78th Meeting of the HL-LHC Technical Coordination Committee – 04/07/2019

Participants: A. Apollonio, V. Baglin, M. Bajko, R. Bruce, H. Burkhardt, F. Carra, F. Cerutti, B. Delille, A. Devred, H. Garcia Gavela, R. Jones, T. Koetnig, M. Lamont, M. Martino, P. Martinez Urios, M. Mendes, A. Milanese, M. Modena, B. Panev, S. Redaelli, L. Rossi, M. Sabate Gilarte, D. Schoerling, L. Tavian, E. Todesco, R. Tomas Garcia, R. Van Weelderen, M. Zerlauth (chair).

Excused: G. Arduini, O. Brüning.

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

M. Zerlauth recalled the actions from the 77th HL-LHC TCC.

The first regards a request for an update in the TCC following the completion of the TANB installation. The second action is a request for a presentation on the details of the chosen solution for the Q1 k-modulation circuit (which is planned for August following the return of F. Rodriguez). The last action regards a clarification on the potential impact of the polarity inversion on the IT STRING configuration which will be reported upon by M. Bajko during her WP16 update end of July.

The minutes were approved without any further modifications.

M. Zerlauth announced the upcoming HL circuit review, which will be held at CERN on 9-10th September and will be chaired by A. Yamamoto. The finalisation of the detailed programme is ongoing.

Outcome of 11 T inspection and revised project plan – F. Savary - slides

F. Savary provided a summary of the observations on the 11 T hybrid magnet disassembly and post mortem analysis and then an update of the project plan.

F. Savary showed the corrected schematic of the 11 T hybrid assembly in slide 3, which was tested in February and March 2019.

The disassembly procedure consisted of several steps, which are defined in detail in a quality control plan. The first step was the inspection of the cold mass assembly. Following the cutting of the shrinking cylinder, cracks were noticed on the anti-torsion bars, which was never observed before. These are attributed to the sudden shear off and rupture of the shrinking cylinder at the root side at the end of the cutting.

The next step was the inspection of the collared coil assembly. The conclusions from the measurements are reported in Slide 21. The deformations measured on the collared coil assembly (negative in horizontal, and positive in vertical directions) are interpreted as plastic deformation of the assembly. The increased outer radius (coherent with the collar deformation) and mid-plane excess are interpreted as plastic deformation of the coil. The mid-plane excess is calculated with the outer radius of the coil and the surface of the loading plate taken as datum surfaces for the analysis process of the metrology data, and therefore deviates due to varying arc curvature. The observed deviations in coil geometry are small in comparison with the tooling error of ±41 μm.

The visual coil inspection revealed superficial delamination and cracks, which seem to be a general feature of CTD-101K impregnated coils. Interfaces are crack initiation features, possibly due to shear and differential thermal contraction, higher probability of voids, or the presence of poorly wetted regions. There is however no evidence of superficial delamination or crack propagation influencing the performance of the magnet. The behavior of SP107 during the next test campaign, will be informative, as severe cracking and delamination were observed through the analysis of the inner radius surfaces.

A Paschen test was carried out to understand how quench heater to coil insulation can affect breakdown voltage, in particular in presence of partial air. The tests for CR-02 (breakdown at 575 V) and GE-02 (breakdown at 680 V) confirmed the presence of air.

Finite element thermo-mechanical models were developed to investigate the impact on coil stress of large temperature variations during the magnet cool down and warm up. The models were able to reproduce the relative increase of the measured strain in the collar nose.

Based on the findings of the post-mortem analysis, a new warm up and cool down procedure was defined and implemented to avoid large temperature gradients.

F. Savary presented the updated scenarios for tunnel installations. With present assumptions, a delay of 8 weeks can be achieved in case of a first installation in S78 (preferred option), while a delay of 14 weeks would occur in case of installing the first assembly in S67. In addition, it was estimated that 41 weeks would be required for installation after LS2, i.e. during a potential EYETS. L. Rossi expressed his surprise for this long installation time and asked why the installation of the 11 T assembly would take so much longer than that of a normal dipole (as done during the last EYETS for magnet A31L2). F. Savary explained that it is related to the higher system complexity, but that this was a first estimate and a more detailed analysis can be carried out.

