PRELIMINARY DESIGN STUDY of a Pre-Booster DAMPING RING for the FCC e^+e^- INJECTOR

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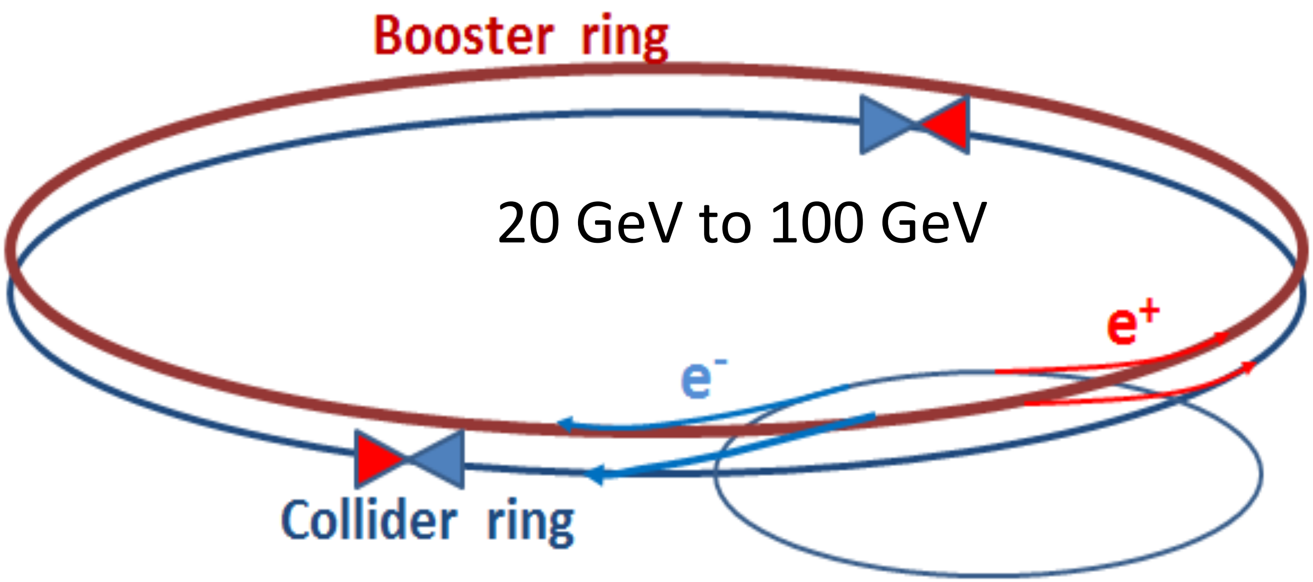
Outline

- Why an alternative Design?
- Parameter scaling
- Some Calculations for general design parameters
- Preliminary Lattice Design
- Straight Sections
- Phase advance-choromaticity-emittance
- Sextupole magnets and dynamic aperture
- Future Study

Alternative Damping Ring Synchrotron Design



- Linac,
- SPS as pre-booster,
- Alternative pre-booster design,
- Booster same tunnel with main ring,
- Collider ring.

around 10 Gev to 20 GeV

- Present design considers SPS as Pre-Booster Damping Ring (PPDR) but issues with:
  - machine availability, synchrotron radiation, new RF system…
- This is why a "green field" alternative design is interesting

Parameter space

Scaling of important parameters impacting machine layout;

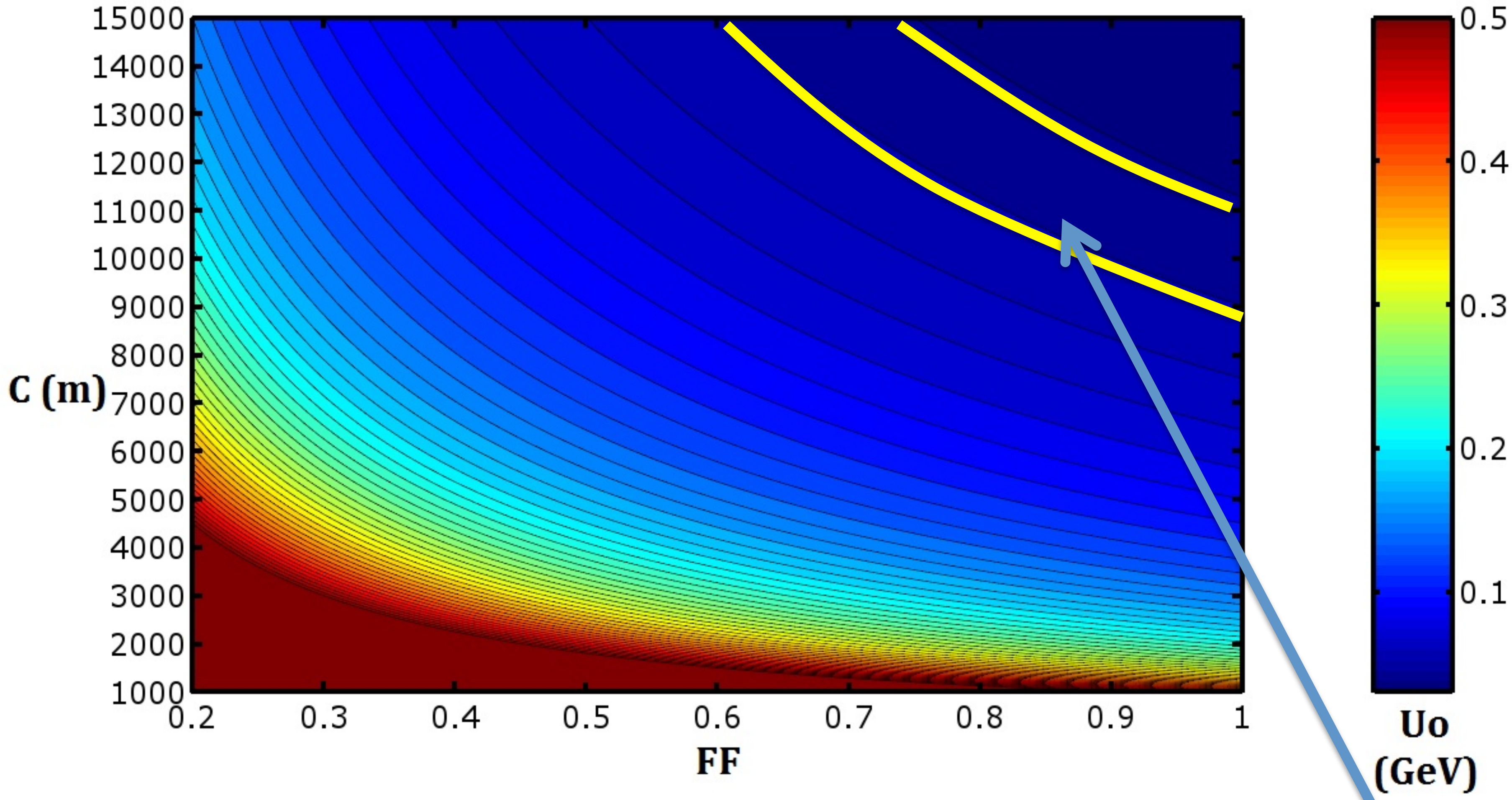
- Energy loss per turn → $U_0 = \frac{2\pi . C_\gamma . E^4}{FF . C}$
- Damping times → $\alpha_s = \frac{E^3 . c . C_\gamma}{FF^2 . C^2}$
- Energy spread → $(\sigma_s)^2 = \frac{C_q . \gamma^2 . 2\pi}{FF . C}$
- Emittance → $\varepsilon_s = \frac{F_{lattice} . C_q . \gamma^2 . (2\pi)^3 . l^3}{FF^3 . C^3}$

Filling Factor

↓

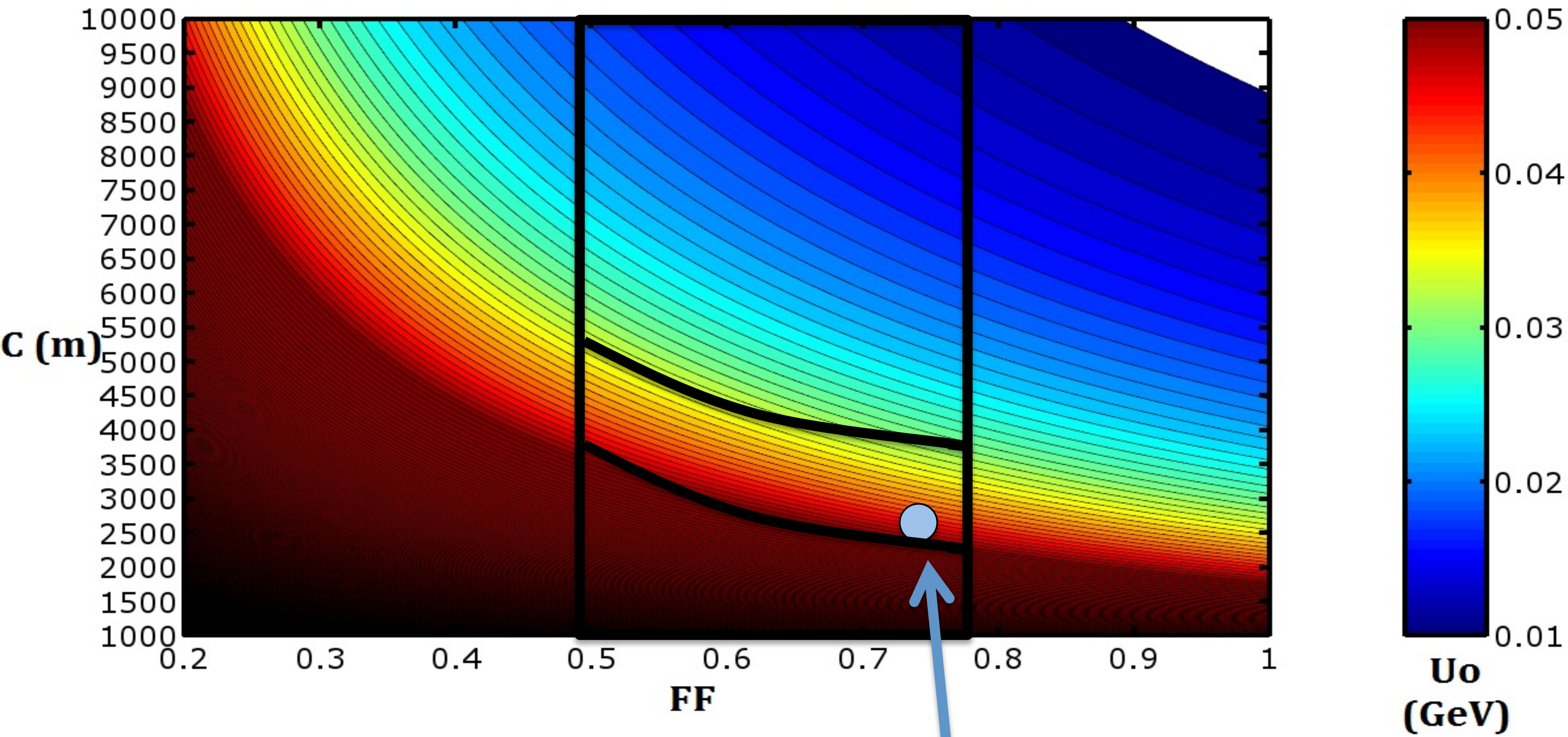
$$FF = \frac{N . l}{C}$$

Energy Loss Per Turn (30 GeV)



