The Beam Loss Monitoring System after LHC Injectors Upgrade at CERN

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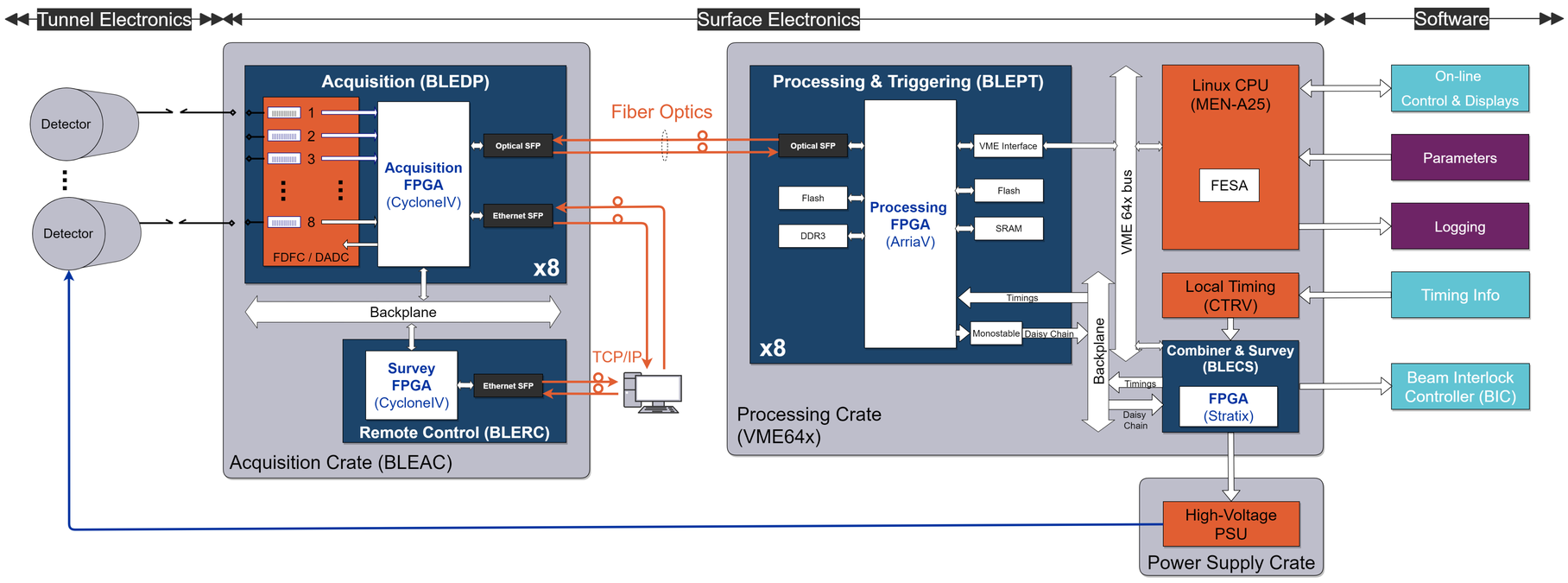
Abstract

The LHC Injector Upgrade (LIU) project aims to increase the available brightness of the beams and improve the efficiency of the whole accelerator chain. The Beam Loss Monitoring (BLM) system is a key element of CERN's accelerator instrumentation for beam optimisation and machine protection by producing continuous and reliable beam loss measurements while ensuring safe operation. The new BLM system for the LHC injectors aimed to provide faster measurements with a higher dynamic range, to install more detectors along the beamlines, and to give the operator more flexible use. A review will be given on the versatility provided by the system to cover requirements from various accelerators and their transfer lines, focusing on the measurements and the operational scenarios.

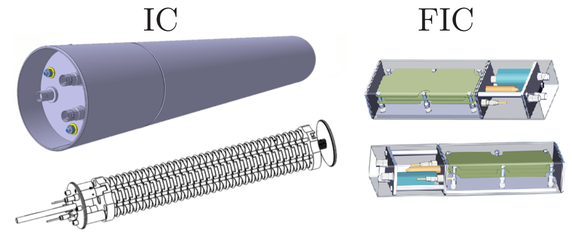
System Architecture



Schematic overview of the BLMINJ system architecture

The acquisition card digitises the beam loss measurements from up to 8 detectors and transmits them every 2µs to the processing crate through fibre optics. The processing electronics then integrates the losses and decides whether or not the beam should be permitted to be injected or continue circulating. The results are also provided for on-line display and long-term storage for off-line analysis.

