WP2 Meeting #187

Tue 9 February 2021, 09:00 – 12:00

Chair:	Rogelio Tomás
Speakers:	Natalia Triantafyllou, Frederik Van der Veken, Ezio Todesco
Participants:	Hannes Bartosik, Philippe Baudrenghien, Xavier Buffat, Rama Calaga, Riccardo De Maria, Massimo Giovannozzi, Giovanni Iadarola, Nicolas Mounet, Yannis Papaphilippou, Konstantinos Paraschou, Giovanni Rumolo, Benoît Salvant, Elena Shaposhnikova, Galina Skripka, Guido Sterbini, Ezio Todesco, Rogelio Tomás, Natalia Triantafyllou, Frederik Van der Veken, Andreas Wegscheider, Carlo Zannini

AGENDA

MEETING ACTIONS

Philippe	Update Crab Cavity noise and emittance growth estimates for HL-LHC.
Frederik	Check if the situations with extreme asymmetry in b3 between the two D2 apertures were already simulated and if it is possible to correct them.
	Pass the MCBXF operational region with FRAS to Ezio for optimization of a3/b3
Ezio	Pass an important message for the production that the two apertures of D2 must have equal b3

GENERAL INFORMATION (ROGELIO TOMÁS)

Rogelio went through the actions of previous Special Joint HiLumi WP2/WP5 Meeting.

There were two talks on heat loads. There was a discussion for in-situ coating in IR2 and IR8 stand-alone quadruples. Data from Run 3 will be analysed to make a decision and to be prepared for LS 3.

There was an update on the field quality in the MCBRD and D2 given by **Ezio**. An action on DA analysis followed (presented today by **Frederik**).

Danilo presented studies on the crystal collimator longitudinal and transverse impedance. The design shows no issue in the transverse plane. Longitudinal plane should be checked as well as the heat loads for the collimator components. **Benoît** and **Danilo** should clarify the bunch length for the q-Gaussian bunch profile used in power loss computations.

Action for **Benoît** was to check the need for copper coating in the Y-chamber.

Rogelio said that **Gianluigi** provided the document for operational scenarios with all possible scenarios the beam will experience in Runs 4 & 5. The document is work in progress.

Today three talks were given: crab-cavity measurements and understanding emittance blow-up in the SPS by **Natalia**, DA specifications for D2 by **Frederik**, and MCBXF field quality model by **Ezio**.

1 NEW RESULTS OF SPS CC NOISE EMITTANCE BLOW-UP ANALYSIS (NATALIA TRIANTAFYLLOU)

Natalia presented new results on emittance blow-up from CC noise in the SPS. Slides are available here. In her talk Natalia discussed the impact of impedance on the emittance growth and the mechanism behind it.

Discrepancy between measured and expected emittance growth was observed in the tests of 2018: growth is different bunch-by-bunch and factor 2-3 lower than predicted by model, up to factor 5 in longitudinally stable bunch.

PyHEADTAIL simulations were done to study possible damping mechanisms from impedance. The CC noise is simulated as kicks on the momentum. Carlo provided the complete SPS transverse impedance model and corresponding wakefields were used in simulations. The main simulation parameters were listed. Local crabbing scheme was used but there is no difference if the global cc kick is applied.

Dependence of emittance growth on amplitude detuning with and without the effect of wakefields was studied (introducing phase noise dominant in the experiment). Suppression of emittance by factor 2-2.5 was found when wakefields were included in simulations for small values of amplitude detuning which could correspond to the realistic machine conditions during the experiment. Additionally, the dependence on amplitude detuning sign was found to be asymmetric.

Natalia also studied sensitivity to chromaticity, as the value was not clearly characterised during the experiment. Emittance growth suppression was found even for zero linear chromaticity. It was also increasing for larger chromaticity values. This was more evident for the negative detuning.

Simulations showed suppression of emittance growth only when phase noise is introduced, leading to a conclusion, that the observed behaviour is related to dipolar motion.

Simulations with the dipolar and quadrupolar impedance components showed that the effect of the emittance suppression is a result of the dipolar components.

The emittance growth from pure dipolar noise kick was simulated and factor 10 reduction was found, confirming the relation to the dipolar motion. In case of f_{CC}=200 MHz the phase noise kick is close to pure dipolar kick and same factor 10 of suppression was found. However, for HiLumi the damper will be the main damping mechanism.

