35th Meeting of the HL-LHC Technical Coordination Committee – 03/08/2017

Participants: A. Apollonio, G. Arduini, V. Baglin, I. Bejar Alonso, R. Bruce, O. Brüning (chair), M. Calviani, F. Cerutti, D. Delikaris, J. Gascon, E. Jensen, M. Martino, E. Metral, S. Redaelli, S. Roesler, L. Rossi, F. Sanchez Galan, E. Todesco, R. Veness, C. Wiesner, M. Zerlauth.

Excused: D. Wollmann.

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

HL-LHC TCC homepage: https://espace.cern.ch/HiLumi/TCC/Default/Home.aspx

Indico link: https://indico.cern.ch/event/657422/

O. Brüning recalled the main points to be followed-up from the 34th HL-TCC:

- The comments from E. Todesco to the minutes and the corrections from F. Cerutti concerning reference values for the heat load on the TANB and the dose on the Q5 coils were implemented.
- Action: I. Efthymiopoulos should present the implications for running LHCb with higher luminosity (to be planned)
- C. Noels asked WP leaders to provide their feedback on the agenda of the parallel sessions for the HL-LHC general meeting in Madrid. O. Brüning stressed that the attendance of CERN members for the annual meeting should be less than 60%, this implies a revision of the participation list for several WPs.

Summary of latest collimation MDs for HL-LHC (S. Redaelli - slides)

S. Redaelli presented an overview of the results from the collimation MDs in 2017. He reminded the TCC about the EYETS activities in preparation of the 2017 MD programme, requiring the installation of new collimation hardware: a low-impedance collimator prototype for HL-LHC (TCSPM) in IR7, two wire-in-jaw collimators for long range beam-beam compensation (TCTPW) in IR5 and two crystal primaries on Beam 2 in IR7 were installed.

S. Redaelli acknowledged the work of many groups at CERN for the collaboration and support.

S. Redaelli provided more details on each of the three collimator designs:

- The TCSPM (low-impedance) prototype was designed with 3 different material surfaces to be possibly exposed to the beam using the collimator 5th axis, to assess the effect on impedance of different coatings (Mo, MoGr, TiN). The discovered vacuum non-conformity was solved in March and installation was successful.

- Wire-in-jaw collimators feature a unique and challenging design, requiring a current of 350 A for achieving the desired compensation. They also rely on the collimator 5th axis for alignment with the beam.

- Crystal collimation benefits from the installation of new goniometers (industry) and crystals (UA9 collaboration).

S. Redaelli presented a preliminary analysis of the MD results, focusing on the hardware performance of the collimators.

Concerning beam-beam compensation, the results have been presented at the 33rd HL-LHC TCC by G. Sterbini. Compensation was clearly shown during the MD. During compensation, i.e. at a current of 350 A, the temperature of the jaw increases only by a few degrees, thanks to the active collimator cooling. S. Redaelli mentioned that during tests with full current without cooling the temperature of the wire went up to 600 degrees. Upon a question from O. Brüning, S. Redaelli explained that the temperature is measured on the back of the jaw and that also the temperature of the cooling water (in-and-out) is measured. O. Brüning noted that also no vacuum degradation indicates a stable temperature of the collimator jaw. F. Carra added that the part of the wire which is not cooled (just when existing the jaw) may heat up to 180 degrees, but that the wire is designed to operate at high temperature. O. Brüning asked if there is an interlock on the collimator temperature. S. Redaelli confirmed this is the case and recalled that the dump threshold is set at 50 degrees (provoking a beam dump as the source of the jaw heating). M. Zerlauth added that also an additional interlock cuts the power of the wire if a voltage measurement indicates an excessive temperature of the wire.

S. Redaelli mentioned that a larger offset (and therefore mechanical tolerance) than foreseen was observed for the TCL during alignment, this is under investigation.

Concerning the low-impedance collimator, a good alignment was achieved. Impedance measurements were performed while moving in and out the collimators (repeating the procedure for different fifth axis position, exposing different coating surfaces) and measuring the resulting tune shift. Very small tune shifts have been measured. CFC induces the largest tune shift, while – as expected – the smallest is achieved for the Mo coating. To increase the effect on the tune shift, additional measurements with smaller gaps were performed, with a good match between measurements and expected tune shift from simulations. O. Brüning asked about the gray area in the right plot of slide 25. S. Redaelli explained that for those measurements one needs to account for beam losses (reduced intensity) induced by the smaller collimator gap. E. Métral pointed out that the previous laboratory measurements highlighting a discrepancy in the coating behaviour with respect to simulations had a problem, measurements now confirm the model predictions.

The crystal MD had the scope of validating the performance of new goniometers and crystals. Measurements of channelling were carried out, both by performing angular scans and linear absorber scans. The vertical crystal behaved as expected, while for the horizontal crystal the behaviour still has to be understood and should be further investigated with new measurements.

S. Redaelli gave an update on the test with the rotatable collimator design from the collaboration with SLAC. The idea of this design is to mitigate robustness limits with rotatable jaws. In case of permanent damage, the jaw can be rotated and a new surface exposed to the beam. This design was late for production for HL-LHC, nevertheless SLAC provided a prototype which was tested in HighRadMat with high intensity beams (shots exceeded 144 bunches at 440 GeV). Visible signs of damage appeared after the 288 bunches shot, a 'clean' surface was successfully recovered after jaw rotation.

