The CMS Silicon Strip Tracker Overview and status

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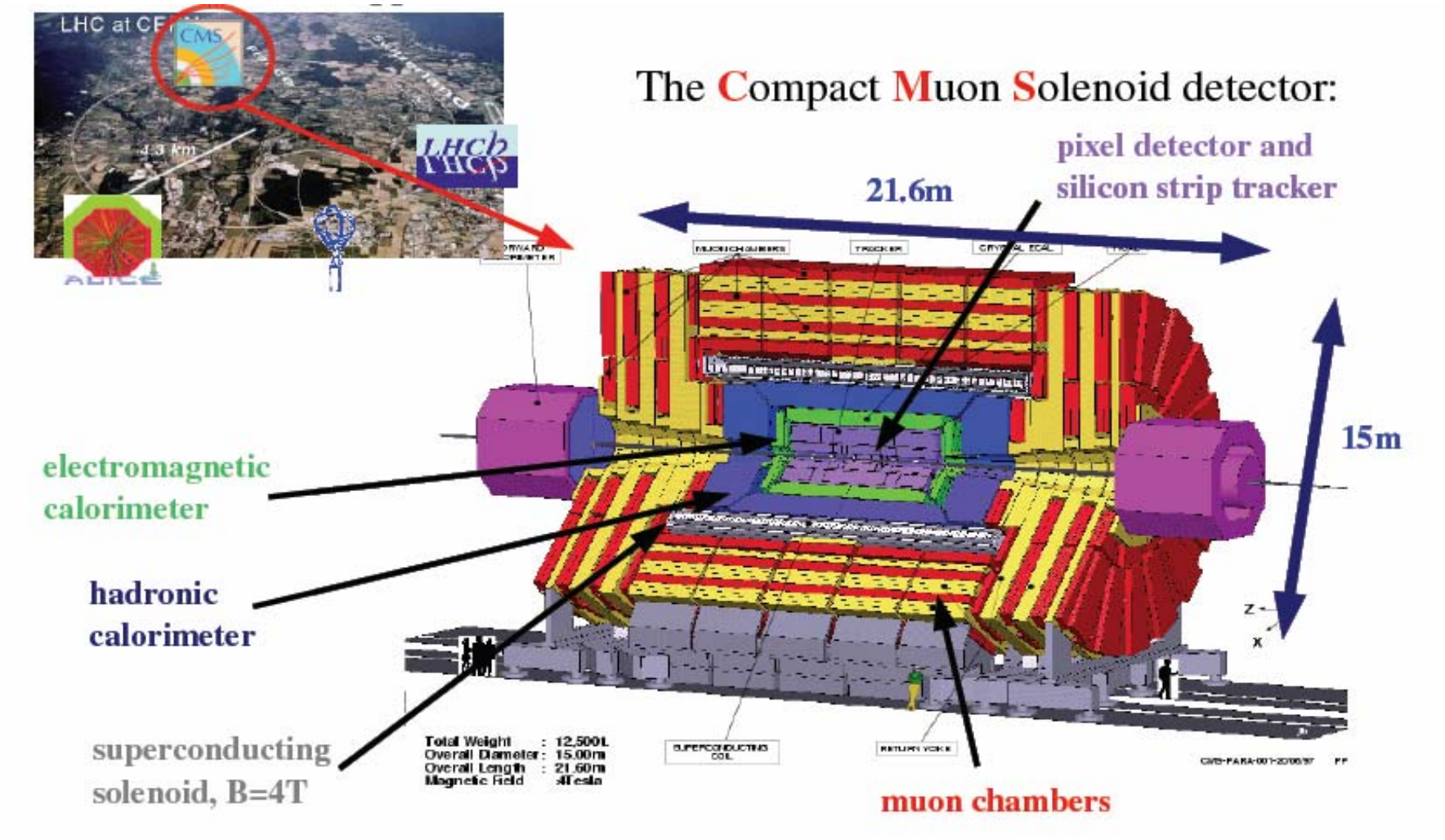
Overview

- The CMS silicon strip tracker
- Mass production and quality control
  - Silicon sensors
  - Front-end hybrids
  - Silicon strip modules
  - Integrated substructures (TEC petals example)
- Tracker integration
- Performance of substructures in test beams
- Summary

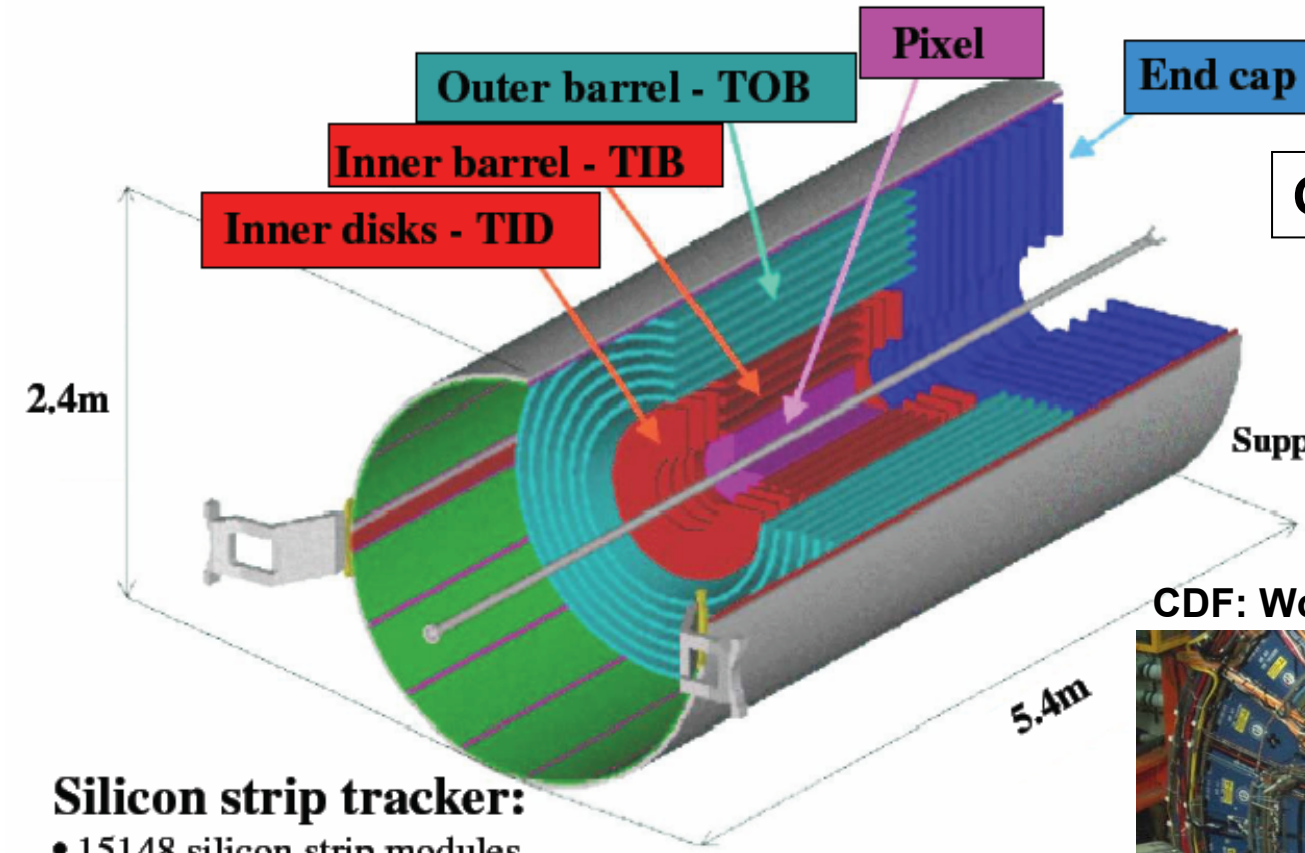
Last results (from summer 2005): preliminary!!!!

The CMS Detector at the LHC

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



The CMS Silicon Strip Tracker



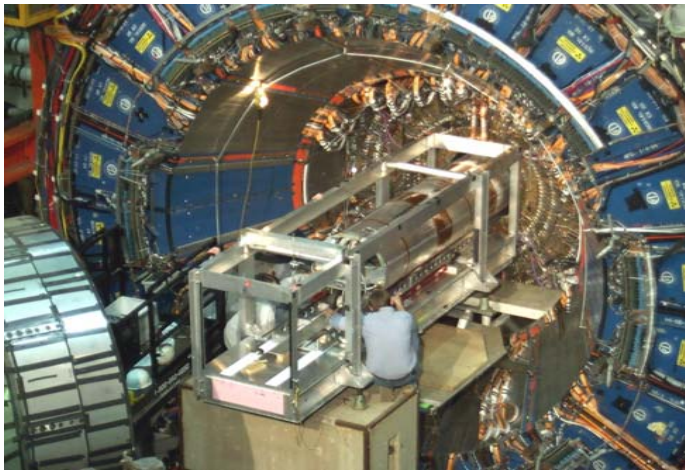
Operated at ~ -20°C

9.65M channels!!

