# Meeting Minutes of the

192nd FCC-ee Accelerator Design Meeting
and 63rd FCCIS WP2.2 Meeting

Indico: `https://indico.cern.ch/event/1456331/`
When: 26.09.2024 15:00-17:00 GVA time

## Agenda

| Presenter | Title |
|---|---|
| I. Karpov | **Transient beam loading for reverse phase operation mode** |
| K. Oide | **Non-local solenoid compensation and associated effects on beam-beam & polarization** |

## 1 General information

**F. Zimmermann** opens the meeting. The minutes of the previous meeting are approved without any further comments. **P. Janot** opposes the idea of reducing the luminosity by 50% for the Higgs operation mode to save 0.5 BCHF as it strongly impacts the physics case. **F. Zimmermann** confirms that it is not part of the Feasibility Study but he suggests that the topic should be examined in the future.

- **Beam lifetime: X. Buffat** and **P. Kicsiny** explain that the beam lifetime discrepancies have been resolved between from SAD and Xsuite and the results are now coherent.
- **Dynamic aperture with finite chromaticity: F. Zimmermann** raises concern about how finite chromaticity values (Q'= 5, 10, 20), useful to mitigate instabilities, might impact the dynamic aperture and the performance of the machine.
- **Same RF system for Z, WW, and ZH: F. Zimmermann** would like to have all relevant aspects clarified for the CGM of October 11$^{th}$.
- **SuperKEKB model development in Xsuite:** Progress is reported on the development of the SuperKEKB model in Xsuite. **J. Salvesen** adds that the linear optics, the solenoid for the Low Energy Ring (LER) are already integrated, with the solenoid for the High Energy Ring (HER) and the beam-beam interactions soon to follow.
- **Xsuite-BDSIM couplings: F. Zimmermann** comments that several institutes have shown interest in the development of Xsuite-BDSIM couplings. **H. Burkhardt** highlights that functionalities should be implemented in Geant4 directly if possible.

**Feasibility Study Report Structure:**

**F. Zimmermann** presents updates on the feasibility study structure. The booster is now separated from the collider and the FCC-hh is not considered in the report so far. He questions whether the section “1.2.2: Requirements" should be further split into more subsections.

**G. Roy** adds that alignment should be covered in the "Operation & performance" section, including details on the time needed for annual (re-)alignment.

**F. Zimmermann** agrees and suggests that shutdowns should also be addressed, outlining their purpose and they would all be necessary, particularly if the RF system changes between the Z-pole and ZH operation modes are avoided.

**Optics Tuning Update:**

**F. Zimmermann** gives a brief report on the last optics tuning meeting with the following highlights:

- 1 mm alignment error for the dipoles provides acceptable results and less costly than aiming for 150$\mu$m precision.
- Tuning seems to perform better with BPMs attached to quadrupoles (instead of sextupoles), to be confirmed.
- The overall target for misalignment error in the arcs is 150$\mu$m (except dipoles), and the current results are going in the good direction.
- The ballistic optics shows better beam lifetime performance than the nominal optics with half the sextupole strength, which is beneficial in the commissioning scenario.
- Quadrupole Beam-Based Alignment (BBA) gives much better results than sextupole BBA, though the methods differ.
- AC dipoles are essential for BPM resolution, in the arcs the requirements are relaxed compared to the IRs where sub-micron BPM resolution seems necessary.

## 2 Transient beam loading for reverse phase operation mode

**I. Karpov** presents an analysis of the transient beam loading effects in reverse phase operation (RPO) mode due to gaps in the bunch filling pattern, *e.g.* abort gaps. These transients affect the cavity voltage and phase, resulting in oscillations of up to $\pm 2\%$ in voltage and $\pm 8\%$ in phase. The beam parameters, such as the synchrotron tune and bunch length also vary significantly: between -21% and +9% around the nominal synchrotron tune, and -9% and +27% around the nominal bunch length.

He explains that in general, abort gaps can be matched to mitigate transients (LHC, PEP-II). The imbalance of charge results in different detuning for electron and positron beams that is most critical during the filling of the machine. Compared to the 1-cell RF system, the 2-cell RF system causes a 15-fold increase in the spread of synchrotron tune and bunch length. A large synchrotron tune spread might leave little room for stable horizontal tune regions due to the interplay between beam-beam interactions and impedance, unless a positive chromaticity is implemented.

