Update on the booster design

Acknowledgements:

Thanks to F. Antoniou and T. Tydecks for their input!

18th FCCee Injector Meeting
16 March 2018

Bastian Haerer (CERN)
for the FCC-ee lattice design team

What is new?

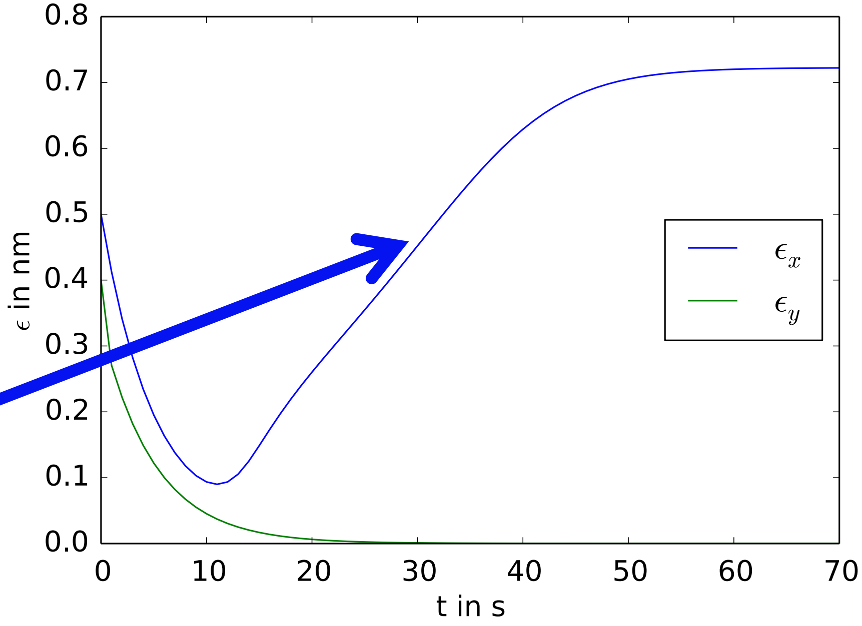
1. Updated wiggler designs
2. Emittance requirements (requested by Salim)
3. New lattice with 100 m long cells in the RF sections (requested by Frank)