Silicon strip tracker:

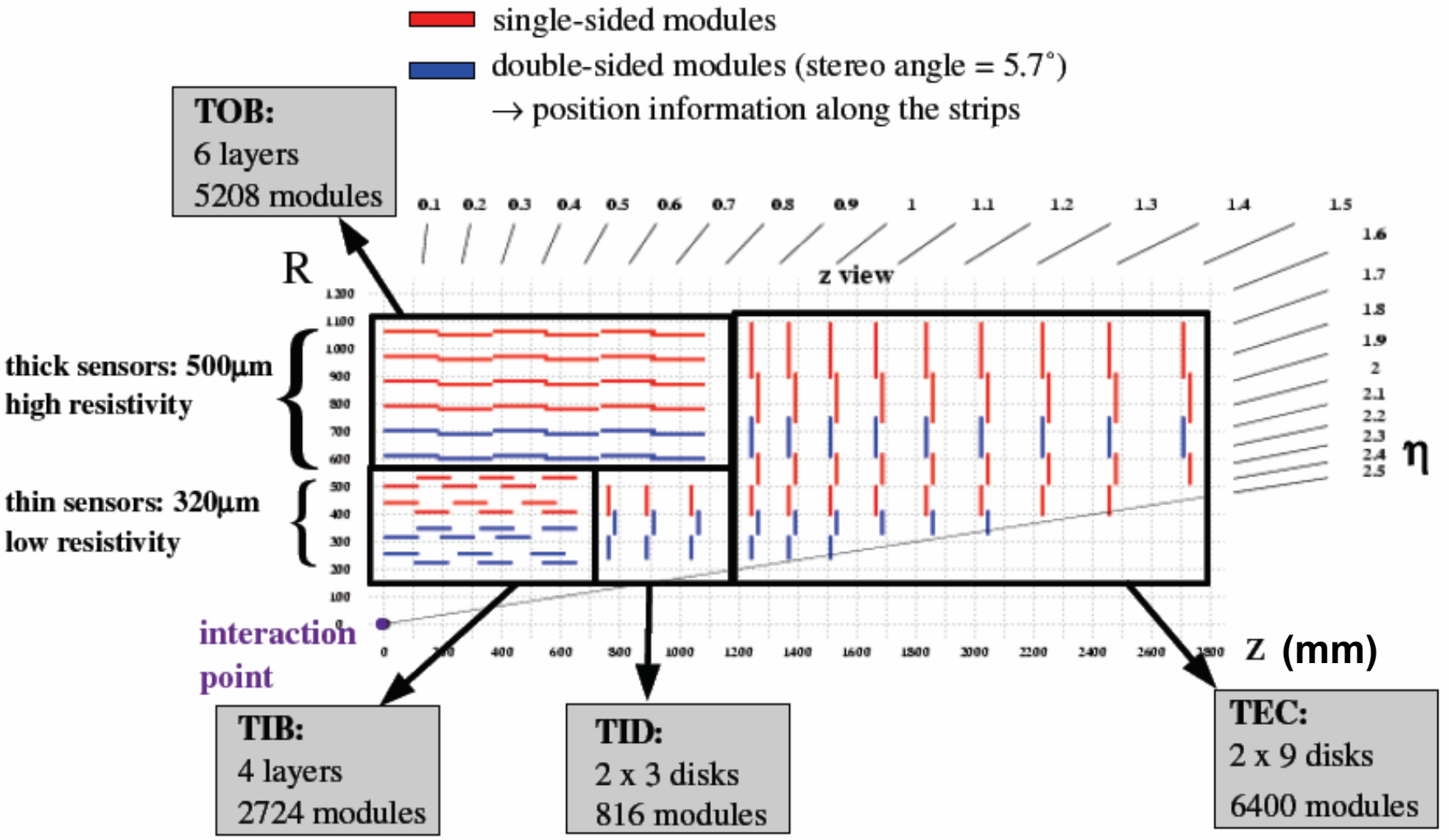
- 15148 silicon strip modules
- ≈200m^2 active silicon area
- ≈10 million readout channels (strips)
- high radiation level: 10 LHC years ≅ 1.6x10^{14}n(1MeV)/cm^2
  → operating temperature below -10° C

CDF: World largest 2000-2007, 7.5m^2

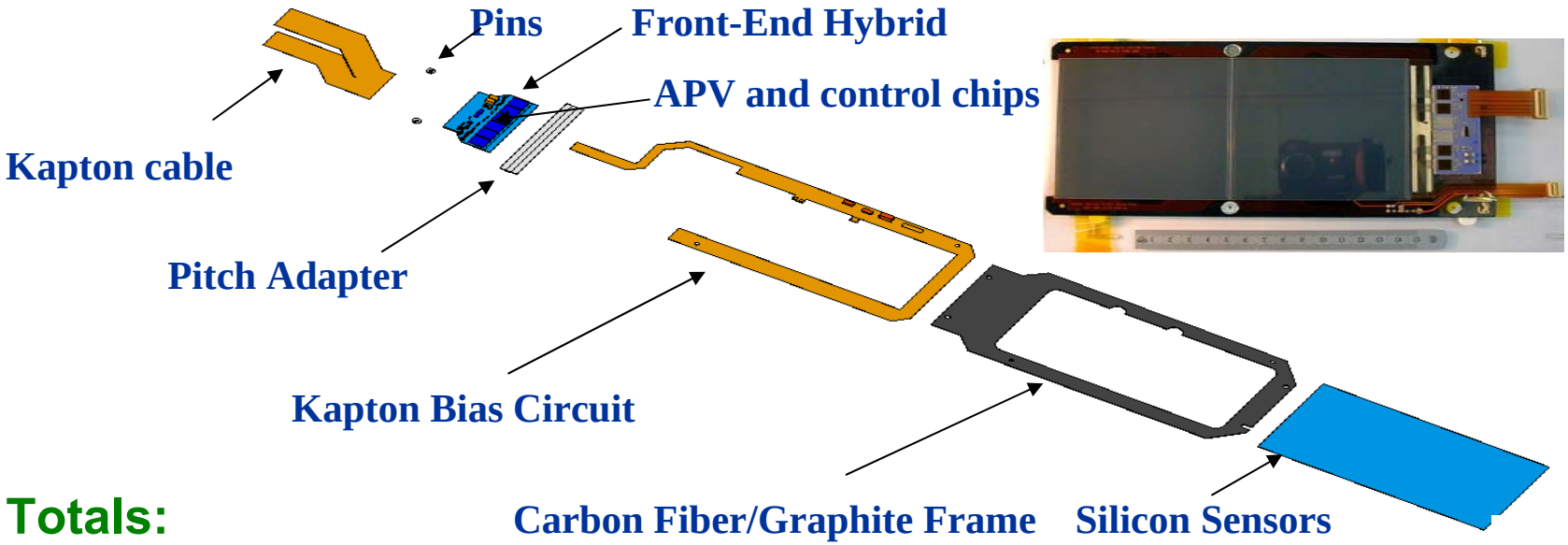


The CMS SST insides

Cross section of one quarter of the tracker:



Module components



Totals:

- 15150 (+10% spare) modules
- 29 types of modules
- 15 types of sensor masks
- 24 types of pitch adapters
- 12 types of hybrids
- 19 types of frames

