CEPC Partial Double Ring Lattice & SPPC Lattice Design

Feng Su Jie Gao Dou Wang Yiwei Wang

Jingyu Tang Tianjian Bian Sha Bai

Huiping Geng Yuan Zhang Yuanyuan Guo

Yuemei Peng Ye Zou Yukai Chen Ming Xiao

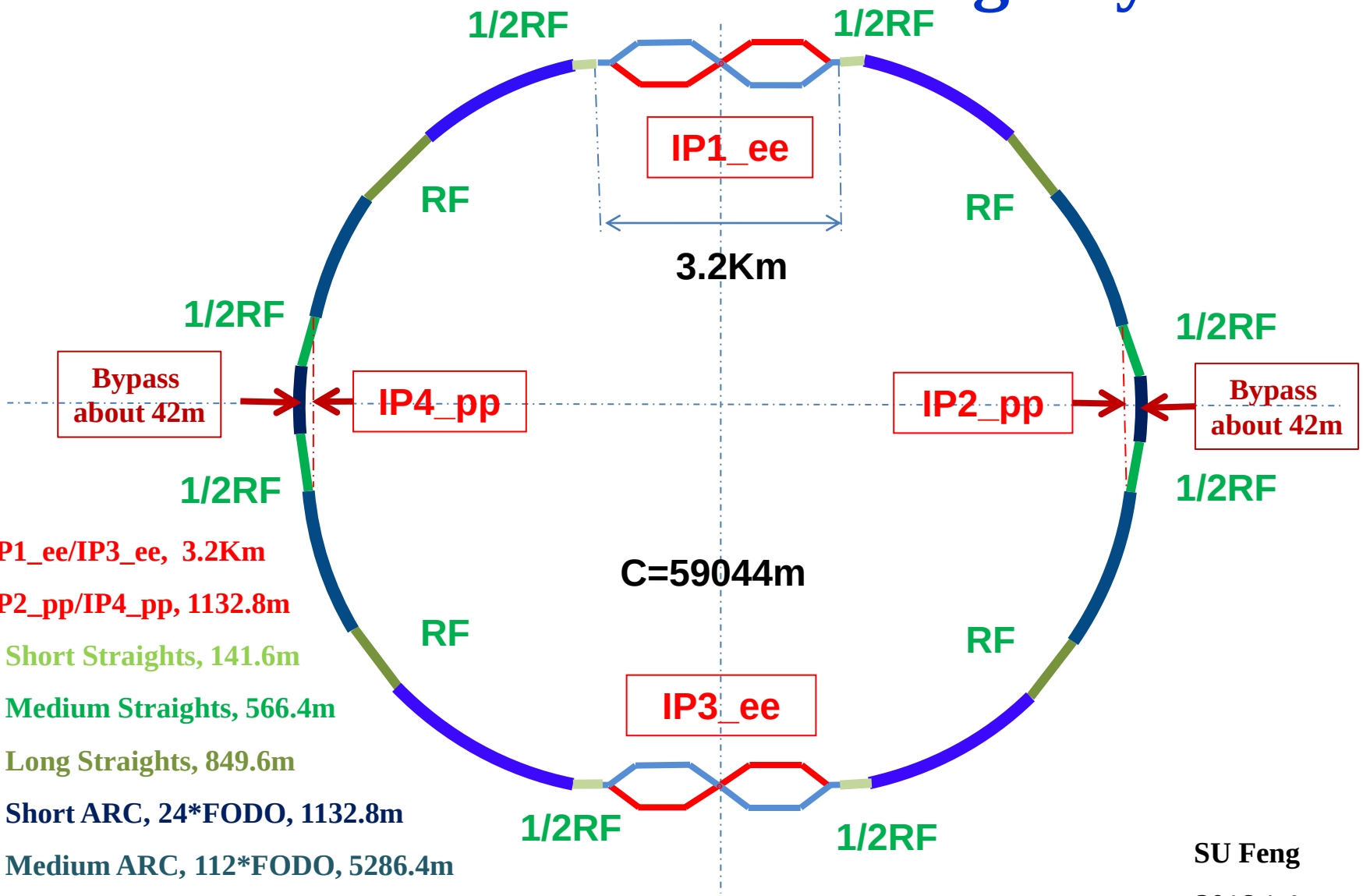
IAS Program on High Energy Physics, January, 2016

Outline

1. CEPC Partial Double Ring Lattice
2. SPPC Lattice

1. CEPC Partial Double Ring Lattice

CEPC Partial Double Ring Layout



IP1_ee/IP3_ee, 3.2Km

IP2_pp/IP4_pp, 1132.8m

4 Short Straights, 141.6m

4 Medium Straights, 566.4m

4 Long Straights, 849.6m

2 Short ARC, 24*FODO, 1132.8m

4 Medium ARC, 112*FODO, 5286.4m

4 Long ARC, 124*FODO, 5852.8m

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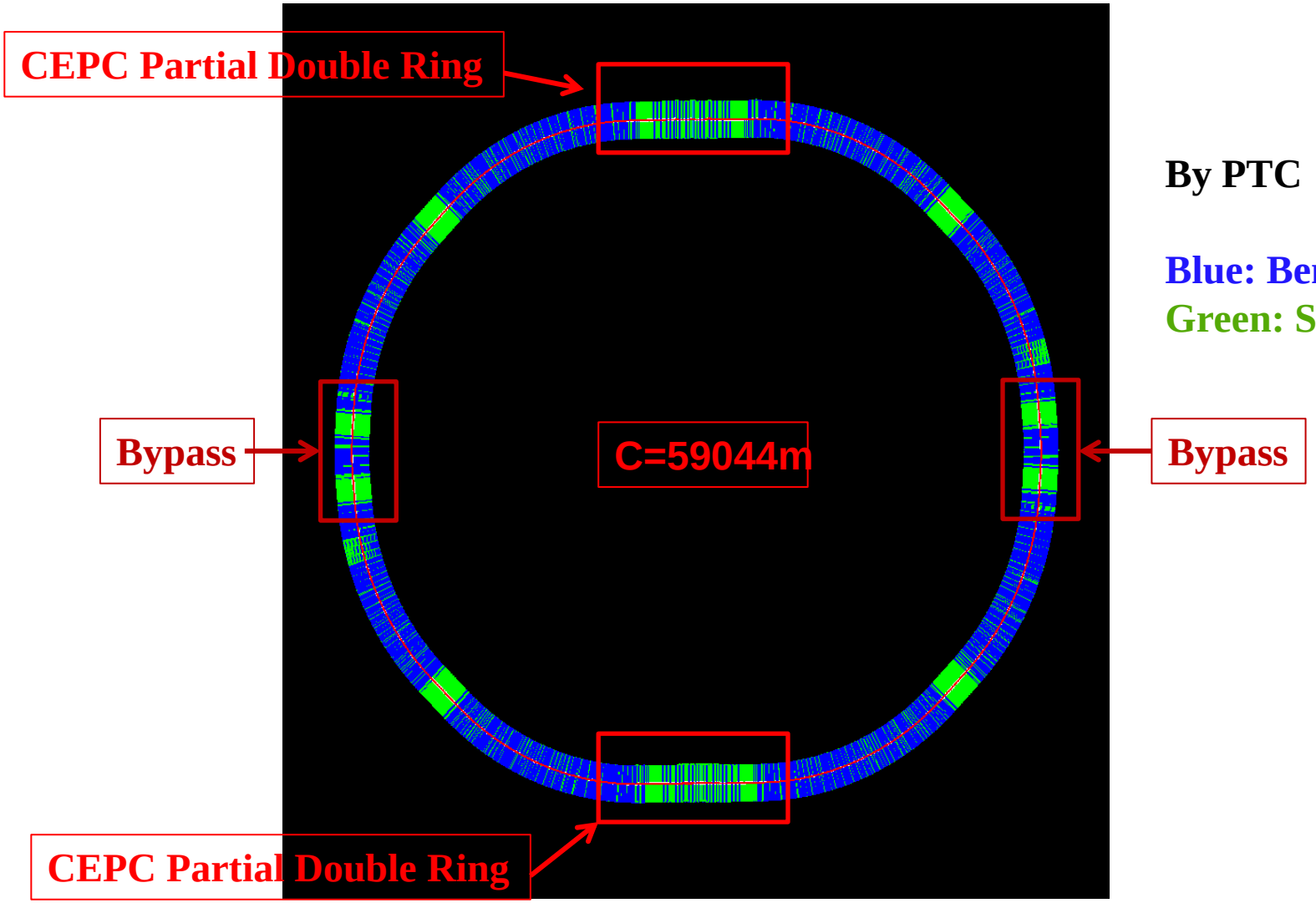
2016.1.4

CEPC Partial Double Ring Layout



By PTC

Blue: Bend
Green: Straight Section

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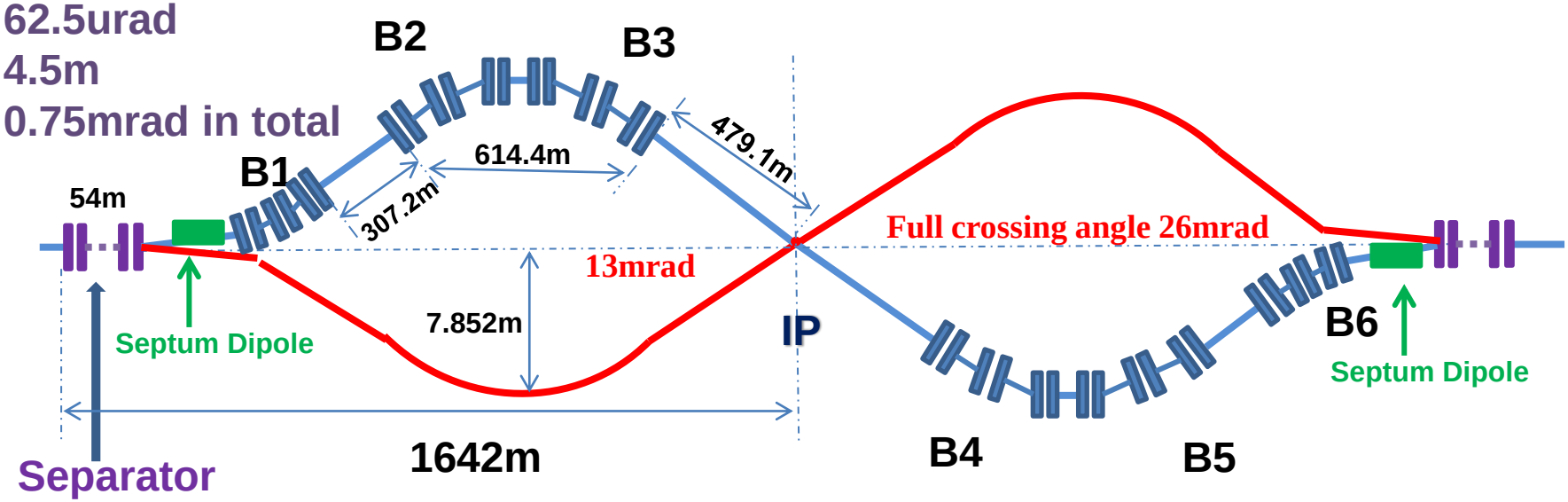
2016.1.4

CEPC Partial Double Ring Layout

12
62.5urad
4.5m
0.75mrad in total



For CEPC 120GeV beam:

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

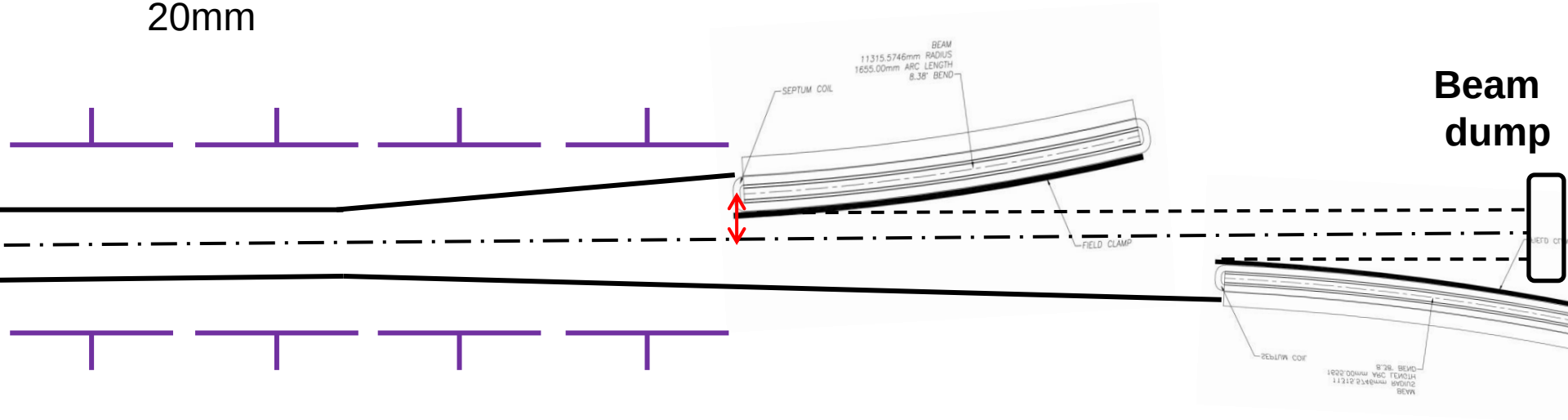
Using Septum Dipole after separator to acquire 13 mrad

