3rd Meeting of the HL-LHC Parameter and Layout Committee

Participants: Roberto Kersevan, Mark Antony Gallilee, Stefano Redaelli, Oliver Bruning (Chair), Francesco Cerutti, Helmut Burkhardt, Rama Calaga, Stephane Fartoukh, Rhodri Jones, Brennan Goddard, Amalia Ballarino, Herve Prin, Gijs De Rijk, Erk Jensen, Rob Van Weelderen, Ezio Todesco, Markus Zerlauth (Scientific Secretary), Andrzej Siemko

Excused: Bernhard Holzer, 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=223686

O.Bruning opened the meeting by approving the minutes of the previous meeting and recalling the agreed actions.
The past Doodle poll did not yield the expected replies; hence a 2nd poll will be launched in the days to come to decide on the final HL-PLC slot. This has been done by now, converging on TUE morning as the most appropriate time-slot for most of the PLC members.
O.Bruning recalled that the 1st meeting was dedicated to organizational aspects of the PLC, followed by a first round of discussions on the potential layout and needs for the main experimental insertions. This first round will be completed with April's meeting; the agenda for the June meeting will aim at tidying up everything and establish a list of outstanding actions. After summer a first round of other insertion regions will be done.
E. Todesco commented that the corrector magnets & packages of the high luminosity regions are currently being looked at and confirmed a possible report in a few weeks, ideally being treated at the same time as a presentation on the related powering aspects.
S. Redaelli added that he is planning to set the date for the collimation review in April or May, aiming at setting directions for the work of the US colleagues on DS dipoles and the overall performance of the collimation system for the coming years – after that he could report back to the PLC including the comments received during the review.
Concerning the Long Range Beam Beam compensator (LRBB) a 1st meeting was held within a Technical committee in January, details of this meeting will follow.
M. Zerlauth reported in absence of B. Holzer on the follow-up actions of ABT concerning the new insertion optics:

"Calculations for the D2 aperture and boundary conditions of an eventual additional Q7 to support the crab cavities are in the pipeline but not yet completed.
The optics with the 150mm triplet aperture on the contrary is mostly ready, including optimizations.
The only missing item is a further optimization of the optic transitions between injection and pre-squeeze. This should be completed however for the next meeting of the Work-Package 2.2 planned for next Friday."

Current Limitations and Plans for CRYO System (arc and insertions) – (R. van Weelderen- slides)

R. van Weelderen presented a status of the work concerning the cryogenic system intended for HL-LHC operation. He added that a few decisions impacting the future of the ongoing work need to be taken soon as things did not converge sufficiently in the latest HL-LHC meeting in Frascati.

With respect to the current layout, the HL-LHC cryogenic layout includes two new cryoplants at P1 and P5 and one new cryoplant at P4 for the SRF modules. In addition there will be new cooling circuits for the sc links and deported DFBs and provisions to support the cryo-collimators and the 11T dipoles at P3 and P7.

Expected limitations are the sector heat loads (i.e. local limitations based on the hardware currently installed like valves and piping which hence are difficult to be exchange).
First estimates show that the static heat load onto the beam screen is not expected to change significantly between the 25 and 50ns HL-LHC scenario. Compared to the current nominal performance, the heat load on the beam screen will nevertheless increase be a factor 3 to 112 W, respectively 123W for the 25ns and 50ns case, leaving around 1W/m of margin for the (yet not quantified) heating from e-clouds.
For the cold masses themselves the margin is equally consider sufficient.

A more global limitation is however imposed by the cryo plants themselves, when aiming at transferring part of the heat load from the 1.9K to the 4.6 - 20K refrigeration. As currently less of the 1.9K refrigeration capacity than originally planned is being used (and the magnet system is well understood), one could attempt such a transfer by changing the way the cryo plant is operated and transfer capacity to the beam screen cooling.

Specific limitations are equally present in the inner triplets for the extraction of secondaries due to:

-) Collapsed and repaired HeII two-phase heat exchanger effectively reducing the available cross-section (will not be consolidated during LS1)
-) Erroneous mounting of passive heater strips for excess liquid evaporation (will be consolidated during LS1)

S. Fartoukh asked whether a budget has been foreseen to cope with the debris on the triplet. R. van Weelderen replied that this is part of the motivation to build a new dedicated cryo plant.

