Pretzel scheme of CEPC

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Outline

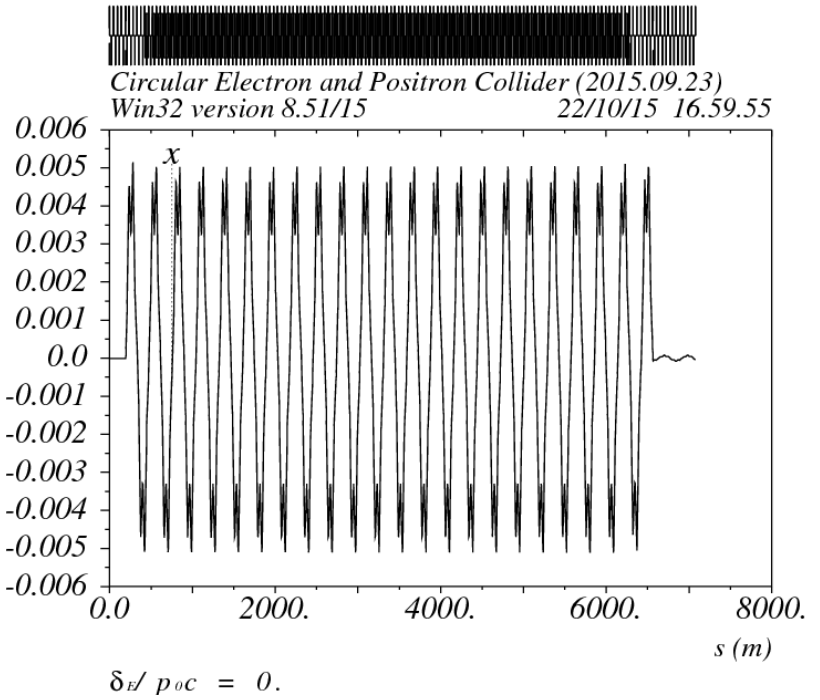
- Principles of pretzel scheme
- Modification of the ring lattice
- Pretzel scheme design
- Issues remained
- Summary

Principles of pretzel scheme

- In single ring collider, pretzel orbit is used to avoid the beam collision at positions except for the IPs
- For ideal pretzel orbit, the following relationship should be fullfilled:

$$\phi_{pc} = N * 2\pi$$

i.e. the phase advance between parasitic crossing point should be a integer number of 2*Pi, this relation guarantees that if the beam is properly separated at the first parasitic collision point, then it can be automatically properly separated at other parasitic collision points.



Principles of pretzel scheme (cont.)

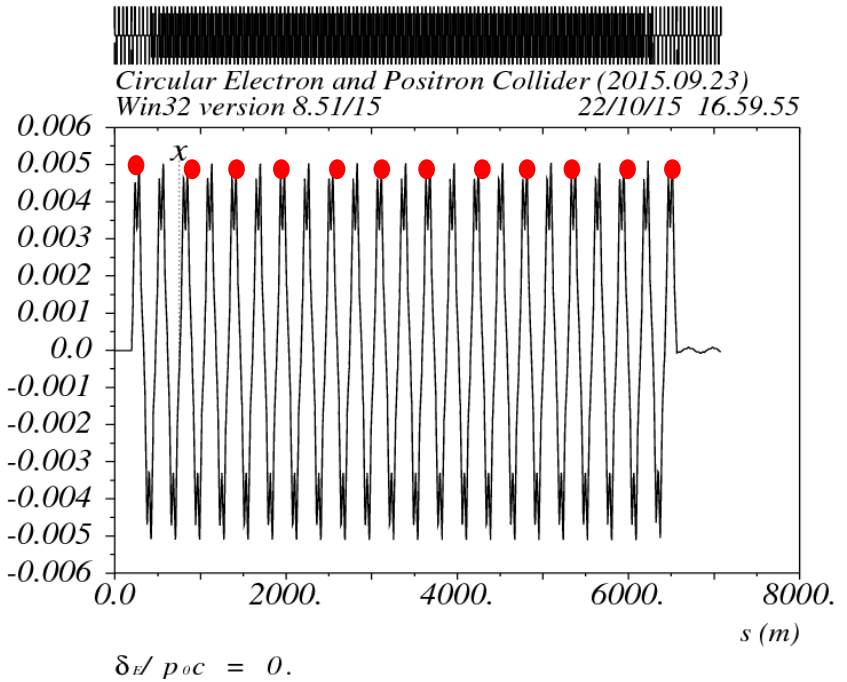
- For our lattice, it is comprised of 60/60 degree FODO cells, every 6 cells have a phase advance of 2Pi, so the relationship can be written as:

$$L_{pc} = N * 6 * 47.2 = N * 283.2\text{m}$$

- For 50 bunches, there are 100 collision points in total, thus the ring circumference must be

