Machine Protection Working Group

Minutes of the 41th meeting held on April 1^{rt} 2005

Present: R. Assmann, B. Dehning, R. Denz, R. Giachino, G. Guaglio, E. B. Holzer, V. Kain, D. Macina, V. Montabonnet, B. Puccio, P. Pugnat, A.Rijllart, R. Schmidt, R. Steinhagen, J. Wenninger, T. Wijnands

Topics of this meeting:

- Summary of the workshop on beam generated heat deposition and quench levels
- Possible staging of the BLM system: questions from the BDI group to the MPWG

Summary of the workshop on beam generated heat deposition and quench levels (P. Pugnat)

Heat depositions due to beams in LHC dipole magnets

- Proton beams:
  - A continuous loss of 10 mW/cm³ cause a $\Delta T \approx 0.2$ K
  - The injection losses have not yet been evaluated.
  - Evaluated loss maps show that without tertiary collimators or absorbers the beam losses for 0.2 h lifetime exceed the quench limits. The control of beam parameters (e.g. orbit) is mandatory. An orbit r.m.s increase of 1 mm increases the expected beam losses by a factor 10. According to **P. Pugnat** (referring to J.B. Jeanneret) 0.2 h lifetime seems to be a too pessimistic scenario, a 2h lifetime and including tertiary collimators would be more appropriate.
    R. Assmann noted that the collimators are specified to withstand the worst case scenario of 0.2 hours lifetime within 10 seconds. Such a scenario is realistic, as it has also been pointed out in the 2004 review on cleaning and collimation by colleagues from other labs.
- Heavy ion beams (Pb 82/82):
  - The effect of e- capture has been underestimated for the shower simulations and significantly affects the energy deposition in matter.
  - Preliminary: Energy deposition in the dispersion suppressor magnets exceeds the quench level by a factor of two. With the present design, LHC cannot accelerate and store ion beams at nominal luminosity. Several ideas are being discussed to improve the situation.

Accelerator operation

- Expected LHC operation:
  - During the ramp, quench margin of MB and MQ reduces significantly.
  - Quench margin of special insertion quadrupoles may decrease during the ramp.
- HERA experience:
  - quench level (adiabatic approximation) for transient beam loss:
    2.1 mJ/cm³ -> $\Delta T \approx 0.8$ K

- x16 the threshold in p/s for continuous loss rate (taken from Tevatron)
- Quenches occurred at about a factor 5 below expectation.
- BLMs cannot protect against instantaneous losses (BLM integration time with 5 ms too long).
- quench statistics:
  - 27% during injection
  - ~1/3 slow losses
  - 12 % due to false alarms (alarm system failure)
  - 10 % due to false BLM alarms
- Tevatron experience:
  - measured quench level for fast losses (<20 us): 4 mJ/cm³
  - quench level for continuous loss: 50 mW/cm³ (**B. Dehning**: Tevatron values seem to scale with a factor 5-10 for the LHC)
  - BLM are considered as "useful" for machine operation.
  - Three stage collimation system is mandatory for superconducting hadron colliders.
- BLM need to know the quench threshold for quench prevention.

Quench levels for LHC magnets

- Extremely small energy density disturbance in a very small volume is sufficient to initiate a quench.
- A safety margin of 2.5-3 for quench limit at nominal luminosity seems to be appropriate. **B.Dehning** points out that the levels could differ by a factor of 1000 for fast losses and 5 for slow losses. **R. Schmidt**: Numbers are too vague and simplistic. A review is needed as soon as possible. Table of different quench and damage levels are needed till autumn 2005 (**ACTION: P. Pugnat**). **B. Dehning** inquires whether there is a list of most exposed magnets. **R. Assmann:** The magnets in the dispersion suppressor are mostly affected by beam losses. For the arcs, there are no locations that are expected to receive significantly higher beam losses than elsewhere in the arc.

Modelling nuclear cascades, quench levels

- The insulation of the superconducting cables is the largest barrier for cooling.
- Accurate determination of some modelling parameters requires experimental verification.
- Test on cables are an excellent tool for investigating the quench levels, but might not be sufficient.

Future R&D:

- The sector test is favoured in order to experimentally determine the actual quench levels.
- No guarantee for ion operation with nominal luminosity.
- Lifetime of magnets 5-7 years if the magnet is always operating just below the quench limit due to radiation damage.
- The weakest part of the magnet is the insulation.

A written summary will be provided and published at http://amt.web.cern.ch/amt

Summary and conclusions are required and should be presented to the LTC (ACTION: **R.Schmidt**).

Possible staging of the BLM system: questions from the BDI group to the MPWG (B. Dehning)

According to BDI, the BLM production and FPGA development might be delayed. Not all detectors might be available for the LHC start-up. Fast interlock on beam losses might also come only later. In case of a delay, the following questions should be addressed:

Question I: Are all BLM monitors needed for safe LHC operation?

- The long straight section will in any case have a fully equipped BLM system.
- The present design foresees 6 monitors (3/beam) in the horizontal plane per arc quadrupole. The locations are 1, 2 and 3 metre away from the connecting vacuum bellow of the upstream magnet.
  - The large amount of the shower is more easily detected in the horizontal plane.
  - Shower simulations show that the best location is 1 m behind a likely beam impact location (e.g. connecting vacuum bellow, centre of the quadrupole).
  - The detection of the shower is sensitive to the location of the BLM. If the BLM is displaced by, say, 2 m with respect to the shower source, the sensitivity is significantly reduced.
  - The planned sector test might yield valuable information of the efficiency of the BLM location for fast losses. There will only be limited information for slow losses from such tests.

R. Schmidt points out that the shower calculations to determine the best locations for a reduced number of BLMs will take time. This time and the resources might be better invested to accelerate the production.

During the initial running of the LHC the number of bunches will be limited to 43 per beam. Operation with a reduced number of BLMs should be acceptable with these assumptions, to be confirmed by further studies.

Question II: Would a measurement on the scale of 10 ms be acceptable for machine protection?

Beam loss monitors at collimators are the most important monitors for protection. As an example, in case of a dipole magnet quench at 7 TeV, the beam would start to touch the collimator jaws in much less than 10 ms. Therefore it is likely that all particles would impact on the collimator jaws. The damage level is in the order to 10^{12} protons. Therefore an operation of the LHC without fast BLMs should be limited to a few bunches, the exact number to be evaluated. The fast BLM signal for dumping the beam has the highest priority for machine protection.

Next meeting 8. April:

- Introduction to CNGS (K. Elsener)
- Status of interlocking for CNGS (J. Wenninger)
- Beam size interlocks for CNGS (A. Guerrero)

R. Steinhagen, 6 April 2005