Commissioning and Calibrating the CMS Silicon Strip Tracker

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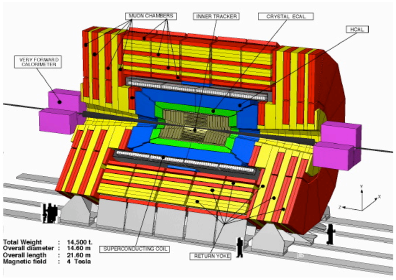
Abstract

The data acquisition system for the CMS Silicon Strip Tracker (SST) is based around a custom analogue front-end ASIC, an analogue optical link system and an off-detector VME board that performs digitization, zero-suppression and data formatting. Sophisticated procedures are required to optimally configure, calibrate and synchronize the SST readout system. We present an overview of these procedures and the software that will be used to commission the SST during Start-Up and operation. Recent experiences from both the CMS Magnet Test / Cosmic Challenge and large-scale system tests at the Tracker Integration Facility are also reported.

1) The CMS Silicon Strip Tracker

The Silicon Strip Tracker (SST) for the CMS experiment, comprising a sensitive area of over 200m² and 10M readout channels, is unprecedented in terms of its size and complexity for a tracking detector.



The CMS experiment.

The readout system comprises 76k analogue Front-End ASICs (the APV25), an analogue optical link system comprising 38k fibres and associated ASICs, and 440 off-detector VME boards (the Front-End Driver or FED). Each FED uses FPGA technology to perform digitization, zero suppression and data formatting, before forwarding event fragments to the CMS online computing farm.

2) Commissioning Procedures

Commissioning such a large-scale readout system requires sophisticated procedures to bring the detector into an operational state suitable for data-taking. These procedures comprise several independent tasks that can be categorized as follows:

- automated detection of the functional readout system, partitioning and cabling;
- optimization of O(100k) Front-End and ~500 Back-End hardware configurations;
- synchronization of the Front-End system, both internally and to LHC collisions;
- determination of calibration constants that are used by both the hardware and, in some cases, reconstruction software.

These procedures are used to validate the operational functionality and performance of the detector during integration, Start-Up and operational phases of the experiment.

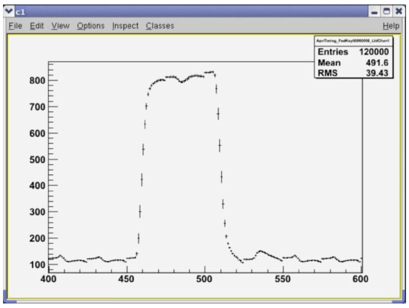
3) The DAQ Software: Control

The software implementation for the commissioning procedures is divided between the CMS online and offline software frameworks, known as XDAQ and CMSSW, respectively.

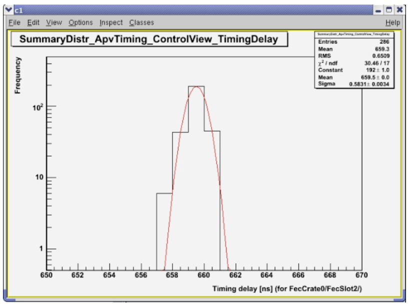
The procedures are defined by data acquisition loops that configure and control the readout and local trigger systems, perform event building and data analysis. Communication between the various, distributed "Supervisor" processes is achieved using the XDAQ framework, which allows to automate the data acquisition loops, so removing the need for repetitive run control sequences and complex book-keeping.

4) The DAQ Software: Data Analysis

Data analysis is performed within CMSSW, which determines optimized hardware configurations and calibration constants from reconstructed calibration pulses, timing delay curves, dynamic range curves and other features of the APV25 data stream. These optimized configurations and calibrations are then stored in a dedicated database and provide the basis for subsequent commissioning tasks or physics runs.



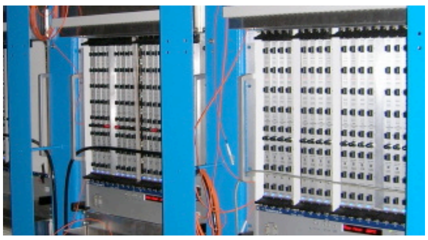
An example of a "tick mark" found within the APV25 data streams, which are used to synchronize the Front-End system. Such plots are produced by the data analysis and are used to infer the optimum hardware configurations.



286 readout "channels" of the SST (each comprising a pair of APV25 chips) are synchronized using APV25 "tick marks", with a spread of only 0.6 ns.

5) Flexible design allows transparent use of local and global resources

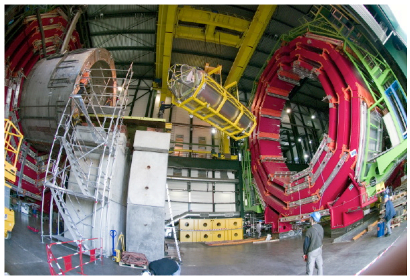
The chosen software design ensures that both the local computing resources allocated to the SST, in the form of VME crate PCs, and the global resources provided by the CMS online computing farm can be used transparently. The former option will be the default configuration used during Start-Up; the latter offers vast improvements in terms of trigger rates and CPU processing power.



VME crates containing FEDs and the PCs hosting the event builder and data analysis processes.

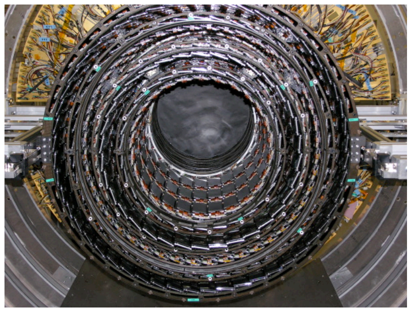
6) CMS Magnet Test / Cosmic Challenge

The DAQ software was used during the recent CMS Magnet Test / Cosmic Challenge (MTCC) to commission a small tracking system comprising ~200 modules. Several milestones were achieved, including integration with the configuration database, Run Control and an error logging and diagnostic system. Additionally, several software components within CMSSW were also used to monitor the system from the global online computing farm.



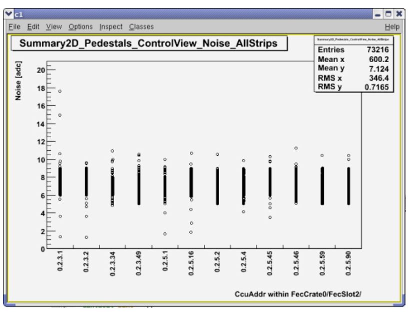
Installation of the tracker setup for the MTCC

7) Tracker Integration Facility



Assembly of the inner barrel at the TIF.

Distributed data analysis is an essential feature of the DAQ software, so that it can handle the huge data volumes generated by the increasingly large readout system as the SST is assembled. This has been demonstrated at the CMS Tracker Integration Facility (TIF), where large-scale system tests have recently started.



A "summary histogram" plotting channel noise, organized according to the sub-structure to which the channel belongs within the tracker at the TIF. Such histograms, generated in real-time by DAQ software and viewable at remote sites using web technology, provide immediate feedback and allow problems to be quickly identified and located.