The Studies of Dynamic Aperture on CEPC

Yiwei Wang, Yuan Zhang, Feng Su, Tianjin Bian,
Dou Wang, Huiping Geng, Jie Gao

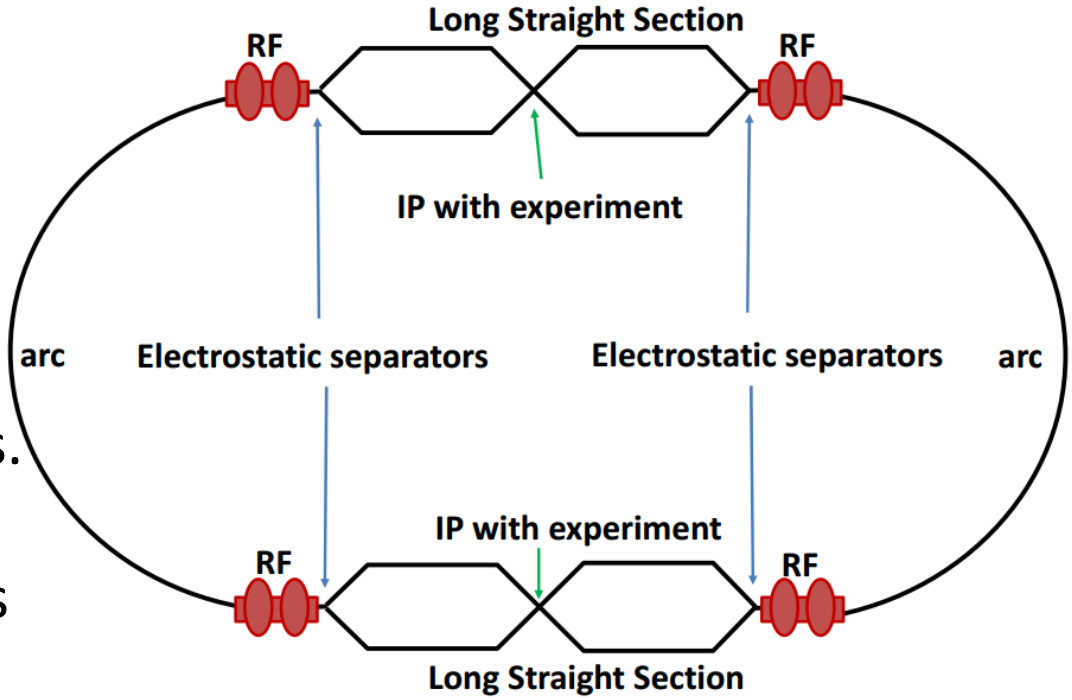
**International Symposium on Higgs Boson and Beyond Standard Model Physics,
August 15-19, 2016, Shandong University, Weihai**

Outline

- Lattice design and dynamic Aperture studies for CEPC partial double ring scheme
  - ARC region
  - Partial Double Ring (PDR) region
  - Interaction Region (IR)

Partial double ring Scheme

- **Main advantage**
  - No pretzel
- **Challenges**
  - Dynamic aperture
  - Crossing angle & crab waist design.
  - Electron cloud issues.
  - Bunch train operation introduces an uneven load to the RF system.



Mike, IPAC15

CEPC parameter for PDR scheme

（wangdou20160325）

	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	54	54	54	54
SR loss/turn (GeV)	3.1	2.96	2.96	0.59	0.062
Half crossing angle (mrad)	0	15	15	15	15
Piwinski angle	0	2.5	2.6	5	7.6
N_e/bunch (10^{11})	3.79	2.85	2.67	0.74	0.46
Bunch number	50	67	44	400	1100
Beam current (mA)	16.6	16.9	10.5	26.2	45.4
SR power /beam (MW)	51.7	50	31.2	15.6	2.8
Bending radius (km)	6.1	6.2	6.2	6.1	6.1
Momentum compaction (10^{-5})	3.4	2.5	2.2	2.4	3.5
β_{IP} x/y (m)	0.8/0.0012	0.25/0.00136	0.268 /0.00124	0.1/0.001	0.1/0.001
Emittance x/y (nm)	6.12/0.018	2.45/0.0074	2.06 /0.0062	1.02/0.003	0.62/0.0028
Transverse σ_{IP} (um)	69.97/0.15	24.8/0.1	23.5/0.088	10.1/0.056	7.9/0.053
ξ_x/IP	0.118	0.03	0.032	0.008	0.006
ξ_y/IP	0.083	0.11	0.11	0.074	0.073
V_{RF} (GV)	6.87	**3.62**	**3.53**	**0.81**	**0.12**
f_{RF} (MHz)	650	650	650	650	650
Nature σ_z (mm)	2.14	**3.1**	**3.0**	**3.25**	**3.9**
Total σ_z (mm)	2.65	4.1	4.0	3.35	4.0
HOM power/cavity (kw)	3.6	2.2	1.3	0.99	0.99
Energy spread (%)	0.13	0.13	0.13	0.09	0.05
Energy acceptance (%)	2	2	2		
Energy acceptance by RF (%)	6	**2.2**	**2.1**	**1.7**	**1.1**
n_γ	0.23	0.47	0.47	0.3	0.24
Life time due to beamstrahlung_cal (minute)	47	36	32		
F (hour glass)	0.68	0.82	0.81	0.92	0.95
L_{max}/IP (10^{34}cm^{-2}s^{-1})	2.04	2.96	2.91	3.09	3.09