Version 1.0
sufeng
2015.12.20

Separator with Thin Septum Magnet

Sigmax=697.8um 20sigma=14mm

20mm



Separator： 62.5 urad
12 个
0.75 mrad

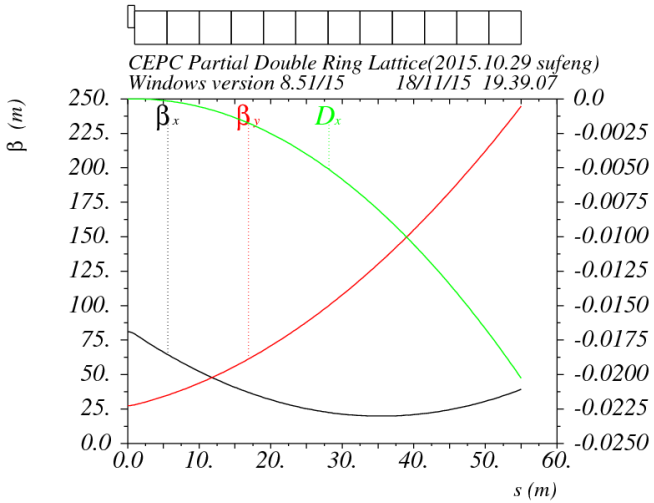
Septum Magnet：L=3m

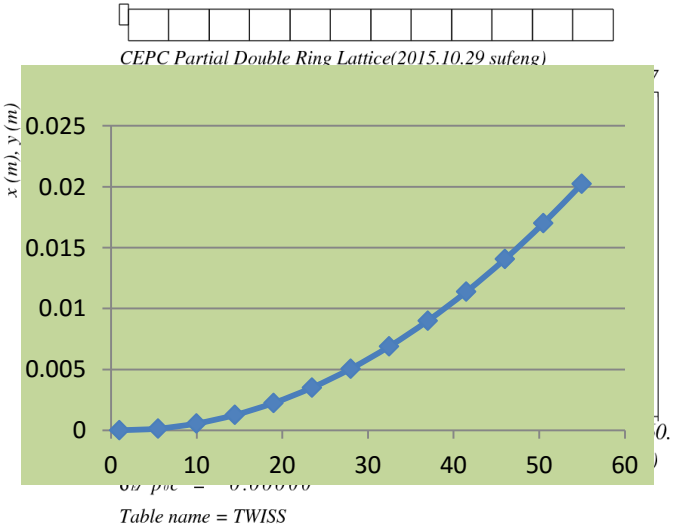
（4.25mrad）thicknes=3-5mm

rho=705.822m B=0.56T

Orbit difference between dipole separator kicker

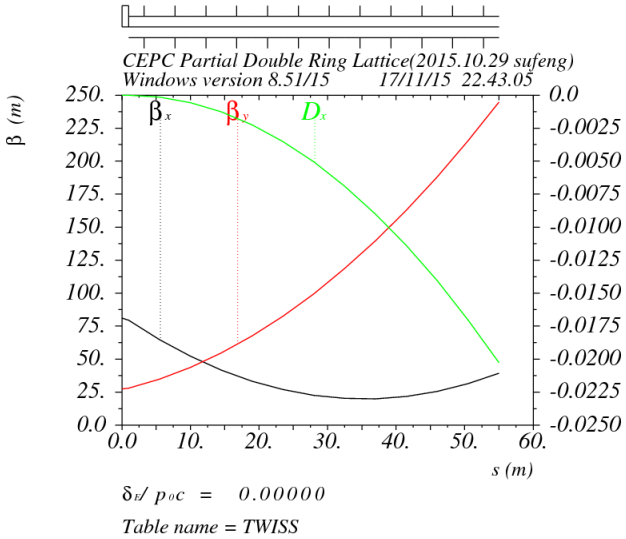
Dipole

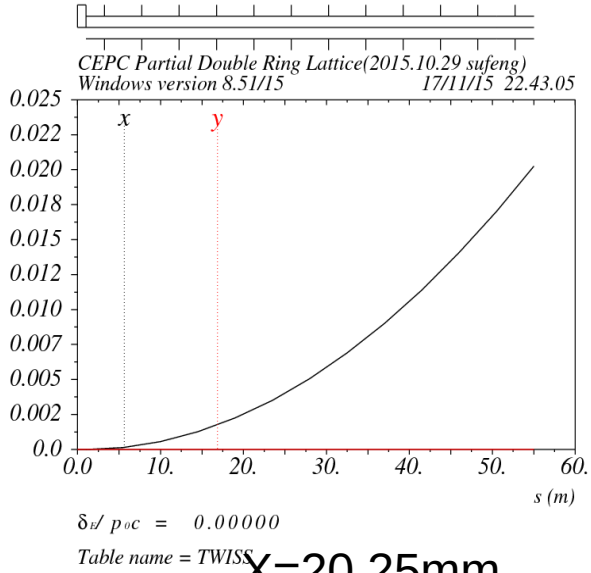




X=20.25mm

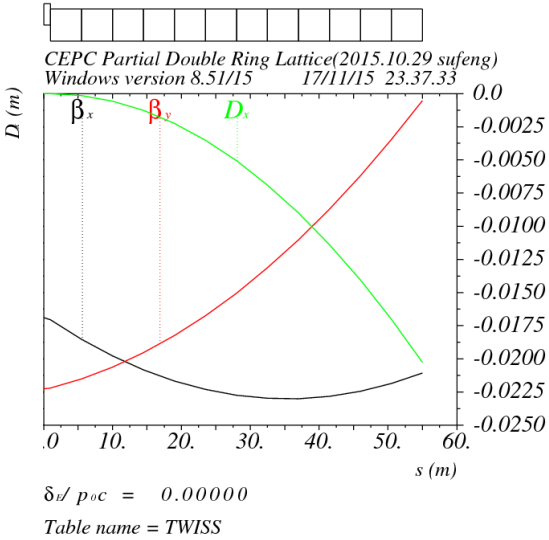
Seperator

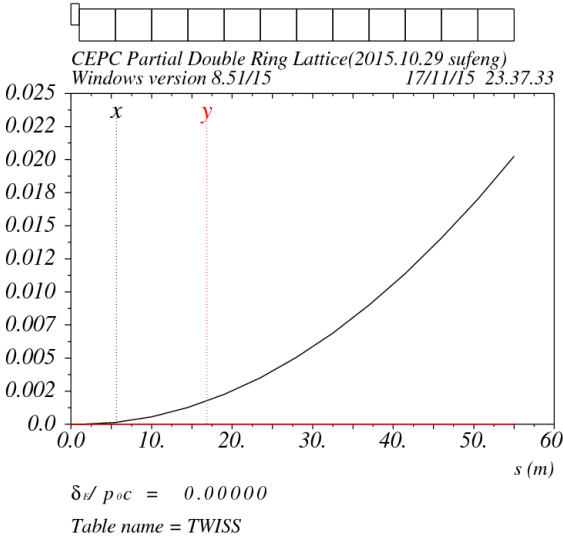




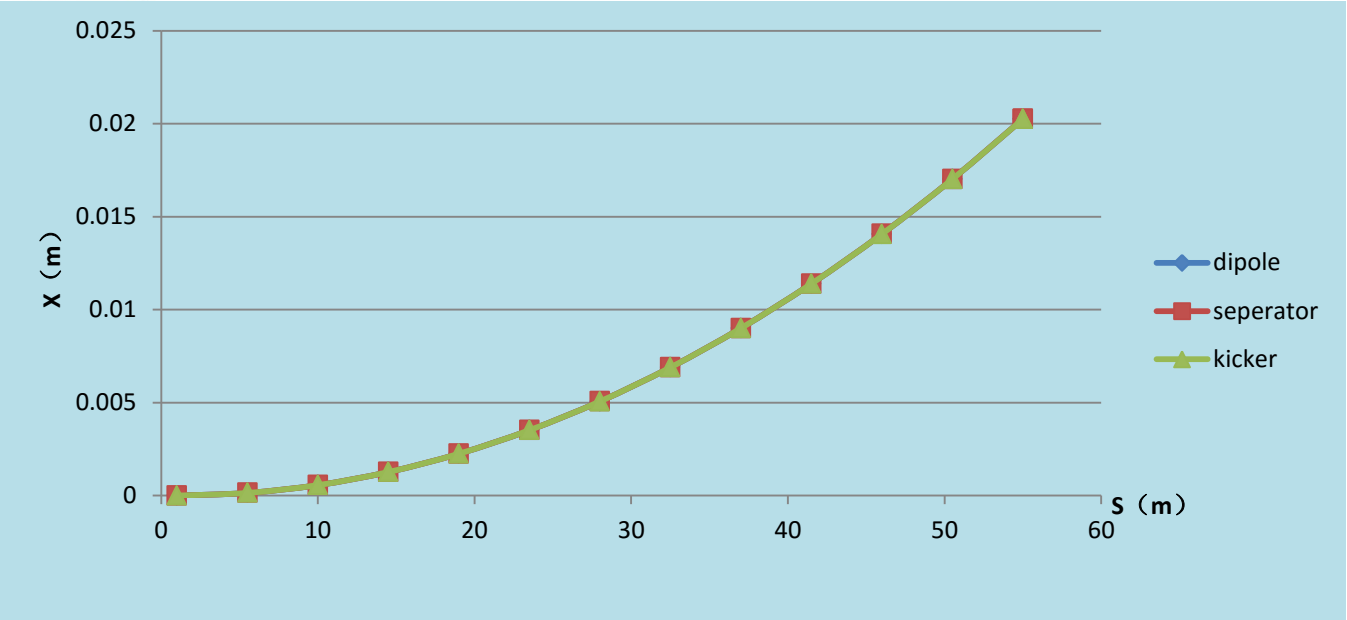
X=20.25mm

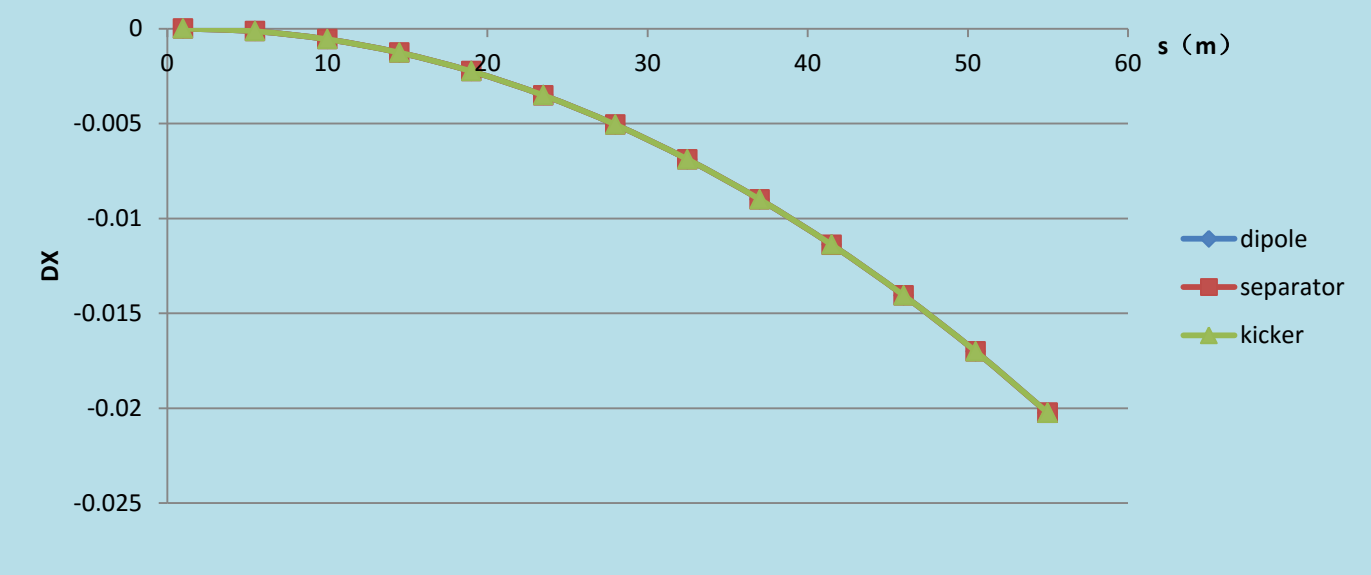
Kicker





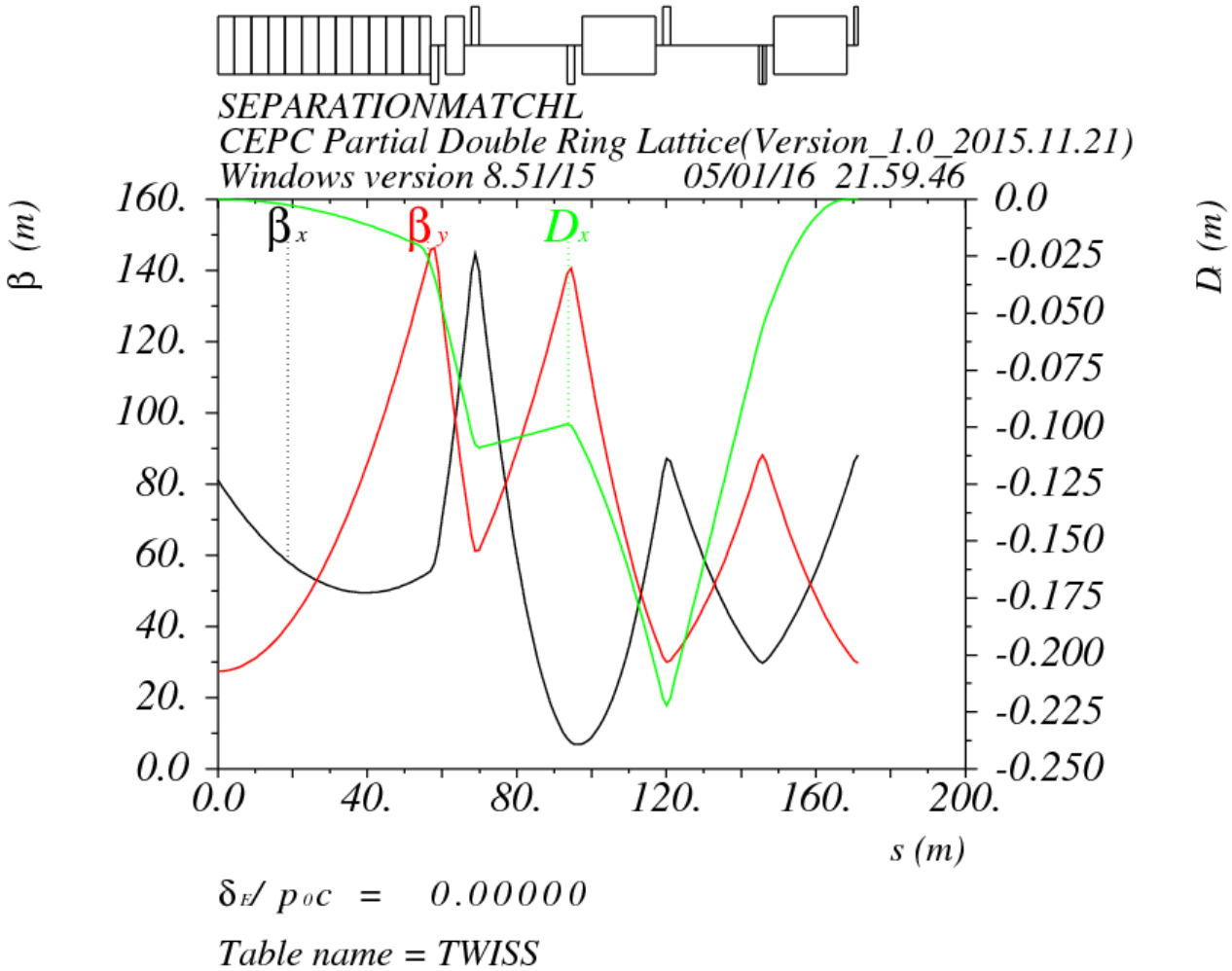
X=20.25mm





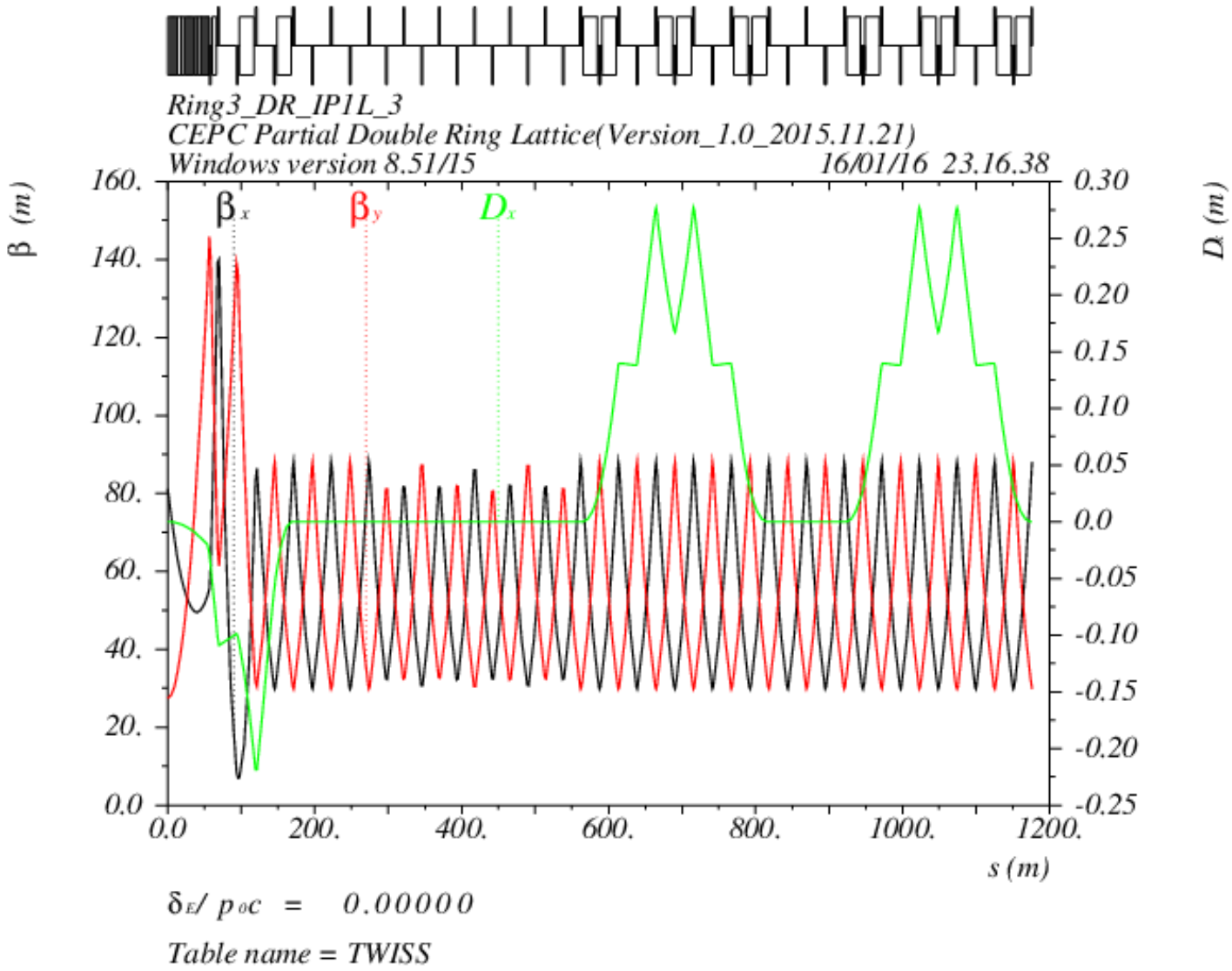
So we use Dipole instesd Seperator in lattice now

