Meeting Minutes of the
189th FCC-ee Accelerator Design Meeting and 60th FCCIS WP2.2 Meeting

Indico: `https://indico.cern.ch/event/1440349/`
When: 25.07.2024 15:00-17:00 GVA time

Agenda

Presenter	Title
F. Zimmermann	**LCWS and KEK report**
K. André	**ICHEP 2024 report**
M. Boscolo	**Update from the MDI working group**
K. André	**DA studies with Xsuite**

1 General information

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

F. Zimmermann notes that he received optics files from the SuperKEKB optics team which could be used to compare the RDTs and optics measurements in the interaction region of SuperKEKB with the data collected by the CERN colleagues.

F. Zimmermann shares outstanding issues namely:

- **Baseline Optics for Feasibility Study Report**: the definition of a baseline optics for the feasibility study is ongoing. This includes the GHC lattice with alternative arc optics, more complete lattices including collimation and injection insertions, and optics tuning. The goal is to complete these tasks by September to enable beam-beam studies. **G. Roy** is following up on this topic.
- **Dynamic Aperture Discrepancy**: There is a discrepancy between codes (pyAT, Xsuite and SAD) to compute the dynamic aperture of the LCC (and GHC) lattices. This issue needs to be resolved to ensure accurate simulations.
- **Beam Lifetime Discrepancy**: There is a discrepancy in beam lifetime between SAD and Xsuite, which might be due to the implementation of synchrotron radiation. This issue requires further investigation to pinpoint and resolve the cause.
- **Beam-Based Alignment scheme for the arcs**: the beam-based alignment scheme for the arcs needs to be finalized and initial alignment tolerances for the arcs need to be defined.

2 LCWS and KEK report

F. Zimmermann reports on the International Workshop on Future Linear Collider (LCWS2024) that took place in Tokyo, and SuperKEKB run 2024ab summary meeting that took place at KEK, in Tsukuba.

LCWS2024 Highlights

The workshop provided an overview of the future projects, including ILC, CLIC, C3, HALFH, XCC and energy recovery applications for linear colliders. Circular collider projects such as CepC, FCC-ee and the muon collider were also presented. Key presentations highlighted the physics goals of a comprehensive Higgs factory program, starting 250 GeV $e^+e^- \to ZH$, moving to 550-600 GeV above the ttH and ZHH thresholds, and culminating with 800-1000 GeV as a final Higgs factory stage. Stating that "the purpose of a Higgs Factory is not to improve the error bars. The purpose is to make discoveries."

On sustainability, the carbon footprints of all Linear Collider (LC) projects are much smaller than those of circular machines. Up to 500 GeV, their power consumption is comparable to the current opwer usage at CERN. However, the total annual operational cost of the FCC-ee has been quoted at more than 1.3 BCHF by the German BMBF, though detailed breakdowns on this figure were not provided according to **F. Zimmermann**.

SuperKEKB Run 2024ab Summary Meeting Highlights

F. Zimmermann then summarizes the discussions from the SuperKEKB run 2024ab summary meeting at KEK:

- **Sudden Beam Loss (SBL)**: SBL combined with abort statistics showed that SBLs do not represent a large fraction of total aborts (163 SBL aborts vs. 2824 total aborts). SBL primarily occurs in the Lowe Energy Ring (LER) but also in the High Energy Ring (HER). The frequency of SBL per hour is dependent on the beam current. Over time, the frequency of SBL has decreased due to the implementation of a knocking mechanism on the beam pipes at the D10 Nikko wiggler section.
- **Luminosity and beam parameters**:
  - $\beta_y^* = 0.9$ mm from 2024 yielded similar specific luminosity compared to 2021 with the same β_y^*; however, $\beta_y^* = 1.0$ mm from 2022 provided higher specific luminosity than $\beta_y^* = 0.9$ mm.
  - The specific luminosity with a larger number of bunches (2346) is lower than that with fewer bunches (393).
  - Single beam blowup limits the bunch current. Before collimator damage (March 1st 2022) no blowup was observed without bunch-by-bunch feedback, but with blowup was observed with bunch-by-bunch feedback at about 1.25 mA. After collimator damage (June 21st 2022), blowup was observed at 0.9 mA with bunch-by-bunch feedback.

