17th Meeting of the HL-LHC Parameter and Lay-out Committee

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Excused: B.Auchmann, M.Giovannozzi, R.Jones, G.De Rijk.

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/447460/

O.Brüning opened the meeting by summarizing the actions from the last PLC: a) a presentation by R.Calaga on the installation timeline for the crab cavities (CC) tests at the new location of BA6 in the SPS (scheduled for the TC of the 8th of October), b) a presentation on the results of a study for the collimator/absorber option in (covered by S.Redaelli's presentation during today's meeting and the LMC talk by J.Jowett), c) an analysis of the wire compensator highlighting the possible limiting factors (e.g. impedance issues) (by H.Schmickler and Y.Papaphilippou towards the end of the year).

O.Brüning continued by introducing of the agenda of the meeting.

Update of HL-LHC Layout, P.Fessia – slides

P.Fessia summarizes the machine layout as of today and in particular the changes of magnetic lengths, magnetic centres and BPM positions, as compared with the original CDD drawings. Regarding the drawings, the 3D model of the 5R and 5L are completed and there is a new process to create for 2D drawings from CATIA. The advantage is that there is a unique parent 3D model from the database, but it is still under serious debugging. In particular, the generation of the excel file to check optics and to position elements with ABP has to be improved and automatized for avoiding inconsistencies.

Tables with the main magnetic length and positions of the different elements are presented, highlighting the changes and the accumulated difference of the location of the magnetic centre. L.Rossi asks whether the magnetic length of Q5 stays unchanged, as presented in the tables (as it is the case for Q4). WP3 being absent, G.Arduini replies that there may be a change of only a few cm. Regarding the BPM table, there is one missing in the IP side of Q1, as followed up by I.Efthymiopoulos, because the position is not yet clarified. S.Fartoukh asks what are the arguments for qualifying some BPMs as "blind". In fact, there are changes, which relax the criteria, as compared to the present LHC. P.Fessia mentions that there is a document describing this (the subject was treated in a WP2 meeting, see minutes). S.Fartoukh explained after the meeting that, as for the LHC specification, and written in these minutes (input from BI), the "BPM needs to be installed in the middle between of two consecutive long range encounters within a band of +/- 80 cm". More precisely, at the time of the LHC design spec's, there were two tolerance bands, the first one set 75/2=37,5 cm for good accuracy even in weak-strong operation (one bunch with low charge and another with high charge), and 75 cm, similar to the 80 cm reported above, to preserve the accuracy only for strong-strong operation. One should clarify that everybody works with the correct assumptions and in case one realizes that all or most of the BPMs are off, one should be aware that the gating on PACMAN bunches will be the baseline operation of these BPMs (with all the implications this may imply). As T.Lefevre confirmed after the meeting, there are MD results from last July (MD note to be published), which will be used to refine the specifications. Y.Papaphilippou asks about the progress on an action in one of the previous TCs regarding the impact of radiation on the BPMs and changes with respect to shielding, with the new positions, that may affect the directivity of the BPMs. P.Fessia answers that there were several meetings between BI, WP2, WP3, and F.Cerruti for converging to the current BPM layout and energy deposition results will be presented during the next HILUMI meeting.

P.Fessia proceeds by describing the detailed changes area-by-area, including the reduction of the length between the TAN and TAS, the triplet and corresponding interconnect length increases and the displacement of the DFM to provide the necessary curvature radius of the SC link for connection. To answer the question by L.Rossi regarding the value of the radius of curvature of the SC link, P.Fessia answers that it is 1.5m and if it becomes smaller there will be less impact to the tunnel, however there will be also some advantages for the surface. O.Brüning asks why the link does not come from the top (vertically) as in the actual LHC in order to gain space. P.Fessia answers that this is a request from WP6 (Cold Powering) 8, because soldering horizontally the required splice is preferable. S.Fartoukh asks if there are details on the beam pipe and beam screen, which will certainly impact the aperture. P.Fessia answers that there is no clear idea yet, there is work in progress to include all these details.

