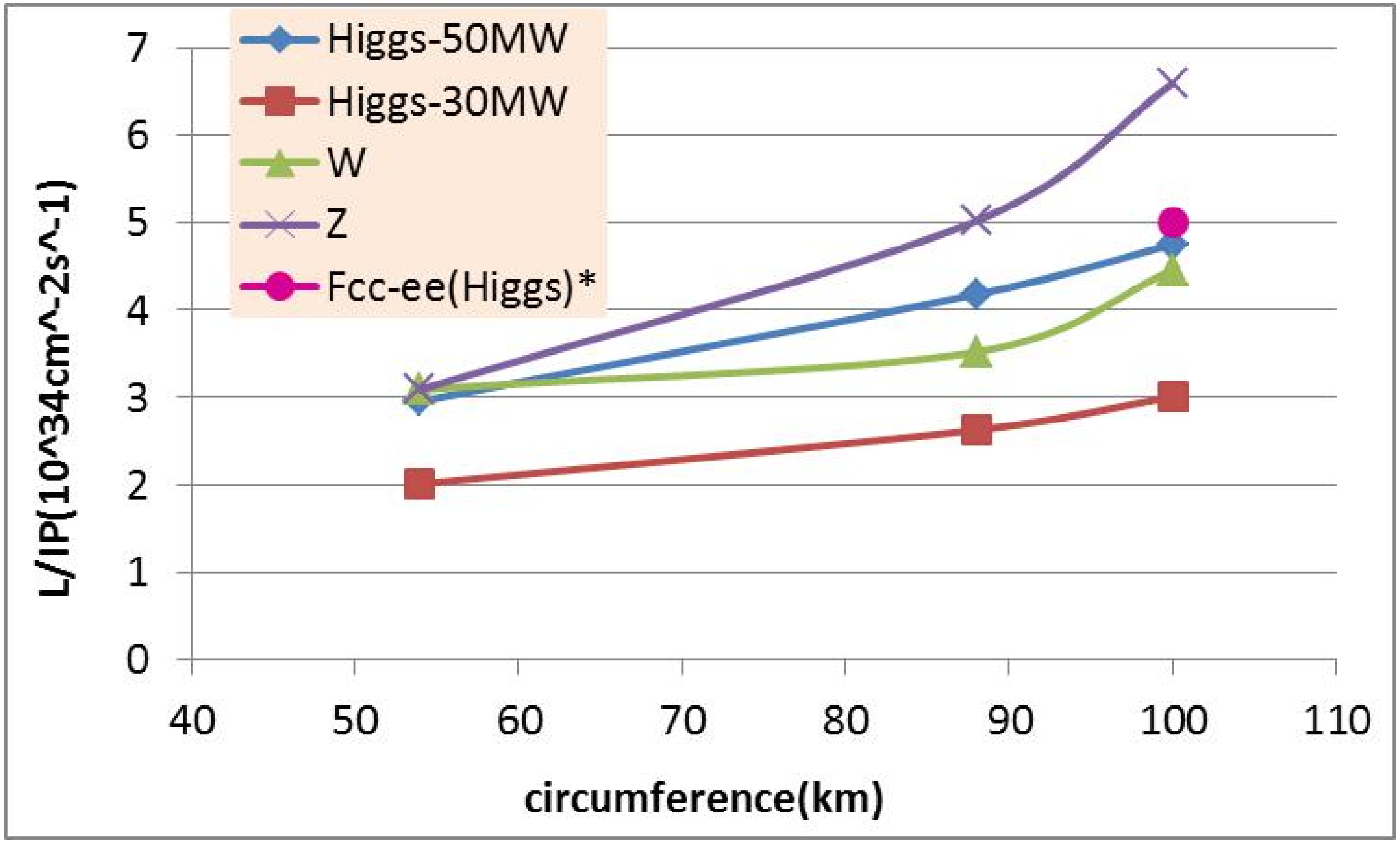
Beam-beam simulation confirmed the H-low power and Z-pole parameter design

Parameter for CEPC PDR-100km

（wangdou20160329）

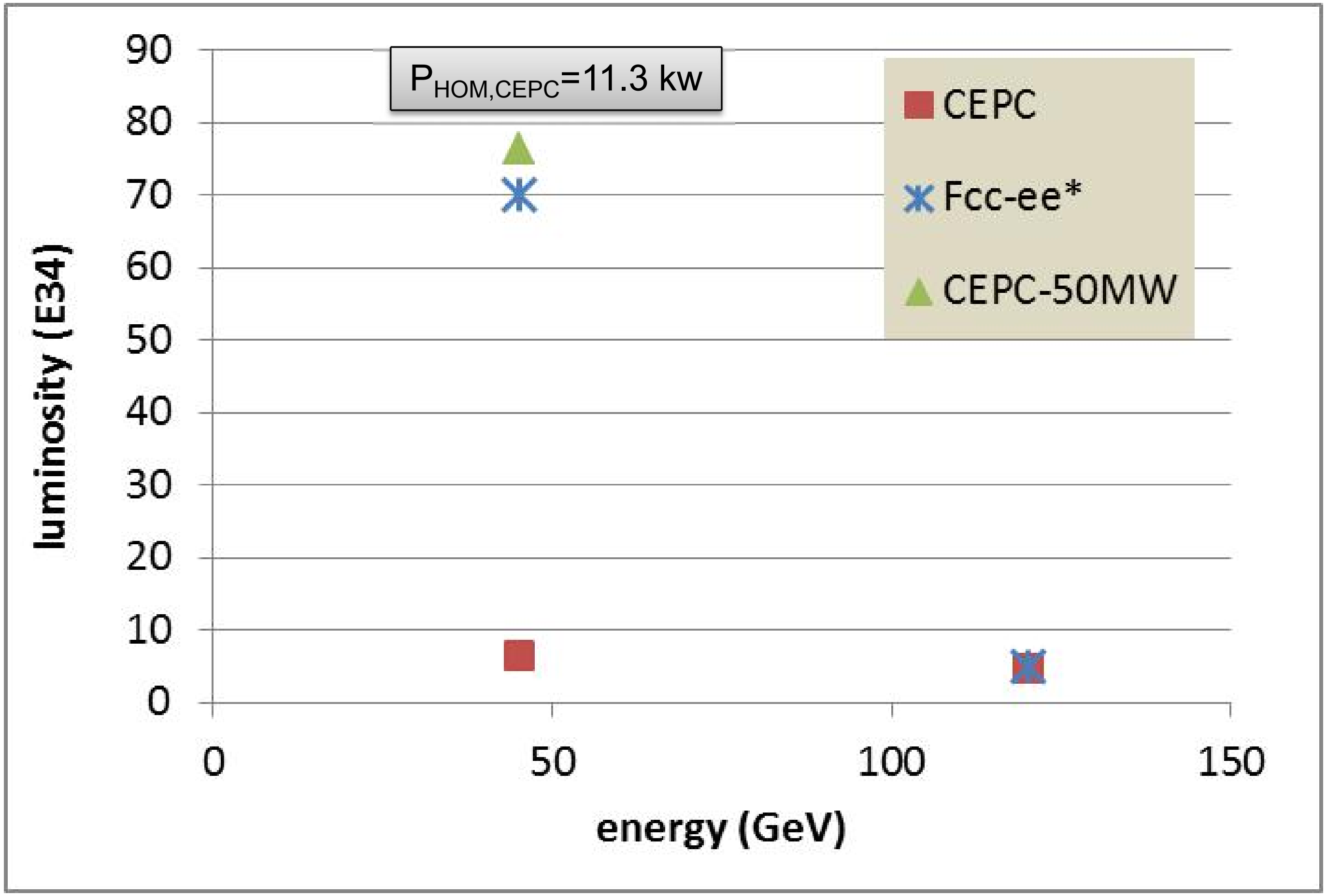
	H-high lumi.	*H-low power*	*W*	*Z*	
Number of IPs	2	2	2	2	
Energy (GeV)	120	120	80	45.5	
Circumference (km)	100	100	100	100	
SR loss/turn (GeV)	1.7	1.7	0.33	0.034	
Half crossing angle (mrad)	15	15	15	15	
Piwinski angle	2.0	2.83	8.65	15.8	
N_e/bunch (10^{11})	1.43	1.22	0.42	0.165	
Bunch number	436	307	2400	15800	182260
Beam current (mA)	30	18	48.7	125.3	1449.7
SR power /beam (MW)	50	30	16.0	4.3	50
Bending radius (km)	11	11	11	11	
Momentum compaction (10^{-5})	1.8	1.4	1.4	1.3	
β_{IP} x/y (m)	0.297/0.0011	0.3/0.0011	0.1/0.001	0.1/0.001	
Emittance x/y (nm)	1.63/0.0049	1.03/0.003	0.46/0.0014	0.14/0.00065	
Transverse σ_{IP} (um)	22/0.074	17.6/0.59	6.8/0.037	3.8/0.026	
ξ_x/IP	0.033	0.025	0.003	0.002	
ξ_y/IP	0.083	0.083	0.055	0.054	
V_{RF} (GV)	**3.1**	**2.25**	**0.41**	**0.053**	
f_{RF} (MHz)	650	650	650	650	
Nature σ_z (mm)	**2.45**	**2.77**	**3.8**	**3.94**	
Total σ_z (mm)	2.94	3.33	3.9	4.0	
HOM power/cavity (kw)	2.3	1.1	0.98	0.97	11.3
Energy spread (%)	0.1	0.1	0.065	0.037	
Energy acceptance (%)	1.46	1.4			
Energy acceptance by RF (%)	**3.5**	**2.2**	**0.9**	**0.7**	
n_γ	0.27	0.28	0.26	0.18	
Life time due to beamstrahlung_cal (minute)	40	49			
F (hour glass)	0.8	0.85	0.96	0.985	
L_{max}/IP ($10^{34}cm^{-2}s^{-1}$)	4.75	3.01	4.46	6.59	76.4

CEPC PDR Luminosity vs circumference



* Fabiola Gianotti, Future Circular ColliderDesign Study, ICFA meeting, J-PARC, 25-2-2016.

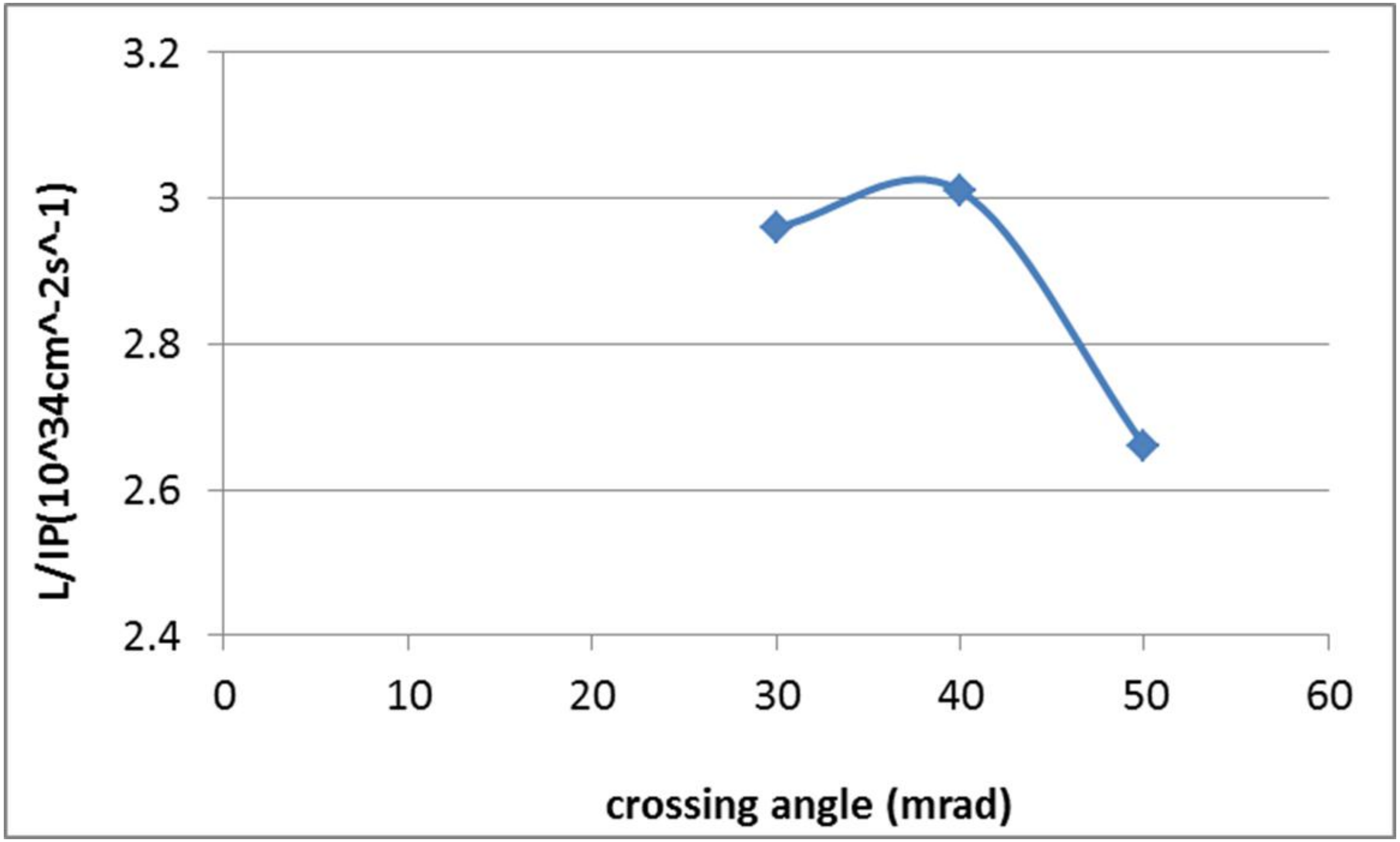
100km CEPC PDR vs Fcc-ee



- The large difference of Z is due to the constraint for RF HOM power

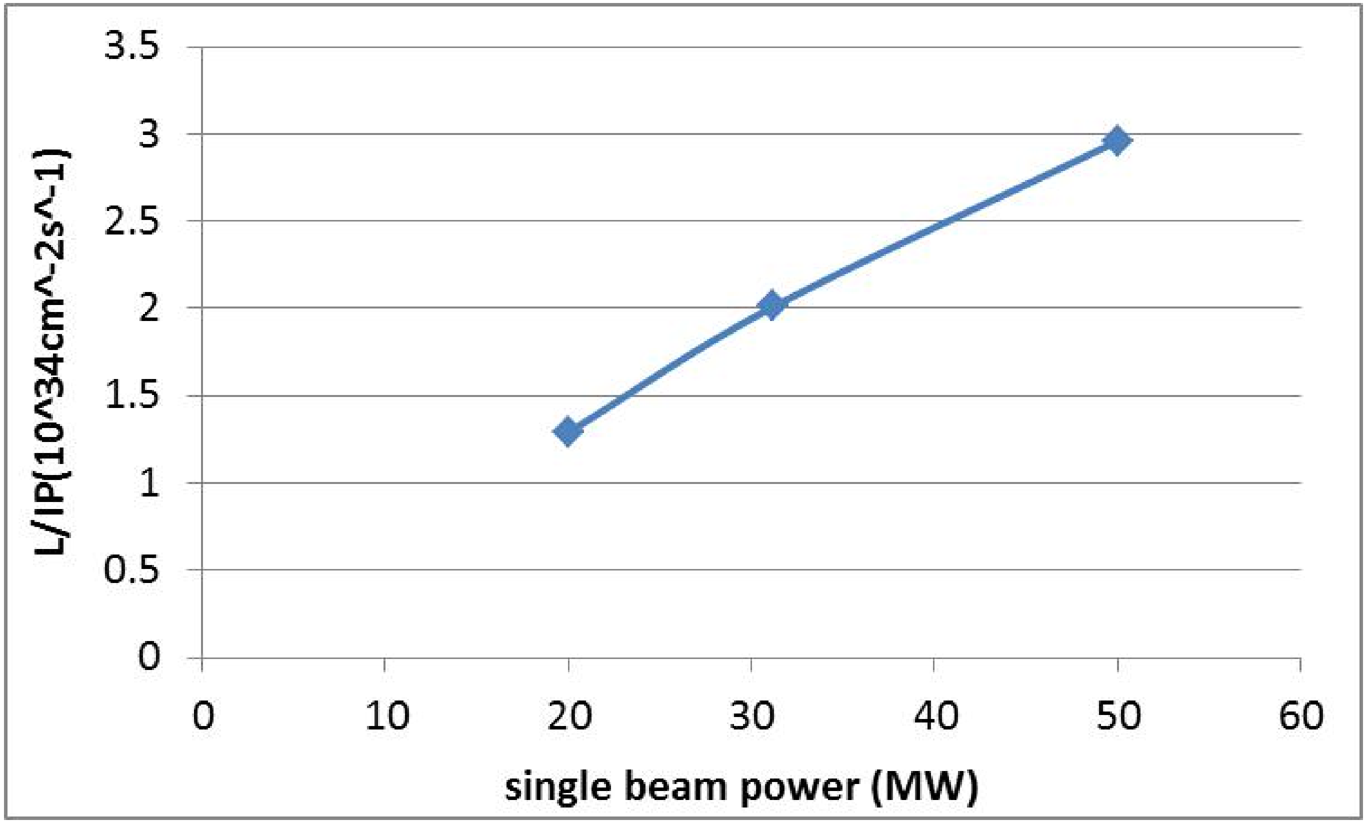
* Fabiola Gianotti, Future Circular ColliderDesign Study, ICFA meeting, J-PARC, 25-2-2016.

CEPC Higgs luminosity vs. crossing angle
(Dou Wang)



CEPC Higgs Luminosity vs beam radiation power

(Dou Wang)

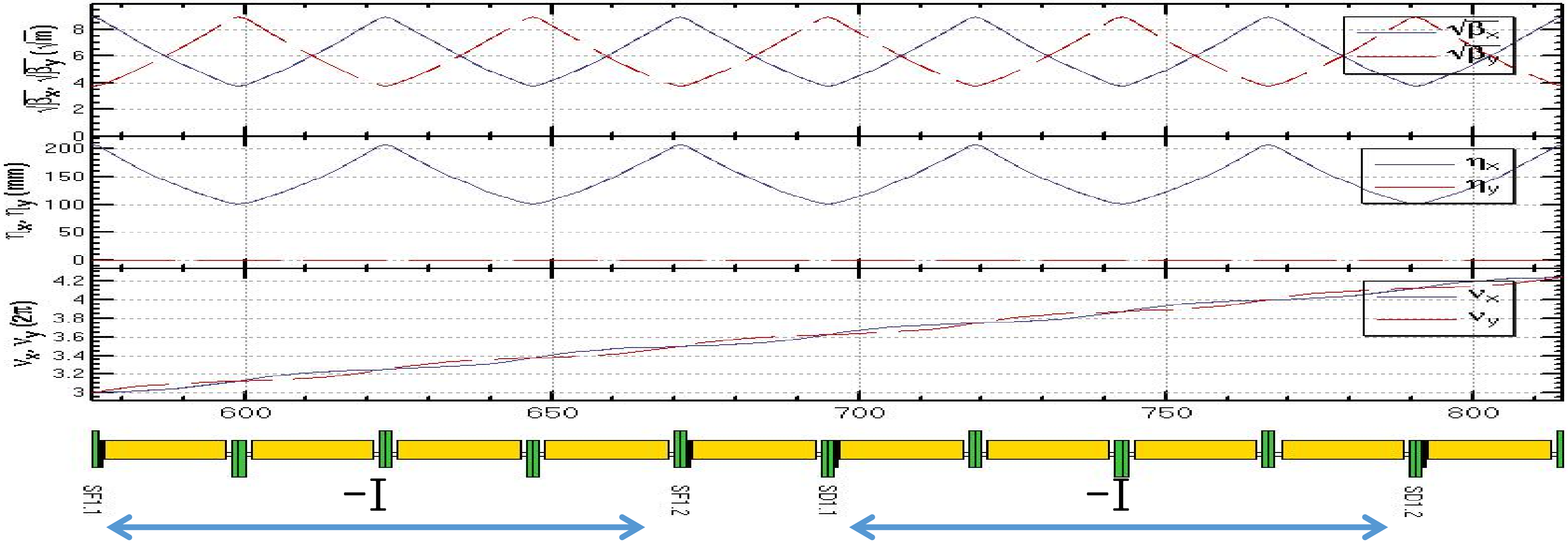


Main ring (no FFS and patial double ring) Design Philosophy

Sextupole scheme	interleave	Non-interleave technique (phy, num)
60 ° /60°	n=6 **All 3rd RDT due to sextupoles cancelled** **All 4th RDT except 2Qx-2Qy due to sextupoles cancelled** **dQ(Jx,Jy): accumalte to be large** **dQ(δ): small even with 2 families** DA on momentum: easy to optim. DA off momentum: easy to optim.	-
90 ° /60 °	**n=12** **All 3rd RDT due to sextupoles cancelled** **All 4th RDT except 4Qx due to sextupoles cancelled** **dQ(Jx,Jy): accumalte to be large** **dQ(δ): small even with 2 families** DA on momentum: easy to optim. DA off momentum: easy to optim.	-
90 ° /90 °	n=4 **All 3rd RDT due to sextupoles cancelled** **4th RDT except 4Qx, 2Qx+2Qy, 4Qy, 2Qx-2Qy due to sextupoles cancelled** **dQ(Jx,Jy): accumalte to be large** **dQ(δ): small even with 2 families** DA on momentum: - DA off momentum: -	n=5 **All 3rd and 4th RDT due to sextupoles cancelled** **dQ(Jx,Jy): small** **dQ(δ): correct with many families** DA on momentum: easy to optim. DA off momentum: with many families to correct dQ(δ) and –I break down
other	DA & RDT…	

PDR arc lattice design

- **FODO cell, 90°/90°, non-interleaved sextupole scheme**
  - period N=5cells
  - all 3rd and 4th resonance driving terms (RDT) due to sextupoles cancelled, except small 4Qx, 2Qx+2Qy, 4Qy, 2Qx-2Qy
  - **tune shift dQ(Jx, Jy) is very small**
    - DA on momentum: large
  - **Chromaticity dQ(δ) need to be corrected with many families**
    - DA off momentum: with many families to correct dQ(δ) and –I break down

