CEPC interaction region design

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Outline

- CEPC parameters and layout
- Interaction region design
- Dynamic aperture
- Size of QD0 and QF1
- Synchrotron radiation load
- Summary

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 [$J\varepsilon$]		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]	$cm^{-2}s^{-1}$	1.98E+34

CEPC layout

IP1 and IP3 for CEPC

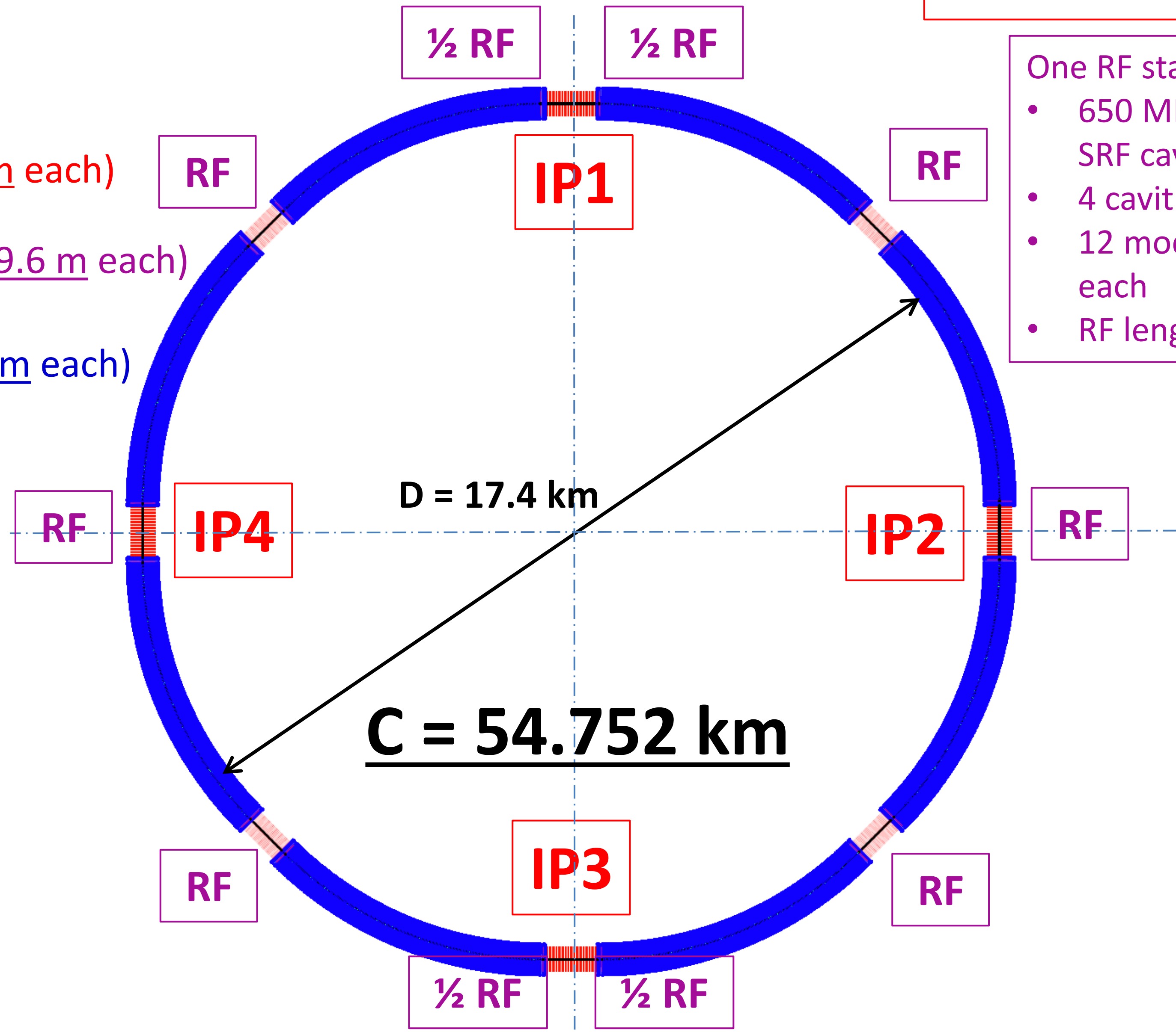
One RF station:

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

(4 IPs, 1132.4 m each)

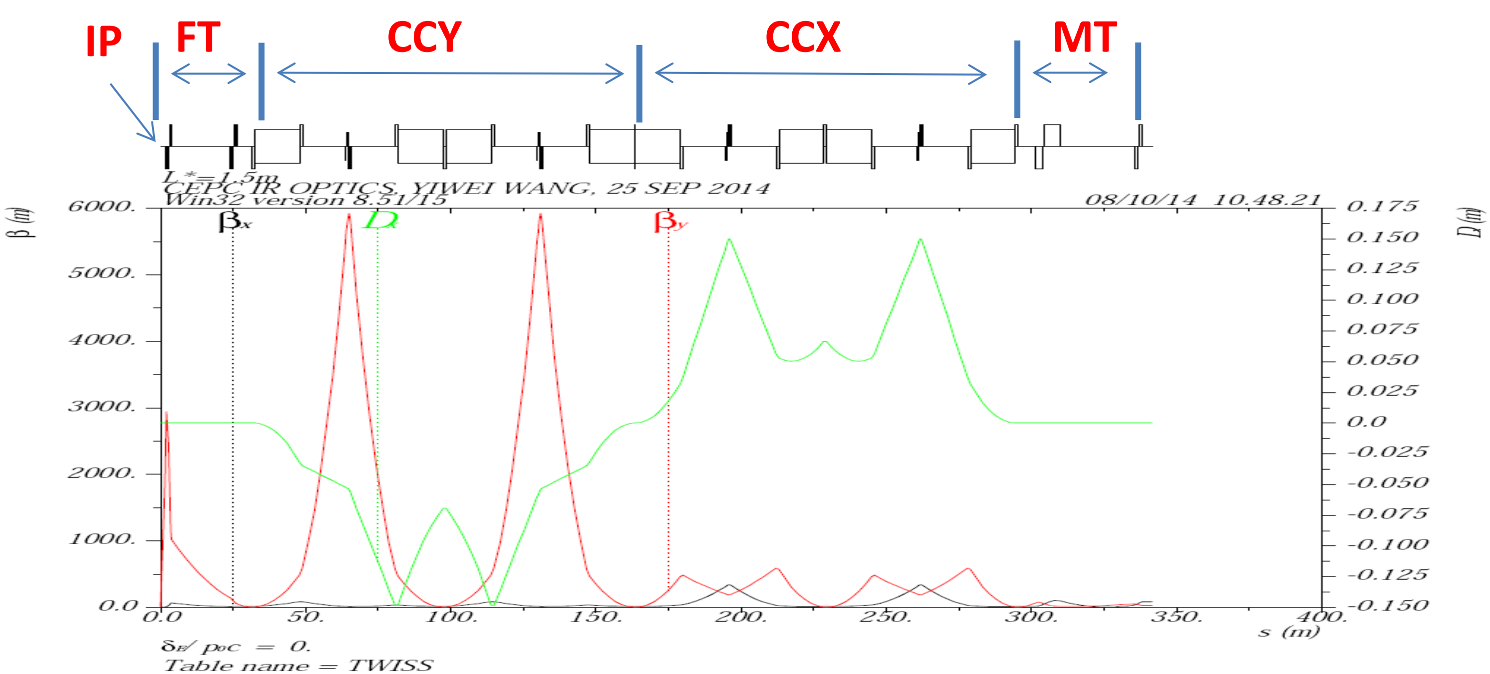
(4 straights, 849.6 m each)

