WP2 Meeting #161

Tue 29 Oct 2019, 10:00 – 12:00

Chair:	R. Tomás
Speakers:	S. Antipov, D. Mirarchi, R. De Maria
Participants:	C. Accettura, J. Andersson, A. Alekou, D. Gamba, H. Garcia-Morales, M. Giovannozzi, S. Kostoglou, E. Maclean, A. Mereghetti, E. Métral, N. Mounet, Y. Papaphilippou, F. Plassard, S. Redaelli, B. Salvant, G. Skripka, G. Sterbini

AGENDA

MEETING ACTIONS

Alessio	Check the TCSPM BPM data to identify possible orbit offsets
Benoit, Stefano	Follow up on the possibility of performing bench resistivity measurements on collimators, including the estimates of DPA they had received during the run
Sergey	Investigate the impact of orbit misalignment in collimators and resistivity variation due to ageing on the octupole threshold
Stefano	Review the requirements for halo cleaning
Daniele, Stefano	Define the parameters, including the starting β^* for further studies of operational scenarios with HE lens

Daniele	Estimate stored energy in the halo versus the gap of the primary collimators using a q-Gaussian distribution, and assess the uncertainty of the estimates
Daniele	Assess tolerances on beam size and roundness and the e-lens in terms of β-functions and emittances.
Nicolas, Stefano	Follow-up on the possible dynamics in case of instabilities when the hollow electron lens is active

GENERAL INFORMATION (R. TOMÁS)

Actions of the previous meeting have been reviewed by **Rogelio**.

Serge is working on the questions related to levelling the luminosity at the start of the physics fill, finalizing the studies. **Rogelio** proposed waiting on the outcome of the studies before defining an operational scenario.

Eleonora is investigating the possibility of slow change of primary settings. Additionally, misalignment of the upstream and the downstream elements is to be followed up together with the Alignment WG. **Riccardo** pointed out the final position of the 11 T magnet has to be provided by November. Improvements to the current baseline could be implemented after the start of the run.

Stefania shall clarify the model used for emittance growth from elastic scattering calculations. **Yannis** noted the implementation itself is not new, it has been in place and used in simulation since 2015.

1 TCSPM IMPEDANCE MEASUREMENTS AND MEASUREMENTS OF COATED SAMPLES (S. ANTIPOV)

Resistivity of coating samples is being followed up regularly with RF cavity measurement technique. The average resistivity of sample coatings in test and production batches is 55 nΩ-m, which is within the acceptance limit of 100 nΩ-m. Measurements of coated irradiated samples are inconclusive: while no significant difference in resistivity has been observed, the sensitivity of the present RF cavity is rather low due to the small size of the samples. A new RF cavity is under development to improve the resolution. Eddy current technique could be better suited for measurements of small samples. First tests of non-irradiated material demonstrate sufficient sensitivity to resolve a 100% increase in resistivity in the range from DC to 2 MHz.

Measurements of materials irradiated at GSI indicate a potential increase in resistivity for MoGr, CFC and Mo coating, although for the last material the error bars are rather large. For CFC the relative increase of resistivity is almost 100% after being exposed to a dose 3 times higher than the one corresponding to the peak value in secondary collimators; for the MoGr used for the production of collimators (Nb8304Ng grade) the increase is around 30%. The detrimental effect is observed already at relatively low doses (1/10 of HL equivalent). For the coating, the change in resistivity could be connected with the change of its structure as revealed by SEM imaging. Several collimators, including primary and secondary are being removed from the tunnel in LS2. In that view it would be beneficial to perform bench measurements of their jaw resistivity (provided allowed by radiation protection) and compare with that of the spares. RF cavity or wire measurement could be used for the test. It is important to know what exact dose the collimators have received to be able to relate the measurements to the tests done at GSI.

The tune shift of the TCSPM prototype collimator has been measured three times: twice in 2017 with nominal and high intensity bunches and once in the end of 2018 with nominal intensity bunches, after a year of operation at nominal settings. Results of the first two measurements agree with each other and

with what is expected from the impedance model, except for the Mo coating stripe. The Mo coating showed a factor 2 greater tune shift than had been expected, which is consistent with DC and RF measurements performed on the coating and is attributed to its microstructure. The last tune shift measurement, performed in 2018, revealed a factor 2 greater tune shifts compared to what had been seen previously for all materials, including the CFC jaw of the TCSG.D4 collimator located next to the TCSPM. Apart from a possible radiation degradation, this result could be explained by an orbit offset in the collimator. A 300 μm offset would create sufficient extra impedance. Even a 100 μm offset could increase impedance of the collimators with the smallest gaps (such as primaries in IR7) by 10-20%. In Run III it will be important to measure the same collimators (primary and secondary) systematically over the years to assess coating performance, aging and radiation damage. Measurements at the gaps smaller than operational improve the resolution. A machine study is needed to investigate the effect of orbit offset on the collimator impedance.

