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Lattice and its related beam dynamics issues in the CEPC storage ring

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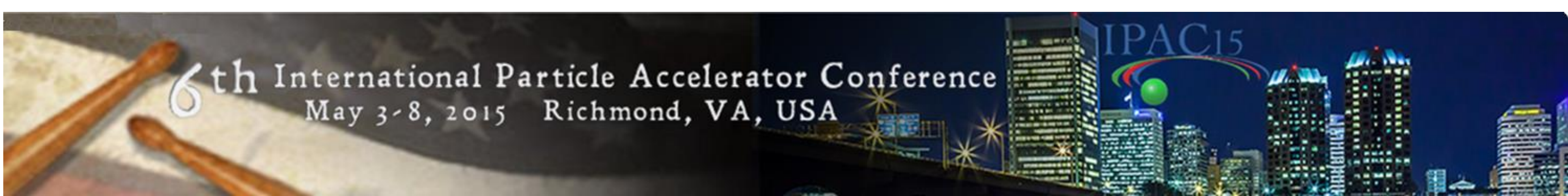
IHEP, CAS, China

6th International Particle Accelerator Conference
Richmond, VA, USA
May 3-8, 2015

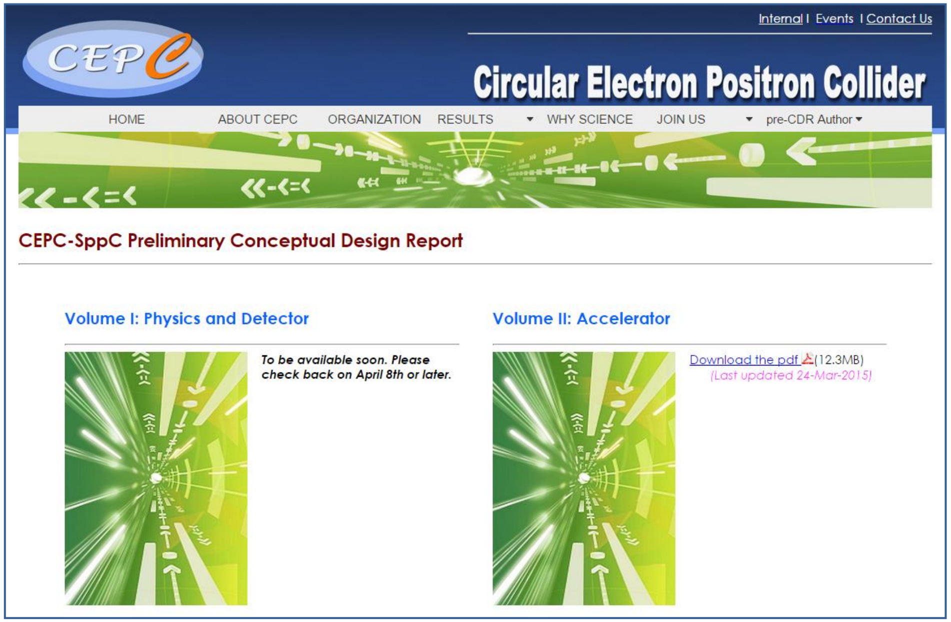


Outline

- Introduction
- Lattice design of the ring
- Pretzel scheme design
- Issues in the ring
- Plan for next steps

Introduction

- CEPC (a Circular Electron Positron Collider) has been proposed to study the Higgs boson
- For different reasons, CEPC has temporarily chosen the single ring as the baseline design
- A circumference of 50 km has also been 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



