Minutes of the 115th WP2 Meeting held on 06/03/2018

Participants: S. Antipov, G. Arduini (GA), E. Bravin (EB), X. Buffat, J. Coello de Portugal (JCP), R. De Maria (RDM), M. Giovannozzi (MG), P. Hermes, R. Kieffer, S. Kostoglou, M. Martino (MM), E. Metral (EM), Y. Papaphilippou, S. Redaelli, A. Rossi (AR), B. Salvant, S. Sadovich, G. Sterbini, T. Lefevre (TL), R. Tomas (RT), M. Wendt (MW)

Agenda:

1. Approval of minutes and general information
2. Optics Requirements for IR4 (A. Rossi, T. Lefevre)
3. Optics Conditions in IR4 for instrumentation and e-lenses (R. De Maria)
4. Tracking and tolerance to flux jumps for triplets and 11T Dipoles (J. Maria Coello De Portugal)
5. Round table

1 Approval of minutes and general information

The minutes from the last WP2 meeting are approved with no comments. Elias Metral (EM) reports that the analysis of the discrepancy between impedance model and measurement have been further investigated by Xavier Buffat et al. Furthermore, studies of beam stability limits as a function of orbit offsets in crab cavities have been carried out by his team. It is agreed that an update on the latter should be presented in the next WP2 meeting the 13/03/18. Stefano (SR) asks if there was a follow-up on the discussion in Chamonix on the collimator coating thickness that is compatible with the impedance limitations. Elias replied in the affirmative and indeed this is already in the agenda for the next WP2 meeting to be held the 13/03/2018.

2 Optics requirements for IR4 (A. Rossi, T. Lefevre)

Thibaut (TL) presents the requirements for possible IR4 optics solutions from the perspective of beam instrumentation (BI). TR explains the IR4 layout illustrating BI devices that are already existing, and others that are foreseen to be installed. The latter can be subdivided into devices for which the location has been already determined and others for which the position has been determined only tentatively. TL highlights three types of devices: the hollow e-lens (HEL) for active halo control, as well as Beam Gas Ionization monitors (BGI) and Beam Gas Vertex Monitors (BGV) for transverse beam profile measurements.

To measure the crabbing, a new generation of pickups is developed, the electrooptical BPM (E/O BPM). It is envisaged to install them in HL-LHC at a location where the phase advance is 90° (modulo 180°) from the crab cavities and 180° from IP1/IP5.

EM asks for the bandwidth of the new pickup. TL answers that the goal is to be higher than 3GHz. EM claims that this is sufficient.

TL continues the presentation and points out that so far, the BGV (Beam Gas Vertex Monitor) in the LHC is a prototype only measuring the beam profile of B2. If the BGV would be selected as a real option to measure the transverse beam size, there would be another one installed for B1 during LS3. TL emphasizes the importance of a large beam size for the E/O BPM, HEL, Schottky pickups, Beam Position Monitors (BPM), tune BPMs and wire scanners. In addition, the BGV and HEL would benefit from possibly round beams ($\beta_x = \beta_y$). The BGI (Beam Gas Ionization Monitor) would only be used for ions.

MG asks if there is a minimum required beam size. TL answers that the minimum is what we have today. MW adds that a constant beam size during the cycle would be helpful as well.

GA asks why the E/O BPM have to be installed in IR4. TL answers that they don’t have to be installed there, but any suitable position in the ring could be feasible. They are rather bound to the phase advance constraint with respect to the crab cavities. TL stressed that it would be important to provide specifications for the instrumentation requirements for the crab cavity commissioning and operation in HL-LHC.

GA asks if an installation of the EO/BPM in IR6 is possible. RDM answers that this is not easy because the phase advance for possible locations in IR6 is not suitable. A space in IR4 has been reserved for the installation of a prototype to be tested in Run3.

SR asks if the vacuum sectorization for the installation of the prototype is already scheduled. SR suggests that the sectorization for HELs can be possibly combined with E/O BPM. It is agreed that a combined sectorization is going to be checked.

RDM asks if the measurement quality of the E/O BPM is not affected by the beta function. EB explains that the value of the beta-function is important and it is desirable to have the largest possible beta function, because it determines the resolution of the BPM.

3 IR4 Optics for HL-LHC (R. De Maria)

RDM introduces his presentation with an overview on optics solutions developed for LHC and HL-LHC so far. Starting from the Design Report (DR) optics, the Twiss parameters were re-adjusted for SLHCV3.0 and HL-LHC V 1.2 to provide the correct phase advance with ATS optics. In 2015 a new optics was put into operation in LHC to enhance the beta functions for instrumentation. For HL-LHC V1.3, it was already foreseen in 2016 that the beta-functions have to be increased for beam instrumentation. However, due to the pending specifications of the HEL, this task was postponed. Besides, modifications to the optics were applied to optimize the MKD-TCT phase advance. Riccardo gives on overview of the HEL specifications. His study does not include BGV and the new synchrotron light source on the D4, this should be done as a next step or one can use present plots and values for close elements as approximated answers.

