CMS HCAL Front-End Electronics

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CMS HCAL Phase 1 Upgrade: HE Front End Electronics

- Motivation for the HCAL Phase 1 Upgrade
- Commitment and current status
- Future plans
- Summary

Motivation for CMS HCAL Phase 1 upgrade

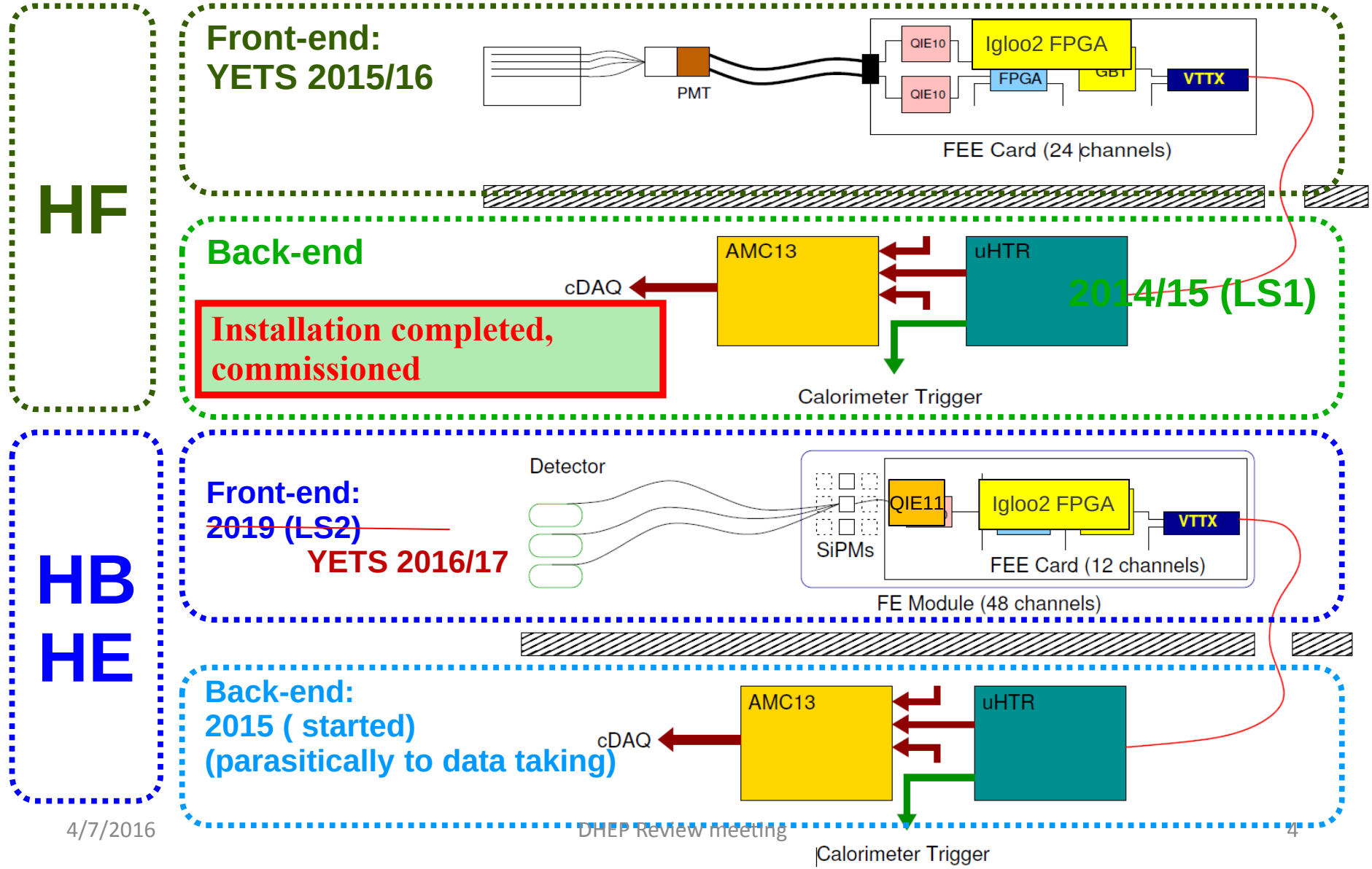
Early phase of LHC operation revealed considerable radiation damage of HCAL

- Mitigation through multiple ways within existing constraints.
- Improved photodetectors, new front-end electronics (including TDC) and new back-end electronics (μTCA)

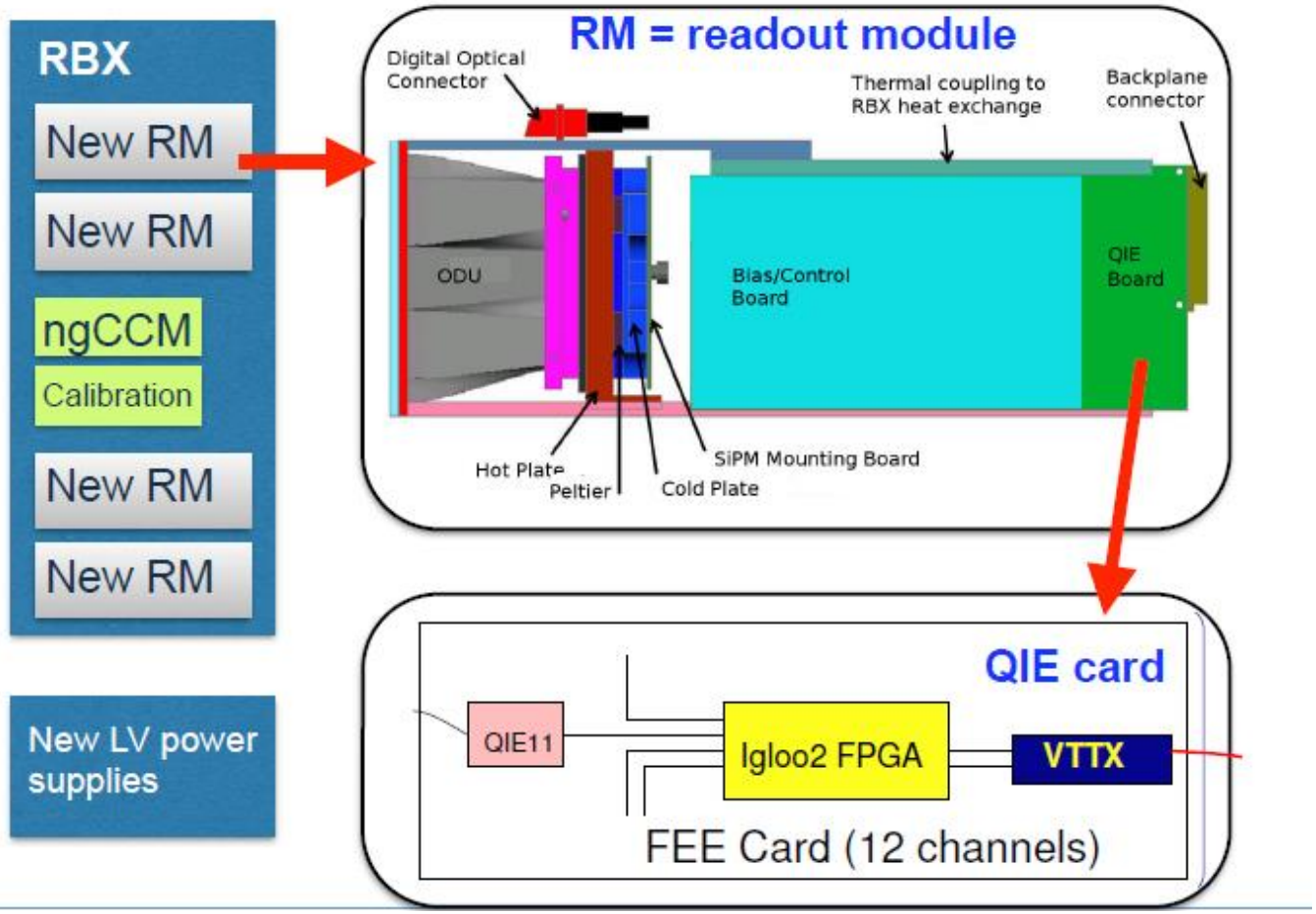
- HCAL electronics upgrade is one of the major phase-I upgrades for CMS
  → Being carried out in a continuous fashion since 2013.
- Font-end electronics for Endcap and Barrel regions to be replaced during 2016- 18.
  TIFR responsibility spelt out in CMS TDR CERN-LHCC-2012-015.
- Improve energy resolution by exploiting finer depth segmentation

Frontend electronics replacement schedule for HE advanced than originally planned.
Installation planned in EYTS of 2016-17

HCAL electronics upgrade timeline



HE Front End Electronics



Commitment from EHEP, TIFR

Calibration Units (CU) for HE and HB FEE

- ~50 CU and 188 SiPM control boards,188 BV Converter boards for HE is highest priority in next one year and first batch by May end at CERN

- **Each Calibration Unit has :**
  - 1 pulser board(6 layer board with Microsemi FPGA)
  - 6 pin diode boards(2 layer)
  - 1 pin diode board mounting plate in derlin(TIFR workshop)
  - 1 QIE Adapter board (2 layer) with special connector components
  - 2 LED brass mounting holders(TIFR Workshop)
  - 1 CU Aluminum Casing (with 17 parts)

