Determination of Main Parameters for a pre-booster damping ring for the FCC e^+e^- injector

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Abstract

The aim of FCC-e^+e^- Lepton Collider is to collide particles in the energy range of 40 to 175 GeV. The FCC-e^+e^- injector complex needs to produce and to transport a high-intensity e^+e^- beam at a fast repetition rate of about 0.1 Hz for topping up the collider at its collision energy. A basic parameter set exists for all the collider energies, assuming a 10 GeV linac operating with a large number of bunches being accumulated in the existing SPS, which serves as pre-accelerator and damping ring before the bunches are transferred to the high-energy booster. The purpose of this study is to provide the conceptual design of an alternative damping & accelerator ring, replacing the SPS in the present scheme. This ring will have injection energy of around 5 GeV and extraction energy of around 20 GeV. Apart from establishing the basic parameters of the ring, the final study work will include the optics design and layout, single particle linear and non-linear dynamics optimization, including magnetic and alignment error tolerances. The study will also contain some basic estimation of collective effects, including intra-beam scattering, single and multi-bunch instabilities and impedances, two-stream effects (e-cloud and ion instabilities) and address the issue of synchrotron radiation handling. In this document, as a part of these studies, basic parameters of the ring, first results of optic design and layout studies are presented.

Parameter Scaling

The "energy loss per turn plot" is shown for the extraction energy of 30 GeV and 20 GeV below in Fig. 1 and 2.

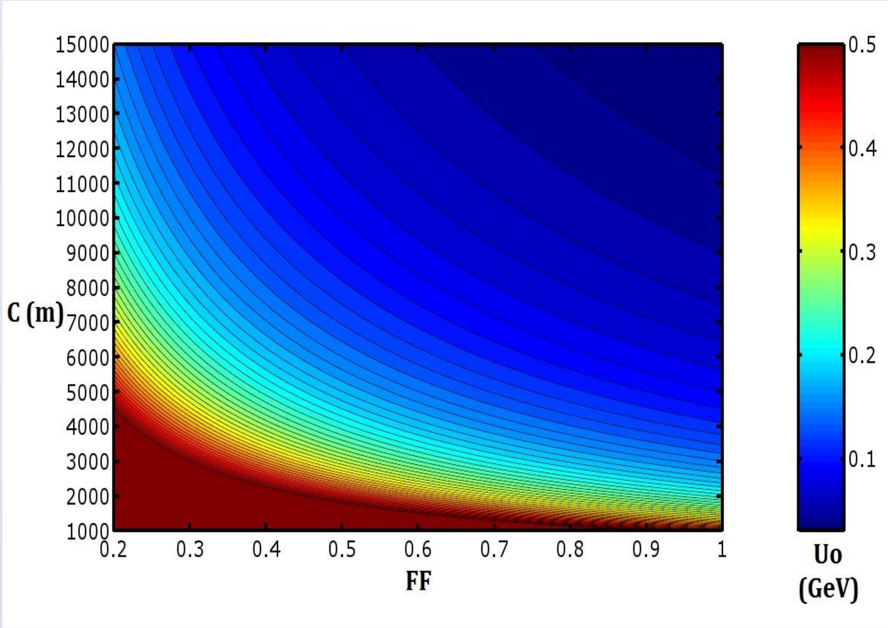

Fig. 1: Scaling of Energy loss/turn with filling factor and circumference for 30 GeV

