D. Mirarchi, M. Valette

128th Meeting of the Machine Protection Panel – joint meeting with the CollWG

Participants: M. Arneodo, J. Baechler, J. Boyd, E. Bravin, C. Boccard, R. Bruce, T. Camporesi, B. Dehning, M. Deile, K. Eggert, M. Frascaris, M. Gasior, H. Goucia, S. Jacobsen, M. Kalliokoski, A. Lechner, S. Mazzoni, A. Mereghetti, D. Mirarchi, Y. Nie, S. Redaelli, R. Schmidt, M. Trzebinski, J. Uythoven, G. Valentino, M. Valette, J. Varela, J. Wenninger, D. Wollmann, M. Zerlauth.

The slides of all presentations can be found on the website of the Machine Protection Panel:
http://lhc-mpwg.web.cern.ch/lhc-mpwg/

1.1 Approval of MPP#127's minutes

- Actions from 127th MPP:
    - Three actions regarding PC interlock and orbit interlocks. Will be the topic of presentations in this meeting.
    - Check PC interlock server status and experience with stability. Done by Markus and Kajetan. The PC interlock server is running on the same operational machine as the SIS (cs-ccr-sis1), therefore, there no problem with reliability is expected.
    - Two propositions for AFP studies, one document has been distributed, the second one is pending (and will be established for the second test with >=300b).
    - Make dBLM more broadly available, ongoing.
- Comments from Maciej, who presented via Vidyo, were received after the meeting and have been implemented. No additional comments were received on the minutes; they are therefore considered approved.

1.2 Measured orbit at collimators and roman pots (G. Valentino)

- G. Valentino summarized the observations of orbit stability near TCL5 collimators and TOTEM pots, both in IR5, together with an analysis related to the possible deployment of interlocks for BPM collimators. These studies are based on data collected during the intensity ramp up.
- A fill to fill analysis was performed to determine orbit reproducibility in BPMs near triplet, TCLs and XRP. About 20 fills were taken into account. In the horizontal plane orbit stability within 200µm (i.e. 1.5σ) was observed, while within 100µm (i.e. 0.3 σ) in the vertical one.
- Data from 32 physics fill during the intensity ramp up were used to determine the number of dumps versus threshold, in the case of interlocks for BPM collimators. From this year centres of TCTs follow the theoretical values expected with ADX during ramp and squeeze, scaled to average of Up and Down BPM-based alignment centres at start and end points, while linear functions were used previously. All BPM interlocks are currently

implemented in the SIS and running reliably, but are masked. Present limits are set to 4σ, except for: 1σ in IR1/5 with a β* of 40cm, 1.5 σ in IR2 with a β* of 40cm, 2.5σ in IR8 with a β* of 3m. Cumulative plots of triggered dumps during the ramp with different threshold (from 0.2σ to 2σ, with steps of 0.2σ) show that the highest contribution would be given by TCTs in IR2. S. Redaelli commented that it has to be take into account the bias introduced by the large gap at which these collimators are placed, because IR2 is not squeezed and such interlocks are too small. Similar observations can be made during the squeeze. However, a significant number of dumps from TCTs in IR5 is also present with 1σ interlock. This is due to an initial orbit shift that become less relevant as the β at the TCTs increases. S. Redaelli and J. Wenninger commented that at this point of the squeeze TCTs are still opened and a 4σ interlock would be present, which do not present a problem in terms of number of interlocks. During Adjust the main contribution is given by the vertical TCT in IR2, where orbit jumps are due to the setup of the levelling. In Stable Beams a similar situation is present, and the main contribution is given by the horizontal TCT in IR2 because of the leveling. J. Wenninger confirmed that this is due to optimization in the separation plane to achieve the required luminosity, and that since at IP2 we have still a β* of 10m, margins can be increased.

