WP2
Meeting #174
Tue 5 May 2020, 10:00 – 12:00

Chair:	Gianluigi Arduini
Speakers:	Roderik Bruce, Rogelio Tomás, Guido Sterbini
Participants (vidyo):	Xavier Buffat, Jean-Paul Burnet, Miguel Cerqueira Bastos, Riccardo De Maria, Joschua Werner Dilly, Paolo Fessia, Davide Gamba, Rubén García Alía, Hector Garcia Morales, Massimo Giovannozzi, Wolfgang Hofle, Giovanni Iadarola, John Jowett, Sofia Kostoglou, Giuseppe Lerner, Ewen Maclean, Michele Martino, Elias Métral, Nicolas Mounet, Yannis Papaphilippou, Konstantinos Paraschou, Stefano Redaelli, Benoît Salvant, Michaela Schaumann, Kyriacos Skoufaris, Galina Skripka, Frederik Van Der Veken, Carlo Zannini

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MEETING ACTIONS

Stefano	Provide a table with an estimate of the DPA accumulated, and the resistivity of the jaw at the end of the period, for each collimator installed.
Rogelio, Roderik	Simulate fills with initial fluctuations from the injectors and check the possible use of Mark Jebramcik's code MBS (so far used for ions).

Yannis	Study the ion scenarios form the beam-beam point of view.
Yannis	Review the different lifetime simulations efforts to understand if the noise from the power converters will have a significant effect on lifetime, when including burn-off and beam-beam effects.
Guido	Document in a note the various noise sources and their impact.

GENERAL INFORMATION (GIANLUIGI ARDUINI)

Minutes from the previous meeting have been circulated, and the following comments were made by **Stefano**:

- Regarding the fabrication of the new cavity to measure resistivity of irradiated samples (see talk from **Nicolo Biancacci**), **Stefano** would like to correct the statement made in his name in the minutes, namely that EN-STI does not fabricate the cavity - he was not that affirmative. After the meeting, he checked with **Inigo Lamas** who explained this was to be done at the STI workshop indeed. **Gianluigi** asked if fabrication delays could be made shorter using an external company, but according to **Stefano**, **Inigo** said it's not worth it because fabrication delays should anyway be less than a few weeks.
- Regarding the irradiation effects, **Stefano** would like to add the precision that there are only a few collimators concerned by high DPA effects, hence a factor 2-3 on resistivity will probably be tolerable. Moreover, the area concerned is longitudinally-limited to a few cm. For the LHC, results regarding the DPA accumulated in collimators, were already presented at two ColUSM meetings (119th ColUSM meeting and 123rd ColUSM meeting). **Gianluigi** asked for a table with the expected DPA and resistivities for each collimator installed (Action: **Stefano**).
- Regarding the measurements of collimators currently in the machine, **Stefano** pointed out that four more collimators (two TCPs and two TCSGs) will come out (on top of the two primaries already out), and measurements are already planned by WP5 (the detailed planning will depend on the measured doses). Endoscopy will also be performed.

Gianluigi then briefly reviewed the talks and the actions from the previous meeting. He mentioned that some of the actions related to the talk on the measurement of collimator block irradiated samples by **Nicolo Biancacci**, were already done by **Carlotta Accettura** (see the above links to ColUSM meetings). Regarding the update on the impedance model by **Nicolas**, **Gianluigi** pointed out the need for an update on the optimization to be done on TCTs and TCLs. **Stefano** mentioned there are ongoing discussions and studies within WP5 and WP10, and that a change of materials was already studied for the mask. Then, the update of stability limits after revision of the impedance, by **Xavier**, ended up with one action for **Gianluigi** regarding the need for a table with all operational parameters - a table will soon circulate with parameters during the collision process, which is the most critical phase. Another action by **Xavier** concerned the possible use of a separation in the crossing plane to minimize the so-called "Shaqiri effect", with positive

results already shown by **Xavier**. Then, the following talk (also by **Xavier**) regarding the beam-beam induced crabbing, showed that such crabbing effect is small, although not minor. The presentation by **Carlo**, providing a follow-up from an action of the 170th WP2 meeting regarding the bunch-by-bunch change of tune separation due to impedance, showed that the variation along the bunch train is of the order of 1e-4, hence quite small. Estimates of the contribution from other effects, in particular electron cloud, have to be provided (action by the e-cloud team). Finally, the talk of **Gianni** regarding the stability from electron cloud for intensities below 2.3e11, confirmed that the worst situation is around an intensity of 1 - 1.2e11, and it gets much better above.

