



Results from longevity studies of the on-detector readout of the CMS Electromagnetic calorimeter

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Motivation for testing

- The Compact Muon Solenoid (CMS) detector was originally designed and tested to operate up to 10 years
- The High Luminosity LHC (HL-LHC) will continue to run the CMS detector until 2035
- The CMS detector must maintain good performance for this extended period

CMS electromagnetic calorimeter

- Homogeneous PbWO₄ scintillating crystal calorimeter
- Scintillation light read out by avalanche photodiodes (APDs) in the barrel and vacuum phototriodes (VPTs) in the endcap



CMS ECAL barrel after initial installation.

ECAL front end electronics

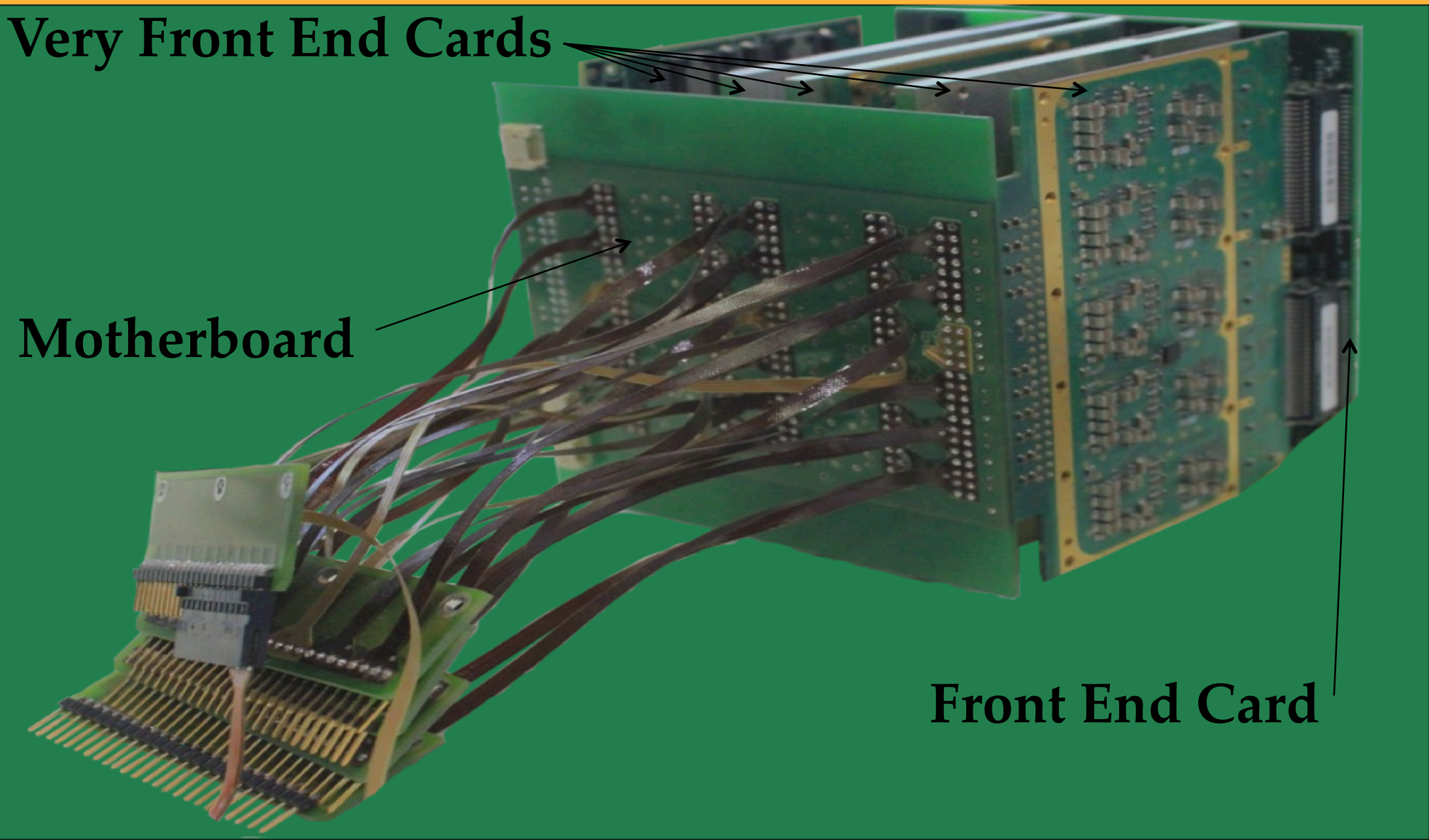


Image of ECAL readout chain. Pins on the left receive input from photosensors. Ribbons connect to motherboard. 5 VFE are mounted on the motherboard. At the other end of the 5 VFE, one FE is installed.

