The Status of the CEPC Interaction Region Design

Yiwei Wang, Huiping Geng, Sha Bai, Dou Wang, Tianjian Bian

Institute of High Energy Physics (IHEP, Beijing)

FCC week 2015

Washington D.C., 23-27 March 2015

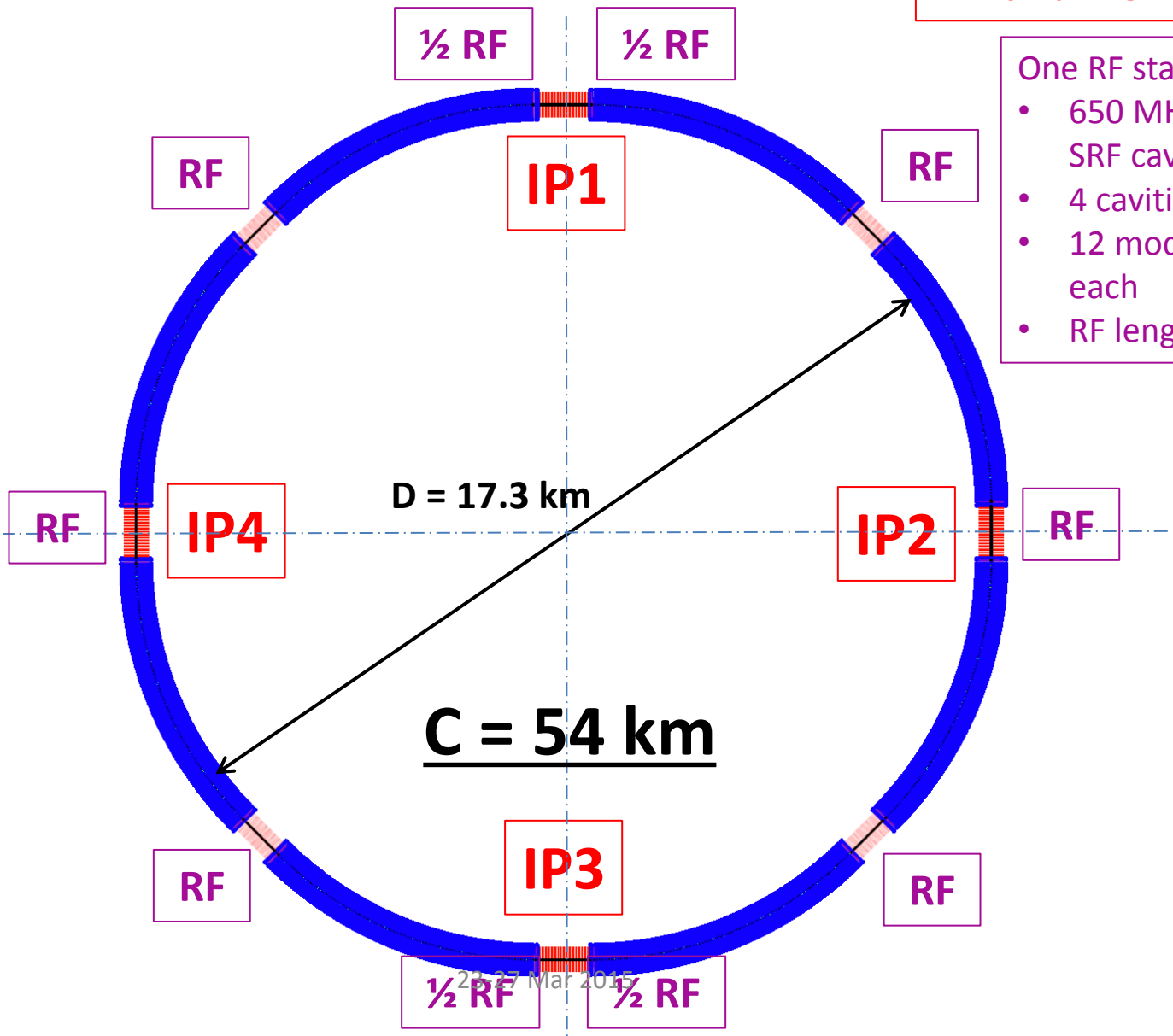
Outline

- CEPC layout
- Lattice design of the Interaction region
- Dynamic aperture
- Size of QD0 and QF1
- Comparison of βy^*=1.2 mm and 3 mm
- Summary

CEPC layout

IP1 and IP3 for CEPC

One RF station:
- 650 MHz five-cell SRF cavities;
- 4 cavities/module
- 12 modules, 8 m each
- RF length 120 m

