23th Meeting of the HL-LHC Technical Coordination Committee

Participants: C. Adorisio, A. Apollonio, O. Brüning (chair), H. Burkhardt, R. Calaga, O. Capatina, S. Claudet, R. De Maria, B. Di Girolamo, P. Ferracin, P. Fessia, J. Gascon, E. Jensen, R. Jones, R. Kersevan, H. Mainaud Durand, M. Martino, V. Parma, Y. Papaphilippou, H. Prin, D. Ramos, A. Rossi, L. Rossi, E. Shaposhnikova, L. Tavian, E. Todesco, R. Tomas Garcia, S. Yammine, D. Wollmann, M. Zerlauth.

Excused: G. Arduini, M. Giovannozzi.

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

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

Indico link: https://indico.cern.ch/event/590397/

O. Brüning announced that due to technical problems the minutes of the previous TCC are not yet available. Nevertheless, no actions were defined.

Beam-Beam Long Range Compensation – Experimental plan for 2017 (Y. Papaphilippou - slides)

Y. Papaphilippou recalled the concept of beam-beam long range wire compensation. For large separation, the beam-beam long range kick can be approximated by the one of an infinite wire. The compensation has to be 'local', i.e. at a phase advance of 90° with respect to the IP, and with the largest possible Beta function. This makes the area of Q4-D2 an interesting area for compensation. L. Rossi asked if the area around the Q4 towards Q5 would be still acceptable for compensation. Y. Papaphilippou explained this is not the case, as for the present LHC other constraints exist. Another factor to be considered is the asymmetry of the optics. The optics is symmetric between the Q1 magnets left and right of the IP, where 50 % of the encounters occur. Initially it was considered ideal to place the beam-beam wire compensation where beta functions are large and with an aspect ratio of 1. In principle, one wire from one IP side (and double the current) could have the same compensation effect (between TAN and D1) in this setup.

However, recent studies for HL-LHC revealed that the optimal compensation is achieved for an aspect ratio of 2 or 0.5, underlining the importance of the long-range beam-beam encounters over the length of the triplet magnets where the optics functions are no longer symmetric wrt the IP. This points to a wire position between the TAN and Q5. In this location one wire per IP does no longer provide good compensation due to the optics anti-symmetry. Instead one needs two wires per IP, powered individually in symmetric locations. Due to the difficult integration of the device in this area, it was decided to have the wires embedded in tertiary collimators between D2 and Q5. In IR5 the horizontal TCT and the TCL will be replaced with wire-embedded collimators. In this case, the optics is very close to anti-symmetric between the two locations. In IR1 the vertical TCT will be replaced with a wire-embedded collimator. The new TCL will be placed downstream of Q4 due to integration constraints, where the optics is not anti-symmetric. There's an ongoing discussion for moving the TCL to a more favourable position, considering the related machine protection implications. O. Brüning asked if the jaws will be independently powered. Y. Papaphilippou explained that only one will be powered, the other is only for tests.

Four wire-in-jaw collimators were ordered from CINEL and are foreseen to be installed in the EYETS 2016-17. For 2017, considering the tight schedule, a scenario with only two collimators in IP5 should be devised.

Tests will be done at 6.5 TeV (flat bottom disregarded) and the devices should be included in the standard commissioning and machine protection tests.

Concerning the experiments, a 'strong' Beam 1 would be needed with a few nominal trains at 25 ns (possibly with $1.3*10^{11}$ intensity) and an emittance which should be small enough to produce a representative long range beam-beam effect. For the 'weak' compensated beam (Beam 2) few bunches are sufficient (many options), with the maximum intensity allowed by machine protection constraints. Presently round optics with β*=~33cm is the preferred choice (ATS or nominal), enabling the enhancement of the LR effect, but flat optics could also be used (if commissioned).

