20th Meeting of the HL-LHC Technical Coordination Committee

Participants: C.Adorisio, M.Alcaide Leon, V.Baglin, A.Ballarino, H.Burkhardt, R.Bruce, K.Brodzinski, O.Brüning (chair), R.Calaga, S.Claudet, D.Delikaris, R.De Maria, N.Dos Santos, B.Delille, B.Di Girolamo, P.Fessia, J.Gascon, S.Gilardoni, E.Jensen, R.Jones, H.Mainaud Durand, F.Menendez Camara, Y.Papaphilippou, V.Parma, F.Rodriguez Mateos, L.Rossi, F.Sanchez Galan, L.Tavian, J.P.Tock, E.Todesco, R.Tomas Garcia, R.Van Weelderen, D.Wollmann, S.Yammine, M.Zerlauth.

Excused: A.Apollonio, G.Arduini, C.Bracco, J.Jowett, M.Giovannozzi, M.Gourber-Paze, S.Redaelli

O.Brüning opened the meeting by reviewing the agenda.

The minutes of the last meeting have been approved with the comments sent to A.Apollonio. The Indico Page contains the latest version. There were two actions related to updates of the design of the dump system to be presented in a future TCC. O.Brüning mentioned that, as we are approaching the end of the year, the TCC team will review the remaining actions and present them in one of the first TCC meetings of 2017.

Strategy and equipment readiness for the tests of the SC links in SM18, A.Ballarino – slides

A.Ballarino summarizes the strategy for the tests of the SC link, as was already presented during the last C&S review. A lot of the information presented here is put together after discussions with several colleagues and in particular M.Bajko. After a brief presentation of the system, A.Ballarino presents the baseline strategy for the testing of a prototype cold powering system for the triplets and for the matching section. The tests of the triplet cold powering are divided in two phases: Phase 1 is starting, at the beginning of 2017 with a reduced system (reduced DFH and a pair of 18 kA leads) for a first validation. Phase 2 starts at a later stage, with a complete system test (full DFH and set of current leads), which will be made available for the string 3 test. The equipment should be available by early next year apart from the DFX. A note was written and is available in EDMS (No:1698461), which contains a significant number of details and technical information of the requirements for the SM18 test. Space exists in SM18, equipped with a cryostat and using helium gas from 5 to 20 k, which is suitable for the phase 1 test qualification. For phase 2, additional power convertors and some integration work is needed, and followed up by M.Bajko. The planning of the activity is summarized, as it was presented in the 2015 and 2016 C&S reviews. The test of the SC link cables (20 m) is completed, including quench propagation, protection and joints. The reduced system will be tested during next year and it is expected that the full test system will be tested

by the end of 2017, with the matching section cold powering tests following at the beginning of 2018.

Regarding the strategy of the tests, each of the eight Cold Powering Systems (plus the two spares) will be tested in nominal operating conditions before integration in the LHC. The test will validate all electrical components and joints. The idea is to have a simultaneous test of SC Link and all current leads, most likely with a dedicated DFH. This will realistically require one month (i.e. one week of cold powering, plus time for installing and dismounting) to validate components and joints, while the number of testing is reduced to minimum. It will be tried to test the full system validating both link and leads, with a dedicated cryomodule. The test of a system validates a component different from what is done in the prototyping phase and around 1 month of time is needed. The String 3 is a dedicated test and will run with its own cold powering system (Phase 2 prototype) but it will not require specific cryogenic and electrical feeding, which will be provided by the String system. This test will validate the DFX in its final configuration.

Next, the series production schedule is presented. The planning foresees that cold testing can start in 2021, starting with the reception of the units in SM18 and will last until 2023 for the full qualification. The work on the options for cold tests of Series is in an early stage. One option is to keep using the existing distribution feedbox in SM18, (with gaseous He at 5 k), and locate the around 100-m-long SC near the String. Another considered option is to move away from the String 3 area and find a location in the vicinity of the magnet test benches. Cluster F is being considered, and the discussions are in a preliminary stage, gathering pros and cons. A drawing from A.Kosmicki is being presented, showing the location of the space corresponding to the two options mentioned before. The use of the existing distribution feedbox has the advantage of the 100 m linear distance and the availability of gaseous He from the existing feedbox. On the other hand, there is limited space for installation behind the String and the power converters need to be shared with the String. It is not the best configuration but the powering will not last for more than one week. For the second option, the pros include the space availability for installation/dismounting, the availability of two times 20 kA power converters (one new and one existing for cluster A) and the availability of liquid He. On the other hand, there is very limited linear length of the order of 30 m, and a way should be found to compact the ring or routing of the line and low current rating power converters are needed.