The agenda of the 174th meeting then followed. The order of the first two talks was inverted because of a connection problem for the first speaker initially foreseen (**Roderik**).

1 Performance aspects with LHCb leveled luminosity at 1.5*10^34 cm-2 s-1 (Rogelio Tomas)

This is a report on the impact of the LHCb upgrade II on the luminosity of ATLAS and CMS, and on the bunch-by-bunch fluctuations. The study shows a limited impact (2%) on the IP1 & 5 integrated luminosity for both nominal and ultimate leveled luminosity. On the other hand, bunch-by-bunch intensity is affected by the modified burn-off from collision patterns involving IP8, hence the maximum bunch-by-bunch luminosity fluctuation increases from around 2% in the nominal configuration, to more than 10% with LHCb upgrade II and the BCMS filling scheme (with a rms of 2%). The standard filling scheme gives better results (no more than 5% luminosity fluctuations) because it is more symmetric, without any bunch colliding only in IP1 and 5. Tolerance is at 10% rms of luminosity fluctuation, which was assumed to be essentially taken by the injectors. CMS requested write-up and discussions on the subject during the 25th EDQ. Open questions remain, in particular on the influence of initial bunch-by-bunch variations (e.g. from the injectors) on the overall effect, possibly with other mechanisms, and on the magnitude of fluctuations during Run 3 (LHCb luminosity should be up to one fifth that of ATLAS and CMS, similarly to HL-LHC).

- **Gianluigi** asked if the burn-off is modified only at the borders of the bunch collision strings. **Rogelio** answered in the positive.
- **Yannis** pointed out that for a few hours towards the end of the fill, the integrated luminosity of LHCb does not increase a lot (as visible in slide 2), which may open the possibility to stop LHCb data taking at that point (e.g. around 5 hours). **Rogelio** said it might be worth checking, but it will be hard to convince them to take (even slightly) less data, which was confirmed by **Gianluigi** (they rather push for more data). **Gianni** then pointed out that actually if there is not much luminosity in LHCb it means one won't mitigate much the losses by switching off the collisions there, because most of the burn-off (and hence bunch-by-bunch variation) must have been done initially. Hence the gain would be minimal.
- **Yannis** insisted on the need to understand other effects that could create more fluctuations, as pointed out by **Rogelio** in his conclusion. **Rogelio** added there is a true concern regarding enhanced fluctuations from other mechanisms, e.g. beam-beam effects, and that we have no experience in this kind of configuration, hence the importance to study it (Action: **Rogelio**).

- **John** mentioned that fluctuations between bunches could be simulated using the code from **Marc Jebramcik** (MBS) which tracks every single bunch and includes burn-off, IBS, radiation damping, and maybe also beam-beam effects. **Gianluigi** said we should benchmark the code, and asked if it is long to run. **Roderik** answered in the negative - it takes a few minutes typically. **John** mentioned the code CTE that could be used as well (Action: **Roderik**).
- **Riccardo** asked if it is possible to use the ADT to modulate the emittance at the single bunch level and hence mitigate the bunch-by-bunch variation. **Gianluigi** answered it would only reduce luminosity.
- **Gianluigi** concluded that the consequences of this upgrade of LHCb will be shown and discussed with ATLAS and CMS. **Rogelio** confirmed that CMS wants to look at this carefully.

2 HL-LHC ION OPERATIONAL SCENARIO (RODERIK BRUCE)

An extensive review is presented regarding the HiLumi operation with lead ions, with details on the filling schemes, beam and machine parameters, as well as the performance estimates for both the Pb-Pb and p-Pb runs. The filling schemes were upgraded to allow more collisions in LHCb without decreasing the luminosity for the other IPs, which can be achieved using well-designed 50ns schemes instead of the 75ns one. Several options are possible which will be discussed at the LHCC/LPC level. Two of them give higher integrated luminosity than the 75ns one, for each of the four experiments.

