Circular Electron Positron Collider

CEPC Accelerator Status and International Collaboration

J. Gao

For the CEPC Accelerator Group

Institute of High Energy Physics
Beijing, CAS

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HKUST Jockey Club Institute for Advanced Study
The Hong Kong University of Science and Technology

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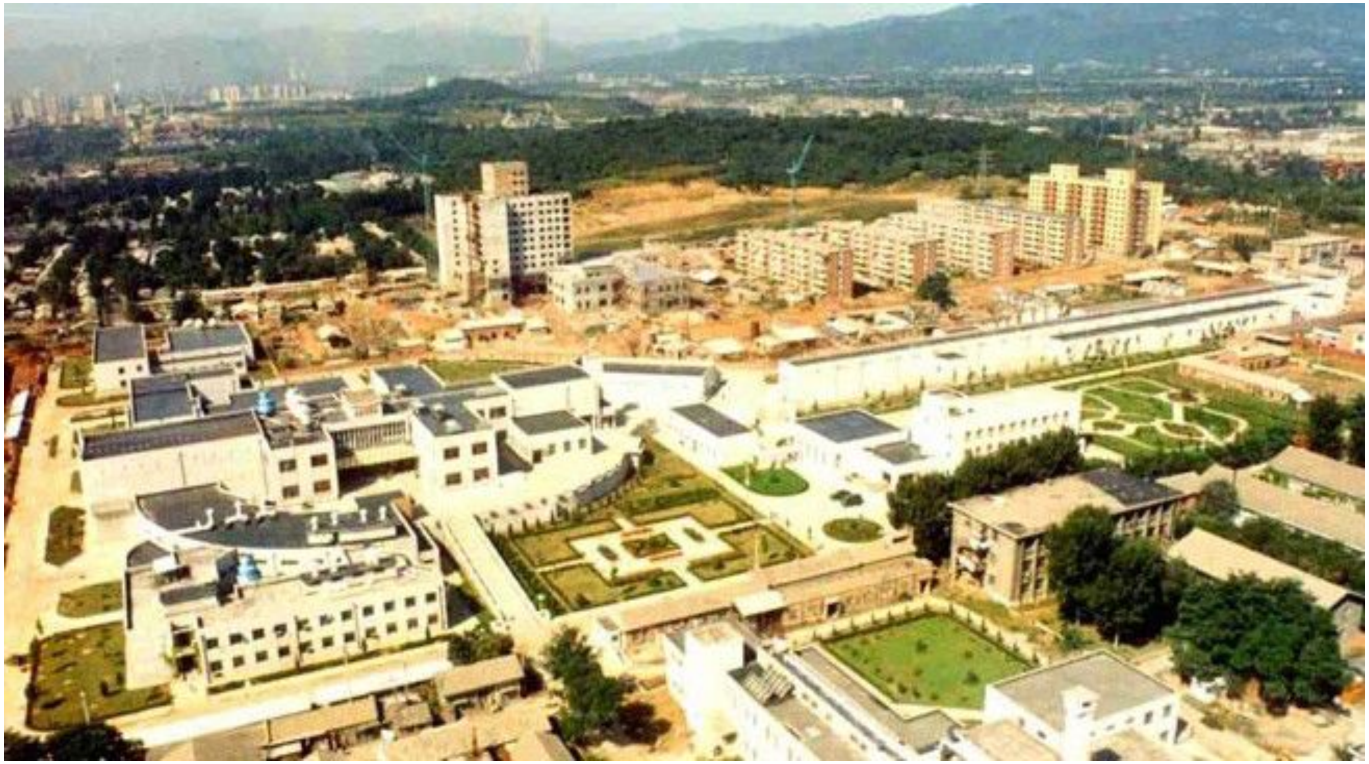
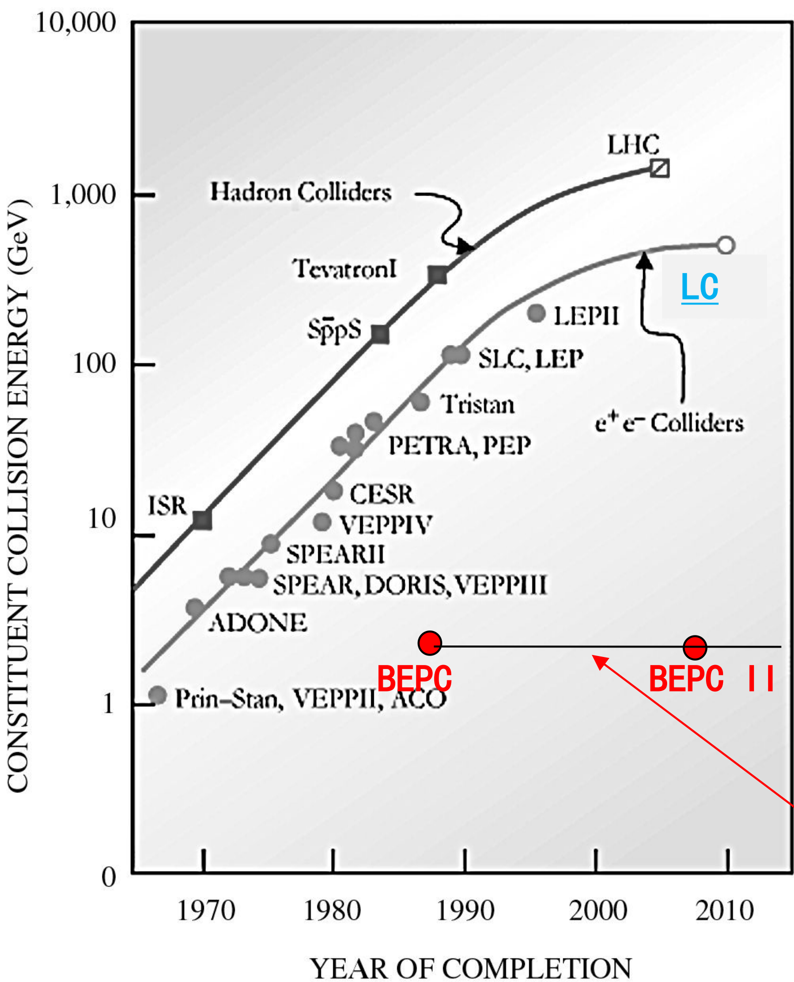
From BEPC to BEPCII

BEPC was completed in 1988 with luminosity $1 \times 10^{31} cm^{-2}s^{-1}$ @1.89GeV
BEPC II was completed in 2009 with Luminosity reached: $8 \times 10^{32} cm^{-2}s^{-1}$ @1.89GeV

After BEPCII what is the next high energy collider?



Lepton and Hadron Colliders' History and China Accelerator based High Energy Physics Development in the Future



Old picture!

CEPC+SppC

CEPC: Ecm=240GeV e+e- Circular Collider
SppC: Ecm=50-100TeV pp Collider

CEPC+SppC will be constructed with international collaboration and participation

HIEPAF: High Intensity Electron Positron Accelerator Facility

History of BEPC and BEPC II

Strategy on Future High Energy Colliders of China

1) On "The 464th Fragrant Hill Meeting， June 12-14， 2013", Chinese High Energy Physics Community arrived at the following consensus:

a) China supports ILC and will participate to ILC construction with in-kind contributions and requests R&D fund from government

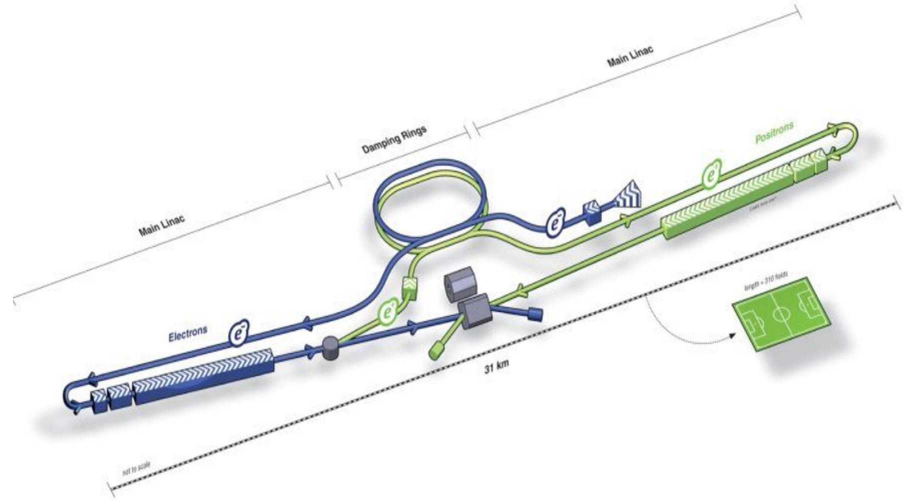
b) After the discovery of Higgs, as next collider after BEPCII in China, a circular e+e- Higgs factory（CEPC）and a Super proton-proton Collier (SppC) afterwards in the same tunnel is an important option and historical opportunity.

2) During the meeting of Chinese High Energy Physics Association on "China High Energy Physics based on Particle Accelerators", Feb. 28, 2014, it was concluded that: "Circular e+e- Circular Higgs Factory(CEPC) +Super pp Collider (SppC) is the first choice for China's future high energy physics accelerator.

- It is considered that CEPC (250GeV upper limit) is *supplementary to ILC in terms of its energy range down to W and Z boson and to the number of detectors from both machines*
- *International collaboration and participation are necessary*

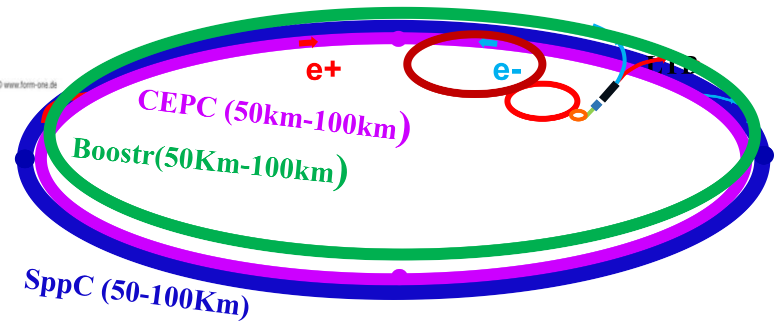
CEPC and ILC

- Higher precision
- Higher energy



1） Linear colliders： ILC-CLIC
from Higgs energy to 5TeV
(Support and Participation)

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

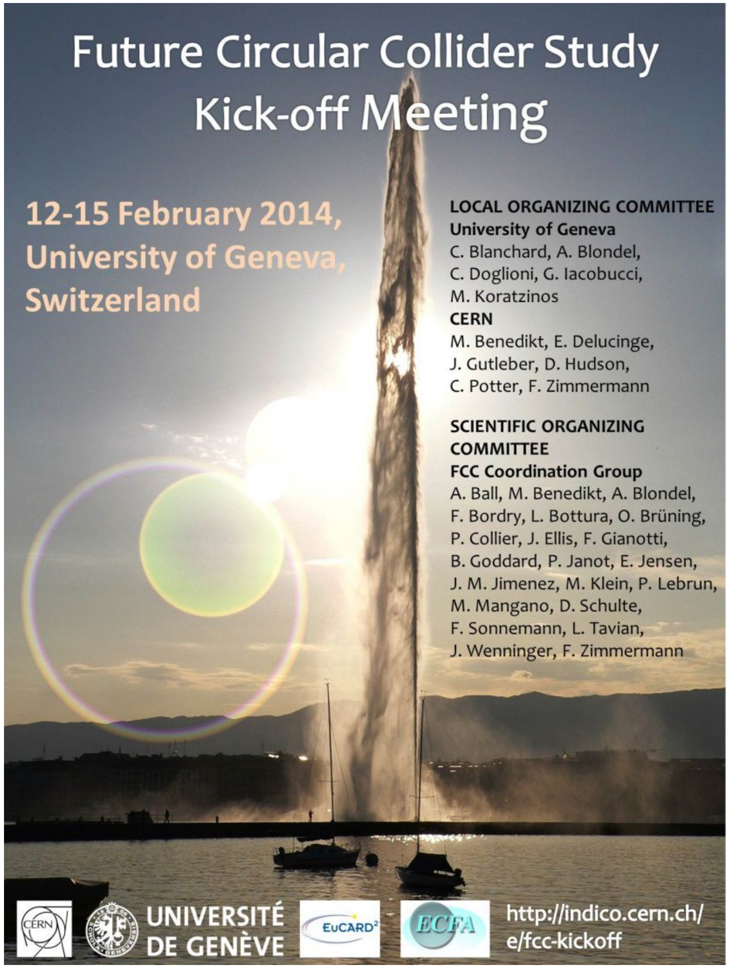


Precision @ e+e- collider
Energy frontier @ pp collider

CEPC/SppC and FCC

- CERN started the Future Circular Collider effort since last year
- FCC kick-off meting in Feb., 2014
- ICFA statement On Feb. 21, 2014 at DESY：

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



ICFA: international committee for Future accelerators
http://www.fnal.gov/directorate/icfa/

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

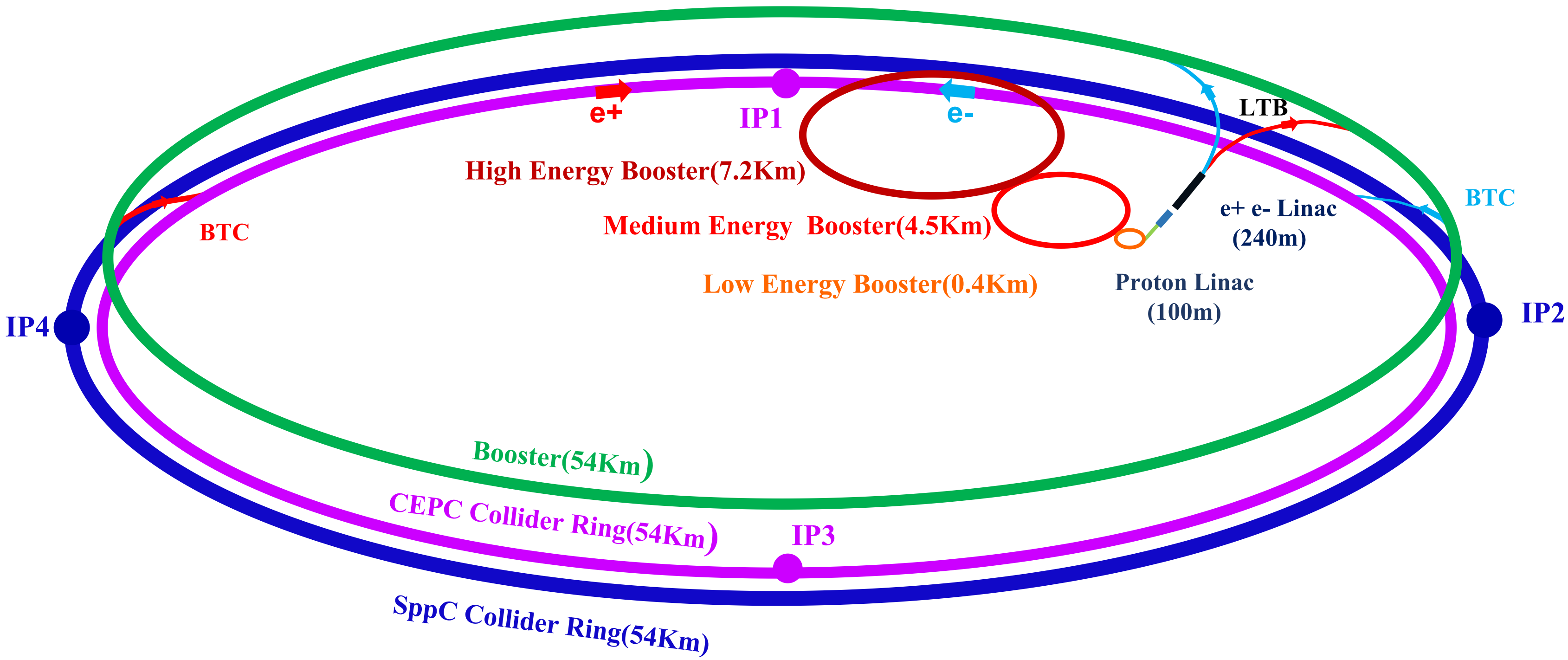
- ILC, CEPC, FCC(ee) have many common technologies and task force overlapes

- 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) "

Introduction to CEPC+SppC

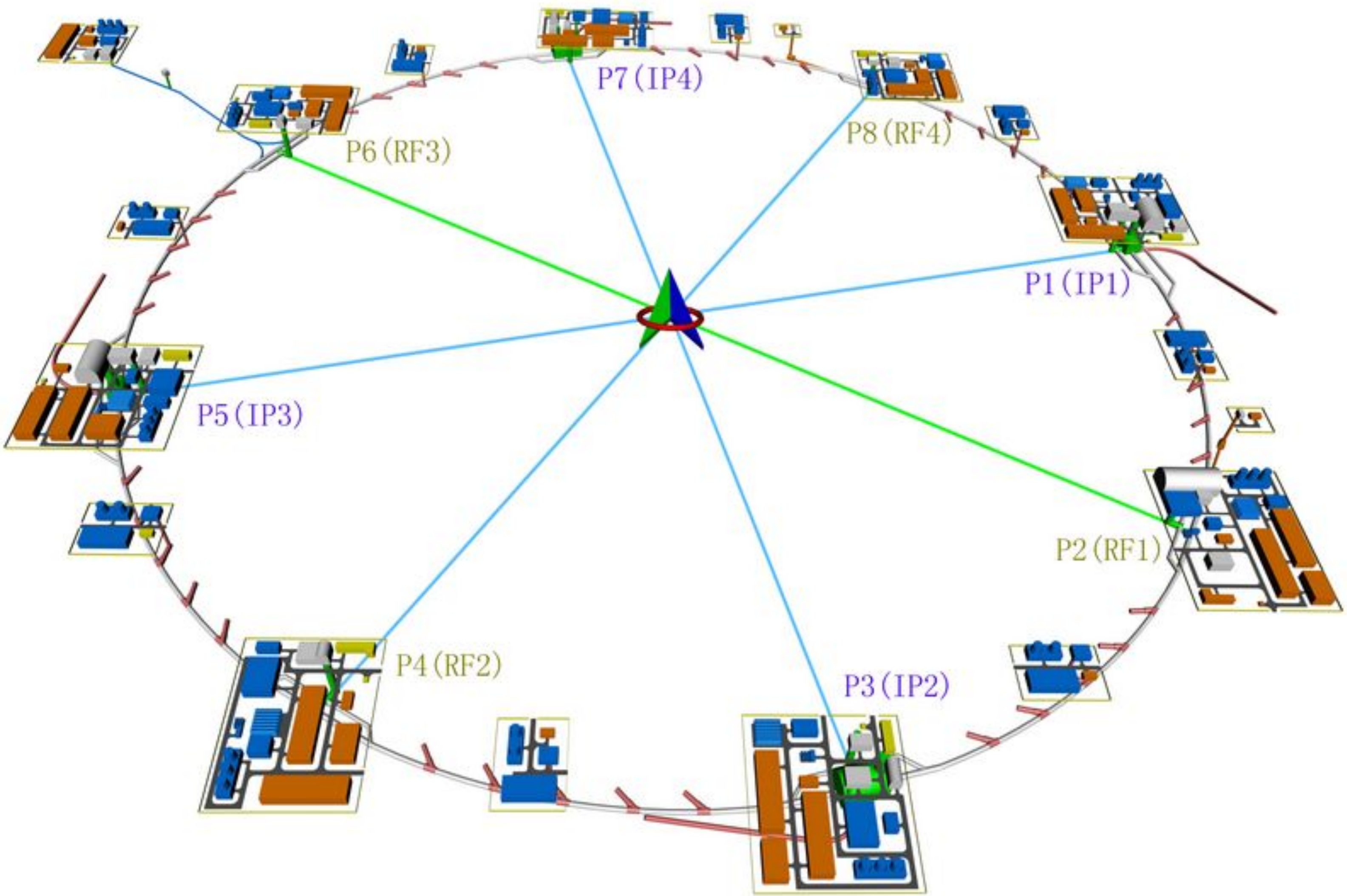
(Pre-CDR)



LTB : Linac to Booster

BTC : Booster to Collider Ring

CEPC/SppC on Site
(Example)



CEPC Design –Higgs Parameters

Parameter	Design Goal
Particles	e+, e-
Center of mass energy	240 GeV
Luminosity (peak)	2*10^34/cm^2s
No. of IPs	2

CEPC Design – Z-pole Parameters

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

Parameter choice for SPPC (Potential)

(F. Su et al)

Table 4. Parameter lists for LHC HL-LHC HE-LHC FCC-hh and SPPC.