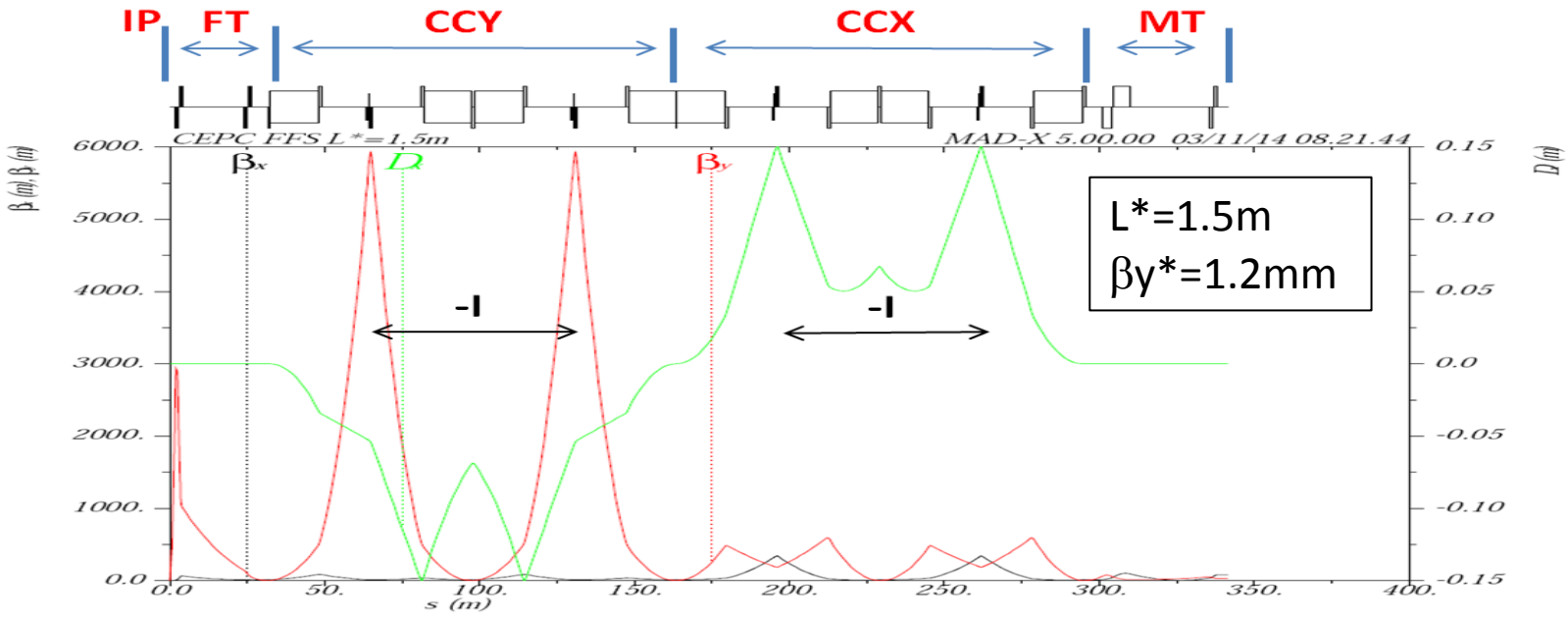


CEPC parameters

Parameter	Unit	Value	Parameter	Unit	Value
Beam energy [E]	GeV	120	Circumference [C]	m	54752
Number of IP[N_{IP}]		2	SR loss/turn [U_0]	GeV	3.11
Bunch number/beam[n_B]		50	Bunch population [Ne]		3.79E+11
SR power/beam [P]	MW	51.7	Beam current [I]	mA	16.6
Bending radius [ρ]	m	6094	momentum compaction factor [α_p]		3.36E-05
Revolution period [T_0]	s	1.83E-04	Revolution frequency [f_0]	Hz	5475.46
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		0.118/0.083
Beam length SR [$\sigma_{s.SR}$]	mm	2.14	Beam length total [$\sigma_{s.tot}$]	mm	2.88
Lifetime due to Beamstrahlung	min		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]		118800	Synchrotron oscillation tune [ν_s]		0.18
Energy acceptance RF [h]	%	5.99	Damping partition number [Jε]		2
Energy spread SR [$\sigma_{\delta.SR}$]	%	0.132	Energy spread BS [$\sigma_{\delta.BS}$]	%	0.119
Energy spread total [$\sigma_{\delta.tot}$]	%	0.177	n_γ		0.23
Transverse damping time [n_x]	turns	78	Longitudinal damping time [n_ε]	turns	39
Hourglass factor	Fh	0.658	Luminosity /IP[L]	$cm^{-2}s^{-1}$	2.04E+34

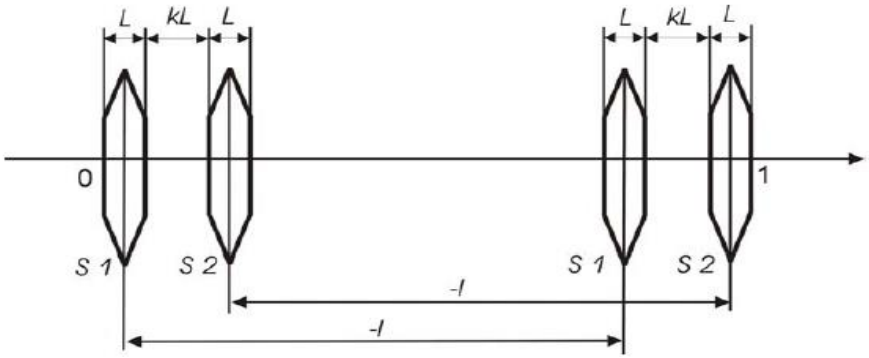
Interaction region design

- L*=1.5m chosen to facilitate design
- length constraint by overall layout consideration
  - maximum 350m for per side



Local chromaticity correction

- Add additional sextupoles next to the main one*
  - Compensate the finite length effect (Lsext=0.3m)



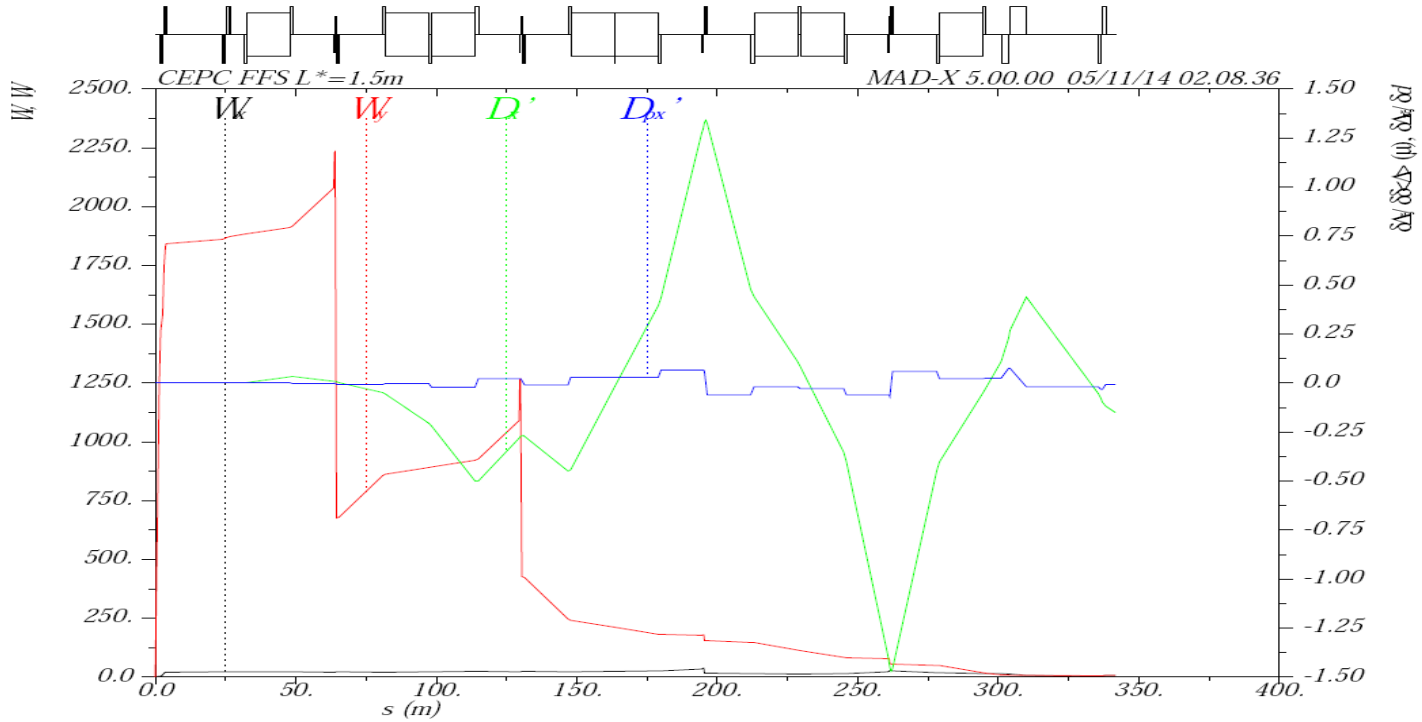
k=1, S1/S2=-0.1

*A.Bogomyagkov et al.
http://arxiv.org/abs/0909.4872

- Adjust the phase advances between the final doublet and the sextupoles to minimize second order chromaticity
  - QD0 and VS1
  - QF1 and HS1

