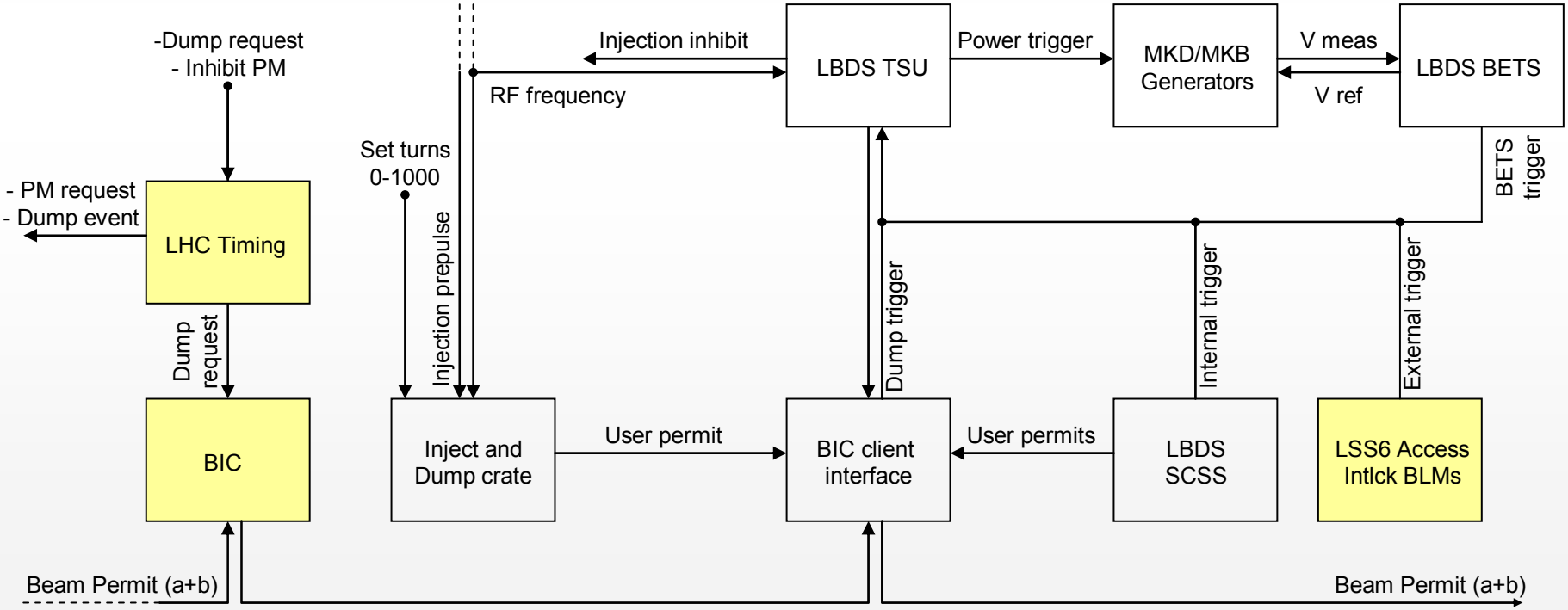
Inject and dump

- **LBDS triggering**
- **Use-case overviews**
  - Inject and dump between 0 – 1000 turns
  - Inject and dump with arbitrary delay
- **Requirements on other systems**

A lot of input from M.Lamont, E.Carlier, B.Puccio, etc.

LBDS triggering

- **The LBDS TSU interfaces with other LHC systems for the triggering:**
  - the BETS, in the event of an energy tracking error;
  - the RF system, for the abort gap fast timing;
  - the injection interlock system, to allow the dump to be armed;
  - the BIS beam interlock system via the local BIC client interface;
  - the redundant IR6 beam loss system and the access system, to trigger the dump independently of the BIS



Inject and dump via HW: 0 – 1000 turns

- For injection setting-up with screens, and studies requiring less than 100 ms of circulating beam, e.g. aperture measurements in injection and extraction channel.
- Will use a dedicated hardware system to trigger the beam dump via the BIS
- Necessary to dump after less than one full turn, to ensure that injection setting up with screens can be performed with a single beam impact.
- To protect the screens, maximum number of turns has to be limited.
- The other entry conditions are that the LHC machine is at injection energy, that the beam permit for the selected ring is TRUE.
- Use a timing event at 1 ms after the requested number of turns to provide redundancy for increased screen protection
- This mode can only be used with the Safe Beam from the SPS.

