Meeting Minutes of the
188^{th} FCC-ee Accelerator Design Meeting and 59^{th} FCCIS WP2.2 Meeting

Indico: https://indico.cern.ch/event/1433104/
When: 10.07.2024 14:00-16:00 GVA time

Agenda

Presenter	Title
K. Oide	**Update on GHC lattice**
J. Salvesen	**Report on IP feedback studies at SuperKEKB**
M. Le Garrec	**Nonlinear optics measurements at SuperKEKB**
J. Keintzel	**Optics tuning working group update**

1 General information

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

He notes that there will not be any changes to the underground for the feasibility study report; it remains the same as Mid-Term Report (MTR); with potential changes in the fall.

F. Zimmermann discusses the promising option using 2-cell RF cavities from the Z-mode through the H-mode operation, despite the large difference in the loaded quality factor. The issue can be addressed with a reverse phase operation, which has been experimentally verified at KEKB, and is also the baseline solution for Electron-Ion Collider's Electron Storage Ring (EIC ESR).

He concludes by mentioning that SuperKEKB reached record luminosity $4.5 \times 10^{34}\text{cm}^{-2}\text{s}^{-1}$ with $\beta_y^* = 0.9$ mm and machine studies suggest that $8.4 \times 10^{34}\text{cm}^{-2}\text{s}^{-1}$ should be possible, but the attempt to increase the Low Energy Ring (LER) beam current to 1.5 A was unsuccessful.

2 Update on GHC lattice

K. Oide presents an update on the GHC lattice.

The addition of octupoles and decapoles to the local chromaticity correction sextupoles, a proposal introduced by **Y. Cai** at the FCC week 2024. This approach results in a comparable DA and MA compared to the original GHC lattice, while reducing the arc sextupole strengths by 12%, thus lowering their power consumption. However, this improvement hinges on the feasibility of such octupoles and decapoles.

K. Oide then discusses alternative arc lattice and optics solutions. These include:

1. **Modulated FODO**: with higher $\beta_{x,y}$ and η_x at the sextupoles.
2. **Interleaved FODO sextupoles** featuring a sextupole at each quadrupole, optimizing the amplitude-detuning.
3. **Nested -I**, SD pair (-I) nested with SF pair ($3\pi/2\pi$).
4. **Non-interleaved sextupoles** with SF/SD pair ($3\pi/2\pi$) without a solution yet to study DA/MA.

Despite these efforts, none of these alternative arc lattice and optics designs have yet surpass the DA/MA performance of the original arc FODO design.

C. Carli asks about the number of sextupole families used in the various arc designs. **K. Oide** responds that they have comparable number of sextupole families in all arc designs.

3 Report on IP feedback studies at SuperKEKB

J. Salvesen presents the IP feedback studies performed at SuperKEKB and outlines the requirements for the FCC-ee.

At SuperKEKB, there are two types of IP feedback systems: the 'iBump' feedback, which is a deflection feedback with dedicated horizontal and vertical correctors in the Interaction Region (IR) straight, and a dither feedback system developed in collaboration with SLAC, which is currently unused but is planned to be tested in the fall. The Low Energy Ring (LER) uses a global feedback system only, whereas the High Energy Ring (HER) employs IR correctors. The 'iBump' feedback system uses Beam Position Monitors (BPMs) placed at 0.5 m from the IP in separated beam pipes, mechanically coupled to the IP.

J. Salvesen details the machine development activities performed at SuperKEKB: a relative offset is calculated from the BPM signal and a feedback target is scanned typically at the start of each shift. This target is observed to drift with the beam current, and it also seems to drift with other events like beam loss. Moreover, measuring the feedback target is difficult as the luminosity is unstable over these timescales which make feedback tuning difficult.

He reports that progress is being made on the Xsuite model of SuperKEKB.

J. Salvesen concludes with open questions for the FCC-ee dealing with:

- Requirements
  - IP position requirements: is the current value of 100 µm the strictest requirement for physics performance ?
  - Beam offset tolerance: Multiple values exist, with the strictest being $\approx 0.02\sigma_y$ (equivalent to the nm level or below)
- Input signals
  - Number and placement of BPMs in the IR, which depends on the cryostat and final focus quadrupoles.
  - Beamstrahlung monitor, with ongoing discussions with the Beam Instrumentation (BI) group.
  - Availability of data directly from the Luminosity calorimeter?
- Correctors
  - Number and placement of correctors. Consideration of dedicated correctors for IP feedback and/or shared usage with other systems. Impact of Synchrotron Radiation (SR) and backgrounds on the detector.

    - Corrector response assumptions for simulations, as well as beam pipe and power supply responses.
- Global feedback
    - Whether global feedback will be sufficient to apply IP feedback to a single beam ?
    - Global feedback strategy, correction timescales, and locations ?
- Error sources
    - Ongoing discussion with LAPP regarding ground motion vibrations and other potential mechanical sources ?