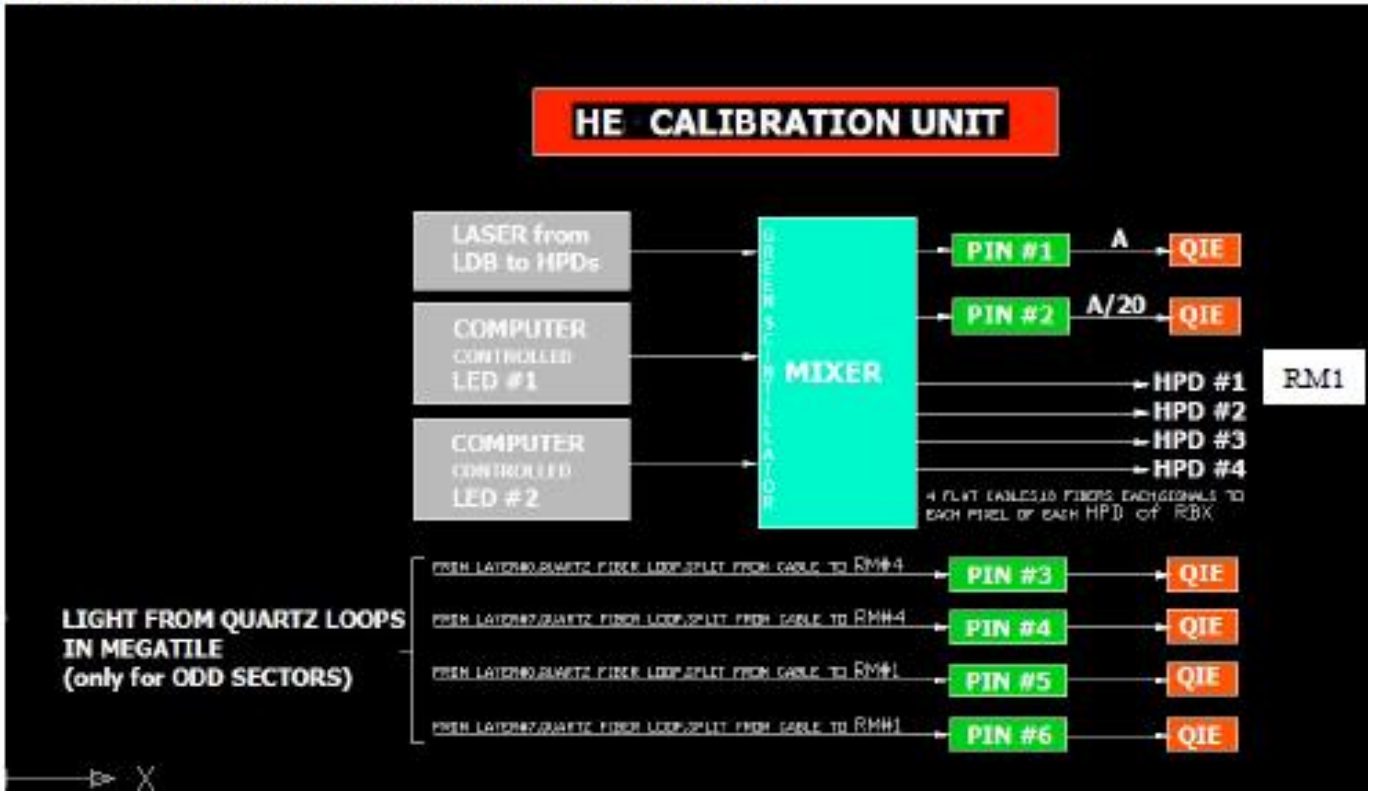
Total Work load at TIFR …

- **Total workload here at TIFR includes:**
  - Fabricate and test 50 pulser boards
  - Fabricate and test 6x50= 300 pin diode boards
  - Fabricate and test the 50 QIE Adapter boards
  - Make LED 100 brass holders
  - Make 50 plates for holding pin diode boards
  - 50 Aluminum CU boxes in TIFR central workshop
  - SiPM Control,BV Boards for HE HB Front End
    - Fabricate and test 188 SiPM control boards
    - Fabricate and test 188 BV converter boards

HE calibration unit

Calibration unit

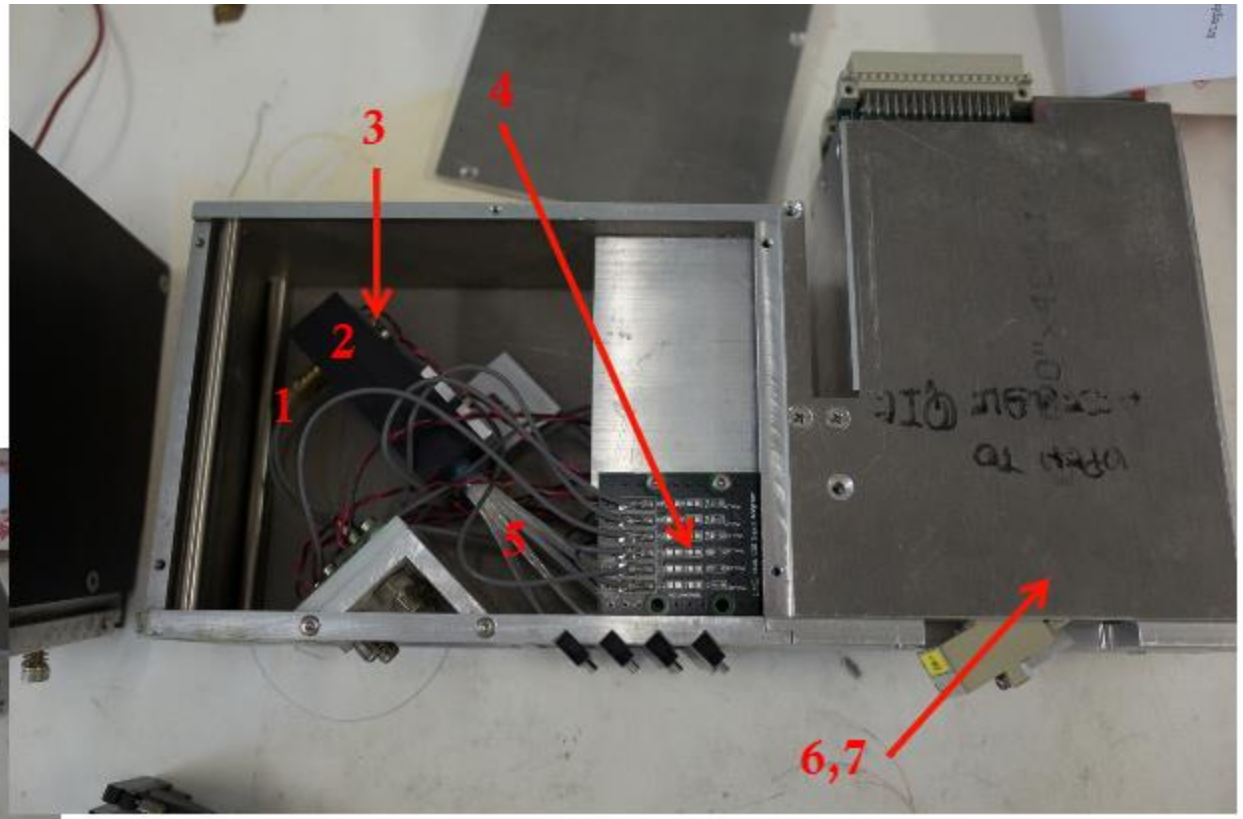
- Delivers computer controlled LED light to photodetectors
- Delivers Laser light from USC to photodetectors
- Reads out laser signal from megatile+quatz fibers



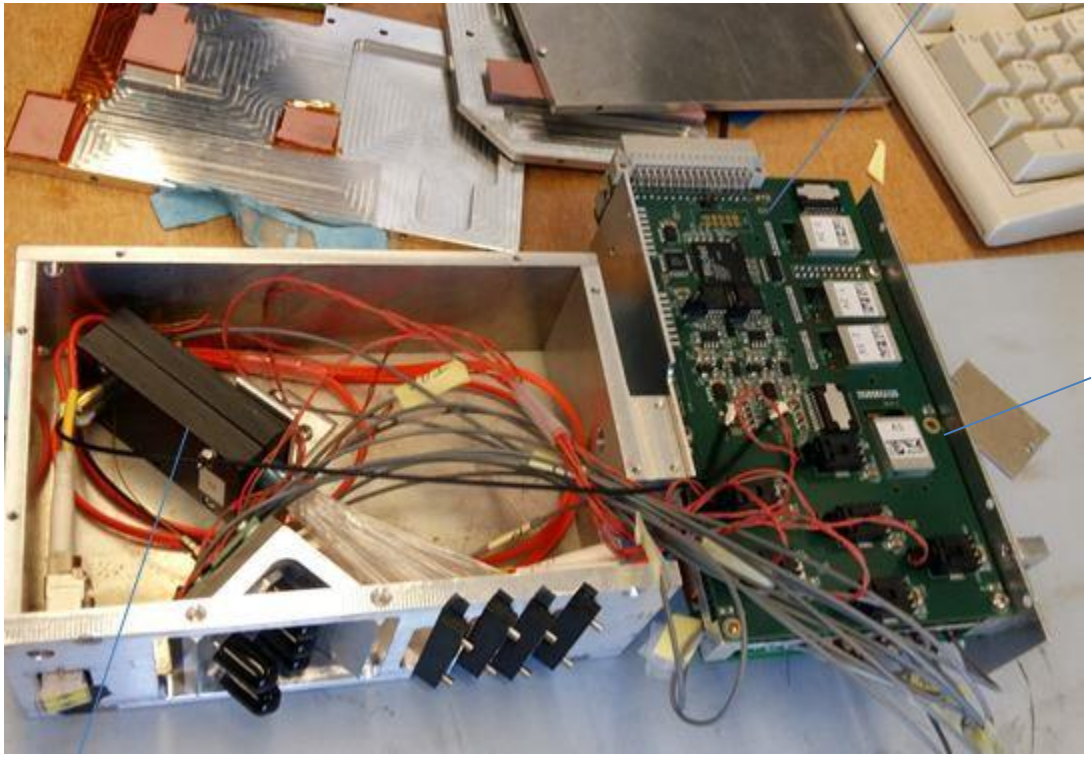
Overview of the HE Calibration unit

Main components

- LED (1)
- Light mixer (2)
- Pin diodes (3)
- QIE Adapter Card (4)
- Fibers (5)
- Pulser board (6)
- QIE card (7)



