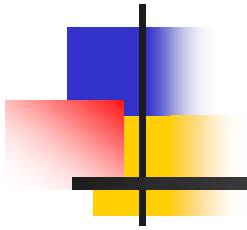


Status of the ATLAS Pixel Detector

TWEPP 2007

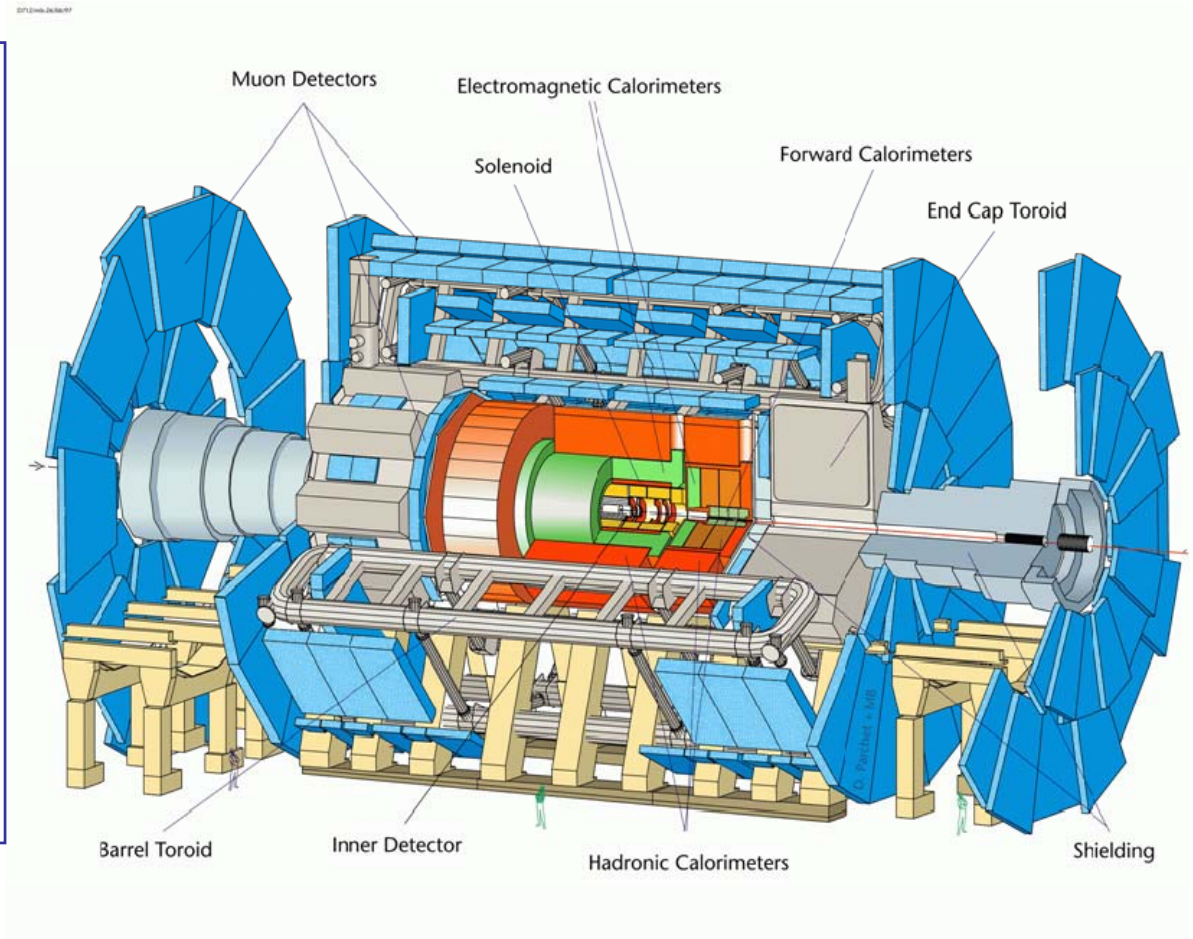
Jean-François Arguin
(Lawrence Berkeley Laboratory)
On behalf of the ATLAS Pixel Collaboration

September 5, 2007

The ATLAS Detector

One of the two general purpose detector around LHC

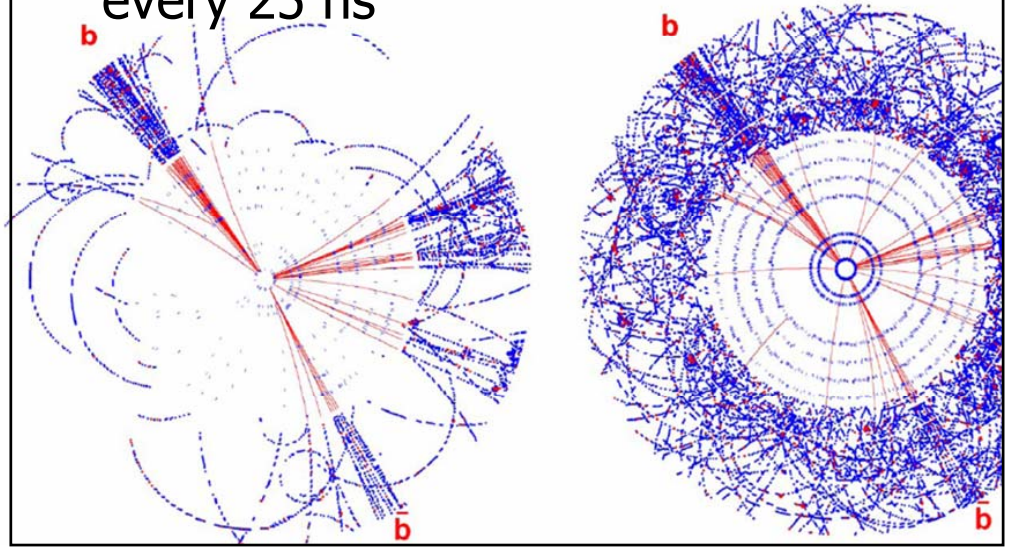
- Inner Detector ($|\eta|<2.5$, B=2T) :
  - Si pixels and strips
  - Transition Radiation Tracker
  - Inside solenoid field
- Calorimetry (LAr, tile)
- Muon Spectrometer with air-core toroids