Beam and machine parameters are designed towards a leveled luminosity of 6.4e27 $cm^{-2}s^{-1}$ at IP1, 2 and 5 and 1e27 $cm^{-2}s^{-1}$ at IP8, using offset leveling. Longitudinally, slip-stacking is assumed in the injectors, leading to a three times larger emittance, which can be adjusted through the blow-up in the ramp. Collisional losses are alleviated thanks to orbit bumps in IR1 and 5, and a new TCLD collimator in IR2. For IR8, no mitigation was found, hence the limit on the leveled luminosity due to bound free pair production (BFPP). Pb-Pb intensity decay is dominated by large burn-off cross section, only 1.5% of which being inelastic (main processes studied by experiments), the rest being mainly due to electromagnetic interactions (still studied by a dedicated physics program). Beam stability does not seem to be a concern - crystal collimator still have to be fully studied but already proved not to be a showstopper during the 2018 run.

Luminosity performance was studied using the MBS (Multi-bunch Simulation) and CTE (Collider Time Evolution) codes, which were both benchmarked (for CTE, against 2018 measured luminosity). For a one-month Pb-Pb run, 24 days of physics with a 50% OP efficiency yield 2.3 to 2.8 nb^{-1} for IP1/2/5 (ALICE is slightly higher than the others because of a better geometric coefficient, related to the smaller crossing angle due to the internal crossing angle generated by the spectrometer) and up to 0.5 nb^{-1} for IP8, which allows to reach the targets in about five runs. Conversely, a one-month p-Pb run would provide 530 - 690 nb^{-1} at ATLAS and CMS, 310 nb^{-1} at ALICE (assuming a leveling at 5e29 cm^{-2} s^{-1}), and up to 150 nb^{-1} at LHCb - this would provide the requested integrated luminosity in two runs for all experiments but LHCb, for which performance enhancements (or a revision of the target) have to be studied. The next studies foreseen concern the possibility to reduce beta*, to increase the LHCb target luminosity in Pb-Pb runs,

the proton filling schemes for p-Pb runs, and a clarification of the crossing angle limitations due to the ZDC in IP1 & 5. An HL-LHC report is under finalization.

- **John** insisted that the large electromagnetic cross sections (from BFPP and EMD) do not necessarily mean the corresponding ions are wasted, as many programs use such electromagnetic events, in particular for physics beyond the standard model. **Roderik** agreed.
- **John** commented that the ZDC detectors at ATLAS and CMS, built to intercept spectator neutrons and integrated in the TAXN, will be upgraded with new and narrower modules for Run 4. **Roderik** confirmed and mentioned that this will introduce an upper limit on the horizontal crossing angle in ATLAS, which is presently under investigation. One solution could be to use instead a vertical crossing angle at both ATLAS and CMS, however, then the beam-beam compensation from opposing crossing planes would be lost. **Roderik** mentioned that this could be studied in collaboration with the beam-beam team. **John** commented that he does not believe that the loss of compensation would be problematic. (Action: **Yannis** to study the ion scenarios form the beam-beam point of view)
- **Gianluigi** asked if there is any interest to use the crab cavities after Run 3. **Roderik** answered that the crossing angle is not huge, and beta* is not so small, so the impact of the crab cavities would not be very large. But if we squeeze more in IP1 and 5 (if we find the right optics), then it could be interesting. **Gianluigi** then pointed out that actually if we go to a crossing plane that is the same in ATLAS and CMS, the crab cavities will not work. **John** also mentioned the set-up time, which should not be too long for a one-month run. **Gianluigi** agreed.
- **Gianluigi** asked if the limit on the LHCb luminosity depends on the installation of a collimator in the cryostat. **Roderik** confirmed and said that one needs a TCLD to be able to release significantly this limit. **John** added that in 2018 it was discussed with **Anton Lechner**, and it did not look safe to go beyond 1e27 cm^{-2} s^{-1}. Also, LHCb is different from ALICE optics-wise, so it is not easy to put a TCLD.
- **Gianluigi** mentioned that there is an ongoing discussion regarding the rotation of the crossing plane for LHCb, for Run 3 (protons). He wondered if there is any interest for the ions as well. **Roderik** answered there is no clear request. If LHCb comes with a request to switch the polarity, then it could be an interesting option.
- **Gianluigi** wondered how the upper estimate of integrated luminosity (40% more than nominal) was determined. **Roderik** said it is coming from the 2018 run (75ns scheme), and from simulations. Looking at the best part of the run (when there was no down time from the injectors, the injectors had ramped up their performance and all LHC issues were sorted out), an integrated luminosity 40% higher than calculated was obtained. **Rubén** added this is a combination of realism and optimism, but that anyway there is no issue there as these 40% can be absorbed (in particular, there is no sensitive electronics there - unlike 2018, when there was some downtime due to QPS). **Roderik** confirmed this number is quite undefined, and that the hope is not to be too sensitive to this. **Rubén** confirmed it is the case, and added there is more dependence on where the losses happen longitudinally. **Roderik** asked to let him know in case of any update. **Rubén** said **Giuseppe** will put this in his specifications and then get back to **Roderik**. **John** commented there is a bigger

issue with the storage requirements for the experiments (pile-up, longer runs, etc.), and that the intensity goes higher year after year, from the injectors.

