

## 125<sup>th</sup> Meeting of the Machine Protection Panel

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Participants: F. Acessio, A. Alici, W. Bartmann, J. Boyd, C. Bracco, G. Bregliozzi, B. Dehning, M. Deile, S. Gilardoni, S. Jacobsen, V. Kain, M. Kalliokoski, A. Lechner, M. Pojer, V. Raginel, M. Rijssenbeek, C. Schwick, J. Uythoven, D. Wollmann, C. Xu, 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#124's minutes

- Actions from 124<sup>rd</sup> MPP:
  - AFP commissioning. It is was enquired whether the logic has been re-tested after putting the jumper in the system to force the home switch signal for the not installed B2 pots to true. M. Rijssenbeek said that the PXI signals have been checked and that the COPY\_HOME signals from the cRIO are correctly received. Therefore, the cRIO must work correctly regarding this function because the mapping of the signals in the interlock-PXI connection was verified earlier. In addition S. Wenig said that he checked that the right home switches have been bridged since he has observed that the correct switches changed state when the bridges had been installed.
  - M. Valette verified that the roman pots are all on the safe side in case of an asynchronous beam dump:
    - Beam 1
      - IP5: the pots are between 195.4 and 220.75 degrees from the kickers.
      - IP1: the horizontal pots are between 254 and 271 degrees, the vertical between 130 and 145.

Since B1 is kicked outwards by the kickers, XRP are on the good side (phase is over 180 so the beam is moving inwards and already a little inwards).

- Beam 2
  - IP5: the pots are between 18.75 and 47.52 degrees.
  - IP1: the vertical pots are between 326 and 340 degrees.

Since B2 is kicked inwards by the kickers, XRP are on the good side (phase is over 0 so the beam is moving inwards and already a little inwards).

- No additional comments were received on the minutes, therefore they are considered approved.

## 1.2 Simulations for TDE and assumptions for operation in atmosphere (M. Frankl)

- Simulations were done for proton runs. For ions run, the graphite stays below 600°C for all energies.
- Keeping the TDE graphite core under inert atmosphere (N<sub>2</sub>) was implemented as a safety measure:
  - From the LHC design report “... if a massive air entry were to occur in the 6 minutes following a high intensity dump, the graphite could burn...”
  - However with present knowledge, burning of graphite under these conditions seems to be unlikely.
  - Literature is however too scarce, thus, EN/STI will conduct additional experimental studies.
- EN/STI recommends to keep the peak temperature in the graphite core below 600°C if the N<sub>2</sub> pressure falls below 1.05 bar.
- First intensity limits have already been derived last year (see presentation of J. Uythoven in the LMC#242 11/11/2015).
- Assumption of the simulations:
  - Adiabatic process during beam dump (overestimation of peak temperature of ~10%).
  - No temperature-dependent specific heat curves exist for the graphite grades used in the dump, a specific heat curve for another grade is used instead. EN/STI plans to measure the specific heat of the graphite grade used.
- The dump core consist of high- and low-density graphite absorbers. The low density graphite is made out of 2mm thick layers.
- Standard and BCMS beam parameters are used as input for the simulations. Standard Beam trains consist of 4 batches of 72 bunches and BCMS Beam train of 3 batches of 48 bunches with a gap of 900 ns between two consecutive train and 225 ns gaps between two batches.
- Two sweep patterns were studies: a regular one and a 2H+2V missing kick (considered rather unrealistic).
- **Dumps at 450 GeV safely remain below 600°C for a full machine and all beam conditions.**
- The peak temperatures in the graphite core are:
  - 1130°C for a 7 TeV Standard Beam Dump with a regular sweep.
  - 1090°C for a 7 TeV BCMS Beam Dump with a regular sweep.
- **Given a temperature constraint of 600°C, beam dumps are limited to a maximum of about 20 bunches at a beam energy of 6.5 TeV if the N<sub>2</sub> pressure falls below 1.05 bar.** Beam dumps suffering from 2H+2V MKB failures don't impose much stronger restrictions with respect to the maximum number of bunches allowed.
- These new results are similar to the ones given last year but with a better confidence in the results. The simulations also helped to understand what the critical parameters are, emittance is not part of the critical parameters.

