WP2 Meeting #169

Tue 3 March 2020, 9:00 – 12:00

Chair: Gianluigi Arduini

Speakers: Davide Gamba, Jorg Wenninger, Ezio Todesco, Riccardo De Maria

Participants: Gianluigi Arduini, Xavier Buffat, Riccardo De Maria, Paolo Fessia, Davide Gamba, Hector Garcia, Massimo Giovannozzi, Giovanni Iadarola, Ewen Maclean, Miguel Mendes, Nicolas Mounet, Yannis Papaphilippou, Marta Sabate Gilarte, Galina Skripka, Guido Sterbini, Ezio Todesco, Rogelio Tomás, Jorg Wenninger

AGENDA

MEETING ACTIONS

Davide, WP3	Re-verify (at a next Magnet Circuit Forum) design changes of the QPS for HL-LHC
Ezio	Check that magnet ramp rates used by WP3 are consistent with the ones used by the Magnet Circuit Forum (which are consistent with those provided by WP2)
Davide, **Ezio**, **Jorg**, **Riccardo**, **Paolo**	Plan magnetic tests for the MCBRD and MCBXF correctors for WP3
Ezio	Recap on the available BS contribution to the field quality in the triplets. Summarize the information available for the HL-LHC

Marta, Riccardo	Update the triplet shift study based on the displacement and orbit considering the correctors and the margin of the full remote alignment

2 GENERAL INFORMATION (GIANLUIGI ARDUINI)

Gianluigi summarized the minutes and the actions of the last meeting. One of the raised questions, from the presentation of Fabien, is the possibility to avoid the installation of the MS10 sextupole. The main issue is to re-analyze the stability close to the collision. This study has to be finalized following the recent results obtained by Xavier, and the final statement on the sextupole installation can only be done after that.

Davide gave an update on flux jumps for the 11T dipoles. The main worry remains for the triplets. One point remains to be analyzed for the 11T magnets - the impact of the flux jumps on ions.

Today's agenda includes presentations related to the corrector budget for the latest optics version, use of orbit correctors for orbit feedback. The talk on the possibility of offsetting the triplets to reduce the radiation is the follow-up of the talk given at the annual meeting.

1 CORRECTOR BUDGET FOR OPTICS V1.5 (DAVIDE GAMBA)

The analysis presented here is similar to previous studies done on older optics version of HL-LHC. Here HL-LHCv1.5, 7 TeV energy, ß*=15 cm round optics was considered. The results only for the right side of IP5 (vertical crossing and horizontal separation) will be shown. For the other IP symmetries apply. The residual orbit and corrector strength are given in 2*rms, which is the standard approach consistent with the LHC experience.

All the results are obtained with the Python framework (written by J. Andersson), assuming fully linear optics with most computations using SVD inversion of response matrices generated from Twiss functions. The orbit correction is done only at BPM locations, which is the more realistic scenario ("correct what can be seen" principle). The framework source code is well documented (POCKPy on GitLab and Joel's master thesis).

The errors considered for orbit correction are the standard ones (quadrupoles: offset ±0.5mm, rotation ±1mrad, field error ±0.2%; dipole: offset ±0.5mm, rotation ±0.5mrad, field error ±0.2%; BPMs: offset ±0.5mm). Longitudinal misalignments are missing due to difficulties in implementation in the present analytical framework. However, their contribution was found to be negligible in previous studies. The values for the expected errors are those used for the LHC but an update is discussed within the Working Group on Alignment (WGA).

The residual orbit after correction in the arc depends on the assumption on the BPM behavior and the results can be very different. In previous studies the quadrupoles were assumed to be misaligned but BPMs were staying on the reference. The target was a zero on the reference at the BPM location. Another scenario is assuming the BPM has an offset as well. In this case targeting the center of the BPM would be equivalent to targeting a random offset. A more realistic 3rd scenario is assuming that the BPMs are mechanically attached to the nearby quadrupole and their movement is therefore correlated to the quadrupole misalignments. Targeting zero at the BPM would be then more similar to targeting the center of the quadrupole. This 3rd scenario is considered to be the most realistic.

For the three cases the orbit w.r.t. the ideal reference or w.r.t. the magnet axis was analyzed. The orbit w.r.t the magnet axis for all cases is found to be in the order of 0.7-0.8 mm.

