UNIVERSITÄT DORTMUND

E IV

Commissioning of the ATLAS Pixel Detector

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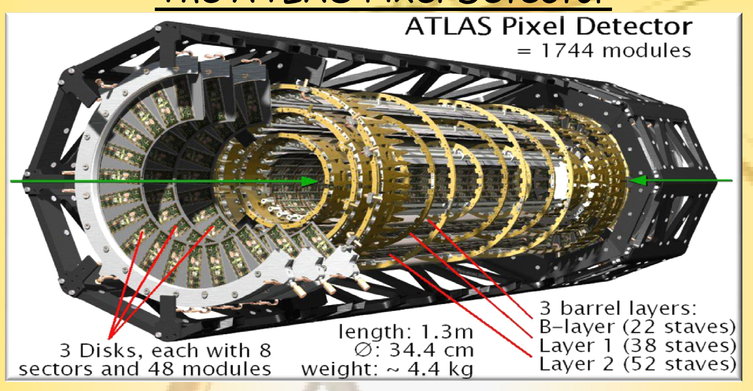
on behalf of the ATLAS Pixel Collaboration

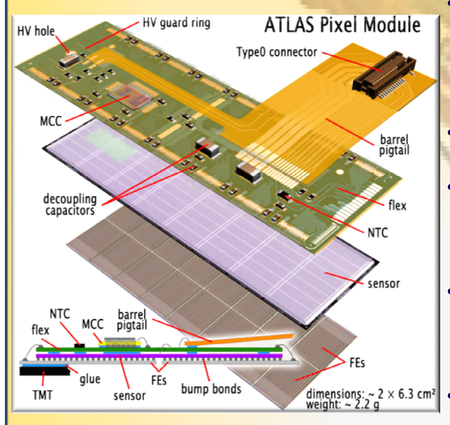
The ATLAS Pixel Detector



- 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
- 1744 modules, 46080 pixel each → 80 million pixels total
- spatial resolution 15um (R-ϕ), 115um (z)
- 3 track points to $|\eta|=2.5$
- zero-suppressed, semi-analog readout → on-chip data reduction
- 1.8m² active silicon
- low-mass carbon fiber support structures → 2.96% X_0 per layer
- 500kGy and 10^{15} n_{eq}/cm^2 lifetime dose and fluence
- bi-phase cooling system integrated into local support structures → operation below 0° C

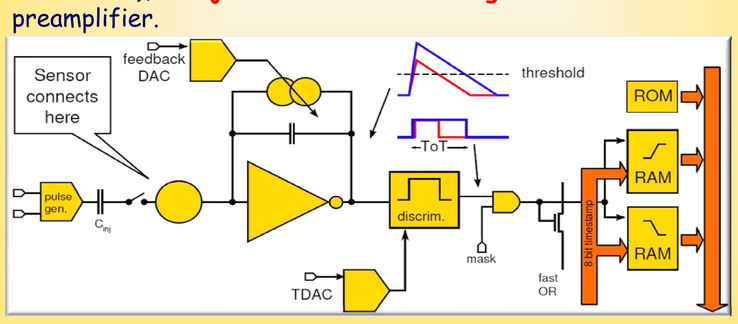
The Pixel Module

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 mm² silicon sensor
  - n⁺-in-n DOFZ
  - 250 um thick
  - pixel size 50x400 um²
  - operated at 150V bias
- 50 um pitch bump-bonding
  - solder or indium
- 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 amplifer-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 synchronisation between sub-detectors
7. debugging of module problems

→ Cosmics Data Taking

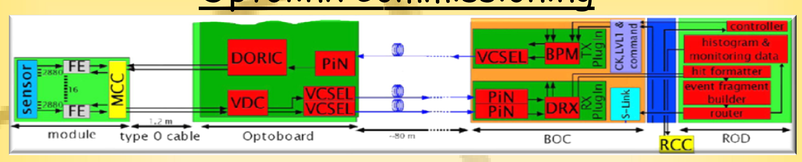
Commissioning in 2008

- 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

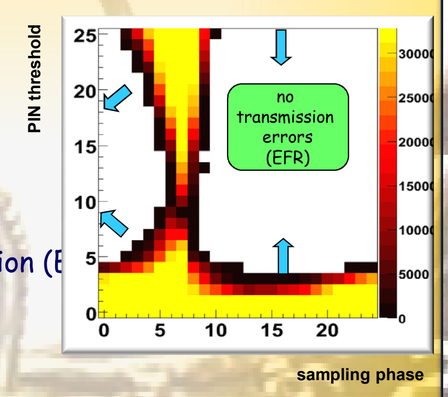


Parameters to be tuned

- 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 (E

- 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 sucessfully by the automated procedure

→ links bad after verification (and some retuning) disabled from calibration/data taking

Threshold Adjustment

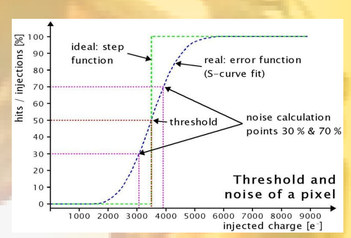
Discriminator thresholds can be adjusted individually (LSB~75e, dyn. range 7 bit)

