77th Meeting of the HL-LHC Technical Coordination Committee – 06/06/2019

Participants: C. Adorisio, A. Apollonio, V. Baglin, R. Bruce, O. Bruning (chair), F. Cerutti, S. Claudet, R. De Maria, A. Devred, P. Fessia, H. Garcia, S. Gilardoni, R. Jones, A. Lechner, G. Lerner, P. Martinez Urios, F-X. Nuiry, Y. Papaphilippou, H. Prin, S. Redaelli, G. Riddone, F. Rodriguez Mateos, T. Rosa, F. Sanchez Galan, L. Tavian, Y. Thurel, R. Tomas Garcia, A. Verweij, R. Van Weelderen, S. Yammine, M. Zerlauth.
Excused: G. Arduini, L. Rossi.

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

Following the approval of the 77th TCC meeting agenda, Oliver also approved the minutes of the 76th TCC meeting (no additional comment was received) while recalling the three main actions (available here).

HL-LHC cumulative IR7 losses and R2E – Giuseppe Lerner

A previous presentation covering IR7 losses has been shown at the LMC (slides 17-22). This presentation describes different calculations of the number of lost protons in IR7 and HL-LHC predictions, with a focus on the R2E impact.

Cumulative IR7 losses during Run 2:
Up to 2018, the BLM Total Ionizing Dose (TID, in Gray) scaled well with the beam intensity. In 2018, an increase of normalized TID by a factor 2-3 in the whole LSS is measured.
The higher dose rate in 2018 fills can be attributed to different operating conditions of the LHC (lower $\beta*$, reduction of $\beta*$ and crossing angle levelling during fills).

O. Bruning observes in the transparencies that a small change on the $\beta*$ apparently strongly affects the TID. He asked what would be the situation during the HL-LHC era. Y. Papaphilippou answered saying there is clearly a combination of effects resulting from the continuous Xing-angle leveling and e-cloud.
Y. Papaphilippou says that historically Beam 1 generates more losses than Beam 2 and it's not yet well understood why.
R. Tomas Garcia confirmed that it is normal when changing settings in the machine that some beam halo is lost here and there. A. Lechner confirmed these statements, saying that losses are coming from a combination of many aspects, but pointed out that Xing-angle leveling stops when $\beta*$ is reduced to 27cm.
Y. Papaphilippou added that it would be good to differentiate the loss patterns at a bunch by bunch level, possibly profiting from the future availability of diamond BLMs, in order to better understand the dependency of the TID on machine settings.

Investigation of lost protons:
Parallel to measuring the BLM TID at the primary IR7 collimators, the Fluka team managed to calculate the number of lost protons in that region (from Fluka simulations fitting with the

measured TID in the BLMs). These calculation are done at top energy (6.5 TeV) and the results for Beam 1 and Beam 2 are available in Slide 6. Up to 5.1×10^{15} protons have been lost (for beam 1) in 2018.

The number of protons lost is continuously increasing over the years, particularly between 2017 and 2018.
At injection energy, the number of lost protons is comparable in 2017 and 2018 but here the losses are not R2E relevant because the TID per unit lost proton is more than 10 times lower than at top energy.

An alternative way to measure the lost protons consists in calculating the difference between the initial and final beam intensity in each LHC fill of the year (measured with the BCT), removing the particles lost in the IP collision (luminosity burn-off) and summing over all fills. This exercise implies the assumption that all non-luminosity losses happen in IR7 (i.e. nothing in IR3).
The results are available in Slide 7, (BCT B1 for Beam 1 and BCT B2 for Beam 2), showing good agreement with Fluka results within +-20% .

Lost protons in IR7 in HL-LHC:
Scaling the Run2 lost protons with HL-LHC integrated beam intensity, one can expect:

- 10^{16} lost protons per year;
- 1.2×10^{17} lost protons for the entire HL-LHC lifetime.

These slightly higher losses (compared to what was presented before) are acceptable for warm magnets in Point 7. There is no impact on the magnet change strategy, it's a pure R2E concern.

