Results from the commissioning of the ATLAS Pixel Detector

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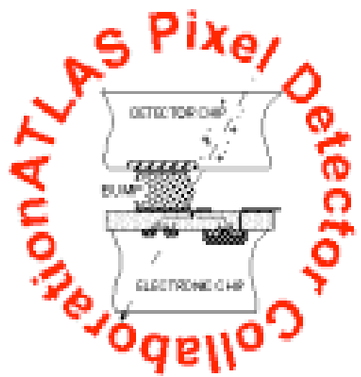

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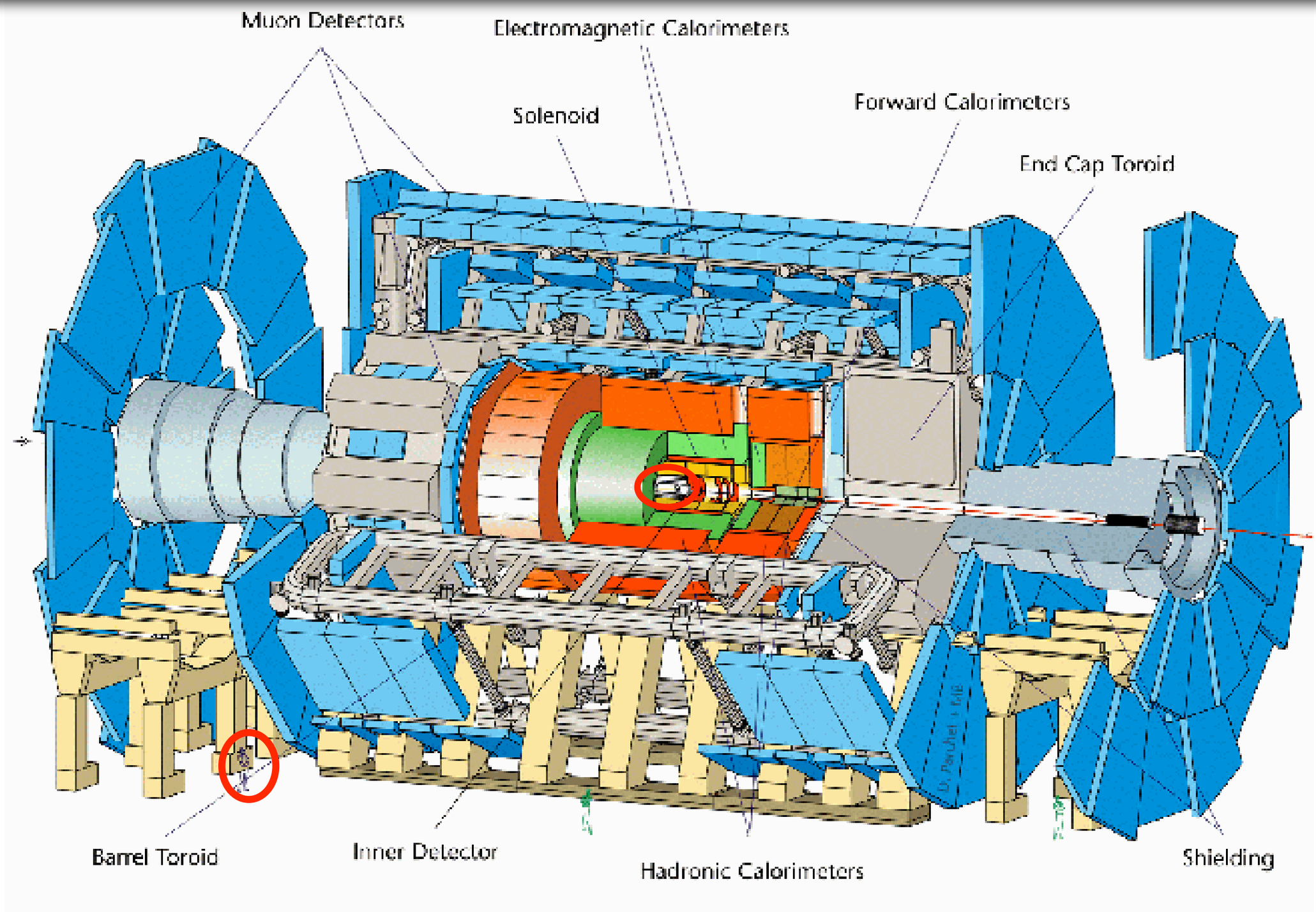
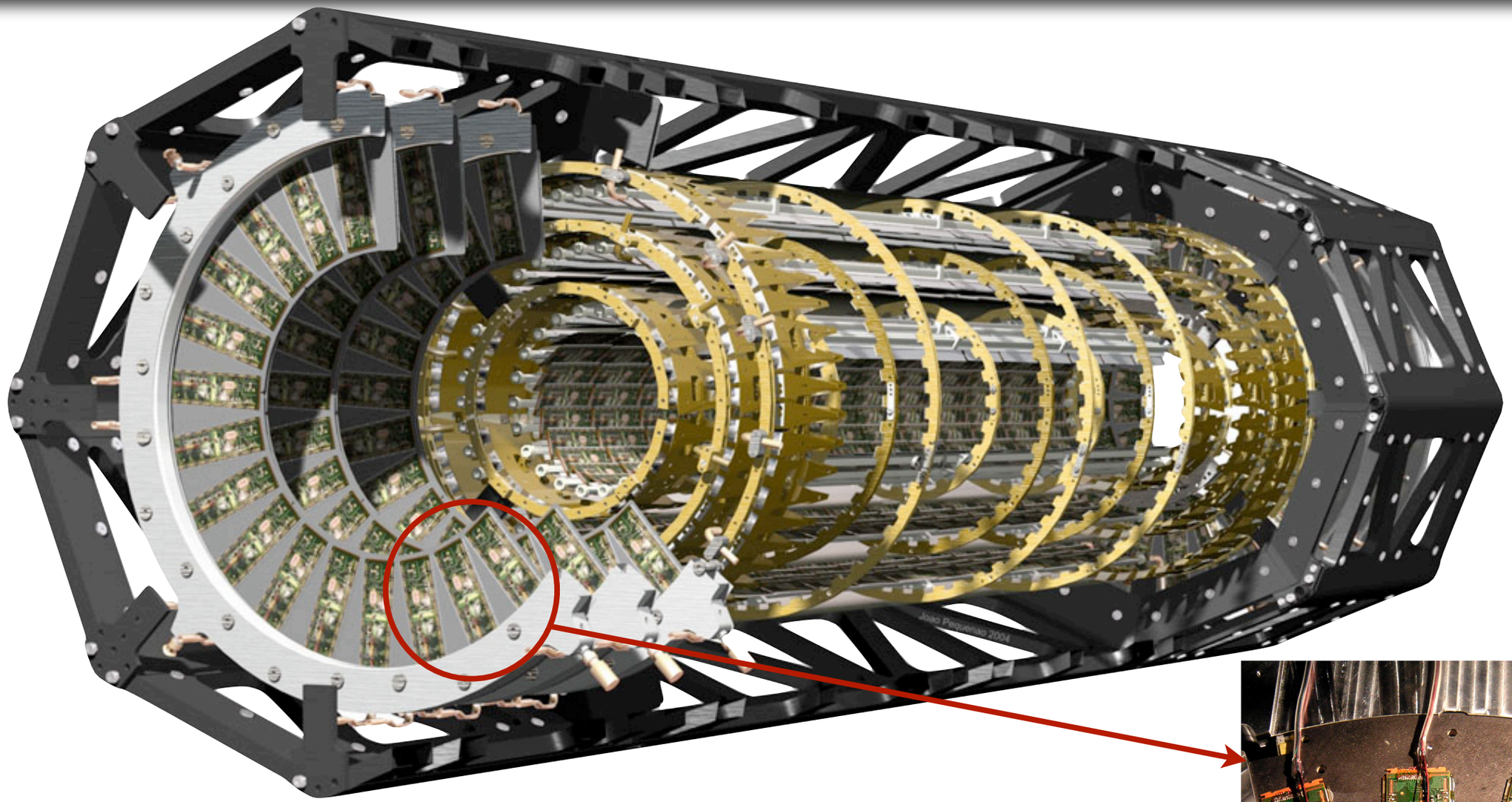
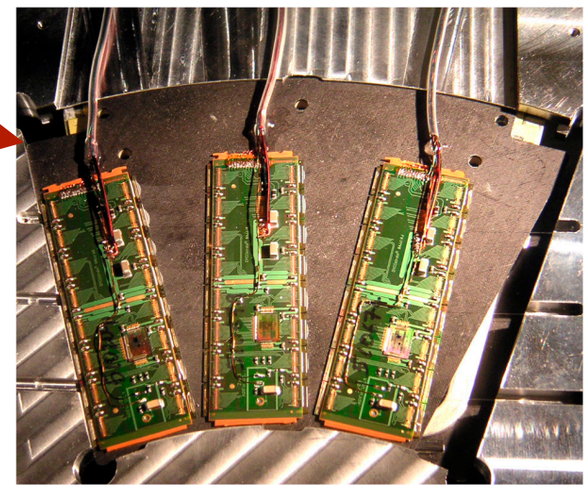
The ATLAS Detector