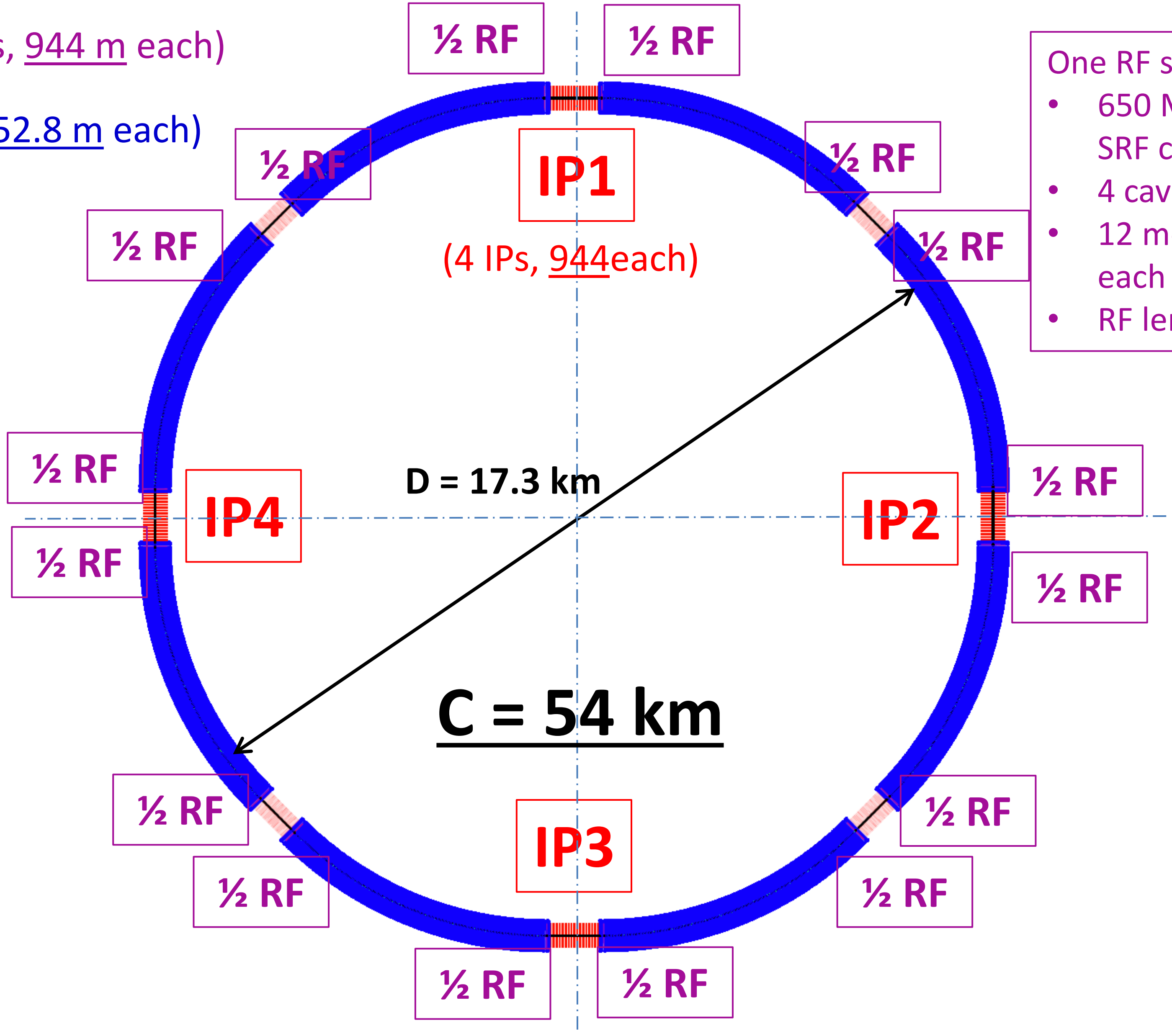
CEPC parameter list

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

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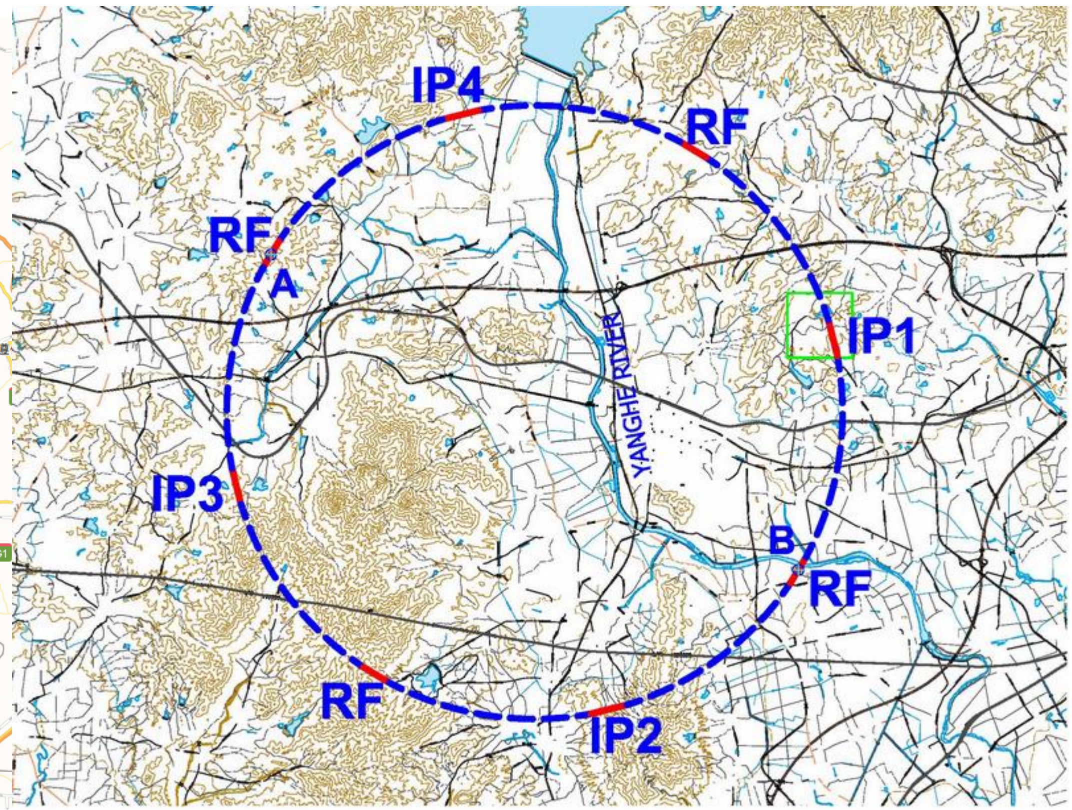
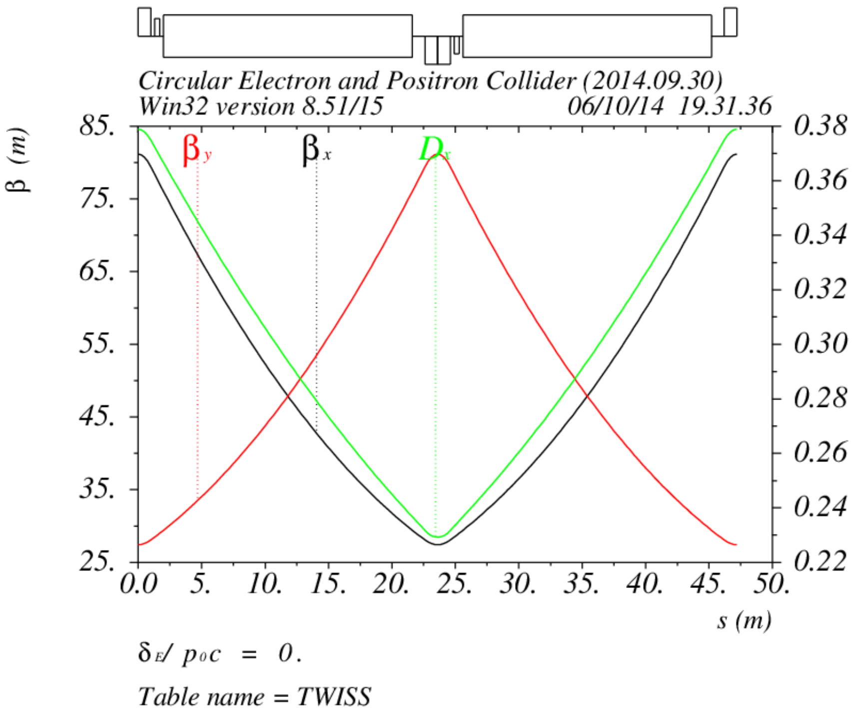
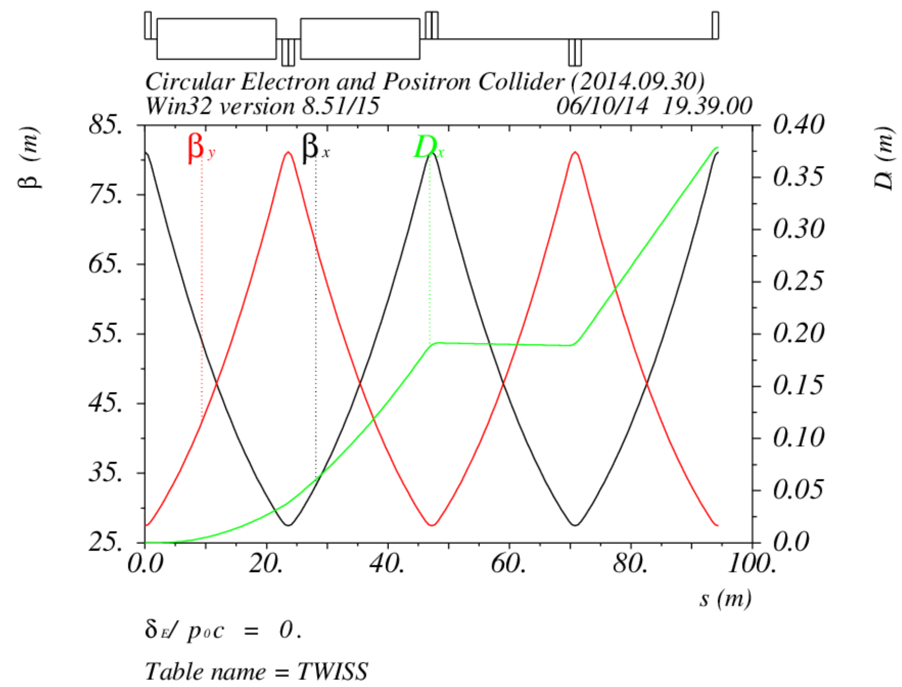


Lattice of arc sections

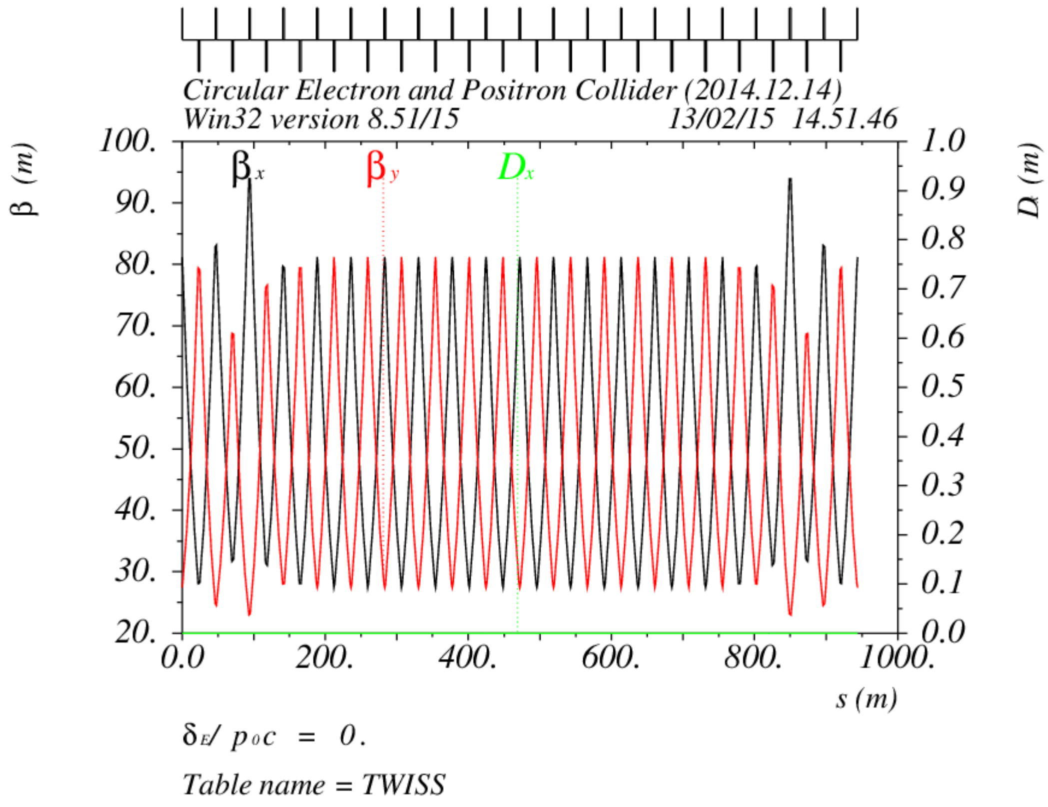
- Length of FODO cell: 47.2m
- Phase advance of FODO cells: 60/60 degrees
- Dispersion suppressor on each side of every arc
- Length: 94.4m