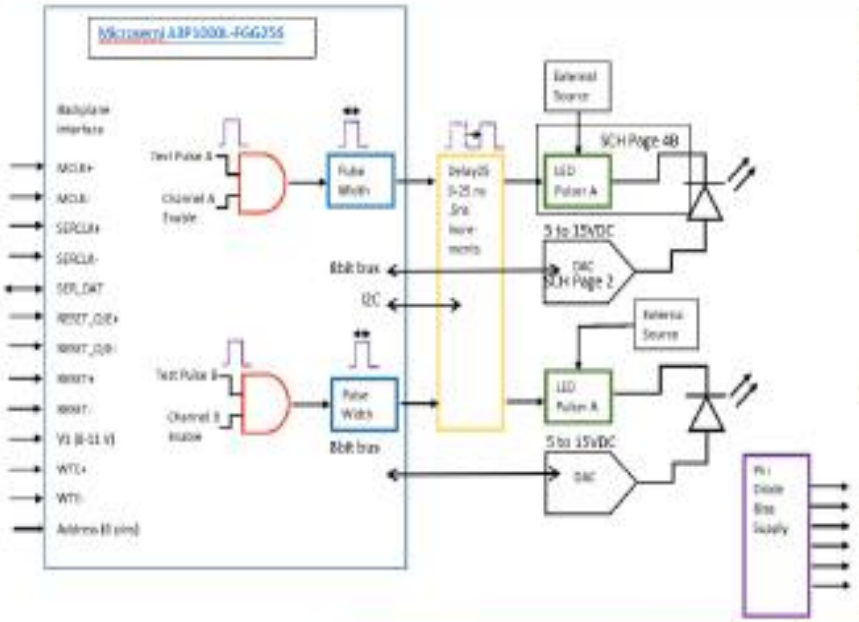
Components of the Calibration Unit



Pulser Board

Light mixer box

CU Electronic boards



Pulser Board

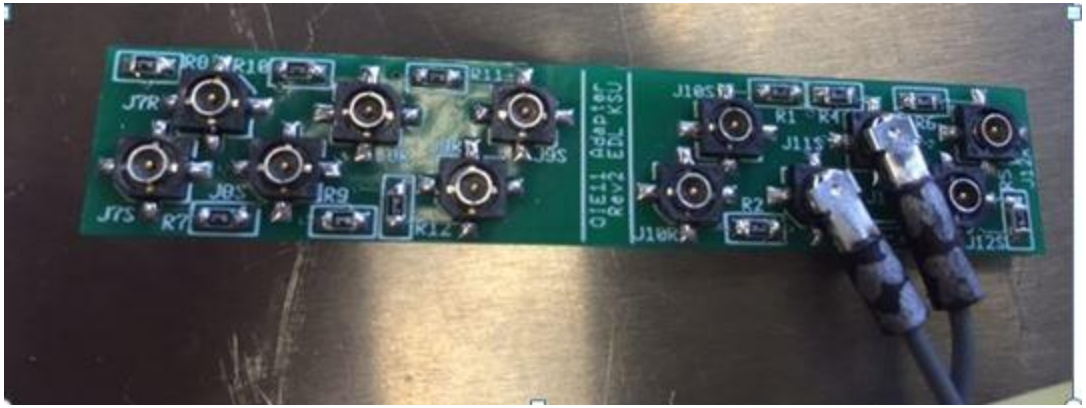
- Full communication with backplane programmable with FPGA
  - Microsemi A3P1000L-FGG256 FPG
- Two independent LED channels for coincident and time delayed pulses
  - CERN Delay25 chip for delaying pulses
- DAC output to adjust LED pulse width, amplitude, delay
- Better control adds ability to fire LED during orbit gap
- Powering QIE11 board
- Power pin-diodes

QIE Adapter Card is designed to deliver pin-diode signal to QIE Card

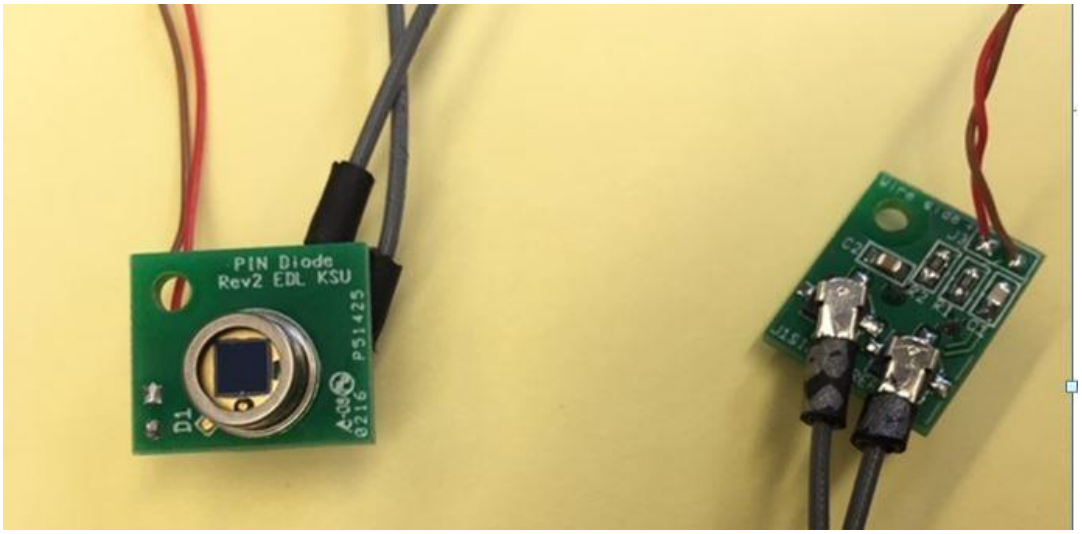
Pin-diode cards are interface to voltage supply connectors

Pin-diode

QIE Adapter and pin diode boards



QIE Adaptor Board



Pin diode board

Current work and status

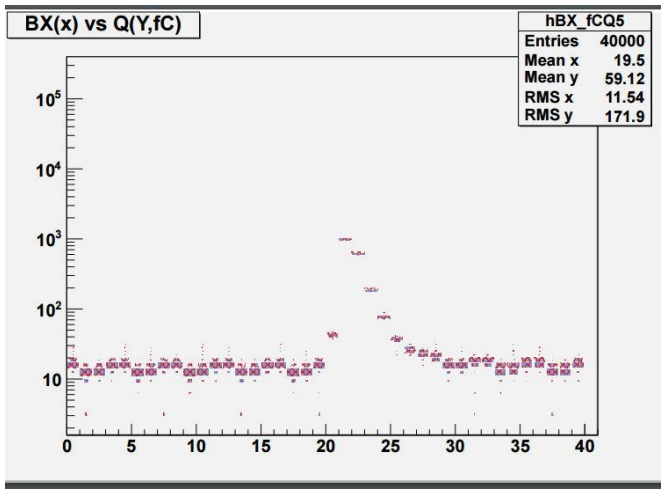
- **Testing of the 4 prototype pulser boards**
  - Tested successfully one prototype pulser boards (fabricated in Bangalore) here at TIFR
  - Tested 1 more prototype pulser board at Fermilab with the full test stand and QIE cards integrated into the Calibration Unit with lot of design iterations going on and on the spot changes on board modifications implemented then and there and tested there successfully
  - Data from the LED calibration using TIFR Pulser boards being analyzed and reported

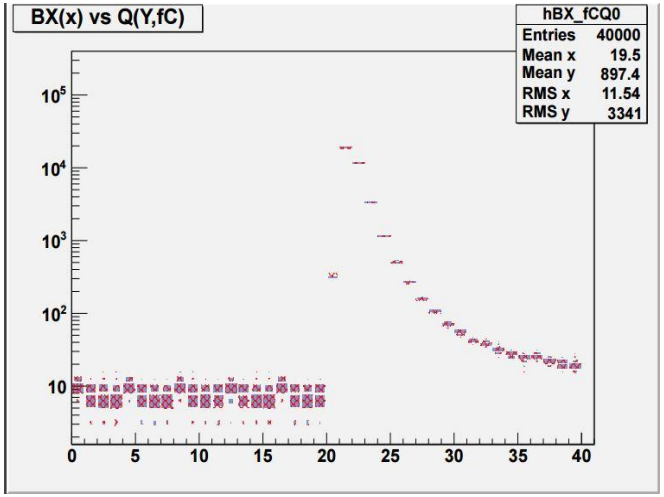
- **Testing of the pin diode board at Fermilab:**
  - Tested the pin diode board and did troubleshooting of the cause of the noisy pedestal
  - The modified pin diode board design was tested successfully for the updated capacitor with the noisy pedestal eliminated was confirmed with data taken

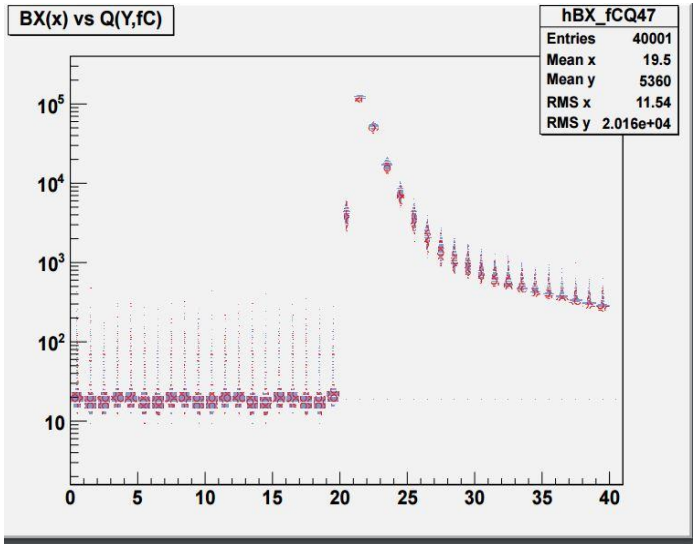
- **Setup a standalone test stand for testing the 50 pulser boards**
  - This involves integrating the CCM Emulator, the backplane ,the firmware uploading to the pulser board FPGA, LEDS, the pin diode board, light mixer and optics assembly
  - I2C interfacing and LED ON/OFF and controls being done using Raspberry Pi
  - With no QIE board just now, we will initially check the LED glow and then see at the pin diode output signal on the scope

