WP2 Meeting #157

Tue 10 Sep 2019, 15:30 – 17:00

Chair:	G. Arduini
Speakers:	S. Papadopoulou, F. Plassard, E. Todesco
Participants:	A. Alekou, S. Antipov, F. Antoniou, R. Bruce, X. Buffat, R. De Maria, J. Dilli, I. Efthymiopoulos, H. Garcia-Morales, M. Giovannozzi, S. Kostoglou, K. Skoufaris, E. Maclean, E. Métral, N. Mounet, Y. Papaphilippou, F. Plassard, S. Redaelli, B. Salvant, R. Tomás, G. Trad

AGENDA

MEETING ACTIONS

Stefania	Study how much the luminosity is off when implying beam intensity from the self-consistent model, and not from the measurement data
Stefania	Check the effect of noise of the bunch-by-bunch emittance
Stefania	Consider the emittance evolution for the first bunches, not affected by electron cloud
Riccardo	Investigate if the proposed MCBXF powering constraints limits operation.
Riccardo, Xavier, Yannis	Study potential issues including beam-beam and PACMAN effects for the three identified MS10 scenarios.

Fabien Summaries the key numbers of the MS10 options in a single Table to be shared with colleagues and used for further studies, including the chromatic β-beating values for IP1.5.

GENERAL INFORMATION (G. ARDUINI)

Minutes of the previous meeting, prepared by Nicolas, have been uploaded and will be reviewed at the next meeting. Due to last minute cancellations the reports from Cryogenics will be rescheduled at a later date, possibly on the 24th of September, to be confirmed.

1 LUMINOSITY MODEL UPDATE (S. PAPADOPOULOU)

Numerical luminosity model predicts the evolution of key beam parameters such as transverse emittance, bunch length, and beam intensity to deduce the major performance criteria – the luminosity. Its physics includes Intra-Beam Scattering (IBS), Synchrotron Radiation (SR) damping, and elastic scattering. New updated of the model also includes linear coupling, feedback or power converter noise, and burn-off (BO). The model assumes an emittance increase by 6% for a burn-off of 20%.

Several model benchmarks have been presented, where the beam intensity is inferred from the experimental data. A 2018 BCMS fill has been chosen as an example. Comparison shows that the updated model is consistent with the BSRT data for colliding bunches – within 1σ uncertainty bounds, while the old model was not. Examination of individual effects reveals that coupling gradually lowers the horizontal emittance over time, while BO and noise increase it. SR damping effect is also clearly visible in the vertical plane. Reduction of β^* provokes visible changes in the slope of emittance evolution in the real data. This is likely due to the transient processes and not accounted for in the model. Thus more accurate predictions can be obtained when looking at the time intervals before β^* steps.

Bunch length evolution is in good agreement with the data for both colliding and non-colliding bunches.

Regarding the luminosity evolution in Collision, the present model had been overestimating the integrated luminosity. The updated model agrees with the better than 5% throughout the process, although the exact values depend on the choice of the initial emittance. Similarly, for the 2017 Fills, for all beam flavors (BCMS, 8b4e, and BCS), the updated model gives a significantly better luminosity prediction.

Looking at emittance evolution at Flat Bottom (FB), there is still a significant unknown emittance growth, mostly in the vertical plane, which cannot be explained only by the presence of electron cloud.

Overall, the updated luminosity model represents well the temporal evolution of real beam parameters. It will be used in future for HL-LHC estimations.

- **Roderick** asked which formula was used for the effect of BO on emittance. **Stefania** replied a numerical approximation and simulation data were used instead. The real emittance increase is somewhere in between the analytical formula for a Gaussian fit, and the numerical result, according to the presented comparison plot. **Yannis** commented what one can see from the plot is that the effect is significant. **Ilias** pointed out one must compare the models based on losses and luminosity, as emittance does not describe the full picture. **Yannis** proposed making a comparison with a curve obtained from the measured luminosity.

- **Elias** pointed out that the equations used to account for the coupling are valid for a static case. In particular, they don't allow emittance exchange. **Yannis** replied the approximation is justified since the coupling is relatively small and can be treated as a perturbation.
- **Roderick** raised a question why in the presented comparison the beam intensity was taken from the measurements, and not from the model. **Stefania** explained it would not account for the extra losses (on top of BO) and thus overestimate the luminosity. **Ilias** commented 17-18% of the overall luminosity loss is due to extra beam losses in the machine. **Georges** suggested presenting the luminosity comparison plots together with the self-consistent calculation from the model – such a comparison would be interesting from the operation point of view (Action: **Stefania**).
- **Georges** inquired about the sensitivity of the model predictions to the initial emittance offset, mentioning the shift between BSRT data and the real emittance (measured by the wire scanner) is not rigid but rather depends on emittance. The agreement depends on the calibration, and in the best case one gets within 10% of the true emittance. **Stefania** confirmed analyzing that data shows there is a difference, which is nonlinear. Different starting point corrections were applied for each plane separately with 10% being an average offset.
- Regarding the evolution of emittance at FB, **Yannis** made a comment that the slope of emittance with bunch number seen in the data is due to IBS: bunches that have spent more time in the machine have a larger emittance. **Gianluigi** then raised a question why one does not see a similar difference due to noise between the old model that does take it into account and the new one that does (Action: **Stefania**). **Yannis** suggested to check the effect of the noise; another thing that could be missing from the picture is the effect of electron cloud, currently modeled as an offset. There can be coupling to the noise-induced emittance growth as the cloud might produce a large tune shift, which in turn affect the growth. **Georges** proposed taking a look at the first bunches in the trains reasoning they should not see much electron cloud. (Action: **Stefania)**
- **Gianluigi** pointed out the emittance predictions seems to be worse for the non-colliding bunches and inquired if it has to do with the electron cloud that these bunches do not see. **Georges** added that for these bunches the ADT gain is also reduces. **Stefania** replied that indeed at the moment the same initial emittance correction is applied to all bunches, including the non-colliding ones.

