16th Meeting of the HL-LHC Parameter and Layout Committee

Participants: C. Adorisio, A. Apollonio, G.Arduini, V.Baglin, M. Bajko, A. Ballarino, R. Bruce, O. Brüning (chair), H. Burkhardt, R. Calaga, S. Claudet, P. Fessia, M. Fitterer, M. Guinchard, J. Jowett, L. Lacny, Y. Papaphilippou, M. Pojer, A. Rossi, L. Rossi, F. Savary, H. Schmickler, E. Todesco

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/PLC/default.aspx

Indico link: https://indico.cern.ch/event/406292/

The minutes of the previous PLC meetings (14th and 15th) have been distributed and are considered approved.

O. Brüning recalled the list of actions from the previous PLC meetings.

14th PLC meeting, the following comments were given for the foreseen actions:

- Concerning the 80 bunch scheme option in the LHC, G. Arduini and S. Gilardoni are expected to give an update in one of the future PLC meetings with a complete parameter set definition. G. Arduini stated that an internal meeting is already scheduled on 24th July to discuss the parameters, before giving an update to the PLC.
- Concerning the discussion on the 11T magnet length, a final number has been already provided to the collimation team, as confirmed by R. Bruce. An update with the final status of the discussion is expected in one of the next PLC meetings.

15th meeting, the following comments were given for the foreseen actions:

- The table containing the magnet circuit parameters will be stored in the PLC website. E. Todesco can remove the table from the WP3 page in order to keep it only in a central place

Recent changes of High Lumi Baseline + options (L. Rossi - slides)

L. Rossi presented a summary of the recent changes to the HL-LHC baseline parameters. According to the new LHC planning, LS2 and LS3 have been shifted to 2019 and 2024, respectively and LS2 has been extended to last full 2 years. The excavation works for HL-LHC will start in 2018 but heavy construction work will start only in 2019 (during LS2). O. Brüning commented that this is also a better solution from the operation point of view, as the old planning featured only 40 days for physics production in 2018 and the time for the preparation time for HL-LHC civil engineering work in LS2 was rather short.

L. Rossi recalled the main parameters and targets of the HL-LHC project. A peak luminosity of 5×10^{34} $cm^{-2}s^{-1}$ with levelling is foreseen, yielding an annual integrated luminosity of 250 fb^{-1}, with the goal of 3000 fb^{-1} over the HL-LHC project duration. The ultimate parameters were also shown ($L_{peak} \cong 7.5$ 10^{34} $cm^{-2}s^{-1}$ and an integrated luminosity of ~4000 fb^{-1}) assuming only exploiting the hardware margins of HL-LHC (as for the LHC) and that the levelled luminosity is not limited by event pileup in the detectors. The plot of the expected evolution of luminosity production over time was presented. This accounts for an initial 'learning phase' with reduced peak luminosity after LS3 and reaching nominal HL-LHC parameters in 2028. No ion runs are assumed after LS4 and minimum a minimum number of technical stops for maintenance and no Mache Developments are expected after LS5, thus allowing up to 200-220 days of physics per year.

L. Rossi presented the hardware baseline modifications:

- L* = 23 m, unchanged (22.7 m under evaluation, mainly to optimize the BPM position) (allowing entrance for vacuum maintenance from experiment side: however some reservation still exists from ATLAS.
- TAXS aperture 54 mm, with a possible enlargement under discussion
- IT Quads: the 5% change of length and decrease of current is in the baseline since the 14th PLC meeting.
- The Q4 aperture is currently 90 mm, but a reduction is under discussion. E. Todesco commented that this depends on the thickness of the shielding; a further optimization is required and will be studied. Presently the heat load simulations show a peak in the pole. The D2 aperture might also be rediscussed, but this is less likely. The aperture is currently 105 mm, as confirmed by E. Todesco

- TAXN: the present configuration has a fixed aperture TAXN and a new TCLX in tungsten, as approved in the 14th PLC meeting and confirmed by R. Bruce.

