CMS ECAL Electronics

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On behalf of the CMS ECAL collaboration

1) Introduction
2) On Detector Electronics
3) Optical Links
4) Token Rings
5) Off Detector Electronics
6) Integration
7) Results SM10

Introduction

Detector

Crystal	conversion of particles energy into light
Photo detector	conversion of light into charge

On Detector Electronics

Amplifier	Amplify and shape the charge pulse
ADC	Digitize the pulse shape
Digital Signal Processing	Data storage/formatting, trigger sum calculation

Data Transfer

Optical Links	Data transmission to off detector electronics

Data Acquisition

Off Detector Electronics	Data transmission/formatting, selective readout

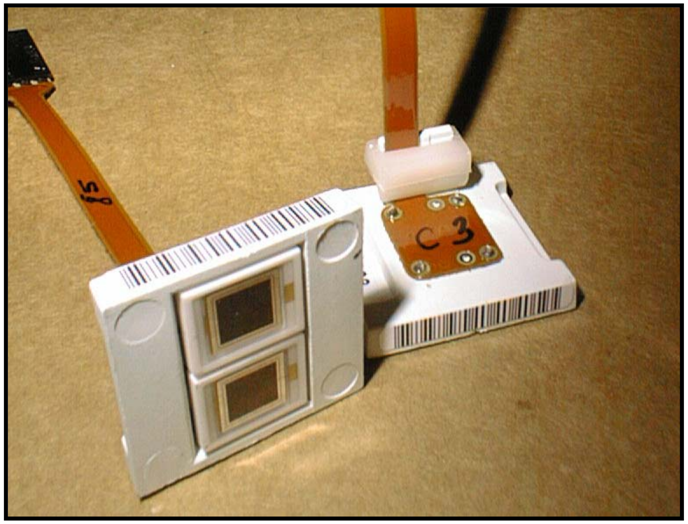
Barrel Photo-Detectors

Nominal gain: 50 changes 3.3 %/V

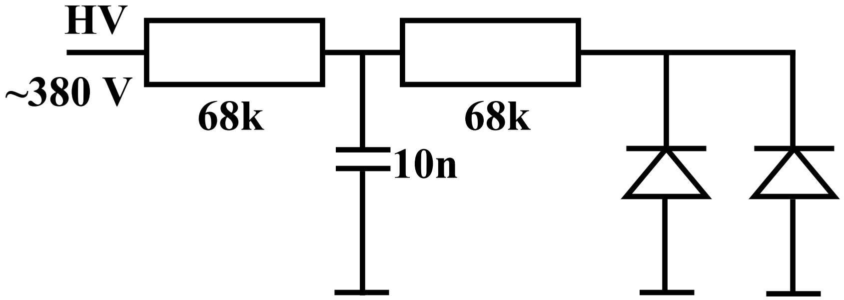
⇒ Bias voltage stable to ± 20 mV

- Two APD's are grouped into a capsule to compensate for different gains
- 50 capsules are powered from the same HV source (CAEN)
- The spread of the gains within a given HV channel is less than 1%, achieved by sorting the ADP's

- Radiation affects only APD leakage current (I_{leak}) ⇒ 200 μA ⇔ 27 V
- Measure I_{leak} and correct HV appropriately
- Limit short circuit current: I_{short} ~ 2.7 mA / capsule ⇒ 2 shorts / HV channel o.k.

