Minutes of the 97th WP2 Meeting held on 27/06/2017

Participants: V. Baglin, P. Santos Diaz, C. Garion, G. Iadarola, R. De Maria, E. Metral, Y. Papaphilippou, D. Pellegrini, B. Salvant, G. Skripka, R. Tomas, F. Van Der Veken.

Excused: G. Arduini

General Information (R. Tomas)

The minutes of the previous meeting have been circulated. Rogelio summarises the outcomes and the actions of the previous meeting.

Review of vacuum design choices, coating, transitions, copper thickness of the beam screen (V. Baglin)

The targets for vacuum for the LHC aims both at minimising the background in the IR region and to guarantee a vacuum beam lifetime >100 h. When the beams are brought into collision the pressure signal rises, although additional spurious signals can be collected by the electronics. Requirements for the vacuum system also come from the e-cloud: it is clarified that an anti-multipacting solenoid cannot be used and we rely on scrubbing.

Several upgrades of the interaction regions will be implemented for HL-LHC, while the only intervention in the arcs will be related to the 11T magnets. a-C performances have to be validated at cryogenics temperature. In-situ a-C coating of the triplet in point 2 and 8 is foreseen during LS3.
Elias asks if there are plans to use LESS (Laser Engineered Structured Surface). Vincent replies that it has been excluded from the baseline.
LHC relies on conditioning to achieve the minimum SEY in the vacuum chamber (copper colaminated on stainless steel) as was foreseen by simulations.

Layouts of the interaction region are shown. Drawings are available, the components under study are highlighted. The baseline data is being collected in a hand-made excel table (EDMS number: 1822227).
Riccardo clarifies that the provided value of beam aperture takes into account the maximum beam size that can be produced by the machine for various optical configurations, also considering errors (e.g. orbit and optics errors) so that the vacuum systems has no chance to become a bottleneck for the optics. The constrains are the triplets beam screen, TAXN, D2, Q4, Q5 beam screens. The aperture is therefore not necessarily the aperture estimated for the nominal optics, but it is larger.

Vincent explains that the aperture values are the sum of the beam aperture, the mechanical tolerance, extra tolerance to avoid realignment and some residual free space to match to the available minimum diameter. The transitions of the vacuum chamber are summarised in a table and a sketch is shown from the triplet to Q4. Riccardo points out that the alignment tolerances are different with respect to the one of survey for the reasons mentioned above.

The choice of the vacuum chamber material is copper for diameter up to the 91mm, and stainless steel above; everything NEG coated, following the LHC baseline.
The VAX area will be upgraded during LS3 together with the TAS exchange. The room temperature TAS will be decoupled from the triplet. Sector valves are also planned to decouple the experiments vacuum from the machine vacuum. The coating of this part is not yet decided.

The layout of the DFX is shown. The new design of the Y chamber is presented (it was commented by Benoit at the 87th WP2).

Concerning the D2 area, the 5th axis was removed from the collimators as there is not enough space to integrate it. The collimator design is being updated with a 2 beams in one vessel scheme, coming with new bellows and supports. The goal of the integration is to minimise the radiation exposure in case of intervention. The vacuum components can be exchanged without the need of realignment and smoothing can be performed during long shutdowns.

The CC areas comes with a second beam pipe (for the non-crabbed beam) which is at cryo temperature and, being longer than one meter, should receive a beam screen. The beam screen however will reduce the aperture below the required value of 80mm. Vincent asks to review aperture requirements. Riccardo commented that the second pipe has to absorb the realignment excursion of the crab cavities. Alternative ideas may consist in beam pipes with antechambers. It has been asked to install vacuum instrumentation inside the cryomodule. **Action: Riccardo to compute the aperture with the beam screen.**

The Long Straight Section will be almost entirely NEG coated, with exception of sector valves, RF bridges, collimators and instrumentation. Gianni asks how the part with two separated pipes is activated, Vincent explains that they use heating jackets which are mounted and dismounted.

The naming conventions are shown. Vincent asks for a summary of the required interventions to the magnets e.g., magnets to be moved, beam screens to be rotated. Riccardo remind that a table has been circulated in my email in December and it is also available in the Task 2.2 website.