S. Redaelli showed an example for a 72 bunch shot, for which a series of metallic debris can be seen after beam impact. Some 'bridging' molten material that connects the two jaws was observed, opening and re-closing of jaws and rotating eventually mitigated this problem. A comprehensive report on the results for the prototype will be produced in collaboration with SLAC.

S. Redaelli concluded that the results are very promising for all collimators but mentioned that further support is required for measurements in upcoming MD blocks.

O. Brüning commented that it would be interesting to see measurements with crystals for ions. S. Redaelli mentioned that some tests with Xenon are under discussion, they will be carried out if possible.

S. Redaelli reminded the TCC that MoGr coated with pure Mo is the baseline for HL-LHC. The present conclusion is that Mo coating is needed, as confirmed by E. Metral. S. Redaelli reported that one company is favoured in the tendering for raw material, a proposal for the financial committee will be ready in September. L. Rossi asked if Mo-coated MoGr was also tested with respect to radiation damage. S. Redaelli commented that the visual inspection suggests that it is as good as CFC, but final results are not yet available from BNL.

Consequences of asynchronous beam dump on (IR5) TCT6 (F. Cerutti - slides)

F. Cerutti started his presentation by recalling the results of the calculations for the impact on the TCT4, already presented at the 6th HL-LHC annual meeting in Paris. Two scenarios (half-bunch impact, full-bunch impact) and two materials (Inermet and MoGr) were considered, for version 1.2 of the optics. The table in Slide 6 summarizes the energy deposition expected in the different elements. A more detailed exposure of the triplet-D1 area was also presented, highlighting that in all elements the peak energy density stays below the damage limit of ~ 100 J/cm^3. This

does not concern the collimator itself, for which different damage limits have been defined by MME (catastrophic damage, ejection of fragments, plastic deformation).

F. Cerutti then addressed the question of quantifying the impact of adding a TCT in Cell 6 on the triplet-MS magnets (particularly on Q5).

A pessimistic scenario was assumed to start with, no TCTs in Cell 4 and - as above - half-bunch and full-bunch impacts, both very unlikely for version 1.3 of the optics. Three materials were considered in this case (Inermet, CuDi, MoGr), although not for all impact scenarios. For all scenarios and materials considered, the peak energy density in the D2-Q5 area is well below the damage limit, even lower in the triplet-D1 region, although quenches cannot be excluded. F. Cerutti stressed that the analysis only looks at energy deposition in the magnet coils. However, also the energy deposition in the beam screen should be calculated to have a comprehensive picture of the effects of the asynchronous dump.

A more realistic case of an asynchronous dump, considering the favourable phase advance between MKDs and TCT from optics v1.3 was then studied, i.e. taking into account that fractions of several bunches will impact on both jaws of the TCT after scattering from TCDQ/TCDS. The reduced number of particles impacting on the collimator results in 20-30 times lower peak energy density as compared to the pessimistic case.

F. Cerutti finally mentioned the impact of the leakage to the experiments (mainly photons, then neutrons). This analysis could serve as an input to verify that no issues are expected for the detectors. Results show that having the collimator in Cell 6 clearly reduces the impact on the experiments, by about one order of magnitude.

F. Cerutti concluded that the Q5 is safe for all collimator materials. O. Brüning asked what is the criterion for choosing the collimator material (as the simulation show that quenching is not relevant for the choice). R. Bruce explained that also other loss scenarios should be considered for the choice of the material. S. Redaelli and F. Cerutti agreed and added that the baseline (CuDi) is a robust material, which also excludes problems with impedance. Inermet is clearly not robust enough, and CuDi allows a better absorption than MoGr. The background to the experiments should be higher from MoGr, as reported in the HL-LHC annual meeting in 2015, where it was stated that about one bunch lost on TCT4 (Inermet) was at the limit for experiments.

G. Arduini asked about the assumption of the collimator setting at 13.3 σ in units of beam emittance; in case one would like to close more the TCT to increase the protected aperture (as done in 2017), what would be the effect? R. Bruce and F. Cerutti commented that no sharp increase of energy deposition is expected, thanks to the good phase advance for optics v1.3. S. Redaelli commented that for the

pessimistic failure scenarios considered in this study, the real aperture dimension should have a small impact but it is good to check for the final layout when available.

Approval of the TDR (I. Bejar Alonso - slides)

I. Bejar Alonso reminded the TCC about the different versions of the PDR and TDR released to date.

- The PDR was published for the March 2015 C&S review and as yellow book in December 2015.
- The TDRv0 was published at the end of the HiLumi study funded by the EU FP7 project.
- The TDRv0.1 was published for the October 2016 C&S review and will be published as a yellow book in October 2017. This includes the re-baselining.
- The TDRv1 will be prepared for the construction of the HL-LHC, as pointed out by L. Rossi.

O. Brüning stressed that the aim is now to release all pending ECRs and to refer them to the TDR, before the 2017 HL-LHC annual meeting in Madrid. As an example, WP2 should prepare an ECR including an update of the parameter list (considering e.g. as well the new bunch length proposed by WP2 and endorsed in a prior TCC meeting).

AOBs

O. Brüning announced the next HL-LHC TCC meeting, to be held on 31st August and chaired by M. Zerlauth. M. Bajko will present the plans and implications for the STRING installation in SM18 to be done with a representative tunnel slope, and there will be a statement from the RF group on the assumptions for the required cooling capacity in Pt4.