Preliminary design of SPPC lattice

Chen Yukai [1)] , Su Feng, Zhang Linhao, Yang Jianquan, Zou Ye, Tang Jingyu.
Institute of High Energy Physics Chinese Academy of Sciences
1) Email: chenyk@ihep.ac.cn

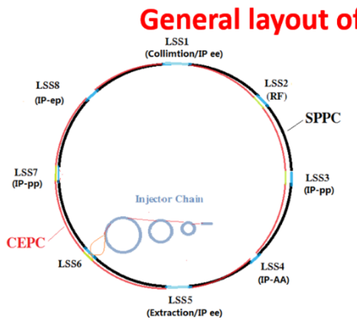
Abstract: **Recently CEPC-SPPC set 100-km circumference as the baseline design. The baseline design can achieve C.O.M energy of more than 70 TeV by using 12 T iron-based HTS technology in 100 km tunnel, and the C.O.M energy may be upgraded to be more than 125 TeV by using 20-24 T iron-based HTS technology. This paper will present the progress of the lattice design of SPPC based on this change. The ARC design is based on FODO cell with phase advance of 90 degrees, and the dipoles filling factor in ARC can achieve about 0.794. The Dispersion Suppressor(DS) is LHC-like, which can help to adjust the layout of the ring slightly. For the interaction section, a strong focus triplet will be used to obtain small beam size at collision point. The beta* is 0.75 m at collision energy, which will be adjusted to about 10 m at injection energy to reduce the beam envelope in the triplet. Dynamics aperture study of SPPC have been started by using SixTrack base on the first version of integrated Lattice. Preliminary result show the DA is about 10σ at injection energy, considering the dipole error(Data quoted from error table may 2015 of FCC). Further research is underway on the optimizing of the Lattice.**

Layout consideration

SPPC main parameters

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

General layout of SPPC



- Use the same CEPC tunnel to build SPPC
- Maximize the beam energy to 37.5 TeV by using ~12T Iron-based SC magnets
- 8 arcs, total length 83900 m
- 2 IPs for pp, 1250 m each
- 2 IRs for injection or RF, 1250 m each
- 2 IRs for ep or AA, 1250 m each
- 2 IRs for collimation(ee for CEPC) , 4300 m each
- **C = 100 km**

- Dipole length needed: 65.45 Km (12 T Dipole, Ep=37.5 TeV)
- Dipole filling factor: 0.79
- ARC length(including DS): 65.45 Km/0.79=82.9 Km
  Considering some reserved length, ARC length is chosen as 83.9 Km, left 16.1 Km for long straight section

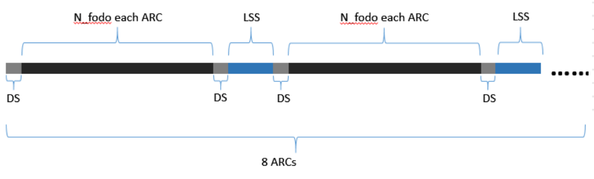
Consideration of geometry

Calculation base on:

Parameters	Beam energy	Strength of Dipole	Length of quadrupole	Space between Q and B	Space between B and B	ARC numbers of the ring	Number of DS each ARC
value	37.5 TeV	~12 T	6 m	3.5 m	1.4 m	8	2

Parameter should be determined:

Parameters	Number of Dipoles each FODO cell (N_dipole)	Number of FODO cell each ARC (N_fodo)	Length of dipole	Length of FODO cell	Total length of ARC	Filling factor
value	10 or 12 or 14 ?	?	14 -15 m ?	?	?	?

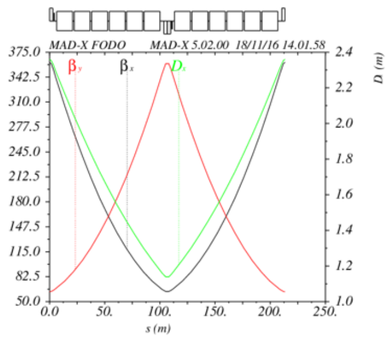


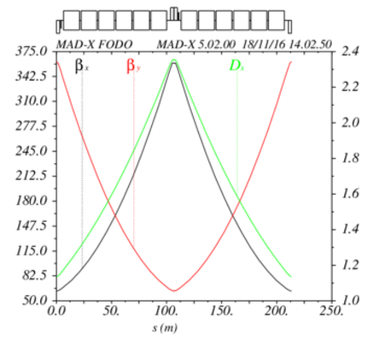
B= 11.8 T

N_dipole each fodo	N_fodo each ARC	L_dipole (m)	L_fodo (m)	length of DS	ARC length (m)	filling factor
10	52	15.30203099	190.2203099	538.8528057	84709.76885	0.786
10	54	14.75940578	184.7940578	524.7445502	85270.24084	0.781
10	56	14.25394668	179.7394668	511.6026136	85833.09146	0.776
10	58	13.78196169	175.0196169	499.3310038	86398.08442	0.771
12	42	15.7657289	229.1887468	585.2404092	82704.24552	0.805
12	44	15.08026242	220.9631491	566.0473479	83300.37566	0.799
12	**46**	**14.45191816**	**213.4230179**	**548.4537084**	**83900.16163**	**0.794**
12	48	13.87384143	206.4860972	532.2675601	84503.16472	0.788
14	36	15.7657289	263.5202046	619.571867	81590.64552	0.816
14	38	14.97177133	252.4047986	595.7531398	82224.63223	0.810
14	40	14.25394668	242.3552535	574.2184003	82863.49146	0.804
14	42	13.60180532	233.2252745	554.6541597	83506.55441	0.797

