Machine Protection Working Group

Minutes of the 16th meeting held on October 11th 2002

Present: R. Assmann, F. Balda, E. Carlier, E. Cennini, B. Dehning, B. Flockhart, B. Goddard, G. Guaglio, M. Gyr, B. Jeanneret, R. Lauckner, S. Lüders, V. Montabonnet, G. Morpurgo, W. Salter, L. Serio, S. Schmeling, R. Schmidt, J. Uythoven, A. Verdier, J. Wenninger, M. Zerlauth

Excused : D. Macina, C. Dehavay

Main topics of this meeting:

- Dump channel aperture (M. Gyr, B. Goddard)
- Orbit Feedback in IR6 (J. Wenninger)
- Detector Safety System (M. Lüders)

Dump channel aperture (M. Gyr, B. Goddard)

M. Gyr recalled the layout and main hardware components of the beam dumping system of the LHC (see the minutes of the 3rd MPWG meeting on 30th March 2001). To protect the septum magnets from un-synchronized beam dump, an absorber block, the TCDS, will be placed in front of the first septum magnet. The design of the TCDS, in particular its width, is a compromise between different boundary conditions and tolerances given by the orbit, the beam size, apertures at the entrance and at the exit of the septa (for the circulating and for the extracted beam).

In order to ensure a primary aperture of $n_1 = 7$ for the circulating beam at **450 GeV** and a closed orbit tolerance of 4 mm, the required clear aperture of the vacuum chamber should have an inner diameter of 51.6 mm. With the present design of the chamber this diameter is only 48.4 mm, and for this size, the acceptable tolerance on the closed orbit is ~2.8 mm for $n_1 = 7$, or inversely, for a tolerance of 4 mm on the closed orbit, the primary aperture is only $n_1 = 6.3$ (see slide 13).

For the extracted beam, the admittance of the extraction channel drops to 4 σ for a closed orbit tolerance of 4 mm even when all 15 MKD kickers fire at **450 GeV**. In the case where only 14 kickers are available at **450 GeV**, the admittance is already smaller than 2½ σ for a closed orbit tolerance of 2 mm. If a large orbit tolerance must be included in the design, the TCDS width must be increased, which reduces the margin at **7 TeV** where the admittance is limited by the available kick strength of the MKD. For a closed orbit tolerance of 4 mm, only about 2 σ of the beam can be extracted, even when all 15 MKD modules fire (see slides 16/17). This problem will be studied in detail also for the case of only 14 MKD modules at **7 TeV**. A summary of the extraction channel admittance is given in the table below.

Energy [GeV]	Nr. kickers	Orbit [mm]	Extraction channel admittance
450	15	2	6 σ
450	15	4	4 σ
450	14	2	< 2½ σ
7000	15	2	6 σ
7000	15	4	2 σ
7000	14	2	to be studied
7000	14	4	to be studied

In the discussion, **A. Verdier** said that for warm magnets, the required aperture was not $n_1 = 7$ but actually $n_1 = 6.5$, which makes the situation 'slighty' less critical for the circulating beam. **R. Assmann** noted that one should also take into account the beam population in the tails between 3 and 6 σ since those particles could easily hit the TCDS if the aperture is tight.

B. Goddard summarized possible ways to overcome the aperture problems in the dump channel, namely

- Better orbit control.
- Improved kicker pulse envelope.
- Use of the TCDS to protect also against the missing kicker fault.
- Larger vacuum chambers.

A better orbit control helps against all aperture limitations, for the circulating beam as well as for the extracted beam and at all energies. All items on the list help improve the aperture at 450 GeV for the extracted beam. **B. Goddard** concluded with a list of questions to the MPWG in order to finalize the extraction :

- What is the nominal stabilized orbit in IR6 ?
- How far can the beam move after a fault before the dump is triggered ?
- How much can the emittance grow undetected before a dump ?
- Is it justified to decouple faults from machine and dump ?
- Is the energy tracking tolerance of ±0.5% realistic ?

E. Carlier and **J. Uythoven** mentioned that when a kicker module is detected as being faulty, the dump is fired immediately (from this internal fault). The machine can only be refilled when the corresponding module is repaired. On the other hand it is possible that when a trigger arrives, only 14 out of the 15 kickers fire correctly, but this is a priori a random event which should not be correlated to the fault that generated the dump trigger. There was overall agreement that dump and machine faults should a priori be independent. **R. Assmann** said that one should assume that the beam could move by 3 to 4 σ before such a movement can be detected by beam losses at the collimators. For the moment, the operation of the collimators assumes that they will not move during the ramp. This implies that the collimators could sit around 15-20 σ at the end of the ramp, and the beam could move rather far (in number of σ) before being detected. On the other hand, the movement in terms of mm will not change as much between start and end of ramp since the collimator opening is fixed. It should not be excluded that, given this new input on the beam dump aperture problem, we may have to revise the collimation strategy in the ramp. **R. Schmidt** indicated that for a D1 failure, the beam moves by approximately 3 σ in 10 turns at top energy with squeezed optics. The beam halo would touch the collimators, losses would be detected by the BLM system, and the beam would be dumped. The situation could be most critical at 450 GeV since the collimators will be ~ at a fixed number of σ. The beam can therefore move further (in mm) before detection by the BLM system. On the other hand, the beam being un-squeezed at 450 GeV, the β-function at the D1 could be significantly smaller. This point must be clarified. Another point to the addressed is the issue of (fast) emittance growth and how to detect it. Concerning the problem of energy tracking **B. Dehning** said that since the dipole field will be known to much better than 0.1%, it should be possible to reduced significantly the tolerance for the energy tracking. Most people however expressed their scepticism that such a tight tolerance could be achieved given the number of inputs to this system. Furthermore we would like to adjust the currents in the septa slightly without having to completely revised the interpolation tables for this energy tracking system, which requires a minimum tolerance on the energy tracking.

