24th Meeting of the HL-LHC Technical Committee

Participants: C.Adorisio, A.Apolonio, G.Arduini, A.Ballarino, V.Baglin, I.Bejar Alonso, D.Berkowitz Zamora, E.Bravin, R.Bruce, O.Bruning (Chair), H. Burkhart, R.Calaga, O.Capatina, S.Chemli, S.Claudet, P. Fessia, J.Gascon, M.Giovannozi, B.Di Girolamo, B.Goddard, E.Jensen, R.Jones, D.MacFarlan, A.Macpherson, T.Otto, Y.Papaphilippou, D.Perini, M.Pojer, H.Prin, S.Redaelli, F.Rodriguez Mateos, A.Rossi, G.Rumolo, F.Savary, J.-P.Tock, R.Tomas, E.Todesco, R.Van Weelderen, S.Weisz, D.Wollmann, M.Zerlauth.

Excused: M.Bernardini, F.Bertinelli, E. Cennini, F.Cerutti, P.Collier, B. Delille, G.De Rijk, M.Lamont, L.Rossi, L.Tavian, A.Siemko

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

HL-LHC PLC/TC homepage: https://espace.cern.ch/HiLumi/PLC/default.aspx

Indico link: https://indico.cern.ch/event/373545/

O.Brüning opened the meeting by going briefly through the actions of the previous meeting. T.Otto mentioned that the Group leaders were added in the safety approval process. In one of the following TCs, an action plan for the Mo-graphite collimator material should be presented. An update on radiation protection issues for installation should be followed up and presented in one of the next TCs.

O.Brüning proceeded by introducing today's agenda.

Update on integration and space constraints in IR4, S.Weisz – slides

S.Weisz introduced the space attribution in Point 4 (P4). The information is linked to several EDMS documents (references given in the slides). He recalls the layout of the left part of the Straight Section at LHC P4 with the existing equipment. There is a dogleg with two magnets D3 and D4 giving a final 420mm separation and 3 quadrupoles as part of the matching section of IR4. The devices considered for this integration study are:

- A modification of the existing synchrotron light monitor (BSRTM), with a new optical path and experimental hutch from the existing BSRTM to UA43. The optical path requires a reservation of 200 mm diameter and must be as short as possible.
- A new light monitor will be also constructed with an in-vacuum mirror located at 20 m from D4 towards D3, and an associated optical path and hutch.
- Two fast wire scanners for HL-LHC per beam and per plane, with a total length of 500 mm, located next to the existing scanners, at both sides of P4. A detector will be

located some 10 to 20 m downstream of the scanners with further details still to be worked out.

- A new set of transverse damper equipment will be installed and space is reserved close to the existing one. More precise specifications will be needed for the exact equipment size and location.
- A hollow e-Lens is being studied and there will be one device per beam, one on each side. The exact longitudinal location has to be defined, but it will require around 6 to 8 m and beam-to-beam separation of 420 mm. It is important to stress that it needs cryogenics.
- A set of 800 MHz RF cryo-cavities are being studied, comprising two cell cryo-modules of 2.7 m each, plus vacuum valves, i.e. around 7 m in total. These modules would just fit transversely, with beam1/beam2 allocation optimized to take care of the QRL bellows.
- There was also a discussion on the 200 MHz cavity option, which would be easier to integrate than the 800 MHz option.

Based on preliminary designs of the various systems and summing up all the space needed, it is clear that the central part of the Long Straight Section at P4, with beam separation of 420 mm, is not long enough to fit all known options. There are actually 4 m missing for including both the hollow e-lens and the 800 MHz cavities. The additional space required could be made available by moving the D3 separation dipoles closer to D4. This would absorb the margin between “nominal” and “ultimate” fields that is part of the design of the D3, D4 magnets. M.Giovannozi mentions that the D3 are slow trainers and maybe reaching the “ultimate” field is difficult. E.Todesco points out that this is true for at least one of them (D3L4). M.Pojer confirms this from the recent LHC hardware commissioning.

R.Calaga asks if the e-lens can move towards the BSRTM on the other side of D3. S.Redaelli answers that the rapid change of the beta functions and the difference between horizontal and vertical sizes are not ideal for the e-lens. R.Calaga says that this is also the case for the RF cavities. S.Weisz stresses that indeed the precise longitudinal positions will depended on the optics. He urges the different WPs to come up with any additional demands for space allocation in LSS4 that have not yet been identified.

Discussion

S.Redaelli asks which of these options are in the baseline. S.Weisz answers that this should be clarified in the discussion. S. Redaelli asks if the optics in IP4 have any special constraints. For example, it would be better to have the e-lenses of both beams on one side of IR4 for the present LHC optics, but this is not the case for the HL-LHC optics. This indicates that there is room to optimize the optics for the available locations where e-lenses could be installed. G. Arduini mentions that some of the devices will have special requests for optics and it is important to know these requests in order to check their feasibility. R.Jones stresses that this is indeed what was done for the mentioned instrumentation in IR4.

