5th Meeting of the HL-LHC Technical Coordination Committee

Participants: C. Adorisio, A. Apollonio, B. Auchmann, V. Baglin, A. Ballarino, O. Brüning (chair), H. Burkhardt, R. Calaga, F. Cerutti, R. De Maria, B. Di Girolamo, J. Gascon, M. Giovannozzi, R. Jones, H. Mainaud Durand, T. Otto, V. Parma, M. Pojer, S. Redaelli, L. Rossi, F. Sanchez Galan, F. Savary, L. Tavian, E. Todesco, A. Tsinganis, D. Wollmann, A. Yamamoto (via video connection).

Excused: G. Arduini, L. Bottura, C. Bracco, J. Jowett, Y. Papaphilippou, M. Zerlauth.

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/TCC/Default/Home.aspx

Indico link: https://indico.cern.ch/event/476995/

O. Brüning recalled the actions from the 4th HL-TCC.

The feasibility of powering the two apertures of Q4-Q5-Q6 in series will be followed-up by WP2.

Following the request from A. Ballarino, the updated assumptions for circuit time constants have been provided by WP7 during the HL circuit review.

R. Jones confirmed that an update from BI on the plans for BLMs in the triplet will be presented in one of the next HL-TCC meetings.

A review of the beam screen/cold bore tolerances for the triplets and in general the impact on the available aperture will be presented in one of the next HL-TCC meetings, as recommended by G. Arduini.

Executive summary of HL-LHC circuit review (A. Yamamoto-slides)

A. Yamamoto presented on behalf of the review panel members the executive summary of the HL circuit review, held at CERN on 21st to 23rd March 2016.

The required modifications of numerous magnet circuits in the High Luminosity insertions (higher peak field, higher current and larger magnetic energy, relocation of power converters far from radiation areas with the use of superconducting links) make the system more complex and technically very challenging. The goal of the review was therefore to examine the baseline choices and evaluate the open proposals for changes in terms of circuit topology, protection, integration, operation, voltage withstand levels and schedule.

Concerning the 11 T dipole circuit, the baseline is to have the 11 T dipole in series with LHC MBs and using correctors or a trim power converter for the required compensation. The operational mode with trims/correctors should be further investigated, including the related failure modes. For protection, the choice of a combination of QPHT and diode (without CLIQ) is supported by the review panel.

For inner triplets, the new proposal featuring a single main power converter with 3 trim power converters is supported by the review panel. For protection the baseline is to use outer QPHT plus CLIQ for redundancy. The options of inner/inter-layer QPHT is under investigation. A recommendation from the review panel is to assemble a summary table with relevant information allowing the overview and basic protection options with their comparisons.

For D1 and D2, the baseline is to have 2 independent circuits. Given the limited cost saving and no strong reasons from the optics point of view to go to series powering, the review panel supports the baseline. For protection, redundant QPHTs provide sufficient protection, thus the use of CLIQ is not envisaged.

For correctors, the review panel supports the proposal to keep the operating current at 180A for MCQSX, while other correctors will be changed to lower operating current. It is recommended to reconsider Energy Extraction (EE) for MCBXF.

As a general strategy for circuit protection, the review panel recommended regular interaction among the involved WPs (possibly in the form of a working group) to systematically and coherently study and establish the integration and protection.

Concerning the use of CLIQ, the implementation for the inner triplets is supported, but this technology still remains to be demonstrated for Nb_3Sn magnets using their full-scale prototype programs.

Although SC links had not been included in the original scope for the review, it had be generally discussed from a viewpoint of the electrical system integration and protection. The baseline relies on MgB_2 cables connected to flexible HTS cables without LTS links. While the R&D for the cable is very well advanced, more work is still required to study the integration and protection of the SC link as part of the magnet and electrical circuit integration. Due to added complexity and technical risk, the present baseline should be well positively evaluated in comparison with other ordinary options (e.g. link with NbTi or normal conducting cables). It may be wise to search for the most dependable and resource effective solution capable of sustaining as well a controlled magnet ramp down (with a time constant in the order of 10^3 sec.) from a viewpoint to realize an ultimate reliability for such fundamental component in the general electrical integration systems.