Analysing the coherent tune and the incoherent spectrum, Natalia concluded that the emittance growth suppression is stronger where the coherent tune is outside of the incoherent spectrum.

To conclude, PyHEADTAIL simulations have shown significant emittance growth suppression from impedance, what partially explains the discrepancy between experimental observations and model. The suppression was found to be a result of dipolar wakes and dependent on amplitude detuning. Studies are on-going together with CEI section, to understand if the overlap between the coherent tune and incoherent spectrum could explain these observations.

- **Yannis** asked where the error bars on simulations come from and why closer to zero detuning they get larger. **Natalia** replied that it is from repeated simulations. Close to zero detuning sequence of random kicks plays a big role.
- **Rogelio** asked if α_{xy} is neglected. **Xavier** replied that it would slightly change the tune spread.
- **Rogelio** asked about the implications for HiLumi as CC noise is not going to be negligible. **Hannes** replied that most likely the impact will be not important because the damper will be much more effective. **Xavier** added that for HiLumi the effect of impedance is studied to a large extent.
- **Rama** asked what happens in horizontal plane. **Hannes** replied that emittance growth was very small. CC kick effect was not studied for the horizontal plane. But can be done.
- **Rama** added that for future MDs different working point where there is no suppression could be studied. **Hannes** replied that this is planned for this year.
- **Rogelio** said that realistic figures of CC noise for HiLumi were requested to Rama and Philippe. **Philippe** replied that initially CCs were thought to be on from injection. But during MD in the SPS, CCs were switched off during the ramp and locked back on the flat top. Maybe this operational scenario in the LHC could save some emittance growth. However, so far no big reduction was obtained in simulations for LHC ramps. Still work in progress. **Philippe** agreed to update WP2 with the CC noise and emittance growth estimates in few weeks (**Action: Philippe**).
- **Yannis** had an academic question if the effect is preserved for Q20 optics with faster synchrotron motion. **Hannes** and **Xavier** replied that it is similar.

2 DA FOR D2 SPECIFICATION (FREDERIK VAN DER VEKEN)

Frederik gave an update on DA for D2 specifications. Slides are available here.

For the study, Frederik has modified the way the magnetic errors are assigned: no systematic components are used and the random errors are doubled, which guaranties a more representative

sampling in the required range of ±4σ for the error distribution. With this approach, some seeds are beyond 4σ, meaning that the simulated DA is slightly lower that one should expect from the strict specification error table.

The increase of DA following from the removal of the systematic component of the errors has confirmed that the effect of D2 random errors on DA is well under control and not a result of internal compensations.

Frederik also checked the impact of larger values of the systematic component of b3 and b5, as was previously requested by Ezio. For large values of the systematic b3, a strong impact on DA was found. When b3 in D2 is corrected by means of the corresponding magnet in the CP, the DA curve is flattened and, remembering that some seeds in simulations were beyond 4σ, this means the actual DA might still increase slightly. Frederik has also checked that for correcting a systematic b3 in D2 of ±6 less than 12% of corrector package budget is needed, leaving enough margin to correct other magnets. Rogelio has previously questioned if the correction of systematic b3 in D2 will introduce beta-beating. Frederik has concluded that when correcting a systematic b3 of ±6 there is a small increase around 1%.

Frederik has estimated if there is enough corrector budget also to correct the field quality of the MCBXF depending on sign configuration. Correctors were found to be uncorrelated on each side of IP and taking ±8.5% of budget for strong MCBXFA and ±2% for weak MCBXFB. In summary, for the worst-case scenario, correcting both the D2 and the MCBXF b3 component, in addition to the b3 of the triplet quadrupoles and of D1, which are routinely corrected by the CP magnets, requires less than 50% of corrector budget, thus leaving enough margin.

Frederik also estimated the impact on DA from systematic b5 in D2 in the range of ±9 units, as requested by Ezio. The impact was found to be very small, which is good news because there is yet no good algorithm for b5 correction.

In conclusion Frederik proposed adding the correction of systematic b3 of D2 to baseline.