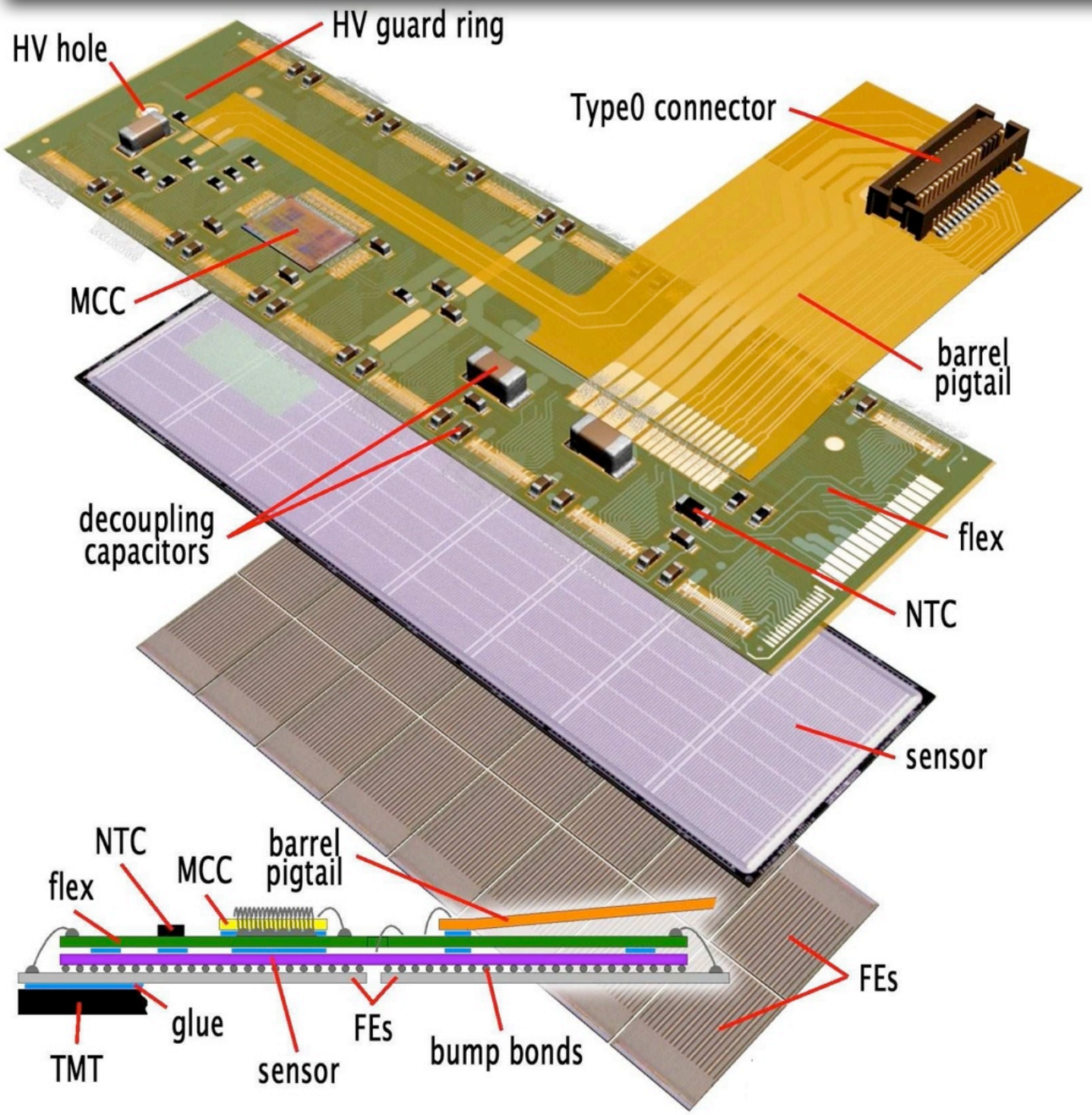
The Pixel Detector





80M channels in 1744 modules, sensitive area 1.6 m^2
Coverage up to $|\eta|<2.5$ with 3 points
Innermost layer at R=5cm

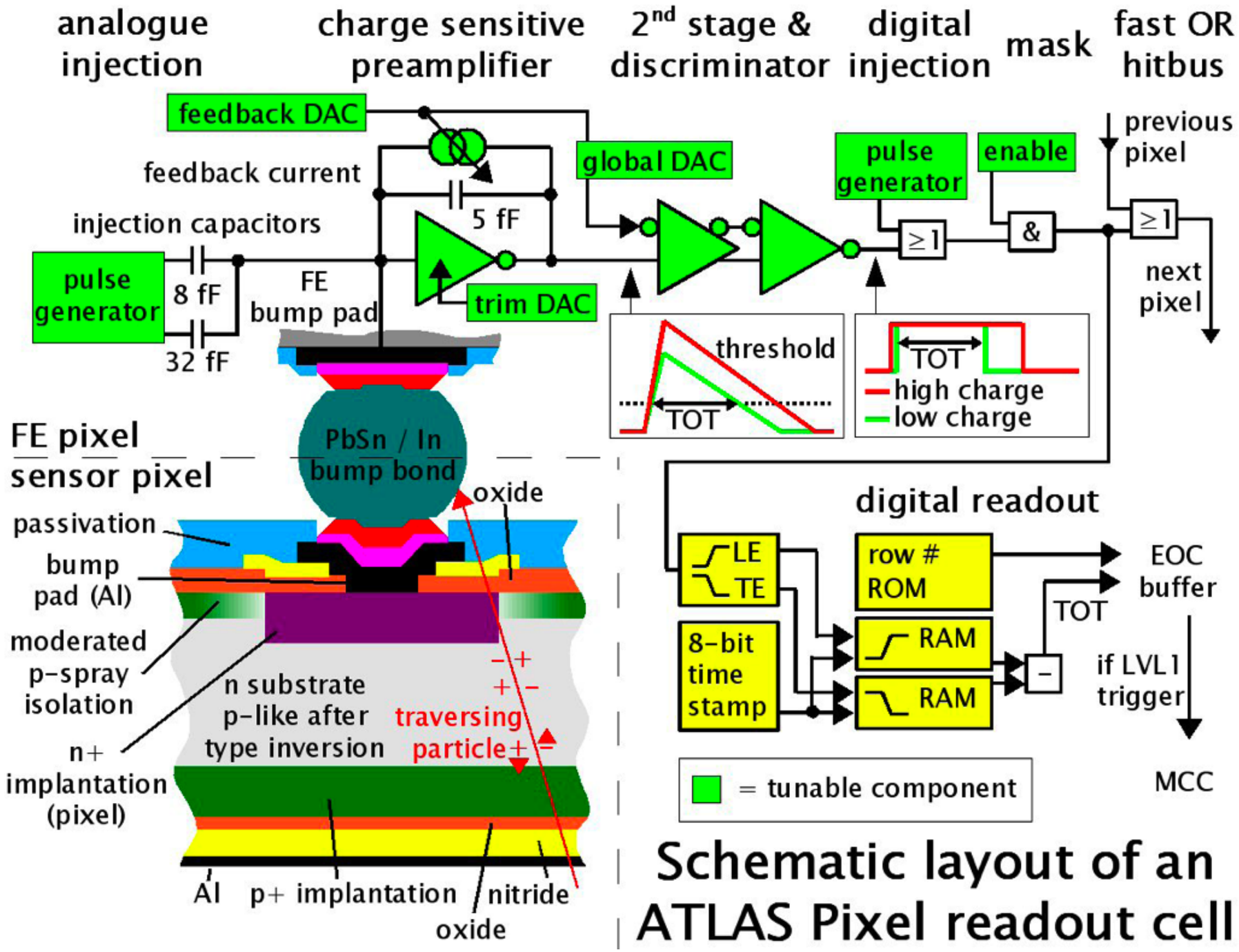
The Pixel Module



Features

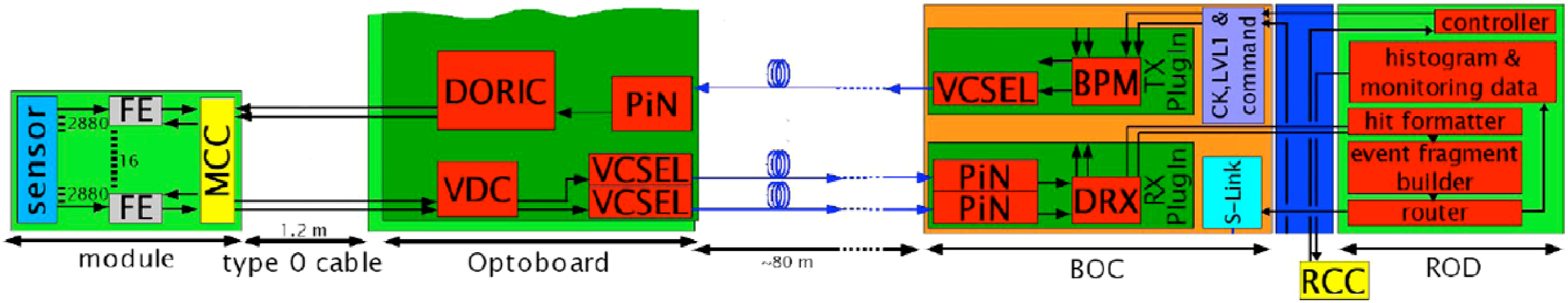
- 60.8 × 16.4 mm^2 × 250 µm active silicon volume
- 50 µm (Rφ) × 400 µm (η) pixels
- 16 Front-end chips, 2 bump bonding techniques
- Module Control Chip on flex hybrid: distribution of commands and event building
- Thickness: 196 µm FEs + 100 µm flex hybrid
- Tested to be radiation hard up to 500 kGy and 10^{15} n_{eq} / cm^2