Detectors



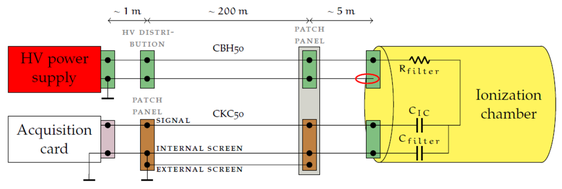
The BLMINJ detector types

Two detector types have been deployed in the BLMINJ system:

IC: The Ionization Chamber - 50cm long, 1.5 litres, nitrogen-filled - is already used in the LHC. It is optimised to give an ion collection time of 85µs and is polarised at 1.5kV.

FIC: The Flat Ionization Chamber is similar to the IC, but with a different geometry for space-constrained locations in the PSB.

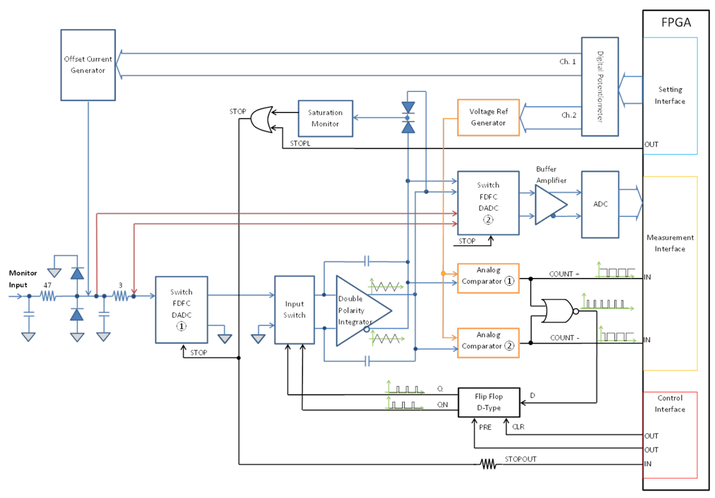
Cabling



Cabling installation diagram

The cabling schema offers the necessary noise immunity by comprising custom coaxial cables and triaxial connectors developed with industry partners. A separate high-voltage cable connects the power supply to each detector for additional reliability and testability.

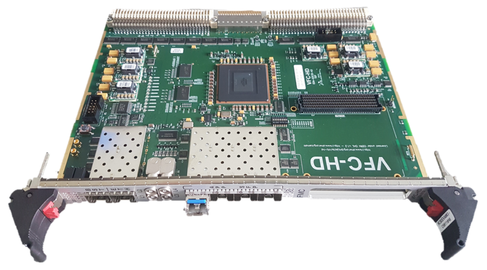
Acquisition



Mixed acquisition circuit

The acquisition circuit uses 2 measurement techniques to cover the 2.10^{10} input range by overlapping: a Fully Differential Frequency Converter (FDFC) and a Direct ADC (DADC). The FPGA manages the automatic switching between modes and generates a 20-bit sample every 2µs period, which represents the beam loss integral accumulated during this period.

