234th Meeting of the Machine Protection Panel

LHC topics

March 24th, 2023, via Zoom

Participants:
F. Alessio (EP-LBC), A. Butterworth (SY-RF), C. Bracco (SY-ABT), R. Bruce (BE-ABP), E. Calvo (SY-BI), G. Cavallero (EP-LBD), V. Coco (EP-LBD), M. D'Andrea (BE-ABP), M. Deile (EP-CMT), Y. Dutheil (SY-ABT), C. Hernalsteens (TE-MPE), M. Hostettler (BE-OP), M.Milovanovic (EP-ADO), D. Mirarchi (BE-OP), F. Moortgat (EP-CMG), S. Morales (SY-BI), D. Lazic (EP-UCM), A. Lechner (SY-STI), B. Lindström (BE-ABP), K. Paraschou (BE-ABP), G. Pigny (TE-VSC), J. Uythoven (TE-MPE), A. Radeva Poncet (BE-CSS), M. Saccani (SY-BI), B. Salvachua Ferrando (SY-BI) R. Secondo (TE-MPE),R. Tomas (BE-ABP),G. Trad (BE-OP), F. Van Der Veken (BE-ABP),C. Wiesner (TE-MPE), J. Wenninger (BE-OP), D. Wollmann (TE-MPE), C. Zamantzas (SY-BI).

The slides of all presentations can be found on the website of the Machine Protection Panel and on Indico (234th meeting).

Minutes and actions from the 233rd meeting (Joint meeting with the Collimation Working Group)

The minutes of the 233rd MPP meeting have been distributed. Daniel recalled the actions regarding the LHCb VeLo aperture and design of the new safety system.

No comment was received, and the minutes are approved.

Proposal for 2023 intensity ramp-up (C. Wiesner)

Christoph first summarized the intensity ramp-up in 2022. The intensity ramp-up is based on a stepwise increase of injected and stored beam energy after YETS and LS. The ramp-up in 2022 consisted of the following steps in number of bunches: 3/12, 75, 300, 600, 900, 1200, 1800, 2400. The bunch intensity was kept at ~1.15e11 ppb during the intensity ramp-up. Then the bunch intensity was gradually increased to 1.4e11 ppb. Each step consisted of at least 3 fills and 20h of stable beams, and was validated with a checklist.

No beam-induced damage occurred during the ramp-up. An important number of issues that would have degraded the protection functionality were found and followed up.

In 2022, the 1200 bunch step was reached in 18 ramp-up days, while 2400 bunches were reached in less than 30 ramp-up days. The typical delays between the end of the last fill and the approval of the checklist were between 8 and 10 hours.

The operation in 2023 will feature an extended range of luminosity levelling, the use of the mixed (BCMS/8b4e) filling scheme and a bunch intensity that will be increased further to 1.8e11 ppb.

The proposed strategy for the 2023 intensity ramp-up remains the same as before, with a modification in the intensity steps: 3/12, 75, 400, 900, 1200, 1800, 2400. The 300, 600, 900 bunch steps are replaced by only two steps at 400 and 900 bunches. For each step a minimum time of 15 hours in stable beams will be required, with at least 2 fills going through the full luminosity levelling process using the operation tool. This reduces theoretically the minimum achievable duration per step from 2.1 day to 1.6 day, and the total duration from 15 days to 10 days.

The proposal is to start with bunch intensities established in 2022 (1.5e11 ppb from the SPS), with the option to gradually increase the bunch intensity after having reached at least the 1200 bunch step. An intermediate scrubbing checklist is required to increase the number of bunches above 500.

Regarding the ramp-up scenarios after stops of nominal operation (e.g. after a TS), the 600-bunch step used previously is replaced by a 400-bunch step, for consistency with the intensity ramp-up steps.

Chiara commented on the required availability of experts for each step and asked if fewer steps consisting of more fills could be used. Christoph commented that the 2-fill requirement is a minimum requirement, if additional time is required, additional fills should be inserted. Daniel added that the 2022 ramp-up shows that above 75 bunches additional fills were performed (see Slide 5). Daniel commented that one should avoid increasing the stored energy too steeply during the ramp-up.

Jorg commented that the 3/12 and 75-bunch step could be validated with a single checklist, as this would reduce the pressure on the teams. Daniel agreed with the proposal. Jan agreed as well. Before going to the 75 bunches a verbal verification with all concerned teams will be performed to ensure that no issues have been overlooked. Both steps will still require fulfilling the 2 fills and 15h criteria.

