Minutes of the 134th WP2 Meeting held on 11/10/2018

Participants: S. Antipov, G. Arduini, S. Arsenyev, X. Buffat, R. De Maria, M. Giovannozzi, N. Karastathis, S. Kostoglou, E. Metral, N. Mounet, A. Oeftiger, S. Papadopoulou, Y. Papaphilippou, F. Plassard, B. Salvant, S. Kostoglou, K. Skoufaris, G. Sterbini, R. Tomas, F. Van Der Veken

AGENDA:

1 GENERAL INFORMATION (G. ARDUINI)

The minutes of the previous, 133rd meeting have been circulated.

2 IMPACT OF NOISE ON BEAM STABILITY (X. BUFFAT)

Present instability predictions are off (too optimistic) by a factor two when compared to the operational experience at LHC. The discrepancy is accounted for in the LHC settings, but for the HL-LHC additional mitigation measures, such as low impedance collimator upgrade and Achromatic Telescopic Squeeze (ATS) optics are required. The source of the discrepancy remains so far unknown.

An example of the yet-to-be-understood behavior is a high latency instability that was observed in LHC at Flat-Top (FT) after 40 min. Another one is a higher measured octupole threshold at some chromaticities at FT when allowing for latency. With short wait time at each octupole step the predictions of the impedance model seem to match the observations, while a factor two higher thresholds are observed when allowing for a sufficiently long delay. Both observations can be qualitatively reproduced in a macroparticle simulation with additional controlled noise, pointing out on the possible nature of the phenomenon. According to COMBI tracking simulations, the noise leads to a change of the transverse distribution, resulting in a loss of Landau damping. A *loss of Landau damping driven by diffusion* is therefore proposed as the name of the effect. So far the change of distribution has only been observed in simulation, confirming it in an experiment seems technically challenging.

The numerical set-up in COMBI assumes a linear transfer map, amplitude detuning, chromaticity and synchrotron motion, a perfect damper acting on the center of mass position only, impedance, and Gaussian (in amplitude) white (uncorrelated in time) noise with 10 random seeds. The simulation results show that the latency time is inversely proportional to the noise amplitude, scales with the third power of the octupole current, and is linearly proportional to the damper (ADT) gain. The measurements at LHC are qualitatively compatible with the numerical model predictions, although a further analysis is required. According to the empirical scaling, the new ADT pickups will increase the latency time by a factor of 1.9.

An instability with a controlled noise can be provoked in an experiment. Data obtained in qualitatively matches the predictions, further analysis is required.

- **Rogelio** inquired if the change of the distribution could be related to resonances. **Xavier** emphasized that in the simulation it is a purely decoherence mechanism, not an excitation of a resonance. **Riccardo** asked if the phenomenon is related to Stochastic Cooling (SC), pointing out the similarity that the phase space becomes more compact. **Xavier** replied it is worth checking, from the first view it is hard to tell if there is a relationship to SC; the emittance seems to be increasing but not uniformly.
- **Gianluigi** asked if a scaling with impedance had been checked in simulation. **Xavier** replied this is one of the things to be done. **Gianluigi** inquired what if the noise is correlated around a certain frequency. **Xavier** answered it is not clear, a similar effect could occur. **Sergey** asked if a repopulation of the distribution should occur, for example through the Intra-Beam Scattering (IBS). **Xavier** clarified that was is happening is a 'flattening' of the distribution, i.e. removal of the gradient in the transverse action configuration space, which in turn leads to a loss of Landau damping. In this situation it is not clear whether IBS would act against the effect, but it is yet to be checked. **Yannis** pointed out that in LHC the IBS timescale is relatively long – of the order of hours. **Elias** summaries that what is shown is a major step in understanding of the effect of noise on beam stability; now it is the time to perform the studies.
- **Rogelio** asked if an impact of the noise on beam emittance is presented at the HiLumi Meeting. **Xavier** replied that the issue was presented last year. No new MD data will be available before the meeting. **Rogelio** proposed highlighting the measurements made at LHC more explicitly.

ACTION (Xavier): Modify the talk, taking into account the comments.

ACTION (Xavier): Check the scaling of the effect with wakefield strength and in the presence of noise at certain defined frequencies as those observed in the beam (see presentation by Sofia)

3 EMITTANCE GROWTH IN THE LHC AND IMPACT ON HL-LHC PERFORMANCE (S. PAPADOPOULOU)

An automated tool for performance follow-up has been developed. Only the fills that made it to Stable Beams (SB) are being followed up. The average emittances in 2018 are 1.40 (Hor.), 1.34 μm (Vert.) for Beam 1 and 1.43, 1.36 μm for Beam 2.

An issue has been identified – the BSRT data cannot be trusted in some cases during SB and at FT. The estimation of emittance at the start of SB and its blow-up during the Ramp come from luminosity measurements and emittance scans.

Comparing the model emittance growth with the measurements, a larger than expected emittance growth is observed at Flat Bottom (FB), the extra blow-up seems to be electron cloud driven. In a chosen example fill for the first bunches of the trains the emittances are close to what is expected IBS, then the emittance shows a familiar e-cloud pattern, increasing from the head to the tail of the train. A work has started to include the predictions from e-cloud. An extra emittance growth has also been observed in SB, it amounts to around 0.05 μm/h and has no clear dependence on the beam brightness.

Several assumptions were made to obtain the HL-LHC predictions: the 2018 fills where the emittance measurements can be trusted were taken, LHC time in the Ramp and no brightness dependence of the blow-up was assumed, and an extra emittance growth was added according to the measurements. Given these assumptions a Standard beam would have a 2.5 μm emittance at Flat Bottom, 3.3 μm at the start of Stable Beams. For the BCMS beam the figures are 2.1 μm at FB and 2.5 μm at SB. The BCMS beam would lose 3% in integrated luminosity due to the extra emittance growth (Standard and Ultimate OP).