1) Wiggler design: reminder

At 20 GeV beam energy

→ τ_x = 10.05 s

→ ε_x = 12 pm rad

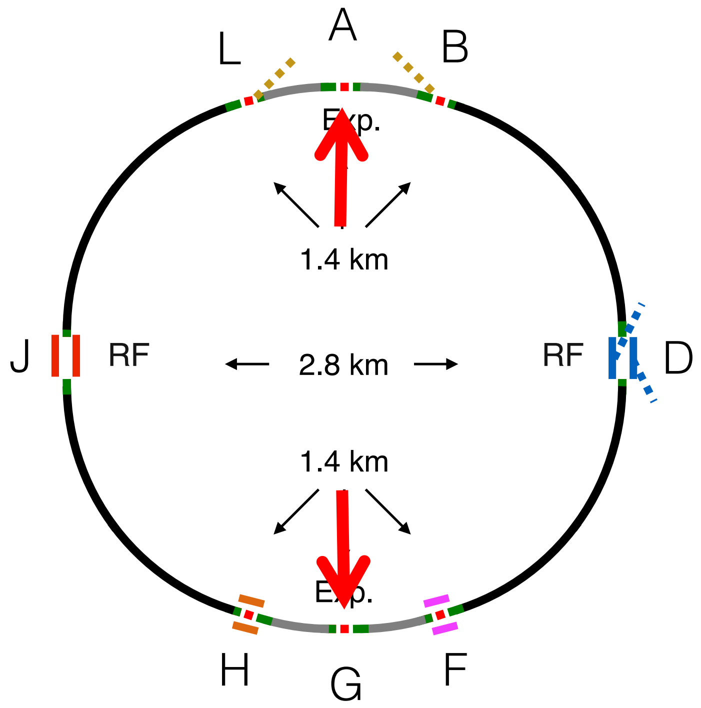


Emittance blow-up due to IBS

ε_x = 722 pm rad

≈ 48 × ε_x without IBS

First wiggler design

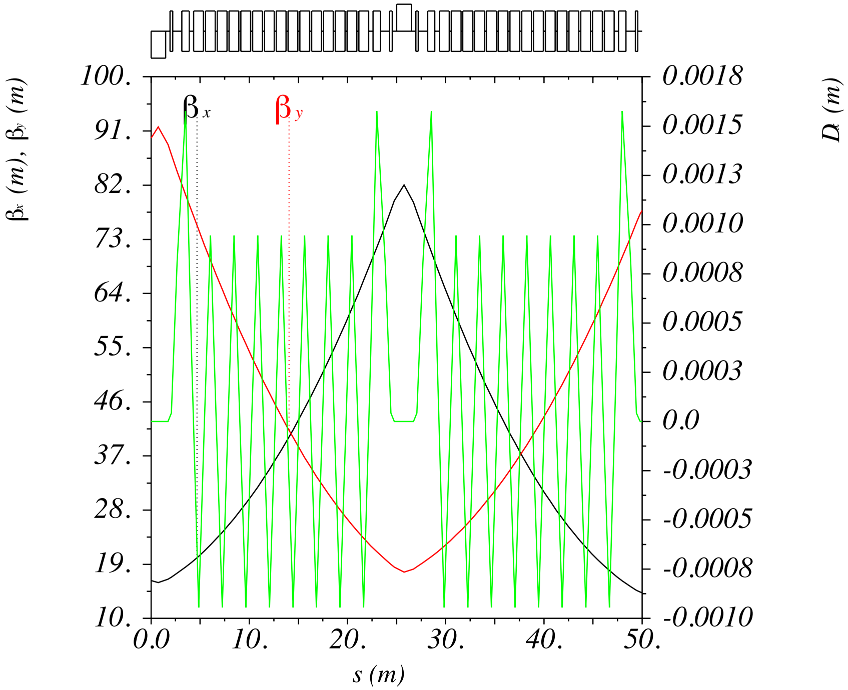


Two purposes:

1. Decrease the damping time
2. Increase the equilibrium emittance

Wiggler length:	22.6 m
Magnetic field:	0.36 T
Number of poles:	19
Pole length:	1 m
Number of wigglers:	112

First wiggler design



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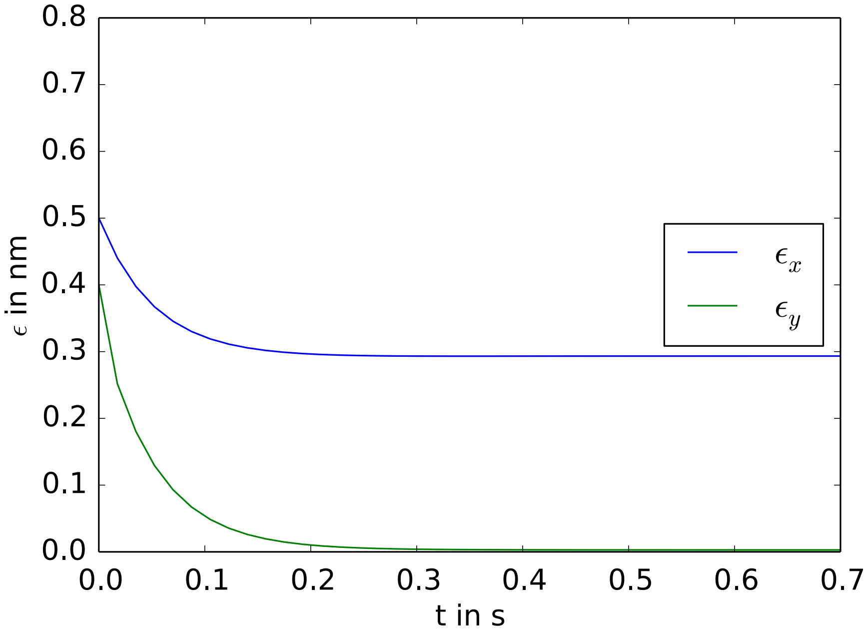
Emittance evolution with wigglers



New damping time: τ_x = 104 ms
New eq. emittance: ε_x = 292 pm rad

Emittances after 7 damping times:
ε_x = 293 pm rad
≈ 1.005 × ε_x without IBS
ε_y = 2.93 pm rad
≈ 1.000 × ε_y without IBS*