Pixel readout cell



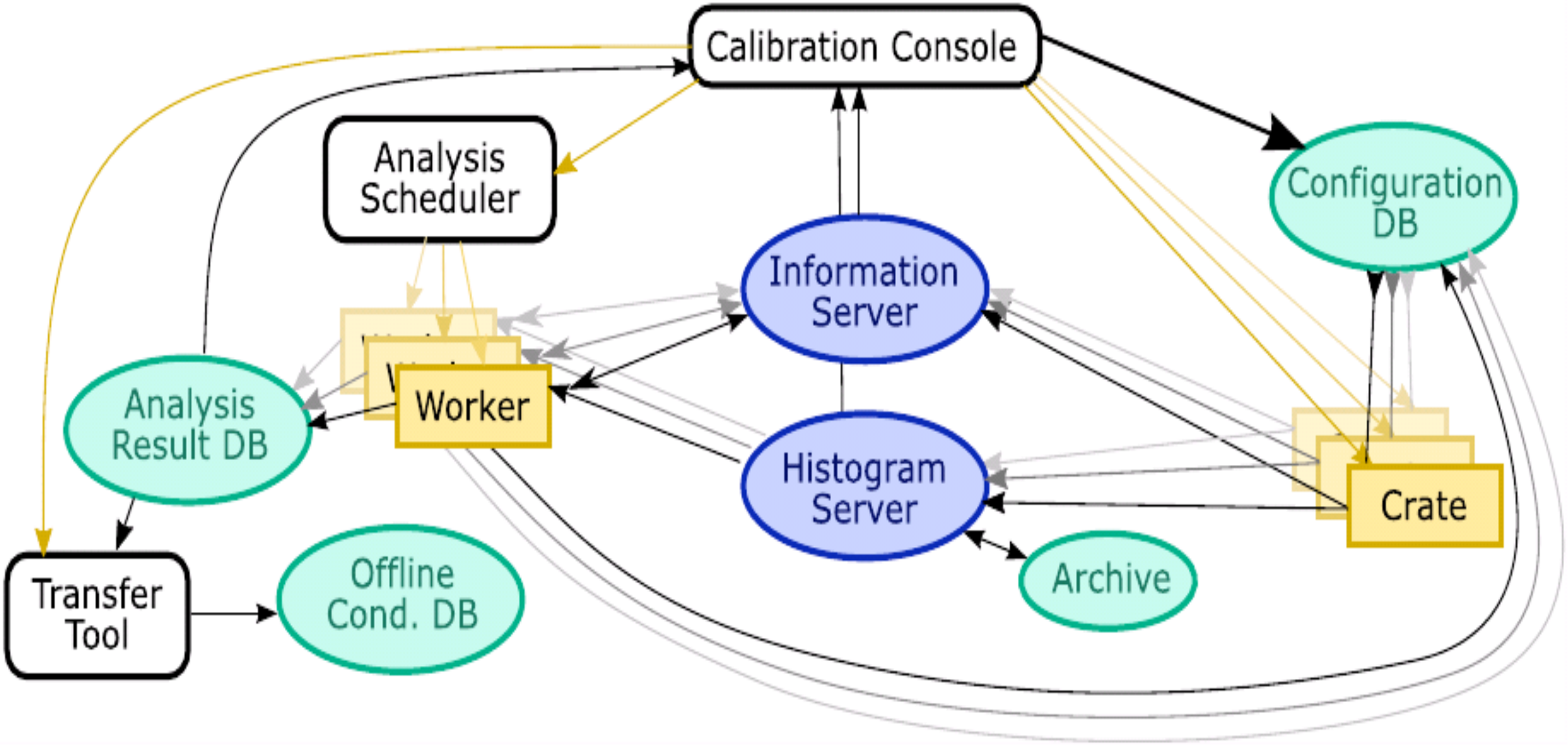
Schematic layout of an ATLAS Pixel readout cell

The readout system



- Connection between on- and off-detector electronics via optical links
- Tunable components:
  - Voltage controlling the amplitude of the VCSEL current on the optoboard (1 per board = 6-7 modules)
  - Phase and threshold of each link (RX plugin)
- Separate paths for data and calibration hits (different occupancy)

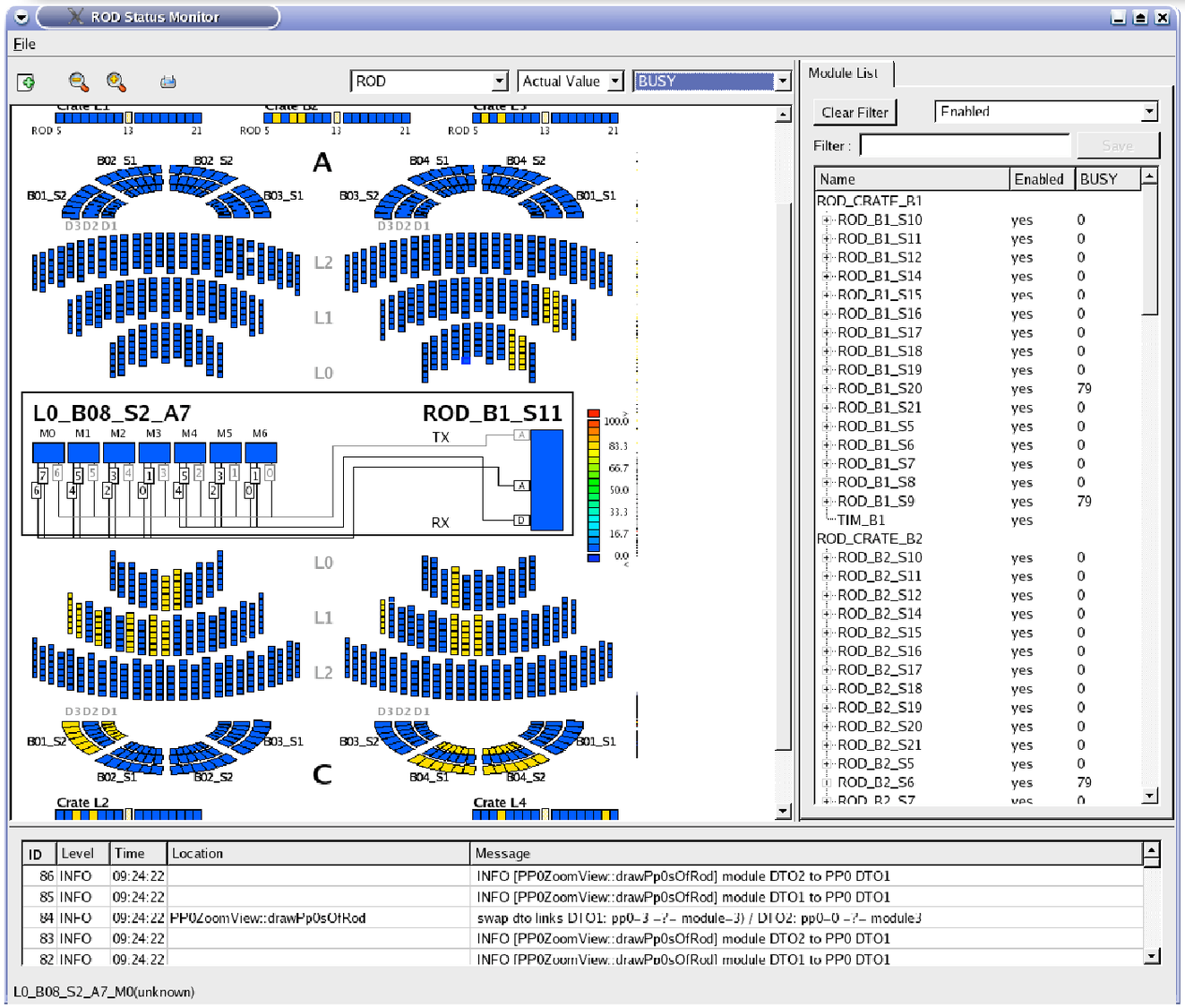
Calibration infrastructure



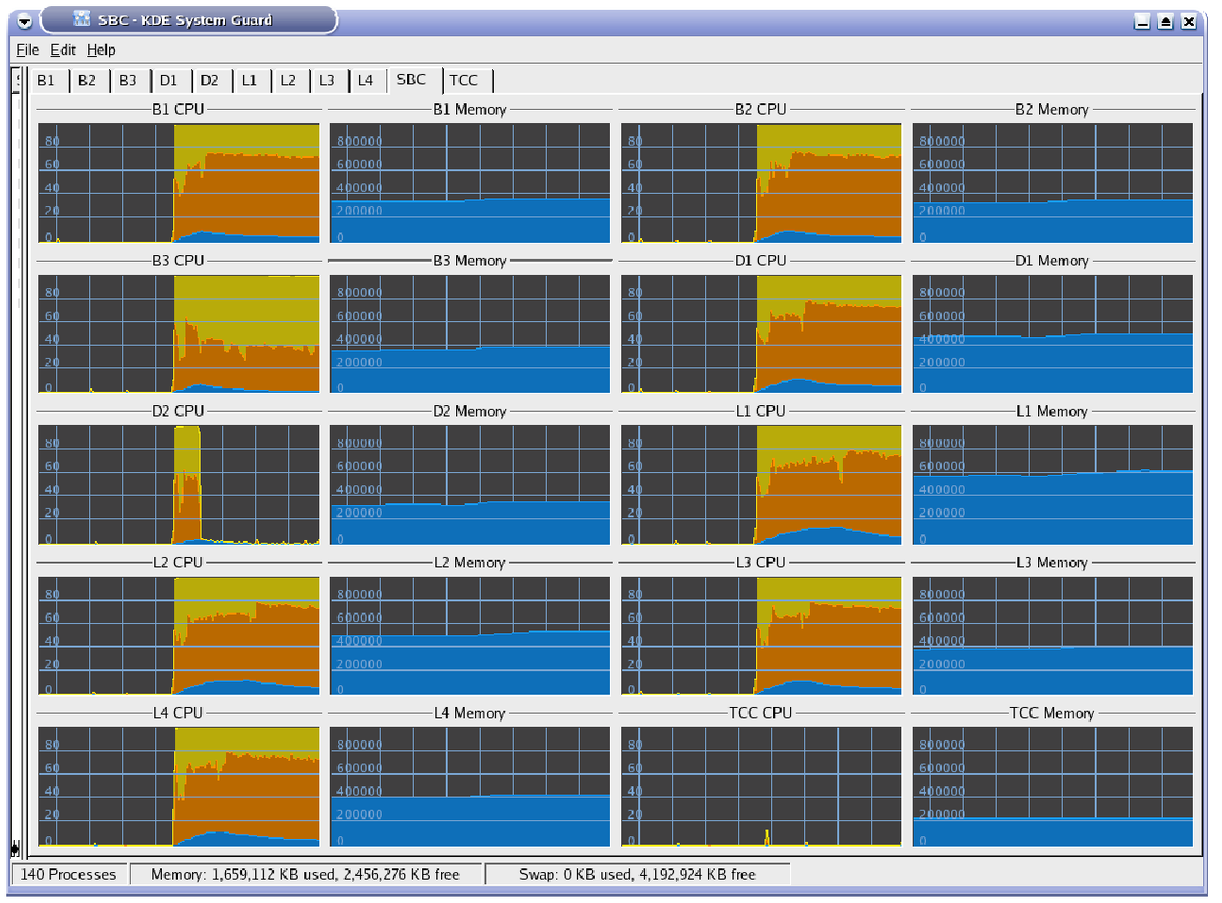
Calibration procedure

- Distributed system steered by a single GUI
- Scans started through 9 single board computers (1 per VME crate) on the RODs
- ROD DSPs send commands to the modules, produce histograms from module data and perform fitting
- Final histograms retrieved via VME bus, stored on a histogram server and on disk and analysed automatically on a dedicated farm

