Trenz-based test systems in CMS HGCAL

SoC Interest Group Meeting

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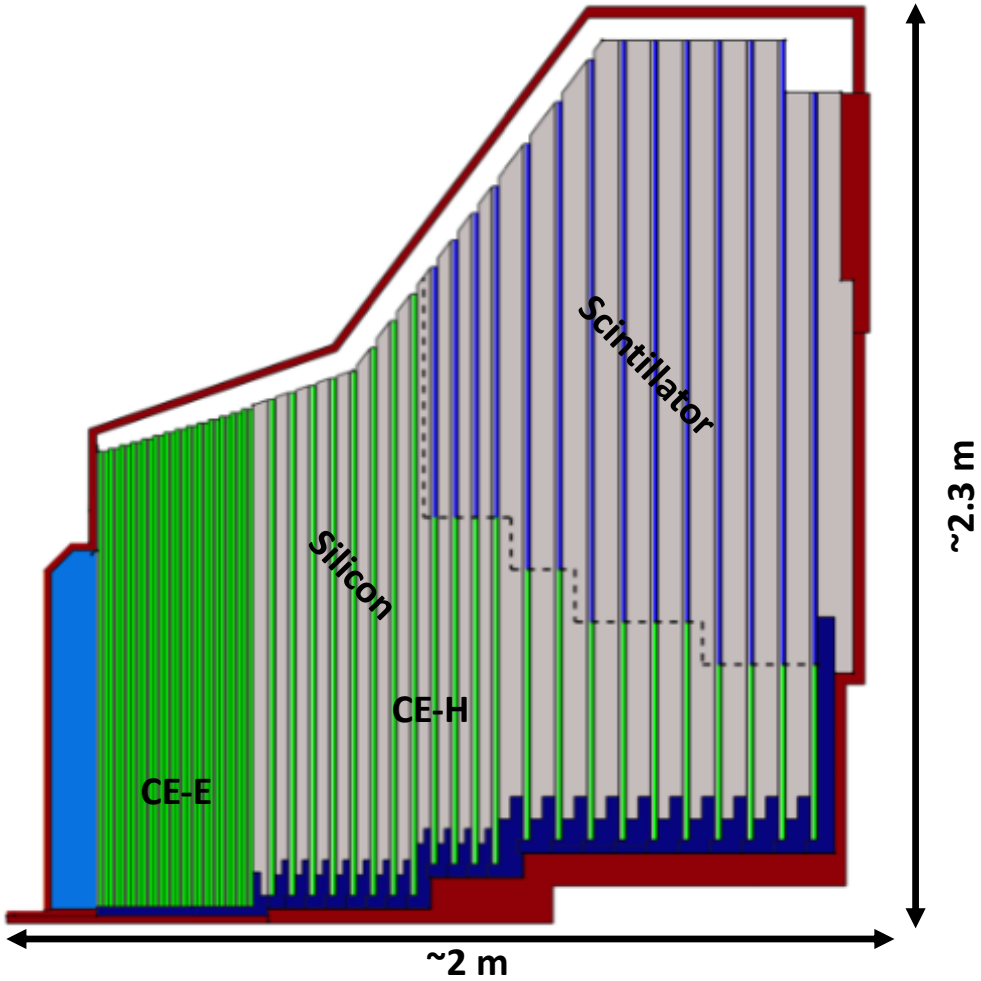
February 16, 2021

CMS HGCAL for phase 2

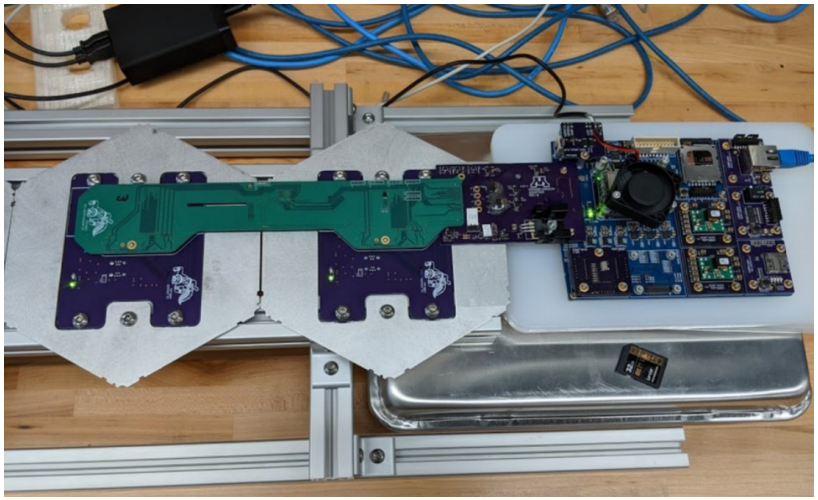


Electromagnetic calorimeter (C**E-E**): **Si**, Cu/CuW/Pb absorbers, 28 layers, 25.5 X_0 & ~1.7 λ

