237th Meeting of the Machine Protection Panel

LHC topics

June 9th, 2023, 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 (237th meeting).

Minutes and actions from the 236th meeting (LHC topics)

The minutes of the previous MPP meeting have been distributed. Daniel recalled the actions from the meeting.

BPM calibration issue, systematic orbit shifts and proposal for mitigation after TS1 (J. Wenninger)

Jorg first recalled the main characteristics of the BPM electronics response. The response of the BPM electronics depends on the bunch separation and the bunch position in the train. Ideally, the BPM calibration should take care of the error, but the available calibration pulse trains do not match perfectly the filling schemes currently used (8b4e 36b trains instead of 72b trains). It is not possible to calibrate the BPM with a pulse sequence that mimics the actual filling scheme, as the calibration is hardcoded in the FEC. The change of orbit response can be seen by the measured orbit changes at the start of each train. The measured offset of most channels is within 0.2 mm. Comparing with the average over all bunches, this leads to a shift of the mean by 60 µm and a rms shift by 80 µm.

Before every injection phase, the BPMs are calibrated with a sequencer task. For the low sensitivity, four calibration options are available: single bunch, 72b train, 40 Mhz (continuous train) and 50 ns. For the high sensitivity, the calibration is always made with a 40 Mhz signal. The calibration results are sent to the FEC and stored in LSA. When the BPM are switched between high and low sensitivity during filling, the calibration is also change in the FEC.

During the LS2 software renovation, the update of the FEC settings was accidentally suppressed. Therefore, since LS2, the FECs have always operated in high sensitivity. The calibration for the probe bunches is applied to all beams. The rms error due to the calibration is ~0.1 mm, which is small compared to the residual flat orbit rms of ~0.3 mm. Even if the 72b train calibration is not ideal for the present filling schemes, it would have mitigated big parts of the observed shift, which is introduced by the orbit feedback due to the offsets read by the BPMs. This shift is clearly observed at the DOROS BPMs on the collimators, which use a different type of electronics and are not affected by this issue.

Two fields are available in the FESA class of the orbit feedback to correct the BPM offsets and scale calibration factors. The offsets are currently used for the Q1/Q2 K-modulation offsets. The calibrations are all set to 1. The settings of those fields are already in LSA.

The OP concept is to be able to apply a beam type dependent correction using the same parameters and fields but to build a hierarchy above those parameters to inject beam dependent offsets.

A set of parameters have been prepared to store corrective offsets for different use cases. They follow 5 pre-defined categories: global, single bunch, 25 ns, 50 ns and MD. These will be made MCS to avoid having mishaps and unauthorized changes.

A separate parameter is used to select which use case to apply at a given time. This triggers the re-calculation of the total offset applied to the OFB offset field. This is then very similar to selecting a BPM calibration type. These offsets can be edited in a special YASP panel.

These need to be tested at injection with single bunch versus trains and verified on the DOROS BPMs. A test ramp will validate it. The corrections should be deployed after TS1. As long as all offset type parameters except the global one are set to zero, no difference will be present with respect to the prior situation.

BI will modify the FEC software to ensure that the FECs switch automatically to the correct sensitivity without the need for external synchronization. Until then a SIS interlock will ensure that the machine is operated in the current way, as the lossmaps etc. have been performed with the high sensitivity calibration.

The testing of the proposed corrections through LSA should be performed next week to allow a full deployment after TS1.

Daniel asked what would happen if now the FEC were updated to have the correct calibration. Jorg replied that also nominal bunches would be affected. At least now we are in a consistent and validated situation.

Jan commented that the tightest beam position interlock is now at the DOROS BPM of the TCPs. The interlock thresholds will not be modified. The effect of the new corrections will help center the beam which will restore some margin.

Daniel asked about the logging of the offsets applied in the OFB. Jorg replied that the offset will be subtracted directly from the raw data and the corrected positions are published to NXCALS. Michi stated that the offset values might already be logged to NXCALS. OP will follow-up on this.

Daniel concluded that the MPP endorses the proposal as presented. If the tests are conclusive, this can be put operational after TS1.

Luminosity fine-tuning by crossing angle after TS1 (M. Hostettler)

Michi recalled the motivation for the change. The experiments are running very close to their pile-up limit. Therefore, a single pile-up unit can make a significant different. With beta* levelling, the luminosities and pile-up's of ATLAS and CMS are linked. Both experiments request to level to different targets. If the difference is larger than ~5%, a combined separation-beta* levelling can be applied. However, this is not stable for smaller differences. The separation is not effective when too close to head-on.