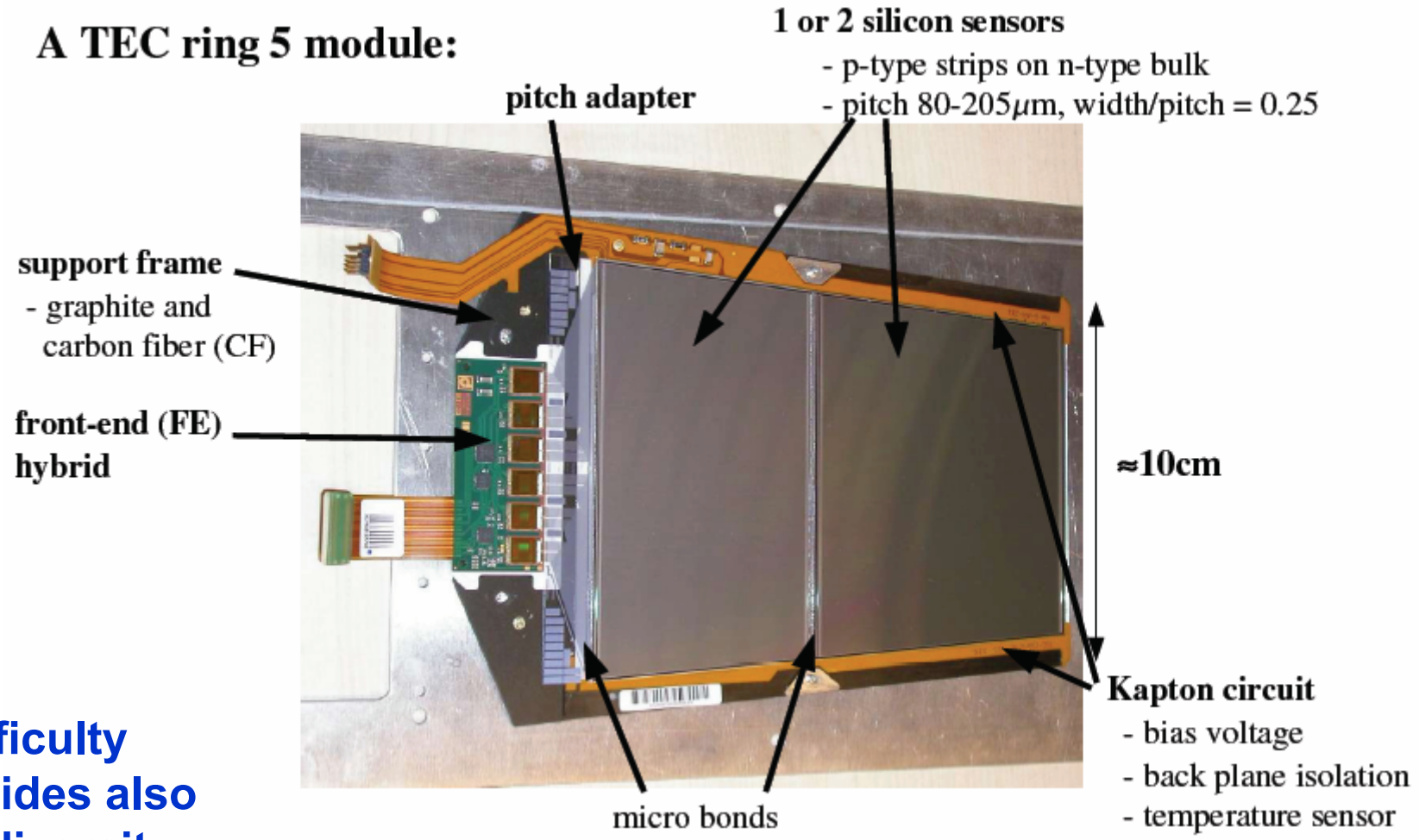
Status overview:

The delivery of each single type of part is monitored on a monthly basis w.r.t the plan and is posted on a dashboard

Nearly all the structural components for the whole module production (including spares) are in hand.

Silicon Sensor and Hybrid deliveries are also very well advanced

The Silicon strip modules



Difficulty resides also in diversity :

29 module types; 512 or 768 strips,1 or 2 sensors, rectangular or wedge-shaped sensors, geometry...

The Front-end Hybrid

4 layer Kapton substrate (flex) laminated onto ceramic carrier

4 or 6 APV25 readout chips

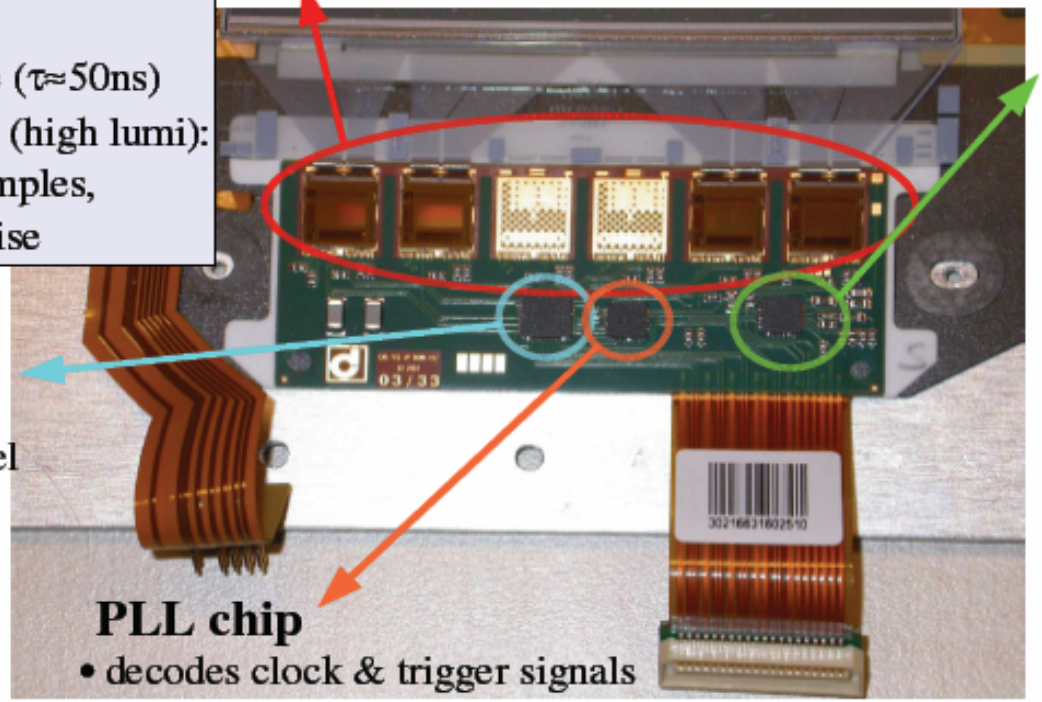
- **radiation hard commercial 0.25μm CMOS technology**
- **128 strips per APV, multiplexed to one analog output**
- **per channel: preamplifier, CR-RC shaper, 4.8 μs pipeline**

2 readout modes:

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

2:1 multiplexer

- 2 APVs multiplexed to one readout channel

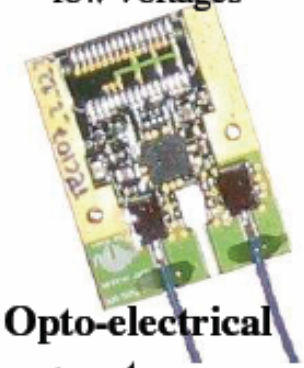


PLL chip

- decodes clock & trigger signals

Detector Control Unit (DCU)

- 12-bit ADC
- 8 channels:
  - hybrid and sensor temperatures
  - leakage current
  - low voltages

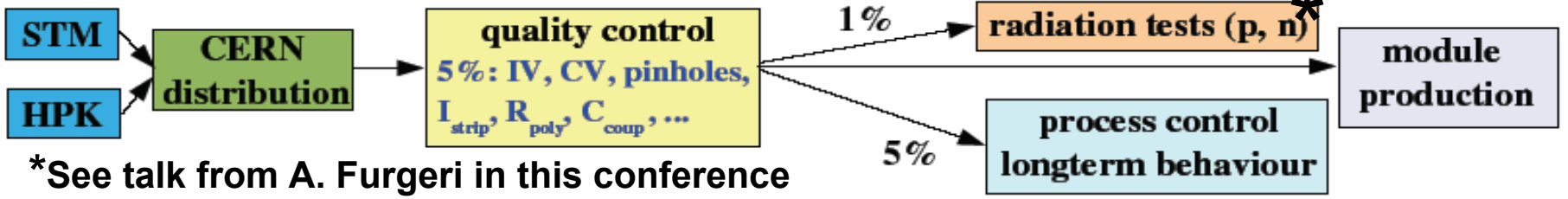


Opto-electrical converter

Analog & optical readout!

