Institute of High Energy Physics
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Lattice design for CEPC main ring

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IHEP, CAS, China

1st Annual Meeting of the Future Circular Collider

Washington D.C., U.S

March 23-27, 2015

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FCC Week 2015

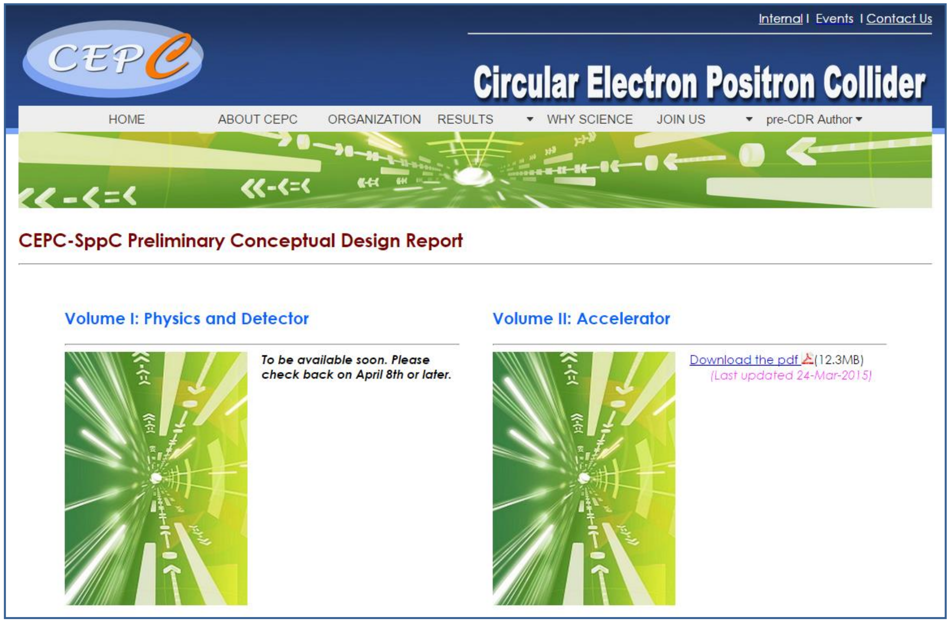
Outline

- Introduction
- Lattice design of the ring
- Pretzel scheme design
- Sawtooth effect
- Work to be done

Introduction

- CEPC (a Circular Electron Positron Collider) has been proposed to study the Higgs boson
- For some simple reason, CEPC has temporarily chosen the single ring as the baseline design
- A circumference of 50km is also chosen to have a reasonable cost

- Quite a lot of work has been done during the past year
- Enormous effort has been spent on preparing the Preliminary Conceptual Design Report, which is available now at: http://cepc.ihep.ac.cn/preCDR/volume.html



CEPC parameter list

Parameter	Unit	Value	Parameter	Unit	Value
Beam energy [E]	GeV	120	Circumference [C]	km	54
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	2.65
Lifetime due to Beamstrahlung (simulation)	min	47	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 [$\sigma_{\delta.tot}$]	%	0.163	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

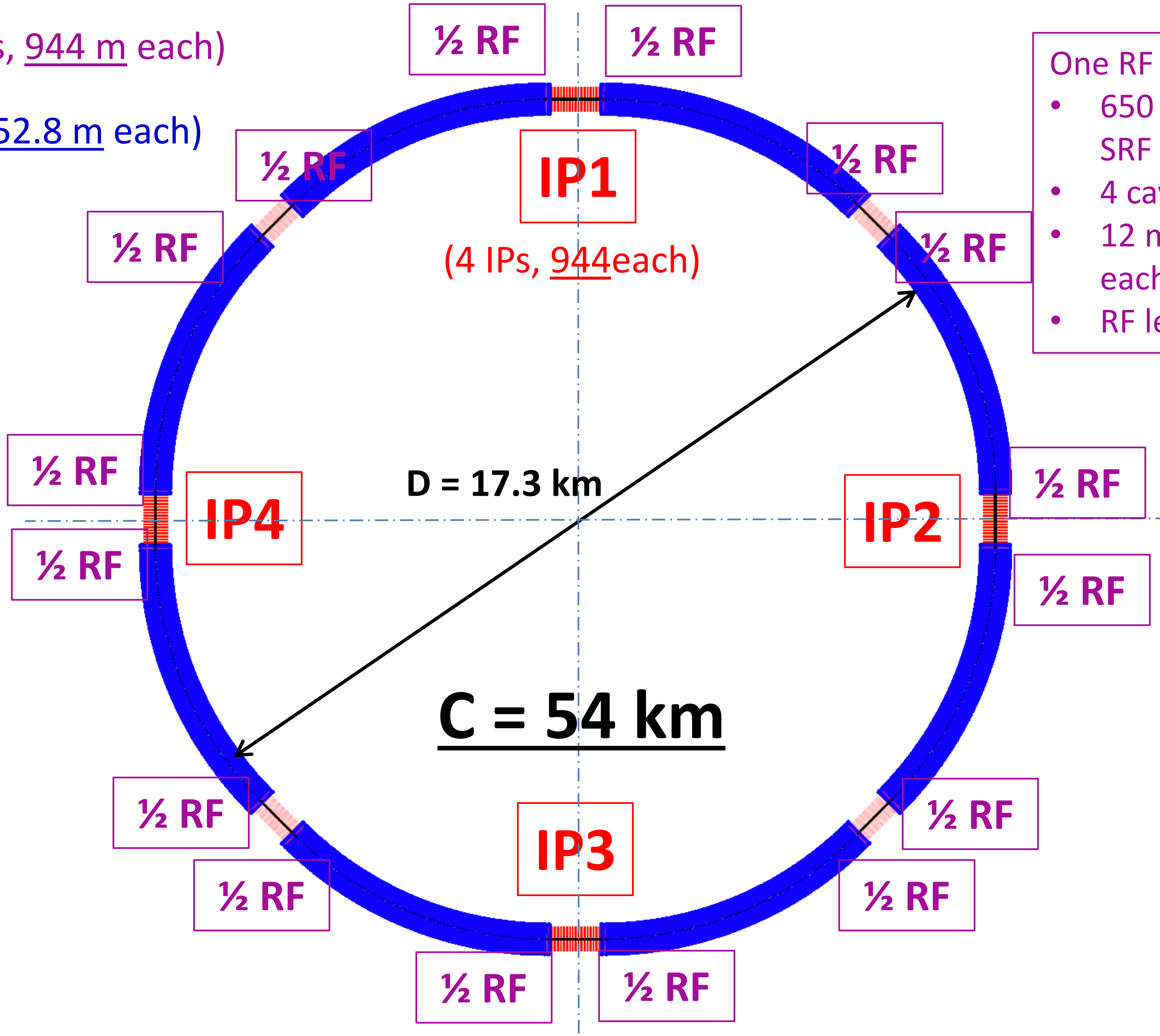
CEPC Lattice Layout (Jan 11, 2015)

(4 straights, 944 m each)

(8 arcs, 5852.8 m each)