The proposal is to fine-tune the luminosity by slightly adjusting the crossing angle. A 10 µrad half crossing angle difference would lead to about 5% luminosity. If we allow a +/- 5 µrad crossing angle tuning, this will minimize the magnitude of changes by using both IPS. This would not be regulated but would be used as a constant offset over the fill.

The effect on the orbit would be around 50 µm at the TCTs (0.1 sigma). This is less than an emittance scan at beta* = 1.2 m. It is also within the uncertainty of machine reproducibility.

Daniel asked when the crossing angle change would be introduced. Michi replied that it would be inserted just prior to the levelling at the target pile-up (so not necessarily at 1.2 m).

Daniel asked how this would be introduced. Michi replied that the interface of the lumi-server can be used. This could be applied by hand at each fill if the experiments requests change often. Michi pointed out that the EIC needs to ensure that the option to move the TCT accordingly is switched off for this change. Filip mentioned that CMS will request 61 for the rest of the year. In the short-term ATLAS will probably always request 60. Therefore, the change could be included in the functions.

Jan asked if we would revert to the same crossing angles at the end of the levelling. Michi confirmed.

Daniel commented that the orbit change at the TCTs is small and that no thresholds nor interlocks are changed. Michi added the TCTs would not be moved as the change is very small.

Jan asked what is limiting the change to +/- 5 µrad. Michi replied that limits in range is difficult as the crossing angle is changing with the levelling and there is applied as absolute value. Michi recalled that the protection is provided by the DOROS interlock at the TCTs. Jan proposed to include the reference crossing angle in the settings panel so that one can restrict the changes around it. Michi agreed and will foresee such a change for a future change of the lumi server (likely not before next year though).

Action: Implement a way to limit the crossing angle change around the reference value (M. Hostettler)

Daniel concluded that the MPP endorses the proposal, with the change to be introduced in a second stage.

Readjustment of anti-collision switches for ALFA (M. Milovanovic)

Marko explained the motivation for the request. The vertical distance between the detectors and the beam is a key parameter in the detector performance. According to the simulations, the optimum distance for this run would be 3 sigma, so an opening of 600 µm. The stations are equipped with an anti-collision safety system, which stops the RP movement when the opening is about ~1 mm. At this distance, the acceptance is significantly degraded. The initial proposal was to re-adjust the anti-collision switches during TS1. In the meantime, the current adjustment of the switches was tested. The AC switches activate at around 1 mm. The steel bars would react between 200 and 300 µm later. The striking criteria for any AC-distance is a minimum gap of at least 0.2 mm to the steel bars.

The proposal is to move the past along the AC-distance and to measure the new gaps using gauges. The agreed settings would not change, the stations that exhibit large difference in actual closest distance would be re-adjusted.

Following any re-adjustment, the BIS revalidation would be performed during TS1.

Daniel asked if the XRP would end up being closer to the beam. Marko mentioned that a beam based alignment will be performed for the high-beta run. These pots are not inserted during the nominal run.

Jan commented that the AC switches will be tested, so that means that the BIC validation can be performed during that procedure. The user permits can be monitored.

Daniel concludes that the proposal is endorsed, given that the BIC validation is performed and asks Marko to share the outcome of the intervention with the MPP.

Action: Share the outcome of the modifications and BIC validation with the MPP (M. Milovanovic)

AOBs

Proposal for TI2/8 momenta adjustment (J. Wenninger)

Jorg presented a proposal to readjust the momentum setting of the transfer lines. The energy offset of the SPS beams injected into the LHC is fluctuating over time during a run in a band of dp/p = +/- 2e-4. Over 24 hours, the range is generally +/- 5e-5. There is increasing evidence that the changes are driven by the SPS, even if small contributions from the LHC cannot be excluded. The changes for B1 and B2 are always correlated. The offset is adapted periodically by adjusting the LHC momentum using the horizontal orbit correctors. Since the TI2/8 lines were set up in 2023, the relative momentum has dropped by 2e-4.

The beam energies of the SPS and LHC are defined by the main dipole field and by the radial position of the orbit (linked to the rf frequency), through the momentum compaction factor. The momentum compaction factor of the SPS is 5 times larger than the one of the LHC. Due to the requirement of the synchronization for SPS to LHC transfer, the SPS rf frequency is locked at extraction to half of the frequency of the LHC (so the SPS has no freedom to adjust the radial position at extraction).

The momentum of the LHC was calibrated using p-Pb beams taking advantage of the large rf frequency difference between the two species. We are slightly above 450 Gev (450.31 GeV). Details on the LHC momentum calibration and accuracy are available in E. Todesco, J. Wenninger, Phys. Rev. Accel. Beams 20, 081003 (2017).

At injection there is a decay of the random b1 errors but the systematic b1 is expected to be very small. The changes of the LHC dipole field are not visible in TI2/TI8 since the SPS beam is not affected.