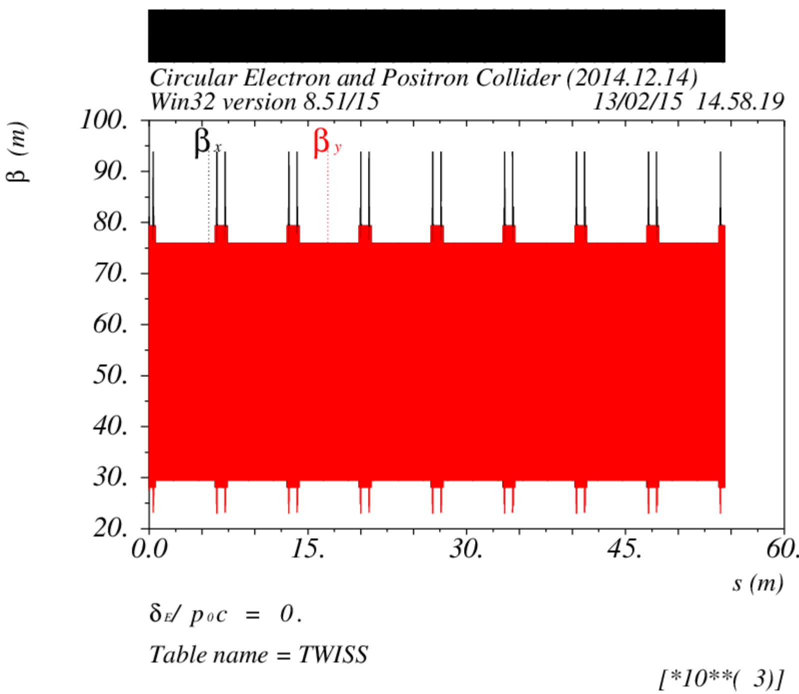
Lattice of straight sections

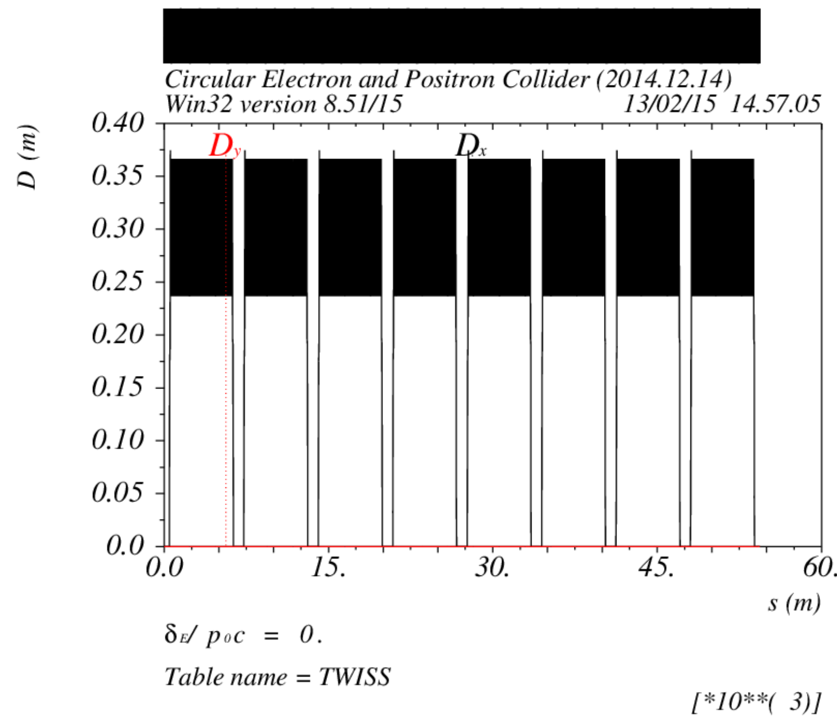
- All straights: 20 FODO cells
- Length: 944m
- Used for adjusting working point and matching
- Can be used for RF, injection and beam dump, etc.



Lattice of the main ring

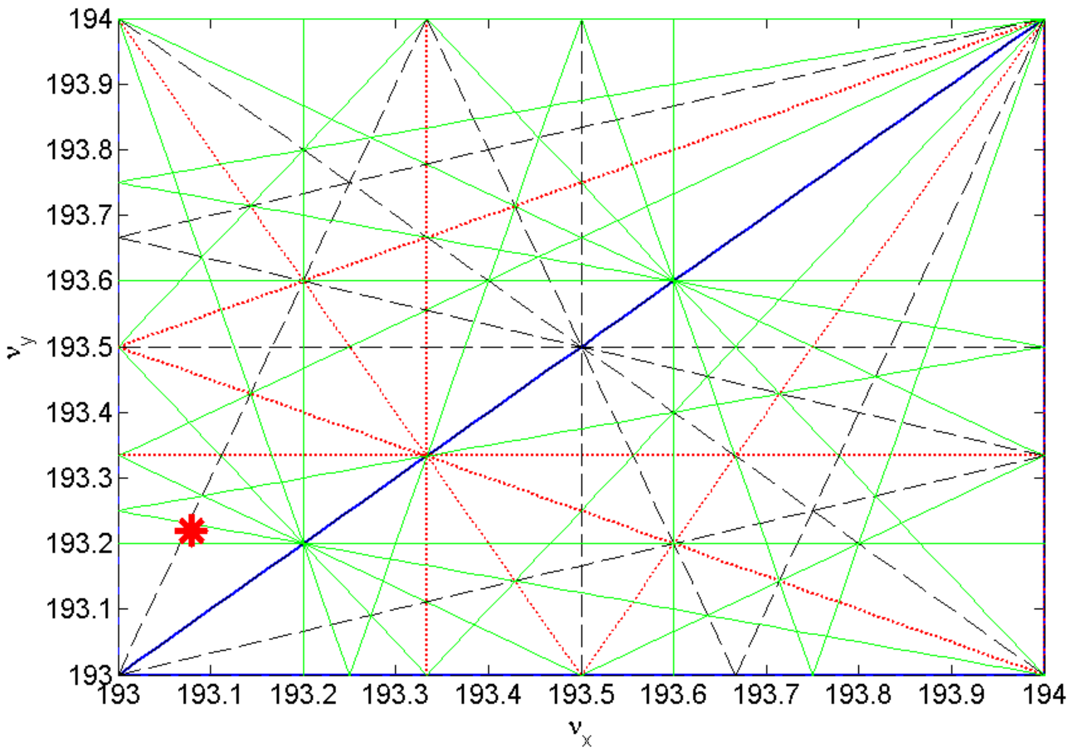
- Eight superperiod, with 2 IPs
- Total length is 54.3744km, as the cell length is 47.2m, the pretzel scheme is designed for 48 bunches/beam.