The design of the beam screen is finalised and prototypes are under production, the preparation for the mass production is on-going. A detailed scheme of the beam screen is shown. Gianni asks to clarify the temperatures, Vincent replies that they are all under revision, especially the 50K assumed for the beam screen which is known to create issues. The thermal link between the cooling tube and the shield is being optimised. The data for the beam screen is collected in a summary table.

Drawings of the shielding of D2, Q4 are shown. Riccardo comments that for the beam screen of Q4 MCBY a rectellipse shape provides a larger aperture instead of octagon due to the large size of the cooling tube and the oval aspect ratio of the beam.

The perforation of the beam screen will be the same as in the LHC. Shields for the pumping slots are installed for the octagonal screens (Q1, Q2, Q3, CP) while Q4, Q5 and Q6 (racetrack shape) will not need them. Gianni reminds that the shielding will be needed as a support for the cryosorber in the magnets operating at 4K, Vincent agrees.

The copper shield thickness is 75 um: 25 um allowing for contamination are added on the top of the 50 um required for the impedance.

The beam screen coating has a first layer of titanium 90 nm and 500 nm of AC on the top of it. Benoit and Elias noted that the numbers in the slides are swapped. Gianni asks about the uniformity of the coating, Vincent replies that the design of the coating device should allow very good uniformity.

Several possible locations of the vacuum modules are identified and highlighted on the technical draw.

The cold to warm transition is made with deformable RF fingers with three convolutions. The recommendation from the WP2 is to keep the angle below 15 degrees. Benoit points out that this computation takes into account only the bellows in the triplet, if more are needed it should be reviewed. The total untreated length of an interconnection is about 1 m including the octagonal to round transition and the BPMs. A set of parameters for the interconnections is collected in a table.

Vincent asks if there is any dependency between the maximum angle and the diameter and the convolution height from the impedance point of view. Action: Elias.

The cold-to-warm transitions, by means of new vacuum modules with deformable RF bridge, is under study.

Room temperature interconnections employ circular apertures to have even strains. All the transitions will be within the vacuum equipment. This will also reduce the number of different components. Benoit points out that this may be suboptimal if one need to exits with an elliptical aperture on both sides, Vincent replies that this is very uncommon, possibly only in D2.

Concerning the interconnections of the crab cavities, Vincent points out that the entire IR up to Q4 will need to be aligned. Benoit asks if 2.5 mm are feasible. Vincent replies that it is not known yet. Riccardo points out different scenarios: normally the cavities needs to be aligned with the orbit bump of the crossing angle which implies a realignment up to 1.6 mm, in case of an IP shift with mechanical realignment no additional shift is needed in the crab cavities, in case of an IP shift without mechanical realignment one needs additional shift of bellows up to 4 mm. Riccardo considers 1mm at each transition enough for the alignment of the triplet bellows in case smooth alignment is possible. In addition the equipment should follow the movements of the tunnel provided by survey on the long term. Rogelio asks when a scenario will be chosen. Riccardo replies that some comments are collected by Paolo for the next TCC, but this should be carefully considered. The baseline for the time being is to have no mechanical realignment and do everything with the correctors, but in this case flexible bellows are needed in the CC. **Riccardo will prepare few slides on this topic (published as spare slides in the talk of Paolo at the 32nd TCC).**

With respect to the 5th collimator axis, Vincent reports that several studies are ongoing on the bellows and on the shields in order to provide the transverse deformation while keeping the RF bridge. Vincent also points out removing the 5th axis from (some) collimators would allow for reducing the number of deformable bellows, **it should be clarified whether this is really needed. Action: Gianluigi to contact Stefano.**

In the VAX and Q1 area some bellows will come without RF fingers, due to complexity and ALARA reasons. In addition in the VAX a 63mm valve is currently in the baseline, restricting the aperture. Work is in progress with the company to provide an 80mm valve. Rogelio asks if this is considered in the design. Riccardo replies that it is not but, confirms that the 63mm will not be a bottleneck. Benoit expresses concerns about the tapering. The drawings of the bellows without shielding are shown.

