# 202nd Meeting of the Machine Protection Panel

## LHC topics

December 11th, 2020 via Zoom

*Participants*:

*Marco Calviani (EN-STI), Mario Di Castro (BE-CEM), Simone Gilardoni (EN-STI), Cedric Hernalsteens (TE-MPE), Keith Kershaw (SY-STI), Anton Lechner (EN-STI), Jorge Maestre (SY-STI), Filip Moortgat (EP-CMG), David Nisbet (SY-EPC), Brian Petersen (EP-ADT), Andrzej Siemko (TE-MPE), Claudio Torregrosa (SY-STI), Jan Uythoven (TE-MPE), Jorg Wenninger (BE-OP), Christoph Wiesner (TE-MPE), Daniel Wollmann (TE-MPE).*

The slides of all presentations can be found on the website of the Machine Protection Panel and on Indico (202nd meeting).

## Minutes from the 198th MPP meeting (LHC topics)

Daniel recalled the actions of the 198th MPP meeting. Jorg commented on the aperture measurement in IR8 which was considered during the meeting: the Alice beam pipe to be installed by the end of LS2 has an aperture of only 13 sigmas (N1 value). Jorg suggested to perform an aperture measurement also in IR2 (at injection). The panel agreed that a future MPP topic should be scheduled on "LHC aperture measurements required at injection energy".

With these comments, the minutes are approved.

## Overview of the mechanical response of the LHC dump and installed instrumentation for its monitoring during Run3 (Jorge Maestre, Claudio Torregrosa)

Jorge presented an overview of the upgraded TDE and its instrumentation. A complete engineering report is also available on EDMS (EDMS-2437709). These minutes follow the general structure of the presentation, as detailed below.

### Overview of the pre-LS2 configuration and instrumentation

Claudio presented the TDE design in its pre-LS2 configuration. The beam-absorbing elements consist of 3 sectors of graphitic materials encapsulated in a steel vessel (12mm thickness) filled with $N_2$. The upstream part is made of isostatic graphite, the middle sector is made of "expanded graphite" (low-density graphite - sheeted), the downstream sector is made of graphite with the conventional density.

An energy of 23.4 MJ is deposited in the vessel itself due to the showers during a nominal beam dump with Run III parameters.

**Questions and comments** Jan asked about the meaning of the temperature plot on slide 6. Claudio replied that it is the temperature at the end of the pulse, in the vessel (steel). Christoph asked about the beam parameters. The plot corresponds to Run II parameters. Anton added that the temperature is for the steel shell, not for the graphite.

Before the upgrade the TDE blocks were connected to the beam line via a connection line (10 m) filled with over-pressure $N_2$. A CFC-steel UHV window was separating the beamline and the connection line.

Nitrogen leaks started from 2015 in both dumps, consistent with an increase in the dumped intensity. Under-pressure of the $N_2$, following the recovery from the over-pressure (due to the temperature increase) triggered interlocks on some occasions. It was discovered that the leaks were coming from the connection flanges on both ends of the connection line and from the downstream flange at the end of the blocks.

Mitigations and monitoring measures were taken during Run II:

- Leak detection, tightening of loosened fasteners, and the addition of lock screws;
- Replacement of damaged helicoflex gaskets;
- Modification of the $N_2$ supply system (continuous injection);
- Installation of interferometers.

The interferometers point to the upstream and downstream ends of the connection line. They record the longitudinal displacement at fast and slow acquisition rates. Fast oscillations were observed (200 ms) and slow displacements were also recorded (more than 6 mm) over multiple dumps.

## New requirements and upgrade for post-L2 operation

The new requirements come from the increased deposited energy for Run III. The energy deposited in the vessel is quite relevant as it leads to the mechanical and dynamics effects. Failure scenarios are also taken into account (2 MKBH missing, flashover in kicker tank and retriggering). The bellows have been rigidly blocked to avoid a downstream moving of the blocks.

## Thermo-mechanical behavior of the TDE dump and windows

The fast movements are due to the sudden temperature increase in the vessel. The slow movements are due to the thermal diffusion from the core to the vessel.

A complete thermo-mechanical simulation and analysis of the TDE has been performed to understand these effects. A longitudinal expansion is confirmed by simulations. Short timescale simulations were also performed to understand the fast oscillations. The agreement between the measurements and the simulations of the oscillation frequency is within 2%.

The TDE is transmitting all these vibrations. The Run III upgrade has then focused on de-coupling the dump from the connection line. The line has been removed and a new window has been installed. In addition, the TDE blocks are now suspended on new supports. There is no propagation of vibrations to other elements and the dump can expand freely. This is a suitable mitigation for the permanent displacement of the dump.

A new upstream window has been designed. It is a 10mm Ti-Gr5 clamped window. The new downstream windows is a bolted 10 Ti-Gr5 window.

## Performance monitoring, instrumentation and protection

Based on the simulation findings, a new monitoring strategy has been defined to:
- Cross-check the accuracy of the simulations (temperature, magnitude of the vibrations, modal behavior)
- Monitor the behavior of the newly implemented features (permanent displacements, behavior of the new rope-hanging system, thermal loads in the downstream window).

The thermal response is measured with PT100 probes. The dynamic response is monitored with strain gauges, LDV (laser-based velocity measurement), accelerometers and trigger system (for the dynamic response). For the slow movements, a LVDT is used. In addition, general monitoring is performed with microphones, a camera and N2 pressure gauges.

**Question** Jan asked a question about the cumulative effect of multiple dumps on the temperature and if the PT100 are limited in term of maximum temperature. Claudio replied that there is enough margin.

The electronics for the instrumentation is located 80 m upstream of the dump cavern in a shielded location below the dump line.

## Summary and conclusions

The major issues observed during Run II are related to the dynamic behavior of the TDE dump. The TDE upgrade aims at solving the observed issues. The main goal of the new instrumentation is to increase the understanding of the operational behavior of the TDE and improve the simulation quality. This will be essential for the potential LS3 upgrades or future designs. The instrumentation is made to provide monitoring of the TDE dump but is not sufficiently reliable to interlock on any of the monitored parameters.

**Questions and comments:**
- Christoph asked if the camera can be triggered on-demand. Jorge replied that different acquisition frequencies can be set remotely.
- Christoph asked how quickly the newly designed windows can be replaced. The downstream window cannot be replaced because it is clamped. The upstream window can be exchanged within a few hours.
- Jan asked if the $N_2$ bottles are kept. The same system will be used as before (rack of bottles on top of P6 and a long line).
- It is an open question if we need to interlock on the $N_2$ pressure sensor. The signal names in the SIS should be verified. Mario commented that the present system should

be kept in the SIS, while keeping in mind that it will need to be consolidated. Jorg commented that one pressure gauge is not working at the moment.

- Daniel asked about the logging of the instrumentation to DFS and if it would be better to consider the post-mortem database. The fast data at each beam dump could be saved in the post-mortem. This is planned for Run III (NXCALS and post-mortem).

**Action**: Update signal names for $N_2$ pressure gauges interlocked in the SIS and re-establish the SIS injection interlock on too low $N_2$ pressure (Mario Di Castro, Jorg Wenninger).

## Summary of actions

The actions from the meeting are:

- Overview of the mechanical response of the LHC dump and installed instrumentation for its monitoring during Run3:
    1. Update signal names for N2 pressure gauges interlocked in the SIS and re-establish the SIS injection interlock on too low N2 pressure (Mario Di Castro, Jorg Wenninger).