P.Fessia shows the length of the different distances to be bridged by the DFM branches to feed the different elements. He adds that, although it is not in the baseline, the BBLR has one reserved space option before D2. There are also several changes with tertiary collimators and the main challenge is their transversal integration. L.Rossi questions why there is a length modification. S.Redaelli answers that this comes due to the changes in the optics with the larger betas. A.Rossi is studying the final integration along with WP2. I.Efthymiopoulos stressed that this layout reflects the changes in the length of the TAXN.

The area of the crab cavities (CC) was modified following changes in the cryomodule and the corresponding impact to the interconnects. S.Fartoukh questions if there are integration considerations taking into account that only half of the cavities may be installed at a first stage. L.Rossi remarks that it may be too early for this, since anyway infrastructure must be done once for the complete system, but agrees that all possibilities should be open at present. P.Fessia remarks that the first and third cavity act on beam 1, whereas the second and fourth on beam 2. He stresses that the cavities may be installed in two phases but all the equipment for the full installation should be there from the early stage.

The area in Q4 includes now the second option for the position of the BBLR. There are some asymmetries in that area between left and right of the IP because of the positioning of the jumper for the SC link (i.e. the free space is not the same). In the area between Q5 and Q6 there are also asymmetries between left and right corresponding to the location of the jumper. Regarding Q6, the units will be interchanged between IP1 and IP5 after modification to be cooled down to 1.9K. If the 4.5 K option is maintained, they should go back to same slots. L.Rossi questions if there is a final decision at this point, remarking again that WP3 (not present) should have been present to give quickly feedback to this point. S.Claudet adds that there is of course advantage to operate everything at 1.9 K but E.Todesco would like to keep the 4.5 K. O.Brüning suggests discussing and taking a decision in a future PLC.

Action: WP3 should present the considerations for having the Q6 magnet cooled down to 4.5K as compared to 1.9K in order to come to decision.

S.Fartoukh asks whether the Q4 is mirror symmetric between the two sides and whether the corrector package is taking into account the polarity changes. In particular, if there is change in the CM of Q5, there will be a problem with one of them. He stresses that three correctors are needed. G.Arduini confirms that this is indeed what WP2 is asking. P.Fessia clarifies that the Q5 cold mass will not be opened. S.Fartoukh answers that in that case it needs to be symmetric. After the meeting, R. de Maria clarified with S.Fartoukh, that the Q5 orientation will not be the same in IR1 and IR5. As a result, an (effective) mirror symmetry of Q5 will be respected but between 5L and 1R and 5R and 1L, making the reuse of the existing Q4's possible w/o opening the cold mass. More precisely while the Q5 jumper will be on the left in IR5, they will be on the right for IR1 (so symmetrizing a little bit the "cryo inlets" between IR1 and IR5).

Space reservations for double decker solution, P.Fessia – slides

P.Fessia describes the evolution of the space reservation for the double decker solution between the cost and schedule (CS) review and today. O.Brüning stresses that this presentation is meant to highlight that the space reservation should be frozen, as the contracts will be soon placed. If there are any additional demands by the equipment groups, they should be made immediately.

P.Fessia proceeds by explaining the reasons why the double decker option was chosen: It allows to have the underground infrastructure on the same side of the LHC tunnel for Point 1 and 5, reduces the depth of the pit by around 11 m and allows RF equipment to be nearer to the CCs and to access the DFM from a convenient angle with respect to SC link. In addition, it reduces the LHC tunnel disruption during LS3, enables the connection of the BBLR equipment (although not yet in the baseline) and increases the distance between the LHC machine and the underground area providing further vibration reduction and good radiation shielding. Two systems (quench heater power units and extra collimation racks) are not yet integrated but there are possible locations identified.

Regarding safety, all required ventilation and safety ducts have been added but there is need of revaluation and optimisation of realistic related loads. The emergency rooms have been installed along the tunnel length. The present solution does not feature yet the safety exit linking the aside gallery to the LHC tunnel in the proximity of UA53 (pending further analysis by Safety unit and PSO and by CE on how to link the LHC tunnel with double decker), but it is transparent from the integration point of view (apart from ventilation and accesses).