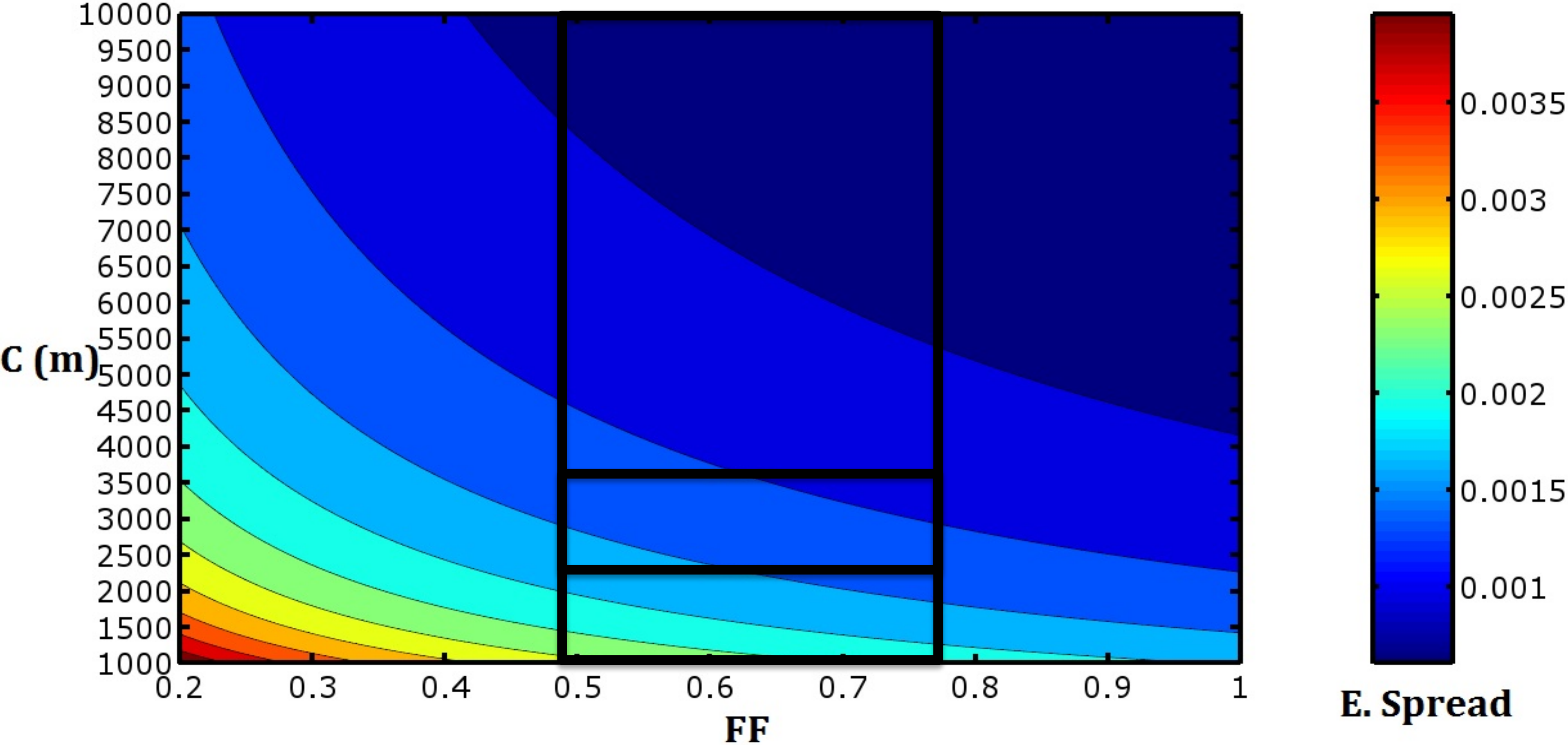
- Scaling of Energy loss/turn with filling factor and circumference
- For 30 GeV, the area below 50MeV/turn is for very high filling factors and circumferences

Energy Loss Per Turn (20 GeV)



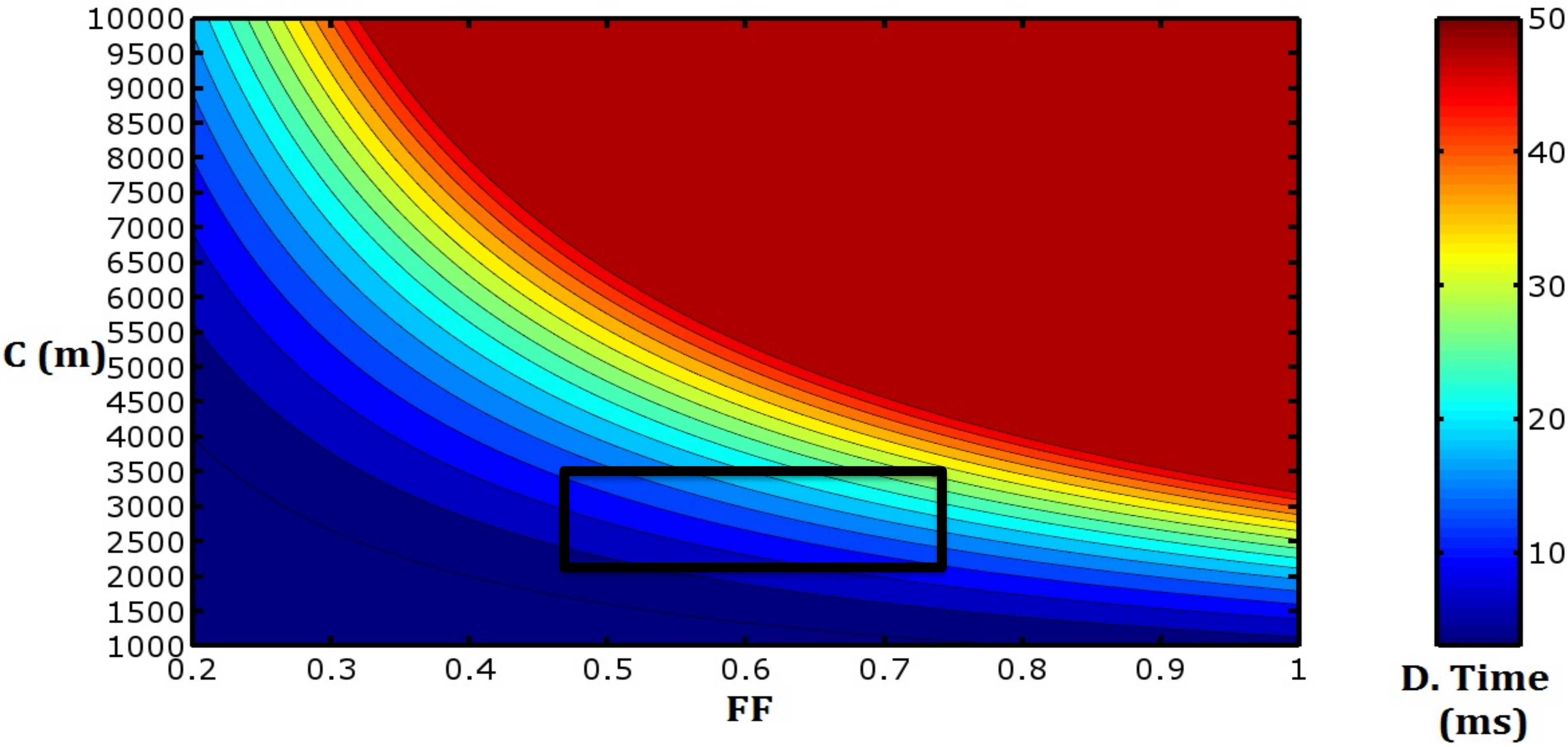
- Scaling of energy loss/turn with filling factor and circumference
- For 20 GeV, the area below 50MeV/turn is wide
- The lowest circumference of around 2.5km is for high filling factors of around 0.7

Energy Spread (20 GeV)



