M.Zerlauth

5th Meeting of the HL-LHC Parameter and Layout Committee

Participants: Andrea Apollonio, Gianluigi Arduini, Oliver Bruning (chair), Helmut Burkhardt, Samy Chemli, Francesco Cerutti, Riccardo De Maria, Stephane Fartoukh, Brennan Goddard, Erk Jensen, Mikko Karppinen, Roberto Kersevan, Mike Lamont, Dominique Missiaen, Lucio Rossi, Ezio Todesco, Rob Van Weelderen, Daniel Wollmann, Markus Zerlauth (scientific secretary)

Excused: Rama Calaga, Jorg Wenninger

The slides of all presentations can be found on the website and Indico pages of the PLC:
HL-LHC PLC homepage: https://espace.cern.ch/HiLumi/PLC/default.aspx
Indico link: https://indico.cern.ch/conferenceDisplay.py?confId=259003

O.Bruning opened the meeting by approving the minutes of the previous meeting and reviewing the agreed decisions and actions.

The PLC slot is now defined to be Tuesday mornings, at 09:30 in room 6-R-012.

Concerning the integration study for crab-cavities: Paolo Fessia has only been appointed recently, hence first estimations on the assessment of space requirements can only be expected after the summer.

The task to establish a list of consolidation and actions that will NOT be performed during LS1 (as input to plan the next longer shutdowns) has been given back to the PLC. Action: Invite Katy Foraz for an upcoming PLC to start working on this list.

S.Chemli commented on the ongoing action concerning the implementation of a first HL-LHC layout in the Layout database. Following a discussion with the database team in CO it turns out that branching within a DB is too difficult to realize. One will either have to work with different machines or versions; hence the issue of configuration management remains to be addressed. The creation of the baseline will be done soon however as first documents are being received.
O.Bruning recalled that whatever solution chosen it should be possible to do a selection of the HL-PLC layout to only extract data applicable to HL-LHC. He reiterated the importance of having a first version of the layout drawings for the HL-LHC meeting in mid-November 2013 in Daresbury. This will require a lot of work by H. Prin who is currently heavily involved in the SMACC activities.
Action: S.Chemli to report back in September along with I.Bejar Alonso (on EDMS Project structure) in order to allow for the archiving of first documents.

O.Bruning announced the upcoming CERN internal LIU review planned for the end of October 29-31st (CERN internal review + MAC, to be held outside CERN however), as well as the HL-LHC collaboration meeting in Daresbury from 11th-15th of November.

HL-LHC optics status (R.De Maria - slides)

The optics repository /afs/cern.ch/eng/lhc/optics/HLLHCV1.0 hosts the **latest optics** and layout model for the HL-LHC, following the progress in the triplet/D1 area up to June 2013.
The version HLLHCV1.0 is now frozen and available for integration and simulation studies, some areas are however still under further development (e.g. squeeze optimizations).
In several areas the layout and optics is still pending validation by the relevant WPs (e.g. TAN Q4 area, Q5 magnet types in IR1-5-6, orbit feedback with MCBX only), and the impact of ground motion stability, field quality and beam-beam effects on performance are still being evaluated.
R.de Maria will be the responsible person to drive the interactions with the WPs.

Action: R. de Maria to report back in September on progress with validation list

Optics studies are continuing, addressing for example more radical changes in the Q4-Q7 region to improve the optics flexibility and reduce the crab voltage demands (although currently not part of the baseline).
Stephane and Ezio commented that Q4/Q5/Q6 cannot yet be freely exchanged as the corrector packages would not fit the new slot. The quad cold-mass could be exchanged, but some redressing would have to be done.

As in principle TOTEM is assumed to disappear until LS3, no optics with a $\beta^*>15$m (needed for VdM scans) are currently being considered.

The required **Crab cavity voltage** is currently calculated as a result of: operational mode (full or partial crabbing), crossing angle (intensity, β^*, emittance), layout (location and aperture of surrounding elements) and the optics.

