Meeting Minutes of the
199th FCC-ee Optics Design Meeting

Indico: https://indico.cern.ch/event/1483845/
When: 12.12.2024, 15:30-17:30 GVA time

Agenda

Presenter	Title
F. Zimmermann	**General information**
I. Karpov, K. Oide	**Update on Transient Beam Loading from Reverse Phase Operation**
I. Syratchev	**RF sources and efficiency**
T. Raubenheimer	**Status and Plan for the FSR**
X. Buffat	**Update on beam-beam simulations including longitudinal wakefields**
P. Kicsiny	**Injection efficiency in presence of beam-beam interactions**

1 General information

F. Zimmermann presents some highlights of the CGM (Coordination Group Meeting) from the week before. Notably, there they presented first drill samples of molasse and limestone from probe drillings. Then he shows some updates on the FCC-ee availability study. The newest estimate is to have about 182 days available for physics data taking for Z and W. Next, he summarizes Tor's proposals and the timeline for the editing of the upcoming FCC-ee feasibility study report (FS volume 2). Notably, the editing process will include completion of the text by the authors with interaction by the technical editors. After the technical editors release a chapter (volume), the copy editors work on the document. The final document will need review for consistency by the technical editors.

2 Update on Transient Beam Loading from Reverse Phase Operation

I. Karpov highlights the impact of pilot bunches and RF feedback. He presents that beam stability constraints required a further reduction of the total RF voltage for the Z mode, with Reverse Phase Operation (RPO) mode. The presence of pilot bunches modifies the synchrotron frequency spread if some gaps remain empty. The RF feedback with finite gain leads to a small increase of the spread and about 30 % RF power transients. Direct RF feedback reduces the impedance the beam would see in the region where the impedance would have two spikes (at the location of the focusing and defocusing cavities). Due to the finite gain of the feedback system, the results in time domain are slightly worse than in frequency domain.

F. Zimmermann asks if we can have pilots in all the gaps? **I. Kaprov** comments that it is to be seen with Yan, not sure as they will see a rising field from kicker, if they remain in the bucket maybe it's acceptable.

C. Carli asks if having pilot bunches in all gaps is a problem for machine protection? **I. Kapros** says that they have relatively small intensity so not sure.

3 RF sources and efficiency

I. Syratchev presents updates on the development of a tristron for FCC-ee implementation scenarios. He gives updates on a technology demonstrator (low cost at short time), which features a retrofit upgrade of an existing ESS, anticipating efficiency increase from 70 % to ∼85 %. They plan on full recycling of the exiting components (gridded cavity, output cavity and collector). The RF circuit and optics design and optimization are planned to be performed at CERN. The tube refurbishment is planned to be done at Thales by introducing extra cavity and compact external solenoid. The testing is at ESS using existing facilities. The estimated schedule is about 18 months. It is a potential candidate for the graceful replacement of ESS klystrons along accelerator life-time. Frequency is close to 800 MHz, needed for FCC. Regarding the FCC-ee 0.5 MW tristron prototype at 400 MHz, the RF circuit and optics design and optimization are to be performed at CERN. The common input cavity vs. clustered option design and cost optimization is foreseen to be done by Thales and potentially CERN. The tube fabrication is potentially foreseen at Thales and possible collaborators. The estimated time for the project is about 36 months. The project would cost 1/3 price of a klystron because much more compact tristron is very promising, but HV power supply is challenging if it is done independently of focusing or defocusing cavities, however, the sum of focusing and defocusing cavity power is almost constant. The main issue is the asymmetry between focusing and defocusing cavities so one needs to power constantly over time but release some of the powering in the load (slightly inefficient) but it is not too bad as there are only 10 more focusing cavities.

M. koratzinos asks why we can't finish the project in 2 years. **I. Syratchev** comments that one reason is a lack of industry support. They are trying to work with EU industry but they have only one French company (Thales) at the moment. The 36 months includes contract negotiations etc. but they have limited resources and industry bureaucracy slows it down. Industry hasn't progressed much for the last 30 years in this direction and they have to take the risk of putting resources and it comes with lots of negotiations. Concept was proven with simulations in mid August. He further adds that the Chinese klystron will be more expensive, bigger but less reliable. The Chinese have more manpower.

