# 38th Meeting of the HL-LHC Technical Coordination Committee – 05/10/2017

**Participants:** C. Adorisio, L. Alekou, F. Antoniou, G. Arduini, V. Baglin, M. Bajko, I. Bejar Alonso, H. Burkhardt, R. Calaga, O. Capatina, D. Delikaris, B. Delille, B. Di Girolamo, P. Fessia, M. Garcia Gavela, C. Gaignant, S. Gilardoni, G. Giovannozzi, R. Jones, T. Lefevre, H. Mainaud Durand, R. Martins, M. Martino, Y. Papaphilippou, M. Pojer, S. Redaelli, L. Rossi (chair), F. Sanchez Galan, L. Tavian, E. Todesco, R. Tomas Garcia, N. Triantafyllou, G. Vandoni, R. Van Weelderen, D. Wollmann.

**Excused:** A. Apollonio, O. Brüning, S. Claudet, M. Zerlauth.

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

In the absence of O. Brüning and M. Zerlauth, L. Rossi chaired the meeting. The minutes of the 37th HL-LHC TCC were approved without further comments. The follow-up of actions will be reviewed in the next meeting.

## SPS crab-cavities - simulations and possible test program in view of reduced voltage, F. Antoniou- slides

F. Antoniou listed a summary of the SPS Crab Cavities (CC) test strategy which is composed by five stages, including RF commissioning (4 weeks between March and April). The four last stages with beam tests are composed of two times 24 h Machine Development (MD) studies.

The first stage corresponds to Crab-RF synchronization at injection and coast energies and will focus on achieving the 2.5 MV voltage per cavity. After a question of L. Rossi, R. Calaga explained that 2.5 MV is a safe limit for cryogenics and there is enough margin to operate in CW mode.

F. Antoniou detailed the second stage, where the transparency during the operation of CCs during beam operation is tested, in view of operation in the LHC. In order for the CC to be transparent during the LHC injection and ramp, it is necessary to control precisely the field and phase. The best observable is the dependence of the closed orbit on the CC phase for different SPS energies, ranging from ± 2 mm to ± 10 mm peak, for 270 and 55 GeV, respectively. Following the question of L. Rossi regarding the CC kick, A. Alekou explained that it is quite small and of the order of a few tens of μrad for the maximum voltage. The validation of the crabbing will be measured with the Head-Tail monitor, whereas an alternative method can be used through the apparent, up to 50 % increase of the beam size, as measured by the wire scanners. The instrumentation validation studies included the first operational deployment of the synchrotron light monitor (BSRT), for continuous non-destructive emittance measurement at 270 GeV. The impact of the longer bunches in the SPS with respect to the RF non-linearity and the validation of the crab dispersion effect are also taken into consideration.

The third stage corresponds to the long-term performance evaluation of the CC in view of HL-LHC operation, including RF performance, RF gymnastics and long-term stability. This last point, which is particularly important for the impact of the CC noise on emittance growth was further detailed. From past experience, the best conditions for the studies correspond to higher energies (120 and 270 GeV) and low intensities (a few $10^{10}$ ppb). Even for these conditions, a similar emittance growth was observed in both planes, which increases with the raise of chromaticity. The effect of scattering on the wire of the scanners seems negligible, whereas IBS can explain part of the horizontal growth. In the longitudinal plane, off-bucket losses were observed and associated with the RF feedback, which has to be switched off for preserving lifetime. Tests with the Q20 optics gave similar emittance growth results and measurements. The residual growth in the vertical plane does not depend on intensity. Finally, there are indications that this growth could be well correlated with emittance growth from gas scattering, and further tests are foreseen for a better assessment of the effect of vacuum conditions on the evolution of the beam distribution.

The fourth stage corresponds to the high-intensity (HI) RF operation, focusing on beam induced failure scenarios, as a function of bunch high intensity and number of bunches, and cavity stability, trip rate, and quenches, including fast transients. Finally, a summary of the presentation is given highlighting the machine development needs for each stage with respect to time and possibility for studies parallel to the SPS physics program and LHC filling.