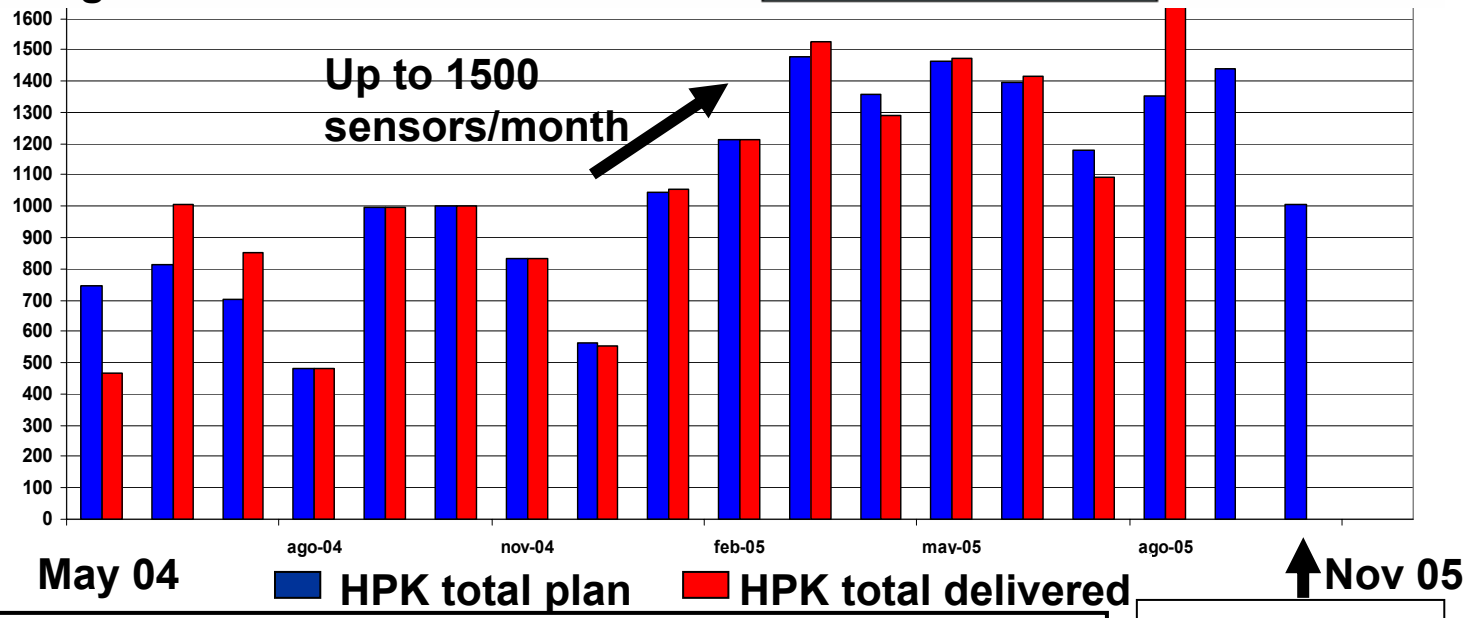
Sensor production

- Suppliers deliver 24244 tested silicon sensors (6" technology)
- 7000 320μm thick sensors: HPK; ~17000 500μm thick sensors: 85% HPK, 15% STM (since 2004)



*See talk from A. Furgeri in this conference

Problems with STM sensors during mass production (unstable leakage current, oxidation, high common mode, ...): bulk of thick sensor production shifted to HPK

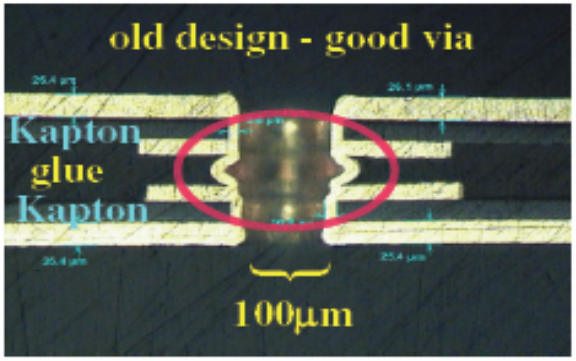


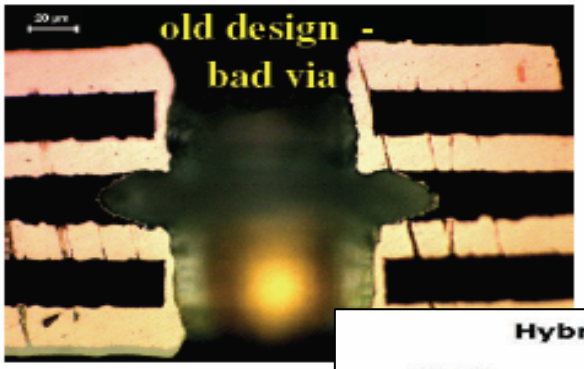
Status (August 2005):
- HPK: 100% of thin and 75% of all thick sensors delivered, excellent quality
- STM: 15% of all thick sensors delivered and qualified

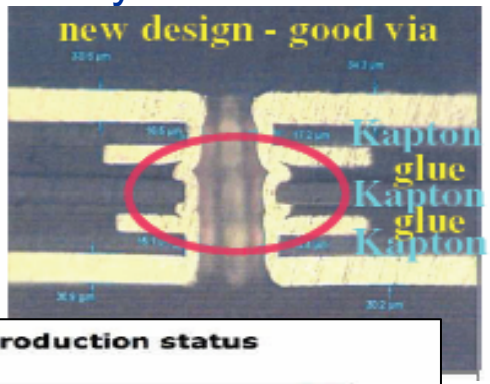
production completed in Oct. 05

Front-end Hybrid production

- 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
- Several problems, e.g.:
  - Lines broken at connector (Ni/Au pads on Kapton) →FR4 stiffener
  - 100μm vias developed bad contact → additional Kapton layer

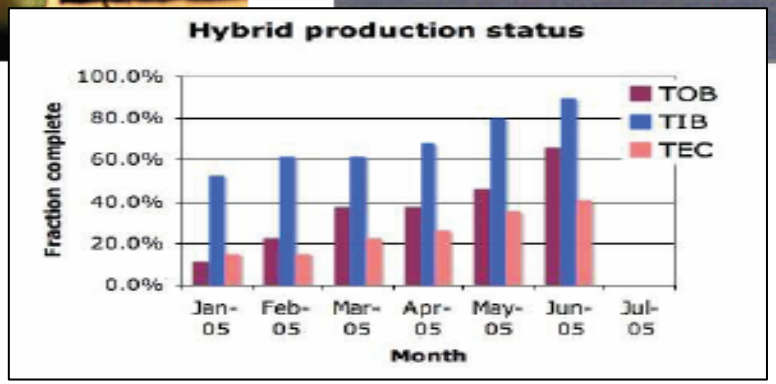






Status (mid July 2005):

- **Improved QA & C**
- **Production rate: ≈400 hybrids/week**
- **70% of hybrids delivered and accepted**
- **Expected end of production: November 05**
- **Backup line being set up**

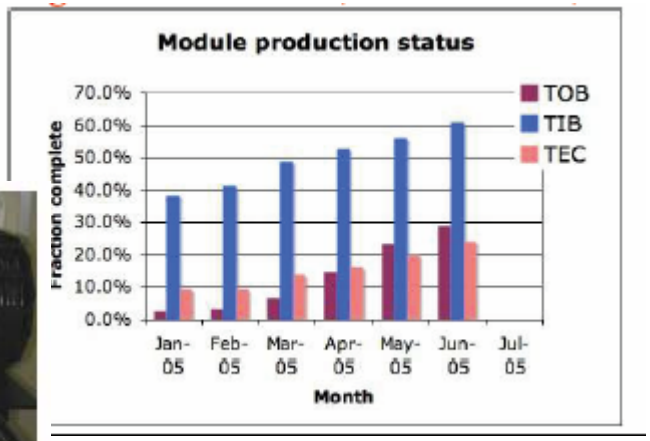


Module production

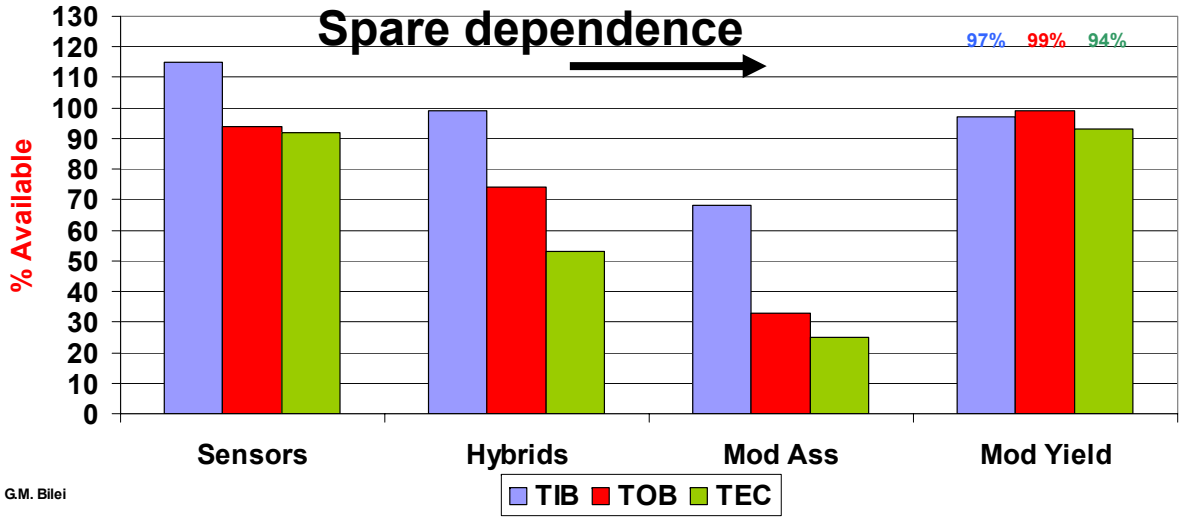
1. Assembly: gluing of sensor(s) and hybrid to the frame with high precision (i.e. coordinate ⊥ strips: 39μm)