For the orbit correction in the triplet one needs to define how to find the IP position. There are three possible options presented. First strategy is to correct the orbit in a way similar to the arc, by correcting at the magnetic centers of the quadrupoles. Another way is to correct at the centers of the BPMs with a given weight. One could target the BPM closest to the IP to have a very high gain, forcing the orbit to pass through their center, but in this case we are not necessarily passing through the IP. The more profitable 3rd strategy is to force the orbit to pass through reference ideal orbit at the location of the BPM closest to the IP. Among the orbits obtained for the three cases w.r.t. the ideal reference orbit and w.r.t. the magnet axis, the one forced through zero at the center of Q1 BPM gives some artifacts (second strategy). The other two strategies give values in the order of 0.7mm w.r.t. the magnet axis. The 3rd is considered as the most representative as what will be used in operation for correcting the orbit at the IP location.

Considering that the BPMs move together with the nearby magnet and the most promising strategy for bringing the beam at the IP, the orbits w.r.t. the ideal reference and w.r.t. the magnetic axis were obtained. On average, the numbers are 0.6mm and 0.8mm respectively. Corrector strengths (in triplet and nearby arc) are on the average less then 1Tm. One should note the presence of crab cavities (CC) for which the alignment strategy has to be defined. In the presented scenario, the beam is aligned to the center of the nearby BPMs, therefore one should expect the need to move the CC up to 0.6 mm to with respect of the ideal trajectory to be on the same axis of the nearby BPMs.

Several knobs are implemented. One knob is the 295 μrad crossing angle in the vertical plane obtained with the 80% "short" and 20% "long" independent knobs. The "short" one closes the knob before the CC, making it the one likely to be used in the crossing leveling. The "long" knob goes into the CCs, thus, also changing the orbit in them (at present 0.66 mm at CC with respect to the ideal reference). The other knobs are a ±0.75 mm separation in horizontal plane, a ± 100 μm IP movement independent for B1/B2 for luminosity scan, a 2mm IP offset obtained by displacing the Q1-Q4 up to 2 mm and Q5 by 1 mm, an additional ±500 μm IP offset with orbit correctors (which requires about 1 mm CC re-alignment) and ±500 μm movement independent for B1/B2 to align in the center of CC. Corrector budget using all these knobs stays within the limits.

Failure scenarios were considered for the aperture limits in the arc of 19.4σ. In the triplet, a modulated limit around 12σ was used according to the specifications given in the CERN-AC-2017-0051. For the 15cm round optics v1.5 the apertures both for B1 and B2 are well above the limit in the arc and have less margin in the triplets. Scanning over the closed orbit error parameter of the aperture command, the radial orbit clearance was calculated. Based on this clearance, different scenarios of corrector failures were studied. Failure of the MBXFA.3 is found to be crucial already for orbit correction due to element misalignments and imperfections. For the knob implementation it turned out that not only the MCBXFA.3, but also any of MCBRDs and non-redundant MCBYs cannot fail, as they are strongly used in the crossing angle implementation. There was a particular interest in the failure of MCBC Q9, since it is more exposed to radiation and is more likely to fail. It was found that its failure could be sustained.

The orbit feedback considerations were presented before by Joel A. (WP2 meetings [#156]() and [#164]()). A typical rms corrector usage was estimated at 0.12mTm. This value for the MCBX orbit correctors is equivalent to 5e-5 corrector usage w.r.t. the nominal strength, corresponding to 80mA rms current variation. Assuming 1 Hz oscillation the maximum ramp rate would be 0.7 A/s. The present requirements for the ramp rates are more than factor 10 larger than the obtained value. In the LHC the MCBX orbit correctors are typically not used by the orbit feedback as their Quench Protection System (QPS) has often mis-interpreted the orbit feedback requests as sign of quench, triggering beam dumps. This limitation will not be there in HL-LHC thanks to a different design of the QPS as mentioned by R. Denz at the HL-LHC Collaboration Meeting in 2018. This will be re-verified at a next Magnet Circuit Forum (MCF) (**Action: Davide**).

In conclusion a generic tool to check corrector budget and residual orbit was implemented. It was used to verify the HL-LHCv1.5 ß*=15 cm round optics. The residual orbit is <1mm (2*rms). The flat optics was also analyzed, but not covered here, since no major differences were found.

