A preliminary 60° lattice for Z

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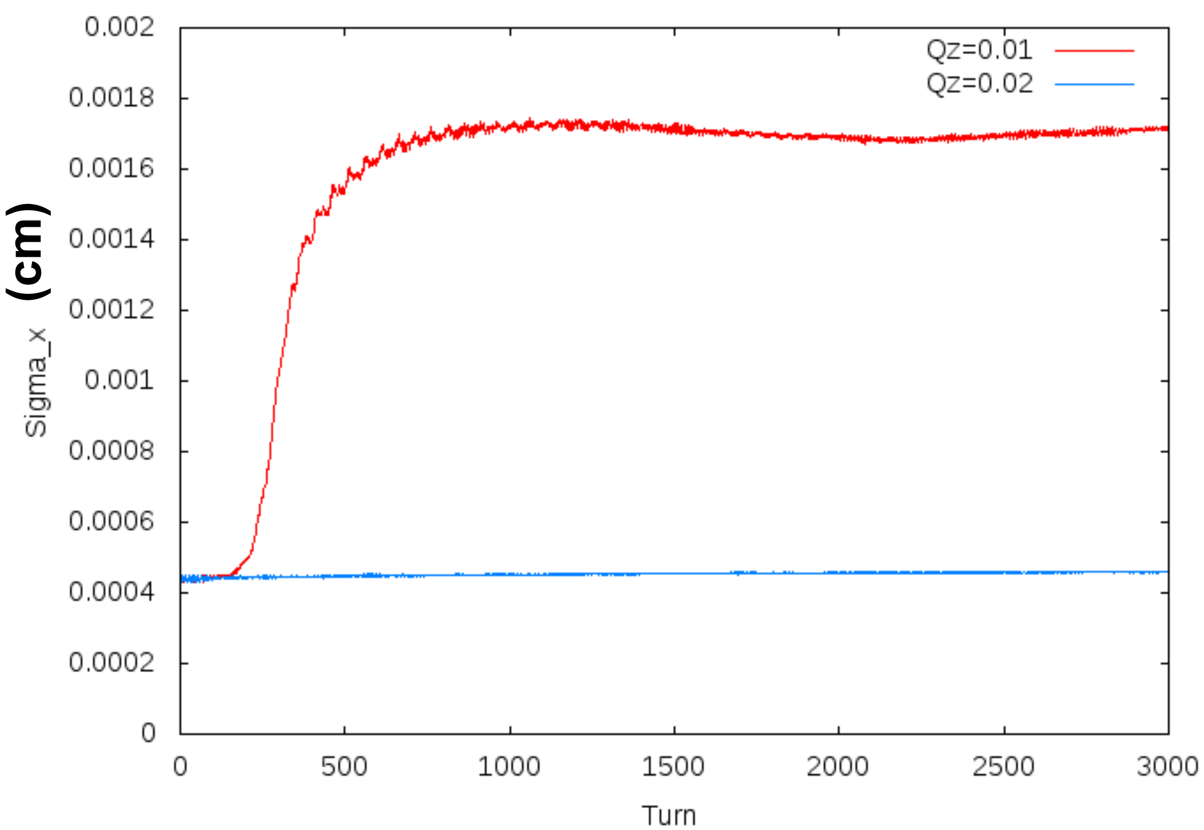
K. Oide @ FCC-ee MDI Meeting

