Meeting Minutes of the
133rd FCC-ee optics design meeting and 4th FCCIS WP2.2 meeting

Indico: `https://indico.cern.ch/event/1014189/`
When: 05.03.2021 9:00-11:00 GVA time

Agenda

Presenter	Title
E. Carideo	**PyHT results and the Impedance model of the Future Circular Collider (FCCee)**
M. Migliorati	**Beam-beam with longitudinal impedance**
D. Shatilov	**Larger Momentum Compaction at Z**

1 General information

F. Zimmermann opens the meeting with the announcement that an FCC-week is planned later this year, likely taking place between 28.6.2021 to 2.7.2021. The conference is planned to take place as a remote-only event. A general announcement and invitation will follow. Further placement studies are ongoing, with a review scheduled in April, which will also include RF-system.

M. Koratzinos inquires if a decision should be made whether to stay with the 2 IP option or continue with 4 IP option instead before the placement studies continue. **F. Zimmermann** and **K. Oide** note that the layout presented in the previous FCC-ee optics meeting is compatible with both options and thus should not interfere with the placement studies.

2 PyHT results and the Impedance model of the Future Circular Collider (FCCee)

E. Carideo starts her presentation by reminding the audience of the results from the last presentation on this topic, using the nominal bunch length σ_z of 3.5 mm and using PyHeadtail (PyHT). The largest loss factor stems from the resistive wall component, with a loss factor of 210 V/pC for σ_z of 3.5 mm and, as inquired by others during the last meeting, 52 V/pC for σ_z of 12.1 mm, the bunch length including beamstrahlung. Comparison between the wake potential obtained from PyHT and from IW2D for the case of a 3.5 mm long bunch show good agreement, as well as between PyHT and CST for different element types. Previously, the number of bellows was set to 8000, however new calculations yield that an increase to 20000 bellows is necessary. Correspondingly, the bellows impedance contribution increases, and due to the developing microwave instability, an increase of energy spread and bunch length above the bunch population threshold and when considering a bunch length of 3.5 mm is observed. For the case of a bunch length of 12.1 mm, the effect on both bunch length and energy spread is not as strong.

M. Koratzinos notes that during operation, a bunch length of 12.1 mm should always be the case. In addition, he is interested what the power loss for this bunch length will be. From scaling, the contribution for 20000 bellows should be in order of 10^{-4}.

K. Oide asks which bellow design is used. **M. Migliorati** replies that the SKEKB design is used, however only a circular shape is assumed without winglets. **K. Oide** further inquires if bellows every 8 m are required. **M. Migliorati** replies that these number have been proposed by **R. Kersevan**. These simulations only represent a first estimate and further discussions on the model and assumptions will follow.

R. Bruce notes that only 20 collimators are included in the model. **M. Migliorati** replies that these represent old estimates from **E. Belli**, but were not included in the presented calculations. **R. Bruce** adds that currently no collimator design is available and will be provided in the future. He also asks what the stability margin is at the moment, noting that collimators will worsen the situation. **M. Migliorati** replies that currently no estimate can be given.

F. Zimmermann asks if each bellow has a flange. **M. Migliorati** that for now only the RF-fingers are included, but flanges should be included in the future.

3 Beam-beam with longitudinal impedance

As a follow-up to the previous presentation, **M. Migliorati** opens his presentation by noting that an interplay between beam-beam effect and the longitudinal impedance may become problematic, which was subject of a number of recently published papers by **Y. Zhang**. A first comparison between the codes PyHT and IBB show good agreement, where in both cases the beam-beam effect was not taken into account. The following simulations were conducted using IBB to include the beam-beam effect and investigate the X-Z instability. Tune scans for different intensities using the total impedance show an island of stability at the nominal intensity of $1.7 \cdot 10^{11}$, while for lower intensities no such stable region is observed. As such, an intensity ramp-up appears not feasible. He warns, that the situation including further elements could become worse.

M. Koratzinos asks what the plan for filling-up scheme is. **K. Oide** replies that 10 steps are foreseen before the full intensity is reached. An alternative scheme where a smaller number of bunches is filled up faster is excluded due to increased filling time and as from the above presented simulations, different tunes for different bunches would be required.

T. Pieloni inquires if it is understood what causes the instability and also notes that areas which show a large horizontal blow-up when considering only one of the effects, the magnitude is drastically reduced in the combined case. **M. Zobov** replies that when taking into account both the beam-beam interaction and the coupling impedance, positive effects, such as the increased synchrotron tune spread potentially suppressing the X-Z instability via Landau damping, as well as negative effects, such as the reduction of the stable tune area, are observed. **K. Oide** replies that synchrobetatron resonances due to the crossing angle appear to be the main cause.