Orbit Feedback in IR6 (J. Wenninger)

To answer the first question raised by **B. Goddard**, **J. Wenninger** discussed the problem of orbit stabilization at the LHC. A real-time orbit feedback is required and desired for the LHC given the very tight aperture and the very bad experience of LEP where such system would have been extremely helpful. The anticipated orbit movement are due to ground motion, persistent current decay, snapback and squeeze, the later being by far the most critical. The movement range between 0.3 and 10 mm, with timescales between few minutes to hours. Given the presently foreseen orbit sampling rate of 10 Hz, a closed loop feedback will only be effective for frequencies below 0.5 Hz, which matches the possibilities of the PC of the cold orbit correctors that have rather large time constants of ~ 200 s. A global orbit feedback will be very effective to stabilize the orbit around the ring. Such a system has no problem to stabilize the orbit to better than 0.2 mm over most of the ring. For areas with very tight tolerances, a local feedback must complement the global orbit loop. In fact, the presence of the TCDQ in the close vicinity of the dump kicker and septa requires an orbit stabilization to better than 0.2 mm over IR6 at 7 TeV with the squeezed optics.

The orbit feedback is a complex system requiring network connections over the whole ring to a large number of equipment, and the system will therefore not be intrinsically fail-safe. Some form of interlock on the beam position in IR6 is required in particular when the beam position information is lost due to network and other failures. **J. Wenninger** concluded that one can assume that the orbit will be stabilized to at least 1 mm over IR6, and probably even much better (~0.2 mm). In the discussion, the possibility to have an interlock on the one or more beam position monitors was mentioned by a few people. The parameters of such interlock must be established (how fast, what limits, etc.). This issue must be followed up in the next MPWG meetings.

Actions:

- Complete the missing numbers in the table (**M.Gyr, B.Goddard**)
- Estimate the probability that only 14 modules fire (instead of 15) when a dump trigger arrives (**E.Carlier** and **J.Uythoven**)
- Effect of a D1 failure at 450 GeV (**R.Schmidt** and **V.Kain**)
- What is the fastest mechanism of emittance growth? What is the maximum emittance that should be considered? (**SL-AP** and **others**)
- Beam position in the interlock chain? (**B.Dehning, J.Wenninger, R.Schmidt)**
- Tolerances for beam energy tracking (to be included in the functional specification to be written – see last MPWG)

Detector Safety System (S. Lüders)

S. Lüders presented the Detector Safety System (DSS) for the LHC experiments, under the responsibility of IT/CO. The DSS will act on the LHC (sub-)detectors, gas systems, racks… and it will use as input a large variety of sensors for temperature, humidity, gas, smoke… The Detector Control System (DCS) is responsible for the overall monitoring of the detector, while personnel safety (level 3 alarms) is ensured by the CERN Safety System. DSS complements DCS and CSS: it must safeguard the experiment and act on equipment when a serious fault is detected. The requirements for DSS are :

- Protection of the experiment
- Improvement of the experiment efficiency by preventing situations leading to level 3 alarms.
- Moderate cost.
- Simple integration into the experiments.
- Adaptability.
- Maintainability.

The functional requirements have been evaluated by the LHC experiments and are described in document CERN-JCOP-2002-012 which can be found at http://itcowww.cern.ch/DSS/StG/Minutes/25-04-02/DSSFRD_20020425.pdf .

The DSS is a standalone system and must have high reliability and availability. It must be easy to configure and be able to perform consistency checks. The DSS front-end are based on PLC technology and will act autonomously on fault conditions indicated by the sensors. The PLC continuously monitors the inputs (cycle time of ~ 200 msec) and compares the values against programmable thresholds. Several conditions can be combined logically to produce an alarm. For each experiment, between 200 and 800 sensors, distributed over the caverns and the surface buildings, must be monitored. The DSS will use be based on Siemens technology and the front-end is a Siemens S7-400 station, interfaced to the back-end over Ethernet. External crates are located near the sensors. They are connected to the front-end S7-400 over Profibus, use Siemens S7-300 CPUs and hold the I/O interfaces whose outputs are failsafe. Finally the whole system is redundant up to the I/O interfaces. At the back-end side, PVSS interfaces provide display and logging, and the action matrix can be modified by appropriate interfaces.

PLC hardware has now been installed in a laboratory and first survey measurements have been started. DSS prototyping has started and a first prototype system should be operational in May 2003. More information can be found on the DSS Web site http://cern.ch/proj-lhcdss .

F. Balda wondered whether the system has been evaluated with respect to the safety norm IEC 61508 and whether safety integrity levels have been assigned to the DSS components. **S. Lüders** answered that this has not been done. **R. Schmidt** mentioned that software to analyse the reliability and availability of systems had been purchased last year. Expertise from **F. Balda** is available to help with such an analysis. **R. Lauckner** wondered how the interlock matrix was actually checked. **W. Salter** and **G. Morpurgo** replied that the modifications to the matrix would be protected and not available to everyone and that changes will be checked for consistency. Users can also define what has to happen when sensors are broken. **R. Schmidt** wondered whether the solenoids of the experiments are also supervises with DSS, and **S. Lüders** said that this task was under the responsibility of the Magnet Safety System build by the EST division. To **R. Lauckner's** question on the allowed downtime of the system, **S. Lüders** answered that 2 days per year are foreseen for system maintenance. **S. Schmeling** indicated that this system must also protect the experiment during shutdown periods and when CERN is closed over Christmas. In such periods the alarm matrix may be somewhat different since the requirements are not the same.