CMS ECAL Upgrade Front End card
Design and performance tests

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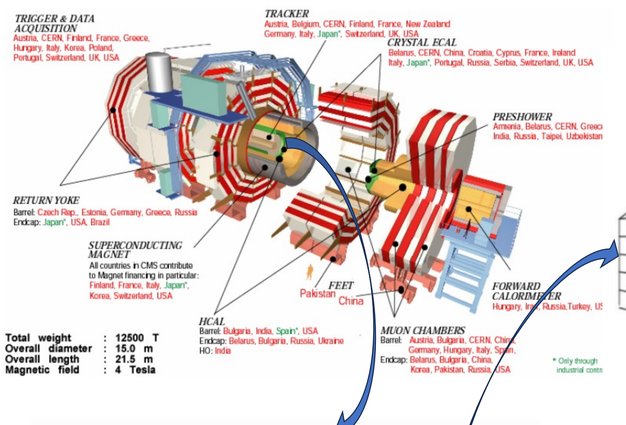
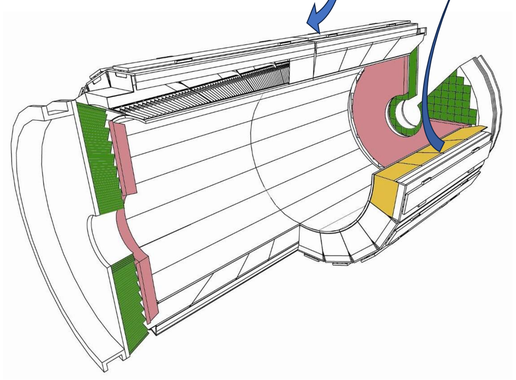
On behalf of the CMS Collaboration

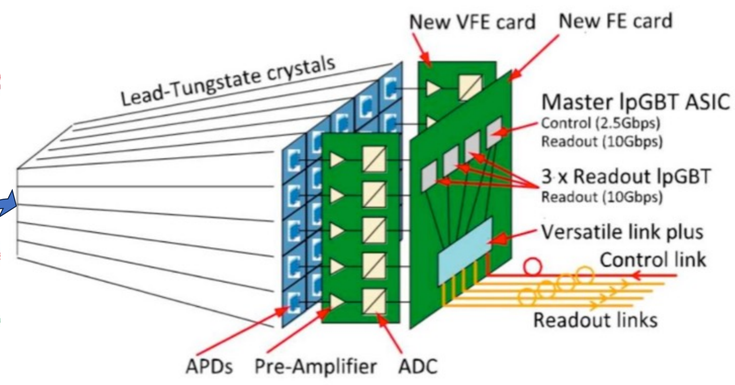
Phase II ECAL on-detector electronics Upgrade





Electromagnetic Calorimeter (ECAL)

Readout Tower



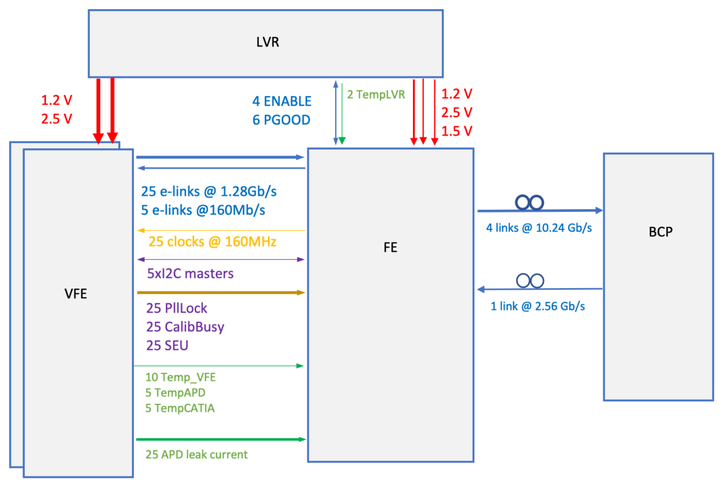
Readout unit of the CMS ECAL detector is the TOWER:

- 5x5 PWO crystals with scintillating light read out by 2xHAMAMATSU Avalanche Photo Diodes each
- 5x Very-Front-End (VFE) cards each containing 5 double gain pre-amplifiers (CATIA) and 5 ADC and data management chips (LiTE-DTU)
- 1x Front-End (FE) card with 4x lpGBT 1x GBT-SCA and 1x 4T1Rx optical transceiver
- 1x Low Voltage Regulator (LVR) card for VFE and FE powering

Upgrade FE card functionality

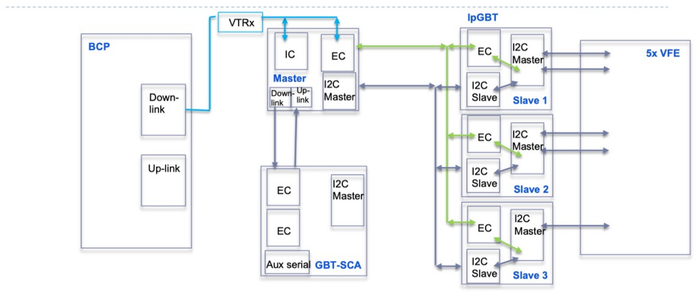
Upgrade FE card is the interface between intelligent VFE chips, CATIA and LiTE-DTU and powerful FPGA – based Barrel Calorimeter Processor (BCP). It provides:

- ✓ 160MHz clock distribution to the VFE readout channels
- ✓ VFE, LVR and FE chips configuration and control via I2C interfaces, one per VFE and LVR board
- ✓ Lossless data streaming from VFE readout channels via 1.28Gb/s serial links (lpGBT – links mechanism)
- ✓ Data transmission to BCP via four 10.24Gb/s optical links
- ✓ Chips status, temperature, power voltage, APD dark current readout via I2C interface and lpGBT optical up-link at 2.56Gb/s



Implementation

FE – VFE slow control



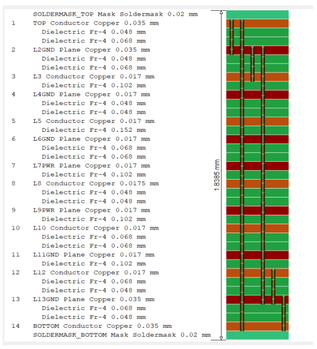
GBT-SCA: EC link emulation by e-links

1. lpGBT down-link: one link from special group, should run at 80MGz
2. lpGBT up-link: one link from special group, Master will sample 80MHz data from SCA at 320MHz, BCP firmware have to deal with the repeating bits: 10 → 11110000
3. **Stable operation**

lpGBT Slave: EC link in multidrop mode

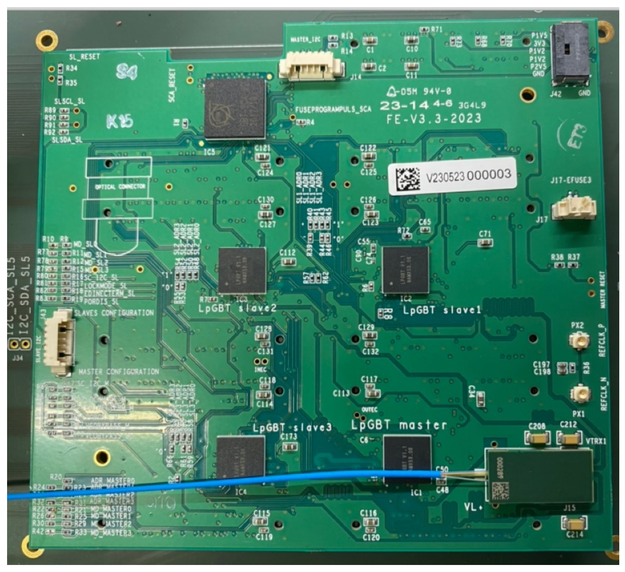
1. Slaves are quiet during operation, acknowledge / replay if addressed by Master ← e-link locking
2. Require good EC-link lines tracing / termination
3. **Stable operation**