Requirements for innermost tracking (pixel) layers

Experimental conditions…

- Large radiation doses (10^{15} neq/cm^2)
- Large event occupancy. E.g. H→bb without and with pile-up events (see below)
- High frequency: bunch crossing every 25 ns

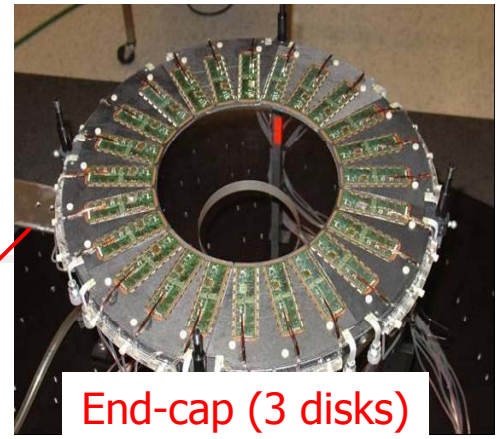


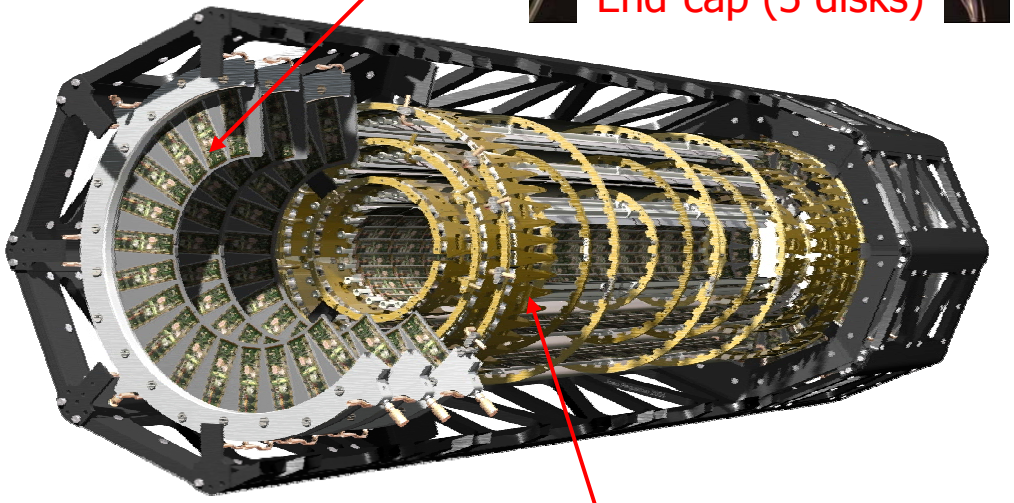
… Motivate the use of a pixel detector. More specifically:

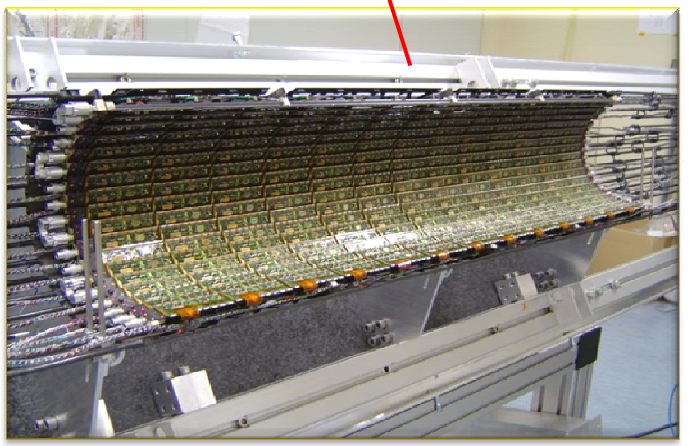
- Low occupancy (~10^{-4}) crucial for pattern recognition
- Good d_0 and z_0 resolution *(12μm and 70μm)* crucial for physics program (e.g. B-tagging)
- Pixel intrinsically rad-hard (e.g. low leakage current)
- Need to design fast and rad-hard electronics

General layout

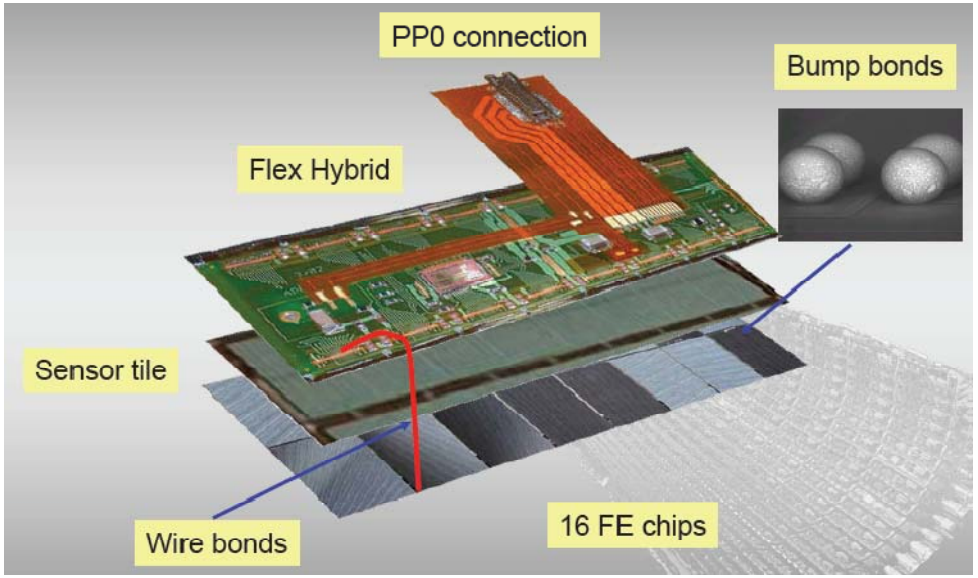
- 3 barrel layers (|η|<1.9) + 3 disks (1.9 <|η|<2.5)
  - Barrel layers at 5, 9, 12cm in radius from IP
- Tracking volume: 1.6 m long, 0.2 m radius, 1.8m^2 of silicon
- 1744 modules
  - Total: 80 millions channels!
- 10% X_0 material at η=0
- Use evaporative cooling to remove 10 kW of power and operate at T~0°C







