53rd Impedance Working Group Minutes

Location: Zoom

Review and approval of minutes from 52nd meeting.

Agenda of 53rd IWG meeting, December, 14th, 2021:

- Review of minutes from the last two meetings (chairs)
- Update on MKP-L and MKI-COOL (Mike Barnes)
- ARP heating and measures (Maciej Trzebinski)
- Impedance studies of the FCC-ee vacuum chamber including bellows (Chiara Antuono)

Present: Antuono Chiara, Benoit Salvant, Christine Vollinger, Mike Barnes, Carlo Zannini, Miguel Diaz, Giovanni Rumolo, Alexej Grudiev, Helene Guerin, Josef Sestak, Michela Neroni, Rui Franqueira Ximenes, Sergio Calatroni, Miguel Valente Dos Santos, Kristof Brunner, Michael Sullivan, Federico Carra.

Review of minutes from 50th meeting and update on ACTIONS:

- **Christine and Benoit**: Concerning the access to the Catia files, how to get them? Can we access just doing training sessions?
- **F. Carra** points out that CERN is changing software, from CATIA to ARAS and training sessions are required if the access has to be kept or given. The main problem is that currently, you need to have also a tutor/supervisor from one of the designers. This requires to be follow up.

ACTION (F. Carra): To follow up how to read the Catia files for IWG purposes (read only/local save to import into CST).

- **Miguel D.** asks if it is required to do also the transverse impedance for the MKP-L. **Benoit** replies that for the heating the priority is the longitudinal. However, if time permits, is good to have also the transverse impedance.

Update on status for the low-impedance MKP-L and MKI-COOL (Mike Barnes)

Mike presents a brief update on the low impedance MKP-L and starts recovering the comparison between the two models, the one with serigraphy connected to ground and the other with the connection to the HV end plates. The latter shows the absence of the dependence of vacuum on pulse length and smaller increase of pressure, however there is still work to do on that model.

He remarks that the high voltage tests which are already carried out confirm the need to reduce the electric field in critical areas at least by 50 %. Several means of achieving this:

- Four serigraphy fingers (instead of five): ~20% reduction in critical electric field
- ‘Slot’ or ‘groove’ at end of third finger: ~35% reduction in critical electric field predicted

- Serigraphy offset towards HV busbar: few % reduction in critical electric field (8mm more available on U-chambers)

Length of serigraphy fingers from pulse output end reduced – from 600mm to 457mm (duration of field reduced by ~25%).

Both plates will be soon ready for installation in next prototype. HV tests will take place early in 2022, to choose ‘groove’ or ‘slot’. He underlines that so far the ‘groove’ is the preferred solution since the slots can pose a risk for the e-cloud.

Mike shows the simulations from Carlo Zannini of the normalized power loss as a function of bunch length that illustrate that even with only four serigraphy fingers per plate, reduced length of serigraphy and, serigraphy offset towards HV busbar, the expected beam induced power deposition in an MKP-L is approximately half of that in the MKP-S kicker magnets. In addition, further offsetting the serigraphy towards the HV busbar (by 8.5mm) doesn’t have a significant influence upon the low frequency resonance or overall power loss. The MKP-L is expected to be ready for impedance measurement on Friday 17/12/21.

Concerning the planning, Mike says that the existing spare 4-module MKP-L will be upgraded to the low impedance version once the last iteration of the prototype MKP-L is HV tested and proven (early 2022). Mike underlines that the 4-module low-impedance MKP-L will be ready during November 2022 and installed during YETS 2022/23 but they just learned about a delay in the delivery of chambers by 1 month. This delay is currently considered not critical as it can be compensated.

Mike explains that the low impedance MKP-L will likely include shielded vacuum valves on the vacuum tank and the replacement of 2 (or 3) ion pumps by NEG cartridges. However, existing MKP-L magnet must operate until the low-impedance version is installed in the SPS.

<u>Mike adds some comments on the MKI-Cool:</u>
He says that with a lot of work from several people, a method for measuring the wall thickness of alumina tubes has been developed and all 2017 tubes and 4 from LS1 have been measured and good agreement between Tomography and Magna-Mike (see MKI-Cool slides) measurements have been found.
One of the results is that the 2017 produced tubes are not suitable for installation. Discussions launched and are ongoing with supplier to avoid issues with any new batch.

Discussion:

Benoit asks if the planning incorporates already the fact that we have to accept this exchange for the YETS.

Mike replies yes because, based on the previous experience, they expect to take almost the same time now for the MKP-L to get everything ready.

Benoit also asks if there is any chance that the results from 2021 will show that the replacement could be avoided. **Mike and Carlo** reply that, based on Carlo's simulations, with a high probability the update is necessary.

Christine asks if the valves are additional valves or replacements. **Mike** replies additional valves.

ACTION (Mike): report on December 17th measurements

ARP heating and measures (Maciej Trzebinski)

Maciej starts with an introduction explaining the main aim of the Roman pots, which are special and dedicated devices to measure the scattered protons during collisions. Roman pots operate during special (low pile-up) and standard (high pile-up) LHC fills. They are moveable devices: in parking position (few cm from the beam) when beams are not stable, 2-4 mm from the beam when taking data.