→ **fully automatic gluing robots: "gantry"**

- 6 gantries in operation
- Issues: precision, calibration
- 99% of modules within specs
- Up to 20 modules/gantry/day



2. Bonding: 23 automatic bonding machines (> 5 mods./machine/day)



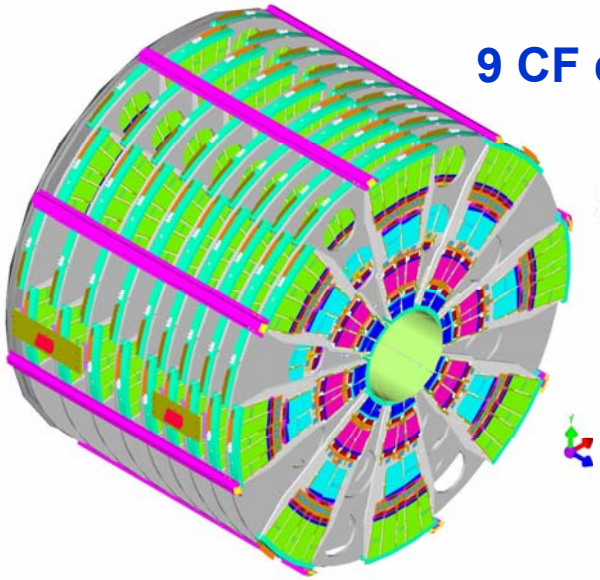
3. Single module test (warm & cold): noise, bad strips, IV, pipeline errors, ...

- Typically 0.1-0.3% of bad strips per module
- Yield > 95%

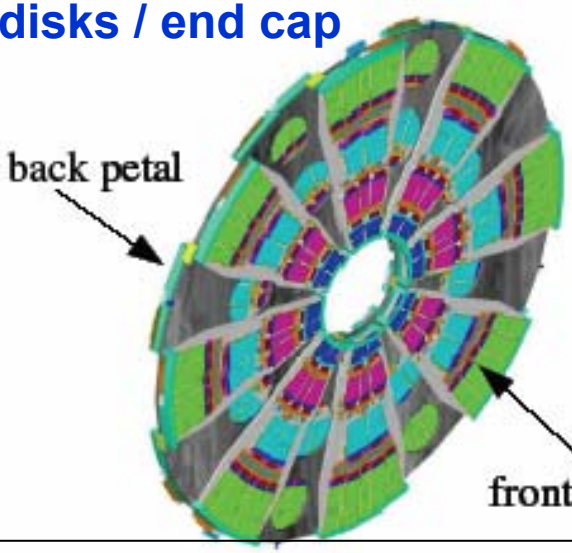
Status (mid July 2005):

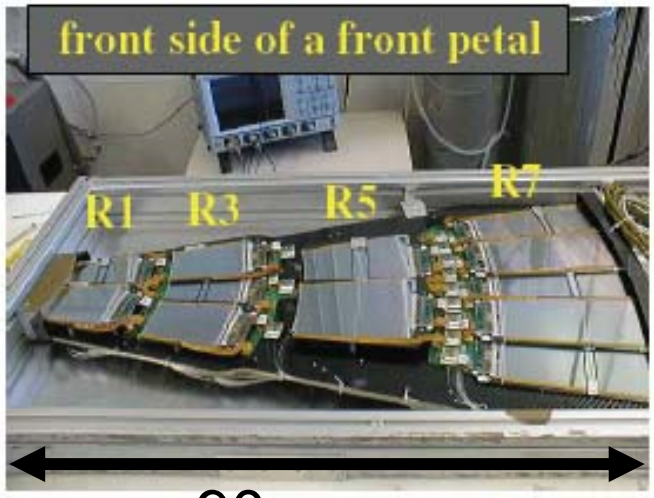
- **5348 production modules built = 35%**
- **Expected end of production: January 06**

Substructure Production (TEC Petals example)



9 CF disks / end cap





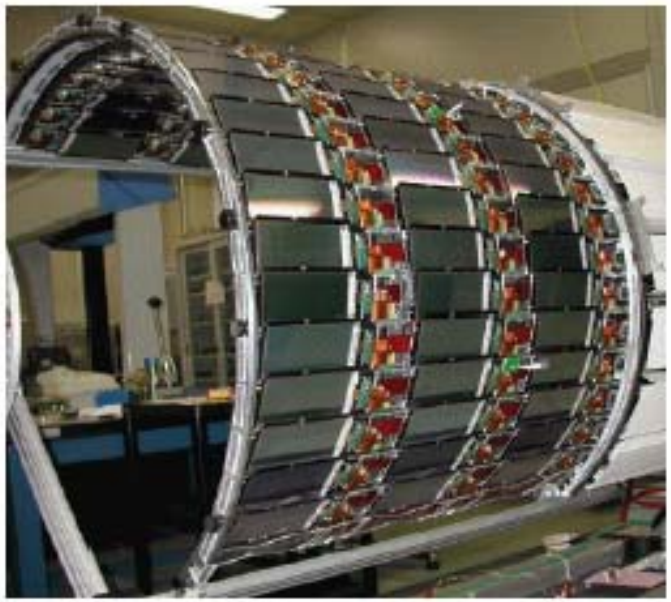
- Modular design: 16 (8+8) removable CF structures (petals) per disk
- Up to 28 wedge-shaped modules per petal, arranged in 7 radial rings: ~17000 channels

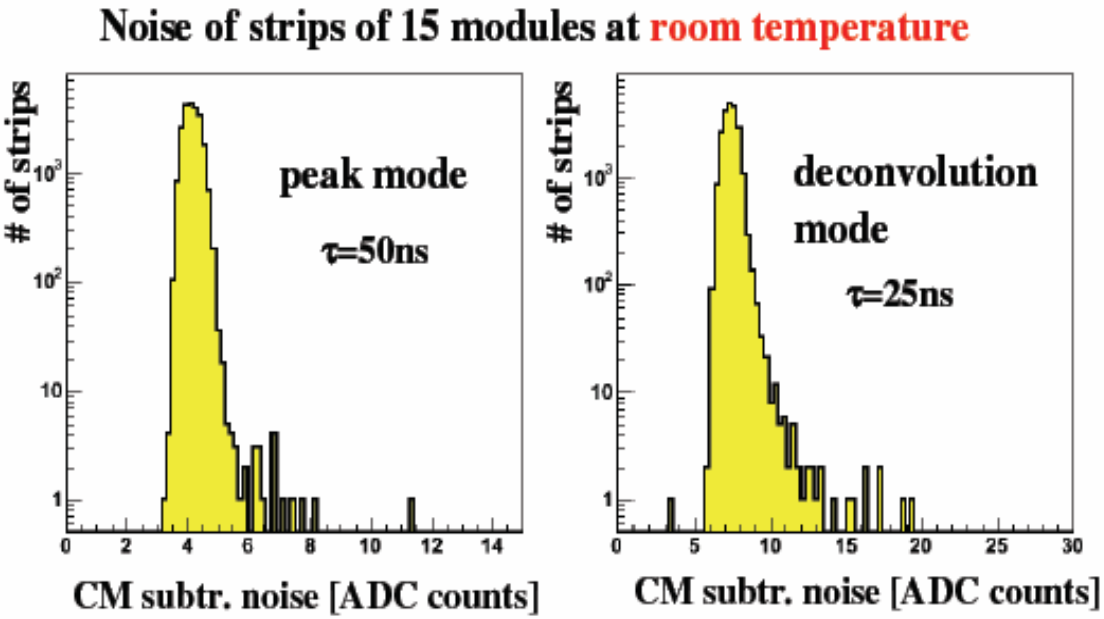
- 40% of petal mechanics with motherboards produced
- Mounting of optical converters (AOHs), routing of fibers
- Assembly of modules and functional test (7 prod. lines in 5 centers)
- Long-term test of assembled petals started in May 05:
  - 6 cooling cycles between room temp. and -20 C → 3 days
  - 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