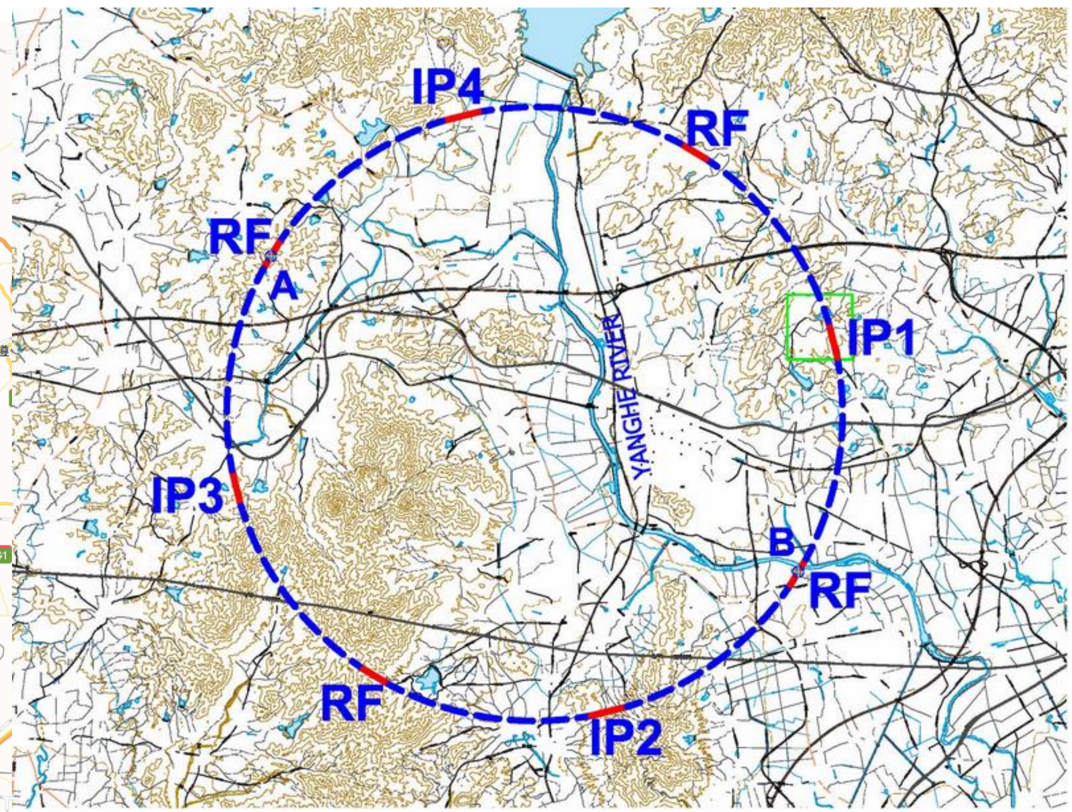
One RF station:

- 650 MHz five-cell SRF cavities;
- 4 cavities/module
- 12 modules, 10 m each
- RF length 120 m



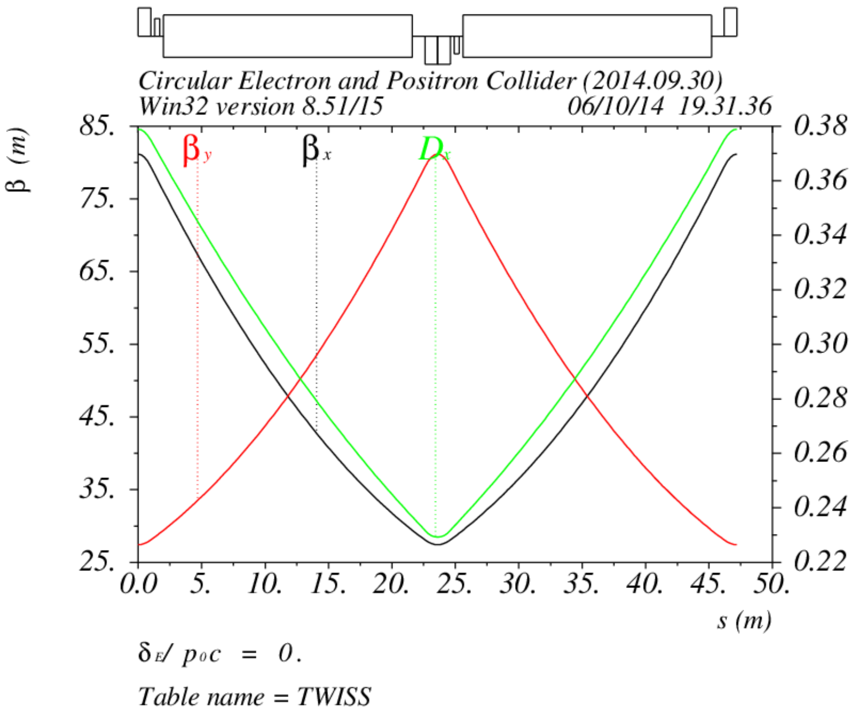
CEPC in real world (one possibility)

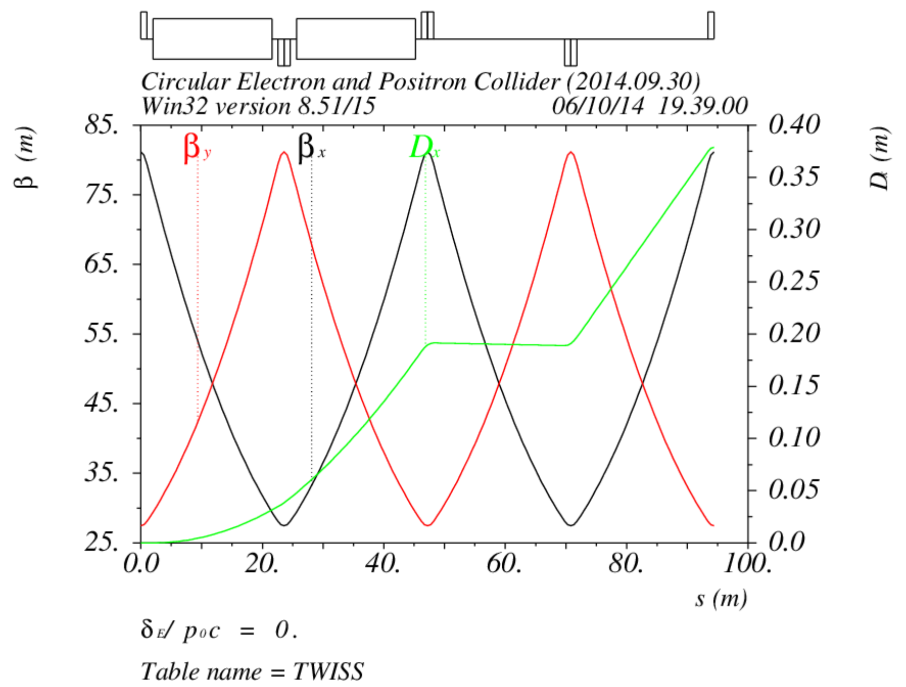
- A few possible locations has been studied
- One of the possible location is: QinHuangDao, east of Beijing, 300km, 3h30m drive



Lattice of arc sections

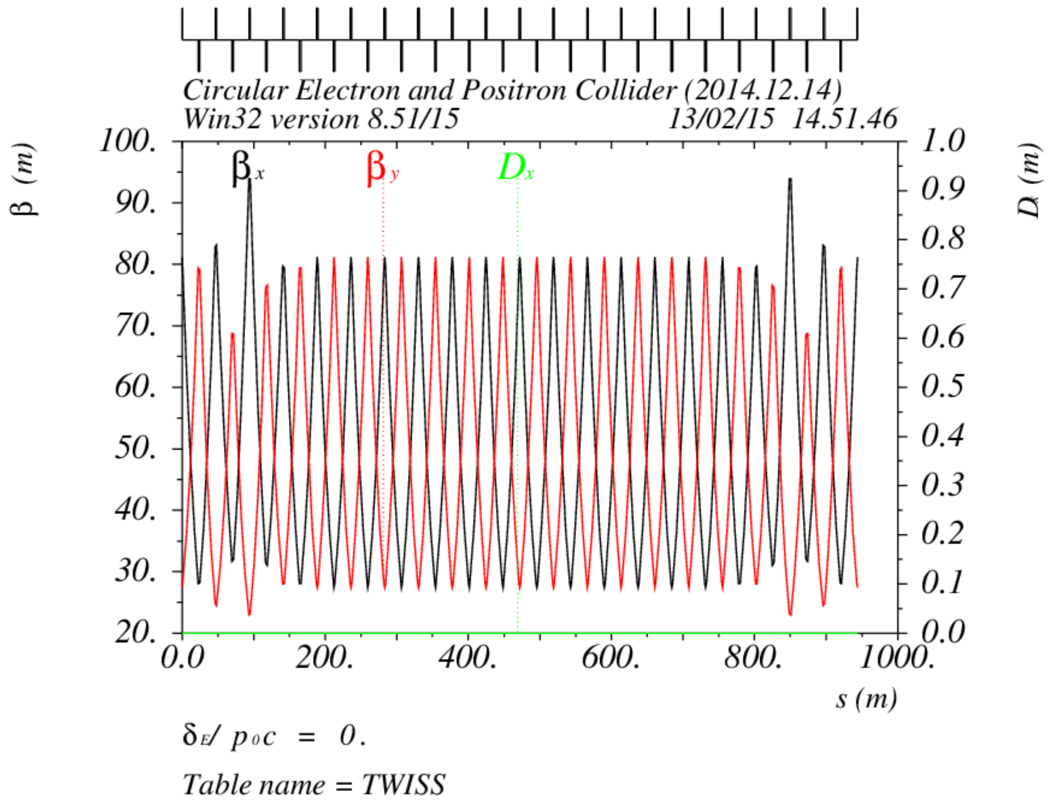
- Length of FODO cell: 47.2m
- Phase advance of FODO cells: 60/60 degrees
- Dispersion suppressor on each side of every arc
- Length: 94.4m





