Minutes of the 77th WP2 Meeting held on 13/09/2016


Minutes, Follow-up of Actions, General Information (R. Tomas)

Yannis’s talk is postponed to September 27. Elias discussed with Elena Shaposhnikova who will give the talk on “Longitudinal stability limit and bunch length specification” on September 23.

HL-LHC IR non-linear correction and options (Massimo Giovannozzi)

Massimo starts by highlighting the differences between LHC and HL-LHC. In LHC the non-linear IR correctors are used in simulation but not yet in operation (see next talk on the commissioning of these correctors). After a question by Ezio on the DA of the current configuration of the machine Massimo replied that without these correctors and octupoles DA is about 5-6 sigma (@3.75um). Yannis added that adding beam-beam further reduces the DA. Rogelio recalled that the current beam emittance is lower than nominal so the situation is better in terms of beam sigmas.

The strategy to set the correctors in simulations is based on the minimization of selected driving terms across the IR. This assumes perfect knowledge of the triplet and D1 magnetic errors. The procedure depends on the working point, to be effective one needs to know well the optics and the transfer functions for the correctors.

The layout of the correctors was shown. The simulation setup was described. The impact of each individual corrector was checked to find out the most effective correctors. The Landau Octupoles tend to wipe out differences and they are excluded. Octupoles, decapoles and dodecapoles have the largest impact on DA.

Systematic and random errors representing a mispowering of up to 30% have been introduced to take into account uncertainties on optics, field quality and/or transfer function. When correctors are mispowered the strongest dependence is on the b3 component although DA variations are in the order of 0.1 sigma. For some mispowering the DA improves, this comes from the neglected factors in the calculation, plus the fact that correctors act for both beams, so one could improve B1, but decrease B2. a_n correctors mispowering have small impacts. The effect on average DA for 10 random mispowering configurations is barely noticeable.

Regarding the field quality correction for D2, one needs to consider that the phase advance is not exactly 90° w.r.t. the IP, (for flat optics is off by almost 2°), therefore the approach may be less effective. Plus it is only possible to correct for the systematic component of b3 and b5 among the 2 beams as D2 is a two-in-one magnet. Ezio recalled that there is a good correlation between field qualities in the two apertures. The error generated for one beam should be fed to the other one and the optimal correction should be computed for both.

The strategy for b3 correction in D2 consists in fixing the correlation between the field qualities in the two apertures (f parameter). There seems to be no relevant impact of the correlation f parameter on dynamic aperture, but need to be further checked.
Outlook: Further checks on the b3 D2 correction. What is the impact of correcting b5? Are there possible alternative correction strategies? Need to develop similar implementation as in the MD studies for an increased reality of the simulations.

Discussion:

Ezio asked if we can relax the b3 tolerance in D2 as 1 unit is challenging. Massimo replied that this could be studied also regarding a possible optimization of b5, for example. Ezio pointed out that the corrector transfer function is not a source of error (1% uncertainty for strengths above 40% of nominal), there is less precision in the measurement of multipoles (10%), but the main source of error might be the knowledge of beta function which gets a large power according to the order of the corrector. Rogelio added that misalignments also have a central role as it is shown in the next talk by Ewen. Orbit or misaligned corrector may require alternative strategies. Massimo commented that the misalignment study should also be performed (Action: Massimo). Ezio pointed out that the beta function at the corrector might have a larger uncertainty than the corrector transfer function. The effect of a deviation in the beta function is expected to grow with the order of the corrector. For the next iteration the mispowering strength could be adapted to the multipole order.

Experience with the LHC IR non-linear correctors (Ewen Maclean):

From the experience in MDs using crossing angle scans: from Run 1 and Run 2 the b3 component in IR2 was very well validated against the model. In IR1: b3, a4 and b4 also show a rather good agreement with model predictions using magnetic measurements.

Yannis asked if chromatic effects are included in the model. Ewen replied that they are but the chromaticity is set to a low value for the measurements to allow the use of the AC dipole (2-3 units).

The strategy for tuning IR5 b4 consisted in minimizing the detuning with amplitude. This can be done thanks to the fact that IR1 b4 correction was validated with the crossing angle scan and the only remaining source of amplitude detuning is IR5.

The skew sextupole (a3 component) of IR1 presents a big discrepancy between model and measurement, plus variations between 2015 and 2016 were observed. These could be justified by an orbit change.

One can infer the closed orbit at sextupoles by changing the corrector strength and measuring the tune shift, this resulted in up to 50% orbit discrepancy compared to the prediction from the MADX model.

