15th Meeting of the HL-LHC Technical Coordination Committee

Participants: A. Apollonio, G. Arduini, V. Baglin, M. Bajko, L. Bottura, O. Brüning (chair), R. Calaga, O. Capatina, S. Claudet, E. Coulinge, D. Delikaris, B. Delille, B. Di Girolamo, S. Fartoukh, P. Fessia, C. Garion, J. Gascon, S. Gilardoni, V. Mertens, T. Lefevre, A. Macpherson, H. Mainaud Durand, M. Martino, E. Metral, S. Redaelli, L. Rossi, B. Salvant, F. Savary, E. Todesco, G. Vandoni, W. Venturini, D. Wollmann

Excused: Y. Papaphilippou, M. Zerlauth.

The slides of all presentations can be found on the website and Indico pages of the PLC:

HL-LHC PLC/TC homepage: https://espace.cern.ch/HiLumi/TCC/Default/Home.aspx

Indico link: https://indico.cern.ch/event/559126/

O. Brüning recalled actions and decision from the 14th HL-LHC TCC.

An update from WP14 considering the remarks on the optics constraints for the injection and dump protection elements should be presented in one of the next HL-TCC meetings.

In addition, following the decision to adopt the octagonal BPM design for Q2, BE/BI should present the associated resource and cost estimates.

The decision was taken to have no shielding in the connection cryostat and the TCC endorsed the proposal to displace the nearby racks.

Crab Cavity Cryomodule status towards SPS test (F. Gerigk - slides)

F. Gerigk recalled the SPS test planning presented by A. Macpherson in March 2016, consisting of a very tight schedule, without any contingency for unplanned showstoppers (i.e. it was assuming a 100 % success rate of each step). According to this planning, developed with a top-down approach, one month of delay was predicted with respect to the project goal. A next iteration identified a possible reduction of the scheduled time by cutting LLRF tests in SM18, reducing HOM coupler tests and extending the testing to the Christmas period. F. Gerigk pointed out the lack of sufficient SRF technicians in the RF group, which also supports HIE-ISOLDE, LHC spare cavities, LHC operation, SRF infrastructures and the related R&D projects.

In May 2016 a detailed workflow and milestone plan was developed, with a bottom-up quantification of the required times for the different activities. The planning included a tooling readiness plan. Options for additional manpower were considered.

The planning consists of 94 steps, with 22 milestones (details can be found in the spare slides), including all cavity and cryomodule production steps from the shaping of cavity pieces to the transport to the SPS. All milestones have a responsible person and an associated quality assurance target. L. Rossi pointed out that for SPS tests the only contributions are from the UK, the possible gain in time coming from these contributions should be considered.

A first iteration to reduce the time allocated for the 94 steps was carried out, resulting in a readiness date 34 days later than the last valid day for installation in the SPS (i.e. 5 weeks before the end of YETS 2017-18). O. Brüning asked if this estimate includes RF conditioning in situ. G. Vandoni explained that the assumption is to perform the cryogenic commissioning after, starting the cooldown after the end of the YETS, during cold machine check-out. After this, there's still the need for a beam vacuum validation before the cryomodule can take beam. Then RF conditioning can be done in parking position with SPS beams circulating.

A further optimization was carried out to recover the overhead of 34 days (details in slide 10). This process allowed respecting the time limits to fit in the YETS17-18, but it is a fully success-oriented planning. As a backup option, the installation of the cryomodule could be postponed to a technical stop in 2018. This would allow a full RF qualification before installation in the SPS. The total installation time in the SPS is about five weeks for cryomodule and service module installations, plus RF power and electrical connections. O. Brüning asked whether it would be possible to prepare everything in advance and just leave the cryomodule installation to be done at a later stage. G. Vandoni explained that time is in any case required for welding of the cryogenic system to service modules and the associated validation (about 2 weeks), plus 5 days for additional actions resulting in a minimum of 3 weeks. L. Rossi asked if this would be feasible in an extended technical stop during the year. The technical stop of the SPS is normally one day, whereas for the LHC it is 5 working days. A request could be done to the LHC management to have an extended time for the installation in the SPS, if required.

F. Gerigk mentioned the available resources and manpower for the SFR section. The bottleneck is for people qualified to work in the clean room. A possibility which is under discussion is to prolong the contract of the team working for HIE-ISOLDE. Additionally, A. Macpherson is organising training courses for work in the clean room.

F. Gerigk concluded that the planning remains tight, with very little margins left. O. Brüning commented that what was presented looks encouraging on paper and recommended coming back to the HL-LHC TCC to discuss any evolution of the planning, in order to allow for time to react, if required. In the worst case, a request could be done to ask for additional time for installation, as done for the anticipated magnet training to 7 TeV at the end of 2016.

L. Rossi added that the main issue seems to be related to the construction. O. Capatina confirmed that there are no margins available, but the schedule is on track. Tests reveal that desired tolerances are met. Tuner tests were also already performed successfully.