Pulser Board test results

Pin diode signals with LED light

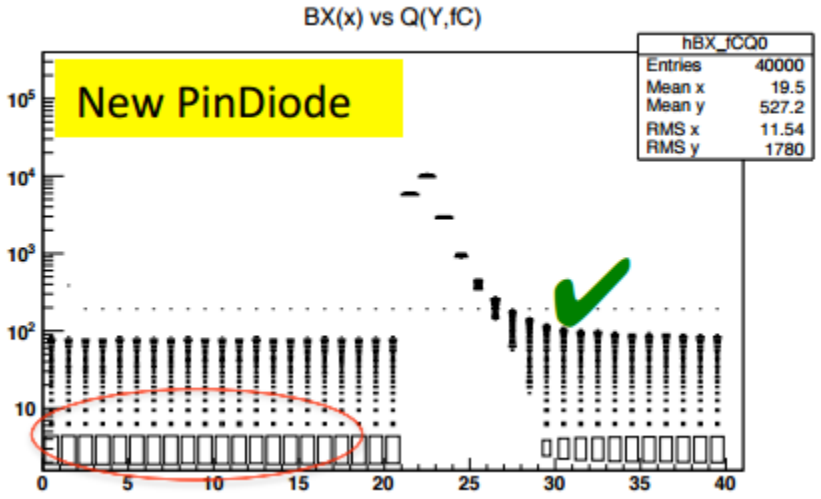






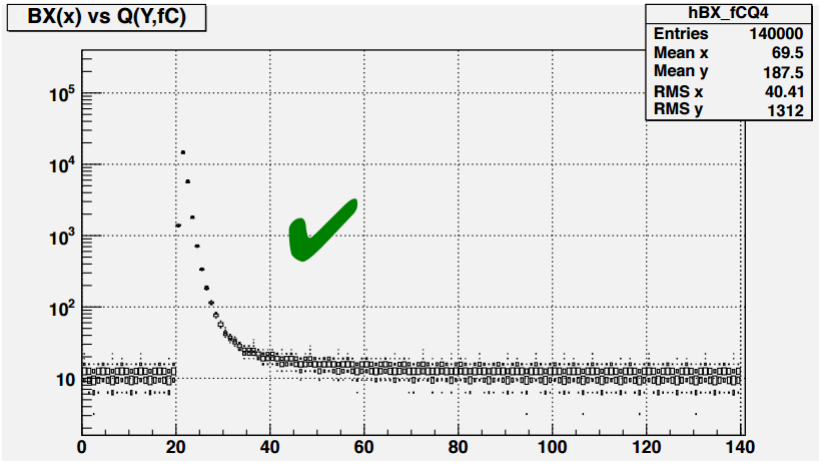
← **SiPM signal with LED light**

PIN Diode signals



← Before Modification

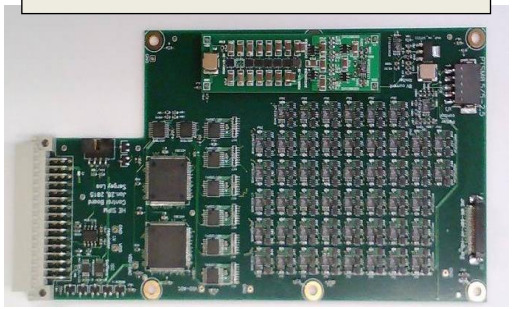
After Modification →



HE-SiPM electronics upgrade

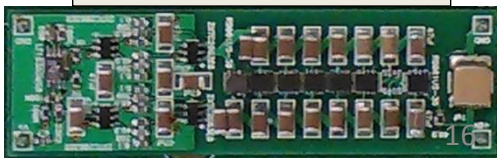
- SiPMs are replacing HPDs as photo sensors → advantages:
  - Immunity to magnetic field
  - Better light detection efficiency
  - Better signal to noise ratio
  - Lower operating voltage
- Additional infrastructure needed for SiPM operation:
  - Accurate voltage control
  - Cooling and temperature monitoring
- SiPM Control board
  - Generates bias voltages for SiPMs
  - Performs additional control and monitoring
- BV Converter board
  - Generates bulk BV from RBX backplane power

HE SiPM Control Board



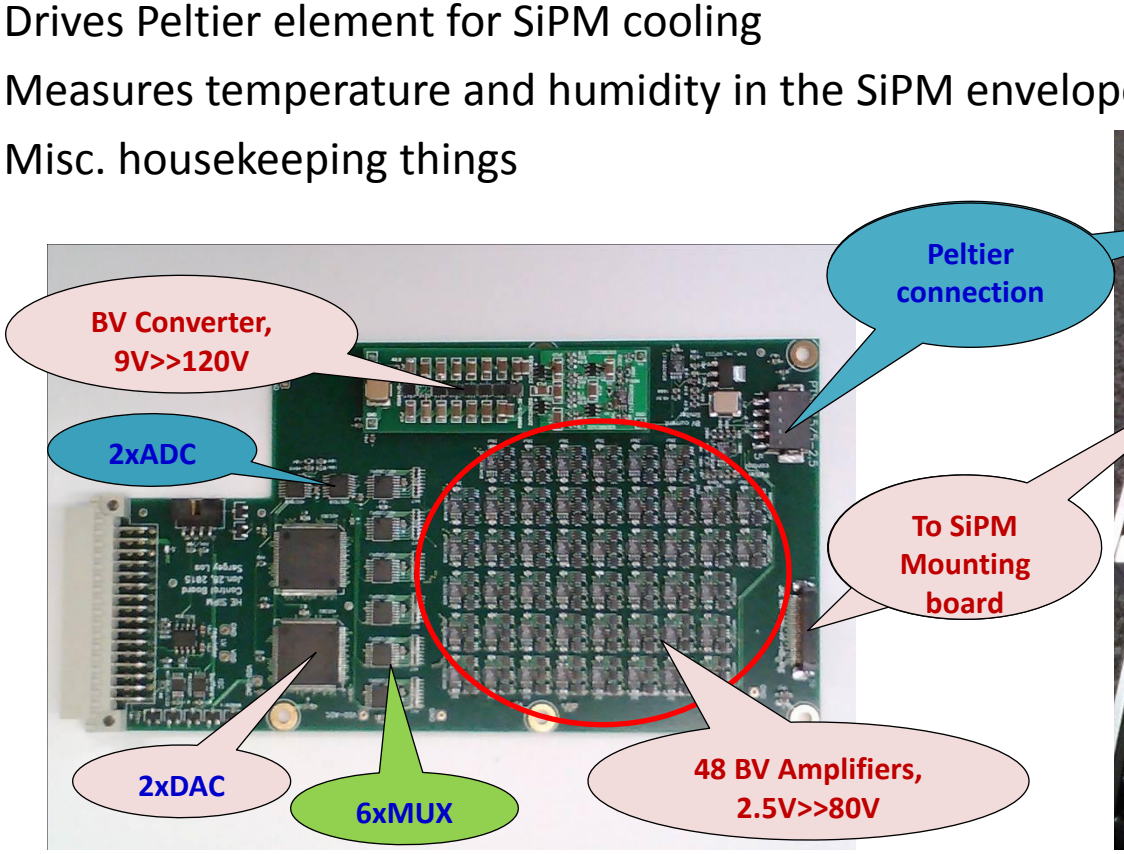
HE mounting board assembled with cooling and SiPM strips