Concerning the crossing angle scan technique there are limitation arising from the non-closure of the orbit bumps: changing crossing in one IR affects also the other one. Hard to track the correction in this scenario. This limitation was overcome in a recent MD by applying a manual orbit feedback during the scan, showing an improved agreement between model and measurement. The deployment of this orbit feedback is not yet foreseen by OP.

A significant orbit offset (about 2mm) was measured also in the IR1 b4 correctors which suggests that misalignments in the triplet quadrupoles can play a very important role in the final multipolar configuration of the magnets. This also forces to cope with B1 to B2 asymmetries.
A possible way to understand the sextupole discrepancies consists in developing dedicated orbit bumps to sample differently the magnets across the IR. Some successful tests with different orbit bumps have already been performed.

In LHC it is hard to see any feed-down to tune from errors above the octupolar order. An alternative that works on simulation is measuring the feed-down to amplitude detuning. This measurement would require considerably longer MD time.

Progress on standard and new techniques to measure DA and resonance driving terms were presented. These could be instrumental to determine higher order corrector strengths.

Conclusions: Basic techniques have been validated and about 30% of the relevant IR multipolar errors for LHC have been evaluated as consistent with magnetic measurements. The IR5 b4 component is clearly smaller than expected by about a factor 2. The understanding of the remaining multipolar errors, especially in IR5, requires further analysis, simulations and measurements. New strategies are already in place and under development to tackle all the remaining challenges.

Discussion:

Ezio asked why everything works without correctors powered. Ewen replied that there could be some compensation of the actual errors since actually discrepancies always suggest lower multipolar errors in the machine than in the model. Rogelio added that at 40 cm beta* the correctors are not really needed according to the simulations from Massimo (probably needed at 30 cm). In simulations correctors have a beneficial effect for beta* below 1 m. Again the possible misalignments are the main suspect to be responsible for the differences between model and measurements.

Elias asked what the expected DA is for 40A Oct and high chromaticity at injection, he added that there are possibly other effects contributing to DA. Yannis mentioned the e-cloud tune shift. Gianni added that the bunches with more losses are always the ones in the tail of the trains. Gianni pointed out that the octupole current is high but the emittance is smaller.

Yannis noticed that it would important to have the b4 experimental corrections/errors to include them in the DA simulations and future beam-beam experiments as they represent 1/3 of the current octupole settings at top energy. Rogelio replied that a knob should be prepared for use in the CCC (Action: Ewen).

Update on RF fingers

Initially the proposals from TE/VSC were reviewed. The bellows need to be shielded to limit the impedance which is huge otherwise. There are some cm of thermal expansion that need to be absorbed by the RF fingers, but if the fingers bend too much they generate themselves impedance. This is made worse by the high beta function at those locations.

A thermal expansion of 27.7mm result in a final finger angle of 15°. Staying above this angle limits the mechanical stress. An increase of this angle to about 40° was requested.

They did mechanical tests for stretch and fatigue. They would like to increase the number of convolutions (number of sets of RF fingers per bellow) to three.
They asked for studies from the beam point of view.

Simulation and measurement work:
The imaginary part of the impedance increases with the angle. The total longitudinal contribution of 28 bellows (although their size and number is still being adjusted) can go up to 1% of the total for large angles 40°, apparently too much. In the transverse impedance the contribution is larger and already significant for smaller angles.

More detailed model with holes between the fingers for HOMs analysis: the shunt impedance remains very small, plus detuning is expected from the different lengths of the modules. Both transverse and longitudinal look ok.

The conclusion is that, although this are very simplified models, significant contribution in the transverse plane are expected and going beyond 15° is seen as a risk.

The results from the ACE3P simulation by Kyrre were presented. The mode coupling is possible but unlikely. The holes between the fingers does not seem to contribute in the longitudinal, for the transverse plane there are no results yet.

For the lateral offset difficulties have been encountered in modelling the deformation, work ongoing.

The measurements on the test bench have pointed out some resonance without bellows mounted but when they are mounted all resonances disappear.

It has been proposed to add an HOM absorber in the bellow, but this may produce too much heat (the system is at cryogenic temperature).

Conclusions: From the impedance point of view an angle of 15° looks reasonable, 40° is out of question. Need to understand if the bellow wall may bring any improvement.

Elias commented on the minimum finger angle: his strategy would be to minimize the impedance as much as possible, to avoid accumulation of small contributions.

*Reported by Dario and Rogelio.*