



ECAL Construction Status



LHC Days, Split, Croatia, Oct 2 - 7, 2006

ETH Zurich, Werner Luster

On behalf of the CMS ECAL group

- 1) ECAL: Barrel, End-Caps and Pre-Shower Detector**
- 2) Crystals and Photo-detectors**
- 3) Mechanics, Assembly and Cooling**
- 4) On Detector Electronics, Integration, Commissioning**
- 5) Off Detector Electronics, Commissioning**
- 6) Services: High Voltage system, Low Voltage System and Detector Control Systems**
- 7) Test beams, Calibration, Installation and Magnet Test**
- 8) Summary and Outlook**

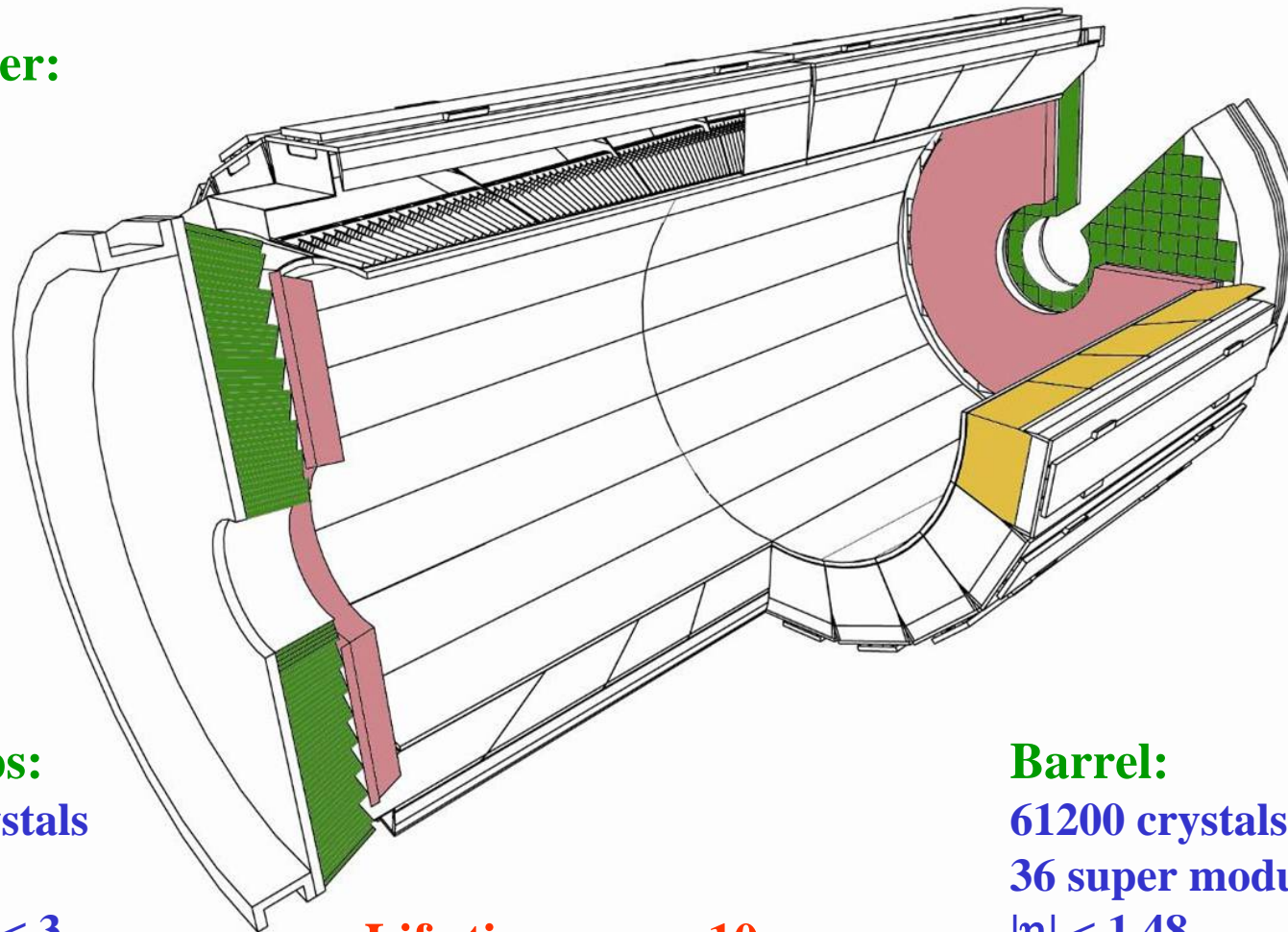


Calorimeter Construction



Preshower:

$3 X_0$
Pb/Si



End Caps:

14648 crystals
4 Dees
 $1.48 < |\eta| < 3$
 $\sim 25 X_0$

Life time: ~ 10 years
Maintenance: zero

Barrel:

61200 crystals
36 super modules
 $|\eta| < 1.48$
 $\sim 26 X_0$



Crystals

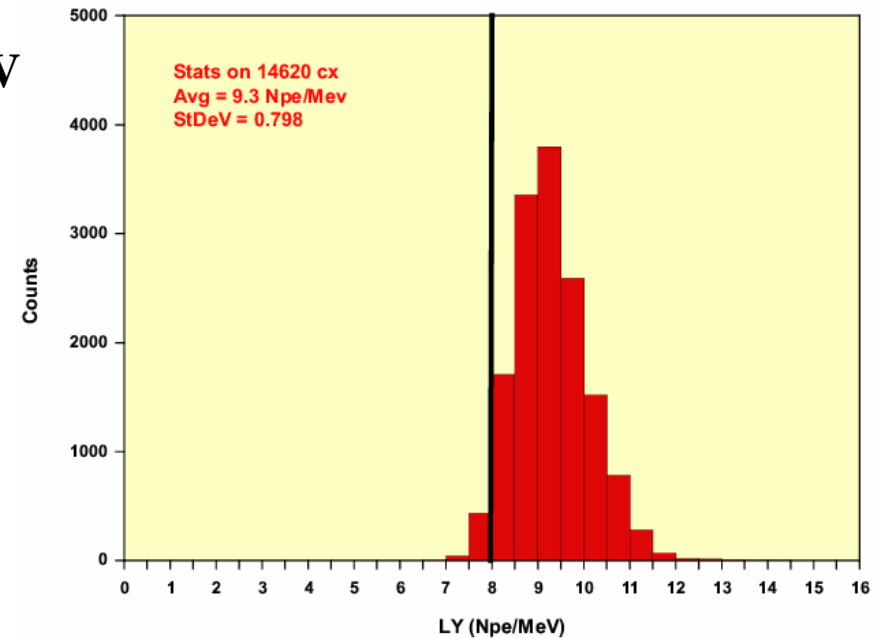


- **Crystals:** Lead Tungstate: PbWO_4
 - **Fast scintillation:** 80% of the light collected in 25ns
 - **Radiation length:** 0.89 cm
 - **Moliere radius:** 2.19 cm
- ⇒ **Compact calorimeter design**
⇒ **fine segmentation**



LY Distribution for All Batches (14620 cx)

- **Low light yield:** 9.3 npe / MeV
 - **Light yield change:** -2% / °C
- ⇒ **requires: $T = (18 \pm 0.05) \text{ }^\circ\text{C}$**
- **Front non uniformity of the light yield:** $|\text{FNUF}| < 0.35 \text{ \%} / X_0$
(de-polish one face of the crystals to $0.35 \text{ }\mu\text{m}$)

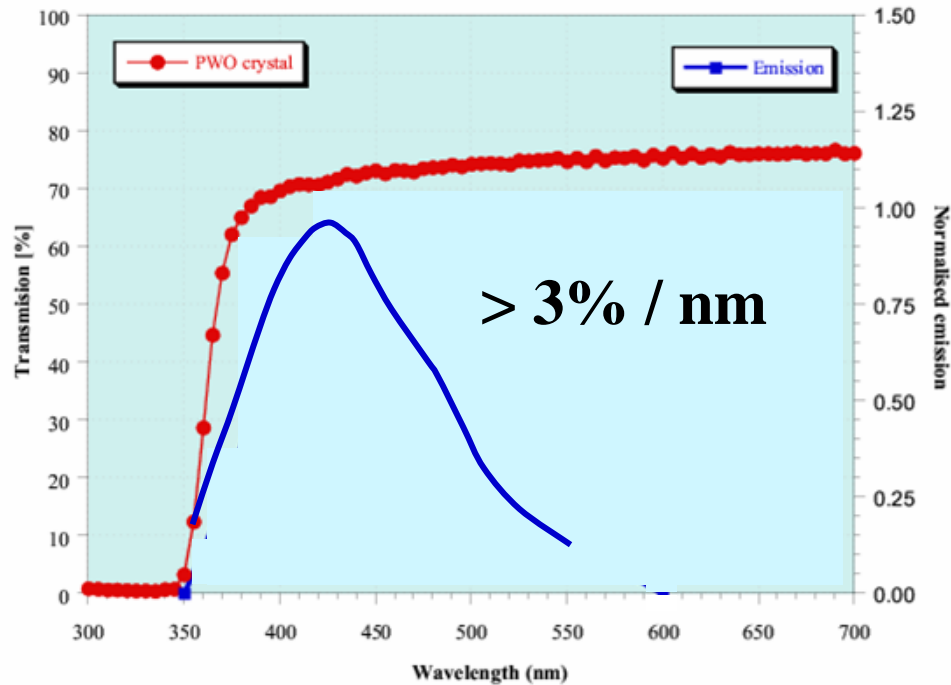




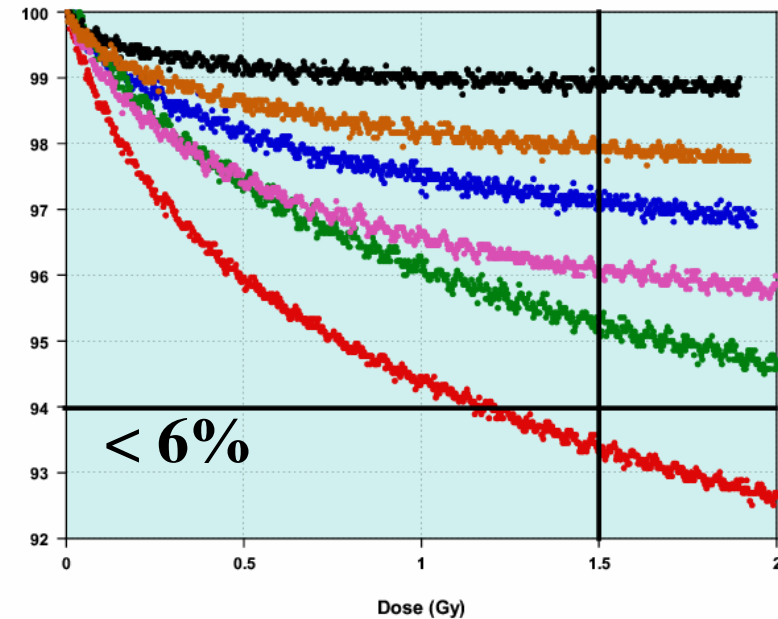
Crystals



Comparison Real Longitudinal Transmission vs. Emission spectrum



Low dose irradiation of some crystals at CERN RC



- **Radiation: affects only the light transmission**
- **Low dose rate (0.15Gy/h) irradiation only on sample basis**
- **Light yield loss correlates with slope of transmission spectrum**
- **all crystals are tested by an automatic crystal control system (ACCOS), CERN, ENEA/INFN Rome**



Barrel Photo-Detectors



APD type S8141 from Hamatsu:

- Active area: (5 x 5) mm²
- Capacitance: 80 pF
- Reversed bias: (340 - 440) V
- Quantum efficiency: 75% at 430 nm
- Gain variation: -2.4 % / °C
- Nominal gain: 50 changes 3.1 %/V

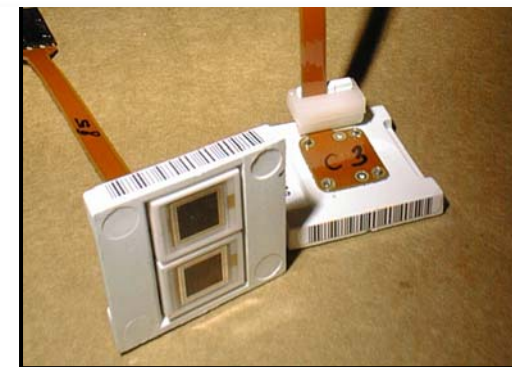
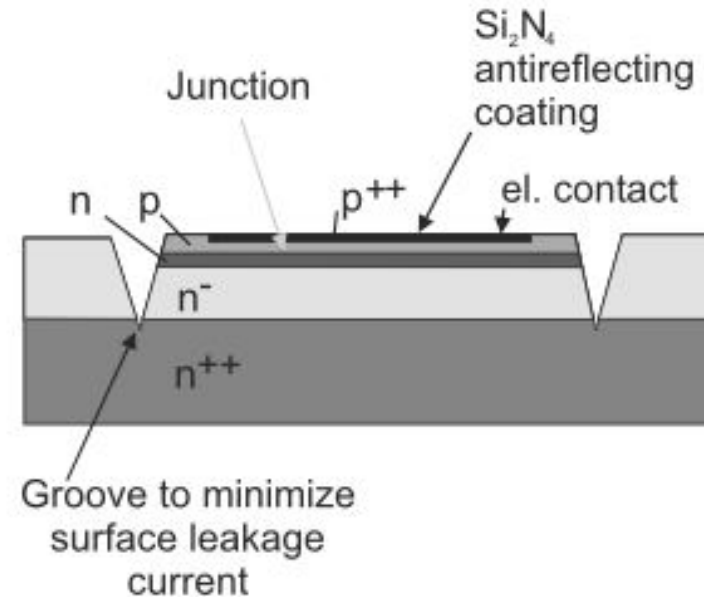
⇒ Bias voltage stable to ± 20 mV