- Dedicated studies were performed IR by IR for the three BP (squeeze, adjust, stable beams). The distribution of expected dumps as function of the threshold in IR1/5 is very close to the 1σ applied at end of squeeze, due to shifts at the beginning of the squeeze. However, this is not a problem because such threshold is applied only at end of squeeze, while 4σ threshold is present during the squeeze. R. Bruce asked if there is a sharp change at end of squeeze from 4σ to 1σ threshold. G. Valentino replied that it is the case, and it would be possible to put in place a dynamic threshold during the squeeze. S. Redaelli commented that applying 1σ threshold along the entire squeeze is a very pessimistic scenario and it would be interesting to make that same study but taking only the last point of the squeeze. In the other IRs (6 and 8) large margin is present. During adjust and stable beams more than a factor 2 margin is present before reaching the dump threshold.
- Checks on orbit stability were also made in each IR. In general, the orbit spread is reduced significantly with respect to last year. Particularly, a spread of up to 400μm was present in 2015, but after introducing the settings calculated from the BPM it is reduced to about 100μm in 2016.
- R. Bruce asked if it is possible to conclude that the interlock threshold in place (but masked) are adequate. J. Wenninger commented that only 4σ in IR2 seems too conservative. S. Redaelli commented that TCTs in IR2 are at 37σ, thus this threshold could be also put at 10σ but dedicated plot must be prepared by G. Valentino for a final evaluation. D. Wollmann asked if would be possible to put a warning when a factor 2 with respect to the threshold is reached, to see a dump arriving due to slow orbit drift. J. Wenninger replied that it could be implemented an automatic SMS when the 75% is reached, because a vocal alarm can be missed. R. Schmidt asked if information about the reached level of dump threshold can be put in the Post Mortem (PM).

S. Redaelli replied that this is planned but it would not take place soon. D. Wollmann commented that we can go ahead with automatic SMS and vocal warning until BI is ready to deploy the PM logging. J. Wenninger commented that to avoid spurious spikes, it would be useful not to dump at the first BPM reading above threshold. G. Valentino and M. Gasior replied that spurious spikes are automatically removed by the BPM electronics.

1.3 Status of collimator BPM software improvement and deployment (M. Gasior)

- M. Gasior summarized the plans for the BPM software. A major upgrade is planned for the TS1. In particular collimator BPMs have the same electronics as standard BPMs. Thus, the software that will be installed during the TS is already tested. Split of served between standard BPMs and collimator BPMs is also planned. Capture mode up to 100,000 turn will be implemented.
- Future development include: extended logging, sanity checks, online monitoring of electronics' box, and Post Mortem.
- R. Bruce asked if the software is ready and stable enough to deploy the interlocks. M. Gasior replied that all the upgrades mentioned are needed, and it will require some time because none of them is implemented. S. Redaelli asked whether the interlocks could be deployed without all proposed upgrades. M. Gasior replied that the only thing ready is the hardware, but the software has to be written entirely. S. Redaelli asked for a tentative timeline. M. Gasior replied that two weeks after the TS1 would be enough to deploy the logging and sanity checks, while online monitoring and PM require more work. J. Wenninger asked which sanity checks are required. M. Gasior replied that only few values are needed. R. Bruce asked if the PM is really required for first deployment of interlocks. M. Zerlauth commented that PM and online monitoring are useful for the future, but the essential part for a first deployment is to be able to retrieve data in case of dump to analyse them. D. Wollmann commented that either logging or PM are enough for first operations. S. Redaelli commented that would be useful to have a sanity check in the first deployment, mainly to avoid dumps due to unavailability of the BPMs.
- In conclusion, logging and sanity checks are essential for interlocks and can be ready shortly after the TS. Online monitoring and PM are part of future development.

1.4 OP observations of orbit (J. Wenninger)

- J. Wenninger summarized global orbit observations in 2016. The response of the BPM electronics depends on the bunch pattern, and calibrations are used to mitigate this effect. Residual errors have an RMS in the range of 20µm to 50µm. Tens on µm could be achieved by doing the alignment with trains instead of single bunches. Train length has an effect as well. Moreover, the orbit feedback (OFB) can correct these systematic errors leading to either an under-estimation of the orbit errors, or to miss a real orbit shift.
- Incorrect calibration can lead to about 200µm RMS, and larger than 100µm mean shift. Systematic shift with trains of 72 bunches are observed this year.

Thus, the OFB shifts the orbit in the opposite direction without a real need. This is not an issue in the arcs given the large aperture at 6.5TeV, while it is a bit more problematic in the insertions due to the not regular optics. This could be cured by doing the calibration with trains. However, the shifts are very small to justify the overhead needed.