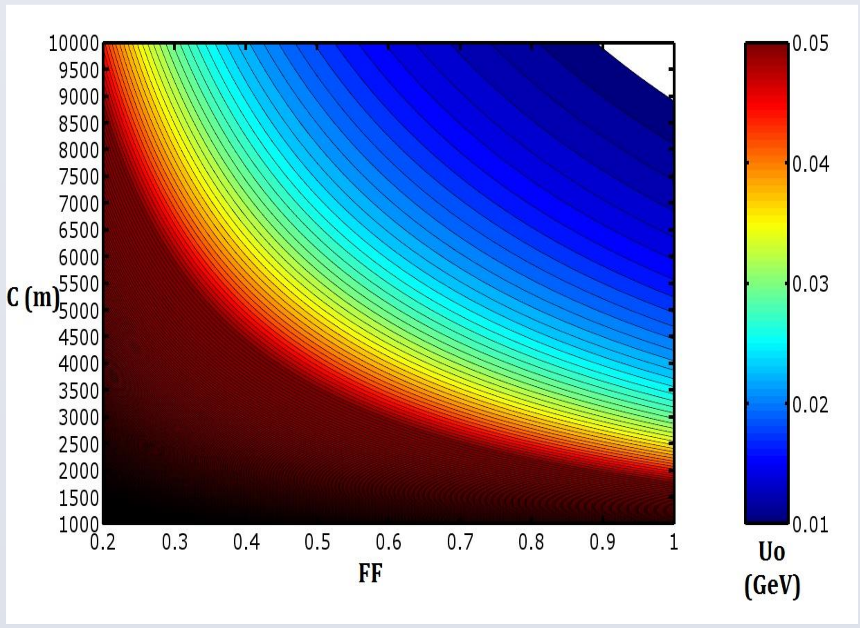

Fig. 2: Scaling of Energy loss/turn with filling factor and circumference for 20 GeV

These results motivated us to study on 20 GeV extraction energy. On Fig. 2, it is seen that 20 GeV gives us the possibility to have a circumference about 2.5 km. With this good results for the machine, it become reasonable to review all other parameters; damping times, energy spread, emittance in addition to energy loss per turn.

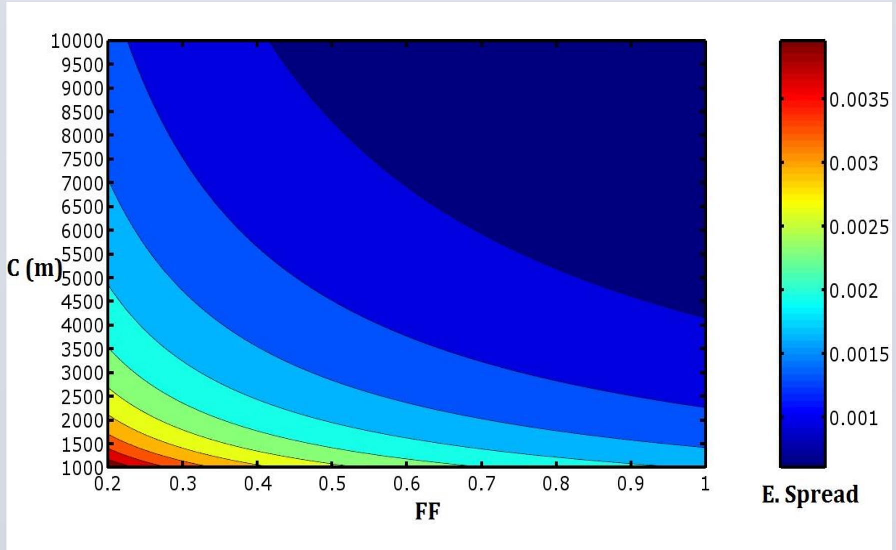

Fig. 3: Scaling of energy spread with filling factor and circumference for 20 GeV