2 Test results of MCBXF prototype (E. Todesco)

Ezio reported on the latest development with the MCBX nested correctors. Today in LHC the MCBX correctors are limited at 400 A instead of 550 A. For the HL-LHC the correctors will operate at a lower field: 2 vs 3 T, but will have a two times larger aperture.

Short models are currently being produced and tested. The nominal current has been reached on the third short assembly after some problems with shimming had been understood and corrected. The problem is that each time the sign of the torque is changed one needs around five quenches to re-train the magnet to the full current. This feature might be limiting for the operation. A safe region (in terms of Inner Dipole field – Outer Dipole field) has been tested in which one can operate the corrector without retraining. The team will try pushing the limits of the accessible region in the second prototype.

There is no reason to believe the situation will be different for long magnets. This is why the WP is asked to verify if the proposed limitation of torque reach might be dangerous for operation.

- **Gianluigi** emphasized the importance of the presented issue and asked to check if the proposed limitations can be tolerated for beam dynamics (Action: **Riccardo**). Riccardo supposed a limitation might come from magnets 1 and 2 due to unknown orbit correction and dipole magnet imperfections, and suggested analyzing the present experience of MCBX powering to see if the worst case scenario fits the proposed bounds. **Ezio** suggested studying optimizing the training procedure to obtain the best suitable shape of the safe region.

3 NO MS10 STUDIES (F. PLASSARD)

The baseline of HL-LHC foresees an installation of an additional main sextupole MS10 to restore an even number of Sextupoles on each side of IP1&5. The symmetry allows better compensation of geometric aberrations and ultimately brings large Dynamic Aperture (DA). Presently, an odd number of sextupoles makes a large impact on resonant driving terms in LHC. For the HL-LHC the MS10 provides a strong 2-3σ increase of DA for the latest v1.4 optics.

Several alternative lattices have been studied to investigate if the installation of MS10 can be mitigated. The 'No MS14F' lattice feature a removal of MS14F magnet to restore the symmetry and a new phase advance between IP's 1 and 5. A phase optimization has been performed to maximize the DA (computed based on 10^6 tracking turns). The new phase advance is compatible with the MKD-TCT phase advance constraints. The 'No MS14F/D' features even number of sextupoles thanks to disconnecting MS14F one side of the IP and MS14D. The disadvantage is that one needs about 20% larger sextupole strength for Q' correction. Phase advance optimization has also been performed for this option, although no significant improvement has been achieved.

After all the optimization the best alternative optics seems to be the 'No MS14F/D', providing 12.4/12.1 σ (Horizontal/Vertical) of average DA, close to the Baseline values of 12.9/12.2 σ. For comparison, running in the present situation without MS10 would bring the DA down to 11.5/11.2 σ. Chromatic β-beating could be an issue for the alternative optics. In IR-7 it can reach 6% for 'No MS14F/D' compared to only 2% for the Baseline assuming 3×10^{-4} rms momentum spread.

A possible option that may also be worth studying is installing only one MS10 out of two – MS10D. Then without MS10F and MS14F one can obtain the DA performance similar to the baseline: 12.9/12.0 σ average DA.

One alternative method to lower the sextupolar resonant driving terms could be to change the powering in the Landau Octupole circuits, reducing the current in the location where there are orbit bumps for dispersion correction and increasing in the others to keep the same tune footprint. The average DA can increase by 1-2 σ at the cost of limiting the octupole strength reach to 300 A (out of 500 A).

In conclusion, all alternative optics have to be validated with beam-beam simulation.

- **Gianluigi** asked to clarify for which case the octupole optimization was studied. **Fabien** replied - for the baseline, but the same procedure can be applied for the other cases. Preliminary results suggest one can also expect some improvement there. **Sergey** emphasized the limitation in the octupole current the method creates. **Riccardo** posed the question if a decision on the non-colliding bunches has been made. **Gianluigi** replied there has not been a discussion yet, it is important to understand how much the non-colliding bunches are limiting the performance.

- **Gianluigi** summaries the three options that look promising are: 'No MS10', 'No MS14F/D', and the baseline (in the likely order of preference for the magnet team) and proposed study potential issue for each of the options: beam-beam effect, PACMAN bunches, etc (Action: **Riccardo**, **Xavier, Yannis**), an summary table listing all the relevant numbers of each of the options has to be created (Action: **Fabien**). **Riccardo** noted the big uncertainty is the acceptable level of β-beating in the arcs, the numbers have to be verified with machine protection. **Rogelio** pointed out only the β-beating in IR-7 is quoted, while IR1&5 might also be important as it may impact the luminosity, and proposed quoting them as well. (Action: **Fabien**)
- **Gianluigi** concluded that the 'No MS10' option could be a starting point for the machine start-up in Run III, then decision can be made based on how much the machine is limited by lifetime effects.

Reported by S. Antipov