Machine Protection Working Group

Minutes of the 23rd meeting held on May26th 2003

Present: J.-C. Billy, H. Burkhardt, A. Burns, E. Carlier, E. Ciapala, B. Dehning, A. Dinius, B. Goddard, G. Guaglio, V. Kain, V. Montabonnet, B. Puccio, P. Pugnat, F. Schmidt, R. Schmidt, J. Uythoven, G. Vossenberg, J. Wenninger, M. Zerlauth

Excused : B. Jeanneret, E. Cennini, R. Denz

Main topics of this meeting:

- Requirements, parameters and failures of fast kickers :
  - Transverse damper (W. Hofle)
  - Q-meter kicker (A. Burns)
  - Aperture kickers (F. Schmid)
- Beam Energy Meter status (E. Carlier)
- AOB

Transverse Damper (W. Hofle)

W. Hofle recalled the main parameters of the transverse damper system that provides a maximum kick of 2 μrad/turn at 450 GeV/c. For the present machine optics amplitudes of 1σ are reached in 4 turns. De-coherence, amplitude detuning… limit however the maximum amplitude that can be reached with the damper: it is not possible (or at least extremely unlikely) to kick the beam to 3σ or more. At 7 TeV an amplitude of 1σ is reached in 16 turns, a growth rate that is similar to the case of the warm D1 failure. The BPM electronics is expected to saturate for amplitudes of ~ 4σ, and it could be envisaged to switch off at that level. A number of failures can occur, for example related to the revolution frequency distribution. The system also accepts external input signals that can be applied to the beam, and a strict verification of the 'integrity' of those signals is very difficult. Some protection may be provided by a beam position interlock, which in that case must act on a turn by turn basis.

Tune Kickers (A. Burns)

A. Burns summarized the 'historical' evolution of the tune and aperture kickers since 1998. The system initially consisted of 4 magnets for the tune kicker system and 4 magnets for the aperture kicker system. In 2001 the two systems were combined and 4 MKQA kicker magnets are now foreseen to be used for both aperture and tune measurements. For aperture measurements all 12 batches (1 batch = 3 (or 4) x 72 bunches) are kicked at the same time to an amplitude of up to 8σ at 7 TeV. A tune measurement kicks approximately 3 x 72 bunches to 80-100% of the peak amplitude, with some perturbation of nearby bunches. The amplitudes reach 2.5σ at 450 GeV and 0.66σ at 7 TeV. Given those parameters the Q-kickers do not pose a particular problem, but interferences with beam position interlocks need to be studied. It should be noted that the aperture kickers cannot a priori be used 'by accident', since a pre-charging of the capacitor banks is required in the first place. Such a pre-charging would anyway be disabled for normal operation.

Aperture Kickers and/or AC Dipole (F. Schmidt)

F. Schmidt recalled the requirements and needs for devices providing large kick amplitudes in collisions to determine detuning with amplitude and to measure the dynamic aperture (DA). The DA of the machine is expected to be ~ 12σ at injection and ~9 – 12σ in collisions. With beam-beam those values are reduced to ~ 9σ and ~ 5σ.

Aperture kickers have the advantage of providing free oscillation and are 'easier' to build. Their disadvantages are large disturbances for the beam and problems for machine protection. Arguments in favour of an AC dipole are the non-destructive measurements and reduced problems for machine protection. On the other hand an AC dipole is complicated to operate, more expensive and the kick is limited to a few σ.

F. Schmidt's main requirement is that there should be at least one device providing large amplitudes at 7 TeV.

In the discussion **A. Burns** said that **H. Schmickler** and **F. Bordry** are studying the design of an AC dipole. Their preliminary conclusion is that a device providing a 4σ oscillation at a sufficiently large distance from the tune would require a power of 150 MVA and dissipate few MW of power in the resistive cables.

R. Schmidt concluded that the AC dipole seems much more complicated to build than anticipated (due to the requirements at 7 TeV). Concerning the aperture kicker, a reliability study / failure analysis should be performed. It is probably possible to kick pilot bunches to large amplitudes at 7 TeV, but rigorous interlocking must be provided to avoid an accidental kick to a high intensity beam. A simple locking/un-locking of the aperture kicker generators with a key does not provide sufficient protection against accidental uses.

