Design of a new front-end electronics test-bench for the upgraded ATLAS detector's Tile Calorimeter

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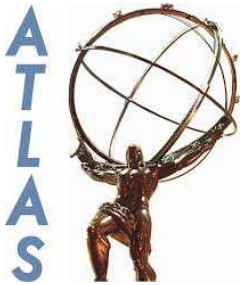
Workshop on High Energy Particle Physics, iThemba LABS (Gauteng), 11 - 13 February 2015

Collaborators



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Outline

Introduction

- In the Large Hadron Collider's Phase II upgrade, there will be a complete re-design of the read-out electronics in the Tile Calorimeter of the ATLAS detector
- The completed new read-out architecture is expected to have the front-end electronics transmit fully digitized information of the full detector to the back-end electronics system
- The back-end system will, thus, provide digital calibrated information with greater precision and granurality to the first level trigger, thereby resulting in improved trigger efficiencies
- The current Mobile Drawer Integrity Checking (MobiDICK4) test-bench will be replaced by the next generation test bench for the TileCal super-drawers, the new Prometeo (A Portable ReadOut ModulE for Tilecal ElectrOnics)

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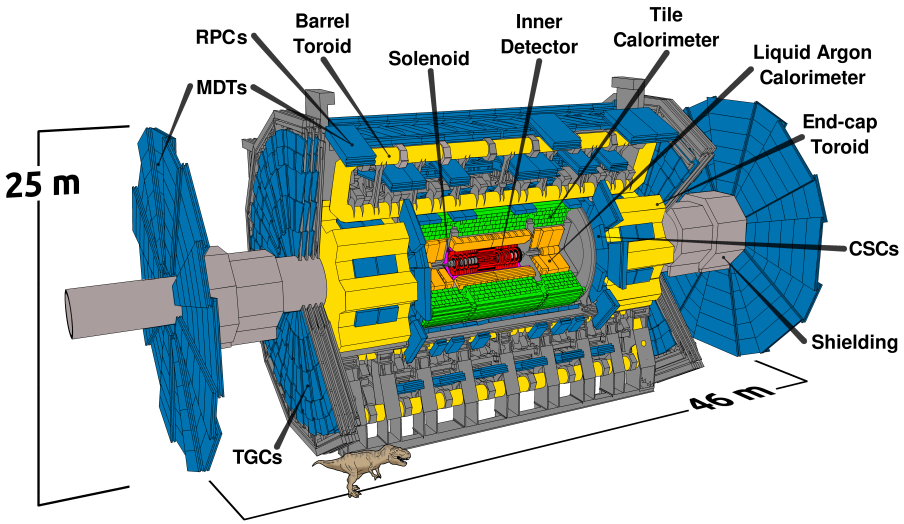
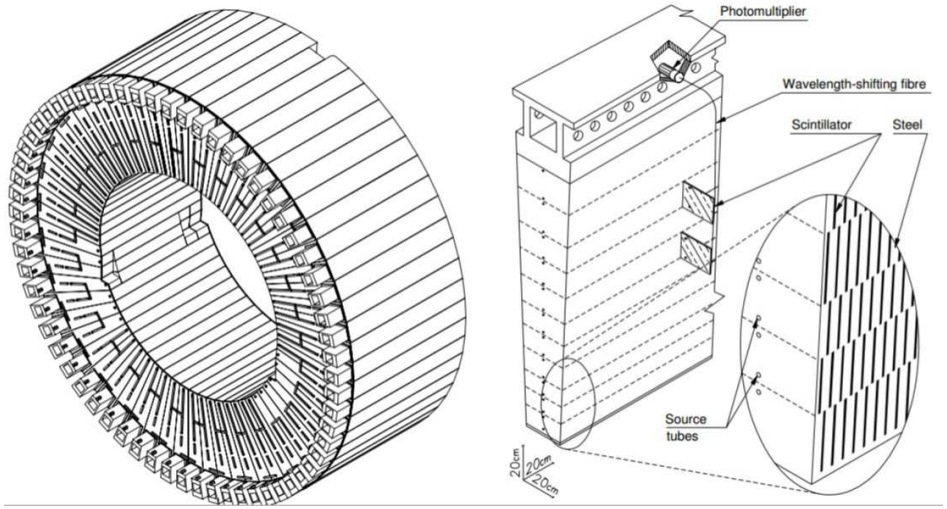
The ATLAS Tile Calorimeter



The ATLAS detector.

