Meeting Minutes of the
182nd FCC-ee optics design meeting
and 53rd FCCIS WP2.2 meeting

Indico: `https://indico.cern.ch/event/1398060/`
When: 04.04.2024 15:00-17:00 GVA time

Agenda

Presenter	Title
K. Ohmi	**Beam-beam simulation with lattice in FCC-ee**
Z. Duan	**Imperfection spin resonances for FCC-ee Booster lattices**
H. Damerau	**Update on the FCC ring circumference**

1 General information

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

The participants list to the FCC week 2024 is still pending approval before being sent around.

2 Beam-beam simulation with lattice in FCC-ee

K. Ohmi presents the development of a new beam-beam simulation code utilizing GPU and providing Particle In Cell (PIC) or Soft-Gaussian (SG) methods, based on the BBSS code. It also includes beamstrahlung, also based on BBSS code. The lattice is converted from SAD.

He presents comparisons of simulation execution durations, showing that PIC simulations are only slightly longer than SG simulations for beam-beam interactions requiring few slices. However, as the number of slices increases, necessary for the FCC-ee Z mode, the PIC simulation duration significantly increases and becomes 2-3 times longer than SG simulations. For very complex non linear lattices such as SuperKEKB with a very detailed IR region, the PIC calculation remains a fraction of the lattice calculation.

He highlights the necessity of using PIC simulation for collisions with zero crossing angle due to non-Gaussian distortions limiting beam-beam performance in PIC, not reproduced with SG approximation. For small Piwinski angle, there is no difference between PIC and SG beam-beam methods. With large Piwinski angle and a linear lattice model, the results of PIC and SG are similar, however, using the nonlinear lattice the instabilities arise with both methods, but with different magnitudes.

Assuming a 4-periodicity of the lattice to study incoherent phenomena, he compares the FCC-ee at ZH threshold luminosity between linear and nonlinear lattice models, noting a 6% difference possibly due to the different treatment of synchrotron radiation.

He presents bunch population dependence studies in which the target luminosity is achieved with PIC and SG, using linear and nonlinear lattices. The resonance peak for the horizontal emittance as a function of the horizontal fractional tune due to X-Z instabilities seem to shift by +0.002 using PIC vs. SG method.

Finally, he notes that using RMS to compute the beam parameters such as emittances and bunch length showed issues with the SG model and a Gaussian fit should be used. Otherwise the PIC model should be used.

F. Zimmermann asks about GPU resources in the group and who has access as well as learning opportunities to use this code here at CERN. **X. Buffat** proposes to discuss with **K. Ohmi** and to use his code to benchmark Xsuite. **X. Buffat** adds that Xsuite already has a PIC model through the pyHEADTAIL module that would not require too much work to adapt it for beam-beam interaction.

M. Zobov suggests to use impedance models for future studies, noting their absence in the current beam-beam studies.

I. Karpov asks if the 4-fold symmetry used in this beam-beam studies has the RF distributed in 4. Because the FCC lattice has a single RF section the about the crab waist strength which is set to 80% for the LCC lattice at the Z energy.

3 Imperfection spin resonances for FCC-ee Booster lattices

Z. Duan presents the estimates of spin depolarisation in the booster ring due to lattice imperfections.

The imperfection lattices were produced using **B. Dalena**'s python and MADX scripts, generating lattice imperfections and conducting closed orbit corrections, although without betatron tune or optics corrections thus far.

He compares resonances from imperfection and intrinsic sources. Intrinsic resonances alone result in negligible depolarization for Z/W/Higgs modes and some depolarization for the top mode, mainly due to a strong resonance between Higgs and top beam energy. However, imperfection resonances are much stronger, even at lower energies. The resulting polarization transmission estimates are typically 90% (Z), 60%(W), 15%(H) and zero ($t\bar{t}$) accross multiple lattice seeds and regardless of the lattice booster design (FODO or HFD).

He notes that the ramping curve can be optimized to partially reduce the depolarization. Moreover, the double parabolic energy ramp provides slightly worse polarization transmission with respect to the cosine ramp (only studied for Z energy).

This preliminary investigation suggests that injecting highly polarized beams into the collider is feasible for the FCC-ee. However, more comprehensive error sources and more sophisticated error correction schemes are yet to be included. A comparison between booster lattice designs for both CEPC and FCC-ee in terms of polarization transmission is foreseen to provide guidelines for lattice optimization, using the same error settings and correction procedures.

F. Zimmermann asks what feature makes the CepC booster lattice better. **Z. Duan** answers that the focusing within the FCC booster is stronger with respect to the CepC booster.

F. Zimmermann notes no dependence between the polarization transmission and the error magnitude. **Z. Duan** confirms observing such dependence for CepC.

F. Zimmermann suggests that injection of polarized beam/bunches could help for calibration.

4 Update on the FCC ring circumference

H. Damerau presents an alternative to adjust the FCC ring circumference to achieve better ratios with the LHC and SPS rings, aiming to facilitate injection into the future hadron collider.

Currently, the ratios between FCC and LHC circumferences stands at 1010/297 and between FCC and SPS circumferences at 1010/77. During FCC week 2023, proposals for improved ratios were discussed, requiring a modification of the ring circumference by ± 180 m (2 options).

The proposed alternative aims for a ratio of exactly 3.4, requiring a reduction of the circumference by 18 m to achieve a 17/5 ratio, which is more favorable for the LHC and does not exclude using the SPS as an injector. This adjustment would result in a new FCC to SPS circumference ratio of 459/35.

Consequently, the RF frequencies for the FCC and its injector chain would be 364.4, 485.8 or 607.3 MHz with a potential fallback option to operate the FCC-ee at 404.8 MHz, closer to the current frequency. However, transitioning from FCC-ee (@404.8 MHz) to FCC-hh would require switching the RF frequency again.

For potential re-use of the SPS as a lepton (pre-)injector, RF frequencies offering integer harmonic numbers are: 364.3 ($h_{SPS} = 8400$) and 485.8 MHz ($h_{SPS} = 11200$). Accommodating 404.8 MHz ($h_{SPS} = 9333.33$) would require non-integer harmonic acceleration in the SPS with new travelling wave cavities (TWC) at 202.4 or 404.8 MHz, or eventually superconducting TWC with filling time well below one turn duration (23 µs).

F. Zimmermann raises concern on the bunch spacing being not exactly 25 ns but 24.7 ns. **H. Damerau** and **H. Burkhardt** argue it poses no issue for the experiments.

F. Zimmermann asks about the reasons behind not accepting a waiting period of 90 ms between injection into FCC-hh due to the current ratio between FCC and LHC. **H. Damerau** explains the need for multiple transfers from the injectors into the FCC-hh and the importance of not constraining the future injection methods until FCC-hh begins.

46 Participants:
K. André, M. Boland, R. Bruce, Q. Bruant, X. Buffat, H. Burkhardt, R. Calaga, F. Carlier, F. Carra, A. Chancé, A. Ciarma, B. Dalena, H. Damerau, L. Deniau, Z. Duan, A. Faus-Golfe, V. Gawas, A. Ghribi, K. Hanke, B. Humann, S. Jagabathuni, I. Karpov, R. Kersevan, R. Kieffer, M. Koratzinos, K. Ohmi, K. Oide, F. Peauger, A. Piccini, F. Poirier, P. Raimondi, A. Rajabi, F. Saeidi, J. Salvesen, G. Simon, R. Tomás, A. Vanel, U. van Rienen, L. van Riesen-Haupt, L. von Freeden, R. Wanzenberg, F. Yaman, S. Yue, Z. Zhang, F. Zimmermann, and M. Zobov