Meeting Minutes of the
143rd FCC-ee optics design meeting
and 14th FCCIS WP2.2 meeting

Indico: https://indico.cern.ch/event/1065014/
When: 26.08.2021 14:30-16:30 CET

Agenda

Presenter	Title
I. Karpov	**Follow-up on transient beam loading**
D. Shatilov	**RF Frequency options at H**

1 General information

T. Raubenheimer opens the meeting, standing in as chairperson for **F. Zimmermann**. No news or general information are reported by any of the participants.

2 Follow-up on transient beam loading

I. Karpov presents a follow-up on the transient beam loading for different cavity options at the Z operation mode. Considerations on the steady-state beam loading and RF power minimization are shown as those factor into the transient beam loading. For the simulations of the transient beam loading, the steady-state time domain method is used as tracking simulation are not practical due to the high number of bunches in the Z operation mode. The results from previous simulations are shown, showing a good agreement between time- and frequency-domain calculations for the beam phase modulation. A strong modulation is present due to the abort gap, and the peak-to-peak beam phase modulation as a function of the abort gap length is presented. While identical transients in both beams can be compensated by abort gap matching, an imbalance in the charge of $\pm 5\%$ will result in a collision point shift of 0.2 σ_z for the case of the single cell cavity, but by 1 σ_z for the SWELL cavity. Calculations by **D. Shatilov** show that the collision point shift should be below 0.4 σ_z to minimize the impact on luminosity. A formula to estimate the maximum displacement is given, illustrating options to reduce the displacement by changing RF design parameters (R/Q), using a smaller abort gap length, or by use of compensation schemes, all option to be further evaluated in the future.

M. Koratzinos asks if the asymmetry of $\pm 5\%$ is the maximum or RMS variation. **I. Karpov** replies that here it was assumed that the charge of each bunch of one beam is larger by 5 %, and decreased by same amount in the other beam. **D. Shatilov** notes that for the 5 % should be assumed as peak-to-peak for each pair of colliding bunches.

D. Shatilov asks why the SWELL cavity has a factor 5 larger transient beam loading. **I. Karpov** replies that this comes in parts due to the higher RF frequency, but also that the R/Q is a factor 3 larger. **D. Shatilov** comments that this factor 5 between the two cavity types will then persist, irrespective of the other input parameter. **I. Karpov** agrees. **T. Raubenheimer** notes that for the SWELL cavity, the R/Q could be decreased to reduce the maximum longitudinal displacement. **I. Karpov** agrees and adds that the 4-cell UROS cavity was used as basis and some further optimization could be done in the future.

On the compensation schemes mentioned on the last slide, **T. Raubenheimer** asks if a phase jump could be viable option. **I. Karpov** replies that one option is to modulate the cavity voltage phase, and with a similar set point modulation, no extra power would be required. If the set point is modulated to reduce the transients, the power requirements may increase significantly.

T. Raubenheimer comments that with an extra 3rd harmonic, the required voltage will decrease, and asks if this has been looked into in detail. **I. Karpov** replies that for FCC-ee, has not been done yet, however some light source have presented studies on those in the past. He recalls one study where due to beam loading in those cavities, the beam distribution is significantly distorted. **R. Calaga** adds that a 2^{nd} harmonic cavity for bunch lengthening has been looked into for the LHC and points to an conference paper.

3 RF Frequency options at H

D. Shatilov presents studies on using an RF frequency of 800 MHz in the ZH operating mode instead of 400 MHz. He notes that one of the main limiting factors is the mitigation of a coherent beam-beam instability, which requires the horizontal tune Q_x to be above 0.5 plus the synchrotron tune Q_s times the Piwinski angle ϕ. For the Z operation mode, the required horizontal tune $Q_x^* = 0.86$ is too large, and instead a lower RF-voltage of 100 MV is chosen to reduce the synchrotron tune Q_s and thereby weakening the resonances close to the working point. For the ZH operation mode, the horizontal tune Q_x is closer to the required one $Q_x^* = 0.6$, thus the coherent beam-beam instability is suppressed. **D. Shatilov** concludes that the RF-frequency at ZH can safely be increased to 800 MHz.

K. Oide comments that here only the 2 IP case is assumed, and that in the 4 IP case the situation will be more complicated. **D. Shatilov** replies that in the 4 IP case, the Q_s per period is smaller, yet the Piwinski angle remains the same. In simulations for this case, no new modes were seen.

R. Calaga asks if with higher RF-frequency and voltage at Z, the Piwinski angle would go down to a sufficiently low value. **D. Shatilov** replies that also the RF acceptance should be taken into account.

I. Karpov asks if with a higher RF frequency of 600 MHz and the increase synchrotron tune Q_s, a 3rd harmonic cavity is needed. **D. Shatilov** replies that with a larger RF frequency at lower energy and the potential increase of the momentum compaction factor, the synchrotron tune Q_s will increase too much and compensation will be needed.

I. Karpov asks if the synchrotron tune spread can be neglected. **D. Shatilov** notes that at higher energy, such as in the ZH case, it can be neglected, whereas in the Z case it will become important.

Follow-up items

TASK
Find minimal feasible abort gap length to determine maximum longitudinal displacement

32 Participants:
J. Bauche, M. Benedikt, M. Boscolo, P. Burrows, R. Calaga, Y.-C. Chae, S. Doebert, H. de Grand-saignes d'Hauterives, M. Hofer, B. Humann, P. Janot, I. Karpov, J. Keintzel, M. Koratzinos, C. Li, R. Losito, M. Migliorati, E. Montbarbon, E. Musa, N. Nikolopoulos, S. Ogur, K. Oide, F. Poirier, A. Rajabi, T. Raubenheimer, S. Redaelli, M. Reissig, L. van Riesen-Haupt, D. Shatilov, F. Yaman, R. Yang, and Y. Zhang