For full crabbing (no transverse offset for $1\sigma_z$ particles) with nominal parameters (β^* = 15 cm, θ_c = 590 µrad) this currently yields a V_{crab} of 12.2 MV.

Voltage reduction options are being studied, either through the module layout (crossing plane independent or optimized), an increase of the β-functions at the present position (by relaxing pre-squeeze β^*, design of the matching section) or, if possible, finding a position closer to the IP.

Finalizing a fully integrated layout is however challenging (because of the many constraints from TAN, TCT, TCL, LR wires, crab, D2, Q4, neutral debris, collimation, dump protection, background), hence the final location might have to shift back towards the arc, resulting in the need of a voltage increase. Achieving 10cm of β^* would require a total voltage of 15MV from the crab cavities.

The **D2 aperture**, initially defined as 105 mm (SLHC-PR 55 in 2010) was recently reduced to 95 mm (S. Fartoukh) and is being explored to:

- leave sufficient space for crab cavities in a high beta region,
- remain compatible with a TAN aperture that does not limit the β* reach more than the triplets,
- D2 has to be protected by the TAN (TAN aperture ≤ D2, but TAN beams are larger and $n_{1TAN} > 7$ according to LHC Report 633);
- D2 is not protected by the TCT from the incoming beam ($n_{1D2} > 14$?).
- Magnets, energy deposition and collimation performance are being studied by WP3, WP10 and WP5.

S.Fartoukh commented that the COLL team already agreed to be able to protect the triplet aperture at 12 σ, hence the simulations should not be performed with the suggested 14 σ.

G.Arduini commented that the positioning of the beam screen needs to be looked at in terms of electron clouds.

E.Todesco requested to receive the list of correctors required around the main quads in the insertion regions.

Answering a question on the sensitivity of crab cavities to radiation/integrated dose, F. Cerutti replied that this will soon be addressed together with R. Calaga.

R. de Maria commented that a fallback version with flat beams is still being investigated, which is why the optics team is trying to avoid introducing limitations which might fully exclude one of the two possible scenarios.

D1 aperture reduction to 150mm (F.Cerutti - slides)

F.Cerutti summarized the implications wrt to the impact of the collision debris for the recently agreed reduction of D1 aperture from 160mm to 150mm.

Based on an updated FLUKA model, the deposition hot spot now shows to appear in the orbit corrector between Q1 and Q2 as well as in the ends of Q2 and Q3 (which is consistent with the slides shown by R. de Maria).

Still in none of these locations the dose will be exceeding 30 MGy for an integrated luminosity of 3000 fb^{-1}.

Comparing with the present LHC, the peak dose for HL-LHC is more or less equivalent to the current LHC at 300 fb^{-1}. This is mainly due to the increased aperture and even more importantly the additional shielding foreseen.

The current model assumes a beam screen interruption in the present machine of ~ 45cm for the Q1-Q2 interconnect and ~15cm for the Q2-Q3. When increasing from a 10 cm to a 50 cm gap, the total peak dose would increase to ~35 MGy in some

locations.

β* leveling will not impact much the deposition studies, as the major contribution is due to the crossing angle. Additional work needs to be done to address the problem of neutron debris which – if the crossing angel becomes too large – cannot be absorbed by the TAN anymore. The decreased aperture has only very little influence on the simulated peak doses (<20%).

The integrated power dissipation in the triplet and D1 cryostat could reach up to 650 W. R. van Weelderen reminded that the current system is only designed for 500W (with the current limitation of the heat exchanger tube this reduces to some 300W).

The current (measured) heat load is around 150W on the LHC triplet, mostly absorbed by the cold-mass due to the very thin beam screen. Hence the current scenario would demand for an increase of the extracted power by a factor of 4.