Georges asked about the way to proceed through the levelling process and the implications for the pile-up. Jorg replied that one can reach quickly 60 cm with acceptable pile-up at 1.4e11 ppb. Christoph added that this was deemed acceptable by the physics coordination. Jan replied that this is the reason why only 2 fills are required instead of 3 fills as previously.

Filip asked about the requirement to not increase the number of bunches and train length at the same time. Filip asked if this could be done for the 400-bunch step to reduce the injection time. Christoph proposed to decide once the filling schemes will be available for both options, but also explained that in 2023 it would only mean a couple of more injections of twelve bunches as compared to 2022.

Action: Define the filling schemes corresponding to each intensity step (C. Wiesner, F. Moortgat)

Decision: Daniel concluded that the MPP endorses the proposal, with the modification that the 3/12 and 75-bunch steps will be validated with a single checklist.

2023 machine revalidation strategy

Collimation settings strategy and updated loss maps list (F. Van Der Veken)

Frederik summarized the collimator settings for 2023. Those are very similar to those of 2022. The TCT.8 will be tightened from 18 to 11.5 sigma during the rotation in LHCb. The TCL6 will always be inserted. During the anti-telescopic levelling, the TCT.1/5 will be tightened from 9.35 sigma to 8.5 sigma. During the second part of the levelling, their gaps will remain constant at 8.5 sigma. The TCL gaps are defined at beta*=30 cm and will be constant in mm during the levelling.

		IR7 [σ]			IR3 [σ]			Dump [σ]		TCT [σ]				TCL [σ]		
		TCP	TCSG	TCLA	TCP	TCSG	TCLA	TCDQ	TCSP	1	2	5	8	4	5	6
Injection		5.7	6.7	10	8	9.3	12	8	7.5	13	13	13	13	-	-	-
Ramp		↓	↓	10	↓	↓	↓	↓	↓	↓	↓	↓	↓	-	-	-
Flat Top		5	6.5	10	15	18	20	7.3	7.3	18	37	18	18	-	-	-
Squeeze		5	6.5	10	15	18	20	7.3	7.3	↓	37	↓	18	-	-	-
LHCb Rotation		5	6.5	10	15	18	20	7.3	7.3	9.35	37	9.35	↓	-	-	-
Tune Change		5	6.5	10	15	18	20	7.3	7.3	9.35	37	9.35	11.5	-	-	-
Adjust		5	6.5	10	15	18	20	7.3	7.3	9.35	37	9.35	11.5	-	-	-
Levelling	120	5	6.5	10	15	18	20	7.3	7.3	↓	37	↓	11.5	↓	↓	↓
	60	5	6.5	10	15	18	20	7.3	7.3	8.5	37	8.5	11.5	↓	↓	↓
	30	5	6.5	10	15	18	20	7.3	7.3	8.5	37	8.5	11.5	17	42	20
XRP OUT															17	

Loss map matrix. Many more steps in levelling compared to 2022. The proposal is to not perform loss maps at all steps to gain time. 5 configurations can be done per fill. This would require 6 fills at top energy. For the fill that ends at 60 cm, one can optionally perform the off-momentum and asynchronous dump test for comparison with 2022. The complete loss map matrix is shown below.

	450 GeV		6.8 TeV																												
	Injection		Non colliding			Colliding XRP IN																								Colliding XRP OUT		
	Prot. IN	Prot. OUT	FT	EoS / EoR	QC	120 cm	112.5 cm	105.5 cm	99 cm	93 cm	87.5 cm	82.5 cm	77.5 cm	72.5 cm	68 cm	64 cm	60 cm	56 cm	52 cm	48.5 cm	45 cm	41.5 cm	38.5 cm	35.5 cm	32.5 cm	30 cm	120 cm	60 cm	30 cm
B1H	✓	✓	✓	✓	✓	✓		✓		✓		✓		✓			✓		✓		✓			✓		✓	✓	✓	✓
B1V	✓	✓	✓	✓	✓	✓		✓		✓		✓		✓			✓		✓		✓			✓		✓	✓	✓	✓
B2H	✓	✓	✓	✓	✓	✓		✓		✓		✓		✓			✓		✓		✓			✓		✓	✓	✓	✓
B2V	✓	✓	✓	✓	✓	✓		✓		✓		✓		✓			✓		✓		✓			✓		✓	✓	✓	✓
+dp/p	✓	✓	✓		✓	✓											(✓)									✓			
-dp/p	✓	✓	✓		✓	✓											(✓)									✓			
ASD	✓	✓	✓		✓	✓											(✓)									✓			

The complete set of loss maps can be performed with 6 fills (in addition to the ones at injection).