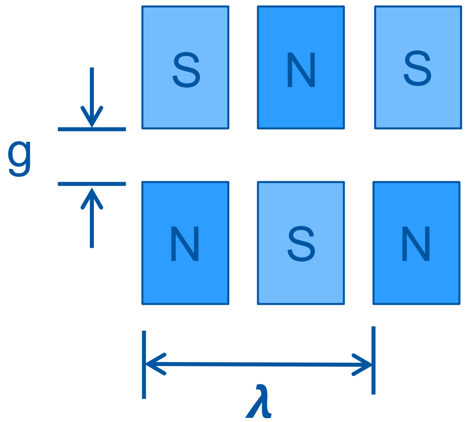
* assuming 1 % coupling

Optimised wiggler design

- Reduce number of wigglers

  → Magnetic pole tip field of 1.8 T

$$B_{\text{pole}} = B_{\text{wiggler}} \cosh\left(\pi \frac{g}{\lambda}\right)$$

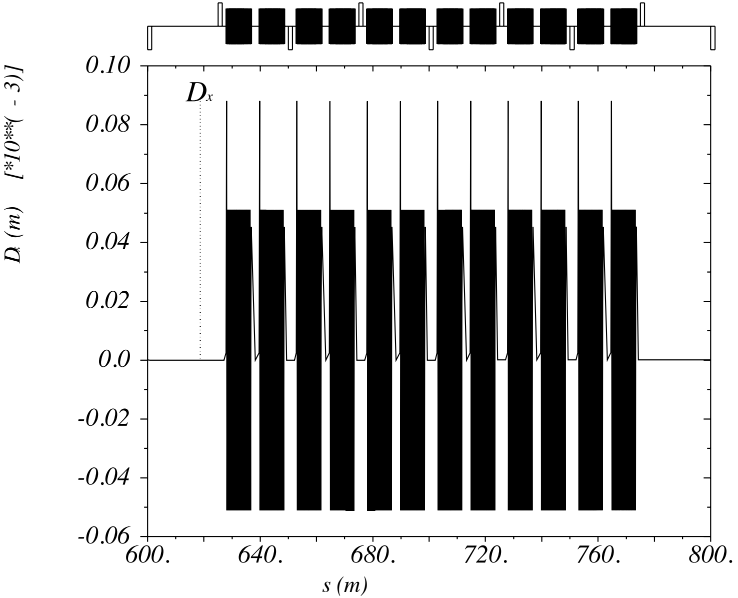


- Two new designs proposed:

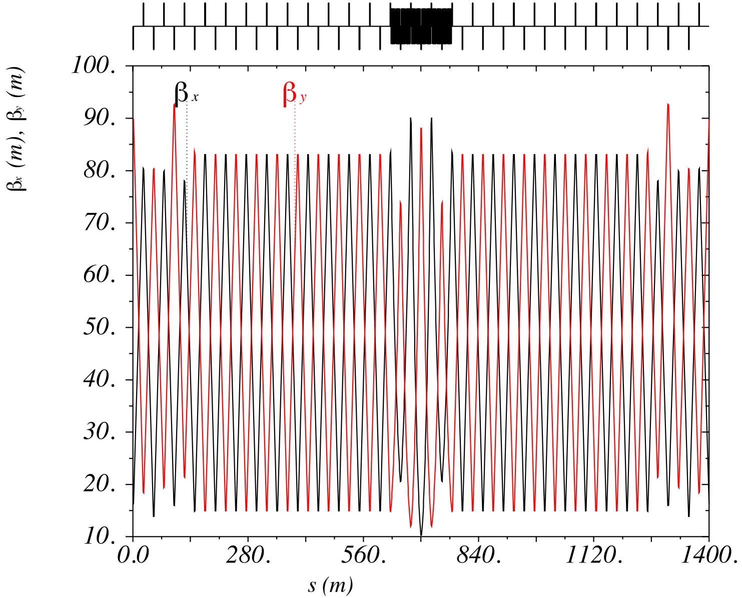
  → g = 100 mm

  → g = 50 mm (would require smaller vacuum chamber)

Optics with 12 wigglers (g = 100 mm)



