Beam Dump and Injection Inhibits

J. Wenninger, CERN, Geneva

Abstract

This document describes the proposed beam interlocking strategy for the LHC experiments and for the experimental magnets. Two different types of interlocks are foreseen: beam dump requests and beam injection inhibits. The interfaces to the LHC beam and injection interlock systems are described. Proposals for implementations and open points are presented.

INTRODUCTION

In 2005 signal exchange for the LHC experiments related to machine operation and protection has been defined and specified [1]. The work was coordinated by the LEADE working group. The architecture of the LHC beam interlock system is described in [2]. The specifications have been based on best knowledge about LHC operation to ensure sufficient flexibility for both machine and experiments. The approval procedure of the specification was launched in November 2005. The final release is expected for february 2006.

INTERLOCK SIGNALS

The following interlock categories were identified:

- Beam dump requests: fast interlock signals based on radiation monitors that concern all experiments.
- Injection inhibits: slow interlock signals to prevent injection when detectors are powered etc. The signals concern all experiments.
- Interlocks of movable devices: protection against uncontrolled movements, inconsistent positioning etc of movable devices. The signals concern Roman pots and LHCb VELO.
- Interlocks of experimental magnets to trigger a beam dump when experiments magnets must be turned off due to a magnet fault.

LHC mode

The LHC mode is used to inform the LHC machine and experiments community what the beam operation crew is trying to achieve at a given moment. The mode names are not officialized yet, therefore the following names were adopted for the interlock specifications:

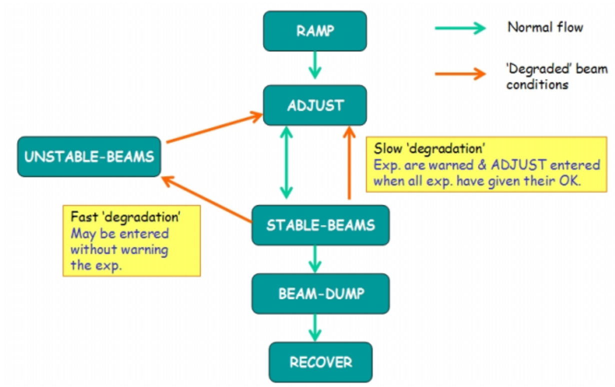

Figure 1: LHC mode transition diagram.

- ADJUST is the mode used to perform the beta-squeeze or other perturbing operations. In this mode all movable devices of the experiments are out of beam. The experiments are 'off' - i.e. in a safe state.
- STABLE-BEAMS is the data-taking mode for experiments. Beams should be colliding, collimators in position and backgrounds OK. Light tuning of beam parameters will be performed. Beam feedbacks will be active.
- UNSTABLE-BEAMS is used to inform experiments that the situation degrades and that more drastic tuning may be required (as compared to STABLE-BEAMS). Such a mode is entered from the STABLE-BEAMS mode when conditions degrade suddenly.

In case of fast beam conditions degradation, the UNSTABLE-BEAMS mode may be entered without prior warning of the experiments. In case of slow degradation the experiments are warned and the ADJUST mode is entered when all experiments have given their OK as shown in the diagram of Figure 1

Beam dump request

The experiment beam dump request is based on data from various radiation monitors. It indicates that there is an immediate danger of damage to the detector. This is expected to be a fast signal. This signal must be very reliable to avoid unnecessary perturbation of machine operation due to spurious beam dumps.

The signal must NOT be used when backgrounds are high. In such a case the experiment must contact the machine control room to request some actions.

Injection inhibit

The experiments have asked for the possibility to inhibit injection without dumping the beam. The injection inhibit is based on the state of the detectors and does not depend on data from radiation monitors. It indicates that the detectors are not in a safe state to cope with potentially rough conditions that will occur during injection. Should one of the injection interlock become FALSE during injection, it is not so clear (from the experiment point of view) if any already circulating beam should be dumped. Injection will also be inhibited after a dump has been triggered (by the same experiment) pending assessment of the causes of the dump.

From the architecture of the Beam Interlock System it is NOT possible to inhibit injection without dumping the beam. A simple solution could be obtained by conditioning an injection inhibit request using the LHC mode (i.e. dump and inhibit only during filling). Possible hardware solutions will be discussed below. Another simple but less reliable solution is a software interlock.

Movable device interlock

Such interlocks concern roman pots (TOTEM and ATLAS) as well as LHCb VELO, since their position (between 10-70 σ) may directly interfere with beam operation. The interlock signal is based on the device position and end-switches are used to define the garage positions ('out of beam').

The interlock signal becomes FALSE when the garage position is left unless the machine mode is:

- STABLE BEAM: to allow data taking.
- UNSTABLE BEAM: on a transition from STABLE-BEAMS to UNSTABLE-BEAMS, movable devices should move back to garage position automatically. This allows operation crews to rapidly intervene on the beam without waiting for VELO and Roman Pots being in their garage position, which may take some minutes for VELO. Operation crews must however keep in mind that VELO and Roman pots are not in a fully safe position until they hit the end-switch.

