Minutes of the 128th WP2 Meeting held on 28/08/2018

Participants: S. Antipov, G. Arduini, R. De Maria, M. Giovannozzi, G. Iadarola, S. Kostoglou, E. Mètral, N. Mounet, A. Oeftiger, F. Plassard, B. Salvant, E. Todesco, R. Tomas, F. Van Der Veken

AGENDA:

1 GENERAL INFORMATION (G. ARDUINI)

The minutes of the previous meetings will circulated shortly. **Gianluigi** reviewed several key actions of the previous meetings.

Regarding the 80 mm valves for the VAX region, **Benoit** reported on the lack of agreement over the baseline among the vacuum group. **Gianluigi** will ask Francisco to provide a definitive answer. (*Note after the meeting: the answer has been provided and it satisfies the Impedance Team*)

Stefano has confirmed the preference of the 50 mm aperture for the hollow electron lens, which is the value **Riccardo** is currently assuming for the v1.4 set of optics.

Elias inquired if the data from the previous measurements of CFC block could be used for understanding the limits of its conductivity with respect to its orientation and agreed that a detailed new measurement of another sample would be useful.

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

Following up on **Ezio's** talk at the 126th WP meeting **Frederick** presented the first results on the impact of large systematic b6 errors on the Dynamic Aperture (DA) and required corrector strength. Several scenarios were analyzed: all MQFX magnets having an error of -6 or -4 units of b6 and one particular magnet having a large b6 error. The results show a margin to correct up to about -5 units of systematic b6 error, even if all the magnets are affected. No significant impact on DA is observed in any scenario with the difference in the average DA within 0.2 sigma with respect to the nominal case.

Magnet-by-magnet analysis shows that the DA and the required corrector strength are most sensitive to b6 errors in Q2 magnets and to a lesser extent to those in Q1 and Q3. The following step of the study is to check the effect of b6 errors in all Q2's.

- **Ezio** noted the outdated figure of the layout in the slides and proposed updating it with the most recent layout to avoid confusion. **Frederick** agreed, noting that the actual layout was used for the study.
- **Massimo** noted that the results of the study are preliminary and based on only 60 machine seeds. Having a higher statistics might lead to more critical results. **Massimo** also pointed out that for the moment when computing DA the systematic b6 error is assumed to be fully corrected, which is not the case for the most critical scenario with -6 units in all magnets.
- **Ezio** asked why the Q2 magnets are the most critical. **Frederick** explained this is due to a larger β-function. **Massimo** suggested that worse magnets could be installed in less critical Q1 and Q3 slots. **Ezio** pointed out that the Q2 magnets cannot be exchanged with Q1's.
- **Massimo** inquired if any systematic effect is expected from the heads (not the body of the magnet). **Ezio** replied that head should yield a small, second order effect.
- During a discussion on whether or not a fine tuning of the MQFX magnets is necessary, **Gianluigi** inquired what happens if one of the b6 correctors fails. **Frederick** replied that the effect of failure would be very strong if all magnets have a large systematic b6 error. There would not be enough margin in corrector strength for b6 of or stronger than -6 units (-4 units can still be corrected). **Rogelio** reminded that from the past operational experience, one could expect some corrector to be broken: currently there are broken correctors in IP1 (skew octupole) and IP2 (skew sextupole and normal octupole). **Massimo** proposed to study a corrector failure scenario. **Gianluigi** supported the idea to study corrector failure cases in order to understand if an action is needed. **Gianluigi** inquired on the DA without correction. **Massimo** replied the DA without correction is only a few sigmas and also pointed out that beam-based correction sometimes requires corrector strength that is different from simulation. **Rogelio** commented that form the present LHC experience the difference could be as large as a factor of two for beam based correction, and it is therefore necessary to have a sufficient corrector strength reserve. **Ezio** pointed out it would be beneficial to act in the magnet production right now as the additional results of magnetic measurements will come too late – in 1.5 years. **Sergey** asked if there any risks associated with the fine tuning. **Ezio** replied in the negative – it is a standard procedure and emphasized that the fine-tuning was foreseen in the design from the beginning, it is a normal procedure based on the past LHC and RHIC experience. The American side is convinced the correction is needed. **Ezio** will

present a strategy of fine-tuning on Thursday. **Gianluigi** thanked Frederick for the rapid follow up on the subject.