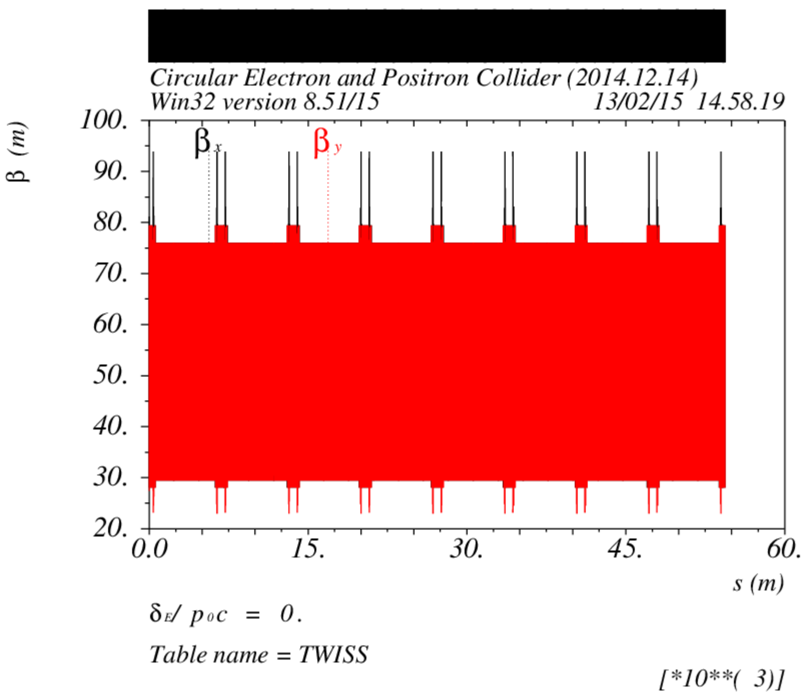
Lattice of straight sections

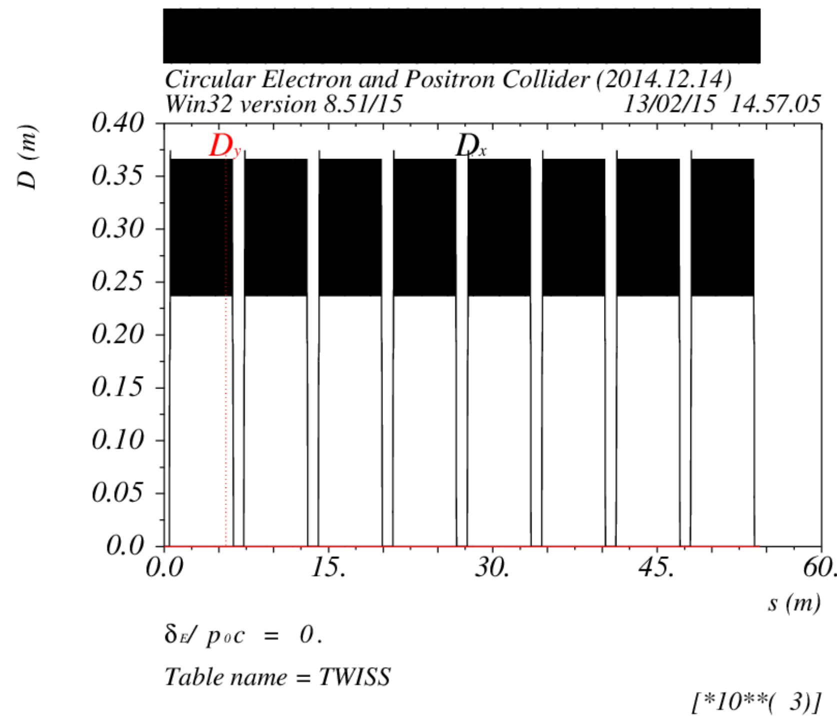
- All straights: 20 FODO cells
- Length: 944m
- Used for adjusting working point and matching
- Can be used for RF, injection and beam dump, etc.



Lattice of the main ring

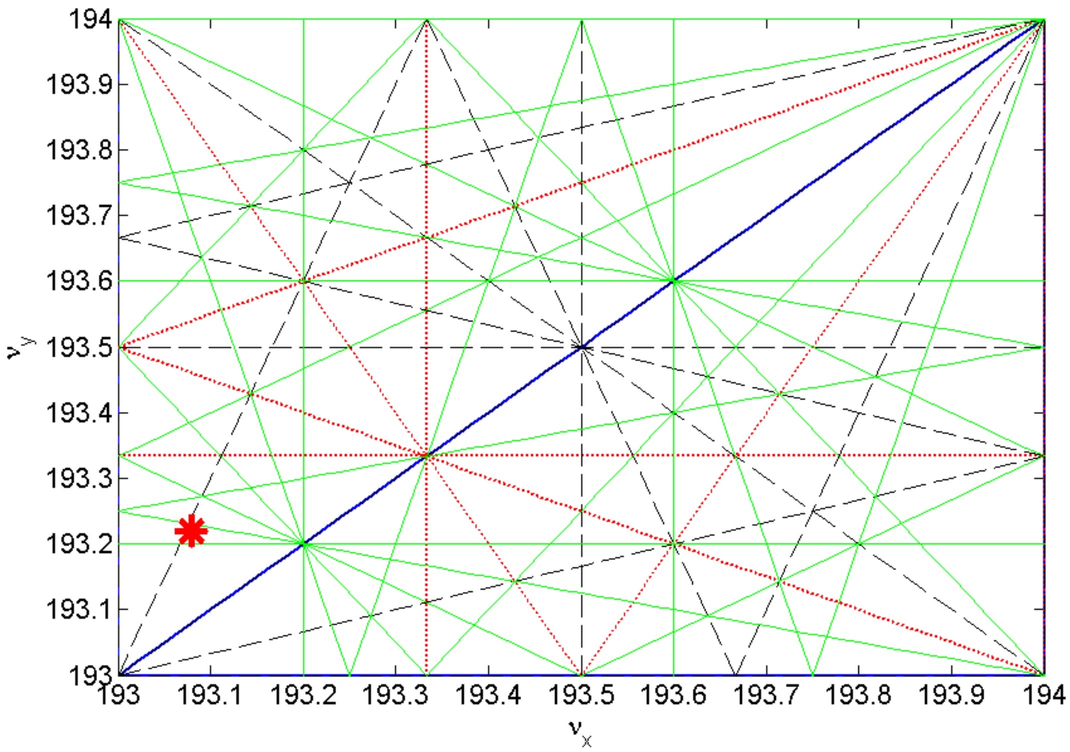
- Eight superperiod, with 2 IPs
- Total length is 54.3744km, as the cell length is 47.2m, the pretzel scheme is designed for 48 bunches/beam.