- The OFB is active only during: injection of probe and nominal (short corrections), ramp, tune change, squeeze, TOTEM bump and Stable Beams. The global orbit stability is very good in Stable Beams, with an RMS of 20µm over 8 hours.
- The orbit reproducibility fill-to-fill with 25ns beams has an RMS of about 50µm in the vertical plane, and slightly more in the horizontal.
- Effects of the triplet temperature on the local orbit has been studied in detail. In particular variations of temperature lead to radial shifts of tens of µm, which induce orbit shifts and separation of beams at the IPs. This is usually mitigated by the OFB, but at a global orbit level. Thus, if IP1 gets separated it has to be re-optimized, while IP5 it is not affected. Horizontal beam separation in IP1 is quite unstable due to these temperature changes, while slower longer term drifts are observed in the vertical one (probably dominated by something else). The situation is much more stable in IP5. Fill-to-fill analysis shows typical changes of about 8µm. Correlation between separation and triplet temperature was probed, taking into account data after the power converter event. A correlation is observed, with a coefficient of about 0.8µm.K^{-1}. A similar effect was observed during the record fill of 36 hours, when the triplet was cooled down by about 30K while in Stable Beams. A change of beam separation in the range of 1µm.K^{-1} to 2µm.K^{-1} is measured.
- In summary: the global orbit RMS is reproducible within about 50µm (25ns beams), a shift of about 100µm is present between real orbit with single bunches and 25 ns beams, triplet movements are small at IP5 and have a negligible effect at TOTEM location. Thus, a 250µm margin would cover both orbit stability and systematic errors. At the Roman Pot with the smaller β this means to have still about 3.5σ margin with respect to TCTs. Thus, no problems are expected to move TOTEM Roman Pots to 15σ without the 500µm margin. If the orbit does not behave as expected one could implement an automatic retraction of Roman Pots in the SIS, otherwise a warning interlock is already available in the SIS. M. Deile commented that the automatic retraction would need a modification of the FESA class and low level software, which would be feasible during EYETS.

1.5 Experience with roman pots insertion in 2016 (M. Deile)

- This is an update from a presentation on 2015 observations, with TOTEM insertions during the 2016 intensity ramp up. No problems were detected.
- Mario reminded us on the expected physics and how the distance of the roman pots to the beam impacts the physics goal, which is 0.5 maximum rapidity Δy. Removing the 500µm safety margin from the 15σ insertions would allow reaching the goal without aggressive beam crossing parameters. The 'TOTEM bump' introduced to increase dispersion at the horizontal XRPs increased the acceptance.

- As agreed at the start of the run 2016 the XRPs were inserted to 15σ+500μm, during the second fill of each intensity step, 2h after stable beams and for the third fill immediately after declaring stable beams.
- The last insertion was successfully performed at an intensity of 1824b.
- EoF studies of 'manual' insertions to 15σ were done at a four intensity steps.
- The orbit stability studies and the tests done in stable beams confirm that the insertion of Roman Pots is mostly transparent to beam operation.
- The losses recorded at BLMs downstream of the XRPs show a linear dependence with luminosity, which indicates that the losses are caused by debris from the IP. Insertions without margin show only minor changes in the loss pattern. In comparison to 2015, the losses registered on B1 in cell B6 and E6 went down because of the removal of a dummy aluminium bar to mimic Cherenkov detector material. Losses in sector 4-5 (B2) went up slightly due to the tighter insertions in 2016.
- Mario promised to add the BLM layout to the presentation in INDICO after the meeting.
    - Stefano pointed out that the losses were monitored during insertions to avoid unnecessary dumps due to losses at or downstream of the XRPs.
    - Mario estimated that this year the losses will only reach 7 to 10 % of the new dump thresholds.
- The equilibrium vacuum pressure with inserted XRPs shows a slight increase with beam intensity during insertions, but nothing worrying. The pressure behaviour is much better than in 2015. Only a very small pressure increase at the moment of the XRP insertion was observed. The insertions without margin show the same vacuum response.
- Temperature response: there are 4 probes next to the pot floor and two on each side. Data for fill number 4947 (40h) shows:
    - The equilibrium temperature for the XRPs without cooling is achieved around 35C, with +2C without the 500μm margin.
    - With cooling the equilibrium temperature reaches 18.5C, which is interesting but not a dangerous level.
- The equilibrium temperature scales with the beam current and not with luminosity. An extrapolation of the temperature increase at an intensity of 3000b and XRP insertion without margin leads to a maximum temperature of 55 C.
- Conclusion: The observations described above indicated no problems when inserting the XRPs to 15σ without margin.
- The MPP approves the insertion of the XRPs to 15σ without margin from this point onward. The update of the XRP positions and interlock limits will be performed in agreement with the machine coordinators and OP before one of the coming fills.
- Roderik requested a short summary of the planned interventions in TOTEM during TS1.
    - J. Varela, project leader of CT-PPS, explained that the planned activities have been split into small separate interventions, which can

