dortmund university of technology

FSP 101 ATLAS

Results from the Commissioning of the ATLAS Pixel Detector with (and without) Cosmics Data

Florian Hirsch
on behalf of the ATLAS Collaboration

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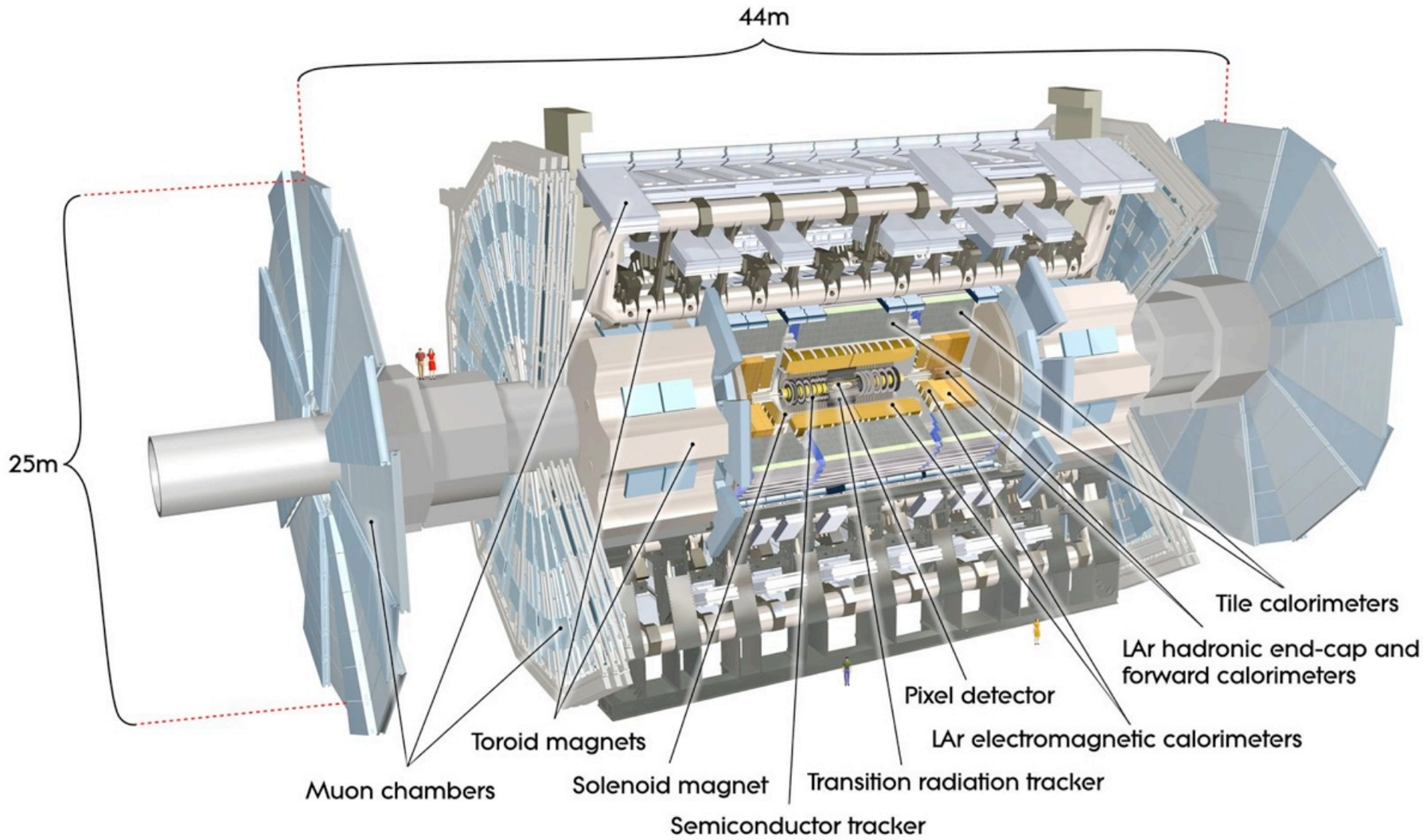
GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

Outline

- Introduction to the ATLAS Pixel Detector
- Results from the calibration periods
  - the way to data-taking: detector response
    - threshold, ToT, charge calibration, quality studies
  - cosmic ray data-taking results
    - alignment, efficiencies, depletion depth, Lorentz angle
- Readiness of the Pixel Detector and perspective