S.Claudet points out that there are indeed space constraints in P4 but there are also equally important time constraints to take into account. From the cryogenics point of view, LS2 is not the best period for working on the QRL of P4. What would be preferable is to recover some equipment during LS2 and foresee an installation during LS3. O.Brüning stresses that this is indeed a very important information that needs clarification and he understands that LS2 activities are targeting the actual LHC in priority. R.Jones points that at the same time there is need for some prototyping to be done in the actual LHC to be ready for HL-LHC. S.Redaelli agrees that for the hollow e-lens this is indeed the case. O.Brüning stresses that a step by step approach is needed for first approving the hollow e-lens as baseline of HL-LHC and then discuss the implications for installation in the LHC during LS2. He reminds that the LS2 organization is not the responsibility of the HL-LHC project and that J.M.Jimenez is the LS2 coordinator, who has to report on a technical level to the LHC and IEFC Machine Committees. He adds that there should be a follow up discussion by R.Calaga on the crab cavities scheduling during LS3 and LS4. Answering a question of S.Redaelli, S.Claudet points out that the intervention is not transparent for cryogenics depending on its position. E.Todesco mentions that in his opinion it is not correct to eat margin between the nominal and ultimate field of D3 and D4. O.Brüning adds that WP2 and collimation team should investigate the implications of installing the hollow e-lens. At the same time, the cryogenics team should investigate the impact on the infrastructure and if there are still issues regarding the available space, the displacement of the dipole magnets should be considered. P.Fessia mentions that in the issued ECRs, the equipment have larger latitude then their real length, and this should be taken into account when the optics optimization is pursued. He further stresses that the transversal space is an equally important parameter and that moving D3 will have a cost impact, as there may be modifications with respect to the jumper, the QRL, etc. S.Redaelli reiterates his question regarding which of this equipment is in the baseline. P.Fessia answers that all equipment apart the 800MHz and the hollow e-lens. A.Rossi stresses that a complete optics optimization will be needed, as a round beam is necessary for the hollow e-lens. O.Brüning mentions that it may be also good to check if the electron beam can be shaped following the proton beam. S.Redaelli commented that an experimental validation of elliptical shape electron beams with the parameters required for collimation does not exist yet, so at this stage, round beams should be assumed. E.Jensen points out that the ADT upgrade is very important for HL-LHC, as it will increase the kick amplitude but also the system will be able to act in a wider band. He will check whether the length could be reduced but also if it could be moved in another location, thereby answering a question of R.Jones. O.Brüning suggests dedicating a future TC on the above-mentioned subjects.

Actions:

- In a future TC, the positioning of the hollow e-lens (but also the other equipment) should be reviewed with respect to optics and collimation performance (WP2, WP4, WP5, WP13).
- A discussion between WP4, WP5 and WP15 should be initiated for narrowing down the uncertainty in positions and lengths.
- A timeline for installation and tests should be also presented, taking into account cryogenic infrastructure constraints (WP5 and WP9)
- The impact of moving D3 with respect to performance and cost should be also further detailed (WP2 and WP3)

- E.Jensen should verify the length and position of the new ADT system.

Decision on SPS crab cavity location, B.Goddard – slides

B.Goddard presents the summary of the discussions on the crab cavity location for tests in the SPS. There was a lot of iteration for that subject during the last month and mainly four locations were investigated:

- In LSS4, after QDA417, inside the COLDEX alcove, the original baseline
- In LSS5, after QF518, on the ECX5 platform
- In LSS5, after QD517, in an alcove enlargement
- In LSS6, after QDA617 in enlarged tunnel

There are two general features to be taken into account. First, it was agreed that it is reasonable to assume that the facility will be needed after LS2, and it cannot be assumed a temporal decoupling of the crab cavity installation with the dump installation in the same machine zone. Second, none of the options is compatible aperture-wise with the FT beam separatrices in the horizontal plane, so the CC test stand needs a by-pass, like COLDEX. Around 10 m of length are assumed.

Each option has some specific features:

- The LSS4 alcove houses the COLDEX test stand and seems a good location for the Crab cavity test stand from the machine point of view, as it is similar to COLDEX. However, the crab cavity test stand installation in LSS4 would exclude a future operation of COLDEX which is judged to be an asset for the HL-LHC related studies.
- The ECX5 platform in LSS5 was completely excluded, as it is incompatible with the planned dump in the area. In fact, the CC aperture will intercept the dumped beam trajectory.
- The LSS5 alcove seems to work from the optics point of view but there is significant impact on the equipment for the LSS5 dump. Although the kicker voltages and tracking functions are almost identical, there is a 0.8 σ loss in the horizontal aperture at MKDV and 1.5 σ at MKDH, for the circulating beam. There is also some minor loss in the MKDH vertical aperture. Finally, the dumped beam position is nearer to the surface of the dump block (i.e. worse) by about 1.5 mm.
- The LSS6 enlarged tunnel is the most flexible and decoupled solution.

