Minutes of the 100th WP2 Meeting held on 10/08/2017

Participants: S. Antipov, G. Arduini, N. Biancacci, C. Bracco, D. Carbajo Perez, L. Gentini, P. Hermes, E. Metral, Y. Papaphilippou, D. Pellegrini, A. Perillo-Marcone.

General Information (G. Arduini)

The minutes of the previous two meetings have been circulated. Gianluigi summarises the outcomes and the actions of the previous meetings.

Oliver is preparing a document on the operation of LHC at the ultimate energy of 7.5 TeV after LS3 therefore with Crab Cavities installed. A first version has been sent around for input. Gianluigi will circulate the document with requests for input.

Update on the TDIS design (C. Bracco)

Currently the TDIS is a single jaw 4.2m long, the plan is to split it in three. This will allow to reduce the effect of the impedance heating which was deforming the jaw and to simplify the positioning with better accuracy. The technical aspects considered are robustness and compatibility with the machine, additional arguments concern vacuum, impedance and e-cloud. The last review raised several actions, in particular requesting estimates of the deposed energy and the implications of copper coating.

The material of the stiffener has been changed from Al to a Mo alloy (TZM); the material of the downstream jaws has been changed from Al/Cu to Ti/Cu. All the filling scheme up to 288 BCMS and 320 Nominal bunches have been considered. What matters for the back-stiffener and the high-Z blocks is the total train intensity.

Gianluigi asks about the width reduction. Antonio Perillo-Marcone replies that this makes it cheaper and easier to install, in addition the material properties can be better controlled with a smaller volume. The original assumption that leaded to a larger width was the estimations of the beam impact parameter, possibly being far from the centre. More detailed studies allowed to optimise the geometry of the jaw, taking into account the position of the beams. Also the change of material of the lateral clamps (SS replaced by Ti alloy) helped in reducing the width. Gianluigi asks about the 3D carbon option, it is confirmed that the baseline is now graphite for the two pairs of upstream jaws and Ti/Cu for the downstream pair of jaws.

The split in three parts comes with some concerns, such as the possibility of fingers scratching the graphite of the adjacent jaw, leading to the risk of production of UFOs if a significant difference in the opening of two consecutive jaws occurs. Mechanical design, cooling and pumping have all been improved.

From the impedance point of view, having longitudinal RF fingers significantly reduces the number of High Order Modes (HOMs) in the frequency range covered by the beam spectrum. The impact of the transverse fingers is smaller. Nicolo' stresses that the HOMs are more worrisome than the resistive impedance as they can lead to local heating and outgassing.

Chiara concludes stating that we should eliminate the risk of UFOs production due to melted Cu coating (which could originate from grazing impacts if the graphite blocks were Cu-coated) and friction between RF fingers and graphite. A possibility consists of having no RF fingers between the first two modules: the graphite ones, or at least removing them from the upper jaws. The objective is to have the design frozen by the end of 2017.

Gianluigi summarises the changes with respect to the initial design: reduction of width, replacement of Al with Ti for the 3rd module. In addition it is proposed to study the impact of not installing RF fingers between the first and the second module, or having the fingers only in the bottom jaw. Antonio wonders if an asymmetry could have an impact on the HOMs. Nicolo' replies that it could, but studies are required.

Elias asks about the mechanism producing UFO. Chiara replies that as soon as the graphite is touched by the RF fingers, UFOs are produced. Antonio adds that this is the case only if two consecutive jaws are displaced too much. Elias concludes that the definitive solution for impedance reduction is to preserve contact, otherwise HOMs are produced. The computation of the HOMs is extremely time consuming, in addition their characteristics depend on construction tolerances and are subjected to uncertainties.

Gianluigi notes that large misalignments between consecutive jaws can be inhibited by an appropriate design the control system. Chiara replies that this is the case but it requires a dedicated development of a control system.

Gianluigi asks about the origin of the dust. Antonio replies that it is in the nature of graphite, it is there even simply touching it. Gianluigi wonders if any graphite element without coating is already in the LHC. Chiara adds that possibly TCLIA/TCLIB are made of uncoated graphite. **Action: Chiara to clarify whether there are uncoated graphite collimators in the machine and what is the experience with respect to the generation of UFO events.** Antonio stresses that the Cu coating of graphite is very fragile; it comes off easily by scratching with a hard part.