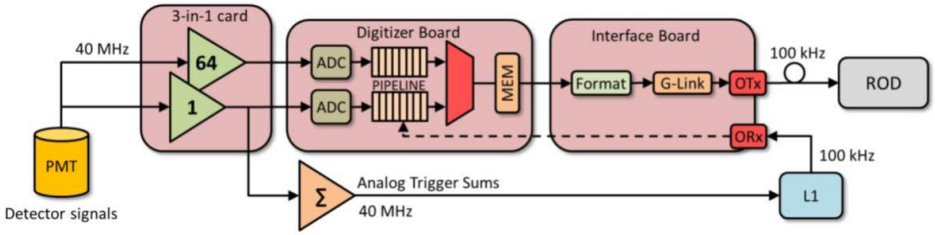


L: TileCal and *R*: Superdrawer.

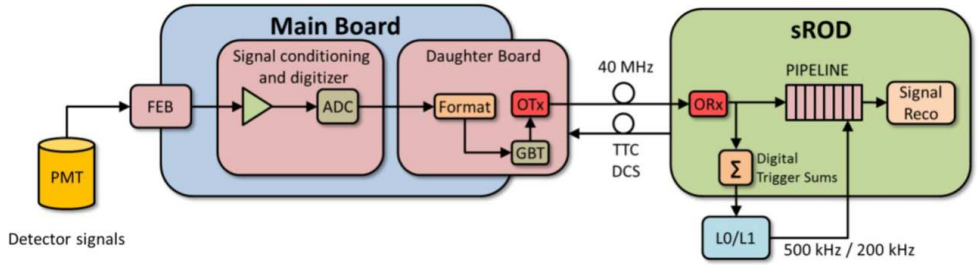
- Largest of all detectors at LHC
- All purpose detector of *pp* collision products
- TileCal measures energy and direction of hadrons, jets and τ leptons

- Absorber (steel) + Scintillator (plastic)
- Data receiving 40 MHz
- Superdrawers contain front-end electronics which process signals

Front-end electronics: present and future



Present front-end electronics.



Front-end electronics after LHC phase II upgrade.

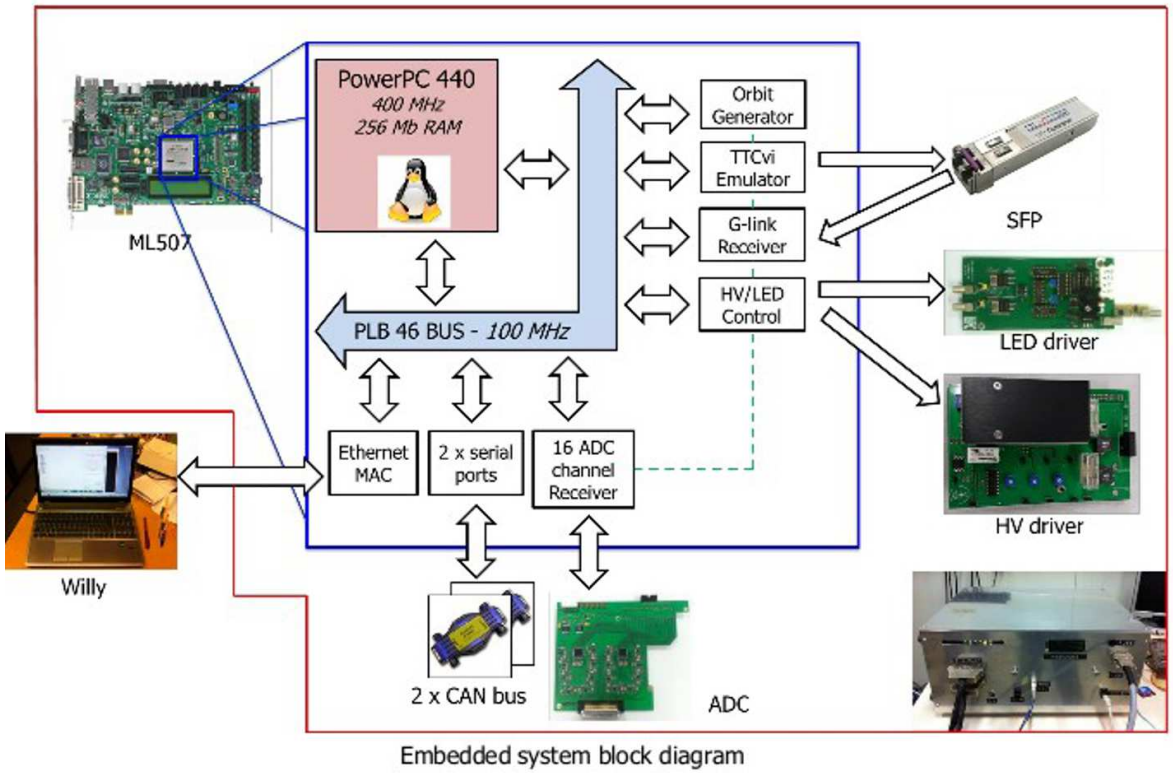
- 3-in-1 card (Amplifies, Shapes and Directs signals to adder board for L1 Calo trigger)
- Digitiser board (Samples high and low gain signals)
- Interface Board (Single link to back-end, 100 kHz read-out)
- No redundancy, Front-end pipeline memories, low transfer rate