Basic Building Blocks of Pixel



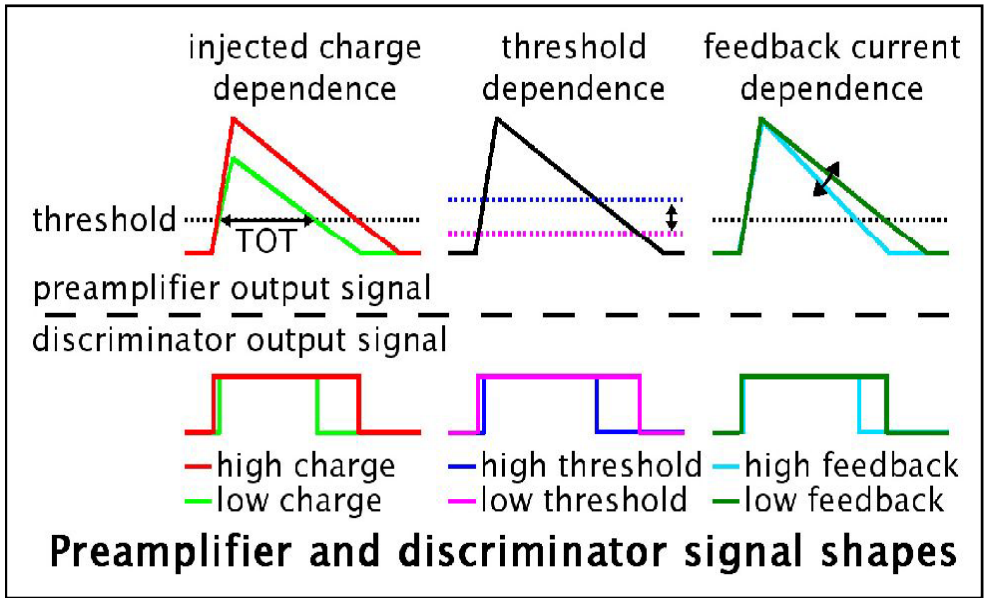
- Each module has 46080 pixels in an area of 10 cm^2 (1.6x6 cm^2)
- Module are placed on cooling/support structure

Modules components:

- Sensors are n^+ pixels on n substrate
- Silicon sensors bump-bonded to 16 FE chips (FE)
- Pixel size is 50x400 μm (in r-φ x z plane)
- FE chips are connected to one controller chip via wire bonding and flex hybrid
- Micro-cable (~1m) connected to service patch panel (PP0)

Front-End Electronics I

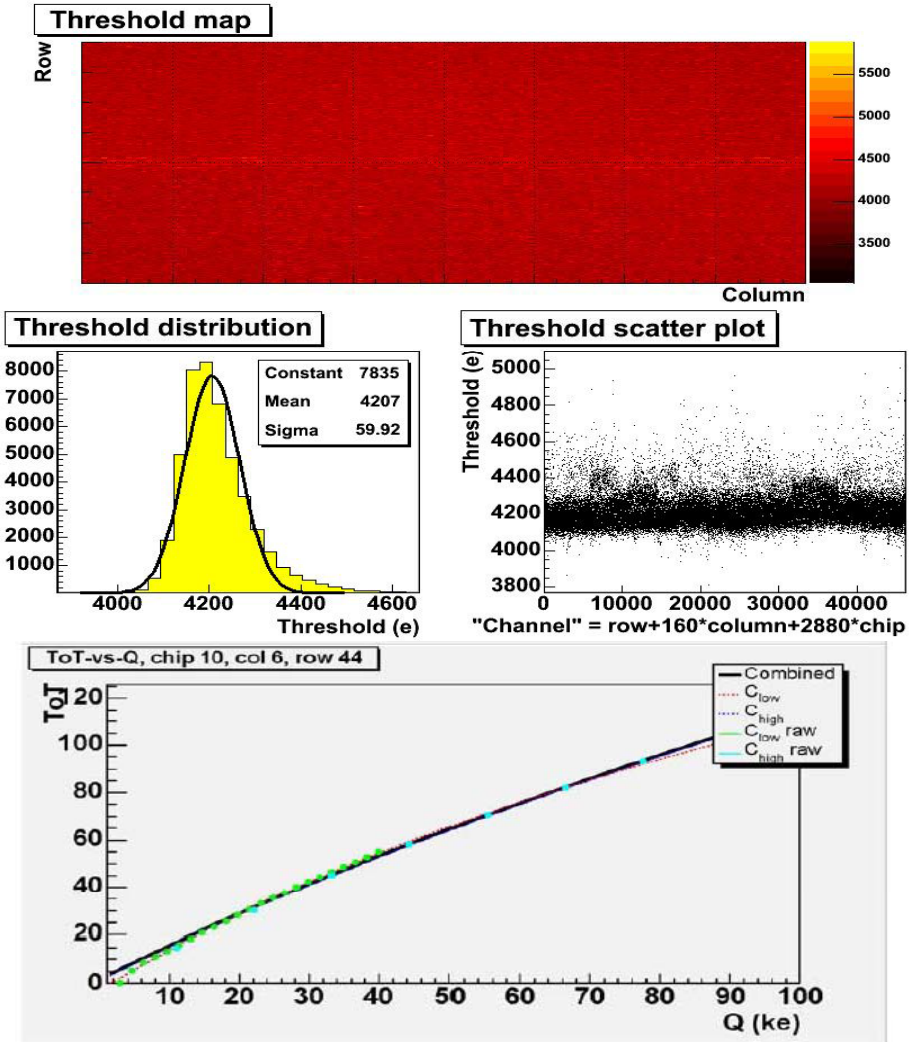
- Each pixel has a feedback preamp that provides very good leakage current tolerance
  - ~12 nA to 100nA after irradiation
  - Tuned to achieve linear dependence between charge and Time-over-Threshold (ToT)



