Minutes of the 125th WP2 Meeting held on 24/07/2018

Participants: D. Amorim, S. Antipov, G. Arduini, N. Biancacci, X. Buffat, F. Carra, F. Giordano, M. Giovannozzi, N. Mounet, F. Plassard, S. Redaelli, B. Salvant, L. Teofili, R. Tomas

AGENDA:

1 GENERAL INFORMATION (G. ARDUINI)

The minutes of the previous meeting have been circulated and accepted without comments. **Gianluigi** reviewed the status of several WP2 action items.

Elias is requested to come up with a machine study to test the thickness and resistivity of Cu layer in LHC beam screens. It would be beneficial to have this discussion at the meeting on the 21st of August, before the LSWG meeting devoted to MD3 preparation. **Benoit** made a comment that they are studying the feasibility of the experiment together with Nicolas et al.

Gianluigi recalled the asymmetric kicks of the Quench Protection System (QPS), observed in the LHC triplet, and proposed to invite Daniel Wollmann to give an update on the subject. **Benoit** mentioned new measurements of Cu resistivity at cold temperatures being conducted by Sergio Calatroni and proposed to put them in the agenda of one of the next meetings.

According to the report made by **Benoit** at the previous meeting, VAX bellows do not create significant impedance issues. It is important, however, to make sure 80 mm vacuum valves are used in order to avoid creating parasitic RF cavities. **Massimo** is going to check with the Alignment WP if the maximum misalignment, currently assumed to be 10 mm, can be optimized.

Amorphous carbon coating of triplet areas was found to have no significant impact on machine impedance both at the injection and at the top energy. **Sergey** will provide an update taking into account the latest values of coating thickness and beam screen temperature.

ACTION (Benoit): Contact Jaime and Vincent to check if the 80 mm valves in the VAX region and at the crab cavity locations is the baseline

ACTION (Daniel Wollmann): Provide an update on the current level of understanding asymmetric quench protection kicks observed in LHC.

ACTION (Benoit, Sergey): Contact Sergio to schedule an update on the recent resistivity measurements.

2 IMPEDANCE STUDIES FOR DISPERSION SUPPRESSOR COLLIMATORS (L. TEOFILI)

Lorenzo presented simulation and measurement results for the TCLD collimator. The collimator has several characteristic features, affecting its impedance: a change in cross-section required for vacuum valves creates an RF cavity; there are pumping holes in the surface of its Tungsten absorber blocks made for outgassing; there are gaps in transverse RF fingers, needed for the motors. Several scenarios for different gap configurations have been studied: that for the collimator in Point 7 and that for Point 2. The numerical simulations were performed using a standard CST package and compared with field probe measurement done on a bench.

Wakefield and eigenmode simulations agree for the main 1.3 GHz mode, although some discrepancy remains, in particular for lower frequency modes. Measurement campaign continues to improve the resolution of the low frequency modes. For the main mode, the EM power is located between the RF fingers; no mode extends into the beam pipe toward 11 T dipoles. The transverse shunt impedance of all the modes was found to be below 100 kΩ/m. At this level their impact on machine impedance is negligible.

- During the discussion of the CST numerical model, **Stefano** commented that the vacuum valve is needed for vacuum sectorization. **Federico** noticed that the actual RF fingers are made of Silver-coated Copper and not of pure Copper. **Benoit** replied that the effect of the actual material is minor, since the fingers are far away from the beam. They need to be present in the model though to establish an appropriate boundary condition for RF modes.
- **Gianluigi** asked to clarify why the modes have no impact on the impedance. **Lorenzo** replied this is thanks to the small shunt impedance and relatively low β-functions of 30 and 130 m. For comparison, the limit set for the modes of the crab cavities, located at $\beta^* \sim 1000$ m, 1 MΩ/m. **Benoit** added that the limit set for longitudinal impedance in 200 kΩ, while the modes only yield 35 kΩ. **Benoit** also emphasized that none of the modes come from the interconnects, meaning there is nothing for WP11 to improve. **Stefano** noticed that the studied settings are those for protons. For the moment the setting have not been optimized for ions, but the intensity is going to be lower. **Rogelio** pointed out that for ions the β-functions might be larger. **Stefano** replied that even in the worst case scenario the β-function shall not exceed 180 m, since the device is located in the dispersion suppressor.
- **Gianluigi** asked whether the trapped modes are common for all the collimators. **Benoit** confirmed that the modes are present in all designs, but the overall impact on impedance is small.

- **Gianluigi** inquired about the timeline of impedance measurements. **Nicolo** replied the plan is to finish within a week.
- **Benoit** inquired if there is an optimum position for the collimators put in parking. **Stefano** replied that an optimal intermediate position may exist; one could perform a scan to optimize the gaps for impedance.

ACTION (Nicolo, Lorenzo): Finalize the impedance measurements and provide an update at one of the following meetings.

