

6th LHC Radiation Workshop



The LHC Beam Loss Monitoring System

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AB / BI, CERN, Geneva, Switzerland

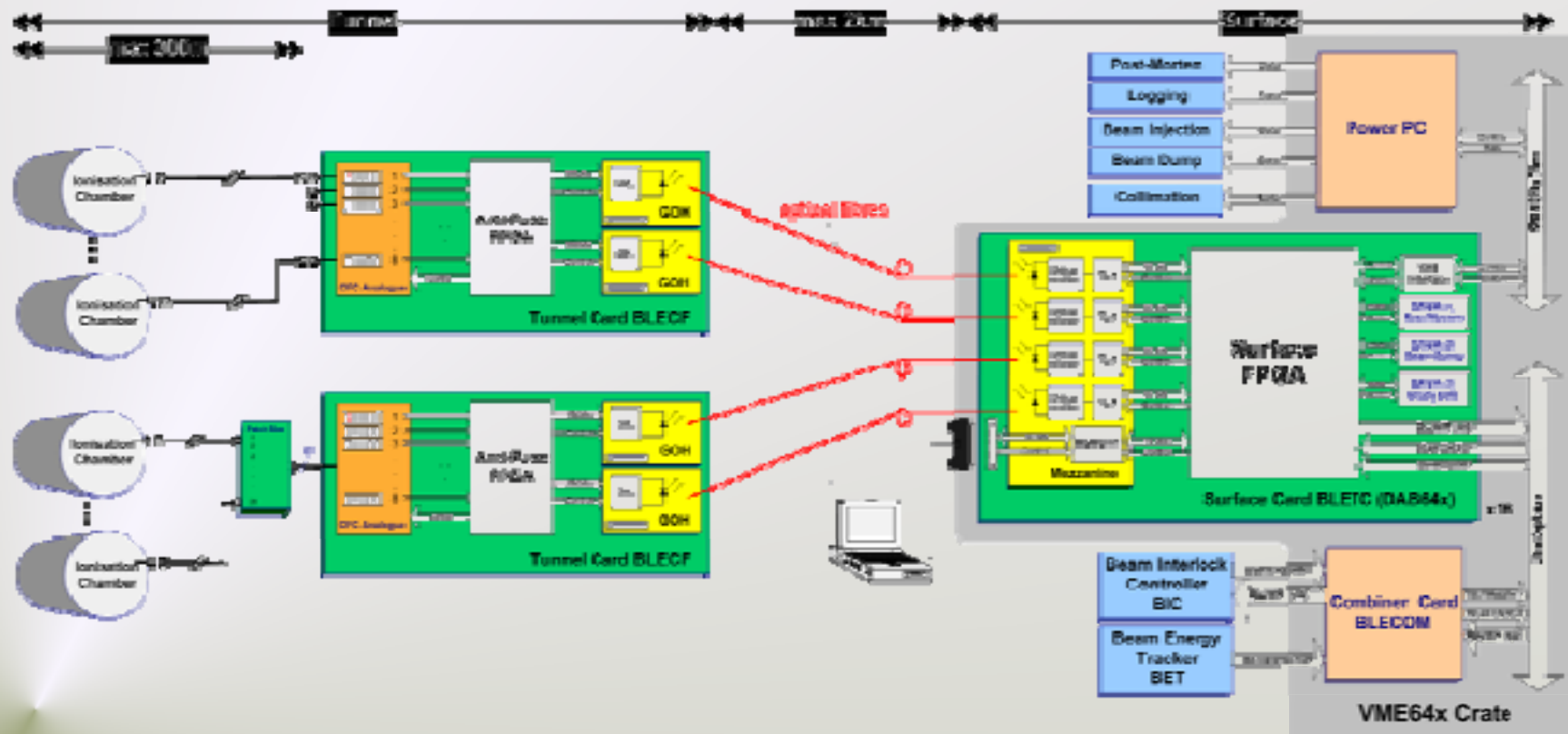


Outline

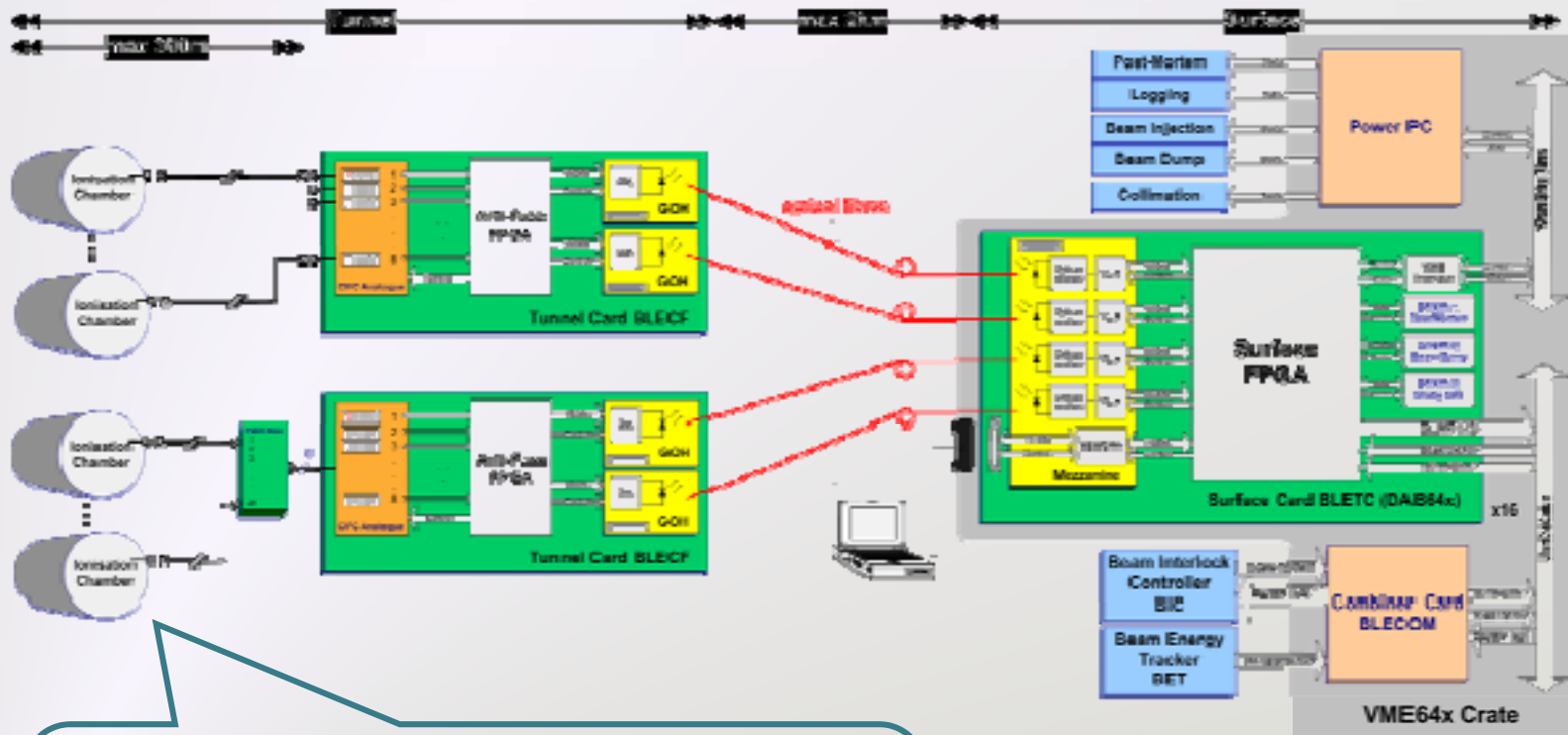
- General
 - BLM System Overview
 - Data Processing Overview
- Data Contribution
 - Logging System
 - Control Room's On-Line Display
 - Post Mortem System
 - Beam Dump System
 - Collimation System
- Summary & Outlook

BLM System Overview

An acquisition system to measure the particle loss rate in the LHC accelerator and request a beam dump when levels exceed predefined threshold limits.



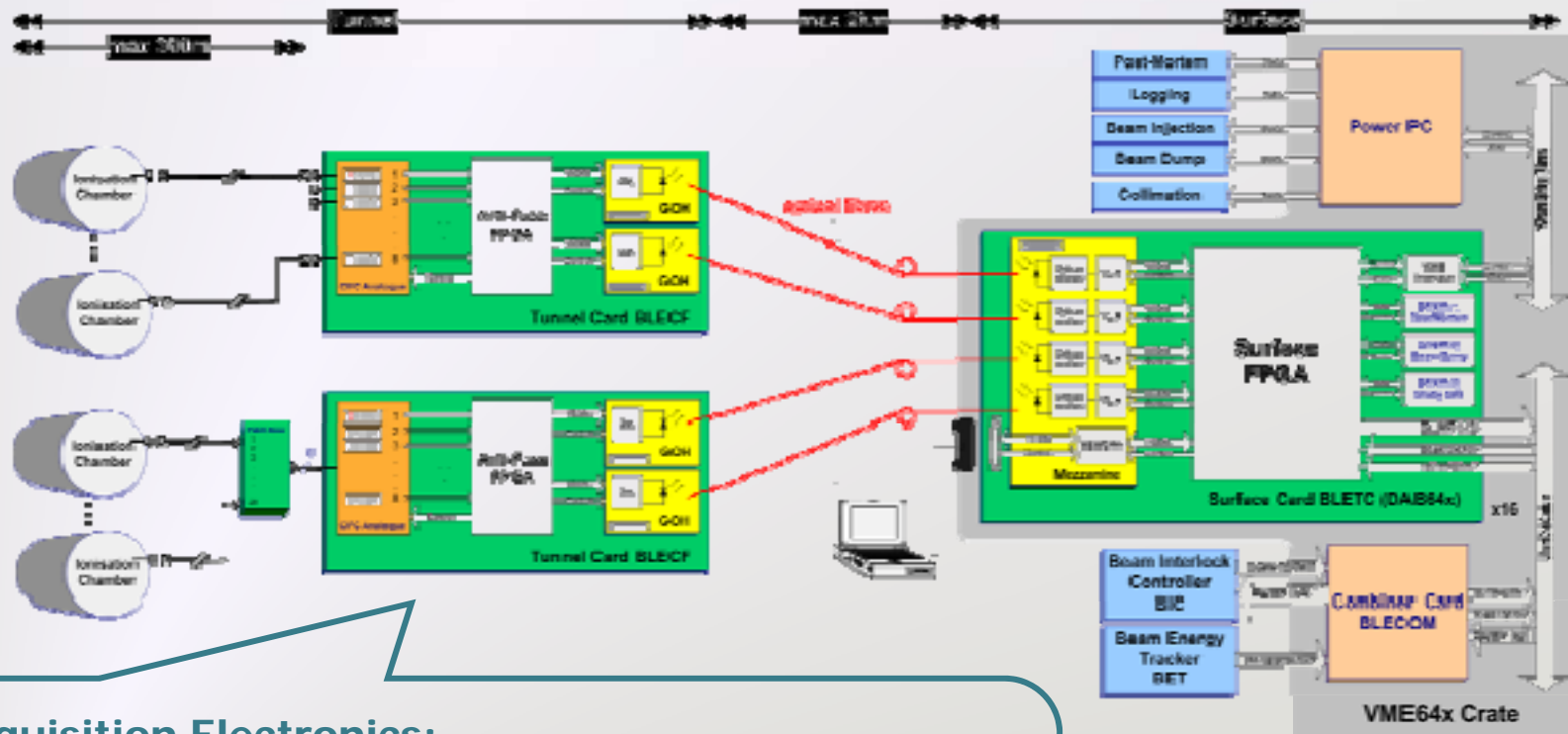
BLM System Overview



Detectors:

- 3700 Ionization Chambers
- 280 Secondary Emission Monitors

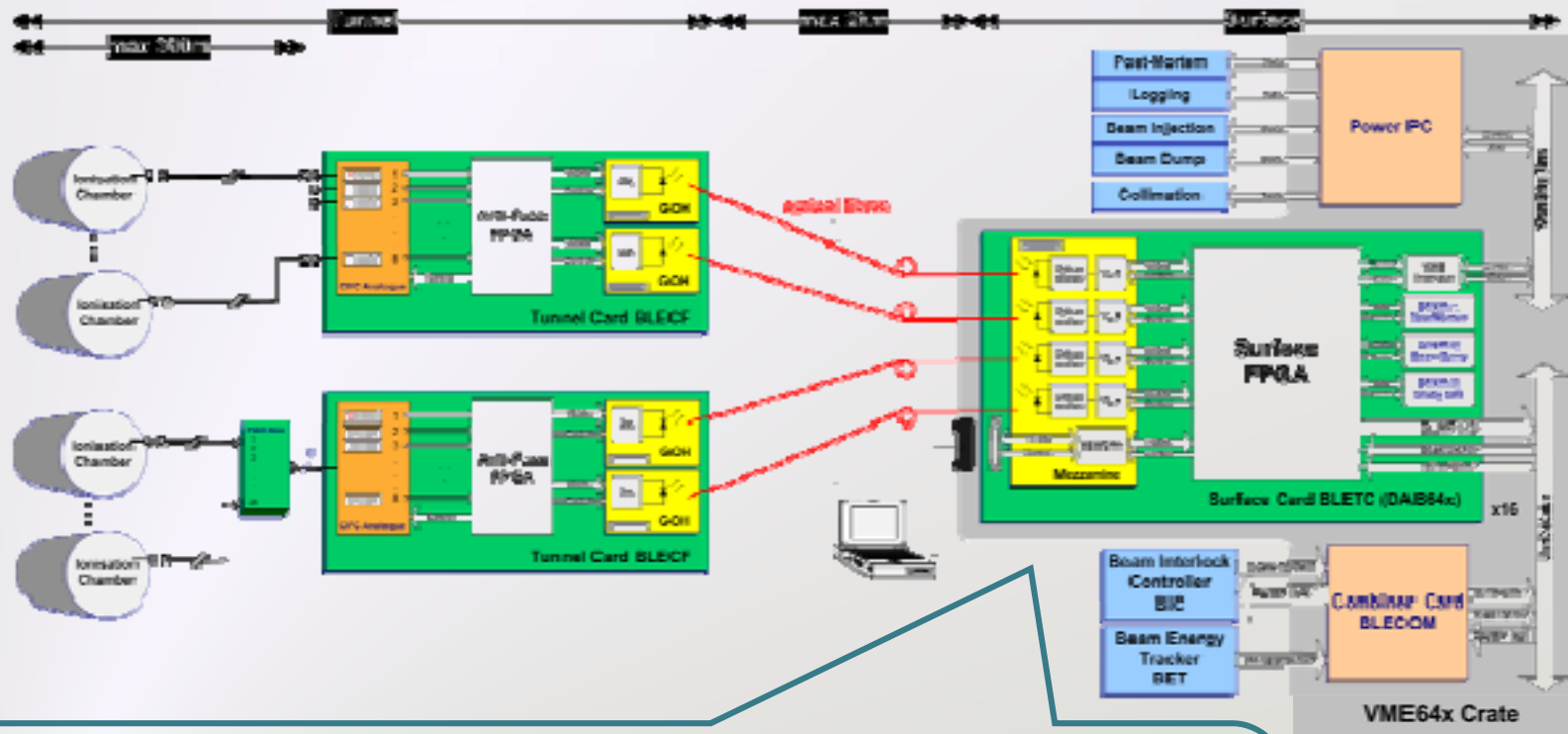
BLM System Overview



Acquisition Electronics:

- Current to Frequency Converters (CFCs)
- Analogue to Digital Converters (ADCs)
- Antifuse FPGAs (radiation tolerant)
- Gigabit Optical Links (with redundancy)

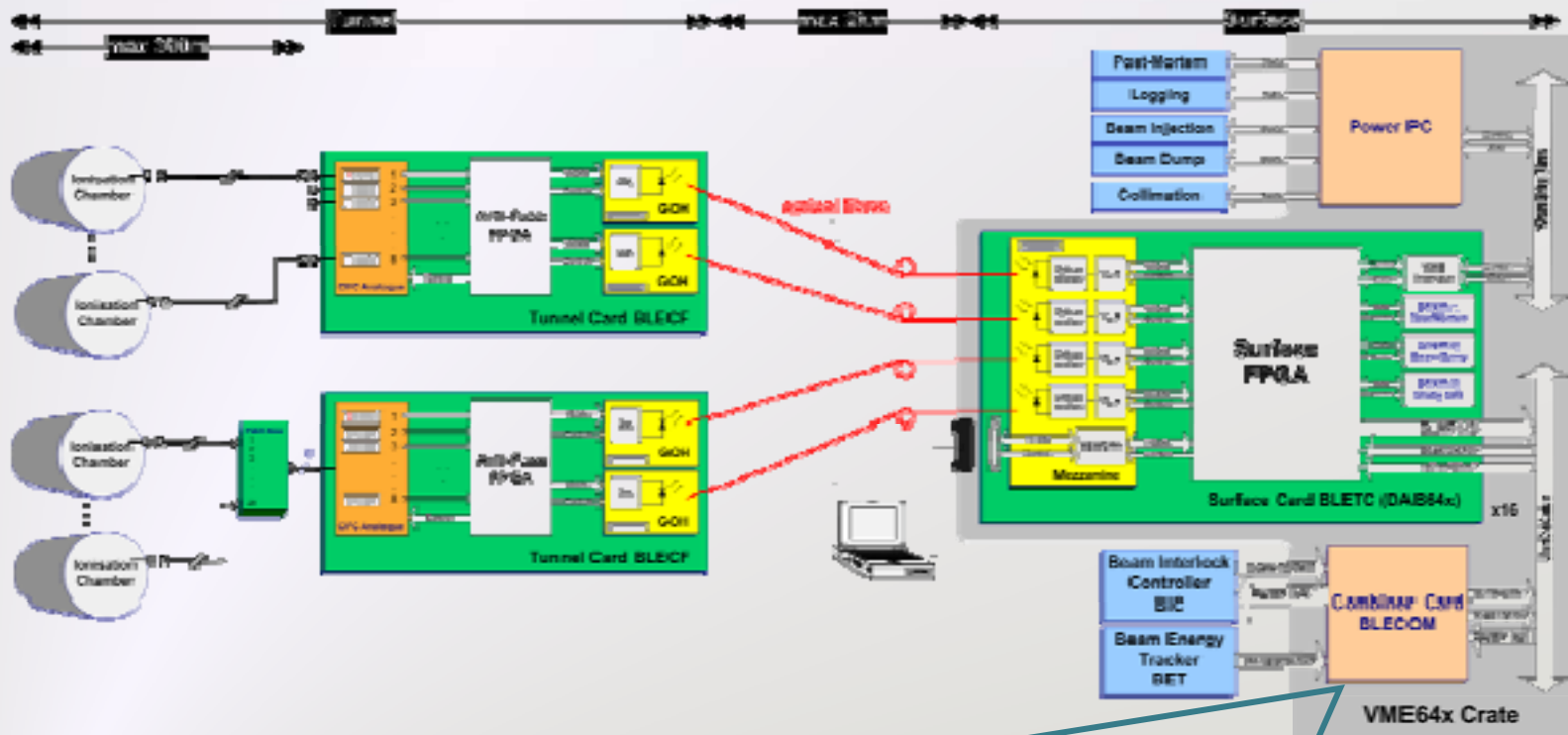
BLM System Overview



Real-Time Processing:

- **FPGA** (medium size, SRAM based)
- **Mezzanine card** for the optical links
- **3 x 2 MB SRAMs** for temporary data storage
- **NV-RAM** for system settings and threshold table storage