Motherboard (MB)

- Passive components
- Well cooled
- Distributes photosensor signal to VFE cards

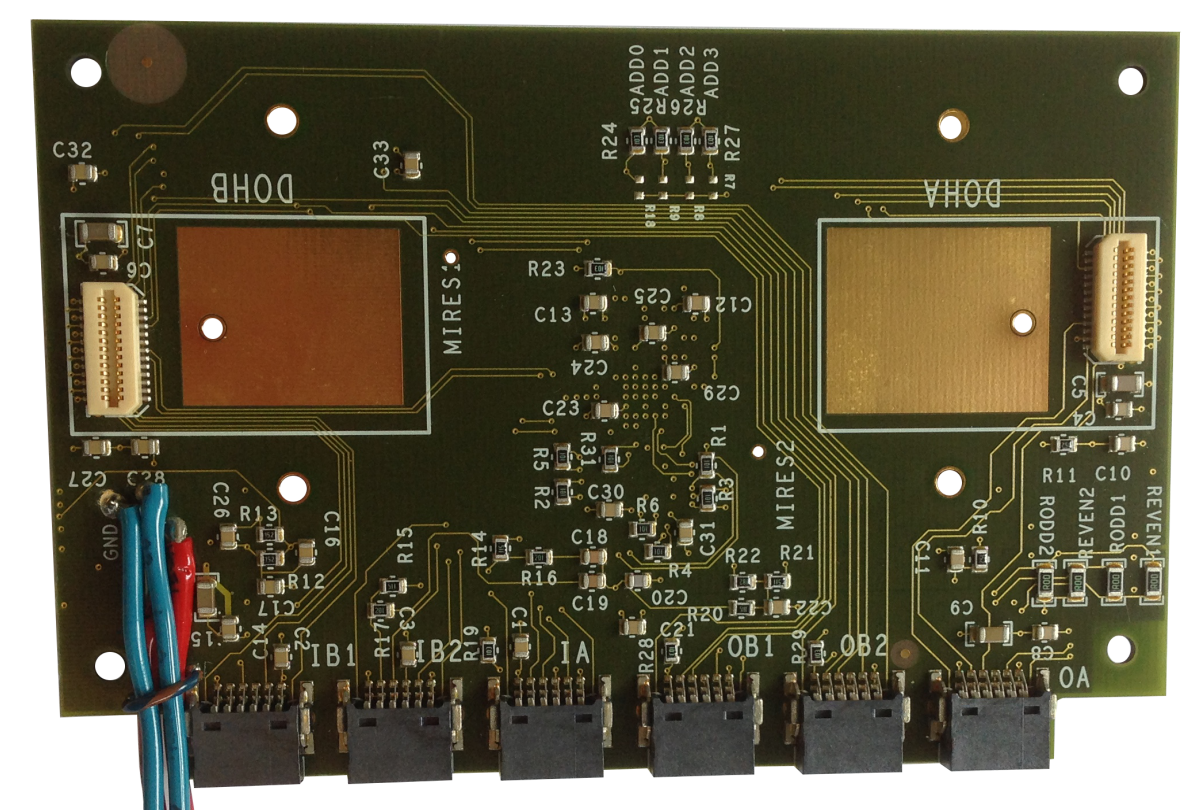


Image of Token Ring Link Board (TRLB). Provides clock and control for 8-10 FE cards.