SEPARATIONMATCHL

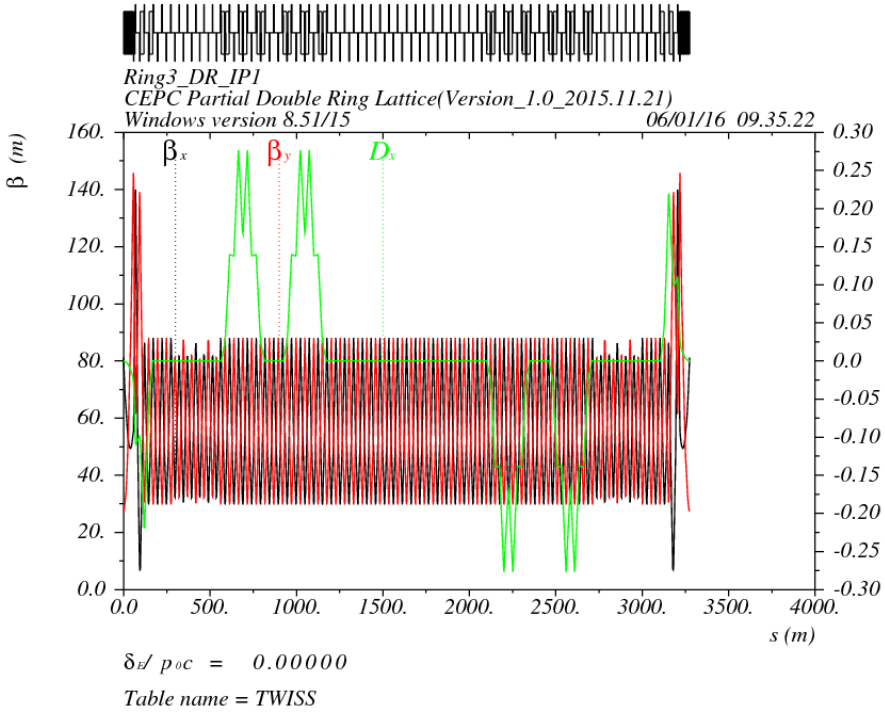


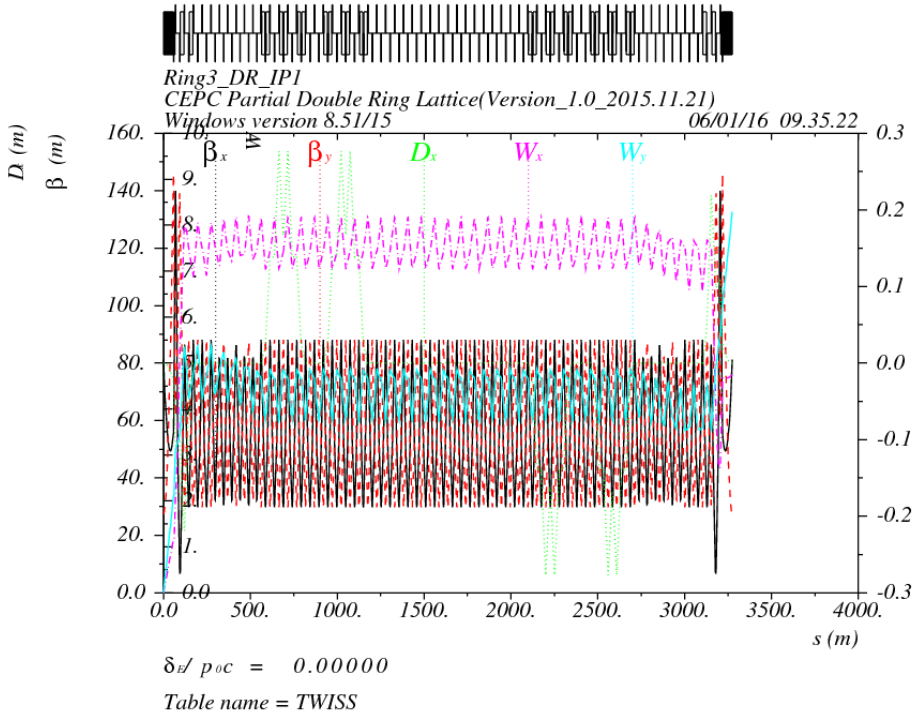
Beta<150m

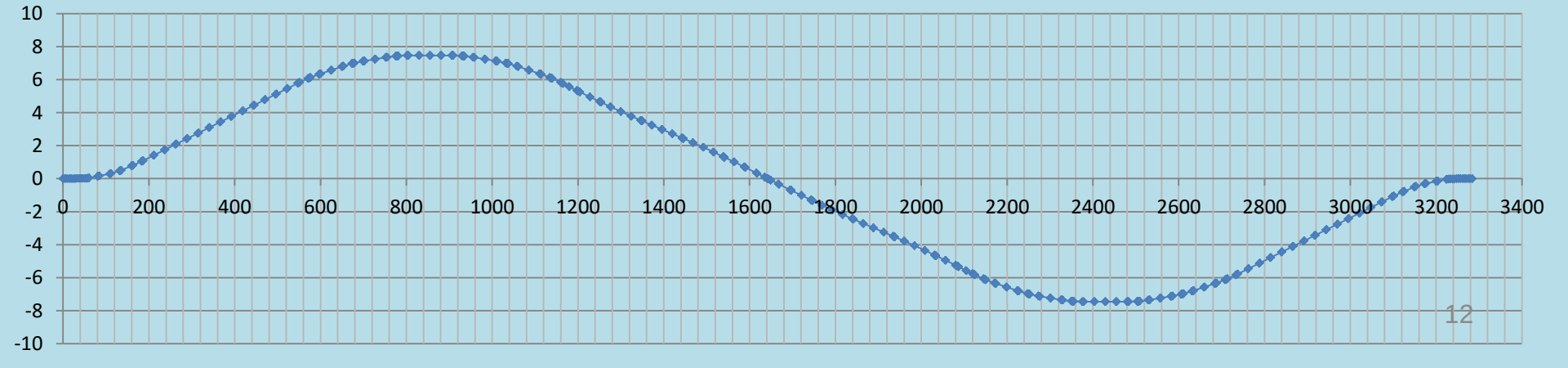
RING3_DR_IP1_3



Orbit (RING3_DR_IP1) Version 1.0 without FFS





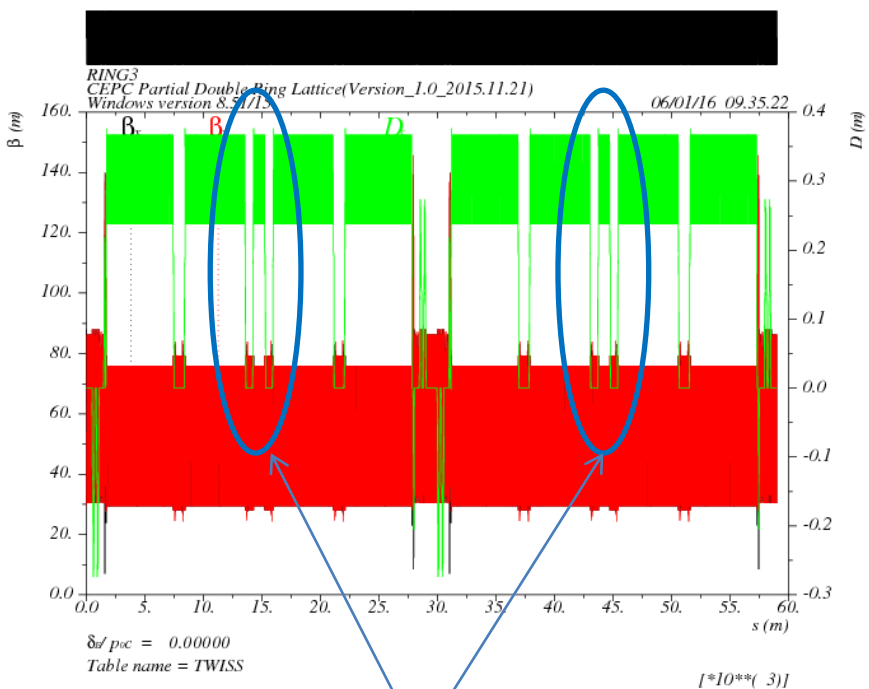


Dipole Strength Version 1.0 without FFS

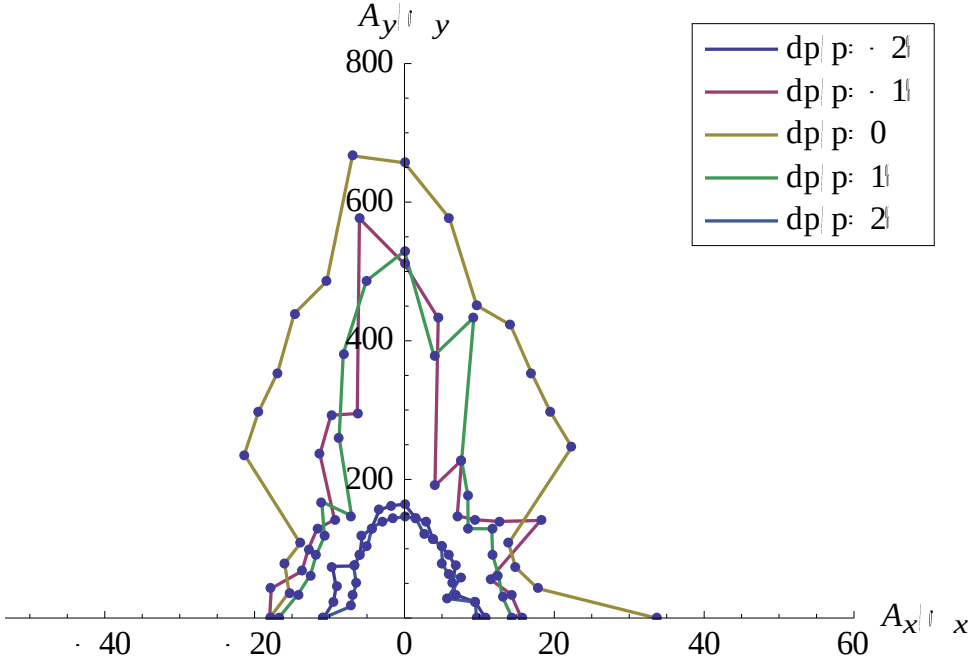
	Angle(mrad)	L(m)	Rho(m)	Brho(E0/c)(T/m)	B(T)	Ek(KeV)	KeV/m
B0	3.232	19.6	6064.36	400	0.06596	631.625	32.226
BSepL	-0.0625	4.5	-72000	400	-0.00556	53.2	11.822
BSeptumL	-4.25	3	-705.822	400	-0.56667	5426.4	1808.8
BMatch1L	-0.469	4.9	-10447.8	400	-0.03829	366.624	74.821
BMatch2L	-3.171	19.6	-6181.02	400	-0.06471	619.704	31.618
BMatch3L	-4.36	19.6	-4495.41	400	-0.08898	852.069	43.473
B2	2.167	19.6	9044.76	400	0.04422	423.494	21.607
B3	2.167	19.6	9044.76	400	0.04422	423.494	21.607
B4	-2.167	19.6	-9044.76	400	-0.04422	423.494	21.607
B5	-2.167	19.6	-9044.76	400	-0.04422	423.494	21.607
BMatch3R	4.36	19.6	4495.41	400	0.08898	852.069	43.473
BMatch2R	3.171	19.6	6181.02	400	0.06471	619.704	31.618
BMatch1R	0.469	4.9	10447.8	400	0.03829	366.624	74.821
BSeptumR	4.25	3	705.822	400	0.56667	5426.4	1808.8
BSepR	0.0625	4.5	72000	400	0.00556	53.2	11.822

Survey & Dynamic Aperture

（Version 1.0 –without FFS）

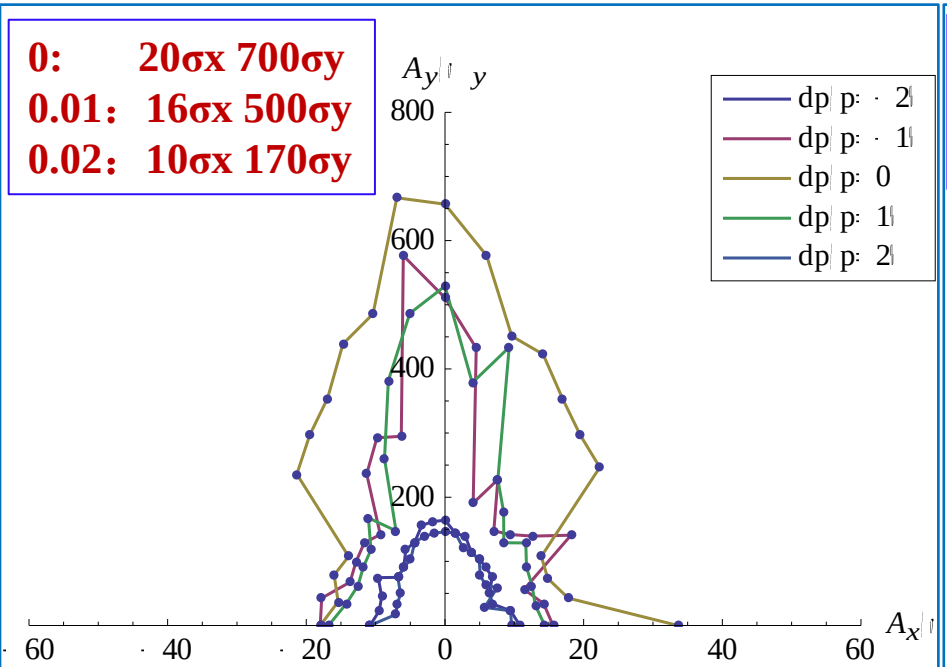


Bypass part at IP2/4



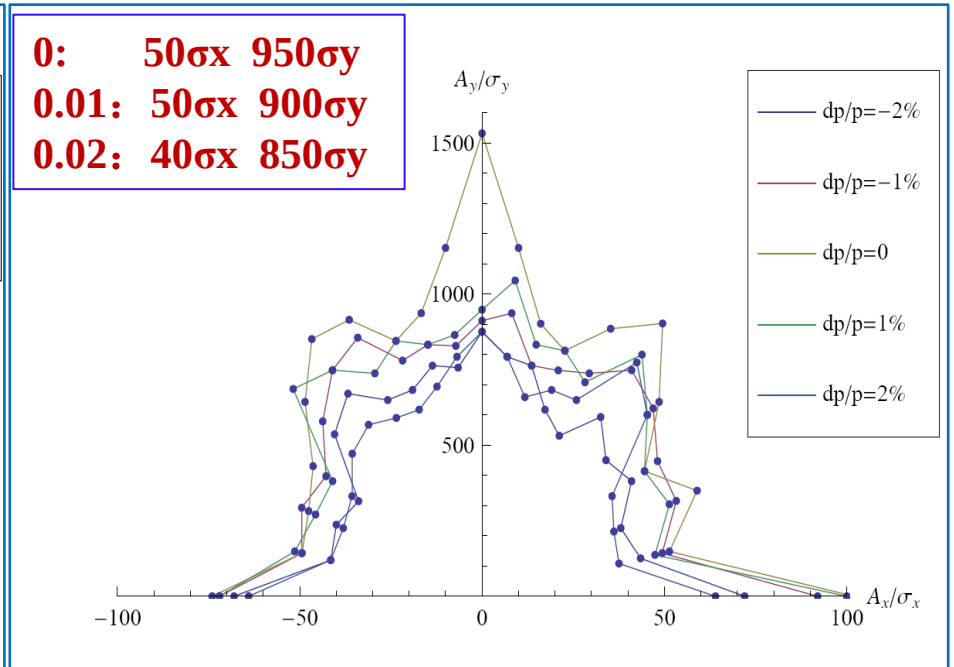
0: 20σx 700σy
0.01: 16σx 500σy
0.02: 10σx 170σy

Dynamic Aperture Comparation



CEPC Partial Double Ring Lattice

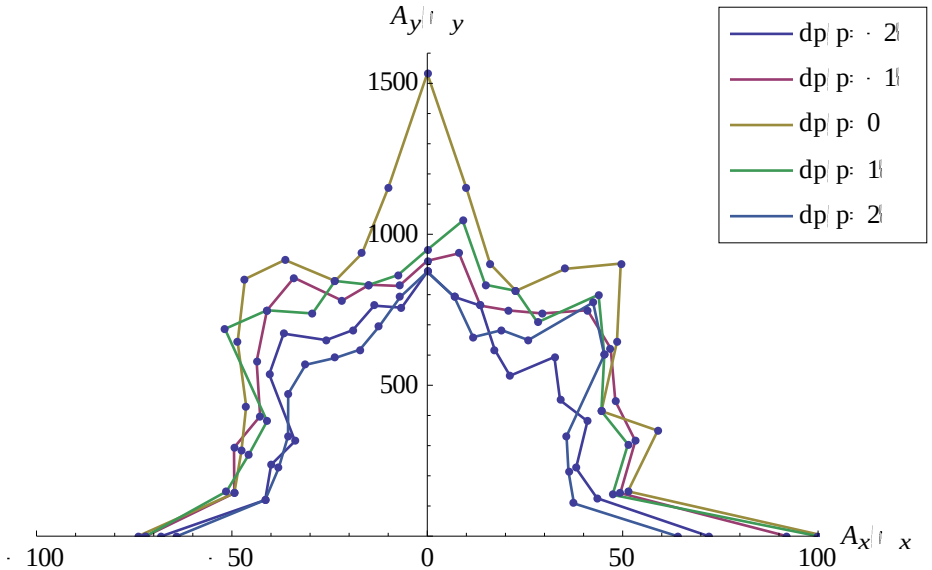
(Version1.0-20160104)



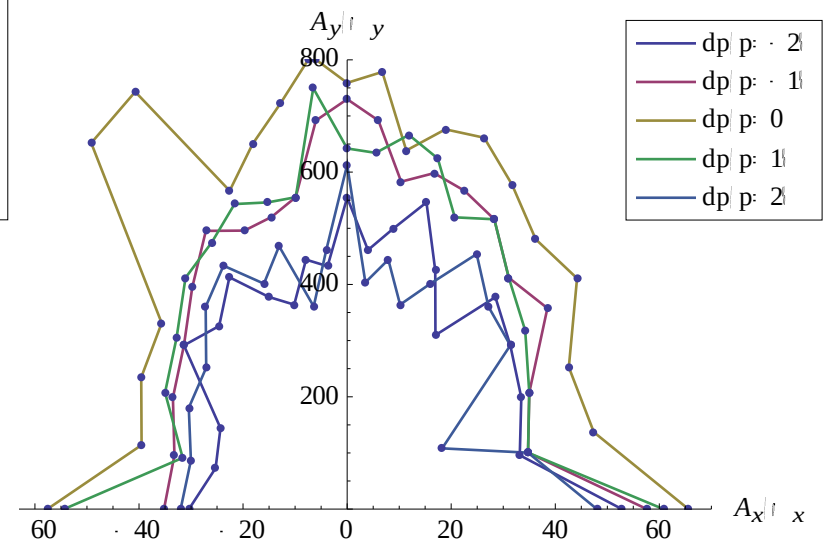
CEPC Main Ring Lattice (without pretzel)

(September 30, 2014 Geng Huiping)