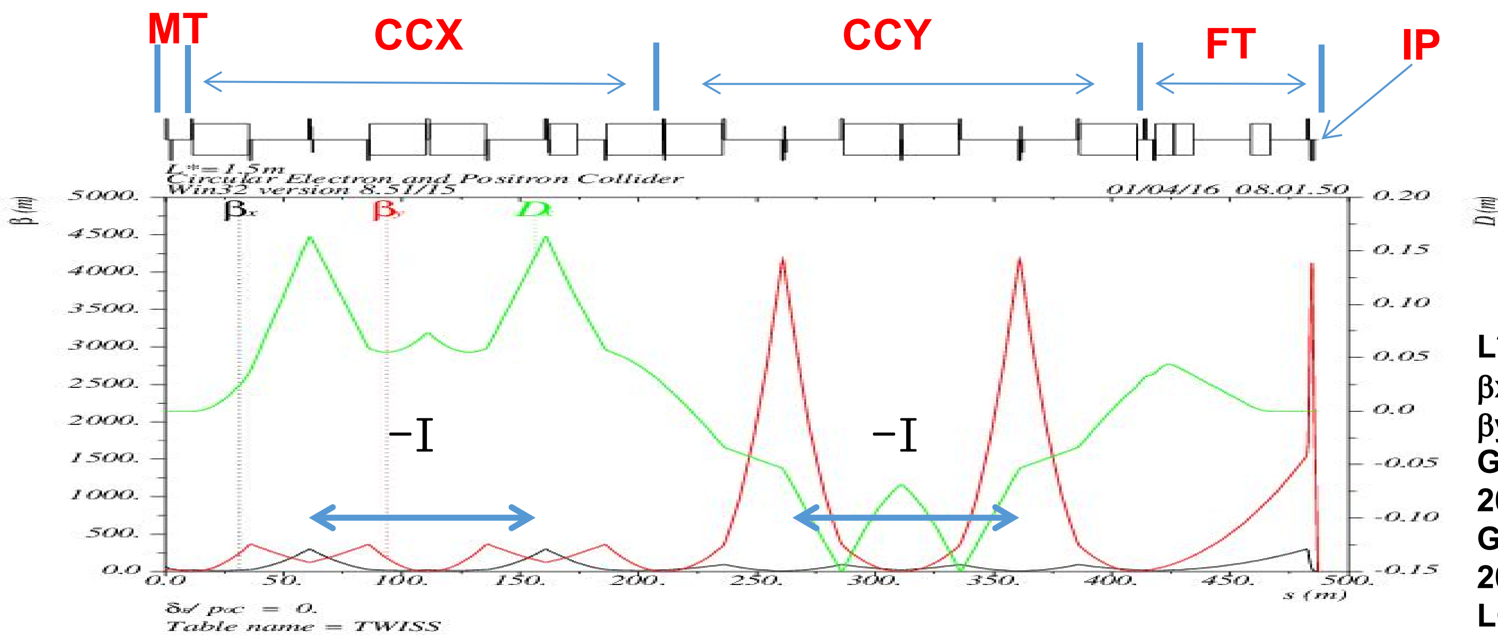


Sextupole configuration

Machine	Author	Parameters	Requirements on FFS design	Features of FFS lattice	Reference
CEPC (PDR)	Dou Wang	L*=1.5m β*=0.25/0.00136 ε=2.45 κ=0.3% Bz=3.5T θc=30mrad	• Local chromaticity correction • Gradient of FD ≤ 200 T/m • SR from the dipoles within 500 m from IP E γ ,c ≤ 190 keV.	• Crab waist collision • Anti-symmetrical IR lattice • need multipoles to correct chromaticity order by order • need large number of ARC sextupoles to optimize momentum acceptance	D. Wang, IPAC16, THPOR010
CEPC (SR)	Yiwei Wang	L*=1.5m β*=0.8m/3mm ε=6.12nm κ=0.3% Bz=3.5T θc=0	• Local chromaticity correction • Gradient of FD ≤ 300 T/m	• Head on collision • Symmetrical IR lattice • with Brinkmann sextupoles to optimize momentum acceptance	Y. Wang, IPAC16, THPOR012
FCC-ee	Katsunobu Oide	L*=2.2m β*=1m/2mm ε=1.26nm κ=0.2% Bz=2T θc=30mrad	• Local chromaticity correction • Gradient of FD ≤ 100 T/m • SR from the dipoles within 500 m upstream of the IP E γ ,c ≤ 100 keV.	• Crab waist collision • Asymmetrical IR lattice • with large number of ARC sextupoles to optimize momentum acceptance	K. Oide, IPAC16, THPOR022
FCC-ee	Anton Bogomyagkov	L*=2.0m β*=0.5m/1mm ε=2.1nm κ=0.2% Bz=? θc=26mrad	• Local chromaticity correction • Gradient of FD ≤ 100 T/m • SR from the dipoles within 250 m from IP E γ ,c ≤ 100 keV.	• Crab waist collision • Asymmetrical IR lattice • With additional sextupoles to correct chromaticity up to 3rd order	A. Bogomyagkov et. al., IPAC16, THPOR019
a Higgs factory	Yunhai Cai	L*=4.0m β*=0.2m/2mm ε=4.5nm κ=0.1% Bz=? θc=0	• Local chromaticity correction	• Head on collision • Symmetrical IR lattice • with multipoles to correct chromaticity order by order	Y. Cai, Lattice for a Higgs Factory, FCC Week 2016

Interaction region lattice design

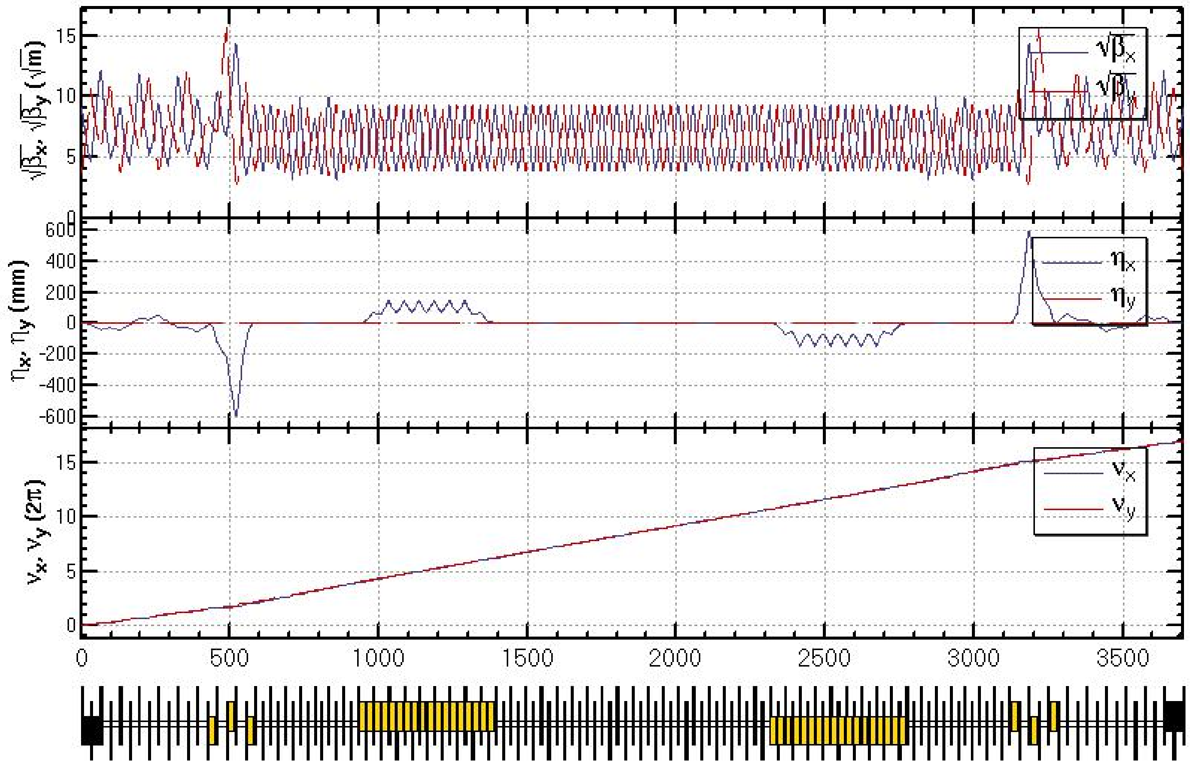
- **Local chromaticity correction** with sextupoles pairs separated by –I transportation
  - all **3rd and 4th RDT** due to sextupoles almost cancelled
  - **up to 3rd order chromaticity** corrected with main sextupoles, phase tuning and additional sextupoles
  - **tune shift dQ(Jx, Jy)** due to finite length of main sextupoles corrected with additional weak sextupoles
  - **Break down of –I, high order dispersion** could be optimized with odd dispersion scheme or Brinkmann sextupoles

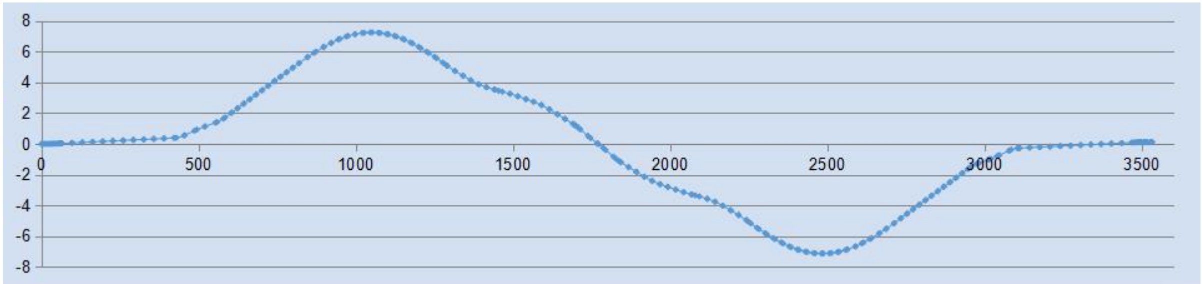


L*= 1.5m
βx^*= 0.22mm
βy^*= 1mm
GQD0= -200T/m
GQF1= 200T/m
LQD0=1.69m
LQF1=0.90m

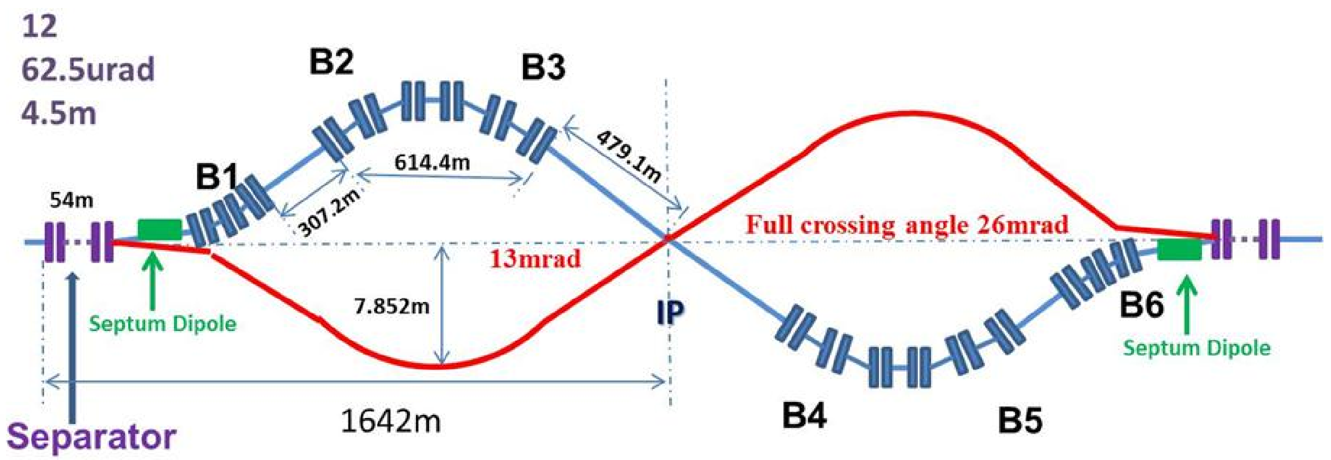
PDR lattice design

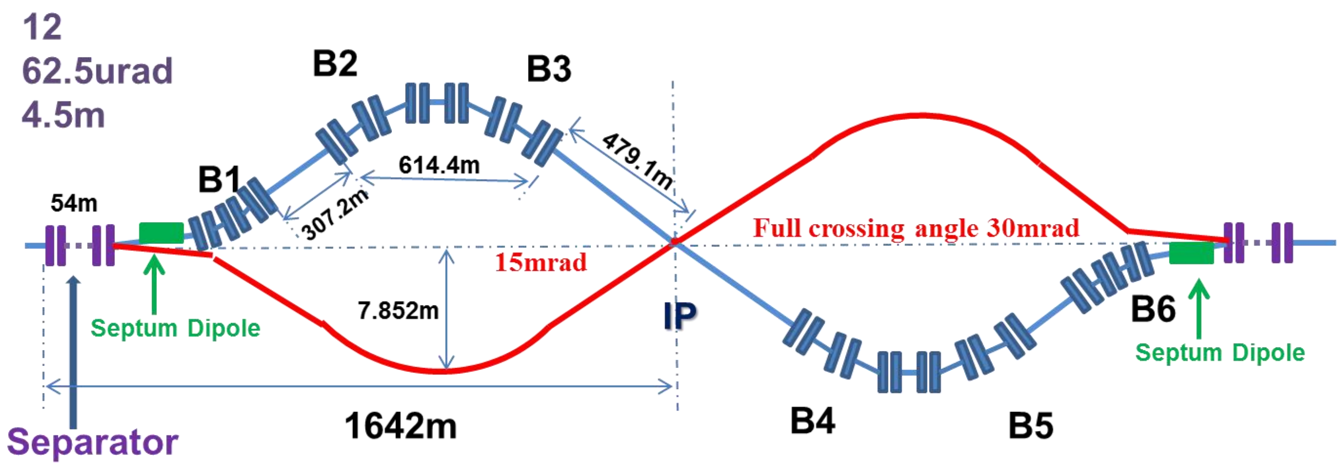
Feng Su, Yiwei Wang





CEPC Partial Double Ring Lattice





For CEPC 120GeV beam:

- **Max. deflection per separator is 66μrad.**

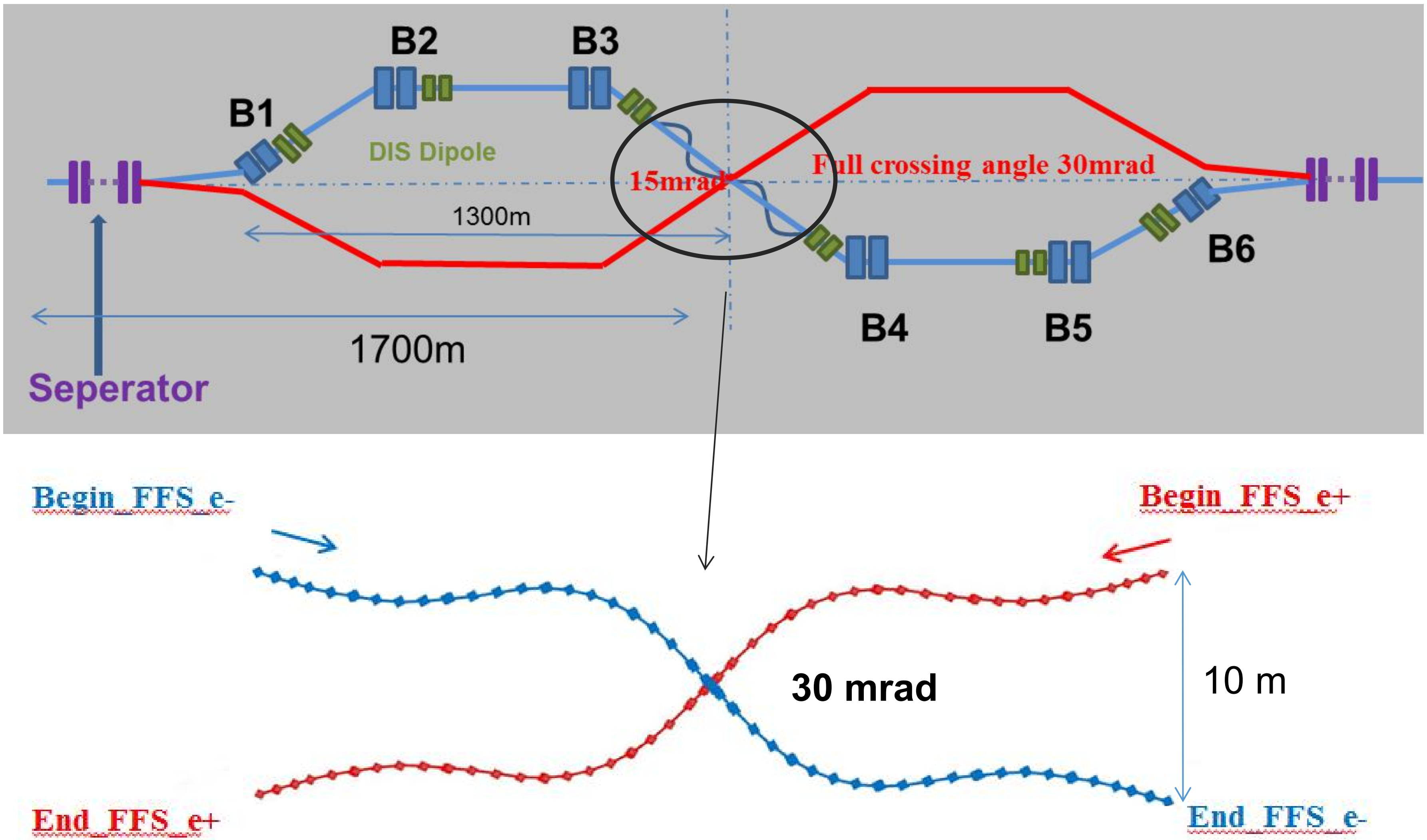
Using Septum Dipole after separator to acquire 15 mrad