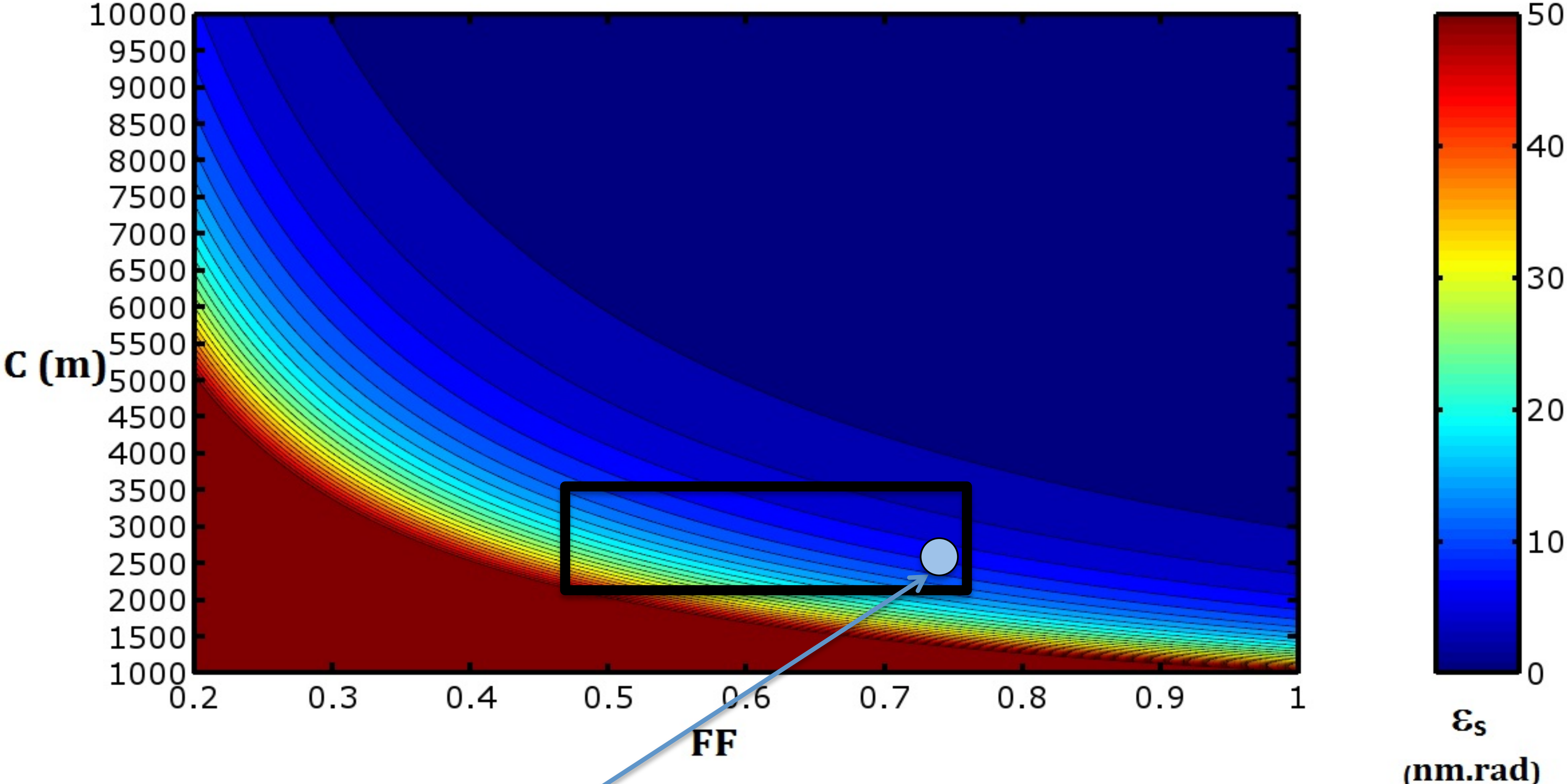
- Scaling of energy spread with filling factor and circumference
- For the area we remarked before, this does not vary so much.

Damping Time (20 GeV)



- Scaling of damping time with filling factor and circumference
- For the area we remarked before, the values are acceptable and does not vary so much.

Emittance (20 GeV)



- For the area we remarked before, the values are nice for emittance.
- It is around 10 nm.rad on the point for around FF:0.7 and C:2.5km

Assumptions and Basic Calculations for Lattice

U=50 000 keV; max Uo for min. C
E= 20 GeV

$$U(keV) = 26{,}5.E^3(GeV).B(T)$$

B = 0.235 T;

FF.C= $N.l_d$ *= 1777.69*

$$U_0 = \frac{2\pi.C_\gamma.E^4}{FF.C}$$

ε_s*= 10 nm.rad*
E= 20 GeV

$$\mathcal{E} = 10^{-11}.E^2(GeV).\theta^3(\mathrm{deg})$$

Θ*=1.357*^{0} → *N= 266*

$$N.l.B = 2\pi.\frac{P}{q}$$

l_d= 6.68 m

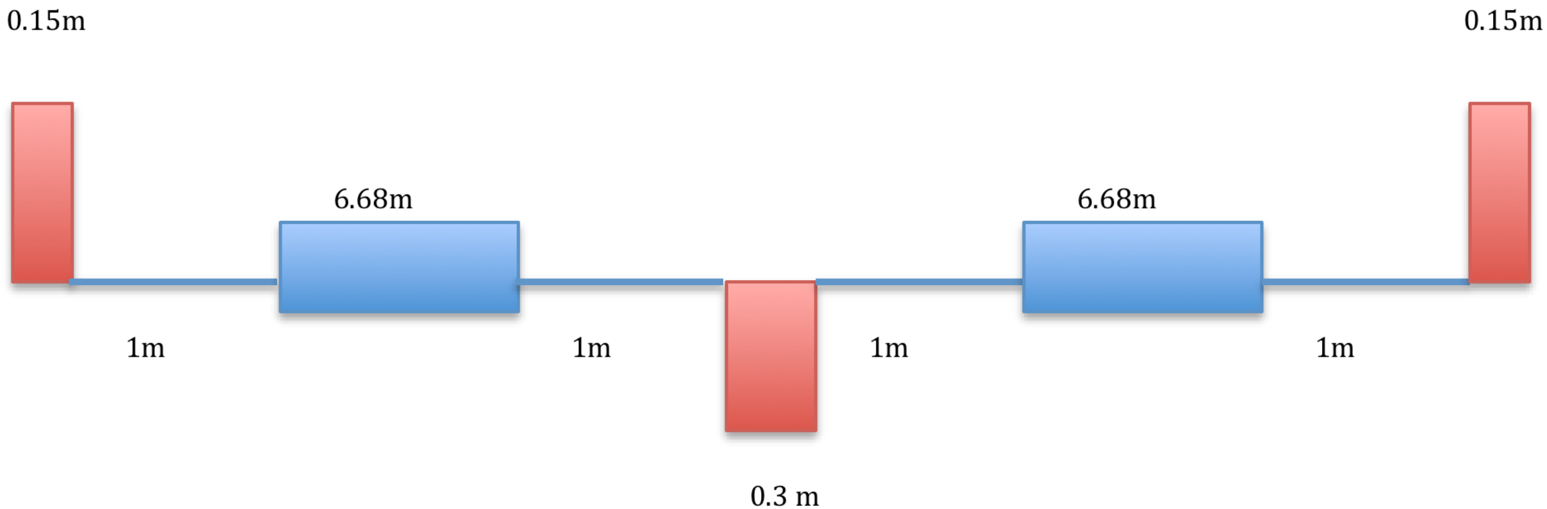
$Sin(\mu/2)=L_{cell}/4f$, *k=1/k.lq*

$\mu=140^0$
lq=0.3m

→

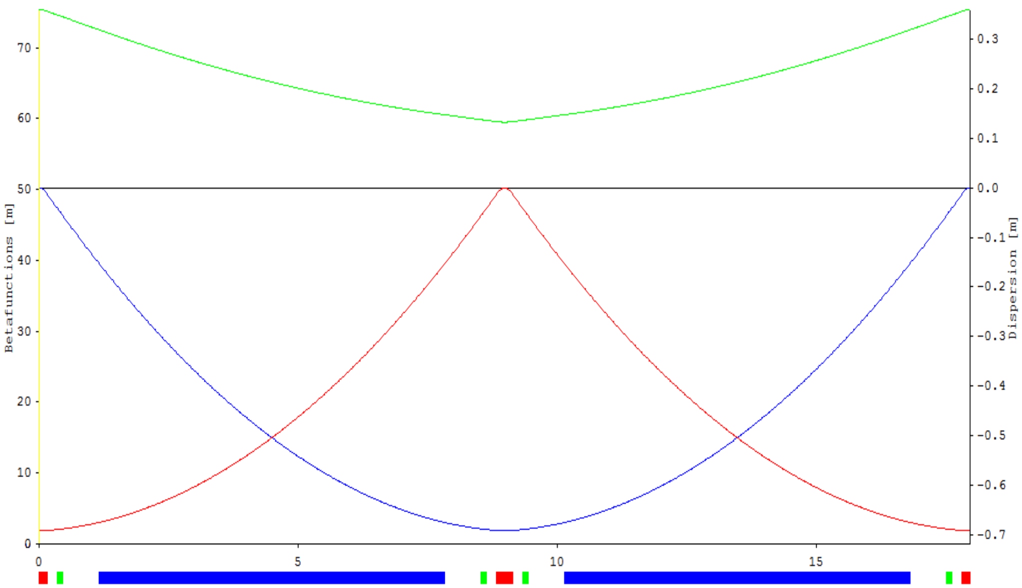
f= 4.7781
k=+-0.697627 m-2

FODO Lattice



L_{cell}	17.96 m
C	2388.68 m
FF	0.74
U_0	50 MeV
B_{max}	0.235 T
ε	10 nm.rad
Θ	1.35^0
l	6.68 m

Betatran Functions of FODO Cell



	6 GeV	20 GeV
C (m)	2388.68 m	2388.68 m
Emittance (nm.rad)	0.674	11.965
E. Spread	0.277	1.019
Chrom X	-124.487	-106.562
Chrom Y	-124.351	-106.402
Uo (keV)	331.9	50045.2
TauX (ms)	347.861	6.373
TauY (ms)	347.664	6.368
TauE (ms)	173.783	3.183

- Sextupole magnet need to be used,
- DA should be checked.