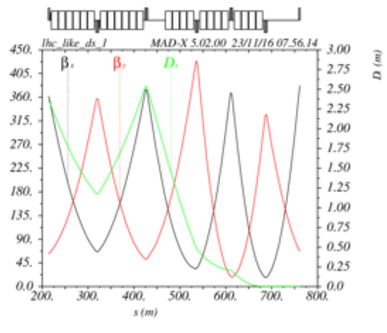
Beam optics design

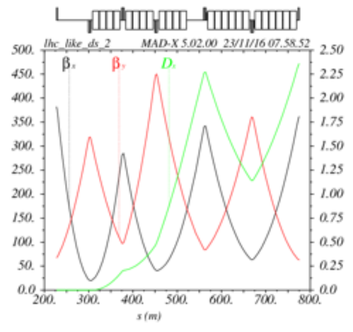
ARC FODO cell





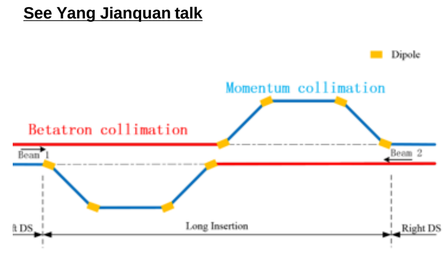
DS design of SPPC



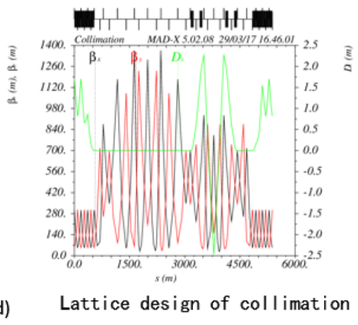


Lattice of Collimation System

See Yang Jianquan talk

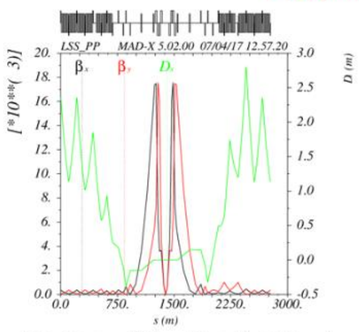


New idea: Combined beta and momentum collimation in one straight section(4300 m is needed)



Lattice design of collimation

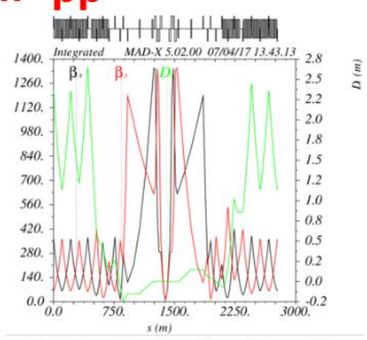
LSS of IP-pp



LSS_PP at collision (beta*=0.75 m)

ε_n=2.4 μm
β_{max}=18 km
Ep=37.5 TeV

$\sigma_{max} = \sqrt{\frac{\varepsilon_n}{\gamma} \cdot \beta_{max}}$=1. 04 mm

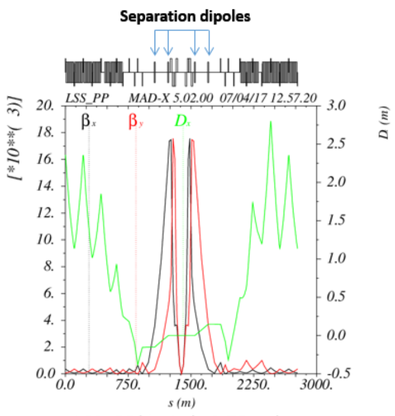


LSS_PP at injection (beta*=10 m)