G. Vandoni remarked that the SPS test is composed of several ingredients, the cryo-refrigeration is on the critical path, as confirmed by D. Delikaris. In addition, the procurement of the movable transfer table was not finalized yet, as the specification is not out of CERN yet and therefore the related market survey remains to be done. A departmental request has already been launched.

RF fingers design for the triplet area – vacuum aspects (C. Garion - slides)

C. Garion recalled the layout principle of the RF fingers design for the triplet area (slide 3). Two bellows are used between magnets, one to compensate for the differential contraction beam screen/cold mass and the other, shielded, for the interconnection contraction.

C. Garion presented the table showing the compensation requirements (slide 4). These are based on the measurements carried out during STRING II operation.

O. Brüning commented that the values for cool down and warm up appear to be very different. C. Garion explained that the presented values account for transient effects, for which the temperature difference between the cold mass and the beam screen is high.

A cross section of the copper beryllium deformable RF fingers design was presented in slide 5. This is a compact and robust design and there's the possibility of having a double wall to shield completely the outer side.

For nominal operation, RF fingers will be elongated by 35.2 mm, corresponding to an angle of 15°.

Mechanical tests were carried out to assess the behaviour of the RF fingers under different fatigue regimes and heat treatments. The number of allowed cycles was estimated to be higher than 1000. The tensile test to rupture on a two convolutions module with 57 fingers proved that the design is very flexible until the rupture of the weld. Results were extrapolated to a three convolutions module with 80 fingers (to be used in practice), highlighting the gain resulting from the introduction of titanium springs.

O. Brüning asked if the impact of radiation was considered when evaluating the change in elasticity of the RF fingers. C. Garion explained that no significant effect is expected due to the use of a metallic welding of copper to copper-beryllium.

P. Fessia pointed out that concerning values presented in slide 4, the missing values for Q1 are now available and can be provided.

G. Arduini asked if the effect of a misalignment would have an influence on the fingers. C. Garion explained that the RF fingers are much more flexible than bellows, so any effect would be observed on the bellows first. In any case, the design is such that they should be able to cope with misalignments. But V. Baglin added that tolerances on transverse alignment should be evaluated and that the main risk is related to the accumulated misalignment effects over time.

RF fingers design for the triplet area – impedance aspects (B. Salvant - slides)

B. Salvant recalled the goal of the impedance studies for the new RF fingers design. The study should assess whether the concept of deformable RF fingers shows any showstopper for use in the HL-LHC triplet area and what is the acceptable angle of the fingers (baseline is 15°).

B. Salvant reminded about the ongoing efforts to minimize the beam impedance of the LHC. In view of higher intensity beams to be used for HL-LHC, it is mandatory to minimize impedance of new designs, when possible, in order not to affect significantly the overall LHC impedance and reduce the LHC and HL-LHC performance reach.

Simulations were carried out to quantify the expected impact of the proposed RF fingers design on the LHC impedance.

- For the longitudinal low frequency impedance, the proposed design would amount to 0.3 % of the total impedance. A change of the angle to 30° would bring this figure to 1 %.
- For the transverse low frequency impedance, the proposed design would amount to 0.5 % of the total impedance. A change of the angle to 30° would bring this figure to 1.5 %.

The contribution is larger in both cases by a factor 3.5 than for the current LHC design. A more detailed analysis was carried out for an assessment of the resonant modes (slide 10-13).

B. Salvant concluded that the impedance contributions are significant, in particular in the transverse plane due to the large Beta functions. These 5 m of the machine would contribute to 1 % of the total impedance, but no showstopper has been identified so far. The argument to adopt such design is that it is more compact and robust, despite the higher contribution to impedance.

E. Metral added that there are still instabilities in the LHC, which are not only due to impedance. The LHC is running nowadays with very high octupole currents and chromaticity through the LHC cycle. Only recently, the octupole current was reduced while in stable beams.

O. Brüning commented that the resonant frequencies presented in slide 10-11 don't show a clear dependence on the angle and that some modes are entering the beam spectrum for very low bunch length. B. Salvant confirmed this and stated that it is important to estimate the possible power deposition, as this could be a delicate item (100 μm thick).

B. Salvant added that making the angle bigger makes the simulations based on a simplified model less accurate, requiring a more complex mesh-based model and justifying the experimental measurements. An important outcome of the first results of the full model is that for longitudinal low frequency impedance the simplified model seems still relevant.

The measurement work has been based on a beam-simulating wire inserted in the structure. The measurements have been carried out with different elongations of the RF fingers, which requires welding and re-matching of the wire for every configuration. The measurement didn't show any obvious resonance (only at very high frequency). Some aspects remain to be understood, no showstoppers have been identified, but some questions remain.

If required, a possible mitigation to suppress some modes could be with a HOM antenna, which would make the design significantly more complex.

B. Salvant concluded that from the combination of simulations and measurements the operating angle should be kept as low as possible and that there seems to be no gain from a double wall option.

