54th Meeting of the HL-LHC Technical Coordination Committee – 02/08/2018

Participants: M. Alcaide Leon, A. Apollonio, I. Bejar Alonso, R. Bruce, O. Brüning (chair), M. Calviani, F. Cerruti, S. Claudet, A. Devred, P. Fessia, M. Freitas Mendes, M. Giovannozzi, J. Jowett, M. A. Gonzalez de la Aleja, E. Mainaud Durand, P. Martinez Urios, M. Martino, R. Martins, J. Oliveira, T. Otto, Y. Papaphilippou, S. Redaelli, F. Savary, F. Sanchez Galan, D. Schoerling, E. Todesco, R. Van Weelderen.
Excused: G. Arduini, L. Rossi, M. Zerlauth.

The slides of all presentations can be found on the website and Indico pages of the TCC.

The minutes of the previous meeting were approved without further comments. There were no particular actions. O. Brüning noted that an update of the test results from the 11 T short model will be given by the end of August. F. Savary briefly stated that the tests are progressing very well, and the magnet had only a few quenches to nominal and ultimate. It reached ultimate current without any quench after a thermal cycle. The agenda of the meeting was reviewed. An AOB was added by I. Bejar Alonso regarding the document summarizing the changes with respect to the last TDR.

Reference situation of cooling capabilities for 11 T and implications for eventual modification (needs and impact), S. Redaelli - slides, R. Van Weelderen - slides

S. Redaelli gave a summary on the collimation losses in IR7 dispersion suppressors (DS). The layout after the re-baselining in 2016, comprises one TCLD collimator per beam and one dipole per side is replaced by 11 T ones. The quench limit of the new magnets is an outstanding item to assess the performance of the new layout. Other possible limitations on the cryogenic system need to be addressed.
Loss map simulations show that the addition of one TCLD reduces the first loss peak by two orders of magnitude, but the second loss cluster remains unchanged. These loss distributions were used as input for energy deposition studies with FLUKA and benchmarked also with measurements. Simulations are performed for 7 TeV beams, with the nominal parameters (see slide 4). Three aspects were identified as critical: the classical quench limits due to losses (both for standard and 11 T dipoles), the total energy deposited in the coil (specific concern for the 11 T dipole) and the total power on cryogenic cells.
Without the upgrade, the peak losses in SC coils reach 21 mW/cm^3 for protons and 58.2 mW/cm^3 for ions. With the TCLD and 11 T dipole, the losses are mitigated, and the limitations are located in the 2nd cell (Q9-Q11), which is not upgraded. For example, the 11 T dipole might get up to about 20 mW/cm^3 (ions) for a duration up to 10 s. It is important that the magnet team assessed if this is sustainable.
The second limitation is from the deposited total power on the 11 T coil, and is calculated by summing up the energy deposition on the coil and cold bore, for 1 h of beam lifetime. It equals to 12 and 21 W for protons and ions, respectively. Finally, the total loads on the cold masses are estimated with FLUKA simulations, for each half-cell giving a maximum power/cell of 70

and 140 W for protons and lead ions, respectively. Following a question of O. Brüning regarding the beam parameters used for the simulations, S. Redaelli clarifies that they are the nominal ones, mentioned in slide 4. F. Cerutti adds that the given numbers can be scaled with the considered lifetime. O. Brüning asks if the considerations are somehow pessimistic, because they correspond to the start of collisions, whereas, during a fill, the intensity is reduced due to burn-off. S. Redaelli agrees adding that on the other hand, this is the critical moment of the fill for beam losses. It is probably pessimistic to assume the 1 h lifetime scenario for time longer than a few minutes. The 0.2 h that might induce quenches is pessimistic in the present LHC operation but is considered as design criterion for the HL-LHC beams. He proceeds by enumerating some other small to negligible power deposition mechanisms (beam gas, e-cloud, impedance, synchrotron radiation). Only the beam gas affects loads on the cold masses. Following a question of R. Van Weelderen, it was clarified after the meeting that the vacuum chambers are not coated in IR7, although coating of the 11 T could be considered. S. Claudet also explained that these are cold masses cooled at 1.9 K, and thereby the beam screen will also be cooled.