Require 99.9% reliability

Radiation tests: Co⁶⁰ to 5 kGy

- Gain, dark current, noise spectrum measurement
- Annealed under bias at 80°C, 4 weeks

⇒ 95% of the APD's passed selection



Capsule directly glued on the crystal rear phase

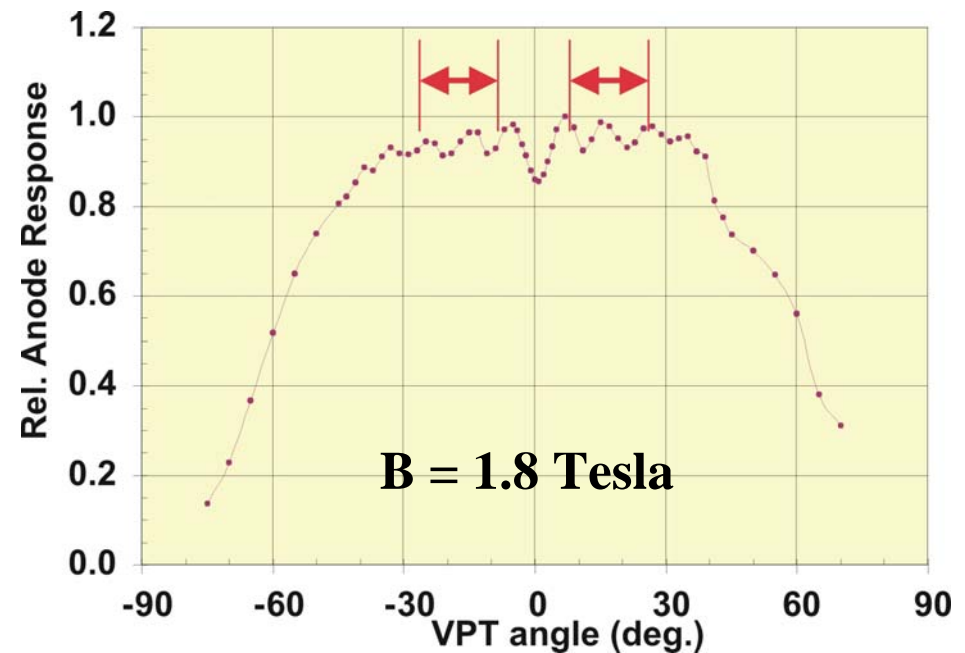


End Caps Photo-Detectors



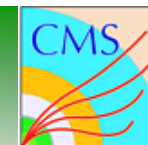
Vacuum Photo Triodes (VPT): single stage photo-multiplier

- Total: ~15000 pcs
 - Active area: 280 mm²
 - Quantum efficiency: 20% at 430 nm
 - Nominal gain: 10
 - Excess noise factor: 3
 - All VPT's tested up to $B = 1.8$ T for angles $|\theta| < 30^\circ$
 - Sample testing up to $B = 4$ T
 - Radiation effects $< 10\%$
- > 14778 pcs delivered and tested





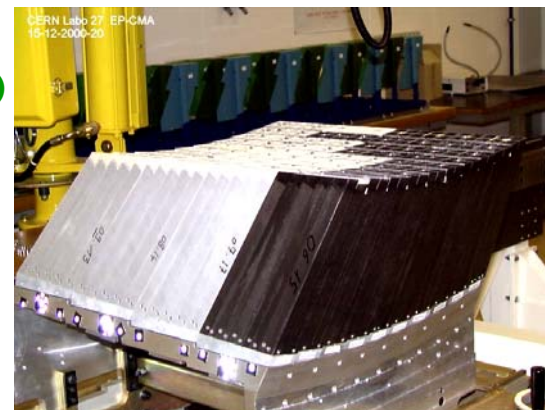
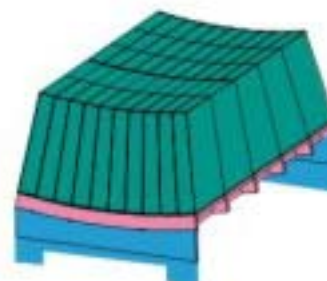
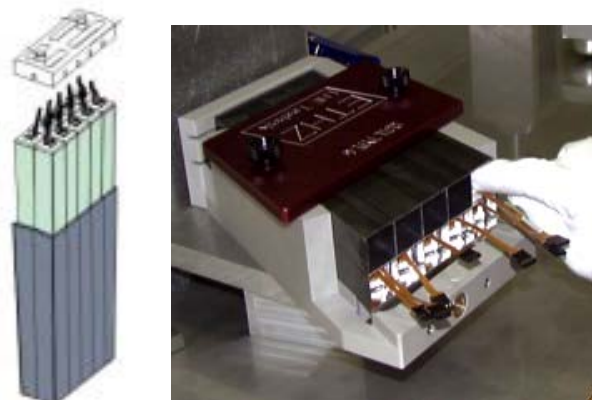
Calorimeter Construction



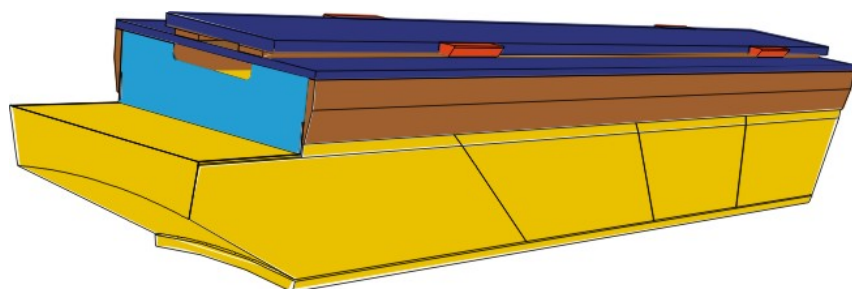
Assembly centers:
ENEA / INFN Rome and CERN EP-CMA

Module assembly
(400 / 500 crystals)

Submodule assembly (10 crystals)



Super module (4 modules, 1700 crystal)



bare supermodule



mi-bare supermodule



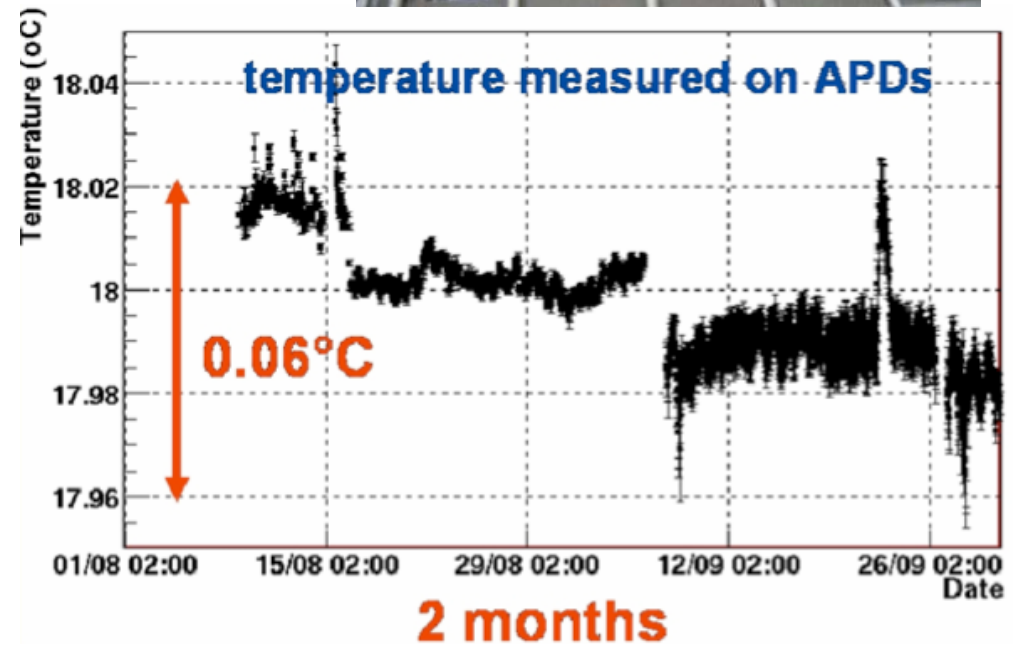


Cooling



Excellent thermal stability of crystals and APD's:

- APD/crystal Stability < 0.1 °C
- Remove ~ 4.5 kW heat per super module
- Electronics connected to cooling bars using thermal interface materials
- Total water flow 50 l / s (barrel)

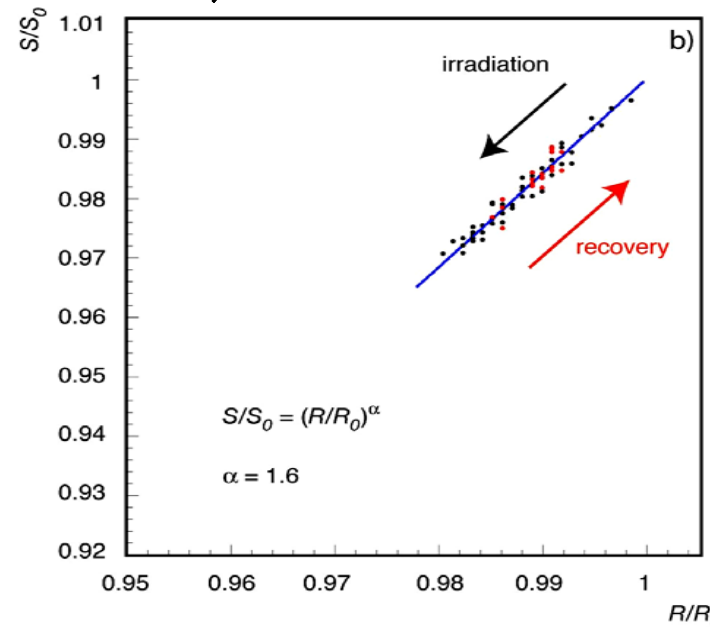
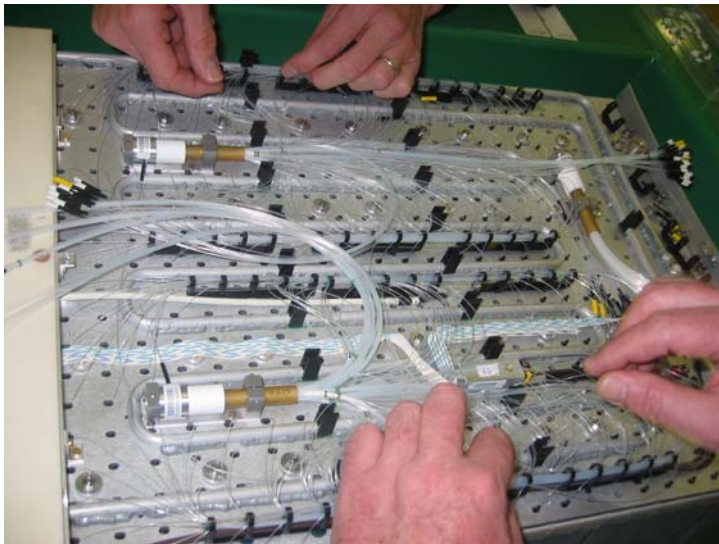
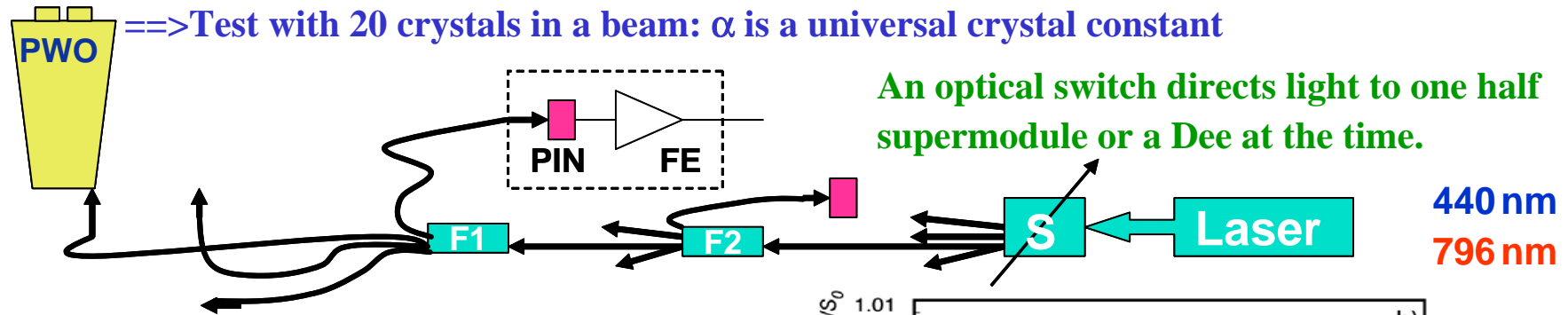




Light Monitoring System

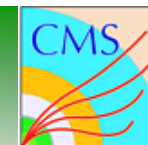


- Crystals light yield changes due to irradiation
==> Monitor response to laser light of 440nm, 495nm and 796nm
- Relative response to electrons and laser light characterized by a single constant α
==> Test with 20 crystals in a beam: α is a universal crystal constant





