Status of the FCC-ee Top-up Booster Synchrotron

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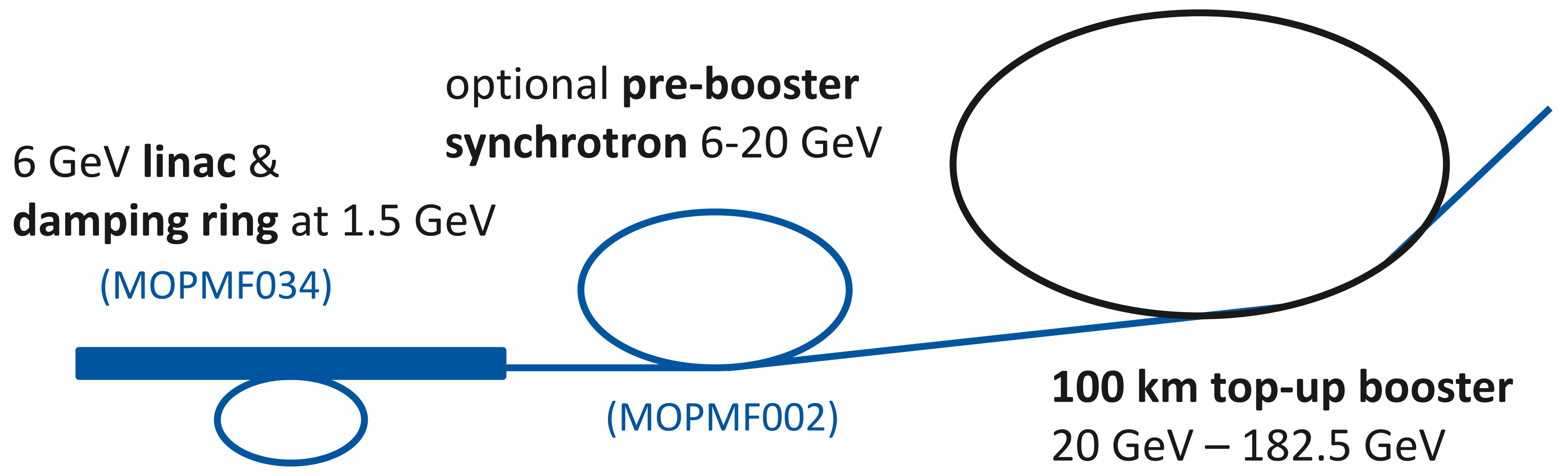
Abstract

This poster presents the status of the top-up booster synchrotron for the FCC electron-positron collider FCC-ee, which is a 100 km electron-positron collider being designed for precision studies and rare decay observations in the range of 90 to 365 GeV centre-of-mass energy. In order to keep the luminosity at a level of the order of $10^{35} cm^{-2}s^{-1}$ continuous top-up injection is required, because of the short beam lifetime of less than one hour. The top-up booster synchrotron will be housed in the same tunnel as the collider rings and will ramp up the beam energy from 20 GeV at injection to the full energy between 45.5 GeV and 182.5 GeV depending on operation mode. The lattice design and two possible optics are presented.
The dynamic aperture was investigated for different sextupole schemes with and without misalignments of the lattice components. In addition, wigglers were installed to decrease the damping time and mitigate intra-beam-scattering.