Dispersion created by wigglers



Re-matched optics

Comparison of parameters

		g = 100 mm	g = 50 mm	
B_{pole}	(T)	1.8	1.8	
$B_{wiggler}$	(T)	1.15	1.45	
L_{pole}	(cm)	13.5	9.5	
L_{gap}	(cm)	2	2	
# poles		59	79	
L	(m)	9.125	9.065	(22.6 m)
# wigglers		24	16	(112)
τ_x	(s)	0.1	0.1	
ε_x (90°/90°)	(pm rad)	240	235	
ε_x (60°/60°)	(pm rad)	185	182	

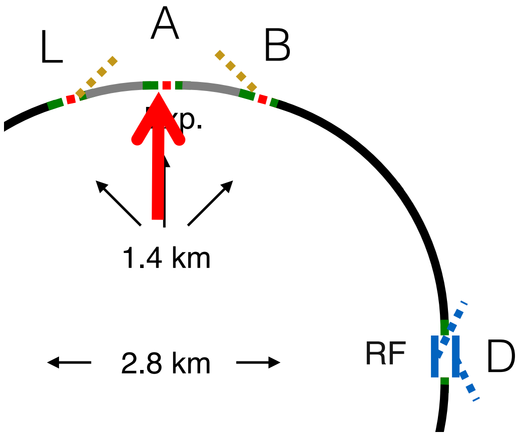
2) New dynamic aperture studies

What is different to the previous studies presented on 6 October 2017?

The new studies include

- radiation and quantum excitation
- 150 µm quadrupole misalignments
- 55 µm resolution

and were performed for 20 GeV beam energy at the beginning of the straight section A



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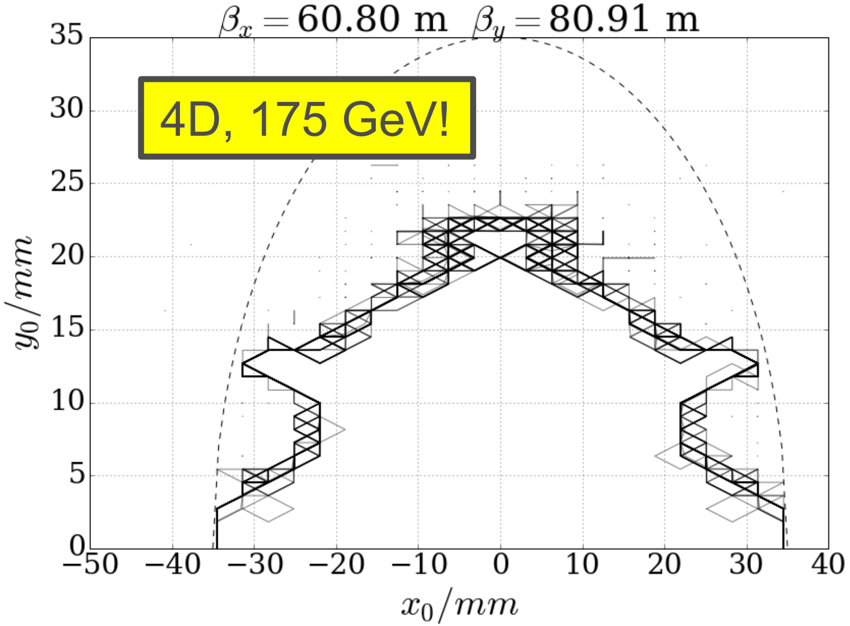
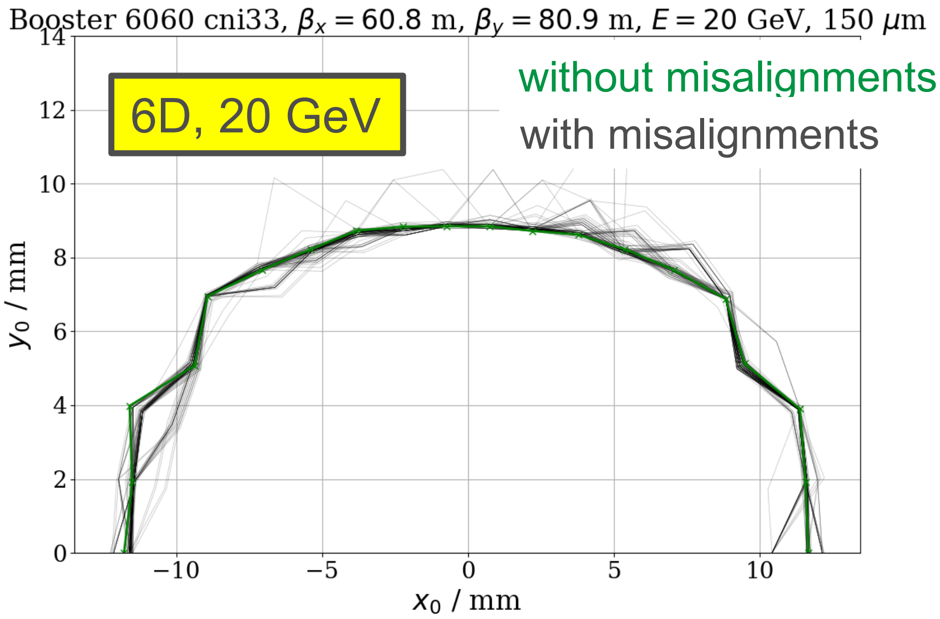
60°/60° optics

