41th Meeting of the HL-LHC Technical Coordination Committee – 23/11/2017

Participants: G. Arduini, C. Adorisio, I. Bejar Alonso, O. Brüning (chair), H. Burkhardt, J. P. Burnet, F. Cerutti, R. De Maria, R. Garcia Alia, T. Lefevre, M. Martino, E. Metral, M. Modena, Y. Papaphilippou, F. Sanchez Galan, O. Stein, A. Tsiganis, E. Todesco, R. Tomas, S. Uznanski, R. Van Welderen, C. Wiesner, D. Wollmann, C. Zamantzas.

Excused: A. Apollonio, L. Rossi, M. Zerlauth.

The slides of all presentations can be found on the website and Indico pages of the TCC.

Regarding the minutes of the 40th HL-LHC TCC, G. Arduini would like to clarify if the project endorses the recommendation to include coating of the matching section R2 and L8 and Q4 and Q5 in IR1 and 5. O. Brüning replied that, the TCC 37 and 40 discussed the option of aC coating in all stand alone magnets and underlines that the TCC concluded that it would be clearly better to minimise the creation of heat load by eliminating the source of the heating (e.g. eliminating e-cloud by appropriate surface treatment) rather than providing more cooling capacity. The TCC therefore strongly endorses the work related to in-situ aC coating as a study and as an implementation for the HL-LHC if the associated risks can be shown to be acceptable. G. Arduini further points out that the impact on UFO's could be also studied, as it seems that aC coating can be beneficial, based on COLDEX measurements. The minutes were approved without further comments. There was an action on radiation and space considerations of the Q1a trim. E. Todesco pointed out that although this is not trivial for the circuit, the work is progressing. The remaining actions are being followed up.

Detection of abnormal beam losses in the HL-LHC triplet (aka the cryo-BLM option), A. Tsinganis - slides

A. Tsinganis introduces the subject of the cryo-BLM integration and background. A year ago, it was concluded that the signature from the abnormal steady-state losses, although apparent, was not significantly above the background signal from collisions. Thanks to some new elements (knowledge of relation between global/local loss rate, presence of inermet shielding implying higher losses to induce quenches), a study was undertaken for calculating the BLM pattern in the triplet for stable operation and loss scenarios in IR5 and evaluate the effectiveness of cold BLMs, as compared to the conventional ones.

The usual FLUKA geometry is presented where virtual BLMs are placed for covering in a fine grain the position and also a cold BLM is placed near the interconnect. Some loss scenarios were produced and the highest losses were recorded at the right side of the IP. Only the losses in the horizontal plane were considered, being the dominant ones. They are concentrated between Q3 and Q2b. They were normalised in order to reach the 4 mW/cm^3 design limit in the MCBX corrector when added to the debris load. The global loss rate corresponds to 5.39 x 10^{12} p/s, which is equivalent to two minutes of lifetime. In such a situation, the beam is dumped and there is no need for local loss detection.

The BLM response to the debris is presented, showing a pattern for guiding the optimization of positions, which is found to be optimal close to the five interconnects. When the contribution of the losses is added, the peak of the losses occurs at the edge of Q2b.

It should be noted that the cold BLM response has a strong azimuthal dependence, with values varying by a factor of 3. Thereby the maximum values were considered. The highest sensitivity is still at the edge of Q2b and there is a detectable change of pattern of the total losses with respect to the ones coming from debris, but still not as good as the conventional BLMs gain, due to the positioning restriction. In summary, abnormal losses in the triplet would lead to very low beam life-times inducing a dump triggered by the collimation system. Even for these extreme losses, the presence of cold BLMs does not increase the detection sensitivity as compared to the conventional ones, whose positioning is less constrained and can be optimized.

Discussion

T. Lefevre asks if the conclusion is that the losses are finally dominated by collision debris. F. Cerutti answers that this is true, unless the beams are not in collision. D. Wollman further explains that this is also true in the present LHC, where for detecting losses in short time-scales, proper thresholds are put in place. F. Cerutti agrees and adds that the study is focused on steady state losses (opposite to fast losses that, as soon as they reach a threatening level, clearly prevail over the collision debris signal). H. Burkhardt points out that the experiments have their own monitoring. In their case detection is difficult, as well. In this respect, the detectors closer to the beam are designed to sustain fast losses quite efficiently. Following a question regarding fast crab cavity losses, D. Wollmann answers that indeed some work has to be done to complement these studies and increase protection based on e.g. a beam current monitor. T. Lefevre points out that this is interesting indeed but a subject of a different study. O. Brüning concludes that there is no added sensitivity to losses by the cold BLMs, as shown in the FLUKA simulations.

