55th Meeting of the HL-LHC Technical Coordination Committee – 16/08/2018

Participants: G. Arduini, V. Baglin, R. Bruce, O. Brüning (chair), S. Claudet, G. D'Angelo, R. De Maria (scientific secretary), B. Delille, P. Fessia, H. Garcia Gavela, R. Garcia Alia, C. Gaignant, Y. Leclercq, P. Martinez Urios, M. Martino, R. Martins, E. Métral, T. Otto, V. Parma, D. Ramos, F. Sanchez Galan, L. Tavian, E. Todesco, D. Wollmann, M.Zerlauth
Excused: L. Rossi.

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.

The following actions have been discussed.

Concerning the 11T discussions, O. Brüning concluded from the last TCC meeting that the project sees at this moment in time no need for additional hardware modifications, neither for the 11T magnet and cryostat, nor for the cryogenic infrastructure. However, in order to address the potential performance limitations in the machine with short lifetimes, both for proton and ion operation, the TCC would like to have a clarification from the magnet group on the available quench margins, both in terms of temperature margin and acceptable heat deposition for both the new 11T and the existing LHC dipole magnets. This information is required for judging if the new 11T system might imply performance limitations with respect to the current LHC configuration. Furthermore. O. Brüning recalls the action for the vacuum group to confirm the expected beam losses due to beam-gas interactions. G. Arduini underlined that this aspect should be addressed both for the proton and the ion beam operation.
O. Brüning informed the TCC that the LMC requested a presentation on the 11 T dipole developments and the potential operational implications of their installation during LS2 for Run III, including potential beam current limitations from quench margins or temperature margins, implications from the trim circuits for operation and protection. Cryogenics aspects may be added if relevant for Run III operations. O. Brüning would like to finalize the discussion on the outstanding questions in a future TCC before scheduling the 11T presentation(s) at the LMC. Planning for an LMC presentation in October, the TCC should receive feedback on the open issues by the end of September.
ACTION: LMC presentation on the 11T magnet development and the implication of the 11 T magnet installation on the LHC operation for Run III in October 2018 (F. Savary, L. Bottura, E. Todesco, S. Claudet, V. Baglin).

The matching section optimization exercise, presented by P. Fessia in the last meeting, is ongoing and very likely has implications on all work packages. All WPs should therefore be aware of the developments. **ACTION: All WPs not yet involved should assess the possible impact on their WP.**

S. Claudet mentioned that he organized a meeting with M. Pojer for the aspects related to the different cryogenic operation modes in the HL-LHC during hardware commissioning.

Radiation hardness of cold-diodes – First report of CHARM test – Giorgio D'Angelo- slides

G. D'Angelo presented a summary of the history of the LHC cold diodes and the specifications for new cold diodes potentially to be used for the HL-LHC triplets and D1 magnets. The specifications assumed the nominal integrated luminosity target of 3000 fb^{-1}.
The main strategy was to re-establish contacts with the Dynex firm, which provided diodes for the LHC dipoles and compare a new production batch, as well as more radiation tolerant prototypes with past data from LHC samples by performing experiments under cryogenic conditions in a controlled radiation environment. A test bench has been setup in the CHARM facility and was used to characterize the main parameters of the diodes as a function of integrate dose and fluence: turn-on voltage, reverse voltage, capacitance and current stack.
The experiments are still ongoing and, besides some small issues, a total irradiation dose of 12kGy is expected to be reached by the end of this year's run. All the tests show that the new prototypes have a better performance and suffer lower degradation during irradiation as the original LHC samples. The main degradation mode is due to the neutron fluence. Hints of positive annealing effects can be already seen when the samples were warmed up for a short time during the necessary stops. The measurements will continue to be monitored on a weekly basis and an assessment of the compatibility of the new prototype with the required specifications for the HL-LHC is expected to be possible at the end of this year's campaign.

In parallel, studies on the diode integration are ongoing. In particular, new simulations of the neutron fluence and radiation showers using the proposed location from a very first integration study show that the radiation dose increases when moving the diode location away from the IP and that the neutron fluence increases when moving the diode towards the IP. The distance of the cold diode from the IP is a very sensitive parameter since small variation towards the IP strongly increases the neutron fluence and conversely a variation towards the arc increases radiation showers. The best compromise seems to be an installation of the diode between the DFX and the D1 magnet, which is also compatible with the initially defined target radiation levels.

Discussion:

O. Brüning asked why the diodes cannot be further shielded. The initial installation proposal foresees a rather exposed location that should be well suited for additional shielding. R. Garcia replied that additional shielding could reduce e.m. showers, but at the price of inducing secondary neutrons and thus increasing the neutron fluence, which is currently seen as the dominating degradation source.
O. Brüning asked whether the diodes could be exchanged during a long shutdown in case their degradation would be too severe. While this seems to be possible with a warmup of the magnets, E. Todesco added that a warm up of the triplets should be avoided if not necessary. S. Claudet confirmed that the triplets could be kept cold while the arc is warmed up. F. Mateos and D. Wollman replied that the most promising healing strategy is the effect of the annealing which is already visible at room temperature and could be further enhanced with higher temperatures. F. Mateos added that the measured electric parameters of the diodes still show very large margins wrt to the values considered critical for operation. D. Wollman concluded that the main goal of the exercise was to re-establish

the measurements done for the initial LHC diodes as well as to prove that the new prototypes had a better performance than the LHC ones, which seems to be the case based on the preliminary measurement results. M.Zerlauth added that – even if the initial target value of 30 kGy cannot be achieved – the current measurements allow to be confident that the known radiation damage effects of the diodes will scale to radiation doses which are a factor of 2-3 times higher. Additional effects may however appear if installed in locations of much higher doses, which will also become very difficult to test for. For these reasons an optimisation of the installation location is absolutely necessary.