- **Rogelio** commented that adding the correction of the systematic b3 of D2 to baseline will have implications. The D2 acceptance criteria does not distinguish apertures and asymmetries between them. Here symmetry is assumed. **Massimo** pointed out that the message from Ezio was that the two apertures are almost identical in terms of systematic b3 and b5. **Frederik** said that the error in the numerical simulations is made of both systematic and random components. The correction is done for the average between the two apertures, but the errors are different for the two apertures. There is no a-priori correlation between apertures. **Rogelio** said that if the correction of systematic b3 of D2 is made part of the baseline, the acceptance criteria should reflect the presence of two apertures and set limits for the random component (±2 units in the existing specification, ±4 units in Frederik's current simulations). In case of large asymmetries appearing during production (giving systematic imbalance) this would guarantee that the correction can still work. **Frederik** replied that these situations with extreme asymmetry were most probably already simulated and it is possible to correct them, but the exact values should be checked (**Action**: **Frederik**). **Rogelio** stressed that the tolerances on the asymmetries between the two apertures should be set and the need for equal

(as much as possible) b3 in both apertures should be reflected. **Ezio** said that an important message for the production is that the two apertures must have the same shimming. This guaranties that b3 are equal as much as possible (**Action: Ezio**). In case the shimming is different it should aim for the equal b3.

- **Ezio** said that updating acceptance criteria should be done after measurements on the prototype and this has been agreed by everyone. He also asked to widen the acceptance interval for b5.
- **Massimo** agreed with this proposal and for b5 the interval of acceptance can be increased to ±4 units.

3 First Elements Towards a Two Dimensional Model of Field Quality in MCBXF (Ezio Todesco)

Ezio presented preliminary information on model of field quality in the nested correctors MCBXF. The slides are available here.

All the presented results are valid for both short and long models.

The main critical nonlinear components are b3 from inner dipole and a3 from outer dipole. For the inner dipole, the iron is far and therefore saturation is not very strong when only inner dipole is powered. The b3 in this case stays almost constant independent of powering. For the outer dipole, the iron is closer and saturation changes a3 value by -5 units when it is powered independently.

In simulations of combined powering saturation strongly affects both a3 (-20 units) and b3 (+25 units). The geometric in this case can be used to set an offset and avoid large values when saturation starts to have an impact at about half of nominal current. If the corrector is used below half of its field only the geometric b3 and a3 play role, and they can be moved by changing the midplane/pole shimming. Shimming in the coil heads is limiting the freedom of setting the geometric. In the current model both b3 and a3 are well within ±20 units. This is a simulation along the 45 deg. loadline (same integrated field in both dipoles). Simulations on other loadlines are planned.

A possible field model should have a3 and b3 as functions of (i) field to nominal field ratio and (ii) alpha – the ratio between inner and outer dipole field. A fit is needed to define forms of the two functions, either *erf* function or a polynomial fit could work. This is a complex field model never used before and has to be investigated. Another option is to use table of values for a3 and b3 for different combinations of inner/outer currents and have a linear interpolation.

Ezio said that running a sensitivity analysis on b3/a3 vs DA (with half the nominal field and full field) to help setting the limits on b3/a3 and better understand where is it best to place the geometric is of interest.

- **Rogelio** asked what the timeline to agree on the 2D model and optimization is. **Ezio** replied that it is not urgent and in the timescale of several months. The production will start in the second half of the year.

- **Massimo** added that with FRAS triplets will be displaced to avoid using the strength of the MCBXF. If MCBXF has deterministic settings with FRAS in place, then a3 and b3 correctors in the triplet can be used to mitigate field quality issues.
- **Rogelio** highlighted that in view of the new operational area an improved optimization is possible as the combined powering to large strengths is not foreseen and these regions could be left with poorer field quality while improving the operational configurations**. Frederik** can send Ezio the foreseen operational region with FRAS**. Ezio** will discuss with **Massimo** and **Frederik** on optimization.
- **Ezio** said he will discuss with Fernando to clarify about the signs of current, if b3 is changed or not. **Massimo** said that now b3 is assumed constant and only the sign of the main field is changing. If actual sextupolar field would have a constant sign this has a big impact on the studies, so this has to be checked.

4 AGENDA OF NEXT MEETING (ROGELIO TOMÁS)

The next meeting will be a Special Joint HiLumi WP2/WP5 on Tuesday, February 23rd, starting at 09:00 with the following agenda:

- Impedance of hollow e-lens device (Benoit Salvant, Carlo Zannini)
- A preliminary study of the electron beam impedance (Nicolas Mounet)
- Comparison of DC and RF electrical resistivity measurement for ion irradiated samples at GSI (Adnan Kurtulus and Carlotta Accettura)

Reported by the speakers and G. Skripka