- S. Gilardoni said in case the N<sub>2</sub> pressure falls below 1.05 bar and the experiments want to run with more than 20 bunches, a replacement of the dump would be mandatory (several weeks). **This limitation is valid until a better knowledge of the behaviour of the graphite at high temperature exposed to air is acquired.**

### 1.3 Interlocking of TDE dump pressure - New sensors and interlock logic? (G. Bregliozi)

- The N<sub>2</sub> injection line is composed of several components:
  - 2 pressure reading, one for the pressure in the N<sub>2</sub> bottles and one for the pressure in the line connecting the bottle to the dump volume.
  - A safety valve with an open-closed state opening at ~1.3 bar.
  - A rupture disk, a pumping valve, a valve between the TDE and injection line and a connection line to the TDE
- G. Bregliozi said that the N<sub>2</sub> volume was not design to be operated with a “large” leak – the safety valve is located too close to the N<sub>2</sub> injection from the bottle limiting the possible N<sub>2</sub> flux of the bottle.
- Normal operation means N<sub>2</sub> pressure of 1250 mbar.
- During the first N<sub>2</sub> leak in November 2015, the N<sub>2</sub> pressure loss was counter balanced by a N<sub>2</sub> injection via the bottle such that the pressure was always above 1 bar.
- With the actual N<sub>2</sub> leak, the N<sub>2</sub> pressure in the bottle drops by ~4 bar per day.
- It has been proposed to:
  - Re-define TDE & N<sub>2</sub> bottle pressure levels to trigger alarms for the injection:
    - **For the TDE – Alarm limit:** If pressure in the TDE is  $\Delta P < 10$  mbar compared to the operational value, trigger an alarm
    - **For the TDE - Lower limit:** Close to the atmospheric pressure value but still over pressure:  $\approx 1.05$ -1.1 bar - **Injection interlock.**
    - **For the TDE – Upper limit:** Anticipate or analyse possible dump problems: 1.30 bar? – Alarm.  
**Action (ABT): Understand where the 1.3 bar upper pressure limit was derived from (e.g. the vacuum window?)**
    - **For the N<sub>2</sub> bottle – Lower limit:** Allow a safe over pressure operation in the TDE until the bottle exchange during next TS.

**Action:** VSC and OP will work on the alarm proposal to implement it in Big Sister.

- **Re-evaluate the pressure value in the dump:** less pressure implies less absolute pressure increase during each dump and less induced stress on the flanges.
- Use the decrease rate of N<sub>2</sub> bottle to estimate the leak rate and for post mortem analysis.
- **Do a consolidation upgrade on the N<sub>2</sub> Injection line & TDE System:**

- New gauges as close as possible to the TDE: for high and low pressure.
  - Remotely activated valve to isolate the injection line to the TDE to analyse the system remotely.
  - New remote primary pumping station: radiation gas pumped remotely, not requiring the presence of personnel.
  - Installation of a rack of 12 N<sub>2</sub> bottles on surface.
  - Add redundancy in the measurement system.
- Action: VSC and STI to propose and implement a solution to achieve a redundant pressure monitoring system.**

S. Gilardoni commented that such interventions on the dump N<sub>2</sub> system are being discussed for implementation during the EYETS.