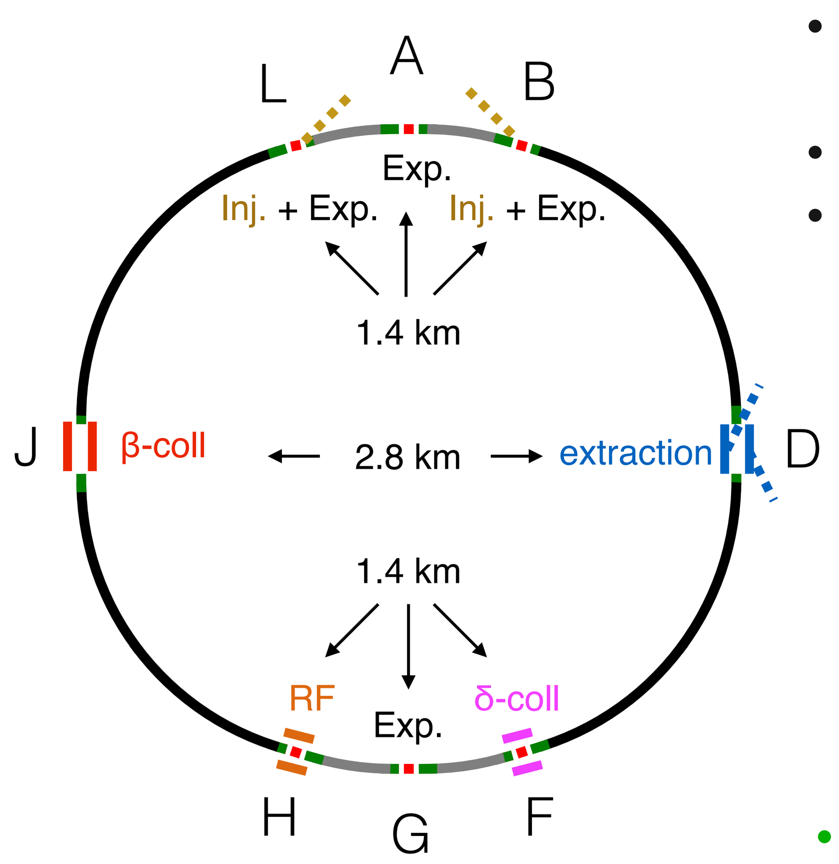
FCC-ee injector chain

Accelerator chain foreseen for FCC-ee:

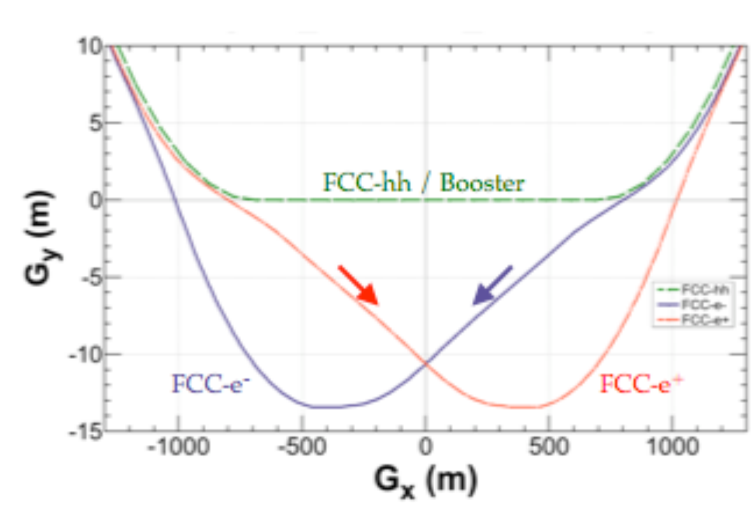


Top-up injection every 6-52 s: 50 – 16640 bunches with up to 10^{11} particles

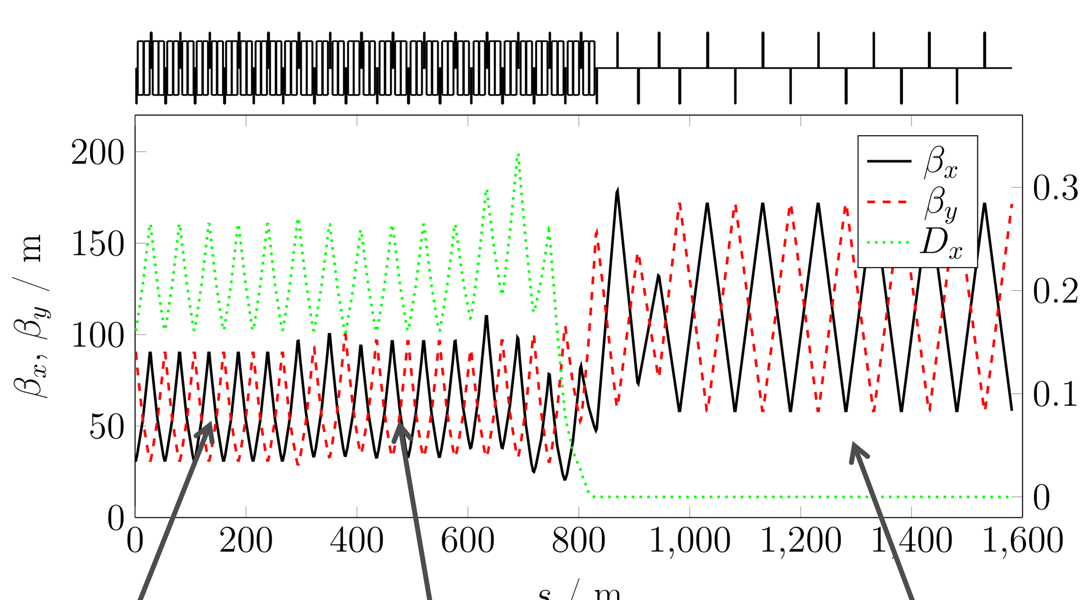
Layout and lattice



- Layout must be compatible with FCC-hh shown on the left
- **Circumference: 97.75 km**
- RF will be installed in Points D and J



- Bypasses around the detector will follow the footprint of FCC-hh [1]



Long arcs
$L_{cell} \approx 54$ m
R = 13.15 km

FCC-hh disp. suppressor
L_{cell} = 56.6 m
R = 15.06 km

Straight section with RF
L_{cell} = 100 m

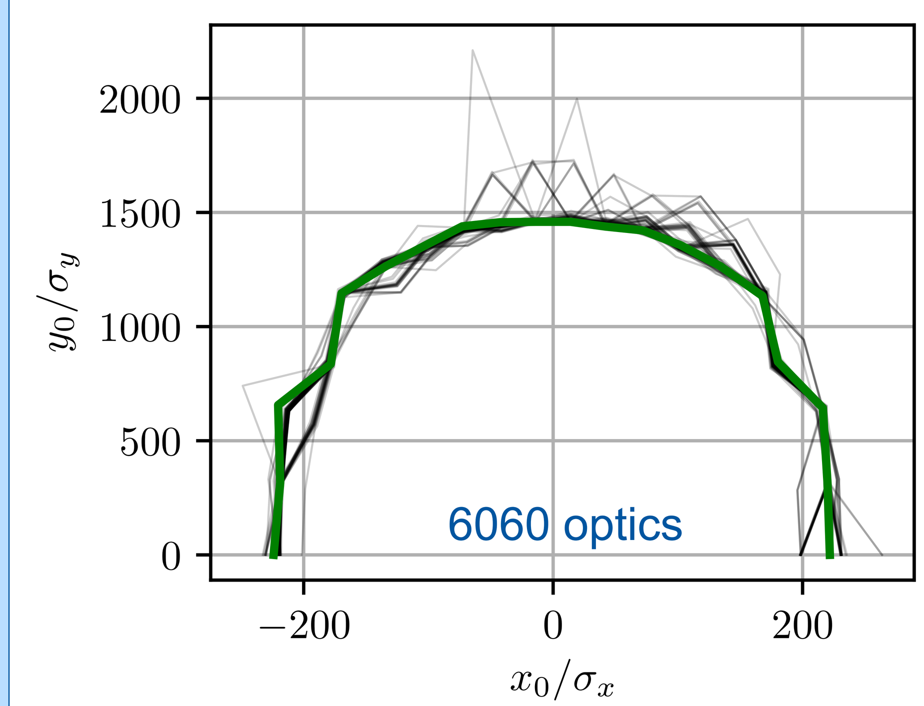
→ Longer cells to maximize space for cryo modules