	LHC	HL-LHC	HE-LHC	FCC-hh	SPPC-Pre-CDR	SPPC-54.7Km	SPPC-100Km	SPPC-100Km	SPPC-78Km	
	Value									Unit
Main parameters and geometrical aspects										
Beam energy[E_0]	7	7	16.5	50	35.6	35.0	50.0	68.0	50.0	TeV
Circumference[C_0]	26.7	26.7	26.7	100(83)	54.7	54.7	100	100	78	km
Lorentz gamma[γ]	7463	7463	14392	53305	37942	37313	53305	72495	53305	
Dipole field[B]	8.33	8.33	20	16(20)	20	19.69	14.73	20.03	19.49	T
Dipole curvature radius[ρ]	2801	2801	2250	10416 (8333.3)	5928	5922.6	11315.9	11315.9	8549.8	m
Bunch filling factor[f_2]	0.78	0.78	0.63	0.79	0.8	0.8	0.8	0.8	0.8	
Arc filling factor[f_1]	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	
Total dipole magnet length [L_{Dipole}]	17599	17599	14062	65412 (52333)	37246	37213	71100	71100	53720	m
Arc length[L_{ARC}]	22476	22476	22476	83200 (66200)	47146	47105	90000	90000	68000	m
Total straight section length[L_{ss}]	4224	4224	4224	16800	7554	7595	10000	10000	10000	m
Energy gain factor in collider rings	15.6	15.6	13.5	15.2	17.0	16.67	17.5	17.5	17.5	
Injection energy [E_{inj}]	0.45	0.45	>1.0	3.3	2.1	2.1	2.9	3.9	2.9	TeV
Number of IPs[N_{IP}]	4	2	2	2	2	2	2	2	2	

Parameter choice for SPPC (Potential)

(F. Su et al)

Physics performance and beam parameters										
Peak luminosity per IP[L]	1.0E+34	5.0E+34	5.0E+34	5.0E+34	1.2E+35	1.2E+35	1.52E+35	1.02E+36	1.52E+35	$cm^{-2}s^{-1}$
Optimum run time	15.2	10.2	5.8	12.1(10.7)	5.87	5.87	6.69	2.47	5.91	hour
Optimum average integrated luminosity/day	0.47	2.8	1.4	2.2(2.1)	3.36	3.36	4.84	12.97	4.28	fb^{-1}
Assumed turnaround time	6			5	5	5	5	5	5	hour
Overall operation cycle	21.2			17.4(16.3)	11.5	11.5	12.5	8.0	12.0	hour
Beam life time due to burn-off[τ]	45	15.4	5.7	19.1(15.9)	9.65	9.65	12.74	2.07	9.78	hour
Total / inelastic cross section[σ]	111/85	111/85	129/93	153/108	140	140	155	160	155	mbarn
Beam parameters										
Beta function at collision[β^*]	0.55	0.15 (min)	0.35	1.1	0.75	0.85	0.97	0.24	1.06	m
Max beam-beam tune shift perIP[ξy]	0.0033	0.0075	0.005	0.005	0.006	0.0065	0.0067	0.008	0.0073	
Number of IPs contributing to ΔQ	3	2	2	2	2	2	2	2	2	
Max total beam-beam tune shift	0.01	0.015	0.01	0.01	0.012	0.013	0.0134	0.016	0.0146	
Circulating beam current[I_b]	0.584	1.12	0.478	0.5	1.0	1.024	1.024	1.024	1.024	A
Bunch separation[Δt]	25 5	25 5	25 5	25 5	25	25	25	25	25	ns
Number of bunches[n_b]	2808	2808	2808	10600 (8900) 53000 (44500)	5835	5835	10667	10667	8320	
Bunch population[Np]	1.15	2.2	1	1.0 0.2	2.0	2.0	2.0	2.0	2.0	10^{11}
Normalized RMS transverse emittance[ε]	3.75	2.5	1.38	2.2 0.44	4.10	3.72	3.65	3.05	3.36	μm
RMS IP spot size[σ^*]	16.7	7.1	5.2	6.8	9.0	8.85	7.85	3.04	7.86	μm

CEPC+SppC Schedule (Preliminary)

- BEPC II will stop in ~2020

- CPEC
  - Pre-study, R&D and preparation work
    - Pre-study: 2013-15 → Pre-CDR by 2014
    - CDR end of 2016
    - R&D: 2016-2020
    - Engineering Design: 2015-2020
  - Construction: 2021-2027
  - Data taking: 2030-2036

- SPPC
  - Pre-study, R&D and preparation work
    - Pre-study: 2013-2020
    - R&D: 2020-2030
    - Engineering Design: 2030-2035
  - Construction: 2036-2042
  - Data taking: 2042 -

CEPC-SPPC Timeline (preliminary)

CEPC

2nd Milestone: 13th Five Year Plan R&D

2015 | 2020 | 2025 | 2030 | 2035

- Pre-studies (2013-2015)
- R&D Engineering Design (2016-2020)
- Construction (2021-2027)
- Data taking (2028-2035)

1st Milestone: Pre-CDR (by the end of 2014) → R&D funding request to Chinese government in 2015 (China's 13th Five-Year Plan 2016-2020)

SPPC

2020 | 2030 | 2040

- R&D (2014-2030)
- Engineering Design (2030-2035)
- Construction (2035-2042)
- Data taking (2042-2055)

CEPC-SppC relations

- CEPC (e+e-) be built first and after 7 years operation SppC (pp) starts to be built in the same channel
- In machine design, CEPC and SppC could be operated at the same time
- Tunnel length is determined by CEPC and SppC jointly

CEPC CDR Goal

- At the end of 2016, we should provide a CEPC design which satisfies the CEPC Higgs and Z-pole physics goal at the same time, and works "on paper", considering some most important technical limitations.

- Choice between CEPC single ring with Pretzel scheme (Pre-CDR) or CEPC with local double ring scheme should be made in early 2016.

CEPC Single Ring with Pretzel Scheme
Vs
CEPC Local Double Ring Scheme

- At the end of 2016, we should provide a CEPC design which satisfies the CEPC Higgs and Z-pole physics goal at the same time, and works "on paper", considering some most important technical limitations.

- Choice between CEPC single ring with Pretzel scheme and CEPC with local double ring scheme should be made in early 2016.

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

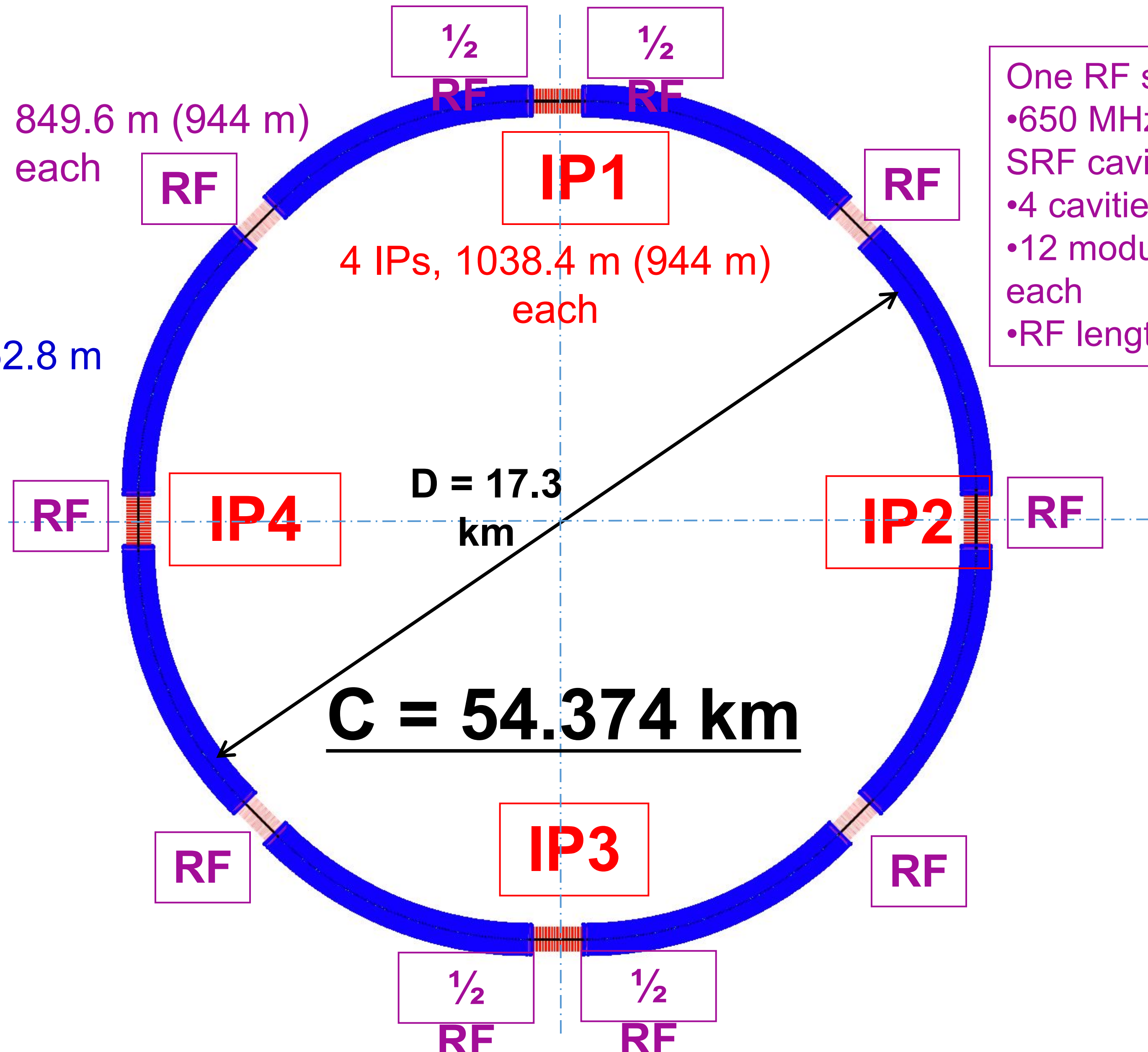
Main Parameters of CEPC SRF System

Parameters	CEPC-Collider	CEPC-Booster	LEP2
Cavity Type	650 MHz 5-cell Nitrogen-dope Nb	1.3 GHz 9-cell Nitrogen-doped Nb	352 MHz 4-cell Nb/Cu sputtered
Cavity number	384	256	288
V_{cav} / V_{RF}	17.9 MV / 6.87 GeV	20 MV / 5.12 GeV	12 MV / 3.46 GeV
E_{acc} (MV/m)	15.5	19.3	6 ~ 7.5
Q_0	4E10 @ 2K	2E10 @ 2K	3.2E+9 @ 4.2K
Cryomodule number	96 (4 cav. / module)	32 (8 cav. / module)	72 (4 cav)
RF input power / cav. (kW)	280 c.w.	20	125 c.w.
RF source number	192 (800 kW / 2 cav)	256 (25 kW / cav)	36 (1.2 MW/8 cav)
HOM power per cavity (kW) and damper type	3.5 coaxial/waveguide @2 K + ferrite@RT	0.05 coaxial@2 K + ceramic@80 K	0.3 W coaxial@4.2 K + ferrite@RT

CEPC Lattice Layout (September 24, 2014)

4 straights, 849.6 m (944 m) each

8 arcs, 5852.8 m each



One RF station:
- 650 MHz five-cell SRF cavities;
- 4 cavities/module
- 12 modules, 10 m each
- RF length 120 m

SPPC Layout

LSS1/5

1107m

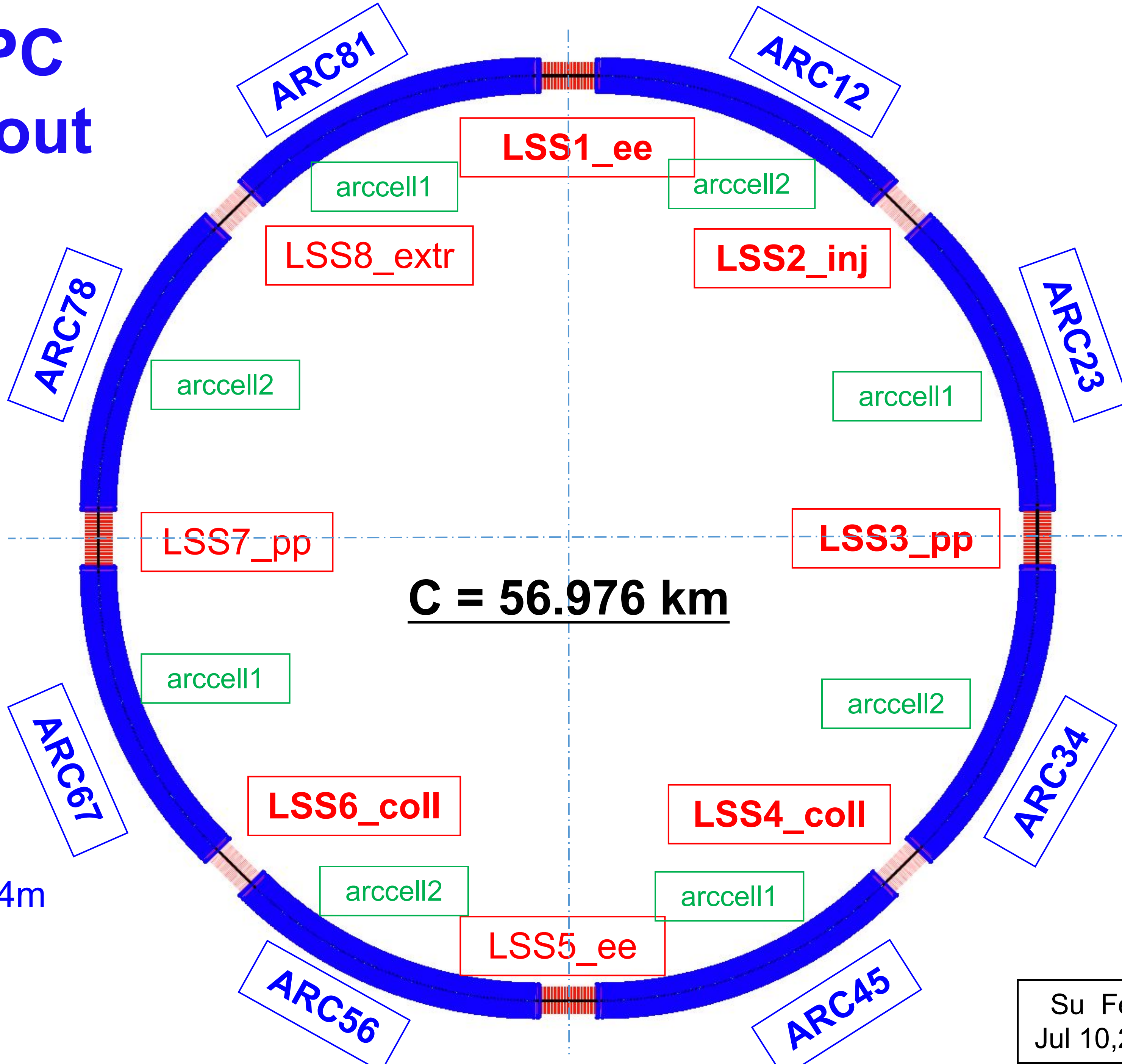
LSS2/4/6/8

959.4m

LSS3/7

1244m

ARC 6077.84m



Su Feng
Jul 10,2015

SppC main parameters (Pre-CDR)

Parameter	Value	Unit
Circumference	52	km
Beam energy	35	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	W/m

[1] Institute of High Energy Physics, China (高能物理研究所)
[2] Institute of Modern Physics, China (近代物理研究所)
[3] Shanghai Institute of Applied Physics, China (上海应用物理研究所)
[4] Peking University, China (北京大学)
[5] Tsinghua University, China (清华大学)
[6] University of Science and Technology of China (中国科技大学)
[7] Shanghai Jiao Tong University (上海交通大学)
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[12] Northwest Institute for Non-ferrous Metal Research, China (西北有色金属研究院)
[13] Northwestern University, U.S.A.
[14] Brookhaven National Laboratory, U.S.A.
[15] SLAC National Accelerator Laboratory, U.S.A.
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[22] University of Milano and INFN Milano - LASA, Italy
[23] University of Chicago, U.S.A.
[24] University of Arizona, U.S.A.
[25] University of Pittsburgh, U.S.A.
[26] Duke University, U.S.A.
[27] University of Massachusetts, U.S.A.