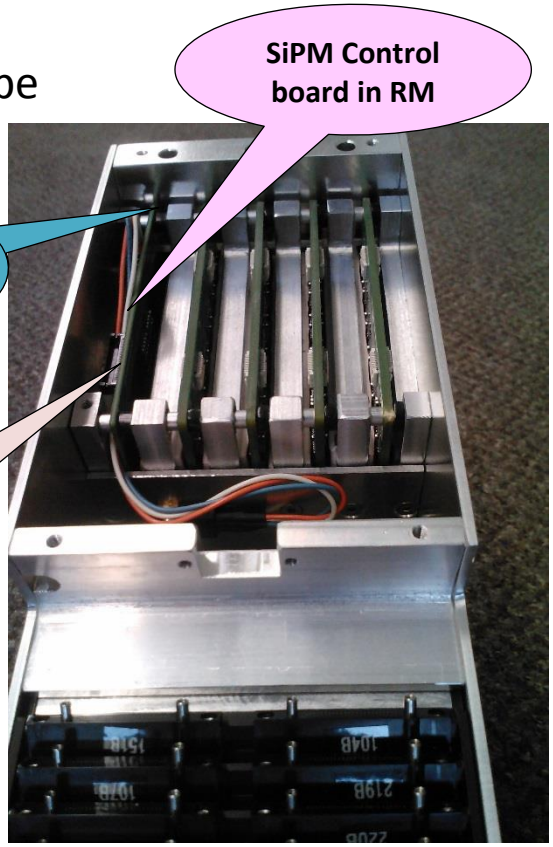
HE BV Converter Prototype



HE SiPM Control Board

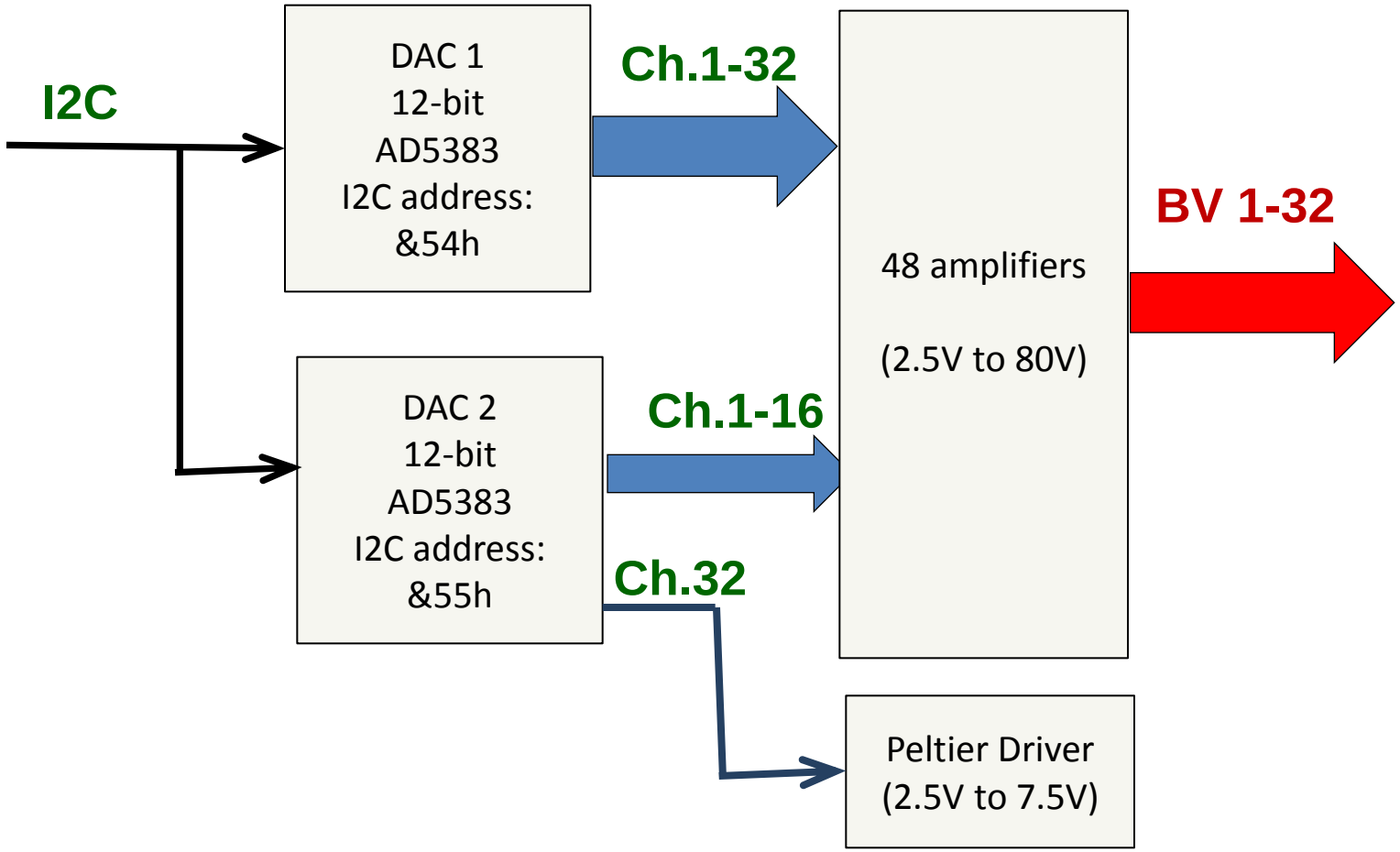
- SiPM Control board is installed in a Readout module (RM) along with four 12-channel QIE boards and performs the following functions:
  - Provides SiPMs with programmable individual BVs
  - Measures SiPM BV currents (on the high side)
  - Drives Peltier element for SiPM cooling
  - Measures temperature and humidity in the SiPM envelope
  - Misc. housekeeping things





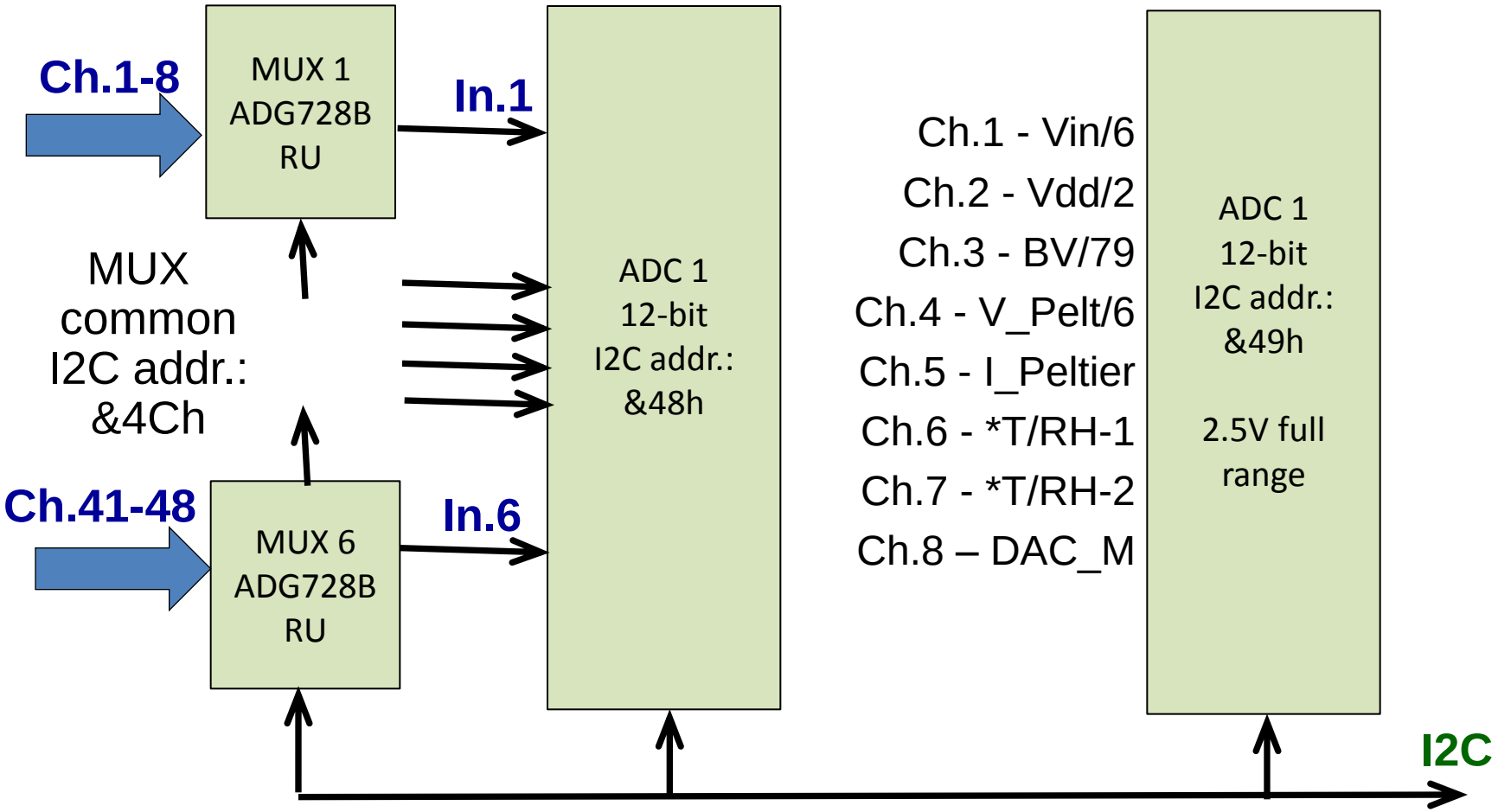
SiPM Control Board DAC

- BV and Peltier Control



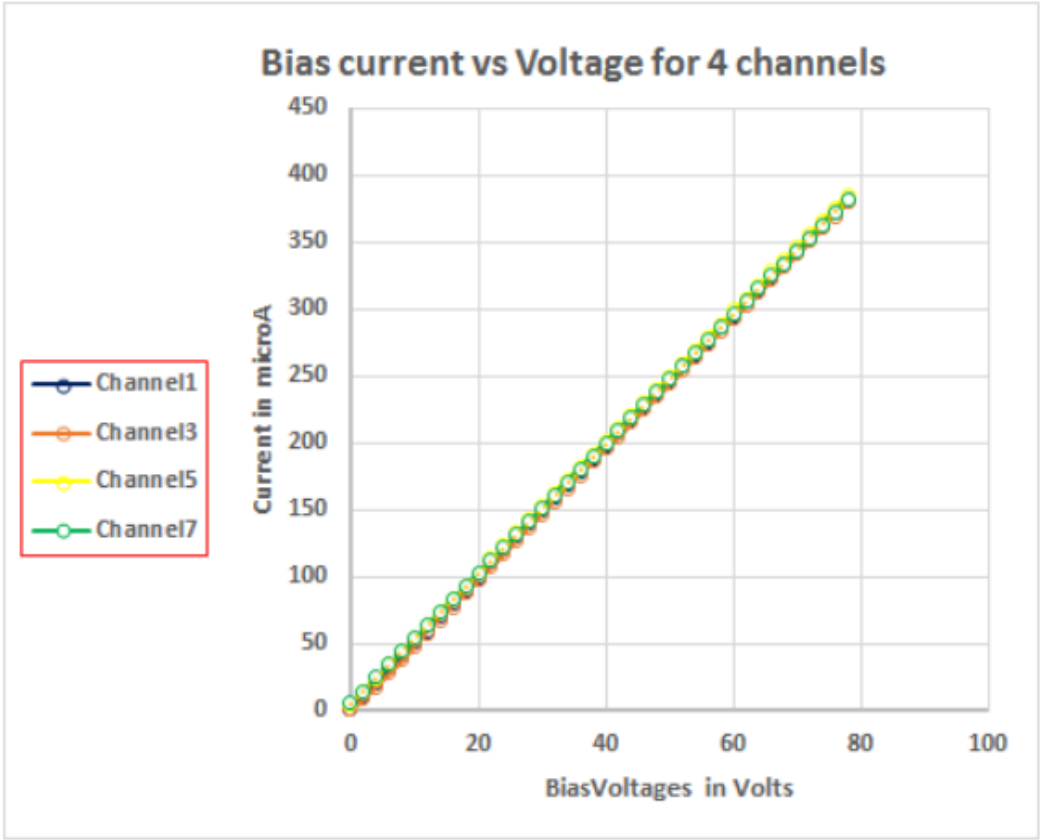
SiPM Control Board ADC

- BV current read-back



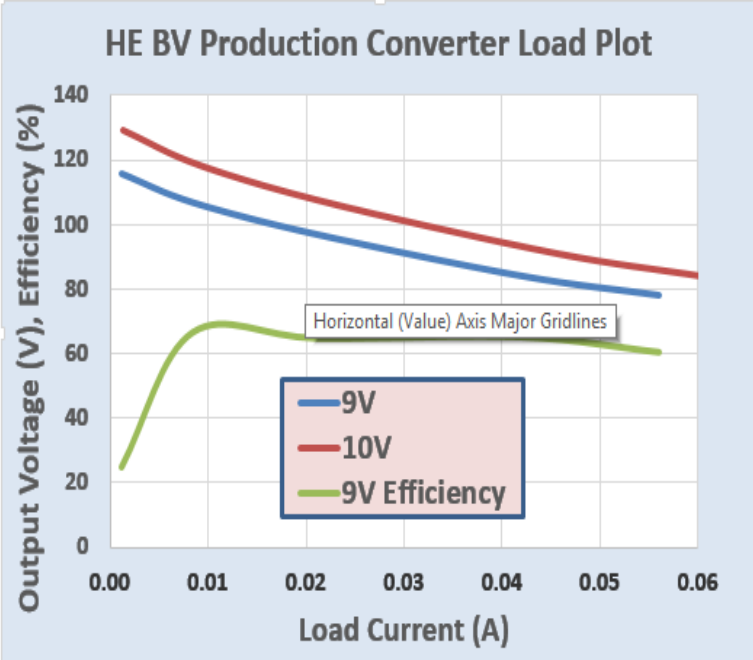
SiPM control board test results

- Connected 220K as load to channels 1,3,5,7 of the regulators
- Specs and requirements:
  - Maximum current at 80V< 500uA
  - Linearity over 0-80 V Bias Voltage