Version 1.0

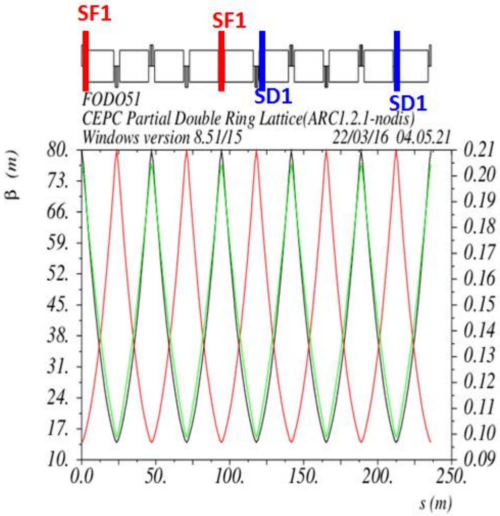
sufeng

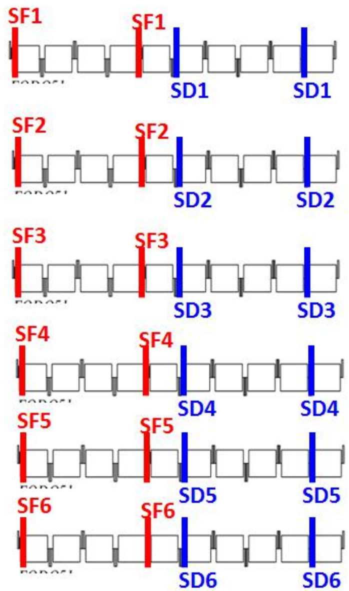
2015.12.20

Combine with partial double ring lattice

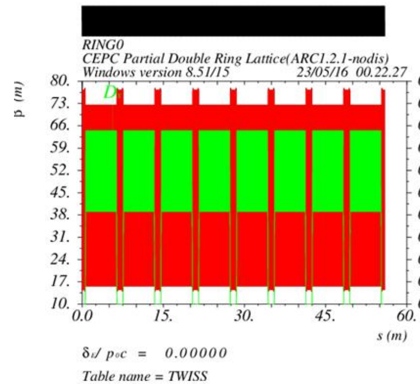


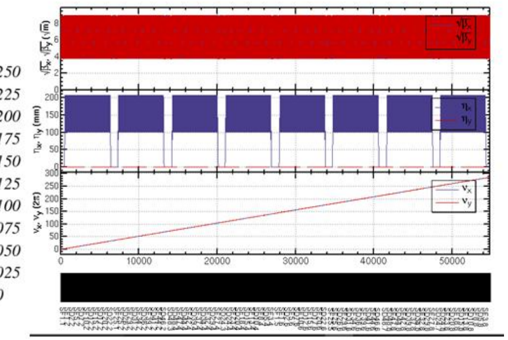
ARC FODO 90/90 non-interleave



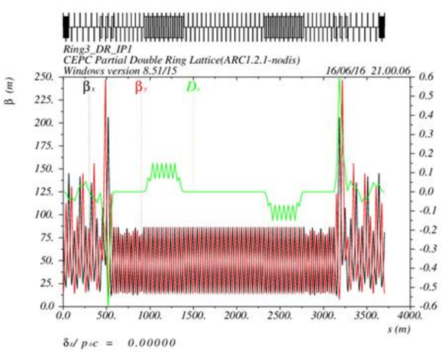


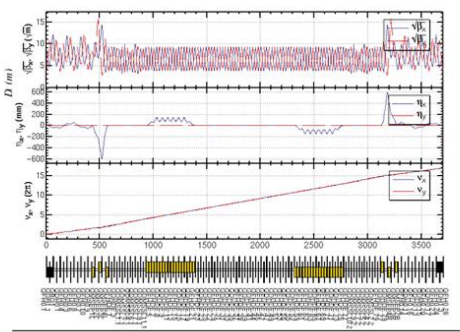
CEPC ARC

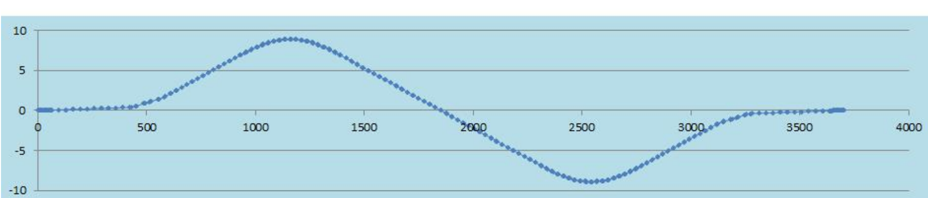




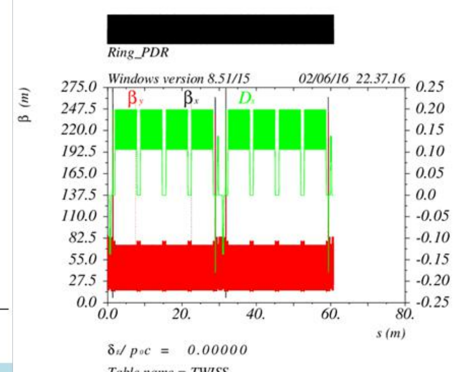
CEPC PDR1.0.3 noFFS

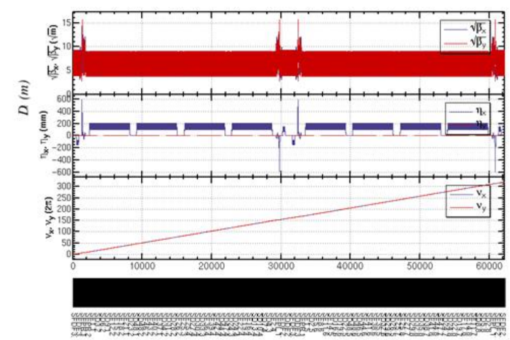






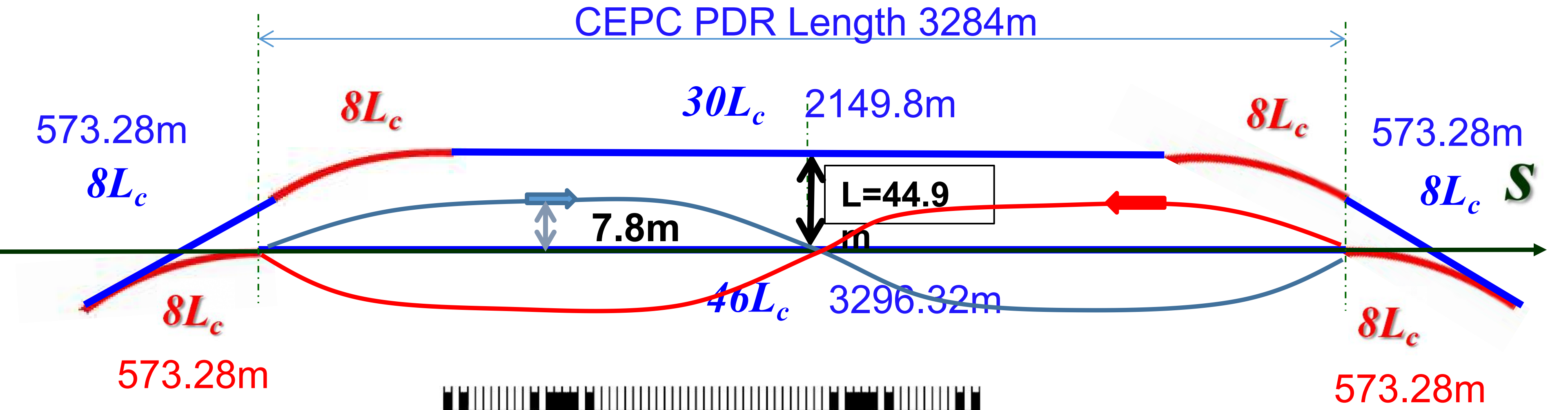
CEPC ARC+PDR

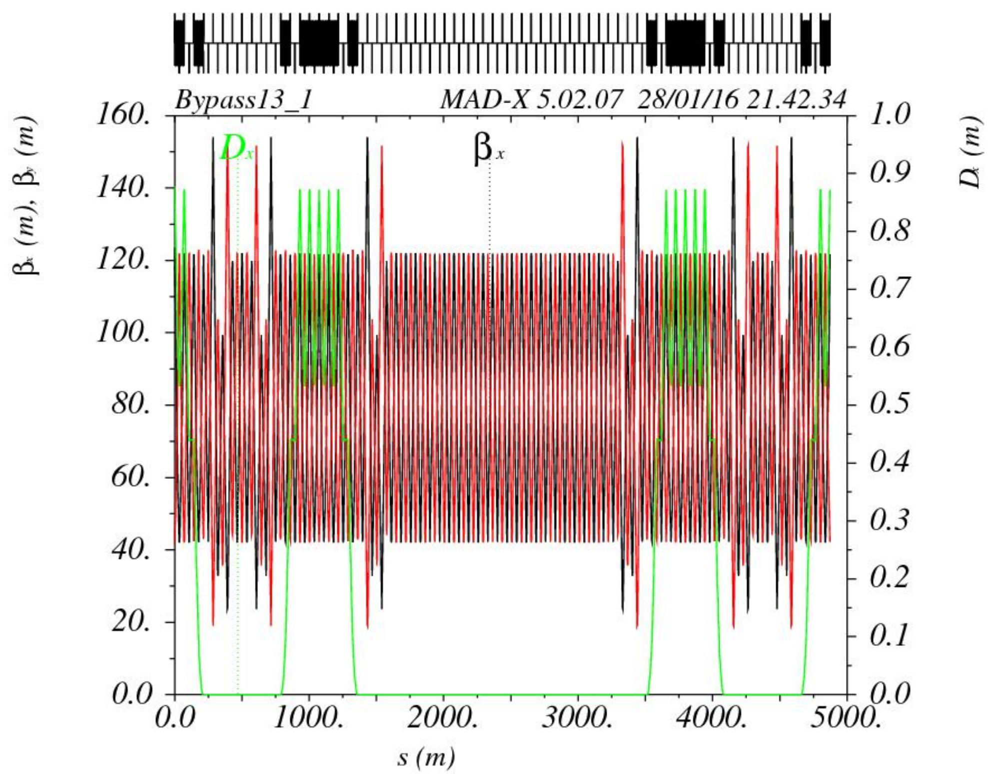




CEPC Booster Bypass at IP1/3 Option1

F. Su

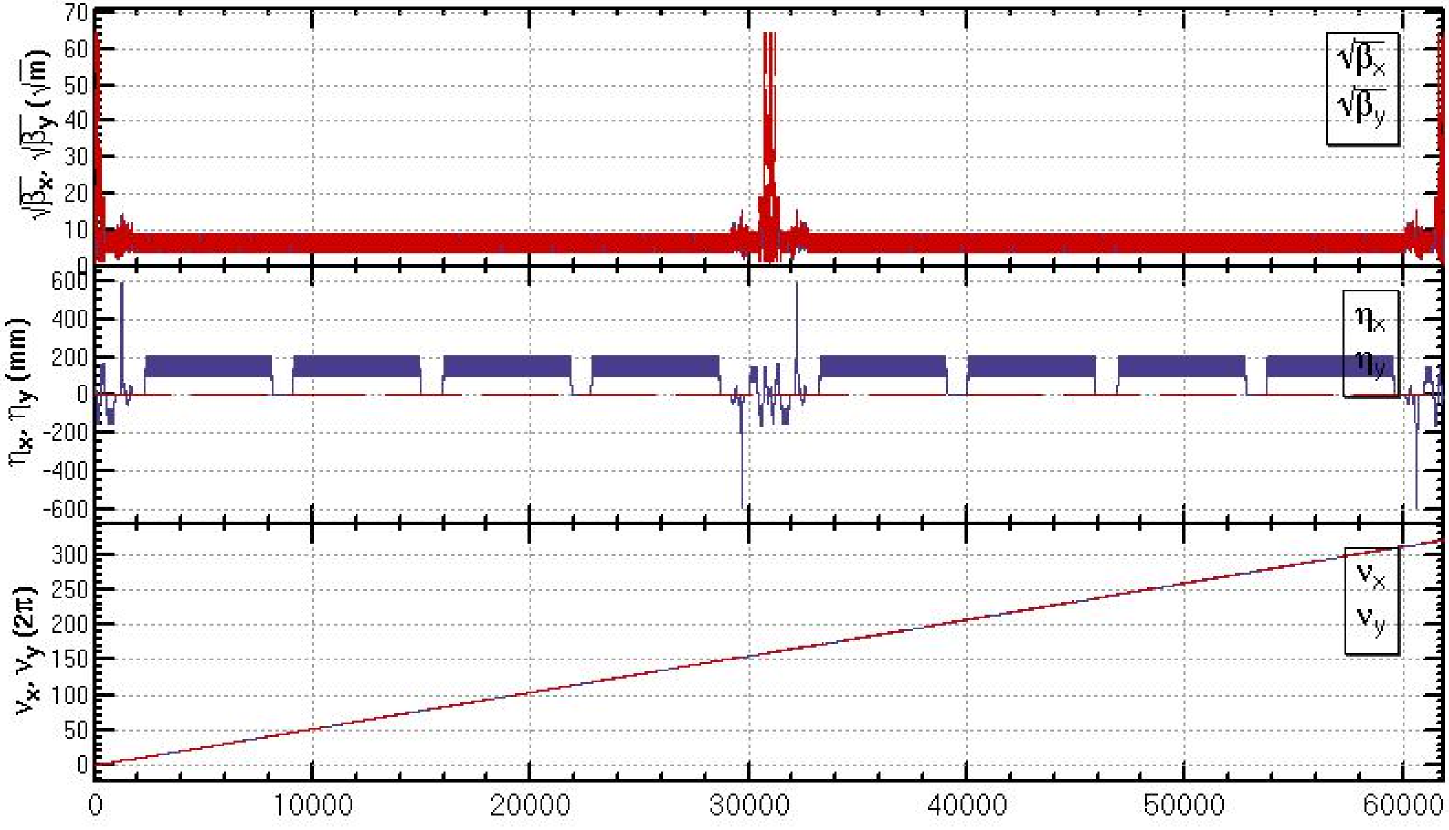




Cell length=71.66m

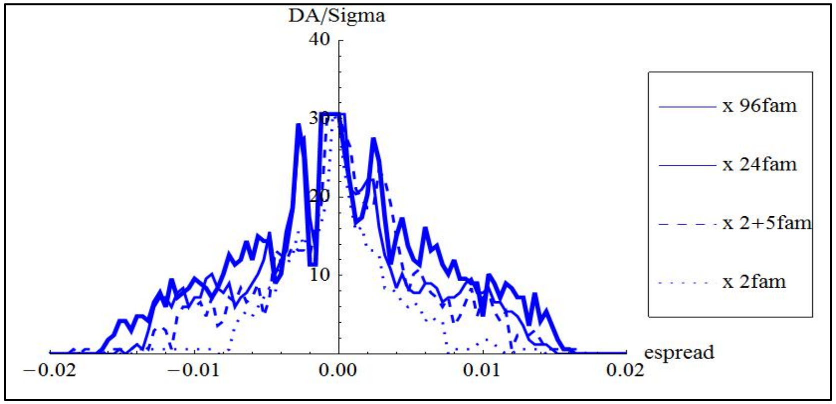
ARC+PDR+IR lattice

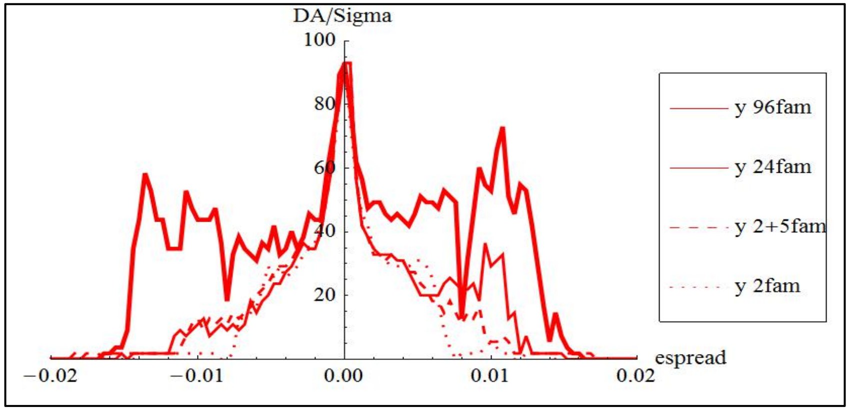
- A lattice of the whole ring (ARC+PDR+IR) fulfilling the design parameters is ready.
- Dynamic aperture optimization for this lattice is under going.



Preliminary Dynamic aperture result for ARC + PDR+IR

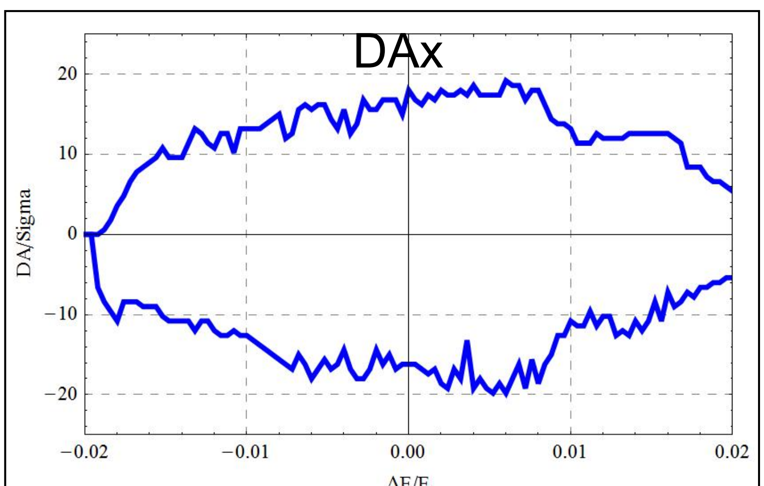
- Preliminary dynamic aperture result
  - With 2 families in ARC + 3 families in IR
  - W/O error of the magnets
  - Synchrotron motion included
  - Tracking with around 1 times of damping time
  - Coupling factor κ=0.003 for εy
  - Optimization with much more families is undergoing

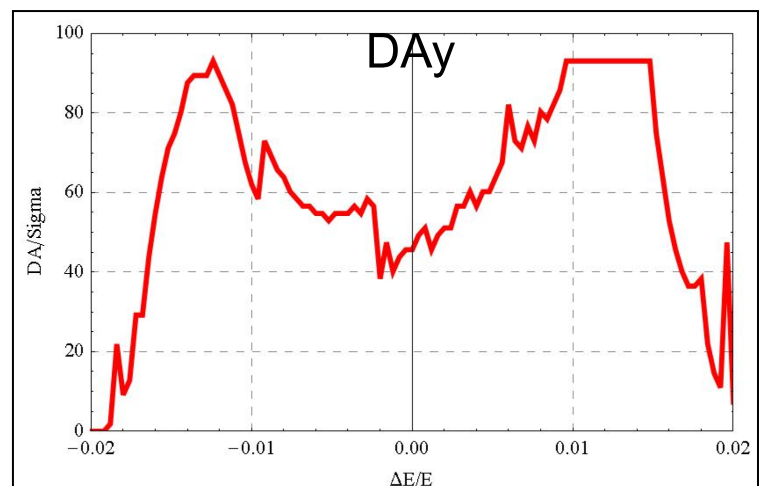




PDR DA result

- Dynamic aperture result
  - W/O error of the magnets
  - Synchrotron motion included, **w/ damping**
  - Tracking with 100 turns
  - Coupling factor κ=0.003 for εy
  - Working point (0.08, 0.22)





Target of dynamic aperture for main ring

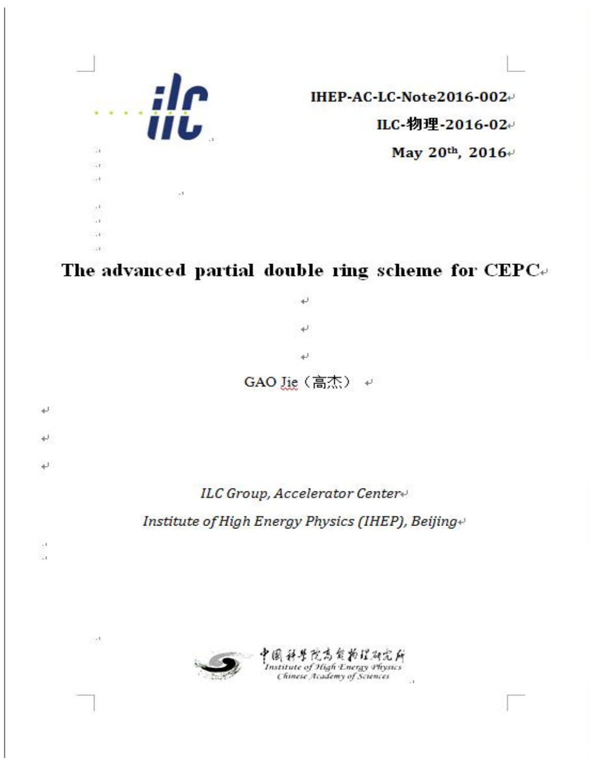
Parameter	Symbol	Unit	Value	Status
Luminosity per IP	L_{max}	$10^{34}cm^{-2}s^{-1}$	2.01	-
Beta functions at IP	β_x/β_y	m	0.275 /0.0013	0.22 /0.001
Main ring emittance	$\varepsilon_x/\varepsilon_y$	nm·rad	2.05 /0.0062	2.15/0.0065
Injection emittance	$\varepsilon_x/\varepsilon_y$	nm·rad	3.5 / 0.17	3.5/0.17
Transvers acceptance*	A_x/A_y	nm·rad	787 / 4.17	
Energy acceptance	A_E	%	2.0	1.9
DA requirement from beam-beam (inclu. errors and beam-beam effect)	DA_x/DA_y	σ	20 / 40 (dp/p=0) 5 / 10 (dp/p=±2%)	16 / 45 (dp/p=0) 3 / 5 (dp/p=±2%) (no errors, mean value for two poles of axis)
DA requirement from injection (inclu. errors and beam-beam effect)	DA_x/DA_y	σ	20 / 26 (dp/p=0 and dp/p=±0.5%)	-

Based on the parameters “wangdou20160918 H-low power” .
*assuming coupling factor κ=5% for injection beam,
$\beta x,r$=200 m, $\beta x,i$=60 m, ws = 4 mm, nr = 5, ns = 5

New idea：APDR

The key problems with Partial Double Ring:
1) Beam loading effect due to bunch train in RF station
2) Sawtooth effects in the signle ring part

A possible solution: Advanced Partial Double Ring



IHEP-AC-LC-Note2016-002
ILC-物理-2016-02
May 20th, 2016

The advanced partial double ring scheme for CEPC

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ILC Group, Accelerator Center
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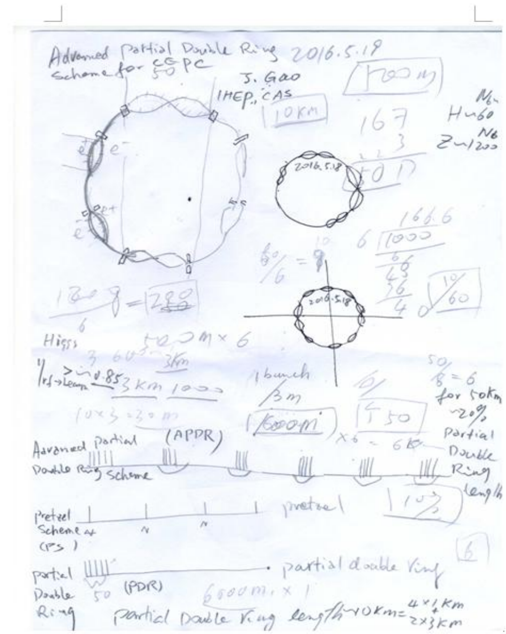
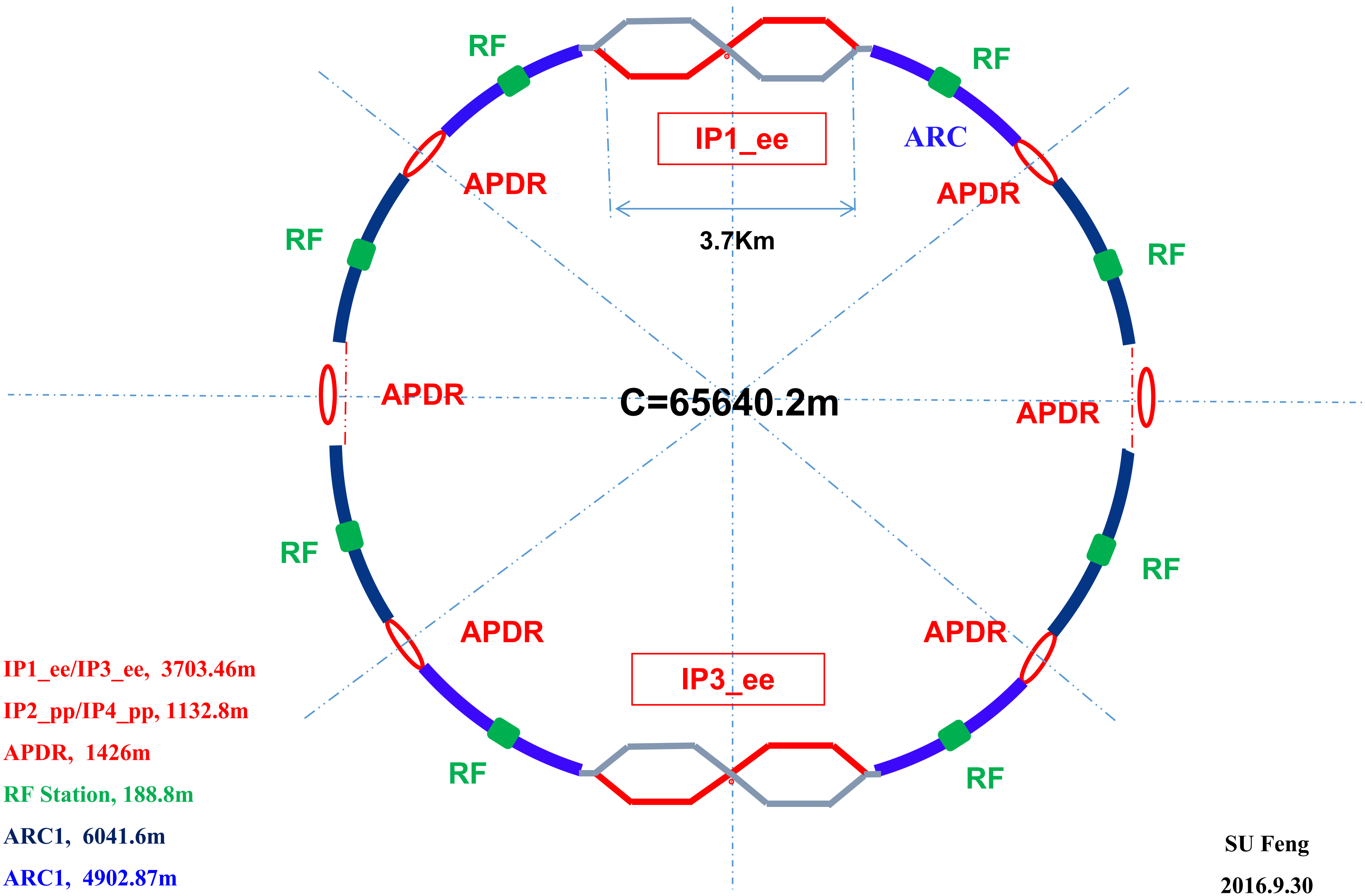
中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences



CEPC Advanced Partial Double Ring Option II



IP1_ee/IP3_ee, 3703.46m

IP2_pp/IP4_pp, 1132.8m

APDR, 1426m

RF Station, 188.8m

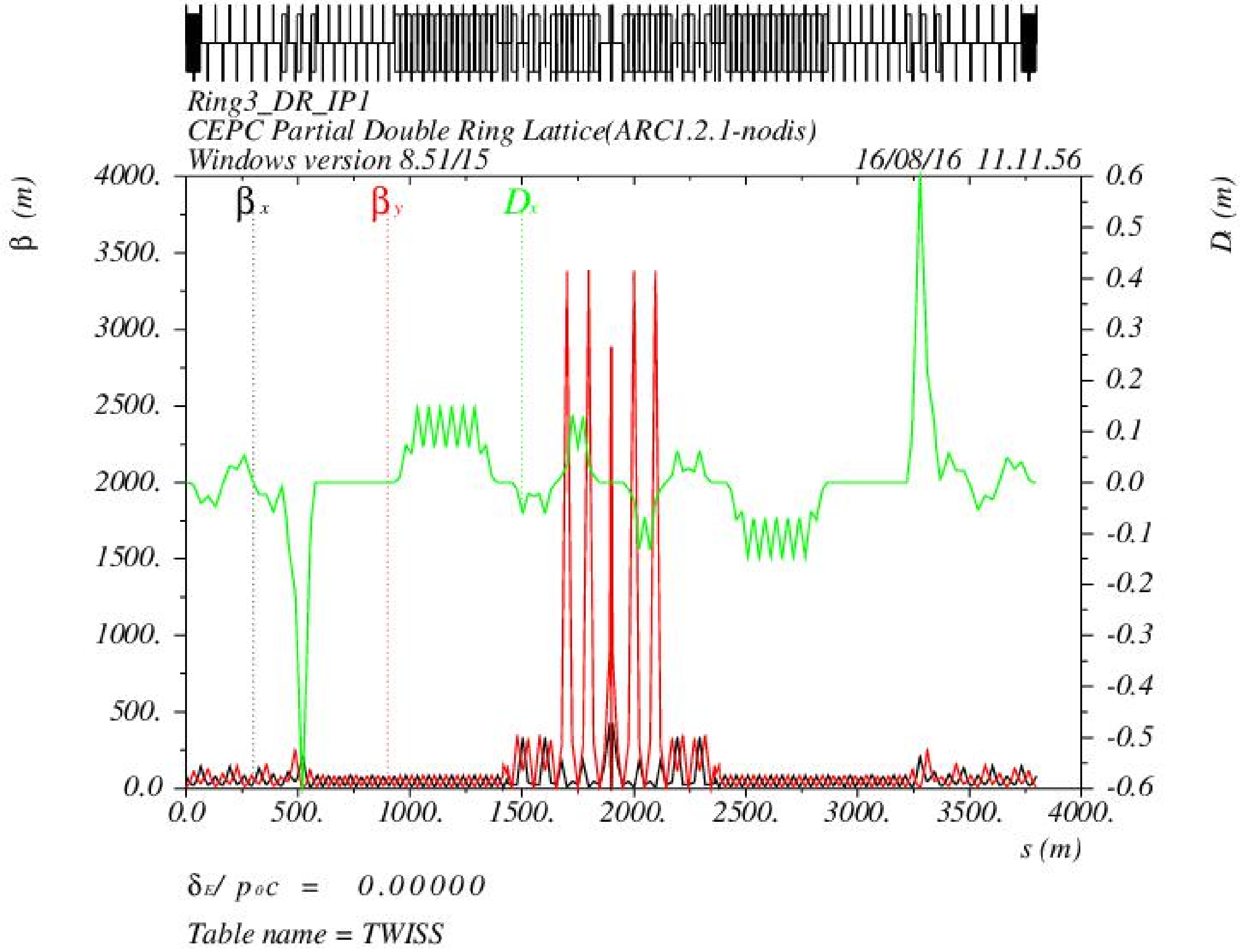
ARC1, 6041.6m

ARC1, 4902.87m

SU Feng

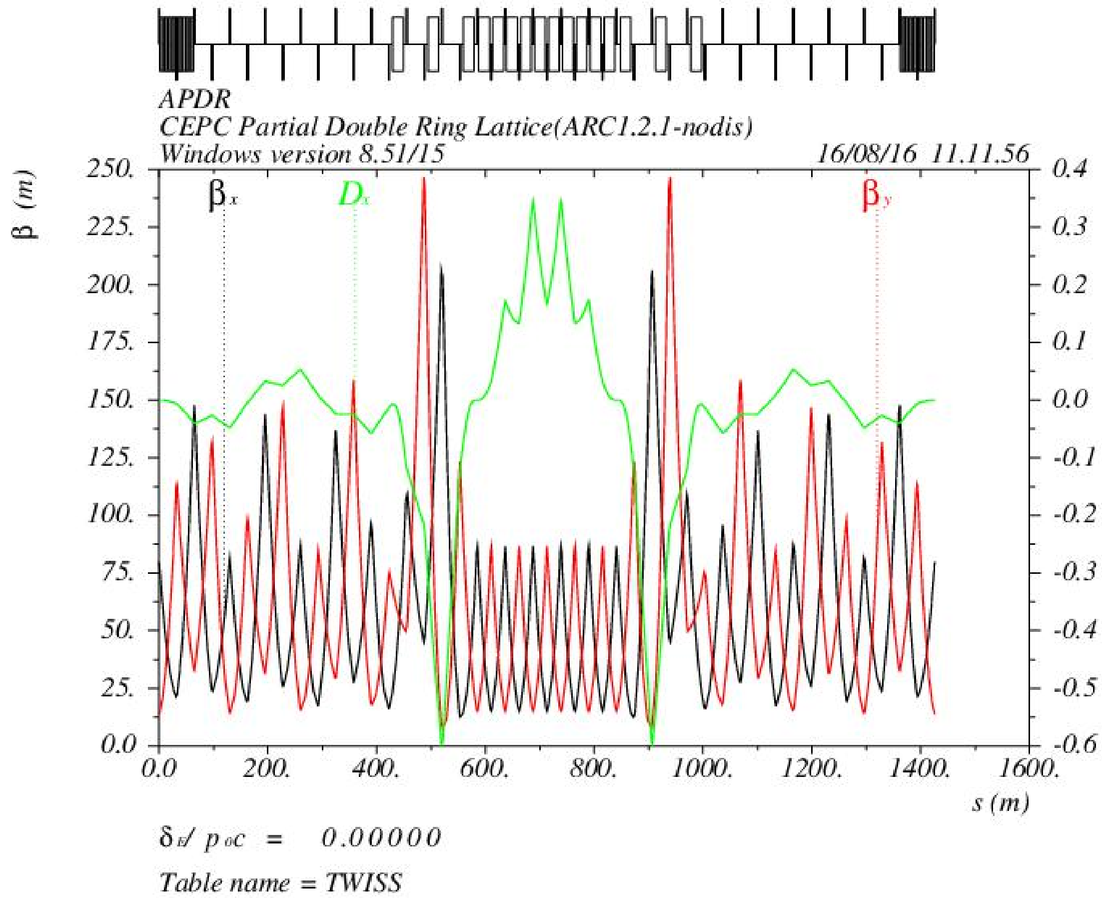
2016.9.30

PDR Part



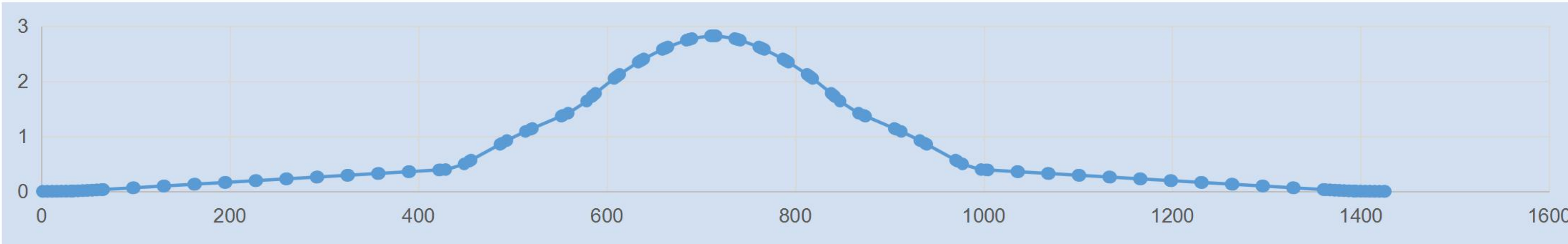
Ring3_DR_IP1
CEPC Partial Double Ring Lattice(ARC1.2.1-nodis)
Windows version 8.51/15
16/08/16 11.11.56
β (m)
4000.
3500.
3000.
2500.
2000.
1500.
1000.
500.
0.0
βx
βy
Dx
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
D (m)
0.0
500.
1000.
1500.
2000.
2500.
3000.
3500.
4000.
s (m)
δE/ p0c = 0.00000
Table name = TWISS

APDR Part

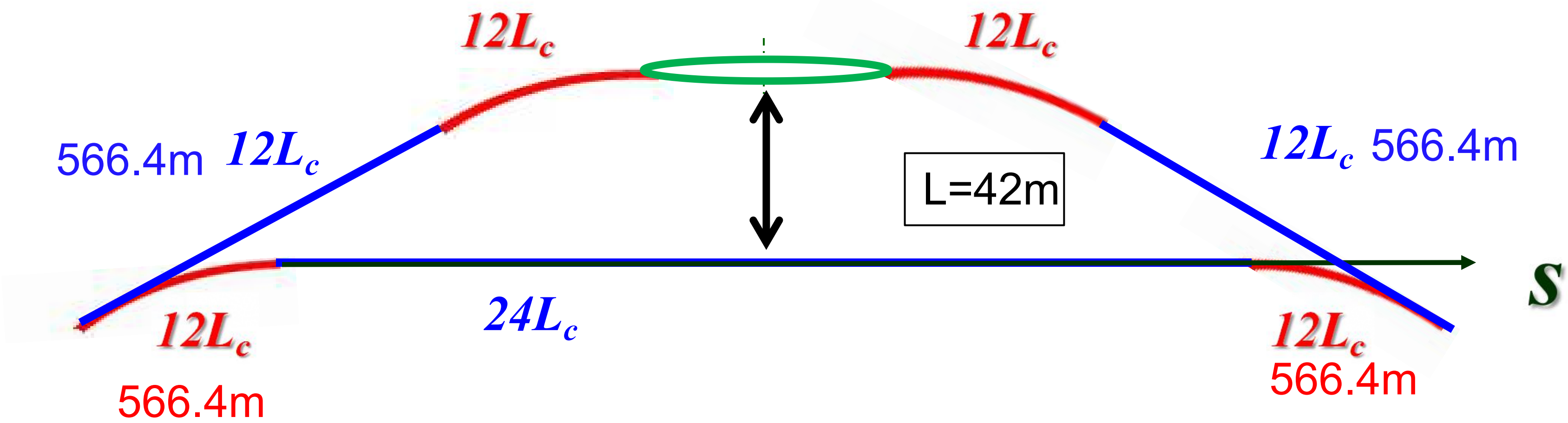


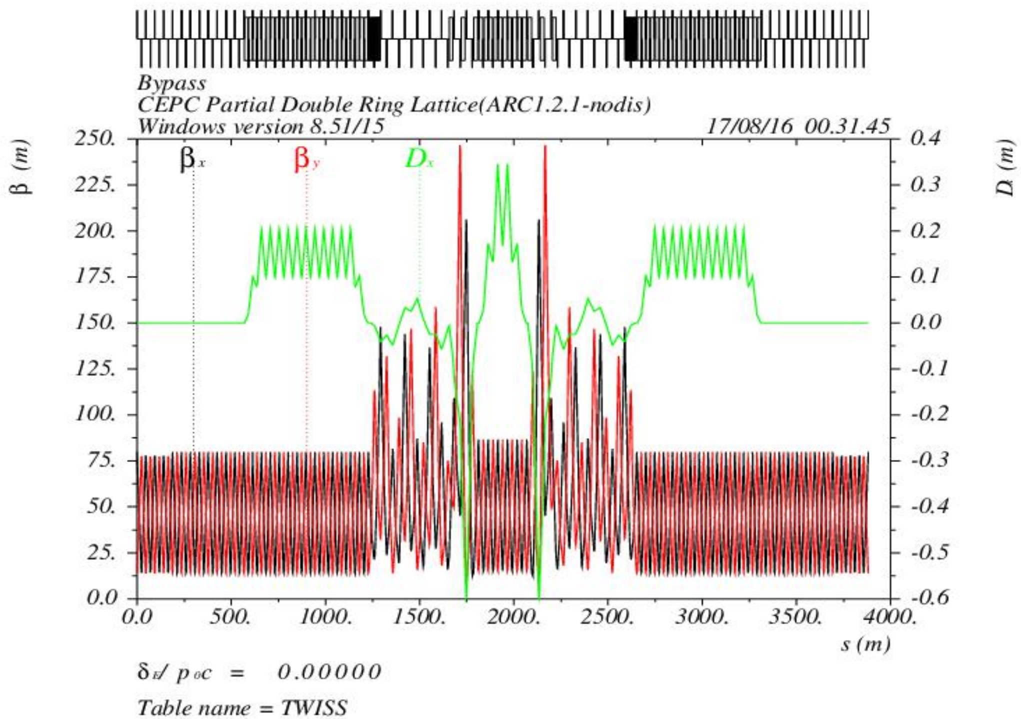
Need update

1426m



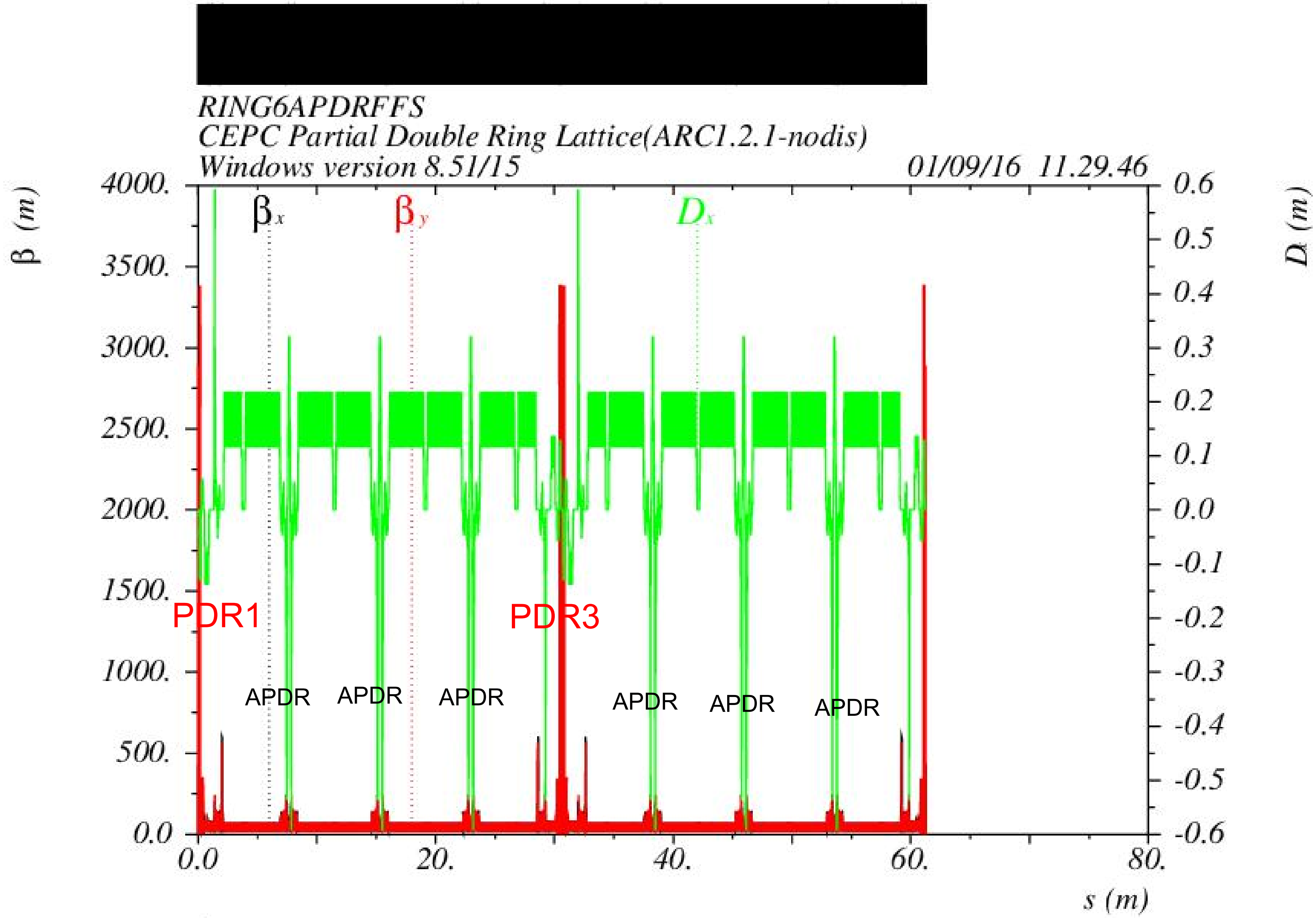
Bypass Part at IP2/4





Cell length=47.2m

CEPC Advanced Partial Double Ring Optics II



CEPC main ring SRF parameter

Parameter: wangdou20160918/23 (周长 61 km)	H	H Low Power	H High Lumi	W	Z
Energy (GeV)	120	120	120	80	45.5
Ring type	Single	PDR,APDR or DR			
Lum. / IP (10^{34} $cm^{-2}s^{-1}$)	2.0	2.0	3.1	4.3	4.5
Toal radiation power (MW)	100	66	100	43	9
Current/beam (mA)	16.6	11.0	16.9	36.5	67.6
RF V_{RF} (GeV)	7	3.51	3.48	0.75	0.12
650 MHz cavity	5-cell	2-cell	2-cell	2-cell	2-cell
Cavity number	384	480	480	192	32
Cryomodule number	96	80	80	32	16
E_{acc} (MV/m)	16.2	16.0	15.8	8.5	8
Q_0 @ 2 K	4E10	2E10	2E10	2E10	2E10
Input power/cavity (kW)	267	137	209	226	277
HOM power/cavity (kW)	3.7	0.5	0.7	0.8	0.9
Loss/cavity @ 4.5 K eq. (kW)	23	22.5	22.1	2.5	0.4

PDR and APDR bunch train beam loading induced phase shift and cavity frequency shift compensation

Parameter： wangdou20160918/23（周长 61 km）	H Low Power	H High Lumi	W	Z	Z 1-cell
Bunch charge (nC)	32	32	18.6	12.5	12.5
Bunch number (per beam)	70	107	400	1100	1100
Bunch seperation (ns) [bunch train lenthen < 3.2 km]	152.3	98.5	26.2	9.2	9.2
Vrf/cavity (MV)	7.4	7.3	3.9	3.7	3.7
Syn. phase (deg)	123	122	128	146	146
PDR 1+1 maximum voltage drop	11 %	18 %	72 %	140 %	70 %
PDR 1+1 maximum phase shift (deg)	12	19	67	/	49
PDR3rd cavity number (frequency shift 29 kHz)	33	51	83	28	14
APDR 4+4 maximum voltage drop	3 %	4 %	18 %	35 %	18 %
APDR 4+4 maximum phase shift (deg)	3	4.8	16.7	24.2	12.1
APDR2nd harmonic cavity number (frequncey shift 79 kHz)	10	16	27	9	4