In this respect, the feasible locations are in LSS4 after QDA417 (alcove), but need to replace COLDEX and in the LSS6, after QDA617, in an enlarged tunnel. This last option has no constraints from the machine side. A surface area of approximately 200 m^2 is needed for the crab cavity test stand infrastructure and might be available in BA6 (this is being currently checked together with TE/ABT). It should be stressed that it is excluded to run the crab cavity tests parallel standard SPS operation when filling the LHC or operating the SPS for FT physics. Extra dedicated MD time needs therefore to be planned in the SPS. Some redesign of support structure is also needed for the passage.

In conclusion, with the increasing incentive to keep COLDEX operational in LSS4 over the coming runs, it was agreed by HL-LHC and LIU to change the baseline Crab Cavity test installation from LSS4 to LSS6.

Discussion

E.Jensen says that formally this is a recommendation but the management has to take a decision. O.Brüning agrees that the accelerator sector director should take the decision. R.Calaga mentions that it may be worth checking in more details the integration implications in that area. He wonders if this should be treated in a future TC. B.Goddard answers that the TE-ABT group is looking after the surface issues in BA6 but agrees that a follow-up is needed. S.Claudet asks if the choice of LSS6 implies installation of dedicated infrastructure, as BA4 should not be touched. In particular some extra pumping will be needed in BA6. O.Brüning points out that with respect to the budget of the LSS4 solution, there is indeed some extra but small cost to be included. He also asks what is the impact on the installation time-line. B.Goddard answers that the use of the 2016-2017 YETS for installation is still valid. A.Macpherson mentions that the cavities will be kept in the SPS during 2017 and 2018. S.Chemli suggests that the LIU Integration working group chaired by J.Coupard should be handling the CC integration in the SPS. R.Calaga thinks that the coordination and the feasibility should be the responsibility of the HL-LHC TC but the LIU integration working group should go deeper on the integration details. A.Macpherson together with. J.Coupard will coordinate this and come back in a future TC to report on the integration details for the new location.

The HL-LHC TC recommends changing the baseline Crab Cavity test installation from LSS4 to LSS6. A presentation in a future TC should be made regarding the integration in the surface and in the tunnel of the CC infrastructure.

Status and Plans for 1/4 wave 200MHz and 800MHz higher harmonic system, R.Calaga – slides

R.Calaga introduces the need for harmonic RF systems in the HL-LHC era. The longitudinal plane stability with respect to couple bunch instabilities (loss of Landau damping) seems ok for HL-LHC intensities. The impedance though is expected to increase and thus the 50 ns variant will be unstable and a trade-off with an increased longitudinal emittance could be foreseen. A 2^{nd} harmonic system will indeed help the beam stabilization. Two options have been proposed. First, it is considered to modify the present 400 MHz system and add a 2^{nd} harmonic 800 MHz system, for stability and bunch manipulations. The second option assumes a compact 200 MHz SC system as main RF, but in that case, a 400 MHz is absolutely necessary for stability and bunch length preservation. Two modules per beam will be needed.

R.Calaga proceeded by explaining that IR4 is used for housing the main 400 MHz system and necessitates the already existing dogleg of 420mm to separate the two beams. For the harmonic system, several consideration favor its placement to the same area, including the zero dispersion, the proximity to the main RF system for phase synchronization (avoid long links) but also the use of existing RF power infrastructure to cope with important beam loading. He adds that integration of a similar size RF system for the former ACN capture cavities was already done and therefore it is ideal to use that location. He stresses at this point that any equipment put in that area (e.g. hollow e-lens) should have a minimum impact with the existing RF infrastructure. A schematic of the zone is presented similar to the one in the previous talk of S.Weisz.

The existing power of 300 kW of the present RF system is already at the limit, but it will not be sufficient for the HL-LHC. There is no straightforward solution for this problem, as a number of individual components of the power chain present this limitation. A solution is being proposed by operating the cavity in a fully detuned mode (AKA optimum detuning), thereby compensating the accumulated 1-turn phase shift. This scheme has the advantage that the power becomes independent to the beam current. It was already successfully tested in MDs with 50 ns LHC beam during run I. The consequence of this scheme is that the phase is modulated and the bunches are delayed by 85 ps. For a symmetric filling between the two beams, the scheme will only result in a modulation of the collision time. O.Brüning asks if this is only a time or also a position modulation, as in the latter case this may have an impact to LHCb. R.Calaga affirms that it is indeed only a time modulation for symmetric filling schemes where the abort gaps coincide for both beams. On the other hand, it should be checked if there is an impact for certain exotic filling schemes. These are indeed the working assumptions but there is still work to be done for making the scheme operational.