ACTION: F. Savary should report in the TCC the outcome of a more detailed analysis/breakdown of the actual required time to install the 11 T assemblies after LS2.

E. Todesco asked if the cutting of the shrinking cylinder without any load, implying a sudden spring back, is not expected to have an effect on the collared coils. F. Savary explained that in this case the coils were already known to be lost for this magnet, so this aspect was not deemed to be critical.

AOB: 11 T – Impact of flux jumps on WP2, WP6 and WP7 – D. Schoerling – link

D. Schoerling summarized the comments received on the ECR, which were all implemented. In particular concerning the impact of flux jumps, this was studied in detail by concerned workpackages and the impact is expected to be negligible for the 11T magnet.

For the ECR presentation at the LMC, L. Rossi suggested to schedule it in the first week of August, to allow some time after the foreseen 11 T magnet tests in SM18.

CuCd based tertiary collimators – S. Redaelli – link

S. Redaelli recalled the recent collimation review, during which the review panel pointed out that the possible use of CuCd collimators should be justified, given the small likelihood of the assumed worst case failure scenario (full single bunch impact on the collimator).

S. Redaelli reminded the TCC the advantages of CuCd, which combines high Z and robustness, making it a suitable candidate for replacing the present tertiary collimators (Inermet180).

Concerns for the integrity of tertiary collimators were already present in Run 1, limiting the beta* reach of the LHC. To address this a request for consolidation of 4 horizontal tertiary collimators was already submitted and is pending approval by the CONS project.

Technical development of CuCd is well advanced, with several tests already performed at HiRadMat, BNL and Kurchatov. Performance studies for HL-LHC confirmed that CuCd is a suitable material for tertiary collimators. The qualification of companies was launched and also a price inquiry for a reliable assessment of the cost of production (order of magnitude for the complete HL needs is 350 kCHF).

S. Redaelli provided more details on the comparison of tungsten and CuCd materials. The onset of plastic deformation is better by a factor 14 in CuCd. Tungsten maximises absorption but has a low damage limit against beam impacts and the collateral damage from fragment ejection is important. The impact on LHC β* performance was mitigated since 2016 with zero-phase optics (TCT-MKD), which worked well so far, considering however that we did not experience yet an asynchronous dump in operations with a full machine (expected to have ~ 1 / year). Single-bunch losses (or equivalent intensity) are unlikely but cannot be fully excluded from the failure scenario, as the machine is in practice not operated at Zero phase advance but close to the allowed limit of 30 deg. M. Zerlauth commented that for standard physics the situation is very well under control, but for special optics this is not an impossible failure case.

R. Tomas pointed out that the installation of CuCd could also allow faster commissioning given the better protection and increased margins.

Following a prior request from O. Brüning, it was investigated whether tightening more the collimation hierarchy could lead to an improvement of performance for HL-LHC. The conclusion is that for round optics there's no big improvement, as everything is already very optimised. For flat optics the gain would be 1 sigma, but overall no big luminosity increase is expected because in the HL levelled scenario, the dependence on β * is limited.

The use of CuCd collimators would also gain optics flexibility (by removing an additional constraint) with respect to a number of other points, e.g. also relaxing constraints on the IP6 optics to determine the beam size at the dump. This aspect could not yet be studied in detail.

R. Jones asked if the lower absorption for CuCd would not create issues for experiments background. S. Redaelli and R. Bruce explained that the background for the experiments was studied and is deemed acceptable (less than 1% effect compared to the luminosity related background), which was also confirmed by H. Burkhardt. With respect to radiation to electronics, F. Cerutti confirmed that the additional dose is very small because these collimators are not part of the physics debris absorption system. S. Redaelli clarified that the TCT intercept betatron halo at very low levels during the long physics runs.

M. Lamont commented that the baseline margin adopted today already ensures protection, so there should be a strong case for justifying additional expenses. S. Redaelli agreed that, in light of the performance of Run 2, there is not a strong case to build from scratch 4 new collimators, unless in Run 3 one wants to push significantly the performance or explore new optics scenarios. He also pointed out that we must nevertheless ensure that the all Run 3 optics will respect strictly the required phase constraints, if collimators are not change. He also commented that for HL, we need to build anyway new collimators so the incremental cost change is small (level of % of the IR collimator upgrade). S. Redaelli believes that, ideally, one could find synergies between CONS and HL and build some CuCD TCTs to be used in Run 3 and re-used in HL.