- **Stefano** pointed out the RF cavity measurement of irradiated Mo coating did not show any significant change in conductivity, contrary to DC. **Sergey** quoted the large error bars of the RF test that do not allow giving a definitive answer.
- **Rogelio** inquired how fast the new methods could be implemented for the irradiated samples. **Sergey** replied that for RF cavity testing the main focus is now on the batch samples. The student who was doing the testing and working on the new RF cavity design finished the contract and is expected to be back two months. **Carlotta** mentioned that more checks on non-irradiated samples are needed to certify the Eddy current method; once the check are complete the measurements could be done relatively fast.
- **Nicolas** noted that actually an irradiation degradation of CFC resistivity has also been observed in Ryazanov's work although to a smaller extent. **Carlotta** commented that the difference of the CFC grades can explain the discrepancy.
- For the higher than expected tune shift measured in 2018, **Stefano** noted that since it is observed among different materials and even collimators it is unlikely to result from radiation. On the other hand, **Alessio** pointed out that the 300 μm orbit offset that could explain the effect seems unreasonable, the offset would unlikely exceed 100-150 μm. **Daniele** and **Stefano** added that such a large offset would cause hierarchy breakage and should have been seen in the loss data. **Benoit** pointed out that the BPM data from TCSPM is available and suggested checking it. **Alessio** replied it will be done as soon as possible. (Action: **Alessio**)
- **Elias** inquired how the impact of orbit offset on impedance had been obtained. **Sergey** replied the IW2D code supports this functionality; there had been a limited benchmark of IW2D solution for asymmetric gaps against CST.
- Discussing possible bench measurements, **Benoit** asked if an endoscope could be installed on a collimator for impedance measurements. **Carlotta** proposed to look into this possibility. **Stefano** mentioned that information on the dose acquired by collimators in the machine should be available and proposed checking with Anton. He proposed following up on which collimators can be measured on a bench (Action: **Stefano, Benoit**). **Rogelio** concluded a measurement on the actual collimators would give valuable information.
- **Elias** emphasized an importance of an MD where the beam would be steered towards one of the collimator jaws. He pointed out the effect seems to be significant, being stronger than a potential

difference in material resistivity. MDs to follow up on the potential ageing of collimator resistivity should also be foreseen.

- **Rogelio** raised a question on the impact of the possible increase of impedance from ageing for the octupole current. **Elias** reported it is under investigation (Action: **Sergey**).

2 BEAM DYNAMICS SIMULATIONS WITH HOLLOW ELECTRON LENS (D. MIRARCHI)

Transverse beam envelope in LHC is not Gaussian, having a greater population in the beam tails above 3.5 sigma. The tails store about 5% of particles and up to 33.6 MJ of energy and can pose danger in case of fast failures, in particular causing damage to primary collimators. A Hollow Electron (HE) lens has thus been proposed as an addition to the collimation system. It utilized an electron beam travelling in the direction opposite to the beam to depopulate it tails. The HE lens has to comply with several machine protection constraints: it should leave witness trains for early beam loss detection, provide a 2 σ clearance to the primary collimators in case of Crab Cavity (CC) failures, and allow for a more aggressive pulsing to fight orbit jitter before entering Collision. The goal of the present study is to define an operational scenario and parameters for HE lens operation.

The study used Dynamic Aperture (DA) and Frequency Map Analysis (FMA) simulations with simplified tracking for 10^6 turns and a complete tracking including collimation system for 10^5 turns. The parameters of interest include electron beam inner radius, pulsing patters, electron beam current, octupole current, and chromaticity. Optics v1.3 was used for the study.

Results show that the Random pulsing mode is the most efficient in cutting the DA at the inner radius of the electron beam with relatively poor depletion demonstrated by a DC current. The difference in efficiency between pulsing patterns decreases with larger e-beam radii. A 3 A current is sufficient for tail cleaning, leaving significant operational margins (assuming the current can go up to 5 A). The DA in the Random mode is not affected by the octupole current, but a larger octupole current usually leads to a smaller initial DA and a smaller rate of its decay. Normally, a greater chromaticity leads to a larger cleaning efficiency. FMA scans reveal that e-lens couples the already present nonlinearitities.

A good agreement is observed between particle losses and DA. One can tune the rate of losses in the tails with the current. At full current (5 A) 50% of the halo can be removed after 10^5 turns, or just 10 sec, leaving a significant margin in e-lens strength.

Next steps will include residual fields for which field maps were recently obtained from BINP. DA, FMA and Halo depletion simulations will be completed for all combinations.