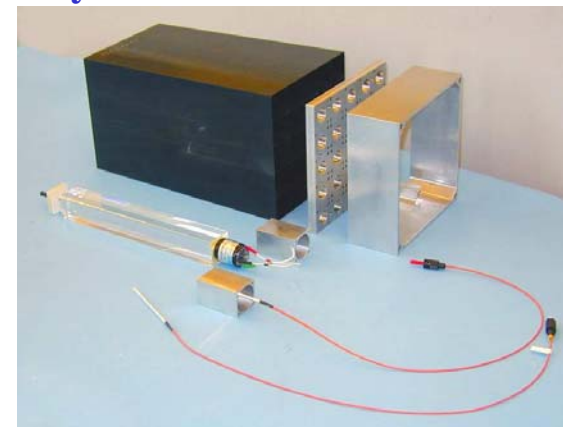
End Caps: Construction, Status and Plan



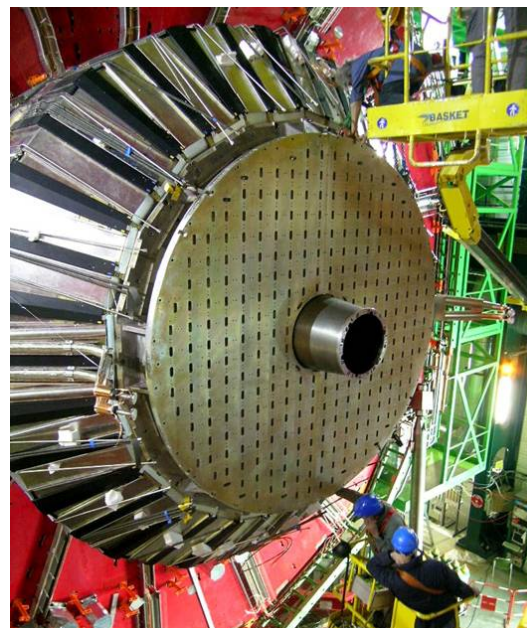
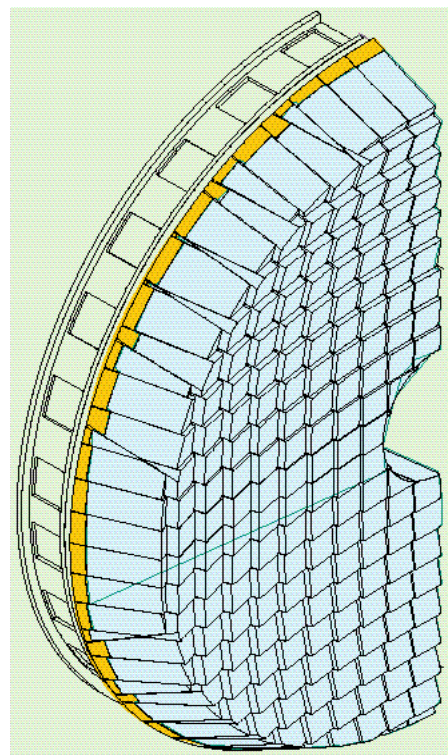
- EE consists of 4 “Dees” of 138 supercrystals each
- remarkable progress on EE design and construction
 - all mechanical parts are delivered
 - D4 (500 crystals prototype) will be assembled by March 2007 and tested in the testbeam at CERN
- ==> start integration of D1 in April '07
- ==> install D1 in Oct. '07 prior to LHC pilot run

Supercrystal:

5x5 crystals in carbon fiber structure



Dee backplate with 4 supercrystals



backplates successfully test mounted on HCAL end-cap



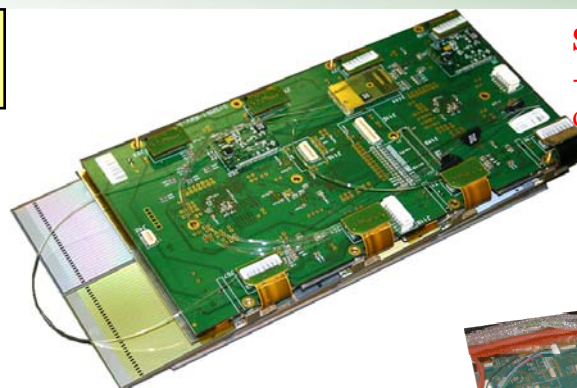
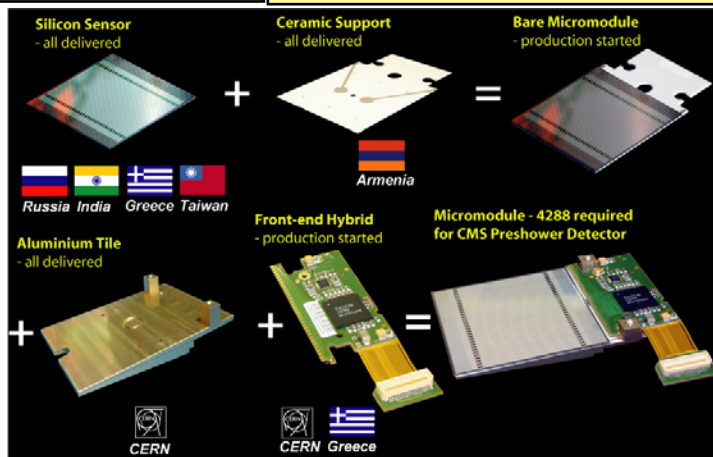


ECAL Pre-Shower Detector: Status



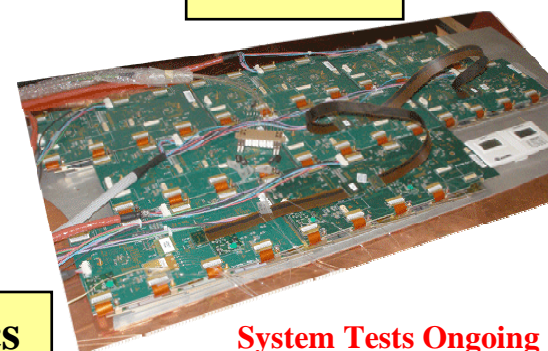
Micromodules

Pre-series underway
Full production by mid 2007



System motherboards
- production started,
due to finish by end 2006

Ladders

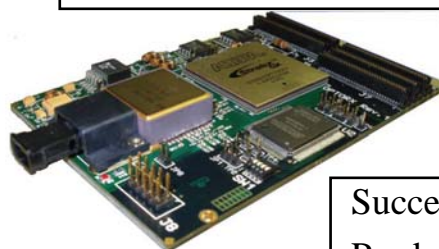


System Tests Ongoing
- 8 ladders shown here

Off-Detector Readout Electronics

Modular design
being developed
jointly with TOTEM

First module already
finalized – 12-channel
optical receiver
(optoRx)



Successful ESR held on 8th May
Production complete ~September 07

Mechanics



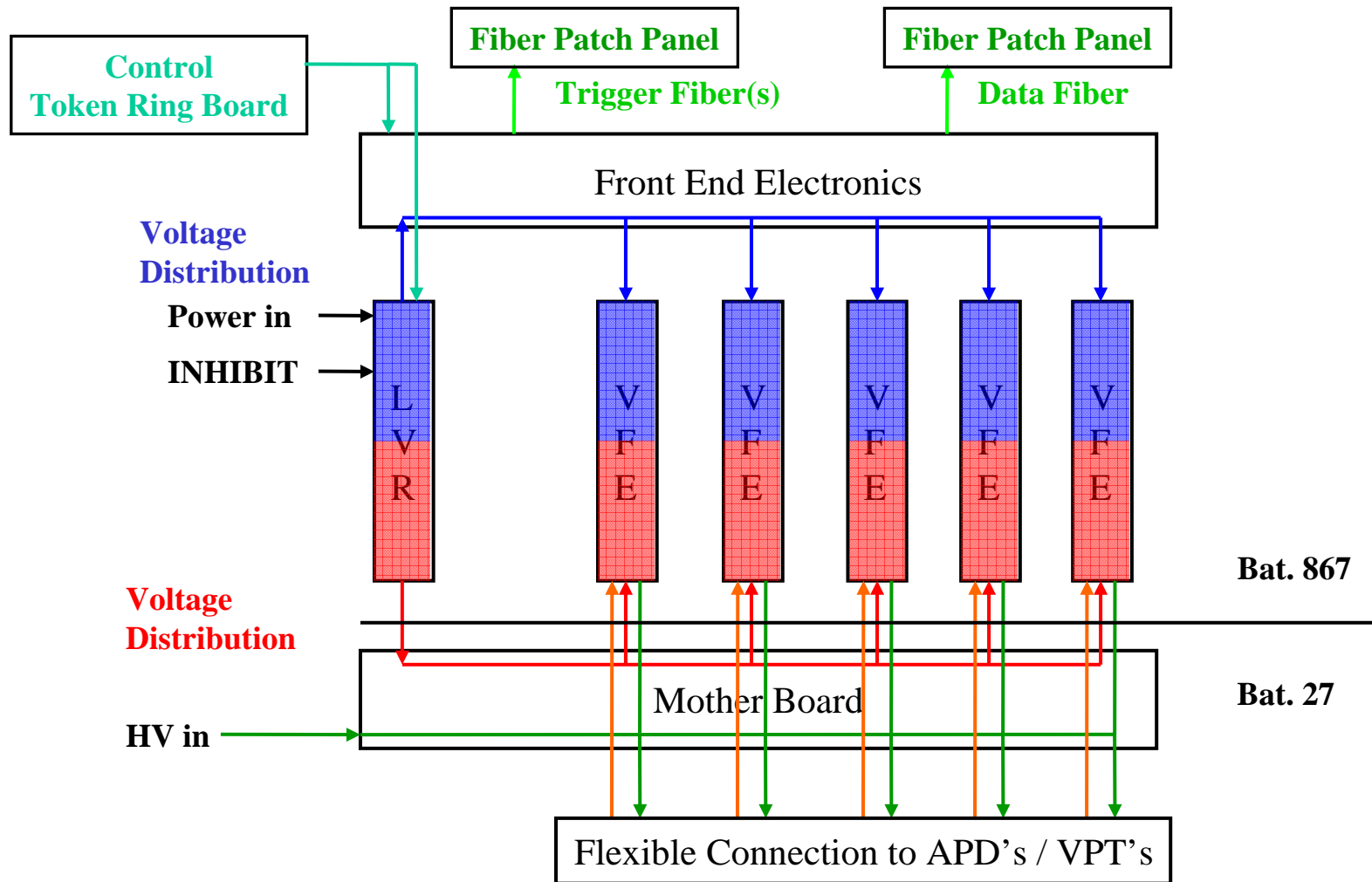
4 Preshower "windows"
(main structural elements)

All ES "complete disc"
elements ready for
installation early 2007
(before the beam pipe)

All other mechanical
elements progressing
well, including
installation tooling etc.