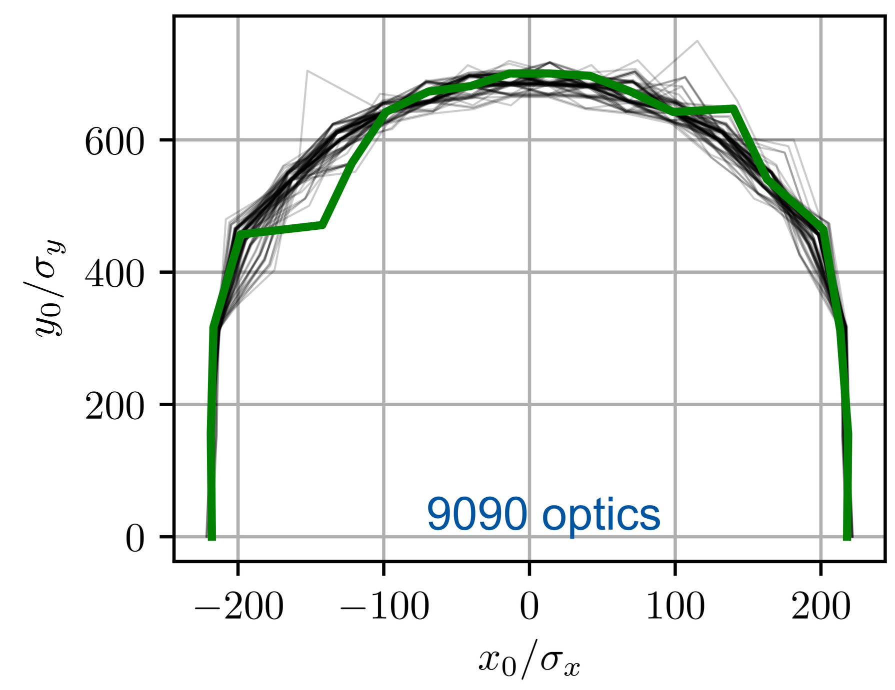
- 60/60 optics: Z & W
- 90/90 optics: ZH & tt
- Non-interleaved sextupole scheme
- No tapering

- Similar emittances in booster and collider
- 60° optics for larger momentum compaction

beam energy (in GeV)	emittance booster (in nm rad)	emittance collider (in nm rad)
182.5	1.30	1.48
120.0	0.55	0.63
80.0	0.73	0.84
45.5	0.24	0.24

DA based on tracking





First tracking studies:

- 20 GeV beam energy
- 1000 turns
- 100 µm misalignments
- no momentum offset

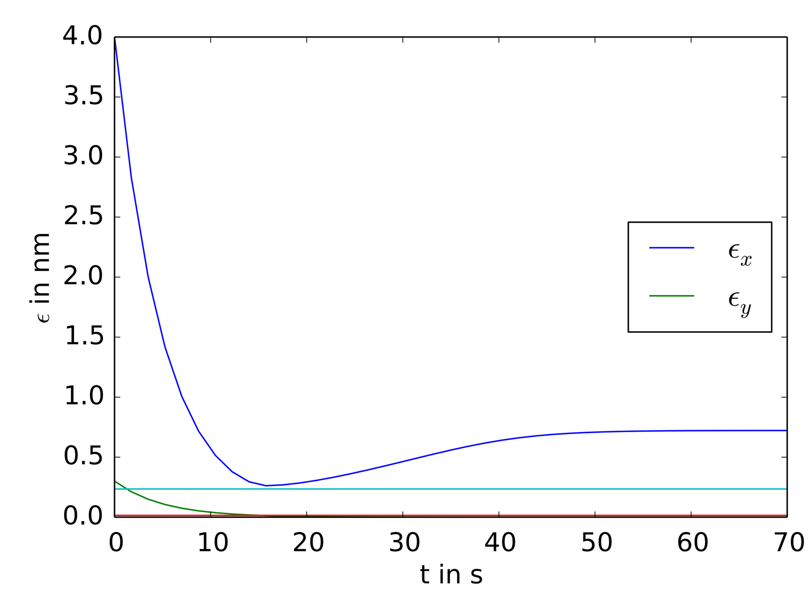
- **Dynamic aperture** determined by survival of particles
- $\beta_x = \beta_y$ = 100 m
- Momentum aperture: δ = ±0.17 %