Considerations on ARC lattice design

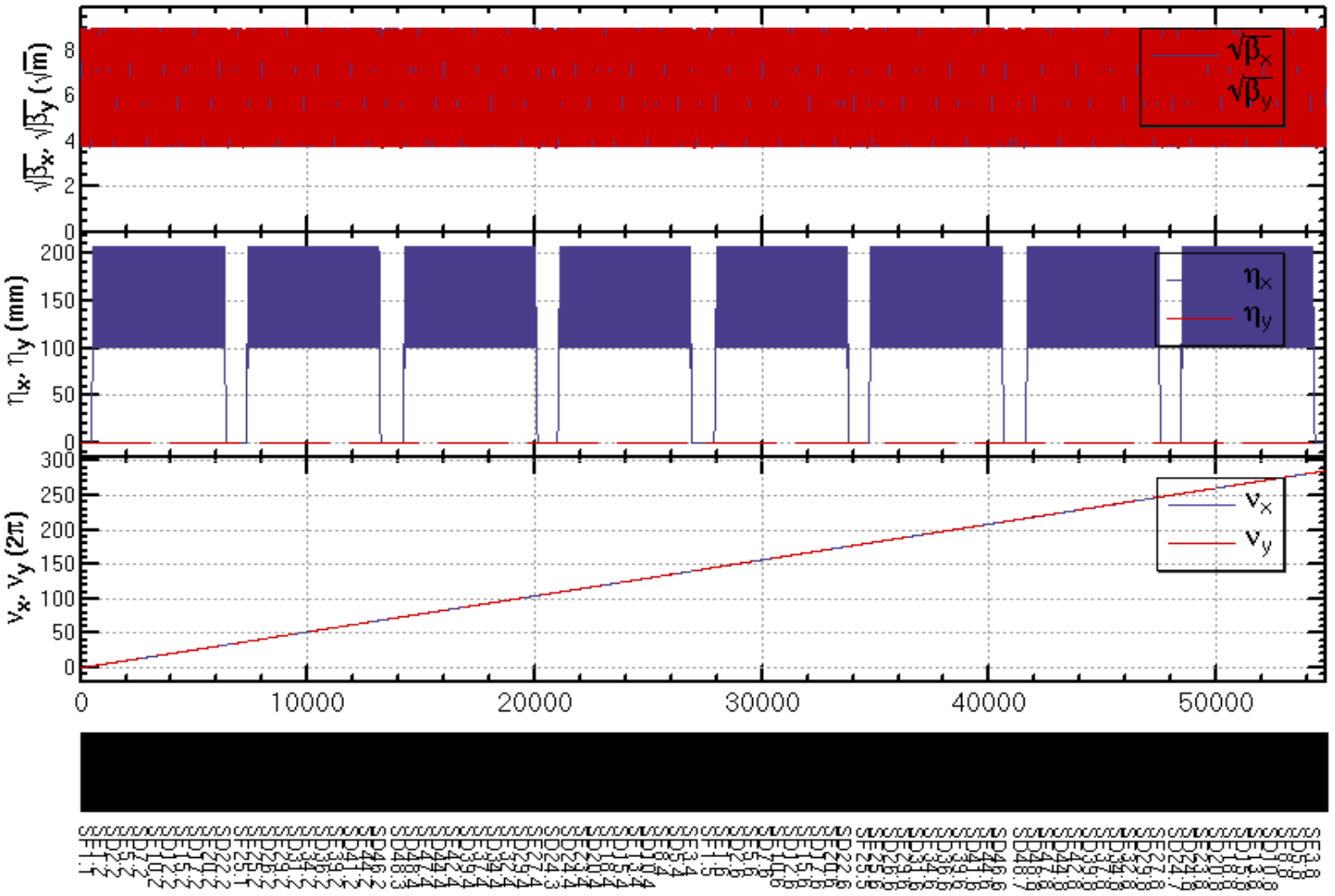
Sextupole scheme	interleave	Non-interleave
60 ° /60°	n=6 **All 3rd RDT due to sextupoles cancelled** **All 4th RDT except 2Qx-2Qy due to sextupoles cancelled** **dQ(Jx,Jy): accumalte to be large** **dQ(δ): small even with 2 families** DA on momentum: easy to optim. DA off momentum: easy to optim.	-
90 ° /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

Considerations on ARC lattice design

- FODO cell, 90 ° /90 °
  - non-interleaved sextupole scheme
  - n=5
  - All 3rd and 4th RDT due to sextupoles cancelled
  - Amplitude-dependent tune shift is very small

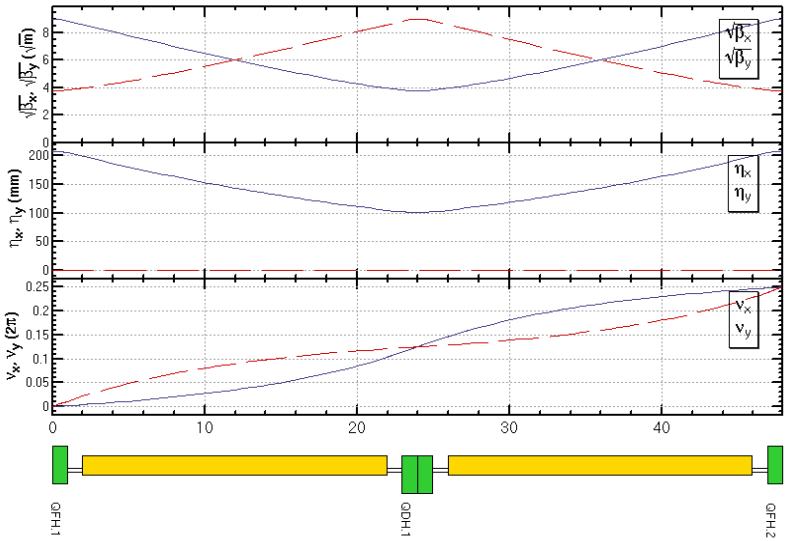
Ncell= 120
LB= 19.96
Lcell= 47.92
theta= .0032188449319567555
Lring= 54820.479999999996
Nstr1= 18
Nstr2= 20
Vrfc= 220625000
frf= 6.5e+08

ARC lattice (w/o PDR, IR)