Y. Papaphilippou asked what would be the number of lost protons during HL-LHC considering the expected HL-LHC equivalent cross section (i.e. if we make the projection assuming luminosity scaling). G. Lerner said that with this approach, assuming an equivalent cross section of ~110mb, the lost protons per beam for the entire HL-LHC lifetime are expected to be around 1.5-2.0×10^{17}.

High Energy Hadron (HEH) fluences (relevant for Single Event Effect, SEE) in caverns around IR7 (RR73 and RR77) measured by Radmons in levels L0 and L1 of the RRs in Run 2 are presented. The HEH fluence is a lot higher (around ×10) at L1 (shielding is only protecting level L0). As for the lost protons, integrated intensity scaling is employed to predict the corresponding HL-LHC levels.
The specified R2E HEH fluences in the IR7 RRs at L0 are:

- 10^8 cm^{-2} / year in Run 3;
- 2×10^8 cm^{-2} / year in HL-LHC.

Specified values in the equivalent RRs in IP1 and IP5 are >10 times higher (3×10^9 cm^{-2}/year in HL-LHC), making the RR73 and RR77 caverns a lot safer for electronics compared to IP1 and IP5 regions.

In the Dispersion Suppressor (DS) regions around the IR7, the radiation levels will change due to the installation of 11T magnets and TCLD collimators. These will generate a TID peak in Cell 9, and some racks (in particular dipole and 11T Quench Protection Systems (QPS) and heater power supplies) are located close to that peak. Because of a high TID gradient in the region (close to a factor 100 over 10 meters only) moving away the 11T QPS rack (even if only by 1

or 2 meters) is highly beneficial, and this will be done in agreement with the WP15 team (compatibly with integration constraints).
To further validate the DS results, the R2E teams will monitor closely these TID levels after the 11T installation (using BLMs as well as optical fibers). If the measured TID levels are found to be too high for the equipment, mitigation measures to replace/relocate/swap racks after the first years of operation can be foreseen in the future.

O. Bruning concluded by saying that the scaling approach confirmed that for the IR7 region the situation is definitely better than in IR1 and 5, although a bunch by bunch analysis shall be followed up. F. Cerutti for WP10 confirmed.
Following a question related to the eventual need of a higher scaling factor for HL-LHC, G. Lerner said that the analysis of past operation years would not justify it. A. Lechner confirmed also this statement.
Finally, F. Cerutti reiterates that, regardless of the uncertainty on the prediction of the number of lost protons in IR7, it is important to ensure that there is a sufficient distance of the electronic equipment (particularly QPS) from the TCLD dose peak. P. Fessia said that there is no more margin for rack movement due to the cable length. However, a preventive exchange would be possible if needed.

Progress update for TANb installation - Francisco Sanchez Galan

LHCb will be upgraded during LS2 and a new protection scheme for D2 is required and has been studied by WP10. The integration layout has also been done and discussed with the concerned WPs. TANb installation activities started in May 2019.

To prevent excessive energy deposition on D2, the TANb absorber made of tungsten will be installed on both sides of IP8, in between the D2 and the TCTP collimator. Following ambient residual dose rate analysis (C. Adorisio) it has been decided to not put any shielding around the tungsten absorber.
A specific mechanical support below the TANb has been developed to allow the precise alignment of the 750 kg TANb absorber.

A new integration scheme is needed in the machine:
The vacuum layout between D2 and the Y-chamber will be modified for releasing space for the installation of TANb. BPM will be relocated from the vicinity of D2 to the vicinity of the Y-chamber. D2, Y-chamber, TCTPH and TCTPV collimators will not be affected.
Electrical boxes are already relocated and vacuum components are now removed as well as BPMs. The space for the installation remains however very limited.
Over the coming two weeks, the floor marking and drilling shall be done; there is just a layout database version issue preventing the survey team to collect the data allowing to trace the TANb locations.
The installation is planned by end of June and mid of July 2019.

Action: it is requested to present a short AOB at a future TCC, once both absorbers will be installed.

Handling of installation discrepancies – Michele Modena

For previous LHC installations (1st and LS1) there was no follow-up of the equipment installation "discrepancies", and this lack of follow-up is impacting today on HL integration done by WP15.