Calibration monitoring



ROD Status Monitor

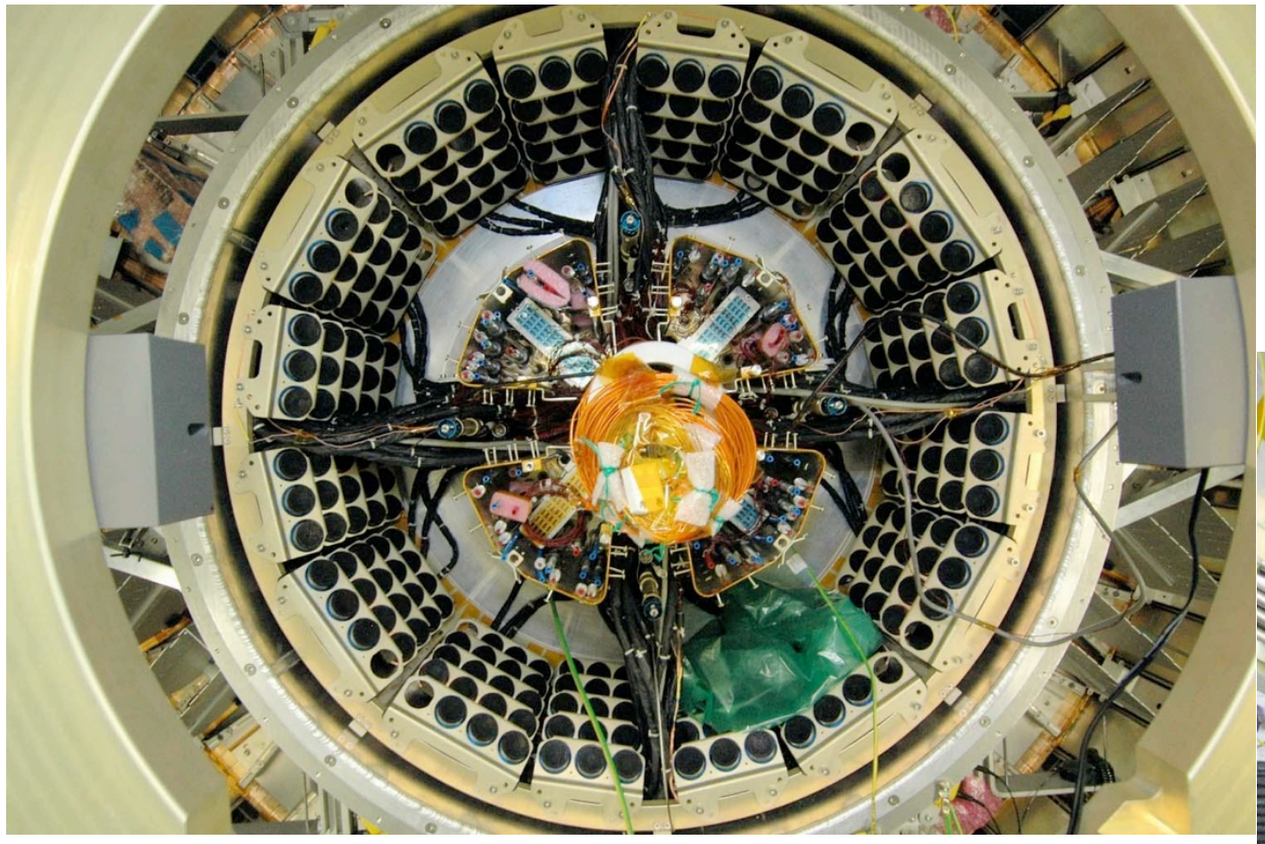


SBC Memory and CPU usage Monitor

Installation

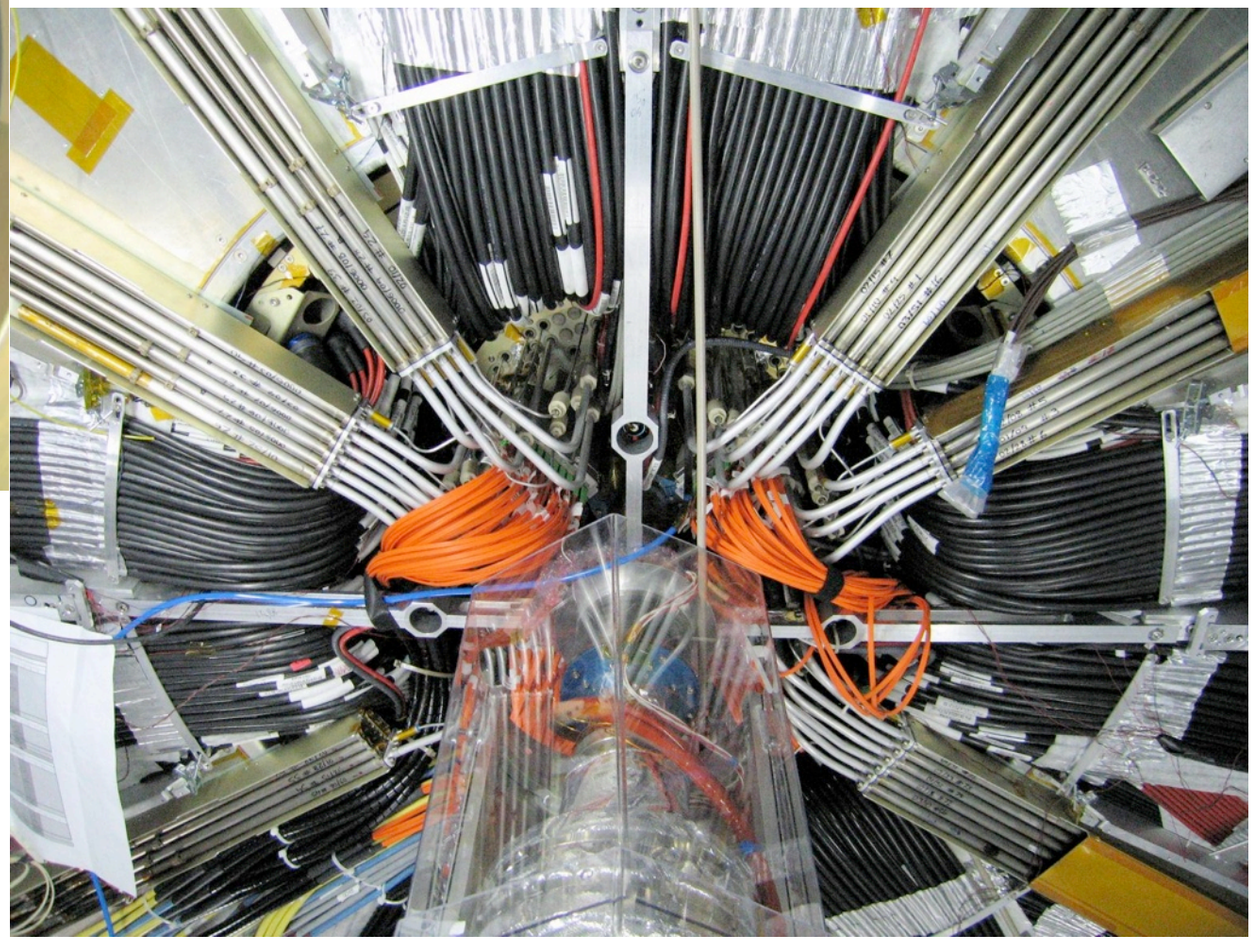
- March-June 2007: Assembly and connectivity test: check mapping from modules up to PP0
- July 2007: Installation of pixel-package in the cavern, then wait for TRT and SCT to finish cabling
- December 2007: Finished services connection and test from PP2 outwards, replaced cooling exhaust pipes at PP1 damaged by corrosion
- February 2008: Connection at PP1and connectivity test: low voltage, high voltage, fibres

PP1 connection



PP1 before...

... and after connection

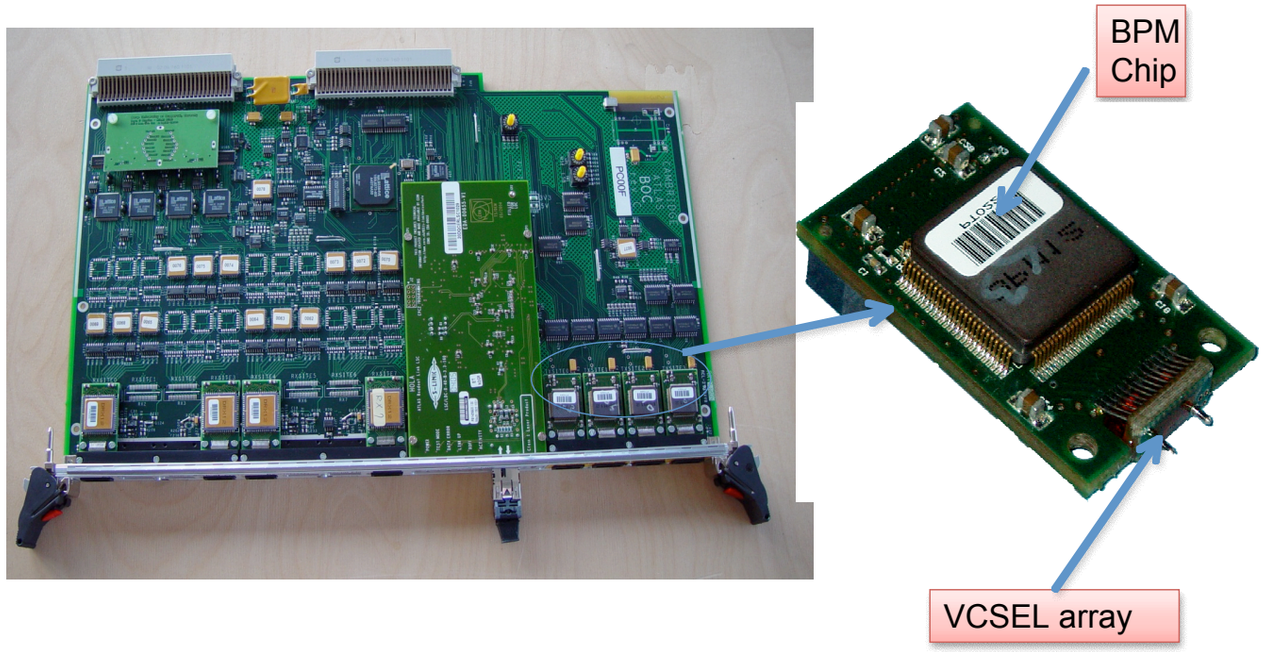


Connectivity test in the pit

- March 2008: Found general fibre swap, reconnection at BOC needed (over Easter)
- April 2008: Checked light transmission to and from detector, that modules can be configured and that the sensor is biased
- No cooling available, could only configure one FE per module and scan 1/10 of its pixels