Very Front End (VFE) card

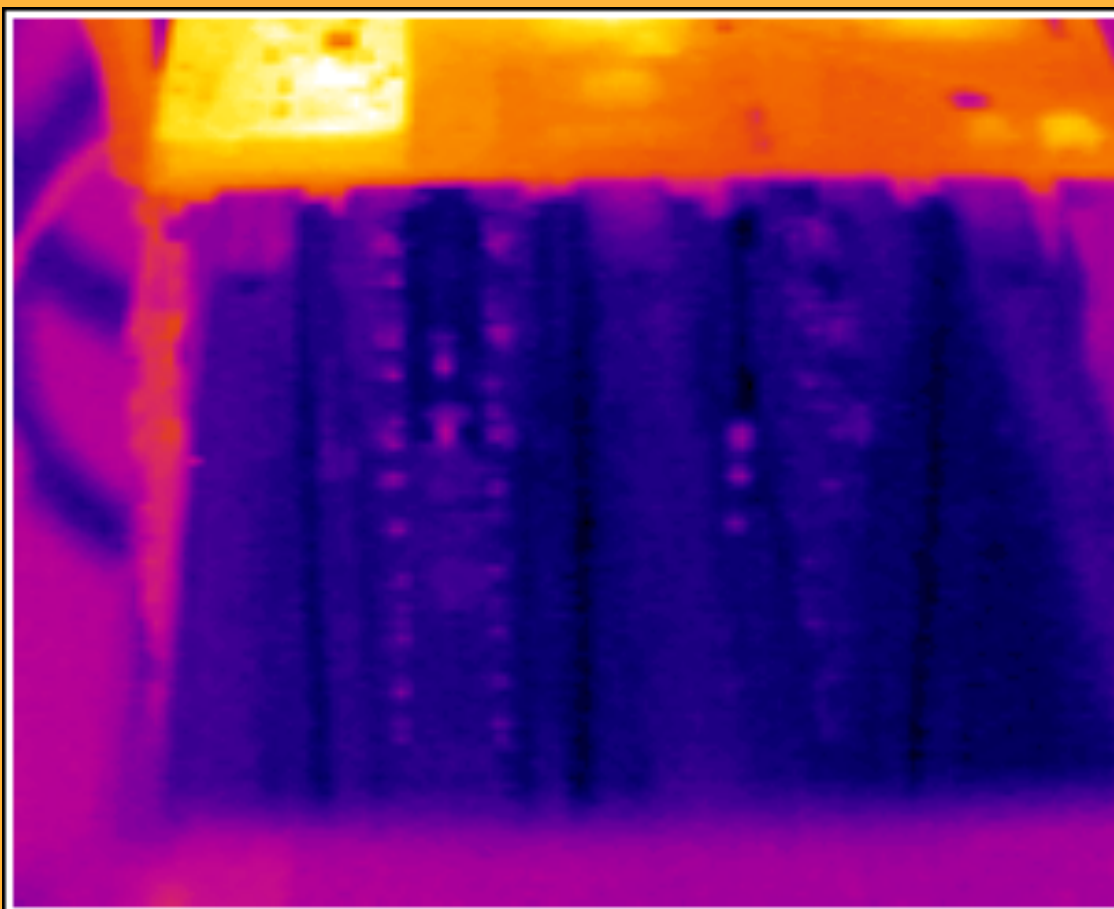
- 5 channels per board
- MGA and ADC
- Well cooled
- Amplifies, shapes, and digitizes signal; sends signal to FE card

Token Ring Link Board (TRLB)