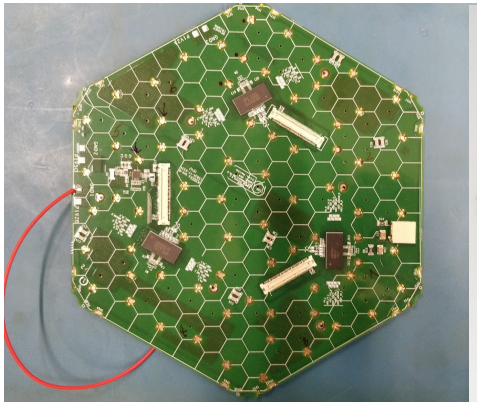
Hadronic calorimeter (**CE-H**): **Si** & **scintillator**, steel absorbers, 22 layers, ~9.5 λ

FE hardware to test in CMS HGCAL

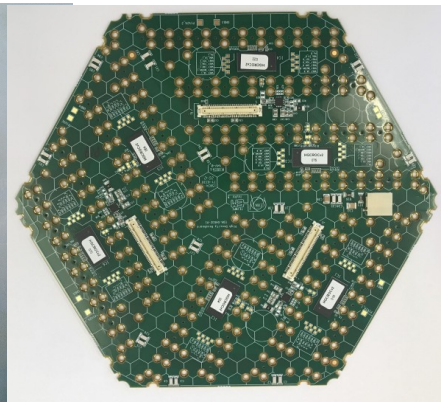
- HGCAL needs test systems to test the quality of many individual components:
  - ≈ 100k HGCROCs (the readout chip)
  - ≈ 25k Si-Modules (and their hexaboard PCB) with 3 ot 6 HGCROCs
  - ≈ 4k Tileboards
  - ECONs : ≈ 2 per module
  - Mother boards (engines and wagons)