M. Zerlauth recalled that a further discussion will take place in the next PSM in September when the results from the price enquiry are known, technically CuCd clearly represents an improvement of protection and the available operational margins and is preferred to tungsten if financially compatible with the project's cost to completion.

AOB: ECR WP5 change of number of low-impedance secondary collimators for HL-LHC – S. Redaelli – link

S. Redaelli reported the status of the ECR for the change of number of low-impedance collimators for HL-LHC. The number will be reduced to 18 new low-impedance collimators (from 22), i.e. two less per beam (which implies keeping 4 more old collimators in IR7). WP2 is confident that this is acceptable for HL-LHC performance, also thanks to the improvement of TCP impedance.

The resulting savings allow to save money for the material procurement for the 12 collimators planned for LS3..

No major comments were received on the ECR to date.

L. Rossi stressed that these collimators were mentioned by F. Gianotti in her mid-year talk as one of the early HL project contributions for LHC that is happening in LS2. HL is anticipating works worth 80 MCHF in LS2, which is an important step towards HL-LHC and is improving the LHC Run 3 performance.

IT orbit corrector preferable orientation and TAXN aperture – M. Sabate Gilarte – link

M. Sabate Gilarte summarized the studies for the exposure of the coils for vertical and horizontal crossing for the IT orbit correctors.

The orientation of the nested orbit correctors affects the maximum dose their coils are exposed to. The recommended configuration is with the inner layer generating a vertical field, i.e. horizontal correction. This way, in the vertical crossing insertion the highest dose is only present in the return coils. This recommendation should be validated by WP3.

M. Sabate Gilarte summarized the considerations regarding the TAXN aperture, taking into account the latest layout changes.

The reduction of the twin aperture moves 70 W from the TCLX4 jaws to the TAXN. The effect on the D2 is minor, i.e. a reduction of 10% in the maximum dose at the IP-side and a decrease of 10% in the total power (20 W at nominal for HL-LHC). No effect is seen on Q4 and its MCBYs: the peak dose in the coils remains above 2 MGy. Therefore, the rotation of the Q4-cryostat could help only to a rather limited extent. Internal shielding is needed to change the picture, if needed, with respect to the MCBY radiation resistance.

M. Sabate Gilarte mentioned the additional ongoing studies for energy deposition in specific equipment (R2E and R2M).

F. Cerutti concluded that for the TAXN the increase in beam separation is beneficial, i.e. the TAXN takes more load and protects better the downstream elements. The reduction of the aperture brings no real benefit for magnet protection, so the aperture can be frozen to 85 mm.

DECISION: the TAXN aperture is confirmed and fixed to 85 mm.

ACTION: E. Todesco should give a statement on the requirement for shielding requirements of the Q4 MCBYs (as a function of their radiation tolerance).

New generation of energy extraction switches for HL-LHC – B. Panev – link

B. Panev reminded the TCC about the needs for Energy Extraction (EE) systems for HL-LHC. In total 28 EE systems are required, of two types (2 kA for MCBXFA and 600 A for MQSXF and MCBRD).

Two technology options were evaluated by the MPE group, i.e. semiconductor-based (IGBT) EE systems and vacuum switches-based EE systems. The selection criteria are based on opening time, maintainability, lifetime, reliability, complexity and cost.

The main points in favor of the vacuum switch technology are that IGBTs require water cooling due to the important constant power losses (while natural convection is sufficient for vacuum switches), and they show a nonlinear behavior at the zero-crossing and have higher cost (20%).

Based on this, it was decided to adopt vacuum switch-based EE systems for the HL tunnel installations, and to keep IGBT-based EE systems for the test stations. The installation of 4 vacuum switches based EE systems for 600A is already planned during LS2, with the plan to gradually replace the present EE systems by vacuum switches-based EE systems.

M. Martino asked what is the price for a unit. B. Panev explained that for the prototype units it is in the order of 40-50 kCHF, but it should be possible make further savings for the series production, also considering the possible replacement of present LHC switches.

M. Zerlauth asked if the controls part will be compatible in case of replacement of the current system with vacuum switches-based EE systems. B. Panev explained that maybe a new firmware will be required, but the same hardware can be re-used.