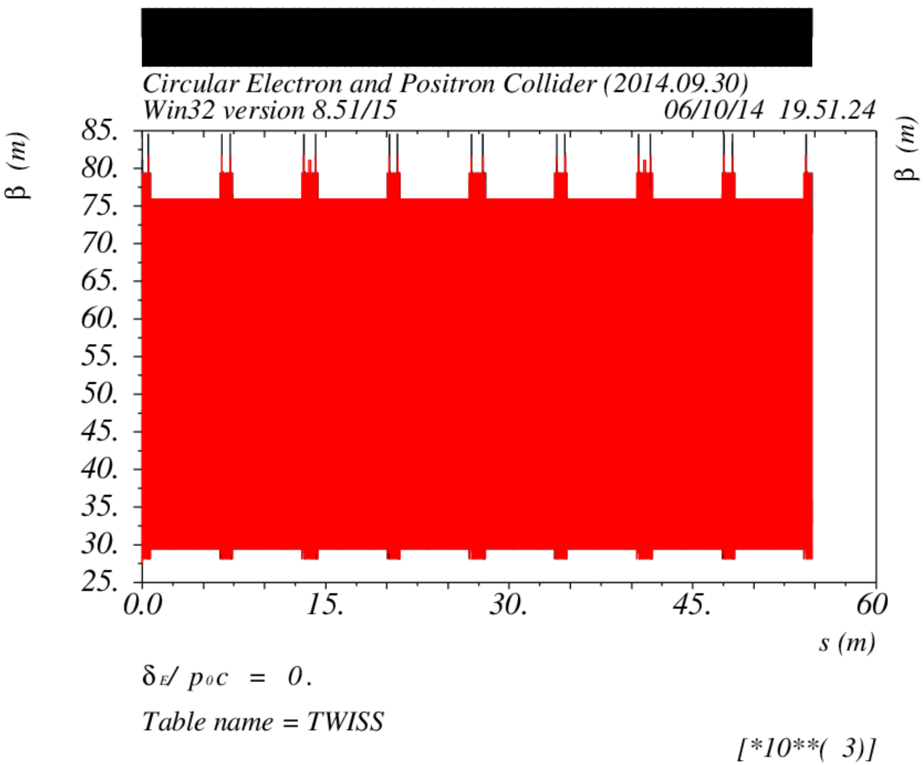
Work point

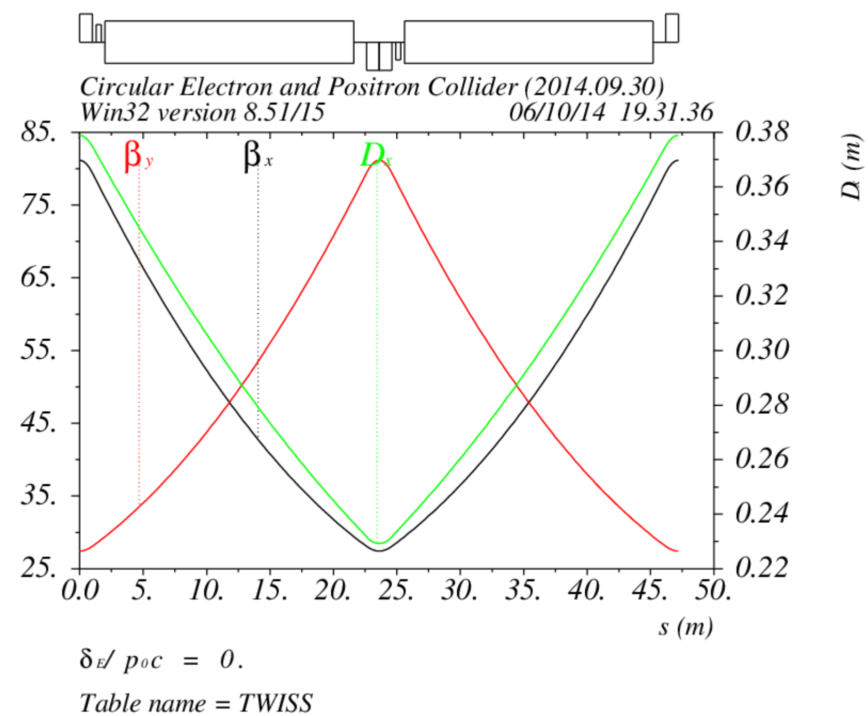
- The working point is chosen as: .08/.22 in horizontal and vertical plane for present study
- Optimization is done with beam-beam simulations, to have a high luminosity
- Will further optimize it



Chromatic correction (1)

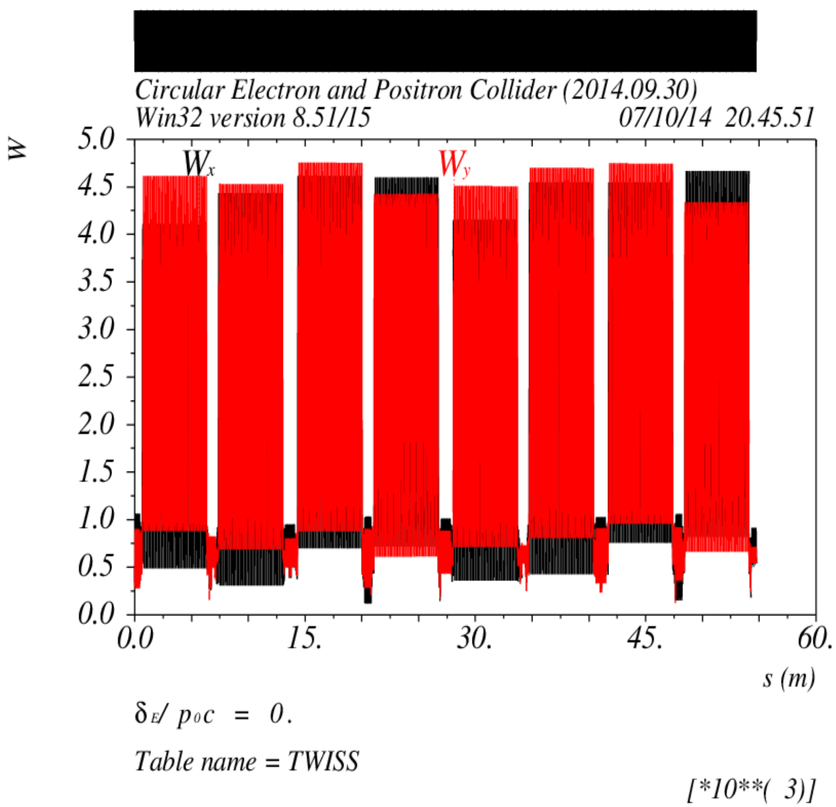
- Two families of sextupoles: one family for horizontal, one family for vertical plane
- One sextupole next to each quadrupole in the arc section (interleaved scheme)

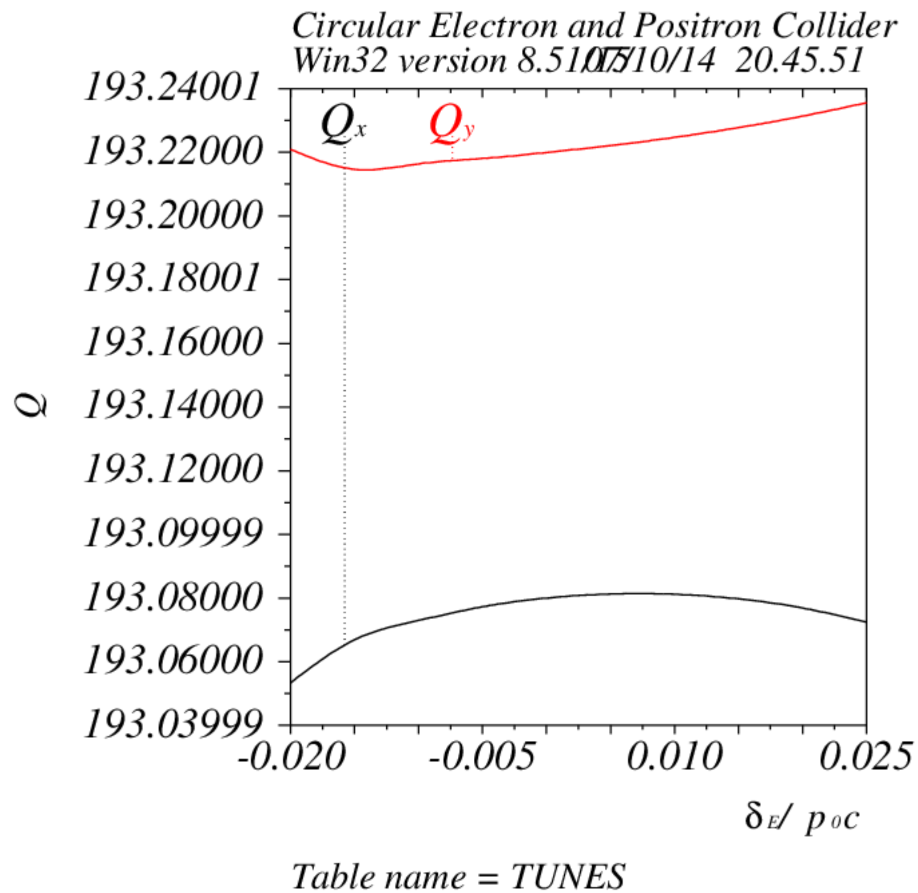




Chromatic correction (2)