Phase Advance, Emittance-Chromaticity

Important parameters to be chosen;

$\epsilon_{fodo} = F_{fodo}\, C_q \gamma^2 \theta^3$ → Emittance

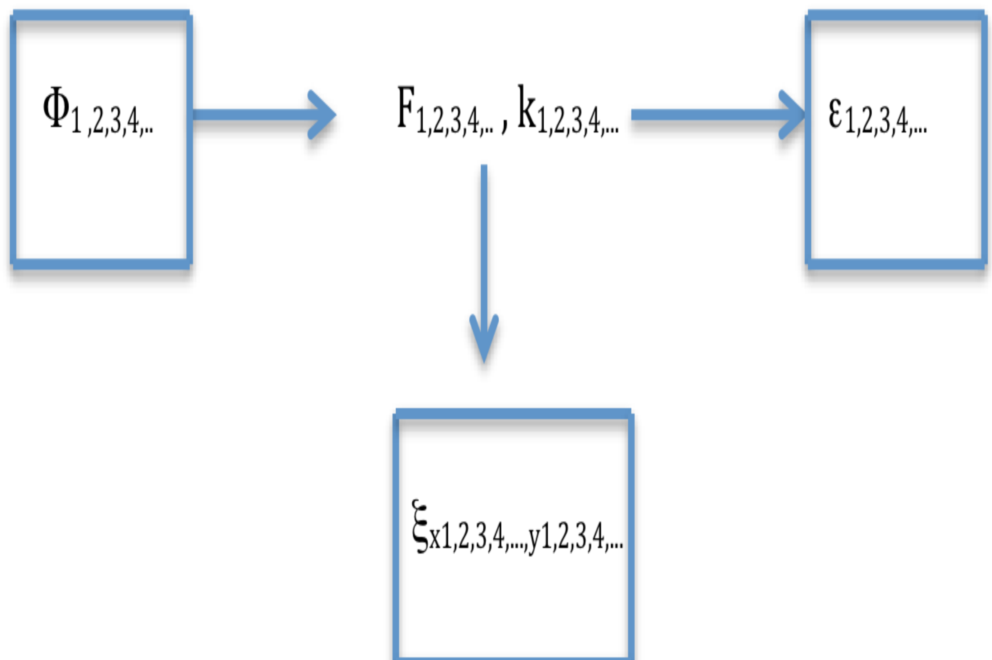
$$F_{fodo} = \frac{1 - \frac{3}{4}\sin^2(\emptyset/2)}{\sin^3(\emptyset/2)\cos(\emptyset/2)} J_x^{-1}$$

$$\xi_{x0} = -\frac{1}{4\pi}\oint \beta_z k d_z$$

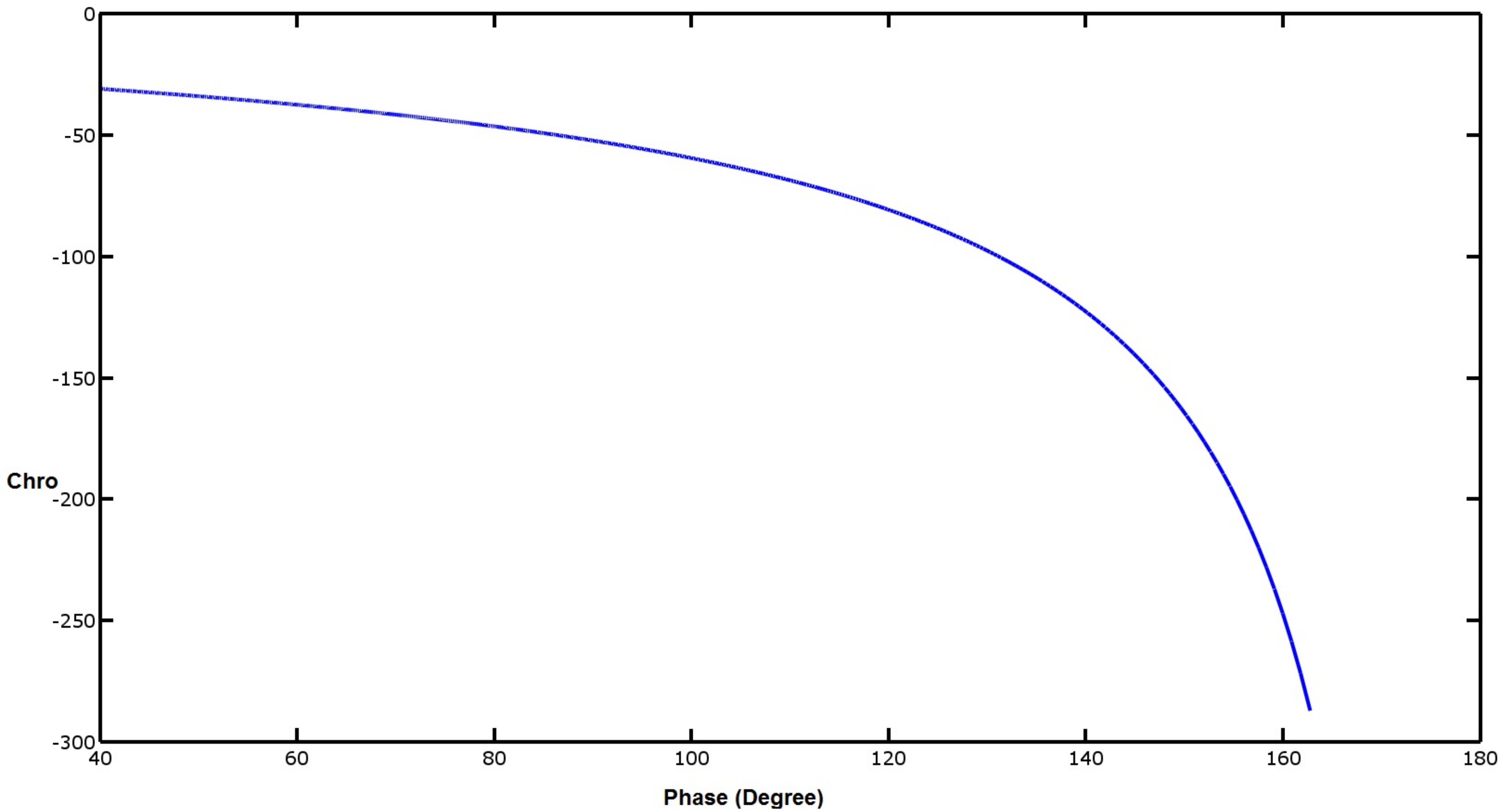
$$\xi_{y0} = \frac{1}{4\pi}\oint \beta_y k d_z$$

