LHC Extraction Kicker

Triggering & Re-Triggering

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LHC Extraction Kicker System

One missing generator ➔ OK

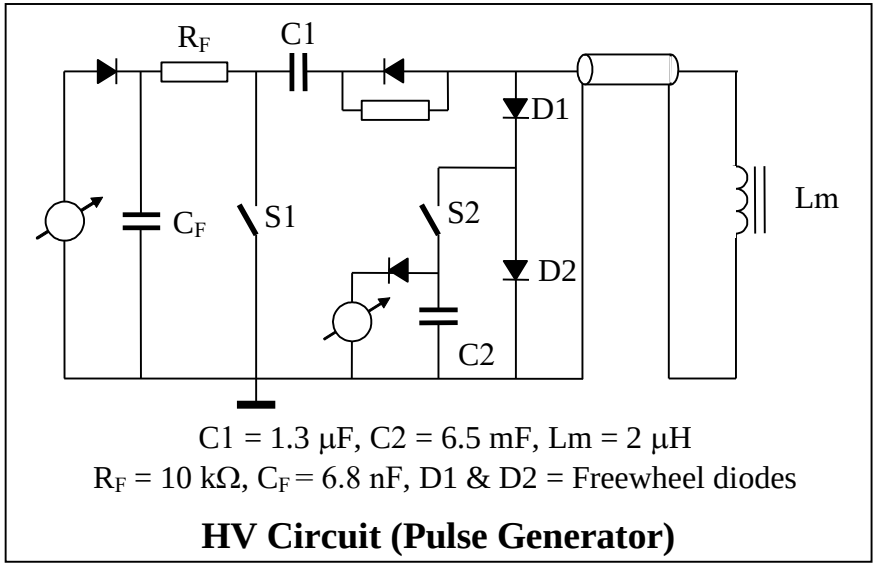
- ➔"Not always" detectable before the pulse.
- ➔Redundancy within the HV generators and the triggering system

One erratic generator ➔ NOT OK

- ➔Early detection of current within the HV generators.
- ➔Redundant Passive Fault Tolerant Re-triggering system.

LHC Extraction Kicker System

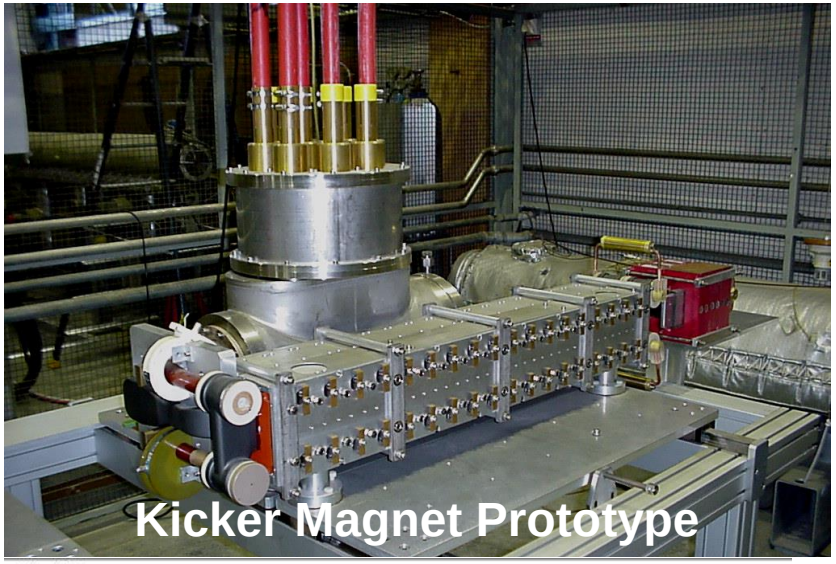
General



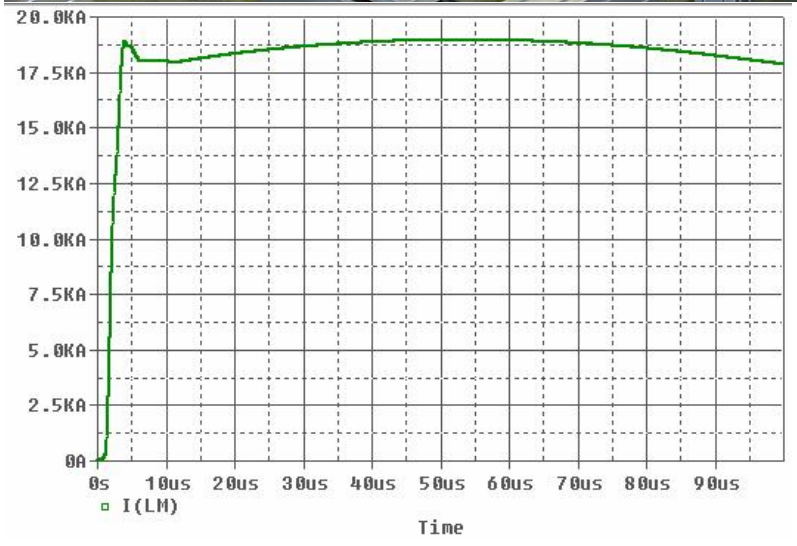
C1 = 1.3 µF, C2 = 6.5 mF, Lm = 2 µH

R_F = 10 kΩ, C_F = 6.8 nF, D1 & D2 = Freewheel diodes

HV Circuit (Pulse Generator)

