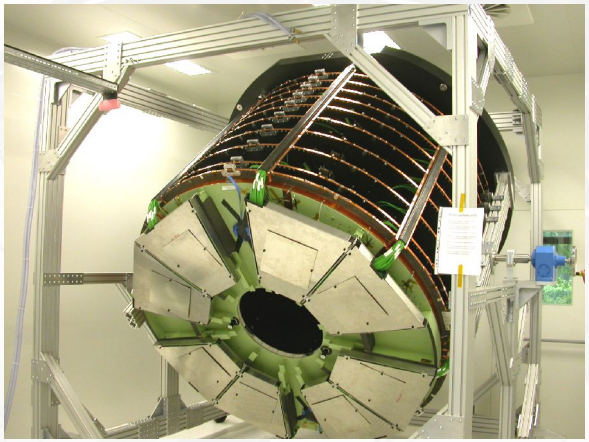
CMS Silicon Strip Tracker End Caps Overview and Status



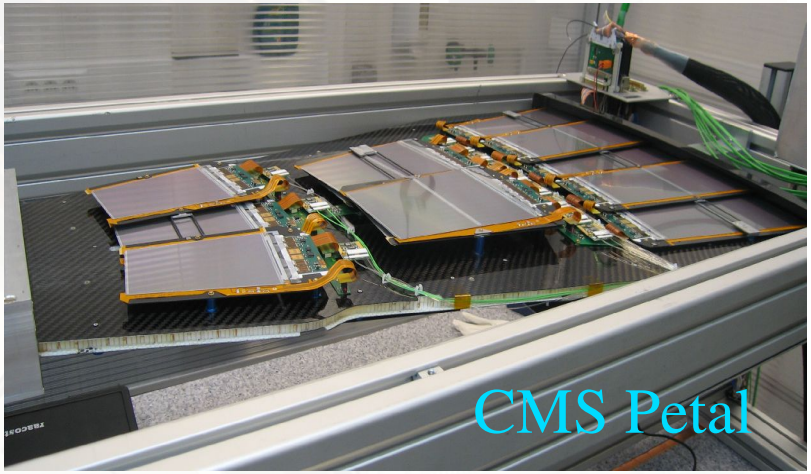
7th International Conference on Large Scale Applications and Radiation Hardness of Semiconductor Detectors

Muriel Vander Donckt, UCL (Belgium)

on behalf of the CMS-TEC community

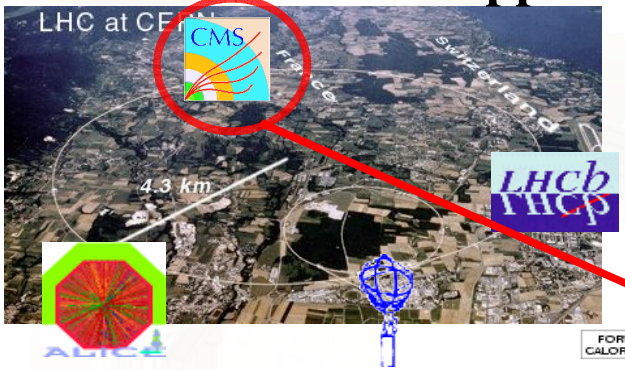
Outline

- The End Caps of the CMS silicon strip tracker
- Mass production and quality control
  - silicon sensors
  - front-end hybrids
  - silicon strip modules
  - integrated substructures (petals)
- Tracker integration
- Performance of substructures in test beams
- DAQ Test
- Summary


CMS Petal

CMS @ LHC

The LHC at CERN: pp collisions @ √s=14TeV from 2007 onwards



The **C**ompact **M**uon **S**olenoid detector:

pixel detector and silicon strip tracker

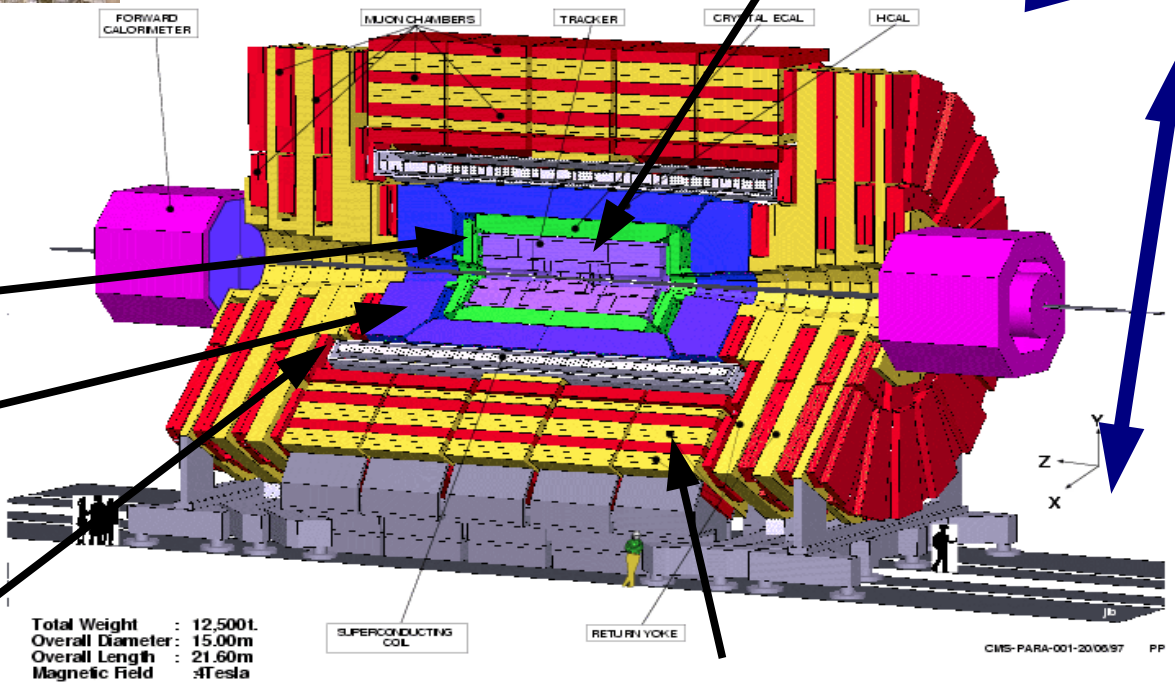
21.6m

15m

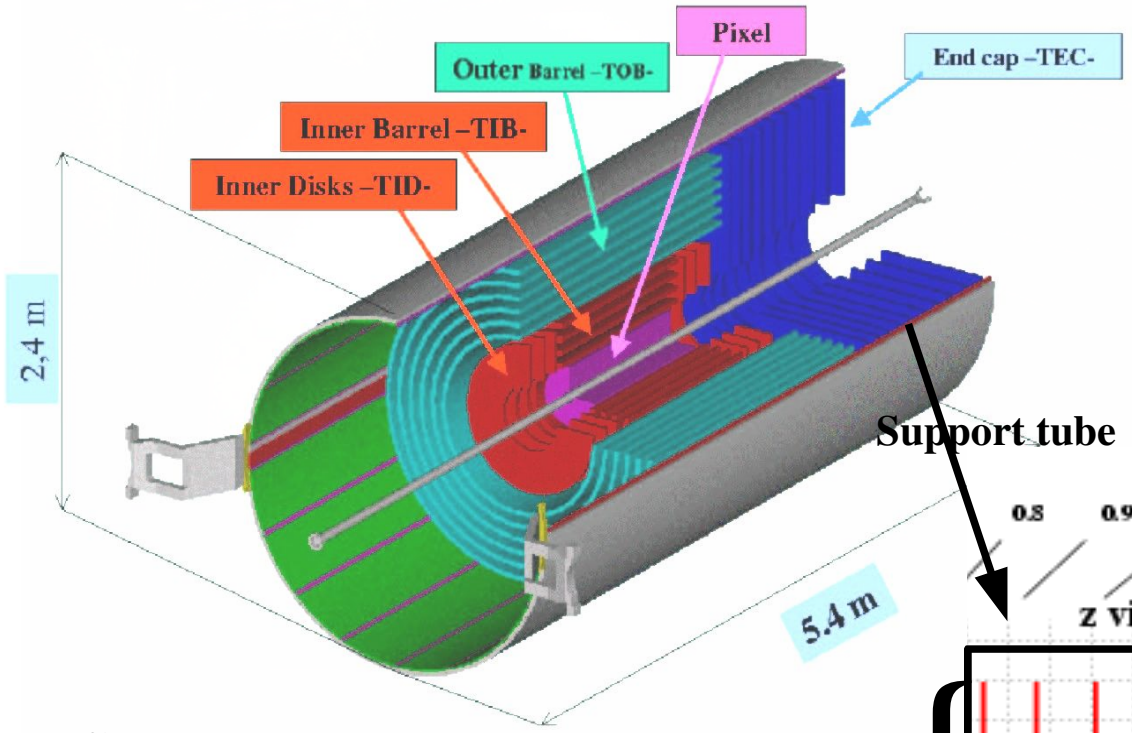
electromagnetic calorimeter

hadronic calorimeter

superconducting solenoid, B=4T



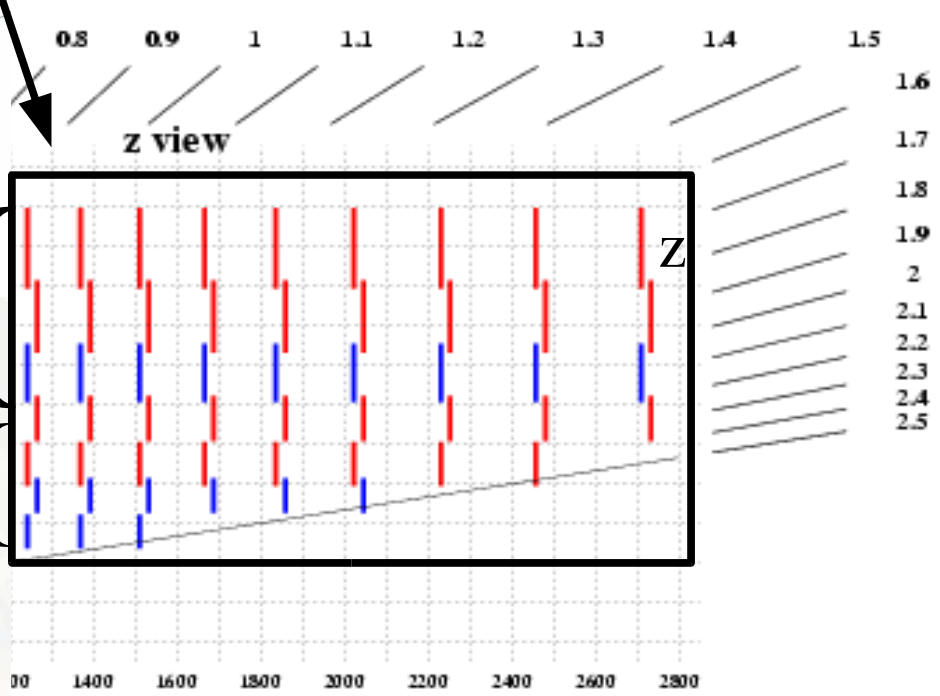
The CMS tracker



double-sided modules
(stereo angle = 5.7˚)
→ position information
along the strips

single-sided modules

Support tube



TEC:

- 2 x 9 disks
- 6400 modules
- high radiation level:

→10 LHC years ≅ 1.6×10^{14} n(1MeV)/cm^2

→ operating temperature below -10º C

TEC silicon strip sensors

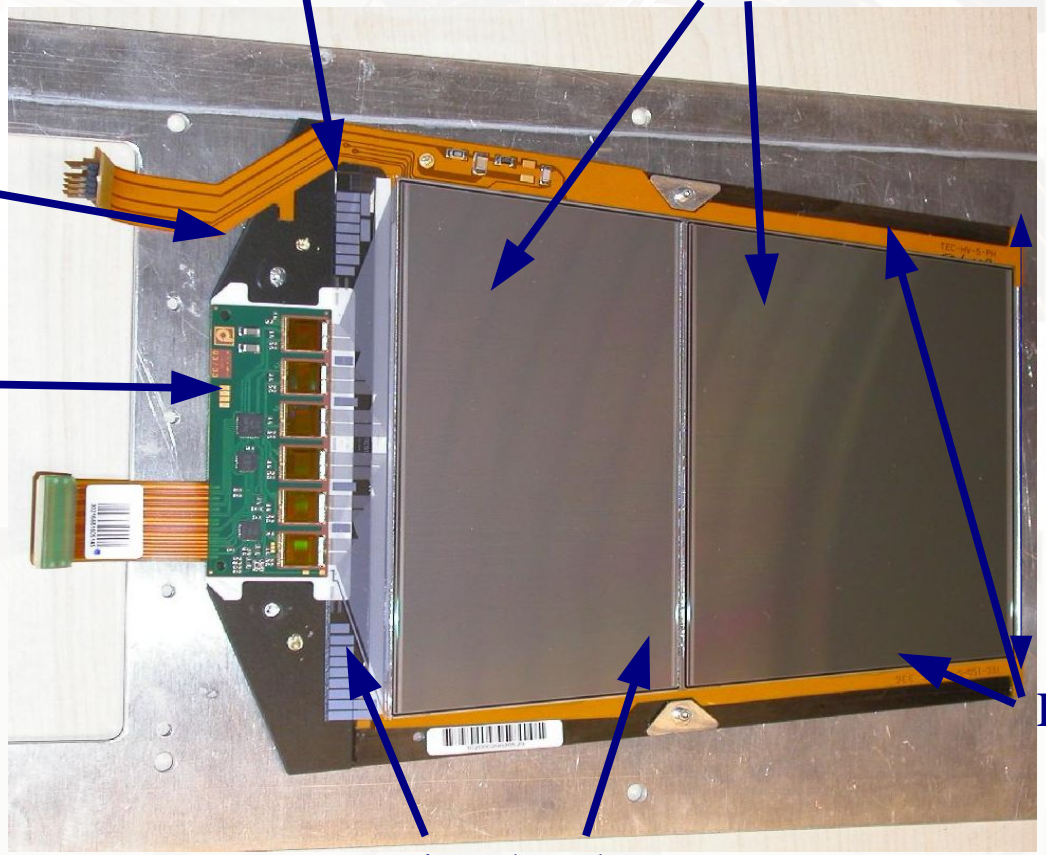
A TEC ring 5 module:

1 or 2 silicon sensors
- p-type strips on n-type bulk
- pitch 80-205μm, width/pitch = 0.25

pitch adapter

support frame
- graphite and carbon fibre (CF)

front-end (EE) hybrid



≈10cm

Kapton circuit
- bias voltage
- back plane isolation
- temperature sensor

micro bonds

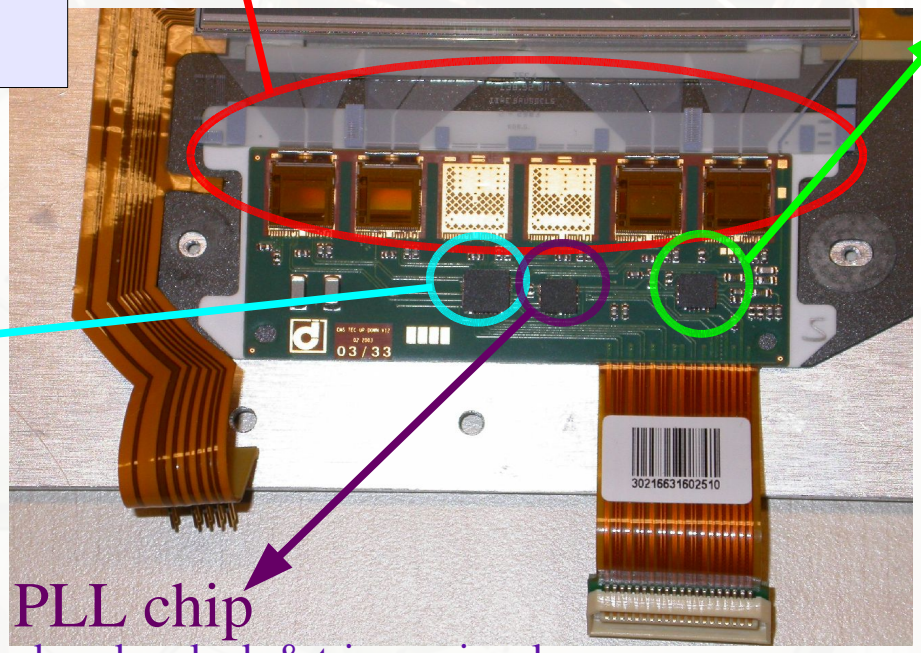
10 module types: 512 or 768 strips, 1 or 2 sensors, wedge-shaped sensors, geometry, coating.....

Front End Hybrid

4-layer Kapton substrate (flex) laminated onto ceramic carrier

4 or 6 APV25 readout chips
- radiation hard commercial 0.25µm CMOS technology
- 128 strips per APV, multiplexed to one analog output
- per channel: pre-amplifier, CR-RC shaper, 4.8 µs pipeline

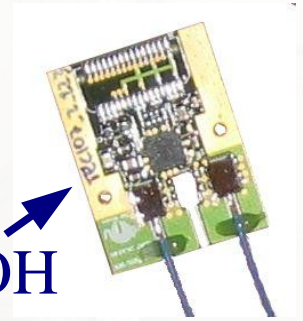
2 readout modes:
- **Peak mode**: 1 sample (τ≈50ns)
- **Deconvolution mode** (high lumi): weighted sum of 3 samples, τ≈25ns, but higher noise



Detector Control Unit (DCU)
- 12-bit ADC
- 8 channels:
  - hybrid and sensor temperatures
  - leakage current
  - low voltages

2:1 multiplexer
- 2 APVs multiplexed to one readout channel

PLL chip
- decodes clock & trigger signals



Analog & optical readout!