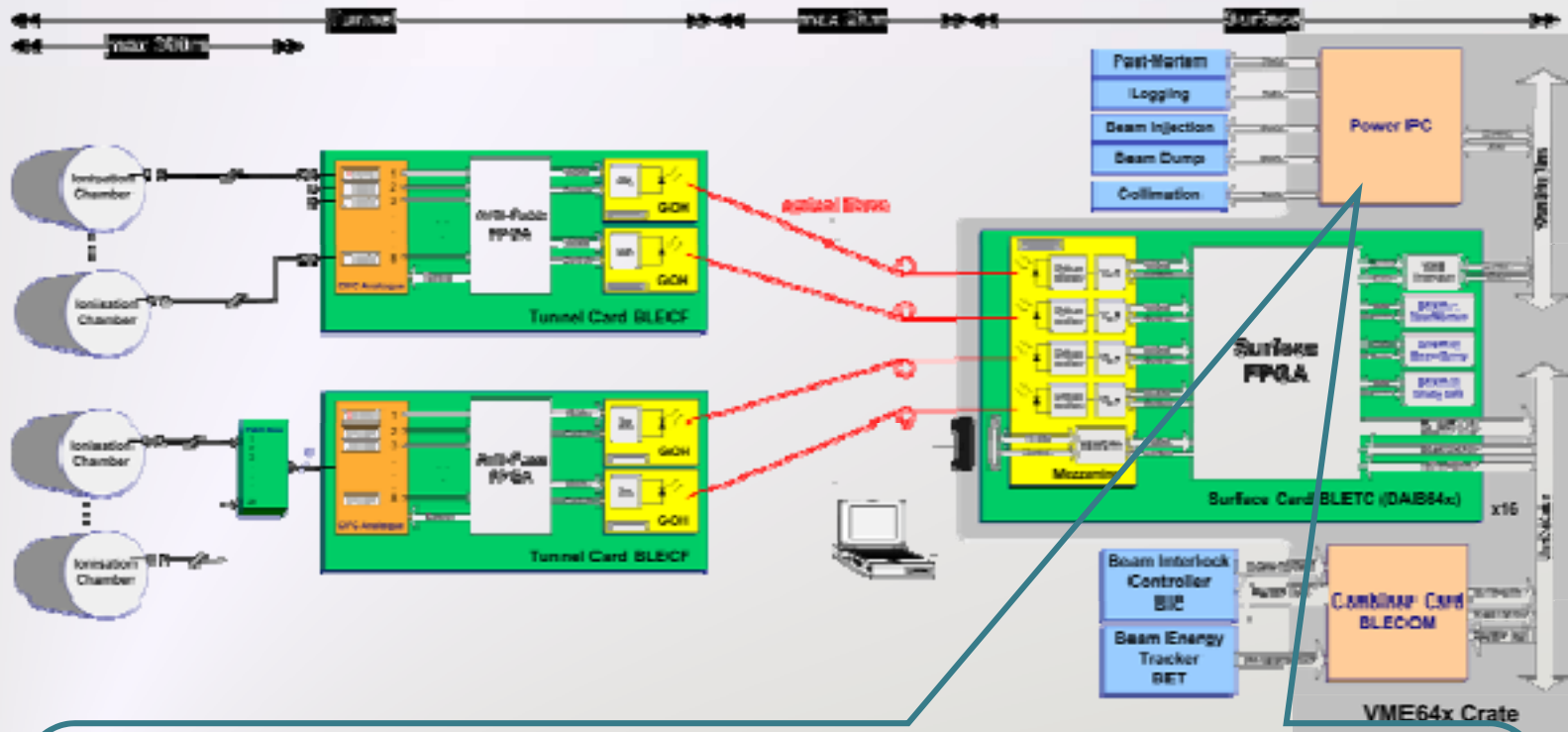
BLM System Overview



Combiner & Survey Card:

- Controls the High Voltage.
- Receives & distributes Signals (Beam Energy, Beam Info , Beam Permit)
- Initiates tests and surveys system.

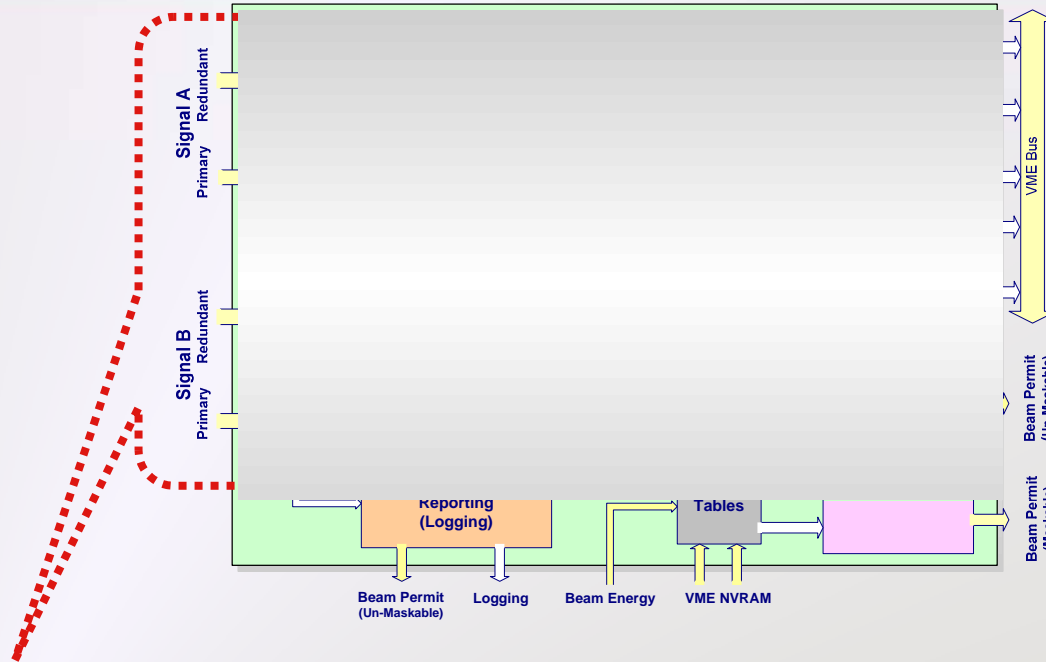
BLM System Overview



Front-End Computer:

- Lynx OS.
- Real-Time control software (built using the FESA framework)
- Collects and prepares the recorded data
- Communicates with the external systems

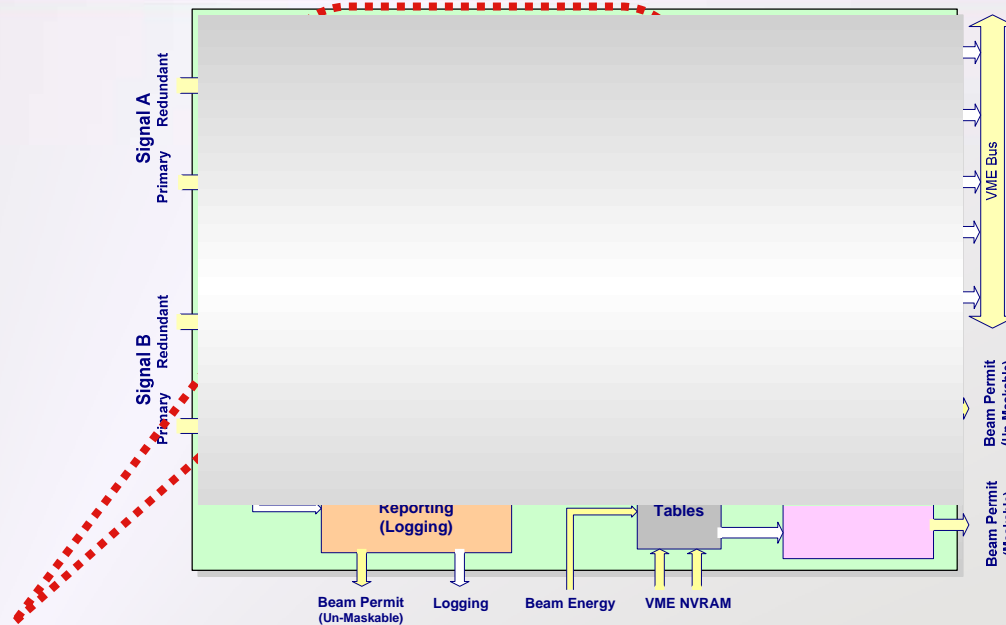
Data Processing Overview



Receive, Check & Compare (RCC)

- Receives, De-serialises and decodes the transmitted packets.
- Checks for errors using checksums (CRC-32 & 8b/10b).
- Compares the packets coming from the redundant transmission.
- Chooses error free data for further processing.

Data Processing Overview



Data-Combine

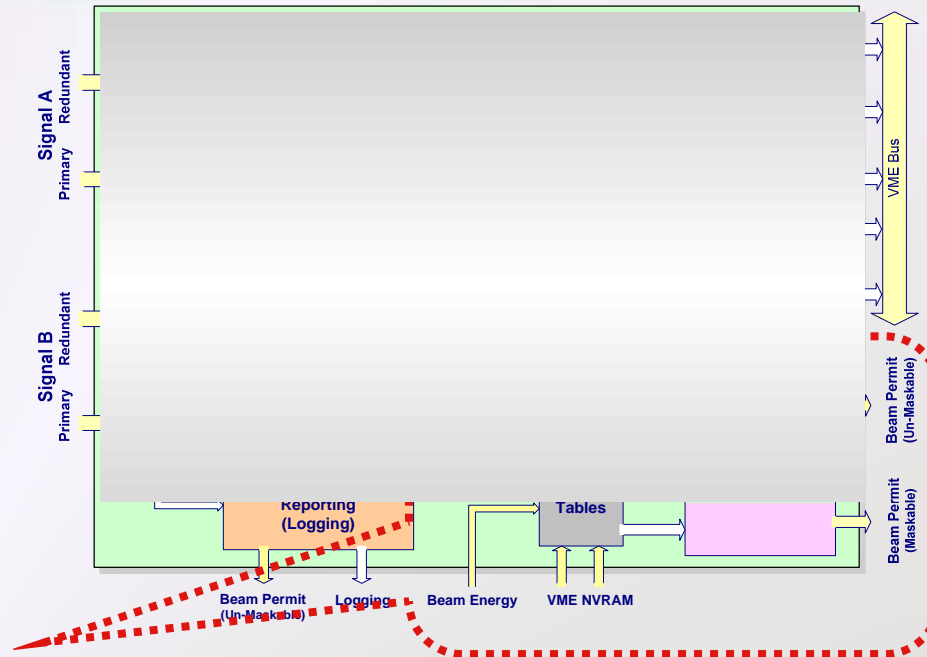
- Applies merging algorithm for the ADC and the CFC data.
- Filters noise.

Successive Running Sums (SRS)

- Produces and maintains various histories of the received data in the form of Moving Sum Windows.
- 12 integration periods spanning from 40 μ s to 84s.



Data Processing Overview



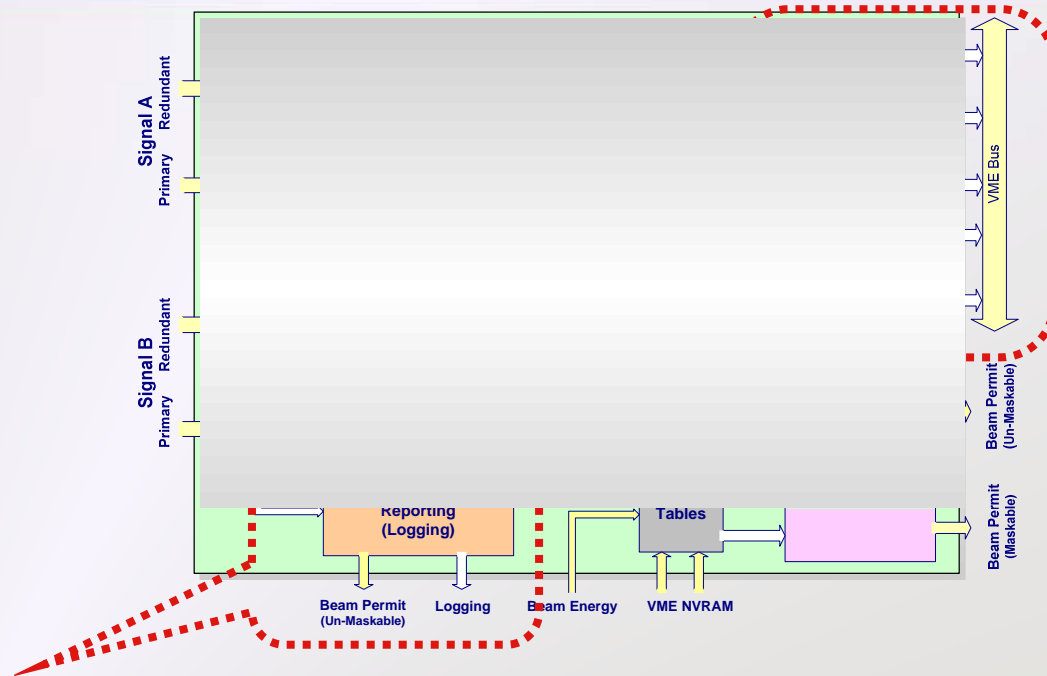
Threshold Comparator (TC)

- Compares continuously the calculated sums with their threshold limits.
- Chooses from energy and topology dependent threshold levels.