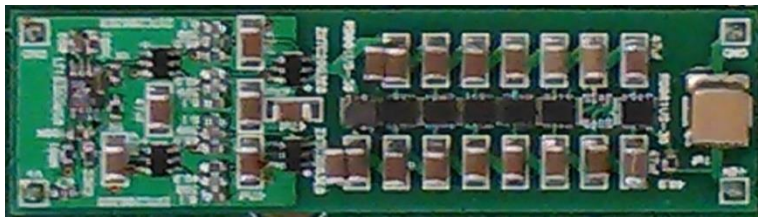


BV Converter Status

- Bias Voltage board locally generates bulk input voltage for 48 SiPM BV regulators
- Requirements
  - 5.5mA @ <120V
  - 55mA @ >85V
  - <2V ripple
- Design is based on HO BV board
  - Clock driver circuitry reused
  - Multiplying topology reversed for negative BV
- Preliminary tests suggest 50% efficiency
- Prototype generates
  - 5.5mA @ 110V
- Prototype irradiated to 3E11 p/cm2 with a minor output voltage decrease (104 to 101V)
- 3 ways will be used to increase maximum load:
  - Stronger driver
  - Larger capacitors for the lower stages
  - Faster diodes (lower current) for the upper stages



HE BV Converter Prototype

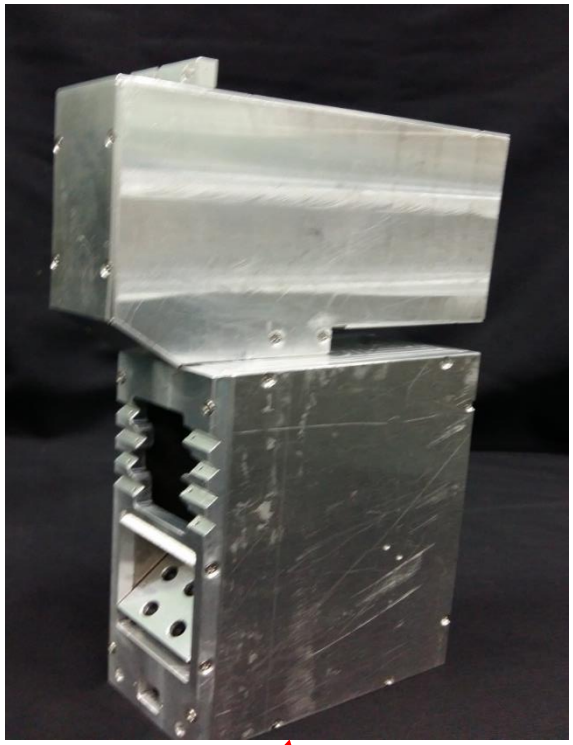


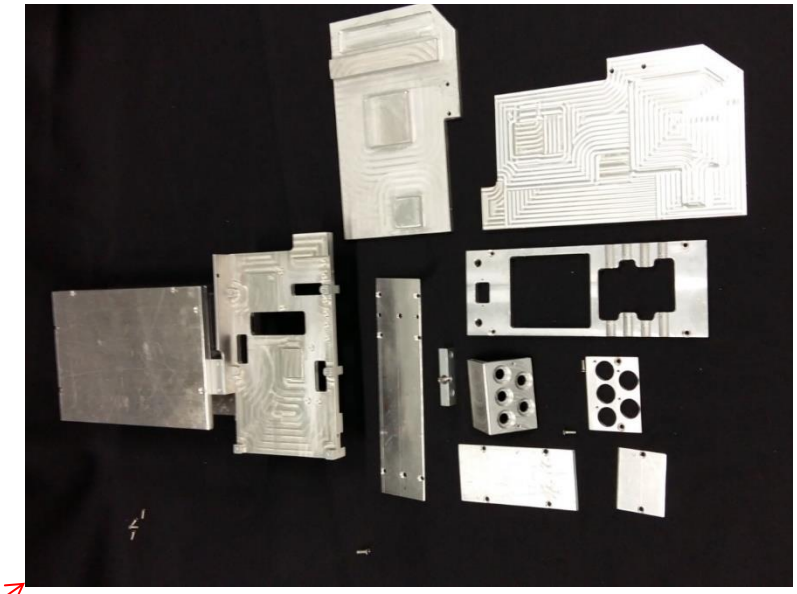
Calibration Unit Mechanics

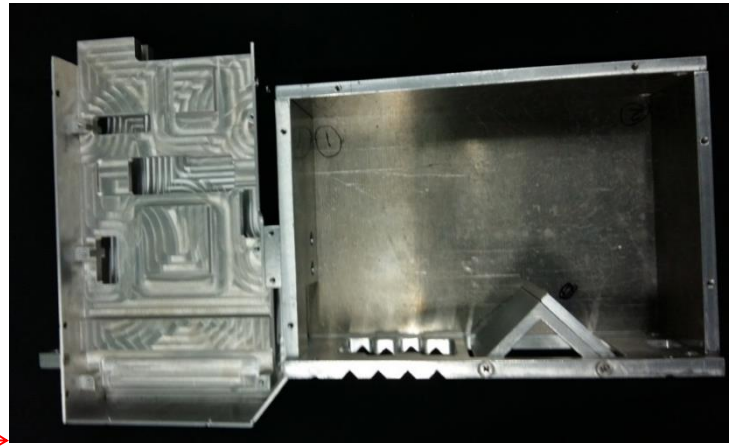
- The Aluminum housing prototype (2 boxes) was made in TIFR Central workshop and 2 in the outside workshop (Metal Shapers)in New Mumbai
- The boxes made outside TIFR had some issues with the alignment and needed some trivial rectifications that was eventually done
- The prototype boxes made met the specifications, but the design changed and the modifications understood
- The TIFR central workshop Engineer Mr. Arora in consultation with the KSU Engineers understood the changes and the work has started for the first batch of the production
- The first batch of 10 Boxes each with 17 parts will be shipped to CERN by April end

Mechanics of the Al CU Box

TIFR workshop



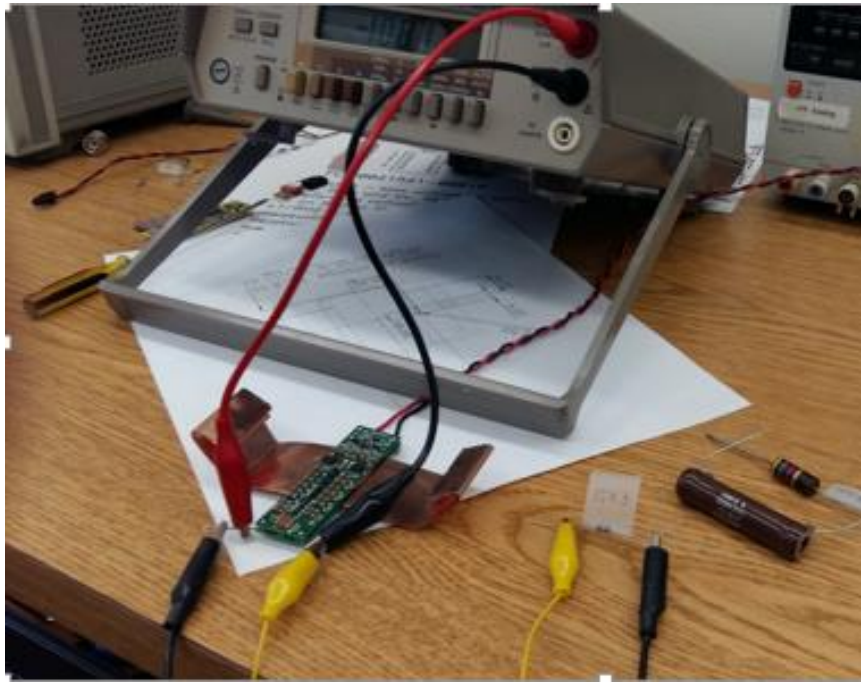


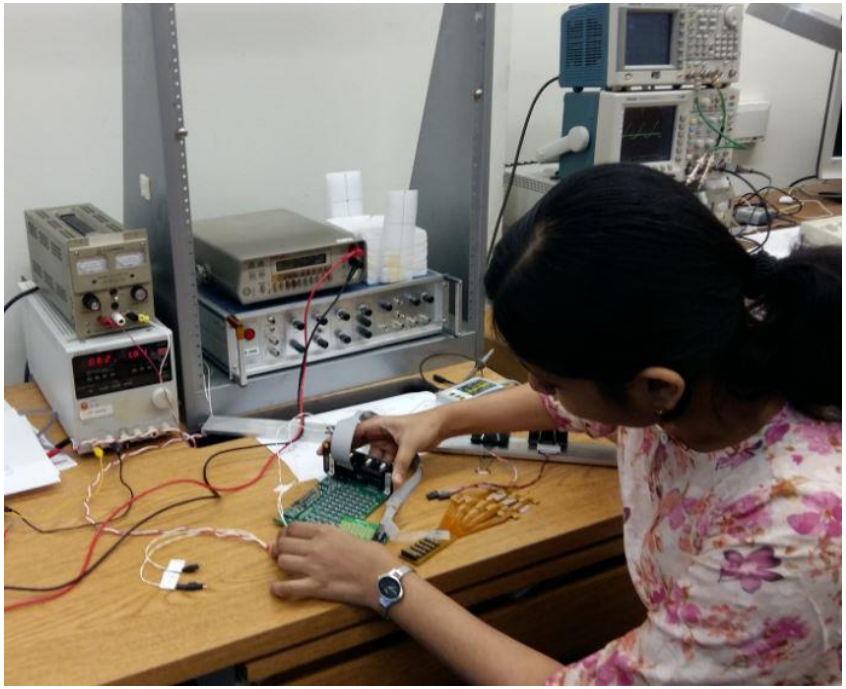


Assembled box components

Open top view

SiPM Control board & BV converter board testing





Plans in near Future

- Automatic standalone test setup to test pulser boards and SiPM boards
- Train students and technical staff members to do the QC of the boards
- Twiki page for the documentation for the test setup details
- Assemble the first batch of CU and test the assembled unit and the SiPM Control boards at CERN in June using the full DAQ system