The main components foreseen in point 1 and point 5 were recalled, with 2 possible layouts emerging. In the 1st alternative the LSS and sector cryogenics are combined whereas the inner triplet and D1 are fed by a new cryo plant, while the 2nd alternative foresees an independent cryogenic sector cooling and the LSS and inner triplet fed by the new cryo plant. The first option would be realized with an additional interconnection box between the arc and LSS cryogenic sectors.

It needs to be considered that the D2 and Q4 magnets would become to long if they were to be built for 4.5K, hence currently the design baseline is for 1.9K. They D2 design does not yet exist on paper, but E. Todesco, commented that it makes indeed sense to foresee it for operation at 1.9K.

A D2-Crab cavities-Q4 Layout would require 3 jumpers if crab cavity cryostats are kept independent (cold/warm transition) from the neighboring magnets.

The decision on Q5, Q6 and Q7 + their operation at 1.9 or 4.5K will severely influence the cryo QRL interface, as 1.9K requires a 2 jumpers design with the present QRL hardware design (which will represent more constraints for integration). Stephane F. confirmed that for Q5, Q6 there should be no reason to go to 1.9K.

S. Fartoukh added that from the optics point of view there is a strong requirement to put D1 as close as possible to the IT to reduce as much as possible the shared region, which will also be an important parameter for the strength of D1 and D2. He hence proposed a decrease of the distance between triplet and D1 (from the current 9m) by 3-4m to remain as compact as possible. The ideal solution would be to feed the triplet directly through the D1.

For the moment the QDSX feebox is not included in the layout, discussions are ongoing this week is to place it eventually on the non-IP side of D1, which then would not impact the layout.

Action: This topic should be iterated in the next HL-PLC together with a presentation on magnet powering plans

The preferred option is to keep cryogenics for LSS (triplet + MS) completely independent from arc, which would require a certain adaption on the powering side on the surface (rearrangement and separation of current leads onto 2 independent DFBs).
Maintaining the existing QRL for the LSS becomes however increasingly difficult.

A. Ballarino comments that both proposed layouts have to be studied in detail before making a decision, including whether the corrector packages should/need to be conduction cooled.

Action: Target should be set to take a decision for 'baseline' layout to avoid parallel lines of development. A. Ballarino confirmed that a preliminary feedback should be possible in one month.

S. Fartoukh asked whether one should not consider a 3rd layout option, where Q5 and Q6 are part of the arc cryogenics and the remaining LSS and IT magnets at 1.9K forming an independent cryogenic sector.

Space requirements in the caverns and shafts were presented. In IR4 new cryogenic equipment would only be required for the SRF modules, for which a new plant is foreseen to feed the cryostats and interconnection boxes.

O. Bruning commented that the eventual installation of electron lenses should be foreseen in IR4 (using a solenoid at 4.5K). Stefano R. added that Serge C. did already perform a first integration study; the required modifications are only possible during a long shutdown.
E. Jensen commented that the higher order harmonic RF system should be considered as well; a considerable margin should hence be foreseen for the dimensioning of the cryo plant in IR4 (by a factor of 2). He added that the potential crab cavity test in IR4 does not influence the decision, as one would move the existing SPS cold box temporarily to the LHC.

Action: Requirements for IR4 cryo-plant have to be agreed in order to allow for an installation during LS2.

In IR7 new cooling circuits for the sc links and deported current feedboxes are foreseen, requiring according new designs for both and an extension of the warm recovery line to the TZ76.

R. van Weelderen concluded by emphasizing that a decision is needed soon for the main sectorization option in order to avoid parallel work and proceed with the detailed studies. The preliminary heat-loads estimates are done and should be compatible with the expected capacity if some of the margins are shifted from magnets to beam screen (final confirmation expected from newly formed Heat Load WG).
Integration studies for underground equipment are well under way.

BI – (R.Jones - slides)

R. Jones introduced the currently existing instrumentation in the LHC experimental insertions.

For HL-LHC BI proposes to maintain the direct couplers in common beam pipe regions, an optimization of the position is however needed to minimize the counter

influence of the two beams. Two different lengths of 220mm and 285mm can be considered for the cold, respectively the warm stripline BPMs.

