

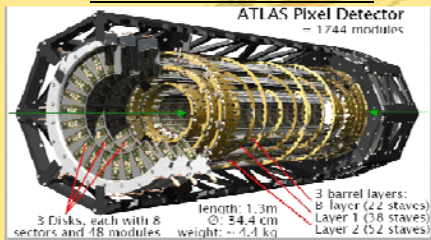


## Commissioning of the ATLAS Pixel Detector

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on behalf of the ATLAS Pixel Collaboration

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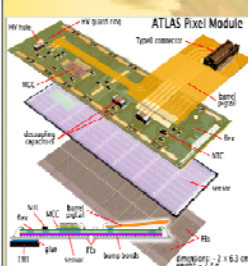
### The ATLAS Pixel Detector



- 1744 modules, 46080 pixel each → 80 million pixels total
- 1.8m<sup>2</sup> active silicon
- low-mass carbon fiber support structures → 2.96% X<sub>0</sub> per layer
- 500kGy and 10<sup>15</sup> n<sub>eq</sub>/cm<sup>2</sup> lifetime dose and fluence
- bi-phase cooling system integrated into local support structures → operation below 0° C
- 1744 modules, 46080 pixel each → 80 million pixels total
- 2us trigger latency → on-detector buffering
- spatial resolution 15um (R-φ), 115um (z)
- 3 track points to |η|=2.5
- zero-suppressed, semi-analog readout → on-chip data reduction
- collision frequency 40MHz
- 2us trigger latency → on-detector buffering
- detect 1000 tracks at every bunch-crossing → robust pattern recognition
- excellent secondary vertex resolution → inner radius 50.5mm

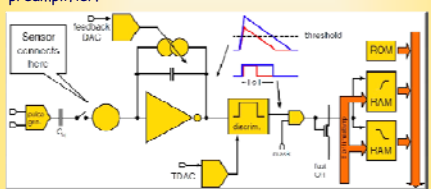
### The Pixel Module

The **Pixel Module** is the smallest functional unit of the pixel detector. It is a sensor-readout hybrid assembly, comprising **46080 electronics channels**.



- 16.4x60.8 mm<sup>2</sup> silicon sensor
  - n<sup>+</sup>-in-n DOFZ
  - 250 um thick
  - pixel size 90x400 um<sup>2</sup>
  - operated at 150V bias
- 50 um pitch bump-bonding
- 2x8 readout ASICs
  - 18x160 cells each
  - 250 nm CMOS technology
  - wire-bonded to Flex
- flexible kapton PCB
  - routing power and data lines
  - passive components
  - connection to external systems
- module control chip (MCC)
  - TTC data to FES
  - basic event-building

The amplifier-discriminator part of **each single pixel** can be tested, employing an **integrated charge generator**. A DAC-controlled voltage step is applied to an injection capacitor (8 fF or 32fF), to inject a **well-known charge** into the preamplifier.



### Commissioning Program

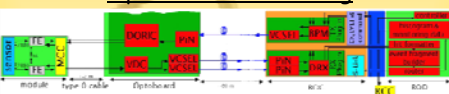
1. Adjust optical link parameters for correct communication
2. Verify communication using hits injected in the digital FE-electronics
  - leads to a sample of modules with good communication (GoodOpto)
3. Threshold scan with and without sensor bias
  - determine threshold per pixel, threshold dispersion across one module and electronics noise
  - verify sensor bias connection
  - tune thresholds if dispersion across the module too large
4. TOT scan injecting 20ke into the preamplifier
  - determine TOT mean and sigma
  - tune feedback current if TOT dispersion across the module too large
5. derive TOT-vs-charge calibration for offline use
6. timing scans to facilitate synchronization between sub-detectors
7. debugging of module problems

→ **Cosmics Data Taking**

### Commissioning in 2008

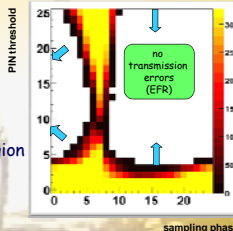
- **Phase 0: april**
  - connection sign-off
  - first pixel cooling loop commissioning
- interrupted by catastrophic cooling plant failure that made substantial repairs and improvements to the cooling system necessary
- **Phase 1: august**
  - cooling loop commissioning
  - optolink operation (incl. optoboard cooling and heating)
- **Phase 2: september - october**
  - optolink tuning
  - definition of largest possible set of modules
  - ATLAS combined cosmics data taking
- **Phase 3: november - december**
  - optolink tuning
  - module tuning
  - debugging of module problems
  - ID combined cosmics data taking
  - various detector studies