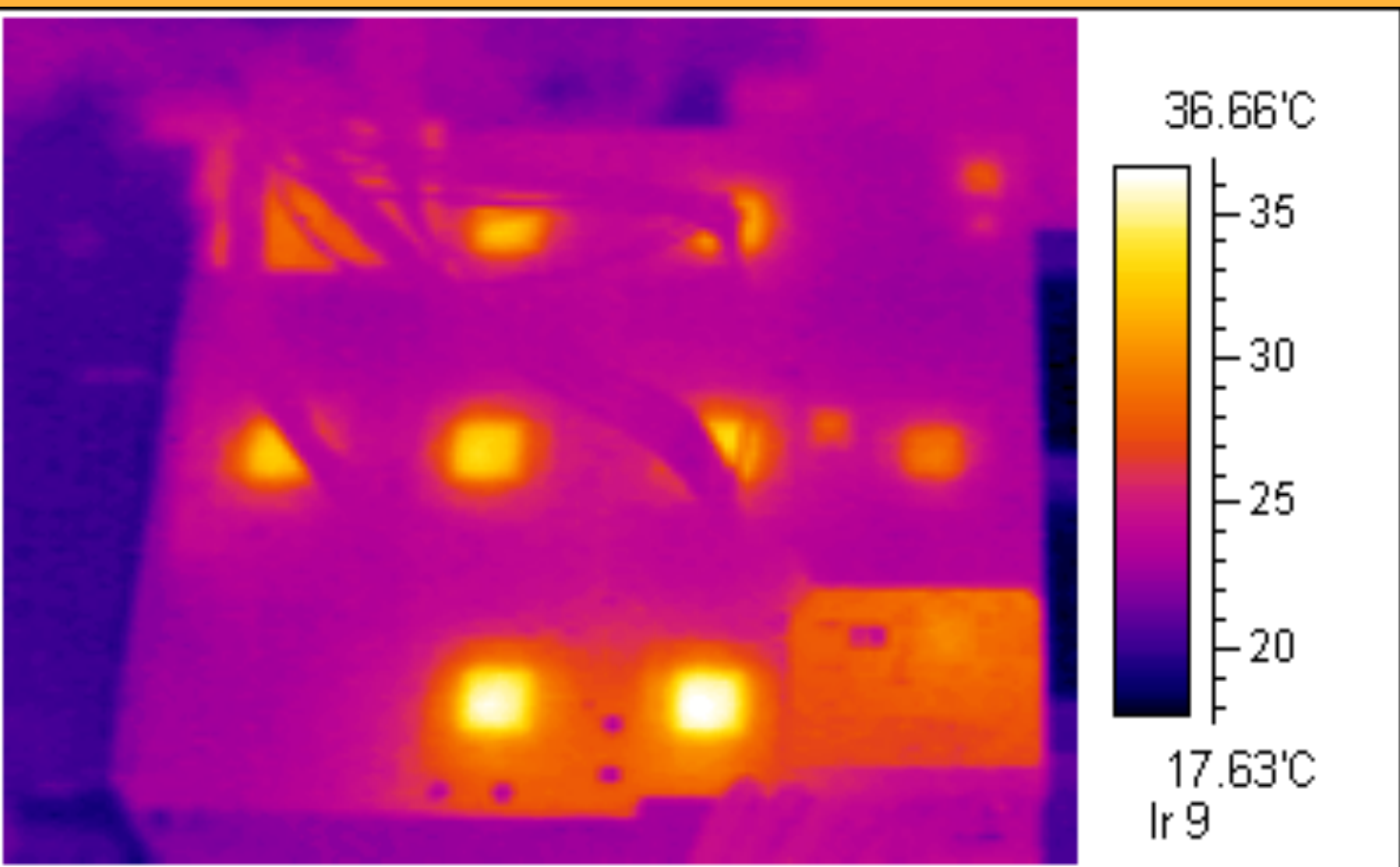
- Well cooled
- Distributes clock and control to FE cards

Front End (FE) card

- 25 channels per board
- Several FPGAs
- Not well cooled
- Generates trigger primitives and stores signals for primary event buffers



Infrared image: side of VFE cards during normal operation. VFE and motherboard are well cooled.



Infrared image: exterior face of FE card during normal operation. FPGAs on the FE are the hottest component.

Longevity tests

- On detector electronics were aged to simulate steps of 2 years (up to 16 years), then 5 years (up to 41 years) of operation
- Combination of accelerated aging, thermal cycling, and ON/OFF cycling were used to simulate aging of electronics

Accelerated aging (high temperature)