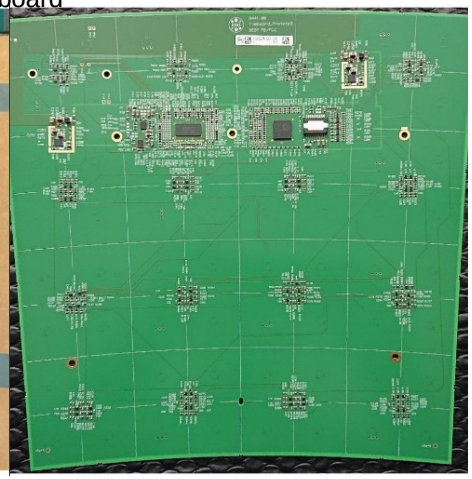
LD Si-module



HD Hexaboard

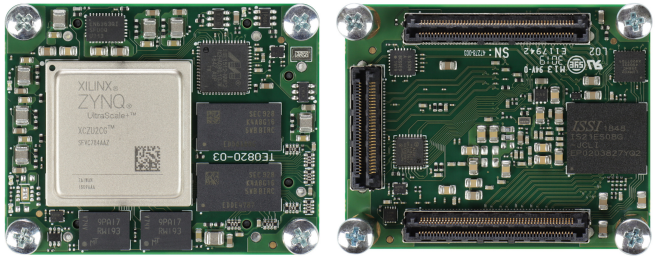


Tile board

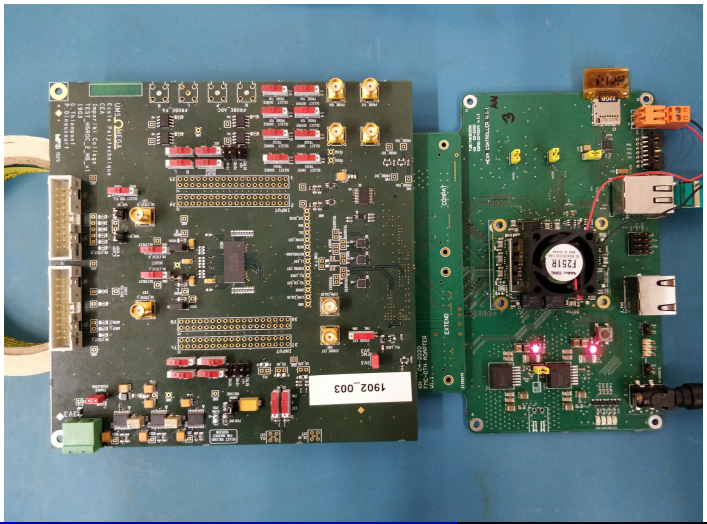


Trenz-based test systems in CMS HGCAL

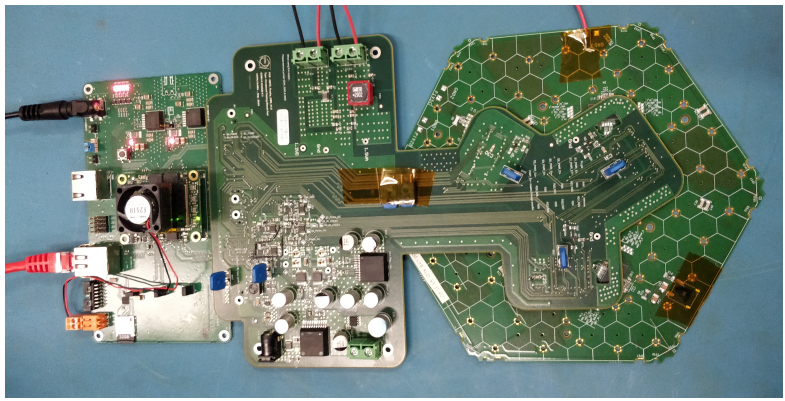
- Test systems based on Trenz module
  - Trenz module in HGCAL : TE0820



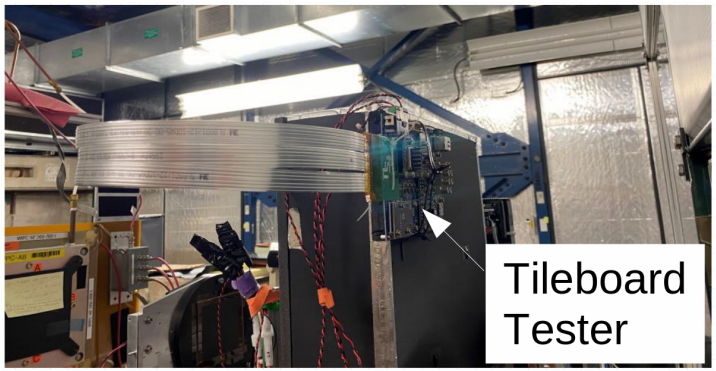
  - Common architecture for single ROC, hexaboard and tileboard tester → same firmware IPs, same software
- Current test systems in HGCAL:
  - Single ROC tester (tested ≈ 200 ROCs → will test ≈ 300 more in few weeks)



- Current test systems in HGCAL:
  - Single Hexaboard test system (tested about 50 boards → 50 more in 2 months)

