Machine Protection Working Group

Minutes of the 19th meeting held on December 13th 2002

Present: R. Assmann, F. Balda, B. Dehning, F. Bordry, E. Carlier, R. Denz, R. Giachino, B. Goddard, G. Guaglio, M. Gyr, B. Jeanneret, R. Lauckner, D. Macina, V. Montabonnet, B. Puccio, R. Schmidt (chairman), J. Uythoven (secretary), M. Zerlauth, C. Zamantzas

Excused: J.Wenninger

Topics of this meeting:

- Update on the beam dump aperture (B.Goddard, M.Gyr)
- Asynchronous beam dump (R. Schmidt)
- Update on D1 failures (M.Zerlauth)
- AOB

Update on the beam dump aperture (B.Goddard, M.Gyr)

M. Gyr presented the latest calculations on aperture limitations in the MSD septum magnet of the LHC beam dumping system. The TCDS absorber protects the MSD aperture and the down stream vacuum pipes in the horizontal plane against beam dump failures. The core of the beam, assumed to extend to up to 2 σ, should not strike the septa in the case of an asynchronous beam dump. The thickness of the MSD vacuum chamber is partly determined by the requirement of a bake-able vacuum chamber, but this is not a critical parameter. The *required* apertures for the extracted beam are > 6 σ at 450 GeV and > 8 σ at 7 TeV beam energy with 15 or 14 MKD kicker magnets firing and assuming a MKD overshoot of 10 %.

For the circulating beam and assuming a MSDC clear aperture of 48.4 mm together with a closed orbit of ± 4 mm, the resulting beam clearance is n1 = 6.25 σ for the circulating beam, which is just acceptable. For the aperture of the extracted beam, and taking into account the 10% sweep of the extraction kicker magnetic pulse, there is a real aperture problem: for a 4.0 mm closed orbit distortion and 15 kicker magnets pulsing, the aperture is 4.0 σ at 450 GeV and 2.1 σ at 7 TeV. With 14 out of 15 kicker modules pulsing, the center of the beam hits the TCDS at all energies.

It was mentioned that on top of the given closed orbit error (± 4 mm for the initial calculations) the beam can move by a substantial distance before the beam dumping system can extract the beam. **M. Gyr** presented a movement in IR6 of 11 mm at 7 TeV for the un-squeezed optics. The amount by which the beam can move before being dumped proved to be a controversial topic; it is important that it can move substantially on top of the closed orbit error assumed for the calculations given above.

The most sensitive parameter to increase the aperture of the extracted beam is the closed orbit at the extraction point. An acceptable aperture can be found assuming an orbit control of ± 1 mm and that in the case that of 14 out of 15 dump kickers are working part of the beam is allowed to strike the TCDS. It was mentioned that a feedback might not be sufficient to obtain a local orbit of ± 1 mm and static faults might require realignment of the elements. Also collective effect can cause a displacement of 0.2 σ to 0.3 σ. The usefulness of having a two-sided TCDS to protect the septa against a beam that sees the MKD kick twice because of an unsynchronized dump was also mentioned.

Assuming a closed orbit controlled to ± 1 mm, the aperture for the extracted beam becomes 6.6 σ at 450 GeV and 27 σ at 7 TeV. For 14 out 15 extraction kickers working, the aperture at 450 GeV is still 3.7 σ. This is valid for a normalized horizontal emittance of 3.75 × 1.42 (safety factor for β-beat…) = 5.3 μm and assumes the same extraction angle for all energies. The TCDS is placed at 14.0 ±1.0 mm. The effective aperture is increased by 0.5 σ for the TCDS and 1.3 σ for the MSDC if the actual kicker waveform is taken into account. For the closed orbit error of ± 1 mm, the acceptance remains above 4 σ for an emittance blow-up up to a factor of three.

It was mentioned that the beam dumping interlock is not connected to the orbit control system but to the beam position monitoring system in point 6. The proposal of a tight closed orbit control at point 6 seems to give realistic beam dumping system apertures and will be proposed at the next LCC.

