64th Meeting of the HL-LHC Technical Coordination Committee – 19/12/2018

Participants: A. Apollonio, A. Ballarino, M. Bajko, O. Brüning (chair), J.P. Burnet, S. Claudet, B. Delille, D. Delikaris, P. Fessia, J. Fleiter, M. Freitas Mendes, S. Gilardoni, N. Grada, Y. Leclercq, M. Martino, M. Modena, T. Otto, A. Perin, D. Perini, M. Pojer, G. Riddone, F. Rodriguez Mateos, L. Rossi, J. Steckert, L. Tavian, D. Wollmann, M. Zerlauth.

Excused: Y. Papaphilippou.

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

O. Brüning recalled the main conclusions from the 63rd meeting of the HL-LHC TCC.

The recent powering tests confirmed that the Q5.L6 magnet can be operated at 4.5 K for 7 TeV considering the required gradients for HL-LHC optics. For ultimate energy, the required currents could not yet be demonstrated during the powering tests in 2018 and operation at 1.9 K might have to be envisaged to reach the required gradient. L. Rossi stated that the decision of the project is to change the baseline planning and to keep 4.5 K as the operating temperature HL-LHC baseline. The 1.9 K variant could eventually be implemented as an HL-LHC consolidation if required in the future.

Action: WP3 and WP9 to issue an ECR describing the baseline change for the Q5.L6 and Q5.R6 operating temperature.

An action was defined for WP5 and EN-STI for a decision on the plans for a possible inspection of the prototype low-impedance collimator currently installed in the LHC. S. Gilardoni commented that discussions on this subject are ongoing, they will report to the TCC in January 2019 with the final decision.

O. Brüning and L. Rossi clarified the scope of the request for a new HL-LHC TDR. After the project re-baselining a new reference document summarizing all changes and updates is needed. The TDR should be short and concise, the new HL-LHC book will follow as much as possible the layout of the TDR and should serve as an extended version for a more detailed explanation of the technical choices. L. Rossi added that having a correct and up-to-date description of the project also serves as a justification for contributions. The deadline is the end of February for the TDR, with the scope of having a finalised version by the next HL-LHC annual meeting. P. Fessia underlined that following the request for a position change of the crab cavities the new version of the layout will most likely not be available by then. M. Martino asked if changes which are still pending approval through ECRs can also be included in the TDR. L. Rossi confirmed that this should be the case. Concerning the comment by P. Fessia, L. Rossi and O. Brüning state that the new TDR and book should document our understanding of

the current baseline to the best possible level, but acknowledges that further modification and changes will certainly still come in the future even after the TDR publication.

L. Rossi announced that the DOE review for the US contributions for magnets and crab cavities was rather successful last week. The review recommended the approval of CD2 and CD3b with the full budget: the approved proposed schedule planning for the US contributions see a small shift of the delivery of the first four IT Quads, with a possible impact on IT String activities (to be followed).

Recent progress on WP6a activities, including Demo 1 and tunnel integration aspects – A. Ballarino - slides

A. Ballarino reported on the recent progress and structure of WP6a activities. Three topical working meetings were organized and coordinated on a weekly basis as from November to follow-up on DFX design, DFM+DFHX+DFHM designs and related integration in the LHC underground areas.

The DFX is the item with the most advanced conceptual design, a conceptual design review is foreseen for the end of January 2019. Based on the feedback received, a detailed design review will follow in March 2019.

For the DFH and DFM the conceptual design is being finalized and a conceptual design review is foreseen for the end February/March 2019. Different concepts of cryostats are still being discussed.