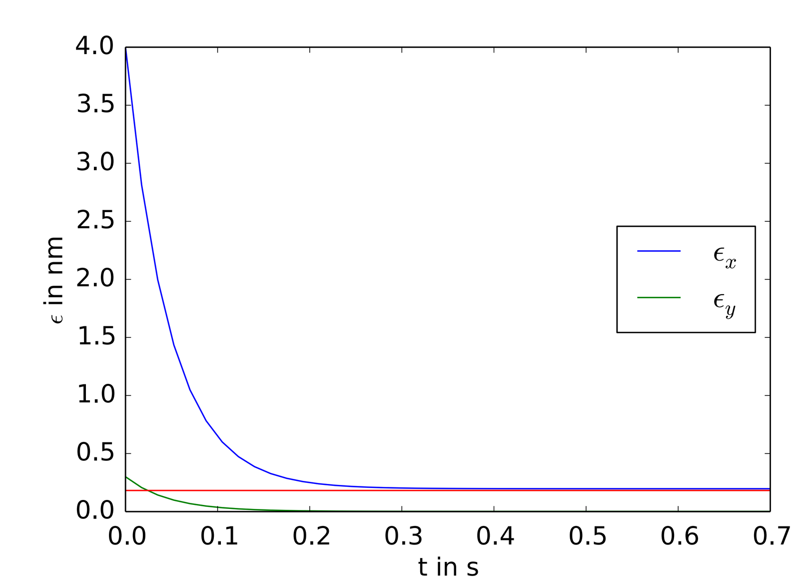
On-axis onenergy injection foreseen.

Intra-beam-scattering

Low synchrotron radiation at 20 GeV beam energy:
→ ε_x = 15 pm rad (90/90 optics)
τ_x = 10.05 s

Installation of
- 16 wigglers with 9 m length
- B = 1.8 T pole tip field





Emittance blow-up due to IBS
ε_x = 722 pm rad
≈ 48 × ε_x without IBS

New damping time: τ_x = 104 ms
New eq. emittance: ε_x = 196 pm rad
U_0 increases from 1.3 MeV to 126 MeV

Conclusions

The FCC-ee booster synchrotron will perform continuous top-up injection in order to keep the bunch intensity within 5 % and therefore achieve luminosities of the order of $10^{35} cm^{-2}s^{-1}$. Depending on the operation mode it will ramp up the beam energy from 20 GeV to 45.5 - 182.5 GeV. The presented lattice obtains similar emittances as the collider for the injected beam using both a 60° and a 90° optics. For the injection energy wigglers are used to decrease the damping time to 0.1 s and to increase the emittance from to ε_x = 12 pm rad to 240 pm rad for the 60° optics and 180 pm rad for the 90° optics. This is necessary to avoid emittance blow-up due to intra-beam-scattering. Quadrupole misalignments do not reduce the DA, the effect of the wigglers is still under investigation.

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References:

[1] K. Oide *et. al.*, "Design of beam optics for the future circular collider e^+e^- collider rings", *Phys. Rev. Accel. Beams*, vol. 19, p. 111005, Nov. 2016.

Acknowledgement:

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