For High-pot/Voltage Qualification, it is proposed to use a reference temperature/pressure per magnet based on a worst case voltage scenario and to derive from this reference a 'scaling factor' for test voltages in air or gaseous helium. The definition of a final strategy nevertheless requires more experience with scaling factors and safety margins.

The risk analyses should be standardized to ease the comparison of different options and systematic dependability studies should be carried out in view of using new protection mechanisms such as CLIQ and to achieve the ambitious availability goals.

The string test in two phases is strongly supported by the review panel, a clear test programme with clear objectives for each phase has to be defined. It may be advised to include an ultimate safety test such as a full power failure mode during the full system operation on surface.

The schedule appears to be very tight, the recommendation of the review panel is to develop a plan with necessary resources accounting for concurrent activities (e.g. during LS2 which partially coincides with the String test) and identify critical bottlenecks.

Taking the triplet circuit series powering as an example, O. Brüning recalled the request to release change documents in view of the US-LARP meeting. I. Bejar Alonso is following-up this activity and it is foreseen to have a systematic approval of change documents in the HL-TCC. O. Brüning underlines that there are only two more TCC meetings scheduled before the USLARP meeting (April 21st and 28th) and discussing the change documents at the TCC before the USLARP meeting implies a swift and efficient follow-up. Besides magnet circuits, other documents to be released regard the update of the collimation baseline (S. Redaelli), triplet BPMs (R. Jones, following the presentation by F. Cerutti on the expected radiation doses) and the baseline update on magnet temperatures. E. Todesco confirmed that this work is ongoing, L. Bottura will provide his feedback soon. D. Wollmann pointed out that updates on the baseline for magnet circuits should include the impact on the protection strategy.

ACTION: three ECRs are expected to be released before the US-LARP meeting in May, i.e. on the updated assumptions for magnet temperatures, on the new collimation baseline and the triplet BPM.

Expected dose rates in IT region (F. Cerutti - slides)

F. Cerutti presented a review of the impact of collision debris on the IT and MS regions for vertical and horizontal crossing, including the effect of optics variations, with a focus on IT interconnects and BPM.

F. Cerutti introduced the shielding for the Q1 and for the Q2 (and beyond). Thanks to the larger available aperture, shielding for the Q1 is thicker as compared to the other triplet magnets. For Q2 and beyond, due to the smaller aperture, shielding is limited. The assumption for the inermet filling factor outside the mid planes was 50 %, but later this was reduced to 20 % (meaning the alternation of 2 cm inermet pieces with 8 cm gaps). The weak point for protection is the interconnect, as the shielding is interrupted in this section.

F. Cerutti presented an overview of the deposited power in the triplet region for ultimate HL-LHC peak luminosity. The total load (for vertical crossing) approaches 1 kW on the cold mass and 1 kW on the beam screen. Loads in horizontal crossing are about 10% lower with respect to vertical crossing.

Concerning the peak power density, this is well below design values (i.e. 12 mW/cm^3 for Nb_3Sn coils). Nevertheless, a pronounced peak can be observed at the interface between Q2a and Q2b, due to the shielding gap in the interconnect, especially for horizontal crossing.

For the coil peak dose associated to 4000 fb^{-1} (ultimate HL-LHC), the worst case is for horizontal crossing, approaching 50 MGy. The estimates for the dose have to be re-evaluated with the 20 % filling factor introduced above, but no major change is expected. L. Rossi asked how long is the area exposed to 50 MGy. This is about 20 cm. The effect of two flat optics scenarios (150 and 210 μrad half-crossing angle) were also studied for both vertical and horizontal crossing, highlighting that the crossing angle plays an important role for the peak dose, i.e. lower dose is achieved for lower crossing angle.

O. Brüning asked if the proposal presented by S. Fartoukh at the LMC to have alternating crossing angles has been taken into account in this respect. F. Cerutti explained that there are two possible solutions to reduce the peak dose, i.e. through optics optimizations or through a hardware mitigation at the level of the interconnect. Nevertheless regular vertical crossing angle polarity inversion in IR1, as endorsed for the present LHC, is not a solution, as 50 MGy would be left in IR5 with horizontal crossing. The solution could be to allow for regular crossing plane exchange or even same crossing plane in both IRs, implying hardware options not in the baseline (crab cavities for both planes or wire compensation). This would allow going back in the range of 20-25 MGy. The worst case is in this case remains the one with round optics and larger crossing angle (30-35 MGy).