Two scenarios for tests are proposed. Scenario 1 (only two wires left and right of IP5), potentially for 2017, with IP1 with large separation and IP5 with a separation such that lifetime would be affected by the long range beam-beam interactions. Scenario 2 (four wires), potentially for 2018, for which both IP1 and 5 have separation such that lifetime would be affected. The main observables to be monitored are lifetime, tail diffusion (for which it's important to have halo diagnostics) and tune-spread. O. Brüning suggests establishing a criterion for acceptance and then to reduce the crossing angle progressively until the beam parameter falls below this limit (e.g. lifetime as a basic observable, tail diffusion, halo, tune spread) and to demonstrate that the powering of the wires can re-establish the acceptance criterion.

The effect of wire compensation was simulated, predicting the beam intensity decay (lifetime) and the decay constant. A significant gain is predicted by simulations, especially for small crossing angle.

Y. Papaphilippou recalled the 1-day workshop, which is going to be held on 20th March. He also stressed the importance of gaining experience through MDs in 2017. O. Brüning asked if the support of the TCC could help for getting high priority to these tests. L. Rossi suggested giving a recommendation at the LMC when presenting the MDs for 2017.

R. Calaga asked why Beam 2 was chosen for the tests. R. Jones explained that the coronagraph for halo monitoring is only installed on Beam 2, so this was the natural choice. Y. Papaphilippou added that it is true that the two beams are behaving differently, but historically the behaviour has changed, so there's no reason to select one beam over the other. Furthermore, the tests will provide relative measurements, so the comparison will still be valid.

S. Redaelli remarked that from a hardware point of view, the collimators were produced at CERN and are ready; Y. Papaphilippou confirmed that the issues are related to the installation and the readiness of infrastructure.

LRBB readiness of HW and installation (A. Rossi - slides)

A. Rossi recalled the plans for tests in the LHC, namely demonstrating long range beam-beam compensation using a local wire on both sides of the IP on a “weak” beam, where the BB effects from the “strong” beam are enhanced.

The advantage of using wire-in-jaw collimators is to have one wire per IP side, on incoming and on outgoing beams, at a favorable location. The wires are moving in the same plane as the beam crossing and there’s as well the possibility to move the wire in the perpendicular plane (collimator 5th axis) to adjust for orbit offsets. L. Rossi asked if the maximum temperature that could be reached during the test was estimated. A. Rossi explained that with active cooling the maximum temperature is reached in a small part of the elbow at the exit of the jaw and amounts to 180°C. L. Rossi asked if the status of the cooling of the device is going to be interlocked. A. Rossi commented that there’s no measurement of the cooling water flux, but just an indirect temperature measurement of the wire through a resistive voltage measurement. In addition, the measurement of the temperature of the jaw is available which is already interlocked by default through the collimation controls system.

A. Rossi presented the layout of the wire-in-jaw collimator. L. Rossi asked how is the wire inserted in the jaw during production. A. Bertarelli replied that the tungsten block is excavated to place the wire in a groove behind the surface of the jaw.

The collimators in IP5 will replace the present TCL.4L5.B2 and the TCTPH.4R5.B2. A document is under preparation to describe the changes; L. Rossi commented this should be approved also in LMC. S. Redaelli commented that the ECR for installation has already been approved in the LMC, whereas for the function of the interlock procedure is to go via MPP and LMC.

A. Rossi described the current status of the activities: the tests of the jaws under vacuum were completed in October 2016. TCTW collimators are ready for electrical tests, to be checked in particular that the LVDT is not affected by the wire. The TCTW installation in Point 5 is foreseen in February and March 2017.

ACTION: A. Rossi should give an update after the installation, with a statement on the readiness of the wire-in-jaw collimators for tests with beam in 2017.

O. Brüning asked if also the related beam instrumentation is ready. R. Jones confirmed that all instrumentation mentioned in the talk by Y. Papaphilippou will be available. The resolution of the coronagraph is 10^{-3}, it has to be verified if it is enough. Y. Papaphilippou added that to see the effect on lifetime one should go close to beam core (3 sigma), where the coronagraph should be sensitive. The coronagraph cannot be operated during standard operation with the BSRT. S. Redaelli commented that diamond BLMs could also be used for the MDs.