- **Ezio** asked what is the relative field strength error in a quadrupole. **Davide** replied that it is taken relative to the quadrupole gradient. **Giovanni** also commented that it is nominal w.r.t. the optics and not w.r.t. the nominal design quadrupole field. **Davide** confirmed.
- **Yannis** asked if arc and IR quadrupoles are distinguished in the study. **Davide** replied that it was done in previous studies, but here everything is put together. However, since there is a strong correction to zero at the center of the CCs, the two are decoupled.
- **Yannis** mentioned that during the construction of the LHC there were measurements of the relative positions of the BPMs to the quadrupoles. Maybe it would be interesting to ask the alignment team if this data is representative or not. **Davide** replied that the Alignment WG is trying to get the values for the errors.
- **Jorg** commented that at the start of the year the location of the IP is unknown, however the real orbit correction gives much better results with 100μm offset maximum. This suggests that the assumptions used in the study for the errors might be pessimistic. **Davide** replied that the present assumptions on errors are the standard values used up to know. More updated/realistic values might come from the Alignment WG. Moreover, the actual result strongly depends on the strategy chosen to correct the orbit.
- **Gianluigi** said that CCs will be aligned w.r.t. the beam. **Davide** added that this can be done by applying a bump through the center of a CC or by moving the CC's electrical center to be on the axis with the closed orbit.
- **Rogelio** asked if the corrections chosen (assuming that BPMs attached to quadrupole and strategy for IP location) are the most optimistic scenario. **Davide** replied that this is the most reasonable scenario since the zero at the BPMs next to the IP is usually not targeted. **Jorg** added that there is no reason to target zero at the BPM.
- **Gianluigi** asked if the 80% "short" would be used for crossing angle leveling. **Davide** said yes, it will be, and **Riccardo** added that for the nominal value of the crossing angle 250μrad only the "short" knob would be enough. The "long" one is there for going to higher crossing angles. It has to be decided in advance if it is going to be used, because the CCs will have to be pre-aligned on the orbit defined by the bump.
- **Gianluigi** pointed out that the 295μrad crossing angle can be used in case of starting with lower luminosity, as requested by the cryogenics team. **Riccardo** replied that the "long" knob would be used in this case. It is less expensive in terms of correctors but it requires more misalignment.
- **Gianluigi** asked if losing the critical correctors really means a stop. **Riccardo** replied that the crossing cannot be implemented without them. **Gianluigi** pointed out that these correctors have to be seen as essential components and their non-nominal performance will imply a reduced performance that will have to be studied once the type of non-conformity is known.

2 OPERATIONAL EXPERIENCE WITH LHC FEEDBACKS (JORG WENNINGER)

This talk covers the current experience with the LHC feedbacks (FB) to check if it is consistent with the HL-LHC requirements.

In LEP times there was no real-time orbit control and the machine suffered from unstable orbits due to temperature driven movements of low-beta quadrupoles, triggering most of the dumps. To avoid similar situation in the LHC, the development of a real-time FB system (using FESA framework) in OP and BI started.

A central FB Controller (OFC) is running in the control room where all data is concentrated, processed and corrections are dispatched. The sensor data (2000 BPM readings) is obtained from ~70 Front End Computers (FECs) and the actuators data (1100 new power converter settings) is dispatched to ~40 Function Generator Controller (FGC) gateways. This system handles the orbit and tune together. The data is transmitted over the accelerator technical network as UDP data packets (no guarantee of delivery).

The FB server hosts two C++ servers: the LHC FB controller (data collection and control loop) and the LHC FB service unit (interfacing to the accelerator control system) with a private Ethernet Gb connection between the two.

The orbit data is published in real time (typical data latencies < 1 ms) and sent at 25 Hz to the central FB controller that collects the data and builds the orbit with BPM readings. This orbit is then compared to an orbit reference in LSA (base orbit at injection + knobs) to define the error signal for orbit and radial position. The base orbit is the same for all references of a given hypercycle and the same through injection to collision. Since 2016 a single reference is used for all pp hypercycles of one year (same for ions by diff. reference).

The tune values are obtained from the 4 BBQ devices (high sensitivity and gated for B1 & B2) (at 7.5 Hz for 2k turn FFTs). For high intensity beams there is a lot more noise and the performance of the tune FB is limited by the quality of the tune signals.

The power converters (PC) are controlled by a FGC with a digital control loop. The PC and/or the Quench Protection System (QPS) impose limits on the converter ramp and acceleration rates. Local gateways receive control inputs (functions, state commands, real-time inputs) through the accelerator technical network. For orbit correctors the PC digital loop period is 80 ms.

