CONSOLIDATION OF RE-TRIGGERING SYSTEM OF LHC BEAM DUMPING SYSTEM AT CERN

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Abstract

The Trigger Synchronisation and Distribution System (TSDS) is a core part of the Large Hadron Collider (LHC) Beam Dumping System (LBDS).

It is responsible for the synchronization of the dump trigger with a beam free abort gap.

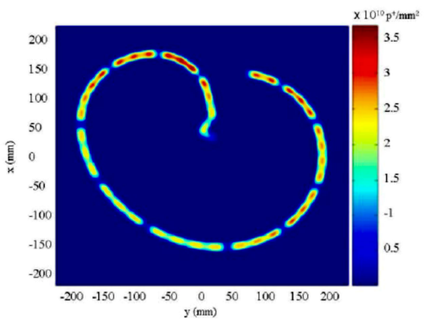
It comprises redundant Re-Trigger Lines (RTL) that allow fast re-triggering of all high-voltage pulsed generators in case one of them self-triggers, resulting in a so-called asynchronous dump.

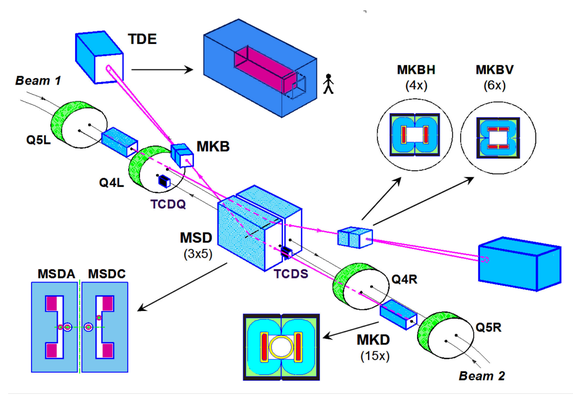
For reliability reasons, the TSDS relies on many RTL redundant trigger sources that do not participate directly in the execution of a normal dump.

The LBDS operated reliably since the start-up of LHC in 2008, but during its Run 2, new failure modes were identified that could induce damage for the beam dump block and the dump protection elements.

In order to correct these failure modes, an upgrade of the TSDS is realized.

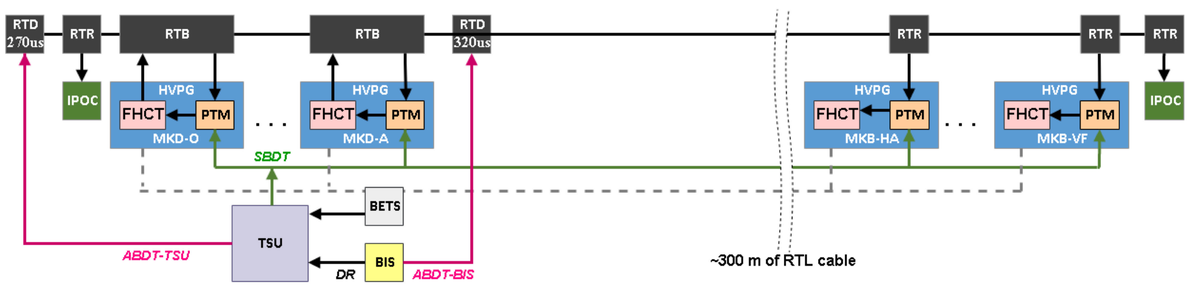
LHC Beam Dumping System





- TSDS sends trigger synchronized with beam abort gap
- Extraction kickers (MKD) give small angle to circulating beam
- Extraction septa extract the beam vertically out of LHC
- Dilution kickers (MKBH/V) make the beam oscillate
- Dump block (TDE) absorbs the beam diluted by MKBs

Current Re-trigger Line Architecture



Normal Beam Dump Scenario (Synchronous Dump):

- BIS is activated and sends asynchronous beam dump triggers (ABDT) on RTL with 320us delay
- TSU detects BIS Dump Request (DR) and sends redundant trigger ABDT with 270us delay
- TSU sends synchronous Beam Dump Trigger (SBDT) with beam abort gap.