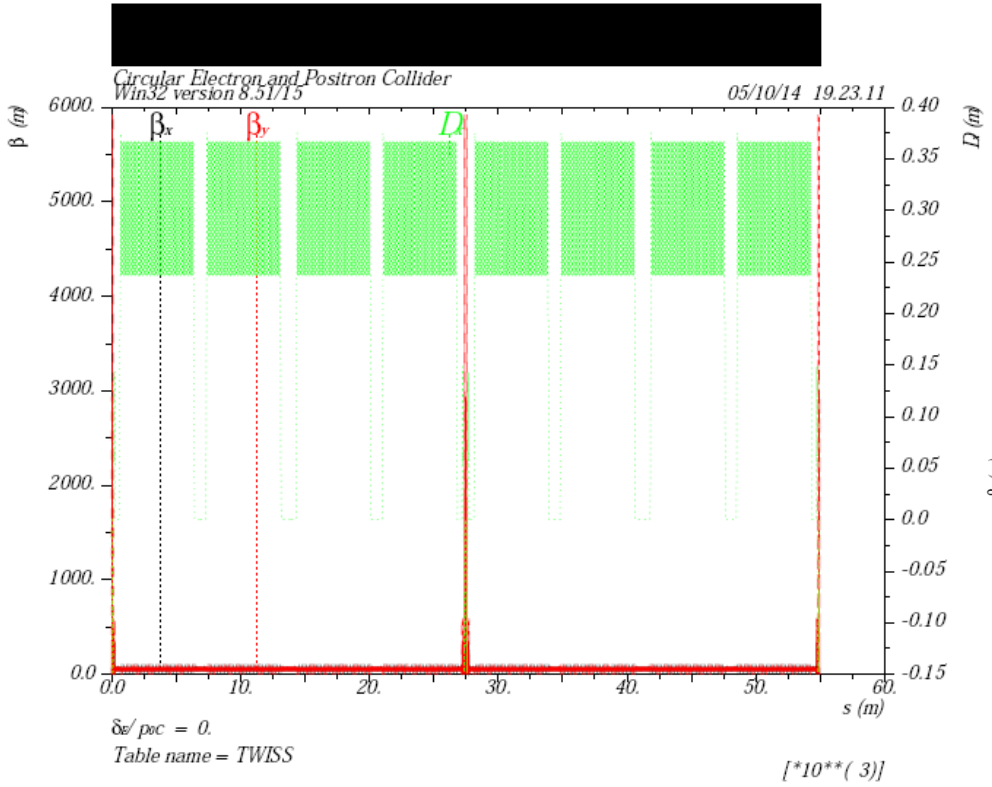
Local chromaticity correction (cont.)

- residual W functions are W_x=6.6, W_y=5.6 and second order dispersion is D'_x=-0.15 m

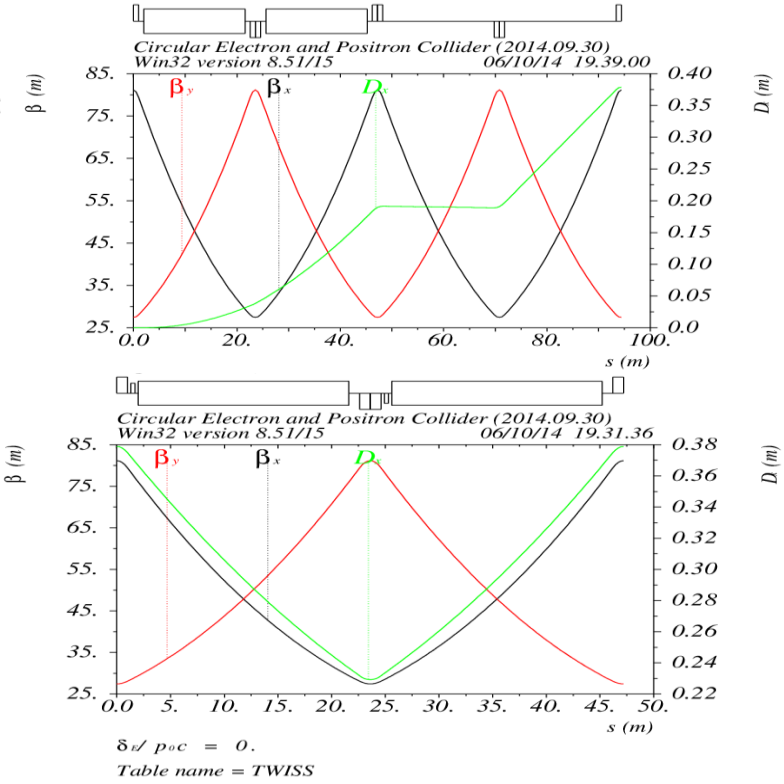


Lattice of the whole ring

- Close the whole ring
  - matching linear lattice function

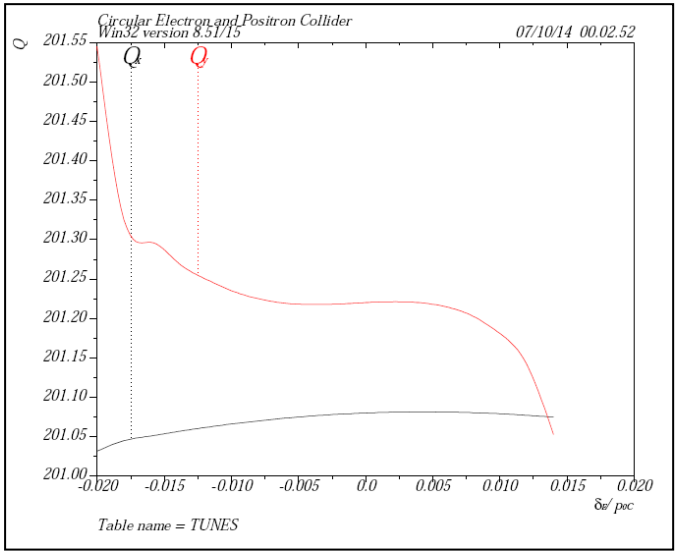


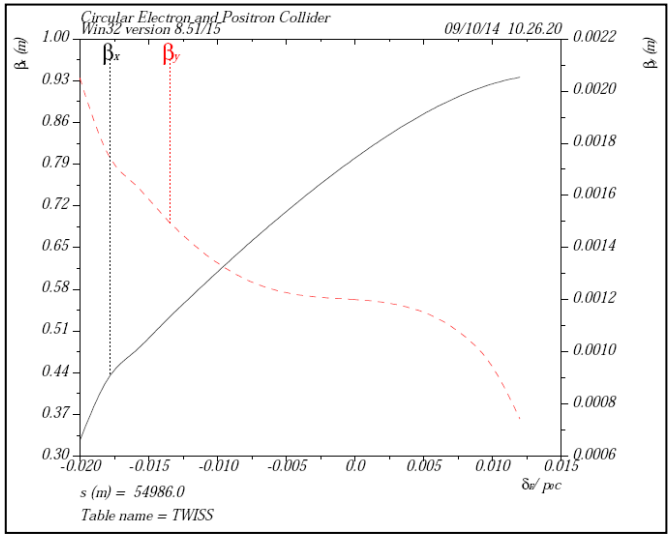
Dispersion suppressor and FODO cell in the ARC