F. Zimmermann asks if the dithering will be used horizontally and vertically and whether it will be only tested or also used during regular operations. **J. Salvesen** responds that it not clear when the system will be operational but in principle it can be used horizontally and vertically.

F. Zimmermann wonders why the 500 µm requirements for the luminosity calorimeter translates into a 100 µm requirements at the IP. **J. Salvesen** answers that this requirement comes from **M. Dam** and is currently the most stringent IP requirement identified.

4 Nonlinear optics measurements at SuperKEKB

M. Le Garrec presents some results from the commissioning of SuperKEKB optics, focusing on detuned and squeezed optics at $\beta_y^* = 8\,\text{mm}$.

He highlights a good reproducibility of the linear optics, which remains consistent across several days and from shot to shot. This reproducibility is notably better in the horizontal plane, attributed to the presence of a kicker. He notes one region with bad BPMs.

Sextupolar Resonance Driving Terms (RDT) measurements have been conducted in both rings ($f_{3000,x}$ in the LER and $f_{1020,y}$ in the HER), though not all measurements were clean, and some discrepancies of a factor 3 between measurements and the SAD model, are yet to be explained.

Good chromaticity measurements for both rings and detuned optics, showing discrepancies with the SAD model for $Q''_{x,y}$ in the HER, originating from octupolar(-like) sources; and for $Q''_{x,y}$ and Q'''_y in the LER, due to decapolar(-like) sources

The amplitude detuning has been measured for the LER with detuned optics, allowing a comparison to the model which could give a more detailed outlook on the discrepancy of Q''.

C. Carli asks if the results come from a single excitation or multiple excitations. **M. Le Garrec** clarifies that they were obtained with one excitation.

W. Hölfe asks which kicker was used to perform the measurements. **M. Le Garrec** responds that the injector kicker was used.

F. Zimmermann suggests that the SuperKEKB optics team should conduct optics measurements particularly at the IR, to compare with the observations made by **M. Le Garrec** and his colleagues. (specifically the tens of percent beta-beating).

F. Zimmermann asks if there are tune feedbacks during the measurements, as it would be beneficial to maintain a stable tune during during measurements. **B. Dalena** comments that the feedbacks are turned off during measurements.

F. Zimmermann comments that the peaks in the RDTs measurements vs. model could be caused by strong sextupoles.

5 Optics tuning working group update

J. Keintzel reports on the activities of the optics tuning working group, focusing on the lattices and alignment, commissioning, beam-based alignment, tuning, and dynamic aperture with errors.

A new arc lattice for the GHC lattice is under study, along with the implementation of twin quadrupoles for the LCC lattice. Drawing from the LEP and LHC experience, 150 μm misalignment in the arcs should be considered, necessitating one major re-alignment per year, and frequent optics tuning throughout the year.

Relaxed optics are being examined, so far with a factor 2 to 3 higher $\beta^*_{x,y}$. The DA with sextupole strengths halved results in only 3σ. The commissioning strategy is yet to be defined.

The correction of the phase advance seems critical to recover good DA/MA including errors. The DA including beam-beam interactions without crab waist, shows a reduction to about 7σ for the GHC lattice. Incorporating IP knobs into the tuning strategy is necessary.

F. Zimmermann asks if the 3σ is for off-energy particles because the DA on-energy should be enlarged with weaker sextupoles. **K. Skoufaris** confirms it is for on-energy particles. **R. Tomás** adds that chromaticity-induced path-lengthening could be a reason for such a DA reduction.

G. Roy asks is the 3σ DA was obtained with the nominal optics. **K. Skoufaris** confirms that it was. **G. Roy** suggests using relaxed optics to weaken the sextupoles, perhaps considering a ballistic optics approach (with final focus quadrupoles turned off) providing nearly no chromaticity from the IR.

F. Zimmermann asks if the tune is corrected when including phase advance errors. **K. Skoufaris** confirms that the tune is corrected.

G. Roy comments that the solenoid model and anti-solenoid should be available on the repository shortly.

Follow-up items

TASK
Need a candidate to develop a relaxed optics (for GHC and LCC ?)

46 Participants:
K. André, H. Bartosik, M. Boland, G. Broggi, Q. Bruant, C. Carli, F. Carlier, B. Dalena, H. Damerau, A. Frasca, C. Garcia, V. Gawas, A. Ghribi, C. Goffing, K. Hanke, W. Hölfe, B. Humann, P. Hunchak, A. Inanc, P. Janot, J. Keintzel, R. Kersevan, R. Kieffer, C. Kiel, M. Koratzinos, S. Kostoglou, M. Le Garrec, C. Li, E. Maclean, M. Migliorati, K. Oide, F. Poirier, A. Rajabi, S. Redaelli, G. Roy, L. Sabato, J. Salvesen, G. Simon, R. Tomás, A. Vanel, L. Watrelot, J. Wenninger, S. Yue, C. Zannini, F. Zimmermann, and M. Zobov