The ATLAS Experiment

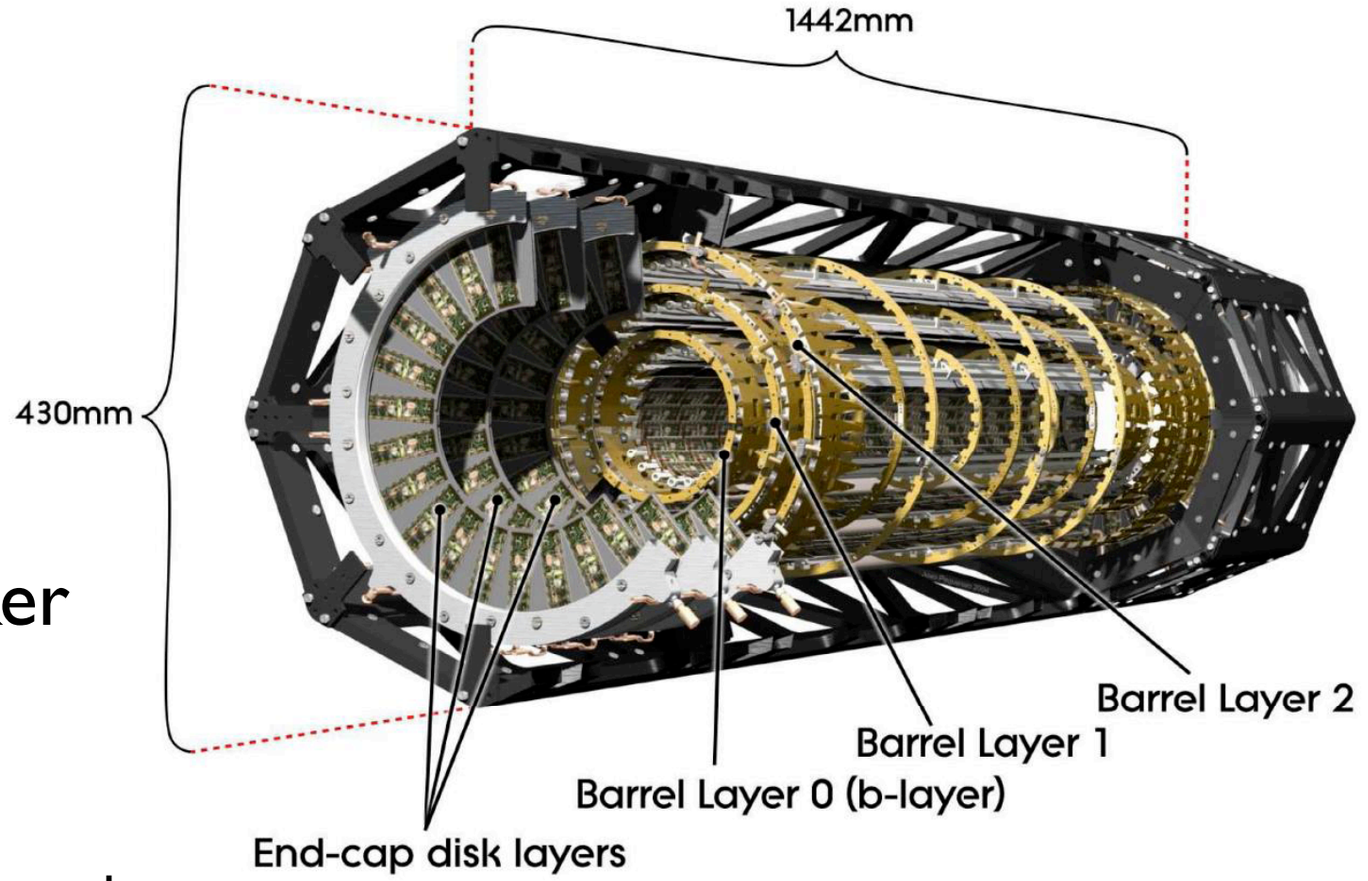
- Largest multi-purpose particle detector at CERN
- Employs a 3-component inner tracking system
  - the Pixel Detector is the innermost part

