4 IP progress

K. Oide

Many thanks to D. Shatilov and K. Ohmi

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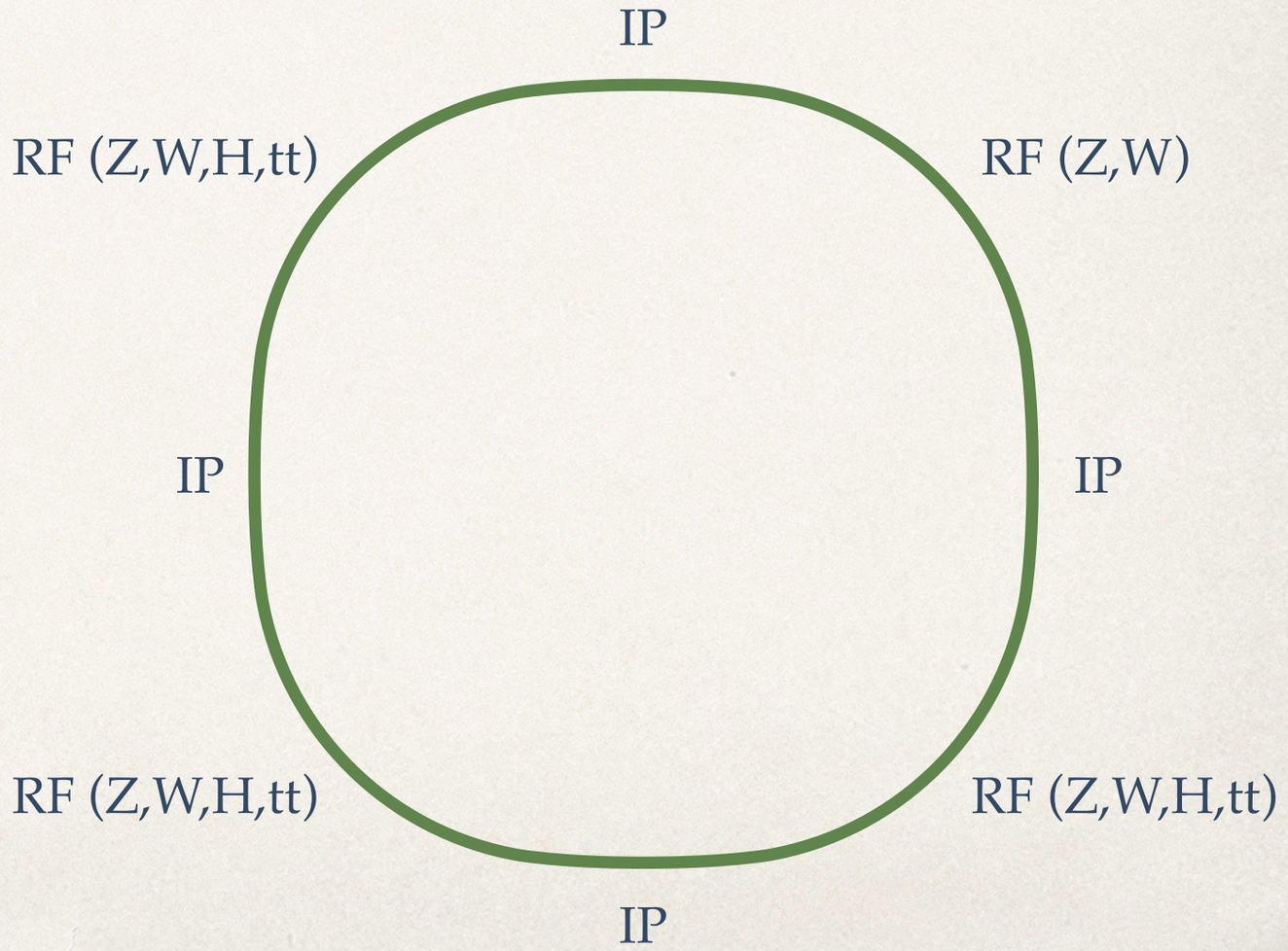
Possible issues

- Layout: perfect period 4 is the best solution:
  - How much is the geographical allowance for the tunnel?
  - FCC-hh must match to FCC-ee's new layout. Requirements for their collimation, injection, and detectors must be addressed.
  - Spaces for injection, beam abort, collimation, Compton polarimeter must be allocated.
- More beamstrahlung per damping:
  - Shorter beamstrahlung lifetime
  - Higher equilibrium energy spread, longer bunch length
- Smaller synchrotron tune per superperiod:
  - Narrower tune space for coherent x-z beam-beam instability, esp. at Z and W. (D. Shatilov, K. Ohmi)
- 2 by 2 bunch collision:
  - Tighter conditions for 3D flip-flop and coherent instability?
- Lattice/Dynamic aperture
- Emittance tuning, beam loss, collimation, etc.