A cross section of the pit (PM) is presented showing the general occupation of the area, justifying the need for a 12 m diameter. 3D sketches of the underground area are presented, with the general view, and the description of different structures and related equipment (leak tight concrete module with the connected pressurised safety area, the 5t crane for cold box maintenance, cryogenic installations, transformers and low voltage distribution racks, support structures for equipment, personnel and services, the Faraday cage for CC and BBLR feeding, cooling, ventilation, transport area, etc.). The comparison of the present section with respect to the one presented during the CS review, shows the reduction of the section but the increase of the volume and the reduced height, allowing cooling water margin. Detailed views of the underground areas are shown, in particular the one dedicated to RF installation and connection with the CCs, the tetrode option integration and the BBLR.

A summary of powering areas is presented as well, with the four (quite voluminous) switches, the racks dedicated for the quench protection (CLIQ, etc.), the SC magnet powering but also the warm cables from D2 to Q6. The Q1 to D1 area is also quite packed. The section of the tunnel is shown including the different equipment and the transport area. This section could be reduced if the dump section was removed. There is of course equipment for survey, electrical supplies and ventilation. The volume to be excavated was almost doubled from the original baseline, what was presented at the C&S review.

Some remaining points until the contract signature (quite soon!) need to be addressed and most importantly the possibility to revise the shaft dimension and achieve a reduction of the diameter. For the underground area, an optimisation of the warm cables and related cooling requirements is needed. With respect to magnet powering, one should consider the suppression of the dumps and switches for a reduction of the volumes. In that case, the Faraday cage becomes the bottleneck for the section size, so some refinement of its occupation may be needed. Regarding RF, the possibility to bring the supply of tetrodes to the surface should be also be studied, for reducing volumes and CV needs, in the underground areas. Finally, the real needs and efficiency for the smoke extraction have to be addressed. O.Brüning stresses that the real estate is very precious and it is useful to have a final review to see what can be gained.

Action: All equipment groups and associated work packages should verify the allocated space for their equipment and refine the occupational space when needed, in view of placing the contracts for the related works quite soon (November 2015).

Update of Cryo baseline for P4-RF, IR1/5 and SPS-BA6, S. Claudet – slides

S.Claudet reported the evolution of the cryogenics since the baseline of last year and, in particular, the changes in P1 and 5, in P4 with respect to RF and in the SPS (BA6) for the CC test.

The original baseline included two new cryoplants in P1 and 5, one new cryoplant in P4 for the new superconducting RF cryomodules and for separating the cooling of the RF from the arc magnet cryogenics, new cooling circuits for SC link in P7, cryogenics' support for cryo DS collimators and 11 T dipoles in P1, 3, 5 and 7. The baseline had to evolve due to the removal of SC links in P7, the evolution of the project baseline for the 11 T dipoles and collimators (1 or 2 pairs and in P1/5 as options) and the CC test relocation from BA4 to BA6 of the SPS.

The schedule is more delicate for the CC test in the SPS, as there is a global shift following the LS2 delay, when the CC cavities are scheduled for installation in the LHC, after the SPS test. In this respect, the YETS (and EYETS) of 2015-2016 and 2016-2017 have to be used for dismounting the cryo-equipment from BA4 and moving it to BA6, for the tests to take place in the SPS in 2017. O.Brüning reminds an action from the last PLC for a presentation of a detailed scheduling regarding the CC installation and test. It would be essential for the project to test the CCs before the scheduled installation in the LHC, during LS2. R.Calaga reminded that based on the original schedule, the tests were foreseen during 2016-17. The review considered to be quite risky to push the installation in the next shutdown. It was proposed to reschedule the installation of one cryomodule during the EYETS of 2016 for tests in 2017 and continue with another module on 2017 for tests in 2018. O.Brüning stressed that the infrastructure should be there earlier and R.Calaga agrees, as indeed mentioned in the present slides for cryogenics, but also for other equipment that needs to be installed in the BA6 area. S.Claudet finally mentions that there would be as well some additional work for the Q5 in P6.

A block schematic vision of the cryo-equipment to by installed in P1/5 is presented, for different magnet types and possible back up for experiments (liquid nitrogen). New flow diagrams were established. It should be noted, that it is no longer possible to use a single bayonet heat exchanger, as in the LHC but two are necessary. For the SC link, the solution of P7 is followed. The integration needs to be corrected following the comment of S.Fartoukh that due to the fact that DFBX is on the IP side, now it needs to be cooled. The SC link cooling safety aspects are also considered. They do not present any major issue, although as mentioned by P.Fessia some risk analysis is needed.