(8 arcs, 5852.8 m each)



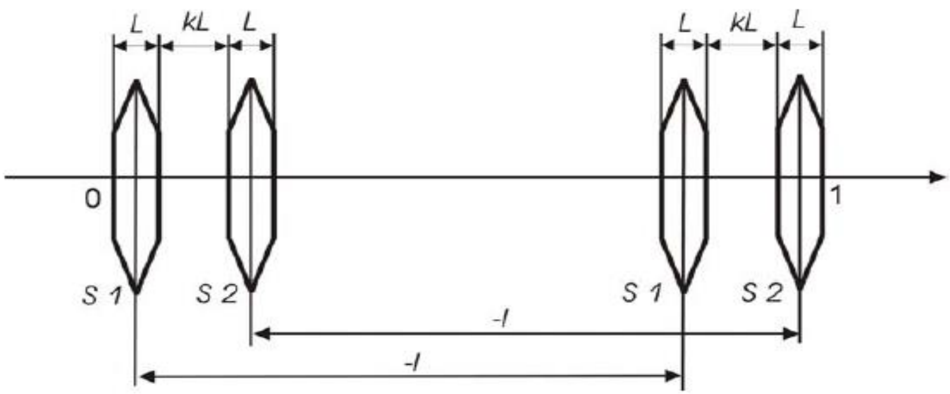
Interaction region design

- L*=1.5m chosen to facilitate design
- length constraint by overall layout consideration
  - maximum 350m for per side
- Apply Yunhai Cai's FFS scheme
  - Large beta peak in chromaticity correction section to reduce strength of sextupoles



Chromaticity correction

- Tune the phases between
  - QD0 and VS1
  - QF1 and HS1
- Optimize beta functions at IP vs. Momentum
- Add additional sextupoles next to the main one*
  - Compensate the finite length effect (Lsext=0.3m)