To cope with the increased aperture (150mm) of the inner triplet an already existing BPM design for 131 mm could be used for triplet region, hence keeping the beam screen diameter constant (in addition to increasing the intensity range of the device). Regions of parasitic encounters are to be avoided for BPMs. This is particularly difficult in the triplet regions where one ideally would need redundant BPMs with good accuracy (see slide 5 for details).

H. Prin commented that it would be beneficial for the integration of a 2-phase separator to remove the 1st pickup in front of Q1. Unfortunately this BPM is the most important one as it is closest to the IP, one maybe could look at combining it with the TAS or placing it right thereafter (but still on the non-IP side). Helmut B. commented that the pickup in front of Q1 was also requested for high beta runs to measure zero crossing – according to his knowledge it was however never used in this way.

Beam Loss Monitors will be maintained external to the cryostat as well for HL-LHC, cryogenics BLMs will be added to all new quadrupole magnets (6 per magnet) aiming to allow distinguishing collision debris from true beam loss. Early qualifications of the mechanical and electrical properties in first magnet prototypes are considered highly beneficial.

R. Jones raised the question whether separate luminosity monitoring from experiments is still to be maintained, namely the need for 40MHz operation, which is currently not being used.

BTVs in injection regions will be maintained in their current number in the layout.

The optimal location of the Long Range Beam-Beam compensator still needs to be defined, as it will depend on the finally chosen optics. It needs to be decided whether one maintains the 5m in the Y-chamber (which is judged more difficult). The preferred option is to maintain the current idea of an in-collimator design before the D2. O. Bruning commented that one would currently maintain the reservations; H. Schmickler will be looking into this in more detail in the HL-TC and report back with the final decision. Stefano R. commented that it is new to him that the in-collimator design is considered for the final design.

Action: ABP to investigate the foreseen collision optics at the locations of TCTV/H and TCL in front of D2 for possible integration of the LRBB compensator

In terms of additional diagnostics for crab cavity head-tail monitors are foreseen. They will be either based on existing strip-lines or higher bandwidth optical BPMs (which are currently being studied). This requires the reservation of 800mm of space at a suitable optics location (i.e. at 90 degrees phase advance to observe the maximum crab effect) and a decision whether 2 measurement points are required

(close to the IR and one after he crab cavities towards the arc to verify the correct compensation of the kick).

Numerous instruments have already upgrades planned during LS1 and LS2 (BSRT, BGI design, BCTs, new fast wire scanners). The ADTs will probably get new BPMs.

A Beam Gas Vertex is currently being studied as a possible alternative emittance monitor, based on the LHC Velo concept (Fellow looking at this). Such a device would require ~ 7m per monitor possibly between Q6 and Q7.

A feasibility study is proposed to study the possibility of an additional synchrotron beam line (as the current one has already 4 diagnostics attached to it). A second line would allow for e.g. additional halo diagnostics, streak cameras for studies of crabbing,… This would require a new undulator near D4 on the incoming beam (with light extraction between D4 and D3).

Discussion:

O. Bruning asked why one couldn't use the LHCb vertex? R. Jones answered that in LHCb one cannot inject has while colliding and that the detector is generally further away from the beam and not IN at injection.

J. Wenninger commented via mail prior to the meeting: *"I just want to insist that in the HL-LHC triplet we need good BPMs and therefore there must be room at good longitudinal locations (or perfect directional couplers) to be able to correctly measure the position. Since the aperture increases, I guess that this is not helping the BPM accuracy."*

Stefano R. commented that for a good accuracy of the BPMs one needs to look beside the layout question also at the acquisition chain.

Future possibilities for halo diagnostics include micro-mirror arrays (similar technique as used for corona measurements for the sun). The question is whether there is enough signal to noise ratio to achieve a sensible measurement with such a technique.
S. Fartoukh proposed to look at the use of the ALICE detector as halo monitor (due to beam separation of 6 sigma).

M. Zerlauth commented that diagnostic possibilities with DIAMONDs were not mentioned? R. Jones replied that they do not require much space and hence can be more easily integrated. Their use during HL-LHC will be discussed in more detail in an upcoming technical committee.