Status (mid July 2005):
22/288 petals built;
12 fully characterized

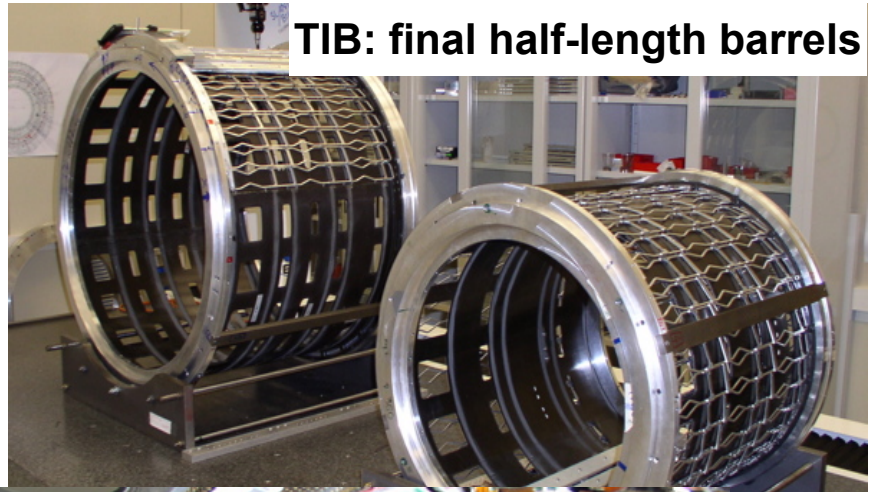
Tracker Inner Barrel (TIB) Integration

- Strings of 3 modules mounted inside & outside of the barrel cylinders
- Cylinders of layers L2+, L3+, L4+ completed
- First single-sided layer (L3+) fully integrated
- Readout test and burn-in of L3+ ongoing
- >99% of good strips, noise level as in test beams
- Grounding/shielding/x-talk under study

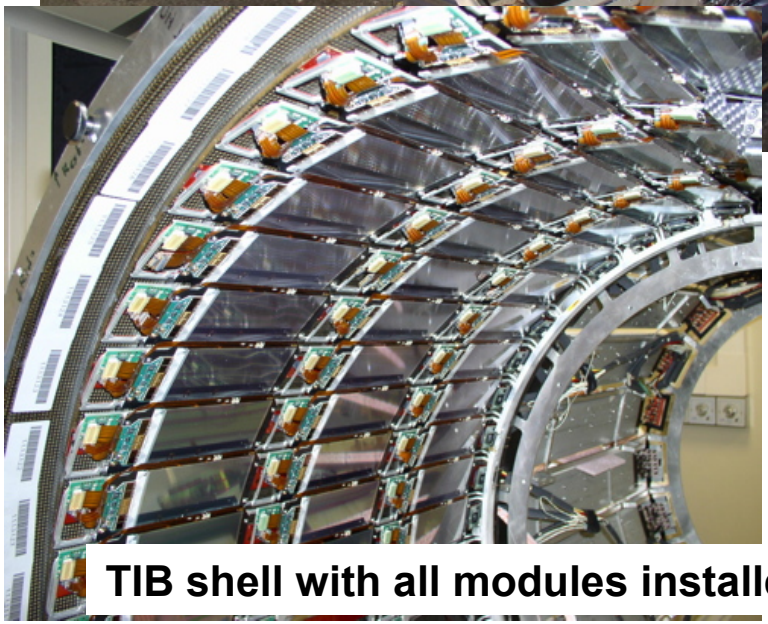




Tracker Inner Barrel (TIB)



TIB: final half-length barrels

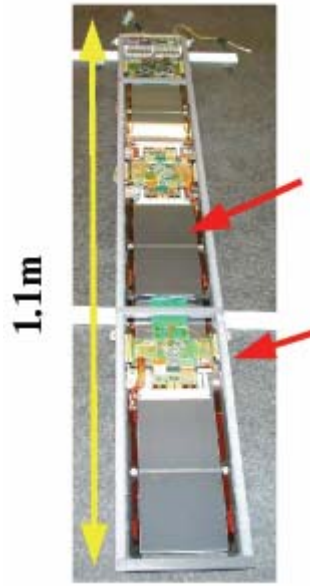


TIB shell with all modules installed

TIB end-flange mock-up

Expect delivery of complete TIB/TID at CERN by end 2005

Tracker Outer Barrel (TOB) Integration



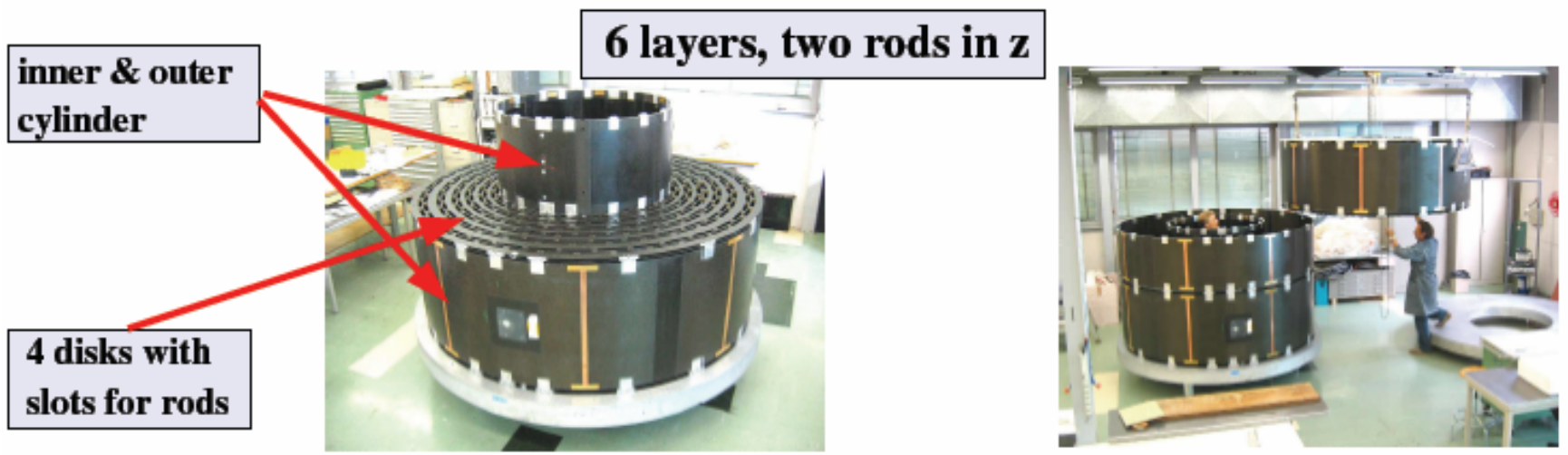
Modules mounted onto rods:

3 single- or double-sided modules per side

CF frame (rod)

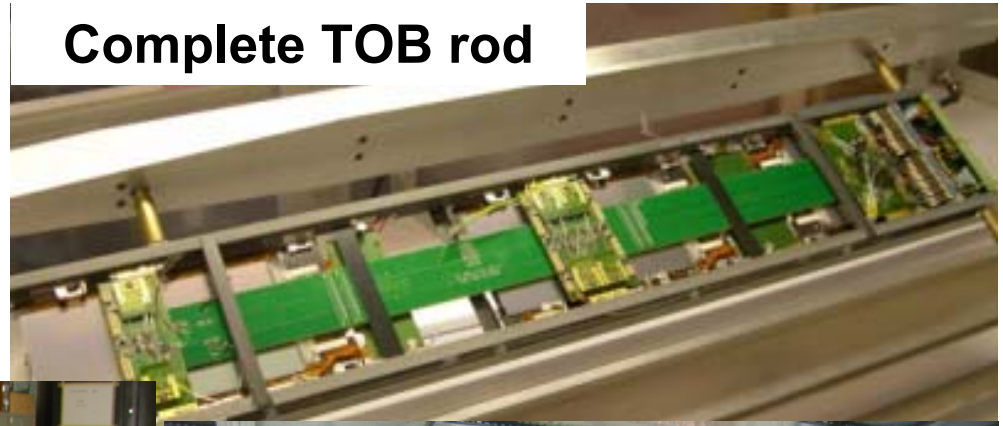
- 100% of rod frames produced:
(precision of positioning pins: σ = 40μm)
- 60% of rods cabled
- rod assembly has started:
24/344 rods assembled and longterm tested
- TOB integration started in August

Mechanical support ("wheel") is ready:



Tracker Outer Barrel (TOB)