Optical sign-off results

- **Light power** on TX channels lower than measured during assembly: compatible with expected fibre attenuation
- **Dead TX channels:** 24 dead channels at the end of the sign-off. Channels dying at a very high rate (few per month)
- Behaviour compatible with ESD damage during production
- More channels dead in pixel than in SCT because lasers were kept on longer



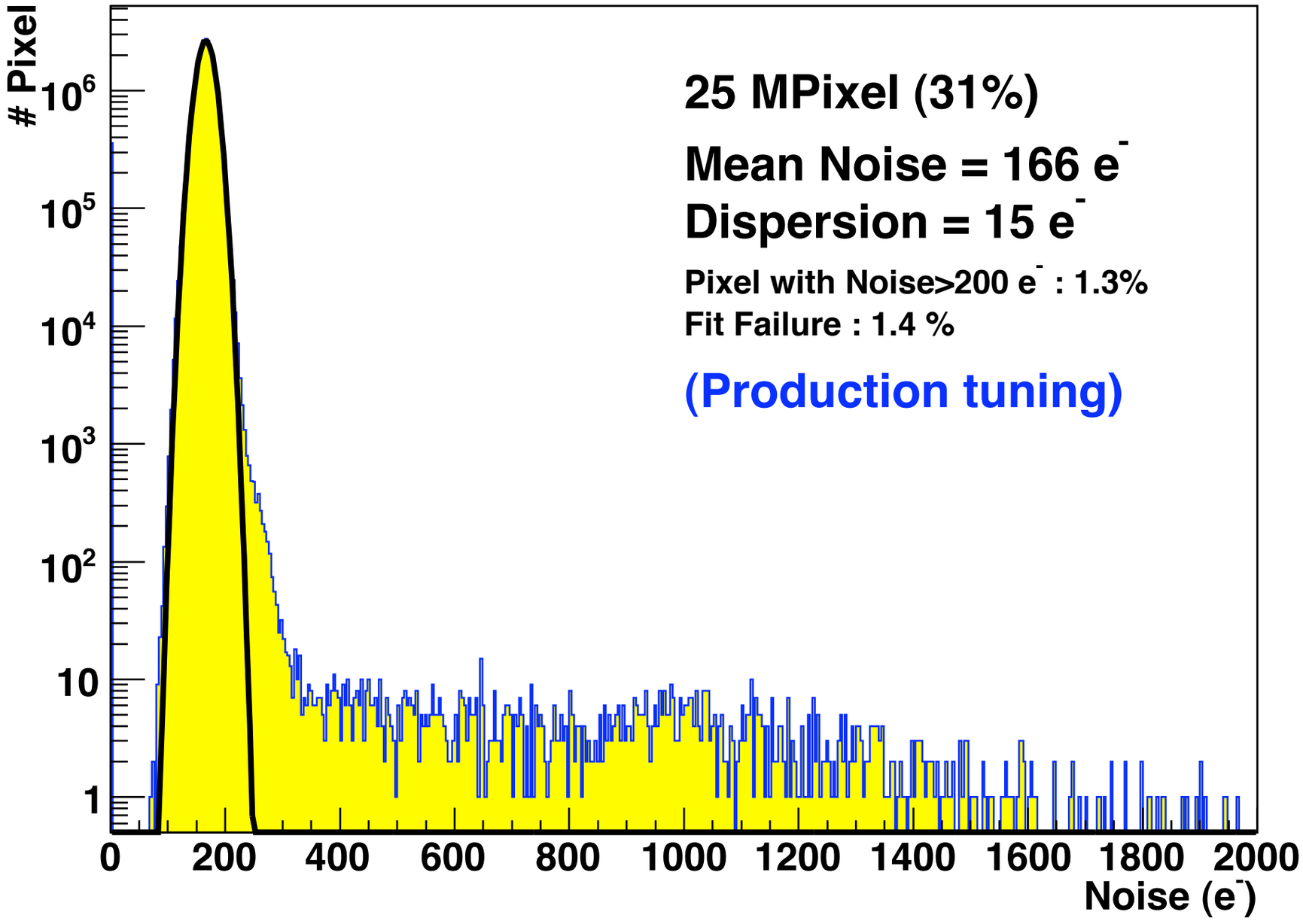
Cooling commissioning

- Cooling available from April 25th
- Tested behaviour of temepratures, back-pressure and heater power with modules off (0 W), normal configuration (4 W) and high power configuration (5.5 W)
- Better stabilisation with configured modules, some instabilities with detector off
- 3 leaky loops found in the disks, but can be operated at least for commissioning
- 77/88 loops tested till May 1st when system had to be turned off due to cooling plant accident

Module status after sign-off

- 8 modules with HV open (mainly in the disks)
- 1 module without clock
- 2 swapped modules (corrected in DB)
- 4 badly tuned modules (to be retuned)
- 3 modules with suspect behaviour (like HV open)
- Modules with (suspect or proven) HV open are kept on for calibration and standalone data taking
- Threshold scan on about 900 modules (all pixels) showed no significant increase of dead pixels wrt production

Pixel noise


Pixel
10^6
10^5
10^4
10^3
10^2
10
1
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Noise (e^-)
25 MPixel (31%)
Mean Noise = 166 e^-
Dispersion = 15 e^-
Pixel with Noise>200 e^- : 1.3%
Fit Failure : 1.4 %
(Production tuning)

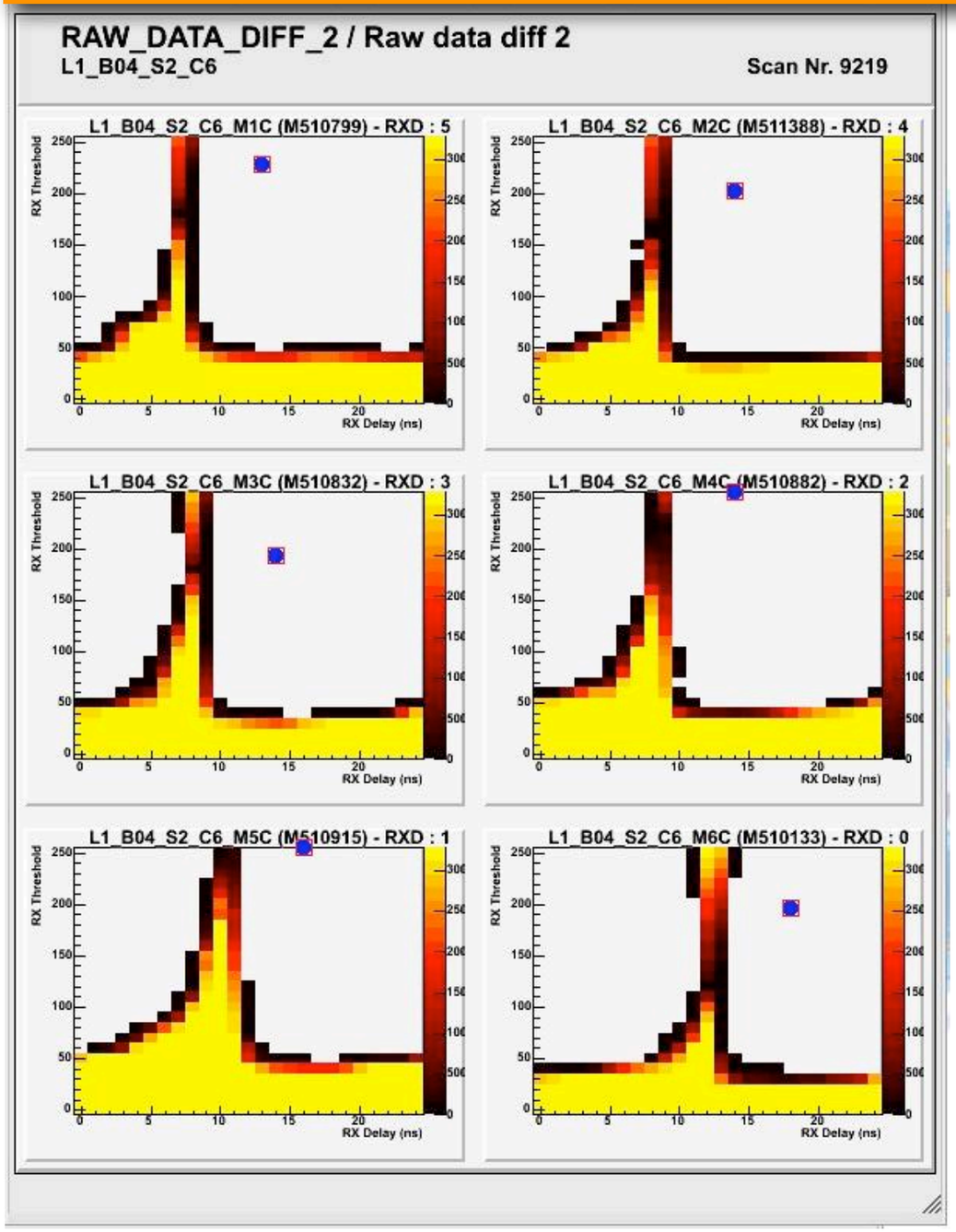
Commissioning restart

- 3 compressors were damaged due to prolonged slippage in the magnetic coupling between the motor and the compressor shaft
- Compressors were repaired and 800 kg contaminated coolant was replaced
- Cooling working again in time for beam-pipe bakeout at the end of July
- Bakeout successful, but with coolant loss of 1kg/hour
- Cooling commissioning till August 11th