Preliminary IR Layout of Crab Cavities (R. Calaga - Slides)

R.Calaga presented the current status of developments and intended layout of the crab cavities (CCs). By now the RF team has a good idea how many crab cavities will

be needed and how and where to install them. The current baseline is 3 cavities / beam and IP to be installed some 155m from the interaction point, i.e. a total of 24 cavities in the LHC. The voltage aim is currently 3.3 MV/cavity, which is considered modest and hence allows for some margin for robust operation against quenching.

A 1st crab cavity from the UK has arrived at CERN, and has been already tested up to half of the nominal gradient. Tests will continue and finish approximately in March. The results achieved so far are promising in view that the cavity has not undergone any treatment so far.

To avoid large imbalances of the beta functions on the cavities on both sides of the IP a staggering of the cavities in the cryo-module is being considered but would most likely complicate the design for a common cryostat. Further iterations are needed; additional shuffling wrt to the presented design is possible.

R. van Weelderen asked whether the call for independent cryostats (to avoid e.g. quench propagation) would require cold-warm transitions between the modules – this could be difficult and should be avoided if possible.

While the cryo-module will not much exceed the size of the standard arc cold-masses, the power couplers will most likely be integrated vertically onto the top of the cryostat. O.Bruning commented that this should be discussed with survey as it might impose restrictions for the laser and alignment lines required in the LSS regions. This point should be discussed before the presentation planned for next meeting.

Presently 3 cavity designs are still being considered, whereas each design is to be tested in the SPS before being installed in the LHC. First rough heat load estimates with cavities at 2K were presented, which amount to some 100W/IP (with a 50% safety margin). These studies still need to be complemented with the expected heat loads at 4 and 80K.

Two possibilities for the cryogenic layout are being considered, the first one to feed the CCs from the inner triplet cryo plant, the second one to feed it from the existing sector (arc) cryo plant.

Furthermore the required power consumption needs to be quantified in more detail, it should however be in the order of 20 or 30 kW, hence a factor of 10 smaller than the current klystrons for LHC. In that power range maybe a single Tetrode could be sufficient, a 40kW prototype exist already for the SPS. For this solution the waveguides would have to be brought to the experimental (or close by) shielded caverns as the low-level RF and SSA drivers must not be located more than some 40-50m away from the CCs.

Action: Integration study needs to be looked at (problem of space in RR13/17). Needs also presence of EPC colleagues to confirm liberation of space.

R. Calaga summarized that the cavity & cryomodule equipment seem compatible with the present constraints and that work is in good progress for the related cryogenics and associated equipment. The major issue seems to identify a close-by shielded area suitable for the installation of RF power, driver and low-level RF controls.

Discussion:

S. Fartoukh commented that for the time being the optics team works with 12.5 MV as total CC voltage – this inconsistency should be sorted out, otherwise one would need to relax on β^* (with an associated loss in performance). He asked further whether one could imagine aligning the cavity onto the beam (e.g. every month should the experiment want to change the crossing angle), with a dynamic range of 4mm. Small orbit movements could then be corrected with close by orbit correctors (not possible for non-closure of crossing angle).
R. Calaga replied that it's definitely challenging but technically not impossible to realize. E.Jensen added that the design of the cryo module should be done taking this requirement into account.

O.Bruning summarized the key points requiring follow-up:

- Voltage/ how many cavities needed
- Integration studies are needed
- BPMs and orbit correctors vs alignment
- Instrumentation needs for CCS in IR1 and IR5 – alternatively what could be done in IR4 (how much coupling would one still need).
- MP considerations still to be looked at in detail

AOB (all)

S. Fartoukh presented a corrected table for the HL-HC parameter list, including the reduction in luminosity due to the hourglass effect for the HL-LHC operational parameters (Slides). The updated list is now available on the HL-LHC PLC Website (V3.0)

Due to time constraints the presentation on new glossary definitions was postponed to a future meeting.

The tentative agenda of the 4[th] PLC meeting in March will be as follows:
-) EDMS structure for parameters & layouts of current LHC project and proposal for HL-LHC
-) First baseline for insertion, including correctors and Q7 improvements
-) Magnet powering for HL-LHC
-) Survey needs for high luminosity insertions