### Optolink Commissioning



#### Parameters to be tuned

- downlink (optional):
  - MSR, laser power
- uplink (less trivial):
  - laser power on-detector;
  - off-detector PIN diode threshold; off-detector sampling clock phase
- maximize error-free region
- optoboard temperature
- bitsequence
- readout bandwidth



Tuning procedure uses 0-1-0-1 pattern to check for transmission errors  
Tuning procedure takes ~1h for full detector

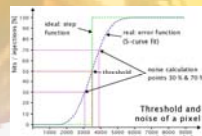
- 96% of the links have been tuned successfully by the automated procedure
- links bad after verification (and some retuning) disabled from calibration/data taking

### Threshold Adjustment

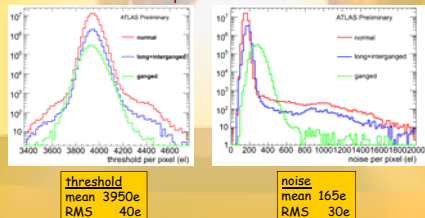
Discriminator thresholds can be adjusted individually (LSB~75e, dyn. range 7 bit)  
Goal: threshold at 4000e

#### Measurement

- inject varying charge to amplifier
- register fraction of hits
- fit gaussian error-function
- threshold & noise



Doing this measurement on the full detector takes ~1.5h  
→ Results for 75 million pixels or 96% of the full detector

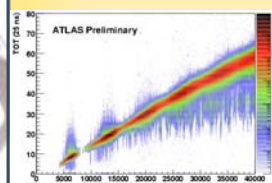


threshold mean 3950e RMS 40e

noise mean 165e RMS 30e

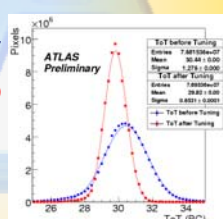
### Charge calibration - TOT tuning

The **feedback capacitance** of the **charge-sensitive preamplifier** is discharged by a **constant, adjustable current**. This results in a nearly linear dependence between the **'time-over-threshold' (TOT)** and the input charge. TOT is measured in units of the bunch-crossing clock (25ns).



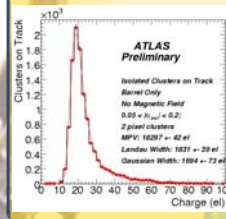
To **calibrate** the TOT an increasing **charge is injected** in the preamplifier input and the **TOT response is parameterized**. An accurate **parameterization** is needed to convert TOT to charge which is used to **improve the position resolution of clusters**.

To **minimize the spread** of the TOT response to a given charge, the **feedback current** is adjusted for every pixel. A charge of **20.000e (MIP signal)** is injected and the TOT is tuned to a response of **30 BC**.



→ after tuning RMS < 1 BC

For both measurements results from 96% of all pixels are shown.



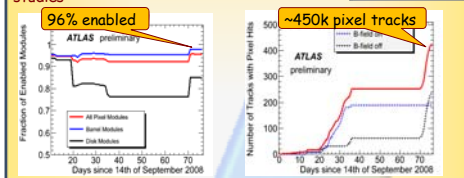
The **charge distribution** for clusters associated to a **cosmic muon track** in the pixel detector (left) peaks at the expected value of **20.000e**, validating the chosen parameterization of the TOT.

The contribution of noise hits, which show a small charge, is very small.

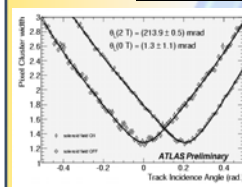
### Cosmic Data Taking

- first joined ATLAS combined data taking on sept. 4.
- Wrong trigger timing → no hits on tracks
- LHC first beam: sept. 10
- next data taking sept. 14, improved timing → first pixel tracks reconstructed
- until then not much time for module debugging → many modules disabled
- this improved with time and detailed module studies

Run 88463  
first pixel track



### Studies using cosmics data



Lorentz angle → 214 ± 0.5 mrad (expect ~224 mrad)

after the latest improvements in tracking algorithms, material treatment etc.  
→ resolution 23.4um in short pixel direction (reminder: pitch/12 ~ 14um)