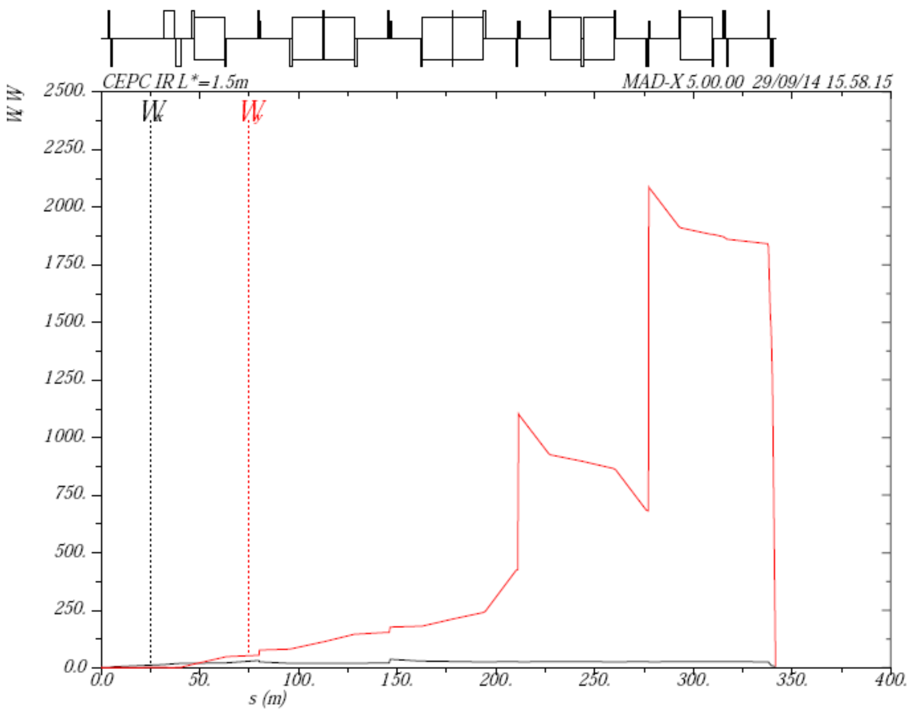
k=1, S1/S2=-0.1

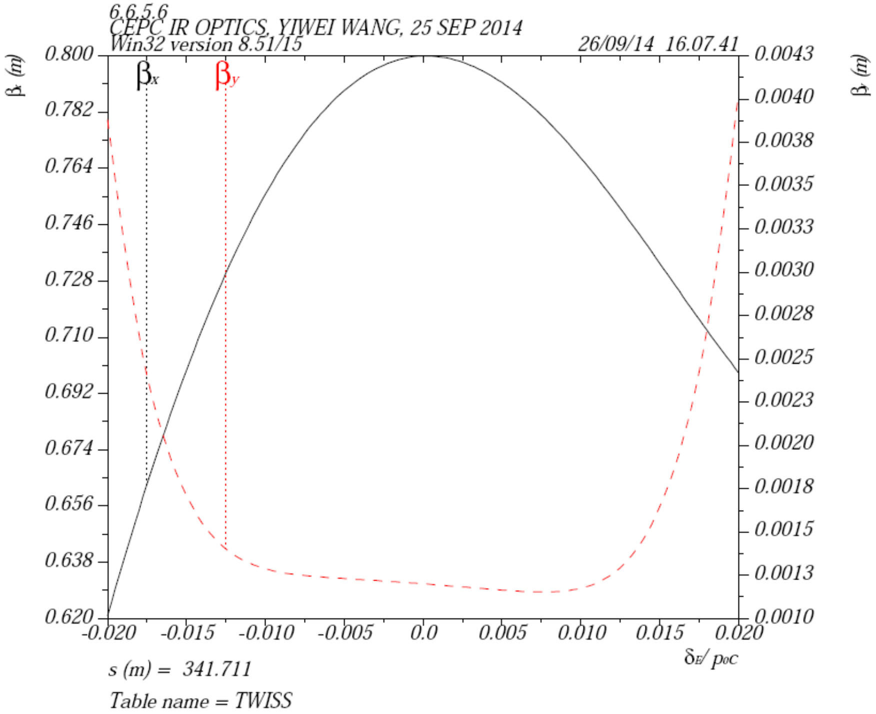
*A.Bogomyagkov et al.
http://arxiv.org/abs/0909.4872

- Re-optimize beta functions at IP vs. Momentum

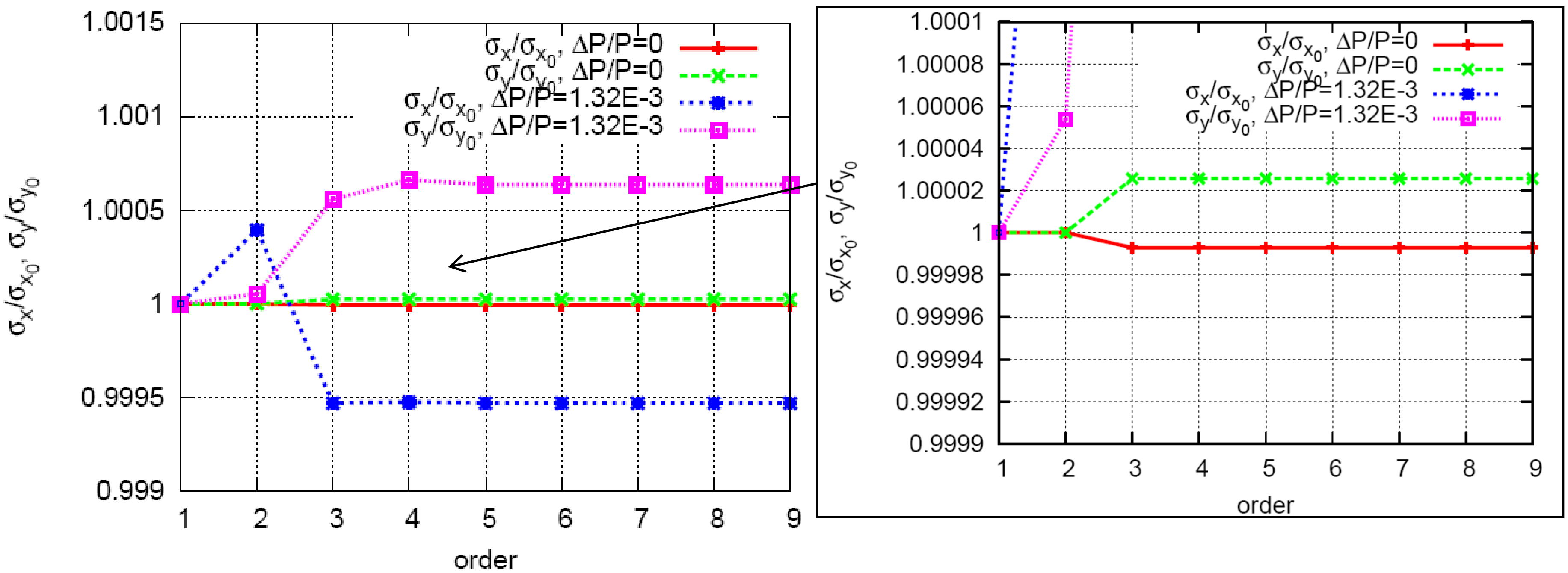
Chromaticity correction (cont.)