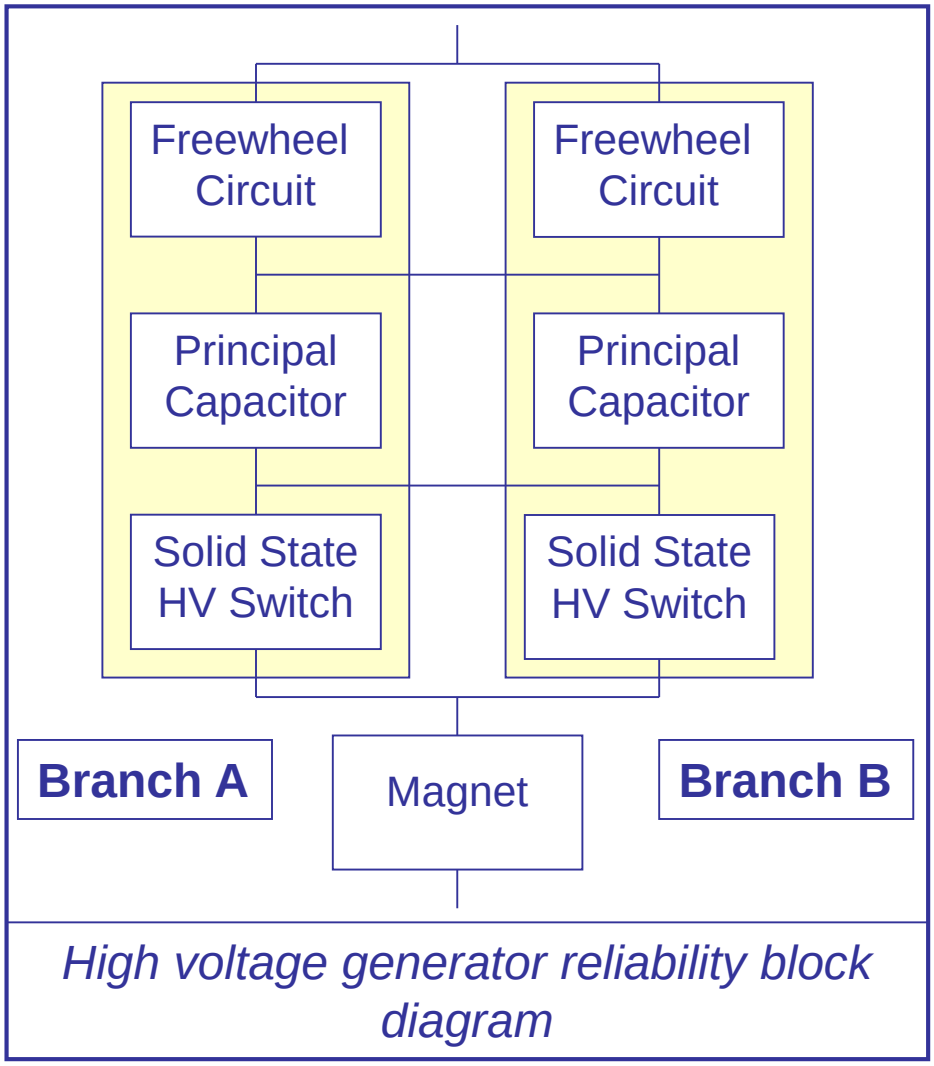


Number of magnets per system	15	
System deflection angle	0.275	mrad
Operating charging voltage range	2.2 to 30	kV
Operating magnet current range	1.4 to 20	kA
Magnet field overshoot	8	%
Field flat top duration	> 90	µs
Field rise time 0.5%-100% per magnet	2.8	µs

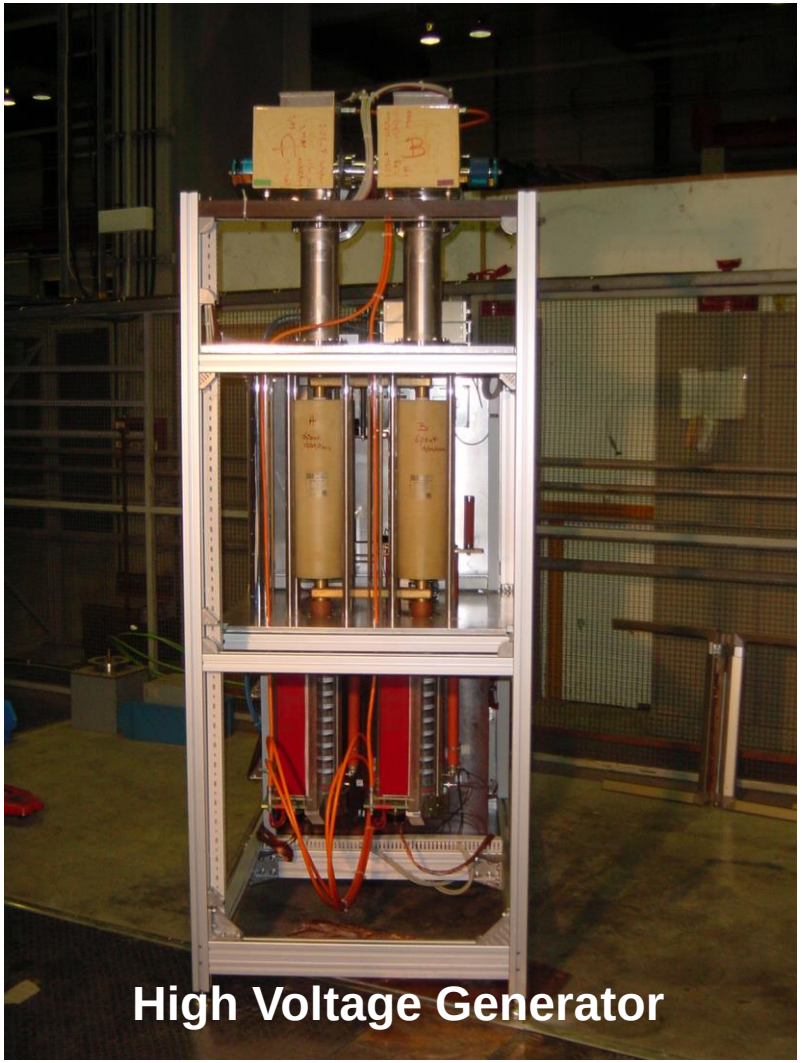


LHC Extraction Kicker System

High Voltage Generator



High voltage generator reliability block diagram



Dump Request Distribution

Dump request distribution uses the
“domino effect”

- **Energy** required **to distribute** the **dump request** up to the kicker HV generator is
  - **Pre-stored within capacitor** at each stage of the triggering chain,
  - **Used to trigger the next stage,** and
  - **Checked before a beam permit** signal is issued,

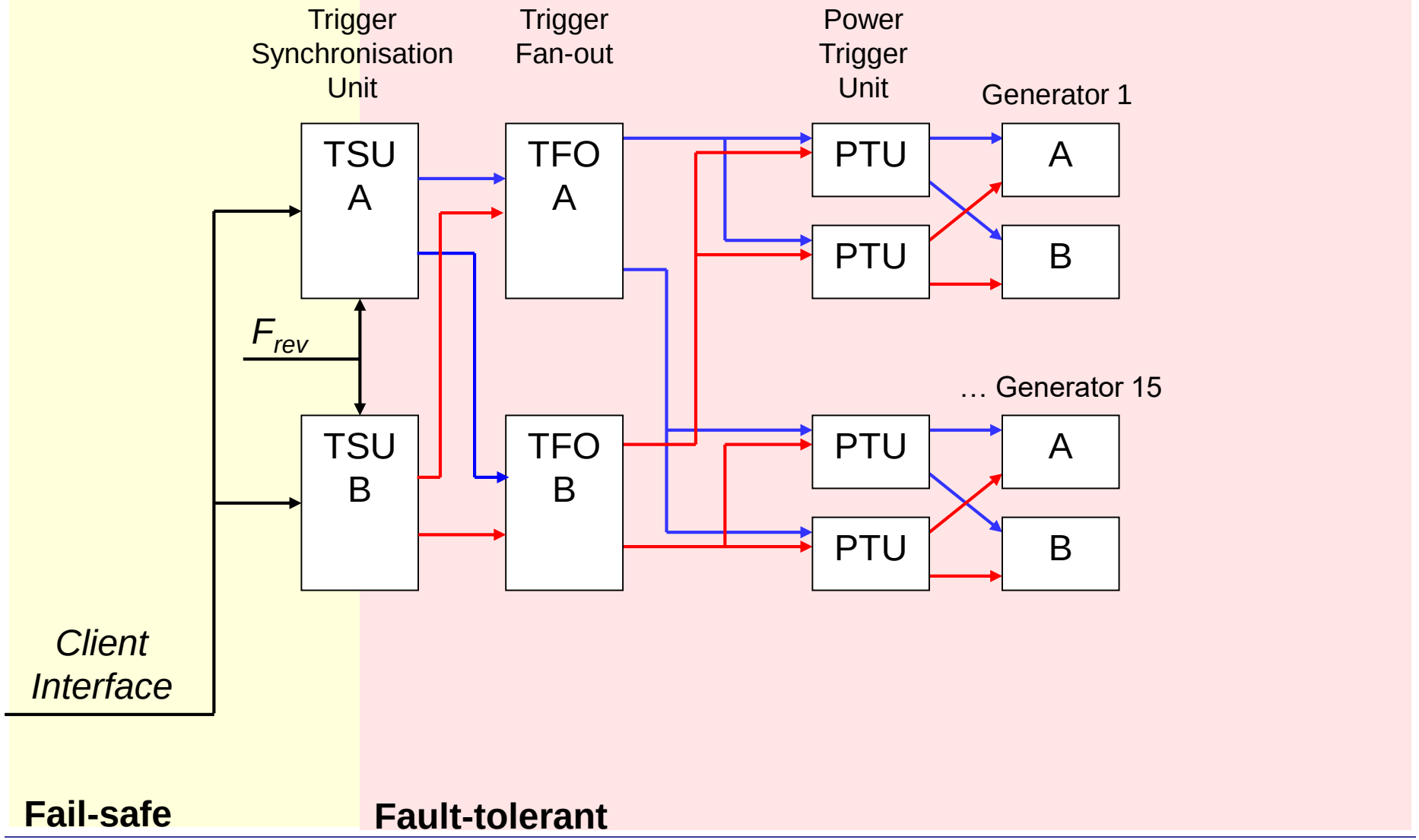
  But, somebody has to trigger the chain… to push the first domino stone!