P. Fessia asks whether the 1 h-lifetime consideration is too pessimistic. S. Redaelli and R. Bruce answer that in particular during Run 1, this lifetime was observed in several occasions. This occurred much less during Run 2. J. Jowett adds that during the heavy ion run, lifetimes of this order were observed at the end of the ramp. S. Redaelli commented that it is pessimistic to assume this scenario for long times, and noted that the total loss rates scales with the decreasing beam intensity during losses. It is important to understand from cryo for how long the losses can be sustained before tripping.

R. Van Weelderen reviewed the situation in terms of cooling of the 11 T dipole (coil and cold mass) but also the DS cell, in general. The thermal quench limit was assessed with cryo-lab tests and numerical simulations. The peak power density was estimate to be 32 mW/cm^3, using FLUKA simulations and measurements for the coil. This leads to a minimum temperature margin of 3.6 K, for a local hot spot and reduces to 1.9 K for a peak power density of 100 mW/cm^3. Following the question of O. Brüning, R. Van Weelderen explained that this margin corresponds to the temperature left before the coil quenches. S. Claudet stressed that it is important to know the design goal for the 11 T dipole. F. Savary stressed that this specification is not ready to be given, and most probably it will become clear only after the analysis of the 11 T dipole short-model tests. Following O. Brüning's question on the LHC temperature margin, L. Bottura communicated through A. Devred that, for the LHC dipole, it is 2 K and, for the 11 T dipole, 4.5 K. S. Redaelli asked if these numbers correspond to temperature rises for which the cryo trips and R. Van Weelderen answered that actually the coil already will quench. S. Claudet explained that although a thermometer may measure an average temperature of 1.9 K, locally the coil may reach higher temperature and quench. He added that there should be indeed difference in the behavior of Nb_3Sn as compared to NbTi. O. Brüning suggested to come back to a future TCC with a clarification about this margin, along with the measurement analysis of the 11 T short model. S. Redaelli stressed that it is important to have a quench limit in mW/cm^3 for the 10 s loss scenarios at 0.2 h lifetime to compare this to simulation results.

ACTION: The temperature margins with respect to quench of the 11 T magnet should be clarified in a future TCC, along with the 11 T short model tests (F. Savary, L. Bottua and E. Todesco).

R. Van Weelderen further explained that, at steady state, the coil heating moves towards the annular space around the beam pipe, and in the absence of cooling holes along the length of the magnet, it moves towards the magnet ends via the said annular space. For helium bath temperatures between 1.9 to 2.1 K, the total power extraction capacity ranges from 60 W to

15 W. Following the question of O. Brüning, R. Van Weelderen explained that if the cooling capacity for the rest of the sector is enough, then this temperature will be maintained. S. Claudet agreed, stating that it depends on losses on the neighboring cells. He added that the absence of additional cooling channels is a design feature of the 11 T dipole and if additional heat extraction capacity is required in the DS, it should be envisaged independently of the 11T case. After the meeting, S. Claudet further clarified that a complete redesign of the DS cooling scheme could be worked out if needed, gradually with larger heat exchangers (+40%) and same bayonets, or doubling bayonets in the magnets as for HiLumi IT, requiring to modify the QRL service modules concerned. This is indeed a possible but very serious modification of the DS zone.

R. Van Weelderen proceeded with the cold mass (CM) cooling limit estimates. Up to 10 W can be taken locally by the 11 T magnet CM, all the rest will be taken by the neighboring magnets, limited to maximum of 50 W. Detailed FLUKA simulations were done for estimating the heat load to the different parts of the CM of the 11 T dipole, for protons and ions, leading to a total of 34 W for protons and 66 W ions, taking into account 1 h beam lifetime. These values are increased linearly with a reduced lifetime of 0.2 h. In conclusion, for 1 h beam lifetime, the thermal design is sufficient (continuous cooling mode), whereas for 0.2 h, although the power deposition is higher, it is still acceptable for the coil but only for a short time. S. Claudet mentions that the lifetime of 0.2 h, cannot correspond to an operational scenario for cryogenics aspects, although the quench tests were done with this lifetime, as mentioned by S. Redaelli. Following the question of R. Bruce regarding the 10 % excess of power with respect to the capacity, R. Van Weelderen explains that 60 W is not a hard limit, there is some margin with the neighboring magnets. S. Claudet adds that this 10 % is within the accuracy of the estimate.