Channel Masking

- Inhibits unconnected channels and
- Discriminates channels into "Maskable" and "UnMaskable".

Data Processing Overview

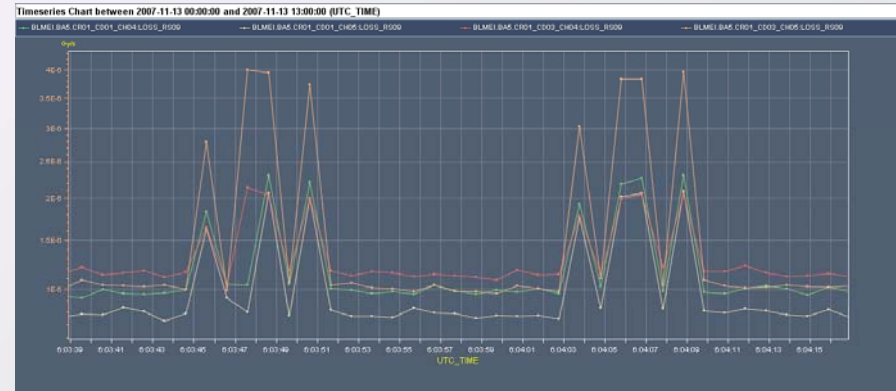
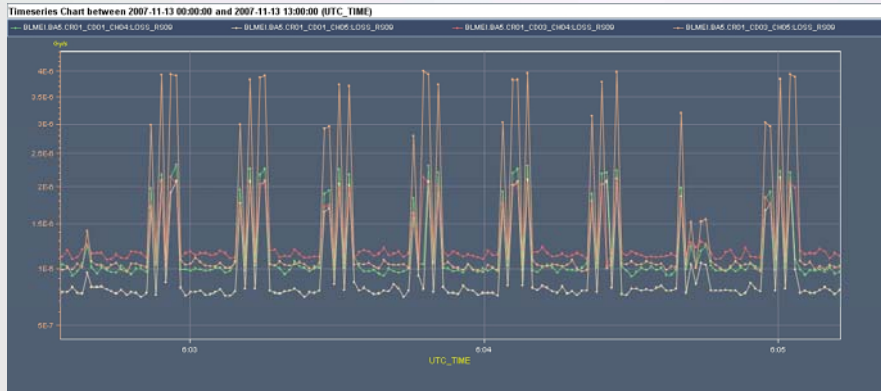


Preparation & Storage of data for external systems

- Produces an error and status report for the whole system.
- Calculates the max beam loss values for each channel.
- Keeps long buffers of acquired data.
- Keeps various buffers of integrated losses.

Outline

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- Data Contribution
 - Logging System
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 - Post Mortem System
 - Beam Dump System
 - Collimation System
- Summary & Outlook



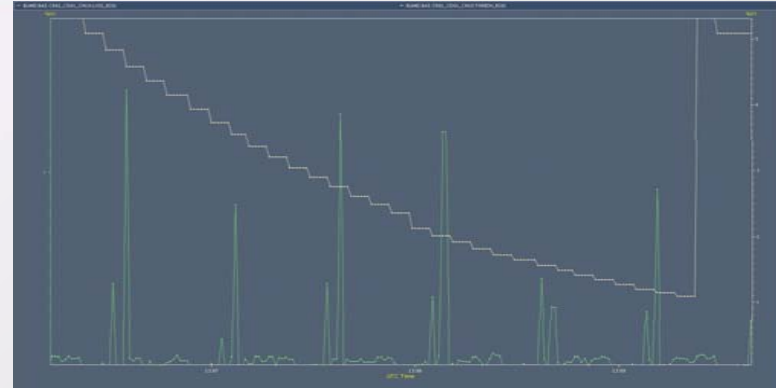
Figures: The 1.3 s integrals from 4 channels showing losses (Gy/s) at the collimator; Recorded during the 2007 'Machine Development' tests in the SPS accelerator and plotted using the TIMBER tools.

Purpose:

- Provide long term storage and fast retrieval of information about
 - the loss levels and
 - the status of the electronics.
- Off-line analysis can show
 - deteriorating components
 - assist in the scheduling of interventions and
 - increase the availability of the machine.



Ten integrals from the same channel showing losses (Gy/s) at the injection;



Simulated energy ramp forcing the decrease of its threshold value.

Recorded during the 2007 'Machine Development' tests in the SPS accelerator and plotted using the TIMBER tools.

Available:

- The maximum loss values observed in the last second in the 12 running sums for each channel.
- Their corresponding threshold values.
- Detailed description of the channel, which include:
 - both the 'official' and 'expert' names
 - Geographical position (DCUM number)
- Detailed error and status information for almost every component of the system.



Logging System (Hierarchy 1)

TIMBER v2.0.1

Data Source: Measurement Database (PRO) Elapsed: 422ms

Query Output Query Variable Hierarchies Variable Search Variable Lists About

Hierarchy Variable Selection

Variable Filters

Name: % Type: NUMERIC

Search Results

Variable Name	Description	Unit	Datatype
BLMEI.11L8.B2I21_MBA:LOSS_RS01	Maximum running sum of losses for BLMEI.11L8.B2I21_MBA with 40us integration time	BLM...	NUMERIC
BLMEI.11L8.B2I21_MBA:LOSS_RS02	Maximum running sum of losses for BLMEI.11L8.B2I21_MBA with 80us integration time	BLM...	NUMERIC
BLMEI.11L8.B2I21_MBA:LOSS_RS03	Maximum running sum of losses for BLMEI.11L8.B2I21_MBA with 320us integration time	BLM...	NUMERIC
BLMEI.11L8.B2I21_MBA:LOSS_RS04	Maximum running sum of losses for BLMEI.11L8.B2I21_MBA with 640us integration time	BLM...	NUMERIC
BLMEI.11L8.B2I21_MBA:LOSS_RS05	Maximum running sum of losses for BLMEI.11L8.B2I21_MBA with 2.56ms integration time	BLM...	NUMERIC
BLMEI.11L8.B2I21_MBA:LOSS_RS06	Maximum running sum of losses for BLMEI.11L8.B2I21_MBA with 10.24ms integration time	BLM...	NUMERIC
BLMEI.11L8.B2I21_MBA:LOSS_RS07	Maximum running sum of losses for BLMEI.11L8.B2I21_MBA with 81.92ms integration time	BLM...	NUMERIC

Select All Select None Add Selected

15:58:18 - ...Found 72 Variables for Hierarchy 'LHCBLM->IP8->11->MBA' Filtered on Datatype NUMERIC

Hierarchy 1:

↙ Octant

↙ Cell

↙ Magnet



Logging System (Hierarchy 2)

TIMBER v2.0.1

Data Source: Measurement Database (PRO) Elapsed: 141ms

Query Output Query Variable Hierarchies Variable Search Variable Lists About

Hierarchy Variable Selection

Variable Filters

Name: % Type: NUMERIC

Search Results

Variable Name	Description	Unit	Datatype
BLMEI.4L8.B1E1_MBXA_LOSS_RS01	Maximum running sum of losses for BLMEI.4L8.B1E1_MBXA with 40us integration time	BLM...	NUMERIC
BLMEI.4L8.B1E1_TCTH.4L8.B1_LOSS_RS01	Maximum running sum of losses for BLMEI.4L8.B1E1_TCTH.4L8.B1 with 40us integration time	BLM...	NUMERIC
BLMEI.4L8.B1E1_TCTVB.4L8.B1_LOSS_RS01	Maximum running sum of losses for BLMEI.4L8.B1E1_TCTVB.4L8.B1 with 40us integration time	BLM...	NUMERIC
BLMQI.10L8.B1E1_MQML_LOSS_RS01	Maximum running sum of losses for BLMQI.10L8.B1E1_MQML with 40us integration time	BLM...	NUMERIC
BLMQI.11L8.B1E1_MQ_LOSS_RS01	Maximum running sum of losses for BLMQI.11L8.B1E1_MQ with 40us integration time	BLM...	NUMERIC
BLMQI.12L8.B1E1_MQ_LOSS_RS01	Maximum running sum of losses for BLMQI.12L8.B1E1_MQ with 40us integration time	BLM...	NUMERIC
BLMQI.13L8.B1E1_MQ_LOSS_RS01	Maximum running sum of losses for BLMQI.13L8.B1E1_MQ with 40us integration time	BLM...	NUMERIC
BLMQI.14L8.B1E1_MQ_LOSS_RS01	Maximum running sum of losses for BLMQI.14L8.B1E1_MQ with 40us integration time	BLM...	NUMERIC
BLMQI.15L8.B1E1_MQ_LOSS_RS01	Maximum running sum of losses for BLMQI.15L8.B1E1_MQ with 40us integration time	BLM...	NUMERIC
BLMQI.16L8.B1E1_MQ_LOSS_RS01	Maximum running sum of losses for BLMQI.16L8.B1E1_MQ with 40us integration time	BLM...	NUMERIC
BLMQI.17L8.B1E1_MQ_LOSS_RS01	Maximum running sum of losses for BLMQI.17L8.B1E1_MQ with 40us integration time	BLM...	NUMERIC
BLMQI.18L8.B1E1_MQ_LOSS_RS01	Maximum running sum of losses for BLMQI.18L8.B1E1_MQ with 40us integration time	BLM...	NUMERIC
BLMQI.19L8.B1E1_MQ_LOSS_RS01	Maximum running sum of losses for BLMQI.19L8.B1E1_MQ with 40us integration time	BLM...	NUMERIC
BLMQI.20L8.B1E1_MQ_LOSS_RS01	Maximum running sum of losses for BLMQI.20L8.B1E1_MQ with 40us integration time	BLM...	NUMERIC
BLMQI.21L8.B1E1_MQ_LOSS_RS01	Maximum running sum of losses for BLMQI.21L8.B1E1_MQ with 40us integration time	BLM...	NUMERIC