- **Yannis** made a comment that the exact effect of octupole current and polarity on DA is working point dependent.
- **Sofia** asked if the sidebands were taken into account. **Yannis** clarified that the resonances in FMA will have sidebands due to the frequency and the nonlinearity of the e-lens kick. It is therefore

important to know how pulsing couples with the natural resonances of the machine as it may reduce the DA. **Daniele** pointed out there are no fields in the beam core. **Massimo** agreed that coupling of the time-dependent kick to the dynamics of the beam could be an issue, noting that in the end what one would like to get from the simulations is an ad-hoc spectrum. The next step would be to add imperfections, which can make the dynamics of the beam core more complicated.

- **Rogelio** pointed out that at the end of the Ramp the β^* is different from the studied 15 cm, being 60 cm for the current Baseline. **Daniele** mentioned this was a good starting point. **Stefano** emphasized the need to define the starting β^* for further studies of operational scenarios with HE lens (Action: **Daniele, Stefano**). **Rogelio** commented that during the ramp there is no need to deplete 2 σ, as expected orbit jitters should not exceed 1 σ. In addition there is a request to open the primary collimator to reduce impedance. These 2 points would reduce energy in the relevant region of the halo by 1 or 2 orders of magnitude. **Stefano** commented that halo must be depleted according to CC RF failures (2 σ) right before CCs are switched on. **Rogelio** proposed reviewing the requirements for halo cleaning (Action: **Stefano**)
- **Davide** inquired what energy deposition the collimation system is able to tolerate and how it corresponds to the 33.6 MJ stored in the tails. **Daniele** reported the maximum rate of losses is 1 MW. **Stefano** proposed refining the numbers taking into account the rate of losses. **Davide** asked if losses on witness trains would be acceptable. **Daniele** confirmed.
- **Rogelio** asked if during the ramp the HE lens inner radius could be controlled. **Stefano** confirmed. **Yannis** asked about elliptical shapes of the beam. **Stefano** replied that this is not foreseen at the moment and seems complicated. **Rogelio** pointed out that tolerances on beam roundness at e-lens are important to know, both for β-functions and emittances (Action: **Daniele**).
- **Davide** proposed adding a DA without the e-lens to the octupole current comparison plots.
- **Yannis** questioned the assessment of bunch population above 3.5 σ, pointing out the measurement data is present only for 4.5 σ and above. **Daniele** explained the estimate is obtained by fitting the measured data with a double-Gaussian. **Sergey** noted the uncertainty of such a fit could be significant. **Yannis** supposed it would be good to have a sense of uncertainty and proposed using a q-Gaussian function instead, which had been used in other collimator studies. **Rogelio** supposed it would be worth it to estimate the energy stored in the halo also for the larger collimator openings (Action: **Daniele**).
- **Rogelio** inquired about ongoing studies for collective effects with the HE lens. **Elias** replied the HE lens is not being followed up at the moment. In the past there was a study of e-lens impedance; additionally the cut tails (at 3.2 σ) are assumed for all stability estimates.
- **Nicolas** supposed it could be worth studying the beam dynamics and the cleaning efficiency of the HE lens in case an instability happens and bunches start oscillating coherently. **Yannis** commented that indeed the instability could become faster and perturbations to the e-lens fields might appear (Action: **Nicolas, Stefano**).

3 OPTICS V1.5 (R. DE MARIA)

Official release of v1.5 optics is expected in mid-November. This will be the first HL optics synchronized with the drawings. The drawings were released only a few days ago with some inconsistencies in them, once they are approved the optics will be released.

Main recent activities included the LS2-LS3 sequence. LS2 sequence has been generated from layout database, and the first working version of the optics has been created. The HL-LHC sequence generation is not ready yet; the MAD-X sequence has to be generated manually. A new layout database brought in new features but also a considerable amount of additional work.

The workflow seems to be rather complex and not well-defined. There are multiple issues: for example, geodesic data exists in the database only from 2012 onwards; the vacuum aperture database is separate from the layout database and maybe inconsistent with it; different databases utilize different conventions, duplicate data exists between databases. In terms of ownership, the data is shared between multiple teams in three departments. Updating the information is therefore time-consuming, which has not been properly accounted for in the planning.

A repository has been created to the new optics, but it has not been made publicly available yet. In the next version of the layout the D1 Beam Position Monitor will be removed, Q4 will be rotated, and there will be adjustments of TAXN Copper length and Y-chamber re-optimization.

- Discussing the workflow, **Massimo** pointed out the lack of global coordination. Other teams may lack global picture (that ABP has), resulting in unrealistic time constraints. A particular risk appears for ECRs arriving at the last minute, for which there might be not enough time to follow the process. A deadline may have to be installed for new ECRs. **Yannis** supported it must be made clear that certain tasks assigned to ABP require a lot of work and coordination. **Massimo** proposed trying to find shortcuts to speed-up the workflow in the framework of LS2. **Rogelio** concluded a summary of such an exercise could be very valuable to prepare LS3.

4 ROUND TABLE

Next meeting will be held the 19th of November.

Reported by S. Antipov, N. Mounet