WP2 Meeting #179

Tue 28 July 2020, 10:00 – 12:30

Chair: Gianluigi Arduini

Speakers: Nicolas Mounet, Xavier Buffat, Sondre Vik Furuseth

Participants: Gianluigi Arduini, Roderik Bruce, Xavier Buffat, Sondre Vik Furuseth, Hector Garcia Morales, Massimo Giovannozzi, Ivan Karpov, Sofia Kostoglou, Ewen Maclean, Lucas Malina, Luis Medina, Elias Métral, James Mitchell, Nicolas Mounet, Konstantinos Paraschou, Benoît Salvant, Galina Skripka, Rogelio Tomás, Carlo Zannini

AGENDA

MEETING ACTIONS

Xavier	Summarize a table of options with requirements for the negative polarity scenario
Nicolas	Investigate the possibility of using the more realistic 5 GHz broadband model

GENERAL INFORMATION (GIANLUIGI ARDUINI)

Gianluigi went through the actions of two previous meetings. From the Joint WP2/WP3 meetings there was action for Lucio to compare the measurements with integrals of simulations to ensure good agreement. Ezio has to provide estimates of the fringe fields in correctors (MCBRD and MCBXF). He also will check the tables for the acceptance criteria for D2, MCBX and MCBRD, because some inconsistencies were found. Susanna was asked to present the comparison of simulations to measurements of beam screen impact on field quality in LHC and in HL-LHC with data measured on short model, summarizing not only the higher order multipoles but also the impact on the main field. She will also check the relative impact on the field from the quadrupole cooling channels, depending on their size and distance form the center. Massimo was asked to check the impact of b2, a2 on the MCBRD on beta beating.

From the last WP2 meeting dedicated to e-cloud there was an action for Stefano to provide data on beam profiles measured at top energy. Kostas then has to repeat simulations with realistic beam profiles, tunes and collimator settings. It was also agreed to organize a Joint WP2/WP5 meeting with electron lens team. This is foreseen for the middle of September.

Today's agenda contains three talks related to beam stability. The first two talks take new operational scenarios into consideration to get a first estimate on the beam stability. Operate with more relaxed collimator settings and also taking into account the initial constraints from cryogenics (collision at lower luminosity). Nicolas will present the impedance model in the new operational scenario. Then, Xavier will talk about stability limits, and Sondre will present the fist data on the crab cavities impact on the instability latency.

1 UPDATE OF THE HL-LHC IMPEDANCE MODEL IN THE NEW OPERATIONAL SCENARIO, AND CONSIDERATIONS ON CRAB CAVITY HOMS (NICOLAS MOUNET)

The impedance model of HL-LHC is revisited using the new operational scenario that has been circulated by Gianluigi. In particular, primary collimators in IR7 have been retracted by 1.8σ, and IR7 secondaries by 1σ, with also a higher β* (between 85 cm and 140 cm, depending on the scenario), to reduce the luminosity at the start of collision. As expected, this retraction has a strong impact on stability with a reduction of the single-beam octupole threshold by 20 to 25% with respect to the previous baseline (with β* = 40cm).

The model was also updated using the newest (v1.5) optics, the new design for the deformable RF fingers in the crab cavities, the LHCb VELO, and updated high order modes (HOMs) for the crab cavities. In the transverse plane, these additions have a much smaller impact than the collimator retraction; the same goes for the impact of the β* value (from 85 cm to 140cm). However in longitudinal, the VELO accounts for an additional 4% to the imaginary (broad-band) impedance close to 1 GHz, and the crab cavities for around 10% more.

A first version of the updated model was provided to Xavier for the two-beam stability analysis, which includes only the main changes, namely the collimator retraction.

Finally, the specifications regarding the shunt impedance of HOMs in crab cavities were revisited using the newest DELPHI code and the updated impedance model. Nicolo has presented previous specifications at the 229th HSC meeting. The update shows stricter specifications due to coupled-bunch modes: +10 A in octupole current (with TeleIndex = 1) is reached when HOMs close to 1 GHz have a shunt impedance of 120 kOhm/m with β* = 15 cm, which would nevertheless happen only during collisions, where instabilities are heavily damped thanks to the beam-beam tune spread. On the other hand, at β* = 40 cm the current crab cavity HOMs are close, and mostly below, the threshold of +10A.