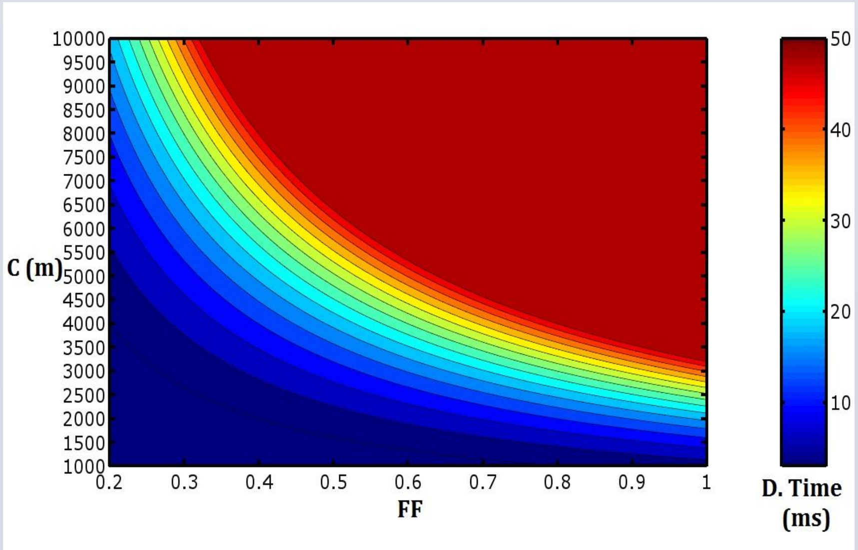

Fig. 4: Scaling of damping time with filling factor and circumference for 20 GeV

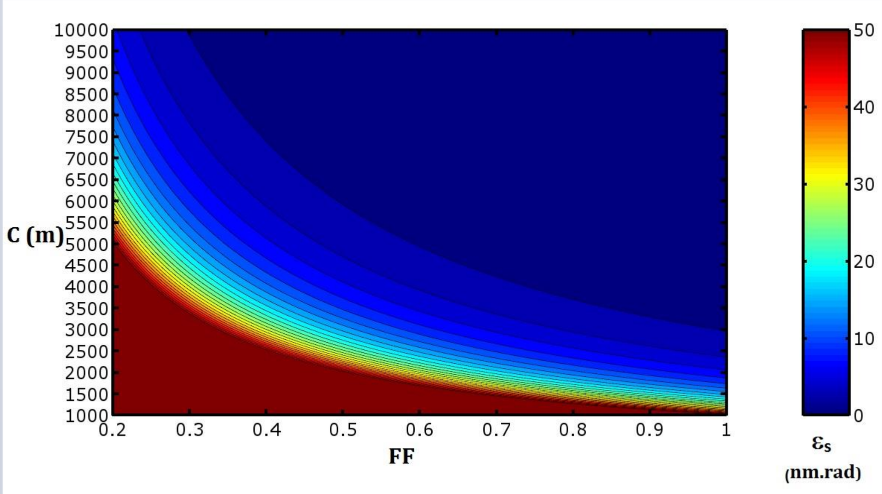

Fig. 5: Scaling of emittance with filling factor and circumference for 20 GeV

The Fig. 3 gives the result on the energy spread is acceptable and does not vary too much in the frame that was determined before for our scaling. The same comments can be made for damping time as it can be seen in Fig. 4.

After reviewing Figs. 1-4, emittance scaling could be a good parameter to be checked for the machine, too.

$$\varepsilon_s = \frac{F_{lattice}.C_q.\gamma^2.(2\pi)^3.l^3}{FF^3.C^3}$$

Chromoticity-Phase Advance-Emittance

Chromaticity, phase advance and emittance, these three parameters are correlated with each other . Thus, it is needed to be checked how they changes according to each other for a period of phase advance to choose the optimized point for all three parameters.