3 SCALING OF THE OCTUPOLE THRESHOLD WITH COATING RESISTIVITY AND THRESHOLD PREDICTIONS FOR UNCOATED MOGR OPTION (S. ANTIPOV)

Sergey explained why the improvement of the octupole threshold after the collimator impedance upgrade is smaller than what one would expect from the ratio of material resistivities. While the resistive wall and the corresponding component of the octupole current indeed scales as a square root of the resistivity (of the bulk if uncoated or of the coating if coated), the presence of other impedance sources might significantly affect the total. For a single collimator, the geometric impedance makes the coating less efficient for the collimator located further away from the beam. For the model of the full ring, other sources of impedance like beam screen and non-upgraded collimators further reduce the octupole current improvement.

In the present baseline, one acts on 50% of the total machine impedance. The improvement of the octupole threshold is estimated to be 180 A for the full collimator upgrade and around 125 A for the LS2 subset (for BCMS beam). In case tighter collimator setting are used in the future, the octupole threshold might increase significantly. For example, for the present LHC collimator settings little or no safety margin is left if the full impedance reduction is not done. For the present CFC collimators the threshold is 580 A for the Standard beam and 700 A for the BCMS beam. The full baseline collimator upgrade brings these thresholds down to 350 and 420 A respectively.

Due to the presence of other impedance sources, mainly the geometric impedance, the overall reduction of the octupole current is less sensitive to an increase in the resistivity of the coating for sufficiently small resistivities. A further reduction of coating resistivity, i.e. Copper (Cu) instead of Molybdenum (Mo), becomes less efficient. If uncoated Molybdenum-Graphite (MoGr) secondary collimators are installed instead of Mo-coated ones, the octupole threshold increase by 50 A, to around 350 A for the BCSM beam, a value close to what one gets with the LS2 subset of Mo-coated collimators.

For Mo coatings, the first samples featured a higher resistivity of 200-300 nΩ-m (compared to the 53.5 nΩ-m DC resistivity of the bulk), including the one installed in TCSPM. This larger resistivity is believed to be caused by the microstructure of the coating, namely the size of its grains and the number of discontinuities, as seen in SEM scans of coatings on different substrates. Thanks to improvement in the coating process, the recent coatings feature a lower resistivity of 60-70 nΩ-m. A limit of 100 is proposed for production Mo coatings. Due to a weak dependence of the octupole current on the coating resistivity in the range of lower resistivities, the expected increase of the octupole threshold should stay within 10%.

- **Gianluigi** proposed putting together a list of octupole threshold contributions by collimator, and identifying, for each collimator, the potential gain from the reduction of its geometric and resistive wall impedance. **Gianluigi** emphasized that the additional improvement after the LS2 upgrade does not seem large, it is therefore important to make sure the chosen collimators are the optimal ones, given the constraints.

- **Benoit** pointed out the nearly factor two discrepancy between the flat taper model and CST simulation results for the TCSPM taper geometry. Based on the past studies such a discrepancy might result from a numerical noise – numerical modelling of shallow tapers in CST turns out to be rather challenging technically. **Sergey** noted that the numerical results for this particular geometry do not seem drastically different from the others and pointed out that the simulation results scale with the frequency and the collimator gap in a way one would expect from the flat taper model. **Benoit** suggested to re-check the simulation results in order identify either the limits of applicability of the flat taper formula or the limits of validity of CST simulations.
- **Nicolas** inquired whether the octupole current threshold is the right measure for the collimator impedance reduction. **Elias** emphasized that the octupole current is (a) a quantity relevant for beam stability (opposed to impedance, for with one has to specify the frequency range in question, real or imaginary part, type of coherent effects in question, i.e. single- or coupled-bunch, etc) and (b) a quantity that can be measured and controlled in the Control Room, alongside with the chromaticity and damper gain. **Gianluigi** supported the strategy of using the octupole threshold for quantifying the improvement of the coherent beam stability.
- **Gianluigi** noted that there has already been an effort of reducing the geometric impedance of the collimators and that this reduction is presently not accounted for. This improvement should be included. He also asked whether further improvements are realistically conceivable. **Benoit** replied that the margin for further improvement are unlikely but this aspect will be studied.
- **Gianni** noted a typo in the slide presenting the experimental MD results of the impact of noise on beam stability, the noise amplitude was decreasing in the direction of the arrow, not increasing.

ACTION (Emanuela): Verify the simulations of transverse impedance of the TCSPM-type tapers and check at what tapering angle the impedance starts diverging from a flat-taper formula.

ACTION (Sergey): Compile a list of potential octupole threshold gains from the reduction of geometric (including the improvement obtained in the new design, not included so far) and resistive wall impedance for each collimator and identify the most promising ones.

4 ROUND TABLE

The next meeting is scheduled on the 4th of September.