All single beam orbit correctors are self-protected (limits are enforced by PC) and have no QPS protection. The common MCBX triplet correctors are protected by an old QPS system that cannot take into account PC induced voltage changes. It is very sensitive to acceleration changes above injection energy (threshold from 2 V to 0.1/0.2 V @ 50 A). The MCBX are deactivated in the FB, since all tests at >450 GeV ended with circuit trips (QPS triggers). No updates of the old QPS system are planned. The MQT circuits are also protected by a QPS system that is also not able to subtract PC induced voltage changes. For the HL-LHC the developments in TE-MPE are ongoing on including an independent current rate measurement into the QPS logic to improve the system.

There are 3 loops in the OFB that can be operated independently (orbit FB, energy FB, radial FB). The radial FB is not active at injection (due to the SPS-LHC RF frequency coupling) and in p-ion mode with unlocked RF frequencies (injection and ramp). The energy FB is a loop on top of the orbit FB and prevents a run-away of the horizontal orbit corrector strength if the radial error is not perfectly subtracted.

In a cycle the FB is on only for a short time during injection to correct the orbit, then, it stays off during the injection. The FB is on during the ramp. For technical reasons at flat top it is switched off when the FB references are changed. Then, it is switched on for the squeeze, switched off when going in collision, and finally off in stable beams.

In Run 2 there were no major issues with OFB. The performance in terms of stability is limited by the BPM reading quality. Residual temperature variations of the temperature stabilized BPM electronics racks (most likely) generate systematic reading errors of the BPMs. OP and BI detected some technical issues such as optics consistency (incorrect BPM calibrations have a significant impact) and data transfer latencies for reference orbits. The absence of MCBX was found to have no real negative impact. The fill-to-fill IP reproducibility, obtained from the corrections applied to steer the beams head-on, is typically around 0.5σ with no degradation at lower ß*. In stable beams the OFB performance was additionally limited by the speed of the reference orbit update (time-consuming for every step in luminosity scan or van der Meer scan).

A feed-forward (FF) application to maintain the real-time trims of the FBs as small as possible is used by OP. For the tunes a single FF per run and cycle is used. For the orbit one initial FF (in a couple of iterations) and one FF per technical stop are sufficient.

A major re-design of the feedback server by BE-BI is in progress during LS2, with support by BE-OP to define the functionality and to set up testing and high level control. The two servers will be merged into a single FESA3 server with better property structure for accessing the server, improved handling of optics and references (faster reference updating), more diagnostics for debugging and testing. The first almost complete functionality should be available in the coming 1-2 months. BE-OP is upgrading the test environment emulating the possibility to close the loop. For the tune FB The re-design has not started yet. The BBQ front-ends will be upgraded to FESA3 and partially redesigned.

There are no major changes for Run 3, so similar performance can be expected. MCBX correctors will still not be used (testing will continue when possible but the risk of losing fills remains high). The Run 3 FB system is ready for HL-LHC.

- **Rogelio** asked if the base orbit usually set at injection could be changed to energy-dependent reference orbit through the cycle. **Jorg** replied that in principle this could be done but become a complication. **Rogelio** commented that, in this case, the reference orbit should be defined at top energy. **Jorg** replied that the procedure is to define it at injection and correct to it at top energy. **Rogelio** said that it should not be difficult to update the reference at top energy. The aperture issues are there at top energy and the magnetic errors are the smallest at top energy. **Jorg** commented that this would not change much and the procedure in place has worked very well in the past. Logically it should be defined at flattop, however, it is more convenient to do it other way around considering the way the machine is commissioned.
- **Davide** asked how the bumps of the reference could be modified at top energy. **Jorg** replied that an extra bump has to be added on top.
- **Gianluigi** asked if for HL-LHC the ramp and acceleration rates provided by Davide for the feedback (including MCBXF) are acceptable. **Jorg** replied in the positive and he noted that it

would be important to simulate the QPS to understand how it reacts. Most of the ramp rate is used by the bumps, the contribution of feedback is very small.

3 RAMP RATES IN THE HL-LHC ORBIT CORRECTORS (EZIO TODESCO)

This presentation summarizes the tests done on the MCBXF and MCBRD corrector magnets by the WP3.

MCBXF is a nested corrector with a nominal current of 1.5 kA and inductance of 58-232 mH. The required ramp rate is 1.5 A/s. In the training the 5 A/s ramp rate is used to speed up testing (documented value). The magnet was successfully tested up to 10 A/s with both inner and outer dipole. From the technological point of view it can run at higher ramp rate if needed (reached up to 100A/s in the inner dipole in standalone configuration).

