Production and Commissioning Performance Tests of the Read-Out Driver Boards for the Hadronic Tile Calorimeter of the ATLAS Detector at the LHC

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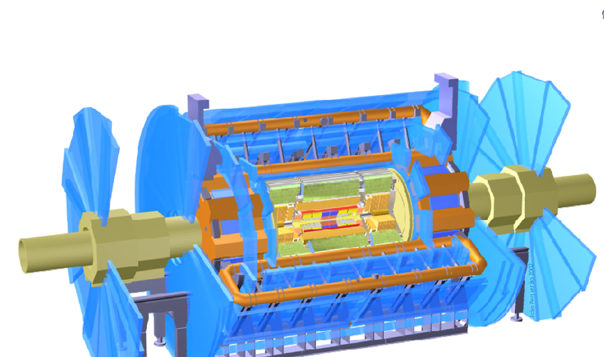
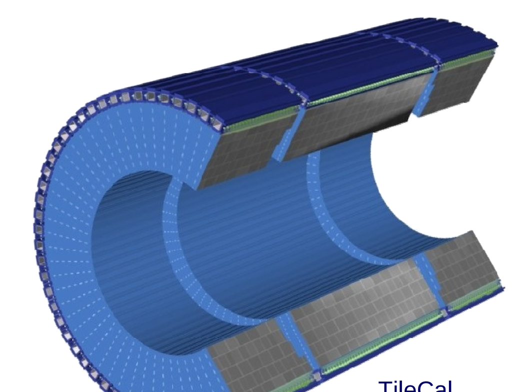
Introduction

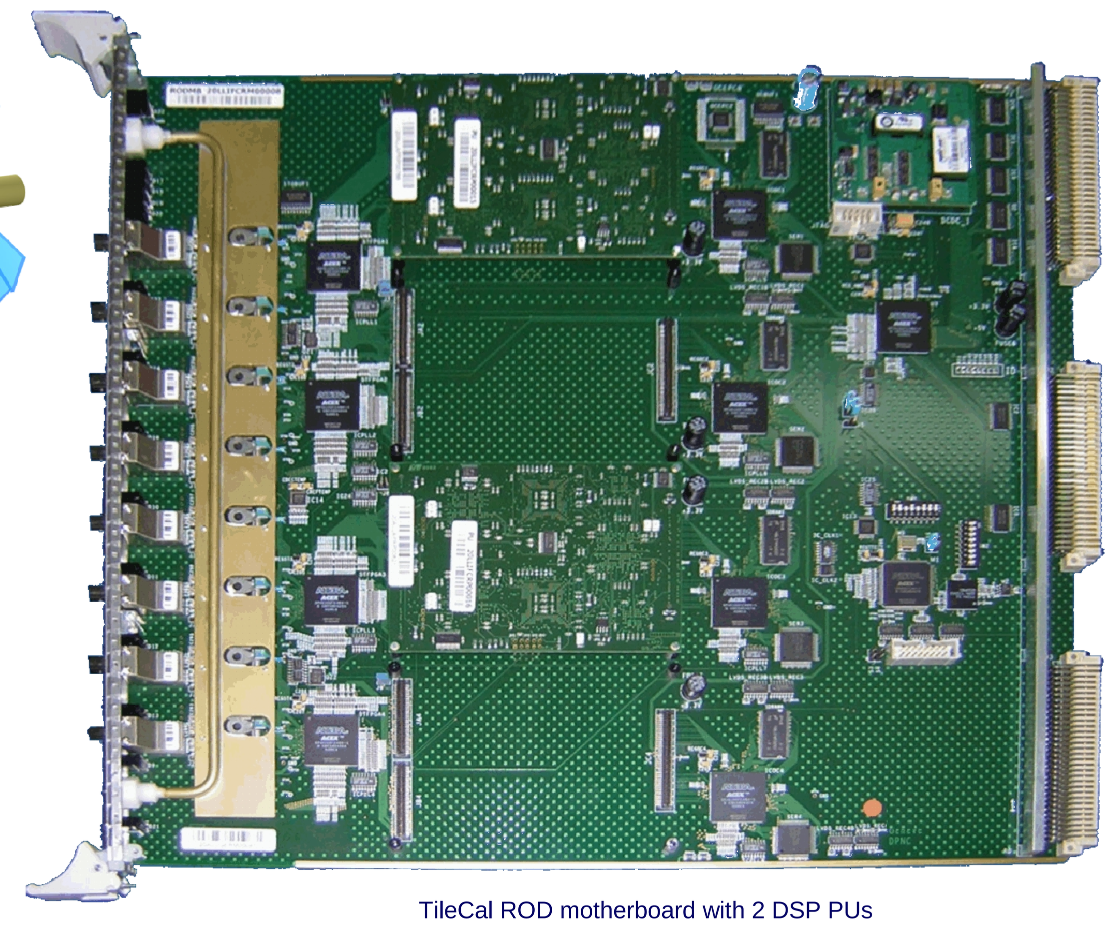
ATLAS is a general purpose experiment for the LHC (proton-proton collider at a 14 TeV center of mass energy), both under construction at CERN. The main goal of ATLAS is to explore the Physics at the multi-TeV scale, with special interest at the Higgs sector and the physics beyond the Standard Model.