Frederik proposed to perform additional loss maps in conditions with strong nonlinearities, for different values of octupoles and chromaticity, with the electron-cloud tunes at injection (with the injection protection devices in and out), at flat top and colliding with beta* = 30 cm. Additional loss maps would be performed to compare the two different injection optics. This requires 5 extra fills.

Jorg commented that the new optics only change the phase advance in the arcs, but the orbit will not be changed in IR7, so the collimation system would not need to be re-aligned. Rogelio commented that beta-beating can be induced, so the gaps should be adjusted.
Daniel asked which injection optics will be used for the alignment of the injection and dump protection devices. Chiara replied that only the new optics will be used.

Daniel asked if the optional off-momentum loss maps and asynchronous beam dump test at 60 cm are required to ensure protection. Yann asked about the change from anti-telescopig to telescopig squeeze at 60 cm. Frederik commented that these were optionally proposed as the optics change is now within a single beam process. Yann commented that it depends how much the optics changes and proposed to perform the asynchronous beam dump test at 60 cm. Daniel agreed with the proposal. Roderik commented that the off-momentum loss maps and ASD test could be done in a single fill. Jan commented that these could indeed be performed (not optionally).

Jorg commented about the orbit interlock at the TCT. There is a risk of spurious dumps if the interlock is kept at 1 sigma thorough the whole levelling process. Jorg proposed to relax the interlock to 1.5 sigma to avoid spurious dumps.

Action: Determine the interlock level for the TCT BPMs for the 2023 configuration (BE-OP / Collimation team).

Daniel asked if the loss maps with high octupoles and sextupoles are only betatron loss maps. Roderik and Frederik confirmed.

Decision: Daniel summarized that the MPP endorses the proposal, including the obligatory off-momentum loss maps and ASD test at 60cm.

Phase advance and aperture margin between IR6 and IR5 TCT (C. Hernalsteens)

Cédric first detailed the method for the phase advance and aperture margin validation between IR6 and IR5 for machine protection. The method uses a long orbit bump extending from IR6 to IR5 for Beam 2 and provides a direct mean, with circulating beams, to validate the protection of the TCT from direct beam impact in case of asynchronous beam dump. Optionally, an aperture margin measurement can be performed with the method, using the collimator beam-based alignment.

MD #7008 in 2022 extended the results from MD #2186 in 2018 by validating the method both for the nominal optics and for optics with purposedly detuned phase advance between the IR6 collimators and the IR5 TCT for Beam 2. Indeed, as the phase advance between the MKD and the TCT gets closer to 90 degrees, particles experiencing the kick from the MKD will reach larger amplitudes in IR5, thus increasing the risk of hitting the TCT. The long orbit bump mimics such trajectory but for circulating beams. The results of the MD show that the collimator BPM readings provided direct information regarding the IR5 TCT retraction margin. A loss of margin of 1.5 sigma was highlighted between the nominal optics and the detuned optics.

The proposal for the 2023 commissioning is to perform the measurements at all lumi-leveling optics steps from 120 cm down to 30 cm for Beam 2 in IR5. The BPM-based measurement will be performed, and if it reveals a non-nominal situation, the beam-based alignment would be performed to obtain direct information on the aperture margin.

The 2023 commissioning data will serve as reference data and will be repeated at upcoming Technical Stops (TS). In addition, the 2023 commissioning data will be validated against the phase advance information obtained from the optics measurements.
Jorg commented that this will require two shifts in 2023 and asked if the gain is enough to justify the invested time.

Roderik asked if the long-term goal is to remove the need for asynchronous dumps in the future. Chiara replied that this does not replace the ASD test. Cedric added that this is indeed not meant to replace the ASD test but that it can be used to validate the intermediate optics steps. We could also consider doing it for a subset of steps.

Jan commented that we want to get some experience with the method, and this is why we would perform it with one beam and not both.

Jorg asked if we could combine it with the loss maps. Roderik pointed out, that these should be done in operational conditions without changes. Jan, Jorg and Daniel agreed that both should not be mixed.

Daniel proposed to invest one fill to use the method for validation so that we gain experience with it. The MPP endorsed this proposal.

Action: Define the optics steps at which the measurement will take place and agree with OP for a slot to perform them (Cedric, BE-OP).

Change of injection optics with phase advance knob (K. Paraschou)

Kostas first summarized the motivation for the phase advance knob. The octupole magnets placement in the LHC is far from optimal and they drive nonlinear resonances. The phase advance can be changed on an arc-by-arc basis to minimize the Resonance Driving Terms (RDTs). The phase advance knob uses the trim quadrupoles in the arcs. This correction provides a significant increase of the dynamic aperture of more than 1 sigma. The knobs are simple addition to the MAD-X model and can be trimmed off easily. They induce a change in the phase advance between the sectors. The tunes and the phase advance inside the IRs remain the same.

