3rd Meeting of the HL-LHC Technical Coordination Committee

Participants: A.Apollonio, G.Arduini, V.Baglin, I.Bejar Alonso, D.Berkowitz, C.Boccard, L.Bottura, C.Bracco, O.Bruning (Chair), H.Burkhardt, O.Capatina, P.Chiggiato, S.Claudet, B.Delille, R.De Maria, S.Evrard, S.Fartoukh, P.Fessia, J.Gascon, F.Gerigk, M.Giovannozzi, M.Guinchard, A.Macpherson, H.Mainaud Durand, Y.Papaphilippou, M.Pojer, S.Redaelli, L.Rossi, F.Sanchez Galan, K.Schirm, R.Tomas, E.Todesco, G.Vandoni.

Excused: J.Jowett, M.Lamont, S.Gilardoni, M.Zerlauth.

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

O.Brüning opened the meeting highlighting the main actions, as reported in the minutes of the 2nd TCC. There are 23 approved decisions of the HL-LHC PLC and TC that need to be documented through ECRs. The first one to come would be the update of the collimation system baseline. The corresponding WP leaders should make sure that all documents are ready for the USLARP meeting.

Regarding the temperature of Q5 in point 6, a decision was taken to change it to 1.9 K for both sides, with one MQY, and related activities will take place in LS3. The corresponding ECR should be prepared. In addition, a recommendation from WP2 on the possibility to relax constraints on the required Q5 gradient should be provided, with the prospect of keeping the operating temperature to 4.5 K on the right side of IP6. This requires input for WP14 concerning the acceptable beam sizes at the dump protection elements. During the meeting, it was suggested to push the MQYs gradient to 180 T/m during a future hardware commissioning campaign to evaluate the possibility of operation beyond nominal/ultimate values at 4.5K. After the meeting, discussions between O.Brüning, V.Montabonet, M.Pojer, L.Rossi, E.Todesco, A.Verveij and M.Zerlauth concluded that the request of pushing a magnet above nominal/ultimate already during Run 2 is far from being trivial, as the present power converter and DCCT is limited to 4 kA and thus cannot supply the necessary current for a gradient of 180 T/m. An upgrade to a 6 kA-type will become necessary along with the change of baseline to 1.9K, however in light of the newly adopted baseline (and prior tests of the magnet type in SM18) the test to 180T/m was concluded not to be necessary. A proposal on the operating temperature of Q6 magnets in point 1 and 5 should be presented by WP3 and WP9 in one of the next TCC meetings, including cost variations associated to the 1.9 K option.

Finally, F.Rodriguez Mateos will present the status of the circuit powering on the TCC of the 10th of March 2016, in view of the scheduled review on 21st-23rd March.

O.Brüning proceeded by introducing today’s agenda and AOBs.

Vibration tests and measurements in LHC, (J.Wenninger - slides)

J.Wenninger mentioned that the presentation would be almost identical to the one he gave in Chamonix 2016, with some additional material. It concerns the effect to the beam of Civil Engineering works but also earthquakes, especially due to the Geothermie 2020 project. He starts his presentation reminding that a lot of drilling is foreseen close to the LHC points 1 and 5 for HL-LHC. The main underground structures are 40m away from the tunnel and all the work has to be done before LS3. The first question asked was the compatibility of this work with beam operation. The main schedule foresees the main excavation during LS2 but some part of the work (shafts) has to be done in 2018 and some after LS2.

The other upcoming problem is a project for geothermal energy managed by Service Industriel de Genève (SIG). The project is in a prospection phase but due to the size of the Geneva canton, the LHC tunnel could be affected due to seismic activity (up to magnitude 2). In Basel, due to the seismic activity foreseen, the project was stopped. In any case, SIG made seismic studies overlapping the LHC tunnel, and CERN could profit from the presence of a 'vibrating' truck to perform vibration tests in point 1.

Vibrations due to both CE for HL-LHC and Geothermie 2020 could trigger beam aborts. The CE works could also degrade performance, e.g. due to beam offsets at the IP, emittance growth from noise, etc.