S. Claudet pointed out that the diodes are presently hosted in a protrusion of the cryostat which, besides being more exposed to radiation, might degrade the heat conduction in spite of the superfluid helium. From the cooling point of view, integrating the diodes in the main cryostat would be preferable. P. Fessia reminded the TCC that the present location is the result of the efforts trying to comply with several boundary conditions coming from the needs of survey diagnostic, cold powering and other services.

O. Brüning concludes the discussions by observing that the preliminary results are very encouraging and that it would be desirable to come back the TCC with an update once the measurement campaign in the CHARM facility has been terminated.

Update on the cryo for the CCs in the SPS, S. Claudet - slides

S. Claudet presented a short update on the operations of the New Cryogenic Facility for Superconducting RF Tests with Beam in BA6 of the SPS. While initially motivated as a test facility for crab cavities, the facility has the potential to offer a permanent testing facility for any future superconducting test with beam in the SPS. The operation that started in April can be divided into three distinct phases: the first offering 4 weeks without issues allowing RF conditioning and tests at 4.5K, a second phase dealing with issues related to the summer heat wave and water leaks, and the last one which is expected to complete in a week's time, allowing the RF team to start crab cavity tests at 2 K. Control logic needs to be further developed and tested.

The facility is now transitioning towards an operational mode in which the cryogenic operators are being trained to operate the facility and the project team, currently contributing to the operation, will only be available for future operation as a backup.

Continuous 2 K operation could possibly start from August 22 (to be confirmed).

Design of triplet cryostat to optimise vibration effects – Delio Duarte Ramos - slides

D. Ramos presented the design principles of the cryostat to be used by the HL-LHC triplets, CP, D1 and D2. Each single cryostat has to be thought of as part of a complete combined system from Q1 to D1 to evaluate the performance in terms of mechanical stability and oscillations. He reminded that the final cold mass will weigh approximately 2 tons per m.
Besides all constraints, the design incorporated the wish of implementing an isostatic support to simplify the alignment procedures and reproducibility. The resulting alignment stability is comparable to that of the LHC SSS and LHC dipoles.

The parameters compromising alignment stability are the installation offsets, quasi static forces, pressure effects during test and thermal cycles. The sources of vibrations can be environment noise (ground motion) as currently studied and, in addition, the impact of helium flow, for which studies are not yet as advanced. The latter is assumed to only affect the beam screens, as the He in the main dipole magnets will be superfluid, and thus, will show no turbulences. For these studies it is assumed that the magnet cold-mass and the beam screen can be considered as independent oscillators. The natural frequencies depend mainly on the mass, the stiffness of the cold supports, and, only to second order, on the jacks for the main magnet cold mass. The cryostat design led to a solution with conical support feet which give an increase of 150% in transverse stiffness, compared to the LHC dipole and SSS. In addition, the interconnect choice of using multiple bellows added increased robustness and allows the decoupling between vibration sources.
A comparison of the oscillation modes measured from LHC dipole and computed for the HL-LHC triplet shows substantial agreement in the mode shapes, with most natural frequencies increasing by a factor 2.

Discussion:

S. Claudet observed that thermal conduction is not to a big issue for the triplet magnets where the dominant contribution to the headload comes from particle debris. One could therefore consider variants with thicker support feet [and higher thermal conductivity] if this could help to reduce vibrations. D. Ramos replied thicker support feet have only a weak effect and that additional support feet could offer a more efficient solution in this case. However, this implies significant additional complexity and cost, and one should therefore clearly establish if this is actually needed.

G. Arduini asked if estimates on the amplification factors could be given, since they are the most relevant quantity to estimate the impact of environmental noise on the beam. D. Ramos replied that those have not been studied yet due to manpower limitations and underlines that it is difficult to judge the results if one is relying only on simulations without calibrations with measurements. He proposed to measure and simulate LHC dipoles to gain confidence on simulation results and to extrapolate them to the HL-LHC triplets. No comparison with the LHC triplet could be made because they feature a very different design for the cold mass support system and their mechanical support structure is difficult to characterize. In addition, the first HL-LHC prototype could be ready by early 2020 for direct tests, e.g. as part of the IT String test program. E. Todesco observed that in principle this could be anticipated with additional resources and by using a dummy cold mass.

O. Brüning asked about the state of studies of beam-screen vibrations induced by the helium flow and mentions that such studies have in the past already been performed on the LHC beam screen. R. De Maria replied that a first discussion was launched within WP2 and that R. De Maria contacted C. Garion to ask for estimates of the possible noise spectra up to 10 kHz. G. Arduini reminded the TCC that the new beam screens are much heavier than those in the LHC and are supported with springs. S. Claudet observed that estimates on the power

spectrum of the helium flow could be given and states that a cold beam-screen test facility for vibration measurements could be relatively quickly setup to perform measurements.

A discussion followed on the number of beam screens to be installed in the IT string test facility. Consensus was established that at least one magnet should be equipped with a full beam screen, if not two, not only to study vibrations, which is already a strong argument, but also to test assembly procedures as remarked by R. Jones.

O. Brüning asked if and what could be changed in the design if future studies identify issues. D. Ramos stated that it is very complicated to introduce design changes at this stage and it will cost certainly time and money to implement changes, if a measure is even possible at all, given all the constraints that the present design has.

O. Brüning concluded that the topic requires full attention and asked the concerned WPs to put it in their action list. The TCC would like to come back to this topic once the aspect of beam screen vibrations has been further addressed and developed by WP2, WP3, WP9 and WP12.

The next TCC meeting will take place on the 30th of August 2018.