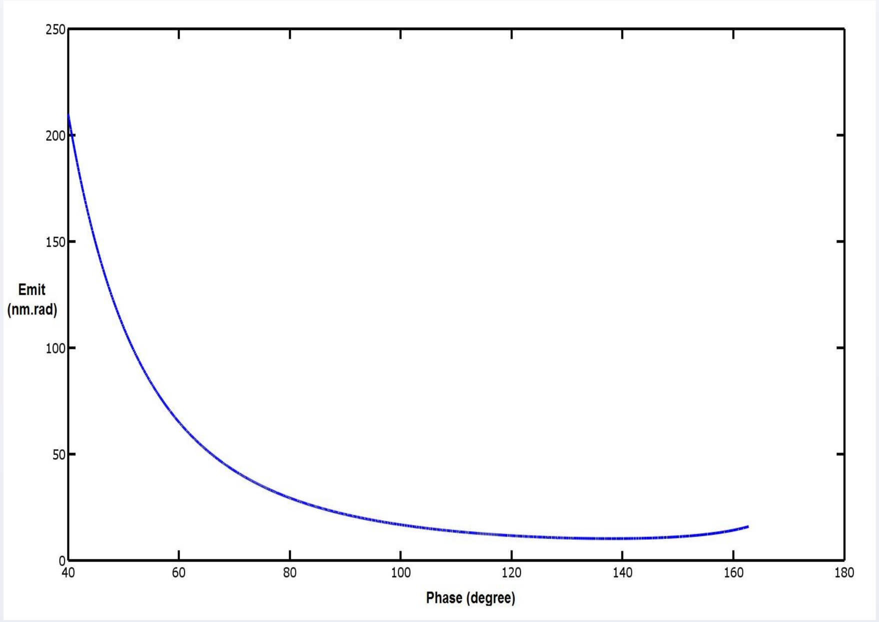

Fig. 6: The relation between phase and emittance

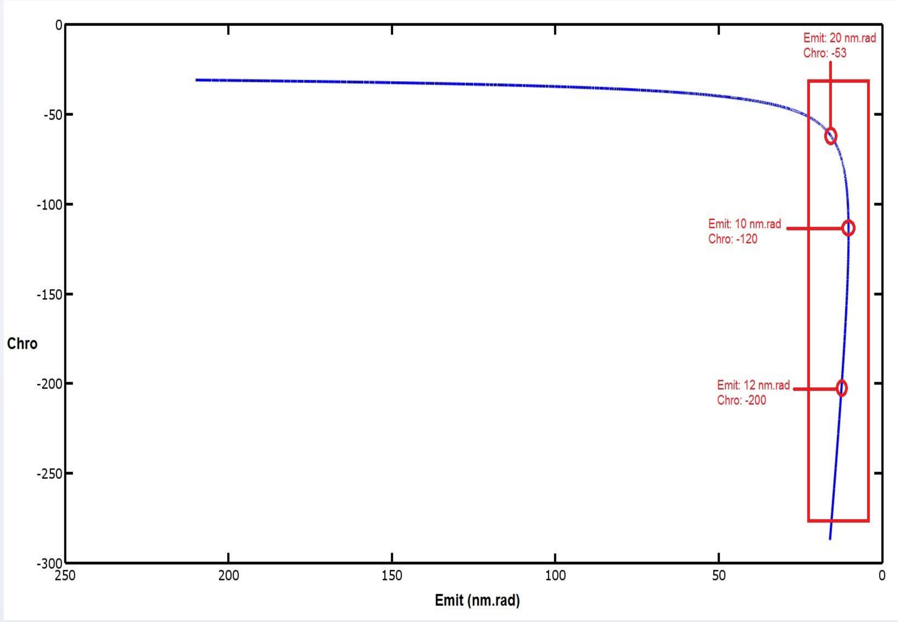

Fig. 7: The relation between chromaticity and emittance

And it also gives the clue that after some point the emittance does not vary so much while chromaticity is changing very sharply, so this graphic give us real information how to choose an optimized point for the machine.

Conceptual Design

In this design, it is used FODO type cell, which can be seen at Fig 10. And the ring, which is 2321.95 m long, comprises of two arcs and long straight section. 260 dipole magnets (0.06 T/0.248 T), 266 quadrupole and sextupole magnets are used in the whole ring.

Betatron function of whole ring and the straight section can be seen below in Fig.8-9.

