SIGNALS FROM EXPERIMENT TO MACHINE

BEAM ABORT

Each experiment will have a single signal made up from hardwired logic that will transmit a beam-abort signal to the machine. The information from this logic will be used by the machine group and the experiment to diagnose the cause of a beam-abort signal after the fact but will not be used to "second guess" the beam abort decision when it happens.

It cannot happen since it triggers directly the beam dump via hardware signal

In general, the beam-abort signal would indicate that backgrounds are either over the acceptable level or the gradient on the background level is high enough that exceeding the acceptable level is imminent. The beam abort will be done in a fail-safe system where the absence of a beam-permit signal from the experiment will cause an abort (i.e. a current loop star distribution) and initiate a "post-mortem" procedure to document the signals from all experiments and the machine at the time of the abort. The experiment will be responsible for the logic, recording its state regularly and recording its state upon any logic transition. The hardware logic for the beam abort signal should be independent of that for the other signals. The output of the monitors used to create the beam abort signal will be continuously provided to the machine on a normalized scale (e.g. 1 is "safe" and 5 is "abort"). These will include the monitor level, gradient and its sign.

BEAM ABORT WARNING

Each experiment will have a single signal made up from hardwired logic that will transmit a beam-abort warning signal to the machine. This logic is the same logic used for the beam-abort signal except that the thresholds for level and gradient will be set at some fraction of those required for the beam-abort. The level, gradient and its sign of inputs to this signal would be monitored online by the experiments and also provided to the machine group. The purpose would be to provide a warning to the machine-group that conditions exist that could lead to a beam-abort signal.

The interlock signal foresees only yes or no. This warning can be included in the output monitors used to create the beam abort signal and provided to the machine. It may be an alarm can be associated to a certain level to warn the operators that conditions exists that could lead to a beam-abort signal so that the operators could take actions and try to avoid it.

The machine group could then take actions to avoid this. Receipt of this warning could be used to examine the input signals to the beam-abort signal to understand the source of an impending beam-abort in order to take more informed actions.

READY FOR INJECTION

Each experiment will provide a "ready for injection", which would be required to be true for injection to take place. This would differ from the abort signal in that its absence would indicate that movable detectors were not in position for injection or the experiment

voltages were not set for injection. The ready for injection system need not be provided by hardwired logic, but is provided by the experiment Detector Safety System and its state and inputs are logged regularly and also provided ot the machine.
DSS is not SIL rated. It is fine since the machine will not ask for it.
For the movable detectors the inhibit signal will be hardwired. In fact the interlock is based on their positions (IN or OUT) and they are allowed to be IN only during stable beams.
The LHC Injection Interlock Systems are responsible to inhibit the injection and to forward the injection inhibit to the SPS Extraction Interlock System to prevent extraction of the beam from the SPS.
The Injection Interlock Systems are local to IR2 for beam1, IR8 for beam2. The users of the Injection Interlock Systems are local to the corresponding IR and involve mostly injection protection elements (TDI, TCLI collimators, etc).
No connections from other IRs are foreseen for the Injection Interlock Systems, it is therefore not possible for the LHC experiments to connect to those systems, unless they provide their own links from their IR to IR2 and IR8.
Without link to the Injection Interlock System, the only possibility to inhibit injection by a hardware signal is over the BIS, which will also automatically dump any circulating beam. For that reason it is important the any injection inhibit signal from the experiments connected to the BIS be properly conditioned by the LHC machine mode to prevent unintentional beam dumps.

It is provided in a fail-safe manner where the absence of a “ready for injection” signal would prevent injection. This signal will not be used as a substitute for voice contact between the machine control room and the experiment, but instead as a safety backup in case voice communication is insufficient or not quick enough.

