FUTURE CIRCULAR COLLIDER

Meeting Minutes of the
195th FCC-ee Accelerator Design Meeting and 66th FCCIS WP2.2 Meeting

Indico: `https://indico.cern.ch/event/1469408/`
When: 22.10.2024 16:00-17:30 GVA time

Agenda

Presenter	Title
A. Chancé	**Booster status and future plans**
A. Ghribi	**Collective effects in the booster**

1 General information

F. Zimmermann opens the meeting. The minutes of the previous meeting are approved without any further comments.

Ongoing discussions regarding fine-tuning the injection and collimation optics designed by **K. Oide**, which preserve super-periodicity.

F. Zimmermann notes that the sawtooth pattern should be able to achieve a 99% reduction in photon reflection, an approach previously developed by **R. Kersevan**. **M. Ady** will take over the studies and will verify whether 99% photon suppression is maintained with both specular and diffuse reflection. **F. Zimmermann** suggests creating a photon distribution to help model photoelectron emission for upcoming e-cloud studies.

F. Zimmermann points out that thanks to the large bunch spacing in the booster the e-cloud threshold requirements seem relaxed. However, the lack of an antechamber or absorbers could make photoelectrons significant. He also wonders what is the situation in the damping ring. **H. Bartosik** comments that presently the bunch spacing in the damping ring is 82 ns and could be increased by running 4 bunches per train instead of 2, maintaining the total number of bunches. **F. Zimmermann** adds that one would need to know the vacuum pipe specifications to produce e-cloud estimations.

F. Zimmermann wonders if a bunch spacing of 5 ns is an issue for the experiment. **C. Carli** adds that the parasitic encounters in the non-experimental straight sections should be evaluated too.

2 Booster status and future plans

A. Chancé presents updates on the FCC-ee booster design progress since the 2024 FCC week, covering recent design changes and future objectives.

The booster is positioned outside the collider ring, with a 8 m bypass outward near each Interaction Point (IP) and 165 mm lateral offset in the arcs to maintain the same circumference as the collider. **M. Koratzinos** asks about the implication of the booster alternating inside and outside placement. **A. Piccini** explains that while the offset is manageable, it increases leverage, impacting stability, and she recommends placing the booster closer to the support pillar for optimal stability. **F. Zimmermann** suggests further assessment of the booster's stability, including the influence on the detector installation and surrounding infrastructure.

New ramp parameters are presented to achieve the lowest emittance at injection into the collider with a total cycling time of about 1 s. Given the large damping time for the Z operation mode, the final beam parameters at extraction strongly depends on the initial beam parameters, *i.e.* linac or high-energy damping ring. For optimal emittance, strategies include energy overshoot, shorter ramp-down time by 170 ms, and/or 5 m-wiggler, and/or an increased field slope (100 Gev/s vs. 80 GeV/s). Using a high-energy damping ring achieves vertical emittance below 2 pm.rad at extraction. Further improvements focus on reducing hysteresis, eddy currents and eddy losses.

Preliminary studies of the booster as light source which should not change the booster operation is presented, highlighting the need for additional wigglers to accelerate damping at flat-bottom, along with lattice modifications and substantial increase of the RF power (x93) and voltage (x4). More accurate studies also require the implementation of the undulator element in MAD-X and/or Xsuite.

The injection section has been included in "V24_FODO" and RF Cavities are included in "V24.1_FODO" which are available in the high-energy booster repository.

C. Carli asks which emittance is used for DA/MA calculations. **B. Dalena** answers that they considers the injection emittance for round beam (linac injector option). **A. Chancé** adds that if one uses the high-e,ergy damping ring, one gets more margin vertically because the emittance is five times lower.

Correction techniques are being refined, following SuperKEKB's commissioning strategies for efficient correction of the orbit, coupling, and dispersion, though emittance growth from misalignment and errors is not negligible and should be addressed with improved tuning/correction algorithm.

R. Wanzenberg asks if the DA/MA has been checked with low/zero sextupole strength as the start of the commissioning demands low sextupole strength, he points out that often the MA is not large enough with sextupoles off, or weak. **B. Dalena** answers that DA/MA with weak/off sextupoles have not yet been checked.