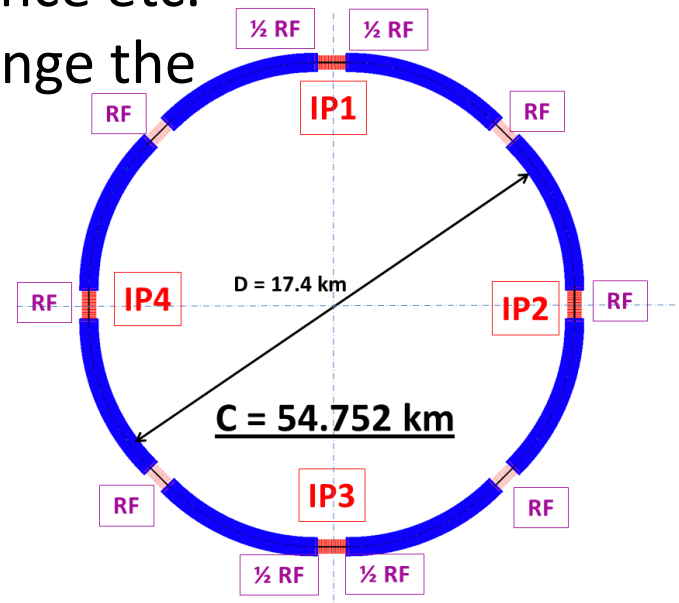
$$C = 100 * L_{pc} = 28320 * N$$

- For a ring with circumference of ~50km, N=2, which means there is one collision point every 4Pi phase advance. The exact length of the ring is 56640m.



Modifications to ring lattice

- To make pretzel scheme works for 50 bunches, a few modifications need to be made to the ring lattice
- Two options(assuming phase advance per cell keeps constant):
  - Change the cell length, which will result in the change of emittance, circumference etc.
  - Change number of cells, e.g. change the circumference
- In the following, we take the easy way, i.e. we change the circumference to make the ring lattice works for pretzel orbit of 50 bunches.

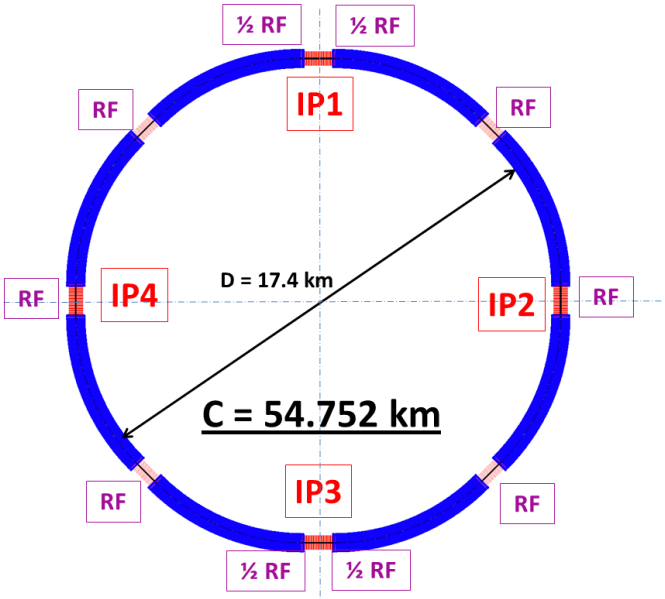


Changes made

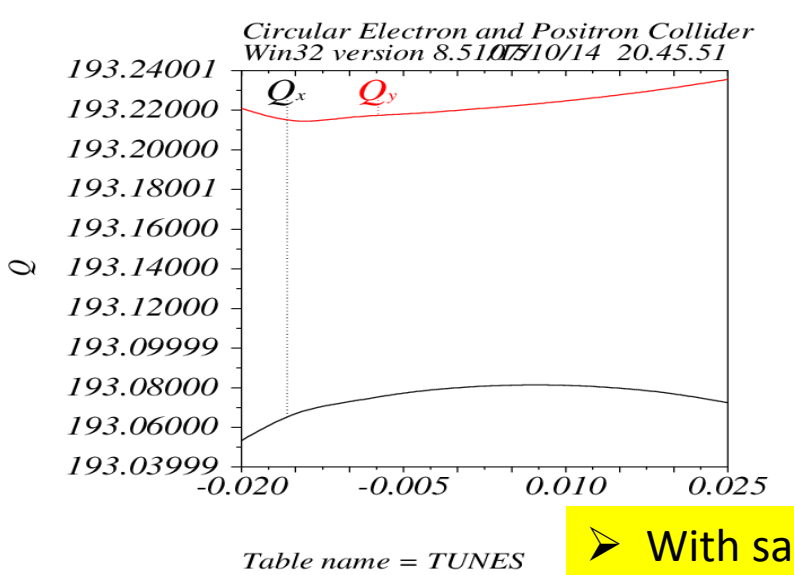
- ARC length:5852.8m
- Short straight: 18 FODO cells, 849.6m
- Long straight: 34 (was 20) FODO cells, 1604.8m (was 1132.8m)
- Circumference: 56.640km