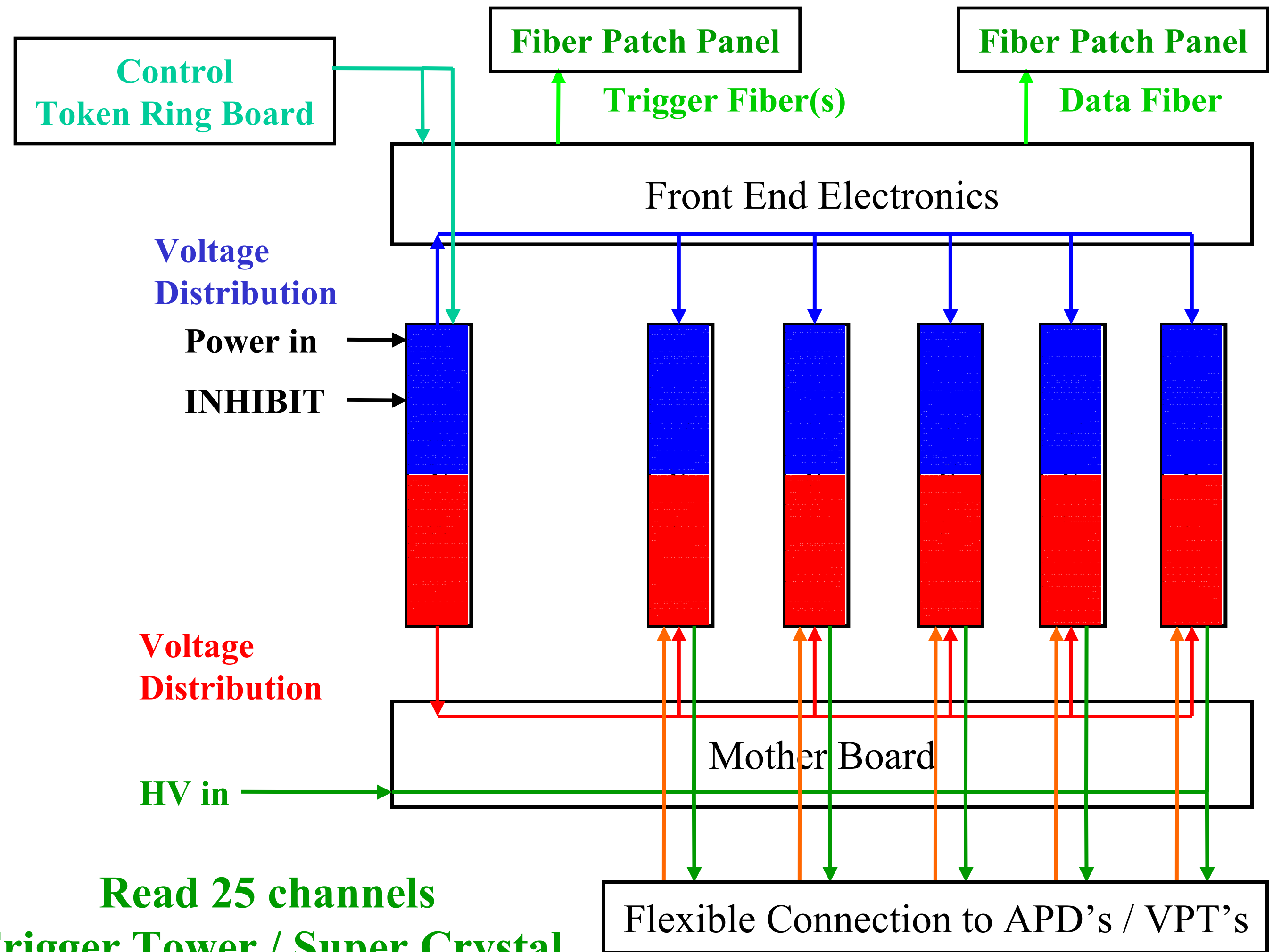


Capsule directly glued on the rear phase of crystals



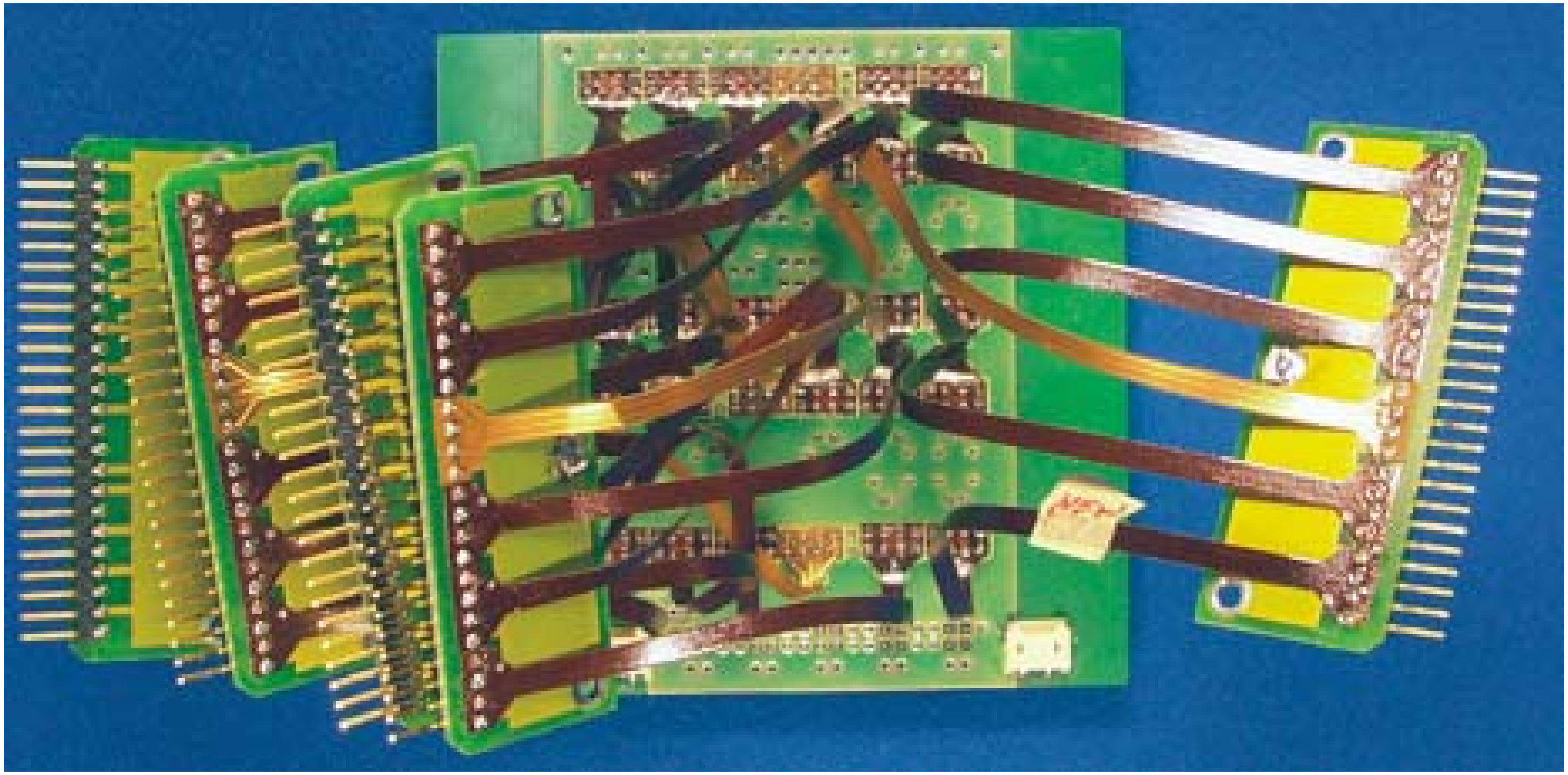
APD bias circuit

Trigger Tower Electronics



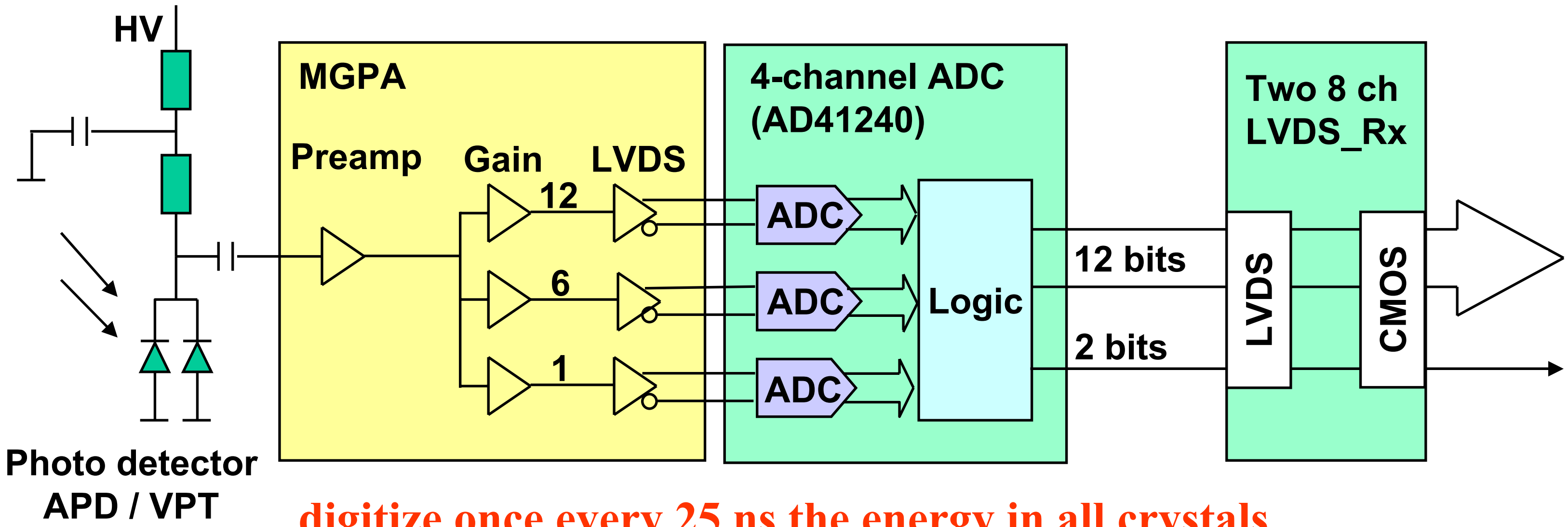
Read 25 channels
Trigger Tower / Super Crystal

Motherboard



- Low Voltage distribution to VFE
- High Voltage distribution to APD
- High Voltage filter network
- Flexible Kapton cables to APD and temperature sensor
- Ground connection to the grid

VFE Readout



digitize once every 25 ns the energy in all crystals

Detector Control Unit (DCU):

- Measure the leakage currents of the APD capsules
- Measure the temperature of the sub-module:

  Each 10th capsule contains a 100kΩ thermistor, dR/dT = -4%

  ⇒ stabilize Temperature to ± 0.5 K (APD and Xtal T dependence -4.3%/deg)

LVDS buffer: Receives and distributes the 40 MHz LHC clock

All components are custom ASIC's in 0.25μm technology

MGPA

Multi Gain Pre-Amplifier (MGPA):

- **Developed by Imperial College**
- **Rad. Tol. 0.25 µm technology**

Full scale:

- **60pC = 1.7 TeV (EB)**
- **16pC = 3.5 TeV (EE)**

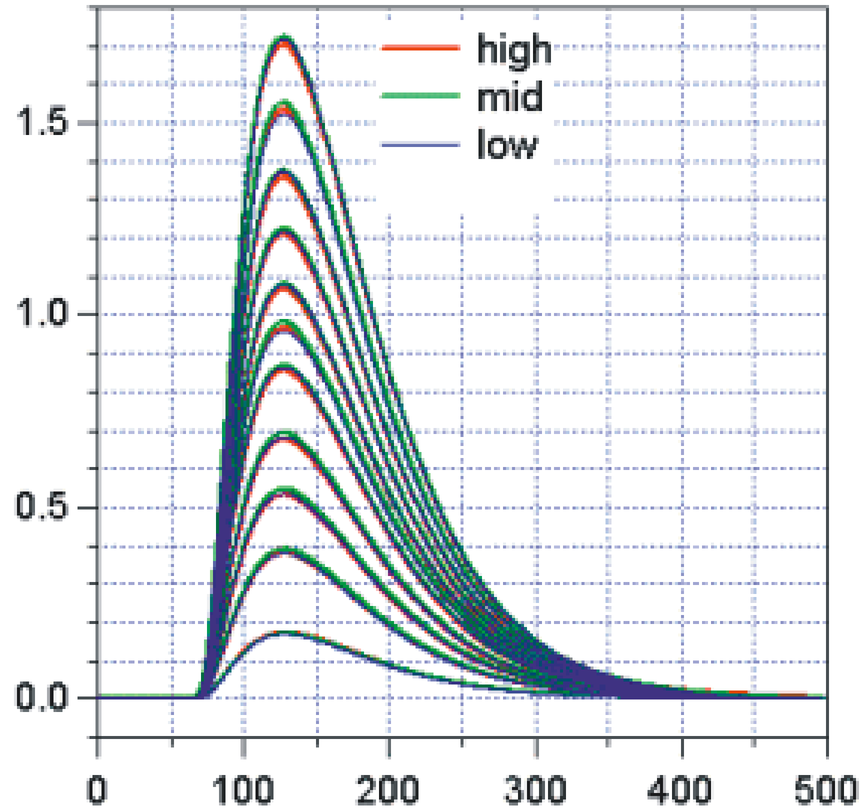
Gains: 1, 6 and 12 (±10%)

Linearity: 0.1% full scale

Pulse shape matching: 0.1%

Noise (measured):

- **8000 electrons gain 6 and 12**
- **28000 electrons gain 1**



- **Programmable charge pulse injection using a DAC**
- **Pedestal DAC for each gain**

ADC

AD41240:

- Developed by ChipIdea and CERN
- Rad. Tol. 0.25 µm technology

4 ADC:

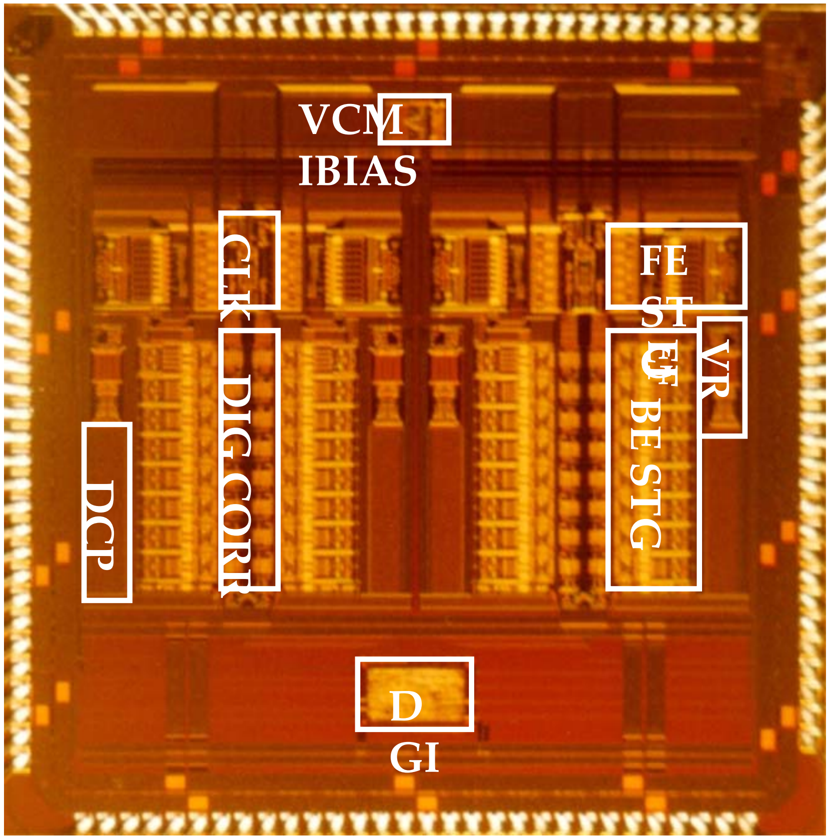
- 40 MHz
- 12 bit
- ENOB measured 10.9

Integrated logic:

- Provides operation in different modes
- ECAL mode: automatic gain selection

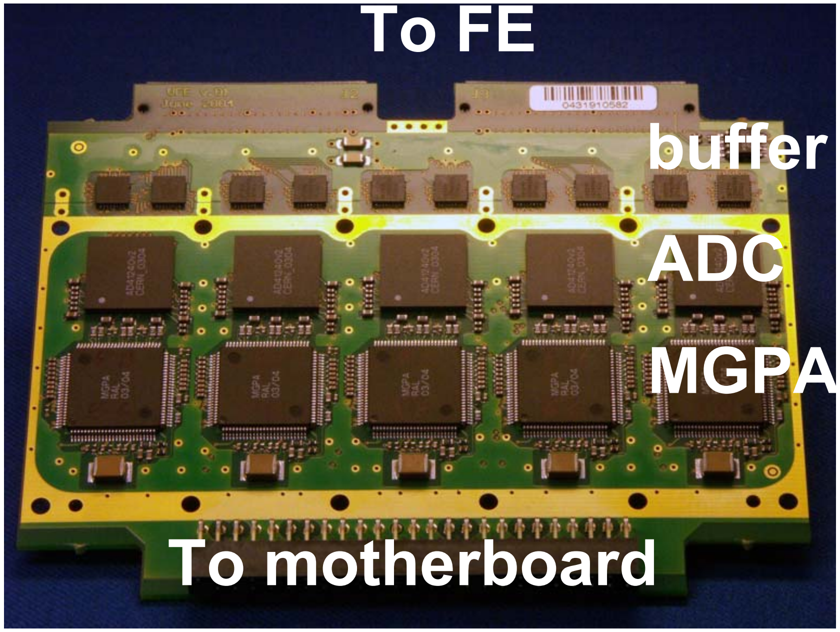
ADC LSB gain 12:

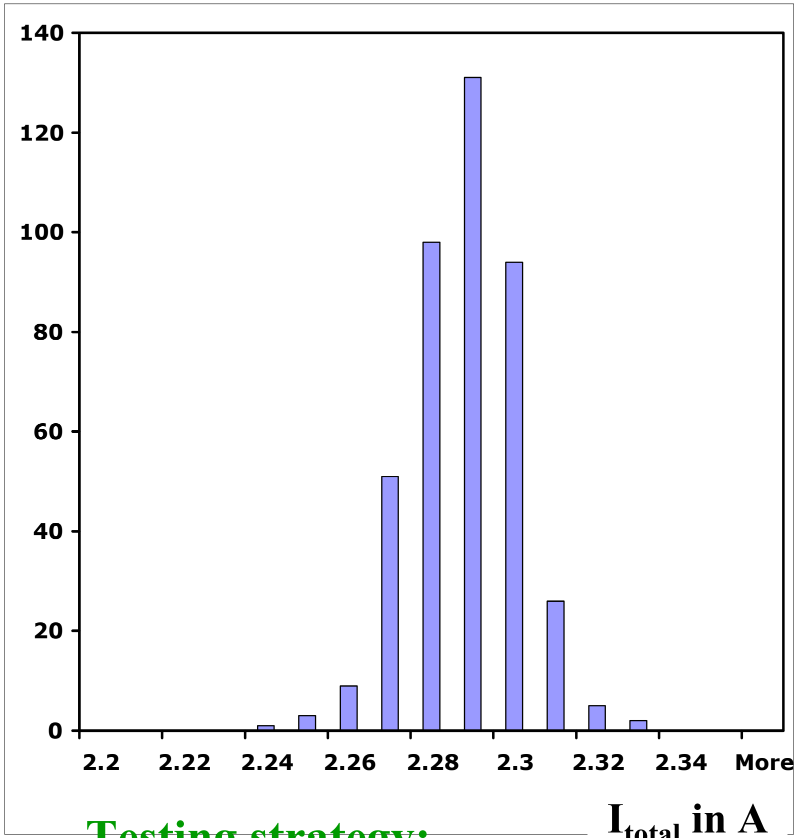
- 34 MeV (EB)
- 71 MeV (EE)