Inject and dump via HW – use-case

i. Timing table containing the four events: “Injection warning”, and with the correct delay (1-100 ms) the “Suppress PM beam 1”, “Unlink beams” and “Dump beam 1” loaded into CTG and executed.

ii. Correct delay (1-1000) turns loaded into Inject and Dump hardware (turn counter).

iii. Injection system receives “Injection warning” event and injection process takes place.

iv. Timing receiver card CTRx at PM suppressor box receives “Suppress PM beam 1” event and masks the PM request transmission for (e.g.) 2 ms.

v. Timing receiver card CTRx at BIC receives “Unlink beams” event and decouples the beam 1 and beam 2 permit loops.

vi. Inject and dump hardware counts to required number of turns and opens Beam permit loop 1 via BIC (loops “unlinked”).

vii. LBDS detects open permit loop and triggers beam 1 dump.

viii. CTG detects open permit loop and sends out “Beam 1 dumped” timing event;

ix. CTG detects open permit loops and generates “Request PM” timing event;

x. The PM request suppressor does not forward the “Request PM” timing event;

xi. XPOC data acquisition triggered by the “Beam 1 dumped” event.

Inject and dump via timing: 0.1 – n seconds

- This mode is required for longer delays between injecting and dumping
- **Will use the timing system to trigger the beam dump via the BIS.**
- Screens are NOT allowed to be in the beam
- In this case there is not a restriction on the beam intensity.

Inject and dump via timing: use-case

i. Timing table containing the four events: “Injection warning”, and with the correct delay (>100 ms?) the “Suppress PM beam 1”, “Unlink beams” and “Dump beam 1” loaded into CTG and executed.

ii. Injection system receives “Injection warning” event and injection process takes place.

iii. Timing receiver card CTRx at PM suppressor box receives “Suppress PM beam 1” event and masks the PM request transmission for (e.g.) 2 ms.

iv. Timing receiver card CTRx at BIC receives “Unlink beams” event and decouples the beam 1 and beam 2 permit loops.

v. Timing receiver card CTRx at BIC receives “Dump beam 1” event;

vi. Beam permit loop 1 opened by BIC (loops “unlinked”).

vii. LBDS detects open permit loop and triggers beam 1 dump.

viii. CTG detects open permit loop and sends out “Beam 1 dumped” timing event;

ix. CTG detects open permit loops and generates “Request PM” timing event;

x. The PM request suppressor does not forward the “Request PM” timing event;

xi. XPOC data acquisition triggered by the “Beam 1 dumped” event.

New Inject & Dump HW

- **Assumed HW located in a rack or racks in point 6 underground, in RA63/67, to minimise the reaction times with the beam permit loop.**
- **Present prepulse envisaged 10 μs prior to injection, to minimise 'dead time' of MKI when injection kick can no longer be stopped.**
- **Detailed analysis of response times and signal delays to be made, to determine whether this is adequate for deterministic dumping on turn 0, or whether another separate prepulse needs to be generated with a longer delay to trigger this system.**
- **The following functionalities are required:**
  - Triggering by RF prepulse
  - Turn counting via RF frequency
  - Interrupt of beam permit loop
  - Adjustable delay in order to trim the system synchronisation during setting up
  - "Set" requested turns via LSA (MCS?)
  - "Read" of requested turns via LSA (for SW interlocks)

Timing system

The timing system will be used for emergency, Inject and Dump and for the other programmed dump events. The following functionalities are required:

- Distributing “request dump beam 1” and “request dump beam 2” events;
- Distributing “Suppress PM beam 1” and “Suppress PM beam 2” events;
- Distributing “Request PM” event.
- Distributing “beam 1 dumped” and “beam 2 dumped” events; • Suppressing or forwarding the “request PM” event if beam permit loop 1 or 2 opens, depending on whether the “Suppress PM beam 1” or “Suppress PM beam 2” event has arrived within the past 1 (?) ms.
- Distributing “Unlink beams” and “link beams” events;

BIS

The BIS is used to trigger the beam dump for all programmed dumps. The BIS must therefore provide a reliable and deterministic response to the interrupt in IR6 coming from the Inject and Dump I system, such that the beam can reliably be dumped after the programmed number of turns. The BIS must also provide an automatic reset for certain machine modes, in order that repeated injection or the injection sequence can continue. (Alternatively such functionality could be provided by the sequencer if it can work in a "real-time" loop.) The following functionalities are required:

- Triggering via timing system, with a delay which can be of the order of a few turns;
- Decoupling beam 1 and beam 2 loops (which are normally linked together) in response to a "Decouple beams" timing event.
- The loops must be recoupled together once the loop is again closed, in the case of the injection sequence, again via a timing event (or LSA command, as less time critical?).