## Discussion

D. Wollman comments that it would be desirable to have a detailed planning of the tests foreseen during and ahead of high intensity operation. Failure scenarios potentially driven by the low-level RF system should be considered and validated. He questions the necessity of high-intensity operation in order to test the reliability of the system. R. Calaga answers that a lot of the tests at low intensity will indeed enable to test the CCs reliability. H. Burkhardt recalled past studies on the effect of RF noise and vacuum in connection with the presently observed emittance growth. V. Kain asked if the BLM in the CC is a standard SPS BLM and R. Calaga answered that actually this is an LHC BLM, with faster reaction. G. Vandoni added that the BLM is included into the Beam Interlock System (BIS) with its own individual threshold. V. Kain further commented that for the HI operation, there will be a lot of setting up for using the Q26 optics. F. Antoniou explained that although there are no strong arguments for using the Q20 optics in coast with low-intensity, it may be considered for the HI operation. L. Rossi recalls that there were considerations for tests with calibrated RF noise that were not mentioned. F. Antoniou answers that preliminary simulation studies from T. Mastoridis and P. Baudrenghien, based on the present prototypes and SPS optics, indicate that the noise effect may be larger and visible. R. Calaga added that, although these results have to be further understood, he strongly believes that the present test program is important for the robustness of the CC specifications towards HL-LHC operation. L. Rossi further asks if there is enough MD time reserved in the SPS for the completion of the tests. R. Calaga answers that the program has been discussed with the injector MD coordinator H. Bartosik, stressing that the first two phases are mandatory. L. Rossi argues that this should be further clarified and probably endorsed by the LMC and IEFC.

ACTION (ABP, RF): The CC MD program should be further detailed, in particular with respect to the available MD time of the SPS. In addition, the HI part of the program should be clarified with an emphasis on assessing the possible failure scenarios at an early stage.

## AOB: Update of CC installation schedule, R. Calaga, - slides

R. Calaga reported on the general status of the CC installation schedule. For the cryomodule, efforts were made for completion of the assembly by the 17th of November, followed by the connection with the cryogenic HW, aiming for a cooldown as of the 4th of December. By the 22nd of December the cryomodule warm-up will be done. The SPS cryogenics' work will start during the last week of December and will be completed by the 21st of February. V. Kain commented that the compatibility of the additional week of access with respect to the present schedule (as confirmed by G. Vandoni), during the SPS HW commissioning, has to be further clarified, in particular because the machine is not sectorised for powering tests. R. Calaga wanted to thank all the teams involved for the great work done. L. Rossi adds his congratulations for the great effort made, allowing time to be recovered.

ACTION (V. Kain and G. Vandoni): Clarify the compatibility of the additional week of access with respect to the current schedule.

## AOB: Interlock modification of SPS extraction interlock to mitigate TED limitation for LIU/HL beams, V. Kain, - slides

V. Kain reminded the functionality of the SPS transfer line beam stopper (TED) and the fact that the current design cannot withstand more than 144 LIU intensity bunches, as the graphite goes beyond the stress limit, as confirmed by simulations of R. Esposito. The present proposal is to keep the current design and limit the extracted intensity to a maximum of 144 LIU bunches. To a question of L. Rossi for the type of interlock, V. Kain answers that this is based on HW, by checking the position and movement of the TED before allowing extraction. The functional specifications explaining all interlock details were sent for approval and are in the phase of the comments' implementation.

A summary of the implications for the TEDs functionality as Element Important for Safety (EIS) for SPS but also LHC is given. An extract of the LIU safety file is presented, quoting that no catastrophic failure is expected even in case of impact of 288 bunches on the TED. Two scenarios are described, involving intrusion while filling high intensity beam, showing that there are several levels of interlocks preventing the beam extraction. In conclusion, the SPS can reliably operate with this limitation.

### Discussion

C. Gaignant agrees that the probability of failure impacting safety is very low, but it is necessary to review the scenarios and validate them. V. Kain asks to provide any comments that could be added in the corresponding documents. Taking into account that the interlocks are based on BCT readings, R. Jones asks if any modification of the corresponding instrumentation is necessary. V. Kain answers negatively. S. Gilardoni stresses that EN/STI is the owner of the equipment but cannot evaluate the impact on personnel safety issues, in particular for a damaged device. This beyond the competence and mandate of EN/STI. Regarding the spares, he clarifies that there is only one for six operating devices. It may be good to consider building a spare that could withstand 288 LIU bunches in case we do not have to replace all the TEDs. In any case, it is too late for LS2 to replace all the existing TEDs but it is necessary to understand how to evolve with the present system. L. Rossi asks whether there is an evaluation on the probability that the TEDs break and V. Kain answers that with the present interlock system, this is not a probable scenario. S. Redaelli asks about the clarification on the probable damage and S. Gilardoni explains that at least damaging the absorbing material is expected. To the question of S. Redaelli for eventual tests of the spare in HIRADMAT, S. Gilardoni explains that this is a unique spare. S. Gilardoni mentioned also that the HIRADMAT beam dump is a TED-like absorber and a decision should be taken if this should be exchanged to be able to cope after LS2 with LIU/HL-LHC beams in the facility. L. Rossi suggests to come back in a future TCC before proceeding with a decision.