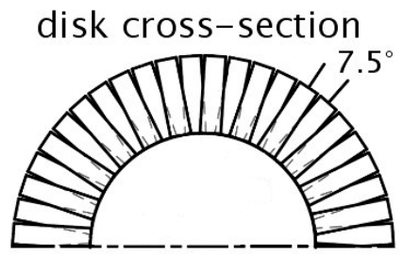


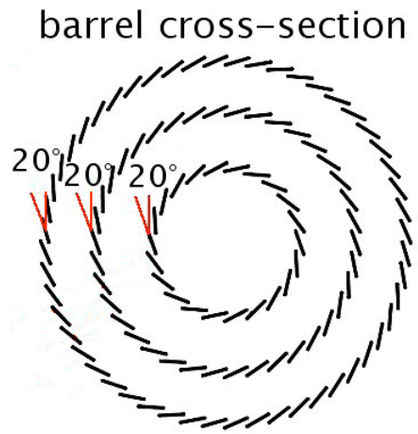
mass: 7000 tons

The Pixel Detector

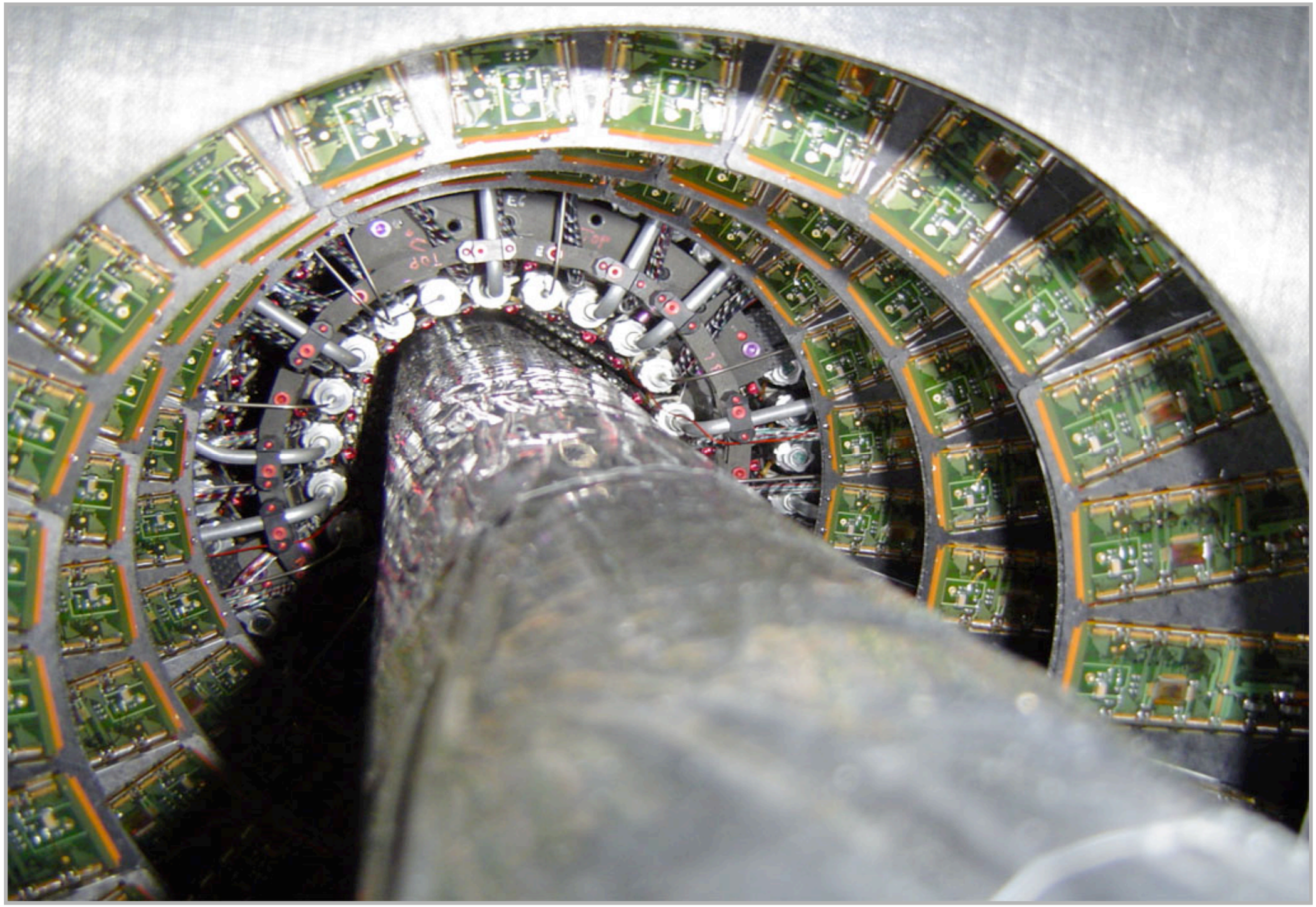
- Requirements
  - resolution in rϕ < 15 μm
  - coverage of |η| < 2.5
  - hit efficiency > 97%
- 3-layered silicon pixel tracker with forward disks in a 2 T solenoid field
  - 1744 modules with 47,232 pixels each, resulting in ~80 million readout channels
  - innermost layer at 5 cm distance to beam pipe