Status and evolution of radiation dose on 60A power converters, R. Garcia Alia - slides

R. Garcia Alia introduces the purpose of this study, namely to re-evaluate the need of a new 60 A convertor design with a more tolerant system with respect to radiation.

After showing the equipment location under the MBB magnets, the traditional failure rate curve is presented with three regions: infant mortality (independent on radiation), followed by random failures, where the failure rate remains constant in time. These failures are stochastic in nature and can be mitigated with shielding. The third region is from wear-out and fatigue and it is no more random. The estimations for the onset of this third region for the 60 A correctors is estimated at 30-50 Gy. The failures leading to a dump in the present LHC are dominated by power convertors installed in the RRs of IR1 and IR5. This may become an availability issue for HL-LHC due to the 10-fold increase of luminosity. In this respect, a development and qualification of 600 A, 4-6-8 kA convertors and FGClite for the HL-LHC lifetime is being pursued. Regarding the FGC development, the target is to reach a resistance to radiation above 200 Gy, which is compatible with HL-LHC requirements. This was deployed already in the 2016-2017 EYETS for the 60 A power converters and showed very good results during the 2017 run. The deployment in the RRs is planned for LS2, together with the 600 A and 4-6-8 kA converters.

Data analysis of the induced losses during the LHC run are used for calculating the Total Integrated Dose (TID) levels in the LHC, normalized with intensity and luminosity. In particular, the RadMON based on commercial components is used to measure quantities relevant to radiation damage. In this presentation, High-Energy Hadron (HEH) fluence values are presented corresponding to Single Event Effects. In the LHC arcs, during 2016-2017, an annual value of 5×10^7 HEH/cm2 was measured. This is considered as the baseline level deriving from beam-gas interactions.

FLUKA simulations are presented with the annual dose and HEH fluence in the LHC arcs. The absolute values are not meaningful, as they depend on a pessimistic consideration of the residual gas density, and indeed they are observed to be 2-3 orders of magnitude lower in the machine. On the other hand, they provide a good scaling between fluence and dose and enable the correlation of the values measured by two different detectors. For example, 5×10^7 HEH/cm^2 corresponds to around 50 mGy.

Tables for the HEH fluences of the different cells and different points are presented, for 2016 and 2017 with similar conclusions. In particular, the peak values are one to two orders of magnitude higher than the baseline. Peak fluences of 10^{10} HEH/cm^2 correspond to 10 Gy, but for the equipment under the magnets, a factor of 3 lower is expected.

The RadMON counts as a function of time for two of the cells with higher loss (16L2 and 19L2) are presented, and compared with integrated intensity and luminosity. The 16L2 losses are following intensity and start increasing at a very early stage (even during the scrubbing), and stop after the flushing of the beam screen. The 19L2 radiation level however clearly follows luminosity. Following the question of O. Brüning regarding the fact that the annual baseline level is constant in time, R. Garcia Alia explains that there is indeed a gradual increase but the traced line corresponds to the maximum. At the end of the year, the radiation levels in 16L2/19L2 in 2017 were a factor 20/100 larger than the baseline value, showing that annual dose peaks of 10 Gy can appear even deep in the arc. Following the question of O. Brüning, whether the effect of the reduced dose is rather due to the filling scheme (8b4e), R. Garcia Alia replies that it is actually very well correlated with the time of the flushing. D. Wollman adds that this correlation is also observed by the QPS.

Integrated doses along sector 12 for 2016 are presented. Most of the losses are on the beam-gas baseline of 100 mGy, with peaks reaching 10 Gy, in particular at the beginning of the arc due to off-momentum particles, and another one in 21L2. During 2017, the baseline was reduced, maybe due to conditioning and improved vacuum, but the DS losses look similar. Similar observations from sector 56 are also presented. Following these observations, the beam-gas baseline levels are expected to scale with integrated intensity and residual gas pressure compatible with beam gas. Taking into account the worst case sectors from 2016/2017 and scaling with intensity (with a safety margin of 10), a dose of 1 Gy per year is expected for HL-LHC, which is acceptable for the lifetime of the present power converter. The peaks of 10 Gy/year observed are a threat for the long-term lifetime of any equipment, though.

