211th Meeting of the Machine Protection Panel

LHC topics

August 13st, 2021 via Zoom

Participants:
W. Byczynski (EP-LBD), P. Collins (EP-LBD), M. Di Castro (BE-CEM), Y. Dutheil (SY-ABT), C. Hernalsteens (TE-MPE), H. Hillemanns (EP-AID), D. Jacquet (BE-OP), G. Kruk (BE-CSS), D. Lazic (EP-UCM), R. Lindner (EP-LBO), M. Milovanovic (EP-LBD), B. Petersen (EP-ADT), F. Sanders (EP-LBD), B. Schofield (BE-ICS), A. Sciuccati (EP-LBO), E. Thomas (EP-LBO), J. Uythoven (TE-MPE), D. Valuch (SY-RF), J. Wenninger (BE-OP), C. Wiesner (TE-MPE), D. Wollmann (TE-MPE).

The slides of all presentations can be found on the website of the Machine Protection Panel and on Indico (211th meeting).

Minutes from the last meetings (LHC topics)

Daniel recalled that the minutes of the two last MPP meetings on LHC topics have been circulated: 209th MPP (actions) and 210th MPP (actions).

LHCb velo wake field suppressor – observed issues and results of recent tests (Freek Sanders)

Freek started by summarizing the VELO upgrade. As the geometry of the detector changed with the upgrade, parts of the vacuum system needed to be modified accordingly: new wake-field (WF) suppressor, new rf foils, SMOG2 and a new beampipe flange. The WF suppressor is fixed on the beampipe on one end and will move to follow the detector movements on the other side while being attached to the rf foil.

During the inspection of the installation, it was found that the two WF suppressor halves are buckled and as a consequence touching when in closed position. This raises the question on the effect of this touching on the surface of the WF suppressor, and on the possibility that the fingers get entangled or cold-welded together. To further investigate this effect, a test setup was used, and an endoscopic inspection was performed. Additional tests have been performed:

- a spare WF suppressor is installed in a test set-up following the normal installation procedure, it buckled in exactly the same manner;
- the system is moved 1000+ times and the difference of the surface at the touching points was analyzed;
- the fingers are clamped (or welded) in position (closed VELO) and the system will be opened to see what will happen in this extreme case, and what effect broken fingers have on the aperture.

After 1155 cycles the surface was analyzed: some scratches occurred but are barely visible. During the motion tests there was no sign of fingers hooking onto each other. The only possibility for the fingers to get attached is through cold welding. The cold welding can take place with high pressure or high vacuum, the surfaces need to be very clean and materials that do not oxidize are good candidates (in this case the surface is Gold coated).

The surfaces have been cleaned to LHC specifications (not at CERN), the installation is done in a regular lab, with gloves and the surfaces have been exposed to air for a long time. An endoscopic inspection showed the presence of dust.

The fingers were clamped with a large clamp and the system was opened (single cycle). The fingers did not break. With a smaller clamp, the finger broke and came loose. The VELO could still move, and the aperture was not affected, with no chance that the broken finger could reach the aperture. Tests with ultrasonic welds were then performed. The finger also broke. The aperture was not affected in that case as well.

Final tests are being performed with the real VELO. The LHCb beampipe was put under vacuum this week. This gave an opportunity to do a cold-weld test by closing the VELO. The VELO is currently in closed position (note after the meeting: when it was opened after several days, no strong cold weld was observed; the fingers did not stick).. The time in this closed position for the test will be greater than the maximum time during operation.

In case of failure, the WF suppressor can be replaced. However, it is very time consuming (several months for being back in operation again) and requires a lot of work from the vacuum group. There is a risk of breaking multiple delicate components.

The stock of WF suppressor is as follows:

- One downstream WF suppressor is installed, one spare is available (with a small 3mm tear in the beampipe section – still repairable), one was destroyed during testing;
- The upstream WF suppressor is obsolete because of SMOG2; one was destroyed during testing and two others were damaged but could be used for further testing.

Discussion

Jan asked about the replacement time. Freek replied that the replacement would require to start over with the bake out and to deinstall some parts of the LHCb systems. Freek clarified that replacing the WF suppressor now would cost months, with two additional weeks if the VELO detector is already in place.

Daniel asked what spare or usable WF suppressor could be used if one chooses to replace the one in place. Freek replied that the available spare with the tear would be usable. The same problems of potential cold welding would be present as well, although the shape of the spare is slightly different, and the contact could potentially be slightly less important.

Daniel asked how long it would take to manufacture a new WF suppressor. Freek replied that it could be done in a few weeks.

Jan asked more details about the replacement time. Freek confirmed that it would take months and it depends on the availability of the involved groups (VELO and vacuum group mainly) Daniel commented that it would be good to estimate the timeline.

Action: propose a proper timeline for a possible replacement scenario (Freek).

Jan asked about the potential consequences of those issues arising during operation. Jan commented that it is important to investigate the worst-case scenario. Freek commented that the velo could be replaced by a beampipe (about a month of work – considering that a bake out is not required). Jan proposed to look at that scenario in more details.

Daniel asked if any movement of a possibly broken finger can be excluded. Jan added that the loose finger could act as an antenna and could overheat. The efficiency of the WF suppressor should also need to be assessed.

