32th Meeting of the HL-LHC Technical Committee

Participants: C. Adorisio, A. Apollonio, V. Baglin, A. Ballarino, S. Claudet, B. Di Girolamo, I. Efthymiopoulos, P. Fessia, M. Giovannozzi, H. Prin, S. Redaelli, A. Rossi, L. Rossi, L. Tavian, E. Todesco, R. Van Weelderen, S. Weisz, M. Zerlauth (chair).

Excused: B.Auchmann, G.Arduini, O. Brüning, S.Baird, P.Collier, J.Jowett, M.Lamont, D.Wollmann

The slides of all presentations can be found on the website and Indico pages of the PLC:

HL-LHC PLC/TC homepage: https://espace.cern.ch/HiLumi/PLC/default.aspx

Indico link: https://indico.cern.ch/event/461413/

M. Zerlauth recalled the actions from the previous technical meeting:

- J. Uythoven recommended to arrive to a consolidated version of the optics to allow for a final design of the passive elements. M. Giovannozzi confirmed the baseline optics is established, the simulations of WP14 have to be redone with latest version.
- An update on the studies related to the passive absorbers in the beam dump region will be given in June 2016.

Update on beam screen temperature for LSS magnets (S. Claudet, V. Baglin - slides1, slides2)

S. Claudet recalled the discussion on the operating temperatures of Q6 at P1/P5. The implications on optics for the choice of operating the Q6 at 1.9 K should be considered. As confirmed by M. Giovannozzi, the choice of running the Q6 at 1.9 or 4.5 K doesn't impose any limitations current HL-LHC on the optics.

S. Claudet then gave an overview of the implications of the possible choices on cryogenics, vacuum and powering schemes.

The different options for the cryogenic schemes for HL-LHC were shown in slide 7. The first option includes Q5 and Q6 fed by SC links and a QXL cryogenic line. The second option foresees instead for the Q5 to be fed by a SC link and the Q6 fed via the arc cryogenic system (DFBL), with a displacement of the valve box between Q5 and Q6. This options allows saving about 10 m of QXL and one (or part of a) SC link, depending on the chosen configuration (A. Ballarino). The implications of the cheap option on integration have to be evaluated, but no major concerns for the feasibility of such option should be present according to P. Fessia. Three collimators are located between Q5 and Q6, therefore the impact of radiation effects on the proposed configuration should be taken into account (S. Redaelli). Dedicated space for powering will be needed in the RR. Given the already foreseen relocation of equipment from the RR, space constraints are not an issue as confirmed by P. Fessia. M. Zerlauth commented that for this option also the quench detection electronics has to remain in the RR, which should be verified for compatibility with the expected radiation levels. P. Fessia commented that powering equipment for the RQ7-RQ10 circuits would remain in the RR even with HL-LHC, but the same radiation tolerant systems will then have to be deployed for the RQ6.

From the presentation given by H. Prin in the 29th HL-LHC TC, if the choice is made to operate Q6 at 1.9 K, an adaptation of the existing cryo-assemblies has to be performed during LS3. The cost estimation for the modification of the four Q6s in IR1/5 is about 800 kCHF, requiring an additional 2.5 FTE from the MSC group over 68 weeks.

S. Claudet stated that from the cryogenic system perspective, the choice of having an operating temperature of 1.9 or 4.5 K has a marginal impact on heat loads. The 1.9 K configuration is easier to implement if made a part of the LSS. If the Q6 is kept at 4.5K, it could be powered by the DFBL and the existing SC link to minimize additional work and costs. This is not the baseline today, but could be envisaged, considering the additional complexity to perform work in the area with existing SC links in place.

From the powering perspective, powering Q6 from the new DSL is considered the baseline. Keeping the existing powering line (DFBL + SC link) does not allow to move the Q6. However, the new design of the Cold Powering System enables individual powering of Q6 via a compact and optimized DFH + DSH (Current Leads + Superconducting Line) system, allowing for some flexibility for the Q6 position. Space in RR will be made available for any power converter configuration that might be required. Q6 is currently the limiting factor for the 'combined ramp and squeeze' mode, therefore it is possible that the power converters will have to be changed from a 1Q to a 2Q converter type. As some equipment will be removed from the RR during LS3, an eventual increase of size of the Q6 converter can be accommodated for.

From the vacuum perspective, V. Baglin gave a summary of the present LHC configuration regarding arc, IT regions and standalone magnets.

For the arc and IT region, the cold bore operates at 1.9 K and the beam screen in the range of 5-20 K. The gas load during machine operation can be as high as $10*10^{15}$ H_2/cm^2. The gas condenses on surfaces with a given vapor pressure. While on the cold bore this is negligible, on the beam screen this pressure increases with operation time and can be larger than 10^{-6} mbar. The solution to this issue is to use a perforated beam screen, for which the holes define the pumping speed. The 1.9 K cold bore hereby provides almost infinite the capacity.