- **Rogelio** raised a question why the BSRT data is used at Injection. **Stefania** replied there are not too many outliers in this data compared to other phases. **Yannis** noted that the wire scanner data is also available, its acquisition is not automated but can be included in the data.
- Regarding the luminosity loss, **Gianluigi** noted the Standard beam has a larger emittance at the beginning. **Yannis** noted that would mean less time to level, since the beam is already degraded. **Gianluigi** emphasized one needs to keep the BCMS option open. **Rogelio** suggested as a figure of merit quoting the loss of integrated luminosity per day.
- For the Annual Meeting, **Gianluigi** proposed adding more info about the single bunches and bunches at the beginning and at end of the train as it allows disentangling the contribution of e-cloud; adding the model predictions for the luminosity loss of Standard beam in HL-LHC; and emphasizing that accurate instrumentation of emittance measurements is needed.
- **Gianluigi** inquired if there is any data from the large ATS index MDs. **Yannis** mentioned they will check if any data is available.

ACTION (Stefania): Incorporate the predictions of electron cloud induced emittance growth in the model

ACTION (Stefania): Include wire scanner data at Injection

4 Beam-beam simulations in the HL-LHC (impact of LHCb, high-telescope, etc.) (N. Karastathis)

Nikos presented results of multiple Dynamic Aperture (DA) studies with beam-beam. For reducing the chromaticity a precise control of the tune is crucial for obtaining the optimal lifetime. Lowering the chromaticity to 7 wins 0.5 σ in DA. There is almost no margin for the beam-beam interaction, therefore one has to look at compensation techniques.

DA studies for different ATS indexes were performed for several key values: 1.0, 1.7, 2.2, 3.1; these are the indexes required for the Ultimate BCMS scenario with asynchronous separation bump collapse for various IR7 coating scenarios. All simulations were performed for the Standard scenario though. 1.7 (corresponding to the full impedance upgrade) and 2.2 (the LS2 subset) seem to be the best from the DA point of view when considering both pre-squeeze and start of collision for the octupole currents stated in the OP Note. In all cases islands of good DA can be obtained scaling down the octupole current.

LHCb is considering a potential additional upgrade to have an integrated luminosity of $1\text{-}2\times10^{34}$ in order to accumulate around 300 fb^{-1}. Simulation show that a reduction of β^* from 3 to 1.5 m does not have a significant effect on DA, a reduction of the crossing angle might impact the DA though. Possible scenarios with horizontal and vertical crossing have been identified.

For the flat optics the BBLR compensation is crucial. The octupoles alone seems insufficient to preserve good DA, whereas islands of large DA can be found with wire compensation.

- During the discussion on DAs for different ATS scenarios **Gianluigi** requested to confirm the exact values in the Table with Xavier and noted that -570 A where assumed by Xavier to stabilize the beam. **Gianluigi** stressed that the key question is if the collimator upgrade can be stopped after LS2 – that depends on whether or not an ATS index of 2.2 can be accepted in the Ultimate scenario with the full negative octupole current of -570 A. **Yannis** noted that on the first sight that looks difficult as already in the Standard scenario the 6 σ area looks rather small. **Riccardo** mentioned he will provide the necessary optics files as soon as possible. **Xavier** proposed that the octupole current reduction goes in stages with the asynchronous separation collapse, this procedure would help reducing the destructive interference of beam-beam and octupole tune footprints. **Sergey** mentioned that in an MD with negative octupole current an instability during collision was particularly hard to trigger: it required a careful set-up and staying at the right separation for a long time, therefore the instability might not happen if the collapse is fast enough and the high ATS index might not be needed for beam stability. **Elias** confirmed that is instability appears to be very sensitive to parameters, whether or not it will happen depends on the transition. For example, in the PS an instability at transition does not occur. For the HL-LHC the stability should be ensure provided a fast enough separation collapse (which seems to be the case), as stated in the OP Note, clearly a sufficient operational margin has to be guaranteed though. **Xavier** pointed out that currently a 1 σ fill-to-fill reproducibility of the collapse is achieved in operation and proposed that it could be a specification for HL-LHC, it should rule out the possibility of ending up with the critical beam separation. **Gianluigi** summarized the specifications for the separation bump collapse need to be reviewed. **Gianluigi** also proposed returning to the 2012 observations to identify what could potentially go wrong during the operation with the negative octupole polarity.

- Regarding the High Luminosity LHCb, **Gianluigi** requested to simplify the slides, highlighting that there are no major showstoppers.
- For the flat optics, **Gianluigi** concluded a wire compensation is required. **Benoit** raised a question if there are significant changes in collimator positions compared to the round optics. **Riccardo** replied the changes mostly affect tertiary collimators, the primary and secondary collimators are unaffected.
- Not for the Annual Meeting, **Gianluigi** asked if there are any implication at the beginning of the leveling. **Nikos** replied this stage has not been checked yet, so far it does not look like there should be any.

ACTION (Nikos): Investigate if a sufficient DA can be obtained for the Ultimate scenario with the ATS index of 1.7/2.2 and 3.0 and -570 A octupole current.

ACTION (Xavier): Review the present and expected fill-to-fill reproducibility of the separation at the end of the collision process on a cycle-by-cycle basis

ACTION (Elias, Davide): Review the specification of the fill-to-fill reproducibility of the separation bump collapse

ACTION (Elias): Review the 2012 operation with the negative octupole polarity to identify potential dangers for HL-LHC