Asynchronous beam dump (R. Schmidt)

R. Schmidt presented a number of aspects of the beam dumping system related to the TCDQ. In the case of an asynchronous dump, part of the beam will hit the TCDQ if deviated at a small angle. The collimation systems in point 3 and 7 should intercept this beam if it passes the TCDQ after the first kick of the asynchronous dump if the beam excursion is larger than 6 to 7 σ. Bunches that make it around the machine receive a second kick from the MKD, arrive at the septa with a large offset and would not fit into the septum aperture. Examples were shown with offsets in the order of 80 mm – 100 mm (needs to be calculated in more detail). For this reason the TCDS should be equipped with a second jaw (see also presentation from **M. Gyr**). These effects should be studied in more detail for different closed orbit distortions at point 6 and for the different energies (= collimator openings).

As a conclusion **R. Schmidt** mentioned that the orbit needs to be controlled very well at point 6 and that the TCDQ needs to be placed rather close to the beam. During the ramp it must be moved towards the beam, which implies the collimators in point 7 must be moved during the ramp as well. How far the collimators would have to move towards the beam is a subject of future studies.

It was briefly questioned whether a beam size measurement in point 6 is required. Probably beam loss monitors close to the TCDQ can fulfill this function. This implies that one needs a double side TCDQ.

Update on D1 failures (M. Zerlauth)

M. Zerlauth recalled that after a D1 failure beam losses are detected after about 8 turns and damage at the collimators occurs already after about 11 turns. The beam dump must be triggered within three turns. This time is determined by the current decay time constant of the D1 magnets of ~2.5 seconds. An increase of the system inductance would also increase the time constant. Since one should not increase the resistance of the system at the same time, a possible solution is a super-conducting coil in series with the magnet system. An additional inductance of 5 H in the 10 magnets circuit (all in series) increases the time constant to about 9 s. The additional inductance also reduces the current ripple by a factor of four. As an example, **M. Zerlauth** showed an industrial standard, stand-alone cryogenics system and a single coil, all within an acceptable system size. Such systems are available from industry for SMES applications (Superconducting Magnet Energy Storage).

As an alternative solution it is also possible to pass the D1 current through the main dipole circuit. This would add an even larger inductance, but these ideas does not look attractive since the consequences on both powering and protection system for the main dipoles could become very complex. It could also compromise the accuracy of the dipole current ramp.

The D1 is by far the element in the LHC that causes the fastest orbit changes in case of failure; the next critical elements are the super conducting main dipoles in case of a quench. The reaction time after measuring beam losses with BLMs of 3 turns (between $3*10^9$ protons at the collimator, and $1*10^{11}$ protons) needs further confirmation. With the halo of the beam, it may be possible to detect the beam movement more rapidly than after the eight turns that are usually mentioned. On the other hand, if there is little beam in the halo (for example due to beam-beam driven resonances), the time could be shorter. The calculations should also be updated, since the collimators should be designed to stand 10^{12} particles.

F. Bordry commented on the diagnoses of the current decay in the D1 power converters. At the moment they are equipped with normal DCCTs, but one may possibly do better to quickly detect a current decay. The problem in the current decay detection is the required filtering of the signal to reduce the noise of the signal. Filtering requires time. It is not clear that a ripple in the current of 10^{-4} can be detected. **B. Dehning** will look at the possibility to use Hall probes to detect a field ripple of 10^{-4} and a fast response time without requiring any absolute precision. This would only be required at full magnet current and a constant field. **R. Schmidt** will ask **V. Kain** to re-iterate her work in order to:

- Update the calculations for D1 failure assuming 10^{12} particles at the collimators
- If the current (or the field) would be measured, what is the required accuracy, and what is the time for such measurement in order to derive a beam dump signal?
- What is the time for beam dump in case of most unfavorable phase between D1 and collimators? Answer: one of the D1 magnets is essentially at the worst possible phase.
- What is the change of closed orbit that could be observed?
- What is the reaction time for other magnets?

AOB

R. Schmidt reported briefly on the previous LCC and the ongoing preparations for the Chamonix workshop. It was proposed to send the abstracts of sessions 5 and 6 to the MPWG for comments.

Jan Uythoven, 18/12/02