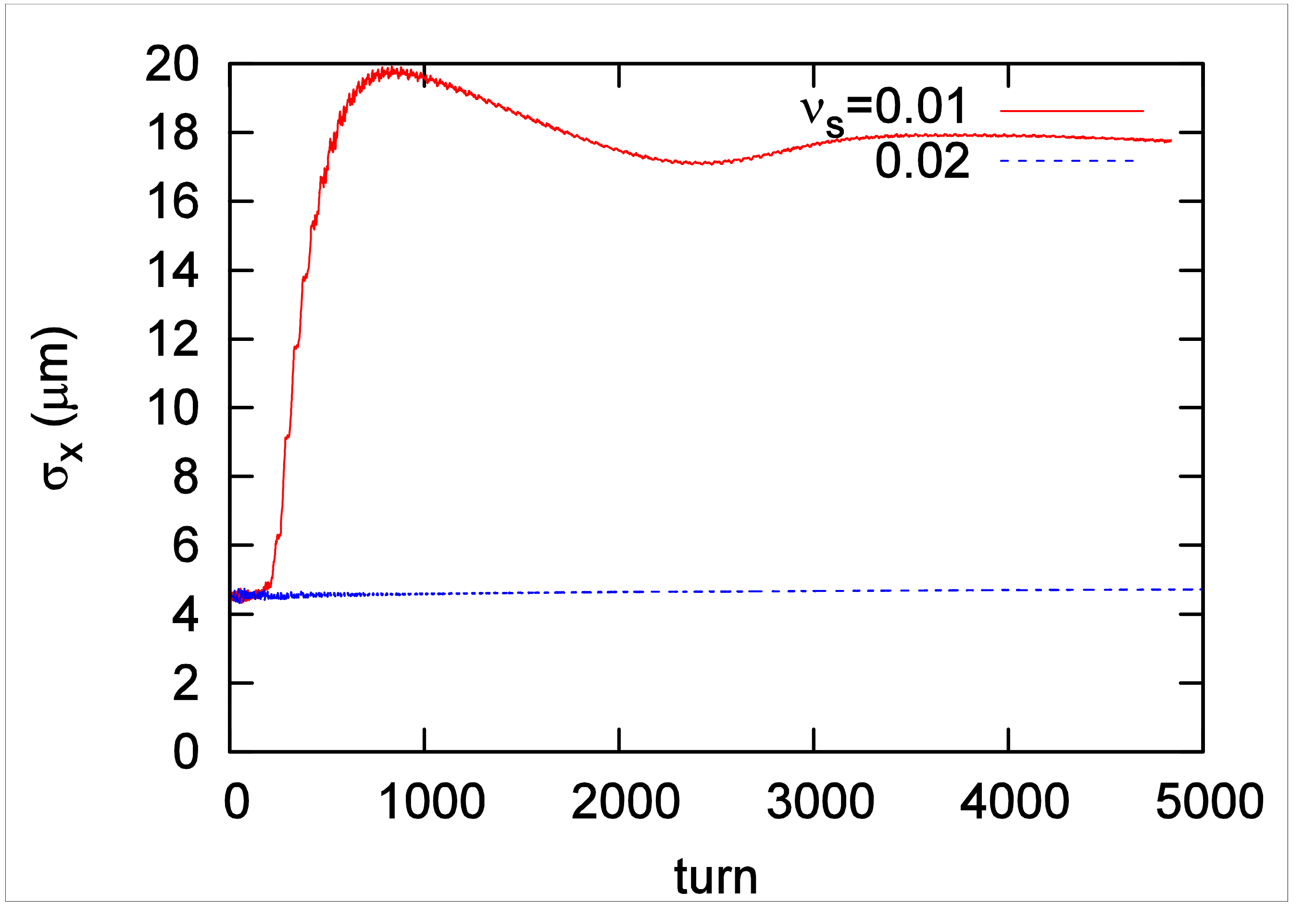
Dependence on ν_z : Lifetrac vs. BBSS

$\nu_x = 0.55$, $\beta_x = 20$ cm, $\sigma_z = 0.5$ cm, $N_p = 3 \cdot 10^{10}$

Lifetrac (D. Shatilov)



BBSS (K. Ohmi)



Good agreement between two independent simulations!

D. Shatilov

A stability criterion (K. Ohmi)

Coasting beam model

- Stability condition

$$U \equiv \frac{\sqrt{3}\beta_x^* c |Z_{peak}|}{8\pi n \eta \sigma_\delta \sigma_z} = 2.4 > 1$$

where $n = \omega_c/\omega_0$.

$\eta = 6.9 \times 10^{-6}$

Unstable

- Coasting beam model is questionable to use in localized beam-beam interaction and discrete synchrotron motion.

E = 45. 6 GeV, single cell parameters

$\Delta\nu$ (deg)	90	60	45
α (10^{-5})	0.85	1.76	3.04
ε_x (nm)	0.085	0.257	0.592

Simulation Results (preliminary)

β_x = 20 cm

1) $\Delta\nu = 60^o$, $\alpha = 1.76 \cdot 10^{-5}$, ε_x = 260 pm, ε_y = 1 pm

URF = 100 MV, σ_z = 3.8 mm, ν_s = 0.01388, ν_x = 0.55, ν_y = 0.59

$N_p = 3 \cdot 10^{10}$, L = $1.20 \cdot 10^{36}$, with beamstrahlung: σ_z => 5.0 mm, L = $0.93 \cdot 10^{36}$

2) $\Delta\nu = 45^o$, $\alpha = 3.04 \cdot 10^{-5}$, ε_x = 600 pm , ε_y = 2 pm

URF = 200 MV, σ_z = 3.5 mm, ν_s = 0.02647, ν_x = 0.56, ν_y = 0.60

$N_p = 4 \cdot 10^{10}$, L = $1.03 \cdot 10^{36}$, with beamstrahlung: σ_z => 4.7 mm, L = $0.84 \cdot 10^{36}$

β_x = 15 cm

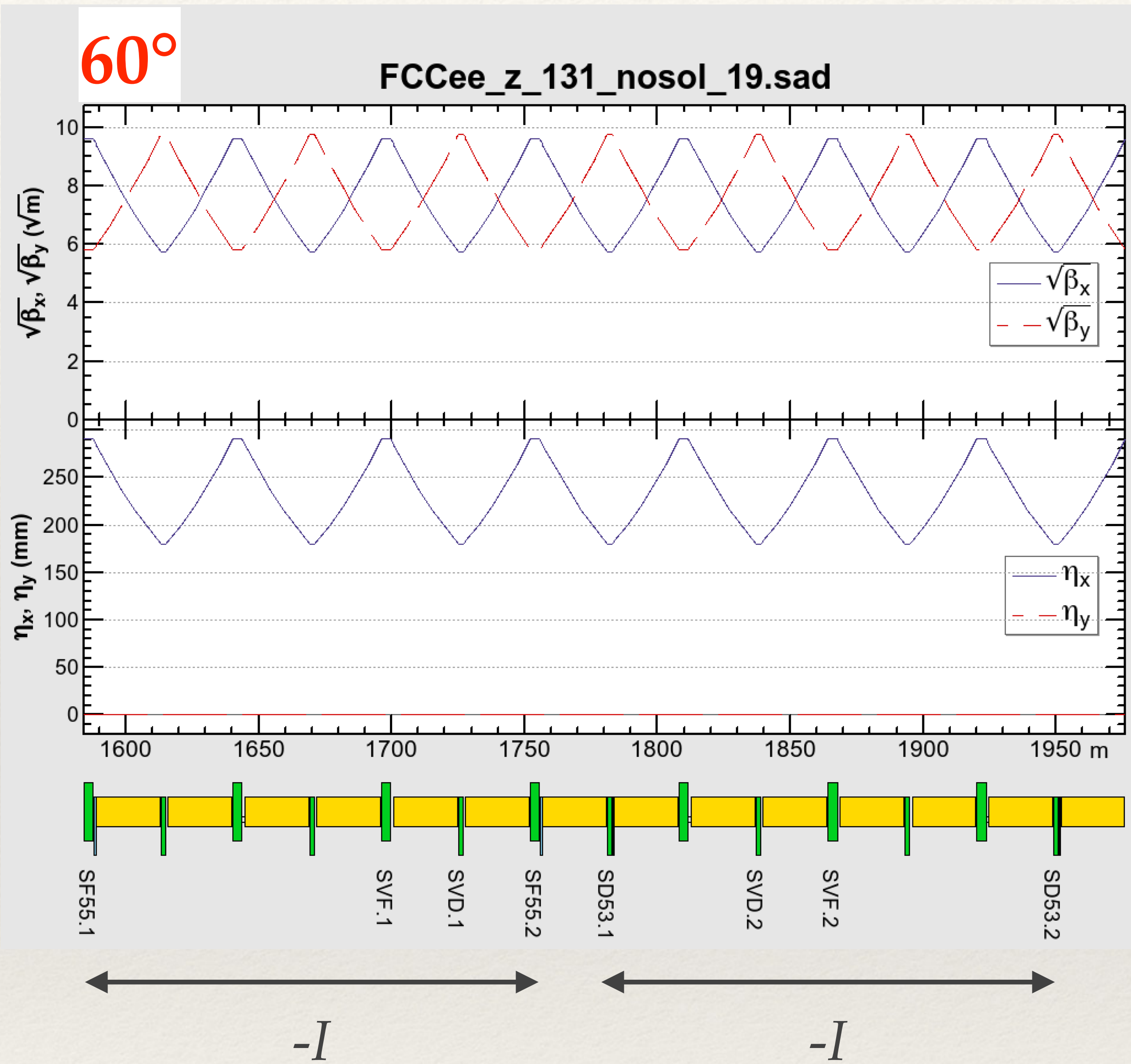
1) $\Delta\nu = 60^o$, $\alpha = 1.76 \cdot 10^{-5}$, ε_x = 260 pm, ε_y = 1 pm