  → **Interface to the LBDS Clients**

- **Propagation** of the **trigger pulse** through the different stages of the triggering chain relies either on an **active fail safe logic** up to the synchronisation with the abort gap and on a **passive redundant fault tolerant logic** up to the HV generator in order to avoid asynchronous beam dumps.

Synchronisation & Triggering

Architecture



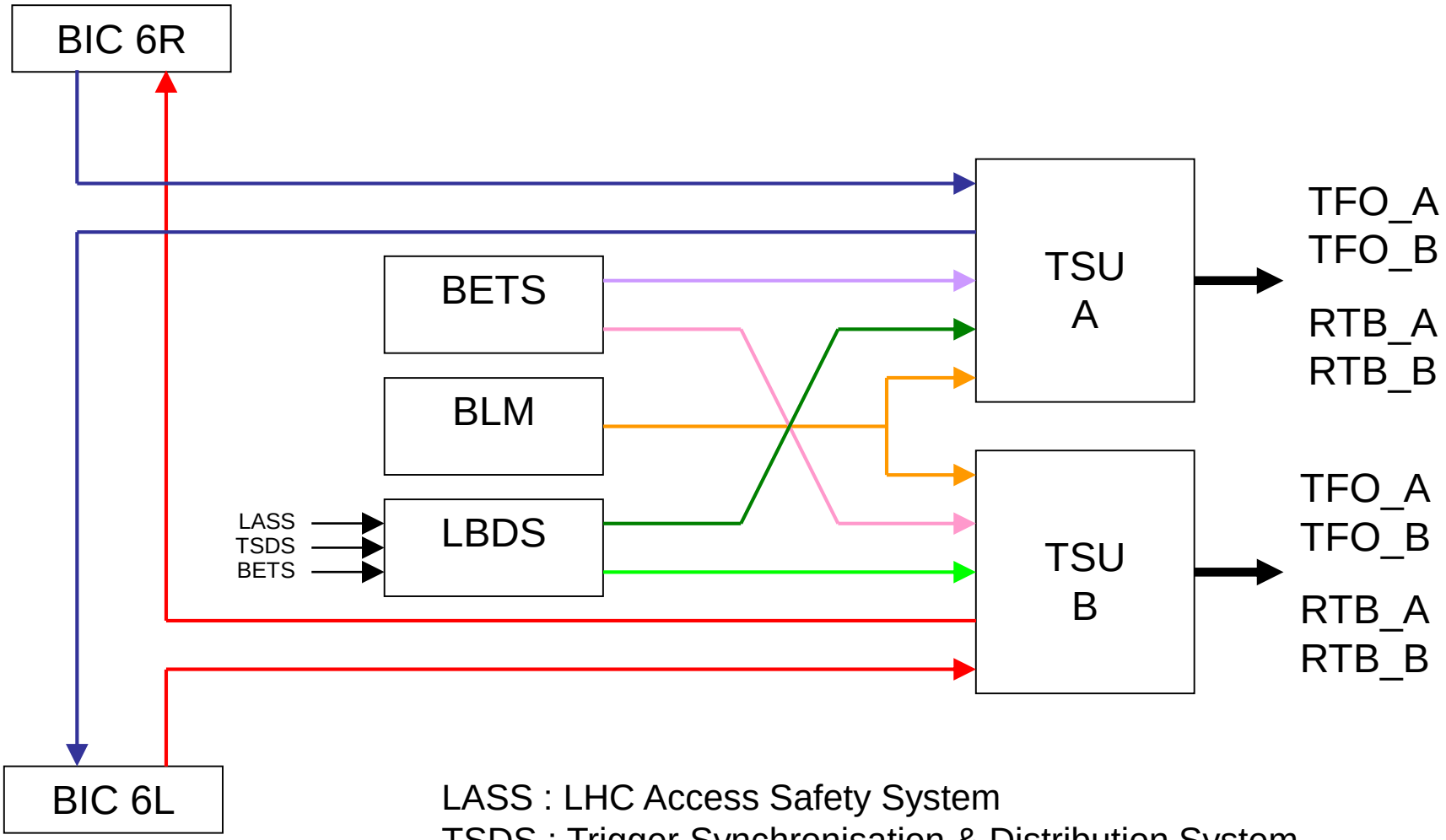
Client Interface

Inventory

Client	Signal Redundancy	Signal Type	Signal Media	Response Time
BIS	Yes	10 MHz Frequency	Fibre Optic	< 150 ns
BLM	No	Current Loop	Opto-coupled copper cable	< 1 us
BETS	Yes	10 MHz Frequency	50 Ω galvanic signal	< 150 ns
LBDS MKD State MKB State TSU State BETS State PMA State LASS State	Yes	Non-Ambivalent Contact	Floating Relay	< 10 ms
CBCM	???	???	???	???