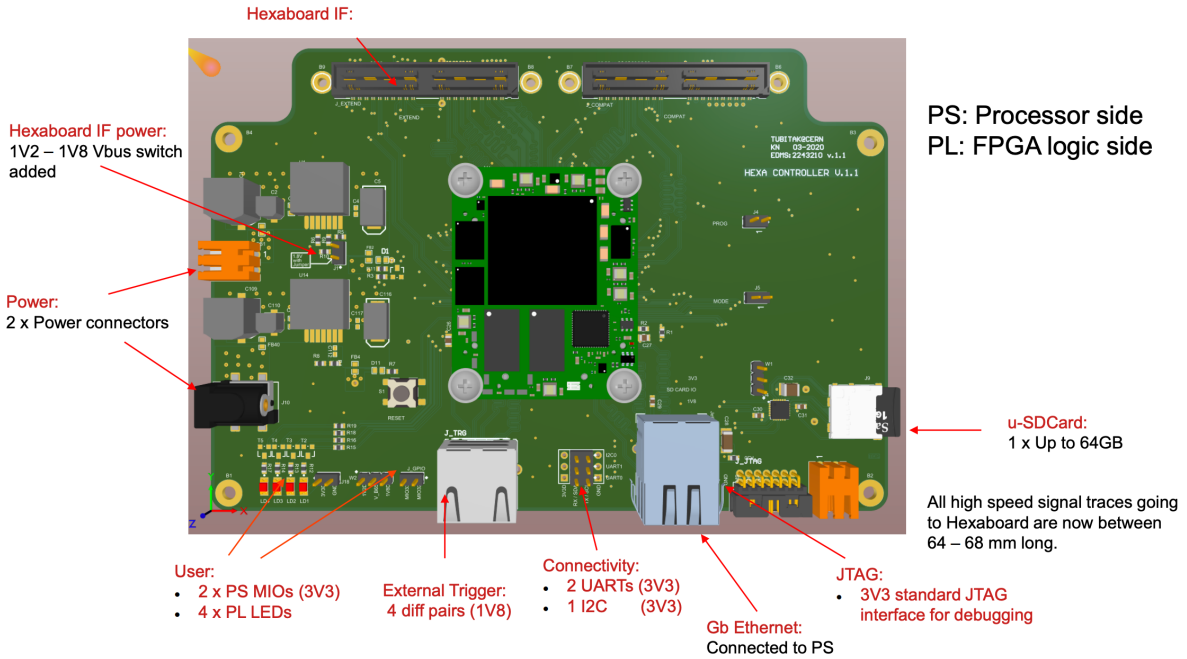


  - TB tester (during a beam test at FNAL)



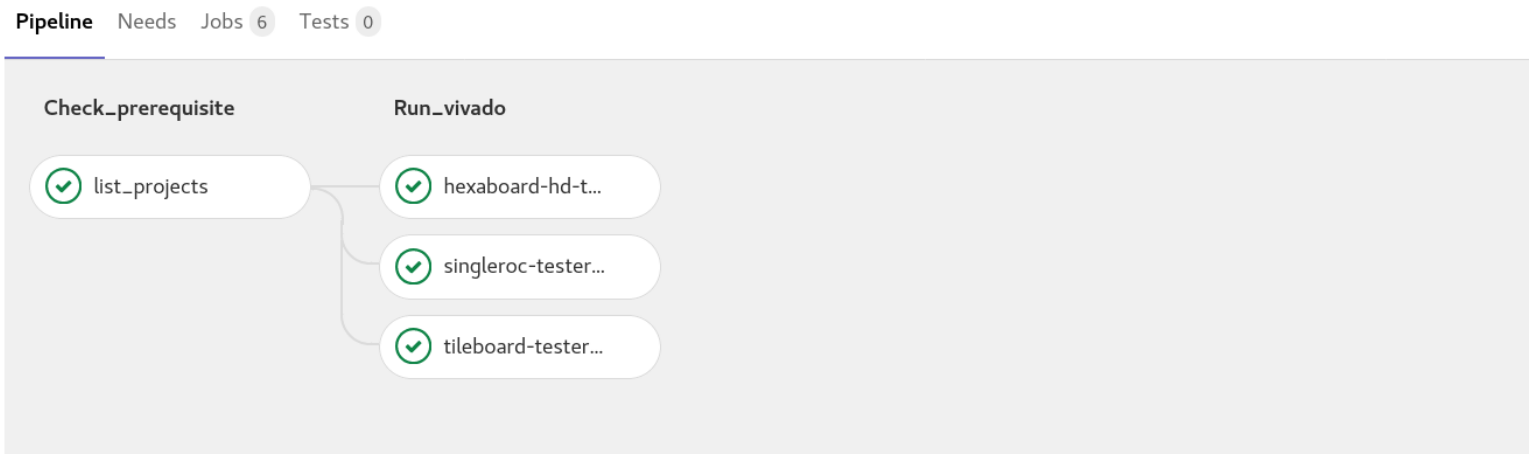
Our trenz based system

- TE0820 module in HGCAL tester:
  - Run a centos 7 image → very convenient for SW development
  - Xilinx IPs:
    - ★ I2C for ROC configuration + ADC (ROC power consumption, DC levels) readout on the "trophy" board
    - ★ GPIO
    - ★ (CDMA testing)
  - Drivers: uio for all non-Xilinx IPs → AXI registers/FIFOs accessible in **/dev/uioX**
  - TE0820 has MAC address EEPROM. Value available to uboot and linux.
- The hexa-controller board:



Our trenz based system

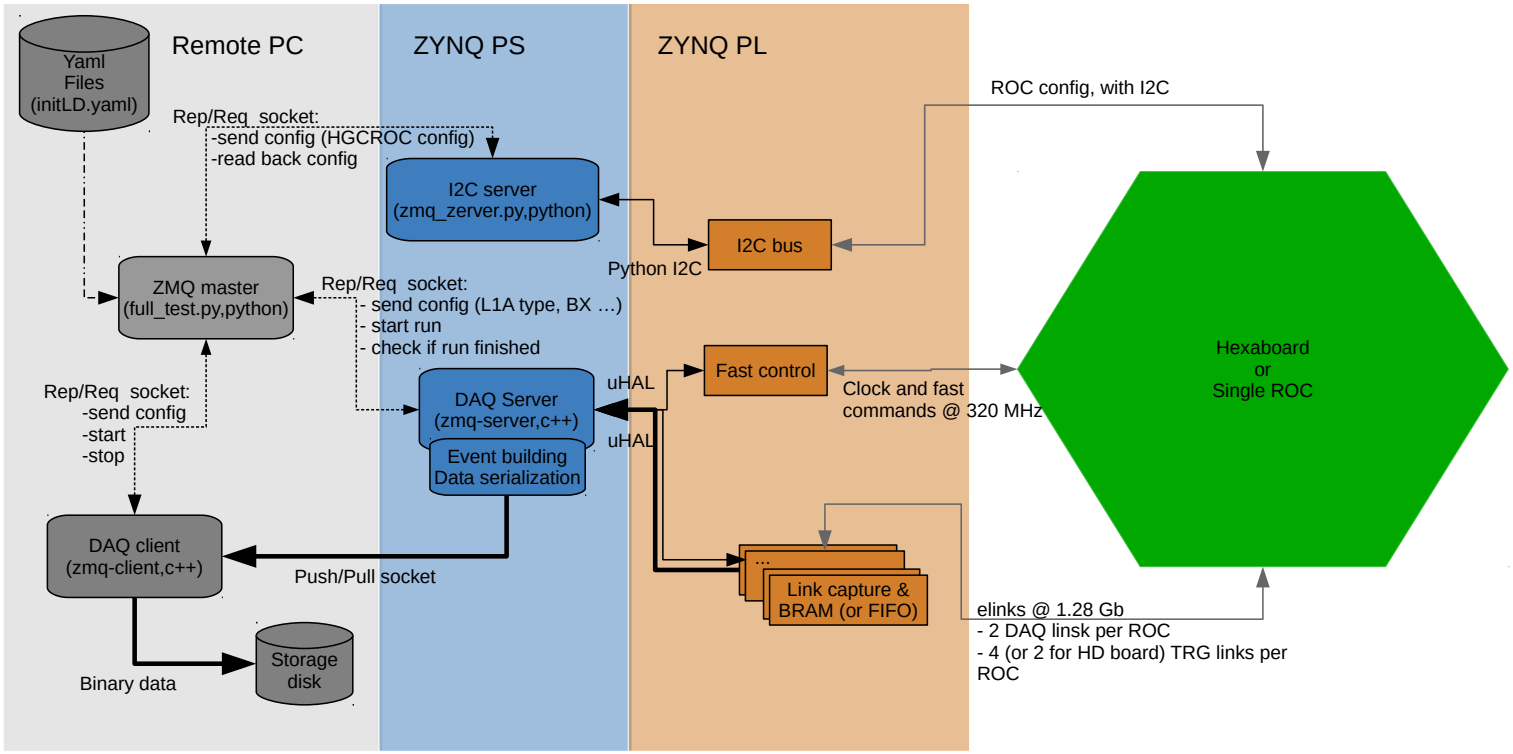
- Firmware .bit and device tree files prepared by gitlab CI/CD for our three designs.



  - Vivado 2019.2 docker in dedicated runner
  - Labels added to the device tree to map UIO devices, I2C buses, GPIO lines
  - Firmware loaded using custom **Makefile**:
    - ★ creates .dtbo from .dtsi files
    - ★ loads the FW using the xilinx **fpgautil** tool : link
    - ★ Link to mylittledt.
  - Firmware can be reloaded without rebooting:
    - ★ when changing the DUT
    - ★ very convenient for debugging
  - Plan to add the .dtbo creation inside our gitlab CI process