FE PCB stack out



TOP	Rx,Tx-diff signals
L2	GND
L3	CLK, DATA-diff signals
L4	GND
L5	CLK, DATA-diff signals
L6	GND
L7	PWR P1V2
L8	PWR P2V5, P1V5
L9	GND
L10	signals
L11	GND
L12	DATA-diff signals
L13	GND
BOTTOM	signals

- 4x lpGBT chips, one in TRx mode (Master) and three in Tx mode (Slaves)
- 1x GBT-SCA chip for the APD dark current readout
- 1x 4T1Rx Versatile link optical transceiver



- Class 3 PCB
- 14 layers
- Micro-vias between layers 1-2, 2-3, 14-13, and 13-12
- Serial lines impedance control with 10% precision

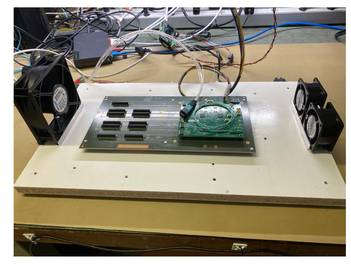
Functionality tests

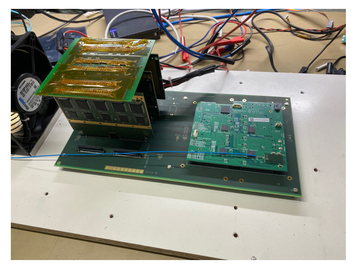
Stand-alone test

- Will be performed by the assembly company
- Electrical I2C control via PiGBT interface
- Electrical system clock from external clock generation
- lpGBT chips configuration
- I2C registers read/write

Functional test

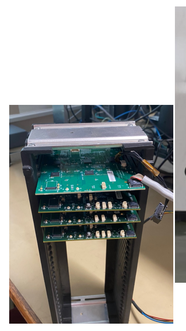
- Will be performed at CERN upon reception
- Clock, control and readout via optical links from BCP
- Production LVR and VFE board for power, control and readout
- Full configuration of FE chips
- Full configuration of VFE chips
- Data alignment, PED and test pulse readout





Thermocycling and burning-in

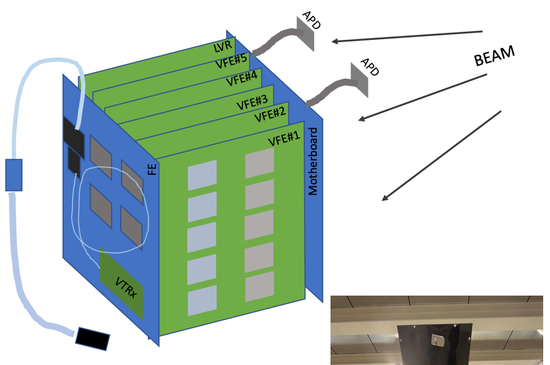
- Climatic chamber
- Power to FE from external source
- Electrical I2C via PiGBT and Keithley switch
- Burning-in at 70C during 72 hours
- Periodic thermocycling 70C→9C→70C
- Periodic I2C initialization – configuration
- Full functional test at the end of operation



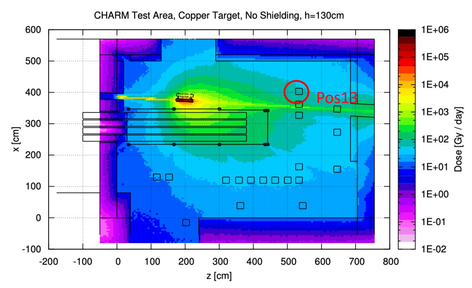
Special thanks to T. Gadek and C. Haller, ETH Zurich, for providing the VFE and LVR cards and for preparing the test setup for the readout tower test, respectively.