A. Ballarino presented the new layout featuring two modules of DFHXs, one (DFHX_1) for 18 kA current leads and the second (DFHX_2) for 2 kA current leads. This solution would simplify the routing of the electrical connections and of the corresponding bus. In addition, the length of the flexible HTS sections has been limited to not more than 4 m – to cope with the required flexibility and at the same time to limit cost. For minimizing the cost, a standardization of current leads (identical leads for each current rating) has also been proposed. For integration in the tunnel, accessibility of leads and power converters has been considered, as well as fitting the equipment in the allocated space in the tunnel. A. Ballarino mentioned that the location of 2 kA trim current leads will be reviewed with WP6b to exclude potential problems of e.m. interferences with 18 kA room temperature power cables. L. Rossi asked to verify if the present MQXF circuit excludes the possibility of having more than 18 kA circulating in the MQXF magnets – in view of the use of the trims. After the meeting G. Arduini confirmed that the current setting requirements will be limited to 18kA with the only uncertainty depending on the final transfer function.

A. Ballarino mentioned the ongoing activities concerning integration also of WP6a ancillary equipment (QDS, thermos-switches, transformer, cyo-equipment, etc.). A functional specification document is being written by WP6a. According to P. Fessia, a re-arrangement of the present integration will likely be needed once the final amount and volume of equipment has been established.

Two large industrial contracts for series production were approved at the Finance Committee meeting of December, i.e. procurement of MgB_2 wire and for cabling.

A. Ballarino recalled the scope and achievements of DEMO1, the demonstrator for cold powering of the triplets. DEMO1 allowed for the qualification of the first industrially assembled MgB2 cables and gaining experience with integration of long cables in the SC link cryostats as well as operation of a cold powering system. High current MgB2 to Nb-Ti and Nb-Ti to Nb-Ti splices were for the first time performed in-situ for the DEMO1 configuration and operated in nominal conditions. Several tests and validations were carried out in DEMO1, no degradation of critical current for MgB_2 cables was observed. Quantification of the thermal contraction was also carried out. The adopted bending radius of tested cables is representative for tunnel conditions, the strain on the cable was limited to acceptable values. The performance in terms of static load for the cryostat was confirmed and amounts to 1.5 W/m. Measurements of splice resistance were performed, highlighting for both MgB_2-to-NbTi and MgB_2-to-MgB_2 low (1-2 nOhm range) and very stable resistance values (both in liquid helium and helium gas environment).

A. Ballarino described the next steps for the testing, including system qualification, qualification of HTS current leads and measurements of the full cable assembly.

L. Rossi acknowledged the great technical achievements. He also recommended addressing the integration aspects as soon as possible, as these have a significant impact also on other WPs.

Status of DFX design – A. Ballarino – slides

A. Ballarino reported on the work carried out on the DFX, developed in the framework of the UK HL-LHC collaboration. A. Ballarino presented the design evolution, leading to the definition of a vertical layout. The SC link will incorporate an ad-hoc protected termination including the MgB2 to NbTi splices (done in the laboratory and not in the tunnel) and the transition to NbTi, requiring only the NbTi part to be bent in the tunnel (see slide 4).

A. Ballarino presented the integration drawings for the current design, underlining that despite the complex integration due to the crowded area in the tunnel, the design is made in order to allow cutting and welding even in the limited available space. Work is ongoing to document procedures for assembly of the DFX in the tunnel.

A. Ballarino pointed out that the location and interface of the λ-plate should still be defined.

L. Rossi asked if any showstoppers for integration were encountered with the present design. P. Fessia commented that there should be no showstoppers, but that integration in this area will be very complex. In particular special supports (not yet designed) should be designed in order to take into account the need of the full remote alignment and to allow access to the beam pipe in case of need. He also pointed out that lots of intermediary tests (vacuum, cryogenics, electrical) should be carried out prior to tunnel integration to avoid problems.

L. Tavian pointed out that in the present configuration it would be the first time for having a splice in vertical position, leading to a new situation for a possible on-site intervention in case of issues. A. Ballarino explained that those splices will be done in the laboratory in a horizontal configuration. The design is such that the splice should be accessible to make interventions in the tunnel possible. J. Fleiter added that vertical splices will be electrically tested in SM18, with the aim to reduce the risk in the tunnel. M. Bajko recalled that vertical splices were successfully tested in SM18 several times.