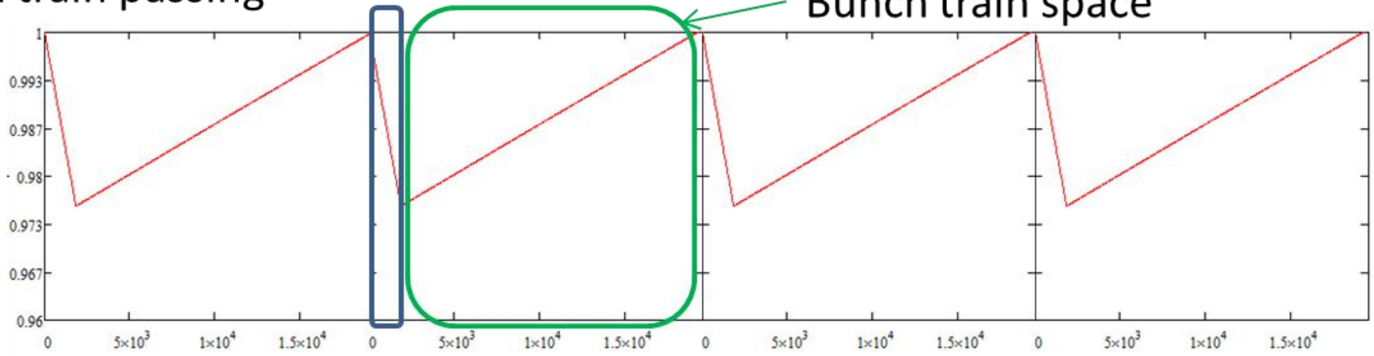
$$\Delta\theta_{1N} \approx \frac{-2kq}{V_{c0}\sin\phi_0}\left[\frac{T_t T_g/T_b}{T/N_t}\right] \approx \frac{-2kI_0 T_g}{V_{c0}\sin\phi_0} \approx \frac{-2kqN}{V_{c0}\sin\phi_0}$$

$$N_{DFCm} = \frac{\Delta V_{RF}}{2V_{DFC}\sin(mN_t\omega_{rev}T_t)}$$

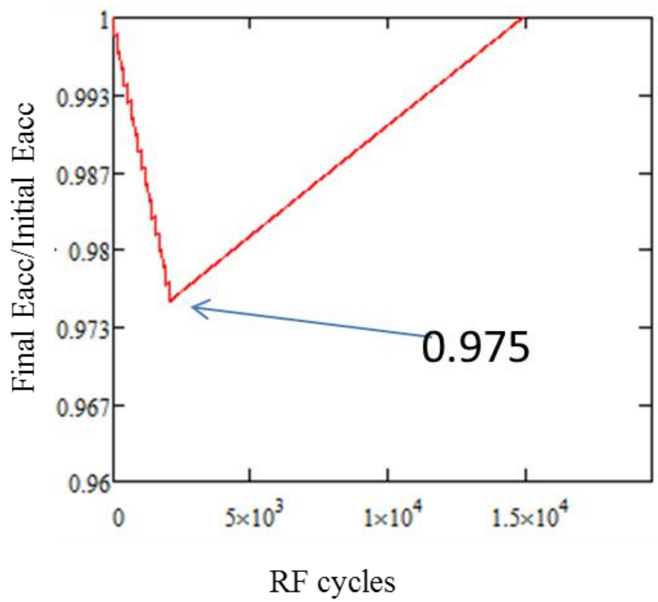
CEPC APDR SRF considerations

Bunch train passing

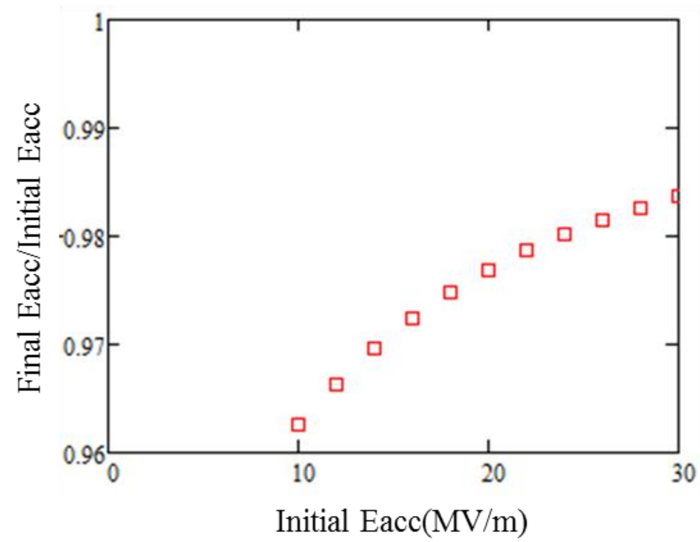
Bunch train space



Assume matching

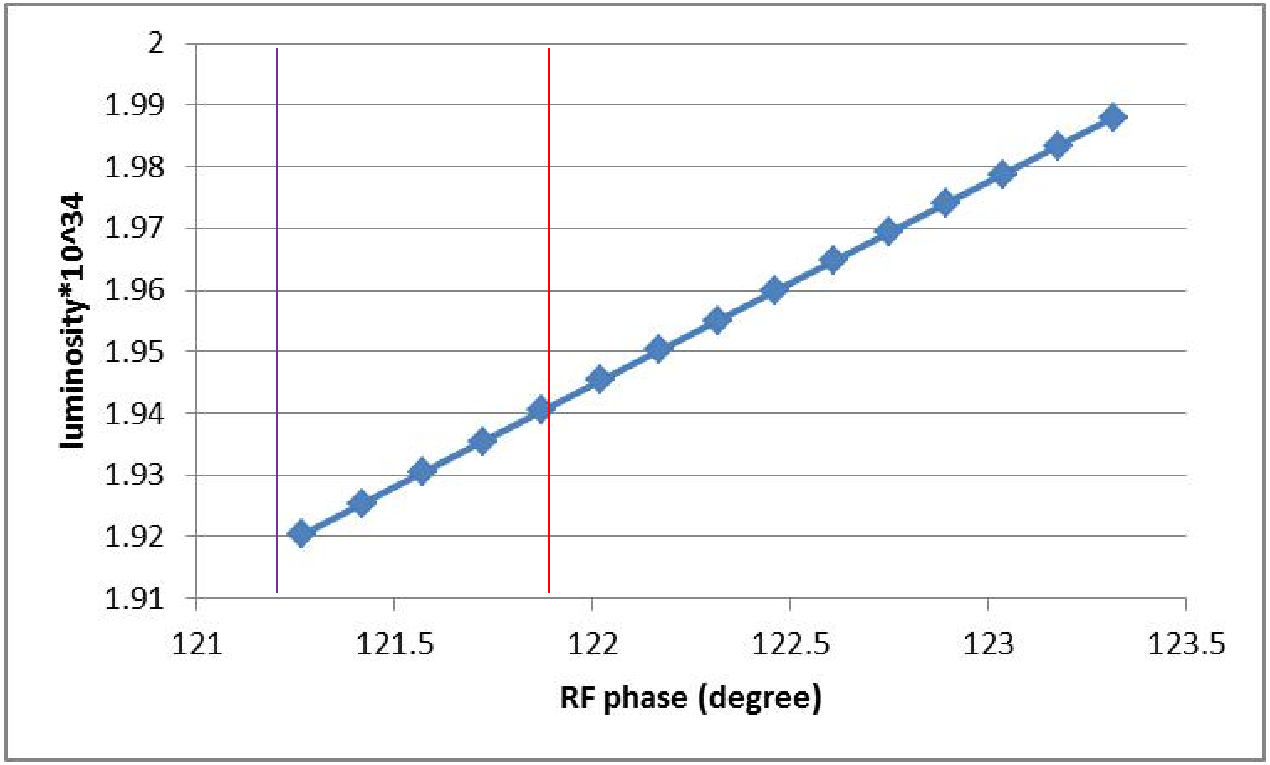


Field evolution in cavity



Field decrease vs. various initial field gradient of the cavity

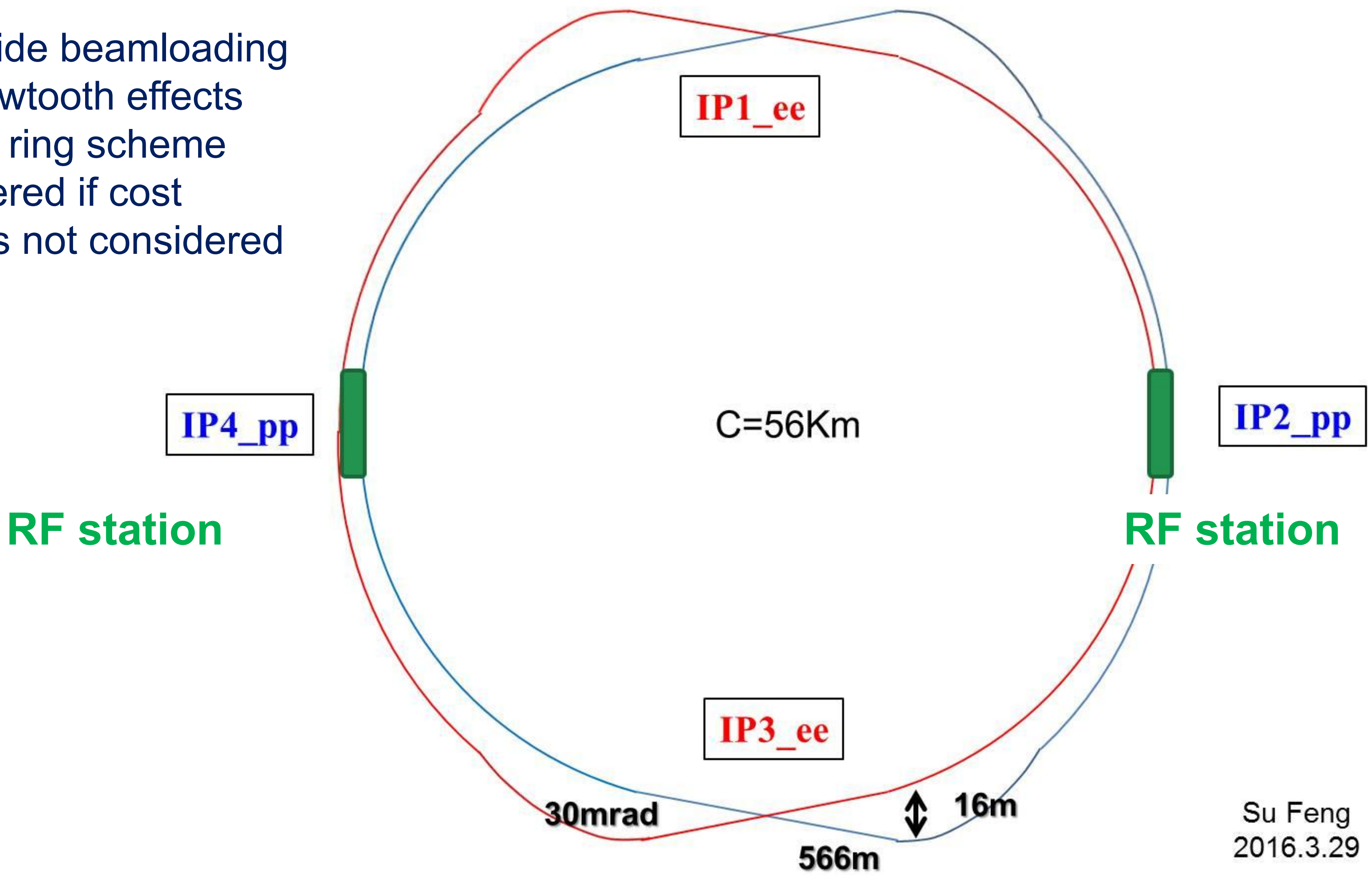
Luminosity error with RF phase adjustment



Error of luminosity: ~ -3.5% (6 ring), ~-2.4% (8 ring)

CEPC Double Ring Scheme Layout

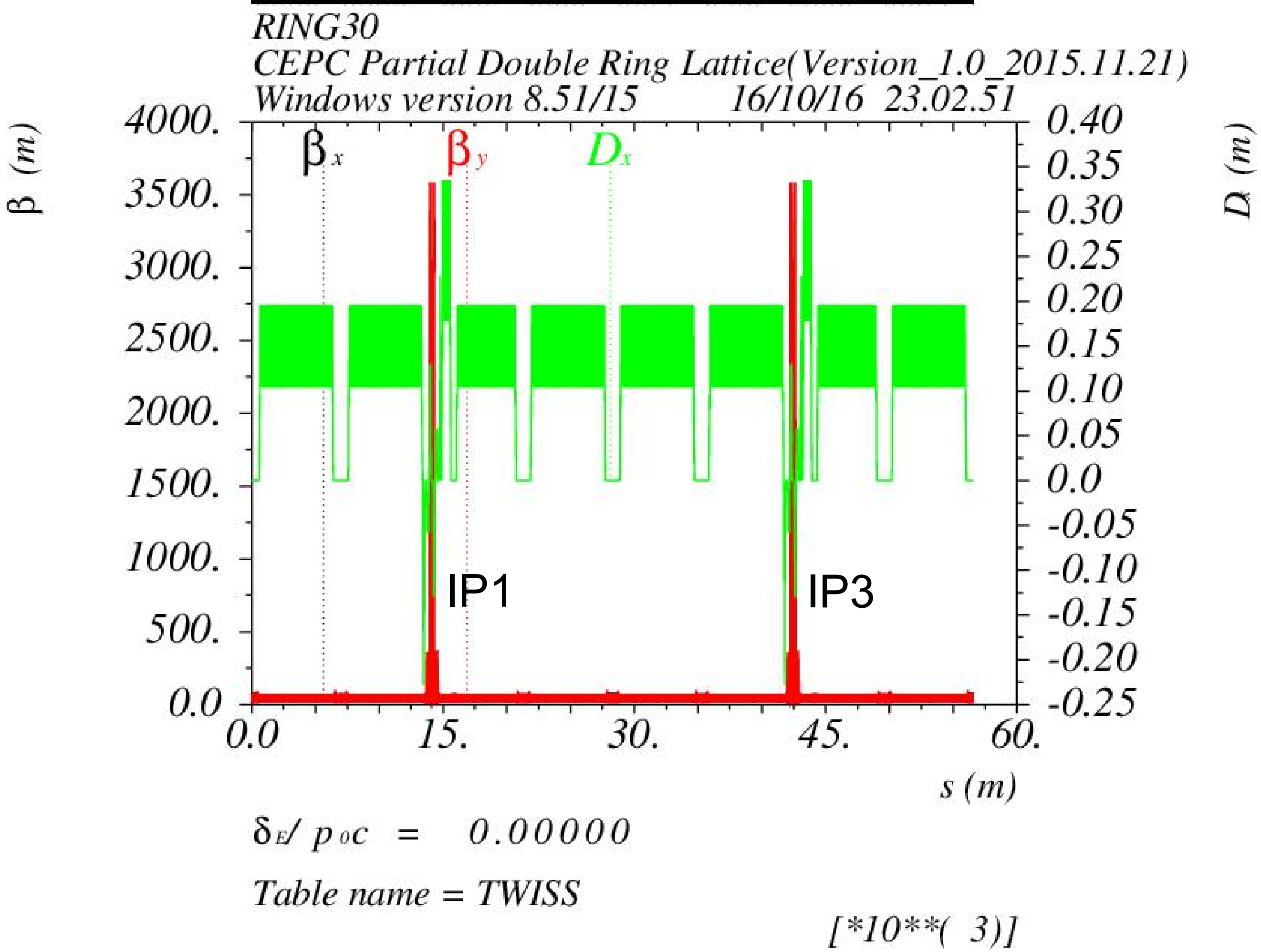
To avoide beamloading and sawtooth effects double ring scheme is prefered if cost issue is not considered



Su Feng
2016.3.29

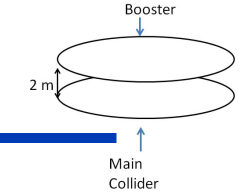
Double Ring Scheme

[redacted]



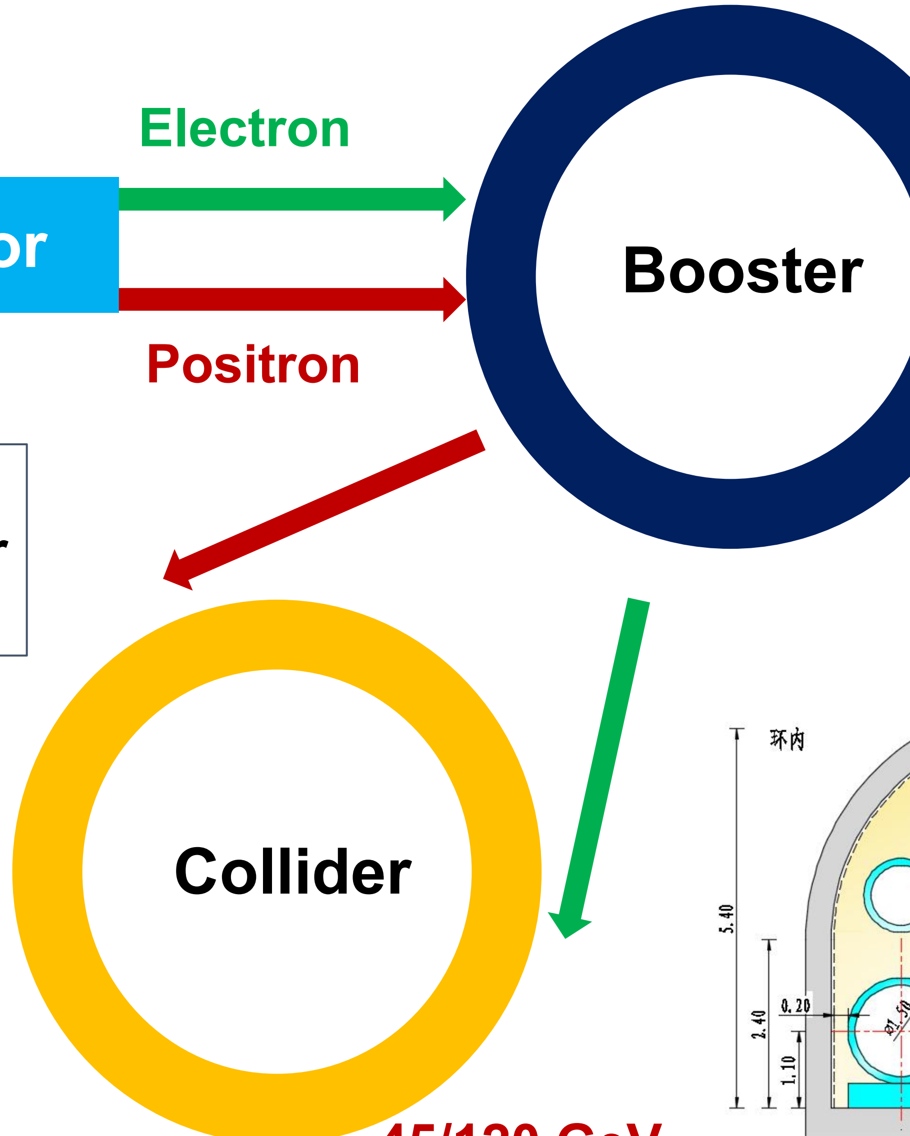
e-ring

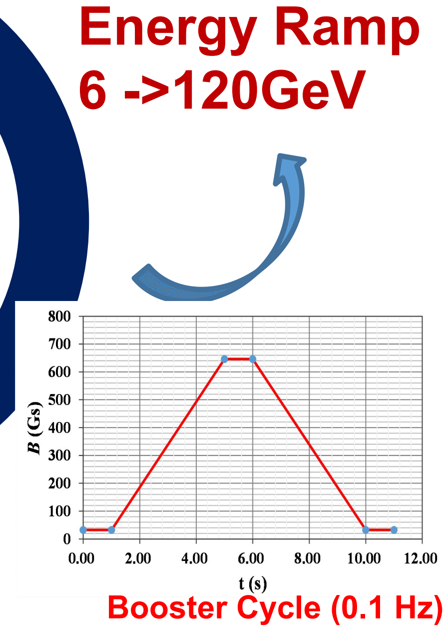
CEPC Accelerator



6 GeV

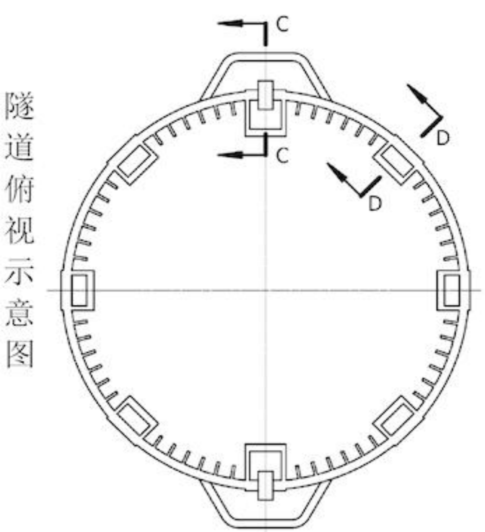
Linac injector

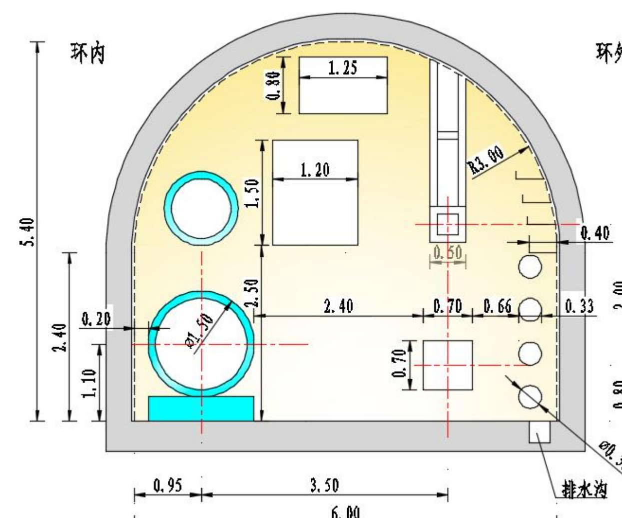




In the same tunnel:

- **CEPC & booster**
- **SppC**





CEPC booster design goal

Design Goal

- For injection, emit of booster@120Gev should be about 3.5E-9 m*rad.
- 1 percent energy acceptance for enough quantum lifetime.
- DA_x and DA_y should bigger than 5~6 sigma for injection with all kinks of error.

Linac parameters

- From : Li Xiaoping, Pei Guoxi, etc, "*Conceptual Design of CEPC Linac and Source*".