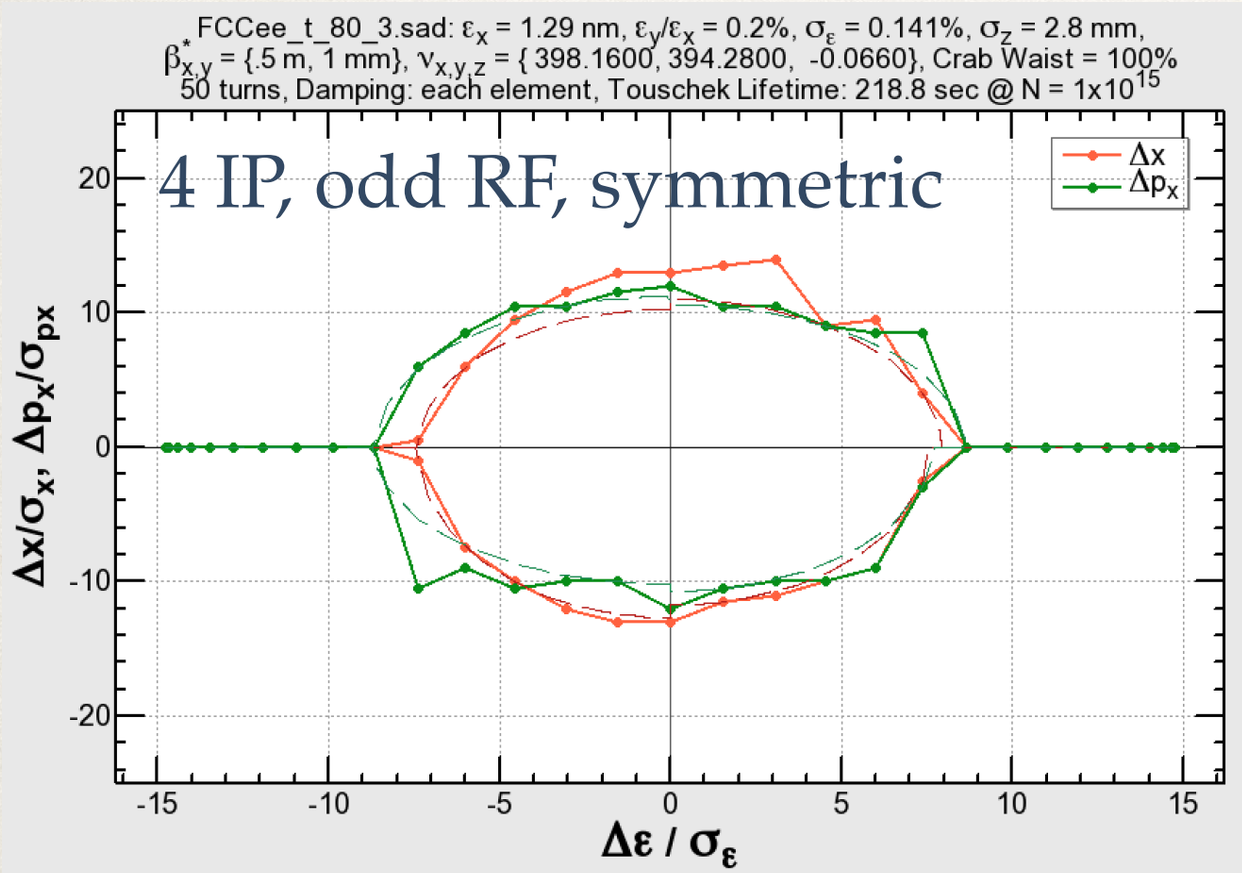
4 IP: layout with perfect period-4

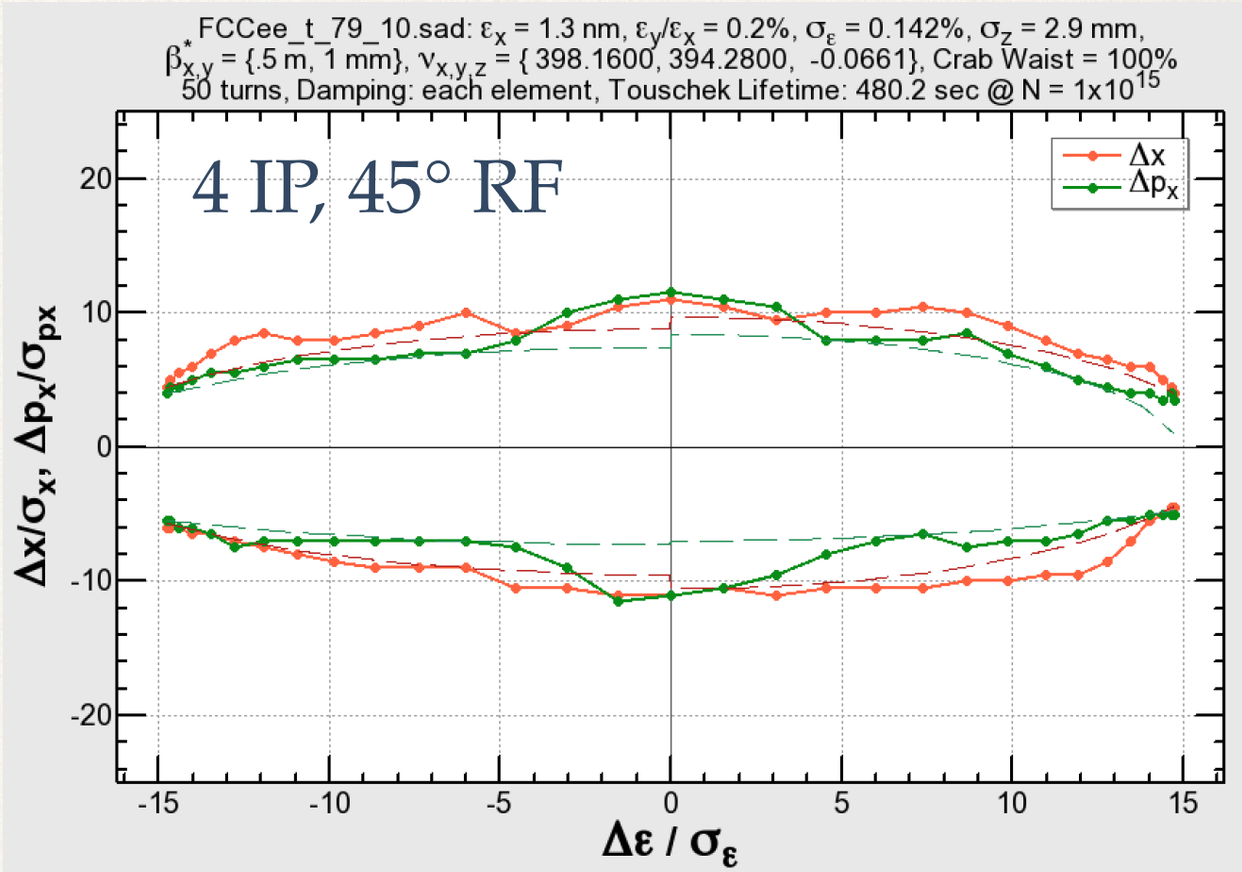
- Equal spacing between IPs:
  - Otherwise more than 4 bunches couple together.
- Complete period 4 periodicity, including RF (at least at ttbar):
  - Better beam-beam, dynamic aperture, etc.
- RF must be at the midpoint of 2 IPs:
  - Beams cross over at the RF.



RF at the odd straight, symmetric: period 2 (2)

175 GeV, $\beta^*_{x,y}$ = (0.5 m, 1 mm)





- The dynamic aperture has shrunk.
- The momentum acceptance has reduced to ±1.0%.
- If we put more conditions on the geometry & IR, it will be even worse.

Rough estimation of the luminosity

	Z		tt	
# of IPs	2	4	2	4
Particles/bunch [10^{11}]	1.7		2.3	
Bunches/beam	16640		48	
$\beta^*_{x/y}$ [m/mm]	0.15/0.8		1/1.6	
Long. damping [turns]	1270		40.8	
σ_z (SR/BS) [mm]	3.51/11.4	3.51/**13.0**	1.96/2.54	1.96/**2.80**
σ_δ (SR/BS) [%]	0.038/0.123	0.038/**0.141**	0.150/0.194	0.150/**0.215**
$\xi_{x/y}$	0.004/0.148	**0.003/0.129**	0.098/0.141	**0.089/0.136**
Luminosity/IP [10^{34}/cm^{2}s]	230	**201**	1.40	**1.31**

- Above are just geometrical calculations: no dynamics involved.
- Real estimation given by D. Shatilov & K. Ohmi are following.

Beamstrahlung for 4 IP vs. 2 IP
(bunch population as for 2 IP)

D. Shatilov

Z σ_δ and σ_z increased by ~15%, luminosity drops by ~15%. Here we are not yet limited by momentum acceptance, so the bunch population can be slightly increased.

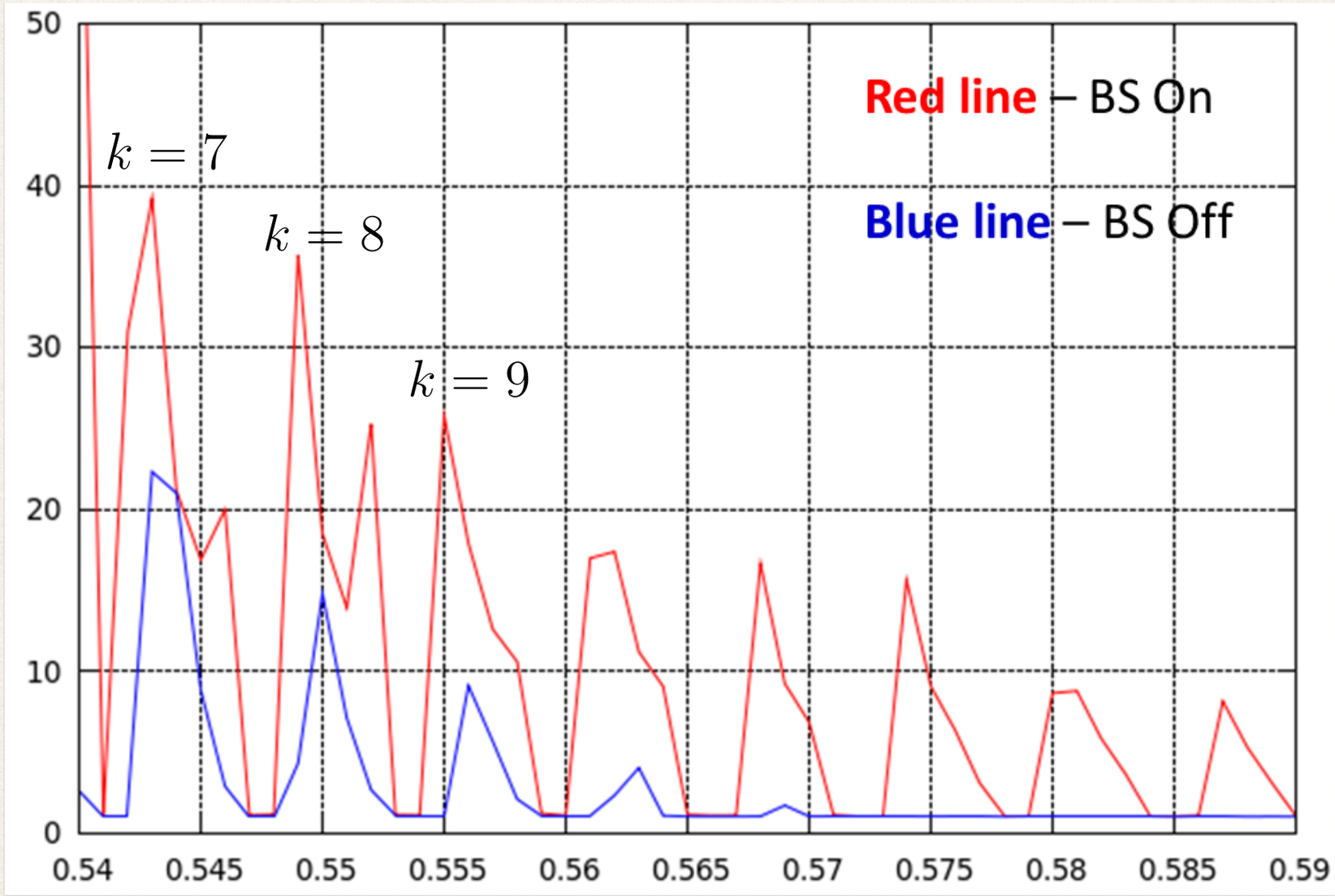
WW σ_δ and σ_z increased by ~12%, luminosity drops by ~12%. Here we are limited by HOM power, not by momentum acceptance. So, some increase in σ_δ is acceptable, while the bunch population should be the same.