VFE Card

- 5 identical readout channels
- ~12800 pcs EB; ~ 3000 pcs EE
- Ascom Systec AG
- 420 pcs pre-series delivered
- Series production:
  ~2000 pcs/month

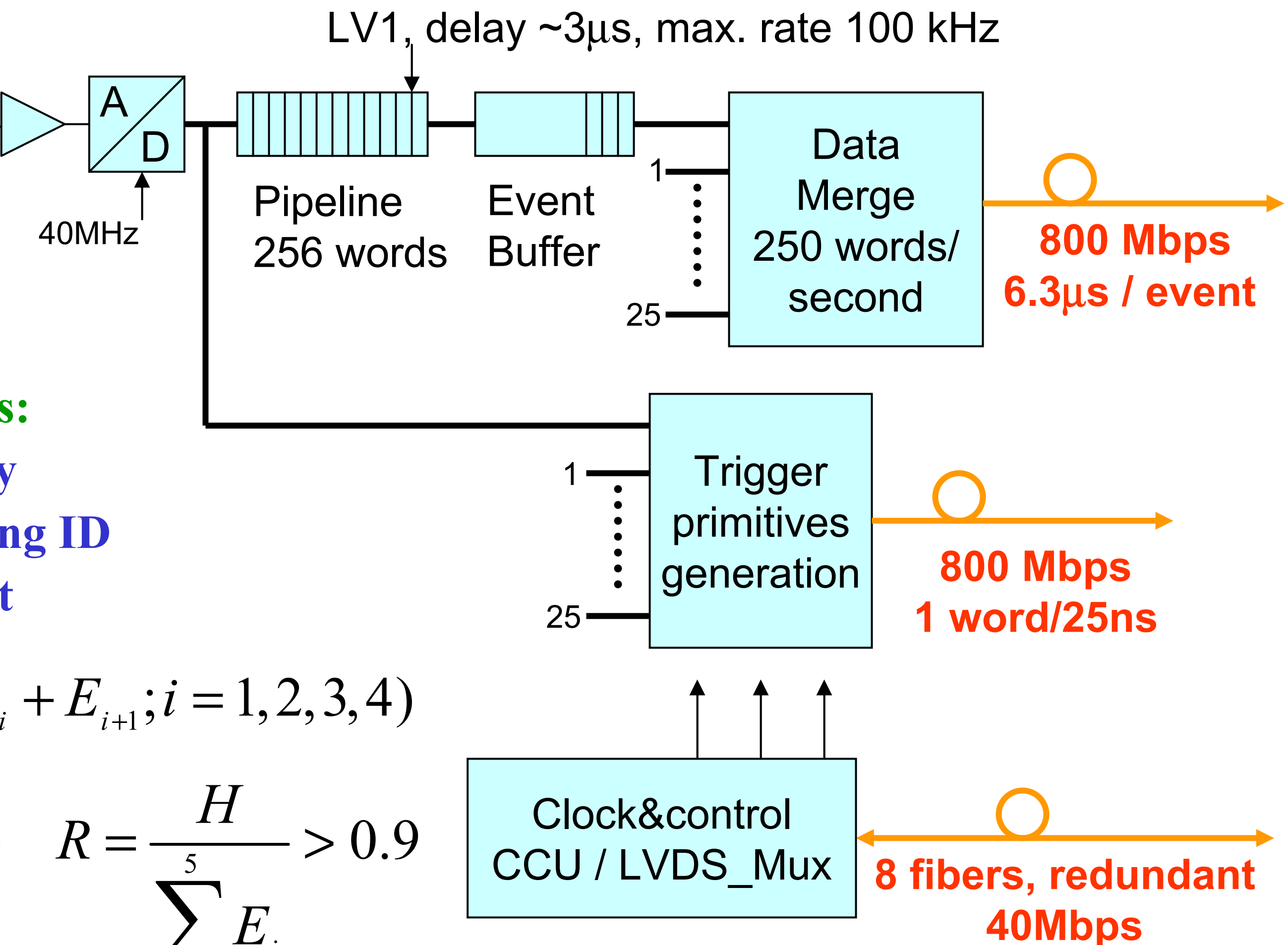




Testing strategy:

- Power ON test
- burn in
- Detailed calibration

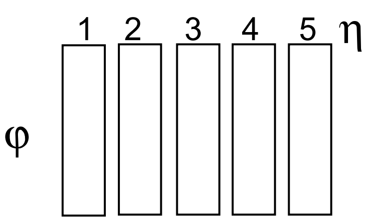
FE Readout



Trigger primitives:

- **Tower energy**
- **Bunch crossing ID**
- **Fine grain bit**

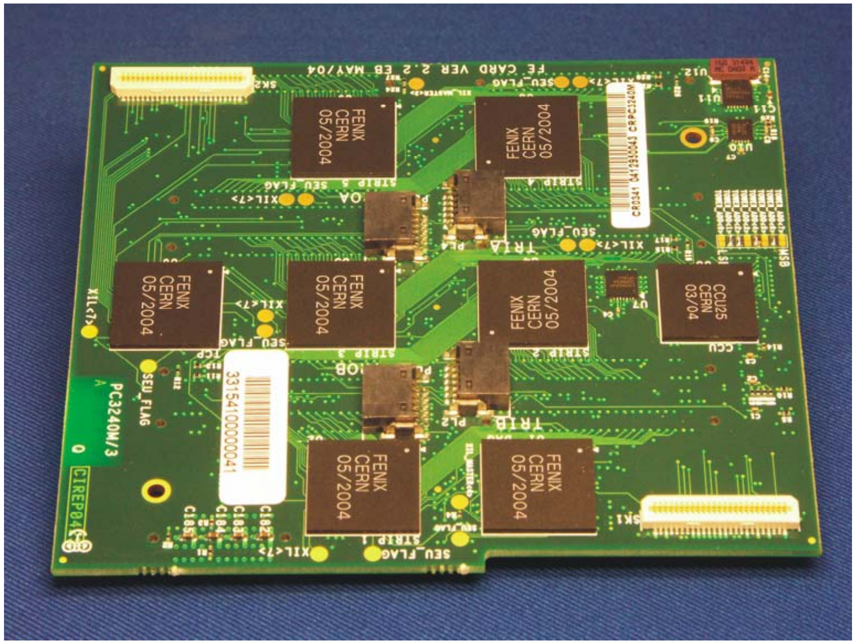
$$H = \max(S_i = E_i + E_{i+1}; i = 1,2,3,4)$$