Parameter	Symbol	Unit	Value
E^- beam energy	E_{e-}	GeV	6
E^+ beam energy	E_{e+}	GeV	6
Repetition rate	f_{rep}	Hz	50
E^- bunch population	N_{e-}		2×10^{10}
E^+ bunch population	N_{e+}		2×10^{10}
Energy spread (E^+/E^-)	σ_E		$<1\times10^{-3}$
Emitance (E^-)			**0.3 mm· mrad**
Emitance (E^+)			**0.3 mm· mrad**

Low field booster parameters (1)

Parameter list for low field magnetic field Scheme (injection)

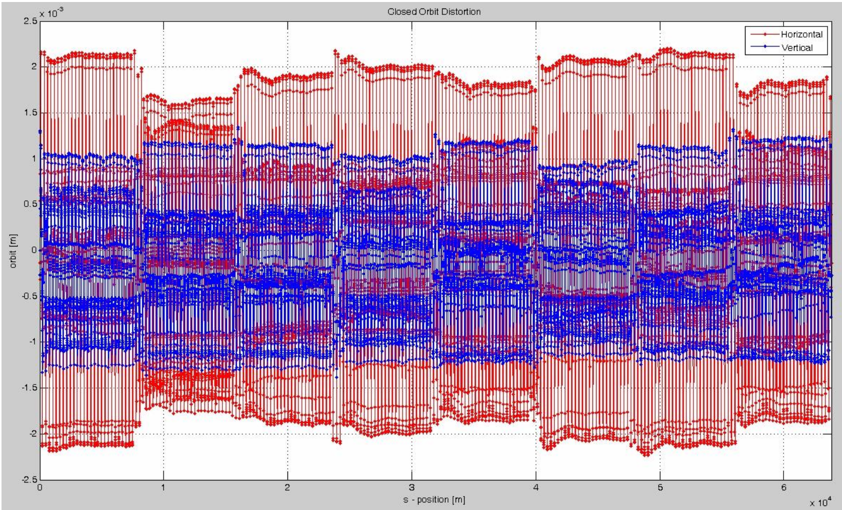
Parameter	Unit	Value
Beam energy [E]	GeV	6
Circumference [C]	km	63.84
Revolutionfrequency[f_0]	kHz	4.69
SR power / beam [P]	MW	2.16
Beam off-set in bend	cm	0
Momentum compaction factor[α]		1.91E-05
Strength of dipole	Gs	**25.8**
n_B/beam		50
Lorentz factor [g]		11741.71
Magnetic rigidity [Br]	T·m	20
Beam current / beam [I]	mA	0.92
Bunchpopulation[N_e]		2.44E10
Bunch charge [Q_b]	nC	3.91681
emittance-horizontal[e_x] inequilibrium	m·rad	0.91E-11
injected from linac	m·rad	3E-7
emittance-vertical[e_y] inequilibrium	m·rad	0.046E-11
injected from linac	m·rad	3E-7

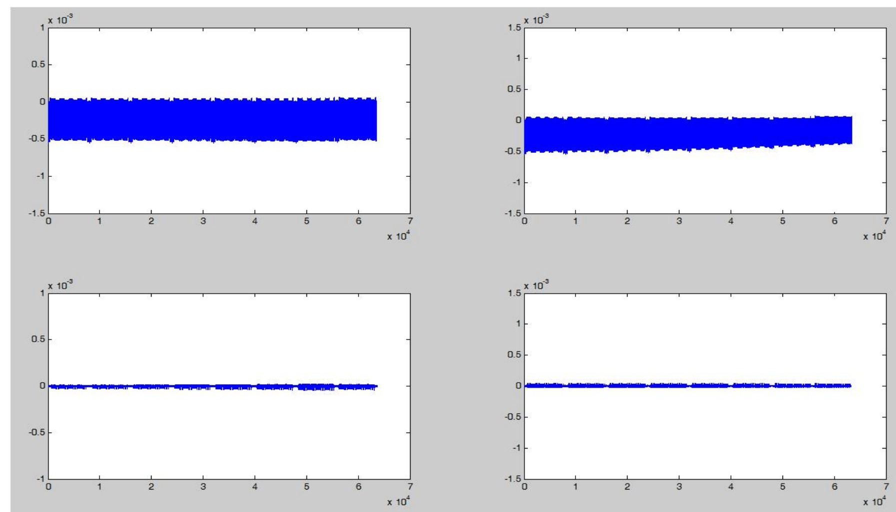
Parameter	Unit	Value
RF voltage [Vrf]	GV	0.2138
RF frequency [frf]	GHz	1.3
Harmonic number [h]		276831
Synchrotronoscillationtune[n_s]		0.21
Energy acceptance RF	%	4.995
SR loss / turn [U0]	GeV	1.47E-5
Energyspread[s_d] inequilibrium	%	7.47E-05
injected from linac	%	0.1
Bunch length[s_d] inequilibrium	mm	5.85E-05
injected from linac	mm	~1.5
Transversedampingtime[t_x]	s	174
	turns	
Longitudinaldampingtime[t_e]	s	174
	turns	

Low field booser earth field orbit correction

Closed orbit correction

➢ After the first turn orbit correction, the closed orbit is existed.





Closed orbit after first turn orbit correction

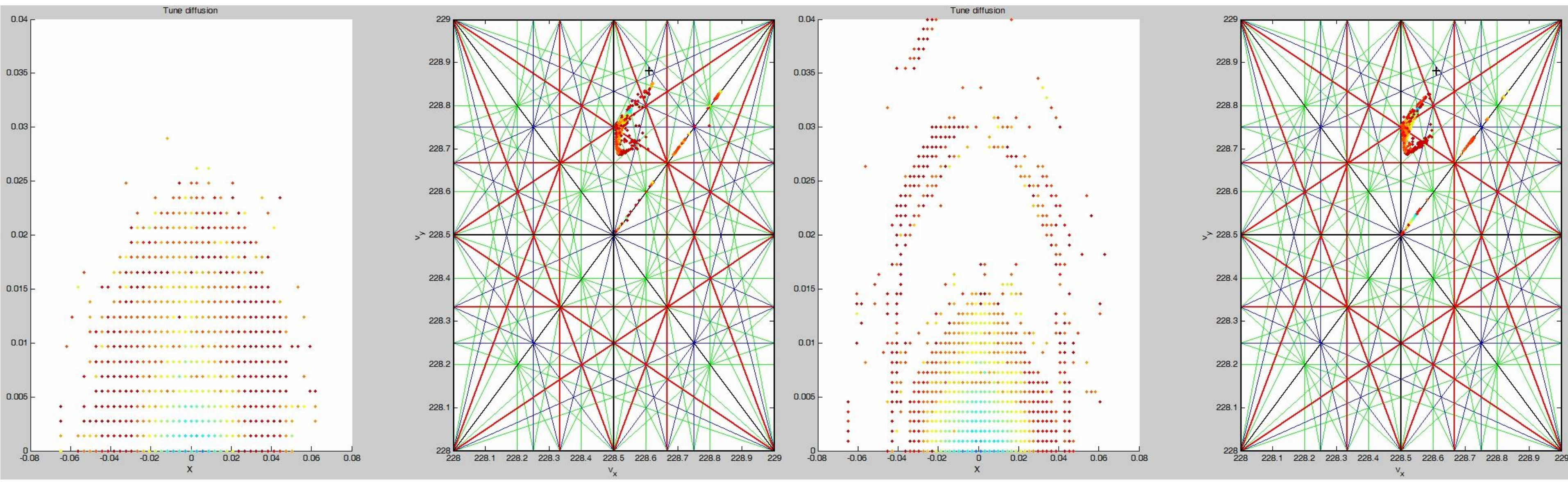
Closed orbit after first turn orbit correction

and closed orbit correction

Low field booster DA result
(T.J. Bin)

- Tune:190.61/190.88 and cavity on

DA is good with errors also reaching r=the design goal of CDR



With error and orbit correction,

dp=0.0

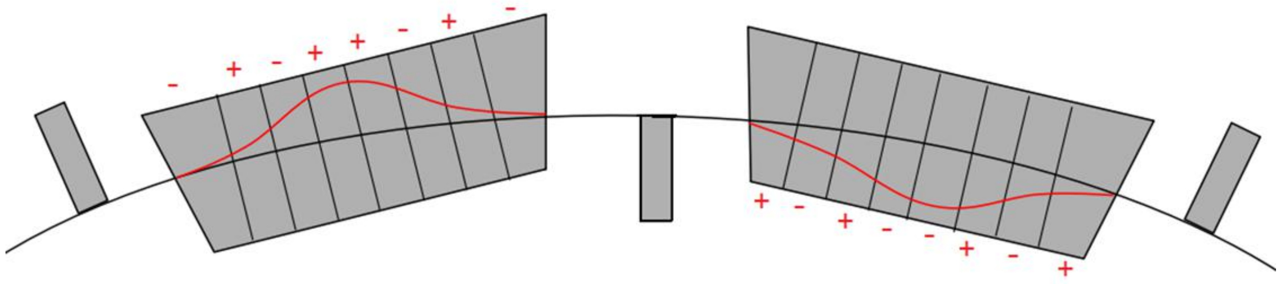
With error and orbit correction,

dp=0.01

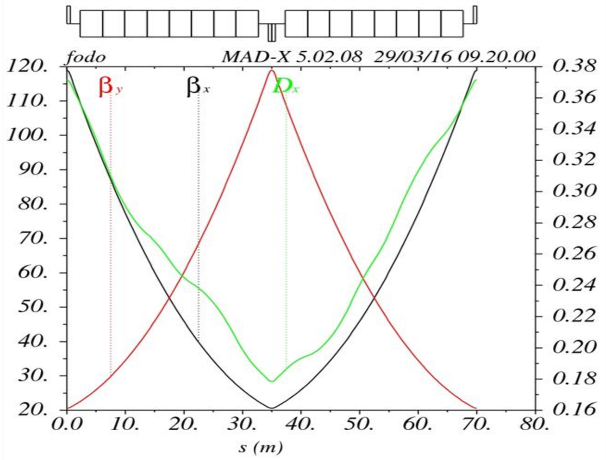
CEPC Booster Design

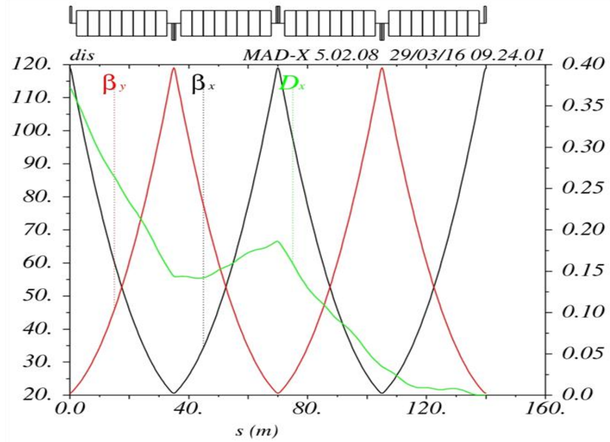
1) Normal Low field Bend Scheme

2) Wiggling Bend Scheme



- **90 degree FODO**
- **FODO length:70 meter**





Wiggling bend booster booster parameters (1)

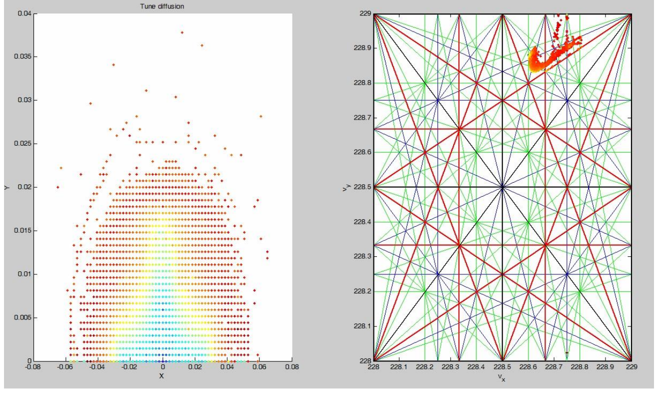
Parameter list for wiggling bend scheme (injection)

Parameter	Unit	Value
Beam energy [E]	GeV	6
Circumference [C]	km	63.84
Revolutionfrequency[f_0]	kHz	4.69
SR power / beam [P]	MW	2.16
Beam off-set in bend	cm	1.2
Momentum compaction factor[α]		2.33E-5
Strength of dipole	Gs	**-129.18/+180.84**
n_B/beam		50
Lorentz factor [g]		11741.71
Magnetic rigidity [Br]	T·m	20
Beam current / beam [I]	mA	0.92
Bunchpopulation[N_e]		2.44E10
Bunch charge [Q_b]	nC	3.91681
emittance-horizontal[e_x] inequilibrium	m·rad	6.38E-11
injected from linac	m·rad	3E-7
emittance-vertical[e_y] inequilibrium	m·rad	0.191E-11
injected from linac	m·rad	3E-7

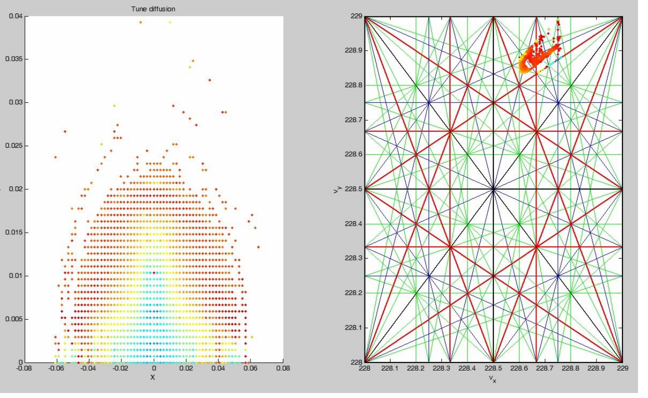
Parameter	Unit	Value
RF voltage [Vrf]	GV	0.2138
RF frequency [frf]	GHz	1.3
Harmonic number [h]		276831
Synchrotronoscillationtune[n_s]		0.21
Energy acceptance RF	%	5.93
SR loss / turn [U0]	GeV	5.42E-4
Energyspread[s_d] inequilibrium	%	0.0147
injected from linac	%	0.1
Bunch length[s_d] inequilibrium	mm	0.18
injected from linac	mm	~1.5
Transversedampingtime[t_x]	ms	4.71
	turns	
Longitudinaldampingtime[t_e]	ms	4.71
	turns	

DA results of booster

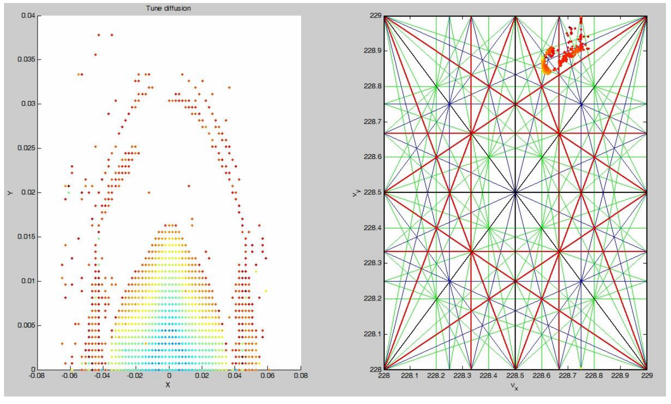
- Tune:190.61/190.88 and cavity on



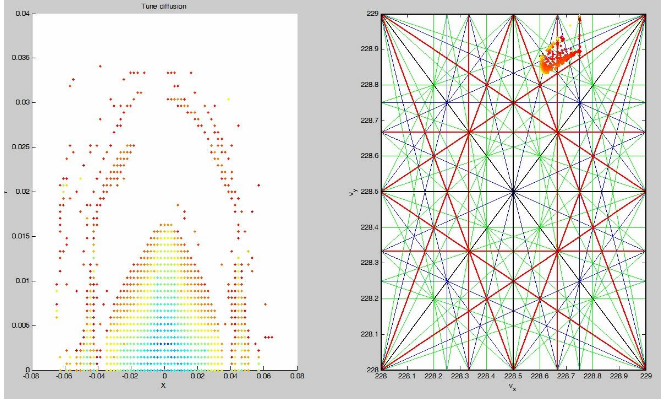
with error, dp=0



with error, dp=0.0



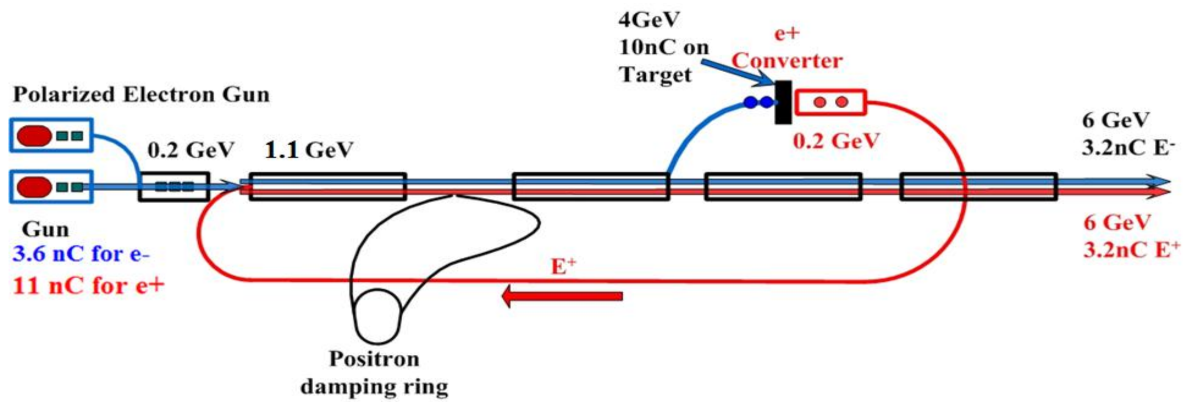
with error, dp=0.01



with error, dp=0.01

CEPC electron-positron injector complex

Layout



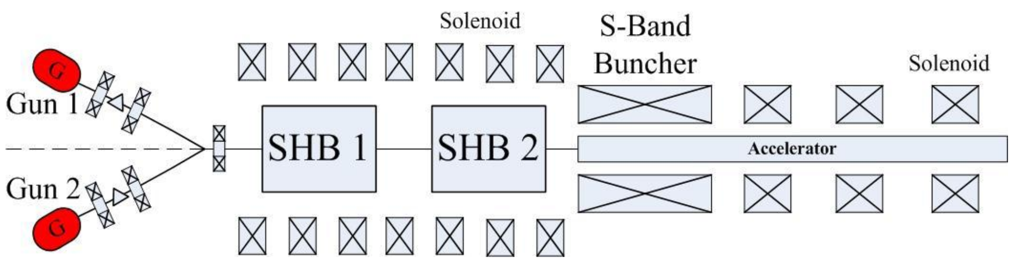
Parameters

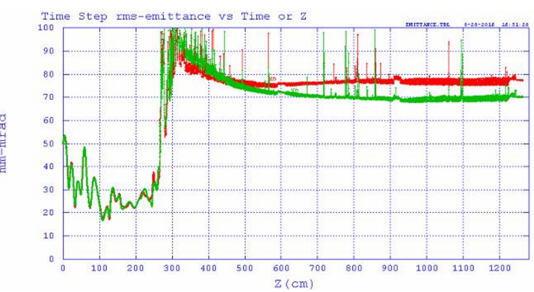
Parameter	Symbol	Unit	Value
e^-/e^+ beam energy	E_{e-}/E_{e+}	GeV	6
Repetition rate	f_{rep}	Hz	50
e^-/e^+ bunch population @ 6 GeV	Ne-/Ne+		2×10^{10}
	Ne-/Ne+	nC	3.2
Energy spread (e^-/e^+)	σ_E		$<1\times10^{-3}$
Emitance (e^-/e^+)			<0.3 mm· mrad
e^- beam energy on Target		GeV	4
e^- bunch charge on Target		nC	10

- **Injection time**
- **1.1 GeV damping ring**
- **SLED (SLAC Energy Doubler):** ***200 MeV~1.1GeV without SLED***
- **Accelerating gradient: different section & different accelerating tube**
- **Frequency of Booster: 1300 MHz=3.25MHz×400MHz**
- **Frequency of Linac: 2856.75 MHz=3.25MHz×879**

Electron source and pre-accelerating

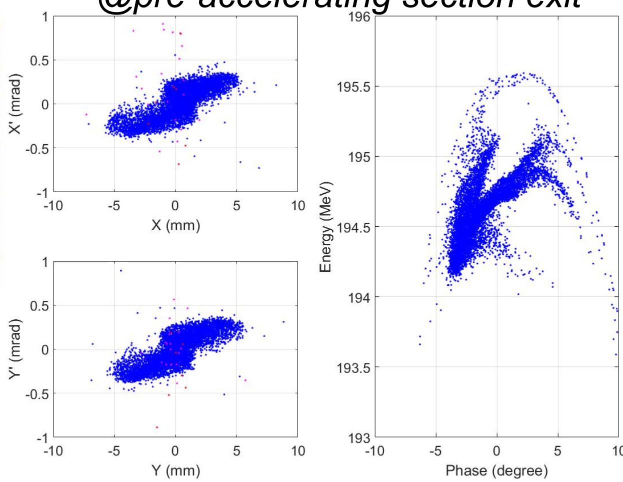
10 nC @ 200 MeV



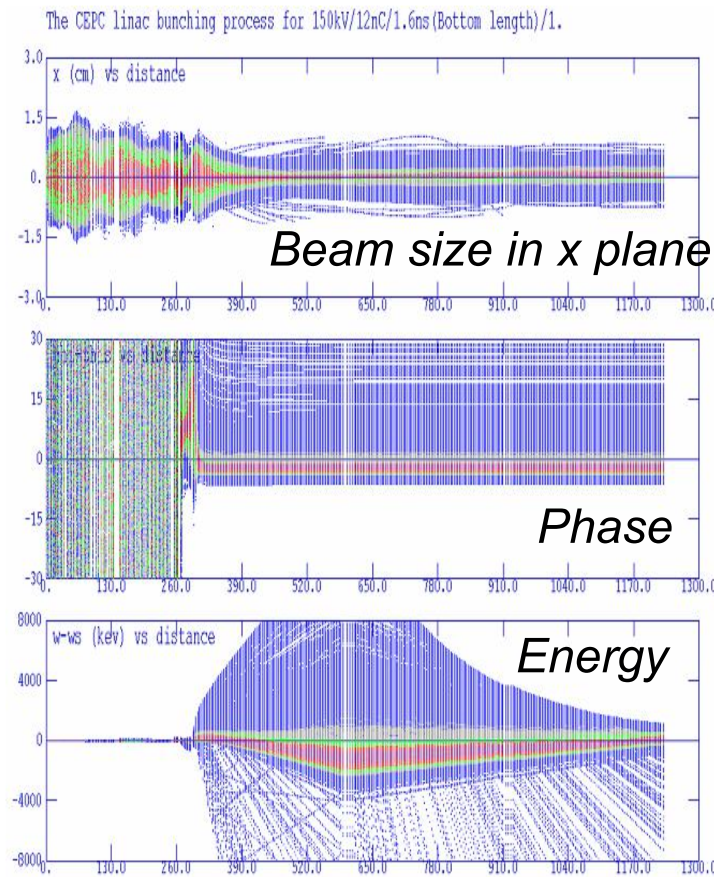


emittance

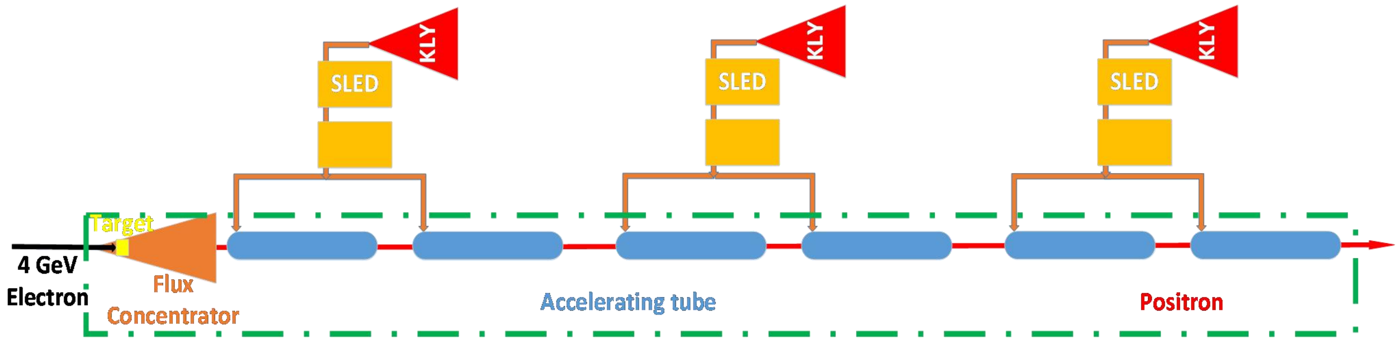
Beam distribution
@pre-accelerating section exit