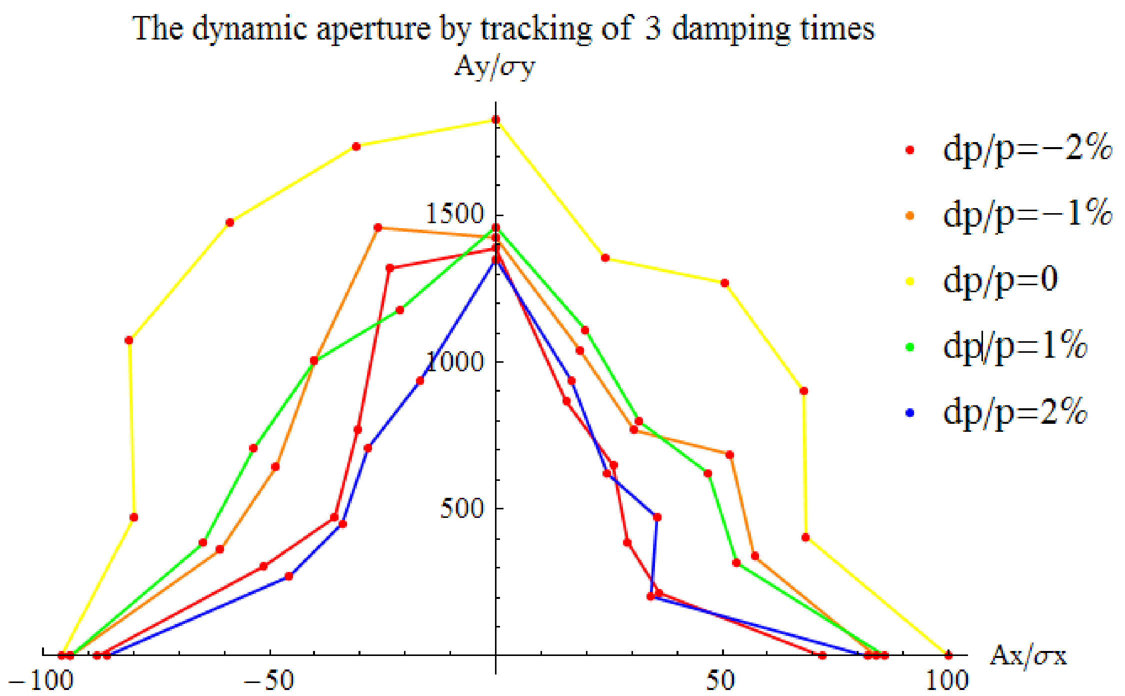
- The W function for the ring is only a few
- The chromaticity in both planes has been corrected to a positive value





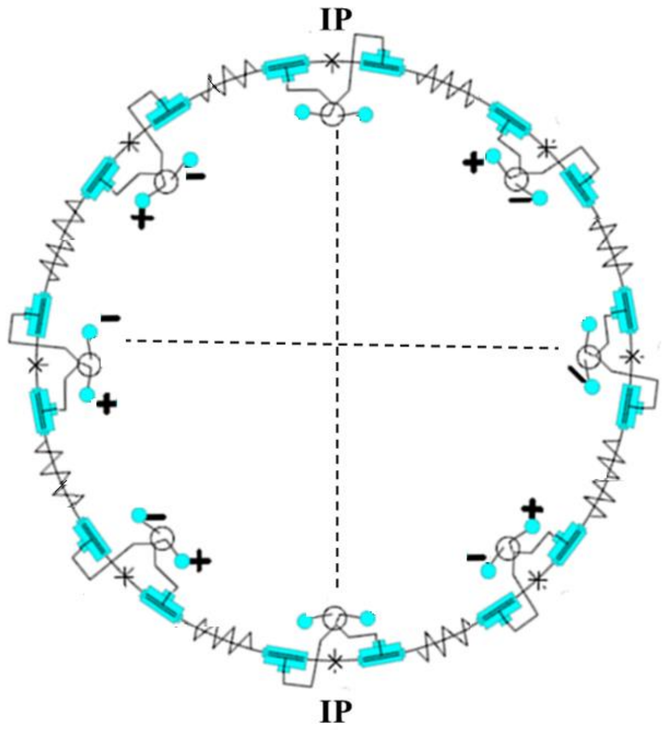
Dynamic aperture

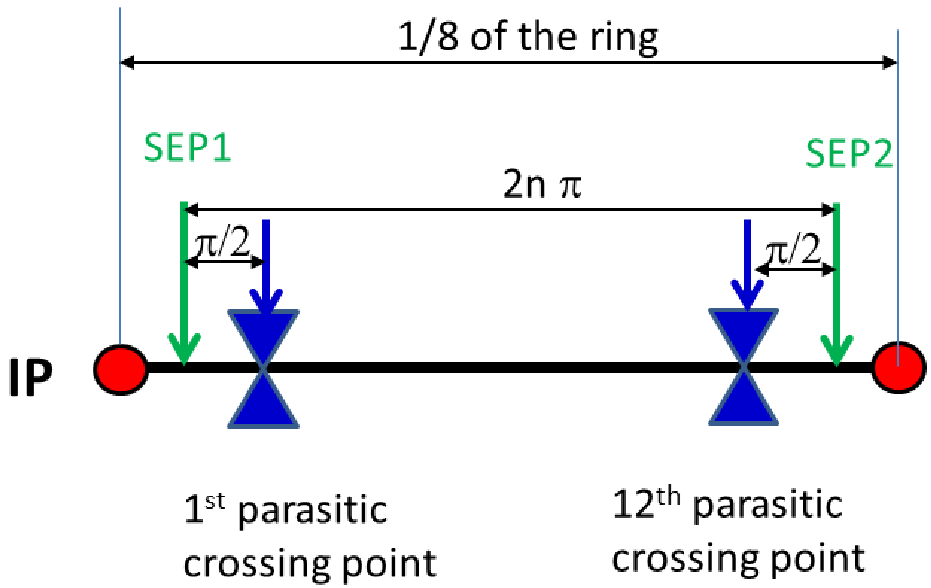
- 240 turns is tracked for dynamic aperture (3 transverse damping time)
- Coupling of 0.3% is used for calculation of vertical beam size
- The dynamic aperture is: ~ $60\sigma_x/1300\sigma_y$ or 60mm/50mm in x and y for ±2% momentum spread



Pretzel scheme (1)

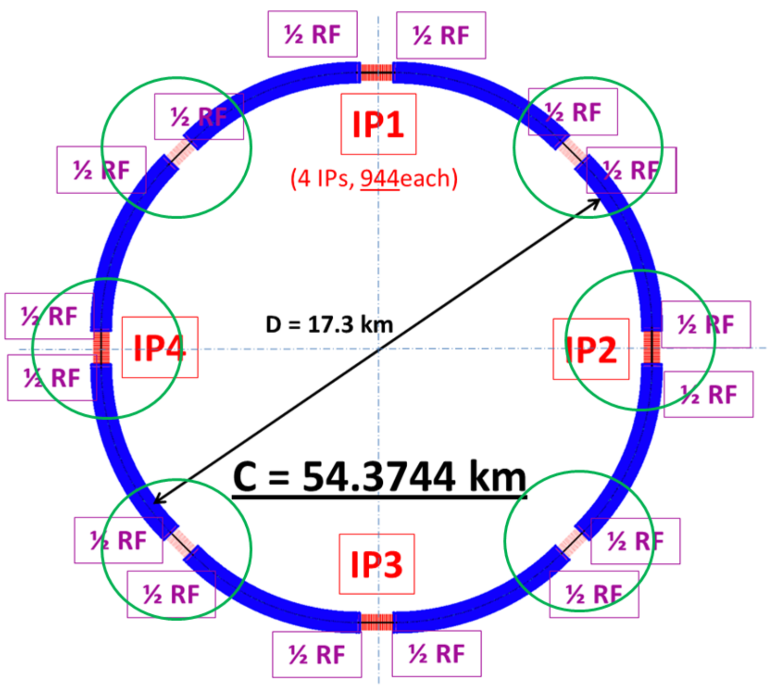
- Designed for 48 bunches/beam, every 4pi phase advance has one collision point
- Horizontal separation is adopted to avoid big coupling
- No off-center orbit in RF section to avoid beam instability and HOM in the cavity
- One pair of electrostatic separators for each arc