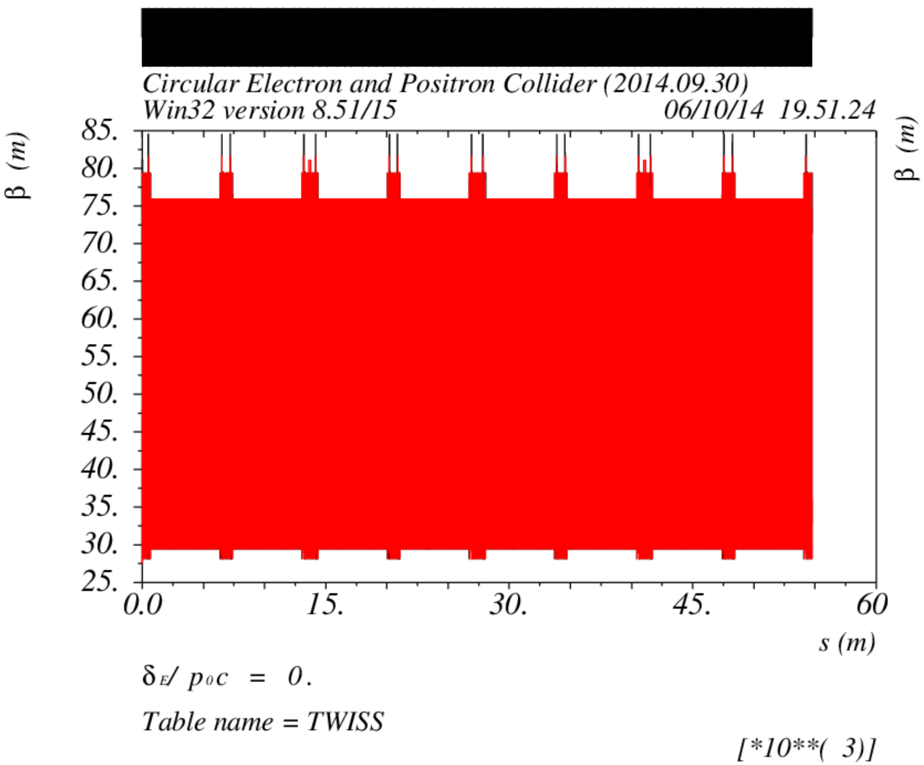
Work point

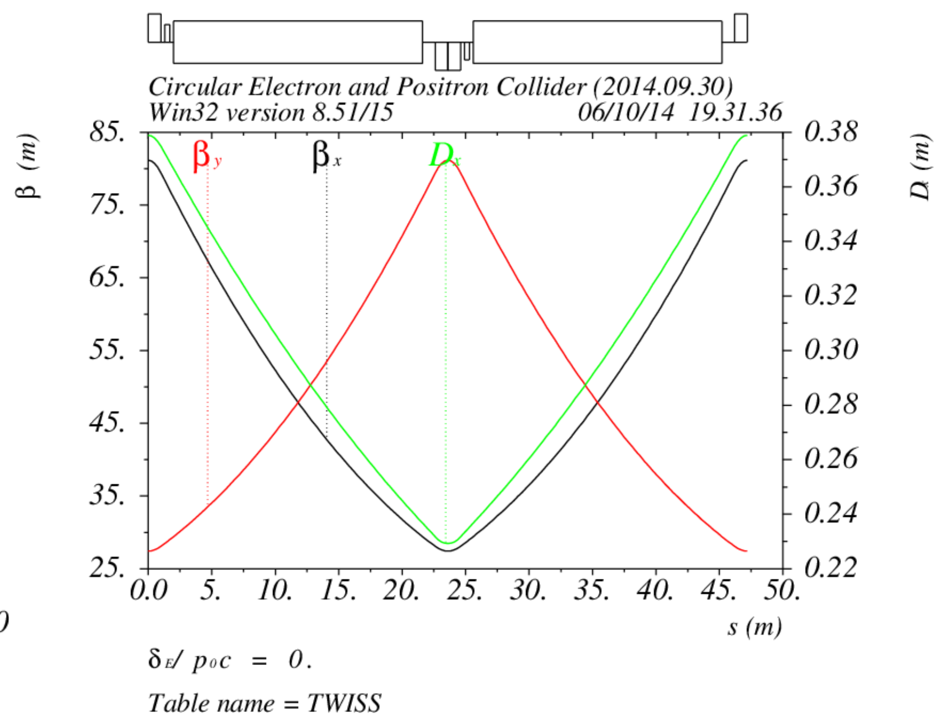
- The working point is chosen as: .08/.22 in horizontal and vertical plane for present study
- Optimization is done with beam-beam simulations, to have a high luminosity
- Will further optimize it



Chromatic correction (1)

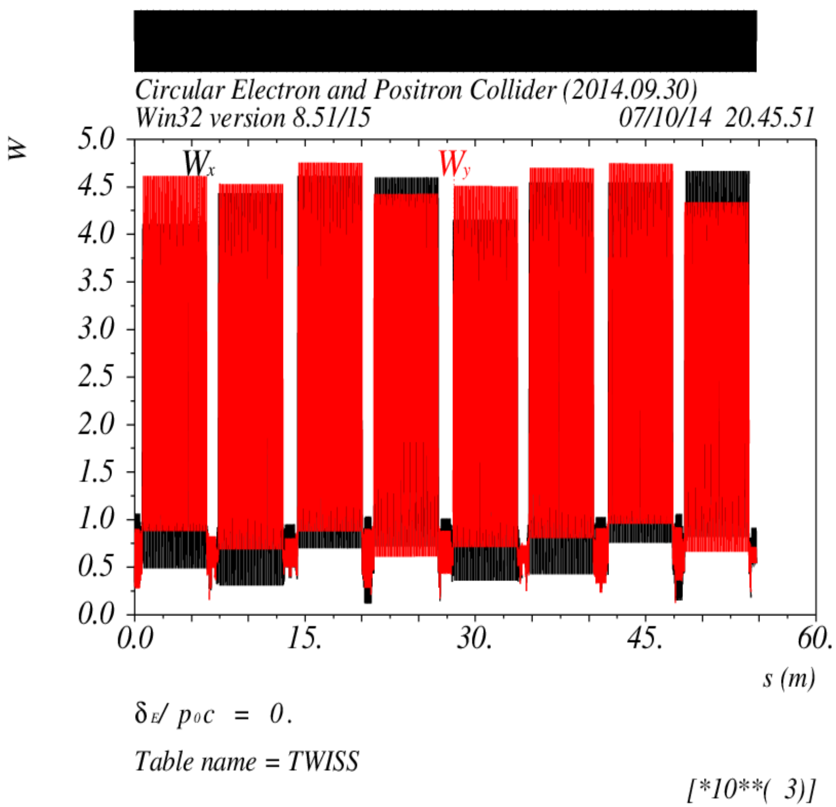
- Two families of sextupoles: one family for horizontal, one family for vertical plane
- One sextupole next to each quadrupole in the arc section (interleaved scheme)

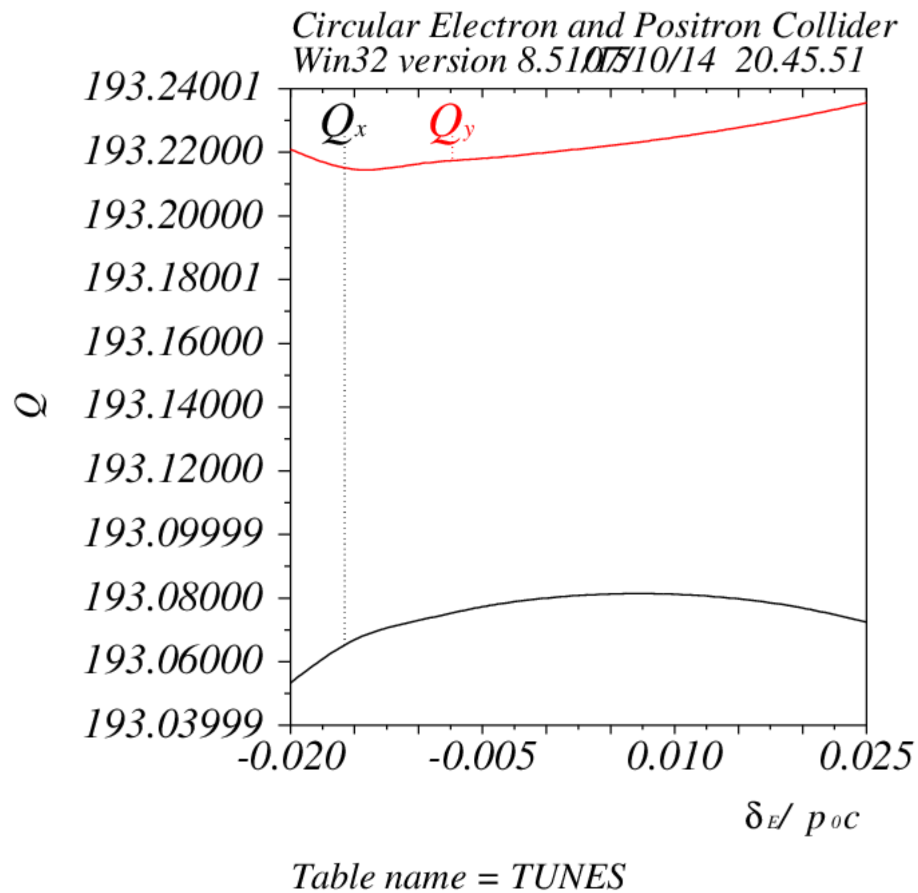




Chromatic correction (2)