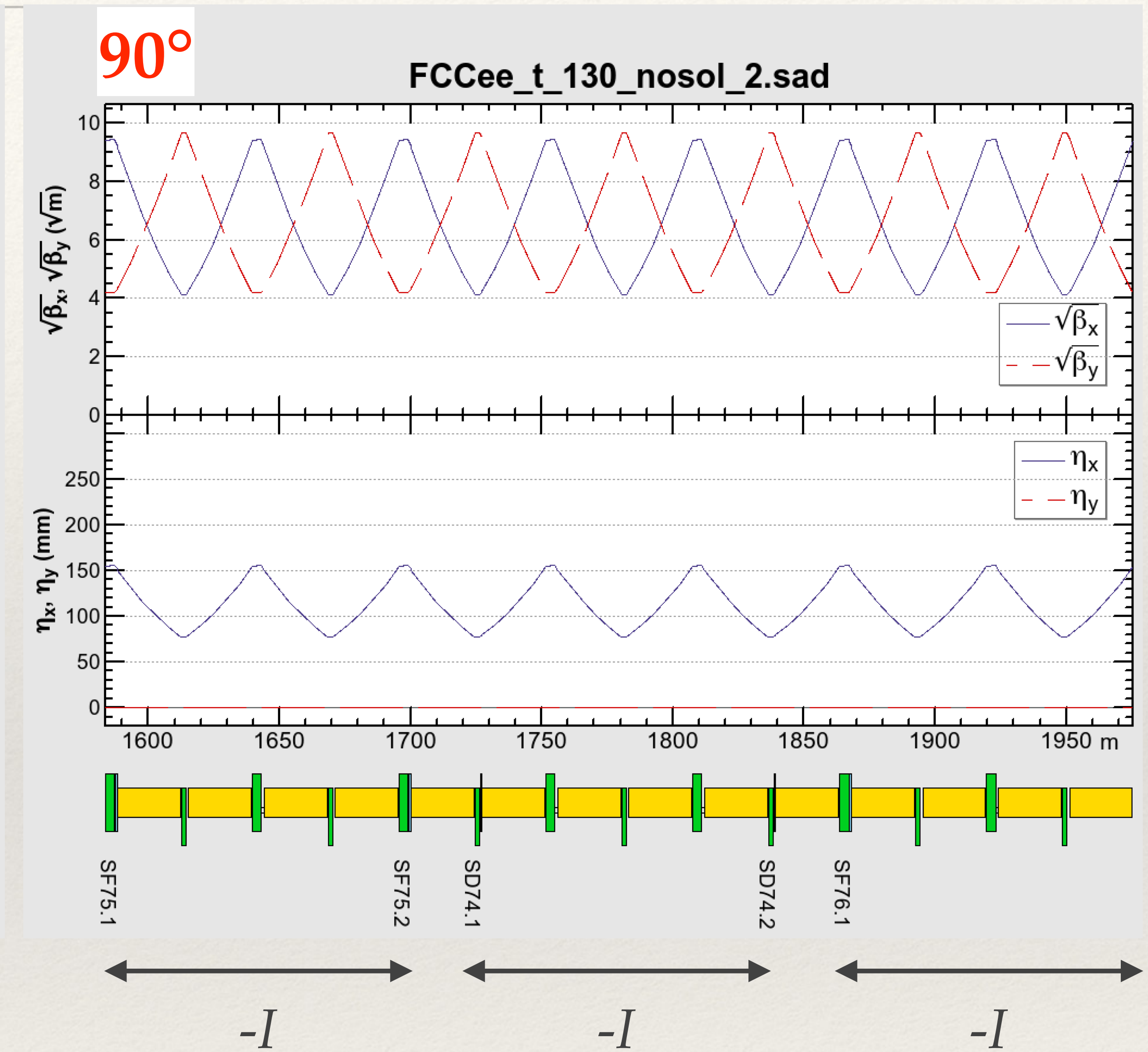
URF = 100 MV, σ_z = 3.8 mm, ν_s = 0.01388, ν_x = 0.575, ν_y = 0.61

$N_p = 4 \cdot 10^{10}$, L = $1.58 \cdot 10^{36}$, with beamstrahlung: σ_z => 5.9 mm, L = $1.04 \cdot 10^{36}$

D. Shatilov

60° Arc Cell


60°
FCCee_z_131_nosol_19.sad
√βx, √βy (√m)
ηx, ηy (mm)
√βx
√βy
ηx
ηy
1600
1650
1700
1750
1800
1850
1900
1950 m
SF55.1
SVF.1
SVD.1
SF55.2
SD53.1
SVD.2
SVF.2
SD53.2
-I
-I


90°
FCCee_t_130_nosol_2.sad
√βx, √βy (√m)
ηx, ηy (mm)
√βx
√βy
ηx
ηy
1600
1650
1700
1750
1800
1850
1900
1950 m
SF75.1
SF75.2
SD74.1
SD74.2
SF76.1
-I
-I
-I