Processing

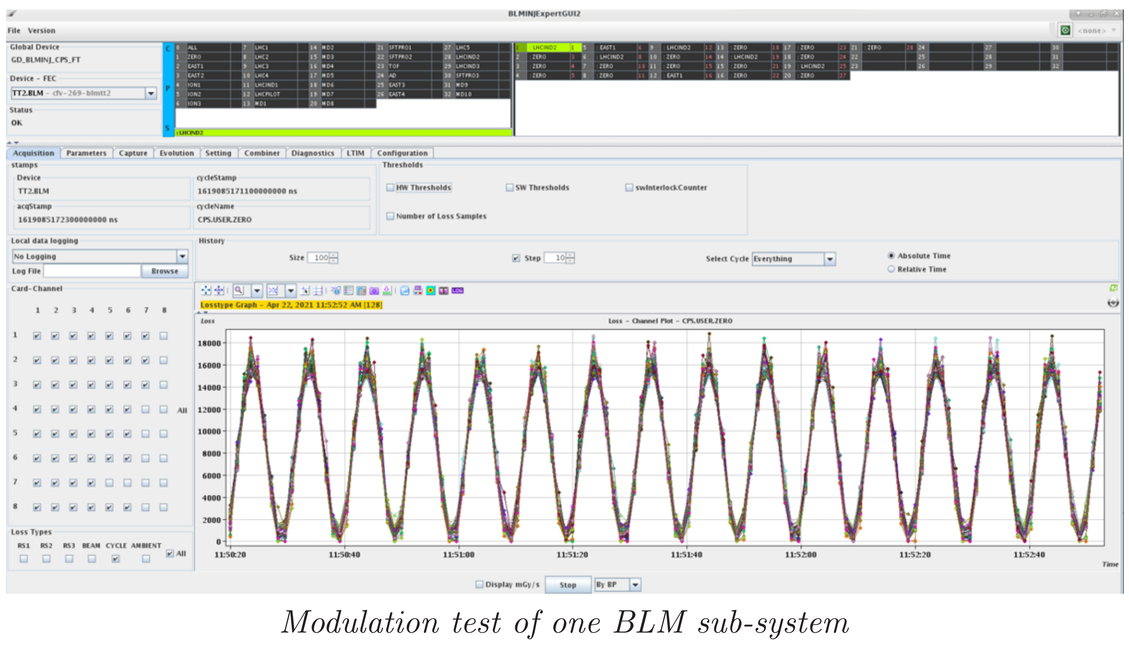


VME processing module

The processing module uses the new BI standard VFC-HD platform which underwent thorough validation. It computes loss integration on 3 different time-scales for up to 16 channels.

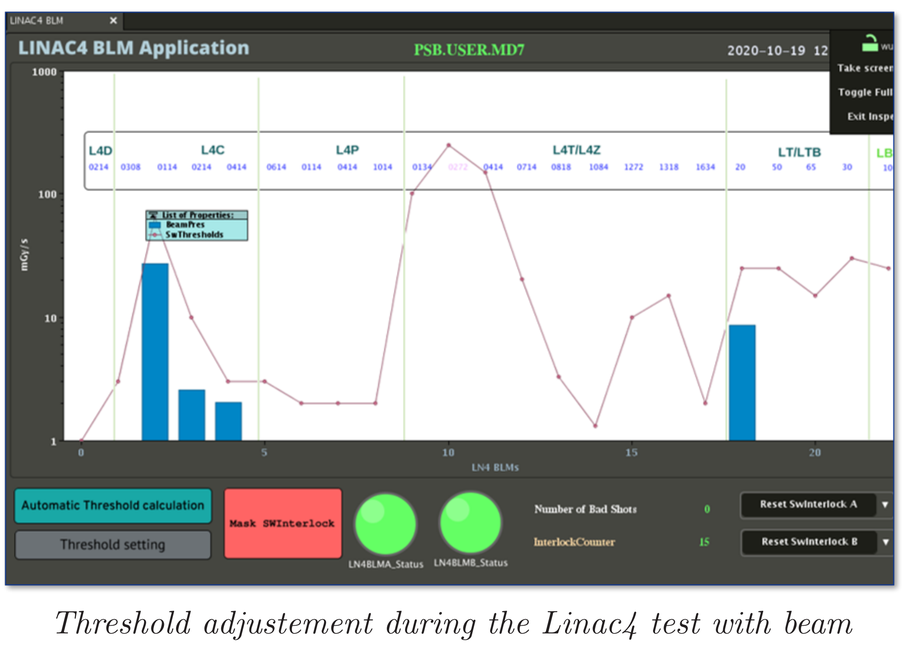
Commissioning

The commissioning of the system followed three stages: Individual System Tests (IST), dry-runs, and beam tests.
The IST verifies the hardware line connections, for each channel from the detector to the electronics, by modulating the power supply and calibrating the acquisition to ensure that all channels have the same offset level, regardless of location and cable length.



Modulation test of one BLM sub-system

Then, BLM experts and machine operators perform the dry-run to validate the connection of the BLMINJ system to the controls infrastructure: warnings, alarms, and beam interlocks are intentionally triggered, the data logged in the measurement database is verified and all the values on fixed display in the control room and on expert applications are compared.
Finally, when the beam is present in the machine, intentional losses are generated at each detector location to trigger the corresponding interlock, measure the value of the loss, and adjust the thresholds.



Threshold adjustement during the Linac4 test with beam

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At the end of this staged deployment, 322 channels have been commissioned, and 14 racks were installed for a total of 51 pairs of acquisition and processing boards.

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