Beam dump

The dump system must be re-armed after every action, which is foreseen to be managed by the sequencer. This is basically an issue during Inject and Dump and during the injection sequence. The LBDS IPOC and XPOC results must be positive and the beam permit loop is then forced closed during a short period, while the LBDS inhibits the injection and forces its own user permit true.

Sequencer

The sequencer must provide the high-level management of the inject and dump machine modes and of the other programmed dumps. The following functionalities are required:

- managing machine mode changes;
- configuring all the systems to meet the entry conditions;
- checking that the entry conditions are met;
- generating the timing events with the correct delays;
- setting the turn counter value;
- requesting checks before injection is enabled;
- requesting the correct beam from the SPS;
- reading the XPOC result;
- arming and re-arming the LBDS;
- re-arming the BIS.

Screen limits

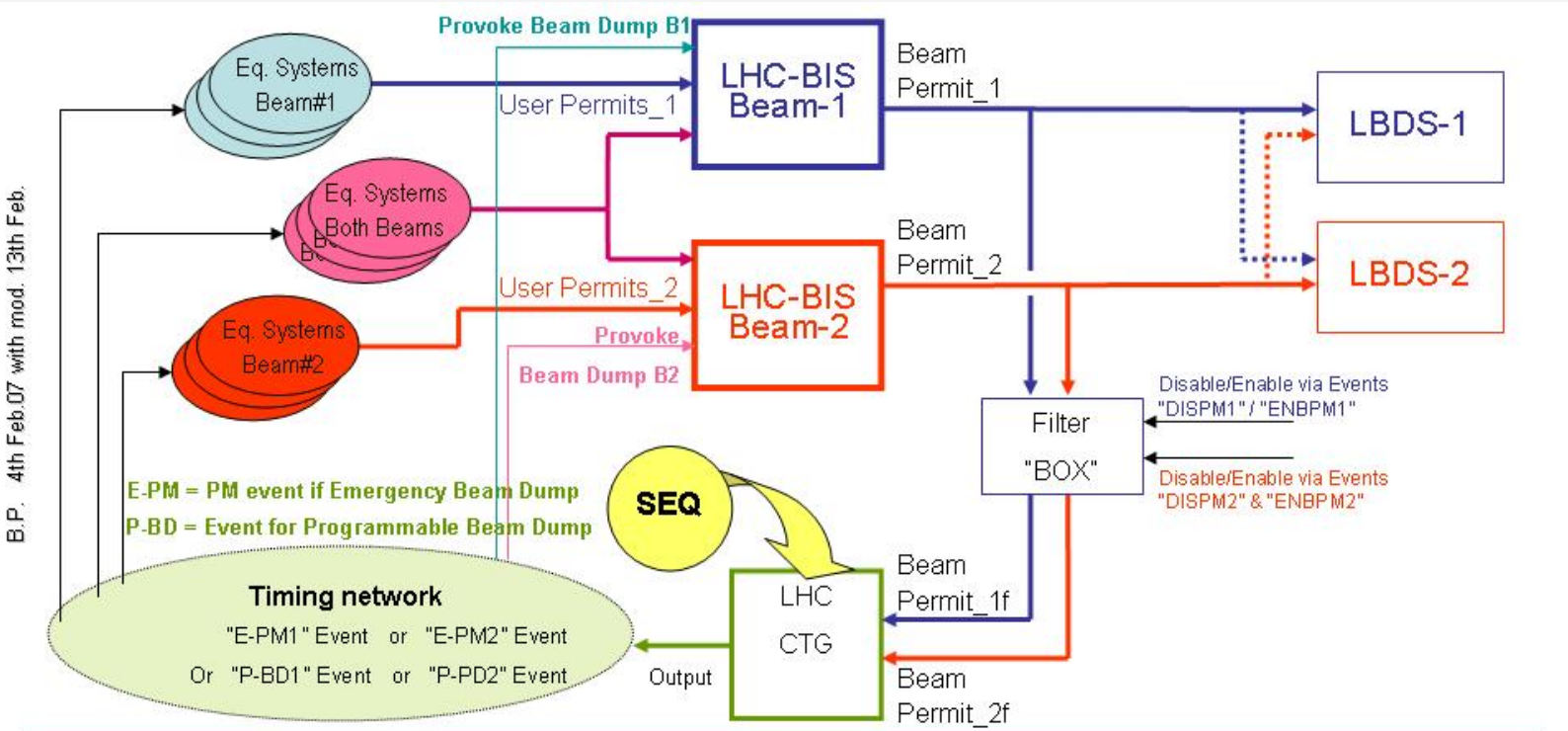
- **Screens can only be in beam in "Inject and Dump HW" mode to ensure protection of screens – AND when turns requested is below safe limit (depends on screen type and intensity)**