- **Gianluigi** asked what is the basis of the p-Pb request from LHCb (for which we are short by a factor of 2). **John** answered they may have good cases for asymmetric p-Pb collisions. **Rubén** said this case was not looked too much in details, they were expecting a few weeks of run. It has to be brought back to the table with an update of the HL-LHC document. **John** added that high losses close to the BLM threshold were observed in the 2016 run and the luminosity had to be limited to avoid beam dumps. Now it should be better with the new TCL settings near IP1.
- **Rogelio** asked if there are seven runs foreseen in total (Run 3 & 4). **Roderik** answered in the positive, plus the p-p reference run. There might also be more with one more year of Run 3. **Rogelio** said this has to be addressed later on. **Roderik** confirmed there are still uncertainties. **Gianluigi** said it could be worth saying if one run per year is enough (as assumed for HL). He also asked if the p-p reference runs are considered as a part of the one-month run. **Roderik** answered in the positive (see backup slide 35).
- About the luminosity numbers quoted for p-Pb, **Giuseppe** asked if the protons are in B1 and the lead ions in B2, or vice-versa, or if all numbers are summed. **Roderik** answered that the presented numbers are summed over the whole 1-month run. Possibly the run could be split, and in that case e.g. half of the luminosity would be with p-Pb and the other half with Pb-p.

3 TABLE WITH THE EXPECTED SOURCES OF NOISE: CHARACTERISTICS, ORIGIN AND MITIGATION MEASURES (GUIDO STERBINI)

Noise sources are unwanted stochastic and time-dependent lattice properties potentially affecting HL-LHC and LHC performance. Most studies concentrate on linear effects (dipolar and quadrupolar). The presentation provides the main characteristics of seven different sources of noise: ground motion and thermal effects (GM), beam screen vibrations (BS), transverse damper (ADT), power converters (PC), crab cavities (CC), flux jumps (FJ), and hollow electron lens (HEL). For each of them, the noise mechanism is identified as well as the main direct effect considered (dipolar and/or quadrupolar). The potential effect on the beam (orbit or emittance blow-up) is indicated, together with its observation in the LHC (if any) and the expected impact for HL-LHC. Characteristics such as the longitudinal localization and the part of the LHC cycle mostly affected are presented. The frequency spectrum of each kind of noise is shown, and can cover from sub-Hz to GHz frequencies. Possible mitigation measures (which heavily depend on the frequency spectrum) are also given, mainly for the dipolar noise. The tables presented can be considered as an entry point for a general overview, and should be always backed up by the references and resources collected at http://noisestudies.web.cern.ch/. The latter website can be edited and improved by the community.

- About the expected emittance blow-up due to noise of the ADT at injection and during collisions (slide 11), **Gianluigi** asked if this is the contribution from the damper alone. **Guido** answered that it is the pure contribution from the model of Lebedev. The fit considers a general noise (resonant

with the beam frequency) and the damper activity. **Gianluigi** asked if it includes IBS, to which **Guido** answered in the negative. During MDs, the other sources were minimized (using e.g. a low intensity). **Gianluigi** then asked if this assumes the present noise level of the pickups. **Guido** answered that **Xavier** scaled from his MDs the model of the LHC to HL-LHC (as the tune spread will change, etc.); to maintain a similar level we have to improve the ADT pickups by a factor 4. **Gianluigi** suggested adding IBS to the model.