For LS2, WP15 therefore proposes to track this aspect systematically.

A procedure to track the installation discrepancies is described on Slide 3 here and shall be followed each time there is a deviation from the "Integration Report for Installation Approval" IRIA documents:

An e-mail shall be sent to HI-LUMI-LHC-WP15-LS2_INSTALLATION_DEVIATION@cern.ch, with the following information:

- System and location: (e.g.: TANB P8 Left);
- EDMS number of the related LHC ECR;
- EDMS number of the related IRIA;
- Description of the problem: (e.g.: conflict with an existing electrical box that had to be further displaced respect to what foreseen in the IRIA);
- Involved parties: (e.g: EN-EL for electrical boxes, EN-HE for transport activities, …);
- Status: (e.g: problem solved / waiting for feedback);
- Cost and schedule impact: (if known).

An updated list of the detected discrepancies at installation is visible here, on the HL-LHC website. So far it mainly concerns ancillary aspects and service systems. It is proposed to release a new version of the IRIAs concerned "*as installed"* at the end of the installation phases (LS2 and then LS3).
WP15 strongly recommends to all groups who detect installation non-conformities to document them.
P. Fessia says it is also a way to prevent installation non-conformities (in principle formalized in MTF, to be confirmed) as it would be done, by the coordination team, if the installation final state is not exactly according to the initial integration model.
Following a question about other consequences (operation, functionality) of an installation discrepancy (for instance if an 11T dipole is finally displaced by 3 mm), P. Fessia said that this installation discrepancies follow-up is not made to monitor these kind of problems, but should be used to keep the integration models updated.
P. Fessia added that today, unfortunately we have to check in great detail (sometimes with several visits to the LHC tunnel) the existing integration models before installing new equipment. The objective is also to prevent similar problems for the future.
S. Redaelli wanted to know how this process is organized by the integration team and P. Fessia said that the information is public and shared with all WPs and other teams.

AOB: ECR for HL-LHC inner triplet circuit including cold diodes – Felix Rodriguez Mateos

This ECR (LHC-MQXFB-EC-0001) covers the changes that occurred to the design of the HL-LHC inner triplet circuit since Internal Circuit Review of March 2017, and puts documentation in line with TDR v1.0.
O. Bruning stated that the conclusion about the specific wire voltage within the Q1a circuit (details of the k-modulation circuit) was never shown at the TCC. F. Rodriguez Mateos answered by saying that they will be described in the ECR.
Action: TCC requests that the final details of the implementation / solution of the k-modulation circuit shall be presented at a future TCC.
F. Rodriguez Mateos agreed.

The ECR is describing four main changes related to the inner triplet main circuit:

1. Suppression of Q2a trim circuit;
2. Addition of a k-modulation circuit across Q1a magnet;
3. Update of the ratings of the superconducting elements of the main circuit of the Inner Triplet;
4. The use of cold diodes.

The Circuit Disconnector Box (CDB) is not included in the ECR, neither the final number of energy extraction systems for the correctors MCBXF which is still under discussion.

Several ECR comments have been discussed and are visible here, on Slide 3.
Among the comments, two have mainly been discussed:

- The suppression of the Q2a trim involves that four RPLBC are not needed anymore. However, four RPLAD are needed for the addition of the K-mod circuit, making the whole process cost neutral;
- O. Bruning insisted on the need for the cold diodes to be considered as a baseline, and the present ECR shall go through the approval process that way. The assumption of cost neutrality is not true anymore and it should be discussed at a next PSM. L. Tavian requested how an ECR could be approved without considering all the project aspects (impact on performance, schedule and cost…). O. Bruning says the potential additional costs for the Cold Diodes will not be large enough to make the project revert the decision on the cold diodes. As the TCC is there to discuss technical aspects and not necessarily budget implications, the TCC should continue the technical discussion with the assumption of having the Cold Diodes in the HL-LHC baseline, while the potential budget implications shall be discussed in the PSM.