TEC module production

HYBRIDS

- Flex circuits **produced by Cicorel, assembly done by Hybrid SA**
- Quick & easy test of > 15000 hybrids: **Front-end Hybrid Industrial Tester**
  - connectivity, electrical test, readout test within 1 minute

Status (mid September):

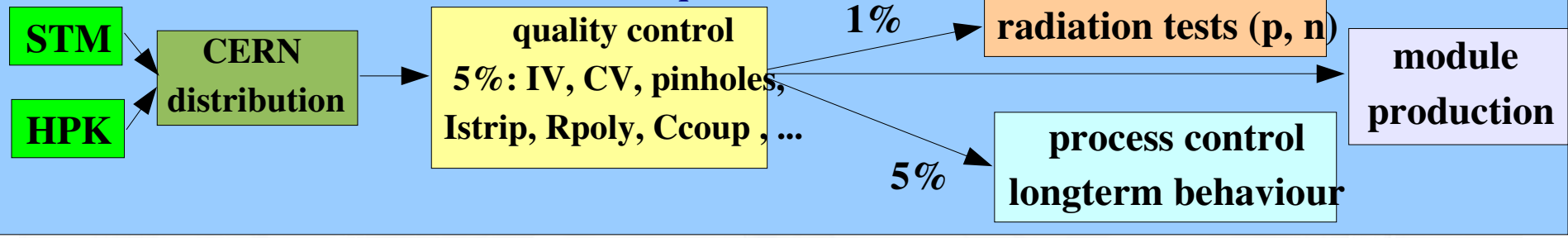
- Improved QA & C
- Production rate: ≈ 400 hybrids/week
- 2950 hybrids delivered to the module assembly line
- Expected end of production: December 05
- Back-up line running

SENSORS

Status (end September):

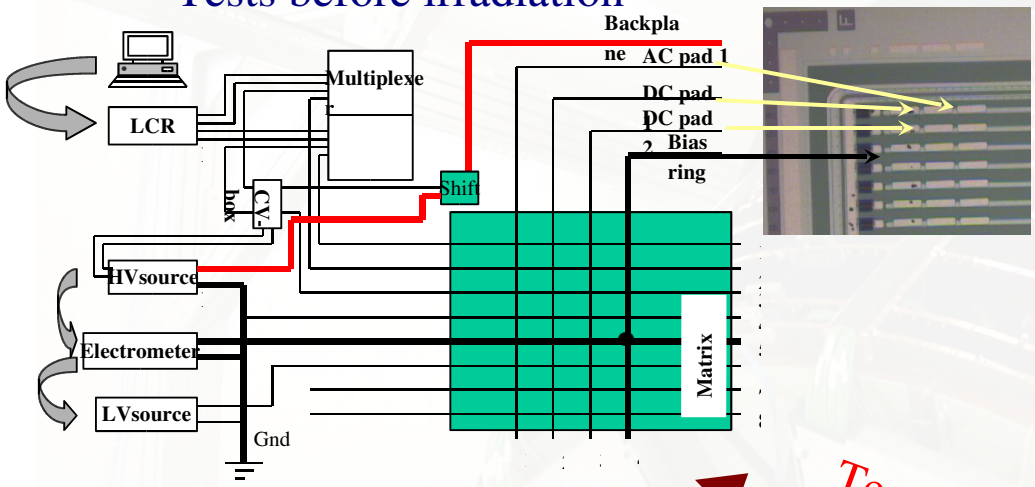
HPK: 99.9% of all ordered sensors delivered, excellent quality, last batch to be received this month

STM: 15% of all thick sensors delivered and qualified

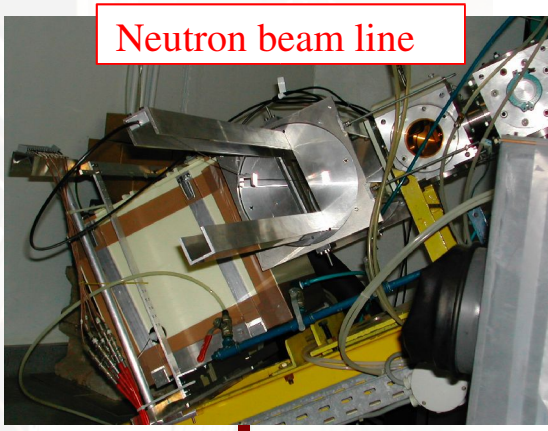


Sensor Irradiation Hardness

Tests before irradiation



Neutrons Irradiation



Oven

Annealing of 80min@ 60°C

Tests after irradiation

Probe station

Analysis of:

- The evolution of the depletion voltage with the neutron fluence
- The interstrip capacitance

Module Assembly

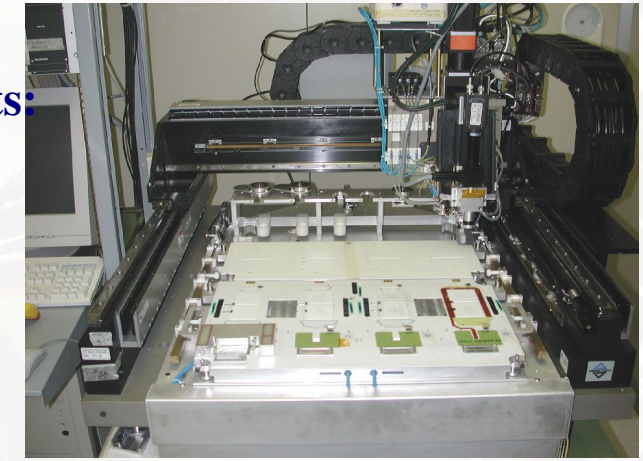
- **Assembly: gluing of sensor(s) and hybrid to the frame**