If the beam conditions degrade slowly, operation crews should go to ADJUST mode after having informed the experiments and received the go-ahead. The mode must only change when Roman Pots and VELO have reached their garage position, or else a beam dump will be triggered.

Magnet interlocks

The Magnet Safety System that surveys the magnets of all LHC experiments is under the responsibility of the PH/DT1 group. The Magnet Safety System will provide an interlock signal to the BIS. In case of a magnet fault an interlock will be generated a few milliseconds before the power converter is switched off. The magnet interlock signal is foreseen as a MASKABLE input channel to the BIS.

The ALICE and LHCb spectrometer dipoles are normal conducting magnets with circuit time constants of $\sim$ 10 seconds. At 7 TeV a powering failure leads to orbit movements of $\sim 1\ \sigma$ in 750 ms. The spectrometer dipoles are not the most worrying elements for machine protection, but operation must stop if the magnets fail: the interlock signals will therefore be connected and active for LHC startup.

The solenoids are not expected to provoke major perturbations on the beam at 7 TeV. At injection the CMS solenoid will induce non-negligible coupling [3]. The former-L3/ALICE solenoid used to induce large orbit perturbations ($\sim$ 10 mm peak excursions) on the LEP orbit at 22 GeV. Scaled to 450 GeV the orbit effect may still be visible at the level of 0.5 mm, i.e. 0.5 σ, which is at the limit of being acceptable for operation with requiring to dump the beam. Time constant are long for CMS and ATLAS (many minutes to hours), but not for ALICE (80 s). Considering the relatively modest effect of the solenoids on the LHC beams, an input is reserved in the BIS for a solenoid interlock signal but the decision if the signal must actually be connected will be taken later (possibly after LHC startup) based on practical experience.

Software signals

Clearly in the initial phases of LHC operation communication between experiments and control room will be done mostly by voice contact. To anticipate the implementation of automatic procedures, the following signals have been defined :

- Each experiment will provide a READY-FOR-ADJUST signal to indicate that it is ready for a procedure with increased risk (of background) like beta-squeeze etc. The signal will be send as a reply to a ADJUST-REQUEST from the machine control room.
- Each experiment will provide a READY-FOR-BEAM-DUMP signal to indicate that it is ready for a scheduled beam dump. The signal will be send as a reply to a IMMINENT-BEAM-DUMP signal from the machine control room.

A time-out will be foreseen for both signals.

TECHNICAL ISSUES

Beam interlock system

The experiments have requested NON-MASKABLE connections to the BIS that must dump BOTH beams for dump requests and movable device interlocks. The experiments will apply their own masks internally. The non-maskable interlock signals must be operational and fully reliable already during the LHC machine checkout period.

Each BIC module has only 7 NON-MASKABLE inputs shared between clients that dump a single beam (1 OR 2) or both beams. In each IR there are 2 inputs available for the experiments. For ATLAS, LHCb and ALICE this is clearly sufficient. In IR5 CMS and TOTEM must share the two available connections. For any new experiment that must be added, we must either share channels, i.e experiments combine their signals, or accept a MASKABLE input, or have a signal concentrator for the interlock signals, for example an independent BIC crate.

Injection inhibit

There are two possible solutions to implement an injection inhibit for the experiments:

- Build an injection interlock loop around the ring. The loop interfaces to the injection elements and to the SPS extractions in IR2 and IR8. Such an implementation has a high price per channel. But it has the advantage that the hardware is identical to that of the BIS, that it is easy to accommodate further clients and that the maintenance is eased.
- Add dedicated point-to-point links between each client experiment and the IR2 and IR8 injection BIC modules (PLC and optical fiber links). This solution has potentially a lower price per channel. On the other hand the hardware is different than for the BIS.

Decisions on implementations depend of manpower and budget decisions.

Safe LHC mode

The LHC mode plays a critical role for the interlocking of movable devices. It must therefore be send to the experiments with high reliability. The LHC mode will be part of the Safe LHC Parameters that will be distributed around the machine in a failsafe and highly reliable way: Within the Safe LHC Parameters STABLE-BEAMS will only be sent when the energy is 7 TeV (or whatever the physics energy will be !). The present concept uses the General Machine Timing system for data distribution, with a special HW module to enter the data into the system. Details have still to be finalized. In addition the mode will also be distributed over the DIP system for data exchange machine-experiments.

CONCLUSION

The experiments will provide up to interlock 3 signals for beam dump request, injection inhibit and for movable device positions.

Interlock signals are foreseen for all experiments magnets: spectrometer dipoles will be connected at LHC startup, while for solenoids and toroids the decision to connect the signals will be taken later.

A number of technical issues have to be solved in 2006: implementation of the injection inhibit, number of signals, cables and rack locations as well as distribution of the Safe Parameters (mostly mode) to the experiments.

REFERENCES

[1] D. Macina, W. H. Smith and J. Wenninger, *LHC Experiments Beam Interlocking*, LHC-CIB-ES-0002 Rev 0.2, EMDS 653932.

[2] B. Puccio *et al*, *The beam interlock system for the LHC*, LHC-CIB-ES-0001-00-10, EDMS No. 567256.

[3] W. Herr, these proceedings.