185th Meeting of the Machine Protection Panel

The meeting took place on **November 29th 2019** in 774/1-079.

Participants: Chiara BRACCO (TE-ABT), Roderik BRUCE (BE-ABP), Andy BUTTERWORTH (BE-RF), Mario DI CASTRO (EN-SMM), Dragoslav-Laza LAZIC (EP-UCM), Filip MOORTGAT (EP-CMG) , Brian PETERSEN (EP-ADT), Matteo SOLFAROLI CAMILLOCCI (BE-OP), Jan UYTHOVEN (TE-MPE), Jorg WENNINGER (BE-OP), Christoph WIESNER (TE-MPE), Daniel WOLLMANN (TE-MPE), Markus ZERLAUTH (TE-MPE), Marco CALVIANI (EN-STI)

The slides of all presentations can be found on the website of the Machine Protection Panel and on Indico.

1.1 Minutes from the 183rd MPP meeting

- No comments on the minutes of the last MPP meeting on LHC topics (183rd MPP) have been received. The open actions have be added to the MPP homepage.

1.2 TDE interventions during LS2 and impact on interlocks (Marco Calviani)

- Marco presented the planned interventions during LS2 on the LHC beam dump (TDE).
- The **current configuration of the dump assembly** consists of
  - a graphite dump block, which is contained in a stainless steel jacket and enclosed in nitrogen overpressure to prevent air influx in case of a leak,
  - an upstream window (15 mm CfC and 0.2 mm stainless steel SS316L), separating the over-pressurized dump region from the LHC vacuum in the dumpline,
  - a downstream window made out of titanium (Ti) grade 2 on the rear side of the dump vessel.
- The following **issues** were **observed since the end of 2015** (Slide 4):
  - Nitrogen leaks due to failing gaskets
  - Loosened bolts of the chain clamps
  - Indication of permanent displacement of the dump of up to 7 mm, plus a rotation of several degrees
- The initial **baseline agreed for the upgrades during LS2** includes a new downstream window made out of Ti grade 5 and the exchange of the nitrogen sector gaskets. The intervention will take place on the spare dumps, which will then be swapped with the operational dumps.
- So far, the **energy-deposition studies** had focused on the graphite core of the dump and the dump windows. During 2019, new studies revealed that the **energy deposited by particle showers in the stainless steel vessel** leads to a significant temperature rise and thermo-mechanical effects in the vessel.
  - For Run3 parameters (2748 bunches, 1.8e11 protons per bunch), an adiabatic temperature rise of ~65°C is simulated. This excites a longitudinal oscillation mode with a 6 ms period and 3-4 mm amplitude in the upstream vacuum window.

  - In addition to the fast oscillations, a slow movement of the dump can be caused. For Run2 parameters (320 MJ stored beam energy), the simulated dump displacement is 5 mm from the direct beam impact plus additional 5 mm due to thermal expansion (~30 min).
  - The displacement mainly depends on the total intensity of the primary beam that is impacting the graphite core, and less on the specific failure case.
- On top of the planned upgrades, the **new proposed baseline for Run3** operation foresees - in addition to the changes of the downstream window - to 1) physically separate the dump line vacuum and the dump vessel, 2) install a new upstream window, and 3) change the dump supporting system.
- **Separation of the dump line vacuum and the dump vessel**: The dump will be disconnected from the beam dump line held under vacuum to avoid mechanical coupling by removing the upstream nitrogen connection pipe.
  - In the new configuration, the VSC group would be responsible for the dump line vacuum and the corresponding beam window, while the EN-STI group would remain responsible for the dump and the windows of the dump block. The beam would therefore travel ~10 m through air.
  - Filip asked if the fact that the beam travels through air has any implications for radio-protection. Marco replied that this was discussed with HSE-RP and a priori no significant radiological impact is expected.
  - Markus asked what the dominant contribution to the activation of the cavern is. Marco explained that the activation is mainly caused by thermal neutrons behind the dump.
- **New upstream window**: The separation of the two vacuum sectors implies the installation of an additional window upstream of the dump vessel. The new upstream window will be made from Ti Grade 5. EPDM rubber seals are foreseen instead of the presently used helicoflex gaskets. In order to avoid that somebody by accident physically damages the new upstream window to the dump, HSE-OHS recommended to install a 1 m long hollow external protection.
  - The upstream window has to withstand the thermo-mechanical loads induced by the beam, the static vacuum/overpressure load and the dynamic load due to the dump vibrations. The induced thermo-mechanical stresses for the considered worst-case failure (high-voltage flashover of horizontal dilution kickers) were simulated and are significantly reduced with the new window design.
  - Replying to a question by Daniel, Marco explained that helicoflex seals are more prone to create leaks due to mechanical deformation, so that a better performance is expected from the more elastic EPDM seals.
  - Responding to a remark by Jan, Marco clarified that indeed a 10 mm thick upstream window is proposed and not, as mentioned on Slide 13, a 5 mm thick window.
- **New dump support**: A new mechanical dump support is planned (Slides 18/19) to hold the dump assembly in position and avoid a slow migration out of its reference position. A prototype in a 1-to-2 scale is planned to verify the functionalities.
- After the installation of the modified spare dumps, no operational **spare dumps** will be available. However, the current dumps will be stored in the cavern.