F. Zimmermann asks if different types of bellows might improve the situation. **M. Migliorati** answers that more work on that topic is required.

F. Zimmermann also notes that studies simulating an intensity ramp up would be of interest.

M. Zobov adds that considering the worrisome situation, countermeasures should be looked into in greater detail, for example harmonic cavities, betatron tunes farther away from the half integer, or use of a higher momentum compaction factor, which is subject of the following talk.

K. Oide asks if the used code is based on a strong-strong or a weak-strong approach. **M. Zobov** replies that IBB is a quasi strong-strong code, similar to the code used by **K. Ohmi**. **Y. Zhang** adds that a gaussian approximation for the bunch distribution is used in the code and is not a PIC code. **M. Zobov** also notes that cross-checks with analytical models have been performed, showing good agreement, though these studies were not performed for the case of the X-Z instability. **F. Zimmermann** proposes that benchmarking between a PIC code and IBB could be performed including impedances.

K. Oide asks if in the model the impedance is distributed over the arc. **M. Migliorati** answers that the machine is split into 4 segments after which kicks are applied, with larger number of segments not changing the results drastically, but increasing the run time of the simulations.

M. Koratzinos asks what coating will be used. **M. Migliorati** replies that a 100 nm thick NEG coating will be used, though at this thickness, conductivity does not play a big role. He adds that other materials with a smaller thickness might help in reducing the impedance. Further reduction might be accomplished by absorbing some trapped modes, though this could also worsen the situation by increasing the broad-band impedance.

4 Larger Momentum Compaction at Z

D. Shatilov's presentation focuses on the advantage of using an optics with a larger momentum compaction factor α_p as another possible option to mitigate problems with the impedance. The increase of α_p can be achieved by switching the arc cell phase advance from $60^\circ/60^\circ$ to $45^\circ/45^\circ$, though this optics does not exist at the moment and results for the emittances and α_p were achieved by scaling. Options are presented, differing in the required RF-voltage, and are discussed in terms of luminosity and other aspects. Simulations where impedance was not accounted for show a larger area of stability in the horizontal tune space. Follow-up questions include the compatibility with the injection complex, feasibility of implementation without hardware changes, and simulations to estimate the impact of longitudinal impedance.

F. Zimmermann notes that options show a lower number of bunches, which might be beneficial for e-cloud. However, this should be studied in simulations.

H. Burkhardt comments that sensitivity to RF-frequency changes is larger with a lower α_p, thus a larger α_p is preferred to avoid for example changes of the energy due to the effect of tides.

5 AOB

F. Yaman presents e-cloud studies for 5 ns bunch spacing and using a smaller bunch population. **F. Zimmermann** proposes to also look into the case of a 50 ns bunch spacing.

B. Härer introduces **M. Reissig**, a new PhD student at KIT, working on diagnostics for the longitudinal bunch profile. **F. Zimmermann** adds that **A. Abramov** and **M. Hofer** have started as fellows at CERN begin of March, working on FCC-ee collimation and beam dynamics.

The next FCC-ee optics meeting will take place the following week, on 12.3.2021.

Next steps

TASK
Comparison between the 2 IP and 4 IP options with respect to the combined effect of beam-beam and impedance
Refinements of impedance model including collimators, bellow-flange model, and discussion on number of bellows; Loss factor at σ_z of 12.1 mm
Simulations of e-cloud, optics-correction, impedance + beam-beam simulations for large α_p option
Benchmark quasi strong-strong code with PIC code
E-cloud studies with a 50 ns bunch spacing and different bunch population

Participants:

A. Abramov, I. Agapov, S. Antipov, C. Antuono, A. Blondel, A. Bogomyakov, M. Boscolo, R. Bruce, H. Burkhardt, P. Burrows, E. Carideo, F. Carlier, A. Chance, A. Ciarma, B. Dalena, I. Efthymiopoulos, O. Etisken, B. Härer, M. Hofer, B. Humann, P. Janot, M. Karppinen, J. Keintzel, A. Krainer, M. Koratzinos, M. Migliorati, N. Mirian, N. Nikolopoulus, S. Ogur, K. Oide, T. Pieloni, M. Reissig, L. van Riesen-Haupt, D. Shatilov, R. Wanzenberg, F. Yaman, R. Yang, C. Zannini, Y. Zhang, F. Zimmermann, and M. Zobov