167th Meeting of the Machine Protection Panel

The meeting took place on August 17th 2018 in 774/1-079.
Participants:
H. Bartosik, K. Cornelis, M.A. Fraser, C. Hessler, Y. Nie, B. Petersen, L.S. Stoel, C. Schwick, F.M. Velotti, J. Wenninger, D. Wollmann, C. Wiesner, 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/749858/

1.1 Approval of MPP#166's minutes

- Actions from the 166th MPP (https://indico.cern.ch/event/742780/):
  - None.
- No additional comments have been received on the minutes; they are therefore considered approved.

1.2 Slow extraction MD in the SPS using octupoles to manipulate the shape of the extracted separatrix in phase space (L.S. Stoel)

- Linda presented the motivation and procedure of a new slow extraction MD in the SPS, using octupoles in addition to sextupoles, with the goal to test a method to further decrease the losses at the electrostatic septum (ZS) during extraction, together with the simulated MD results and error studies. The MD procedure has been summarized in a document entitled "Separatrix folding with octupoles during resonant slow extraction" (EDMS 2014948).
- Resonant slow extraction is currently used at the SPS LSS2, where sextupoles at 1/3 integer horizontal tune drive a resonant amplitude growth. The extraction is initiated by a very thin ZS. Activation of the elements and the adjacent area due to beam impacting the thin ZS wires limits the amount of beam that could be delivered to the future experiments.
- In order to reduce the beam losses at the ZS wires during extraction, octupoles can be used to change the phase-space representation at the separatrix in such a way that the density of the extracted beam profile is reduced at the thin ZS wires. Additional sextupole strength is then required to keep the extracted beam size the same. The planned MD aims to demonstrate that we can control the phase-space representation using the sextupoles and octupoles simultaneously. After this proof of concept, a second MD to identify the optimum working point minimizing the losses might be proposed.
- In the proposed MD, a very low intensity (VLI) version of Multi-Turn Extraction (MTE) at about 5×10^{11} ppp (60 times below nominal) will be used. The beam intensity, which has been prepared in the injectors and tested, is below the expected ZS damage threshold (which has been identified as 2×10^{12} ppp). A dedicated RF setup will be necessary in the SPS due to the lower intensity beam which impacts the related RF diagnostics. The recently developed Constant Optics Slow Extraction (COSE) will be used in this MD, rather than the currently operational tune sweep method. The normalized (to extracted intensity) BLM

interlock limits in the ZS region will be increased, while the absolute BLM interlock limits will accordingly be reduced compared to the nominal settings.

- Simulations have shown however, that when large octupole strengths are applied, the beam driven out of phase-space centre by sextupoles can be trapped within the acceptance by octupoles. This should be avoided as it would potentially increase the particles impacting on the ZS wires.
- The MD will therefore be split into two parts. The first part will focus on verifying the understanding of the stabilizing/trapping effect of the octupoles during slow extraction in combination with the extraction sextupoles while still using safe beam intensities. In the first part, the extraction bump will be off, so that the beam will either stay trapped or be lost on the TCSM collimator, which will be inserted for this purpose. In the second part we will then proceed to measure the effect of the combined sextupolar and octupolar fields on the extracted beam, with predetermined limits on the octupole strength.
- The first part of the MD will be performed after extraction setup and TCSM alignment. With TCSM IN and extraction bump OFF, the main steps include:
    - Increase octupole strength to find beam trapping.
    - Define safe limit for octupole strength to avoid trapping beam near ZS wires.
    - Measure trapped beam profile via the BGI to compare it to the theoretical one.
    - Note that the octupole strength will be scanned for the two signs, at both nominal and higher sextupole strength.
- The second part of the MD will be performed with TCSM OUT and extraction bump ON. The main steps are:
    - Add LSA octupole limits determined in the first part.
    - Starting from 0, increase octupole strength in small steps, while measuring the extracted beam profiles and ring losses.
        - The simulation results showed that at nominal sextupole strength, as the octupole strength increases, more particles will not be extracted because more particles will be lost at the ZS wires or the TPST absorber, or even stay trapped. Daniel asked about the risk to the ZS wires. Matthew commented that the damage limit of the ZS wires was estimated at about 10^{12} protons. To be safe, the beam intensity will therefore be kept as low as possible (below 5×10^{11} ppp) to mitigate the worst case, namely the possible combination of sextupole and octupole strengths resulting in the highest losses at the ZS wires.
    - At the limit of octupole strength, realign the ZS girder to minimize beam losses by compensating for the change in extracted beam angle due to the bending of the separatrix.
    - Increase the sextupole strength in small steps at the limit of octupole strength, and realign the ZS girder at each step.
        - Karel expressed that his main worry with this MD is that the sextupole scan may cause losses onto the ZS cathode, which is already experiencing HV breakdowns and should therefore not

be further stretched, with high sextupole strength. He proposed to keep the cathode at all times in the shadow of the TCSM during the sextupole scan (establish extraction by slowly removing the TCSM and then keep the TCSM to protect the cathode). This proposal was supported by the MPP and will be included in the procedure by Linda.

  - Set the octupole strength back to zero, the sextupole to nominal, and put the ZS girder back to nominal alignment.
  - Repeat the procedure for the opposite octupole sign.
- In summary, the addition of octupoles to the slow extraction at the SPS LSS2 could reduce the beam losses at the ZS wires, which has been simulated. This first MD aims at understanding the beam dynamics involved. The circulating beam centre will not move significantly. The MD is structured so that safe limits for the octupole strength can be identified and implemented before extraction with octupoles is tested. The procedure explicitly makes use of constant small steps, so that shot-by-shot changes will be small and high loss scenarios can be avoided.
  - Markus asked about the next plans after this first MD. Linda said that in the currently planned MD, they would try to find a combination of sextupole strength, octupole strength and ZS alignment for which the beam losses at the ZS wires are comparable to nominal. In a future MD, they would try to reduce and optimise the losses by e.g. changing the angle of the extracted beam. A use of this new method for nominal extractions is not foreseen for this operational year, as it would require a series of other changes in the area, but is a long-term investment.
  - Matthew and the co-authors will update the MD procedure with the comments from the MPP. Markus and Daniel thanked Linda and colleagues for the very detailed and well written MD procedure, and proposed to include the final MD procedure in the MPP EDMS tree for distribution.
  - From an MPP point of view the MD is approved with the comments and changes mentioned above.