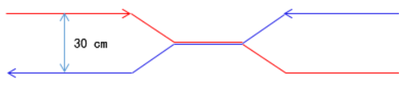
ε_n=2.4 μm
β_{max}=1.3 km
Ep=2.1 TeV

$\sigma_{max} = \sqrt{\frac{\varepsilon_n}{\gamma} \cdot \beta_{max}}$=1. 18 mm

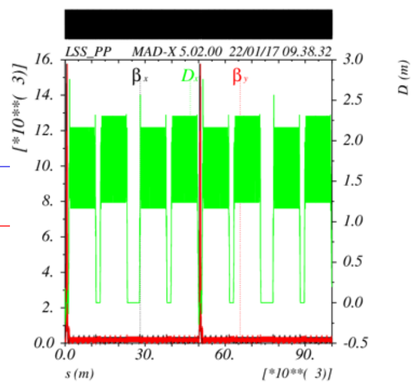
Beam separation and combination



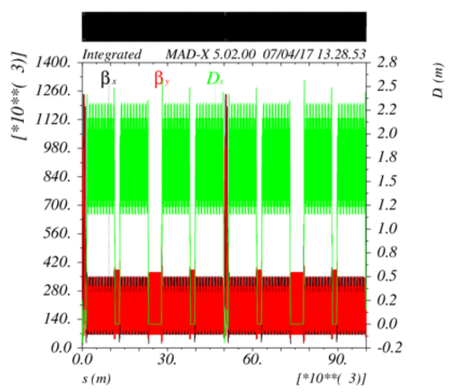
LSS_PP(beta*=0.75 m)



Integration lattice



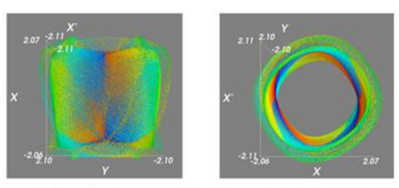
Integrated Lattice with PP(beta*=0.75 m)



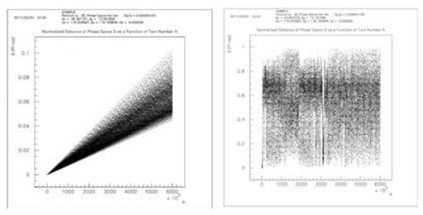
Integrated Lattice with PP(beta*=10 m)

Dynamics Aperture

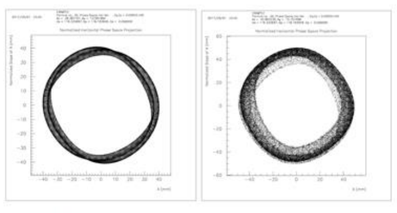
DA study with SixTrack



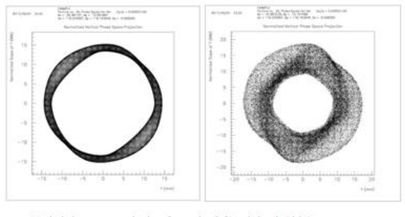
4-Dimension phase space for regular and chaotic motion (cm).



Evolution of the distance of phase space for regular (left) and chaotic (right) motion.

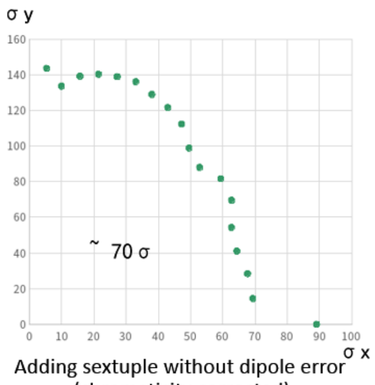


Horizontal phase space projections for regular (left) and chaotic (right) cases.



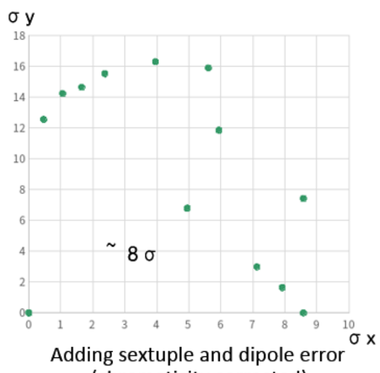
Vertical phase space projections for regular (left) and chaotic (right) cases.

DA at collision



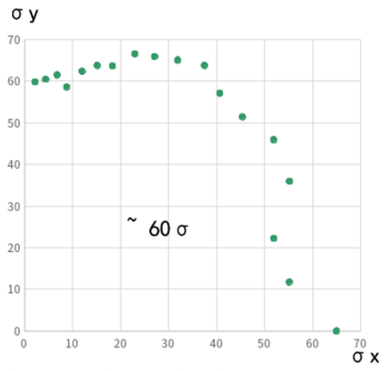
Adding sextuple without dipole error (chromaticity corrected)

Normalized rms transverse emittance: 2.4 μm
Proton energy: 37.5 TeV



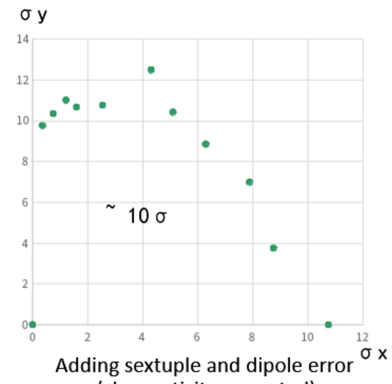
Adding sextuple and dipole error (chromaticity corrected)

DA at injection



Adding sextuple without dipole error (chromaticity corrected)

Normalized rms transverse emittance: 2.4 μm
Proton energy: 2.1 TeV



Adding sextuple and dipole error (chromaticity corrected)