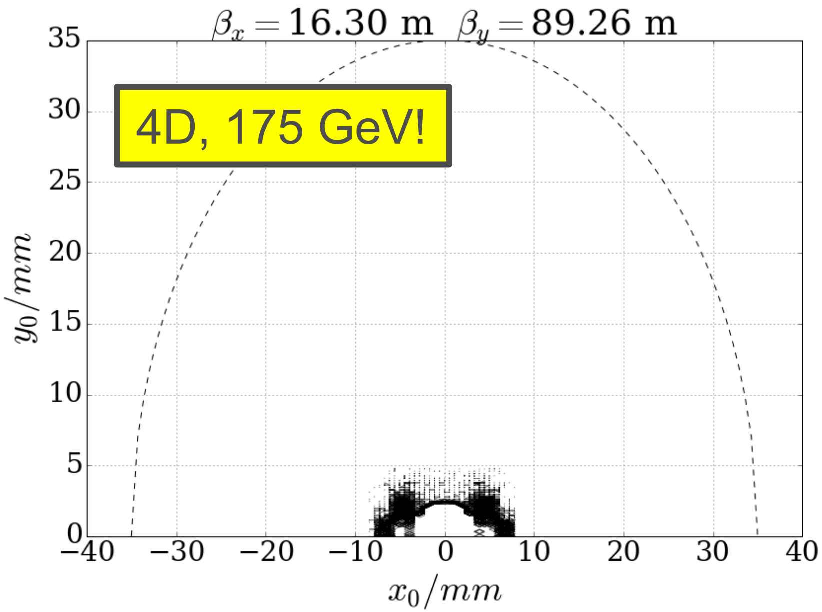


5 October 2017

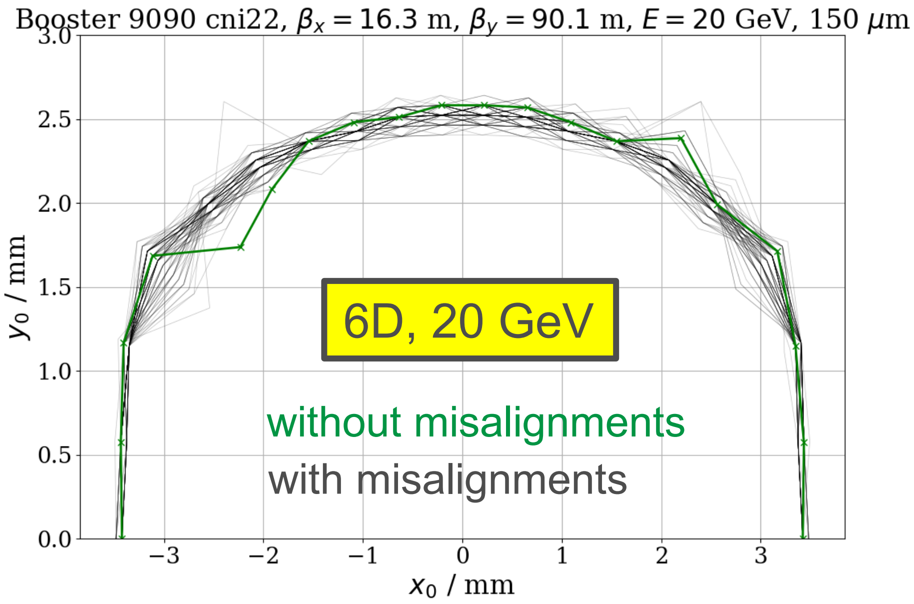


14 March 2018

90°/90° optics



5 October 2017



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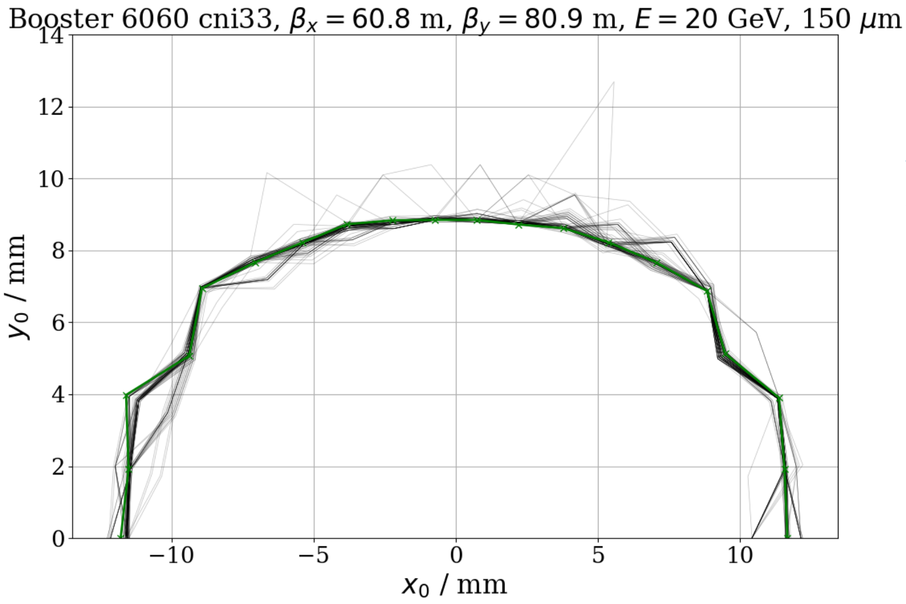
Emittance requirements for 60°/60° optics