READY FOR HIGH RISK PROCEDURE

Each experiment will provide a “ready for high-risk procedure”, which would be required to be true for the machine-group to start high-risk procedures that are “voluntary”, i.e. improve beam conditions or operation, but not required to maintain beam. This signal is an “acknowledge” in response to the “High-Risk Procedure” signal from the machine.
The implementation of the whole procedure needs further discussion with the machine.
It indicates that whatever steps should be taken by the experiment to minimize damage during machine high-risk procedures have been taken and the experiment is ready for these conditions. Since such steps as ramping down voltages or remotely moving detector components take time, receipt of this signal would prevent initiation until these steps are complete. The “ready for high-risk procedure”, need not be provided by hardwired logic, but is provided by the experiment Detector Safety System and its state is logged regularly. This signal will not be used as a substitute for voice contact between the machine control room and the experiment, but instead as a safety backup in case voice communication is insufficient or not quick enough.

READY FOR BEAM ABORT

Each experiment will provide a "ready for beam abort", which would be required to be true for the machine-group to abort the beam after alerting the experiments that the beam would be aborted. These beam aborts would be those that are needed on a time scale too quick for voice communication between the machine group and the experiment, but yet not of an emergency nature requiring an immediate response from the machine. This signal is an "acknowledge"[i] in response to the "beam-abort" signal from the machine. It indicates that whatever steps should be taken by the experiment to minimize damage during machine abort have been taken and the experiment is ready for the beam abort. Since such steps as ramping down voltages or remotely moving detector components take time, receipt of this signal would prevent initiation until these steps are complete. The "ready for beam abort", need not be provided by hardwired logic, but is provided by the experiment Detector Safety System and its state is logged regularly. This signal will not be used as a substitute for voice contact between the machine control room and the experiment, but instead as a safety backup in case voice communication is insufficient or not quick enough.

SIGNALS FROM MACHINE TO EXPERIMENT

INJECTION

The machine is injecting or attempting to inject or about to inject beam into the LHC.

LUMINOSITY (or "stable beams")

Beam conditions are stable and changes in beam operation are unlikely to occur.

HIGH RISK PROCEDURE (or "adjust")

Indicates during running that a high-risk beam procedure is about to be initiated (i.e. major retuning, beta-squeeze, etc.). The experiments could then choose to move back some detectors or reduce high voltage during this time. This signal will not be used as a substitute for voice contact between the machine control room and the experiment, but instead as a safety backup in case voice communication is insufficient or not quick enough.

When the beam conditions are good (or acceptable) and the beams are colliding at the interaction points, the machine mode switches to 'stable beams' which corresponds to the data taking periods for the experiments. In this mode the backgrounds should remain low and only minor adjustments are made to the beam conditions to maintain the beam and background quality. It is important to realize that in the stable beams period, a number of feedbacks may be permanently acting on the beam, and that failures of this feedbacks cannot be avoided.

In case the beam conditions degrade during the 'stable beams' period, the operator will set the mode back to 'unstable beams' until the problems are resolved. It is important to

realize that there is no absolute definition of the 'stable beam' conditions, and that it is therefore always subject to interpretation. Also conditions may be consistent with 'stable beams' for one of the experiments, but not for some of the others.

Likewise a failure requiring an immediate (i.e. on the time scale of milliseconds) beam dump can occur at any time during the stable beams period. The fastest failures due to the powering system are among the most critical for the LHC, and it is the role of the Machine Protection System to safely abort the beams. It is clear however that the experiments must be able to cope with the potential high background or radiation level that may occur during the transients before the beams are dumped.

BEAM DUMP

Fast signal to alert experiments that the beam is about to be dumped. It might not be possible to provide this in all cases, but when a controlled dump is planned, this should be raised in advance. For a controlled beam dump, this signal will not be used as a substitute for voice contact between the machine control room and the experiment, but instead as a safety backup in case voice communication is insufficient or not quick enough.

OTHER SIGNALS

The experiments request to know the LHC existence, use and definitions of the following signals employed during LEP running: "shutdown", "ready for injection", "injection", "ramping", "squeeze", "ready for collisions", "colliding", "adjust", "collimators at physics settings", "stable beams", "ready to dump" and "dump"[ii].
The machine modes are going to be finalized in a dedicated paper that will be issued soon taking into account the issue of the "high risky procedure"

[i] Reference on LHC Beam Interlocks: LHC-CIB-ES-0001-00-10, EDMS: 567256

[ii] Special thanks to Austin Ball for this information.