A. Rossi will soon send an invitation to the workshop in March.

S. Redaelli added that he will propose to dedicate 1-2 shifts with beam for testing, including the functionality and the interlocks of collimators. The possible support from HL-LHC TCC to his proposal should facilitate the tests.

Status of triplet cryostat and magnet support scheme (D. Ramos - slides)

D. Ramos presented the status of the studies on triplet cryostat and magnet support. The same alignment principle in use for the LHC is proposed to be used also for HL-LHC. The preference is for the design of column support posts, as it is easier to predict deformation and the structure is stiffer, but the LHC layout cannot fit a larger cold mass plus pumping lines. Integration inside the cryostat is driven by the 100 mm pumping lines and the free longitudinal cross section for HeII and the size of phase separators.

For the new LHC triplet cryostat due to space constraints it was decided to keep the same cross-section dimensions as for the present LHC, but creating an offset in the cold-mass and placing the piping on top which is also conveniently closer to the jumpers. In this design, the supports have to come out from the cold mass, which adds complexity, as they can only be mounted if the cold-mass is inside. L. Rossi asked if the support posts are all under vacuum, D. Duarte confirmed this is the case. Thermally, the behaviour is worse than the LHC because a thermalisation at 5K will not be available however, this is not an issue because the total static heat loads are anyway one order of magnitude lower than dynamic loads. L. Rossi noted that the design looks more complicated than today and asked what determines the diameter of the vacuum vessel. D. Duarte explained this is determined by transportation needs. It would have been possible to increase the width at most by 17 mm, but this is not a significant change, it was therefore decided to keep the standard LHC dimensions.

The required distance between cold mass supports to minimize the deformation is 3.5 m, the corresponding document has to be released.

The structure will feature a fixed support in the center of the cold mass, which rigidly connects the cold mass to the vacuum vessel, plus two sliding supports bolted to the cold mass and sliding on the vacuum vessel.

For the cryostating tooling, the principle currently in use for dipoles and SSS will be adopted (extraction sledges).

Concerning stability specifications, the reproducibility in the LHC cryo-magnets was measured after repeated thermal cycles and it was larger than expected horizontally.

Work is ongoing (H. Mainaud Durand and M. Sozin) on the development of frequency scanning interferometry to measure the cold mass position inside the cryostat and therefore allow for alignment corrections if necessary.

L. Bottura asked if horizontal corrections are needed in the structure (as vertical are corrected with shims). D. Duarte replied that it seems they are not needed. L. Bottura commented that this should be further discussed, as it’s important to know if adjustment mechanisms are needed for the IT. L. Rossi supported the statement of L. Bottura and added that this could be tested on the magnet prototypes.

For the vacuum vessel, isostatic supports were chosen to ease the alignment, tests will be carried out this year with LHC magnets. The downside is the requirement of a stiffer vessel. A second iteration on the vacuum vessel is ongoing for manufacturing considerations.

L. Rossi suggested considering the contingency and the possibility that no tests in the STRING will be possible. He recommended developing a plan for tests in the STRING for the longer term.

D. Duarte recalled the different sources of vibrations. Excitations in the order of nm can be generated by background noise. In addition, the helium flow can induce vibrations. O. Brüning commented that studies are available on this topic; R. De Maria could provide a reference. If vibrations prove to be a problem, one could consider an active beam feedback or to increase the natural frequencies of the vibrations by increasing the stiffness.

L. Rossi recommended for the STRING test to equip the magnets to measure vibrations, in order to allow time for modifications, if required. The STRING tests offer a unique opportunity to test also the mechanical behaviour of the components. He therefore suggested making a plan of the measurements to be carried out and to plan for the required diagnostics accordingly. V. Parma commented that the STRING will serve as a validation of the cryostat design, if major changes are needed it could be late for implementation in the final design.