    - Jan asked what it would imply to reuse the current dumps as spares. Marco replied that, in principle, one could reinstall them, but it would require to work on the activated dump, including the installation of the new upstream window. A dose of around 1 mSv is estimated for these works.
- The dump core and the new windows are considered compatible with Run3 beam parameters. However, it has to be analysed if a **limit in the number of consecutive dumps or a minimum time between the dumps** has to be defined and enforced.
    - Action (M. Calviani/EN-STI, C. Bracco/TE-ABT): Analyse if a limit in the number of consecutive dumps or a minimum time between the dumps is required for Run3 operation.
- **Improved instrumentation for the dump** includes Pt100 sensors to monitor the temperature evolution and LVDTs to measure the permanent dump displacement.
- It was discussed if the **interlock strategy** should be adapted in view of the new hardware and instrumentation. Currently, the nitrogen pressure inside the dump assembly is interlocked. With the new instrumentation in place, one could foresee additionally interlock capabilities:
    - **Interlock on the external temperature of the dump vessel** (Pt100 sensor)
        - Jan asked for which failure case the temperature interlock should be designed. Marco explained that the stainless steel vessel should be protected from overheating and a temperature of 400°C to 500°C is considered acceptable.
        - Jan remarked that the temperature will build up in case of successive dumps, and that the pressure rise in the vessel should also be indicative for the temperature increase.
        - Daniel asked where the pressure is currently measured. Marco answered that the sensor is located at the expansion vessel approximately 10 m from the dump.
        - Markus suggested to perform a worst-case simulation for a high-intensity dump every two hours. Marco confirmed that this is indeed planned.
        - Daniel wanted to know how many Pt100 sensor would be installed. Marco replied that it is currently planned to install 9 sensors.
        - Daniel asked about the risk of failing temperature sensors due to the radioactive environment. Marco answered that the Pt100 sensors should be able to withstand the radiation, but that there are concerns that they might be mechanically detached by the movement of the dump assembly.
    - **Interlock on the permanent mechanical displacement of the dump** (LVDT)
        - One would require a 'grace period' to avoid interlocking on the initial expansion within the first 1 to 2 hours.
        - Replying to a question by Jan, Marco confirmed that the last part of the nitrogen supply line is flexible to allow for mechanical movement of the dump block.
        - Jorg asked if a hardware interlock should be foreseen for this purpose. Jan replied that it depends on the criticality of the failure case. Daniel added that one could foresee a hardware interlock but do not activate it directly after LS2. He stressed that, if a hardware

        - interlock is required later during Run3, one would need to install it already during LS2.
        - Action (M. Calviani/EN-STI, MPP): Decide if hardware interlock possibilities for the permanent mechanical displacement of the dump have to be foreseen.
- Markus remarked that the **likelihood of having leaks** should considerably decrease with the implementation of the proposed changes. Therefore, one should re-define/re-confirm the long-term interlocking strategy following the hardware implementation post LS2.
- Daniel asked what **dump upgrades** are planned **for HL-LHC**. Marco replied that it is considered to install a new dump vessel made out of Ti and a new graphite core (lower density graphite in the beginning, higher density in the end) to reduce the peak temperature without changing the overall length of the graphite assembly.
- Christoph asked about the current status on the **characterisation of the graphite material properties** used in the dump core. Marco replied that there are no new findings and that results from the ongoing study are expected within a few years.