→ Chromaticity

$\emptyset = arc(1/2\ trace\ (M))$ → Phase

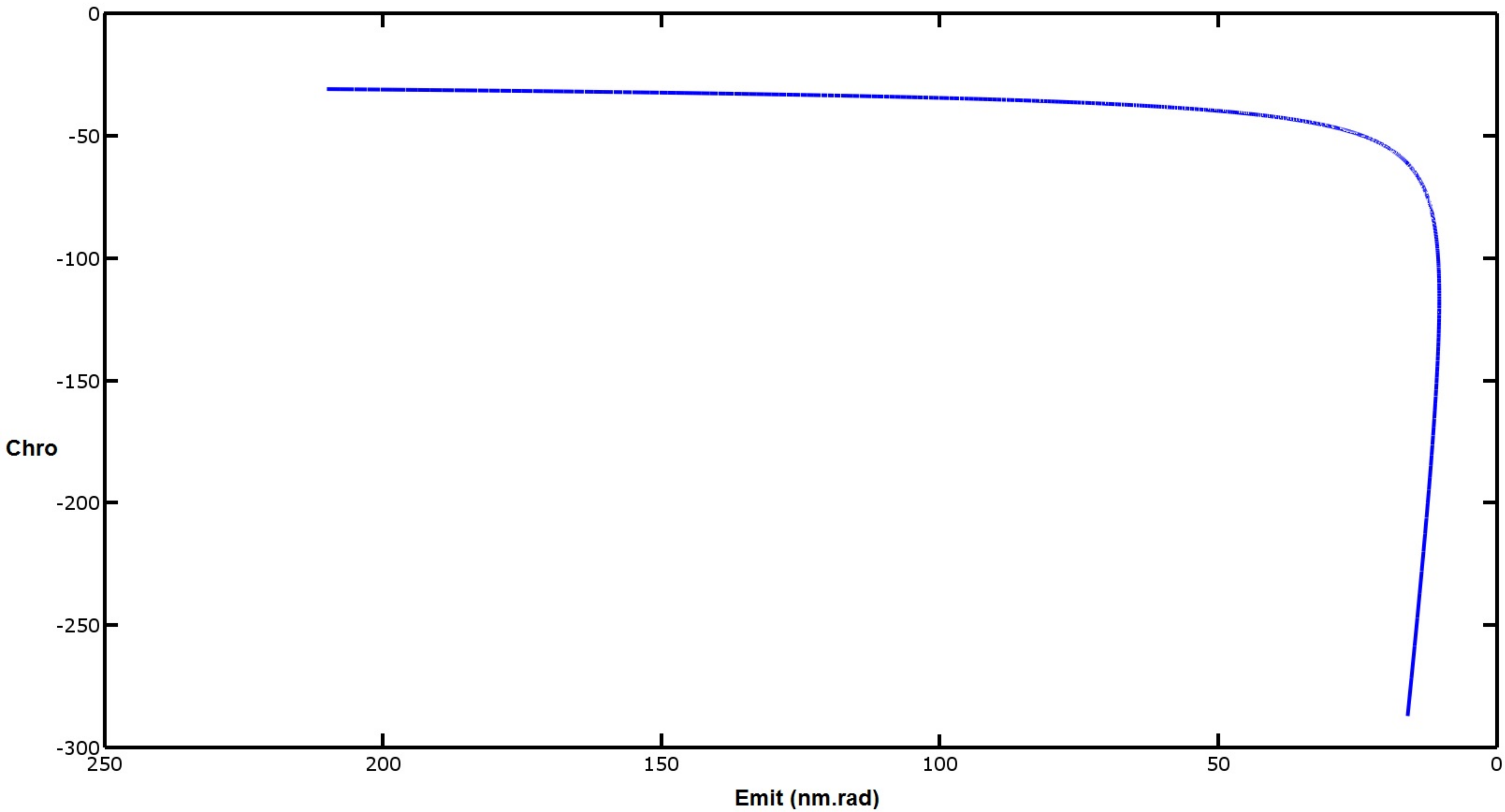


Choromaticity-Phase Advance-Emittance



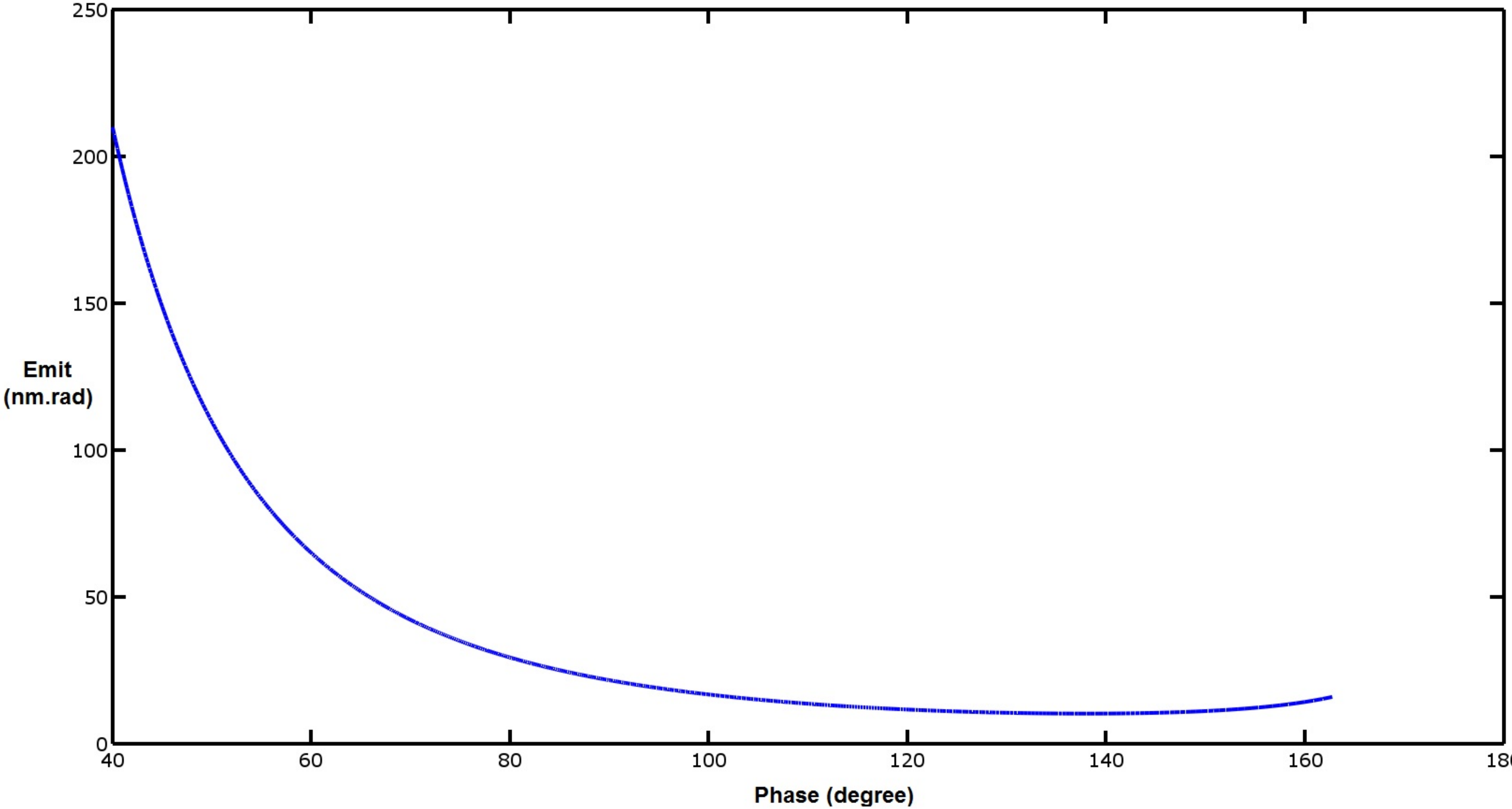
- Scaling of phase with choromaticity

Choromaticity-Phase Advance-Emittance



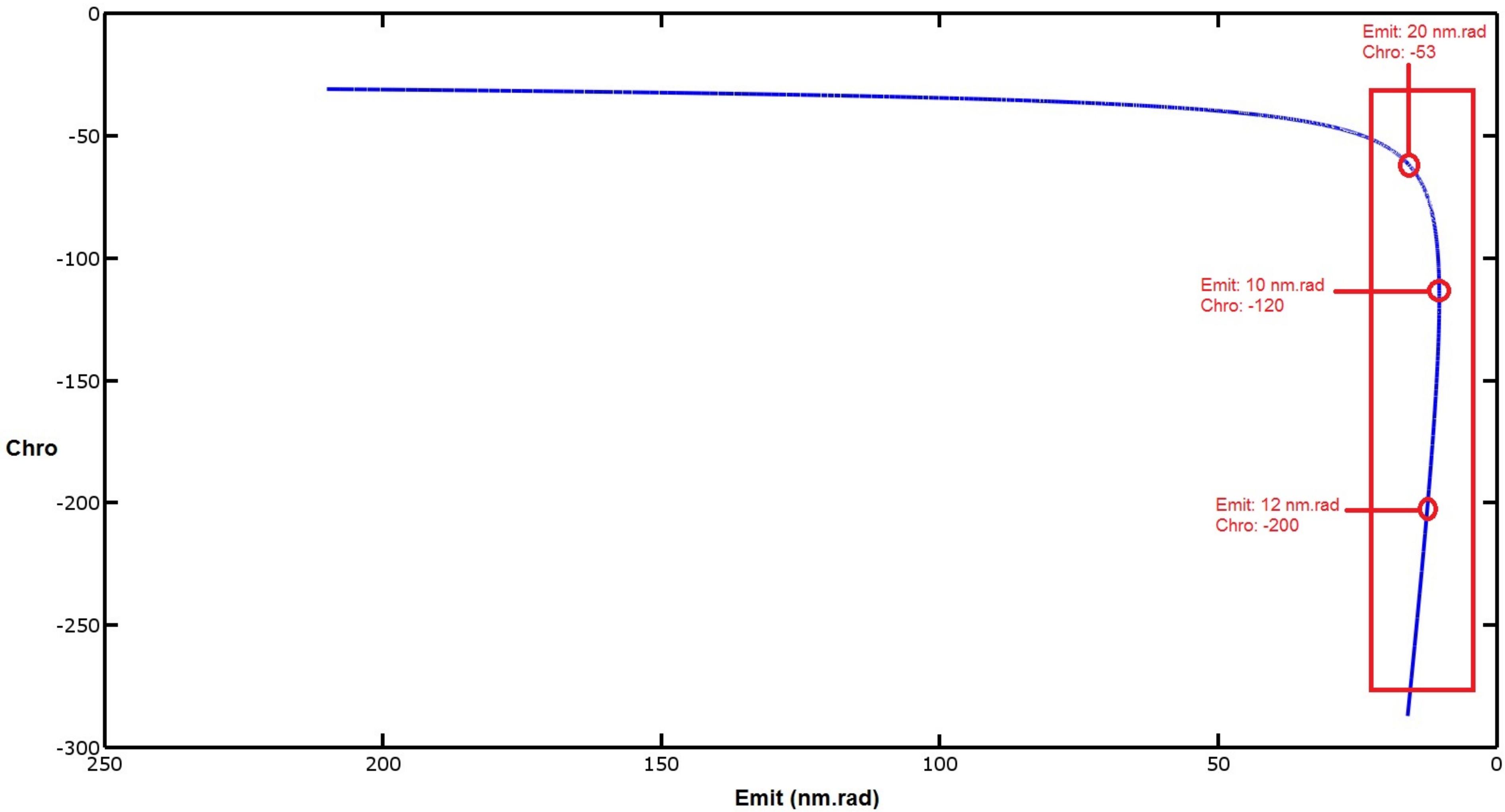
- Scaling of emittance with choromaticity