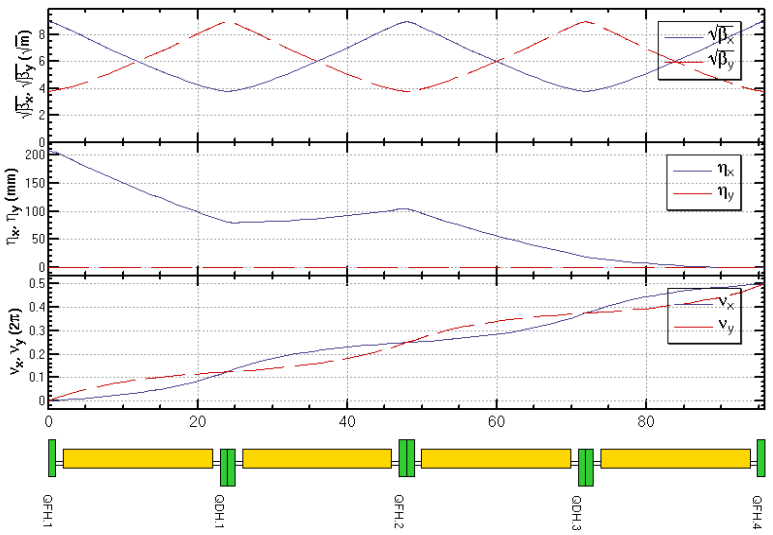


ARC lattice

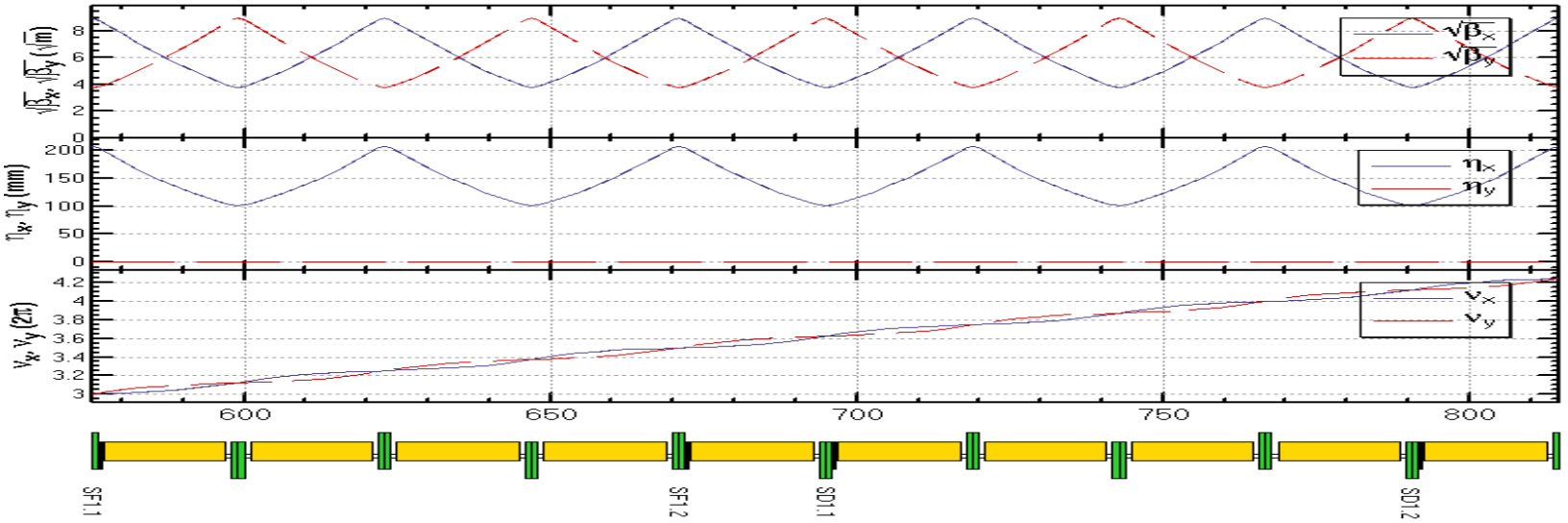
FODO cell



Dispersion Suppressor

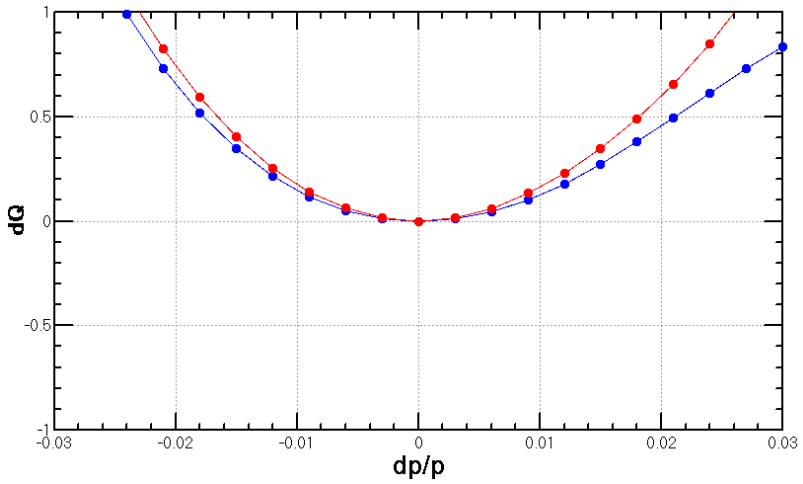


Sextupole configuration



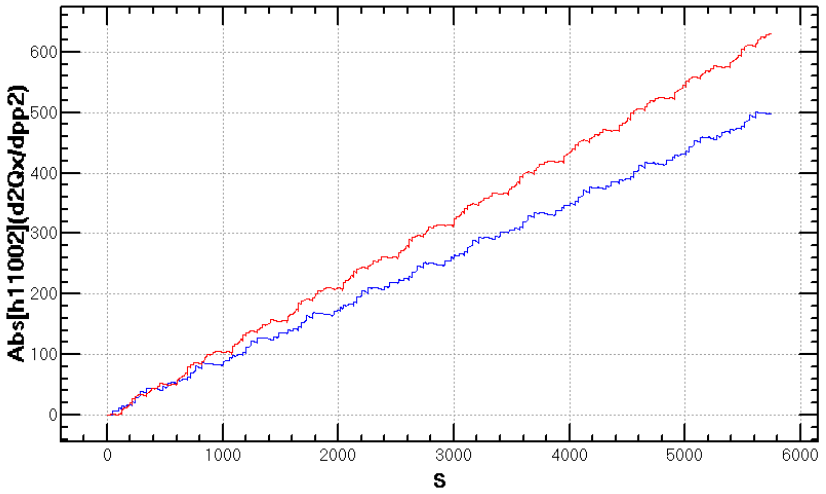
Chromaticity of the ARC lattice

- Second order chromaticity due to non-interleaved sextupole scheme
  - accumulating with period=5 cells



