# 152nd Meeting of the Machine Protection Panel

Participants: W. Bartmann, J. Boyd, A. Gorzawski, S. Jakobsen, D. Lazic, A. Lechner, B. Lindstrom, Y. Nie, T. Medvedeva, V. Raginel, S. Redaelli, C. Schwick, M. Valette, J. Wenninger, C. Wiesner, D. Wollmann, M. Zerlauth.

The slides of all presentations can be found on the website of the Machine Protection Panel:
http://lhc-mpwg.web.cern.ch/lhc-mpwg/

## 1.1 Approval of MPP#151's minutes

- Actions from the 151st MPP:
  - Björn Lindström: Verify expected beta beating at critical elements like TCTs or IR6 dump protection in case of a CLIQ mis-firing.
    - This study is ongoing and has led to preliminary results that now need to be checked with collimation.
  - TE-ABT, BE-BI: Summarize planned changes in the BLMs around the TDEs in an ECR.

## 1.2 CT-PPS experience during intensity ramp-up and physics and recent auto-retraction (M. Deile)

- Mario first presented a summary of the roman pot insertions during the intensity ramp up. The TOTEM pots have been operated up to the highest intensities in the LHC without problems. The BLM signals scale linearly with luminosity and are compatible with 2016, all signals are below warning levels. The vacuum quality doesn't seem to be correlated with the presence of the pots, a small spike can be recorded at insertion with levels in the order of $3x10^{-10}$ mbar. Heating-wise the flange temperature goes up by 12.5 degrees to 40 $^{o}$C, as it is not cooled, which is not worrying.
- Regarding the recent spurious retraction of the CT-PPS roman pots: in the past EYETS a digital filtering of the LVDT data was implemented and a dump would now be issued if the threshold is reached for three consecutive read cycles. On September 11th, a spurious retraction of all pots happened without causing a dump. No post-mortem file was generated since the threshold was not reached. As all pots were retracted at the same time, this points to a glitch in one of the flags like STABLE_BEAMS. The creation of PM data, when reaching a warning level, which causes the retraction of the roman pots will be implemented during the coming YETS, as this includes changes to the safety critical code requiring a full re-commissioning.
- For the restart after TS2 an alignment of the pot was performed as well as a calibration with all three crossing angles and the new physics settings (TCT settings plus 3 σ plus 0.3 mm).
  - Daniel commented the retraction without causing a dump is unpleasant but not worrying as it only causes the loss of data.

- Mario added that the position of the far pots was found to be shifted by 250 µm after the TS2, which was also observed for ALFA, which is unexpected.

### 1.3 Summary of ALFA interlock tests performed during TS2 (S. Jakobsen)

- Sune presented the results of the tests performed during TS2 on the AFP roman pots. It was expected that everything would work as nothing was touched since the validation in 2015. The tests performed included the injection permits validation and the response of the LVDT-to-limit comparison. On one occasion, some ringing of the USER_PERMIT was observed for all pots. The test of USER_PERMIT and automatic extraction as a function of all input flags was not done as it would require the other experiments to stop listening to these flags. Sune asked the MPP if this test was really necessary as the pots will only be operated in ADJUST mode with the override key in 2017, all the data taking in STABLE_BEAMS in 2017 will be done in "holiday" mode with the motors off by hardware and LVDT comparison bypassed. MPP agreed that the performed test are sufficient to operate the ALFA RP during the high beta run planned for the end of the year.
  - Mario added that this test was not performed for TOTEM as well in the last two commissioning periods. Jorg proposed that some of the beam modes in the list like DUMP and UNSTABLE_BEAMS are practically not used and will be removed after LS2.
- In conclusions the ALFA pots are working properly and the EDMS document 1847628 is being prepared for approval.

### 1.4 First results from magnet component damage experiments due to beam heating (V. Raginel)

- In the framework of fast failure studies for the HL-LHC one of the unknowns is the damage limit of superconducting magnets in case of instantaneous beam impact. The critical components of sc. magnets have been identified as the polyimid insulation and the superconducting strands. Their damage mechanisms have been studied during three dedicated experiments. This talk focussed on the latest experiment performed at the HiRadMat facility designed to study the impact of a 440 GeV proton beam on superconducting cables and strands.
- In that experiment, stacks of Nb-Ti cables, Nb-Ti and $Nb_3Sn$ strands were mounted in a tank with Argon atmosphere. The temperature profile in the samples were derived from FLUKA simulations and resistance measurements. A temperature of up to a thousand Kelvins was reached. From previous experiments and a model developed, it is known that the degradation of the polyamide insulation behaves exponential with temperature and exposure time and starts to be significant at 800 K. For the beam experiment no significant degradation of the insulation was observed for any of the samples.

