WP2
Meeting #168
Tue 25 Feb 2020, 16:00 – 18:00

Chair:	Gianluigi Arduini
Speakers:	Fabien Plassard, Davide Gamba
Participants:	Roderik Bruce, Riccardo De Maria, Joschua Dilly, Gianni Iadarola, Ewen Maclean, Alessio Mereghetti, Elias Métral, Nicolas Mounet, Yannis Papaphilippou, Stefano Redaelli, Giulia Russo, Galina Skripka, Guido Sterbini, Rogelio Tomás, Frederik Van der Veken, Leon Van Riesen-Haupt

AGENDA

MEETING ACTIONS

Serge Claudet	Report on the constraints on peak luminosity from the cryogenic point of view.
Sofia Kostoglou, Xavier Buffat	Review of the situation without MS10 at the beginning of collisions and at the end of the leveling with the right intensity and crossing angle for positive octupole polarity. Optimization of the phase advance with beam-beam effects included checking also interactions with pacman effects.
Davide, Alessio, Stefano, Roderik	Check the impact of flux jumps in 11 T magnets on ions and conclude on the available margin for LHC and HL-LHC.

GENERAL INFORMATION (GIANLUIGI ARDUINI)

Minutes of the previous meeting were circulated and no comments have been received. **Gianluigi** summarized the talks and actions from last week. Regarding the flux jumps, **Gianluigi** highlighted the need to understand the cross-talk between power converters in a nested configuration, and the evaluation of dipolar flux jumps in quadrupoles. Another important question concerns the improvements of the measurements of the MQXF, in particular regarding measurement resolution. An attempt with NMR will be made for the measurement of stability with 11 T magnets. Finally, the last talk showed that the contribution to amplitude detuning due to the misalignments in the IRs, is relatively small.

One of the talks of the previous meeting, regarding the effect of flux jumps on the orbit, will get an update today by **Davide**.

1 UPDATE ON THE NO MS10 STATUS FOR HL-LHC (FABIEN PLASSARD)

This is a follow-up of the two previous talks on the subject (see 158th and 144th WP2 meetings). The presentation first describes the four possible layout options (in terms of sextupoles) for HL-LHC and summarizes the assets and drawbacks of each of them, then presents a comparison between the options in terms of dynamic aperture (DA) after an optimization of the phase advance between IP1 and 5, and finally provides further DA results with weak-strong beam-beam interactions included.

The baseline option includes one MS10 per beam on each side of IP1 &5, which restores an even number of sextupoles on each side and thus allows compensation of geometric aberrations. While this is the best solution in terms of DA and available sextupole strength, it comes at an extra cost (installation of 4 new sextupoles per beam). Other options without MS10 but still preserving an even number of (strong) sextupoles on each IP side, are the "No MS14F" and "No MS14F & MS14D", which both have no extra cost and improve the DA (especially the "No MS14F & MS14D" option) with respect to a "No MS10" (LHC-like) option which would exhibit large geometric aberrations. This comes at the expense of important optics change for the "No MS14F" option, or a decrease of the available sextupole strength, on top of a leakage of vertical chromatic β-beating, for the "No MS14F & MS14D" option.

Optimization of the phase advance between IP1 & 5 enables partial compensations of high order resonances; it is performed here on DA itself (computed without field imperfections but with maximum octupole current) while considering optics constraints (in particular for machine protection, e.g. the phase advance between MKD and TCT should be <20deg). Optimization allows indeed large DA improvements for all options without MS10. When field imperfections are included, the ranking between the options remains as described previously but the "No MS14F & MS14D" becomes almost as good as baseline.

With beam-beam weak-strong effects (at β*=15cm, intensity 2.2e11 protons/bunch and large crossing angle of 295µrad), all options without MS10 show a clear DA improvement with the phase optimization, contrary to the baseline DA which is barely modified. The "No MS14F & MS14D" option remains the best solution without MS10. The DA is further improved if a lower intensity (1.2e11 protons/bunch) is used for β*=15cm, as these are more realistic conditions at the end of the levelling. On the other hand, this beneficial effect is partly compensated by a reduction of the crossing angle.

In conclusion, optimization of the phase advance between IPs clearly improves the DA of all "No MS10" options, also when including field imperfections and beam-beam effects, such that the LHC-like option becomes viable. The "No MS14F & MS14D" option is a robust, cost effective, alternative to baseline, but requires to push the operation of the strong defocusing sextupoles to 95% of their maximum current (instead of 90%) in order to keep the same level of chromatic β-beating and in addition it requires an intervention on the cryostat.