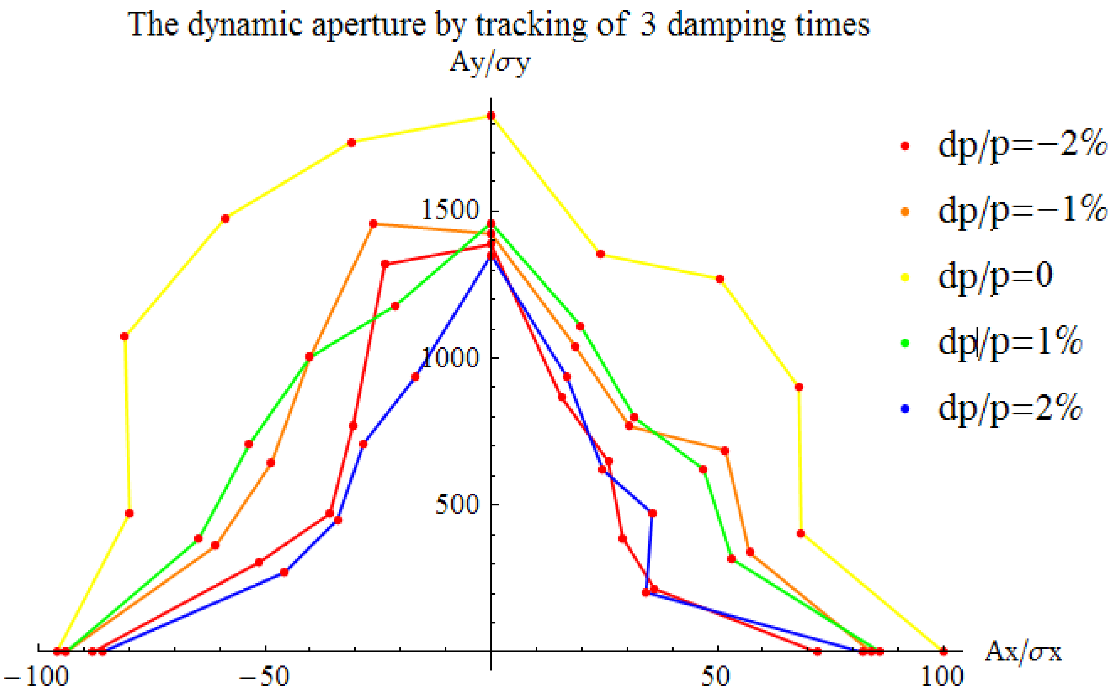
- The W function for the ring is only a few
- The chromaticity in both planes has been corrected to a positive value





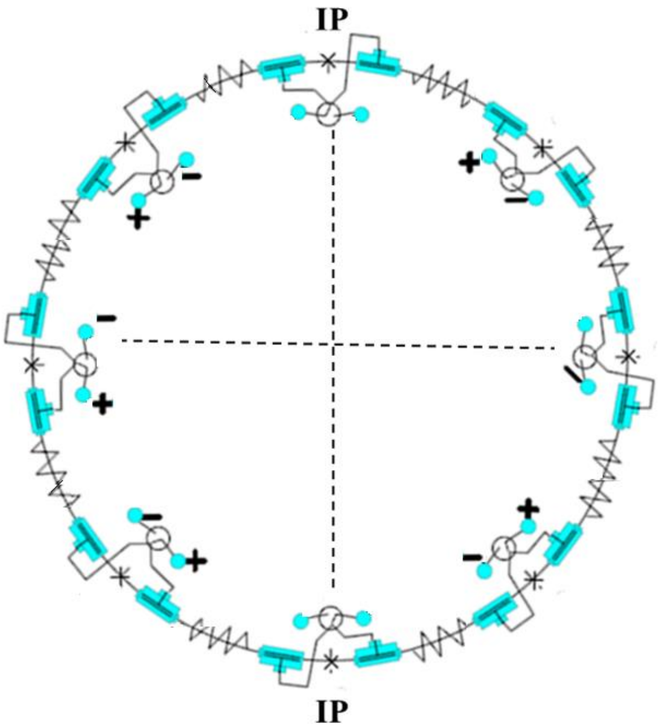
Dynamic aperture

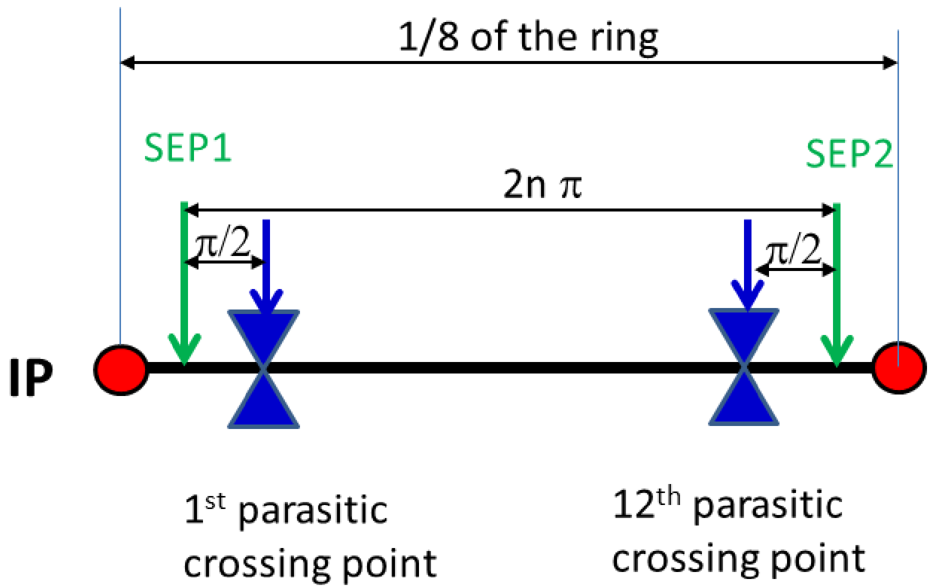
- 240 turns is tracked for dynamic aperture (3 transverse damping time)
- Coupling of 0.3% is used for calculation of vertical beam size
- The dynamic aperture is: ~ $60\sigma_x/1300\sigma_y$ or 60mm/50mm in x and y for ±2% momentum spread



Pretzel scheme (1)

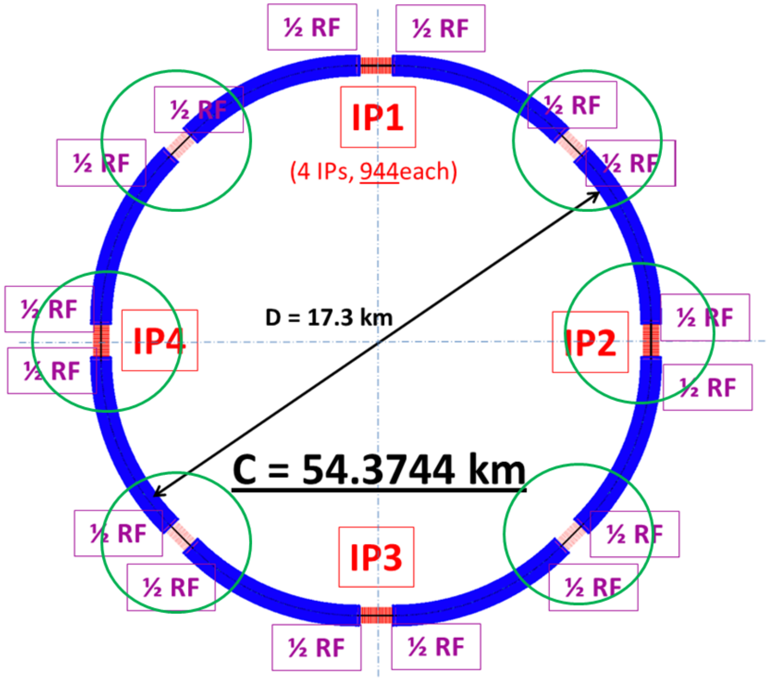
- Designed for 48 bunches/beam, every 4pi phase advance has one collision point
- Horizontal separation is adopted to avoid big coupling
- No off-center orbit in RF section to avoid beam instability and HOM in the cavity
- One pair of electrostatic separators for each arc