dQ vs. dp/p for Whole ARC

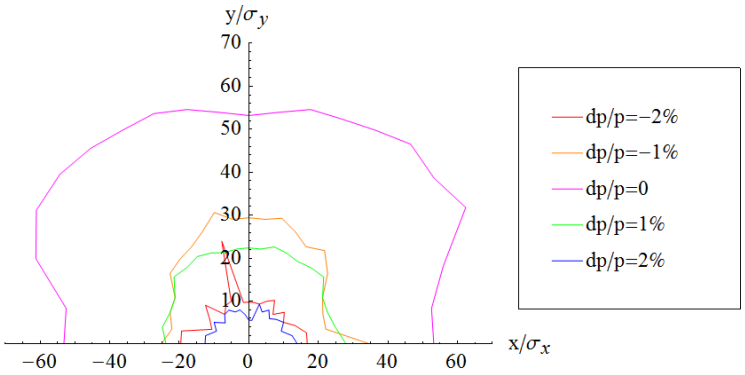
Mainly second order chromaticity

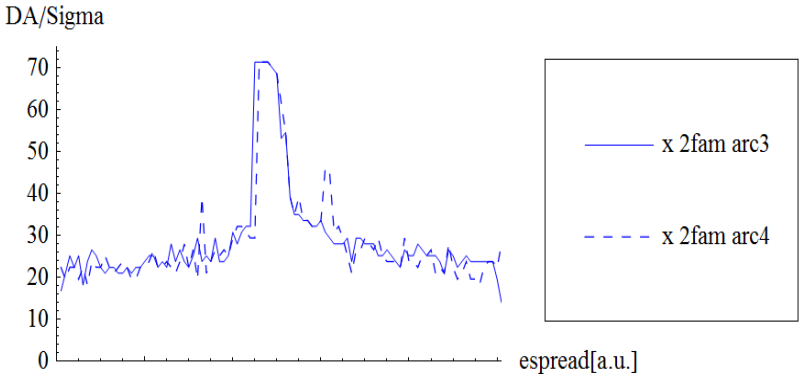


ARC section: 24× 5 cells

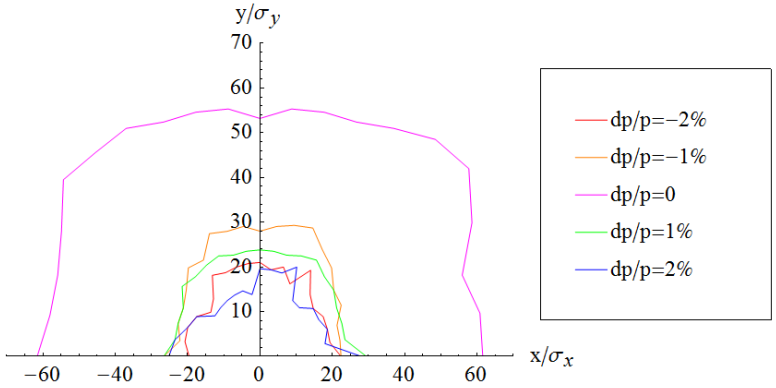
Tune phase advance between sections

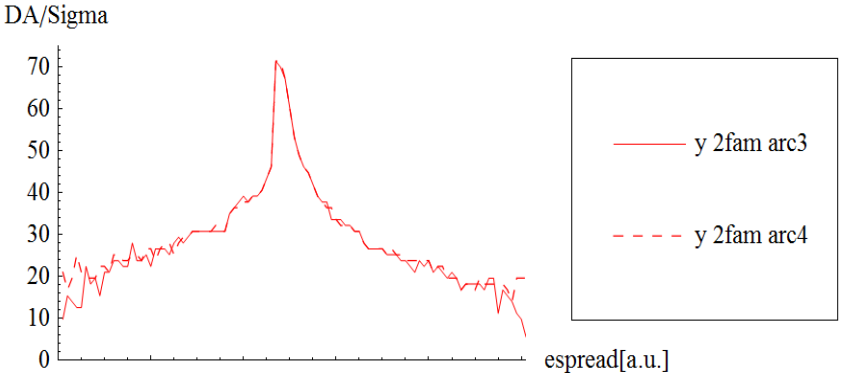
Before