Choromaticity-Phase Advance-Emittance



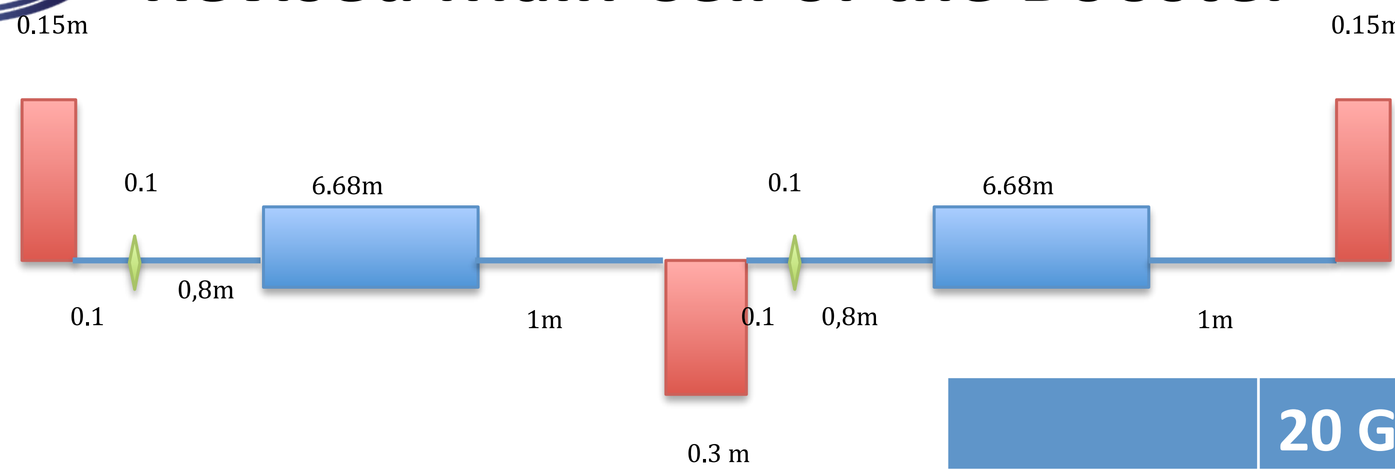
- Scaling of phase with emittance

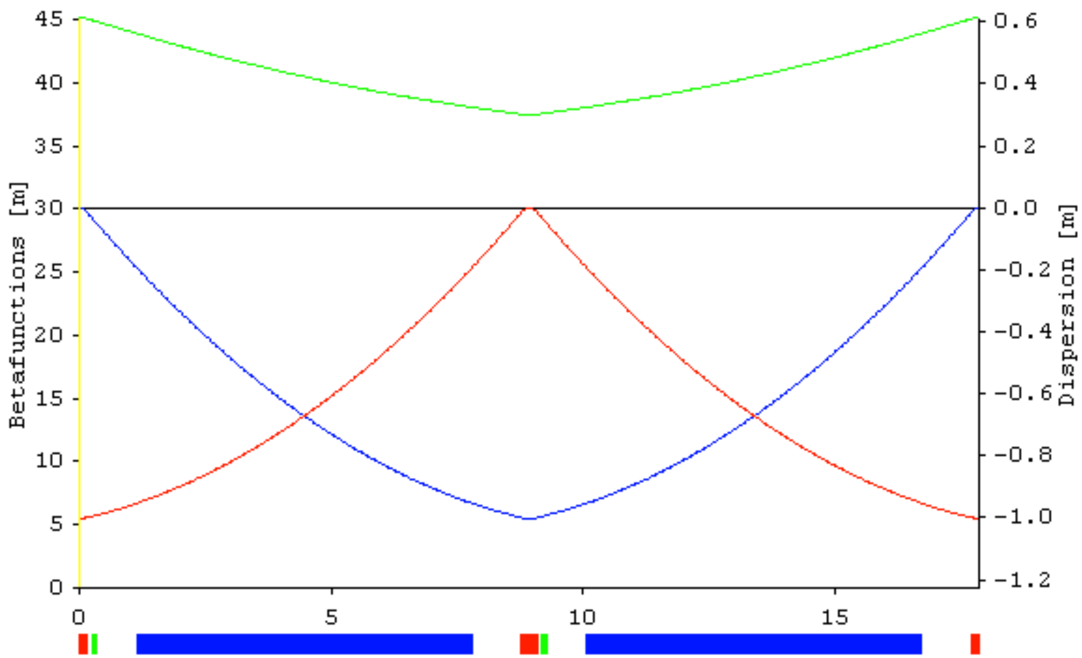
Choromaticity-Phase Advance-Emittance



- Scaling of emittance with choromaticity on specified points

Revised Main Cell of the Booster

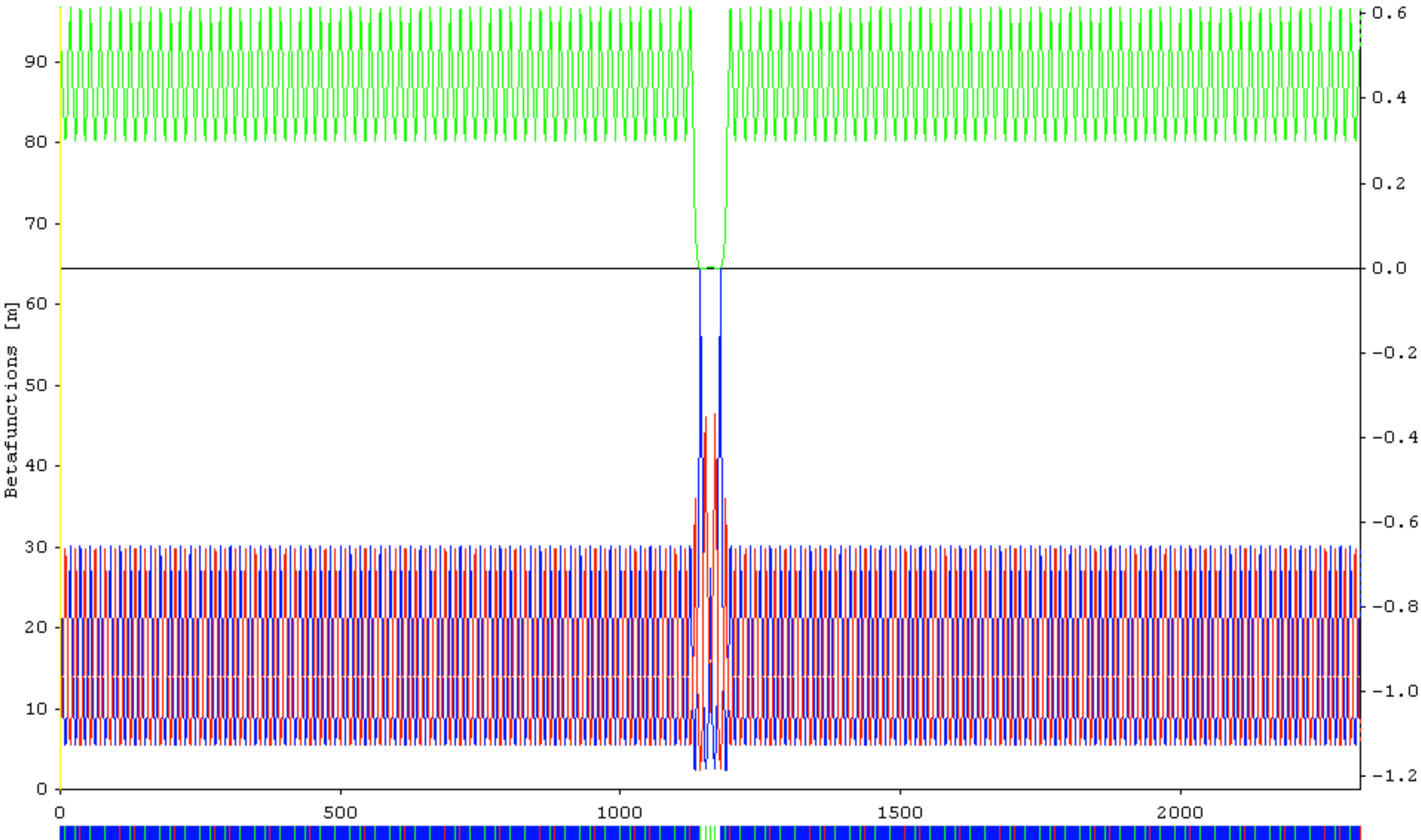




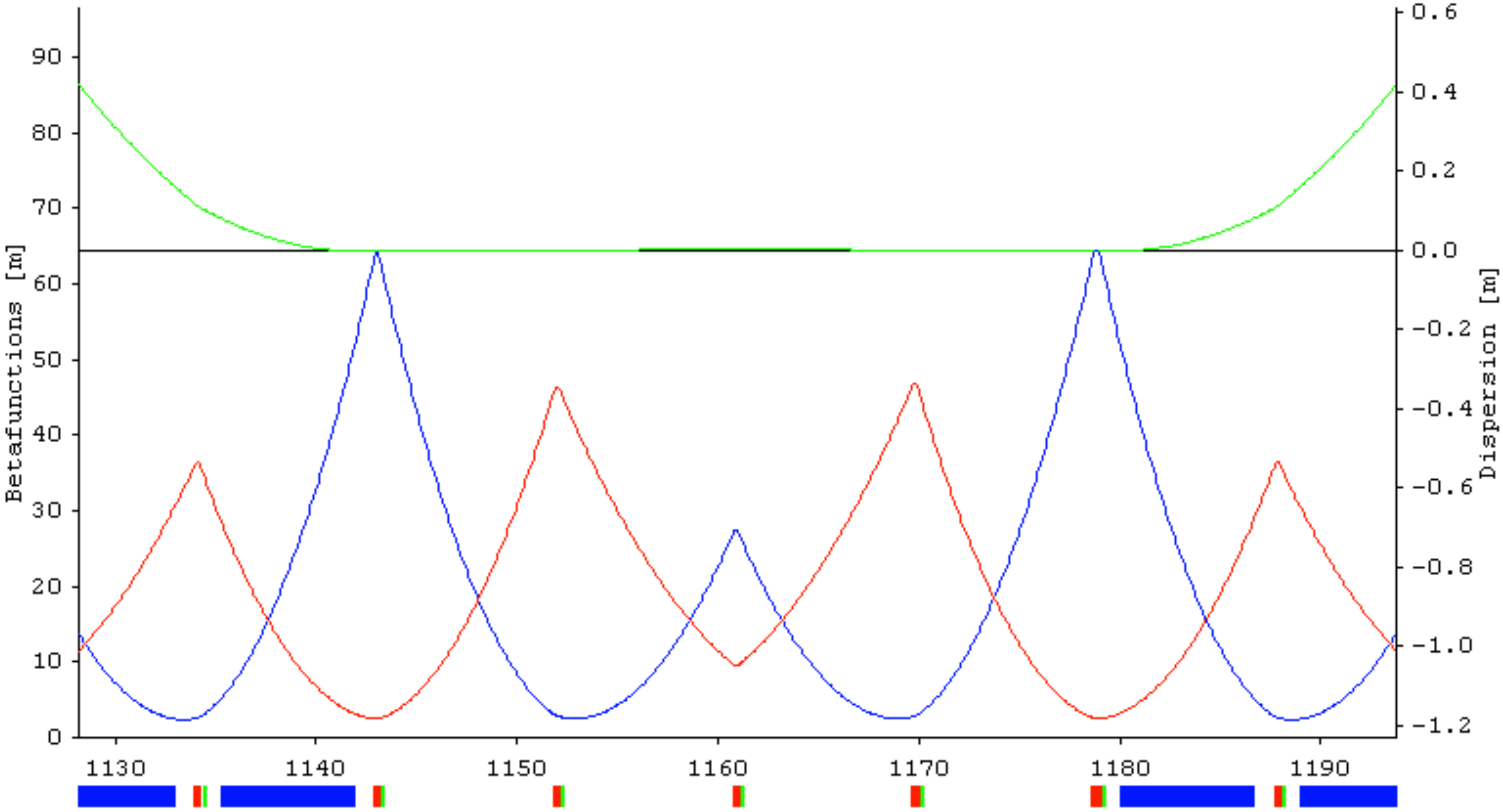
	20 GeV
C (m)	2321.95 m
Emittance (nm.rad)	30.971
E. Spread	1.042
Chrom X	-41.361
Chrom Y	-40.437
Uo (keV)	52392.3
TauX (ms)	5.923
TauY (ms)	5.913
TauE (ms)	2.954