Client Interface

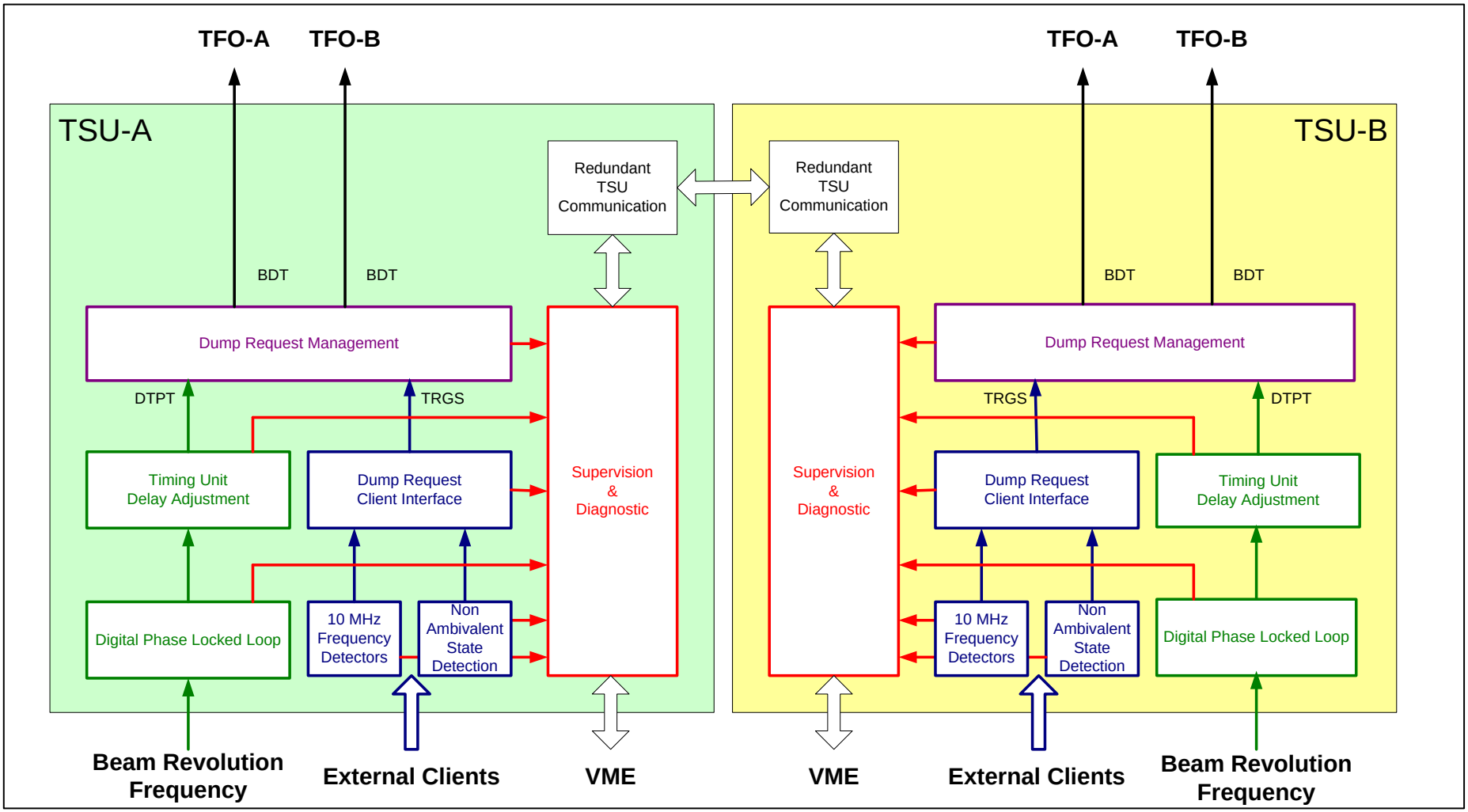
Inter-Connection



LASS : LHC Access Safety System
TSDS : Trigger Synchronisation & Distribution System
BETS : Beam Energy Tracking System

Trigger Synchronisation Unit

Block Diagram



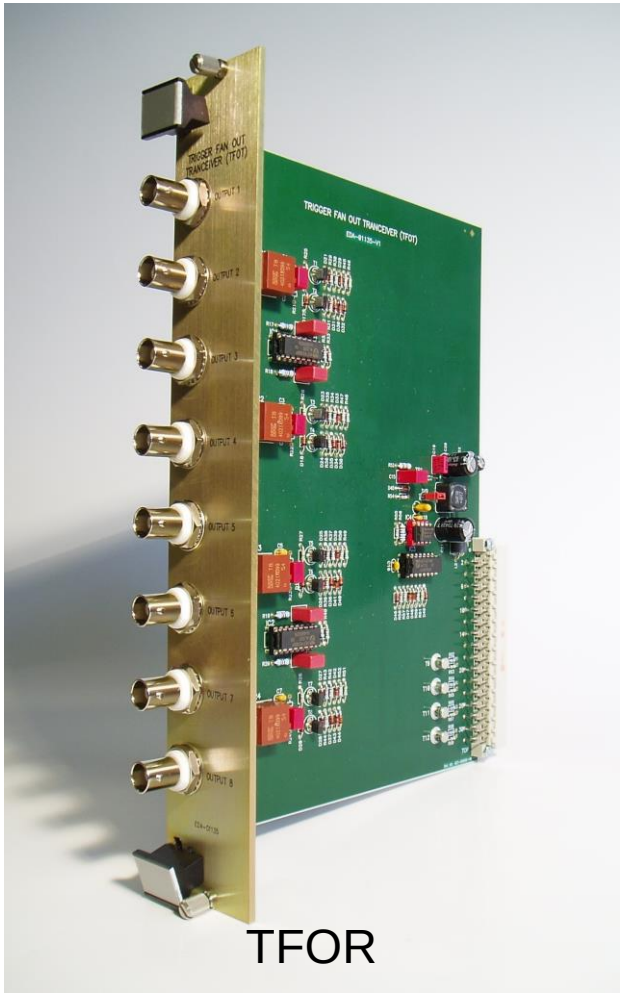
Trigger Synchronisation Unit
10 MHz Interface

- Redundant detection logics in each TSU
  - Implemented within two separate CPLDs
  - Detection circuits within the CPLD will developed by two different persons
- Surveillance of the 10 MHz frequency instead of detection of 10 MHz presence
  - Digital Re-Triggerable Monostable
  - Up-Down Resetable Counter Timer
- Interlock sensitivity will define the reaction time
  - Base clock detection frequency will be 100 MHz (10 ns resolution)
  - OK if 10 MHz frequency within a predefined window

    Typ. 8 MHz < f < 12.5 MHz → 20 ns reaction time

Trigger Distribution

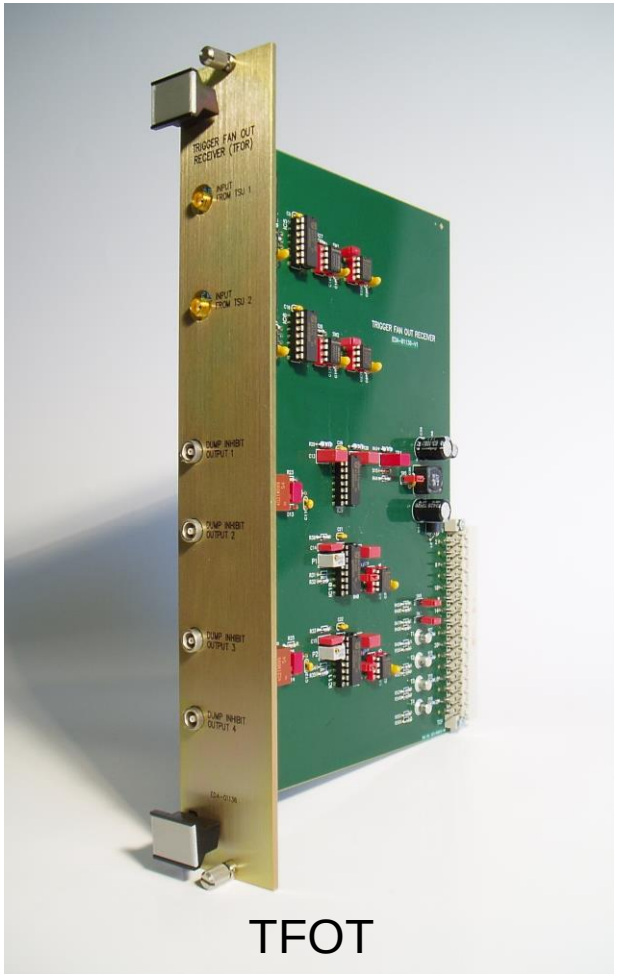
Hardware



TFOR

Two redundant TFOs will be used to **distribute** the **dump request** coming from the **TSU**s to the **PTU**s.

