Machine Protection Working Group

Minutes of the 13th meeting held on May 23rd 2002

Present: F. Balda, B. Camanzi, E. Carlier, E. Chapochnikova, C. Dehavay, B. Dehning, J. Dieperink, W. Höfle, B. Jeanneret, T. Linnecar, V. Montabonnet, G. Mugnai, B. Puccio, R. Schmidt, J. Wenninger, M. Zerlauth

Excused : J.C. Billy

Main topics of this meeting:

- The abort gap: longitudinal time scales and possible diagnostics (E. Chapochnikova)
- Abort gap cleaning with the transverse damper (W. Höfle)
- AOB :
  - Interface between Beam Interlock Controllers and other systems (R. Schmidt)

The abort gap: longitudinal time scales and possible diagnostics (E. Chapochnikova)

E. Chapochnikova first gave an overview of the time scales for longitudinal particle motion with RF off and on. More details can be found her LHC project note 281, published in March 2002. When the RF is switched off, the longitudinal position change increases linearly with time and is proportional to the momentum offset of the particle, the slip factor and the revolution frequency. For times much larger than the debunching time (3 to 7 ms), the bunch length also increases linearly with time. The time scales to fill the 3 μs gap range from 5 s at 450 GeV to 20 s at 7 TeV for the normal LHC parameters.

With RF on, the expressions for the time scales are more complex. The time scale depends on the ratio q between the maximum momentum offset and the bucket height. As q approaches 1 (i.e. for particle very close to the separatrix) the time increases to become 'infinite' for q = 1 when the particle is just at the edge of the bucket. For particles with a momentum offset at the edge of the collimator cut-off, the time scales to fill the 3 μs gap range from 1.6 s at 450 GeV to 4.3 s at 7 TeV for the normal LHC parameters.

In anticipation of the following presentation by **W. Höfle**, **R. Schmidt** said that to clean the gap by exciting the beam that is inside it, it should be sufficient to excite for approximately 30 s before the ramp starts to be sure that ~ all un-captured beam is removed. The duration is given by the time it takes for the most distant un-captured particles to drift towards the gap.

Diagnostics for the beam inside the gap based on the detection of a beam signal component due to un-captured beam at the RF frequency of 400 MHz is difficult because the signal is small. For 5% of the beam un-captured, the ratio between the signal component from un-captured and captured beam at 400 MHz is ~ 1-2%, which seems

very difficult to detect, although one might try to measure only inside the abort gap. Finally **E. Chapochnikova** presented some methods that could be tested in the SPS to detect un-captured beam. Answering a question of **R. Schmidt**, **B. Dehning** confirmed that SL/BI is still planning to build a monitor based on synchrotron light to detect beam in the abort gap and the measure longitudinal profiles.

In the discussion **T. Linnecar** asked for the maximum number of particles that can be accepted in the gap, which is an important input for the design of the detection method. **B. Jeanneret** replied that this number depends on the design of the TCDQ, the absorber that should protect the Q5 quadrupole in IR6 from particles that are not correctly extracted (in case of unsynchronised dumps or when there are particles in the abort gap for a properly executed dump). It is not yet entirely clear how much protection the TCDQ gives. **T. Linnecar** also indicated that at 7 TeV the damping from synchrotron radiation (damping time of 13 hours) is stronger than the RF noise (expected lifetime 20 hours or more), while the intra-beam scattering lifetime is ~ 60 hours. **B. Jeanneret** said that due to the energy loss of 7 KeV/turn, a particle just outside the bucket reaches an energy low enough to hit the momentum cleaning collimators in about 100 seconds. **E. Chapochnikova** however questioned the correctness of this simple estimate since she thinks that not all particles that leave the bucket just drift down in energy. **B. Dehning** pointed out that at HERA there is a large amount of un-captured proton beam whose origin does not seem to be understood. On a question by **T. Linnecar** on the importance of detection tests in the SPS, **R. Schmidt** suggested that this should be studied more carefully with all the inputs clarified.

Action : **B. Jeanneret** and **E. Chapochnikova** should get together to clarify the questions raised in the meeting.