3 ICHEP 2024 report

K. André reports on the International Conference for High Energy Physics (ICHEP) that took place in Prague.

He presents the agenda focusing on Accelerators: Physics, Performance, and R&D for future facilities, including four parallel sessions on Thursday and two parallel sessions on Friday. Additionally, two plenary talks on "Present and Approved Accelerator Facilities" and "Future Facilities and Advances in Accelerator Technologies" took place as well as a panel discussion on future colliders.

He highlights keypoints from SuperKEKB beam commissioning after the Long Shutdown 1 (LS1), particularly addressing sudden beam loss issues. Countermeasures planned during the summer shutdown include turning some sections upside down in the Oho straight section, where dust is suspected to initiate sudden beam loss. Visual check and dust cleaning are also planned for beam pipes not turned upside down.

A strategy to reach $1 \times 10^{35}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ is presented targeting beam currents of 2.08 A and 1.48 A at $\beta_y^* = 0.8\,\mathrm{mm}$ and later $2.4 \times 10^{35}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ with beam currents of 2.75 A and 2.2 A at $\beta_y^* = 0.6\,\mathrm{mm}$.

Next, highlights of a crystal-based positron source for the FCC-ee are presented. Compared to the conventional source with an electron beam on a tungsten target, an alternative hybrid source using a crystal plus tungsten target or a single crystal yields more positron per incident electrons (+12%), a smaller target deposited power (-31%) for a smaller incident electron bunch charge (-11%). The next steps include integration studies and beam tests, with a potential proof-of-principle at P^3 experiment at PSI.

Plenary talk on "Present and Approved Accelerator Facilities"

This talk summarized the current state of accelerator facilities. Presently there are five electron-positron (ee)-colliders and two hadron-hadron (hh)-colliders. Low-energy colliders serve as technology test beds for beam-beam compensation, crab crossing, beam cooling, collimation, etc. SuperKEKB, with its very high luminosity is a prototype for future ee-colliders and the Electron-Ion Collider (EIC). hh-colliders are becoming increasingly flexible regarding energy and species.

There are two colliders under construction: The EIC aiming for approximately 100 times HERA's luminosity, with polarized electons, protons, ^{3}He, and heavy ions; and the Nuclotron-based Ion Collider fAcility (NICA).

There are high-intensity machines with beam power above 1 MW, ν beams drive increases. There are also synergies with other applications such as spallation neutron sources, nuclear physics, Accelerator Driven Systems (ADS).

Plenary talk on "Future Facilities and Advances in Accelerator Technologies"

This talk mostly covered the FCC integrated program (ee + hh) and the following key technologies:

- SRF Technology R&D: highlighting the new SRF facility to be built at CERN for mid 2029.
- High Field Magnets: Progressing from NbTi to Nb_3Sn to HTS. The FCC-hh requires higher temperature magnets. Current LHC dipoles at 1.8 K in the FCC tunnel would consume 4 TWh, four times CERN's electric consumption.
- Muon Collider: The magnets need to have high gradients and must survive high heat load (5-10 kW) and high radiation dose (20-40 MGy).

4 Update from the MDI working group

M. Boscolo presents an update on the activities of the Machine-Detector Interface (MDI) working group, focusing on the mechanical design of the interaction region vacuum chamber to be fabricated for a mock-up at INFN Frascati. There is an optimization of the material budget in front of the lumical and for the detector. The copper cooling manifolds have been replaced by AlBeMet manifolds, a Beryllium chamber instead of AlBeMet is under discussion. Additionally, the use of water instead of paraffin for coolant is being evaluated due to safety concerns because paraffin is flammable. The length and thickness of the gold coating are also under investigation. Regarding the IR magnet system, work is ongoing for the definition of the number of cryostats (1 or 2) to be integrated on a raft, as well as other topics such as shielding within the final focus quadrupoles.

