Minutes of the 113th WP2 Meeting held on 19/12/2017

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General Information (G. Arduini)

The minutes of the previous meeting have been circulated. Gianluigi summarises the outcomes and the actions of the previous meeting. The minutes are approved without comments.

Davide verified that the there are differences between nominal and ultimate currents for the correctors. Gianluigi asked to verify also for the existing auxiliary circuits (including octupoles and sextupoles). **Action Riccardo and Davide.**

Gianluigi initiated a discussion with Ezio concerning the stiffness of the cryostat support and the implications of moving the vibration modes to higher frequencies.

Update on Beta beating from head on/long range: is it a problem? Can we measure and compensate it? (L. Medina)

Luis considered the baseline case including head-on and long range interactions. The peak beta beat is up to 15%. A large detuning with amplitude is observed, mostly along the diagonal. The amplitude-dependent beta beat was evaluated at the positions of the primary and secondary collimators. The values were found to be well within the tolerance of 20 %.

Elias asks if the conclusion is that no action is needed. Gianlugi points out that one could still get luminosity imbalance, which however is masked during the levelling and becomes rather limited afterwards. The beta beat at the collimators was the main concern, but it appears to be within the tolerances. Rogelio points out that it is nevertheless important to continue with these studies going more in depth and following up the evolution of the operational scenarios.

Xavier points out that the Van Der Meer scans with full intensity may be affected by these values of beta beat and they will require a correction. Rogelio confirms that in the Van Der Meer optics a very precise optics is already being requested, while in the past it was not the case. Elias asks for the current detector luminosity precision, Rogelio replies that the current one is about 3% and it should be improved to 1%.

Gianluigi points out that the beta beat depends on the phase advance between IPs. Xavier replies that by tuning the phase one can only achieve a global compensation, while one may pursue local corrections of the IPs.

Dario points out that proposal for a working point close to the half integer may significantly suffer from the dynamic beta beat. It will be very important to have a knob to adjust the phase between the IPs in order to suppress it. Riccardo commented that the margin for the phase adjustment is very limited.

Results from operation and MDs and implications for HL-LHC: Linear corrections (J. Coello De Portugal)

During the MD on flat optics a local error was found in IP1. In addition the global correction appeared ineffective in sector 45 with a peak beta-beating of 25%. Jaime tried to include the sextupoles in the global correction, but this resulted in a very large predicted bump which might not be used in the machine. Further investigation is required.

The fact that the optics control with the current global correction is harder for the HL-LHC optics is observed in simulation. Sergey asks if the few seeds with a beta beat of > 50% are real. Rogelio replies that this comes from applying the same tool to all the cases. Gianni suggests trying to manually correct one of the bad seeds. **Action: Jaime**

An important requirement of the corrections is a very accurate tune determination. Precise tune measurements with the AC dipole show an increase of the tune uncertainty for smaller beta* and larger tele-indexes, although the ones with flat optics were inconclusive. The upgrade of the dipole power suppliers in the ATS bends appears to be critical to maintain a small tune jitter allowing for good optics correctability.

An oscillation of the tune at the rms level of 3e-5 with a period of 100s was observed at flat top (1m beta*). Rogelio clarifies that the measurement requires very dedicated settings: high intensity, low chromaticity and octupoles. Gianni asks if the orbit feedback could be the cause. Rogelio mentions that Jorg suggested a temperature drift among several other possible effects. Gianluigi proposes to make a test without the orbit feedback. Rogelio replies that it is a good suggestion. Gianluigi identifies the regulation of the power converters, Rogelio does not exclude it.

A new automatic correction has been tested in simulation considering HL-LHC v1.2. Jaime explains the assumptions of the simulations and he shows how the automatic tool corrects down to the limit given by the tune measurement and properly distributes the strength errors. The beta beat distributions at several elements presents the majority of the seeds below 1% although few cases are above 2 %.

Gianluigi asks if the locations giving significant optics errors are consistent across the various optics measured. Rogelio replies that the IR1 error appearing in flat optics was not observed before with round, not even at 10 cm although this was measured the previous year and some deterioration may have taken place. He adds that a large impact is observed from longitudinal triplet displacements, this will be better decoupled in HL-LHC.

Gianluigi asks about the magnitude of the IR1 correction. Rogelio replies that it was small, still it does not agree with other optics. Riccardo suggests that the only way to disentangle a longitudinal misalignment is with k-modulation in Q4 and Q5.

Ezio proposes to have a Fidel meeting to discuss all the observation so far and compare with the magnetic measurements and expectations

Gianluigi notes that if the limit of the correctability comes from the power converter noise, there might be a way to probe it by stopping the pre-squeeze earlier for the same value of beta*. Riccardo points out that even if the presqueeze is fully correct, whatever one does from outside the IR will be reflected at the IP. Rogelio comments that the more optics one measures, the better it is. Riccardo asks if for the nominal optics one can find a correction that fits the entire beta* squeeze. Rogelio replies that this was done in the past and proved to be effective, but when reaching for smaller and smaller beta*, the last point becomes dominating. Rogelio identifies other possibilities to probe the optics such as measuring the luminosity against waist shifts.

Dario recalls that a 35 cm optics with teleindex 3 already went into the machine for the MD with negative octupoles; he asks if anything can be concluded concerning the power converter noise by comparing that optics to the standard ones at 40 and 30 cm. Rogelio replies that the analysis should be done. **Action: Rogelio.**

Riccardo asks if one can reduce the target for the beta beat in the IR as this has an impact on the design of the protecting elements. Rogelio replies that the current 4% rms beta*-beating and 2% at key elements comes from the triplet alone. Riccardo points out that at the smallest beta*, the beta beat will be still around 10%. Rogelio confirms and he adds that the next step in simulations is considering errors all around the machine ; he also points out that the upgrade of the dipole power supplier was assumed, while it is not in the baseline. **Action: Rogelio to evaluate the impact of the errors around the machine on the beta beating.** Gianluigi stresses the need of being consistent with what is required and what can be achieved.