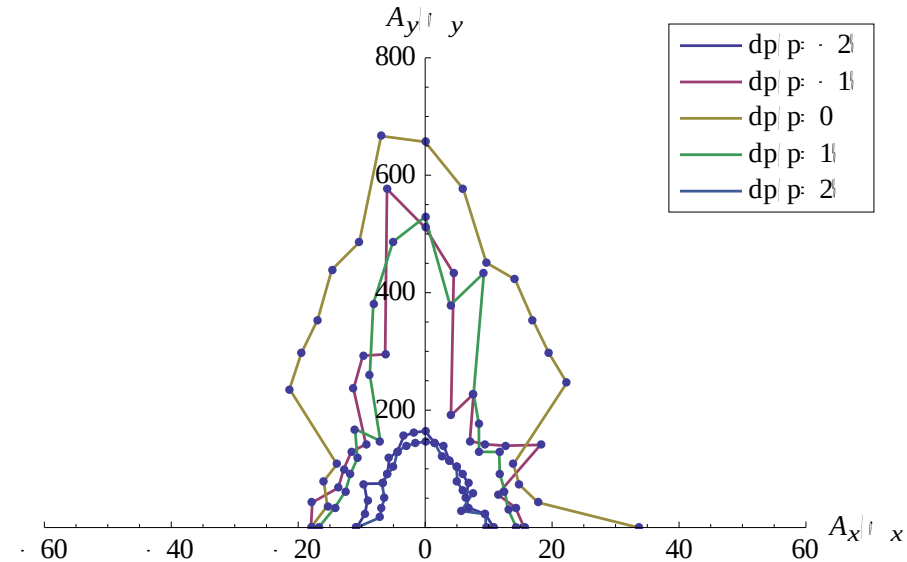
CEPC-Single



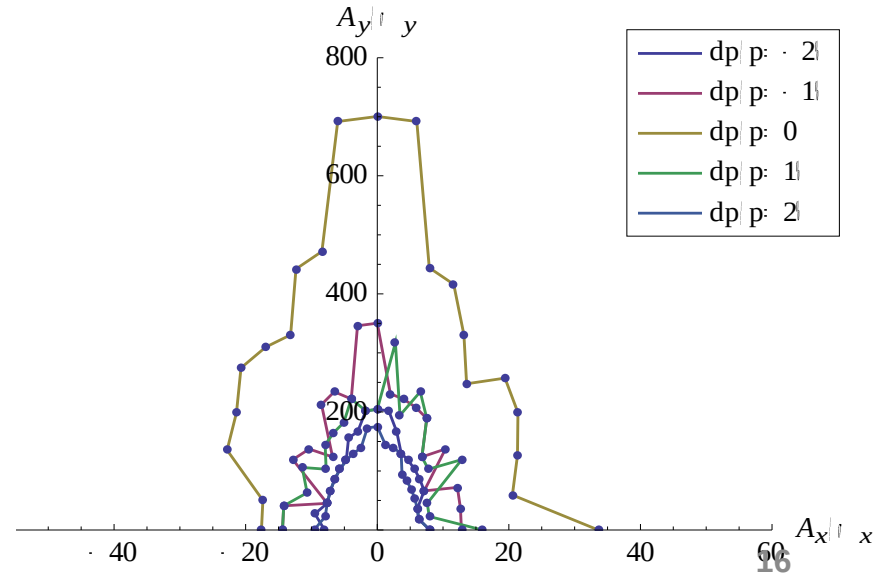
CEPC-Single-Bypass



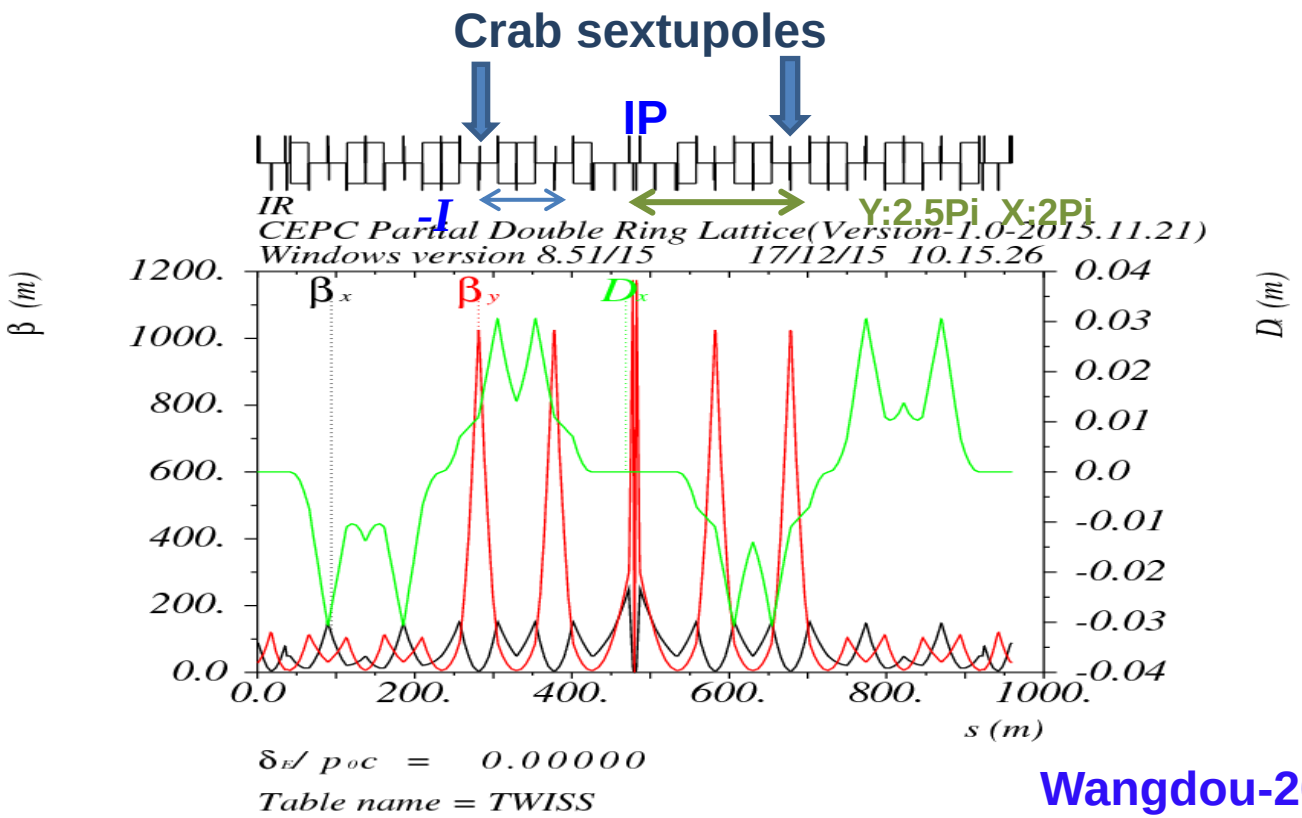
CEPC-PDR-Bypass



CEPC-PDR-Bypass-PDRnPi

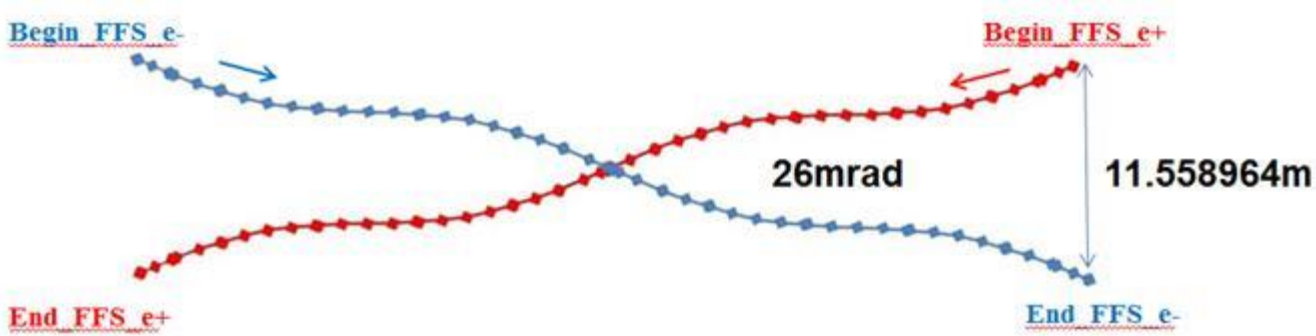


FFS Part

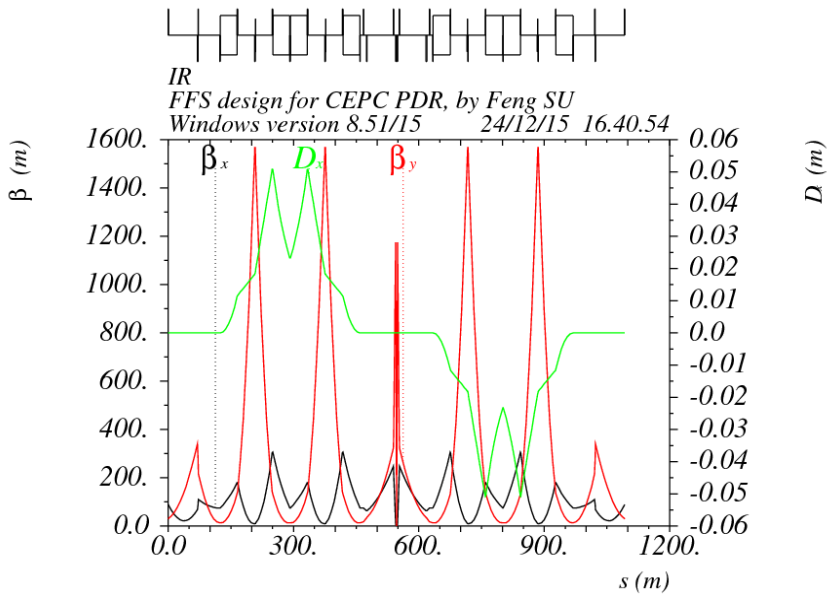


K2=-126.77

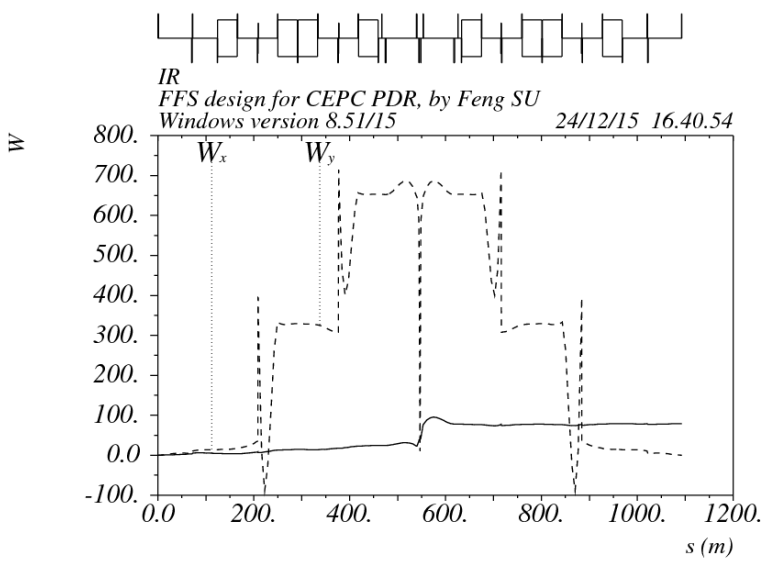
Wangdou-20151216



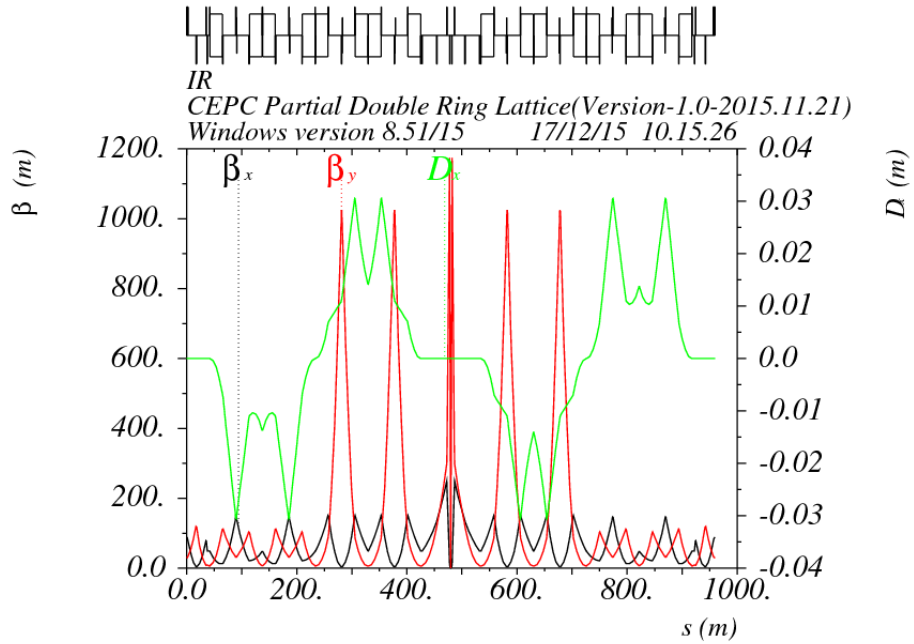
Sufeng-20151224



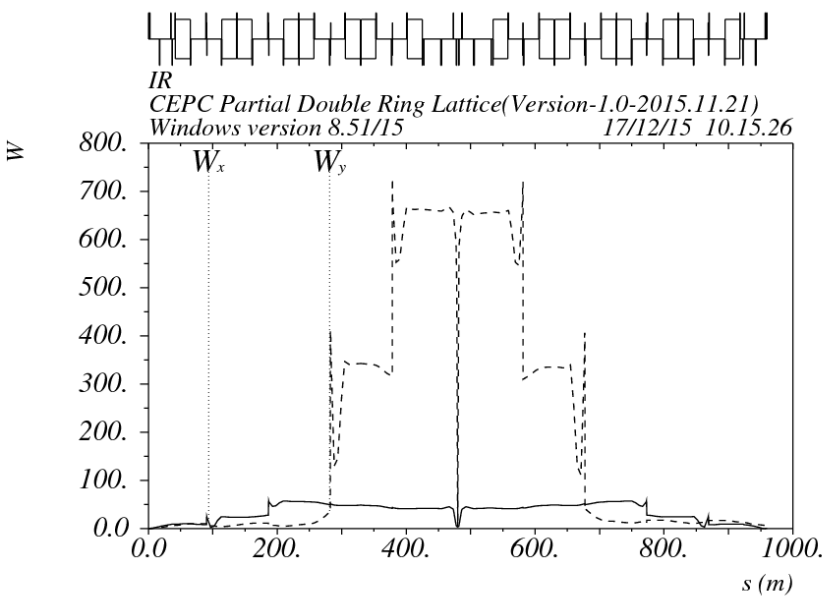
K2=-48.57



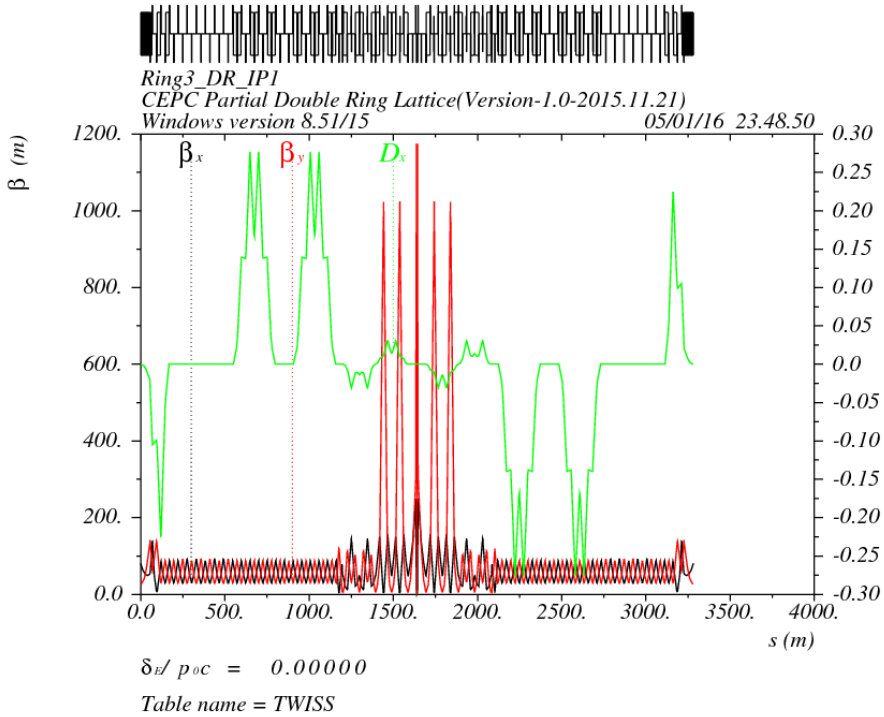
Wangdou-20151216

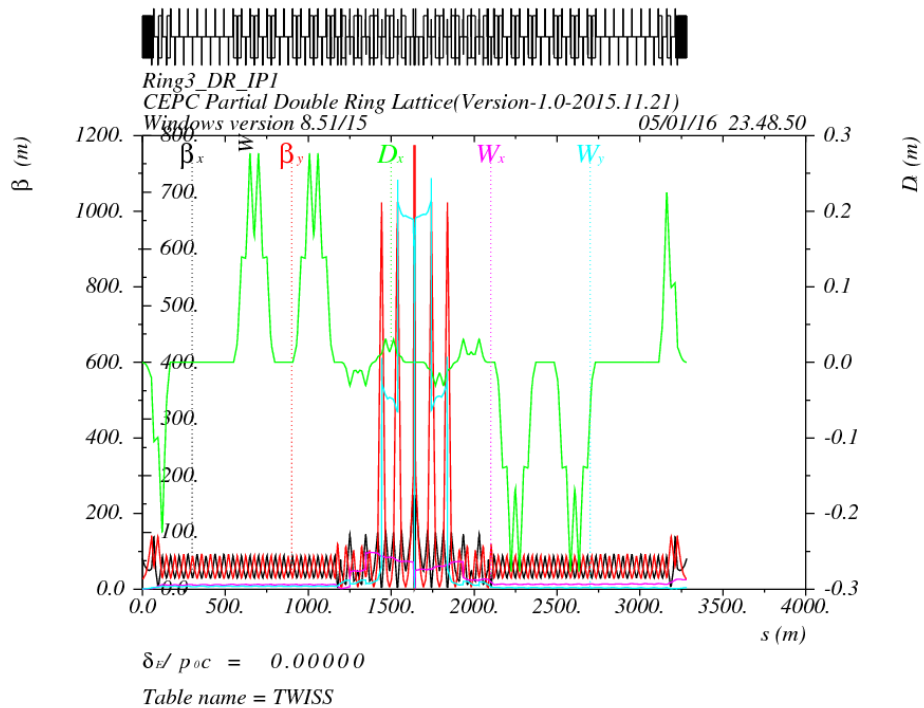


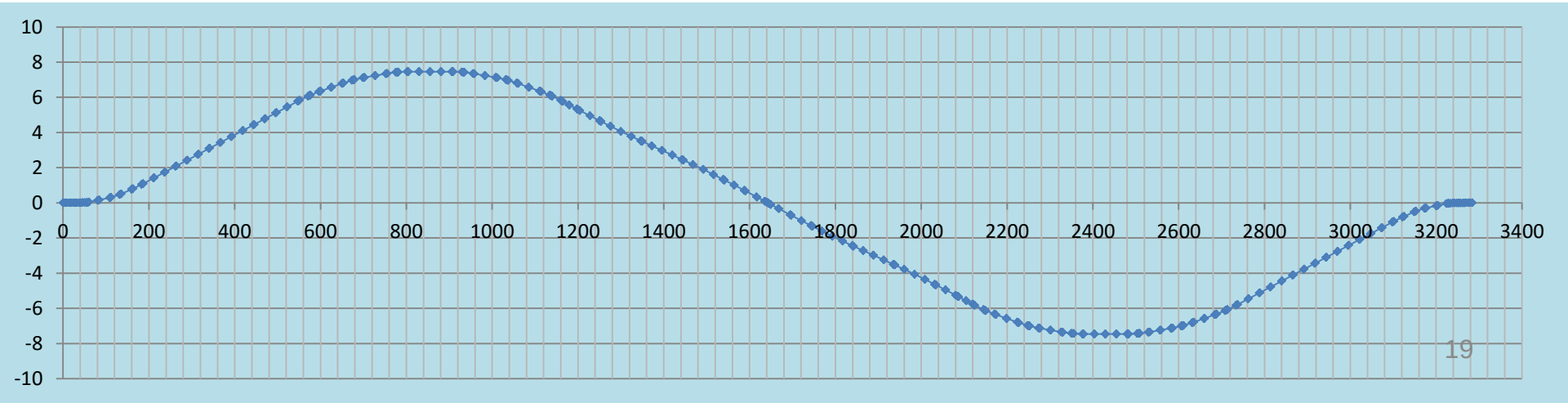
K2=-126.77



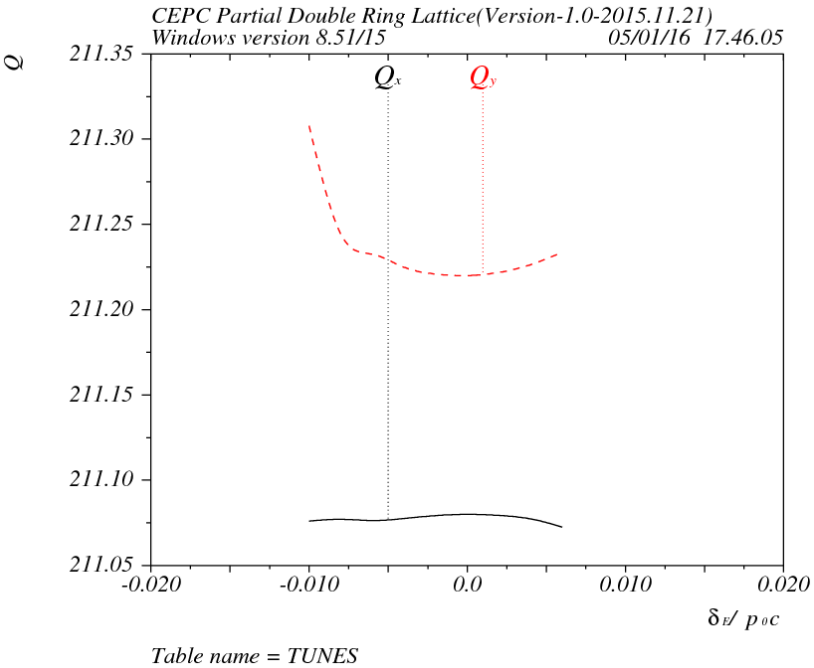
Orbit (RING3_DR_IP1) Version 1.0 + FFS(20151126)



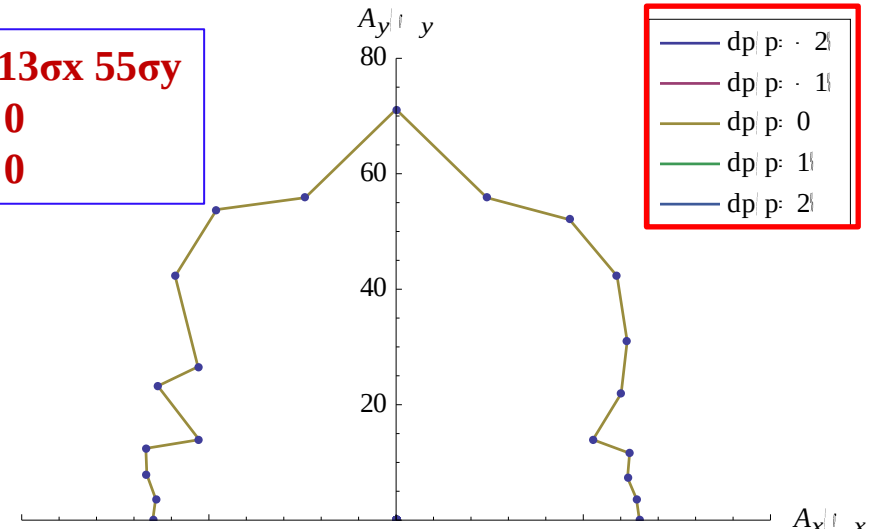


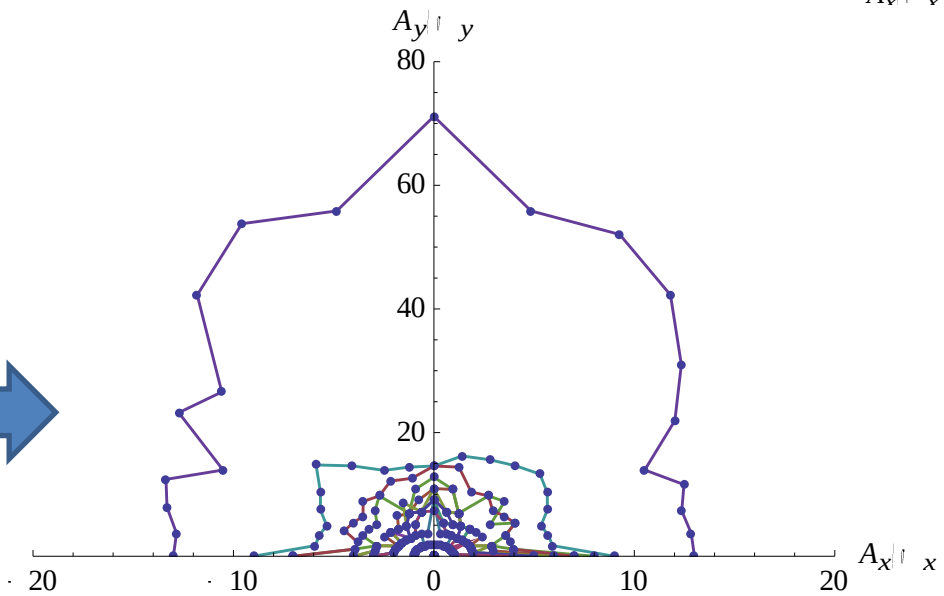


Tune/DA with FFS



0: 13σx 55σy
0.01: 0
0.02: 0



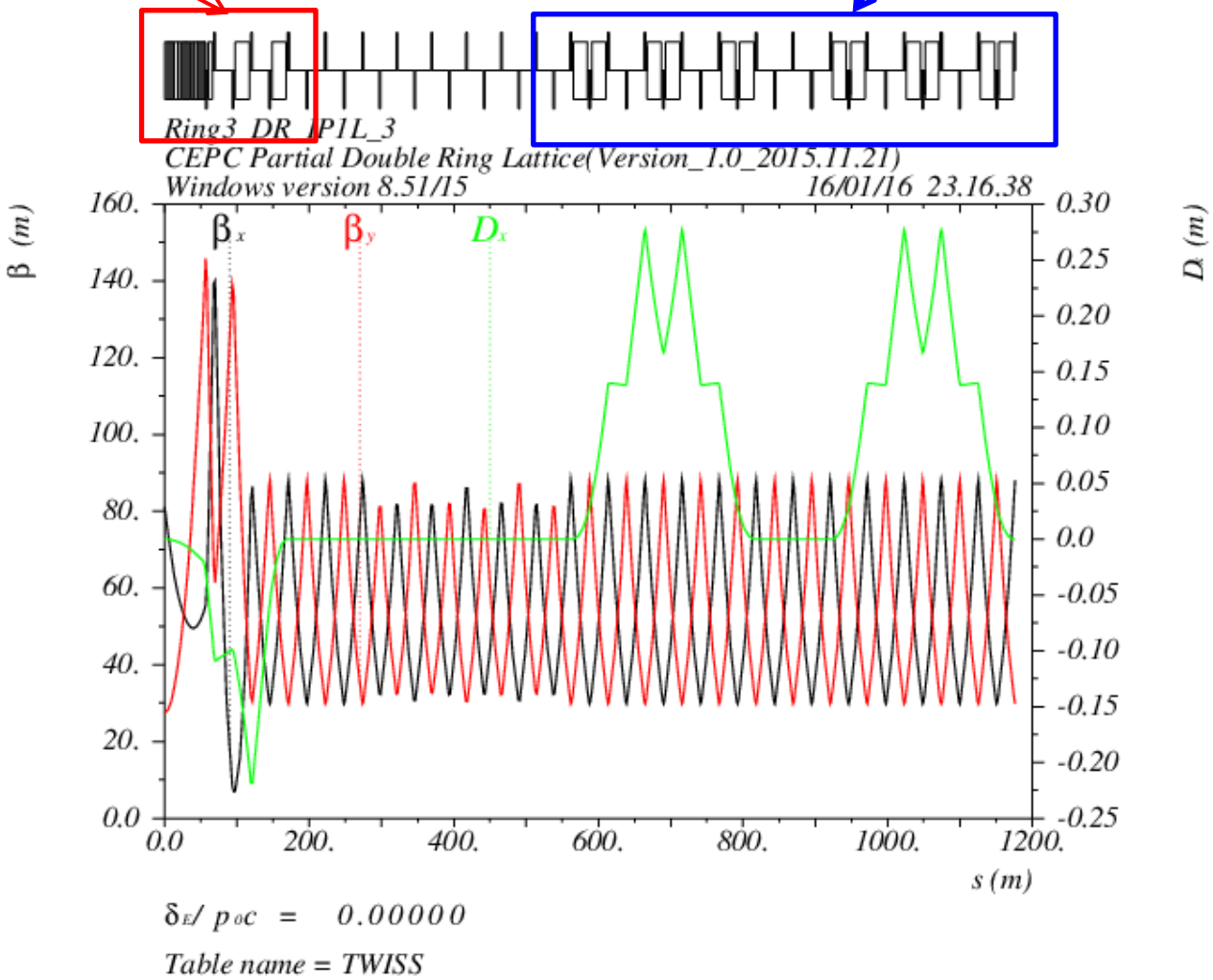


For details:
Energy spread between -0.8628% and 0.719% has DA, out is 0.