RDM points out that the HEL for B1 is on the left hand side and the HEL for B2 is on the right hand side of IP4 according to integration drawings.

SR asks if the orbit specification is +- 2mm. RDM points out that this was mentioned at the e-lens review and it is the typical uncertainty used in the aperture calculations.

RDM shows a table with the beta-function at the beam instruments for LHC in Run1, LHC 2015-2016, LHC in 2017 and HL-LHC version up to V1.3 (included). He browses through some instruments and comments on the beam size and roundness:

- HEL: in Run1 small beta in the vertical plane (B1) and not very round, but round in B2. In 2015 we gain roundness in B1 but lose it in B2. In 2017 better in B2. For HL-LHC the beams are almost round.
- The BSRT suffers in both roundness and beam size in HL-LHC compared to previous optics. This situation is even worse for the wire scanner.

RDM explains that the presented values correspond to injection optics. During the telescopic squeeze there will be some differences.

The options for future HL-LHC optics (HLLHCV1.x) are outlined:

I. The optics can be improved without optics changes during the ramp, which is constrained by the available aperture at injection.
II. The optics can be changed during the ramp, which is constrained by the phase advance and the ATS squeeze. This approach slightly complicates the ramp, but not significantly. With this approach the beams can be provided
    a) Round and as large as possible at the HEL.
    b) Round beam left, right as large as possible.

Performing optics transitions during the ramp needs optics measurements and calibrations during the ramp. It is discussed if the optics can be measured during the ramp. RT answers that it is possible and indeed it is planned to have more measurements and corrections during the ramp already in 2018.

RDM shows the present situation (HL-LHCV1.3) and improved optics for option I (no optics changes during ramp). At the HEL, this optics is perfectly round for both beams (bx=by). The beta function is now 280m for both beams in both planes.

SR asks which beta* he assumes. RDM answers that the values are constant up to 15 cm.

RDM shows the IR4 aperture calculation at injection for option I. The aperture is compatible with the constraints and slightly worse than before. B1 is more challenging than B2. Overall the aperture at injection is above the target of 12.6 sigma for nominal HL-LHC emittance.

RDM shows the new IR4 optics for the options II. a) and II. b). He shows a table with the beam sizes indicating that for option II. a) the maximum reachable beta at the HEL is 500m. This is significantly better than the option I without optics changes in the ramp. Option II. b) is better for the BSRT but however can not provide larger beam sizes at the HEL.

MW points out that the beta functions at the Schottky monitors differ by a factor two, which is too much. RDM asks how much is possible, MW replies around 10-20%. MG asks if it is possible to move the element to a location where there are less constraints. GA agrees and suggests to try evaluating new locations in order to improve the situation.

RDM shows an animation of the optics change for B1/B2 during the ramp. The dispersion is matched to zero in the straight section. RDM explains how in the ATS optics orbit bumps in the arc can be used to correct dispersion. This corrects the dispersion from and in IR1 and IR5 , but in point 4 there is a leakage of dispersion mostly from the crossing angle in IP8. A reasonable baseline should be defined, which may have margin for optimization. RDM points out that the dispersion is smaller than 50cm and if it is a constraint one can study if it can be corrected further.

The phase advance constraints from IP1/IP5 to IP4 cannot be resolved today. MS10 Option has an impact on delta muy jump between IP1/5 and IP4. Lifetime studies depending on delta mux/y IP1-IP5 can further constraint the phase. The phase advance between MKD and TCT constraints the phase advance in almost all the ring. During ATS Delta mux IP1 to IP1/5 changes during ATS squeeze. The best bet is two location spaced by pi/2 (as the ADT) to be at least sensitive in one instrument. Another alternative would be to install EO/BPMs at pi from the IP both in IR1 and 5 close to Q6. RDM points out that a commitment to a specific phase can not be made now in point 4.

EB points out that a streak camera would work better than a E/O BPM. Without enough sensitivity it doesn't make sense to use it.
TL says that in WP13 it is proposed to use two additional BPMs for crabbing per beam. GA asks if we should look for options to have two pairs of BPMs 90 degrees apart. TL says yes, with a reasonable beta.

The phase advance at the position of the current BSRT (using the light in streak camera mode) is not adequate to measure the crabbing, it would only work for one plane. It should be checked what the phase advance is with the new BSRT at the D4, but the same uncertainty mentioned above would apply anyway.

EB asks if we can adjust the phase, or estimate what it is going to be. RDM explains that the global phase is used for many things and cannot be constrained. EB mentioned that a beta_x of 200 m for the BSRT in some of the scenario would be too small. Riccardo replied that he can re-optimize the scenarios to increase the beta at BSRT at the cost of the e-lens for which 250-280 m are anyway sufficient.

RDM continues the presentation with an overview on the orbit in IR4 with the HEL. The bent solenoids introduce a dipolar horizontal kick, especially at injection. Since there are no orbit correctors available to correct this kick, we need to absorb the orbit change with a local orbit corrector. SR comments that this is probably possible. Discussions with the HEL designers are ongoing. In principle the D3/D4 can also be used.