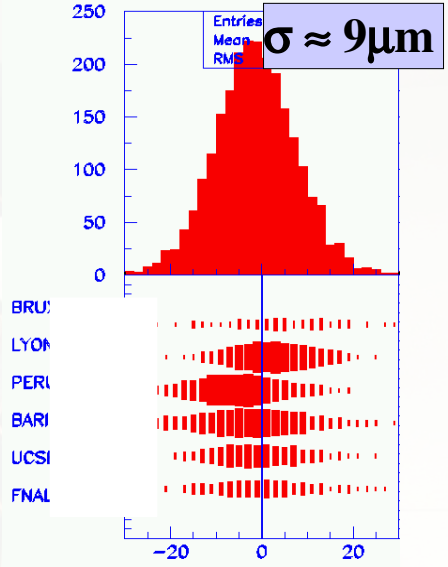
6781modules need to be assembled with high precision

(e.g. coordinate ⊥strips: 39µm)

⇒ **fully-automatic gluing robots: "gantry"**

- 4 gantries in operation
- Issues: precision, calibration
- 99% of modules within specs
- 170 modules/week





x(measured)-x(nom.)

(x ⊥ strips)

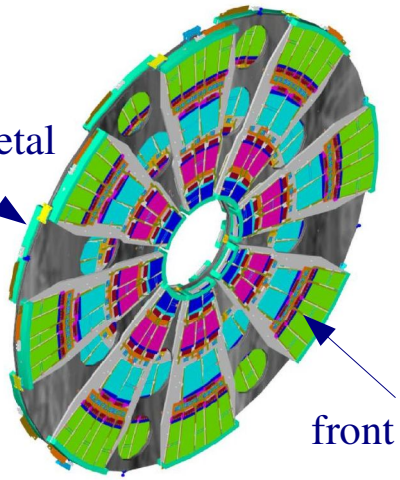
- **Bonding: 7 automatic bonding machines (6 labs)**(> 5 modules/machine/day)
- **Single module test** (warm & cold): noise, bad strips, IV, pipeline errors, ...

Status (Sept.19th):

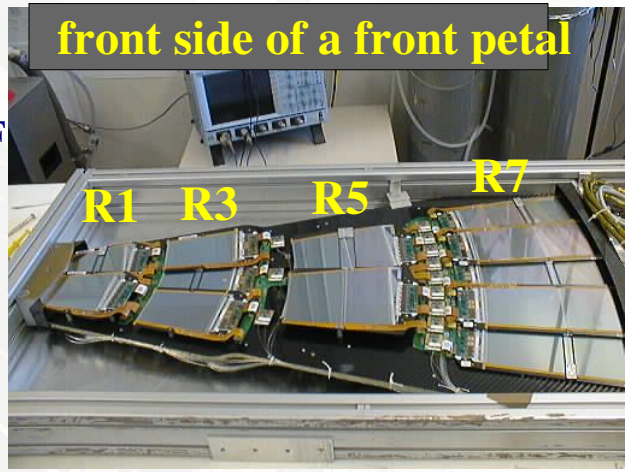
➔ **2305 production modules built = 34%**

Expected end of production: February 06

Petal Assembly



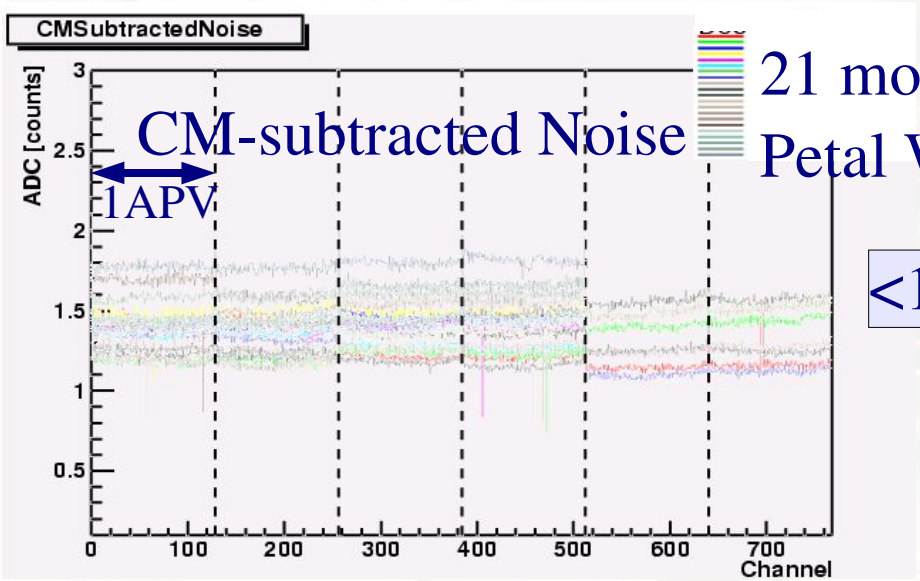
- Per end cap (TEC): 9 CF disks
- Modular design: 16 removable CF structures (petals) per disk
- Up to 28 modules per petal, arranged in 7 radial rings



- 40% of petal mechanics with motherboards produced
- **Mounting of optical converters (AOHs), routing of fibers**
- **Assembly of modules and functional test (7 prod. lines i 5 centers)**
- **Long term test of assembled petals: started in May 05**
  - 6 cooling cycles between room temp. and -20˚C → 3 days
  - grading: # of bad strips, noise, longterm stability, IV
  - petals have only 0.1-0.4% of bad strips
  - ramp-up phase, expected rate 1 petal/week/line, within 6 weeks:1.5 petals/week/line

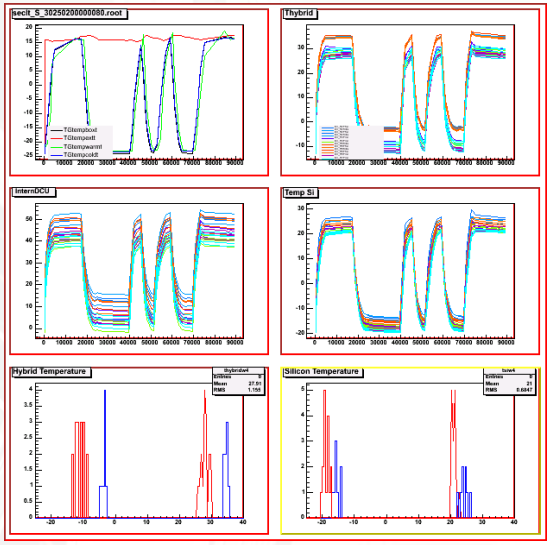
Status (end September): 42/288 petals built; 23 fully characterised

