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SciFi Front-End Electronics Test System

A test bench to electronics of the new scintillating fibers tracker at LHCb

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ABSTRACT: The association of small diameter scintillating optical fibers with high density SiPM photodetectors (Silicon Photon-Multipliers) enabled the development of the new generation of particle trajectory detector for the LHCb experiment. Due to replacement of the detector technology and the substantial increase in the number of channels was necessary redesign the signal acquisition electronics and, given the complexity of these circuits, a test bench to commission must be built. In this context, a CBPF group (in close collaboration with Nikhef) is designing a multi-channel pulse injector, its control peripherals and the control system to automate the test procedure of the new detector modules.

1. LHCb Experiment / CERN

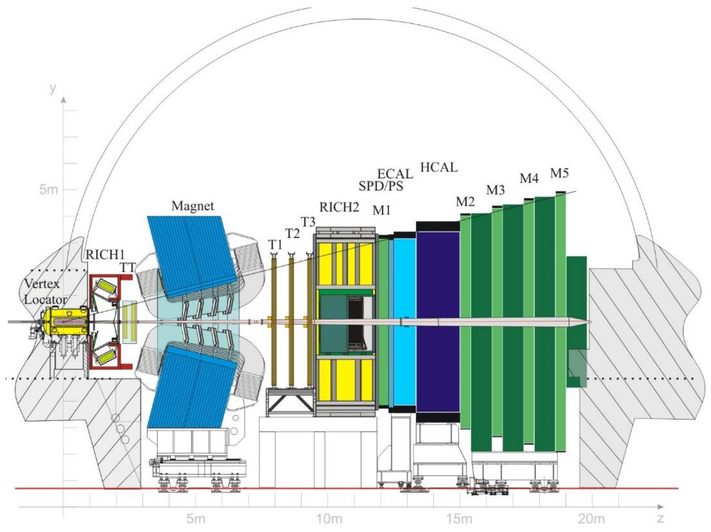

Fig. 1 – LHCb Experiment

ACTUAL

Inner tracker (silicon detector)
↳ Δp/p = 70 μm
Outer tracker (straw tube gas detector)
↳ Δp/p = 250 μm
Physics measurements limited at 1MHz by L0 trigger

2. LHCb Upgrade
SciFi: The new Tracker System

The upgrade of the LHCb detector will **extend the physics reach** of the experiment by allowing it to run with the higher luminosity provided by HL-LHC (High Luminosity LHC)

New tracker requirements:
- **Faster**: To increase measurements from 1MHz to 40MHz;
- **Lighter**: Minimum interaction with particles;
- **Precise**: At least same **resolution** of actual inner tracker (Higher luminosity = Increase of simultaneous tracks)
- **Radiation-proof**: Extend acceptance closer to the beam line

Detector elements:
- **SciFi** – Scintillating Fibers with 250μm of diameter;
- **SiPM** – Silicon Photo Multiplier

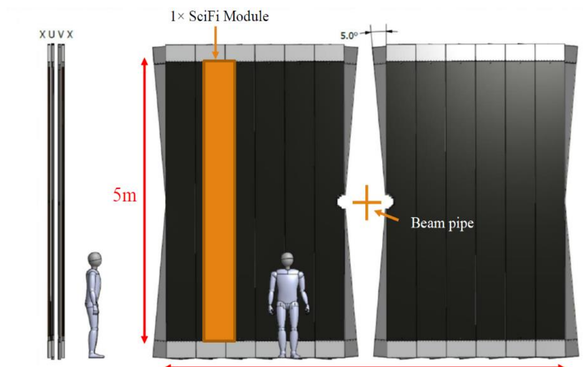

Fig. 2 – SciFi Tracker mechanical assembly

New Front-End Electronics:
- ~ **200 modules** (2048 channels each) in production
- **40MHz** trigger at FE electronics.
- Modular design:
  - Master Board (**power** distribution, data **TX/RX**, **control**)
  - Clusterization Board (make clusters to **optimize** data paths)
  - Pacific Board (**readout** ASIC: preamp, shaper, digitization)