Tune vs. momentum deviation

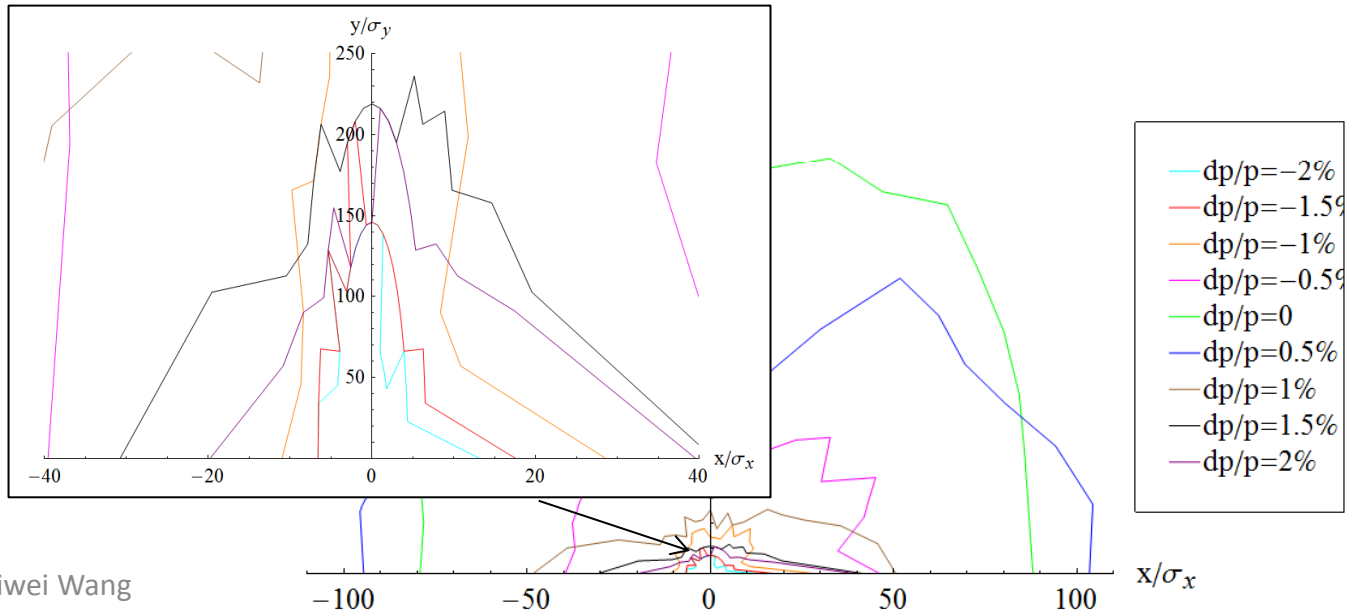
- Adjust the tune to be .08/.22 (νx/νy)
  - determined by beam-beam study
- match Q' to be ~0.5 with the sextupoles in the ARC
  - Currently only 2 family of sextupoles in the ARC
- Good region of ±1% in Dp/p





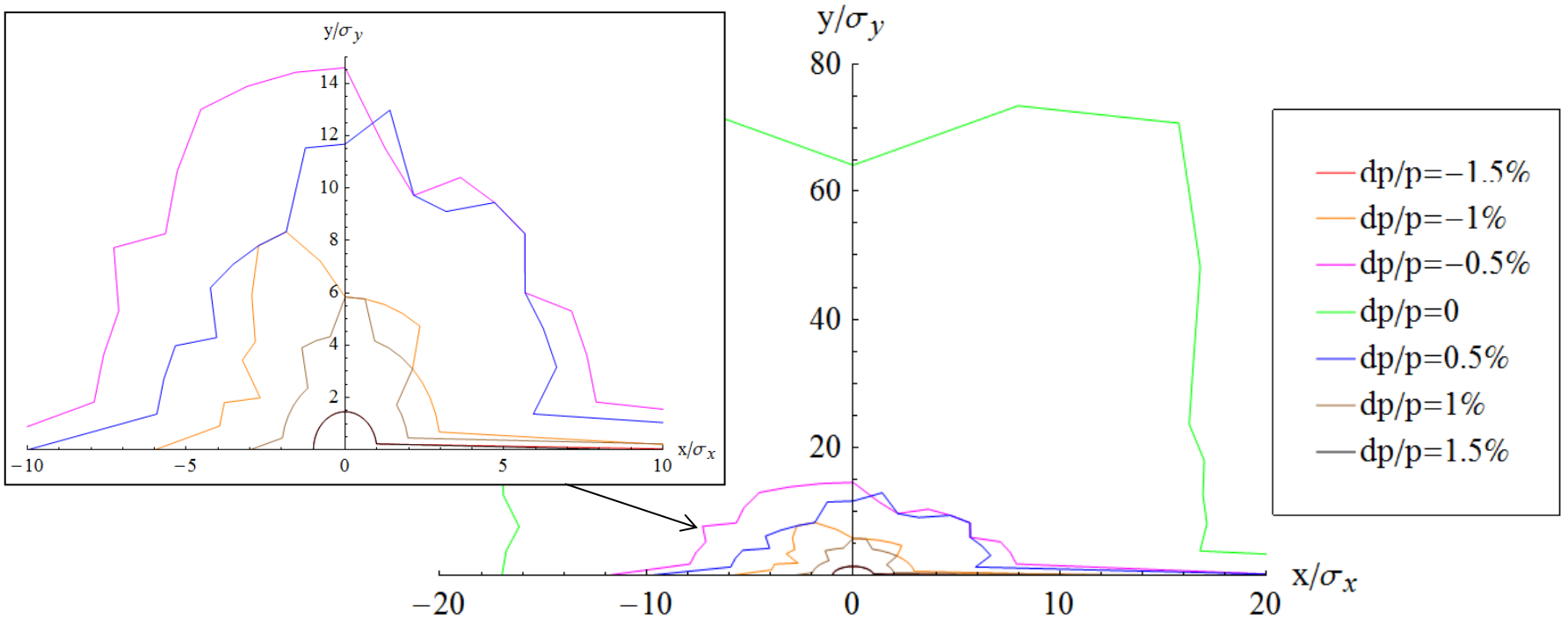
Dynamic aperture

- The parts other than IR are replaced by linear matrix
- without radiation, error of the magnets
- Synchrotron motion included
- Tracking with 3 times of damping time
- Coupling factor κ=0.003 for emitty
- DA for off momentum: **2% (20σx , 150σy)**, **-2% (7σx , 150σy)**



