230th Meeting of the Machine Protection Panel

LHC topics

October 21st, 2022, via Zoom

Participants:
C. Bracco (SY-ABT), R. Bruce (BE-ABP), A. Butterworth (SY-RF), F. Carlier (BE-ABP), M. D'Andrea (BE-ABP), P. Hermes (BE-ABP), C. Hernalsteens (TE-MPE), M. Le Garrec (BE-ABP), A. Lechner (SY-STI), B. Lindstrom (BE-ABP), E. Maclean (BE-ABP), L. Mether (BE-ABP), F. Moortgat (EP-CMG), K. Paraschou (BE-ABP), B. Petersen (EP-ADT), V. Rodin (SY-STI), B. Salvachua Ferrando (SY-BI), R. Steerenberg (BE-OP), G. Sterbini (BE-ABP), J. Uythoven (TE-MPE), A. Verweij (TE-MPE), 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 (230th meeting).

Minutes and actions from the 229th (LHC topics)

The minutes of the 229th MPP on the FRAS are available. The actions are to prepare the detailed specifications for the interlocks (FRAS team) and to distribute the specifications (F.-X. Nuiry and WP5).

MKI RF damper cooling interlock strategy (M. Barnes)

The new MKI-COOL is planned to be installed in IR8 during the YETS. To reduce beam induced heating, MKIs were refurbished during LS1 and 24 screen conductors inserted in slots on the inside of an alumina tube (instead of the original 15). The alumina tube is installed in the aperture of each MKI kicker magnet. A set of ferrite rings is installed on each end of the alumina tube. With HL-LHC type beams, the RF damper rings and part of the ferrite yoke would reach its Curie temperature (resulting in loss of magnetic properties). The RF damper in the MKI “COOL” will allow to reduce the beam induced heating.

During the YETS 2017/18, the MKI8D was installed with a redesigned ferromagnetic ring (RF damper) to relocate the beam induced power from the ferrite yoke to the damper. The RF damper is not at pulsed high voltage. It reduced the yoke temperature but still required further improvements to reduce the maximum temperature reached for HL-LHC beams.

The cooled version, MKI-COOL, features the RF damping elements and additional includes water cooling. The MKI-COOL is expected to operate significantly below the ferrite’s Curie temperature for HL-LHC type beams. There is no brazing inside the vacuum tank, all joints are outside.

The cooling circuit uses demineralized water from the tunnel, with a needle valve to reduce the pressure. An Eletta flow monitor with direct reading dial with independently adjustable upper and lower flow alarm will be implemented. The status of the low-flow and high-flow micro-switches (dry contact) will be read back by the PLC of SY-ABT. Two PT100 are installed on the cooling pipes (outside the MKI vacuum tank) and one PT100 is installed on the RF damper. A "turbine" analogue signal will be installed to readback analogue signals proportional to the flowrate using a radiation resistant sensor.

The low-flow micro-switch from the Eletta flow-monitor will be used as an interlock, to prevent injection and to request a beam dump if the water flow is too low to prevent possible boiling of the water in cooling pipe, resulting in a high pressure. The low flow micro-switch will be cabled to a SY-ABT PLC requesting a beam dump via the BIS. The upper flow alarm will be used as a warning. A temperature interlock to dump the beam through the BIS will use the RF damper PT100 probe. The threshold value will be a FESA property, which would allow in the future to implement in addition a SIS interlock. All values will be logged (WinCC and NXCALS).

Jorg mentioned that a SIS interlock is not required as there is already HW interlock implemented via the BIS. Mike agreed that it may not be required at all. Daniel confirmed.

Daniel asked how the interlock and logged data are generated. The probes will be connected to the PLC, which will have a direct connection to the CIBU for the interlock.

Daniel asked about the reliability of the PT100 probes and how well these sensors are expected to measure the actual temperature of the damper and cooling pipes. Mike replied that the used PT100s are expected to suffer much less from EM interferences than regular off-the-shelf PT100. The connectors outside the tank will be protected from mistreatment. Mike confirmed that the thermal contact is excellent due to the brazing which is used on the ferrite.

Daniel concluded that the MPP endorses the proposed interlocking via the ABT PLC and the BIS (flow switches and temperature sensors).

