# Minutes of the 137th WP2 Meeting held on 11/12/2018

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## 1 GENERAL INFORMATION (R. TOMÁS)

**Rogelio** recalled the issue with spatial constrains of Crab Cavity (CC's) cryomodules (CM's) and the impact of proposed CM shifts on accelerator performance and proposed to open the meeting with a follow-up from Riccardo.

## 2 AOB: CRAB CAVITY SHIFT (R. DE MARIA)

**Riccardo** reported that Rama and Ofelia followed up with a preferred solution ('called baseline') which has about 6m drift between the 2 crab cavities. The motivation behind it is that the cryogenics prefers the same situation for access on both sides of both CMs.

The implications for RF voltage are: (1) no asymmetry that could be used to optimize a particular side; (2) the crabbing angle is reduced to 350 µrad; (3) virtual luminosity reduces by 5.6% and the integrated luminosity – by 0.6% for Standard and 1.4% for the Ultimate operational scenario (OP).

- Regarding the 'baseline option', **Paolo** stressed it is an option to be discussed, there a lot of things to be changed with implications for many WPs. An impact is foreseen on civil engineering, remote alignment, cryogenics, and vacuum layout, which will come at a significant extra cost. **Rogelio** inquired about the timeline for making the decision. **Paolo** replied it would be good to finalize in 1-2 months.
- **Ofelia** inquired what the sensitivity on separation length is. **Riccardo** replied it is almost linear. **Ofelia** mentioned an option of 4.6 m shift with reworking from cryogenics and proposed trying to optimize optics for this shift.
- Regarding the layout optimization, **Riccardo** noted that D1 lengths and field strengths cannot be increased, meaning the D2 magnet cannot be moved towards IP.
- **Ofelia** asked if, from the beam dynamics point of view, there is a preference for the order of the cavities: B1/B2 vs B2/B1 (CC's are not symmetric, the first option is preferred). **Riccardo** replied there is no impact for the B2-B1 B1-B2 scenario. **Ofelia** asked about shifting both CMs? **Riccardo** replied there are no significant margins either.
- **Riccardo** raised a question if the current situation implies the layout with 4 cavities per side per beam (the old baseline) would have not been possible. **Paolo** replied this is so according to Serge. **Rogelio** proposed to have a joint meeting with Serge, emphasizing that the current proposal removes 10-15% of CC improvement and comes with extra cost. The meeting could be hosted early January.

ACTION (Riccardo, Ofelia): Optimize optics for the preferred solution with a 4.6 m CM shift

ACTION (Rogelio, Riccardo, Rama, Serge, Paolo): Review reasons for the change, beam dynamics and performance implication of the cryomodule shift.

# 3 Review of IR correction macro & Asynchronous MO polarity swap (E. McLean)

**Ewen** presented on several topics related to nonlinear corrections and Dynamic Aperture (DA). He first discussed whether the existing strategy is optimal for DA. The nominal correction minimizes selected resonance driving terms (RDT's). It is compromise between B1 and B2, which have slightly different optics. In order to study the impact of RDTs on DA an alternative weighting with β-functions has been considered to further suppress sextupole RDTs in only one beam (the other deteriorates). The optimization has very little effect on short-term DA for the negative octupole polarity, and some effect is seen for the positive polarity. The benefit for positive polarity could motivate to explore additional correction strategies, for example including the MSS in ATS arcs for the RDT correction.

The second topic is if RDTs and DA should be the highest priority for IR nonlinear correction. All normal/skew sextupole corrections in LHC are done based on feed-down (FD). This year the team struggled to correct a large FD to linear coupling at IP2, in B1 it has been corrected, but a large FD has been left in B2.

For the octupole correction, the normal approach is based on amplitude detuning and can be done very well in LHC. Octupole beam-based correction in HL-LHC looks more complicated than in LHC, because the cross term becomes of the same magnitude as the direct one. The residual uncorrected detuning may affect the quality of K-modulation measurements. Correcting the cross term with Landau Octupoles (LOF and LOD) does not seem viable.

- **Rogelio** pointed out that the cross term is out of control and inquired about the potential impact on the Stability Diagram (SD). **Xavier** replied that the cross term is not relevant for the negative polarity, where the beam stability is dictated by the direct detuning term, yet it would be useful to have the detuning values after correction to evaluate SDs for the octupole positive polarity.
- **Yannis** raised a question whether the optimization of RDTs could be added to DA simulations. **Ewen** replied what is shown is just the first attempt, the existing strategy seems optimal for the negative polarity at the moment.

ACTION (Joschua, Ewen): Compute detuning terms after correction for Xavier.