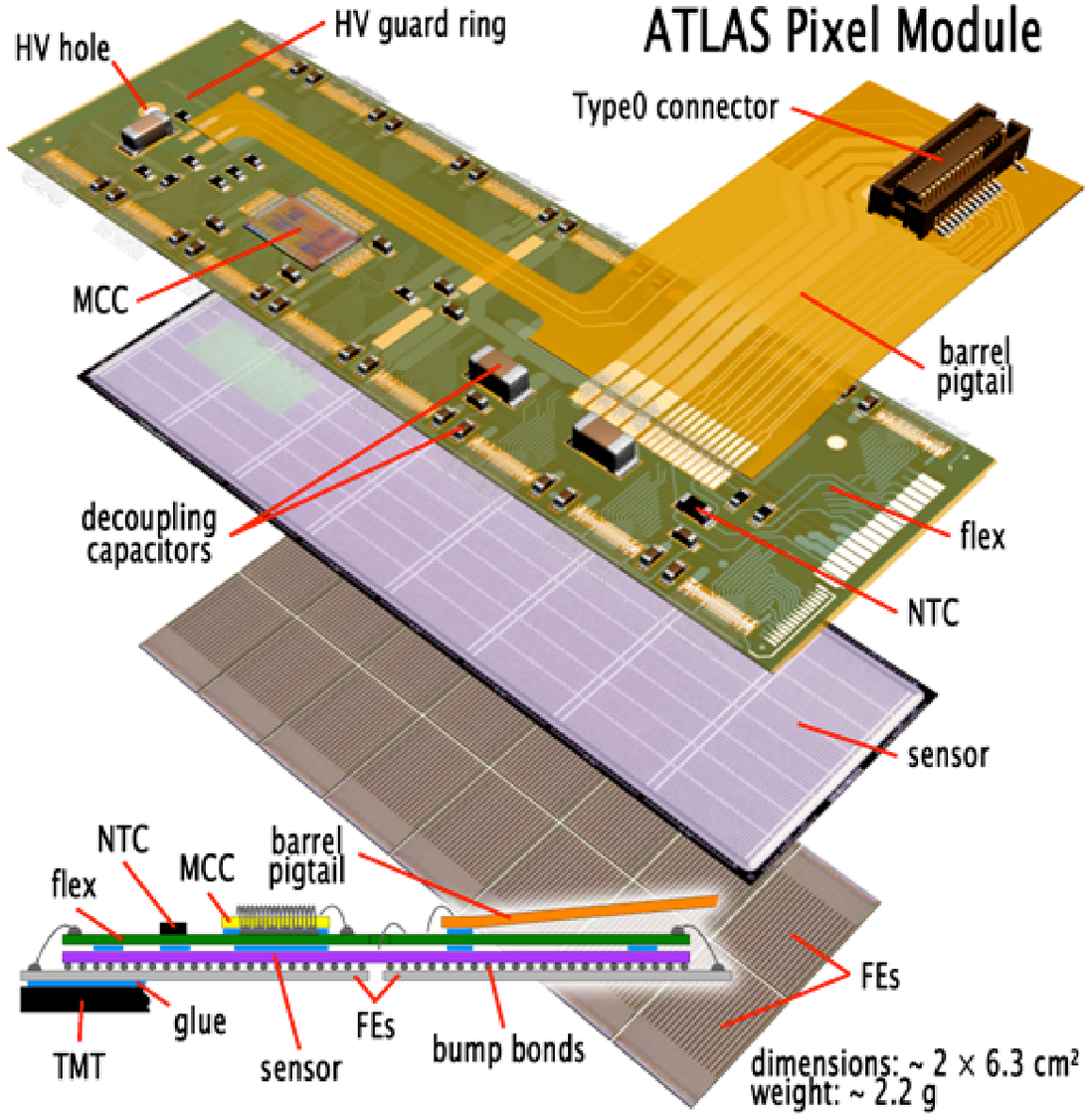


Inserted Pixel Detector



Pixel Detector Module

- Sensor properties
  - n-in-n Si sensor with 250 µm thick pixels
  - 150 V bias voltage before irradiation
    - apply up to 600 V during runtime
  - (normal) pixel size 50 µm x 400 µm
- Electronics
  - 16 front-end chips with bump bond connections to pixels
  - each pixel is read-out using a preamplifier and a comparator with an adjustable threshold
  - electronics contain a charge injection circuit which allows some calibration without data