Preamplifier and discriminator signal shapes

- Pixel digital circuitry calculates ToT (difference between leading and trailing edge) with 40 MHz timestamp
  - Typical ToT: ~30 bunch-crossing
- Pixel-level control logic (14-bits) to adjust e.g. threshold and ToT
  - Front-end-level control logic e.g. to tune global threshold, ToT and charge injection
- Charge injection circuitry can calibrate relevant parameters

Front-End Electronics II

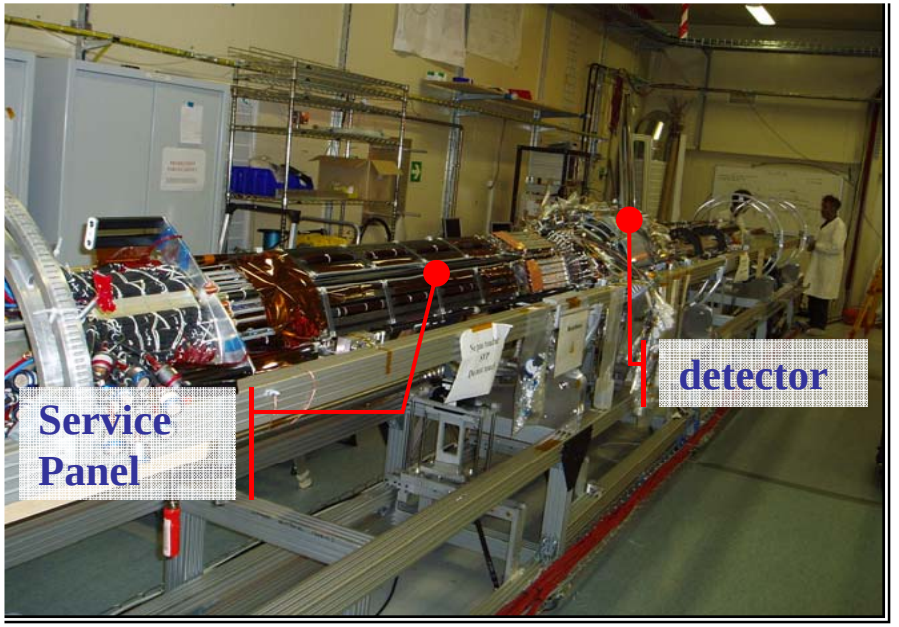


- Hits (address+ToT) transferred to End-of-Column (EoC) electronics
- EoC contains 64-hits buffer (enough for 3.2 μs Lv1 latency)
- Coincidence with Lv1 performed
  - If accepted, events transmitted to module controller chip (MCC)
- The controller chip collects data from 16 FE chips
  - Performs initial data formatting and sends module event data off-detector

Service Panels and Optoboard

- Service panels bring services out of inner detector volume (7m)
- Active part: optoboards that provide electrical/optical data conversion

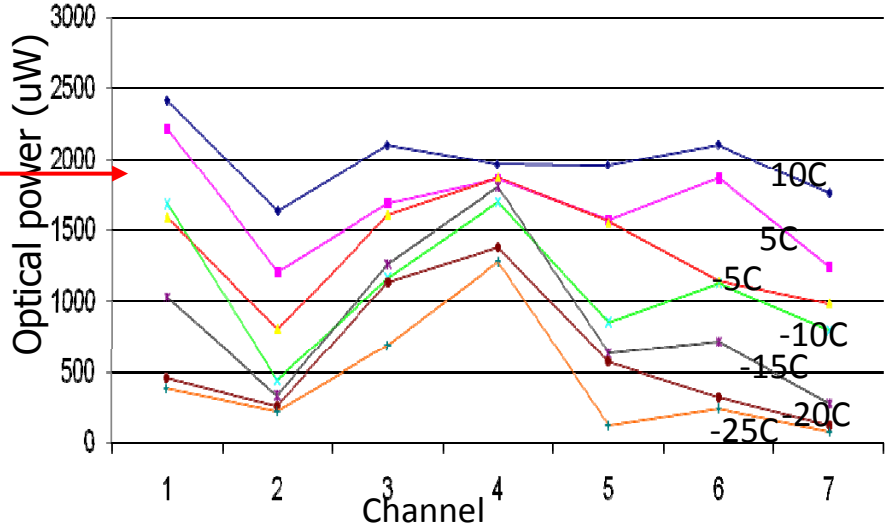
- Optoboards:
  - Laser diode sends data-out at rate of 40 to 160 Mbit/s to off-detector electronics
  - PiN diode converts data-in (commands, clock, Lv1)

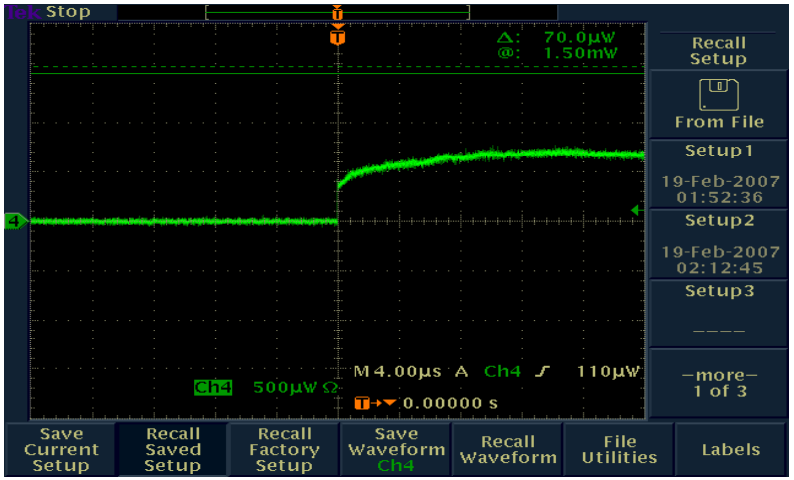


More on Optoboards

Three problems affects the optoboard's laser diodes (VCSELs):