In conclusion, the WP6a strategy envisages the test of the series components before integration in the tunnel. The design of the system and schedule, with testing from 2021 to 2023, enables these qualification tests. The budget for the test of the series components is within WP6a. There is not a specific request for the link in the string. Technical studies are still needed in order to select the best solution. There should not be a significant cost difference in particular for using the existing infrastructure (cryogenics). The String 3 will run with its own Cold Powering System and the schedule seems fine. The activity in the SM18 is being defined and will be coordinated by the SM18 team led by M.Bajko.

Discussion

D.Delikaris would like first to point out that P.Gayet is assuring the coordination with all the cryo users. In addition, he would like to ask if the cryo feedbox needs to be moved from its present position. A.Ballarino answers that this is not necessary, the idea is to keep it in its present position which is her personal preference or to use another location but without moving the feedbox. L.Rossi suggests to have a provisional budget estimate for the two options for the series cold tests. O.Brüning concludes that with this presentation, the action of the 15th TCC on a more detailed plan for the STRING should be considered closed. The adaptation following the different options is in the budget of WP6a. A.Ballarino agrees and adds that the feedbox is quite complicated. A simpler but different one, with additional work for the interface could be foreseen, if the option for moving in the other SM18 area is chosen. P.Fessia stresses that the DFH is in series with the one tested during the SC link test and asks about the DFX test. A.Ballarino answers that this is done in the STRING but it is not part of the system in each cryostat. The main goal of the test is to validate the electrical components and there is no plan for individual DFX testing. V.Parma points that this is a strategic decision to take and adds that this is a complicated system and one should be really confident for skipping a test of the individual DFX. His preference would be indeed to have each individual DFX tested. A.Ballarino points out that in any case this test has to be made in the tunnel. She adds that if this is adopted, the arrival of the component has to be adapted for allowing the test. L.Rossi proposes that the decision is made by February-March 2017, as the implementation takes time and the SM18 testing needs some adaptation. V.Parma explains that this was triggered during the C&S review and it is still quite fresh for a final decision. B.Dellile asks if this could be the occasion for taking the decision between the two options for the series tests. A.Ballarino answers that this should be decided not later than March. L.Rossi suggests to group this decisions for future TCC in February-March.

ACTION: A decision for the necessity of testing the DFX in SM18 and the two options of the STRING test should be taken by February-March 2017.

O.Brüning asks about the progress on the actions triggered from the presentation during the 13th TCC of last August regarding the circuits of the matching section. A.Ballarino answers that there was already a presentation during the circuit review. F.Rodriguez Mateos explains that what remains for concluding is the (reduced) number of correctors. In addition, it should be understood if it is essential during LS3 to implement the feeding for 600 A correctors. There is a need to get input from the project for this, as it has significant impact. A.Ballarino stresses that the main issue is the need for a 600 A busbar.

Update on cryo configuration of IR4 in HL-LHC, Serge Claudet - slides

S.Claudet provides an update towards a decision process for the final cryo configuration in IR4. First, he reminds the original baseline in point 4 which was foreseeing a dedicated 4.5 K refrigerator for RF. Certain considerations led to the alternative proposal with an upgrade and a mobile refrigerator.

The biggest motivation for the IR4 cryo upgrade is the necessity to test an RF module during a long shut-down, while the cryo is under maintenance. L.Rossi asks about the possibility to do an RF module test knowing a few months in advance about this. S.Claudet answers positively that this can be prepared but underlines that this is impossible in case of emergency. Then he proceeds on reviewing the failures during the 2012 run (indeed similar with 2015), where one third of the failures were due to the cryoplants, corresponding to approximately 80% of the down time. A positive impact in availability should be expected by limiting the number of cryoplants. The timeline for the upgrade depends on a series of actions necessary for LS2. The feasibility study is done, the distribution studies are on-going and a decision should be expected soon.

A table of R.Calaga from Chamonix 2014 is presented, showing preliminary figures for the necessary cooling capacity for different type of cavities, and divided into static, dynamic and total power needs. Observations during the intensity ramp-up from April to June 2016, show that the cooling needs do not evolve significantly with beam intensity. L.Rossi asks why a square of the field was taken for LHC design. L.Tavian answers that it was just a scaling. R.Calaga explains that there are losses on cavity fields but also image currents. The estimates of Chamonix 2014 were considering only the fields. In reality there are some additional losses from the image current but they are not really visible. He adds that WP2 included a scaling for Synchrotron Radiation, and all figures were grouped in the HL-LHC design report.