Discussion:

Benoit stresses that the impedance should be as small as possible, but the updates to the design increases it. Vincent points out the many constraints that they have to face. Elias stresses the importance of sharing the information on the new equipment in order to understand what is important and what can be avoided.
Rogelio asks if some evaluations have been performed with the design updates, Benoit replies that several open points in the design should be clarified first. **The need of balancing the conflictual requirements for low impedance and alignment capabilities is highlighted.**

Recommendation from impedance simulations (B. Salvant)

The summary of the guidelines compiled for the CAS on Vacuum is shown, together with the main topics in impedance.

Comments are made for the removal of the 5th axis to be checked with WP5. LESS is not considered by vacuum.

Recommendations for the triplet bellows and the limitations of the simplified simulations are summarised. The total impedance contribution coming from the bellows both for the longitudinal and transverse plane, the latter is more critical with the max angle fixed at 15°, but no showstopper has been identified so far.

Concerning the VAX area, an analytical computation showed that the 12 recently introduced extra bellows (three per IP side) will contribute to the 3% of the total impedance, additional concerns follow from the high beta at that location. The addition of extra transitions is worrisome in case the angle is not kept flat. In the proposed design for the cold-to-warm transition a cavity could be formed. Benoit stresses that the gain coming from the collimator shielding is not to be spent in other locations.

The abandon of the collimator 5th axis is positive for impedance. Benoit asks what is the maximum transverse offset with the RF fingers at 15°. Cedric replies that a test can be performed.

Benoit points out the need to identify the exact total number of bellows in order to establish the budget.

Concerning the coating, the ratio between the thicknesses of aC and titanium is not really important as both have a much worse conductivity with respect to copper. Investigations were performed and the conclusion is that the coating does not have a big impact on the total impedance.

The model of the new Y-camber is shown, comparing the HL-LHC design with the current one. No modes are present in both cases. The chamber looks in general very good, the only remark is to avoid a restriction in the vicinity of the large diameter side. Pablo confirms no restriction is foreseen for several meters.

Benoit concludes that the main problem is the addition of extra bellows, especially the unshielded ones. More iterations with vacuum will be needed.

Action: Elias and Benoit to make a table with the list of items of concern and the expected impact on impedance and present it at WP2 with the corresponding impact on beam stability (octupole current required for stabilization).

Review of the recommendations from e-cloud simulations (G. Iadarola)

A plot of the heat load along the IR is shown, comparing two values of the SEY. The 1.1 case brings the heat load down to 150W as compared to 1475W for 1.3 case. However the SEY is not uniform along the IR, therefore the contributions of short uncoated areas is investigated. Assuming an SEY of 1.3 for anything outside the cold mass, the heat load raises to 373W. The exact lengths are collected in summary tables.

Gianni asks to provide detailed information about the SEY profile along the IR. Vincent replies that this can be done, he also points out that 1.1 is really the upper limit for the SEY, which is typically in the range between 0.9 and 1.1. Gianni replies 1.1 was assumed also to keep margins for the cryogenic system in particular if a tail of the distribution happens to be at a triplet magnet. The simulations can be repeated with more realistic SEY profiles as soon as they are provided.

The other IRs are shown, coming with smaller heating.

Gianni reminds that the shielding of the pumping slots contributes to the e-cloud build up and the side exposed to the beam should be coated.

Summary tables collect the contribution to the heat load from every component.

A plot shows the simulated heat load in the TAS as function of the SEY. The multipacting is suppressed for SEY below 1.2. Gianni asks which coating material is foreseen for the TAS. Vincent points out that NEG coating will require baking, relying on two sector valves, of which one has been currently removed, therefore aC will probably be a better choice. Checks of the required SEY should be performed by vacuum.

The different heat loads between the different arcs is not well understood. Vincent comments that this difference is reduced for larger bunch spacing. Gianni agrees but he adds that this is an additive source which is not reduced by scrubbing, possibly attributable to e-cloud in presence of surface differences.

The current load on the cryoplant is compared to the HL-LHC one. The higher heat load from synchrotron radiation and impedance due to the larger beam current, makes it important to understand precisely the e-cloud contribution.

Rogelio asks if the different e-cloud in the arcs can be due to the surface. Gianni reports that it could be but it is not confirmed. There are huge cell-to-cell variations within the same arc. The possibility of instrumentation issues has been considered but does not seem to be the case.

Reported by Dario, Gianluigi, Riccardo and Rogelio.