CEI section meeting 12-09-2024

Present: Bernardo Abreu, David Amorim, Chiara Antuono, Xavier Buffat, Elena de la Fuente García, Dora Gibellieri, Miguel Gonzalez Torre, Jintao Li, Frederik Grønvold, Lotta Mether, Elias Métral, Nicolas Mounet, Malthe Raschke Nielsen, Giovanni Rumolo, Leonardo Sito, Roxana Soos

Online: Lorenzo Giacomel, Elena Macchia, Ingris Mases Sole, Carlo Zannini

Scientific secretary: David Amorim

General information (Giovanni Rumolo)

New arrivals

- Simon Fanica (Sietse) Buijsman: doctoral student at EPFL with Gianni on "Xsuite modeling of beam-based measurement and correction in lepton storage rings”
- Jintao Li: doctoral student at IHEP (Beijing) with Na Wang, associate for one year with Carlo on “Development of an Advanced Simulation Model for LHC Target Dump Injection Segmented (TDIS) to Analyse Beam Coupling Impedance Effects”
- Malte Raschke Nielsen: trainee with Elena and Carlo on “A genetic algorithm for wake calculation of narrow-band resonators”
- Peter Kicsiny: back in the section as fellow, working with Xavier on beam-beam effects for FCC-ee

Communications and Arising matters

- JAP workshop 10-12 December in Montreux, the first draft of talks and speakers schedule will arrive by the end of the week.

Machine operation

- Injectors: Ion comissioning in the injectors will start next week (specific long cycles in the SPS).
- SPS: The limit on high intensity LIU beams in SPS has been lifted. MD reached 2.2e11 p/b at 450 GeV, on Sep. 12 it will try to reach >2.3e11 p/b. Nicolas asked if other beam flavours will be tested (e.g BCMS). Giovanni answered that indeed it should be tried at some point.
- LHC: already 100 fb-1 produced, a record for a single year. Good last few weeks, performing better than projections. For heat-loads, a slow conditioning seems to be visible. Sector 7-8 went below 160 W/half-cell. The impact on possible filling schemes, number of bunches and bunch intensity will be presented by Lotta at LBOC on Sep. 24th.

SPS growth rate measurements and analysis (Miguel Gonzalez Torre)

- This project started from the vertical growth rate measurements in the SPS in 2022-23. **In the vertical chromaticity range -1<Q'/Q<-1.75, a growth rate larger than predicted from the wake model is present**. This points towards a missing (yet unknown or underestimated) element in the SPS impedance model, in the vertical plane, dubbed the "dark impedance".

    - The evolution of several observables along the MD cycle is used: average vertical position, bunch intesity, intrabunch motion of the bunch with the Headtail monitor.
    - The growth-rate is computed from the position data by applying a moving FFT window, and then finding the start and end of the exponential growth. This last step was automatised to make the processing less cumbersome.

- To find more information on the dark impedance, which may point to its source, several **growth-rate measurement** sets were done **versus energy and vertical tune set point**.

    - For a fixed Q', the vertical tune Q was scan to check if there is an effect from the integer resonance. No effect of the tune was observed.
    - Measurements at 100 GeV were also carried out. This was the first time a cycle with a long plateau at 100 GeV was used in the SPS for this type of measurements. Headtail motion with a mode 0 is observed consistently, also at high negative chromaticity.
    - Elias asked if the node profile is fully symetric: a small asymetry could point to the influence of other modes on the main mode. Giovanni believes that the larger gap between real and reflected signal at 100 GeV is mainly due to the shorter bunches at this energy.
    - Elias highlighted that the headtail mode (its number of nodes visible on the headtail signal) is related to the radial mode number. A mode with higher azimuthal mode number can have a different number of nodes in the headtail signal.

- **Simulations with PyHEADTAIL and Xsuite were performed**, benchmarking the two codes and checking the contributions of each element of the SPS impedance model.

    - In both cases a linear map is used for the lattice. There is a small difference (few percent level) between Xsuite and PyHEADTAIL results for the instability growth rate.
    - Lorenzo remarked that high order chromaticity could play a significant role for the growth rate, as well as the number of slices used in simulations. It sometimes needs to be pushed towards ~2000 slices. Miguel noticed that what matters is also the ratio between total number of macroparticles and number of slices (i.e., the number of macroparticles per slice)
    - Simulations using the separate contributions (resistive wall, kickers, transitions) of the wake model were done. Elias and Giovanni drew the attention on that the growth rate vs chromaticity simulation results when considering only the step transitions match the behavior that is looked for with two symmetric peaks around Q'/Q = -1. This may point to an underestimation of their contribution. Carlo thinks that the double-peak behaviour comes from the existence of two clusters of step transitions with two different cut-off frequencies.
    - These simulations also found that there was a bug in the wake computation: the resistive wall contribution was not added in the total model.
    - Lorenzo asked how the wake of step transition are computed, and if they are then weighted by the β functions at each location of the steps. Carlo answered that the wake functions of transition steps are computed with CST by always considering a step-in + step-out because CST does not like simulations that have different geometries at entrance and exit ports. The beta function weighting uses an average of the beta function at every transition.

- **Tune shift measurements** were also caried out to investigate the imaginary part of the impedance.

    - The measurements were carried out versus chromaticity: the bunch intesity was kept constant, and the chromaticity was changed in the SPS. The measurement can be

perturbed if the SPS supercycle changes, as this affects the real machine chromaticity.
    - High amplitude and long injection oscillations were observed, in the order of 1500 ms, despite the high chromaticity. The damper was turned off for these measurements.
    - The tune shift versus intensity could be measured up to a chromaticity of Q'/Q = 1.
    - Simulations with PyHEADTAIL were attempted but the decoherence of the kick is even faster than in measurements.
    - Elias and Giovanni remarked that space-charge could be the mechanism that slows the decoherence in the machine. See for example the HEADTAIL manual (figure 13): https://cds.cern.ch/record/702717/files/sl-note-2002-036.pdf
    - Measurements at higher chromaticities could not be taken because of the difficulty to measure tunes with these settings.

- At high chromaticity, the instability can become very noisy. On some of the measurement data, a large growth rate is measured but the instability amplitude is not very high

- The Headtail monitor data is clearer. Nicolas suggested that this could be used to measure the growth-rate, if the buffer is long enough and is triggered at the right moment.

- For the missing impedance, Lorenzo remarked that the resonator used to model the missing impedance has a resonance frequency (1.6 GHz) that is just above the beam pipe cut-off frequency (1.4 to 1.6 GHz).

- Carlo added that the CST model of the step transitions, based on the extrapolation from step-in + step-out, may indeed introduce inaccuracies both on the real and imaginary parts of the impedance. It would be worth reviewing it, maybe also using other tools than CST, to be sure we are as close as possible to reality. There are also different types of transitions in the machine, with different dimensions, which therefore have different wakes and cut-off frequencies.

AOB and end of the meeting

The next meeting will take place on the 19th of September. Fredrik Grønvold will present his work on "FASTION simulations of the CLIC linac with PyEC4PyHT".