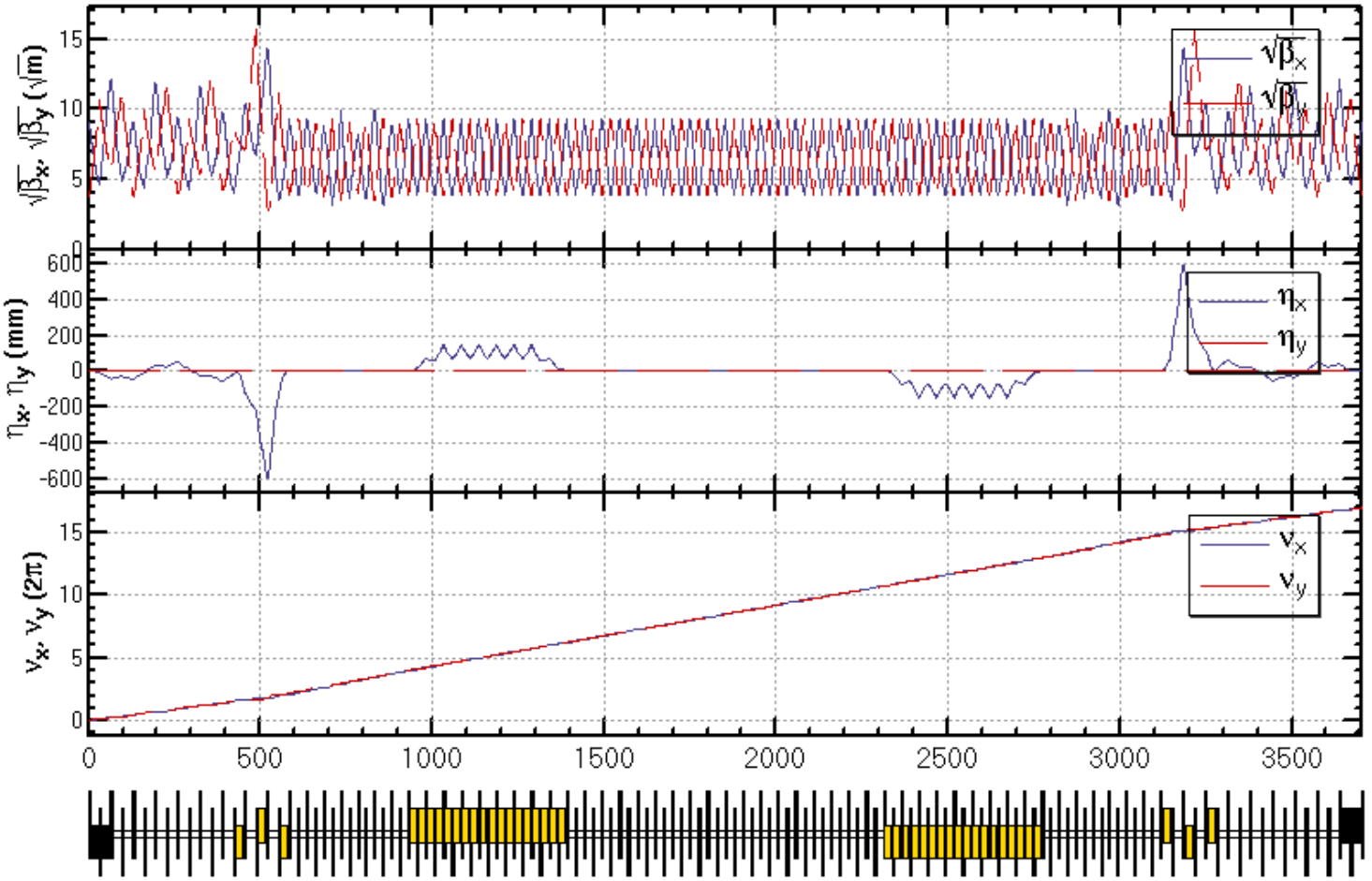


After

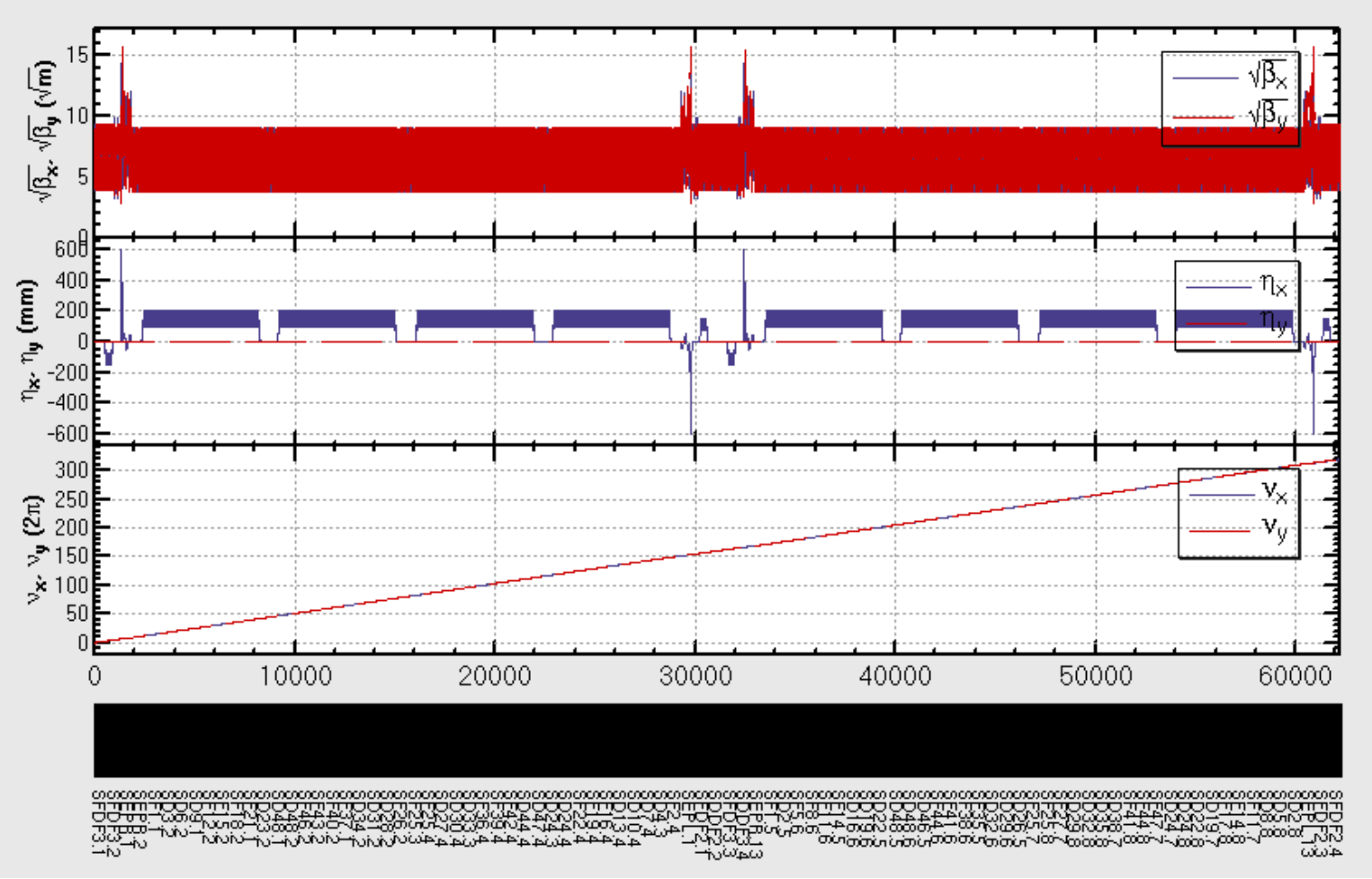




Partial double ring region (w/o IR)



ARC + Partial double ring region (w/o IR)

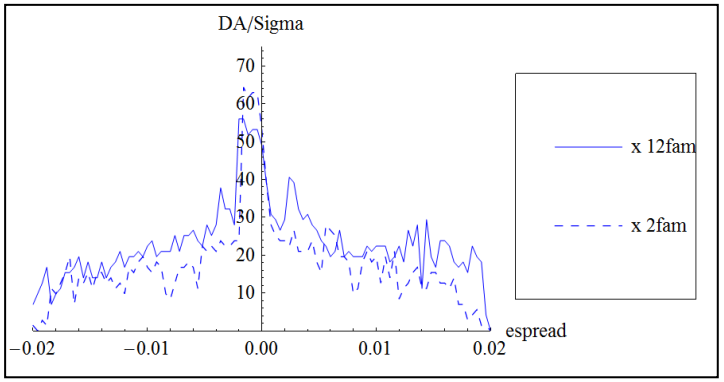


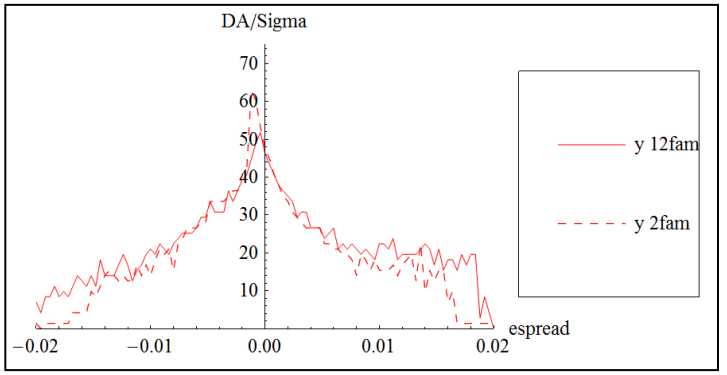
Dynamic aperture optimization for ARC + PDR (w/o IR)