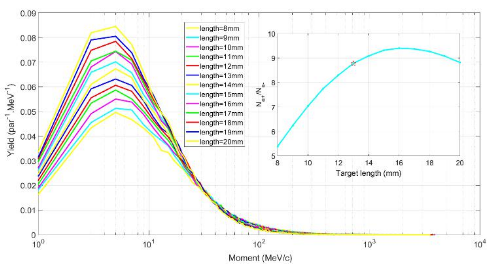


Envelope

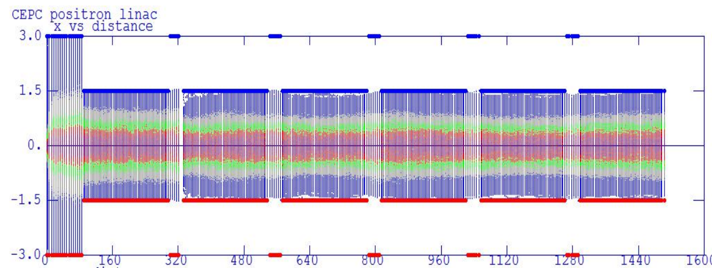


Positron source and pre-accelerating

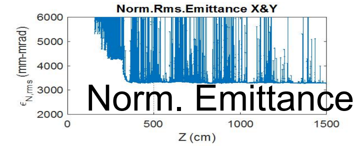




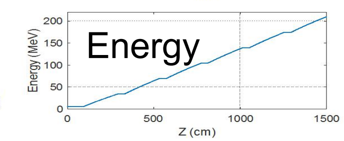
Positron yield VS. target length



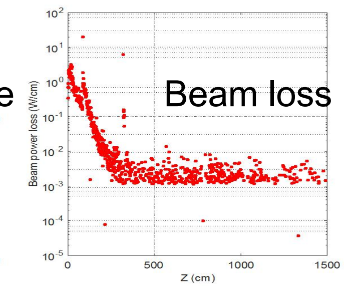
Beam size



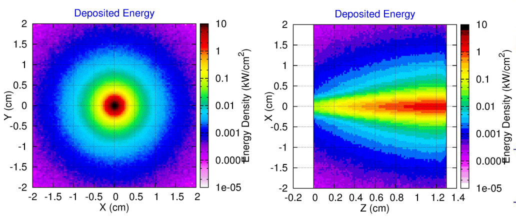
Norm. Emittance



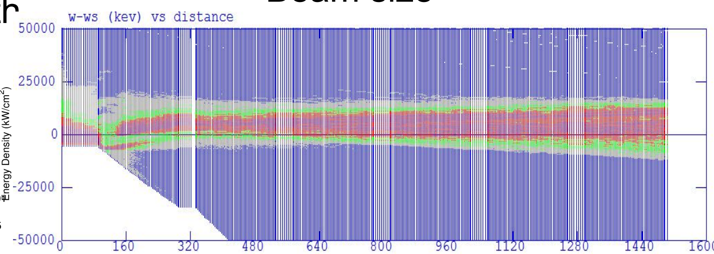
Energy



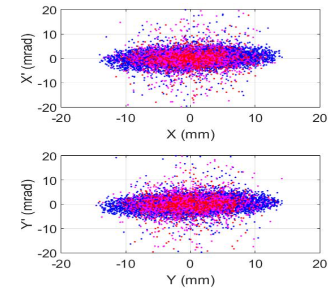
Beam loss

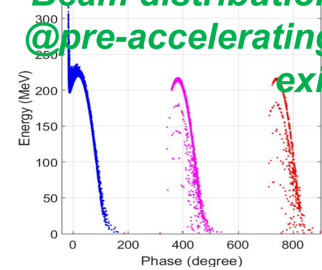


Energy deposition



Δ W

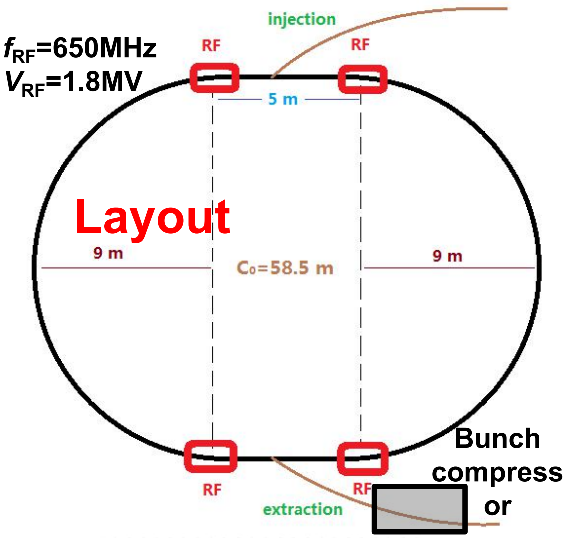


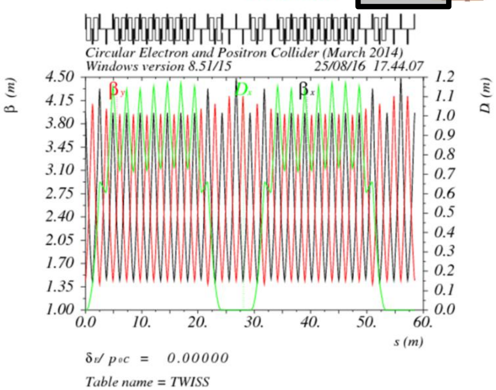


Beam distribution @pre-accelerating exit

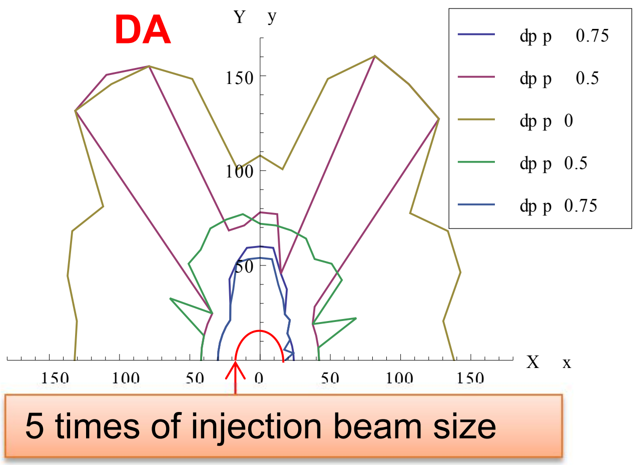
Damping Ring Design

Design has been done



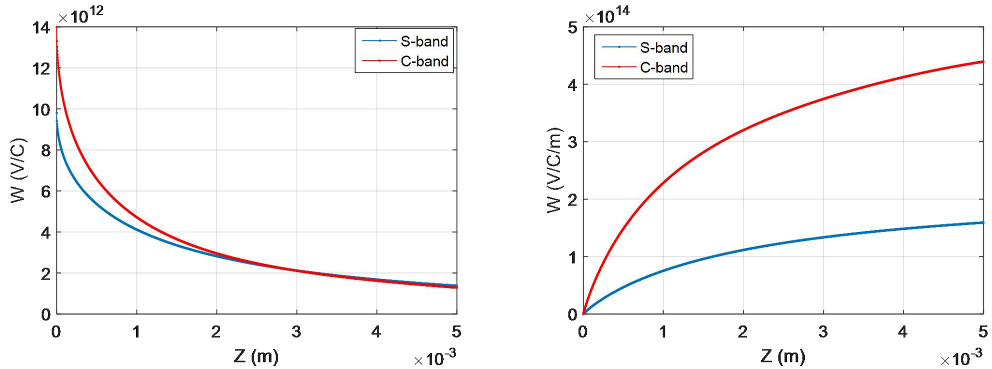


	DR V1.0
Energy (GeV)	1.1
circumference	58.5
Bending radius (m)	3.6
B0 (T)	1.01
U0 (keV/turn)	35.8
Damping time x/y/z (ms)	12/12/6 (61538 turns)
δ0 (%)	0.049
ε0 (mm.mrad)	302
Nature σz (mm)	7 (23ps)
Extract σz (mm)	~7 (23ps)
εinj (mm.mrad)	3500
εext x/y (mm.mrad)	434/145
δinj /δext (%)	0.25 /0.05
Energy acceptance by RF(%)	1.0



FODO length (m)	2.4
Phase per cell	60°
Dipole length (m)	0.71
Dipole strength (T)	1.0
Quadrupole length (m)	0.2
Quadrupole strength (m^{-2})	4.1
Sextupole length (m)	0.06

CEPC injector main linac

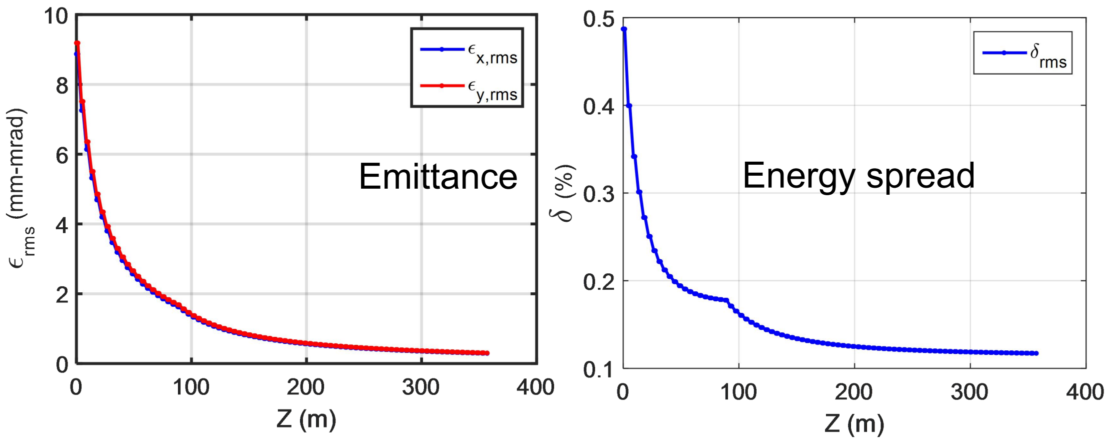


Longitudinal Short-Range Wakefield

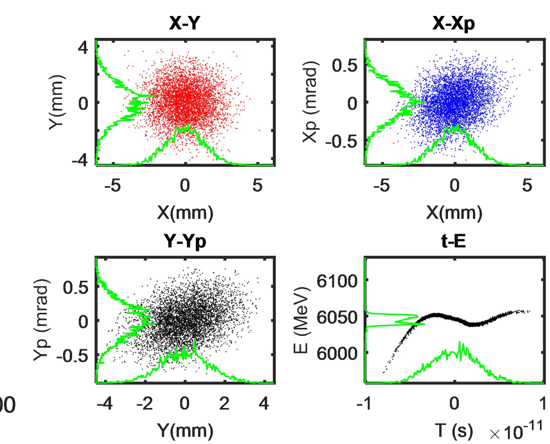
Element	No.
Accelerating tube	82
Magnet	246

3.2 nC @ 6 GeV @ 82 period

Positron linac



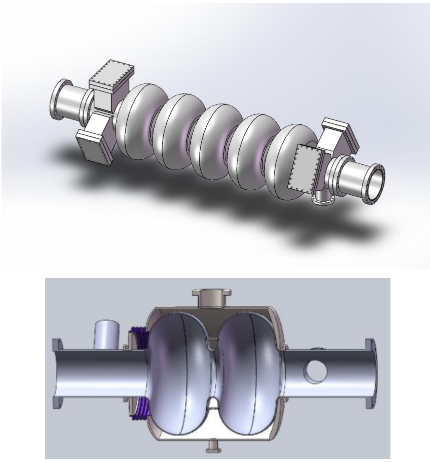
Beam distribution @ 6GeV



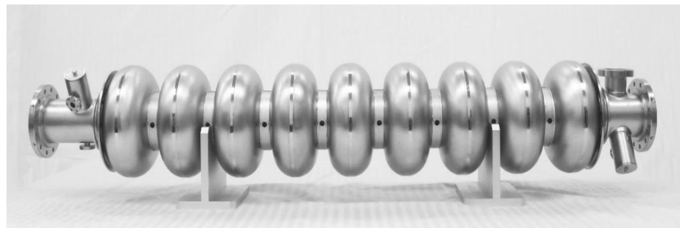
Main parameters of Injector

Parameter	Symbol	Unit	Value	Status
e^-/e^+ beam energy	E_{e-}/E_{e+}	GeV	6	6
Repetition rate	f_{rep}	Hz	50	50
e^-/e^+ bunch population @ 6 GeV	$Ne-/Ne+$		2×10^{10}	2×10^{10}
	$Ne-/Ne+$	nC	3.2	3.2
Energy spread (e^-/e^+)	σ_E		$<1\times10^{-3}$	*1.2×10^{-3}* @Long.wakefield
Emitance (e^-/e^+)		mm· mrad	<0.3	<0.3 @ e^- *0.32 @ e^+*
e^- beam energy on Target		GeV	4	4
e^- bunch charge on Target		nC	10	10

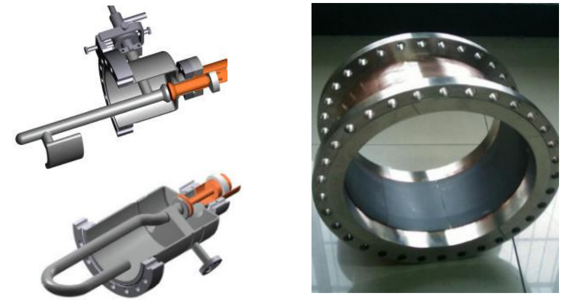
SRF technology R&D



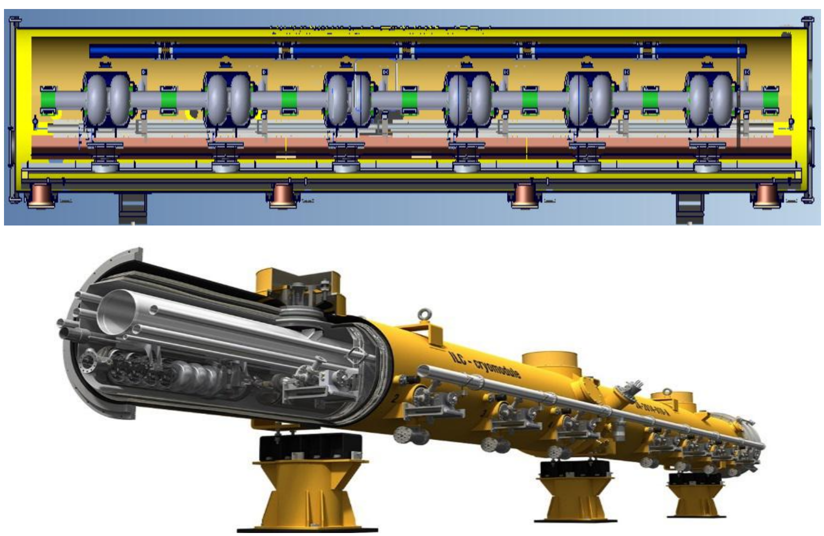
650 MHz cavity in fabrication



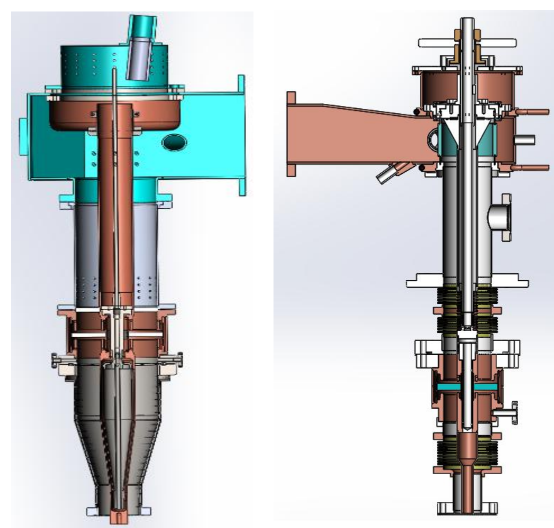
IHEP made 1.3 GHz cavity



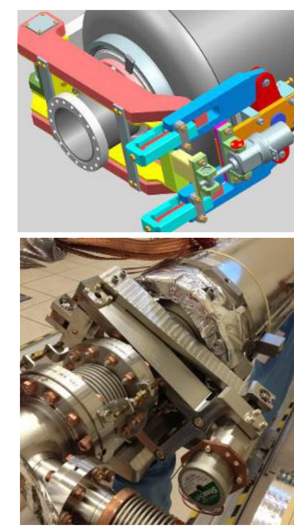
HOM Coupler and Absorber



Cryomodule



Input Coupler

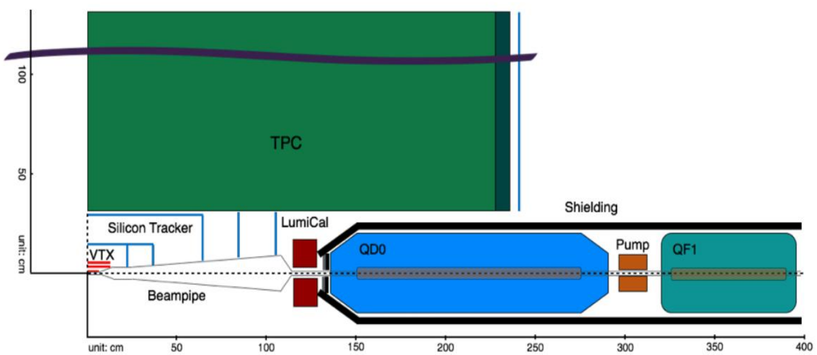


Tuner

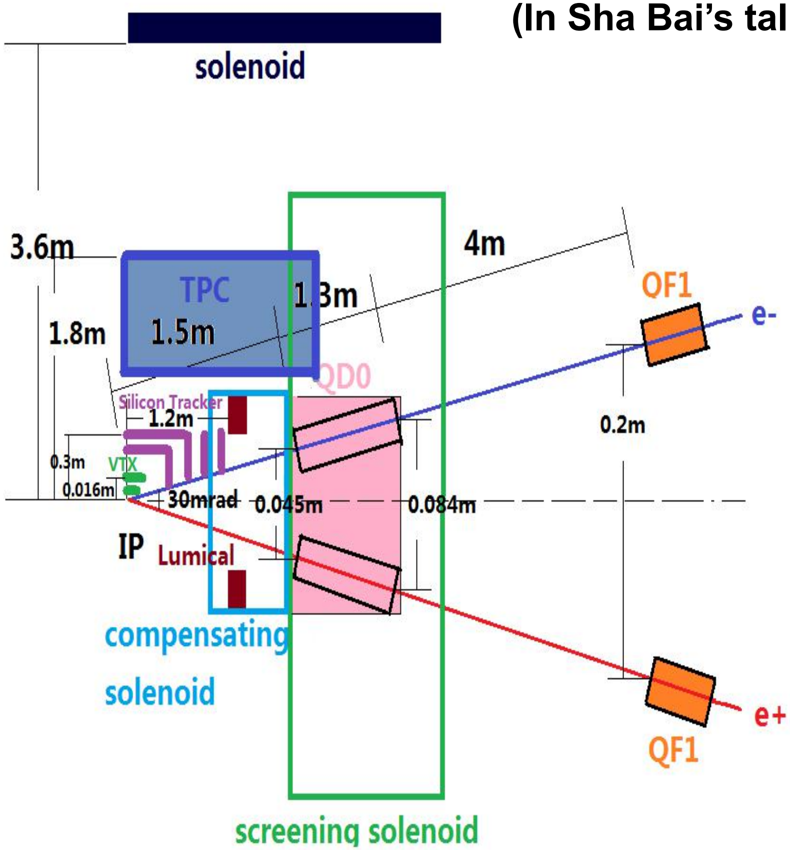
MDI layout and issues : single → partial double ring

- Beam background
- Shielding design
- Collimator design
- SC magnet design
- Beam pipe
- Solenoid compensation
- Lumical & fast lumi measurement & feedback
- ……..

(In Sha Bai's talk)



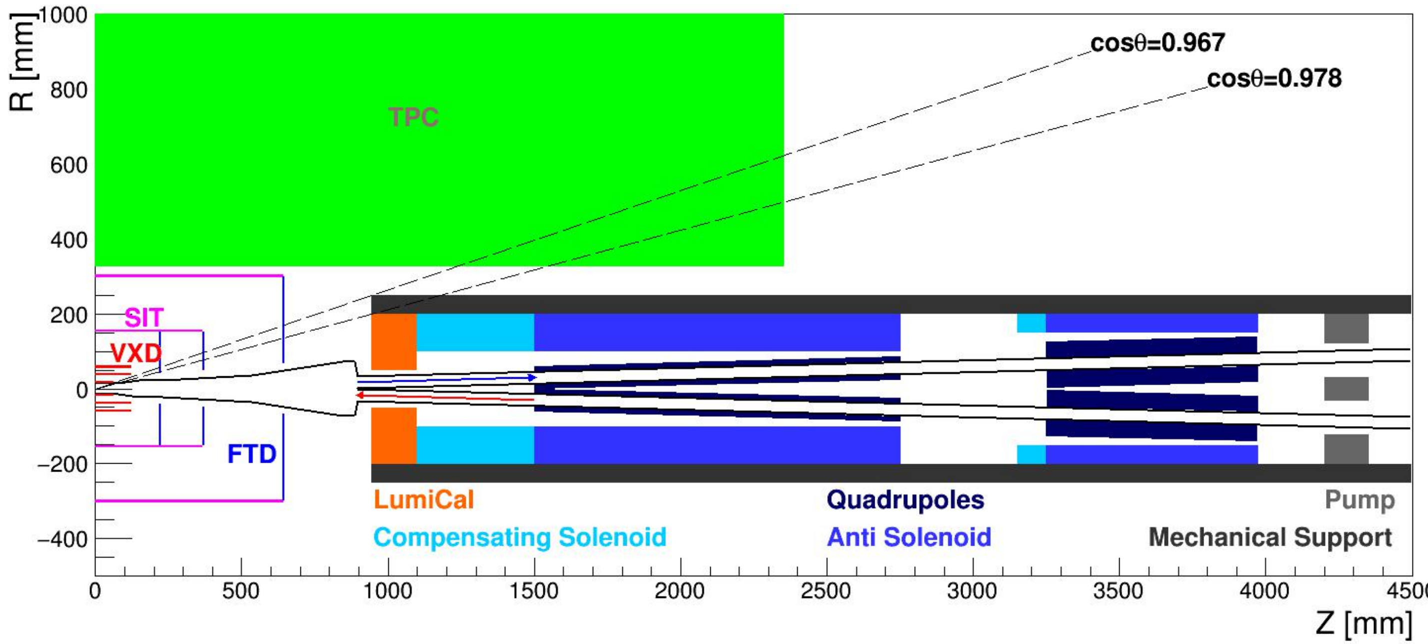
Single ring MDI



Partial double ring MDI

CEPC partial double ring IR layout

(S. Bai, H.B. Zhu, et al)



- Background study in the preliminary lattice design: radiative Bhabha scattering, beamstrahlung, synchrotron radiation, Beam-gas scattering, beam thermal photons scattering.
- SC magnets are designed. Solenoid compensation was first tried in the preliminary lattice design， 13T compensating solenoid was designed.