R.Calaga continued with the presentation of the motivation and requirements for a 2nd harmonic cavity. There are two possible modes, bunch shortening (BS) and bunch lengthening (BL). The BS mode is more preferable as the BL mode imposes a strict phase control with respect to the main 400 MHz system and the length of the system is quite important. The technical design will be soon launched followed by prototyping and tests. There are already some ideas of how to integrate the system in P4. S.Weisz points out that there may be an issue with the position of the QRL. R.Calaga replies that this is not the final configuration. If the proximity with the QRL is a problem, a square module configuration will be considered. The cryostat is similar to the one of crab cavities. Indeed, the longitudinal position depends on integration and the cryogenic equipment.

A 200 MHz main RF system is another concept, which will allow the capture and acceleration of higher bunch intensities in the HL-LHC. Four cavities, with 6 MV each, are necessary for providing reasonable bunch lengths. The 400 MHz will be kept as a 2nd harmonic system. Regarding power, the limit is at 500 kW and the overall design looks feasible. A preliminary table regarding cryogenic requirements is presented, similar to the one shown in the last Chamonix workshop. It comprises the static, dynamic and total power but some uncertainty should be expected especially for the harmonic systems. The existing RF system requires 1360 W, the 800 MHz system with max voltage will require 640 W of cryogenic power, whereas the 200 MHz is the less demanding with respect to cryogenic power (200 W). E.Jensen points out that if the 200 MHz is followed-up, one module of the 400 MHz should be removed. S.Claudet states that from that cryogenics are getting ready for the maximum power needed, i.e. the 400 MHz plus the 800 MHz harmonic system.

R.Calaga concludes by resuming the three options for the HL-LHC RF system. First, a 400

MHz system only operated with the full-detuning scheme for HL-LHC and, as a consequence, the expected phase modulation. As a backup, doubling the system may be considered, which would necessitate a half-detuning scheme. The second option corresponds to a 400 MHz system and a 800 MHz harmonic one, operated in BS mode for stability. It is compatible with the present QRL in P4 and needs around 5 m per beam close to the existing 400 MHz system. The last option corresponds to a 200 MHz as main RF system and one module of the existing 400 MHz as 2nd harmonic system. This will enable higher currents and longer bunches, so a discussion with the experiments should be undertaken. There is no need for additional space, as the 200 MHz system will replace one module of the 400 MHz system. Both harmonic systems need prototyping and technology validation during the next 5 to 6 years.

Action: A discussion with the experiments should be undertaken regarding the impact of longer bunches. This is critical for down selecting between the 800 and 200 MHz RF options.

Discussion

O.Brüning asks that apart for the MDs on stability, what other MDs should be done for the full detuning scheme. He adds that the 800 MHz harmonic and 200 MHz main systems should be considered as scenarios in case of failure of the CC, for recovering performance. The RF group should assert that the option 1 (without harmonic system) is ok for stability. R.Calaga answers that there are indeed a number of MDs planned and suspects that the full detuning should be demonstrated with the nominal 25 ns beam of run II. He reminds that there is no damper in the longitudinal plane and the behavior of HOMs in the run II conditions is not yet known. The first priority is indeed to prove that the full detuning scheme works irrespective of the use of a harmonic system. He adds that flattening the bunch for gaining stability is to be considered completely decoupled with the crab cavities. S.Claudet mentions that from the cryogenic point of view, the 200 MHZ system is less demanding, whereas the 800 MHz is the most demanding. R.Calaga stresses that the 200 MHz system option has also the advantage that it is space neutral. Regarding the heat load, he adds that there will be a new cryomodule for the 800 MHz cavity which will be more efficient. G.Arduini asks why the 50 ns was considered. R.Calaga answers that it was just done for completeness. He adds that the 8b+4e scheme is a better back-up solution, reducing only by 20% the peak luminosity. R.Tomas mentions that the 200 MHz has the additional advantage of suppressing e-cloud. O.Brüning stresses that the presentation was meant to give information for the space conflict in P4. The different scenarios should be treated in another meeting (probably a PLC). R.Calaga suggests that until there are results from MDs in the present run, the space in P4 should not be reserved for other equipment. He further raises a question, whether with some further integration optimization, both 800 MHz and hollow e-lens could fit in the dog leg. O.Brüning states that it should be also investigated if the hollow e-lens or any other equipment can be placed between D3 and D4. P.Fessia stresses that budget issues should be also considered and O.Brüning absolutely agrees.

Next TC on the 30th of July.