245th Meeting of the Machine Protection Panel

LHC topics

March 22nd, 2024 in hybrid format.

Participants:

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The slides of all presentations can be found on the website of the Machine Protection Panel and on Indico (245th meeting).

Minutes and actions from the 243rd and 244th meetings

The minutes of the previous two MPP meetings have been circulated. Daniel recalled the actions from the 243rd and 244th meetings. For the 243rd meeting, the only action concerns the follow-up regarding FLUKA simulations to guide the TCL settings. For the 244th meeting, the only action concerns the enabling of the BIS input of the BCCM which is to be followed-up with the MI team.

SPS bunch intensity interlock using the FBCT in BA3 (T. Levens)

Tom first summarized the event on 9 March 2024 when bunches were injected from the PS to the SPS with an intensity of 4e11 ppb. The OP crew noticed after two injections. The injections took place on a 4-batch SPS cycle. Three cycles were eventually injected like this, and the beam circulated at flat bottom for about 7 seconds. This led to vacuum spikes on the MKE. The beams were dumped by vacuum interlock and one hour of re-conditioning was required to reach the baseline vacuum levels.

The issue was traced to the failure of the 1st double splitting in the PS, due to the incorrect phasing of the 20 MHz cavities. In such a situation, the majority of the “macro bunch” intensity ends up in the first pair of 25ns bunches. An electronics board was replaced by rf experts, however the issue reoccurred over the weekend on March 16. In that occurrence, 5e11 ppb were injected. There are indications that similar events also took place in 2023. A new interlock is proposed to mitigate this failure mode.

Tom presented three potential options for the interlock. The first option would feature an interlock at the PS level. This would prevent from injecting the beam in the SPS in the first place. However, in the PS, the 1^{st} double splitting happens only 60 ms before extraction. Sending the beam to the external dump (TT2-D3) requires inhibiting the BHZ370 ramp-up 350 ms before extraction. In addition, there is no operational FBCT at the PS flat-top. One possibility would be to observe the 1^{st} double splitting using the wall current monitor OASIS acquisition, then inhibit the extraction kicker and finally trigger the internal dump using the existing DC BCT intensity comparator mechanism. This would however require a longer flat top. Nevertheless, a failure of the 2^{nd} splitting would pose the same problem and the available time at flat top would not be sufficient. This option does not appear viable at the moment.

The second option is to interlock using measurements in TT2-TT10. The SPS FBCTs in TT2-TT10 measure the bunch-by-bunch intensity and a FPGA is available to implement a hardware interlock. However, the propagation time from the TT2 to the SPS injection kicker is only 2.5 us. Even time permitting, inhibiting the injection in such a case does not appear to be a desirable option.

The third option, which has been implemented, interlocks based on circulating beam intensity during the first turns in the SPS and dumps the beam to the SPS external dump. The interlock relies on the SPS ring FBCT in BA3. Using 20 ms averaged data (which is the typical averaging time of the device) the beam would be dumped 20 ms after injection. Using the raw data from the FBCT would allow a faster reaction time but would make the "post-mortem analysis" more difficult as it would not be visible on the logged FBCT data.

The option of a SIS interlock discussed was also discussed, but would only evaluate the intensity at the end of the cycle and not inhibit further injections. An adaptation would be possible, but would add complexity to the operation.

An existing cable from the BCT3 CIBU, which was removed during YETS has been reused. The implementation only required minor firmware and software work on the FBCT, the reinstallation of a CIBU and the connection to the BIS.

A single non-PPM threshold set to 3.5e11 is used: any bunch intensity measurement from the FBCT exceeding the threshold will trigger a dump. The value of 3.5e11 is used to cover the high-intensity AWAKE beams. The threshold is a single LSA parameter (updated after the meeting: this parameter is now MCS). If the interlock triggers the beam dump, further injection onto the same SPS cycle will be inhibited. The FPGA and FESA implementation was tested in the lab on March 19. The deployment and hardware installation was performed on March 20. The validations with beam were performed in the afternoon of March 20.