- **Gianluigi** asked if phase optimization strongly constrains other parameters, or if it is rather easy. **Riccardo** says this is related to the question of Xavier Buffat about pacman effects on the orbit – we are in an intermediate situation with respect to that. **Yannis** also confirmed the need to check for pacman effects. **Fabien** also mentions that the “No MS10” change of phase advance is actually very small.
- **Yannis** wondered if the phase optimization is done without beam-beam. **Fabien** answered that indeed, it is the case. **Yannis** said that maybe the phase optimization should be done with beam-beam as there can be extra effects, such as beta-beating.
- **Riccardo** argued that the same study should be done for flat optics – there will be more constraints. **Gianluigi** also added that a study at higher β^* is needed, as 15cm will not be reached before LS4, most probably. **Riccardo** mentioned that the optimization of the phase advance is required only for telescopic factors larger than 1.
- **Gianluigi** summarized the studies still to be done: review of the situation without MS10 at the beginning of collisions for positive octupole polarity, as stability considerations do not require a telescopic factor larger than 1, and at the end of the leveling with the right intensity and crossing angle. Optimization of the phase advance with beam-beam effects included checking also interactions with pacman effects should be pursued (Action: Sofia Kostoglou, Xavier Buffat).
- **Elias** said we should check what Xavier Buffat has done already, in particular regarding stability during the leveling.
- **Rogelio** wondered if we know the final peak luminosity limit at the start of collisions from the cryogenic point of view. **Gianluigi** said 2.5e34 is acceptable, to be confirmed (Action: Serge Claudet).

2 Update on DA at injection for HL-LHC (Fabien Plassard)

This is an update of the talk by Nikos Karastathis at the 149th WP2 meeting, where DA results at injection were presented, showing an intriguing large reduction of DA in HL-LHC vs. LHC. Here the goal is to try to understand this reduction, and to update the results by including beam-beam effects.

Results with beam-beam (using optics v1.4) actually show a larger DA than those obtained previously by Nikos. Moreover, with positive octupole polarity (and a current of 40A), the DA is better than with negative polarity, contrary to Nikos’ results. The reason is identified as being a small error in the mask files used by Nikos, where the dispersion correction knob was set on (“on_disp=1”), thus introducing large (~1cm) orbit bumps which have a large impact on DA.

The DA plots are now much better than before, and the HL-LHC DA at injection is comparable to the LHC one. Scans vs. chromaticity and octupoles at the e-cloud-optimized working point (62.27, 60.295) show that the positive polarity is favorable. In the case of negative polarity, the location of the best tune area for DA is displaced similarly for both LHC and HL-LHC.

- **Gianluigi** mentioned that the positive octupole polarity is now better for high chromaticity (because of the working point).
- **Gianluigi** commented that more user-friendly mask files could prevent this kind of error. **Yannis** agreed.

3 Update on impact of flux jumps in 11T dipoles in Run III (Davide Gamba)

The idea of this update to the previous talk (see 167th WP2 meeting) is to check the impact of flux jumps in 11T dipoles, which will be in the machine during Run III. The main question is whether the impact is sizable enough to be visible, or even to trigger a dump. Only dipolar flux jumps are considered, and their related orbit effect (quadrupolar effects from the flux jumps are neglected).

The probability to be in a jump in a given direction has been updated and is now set to ½ (it was ¼ in the previous talk), as all jumps are in the same direction. The jump due to the reaction of the trim power converter is really negligible (0.01 units, compared to 0.2 units for a flux jump). Probability considerations show that in each ramp there will be events when the 11 T magnets experience a jump, hence adding up their effect and introducing an orbit jump at the TCPs of up to 2% sigma for an average jump of 0.2 units, or 6% sigma in the worst case scenario of the maximum jump observed (0.6 units).

Assuming a double Gaussian beam transverse distribution (as measured in the LHC) and TCP jaws at 6.7σ (with σ defined for 2.5µm emittances), an orbit jump of 1% sigma at the TCP would give 7e-6 relative losses, so 2.3e9 protons lost for a full LHC beam of intensity 3.22e14 (resp. 4.3e9 protons for a full HL-LHC beam of intensity 6.1e14). This scales linearly with the orbit jump, so in the worst case of a 6% σ orbit jump, one obtains losses of 1.4e10 for LHC (resp. 2.6e10 for HL-LHC). This is compared with BLM thresholds RS06 and RS07 (for which the time window is between 10 ms and 82 ms so comparable to the rise time of flux jumps of 50ms), which are resp. set to 9.49e10 and 7.59e11 at 2.95TeV (which is higher than the maximum energy at which flux jumps are expected), hence more than a factor of 7 higher than the flux jump worst case scenario for LHC. BLM warnings could then occur, but no dump.