Nevertheless, half of the samples exposed to temperatures higher than 800 K for millisecond long heating showed breakdowns at the position of the beam impact during high-voltage tests.

- The degradation of the critical current was derived from magnetisation measurements at the University of Geneva. Samples exposed to temperatures higher than 924 K during beam impact showed degradation, more precisely reduction of the pinning force and a modification of the pinning behaviour with the maximum shifting to lower reduced field values. This reduction of the pinning force can be explained by a diffusion process changing the size and distribution of the non-superconducting Ti phase in the superconductor. Measurements of the critical field ($B_{c2}$), showed a degradation as of 905 K.
- $Nb_3Sn$ strands, which only showed degradation above 977 K in a previous capacitive discharge experiment, degradation was observed for every sample exposed to beam impact (> 700 K). The pinning behaviour appeared unchanged but with lower strengths. The main degradation mechanism is suspected to be the stresses due to large temperature gradients leading to cracks in the material. Further investigations are ongoing. Another experiment with beam at cryogenic temperatures is scheduled for mid-2018.
    - Daniel asked Vivien, what he would conclude from the experimental results for the damage limit of the HL-LHC magnets. Anton reminded, that the current baseline sets a limit of 86 $J.cm^{-3}$ for beam impacts scenarios, which corresponds to ~100 K hotspot temperatures for cold materials. The presented results imply that this limit is far too conservative. Vivien added that the experiment involved cables at room temperature and limits might be lower for real magnets in operating conditions (currents, field, temperature, stress), which are all the more reasons to perform the cryogenic experiment.
    - Anton commented he was surprised no mechanical damage was observed on the Nb-Ti samples. Ruediger answered, that NbTi is a strong material which can undergo large strains.
    - Anton also asked, what were the currently assumed frequencies for injection failures in the HL-LHC? Daniel answered they are expected to occur multiple times per year, as is currently observed in the LHC. Anton then suggested it would be interesting to try impacting beam several times at the same position in a later experiment to verify no damage build-up can occur. Ruediger added that with diffusion it wouldn't change much from one shot to the next but if cracks are involved in the degradation of $Nb_3Sn$ they might build up.
    - Daniel concluded that it is important to identify the different degradation mechanisms Nb-Ti and $Nb_3Sn$.
    - Rudiger proposed to perform an experiment by shooting beam at an LHC magnet would be performed before LS2.

### 1.5 rMPP proposal for operation with B2 TDE at atmospheric pressure until YETS 2017/18 (M. Zerlauth)

- Markus presented a memo which is currently being prepared, collecting all studies and simulation results from the teams involved in the TDE issue so far and which is to be submitted to the ATS management on the possibility of operating the beam dump in air without a Nitrogen overpressure of 1.2 bar. Marco will give a presentation in the next meeting to detail the simulations and experiments, which were performed.
- The inspection of the downstream window showed the leak was not a punctual leak but more of a distributed one, with flows up to 15 L per hour.
- New FLUKA simulations show that the temperature of the carbon material was underestimated by ~300 K due to neglecting of the beam tales in the simulations for the LHC design report. The hot spot is always located in the second part of the low-density section of the block. The temperatures with 2556 bunches and 1.2e11 protons/bunch at 7 TeV reach below 1000 $^{o}$C, and is even lower when using 8b4e. Assuming failures of dilution kickers, the temperature of the surface open to the gaseous volume in the back goes up to 1140 and 900 $^{o}$C with 25 ns beam and 8b4e respectively.
- It can be assumed that even with considerable leaks the air flow between the graphite block would be slow so no massive oxidation is expected. Experiments with amorphous carbon heated to 2500 $^{o}$C and exposed to a finite amount of air showed oxidation leading to a mass loss of about a percent but no burning. Another set of experiments in which the carbon was heated to 850 $^{o}$C and exposed to air for 100 s showed no oxidation. These will be repeated with temperatures of 1000 $^{o}$C following the latest FLUKA results.
- In conclusion, the risk of ignition of the dump is discarded for the operation of the dump in air with nominal dilution current 8b4e beams. In case of a dilution failure, oxidation cannot be excluded and could lead to mechanical degradation. The proposal is thus to keep the system operating with a nitrogen influx at the upstream end to preserve the full mechanical integrity of the beam dump block. Physics operation would not be interrupted if a nitrogen bottle needs to be changed.
    - Jamie asked about the possibility of steering the beam so it hit different places each time and avoid the consequences of mechanical degradation. Wolfgang answered that there are already small variations from dump to dump. Nevertheless, if one would want to steer the 7TeV beam, additional strong kicker type magnets would be required.
    - Daniel added some experimental data are missing to make a definitive conclusion, one might be oxidising away some material at every shot but the margins in the dump design are sufficient that the dump performance is not affected with a little degradation.
    - Anton also mentioned there is a 10-15% error margin on the temperatures derived from FLUKA simulations, which need to be taken into account for the conclusions.