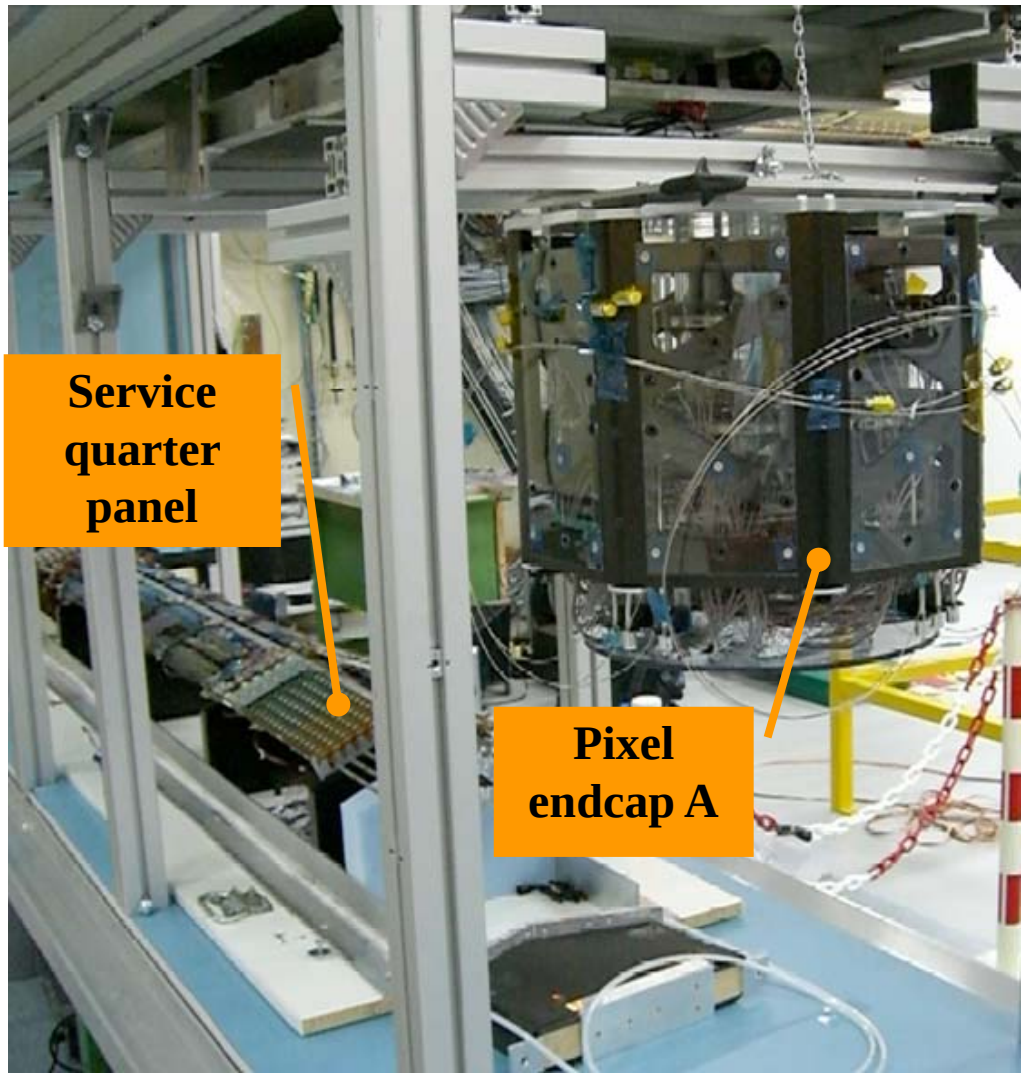
- Temperature dependence
  - Low optical power at low T, but optoboards coupled to cooling
  - Forced the use of heaters
- Common-Series-Resistance
  - Symptom: VCSEL dying during production (aging process?)
  - No dead VCSEL observed since Oct. 2006
- Slow-Turn-On:
  - Shown later not to affect operation after tuning of optical threshold



