WP2 Meeting #159

Tue 17 Sep 2019, 10:00 – 13:00

Chair:	G. Arduini
Speakers:	R. Bruce, X. Buffat, T. Persson
Participants:	A. Alekou, S. Antipov, R. De Maria, R. Calaga, I. Efthymiopoulos, H. Garcia-Morales, M. Giovannozzi, E. Maclean, L. Malina, E. Métral, N. Mounet, S. Papadopoulou, Y. Papaphilippou, K. Paraschou, F. Plassard, S. Redaelli, B. Salvant, G. Skripka, G. Sterbini, R. Tomás, F. Van Der Veken

AGENDA

The meeting was devoted to the problem of achieving simultaneously a robust coherent stability and a sufficient dynamic aperture under constraints of coupling, nonlinearities, beam-beam, and impedance.

MEETING ACTIONS

Elias, Xavier	Define a strategy for strategy for measurement and correction of the coupling
Tobias	Determine the accuracy of the coupling measurement for the bunches that are used as reference according to the defined strategy
Xavier, Nikos	Study the gain from retraction of the IR-7 collimators: primary and secondary by 0.5 and 1.0 coll. σ, focusing on the Nominal scenario with full beam intensity
Benoit, Stefano, Gianluigi	A summary of the resistivity measurements should be presented in a joint meeting WP2/WP5

GENERAL INFORMATION (G. ARDUINI)

Minutes of the two previous meetings have been circulated. **Gianluigi** reviewed key action items of the meetings.

An issue has been identified with false readings of certain Beam Position Monitors (BPMs) due to incorrect termination. Connected to this, **Manfred** is to provide the list of potentially faulty BPMs, while the **Impedance team** is to simulate the modes for shored BPM striplines.

For the aperture restriction at the exit of the D1 dipole, **Paolo** is checking with WP3 if tilting of the magnet could be done. **Massimo** commented that **Ezio** has been put in contact with other WPs for this matter.

An extra BPM in the D1 does not seem to help improving the orbit due to alignment issues. An ECR has to be prepared stating the BPM is not needed in that location. A potential mitigation could be using the BPMs in the Tertiary collimators (TCTs) close to D2. **Stefano** has been informed about the issue. **Riccardo** commented that the position of the collimator jaws with the respect to the tank is well known, making it possible to use the TCT BPMs; discussions with **Helene** are ongoing. **Gianluigi** pointed out it is important to know the accuracy of the position of those BPMs.

Stefania sent around an update with a few additional plots based on the comments received at the meeting. In particular, the slope generated by the noise on the bunch-by-bunch emittance is clearly seen. An important question remains how much the real luminosity is off from the self-consistent model (that does not consider extra losses).

Riccardo has been asked to check the MCBXF strength requirements. **Riccardo** noted that in some MDs the MCBX could be used a lot, unlike in normal operation, including swaps of torque. **Gianluigi** concluded that first one has to check the operation is guaranteed; then a procedure for MDs can be written, highlighting the overhead to train the magnets.

MS10 options have been identified. **Riccardo**, **Xavier**, and **Yannis** will perform a comprehensive analysis of the options. **Fabien** is to summarize the key numbers to be used as input for their studies, preferably as soon as possible.

1 STABILITY OF LINEAR COUPLING IN RUN 2 (T. PERSSON)

Tobias reported on the stability of coupling in Run 2 and expected performance for HL-LHC. The coupling is quantified as C^-, i.e. the closest tune approach.

A new ADT-based tune measurement system improves the resolution of C^- via better bunch by bunch tune measurement. The plan is to have it as an operational tool for Run 3.

At injection C^- changes by 3-4x10^{-3} over 2 hours, which is linked to the powering of MCS sextupole corrector magnets. A mitigation procedure, utilizing an uneven powering of the MCS correctors, was proposed and tested successfully in an MD. With the new procedure the drift should not exceed 10^{-3}. On a long term scale, there is no significant drift of coupling knobs at injection, assuming corrections are done every fill. The magnitude of corrections is several units of 10^{-3}, being a bit larger in Beam 2 than in Beam 1. This discrepancy is likely to be caused by an additional effect like a change in the orbit. Beam intensity does not affect the coupling within the measurement uncertainty.

At Flat-Top the short-term coupling stability is better, at the level of 10^{-4} (limited by the resolution of the measurement). No long-term behavior has been observed.

At the End of Squeeze the short term C^- stability is within 10^{-3} and long term – 2-3 units of 10^{-3} over 6 months. The long term drifts of coupling can be explained by the tilts of the triplets.

Change of a filling scheme leads to a change of coupling (observed as Im C^-) of the order of several units of 10^{-3}. Long range interaction seem to affect the C^- significantly. This fact raises a question which bunches should the coupling be corrected for. Currently the coupling is measured on the 12 non-colliding bunches, but it might not be the optimal strategy.