- **Safe numbers of turns….**
  - Al_2O_3 screens withstand 10^{13} p+/mm2, and Ti screens 10^{14} p+/mm2. For nominal optics, p+ density at screen for injected nominal batch of 3.3×10^{13} p+ is $\leq1.1\times10^{13}$ P+/mm2.
  - Assuming that the safe beam limit is 10^{12} p+ at 450 GeV, safe number of turns for Ti screens is ~ 300, and for Al_2O_3 screens ~30.
  - Taking $\times3$ margin, max. turns with safe beam should be 100 for Ti and 10 for Al_2O_3 screens.
  - What about 1000 turns with pilot beam? Product of [turns $\times$ intensity] must not exceed 10^{13} for Al_2O_3, and 10^{14} for Ti screen (so pilot is safe for both screen types).

Screen interlocking

- **Screen interlocking**
  - HW interlock from screens to inhibit user permit for unsafe beam, if screen in beam.
  - Sequencer to ensure that: mode = Inject and dump, turns loaded into I&D crate, beam intensity = safe in SPS, beam intensity in SPS below limit (use SPS intensity interlock for this? It works…).
  - SW interlock: turns requested, SPS intensity and screen type to allow or inhibit injection.
- **Additional protection measures**
  - Limit the maximum number of turns to 1000 in Inject & Dump HW
  - In this mode always include a timing event 1 ms after the I&D dump
  - As a real HW interlock with no software dependence, use (existing?) BLMs at each screen, with interlock threshold at an appropriate integration time, to dump beam if losses detected exceed dangerous level (being checked by BI).

BIS, PM and XPOC triggering



In case of Emergency BD*, the 2 beams will be always dumped thanks to a coupling between BIS-1 & BIS-2

⇒ The "Filter Box" is not activated, and the two Beam_Permit changes are detected by the CTG
⇒ PM Events (lets call them E-PM1 and E-PM2) will be both broadcasted over the Timing Network
⇒ in order to freeze their PM buffers, the Equipment systems have subscribed to E-PM1 and to E-PM2.
** Whatever was the request' source: from "Both Beams Systems" **or** from "Individual Beam systems"*

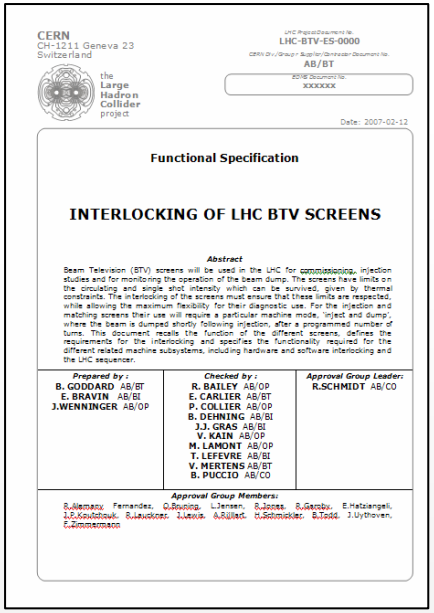
In case of Programmable BD, only one beam is dumped (no coupling between BIS-1 & BIS-2)**

***always provoked by LHC-SEQ via the Timing*

⇒ one PM Event (lets call it P-BD1 or P-BD2) will be "generated" by the LHC-SEQ via the CTG.
⇒ This event is used to provoke a beam Dump. In addition, CTG generates the Disable Event ("DISMPn") for the Filter box.
⇒ As the Filter Box is activated: the corresponding Beam_Permit change is masked to the CTG (other one not masked).
⇒ (If needed for few systems) Freezing PM buffers is still achievable if they have also subscribed to "P-BD1" or "P-BD2"

Documents floating around

- FS on screen interlocking (EDMS 821083)
- FS on sequencer requirements (EDMS 810407)
- Draft ES on PM triggering and suppression
- Draft FS on Programmed dumps (including Inject & Dump)



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Date: 2007-02-12

Functional Specification

INTERLOCKING OF LHC BTV SCREENS

Abstract

Beam Television (BTV) screens will be used in the LHC for commissioning, injection studies and for monitoring the operation of the beam dump. The screens have limits on the circulating and single shot intensity which can be survived, given by thermal constraints. The interlocking of the screens must ensure that these limits are respected, while allowing the maximum flexibility for their diagnostic use. For the injection and matching screens their use will require a particular machine mode, 'inject and dump', where the beam is dumped shortly following injection, after a programmed number of turns. This document recalls the function of the different screens, defines the requirements for the interlocking and specifies the functionality required for the different related machine subsystems, including hardware and software interlocking and the LHC sequencer.