- W function at IP: Wx=7, Wy=6





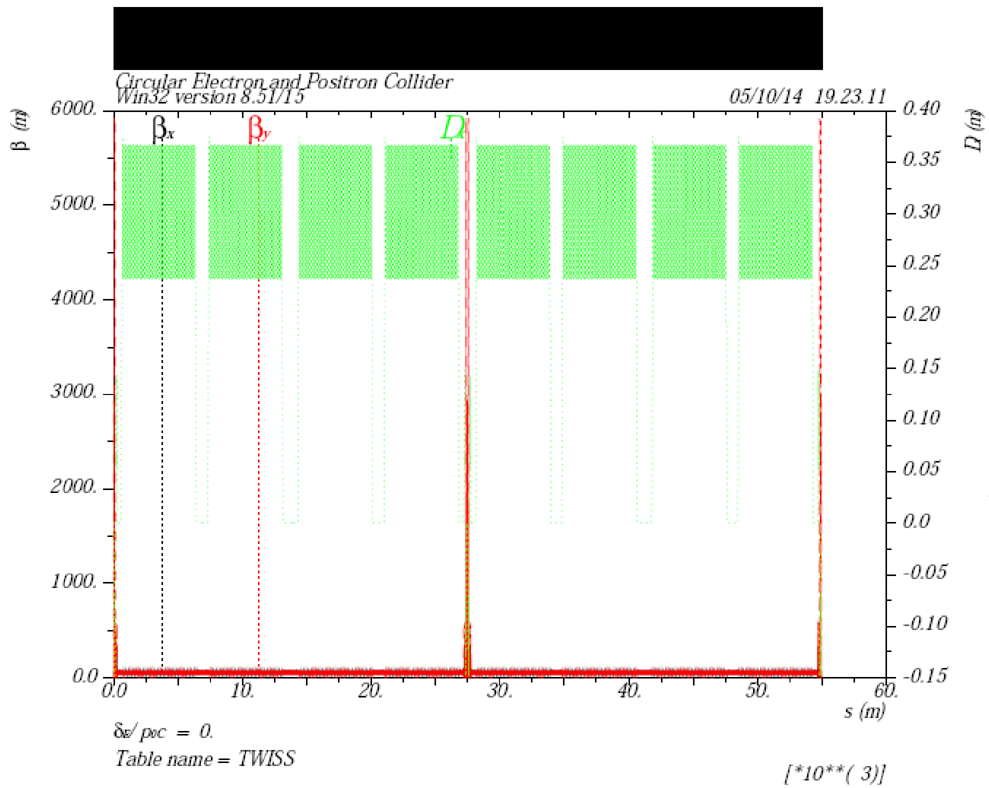
Residual aberration for FFS

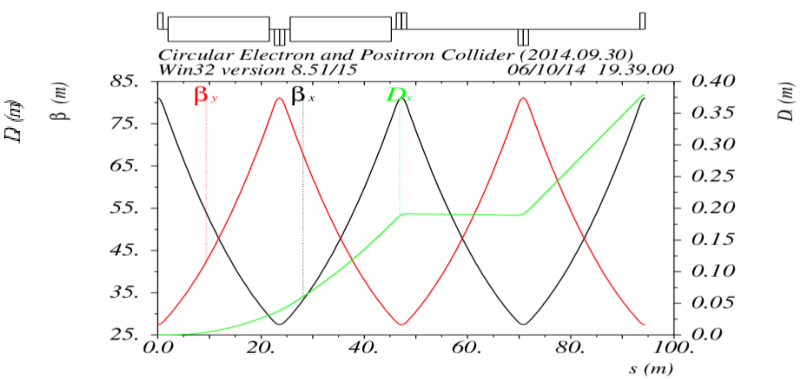


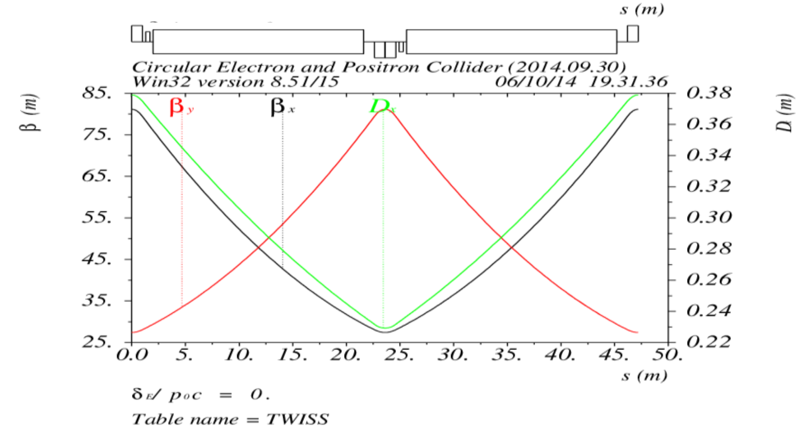
- Contribution of geometric aberrations to beam size at IP
  - geometric ~0.002%
  - chromatic ~0.05%