In conclusion, the development of radiation tolerant equipment is considered for the 60 A convertors in the HL-LHC era, based on qualified components already used for the of 600 A, 4-6-8 kA and the FGClite, and also used as a basis of the 120 A power convertors. The newly produced redundant 60 A convertors will be deployed in LS3 and the removed units will be used as spares. Active monitoring of radiation levels is needed. O. Brüning asks if by “redundant” one refers to more robust convertors. R. Garcia Alia explains that there are two aspects, namely robustness due to radiation and general electrical reliability, which is very difficult for an MTBF of 10^6 h. Following a further question of O. Brüning, R. Garcia Alia explains RadMON is a distributed system and cannot provide local measurements. The idea is to have an in-situ system in the converters, thereby exploiting FGClite by embedding part of the RadMON capabilities. The estimations on lifetime could be significantly improved by testing several systems in the CHARM facility. The new 60 A design could also need a new PSU for the FGS, thereby also requiring a radiation tolerant development. Finally, it is important to consider aspects of obsolescence, or other types of degradation and availability of spares, thereby changing the presented scenario.

Discussion

O. Brüning states that the approach of developing radiation tolerant and redundant components is adequate. R. Garcia Alia further explains that this is important for the resources of the project. G. Arduini asks if any difference is observed in the dose between 2016 and 2017, in particular with respect to the distribution. R. Garcia Alia answers that the peaks were mostly in Sector 1-2 (21L2 in 2016 and 16L2/19L2 in 2017). One could indeed try to correlate with machine settings. G. Arduini stresses that it would be interesting to find out if this is correlated with intensity or luminosity. He further adds that the distribution of the losses in the cell shows two peaks in the interconnect and the minima in the dipole. R. Garcia Alia answers that indeed the racks are in the middle of the dipole and RadMONs are located in the interconnects.

AOB: Observations and Conclusions from the general meeting in Madrid, O. Brüning

O. Brüning gives a few non-exhaustive examples of important points discussed in the project’s general meeting in Madrid and asks the TCC members to send subjects to be discussed in the TCC during next year.

- WP10

    - The dispersion suppressor magnets will suffer from a radiation dose of 40 MGy for 4 ab^{-1}: Studies on remedies, including absorbers inside cryostat, magnet replacement is clearly needed. In this regard, F. Cerutti communicated after the meeting that the reported value, corresponding to a localized maximum in the MQMC, was found to be due to an unintended 700 µm aperture restriction in the beam screen model of that magnet. This implies that, in the absence of aperture discontinuities, a maximum dose at least twice lower should tentatively be expected (significantly improving the picture). Nevertheless, the effect of actual aperture imperfections should not be disregarded. Respective studies are planned in the short term.
- WP2
    - Timeline of approval for change in crossing angle planes between IR1 and IR5
    - Clarification in the luminosity levelling baseline and to what extend this could be demonstrated in MDs (studies needed and time)
    - MD results on long-range beam-beam compensation: how conclusive are the tests and how can the interpretation be improved for future studies?
    - New theory for TMCI instability: feedback system results in lower instability thresholds
- WP2 and Experiments:
    - Experiments accept bunch length of 8 cm and are no longer interested in the Crab Kissing scheme but rather prefer to invest in a timing system. Implication for keeping second half of CC system as “option”.
- WP2 and WP9:
    - Heat-load due to e-cloud in standalone quadrupoles. The cryogenics’ presentation mentioned two options: a) upgrade of cryogenic systems or b) coating, which is the preference from the TCC
- WP4
    - Still interested in 800 MHz for beam stabilisation and RF power. This requires a follow-up on the RF side on the possibility of implementing a full de-tuning scheme in the SPS during beam transfer to the LHC (in order to match the bunch positions in the LHC with full detuning) and on the best option for addressing the need for more RF power.
- WP12
    - Beam screen stability with CLIQ during magnet quench with realistic alignment tolerances and estimates.
- WP14
    - MKI temperature limited in Run 3: ensure that nominal HL-LHC intensity into the LHC can be obtained before LS3
    - Similar statement for the beam dump system and the windows: Measures to push the intensity to nominal HL-LHC levels, at least during beam study periods.
- WP13
    - Halo monitor and measurements: More systematic (e.g. end-of-fill) halo measurements in the LHC are needed
    - For diamond monitors: Any concerns about radiation hardness.

AOB: HL-LHC ECR approval: WP3 Increase of iron yoke holes diameter from 60 to 61 mm for heat exchangers in D1 and MCQSXF, I.Bejar Alonso

I. Bejar Alonso introduces an ECR from WP3 for the change of diameter in the iron yoke holes of the heat exchangers for the D1 and skew quadrupole corrector MCQSXF. As explained also by E. Todesco, the justification is that the LHC heat exchangers can be. No impact on field quality is expected. A reduction in cost of the order is expected and the only action is the change of drawings. As there were no further comments, O. Brüning proposes to approve the ECR. In the question of E. Todesco for an approval from the LMC, O. Brüning answers that this is only required for HL-LHC ECRs affecting the present LHC.

The next TCC meeting will take place on the 7th of December 2017.