#### 1.4 Procedures in case of missing dump pressure (W. Bartmann)

- From EN/STI studies (see presentation M. Frankl, A. Lechner this MPP)
  - In case of N<sub>2</sub> level in dump pressure circuit below 1.1 bar
  - No limit of #bunches at 450 GeV
  - 20 bunches at 6.5 TeV in worst case spacing
- Pressure level reading is interlocked via SIS and XPOC (only in case of a dump) – consider this sufficient from ABT point of view
  - Can upgrade XPOC check of pressure while arming LBDS
- Operational use of several 12 bunch trains at 6.5 TeV with sufficiently spaced gaps is difficult to be interlocked
- In case of pressure problem limit to 12 bunches at 6.5 TeV and repair non-conformity
  - In case machine needs to be filled at injection (e.g. scrubbing) the start of a ramp should be avoided, e.g. using the SIS or by procedure.

#### 1.5 Issue of injecting a nominal bunch into empty LHC (B2), sequence of events, short term mitigations and long-term options (J. Uythoven)

- On Saturday 9 April 2016 at 23:20:47 an indiv bunch was injected into an empty LHC:
  - Normally one should always first inject a probe beam, followed by an indiv bunch, followed by higher total intensity trains.
  - Normally the SPS extraction BIC should protect us from this, taking into account the SPS Safe Machine Parameter system (SMP), Probe Beam Flag (PBM) and Setup Beam Flag (SBF) which are derived from the SPS BCT.
- SPS BCT investigation: BCT reading system failed, leading to a reading of 0 intensity. Thus the flag for safe injection into the LHC became TRUE.
- Actions that were taken after that the event:
  - On the BCT side, in BA3 and BA4:

- All ADC hardware memory locations are reset to 0x0 before the 1<sup>st</sup> beam injection.
- During the SMP RT action, 10 ADC values are read from the hardware.
- If all 10 values are 0x0 then we consider that the acquisition has not started correctly -> unsafe.
- The value 0x7FFF is sent from BA4 ( $\sim 3.278 \times 10^{12}$  charges) and BA3 ( $3.28 \times 10^{14}$  charges) on the SPS-SMP cable and stored to the sbfIntensity acquisition field (used to calculate the PBF and SBF of the SPS).
- Add a check in the IQC on the correctness of the SPS BCT4 buffer published.
- Check that the SPS SBF limit is set to  $5 \times 10^{11}$  p+.
- Done 19th April evening by scraping the beam, the limit was found to be  $5.2 \times 10^{11}$  p+.

**Action:** OP, BI, ABT need to discuss how to check the status of the BCT buffer. Evaluate the new IQC module to see how often the SPS BCT buffers jump to zero.

- V. Kain proposed to also use the BCT in BA5 as a redundant channel to determine the setup beam flag of the SPS. B. Dehning reminded that all the BCT have a software treatment before sending information, inherently limiting the achievable integrity level.

#### **AOB – Proposal for settings strategy for AFP XRP during high intensity fills (M. Trzebinski, M. Rijssenbeek)**

- Results on the beam-based alignment were presented.
- The proposed physics position and limits are the following:
  - XRPH.B6R1.B1 (FAR): inner warning limit 2.289 mm, inner dump limit 2.189 mm.
  - XRPH.B6R1.B1 (NEAR): inner warning limit 5.282 mm, inner dump limit 5.182 mm.
- Re-alignment of the AFP NEAR pot is not possible as all the validation steps will have to be re-done before (it was probably stopped too early in the previous alignment).
- AFP Qualification. ATLAS wants AFP qualification at least for 500 bunches, this value has to be validated by the dose rate measured by ALFA.
- In principle the proposal is approved waiting for feedback from J. Wenninger.
- **Action:** Request to the logging service a modification to archive the AFP positions, limits etc. in TIMBER.

#### **AOB – Recap of intensity ramp-up check-list, verify responsibilities and update items if necessary (M. Zerlauth, D. Wollmann)**

- Check list is a very successful tool for detecting and documenting issues in MP systems and essential for the intensity ramp-up.

- Green light required from every system responsible before increase in intensity.
- Assure readiness of all protection relevant systems for next intensity step.
- **Action (all):** Verify content of checklist and update, if necessary.