Optolink tuning

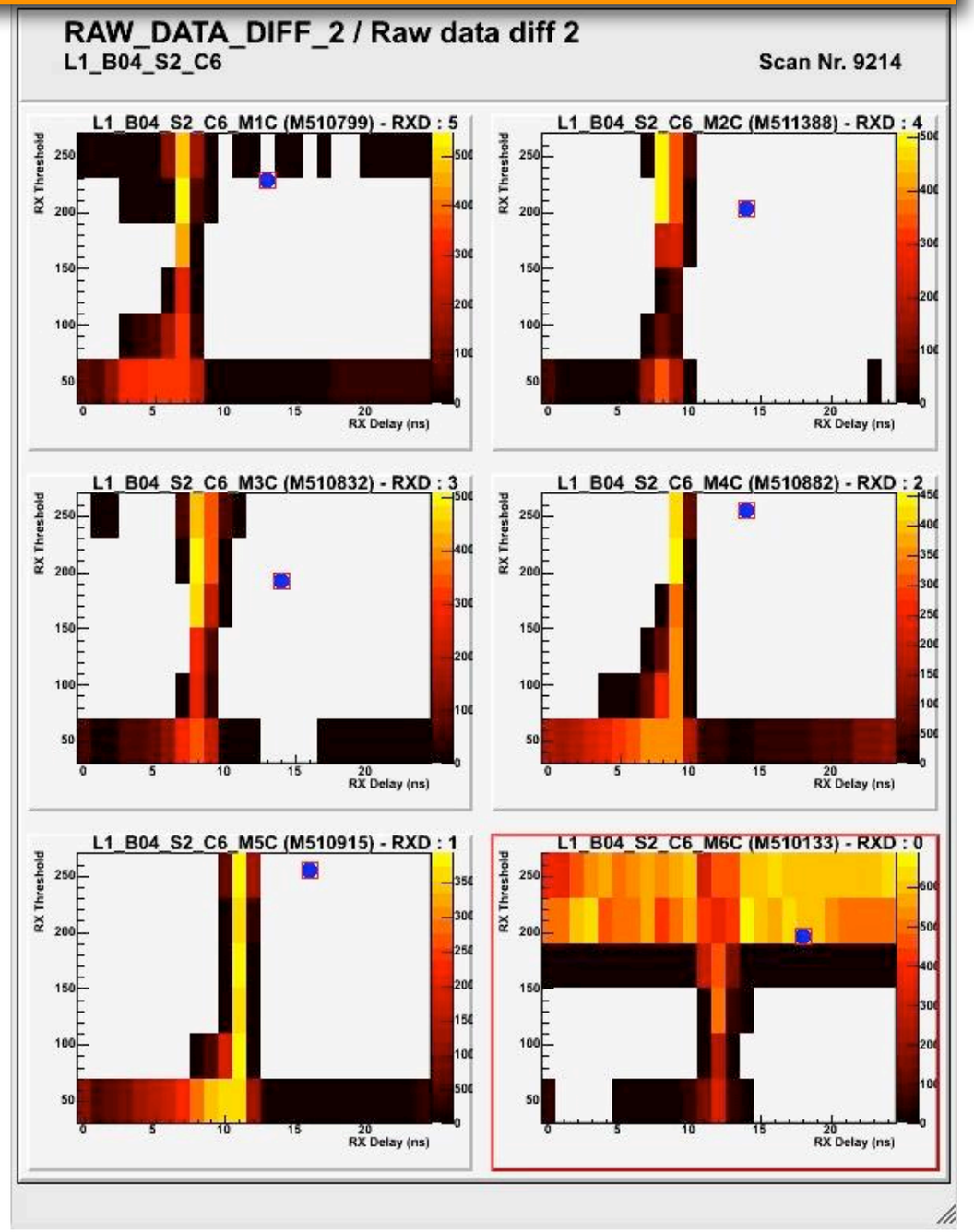
- Modules operate at -2 to 4°C, too cold for stable operation of optoboards
- Heaters can keep optoboards at room temperature
- Tried to run at 10°C to preserve laser channels from dying
- Optolinks could only be tuned at 20°C, that was finally chosen as the operating temperature
- On August 28th the whole detector could be turned on and 1662/1744 modules could be further tested (communication ok)