BCCM commissioning experience and status (M. Gasior)

Marek summarized the working principles of the BCCM (dI/dt) system. The signal from a BPM is amplified, the electrodes are summed and sent to an edge detector. A low-pass filter is applied before the ADC (16 bits) and performs a sampling at 40 MHz. The signal processing provides the "raw dI/dt signal" as a difference between two consecutive turns. The signal in the five integration windows is calculated as running sums of the one-turn raw signal. Each running sum is compared every turn to their threshold and a potential beam dump trigger is generated. All real-time calculations are done in the FPGA in an integer arithmetic.

Marek mentioned the proposed changes of the thresholds to be better aligned to the BLM thresholds and make the system less sensitive to other effects.

The intensity measured by the BCCM varies (in the order of 0.5%) due to the change in bunch length during the ramp. This is not an issue if the changes are slow. For the longest integration window, and the present thresholds, a beam dump would be triggered by the BCCM seeing fake intensity changes induced by the RF blow-up. Fast bunch length changes perturb the system. The effect was confirmed during a fill where the longitudinal blow-up was active for only one beam.

A first attempt to address the issue consisted in adjusting the window lengths, so that they are not close to multiples of the synchrotron period. Window lengths of 420 and 840 turns are good candidates to cover the whole energy range.

A second attempt is to add a first order low pass compensation. This comes at the expense signal reduction by 80%. This is currently being tested on the Beam 1 "A" system. One issue concerns the stability of the signal baseline.

During the 2022 run the four BCCM systems have been evolving quite a bit and have been tested with beam. The hardware and FESA are close to final and very reliable. Extensive logging of operational data is implemented, including continuous turn-by-turn logging of the most important data, and on-demand 73-turn snapshots of the 40 MHz raw ADC samples (currently also stored every beam dump).

The residual bunch length dependence of the BPM signals is the only known problem with the current implementation of the system. The problem shows up during beam injections and when the RF longitudinal blow-up is active.

Marek proposed to investigate the two options. First, a less aggressive first order low-pass filter. Secondly, to investigate using the FBCTs as beam signal source, as they have a flat frequency characteristic.

Jorg commented that the RF longitudinal blow-up will also be used in stable beams in the future and not only during the ramp. The response of the system should be verified in that situation.

Raffaello commented that the energy information should be received by a standard timing card instead of decoding the signal in the FPGA. Alternatively, a flag could be sent externally to swap between the two energy levels.

Daniel asked what the plan is for 2023: are we ready to make the interlocks active? Marek replied that the two options need to be investigated until the end of the year before decisions can be taken for 2023.

Daniel agreed that the topic will come back to the MPP after the end of the run to propose how the system will be used in 2023.

Action: Report on the options tested to minimize the bunch length dependence of the BCCM signals in the MPP in December 2022 or January 2023 (M. Gasior).

Proposal for adjusted BCCM thresholds (C. Hernalsteens)

Cedric gave an overview of the requirements that the BCCM thresholds should satisfy. The BCCM is meant to interlock on global losses, as a redundancy to the BLM system. The BCCM is not meant to be a primary beam loss interlock, so a margin should be kept on top of the BLM threshold levels.

The present thresholds have two energy levels (below and above 0.5 TeV), and 6 integration windows (from 1 to 1125 turns). The integration windows correspond loosely to RS2 to RS6 of the BLM system.

The basis for the BCCM thresholds are the BLM thresholds in the collimation region in IR7, as global losses are expected to be located in IR7, which are in turn based on the damage limits. Other types of local losses cannot be protected against with the BCCM.

Cedric showed how the BCCM and BLM thresholds compare. It is observed that the thresholds for the two longest BCCM running sums are decreased as compared to the previous RS and reach levels lower than the BLM thresholds.

The proposed thresholds are shown in Table 1.

Energy	Integration window length						
	1	4	16	64	225	1125	
	89 us	356 us	1.4 ms	5.7 ms	20.0 ms	100.1 ms	
	Dump threshold levels in 10^{11} charges						
< 0.5 TeV	6	6	6	6	6	6	Initial
< 0.5 TeV	6	6	6	6	6	10	Proposal
>= 0.5 TeV	3	3	3	3	2	0.5	Initial
>= 0.5 TeV	3	3	3	3	5	10	Proposal
	Dump threshold levels in 10^9 charges per turn						Initial
>= 0.5 TeV	300.0	75.0	18.8	4.69	0.89	0.04	Proposal
>= 0.5 TeV	300.0	75.0	18.8	4.69	2.22	0.89	

Table 1 Proposed BCCM threshold values.