S.Claudet presents an updated plot with the RF heat loads, for LHC, Run3 and HL-LHC baseline, for which the heat load is around 1.5 kW. L.Rossi asks if the RF phase modulation could impact the consumption. O.Brüning answers negatively. S.Claudet explains that the two RF options need between 1.8 and 1.7kW, while the crab kissing needs an extra 0.5 kW. O.Brüning points out that crab cavities are not for point 4 (but for 1 and 5) but that electron lenses might imply an additional cryogenic load in IR4. S.Claudet thanks for the correction which will be indeed included. An upgrade study for the refrigerator in S4-5 was undertaken. The result shows the need for an additional 4.7 kW with respect to the actual LHC, mainly driven by RF cavities and mixing.

Regarding the upgrade of the 18 kW @ 4.5 K, refrigerator, a dedicated study was undertaken from a manufacturer. A very promising technical outcome with a significant cost reduction of 1-2MCHF was found if a smaller upgrade is envisaged. The global picture including cost was presented in October and now there is a possibility to proceed with a non-competitive tender.

An additional parametric study for the capacity of each upgrade with respect to RF heat load was done. The slope of the curve of the heat load with respect the upgrade power is almost linear in 2.3 kW of upgrade per kW of installation, including 15% operational margin in sector 4-5 (as for sector 6-7). A comparison of equivalent refrigerator capacity in the different LHC sectors also showed that S34 shows one of the smallest capacities.

Applying the present baseline for cryogenic upgrades in Point 1 and Point 5, it seems strange to add capacity in S45 when S34 still shows an even stronger limitation. This observation drove an alternative upgrade scenario of not touching the refrigerator in S45 but to upgrade the cryogenics in S34. By doing this, we alleviate the issue with the weakest sector and S45 becomes comparable to S56 and S34 become comparable with S67. The equivalent

refrigerator margins are then presented, for the LHC, HL-LHC baseline and alternative. For the LHC, the problem is focussed on sectors 3-4 and 4-5 which are the weakest. For the HL-LHC baseline, there are significant margins. The upgrade of S45 brings it to the same capacity as S67, and would align S81 and S12 and reduce by 1 kW the upgrade need.

The alternative upgrade considers two options. One aligning the capacity of sector S45 with S67 or with S81. A final idea came up to look at a moderate upgrade of S34 by 760 W plus margin, which seems to fulfil the needs. This solution was not previously considered as that sector had already two upgrades, but it seems that this final solution is optimum. O.Brüning asks about the necessity of the mobile plant in this last upgrade consideration. S.Claudet answers that this needs to be clarified. In summary, there is no longer a need for 6kW@4.5K, that only a new dedicated refrigerator could handle. With sector 4-5 relaxed from left side of point 5, it is now demonstrated that an upgrade of that sector providing 2.6kW@4.5K additional capacity for all RF needs would be sufficient. Considering the situation of the capacity margins for the 8 sectors, there is a possibility to even reduce the cooling capacity requirements for P4 if we accept to align the margin of S45 on the one of S81 for instance. Pushing the reasoning further, we could even consider not to touch the refrigerator of S45 and only perform a moderate upgrade of the one in S34 (1.2-1.5kW@4.5K), with feasibility to be checked, a.s.a.p. For "long term" flexibility etc., we should consider that time to deliver cryogenic capacity and distribution should not be longer than the time required to develop new RF modules ready for installation in LHC (3 years). During 2017-2020, there will be specs to equipment to be delivered. L.Rossi agrees that a 3+2 year cycle should be enough.

Some photos are presented showing the actual cryo-distribution in point 4. The cryodistribution schematics for the HL-LHC baseline but also the alternatives are presented and compared with the actual LHC. The present machine has an interconnection block to the QRL. The 2nd alternative is the most attractive as it keeps the existing QRL and extension, and a service module can be added for options on either side. There is no modification from present and only proceed when needed for spending.

A final summary table is presented with all options and associated cost. The cheapest solution is the alternative 2 as it keeps the same equipment for the 400 MHz and adds the rest when needed. O.Brüning asks if one should consider also the extra cost for the SPS unit. S.Claudet answers that this is around 2 MCHF, and actually it is not included in the baseline but it is included in the rest. He summarises his presentation by reviewing all possibilities mentioned, including the work to be done for LS2.