1.3 Proposal for orbit interlocking in Run3 (Jorg Wenninger)

- Jorg presented a proposed **new way of interlocking the LHC beam orbit via the SIS**.
- Currently, a **3-way strategy is implemented** to interlock the orbit a) at injection, b) in stable beams and c) during the cycle (ramp, flat top, squeeze, adjust). During injection and in stable beams, there exist clearly defined target orbits, which allow to set tight interlock tolerances. However, **during the cycle the reference orbit can change up to several millimetres** in parts of the machine, due to the change of e.g. crossing angles, separation or ATS dispersion bumps. Therefore, using a tolerance window around a single reference value implies to use large tolerances, which makes the interlocking inefficient.
- For this reason, Jorg proposed to change the interlock strategy during the cycle. He presented **three possible new options** (Slides 4-6):
    - **Option 1:** Build a server that works on the same principle as the power converter **(PC) interlock server** but that uses the BPM readings instead of the measured PC currents. It would be based on reference and tolerance functions for all BPMs throughout the cycle.
        - Replying to a question from Jan, Jorg estimated that several man-months of work would be required to implement this option.
    - **Option 2**: Build a server that works along the same principle as the **LHC state tracker**, but uses reference and tolerance functions for all BPMs as tracked parameters. The BPMs could be grouped to reduce the number of subscribed parameters.
        - Answering to a question from Daniel, Jorg confirmed that the BPM functions would be based on the expected values.
    - **Option 3**: Use the actual reference for the **Orbit Feedback (OFB)** as reference for the SIS. This option would be based on the SIS orbit interlock logic but using dynamic references with a fixed tolerance window throughout the cycle. The disadvantage is that the two systems would not be fully independent anymore. Therefore, if the OFB is stuck or if the

published reference is not correct, one will interlock on the wrong reference.

- Matteo remarked that if the reference is wrong, you might believe to be protected by this interlock, but it is effectively not working.

- **Option 1 is the preferred option, but might not be possible to implement during LS2** due to a lack of resources. Option 2 is, without using published data grouping, in principle already available, and could later be extended to Option 1. The third option is SIS-internal and could be implemented by OP during LS2.
  - In case that no resources can be allocated during LS2, Jorg proposed to implement Option 3. If more resources become available, one should go for Option 2 or, preferred, Option 1. In any case, Option 1 should remain the long-term goal.
  - Markus added that very limited MPE resources are available until the start of hardware commissioning (September 2020), but more resources might become available afterwards to contribute to such a development.
- Daniel summarised that **the proposed strategy is endorsed by the MPP**. He emphasised that Option 3 would already be an improvement compared to the current situation, but Option 1 is clearly preferred.
  - Jan stressed that it would be definitely worth to go to Option 2 during LS2, which would also allow to check if the orbit reference is correct, with a possible upgrade to Option 1 during a YETS.
- Action (J. Wenninger/BE-OP): Verify available resources to implement the new orbit interlocking during LS2.

1.4 Open Actions

The actions from the meeting are:

- Action (M. Calviani/EN-STI, C. Bracco/TE-ABT): Analyse if a limit in the number of consecutive dumps or a minimum time between the dumps is required for Run3 operation.
- Action (M. Calviani/EN-STI, MPP): Decide if hardware interlock possibilities for the permanent mechanical displacement of the dump have to be foreseen.
- Action (J. Wenninger/BE-OP): Verify available resources to implement the new orbit interlocking during LS2.