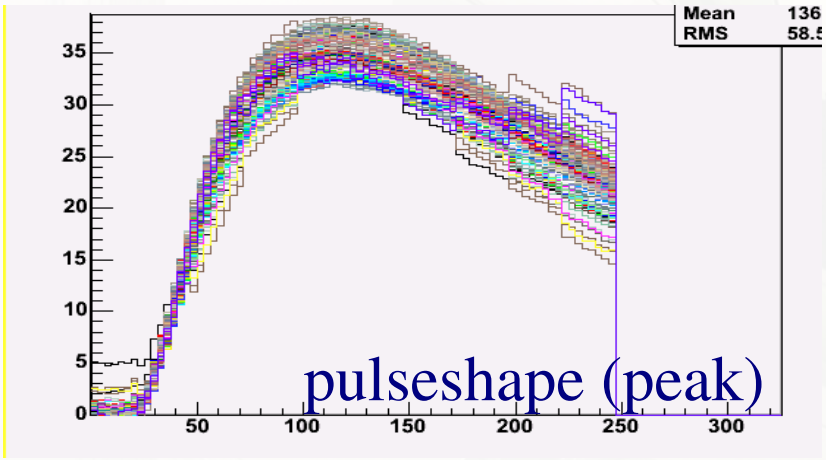
Typical Long Term test data

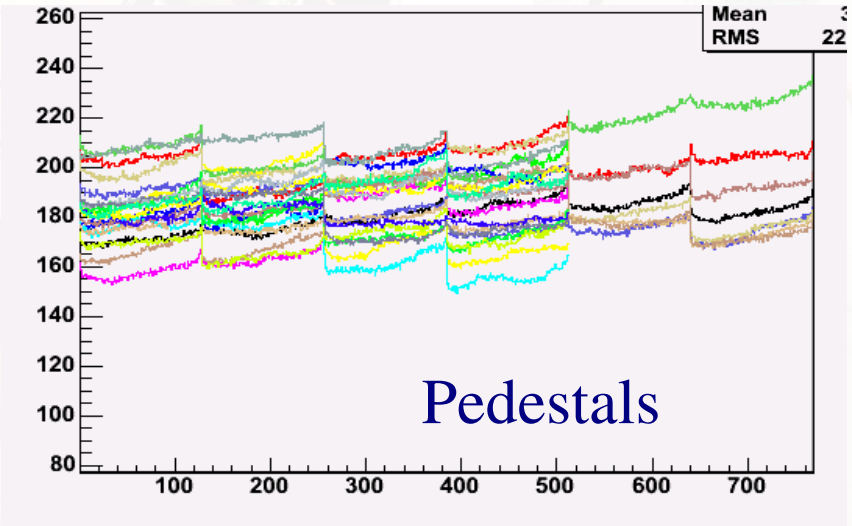


21 modules (Back Petal Wheels 4 to 6)

<1% bad strips!

