Novel Data-Acquisition System for Silicon Tracking Detectors

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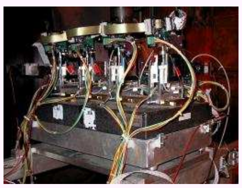
We have developed a novel data acquisition system for online reading, processing and storing data of silicon strip detectors. The system is based on commercial VME modules and a Linux PC running C++ software that has been optimized using object-orientated techniques. The performance of the system was succesfully tested while taking measurements of a novel Czochralski silicon detector.

Introduction

Helsinki Institute of Physics operates a Silicon Beam Telescope (SiBT) at the CERN H2 test beam. The telescope is used to measure tracks of incoming particle beams with high resolution. SiBT is based on position sensitive Silicon detectors attached to adequate readout electronics and data acquisition system.

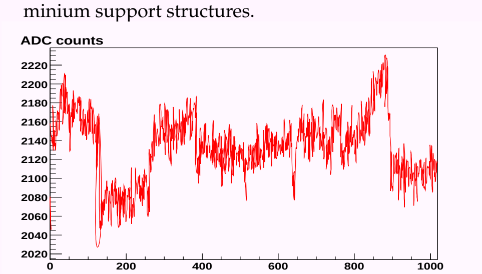
In the CERN CMS collaboration the SiBT offers reference measurements for research groups testing their detectors at H2. For the summer 2002 beam tests, the SiBT was upgraded with a new VME based commercial Analog-to-Digital Converter and a new PC operated data acquisition system.



Silicon Beam Telescope (left) and Commercial VME modules of DAQ: VME-PCI interface, ADC and scaler unit (right)

Silicon Detectors

The incoming particle beam passes through eight silicon strip detectors. Each detector is connected to front-end electronics based on VA1 readout chips. Additional amplification is performed in repeater cards, which also deliver control signals to the VA1 chips. The detectors and their front-end electronics are fixed on a granite block with appropriate aluminium support structures.

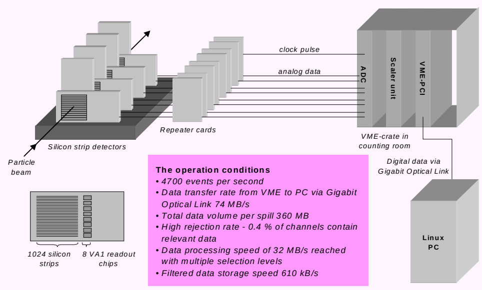


Pedestal spectrum of a silicon strip detector. The differences of the 8 VA1 chips are clearly visible.

DAQ Hardware

- Commercial ADC VME module was used to convert the data into digital form. The VME crate is controlled and accessed through a commercial VME-PCI interface that uses Gigabit Optical Link between the PC and the VME card.

- The events are synchronized to the accelerator hardware. This allows synchronizability of the events with other experiments using the same testbeam.



DAQ Software

The DAQ software is realized with Linux-based C++ code using object-orientated techniques. The objects and the required memory of 380 MB are allocated at the program start and thus further time consuming allocation is not necessary once online. The number of time consuming accesses to the VME bus during the spill cycle are minimized by reading the data from the ADC in as large continuous data segments as possible.

The ADC has two memory banks for each channel pair, and it can thus be operated in circular buffer mode. The full ADC bank can be read while the other bank continues to take data to minimize dead time. The data is stored via a Gigabit optical link directly into the memory of the PC.

During the idle time between the spills, multiple selection levels are imposed on the accumulated data to suppress the noise as fast and as efficiently as possible. Selection criteria for level 1 is:

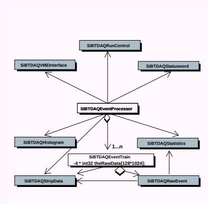
$$R - P > 0, \tag{1}$$

where R is the raw data value and P is the long term average pedestal value. Roughly 50 % of the data is rejected with this simple requirement.

The criteria for selection level 2 is:

$$R - P > k_P, \tag{2}$$

where k_P is required constant pedestal level. Further 80-90 % of the data is rejected here.



SiBTDAQEventProcessor owns the other classes. Data is capsulated in separate classes and accessed via pointers. Data reading process is optimized for reading large blocks to SiBTDAQEventProcessor. Data processing is optimized by accessing the data through SiBTDAQRawEvent-objects containing data segment pointers.

The third selection level is defined as

$$S > (N + k_{N_1}) \cdot k_{N_2}, \tag{3}$$

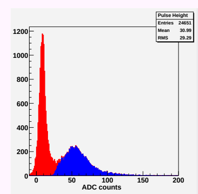
where k_{N_1} is a small constant set to avoid dead strips and k_{N_2} is usually set to 4.5 in order to make approximately a 4.5 σ cut on the signal.

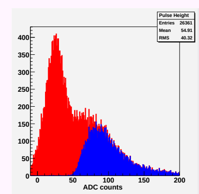
After the selection levels, only 6.5 MB of data is left to be stored on hard disk. The detector alignment, track reconstruction and analysis are conducted with a separate offline code. For fast analysis, some plots can be retrieved online using a histogram package. The DAQ software is operated via a graphical user interface made with Qt.

Test Results of a Czochralski Silicon Detector

During summer 2002, SiBT was used to study the performance of a novel Czochralski silicon strip detector in a 225 GeV muon beam. The detector performance, including pulse height distribution, signal to noise ratio, efficiency and resolution, were succesfully measured for the studied detector.

Important detector parameters, including signal size distributions and signal to noise distributions, were successfully extracted from the detector under study. The efficiency of the detector was measured to be 95 %, the resolution 10 μm and the signal to noise ratio close to 10.

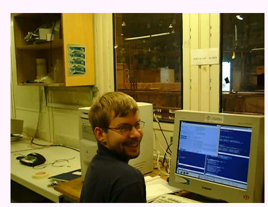




Pulse distribution from Si strip detectors. The right plot shows the pulse distribution of the studied Czochralski detector. Red color displays data after level 1 selection and the blue color displays data after level 3 selection.

Conclusions

- The new DAQ system can be used in an LHC-like environment with large number of channels and high event rate of 4.7 kHz
- The high demands of a real time online environment, controlling hardware and processing large data volumes in short time have been shown to be achievable using a linux PC running software based on C++ with optimized object-orientated structure under CERN RedHat 7.1 Linux
- Although the DAQ is designed to work as a fully independent standalone system, its synchronizability feature allows it also to be used to provide reference measurements for other detectors
- The physical performance of the DAQ was successfully tested while measuring a novel Czochralski silicon detector
- Support and maintainability of the DAQ are maximized with the use of commercial VME modules and object-orientated modular software architecture



Taking night shift measurements at the CERN H2 test beam.

References

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