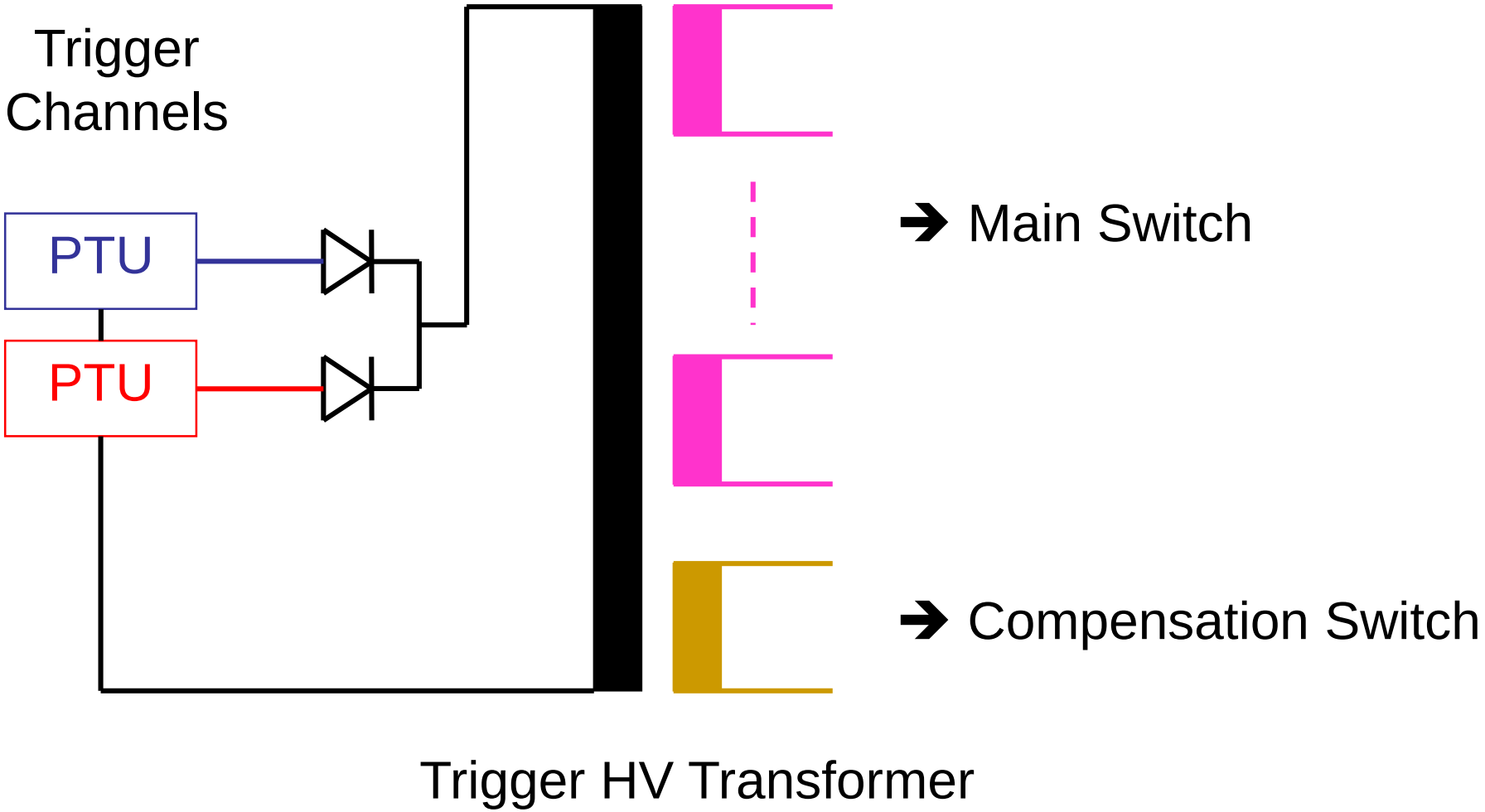
Each **TFO** is divided in **three main circuits**: the **Trigger Fan-Out Receiver** (TFOR), the **Trigger Fan-Out Transceiver** (TFOT) and +/- 15V **redundant power supplies**.



TFOT

LHC Extraction Kicker High Voltage Generator

Triggering Circuit



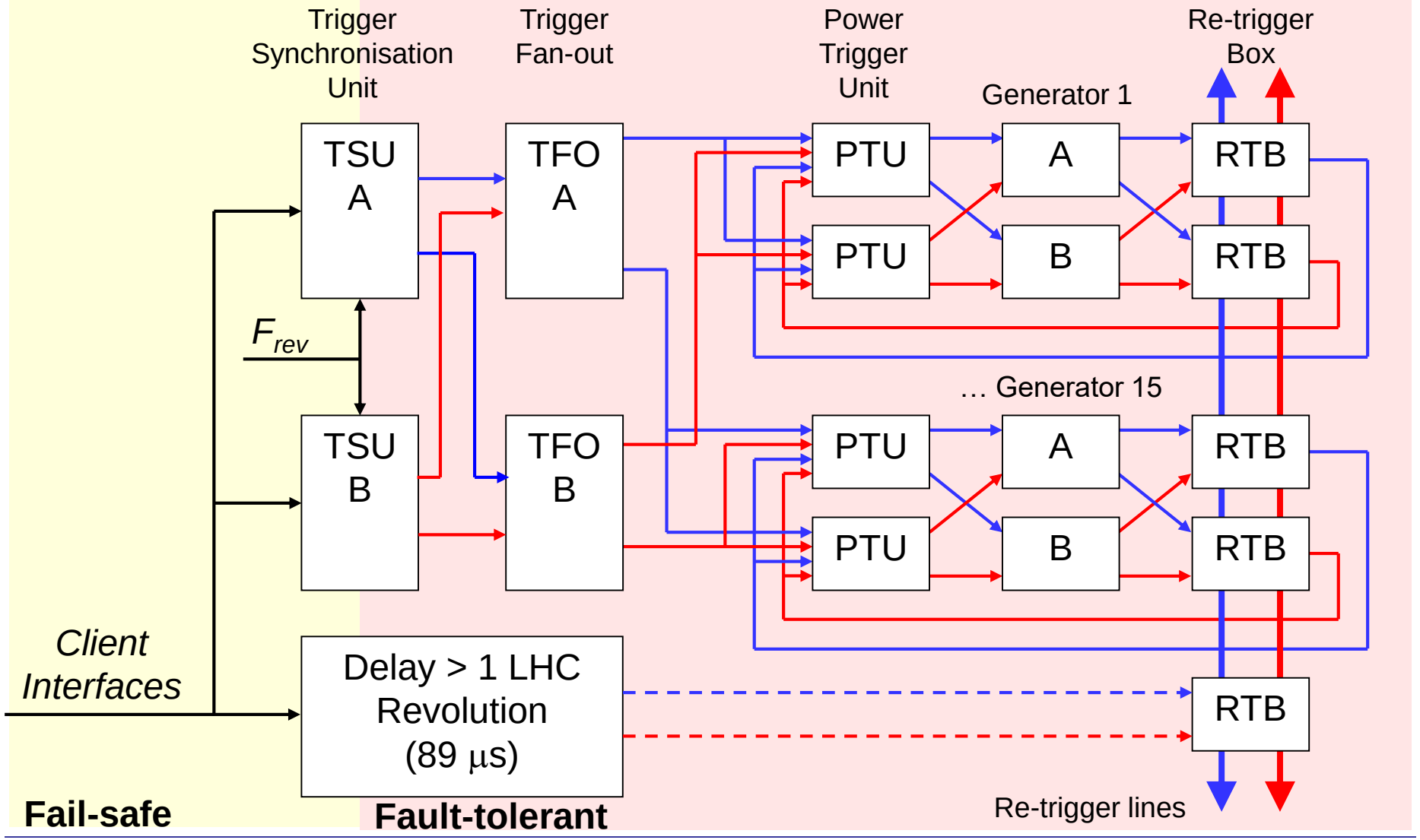
Synchronisation & Triggering
Summary

- **1oo2** 'Trigger Synchronisation Unit' systems can synchronise the dump request.
  - Both systems are independent.
  - The mission time for tests is 89 µs.
  - Continuous cross check between the two units
- **1oo4** independent trigger channels can issue the dump trigger.
- Synchronous triggering of Main and Compensation circuits within a generator.