The cell turned into this design after checking all the graphics

Whole Ring Optic Design With Selected Parameters

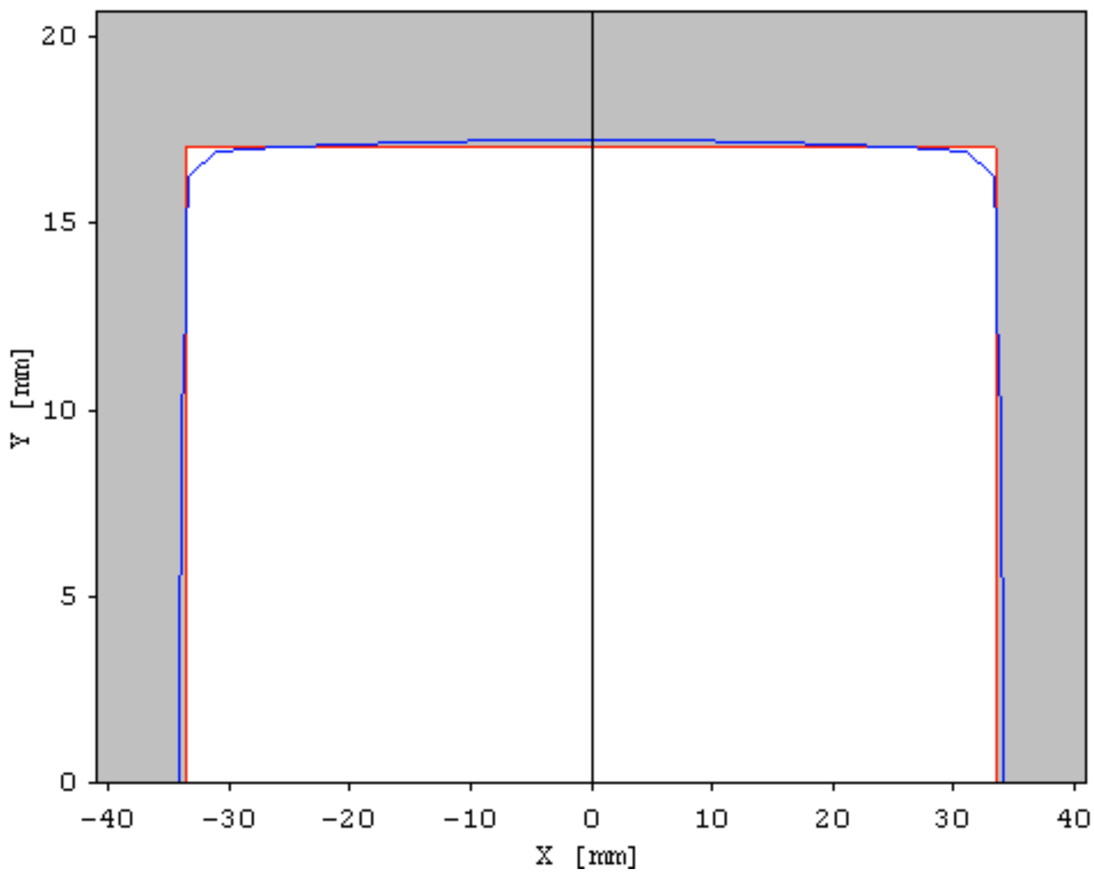


Long Straight Section



- Straight section is provided for RF, injection and extraction elements,

Dynamic Aperture



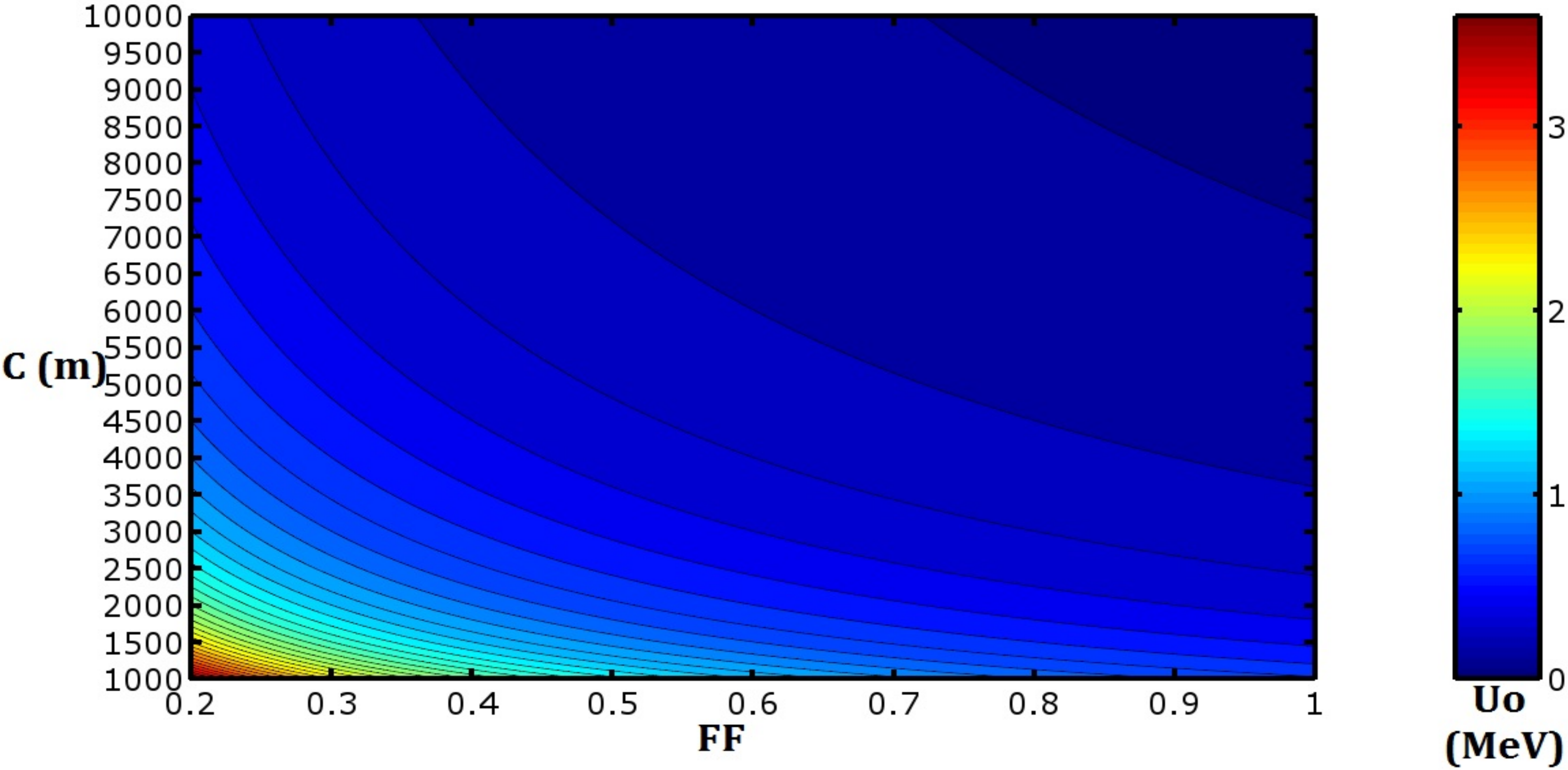
- Since sextupole magnet is included in design, the dynamic aperture is needed to be checked.
- Detail studies will be performed.

Future Studies

- Checking the sextupole strength and dynamic aperture for machine,
- Injection and extraction design,
- Collective effects.