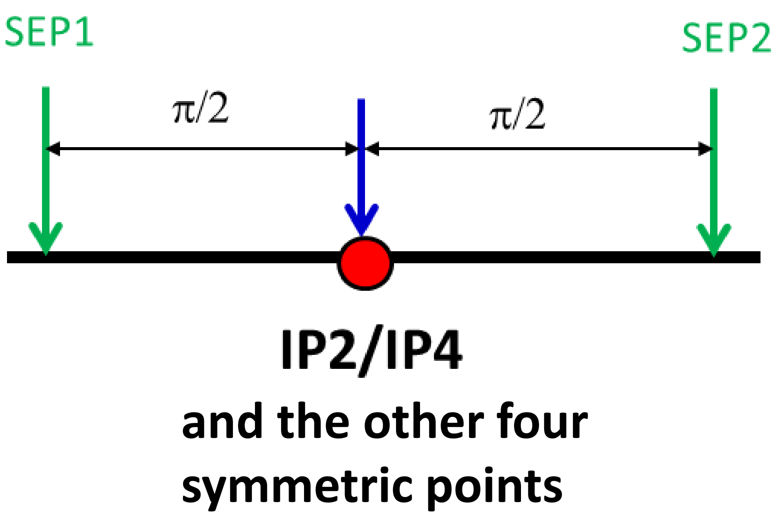




Pretzel scheme (2)

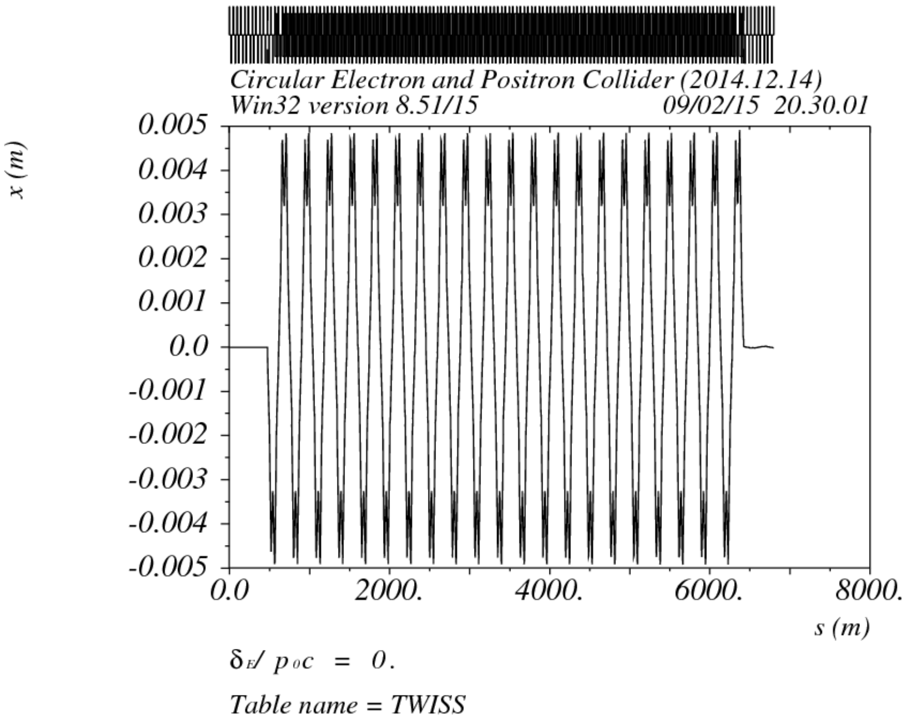
- At straight sections, IP2 /IP4 and the other four symmetric points are parasitic crossing points, but have to avoid collision
- Six more pairs of electrostatic separators for these crossing points



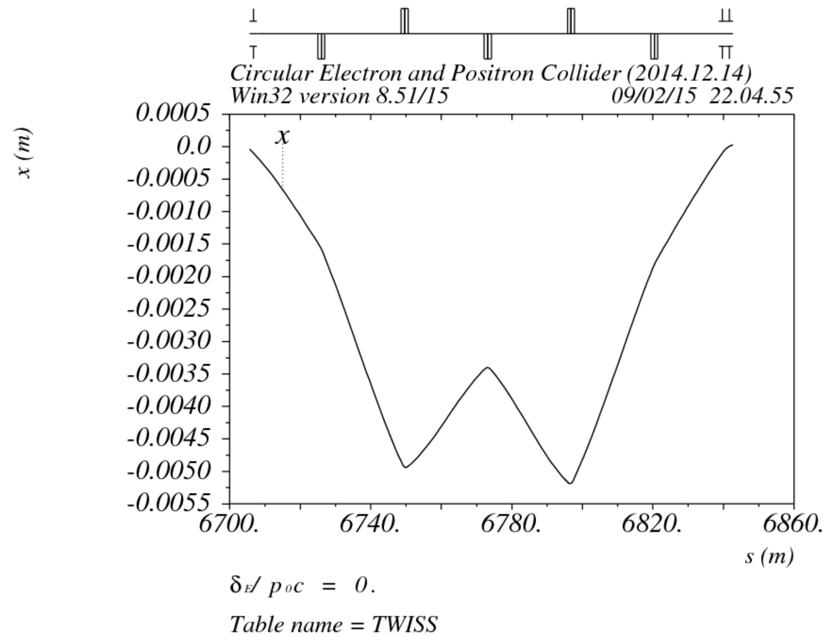


Pretzel scheme (3)

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



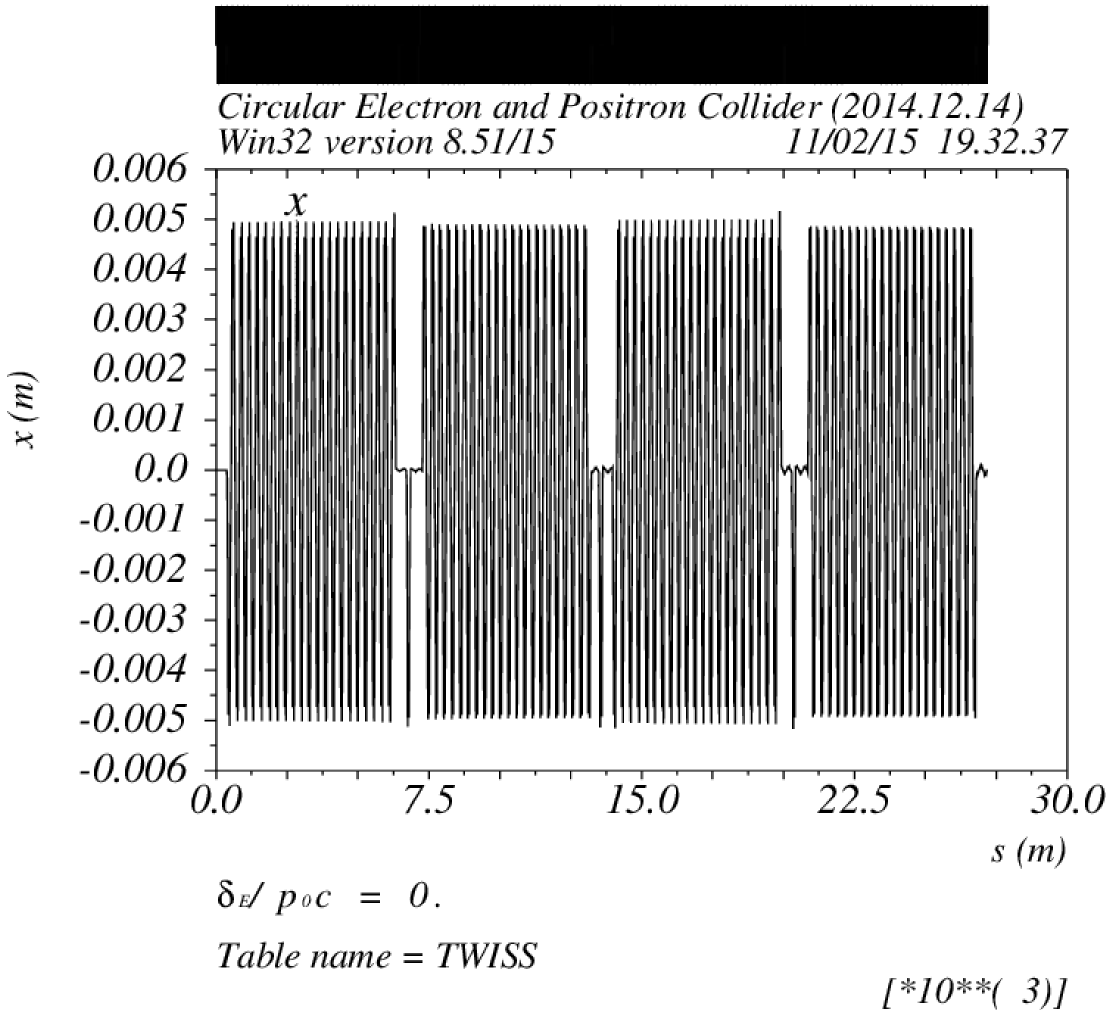
Orbit for the first 1/8 ring



Orbit for IP2/IP4 and the other four symmetric points

Pretzel scheme (4)