Daniel asked if it is possible to estimate the force that the cold weld could handle.

Rolf asked how realistic this cold weld is or if it is just a theoretical concern. Daniel replied that even if this is a small risk, the consequences are huge. How could we estimate the probability of having a cold weld? The vacuum group raised the initial question on the cold weld.

Freek mentioned that a possible solution would be to add a coating on the spots that would be in contact. This is still achievable. Jorg cautioned that this should not be done in urgency.

Paula mentioned that the on-going test is highly relevant: the system will be closed for several days with the surfaces in contact. Paula added that in case of a broken finger, it would be possible to cut off the damaged finger without impacting the WF suppressor and without the need for a bake out. Jan then asked why one would not cut off the possibly problematic ones directly.

Daniel asked about the size of the scratches. Freek replied that they are about one millimeter long.

Jan proposed to ask inputs from Stefano Sgobba (EN-MME-MM). A test with trying to obtain a cold weld in a dedicated set-up under vacuum and then measure the force required to separate the weld was proposed (and later accepted by the LMC).

It was concluded that the buckled WF suppressor does not propose a particular concern for the aperture nor for the beam impedance as long as the fingers don't break. The breaking of a finger should really be avoided. Further investigations with the help of EN-MME are recommended.

Action: Obtain more inputs on the possibility of a cold weld from EN-MME (Jan).

Action: Perform opening test with the velo before the LMC, including video (completed a few days after the meeting and before the LMC; no cold weld was noticed when opening).

Allowed ADT window length for coherent excitation

Cedric first summarized the failure scenario when operating the ADT in coherent excitation mode. In this mode, the orbit excursion is the superposition of a coherent excitation and the always-on damping action of the ADT. This fast failure would lead to beam losses reaching the critical loss limit within a few milliseconds.

The objective of the study is to provide estimates on the time-dynamics of the beam losses for various ADT modes and to determine the operational envelope for allowed operation with the ADT in coherent excitation, during Run III and for HL-LHC, in terms of the length of the excitation window (or number of bunches) and on the maximum allowed voltage.

The integrated beam losses occurring as a consequence of the large orbit excursion are estimated using a semi-analytical model, by integrating over the beam distribution. The critical loss limit assumed for machine protection is taken to be 1 MJ. The BLM thresholds for the short running sums is 125 kJ, which is assumed to be in IR7, over a few milliseconds. The BCCM threshold is taken at 3e11 protons for the 1-turn window.

The failure detection is indirect: the onset is not detected and one needs to consider the margin between the failure detection and the critical loss limit.

For a given number of bunches, the 1 MJ critical loss limit, the BCCM loss limit and the BLM loss limit are calculated. Then, these limits are used together with orbit excursion and beam loss pattern to estimate the turn number at which these limits are reached. The margin between the BLM/BCCM trigger and the damage onset is then computed.

These estimates are computed for Run III parameters and for HL-LHC parameters, at top energy and at injection energy:

- At top energy for Run III and for a nominal ADT voltage of 7.5 kV, a conservative 10 turn margin is kept for up to two batches (480 bunches)
- At top energy for HL-LHC, with a voltage of 10 kV, 2 batches still provide sufficient margin with respect to the BLM threshold, and acceptable limits (7 turns) with respect to the BCCM threshold
- At injection energy it is observed that the BLM will not trigger before the BCCM (contrary to the case at top energy). Also, due to the very fast dynamics, the margins are relatively constant with the number of bunches
- At injection energy for Run III, the nominal voltage does provide enough margin
- At injection energy for HL-LHC, the nominal voltage does not provide sufficient margin. The voltage needs to be reduced to 5 kV to restore a 10-turn margin for up to 2 batches.

The proposed operational limits are to limit the ADT excitation to a maximum of 480 bunches for Run III and for HL-LHC. In addition, the maximum voltage must be limited to 5 kV at injection energy. Daniel W. concluded that the MPP agrees to implement these limits.

Action: Implement the proposed operational limits for the ADT excitation (Daniel Valuch)

Discussion

Jorg asked who would need 480 bunches to be excited. Daniel V. replied that several hundred bunches have already been excited in the past, which required ADT expert support.

Daniel V. mentioned that a reduction of the available voltage can be implemented in the ADT. A previous implementation of this functionality was quite bulky and required significant validation time before the excitation could be started, which made it impractical to use.

Follow-up of MPS re-commissioning via checklist tool

Cédric presented the progress and status regarding the MPS re-commissioning checklists that are being implemented in the checklist tool:

- The following checklists are fully available: Injection protection system, PIC, vacuum, LBDS, FMCM, WIC, SMP, Totem, ARP, SIS.
- The following checklists are being finalized: collimation, BIS, BLM, BCCM, BBWC, ADT.

Summary of actions

The actions from the meeting are:

- LHCb velo wake field suppressor – observed issues and results of recent tests
    1. Propose a proper timeline for a possible replacement scenario (Freek)
    2. Perform opening test with the velo before the LMC, including video (Freek)
    3. Obtain more inputs on the possibility of a cold weld from EN-MME (Jan)
- Allowed ADT window length for coherent excitation
    1. Implement the proposed operational limits for the ADT excitation (Daniel Valuch)