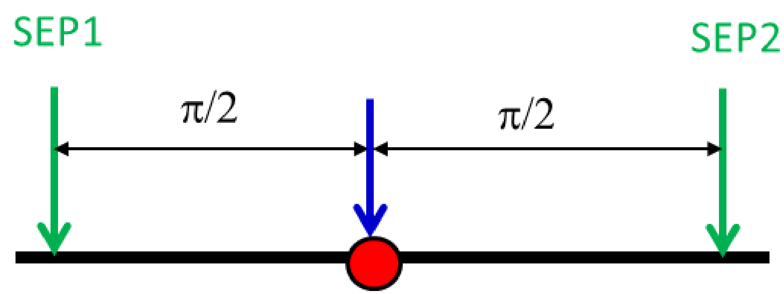




Pretzel scheme (2)

- At straight sections, IP2 /IP4 and the other four symmetric points are parasitic crossing points, but have to avoid collision
- Six more pairs of electrostatic separators for these crossing points

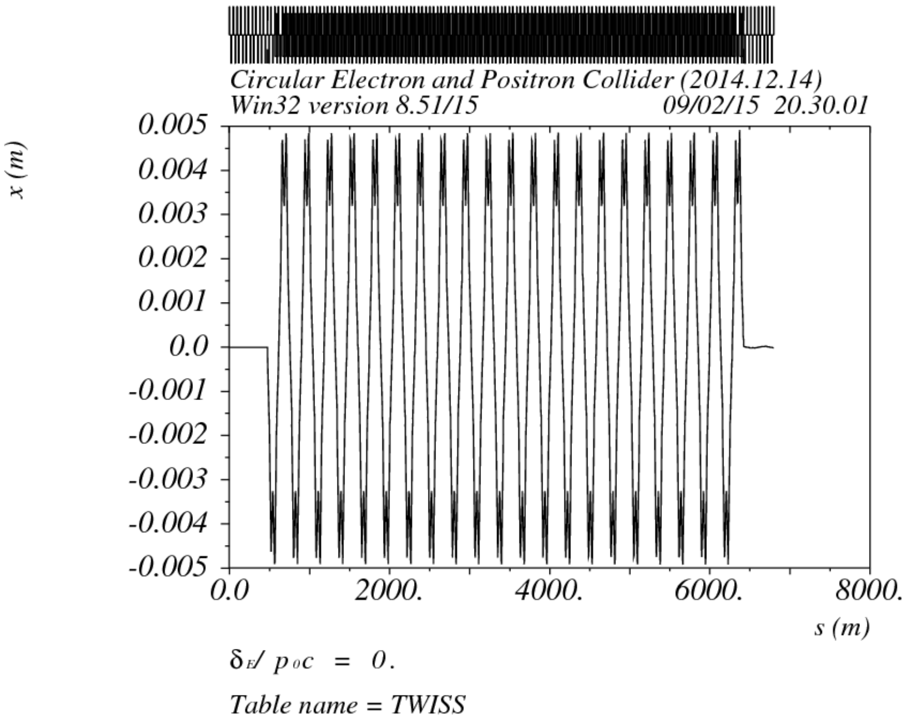




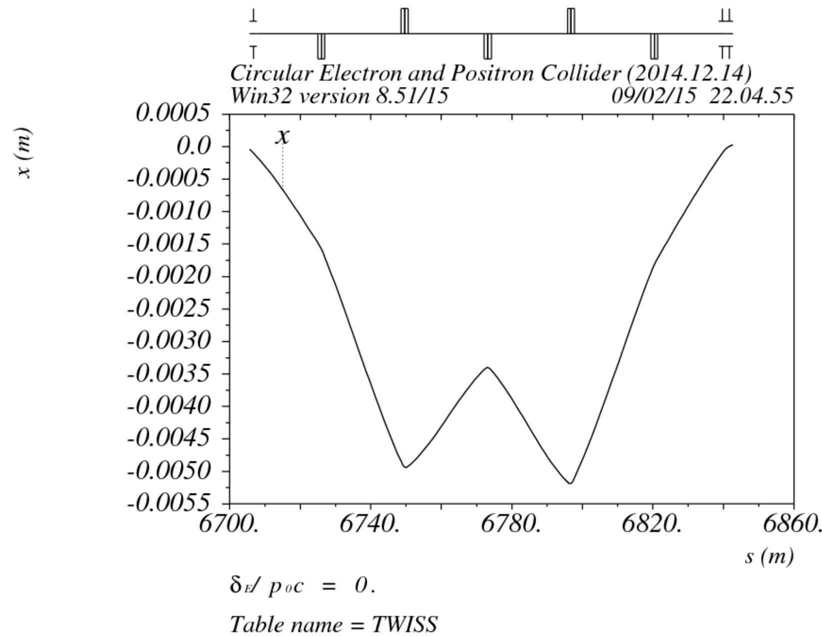
IP2/IP4
and the other four symmetric points

Pretzel scheme (3)

- Separation distance: ~5 σx for each beam (10 σx distance between two beam)
- Maximum separation distance between two beams is : ~10 mm



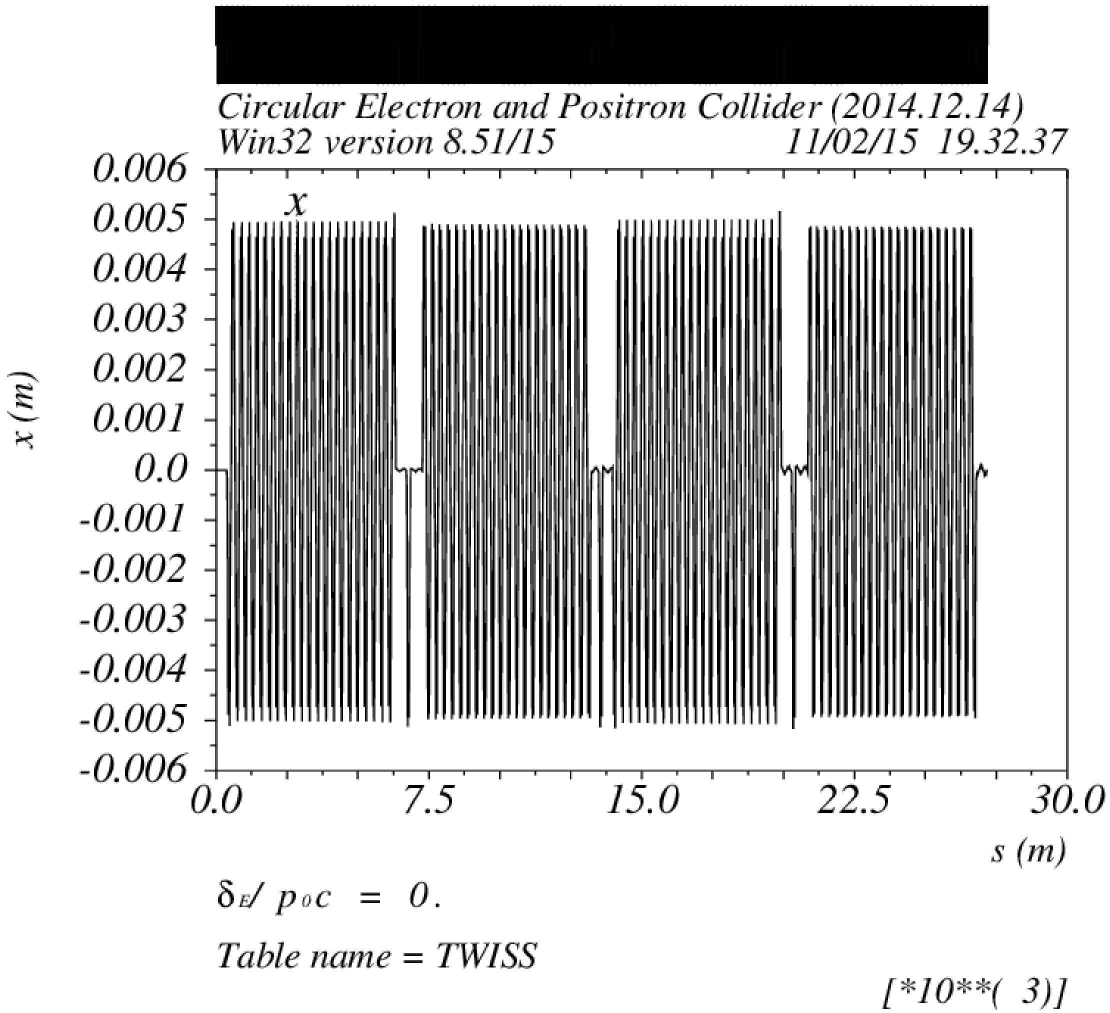
Orbit for the first 1/8 ring



Orbit for IP2/IP4 and the other four symmetric points

Pretzel scheme (4)