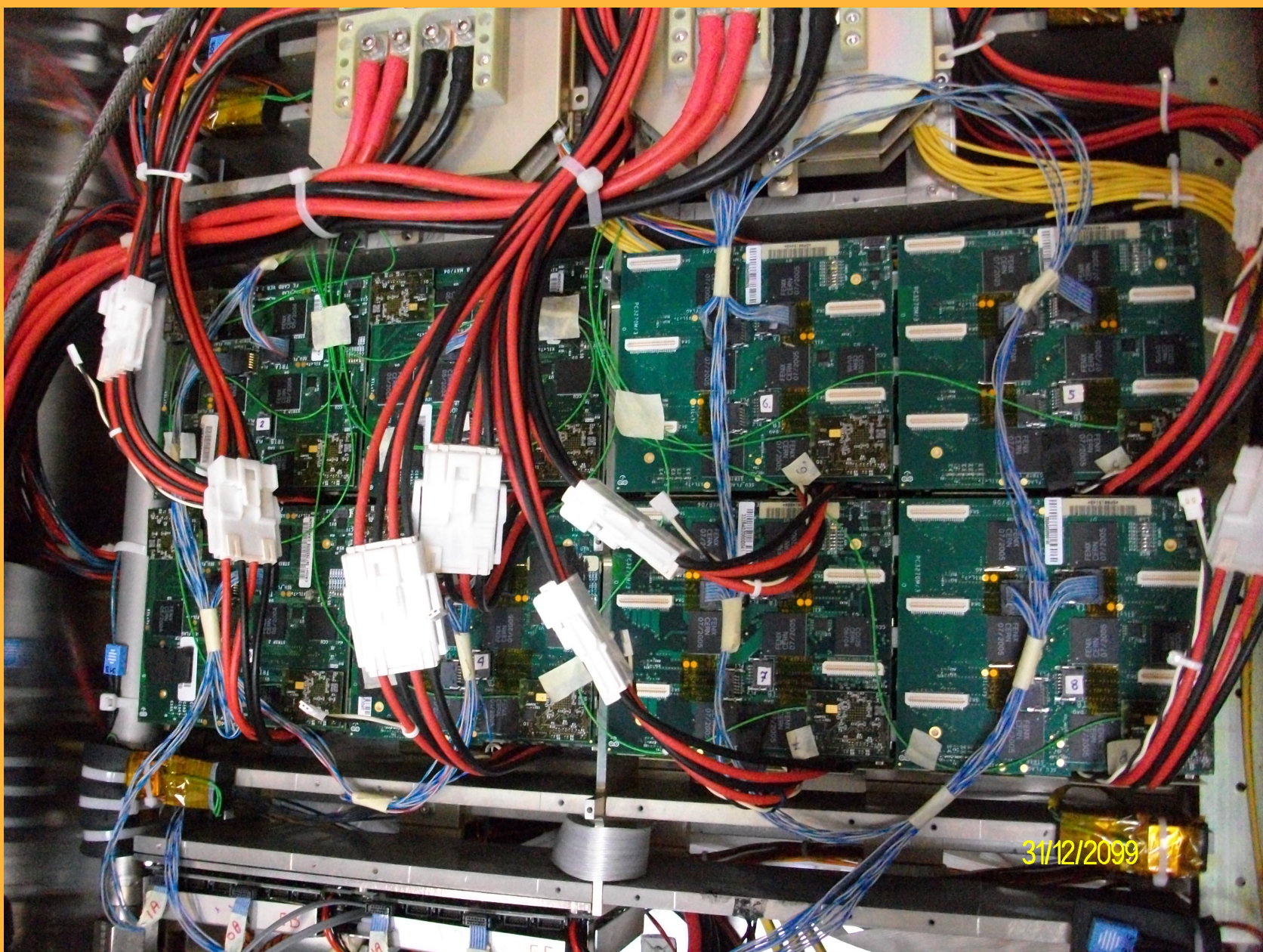
- To simulate aging of the electronics, all boards were stored at temperatures of 120 deg C
- 14.5 days at this temperature corresponds to 40 years of normal operation

Thermal cycling

- Operating temperatures of electronics fluctuate, putting mechanical stress on joints and components
- FE card is the only board which suffers large temperature fluctuations
- Simulated by cycling between 5 and 50 C every 30 minutes

ON/OFF tests

- Large changes in voltage (during power on/off) put mechanical stress on the system
- FE coards were installed in a test facility where power could be supplied as in-situ
- Supplied voltage was raised to operating values, held until the system equilibrated, then was turned off until the system equilibrated again



Front end cards in ON/OFF apparatus. Full CMS ECAL readout chain is present (excluding scintillating crystals and photosensors). The voltage was automatically cycled every 20 minutes to simulate powering of the boards in situ.

Performance testing after each aging cycle

- Visual inspection
- FE and VFE boards installed in test stand with full CMS readout chain
 - Measured the signal amplitude of the pedestals and the MPGA's internal test pulse generator
- Motherboards and TRLBs were tested separately

Results of performance tests

- FE and VFE boards showed slight signal amplitude drift, well within operational tolerance
- Motherboards were fully functional
- TRLBs were fully functional

	Accelerated aging	Thermal cycling	ON/OFF cycling	Results
8 FE	Yes	Yes	Yes	Good
8 VFE	Yes	Not needed	Not needed	Good
8 MB	Yes	Not needed	Not needed	Good
5 TRLB	Yes	Not needed	Not needed	Good

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Conclusions

The CMS ECAL front end electronics were tested to extended lifetimes:

- Of 5 TRLBs none suffered failures over 27 years
- Of 8 motherboards, VFE cards and FE cards no failures over 41 years of simulated aging

The measured lifetime of the on-detector readout for the CMS ECAL would allow the current electronics to operate throughout the extended running period of the HL-LHC