Lattice of the whole ring

- Close the whole ring
  - match β and α function

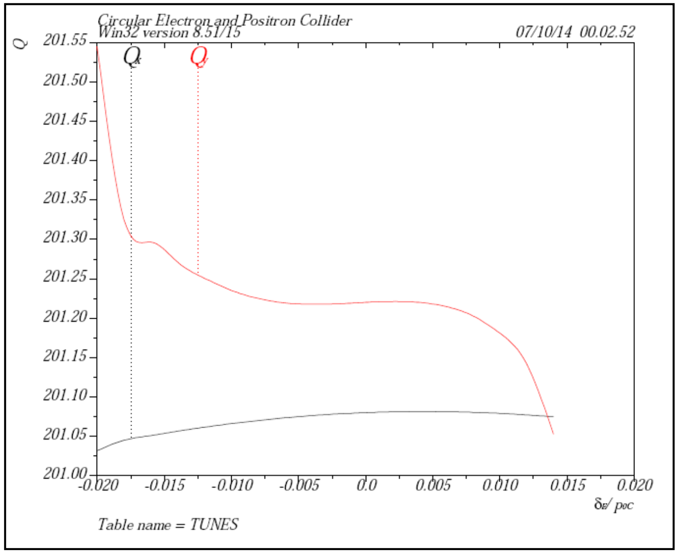


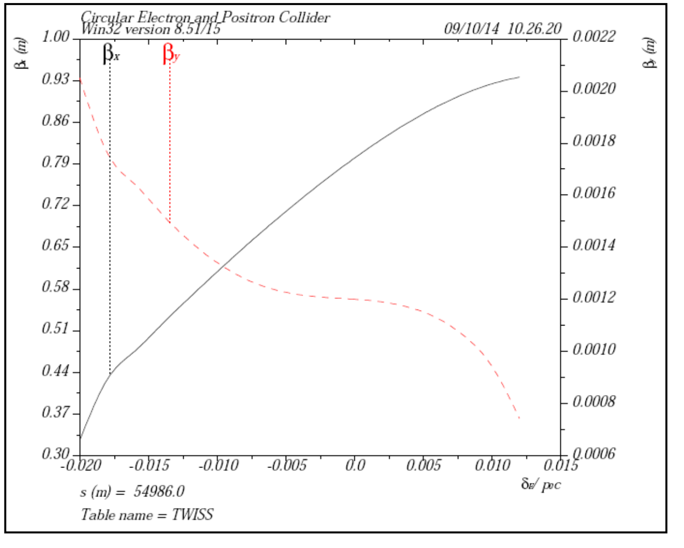




Tune vs. momentum deviation

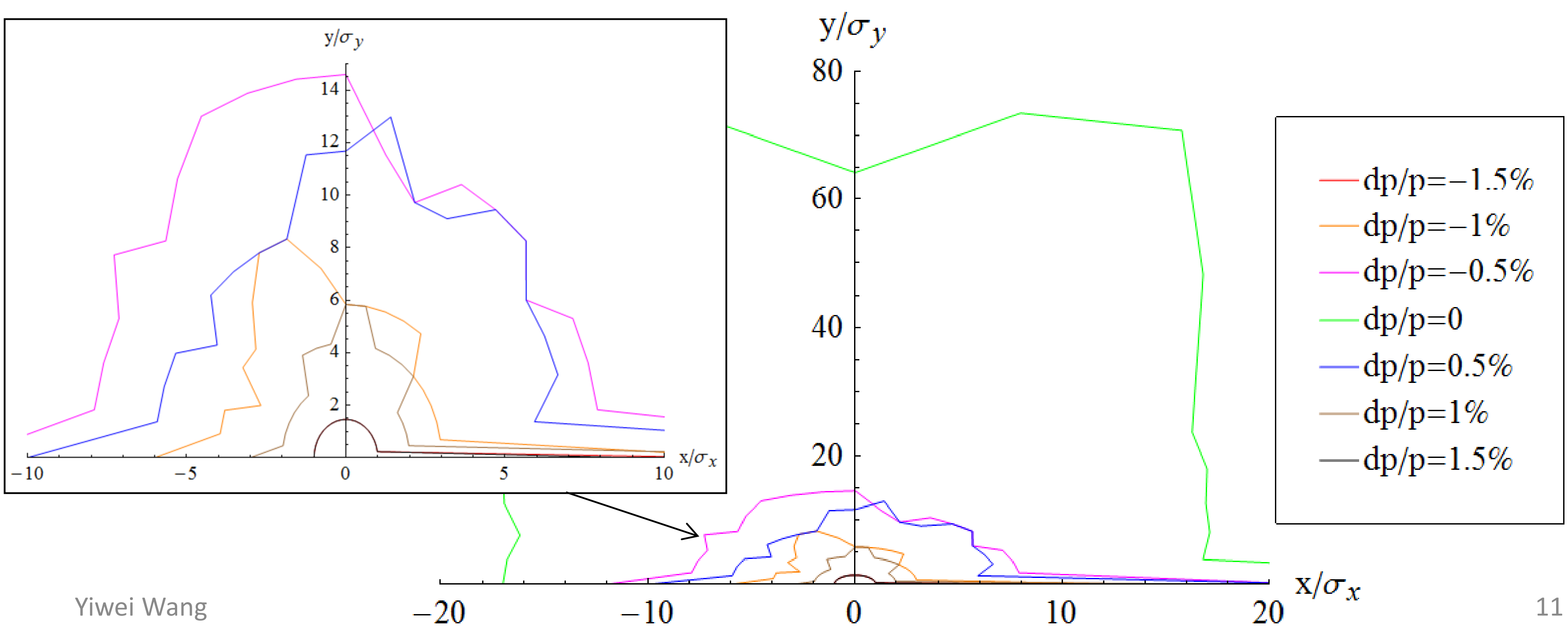
- Adjust the tune to be .08/.22 (νx/νy)
  - determined by beam-beam study
- match Q' to be 0.5 with the sextupoles in the ARC
  - Currently only 2 family of sextupoles in the ARC
- Good region of ±1% in Dp/p





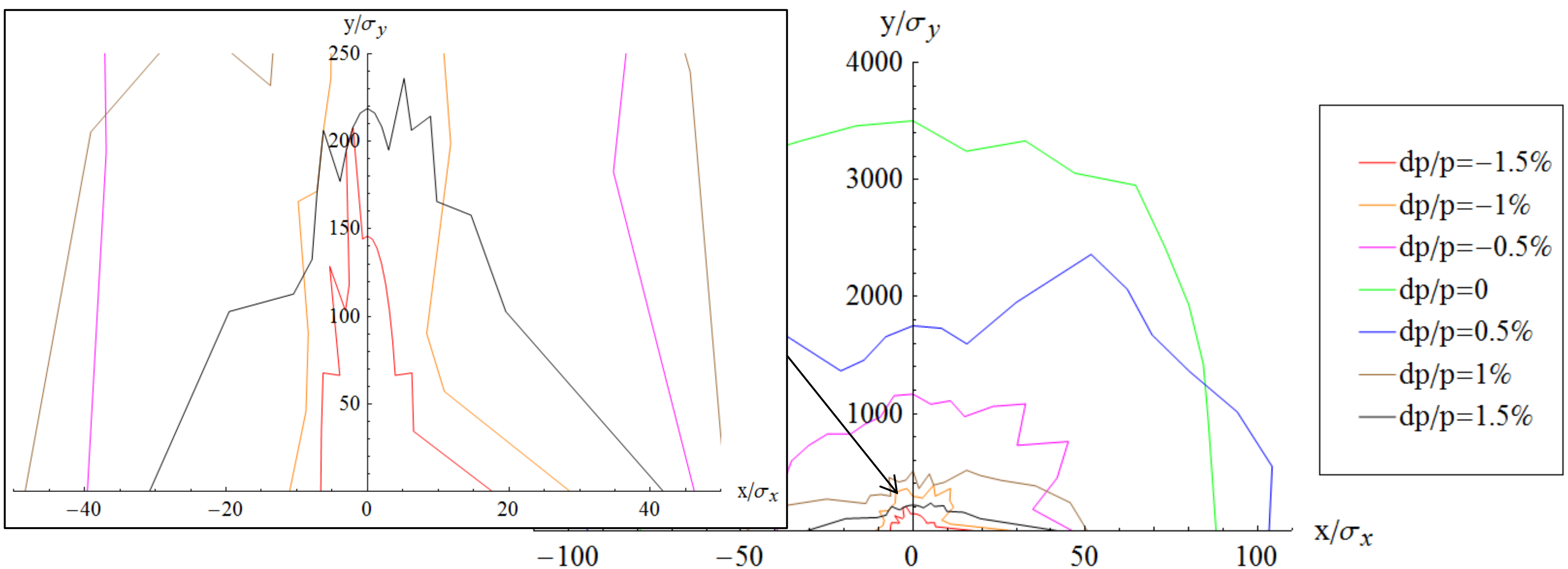
Dynamic aperture

- 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 on momentum: 17 σx and 70 σy



