Machine Protection Working Group

Minutes of the 14th meeting held on June 14th 2002

Present: F. Balda, E. Ciappala, B. Dehning, E. Gschwendtner, R. Giachino,
B. Jeanneret, V. Montabonnet, B. Puccio, R. Schmidt, J. Wenninger,
T. Wijnands, M. Zerlauth

Excused : E. Carlier, R. Denz, C. Dehavay

Main topics of this meeting:

- Specifications of the LHC Beam Loss Monitors (B. Jeanneret)
- Design of the LHC Beam Loss Monitors (E. Gschwendtner)
- AOB

Specifications of the LHC Beam Loss Monitors (B. Jeanneret)

B. Jeanneret presented a summary of the specifications for the LHC beam loss monitor (BLM) system. The specifications for the instruments are prepared by a small team of people with experience in accelerator physics and operation headed by J.P. Koutchouk of SL/BI. The functional specification for the BLM system will be released in the near future.

The energy deposited by a single 7 TeV proton is ~ 1 μJ. At this beam energy, the longitudinal profile of the average energy deposited in the most exposed cable peaks at 6 GeV/cm^3 (i.e. 1 nJ/cm^3) approximately 0.4 m downstream from the impact point. At 450 GeV the average energy density deposited in the innermost l1 cable is ~ 0.1 GeV/cm^3 which is already almost 2 orders of magnitude smaller than the energy density on the beam screen (More details can be found in LHC **report 44** by **J.B. Jeanneret *et al*.**). Proton loss rates are estimated for the BLMs under different beam conditions (lifetimes, intensity, collimation…) under the assumption that there is a single aperture limitation in the ring. From the quench and damage levels it is possible to set thresholds for various actions (beam dump, warnings…) based on the loss rates for steady and transient losses. In the case of transient losses, the quench level is given by the heat reserve in the cable and damage to components requires loss levels that are more than 2 orders of magnitude above this quench level. On the other hand, for steady losses the damage threshold is only ~ one order of magnitude above the quench level which is due to the lower cooling capacity for the beam screen compared to the SC cables (poor(er) thermal conductivity).

Some important conclusions:

- Operation with collimators is mandatory for all beams except for pilot bunches at 450 GeV.
- Transient losses can be very large.

- The BLMs must have a very large dynamic range.
- The BLM time resolution must be
    - better than one turn at the collimators.
    - ~ 2.5 ms for arc collimators.

As a consequence four different types of loss monitors will be needed to cover the different requirements.

R. Schmidt wondered what would happen in case a hole is made with the beam in the beam screen. **B. Jeanneret** replied that we would probably never notice since the beam screen is anyway full of holes. In fact it is clear from slide no. 5 that the energy deposited on the beam screen is much higher than at the SC cable.

The problem of thunderstorms was also discussed after this presentation. It was felt by many people that it must be verified that we are able to extract the beams before everything 'breaks down'. In particular the combined effect of switching off all PCs with their individual time constants should be tested in simulation. **R. Schmidt** mentioned that the UPS system will also give an input to the PIC. The 'red (emergency) buttons' must also be included.

Design of the LHC Beam Loss Monitors (E. Gschwendtner)

E. Gschwendtner gave an overview of the present design state of the BLMs. The design stages / inputs include:

- the definition of the quench levels.
- the proton loss distribution.
- the shower simulations in and around the cryostats.
- the development of the monitors.

The quench levels expressed in lost protons per meter and per second vary by many orders of magnitude as a function of beam energy and as a function of the loss duration. To define the proton loss distribution from the tertiary halo, particles are tracked through the machine elements to determine the longitudinal position of the losses. Most losses occur in the quadrupoles or around the transition bellows, in particular when they are misaligned. Simulations with GEANT indicate that the shower maximum occurs ~ 1 m downstream from the impact point. Three loss monitors will be installed per ring around each short straight section in order to cover losses at quadrupoles and bellows. The signals of the monitors will be combined to localize the loss point. It will be challenging to set interlock levels for quench and damage prevention since the signals in the BLMs depend on the exact loss position.

An ionisation chamber constitutes the present baseline detector for the losses. The chamber current will vary between 60 pA and 150 µA. The signal will be read out by current to frequency conversion (CFC). Tests performed on such a system show that it is able to cover the entire dynamic range. The CFC electronics will be located in the tunnel and only digital data will be sent to the surface after being multiplexed. Tests on the SPS dump with very high currents show the expected fast electron and slower ion signals in the chamber. For very high rates the ions signal could give pile-up problems that have to be investigated.

The same electronics and concepts will be used for all monitors to increase the reliability and reduce the number of different components. Every component will be doubled beyond the 8-bit CFC counters. 6 monitors will be installed around each quadrupole to increase the reliability, to be able to determine the loss location and identify the ring where the loss occurs.

The present state of the design can be summarized as follows:

- Loss distributions and shower developments require further simulations.
- Monitors:
  - The front-end electronics is designed and the circuits will be tested soon.
  - The signal transmission mode (twisted pair or optical fiber) will be decided soon.
  - Design of the beam loss monitor controller, whose task is to decide when to dump the beam, will start soon.
  - The high intensity behaviour of the detectors will be tested in the PS this summer.
- Reliability studies will be performed by a PHD student.

AOB

R. Schmidt raised the point of what would happen if the beam dump does not fire or if the connection to the beam dump is somehow interrupted. This question pops up regularly and so far we have no answer to it. The ‘technical’ answer is the beam dump reliability must be SIL4, but not everybody may be satisfied with this answer. It is clear that we must address this question and provide answers, in particular on what damage is done to machine in such a situation. One idea would be to install a ‘fuse’ somewhere in the machine to make sure all the damage is localized in and around the fuse.