WP2 Meeting #145

Tue 2 Apr 2019, 09:00 – 12:00

Chair:	G. Arduini
Speakers:	M. Barnes, H. Timko, B. Salvant
Participants:	A. Alekou, S. Antipov, N. Biancacci, X. Buffat, R. Calaga, R. De Maria, M. Giovannozzi, W. Hofle, G. Iadadola, S. Karastathis, M. Krupa, A. Kurtulus, E. Métral, N. Mounet K. Paraschou, E. Shaposhnikova, R. Tomás, F. Van der Veke

AGENDA

The meeting was devoted to issues related to impedance and RF, in particular intensity limitations at Injection.

MEETING ACTIONS

Mike	Investigate the possibility of obtaining a more accurate estimate of MKI heating using realistic longitudinal beam profiles
Gianluigi and Rogelio	Raise the question on the acceptable level of losses at Injection with Machine Protection
Elena and Helga	Provide an updated value of the injection RF voltage for HL-LHC
Stefano	Review the proposed coating measurement procedure within WP5

Riccardo Revise the motivation of the increase of the beam screen size at the exit of D1

GENERAL INFORMATION (G. ARDUINI)

Minutes of two previous meeting have been circulated. **Rogelio** reported there were comments from Stephane and Michele that have been incorporated in the minutes. Gianluigi then proceeded with reviewing the action items.

Feed down estimates have been added to MCBDR field quality studies. No impact on β-beating has been observed for MCBRD, but there is some for MCBXF. **Massimo** suggested that Frederick proceeds with DA simulation and makes an update when ready.

Related to heat load limits, **Gianluigi** proposed to raise a question at the heat load task force on the 3th of April.

No satisfactory solution has been found so far for suppressing the installation of the MS10, studies ongoing.

Aperture studies indicate the crossing angle can be increased to nearly 1000 μrad. **Gianluigi** emphasized the importance of understanding if it could be beneficial for avoiding the beam-beam kicks, in particular one has to check whether the kicks are dominated by Points 1&5 or by 2&8. **Xavier** will give an update at one of the following meeting.

1 LHC INJECTION KICKERS: SEY AND IMPEDANCE STATUS AND PLANS (M. BARNES)

Post LS-1 MKIs limit the beam intensity at 1.6×10^{11} for 1.2 ns (Gaussian distribution – 4 sigmas) bunches and thus need to be upgraded for HL-LHC.

First, alumina tube, which is necessary for providing High Voltage (HV) insulation, causes problems with dynamic vacuum in the interconnect near the Q5 magnet. Its Secondary Emission Yield (SEY) reaches maximum values of 10. Cr_2O_3 coating installed on MKI8D in 2017-18 YETS lowers the SEY to 1.5, according to measurements. Comparing uncoated Q5-MKI2D and coated Q5-MKI8D tubes, the normalized pressure goes down for coated interconnects, showing a significant improvement. Regarding the UFOs, since LS1 MKIs do not produce a significant number of UFO and no statistically significant change has been observed with the CR_2O_3 coating.

Regarding the beam coupling impedance, screen conductors are used to suppress beam induced heating. All the beam screens (BS) were upgraded to have 24 conductors in LS1, which lowers the heating by 3-4 times. The BS design was changed to move the 1st resonance frequency from below 0.5 to around 1 GHz in order to further suppress beam induced heating. The peak is 3 orders of magnitude below the threshold set for longitudinal beam stability.

To further reduce the temperature, a cooling circuit has to be installed for HL-LHC. It is expected to lower the temperature of the hottest yoke from 125C to around 50 C, bringing it below the Curie point. A good thermal contact is needed between the ferrite and water. Good performance is expected with brazing techniques. An extra inner cylinder makes the power distribution more uniform. That eliminates the risk of significant thermo-mechanical stresses caused by heating.

The current plan is to exchange MKI2B during LS2, rest of Point 2 - in YETS'22-23, and Point 8 – during LS3. Steady state conservative estimates limit the beam intensity for Run 3 at 1.8×10^{11} ppb with 1.2 ns bunches. With the cooling upgrade 2.2×10^{11} ppb will be possible for HL-LHC.