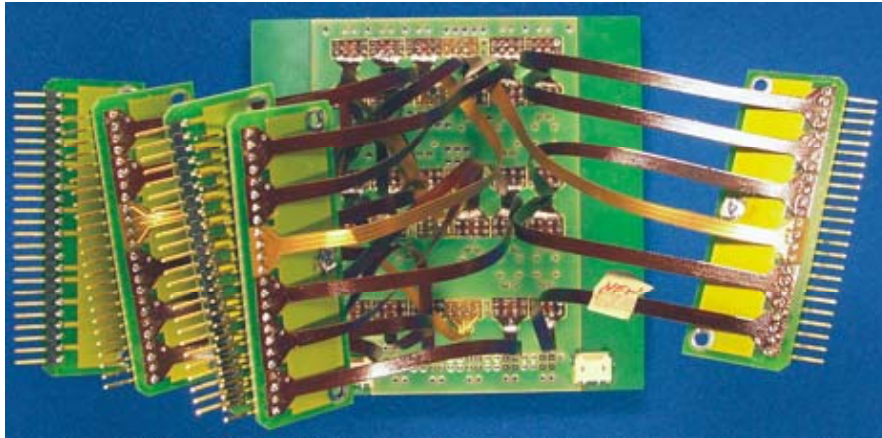


Trigger Tower Electronics

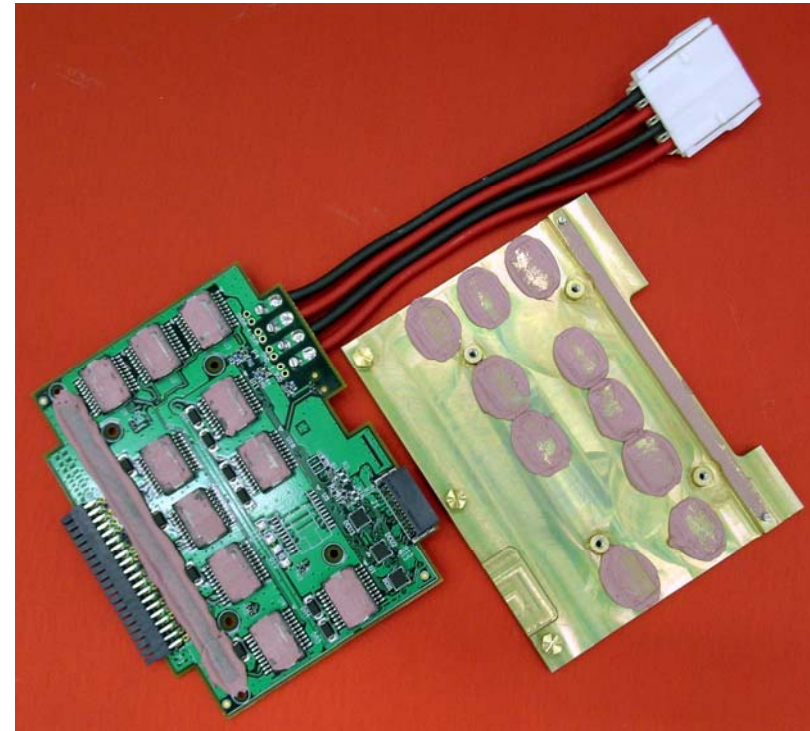




Motherboard and LVR card



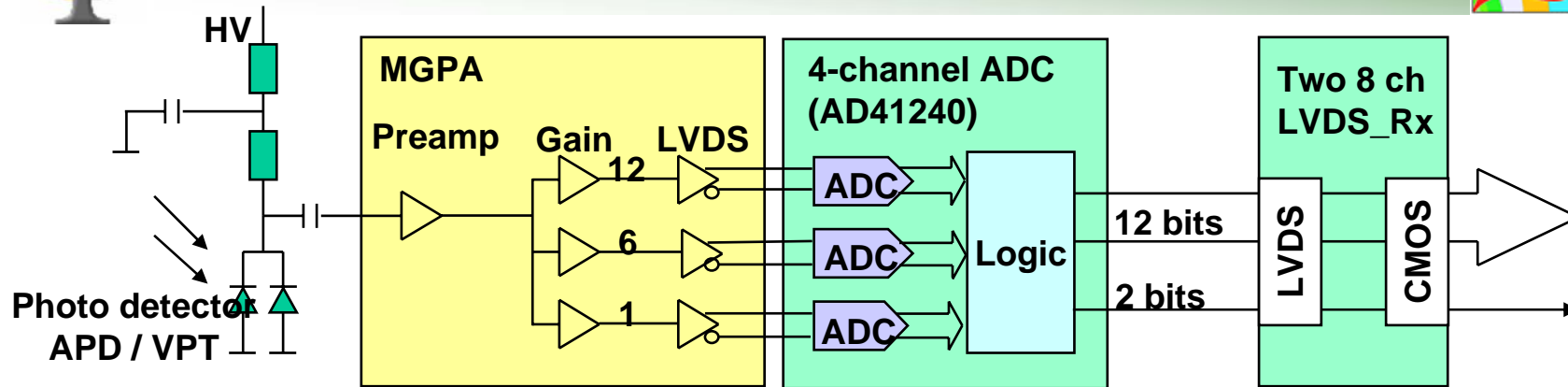
- **Low Voltage distribution to VFE**
- **High Voltage distribution to APD**
- **High Voltage filter network**
- **Flexible Kapton cables to APD and temperature sensor**
- **Ground connection to the grid**



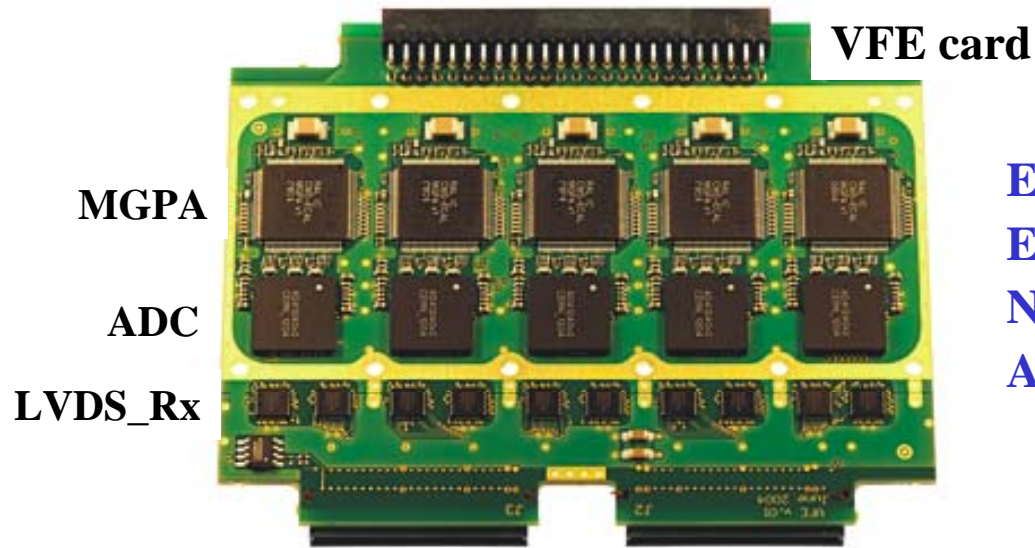
- **Low Voltage Regulator (LVR) card with housing**
- **Gap filler 2000 is used as thermal interface**



Readout Electronics



digitize once every 25 ns the energy in all crystals



ENC: 8000e- gain 6, 12

ENC: 28000e- gain 1

Noise: ~45 MeV (g12)

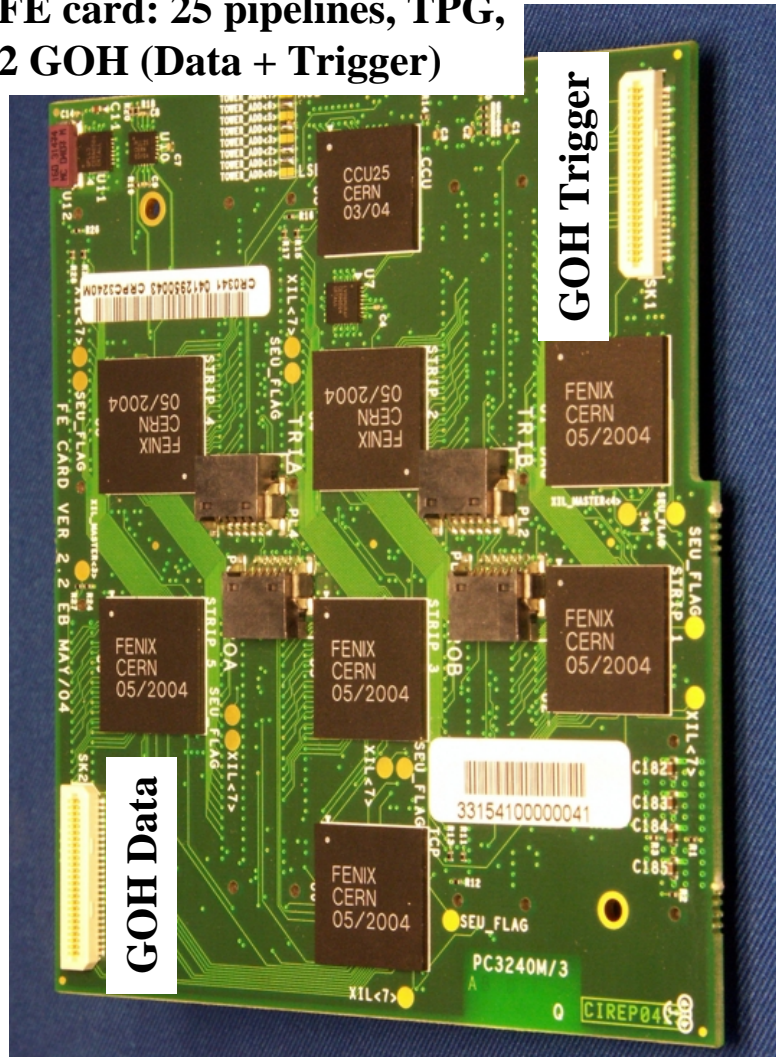
**ADC: 12 bit (ENOB 10.9),
40 MHz**



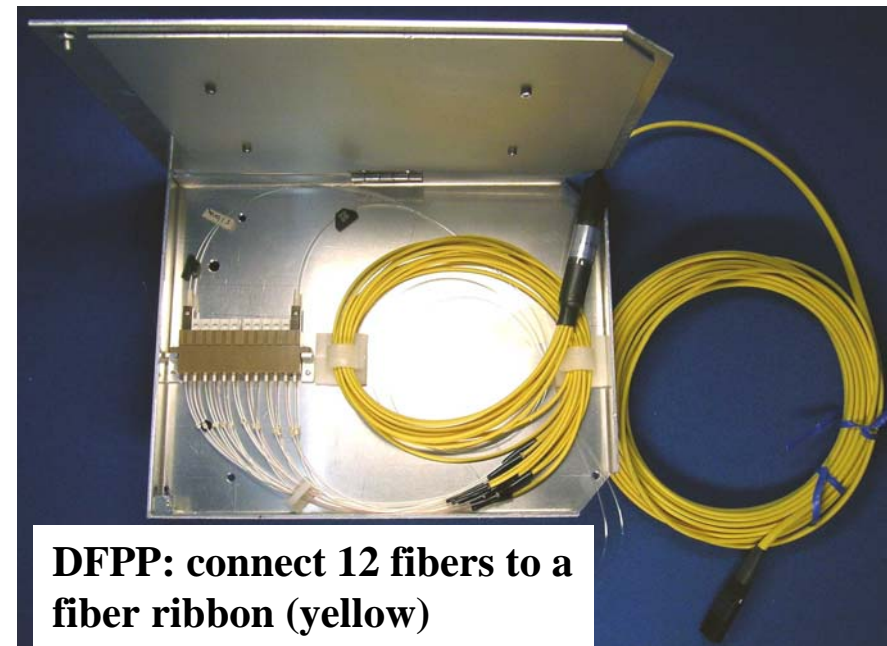
GOH and DFPP



**FE card: 25 pipelines, TPG,
2 GOH (Data + Trigger)**



GOH: 800 Mbit / s





Integration Area



SM 21

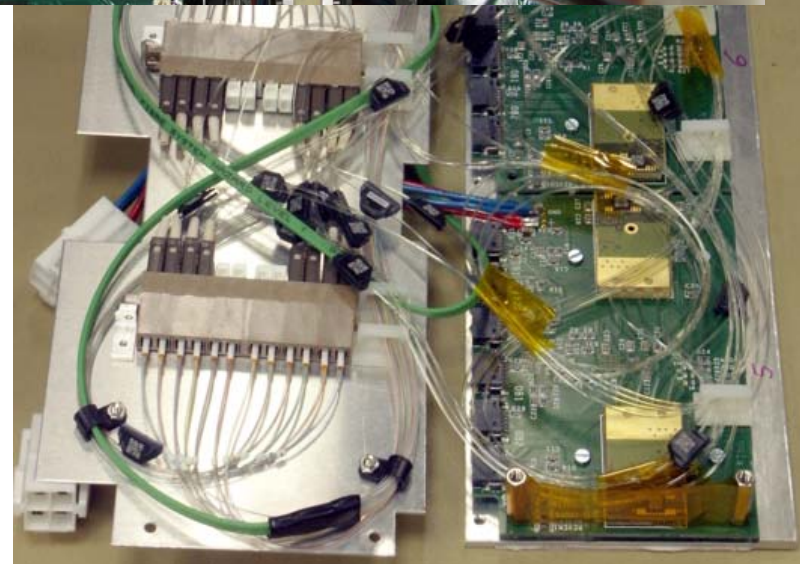
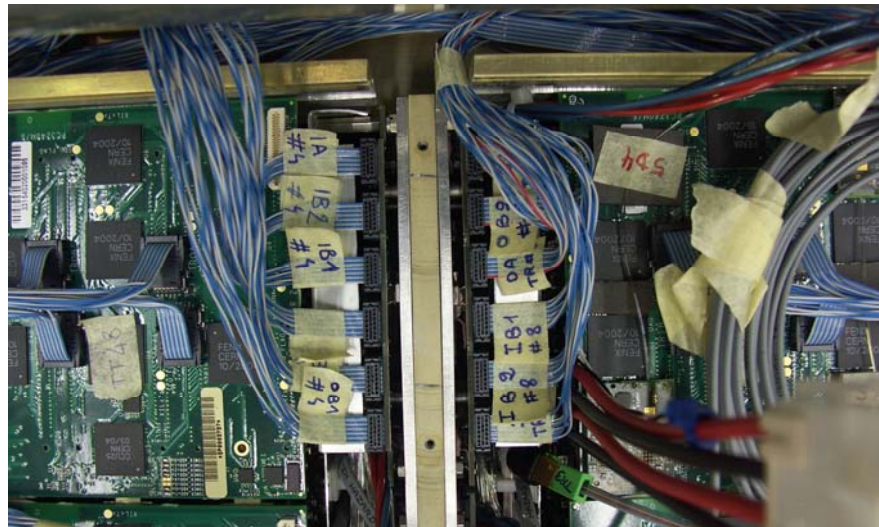
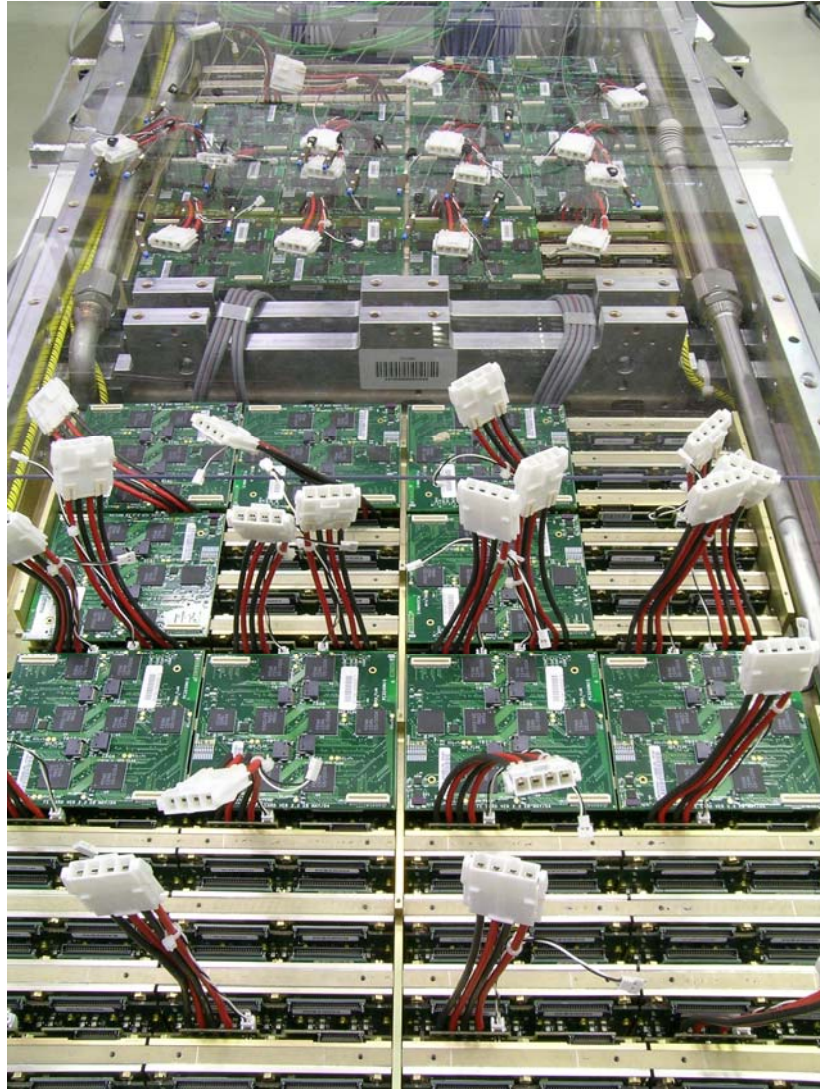
SM 13