be performed in a relatively short stop. For the moment no re-alignment of the XRPs was foreseen.
    - Mario added that the planned TS1 intervention involves installing diamond detector packages in the two horizontal cylindrical XRPs, XRPH.E6L5.B2 and XRPH.E6R5.B1.
    - J. Baechler points out that this will not change the mechanical properties but as it is a mechanical manipulation it can affect the alignment of the XRPs to the beam.
    - Stefano explained that he would strongly advice to perform a beam based alignment of the concerned XRPs after such an intervention. The beam based alignment of the two XRPs will take about one hour.
    - J. Baechler explains that such an alignment should not be counted as physics time, but be included to the re-commissioning after the TS.
- There are two horizontal XRP units, D6L5 and D6R5, that – in case of radiation damage to the silicon detectors – might at some point need to be mechanically raised by about 0.5 mm, in order to vary the main impact spot of diffractive protons on the detectors. This might happen in a machine stop between TS1 and TS2. Given that the XRP units concerned by this issue are the ones that are rotated by 8 degrees around the beam axis, a vertical shift of these "almost horizontal" pots would slightly affect the distance from the beam. Hence a realignment would be necessary.
    - Jamie points out that interventions on the XRPs, which require a re-alignment and following re-qualifications, cannot be performed outside a technical stop as these would call for additional alignment/qualification fills for TOTEM
- The MPP requests, after any HW intervention on a XRP, that the beam based alignment has to be verified. If the position changed by more than can be explained by the observed orbit variations (<=150µm), a re-qualification of the collimation hierarchy for the new settings with loss maps and asynchronous beam dump will be required. This request is valid for any intervention on movable devices operating close to the LHC beam.
- Markus mentioned, that during the fill last night, the TOTEM XRPs could not be inserted and asked if the reasons have been understood
    - Stefano and Jorg responded that the TOTEM PXI experienced a communication problem, which led to a mismatch of settings between FESA / middleware and the low level position control system. The problem was solved by rebooting the TOTEM PXI.
- **Action (Collimation, Stefano)** prepare a list with loss maps required after the XRP intervention. From that the machine coordinators can derive a list of required fills.

AOB - BLM thresholds at TCLs and TCTs (A. Mereghetti)

- The BLMs of the TCTs and TCLs see background losses from the luminosity debris. At a peak luminosity of $14 nb^{-1}.s^{-1}$ these losses would reach the dump limits in long running sums. Already now the warning levels are reached. It is therefore proposed to increase the thresholds by 20% to avoid dumps due to possible jumps in luminosity. To avoid running these BLMs continuously within the warning level the thresholds in the long running sums (RS8 and RS12) should be increased by a factor 3 to 4. IP8 is the main driver for this limit in IP2 luminosity is so low we don't have to worry about it for a while.

- Proposal: increase the dump level in running sums 8 and above by between 40% and a factor 4 depending on the families.
    - Rudiger asked, what the long thresholds protect the TCTs and TCLs against?
    - Anton replied that they protect the collimators against transients in luminosity or IP solenoids.
    - Stefano asked why it is a problem to run with BLMs in warning level?
    - Jorg responded that this blinds to shift crew from noticing unexplained losses before they become problematic and cause a beam dump.
    - Stefano pointed out, that the short running sums should not be touched, as they are very important for the protection of the TCTs and TCLs.
    - Rudiger asked if any temperature changes have been observed in these collimators due to the losses so far.
    - Stefano responds that this hasn't been the case due to extensive water cooling.
    - Daniel explains that detailed studies to update the BLM thresholds for collimators based on more realistic damage cases are ongoing in the BLMTWG.
    - MPP approved the proposed threshold increase by a factor 3-4 for long running sums in the TCTs and TCLs
    - Anton explains that an ECR has to be prepared for this change. Furthermore, the proposal will be quickly presented to the LMC. The changes can be implemented next week, requiring a few hours,

AOB - General

- Next meeting on June the 10th.