Re-Triggering System

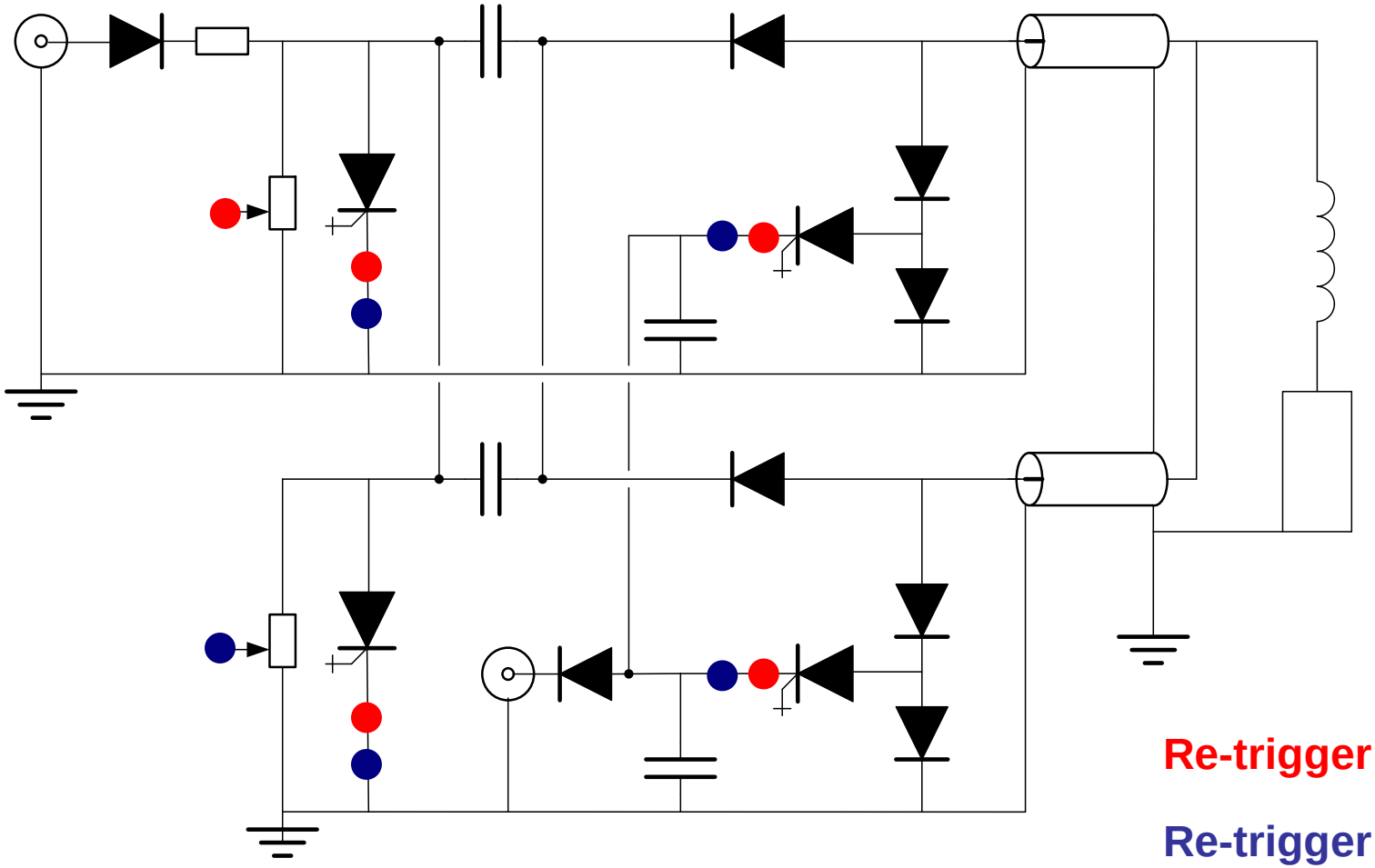
- The **main task** of the **Retriggering System** [RTS] is to **re-distribute**, as fast as possible, a **trigger request** issued from a **spontaneous firing** of one generator **to the remaining** 14 **generators**.
- A **redundant chained input/output system** has been chosen for the RTS. **Each pulse generator** has **5 re-trigger source sensors** per chain with **enough powering capabilities** to **trigger** all the PTU of the remaining other **14 high voltage generators**.
- Due to the architecture of the system, an **avalanche mechanism** is started **after** a **detection** of a **spontaneous firing.**