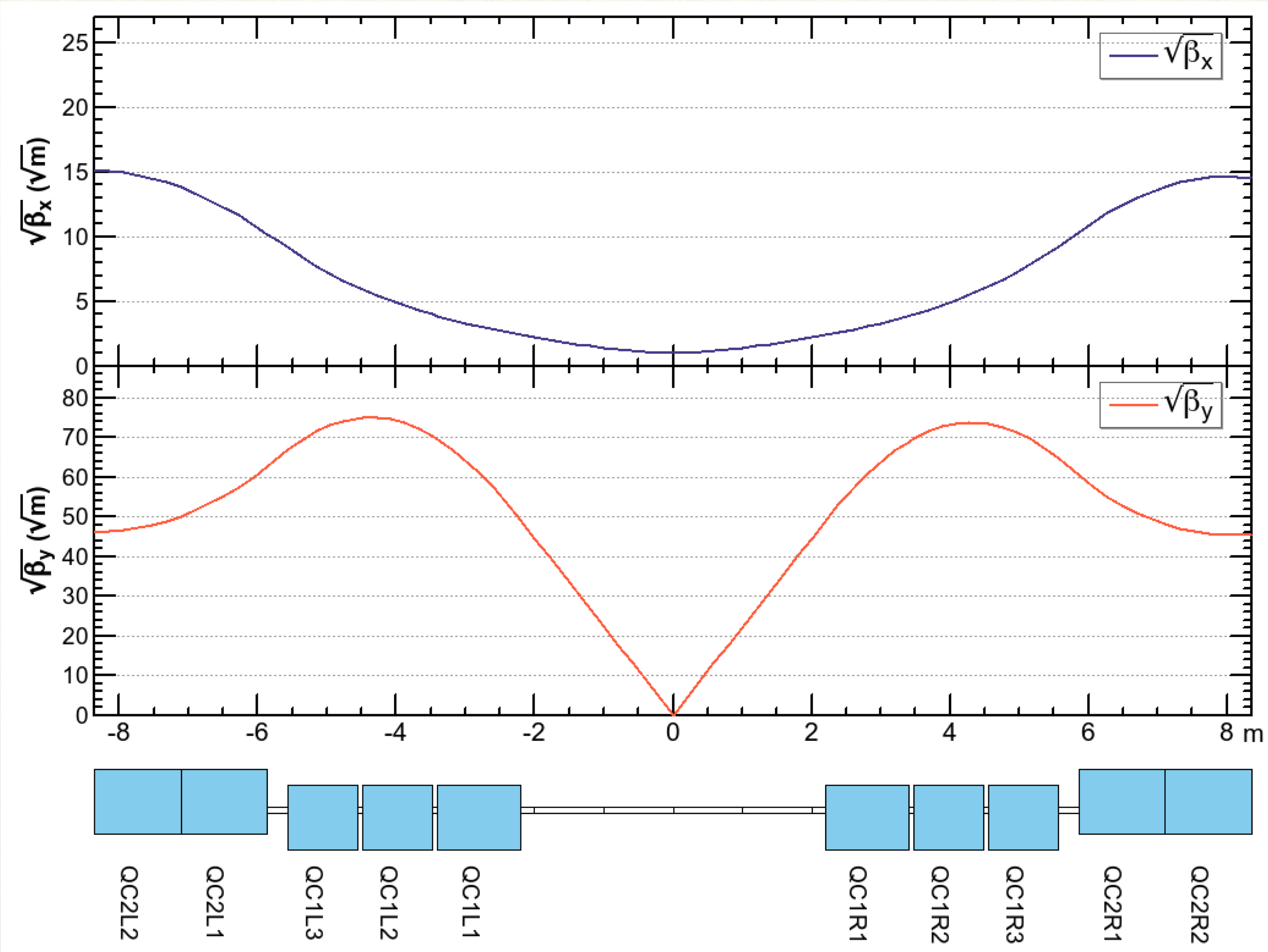
Additional sextupoles

Δv (deg)	# of sexts	additional sexts	unused sexts
90	~1200	0	0
60	~860	~510	~770
45	~600	~300	~900