A summary of the new baseline in P1 and 5 is presented. The current leads are located in the underground area, the integration is being finalized and the CE works are defined. Flow diagrams are now prepared for the LSSs. A safety/risk analysis for the SC links (MCI) was initiated. There are always 8 sectors but with only four LSS and 10/11 refrigerators as compared to 8. There are also some preliminary studies for feeding detector cryogenics. The next steps include the definition of circuit parameters through the heat load, which will enable the sizing of the process pipe and major components, the elaboration of a complete distribution scheme with overall process & flow diagram and then iterations for heat loads and integration optimization.

Regarding the P4 cryogenics for RF, the original baseline corresponded to a unique 4.5K refrigerator. Because of the upgrade staging, new ideas emerged for an upgraded refrigerator proposed to match the RF needs and possible different options, by boosting the existing refrigerator and include a mobile one that can be shared between P4 and the SPS crab cavity installation in LSS6.

S.Claudet describes the model and methodology for estimating the cooling capacity needed and then the evaluation of capacity per level of temperature. This is based on an "LHC-like" approach by converting the static and dynamic heat loads into cooling capacity requirements and enables to establish if there is sufficient margin at nominal and ultimate parameters. The conclusion of this exercise shows that it is required an upgrade of around 2.5kW @4.5K, for sector 4-5. This upgrade seems feasible and it is presently under evaluation, possibly with industry. If this option is found adequate, the baseline should be changed. L.Rossi would like to have a more detailed view of this upgrade. S.Claudet answers it concerns an upgrade of the cold box and turbines, which will allow more flow to the compressors. A 20% increase of mass flow increase could be possibly achieved with modification of the existing cold box, unless it is found too difficult or costly.

S.Claudet further explains that, with this upgrade, Sector 4-5 will be no longer a week point, as it will be aligned with the other sectors. S.Fartoukh questions whether sectors 7-8 and 8-1 will need more cryogenic power due to the demand of LHCb for higher luminosity and the possible heating of the beam screens. S.Claudet answers that calculations are in the pipeline, although this should be a smaller effect. S.Fartoukh adds that there may be a big impact from experimental debris. S.Claudet says that this should be discussed with I.Efthymiopoulos when the subject will be treated in the following TC. He added that F.Cerruti will provide the corresponding heat loads to cryogenics for evaluation. L.Rossi points out that the request from LHCb experiment was to evaluate this possibility, but there is no decision yet taken.

Regarding P4, the distribution line could be modified to provide cooling for the area for additional RF options and the hollow e-lens. This necessitates the modification of the QRL, the roof of the area and consequently a more detailed study. The cavity tests during shutdowns could be done at the surface, connecting a compressor in safe mode with a cold box in the tunnel, using a transfer line which will prevent the high pressure and presence of cold gas while people are working in that tunnel area.

The change of baseline during last June for the relocation of the CCs in BA6, requires a completely new cryogenic infrastructure. Studies started for a new refrigerator, distribution line, gas storage, valve boxes, etc. Before that, it is necessary in priority to make sure that the CC laboratory tests can be accommodated in SM18, with a specific interface required towards the cryo distribution line in bunker M7. This modification of the infrastructure has to be first designed and procured and it should be ready in one year from now. Finally, some basic rescheduling is needed, keeping in mind the connection windows (E-YEATS) and shutdowns of SM18.

The mobile refrigerator from P4 will be used for the CC SPS tests as well, for which the equipment will be moved at the end of the run for the test and then back to its initial location. Locating the cold box underground would really simplify the cryo-distribution.

Finally a summary is given, where S.Claudet stresses that during the rest of 2015, the focus will be on integration and the heat load model. From 2016, increased resources will be required to cope with the future workload.