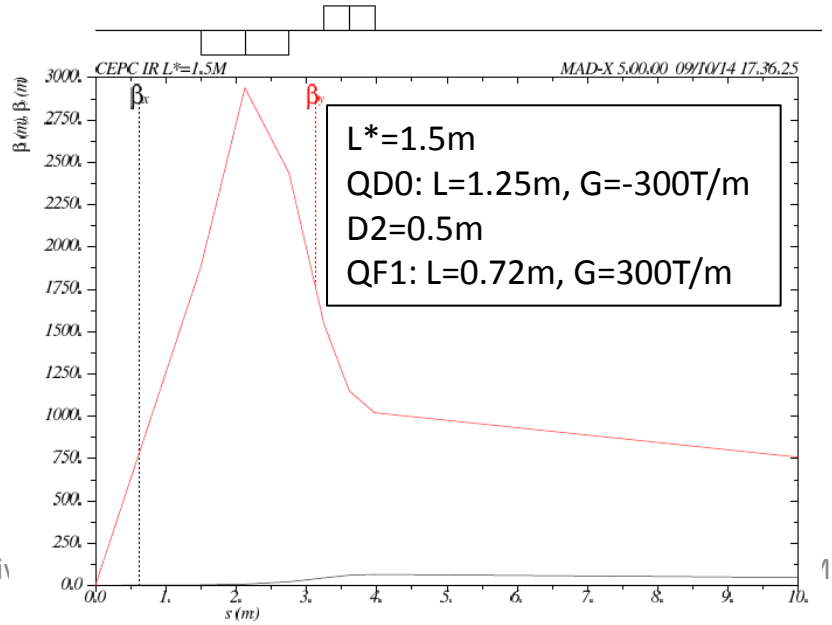
Dynamic aperture for the ring

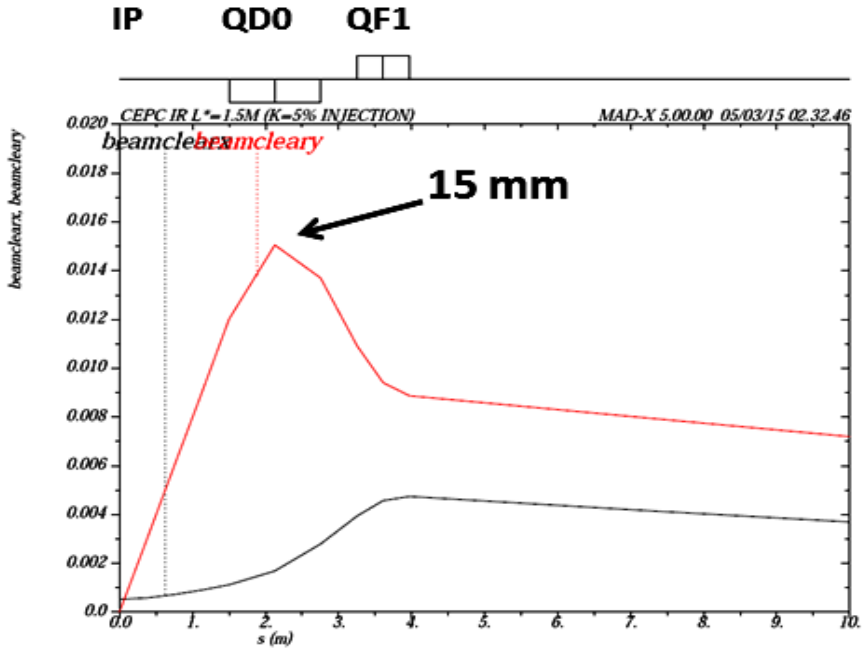
- With the real ring
- DA for off momentum largely decreased



Beam stay-clear region at FD

- The beam stay-clear region determined by considering the requirements for injection
  - choose vertical injection as the horizontal injection will affect the pretzel orbit
  - Red line in right plot: distance between the center of beam pipe and the outer edge of the injected beam