ACTION (HL-LHC PSO, BE-OP-SPS and BE-DSO): A statement on the personnel safety impact of the present TED interlock solution should be given to the TCC before a final decision is taken.

## First results with Laser treated surface in COLDEX, V. Baglin - slides

V. Baglin reported on the beam tests of the beam screens with Laser treated (LESS) surfaces in COLDEX, being the result of a collaboration with SFTC and Dundee University. This treatment is supposed to reduce radically the Secondary Electron Yield (SEY). A segment of the laser treated surface is shown. These segments are assembled to produce the 2.2 m-long beam screen, which is inserted into COLDEX in the SPS (mimicking a LHC-type cryogenic beam vacuum system), for heat load measurements. V. Baglin stressed that this work has been carried out mainly by a fellow, R. Saleme, whose replacement is not yet finalized.

A further schematic of COLDEX is presented, including the set-up and systems to measure pressure, heat load and electron activity, with or without gas condensates. In particular, a chimney is located in the middle of COLDEX, collecting the gas from the beam screen which is maintained at cryogenic temperature. Electrodes are inserted into the chimney and behind the BS slots. Solenoids are wrapped at the COLDEX extremities, including a warm calorimeter (WAMPAC) made of laser treated copper. Total and partial pressures can be measured in the centre and at the extremities. The heat load can be derived from temperature sensors and He flow meters. The experiment includes also a gas injection system.

The studies included eight dedicated SPS 24 h-MD requests, for vacuum characterisation at different temperatures with gas. Additional studies may be requested in due time if needed. V. Baglin further explains that all topics are different and in case of failure of some MD, additional requests will be placed beyond this 2017 program. The beam conditions for the tests correspond to four LHC 25 ns-type of batches in the SPS injection (26 GeV), with 0.9 to $1.4 \times 10^{11}$ ppb.

The observed pressure rises at the COLDEX extremities are in the $10^{-7}$ mbar range. The pressure with the beam screen at 10 K is below $10^{-10}$ mbar, whereas it is of the order of a few $10^{-9}$ mbar at 50 K. This rise is mainly associated to $H_2$. Following a question of L. Rossi about the presented pressure curve evolution, V. Baglin answers that a more careful analysis should be undertaken, normalising with the corresponding beam intensity. When the solenoids are switched on, the pressure at COLDEX extremities and the dissipated power on the calorimeter are reduced. On the other hand, pressure in the middle of COLDEX is not reduced, indicating that desorption is happening inside COLDEX. Varying the beam screen temperature at 50 ± 10 K had no significant impact on pressure.

When scanning the applied voltage from 0 to 80 V in steps of 20 V, electron currents up to 0.1 μA were measured at the beam screen electrode. The solenoid field did not reduce significantly the measured current, indicating that the collected electrons are produced inside the beam screen.

The heat load on the beam screen at cryogenic temperature is below 0.5 W/m. At room temperature, the heat load as observed on the Cu calorimeter (0.9 W/m) is reduced on the LESS one (0.2 W/m). The last point is on observations of gas release during the natural warm-up, where there is an $H_2$ peak at 20-30 K followed by a $CO/N_2$ peak at 30-35 K. Following a question of L. Rossi, V. Baglin explains that at present the beam screen functions between 5 and 20 K. He finishes his presentation highlighting the main results, namely that the LESS mitigates multipacting at cryogenic temperature in the studied range (10 – 50 K). The thermal desorption studies showed that $H_2$ is desorbed from the LESS surface in the range of 20-30 K. The observed $N_2$ is probably due to air trapping within the LESS.

L. Rossi thanks the speaker and stresses that these are very encouraging results for a novel technology, which may be used in the future for e-cloud mitigation. G. Arduini points out that with the present LESS treatment, the impedance is increased by an order of magnitude. B. di Girolamo adds that there can be a change on the microstructures of the grooves that could allow the reduction of impedance. Answering a question of L. Rossi, V. Baglin explains that the expected SEY from LESS is 0.9, and the experimental program is focused on the impact of gas to SEY. G. Arduini suggests to make measurements with a solenoid in a coper surface for comparison and V. Baglin agrees that this is a good point.