# 4 UPDATE ON DYNAMIC APERTURE IN THE PRESENCE OF B6 TRIPLET FIELD ERRORS (F. VAN DER VEKEN)

**Frederik** presented an update on the impact of large b6 on DA. In the past it was reported that the body of the MQXF magnets might have a large systematic b6 up to -4 units vs the current nominal value of -0.64 units. According to previous studies, the effect on DA is visible although small.

For pairs of magnets with large b6 errors no significant effect is found for most studies scenarios, except if both are of Q2a type when up to 0.3 $\sigma$ DA reduction is possible. For corrector failures with no LO and small Q' the effect might be rather strong with DA going down by several units: up to 2.75 $\sigma$ in min. DA if one corrector fails and 4 $\sigma$ in the unlikely case that all fail. This 'failure' case is relevant for commissioning stage where one will have to work without the correctors. There is no effect of failing correctors on DA for the nominal b6. The situation is similar for corrector failures with nominal LO and Q', but becomes on average 1 $\sigma$ more critical.

Magnet acceptance criteria are proposed that are based upon considerations on the field quality: if the measured multipoles are all within 3 $\sigma$ from the expected values, the magnet is accepted whereas if they are beyond 9 $\sigma$ the magnet can be rejected. This proposed criterion has been scrutinized using the available correctors' strength as observable. It turned out that while for an error distribution within 3 $\sigma$ all correctors do not exceed their strength (for a sample of 1000 realizations), for the case of 9 $\sigma$ several correctors are running out of strength. Hence, it has been proposed to set the rejection threshold to 6 $\sigma$ for which the number of out-of-strength correctors is really negligible. Simulations show an effect on DA for the regular cases, namely 3, 6, and 9 $\sigma$: a decreasing trend towards higher $\sigma$. Investigations for borderline cases are ongoing.

- **Rogelio** inquired if Ezio has been informed about the results of the study. **Massimo** reported that will be done as soon as the results are available.
- **Ewen** raised the point on the impact for imperfect optics corrections and beam-based settings. **Massimo** mentioned that indeed in the past studies were done with some mispowering representing the possible errors.

ACTION (Frederik, Massimo): Update Ezio on the outcome of the studies and document in general the studies defining the acceptance criteria for field quality.

# 5 EFFECT OF SYSTEMATIC B6 ERRORS ON BEAM-BEAM (N. KARASTATHIS)

**Nikos** followed up the analysis done by Frederik, including the beam-beam interaction. The worst performing seed from DA studies was analyzed. The simulations were done for $\beta^*$ of 15 cm. Overall, the impact of b6 is in the shadow of beam-beam interaction, as expected.

According to numerical simulations, at the end of levelling there is an area of 6 $\sigma$ DA for the OP scenario. Corrector errors may require shifting the WP slightly. If all b6 correctors fail the DA reduces by 1 $\sigma$. At the start of levelling there is a large area of DA > 7 $\sigma$.

- **Rogelio** asked if the simulations could be done for 40 cm $\beta^*$, or other larger value, pointing out that it would be interesting to see at what $\beta^*$ it is safe to run without b6 correctors.

ACTION (Nikos): Find out at what $\beta^*$ it is safe to operate without b6 corrections with beam-beam interaction.

# 6 AMENDMENT TO HL-LHC CIRCUITS SPECIFICATIONS (D. GAMBA)

**Davide** reported on multiple requests from WP6b to verify new Power Converter (PC) specification, powering, and noise class. A new class of PC's has been introduced – Class 1-2 – essentially it is a Class 2 PC with a different ADC module. Table of main parameter for each circuit has been presented.

Analysis of the impact of noise on tune variation for baseline and flat optics shows that the most critical elements are Inner Triplet (IT) and ATS dipoles. Therefore, ideally, the best available PC's should be installed in these regions.

For LHC the tune stability seems to be roughly consistent with the PC noise estimates, with visible exceptions. Regarding the expected tune stability, the impact of the new PC class 1-2 is negligible with no sizable improvement. The tune stability is still far from the target - the shot time tune stability is above $4x10^{-5}$, while it should be below $1x10^{-5}$ to go down to 1% $\beta^*$ level. $4x10^{-5}$ tune jitter leads to an error of

~30% for the 15 cm optics. Upgrading ATS arc dipoles to class 0 brings this value down to $2.9 \times 10^{-5}$. The flat optics represent a huge challenge with a tune stability of about $6 \times 10^{-5}$.

Preliminary DA studies were performed by **Sofia**, who examined the impact of dipole PC ripple. No major difference with the crab cavities.