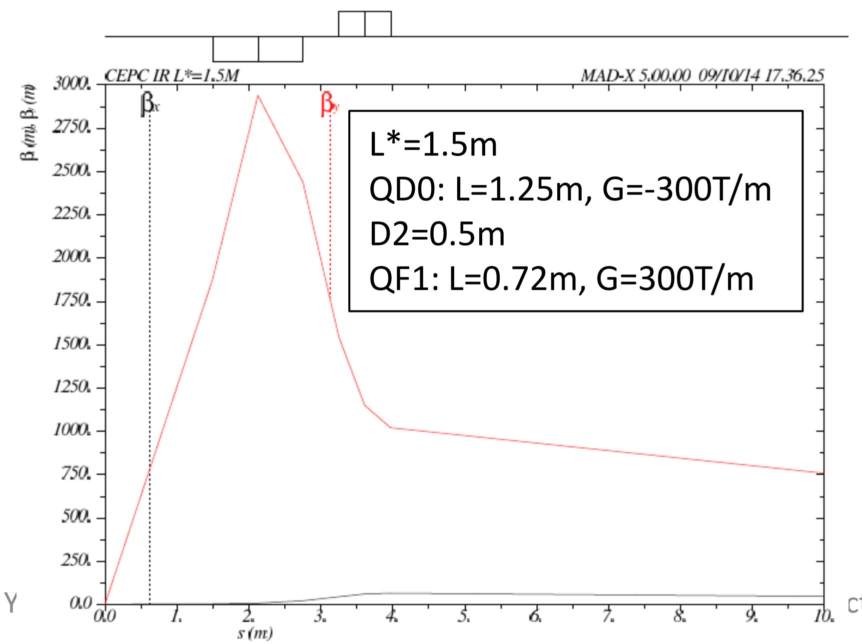
Dynamic aperture

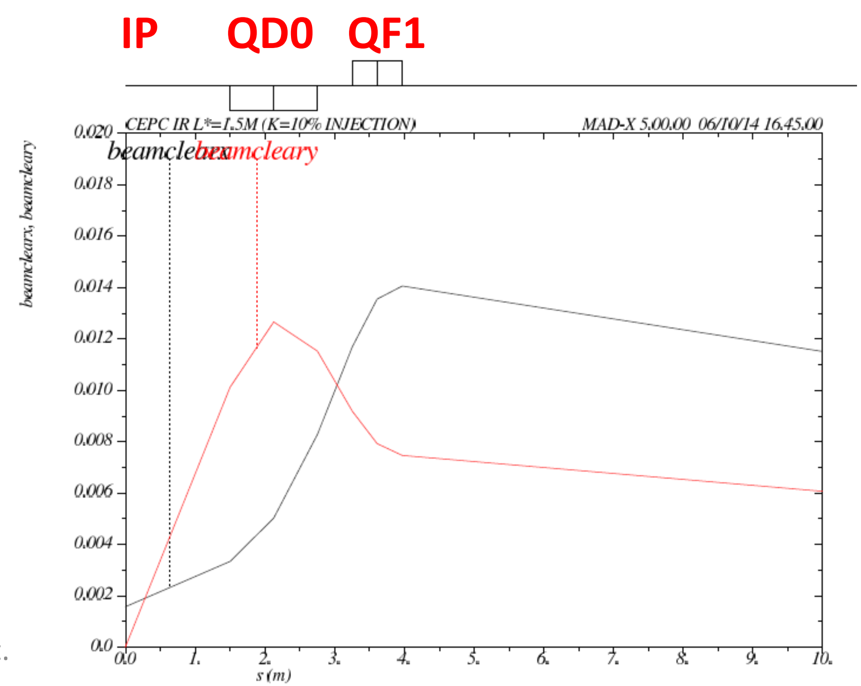
- The parts other than FFS are replaced by linear matrix
  - Suggested by A. Bogomyagkov
- DA for off momentum -1.5%: 7 σx and 150 σy