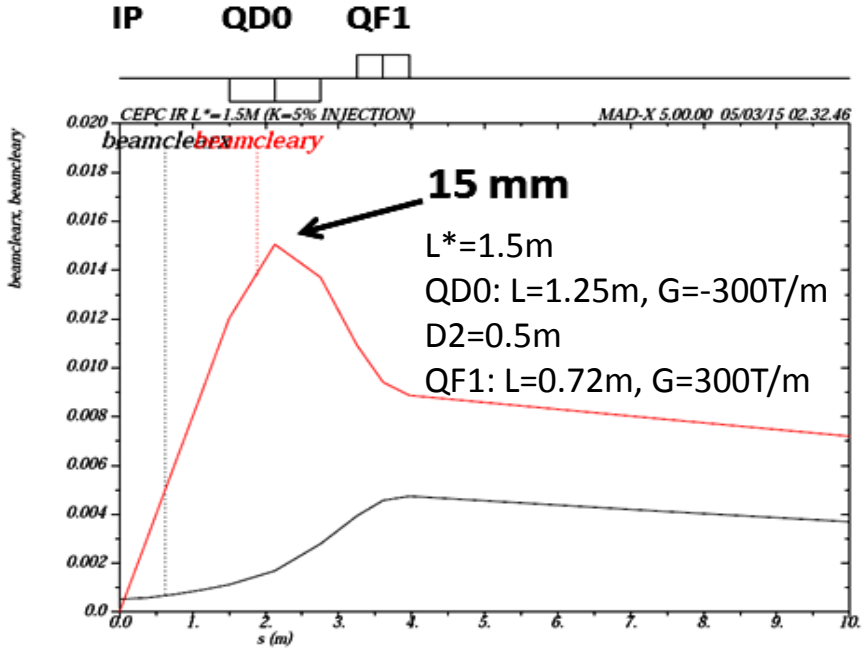


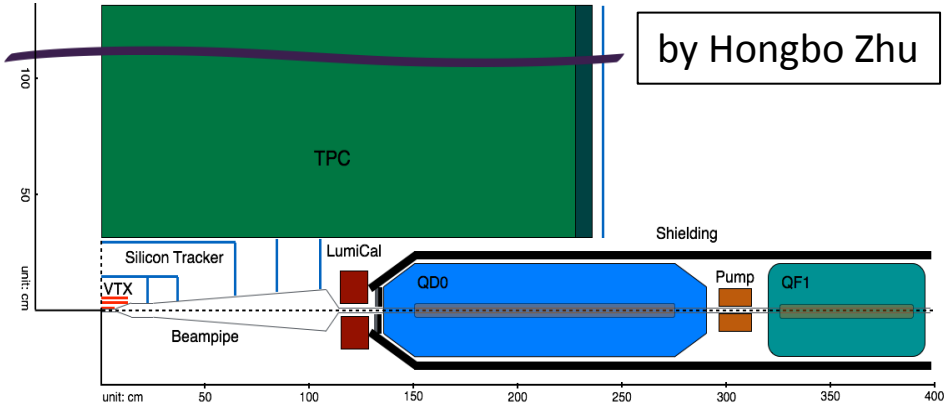


by Xiaohao CUI, Yiwei Wang

Size of QD0 and QF1

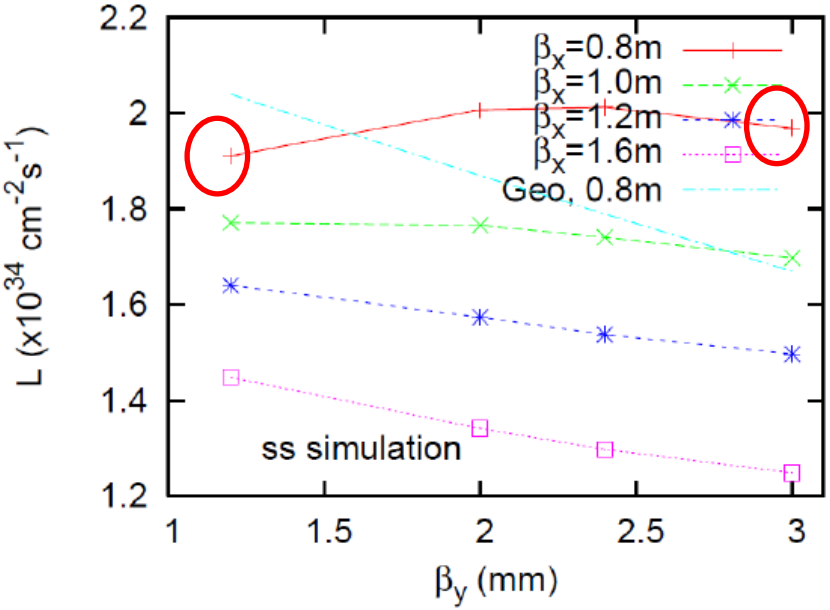
- coil inner radius = 21 mm
  - beam pipe inner radius = 17 mm (2mm for safety)
  - pipe wall thickness = 2 mm
  - gap between pipe and coil = 2 mm
- gradient = 300 T/m
- estimated cryostat diameter = 400 mm
  - Including anti-solenoid
  - acceptable for detector





Comparison of βy*=1.2 mm and 3 mm

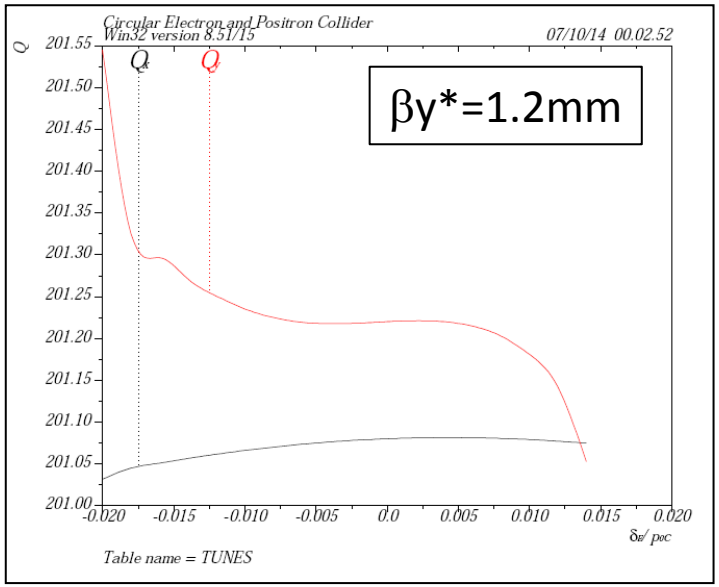
- As shown in beam-beam simulation including the dynamic beta effects, the luminosity are almost the same when βy* increased from 1.2 mm to 3 mm .

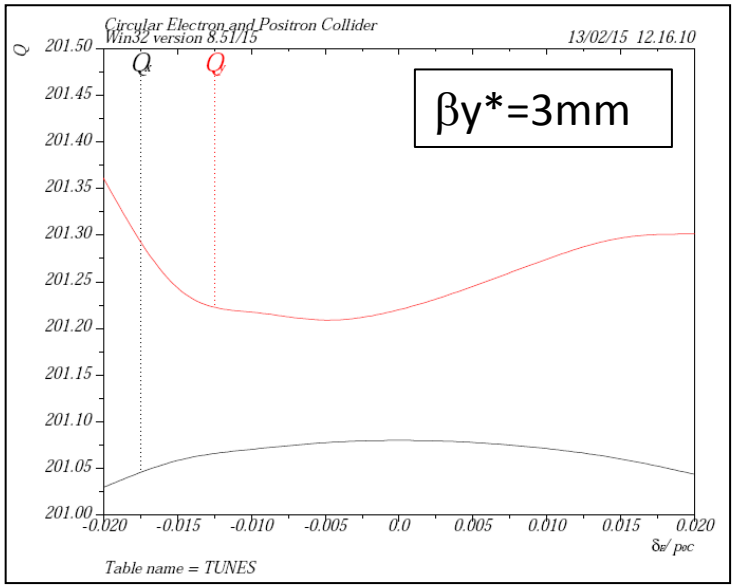


- For the first try, we just refit the final transformer.
  - the parts other than FT are almost kept

Chromaticity Correction

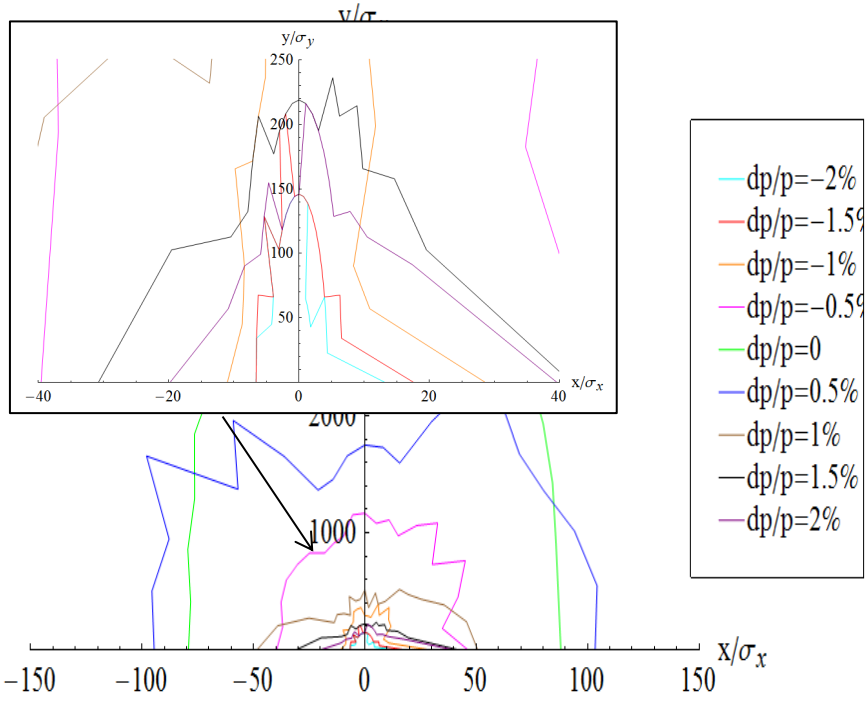
- Strengh of sextupoles in IR reduced
  - For βy*=1.2mm: k2vs = 17.2 m^{-3}, k2hs = 2.92 m^{-3}
  - For βy*=3mm: k2vs = 10.58 m^{-3}, k2hs = 2.80 m^{-3}
- Tune vs. momentum deviation for the ring

