73rd Meeting of the Machine Protection Panel

Participants: B. Auchmann, T. Baer, J.C. Bau, M. Bednarek, V. Chetvertkova, B. Dehning, E. Effinger, C. Garion, W. Hofle, E.B. Holzer , R. Jacobsson, A. Jeff, I. Kozsar, A. Lechner, E. Nebot, A. Priebe, B. Salvachua, M. Sapinski, R. Schmidt, J. Uythoven, S. Wenig, D. Wollmann, C. Zamantzas, M. Zerlauth

1 Presentations

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

1.1 Modification of HV interlock of BLM to allow for 200kW loss – (E. Effinger)

- HV-SIS interlocks were introduced to detect the cut of HV after an incident in April 2011.
- This SIS interlock triggered several times due to high losses in IR3 and IR7, when the HV went below the threshold.
- The high voltage supply is implemented with two Henzinger HV power supplies per IP. The operational HV supply has V_nom=1450V, the backup HV has V_nom2=1440V. The maximal total current is I_max=40mA (20mA per HV) per IP, which is equivalent to 740GY/s.
    - Markus wants to know if the BLMs take current from both HV supplies, when high losses appear. Ewald confirms this.
- Ewald shows the two different high voltage schemes. One is used in the areas with lower radiation and the other for areas with higher losses.
- All problems with the SIS interlock have been seen in areas with high losses. In these cases there is a voltage drop due to a current flowing through the filter resistor. Originally a dump was triggered if the voltage dropped below 1370V for more than 10 or respectively 60s. This threshold was later lowered in some boards of IR7 to 950V.
- Ewald shows some measured data from boxes, when a drop of HV appeared.

- Bernd explains that the detectors show linearity as long as the losses increase. When the voltage goes down one can see a hysteresis and the sensitivity goes down by about 30%.
- Due to the limitations a suppressor diode was introduced in three boxes during TS3. This should limit the voltage drop. Since then no interlock from these boxes was registered.
- With the suppressor diode and the lower voltage limit, a maximum of 518Gy/s can be tolerated. Without this diode change the high voltage error would appear at 11.93Gy/s. The latter is sufficient for the arcs and other low loss areas.
- The SIS dump request delay is 10s in IP 1, 2, 4, 5, 6 , 8 and 60s in IP3 and IP7.
- In case the suppressor diode breaks due to radiation:
    - High-ohmic: situation like without the diode.
    - Short-circuit: detected by the modulation test, which is done before each fill.
        - Markus asks, what would happen, if the short circuit would develop during a fill. Ewald responds that this would only lead to the situation that the BLMs suck more current from the HV.
        - Markus asks in which IPs the suppressor diode will be introduced. Ewald responds that this will be only done in IR3 and IR7.

1.2 Issue with beam transfer between SPS and LHC – (J.-C. Bau)

- Jean-Claude explains, how the LHC injection scheme is functioning.
- The SPS.LHCSEQE.NLHCINJ() (pre-warning) flag and the SIX.FW1KFO-CT() flag need to be present in the same SPS cycle.
- All the information from the LHC injection request must arrive 450ms before the SPS injection.
- Issue on the 30th November:
    - LHC requested injection of beam into ring 1.

  - The beam was correctly prepared in the SPS and extracted into TI2.
  - Surprisingly LHC injection kickers in ring 2 fired instead of the kickers in ring 1 and the beam was sent onto the TDI.
- The reason for the issue: The event HX.RNGI-CT, which contains in its payload the LHC beam destination, was not sent because SPS.LHCSEQE.NLHCINJ and SIX.FW1KFO-CT did not arrive in the same cycle. Therefore the pre-pulse switch remained in the previous (B2) position.
- Improvements:
  - Constrain the LIC central timing to not let the first SPS injection occur later than 990ms. This change will be applied to all SPS beams. This will not solve the problem, if the injection into the SPS has to be postponed.
  - Change the injection scheme for the LHC: There will be a new pre-warning 1000ms before the first SPS injection, which contains the dynamic SPS destination. This pre-warning will go through the LHC central timing. Only if the information from the LHC and the SPS agree, the injection will be performed. Otherwise the beam will be dumped in the SPS.
  - The information of the first SPS injection will be feed into the LHC-sequence and read back to the SPS.
  - The modification of the LHC injection scheme is more flexible, as the pre-warning is not depending on the SPS cycle anymore. But the next LHC injection request may be delayed. This could be implemented during LS1.
- These improvements may not be sufficient as there could appear:
  - Unexpected failures in the central timing (LIC or LHC).
  - Timing distribution failures (timing repeaters down, timing cable cut, event lost).
- To overcome this:

    - Introduce a SIS interlock to dump the beam in the SPS in case of a problem. But, this does not guarantee that the timing distribution is correct.
        - Jorg comments that a SIS interlock is only possible in some cases.
    - Monitoring of timing distribution close to the equipment. This would be a case by case action. Similar solutions are already implemented in the SPS to dump the SPS beam, when a bad timing reception was detected or the LIC central timing software crashes..
- Conclusion: The equipment specialists should not rely on the correct distribution of the timing, but protect their equipment (e.g. by SIS).