Beam stay-clear region at FD

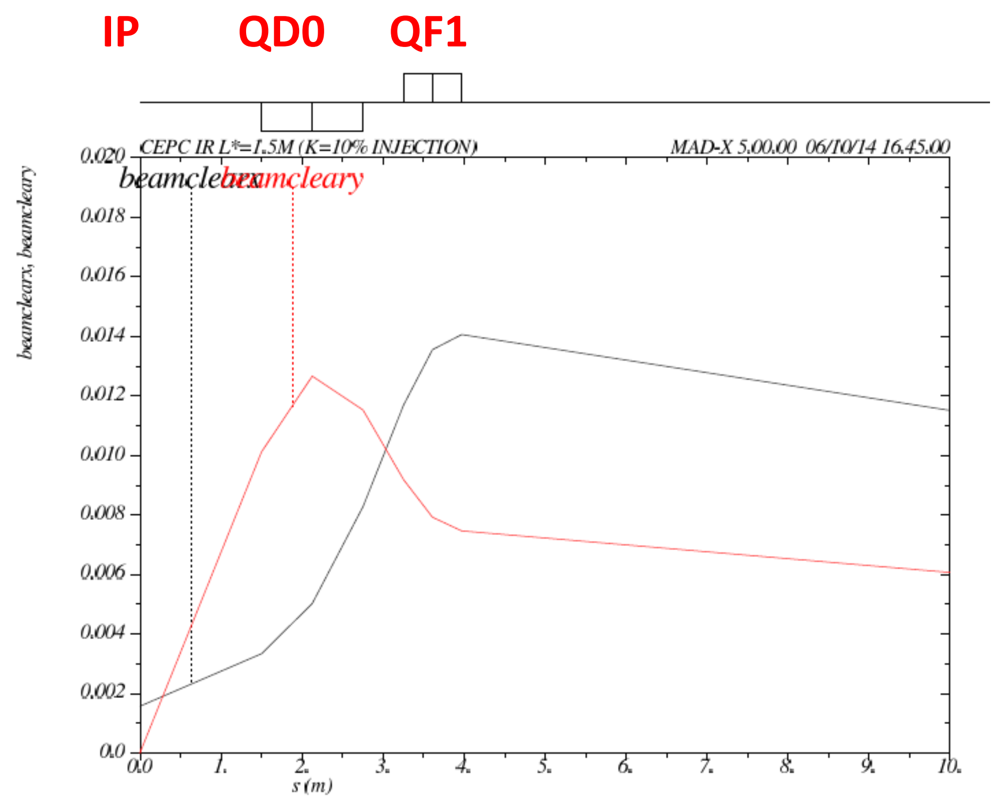
- The beam stay-clear region determined by considering the requirements for injection
- horizontal injection as in final doublet βy>> βx
  - 2Jx= 11.8 mm, 2Jy= 4.0 mm





Size of QD0 and QF1

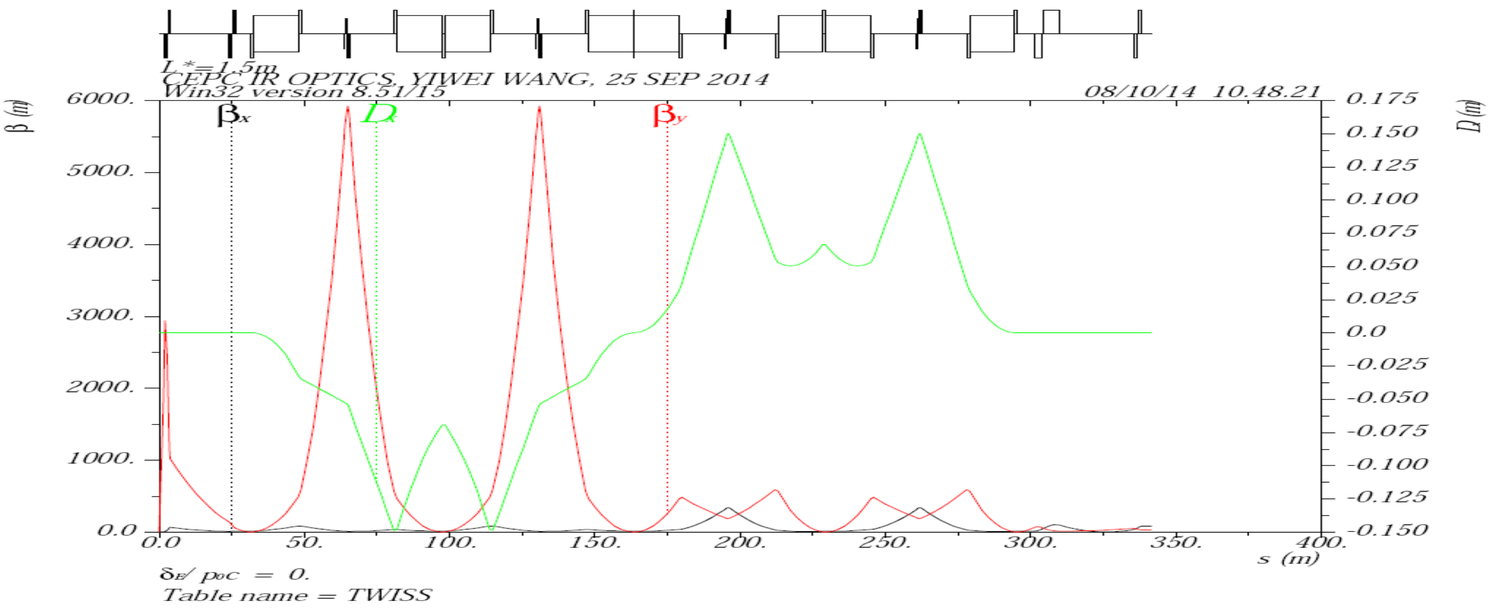
- coil inner radius = 20 mm
  - beam pipe inner radius = 16 mm (2mm for safety)
  - pipe wall thickness = 2 mm
  - gap between pipe and coil = 2 mm
- gradient = 300 T/m
- estimated cryostat diameter = 400 mm
  - acceptable for detector



L*=1.5m
QD0: L=1.25m, G=-300T/m
D2=0.5m
QF1: L=0.72m, G=300T/m

Synchrotron radiation load

- beam current 16.6mA
- For last bend
  - S=30m, L=15.5m, ρ=3762m
  - Critical energy in last bend: 958 keV
  - Power in last bend: 50 kw



Summary

- We got a primary optics design for L*=1.5m interaction region
- need a lot of optimization to get a reasonable dynamic aperture for the whole ring
  - optimize dynamic aperture for on momentum particles
    - Optimize the strength of the additional sextupoles
    - One more sextupole to cancel x and px simultaneously
  - need efforts to achieve bandwidth ±2%
    - Match W function and its phase between FFS and the ARC
    - with more families of sextupoles in the ARC
    - with octupoles
- aberration analysis for the whole ring need to be carried out

Summary

- Size of QD0 and QF1 are estimated for the current design
  - estimated cryostat diameter = 400 mm
  - still acceptable for detector
- Synchrotron radiation load estimated