Optolink tuning problems

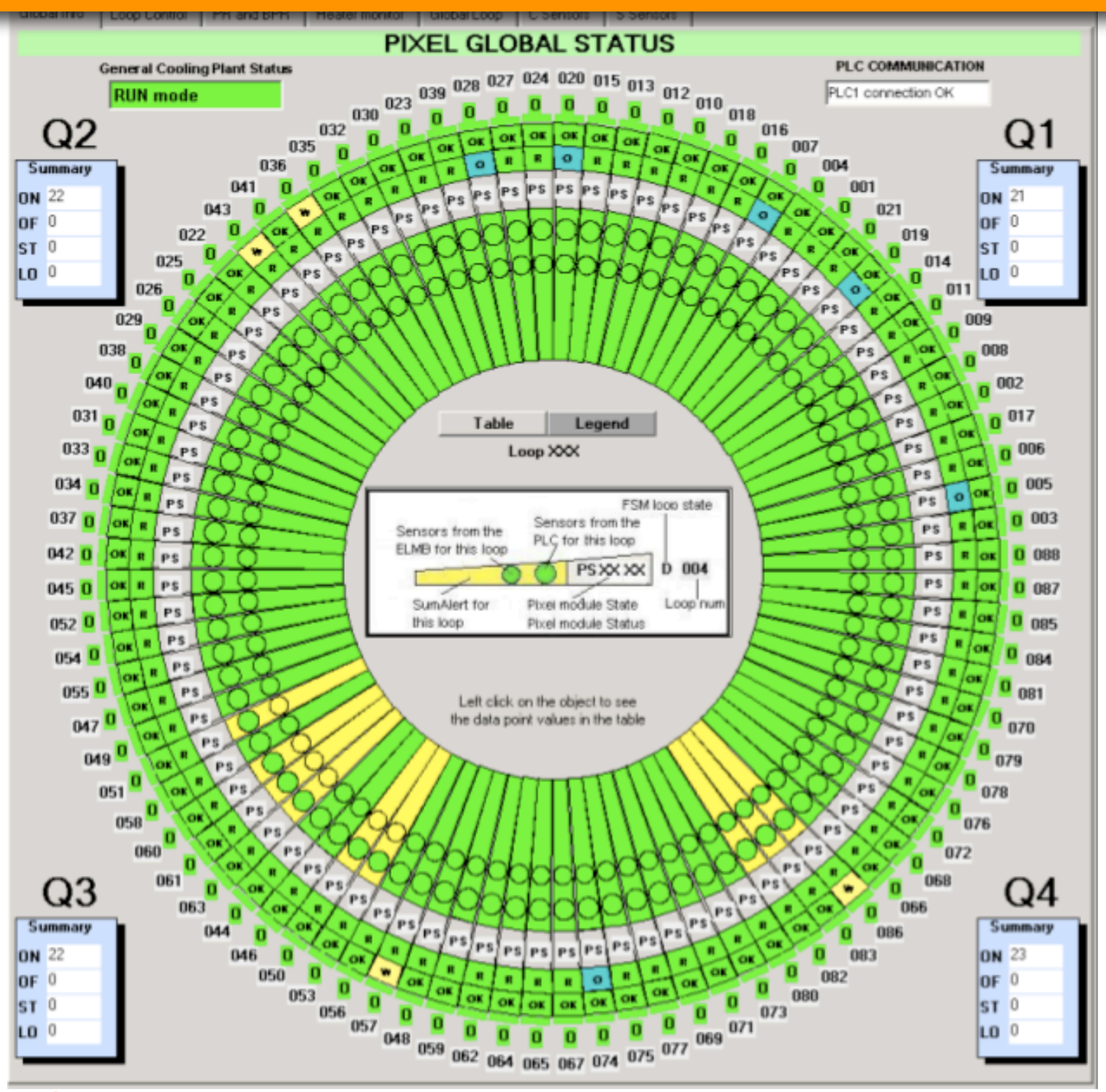


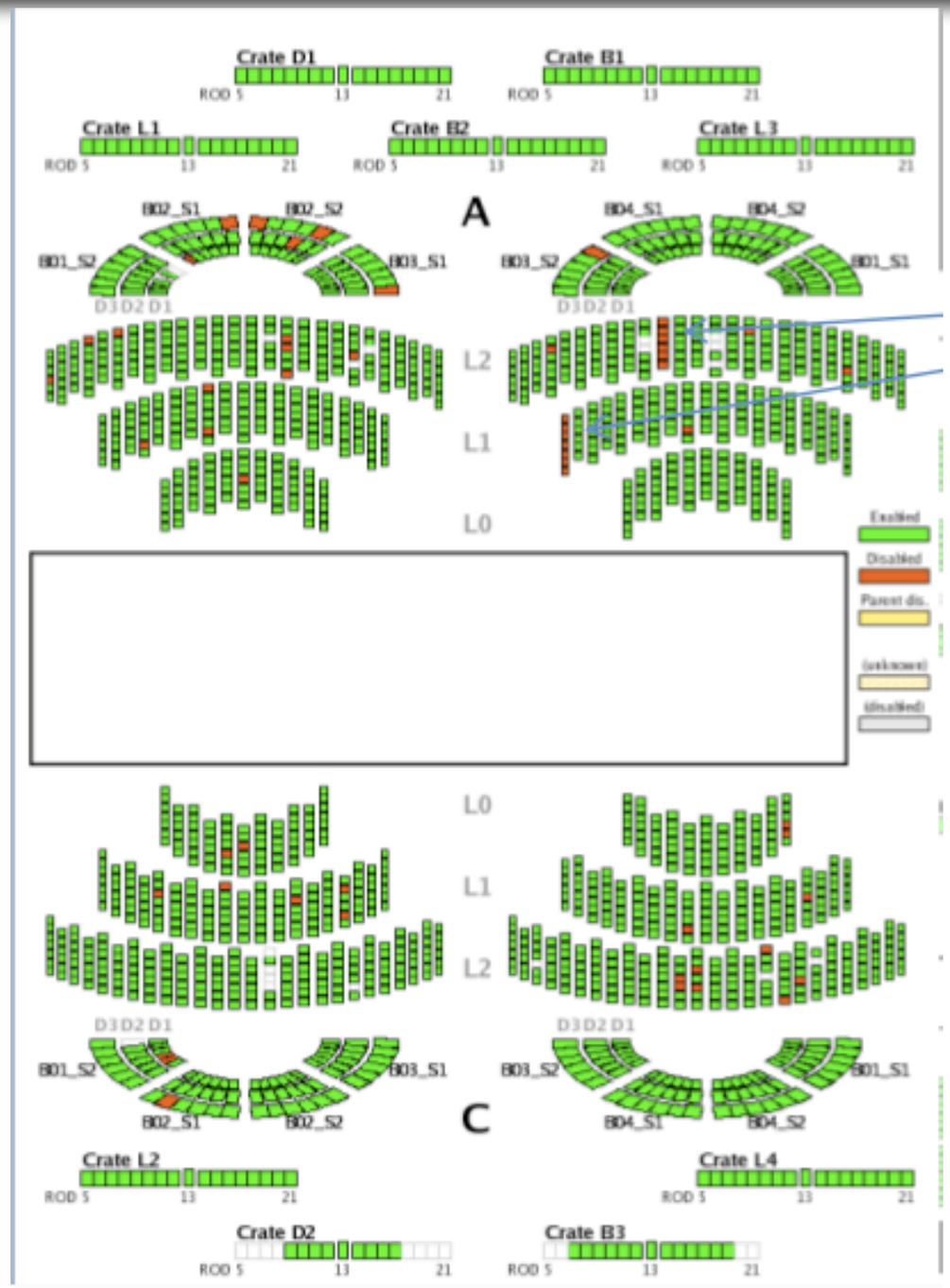
Optoboards at 10°C

Different data patterns give different optimal threshold/ phase settings. Can only tune with the faster one (left)



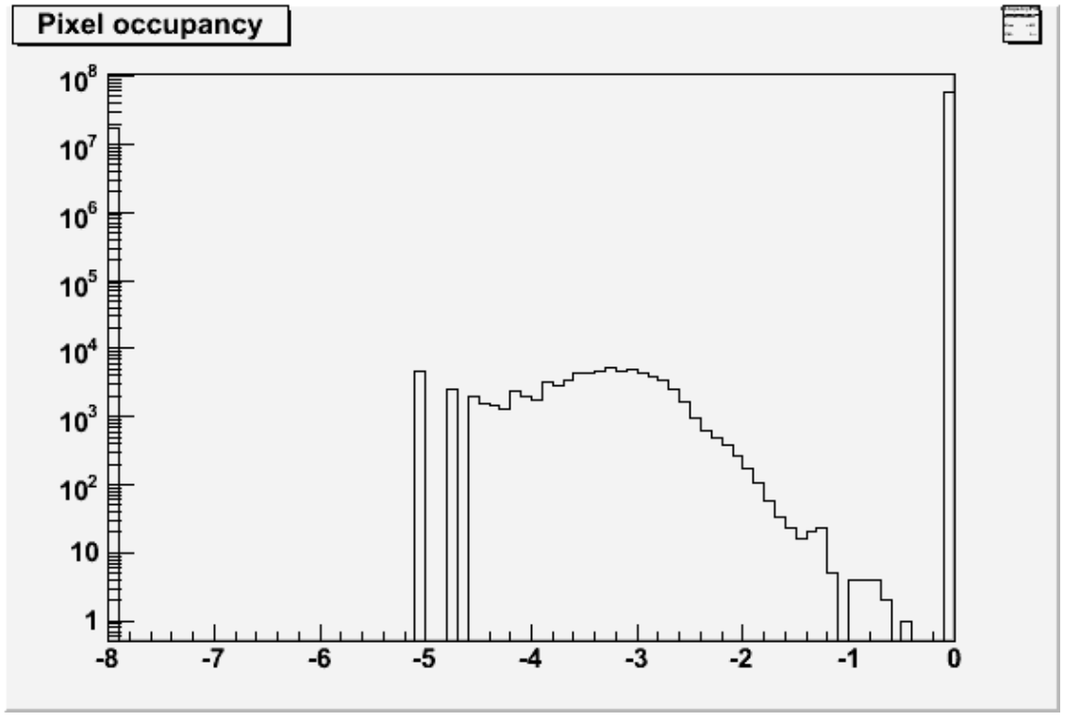
95% of detector working





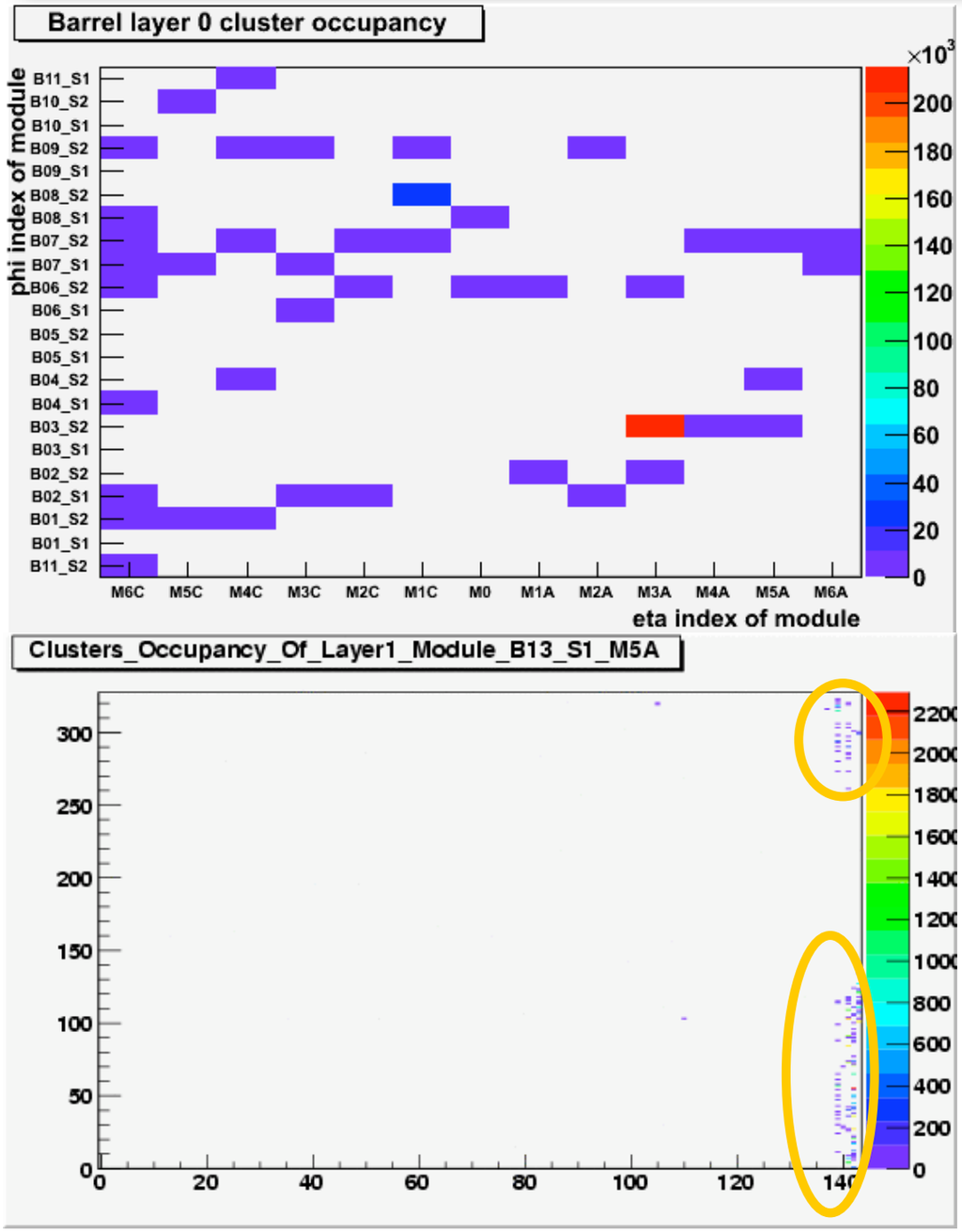
Noise runs

- First noise runs on whole detector taken end of August (1-2 million events)
- Disabled problematic channels for data taking, almost complete overlap with module selection for calibration