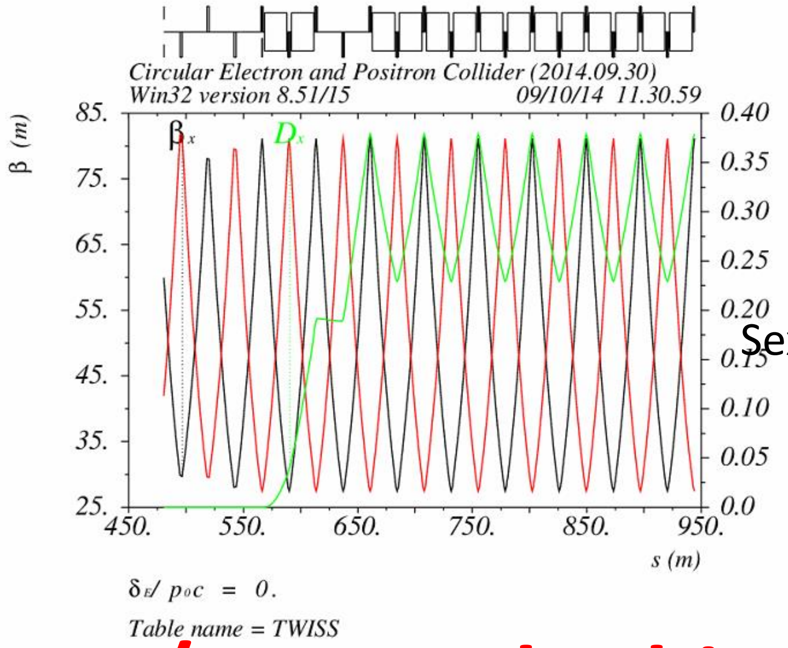
- Orbit of half CEPC ring



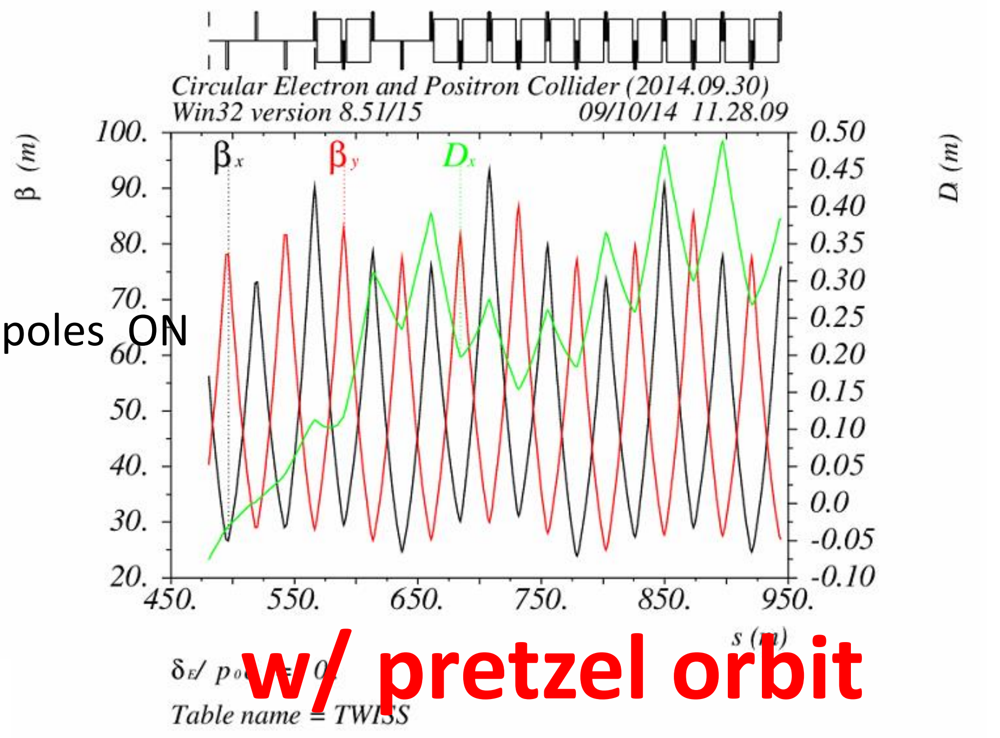
At least 14 pairs of electrostatic separators will be needed for the ring.

Issues with pretzel orbit (1)

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



Sextupoles ON



w/o pretzel orbit

w/ pretzel orbit

Issues with 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

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

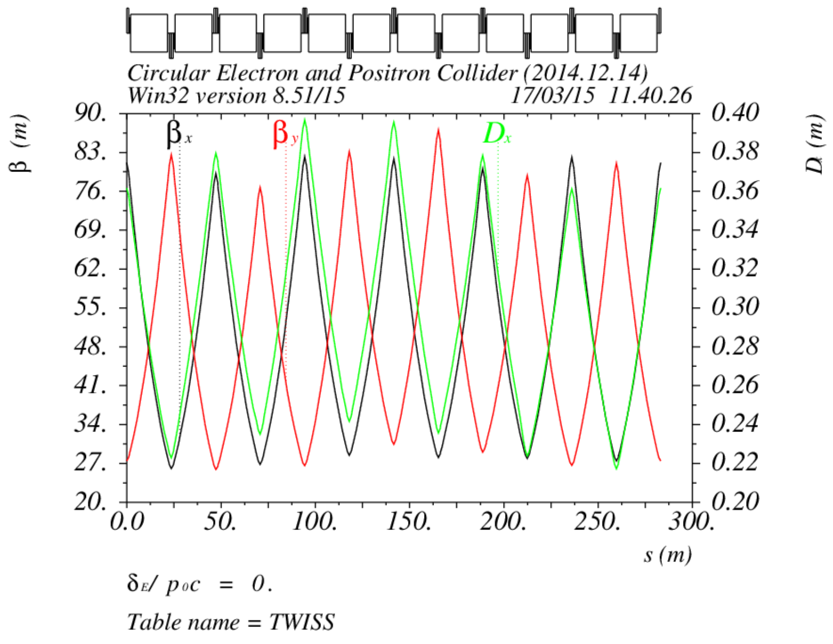
$$\Delta K_1 = K_2 \cdot \Delta x = 0.0019$$ ➡ **Quadrupole field of the ring *K_1*=0.022.**