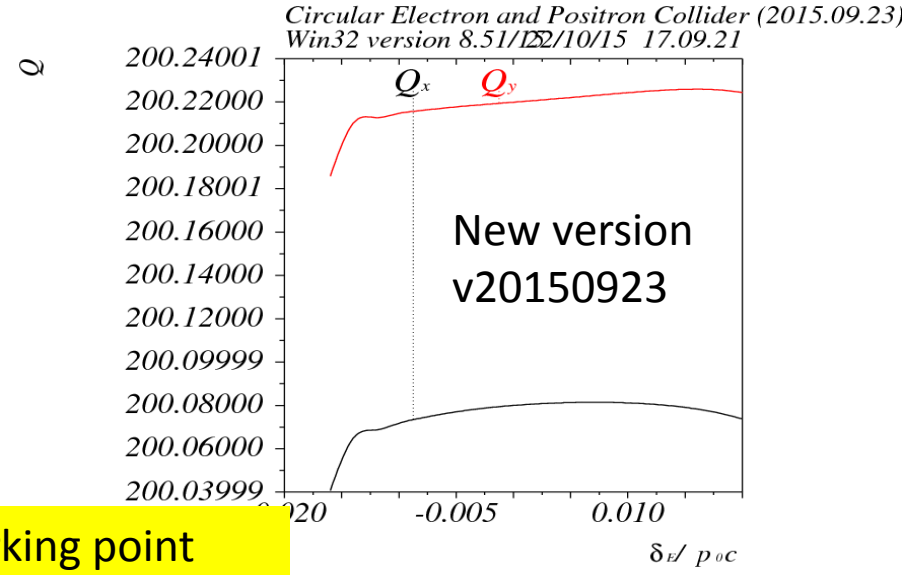
$$L_{pc} = 56640/100 = 566.4 = 2*283.2$$

After making this change, every nearest parasitic collision points will have a phase advance of 4Pi.

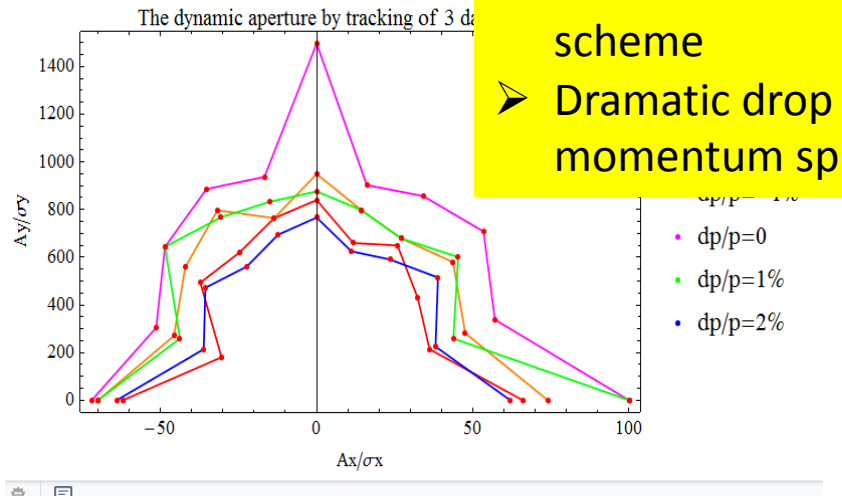


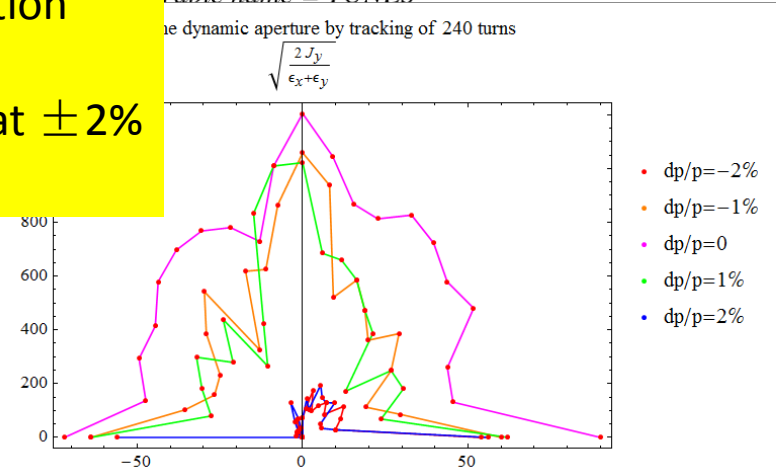
Comparison of DA results before adding pretzel