Acknowledge

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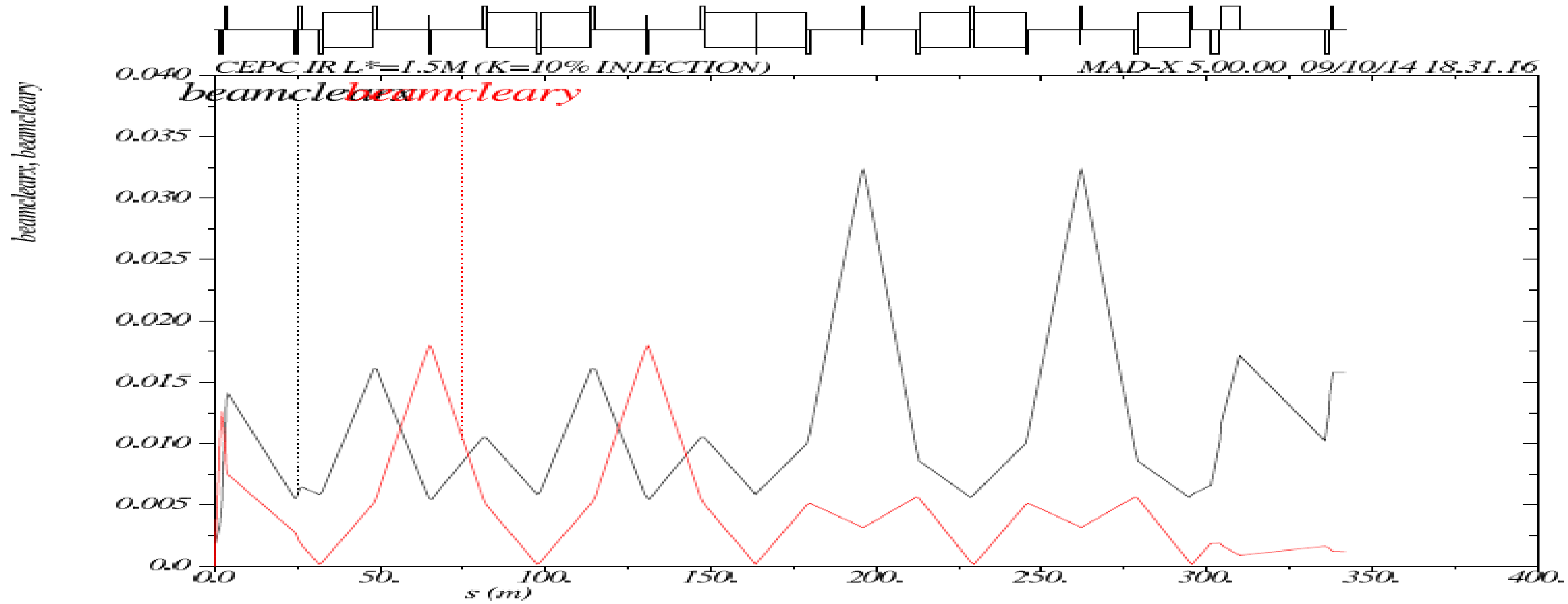
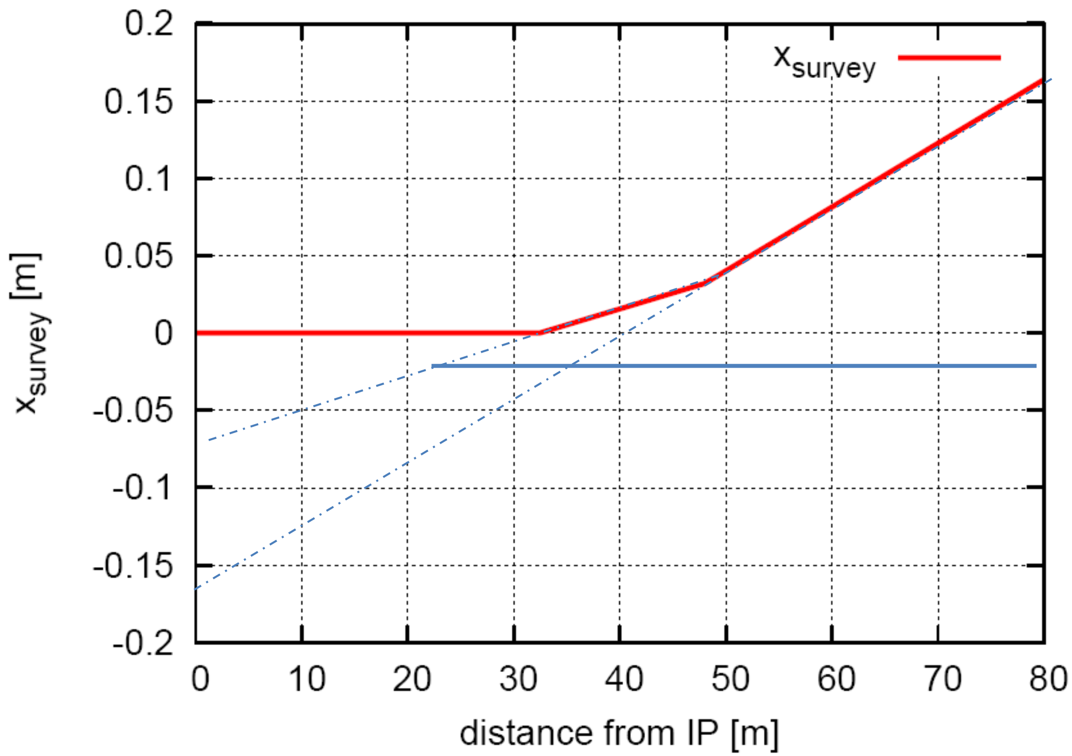
- Thanks for your kind help and beneficial discussion!

Thank you!



CEPC IR L*=1.5M (K=10% INJECTION)
MAD-X 5.00.00 09/10/14 18.31.16
beamclearx beamcleary
beamclearx, beamcleary
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.0
0.0
50.
100.
150.
200.
250.
300.
350.
400.
s (m)



x_{survey}
x_{survey} [m]
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
0
10
20
30
40
50
60
70
80
distance from IP [m]