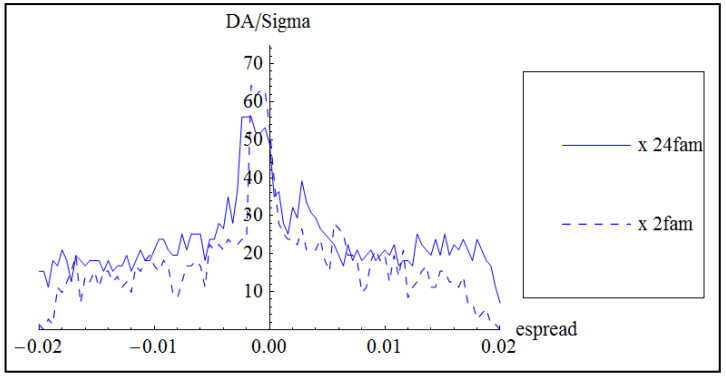
- The sextupoles in present PDR lattice don't help much to the 1st order chromaticity correction, i.e. can't make local correction. Possible way:
  1. **Keep lattice; correct 1st and high order chromaticity with only ARC sextupoles ; correct high order chromaticity with help from PDR sextupoles.**
  2. More sextupoles in PDR
  3. Re-design PDR lattice

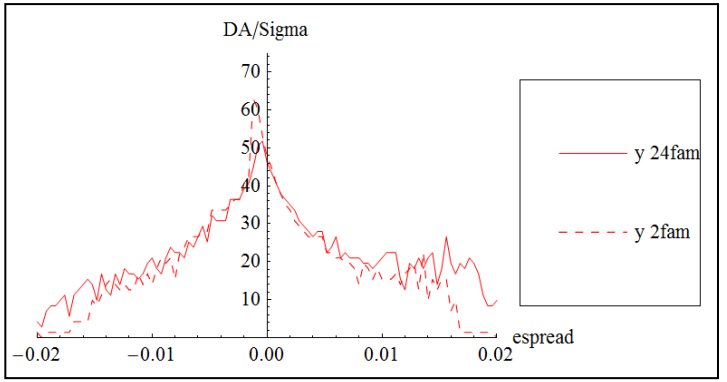
Dynamic aperture optimization for ARC + PDR (w/o IR)

- Optimize DA directly
  - 2, 4, 12, 24 families of sextupoles tried
  - DA increased significantly for large momentum particle (for dp/p=±2%, DA~5-15 σ) when 24 families of sextupoles in the ARC used
  - Further optimization is possible