- Higher luminosity(5-7X)
- Increased radiation tolerance
- Improvement of system reliability
- Increased data precision
- Improved level one (L1) trigger system
- Improved Signal to Noise Ratio (SNR)

Electronics test-bench: what to test

- A typical electronics test-bench tests the following:
  - Communication between all components
  - Digitized shape
    - from injected charge in 3-in-1 cards to test the front-end electronics
    - LED illuminates PMTs to test PMT + front-end electronics
  - Noise measurement

MobiDICK4 test-bench

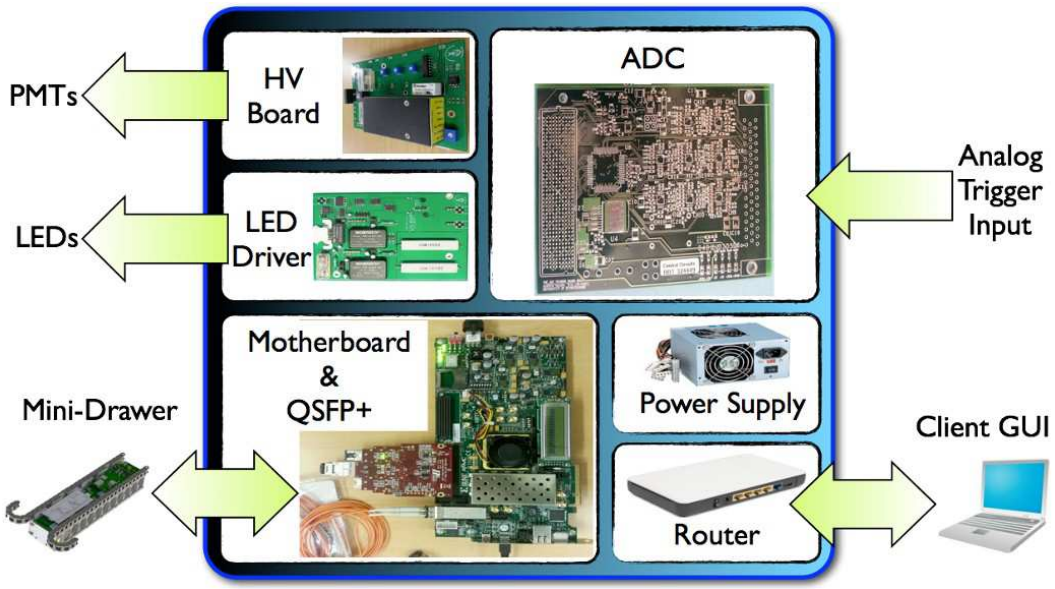


Embedded system block diagram

MobiDICK4 test-bench.

- Main board: Xilinx ML507 evaluation board
- Recording data after L1 trigger @ 100 kHz
- Using slow canbus to control 3in1 cards and HV in each PMT
- Server running on PPC, connects to client via Ethernet

