225th Meeting of the Machine Protection Panel

LHC topics

June 3rd, 2022, via Zoom

Participants:
TODO

The slides of all presentations can be found on the website of the Machine Protection Panel and on Indico (225th meeting).

Minutes and actions from the 224th (LHC topics, joint meeting with CollWG)

The minutes were circulated, and the actions have been circulated. No comment was raised, and the minutes are approved.

TCDQ/TCDS for Run 3 and HL-LHC: Characterization, Simulations and HRMT-56 Test Results (Pablo Andreu Munoz)

Pablo first recalled the geometry and in-operation assessment of the TCDQ and TCDS. The TCDS is a fixed diluter block installed immediately upstream of the MSD septa. The TCDQ is a mobile diluter block to protect the Q4 magnet. An asynchronous firing of the MKD kickers would cause the beam to sweep over the septum walls.

The TCDS is composed of two parts. The TCDSU, made of three parts: 0.5 m of graphite (1.8 g/cm3), 0.5 m of CFC (1.7 g/cm3) and 2 m of CFC (1.4 g/cm3). The TCDSD is also made of three parts: 1.5 m of CFC (1.7 g/cm3), 1 m of graphite (1.8 g/cm3) and 0.5 m of Ti-alloy (4.4 g/cm3). All graphite and CFC parts are Cu coated. Fluka simulations have been performed to obtain the energy deposition profile of an asynchronous dump at 7 TeV.

The TCDQ is a 10.4 m long 3-tank system with 9 m of absorber installed 12.5 m in front of Q4. Each tank contains 12 absorber blocks, all made of CFC with two different densities (1.75 g/cm3 and 1.4 g/cm3). The block reaching peak energy density was identified from a Fluka simulation of the energy deposition of a 7 TeV asynchronous dump.

The study aimed at solving past issues related to the available characterization of the properties of the CFC. In addition, available material data characterize CFC as a homogenous material despite its layered structure. A correct non-isotropic treatment is required as the beam impact occurs within 1 layer (1.5 mm). The installed material was re-characterized with a dedicated layered characterization to serve as input for the simulations. Representative samples were then assessed during the HRMT-56 experiment end of 2021.

It must be noted that the characterization data confirmed a long pseudo-plastic regime of damage evolution for the CFC samples until complete failure, in contrast with the brittle behavior of graphite.

Pablo then presented the simulation results for the TCDS. The temperature profile resulting from the beam impact is first obtained, and then used in a mechanical model to obtain the maximum principal stresses which are used as input for Christensen's inverse damage criterion. No damage is detected for the second TCDS block. For the 9th block, possible damages are present at the entrance and exit faces, localized on the edges. Localized failures were possible identified for the 19th block.

Results from the simulations show that the CFC blocks of the TCDS are expected to be safe and not trigger operational issues. Localized damages are not propagating. The graphite blocks are brittle, meaning that reaching maximum strength can lead to sudden fracture. However, no critical failure is expected for the graphite (C2020) blocks.

For the TCDQ blocks, possible localized damage was identified for the 4th block. Similar results were found for the 8th block. Block 8 is the most loaded but the compression in the first layer, although high, is very localized along a line and is expected to be safe for operation.

Analyzes of the HRMT-56 samples found no damage on the TCDQ high-density samples. The same analyzes were applied to the low-density TCDQ samples. No damage was observed. For the TCDS high-density and low-density samples, again, no damage was found.
The conclusions for the TCDQ and for the TCDS are as follow. No operational limitations were found for the TCDQ during Run III. The CFC blocks are expected to be robust enough. The TCDQ blocks are forecasted to be suitable for HL-LHC. The local damage on CFC is not expected to involve operational limitations. The graphite and CFC blocks of the TCDS do not present limitations for Run III. The TCDS graphite blocks integrity is however not guaranteed for HL-LHC. The replacement of graphite blocks within the TCDS by CFC blocks could be considered. The Titanium alloy blocks of the TCDS present distortion that remain acceptable for bunch intensities up to 1.8e11 ppb. Simulations show plastic strain reaching 1.2% for HL-LHC intensities (2.3e11 ppb) and material integrity for several accidental shots should be assessed.

Discussion

Matteo asked about the limitations of the TCDQ material for HL-LHC. It appears that the blocks are fine for Run III and that they are expected to be suitable for HL-LHC as well. Pablo clarified that indeed no operational limit is identified for HL-LHC now.

Christoph asked which waveform is assumed for the asynchronous dump. This will be clarified offline by Anton.

Jan asked about the limitations for the TCDS and if they are solutions available. Pablo replied that Sigraflex would be suitable and that other CFC-based materials are being assessed. Jan then asked about the Ti-alloy. Pablo replied that one option is to change the alloy and its grade. CFC/Si-carbide options are also investigated. François-Xavier added that it is not yet confirmed that the Ti-alloy blocks would need to be replaced for HL-LHC, and that the simulations need to be investigated further. Anton is checking the option of replacing the Ti-alloy blocks by CFC blocks with reduced absorption capability.

Yann commented that it should be confirmed that these permanent deformation on the TCDS are not acceptable for operation, as the TCDS is far from the circulating beam. François-Xavier agreed and added that one also needs to evaluate the probability of asynchronous dump events. Yann replied that these are indeed very rare events (not multiple events per year). François-Xavier commented that multiple shots should be acceptable but that an accumulation of plastic strain would be detrimental. Pablo commented that this would be an issue for the brittle graphite blocks. Yann asked if broken blocks would fall away from their support. François-Xavier added that one would indeed macroscopical cracks, but these have never been observed at HiRadMat.

Yann asked about the support mechanism for the TCDS graphite blocks, and if a fractured block could fall-off. François-Xavier and Pablo replied that the blocks are under compression by a spring and can lead to different consequences (sliding or movement inward). François-Xavier suggested to follow-up on Yann's suggestion of considering if the upgrade of the blocks is necessary for HL-LHC within WP 14. The exchange of the blocks is part of the current baseline. Matteo confirmed that the final decision is the responsibility of WP 14 but that the MPP could provide recommendations. Christoph agreed and asked that the worst-case consequence of the cracking of the graphite blocks is characterized.

Summary of actions

No action has been identified.