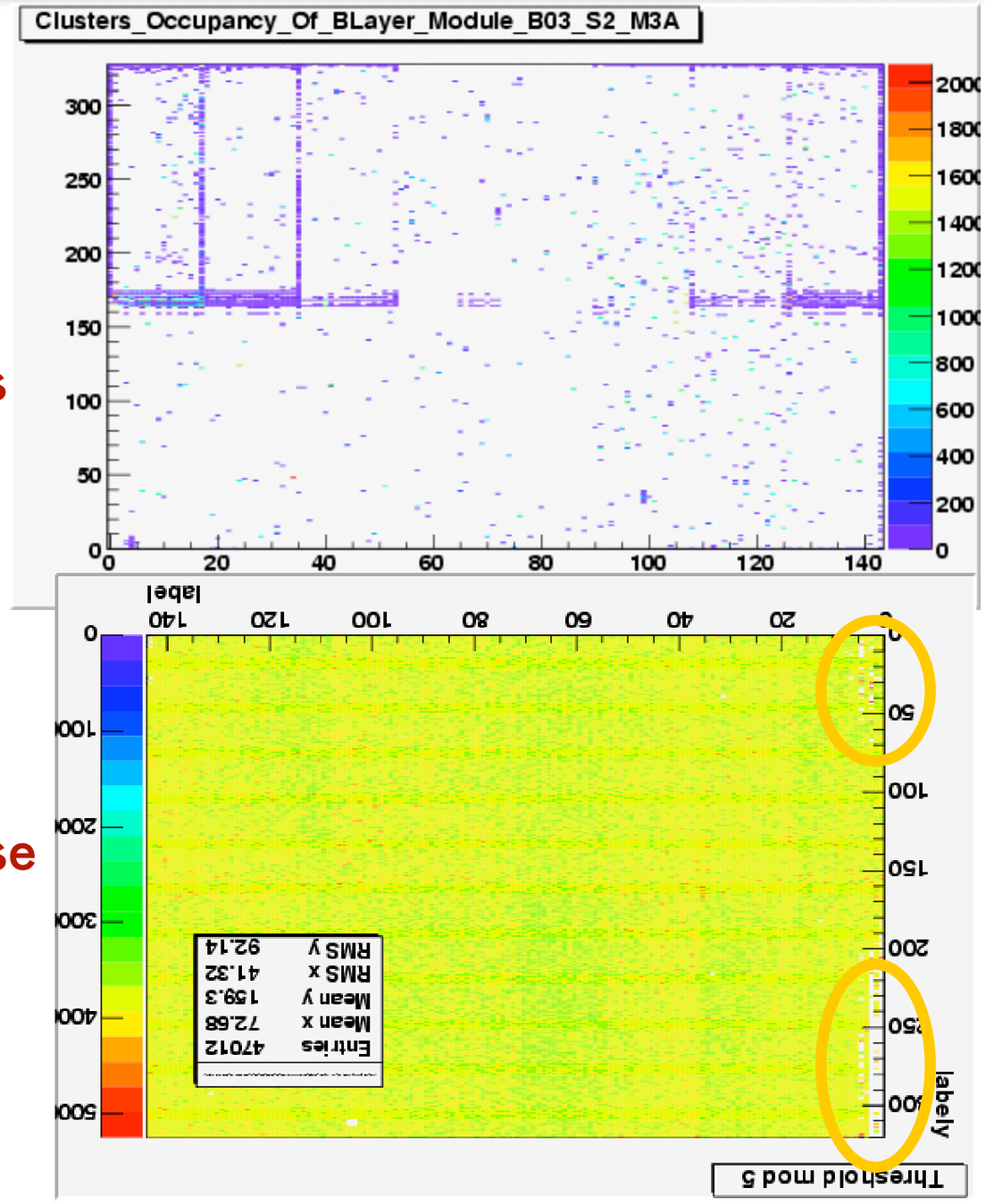
- Modules with HV open included to check their behaviour
- Less than 400 modules with noisy pixels (occupancy > 10^{-4}), about 130000 pixels masked
- 100 clusters/BC without masking

Modules without HV



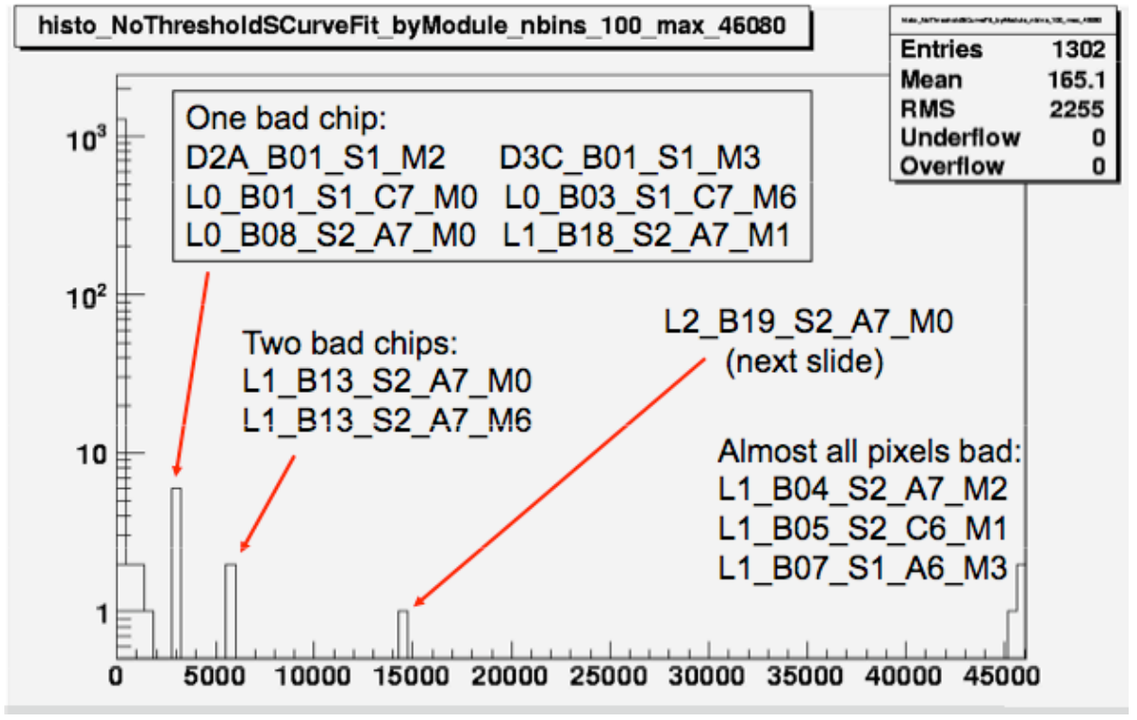
Most clusters from single noisy modules

Good agreement between noise data and threshold scan



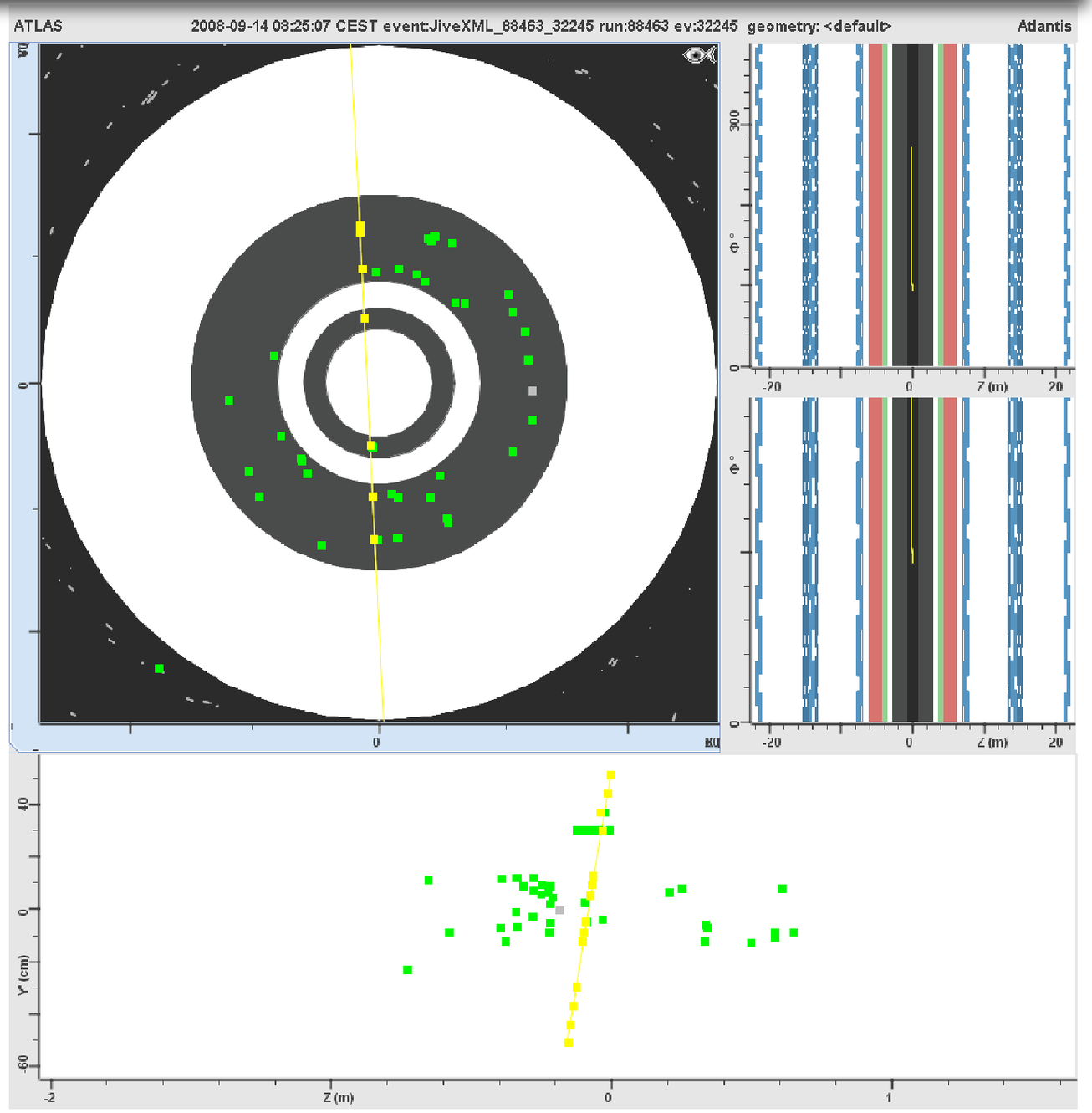
Calibration with prod tuning

- **Plan for first September week:** complete collection of calibration data with production tuning for modules without communication problems
- **Threshold scans:** completed
- **In-time threshold scans:** completed
- **ToT scans:** partially done
- Number of **pixels failing S-curve fit** per module (see figure):
  - 3 modules almost completely bad
  - 8 modules with bad FEs + 1 with strange behaviour
  - About 30 other modules with few hundred bad pixels



Combined cosmics runs

- **September 4th:** first combined cosmics runs with TRT
- Bad timing, no tracks with pixel hits
- **September 14th:** combined cosmics runs with SCT
- Changed time window for readout, reading 8 BCs
- **First track:** 7 pixel hits and 16 SCT hits
- Alignment studies ongoing, just few tracks available



Conclusions

- Have to run optoboards at 20°C to get stable optolink tuning
- 95% of the Pixel detector was calibrated and is running fine using production tuning
- 3 leaky cooling loops (36 modules) were also commissioned, but will not run this year
- New threshold and ToT tuning foreseen but not strictly necessary
- Debugging of excluded modules has lower priority for the moment
- Identification of bad pixels agrees well enough between calibration and noise runs
- Cosmics tracks being collected, but beam commissioning doesn't allow to have HV on all the time