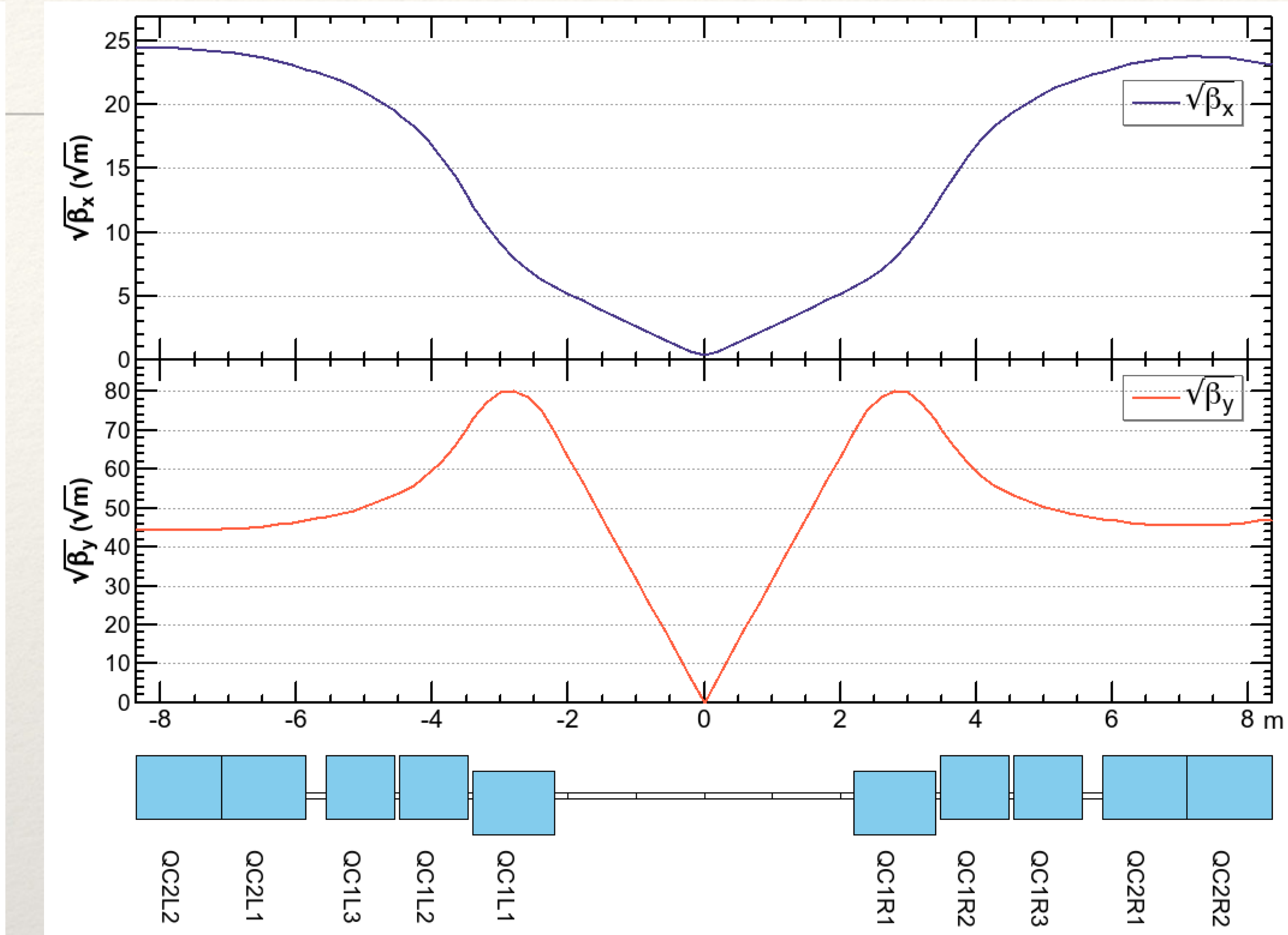
"Unused" sextupoles still can be used for correctors.

Optics around the IP

$\beta_{x,y}{}^* = (1\text{ m}, 2\text{ mm})$ @ tt



$\beta_{x,y}{}^* = (15\text{ cm}, 1\text{ mm})$ @ Z



- Divide QC1 into three independent pieces. (suggested by D. Shatilov)

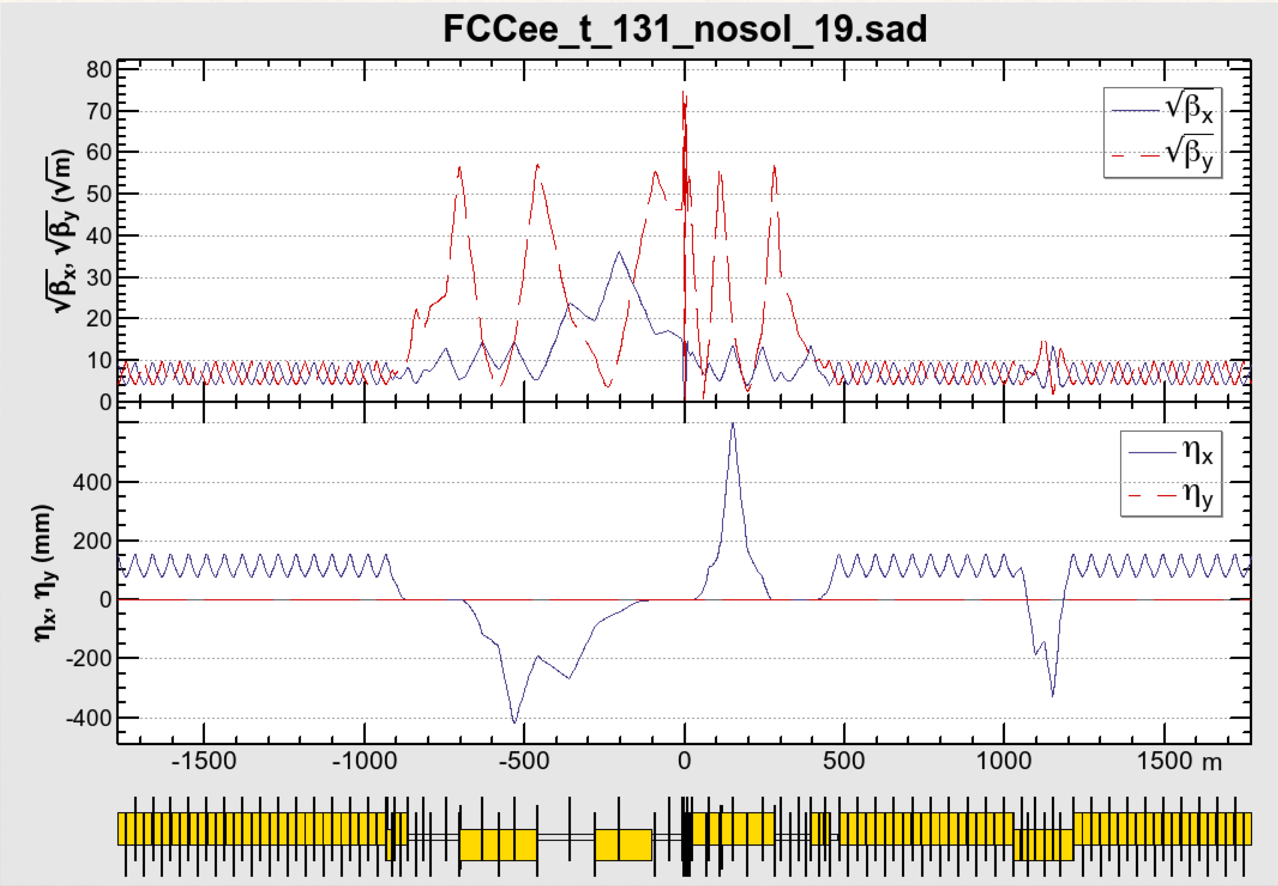
	L (m)	B′ @ tt (T/m)	B′ @ Z (T/m)
QC1L1	1.2	-92.9	-95.8
QC1L2	1	-99.5	+47.2
QC1L3	1	-98.6	+14.3
QC2L1	1.25	+62.9	+6.6
QC2L2	1.25	+62.9	+2.2