Discussion:

- Jorg comments that there has been a lot of work done in the SPS to protect against timing issues, since CNGS started.
- Jorg also points out that there is another possible error due to the RF-timing pre-pulse generation.
- Markus asks, when the changes will be performed. Jean-Claude explains that he currently makes the planning for LS1.
- Markus asks if there is a way to verify the correct timing already now? Jean-Claude responds that the modifications are currently tested in the Lab. Jorg comments that this can then be tested in detail before the restart of the SPS in June 2014.
- Markus points out that it would be good to document the planned changes and distribute them to the experts of the concerned systems (RF etc.).
- **Action:** The planned changes in the LHC injection scheme, SPS SIS, etc. should be summarized and distribute to the experts of the concerned systems. (J.C. Bau, I. Kozsar)

1.3 Fast vacuum valves for the LHC – (Cedric Garion)

- The motivation for the installation of fast vacuum valves is coming from the 2008 incident in sector 3-4. The task force proposed to introduce fast shutters to protect sensitive systems like the RF cavities from contamination / damage by pressure waves carrying small particles.

- The velocity of the pressure wave was observed as ~1000 m/s at room temperature and ~35m/s in cold systems (LHe).
- The requirements for such valves are:
    - Fast closure (~20ms).
    - Bake able.
    - Minimum aperture: 80mm.
    - Local/remote control.
    - Small and smooth aperture change.
- Main requirements for the blade:
    - Fast closures in the 20ms range.
    - Dust free to not contaminate sensitive adjacent elements.
    - Vacuum compatibility and leak tightness (~1mbar.l/s).
    - Transparency and high fusion temperature in case of closure with beam.
- Due to the propagation speed of the pressure wave and the time response of the shutter the non-protected length distance is 20m at room temperature and 0.7m in a cold. Thus, the fast shutters should be placed as close as possible to the RF cavities.
- Cedric shows the mechanic components of the fast valves, with pneumatic actuator, titanium/glassy carbon blade.
    - The disc support is made out of titanium with a thickness of 2mm.
    - The disc itself is either titanium or glassy carbon with a diameter of 100mm and thickness of 2mm.
    - The material properties of Titanium and classy carbon for the fast shutter parts are compared in a table:
        - The radiation length of Carbon is a factor 10 longer than titanium and is therefore preferable.
        - Titanium has better mechanical stability.
- The mechanical stresses in the disc and disc support have been studied and fatigue and rupture tests have been performed with the glassy

carbon. More than 200 closing cycles have been successfully performed. The failure pressure in the rupture test was 4.3bars (difference pressure).

- In addition the temperature profile in the disc in the case of beam impact has been studied. The assumptions made :
  - Beam size: sigma=0.9mm.
  - Disc rotation speed 80rad/s; aperture center reached after a rotation of 25 degree.
  - Time delay for full beam extraction was assumed to 320us.
- Simulation results:
  - Maximum temperature due to beam impact on glassy carbon blade was ~2500T. Due to the lower radiation length, the titanium would be heated up by a factor 4 more.
  - Maximum stress in glassy carbon is 128MPa in compression and 12MPa in tension.
    - Jan asks what the conclusion is: Cedric answers the carbon could withstand the impact (with a margin of 600K to the melting temperature). The maximum stress is a factor 2-3 below the limit.
    - Markus, Jorg, Ruediger and Anton state that the disc is not the problem, but the energy deposited in the elements downstream due to the showers created in the disc.
    - Markus points out that detailed FLUKA simulations will be required.
- Next steps:
  - A measurement of the closure motion parameters is required. Tests are foreseen in early 2013.
  - Studies with the titanium disc based on realistic heat deposition need to be performed.
  - In addition the control system to trigger the fast valves has to be Studied and defined.

Discussion:

- Jorg asks, how to trigger and interlock the valves. Markus answers that there are ideas to trigger the fast valves by the QPS. This clearly needs further discussions.
- Jan points out that the current vacuum valves only start moving, when the beam dump was triggered. Ruediger re-enforces that the reason for this is that for all beam dump triggers the BLMs are the redundant system. They are in all cases fast enough to dump the beam in case of a vacuum valve moving in with stored beam.
- Jan points out that in case of the movement of the valve the beam must be dumped before the blade arrives at the beam.
- Markus asks if the valves need to be so fast. Cedric replies that in case of the failure in the D1 (warm) the propagation speed of the pressure wave is very high. If a problem in the cold region happens the pressure wave is much slower.
- Jorg points out that after the consolidation during LS1, which should protect us against an incident like sector 3-4 for about 20 years, the fast valve should not produce a failure, which triggers such type of incident.
- **Action:** Discussion should go on about these issues. Detailed FLUKA studies should be scheduled.