On the SPS side, the momentum was calibrated using p-Pb and In (indium) beams taking advantage of the large rf frequency different. The real SPS momentum is lower than the setting. Due to these errors, the SPS momentum LSA setting at FT is 451.15 GeV for LHC cycles.

The LHC circumference changes are mainly driven by periodic tides and slow circumference changes. This was already observed at LEP, with the ring expanding in the summer and contracting in the winter. If left uncorrected this leads to a dp/p change in the range 2e-4. The orbit feedback center the beams on the same reference orbit with a rf frequency trim, no dp/p on LHC beam. For tides SPS and LHC should be similar, no impact on SPS beam momentum (LHC correction compensates SPS). For long term changes of the circumference it is expected for SPS and LHC to be completely different. We can monitor some effects that impact the SPS & LHC energies but none of them explain the steps and structures that we are observing.

Steering issue in the transfer-lines: There are uncorrectable structures that appear during the year. It is impossible to remove the horizontal trajectory offsets in the collimation (TCDIL) region with the correctors in the transfer-line.

A momentum change in the SPS adds a dispersive trajectory component. The dispersive component adds to the other trajectory drifts and it is difficult to disentangle both effects. Steering away the dispersive trajectory is not possible due to the distribution of orbit correctors.

The steering could be improved with more consistent settings. Adapt the momentum level at SPS FT, a bit tricky due to rounding. To be followed up. Would clearly be the cleanest solution as this is the real source of change. Other solution is to adapt the momentum of the lines at the same time as the momentum of the LHC is adjusted. This will make the situation more consistent. The changes are at the level of 10e-4.

The change was tested, the dispersive structure disappeared. The impact on the FEI (PC current interlock): quad tolerance 0.5% no impact. COD tolerance 10 µrad no impact. Dipole tolerance few 10e-4 only impact for RBI.2221 (tolerance just below 2e-4). Adapting the tolerance by 30% would provide the required margin.

Daniel asked if this has other impacts on the validation of the transfer lines. Chiara commented that this has no impact as the original (validation) situation is recovered.

Daniel asked when the energy trim should take place. Jorg replied that it should take place after TS1 or even before MD1. Chiara pointed out that it would be advantages to implement the momentum change of the lines before MD1 as this might ease the setup of the injection of trains with bunch intensities up to 2e11ppb.

Daniel concluded that the MPP endorses the proposal to trim the energy and to perform the changes before MD1.

Proposal for intensity ramp-up after TS1 with LHCb VeLo (C. Wiesner)

Christoph summarized the requirements in terms of intensity ramp-up following TS1 and the ones required for the LHCb VeLo ramp-up (see figure). Additionally, a calibration transfer fill is requested by ATLAS, using 140 individual bunches. As little as possible luminosity production should take place before that fill.

A dedicated checklist for the VeLo insertion including its motion system, heating and vacuum will be prepared and filled at each step starting at 400b.

Christoph commented that the actual sequence of fills can either follow in a linear fashion or in an interleaved manner.

Jorg asked at which point of the cycle the VeLo should be inserted. Daniel commented that it can be closed from the beginning of stable beams and does not have to wait for the end of the beta* leveling. Jan agreed.

Daniel concluded that the MPP endorses the proposed intensity ramp-ups and added that it will be presented to the LMC by Jan next Wednesday.

Ramp-up requirements after TS*	VELO ramp-up	Calibration Transfer Fill
3b into SB (cycle revalidation)	3b (VELO insertion to 36 mm, check motion)	
		Calibration Transfer Fill ATLAS (140 INDIVs, 7h fill, low beta)**
75b (1-2h in SB, full lumi levelling)	75b (VELO insertion to 36 mm, do tomography if enough resolution)	
400b (>2h in SB, full lumi levelling)	400b (VELO insertion to 36 mm, do tomography, move VELO to 32 mm by steps of 1 mm, stay >1h)	
	900b (VELO insertion to 32 mm, stay >1h)	
1200b (>5h in SB, full lumi levelling)	1200b (VELO insertion to 32 mm, stay >1h)	
	1800b (VELO insertion to 32 mm, stay >1h)	
Back to 2400b	2400b (VELO insertion to 32 mm)	
Remark: No checklists foreseen	**Remarks: Dedicated checklist (motion system, heating, vacuum) for each step starting at 400b**	

Summary of actions

The pending actions from the meeting are:

1. Luminosity fine-tuning by crossing angle after TS1
   - Implement a way to limit the crossing angle change around the reference value (M. Hostettler)
2. Readjustment of anti-collision switches for ALFA
   - Share the outcome of the modifications and BIC validation with the MPP (M. Milovanovic)