3 TMCI MEASUREMENTS AND IMPLICATIONS FOR HL-LHC (D. AMORIM)

Transverse Mode Coupling Instability (TMCI) might affect the luminosity, limiting the maximum bunch intensity in the machine. In LHC the instability happens when the impedance induced tune shift of transverse azimuthal mode 0 (dipolar mode) brings it in close vicinity of the mode -1, and the two modes couple. The LHC collimation system is the main contributor to its impedance, governing this process.

The experimental procedure was to measure the tune shift of mode 0 at different intensities and linearly extrapolate it until the intersection with mode -1 where a TMCI happens. The measurement was done with single bunches at low chromaticity at the machine's Flat Top. Several cases were studied: (1) the current LHC operational settings and (2) the Mo coating upgrade of its IR7 secondary collimators that was modelled in the experiment by retracting the collimators from 6.5 to 14 beam sigmas (for a normalized emittance of 3.5 μm). Additionally, two future scenarios were studied in simulation only: (3) the LS2 collimator upgrade and (4) the HL-LHC baseline.

Simulation shows the threshold of $2.6*10^{11}$ p for the current LHC, $5.0*10^{11}$ p for the LHC with retracted secondary collimators (14 sigmas), $6.4*10^{11}$ p for LS2 upgrade, and $8.7*10^{11}$ p for HL-LHC. The presented measurement results (for the first two cases) agree with simulation predictions within the uncertainty of the measurement, both in terms of the tune slope and the TMCI threshold, although the measured tune shift is a bit larger than the simulated one. The observed significant improvement of the TMCI threshold between scenarios (1) and (2) indicates that the IR7 secondaries are the right impedance contributors to act on.

- **Stefano** pointed out that from the machine protection point of view more bunches could be added when using tighter collimator settings and raised a question if there is an interest in qualifying the settings for future studies. **David** replied that it could be useful in many cases, for example, in a complex tune shift MD performed earlier this year. **Nicolas** noted that the multibunch TMCI threshold can be lower than single-bunch by 10-20%. **Rogelio** mentioned that the injectors are preparing for 12-bunch high intensity trains that could be used to study multibunch effects in an MD. **Gianluigi** inquired what is the minimum number of bunches to see the multibunch effect on TMCI.

- **Gianluigi** mentioned that it would be interesting to know what the threshold for HL-LHC scenario with uncoated MoGr secondary collimators is.
- **Nicolas** asked why in simulation both the threshold and the tune slope are higher than in experiment at the same time. **David** explained it has to do with nonlinearity of the tune shift with intensity close to mode coupling that increases the threshold. It can be seen in simulation, but not in experiment where the measurements were done at relatively low intensities below $2*10^{11}$ p.

ACTION (David, Sergey): Compute the TMCI threshold for a case of uncoated MoGr IR7 secondaries for the post LS2 configuration

ACTION (David, Nicolas): Find out the minimum length of the bunch train to observe a multibunch effect on TMCI threshold.

4 AOB: MoGr and CFC: influence of the orientation on the electrical conductivity (F. Carra)

Molybdenum-Graphite (MoGr) is an anisotropic material that features the highest resistivity in a specific plane. In order to achieve collimator impedance reduction it is important to make sure the correct orientation of MoGr absorber blocks. Fortunately, it is impossible to mount the block in a wrong way due to a limited thickness in the direction of the lowest conductivity, coming from the way the blocks are manufactured.

The grade of CFC produced by Tatsuno has changed. The conductivity in the normal (to the direction of beam propagation) plane has decreased from 0.18/0.24 to 0.12/0.17 MS/m. This worsening of the specification should not affect the HL-LHC baseline though, since MoGr will be installed on the primaries.

- **Gianluigi** inquired if the effect of asymmetric conductivity could be present in Graphite, recalling that Graphite is used in TDIS. **Nicolas** replied that while Graphite is three times more resistive than CFC, it should be isotropic. **Stefano** pointed out that there are no Graphite collimators for cleaning, but there is a request to study 3D carbon from STI.
- **Stefano** noted that another issue could be poor thermal conductivity in the direction of the plane of collimation. **Benoit** commented they are studying the issue with Nicolas; the conductivity in the other direction of the plane, normal to the beam propagation, may be not relevant for the impedance.
- **Gianluigi** raised a question if some of the CFC blocks could have been installed the wrong way. **Federico** replied it is unlikely since normally a company rolls the material in the preferred direction. The directions on the measured jaw were correct. **Stefano** suggested to discuss the question with Oliver.

ACTION (Benoit): Check with Inigo if Graphite used in TDIS has a preferred direction in terms of its electrical conductivity.

ACTION (Stefano): Confirm that the CFC blocks were installed in the collimators were properly aligned along the axis of the lowest resistivity.

5 FOLLOW-UP AFTER THE MEETING

Stefano discussed the issue of anisotropy with O. Aberle. He confirmed that also for the CFC collimators, the possibility to install them along the orientation with a lower conductivity was excluded by the geometry of the material blocks. There was no room for wrong manipulations.

Benoit contacted S. Calatroni for the beam screen copper resistivity measurements at cold temperatures. The measurements have not been performed yet due to a technical problem with the wire erosion machine that is needed to prepare the samples.