HZ σ_δ and σ_z increased by ~10%, luminosity drops by ~12%. But here we are limited by momentum acceptance, so the bunch population should be decreased to preserve the lifetime. Luminosity will decrease by 15-20% (not yet done).

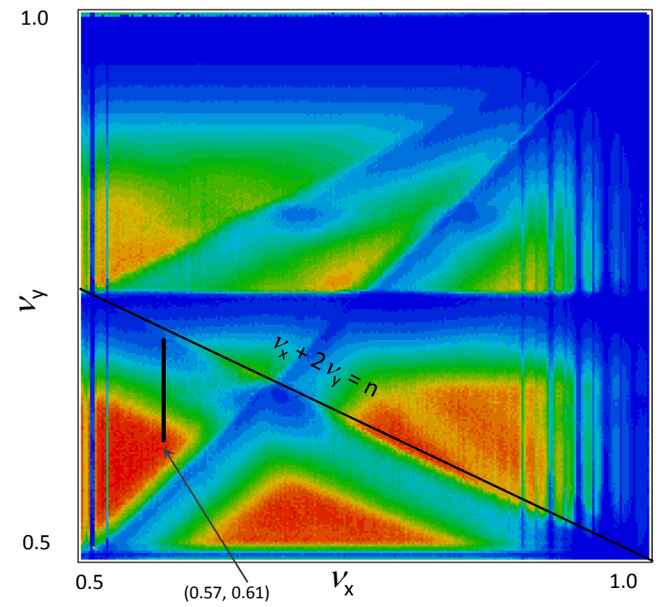
ttbar σ_δ and σ_z increased by ~14%, luminosity drops by ~9%. Again, we are limited by momentum acceptance, so the bunch population should be decreased to preserve the lifetime (not yet done).

Coherent beam-beam instability with 4 IP

D. Shatilov



(2 IP tune space)



$$2\nu_x + k\nu_z = N$$

$$\nu_z \approx -0.0125 \text{ @Z}$$

- The allowed tune space is tighten by beamstrahlung.
- Wigglers for higher energy spread may improve the situation.

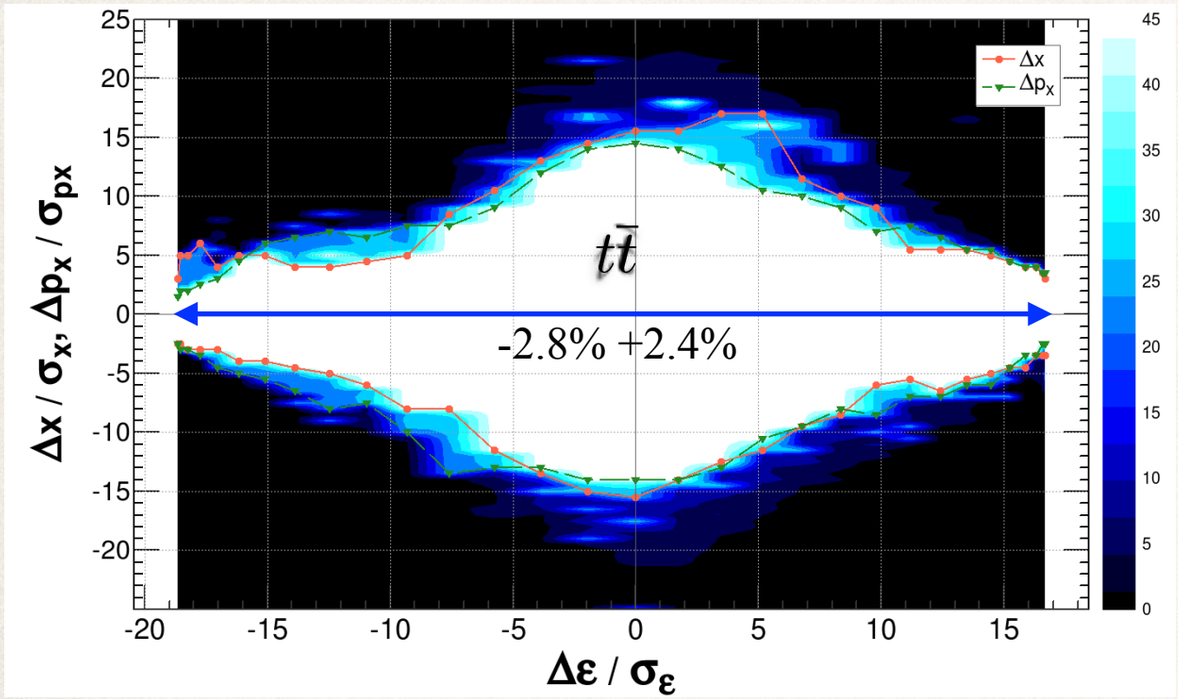
Summary of 4IP simulations

K. Ohmi

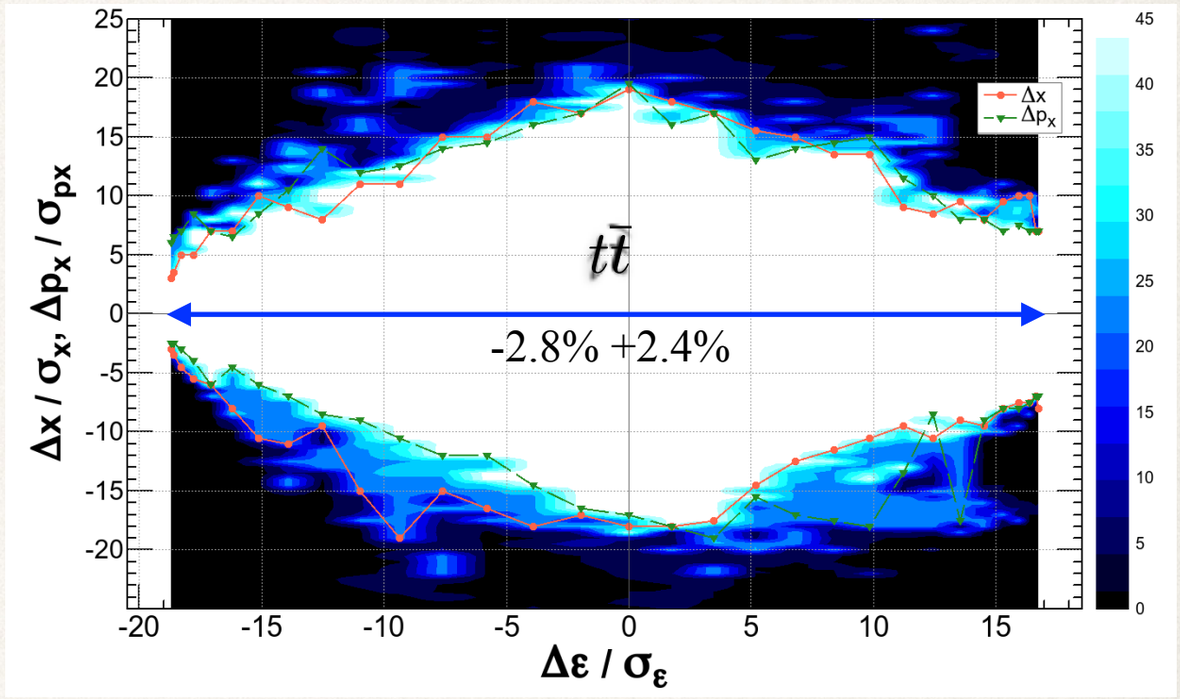
- Ideal case of 2/4IP, in which perfect periodicity is kept, was studied.
- beam-beam head-tail (BBHT) instability limits the performance, because of smaller ν_s per IP.
- Depending on parameters, choice of ν_s helps the instability.
- Luminosity/IP for T and H are 10% loss compare with 2IP.
- Tune scan of Z is understudied, because simulation time is long.
- ½ model gave same result as 2IP simulation.
- Probably, ¼ model gives the same result as 4IP simulation.
- Imperfection of each IP break periodicity.
- Bunch current unevenness ~10% gave weak effect in tt.