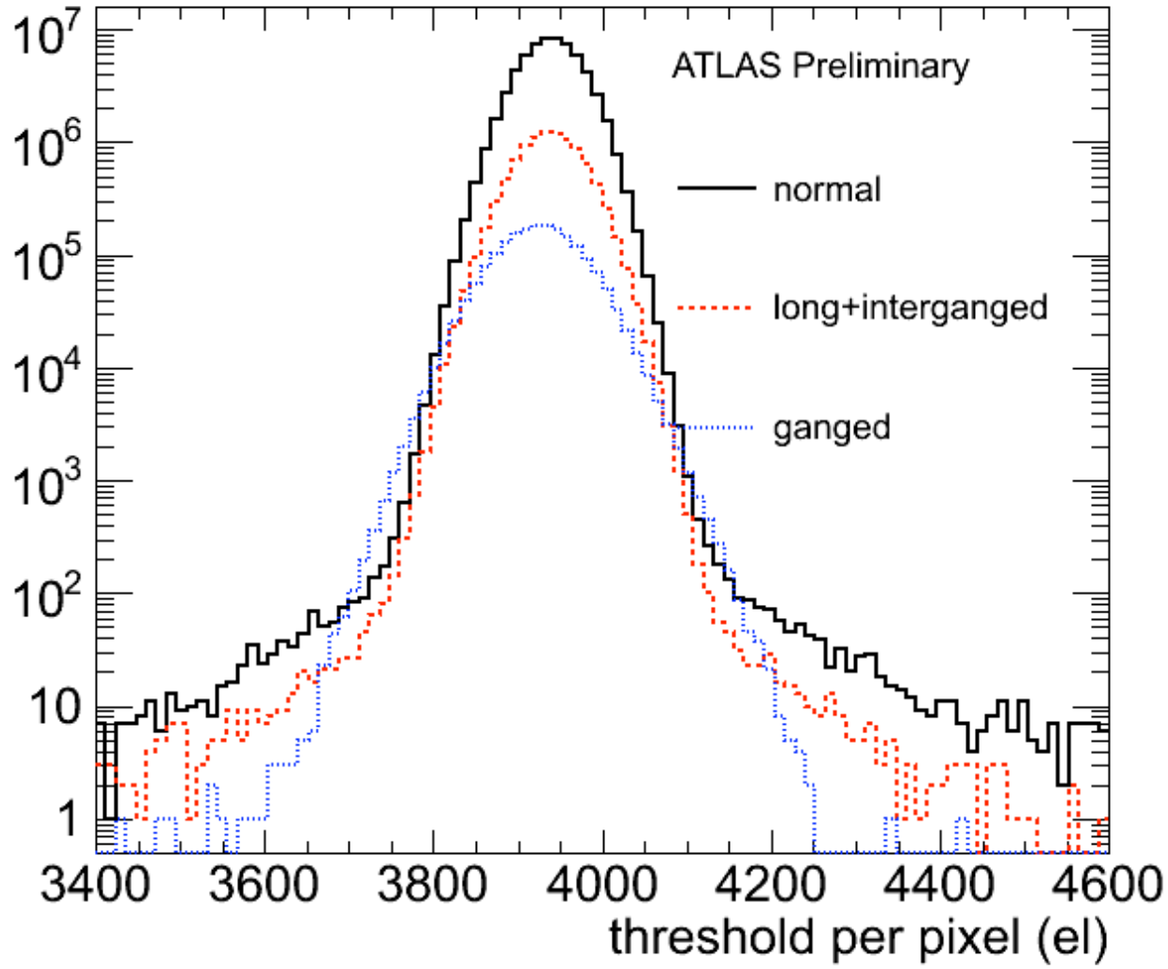


Operation Periods

- August - December 2008
  - sign-off finished (foreseen in May, but delayed due to cooling plant failure)
  - calibration and cosmic ray data-taking
  - LHC injection test, but no data from Pixel Detector for safety reasons
- May - July 2009
  - restart after cooling plant consolidation
  - some calibration and cosmic ray data taking
- August 2009 - now
  - new detector calibration and recovery of bad modules
  - started cosmic ray data taking until LHC start