CEPC-SPPC:Pre-CDR

February 2015

The CEPC-SPPC Study Group

IHEP-AC-2015-001

CEPC-SPPC

Preliminary Conceptual Design Report

February 2015

258 authors
from 45 institutions
in 9 countries

The CEPC-SPPC Study Group

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

Main progresses after pre-CDR towards CDR

line 1

- CEPC local double ring design and crab-waist CEPC parameters (avoid: pretzel scheme, high AC power and low Z luminosity) (Dou Wang, Feng Su, et al)
- The criterion for CEPC DA to reach the requirement of CDR with beam-beam effect (J. Gao, Yiwei Wang, Dou Wang, et al)
- CEPC FFS design (Y.W. Wang, D. Wang, et al)
- CEPC DA optimization (Y.W. Wang, Y. Zhang, D. Wang, et al)
- New Booster design to solve the problem low magnetic field and DA (Tianjian Bian, et al)
- CEPC magnets error on DA (Sha Bai, et al)

line 2

- CEPC pretzel scheme (Huiping Geng, et al)
- Pre-CDR Booster: residule field in the tunnel (BEPCII), lattice (Xiaohao Cui, et al)
- CEPC MDI (Sha Bai, et al)

CEPC accelerator design activities towards CDR

Weekly CEPC Accelerator design beam dynamics meeting
after Pre-CDR towards CDR:

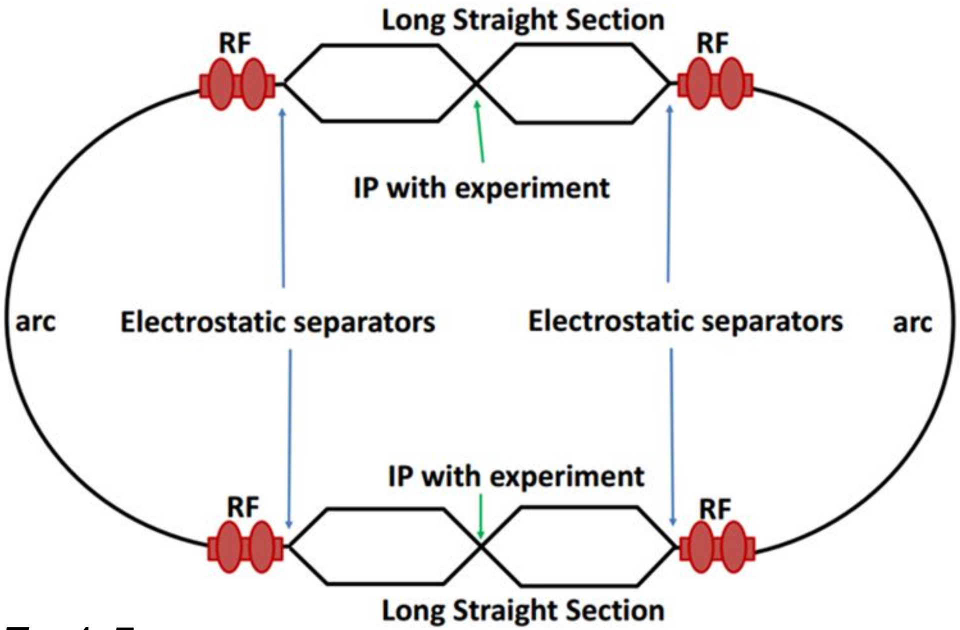
http://indico.ihep.ac.cn/category/350/

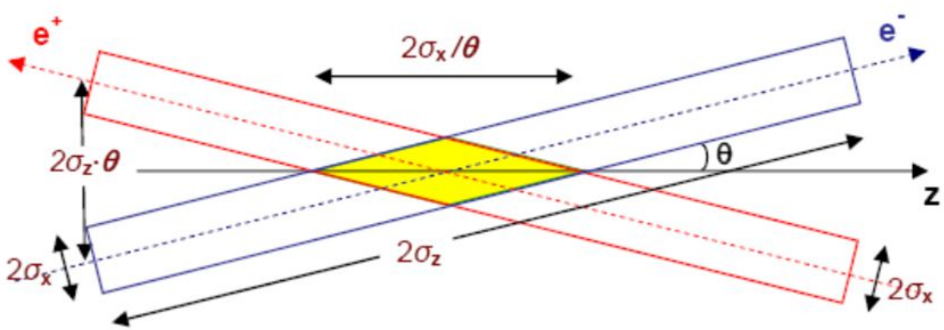
Website contents:
1) Talks ppt
2) Minutes

The main working fields:
1) Double ring shceme
2) Crab-waist parameters
3) Pretzel scheme
4) Dynamic aperture optimiazation (with FFS)
5) Boosters (conventional and alternating dipole field schemes)
6) Magnet error effects on DA
7) MDI
8) SppC lattice design
9) CEPC bunch lengtening effects (collective effects)
10)….

Machine constraints / given parameters
(D. Wang et al)

- Energy E_0
- Circumference C_0
- N_{IP}
- Beam power P_0
- β_y^*
- Emittance coupling factor κ_ε
- Bending radius ρ
- Piwinski angle Φ
- ξy enhancement by crab waist F_l~1.5
- Energy acceptance (DA)
- Phase advance per cell (FODO`





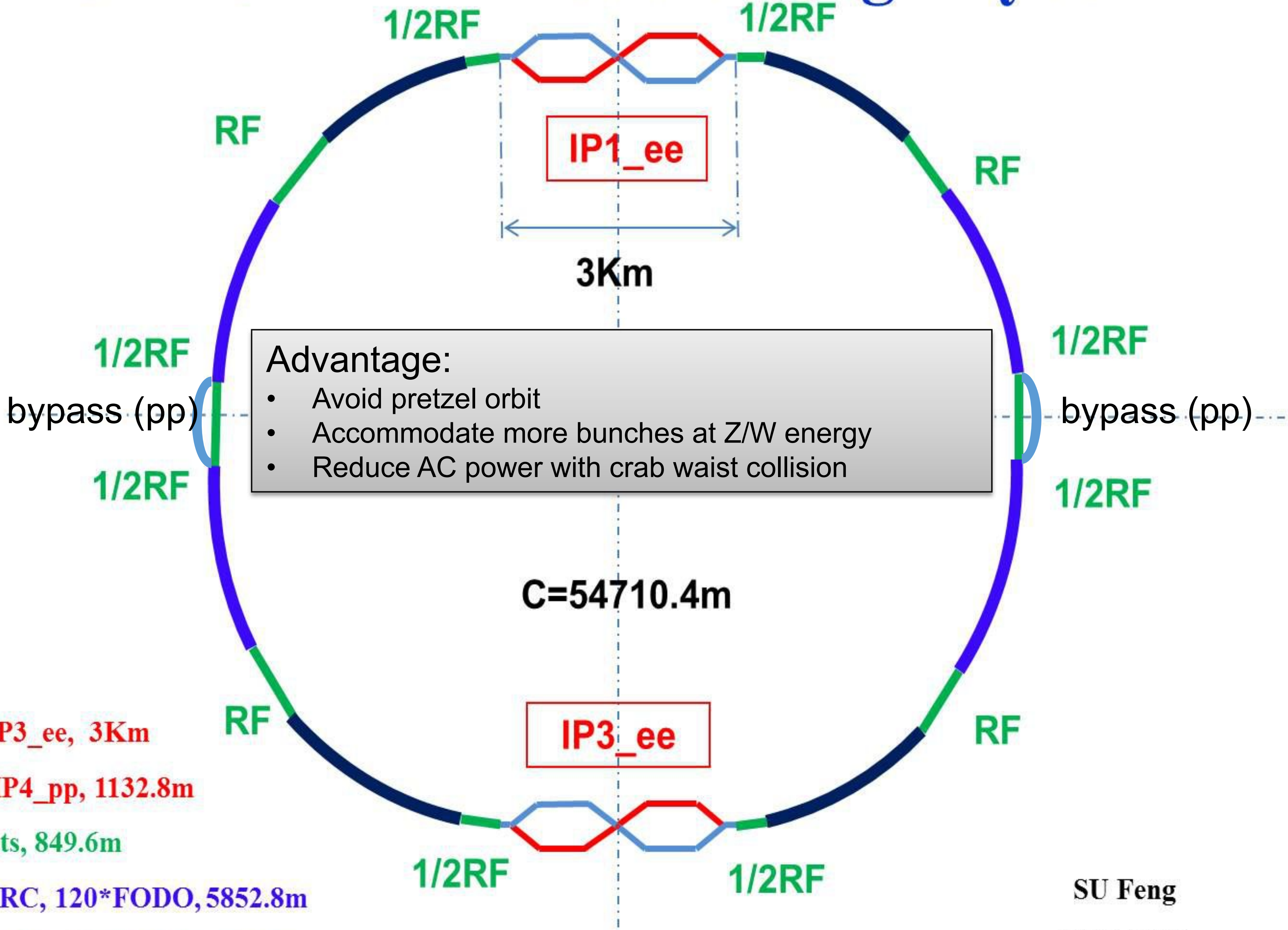
Primary parameter for CEPC local double ring (D. Wang et al)

	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	54		54		54
SR loss/turn (GeV)	3.1	2.96		2.96		0.062
Half crossing angle (mrad)	0	14.5	8.9	11.5	8.7	16.5
Piwinski angle	0	2	3.1	2	2	2.6
N_e/bunch (10^{11})	3.79	3.79	1.32	2.81	2.0	0.37
Bunch number	50	50	144	40	57	1100
Beam current (mA)	16.6	16.9	16.9	10.1	10.1	36.2
SR power /beam (MW)	51.7	50	50	30	30	2.2
Bending radius (km)	6.1	6.2	6.2	6.2	6.2	6.1
Momentum compaction (10^{-5})	3.4	3.0	2.3	2.6	2.5	5.4
β_{IP} x/y (m)	0.8/0.0012	0.306/0.0012	0.058/0.0016	0.22/0.001	0.115/0.001	0.3/0.001
Emittance x/y (nm)	6.12/0.018	3.34/0.01	2.32/0.0058	2.67/0.008	2.56/0.0078	1.18/0.0069
Transverse σ_{IP} (um)	69.97/0.15	32/0.11	11.6/0.097	24.3/0.09	17.6/0.088	18.8/0.083
ξ_x/IP	0.118	0.04	0.01	0.04	0.028	0.02
ξ_y/IP	0.083	0.11	0.11	0.11	0.11	0.042
V_{RF} (GV)	6.87	**3.7**	**3.6**	**3.6**	**3.7**	**0.28**
f_{RF} (MHz)	650	650	650	650	650	650
Nature σ_z (mm)	2.14	**3.3**	**3.0**	**3.2**	**3.0**	**3.0**
Total σ_z (mm)	2.65	4.4	4.0	4.2	4.0	3.0
HOM power/cavity (kw)	3.6	3.3	1.0	1.5	0.95	0.73
Energy spread (%)	0.13	0.13	0.13	0.13	0.13	0.05
Energy acceptance (%)	2	2	2	2	2	
Energy acceptance by RF (%)	6	**2.2**	**2.2**	**2.2**	**2.4**	**2.0**
n_γ	0.23	0.49	0.46	0.47	0.46	0.08
Life time due to beamstrahlung_cal (minute)	47	53	32	41	32	
F (hour glass)	0.68	0.73	0.89	0.69	0.7	0.83
L_{max}/IP (10^{34}cm^{-2}s^{-1})	2.04	2.97	2.75	2.03	2.07	1.25

CEPC single ring parameter (D. Wang et al)

	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
Beam current (mA)	16.6	16.6	55.5
SR power /beam (MW)	51.7	50	3.45
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
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

CEPC Partial Double Ring Layout



IP1_ee/IP3_ee, 3Km

IP2_pp/IP4_pp, 1132.8m

4Straights, 849.6m

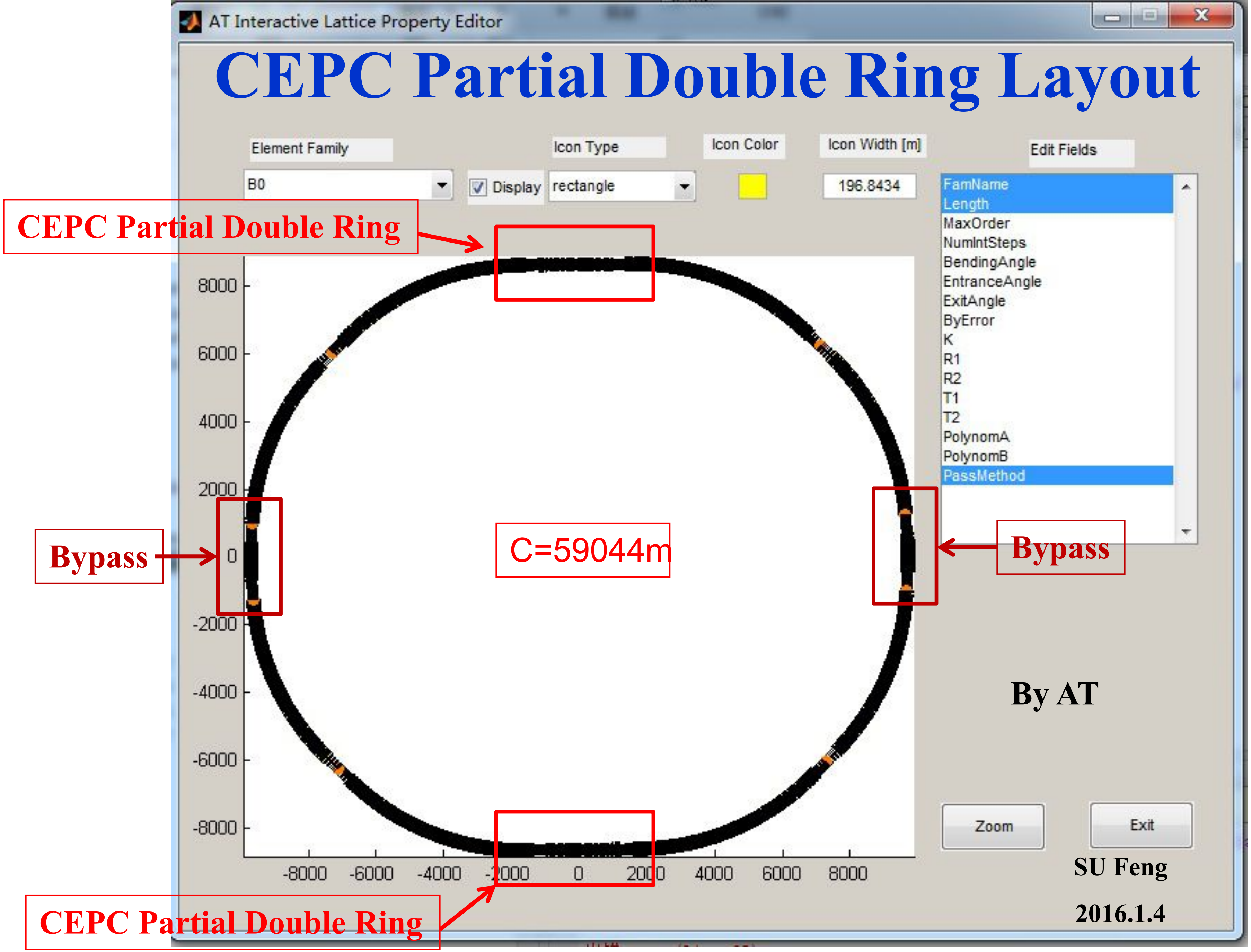
4Long ARC, 120*FODO, 5852.8m

4Short ARC, 100*FODO, 4908.8m

SU Feng

2015.10.12

CEPC Partial Double Ring Layout

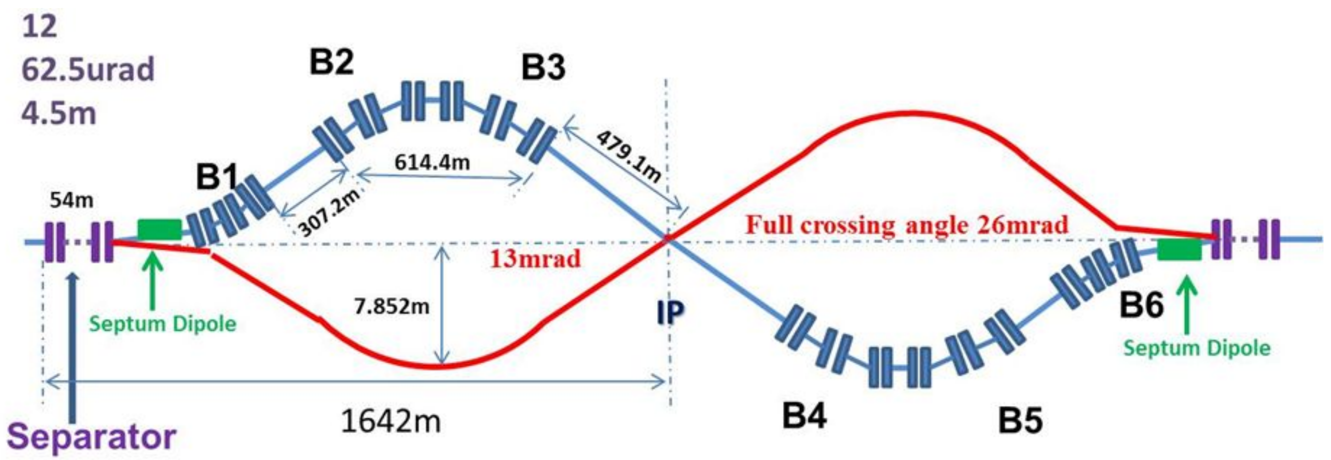


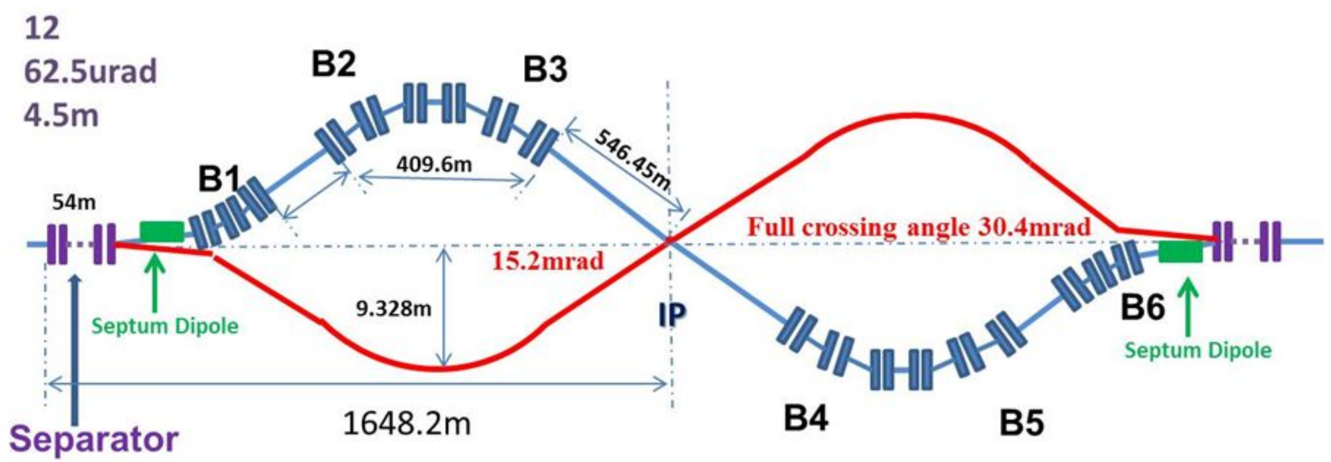
By AT

SU Feng

2016.1.4

CEPC Local Double Ring Lattice (F. Su et al)





For CEPC 120GeV beam:

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

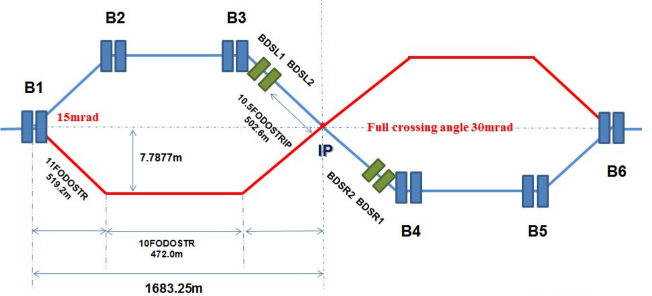
Using Septum Dipole after separator to acquire 13 mrad

Version 1.0

sufeng

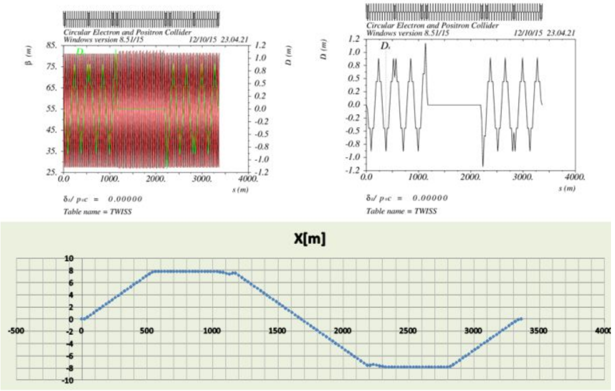
2015.12.24-new

CEPC Partial Double Ring Layout



Version0.0
sufeng
2015.10.12

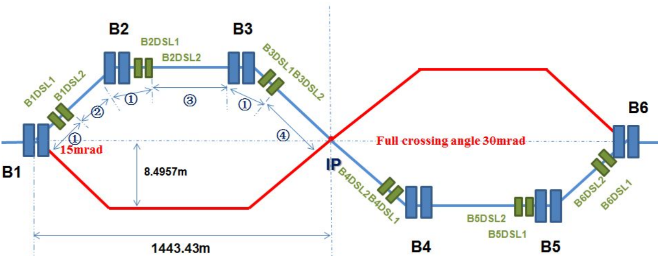
Orbit (DR_RING_e1) Version0.0



Dipole Strength Version0.0

	Angle(mrad)	L(m)	Rho(m)	Brho(E0/c) (T/m)	B(T)	Ek(KeV)	KeV/m
B0	3.506	19.6	5590.42	400	0.07155	685.173	34.9578
B1	-7.5	19.6	2613.33	400	0.15306	1465.71	74.7813
B2	7.5	19.6	2613.33	400	0.15306	1465.71	74.7813
B3	2.499894	19.6	7840.33	400	0.05102	488.551	24.9261
BDSL1	-19.865386	19.6	986.641	400	0.40542	3882.26	198.075
BDSL2	29.865598	19.6	656.273	400	0.60950	5836.59	297.785
BDSR2	-29.865598	19.6	656.273	400	0.60950	2836.59	297.785
BDSR1	19.865686	19.6	986.641	400	0.40542	3882.26	198.075
B4	-2.499894	19.6	7840.33	400	0.05102	488.551	24.9261
B5	-7.5	19.6	2613.33	400	0.15306	1465.71	74.7831
B6	7.5	19.6	2613.33	400	0.15306	1465.71	74.7831

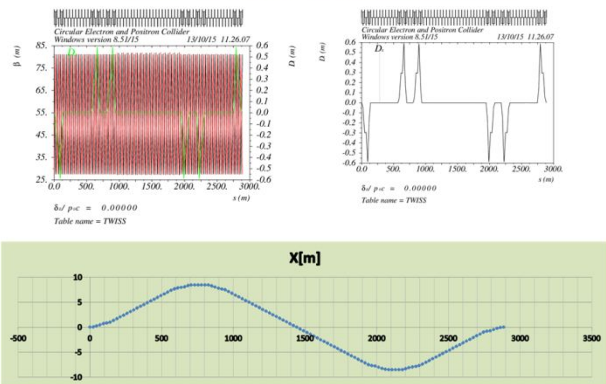
CEPC Partial Double Ring Layout



① : 141.6m (3FODO)
② : 424.8m (9FODO)
③ : 94.4m (2FODO)
④ : 502.6m (10.5FODO)

Version0.1
sufeng

Orbit (DR_RING_e1) Version0.1

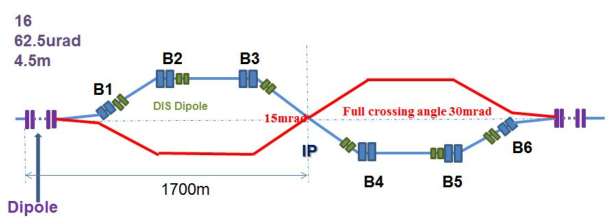


Dipole Strength Version0.1

	Angle(mrad)	L(m)	Rho(m)	Brho(E0/c) (T/m)	B(T)	Ek(KeV)	KeV/m
B0	3.506	19.6	5590.42	400	0.07155	685.173	34.9578
B1	-5.0	19.6	3920.0	400	0.10204	977.143	49.8542
B1DSL1	9.9336755	19.6	1973.09	400	0.20273	1941.32	99.0417
B1DSL2	-14.93323	19.6	1312.51	400	0.30476	2918.38	148.897
B2	5.0	19.6	3920.0	400	0.10204	977.143	49.8542
B2DSR1	-9.933058	19.6	1973.09	400	0.20273	1941.32	99.0417
B2DSR2	14.93292	19.6	1312.51	400	0.30476	2918.38	148.897
B3	5.0	19.6	3920.0	400	0.10204	977.143	49.8542
B3DSR1	-9.93336	19.6	1973.09	400	0.20273	1941.32	99.0417
B3DSR2	14.93323	19.6	1312.51	400	0.30476	2918.38	148.897

CEPC Partial Double Ring Layout

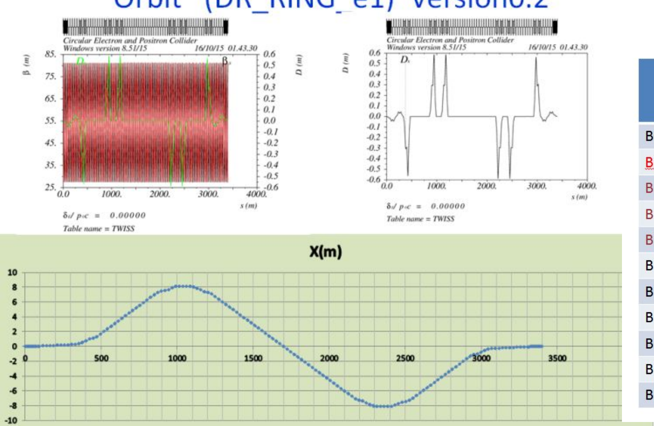
16
62.5urad
4.5m



For CEPC 120GeV beam:
➢Max. deflection per separator is 66μrad.
Using Dipole after seperator to acquire 15 mrad

Version 0.2
sufeng
2015.10.15

Orbit (DR_RING_e1) Version0.2



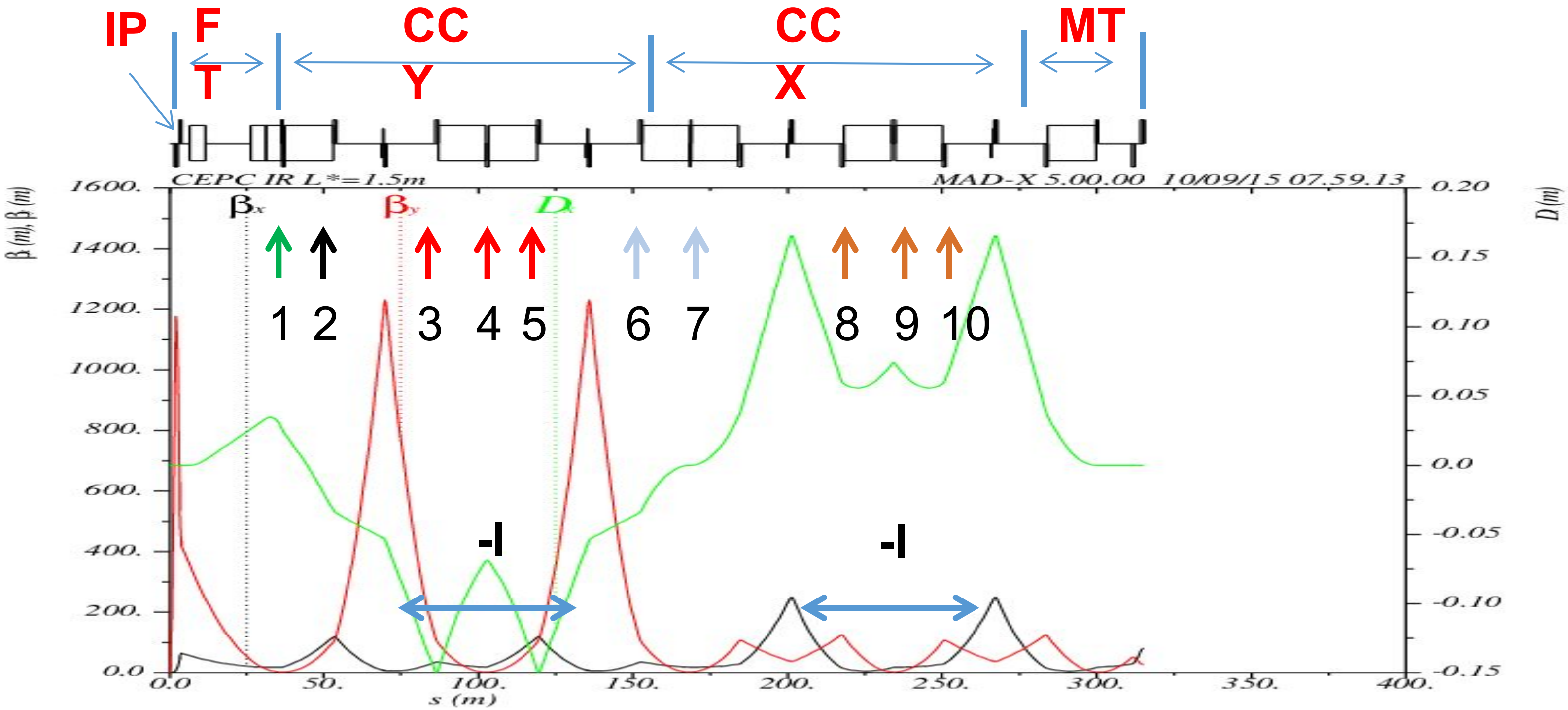
Dipole Strength Version 0.2

	Angle(mrad)	L(m)	Rho(m)	Brho(E0/c) (T/m)	B(T)	Ek(KeV)	KeV/m
B0	3.506	19.6	5590.42	400	0.07155	685.173	34.9578
Bsp	0.0625	4.9	78400	400	0.00510	48.8571	9.97
B1	-4.416	19.6	4438.41	400	0.09012	863.031	44.031
B1DSL1	9.021	19.6	2172.71	400	0.18410	1962.96	89.947
B1DSL2	-14.187	19.6	1381.55	400	0.28953	2772.55	141.456
B2	5.0	19.6	3920.0	400	0.10204	977.143	49.8542
B2DSR1	-9.933058	19.6	1973.09	400	0.20273	1941.32	99.0417
B2DSR2	14.93292	19.6	1312.51	400	0.30476	2918.38	148.897
B3	5.0	19.6	3920.0	400	0.10204	977.143	49.8542
B3DSR1	-9.93336	19.6	1973.09	400	0.20273	1941.32	99.0417
B3DSR2	14.93323	19.6	1312.51	400	0.30476	2918.38	148.897

IR Design and sextupoles (Y.W. Wang et al)

- Idea from Brinkmann
  - correct the high order chromaticity, break down of –I, second order dispersion

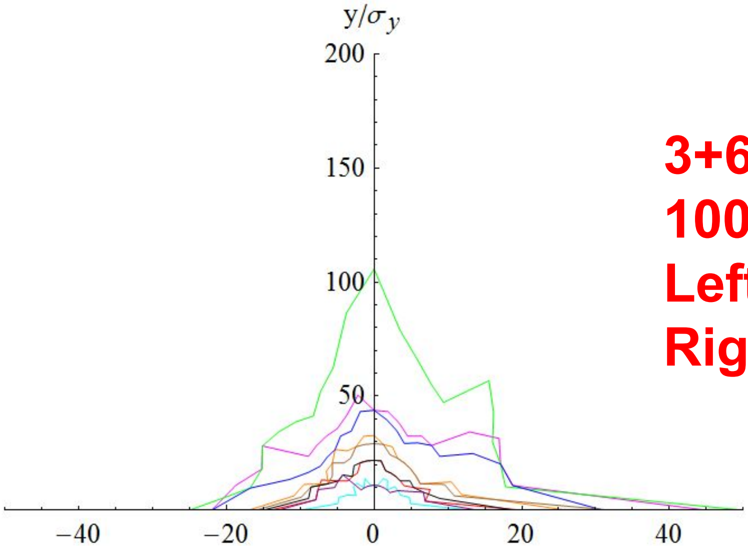
FFS_3.0mm_v3.0_Sep_2015, Yiwei Wang

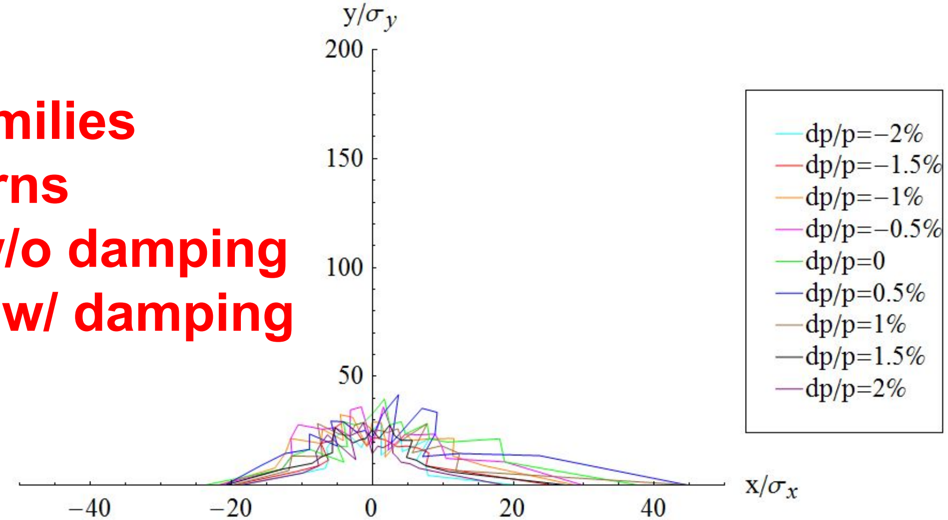


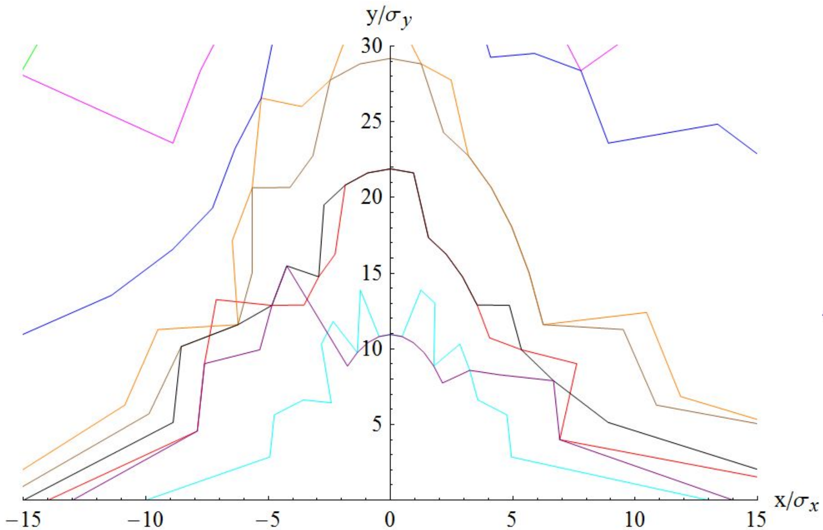
CEPC Single Ring DA Study (Y.W. Wang et al)

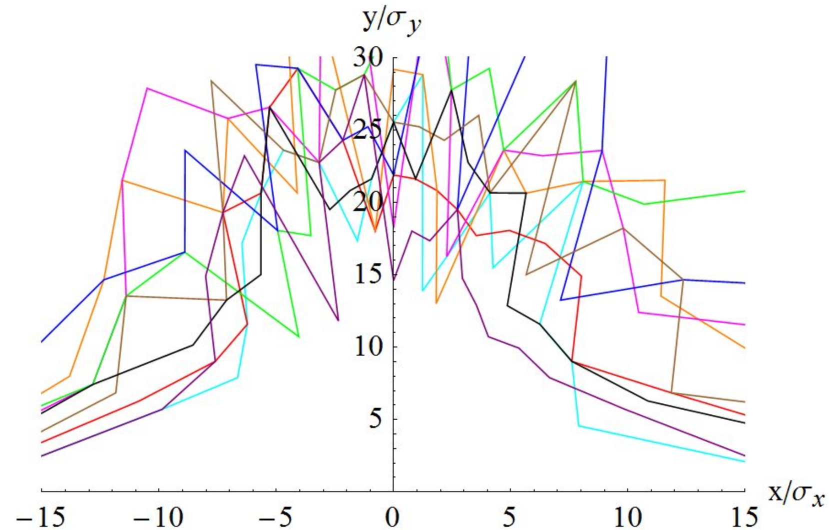
FFS_3.0mm_v3.0_Sep_2015, Yiwei Wang

3+6 families
100 turns
Left: w/o damping
Right: w/ damping

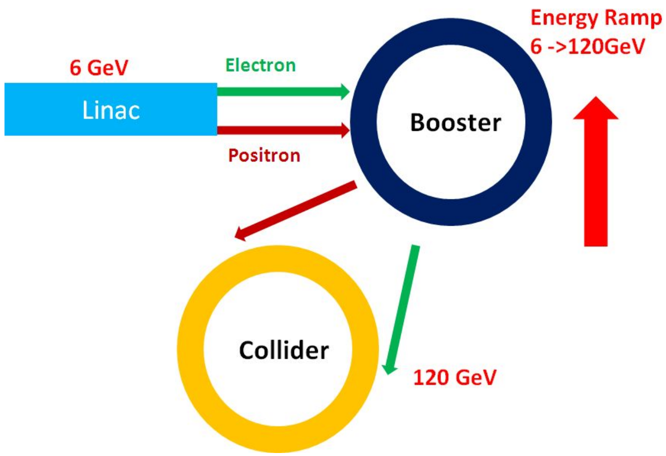




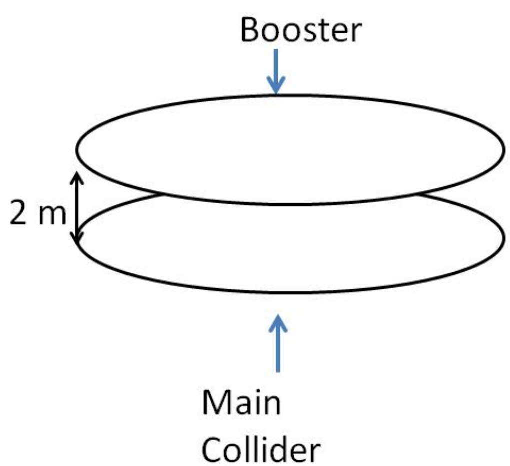


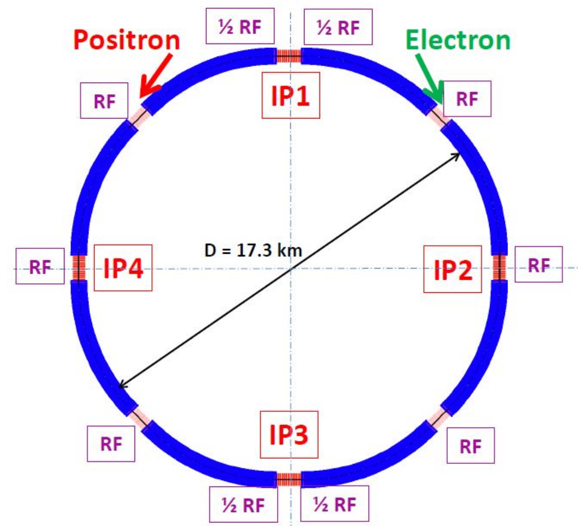


CEPC injectors

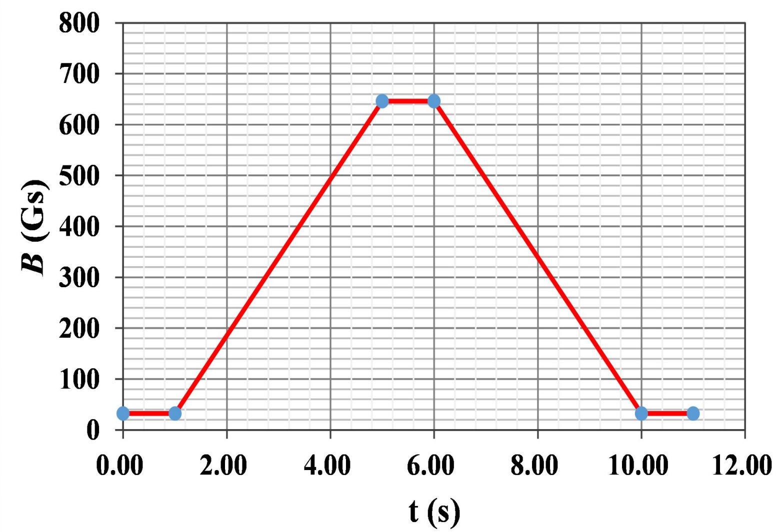


Top-up Full-energy Injection





Booster Cycle (0.1 Hz)