Discussion

Jan asked if the interlock is latching. Tom confirmed that the remaining injections on the same SPS cycle will be inhibited. Latching for subsequence SPS cycles would be more difficult. If the same issue happens, as the beam will remain in the SPS for only around 20 ms, the impact will be very limited.

Belen asked if the LSA parameter is protected. Tom replied that it should be.

Action: Ensure that the LSA parameter controlling the threshold is properly protected (T. Levens). It has been confirmed that the LSA parameter is now MCS.

Daniel and Jan requested the writing of an ECR to document the present implementation.

Action: Document the interlock implementation in an ECR (Tom).

Jorg commented that the LHC is protected against these kinds of events by the BQM. The BQM would capture the imbalance in intensity. Kevin highlighted that the goal of this interlock is the protection of the SPS and that the LHC is indeed already covered.

Daniel concluded that the MPP endorses the implementation of the interlock and thanked all the teams involved.

First experience with beam regarding the reduced sensitivity of the newly installed BLMs (B. Salvachua)

Belen presented the first data analysis regarding the newly installed BLMs in IR7. The results of BLM latency tests are discussed at the end.

As a reminder, during the 2023 proton run losses in IR7 during the injection process regularly dumped the beam with trains of 236b. The losses were above threshold only for Beam 1. The fast losses in running sum 1 (RS1) reached saturation at the BLM electronics limit.

Using downstream BLMs that did not saturate it was possible to express the fast beam losses in terms of number of protons impacting the primary collimators at injection. It is emphasised that although these losses are not a direct concern for machine protection, the solution would have MP consequences. The SEMs installed in IR7 cannot be used as their sensitivity is too low compared to the IC BLM (by a factor 70 000). Ten of them were replaced by LICs (Little Ionisation Chambers) in IR7, which have a response factor 14 times lower than the IC BLMs. To completely avoid saturation before reaching the damage limit of the primary collimators, a factor 100 times lower response would be required.

New IC BLMs have been installed in 6L7. Two sets of BLMs were installed: about 40 cm displaced from the current BLM positions and along the inside wall of the tunnel. The details are provided in the ECR (EDMS 3019883). The response of displaced BLMs has been evaluated in simulation.

Tests at injection were performed on March 11. A low intensity beam was injected with closed TCP jaws. The results show that the “standard” BLMs and the displaced BLMs are in saturation. The BLMs installed on the wall do not saturate and have a suitable response factor. The saturation of these wall BLMs would occur for 3.0e10 protons impacting the horizontal collimator and for 3.4e10 protons impacting the skew collimator.

The data from the LIC have not been analysed so far. For the moment, they cannot be used operationally as interlocking BLM as their stability over time must first be assessed.

Scraping tests were performed to assess response factors of the wall BLMs with circulating beam. The tests were performed on March 16 were inconclusive as the losses took place in more than one plane at a time. The scraping at very low intensity indicated that the wall BLMs can resolve beam losses from direct impact at the collimator in the range 1e6 to 1e7 protons. For the displaced BLMs, the measurements match the estimates from the FLUKA simulations.

Belen then discussed the thresholds strategy for these new BLMs. The final response factors will be derived from the loss maps. The proposal is to create three new families for the wall BLMs. These would be used for interlocking. The BLM for the vertical TCP remains untouched as no limitation was observed in 2023 in the vertical plane. The new families will have the same models as the existing ones, but the response factors will be updated. The signals of the LICs will be monitored during the 2024 run to define the final strategy for the upgrade of the BLM system.

Further studies are required to finalize the thresholds and to decide to move the interlocking to the new wall BLMs.

Jorg commented that the injection of the first trains might happen before the loss maps are finalized. Anton commented that the above be mentioned at the LMC. Jan agreed.