Results from operation and MDs and implications for HL-LHC: Non Linear corrections (E. Maclean)

The non-linear correction commissioning of IR1 and 5 was done for the first time this year, as operating the machine below 40cm beta* started to make non-linear errors relevant.

The amplitude detuning from the IRs (with Landau octupoles off) was very well corrected.
The sextupole correction was also introduced. Some of these corrections were proved effective by observing a reduction of the corresponding resonant driving terms. Ezio asks how the measurement of the RDT is done. Ewen explains that the histogram is built by collecting the amplitude of the corresponding peak in the spectrum of each BPM.

Ezio asks if by measuring global quantities such as amplitude detuning and lifetime one can deduce that the correction acts on a local point. Ewen replies that this is the case because the Landau octupoles were switched off and the source is well identified. Dario asks if one could still have some residual octupolar strength due to hysteresis. Ewen replies that it would correspond to an unrealistic value of 200 A.

The non-linear correction also improves the linear part. The octupole correction allows achieving a better tune measurement from the BBQ. The sextupolar correction directly impacts on the linear optics via feed-down; it is shown that once this is put in place the linear correction is more effective in reducing the beta beat. Ewen stresses that the non-linear effects will be more severe at smaller beta*. A more iterative commissioning strategy bouncing back and forth between linear and non-linear corrections will be required in HL-LHC.

The results of correcting IR1 are shown as a function of the crossing angle. Ezio asks about the reason for starting with the b4 correction. Ewen replies that the value was already computed in MDs in 2016, it was helpful for improving the BBQ measurements, plus this avoids feed-down effects; it was indeed observed that the a4 correction spoils the a3 correction. Gianluigi asks if one can estimate the misalignment of the correctors. Ewen replies that it is expected to be around 1 mm. Ezio suggests always reporting the strengths and the currents of the correctors. Ewen replies that the currents are around 5-20 A. Ezio comments that a large systematic b4 was consciously left in the triplet (which will not be there in for the HL case) while a4 is random; he suggests clarifying if the corrections are based on fidel or on the beam. Ewen replies that they are all based on beam measurements. Stephane asks if cross talks between different orders in the corrector package can be expected as iron is present. Ezio is sceptical. Rogelio comments that the IR errors will be larger in the HL case, on top of larger betas; Ezio agrees, although he reminds that the systematics will be smaller. Gianluigi asks if the correction agrees with the magnetic measurements, Ewen confirms the right ballpark but a 30% difference is observed.

The HL regime was replicated introducing a large skew sextupole component by means of KCSSX3.R1. In this case even small AC dipole kicks appear to be no longer adiabatic, leading to large emittance growth.
Gianluigi asks if this measurement is done with pilot bunches, Ewen confirms. Gianluigi asks if one can measure on a single bunch in a beam consisting of more bunches. Rogelio replies that this might eventually be possible

by using the ADT as an AC dipole; this is being followed up by Tobias. Stephane points out that the emittance growth might be caused by hitting a resonance, if this is the case tune adjustments might help; he proposes to stay at injection tunes. Ewen points out that there are hardware limitations on the AC dipole but a tune optimisation is being considered.

The strategy for what and how to correct is being discussed. b6 might become relevant for small beta* (scaling with the third power), by powering the corrector at the maximum current at 40 cm, lifetime degradation was observed. The feed-down effect is also considered. Stephane points out that the feed-down of the systematic b6 on b4 will be compensated by the V/H crossing schemes in IR1/5. Dario suggests that this is true only for the systematic part. Rogelio adds that one may have different errors, orbits, even crossing angles to compensate for different H and V emittances, therefore one should not rely on that compensation

The a4 was observed to be over corrected, a strong impact on the amplitude detuning was observed especially for the particles approaching the diagonal, with large distortion of the tune footprint.

Ezio remarks that the strong systematic b4 in the current LHC will disappear in HL; one should not over-tune the correction algorithms. Ewen replies that this is not a problem; the b4 correction is indeed easy, being directly connected to the detuning with amplitude which is a very good observable.

Ezio stresses the willingness to organise a fidel meeting.

AOB: Outcome of the last ATS MD (S. Fartoukh)

Stephane points out that a 35 cm optics with a teleindex of 3 (pre-squeeze stopped at 1 m) was put in the machine. This addresses the points of having to replace the power suppliers of the dipoles (and eventually quadrupoles) in the telescopic arcs.

The lifetime was shown to be acceptable all along the cycle. The emittance growth is comparable with the 0.05 um/h observed along the year. The growth rate is slightly smaller for the 25ns bunches with most long ranges encounters, possibly due to shaving. These points do not appear to require the upgrade.

Rogelio replies that the proposal of improving the power suppliers addresses the low frequency noise and aims at improving the tune stability, which is required for the optics corrections as was shown by Jaime.

Xavier comments that the high frequency part of the noise appears to be in the shadow of the feedback noise also in the high intensity part of the MD.

Gianluigi summarises the outcomes of the discussion:

1. The emittance blow-up and lifetime present no visible deterioration due to the power suppliers.
2. It appears that the noise from the feedback system is dominating.
3. We need to better clarify the implications in terms of beta beat of the power suppliers noise, where the tune ripple is relevant for quality of the optics measurements.

Gianluigi makes the best wishes to everybody for the Christmas break.

Reported by Dario, Gianluigi, Riccardo and Rogelio.