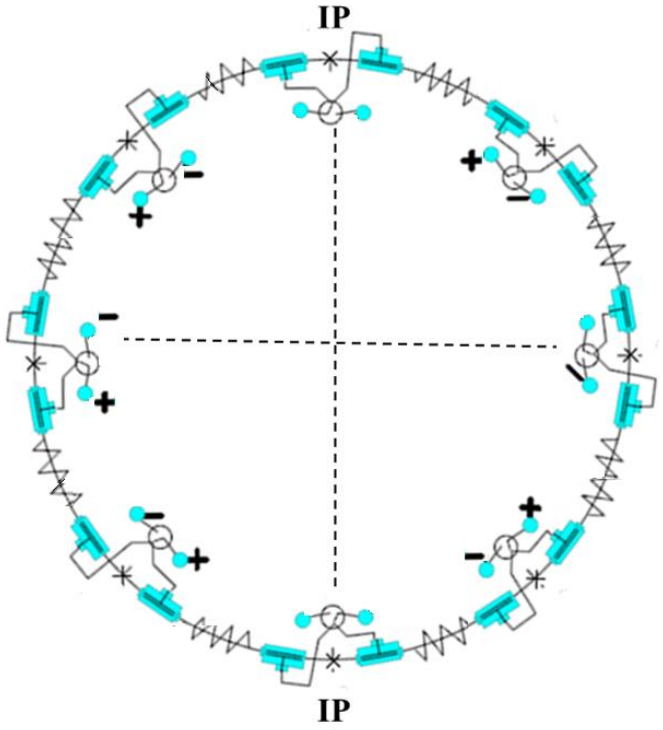
- With same working point and chromatic correction scheme
- Dramatic drop of DA at ±2% momentum spread

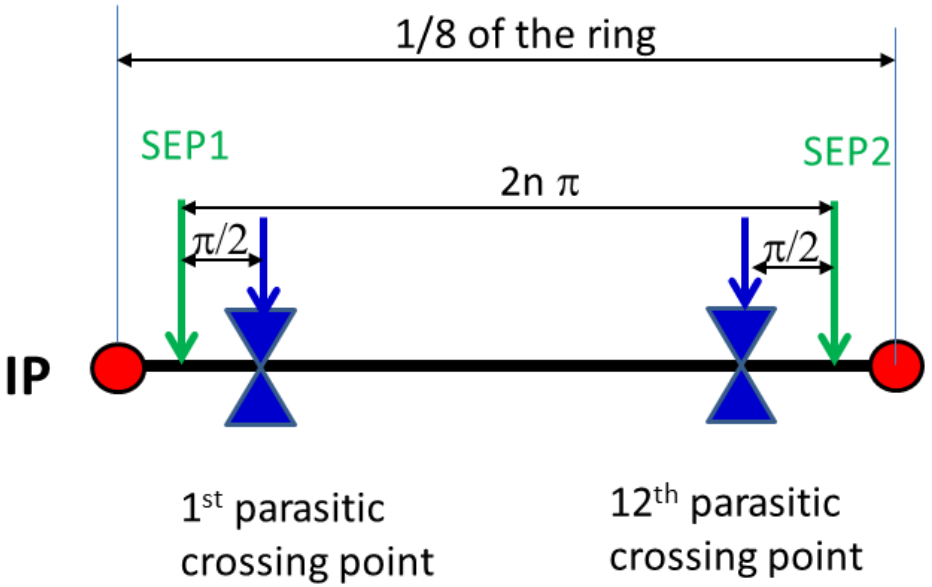




Pretzel orbit design

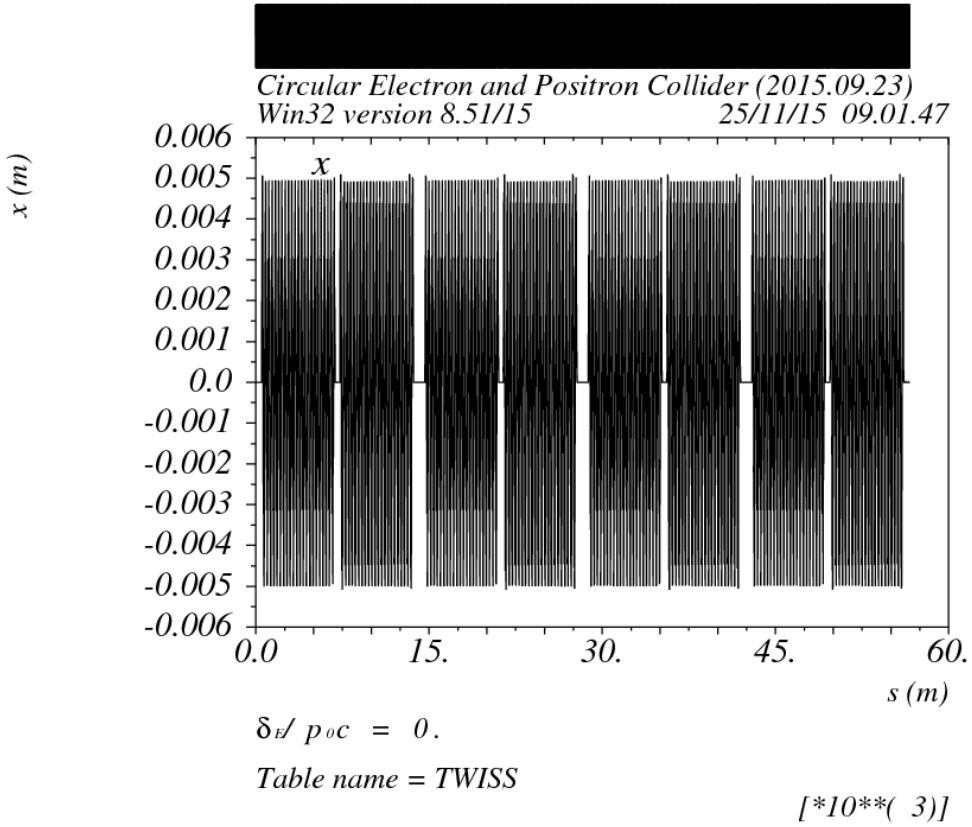
- Designed for 50 bunches/beam, every 4pi phase advance has one collision point
- Horizontal separation is adopted to avoid big coupling
- No off-center orbit in RF section to avoid beam instability and HOM in the cavity
- One pair of electrostatic separators for each arc