Goal: threshold at 4000e

Measurement

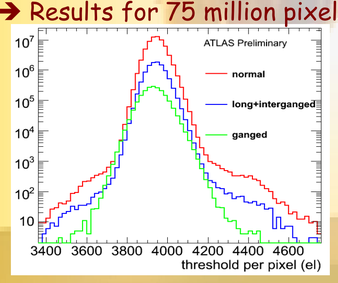
- inject varying charge to amplifier
- register fraction of hits
- fit gaussian error-function

→ threshold & noise

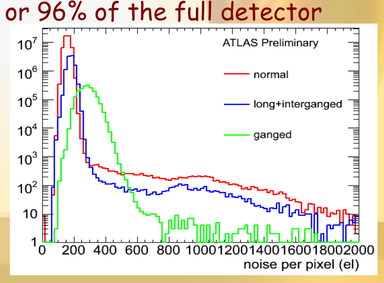


Doing this measurement on the full detector takes ~1.5h

→ Results for 75 million pixels or 96% of the full detector



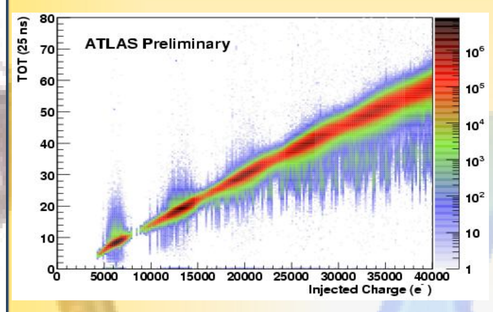
threshold
mean 3950e
RMS 40e



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).

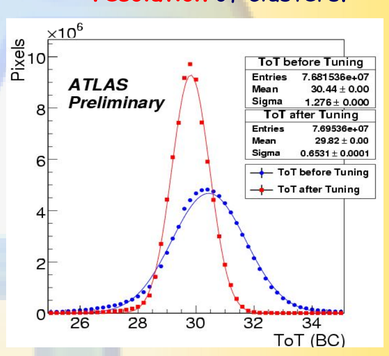


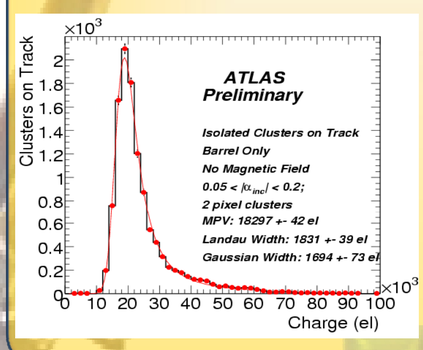
To **calibrate** the TOT an increasing **charge is injected** in the preamplifier input and the **TOT response** is parameterized. An accurate **parametrization** is needed to convert TOT to charge which is used to **improve the position resolution** of clusters.

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.





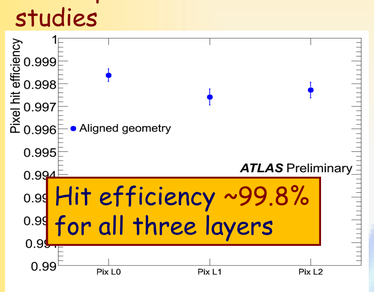
The **charge distribution** for clusters associated to a **cosmic muon track** in the pixel detector (left) peaks at the expected value of **20.000e**, validating the chosen parametrization of the TOT.

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

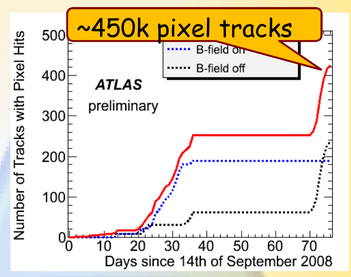
Cosmic Data Taking

- 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

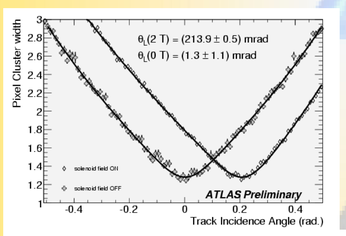
Run 88463
first pixel track



Hit efficiency ~99.8% for all three layers



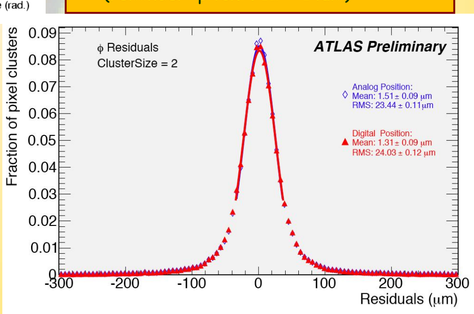
Studies using cosmics data



after the latest improvements in tracking algorithms, material treatment etc.

→ resolution 23.4um in short pixel direction
(reminder: pitch/√12 ~ 14um)

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



Bundesministerium für Bildung und Forschung