Select All Select None Add Selected

16:15:16 - ...Found 34 Variables for Hierarchy 'LHCBLMbeam1->LOSS->RS01->IP8->1' Filtered on Datatype NUMERIC

Hierarchy 2:

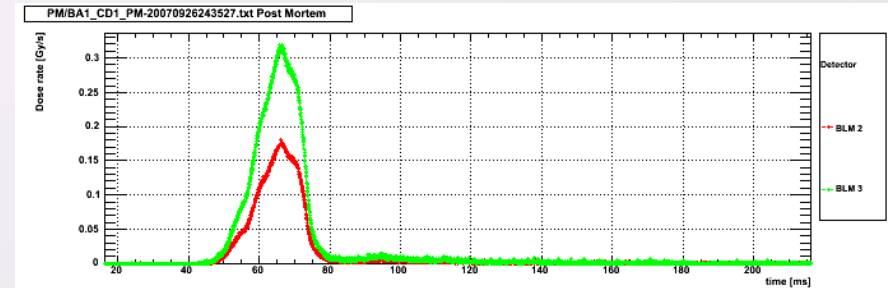
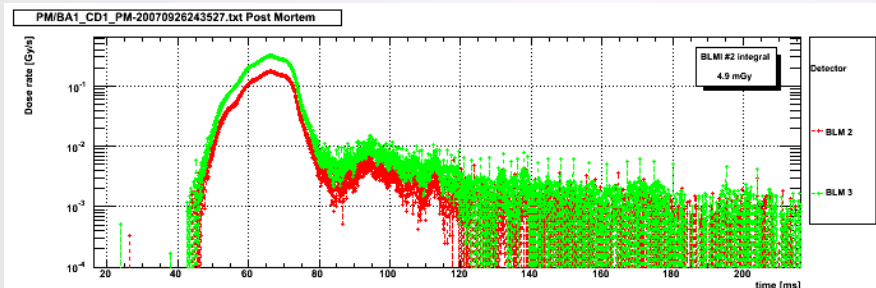
- Beam 1 or 2
- Losses or Thresholds
- Running Sum (40 μ s to 84 s)
- Octant (1 to 8)
- Position in Magnet (1 to 3)



Logging System (Status)

- Concentrator server avail.
 - 3/25 Front-ends connected
 - Agreement on all variable names
 - Running Sums & Thresholds (> 96,000 variables)
 - Status & Errors (> 4000 arrays)
 - Complete load test expected after 03/2008.
 - Few Status variables missing (< 100 arrays)
 - Choose final hierarchy.
- } since 09/2007

Post Mortem System



Figures: Examples of losses recorded in the dump area of the SPS (zoomed in the relevant 200ms).

Purpose:

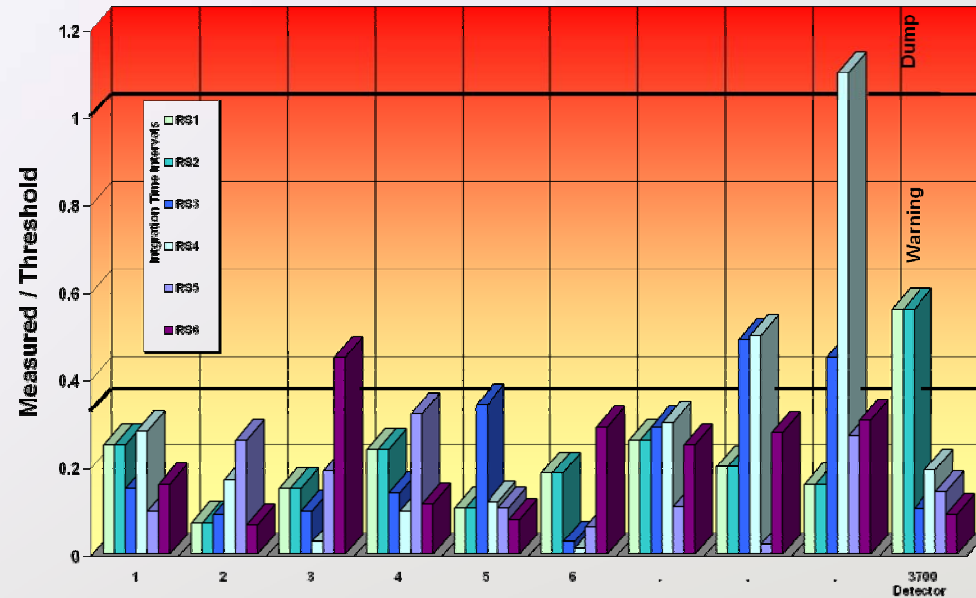
- Provide detailed information about the losses that caused an 'unforeseen' dump of the beam.

Available:

- 42,690 samples of 40 μ s integrals per channel (1.7 s in total).
- 512 samples of 1.3 s integrals per channel (11 m in total).
- Status of the system (inc. which channels/Running sums triggered a dump)
- Threshold Values used.
- Data are frozen by an event in the timing information.

Control Room's On-Line Display

Figure: Artist's view of the fixed-displays



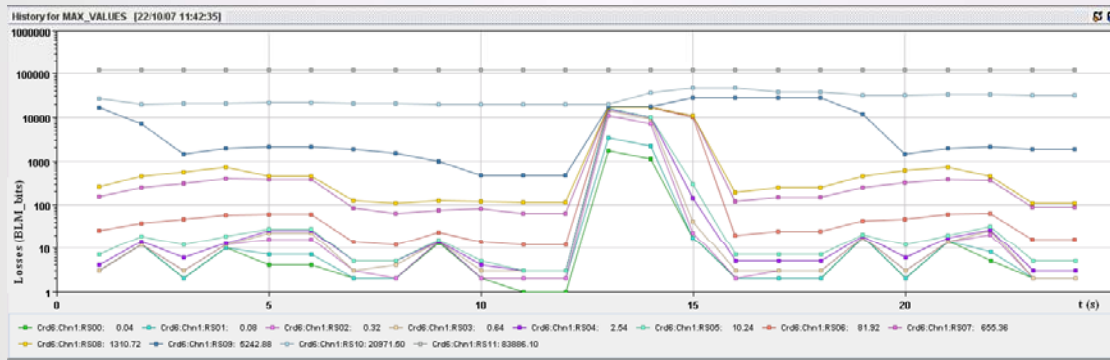
Purpose:

- Provide to the operators a visualization of the ring's beam loss map.
- Provide detailed view of the channels and status of the system.

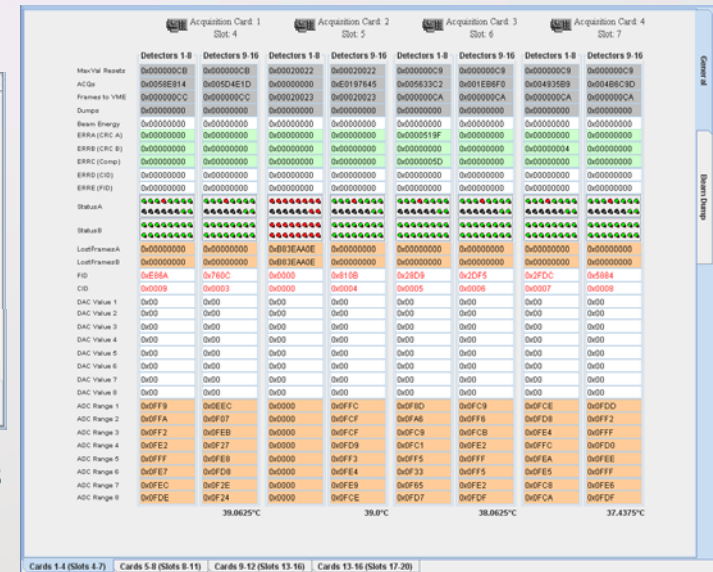
Available:

- Published continuously at 1 Hz.
- Normalized beam loss levels to their threshold limits.
- Data reduction based on 'interesting' data.
- Warnings on positions approaching their quench level.
- Ability to the operator to interact with the display.

Control Room's On-Line Display



Figures: Examples of the 'detailed view' in the on-line displays for the losses (left) and the status information (right).



Screenshots from the BLM Expert GUI.

Purpose:

- Provide to the operators a visualization of the ring's beam loss map.
- Provide detailed view of channels.

Available:

- Published continuously at 1 Hz.
- Normalized beam loss levels to their threshold limits.
- Data reduction based on 'interesting' data.
- Warnings on positions approaching their quench level.
- Ability to the operator to interact with the display.

Beam Dump System (XPOC)

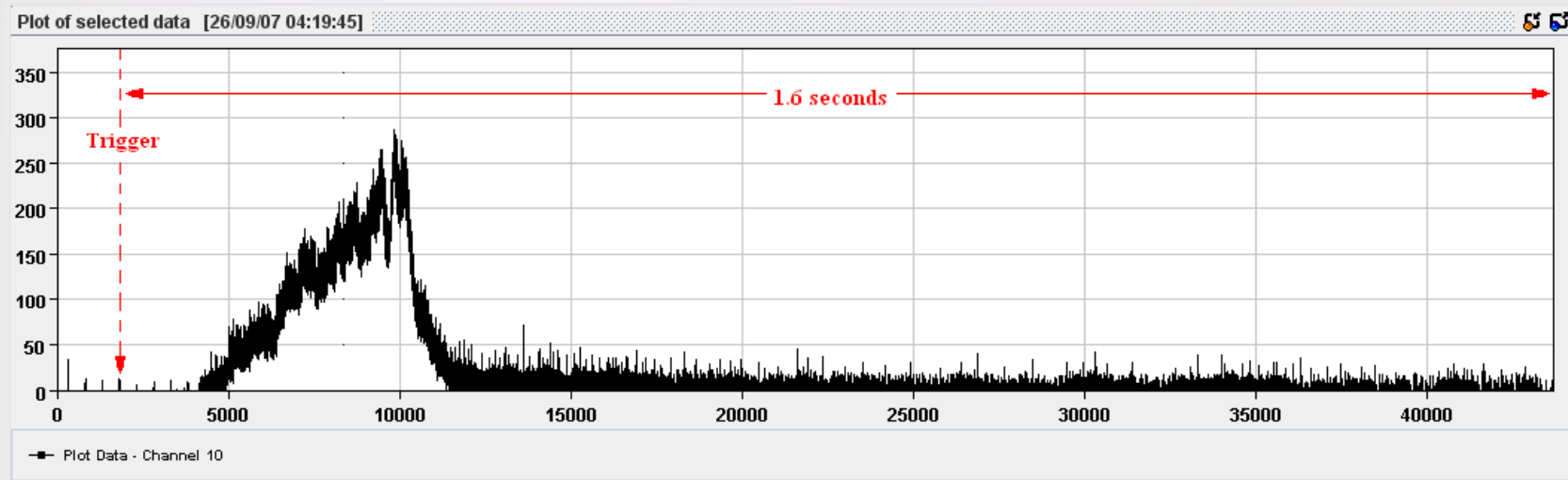


Figure: Losses recorded in the collimation area of the SPS (triggered by the collimator movement).

