

Minutes of the 88th WP2 Meeting held on 21/03/2017

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General information (G. Arduini)

The minutes of the last two meetings have been circulated. Gianluigi summarises the outcomes and the actions from the last meetings.

In the last technical committee recent results of D1 short model test have been presented and it has been mentioned that the cross section is going to be changed; however it is expected that the field quality will not be affected. A non conformity on the HOM port of a crab cavity to be installed in the SPS has been observed, but this should not have a significant impact on the SPS test. The integration study of hollow e-lens in IR4 has been presented. This could be in conflict with the space requirements for the installation of additional 200 MHz cavities, but the present proposal for the 200 MHz option is to replace a 400 MHz module. It would be important to document in a note the 200 MHz option. **Action: Rogelio.** Rogelio gave an update of the HL-LHC parameter table proposal taking into account the latest information on the longitudinal distribution provided by E. Shaposhnikova.

The Internal Circuit Review has taken place.

Status Update of Power Converter Precision & Accuracy Performance (M. Martino)

The aim of the study consists in determining the relation between variations in current (PC specs) and variations in fields (Beam Dynamics specs). The involved quantities are the frequency, the inductance, and several transfer functions.

A linear relation is expected for frequencies below f_0 (current control), but it is more complicated above f_0 , where the PC is operated in voltage control. The value of f_0 depends on the specific circuit: for the main dipoles it is 0.5 Hz, for the quadrupoles few Hz, the triplet is the critical one but still below 10 Hz. Michele reports some margin to optimise f_0 .

A plot shows that the inductance as function of the frequency strongly depends on the presence of the beam screen.

The model of the PCs is explained in details. In general, for the range of frequencies considered, the current in the magnet will be a low pass version of the current in the PC. Good agreement with data is reported for an impedance depending on the square root of the frequency.

The model can be well fitted to measurements for the current response both for warm and cold temperatures. The reported measures refer to a magnet without cold bore and beam screen, therefore no screening effect is considered.

Simulations have been performed to investigate the variable magnetic field attenuation due to the presence of the cold bore and beam screen (including the Inermet shielding) as a function of frequency. For Q1 (beam screen at 80 K) 20db attenuation is obtained at 150 Hz. For the Q2 the 20db is reached at 300 Hz, similar for D1. D2 is going to be kept at 20K and the resulting cut-off frequency is 120 Hz. Simulations have been performed for the LHC main dipoles and quadrupoles as well.

8 ppm peak-to-peak noise in the current of the Power Converter (measured at 1Ksamples/second) results in 3 ppm in the field when the low pass is applied mimicking the presence of the cold bore and beam screen.

Elias asks about the final relation between dB/B and dl/l. Michele replies that at low frequency it is 1, at higher frequencies it is less, the precise relationship will be given when the study will be completed. For a worst case scenario one can consider a 50 Hz first order low pass.

Elias asks if the beam screen could have been designed differently. Michele replies that it could have been more optimised for shielding effects. Marco Morone points out that for example the thickness of the copper is good for screening, but also detrimental for mechanical stability during quenches, therefore, in general, the optimisation is not trivial. It might be good to know what is the maximum copper thickness compatible with the mechanical stability in case of quenches. **Action: M. Morone, C. Garion.**

Gianluigi asks about the maximum peak-to-peak value assumed for the current error. Rogelio replies that it is 0.1 ppm Gaussian RMS. Michele confirms the number for low frequency (<1Hz) but he points out that it is about 1 ppm for the higher frequencies investigated in this study. Riccardo wonders what will be the frequency giving the peak noise. Michele replies that the study needs to be completed. Riccardo proposes to use the low pass at 50Hz as more realistic estimation for the time being.

Elias asks about the future plans. Michele is going to perform additional measures, after these Miguel aims at writing specifications for the power converters ripple.

Jean-Paul Burnet points out that the switching frequency will be increased for the new generation of PCs, reducing also the ripple. Miguel adds that the control system can also introduce noise, but typically at frequencies attenuated by the beam screen. Michele underlines that the measurements of the current out from the PCs are really the worst case for the estimation of the field ripple.

Operational scenario update (stability vs DA constraints) (E. Metral)

Elias summarises a number of new inputs for the stability studies.

It was shown by Dario that it is possible to trade chromaticity for crossing angle at constant DA; therefore it is important to understand if the chromaticity can be reduced by means of other stabilisation techniques, e.g. a wide-band feedback.