- **Rogelio** asked if with TeleIndex corresponding to β* = 40 cm the actual octupole current will be lower. **Nicolas** replied that it will be 30% lower, the gain is factor 1.3 with TeleIndex = 2.
- **Gianluigi** asked if for the case of β* = 40 cm (which should be considered as worst case in ultimate scenario) with the present crab cavity modes it should be ok. **Nicolas** said yes.
- **Gianluigi** asked if the factor 2 was applied? **Nicolas** replied that it was not applied because it is not clear where to apply it. In any case, the results would not change dramatically as they are in relative (in the worst case, +10A might become +20A).
- **Gianluigi** commented that this study is done assuming that the machine is full. Is there any change when going to realistic filling patterns? **Nicolas** replied that probably some but not large. In the past it was shown that what matters is the bunch spacing
- **Gianluigi** asked if 350 A for the full model is given for multi- or single bunch? **Nicolas** replied that it is for multibunch. **Elias** added that there was factor 2 included and it is done for chromaticity 10. Later in the meeting (see discussion after the presentation of **Xavier**) it was specified that these results were obtained with an emittance of 2.1 μm, hence not the most critical possible emittance of 1.7 μm that **Xavier** uses.
- **Ivan** asked if 50 GHz broadband model is still used for the longitudinal impedance. **Nicolas** confirmed. **Gianluigi** added that going to 5 GHz would be the next step. **Nicolas** said that it could be done for longitudinal but not transverse plane. There is a big change in the real part of the impedance that changes the picture dramatically and possibly un-physically. This has to be investigated in detail. **(Action: Nicolas)** to investigate the possibility of using the more realistic 5 GHz broadband model.

2 Stability Limits with the New Operational Scenario (Xavier Buffat)

An update of the stability limit with the new operational scenario was presented. The new octupole threshold, maintaining the same assumption as for the old baseline, are still not compatible with dynamic aperture with the negative polarity of the octupole. On the contrary, the requirement with the positive polarity is reduced from 550 A to 460 A, which is acceptable. It was highlighted that the driver for the high requirement with the negative polarity is the compensation of the detuning from the arc octupoles by the long-range interaction at the IP, not the parasitic ones. This contribution can therefore hardly be reduced with a change of β* or crossing angle. Nevertheless, if one accepts a short transient with a loss of Landau damping during the collapse of the separation bumps, the requirement with the negative polarity becomes acceptable from the point of view of dynamic aperture. The absence of impact on the beam quality when losing Landau damping for a transient time shorter than the instability rise time was shown experimentally in MD in 2018.

When operating with the positive polarity of the octupoles, the option 1 proposed (β* = 140 cm and crab cavities enabled) does not feature any reduction of Landau damping due to beam-beam interactions through the cycle, therefore, the requirement is defined by the single beam stability. The option 2 (β* = 105 cm and crab cavities disabled) features a loss of Landau damping during the collapse of the separation bumps if they are executed synchronously in IPs 1 and 5. Alternatively, the bumps in each IP can be collapsed one after the other to fully mitigate this loss of Landau damping. Another alternative that fully mitigates this effect on a wider range of parameters would be to introduce a separation bump in the crossing plane. An implementation of such a scheme was proposed. Nevertheless, detailed analysis revealed a new type of mode coupling instability that requires further investigation.

When operating with the positive polarity of the octupoles, levelling with an offset at the two low-luminosity IPs is mostly ok from the point of view of Landau damping. Only the levelling in IP8 with the spectrometer polarity that enhances the crossing angle at the IP could result in a loss of Landau damping for the bunches that do not collide in IPs 1 and 5.