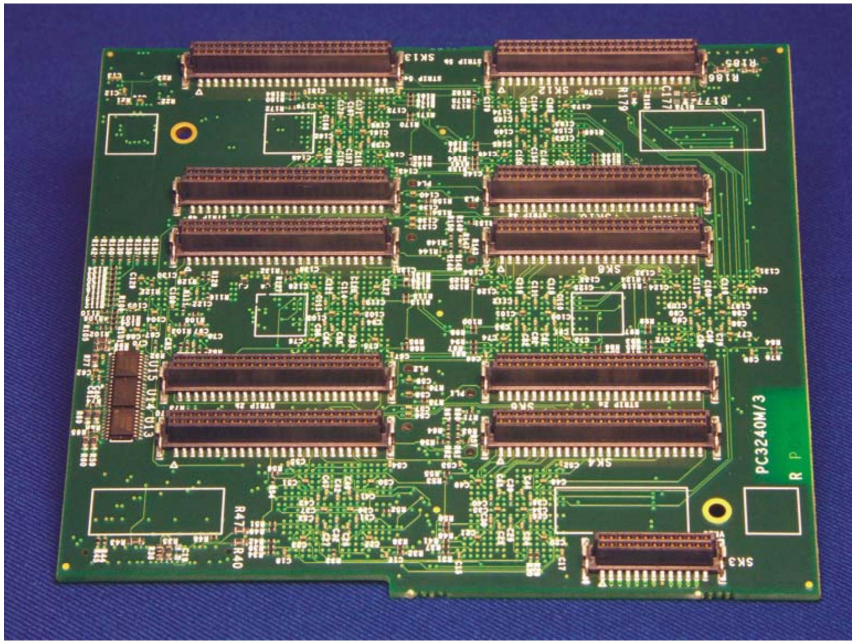


$$R = \frac{H}{\sum_{i=1}^{5} E_i} > 0.9$$

FE Card

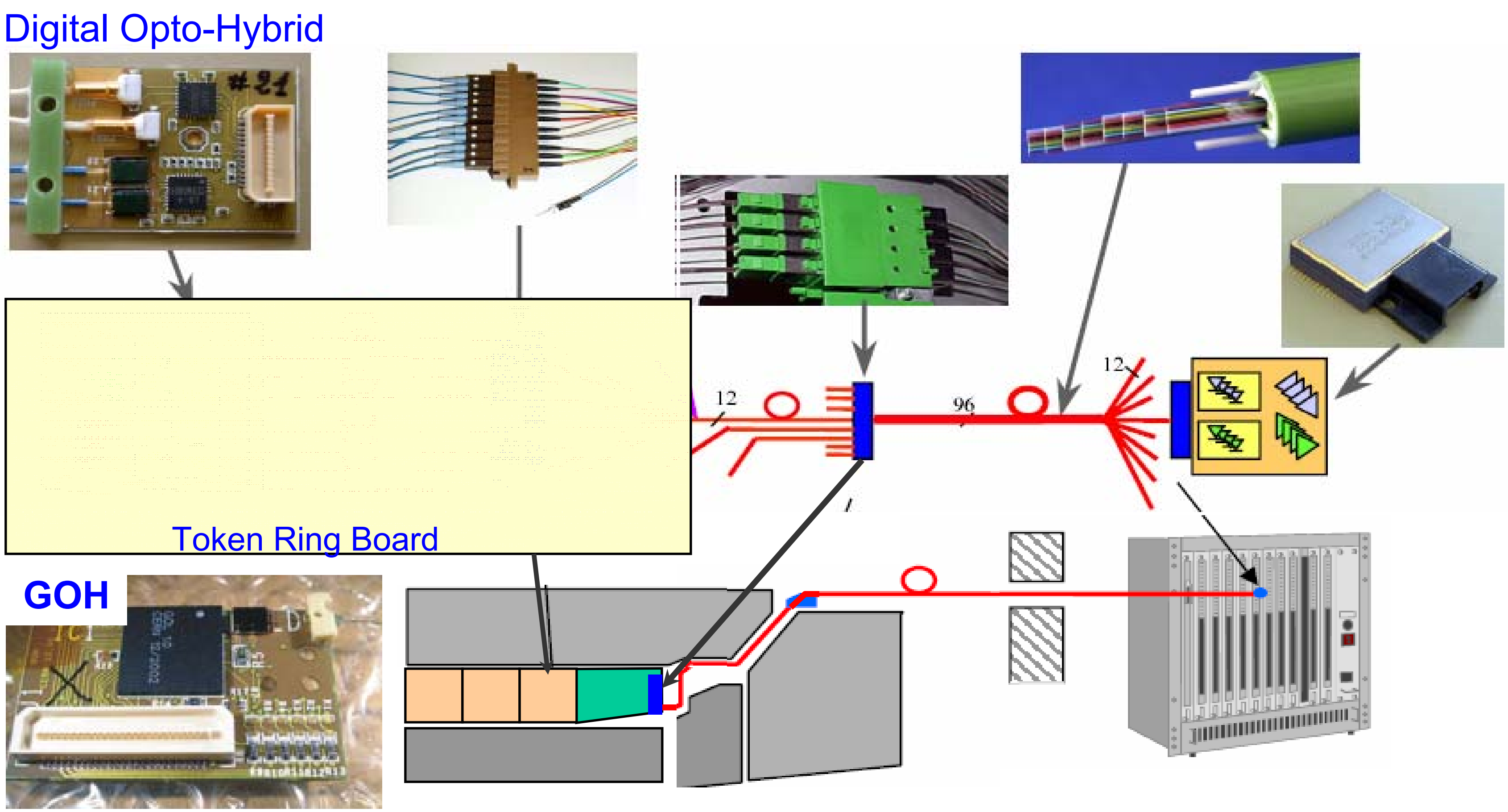
- 5 Strip sum Fenix (pipeline buffer for data)
- 1 Trigger Fenix (trigger primitives)
- 1 Data Fenix (event formatting)
- Slow control LVR (read voltages and currents)
- Slow control VFE (read APD I_{leak} and capsule temperature sensor)