L.Rossi questions whether the 14% missing cooling power in P4 includes all possible options. If, e.g., the 800 MHz RF option is not pursued, the cryo needs should be reduced. S.Claudet agrees, but the dominant part is the cryo-requirements for the 400 MHz standard RF cavities. The demands for the 800 MHz are lower and the e-lens is in the shadow of both. In conclusion, there is margin, which allows coping with future demands. O.Brüning asks about the observed transient cryo problem in the present LHC and its impact on the remaining arcs. As the HL-LHC will have about a factor 4 higher batch currents as compared to the current LHC operation one could imagine further consolidation needs of the arc cryogenic systems. S.Claudet answers that this should be studied, lessons drawn and come back to in a future HL-LHC TC meeting for reporting the findings.

Collimator roadmap (consolidation vs upgrade and options), S.Redaelli – slides

S.Redaelli first reminds the PLC members of the HL-LHC challenges with respect to collimation. He stresses that 50-70 collimator units will also have to be changed in the present LHC for consolidation. He first reviews the baseline of the collimation upgrade for HL-LHC, which includes a redefinition of the layout in IR1 and 5 for the incoming beam and physics debris, the DS collimation in IR7 with 11 T dipoles, including better materials to mitigate impedance issues for present collimators and the DS cleaning in IR2, without 11 T dipoles but with a collimator needed, as will be elaborated in the presentation. The final decision on installation strategy should be taken, based on Run II experience.

The non-baseline upgrades include DS collimators and 11 T dipoles in 1 and 5, the hollow e-lens, the low impedance material collimators in IR3, the crystal based collimator and more robust collimators in 2 and 8. A table is shown on the collimator settings for the baseline (ready since 2013), based on the 2 σ retraction principle in IR7 and are consistently used for cleaning and impedance estimates. These now include the new TCTs and TCLs and are updated with a column corresponding to the nominal emittance of 2.5 μm.

G.Arduini points out that if the TCTs with more robust material are considered, it may be possible to reduce their gap for better protection. S.Redaelli answers that when the baseline settings were established, there was no beam test on the new materials. On the other hand, with the recent encouraging results of HIRADMAT, it is clear that something could be gained. R.Bruce explains that the value of 10.9 σ for the TCTs could a priori go down to approximately 9 σ, provided that more robust material is considered and a favorable phase advance.

Three main changes of the baseline have occurred right before the C&S review, but were not reported fully at PLC: For ions, in IR1 and 5, there are now convincing arguments for an alternative solutions without the need of TCLD collimators and 11 T dipoles. The second change is that the momentum cleaning area will not need low impedance collimators. Finally, the budget for new robust tertiary collimators in IR2/8 would move to consolidation, but needs revision following the high luminosity request of LHCb.

Regarding impedance, studies of N.Biancacci indicate that without replacing the IR3 collimators, the impedance increase is of 55% instead of 40%. This seems acceptable, as it can be recuperated by relaxing the settings (to be confirmed by radio-protection) and other instability mitigation methods (on-going machine studies in the LHC). P.Fessia mentions that the there are 90% of the losses in IR7, whereas only 3% of the losses in IR3, o the opening of collimators in IR3 would not dramatically change the loss sharing. G.Arduini stresses that some margin could be gained, if the TCTs with more robust and low impedance material were further closed. In that case, the impedance could be further decreased by opening other collimators. It is important to review where are the margins and how to use them more efficiently.

Regarding the new MoGR collimator material, two types of tests are being followed for fast failures (short-term) and high irradiation (long term). For the first type, there are recent excellent results from A.Bertarelli's team in HIRADMAT, where a MoGR jaw survived 288 bunches of 1.3x1011 p with σ of 350 μm (a density beyond the LIU parameters for IR7). For the long-term behavior, there were tests reported by N.Simos (BNL) in the last LARP meeting, where some MoGR samples became brittle and broke when exposed to radiation with high fluence of 1.1×10^{21} p/cm2. L.Rossi thinks that indeed 10^{21} p/cm2 is dangerously near the value that the collimators will be exposed in HL-LHC. S.Redaelli says that there is an international debate on the issue of how much damage induced by low energy protons are representative of damage by high energy ones, and that probably a couple of collimators, which are the most exposed in radiation will be close to this value. In any case, tests will be repeated at BNL with better samples and more representative parameters.