MCBRD is a much easier magnet. It has two apertures, with very weak mechanical and electromagnetic interaction. The nominal parameters are 392 A current and 800 mH inductance which is quite high (keep in mind a large inductance variation with current in the order of 2.5). The required ramp rate is 0.4 A/s. For the training the 5 A/s ramp rate is used. The magnet was successfully tested up to 6 A/s in the test bench; higher values could not be used due to limitations in the power converter. In principle, for the higher ramp rates (10-50 A/s) there are no limitations. QDS has to be also checked but it is not as critical as for the MCBXF.

- **Davide** pointed out that in the specification table the MCBXF ramp rate is 15 A/s. The requirement from the orbit correction and the separation knob are much lower, but 15 A/s is a magnet specification and should be also used in the tests. **Ezio** replied that it is not a problem, since in the training higher values than specifications are used. **Gianluigi** added that there should be consistency in the numbers.
- **Ezio** asked if the message from WP2 (David's talk of today) is that the long MCBXF is used to open the crossing angle and without it operation is not possible. **Davide** confirmed. **Ezio** added that special attention should be put on the acceptance of these magnets.
- **Giovanni** asked if there is any reason for correctors to be more fragile than the main magnets. **Ezio** replied that there is no reason for that, even though MCBXF is a difficult nested magnet.
- **Gianluigi** asked to add the ramp rate for the MCBRD consistent with the numbers from Divides' talk. **Davide** added that it would be 2 A/s. **Ezio** agreed that the documents should be consistent and the value will be changed. The tests are done at 5 A/s.
- **Gianluigi** again stressed that the numbers used as specifications should be the same (**Action**: **Ezio**). He also added that WP3 and WP7 together should see that the QDS will not create problems. **Davide** and **Ezio** said that there should be a meeting and an official discussion/meeting on the QDS (**Action: Davide, WP3**). **Gianluigi** added that once there are prototypes the QDS tests should be done to stress the system. **Ezio** said that in SM18 usually high ramp-rate tests are done. **Davide** added that the problem for QDS is not the ramp rate but the acceleration rate.
- **Gianluigi** said that string tests should be done on the magnets. **Ezio** said that tests will be done on the individual magnets and then they can be repeated at the string
- **Riccardo** asked if the sinusoidal excitation at given frequency and amplitude will be tested. **Ezio** replied that any test request can be discussed. **Gianluigi** added that maybe some tests in the situation usual for the use of the feedback systems could be done. **Ezio** said that every

magnet has a test plan that is preapproved. There, tests could be added. **Davide**, **Jorg**, **Riccardo** and **Paolo** should see which tests could be done. (**Action:** **Davide**, **Jorg**, **Riccardo**, **Paolo, Ezio**)

4 UPDATE ON B4 CORRECTION IN THE LHC TRIPLETS (EZIO TODESCO)

A complete report on this topic will be given on the FiDeL meeting in a couple of weeks. Today a short review is given.

In the LHC triplets of today before the correction there is discrepancy between the beam measurements and the estimated values based on magnetic model. Last week an important crosscheck was made between WISE values, the database with all the coefficients used in FiDeL and the reports used as a source. A complete consistency was found. Initially discrepancies were found, but they were tracked to the component of the beam screen, that was not considered in the initial crosscheck. Ewen noted that if the sign of the beam screen contribution in IR5 is changed a perfect agreement between beam-based correction and field model is found. This relevant observation is triggering a series of crosschecks on the beam screen orientation and simulations of its magnetic impact.

- **Gianluigi** asked if there is still discrepancy in the beam measurements and magnetic measurement for one IP. **Ewen** replied that IR1 is now exact but IR5 has discrepancy. If the BS contribution in IR5 would not change sign due to BS orientation, agreement would be good.
- **Gianluigi** pointed out the effect of the BS has to be estimated for the HL-LHC. **Ezio** replied that HL-LHC BS has quadrupole symmetry, so, there is no contribution on b4 but only on b6.
- Gianluigi asked to summarize the information available for the HL-LHC. Ezio will organize a WP3 meeting to recap on the available BS information. (**Action:** **Ezio**)

5 POSSIBLE TRIPLET SHIFT (RICCARDO DE MARIA)

This presentation is a follow-up of the study presented at Madrid meeting. A 2mm offset of a triplet in the direction of the outgoing beam in the crossing plane was found to be beneficial in terms of accumulated dose. The opposite case was found to have a detrimental effect. Before the full remote alignment optimization with the full corrector strength a 2 mm IP shift could be provided. This raised a question if a voluntary IP shift can still be applied after the full remote alignment optimization that reduced the number of orbit correctors.