A comparison between the solenoid compensation schemes is shown:

- **Alternative (non-local) scheme**: skew quadrupolar components in the Final Focus Quadrupoles (FFQs) align the magnet axis to the rotated reference frame of the beam. Correctors directly after the beam pipe separation and around the FFQs correct the orbit deflection caused by the crossing angle in the detector field. An anti-solenoid (or skew quadrupoles placed about 20 m from the IP) corrects the coupling. The vertical emittance growth is 0.2% of the nominal 1 pm.rad, and the vertical emittance increase remains small within the range $\delta = \pm 4\%$. Synchrotron Radiation (SR) power generated is about 12 kW.
- **Baseline (local) scheme**: featuring anti-solenoid around the detector solenoid to compensate locally the coupling. The vertical emittance growth is 20% of the nominal 1 pm.rad and, the vertical emittance increase remains small within the range $\delta = \pm 4\%$. SR power generated is about 78 kW.

The vertex detector design is progressing with a lighter concept featuring curved and stitched MAPS (inspired by the ALICE ITS3 design). The engineering, services integration, and cooling are being finalized. Accessibility for maintenance must be considered when designing the vertex detector. Large caverns can have the endcaps open on the side, whereas smaller caverns can only open endcaps along the beam line, which must be taken into account in the design.

Beam backgrounds:

- Initial studies on hit occupancy in detector sub-components (IDEA vertex detector, IDEA drift chamber and ALEGRO ECAL) caused by Incoherent Pair Creation (IPC) have been performed. The next objective is to cover more sub-components and evaluate more background sources.
- Synchrotron radiation in the IR has been simulated including beam tails, injected beams and various optics design up to the internal beam pipe.
- First evaluation of beam-gas losses using the Xsuite-BDSIM simulation tool up to the internal beam pipe.

Next steps involve tracking these particles to a suitable surface before the detector to evaluate hit occupancy, energy deposition and radiation levels using the detector model.

G. Roy and **F. Zimmermann** discuss the use of skew quadrupoles compared to anti-solenoid to correct the coupling induced by the detector solenoid. **G. Roy** points out that LEP only used skew quadrupoles, and suggests considering their effect on polarization as well.

G. Broggi comments that the beam gas results correspond to a high vacuum pressure from the early commissioning period and should improve with the conditioning of the machine, eventually reaching beyond 100 h of beam lifetime, comparable to LEP.

J. Salvesen adds that together with **V. Gawas** they will prepare a repository collecting the beamstrahlung photons with non-optimal settings, such as dispersion at the IP and transverse misalignments, and it should be beneficial for MDI studies.

5 DA studies with Xsuite

K. André presents Dynamic Aperture (DA) studies performed with Xsuite.

He begins by discussing the impact on the Momentum Acceptance (MA) when changing the nominal LCC lattice from four RF sections to one RF section, and with 10 to 15% total RF voltage reduction. The MA shows a gradual reduction from beyond $\pm 3\%$ to $[-2.0, +2.6]\%$. Concurrently, the synchrotron tune reduces from $Q_s = 0.114$ to $Q_s = 0.084$, and the bunch length increases from 1.8 mm to 2.4 mm over the same RF voltage range.

He adresses potential reasons to explain discrepancies between the MA resulting from SAD and Xsuite for the LCC lattice. He points out that the variable "cs_comp" and the decapoles are not used in SAD. He performed the MA calculations without decapoles and with "cs_comp=0" to replicate SAD's conditions. However, these attempts were unsuccessful in reproducing SAD's results.

Finally, he presents MA results from relaxed optics at the IP for the GHC and LCC lattices compared to the nominal optics. The GHC lattice has the maximum normalised horizontal amplitude extending beyond $25\sigma_x$ in the range $\delta \in \pm 0.5\%$ with the detuned optics showing roughly twice the performance of the nominal optics. In contrast, the MA for the nominal LCC lattice extends beyond $25\sigma_x$ in the range $\delta \in \pm 0.75\%$ with the detuned optics and $15\sigma_x$ even for $\delta = \pm 1\%$ showing roughly twice the performance of the nominal optics.

Follow-up items

TASK

42 Participants:
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