SM 17

SM 19

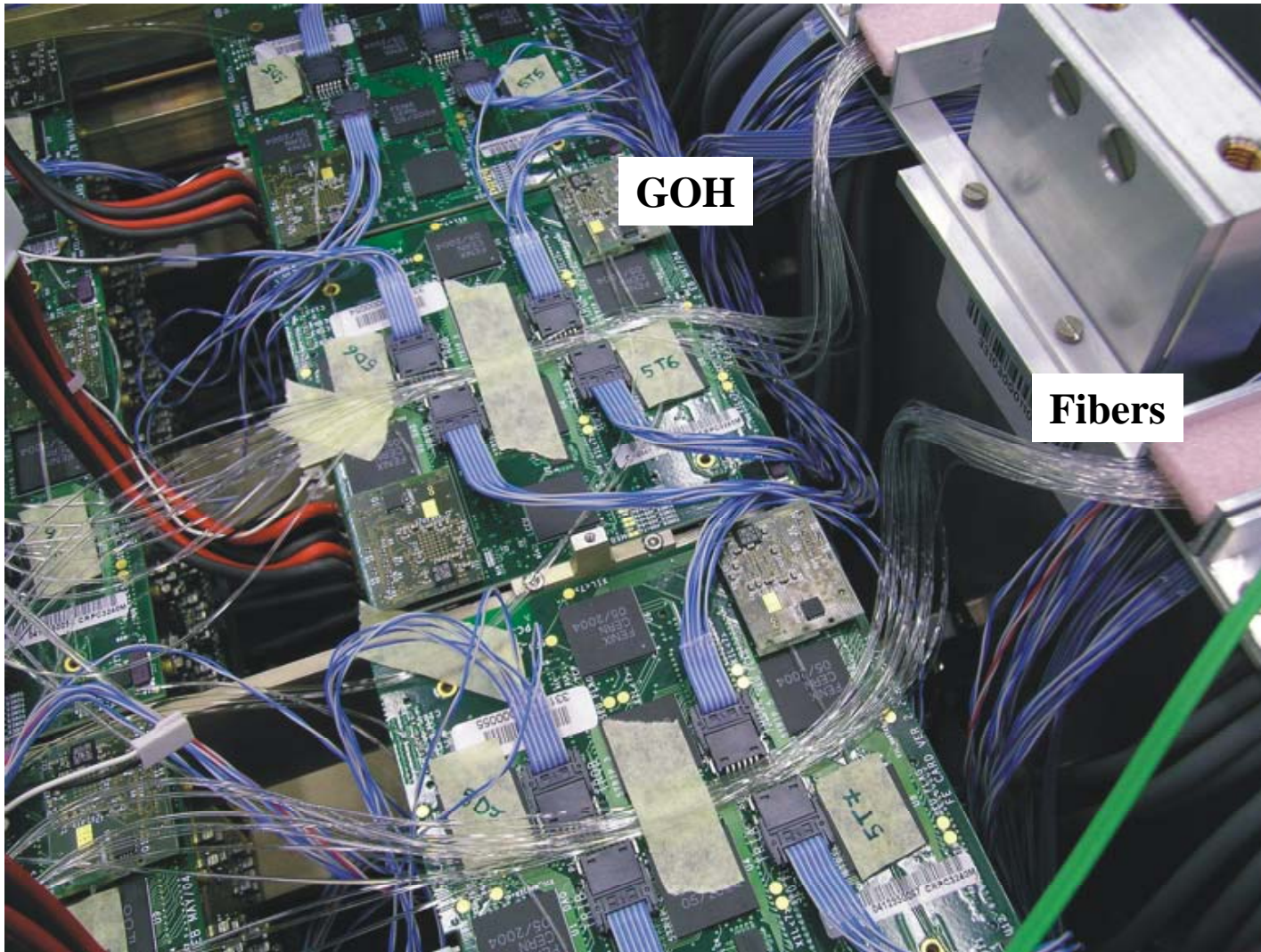


VFE/LVR/FE/TR Installation



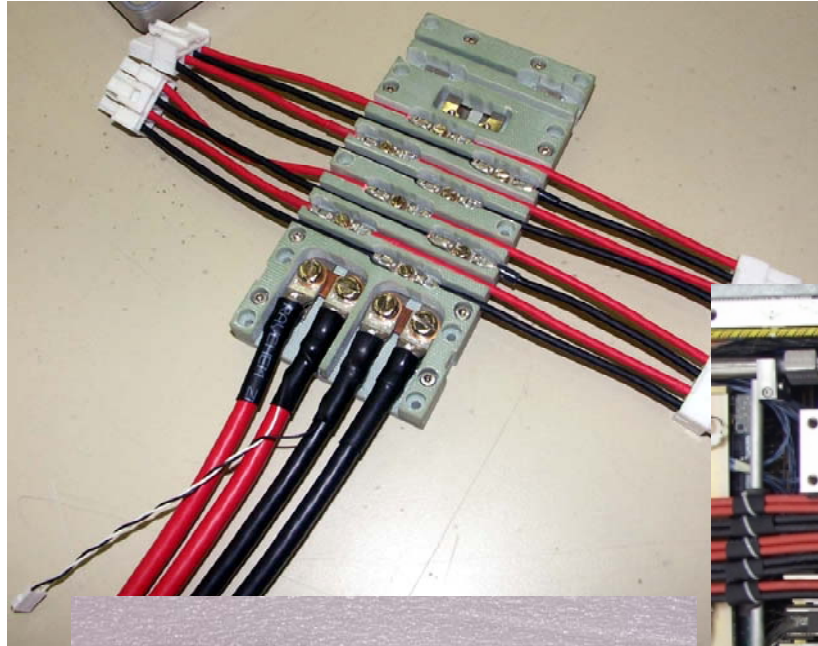


Installation of Optical Links (GOH)



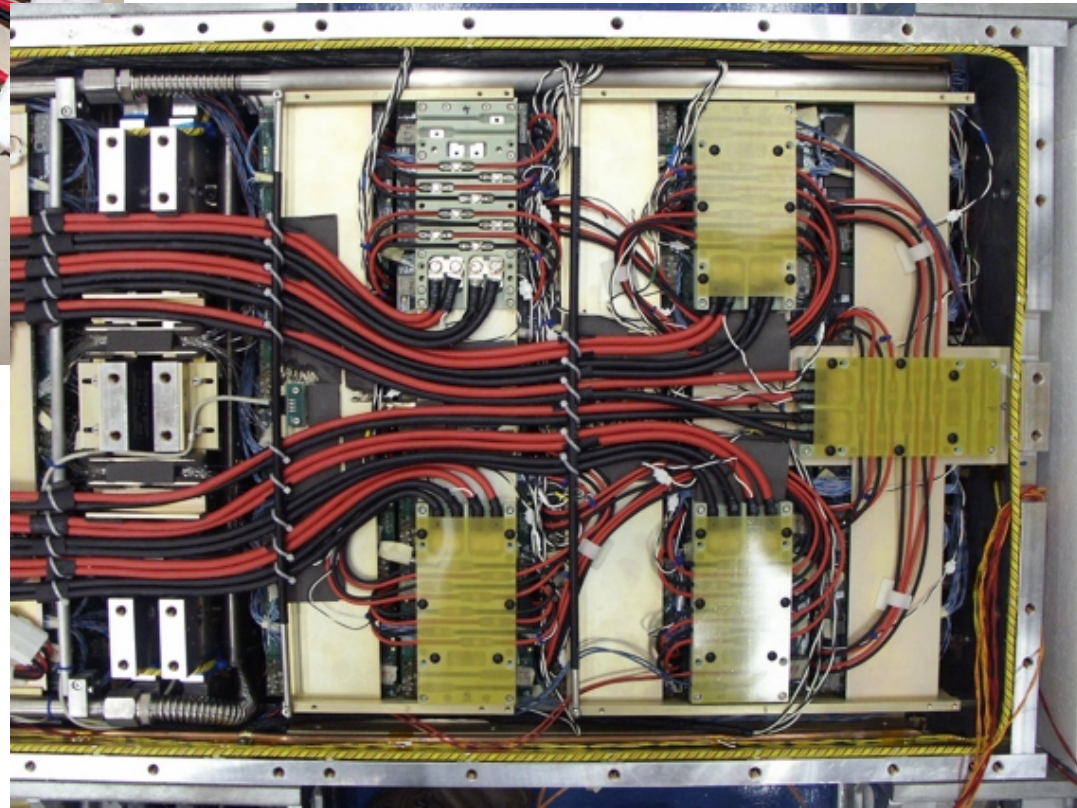


Low Voltage Distribution Block (LVD)



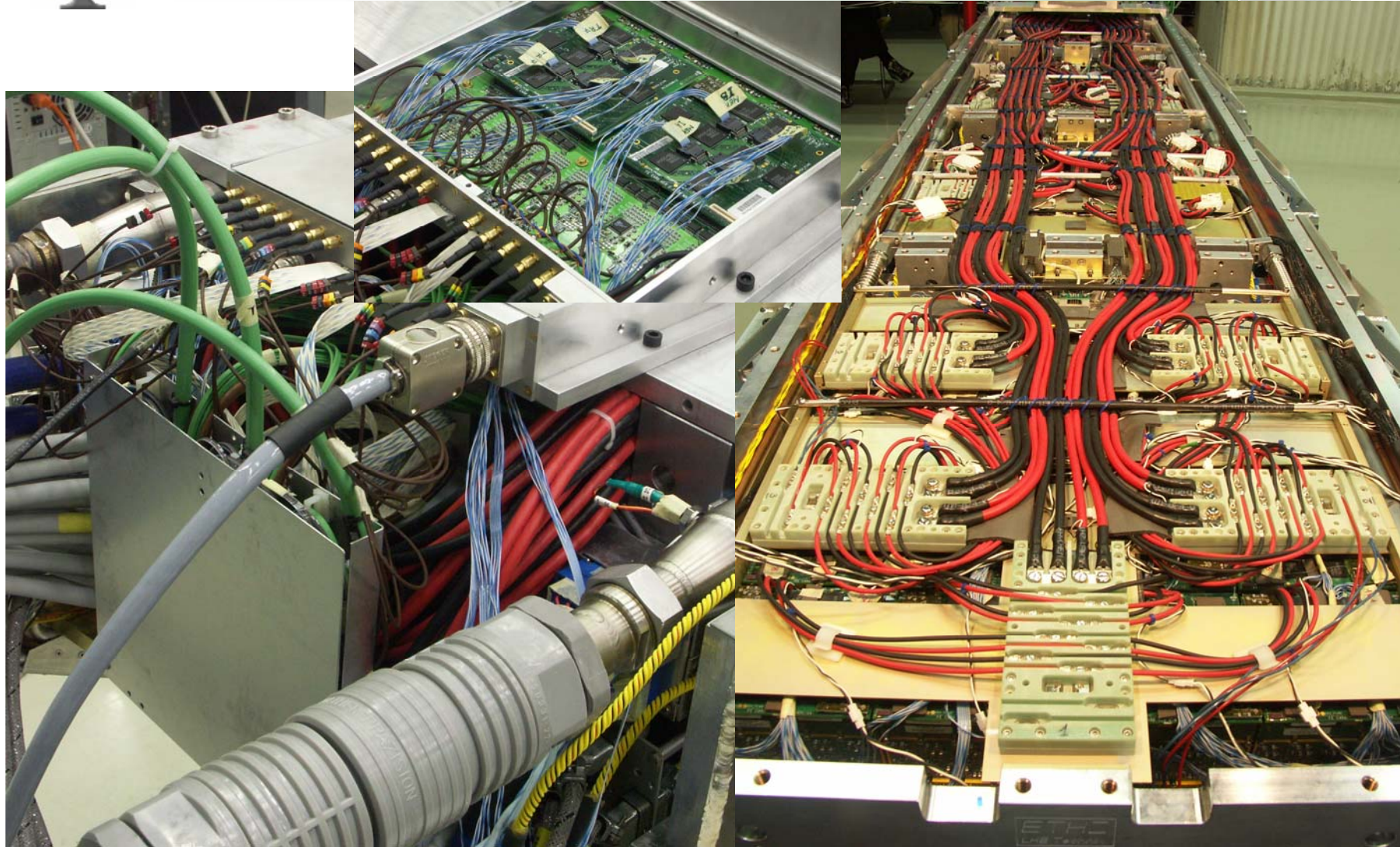
Assembled in the integration center,
like remote sense and inhibit cables
(100 % ready)

Remote sense wire connected to the
power cable is secured by a 120 ohm
serial resistor.



