Joint meeting of the 224th Machine Protection Panel and 263rd Collimation Working Group

LHC topics

April 29th, 2022, via Zoom

Participants:
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The slides of all presentations can be found on the website of the Machine Protection Panel and on Indico (224th meeting).

Minutes and actions from the 222nd and 223rd meeting (LHC topics)

The minutes of the 222nd were circulated, with actions that had been summarized already at the 223rd meeting.

Christoph recalled the actions from the 223rd meeting. The minutes have been circulated. No comment was raised, and the minutes are approved.

In-jaw beam-beam wire commissioning procedure and schedule (A. Rossi)

Adriana first recalled the present installation layout of the TCTs with in-jaw wires. Four collimators are equipped with wires: TCTPV.4L1.B1, TCTPV.4R1.B2, TCTPH.4L5.B1, TCTPH.4R5.B2. Each collimator is equipped with two wires in series with current flowing in the beam direction. The nominal power converter current per wire is 350 A while the wires themselves can withstand up to 378A.

The commissioning procedure is detailed in EDMS-2384198 which is currently under review.

The protection of the devices is achieved with the wire temperature interlock. A beam dump is triggered in case of wire overheating (measured indirectly through the voltage across the wire which increases with temperature), in case the control card is not in place or is faulty or in case of non-continuity in the circuit. The wire temperature interlock is implemented through the WIC. It can be tested by using a current of 375A which will trigger a temperature interlock within 2 minutes.

The other interlocks protect the machine: the power converter interlock will trigger a beam dump following a power converter internal failure or an earth fault in the BBCW circuit. The power converter interlock is also implemented via the WIC.

Another set of interlocks protects from overcurrent. The FGC software will only accept current settings in the range [-375A, 375A] during commissioning and in the range [-350A, 350A] during normal operation. Matteo commented that the FGC settings are not linked to the CCC RBAC role. This change needs to be done by a power converter expert. Matteo clarified that this is not protected by RBAC.

The SIS interlock will dump the beam and switch off the BBCW power converter in case the current exceeds 350A during normal operation. This SIS interlock will be masked during commissioning.

The effect on the beam will be compensated by Q4. The PCinterlock will dump the beam (but keep the power converter running) if the Q4 current goes outside the limits defined for operation.

Finally, the temperature interlock on the wire (HW interlock) intrinsically limits the current to 375A.

Adriana then described the 2022 commissioning steps. The tests verified the equilibrium temperature reached for nominal current (via the jaw temperature sensor) with respect to the measured resistive voltage of the wire. It was verified that for a current set at 375A the interlock triggers within 2 minutes via the voltage measurement. The vacuum pressure was also monitored.

Adriana summarized that the interlocks have been implemented to protect the hardware from overheating and the machine from BBCW failure. The interlock commissioning without beam was carried out with success after installation in 2019 and repeated remotely from the CCC in 2022.

Jorg, Matteo and Stefano confirmed that the tests do not need to be repeated with beam.

Jorg commented that the operational use of the wires still needs to be clarified: the tune and beta-beating correction is not fully defined. Roderik added that the compensation scheme must be tested with beam. Yannis commented that a baseline solution has been defined for the compensation using the Q4s only. Jorg commented that new questions arose regarding that solution. Yannis reiterated that the baseline solution should be put in place as the doubts only concern beta-beating for forward physics. The beta-beating induced by the tune correction with the Q4s remains within the range of beta-beating introduced by beam-beam.

Stefano commented that the vacuum could be monitored for longer periods of time during beam operation. Adriana agreed and added that the jaw temperature should also be monitored.

Christoph suggested to test the beam reaction in case of abort on the power converter side. Jorg replied that this can be observed through the post-mortem.

Action: Define and organize a test with beam to confirm that the beam is not affected in case of an abort of the wire power converter during the timeframe of the interlock reaction time of the WIC and BIS (OP, ABP).

Stefano commented that the required loss maps must also be defined.

Action: Define the list of required loss maps for critical scenario (OP, COLL).

Considerations on BSRTM aperture and operational settings (R. De Maria, R. Bruce)

Riccardo first summarized the status of the BSRTMB which is foreseen for HL-LHC. During Run III it will be operational for validation purposes. Target settings (regarding the insertion and the aperture) have been given for the nominal HL-LHC lattice V1.5; however, the actual settings for Run III depend on the machine conditions and commissioning state. During Run III this instrument should not worsen the global aperture as it is not a critical device.