In summary, the first study on the foreseen 150mm triplet indicates that continuous tungsten shielding of 16mm in Q1 and 6mm up to D1 allows not to exceed the peak dose value expected for 10 times less integrated luminosity in the present triplet and to keep peak power density quite below the envisaged quench limits. The beam screen shielding interruption in interconnects (along the BPMs) features an evident worsening on the front face of Q2B, Q3 and in the CP orbit corrector. Along the Q1-D1 string, cold mass and beam screen are each subject to a load of more than 600W at $5L_0$. No significant effect is found for the D1 aperture shrinking to 150mm, potential optimization of the Q2 effective aperture need to be further studied. The HL-LHC crossing angle and (TAN) aperture are expected to expose the downstream elements (D2 in primis) much more than now, especially for horizontal crossing.

Oliver commented that one should envisage operational scenarios with lower crossing angle (in case we might be limited at some point by the crab-cavities).

Action: The total heat load dissipated in the triplet cryostat requires follow-up. Stephane commented that a deposition study with 45/135 µrad of crossing angles (i.e. a 45 µrad tilt with respect to present design) should be considered.

Cryogenics separation vs powering for IR1 and IR5 (R.van Weelderen - slides)

R.van Weelderen briefly recalled the cryogenic baseline for HL-LHC, including 2 new cryoplants at P1 and P5 for the high luminosity insertions, a new cryoplant at P4 for the SRF cryomodules and new cooling circuits at P7 for the superconducting links and deported DFBs.
The main issues to be settled for a detailed baseline in the high-luminosity insertions IR1 and IR5 are the definition of:

1. range of hardware to be serviced by the new cryoplants
2. redundancy service between existing and new cryoplants

3. operating temperatures of MS, D1 & IT magnets
4. location of ARC, MS, D1 & IT Current Feed Boxes (resp. DFB- A, L, X)

During a follow-up meeting the following proposal has been endorsed:
The arc cryostat (as of Q7) remains completely separated from matching section + inner triplet (the latter to be fed by the new cryoplant). The main reasoning is to have the possibility to quickly warm up and cool down the matching section.
The DFBX and DFBL (servicing D1&IT, respectively the MS) will be brought to the surface, while the DFBA (servicing the continuous arc cryostat) remains in the tunnel.

Additionally the Q5 and Q6 magnets are proposed to work at 1.9K to increase the operational margin by ~ 20% (cryogenics already need a solution for a short magnet to function at 1.9K, which can be extended to Q5 and Q6). The existing QRL needs anyway to be modified up to the Q6, hence modifications can be integrated if decided upon early enough.
Action/Decision: E.Todesco and CRYO to verify the implications of 1.9K (cryostat, piping...), but 1.9K is approved as current baseline.

It remains to be clarified whether the crab cavities do require saturated or pressurized (1 bar) He at 1.9K. With pressurized helium one would not need to pump in the vicinity of the cryostat, which would be beneficial for the stability of the He bath.
Action: E.Jensen to verify the operational working point

The level of cryogenic redundancy remains to be detailed at a later stage as well as the space requirements for the cold connection box (CCB) and shaft-piping.

Update on vacuum/beam screen needs (R.Kersevan - slides)

R.Kersevan presented an update on the vacuum/beam screen (BS) needs following recent interactions with the optics and BI teams. The update includes preliminary studies of beam screen behavior under quench conditions, the cold BPMs for the triplets as well as possible W shielding.
BI proposes to use a new type of strip line pickups with 4 electrodes. This new BPM geometry will require a more detailed impedance modeling and cooling due to new tungsten inserts, which probably will have to be connected in series with beam screen cooling.
The baseline assumptions for the BS were recalled along with remaining engineering/integration issues. In order to avoid soldering of the BS and guarantee a precise fitting of the external CB surface to the ID of the magnet coil, a 159mm tube with 11mm wall thickness will be used to machine the BS.

Several issues have been settled to advance with the prototype design and fabrication of the BS:

1. Finalize beam-stay-clear area (increased +2 mm ID, see below)
2. Define new BPMs w/ W shielding (discussed with R. Jones et al.)