Optimize

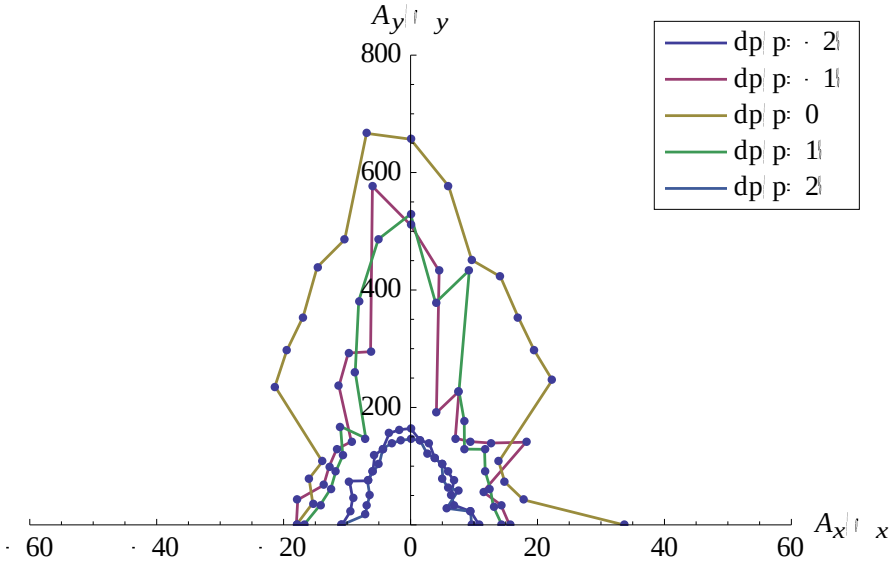
1、We tried to add sextupoles here, but not help for DA. Because it's not easy to match the phase advance between them.

2、Try to add some Sextupoles to correct high order chormaticity here.

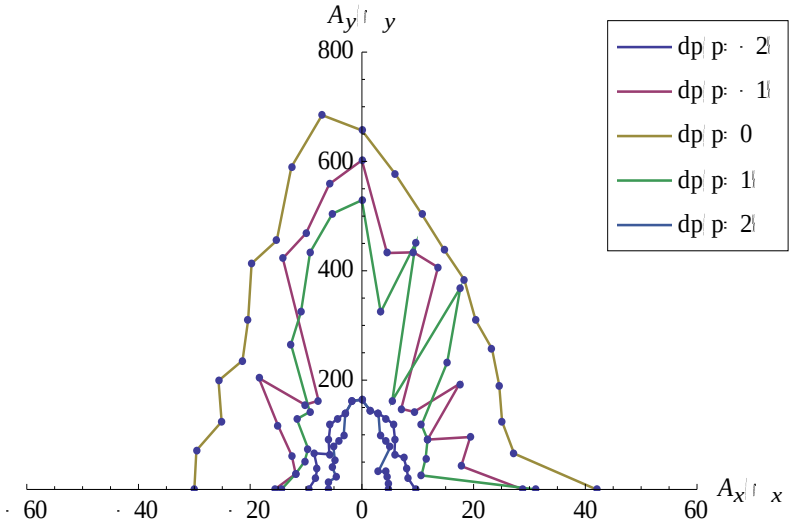


DA Comparation

CEPC-PDR-Bypass



CEPC-PDR-Bypass-Sex



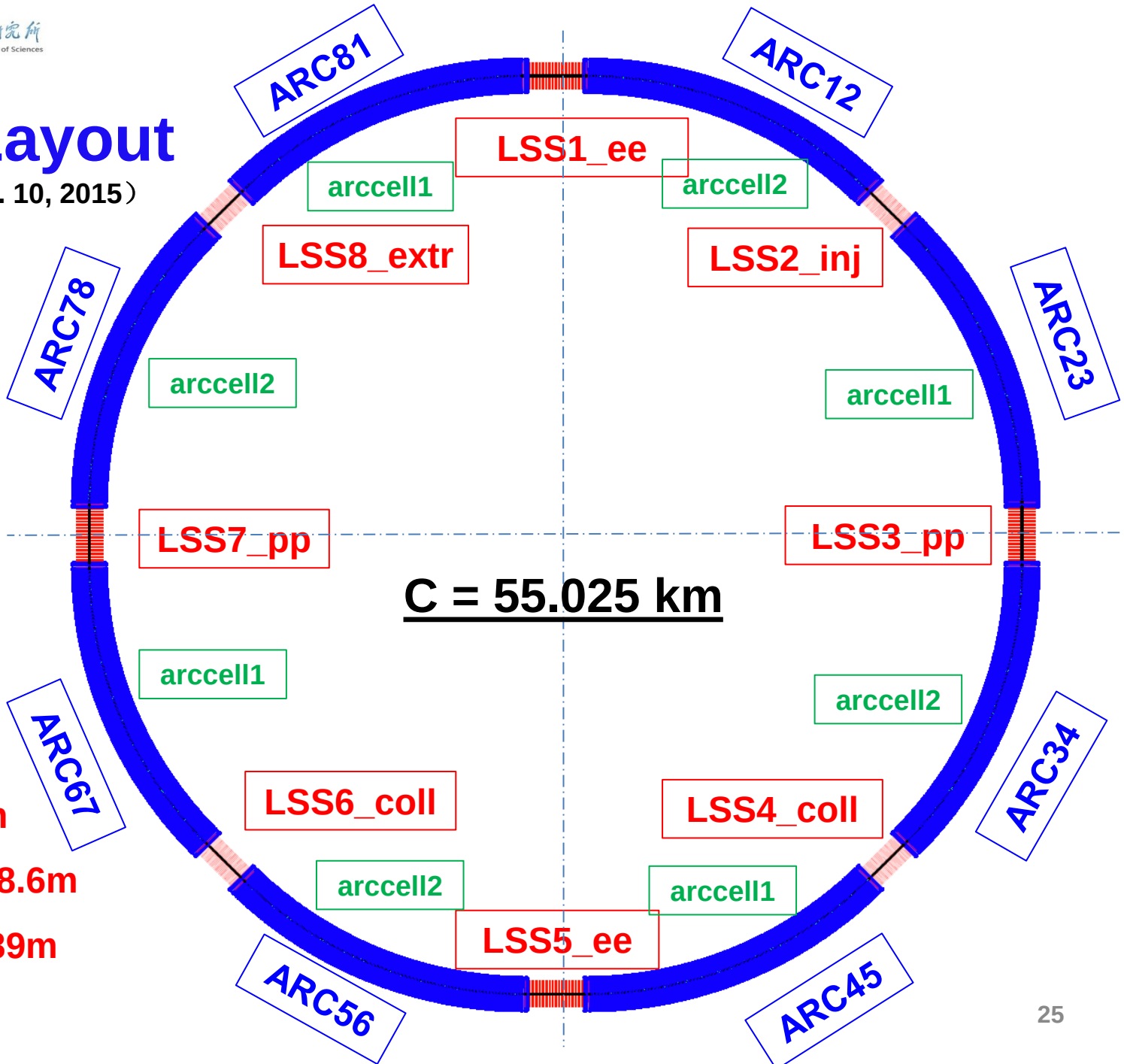
Summary for part 1

- The first version of CEPC Partial Double Ring Lattice was designed (Version 1.0). The whole length of CEPC PDR is 3281.27m, full crossing angle is 26mrad, maximum distance between two ring is 14.913m.
- The Dynamic Aperture need to be optimized. Now the DA of CEPC with PDR and Bypass(at IP2/4) and without FFS is better than before, but the DA with FFS is not good enough.
- We may add more sextupoles in PDR to correct the high order chromaticity , or use more group of sextupoles in ARC to optimize the DA.
- The linear lattice of PDR may also be optimized.