Complete TOB rod

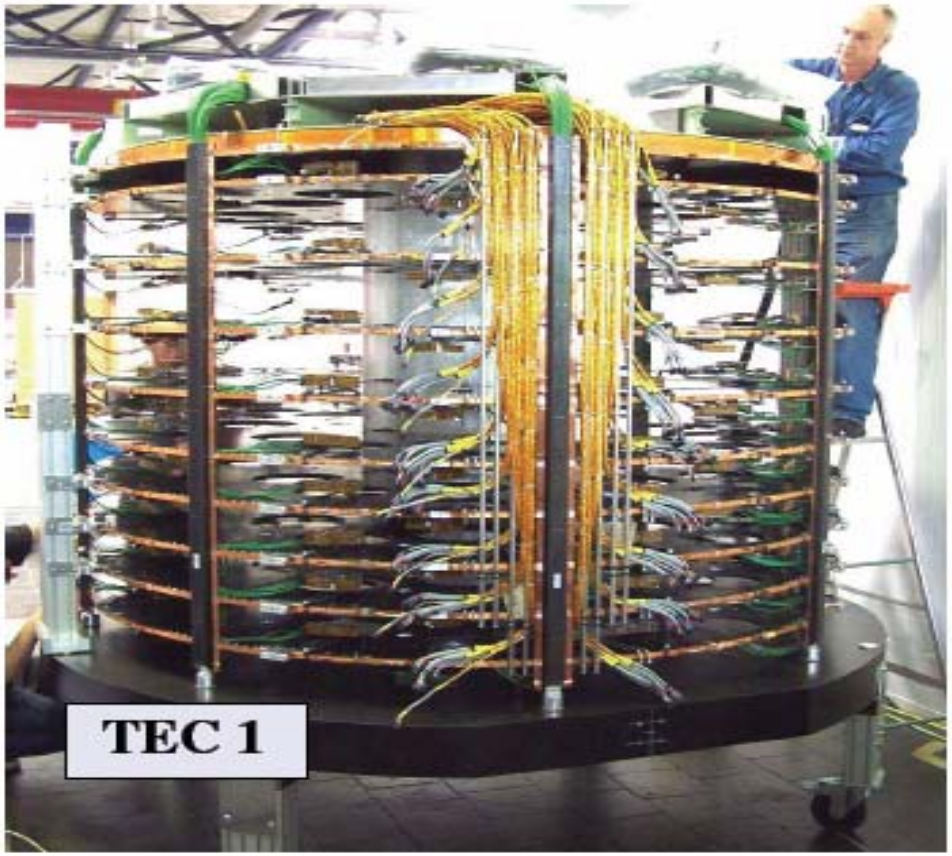


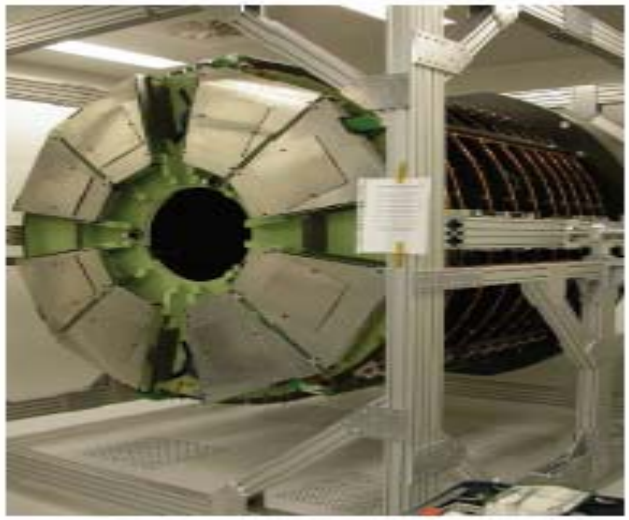
Tracker Support Tube and Thermal Screen being Prepared for Commissioning

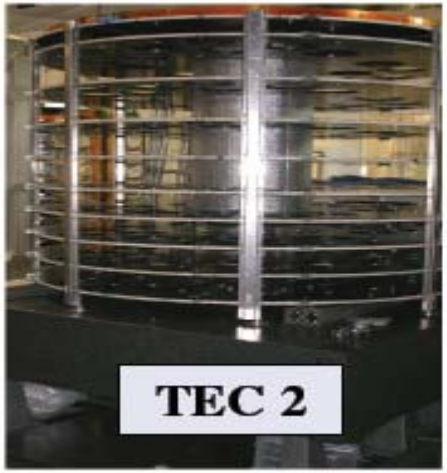
TOB disk

Tracker support tube & thermal screen

Tracker End Cap (TEC) integration



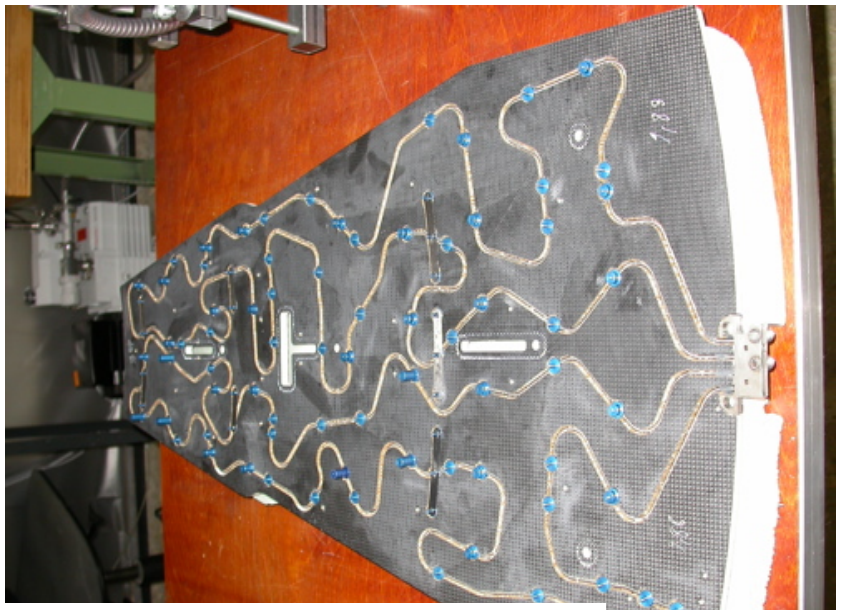




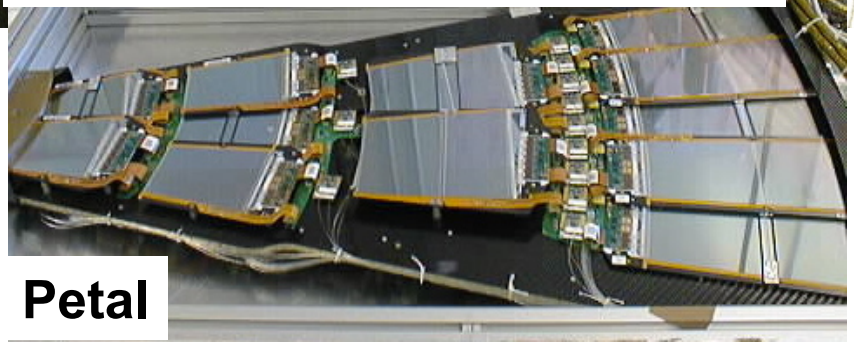
- First end cap assembled, ready for petal insertion
- Assembly of second end cap far advanced
- TEC integration started in August

Tracker Endcap (TEC)