Belen then presented the results of the latency tests. The data was collected by OP following the approved procedure. All IRs were able to trigger a beam dump request within 3 LHC turns. The outlier in IR8 for Beam 2 is a measurement artefact. Indeed the collimator used to induce the losses has a BLM equipped with a low pass filter (TCTPH.4R8.B2). However the IR8 latency is validated by the Beam 1 results.

Daniel asked if these results are comparable to the post-LS2 and 2023 results. Belen confirmed that they are similar.

Christoph asked how the "corrected latency" is computed. Belen replies that the raw results are corrected for the time of flight. Daniel clarified that the specifications are to open the beam permit loop within 3 turns. The results show that for most IRs this delay is actually shorter than 2 turns.

Daniel concluded that the MPP endorses the proposal to define new families for the wall BLMs and to prepare to use them as interlocking BLMs.

LHCb VeLo revalidation strategy (V. Coco)

Victor presented the tests regarding the LHCb VeLo aperture. Metrology measurements were performed in situ and provided good estimates of the aperture. The same features as in 2022 were observed: a slight deformation with respect to the CAD model and a rotation along the horizontal axis of one half compared to the other. This will likely provide a 3 mm aperture in nominal (fully closed) position.

The tomography results can be used as a proxy for aperture measurements. This was used in 2022 for internal tests and in 2023 the tomography results were compared with aperture measurements and were shown to be in good agreement. Victor proposed to use these tomography measurements also in 2024, as the aperture cannot be directly measured when the VeLo is closed.

During the first fill where the VeLo will be closed, a “quick” tomography will be performed with a 2 mm before full closure (as was done in 2022). This will require around 30 minutes of data tacking and 30 minutes of data analysis before proceeding with the full closure. Another “quick” tomography will then be performed with the VeLo fully closed. The first full tomography will be done at the 400 bunch step.

Jan asked how many bunches are required for the “quick” tomography. Victor replied that 2 bunches are sufficient.

Victor then discussed the checks to be performed as part of the intensity ramp-up:

- Vacuum signals
- Motion system
- VeLo temperature
  - Rf foil, SMOG and tank
  - Temperature sensors on the cooled modules: Victor proposed to drop these checks. These readings are dominated by the cooling system. These checks were introduced in 2023 and proved not useful.
- Online tomography: no detailed analysis is possible per fill but it can be checked that the distribution of the interactions with material are similar between intensity ramp-up fills.

The list of checks will be implemented in the intensity ramp-up checklist.

Action: Christoph will follow-up with Victor regarding the preparation of the checklists.

A final topic of discussion concerned the flickering of the beam permit signal that has been observed. On Wednesday morning, during the access a new motion system firmware was uploaded. It included new calibration data. The potentiometer ADC fluctuations shortly brought the reading out of range, producing the flickering of the beam permit. It took 30 minutes to trace the root cause and fix the issue temporarily. A coming update of the firmware will fix the issue permanently.

Jan asked when this new firmware will become available. Victor replied that it can come next week. Jan suggested to ensure that this new upgrade is performed while we are still in the low intensity commissioning steps. Victor replied that it will be coordinated with OP and the machine coordinator.

AOB - Status of the procedure in case of sparking RF finger (D. Wollmann)

Daniel summarised the status of the discussions for the procedure. The slides of the meeting can be found in Indico (https://indico.cern.ch/event/1390492/ & https://indico.cern.ch/event/1394006/). A draft procedure is in preparation. It will be updated shortly and then discussed with MP3. It will be presented at the MPP afterwards and finally presented at the LMC.

Daniel added than comments and further inputs are welcome.

Summary of actions

The actions are:

- SPS bunch intensity interlock using the FBCT in BA3 (T. Levens)
  1. ~~Ensure that the LSA parameter controlling the threshold is properly protected (T. Levens).~~ It has been confirmed that the LSA parameter is now MCS.
  2. Document the interlock implementation in an ECR (T. Levens).

- LHCb VeLo revalidation strategy (V. Coco)
  1. Christoph will follow-up with Victor regarding the preparation of the checklists.