Maciej also shows an animation to illustrate how it looks when the pots is inserted, starting from the parking position and approaching the beam (when the stable beam is created) from the left side. From the slide we can see the characteristic pattern that will be measured. The plots on the right of the slides explain the physics range of the measurement.

He underlines that all the measuring detectors are present and are cooled inside the pots. The cooling system keeps the temperature on the sensor down to -30 C. To measure the temperature, sensors are installed both inside and outside the pots so it is possible to measure both temperatures.

Maciej says that in Run 3 LHC will operate a higher intensity than in Run 2. This may increase the temperature on SiT and they hope to solve that by installing a new heat exchanger operating with foam. Another concern is heat induced on RP.

Maciej shows as an example a plot from Run 2, giving the temperature on C FAR station during four LHC fills as a function of luminosity: at the beginning (highest luminosity) the pot is pre-cooled to 15-20 C, as time passes, the beam heats the pot more than it can be cooled, at one point there is equilibrium state between dissipated power (coming from the beam) and cooling system → indicating the expected, linear dependence between luminosity and temperature, this can be extrapolated to higher intensities, however, the reality at Run 3 will be even more complicated due to lumi-levelling. Extrapolations based on Run 2 data are a starting point only and not fully conclusive.

He explains that several tests with different setups were planned, to simulate the heating-up of the pot and to test few solutions to dissipate induced heat. With such setups various heating scenarios were tested.

Several heat-sink solutions were tested assuming various locations of the heat source. As the exact design of the heat-sink depends on the heat source and expected amount of power to be dissipated, decision was to: prepare special temperature sensor setup to investigate temperature gradient in the pot with real data (first year of Run 3), design adequate heat sink, if needed (based on Run 3 year 1 data).

During installation of detector packages (Mar. ’20 and Sep. ’21) temperature sensors inside pots were placed in a special way and they will allow in 2022 to understand where exactly heat is induced and the need of heat-sink for 2023-2025 data-taking

Maciej explains that initial tests were carried out, but (as expected) without visible effect due to the small beam intensity and the large pot-beam distance. It will be properly studied during the first intensity ramp in 2022.

AFP detectors will take data during (almost) all fills with STABLE BEAMS in Run 3. When operating in a close vicinity of LHC beam, Roman pots are heated. AFP cooling system actively keeps temperature of about -20 C on the detectors and passively cools the pot. Effect of heat induction will be studied using data-driven methods starting from first intensity ramp in 2022: special setup of temperature sensors inside AFP pots, a quick look on pilot beam data was done. Several heat-sink solutions were tested during 2019 mini-campaign in the AFP lab. Depending on the measured data, the following scenarios are considered: no special action – in case of being cooled enough with the existing setup (note: new heat exchangers installed in LS2), design and installation of heat-sinks during YETS 2022-2023 in case heat from pot bottom needed to be dissipated more effectively.

Discussion

Benoit asks if the variables in slides 10 are available in Timber. **Maciej** replies that they are stored in the ATLAS database, but he is not sure if they are public available**. Benoit** adds that could be helpful to have access to the data to monitor them.

Benoit points out that the ALFA pots are not mentioned in the talk and it is possible that these pots give a problematic contribution even in parking position. This is to be checked with the equipment owner.

Benoit comments that it will be good to check what happens if the temperature reaches 50 degrees and also to have a clear understanding of the consequences in that case (e.g. stop operation, move the pot out…?)

Maciej adds that one of the main issues to address is where the main heat is, if it is on the ferrite or in the core bottom.

Sergio C adds that as far as he knows there are no specifications for the outgassing temperature.

Christine also asks what type of ferrite was used and suggests checking this.

ACTION (for Maciej): report the situation of ALFA pots back to IWG (also ferrite type).

ACTION (for Maciej): check that all temperature readings are logged in Timber for follow up during the intensity ramp up and cruise.

Impedance studies of the FCC-ee vacuum chamber including bellows (Chiara Antuono)

-Chiara presents the talk given during the FCCIS workshop on the studies of the impedance of the FCC-ee vacuum chamber including bellows. She starts explaining the motivation of the study, underlining that the results obtained so far for the FCC impedance already demonstrate how the collective effects can be critical to the machine. Further, she shows preliminary results for a simplified round model of bellows and indicates the related critical impedance contribution, that is the second source of machine impedance after the resistive wall between the components evaluated so far.

-Chiara describes the strategy of her study, starting from a first simplified model to the more realistic one which was provided by colleagues of the vacuum group. She explains that all results obtained so far, i.e., the simulated longitudinal and transverse wake potential and impedances have been computed using the wake field solver of the CST Studio Suite. The results will be used by M. Migliorati and colleagues as input to perform beam dynamics studies.