Dynamic aperture for 4 IP (ttbar)

4 IP (in progress)



2 IP (CDR)



- Due to a half number (148 instead of 294) of sextuple families, it is more difficult to achieve the same momentum acceptance as the 2 IP.
- Additional octu-, deca-, dodeca-pole coils are added to 8 sextuples close to each IP, using superconducting design are added for more degrees of freedom.
- Designs for other energies will follow.

Summary

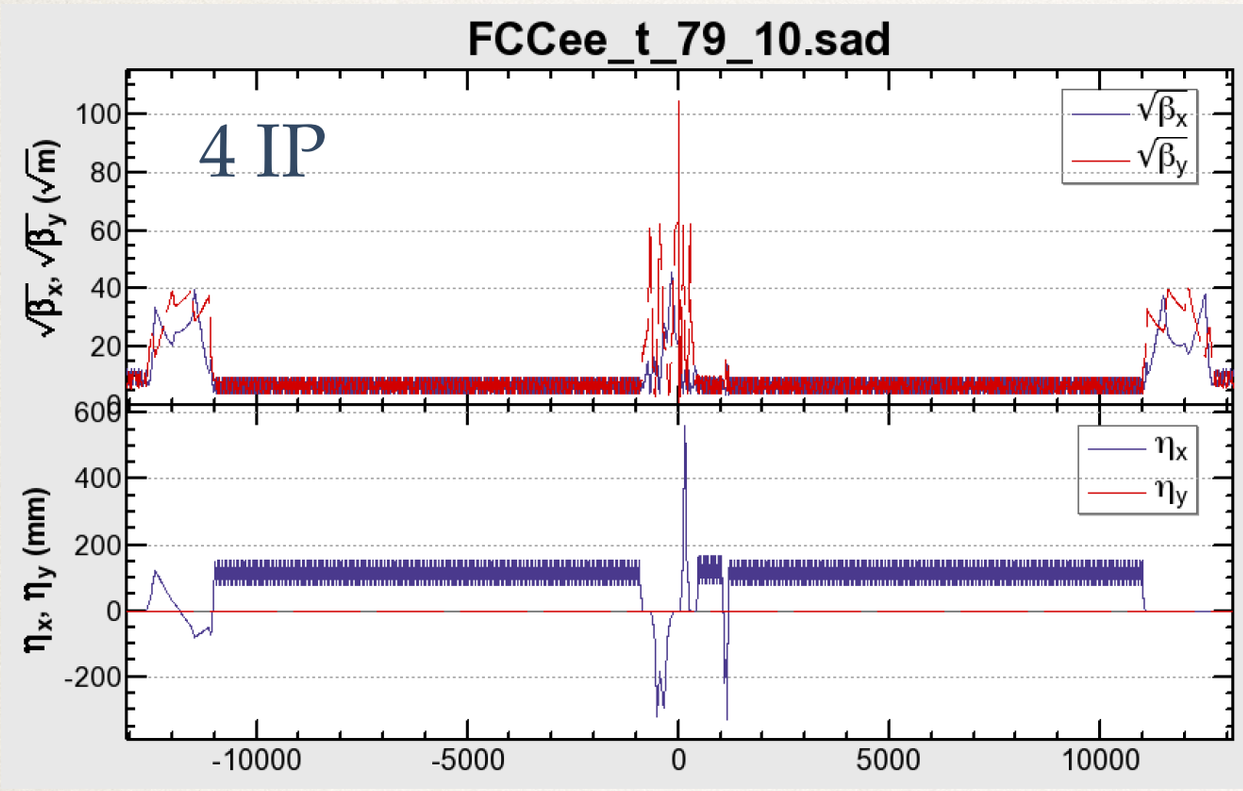
- Beam-beam and lattice studies have been started for 4 IP scheme.
- A reduction of luminosity per IP up to -15% is expected so far.
- More studies must be done for beam-beam, layout, dynamic aperture, and all issues done for 2 IP.