RF options in IR4 (E. Jensen - slides)

O. Brüning recalled the motivation for bringing this topic to the HL-LHC TCC, namely the need of cooling requirements for the design of the cryogenic system in IR4.

E. Jensen introduced the HL-LHC baseline, which is based on the existing single harmonic 400 MHz system, operated with the full detuning scheme due to the increased intensity. He added that there are unknowns for future operational parameters (e.g. bunch length requested by the experiments) for which further options would need to be studied. The related studies require an investment which is small compared to the risk of being limited in the parameter space for future operation.

E. Jensen mentioned the need for controlled emittance blow up to ensure beam stability, which would be easier with a double harmonic system.

With the higher harmonic option, one could go down to a bunch length of 0.85 ns. This solution only allows for the bunch-shortening mode (full detuning excludes the bunch-lengthening mode).

With the lower harmonic option one could get bunches longer than 1.6 ns. This option allows for an increased intensity limit ($2.4*10^{11}$) and an increased acceptance of the beams transferred from the SPS.

E. Jensen recalled the priorities for future studies. The 800 MHz study is ongoing and it exploits the synergy with the FCC study. For the 200 MHz option, no synergy was found up to now, E. Jensen asked for the support to this R&D to prepare for future needs. O. Brüning commented that the required investment is not only in terms of money, but also manpower. As an important focus of the project is on crab cavities, the additional studies must not jeopardize the crab cavity design.

E. Jensen explained that it is not possible to set priorities before LS2, and due to the long developments required, one should not wait with launching the studies. L. Rossi mentioned the relaxed constraints from the experiment on pile-up density, which make the 200 MHz option more interesting because of the extended intensity limit. E. Jensen agreed on putting the priority on the 200 MHz option, considering that the 800 MHz is already covered by the FCC synergy.

R. Tomas Garcia commented that possible limitations could be overcome in other ways than the bunch lengthening in order to deliver more luminosity.

O. Brüning mentioned the decision to introduce project steering meetings periodically in the future, exactly to take such kind of decisions.

S. Claudet concluded that as the decision is not yet taken and that the cryogenic system design must be kept open at this stage to connect any line once a decision is taken.

TCC actions (A. Apollonio - slides)

A. Apollonio presented tables reflecting the actions followed-up by the TCC. He focused on the ones that still need a follow-up. O. Brüning mentioned that some of them should be treated already in the Chamonix workshop. For action 16 on the "evaluation of Q4 magnet options (4 correctors, 3 correctors and MQYY option) and impact on costs and performance", L. Rossi mentioned that the optimization involves more WPs (cryo, circuits, etc), this action requires offline discussions to follow it up. M. Zerlauth mentioned that the Magnet Circuit Forum is the natural forum for this kind of discussions across WPs. O. Brüning proposed to circulate the table among the WP leaders for comments. Regarding the 20th action, P. Fessia mentioned that WP6a should be also involved. O. Brüning suggested sending all comments to A. Apollonio in order to update the list.

Update on circuit drawings (S. Yammine - slides)

S. Yammine presented the updated version of the HL-LHC circuit drawings. P. Fessia reminded about the discussion on the Q4 powering and the importance to reflect the correct position of the power converters in the different galleries.

The circuit drawings are accessible from the magnet circuit forum webpage. M. Zerlauth mentioned that the approval owner of the drawings has not been changed in the past, so it is still S. Russenchuck. One could consider revising this and have Mr. Circuit or the magnet circuit forum in charge of the approval.

H. Prin commented that also for the polarity check someone should be named responsible. L. Rossi commented this should still be Mr. Circuit.

O. Brüning announced that the next meeting of the TCC will be on 9th February, following the project steering meeting. L. Rossi recalled the scope of the project steering meetings, serving as an interface with WP leaders and GLs to align on deliverables, decisions, etc. The meetings will be held approximately every 3 months, the first in the week following the Chamonix workshop.