Minutes of the 63rd WP2 Meeting held on 15/03/2016

Participants: G. Arduini, X. Buffat, J. P. Burnet, J. Coello De Portugal, R. De Maria, S. Fartoukh, D. Gamba, M. Giovannozzi, N. Kos, K. Li, L. Medina, E. Métral, E. Todesco, B. Salvant, G. Sterbini, R. Tomás, F. Van Der Veken, D. Wollmann.

Minutes, Follow-up of Actions, General Information (Gianluigi)

Minutes of the last meetings approved. Stephane expressed the worries that changing the units of the normalised emittance could lead to confusion in the teams working both on LHC and HL-LHC. Gianluigi reiterated the simplification for HL-LHC will outweigh the overhead in converting the values.

D1/D2 difference in transfer function in series (E. Todesco)

The designs of D1 and D2 have by chance the similar transfer functions and their respective integrated field is identical during the powering cycle. It is worth evaluating the savings in cost of powering the two magnets in series. The saturation component of transfer function in particular for D2 is large and this is reflected in a different transfer function for middle currents even though the extremities are almost coincident (exactly at the equivalent 7TeV). The largest imbalance is quantified in 0.5 Tm missing at 5 TeV. The option for equalizing the strengths are: trim power converters, use of the MBRD power converter (to be increased in length if needed) or MCBXA.

Jean-Paul commented that using the orbit correctors and therefore saving the half of the power converters would not result in a cost saving of a factor of 2 (~ 1MCHF as estimated by Ezio), because the MQ power converter cannot be used (even if they have the same current rating) and the development costs do not scale linearly with the number of converters. The trim option will have similar cost than the baseline despite the lower current rating of trims due to the added complexity. Gianluigi asked to bring back the cost saving estimate to the forthcoming circuit review and the TCC before proceeding further because the previous recommendation of the TC was to explore the idea based on important cost savings.

The discussion touched also the following points:

- Stephane noted that the large saturation in D2 mentioned by Ezio could lead to important field differences in the aperture 2-in-1 aperture and therefore requiring a trim for compensation. Ezio did not agree. **Action: Ezio provide an estimate of the main field imbalance between the two apertures of D2 so that the impact on the MCBRDH corrector strength can be evaluated.**
- Stephane commented that adjusting any imbalance of D1 and D2 with orbit corrector should be avoided because it would mix orbit and geometry. Gianluigi and Massimo noted that this is indeed the request of WP2 (i.e. to add a trim power converter).
- If orbit correctors are being used for the purpose, it would save much more cost to use D1/D2 as orbit horizontal correctors and save the long MCBXFAH and the MCBRDH as proposed in the past, although Stephane would not recommend this solution. Gianluigi replied that the D1/D2 would be too slow as orbit corrector. Stephane reminded that the change of corrector strength for the crossing angle bump are small during the squeeze.
- Gianluigi commented that one advantage of the D1/D2 common powering would be the cancelling the effect of the power converter ripple.

Alignment tolerances for triplets (E. Todesco)

The specification on the waviness of the magnets is needed by DOE. As an example for the MB the center of the magnet is located in a band of 0.1 mm.

A proposal for ±0.5 mm for the centre and ±2 mrad transverse tilt (about ±-40 units of a2) peak-to-peak is made. Stephane commented the last value is particularly large. Ezio replied that this is the local deviation and the average will be measured and realigned. Ezio added that it is however not clear how precisely the tilt can be measured and corrected and confirmed that this estimate is the quantity to be reported in the error table. Rogelio noted that the average value is important and so far a tolerance of ±0.5 mrad (see WP2 meeting held on 3/7/2015) has been provided but the tolerances are being reviewed and will be presented in a forthcoming meeting. Gianluigi asked whether these are fabrication/positioning tolerances of the coils of the triplet and whether these have been assumed for the estimation of the field quality of the triplet. **Action: Ezio, estimate uncertainty in the tilt of the average of the mid-plane and evaluate the impact of the tolerances on the field quality.**

Q1/Q3 are made out of 2 magnets (MQXFA) that needs to be aligned. A first guess of the specifications of the roll, yaw, pitch are given, which would result in displacement larger than the clearance between the cold bore and coil insulation presently foreseen (about 1 mm). Riccardo suggests defining the tolerance as a shape tolerance that would allow having sufficient margin between coil insulation and cold bore as done similarly for the beam screen. **Action: Ezio, Cedric, check that the cold bore shape and the cable insulation geometry have consistent tolerances and define a combined shape tolerance for the coil aperture for the two MQXFA.**

Riccardo asked whether we could organize a combined review of magnetic measurement and survey campaign to quantify the initial magnetic and geometric imperfections and the residual uncertainty after correction. Ezio found that this was a good idea. **Action: Ezio to organize it.**

<u>Heat load estimates for HL-LHC (E. Metral)</u>

Elias presented a table of head load in W/m for quadrupoles and dipoles in the IRs from different sources: induced current, e-cloud, synchrotron radiation (assumed to be absorbed at the position where it is generated). The heat load is dominated by e-cloud in the matching section (which was assumed to be uncoated but scrubbed). While the arc (assuming no e-cloud) synchrotron radiation and induced current have similar effects.
An integrated estimate should be given for the triplet including the drift. The e-cloud is very large for Q4 and Q5, although for Q5 in IR2/IR8 is not. Elias confirmed that for the quadrupole the shape and beam screen dimension is dominant effect, however it is not clear which aperture has been chosen for IR2/IR8 since Q5 left and right are different. Gianluigi noted that the e-cloud heat load, when integrated could already be above the budget considered so far. It is important to estimate also the heat load for the matching sections in case these would be coated (SEY=1.1). **Action Elias: clarify the assumptions for the shape used in IR2/IR8 and in general for the various elements, give the expected heat load in the remaining section of the IR, and assemble an additional table with integrate quantities element by element over the length.**

Stephane asked whether the beam size is taken into account for synchrotron radiation calculation in the quadrupoles. Massimo clarified that only the orbit has been considered and that the exact distribution of the losses due to synchrotron radiation is being estimated.

Fill to Fill Reproducibility specifications for HL-LHC (J. Coello)

A study on the effect of PC ripple on tune ripple has been carried out for round and flat optics for HL-LHCV1.2 for the baseline powering circuit and the new proposal with one common main power supply per triplet. A Gaussian noise source of 1 ppm rms has been applied on the triplet strength for two different powering schemes. A difference of a factor of 3 has been found with respect to previous studies for HLLHCV1.0, however those studies assumed a uniform distribution of ±1ppm peak to peak, which would explain part of the difference. **Action Jaime, Rogelio, Riccardo: Further differences between studies and the correct noise distribution should be clarified with PC experts.**

Flat optics are about 10% 06re sensitive than round optics in terms of tune ripple and beta-beating.

The new powering proposal with a common PC for the full triplet features a factor 2 lower tune ripple and beta-beating. Therefore this powering scheme is highly preferred for tune ripple considerations.

Beta-beating errors were always well below 1% and therefore not a concern for all cases under study.

J-P. Burnet asked whether there is the need to go below 1 ppm because it implies a change in technology and the power converter R&D program. He also noted that the present Class 1 power converters specified for 1 ppm ripple can already achieve sub-ppm ripple. Gianluigi suggested to re-evaluate the situation with realistically achievable power converter parameters. **Action: Jean-Paul to provide updated data on the power converter performance.**

Reported by Gianluigi, Rogelio and Riccardo