For standalone magnets, the cold bore operates at 4.5 K and the beam screen operates in the range of 5-20 K. In this case, H_2 accumulates on the cold bore reaching the 4.5 K saturation vapor pressure and the cold bore does not provide enough pumping capacity. The solution is to implement a cryoabsorber (woven carbon fiber), installed on the back of the beam screen. The cryoabsorbers for D2, D3, D4, Q4, Q5 and Q6 require regeneration at 80 K during shutdown periods for removing the accumulated H_2. This action is performed by an external pumping system. In this process also the beam screen is warmed up to more than 80 K and the cold bore to more than 20 K. L. Rossi asked what is the frequency at which this is being done for the LHC. V. Baglin explained this is typically done only during long shutdowns, but if required this could be done also during technical stops (requiring roughly a day for the whole process).

For HL-LHC, if the cold bore operates at 1.9 K, the beam screen could also operate at 40-60 K. The perforated beam screen provides the H_2 pumping speed and capacity. If aC coating is used, H_2 is released from 400 nm thick aC coating in the 40-50 K range, thus the 40-60 K window is not appropriate. Studies are ongoing to assess the validity of the 50-70 K temperature window as an alternative. The aC coating also acts as a 'cryoabsorber' (capacity at 10 K about 100 times more than Cu).

As an alternative option for HL-LHC, a cryoabsorber working above 40 K with a perforated beam screen could be envisaged, but the design of such cryoabsorber seems not realistic considering the time constraints of the HL-LHC project (it is already known to be one of the major challenges for FCC).

A decision on the extension of the use of the a-C coating should be taken. It would be possible to have a-C coating only for the triplets. L. Rossi pointed out that this decision is related to the background generated for the experiments.

ACTION: follow-up with H. Burkhardt the requirements for the background in the experiments and the need for a-C coating also in the matching section (D2-Q6).

S. Claudet summarized the baseline temperatures for IT and MS, confirmed by all people involved.

DECISION on beam screen temperatures: Magnets from Q1 to D1 will operate at 1.9 K, with the beam screen at 40-60 K (or equivalent). Magnets from D2 to Q6 at 1.9 K (with Q6 possibly at 4.5 K) and the beam screen temperature for all magnets at 4.5-20 K.

The cooling scheme for HL-LHC standalone magnets (short) will probably have to be revised, studying alternatives to the bayonet heat exchanger. This solution could also apply to Q5-P1/P5 and Q5-P6. A homogeneous solution should be found for the all magnets in the MS. E. Todesco asked if the same approach could also be applied to D2 (including 2 correctors), which is around 12 m long. R. Van Weelderen commented this can certainly be done.

S. Claudet pointed out that detailed integration studies of all the area are required to make a decision on the chosen configuration. The next iteration of the studies with the integration team will start in January 2016. Depending on the chosen solution, access constraints for maintenance in the area could become more restrictive. P. Fessia commented that the big change in this respect will be imposed by the crab cavities. M. Zerlauth pointed out that the impact on the current access rule should be minor, as already today basically no access is allowed to the close-by underground areas if powering is ongoing in the LSS or arc region.

L. Tavian asked if it would be possible to have the cryoabsorber attached to the cold bore rather than to the beam screen, but V. Baglin explained that it has to be on the beam screen in order to allow for regeneration without a total warm-up of the cold bore.

L. Rossi requested to M. Giovannozzi the final confirmation that the Q6 will not be subject to movements due to optics considerations. This decision has to be finalized.

ACTION: M. Giovannozzi and WP2 to report back in a future AOB to confirm that no displacement of Q6 is needed for the HL-LHC optics variants.

L. Rossi asked if issues related to the reliability of the DFBL should be expected in the long term if only kept operational partially for the Q6 (while D2 and Q4, Q5 will be powered from the IR side). A. Ballarino replied that icing is not expected to be an issue, provided that the heating is kept operational. L. Rossi stressed that it's important to address long term maintainability of equipment. M. Zerlauth asked if the current leads could be extracted from the DFBL to be used e.g. as spares. L. Rossi replied the extraction also entails some costs, so this should be evaluated.

Action: L. Rossi recommended that in order to take a final decision on the operating temperature of Q6 magnets accounting for all aspects (design implications, integration, costs for equipment, operational costs), P. Fessia would gather inputs coming from all involved parties (A. Ballarino, E. Todesco, S. Claudet) and present a report by the end of January 2016. A decision will be taken in this meeting.

P. Fessia added that the cost for the reconfiguration of the RR should be accounted for as well.

Status and proposal for layout and integration around TAS (I. Efthymiopoulos - slides)

I. Efthymiopoulos presented an update of the layout and integration in the region around the TAS. Access in the TAXS-Q1 region needs to be optimised during HL-LHC operation, given the expected radiation levels. Serveral types of equipment are installed in the area (warm BPM, 2 vacuum valves, bellows, bake-out equipment).