- DA should be 15 σ

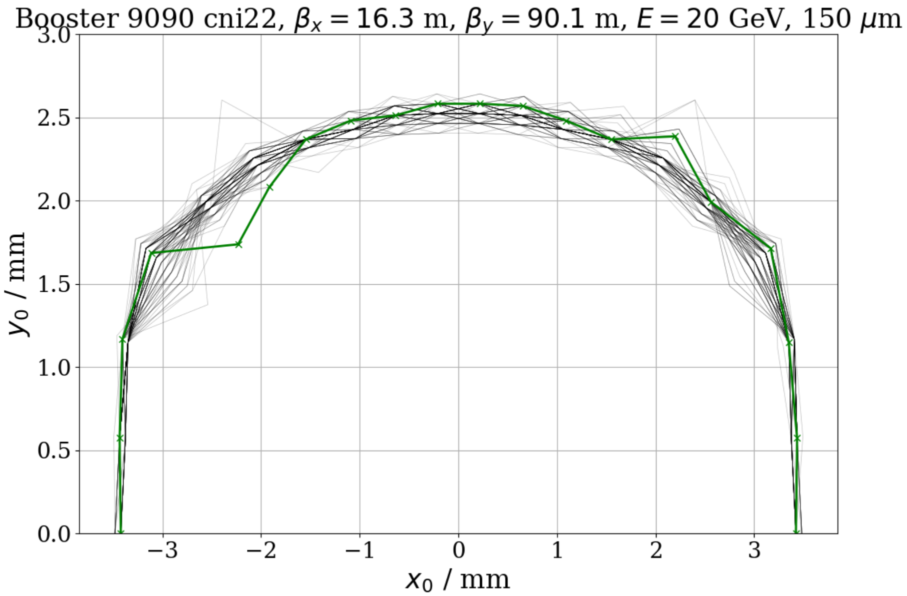
x_{max} = 12.5 mm → $\sigma_{x,max}$ = 834 µm

y_{max} = 8.75 mm → $\sigma_{y,max}$ = 584 µm

$$\sigma_u = \sqrt{\epsilon_u \beta_u}$$

- with β_x = 60.8 m, β_y = 80.9 m
  → $\varepsilon_{x,max}$ = 11.4 nm rad
  → $\varepsilon_{y,max}$ = 4.2 nm rad