Abort gap cleaning with the transverse damper (W. Höfle)

W. Höfle discussed the possibility of cleaning the LHC abort gap with the transverse damper. He first stated that important boundary conditions are a precise and reliable synchronization signal, an excitation on a betatron frequency below 1 MHz and no perturbation of adjacent bunches. The total kick per turn at 450 GeV corresponds to a deflection of 2 μrad (0.13 μrad at 7 TeV). The kicker rise times are 320 ns (10-90%) and 720 ns (1-99%), implying that the cleaning will only be 100% effective within a 1.5 μs long central part of the gap as shown in the Figure below. The time to reach an amplitude of 7 σ is very short, namely 4.4 ms at 450 GeV and 17.3 ms at 7 TeV. The numbers are based on an estimated betatron function of 150 m at the kicker. Particles at the edges of the gap feel a smaller kick and take more time to reach the aperture. The numbers apply only for a coherent excitation at the tune frequency and are affected by the tune spread. If the decoherence time of the beam is much larger than the time required to reach the desired amplitude, as is the case at 450 GeV (decoherence time of ~ 68 ms), the numbers are realistic. It may in fact be desirable to modulate the excitation frequency slightly to cover the full tune spectrum. This would increase the required excitation time, but not change the order of magnitudes. An excitation with white noise would be very inefficient since most of the power would be outside the spectral density of the beam. Finally, it is clear that some knowledge of the tune spread is require to refine the estimates for the required excitation time.

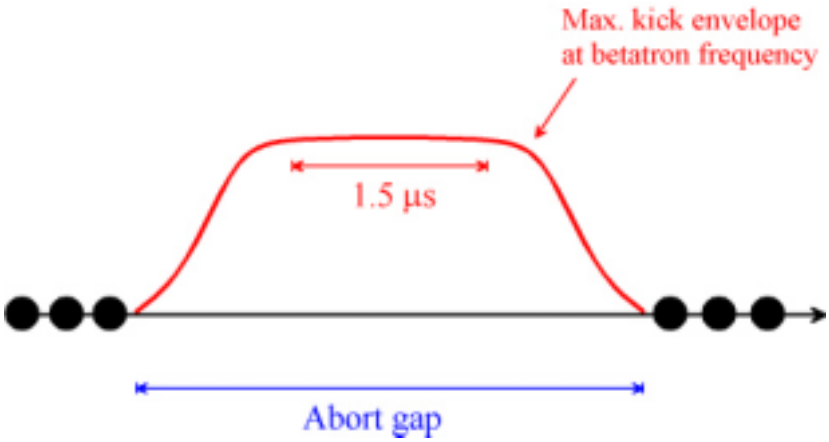

Figure: Envelope of the transverse damper kick inside the abort gap. The excitation frequency should be higher than the fundamental frequencies of 3 and 8 kHz (but smaller than 1 MHz) to spread out the tune in phase space and avoid that all beam hits the collimator in a too short time interval.

To the question of how to trigger the cleaning action, **R. Schmidt** replied that it should be based on the same signal that is used by the beam dump to synchronize with the gap. This signal is checked continuously by the beam dump system and any problems with it will immediately trigger a dump.

Action : **R. Schmidt**, **J.Wenninger**, **W. Höfle** and **E. Carlier** should go into more details with this procedure.

AOB

R. Schmidt raised the question about the interest of the equipment systems to receive from the BIC signals indicating the status of the Beam Permit Loops. So far only the vacuum group is requesting such a 'feedback'. In case of a dangerous pressure rise, they will request a beam dump in order to close the relevant valves. But they want to be sure that the beam is dumped before closing valves. During the meeting nobody indicated any interest.

J. Dieperink presented a revised version of his presentation at the last MPWG on April 12th. The changes have already been appended to the minutes of that meeting. The main difference, due to a change of the initiating event which is the number of dump request, is that the beam dump system is must be classified as SIL4 for most functions. This safety level is reached for all cases except internal dump requests due to pulse generator failures when 14oo14 modules are required to work correctly, in which case the system classifies as SIL3 or SIL4 dependent on whether the system is considered high or low demand mode of operation. **J. Dieperink** stressed once more that energy tracking failures are by far the most dangerous failures. **R. Schmidt** remarked in this context that it is now important to rapidly define which group should take the responsibility for the BEM (Beam Energy Meter).

The MPWG has been asked to report on topics such as synchronization with the abort gap and gap cleaning in the forthcoming LCC meetings. In addition there will be a Seminar by **R. Schmidt** on LHC machine protection some time later in the year.