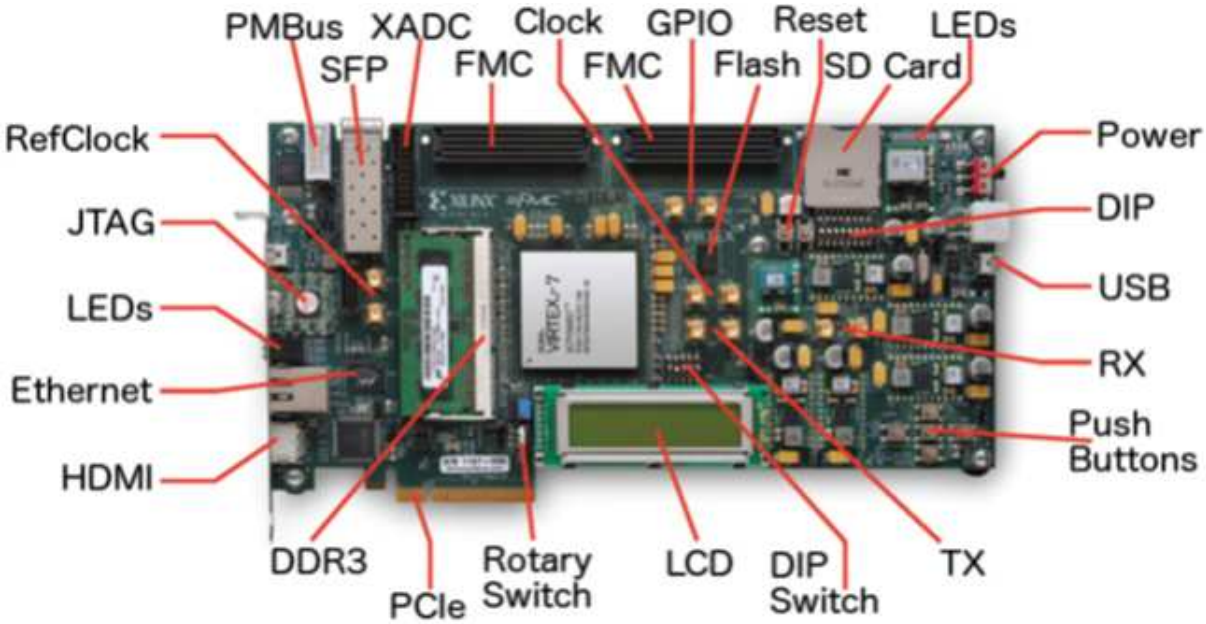
Prometeo test-bench



Design of Prometeo.

- Main board: Xilinx VC707 and QSFP to transfer data through FMC connectors at 40 MHz
- Bandwidth upgrades from 640 Mbps/s to 40 Gbps
- Full compatibility to sROD in the TileCal, sharing the main board
- ADC board processes the analog signals from mini drawers
- Remove Canbus dongles
- Using IP bus protocol, firmware manipulated directly by client via ethernet

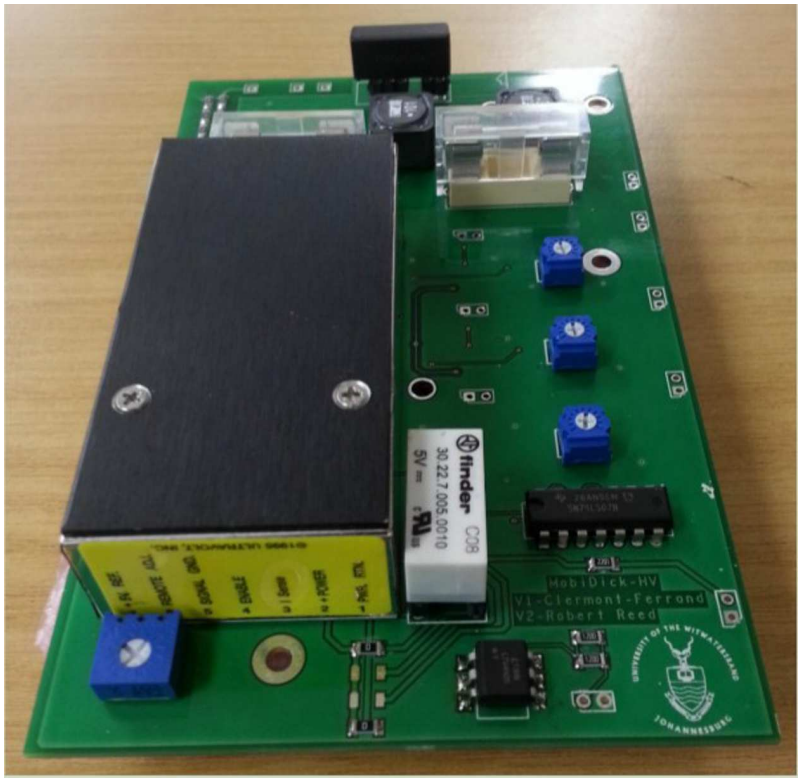
Prometeo main board



Xilinx VC707 evaluation board.