Emittance requirements for 90°/90° optics



- DA should be 15 σ

x_{max} = 3.5 mm → $\sigma_{x,max}$ = 233 μm

y_{max} = 2.5 mm → $\sigma_{y,max}$ = 167 μm

$$\sigma_u = \sqrt{\epsilon_u \beta_u}$$

- with β_x = 16.3 m, β_y = 90.1 m
  - → $\varepsilon_{x,max}$ = 3.4 nm rad
  - → $\varepsilon_{y,max}$ = 0.3 nm rad

Discussion

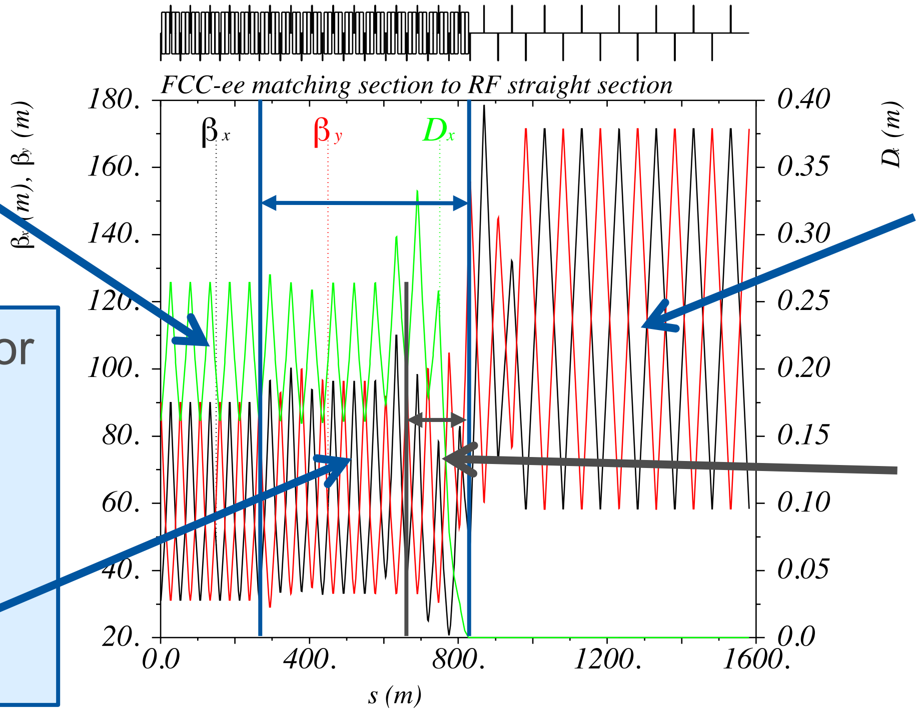
The emittance requirements are not compatible with current pre-booster

Possible solutions:

- Reduce emittance of pre-booster (cell length, circumference, wiggler)
- Discard 90°/90° optics of booster
- Change lattice of booster (60°/60° emittance fits collider 90°/90° collider emittance)
- Relax DA demand: 15 σ → 10 σ? (90°/90° optics: $\varepsilon_{x,max}$ = 8.75 nm rad)

3) New lattice with longer cells in RF sections

Arc FODO cells
L ≈ 54 m
R = 13.15 km



FODO cells
L = 100 m

Dispersion suppressor of hadron machine:
→ L = 566 m
→ R = 15.06 km

10 FODO cells
L ≈ 56.6 m

Quadrupole based dispersion suppressor

60°/60° optics

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New lattice: further remarks

- The new lattice is still under construction
- There will of course be a 60°/60° optics and a 90°/90° optics
- The lattice will follow FCC-hh footprint with 1.26 m offset

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Thank you for your attention!