RDM explains a request by W. Hofle for an aperture restriction to fit a small aperture structure (high bandwidth pickup). The best location for a round structure like this would be close to the HEL, where the beam size in both transverse planes is the smallest.

AR mentions that if there is aperture margin, the aperture of the HEL solenoid should be reduced to about 50mm. Simulations have to be carried out to study this.

GA and TL summarize

- We have optics solutions that satisfy almost all the requirements from BI **the proposal is to use the option without optics change during the ramp** for simplicity reasons and knowing that we could further optimize if needed. **Action: Riccardo.**
- TL should provide a list of the instruments that can be moved longitudinally and by how much to further optimize the optical parameters. **Action: Thibaut**.
- Optics parameters should be estimated at the location of BGV and new BSRT using the light from D4. **Action: Riccardo**. For that, exact positions should be provided. **Action: Thibaut**.
- The values of the dispersion should be provided at the location of the beam instrumentation and the possibility of correcting it should be investigated. **Action: Riccardo**.
- The imbalance in beta functions at the Schottky monitors between B1 and B2 should be reduced, also considering the option of moving the monitors longitudinally, if needed. **Action: Riccardo**.
- Increase the minimum beta at the BSRT above 200 m while keeping the beta at HEL bigger than 250 m. **Action: Riccardo**.

- The possibility of further reducing the aperture of the HEL (below 50 mm) should be studied. **Action: Riccardo**.
- Blocking the phase advance at the BSRT with respect to the two IPs would limit significantly the optics flexibility and the solution of installing one pair of electro optical BPMs per beam is proposed. The positions close to Q5 and Q6 at IR1 or 5 are proposed. Thibaut will discuss this with the integration team. **Action: Thibaut**.
- Specifications for the instrumentation requirements for the crab cavity commissioning and operation in HL-LHC should be provided. **Action: Gianluigi and Rama to organize the collection of the requirements**.

MW asks what is the range of crabbing that can be expected. RDM replies that it is 3% of a sigma, but can be 2.8 sigma if one crab cavity fails.

TL explains that the proposal without optics changes during ramp looks good and is more uniform, which is better for the Schottky pickups.

4 Flux jumps in the HL-LHC IR (J. Maria Coello de Portugal)

JCP introduces flux jumps as an unstable behavior shown by all type II Superconductors (SC) when subjected to a magnetic field. They are likely to happen during the ramp, but their actual magnitude is unknown.

MM asks what causes flux jumps. RT answers that the underlying physics is unknown. Even magnitude and time are unknown. GA asks what needs to be known to investigate what it is. MM says it needs to be known if it is a sudden change of inductance and what the amplitude is. RT mentions that it is a feature of the Nb_3Sn superconductors.

JCP continues and explains that the duration of the jump is unknown so he assumes the worst case scenario (1 turn) and extrapolates it to the number of turns. It is also unclear if the effect will show up at a circuit or magnet level. Therefore he simulates both cases, jumps in the circuit and jumps in individual magnets.

He explains that in his study only dipolar kicks of D1, D2 dipoles and from triplet quadrupoles with closed orbit are considered. GA comments that D1/D2 are based on the same SC technology as it is used now in the LHC, so we don’t expect flux jumps. Therefore, results for D1/D2 can be ignored. Only triplets and 11T dipoles will be based on the new technology.

JCP explains that a flux jump will appear like a fast error in the field. For dipoles an error in the kick angle. The effect of the kick will be an emittance blow-up. This is what he is studying. He explains that the quadrupolar contribution is small and can be neglected. For quadrupoles only dipolar contributions are taken into account.

JCP assumes a relative flux jump of 1e-6. The simulations are carried out magnet-by-magnet and circuit by circuit. He studied IP1.

He presents the results for injection optics and energy, showing that, considering every magnet individually, the kick in beam size takes values up to 2e-4. This applies also when the circuits are considered.

At top energy with 15cm optics the situation is different. Here the kick in beam size peaks at around 6e-3 when every magnet is considered individually, but also considering the circuits. Assuming that dipoles and quadrupoles are equally likely to have a flux jump, the kick on the beam size can be modelled, with the flux jump developing over N turns. JCP presents a table indicating the total number of individual 1-turn kicks of 1e-6 strengths required to induce a 1% emittance growth. The worst case scenario here is 7TeV magnet-by-magnet in the horizontal plane. In this scenario a 1% increase of the emittance requires only 52 turns (including the dipoles).

GA comments that one also needs to look at the filamentation time, RT agrees. After the summary RT comments that with concrete numbers from the magnet team better estimates can be given.
GA comments that for the 11T dipoles the effect will be smaller, because the beta is smaller. One should get an idea what happens with the 11T dipoles. **Action: Jaime to provide the estimates for the 11 T dipole and correct the estimates for the IRs including only the triplets**.

5 Round table

GA explains that in Chamonix there was a discussion about possible full remote alignment for IR1 and IR5. This is not yet in the baseline. Lucio mentioned at the last technical committee that future work should be based on the hypothesis that this will become the baseline for HL-LHC. Estimates of performance etc. should include this.