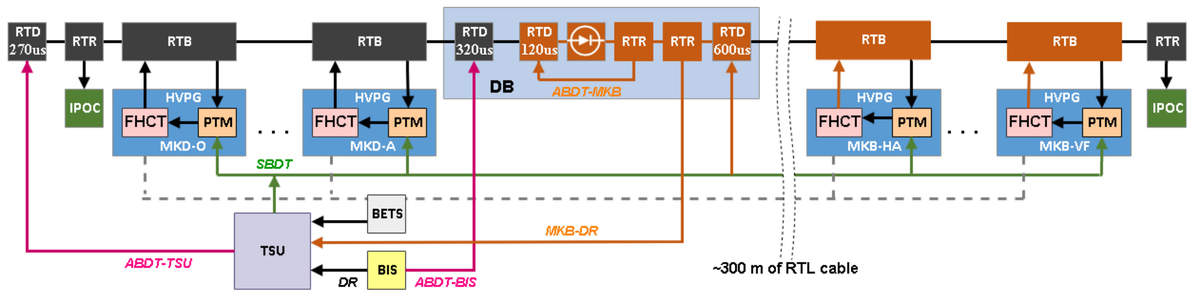
MKD Self-Trigger Scenario (Asynchronous Dump):

- One MKD self-triggers, and inject pulses on the RTLs
- All other MKD/MKB are triggered by pulses propagated on RTLs
- BIS is activated by dump and sends redundant trigger ABDT with 320us delay
- TSU detects BIS DR and sends redundant trigger ABDT with 270us delay
- Beam present on the MKD rising edge to be absorbed by protection devices

MKB Self-Trigger Scenario (Synchronous Dump):

- No Re-Trigger of MKD/MKBs in case of self-trigger of one MKB
- Slow detection of MKB self-trigger by BETS
- TSU detects BETS DR and SBDT synchronized with BAG, all HVPG pulse.
- Possible phase opposition with other synchronously triggered MKB by TSU

New Re-trigger Line Architecture

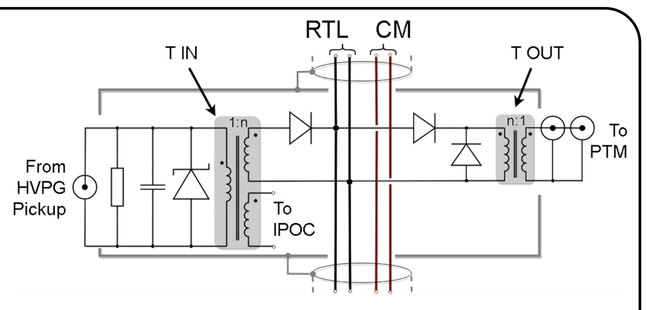


New MKB self-trigger Scenario:

- Re-Trigger of all MKBs in case of self-trigger of one of them
- Decoupling Box (diodes) to block propagation to MKDs
- TSU detects MKB DR and sends SBDT, all MKDs pulse.
- No more phase opposition between MKBs.

New Re-Trigger Box design

Remove Coupling between MKBs:
Floating inputs and outputs through isolated connector. Box isolated from chassis, connected to cable shield.



Remove Pulse Attenuation:
Input transformers saturate earlier than output transformers, to solve problem of pulse attenuation

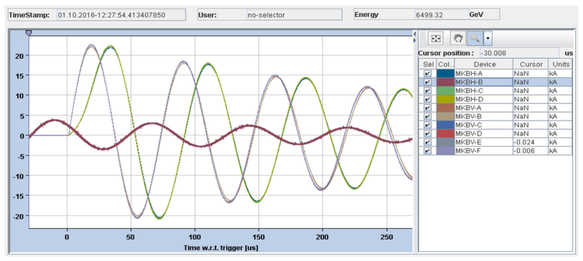
Problems observed in operation

Phase opposition between MKBs:

- Self-triggered MKB can be in phase opposition with other MKBs
  => Up to two MKBs can be lost

Coupling between MKBs:

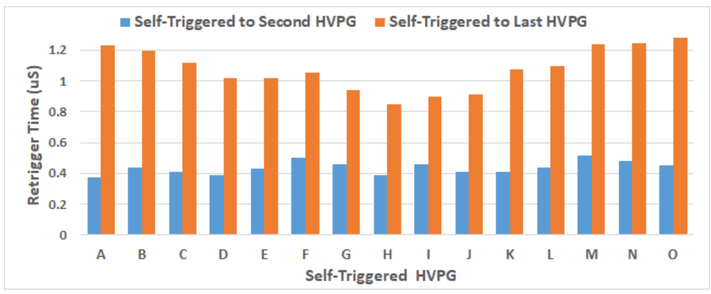
- Self-triggered MKB provoked the trigger of its neighbors



These problems could yield loss of more than half of dilution:
Not accepted failure mode for TDE

Re-Trigger Time Improvement

The re-triggering time, from self-triggered MKD to the last triggered MKD, should be minimised to limit the energy deposited in protection elements in case of asynchronous dump.

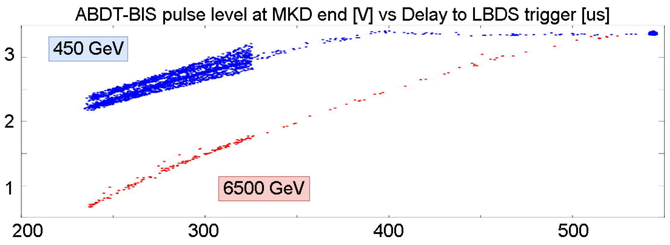


- **Detection Time (blue)** improved with New Power Trigger Module design
- **Propagation Time (orange - blue)** improved with shorter RTL cables

Re-Trigger Line Pulses Attenuation

Observed during LHC operation:

- Redundant pulses (ABDT) attenuation after dump execution
- Problem of diagnosis for IPOC, not safety issue



Analysis of thousands of pulses executed during LHC operation:

- Attenuation depends on both HVPG voltage, and ABDT position

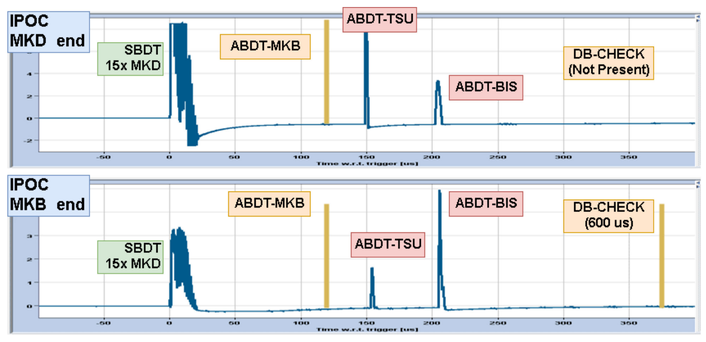
Understood to be due to output transformer saturation in RTB:

- Saturated transformers show low impedance, absorbing pulses.

Redundant Trigger Diagnostics

The redundant triggers (ABDT) are sent on the line after the beam dump.

They do not participate directly in the dump action, but are needed in case of failure of the TSUs.



After every dump, IPOC captures and analyses signals on both RTL ends.
Amplitude and time of redundant triggers is validated.
With new architecture, new redundant triggers need to be analyses.

Summary

LBDS performed very well since the beginning of LHC operation, but unforeseen failure modes occurred, which could yield damage to TDE and the dump protection elements in condition of HiLumi-LHC beams.

A new architecture of TSDS is being implemented, solving problems related to the retrigger system observed in operation since the start-up of LHC.

The new LBDS re-triggering system will have to be fully re-validated before the start of LHC Run 3, during a long reliability run without beam.

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