168th Meeting of the Machine Protection Panel

The meeting took place on August 31st 2018 in 774/1-079.
Participants:
A. Andrea, M. Deile, B. Dziedzic, L. Esposito, V. Kain, K. Li, B. Lindstrom, A. Mereghetti, Y. Nie, B. Petersen, E. Ravaioli, R. Schmidt, B. Salvachua, C. Schwick, M. Trzebinski, J Uythoven, M. Valette, A. Verweij, J. Wenninger, D. Wollmann, C. Wiesner, C. Zamantzas, 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/ and https://indico.cern.ch/event/752454/

1.1 Approval of MPP#167's minutes

- Actions from the 167th MPP (https://indico.cern.ch/event/749858/):
    - None.
- No additional comments have been received on the minutes; they are therefore considered approved.

1.2 Summary on SPS vacuum issue due to instability causing losses in MB 33130 and planned mitigations (K. Li)

- In a fixed target cycle of the SPS on the 20th of August, the working point at the start of flat top was Q_x=26.62, Q_y=26.58. During the adjustments of the vertical tune, the proposed trim by the AutoQ application was much too large in absolute terms. There was no automatic check on the magnitude of the trim. The trim ended on the half integer resonance, leading to a fast excitation of the fixed target beam (about 3×10^{13} ppb) at flat top (400 GeV). Severe vertical beam losses happened at the aperture bottleneck where the MBB.33130 is located. The resulting vacuum leak eventually triggered the beam interlock system, when the vacuum valves moved in. As a result of the important vacuum leak the magnet with its vacuum chamber had to be exchanged. The SPS was out of operation for more than 2 days.
    - Daniel asked if it is possible to estimate how many protons were lost at the damaged vacuum chamber, in order to calculate the energy deposition. Jorg commented that it would be very difficult to estimate this number.
- During this event, about 80% of the beam was lost over a time period of only 15 ms, which was faster than the reaction time (20 ms) of the BLMs in the arc. Nevertheless, the BLMs did not trigger the beam dump, as the loss was below the threshold and the existing systems does not contain different running sums as the LHC system. The trim event was accidental, but there are several other ways which could lead to similar events, e.g. a damper trip, which did happen on the 23rd of August "but" fortunately in the horizontal plane. The consequences would be severe, if the vertical damper tripped, as the BPM interlock is implemented in ALPS only in the horizontal plane for the time being.

- It has always been an issue for the SPS that it cannot be protected by BLMs against beam losses in the arc faster than 20 ms. The issue will become even more critical after LS2 when we have the LIU beams with much higher bunch intensities compared to the beams involved in the trim event. Several short-term and long-term mitigation strategies were proposed.
    - Software sanity checks before trim.
    - Revised BLM thresholds and strategy.
    - Interlocks on the BCT (dI/dt) with a reaction time < 1 ms.
    - Ideally, faster BLMs everywhere not only in the LSS and (known) aperture bottlenecks with appropriate thresholds, triggering on running sums rather than absolute loss levels.
        - Christos said that it might be possible to make the integration time of the SPS BLMs half or quarter (from 20 ms to 10 ms or 5 ms), which is under study. For triggering on running sums, implemented at the software level, is a request pending already for some time. New more performant CPUs have been this year been deployed to all crates and this request will be revisited. Equipping all crates with hardware interlock (LSS type) is not possible due to missing electronics. The future version of the SPS electronics is under design with deployment foreseen at LS3. First design will be reviewed at the BI technical board end of September.
- The following solutions are currently under investigation in close collaboration with BI.
    - dI/dt interlock on BCT, which needs a separate BIC channel. Light monitor could also be an option.
    - BPM interlock implemented in new ALPS.
    - Relocate some fast BLMs (LHC type) to more crucial locations in the SPS.
        - Christos commented that the interlock on dI/dt looks most realistic, which could interlock on the loss of 1×10^{12} p within 1 ms using the slow BCTs. The BPM interlock cannot be realised soon. If for the future deployment of the BLM system significantly more ionization chambers, such as to cover better or more locations, are required, BI needs to be informed now. The production of new ionization chambers is planned to start next year. A significant increase in the numbers to be produced should not be a problem, whereas the additional production of even a small number later will be very difficult or impossible.
- After TS2, there will be a different aperture distribution in the SPS, while the aperture at 331 is expected not to be the bottleneck any more.
    - Rudiger commented that there would be a bottleneck in any case, which in principle should only be at the beam dump or at collimators. It should be considered if a small collimator system could be designed to define the aperture bottleneck.
- Jorg commented that a comparably severe accident occurred in ~2008. Nevertheless, due to the LHC depending on SPS beam, these type of events are

more critical, as this time the LHC stopped lumi production for almost 4 days. This fact could maybe help to increase the priority for a fast BLM system in the SPS.