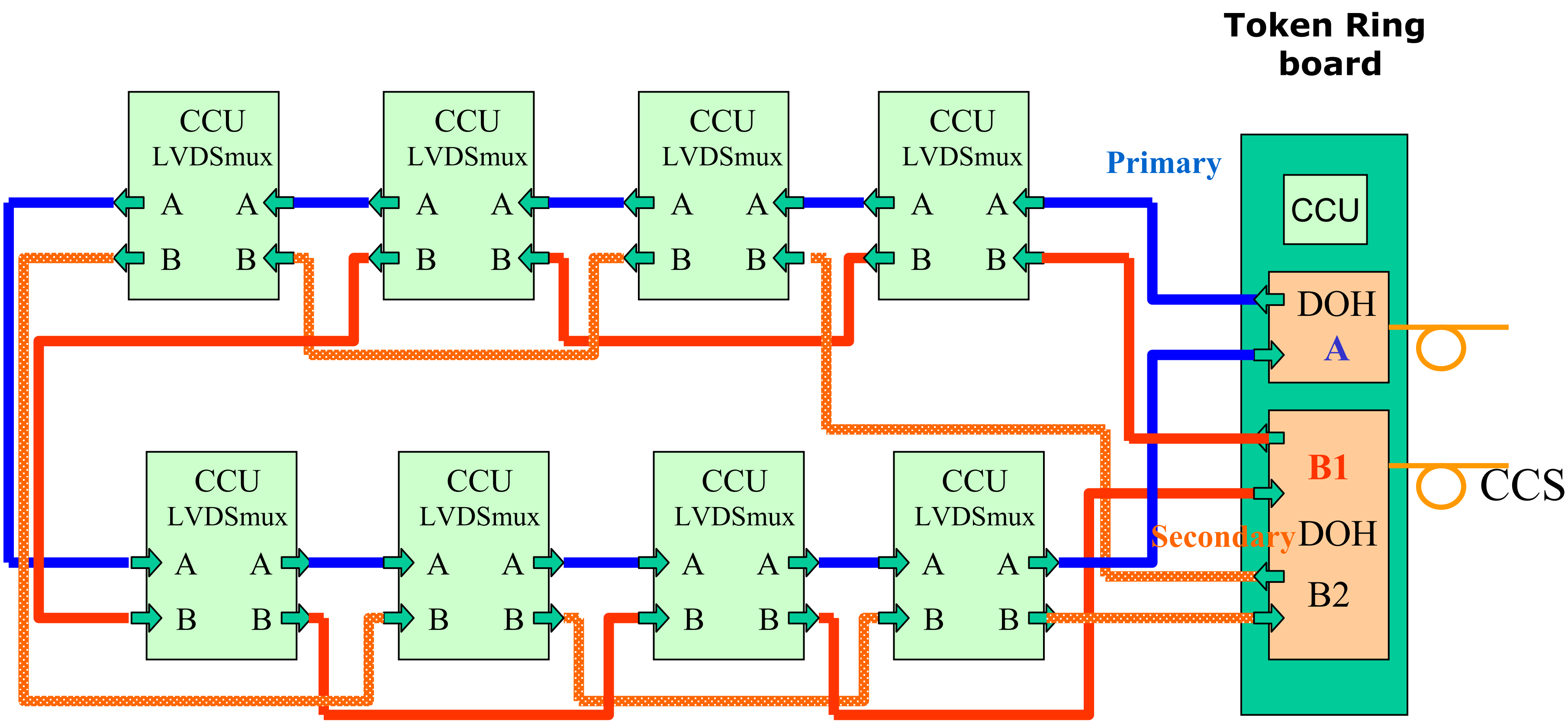


Optical Links

ECAL reuses optoelectronic components from the CMS Tracker



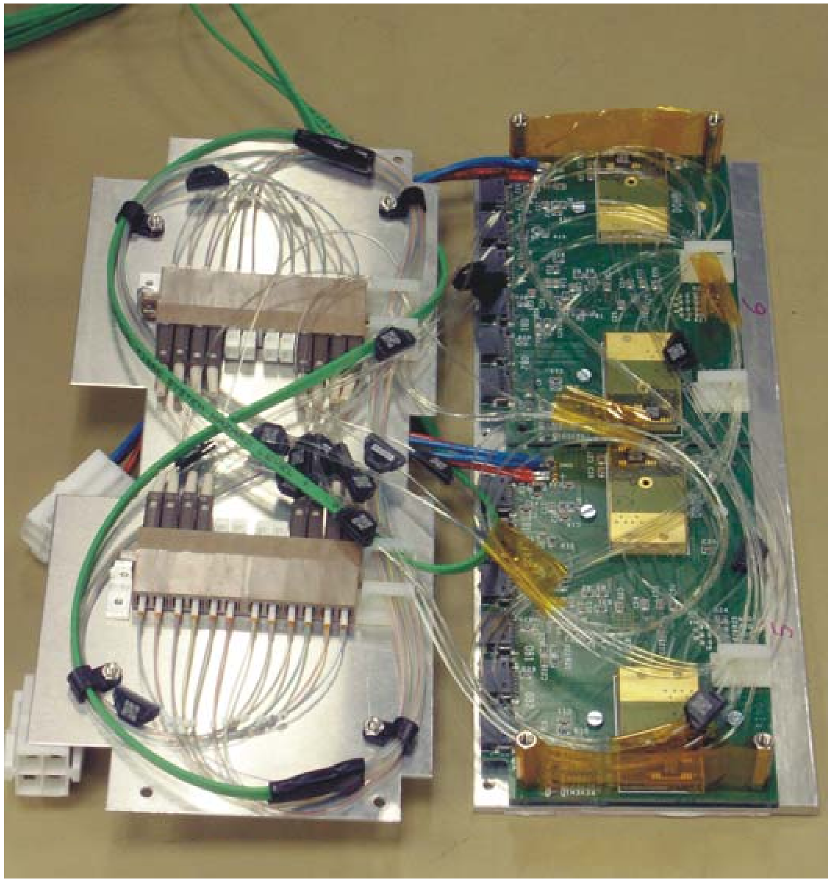
Token Rings



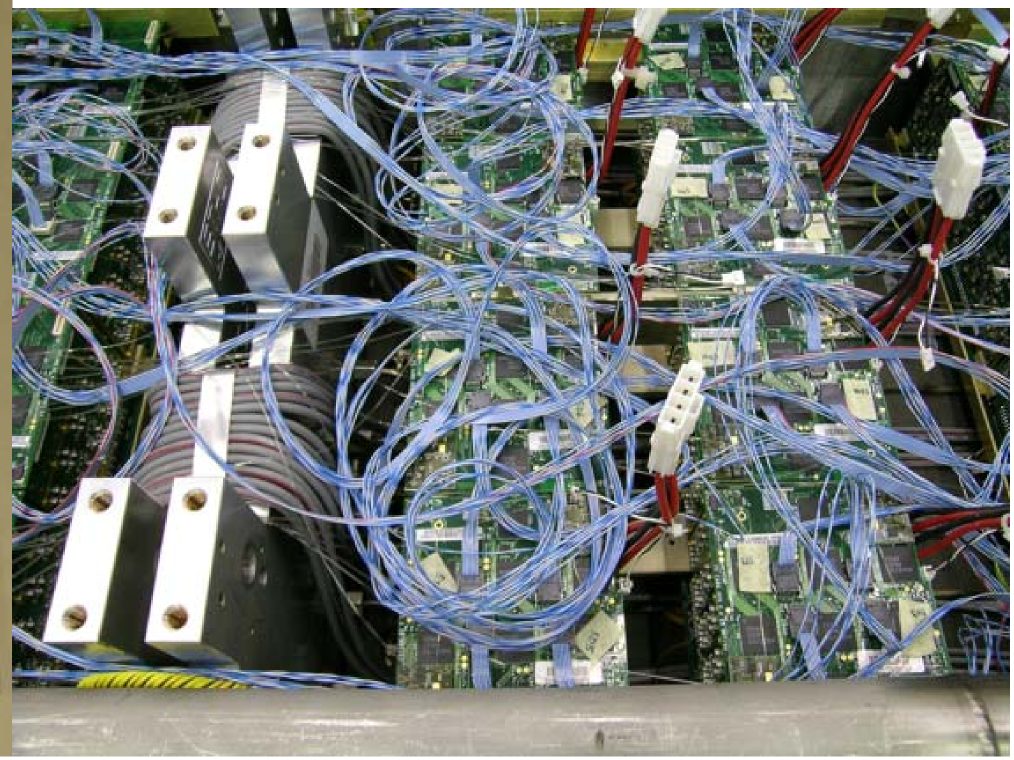
8 token rings per SM:

4 with 8 TT
2 with 10 TT
2 with 8 TT + 1 MEM

Token Ring Link Boards

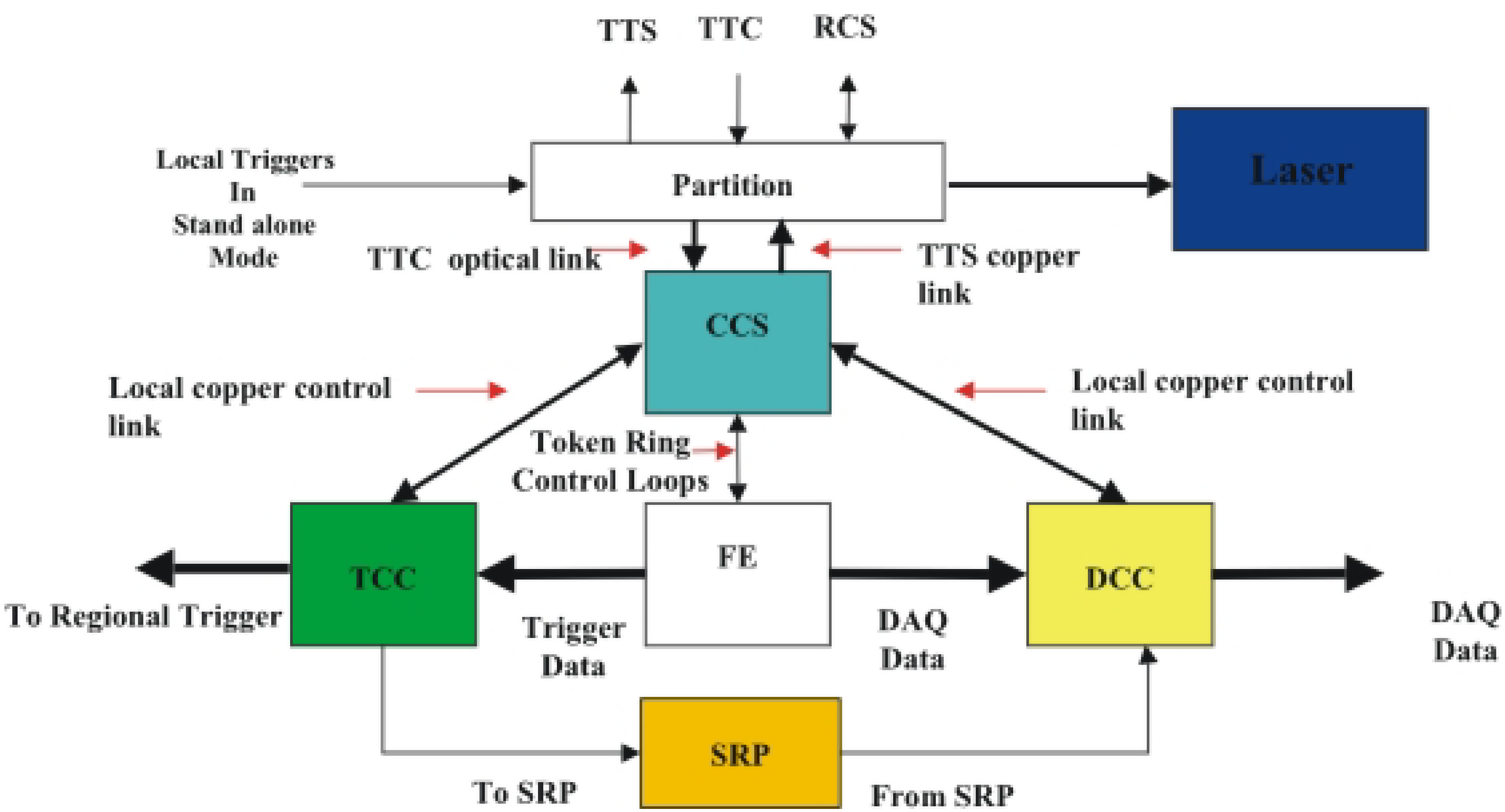


Two token ring boards together with fibers and housing



Token ring cables before being arranged

Off Detector Electronics



Selective Readout

ECAL Event Size transferred to DAQ should be 100 KB on average (~2KB per DCC).

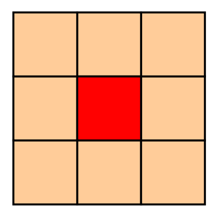
Full ECAL event size is 1.86MB -> Data reduction techniques must be applied to achieve a reduction factor of ~20 in ECAL data:

Zero Suppression (done in the DCC)

Suppression of crystals with energy lower than ~ 60MeV (Barrel) and ~ 300 Mev(end-caps)

Selective Readout:

- **use 2 energy thresholds for trigger tower energy (E_T)**
- **low threshold (~600MeV): $E_T > L_T$? Read the tower**
- **High threshold (~2GeV): $E_T > H_T$? Read tower and all its neighbours across super module boundary**
- **otherwise do not read**
- **Mapping generated by SRP and send to DCC**