Pretzel orbit design (cont.)

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



Issues with pretzel orbit

- 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

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

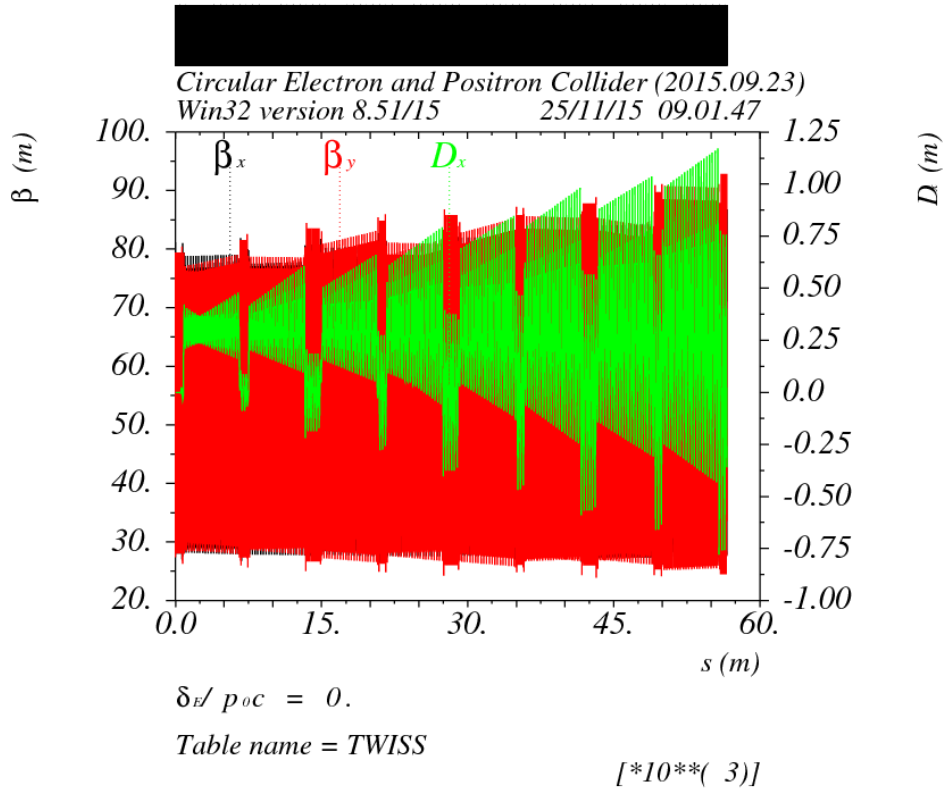
$$\Delta K_1 = K_2 \cdot \Delta x = 0.0019$$ ➡ **Quadrupole field of the ring K_1=0.022.**

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

This causes the beta function, especially the dispersion function to oscillate as can be seen in the following slide.

Issues with pretzel orbit

- Beta function and dispersion function will oscillate due to pretzel orbit, in which the off-center particles see extra fields in magnets