Regarding the 11 T dipoles, there is now more confidence for the impact of ion beams and the quench limit of SC magnet. At the same time, beam induced quench tests in Run II are vital for refining the quench model, in particular for the operation with ions. New simulations with bumps have shown that in the case of IR1 and 5, the losses could be moved at the location of the connection cryostat without risk of quenching. This means that there is no need for collimators and of course of 11 T dipoles. In IR2 though, the situation is different. Because of the anti symmetric optics design of the LHC, there are different dispersion peaks in IR2 as compared to IR1 and IR5, so a collimator will be necessary, but can be placed in the connection cryostat, eliminating the need of the 11 T dipole. A table is shown with the evolution of the needs for the 11 T dipoles during the 2013 collimator review and today. L.Rossi does not agree with the question mark on the 11 T dipole need in IR7 for protons after LS3. It is indeed necessary, as we now know that there is no reasonable margin with respect to quenches. What is questionable is whether the 11 T dipole in IR7 is needed before LS3. S.Redaelli replies that, as was marked in his slides (p.14), there was a factor of 2 "gained" from analysis of quench tests.

He proceeds by presenting some caveats with respect to the present considerations on the baseline, including the uncertainty on quench margins at 7 TeV (quench tests for both ions and protons are needed). In addition, the bump technique for all IRs needs to be demonstrated operationally, although there should be no issue. L.Rossi thinks that this point (use of bump to avoid use of 11 T dipole in IR2) was endorsed by the LMC. O.Brüning asks what is the position of MPP on this. M.Zerlauth answers that there are still a few open points, in particular the behavior of the cold diode with higher heat load. S.Redaelli adds that the bump method in IR1/5 was tested in 2011 and was presented during the 2013 review. At that point, it was concluded not fully reliable, based on simulations and now is part of the baseline, again based on simulations. O.Brüning stresses that any concerns should be used to motivate tests with beam operation during LHC RunII. S.Redaelli comments that all the considerations depend on the beam energy (7 TeV was assumed), and have to be reviewed, in case of operation at lower energy. Detailed energy deposition studies indicated potential issues with loads to cryogenics beyond the quench limits, still to be understood and validated in operation.

L.Rossi would like to clarify the situations about the 11 T dipoles. Two units are prepared for LS2. If they are not needed in IR2 (the present baseline change) they can be used either in case of problems or for IR7. The idea is to go now with four 11 T dipoles and not six, in total. However for the moment the budget is unchanged, pending final decision (that will be irreversible). O.Brüning adds that the information should be passed to the group developing the cryostats, i.e. that they will have to fabricate two cryostats without magnet.

S.Redaelli finally proposes that these points are reconsidered in a dedicated review in 2016. L.Rossi stresses that it is important to have quench tests for ions and protons by December. O.Brüning agrees and reminds that this was indeed given high priority in the LMC. S.Fartoukh points out that in IR1 and 5, the Q11 is focusing, whereas in the even IRs, it is defocusing and this makes the difference in bump efficiency for the different IRs. On the other hand, one could test the bump approach in IR7. S.Redaelli mentions that J.Jowett considered this for ions (the momentum spread distribution is different) and it seems that it does not work. R.Bruce points out that there was exactly an MD request during Run I to test the bump technique in IR7 but the machine study was finally cancelled. O.Brüning stresses that this is a good suggestion that should be followed up.

Action: The collimation and ion team should review the possibility to pursue a bump method loss mitigation approach in IR7.

Regarding the status of TCDL, the main focus is now on the integration into the connection cryostat and the detailed work will start in 2016, as WP11 is presently quite busy. Before concluding, a few slides are presented for consolidation, where a number of collimators will be changed for the present LHC. It is important to stress though that, without this upgrade, the HL-LHC considerations may be not valid. The budget request was made and if consolidation cannot cover certain items, it should be re-discussed with the HL-LHC project.

AOB: Approval of 8b+4e and ion parameters – table

The 8b+4e parameters were added to the PLC web-page parameter table replacing the 50ns, with the footnote that this is an option for e-cloud mitigation. The BCMS beams are still there with a footnote that they may be interesting if the emittance growth in HL-LHC is larger than expected. Both options are therefore not meant to replace or question the 25ns baseline configuration. J.Jowett will soon provide a table for ions based on a document he has issued.