Gianluigi asks to quantify the added risk of UFOs coming by simply adding a graphite element in the machine (without RF fingers). In addition he asks to evaluate the implication of an additional layer on the control system to prevent the large displacement. **Action: Chiara.**

Gianluigi asks to have a list of deadlines for items in which WP2 contributions are expected for discussion in order to guarantee a proper planning of the activities and to allow sufficient time for the various phases and in particular for prototype and series production validation (e.g. impedance measurements). **Action: Chiara to provide the timeline for the production and validation steps of the prototypes and series production up to their installation and in particular the timeline for the aspects requiring WP2 input.**

Antonio comments that the prototype is a full TDI and we should make the most out of that. He adds that the fingers can be removed or installed relatively easily on the prototype. He recognises that it is important to agree on a schedule taking into account the various configurations to be measured.

The design of the prototype will be frozen by the end of 2017. Antonio adds that the series production should start by the end of 2018 to be ready for installation in early 2020. Minor interventions like the addition of RF fingers can go on in parallel with the series production.

Impact of fingers removal on TDIS impedance (N. Biancacci)

The recommendation of having RF fingers was made in the review. The heating of a specific mode can go up to 800W in case of bad or no contact. The coating of the jaws was also recommended as significantly reduces the heating but given that no significant impact on stability is expected as a result of the absence of the coating, this is not mandatory provided that the cooling system is designed to cope with the additional heat load. Antonio confirms that this is the case, as coating is seen as an additional risk factor. Heating maps can be provided to check the cooling system.

Comparisons of the impedance of the single-jaw and three-jaw designs are shown. Nicolo' stresses that these are rough estimates done in time domain and one would need eigenvalues analysis around the peaks to extract accurate values for the HOMs. Sergey asks if there are beam frequencies above 1 GHz, where the impedance seems to grow significantly. Elias adds that this needs to be verified for different longitudinal distributions and filling schemes. This needs to be done in any case for the high frequency HOMs which are present also with longitudinal RF fingers installed. **Action: Elias.**

The effect of the fingers are summarised in several plots for different jaw openings. The removal of the fingers increases the power loss from few watts to several hundreds of watts. Opening the jaws most of the frequencies shift down, although few modes pop up. This means that the localised heating can move along the jaws according to the opening and requires a detailed analysis as a function of gap opening and mechanical tolerances.

Nicolo' plans to refine the simulation with the eigenmodes technique. The local power loss could be investigated more in order to identify possible locations. The timescales required for the finalisation of simulation and prototype measurements are presented. Antonio points out that cooling is planned only for the jaws. The RF screens are not actively cooled.

Gianluigi proposes to identify one or two critical HOMs close to delicate components **(Action: Nicolo')** to be provided for a thermo-mechanical analysis to assess heating and outgassing **(Action: Antonio, David)**.

Chiara asks if issues could appear also in the transitions next to the TDI. This is confirmed by Elias and Nicolo'. **Action: Nicolo' to evaluate the impact of the transitions.**

It appears that the removal of the fingers can only deteriorate the performance of the device and the associated risk should be carefully compared with the risk (if any) of a dedicated control system preventing excessive misalignment among consecutive jaws during operation.

Chiara points out that some modes are there even with the fingers installed, however she recognises that the risk in this case is significantly smaller. She agrees to identify the worst case with the fingers installed. Gianluigi suggests comparing the worst cases with and without fingers. Chiara asks if two-week time looks reasonable to identify these worst case scenarios. Nicolo' replies in the positive.

Elias adds that at some point stability studies need to be performed in addition of heating studies. **Action: Elias.**

Gianluigi stresses that once the preliminary analysis of the effect of the worst HOM in terms of heating and outgassing is performed together with the analysis of the impact on beam stability the corresponding risk in terms of reliability should be compared with the one resulting from the implementation of an appropriate control system and the results presented at the HL-TCC.

Gianluigi highlights the need to involve vacuum people. Antonio clarifies that all the involved materials can take the temperature, although graphite is the one giving the most outgassing. He also adds that coating does not have a beneficial effect on outgassing: it only delays it slightly.

Gianluigi asks about the studies involving the opening of the TDI, recommended by the reviewers. Antonio does not see any risk with this, although he would prefer to avoid touching a working device. He proposes to delay the studies towards the end of the run and in any case to have a separate discussion about it involving S. Gilardoni.

Reported by Dario, Gianluigi, Riccardo and Rogelio.