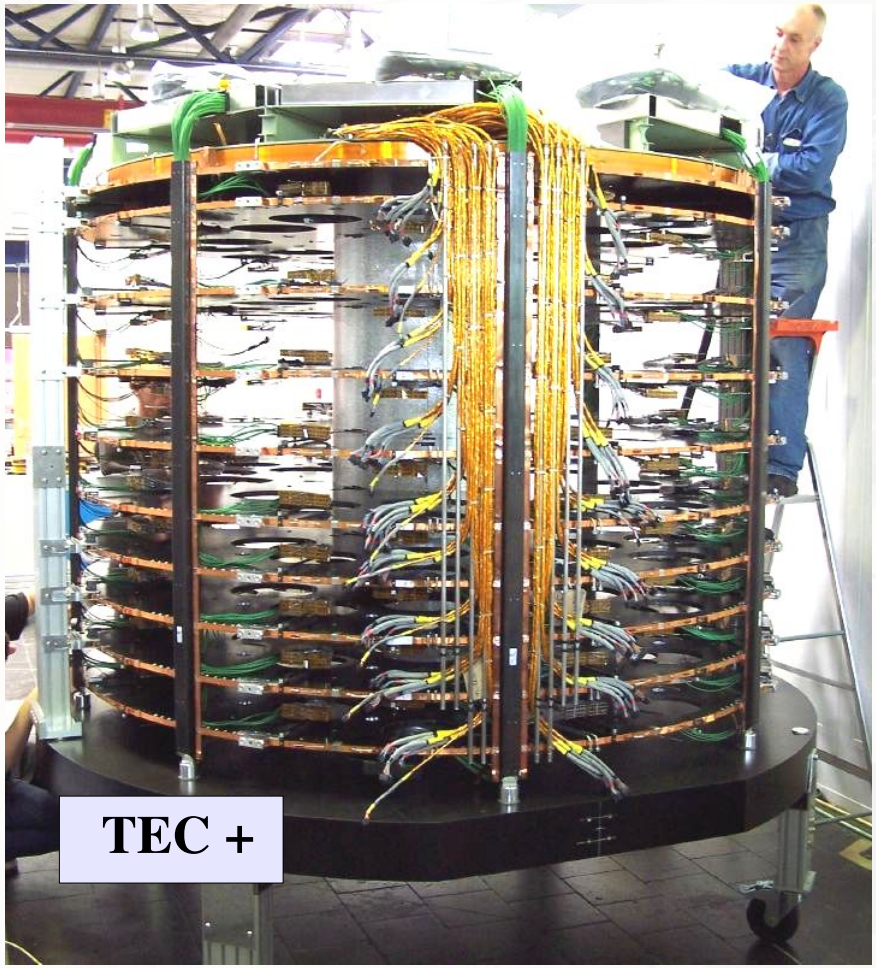


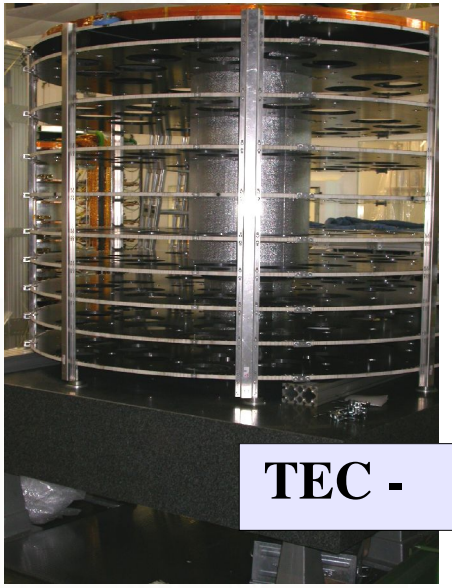




ns

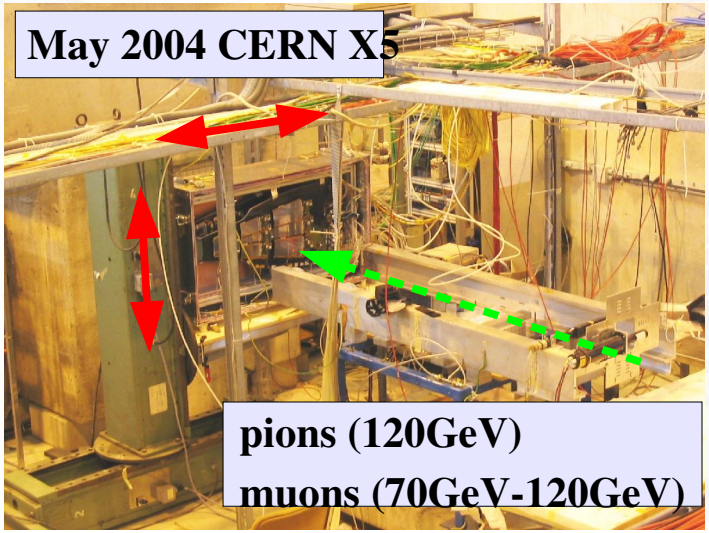
TEC integration





- TEC+ assembled, ready for petal insertion (November), 1st petals received
- Assembly of TEC- ready for insertion test into the tracker tube

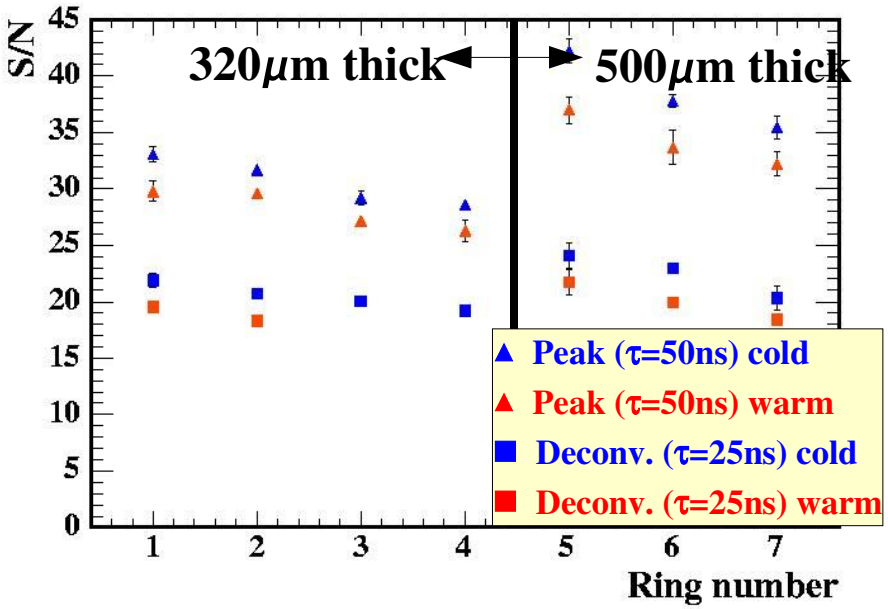
TEC petals in the Test Beam

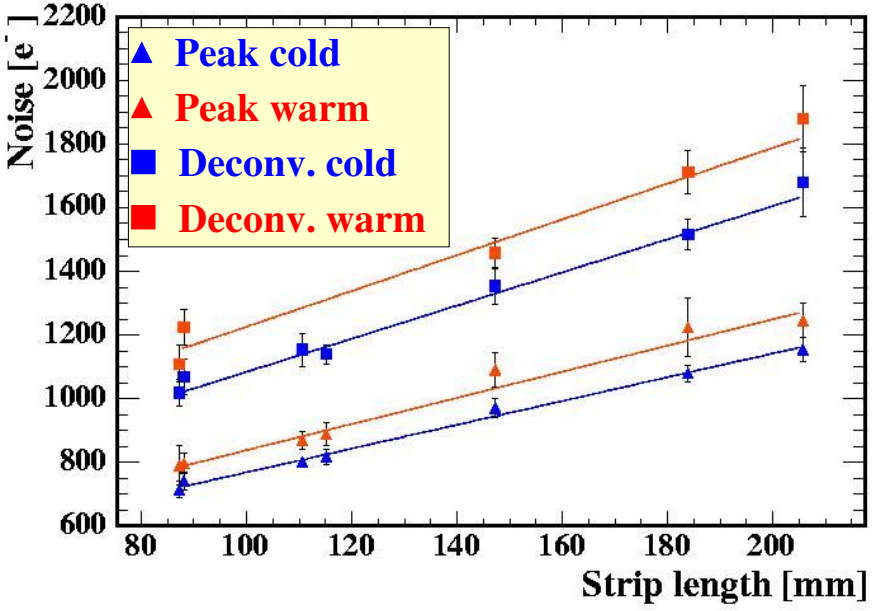


Setup: 2 petals (1% of the TEC), operated at CMS temperature (≈ -10˚C)