Alternative optics based on HFD should be updated to the newest geometry and dynamic aperture calculations will give tolerances on multipolar effects (*e.g.* b_3).

Regarding collective effects, the impedance budget should be completed and refined including RF contributions, bellows, etc. **M. Koratzinos** wonders if the increase to 60 mm diameter impacted the cost or magnet design. **F. Zimmermann** notes cost savings from removing the baking and the NEG-coating, the vacuum degraded but the impedance has reduced.

Tapering is planned to be addressed on a longer time scale also during the ramp. **F. Zimmermann** asks if tapering in the booster across eight octants is sufficient or more granularity is required. **A. Chancé** answers that for all except ttbar operation mode, tapering is not required. The ttbar operation mode needs to be checked (minimal number of sectors) but before a good tuning should be achieved.

L. von Freeden comments that by the FSR it is unlikely that the quadrupole length of 1.5 m will be fully investigated and ready, need to make sure magnet and optics experts use the same numbers/specifications in the report. Progress on the magnet for booster should be presented at the next ATDC meeting (October 31st) provided there is good progress in the testing.

S. Yue and **W. Bartmann** ask if an injection damper is considered to ensure the stability of the beam during injection because the stability requirement is +/- 1σ beam jitter. **A. Chancé** answers that it is possible and a transverse damper in the booster is foreseen too. Decoherence time for the booster with and without errors should be studied.

I. Karpov advocates for wigglers in the booster to counteract Reverse Phase Operation (RPO) to damp stronger high-order modes caused by more RF cavities, specifically, the present damping time is not sufficient. **F. Zimmermann** asks what the damping time with wigglers at injection is. **A. Chancé** answers that with wigglers the damping time at injection drops from about 10 s to 2-3 s, though at the cost of increased power consumption.

3 Collective effects in the booster

A. Ghribi presents the latest results on collective effects for the FCC-ee booster, focusing on a design compromise involving a 30 mm radius copper beam pipe. A revised momentum compaction factor of 7.12×10^{-6} is now used for all configurations, *i.e.* the same optics is used for all energies. This adjustment relaxes the Transverse Coupled Bunch Instability (TCBI) with a growth rate extended from 8 turns to 310 turns if the wake potential is doubled meaning, adding stability margin to the nominal operation.

Still a full impedance budget for the booster is required. Additionally, a transverse damper will be necessary, though with the revised baseline, the requirements are less challenging.

On-going studies and future plans:

- **Migration from pyHEADTAIL to XSuite:** Current studies compare IBS (IntraBeam Scattering) models in Xsuite, including the Nagaitsev and kinetic models, to MADX kinetic mode with a very good agreement though simulation speed remains a challenge. An attempt at implementing a map of the collider including IBS is in-going for faster simulations. This has been unsuccessful so far. Potentially due to dispersion dependencies of IBS. **K. Oide** asks if synchrotron radiation (SR) damping is considered in these simulations. **A. Ghribi** confirms that there SR damping is included with an equilibrium appearing beyond 60k turns. Current result do not account for wakefields and the IBS/wake interplay as well as jitter studies (with amplitude detuning) are foreseen.

A Memorandum of Understanding (MOU) has been signed between CERN and GANIL, and a postdoc position has been opened to support collective effects research for the FCC-ee booster.

40 Participants:
M. Ady, K. André, H. Bartosik, W. Bartmann, M. Boscolo, G. Broggi, Q. Bruant, H. Burkhardt, C. Carli, A. Chancé, B. Dalena, H. Damerau, D. Domange, A. Frasca, C. Garcia, V. Gawas, A. Ghribi, C. Goffing, E. Howling, S. Jagabathuni, I. Karpov, J. Keintzel, P. Kicsiny, R. Kieffer, M. Koratzinos, G. Lerner, L. Mether, G. Nigrelli, K. Oide, G. Pérez, A. Piccini, L. Sabato, J. Salvesen, K. Skoufaris, L. van Riesen-Haupt, L. von Freeden, R. Wanzenberg, S. Yue, C. Zannini, and F. Zimmermann