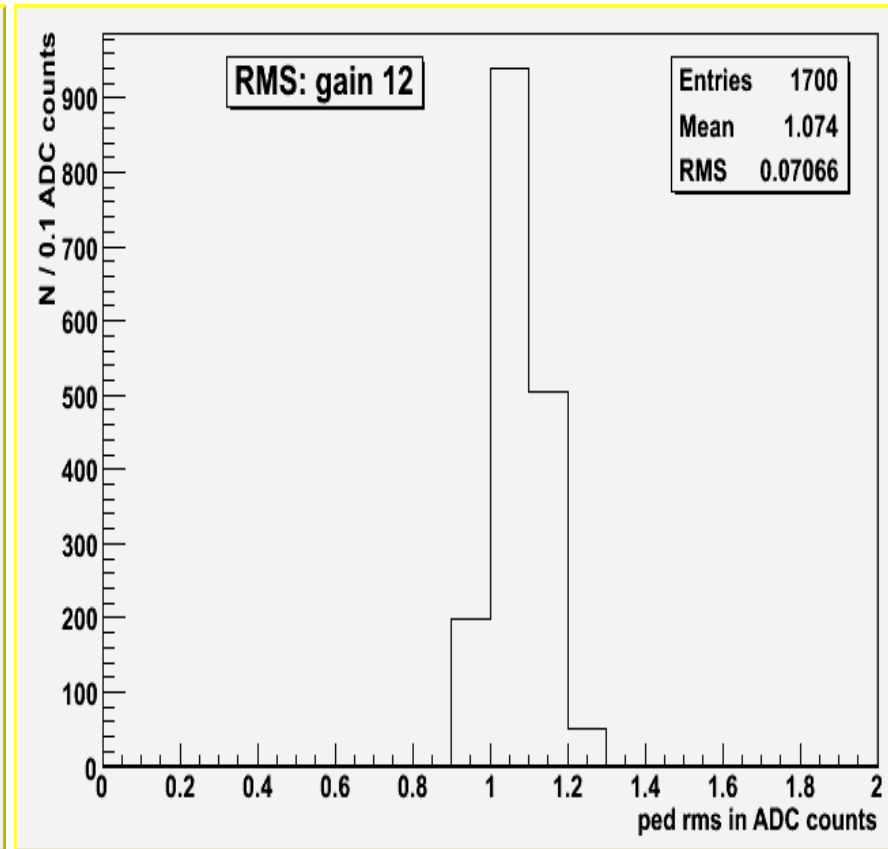
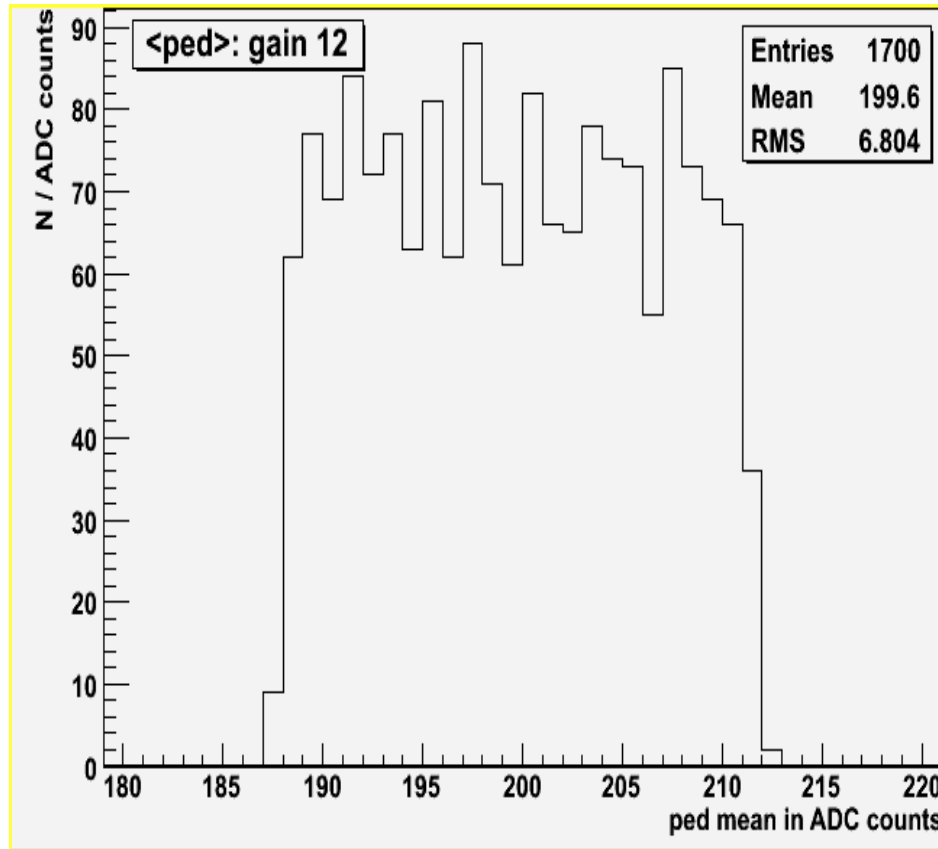


SM completed





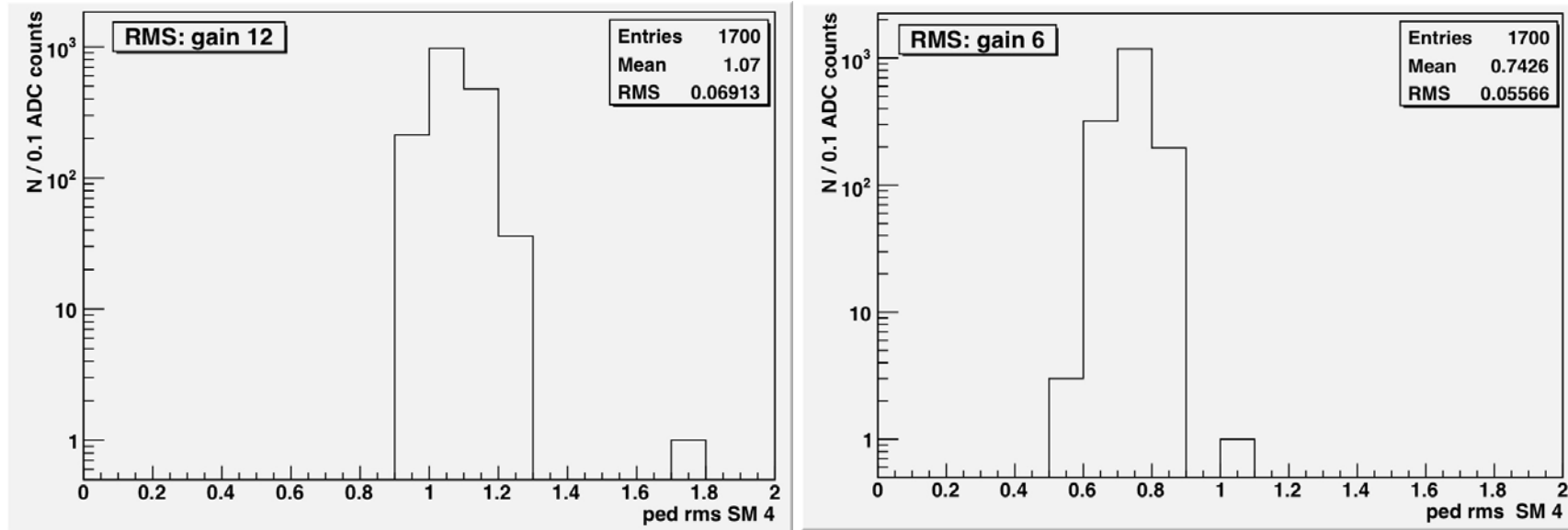
SM13 pedestal gain 12



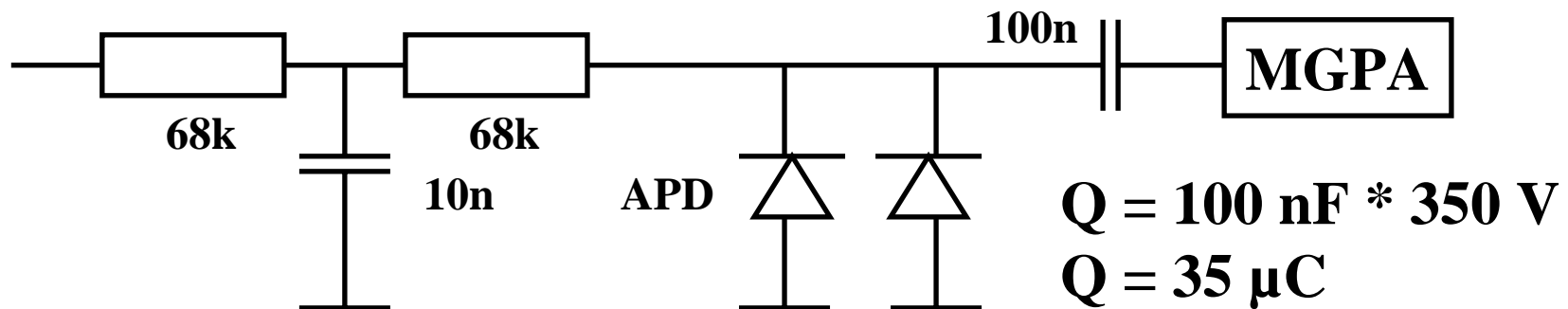
Typical RMS of the pedestal: 0.6 ADC counts gain 1
0.8 ADC counts gain 6
1.1 ADC counts gain 12 \Leftrightarrow ~45 MeV



SM4 pedestals gain 12 and 6



Increased RMS of the pedestal: correlates with broken or badly soldered HV filter capacitor in the motherboard ==> this is corrected in almost all cases



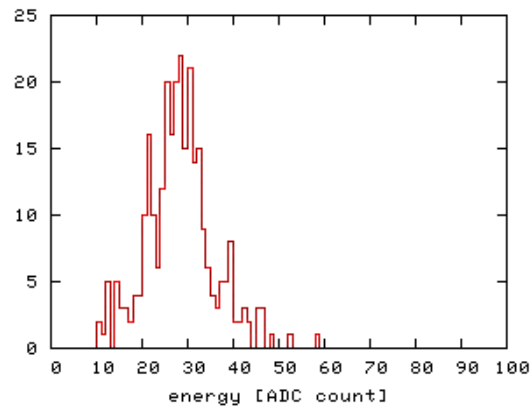


Laser Amplitudes



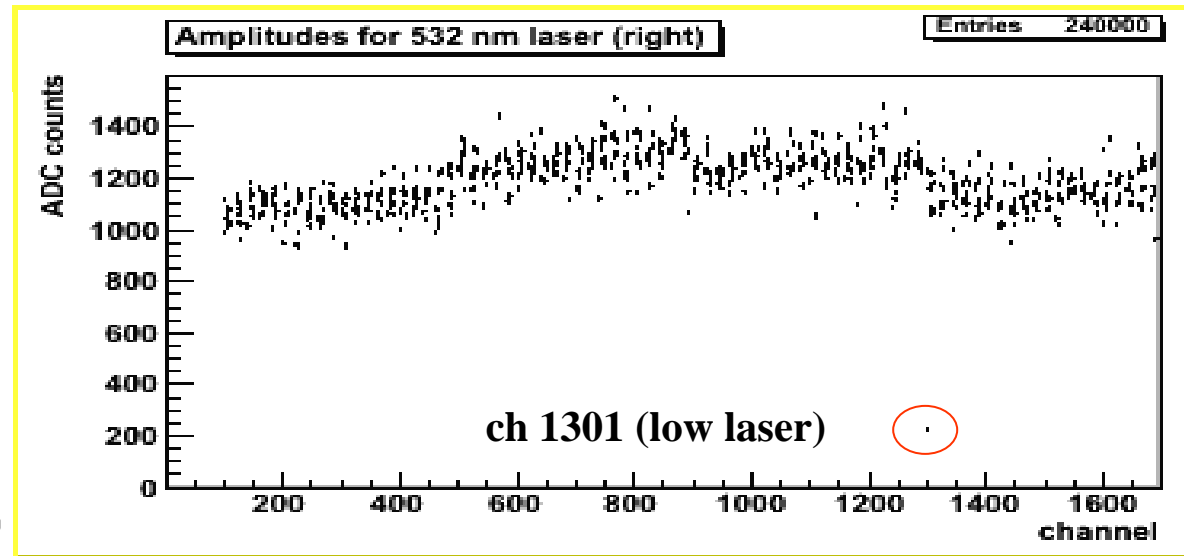
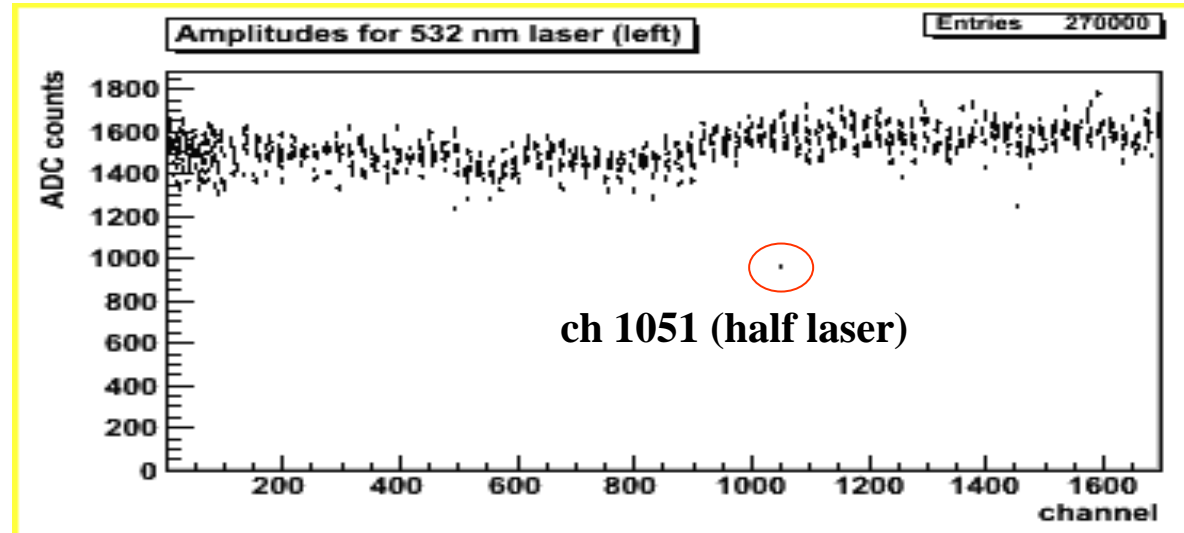
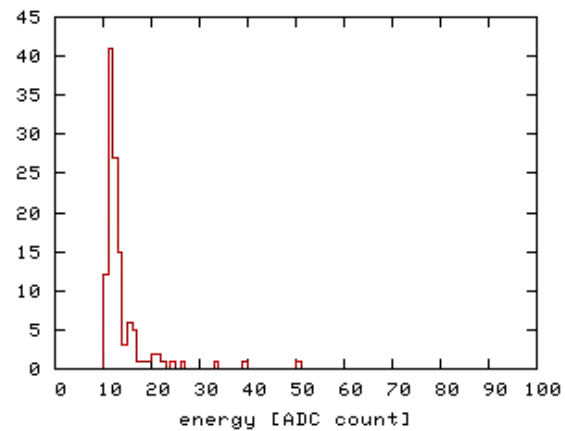
SM13: channel 1051 works with muons