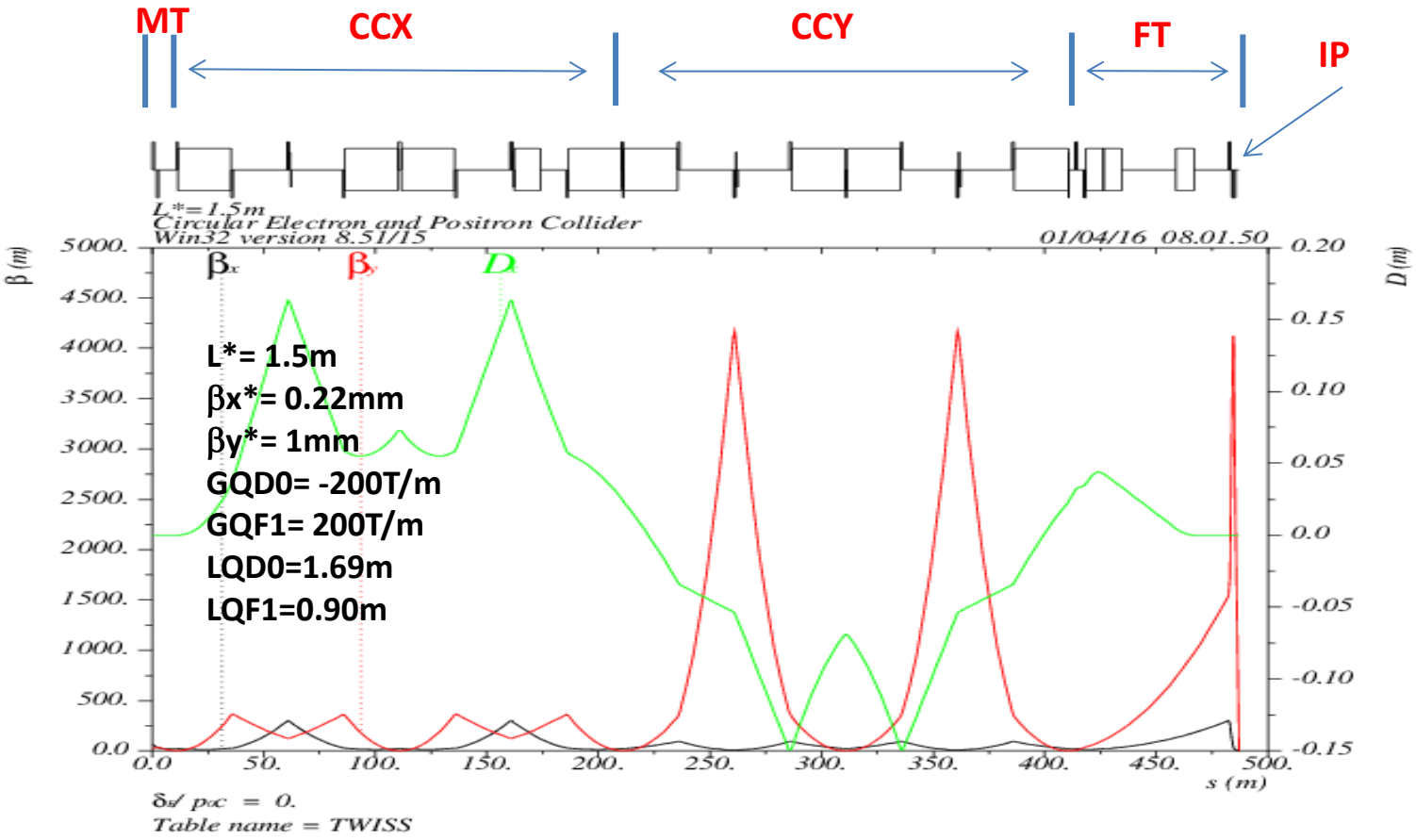




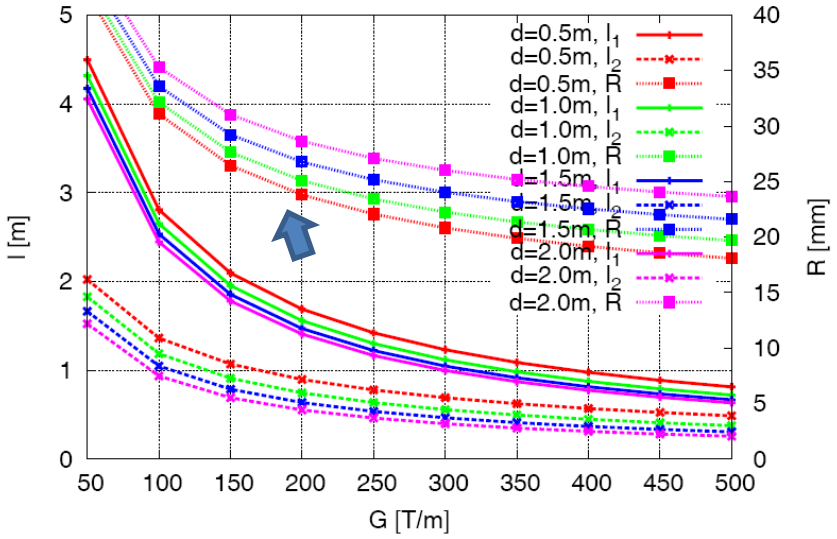


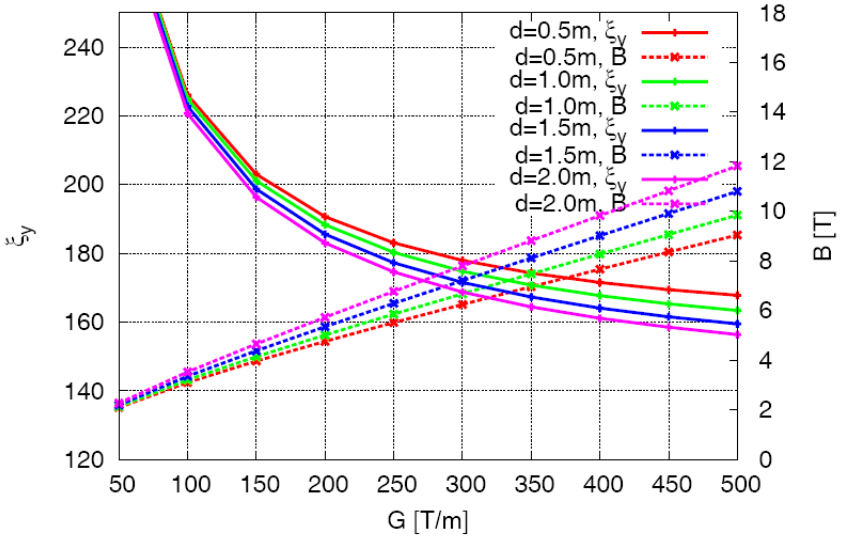


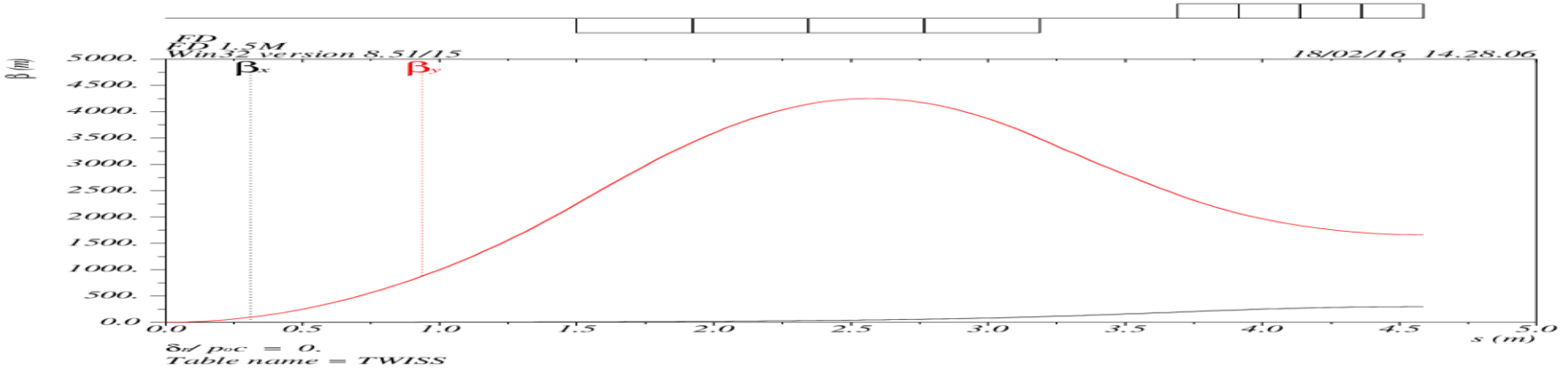
Lattice of Interaction Region



Final doublet





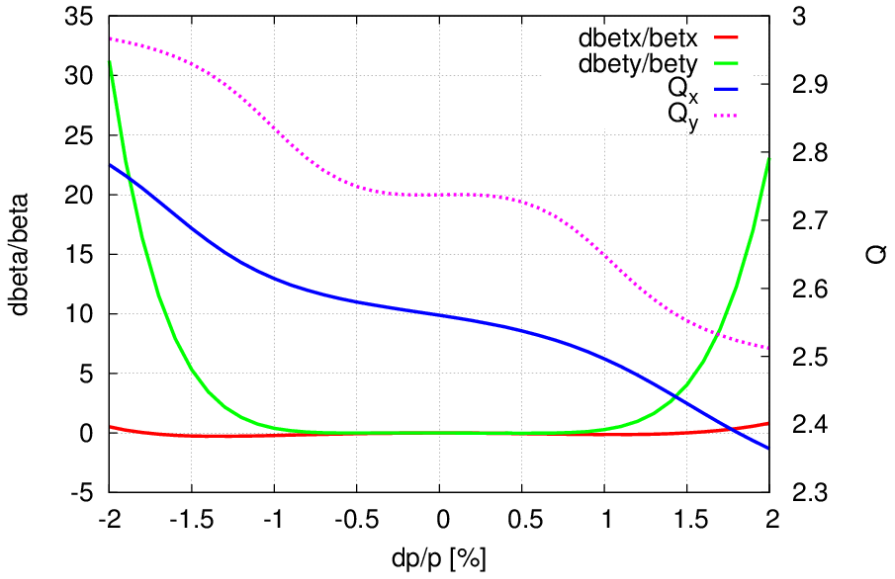


LD1	LD2	G1	G2	LQ1	LQ2	KSIY	KSIX	B1	B2
1.5	0.5	-200	200	1.68924427	0.8975406954	-190.6883514	-6.165431938	-4.762983257	4.762983257
R	Δx								
0.025	0.0225*2								