In order to estimate the impact on the beam, it was attempted to determine the transfer functions to the tunnel for horizontal and vertical vibrations, translated to movements of the cold mass (CM), inducing beam orbit movements. Several measurements and even parasitic beam observations were done at SM18, the AWAKE area and LHC tunnel.

First, at SM18, a spare Q1 was instrumented with sensors to estimate the vibration of the cold mass, while some ground CE work was taking place. The actual triplet movement may indeed be more complicated, as in the tunnel, Q1 is connected with the other triplet CMs, but it was assumed that the interconnects have limited impact on the response. The highest frequency peaks measured were at 21.5Hz (vertical), 8.4Hz and 12Hz (lateral) with an amplification factor of 100.

In the tunnel area of AWAKE (old CNGS TT41), a CM was excited by a shaker at a distance of 40 m (for lateral TF estimation). Geophones were placed in various positions in order to understand transmission. In addition, a vibrating truck oscillating between 4-100 Hz was placed in two positions at 89 and 141 m from Point 1 (for vertical TF estimation). In that case, there were also beam observations done during the ion commissioning. At TT41, the measurements showed, a general horizontal attenuation of a factor of 2 was observed for 40 m distance difference. The attenuation factor becomes 20 or higher close to 10Hz.

Different triplet movement scenarios were also considered in order to identify the worst one (alternated displacement) which can cause IP separation (performance reduction) or 170 μm residual orbit on collimators which can induce beam abort.

Frequency analysis of 2010 and 2015 data from the transverse damper and DOROS confirm the existence of a 4.5 Hz line. There is some activity around 20 Hz, 12 Hz but not at 8 Hz. The amplitudes are on the scale of a few μm.

During the vibrating truck measurements, there is a clear effect observed on the BPM and ADT data. It indeed only affects the vertical plane (as M.Guinchard pointed out replying to a question of O.Brüning), as the truck was vertically positioned in point 1 with respect to the triplet and only when its frequency is resonant to the triplet. There is also an interesting amplitude ratio of 2.5 between beam 1 and beam 2, implying that Q2 moves differently than Q1 and Q3. The oscillation amplitudes of the triplet CMs were in the few μm range for ground motion amplitudes of ~50 nm in the tunnel, confirming again the amplification factor of roughly two orders of magnitude. L.Rossi points out that if the movement affects the magnetic center of the actual cold mass (as compared to the outer cryostat), the effect on the beam should be higher. J.Wenninger answers that indeed this is the case and depends amongst others on β^*. L.Rossi concludes that from the plots shown, there is roughly three orders of magnitude amplification between the ground and the beam.

Some tests and measurements were also done with core drilling in point 1 and confirmed that the expected motion of the triplet magnetic center vs depth remains acceptable (0.1-0.2 μm). O.Brüning points out that this seems to be in line with the present strategy to start drilling before the start of LS2. P.Fessia stresses that the drilling tests were done with a machine that provides less vibration but works like a hammer, which is quite different as compared to the real one used in CE works. A new campaign was initiated with M.Guinchard using a real drilling machine. J.Wenninger adds that the effect depends heavily on the excitation spectrum.

The dimensioning of an active beam feedback system to allow the vibration mitigation was presented. The issue is not so much the integrated dipole field needed (<0.2Tm) but rather that they must be more than 100 times faster than the other LHC closed orbit correctors. This may be feasible but there is no time for such a development for 2018. L.Rossi asks that it may useful to have it for after LS2 (2021). J.Wenninger agrees that it is worth investigating the feasibility of such a magnet for after LS2 or HL-LHC. S.Fartoukh asks if the ADT or the WB feedback could be used instead? J.Wenninger answers that the actuator should provide a strong kick and S.Fartoukh iterates that one could locate it in an area where the β-function is ~ 1000 m. O.Brüning concludes that although not achievable for the next couple of years, these indeed are interesting considerations and developments to be followed-up for HL-LHC, as it seems that cultural noise may have a rather big impact.

