# Machine Protection Working Group

*Minutes of the 22nd meeting held on April 14th 2003*

**Present:** L. Arnaudon, R. Assmann, J.-C. Billy, E. Carlier, E. Cennini, B. Dehning, R. Denz, J. Gimeno Vicente, B. Goddard, G. Guaglio, R. Jones, R. Lauckner, V. Montabonnet, G. Mugnai, B. Puccio, P. Pugnat, R. Schmidt, F. Szoncso, J. Uythoven, J. Wenninger, M. Zerlauth

**Excused** : B. Jeanneret

**Main topics of this meeting:**

- Orbit surveillance and interlocks for machine (J. Wenninger)
- Beam Interlock Controller client interface (B. Puccio)
- AOB

**Orbit surveillance and interlocks for machine (J. Wenninger)**

**J. Wenninger** presented the current situation on interlocks for the beam position in the LHC. The need for such a form of interlock in the beam dump area was clearly an outcome of the Chamonix Workshop help in the beginning of March. Such an interlock should be compatible with normal operation, i.e. tune measurements by kicks should remain possible. Furthermore the orbit and injection oscillations ($2\sigma$ amplitude is considered "normal" margin) may show large excursions when the beam is first injected after a machine cycle. Interlocks on the beam position should not prevent injection.

An interlock on the beam position to ensure a correct extraction of the beam through the extraction channel is the first beam position interlock that is considered. The required interlock level is ± 4 mm. A system of dedicated and redundant BPMs on either side of the magnetic septum near the Q4 quadrupoles is proposed for this interlock. The system should work on a bunch by bunch basis and be auto-triggered, thus requiring no timing. In the case of a fast warm D1 failure the orbit moves by ~ 60 µm in that area. For a total delay for detection and propagation to the dump of 3 turns, the actual threshold for the system should be set around 3.6 mm. The reliability (false triggers…) of the system must still be evaluated.

A second issue for the beam position concerns the protective role of the TCDQ. At injection the machine aperture in the arcs is specified to be at least $10\sigma$ (although the actual value is presently only $8.5\sigma$ !) and the TCDQ must be positioned at a smaller aperture to protect the machine against asynchronous beam dumps. At injection the nominal beam size at the TCDQ is 2.2 mm, and the interlock with a threshold of 4 mm discussed above would dump the beam for orbit movements corresponding to ~ $2\sigma$. If the TCDQ aperture is set ~ $2\sigma$ tighter than the arc aperture, this interlock would then also protect against failures due to asynchronous beam dumps occurring for large orbit offsets. Since during the ramp the optics remains constant, the protection by the TCDQ is maintained without requiring any movement of the TCDQ, but a reduction of the TCDQ aperture to 20-25σ at 7 TeV (un-squeezed) would give a better safety margin. The situation for squeezed beams was discussed in the previous meetings by **R. Schmidt**. Without tighter or additional interlocks, the triplets must be protected by additional absorbers.

During a fast failure of the warm D1 separation dipoles, the orbit at the TCDQ changes by ~ 0.6 mm in 10 turns. For any other failure, the orbit change is slower by a factor 2 or more. Contrary to the beam loss monitors that can only act when the first losses are detected after a failure (a delay of ~ 15 turns with Gaussian tails), the orbit changes are visible as soon as the failure occurs, thus gain ~ 15 turns to make a decision. For an orbit position interlock, a threshold corresponding to an orbit change of ~1 mm over 15-20 turns would protect the machine against a failure of the warm D1. For other failures the same orbit shift develops over 60-80 turns.

In conclusion,

- Beam dump aperture: a beam position interlock with a threshold of 3.5 mm is required. Such an interlock seems feasible, even for fast failures (warm D1).
- Protection of the machine by the TCDQ: at injection, the protection of the machine can be ensured at injection with the same interlock of 3.5 mm provided the TCDQ aperture is at least 2σ tighter than the machine aperture. With squeezed beams the triplets should be protected by absorbers.
- Fast failures: an interlock on the beam position change with a threshold in the order of 0.5-1 mm in 15-20 turns (β function of 500-600 m) could complement the protection by the beam loss monitors at the collimators.