- The complete crab cavity system is in the baseline of the HL-LHC project. However, following the Cost&Schedule Review a progressive installation is foreseen to gain experience with the system (2 per side per IP in LS3 and 2 in the YETS –possibly an EYETS - after LS3) and to ease the timeline constraints for production and installation. The SPS test location has changed in the framework of a general optimization of the SPS space allocation. The chosen location is now in BA6, which requires new integration studies and surface installations. The installation is still planned between 2017 and 2018 and tests should be performed in 2018, i.e. before LS2. No major showstoppers are expected for the integration in BA6.

ACTION: a general overview on the integration plans in BA6 will be given in mid September in the HL-LHC TC, as proposed by R. Calaga.

O. Brüning recalled the discussion on triplet powering schemes as one of the items to be followed-up. He asked whether the individual powering for all quadrupoles is currently the main option. E. Todesco replied that at the moment two powering circuits are foreseen, but it is under discussion whether to adopt one per IP side. This has strong implications on power converter design and controls. He added that at the moment this study is waiting for results of quench protection simulations.

O. Brüning also recalled the discussion on the powering of D1 and D2 magnets. As the current levels are very close, the option to power them in series should be considered. A. Ballarino and S. Claudet commented that some other aspects, as the impact on cooling and cryogenics schemes, would need to be studied. L. Rossi expressed his interest in having these studies included in the TDR, i.e. by October 2015.

L. Rossi presented the changes outside the insertion regions:

- 11T magnets for ions have been removed from the baseline for LS2. L. Rossi explained that the need for collimators or absorbers in the connection cryostats of IP2 (where losses are pushed thanks to the magnetic bump as proposed by J. Jowett) has to be studied in detail and supported with calculations of energy deposition. The decision will also depend on the allowed intensity for the ion runs. The current plan, as confirmed by F. Savary, is to manufacture two 15 m long units before the end of LS2 or the beginning of RUN3. The first unit 11T will be ready by the beginning of LS2, indeed, while a second unit will be manufactured immediately afterwards.

ACTION: J. Jowett will present the results of a study for the collimator/absorber option in IP2 in one of the next TC.

L. Rossi confirmed the new civil engineering baseline, including the underground tunnel hosting the EPCs and DFHs, in the so-called “Double Decker” version.

P. Fessia reminded people – and in particular WP leaders and project engineers - about the urgent need to contact the EN-EL group to discuss requirements for cabling.

Update and status of BBLR (H. Schmickler - slides)

H. Schmicker presented the status and updates for the BBLR compensation options.

Some demonstration studies are ongoing, with the aim to have by the end of 2018 enough experimental evidence such that BBLR compensation becomes a “construction option” for HL-LHC.

Wires in the SPS are available for use. Only one power converter is left, but this configuration can be used for experiments. This setup can be used for parasitic MDs. Nevertheless there’s no possibility for remote control of the wire position, therefore a steering of the beam will be required.

Four ‘wire in jaw’ collimators were ordered from CINEL and their delivery is expected in spring 2016. The installation is scheduled during the WS 2016/2017. Two configurations are under discussion: full compensation of one beam (option 1) or compensation of both beams on the ingoing or outgoing side (option 2). Option 1 is the preferred one. A MD is planned to test it, with the following configuration: one beam made of one bunch plus a witness bunch and the other beam having enough bunches to have full LRBB. This would allow to go as close as possible to the beam with the wire (10-12 sigma). L. Rossi asked whether it would make sense to perform the experiment with a bigger emittance (making the distance in σ_{beam} due to the thickness of the collimator less important). Y. Papaphilippou commented that this may help but the impact will be minor, unless the emittance is blown up by a large amount

H. Schmickler presented an overview of the options for instrumentation related to these studies.

A coronagraph is a device that allows the 2D transverse profile measurement of the beam halo. A collaboration agreement was signed with KEK for the design and construction of a coronagraph in the LHC. For the present design the contrast between the core peak and the visible halo is only 10^{-4}, whereas it would be desirable to reach 10^{-5}.

Other options for instrumentation are being considered: beam tune spectra measurements, a high dynamic range camera and a beam gas vertex detector (BGV). Gianluigi asked whether wire scanner also being considered as an option. H. Schmickler explained that this was considered but would require a modification of the present wire scanner setup. Furthermore the use of wire scanner entails the risk of modifying the halo distribution.