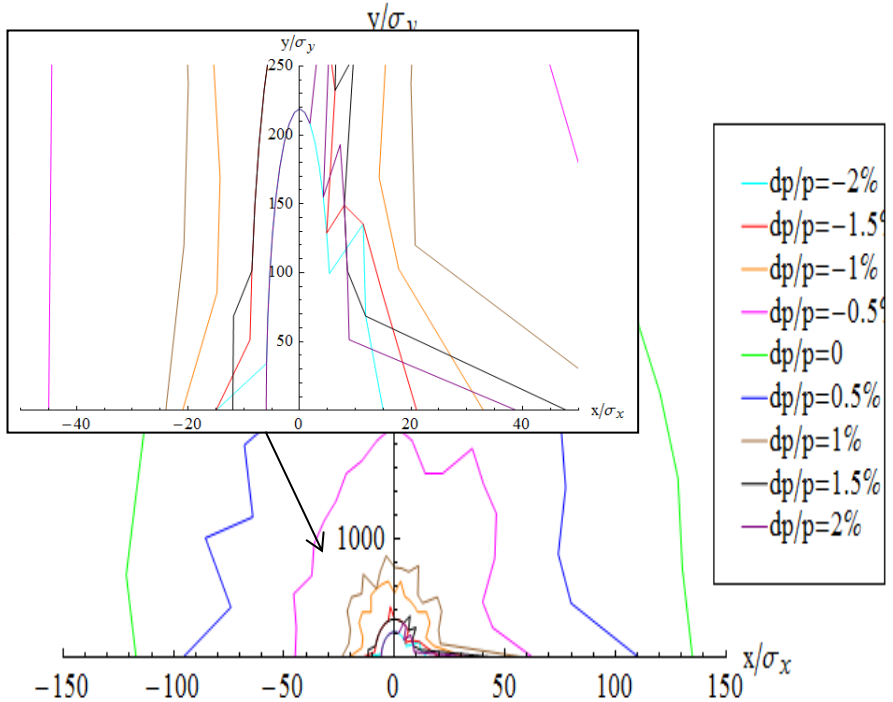




Dynamic aperture

- The parts other than FFS are replaced by linear matrix
- DA for off momentum:
  - For βy*=1.2mm: **2% (20σx , 150σy)**, **-2% (7σx , 150σy)**
  - For βy*=3mm: **2% (7σx , 220σy)**, **-2% (15σx , 200σy)**

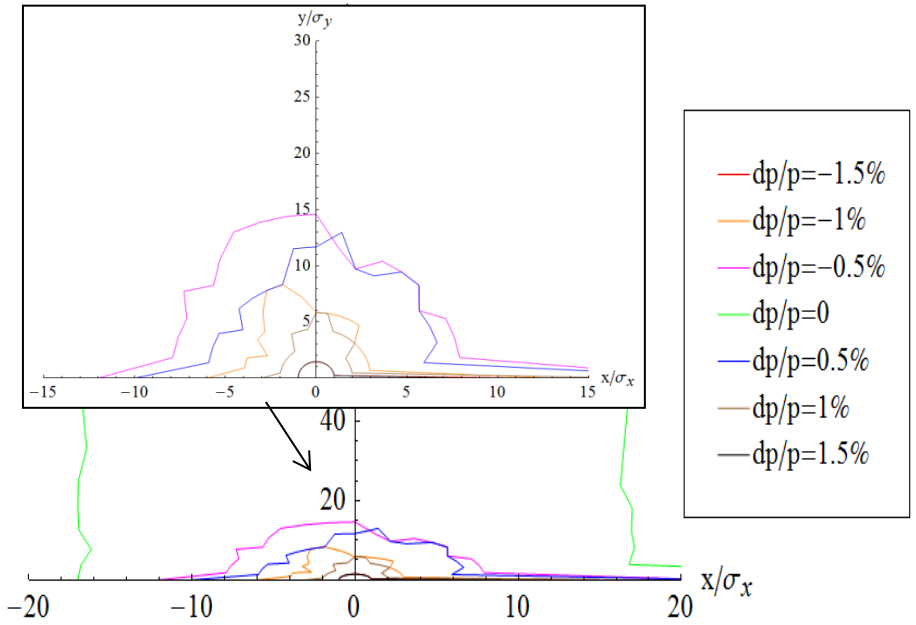




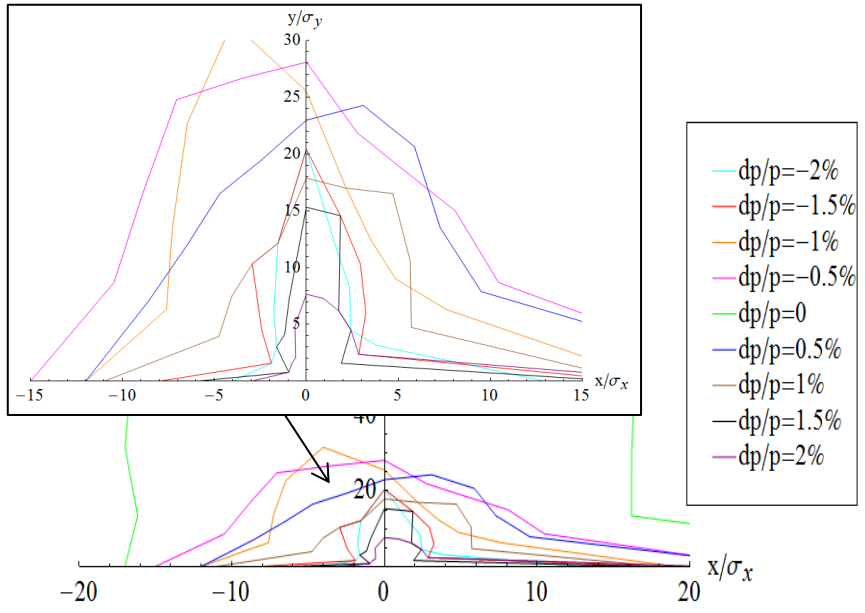
Dynamic aperture for the ring

- With the real ring
- DA for off momentum:
  - For βy*=1.2mm, the DA is almost zero for off momentum 2%
  - For βy*=3mm, the DA has been extended to 2% region:

    -2% (2σx , 20σy), 2% (1σx , 7σy)