Belen commented that it is a good approach to align the BCCM thresholds to the damage limits for the collimators, as the losses are expected to be localized in IR 7.

Daniel concluded that the MPP endorses the proposal to update threshold specification of the BCCM.

AOB – Combiner and BCCM connection to BIC (T. Levens)

Tom mentioned that the combiner has been developed by the BI team. He therefore proposes to change the connection scheme of the BCCMs so that all systems can be connected to maskable BIS channels.

The MPP thanks the BI team for development of the combiner and endorses this proposal.

Plans for LHC Pb ion test (R. Bruce)

Roderik presented the plan for the 2022 2-day ion test foreseen in November. The objectives of the test are to provide Pb-Pb collisions to the experiments, to the new ALICE detector, and to learn as much as possible on the machine side to finalize the energy choice, and for future performance estimates and optimizations.

The plan is to provide stable beams conditions at the new record-high energy. Crystal collimation tests will be performed, and the slip-stacked beams will be tested for the first time in the LHC.

The tests will be performed with low intensity (< 3e11 charges / beam) using the standard proton cycle to minimize the time necessary for commissioning and validation. 36 hours are allocated.

The required commissioning activities include the transfer line steering, LHC injection and RF setup.

The crystal collimation test prepares the Ion operation for next year, which relies on crystal collimation. The hope is to improve the availability and minimize the 10 Hz dumps with improved cleaning efficiency. The main study will be the cleaning performance, which is a critical input for the decision on the beam energy next year. The test will require 20 non-colliding bunches per ring (staying below 3e11 charges / beam). The test will be performed at flat top.

The future LHC Pb ion physics program relies on the new slip-stacking in the SPS. The goal of the test is to setup, inject and study short slip-stacked trains of 8 bunches.

The last part of the ion test are physics fills with stable beams conditions. The first fill relies on single bunches (similarly to the Xe run) and 4 non-colliding bunches for loss maps. The goal is to validate with loss maps on the fly. For the second fill, two slip-stacked 8-bunch-trains will be used.

A change of the ALICE crossing angle will be required: reversing of the spectrometer polarity and reduction of the external crossing angle at or below 172 μrad to be within the ALICE ZDC acceptance. Before trimming the crossing angle, the IR2 TCTs will be opened symmetrically. Roderik recalled that the aperture in IR2 is large (> 40 sigma) due to the large beta-star values.

The machine protection validation conditions for stable beams are as follows:

- The standard proton cycle and collimator settings are used, the aperture is fully protected
- A beam fulfilling the “setup beam” condition will be used (< 3e11 charges), with about 1.5e10 charges per bunch. For asynchronous dump with single bunches, only one could hit, with 2 8-bunch trains, more bunches could be affected, but the bunch spacing is 50ns.

A “light” validation is proposed similar to the 2017 Xe test, when betatron loss maps were performed just before stable beams.

The proposed procedure is:

1. Go to end of squeeze
2. Insert crystal, open IR2 vertical TCTs symmetrically
3. Go in collision (change of ALICE crossing in beam process), optimize
4. Perform betatron loss maps, validate on the fly
5. Declare stable beams.

The number of masked interlocks must be reduced as much as possible, at the same time it should be avoided to dump unnecessarily.

The optional activities for the ion test include the verification of the ZDC acceptance, the exploration of the beam-beam limits and the test of the TCLDs in IR2 to intercept BFPP ions. If this is tested, a bump in IR2 will be required.

Belen asked if changes of the BLM threshold are expected and if they should be lowered. With the present thresholds the intensity would be too low to dump on loss in IR7. Roderik commented that the intensity is very low and that the TCT will be safe. The hierarchy will be guaranteed as it is the same cycle as for protons. Daniel concluded that the global protection via the BLMs in IR7 is not present and that we will rely on the local protection by the BLMs in the ring.

Daniel asked if we could perform an async. dump test prior to the fill with the trains. Roderik reminded that each bunch is like a fat pilot bunch. Daniel agreed that this is not a strict requirement. An asynchronous dump test will be optionally performed at the end of the first fill.

Daniel commented that the TCLD insertion and bump should be done before the loss-maps or as end of fill in Adjust mode if the BLM readings look promising.

Daniel concluded that the MPP endorses the proposed machine protection validation procedure.

Summary of actions

The actions from the meeting are:

- BCCM commissioning experience and status
    1. Report on the currently tested options to minimize the bunch length dependence of the BCCM signals (M. Gasior)