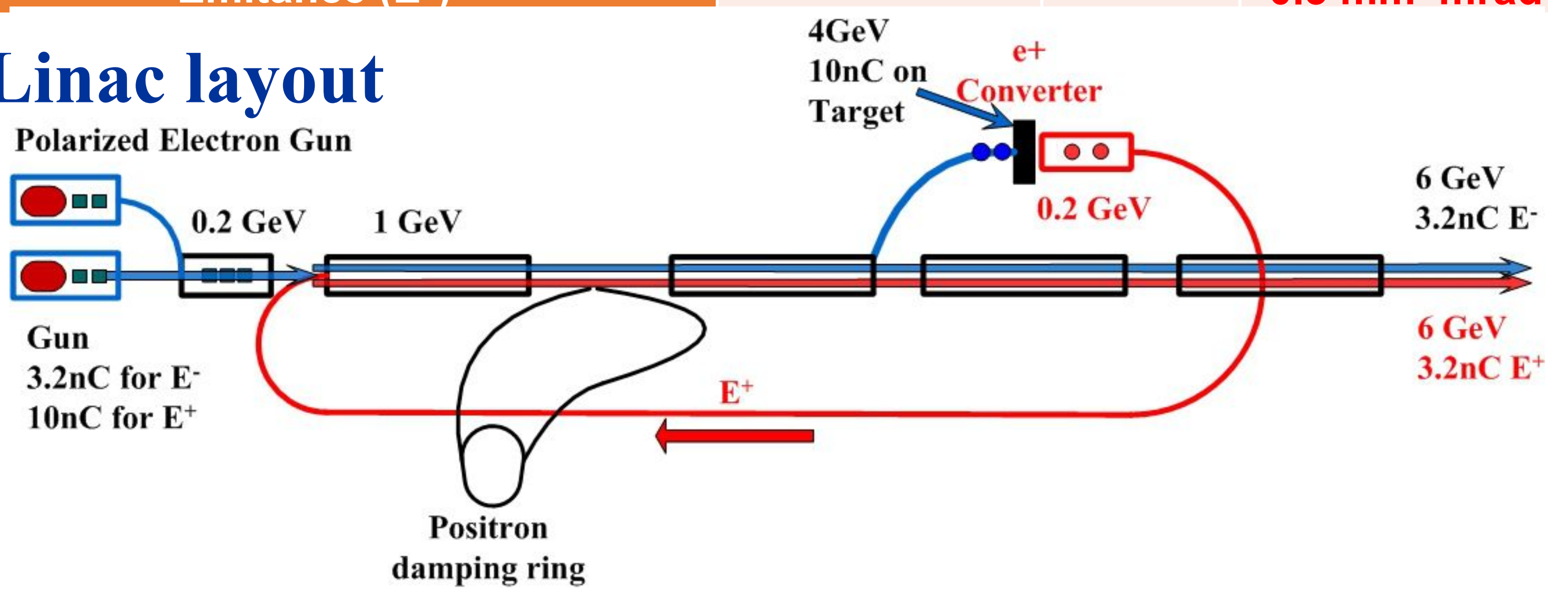


CEPC Injection linac overview

- **Main parameters**

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**

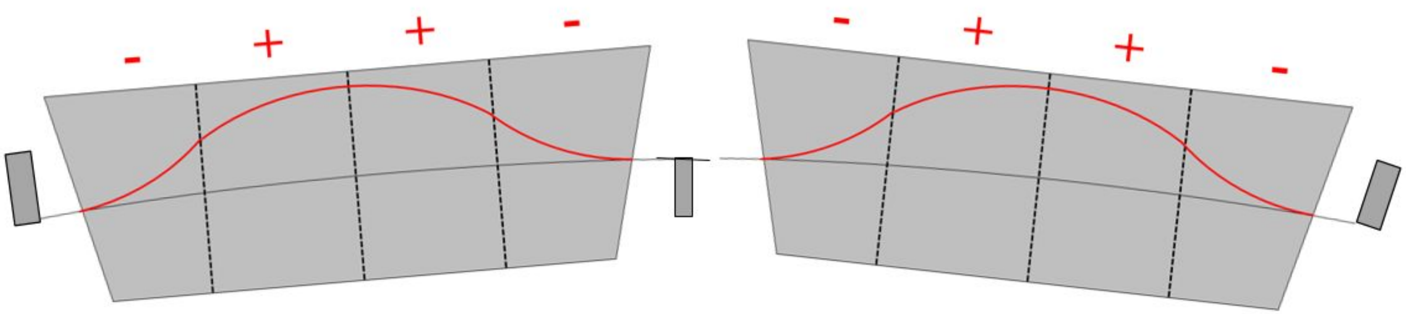
Linac layout



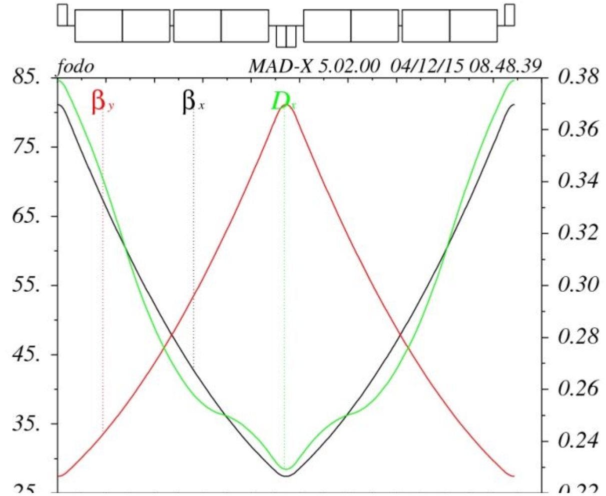
CEPC new booster design with alternating (Wiggling) bend scheme (T.J. Bian et al)

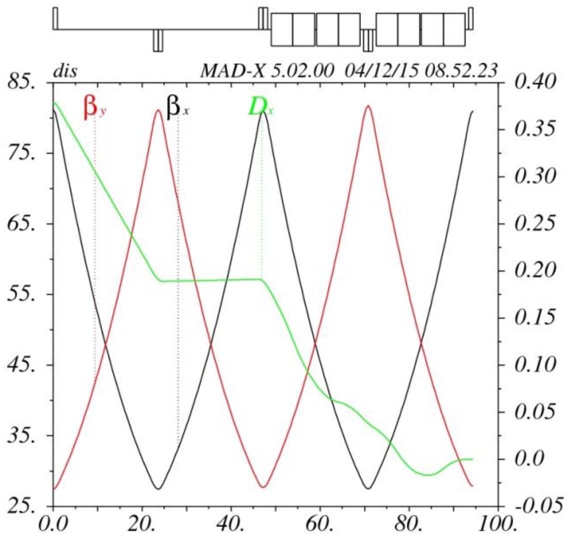
• Introduction of Wiggling Bend Scheme

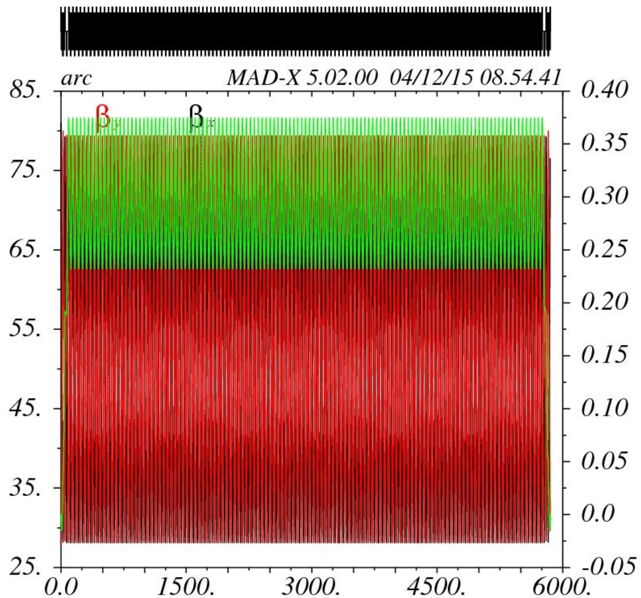
- ➢ The inject energy is 6GeV.
- ➢ If all the dipoles have the same sign, 33Gs@6GeV may cause problem.
- ➢ In wiggling bend scheme, adjoining dipoles have different sign to avoid the low field problem.
- ➢ Shorten the Damping times greatly.
- ➢ The picture below shows the FODO structure.

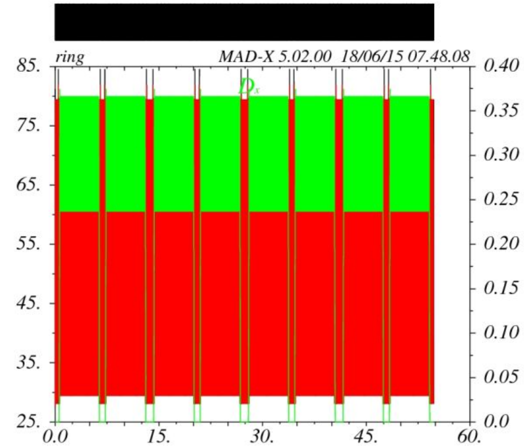


New Booster Linear Optics (T.J. Bian et al)









Booster Parameters (T.J. Bian et al)

- Main difference in parameters between Pre-CDR booster (old) and the alternating field booster (new)

	Old@6GeV	New@6GeV
Parameter		
U0 [MeV/turn]	0.019	0.70
Damping times(x/y) [s]	115.61	3.12
Emittances(x) [pi nm]	0.015	0.11
Strength of dipole [Gs]	33	-164.3/+229.9
Beam offset in dipole[cm]	0	2.3
Length of dipole [m]	19.6*1	4.9*4
Length of FODO [m]	47.2	47.2

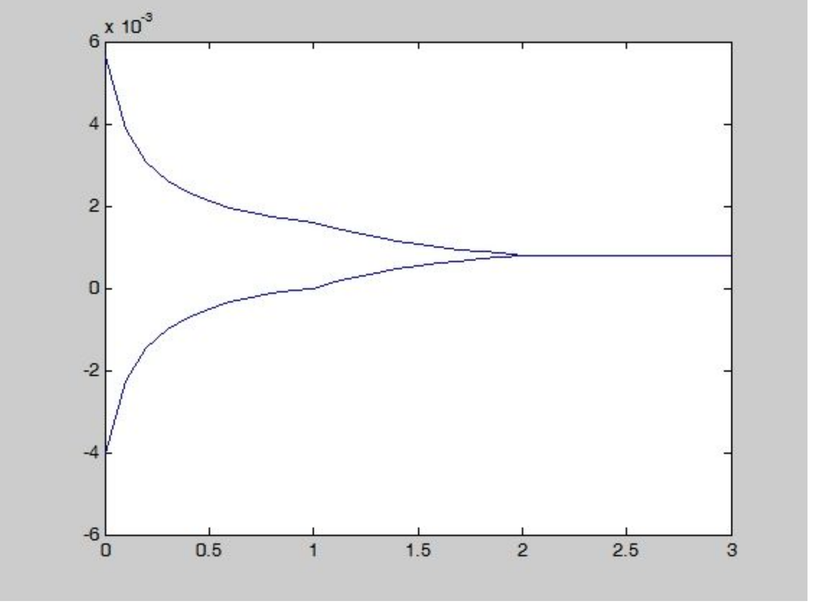
New Booster Parameters (T.J. Bian et al)

Booster Parameter List for Alternating Magnetic Field Scheme.

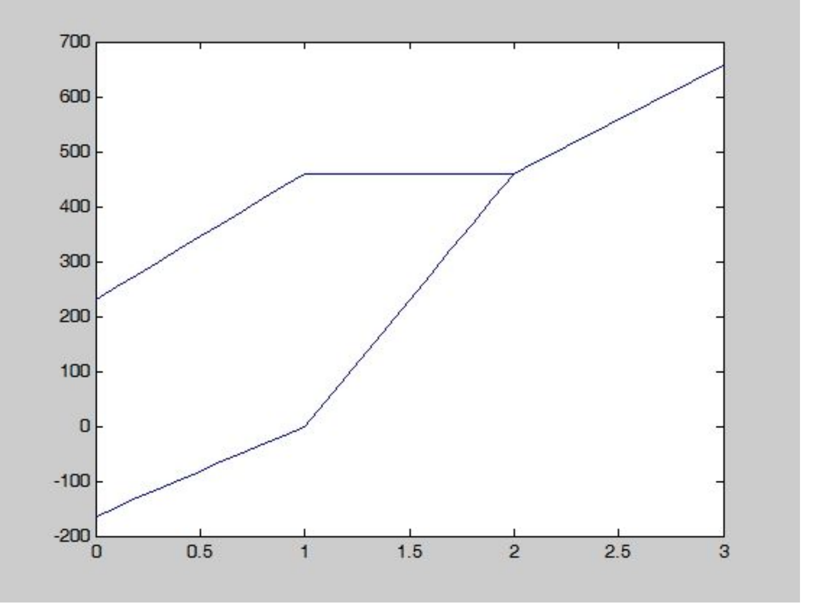
Parameter	Unit	Value
Beam energy [E]	GeV	6
Circumference [C]	km	54.3744
Revolutionfrequency[f_0]	kHz	5.5135
SR power / beam [P]	MW	6.41E-04
Beam off-set in bend	cm	2.30E+00
Momentum compaction factor[α]		2.70E-05
Bending radius [r]	m	
n_B/beam		50
Lorentz factor [g]		11742.9
Magnetic rigidity [Br]	T·m	20.01
Beam current / beam [I]	mA	0.9197
Bunchpopulation[N_e]		2.08E+10
Bunch charge [Q_b]	nC	3.34
emittance-horizontal[e_x] inequilibrium	m·rad	1.11E-10
injected from linac	m·rad	3.00E-07
emittance-vertical[e_y] inequilibrium	m·rad	1.11E-12
injected from linac	m·rad	3.00E-07

Parameter	Unit	Value
RF voltage [Vrf]	GV	0.213867
RF frequency [frf]	GHz	1.3
Harmonic number [h]		235800
Synchrotronoscillationtune[n_s]		0.190183
Energy acceptance RF [h]	%	5.95053
SR loss / turn [U0]	GeV	6.97E-04
Energyspread[s_d] inequilibrium	%	0.01610
injected from linac	%	0.1
Bunch length[s_d] inequilibrium	mm	0.05
injected from linac	mm	~1.5
Transversedampingtime[t_x]	ms	3124.6
	turns	17228
Longitudinaldampingtime[t_e]	ms	1.6
	turns	9

New Booster Operation (T.J. Bian)



Angle of dipole v.s. time



Field of dipole v.s. time

CEPC MDI design study (S. Bai et al)

Beam background

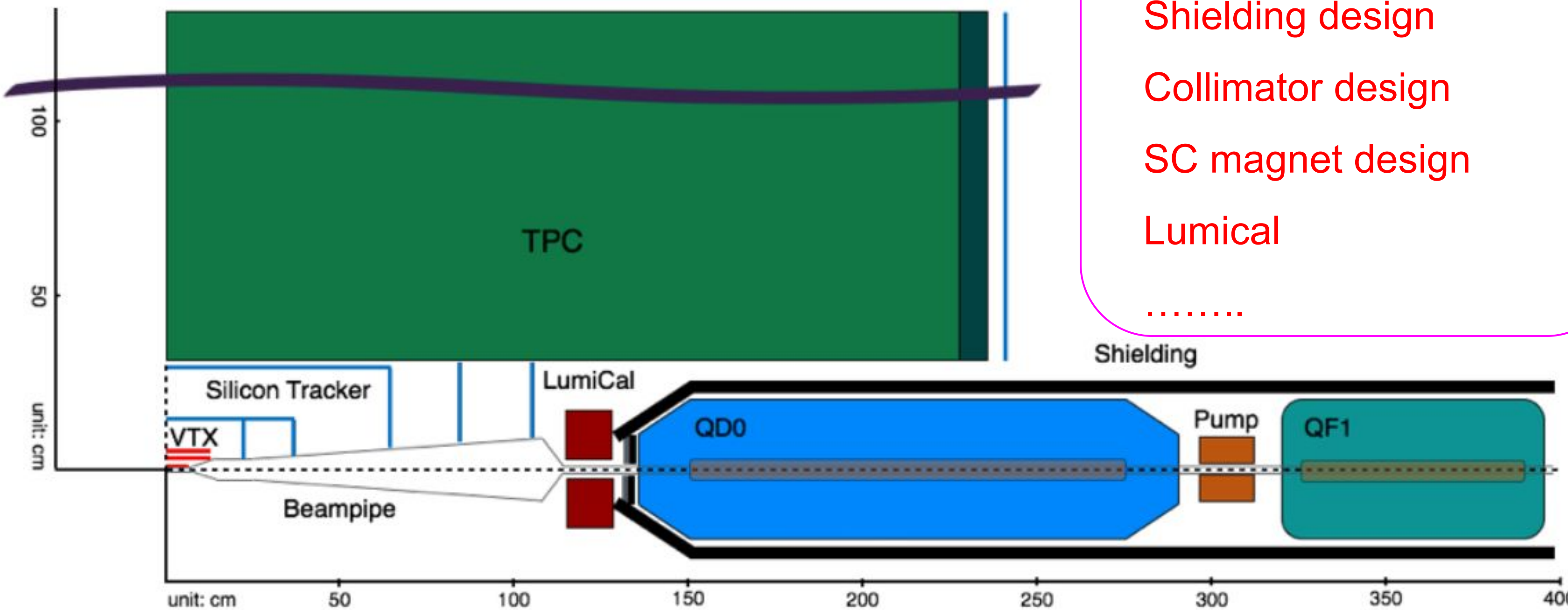
Shielding design

Collimator design

SC magnet design

Lumical

……..