As a summary of the discussion, the following list of items are being followed up within the WP6a activity – and before the DFX conceptual review:

- Support structure to be designed and matched to integration needs
- Validation of the connector box (instrumentation ?) interference with the tunnel cores and ability to work on interventions during maintenance
- Burst disc design and safety aspects of the He release
- Validation of vertical splice and procedure definition for interventions
- Detailed step description for the assembly procedure in the tunnel (this work is being reported in a functional specification document).

Status of DFM and DFH design – Y. Leclercq – slides

Y. Leclercq reported on the status of the design for DFM and DFH modules, summarized in Slide 3 of the presentation. Functional and interface specifications are available for all modules, with a conceptual design proposal already available for DFX, DFHx, DFHm and DFM. Iterations with system interfaces are ongoing for all modules. Conceptual design reviews, followed by detailed design reviews are foreseen in 2019. Procurement and manufacturing will start in 2019 for DFX and DFHx, with delivery of pre-series units scheduled for Q1 2020. For the STRING tests it is foreseen to use a prototype which will be available in early 2020. The DFM will not be used in the STRING, so the uncertainty on its delivery will not have an impact on the STRING. M. Bajko pointed out that the installation of warm cables for 13 kA and 18 kA (to be procured for 2020) is on the critical path for individual tests of the pre-series modules. A response from EN-EL on this point is still pending.

ACTION: clarify with EN-EL the availability of cables for tests of pre-series modules in SM18.

Y. Leclercq went through the details of the conceptual proposals for the different modules.

On the DFHx conceptual design proposal, Y. Leclercq mentioned that the length of a DFHx module 1 will be about 4 m. L. Rossi asked if module 2 could be shorter. Y. Leclercq confirmed this is the case, but it should still be quantified with the consequent impact on integration. L. Tavian asked if the bending is not a problem for DFH (as for the DFX). A. Ballarino mentioned that the length of the modules is still being optimized – concepts are under discussion: One difference is that for DFX the complete cable needs to be bent, while in the DFHx one need to bend individual circuit (sub)cables. A similar approach will be followed for the DFM. The location of the DFM will be above the D2 magnet, but how to support this solution in the tunnel still needs to be addressed. L. Rossi commented that the possible shift of the crab

cavities could open the door for an optimization of the DFM position as well.

P. Fessia asked if it is foreseen that the SC link will also have to be 'waved' on the tunnel size. A. Ballarino confirmed this is the case. P. Fessia commented that a solution should be found for this as soon as possible, as this was never discussed and the integration footprint in the tunnel will be difficult to accommodate for.

ACTION: WP15 and WP6a should discuss a possible implementation of the SC link 'waving' in the tunnel.

Circuit Disconnector Boxes – M. Martino – slides

M. Martino reported on the latest updates concerning the circuit disconnector boxes.

As in the present layout proposal, the SC link (actual the HTS cable on the warm end) does reach the exact location of the power converters and water cooled cables for the 18 kA and 2kA circuits are likely to be needed. For circuits up to 2 kA, two circuit disconnectors are now proposed. The configuration with some IT circuits/terminals connected to DFHx1 and some connected to DFHx2 should be avoided for e.m.c. reasons.

A. Ballarino explained that the current version aims at standardizing the design of the components. P. Fessia pointed out that the needs for cooling water in case also water-cooled cables will be employed should be evaluated, as the assumption was that the cooling water would only be used for the bars of the disconnector boxes. M. Martino commented that the overall resistance in the circuit will not change so no impact on cooling requirements should be expected.

L. Rossi pointed out that the original solution based on only one DFH module is still valid and should be re-considered given the complications of the new designs. A. Ballarino proposed to re-discuss the topic in a technical meeting, where all pro- and cons can be presented. Routing of room temperature bus (flexible connections) from disconnector boxes to current leads shall be included in integration studies – to understand implications.

F. Rodriguez Mateos proposed to treat this topic in the Magnet Circuit Forum with a detailed technical discussion and then report back to the TCC in the end of January 2019.

ACTION: F. Rodriguez Mateos should give a report on the technical discussions concerning disconnector boxes and DFH in the TCC at the end of January 2019.