The Hadronic Tile Calorimeter (TileCal) is a sampling calorimeter made of iron and scintillating tiles. Longitudinally TileCal is divided in a long barrel (LB) and two extended barrels (EB). Each barrel defines a detector partition, with its own trigger and dead-time logic, independent from the data acquisition point of view. In *the* ϕ direction, TileCal is divided in 64 modules for each barrel. The energy deposited by the particles in the calorimeter produces light in the active medium. This light is routed to photomultiplier tubes (PMT), which are the first element of the Front End (FE) electronics. All FE electronics (shapers, amplifiers, digitizers, etc.) are integrated in a compact structure at the end of the modules called drawer. There are two drawers in each LB module and one per EB module.

The Read-Out Driver (ROD) is the central element of the TileCal Back End (BE) electronics. The ROD is a 9U VME board which receives as input the fibers from the FE containing the digitized samples of the electronic pulse at a Level 1 trigger rate of 100 kHz. One ROD can handle 8 input fibers from 8 different modules. Thus, 8 RODs are needed to read-out a TileCal partition (64 modules). The ROD has to process the data in real time, reconstruct the pulse and send information about the energy, timing and pile-up estimation (χ^2) to Level 2 trigger. It is also responsible for the TTC synchronization, error detection, busy generation, etc.