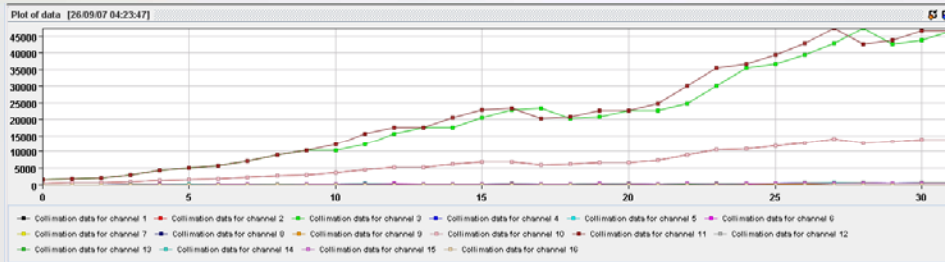
Purpose:

- Provide information to verify the correct beam extraction.

Available:

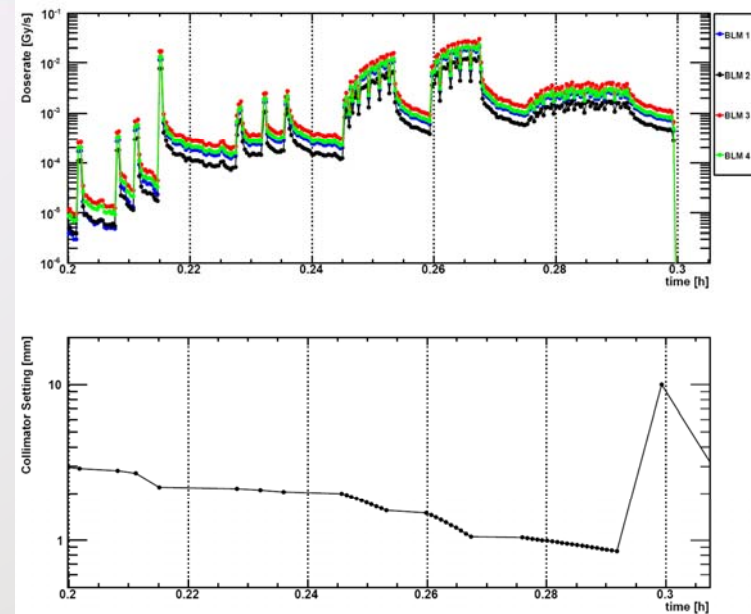
- 200 LHC turns of 40 μ s integrals per channel.
- Description of the channels (Names & DCUM numbers).
- Triggered acquisition by an event in the timing information.

Collimation System



Figures: Beam Losses induced by the collimator movement.

a: collimation triggered 82 ms data acquisition recorded
b: Maximum value of the 1.3 s Running Sum measured in the last second.
c: Relative position of the collimator w.r.t. the centre of the beam over time.



Purpose:

- Assist in the correct setup of the collimators along the ring.
- To be used by its automatic beam-based alignment control system.

Available:

- Continuously at 1 Hz,
the 1.3 s integrals for each channel.
- Triggered by the collimator movement,
32 samples per channel of the 2.54 ms integrals (i.e. 82 ms).



Summary and Outlook

- The BLM system will be able in the LHC start-up to provide not only the baseline requirements but also all of the advanced features.
- Various types of data are provided;
 - Some of them in a continuous and other in an triggered mode.
 - All of them are as detailed as necessary – no compromise.
- Each of these processes are available and has been tested excessively in the lab and under beam conditions in test facilities at HERA (DESY) and at SPS (CERN).
- Several systems will use those data, to either overview their operation or to adjust their instruments.

- Fully automatic and dynamic usage of those data should be the attitude for the future. That will allow easier, safer and faster operation of a very complex machine.



Acknowledgement

The BLM team would like to thank:

FECs + Expert GUIs

S. Jackson, JJ. Gras

ASICs

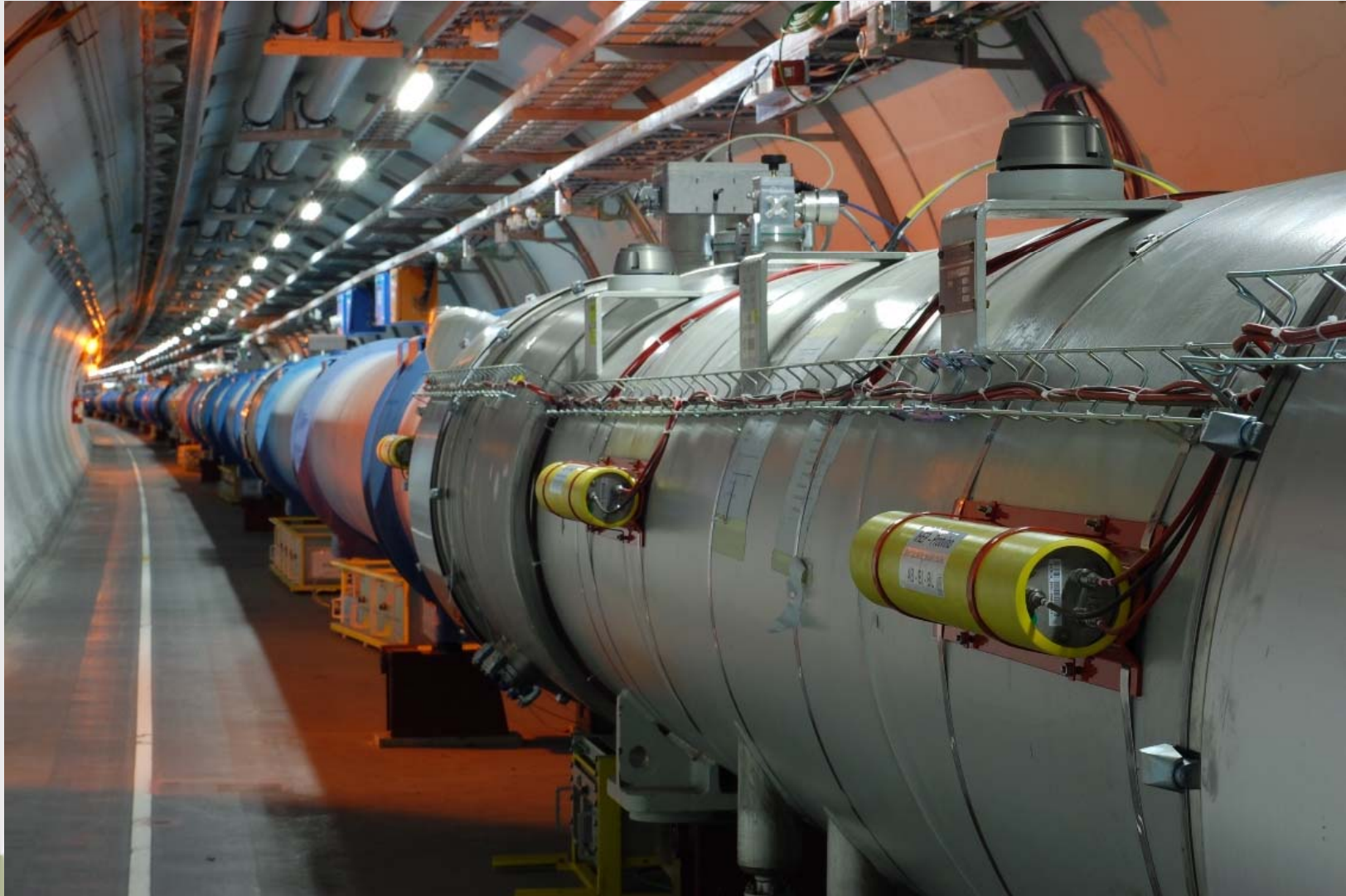
K. Kloukinas, P. Moreira, A. Marchioro

Concentrator

M. Misiowiec, G. Kruk, M. Lamont

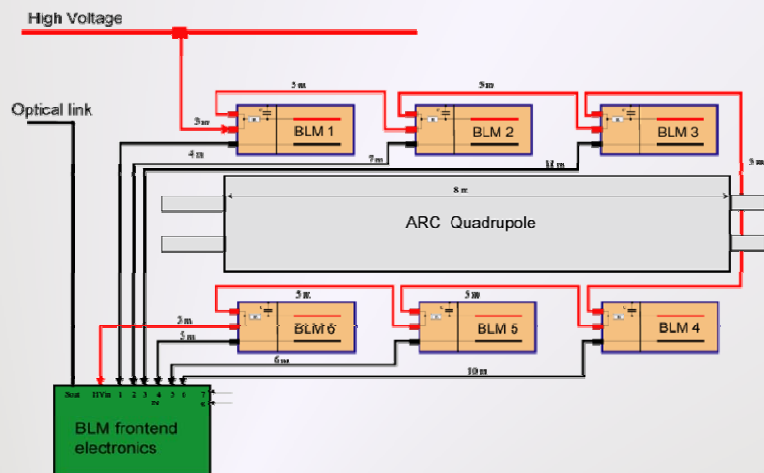
Databases

C. Roderick, R. Billen



Reserved Slides

Detectors



Standard installation:
6 detectors per Quadrupole

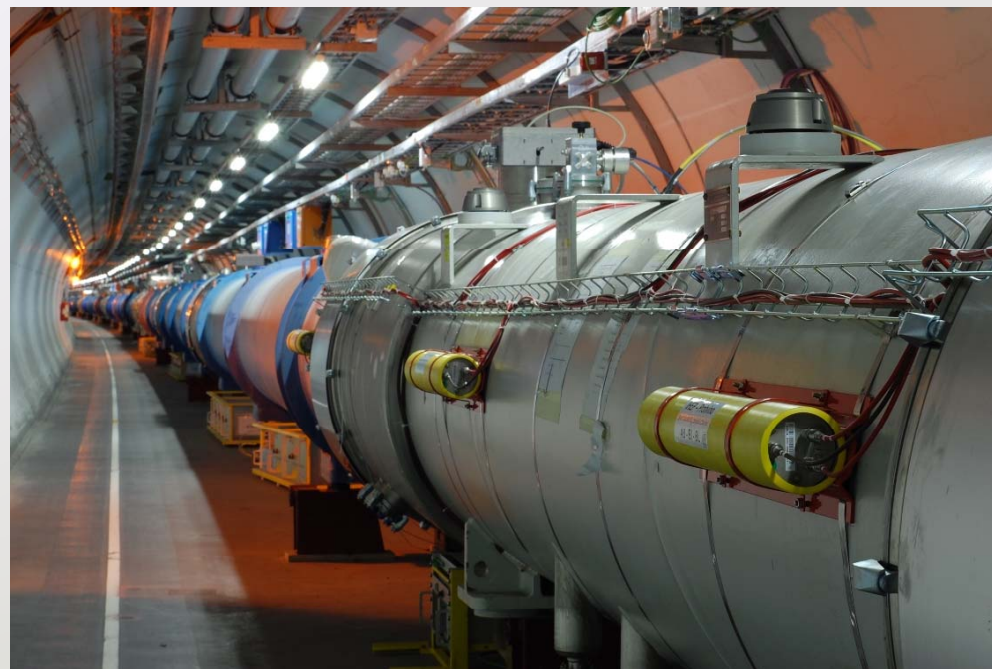
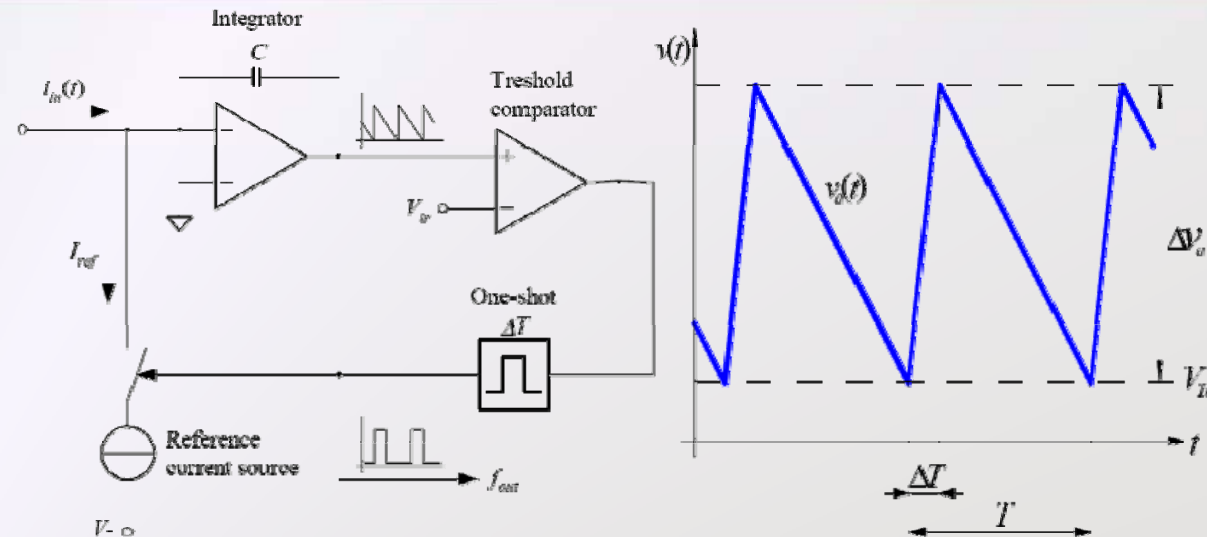


Photo of installation in LHC

Acquisition Overview

Figure: Principle of the balanced charge Current-to-Frequency Converter.



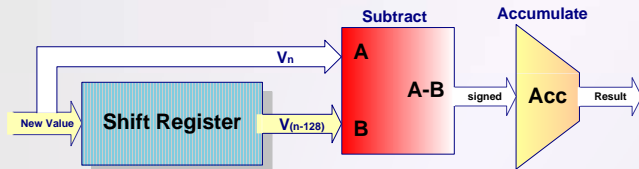
Current-to-Frequency Converter

- Measuring range 2.5 pA to 1 mA (8 decades – 160dB)
- Radiation tolerant up to 500 Gy (20y - LHC lifetime)
- Reliability level SIL3 (10^{-6} to 10^{-7} failure/h)

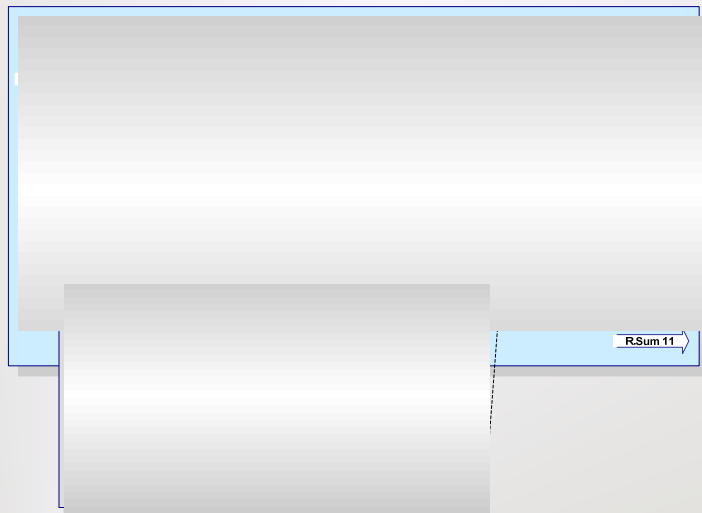
ADC

- Increase of accuracy
- Radiation tolerant up to 10 KGy

Successive Running Sums



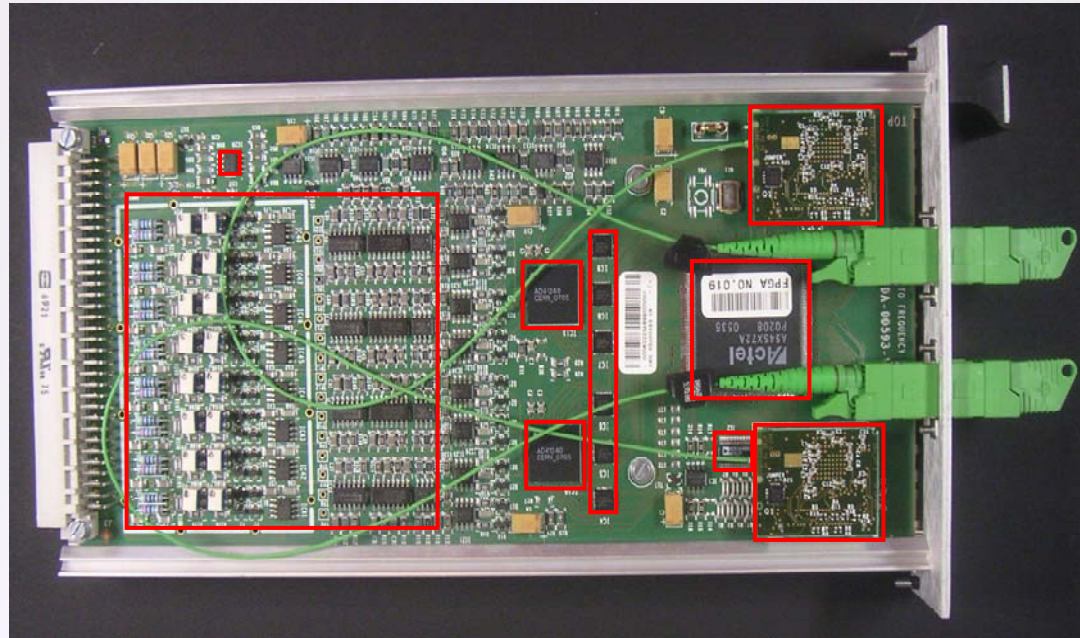
Optimised Running Sum



Configuration of SRS

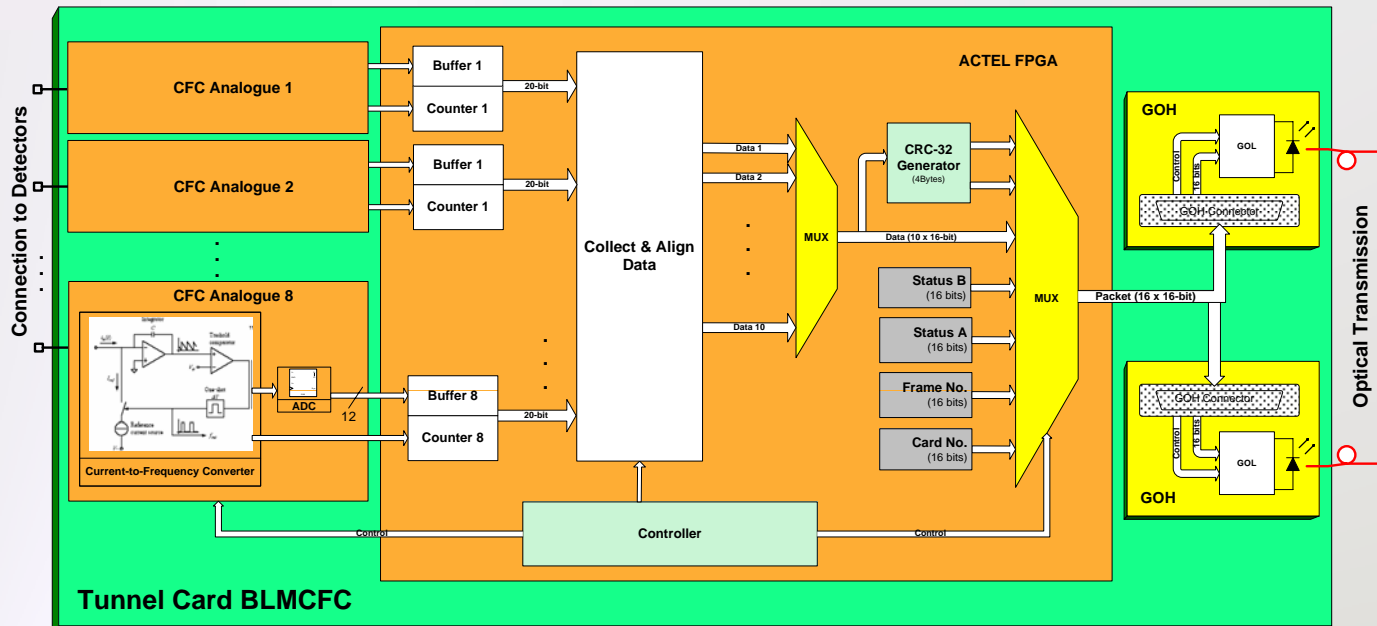
- Successive Running Sums to overcome space
- 12 integration periods from 40 μ s to 84 s