Finally, observations made at 6.5TeV in 2018 during fill 6757 showed that ground motion introduced orbit jumps of around 10% σ and losses of a few 10^{-5}, and no beam dump was triggered. This appears to confirm the scaling shown for flux jumps (still, this is a much rarer event). Similarly, collimator jaw steps (5 µm) during the ramp are equivalent to orbit jumps of ~3% sigma and no critical BLM spike was ever observed.

- **Gianluigi** pointed out the possible effect from quadrupolar (b2) components on the β-beating. **Davide** said these components should anyway not introduce any dump. As a follow-up to the meeting, **Rogelio** indicated that the β-beating due to 0.15 units of flux jump of the b2 component, for a single magnet jumping (with a reference radius of 17mm), produces a peak β-beating of 1.2% at most. The 0.15 units of b2 were also confirmed by Lucio Fiscarelli after the meeting.

- **Elias** asked if there are any differences in the parameters with respect to the previous presentation (slide 2). **Davide** answered in the negative, except for the ½ probability to be in a jump, instead of ¼, as all jumps are in the same direction. **Gianluigi** commented that this is a pessimistic assumption, as well as for a number of other assumptions (e.g. energy, collimators, peak flux jump of 0.6 units).

- **Roderik** commented that very likely the four 11T dipoles will come only after LS3, while only two will be in after LS2.

- **Gianluigi** asked if relative losses due to flux jumps will change in the HL-LHC case with respect to LHC. **Davide** answered in the negative.

- **Gianluigi** asked if one can re-do the estimation of losses with the TCPs at 5σ instead of 5.7σ (3.5µm emittances) and at top energy. **Davide** answered it is possible.

- **Stefano** commented that the step of collimator during the ramp is 5 µm.

- **Stefano** commented that the numbers indicate there should be no issue – it is not even sure we can measure this. He asked if we all agree with this statement. **Gianluigi** said the margin does not seem enormous, but he pointed out that the losses expressed as an energy are confusing because of the choice of 7TeV instead of 3TeV. **Davide** indicates that all things included and in the worst case scenario (6% σ orbit jump at 3TeV), for the LHC we have almost one order of magnitude margin (factor 7).

- **Roderik** wondered if one should also check for ions. Collimators are much closer (4σ), as the cleaning efficiency is worse. **Davide** asked what else would change for ions, and **Stefano** answered that there is more energy lost per particle loss and the BLM thresholds are lower. **Stefano** also pointed out the 10Hz event, but **Gianluigi** argued that the orbit jump was amplified for the ions by the optics in the case of the 10Hz event. Intensity is so low that this is still much below the dump threshold. **Alessio** also pointed out that for ions the BLM threshold have never been changed and can probably be relaxed.

- **Guido** asked about a possible impact of the damper. **Davide** said it cannot act at such small frequencies, unless a change of the system is done, according to Daniel Valuch. For the orbit feedback it is the opposite: it is too slow. **Stefano** wondered about the possible development of a faster orbit feedback. **Gianluigi** said it is not sure it will happen.

- **Alessio** mentioned we can check the scrapings end-of-fill tests (in particular the margin vs. BLM thresholds), as the collimators do small steps, rather slowly. Each single step is almost instantaneous and one could get how much it means in terms of orbit jump and losses. **Davide** said indeed the time scale seems comparable.

- **Alessio** commented that BLM thresholds have always been corrected upward (relaxing them). Most probably the thresholds at 3TeV are too tight. On the other hand, **Stefano** mentioned that the collimation team has been asked to reduce the thresholds on collimators in order to dump on collimators and not on the magnets.

- **Stefano** asked if the energy at which flux jumps occur is the same for the triplets. **Davide** answered in the positive. **Stefano** then added that we need to check if we can switch the elens (3TeV should be possible, the minimum energy is 1.5TeV or so). **Rogelio** then indicated we can set it at a higher number of σ (e.g. 5σ instead of 3σ).

- **Gianluigi** concluded that another iteration is needed to check the impact on ions and clarify some of the numbers (Action: Davide/Roderik/Alessio/Stefano). **Davide** said we can also collect information from Run III on the 11T magnets, then we will be able to evaluate the impact of triplets.

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4 AGENDA OF NEXT MEETING (GIANLUIGI ARDUINI)

The next WP2 meeting will be on March 3rd, starting at 9:00, in room 6/2-004. The agenda will be

- Corrector budget for optics v1.5 (D. Gamba)
- Operational experience and requirements from the orbit feedback implementation (J. Wenninger)
- Present performance and expectations of the triplet orbit correctors MCBX (E. Todesco)
- Update on b4 correction in the LHC triplets (E. Todesco)
- Possibility of Offset the triplet to reduce radiation to it (R. De Maria)

Reported by N. Mounet