DCC

70 Optical Receivers (800Mbds):
- **68 Trigger towers (1 SM)**
- **2 for light monitoring**

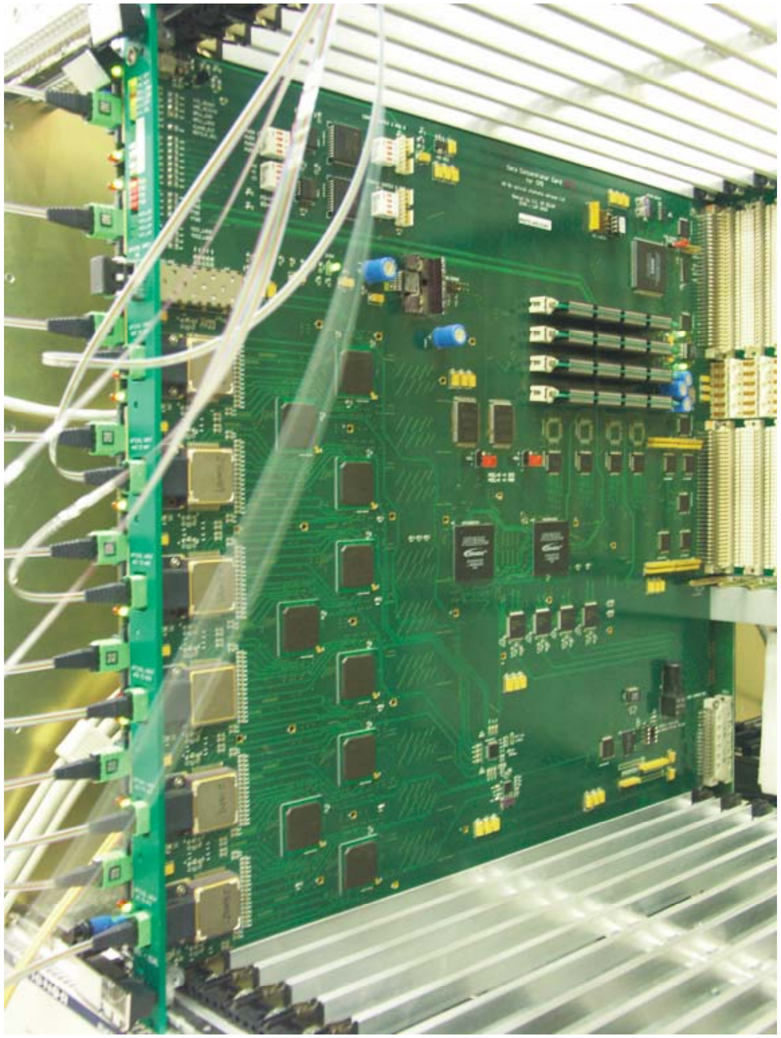
Data integrity checks

Event formatting

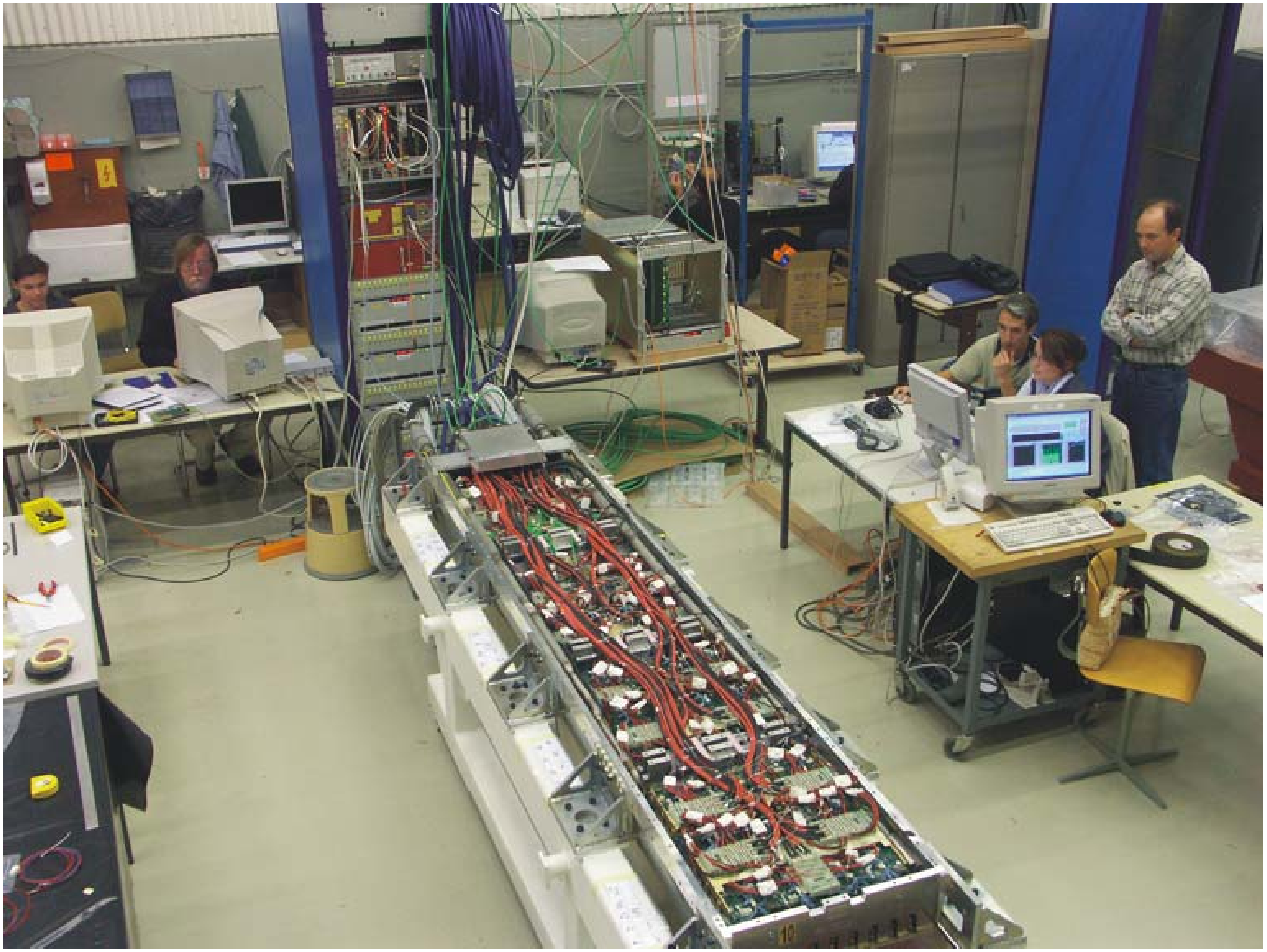
Bandwidth to DAQ:
- **Maximum 528 Mb / s**
- **Average 200 Mb / s**

Data Reduction:
- **Selective readout**
- **Zero suppression**

⇒ Suppression factor ~20

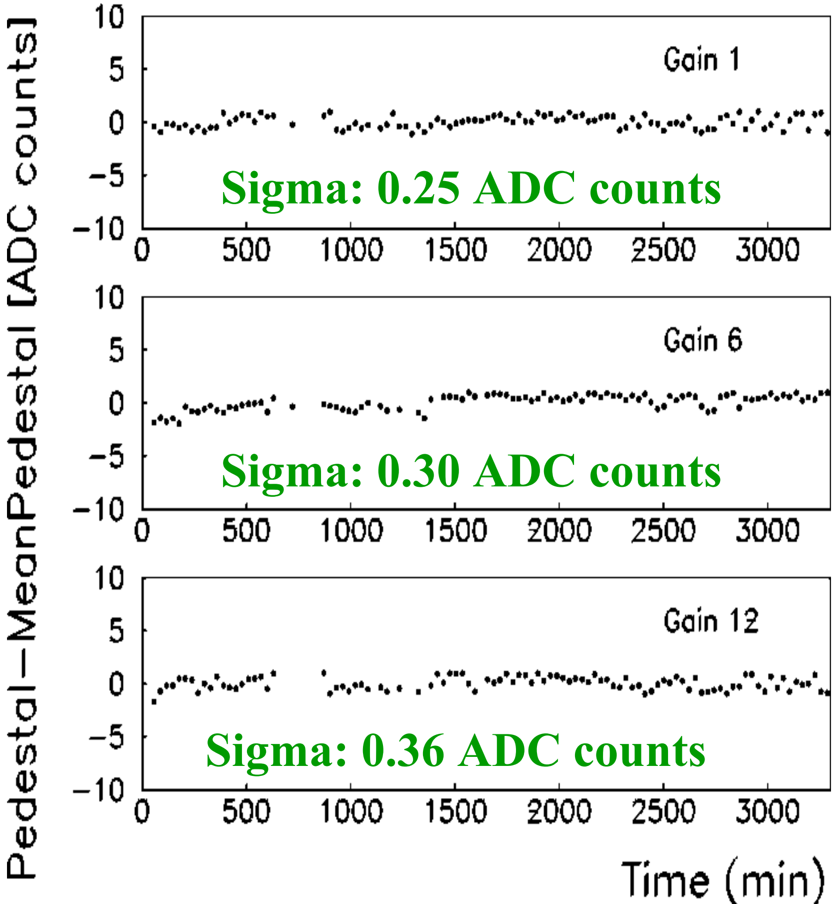


Integration



Integration

Pedestal / Noise SM10



Pedestal stability over 2 days

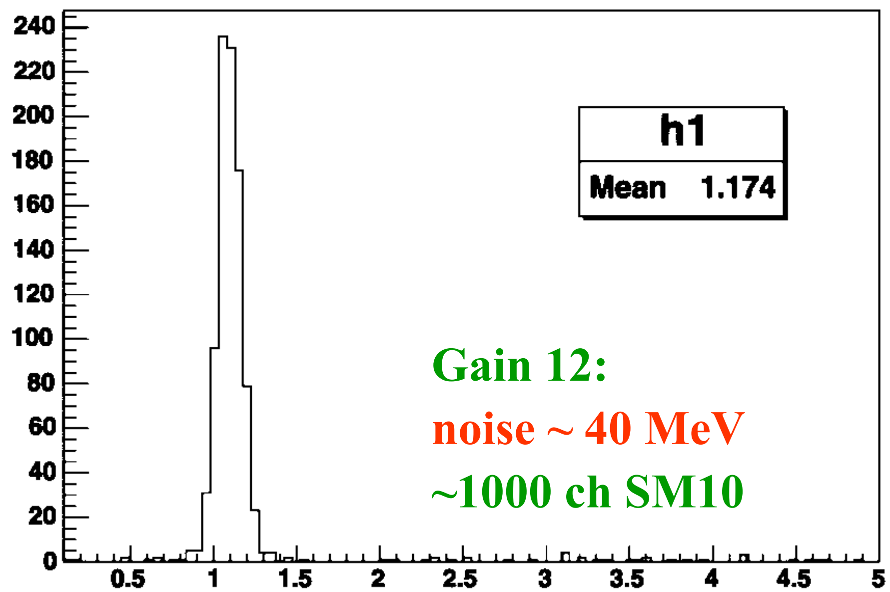
Stable to the level of noise

Noise measured for 675 channels:

Gain 1: 0.54 ADC counts

Gain 6: 0.73 ADC counts

Gain 12: 1.10 ADC counts



SM10 construction completed in time

Ready to start the production of 36 SM's