It should be noted that no BLM is installed in the close vicinity of the BSRTMB. Therefore, special commissioning is required as it is not clear that the beam loss pattern, as seen from the BLMs, will be affected in case of local losses at the BSRTM. Additionally, the mirror could act as a thin scatterer and might induce a different loss behavior elsewhere in the ring compared to other aperture bottlenecks.

Based on these considerations, the settings for Run III were presented. The HL-LHC settings provide a normalized aperture of 11.2 sigma at injection, to which an additional margin of 1.7mm (roughly corresponding to 1 sigma) is added for Run 3, and 17.7 sigma at 6.8 TeV, with no additional margin needed a priori. At injection the calculated aperture is close to the ring aperture, tentatively adding a 1-sigma margin. At flat top, no additional margin should be required as other bottlenecks are expected.

To validate the mirror position, the following commissioning steps are proposed:

- The mirror should be part of the aperture measurements, standard loss maps and asynchronous dump tests.
- As no BLM is installed close to the instrument, additional aperture measurement must be performed to compare the loss pattern and global aperture with mirror in parking and at nominal position.
- If the mirror is not transparent in terms of aperture, additional margin should be added to the operational settings.

Stéphane asked to confirm the aperture with margin at injection in terms of beam sigma. Riccardo replied that it is 12.2 sigma. Stephane commented that this would remain larger than the IR6 MQY aperture (10.6 sigma). Stephane asked what the upper limit of the settings is. Riccardo replied that it can be opened to 34 mm.

Stefano commented that the values at the level of ± 1 sigma will be known from final measurements. Stefano reiterated that it should be agreed that the mirror does not become an aperture bottleneck. Enrico added that during the aperture measurements in the past weeks the mirror was already in at 24.5 mm (corresponding to the proposed settings with margin) and was indeed not the bottleneck. Roderik commented that there is no BLM close to the instrument and that it might be that losses were not observed for that reason.

Enrico asked to confirm the value at flat top. The original value was 12.9 mm, which corresponds to the proposed value (11.2 mm) with a margin of 1.7 mm added on top. The present proposal does not include this additional margin for the reasons mentioned above.

Stefano suggested to measure the aperture at flat top before the squeeze (before the triplets become the bottlenecks).

Belen commented that she had not received a request to install a BLM but that it could be reconsidered, and Enrico asked what could be gained in the settings if a BLM is added. Roderik replied that it would depend on the measured global bottleneck. The local BLM could then be used to verify that the mirror does not induce losses if positioned just above the global aperture. Stéphane added that a local BPM can be used to reduce the margin relative to the measured beam position.

Enrico confirmed that the interlock is in place and has been tested (maskable BIC input).

Roderik summarized that the proposed settings raise no additional objection and are approved, pending further aperture measurements.

Jan proposed to make a request to install a BLM during the next YETS next to the device unless a specific reason is brought forward. This was agreed and Belen said that she will follow this up.

Action: Install a BLM close to the BSRTMB in IR4 during the YETS (Belen S.)

Enrico asked if a BPM should also be requested. Stéphane replied that it would be a very good idea. Jorg commented that the BPM installation would not come before at least one year of operation at high intensity, for a device which is not critical for Run III, and that therefore the gain would be marginal.

BPM interlock implementation (J. Wenninger)

Jorg summarized the way the BPM interlock is implemented in the SIS. The aim of the SIS interlock is to ensure that the beam position is correctly centered at the collimator BPMs (originally only for the TCTs and the TCSP), which could be critical for the protection of sensitive collimators.

The following inputs are used for the interlock logic:

- The collimator BPM reading
- ß* from the timing telegram
- The beam energy from the telegram
- A table with the beta values at the collimators as a function of ß* from LSA
- The tolerances in sigma as a function of ß* and of the emittance.

The dump logic is as follow:

- If the readout is redundant (4 BPM readings), the interlock is triggered if at least 2 readings are out of tolerance
- If the readout is non-redundant (2 BPM readings), the interlock is triggered if at least 1 reading is out of tolerance
- The dump is triggered if the interlock is active in 5 consecutive updates (10 s)
- There is a 60 s grace period in absence of data, after which the dump is triggered.