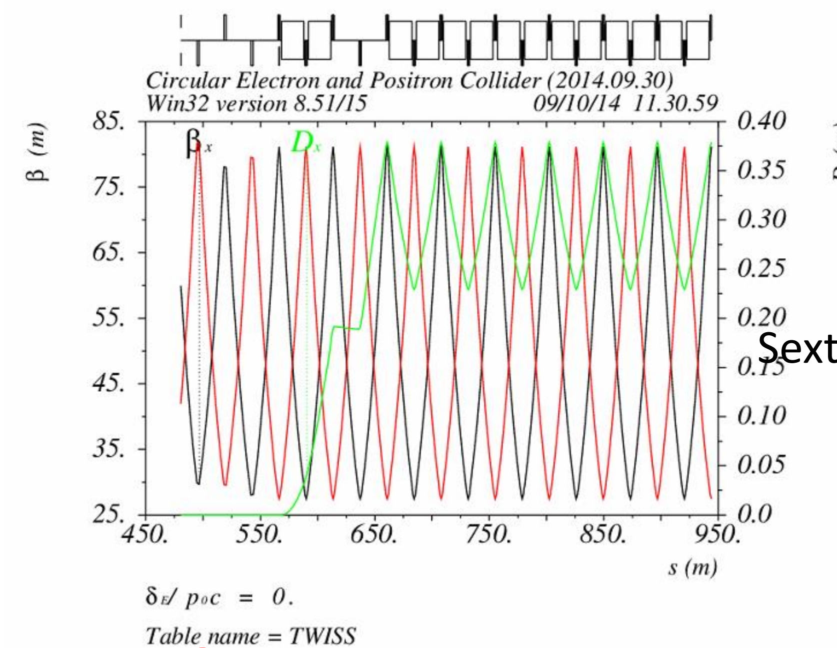
- Orbit of half CEPC ring



At least 14 pairs of electrostatic separators will be needed for the ring.

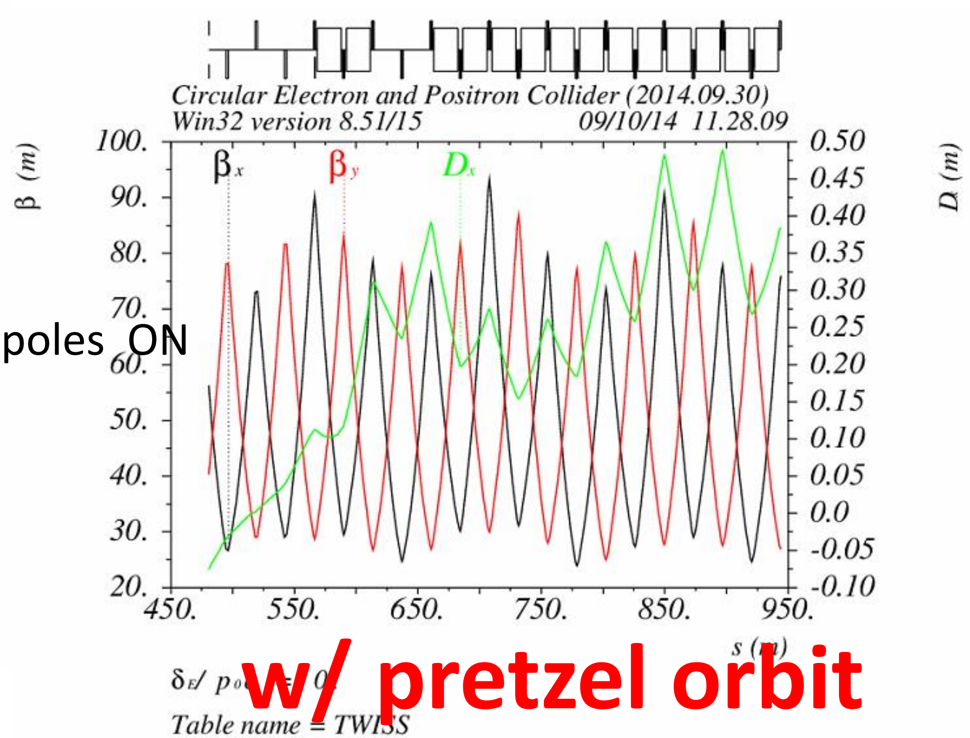
Effects of pretzel orbit (1)

- Pretzel orbit has effects on:
  - Beta functions, thus tune
  - Dispersion function, thus emittance
  - Dynamic aperture



w/o pretzel orbit

Sextupoles ON



w/ pretzel orbit

Effects of pretzel orbit (2)

- Estimation of dipole field strength in quadrupole

$$K_1 = 0.022, \quad B\rho = 400, \quad \Delta x = 5\,\text{mm}$$

$$\Delta B = K_1 \cdot B\rho \cdot \Delta x = 0.05\text{T}$$ ➡ **Dipole field of the ring 0.066T.**

- Estimation of quadrupole field strength in sextupole

$$K_2 = 0.38, B\rho = 400, \Delta x = 5mm$$

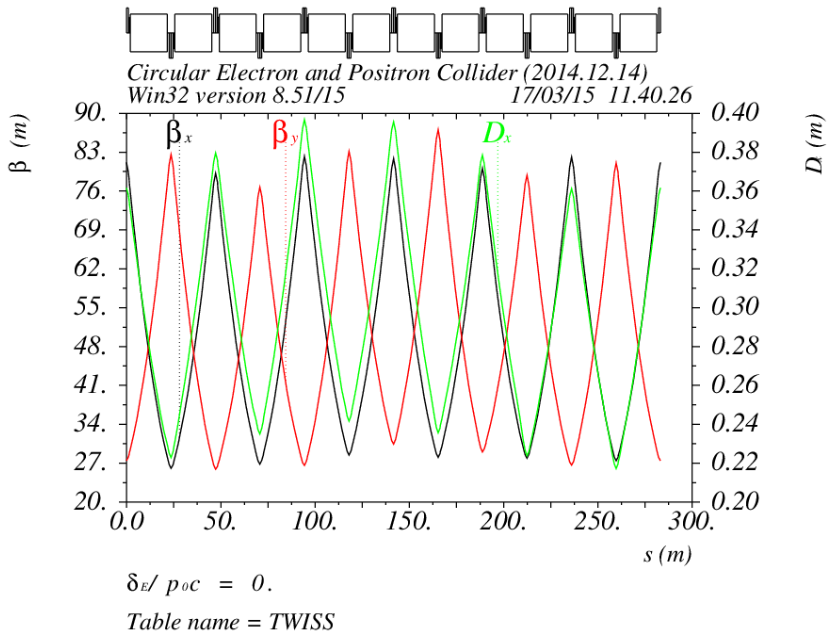
$$\Delta K_1 = K_2 \cdot \Delta x = 0.0019$$ ➡ **Quadrupole field of the ring K_1=0.022.**

$$\Delta B = K_2 \cdot B\rho \cdot \frac{\Delta x^2}{2} = 0.0019\,\text{T}$$ ➡ **Dipole field of the ring 0.066T.**

This explains why the dispersion function has been changed so much.