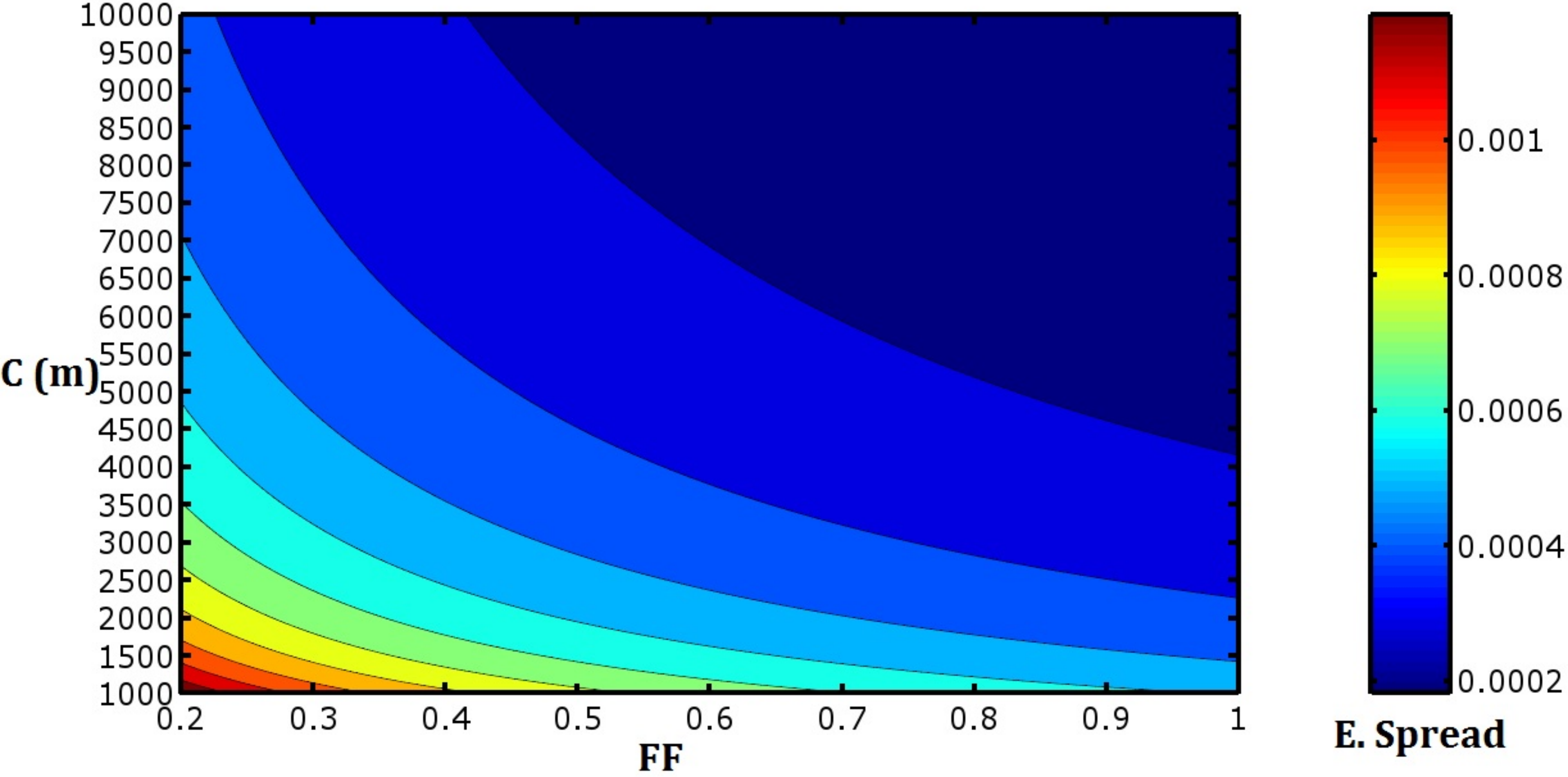
Thank you!

Appendix 1:



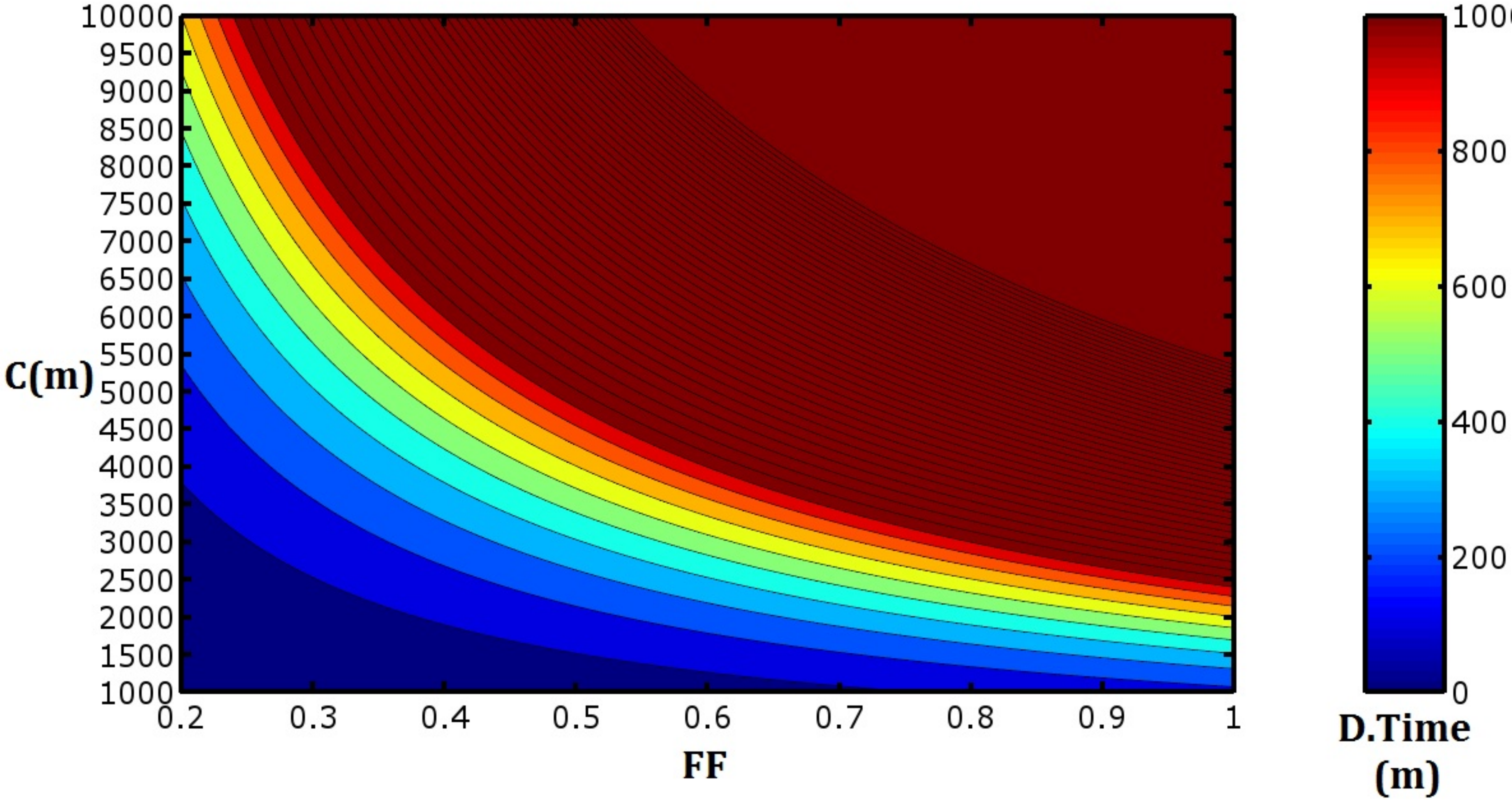
- Scaling of Energy loss/turn with filling factor and circumference

Appendix 2:



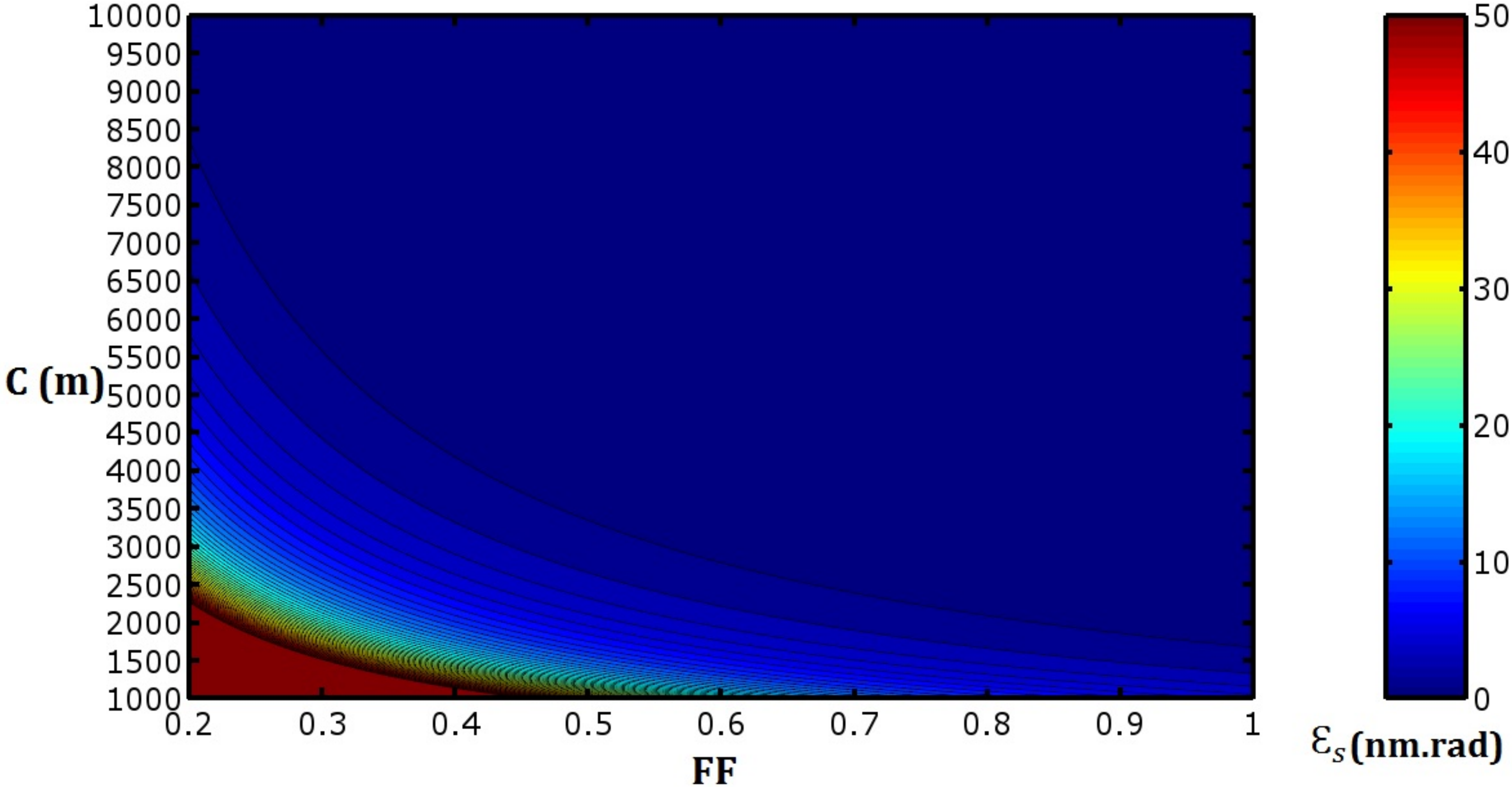
- Scaling of Energy spread with filling factor and circumference

Appendix 3:



- Scaling of damping time with filling factor and circumference

Appendix 4:



- Scaling of emittance with filling factor and circumference