- Markus concluded the final draft will be circulated soon for a final round of comments by the equipment teams before submission to the management.

### 1.6 AGK and Injection sequencer changes following the first injection of 112b trains 8b4e (W. Bartmann)

- Wolfgang presented a summary of the event from September the 4th when the last train of 8 bunches during the first injection of 8b4e trains was injected into the abort gap. The problem came from the 112 8b4e bunches requiring 168 bunch slots instead of the 160 usually needed from the 144 bunches of BCMS beam. The last injected bunches were injected on the already falling edge of the MKE waveform and showed significant oscillations. The dump issued by the operator at the beginning of the ramp was classified as clean by the XPOC but with unusually high losses on the septum. The scenario envisioned now is that these bunches got a small kick from the beginning of the MKD waveform and were dumped on their second turn with a small kick and ended up on the outer blade of the septum which is not meant to protect the aperture but only the magnet.
- Actions were taken to correct the situation immediately, the MKI flat top was increased by 200 ns as well as the AGK. Injection of a full train up to the last legal bucket was confirmed afterwards. This could also have happened with the hardcoded version of the AGK. From now on, a train too long for the MKI flat top will inhibit injection instead of warning message, which can be ignored, as happened.
  - The abort gap population increased to several $10^{11}$ p+ during this event, Wolfgang asked if there was a threshold, which would lead to a dump. Jorg confirmed it is the case but the threshold is higher than this.
  - Wolfgang asked if it was possible to check such things in the BQM, Jorg answered one should ask Giulia if there is enough CPU there to have it before injection in the LHC. Daniel commented the information could come after the injection since at injection energy having beam in the abort gap is not worrying but one would need to know about it before ramping.
  - Jorg commented the IQC has an archaeological variable called last bucket allowed for injection but is not used and should be cleaned in order for people not to rely on it.
- Wolfgang concluded switching beam types in the LHC is always a critical procedure which involves risks, which is why the current procedure requiring two people with two different RBAC roles should be kept. He also asked if something more formal should be set up such as an MPP or rMPP request, which is currently the case for changing the AGK length.
- Daniel stated the parameters required for a new injection setup should be documented.
- C. Schwick asked if more bunches could have been injected in the abort gap and recirculate before being extracted. Daniel commented that since the

phase advance to the TCTs and TCPs is 0 [π] they would only be stopped by the TCDQ from a certain point in the abort gap. Stefano commented the constraint on the phase advance from the MKDs to the TCPs is not strictly verified for the latest optics.

**Action (TE-ABT, Coll): Verify the phase advances from the MKDs to the TCPs and how many bunches can escape the TCDQ if injected the abort gap.**

**AOB - Final activation of DOROS BPMs in SIS in view of reduction of beta* after TS2 (A. Gozwaski)**

- Arek presented a short recap on the implementation of the interlock and some final conclusions. The logging from August 4th to September 11th showed no spurious triggering of this interlock during operation. A small cluster of events appeared on the 11th during the commissioning of the 30 cm optics, which is expected. This interlock will be masked when performing such tests. The TCT orbit has demonstrated good reproducibility, within +/- 150 µm. On top of this, all Collimator BPMs responded correctly and passed the tests during the last campaign. This interlock is therefore recommended to be activated in operation for IP1 an IP5.
    - Marek commented he would like to get the list of BPMs involved in this interlock. Arek will provide it to him.

**AOB - all**

- Another MPP will be held next week with more details on the operation of the TDE in air.