aligned muons - SM13 - crystal 1051



SM4: channel 1301 does not work with muons

aligned muons - SM04 - crystal 1301





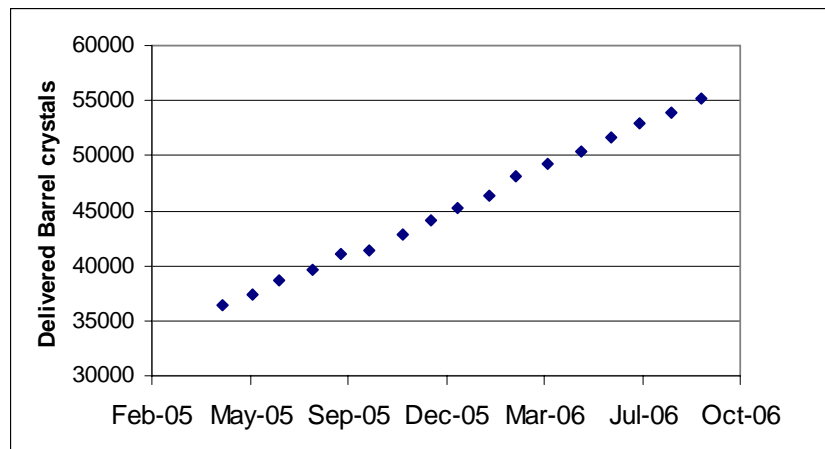
Status: Crystal Delivery



ECAL Barrel:

- 54210 BTCP + 1625 SIC crystals
- Typical 98.5% are accepted for the SM construction
- SIC will complete barrel crystal production with a last delivery end of Oct. 06
- BTCP will continue barrel crystal production until end of Feb. 2007

==> Completion of the barrel crystals production is expected for Feb. 2007



ECAL End-Caps:

- 500 crystals are in our hands and will be used for the Dee 4 prototype assembly
- SIC will deliver 100 crystals / month between Nov. 06 and Feb. 07
- BTCP will deliver ~1000 crystals / month starting in March 2007
- SIC will increase the capacity to 200 crystals / month for March 2007, installation of the necessary equipment is actually ongoing.

==> Completion of the end-caps crystals production is expected for Feb. 2008

Given the experience of the last 18 months, we are very optimistic that our projection into the future is correct.



Status: supermodules construction



Modules (4 per supermodule):

- 30 x 4 modules are ready
- the next 4 are ongoing

==> production is limited by the crystal delivery

Mi-bare supermodules (including cooling + motherboards):

- 24 are ready
- 4 are prepared for cooling / motherboard installation

Bare supermodules:

- 29 are ready
- the next one is ongoing

Fully integrated supermodules:

- 22 are read
- 2 more are in the commission phase

“Final” preparation of supermodules for installation in to CMS started 28 Sept. 2006:

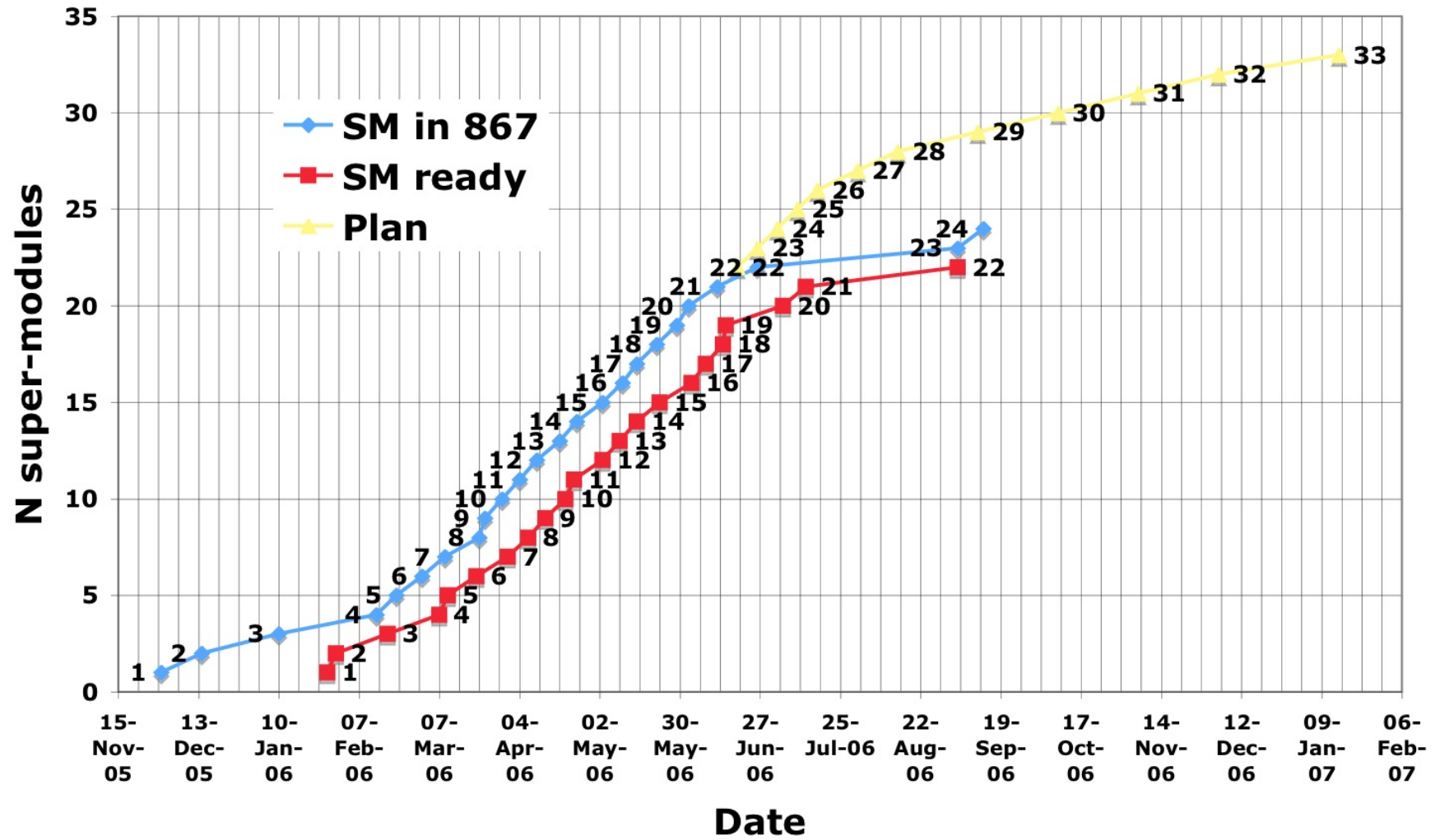
- re-test supermodules connected to the DAQ in the integration center (one per day)
- mechanical preparation (measure the envelope, change screws, add support rails for installation into the HCAL) one per day

Installation into the hadron calorimeter:

- first half barrel (EB+) in Nov. - Dec. 2006
- second half barrel minus 4 supermodules during Feb. 2007
- 4 supermodules in June 2007 (due to crystal delivery schedule)

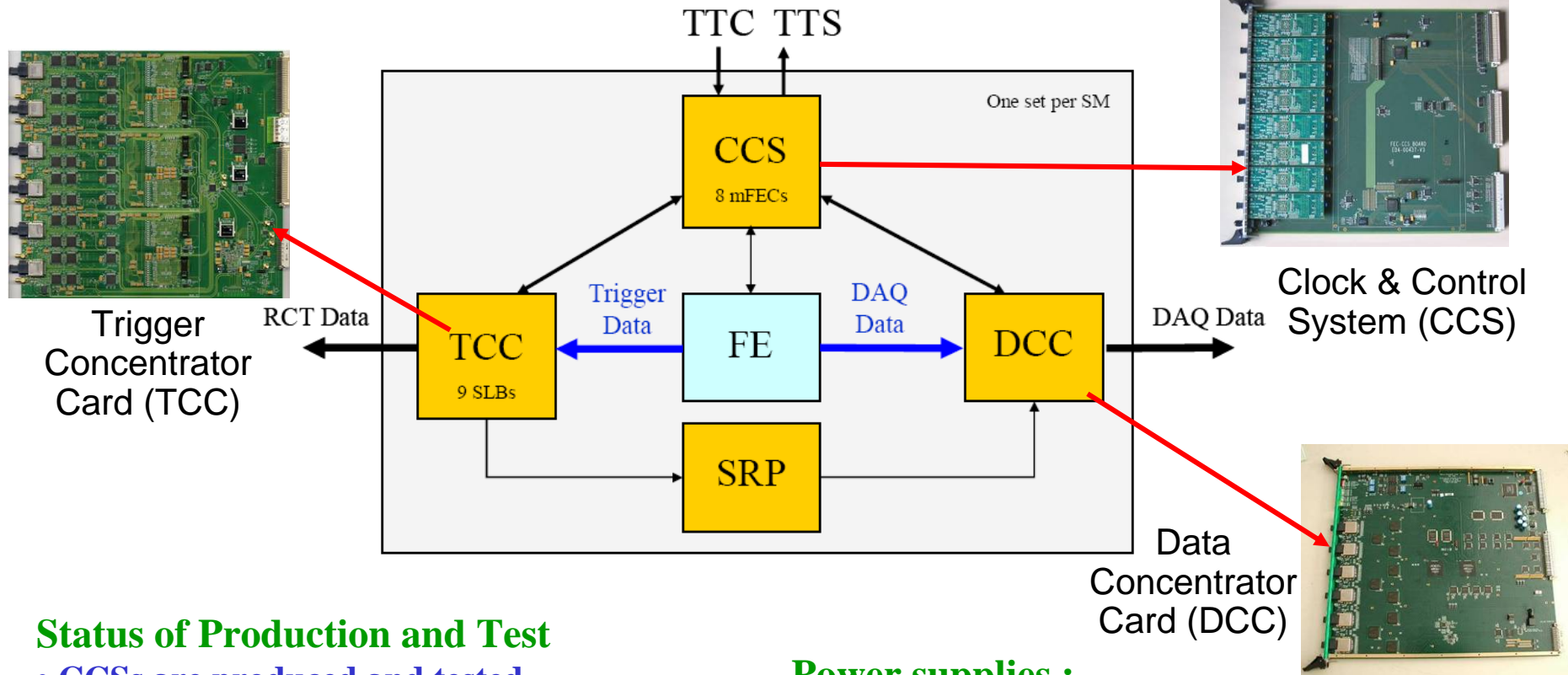


Integration Progress





Off Detector Electronics



Status of Production and Test

- CCSs are produced and tested
- DCCs are produced and currently tested
- TCC for the Barrel are produced and currently tested
- Triplet test (1 DCC, 1 TCC and CCS) should start next month

Power supplies :

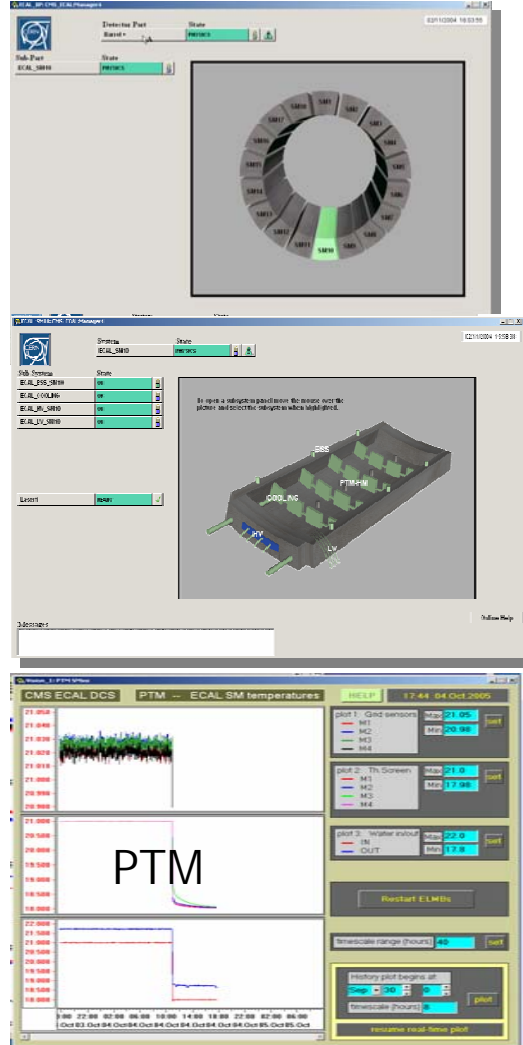
- All EB HV supplies (CAEN) are tested
- LV EB : 108 Wiener Marathon supplies
 - ==> 12 are existing
 - ==> 60 will be delivered by November '06
 - ==> 80 will arrive by April '07 (including EE)