1.4 Machine protection during quench tests (M. Sapinski)

- The goal of the presented quench test is to measure the quench limit of the arc magnets for UFO-timescale losses (~ some ms). This test will verify the QP3 predictions on quench limits at 6.5-7TeV. The test needs to be performed in a controlled way with the ADT.
- Previous tests:
    - Wire scanner quench test (2010). This test showed losses, which were much slower than expected (loss duration 20ms).
    - MD on October 13th and June 22nd 2012: Losses were generated with the help of the ADT in the ms-timescale. The assumed quench limit in this timescale is about 30-40mJ/cm3. This is equivalent to N_prot >=10^8p.

        - Tobias ask, what we would need to quench the main bending magnet. Mariusz and Bernd reply that the bends were quenched with horizontal losses and the MQ with vertical losses. The quench limit should be comparable in the MQ and the MB. Bernhard confirms this.
        - Anton comments that it would certainly be very interesting to understand the distribution of the beam impact for the new and also for the previous quench tests.
- UFO case produces about a factor 10 lower energy depositions in the MQ/MB than the bump case. The vertical size of the impact area of neutral particles is larger than the vertical beam size. Therefore to reproduce this condition a vertical blow up is needed.
    - Anton points out that this needs verification.
    - Bernd explains that the scattered particles should have an opening angle 1/gamma, which is the lower limit. The further dilution can just be more.
    - Wolfgang asks if also a blow up in the horizontal plane is needed.
- Proposal from the ADT team:
    - Accelerate 10 small pilot bunches (each 5e9p) at 4TeV.
    - Us new damper settings with ultra-low sensitivity.
    - Reduce bunch intensity by gated vertical blow-up/loss until target intensity is reached.
    - Apply procedure with flipping sign of H damper proceeded by Q-kick as tested in previous MD. If no quench scrape less at the next bunch.
        - Jorg points out that due to coupling between the planes the larger beam size in the vertical plane will also couple into the horizontal plane. This would mean a further dilution in the other plane.
        - Belen mentions that during the longitudinal impedance MD scraping was performed with the q-kicker. This could also be a solution. Jan and Tobias respond that the strength of

the q-kicker at 4TeV is much lower. Therefore the ADT seems to be the only solution.

- Ruediger and Bernd point out that it is mainly important to know the beam size and the intensity, which could be done by using the wire scanners.

- There is some testing required before hand. This could maybe done at the beginning of January during the p-Pb setup or loss maps:
  - Test of ultra sensitive ADT settings.
  - Test kick procedures and blow-up at 450GeV.
  - Calibrate intensity versus losses.
- The low intensities can be measured by (slide 10):
  - The longitudinal density monitor (up to 10^7).
  - BLM calibrations from previous measurements could help to estimate the number of lost protons.
  - FBCTs can go down to 10^8 protons. Discussions with experts are ongoing.
  - ADT sum signal can also give an indication of the bunch intensity. This needs to be tested with low intensity bunches.
    - Wolfgang points out that for the ADT they will have to take out the limits, which will make also noise and reflections visible.
- Fast QPS measurements: Mateusz states that it is probable that the number of particles impacting on the magnet induces the signal measured. It seems not to be a resistive signal. The measurements will probably be performed with a scope. Mateusz points out that the installation will be done as late as possible. Ruediger mentions that the test will be done in B2, which should be taken into account. Daniel points out that one should look into the BLM data from last years ion operation, to see if a loss spike appears in Q12L6.
- The experiment will take place at Q12L6. More BLMs will be installed in this cell.
- The interlocks in the BPMs in IR6 need to be disabled.
- Beam screen issues need to be discussed in January.

- The tests at injection will need about 6h of beam.
    - Markus and Jorg point out that the pre-tests should be done during the p-Pb setup at the beginning of January, to sort out potential limitations.
    - Tobias mentions that we need to be well below the saturation level of the BLMs. Mariusz responds there will be enough BLMs so that some maybe saturated but the others not.

1.5 Miscellaneous

- AOB: Ruediger mentions that there will be a request from TOTEM and ALFA to put the Roman pots to about 12 sigma. Benedetto proposes only to put vertical pots, as problems appeared with the horizontal TOTEM pots earlier. Markus proposes to ask Mario to write a document with beam sizes and pot positions.