This logic does not involve the energy as a primary variable and therefore energy-dependent thresholds must use the dependence of ß* on the energy. For that reason, the collimators in IR6 and IR7 (for which there is no true ß*) are associated with IR5.

So far, the concept has worked well for all configurations except for non-OP configuration like the ballistic optics. It also does not work for IR2 as ß* is constant, although these collimators could be associated with IR1 to provide a ß* or energy-dependent input.

The settings are stored as MCS in a virtual device protected by RBAC.

During Run II, the tolerances were set to 1 sigma for IR1 and IR5 TCTs and progressively tightened towards that value, starting from 4 sigma prior to the squeeze. The tolerance was set to 2.5 sigma for the IR8 TCTs, to 4 sigma for the IR2 TCTs and to 1.5 sigma for the IR6 TCSP (all along the cycle).

These SIS interlocks are automatically masked if the Setup Beam Flag is true.

A potential improvement is to move the logic from the SIS into a UCAP node. The node would then publish the results and values used in the logic, and the SIS would use that as an input. The additional benefit is that the data could then be logged in NXCALS to improve the diagnostics and monitoring.

Jorg confirmed that the new collimators are included (primary and secondary collimators in IR7 equipped with BPMs).

Stéphane commented that the reduction from 4 sigma to 1 sigma for the IR1-5 TCTs was for Run II and asked what these values will be for the Run III squeeze. Jorg replied that this is not defined yet. More details will be provided at a future meeting.

Orbit analysis, proposal for 2022 BPM interlock settings and staging (B. Lindstrom)

The SIS BPM interlock is extended to the new collimators as the new Mo-coated TCSPM installed during LS2 must be protected against primary beam losses and all new collimators now have in-jaw BPMs.

Bjorn presented data, in terms of variability and stability, from 2018 regarding the readings of the individual BPMs in IR7 (up to half-cell 9) and of the collimator BPMs (TCP.C6L7.B1, TCSPM.D4R7.B2, TCSP.A4R6.B1, TCSP.A4L6.B2).

The RMS error over each fill is found to be of the order of 100 µm for the IR7 BPMs (horizontal and vertical) and the maximum absolute error for the TCP.C6L7.B1 (horizontal) is slightly lower. The fill-to-fill orbit offset as measured by the IR7 BPMs is 0.18 sigma with a statistical variability of 0.16 sigma for both planes.

The conclusions are:
- The mean squared error of average orbit in IR7 BPMs increased over the year 2018, but this behavior was not observed for the collimator BPMs
- The IR7 BPMs reach above 200 µm in several fills
- The IR7 collimator BPM fluctuations are small (20 µm), but the margin is lost due to the overall offset
- Considering a 10% beta-beating, the hierarchy margin is 0.97 sigma.

The proposal regarding the use of the interlock is:
- Activate the interlock with tentative relaxed thresholds (300 µm)
- Continuously check the new collimator BPMs during commissioning
- Tighten the thresholds when possible
- Use the BPMs for collimator alignment to allow for tighter thresholds.

Jorg asked if a cut was applied on the intensity when considering the fill-to-fill variability. Bjorn replied that only fills reaching stable beams with an intensity larger than 1E14 p^+ were considered.

Jorg commented that one could consider removing the initial offset seen in the collimator BPMs. Stefano added that indeed a readjustment after the initial setup, or after technical stops, would improve the situation.

Stéphane commented on the hierarchy margins: assuming the worst case, negative beta-beat at the primary, positive at the secondary, make senses because the phase advance between them is close to 90 degrees thus flipping the sign of the beta wave. However, in case where the phase advance is close to 180 degrees, this worst-case assumption would not be very relevant. A more accurate estimation of the margins could then be done before concluding on the required thresholds.

Roderik summarized the proposal of starting with a 300 um threshold, to continuously monitor the orbit deviations and possibly adjust the threshold later, as well as studying the removal of initial offsets, which was agreed upon.

Summary of actions

The actions from the meeting are:
- In-jaw beam-beam wire commissioning procedure and schedule
    1. Define and organize a test with beam to confirm that the beam is not affected in case of an abort of the wire power converter during the timeframe of the interlock reaction time of the WIC and BIS (OP, ABP)
    2. Define the list of required loss maps for critical scenario (OP, COLL)
- Considerations on BSRTM aperture and operational settings
    1. Install a BLM close to the BSRTMB in IR4 during the YETS (Belen S.)