Excellent system behaviour:

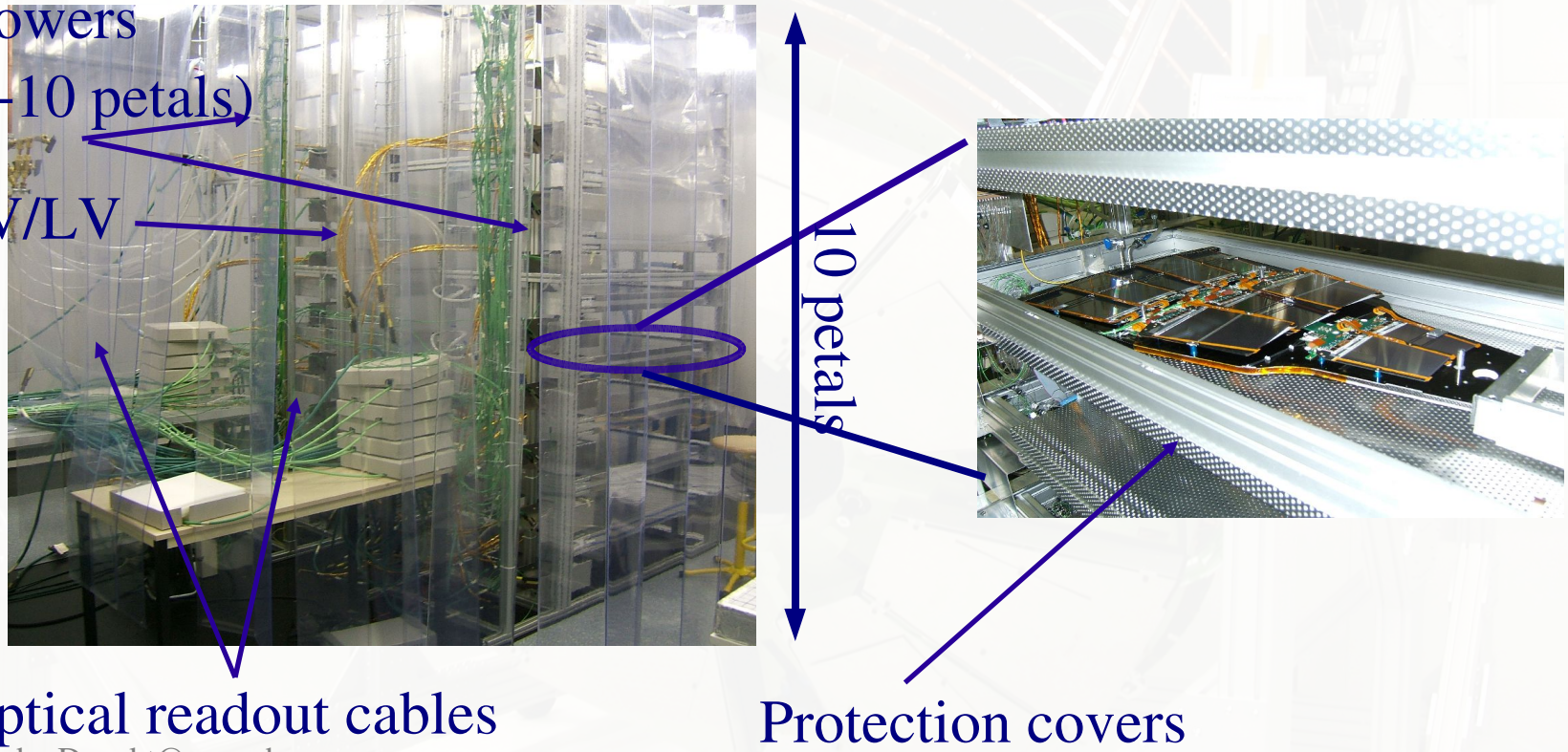
- stable communication and readout at all temperatures
- uniform noise distributions, small common mode
- signal/noise > 20
- equivalent noise charge consistent with expectation from measurements with single APVs





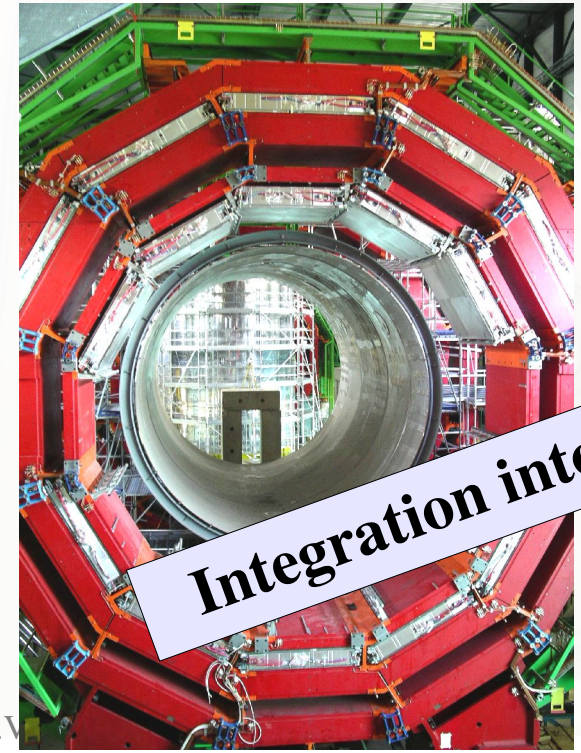
DAQ Test

- 18 petals currently under test with final DAQ software in Lyon until mid-October → ~400 modules !
- Automatic mapping working. Readout already OK for 14 petals.
- noise and communication instabilities under investigation.
- Cosmic data taking foreseen in the coming days



Conclusion and Outlook

- **Excellent performance of components proven in system tests and test beams**
- **Module production running smoothly**
- **34% of modules built with high quality, production completed early 2006**
- **Integration of modules on petals ramping up**
- **Integration of the end-caps to end spring 2006**
- **Learning a lot with the DAQ test**



Integration into the CMS detector in autumn 2006