O.Brüning expresses his preference for the newest alternative which is indeed very attractive. L.Tavian questions if the 2.3 kW mentioned in the summary table for sector 3-4 is a correct figure. S.Claudet clarifies that this is the total shared in half by half S3-4 and S4-5. P.Fessia points out that the 1st and a bit less for 2nd solution have some extra cost on infrastructure to be considered. D.Delikaris stresses that based on technical arguments, a new refrigerator, with 8 cryo plants, plus a new one would impact on availability. R.Calaga had very recently discussions with the ABP group to update the RF system needs. L.Rossi asks that this table is finalised, by Chamonix. S.Claudet agrees that the capacity is important and has to be confirmed. Regarding the 2nd alternative, there is work to be done on the feasibility and he is

expecting results by March. O.Brüning asks if we need to do this in one step. S.Claudet answers that first the dedicated cryo system should be removed, then 2 options for the revised baseline should be fully assessed. There are further minor details if taking the 1st, or the 2nd alternative. L.Rossi agrees with the reasoning of D.Delikaris that, to upgrade the weakest sector with 1 cryoplant and the rest can come when it is needed. D.Delikaris would like to stress that there is some uncertainty in the cost, as it was just an original estimate. O.Brüning summarizes that the alternative option looks very appealing. He adds that maybe one could decide for the 1st alternative and then look at the possibility of the 2nd alternative. For P.Fessia, the alternative 2 has very moderate uncertainty, whereas the 1st alternative has larger uncertainty. He would like to come back in March with the impact to all the other infrastructure. L.Rossi suggests to have a dedicated TCC on point 4, potentially during March or April.

ACTION: The alternatives for the cryo upgrade should be discussed in a future TCC, including the impact on infrastructure (March-April 2017).

Requirements for the background in the experiments and the need for a-C coating also in the matching section, H.Burkhardt-slides

H.Burkhardt introduces the subject stressing that machine induced backgrounds have been an issue and performance limitation in many colliders, like HERA, LEP, etc. It was very important to follow this up in the LHC, and after a background workshop, a working group was formed since 2009. The sources are beam gas scattering, halo and collision related.

Some early simulations from Run I, show that beam-gas backgrounds generally dominate, and are generated over several hundred meters from the IP. These are followed by halo-background, of similar importance in the muon background component. They tend to be higher energy and generated further away and thereby vacuum should be good everywhere.

Early observations show that background can be as low as observable and potentially affect the luminosity measurement. Presently at the LHC a small fraction of the luminosity is sacrificed in order to have non-colliding bunches, as they can be distinguished by the lack of typical afterglow of the colliding ones.

Background measured in inner detectors can be correlated by vacuum, and is proportional with the pressure measured at one gauge not too far from experiments. There are four orders difference in signal to background ratio, as measured in CMS during 2011. This can be more significant for low luminosity experiments. One example is ALICE, which wanted vacuum better than 5×10^{-9}mbar, but during 2012 and due to issues with the TDI heating, it was not better than 3×10^{-8} mbar, preventing clean data acquisition during half of 2012. There is a major effort from the vacuum group, to upgrade sectorisation and to apply NEG coating. In the case of ALICE, improved vacuum solved the problem since 2015. As expected, in Run2 there was increased background and vacuum. For example, ATLAS could observe from 2-5 Hz, and the

change was much more dynamic, during the fill. As there were margins, this was never an issue.

A study with localised pressure bump at different regions was done, during the intensity ramp up of 2016. A pressure bump from heating the NEG could go up to $1x10^{-7}$ mbarn and completely dominate the background. The effect is visible up to D1 and becomes small only near the TAN. Beam gas collisions further downstream at 150 m contribute less to background rates as seen by the BCM and Pixel detectors in the central region around the beam pipe, but far beam-gas is important for backgrounds at larger radius, seen as "fake jets", clearly observed in recent vacuum bump tests.

In summary, Run2 backgrounds generally increased and became more dynamic than in Run 1, but well acceptable. ALICE improved thanks to vacuum upgrade in LSS2 during LS1. On should expect further increase for HL-LHC, due to the higher intensity, and the fact that detectors are more exposed (TASX) and the halo component is increased for tighter collimation and/or lower β^*.

A rough specification for vacuum pressure is to aim below a few 10^{-9} mbar (based on ALICE experience during 2012, scaled to HL-LHC). It is very important for the experiments that vacuum quality is as best as (reasonably) possible. It should be encouraged to implement all affordable aC-coating (ecloud minimization) and pumping upgrades with emphasis on long straight sections including matching sections and beginning of arcs. Any local heating should be avoided and monitored.