## Feasibility and implication of installation of the string test in SM18 with a slope, M. Bajko- slides

M. Bajko first recalls the open technical issues, as presented in September 2016 and under discussion for the IT STRING test, including integration, cryogenics, magnets, alignment and vacuum. Regarding integration, the plan is to reproduce in SM18 the configuration of the P5L, as it is the most complicated (as the tunnel is the smallest) and coherent set up with the SM18 installations. It was decided to choose the P5L as it is the most complicated and coherent set up with the SM18 installations and the tunnel is the smallest. A schematic is shown with the corresponding space constraints. Regarding the slope, discussions were undertaken with equipment groups and WPs. It was found that it is of no interest to implement a slope. In particular, there is no formal request from the point of view of cryogenics, as most of the relevant slope aspects have already been studied in detail in the LHC. M. Bajko points out that in order to make integration easier, the order of installation of Q1 and Q3 may be exchanged, with respect to their arrival.

Regarding cryogenics, the pumping needs for SM18 have been evaluated since years ago within the SM18 upgrade project. The preliminary conclusion was that there is no need of additional pumping capacity to the existing 12 g/s. M. Bajko considers that the cooling capacity may not be sufficient, and asked for a re-evaluation of the needs based on present more detailed and precise planning and consumption of the different test cryostats. D. Delikaris is skeptical on the re-evaluation of the needs and, in addition, any upgrade will be difficult at this point. M. Bajko pointed out that in case of need, an alternative solution is to delay certain tests and/or reduce the number of quenches on both magnets and STRING test. L. Rossi concludes that the needed cryogenic capacity (pumping to 1.9 K) for the tests has to be reviewed.

ACTION (MSC and CRG): The cryogenic capacity needed for the STRING test and all SM18 test has to be refined and presented in a future TCC.

A table is shown for the magnet tests and number of quenches with the associated current, that is considered necessary during the HW commissioning of the STRING. Some numbers could be reduced, in particular if special tests can be done during HW commissioning. The idea is to have a number of quenches after a thermal cycle and limit the tests to nominal current.

Regarding vacuum, beam screens will be installed. Based on the need in testing of all types of beam screens, three different beam screens will be instrumented (Q1, D1 and Q2a or Q2b) only in the prototype magnets. Regarding planning, M. Bajko with M. Pojer made a draft one which includes all tests and corresponding number of quenches. In order to answer the points raised by D. Delikaris, the colleagues from cryogenics should check if this is realistic. If this is not the case, the recovery time should be reviewed and as a consequence also the planning. The idea is to converge by the end of October 2017.

## Discussion

L. Rossi suggests that the TCC endorses the conclusion of the absence of slope in the IT STRING tests. G. Arduini wonders if the corresponding longitudinal force (10 kg for a 500 kg object at 2 % of slope) is taken into account. P. Fessia explains that there is a fixed point in both SSSs and dipoles. In any case, the slope can be also tested with single magnets. L. Rossi asks the WPs to think about the list of tests that cannot be done in the absence of slope. M. Bajko points that a survey of needs for testing was circulated and has to be sent back to WP16 by the 10th of October. M. Pojer adds that it is important, based on this input, to establish a baseline but also a list of additional studies and come back to the TCC with a completed planning. L. Rossi further asks if there is agreement on the choice of P5L, and it seems that there is no objection from the TCC. He asks why only one thermal cycle is considered and M. Pojer answers that this is due to limited time. L. Rossi reiterates that this should be reconsidered in case time is available. He further asks why the tests are done only up to nominal current. He recalls that the groups have received a memo from the DG for having an equipment assessment to reach the ultimate energy, the magnet system being the only one already fully designed for operation at 15 TeV. He recommends that at least one test is done at ultimate current, at the STRING. P. Fessia adds that the working group on alignment may recommend to have more than one thermal cycle in order to measure the impact on positioning of the different components.

ACTION: The TCC endorses the proposal of not including a slope in the IT STRING tests and choosing P5L for the tests. A list of tests that cannot be done with this set-up has to be communicated by the different WPs. The TCC recommends considering tests not only at nominal but also at ultimate current.

## AOB

L. Rossi proposes and the committee agreed to move the AOB presentation of H. Garcia Gavela on “Make or buy plan status” for the next TCC.

The next TCC meeting will take place on the 12th of October 2017.