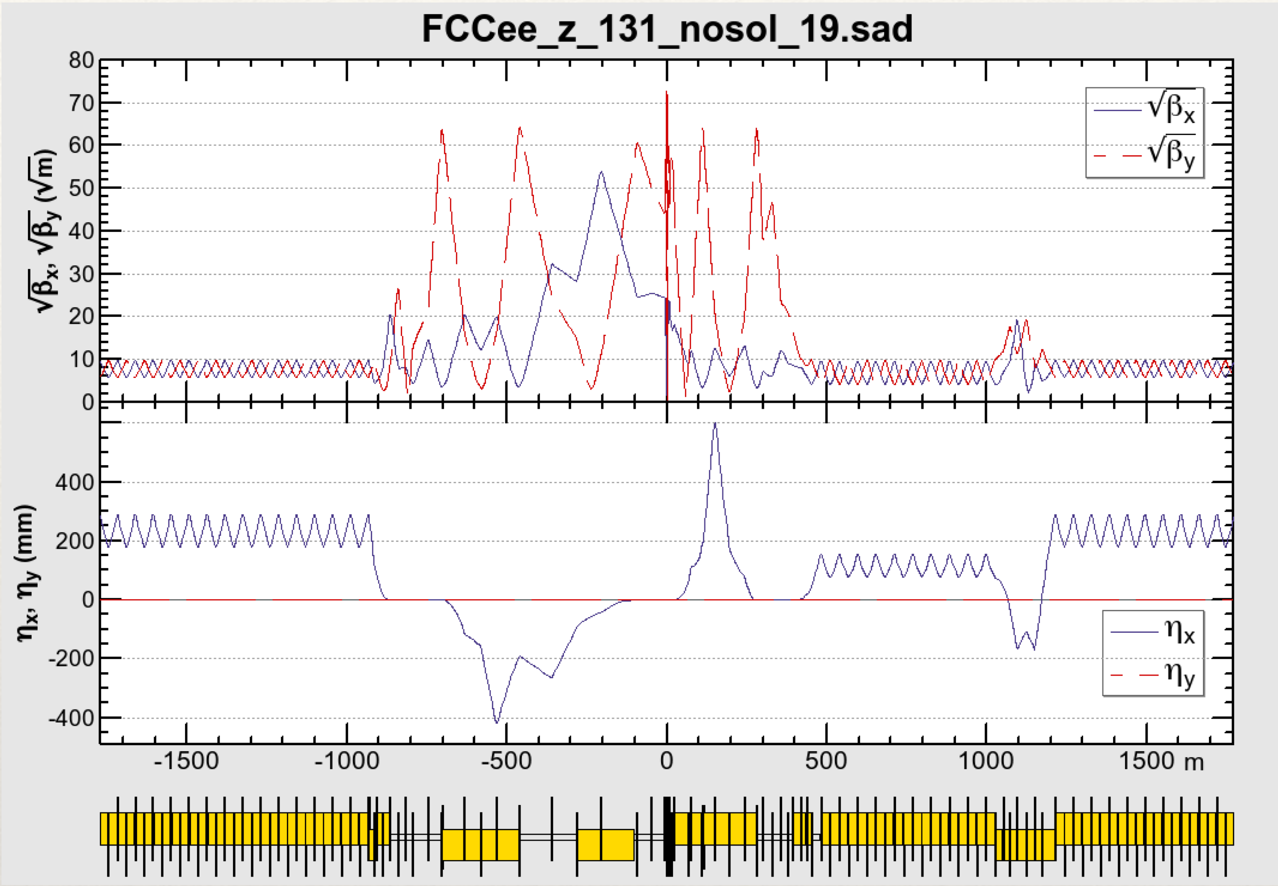
	L (m)	B′ @ tt (T/m)	B′ @ Z (T/m)
QC1R1	1.2	-99.9	-96.2
QC1R2	1	-99.9	+48.5
QC1R3	1	-99.9	+14.4
QC2R1	1.25	+77.6	+7.4
QC2R2	1.25	+77.6	+7.3