Following the meeting a number of electronic messages relevant to the AC-dipole discussion were exchanged between **A. Burns, H. Schmickler, F. Schmidt, R. Schmidt** and **J. Wenninger. A. Burns** indicated that the massive 150 MVA quoted during the meeting corresponds to a 4σ excursion at 7 TeV for an excitation frequency separated from the tune by 0.02. At such a distance from the tune, there should be no significant emittance blow-up. It seems clear that such a power supply will not be built, hence the need to study now a new magnet design. On the other hand it is also clear that for relaxed emittance blow-up criteria, one can excite much closer to the tune and obtain the same excursions for much less power. Given the much greater flexibility of the AC-dipole and the easier job involved in operating it safely (e.g one could simply monitor the excursion level and stop the excitation once the excursion reaches a certain threshold), **H.**

Schmickler proposes a discussion between the BDI and BT groups on what savings could be made by stopping the development of the aperture kicker generator. The rest of the MKQA design would be kept compatible with big kicks so that the aperture kicker generator could be added "later" (meaning after the LHC start-up), should it prove impossible to build an AC dipole of sufficient strength. In any case, the dynamic aperture could be studied at 450 GeV using the damper kickers in AC-dipole mode. **F. Schmidt** replied that he is worried that under those conditions, there is a high risk that no element will be available to kick the beam to large amplitudes at 7 TeV. **H. Schmickler** understands the worries of **F. Schmidt**, but he also stated that a proper interlocking system for the aperture requires development efforts that he cannot presently provide. Concerning the collimators, **R. Assmann** stated in a message that the jaws should survive the impact of up to 8 nominal bunches at 7 TeV: a mis-kicked pilot bunch should therefore not be a problem for the collimators themselves. It must be noted that for a dynamic aperture measurement at 7-8σ, the collimators must be retracted to 9-10σ which should normally be acceptable at 7 TeV, provided the aperture in the triplets provides a sufficient safety margin.

Status of the Beam Energy Meter and Beam Energy Tracker (E. Carlier)

E. Carlier presented the status of the Beam Energy Meter (BEM). The BEM is a device that converts a physical measurement (for example a PC current) into a value proportional to the beam energy (it is **not** a *real* energy measurement !).

The first component of the BEM is the BEAM Tx board that is installed in the FGC of the power converter. The BEM Tx sends out the measured DCCT value as well as 1 mV and 10 V constant reference voltages at 1 kHz. The choice of the reference voltages is dictated by the requirement to lie outside of any DCCT value expected in the LHC working range of 0.45 to 7 TeV. The DCCT signal will be provided by a 'low-precision' DCCT (0.1% accuracy). For the MSD septa PCs, the same DCCT is also used in the regulation of the PC. For the main dipoles however, the low-precision DCCT is not used for the PC control. Since this an unsafe situation, redundant signals will be used from the MB converters on the right and left side of IR6. The FGC may potentially provide calibration signals directly, but **E. Carlier** prefers to rely on the 2 fixed references to avoid failures where the calibration signal of the PC is accidentally used for the beam energy instead of the DCCT signal. Each data frame sent by the BEM Tx contains the reference signals, the measurement signal and status information. The frames are received by the BEM Rx board that converts the measurement to an energy and re-emits the signals, but with the initial measurement replaced by an energy. The energy is reconstructed from an internal look-up table. Finally the BET (Beam Enrgy Tracking) module receives 2 or more signals from independent BEM Rx modules. It generates the energy from its input signals (average) and an interlock for the BIC whenever the energies differ by more than a certain maximum bound. The energy information can easily be distributed over the ring provided one BET is installed in each IP. Two optical fibres are required for signal distribution. Potential clients of the system are beam loss monitors and other instruments that perform safety functions, the timing system, the vacuum and RF systems and of course must kicker systems. **Action :** Proposal for the distribution of the beam energy information around the LHC (**E. Carlier** and **B. Dehning**).

AOB

M Zerlauth gave an update on the feasibility of adding a super-conducting solenoid as load inductance to increase the time constant of the D1 circuit. From the point of view of the ACR group, the solutions are (in decreasing order of preference):

- A local cooling device (cost ~ 100 kCHF).
- Tapping the experiments cryogenics system.
- Refilling the system on a weekly basis.
- Tapping the QRL (very expensive to modify).

M. Zerlauth is still waiting for an offer from ACCEL for a 4.1 H solenoid that would increase the time constant of the D1 circuit to 10 seconds. The present cost estimate is 450 kCHF for one unit.