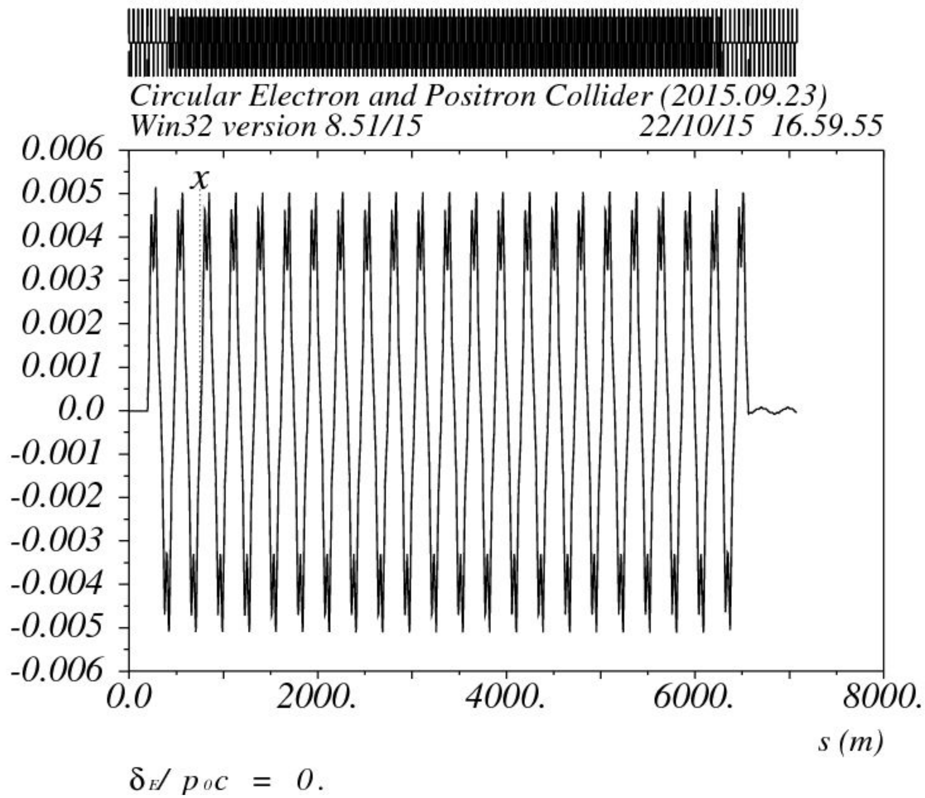
Illustrated design without realistic considerations

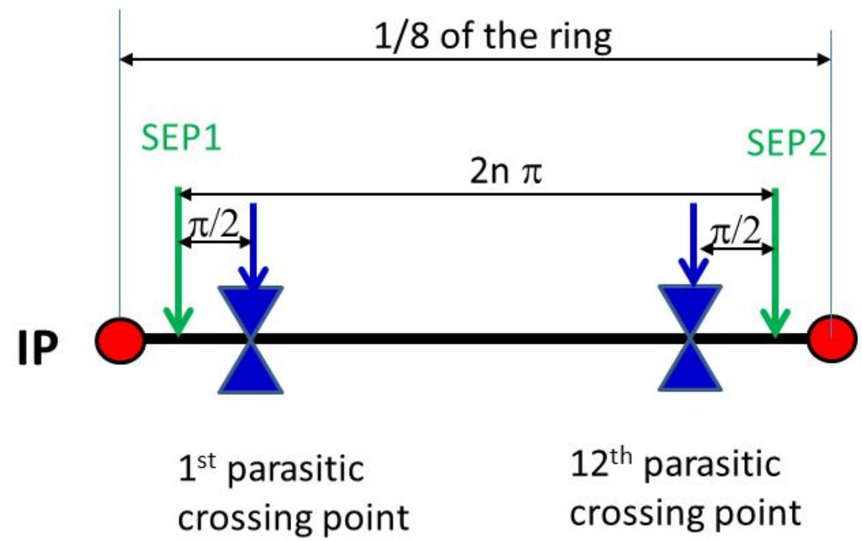
To meet requirements from both accelerator and detector

CEPC Pretzel Orbit Design

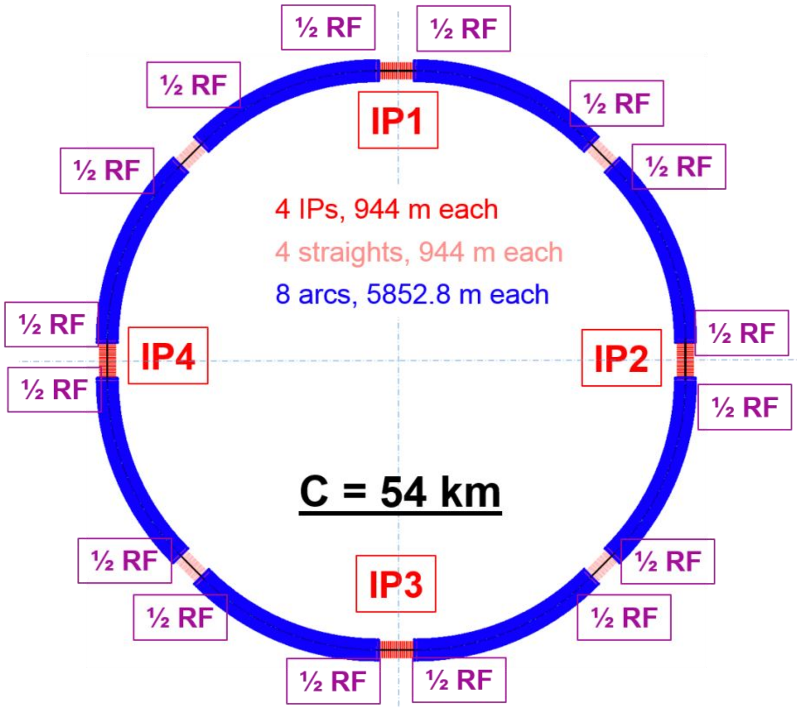
(Huiping Geng)

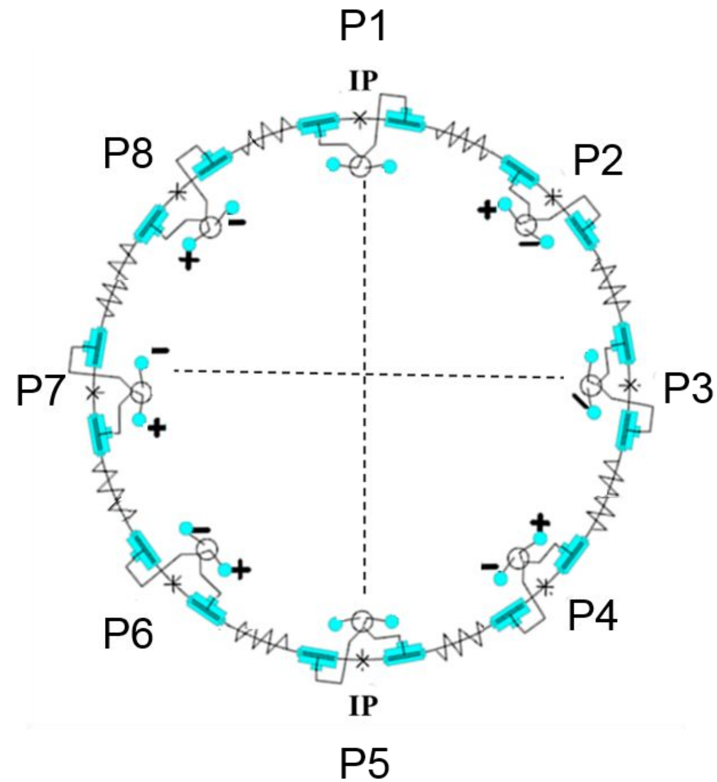
Find proper positon and strength of static electric separators, then the pretzel orbit can be well generated.





CEPC Pretzel Scheme





- 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

SRF Parameters and R&D Goals

Parameters	CEPC-Collider	CEPC-Booster
Cavity Type	650 MHz 5-cell Nitrogen-doped Nb	1.3 GHz 9-cell Nitrogen-doped Nb
Operating E_{acc}	15.5 MV/m	19.3 MV/m
Operating Q_0	4E10 @ 2K	2E10 @ 2K
Cavity vertical test qualification	20 MV/m @ 4E10	23 MV/m @ 2E10
Input coupler power (CW)	320 kW	20 kW (DF 20%)
HOM damper power (CW)	10 kW ferrite + 1 kW hook	50 W (hook + ceramic)
Cavity number	384	256
Cryomodule number	96 (4 cav. / module)	32 (8 cav. / module)

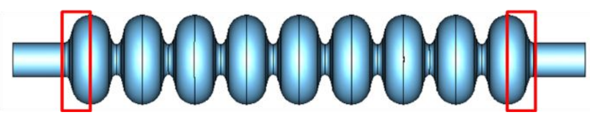
And cryomodule heat load …

CEPC Cryomodule Layout

CEPC Booster 1.3 GHz Cryomodule

Euro-XFEL/ILC/LCLS-II type

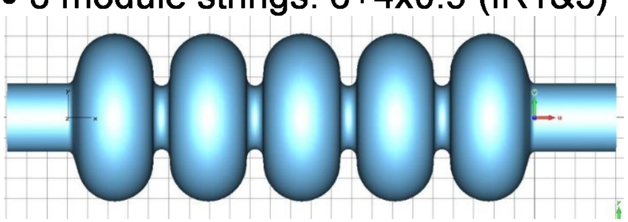
- 8 1.3 GHz 9-cell cavities per module
  2 HOM couplers per cavity
  1 beamline HOM absorber at 70 K
- module length: 12 m (no SCQ)
- 4 modules per module string
  connect without cryo & vac interval
- module string length: 48 m
- 8 module strings: 6+4x0.5 (IR1&3)

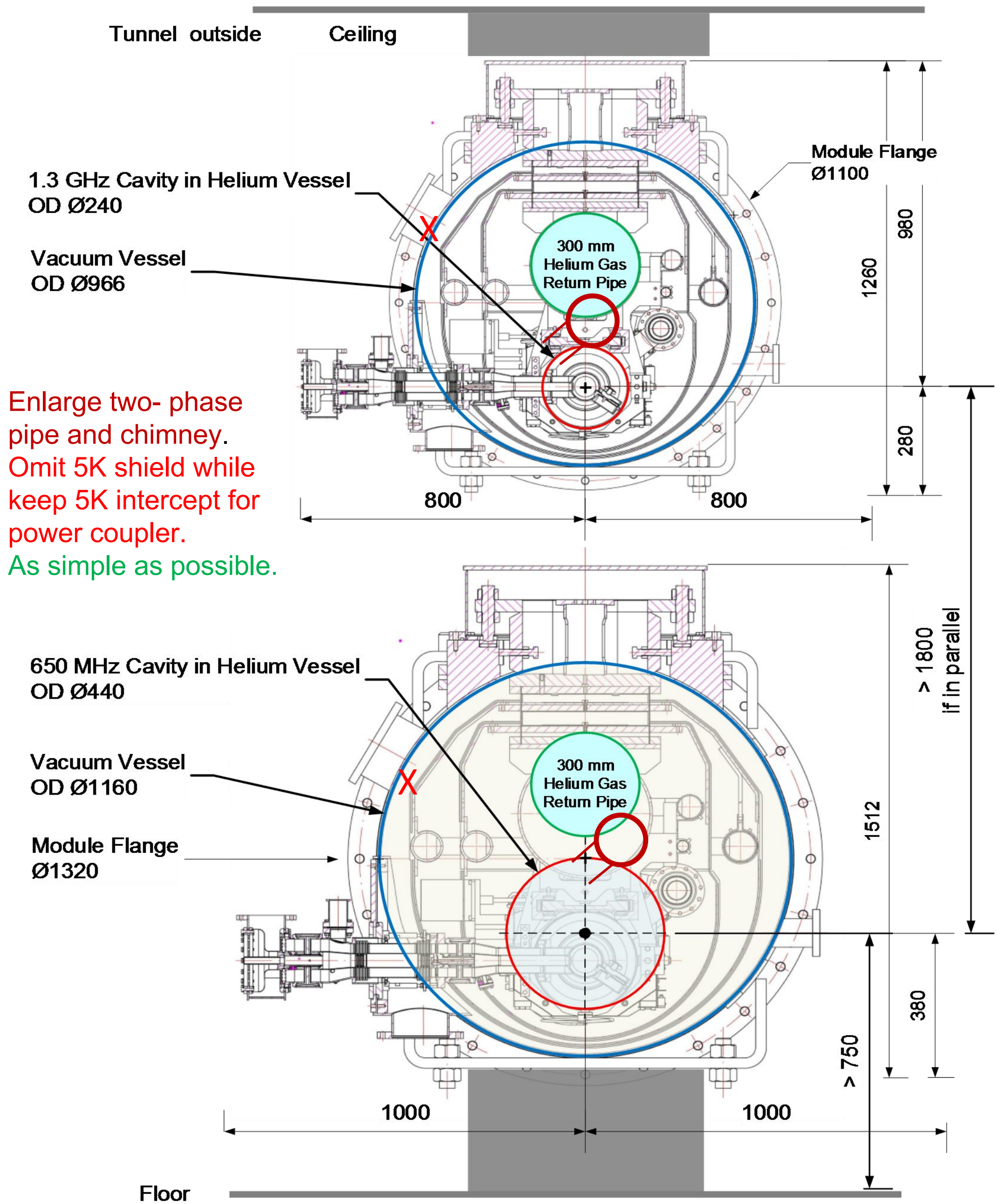


CEPC Collider 650 MHz Cryomodule

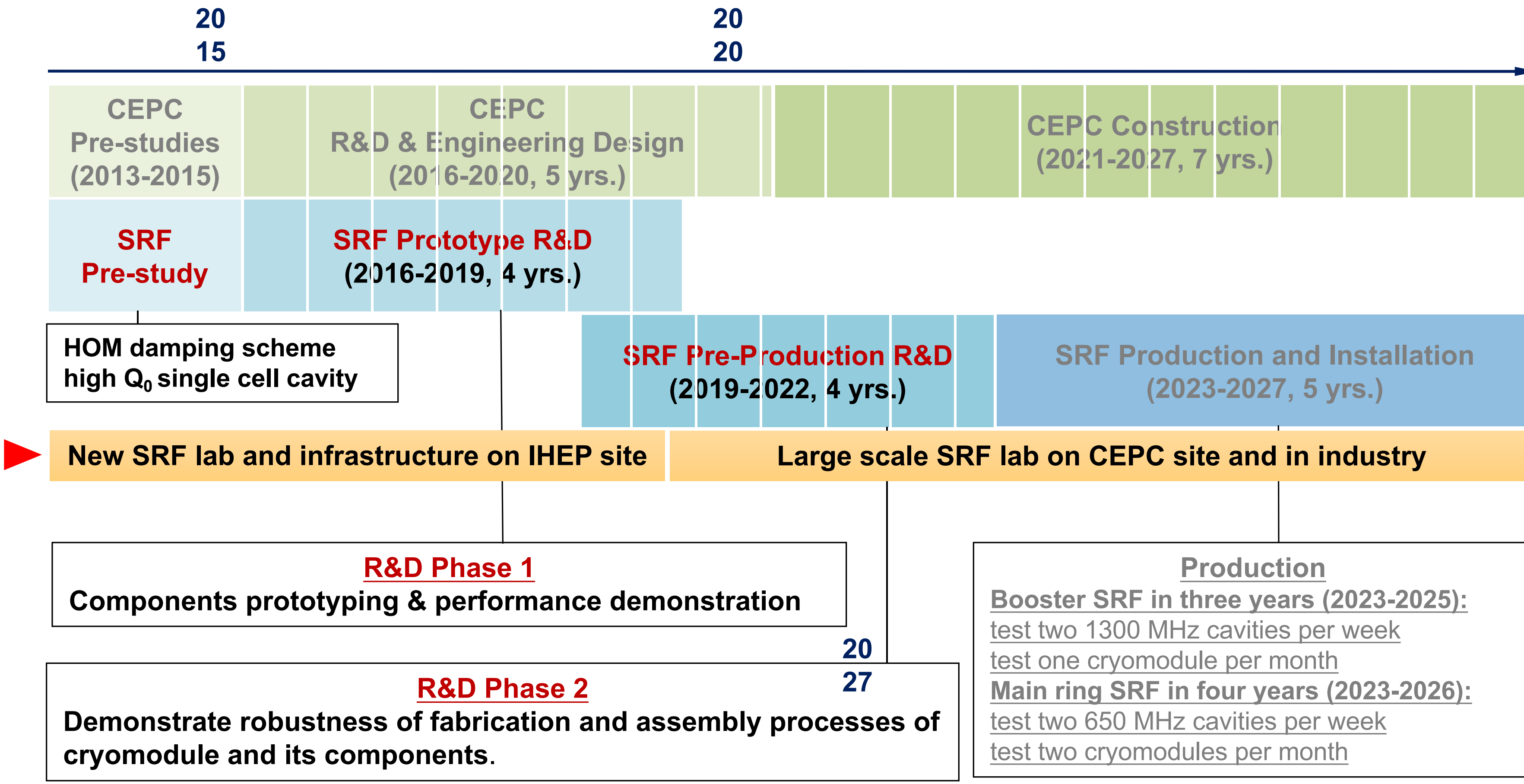
scaled from 1.3 GHz cryomodule

- 4 650 MHz 5-cell cavity per module
  2 HOM couplers per cavity
  2 beamline HOM absorbers at RT
- module length: 10 m
- 12 modules per module string
- module string length: 120 m
- 8 module strings: 6+4x0.5 (IR1&3)