The knobs induce a beta-beating of around 5% for both beams. This is very small compared to the beta-beating of the uncorrected machine. The response of the linear coupling knob has only small changes and the linear coupling knob remains almost orthogonal with the introduced phase change.

The phase change is small and induces only minimal perturbations to the optics. No obstacle has been identified and the knobs for both beams are ready to be tested.

Rogelio commented that there are no constraints regarding the phase advance between IR6 and the TCTs for the injection optics.

Jan commented that as all the alignment and validation will be performed with the knob in place, one should not go back later. To avoid that, the knob should be moved to the optics itself.

The initial alignment will be performed with the new optics and then the comparison will be performed so that a final decision can be taken.

Rogelio commented that the Beam 1 knob has been fully benchmarked in simulation. Dynamic aperture results are expected shortly for Beam 2.

Frederik presented loss maps simulation results. The knob appears to have a beneficial effect for on-momentum and for off-momentum loss maps for Beam 1. The results for Beam 2 do not show an improvement as large as for Beam 1 and are unconclusive.

Chiara commented that the issue in 2022 concerned the continuous losses that were visible only at the TDIS in IR2. Frederik replied that in addition to that, one must ensure that the knob for Beam 2 does not break the hierarchy for the TDIS in IR8 during either on- or off-momentum loss maps.

Daniel concluded that the MPP endorses the stepwise approach to put in place the new optics as presented by J. Wenninger in the LMC.

Readiness for first beam

The MPS tests and checklists for the different systems can be found here.

BIC, PIC, WIC, FMCM, SMP (R. Secondo)

All 8 WIC systems are operational. No changes were performed except for IR1 and IR5 regarding the BBCW. The interlock cables of the power converters of the Beam 1 BBCW were disconnected and replaced by a bridge. The remaining Beam 2 BBCW in IR1-5 are protected by the WIC.

The PIC HW commissioning was performed with AccTesting. The "PIC to BIC test" is ongoing. The "AUG connection to the PIC" tests are being analysed.

A Boron Carbide (B4C) shielding has been installed around the PIC in UL14 and UL16 during YETS 22-23. Monitors have been installed to monitor the neutron fluences at these locations.

The FMCM tests are waiting operation for LHC and SPS transfer line tests.

The SMP tests of the DC-BCT1 and DC-BCT2 were performed successfully. Also all other SMP tests passed. The beam tests are awaiting to be performed.

The BIS connections for the BCCM are disabled. The jumpers for the injection BIS were removed on March 21. New jumpers were placed on LHC TZ76 Channel 1 (beam vacuum), for the needs of the crystal intervention. The IST tests passed successfully for the injection BIS and ring BIS. They will be repeated on TZ76 after the jumpers are removed.

The LHC injection BIS now performs the masking using correctly the SPS Setup Beam Flag instead of the LHC Setup Beam Flag.

Beam loss monitor system (M. Saccani)

Mathieu presented the LHC BLM system readiness for first beams in 2023.

Two minor changes concern the installation of 2 temporary detectors in IR2 and 2 detectors on the cryo-BLM in SR5 and SR7.

The hardware modifications are mostly preventive maintenance.

Major changes took place on the firmware. The issue with the RS12 channels 6 and 14 has been solved. The combiner and survey card firmware was updated to solve the VME incompatibility with MEN-A25 (where the FPGA was responding too slowly) and to improve the VME throughput and stability. Minor processing improvements were also performed.

The software and databases also underwent major changes. The CPU migration was performed. A new version was released for the LHC data concentrator.

The hardware checkout tests were completed on March 20. The IST tests are scheduled for April 3. The tests with beam are also planned in the schedule.
The only identified limitation is for the blindable channels inhibit at injection. It has never been tested with beam. The feature is now present in all crates. By default, it is disabled. It is triggered by the injection warning (from the BST) with programable timer per crate. This feature must be commissioned, and the blinding time must be determined.

Christoph asked about the issue on the memory corruption in the card, leading to faulty BLM signals. Mathieu replied that the fix has been deployed.

Daniel agreed that the test on the direct dump BLM can be skipped as it was performed last year. The MPP endorses the proposal.

Injection & LBDS (Y. Dutheil)

Yann summarized the status: a very short reliability run has been performed, checkout tests have started. Yesterday some BLM data were missing in the XPOC/PM.