M. Koratzinos asks what is the price of the klystron? **I. Syratchev** comments that the cost is 1 million per klystron and 150 of them needed for the FCC Z. The triston costs 300k.

4 Status and Plan for the FSR

T. Raubenheimer presents the status of the editing of the FCC-ee design report volume 2. The link to the excel sheet can be found here.

F. Zimmermann comments that the studies with the HTS optics are ongoing but not represented at the moment. We should include it in the future discussions.

T. Raubenheimer comments that Chapter 11 has to be extracted and distributed to the various technical systems.

5 Update on beam-beam simulations including longitudinal wakefields

X. Buffat presents the status on beam-beam simulations including longitudinal wakefields. He highlights that there exist acceptable working points for bunches experiencing significant RF voltage spread due to the 2-cell cavities in RPO only with the lowest voltage considered (88 MV $\rightarrow$ min/max: 79/93 MV), including impedance margin (2x current model). In addition, high chromaticity (5 units in both planes) is required. Robustness and stability during the injection process with intermediate bunch intensities requires further investigation e.g. to assess the sensitivity to chromaticity changes, beam parameter asymmetries. A better understanding of the mitigation of the X-Z instability and of the mode coupling instability of colliding beams in the vertical plane with chromaticity is required (also with 1-cell cavities) to clarify the limits.

F. Zimmermann asks if there is hope to increase voltage again? **X. Buffat** comments that it will cost chromaticiy so he doesn't expect it can be increased a lot.

F. Zimmermann asks what is the chromaticity on K Odie's plot. **K. Oide** comments that the vertical chromaticity was 5 and the horizontal chromaticity was not 5. **X. Buffat** adds that the role of vertical chromaticity in the horizontal instability is not understood. He further adds that the scan should be repeated for the highest voltage setup.

X. Buffat also points out that the parameter table can be done for a nominal voltage of 88.5 MV but also one can add details on the extreme bunches seeing V_{min}=79 and V_{max}=92.5 MV respectively.

C. Carli says that the main issue is the X-Z instability, but there seems to be also a problem vertically. **X. Buffat** adds that the reason for this is still unclear.

6 Injection efficiency in presence of beam-beam interactions

P. Kicsiny presents the status simulations of longitudinal top-up injection efficiency. He first introduces the tracking model, which includes beam-beam, beamstrahlung and linear tracking with effective synchrotron radiation, and the numerical modeling of the injection. This model features a momentum cutoff but no transverse DA, so it is not indicative of the eventual beam losses on a realistic DA and reduced beam lifetime, but it allows to study the equilibrium beam dynamics. He presents highlights from parameter scans under asymmetric beam parameters using the linear tracking model. In general, the observed flip-flop mechanism results in a new equilibrium with reduced luminosity. Reaching this new equilibrium is fast ($\sim$synchrotron radiation damping rate) and no reduction of injection efficiency/beam loss was observed due to beam-beam. The simulation details can be found in a paper here. The next steps should include tracking with a full lattice which features a proper transverse DA (which is not present in the linear tracking model).

M. Boscolo asks if RF and tapering are included in the linear model? **P. Kicsiny** comments that no, this model is only using a linear transfer matrix, crab sextupoles and beam-beam, but no RF or tapering.

X. Buffat comments that Bhabha scaterring will not change the beam dynamics.

K. Oide asks if the injection is on-axis, and why is there a blow-up right after the injection? **P. Kicsiny** says there is a negative offset in relative energy for the injected beam so it is on axis off momentum injection, and the blowup is there because of the computation of the rms beam size, which then includes the injected (offset) particles. Due to the crossing angle, there is an x-z coupling at the beam-beam so the offset will translate into an offset in the transverse beam sizes too.

K. Andre asks if one sees something vertically. **P. Kicsiny** answers that there is a slight increase.

X. Buffat asks if the injection parameters should be different from the collider parameters? **C. Carli** and

F. Zimmermann comment that it should be discussed with **A. Chance** but it is certainly an advantage if the vertical emittance has not converged yet.

G. Roy asks about the coalescence of the beam creating the blowup in horizontal direction, that it can be a good idea to check the phase space of the injected beam during this blowup.

G. Broggi reports observing a vertical emittance blowup by approximately a factor of 10 over 1000 turns in tracking simulations with beam-beam when super-periodicity is broken by including the injection optics in the collider.

43 Participants:
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