Acquisition Module (BLECF)

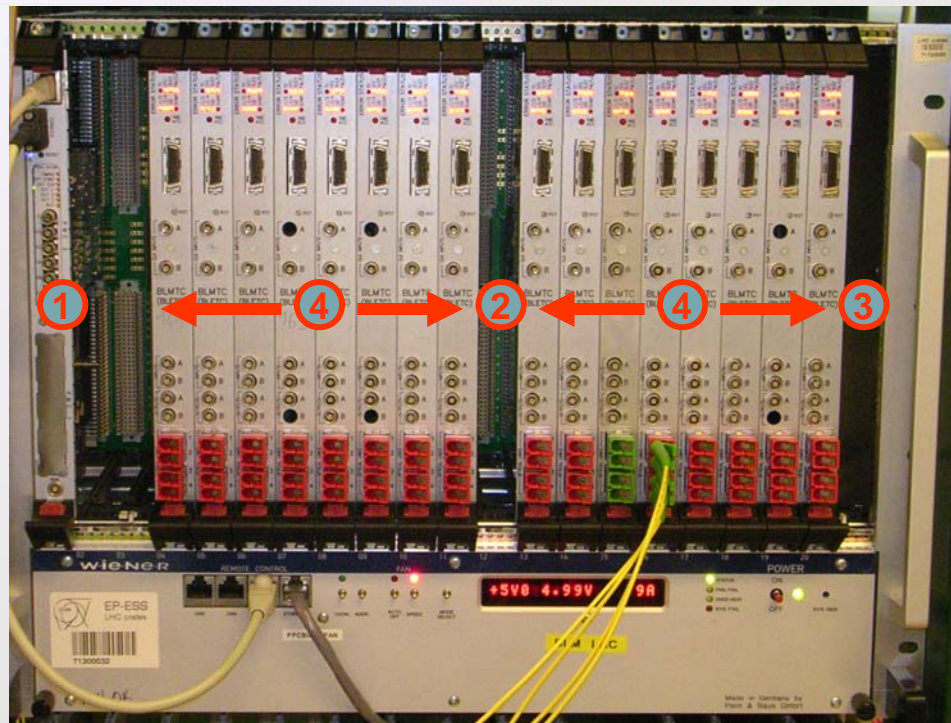
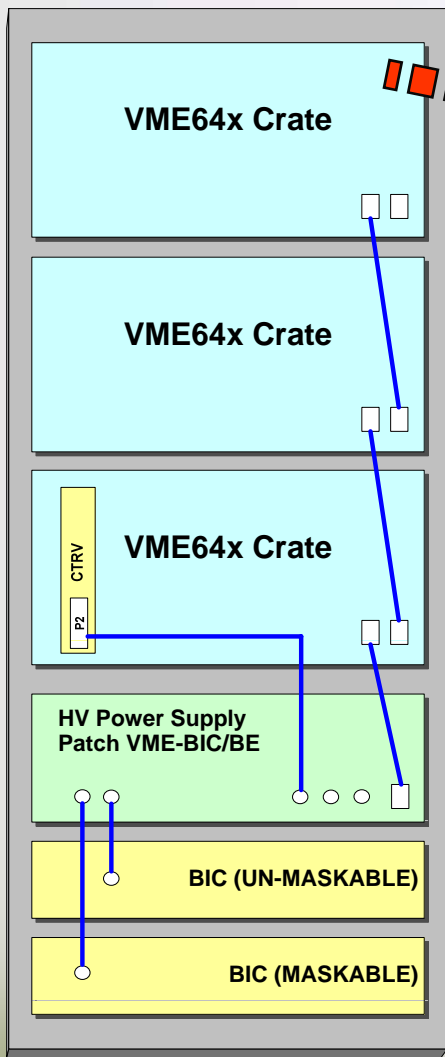


- 8 current inputs (CFC)
- ADC AD41240 (CERN ASIC)
- LM4140 voltage reference
- FPGA for data acquisition
- Redundant GOH (from CMS including CERN ASIC)
- Line driver CRT910 (CERN ASIC)
- DAC AD5346

Acquisition Module (BLECF)



Surface Installation (per IP)



- ① **Crate CPU** PowerPC with LynxOS.
- ② **Timing** card (slot 12) is the Timing Trigger and Control (TTC) card
- ③ **Combiner & Survey** card
- ④ **16 BLETC Processing Modules.**

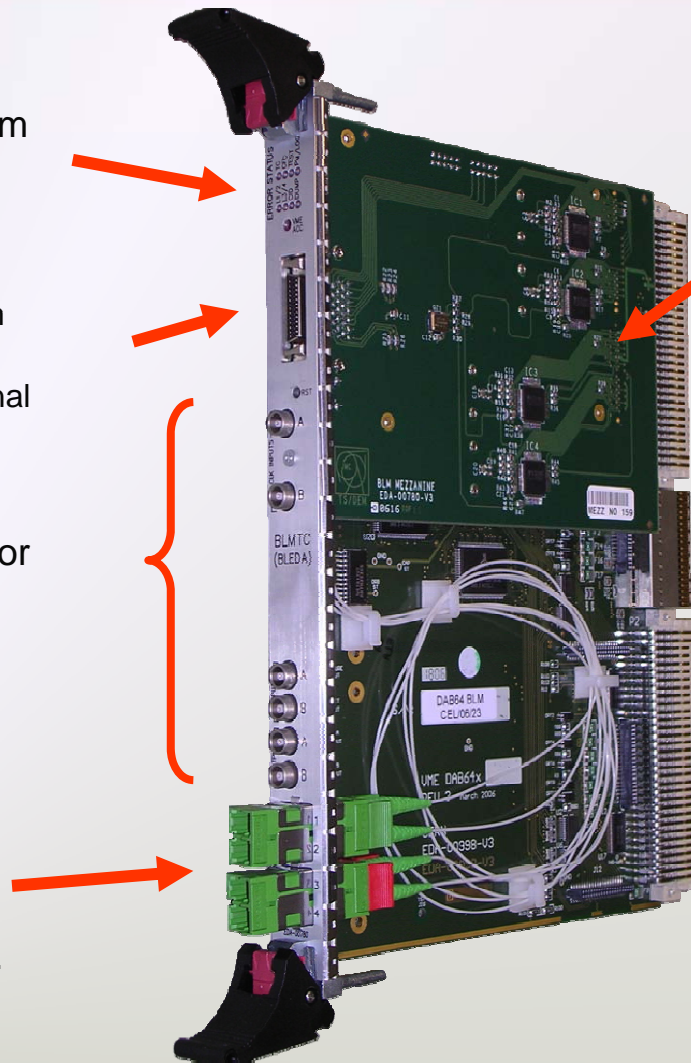
Processing Module (BLETC)

LEDs showing system and communication status

Connector to program the FPGA & Configuration devices, and gives additional access to 9 FPGA's I/Os.

LEMO connectors for accessing FPGA I/Os.

E2000-APC input connections to four optical fibres.



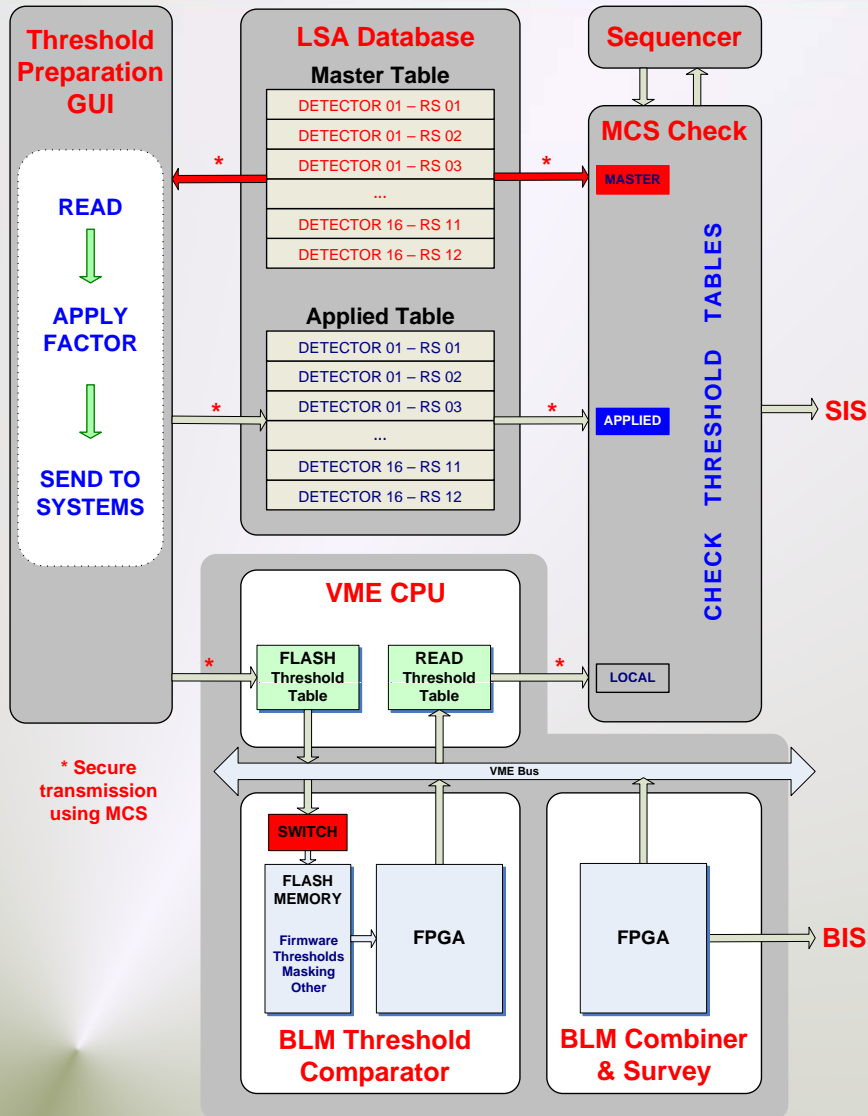
The **BLM Mezzanine**

- 4 x Gigabit Optical Links.
- Aux. Non Volatile Memory
- 2 x JTAG links

The **P0** connector

- Custom-made Backplane
- Daisy-chain two beam permit lines
- Beam Energy Data
- Safe Beam Information.

Management of Thresholds



- Threshold GUI
 - Reads the "master" table
 - Applies a factor (<1)
 - Saves new table to DB
 - Sends new table to CPU
- CPU flashes table if allowed (switch)
- Thresholds are loaded from the memory on the FPGA.
- Combiner initiated test allows CPU to read 'current' table.
- Management of Critical Settings (MCS)
 - Compares tables
 - Software Interlock System (SIS)