H. Schmickler then gave an update on the new activities related to the physical wire option. A proposal was made in 2008 by A. Ballarino to use HTS wires and this is now being studied again. S. Fartoukh studied the required field distribution to be generated by the wires. The contribution of the different terms of LRBB interactions could be approximated by a single kick with a 1/r dependence. New proposals for alternative geometries producing the desired field configuration could be studied, improving mechanical stability and cooling. This activity requires support from ABP.

H. Schmickler presented more details for the HTS wire option, based on the work of A. Ballarino in 2008. The analysis revealed no issues from the vacuum point of view. The study was assuming a static wire, but currently a movable wire would be required. Furthermore beam-induced effects on the wire should be studied (losses, heat), as well as the radiation tolerance of the HTS. L. Rossi asked what would be the limitations of having a static wire in place of a movable one. Y. Papaphilippou explained that a static wire could become an aperture limitation at injection. In addition, the movement in two directions is necessary to compensate for changes in the crossing angle.

ACTION: An analysis of the wire compensator option should be presented in one of the next TC meetings, highlighting the possible limiting factors (e.g. impedance issues).

H. Schmickler presented the e-lbeam option for BBLR compensation. This option poses no machine protection problems, but HL-LHC requirements in terms of e-current are four times more demanding than presently achieved at Tevatron. In addition, the efficiency of the compensation with a (transversely) gaussian e-beam has to be studied. H. Schmickler made a proposal for a test stand at CERN. The test setup would consist of one SC solenoid (cryogenic supply configuration to be defined in collaboration with S. Claudet) and two NC solenoids. The design of the prototype solenoid is ongoing and the prototype will be ready in summer 2016. The expected cryoload is < 4 W. L. Rossi commented that this seems a rather conservative number, it would be worth having more detailed estimates with better cryostat insulation for the cryoload.

H. Schmickler presented the plans and the alternatives for a possible test station for the e-lens (slides from S. Claudet). It is assumed to have 2 to 3 years of R&D for halo collimation studies (for LHC-P4) and up to 7 years in total for BBLR compensation studies (for P1/P5). Different alternatives were considered for the location of the experiment. BA7, considering an installation already foreseen for the CRG group, seems the best possible candidate at the moment.

The goal of the project is to have at first a working 'copy' of the Tevatron gun and then push the current to the required level with a new design. For the modulation of the e-beam current a collaboration with JSC Moscow - specialized in high-efficiency high-power klystrons - is under consideration.

A study of an overlap monitor providing the 2D transverse profile in the overlap region of proton and electron beams is also foreseen in collaboration with the university of Liverpool. This project looks promising but the monitor is too big (order of 1 m) to be installed inside the SC solenoid. It is under consideration whether to place it outside, between the SC and the NC solenoids.

H. Schmickler presented the possibilities for the BBLR integration (study by A. Rossi). In a recent study it was shown that the optimal compensation is achieved if the ratio between the horizontal and vertical beta functions amounts to 0.5 or 2. L. Rossi asked if this is a valid statement for both round and flat beams. Y. Papaphilippou explained that this is the case if the device is 'local', i.e. if the phase advance to the location of the BBLR compensator is 90 degrees. The fact that the optimum point is reached for inverse values of the ratio of the beta functions is instead due to the anti-symmetry of the optics. The optimal values and corresponding longitudinal wire locations have to be understood for round optics. For flat optics, the two possible longitudinal wire positions mentioned above are still optimal for the LR compensation, but the corresponding beta aspect ratios at the wire location scales with the beta* aspect ratio.

The old belief that the optimum point would be found for equal betas is related to the qualitative consideration that most of the LR interactions take place at a beta aspect ratio of 1, in the drift between the IP and Q1 (for more details, see: https://indico.cern.ch/event/402412/).

Considering these aspects, the resulting ideal location of the LRBB compensation is between Q4 and Q5. This region is free from equipment at the moment.

