Minutes of the 118th WP2 Meeting held on 10/04/2018

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AGENDA:

1 GENERAL INFORMATION (R. TOMAS)

In the absence of Gianluigi, Rogelio chairs the meeting. Minutes of previous meeting will be distributed soon.

2 UPDATE ON CU COATING THICKNESS AND HL-LHC OCTUPOLE THRESHOLDS (S. ANTIPOV)

Cu coating is being considered as a backup alternative to Mo. Based on **Sergey's** presentation at the 116th WP2 meeting, 3 μm of Cu provide an adequate octupole current reduction for any value of chromaticity. At the same meeting **Federico** noted that more than 2 μm of Cu coating might be challenging.

For most chromaticities 2 μm Cu coating seems acceptable, both on CFC and MoGr. There are certain chromaticity values that require up to 100% more octupole current compared to a thicker coating, but it occurs only in a small range of chromaticities. The amount of Landau octupole current at the most critical chromaticity values around Q' ~ 10 is not affected by the reduced thickness of the coating.

Benoit reminded that the baseline coating thickness is 5 μm and suggested that there should be a strong reason to reduce it. **Xavier** pointed out the importance of understanding of the coating thickness tolerances. **Benoit** stressed that before taking the risks associated with a lower thickness one has to understand the benefits. **Nicolo** noted the existing experience with Copper coated collimators: TDI and TCDQ that were coated with Cu with the thickness up to 5 μm. **Rogelio** summarized that the implications of having a thicker coating have to be fully understood before settling for a thinner one, including potential impact on beam stability, achievable thicknesses and thickness tolerances, and cost.

ACTION (Federico, Vacuum team): Investigate the feasibility and cost of having 3 μm Cu coating for the secondary collimators. Provide an estimate of thickness tolerance.

3 POWER SUPPLY RIPPLES & 6D FREQUENCY MAP ANALYSIS (S. KOSTOGLOU)

Sofia presented the progress on Frequency Map Analysis (FMA) studies of the effect of Power Supply (PS) ripple and synchrotron motion on the Dynamic Aperture (DA). FMA allows identifying potentially dangerous resonances, arising from modulation effects. **Sofia** first showed a simplified model (only transverse dynamics), where the tune modulation caused by quadrupole PS ripple can reduce the DA, depending on its frequency and strength. A problem identified for large modulation indexes – the Fourier spectrum is dominated by modulation sidebands; analytical fitting is necessary to restore the tune from tracking data. The first results of a full 6D tracking with synchrotron motion and beam-beam interaction were presented. The results suggest that the synchrotron motion is more critical for DA than the PS ripple. Future work includes investigating the impact of 6D beam-beam interaction on the modulation of the synchrotron motion, simulation of beam distributions, and implementation of a realistic spectrum of PS ripples.

- **Rogelio** mentioned that dipole ripple also affects the tune, according to **Davide**. **Yannis** replied that the dipole PC ripple is not in the model yet, but will be included eventually. **Rogelio** asked how the fit is made in the simplified model. **Sofia** replied that the fit is done analytically, by decomposing the signal in a series of Bessel functions. **Yannis** commented that this linear approximation works well in the simplified approach.
- **Riccardo** asked if threshold amplitudes of the ripple could be identified. **Yannis** confirmed the possibility to do this, to the order of magnitude. Even though the machinery is still under development, one can already obtain lifetimes similar to observed in LHC without beam-beam. **Riccardo** suggested using a simple rule-of–thumb to use for rapid feedback: when the resonance enters the beam core - its amplitude becomes unacceptable.

4 ITERATION ON LENGTH OF HIGH ORDER CORRECTORS (E. TODESCO)

Ezio provided follow-up on **Massimo**'s talk at the 116th WP2 Meeting, who showed that, presently, the a4 and b5 correctors are at about 90% of their nominal strength. The two options on the table are increasing the current or the length of the correctors. **Ezio** reminded that the decision has to be made by the end of the month of April.

Room for the longer a4 and b5 correctors can be made by reducing the length of the skew quadrupole a2 correctors by 30%. In the present design, the a2 correctors are stronger than in LHC, corresponding to 50 units vs 39 units in LHC. If this option is chosen, the strength will decrease to 35 units. No significant impact on beam dynamics is expected, based on the current operational experience at LHC, where the skew quadrupole correctors operate at 40% of their maximum current.

- **Rogelio** pointed out that a sufficient safety margin is needed is case one of the correctors fails.

5 SKEW QUADRUPOLES STRENGTH REQUIREMENTS (J. COELLO DE PORTUGAL)

Jaime presented the results of a detailed numerical study on the required strength of the skew quadrupole, a2 correctors in the latest v1.3 optics. The study was performed for 250 μrad crossing angle, nonlinear errors in IRs, and 1 mrad (baseline) and 2 mrad tilt error in IR1, IR5 triplets and Q4, Q5 quadrupoles. A margin of factor 2 should be accounted for in case one of the a2 correctors breaks.