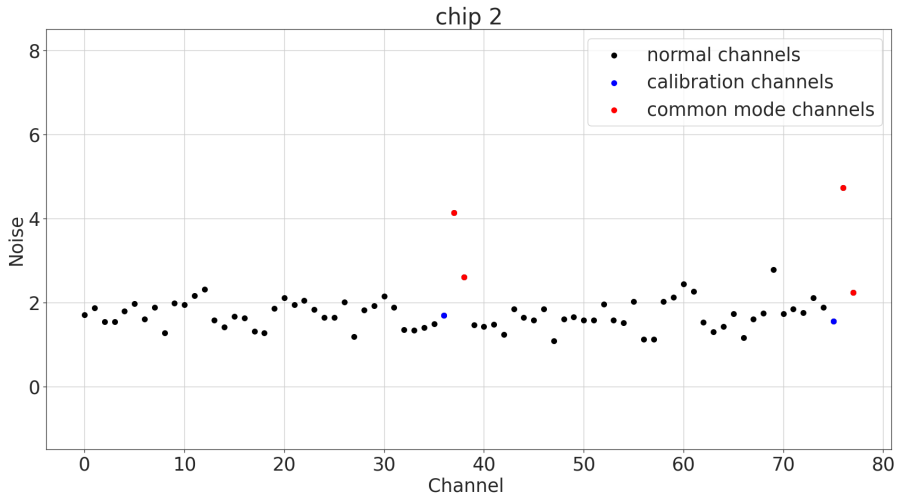
DAQ overview

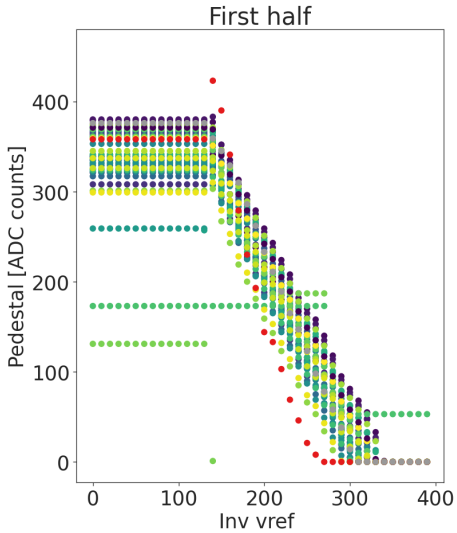
- Using an extended uhal library to memory map the AXI registers and read the FIFOs : Dan Gastler's presentation. We added:
  - Interrupt signal handler
  - "Non-incremental" block read (to read FIFOs)
- Synchronization of the software by using zmq library https://zeromq.org/

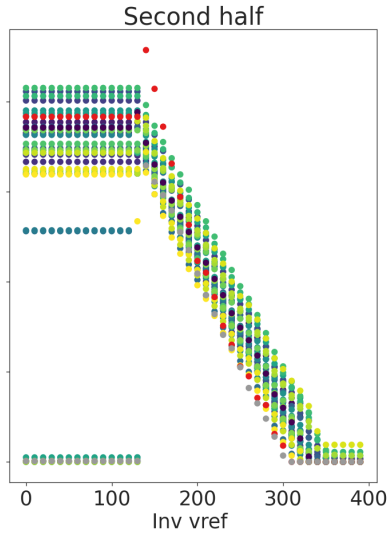


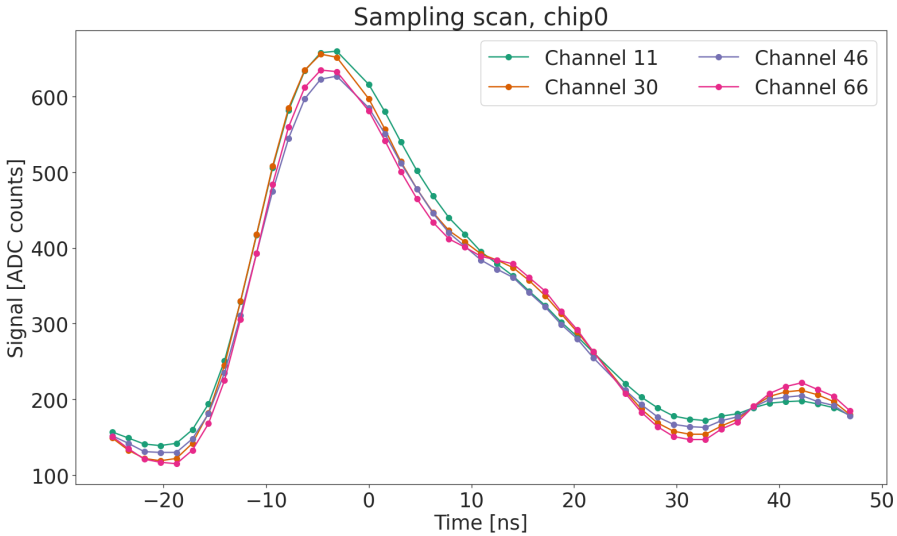
- No direct I2C for the tileboard:
  - A GBT-SCA is used to configured the ROCS
  - Interface between GBT-SCA and SW using the same "AXI-over-uio-over-uhal"