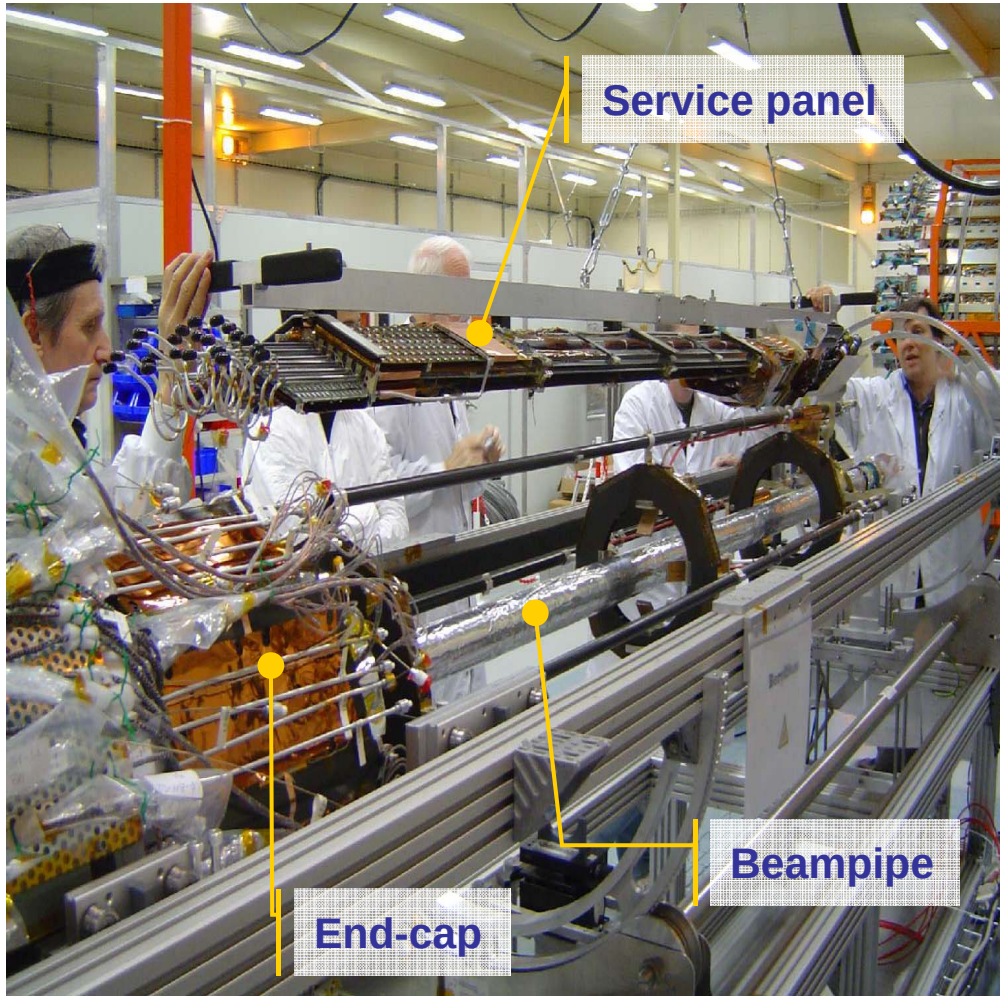


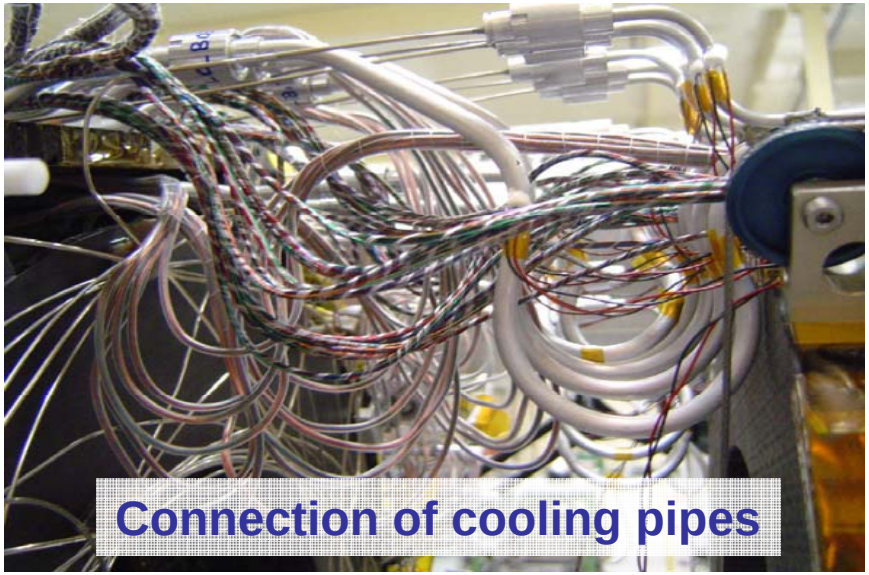
Commissioning of End-Cap

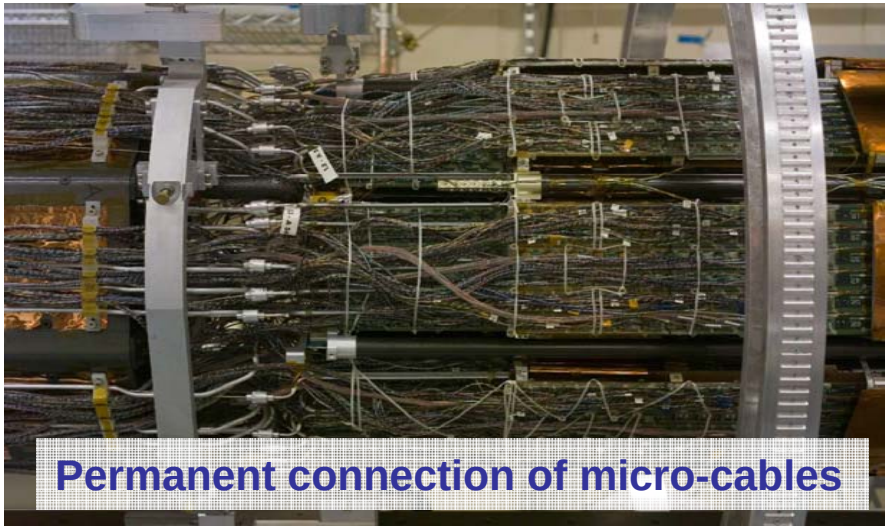
- In fall 2006: performed a 10% system test
  - One end-cap (144 modules)
  - Scintillators for cosmics trigger
  - One prototype service panel
  - Services close to final version
- Achievements:
  - Commission services
    - E.g. uncovered optoboard T-dependence
  - Commission DAQ and offline with cosmic and random triggers, measured e.g.
    - Noise occupancy ~10^{-6}
    - Pixel efficiency of 99%
    - Alignment of modules



Pixel Package Integration (Winter-Spring 2007)