- Regarding the choice of distribution for the analysis, **Elena** pointed out that since the results are rather sensitive to bunch length, one has to use the realistic beam profiles that are quite reproducible in operation and not Gaussian (Action: **Mike**). **Benoit** replied that alternative distributions have been checked and what is shown represents the worst case scenario for the power loss. Gaussian distribution was used for thermal simulations that are very computationally demanding. **Gianluigi** inquired if the presented limits are overly pessimistic and could be loosened. **Mike** pointed out there are too many unknowns.
- **Wolfgang** asked if the turn-around time has been taken into account for the temperature estimates. **Mike** replied a steady state approximation was used. **Gianni** pointed out a potential margin – burn-off that is not taken into account in the analysis. **Mike** replied the bunch length goes down and compensates, at least partially, the burn-off; the overall is hard to quantify. **Gianluigi** and **Rogelio** noted that longitudinal blow-up can be applied to avoid excessive reduction of the bunch length ideally keeping constant the bunch length. **Mike** emphasized that there are too many unknowns to make a more precise estimate, both optimistic and pessimistic.

2 RESULTS FROM RF STUDIES AND IMPLICATIONS FOR HL-LHC (H. TIMKO)

Full detuning reduces the required klystron power during the ramp and at flat-top, offering a factor two saving with typical Run II beam parameters. At injection, non-rigid dipole oscillations can persist for a long time. These oscillations are seen both in simulations and measurements and can potentially lead to non-negligible beam losses along the flat bottom. Two MDs were done to check the power and voltage with the half-detuning scheme at injection. With the present operational scheme one can attain a maximum voltage of 9 MV at 1.15×10^{11} ppb and with a reduced klystron high-voltage of 50 kV. Asking for less voltage in the 'weak' lines and pre-detuning the cavities, one can avoid transient behavior and reach 10 MV maximum voltage at 1.3×10^{11} ppb, with full klystron power (high voltage at 58 kV), which seems to be the limit of the present system.

In theory, about 8 MV/beam should be achievable at injection with HL-LHC beam current, but in reality the lines saturate at lower voltages. A question remains open if the system can be further optimized or the limitation is fundamental.

Conservative estimates for Run 3 limit the RF voltage to 6.6 MV for 1.8×10^{11} ppb and 5.2 MV for 2.3×10^{11} ppb. Both for Run 3 and HL-LHC, a minimum 6.4 MV is needed in order to minimize mismatch in the bunch to bucket transfer and to avoid capture losses with the Q20 optics (seems acceptable), and 7.9 MV with Q22 (seems out of reach). In general, losses increase with energy mismatch (and lower RF voltage).

Regarding the controlled emittance blow-up, it has been used in operation since 2016. Tests with the fast PPLP ramp reveal a challenge to blow up emittance fast enough while avoiding losses in the Ramp. More studies are needed to optimize the procedure.

- **Elias** raised a question how the measurement of dipole oscillations relates to simulations. **Helga** replied the phase space projections seem to match. In general, the effect disappears below a certain intensity, error, or RF voltage.
- **Gianluigi** raised a question if the presented dump threshold should be multiplied by two for HL-LHC. **Helga** replied that dump thresholds should be reviewed, and in parallel one needs to understand the source of losses. **Gianluigi** inquired about the magnitude of intensity loss, suggesting that the thresholds could be increased. It would be interesting to have a plot of observed beam intensity losses. **Helga** replied that the losses are really small, probably below 1%. **Gianni** made a comment one the need to deploy a blindable Beam Loss Monitor system in Run 3; that would also be beneficial for electron cloud studies. **Helga** commented that the blindable BLMs only help for the injection losses, but not for the start-of-ramp losses that contain both capture and flat bottom losses. **Gianluigi** concluded one has to raise the question what is the margin for beginning of ramp losses from the point of view of machine protection noting that the losses in intensity appear to be negligible and therefore not affecting performance (Action: **Gianluigi and Rogelio**).
- **Gianluigi** pointed out that the energy mismatch seems to be a dominant effect, and emphasized it would be beneficial to reveal its time evolution (if any). **Helga** responded that not much statistics has been analysed so far. It is hard to say what happens at a lower relative offset; one needs to accurately quantify losses. **Elena** inquired why there is a difference between Beam 1 and Beam 2, pointing out it must be something LHC-related. She made a comment that while a slow drift can probably be corrected, the most dangerous are the fill-to-fill or injection-to-injection variations which are very hard to correct. **Elena** stressed the importance of a joint effort between SPS and LHC to correct the offsets. **Gianluigi** noted that energy matching has only been done once last year. He proposed to start with an idea how often it needs to be implemented, then how it can be improved.
- **Gianluigi** asked if a full detuning at injection has been looked into. **Helga** reported that preliminary studies show that the gain is insignificant. **Elena** added that the performance is limited by the transients. Half-detuning seems optimum for injection.
- **Elias** asked whether the beam stability is improving when going from 6 MV to 4 MV. **Helga** replied the beam seems stable in this range of RF voltages, there is no limitation from beam stability.
- **Gianluigi** inquired about the optimum voltage to be assumed for HL-LHC injection. **Elena** replied the values need to be rechecked. (Action: **Elena and Helga**)