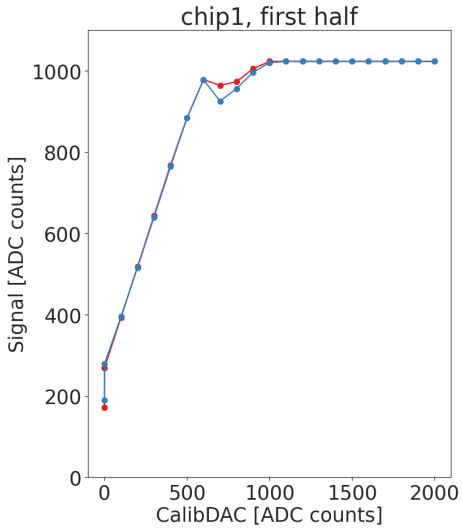
Test system output

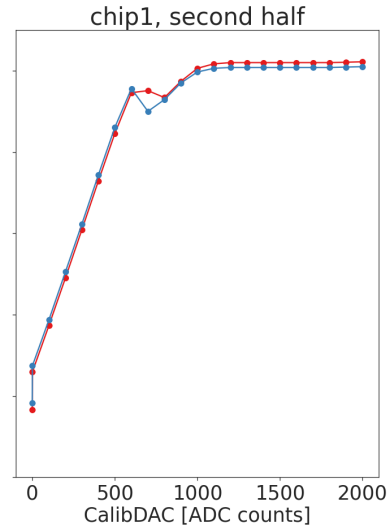






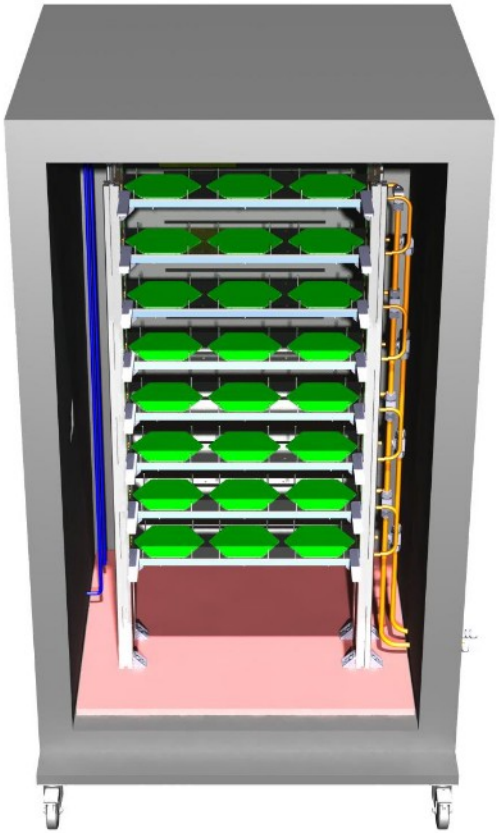


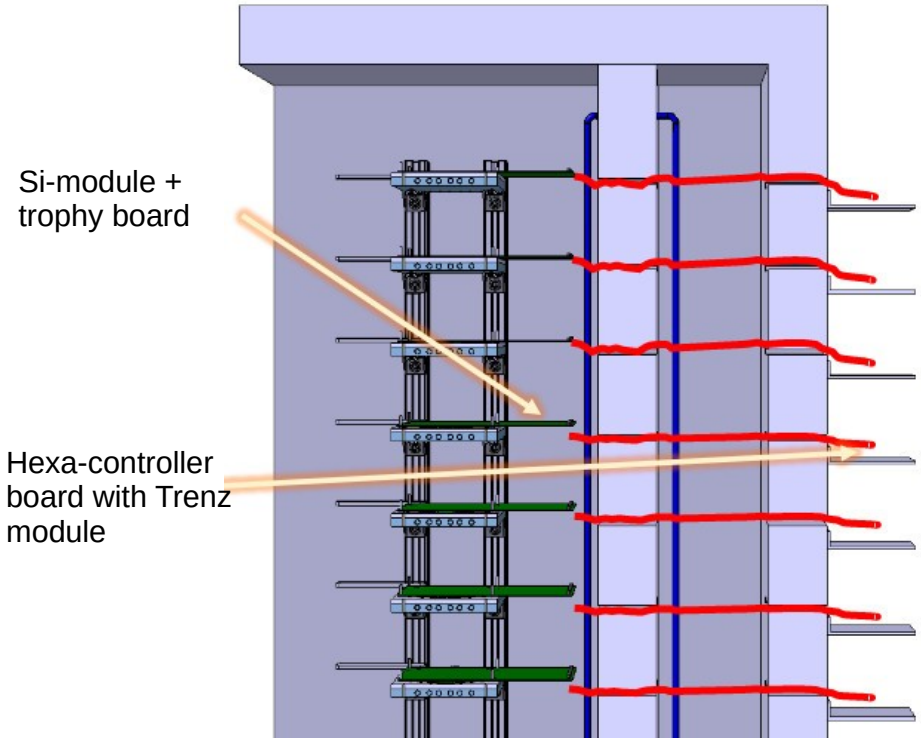




Future multi-module test system

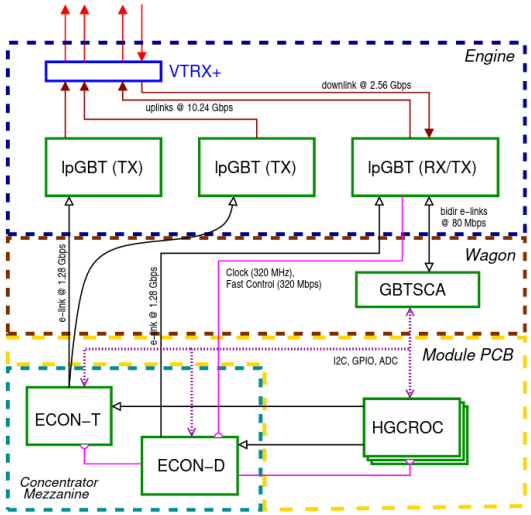
- Si-modules will be tested inside a cold box ($\approx$ -30°C) after assembly

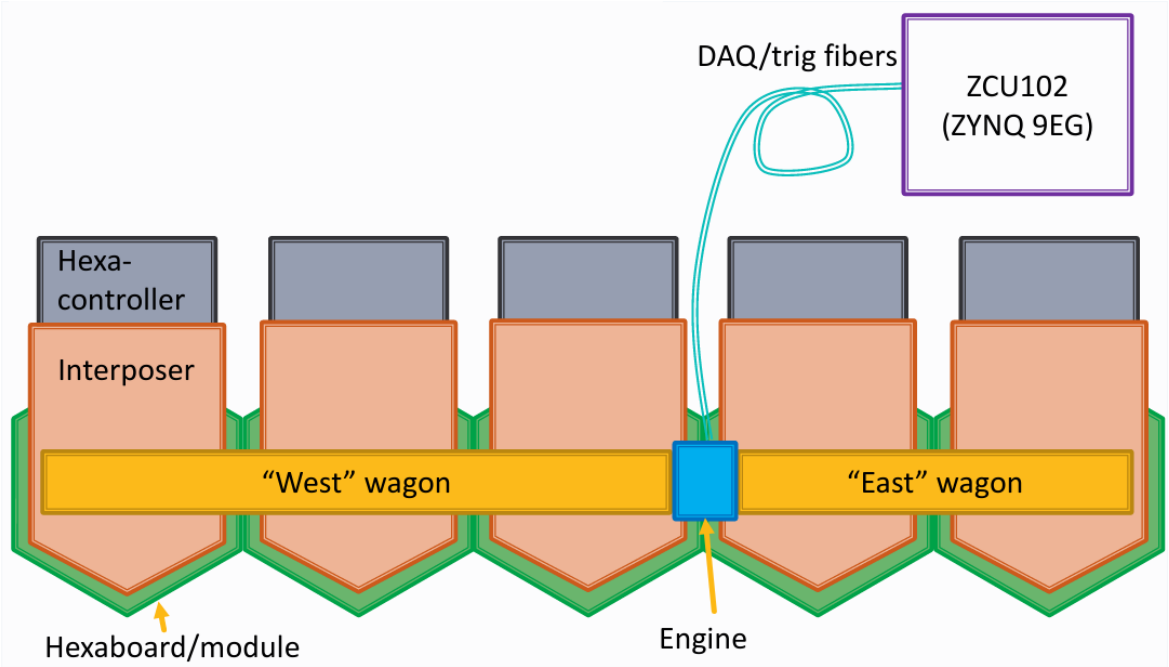




"V2" test system

- HGCAL communication chain : ROCs → ECONs → lpGBTs → BE
- "V2" test system : first system with full communication chain ("V2" ↔ 2nd version of the HGCROC):
  - ECONs not yet available (ECON-T design review was Feb 03)
  - ECONs emulated in the ZYNQ of hexa-controller boards





Summary

- CMS-HGCAL test systems started to use test board with Trenz module about 1 year ago
  - Trenz based test systems used for several plateforms (single ROC, hexaboards or Si-modules and tileboard/tilemodule).
  - All test systems use the same (or almost the same) firmware and software
- Test systems are now being distributed to Si-module and tile-module assembly centers (Germany, Taiwan, US).
- Knowledge on the Trenz is being useful for the "V2" test system:
  - Hexa-controller will be used as ECON chip emulators
  - FW and SW developped for the hexa-controller board and the tiler board testers will be recycled with the ZCU.
- Future multi-module tester plans to use the hexa-controller boards.
- Links to our gitlab repos (Access may need to be requested):
  - firmware repo.
  - software repo.

Back-Up