O. Brüning asked D. Wollmann if the alternate crossing angle could have an impact on machine protection. D. Wollmann and S. Redaelli explained that this should be studied, but that in principle the protection depends on the aperture bottleneck and not on its position, so no big impact is expected. S. Redaelli added that a dedicated study (WP2) should be carried out for ATS optics to explore the possibility of having 0-phase advance between dump and triplet in IP5. ACTION: WP5 and WP7 should come back to the HL-TCC with a statement on the implication of alternating crossing angles on machine protection.

After the meeting, S. Redaelli confirmed that there are no implications from alternating the crossing planes in the present baseline, as the settings and protected aperture assume worst case phases between dump and IR1/5. For the LHC in 2016 an optics (non-ATS) with zero phase advance between dump and all IR1/5 triplets has been adopted. If such solution can also be found for HL with ATS, it would still have not impact on the alternating crossing. There could be a potential impact only if one decides to rely on phase advance constraints AND if one could not have zero phases for both IR1/5. In this case, more detailed studies should be carried out to evaluate the implications of the proposed scheme.

F. Cerutti presented a proposal for shielding improvement, consisting of a 7 cm extensions of the tungsten absorber between Q2a and Q2b. This would bring a 15-20 % reduction of the peak dose (40 MGy for ultimate luminosity). For the BPM, the tungsten absorber would need to be displaced by 5 mm, thus producing no significant effect. To be effective, the radial position of the shielding should be as in the rest of the magnet. The degradation of the shielding due to radiation effects was also studied and no significant alteration of relevant material properties is expected.

An overview of the annual dose in the tunnel area was shown, assuming a yearly luminosity production of 300 fb^{-1}. The operability of exposed equipment (e.g. BLM electronics and cables) in such environment should be evaluated. ACTION: L. Rossi recommended addressing the impact of this significant increase of dose in the IT region on the concerned equipment. T. Otto confirmed the follow-up of this point for safety systems and L. Tavian concerning technical infrastructures. V. Baglin will also verify the operability of vacuum equipment used in the area.

F. Cerutti presented similar studies for the matching sections, assuming all collimators (TCLs.B1 and TCTs.B2), Q5 and Q6 masks and TAXN in place. Besides the protection of the triplet and experiments from incoming beam losses, tertiary collimators (TCT) also provide shielding from collision debris. The deposited power shows larger leakage from TAXN for horizontal crossing (50 W on D2). The possible removal of TCT4 has to be evaluated with respect to the internal bore exposure to TAXN leakage. Considering the peak power density, the front face of the first Q4 corrector magnet is the most impacted assuming a 90 mm aperture. Being a NbTi magnet, quench limits are more strict (by a factor 3) with respect to the IT. A 105 mm Q4 corrector aperture, in addition to providing an important reduction of the peak power density, allows to shield the Q4 (that has an aperture of 90mm) if the aperture gap in the correctors is filled by a 7mm (~(105-90)/2) thick dense layer (e.g., copper, stainless steel or tungsten). E. Todesco confirmed that 105 mm is the reference corrector aperture to be considered (baseline).

F. Cerutti finally presented an overview of the annual dose in the tunnel for the matching section.

L. Tavian asked if a degradation of the BPM could be expected. F. Cerutti commented that the power load has been provided to BI, the impact of this has then to be evaluated.

E. Todesco commented that concerning radiation doses the assumption was to tolerate 25 MGy for nominal HL-LHC, adding 30 % for ultimate (about 33 MGy). He recommended keeping 33 MGy as a reference number for ultimate HL-LHC. The TCC confirmed this proposal to keep the maximum dose of about 33MGy for the magnet design.

S. Redaelli asked if the option of alternating crossing angles between IP1 and 5 is compatible with crab cavities. R. Calaga explained that this is not the case in the baseline configuration, so this option requires more studies and follow-up.

AOB

F. Savary presented a draft of the ECR for 11 T collimators. L. Rossi suggested removing the paragraph related to the RRP cable and adding that despite not having detailed cost estimates in the ECR, a saving is expected.

O. Brüning announced that the next HL-TCC meetings will be held on 21st and 28th April.

S. Redaelli pointed out that the agenda of the US-LARP meeting should still be discussed.