-She shows the longitudinal wake and impedance comparing the three different models and points out that the main difference is the absence of the resonance around 11 GHz for the models with the realistic vacuum chamber (chamber with winglets). The same behaviour can be observed for the transverse impedance where also no major transverse mode can be identified.

-Chiara explains that several tests have been carried out on the main geometric parameters of the bellow model to understand the effect on the impedance and wake. Further, she points out that the most significant role is played by the distance between the convolutions and the height of the bellows. The largest effect is visible on the short range wake potential and it was of interest for the beam dynamic studies.

-In the context of the understanding of the source of the impedance resonances, she first shows the comparison between a simplified circular model where the RF shielding is substituted by a simple aperture and the standard circular model with the overall RF shielding.

She shows the desired effects of the shielding which effectively suppresses the low frequency resonances due to the bellows (below 5 GHz). The resonances around 11 and 27 GHz are already present in the magenta curve and are slightly attenuated by the shielding.

-The behaviour of the resonance at 11 GHz has been deeply investigated. She shows the frequency shift of the first resonance as a function of the ratio between the radius of the beam pipe and the radius of the bellow cavity. Up to a certain value of the ratio (around 0.3), the frequency shift of the resonance is almost zero, when the radius of the pipe increases the coupling between the pipe and the cavity also increases causing a visible frequency shift. Finally, it has been observed from these simulation studies, that when the radius of the beam chamber approaches the radius of the bellow cavity, the resonance decreases its amplitude more and more until it is suppressed in the limit case of equal radius. Given these studies, it is not surprising that the resonance is almost suppressed in the case of chamber with winglets, since the horizontal aperture of the chamber approaches the radius of the bellow cavity. And also, from simulations she checked that the cut-off frequencies of the modes of the round model are very similar to those of the model with winglets.

-She points out that numerical convergence of the results has been preliminary studied to ensure the stability of the results given the huge complexity of the considered models. In fact, the design of the fingers of the RF shielding as well as its discretization with the mesh cells used by the CST is a difficult and delicate task of the study. In addition, the simulations required important computational resources and are time consuming. The study has been performed on three models, starting from a simplified version and ending with the realistic one. The realistic model seems to have better impedance behaviour, indeed the first resonances appears above 20 GHz both for longitudinal and transverse impedance. Concerning possible future works the inclusion of the vacuum flanges is essential to have a complete impedance model of the interconnections of the FCC-ee beam vacuum chamber.

Mike B. asks information about what kind of computing resources is needed to perform the simulations since they required important computational resources. Chiara replies that she uses a powerful server from her University and that that kind of simulations required a RAM of 24 GB.

Alexej asks if also eigenmode simulations were done since with for eigenmodes, the computation time is considerable reduced, and **Chiara** replies that she didn't perform eigenmode simulations so far, since the priority of the study is to make available wake and impedance for beam dynamics studies.

To avoid misunderstanding, Chiara would like to add that, she didn't perform eigenmode simulations, however she put a field monitor and ports to further study the behaviour of the resonances and to look at the electric field pattern. Therefore, the study was carried out not only performing wake field simulations.

Benoit asks about the results of the wake potential as a function of the distance between the convolutions of the bellows, and he is surprised to see such a difference while varying that distance. **Chiara** replies that, probably the plot shown like this could be equivocal, however the effect on the impedance is almost negligible in the frequency range of interest.

ACTION (for Chiara): check with eigenmode (if possible since the first mode is propagating).

News and AOBs

ECRs

Removal of the prototype Electro-Optical BPM from LSS4 of the SPS during YETS 2021-2022: The ECR was discussed in the 51st IWG meeting and the proposed changes are fully accepted by the IWG that also consider the introduction of smooth tapers and the removal of enameled flange beneficial to the impedance contribution.

LMC 428th meeting

M. Lamont thanked the speaker for the presentation and all the impedance working group for the fast response time with the simulations, which helped to take the tough decision to warm up the sector 23 to repair the PIM non-conformity.

Evian workshop

There was a talk from Helga on Beam dynamics studies for Run 3 where she discussed an improved longitudinal impedance model.

Montreux IEF Workshop

SPS aperture restriction-QDs: Layout nonconformities being addressed during LS2 in 25 positions and few locations are non-conform still. As a possible solution, the alignment of the half-cell confirmed during TS2. 209 other positions were checked during YETS and no non-conformities found. BPCN mask limits the aperture and will be removed.

SPS aperture restriction-218 : There was an issue with the transition chamber given in the design of the model that was produced with the wrong aperture. The vacuum chamber was replaced and as a future work the integration of 3D beam envelopes in Catia would help to avoid that kind of mistakes.

FCC

There was a morning dedicated to collective effects during FCCIS workshop on the 09/12/21. M. Migliorati gave an introductory talk on impedance models and single beam instabilities, C. Antuono explained her results from bellow impedance studies and E. Carideo gave a talk on the TMCI instability. A. Rajabi from DESY presented preliminary studies on a new impedance code which he is developing. He had a claim concerning the reliability of CST for computation of resistive wall impedance without showing strong evidence in support of this.