Regarding the impact of earthquakes, J. Wenninger first points out that due to the low seismic activity in Switzerland, the monitoring is very poor. In the context of Geothermie 2020 project, though, the Geneva University needs to build a network for monitoring the natural seismic activity. On the CERN site, geophones will be installed in the service areas of LHC, measuring the cultural noise and also detect any seismic activity. The data will be transferred to the Swiss central seismic institute. In addition, DOROS has been upgraded to get synchronized TBT data and the ADT observation box will provide better monitoring of beam oscillations for analysis. **ACTION: O. Brüning proposes that another presentation should be given by the end of this year with some assessment of the 2016 measurement and proposals for HL-LHC.**

The engineering company Resonance SA was mandated by the SIG and published a report for impact at CERN. A maximum earthquake magnitude of 3 is to be expected, although most will be of magnitude 2. The CM movement prediction is around 1-10 μm for magnitude 2 and ten-fold for magnitude 3, which is indeed relevant for HL-LHC (although the company concluded the opposite).

Earthquakes are quite short (~second), so the triplet cannot enter in full resonance. On the other hand, the earthquake rates are difficult to predict. In the initial phase of exploitation hundreds of earthquakes may be generated over few months. An example from an earthquake due to geothermal exploitation at BASEL and similar ground as LHC tunnel, shows maximum movement of 10 μm and duration of 10 s. The company recommended that the beginning of exploitation should coincide with an LHC long shut-down.

Earthquake waves are of three different kinds (pressure, shear and surface) with different speeds. The pressure wave arrives first, followed by the shear and than surface waves. The frequency spectrum extends from mHz to 100 Hz. Large distant earthquakes are dominated by very low frequencies (<1Hz), whereas local earthquakes extend to higher frequencies. The response of the LHC ring to ground motion depends on their wavelength and direction and there may be another amplification factor of 100, for the worst wave direction.

An example of the Costa Rica earthquake in September 2012, arrived at the LHC while in stable beams (fill 3032). There were indeed radial beam movements with 100 μm amplitude but the luminosity of $6\times10^{33}cm^{-2}s^{-1}$ was not affected (as the movement was mostly radial), and there were only some loss spikes. In the question of L.Rossi regarding the frequency of the radial movement, J.Wenninger answered 40 μHz. S.Redaelli asks whether there were important orbit shifts. J.Wenninger answers that it was rather small (maybe slightly bigger at the momentum collimators).

For a second example corresponding to the Italy earthquake on May 2012, there were losses observed on luminosity and orbit movements but they were completely unnoticed at the time. The dominant frequency was higher, as the location was closer. The effect on the luminosity (7 % drop) was difficult to observe because the spike seemed as if it was a luminosity optimization. There was a strong transverse offset effect in the vertical plane, losses reached 10% of the dump threshold (~0.4% of intensity drop). L.Rossi asked on which time scale, these losses occurred. J.Wenninger answered that it was for over a minute so the power was not very high.

In conclusion, large earthquakes can have an impact at LHC. The LHC beam survived all present events. A network of geophones and improved beam measurements will be used to monitor ground motion and low magnitude natural earthquake activity. Tail cleaning with e.g. hollow e-lenses could mitigate the impact of Earthquakes. Regarding vibrations, it was confirmed that resonances with the triplet can boost amplitudes to problematic levels. The excavation of caverns and underground structures should be made during LS2, but the construction of vertical shafts is compatible with beam operation (2018). Finally, the mechanical design of the CM for the HL-LHC triplet should try to take into account the observations made on the existing triplets.

Discussion

O.Brüning stressed that it would be important to evaluate the eventual loss spikes observed during this year, due to ground motion. J.Wenninger agreed and added that lower β* will enhance any effect. M.Guinchard added that he is in contact with Swiss seismological services and he is informed whenever an earthquake event occurs. L.Bottura questions the ability to mitigate the effect especially if it is in the warm foot. P.Fessia points out that extremities of the CMs rely on the same jacks on the ground. There seems to be an implication of what happens outside, as the effect is different for the different sides. G.Arduini suggests that it may be useful to spread the frequencies among the different CMs. O.Brüning agrees that this is indeed something to follow up. P.Fessia adds that a computational analysis is being carried out and from there one could understand which are the guiding points for the movements. M.Guinchard points that Q1 and SSS show similar frequencies although their internal support is different. O.Brüning suggests that the string tests in SM18 could help investigate further the triplet vibrations. P.Fessia finally informs that there is a mini-string setting up to be used as a test bench for the vacuum group, HL-LHC alignment but also vibration studies.