2. SPPC Lattice

SPPC Layout

（Su Feng, Jul. 10, 2015）



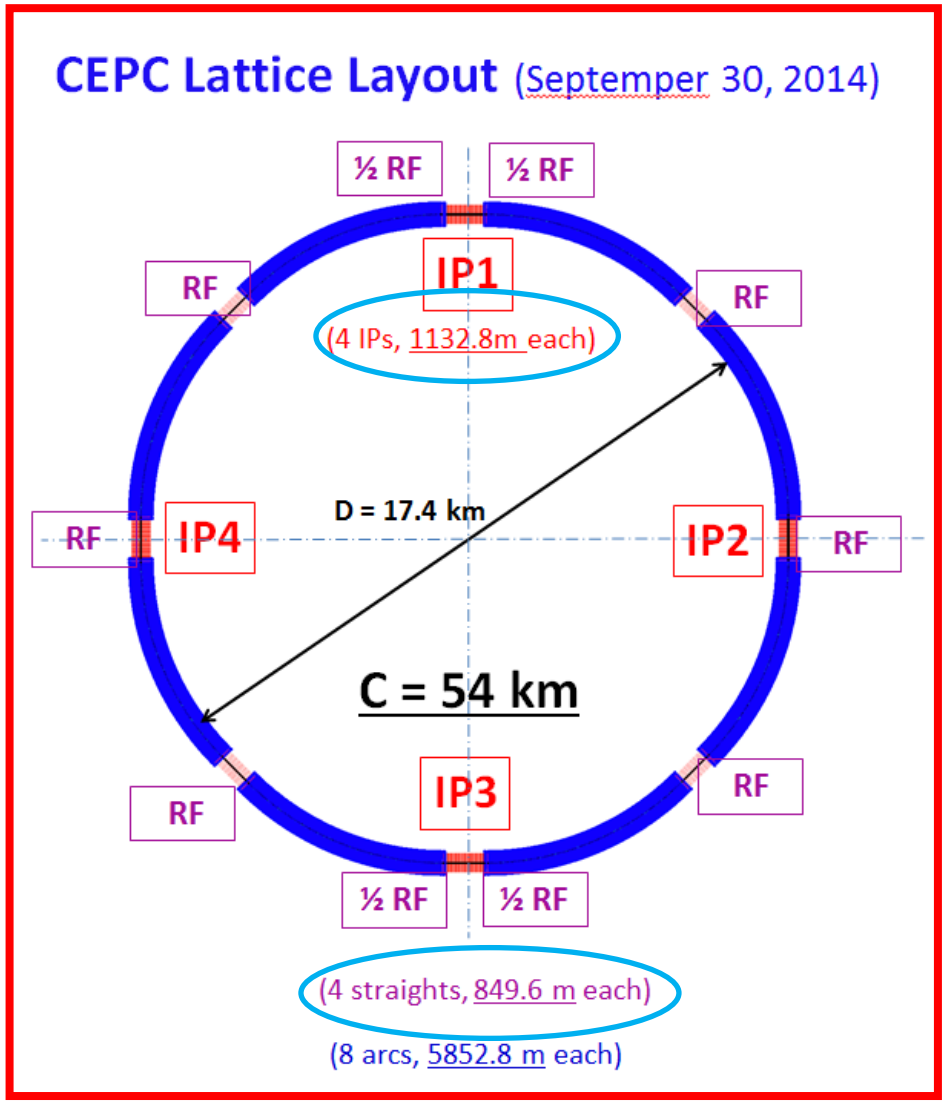
LSS1/5 : 1083m

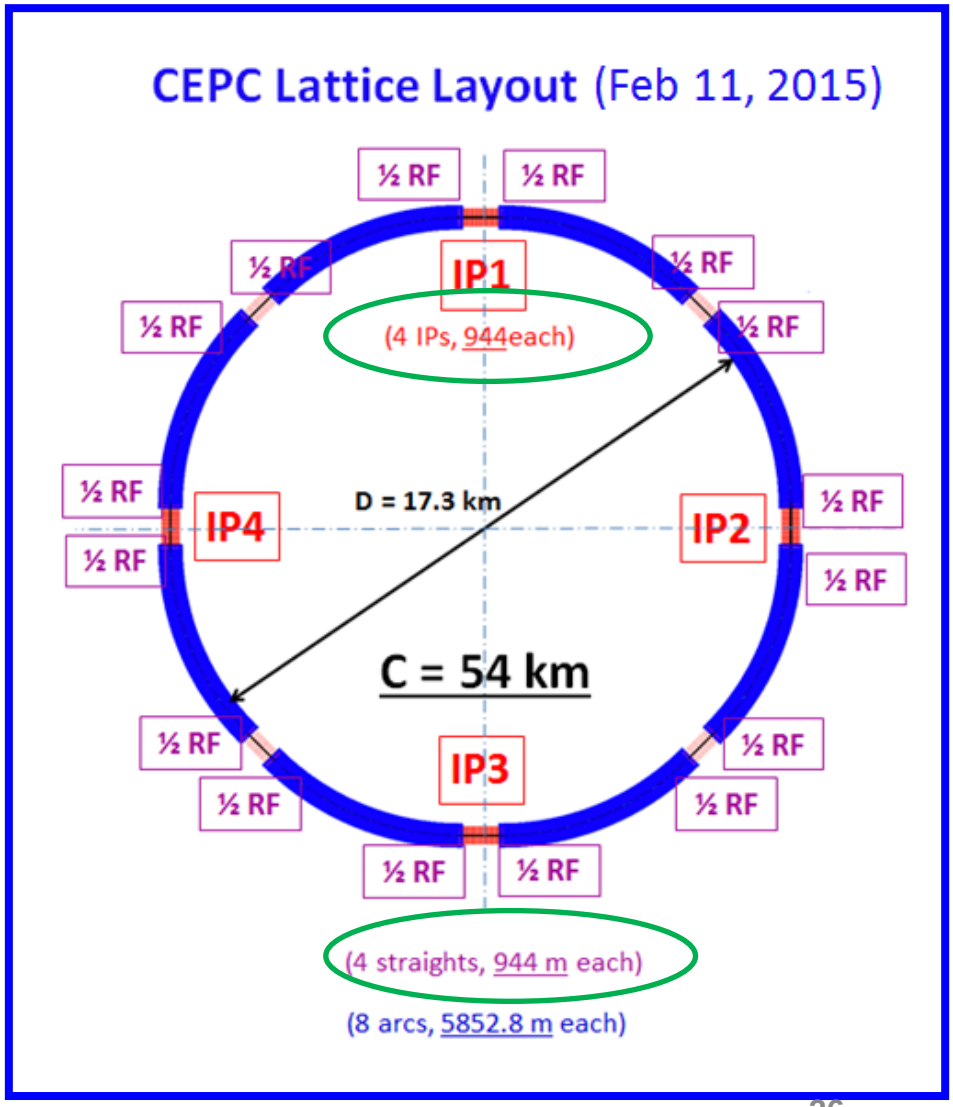
LSS2/4/6/8 : 938.6m

LSS3/7 : 1070.89m

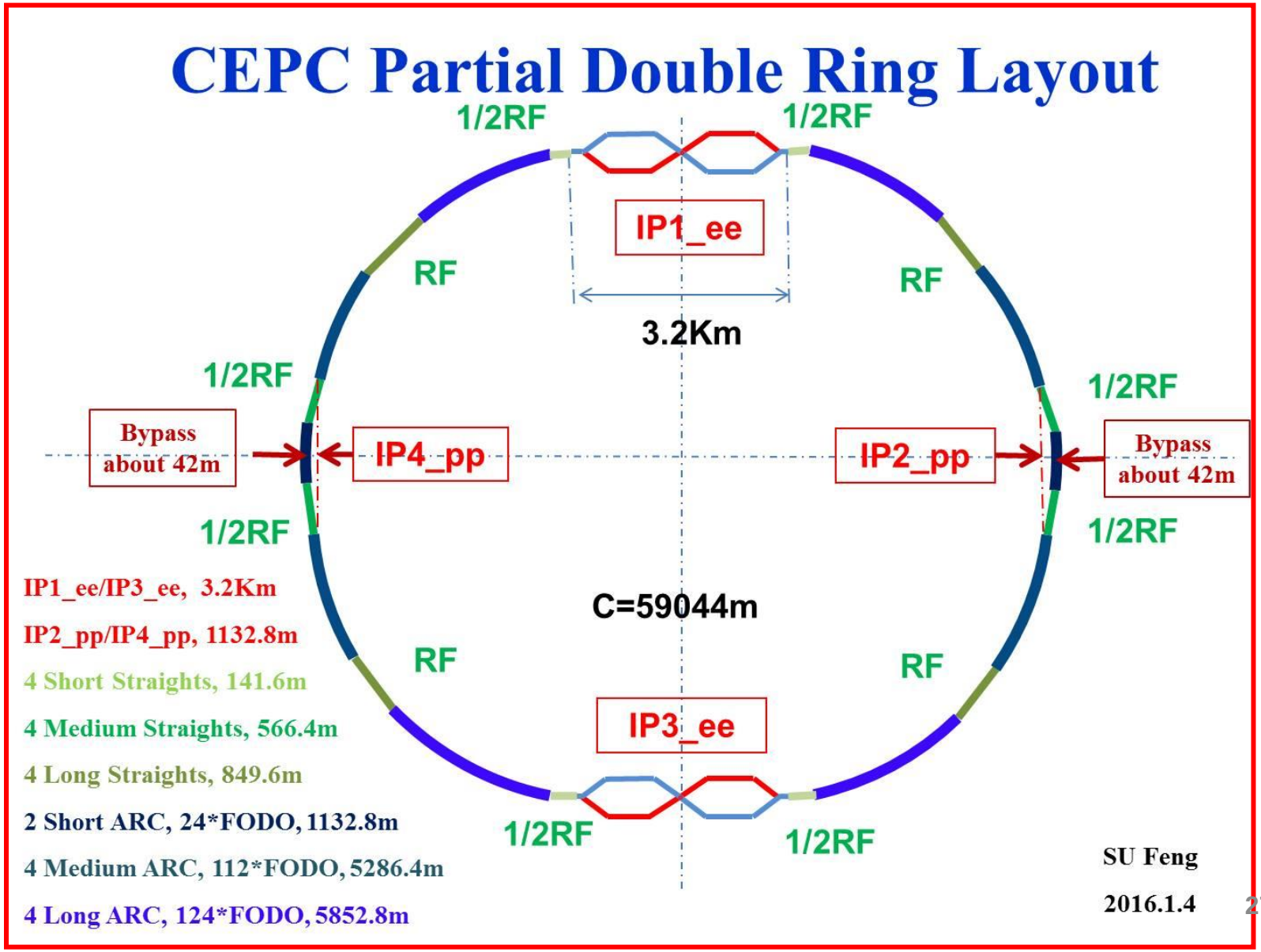
ARC 5920.4m

Layout of two CEPC lattices



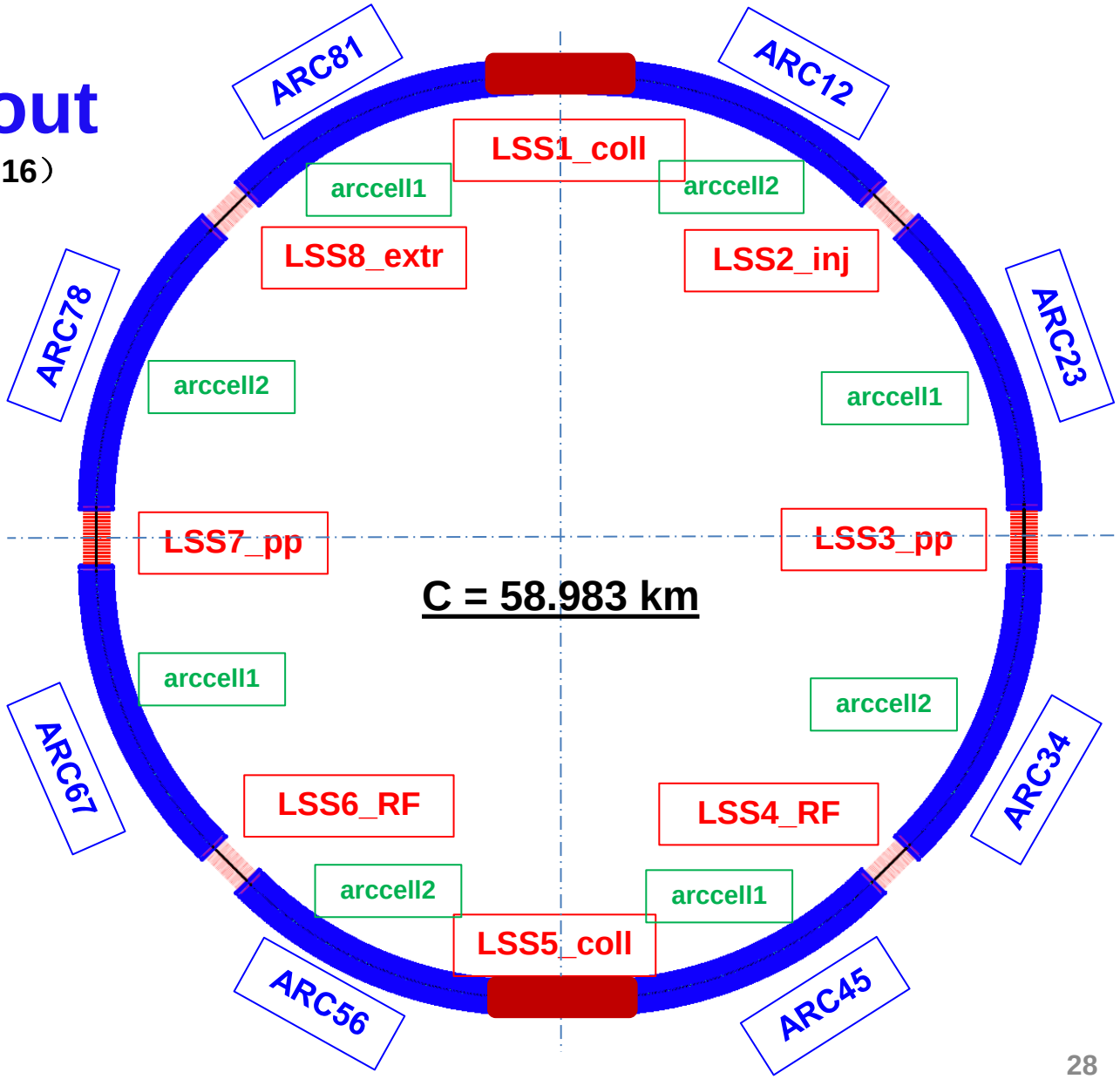


Consideration of CEPC New Layout with PDR



SPPC Layout

（Su Feng Jan. 10, 2016）



LSS1/5_coll ： 3.2Km

LSS2/4/6/8： 788.31m

LSS3/7_pp: 973.83m

ARC: 5963.2m

Parameter Estimate for ARC CELL

$C = 58\ \mathrm{Km}$

$LSS = 12\ \mathrm{Km}$

$L_{ARC} = 58 - 12 = 46\ \mathrm{Km}$

arc filling factor = 0.8

$L_{Dipole} = 46 * 0.8 = 36.8\ \mathrm{Km}$

$$\rho = \frac{L_{Dipole}}{2\pi} = 5856.9\ \mathrm{Km}$$

$L_B = 14 - 15\ \mathrm{m}$

$$n_B = \frac{L_{Dipole}}{L_B} = 2453.3 - 2628.57$$

$E0 = 35\ \mathrm{TeV}$

$$\gamma = \frac{35\ \mathrm{TeV}}{938\ \mathrm{MeV}} = 37\,313.4$$

$\beta = 1$

$B\rho = 3.1267\ \beta\gamma = 116\,635.29\ \mathrm{Tm}$

$$B = \frac{116\,635.29}{5856.9} = 19.92\ \mathrm{T}$$

High Field Dipole in Pre-CDR：20T，15m

$$\frac{2453.3}{256} = 9.58 < n < \frac{2628.57}{256} = 10.265$$

$n = 10$

$n_B = 2560$

$$\theta = \frac{2\pi}{2560} = 0.002454369$$

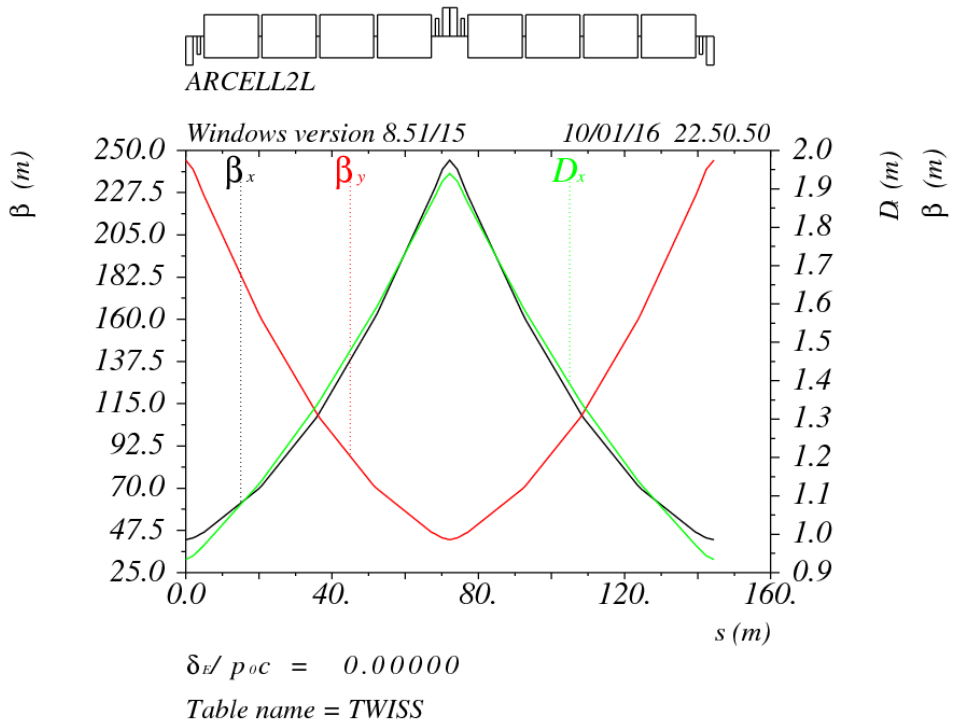
$L_B = \rho\theta = 14.375\ \mathrm{m}$

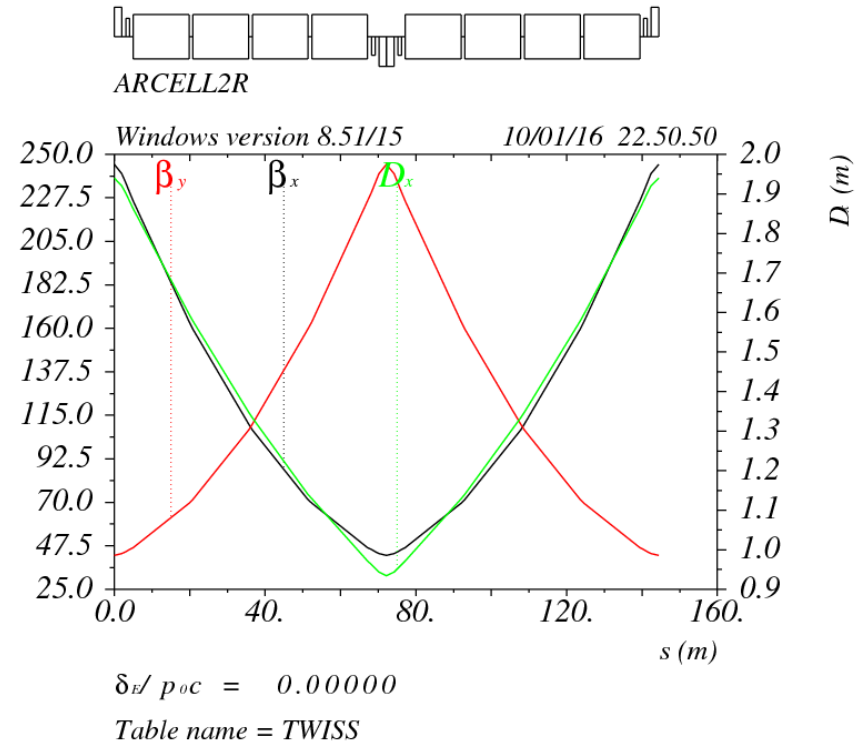
$$L_{cell} = \frac{8 * L_B}{0.8} = 143.75\ \mathrm{m}$$

$$\beta^{\pm} = \frac{\mathrm{Lcell} * \left(1 \pm \mathrm{Sin}[\frac{\mu}{2}]\right)}{\mathrm{Sin}[\mu]} \qquad \alpha^{\pm} = \frac{\mp 1. - \mathrm{Sin}[\frac{\mu}{2}]}{\mathrm{Cos}[\frac{\mu}{2}]}$$

$$D^{\pm} = \frac{\mathrm{Lcell} * \psi * \left(1 \pm 0.5 * \mathrm{Sin}[\frac{\mu}{2}]\right)}{4 * \mathrm{Sin}[\frac{\mu}{2}]^2}$$

FODO CELL in ARC





arccell1

L=144.4m

arccell2

Betax: 244.878/42.57
Betay: 42.569/244.869

ARC CELL

	LQ	DQS	LS	DSB	LB	DBB
SPPC	4m	1m	0.5m	1m	14.8m	1m
FCC-hh	6.3137m	1m	0.5m	2.184m	14.3m	1.36m

B max [T]	G max [T/m]	k1	k2
19.61	582.156	4.9899E-3	0

Pre-CDR:

Dipole: L=15m B=20T

Quadrupole:

D = 45 mm **B_{pole}=16 T**

G=711.1T/m K1=6.097*10^-3

Betax: 244.878/42.57
Betay: 42.569/244.869

(ϵ_n =4.1um)

$$\epsilon = \frac{\epsilon_n}{\gamma}$$

E (Collision: 35TeV)
(Injection: 2.1TeV)

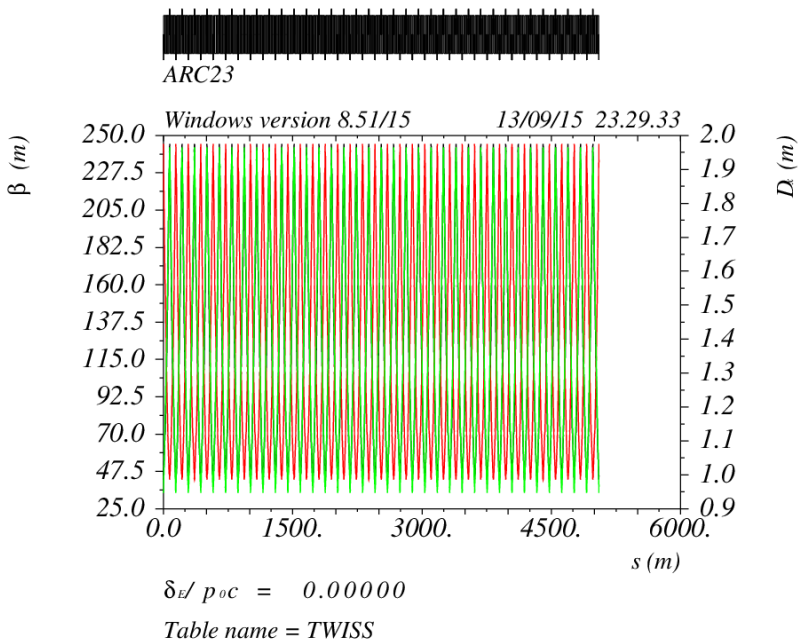
ϵ (Collision: 1.099*10^-10m=0.1099nm)
(Injection: 1.83*10^-9m=1.83nm)

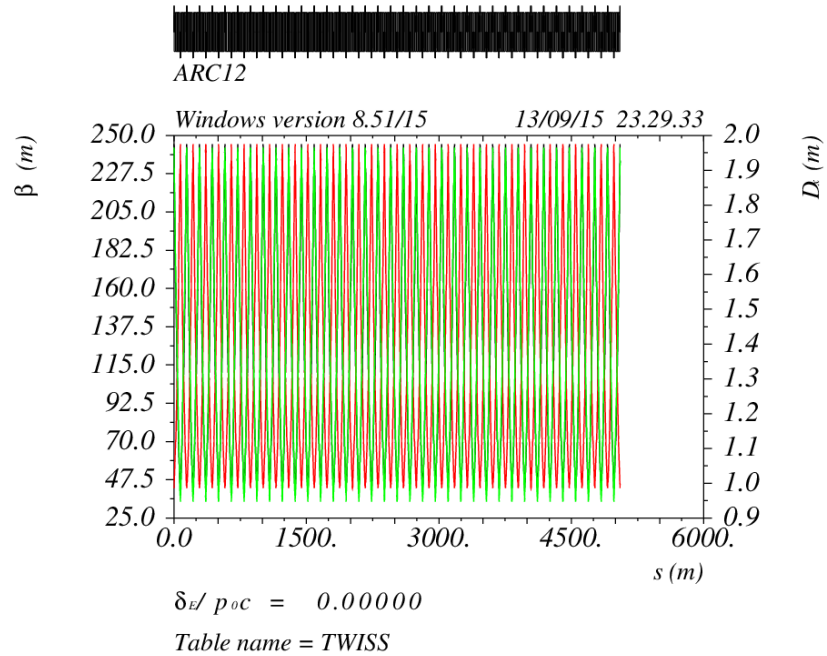
σ (Collision: 1.66*10^-4m=166um)
(Injection: 6.76*10^-4m=676um)

R=20*σ_{Inj}=13.52mm

D=27.04

ARC （ARCDSPL,36 CELL, ARCDSPR）



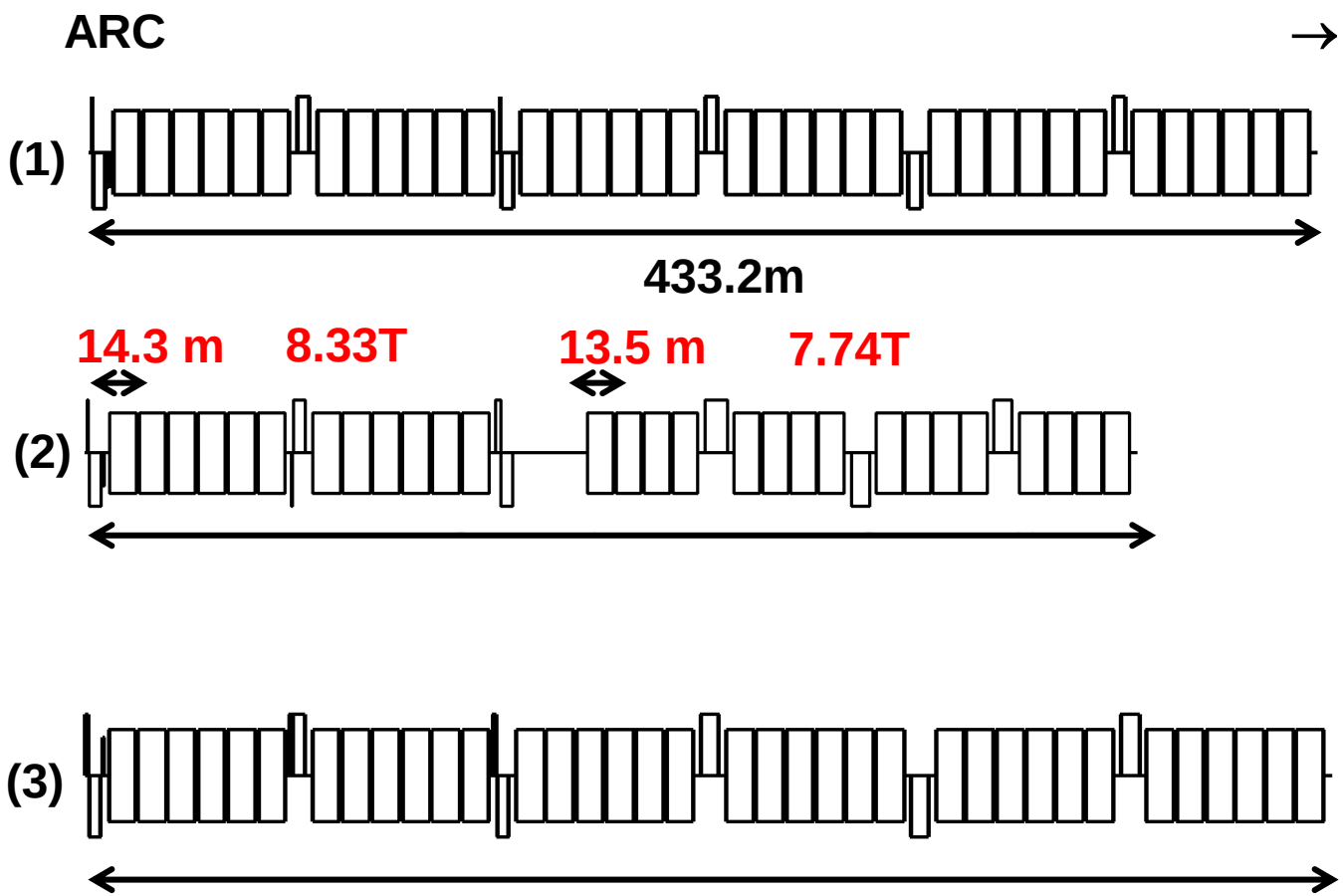


ARC23
ARC45
ARC67
ARC81

L=5963.2m

ARC12
ARC34
ARC56
ARC78

Dispersion Suppressor (DS) types



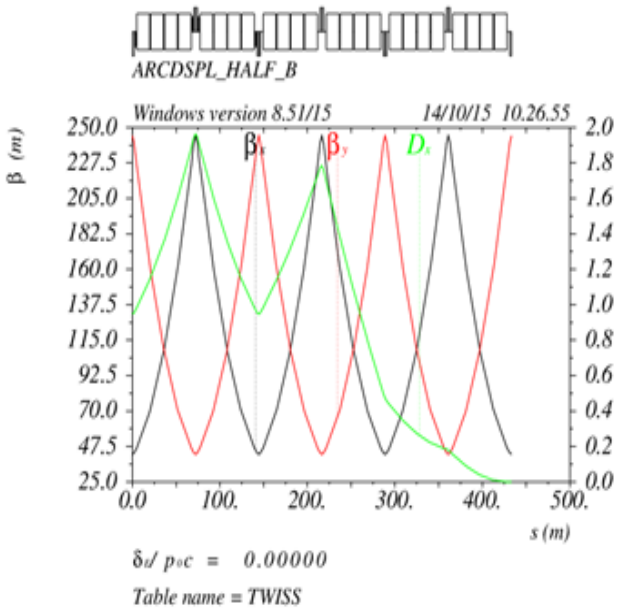
Half Bend
(half weak dipoles)