Jan asked, which relevant HW changes had been performed in the systems during the YETS: One MKB for beam 2 which has been conditioned. A MKB waveform measurement is planned. Additional NEG cartridges were added.

One MKI was replaced by the MKI-Cool which has been conditioned. The waveform measurement will be performed with beam. Daniel asked if the agreed interlocking of the temperature and flow of the cooling water had been implemented and commissioned? Yann confirmed that this has been done. He added that the commissioning procedure hadn't been changed.

Collimation (D. Mirarchi)

Daniele summarized the status of the tests. All tests passed, except for the temperature tests which are ongoing and for the interlock threshold function limits which will need to be re-tested for TCPCH.A4L7.B1 (crystal collimator) and for which the interlock on the replacement pipe still needs to be tested.

The threading beam processes and sequences have been tested and are ready for the first beam. The coarse settings are being prepared.

The energy, beta*, and inner pot limits will be stored in a dedicated discrete beam process to increase the flexibility while keeping the settings safe.

Daniele outlined the issue with the TCPCH.A4L7.B1 where the linear stage failed. The re-installation has been delayed to TS1. The root cause is still under investigation; the spectrum of the crystal vibration is to be considered as potential observable for future commissioning.

Vacuum system (G. Pigny)

Gregory summarized the tests, following the structure of the vacuum checklist. The machine checkout has been completed successfully except for minor issues that have been corrected. The status of the test on the confirmation of the logging must be confirmed and followed-up with C. Martin.

ADT (D. Valuch)

Daniel V. provided a written summary. All amplifiers in the tunnel have been checked and the tube transfer functions have been measured. All 16 are OK. The control from the CC application has been tested and works. The abort gap and injection gap cleaning have been tested. Daniel V. confirmed that the ADT is ready for the start-up.

TOTEM/CT-PSS (M. Deile)

Mario confirmed that the checklist is completed. It was agreed beforehand that the beam mode and flags tests did not need to be performed as the interlock logic card was not modified and the tests had been performed in 2022. No anomaly was observed and the XRP system is ready for beam.

ALFA/AFP (M. Milovanoci)

Marko confirmed that the checklist is completed, and that the system is ready for beam. As for TOTEM/CT-PPS, the tests of beam modes and flags were not performed.

SIS (J. Wenninger)

Jorg confirmed that the testing is on-going and that no issue was found so far.

Daniel summarized that a few tests were remaining in the MP systems before the first beam. These tests are well identified and under control by the responsible HW teams. All in all the MP systems are in good shape to start the commissioning with beam.

AOBs

Diamond BLMs changes during YETS 22-23 (E. Calvo)

Eva described the displacement of two diamond BLM in LSS7. The changes are summarized in ECR LHC-BLM-EC-0017. The proposal for the displacement is related to the loss maps and beam scrapping analyses that took place in 2022. The changes aim at improving the BLM response factor based on the scraping data at injection energy. The change also improves the response factor at top energy and the response factor from loss maps with ions at top energy using crystal collimation. The diamond detectors were moved by 19 m (Beam 1) and by 55 m (Beam 2).

The displaced detectors have been renamed according to their new locations.

Another advantage of the new location is that they are more symmetric between the two beams.

Christoph asked about the UFO detection algorithm. Eva replied this has not been changed but the settings are not configured in the low level. The new FESA version will allow to load and log these settings. The data will be available for the run this year.

Daniel thanked all the teams for their excellent work and the speakers and participant for their patience during this long MPP.

Summary of actions and decisions

Actions

- Proposal for 2023 intensity ramp-up (C. Wiesner)
    - Define the filling schemes corresponding to each intensity step (C. Wiesner, F. Moortgat)
- 2023 machine revalidation strategy – Collimation settings strategy and updated loss maps list (F. Van Der Veken)
    2. Determine the interlock level for the TCT BPMs for the 2023 configuration (BE-OP / Collimation team)
- 2023 machine revalidation strategy – Phase advance and aperture margin between IR6 and IR5 TCT (C. Hernalsteens)
    3. Define the optics steps at which the measurements will take place and agree with OP for a slot to perform them (Cedric, BE-OP)

Decisions

- Proposal for 2023 intensity ramp-up (C. Wiesner)
    - Daniel concluded that the MPP endorses the proposal, with the modification that the 3/12 and 75-bunch steps will be validated with a single checklist.
- 2023 machine revalidation strategy – Collimation settings strategy and updated loss maps list (F. Van Der Veken)
    - Daniel summarized that the MPP endorses the proposal, including the obligatory off-momentum loss maps and ASD test at 60cm.