- **Ezio** suggested that the 2 mrad misalignment angle is pessimistic, he is confident that magnet alignment can be measured better than 1 mrad. **Rogelio** concluded that a proposed a2 strength reduction from 1 to 0.7 10^{-3} m^{-2} complies with a factor 2 safety margin requirement, provided that the capability to measure better than 1 mrad is noted in the functional specification.
- **Ezio** asked about the distribution of random errors used for the study. **Jaime** replied that a flat distribution was used.
- **Riccardo** mentioned presence of stringent constraints from the bellows, posing a challenge for alignment. **Ezio** proposed to write a specification for installation and alignment and will check the details. **Rogelio** pointed out that there has already been a discussion with the alignment working group. A preliminary estimate is well below 1 mrad, but it is necessary to obtain a final number from the alignment. The data has to be requested as soon as possible. **Ezio** stressed the importance of presenting an ECR at the TCC by the end of the month (April).
- **Riccardo** raised a question about the end covers that cannot be tilted with respect to the magnet. **Ezio** replied that the constraint becomes a requirement for the end covers that have to have sufficient tolerance.

ACTION (Ezio): Update the functional specification of MQXF to report on the accuracy of the average field tilt. Contact alignment experts to obtain specifications on the tilt accuracy, taking into account

actual reference points. The target is to achieve 1 mrad total uncertainty on the triplet quadrupole tilt. Prepare the ECR with the a2 length reduction.

6 REVIEW OF ADT IMPACT ON EMITTANCE GROWTH (X. BUFFAT)

Xavier presented a numerical model of emittance growth due to decoherence of coherent modes. Two sources of decoherence are taken into account: damper (ADT) noise and power converter (PC) ripple. The model is in good qualitative agreement with a measurement done at LHC.

For the PC ripple, model allows identifying the major contributors to the emittance growth. The model can be tested at the end of the ramp, where the noise is expected to be lower due to no impact from the cold separation dipoles that have a large contribution. Ground motion does not have a significant impact on the emittance growth thanks to the rapid ($1/f^4$) decay at high frequencies.

The emittance growth starts being dominated by the ADT noise at large gains. For the LHC case, there is a saturation gain, above which the growth becomes constant as the damping produced by the feedback is compensated by the noise it introduces. For the HL-LHC case, on the contrary, the emittance growth keeps increasing with the gain due to a larger tune spread. It is critical to reduce the ADT noise level for the HL-LHC upgrade. That can be done either by improving the pick-up resolution by a factor of 4 or by reducing the ADT bandwidth. The latter option can be checked in a dedicated MD.

- **Rogelio** asked to clarify why the impact of noise on emittance growth is not critical at injection. **Xavier** replied this is due to electron cloud, responsible for nearly 80% of emittance growth. **Rogelio** asked if one can act of the electron cloud induced emittance growth. **Gianni** replied that it depends on the nature of the growth: whether it is phase space diffusion or decoherence. **Gianni** proposed to measure the noise at injection with a 50 ns beam without the cloud or with 8b+4e beam with the electron cloud suppressed compared to the 25 ns beam. **Yannis** suggested that the e-cloud free measurement is done with single bunches at injection.
- **Rogelio** inquired what the impact of the beam pipe on the noise spectrum is. **Riccardo** pointed out that, normally, the beam pipe reduces the noise at low frequencies. Rogelio concluded that the model is likely to be pessimistic. **Xavier** agreed and noted that the effect is hard to assess; nevertheless, the noise estimates are in the right order of magnitude and provide a good understanding of emittance growth.
- **Rogelio** inquired on the feasibility of reducing the ADT bandwidth so it can be used in MDs in 2018. **Daniel** replied that the bandwidth can be reduced down to 100 kHz. **Xavier** noted that the reduction of the bandwidth might affect the stability of high frequency coupled-bunch modes. **Rogelio** asked how large would an impact of crab cavity (CC) noise would be compared to the feedback. **Xavier** replied that, by design, the CC noise is a bit lower than the damper one; its addition might nearly double the estimate of the overall emittance growth. **Daniel** commented that it is planned improve the feedback resolution to act on the head-tail CC noise. **Yannis** suggested that some insight on the CC noise could be obtained from the SPS studies.

7 ON IMPROVING THE ADT PICK UP RESOLUTION (D. VALUCH)

Daniel presented the current architecture of the feedback system. Its beam position modules are identified as the main contributors to the noise in the system. The sampling is performed at a rate of 1 sample per bunch – state of the art at the time of construction, but can be done much faster nowadays. The upgrade of beam position modules started in LS1. Initial tests done in January 2016 showed a factor 3-10 improvement in the noise floor. That allows reducing the rms position uncertainty to below 1 μm with a single BPM, compared to the present 1.2-1.8 μm. A further improvement can be achieved by combining the readings of 4 BPMs. The firmware has to be tested by the end of the run this year, which requires about 6 months of works.

- **Daniel** thanked ABP for the progress in establishing a common communication language between beam dynamics experts and the ADT group.
- **Xavier** pointed out that a factor 10 improvement is not necessary from the emittance preservation point of view, and a factor 4 would be sufficient. **Daniel** relied that the improvement would be essential for acting on the CC noise and useful for observations.
- **Rogelio** noted that the 6 month timescale of the upgrade looks tight to perform MDs in 2018 with protons. **Daniel** was positive that the project can be completed in time, provided there are no unexpected interruptions. **Rogelio** emphasized the high priority of tests with the ADT upgrade in 2018 both for HL-LHC and for the LHC run III.

ACTION (Daniel): Proceed with the planned upgrade of the beam position modules.

8 ROUND TABLE

Next meeting is scheduled on the 17th of April and will be devoted to vibration studies.