Backups

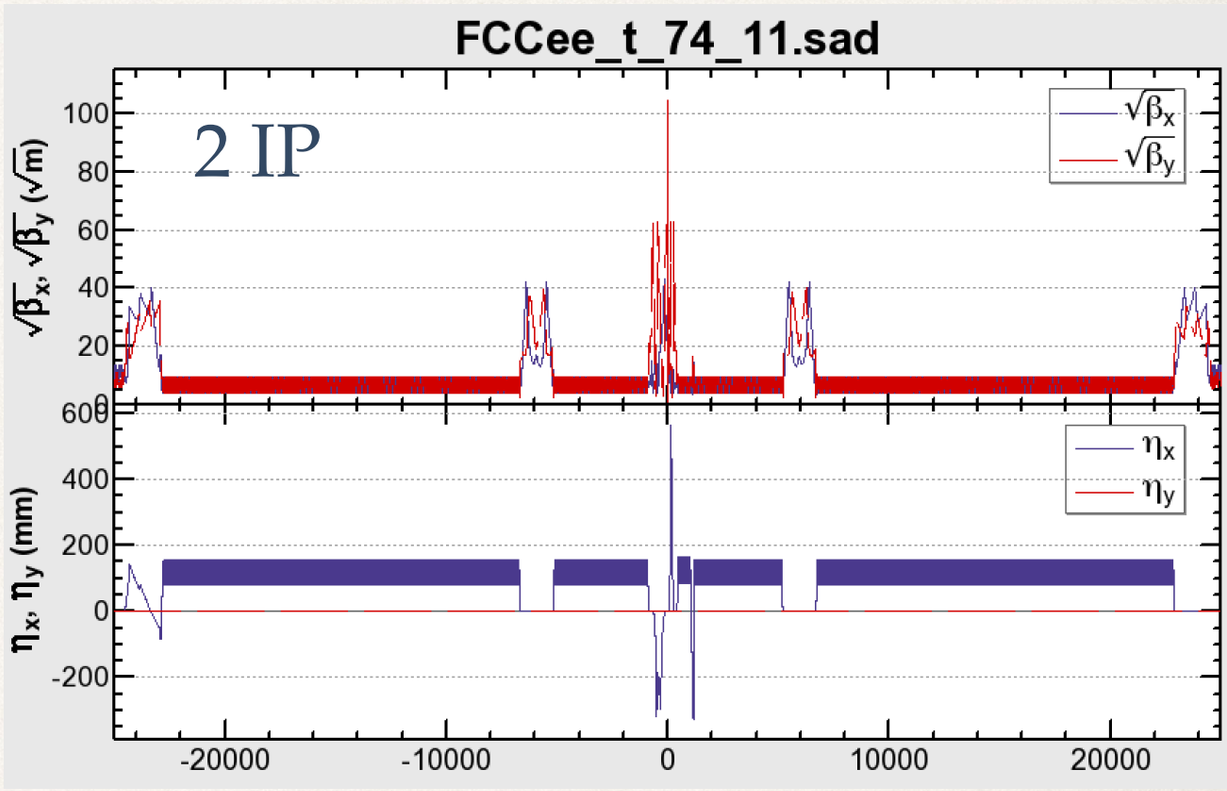
Ideal case: perfect period 4, RF at 45°

175 GeV, $\beta^*_{x,y}$ = (0.5 m, 1 mm)

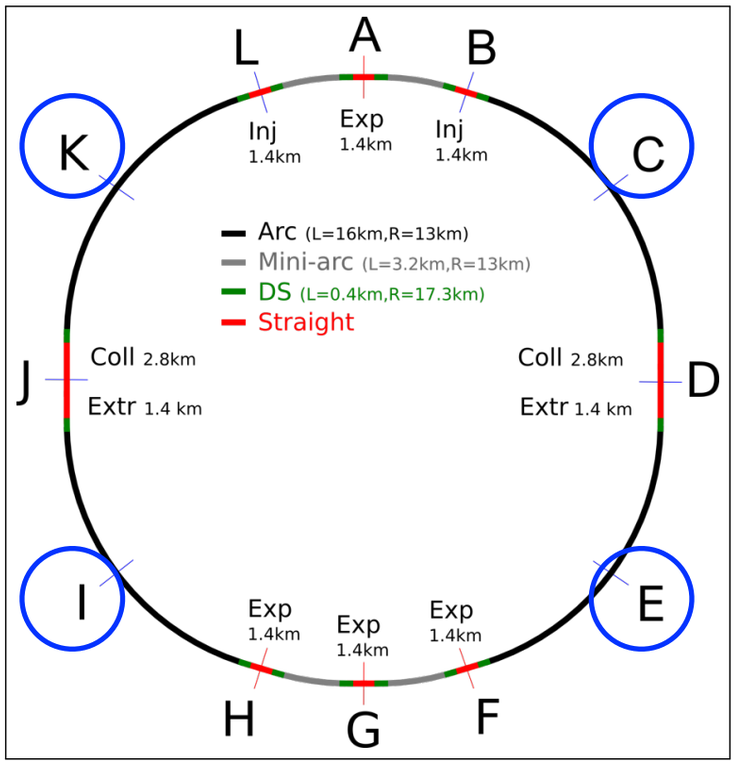
Period 4, 1/4 ring



Period 2, 1/2 ring

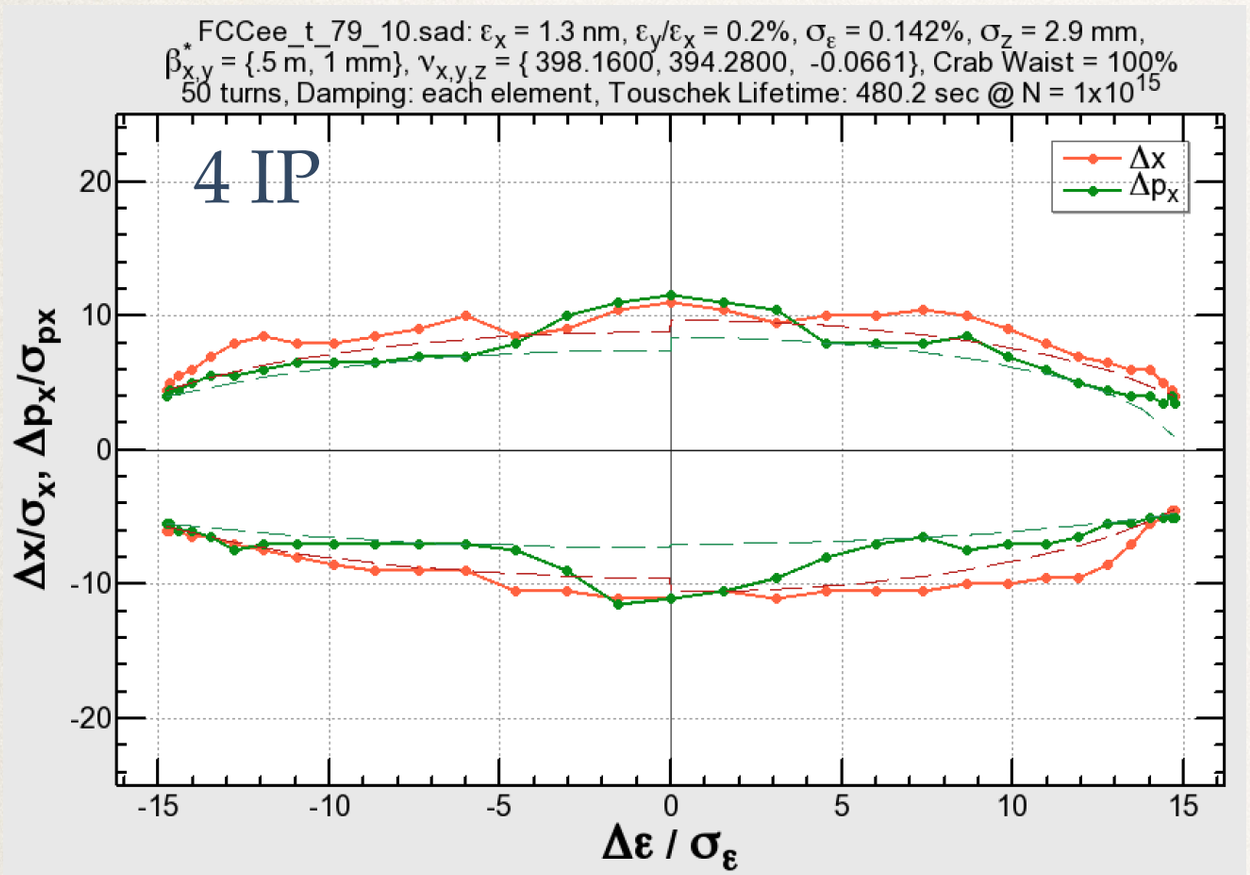


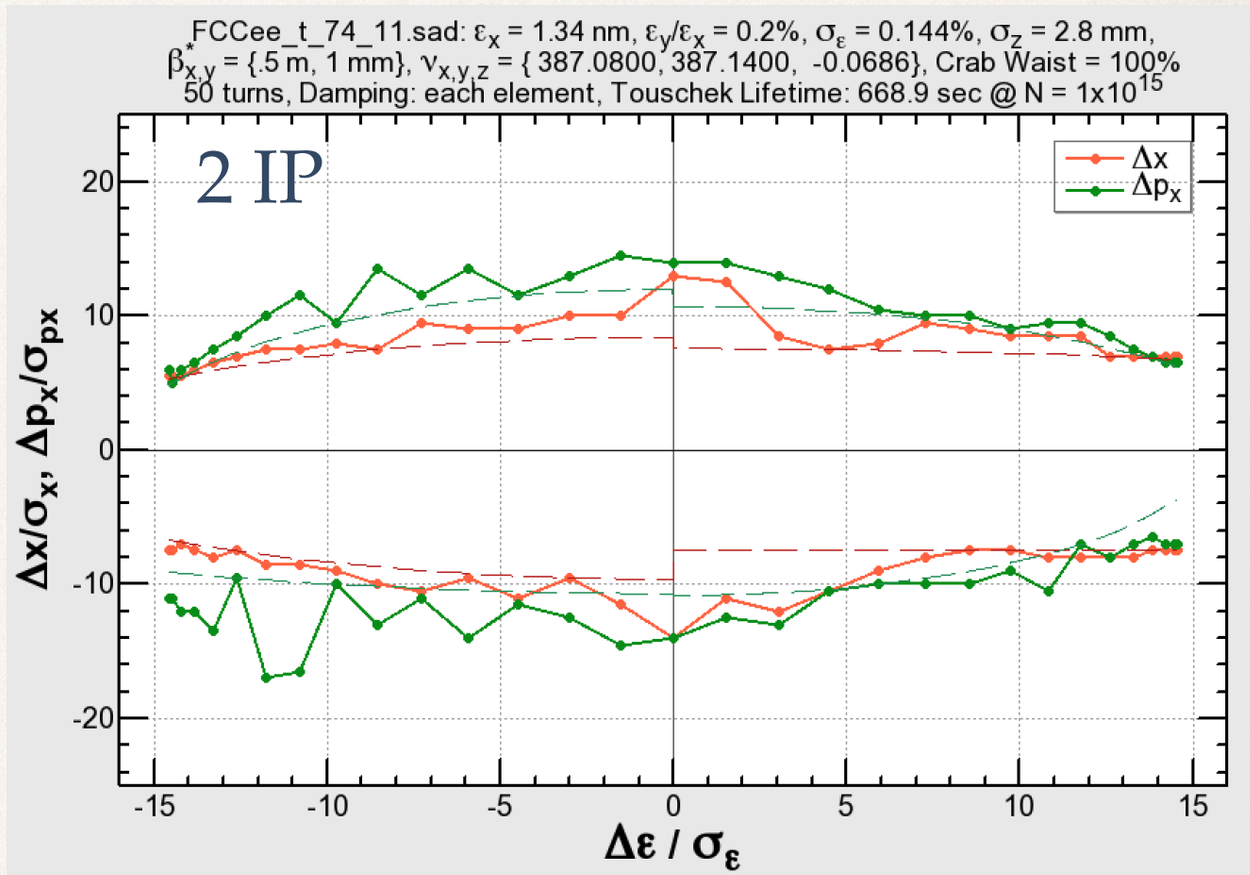
- First a perfect period 4 ring is tried as a nearly ideal case.
- RF is placed at 45°, in the midpoint of arc (CEIK of FCC-hh).
- IR and RF sections, and the arc unit cell are identical to the 2 IP optics.
- The beam line does not match the FCC-hh tunnel.