- **Gianluigi** asked if results presented by Nicolas are for the single beam 350 A is assuming tails cut at 3σ? **Xavier** replied that he uses a Gaussian that is cut at 3σ and **Nicolas** is using a parabolic cut at 3.2σ. The difference however is small. **Gianluigi** asked if with negative polarity worse situation is expected if cutting the tails. **Xavier** confirmed that it is about 30% worse. With more tails situation improves for negative polarity.
- **Gianluigi** commented that, when cryogenics will gain a better understanding of the system, directly going to high luminosity would not be an issue. What is the most promising option in this case when lowering β*? **Xavier** replied that with option 1 and crab cavities enabled any type of collapse would work even with low β*. The problem with option 1 could appear if the crab cavities are not available temporarily. As a backup lumi-scan knob could be used to introduce a parallel separation. If going for option 2 the only way is the separation in the crossing plane. **Gianluigi** added that not if we go with relaxed collimator settings and asynchronous IP1/5 collapsing.
- **Gianluigi** said that running with negative polarity is still possible. **Xavier** added that positive polarity is very safe. But, if wanting to profit of advantages of having closer collimators and DA, then testing negative polarity in Run 3 maybe an option. **Gianluigi** asked if there is a difference with crab cavities on/off. **Xavier** replied that for the negative it is beneficial not to have them on during the collapse of the separation bump. **Gianluigi** asked to summarize a table of options with requirements for the negative polarity scenario (also for low β*) **(Action: Xavier).** Then options can be compared and some eliminated.
- **Nicolas** commented that the discrepancy in octupole threshold between his studies (350 A) and the ones of **Xavier** (460 A) are explained by the emittance difference (2.1 μm vs 1.7 μm used by **Xavier**).
- **Sofia** commented that the DA plots shown by Xavier were done with C-=0.005 while the agreed tolerance should be 0.001. **Gianluigi** agreed and highlighted the need for new DA studies with final settings.

3 INSTABILITY LATENCY IN THE HL-LHC – A FIRST LOOK AT CRAB CAVITIES (SONDRE VIK FURUSETH)

Xavier presented the slides of Sondre on the instability latency in the HL-LHC. A closed analytical formula for the latency was derived based on few assumptions that could be validated with numerical estimates. The latency mainly depends on the margin in the octupole current with respect to the instability threshold, the noise amplitude and the head-tail mode sensitivity to the noise. Due to the high sensitivity to the octupole margin, the uncertainties on the measured beam parameters generate large uncertainties in the predictions such that comparison to data is rather difficult. Nevertheless, the experimental data obtained in a dedicated MD in 2018 is compatible with the predictions of the model.

The impact of the crab cavities impedance on the latency is rather low. However, the impact of crab amplitude noise might be important due to the higher sensitivity of the beam to 'head-tail' noise compared to 'rigid bunch' noise in the presence of the ADT actively suppressing the rigid bunch mode. First COMBI simulations with crab amplitude noise seem to support this hypothesis but further verifications are needed.

For the same noise amplitude (i.e. neglecting crab cavity noise), the instability latency is expected to be longer in the baseline HL-LHC configuration w.r.t. the LHC 2018 configuration. This difference arises from the margin in octupole current, which is higher in the HL-LHC design w.r.t. the LHC 2018 configuration with a single beam.

A plot of the latency as a function of the noise amplitude and the octupole margin was suggested to help in drawing specifications for these quantities and highlighting the need for an accurate noise model of the LHC and HL-LHC.

- **Gianluigi** asked if keeping crab cavities off until going into collision could be advantageous? **Xavier** confirmed. The latency could be a matter of minutes, which could be problematic. **Gianluigi** asked if the cavities can be not really off but counter-phased. **Xavier** replied that since noise is uncorrelated among cavities, it would be similar. With low voltage should be fine, but it should be specified how low.
- **Gianluigi** asked if twice the specified noise amplitude is assumed. **Xavier** answered that the simulations are pessimistic in two ways: First the amplitude noise is defined assuming that the maximum emittance growth specified for the crab cavities results from amplitude noise, whereas this specification holds for the contributions of both phase and amplitude noise. In addition, the noise amplitude in the simulation is twice this specification.

4 AGENDA OF NEXT MEETING (GIANLUIGI ARDUINI)

The next meeting will be on Tuesday, September 1st, starting at 10:00. The agenda is being finalized and will be announced shortly.

Reported by the speakers and G. Skripka