LHCb Front-End Electronics and Data Acquisition System

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- ❑ Summary

Introduction to LHCb

- ❑ Special purpose experiment to measure precisely CP violation parameters in the BB $\bar{\nu}$ system and rare B decays
- ❑ Detector is a single-arm spectrometer
- ❑ Total b-quark production rate is ~ 75 kHz
- ❑ Expected rate from inelastic p-p collisions is ~ 15 MHz
- ❑ Branching ratios of interesting channels range between 10^{-5} - 10^{-4} giving interesting physics rate of ~ 5 Hz

LHCb in Numbers

Number of Channels	950000
Bunch crossing rate	40 MHz
Level-0 accept rate	1 MHz
Level-1 accept rate	40 kHz
Readout Rate	40 kHz
Event Size	100 kB
Event Building Bandwidth	4 GB/s
Level-2 accept rate	~ 5 kHz
Level-3 accept rate	~ 200 Hz
Level-2/3 CPU Power	$2 \cdot 10^6$ MIPS
Data rate to Storage	20 MB/s

LHCb Detector

Typical Interesting Event

Trigger/DAQ Architecture

Front-End Electronics

LHCb has two levels of 'hardware' triggers

- Front-End Electronics has to buffer data twice for the corresponding latency
- Split Front-End Electronics into two parts
 - ↳ Level-0 Electronics on or very close to the detector
 - ↳ Level-1 Electronics near (~few meters away) the detector

Front-End Electronics Architecture and Functionality

- ❑ Amplify/Shape detector signal
- ❑ Strobe detector data at Beam-Crossing Rate (40 MHz)
- ❑ Data buffering for Level-0 latency
- ❑ Digitization
- ❑ Data buffering for Level-1 latency
- ❑ Zero suppression and data formatting

L0 Electronics Implementations

Detector	Signal	Candidate Chip(s)	Technology
VELO	Analog (8bit)	Modified SCTA/Beetle	DMILL/0.25 μ
Inner Tracker	Analog (8bit)	Modified SCTA/Beetle	DMILL/0.25 μ
Outer Tracker	Time (digital, 0.5 ns)	HPTDC	0.25 μ
Rich 1 & 2	Analog (8bit)/ Binary	Modified SCTA/Beetle Pixel Readout	DMILL/0.25 μ
Preshower	Digital (8-10bit)	Hybrid	
ECal	Digital (12 bit)		
HCal	Digital (10 bit)		
Muon	Binary		

Radiation Environments:

- Velo: ~ 1 Mrad/y
- Others: < 100 kRad/y
- L1 Electronics: < 1 kRad/y

- ❑ Provide common and synchronous clock to all components needing it
- ❑ Provide Level-0 and Level-1 trigger decisions
- ❑ Provide commands synchronous in all components (Resets)
- ❑ Provide Trigger hold-off capabilities to prevent buffers from overflowing
- ❑ React to 'Throttles' from the readout system
- ❑ Support Partitioning

DAQ Functional Components

Readout Units (RUs)

- Multiplex Front-end links onto Readout Network links
- Merge input fragments to one output fragment

Subfarm Controllers (SFCs)

- assemble event fragments arriving from RUs to complete events and send them to one of the CPUs connected
- Load balancing among the CPUs connected

Readout Network

- provide connectivity between RUs and SFCs for event-building
- provide necessary bandwidth (4 GB/sec sustained)

CPU farm

- execute the high level trigger algorithms
 - Level-2 (Input rate: 40 kHz, Output rate: 5 kHz)
 - Level-3 (Input rate: 5 kHz, Output rate: ~100 Hz)
- ~2000 processors (à 1000 MIPS)

Note: There is no central event manager

Control System

Common integrated controls system

➤ Detector controls (classical 'slow control')

- ➔ High voltage
- ➔ Low voltage
- ➔ Crates
- ➔ Temperatures
- ➔ Gas
- ➔ Alarm generation and handling
- ➔ etc.

➤ DAQ controls

- ➔ Classical RUN control
- ➔ Setup and configuration of all components (FE, Trigger, DAQ)
- ➔ Monitoring

➤ Same system for both functions

Event-Building Network

□ Requirements

- 4 GB/s sustained bandwidth
- scalable
- expandable
- ~100 inputs (RUs)
- ~100 outputs (SFCs)
- affordable and if possible commercial (COTS, Commodity?)

□ Readout Protocol

Pure push-through protocol of complete events to one CPU of the farm

- Simple hardware and software
- No central control → perfect scalability
- Full flexibility for high-level trigger algorithms
- Larger bandwidth needed
- Avoiding buffer overflows via 'throttle' to TFC sub-system
- Static load balancing between RUs and SFCs

- ❑ Simulated technology: Myrinet
 - Nominal 1.28 Gb/s (next year 2 Gb/s)
 - Xon/Xoff flow control
 - Switches:
 - ideal cross-bar
 - 8x8 maximum size (currently)
 - wormhole routing
 - source routing
 - No buffering inside switches
- ❑ Software used: "Ptolemy" discrete event framework
- ❑ Realistic traffic patterns
 - variable event sizes
 - event building traffic
- ❑ ATM studied in framework of RD31
- ❑ Work started on Gb Ethernet simulation

Network Simulation Results

Switch Size	Fifo Size	Switching Levels	Efficiency
8x8	N A	1	52.5 %
32x32	0	2	37.3 %
32x32	256 kB	2	51.8 %
64x64	0	2	38.5 %
64x64	256 kB	2	51.4 %
96x96	0	3	27.6 %
96x96	256 kB	3	50.7 %
128x128	0	3	27.5 %
128x128	256 kB	3	51.5 %

- FIFO buffers between switching levels allow to recover scalability
- 50 % efficiency “Law of nature”
- Results don’t depend strongly on specific technology (Myrinet), but rather on characteristics (flow control, Buffering)

Summary

- ❑ LHCb is a special purpose experiment to study CP violation
- ❑ FE Electronics split in two to cope with two levels of hardware triggers
- ❑ DAQ is designed with simplicity and maintainability in mind
 - **Push readout protocol** → Simple, e.g. No central event manager
 - Harder bandwidth requirements on readout network
 - Simulations suggest that readout network can be realized by adding FIFO buffers between levels of switching elements
- ❑ **Unified approach to Controls**
 - Same basic infrastructure for detector controls and DAQ controls
 - Both aspects completely integrated but operationally independent

Project Organization