A description of the steady state cooling limits of the cryo hardware in the DS is given. The heat exchanger in the QRL is limited to below 100 W at 1.9K per cell. For both proton and ions, and considering 0.25 W/m, and negligible loads beam-gas based on present LHC vacuum, 77 W are available in the DS. S. Claudet mentions that it would be important to have a statement from vacuum colleagues that these rest-gas considerations, similar to the ones of the LHC design report, are adequate also for HL-LHC.

ACTION: The vacuum colleagues (V. Baglin) should verify if the beam gas considerations based on LHC considerations are adequate for HL-LHC.

Taking into account the beam lifetime scenarios, for protons and 1 h lifetime, the total loads are below 200 W and can be maintained by cryo-hardware in steady state. For the ions and the same lifetime the loads exceed 200 W, and the heat capacity of the DS-helium content will have to be used. For 12 min. lifetime, the level of 200 W is exceeded by far for protons and even further for ions. O. Brüning mentioned that it is important to know how long this excess of power can be sustained. R. Van Weelderen showed that for protons and 1 h of beam lifetime, the 12 W which should be extracted can be sustained continuously, whereas for ions and for the same lifetime, the 21 W are reached after much more then 1 h For the 12 min. beam lifetime and both species, the higher power cannot be sustained by He at 1.95 K (so far estimated to 3-5 seconds) and adiabatic temperature rise of the coil is expected and has to be evaluated. This is also true for the main dipoles of the neighboring cells and ions with beam lifetimes of 1 h. As follow-up, R. Van Weelderen updated some numbers after the meeting without changing the main conclusions.

S. Redaelli asked whether the TCC could support a measurement with 1 h lifetime in order to observe how the cryo can react in the presence of a quench. O. Brüning answered that this should be first discussed with the magnet and cryo colleagues and should come with a clear observation goal (what can be measured and what can be concluded and what can still be modified for the HL-LHC). With that information at hand, the TCC can comment and eventually support the proposal at the LMC.

Status of the advancement of the M.S. optimisation and remote alignment study, P. Fessia, S. Claudet - slides

P. Fessia reported the progress made on the Full Remote Alignment (FRA) study and the Matching Section Optimisation (MSO). The main purpose of the FRA study is the identification of the best options to remotely align the LSS components. Since April, several discussions took place in particular for proposals regarding collimators, beam instrumentation, masks and crab cavities. Alignment scenarios and strategies are developed for the first and following years of operation and remote alignment is involved when possible limiting human intervention during YETS and TSs, mainly in order to recover the full 2.5 mm of remote alignment capacity.

The FRA components include motorized jacks and monitoring sensors, with platforms designed by WP15, as the standard alignment interface. The TAXS will be aligned manually with the given radiation level in that area. Girders can provide a solution for combining several components in one platform, such as vacuum valves, BPMs, etc. The choice has an impact on vacuum layout, in particular RF bridges and deformable fingers.

A summary of the discussions within different work packages (WPs) is further given. Regarding WP4, in particular the impact on cost and it has been accepted as principle by WP4. Regarding WP5, remote alignment enables the reduction of tolerances for IR collimators between TAXN and D2 and simplify their design. The possibility of including other equipment on the collimator support is being envisaged. A conceptual design with the cost impact is expected by mid-September. A preliminary discussion with WP8 found no show-stopper for the present alignment strategy with the present experimental beam vacuum, but more in depth analysis is foreseen for the 21st of August (WP8 and WP15 joint meeting) . Finally, a list of actions is being presented for WP12, in particular evaluating the impact the possible advantages for moving the IP correction from ±2.5 to ±2 mm, in collaboration with WP2.

A summary for the MSO is further given, involving the work of several WPs. A meeting to fix the choices for WP3, WP6b, WP7 and WP9 was organized.

The implications for Q5 L/R were presented by H. Prin. The idea is to rotate the beam screen without changing anything else and re-install the magnet at the present location, thereby reducing cost for a new beam screen. Q4 L/R is moved by 10 m towards the DS, the correctors act on the perpendicular plane, with one beam screen rotated. The cryo distribution needs to be adapted. For HL-LHC, the Q4 magnets will be swapped from IR5 to IR1 and from L to R, in order to minimize changes of magnets, satisfying also the requests of optics.

Q4 will be converted from a semi-stand alone to a stand-alone, implying the integration of D2 cryo lines into a second service module and jumper on the other Q4 extremity. The position of the correctors with respect to the quadrupole will be inverted without opening the existing cold masses and keeping existing QRL service modules.