Compatibility of the ALICE beam pipe with HL-LHC parameters (M.Giovannozzi- slides)

M.Giovannozzi reported on the compatibility of the ALICE beam pipe for the nominal LHC but also HL-LHC. The discussion started in the LEB WG (April 2012) with the purpose to reduce the outer diameter from 6 to 3.6 cm. After aperture checks, it was reported that this diameter was too small, beyond 2 m from the IP. By the end of 2013, a new layout was submitted with the same diameter but over a much shorter part of the pipe. In spring 2014, the central section was slightly increased to 3.8 cm in order to relax alignment tolerances. In conclusion, the main change is the reduction of the 6 cm outer diameter to 3.8 cm, and only along the beryllium pipe (length of 88.8 cm).

The estimate of the mechanical tolerances has evolved in paralell. Before, it was constant, including a big component for cavern movement. At present, there are different tolerances for the different parts, in particular due to the different supports.

The evolution of tolerances and beam pipe radius along the IP area is reflected in the evolution of the n1 parameter, for the nominal LHC and after LS2. In addition, a vertical shift of -2 mm is currently applied in the IP in collision, due to the misalignment of the detector, impacting aperture in collision in the inner triplet (IT) and corrector strengths, in particular for ions. By LS2, the detector should be aligned not to present these limitations any longer, thereby recovering a better aperture. The last important point for LHC, is the request to change the philosophy of crossing angle in LS2 towards a scheme similar to LHCb, allowing quick polarity changes, with fixed external crossing angle. This implies increasing the parallel separation from 2 to 3.5 mm and an angle of 40 μrad at injection. This is a carbon copy of S.Fartoukh's scheme proposed for IR8 which was crucial to enable LHCb data taking in Run 2, with 25 ns bunch spacing, and full spectrometer strength since injection, for either spectrometer polarity. At collision, the external crossing angle is increased to 200 μrad.

Based on the experience from Run 1, the parameters used for aperture computations have been reviewed. At collision, they are already documented in CERN-ACC-2014-0044. The target aperture is 12 σ (for a normalized emittance of 3. 5 μm. rad) over the momentum spread between 0 and $\pm\delta_p$ (8.6×10^{-4} for LHC and 2×10^{-4} for HL-LHC). The parameters for injection are currently being reviewed in collaboration with ABT. The target aperture is 10.6 σ (for a normalized emittance of 2.5 μm.rad).

At injection, the aperture for the nominal and new crossing scheme is always larger than 24 (standard crossing scheme) and 18 σ (LHCb-like crossing scheme) (with 2.5 μm.rad normalized emittance). At collision, for three different configurations (i.e. β* for protons, ions and VdM) and emittance of 3.5 μm.rad, the aperture is always quite comfortable.

In conclusion, although the central part of the ALICE beam pipe is reduced by a sizeable amount, for both LHC and HL-LHC, this is acceptable with respect to aperture. The alignment of the detector should be improved as it will be difficult to cope with the current IP offset after LS2. The proposed crossing scheme reduces aperture at injection and the situation should be monitored after LS2. Any possible impact on background should be evaluated.

Discussion

Regarding the last point of the conclusion, H.Burkhardt mentioned that the amount of beam gas background should be expected to be little. S.Fartoukh questions the use of 2.5 μm.rad normalized emittance at injection, as the 5 σ aperture margin shown as compared to, e.g., the normalized aperture of the arcs, corresponds to a very small physical aperture of 1.25 mm (i.e. only 20 % of the mechanical tolerance estimate). M.Giovannozzi replies that the analysis for the new set of parameters was done also in case of an asynchronous beam dump. R.De Maria adds that the PLC recommended to start employing the same emittance for DA and aperture (collimator) computations to avoid confusion. S.Redaelli stresses that at present 3.5 µm.rad is still used for collimation. G.Arduini points out that this is just a unit and the limits have been scaled accordingly. The next scheduled WP2 meeting will review the definitions and propose a revision of the units to avoid confusion in the future. O.Brüning concludes that it should be clarified that everything is conform to tolerances for protection. L.Rossi asks if the TCC has to present this to the LMC for approval. M.Giovannozzi answers that the presentation was already done at the LMC and the point today was the compatibility with HL-LHC. L.Rossi points out that the procedure was not followed correctly, as the issue should have been first discussed in TCC before getting the LMC approval. He proposes to contact P.Collier in order to rectify this and O.Brüning agrees. P.Fessia recalls as scientific secretary of the LMC that it was explicitly mentioned in that meeting that HL-LHC should come back with an approval of the proposal. O.Brüning will investigate with the LMC team about the procedure, mentioning also the concerns of S.Fartoukh. S.Fartoukh further stressed that if the 18 σ aperture is for the new crossing angle, there is indeed no difference between the present LHC and HL-LHC. S.Redaelli asks if anyone has looked into impedance issues. G.Arduini replied that this has been looked at and presented (also for HL-LHC parameters) and monitoring of the temperature of the vacuum chamber has been recommended to evaluate whether the estimated heat load can be efficiently dissipated.