- **Gianluigi** asked if coupling is measured and corrected every fill, how well can it be controlled. **Tobias** replied it cannot be done better than 10^{-3} with the present ADT excitation scheme, the limitation coming from BPM noise.
- **Elias** inquired about the measurement of coupling in the Ramp. **Tobias** replied it can be done with ADT, although limited to one try a fill. Potentially several measurements could be done in a row, as a measurement only takes 5 sec.
- **Yannis** inquired about the possibility to study the impact of the beam-beam force on coupling IP-by-IP. **Tobias** confirmed it could be done. **Elias** proposed measurement of coupling vs separation could be done or at least some predictions could be useful. **Ewen** noted there is data on coupling vs crossing angle that could be analyzed.
- Regarding the measurement strategy, **Xavier** pointed out that the bunches colliding in IP1,5 have to be controlled, since they are the ones that need to be optimized for stability and dynamic aperture. **Gianluigi** concluded that, first, the strategy to measure and correct C^- for 2021 must be established, identifying for which bunches the coupling should be corrected and the target values for injection and Flat-Top (Action: **Elias, Xavier**) and, second, one has to check if the measurement on the selected bunches is precise enough (Action: **Tobias**).

2 UPDATE ON THE OPERATIONAL SCENARIO TAKING INTO ACCOUNT OF THE CONSTRAINTS ON COUPLING (X. BUFFAT)

For coherent stability the most critical point of the operational scenario is the End of Squeeze and start of Collision. The goal is to ensure static stability at every step in the cycle. The present estimates do not rely on the distribution tail – they are cut at 3σ. From the present OP experience a factor two safety margin is needed assuming perfect correction of coupling and nonlinearities. The implication of realistic targets on linear coupling and nonlinearities correction need to be included in addition.

The collimator impedance upgrade brings the octupole current within the factor two margin of the capabilities of the system. Beam-beam effects compensate the tune spread for the negative polarity, requiring extra amplitude detuning to stabilize the beam. The Achromatic Telescopic Squeeze (ATS) optics should be used to regain stability. For the positive polarity the bare octupole tune spread is sufficient, but stability of non-colliding bunches shall nonetheless be ensured.

Numerical simulations of separation bump collapse have been refined to confirm the constraints on the separation – current plot. Crossing the unstable beam separation region would lead to an instability with a rise time of around 12 sec with the full impedance upgrade. The ramp and acceleration rates of the orbit correctors involved in the separation bums have been selected so that the time required to cross the unstable region is much shorter as compared to the expected rise time, but orbit drifts could be an issue – and separations equal or larger than 1 σ should be avoided at the end of the collapse.

From the optics perspective achieving a C^- of 10^{-3} seems challenging. Already such a level of coupling reduced the footprint according to tracking in PTC, although no impact from ADECTA (Amplitude Dependent Closest Tune Approach) is foreseen for particle below 3σ. The coupling has a 5-15% estimated impact on the coherent stability factor. On top of the coupling, nonlinearities (b4 and feed-down from higher multipoles): up to 30-50 A need to be compensated depending on the polarity with positive polarity being more critical.

Adjusting the octupole limit to account for the ratio of coupling to tune separation of 0.2 and the nonlinearities one obtains the stability limits of 410 A and ATS factor of 1.0 (but reduced octupole current of approximately 450 A) for the positive polarity and 2.0 for the negative polarity at the maximum octupole current for the full collimator upgrade. The telescopic factors would be 1.5 and 2.4 for the positive and negative octupole polarities, respectively, assuming maximum octupole current after the LS2 collimator upgrade.

Design criterion for the dynamic aperture (DA) is 6σ in the absence of lattice errors. The DA shrinks as the ATS index increases. For the negative polarity the telescopic index has to be below 2.0 and the tune separation – at or below $6x10^{-3}$ assuming the full collimator upgrade, to reach the limit of acceptable DA. For the positive polarity all ATS indices above 1.0 are excluded and the tune separation has not to exceed $6x10^{-3}$. Both cases are at the limit of acceptable DA and require tune control better than 10^{-3}. The estimates might be slightly pessimistic but are nonetheless rather worrisome.

There is only a marginal improvement of DA if one decides to sacrifice the beam intensity. One would need to lower the intensity to $1.8x10^{11}$ p per bunch to achieve stability with 2.0 ATS index and LS2 collimator upgrade. In that case the DA should be acceptable.