1.3 Fast failure due to triplet event (03.06, 19:28): the magnet view (E. Ravaioli)

- Previous presentations give the event description and primary analysis (LMC presentation) about the event of 2018-06-03 19:28 RQX.R1 quench. Emmanuele presented here the latest RQX simulations using STEAM, trying to explain three main unusual features of the event.
- In the event, the magnet current was discharged very quickly. The simulations coupling PSPICE, LEDET and COSIM reproduced the power supply voltages / currents before the power abort, which confirmed that the current in Q1 equalled to the measured RQX and RTQX1 currents. In order to match the fast current discharge, a very high normal zone propagation velocity was assumed.
    - Jorg commented that reducing the magnet current by several A in 20 ms requires indeed a very fast quench propagation.
- Another unusual behavior of the event was that the quench detection system was not triggered until about 20 ms after the beam dump. The measured helium bath temperature at the moment of the event was >2.15 K. A hypothesis is that the quench propagated very quickly and symmetrically in the two magnet halves (due to the much reduced margin at 2.15 K), so the quench detection based on voltage monitoring was triggered only later.
- The third unusual behavior of the event was that B1 changed its orbit about 3 times more quickly than expected, while B2 did not change its orbit obviously, contrary to expectations. Simulations showed that the Inter-filament coupling currents (IFCC) must not be neglected, as they have a considerable influence on the magnetic field in the bore. The IFCC-induced field in the bore can be asymmetric, hence it can generate a dipole kick on both beams, or only on one beam, or opposite kicks on the two beams. However, the IFCC effect itself is too small to explain the observed beam position changes, missing about one order of magnitude. Further analysis will be performed including the inter-strand coupling currents and magnetization (persistent currents). In parallel, it would be interesting to perform K modulation tests at frequencies > 10 Hz to verify / disprove the model results, however this is not possible due to hardware limitations.
    - Rudiger asked if the observed effect on the beam could also be explained by current re-distribution during the quench. Emmanuele replied that this hasn't been checked yet, but would be worth to implement in the model.

1.4 Fast failure due to triplet event (03.06, 19:28): the beam view (B. Lindstrom)

- Bjorn presented the triplet quench event on the 3rd of June from the beam point of view.
- The quench led to a vertical orbit shift in B1, up to about 180 µm in the center of the MQXA.1R1 (Q1).

  - Jorg asked how the offset in the center of the magnet was determined. Bjorn replied that he scaled it with the beta functions of the nominal optics as an approximation. Jorg continued that the crossing angle also affects this a bit. Bjorn replied that this is only of the order of a few percent and has been ignored for the moment.
- Since the kick was slow it effectively led to a change of the closed orbit. The BPM measurements throughout the ring were then fitted by an amplitude modulated sine wave, giving the magnitude of the kick. Bjorn showed the orbit offset, normalized to the beta function, around IP1, where one can see a cusp in the sinusoidal wave. This indicates that the kick was applied at this location, confirming that it occurred only in the triplet right of IP1 and not elsewhere in the ring.
- The total kick on beam 1 was 0.2 µrad, when the beams were dumped around turn 240 after the onset. Under the assumption of a perfect quadrupolar field, this would correspond to a magnetic field change of 0.68 mT. However, from the magnet point of view, the change is expected to be on average 0.23 mT under the same assumptions.
- The expected kick from the magnet was numerically integrated using the magnet transfer function and the measured current change of 1.7 A, leading to vertical kicks of 6.7×10^{-8} rad for B1 and 6.0×10^{-8} rad for B2. This would lead to an orbit offset of 82 µm and 39 µm respectively, in the BPMS.2R1.B1. However, the measured orbit offsets were 250 µm for B1, and nothing for B2 (< 10 µm).
- After the quench event, a k-modulation of the MQXA.1R1 was conducted, using the same circuit that saw a current drop during the quench. The resulting orbit offsets from this modulation was 51 µm/A for B1 and 24 µm/A for B2, which agrees with the offsets calculated from the magnet circuit point of view (82 µm/1.7 A and 39 µm/1.7 A). This confirms that there is something missing in the understanding of the magnetic field changes during the quench.
  - Jan asked if there might be a short in the magnet. Arjan answered that probably it will be possible to explain what is observed with the IFCC and other transitory effects.
  - Daniel added that there had been several issues around Q1 recently, leading to beam dumps, and asking if there might be a common cause. Arjan replied that the recent Q1 events were due to different causes and are not believed to be related to one another.
  - Rudiger asked about the reason for the magnet quench. Daniel/Markus/Arjan confirmed that some unusual behavior in the cryogenic regulation was reported (with a clocked value), which led to the unusual temperature excursion to >2.15 K and entailing a much reduced quench margin for collision debris.
  - Daniel asked if anyone has any idea from the beam point of view that we might be missing in the current analysis. Jorg said that a quench in the MCBX could explain the asymmetry between the beams, but we should have seen this in the circuits.