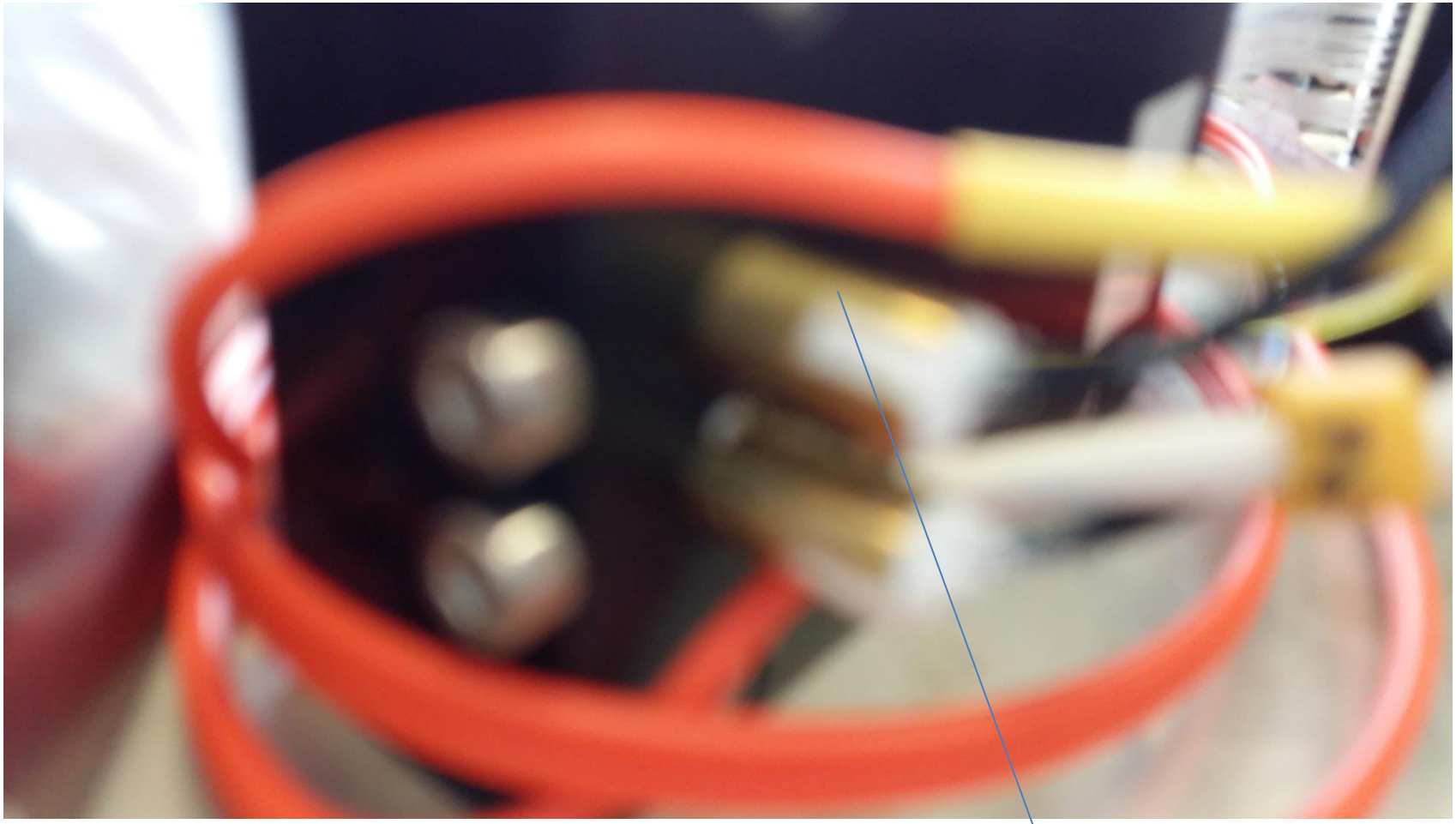
- **Full Fledged Test STAND setup using MicroTCA and Back End**
  - Will get the QIE11 board ,the uHTR and AMC13 module by April end
  - Full fledged TEST setup close to the final version will be done after the testing of the first batch at CERN in June
  - Both the remaining 35 Pulser boards, the 150 SiPM Control boards with the BV Converter mezzanine boards will be tested in the final test stand at TIFR

Summary

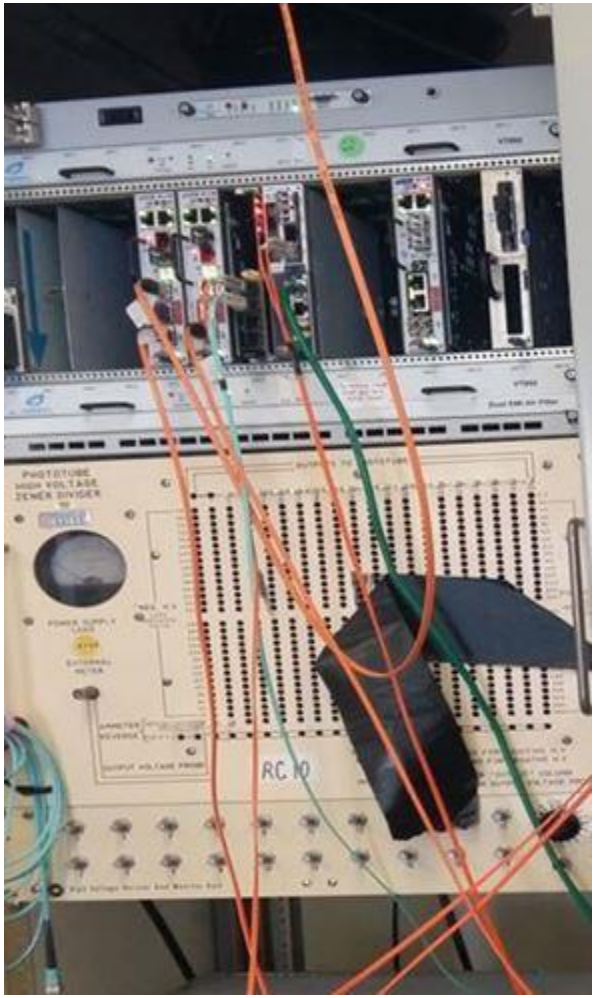
- Tight timeline with highly demanding efforts needed
- Confident in contributing towards the entrusted delivery of the CU boards, SiPM boards and other parts, in time, after testing individual parts
- A learning and enlightening experience, thanks to the collaborating team with efforts appreciated
- Developed expertise and confidence to be able to setup, the complete DAQ test stand with backend (uTCA) to front end integration