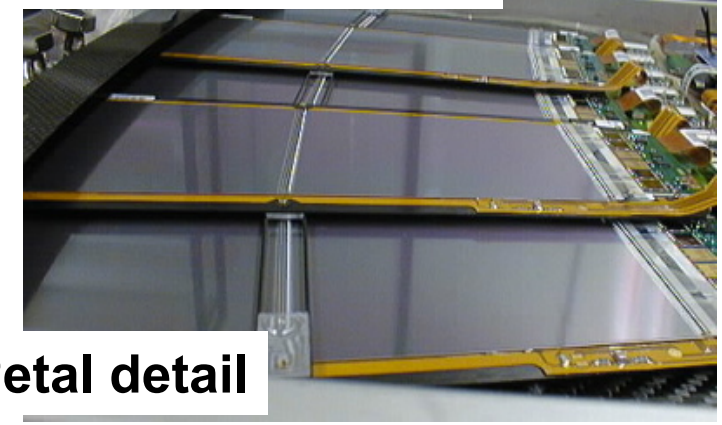
Disks of one complete TEC



Cooling pipe within petal

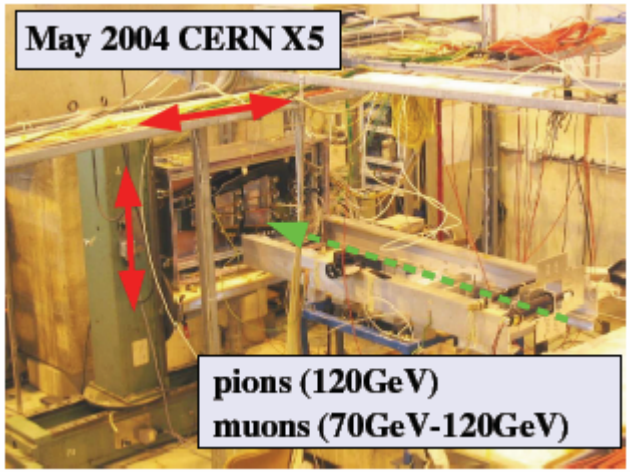


Petal



Petal detail

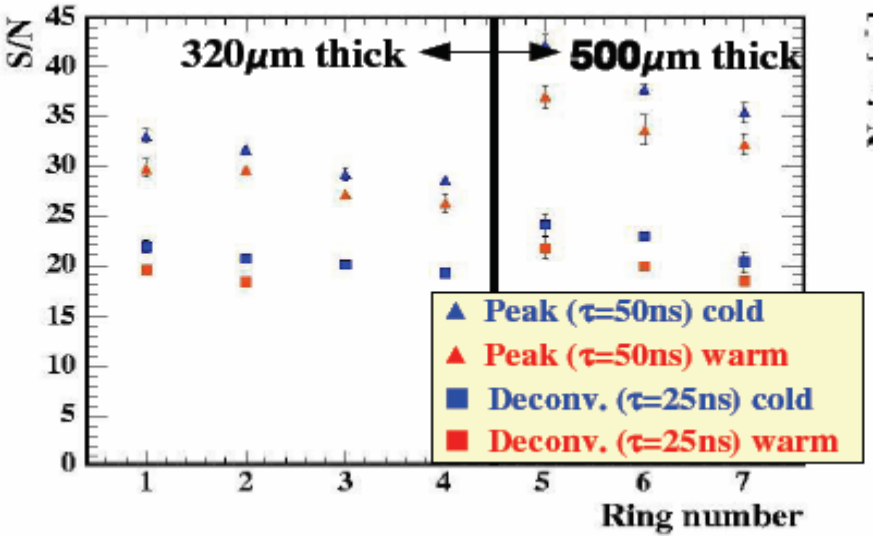
TEC Petals in Test Beam

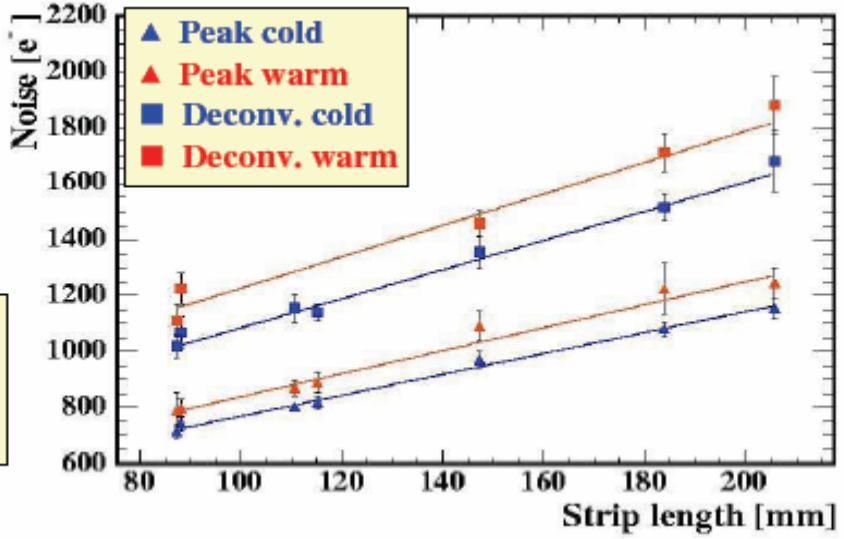


Setup: 2 petals (1% of the TEC), operated at CMS temperature (≈ -10 ˚C)

Excellent system behavior:

- **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**



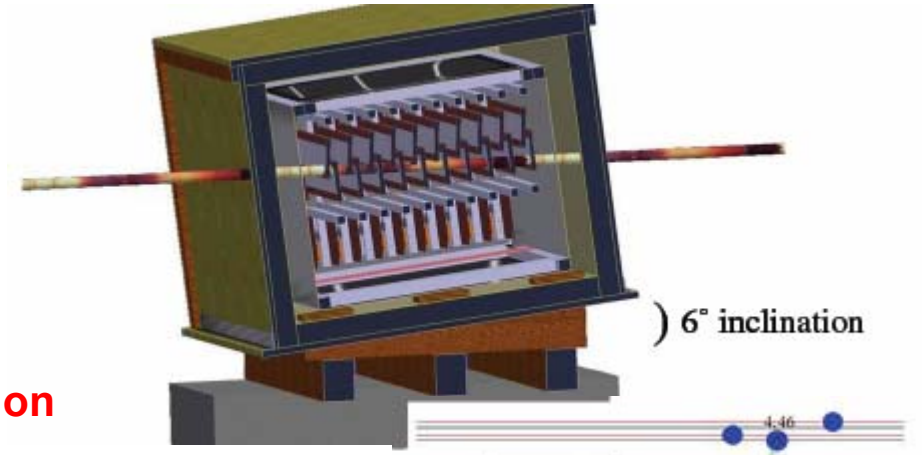


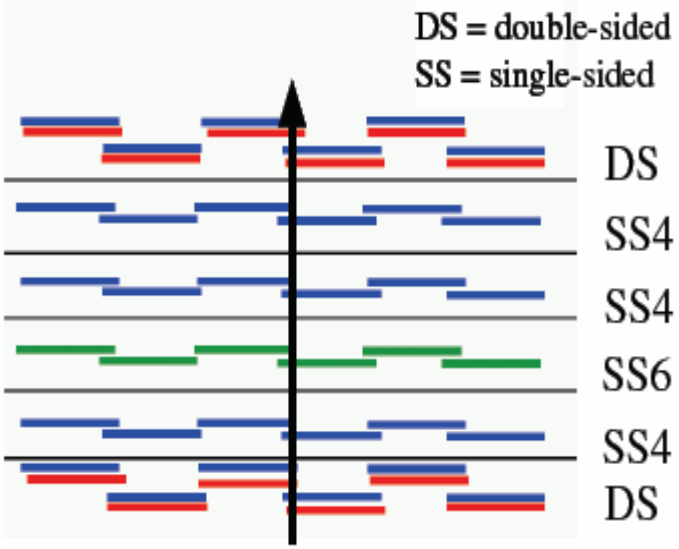
TOB Rods in Test Beam

Setup: TOB cosmic rack with 6 rods

Precision support structure with integrated cooling:

- **Stable readout at all temperatures**
- **Uniform noise**
- **S/N≈ 24 in deconvolution mode**
- **Tracking with expected spatial resolution**

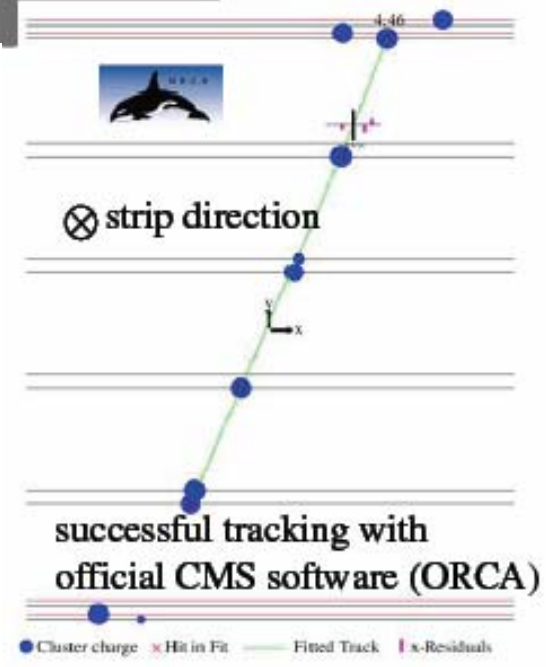




pitch/√12=35µm (SS6) and 53µm (DS, SS4)

resolution [µm]

⊥	∖
45	29
45	23
42	38
35	28
54	33
50	30



Summary

- Excellent performance of components proven in system tests and test beams
- Technical problems with sensors and hybrids seem to be overcome
- 35% of modules built with high quality, production completed early 2006
- Integration of modules on petals, rods and shells has started
- Integration of large structures until spring 2006
- Readout test of 25% of the tracker with final DAQ system

Integration into the CMS detector in autumn 2006