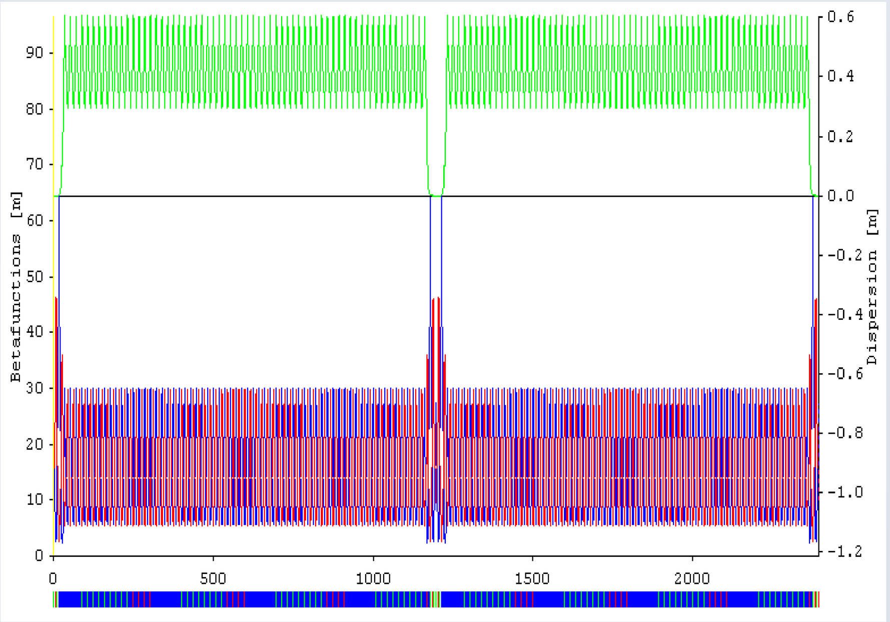

Fig. 8: Betatron functions of whole ring

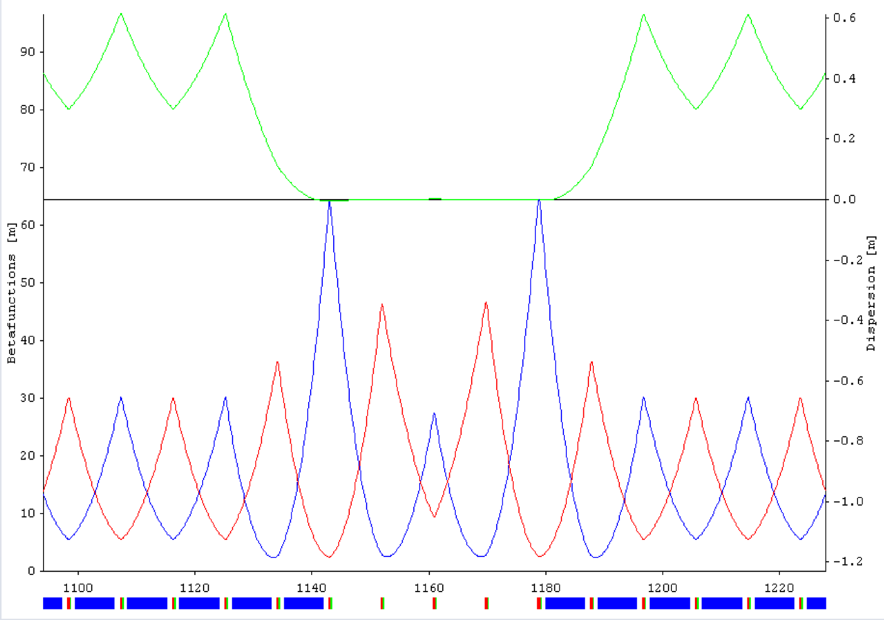

Fig. 9: Straight Section of the Ring for Injection&Extraction and RF

Main parameters and main cell of the ring can be found below.

Table 1: Main parameters

	Injection Energy	Extraction Energy
Energy	5.0 GeV	20 GeV
Perimeter	2393.54 m	2393.54 m
Emittance ε_x / ε_y	1.809 nm.rad	28.987 nm.rad
Energy Spread (10^{-3})	0.258	1.034
Energy Loss per turn	201.5 keV	51586.2 keV
Natural Chromaticity ξ_x/ξ_y	-44.195/ -42.358	-44.195/ -42.358
Cell Type	FODO	FODO

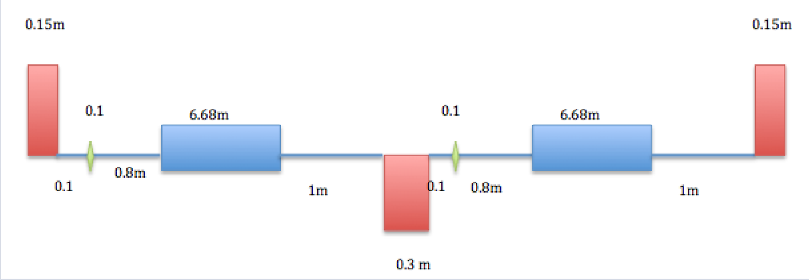

Fig. 10: Main cell of FODO

Conclusion and References

In this study, we have proceeded to parameter scaling, with respect to several radiation related parameters, and have proceeded to a preliminary design based on fodo cell including sextupole magnets.

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