IR Optics

$90°, \beta_{x,y}^* = (1\ \text{m}, 2\ \text{mm})$ @ tt

$60°, \beta_{x,y}^* = (15\ \text{cm}, 1\ \text{mm})$ @ Z



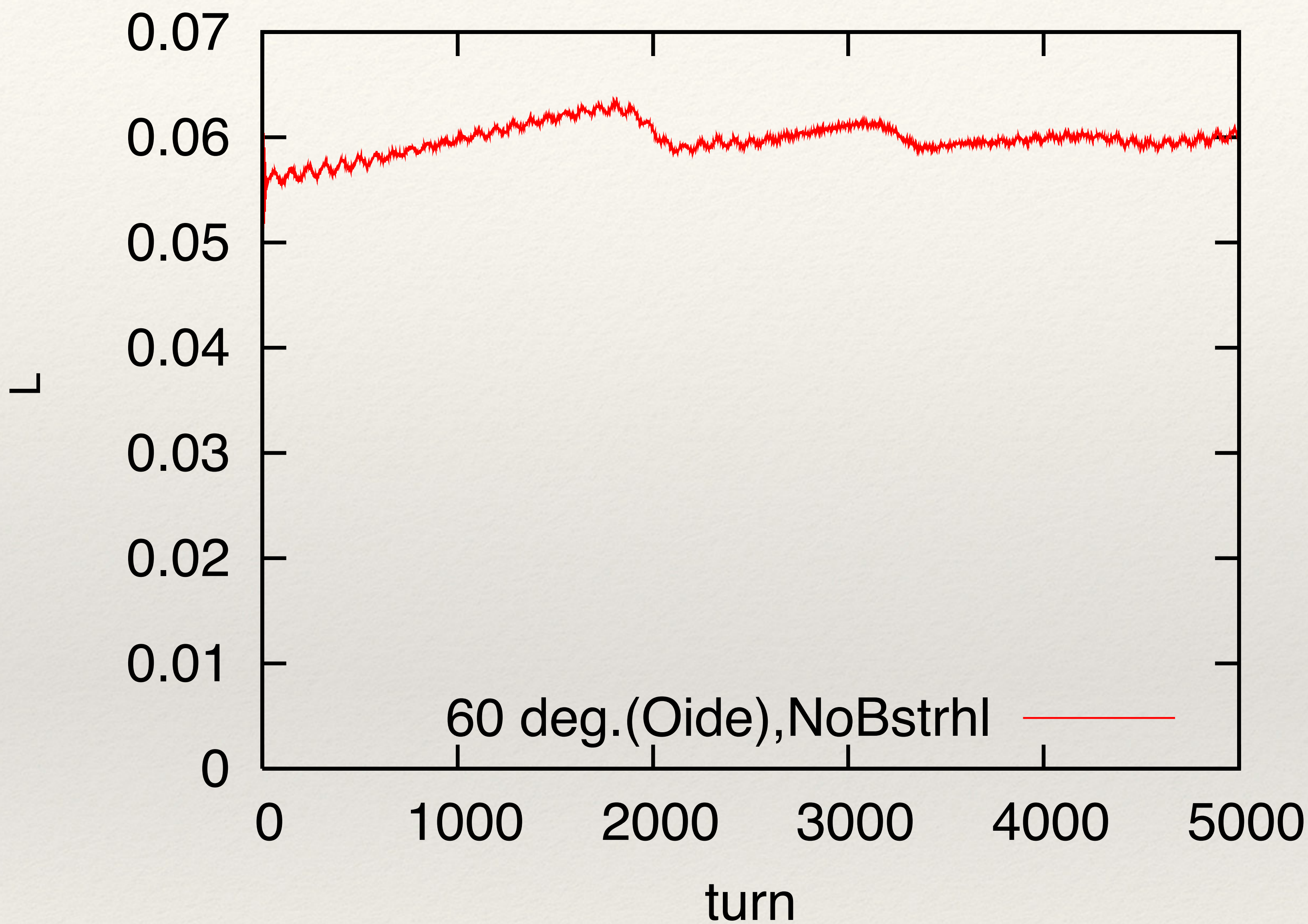


- Only quadrupole strengths are changed to rematch.
- Solenoids are temporarily removed.

Parameters at Z with the entire ring

Phase advance	60°	90°	
		low lumi	high lumi
Beam energy [GeV]	45.6		
$\beta^*_{x/y}$ [cm/mm]	15 / 1	100 / 2	50 / 1
ε_x [nm]	0.255	0.083	0.2
α_p [10-5]	1.465	0.717	
$\sigma_{\varepsilon 0}$ [%]	0.037		
σ_{z0} [mm]	3.6	2.4	
V_c [MV]	88.8	96.0	
$\nu_{x,y}$	265.14 / 267.22	387.08 / 387.18	
ν_z	-0.0234	-0.0172	
Beam current [A]	1.45		
# of bunches	73770	91500	30180
particles / bunch	4.0	3.2	9.8
Luminosity / IP [$10^{34}cm^{-2}s^{-1}$]	1.04	0.90	2.07

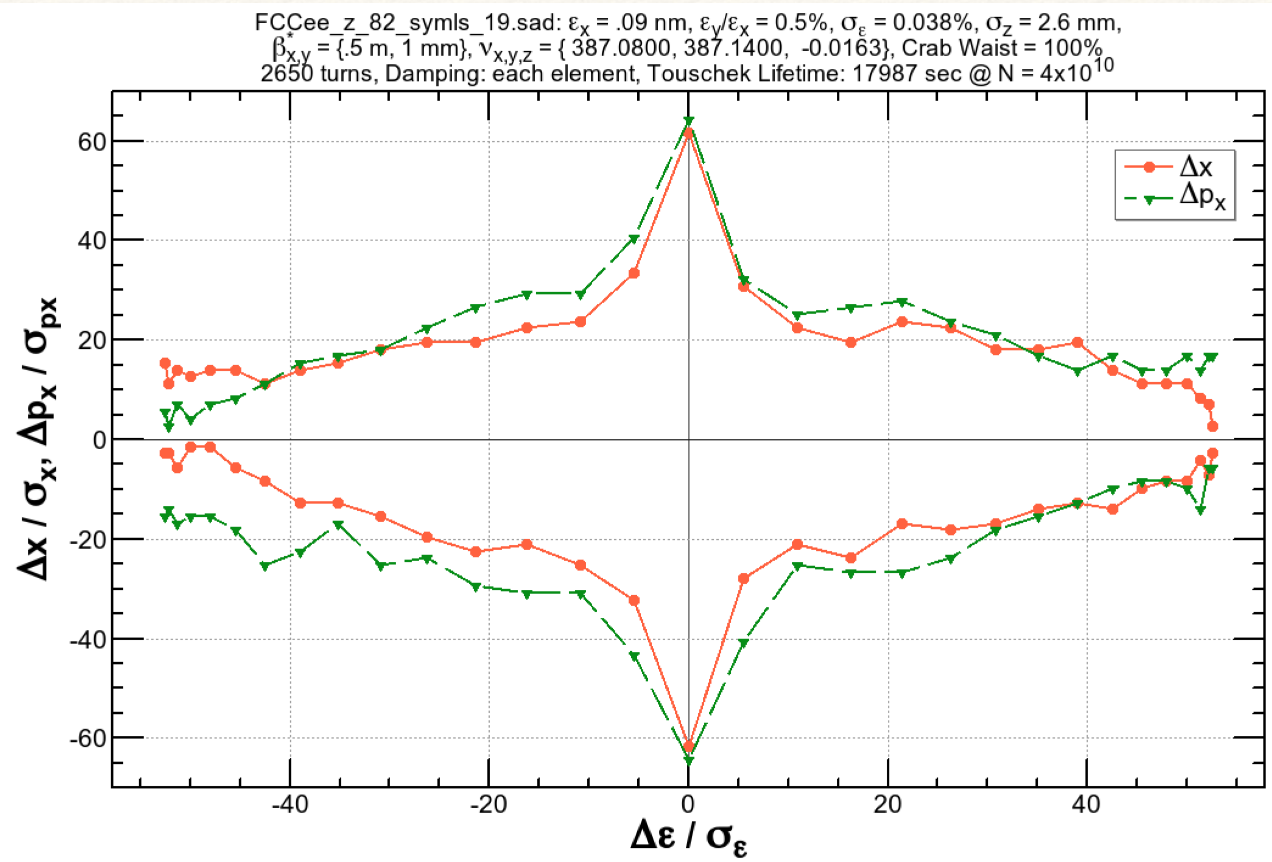
Check for the beam-beam stability (K. Ohmi)