ATLAS

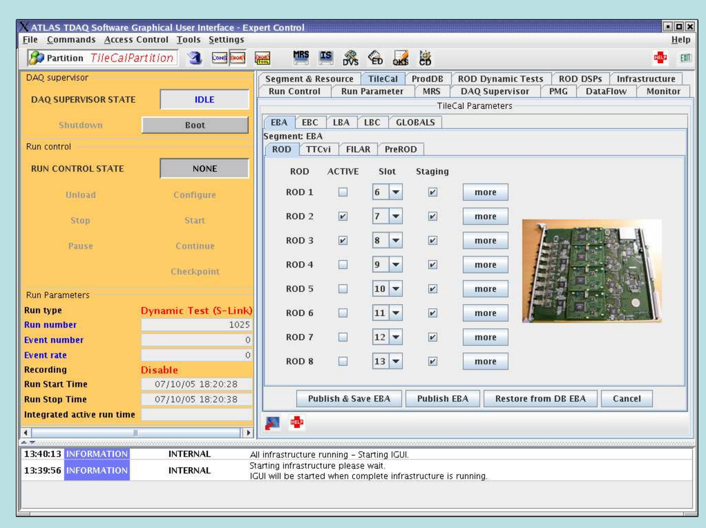

TileCal

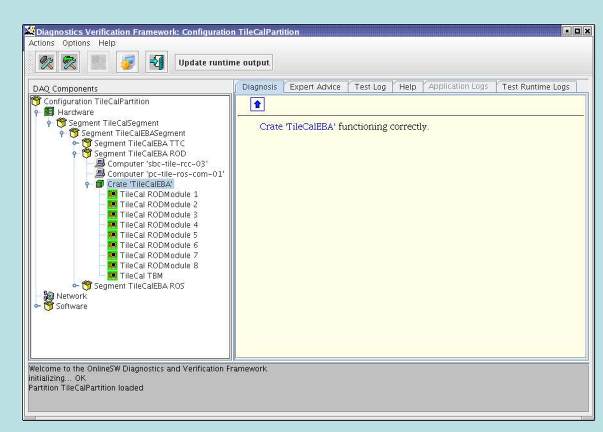

TileCal ROD motherboard with 2 DSP PUs

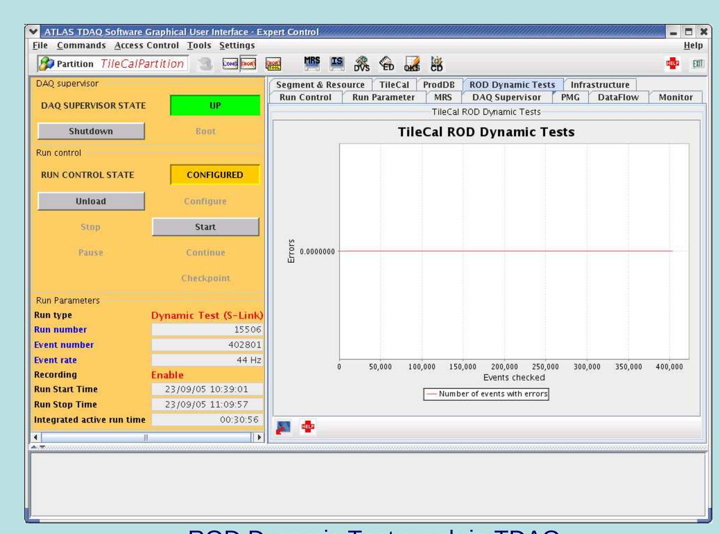
ROD Production

TileCal ROD is based on the ATLAS Liquid Argon calorimeter ROD, with hardware and firmware modifications according to the TileCal FE requirements. Valencia is responsible for the design modifications, development, production, commissioning and future operation of the TileCal RODs. During 2005 all the RODs and related modules are being produced at Valencia. To verify the integrity and functionality of the RODs, a set of tests have been prepared to be performed systematically on the boards in a controlled environment. These tests have been developed inside the ATLAS standard framework for online tasks: TDAQ (Trigger and Data Acquisition). Specific GUI panels have been added to the TDAQ main window for intuitive configuration of the ROD modules. Two kind of tests are performed on the RODs:

• **Static Tests**: their main purpose is to check the status and detect any malfunction in the boards. Basic functionalities are checked for all the devices in the ROD: communication, VME register read/write operations, correct Processing Unit booting (see below), etc. For this, specific tests in the Diagnostics Verification System (DVS) inside TDAQ are used.


TileCal ROD Panel in TDAQ


DVS test for a ROD crate with 8 RODs


ROD Dynamic Test graph in TDAQ

• **Dynamic Tests**: their main purpose is to validate the RODs from the data flow point of view. Data with a predefined format is injected to the ROD by dedicated electronic boards (PreROD prototypes, which are boards in development with double functionality: data multiplexers and injectors). Specific TDAQ ROD Crate DAQ (RCD) applications have been developed for transmitting the data through the RODs in short runs and burn-in tests. To check the correct transmission of data a dedicated monitoring task inside TDAQ has been developed, which checks the acquired data and plots the number of errors found in a graph inside TDAQ main window.

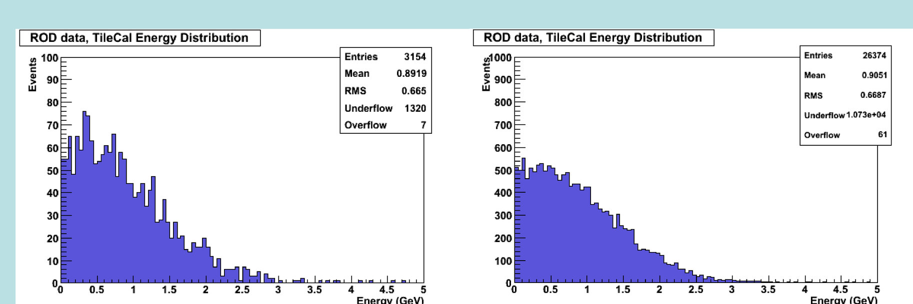
All the modules produced together with the results of the tests performed on them are stored in a mySQL data base accessible from the web.