LHC-like

Full Bend

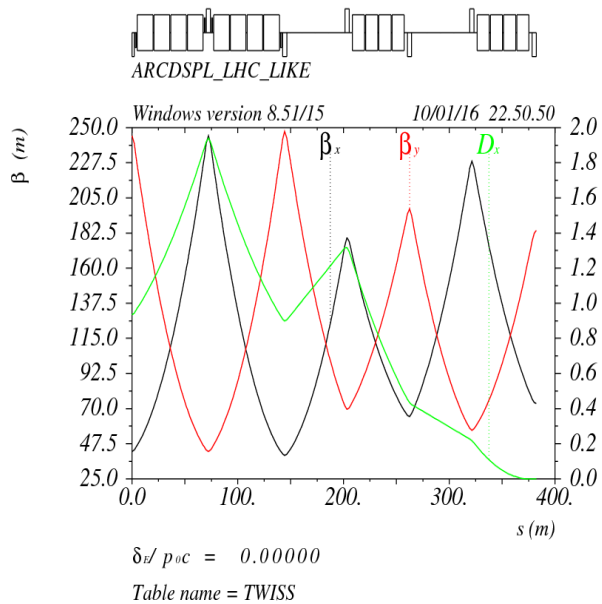
Longer DS but less cells in the Arcs

(1) Half Bend



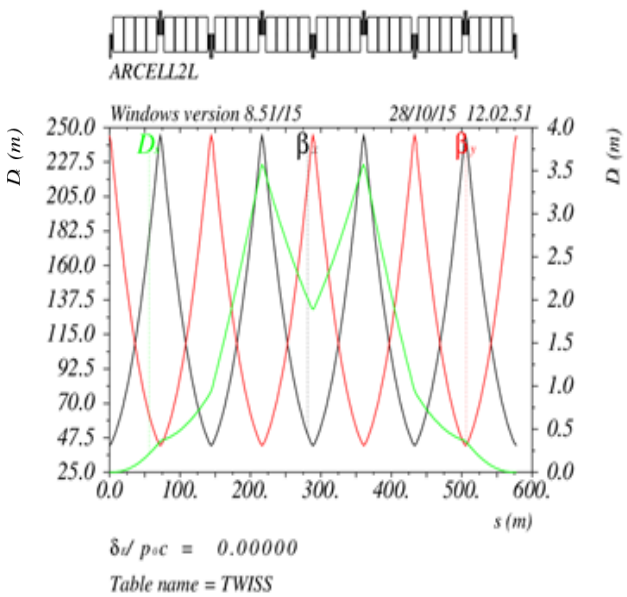
L=433.2m

(2) LHC Like



L=382.4m

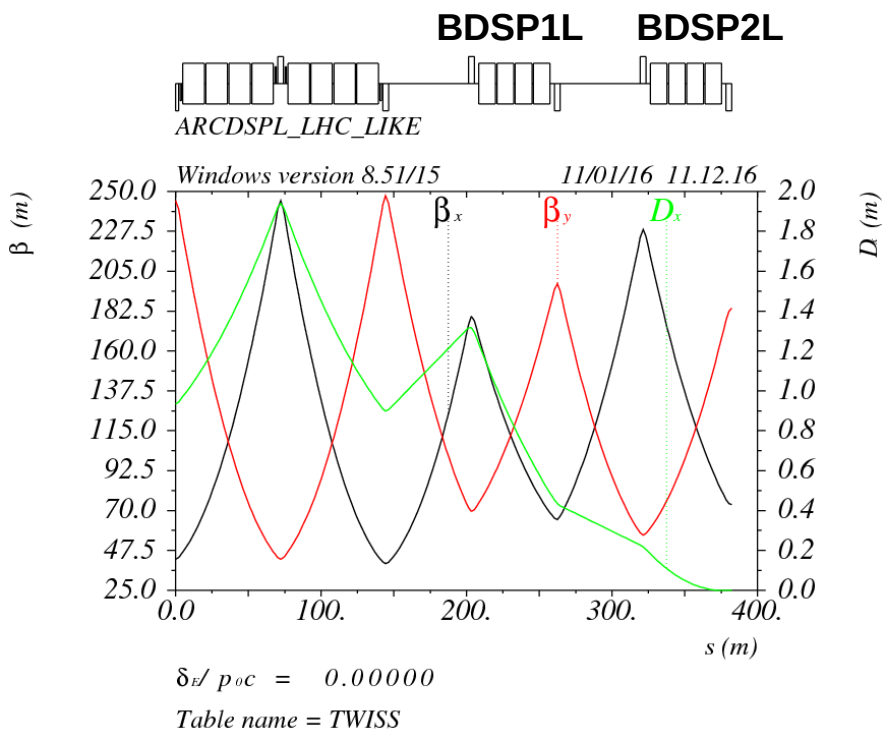
(3) Full Bend

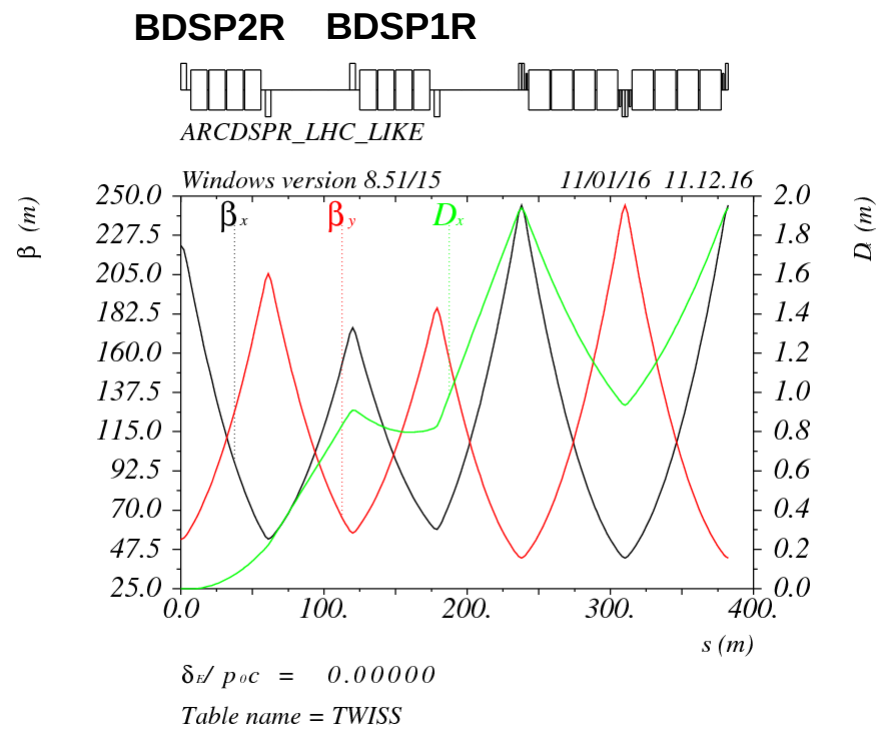


L=577.6m

	BDSP1L	BDSP2L	BDSP1R	BDSP2R	B0	
(1)	9.93	9.93	9.93	9.93	19.86	(T)
(2)	18.93	18.93	18.93	18.93	19.86	(T)
(3)	19.86	19.86	19.86	19.86	19.86	(T)

Dispersion Suppressor (DS)