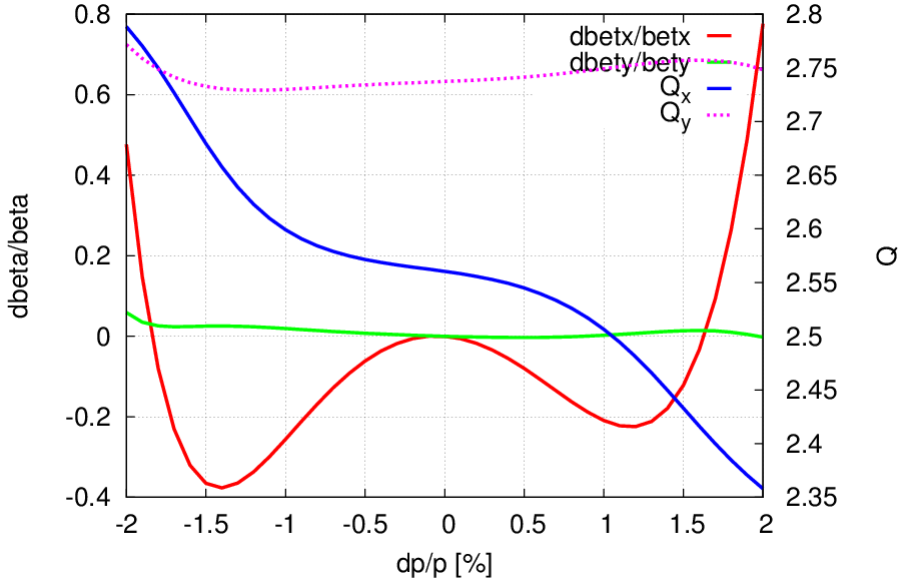
RQ1 could be smaller than RQ2 to avoid conflict of Q1,e+ and Q1,e-

Chromaticity correction of IR

Correct 1st and 2nd order chromaticity



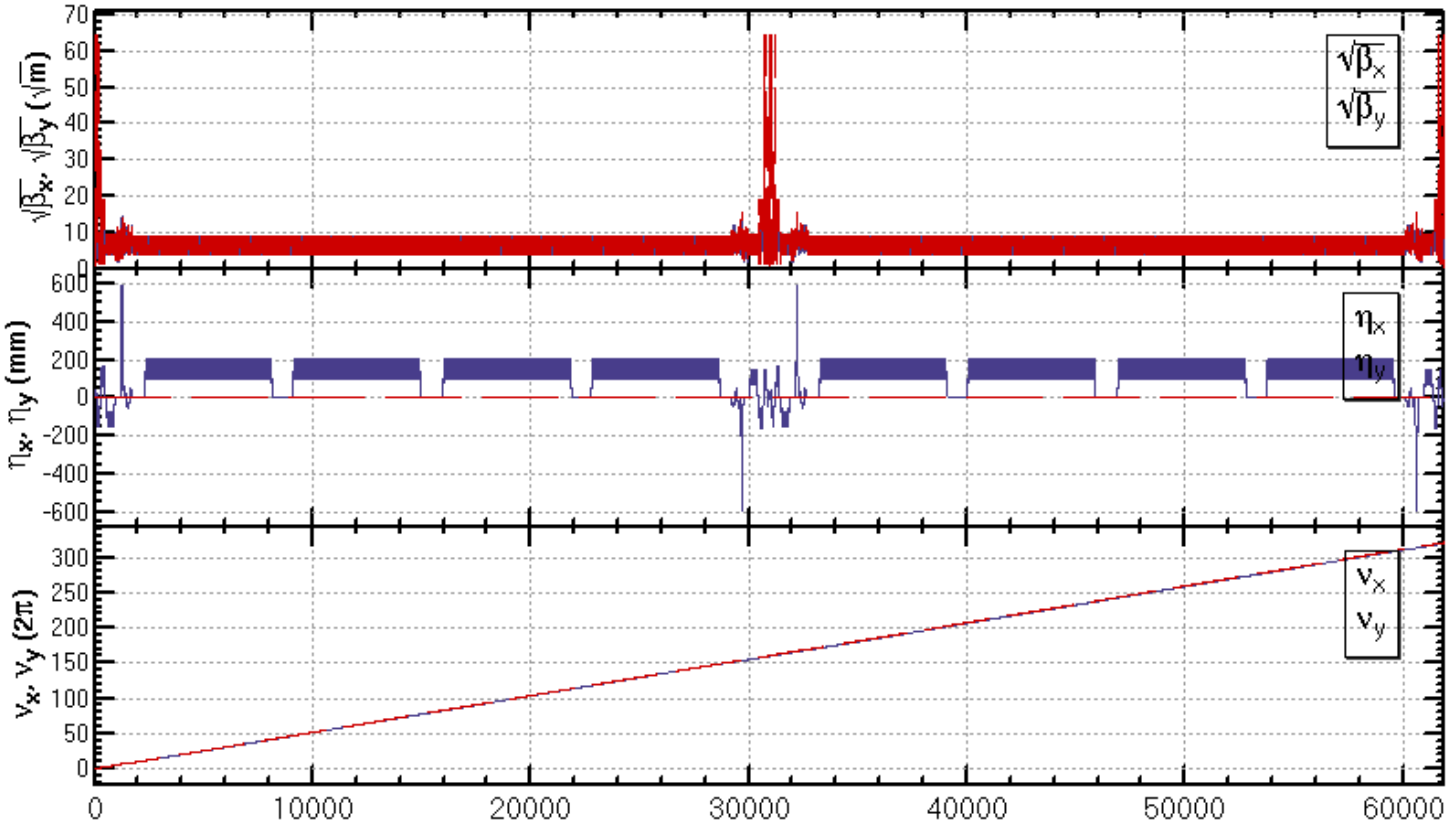
Correct 3rd order chromaticity



3rd order chromaticity in the horizontal plane could be corrected with an additional sextupole at second image point or ARC sectupoles

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.



Summary

- A lattice of the whole ring (ARC+PDR+IR) fulfilling the design parameters is ready.
- Dynamic aperture for ARC+PDR lattice is optimized directly with the sextupoles in the ARC region
  - DA increased significantly for large momentum particle (for dp/p=$\pm$2%, DA~5-15 σ) when 24 families of sextupoles in the ARC used
  - Further optimization is possible
- Dynamic aperture for ARC+PDR+IR lattice is under going.