S. Claudet and the cryo team provided a solution for the optimization of the QRL, as some of elements are removed and others displaced. The idea is to move Q4 and Q5 by the same amount allowing to use the same jumper and QRL components. The small modification in optics is agreed with WP2. The design of the junction module QRL-QXL is being finalised.

A list of changes is presented and its cost impact will be evaluated by the end of August. The following discussions concern WP6A in order to agree on a DSL modification strategy.

O. Brüning thanks the colleagues involved for the very attractive and appealing solution for the MSO, and asks to verify that there are no hidden costs, in view of a final decision, hopefully by the end of the year.

Decision on the operation mode to be guaranteed when the cryogenic system of the triplet is down: possible scenarios – S. Claudet - slides

S. Claudet recalls first the cryo global architecture of the LHC. A fallback solution exists using only with a distribution box to allow the use of only one cryoplant in two sectors. Operation modes with decreasing cooling capacity have been identified for HL-LHC, from ultimate luminosity to magnets warmed-up to 20 K. The question raised was what could be achieved in the various operation conditions if P1/P5 cryogenics would be down. A block diagram for P1 and 5 with the present fallback solution is presented. A study to move cryo elements to the 2nd half of CCs has been undertaken. The flow diagram of this junction module is being presented, which fits between Q1 and the CC. In case of space limits, it will be necessary to study a simplified solution. The junction module and bridge between WRL's is recommended covering all LHC operation modes. The cooling capacities and impact particularly in size and cost have to be further investigated.
O. Brüning stresses that the study is very appealing, but it is important to understand the impact on cost, integration and with respect to other equipment. An iteration has to be done also with the operation team involved in the cold check-out. S. Claudet will indeed discuss this with M. Pojer.

AOB: ECRs for the TCLD installation in IR2 and IR7 – R. Bruce – links to EDMS documents 1, 2, 3, 4, 5

R. Bruce briefly presented the ECRs on the TCLD installation in IR2 and IR7. The deadline for comments has expired a few days ago. The losses for the 11 T magnets are documented in a separate ECR. O. Brüning stressed that unless there are major comments, these ECRs should be approved, and the TCC serves as the point of last warning. Following the TCC endorsement, the equipment groups should proceed with the work planning during LS2. S. Redaelli mentioned that there are three additional ECRs (on IR7 TCSPM, the IR7 TCPPM and the crystal test stand), which are circulated and the approval progress is closed. O. Brüning suggests that the EDMS links of all these five documents are included in the minutes of the TCC, so that they are approved as well by the TCC. After the meeting, R. Bruce circulated the links and mentioned that most comments concerned minor clarifications or phrasing. In particular, L. Bottura asked to ensure coordination with LS2 team to minimize co-activity in the tunnel. G. Arduini mentioned that the impedance of each collimator should be measured, which has to be checked for compatibility with the installation schedule. M. Taborelli asked to clarify more explicitly that the formal decision on TCSPM coating is not yet taken.

AOB: Documentation of post-TDR changes – I. Bejar Alonso

I. Bejar Alonso explained that a baseline reference document will be produced instead of a full updated TDR, containing a small chapter for every WP reflecting all changes, including the equipment main components. These tables, included in MTF, will be collected by Beatriz during August, in order to have the draft document ready during September. P. Fessia remarks that there is on-going work in several fronts, as, for example in remote alignment and this may be incompatible with the timing of the document, as the design is not yet frozen. O. Brüning points out that the specifications that are frozen can be already prepared for the document. I. Bejar Alonso adds that the document should contain all approved changes up to this point. O. Brüning stresses that this document and tables is a good preparation for the project rescoping and Cost & Schedule (C&S) review, showing a snapshot of what is the baseline equipment. S. Claudet questions whether this document could wait until the end of 2018, as even at that point, it will be still on time for the C&S review. M. Martino explains that for the power convertors as well, there is on-going work and some specifications are still being revised. O. Brüning replies that it certainly makes sense to time the publication of the document such that important changes, such as the matching section optimization can be included. The document should describe the baseline to the best possible level, and some potential changes, but not all options and studies. It might therefore make sense to plan the publication for the beginning of 2019 if this allows the finalization of the matching section studies. This will be further clarified by the project leader.

The next TCC meeting will take place on the 16th of August 2018.