Ideal case: perfect period 4, RF at 45° (2)

175 GeV, $\beta^*_{x,y}$ = (0.5 m, 1 mm)



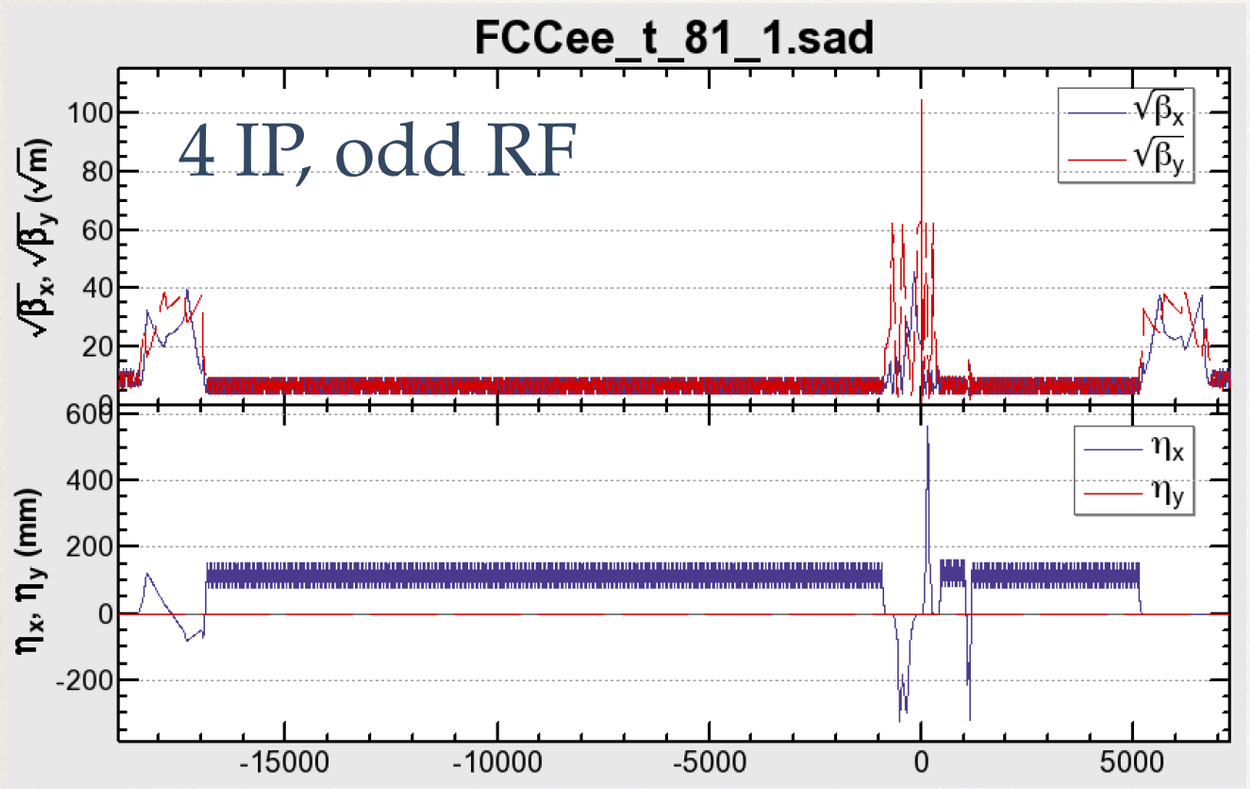


- The effect on the dynamic aperture is small.
- ±2% momentum acceptance is maintained.

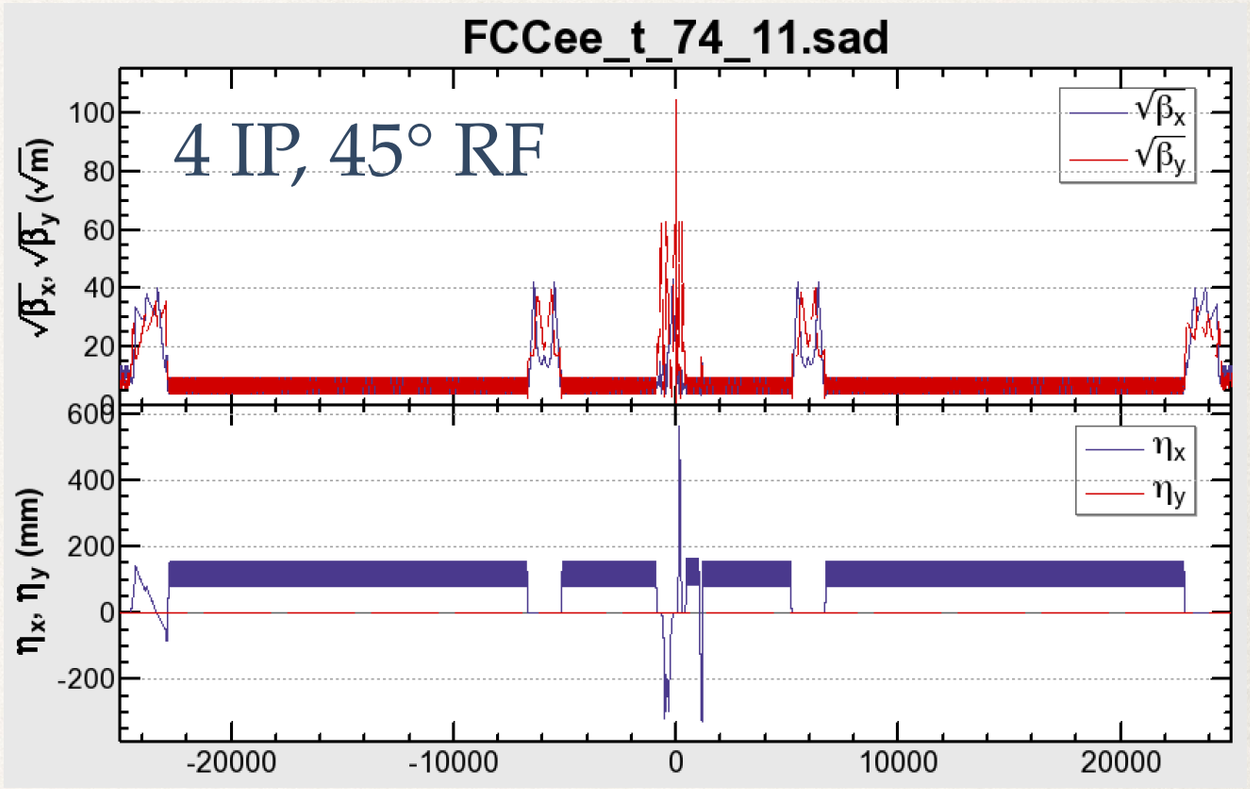
RF at the odd straight: perfect period 4