- About noise from crab cavities, **Gianluigi** asked if the values were provided by **Philippe Baudrenghien** and his model. **Guido** answered in the positive. He also mentioned the crab cavity MDs in the SPS, which showed a lower emittance blow-up than expected (notwithstanding the difficulty to measure it because of the losses observed - a contrario to the lossless model). Hence, the model might be conservative.
- About ground motion and its absence of impact on emittance, **Sofia** asked if there is any study that considers the quadrupolar effect, i.e. tune modulation, which could create emittance blow-up. **Guido** answered there is none, to his knowledge. He guessed that ground motion on sextupoles could create such an effect through feed-down. **Sofia** said there could be low-frequency sidebands, but strong non-linearities (e.g. beam-beam) could also be important.
- **Sofia** asked if some priorities could be set among the list of noise sources. **Gianluigi** argued that this should be based on its impact. **Guido** said that, for low-frequency quadrupole modulation, one could first investigate its presence in available beam spectra.
- **Yannis** commented that the table should contain some tolerances; this would also facilitate the definition of priorities. **Gianluigi** wondered if this should be based on the present estimates of noise. **Yannis** and **Guido** answered in the positive. But **Yannis** argued that we do not have tolerances for everything. **Gianluigi** said we should estimate its emittance blow-up or orbit effects, and get tolerances from this.
- **Davide** said there might be special cases that do not fit into the general table. **Gianluigi** answered that the point is to identify the most important sources of noise by starting putting everything together.
- **Wolfgang** asked if the results of the Lebedev model are published. **Guido** and **Xavier** answered in the positive: there is an MD note and a PRAB paper. **Wolfgang** wondered then if this was only at low intensity, and what happens at high intensity (with the correct tune spread, etc.). **Xavier** said it is all in the note and paper; in the MD there were both colliding and non-colliding bunches, such that one could separate the IBS from the emittance growth purely due to the noise.
- About the noise from the power converters, **Michele** said that the reduction in lifetime is significant in relative (15%). But on the other hand, 200 hours lifetime is a lot, so he wondered if the effect has any importance in absolute value, in the end. **Guido** confirmed that the numbers are given in relative, and that 200 hours could appear to be a relatively long time scale w.r.t. to the typical one of 15-20 hours. Still, there are many approximations and assumptions in the simulations which are performed in an ideal configuration, so if there is a visible impact with such idealizations it means one needs to look more in detail. Therefore, the absolute value is less important than the relative impact. **Sofia** agreed. **Gianluigi** asked if the simulations are without beam-beam. **Sofia** answered in the negative: there is beam-beam; on the other hand there are no errors and no electron cloud. **Yannis** said these are regular beam-beam bunches (i.e. colliding

in IP1 and IP5 and considering all the possible parasitic encounters), without extra non-linearities except octupoles and chromaticity. The dynamic aperture is 5 or 6 sigmas, with very good lifetimes. **Gianluigi** asked if 200 hours is consistent with the lifetime simulation of **Konstantinos**. **Gianni** and **Yannis** confirmed that this is consistent with the simulation of **Konstantinos**, which are consistent with measurements for bunches not suffering from e-cloud. **Gianluigi** said there is a visible effect on lifetime from collisions beyond burn-off, and asked if the lifetime is lower than expected from the simple burn-off. **Yannis** answered in the positive. **Gianluigi** concluded that we should put the numbers together to answer the question of **Michele**, which is to understand if this is relevant or not. Probably the effect is still small compared to the burn-off lifetime (Action: **Yannis**). After the meeting, **Sofia**, **Gianluigi** and **Yannis** clarified that the absolute value of the lifetime also depends on the assumptions of the physical aperture.

- **Gianluigi** commented that it is important to provide feedback to **Guido**, and that a note should be written reviewing the various noise sources (Action: **Guido**).
- **Gianluigi** wondered about the possible effect of the Uninterruptible Power Supplies (UPS), and whether it is negligible. **Guido** said that around 8 kHz, we are dominated by harmonics of 50 Hz. There are also fixed harmonics at specific points of the cycle (e.g. at injection). **Gianluigi** commented that we should also highlight this, such as not to forget it.
- **Gianluigi** asked to put a link to the website created by **Guido** to the WP2 pages; this was done after the meeting.

4 SUMMARY OF POWER SUPPLY RIPPLE OBSERVATIONS IN THE LHC AND IMPACT ON THE HL-LHC (SOFIA KOSTOGLOU)

Due to lack of time, the presentation was postponed to next week.

5 ROUND TABLE (GIANLUIGI ARDUINI)

The date of the next meeting is May 19th. The meeting will start at 9am. The agenda will be:

- Summary of power supply ripple observations in the LHC and impact on the HL-LHC (Sofia Kostoglou),
- DA after feed-down correction (Frederik Van Der Veken),
- Update on the field quality of MCBRD (Ezio Todesco),
- Recap on the available BS contribution to the field quality in the triplets for the HL-LHC (Ezio Todesco).

Reported by N. Mounet