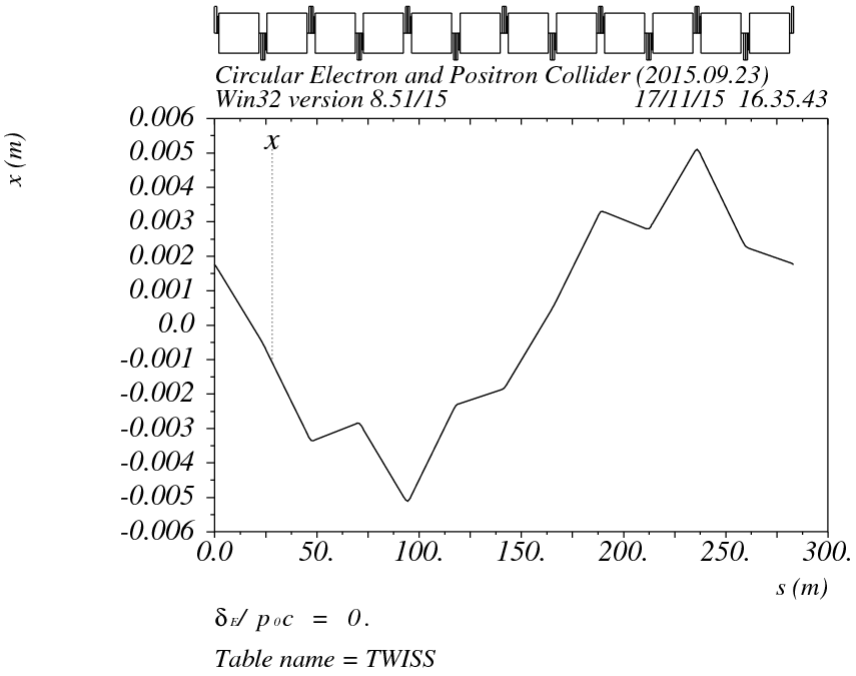


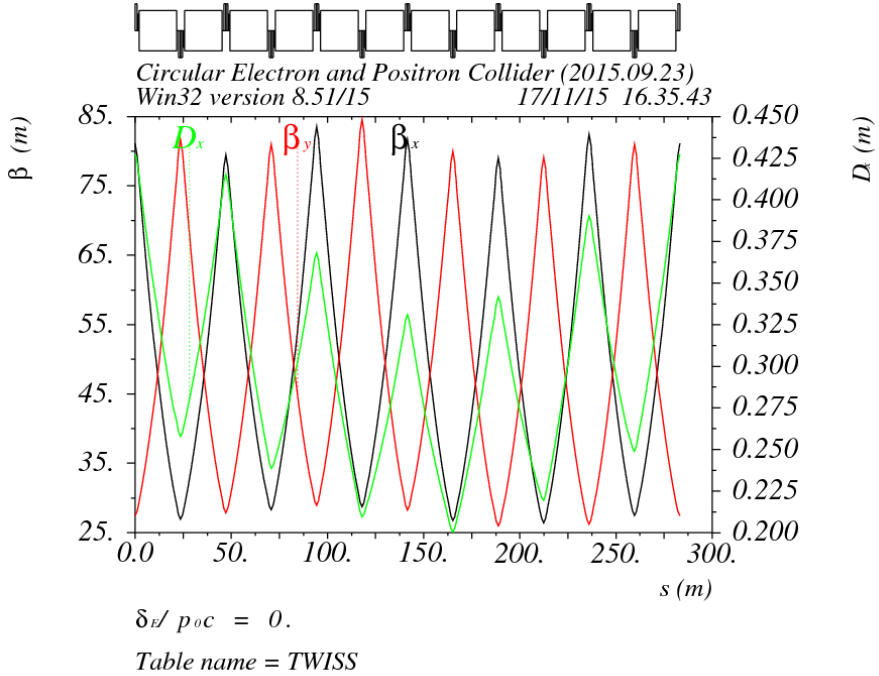
Correction of pretzel orbit effects

- 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

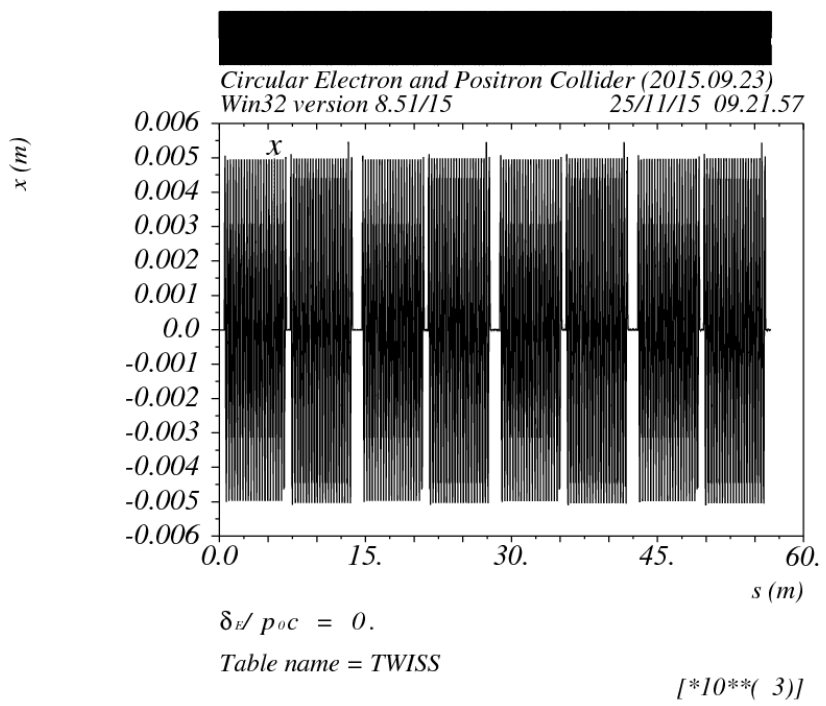
- A new periodic solution can be found by grouping 6 FODO cells together as one new period