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

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

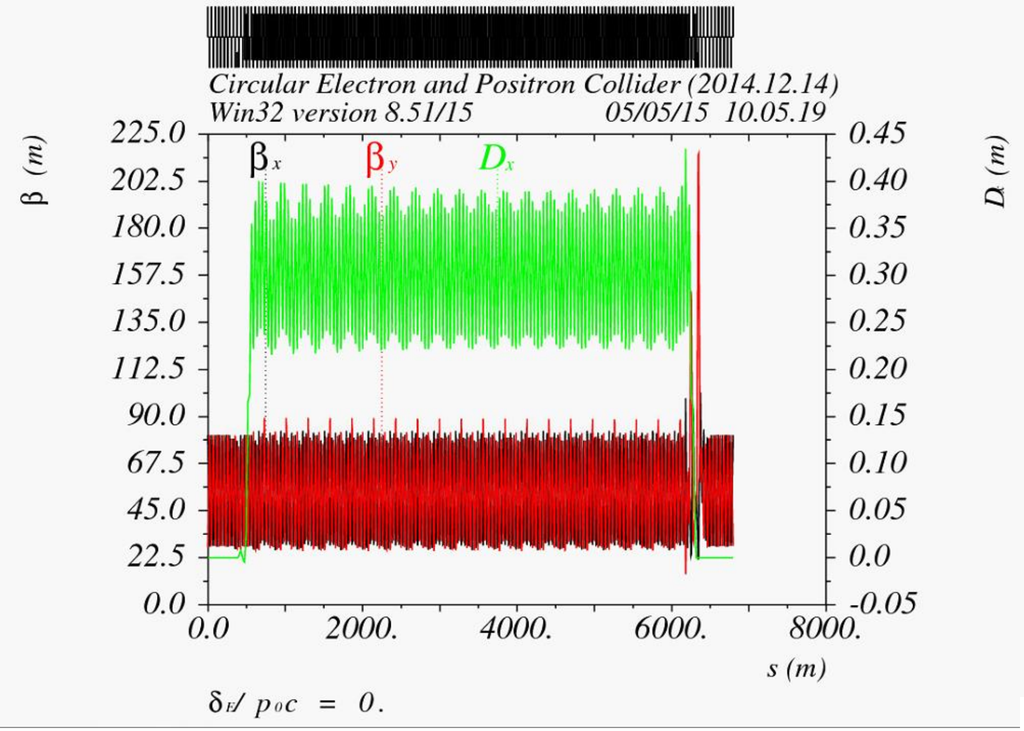
Correction of pretzel orbit effects

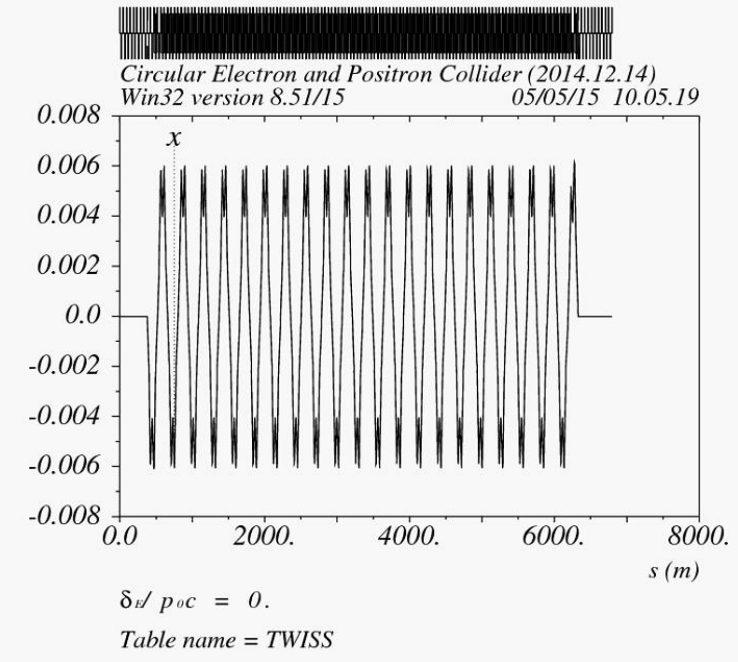
- The distortion of pretzel orbit effects on beta functions and dispersions can be corrected by making quadrupoles individually adjustable, which can be done by adding shunts on each quadrupoles
- A new periodic solution can be found by grouping 6 FODO cells together as one new period
- The maximum adjustment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



New lattice after correction

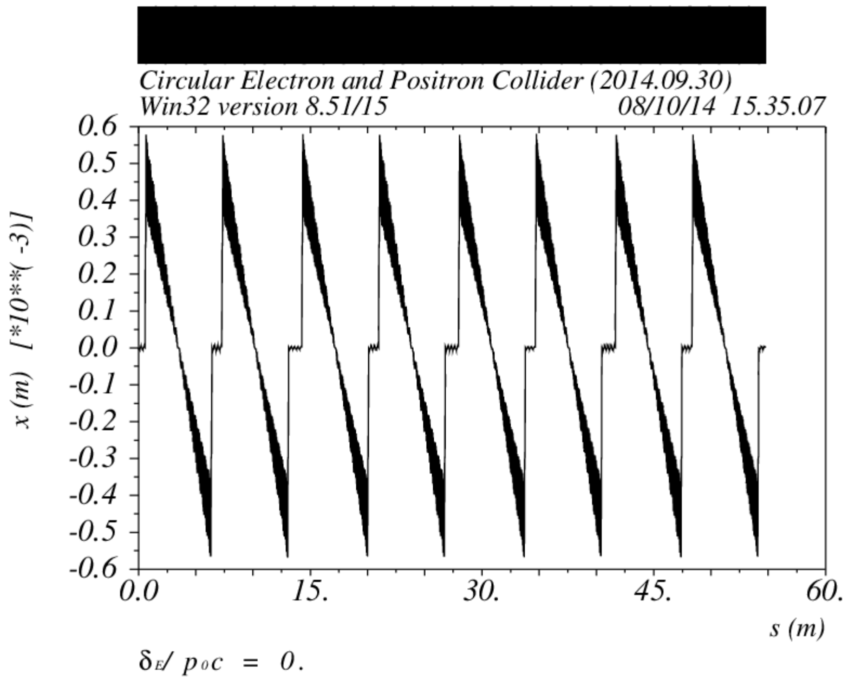
- After correction, the lattice regains periodicity
- The distortion effects from pretzel orbit could be corrected
- Dynamic aperture of the ring after correction still need to be studied

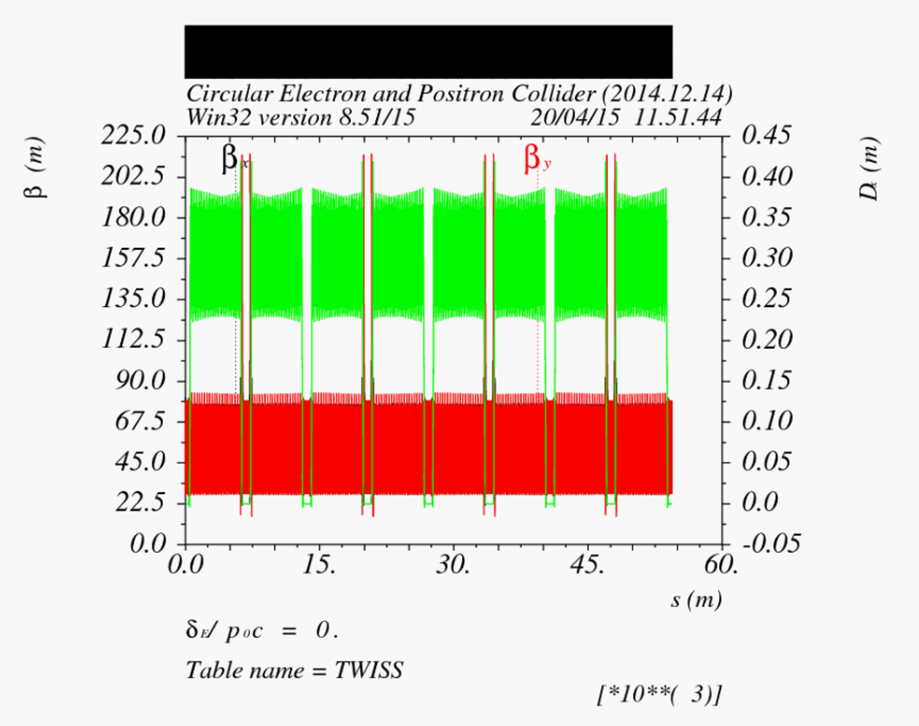




Other issues

- The maximum saw tooth orbit distortion is ~0.6 mm, which results from the 3.1 GeV synchrotron radiation loss per turn
- The lattice for e+ and e- are not symmetric for now, symmetry has to be guaranteed with pretzel and saw tooth orbit





Our plan (personal view)

- There are many different options for the lattice that we could in principle try out, e.g. FODO cells with different phase advances, different cell length, double ring scheme, etc….
- But, what we want to/should do is: Focusing on one option (for now it is one ring scheme with 60/60 degree FODO cells and 47.2m cell length), investigate it deeply, and try to make it work
- Then, we can study and compare with other options

- And this is what we are doing now.

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 !