3 UPDATE ON IMPEDANCE STUDIES AND IMPLICATIONS (B. SALVANT)

Benoit presented an update on a broad range of activities currently under way at the Impedance Working Group.

MKI: Gaussian distribution gives the most pessimistic estimate of the power loss, around 30% higher than binomial. The filling scheme does not have a large impact on the power loss, because the frequency peak is rather broad. The MKI is already in the LHC model and should be added to the HL-LHC model; its impact seems to be small compared to Resistive Wall, but the impact on beam dynamics is being looked at.

New collimators: For some collimators the discrepancy between measured and simulated tune shift can be up to a factor 3, especially for the ones that have lower impedance, this is likely caused by large measurement uncertainties. The overall collimator tune shift is within 50 % of the model. Specifications were made for Mo coating and the company DTI has been validated for performing the coating. Their process seems to yield a lower resistivity. Promising results of Mo coating on Graphite have been obtained too and this solution could be envisaged for the remaining collimators to be installed during LS3. IWG recommends not to measure any block in the next batch unless measurements on samples are worrying, a proposal yet to be presented at WP5.

No major changes since January 2019 concerning Crab Cavities. Next prototype will be carefully measured, in particular for the 1.92 GHz mode that may have a large transverse shunt impedance.

For Beam Screens (BSs), there is a request to increase the aperture in D1 by 1.5 mm (it currently has a 60 mm radius). The impact on impedance seems marginal, recommendations were given on how to optimize the transition.

Avoiding the randomization of pumping hole sizes and positions could reduce the production cost. It turns out that even without the randomization the impedance the impact on the transverse impedance is negligible. The increase in longitudinal impedance also seems small, 0.03 mOhm, according to first estimates.

New BPMs: 3D models are being simulated. There is a slight increase of impedance due to closer striplines, which seems acceptable at this point. The design is not final, studies will follow its evolution.

Measurements of deformable RF fingers show no mode below 2 GHz, which is good news from impedance point of view.

Velo and SMOG2: power loss could go up to 50 W for 2 circulating beams; this value will be specified in an ECR. Measurements on a mock-up have been done and seem consistent with simulations.

There are a couple new inputs from Experiments as well. First, forward physics: in IR5, CMS plans installing new Roman pots in different locations, but there is no official request yet. Then, fixed target experiments are proposed in ALICE and potentially LHCb. The design requires both a crystal intercepting beam halo and a target a couple of meters away from the ALICE IP, which will not be transparent for beam impedance as the plan is to have these operate with full LHC beam during the HiLumi era. It is therefore not clear whether it can be allowed to operate with high intensity beams.

- **Benoit** proposed, if needed, to have more detailed reports at WP2 on certain topics, including coating resistivity measurements (A. Kurtulus) and Velo and SMOG2 (B. Popovich).
- **Elena** proposed presenting an update on longitudinal stability requirements, pointing out that the presently used 200 kOhm limit was specified in 2010, and suggested Ivan Karpov as the speaker.
- **Gianluigi** raised a question whether the collimator measurement procedure has been agreed upon with the Collimation group and emphasized the need to present it at WP5 as soon as possible (Action: **Stefano**)
- For the BS design adjustment, **Riccardo** estimated it gives an extra 0.5 σ of horizontal aperture, removing the bottleneck. **Gianluigi** inquired about the impact of alignment and tolerances. **Riccardo** replied new input from alignment can give a bit of extra margin. **Gianluigi** noted that it would be good to revise the motivation for that at one of the WP2 meetings. (Action: **Riccardo**)
- Regarding CCs, **Rama** assured both designs of HL prototypes will be ready for testing within 1 year timeline.

Reported by S. Antipov