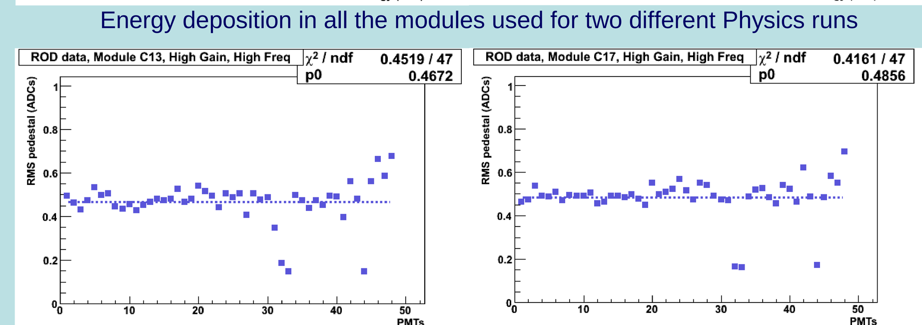
Commissioning

By summer 2005, the TileCal LB has been fully assembled in the ATLAS cavern. The main objectives of the commissioning phase of the experiment are the integration of all the hardware and software elements and the test the whole system in a setup close to the final one.

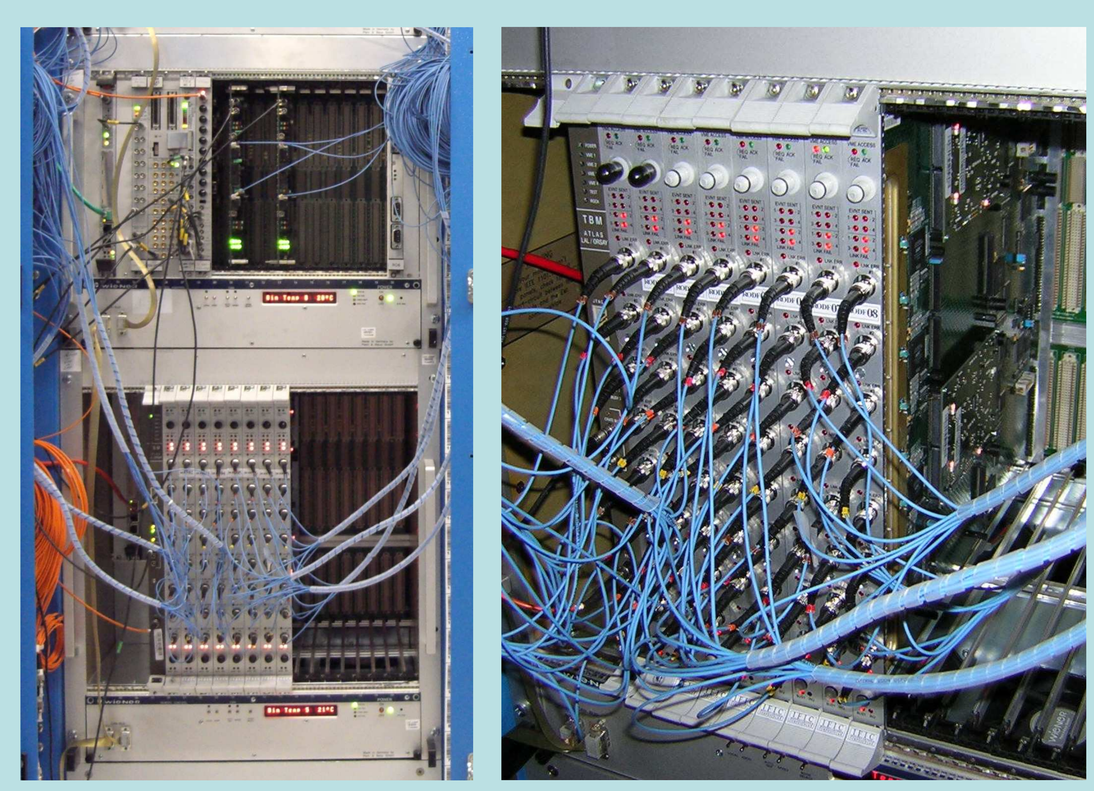
One of the most important tests consists in verifying the whole data acquisition chain with final components. For this purpose, 8 RODs validated during production have been recently installed in the ATLAS electronics cavern (USA15) and integrated in the general TDAQ environment together with the dedicated software for the FE configuration.

We have been able to read-out data from the TileCal drawers using the RODs successfully during last month in Physics, Pedestal and Calibration runs. In the Physics runs, cosmic rays triggers based on the energy deposited in a calorimeter single tower or in back-to-back towers are used.


Energy deposition in all the modules used for two different Physics runs


Noise values for the PMTs in two different modules

The data acquired with the ROD for several runs have been analyzed in terms of pedestals, noise and energy deposited as figures show. This consists a successful first step in the validation of the RODs in the final Commissioning setup.