During the discussion **R. Assmann** said that if the TCDQ aperture is set to 8σ instead of the present default of 10σ, the losses at the TCDQ may be so high that downstream cold magnets may quench. This point was also mentioned in the presentation, i.e. that the increased beam losses following an orbit movement at the TCDQ may be used to dump the beam irrespective of a position interlock. Otherwise the collimators may have to be set to an even tighter setting than the presently accepted 6σ. He also thought that the orbit feedback should maintain the orbit to within 0.5σ at the TCDQ, in which case no interlock is required. **J. Wenninger** replied that an error in the feedback reference must be caught somewhere ‘outside’ of the feedback. One possibility would be a slower software interlock system. One important issue that came out of the discussion was the need to evaluate the impact at injection of a few bunches on an aperture in the machine due to an asynchronous dump. It cannot be excluded that, due to the larger beam size and the different rise of the kick pulse at injection with respect to top energy, the impact of a few bunches is acceptable. **R. Jones** pointed out that the BPM system of the LHC was not designed in view of the highest possible reliability, and that one should be cautious for ‘complex’ position interlocks. He would also like to have more precise requirements on all the position interlocks in order to evaluate their feasibility. He was particularly concerned about the interlock on the fast orbit changes (false triggers…). Some persons also questioned the logic for the interlock for the beam dump aperture: the present idea is to dump as soon as any bunch is detected above that threshold. Such a system may be too sensitive to collective / multi-bunch effects and instabilities where few bunches oscillate with large amplitudes. Some form of position average over one turn would improve the situation in that respect.

**Beam Interlock Controller client interface (B. Puccio)**

**B. Puccio** proposed the concept of an Interlock Client Interface that should be installed inside the client racks. This interface consists in a 1U box with TTL or PLC (24 V) inputs (one per LHC beam) for the client requests. In addition, the status of the 2 Beam Interlock Loops is available in the form of TTL/PLC if the client is interested in their states. The connection of this interface to the nearest Beam Interlock Controller is the responsibility of the interlock system.

In the discussions, **F. Szoncso** insisted that the design of the system must take into account electromagnetic compatibility. He also pointed out that the time response should not be too fast to avoid a too high sensitivity of the system to perturbations. It seemed however that for the expected response time of ~ µs, there should be no problem. **E. Cennini** and **R. Lauckner** proposed to add a test signal input which would allow a client to indicate if its system is under test or not. Finally **B. Dehning** wondered if the reliability is high enough with a single signal from the client. Some persons in the audience suggested doubling the input signals. For the personal protection system the signal and its (logical) inverse are always used together to increase the overall safety.

**AOB**

**R. Schmidt** mentioned that as a follow up of Chamonix and of various discussions, the injection process will be simulated in a coherent way by **H. Burkhardt**. The simulation will handle the entire injection phase starting from the SPS extraction kickers up to the first LHC turn. The influence and protection given by all collimators and absorbers should be evaluated carefully for various failure scenarios. A first meeting was held to organise the work and outline the failures. Engineering guidelines for the transfer line collimators are needed for June 2003.

**R. Schmidt** informed the audience that an informal collaboration has been set up with GSI Darmstadt to simulate the full impact of an LHC beam on a block of material. Colleagues at the GSI laboratory have the special codes to compute the thermo-dynamic effects that occur under the impact of such a high energy density.

In the next meetings the following topics will be addressed (or followed up) :

- Study of a solenoid for the warm D1 magnet (**M. Zerlauth**).
- Status of the Energy-Meter (**E. Carlier**).
- Requirements and problem of the aperture kickers (**F. Schmid**t).
- UPS (**R. Denz** and **B. Puccio**).