- Above is without beamstrahlung, which relaxes the strong-strong instability.

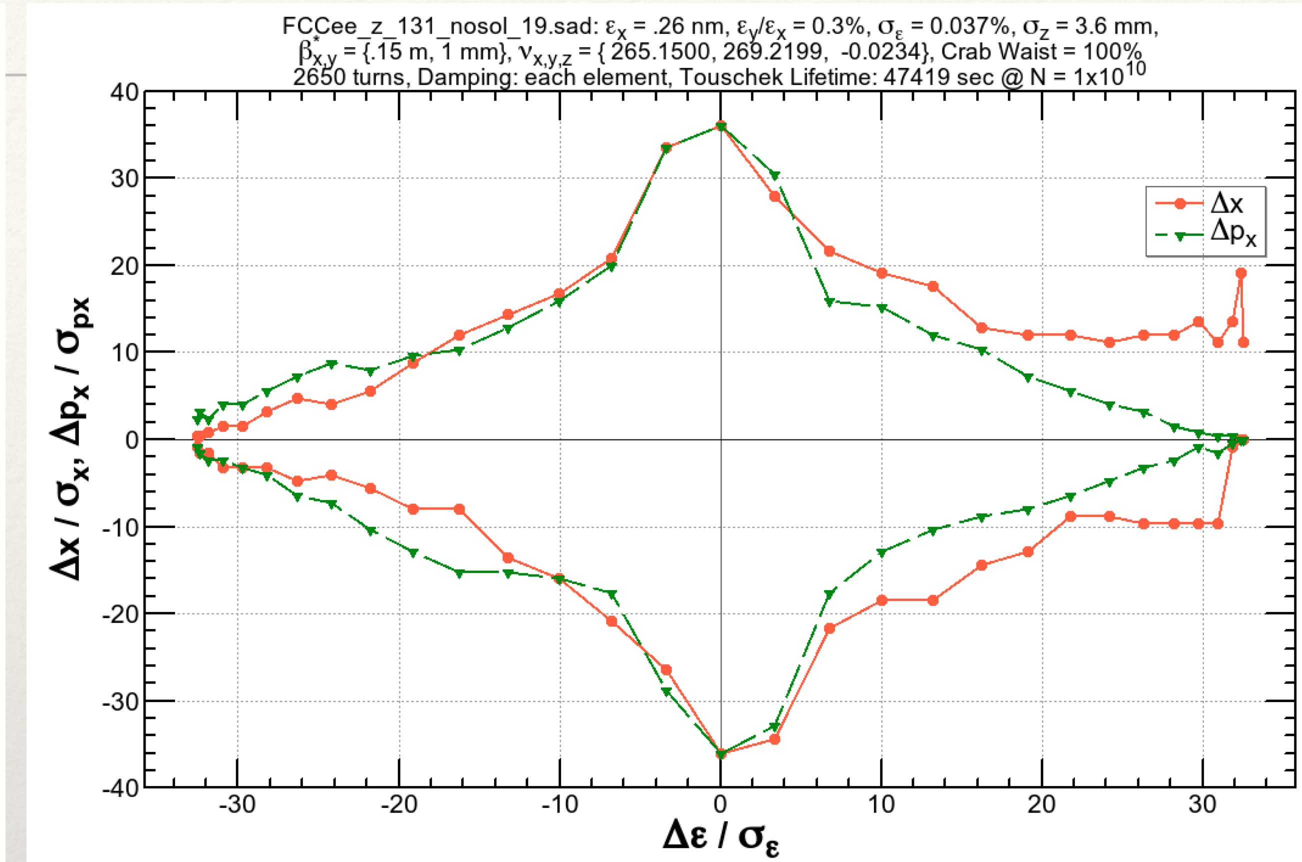
Dynamic Aperture

$\beta_{x,y}^* = (0.5\text{ m}, 1\text{ mm})$ @ Z



±2%

$\beta_{x,y}^* = (15\text{ cm}, 1\text{ mm})$ @ Z



±1.1%

- The momentum acceptance with $\beta_{x,y}^* = (15\text{ cm}, 1\text{ mm})$ @ Z has shrunk to ±1.1%, which is still allowable for beamstrahlung:

$$\sigma_{\varepsilon,\mathrm{BS}} = \sigma_{\varepsilon 0} \times \frac{\sigma_{z,\mathrm{BS}}}{\sigma_{z0}} = 0.037\% \times \frac{5.9\text{ mm}}{3.8\text{ mm}} = 0.057\%$$

$$\pm 1.1\% = \pm 19\ \sigma_{\varepsilon,\mathrm{BS}}$$

Summary

- A preliminary design of a lattice with 60° arc and $\beta_{x,y}^* = (15\text{ cm}, 1\text{ mm})$ to mitigate the strong-strong instability at Z has been presented.
- The lattice is compatible with 90° optics at higher energies, with additional ~500 sextupoles in the arc.
- Although the momentum acceptance with the 60° arc becomes ±1.1%, which is still sufficient for the beamstrahlung at Z.
- Now a synchrotron injection at Z becomes more difficult.
- Further optimization will be done by taking into account the way of division of QC1, common quads in the arc, new FCC-hh layout, etc.