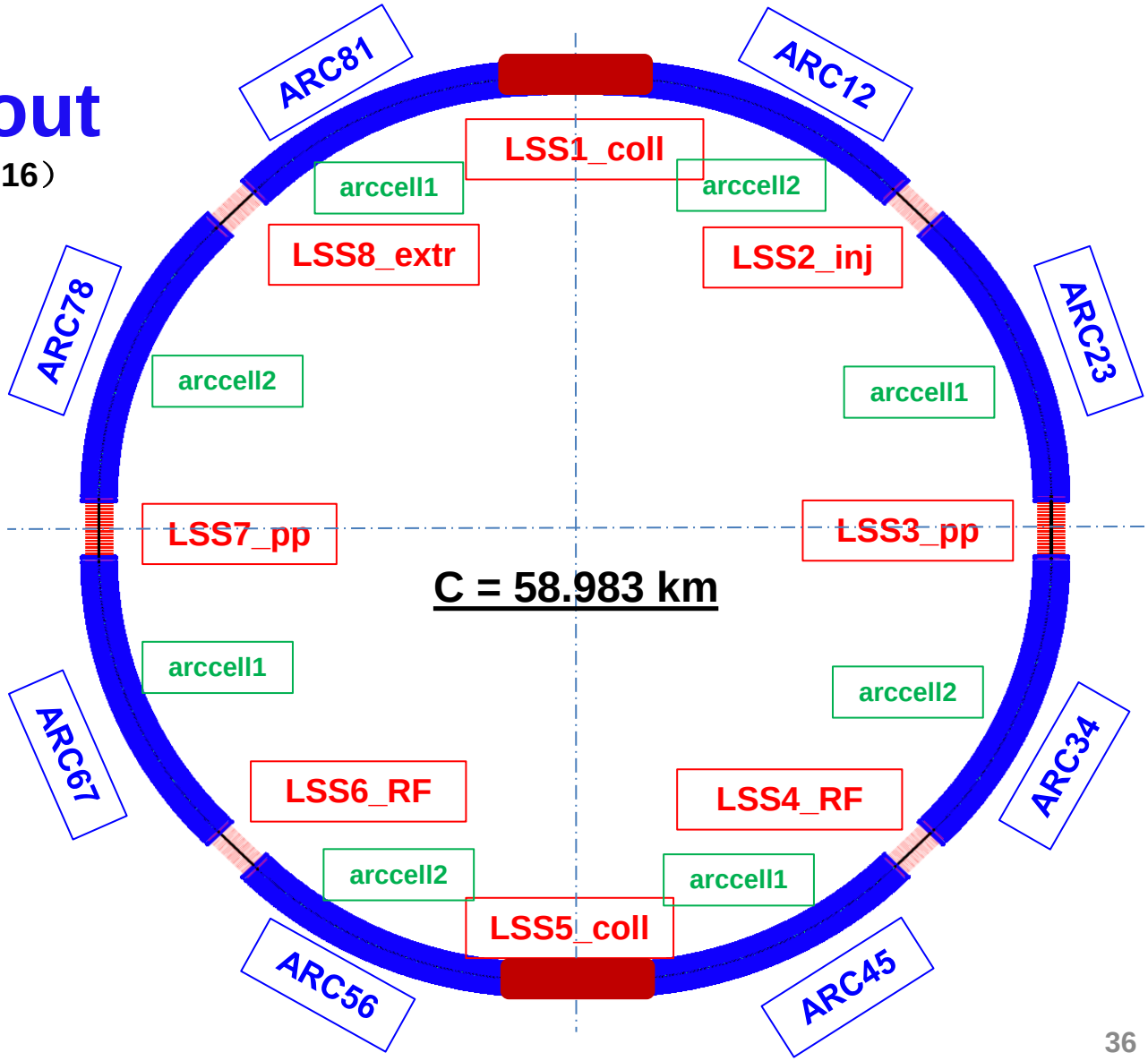
382.4m

	BDSP1L	BDSP2L	BDSP1R	BDSP2R	B0	
B	18.93	18.93	18.93	18.93	19.86	T
L	11.5	11.5	11.5	11.5	14.8	m

Long Straight Section

SPPC Layout

（Su Feng Jan. 10, 2016）



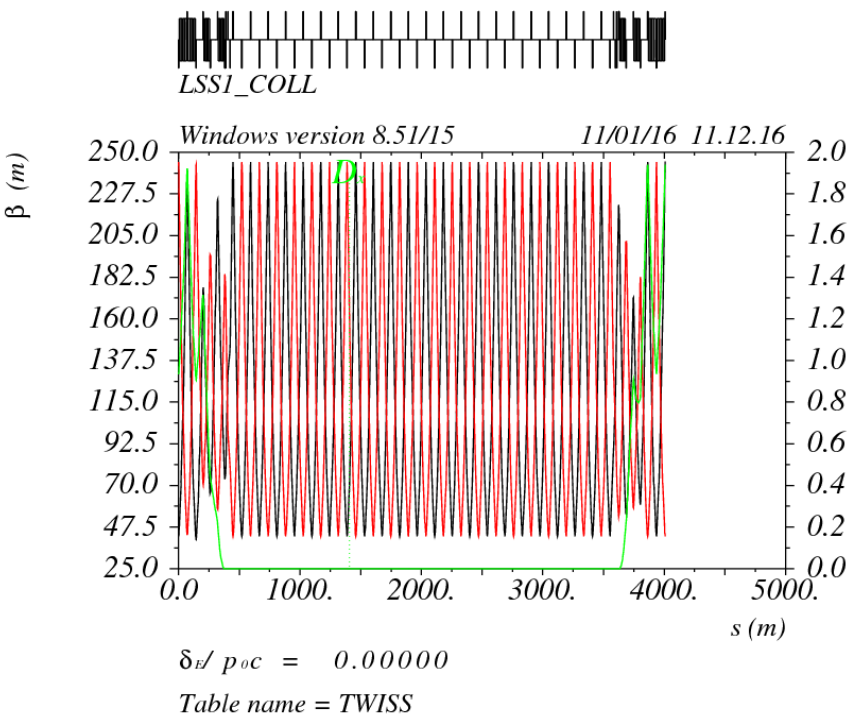
LSS1/5_coll： 3.2Km

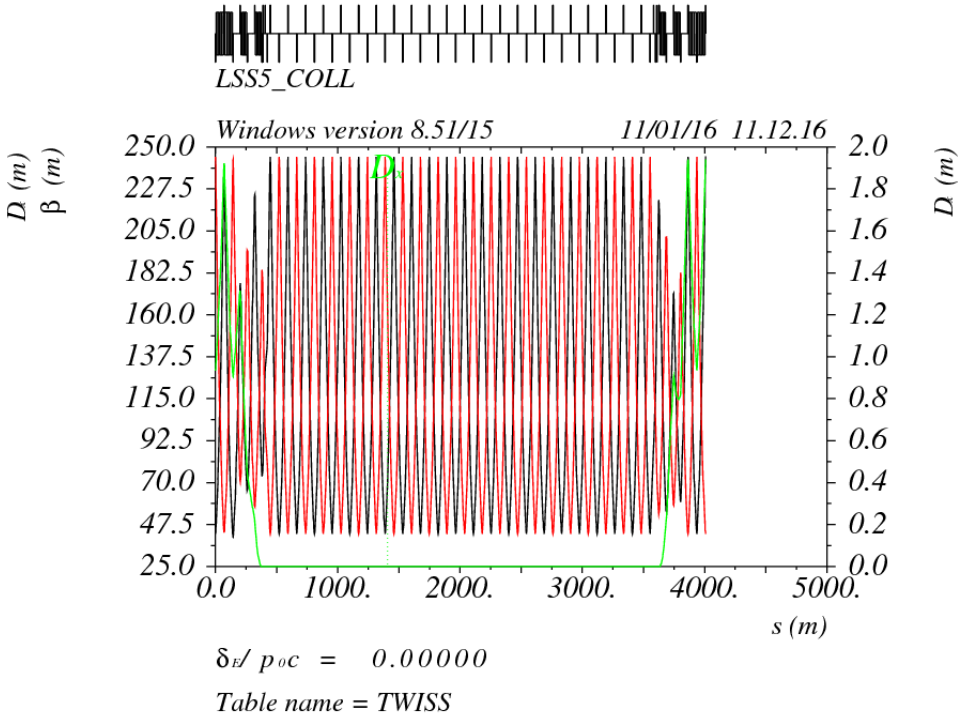
LSS2/4/6/8： 788.31m

LSS3/7_pp: 973.83m

ARC: 5963.2m

LSS1/5_coll



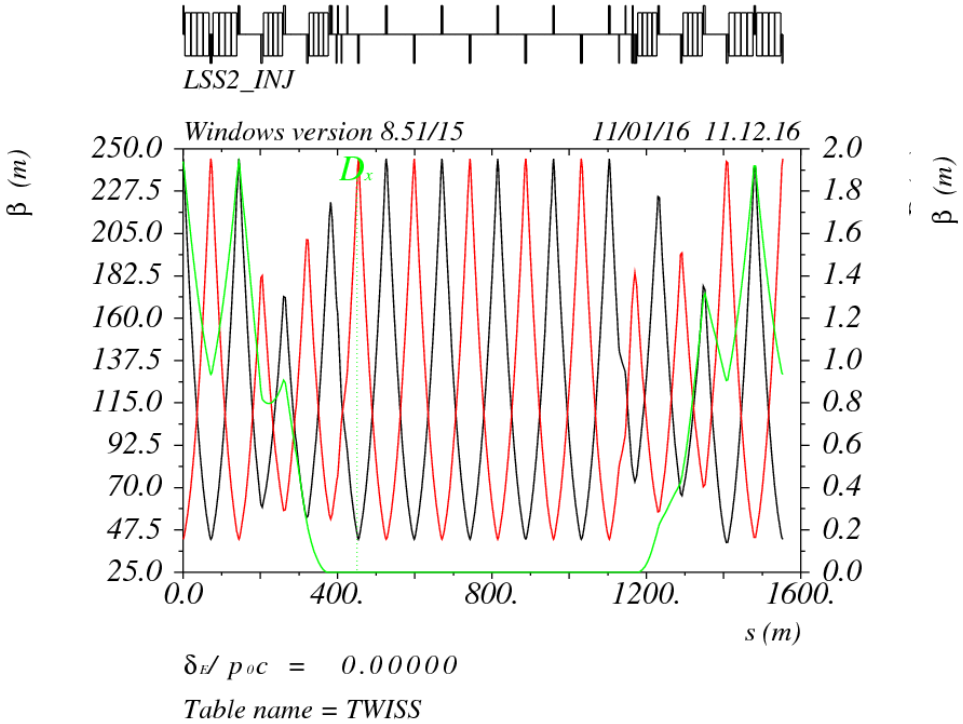


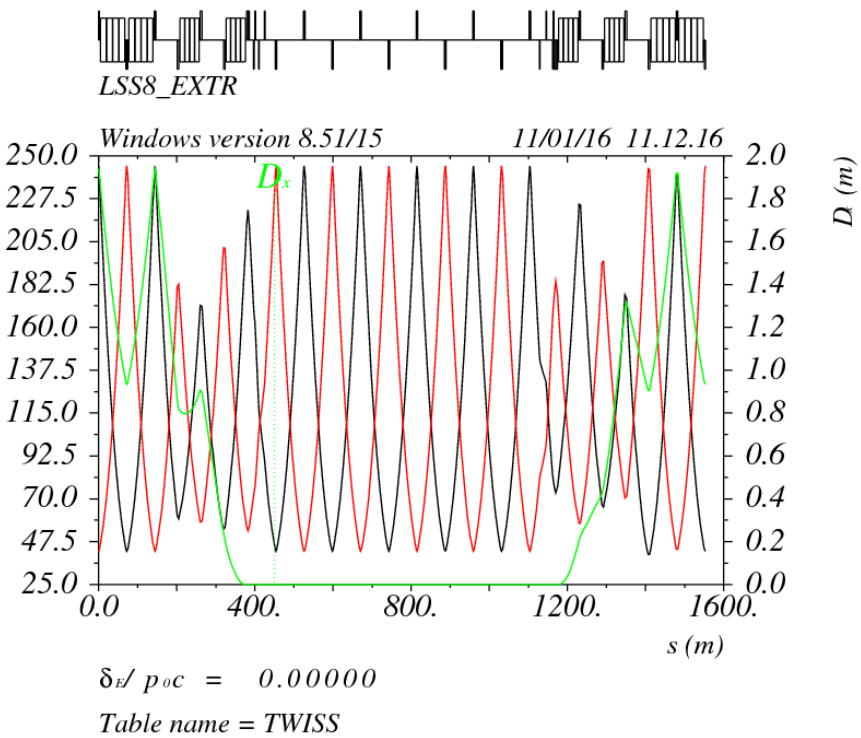
L=3243.106m

ARCDSPL, ARC_to_STR, 21.5*STRCELL, STR_to_ARC, ARCDSPR

382.4m, 71.719m, 3104.6m, 66.789m, 382.4m

LSS2_inj/LSS8_extr



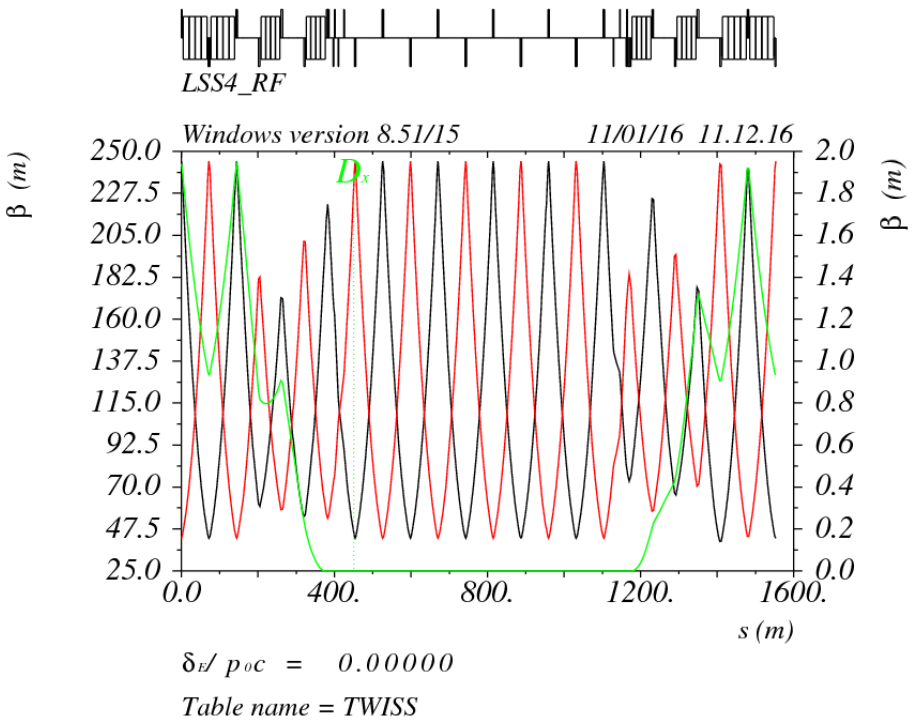


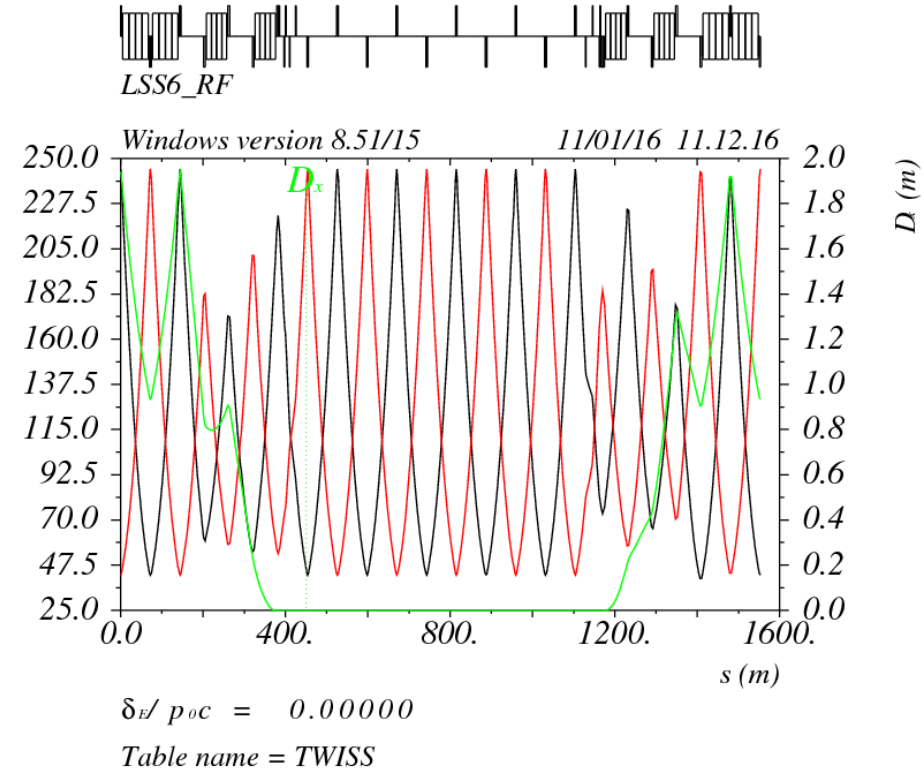
L=788.306m

-ARCDSPR, ARC_to_STR, 4.5*STRCELL, STR_to_ARC, -ARCDSPL

382.4m, 71.719m, 649.8m, 66.787m, 382.4m

LSS4/6_rf



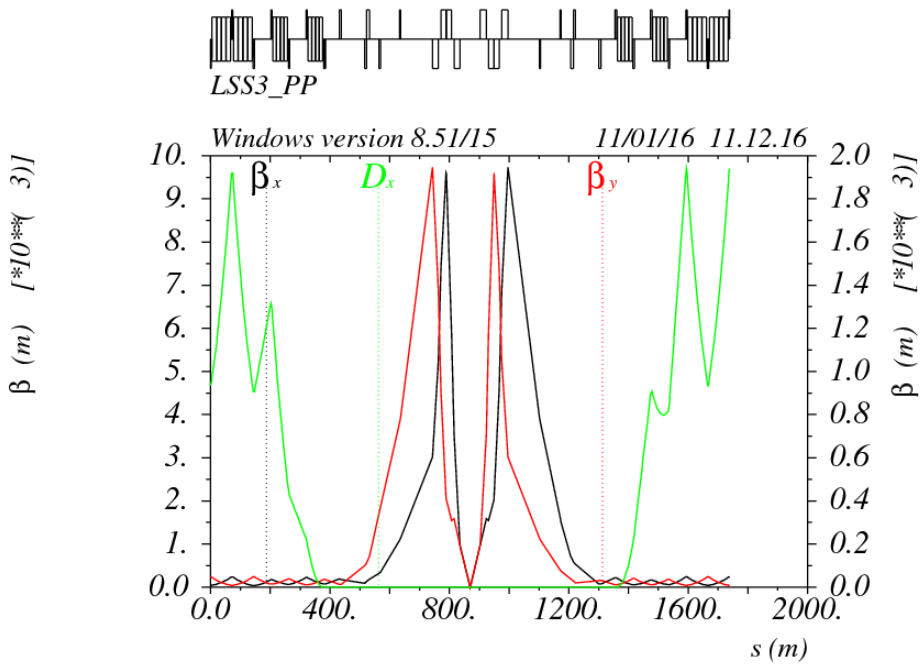


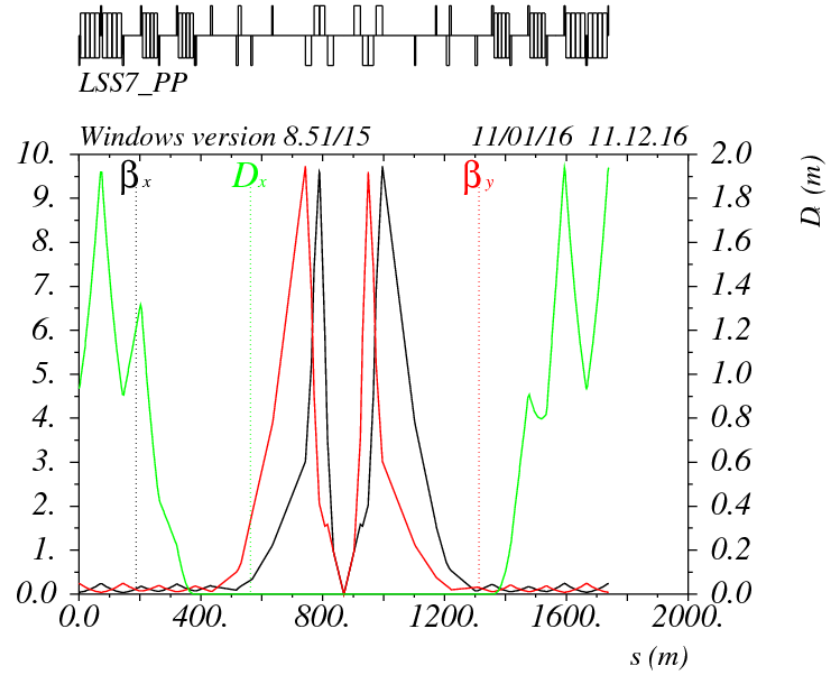
L=788.306m

-ARCDSPR, ARC_to_STR, 4.5*STRCELL, STR_to_ARC, -ARCDSPL

382.4m, 71.719m, 649.8m, 66.787m, 382.4m

LSS3_pp/LSS7_pp





L=973.829m

ARCDSPL, ARC_to_STR, 21.5*STRCELL, STR_to_ARC, ARCDSPR

382.4m, 71.719m, 973.829m, 66.789m, 382.4m

	K1(m^-2)	G（T/M）	L(M)	βmax
K1.QT.1R	4.9751e-03	580.428	6	3543.69
K1.QT.A2R	-5.2595e-03	-613.668	9	9601.686
K1.QT.B2R	-5.2595e-03	-613.668	9	9601.686
K1.QT.3R	5.3434e-03	623.369	8	9731.53
K1.QM.4R	-2.2804E-04	-266.04	4	3798.29
K1.QM.5R	8.8592E-04	103.36	4	1506.53
K1.QM.6R	-1.2144E-03	-141.68	4	587.87
K1.QM.7R	1.0640E-04	124.133	4	531.25
K1.QM.8R	-4.2431E-03	-495.028	4	162.20
K1.QT.1L	-4.9751e-03	-580.428	6	3543.69
K1.QT.A2L	5.2595e-03	613.668	9	9601.686
K1.QT.B2L	5.2595e-03	613.668	9	9601.686
K1.QT.3L	-5.3434e-03	-623.369	8	9731.53
K1.QM.4L	2.2804E-04	266.04	4	3798.29
K1.QM.5L	-8.8592E-04	-103.36	4	1506.53
K1.QM.6L	1.2144E-03	141.68	4	587.87
K1.QM.7L	-1.0640E-04	-124.133	4	531.25
K1.QM.8L	4.2431E-03	495.028	4	162.20

Q Strength

Pre-CDR:

IR:

D = 60 mm **B_{pole} = 20 T**

G=666.7T/m **K1=5.716*10^-3**

R=30mm

20mm=20σ

σ=1mm

β=σ^2/ε=10.03km

Matching section:

D = 60 mm **B_{pole} = 16 T**

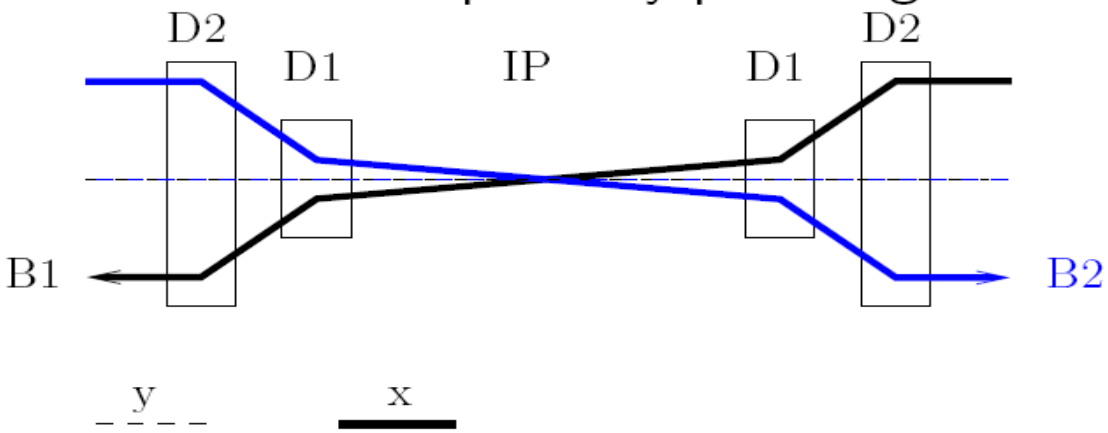
G=533.3T/m **K1=4.572*10^-3**

Separation Dipole

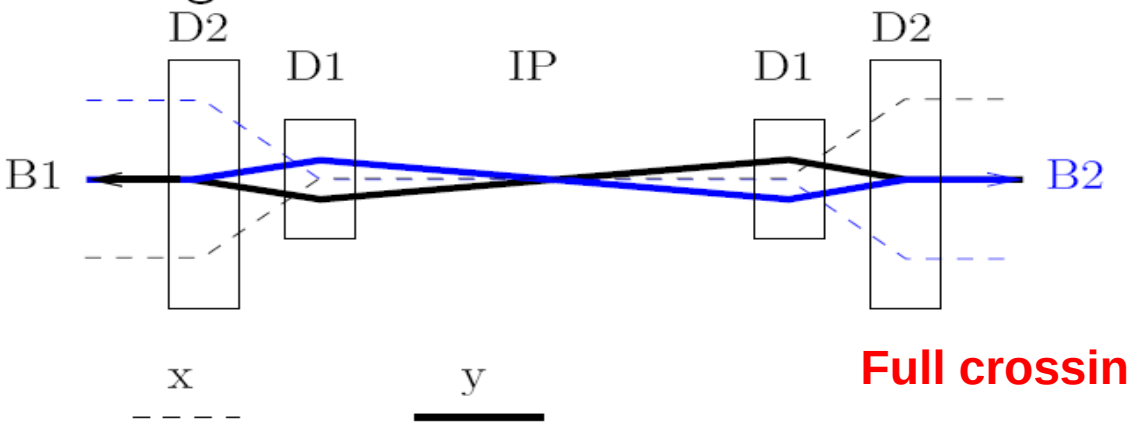
Crossing angle schemes

Crossing angle is achieved:

- for the horizontal plane by powering differently D1 and D2

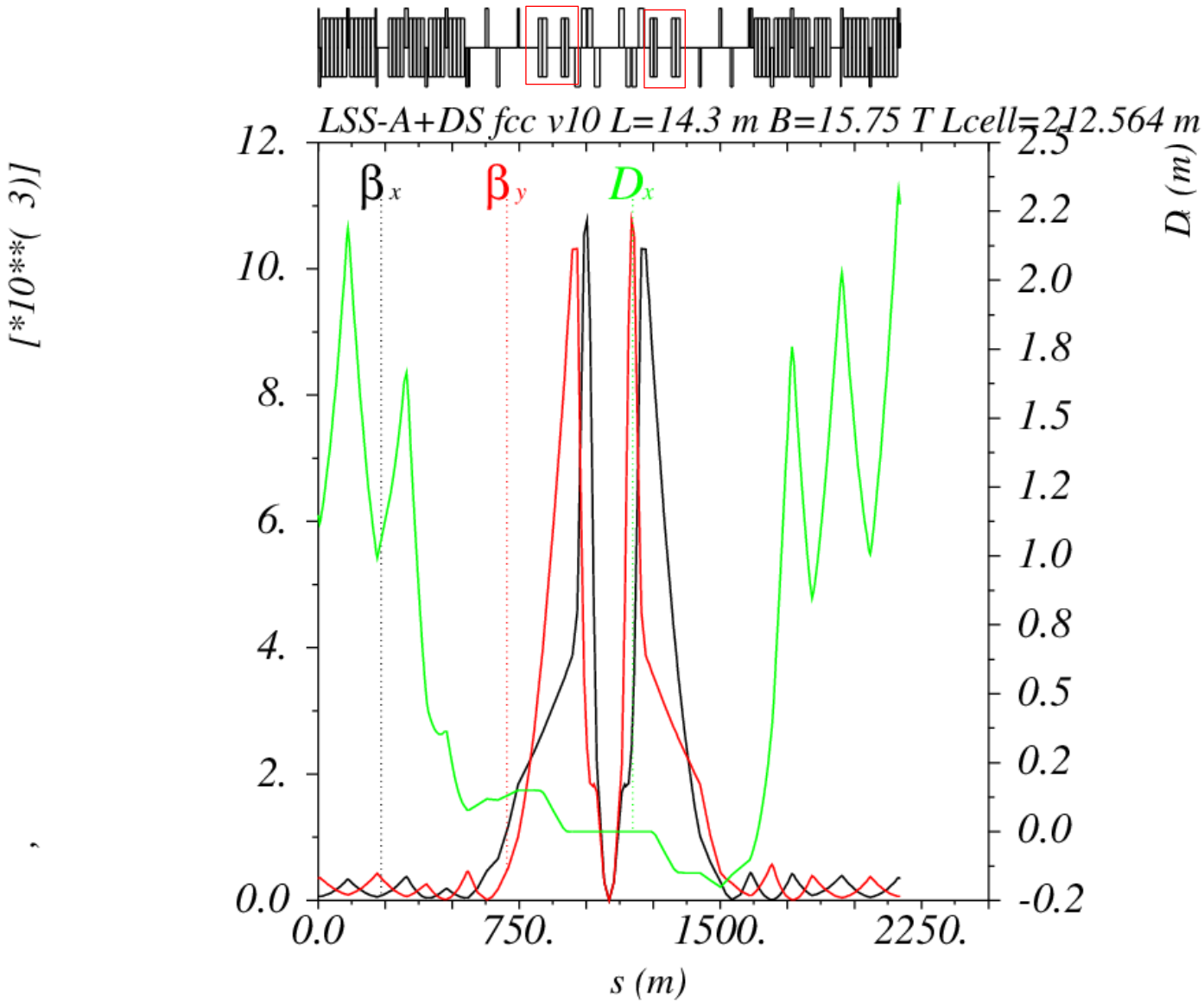


- for the vertical plane by tilting D1 and D2 resulting in a vertical deflection



Full crossing angle=146μrad

Separation Dipole



Summary for part 2

- The first version of SPPC Lattice was designed . The whole length and layout is according to CEPC lattice layout. full crossing angle is 146urad.
- Crossing angle and Separation Dipole need to be studied and installation.
- LSS3_pp low-β pp optics need to be studied and optimization.
- The Dynamic Aperture need to be studied: MADX or Sixtrack.

Acknowledge

- Gang Xu, Qing Qin, Yuan Zhang, Yuemei Peng, Qingjin Xu, Yukai Chen, Xiaohao Cui, Zhe Duan, Yudong Liu, ……
- Thanks for your kind help and beneficial discussion!

Reference

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[2] LHC Design Report, Vol.1, CERN-2004-003.

[3] J. Gao, IHEP-AC-Note-2013-012.

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[8] R. Martin, et al, “Status of the FCC-ee interaction region design”, HF2014 Workshop, Beijing, China, 9-12 October, 2014

中国科学院高能物理研究所
Institute of High Energy Physics Chinese Academy of Sciences

Thank You !

Back up

Electrostatic Separator in LEP

Separator length	4.5 m
Inner diameter of separator tank	540 mm
Electrode length	4.0 m
Electrode width	260 mm
Nominal gap	110 mm
Maximum operating field strength	20 kV/cm
Maximum operating voltage	± 110 kV
Max. deflection per separator at 55 GeV	145 μrad
Conditioning voltage on the test bench	± 200 kV
Conditioning voltage after installation	± 160 kV
Maximum voltage for vernier adjustment	± 35 kV
Range of vernier adjustment at 55 GeV	76 μm
Horizontal good field region (1% limit)	± 80 mm
Maximum tilt per electrode	± 5 mrad
Pumping speed of sputter ion pumps	800 l/s
Pumping speed of sublimation pumps	1300 l/s
Nominal vacuum pressure in the low-beta insertions	$2.7 \cdot 10^{-8}$ Pa
Number of separators per collision point	4
Total number of separators	32
Total number of high voltage circuits	32

L=4.5m

$L_{electrode}$=4.0m

E_{field}=2MV/m

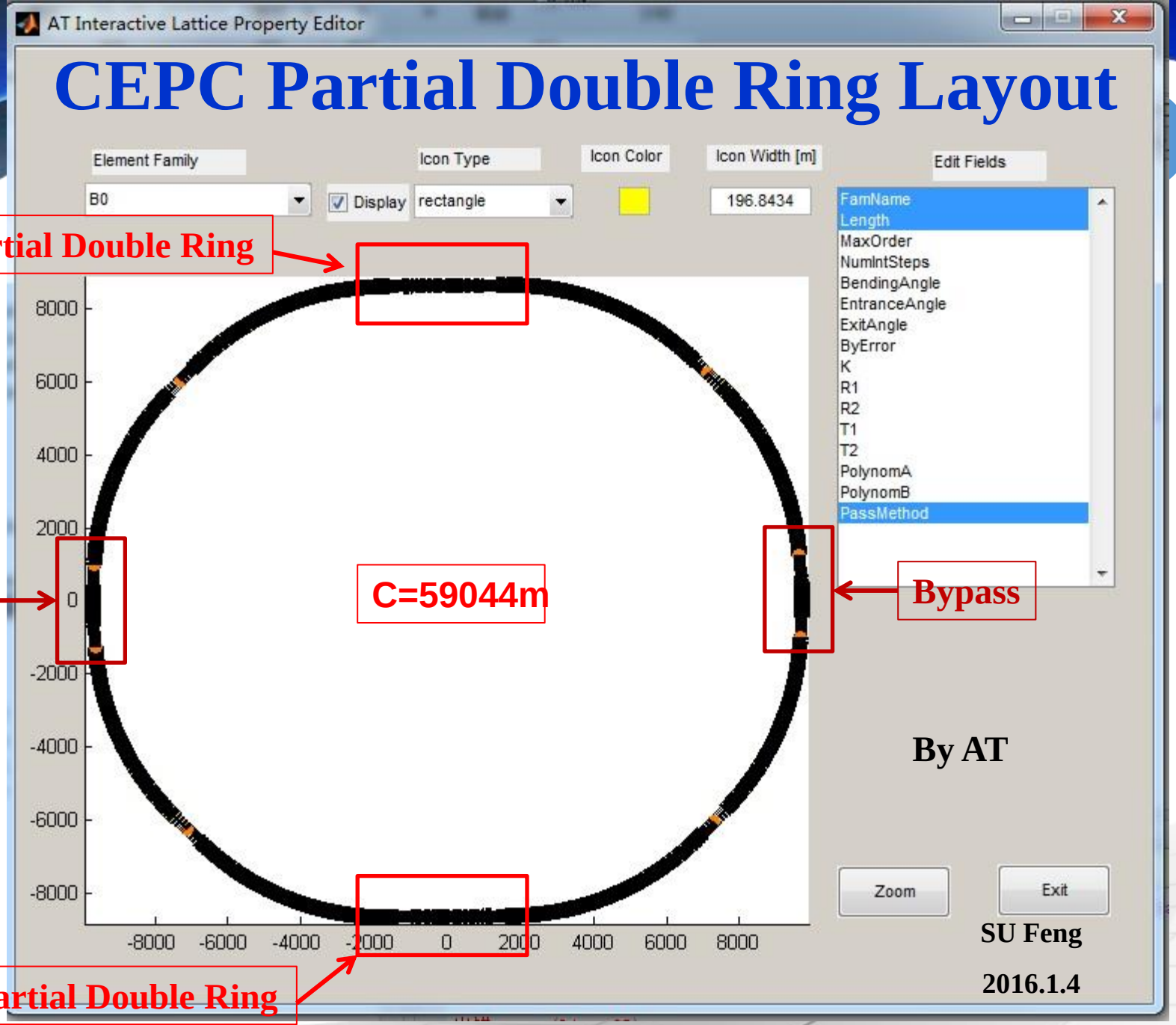
E=55GeV

Angle=154urad

E=120GeV

Angle=66urad

CEPC Partial Double Ring Layout



CEPC Partial Double Ring

Bypass

C=59044m

Bypass

By AT

SU Feng

2016.1.4

CEPC Partial Double Ring

Orbit of FFS Part