When the IP shift is present there is a feed-down effect from the triplet that require correction. There are two hard limits: orbit leakage into the crab cavities (CC) and a limit in orbit corrector strengths. There is also an aperture reduction issue when the triplet is shifted, but this could be recovered by increasing ß*.

From the corrector budget (Davide's talk of today) there is not much margin for additional orbit manipulations. This study is done for the nominal 250 μrad crossing angle and a different budget (0.5 Tm in MCBXFA, 3 Tm in MCBXFB, 4.5 Tm in MCBRD, 2.25 Tm in MCBYs and 2.1 Tm in MCBC) for both crossing and the IP shift.

For a given triplet shift the orbit at the CC, the difference in the orbits of B1/B2 at the CC and the aperture were calculated. The orbit at the CC and the separation increase as the triplet shift increases and goes up to 5 mm and 3.5 mm respectively for 1.5 mm triplet shift. This goes in the same direction as what we had before the full remote alignment and we needed a very strong CC re-alignment to sustain such orbits. In terms of aperture there is a small loss (from 13.1σ to 12.2σ).

In conclusion, with some compromises it is possible to implement the triplet offset up to 1.5 mm (with round optics) to mitigate radiation. It complicates a lot the alignment of the cryomodule. One has to rely on the full range RF deformable bridge (7 mm given by the vacuum team). It also requires a very strong misalignment of CCs that is difficult in the full remote alignment. An intervention in the tunnel for realignment is possibly needed.

To recover corrector strengths in the horizontal plane D1 and D2 can be used together with the MCBRD, MCBY to mitigate the issue at the CCs. Since in horizontal plane it is not possible to apply the flip of crossing sign to mitigate the radiation, this solution can be appealing. In future studies for radiation mitigation, the motivation for misalignment only in the horizontal plane will be studied. If the horizontal plane is found to be the worst because the flip cannot be applied, the possibility to use D1 and D2 in the crossing will be studied to mitigate the issue of the misalignment of the CCs.

- **Marta** commented that the improvement when the horizontal crossing is considered is 20-25% reduction in radiation. In case of vertical crossing it is 15% reduction. **Riccardo** added that the horizontal plane is worse because the sign flip cannot be applied.
- **Yannis** asked if the long-range separation changes much. **Riccardo** replied that the BBLR compensation is lost a little. Alignment is tricky but this is an additional part.
- **Paolo** asked if the shift is from Q1 to D1. **Riccardo** replied that it is from Q1 to Q3. **Paolo** added that if shifting from Q1 to D1 there will be extra constraints from the Q1 to TAXS bellow. If the Q1 to Q3 are moved then this would use partly the range of the full remote alignment. **Gianluigi** commented that this is a measure to gain margin in radiation. **Paolo** added that the time for alignment/displacement of the triplet is an important factor. It is more difficult to act during the operation, since this would require an intervention on a very radioactive area.
- **Rogelio** asked if the studies of the FLUKA team took into account any changes in the orbit correctors. **Marta** replied that just the triplet displacement was assumed.
- **Gianluigi** asked for an update based on the displacement and orbit considering the correctors and the margin of the full remote alignment (**Action: Marta, Riccardo**). This is not a standard mode of operation but a backup plan in case of radiation issues.
- **Davide** asked how much gain in lifetime is gained by the triplet shift. **Rogelio** replied 1-2 years. **Gianluigi** added that this option in interesting for ultimate operation.

6 AGENDA OF NEXT MEETING (GIANLUIGI ARDUINI)

The next WP2 meeting will be on March 10, starting at 09:00. The agenda will be

- Update on impedance considerations for HL-LHC equipment (B. Salvant)
- Update of the HL-LHC impedance model, with considerations about MKI and triplet beam screens (N. Mounet)
- Laslett tune shift for the HL-LHC scenarios (C. Zannini, N. Mounet, S. Antipov)

- Impedance model of the LHC: summary of the present understanding of the measurements (detuning with intensity, growth rates, BTF) (E. Metral, X. Buffat)
- An update on HL-LHC octupole requirement (X. Buffat)

Reported by G. Skripka