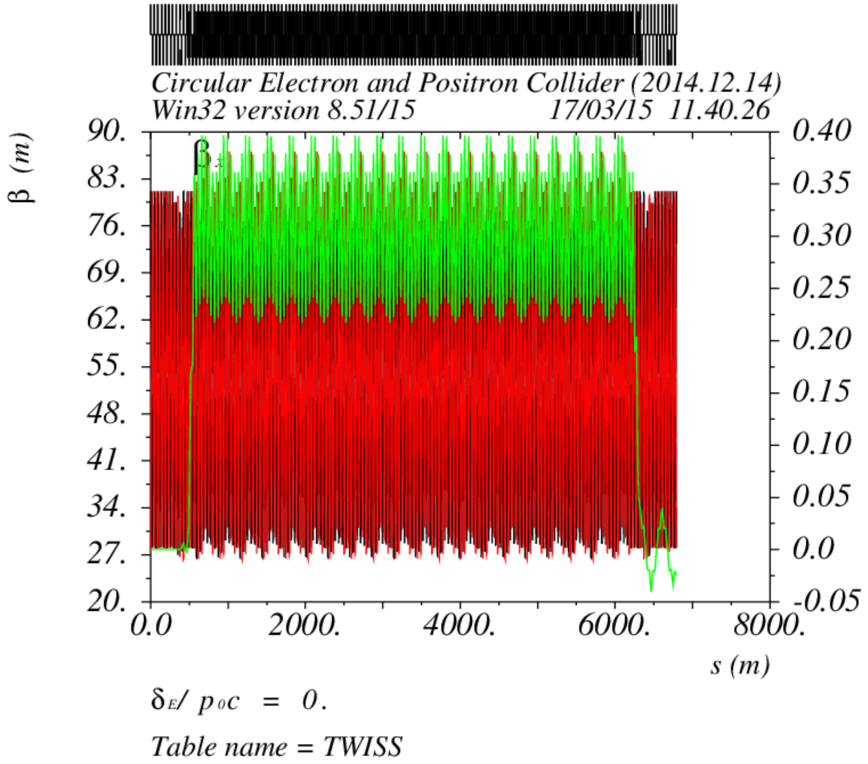
Correction of pretzel orbit effects

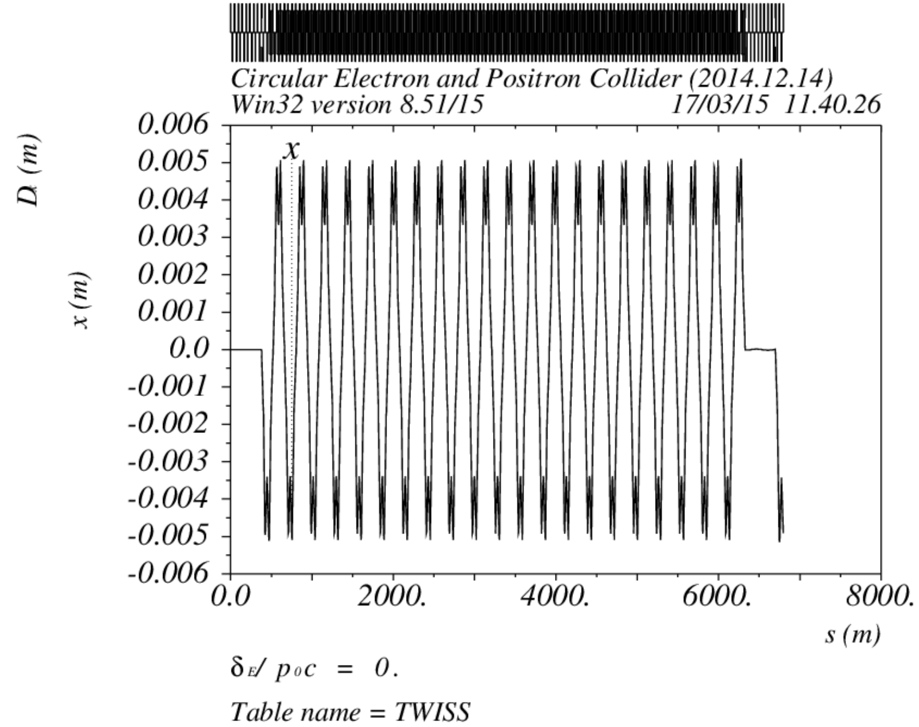
- The distortion of pretzel orbit effects on beta functions and dispersions can be corrected by making quadrupoles individually adjustable, which can be done by adding shunts on each quadrupoles
- A new periodic solution can be found by grouping 6 FODO cells together as one new period
- The maximum adjustment of quadrupole strength is ~2%



New lattice after correction

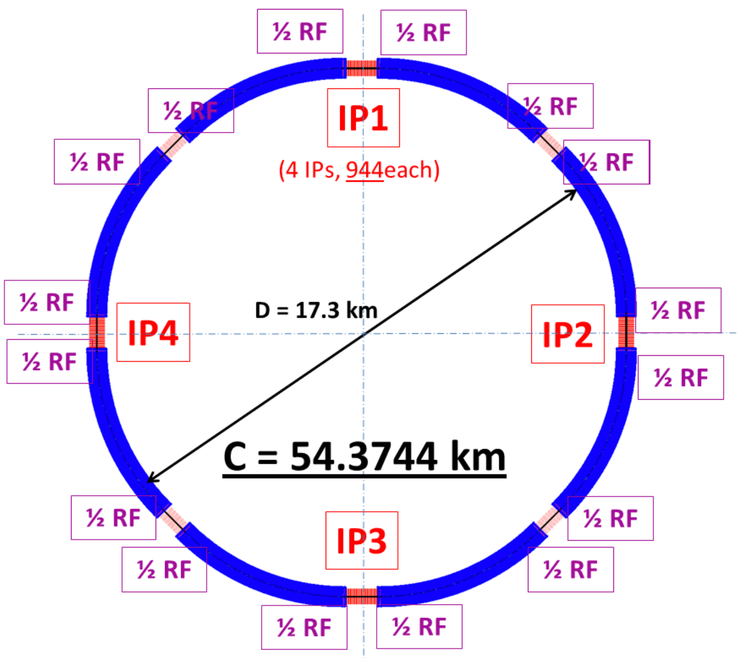
- After correction, the lattice regains periodicity
- The correction of distortion effects from pretzel orbit looks promising
- Dynamic aperture of the ring after correction still need to be studied

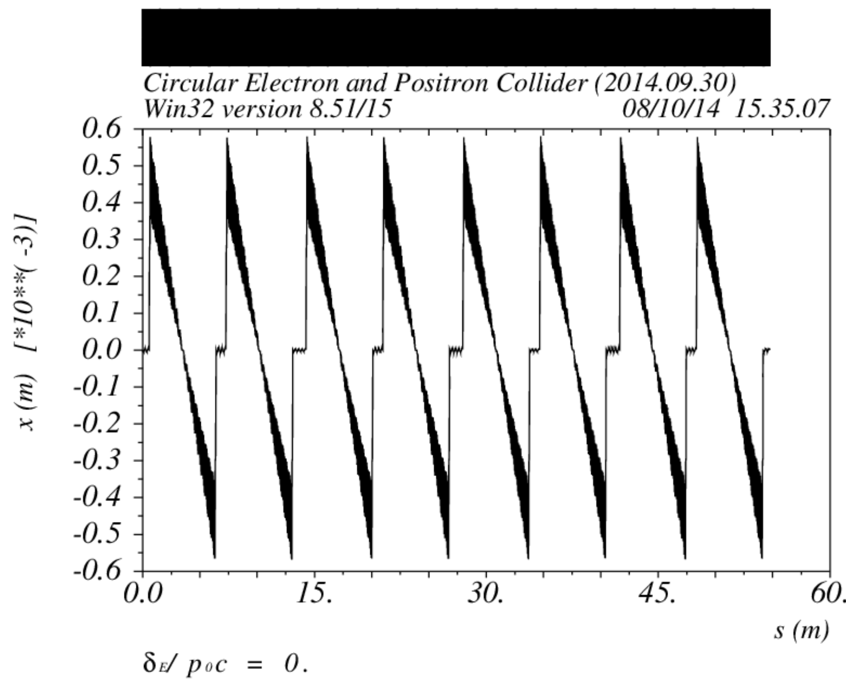




Saw tooth orbit

- Synchrotron radiation energy loss in the arc sections can only be compensated at restricted areas (at straight sections where RF cavities are located), which will result in an energy saw tooth
- The total synchrotron radiation energy loss in CEPC ring is 3.1GeV
- The beam will have 0.3% energy difference between the entrance and exit of each arc
- The maximum orbit distortion is ~0.6 mm





Work to be done

- Finish the correction of pretzel orbit distortion on lattice
- Address the tolerance on saw tooth orbit
- Optimize for a larger dynamic aperture with saw tooth and pretzel orbit
- Integrate with FFS
- Carry out error analysis and address the tolerance on different errors
- Study different lattice schemes

Acknowledgement

- We would like to thank Yunhai Cai, Richard Talman, Dave Rice, Yoshihiro Funakoshi, Dmitry Shatilov , Kazuhito Ohmi , Yuhong Zhang, and those who are not mentioned here, for their help and useful discussions !

Thank you !