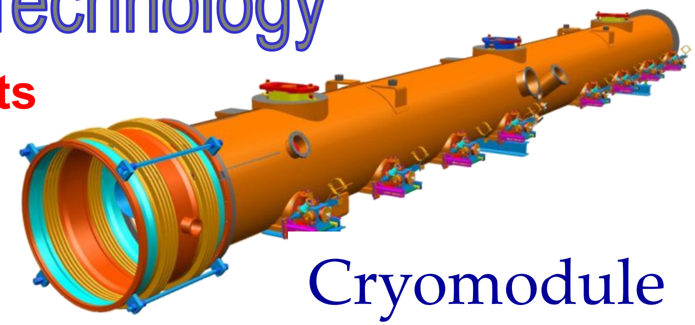
CEPC SRF R&D Plan
(Example)



Global Superconducting RF Linac Technology

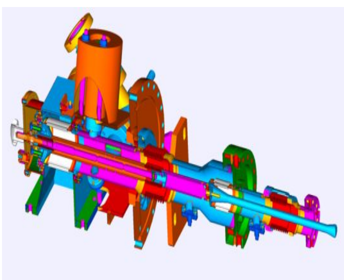
CEPC has common interests

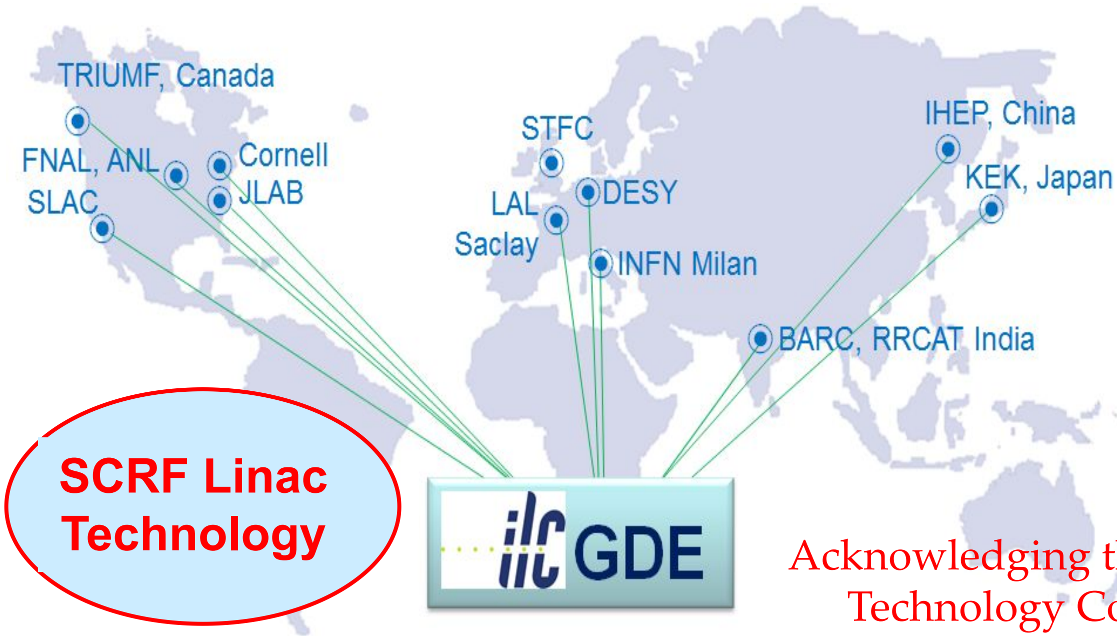
RF Cavity



Cryomodule

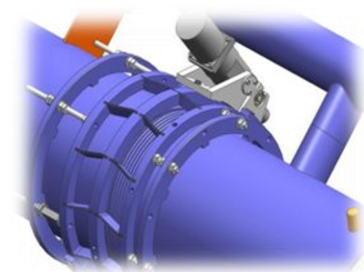
Power Coupler





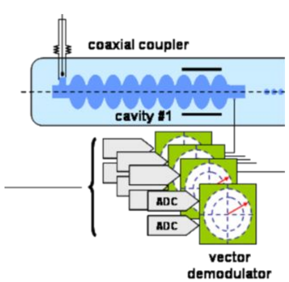
SCRF Linac Technology

Frequency Tuner



Acknowledging the efforts of the Tesla Technology Collaboration (TTC)

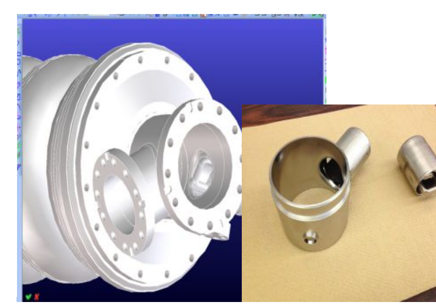
LLRF



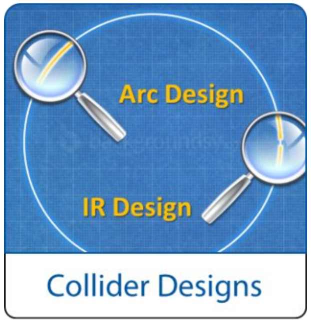
RF power

Klystron (10 MW)
1.65 ms, 10 Hz Multi-beam Klystron

HOMs
(higher order modes)
coupler

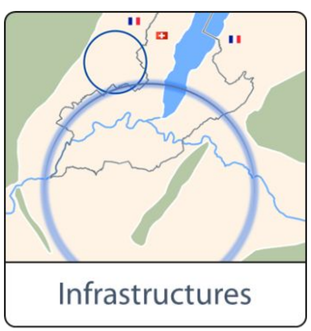


FCC Scope: Accelerator and Infrastructure



FCC-hh: **100 TeV pp collider as long-term goal**
→ defines infrastructure needs
FCC-ee: **e^+e^- collider**, potential intermediate step
FCC-he: **integration aspects** of pe collisions

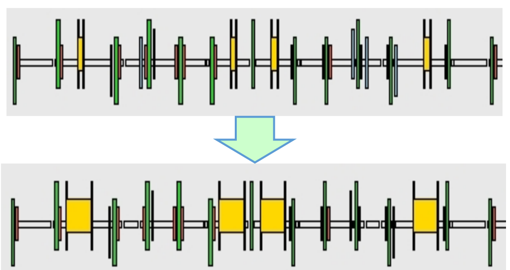
Push key technologies
in dedicated R&D programmes e.g.
16 Tesla magnets for **100 TeV** pp in **100 km**
SRF technologies and RF power sources



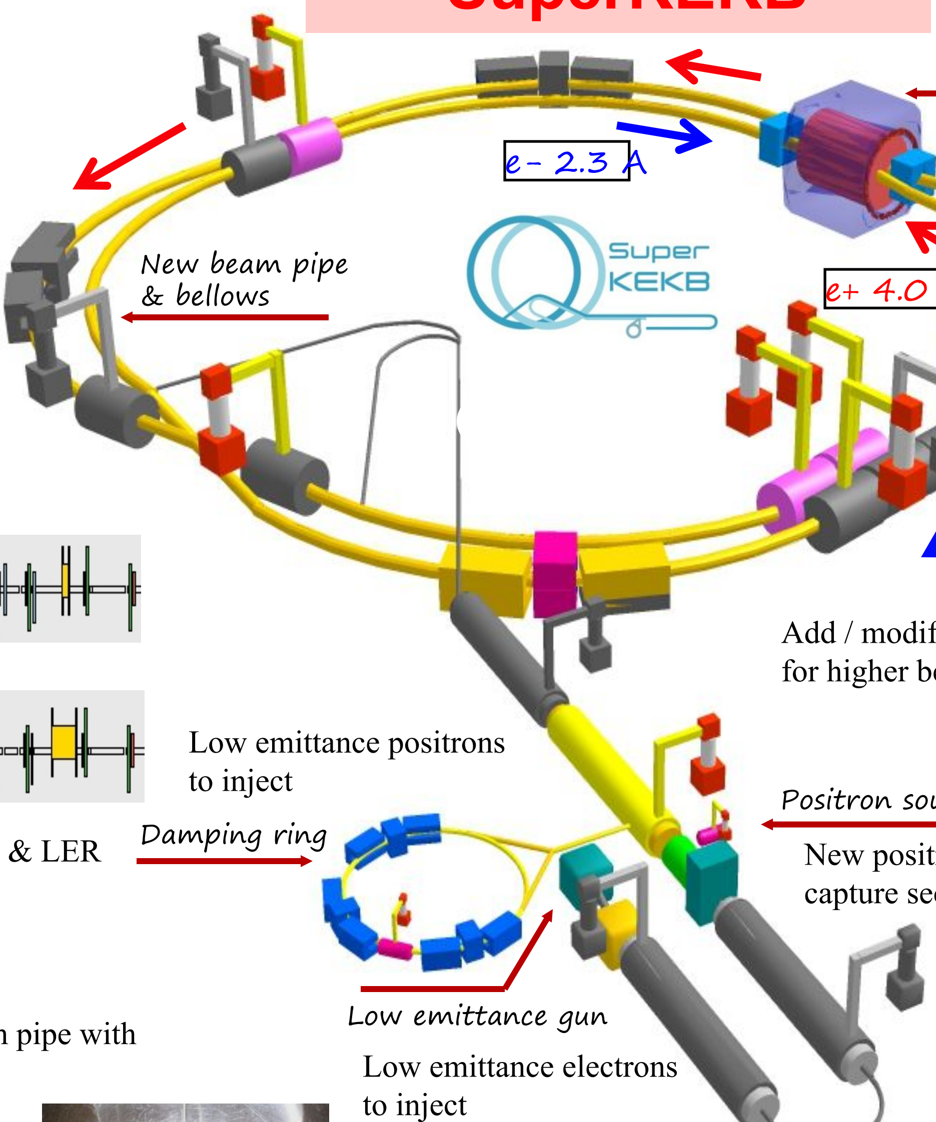
Tunnel infrastructure in Geneva area, linked to CERN accelerator complex
Site-specific, requested by European strategy

SuperKEKB

Replace short dipoles with longer ones (LER)



Redesign the lattices of HER & LER to squeeze the emittance

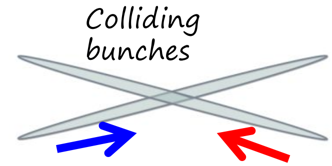


Low emittance positrons to inject

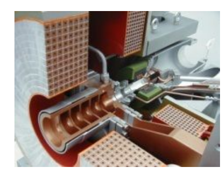
Add / modify RF systems for higher beam current

New positron target / capture section

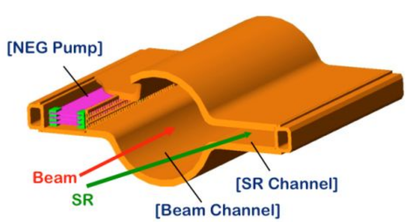
Low emittance electrons to inject



New superconducting /permanent final focusing quads near the IP



TiN-coated beam pipe with antechambers



L=8·10^{35} s^{-1}cm^{-2}

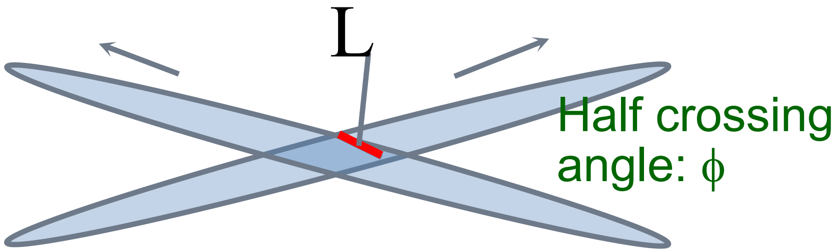
$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right)$$

x 40 Gain in Luminosity

CEPC has common interests

Nano-Beam Scheme

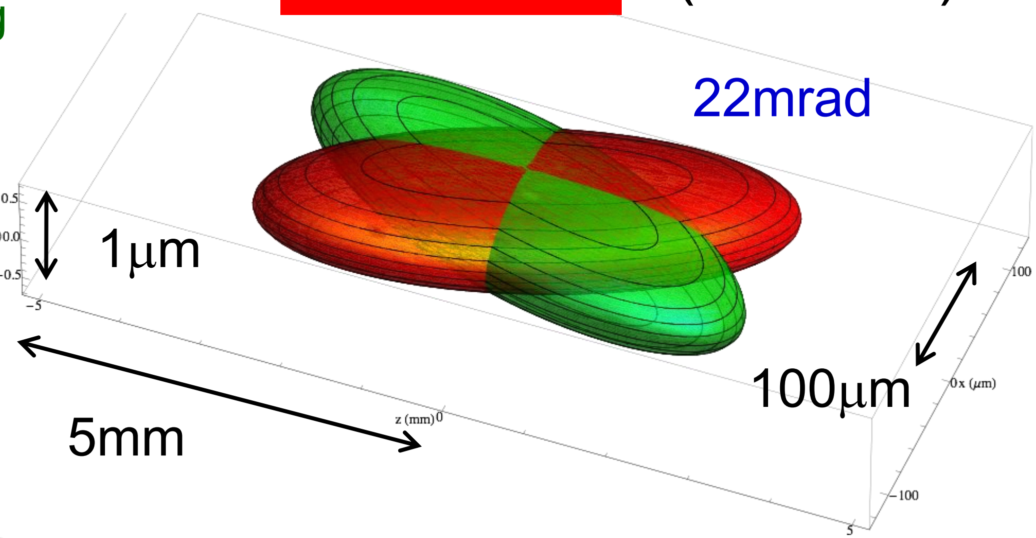
CEPC has common interests



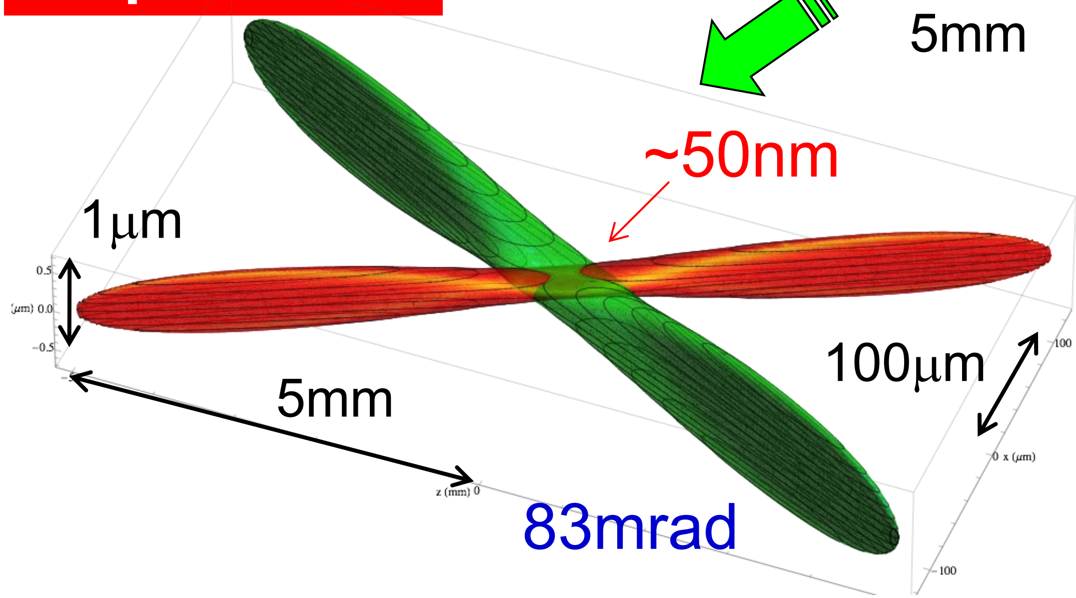
Hourglass condition:

$\beta_y^* >\sim L = \sigma_x / \phi$

KEKB (w/o crab)



SuperKEKB



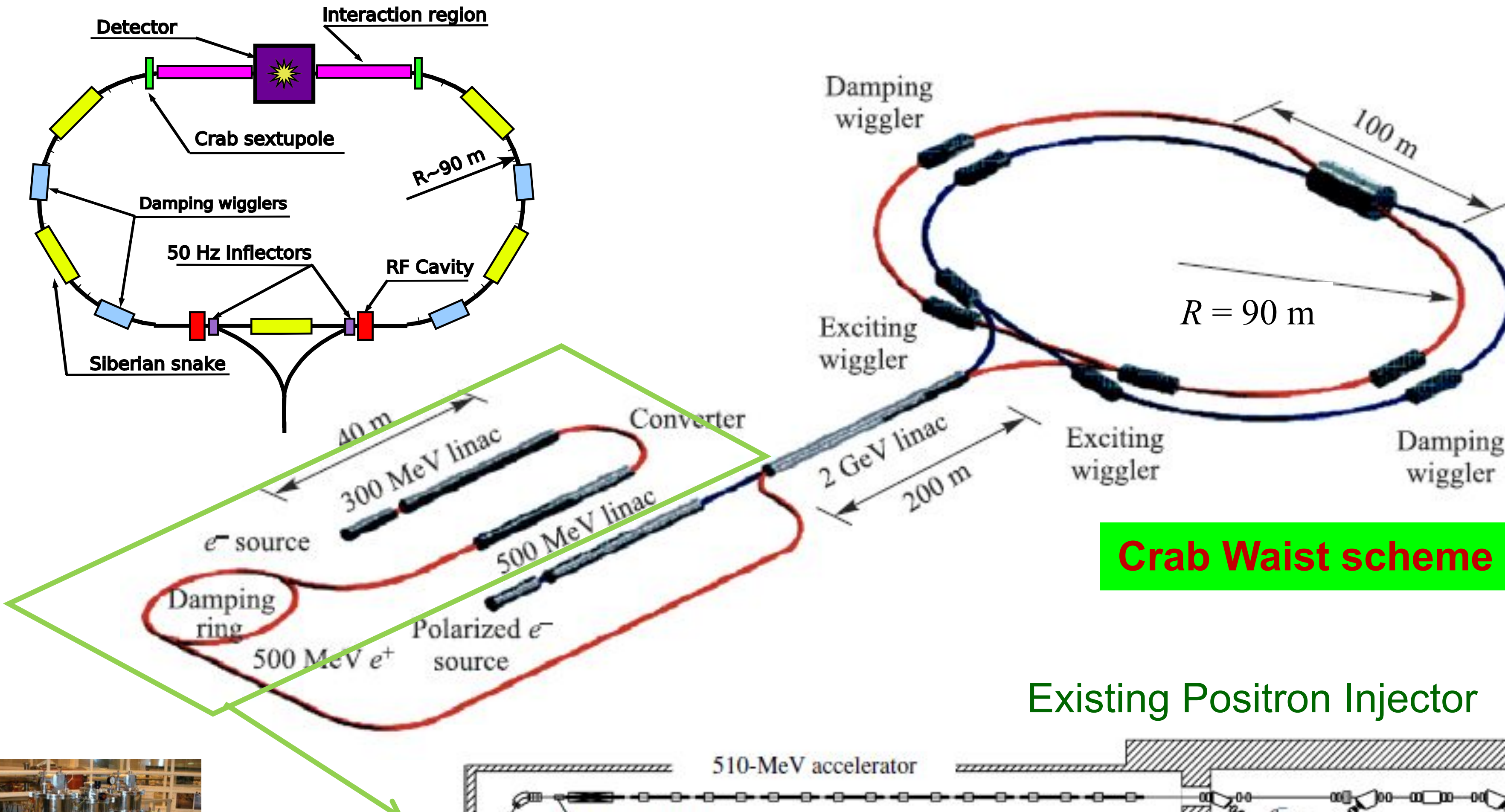
$$L = \frac{\gamma_\pm}{2 e r_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\left(\frac{R_L}{R_y}\right)$$