Retriggering
Architecture



LHC Extraction Kicker High Voltage Generator

Re-Trigger Sensors

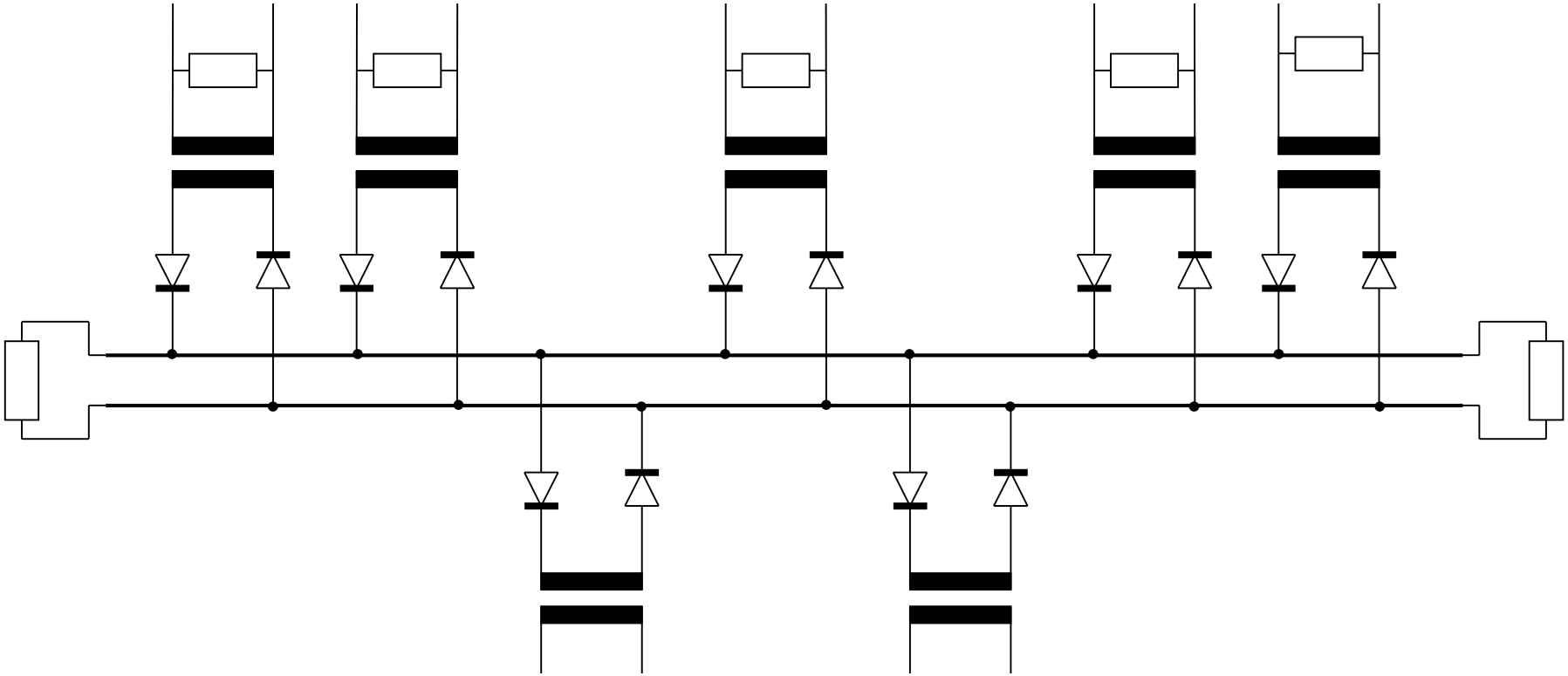


Re-trigger Line A

Re-trigger Line B

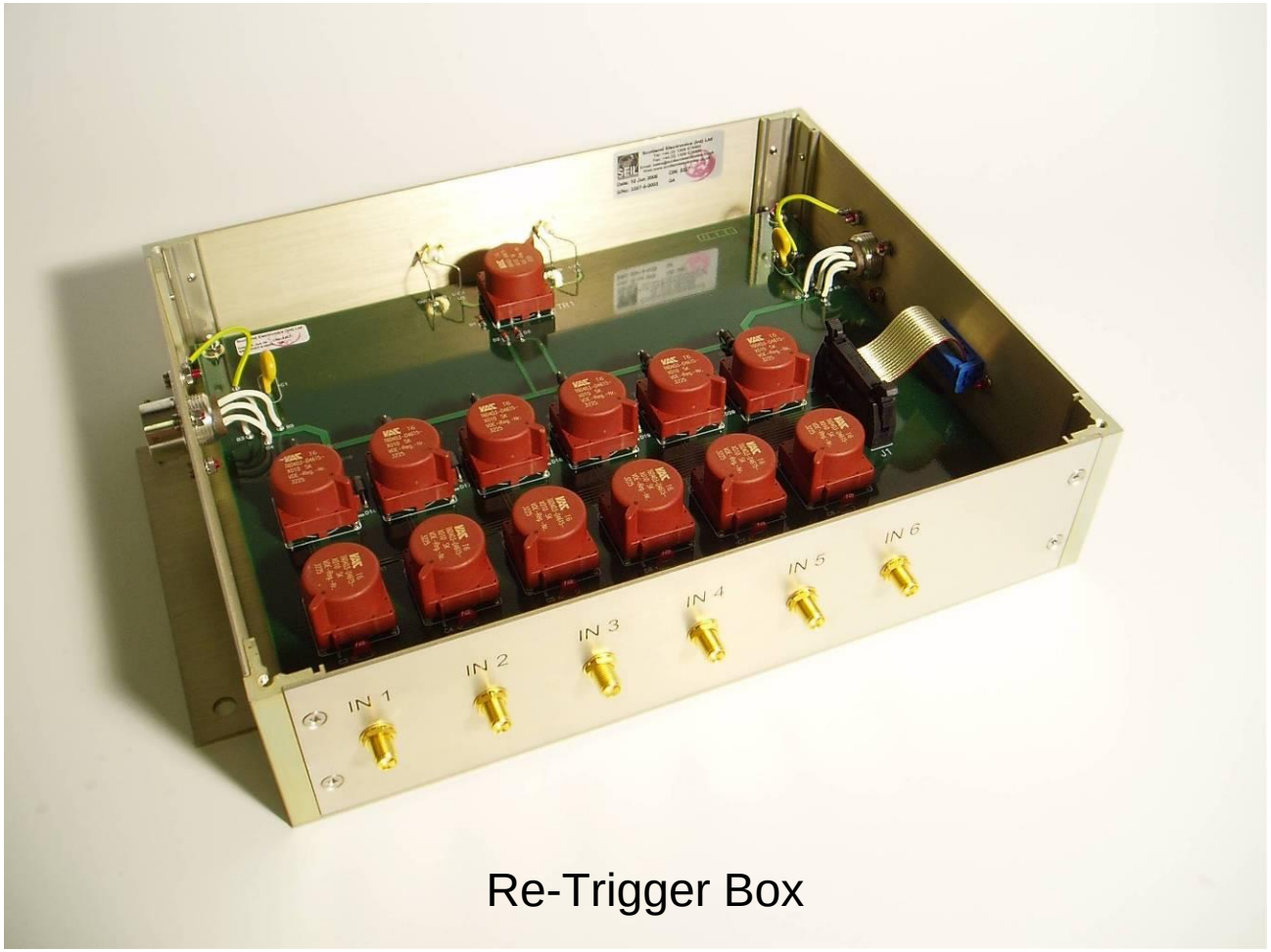
Re-triggering Box
Principle

Sensors



To Power Trigger Unit

Re-triggering Box
Hardware



Re-Trigger Box

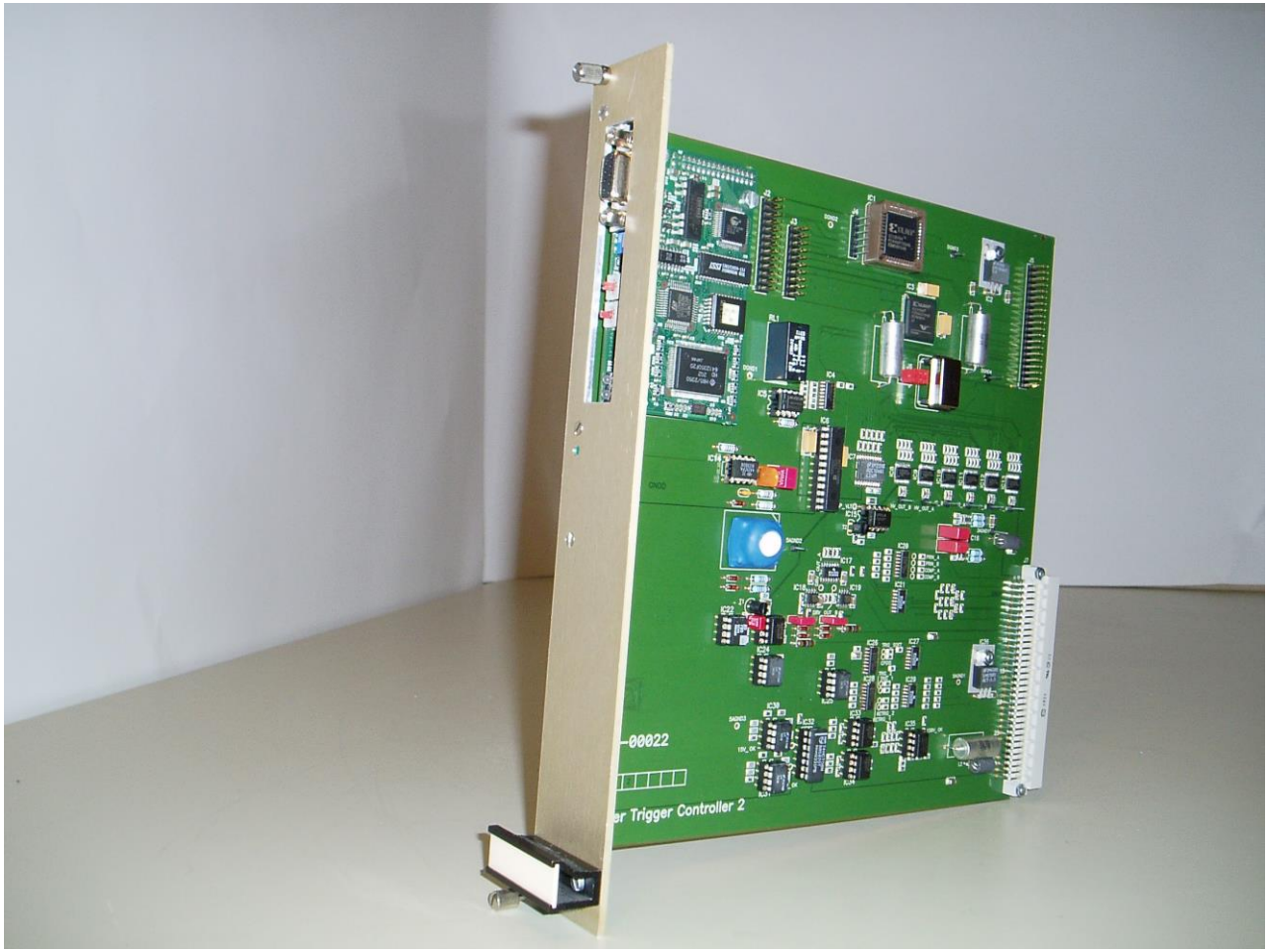
Re-trigger Distribution

- Fully passive fault tolerant system
  - Complete post-mortem analysis after each dump action
- All the power needed to re-trigger the complete extraction kicker system is available directly from the sensors
  - Current pick-ups
  - High voltage dividers
- Re-trigger delay is due to
  - Detection time
  - Propagation time over the 14 remaining generators
  - Power trigger & Main switch turn on delay

Re-Triggering System
Summary

- Each branch has 5 re-trigger sources which feed 2 re-trigger distribution lines.