Pixel Connectivity Test

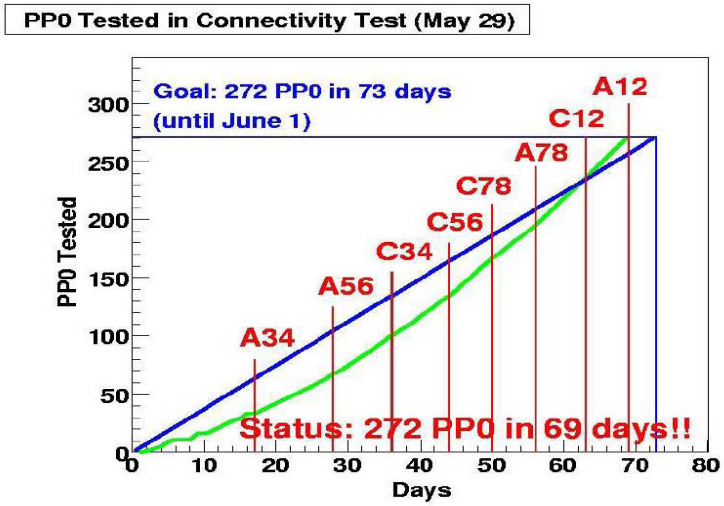
- Package integration took place between Feb-Jun 07
- In parallel: connectivity test to check
  - Permanent module connection to services
  - Last chance to repair before installation in the pit!
  - The first time the full detector is readout using the full readout chain
- General goal: pixel has to be ready for installation (mid-June)

- Connectivity test setup:
  - Use cosmic test hardware (can only test ~10% of pixel at a time)
  - No cooling available: must iterate on active part

Results of the Connectivity Test

Check optical and electrical connections:

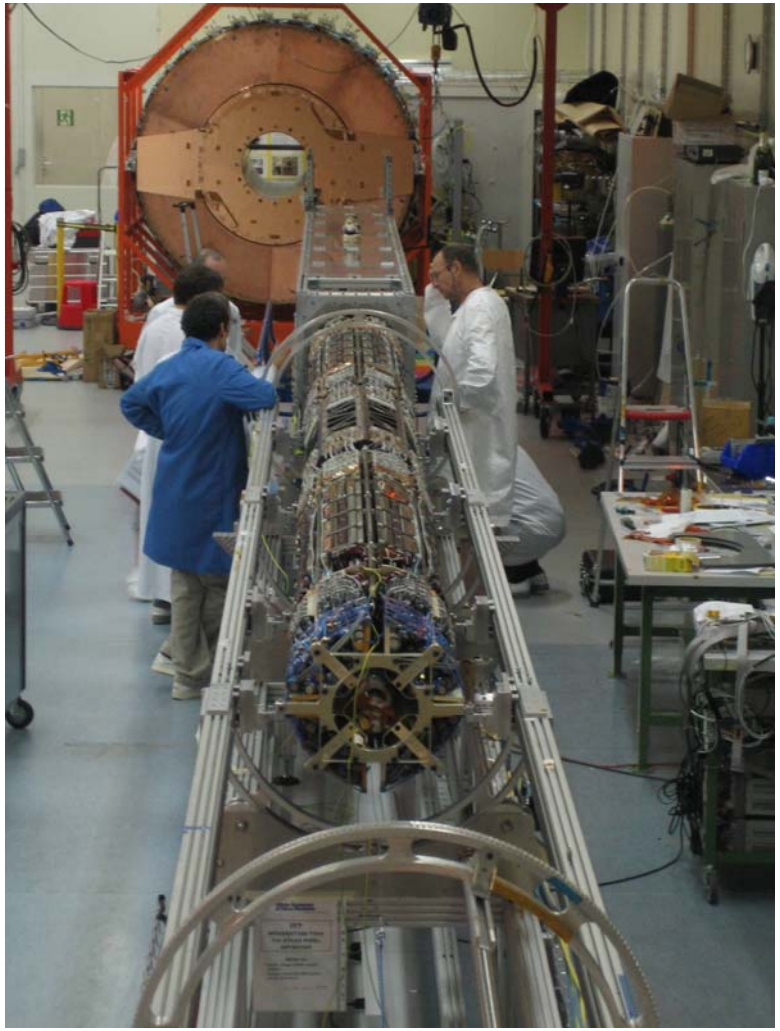
- LV, HV, Env sensors
- Micro-cables mapping
- Optical fiber mapping
- Optoboard tunability

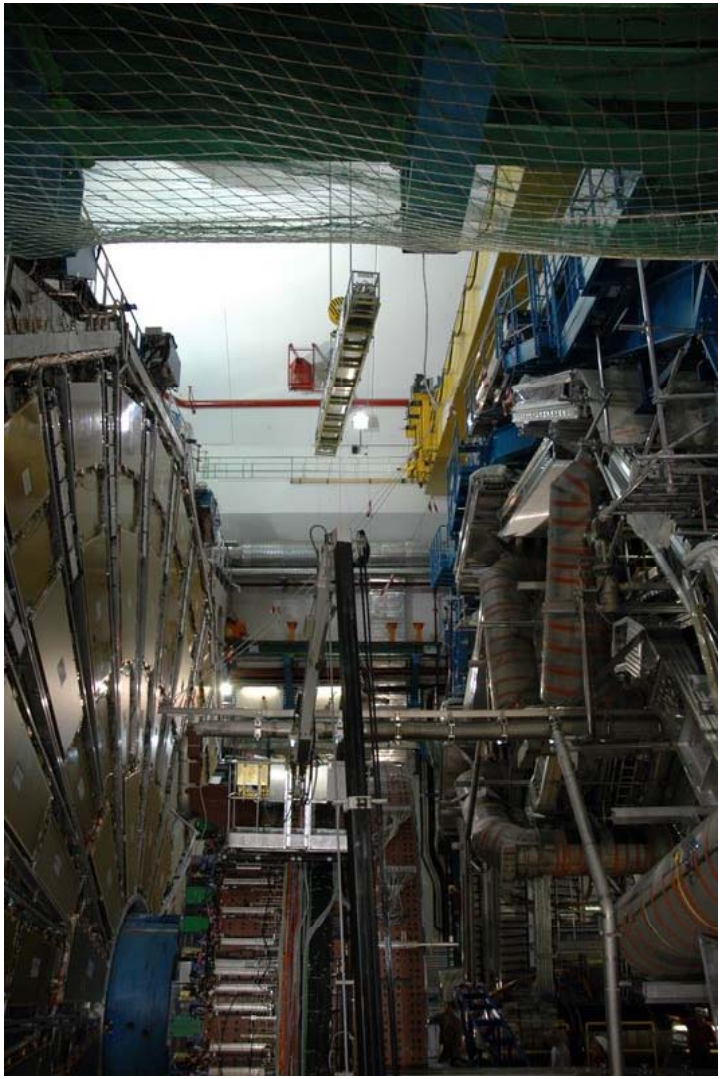


Results:

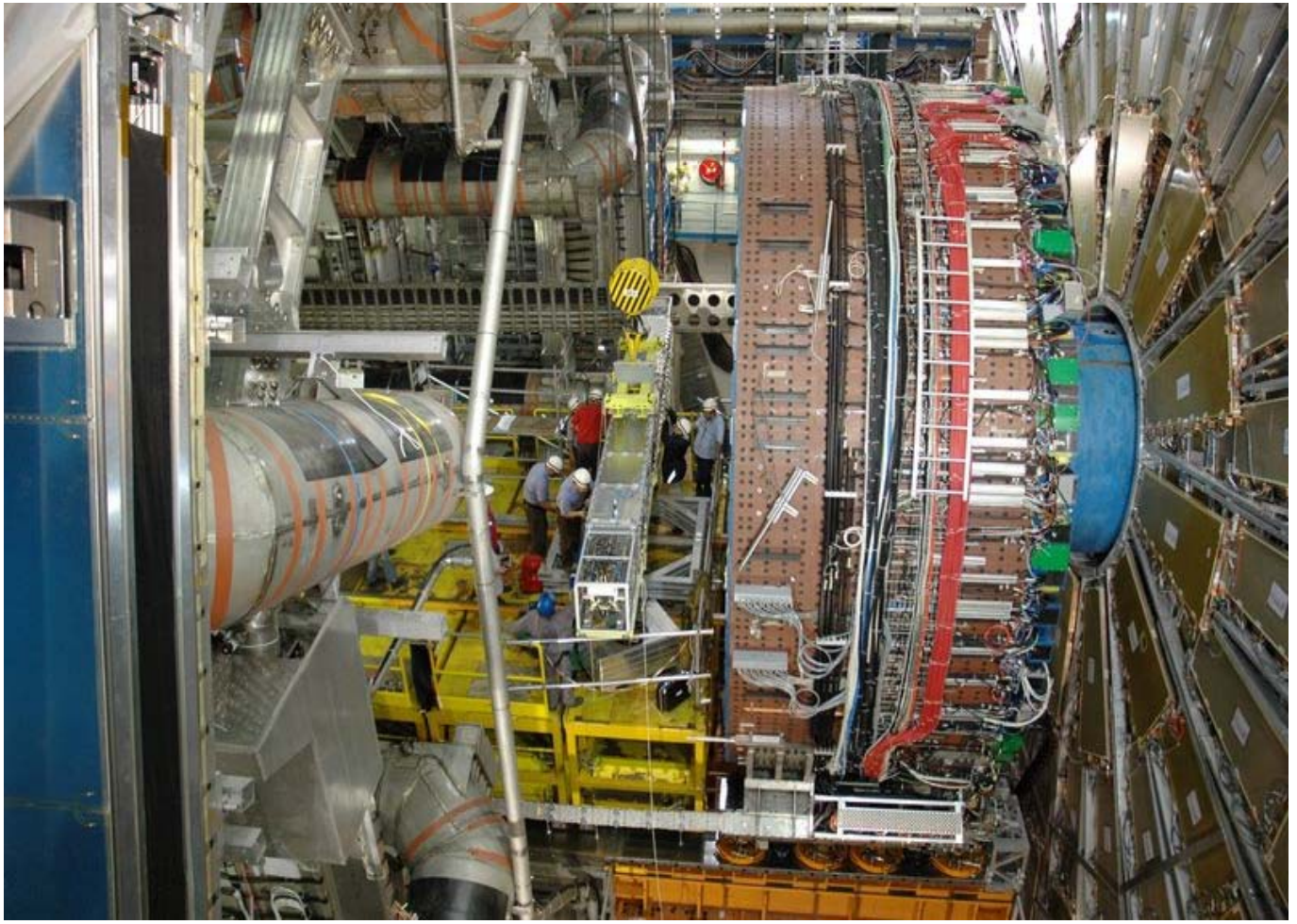
- Only 3 module failures:
  - One broken HV cable
  - Dead optoboard PiN diode
  - LV short problem
- Every optoboard tunable (e.g. no serious slow-turn-on)
- Required DCS/DAQ development

Installation of Pixel Package





Installation of Pixel Package II



Installation of Pixel Package III

Conclusions and Future Plans

- After connectivity test: 99.6% of detector is operational
  - Module/optoboard/FE failures: 0.2%
  - Bad pixels in production: ~0.2%
- After installation:
  - 1 module temperature sensor open (not a big problem)
  - 11 modules with HV line open (all fixeable)
  - Probably due to packing of cables rather than installation

Tentative Schedule:

- Connection of detector starts in mid-November
  - SCT until then to sign-off end-cap and commission cooling
- Electrical/optical/cooling connection to take place from ~ Nov to ~ Jan/Feb
- Commissioning:
  - Cooling: ~February
  - Incremental switching on of detector: ~February
  - Cosmics data-taking: ~ March-April

Back-up slides

Upgrade Activities and Plans

- We expect to replace the B-layers in ~2012
  - Have time for very limited R&D
  - Will consider some improvements (reduced radius, reduce material, increased granularity in z…)
- An increase in luminosity (SLHC) to ~10^{35} is expected around 2016.
- Upgrade activities concentrate on micro-electronics and sensors
  - Seem to favor 3D sensor approach at this point at least for SLHC