G.Arduini reiterated that the aperture after subtraction of the tolerances defined and agreed with WP5, 8 and 14 at injection and collision and after consideration of the possible failure scenarios is larger than the protected aperture and therefore acceptable. S.Fartoukh emphasized that apertures inside a detector should be taken with more care as compared to similar magnets, in addition because there are no BPM at IP2. Indeed, an aperture of 8 mm (including the standard 4 mm closed orbit uncertainty at injection) is very tough at injection. G.Arduini noted that this remains after subtraction of all the tolerances. L.Rossi asks that WP2 and WP8 provide a conclusion. G. Arduini asserts that, based on the presented information and coherently with the definition of the tolerances, this beam pipe design is acceptable for the given tolerances that were also discussed at the HL-LHC Technical Committee on 19/11/2015. H.Burkhart suggests that ALICE should make a statement about the amount of losses that are tolerable within the detector.

SM18 readiness for validating and preparing CC cryo-modules for SPS test (A.Macpherson - slides)

A.Macpherson opens his presentation by an outline, which includes the SM18 infrastructure, the preparation activities and discussion on the workflow from bare cavity to cryomodule for the SPS installation. The roles and responsibilities are identified across the CERN groups from the cavity production to the final cryomodule testing. Answering the question of L.Rossi, if the cryomodule is built in collaboration with the UK, O.Capatina answers that they provide the equipment and design but cavities are built at CERN.

A.Macpherson proceeds to the identification of working space at SM18. In particular, there was quite a lot of work for the facility upgrade. This period is though quite busy, as in 2016-2017 the SM18-RF facilities must handle 4 different projects. L.Rossi asks if the project is suffering from this. A.Macpherson replies positively and O.Brüning recalls that there was a discussion with E.Jensen for providing additional technical support. K.Schirm explains that this support is shared with the magnet group and sometimes can be difficult due to the different priorities.

The clean room is becoming operational. A detailed schedule overview is presented which is quite tight. The bottom line is that it is very important to prepare the infrastructure during 2016, as the assembly is scheduled to take place in 2017.

Regarding the SM18 infrastructure, the horizontal bunker is critical for the installation of cryogenics. In particular, for the LLRF development, there is no space in the present cable trays or room on top of racks. O.Brüning points out that these are RF group cables. A.Macpherson agrees but they need to be sorted out, so there is a significant amount of work. In conclusion, April 2016 will be busy with infrastructure activities. For the vertical cryostat, the main point is the insert upgrade for the tuner, as the other one is not sufficient for the tests. The tests are scheduled for May 2016.

Regarding cryogenics, which include the supply from distribution line to cryomodule, the specifications are expected by mid-May to proceed with the fabrication. In the present schedule, there is some contingency period of a few months. The placement of cryomodule adheres the constraints imposed by the SPS. For getting the power into circulators and cryomodules, a way was found to get it from the other side of the wall without removing shielding. The power tests will be done with two cavities at the same time in parallel, with IOTs instead of tetrodes. The present plan assumes that the power system will be installed again with some contingency.