**I. Karpov** presents two mitigation strategies: reducing the abort gap or increasing the RF voltage. The first results in a synchrotron tune and bunch length spread reduced to a factor 3 compared to the 1-cell RF system by halving the abort gaps to 600 ns. However this is likely unrealistic due to the 1 $\mu$s kicker rise time which is limited by the technology.

**K. Oide** argues that a faster kicker rise time, just for the Z-pole operation could be possible, *e.g.* at SuperKEKB they have a 0.1 $\mu$s kicker rise time for a 8 GeV beam energy. He proposes to use several of these kickers for the Z-pole.

**J. Wenninger** comments that this filling scheme does not consider the polarization pilot bunches. **I. Karpov** agrees and will look into it.

The second option is to increase the RF voltage to 195 MV, which would reduce the spread to 5%. However, this would have an impact on several critical parameters, such as the bunch length, synchrotron tune, RF acceptance, beam-beam parameters and luminosity.

He points out that a higher synchrotron tune creates stronger low order resonances but there is more space between them and shorter bunches will experience stronger beamstrahlung. Higher synchrotron tune could enhance resonant depolarization.

**X. Buffat** suggests investigating the effect of the chromaticity on the lattice performance, including DA & MA, as the beam-beam studies do not include the lattice. **K. Oide** proposes implementing a +5 chromaticity in both planes comparing to the current [Q'$_x$, Q'$_y$]=[0,+5] for Z-pole operation.

## 3 Non-local solenoid compensation and associated effects on beam-beam & polarization

**K. Oide** presents preliminary results from the non-local solenoid compensation. He begins by describing the layout where the beam orbit is bent vertically by the detector solenoid field. The final focus quadrupoles are aligned along the beam axis to prevent additional orbit or dispersion deviations. The solenoid field is fully shielded by the shielding solenoid up to a distance $l_{sol}$, from the IP, ensuring that the final focus quadrupoles operate in a field-free region. The vertical bending angle introduced by the solenoid is corrected using two dipoles on either side of the IP after the compensation solenoid.

**K. Oide** introduces two types of vertical bump named:

1. W-vertical bump: for which the IP is on the same planed as the arcs.
2. Λ-vertical bump: for which the IP has a vertical offset relative to the arcs by a few millimeters.

Results show that the W-vertical bump yields better beam-beam interaction performance with less emittance blowup and a longer lifetime. The emittance blow-up caused by the solenoid fringe fields depends on $l_{sol}^7$ and is optics-independent outside $pml_{sol}$.

The W-vertical bump shows better symmetry around the IP considering the x-y coupling and vertical dispersion corrections. While beam dynamics performance (emittance, lifetime) is favorable, the equilibrium polarization is below 1%, necessitating a polarization-bump tuning.

**F. Zimmermann** wonders if the reason for poorer performance of the Λ-vertical bump with beam-beam could be due to higher order effects. **K. Oide** answers that it is probably the reason. It could also be due to the asymmetry observed around the IP.

**J. Wenninger** raises concern about how commissioning challenges, particularly how to proceed with beam alignment when the solenoid is considered “on by default" in this model. When transitioning between operation modes (*e.g.* Z to W), how does one realign the quadrupoles with the beam axis that differ with the beam energy. **H. Burkhardt** comments that there should be orbit correctors by default to handle trajectory adjustments with the solenoid turned on or off.

**50 Participants:**
M. Ady, K. André, A. Apyan, H. Bartosik, M. Boland, M. Boscolo, G. Broggi, R. Bruce, Q. Bruant, O. Brunner, X. Buffat, H. Burkhardt, K. Cantun, F. Carlier, A. Chancé, A. Ciarma, B. Dalena, H. Damerau, D. Domange, Y. Dutheil, C. Eriksson, V. Gawas, A. Ghribi, C. Goffing, K. Hanke, C. Hernalsteens, W. Hölfe, E. Howling, S. Jagabathuni, P. Janot, I. Karpov, P. Kicsiny, A. Lechner, M. Migliorati, K. Oide, F. Palla, F. Peauger, T. Pieloni, S. Redaelli, G. Roy, L. Sabato, J. Salvesen, G. Segurana, K. Skoufaris, R. Tomás, J. Wenninger, S. Yue, C. Zannini, F. Zimmermann, and M. Zobov