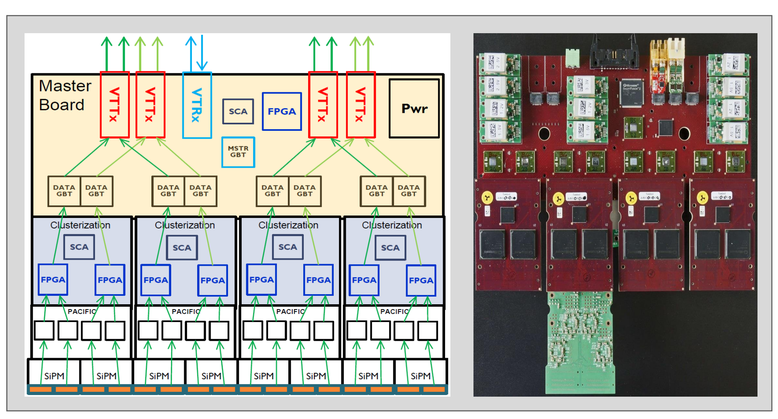

Fig. 3 – New Front-End Electronics

3. The Test Bench – Injector and MiniDAQ

The test bench that is being developed will have an automated control system and will be able to perform this tasks:
- Identify defective and noisy channels, as well crosstalk and phase difference between channels;
- Verify the functionality of the PACIFIC Chip like as uniformity of the gain threshold features, control DAQ of SiPM voltage, base line of shaper and pole-zero cancellation;
- Verify the integrity of an emulated physics measurement through the injection of a charge equivalent to that generated by photomultiplier when excited by real physical measurements.

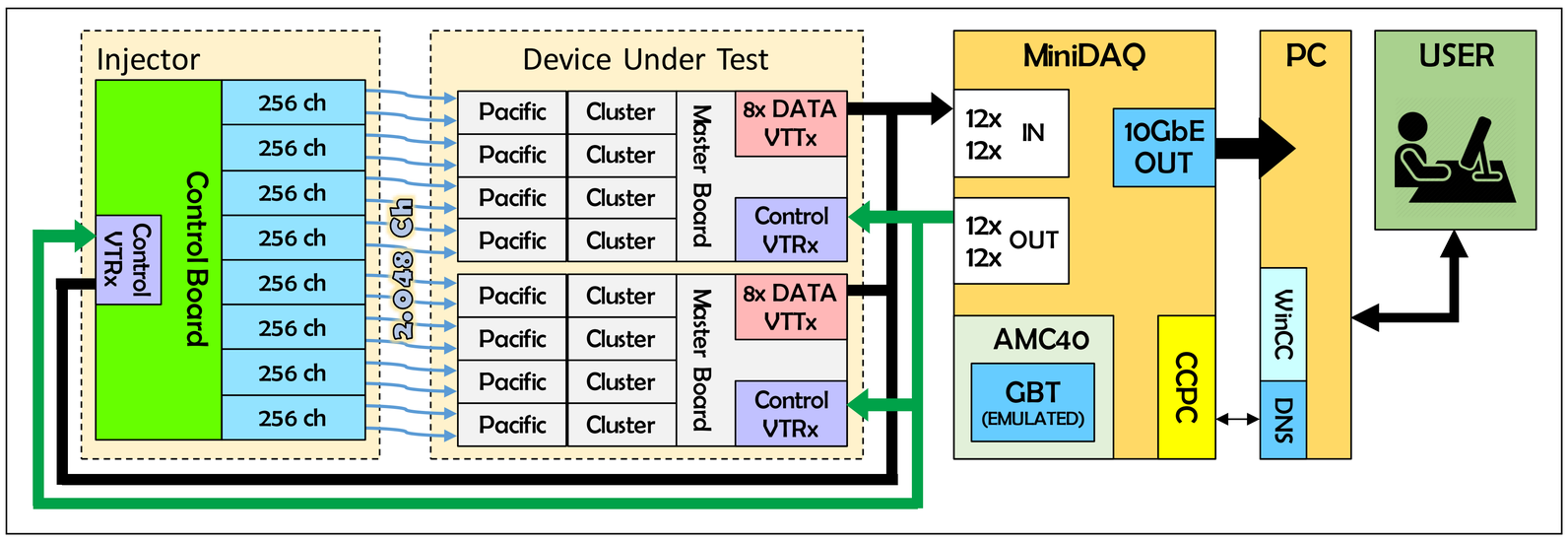

Fig. 4 – Test system – Block Diagram

3.1. Injector

A *Charge Injector Board* was designed to provide **2048** analog output channels with **individually** customizable pulse shapes in order to make the test, characterization and commissioning of all readout boxes which were manufactured for LHCb tracking system upgrade. Although its development has been motivated for this specific purpose, several design features offer a high level of customization and allow this device to be used for other purposes in the future.