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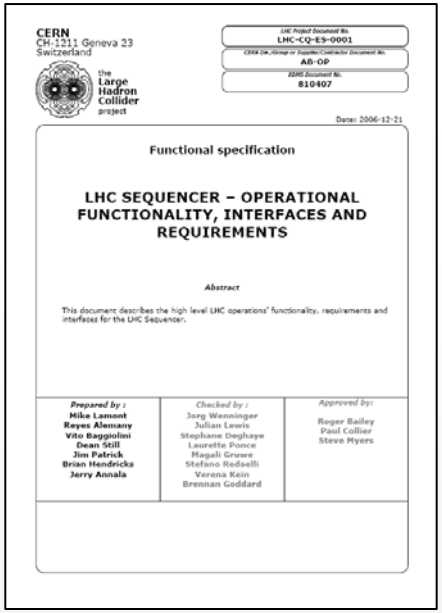

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EDMS Document No.
810407

Date: 2006-12-21

Functional specification

LHC SEQUENCER – OPERATIONAL FUNCTIONALITY, INTERFACES AND REQUIREMENTS

Abstract

This document describes the high level LHC operations' functionality, requirements and interfaces for the LHC Sequencer.

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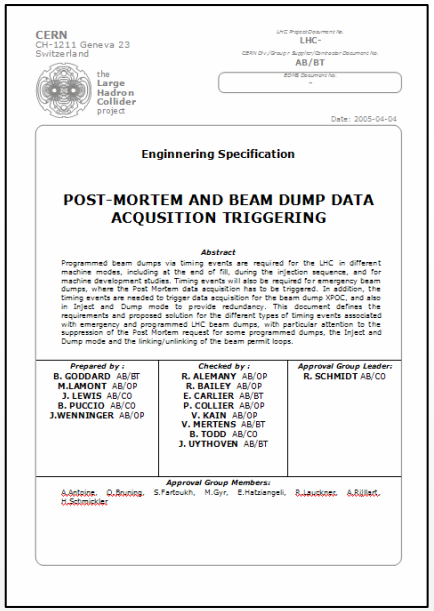

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EDMS Document No.
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Date: 2005-04-04

Enginnering Specification

POST-MORTEM AND BEAM DUMP DATA ACQUISITION TRIGGERING

Abstract

Programmed beam dumps via timing events are required for the LHC in different machine modes, including at the end of fill, during the injection sequence, and for machine development studies. Timing events will also be required for emergency beam dumps, where the Post Mortem data acquisition has to be triggered. In addition, the timing events are needed to trigger data acquisition for the beam dump XPOC, and also in Inject and Dump mode to provide redundancy. This document defines the requirements and proposed solution for the different types of timing events associated with emergency and programmed LHC beam dumps, with particular attention to the suppression of the Post Mortem request for some programmed dumps, the Inject and Dump mode and the linking/unlinking of the beam permit loops.

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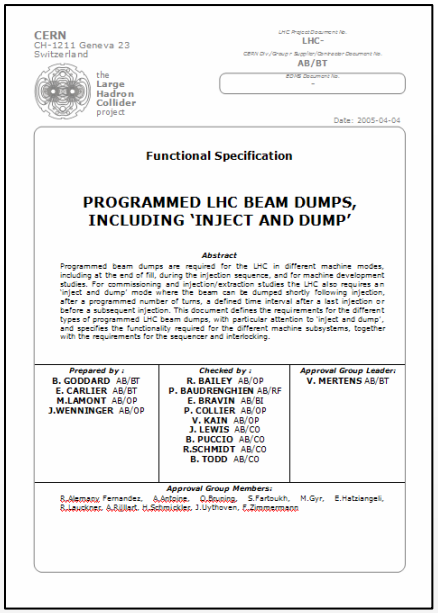

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Functional Specification

PROGRAMMED LHC BEAM DUMPS, INCLUDING 'INJECT AND DUMP'

Abstract

Programmed beam dumps are required for the LHC in different machine modes, including at the end of fill, during the injection sequence, and for machine development studies. For commissioning and injection/extraction studies the LHC also requires an 'inject and dump' mode where the beam can be dumped shortly following injection, after a programmed number of turns, a defined time interval after a last injection or before a subsequent injection. This document defines the requirements for the different types of programmed LHC beam dumps, with particular attention to 'inject and dump', and specifies the functionality required for the different machine subsystems, together with the requirements for the sequencer and interlocking.

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