Effect of noise on orbit stability is negligible (both for the new and the old specifications), with related luminosity loss being much less than 1%.

There is no limitation from power circuit side on the orbit separation collapse, it can be done significantly faster if needed.

In summary: (1) it is ok to use class 4 PCs for 120A circuits. RQSX can be powered by a 600A PC. RTB8 can be powered by a 600A PC; (2) there is no sizable improvement from adopting class 1-2, so this new class is not needed; (3) there is no need of a remote calibration system for class 0 PCs. The noise in the 0.1-few Hz and the high frequency lines need to be further studied.

- Regarding the DA studies, **Rogelio** inquired about the frequency mesh used for the analysis proposed refining it, additionally checking the potentially harmful frequencies close to the beam spectrum lines and the quadrupolar resonance $2Q_x=Q_{ripple}$. **Sofia** replied the analysis can be done and mentioned that previous studies also showed an effect of FD on DA. Quadrupolar modulation can be checked as well. **Yannis** asked to clarify the expectation of the ripple. **Miguel** replied it is defined as the limit for any present frequency line. **Michele** pointed out that other mechanisms might be playing a role, for example resonances in circuits that might be triggered by power converters. A separate discussion is needed. **Miguel** proposed narrowing down the list of relevant frequencies.
- **Michele** commented on sources of noise limits. The 0.1 Hz specification came from beam dynamics requirements for K-modulation measurements. String test will probably give a number to rely on for a range from 0.1 Hz to a few Hz. From 10 Hz the spectrum is covered by a gabarit line. If there is a nonconforming line in the frequency it will be detected and removed. The definitions can be improved if needed.
- **Michele** asked if Davide's results imply approval of the proposals and if eventually they should be presented in the TCC. There was consensus that indeed this is the case. **Yannis** agreed to consider this topic in a future TCC.

ACTION (Sofia): Check the impact of potentially dangerous noise frequencies, in particular near to the tune and twice the tune, on DA.

ACTION (Miguel, Michele): Estimate the possible high frequency spectral lines, specifcially in the range above 6 kHz to come back to WP2.

# 7 POWER CONVERTER SPECIFICATION (M. CERQUEIRA BASTOS)

**Miguel** explained how the PC performance figures are derived. The PC performance is defined by (1) by precision components: ADCs and DCCTs; (2) the current regulation loop; and (3) by voltage source and load. The first two affect the low frequency performance, whereas the latter – the high frequency ripple. Several different ADC platforms and DCCT types will co-exist in HL-LHC, and that imposes certain constraints. As an example, Q4,5,6 PCs are upgraded with a radiation hard version which will have a different jitter.

The specifications are based on the parameters from beam dynamics. They are compared with performance data for all the different devices and then the results are combined to get the expected performance of the PCs.

- **Rogelio** inquired if the tune jitter is expected to be different after the shut down as a result of quadrupole PC upgrade. **Michele** ensured the PC will stay in Class 2, but they might be different within the same class. **Rogelio** proposed producing the estimates for the next run, emphasizing that comparing the data of this run with the future measurements would give confidence in the models.
- **Miguel** noted that the beam screen can help attenuating the voltage ripple. **Michele** further elaborated that the magnet itself would act as a low pass filter, although the attenuation is not large. Therefore, the estimates based on a constant assumption (as the one done by **Davide**) are slightly pessimistic.
- **Rogelio** asked if the changes in PC specification need to go through an ECR. **Miguel** proposed presenting the final numbers at TCC to figure out if an ECR is required.
- **Michele** commented on sources of noise limits. The 0.1 Hz specification came from beam dynamics requirements for K-modulation measurements. String test will probably give a number to rely on for a range from 0.1 Hz to a few Hz. From 10 Hz the spectrum is covered by a gabarit line. If there is a nonconforming line in the frequency it will be detected and removed. The definitions can be improved if needed.

ACTION (Davide): Estimate the effect of quadrupole PC upgrade with radiation hard version on tune jitter.

ACTION (Miguel, Michele, Davide): Present the outcome of the studies at TCC

# 8 ROUND TABLE

**Michele** mentioned they have a new Technical Student who is starting to work on the flux jumps and proposed to postpone the presentation on flux jumps and transfer function until circa mid-March when the student could have some new results to present.

# 9 FOLLOW-UP AFTER THE MEETING

**Riccardo** discussed the cryomodule shifts with Serge, Paolo, and Ofelia. The preferred option underwent some changes, Paolo will send the new layout to test early next year. **Paolo** would like to receive a final statement on displacement of crab cavities at an Integration WG meeting on Jan 18.