- Alessio mentioned that B1 is outgoing and directed upwards in the triplet, so it is reasonable to assume that there was a symmetric quench in the top half of the magnet.
- Studies are ongoing and it is hoped that these will be able to explain the observable behavior.

AOB – Changes in TOTEM / CT-PPS during TS2 and revalidation requirements (M. Deile)

- For the CMS-TOTEM Precision Proton Spectrometer (CT-PPS), the position of the sensor / chip needs to be moved during TS2 to re-distribute the irradiation vertically. Specifically, the horizontal XRP units of 210 far and 220 far will be lifted and lowered by 0.5 mm, respectively. The mechanical procedure is identical to last year and during TS1. Detector package in cylindrical pot 56-220-C-H will be replaced. Service work on electronics components will be performed. Optionally, scopes might be installed in the tunnel and removed after re-validation, which would need a short access to the tunnel as after TS1.
- The bellow interconnecting has been X-rayed after the position change during TS1. If the proposed vertical variation during TS2 is ok for the vacuum group, only X-rays will be needed after the position change.
  - Daniel asked how to go about the beam-based alignment in TS1. Mario answered that the change of centers measured with the beam-based alignment was of the order of 100 µm, smaller than the threshold.
  - Daniel proposed to provide an alignment procedure for the collimation team to be best prepared.
- During TS2, 5 horizontal pots will be touched, which need to be realigned afterwards. Loss maps will then be needed as usual. No interlock components will be touched. Additional calibration data will be needed, the details of which will be communicated via CMS run coordination with the LPC.

AOB – Changes in AFP during TS2 and revalidation requirements (M. Trzebinski)

- For the ATLAS Forward Proton (AFP) detector, there will be several interventions during TS2.
  - Investigation of the cause of C NEAR self-extraction (minor intervention).
    - The C NEAR self-extraction have happened 5 times from this May to August. Once the station is extracted, it remains in garage until the end of the fill, as a result, the data is not useful for most of the two-proton high-μ analyses.
    - The LVDT has been changed during TS1, since the reason of the self-extraction was thought to be the LVDT glitch. Now a strong correlation with the vacuum pump has been found. One hypothesis is that a mechanical shock wave caused by the valve switching is transmitted to the LVDT, leading to the self-extraction.
    - Since this correlation is strange and of low frequency, it is not guaranteed that it will be successfully solved during TS2. Maciej

asked the MPP that if we could have a procedure which allows re-insertion during the fill.

- Jorg and Belen commented that we would need to create a sequence to do the re-insertion, since we do not have such a sequence presently.
- Jan said that he would hesitate to perform a re-insertion before knowing what has happened.
- Daniel commented that he would propose to keep this request open for the moment, since we do not actually know if the 5 events were caused by the same origin or not, and the current behavior is safe.

- Investigation of the cause of C NEAR high voltage trips (minor intervention).
  - The detector package will not be dismounted (only check the cables), so there is no need for re-alignment.
- Adjust of the cooling system to lower its temperature, namely to increase the pressure (minor intervention).
  - Such adjustment was performed during TS1. To further decrease the temperature during TS2, a visit in the tunnel will be required, since the valve is manual.
- Installation of ToF detectors in FAR stations (major intervention, which is to be decided in the ATLAS review on the 13th of September).
  - Maciej remarked that if a ToF system is installed, the TCL6 would have to be closed to reduce the radiation in ALFA.
    - TCL6 insertion needs preparation by the collimation team and verification for increased radiation levels in the RR (IP1).
    - Alessio commented that the plan is to keep TCL6 open, so one would need to prepare how to establish the settings in case TCL6 is required to close.
    - Daniel commented that an early preparation would be preferred, once the ToF request is confirmed by ATLAS and LPC.

AOB – Required revalidation after TS2: loss maps, asynchronous dump tests, intensity ramp-up, etc (D. Wollmann)

- Daniel presented the loss map validation matrix (in collaboration with the collimation team) after TS2, and the proposal for intensity ramp-up after TS2. There will be in total 3 fills (50b, 600b, 1200b) for intensity ramp-up after loss maps. The proposal integrated the requests from ATLAS.