$$L = \frac{N_+ N_- f}{4\pi\sigma_x^*\sigma_y^*} R_L$$

Crab Waist : planned in Super τ/c

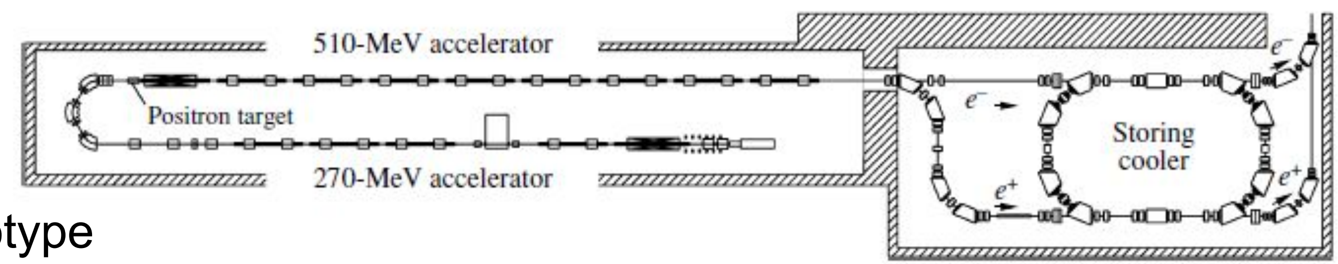
BINP Super tau/charm Factory

CEPC has common interets



Crab Waist scheme

Existing Positron Injector

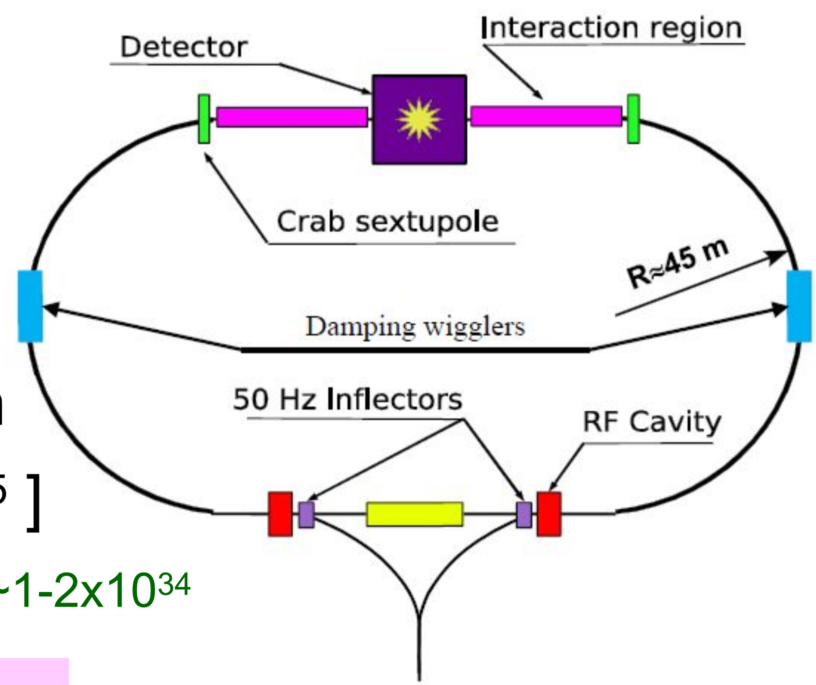


Damping wiggler prototype

BINP Super $\phi/\tau/c$ Factory

CEPC has common interets

- Beam energy from 0.5 to 2.1 GeV
- Peak luminosity is 10^{35} $cm^{-2}s^{-1}$ at 2 GeV (~whole range)
- Circumference 366 m to fit in the existent tunnel of VEPP4-M (R = 45 m)
- Conform as much as possible to existent infrastructure
- Longitudinal polarization at some energy points
- Energy calibration by Compton backscattering [~(5–10) 10^{-5}]



Also option to use VEPP3: 0.5-1.55 GeV, L~1-2x10^{34}

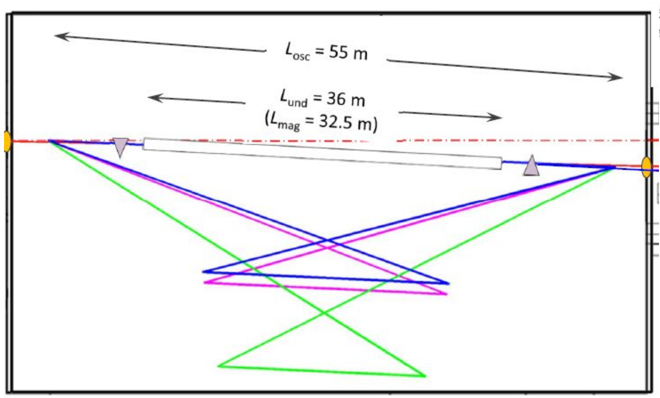
◆ Total cost : much cheaper

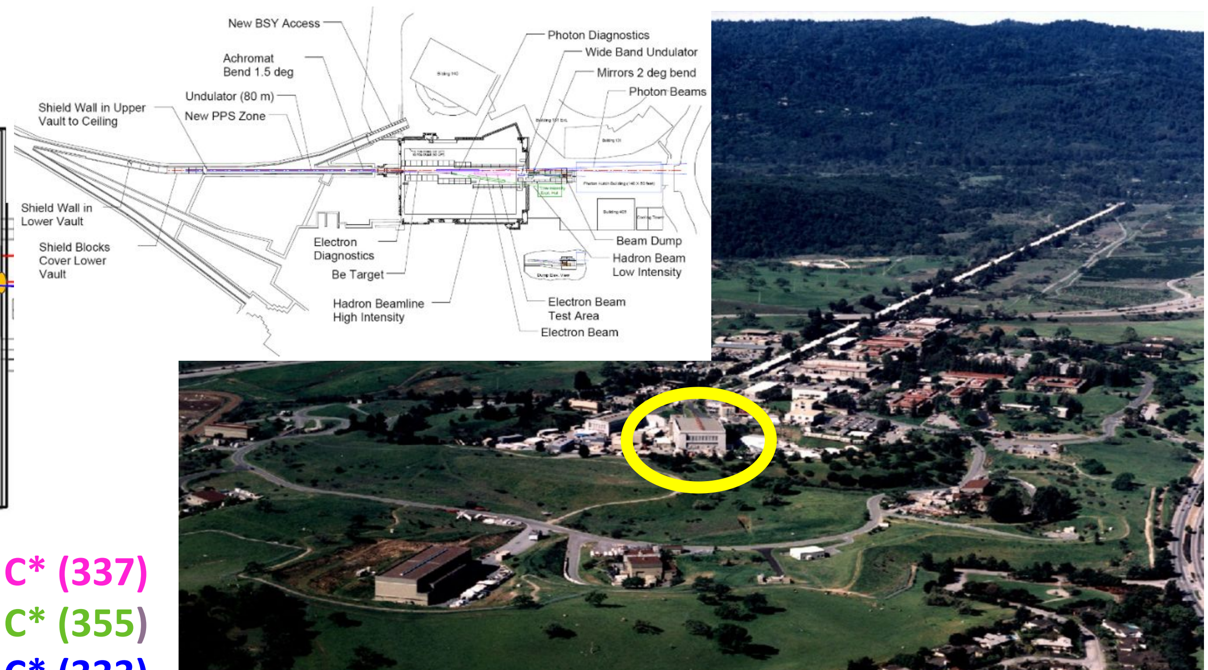
Drive Accelerator: A Multi-GeV SCRF Linac with Few MHz Rep Rate (CW)

CEPC has common interets

The 17.5 GeV European XFEL linac can run a pulsed XFELO, or CW at 7 GeV (J. Sekutowicz)

4 GeV LCLS II linac can drive a hard x-ray XFELO by operating at 5th harmonic





E_{ph} = 14.4 keV, 2 θ_r = 18.4°, C* (337)

E_{ph} = 13.8 keV, 2 θ_r = 29.3°, C* (355)

E_{ph} = 9.13 keV, 2 θ_r = 17.0°, C* (333)

International efforts

- CEPC-SppC pre-CDR international review have been done in the beginning of 2015
- CEPC-SppC International Advisory Committee has been established and the first meeting was held in Sept. 2015 at IHEP
- Start with International working groups
- Establishing CEPC international collaboration common task forces
- More Synergy with LCC (ILC, CLIC)
- More synergy with FCC (ee, pp)
- ...

CEPC is a chanlleging machine in terms of design, construction and operation for the high energy comminity of the world

CEPC-SPPC international working groups (to be established in 2016)

- CEPC Groups (member sources):
- CEPC Design Group (CERN, BINP, SLAC, KEK, INFN, Cornel, DESY, etc)
- CEPC MDI Group (KEK, SLAC, CERN, LAL, etc)
- CEPC SCRF Group (KEK, DESY, FERMI, SLAC, JLab, INFN-Milano, etc)
- CEPC RF Source Group (KEK, FERMI, SLAC, etc)
- CEPC Green Energy Group (KEK, IN2P3)

CEPC International Collaborations
(in addition to ILC collaboration)

- KEK (with Super KEK B and ILC team) (Yiwei Wang visited KEK in 2015)
- BINP (Super-Tau Charm team) (BINP team joins CEPC in 2016)
- SLAC (Lattice design) (Tianjian Bian will visit SLAC in 2016)
- BNL (Daynamic aperture) (Feng Su will visit BNL in 2016)
- INFN (Crab-waist) (IAS Hongkong)
- LAL (Collimation) (Sha Bai will visit LAL in 2016)
- CERN (FCCe+e-, Booster) (Oide and Mike visited IHEP)
- ....

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

4) CEPC Working Group Meeting, IHEP (http://indico.ihep.ac.cn/event/5277/)

5) The first CEPC International Collaboration Meeting (TBD)

The First IHEP-BINP CEPC Accelerator Collaboration Workshop
Jan. 12-13, 2016, IHEP

http://indico.ihep.ac.cn/event/5410/other-view?view=standard

Workshop Program

The first IHEP-BINP CEPC Accelerator Collaboration Workshop

chaired by Prof. Jie GAO

from Tuesday, 12 January 2016 at **09:00** to Wednesday, 13 January 2016 at **18:00** (Asia/Shanghai)
at **IHEP (A415/C407)**

Manage

Vidyo Info Room Name IHEP-BINP
Link http://vidyo.ihep.ac.cn/flex.html?roomdirect.html&key=IGvrwkPyEFRikFtaLQPUWVRmHw
Extension 002016010700

Go to day

Tuesday, 12 January 2016

09:00 - 12:00 Session I
Convener: Prof. Jie GAO
Location: A415

- 09:00 **Welcome and Introduction** *10'*
  Speaker: Prof. Xinchou LOU
- 09:10 **CEPC(SppC) accelerator design status and challenge (including the field of interested collaboration)** *30'*
  Speaker: Prof. Jie Gao (IHEP, CAS, Beijing)
- 09:40 **CEPC double ring scheme and CEPC crab-waist parameters** *20'*
  Speakers: Dr. Dou WANG (IHEP), Mr. Feng SU (高能所)
- 10:00 **CEPC Final focus design and DA studies** *20'*
  Speaker: Mr. Yi Wei Yiwei Wang (高能所)
- 10:20 **Coffee break** *20'*
- 10:40 **DA aperture optimization method study** *20'*
  Speaker: Mr. Yuan Zhang (IHEP, Beijing)
- 11:00 **Preztel scheme of CEPC** *20'*
  Speaker: Ms. Huiping GENG Huiping (高能所)
- 11:20 **CEPC booster design** *20'*
  Speaker: Mr. Xiaohao Cui (Accelerator Center)
- 11:40 **CEPC Alternating field booster design** *20'*
  Speaker: BIAN Tianjian

12:00 - 13:30 Lunch (Expert restaurant)

13:30 - 17:20 Session II
Convener: Prof. EUGENE LEVICHEV
Location: A415

- 13:30 **MDI study for CEPC** *20'*
  Speaker: Dr. Sha Bai (高能所)
- 13:50 **CEPC DA due to magnets' error** *20'*
  Speaker: Dr. Sha Bai (高能所)
- 14:10 **SppC lattice design** *20'*
  Speaker: Mr. Feng SU (高能所)
- 14:30 **Beam-Beam Effects and Luminosity Optimization for e+e- Colliders at High Energies** *20'*
  Speaker: Dmitry Shatilov
- 14:50 **Optics and IR study for electron-positron Higgs factories** *20'*
  Speaker: Anton Bogomyagkov
- 15:10 **Coffee break** *20'*
- 15:30 **MDI and head-on collision option for electron-positron Higgs factories** *20'*
  Speaker: Sergei Sinyatkin
- 15:50 **On denamic aperture study for high performance e+e- colliders** *20'*
  Speaker: Eugene Levichev
- 16:10 **Energy calibration issues in electron-positron Higgs factories** *20'*
  Speaker: Ivan Koo
- 16:30 **Beam energy calibration without polarization** *20'*
  Speaker: Nikolay Muchnoi
- 16:50 **Discussion** *30'*

18:30 - 20:30 Dinner (Expert Restaurant)

Wednesday, 13 January 2016

09:00 - 18:00 Session on 13 Jan.
Location: C407

IHEP-BINP CEPC Accelerator Working Groups Established
Jan. 2016

IHEP-BINP (BINP-IHEP) Collaboration on CEPC (Accelerator)

(2016-01-15)

Form small international groups of young scientists under supervision of experienced experts (two tasks are solved: education + real project development).

1. Particle motion simulation in realistic lattice, development of algorithms for tracking at high energy including radiation distributed properly along the lattice and radiation from quadrupoles. Dynamic aperture study and optimization.

Young scientist from BINP: Sergey Glukhov, Ksenia Karyukina, Ivan Morozov
Supervisor from BINP: Eugene Levichev
Young scientists from IHEP:
Supervisor from IHEP: Jie Gao

2. Design and study of FF area with solenoids and anti-solenoids, 3D magnet field calculation, beam tracking
in the area of MDI

Young scientists from BINP: Ivan Okunev, Grigory Baranov
Supervisor from BINP: Sergey Sinyatkin
Young scientists from IHEP:
Supervisor from IHEP:

3. Strong gradient FF quadrupole and IR chromatic/crab sextupoles: design, prototyping, etc.

Young scientists from BINP: Ivan Okunev, Grigory Baranov
Supervisor from BINP: Sergey Sinyatkin, Pavel Vobly
Young scientists from IHEP:
Supervisor from IHEP:

4. Low field dipole magnet study, development and prototyping.

Young scientists from BINP: Ivan Okunev, Grigory Baranov
Supervisors from BINP: Yury Pupkov, Ivan Koop
Young scientists from IHEP:
Supervisor from IHEP:

5. Precise energy calibration with/without polarization.

Young scientists from BINP: Slava Kaminsky
Supervisors from BINP: Ivan Koop, Nikolay Muchnoi
Young scientists from IHEP:
Supervisor from IHEP:

IAS Conference Accelerator Program
(Jan. 18-21, 2016)

Jan, 18, 2016

Plenary

10:15 John Seeman, "A Brief History of Circular e+e- Colliders Emphasizing Future Applications"

10:45

11:15 Jie Gao, "CEPC Status and International Collaboration"

11:45

Parallel Session chair: J. Gao

14:00 (1) Oide, "Design of Beam Optics for Future Circular Colliders"

14:30 (2) Dou Wang, "CEPC Parameter and Lattice Design with Crab Waist Scheme"

14:50 (3) Anton Bogomyagkov, "Chromaticity Correction of the Interaction Region"

15:10 (4) Catia Milardi, "DAFNE Experience with the Crab - Waist Collision Scheme"

15:30 (Coffee)

15:45 (Coffee)

Parallel Session Chair: Eugene Levichev:

16:00 (5) Yunhai Cai, "An Accelerator Design of Circular Higgs Factory"

16:20(6) Michael Koratzinos, "Challenges of Modem e+e - Colliders"

16:40 (7) Dmitry Shatilov, "Beam - beam Effects and Luminosity Optimization for e+e - Colliders at High Energies"

17:00 (8) Kazuhito Ohmi, "Beam Dynamics Issues of Future Curcular e+e - Colliders and Hadron Colliders"

17:20 (9) Eugene Levichev, "Nonlinear Perturbations for High Luminosity e+e - Collider Interaction"

17:40 (10) Valery Telnov (TBD)

18:00

Jan, 19, 2016

Plenary

10:15 A. Yamamoto, "ILC Accelerator Status"

10:45

11:15 W. Chou, "Future High Energy pp Colliders and Challenges"

11:45

Parallel Session Chair: Marica Biagini

14:00 (11) Jongjun Li, "Multi - objective Optimization of Dynamic Aperture in Storage Rings"

14:30 (12) Yuan Zhang, "Comparison Between Crab - waist and Head - on Scheme in CEPC"

14:50 (13) Huiping Geng., "Pretzel scheme for CEPC"

15:10 (14) Ivan Koop, "Energy Calibration Issues"

15:30 (Coffee)

15:45 (Coffee)

Paralle Session Chair:: W. Chou

16:00 (15) Kaoru Yokoya, TBD

16:20(16) Nikolay Muchnoi," Polarization Free Methods for Beam Energy Calibration"

16:40 (17) Jingyu Tang, "SPPC Status and R&D Planning"

17:00 (18) Feng Su, "CEPC Partial Double Ring Lattice Design & SPPC Lattice Design"

17:20 (19) Stephen Gourlay," The US High Field Magnet Program"

17:40 (20) Qing Jin Xu, "SPPC High Field SC Magnet R&D Issues"

18:00

Jan, 21, 2016

Plenary

10:15 Accelerator Summary, Qing Qin

10:45

14:00 Forum Discussion ((De Roech, K. Yokoya, J. Gao, Wang, Kotwal)

15:30

The important role of Hong Kong

- The IAS Program/Conference on High Energy Physics series of HKUST Jockey Club Institute for Advanced Study, the Hong Kong University of Science and Technology, has played and will play a very important platform role for the synergies among CEPC/SppC-LCC(ILC,CLIC)-FCC(ee,pp) for the high energy community world-wide

- Hong Kong could be geograhic gate to CEPC/SppC if the site is chosen closely (say near Shenzhen)

Concluding remarks

- CEPC shaping well towards CDR with reuiqred physcis goals
- Design and key technologies' R&D progress well
- International collaboration has started and will continue to develop towards full scale
- Synergeis of CEPC/SppC with FCC(ILC, CLIC) and FCC(e+e-,pp) are very important for the community
- Multifold efforts and supports are necessary and welcome
- Young generations are the key force to realize the goals

Thank you for your attentionand have a good exchange of ideas and discussions!