175 GeV, $\beta^*_{x,y}$ = (0.5 m, 1 mm)

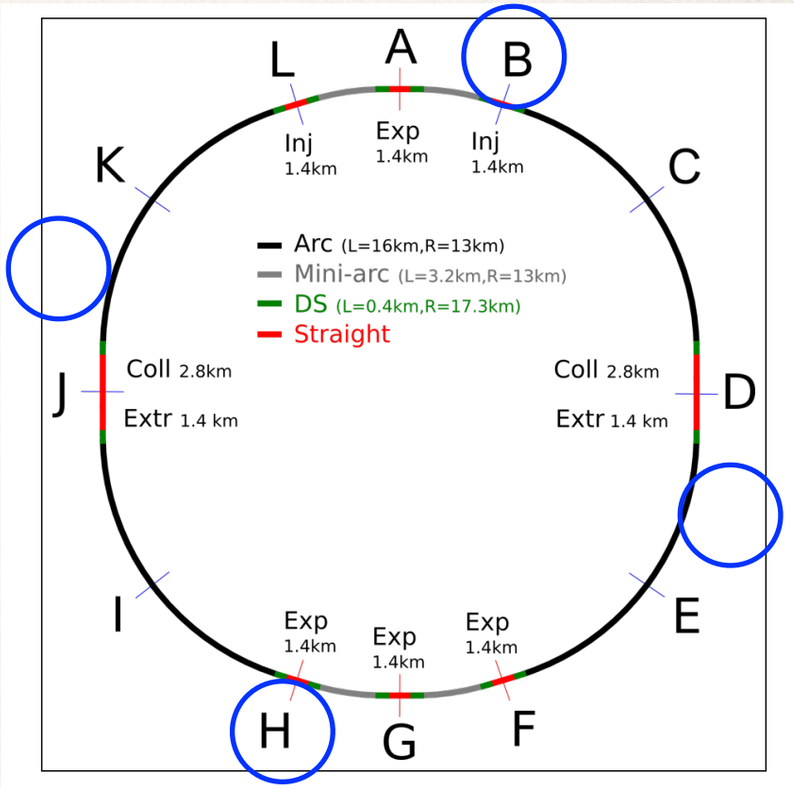
Period 4, 1/4 ring



Period 4, 1/4 ring

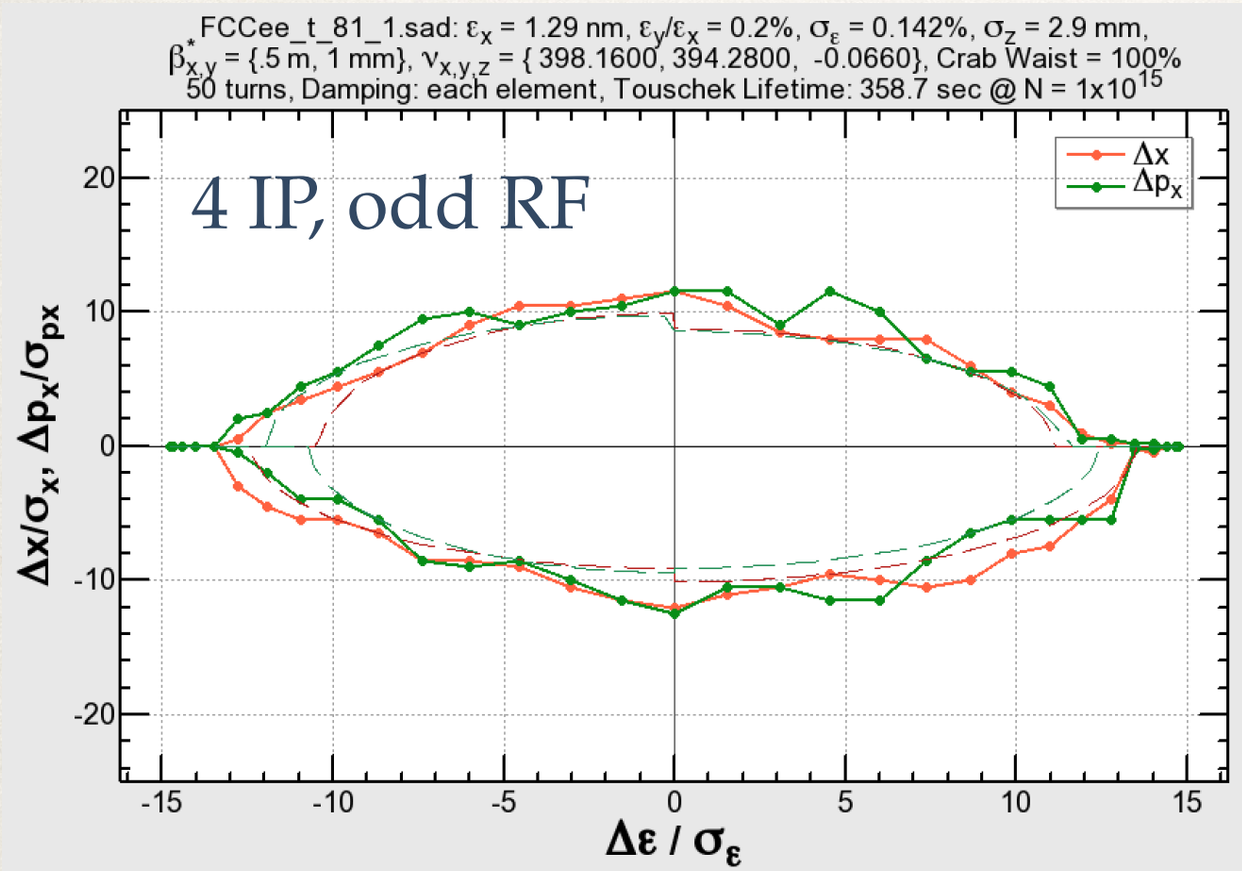


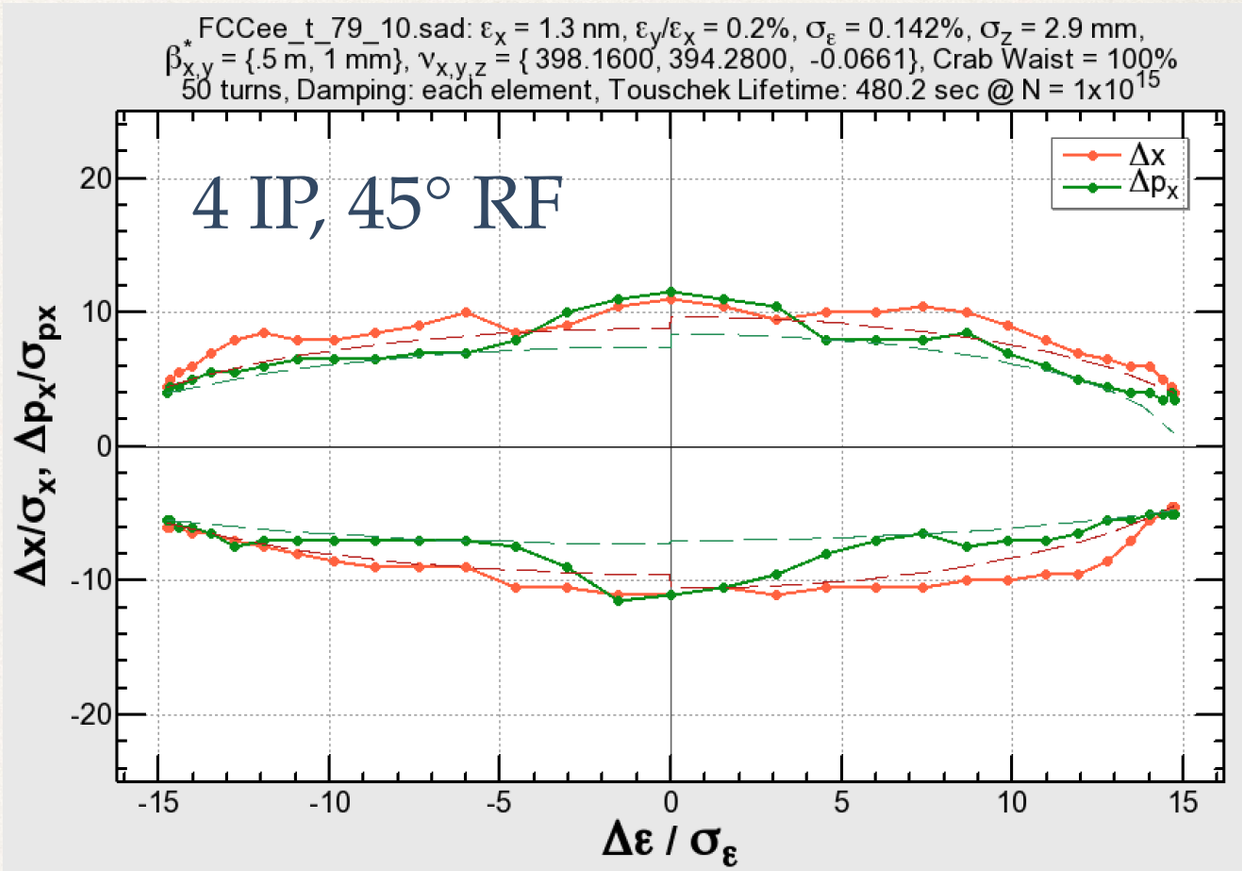
- As the RF should be placed at the short straights (B_H_) to utilize the FCC-hh layout.
- Still assume a complete period 4.
- The geometry is not yet close to FCC-hh.