- Xilinx VC707 evaluation board, Virtex-7 FPGA chip, 1GB DDR3 RAM, two FMC connectors.
- Firmware shares from the super Read-out Driver (sROD) in the minidrawer
- Communication: QSFP card, HTGFMC-X2QSFP+; sends Trigger Timing Control (TTC) commands and receives data at 40 Gbps

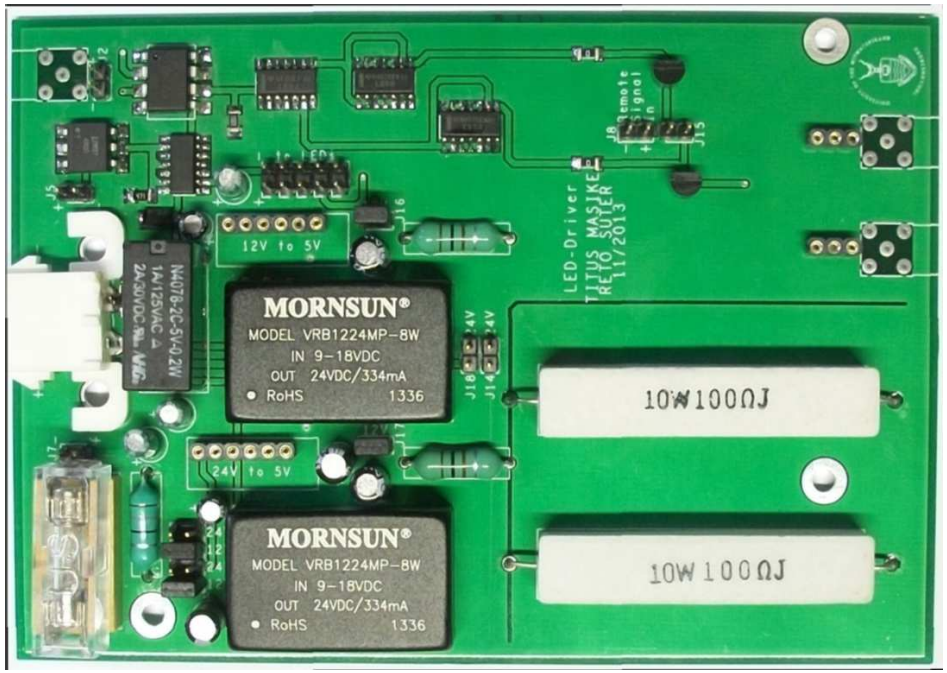
Prometeo HV board



HV board for Prometeo.

- Providing the -830 V voltage that turns on/off the HV, to power on the PMTs
- Prototype assembled and tested
- Five more boards sent in for populating
- All work perfectly

Prometeo LED and ADC board



LED board for Prometeo.

- Generates a 20 V, 20 ns wide pulse to drive an LED that eluminates the PMTs
- Prometeo ADC board (see talk by Matthew Spoor)

Prometeo test-bench

Prometeo mechanical enclosure.

- Mechanical design:
  - Aluminum enclosure 50 cm $\times$ 35 cm $\times$ 20 cm, 3 mm thick and weights 8 kg
  - 2 $\times$ optical fiber, 2 $\times$ LED, 2 $\times$ ethernet, 1 $\times$ HV male socket and 1 $\times$ 50 pins for trigger input
- Prometeo must:
  - read-out 16 channels at the LHC bunch crossing frequency
  - assess the quality of data in real-time
  - be self-contained and portable
  - be low-cost and scalable for network usage

sROD emulator

sROD emulator + minidrawer.

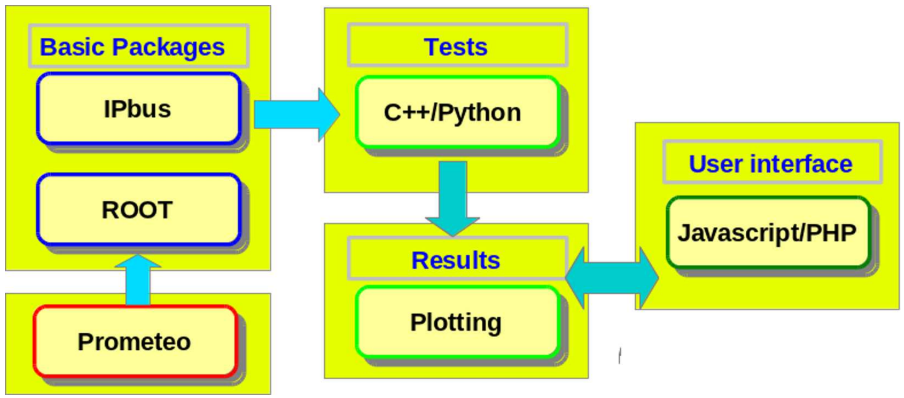
- sROD emulator connected to a mini-drawer demonstrator
- Testing of data transmission and communication