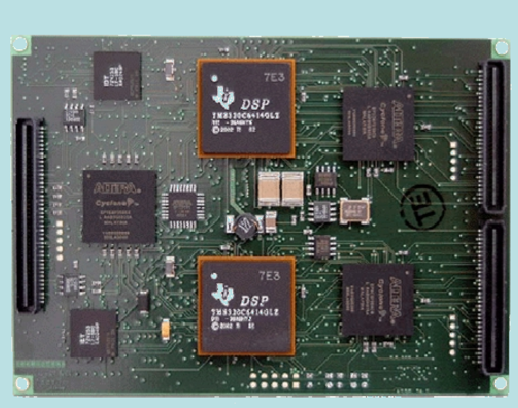

RODs installed in USA15 for TileCal Commissioning

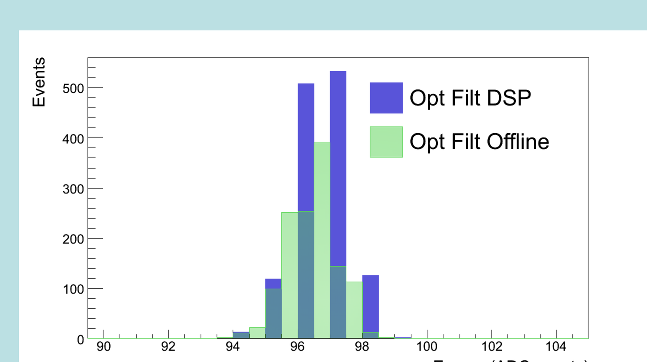
DSP Processing Units

The TileCal ROD is equipped with 2 Processing Units (PUs). Each PU consists in a mezzanine board and contains 2 TMS320C6414 Digital Signal Processors (DSPs). In normal ROD operation mode (called *Staging Mode*), each DSP will process the data coming from 2 FE fibers with a maximum latency of 10 µs to avoid dead-time. Online energy reconstruction algorithms such as the Optimal Filtering (OF) can be implemented in the DSPs.

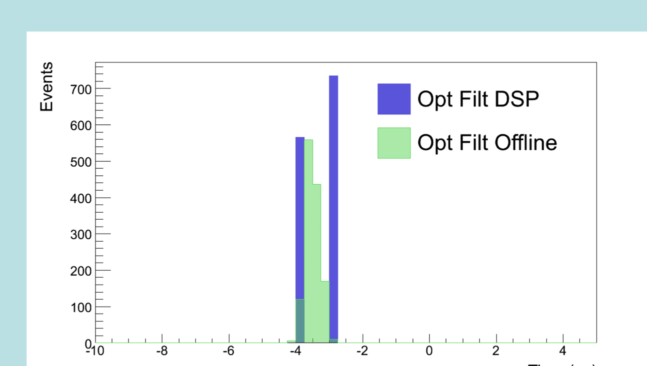
The OF algorithm reconstructs the amplitude of the pulse (which is proportional to the energy deposition) as a weighting sum of the digitized samples in such a way that the contribution of the noise is minimized. It also computes the time of the signal and a quality factor of the reconstruction (χ^2). The weights to be used in the OF are obtained from the signal shape and the noise autocorrelation function.

OF is being implemented in the core of the DSPs using C and assembler for different types of run (Physics, calibration, different number of samples, etc.).


DSP Processing Unit mezzanine board



OF energy reconstruction for a given channel



OF time reconstruction for a given channel

The DSP can be configured to transmit the raw data without applying online reconstruction (*Copy Mode*) or transmit the raw data together with the online reconstruction. DSP Copy Mode has been extensively tested in laboratory and in the Commissioning for different data formats. A first version of the OF algorithm (not with the final weights) has just being implemented and successfully tested with calibration FE data in the Commissioning setup.

The figures show the result of the energy reconstructed online in the DSP, which are fixed-point processors compared with the offline reconstruction of the same data in a normal PC for a charge injection run. Only an integer precision is achieved in the energy value for the moment. A good agreement is found, although due to the use of non optimized weights distributions are wider than expected. In the final DSP code, appropriate weights for each channel will be applied and precision will be increased.

The DSPs will also be used for online monitoring and histogramming of the data at the ROD level. Furthermore to exploit the online processing capabilities of the DSPs, the computation of the Missing Transverse Energy and a low p_T muons tagging algorithm based on their distinctive energy deposition signature will also be implemented.

Poster presented at the IEEE 2005 NSS/MIC Conference, Puerto Rico