P. Fessia said that there is so far no transport solution for this new equipment (the D1-DFX Connection Box, a cryostat which contains among other equipment the cold diode assembly), but of course the diodes shall go along with its attached box. P. Fessia added that the related instrumentation is linked to WP17. O. Bruning added that there is no layout for the D2.
About the cost implication, F. Rodriguez Mateos added that reverting back to warm diodes is not a technical issue, although it's clear that the baseline is now the use of cold diodes (as proven technically and presented earlier by D. Wollmann at the TCC's 66th meeting and G. d'Angelo at the TCC's 73rd meeting).
Following a question related to the Q2a circuits removal and the reminder by G. Arduini that the TCC endorsed the circuit removal based on the assumption that the Q2 magnets can be sorted for the final installation, L. Tavian enquired whether this has not cost or schedule implications. Assuming a timely delivery of all magnets, this should indeed be cost and resource neutral.

Other ECRs related to the Inner triplet circuits are listed on Slide 4. The ECR shall be updated with comments and come back to the TCC only if there are rejections or important comments.

AOB: ECR on pole order of the HL-LHC IT circuit and resulting implications – Hervé Prin

ECR: LHC-LMQXFE-EC-0001
To eliminate additional splices in the Q1/3 cold masses and to be able to perform vertical tests of MQXFA magnets at BNL, the pole order of the quadrupole magnets is proposed to be reverted. The polarity of the main circuit has then to be revised accordingly.

Reason:
The Q1 assembly consists of two shorter magnets that need to be properly connected to be able to test them in the BNL Vertical Tests Facility. Lead A shall be cut during that test which would involve an additional splice which is not compatible with the expansion loop foreseen in that region.
In order to minimize the number of splices inside the cold mass, it is proposed to invert the current direction.

Consequences for Q2:

- Inverting the current direction in the MQXFA involves also inverting the current direction in the MQXFB;
- Leads of the MQXFB have to be re-arranged;
- Cold diodes direction shall be inverted;
- 18kA and 2kA trim circuits polarities shall be inverted;
- CLIQ and QH power supplies must be connected according to the updated electrical scheme;
- No major cost is identified;
- The risk of faulty splices is reduced (6 splices could be eliminated).

A list of actions is listed in Slide 8, if the ECR is approved. Among them, new IT circuit failure simulations shall be done because the voltage-to-ground will change.

O. Bruning asked how the synchronization of all the changes will be done with all the other teams, and underlines his worry that somebody could still use old drawing versions after the pole order change.
H. Prin said that the latest versions of all schematics are available on the Magnet Circuit Forum (MCF) webpage.
A. Verweij asked if there were any consequences for the triplet and the IT STRING tests in SM18.

H. Prin replies that the answer is not known and at the moment people concentrate on the general drawings.
F. Rodriguez Mateos asked if the IT STRING configuration changes and it has been said that the SM18 configuration will probably be different.
H. Prin confirmed that the mechanical configuration as well as the cryogenic configuration are defined.
O. Bruning finished by requesting to make sure all parties involved are aware of the changes.

Action 1: Clarify with M.Bajko (WP16) the potential impact of the polarity inversion on the IT STRING configuration.

Action 2: When the ECR will be approved, one shall make sure that all WP leaders (and the HL-international collaboration) acknowledge the polarity inversion and use the latest drawing versions.

AOB: ECR on reduction of Q1 beam screen cooling tube diameter – Nicolaas Kos

This ECR (LHC-VSM-EC-0002 v.0.9) explains the reasons of reducing the Q1 beam screen cooling tube from Ø16 mm to Ø10 mm. The main reasons are summarized on Slide 2 here.

It has been asked if there is no cooling issue with such a smaller tube. S. Claudet replied that the tubes were initially defined with a bigger diameter because a bigger tungsten shield was proposed. However, a good thermal contact between the screen and the tube is possible with a Ø10 mm tube and the cooling test performed at the *cryolab* with a higher coolant pressure gave acceptable results.
F. Cerutti added that increasing the tungsten thickness is not needed to protect the cold mass.
Finally, O. Bruning asked if we could expect any torque on the beam screen during quenches and N. Kos answered that the tube diameter change has no effect on that.

Next meeting: 4th July.