ECAL DCS

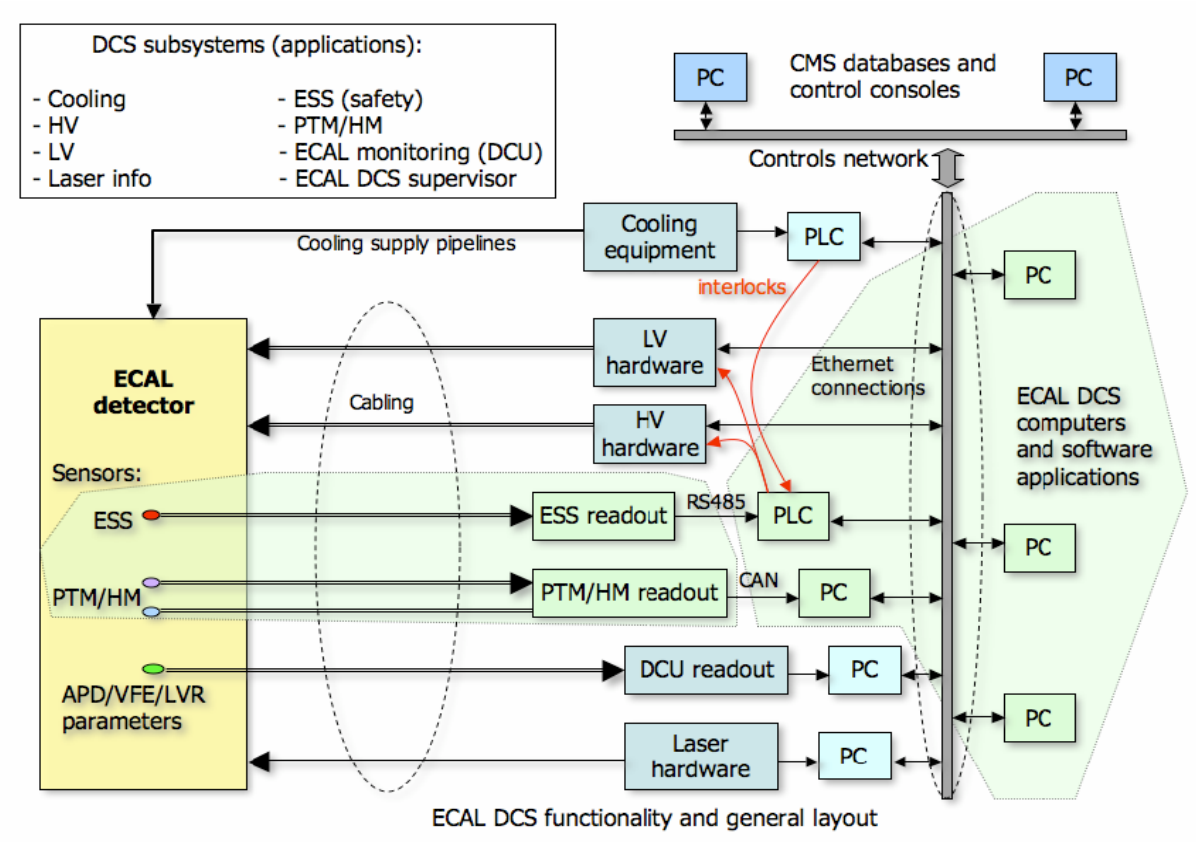


ECAL DCS Supervisor



Data rates and volume:

- ~120'000 of channels and parameters to monitor;
- ~10 Mbytes/hour raw data rates;
- ~1.5 Gbytes/month to archive in the CMS conditions database





Important achievements (1)



Supermodule calibration at CERN testbeam in H4

- at present 6 supermodules calibrated using electrons at 120 GeV
- min. two (max. four) more will be calibrated until end of Nov.

==> see talk of W. Funk

HCAL - ECAL combined test at CERN testbeam H2

- about one month of mixed particles beam
- using particle identification (Cerenkov, TOF, ...) down to 1 GeV
- very interesting and detailed measurements

==> see talk of W. Funk



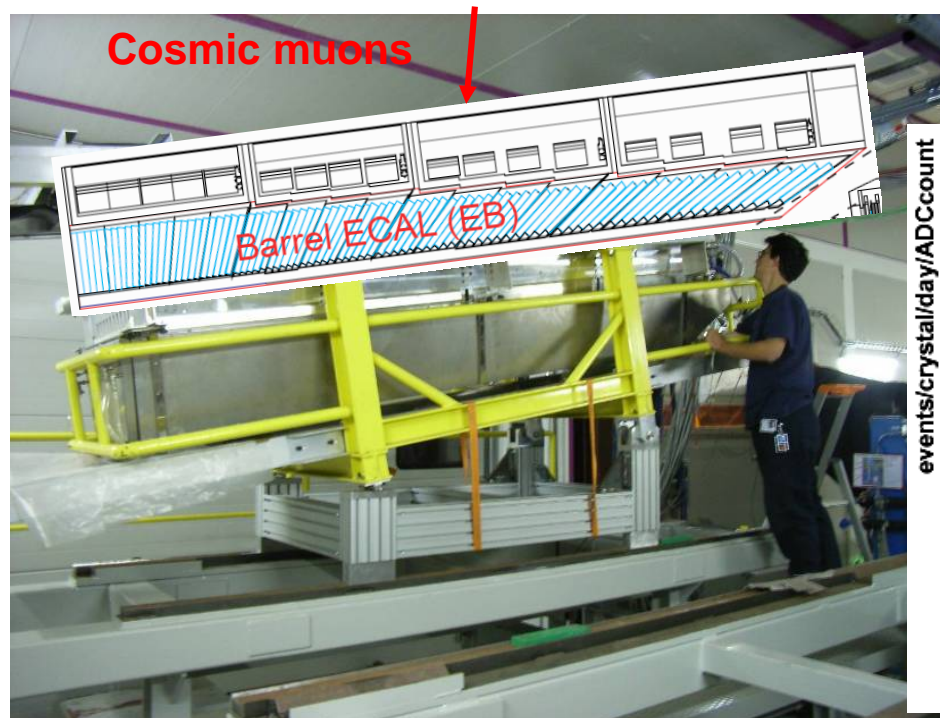


Important Achievements (2)

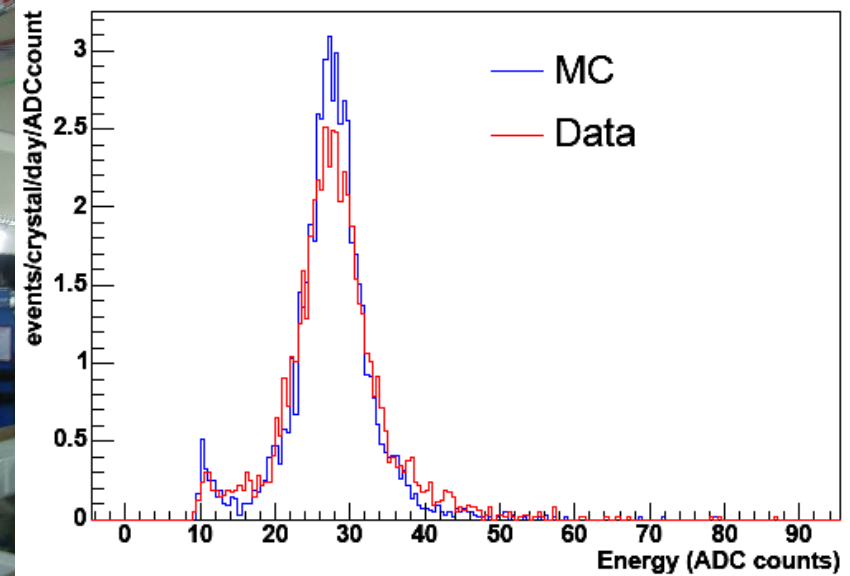


ECAL supermodule testing and calibration with cosmic muons

- 21 supermodules tested
- typically ~5 Mio. events per supermodule
- excellent agreement of extracted calibration constants with those obtained in the testbeam

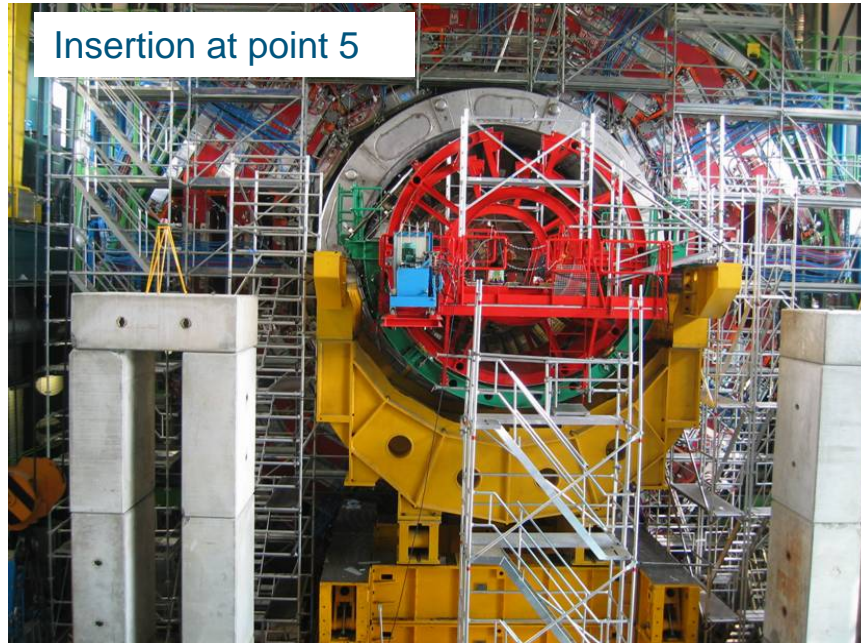


==> see talk of F. Ferri





Important Achievements (3)

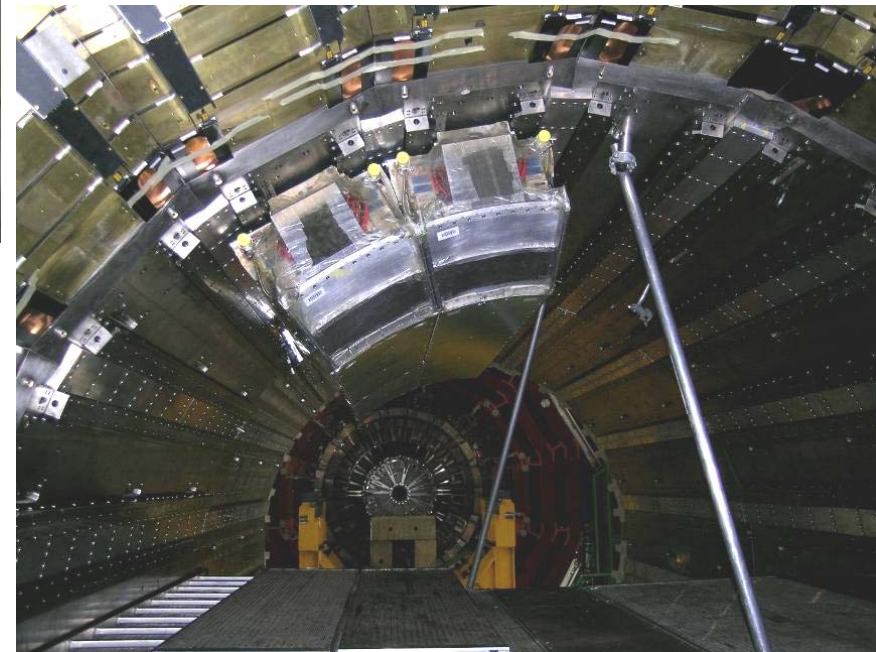


Supermodule insertion into CMS and magnet test

- 2 supermodules successfully installed

Magnet test

- one month of data taking in the magnetic field (4 T) indicate that the noise (RMS of the pedestal) is identical to the one measured during integration and cosmic ray calibration





Summary / Outlook



Crystals ⇒ Production quality within specifications

Photo Detectors (radiation hard and stable)

⇒ APD production and testing completed

⇒ VPT production and testing running smoothly

Cooling ⇒ Thermal stability achieved

Light monitoring system ⇒ working as expected

On-detector Electronics ⇒ achieved final performance

Off-detector Electronics ▪ ⇒ close to completion

ECAL DCS ▪ ⇒ operational in all test sides, ready in 2007

Supermodule integration ⇒ follows crystal production

Pre-Shower ⇒ on time

End-Caps ⇒ very good progress

The enormous progress made during the last year and the smooth operation of the supermodules in the H4 muons test, in the testbeam and during the magnet test make us very optimistic to install and commission ECAL as planned.



MGPA test pulse gain 1