O.Brüning stresses that the main difference between Run1 and Run2 is the increased e-cloud, which should be reduced due to aC coating. L.Rossi asks V.Baglin if there will be a presentation touching these subjects from the vacuum point of view (coating in the matching section) during Chamonix. It would be nice to have all the elements in order to be able to come up with a more quantitative statement by that time. V.Baglin points out that he understands the importance to maintain the same vacuum pressure level for HL-LHC as we have today. Indeed, if we are considering double beam current, the SR and pressure will also be doubled. In the area with aC no multi-pacting is observed so gas from e-cloud is much lower. H.Burkhardt points out that there is not really a hard number (apart from ALICE). S.Gilardoni points out that he is surprised by the lowering of background in ALICE as the TDI is the same as in 2012. H.Burkhardt answers that this year the situation is good, and a report from ALICE shows that between 2015 and 2016 the backgrounds are comparable. O.Brüning proposes to close the discussion and continue it Chamonix.

Conceptual HL-LHC Circuit Drawings & Nomenclature (Circuits + Power Converters), S.Yammine - slides

S.Yammine first presents schematic views of the different circuits and then the details for inner triplet and correctors, D1 and D2, correctors and 11 T dipole, Quadrupoles Q4, Q5 and Q6 and correctors. L.Rossi informs the TCC that there will be a talk from WP2 in Chamonix,

reviewing the number of correctors. It is important to know soon if we are able to suppress them (see the presentation by Amalia above). R.De Maria points out that the Q4 circuit is faster than Q5 and Q6 and wonders if the same circuit is needed. S.Yammine answers that there are two solutions, with a warm cable or diode in series. R.De Maria further asks if we could have the fastest, as the baseline. S.Yammine cannot give a definite answer as there are on-going discussions with EPC on the subject.

Regarding the nomenclature, the same conventions as LHC are used for the circuit names: R + Optical Function + . + Machine Position + Beam Number (if applicable). A concern was raised by EN/EL, on the duality of the circuit names between operation (LHC) and development (HL-LHC) in the different databases. F.Rodriguez Mateos stresses that the problem is relatively serious, as the databases will co-exist for LHC and HL-LHC, and asks if a version could solve the name conflict. L.Rossi agrees that it is very bad to have for two things the same name. F.Rodriguez Mateos reiterates that in his opinion the problem comes because of the lack of versioning. O.Brüning agrees that a version number could solve the issue. L.Rossi then proposes to have a version as integral part of the name. M.Zerlauth suggests that a name inspired by optics with a version of the optics could solve the problem. For the layout and control system (ELSA), the use of versioning can indeed solve the conflict. R.De Maria remarks that for the LHC the circuit of Q4 was changed and it was properly updated.

Decision: O.Brüning summarizes that the TCC recommends versioning.

S.Yammine proceeds to the description of the power converter nomenclature, following the pattern: PC_Family_Name.Machine_Position.Circuit_Name. He ends his presentation with a short conclusion. F.Rodriguez Mateos insists that everyone uses this scheme from now on in order to avoid confusion. After all, these are the reference drawings. O.Brüning suggests to have the link apparent in the TCC web-site, by the HL-LHC meeting. L.Rossi asks a side question on the progress of finalizing the HL-LHC circuit layouts. F.Rodriguez Mateos committed to do this for the end of the year but it is not yet finished. L.Rossi thinks that the configuration is done, but it is now necessary to fix the reasonable worst case scenario for circuit layout evaluation.

AOB: Outcome of C&S meeting, L.Rossi

L.Rossi points out that the project came out very well from the C&S review. It is clear that some issues were discovered while preparing it and in the future, he suggests to be more pro-active in order to anticipate them early enough and not at the last moment. The next one will be during March-April 2018. The main interest of the project is to freeze things and proceed to construction. There is indeed a high risk in CE, but an enormous amount of work was done to make the estimates solid. He would like to stress that there is no time for further optimisation, sensible decisions should be made, design should be frozen in order to proceed to construction. The report of the close-out was sent to WP leaders and expects their feedback for eventual changes on the phrasing. There is the usual comment on lack of contingency, but in his opinion there is not much margin on this. For the first time, the project is asked to start preparing for installation. The reviewers recommend a detailed plan but this may be thought as an overkill at this early stage. On the other hand, we have to realise that the LHC was

installed in 3 years and the HL-LHC will need 2.5 years. L.Rossi would also like to ask that the WPs are responsive on the comments of the reviewers. He would like to congratulate all the project members for the quality of the presentation and associated work. O.Brüning would like to thank everybody, stressing that the scope of the project was changed in June, and there was very little time for preparation. L.Rossi adds that now is the time to discuss about the roadmap for all the options.

The meeting is closed with a summary of the preliminary next agenda.

The next TCC meeting will take place on the 24th of November 2016.