Overall, considering the limitations posed by DA and coherent stability there is no operational room left. The options could be (1) start collision at a larger β^* of 64 cm and increased crossing angle to minimize beam-beam effects. In this case only 1.9 ATS index is needed with the negative polarity. (2) Relax the collimator setting, utilizing the margin provided by remote alignment. Moving the IR-7 primaries together with the secondaries seems promising. (3) Accept transient unstable modes. (4) Perform an asynchronous collapse: bring one IP in collision without crab cavities, re-optimize, reduce the octupole strength, collide the other one, and turn the crab cavities on.

- Regarding lowering the intensity, **Gianluigi** made a comment that could be considered as an option for machine start-up, but not the only one.
- Discussing the limitations posed by non-colliding bunches, **Gianluigi** concluded their brightness might have to be reduced if needed, suggesting to focus on the nominal ones.
- **Massimo** inquired if estimates of nonlinearities exist for LHC. **Ewen** quoted a 2018 MD data where without correction around 250 A of effective detuning is split focusing and defocusing octupoles due to feed-down from higher multipoles. **Sergey** inquired if this can be the reason behind the factor two discrepancy between the ideal model stability predictions and the operational requirements. **Xavier** pointed out that the feed-down arises due to the crossing angle; at Flat-Top normally the nonlinearities are well corrected. **Rogelio** and **Massimo** pointed out that the implementation of the full non-linear correction will take some time and cannot be expected from the start-up.
- **Riccardo** proposed reducing the octupole strength after the separation bump collapse. **Xavier** replied it can be done for the colliding bunches, the brightness of the non-colliding ones would have to be reduced. **Riccardo** quoted that at β^* = 15 cm the ATS will have to go up to 3.3. **Xavier** replied that a DA with 300 A current has been studied for 15 cm and it is marginal at lower intensity (corresponding to the one at the end of levelling).
- **Sergey** raised a question if the 6σ DA goal shall be relaxed. **Yannis** pointed out the errors and uncertainties are likely to reduce the DA by 1σ. **Gianluigi** noted that the 2018 experience has shown that reducing the DA below 6σ leads to a significant increase of the losses above the burn-off limit, and a scaling of the R2E effects showing a faster than linear dependence from the luminosity has been observed. Radiation started seeing losses with intensity that might affect the electronics in IR-7. It is important to minimize the losses to avoid installation of additional hardware. **Stefano** mentioned the limit of losses in IR-7 has not yet been approached.
- **Gianluigi** inquired about the possibility of opening the collimators and posed a question what would a reasonable assumption for the collimator efficiency be. **Stefano** mentioned that the aperture gain due to remote alignment has not yet been demonstrated. Riccardo noted that with no full remote alignment the corrector strength is insufficient. The alignment will therefore have to be done manually, otherwise experiments will not be able to take luminosity due to inner trackers not being aligned.

3 MITIGATION OF LOSSES ON 11T DIPOLE (R. BRUCE)

In **Eleonora**'s absence **Roderik** gave a summary report on her behalf. The full presentation will be given at the next meeting.

Studies of cleaning efficiency vs collimator opening indicate the losses increase when relaxing the IR-7 settings by up to 30% over 2 collimation σ. The losses in the 11 T dipole are the most critical. Opening the primaries together with the secondaries seems preferable.

- Discussing options for a further reduction of the collimator impedance, **Benoit** asked if the asymmetric cleaning scheme is on the table. **Stefano** replied it introduces a reduction of cleaning efficiency similar to opening the collimators. **Roderik** proposed trying to re-optimize the IR-7 optics to improve both the impedance and the cleaning, but this should be first validated with Machine Studies.
- **Roderik** mentioned results of irradiation tests indicating that Molybdenum-Graphite resistivity may degrade over time. **Stefano** commented there seem to be a relatively large step, up to 50%, in resistivity at relatively low doses. **Gianluigi** asked to make sure to identify that ideal resistivities are used for the stability analysis. A summary of the measurements should be done in a joint meeting WP2/WP5 Action: (**Benoit, Stefano, Gianluigi)**.
- **Gianluigi** raised the question whether it is realistic to consider opening the IR-7 and if yes what is the range to consider. **Stefano** and **Roderik** replied one can tolerate increasing the losses by at most 40%, although the current margin of *only* 40% is not comfortable enough already, as pointed out by the Collimation Review. An increase in losses can likely be accepted if it corresponds to other measures identified to reduce the losses (orbit shift, etc.) **Gianluigi** concluded that the next steps should be to study the gain from retraction of the IR-7 collimators, primary and secondary, by 0.5 and 1.0 coll. σ, focusing on the Nominal scenario at ultimate luminosity with full beam intensity (Action: **Xavier**, **Nikos**).

4 ROUND TABLE

Next meeting will be held on Sept 24 and start at 9 am. It will open with the two talks from Cryogenics (**Serge** and **Krzysztof**), rescheduled from the 10th. **Eleonora**'s report on collimator cleaning efficiency will follow the talks at 10 am.

Reported by S. Antipov