3. Set number and position of plug-in modules (default is one at each cryostat interconnection)… (same as 2)
4. Define thickness of W shielding bars, and possibly their brazing/fixation technique
5. Define minimum length of prototype (8m, like Q1/Q3?) → 2 m should be enough (job at MME launched soon)

The mechanical behavior of the proposed BS under quench conditions has undergone a preliminary study, showing that during a magnet quench the physical properties of W drive the dynamics of the system and hence define the acting forces. A thinner BS would clearly be preferable; however bonding techniques for W inserts need R&D and prototyping due to different thermal contractions. A smaller annular gap between cold bore and beam screen would keep deformations and stresses down; hence the BS needs to be matched to the inner diameter of the cold bore. W shielding integrated into the BPM design would definitely be beneficial. This requires however a careful design of the cooling path, and an estimation of the impedance contribution due to the modified new geometry.
L.Rossi pointed out that it will be a big challenge to respect the given alignment tolerances, especially in view of the very heavy W inserts which will be fixed on the BS. He strongly recommended measuring the deformation/stress once in realistic conditions such as e.g. SM18 in order to validate the simulations.

Update on survey needs wrt Crab Cavity installations (D.Missiaen - slides)

Reporting on a follow-up on the survey needs in the high luminosity insertions, D.Missiaen reminded that the horizontal alignment will need to be extended into the matching section to cover as well the crab cavities. It remains to be clarified whether a permanent wire needs to be installed for this purpose.
An additional deep reference point close to the Q4 would most likely be satisfying the requirements in vertical direction (in addition to the existing water reference stretching across the IP).
Space reservations for the alignment system should not exceed 25cm in horizontal and 50cm in vertical direction (on top of the equipment to be aligned). This has been confirmed to be compatible with the scenario of transversal waveguides (towards a new cavern next to the crab cavities), but remains to be validated for the scenario of longitudinal waveguides.

Action: Survey/RF to report back on this space reservation request as well for the RR case (i.e. waveguides travelling longitudinally from the crab cavities to the RRs or UAs).

E.Jensen commented that the crab cavities will more likely require an alignment accuracy of down to 0.1mm (compared to the initially announced 0.25mm), which may require continuous (active) alignment of the crab cavities.

Crab Cavities (E.Jensen - slides)

E.Jensen briefly recalled the baseline layout for crab cavities, including 3 crab cavities per IP per beam. Currently a common cryostat to house the 6 individual cavities on one IP side is being studied.

First measurements of the 3 cavity designs are ongoing in SM18. Results with the ULANC – 4ROD design were not satisfying, but suffered problems while testing due to vacuum leaks, wrong flanges,… These are being solved now and the cavity will be retested in the coming weeks.

Results from the ODU-RFD are very encouraging, reaching a Q of 3E9 and quenching only at >6.5MV, which would be sufficient to achieve the 12.2 MV with 3 cavities (while maintaining some margin).

First measurements with the BNL – DQW were also below expectations, but will be tested a 2nd time along with the ULANC model.

In summary, more tests are needed to fully conclude, hence all three cavity types will be retested before the HL-LHC meeting in November. The issue of radiation effects (e.g. neutrons, cryostat, insulation...) remains to be addressed.

In addition the geometry of the current ODU-RFD cavity does not fully comply with the mechanical constraints of integration, requiring a minor change of the support structure.

Replying to a question of S.Fartoukh, E.Jensen answered that the decision of horizontal/vertical crossing needs to be designed into the cavity and cannot be changed on the fly anymore.

AOB (all)

Due to lack of time the presentation on additional glossary definitions was postponed to the next meeting.
The tentative agenda of the 6th PLC meeting on the 3rd of September at 09:30 will be as follows:

- Survey space requirements for longitudinal waveguides of crab cavities (H.Mainaud Durand)
- HL-LHC Layout and EDMS (S.Chemli, H.Prin, I.Bejar Alonso)
- BPM positioning (R.Jones)
- Summary of COLL review (S.Redaelli)
- List of actions/activities post LS1 (K.Foraz)
- Definitions and Glossary (M.Zerlauth)
- Progress with optics validation (R. de Maria)