The tooling had to follow the change in baseline for CCs that are finally built at CERN. This includes the surface preparation, clean room for assembly and other steps. The schedule again includes some small contingency but it is not that flexible. Validation process includes both tooling and process. The weight of objects is a worry, so there is need to reinforce the floor. O.Brüning asks when this will be done. K.Schirm answers that ideally during the shut-down period but it is not fully clear, as the strategy should be better evaluated, following the three programs running all in parallel. O.Brüning suggests to have another presentation when there is a clear planning. K.Schirm explains that it should not be that critical but it is clearly something to follow up. L.Rossi asks if the clean room of ISOLDE cannot be used, as initially thought. A.Macpherson says that this is not easy. O.Brüning points out that 1- month contingency for tooling is quite limited. A.Macpherson agrees, but there is some hope to squeeze some other activities.

Tooling needed to minimize risk of RF Surface contamination. A conceptual study by EN-MME, now matches to cleanroom procedure. The high pressure rinse station was commissioned but it is necessary to make sure that all equipment with complicated geometry fits.

The chemical treatment of CC surfaces (polishing), is ready to be pursued at CERN, as for the PoP cavities. Nothing changed since the CC review, regarding the cavity and cryo assembly. There is very limited contingency and one could recuperate some time in preparation for the 2nd cavity. During 2016, the assembly process could be re-optimized but it is indeed tight.

The CM validation tests are quite difficult as they are scheduled from November to January (including Christmas) and the schedule is very tight. O.Brüning stressed that, in his opinion, this schedule seems unrealistic. A.Macpherson understands this but there is not an easy solution. Maybe something could be done for the LLRF (reduce below 2 weeks) or some work should be dropped. This is indeed not ideal because debugging should be then pursued in the tunnel. S.Claudet made two points: first, there is a periodic coordination management meeting organized by P.Gayet and second, there is no service for testing modules across Christmas. A.Macpherson, indeed assumed a 2.5-week break for Christmas.

For the string assembly, tooling is necessary and in each step, the workflow, is straightforward, but one needs to make sure that tools are right. The cryostating, which is the responsibility of EN-MME, is frozen since the review.

A.Macpherson concludes pointing out the open issues and concerns and giving a general summary. This is indeed a mature and finalized design. It is necessary to make sure that the surface preparation and cavity-testing process is mastered. In addition, cryo validation is very tight. The resources are sufficient, and manpower is now being reassessed. Resources should be invested in 2016 for cleanroom and cyrostating preparations to validate workflow and procedures.

Discussion

O.Brüning stresses that all this seems to him extremely tight so if the project runs out of margin, it should be again presented to the TCC for feedback. If technical support is needed, the project can ask for help. K.Schirm stresses that this is difficult, as very skilled people are needed, the training is long and they are difficult to be replaced. O.Brüning mentions that, e.g. the European X-FEL has gone through the same process and they could maybe help. K.Schirm adds that the main problem is not setting up tools and planning but how to learn the surface preparation, as it was decided relatively late in the project. F.Gerigk emphasizes that this was never done before at CERN.

AOB: Chamonix summary of relevant HL-LHC (O.Brüning, - slides)

O.Brüning decided, due to lack of time, not to go through his presentation. He asked the TCC members to look at the slides and provide comments, as they will be presented during the Chamonix summary at CERN, on the 3rd of March.

AOB: Procedure for layout and optics approval (P. Fessia - slides)

The idea of this presentation is to identify the timeline for new optics and layout for the LHC. P.Fessia shows a table with several steps starting after the annual meeting and finishing roughly 12 months after. In particular, the conversion from 2D to 3D drawings is a very time consuming operation.

The main HW changes for this layout version are shown. They include the Q5 temperature as discussed in the last TCC, the revision of magnet lengths (data from WP3) and work for BPM near Q1 and its placement in the experimental area. It is indeed quite tight, but there are two options and the proposal will be brought to the TCC for approval. The change of the cooling approach for the MS, implying the change of jumper position will be started. In the integration meeting of the following day, the underground walls in P1 and 5 will be frozen. The drawings will be then given from CE to the consultant company to start work. Any further change will have an impact. In the Faraday cage, there were 8 racks for LLRF, plus 4 BBLR. It was decided to reduce the number of racks in order to recover more latitude to place the SC link.

The next meeting will take place on the 10th of March and, in the absence of O.Brüning, it will be chaired by M.Zerlauth.