O. Brüning asked if all undulations of the design always behave the same (i.e. they see the same force). C. Garion commented that this is true provided they have the same starting conditions. O. Brüning added that this might not be respected in presence of a large transverse offset and recommended reviewing transverse tolerances.

ACTION: an update on the transverse tolerances for the RF fingers in the triplet area should be presented in one of the next meetings.

R. Calaga pointed out that if the high frequency modes have to be suppressed one could consider spacing the fingers unevenly to break the symmetry of the structure. B. Salvant confirmed this could be considered if some modes show to be problematic.

S. Fartoukh underlined that with Beta* levelling the contribution for the transverse plane can decrease by a factor 4 at the start of the fill.

Update on WP16 String test (M. Bajko - slides)

M. Bajko recalled the goal of the IT STRING test stand. The test stand will allow testing the collective behaviour of different systems (magnets, protection systems, cryogenics, alignment, etc.), previously only tested individually. O. Brüning asked if the tests stand will already include the beam screens and M. Bajko confirmed this is the case.

M. Bajko gave some examples of lessons learnt with the LHC STRING tests (slide 8-9). Tests allowed for example assessing that magnets moved while pumping the vacuum.

The comparison of LHC and HL-LHC triplet parameters highlights the challenges of the new design. Experience will have to be gained in a number of aspects, e.g. those related to the specific properties of Nb_3Sn. As an example, flux jumps in Nb_3Sn magnets are a known issue and can potentially trigger protection systems. Suitable measures, as for example variable QPS thresholds, could be studied.

M. Bajko introduced the required SM18 upgrades for the HL-LHC STRING. Over time, about 20 magnets will be tested, including LHC magnets taken out during LS2. The cryogenic cooling production will be increased by 35 g/s to 60 g/s, which is required for running the HL-LHC STRING in parallel with magnet testing. The demineralized water production will be increased by 150 m^3/h and the network powering to 3 MVA. L. Rossi asked if the requirements for cryogenics and powering are needed only for parallel magnet cooldown or also for normal operation. D. Delikaris commented that 60 g/s is the overall SM18 capacity. M. Bajko confirmed that considering a cooldown not in parallel would reduce the requirements. The capacity of 60 g/s is needed to cover the peak shown in slide 15. D. Delikaris explained that the two pumping units are independent, i.e. they can deliver at the same time 12 g/s each. If needed, a third unit could be added, but currently the baseline is not to add it, keeping the present configuration.

M. Bajko presented the members of the HL-LHC STRING team, led by M. Bajko and M. Pojer as deputy.

The current layout and integration of STRING in SM18 was shown in slide 23. Due to space limitations, the test of the 110 m long SC link test stand will not use the IT STRING cryogenic installations.

M. Bajko introduced the schedule towards STRING operation. Installation is now foreseen in one go, to take place over 3 months in 2021, after LS2, once all magnets are available and not, as previously presented, in two phases. L. Rossi suggested starting the preparation already earlier, even if not all magnets are delivered. D. Delikaris pointed out that the contribution of the cryogenic group and the required upgrade could be re-discussed considering the schedule for the STRING (mid 2021), due to parallel work in LS2. M. Bajko explained that the main drivers of the schedule are EN/EL and CV, which are coupled to the cryogenics upgrade. S. Claudet commented that the tendering was done not to delay the STRING tests, but this could be re-discussed and optimized with possibility of some savings with more time for discussion with the suppliers. This requires some follow-up amongst the involved groups. L. Rossi added that considering also the reduced number of 11 T magnets to test and considering the possibility to have some tests done in the US, additional savings are possible. E. Todesco confirmed that releasing some pressure from SM18 in 2018 and 2019 would be beneficial for the planning, as already the last C&S review found the planning to be a critical point.

A. Macpherson asked if the presented assumption for the consumption includes the RF systems and it was confirmed this is the case.

M. Bajko presented the estimates for the required budget for the upgrades, amounting to 4.5 MCHF. All main components usable in the HL-LHC should be part of the individual WP budget, while the rest should be paid by the WP16 budget.

Out of the 4.5 MCHF, 2.5 MCHF are for cryogenics upgrades. S. Claudet stressed that this is only for STRING, not covering SC links. L. Rossi asked if this could be shared with the SC link budget, this has to be discussed.

ACTION: a more detailed budget plan for the STRING should be presented before the C&S.

T. Lefevre proposed including someone from BE/BI in the list of the STRING team. L. Rossi supported this idea, the name should be provided by R. Jones.

AOB

O. Brüning stated that, following the feedback of the WP leaders, some modification have been introduced to the program of the parallel session of the general HL-LHC meeting in November. O. Bruning encouraged all TCC members to look at the updated agenda of the general HL-LHC meeting in November which is available online under the following URL and to provide their feedback. Information from WP5 is still missing.

https://indico.cern.ch/event/549979/timetable/#20161115.detailed

L. Rossi reminded that the rehearsals for the C&S review presentations will start next week.