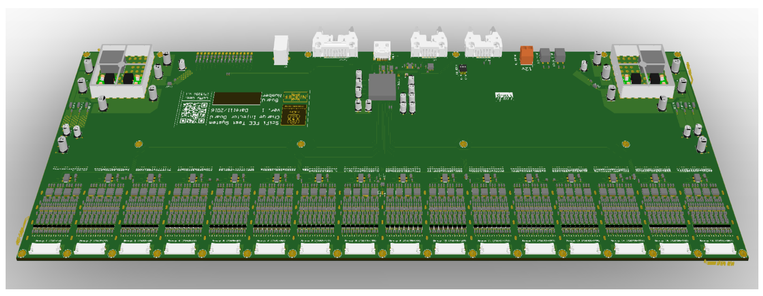

Fig. 5 – 3D view of Injector Board PCB

Due to number of outputs we are building 8 Injector Boards with 256 channels each. A Control Board provides interconnection between Injector Boards and the control system (MiniDAQ).

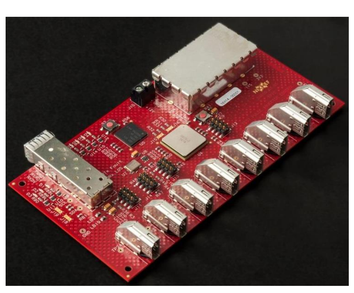

Fig. 6 – Control board

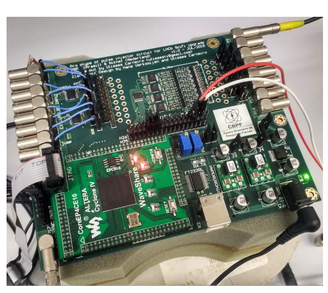

Fig. 7 – Prototype

A 16-channel prototype built to validate the conceptual design of the injector was successfully tested when directly connected to the PACIFIC chip. The 2048-channel injector is now in production and expected to be ready in Q3'2017.

MAIN CHALLENGES

- Timing tune: Output of 2048 analog pulses in sync and low jitter (tolerance < 1 ns)
- Parameters to control: Amplitude, width and phase of 2048 channels under automatic control to perform a full and quick evaluation on all FEE circuits;
- Large form factor: 50 cm wide PCB to connect a full readout box at once = Track Lengths up to 35cm

3.2. MiniDAQ

To establish communication between charge injector, all front-end boards and computer running the automated test control algorithm, we are using a MiniDAQ, which is an autonomous data acquisition platform developed by the Center for Particle Physics of Marseille (CPPM), initially intended to be used as back-end electronics of LHCb. MiniDAQ main specifications:
- 24x in/out Optical GBT Links (4.8Gbps)
- 12x in/out 10Gb Ethernet
- CCPC (1.6GHz) running Scientific Linux

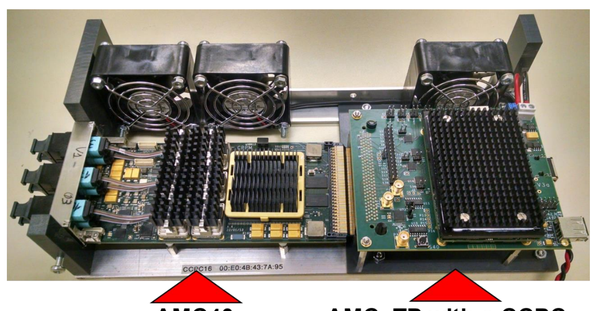

Fig. 8 - MiniDAQ

The FPGA of MiniDAQ has been programmed to emulate the functionality of GBTX specifications. The GBTX is a radiation tolerant chip that is being used to implement multipurpose high speed (4.48 Gb/s user bandwidth) bidirectional optical links between back-end and front-end electronics in the LHCb tracker upgrade. In this test bench GBTX links are being used both for readout of electronics under test and for control of the charge injector.

Fig. 9 - CCPC

4. Conclusion

The injector prototype test reached our expectations. We are able to inject at the input of the PACIFIC chip the amount of charge required to test its operation, and vary this amount in sufficiently small steps in order to observe its dynamic response. A full platform able to evaluate in a short time all of about 200 electronic modules of the new tracker can't be assembled using common devices that can be found on the market. Therefore, we are developing the hardware and software to achieve this goal.