Additional Slides

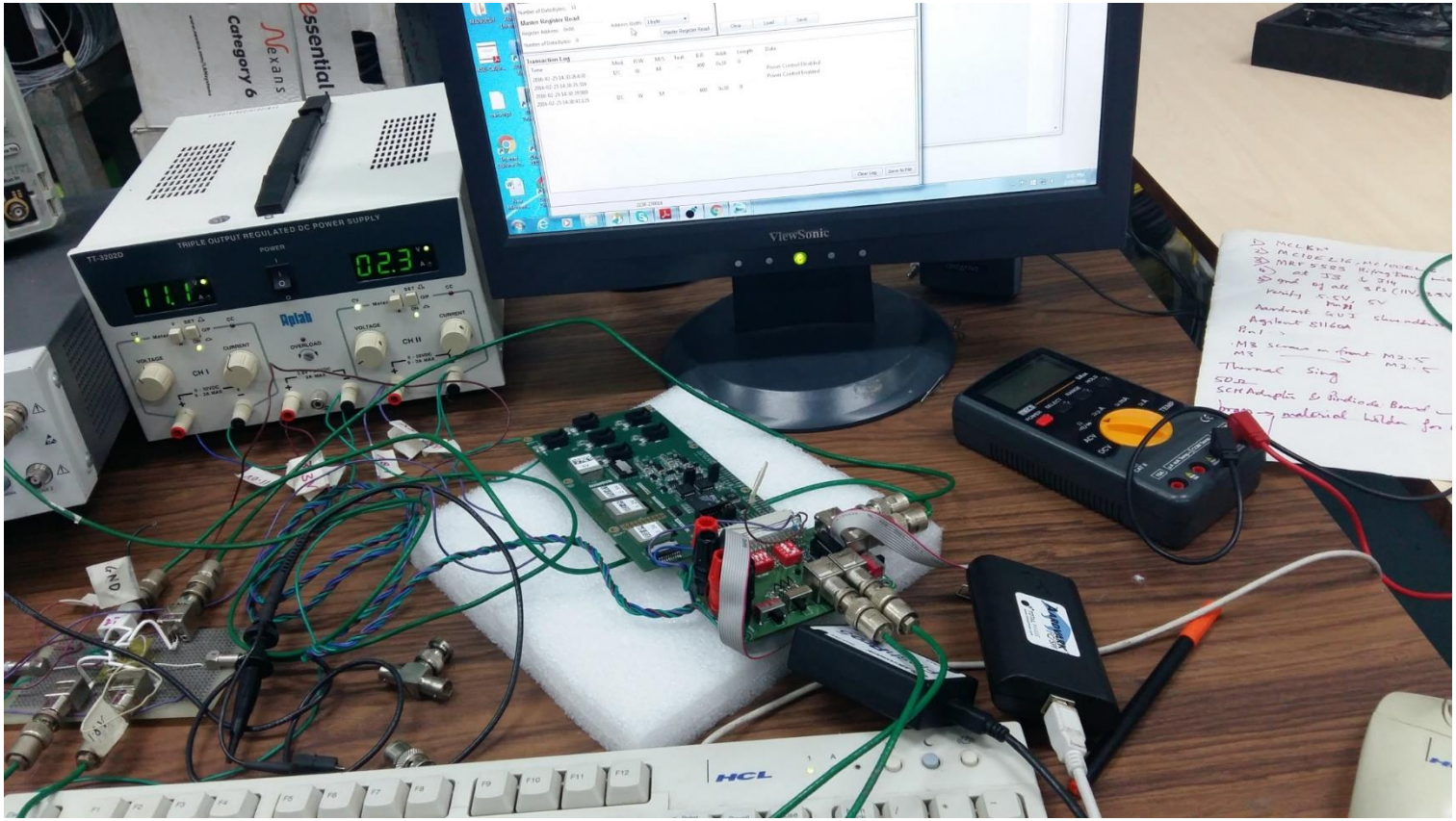
LED Mounting sleeve



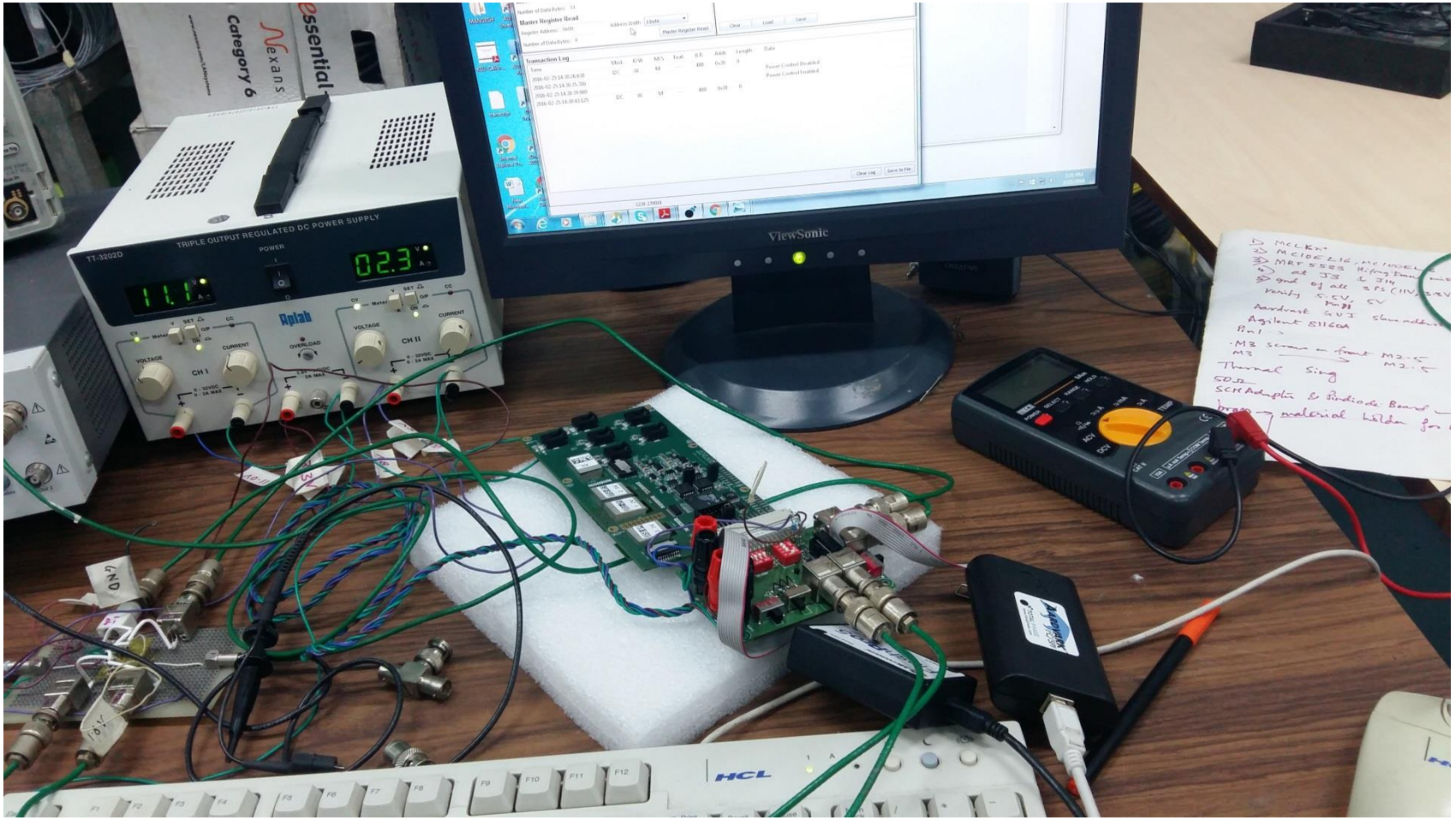
Back End Electronics of the DAQ



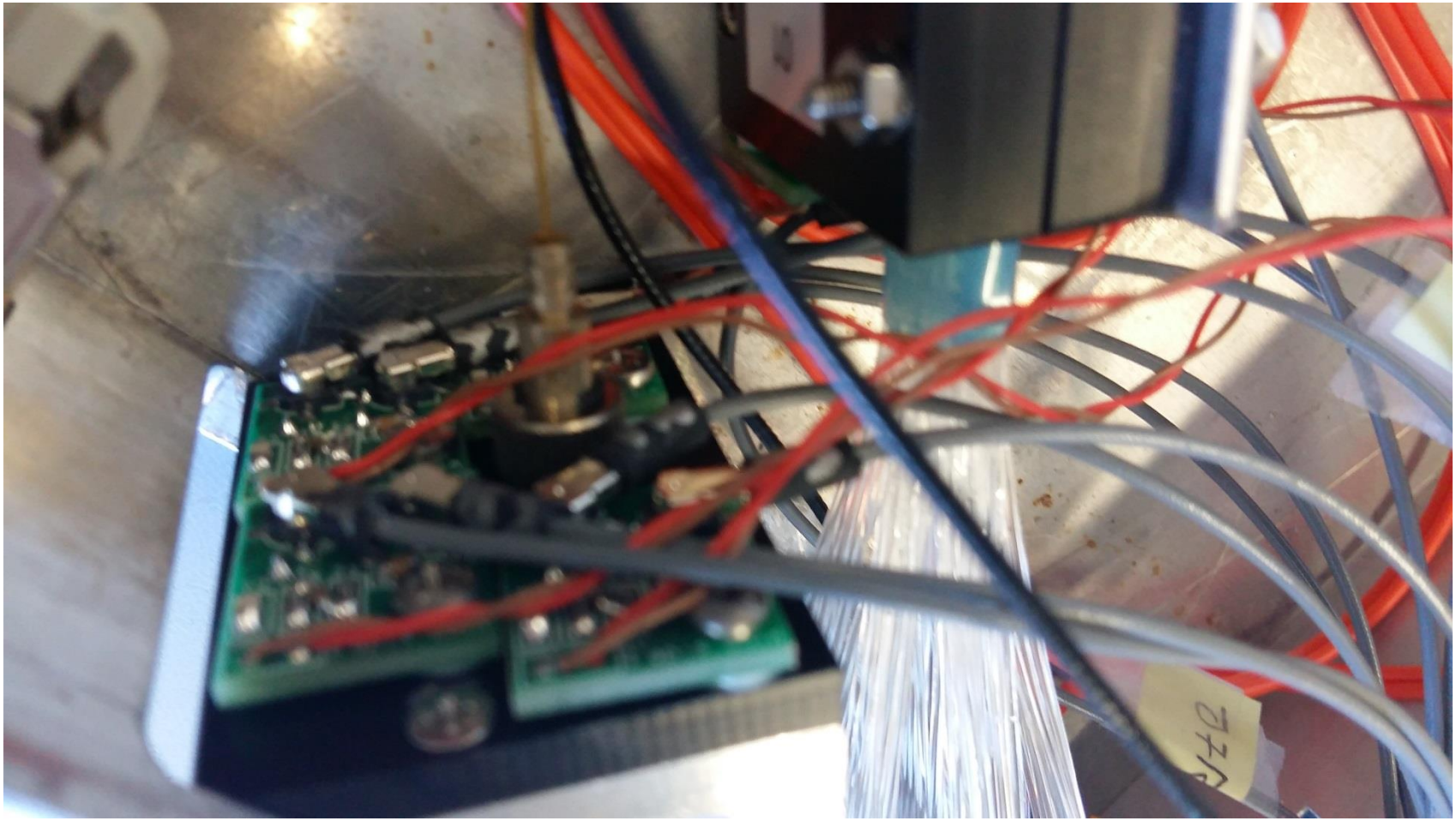
TIFR Testing



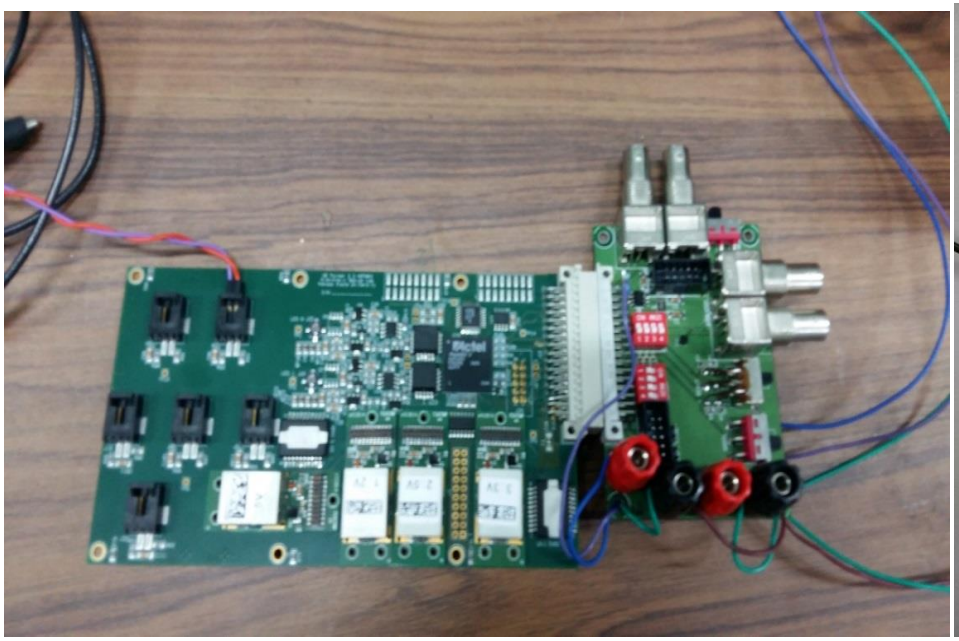
Pulser board testing at TIFR



Pin diode boards inside the CU



Pulser board and Backplane Board at TIFR



Pulser Board Testing