Prometeo software

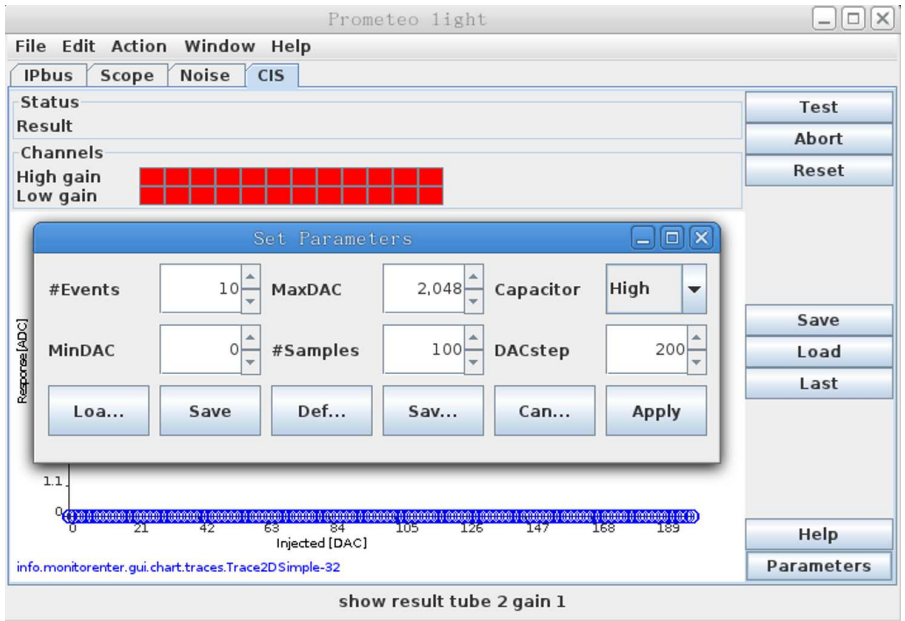
- Software designed to perform tests on the mini-drawers and to show the results on a friendly user interface

- Software features:
  - Using IPbus protocol to communicate between the main board and the user interface
  - The GUI is an interface to show the test result, including status of all PMTs, histograms of the pulse shape, noise shape and fit results
  - An emulator is also designed to help in the development of the software when Prometeo is not connected
  - Source code written in Java and Python, over platform executable files

Prometeo software



Structure of Prometeo web interface.



Screenshot of Java GUI.

Summary

- Upgrades of TileCal Electronics:
  - Superdrawers $\rightarrow$ Minidrawers
  - ROD (100 kHz) $\rightarrow$ sROD (40 MHz)
- Upgrades of the test-bench:
  - Mobidick4 $\rightarrow$ Prometeo
    - Main board to match the ROD $\rightarrow$ sROD
    - Remove canbus dongles
    - Using Ipbus to control the sROD and minidrawer
- Prometeo has been designed and the first prototype is manufactured. All components are in-hand and the firmware and software are online. Test pulses have been observed from a mini-drawer demonstrator

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For Further Reading I

F. Carrio, H. Y. Kim, P. Moreno, R. Reed, C. Sandrock, A. Shalyugin, V. Schettino, J. Souza, C. Solans, G. Usai, A. Valero, *Design of an FPGA-based embedded system for the ATLAS Tile Calorimeter front-end electronics testbench.*
JATL-TILECAL-PROC-2013-017, Nov 2013

The backup plan

- There are two version of software to perform the tests: the Java GUI and the Python scripts. The Java GUI is for Prometeo users and the Python script is for quick testing on the super read-out driver.
- The tests include:
  - I/O test: basic register read/write.
  - Charge injection (CIS) test: charge the 3- in-1 card of the mini-drawers then discharge and read out the pulse shape to test the ADC and readout
  - LED test: diagnose the whole chain from the PMTs to the reconstructed pulse shapes
  - Stuck bits test: diagnose the stuck bits in digitized data
  - DAC test: linearity check of the digitizer
  - Noise test: measure the noise and pedestal of the electronic system