Full readout tower validation in radiation environment

- A complete tower with the latest versions of VFE and FE
- Five APD capsules connected to VFE_0
- Continues Reset/Config/Readout cycles by ECAL off-detector readout board (BCPv1)



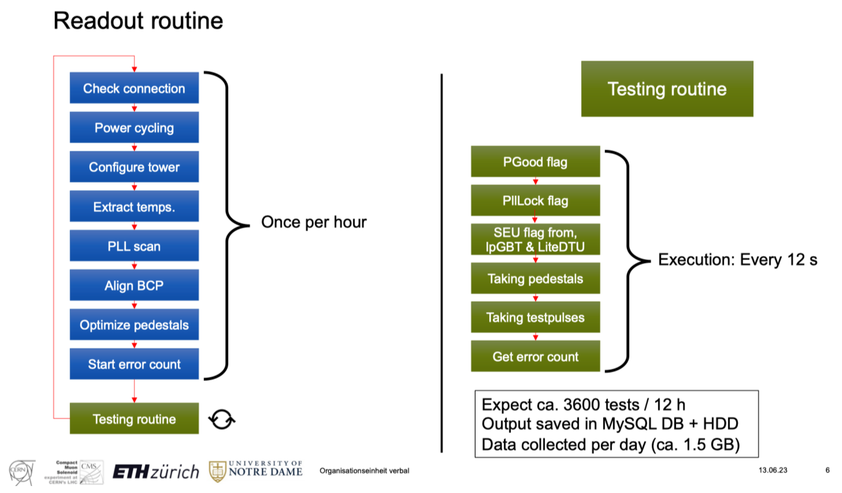
CERN CHARM facility

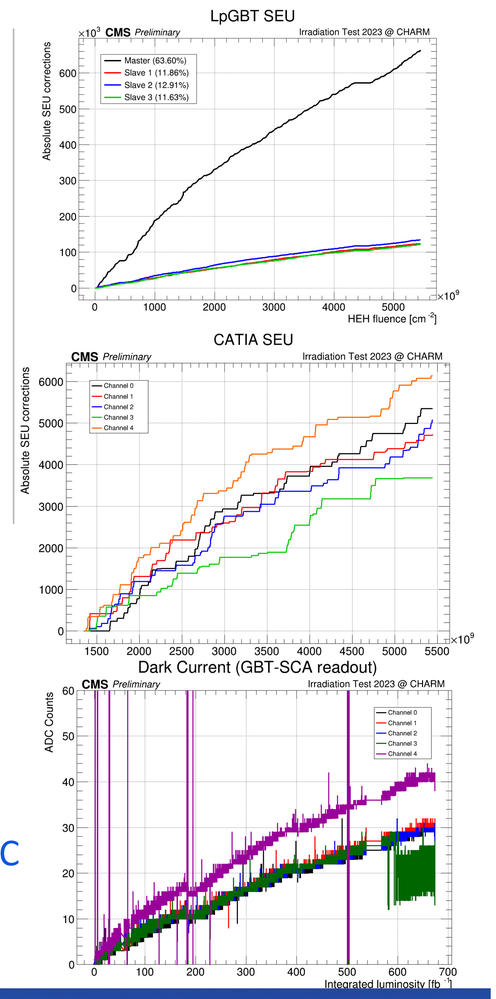


Tower at η=1.41 vs CHARM pos13

	HL-LHC (3000 fb^{-1})	CHARM (17 days)
Dose rate	**9.57e-05 Gy s^{-1}**	**7.84e-04 Gy s^{-1}**
Charged hadron flux	**7.38e+04 $cm^{-2}s^{-1}$**	**1.48e+06 $cm^{-2}s^{-1}$**
Total dose	**5'740 Gy**	**1'380 Gy**
Total Hadron fluence	**4.43e+12 cm^{-2}**	**5.48e+12 cm^{-2}**

Readout routine





- Stable operation in hostile radiation conditions (Charged hadrons flux 20 times higher than max. expected for ECAL tower at HL-LHC at η=1.41)
- SEU cases detected and handled by chips
- Good APD dark current readout by GBT-SCA ADC

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TWEPP-23
Topical Workshop on Electronics for Particle Physics
Geremeas, Sardinia, Italy, 2 – 6 October 2023