P. Fessia commented that a talk on LRBB was scheduled at the LMC for 29th July. Y.Papaphilippou proposed to postpone it to a later date (September) to allow for more time for analyses and simulations.
L. Rossi supported the plans for the tests and added that hollow e-lenses may become an interesting item to increase of in-kind contributions from the US, if a larger budget would become available as suggested recently by DOE officials. H.Schmickler concluded that the aim of the e-lens test-stand is not to enter into magnet-development, but to get a working SC solenoid with the minimum financial and manpower effort. Even lowering the heat-load with a significant design effort (and risk) by a factor 2 the effort on cryogenics would be the same.

Vibration analysis of TT41 TAG41 (M. Guinchard - slides)

M. Guinchard presented the analysis of the impact of civil engineering activities on the triplet region. The study aims at quantifying the propagation of vibrations caused by civil engineering works to the magnet cold masses.

The approach that was followed consists in the determination of two transfer functions:

- A transfer function to account for the propagation of vibrations from work areas to magnet supports (H1)
- A second transfer function to account for the propagation of vibrations from magnet supports to the cold mass (H0)

The study was made in the attempt to demonstrate what excitation could cause a displacement of 1 µm on the beam. L. Rossi asked G. Arduini if 1 µm is effectively acceptable for operation. G. Arduini stated that 1 µm is already above what could be tolerated for operation.

Two types of sensors were used for the analysis: seismic geophones (3D sensitivity and absolute velocity measurement) and accelerometers. A spectrum analyzer was used for vibration measurements.

For the calculation of the H0 transfer function, two types of excitations (input vibrations) were used (a machine available in SM18 and a hammer). An amplification of up to a factor 100 of the vibrations can be observed e.g. at 20 Hz for the vertical mode. High vibration amplification between the floor and the cold mass was measured mainly due to the dynamic behavior of the Q1 structure. H. Schmickler pointed out that this is a resonance effect which depends on the test configuration. As the magnet cryostat was open during the test, he would expect different frequencies in the final configuration. M. Guinchard confirmed this, but he’s not expecting a huge difference for the resonant frequency. H. Schmickler added that different bellows could be used to tune and control the resonant frequency. G. Arduini commented that the frequency of vibration is of secondary importance compared to the amplitude, the scope should be to damp the vibrations independently of the frequency.

High vibration amplification between the floor and cold mass was measured mainly due to the dynamic behavior of the Q1 structure (max gain of 100 on the 0-100 Hz bandwidth). Several natural frequencies were identified below 50 Hz, and are comparable to LHC quadrupoles. Triplet interconnections are expected to have a limited impact on the dynamic behavior. At SM18 without civil engineering activities (CE), the cold mass motion is close to the limit of 1 µm. With CE activities, a level of several µm is achieved. According to the transfer function measured at SM18 on Q1, the expected motion of the coldmass during LHC operation is around 0.1 µm integrated from 100 Hz.

For the calculation of the H1 transfer function measurements were performed in the TAG41 (service tunnel) - TT41 area, which presents a similar environment compared to LHC P1 and P5 (molasses rock). An electro-shaker was used as a vibration source and measurements were performed in two different configurations (40 m and 80 m)

An attenuation factor of 20 (@6 Hz) to 50 (@100Hz) was measured between TAG41 and TT41 tunnels, separated by 40m of molasses rock. The attenuation scales linearly with the distance (it doubled for the 80 m measurements as compared to 40 m). The measured velocity of waves generated during the measurements was around 950 m/s, consistent with a shear wave and vibration results are consistent with literature.

The combination of transfer functions H0 and H1 yields an overall attenuation of a factor 10 of the vibrations (except for peaks at few critical frequencies reaching no attenuation), despite the high amplification measured between the floor and the cold mass.

P. Fessia pointed out that damping concrete was already considered during CLIC studies and could be used for the triplet area. M Bajko commented that already changing the substrate for the magnet support could bring a significant improvement. G. Arduini added that if these measures prove to be ineffective local beam feedback could be considered.

The measured transfer functions suggest at the moment that civil engineering work in the vicinity of the LHC tunnel should be avoided during LHC operation.

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