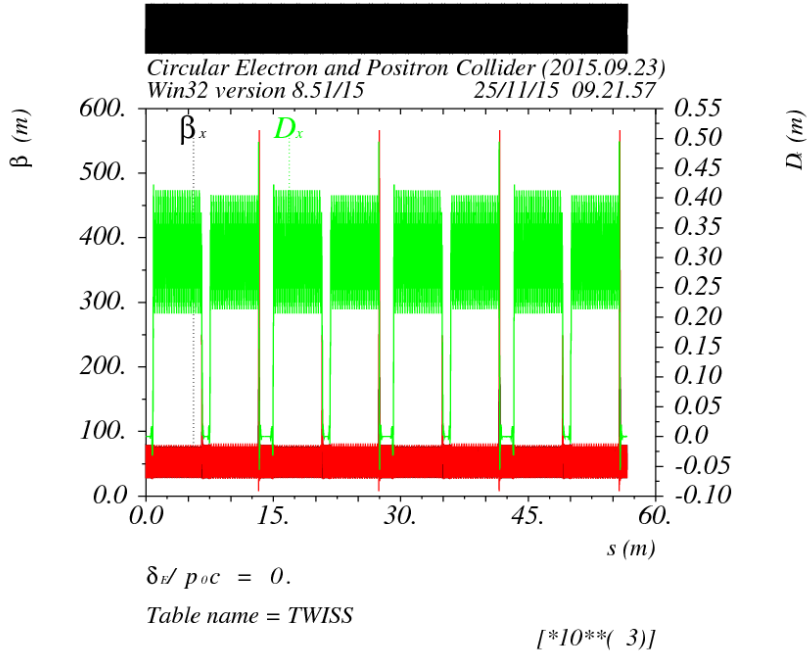




New lattice after correction

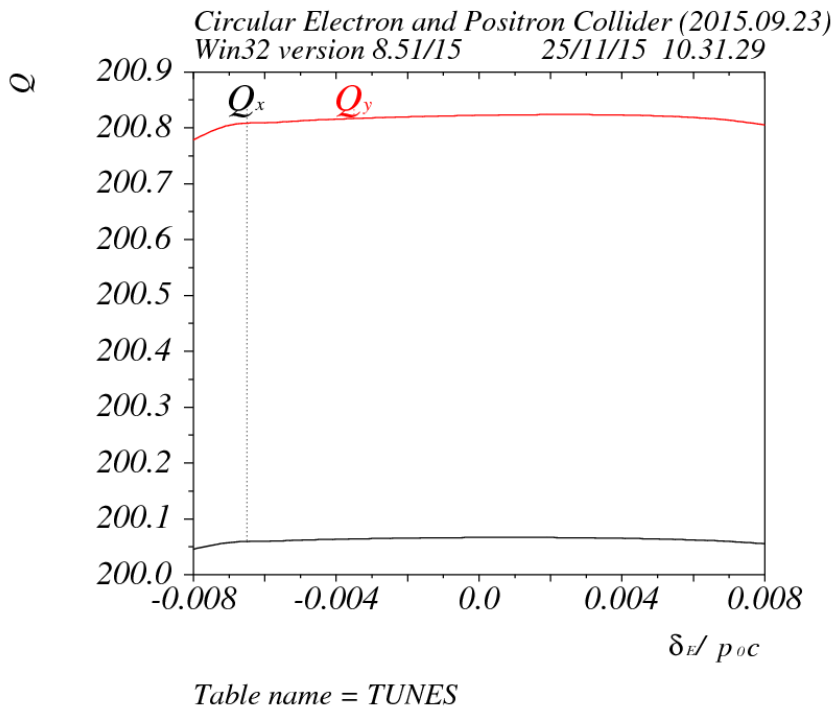
- After correction, the lattice regains periodicity
- The distortion effects from pretzel orbit is corrected