CEPC Accelerator Design Status towards CDR

- **CEPC-SppC parameter space (map) scan (Done)**
  - Ring circumference from 54km-100km (CEPC and SppC)
  - Energy (Higgs, Z, W), luminosity, beam ridiation power, crossing angle
    (Done and cross-checked with beam-beam simulations)

- **CEPC design with four option proposals (Under study with PDR more advanced)**
  - Main ring options: Partial Double Ring (PDR),
    Advanced Partial Double Ring (APDR), Double Ring (DR) , Pretzel (head-on),
    (Corrsponding DA optimizations is underway with good progress)

- **CEPC main ring collective effects for Higgs and Z energies (Under study)**

- **CEPC MDI designs with head-on collision and with crossing angle (Under study with crossing angle)**

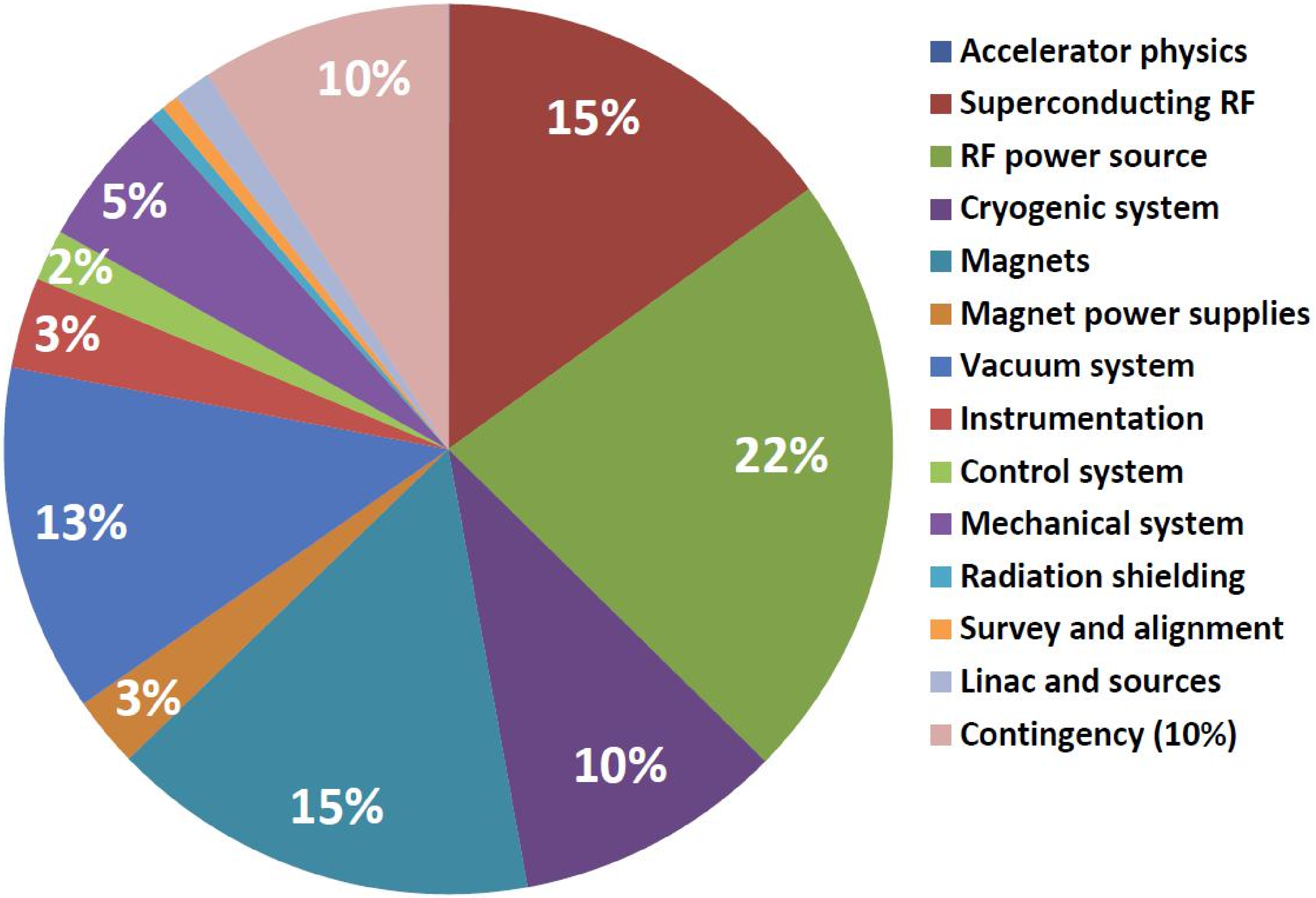
- **CEPC boosters with too option proposals (Done)**
  - Low Field Scheme (LFS) and Alternating Field Scheme (AFS)
    (Done with good DA satisify CDR)

- **CEPC injector (e+e-) with two option proposals (Done)**
  - S-band injector and C-band injector (S-band satisfy CDR)
  - Injector damping ring (Done)

- **CEPC key technologies' R&D located (with some started)**
  - 650MHz klystron, 650MHz 5 cell and 2 cell cavity, Nitrogen dopping, instrumentation...
  - 1.3Ghz 9cell caity (Done)

- **SppC lattice and minimum ring circumferce question (Done) (61km)**

CEPC Pre-CDR Relative Cost Estimate (single ring scheme)



Parameter for CEPC partial double ring （wangdou20161115-100km）

CEPC and SppC CDR Circumference will be 100km

	Pre-CDR	**H-high lumi.**	**H-low power**	**Z**
Number of IPs	2	2	2	2
Energy (GeV)	120	120	120	45.5
Circumference (km)	54	100	100	100
SR loss/turn (GeV)	3.1	1.67	1.67	0.034
Half crossing angle (mrad)	0	15	15	15
Piwinski angle	0	2.9	2.9	5.69
N_e/bunch (10^{11})	3.79	0.97	0.97	0.46
Bunch number	50	644	425	1100
Beam current (mA)	16.6	29.97	19.8	24.3
SR power /beam (MW)	51.7	50	33	0.84
Bending radius (km)	6.1	11	11	11
Momentum compaction (10^{-5})	3.4	1.3	1.3	3.3
β_{IP} x/y (m)	0.8/0.0012	0.144 /0.002	0.144 /0.002	0.12/0.001
Emittance x/y (nm)	6.12/0.018	1.56/0.0047	1.56/0.0047	0.93/0.0049
Transverse σ_{IP} (um)	69.97/0.15	15/0.097	15/0.097	10.5/0.07
ξ_x/ξ_y/IP	0.118/0.083	0.0126/0.083	0.0126/0.083	0.0075/0.054
RF Phase (degree)	153.0	131.2	131.2	160.8
V_{RF} (GV)	6.87	**2.0**	**2.22**	**0.11**
f_{RF} (MHz)	650	650	650	650
Nature σ_z (mm)	2.14	**2.72**	**2.72**	**3.93**
Total σ_z (mm)	2.65	2.9	2.9	4.0
HOM power/cavity (kw)	3.6 (5cell)	0.64 (2cell)	0.42 (2cell)	0.11 (1cell)
Energy spread (%)	0.13	0.098	0.098	0.037
Energy acceptance (%)	2	1.5	1.5	
Energy acceptance by RF (%)	6	2.2	2.2	1.1
n_γ	0.23	0.26	0.26	0.18
Life time due to beamstrahlung_cal (minute)	47	52	52	
F (hour glass)	0.68	0.95	0.95	0.91
L_{max}/IP ($10^{34}cm^{-2}s^{-1}$)	2.04	3.1	2.05	1.19

SPPC Parameter Choice and Optimize

CEPC and SppC CDR Circumference will be 100km

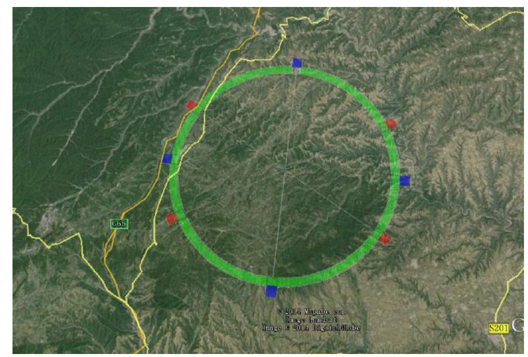
Table 1: SPPC Parameter List.

Version 201607

	SPPC(Pre-CDR)	SPPC-59.2Km	SPPC-100Km	SPPC-100Km	SPPC-80Km
Main parameters and geometrical aspects					
Beam energy[E_0]/TeV	35.6	35.0	50.0	65.0	50.0
Circumference[C_0]/km	54.7	59.2	100.0	100.0	80.0
Dipole field[B]/T	20	19.70	15.52	19.83	19.74
Dipole curvature radius[ρ]/m	5928	5921.5	10924.4	10924.4	8441.6
Bunch filling factor[f_2]	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
Total dipole length [L_{Dipole}]/m	37246	37206	68640	68640	53040
Arc length[L_{ARC}]/m	47146	47700	88000	88000	68000
Straight section length[L_{ss}]/m	7554	11500	12000	12000	12000
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}
Beta function at collision[β^*]/m	0.75	0.85	0.99	0.22	1.06
Max beam-beam tune shift per IP[ξ_y]	0.006	0.0065	0.0068	0.0079	0.0073
Number of IPs contribut to ΔQ	2	2	2	2	2
Max total beam-beam tune shift	0.012	0.0130	0.0136	0.0158	0.0146
Circulating beam current[I_b]/A	1.0	1.024	1.024	1.024	1.024
Bunch separation[Δt]/ns	25	25	25	25	25
Number of bunches[n_b]	5835	6315	10667	10667	8533
Bunch population[N_p] (10^{11})	2.0	2.0	2.0	2.0	2.0
Normalized RMS transverse emittance[ε]/μm	4.10	3.72	3.62	3.10	3.35
RMS IP spot size[σ^*]/μm	9.0	8.85	7.86	3.04	7.86
Beta at the 1st parasitic encounter[$\beta 1$]/m	19.5	18.70	16.36	68.13	15.31
RMS spot size at the 1st parasitic encounter[σ_1]/μm	45.9	43.20	33.31	55.20	31.03
RMS bunch length[σ_z]/mm	75.5	56.60	65.68	14.88	70.89
Full crossing angle[θ_c]/μrad	146	138.23	106.60	176.66	99.28
Reduction factor according to cross angle[F_{ca}]	0.8514	0.9257	0.9247	0.9283	0.9241
Reduction factor according to hour glass effect[F_h]	0.9975	0.9989	0.9989	0.9989	0.9989
Energy loss per turn[U_0]/MeV	2.10	1.97	4.45	12.71	5.76
Critical photon energy[E_c]/keV	2.73	2.60	4.11	9.02	5.32
SR power per ring[P_0]/MW	2.1	2.01	4.56	13.01	5.89
Transverse damping time [τ_x]/h	1.71	1.946	2.08	0.946	1.28
Longitudinal damping time [τ_ε]/h	0.85	0.973	1.04	0.473	0.64

Site selections (some main places)

1)



2)

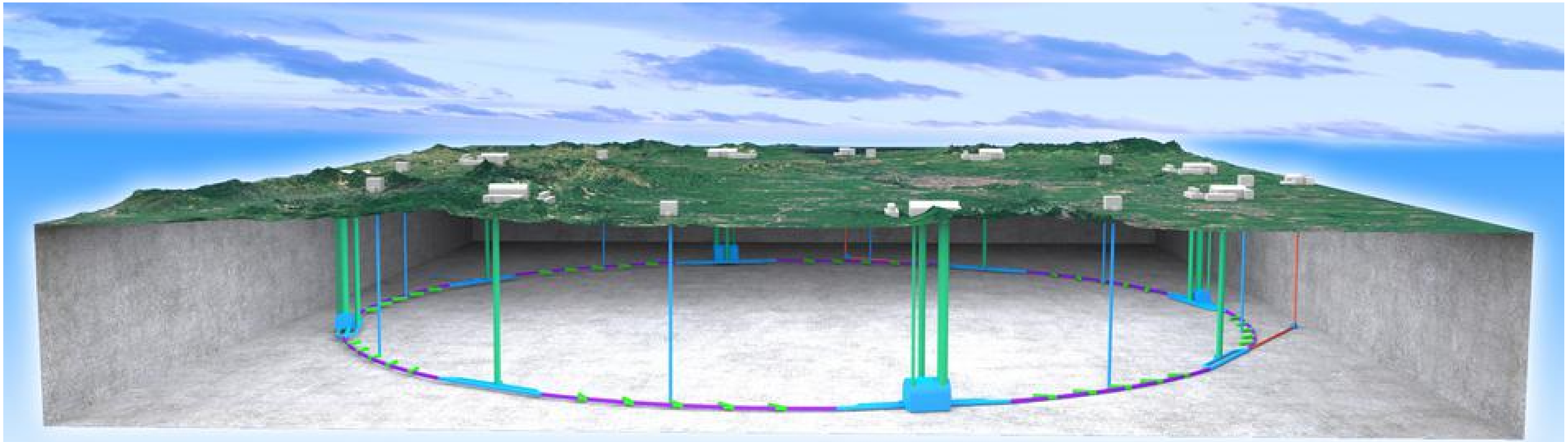
3)

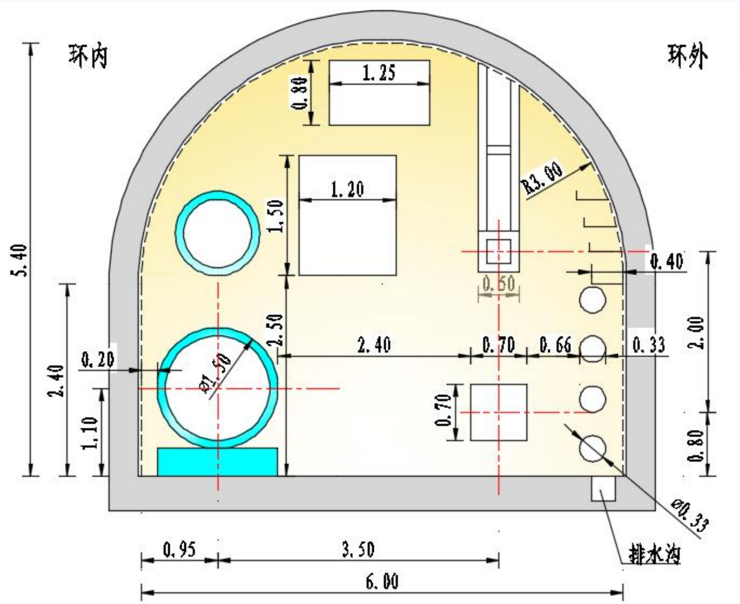
1) Qinhuangdao

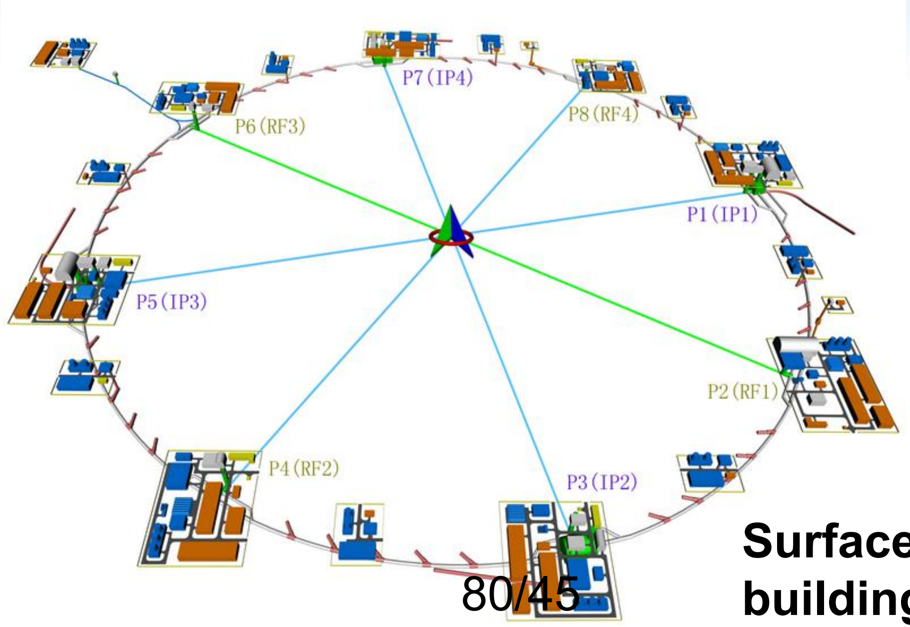
2) Shanxi Province

3) Near Shenzhen and Hongkong

Civil Construction







Surface buildings

International Collaboration

- Limited international participation for the pre-CDR
  - An excise for us
  - Build confidence for the Chinese HEP community

- International collaboration is needed not only because we need technical help
  - A way to integrate China better to the international community
  - A way to modernize China's research system("open door" policy)

- A new scheme of international collaboration to be explored

- An international advisory board has been formed to discuss in particular this issue, together with others

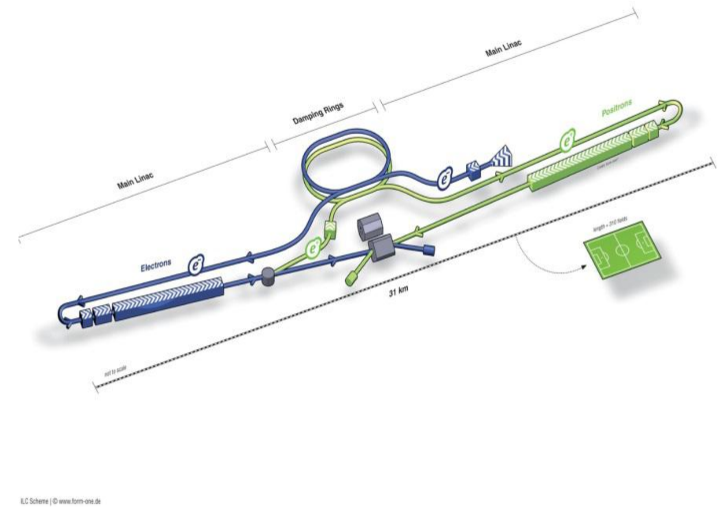
- A number of MoUs have been signed between IHEP and relevant labs, such **BINP** and VINCA, more than 10 now.

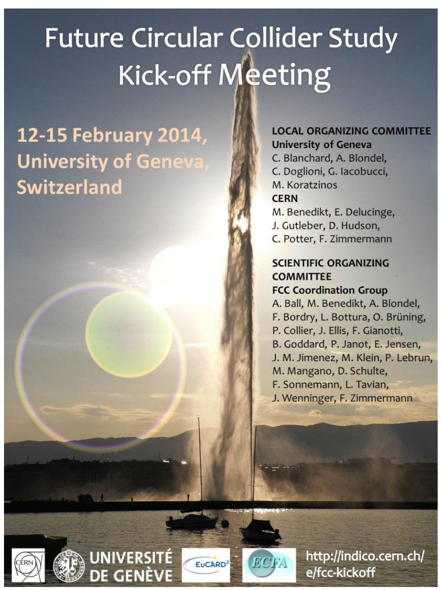
CEPC-LCC-FCC in Synergy

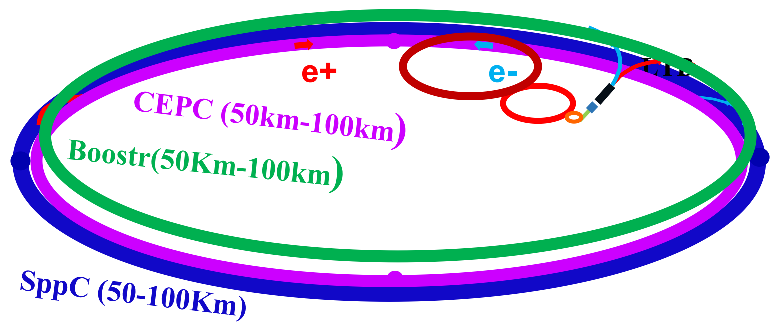
1） Linear colliders： ILC-CLIC
from Higgs energy to 5TeV

2） Circular Colliders： CEPC-SppC e+e- Higgs factory-pp collider at 50~100TeV

3) FCC kick-off meting in Feb., 2014







CEPC – Web :Documentation and Meeting Annoucement

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

CEPC-SppC Study Group Meeting in September 2-3, 2016, Beijing

http://indico.ihep.ac.cn/event/6149/

Some milestone meetings in 2016

1) The first IHEP-BINP collaboration workshop on CEPC, Jan 12-13, 2016, IHEP

2) IAS Conference on future of high energy physics, Jan. 18-21, 2016, Hongkong (http://iasprogram.ust.hk/hep/2016/organizers.html)

3) AFAD 2026 Workshop, Feb. 1-3, 2016, Kyoto, Japan (http://www.acfa-forum.net/afad2016/)

4) CEPC-SppC Symposium, April 8-9, IHEP (http://indico.ihep.ac.cn/event/5277/)

5) CEPC-SppC Study Group Meeting, Beihang University (http://indico.ihep.ac.cn/event/6149/other-view?view=standard)

End of 2016, CDR Progress Report for CEPC Accelerator

Concluding remarks

- CEPC shaping well towards CDR with reuiqred physcis goals and with different schemes
- Fund from MOST succeded in June 2016
- Design and key technologies' R&D progress well
- International collaboration has started and will continue to develop towards full scale, which is necessary and important
- Synergies of CEPC/SppC with LCC(ILC, CLIC) and FCC(e+e-,pp) are very important for the community
- Young generations are the key forces to realize the goals
- The started CEPC/SppC will continue to progress , and be realized in the future

Thank you for your attention

Thanks go to CEPC-SppC Collaboration
colleagues
and international collaborators