RF at the odd straight: perfect period 4 (2)

175 GeV, $\beta^*_{x,y}$ = (0.5 m, 1 mm)



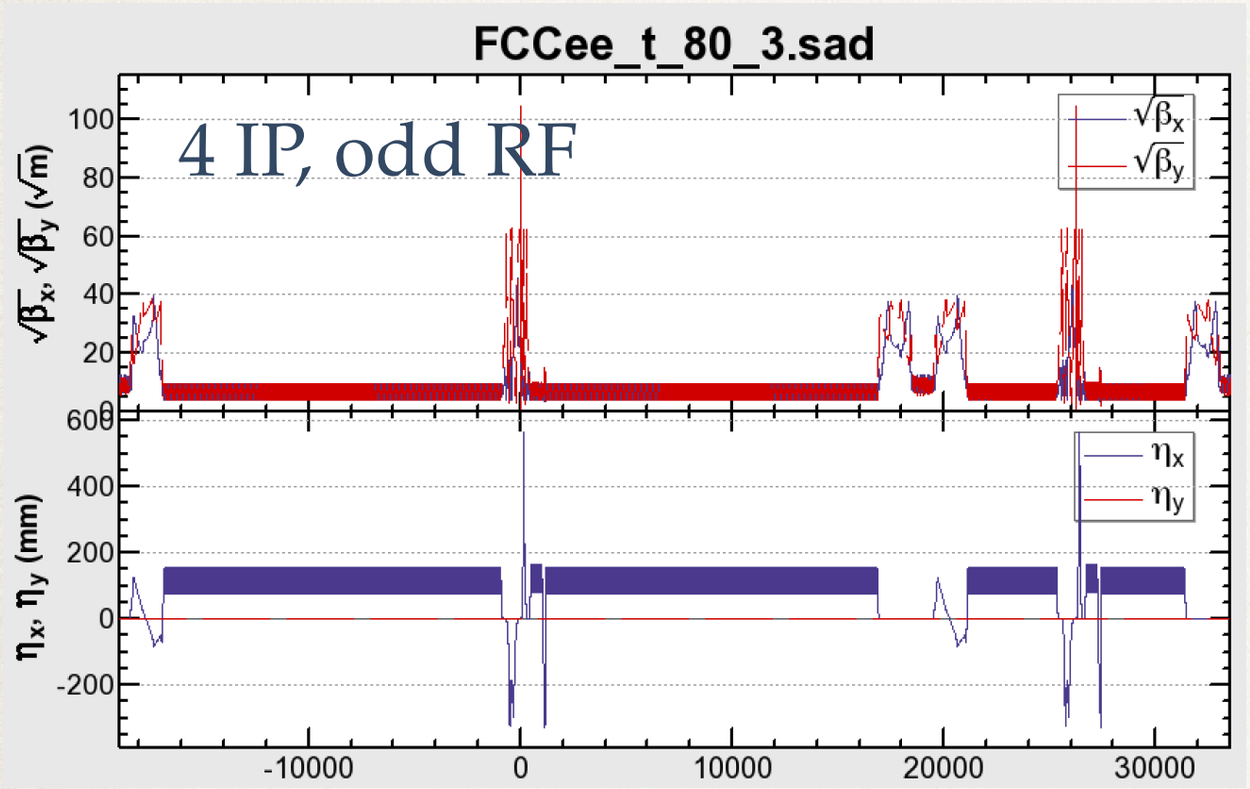


- The dynamic aperture has shrunk a little.
- The momentum acceptance has reduced to ±1.7%.

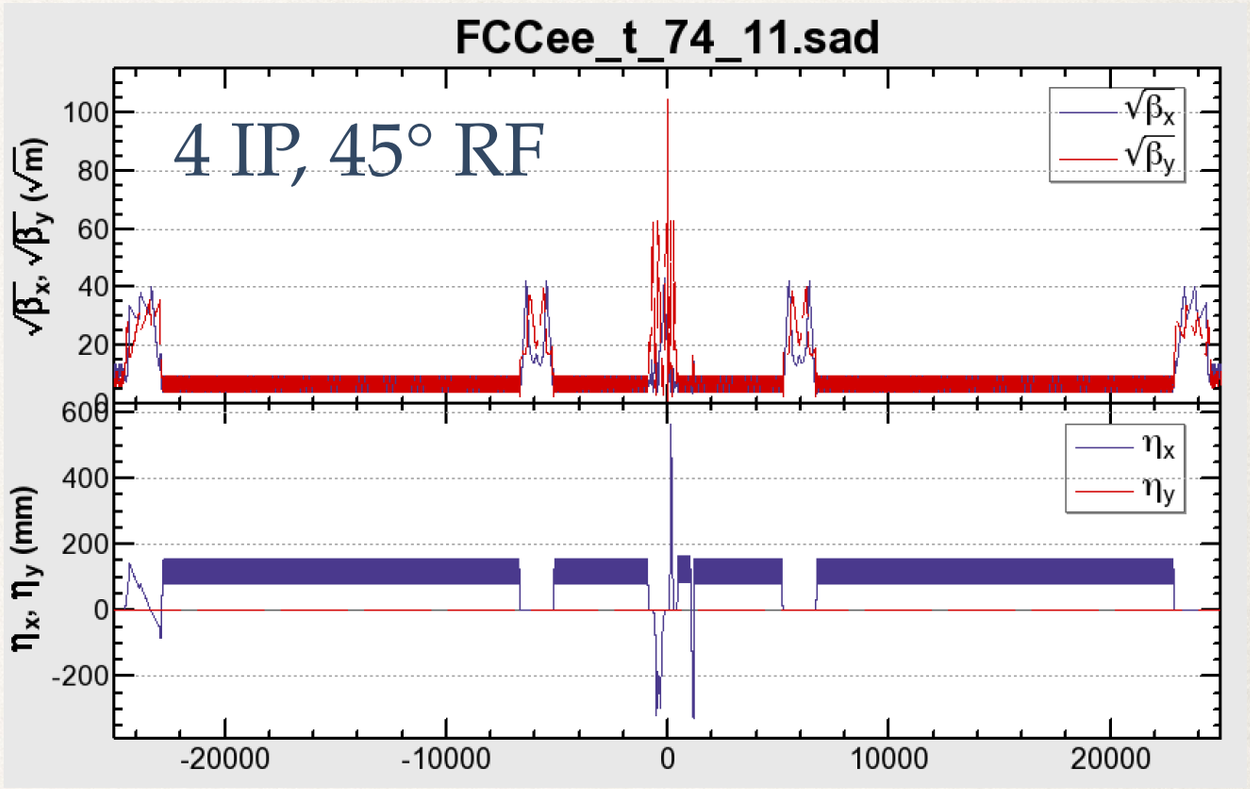
RF at the odd straight, symmetric: period 2

175 GeV, $\beta^*_{x,y}$ = (0.5 m, 1 mm)

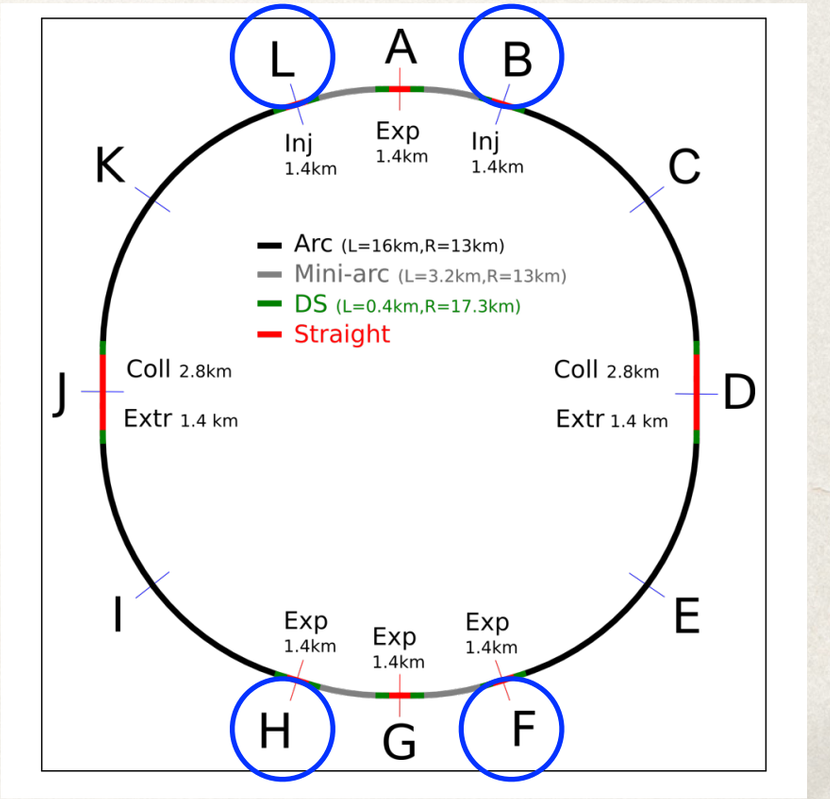
Period 2, 1/2 ring



Period 4, 1/4 ring



- Now place the RF symmetric, at sections BFHL.
- Then the periodicity is reduced to 2.
- The layout becomes closer to FCC-hh, but not perfect, since the length of the RF section is not correct, and the 4 IPs are still identical.



K. Oide, July 18, 2016 @ MDI Meeting

Summary for 4IP

- A preliminary design for optics with 4 IP is tried.
- Usable optics will be possible by locating the RF at 45° at the arc.
- Placing the RF at the short straights of FCC-hh reduces the dynamic aperture drastically.
- More investigation/ideas are needed for 4 IP with the geometry of FCC-hh.