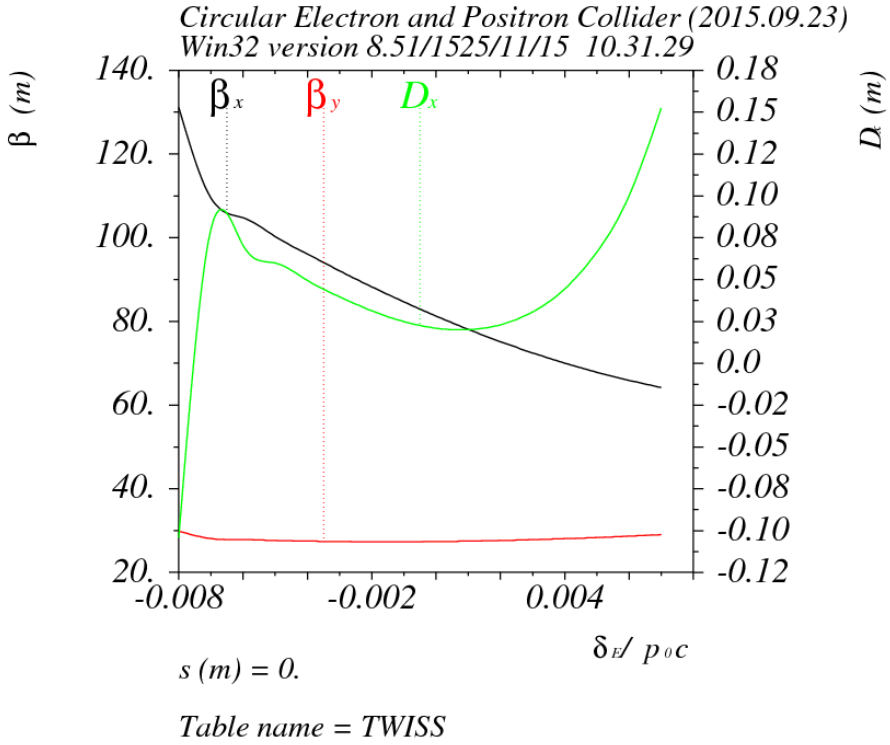




Chromatic properties

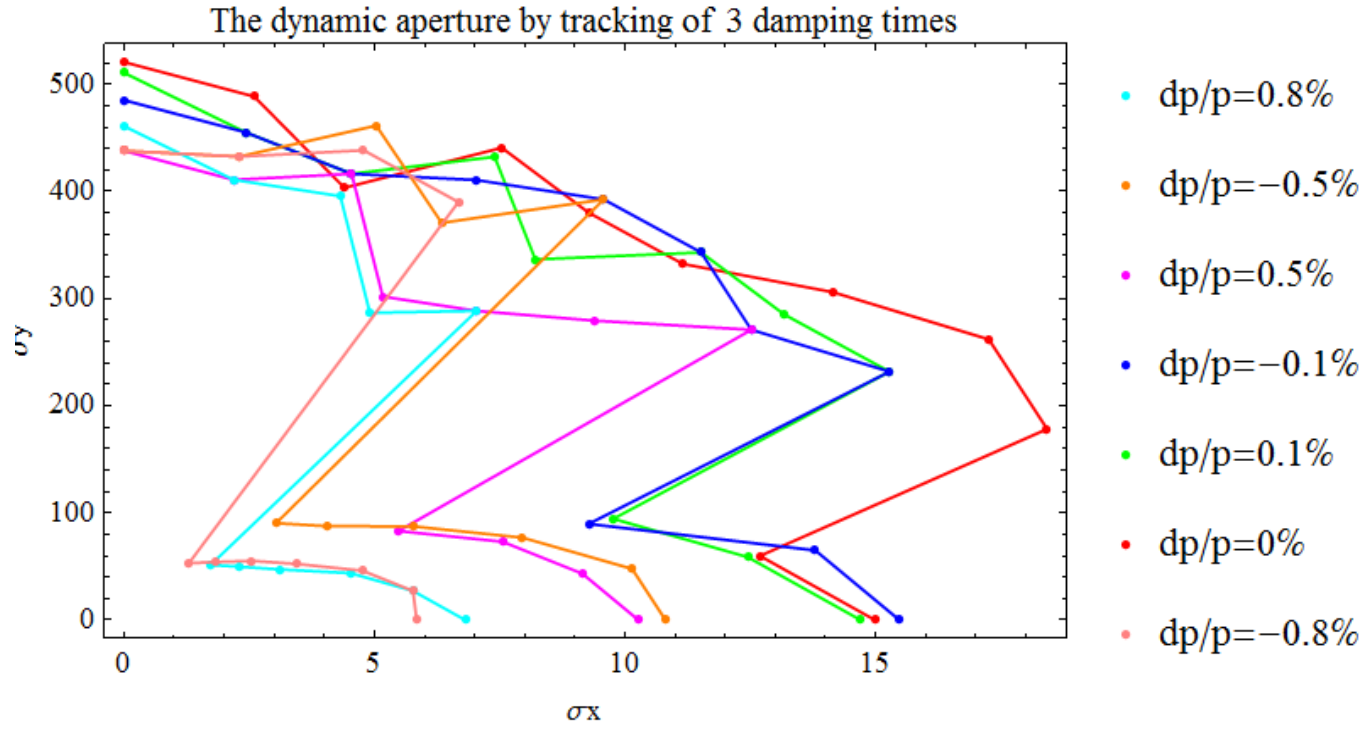
- Tune is quite stable within ± 0.8% momentum spread
- Beta function and dispersion function changes a lot within ± 0.8% momentum spread





DA with pretzel

- DA tracking is done with MAD8
- 240 turns (or 3 times transverse damping time) is tracked
- The DA is (6 σx*420σy) at ± 0.8% momentum spread



Issues remained&Plan for next steps

- DA results with MAD8 need to be checked with other codes, e.g. SAD, MADX etc..
- Current pretzel correction scheme breaks the symmetry of lattice, which results in different optics seen by electron and positron beam, and should be corrected
- The FFS should be combined with pretzel orbit
- DA optimization should be done with pretzel orbit
- ……

Summary

- A ring lattice is developed for accommodating 50 bunches with pretzel orbit
- A primary design of pretzel orbit is done
- The primary DA tracking result shows a is (6 σx*420 σy) at $\pm$ 0.8% momentum spread
- The DA result need to be checked with other codes and DA optimization should be carried out
- More work is ahead ……

Thank you !