  - Twice **1oo5.**
  - Each source can deliver sufficient energy to trigger all power triggers of all magnets MKD/MKB.
- Continuity of the re-trigger lines is continuously checked (pulse train).
- Re-trigger system will always be asynchronous with the circulating beam
- Re-trigger system will always be checked after each beam dump action

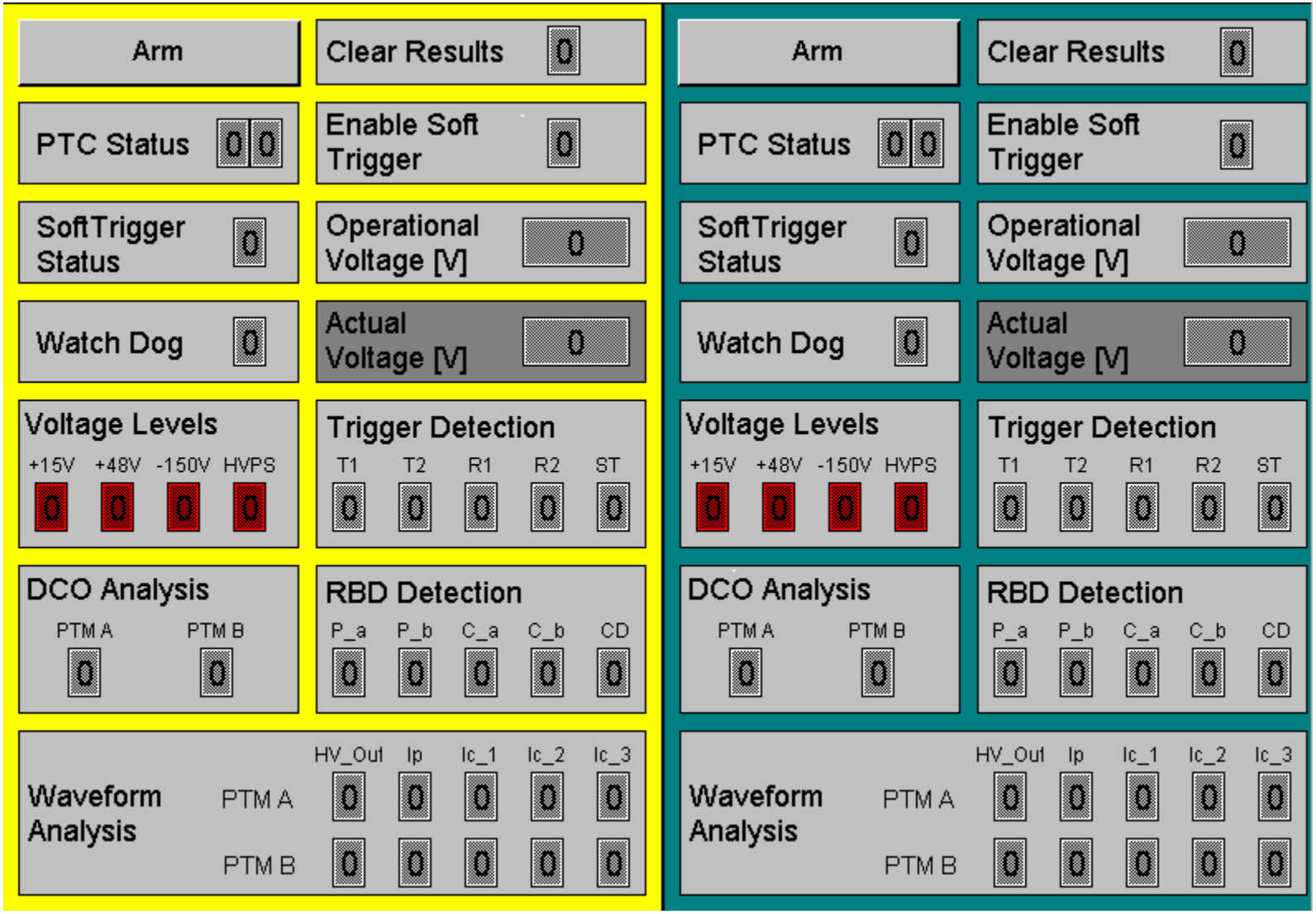
Power Trigger Controller
Hardware



Control & Monitoring of Triggering & Retriggering System

Power Trigger Unit and Re-Trigger System

Monitoring



Summary

- Fully redundant system
  - Synchronisation
  - Distribution
  - Triggering
  - Re-triggering
- Fully monitored
  - Internal Post-Operation Check before next dump will be permitted
- Trigger sources
  - BIS, LBDS, Direct-BLM, LASS
  - CBCM (Inject and Dump, Standard Dumps)
- Critical points
  - Dump request detection
  - Arming procedure