The injection working point has been re-optimised and a number of proposals are presented already for the 2017. Laslett tune shift and linear coupling are connected to instabilities, corrections techniques and thresholds have been established for both. The maximum acceptable value of the coupling along the cycle should be specified in the updated version of the note describing the operational scenario. An estimate of the Laslett tune shift should be provided. **Action: Elias.**

The bunch length has been updated and new parameters from the SPS have been defined. Stability in the SPS is expected after the RF upgrade and the reduction of impedance (LS2).

Elena asks if precise estimations of the longitudinal emittance, taking into account the potential well distortion could be important for us, in particular in view of possible updates of parameters. Elias replied that it will be useful to include the one at full intensity (the value in the table do not consider the impedance effect). In reply to a question from Elena, Yannis clarifies that the q-Gaussian is a generalisation of the binomial distribution proposed by Elena not a different one.

The current operational idea for crab cavities consists in having them on since the injection; an adiabatic variation of the relative phase difference among the cavities is required at flat-top to bring the cavities in phase. The implications of these manipulations in presence of high chromaticity, octupoles and e-clouds are not yet clear, but studies are on-going. We need to specify the voltage and phase of the cavities during the various phases of the cycle. **Action: Elias.**

The e-lenses and the depletion of tails come with a reduction of stability; however simulations predict that the beam is always stable for more than ± 300 A in the octupoles assuming the impedance reduction of the secondary collimators in LSS7.

In 2016 the e-cloud is suspected to have manifested during stable beams as a pop-corn instability, involving a fast emittance blow up of some bunches in the tails of the trains. Requirements for coating have been defined.

For low values of chromaticity, very high octupoles were necessary for stability during measurements in 2015. This regime is being studied: a destabilising effect of the resistive transverse damper has been identified. The next step is to check the impact on the required Landau octupoles current to see if this can explain the past observations.

The above considerations are summarised in updated parameter tables. Gianluigi reminds that simulations of the DA have been done for 20A in the octupoles (see presentation of F. Van der Veken at the 70th WP2 meeting). The simulations should be updated to consider the latest parameters, the beam-beam effects should be also included to validate the scenario (including the crossing angle and separation as suggested by Gianni). Riccardo points out that varying the crossing angle during the ramp might add some additional complication for the control of the orbit at the crab cavities but it should be feasible. **Action: Massimo, Yannis.**

Elias noted that ramp and squeeze should be considered as part of the operational scenario. Normally we should be able to reach the beta* corresponding to the start of the levelling at the end of the ramp.

This should be verified studying the DA for ~65 cm (and ~40 cm for the ultimate scenario) beta* without collision should be checked with and without long range beam-beam.

It is asked why the octupoles are set at -570A, while only -300A are foreseen by the model. Nicolo explains that previous predictions from the model were not confirmed by measures. Dario adds that the DA is not very sensitive to the setting of negative octupoles. Gianni expresses concerns for requiring the maximum settings of the octupoles, as stability may not be guaranteed in case of faults. Gianluigi reminds that the power suppliers can actually go up to 600A.

Gianluigi suggests adding the settings of crab cavities and of the collimators in the table, Elias also identifies coupling as a missing parameter. The note should be updated and circulated so that it can be used for future evaluations. **Action: Elias.**

Gianluigi proposes to recheck the crossing angles and separation numbers for LHCb and Alice, too. Riccardo noted that the separation in IP1 and 5 should be reduced to 0.75 mm. **Action: Elias, Yannis, Riccardo.** The impact of e-cloud on beam stability should be evaluated assuming that it is suppressed at least in the dipoles. This is planned for the second half of the year.

11 T Field quality specification (P. Hermes)

New tables for field quality have been recently collected and used for this study. The impact of b2 on beta-beating is investigated together with the one of all the other multipolar components on DA.

Simulations of the beta beating show a maximum variation of $\pm 10\%$, with the main contribution coming from MB, while MBH is less important also because the number of magnets is much smaller. Massimo clarifies that if more 11T magnets were added (up to a full 11T LHC), the systematic part could be cancelled as the beam would be going through one aperture for half of the arcs and in the other one for the other half. In addition the b2 component of MBH can possibly be compensated by adjusting the strength of the nearby MQTL8/R8.

MBH field errors have a tiny impact on DA both at injection and collision. The DA values are reported for a 3.75 um emittance and they should be normalised to 2.5 um. **Action: Pascal**

The b2 component increases by a factor 10 in the ramp, studies will be required to investigate the effect.

Reported by Dario, Gianluigi, Riccardo and Rogelio.