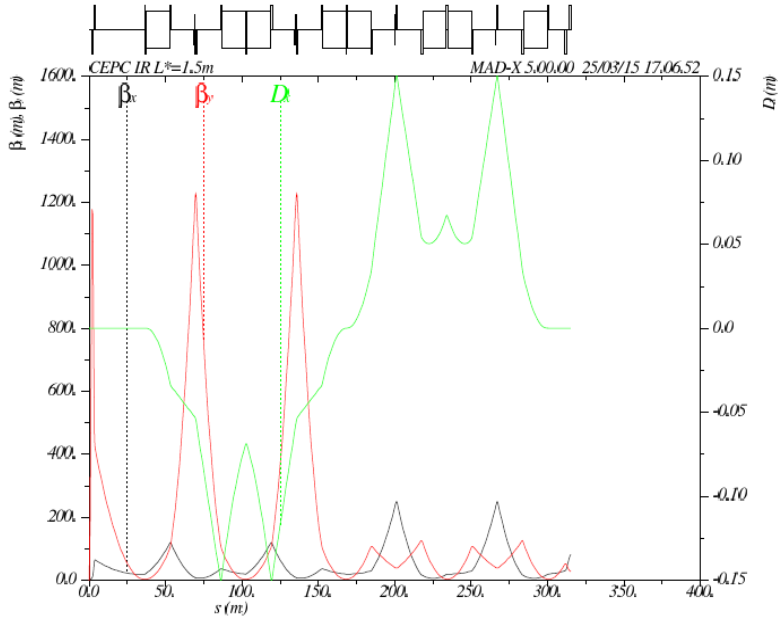
βy*=1.2mm

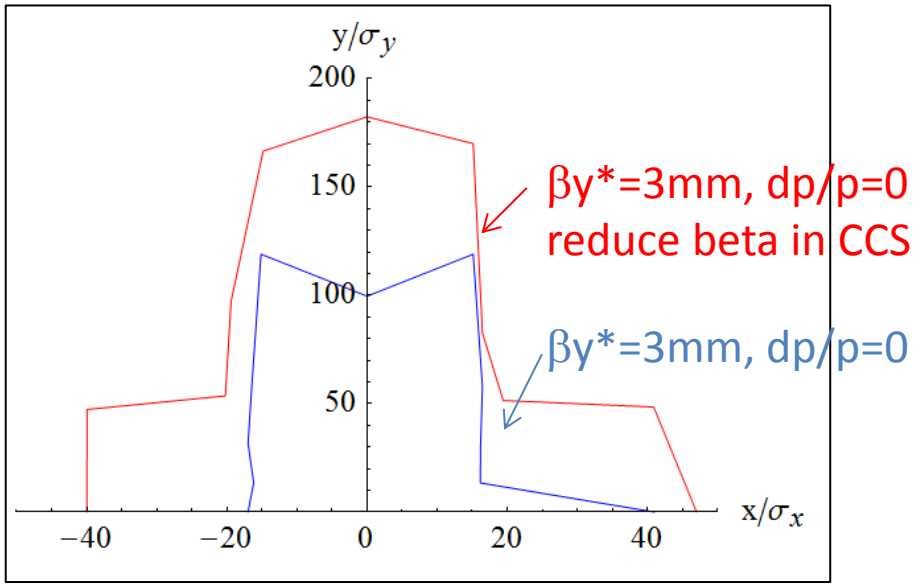


βy*=3mm

Further optimization

- Further optimization is possible
  - reduce beta peak in CCS
  - reduce the chromaticity at the “wrong phase” quadrupoles to further reduce nonlinear chromaticity
  - reduce second order dispersion
  - odd dispersion scheme for the break down of –I transport
  - with more families of sextupoles in the ARC





Summary

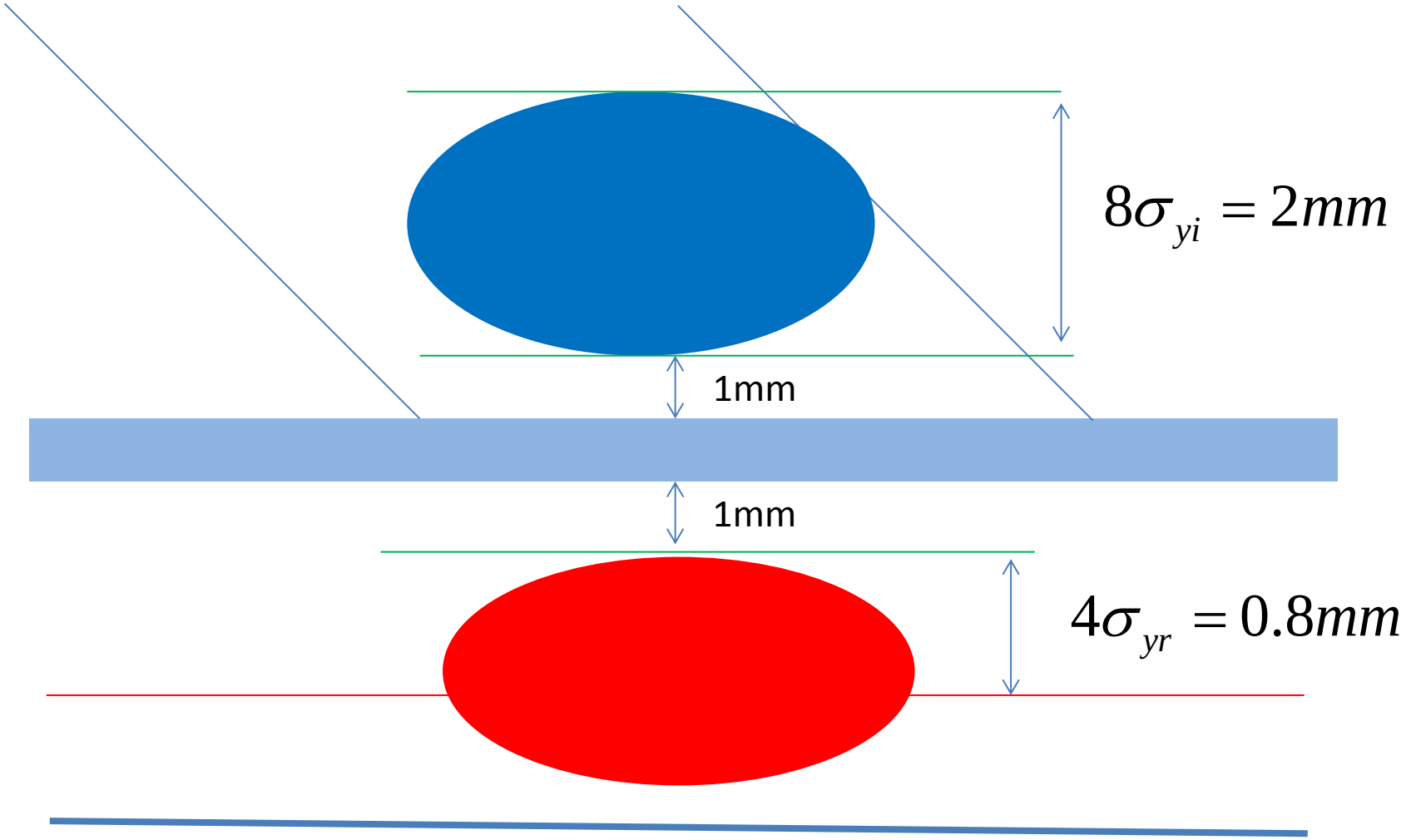
- We got a preliminary design for the CEPC interaction region
- We need more optimization to get a reasonable dynamic aperture for the whole ring
  - reduce the chromaticity at the “wrong phase” quadrupoles to further reduce nonlinear chromaticity
  - reduce second order dispersion
  - odd dispersion scheme for the break down of –I transport
  - with more families of sextupoles in the ARC
- First IR design with βy^*=3mm
  - Further optimization is undergoing
- Size of QD0 and QF1 are estimated for the current design
  - estimated cryostat diameter = 400 mm
  - acceptable for current detector design

- **The CEPC-SppC accelerator preCDR is available on the CEPC site http://cepc.ihep.ac.cn/preCDR/volume.html**

Thank you for your attention!

Acknowledge

- Yunhai Cai, Xiaohao Cui, Yingshun Zhu, Yuanyuan Guo, Tianjian Bian, Feng Su, Ming Xiao, Zhe Duan, Gang Xu, Jie Gao, Qing Qin, Demin Chou, Kazuhito Ohmi, Yoshihiro Funakoshi, Yukiyoshi Ohnishi, A. Bogomyagkov, Luis Eduardo Medina Medrano
- Thanks for your kind help and beneficial discussion!



注入点震荡幅度 6.8mm