The presently installed BPM is not optimal in terms of operation. It is located in a non-optimal location due to the beam overlap during collisions, it shows difficulties in alignment and represents a weak point in the design in case of a vacuum leak.

The TAS-Q1 layout baseline for HL-LHC operation currently maintains the same location of Q1 (L*=23 m) and includes the BPM in the cryostat. This improves the possibility of alignment and mitigates the risk of a vacuum leak. The design of the new TAS (TAXS) with C-coated vacuum removes the need for bake out of equipment. In addition, a remote connection/handling for the TAS-Q1 vacuum is under development. All vacuum equipment will be relocated in the experimental cavern to allow for full remote operation. The remote replacement will be possible within a week. As pointed out by V. Baglin, such intervention was already required during LS1 due a blocked valve.

The proposed layout uses standard gate valves (DN63) and leaves a clearance of only 1.5 mm in radius to ensure that the gate valves remain in the shadow of the TAXS, to limit the background to the experiments and avoid beam impact on the gate valves. The TAXS vacuum ID tolerance is about +- 0.5 mm. The TAXS–gate valve relative alignment error is 1 mm. This is a pessimistic assumption, considering that this was currently measured to be 0.1 mm. Considering these aspects, it was proposed to extend the TAXS aperture to 61 mm. P. Fessia pointed out that one should consider that new underground structures are going to be built, therefore one could expect some geological changes possibly leading to an additional misalignment. L. Rossi asked whether a 59 mm aperture would represent a problem from the optics perspective. M. Giovannozzi there's no way to estimate that the aperture will be really 59 mm and not smaller, therefore it is recommended to keep the margin.

M. Giovannozzi asked why only the use of standard components is considered given the highlighted constraint in the region. L. Rossi explained that this item is very critical not to induce excessive background to the experiments, so also the reliability aspect needs to be taken into account. I. Efthymiopoulos commented that he will cross-check with experiments what are the effective requirements in terms of background generated. B. Di Girolamo added that activation issues must also be considered while making a choice for the material and design of the valve.

I. Efthymiopoulos presented three options to proceed with the work, highlighting advantages and disadvantages of all possibilities.

- Option A: remain with the baseline solution
- Option Ba: eliminate the BPM-exp
- Option Bb: rearrange the LSS layout to maximize the number of BPMs in the good region (major redesign required)

Concerning options Ba and Bb several possibilities can be studied:

1. Displace BPM-Q1 inside the Q1 cryostat (i.e. displace by 183mm)
2. Displace whole Q1 inside the cryostat, bring BPM-Q1, and BPM-Q2 in good region
3. Position BPM-Q1 in the warm area but in secondary vacuum
4. Displace the whole Q1 as option 2 but attach the TAXS to the cryostat of Q1
5. Embed a warm BPM in the TAXS on either side

Options 1 and 2 are the most realistic, the studies will hence be carried out starting from these two options in collaboration with the involved WPs. L. Rossi asked if these would be suitable solutions from the optics point of view. M. Giovannozzi explained that option 1 is the easiest solution to be implemented and that with option 2 one would lose the 180 mm margin.

P. Fessia pointed out that option 4 requires a complete redesign of the cryostat, including a more difficult alignment of the TAXS along with the Q1. Realistically, studies on the subject could be carried out in a timeframe not below 2 years. It was confirmed that the movement of the BPM as foreseen for options 1 and 2 is still compatible with option 4. P. Fessia added that the movement of the BPM has implications on civil engineering works, as the D1 would need to be moved by 2 m and the connection for the SC links consequently.

Option 2 from the optics point of view does not have a dramatic effect, as confirmed by M. Giovannozzi, but the achievable β* gets worse due to the smaller L*. L. Rossi concluded that the preferred option seems to be option 2, but the study of option 4 is encouraged.

ACTION: an update concerning options 1 and 2 will be presented at the TCC at the end of January 2016.

AOB (L. Rossi)

L. Rossi recalled the discussion between E. Todesco and S. Claudet on the cooling of Q5 in P6. The baseline foresees to double the Q5 in P6. Having an operating temperature of 1.9K would allow for 20% more magnet strength and a reduction of costs as it avoids the construction of an additional magnet. M. Giovannozzi commented that the input of WP14 (for the acceptance constraints of the optics in the beam dump region) needs to be finalized. Eventual unbalances of the required strength left and right of IR6 could be dealt with installing the most performing magnet in the critical slot and powering it beyond the nominal values. S. Claudet commented that the conclusions from the future studies on the Q6 operating temperature could also be relevant in this respect. P. Fessia pointed out that this discussion was already presented in October 2014 (12th HL-PLC meeting). This decision is on the critical path for LS2, it is recommended to converge by January 2016.