Threshold

- Threshold has to be tuned
  - need good signal/background
  - need to have high hit efficiency for charged particles
- Threshold tuned to be 4,000 e^-
  - a MIP deposits ~20,000 e^- in the sensor
  - dispersion ~40 e^- (note the logscale)



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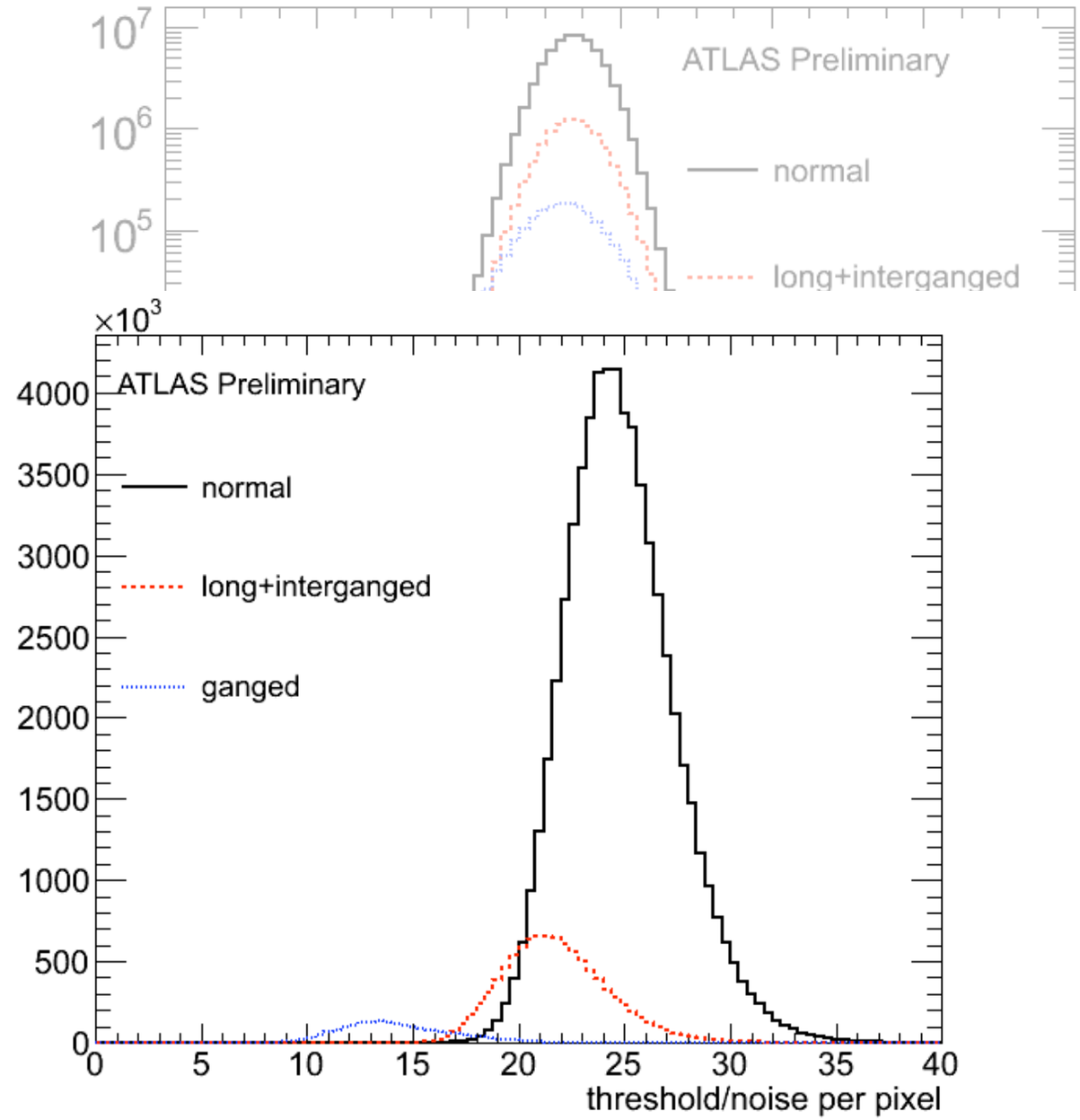
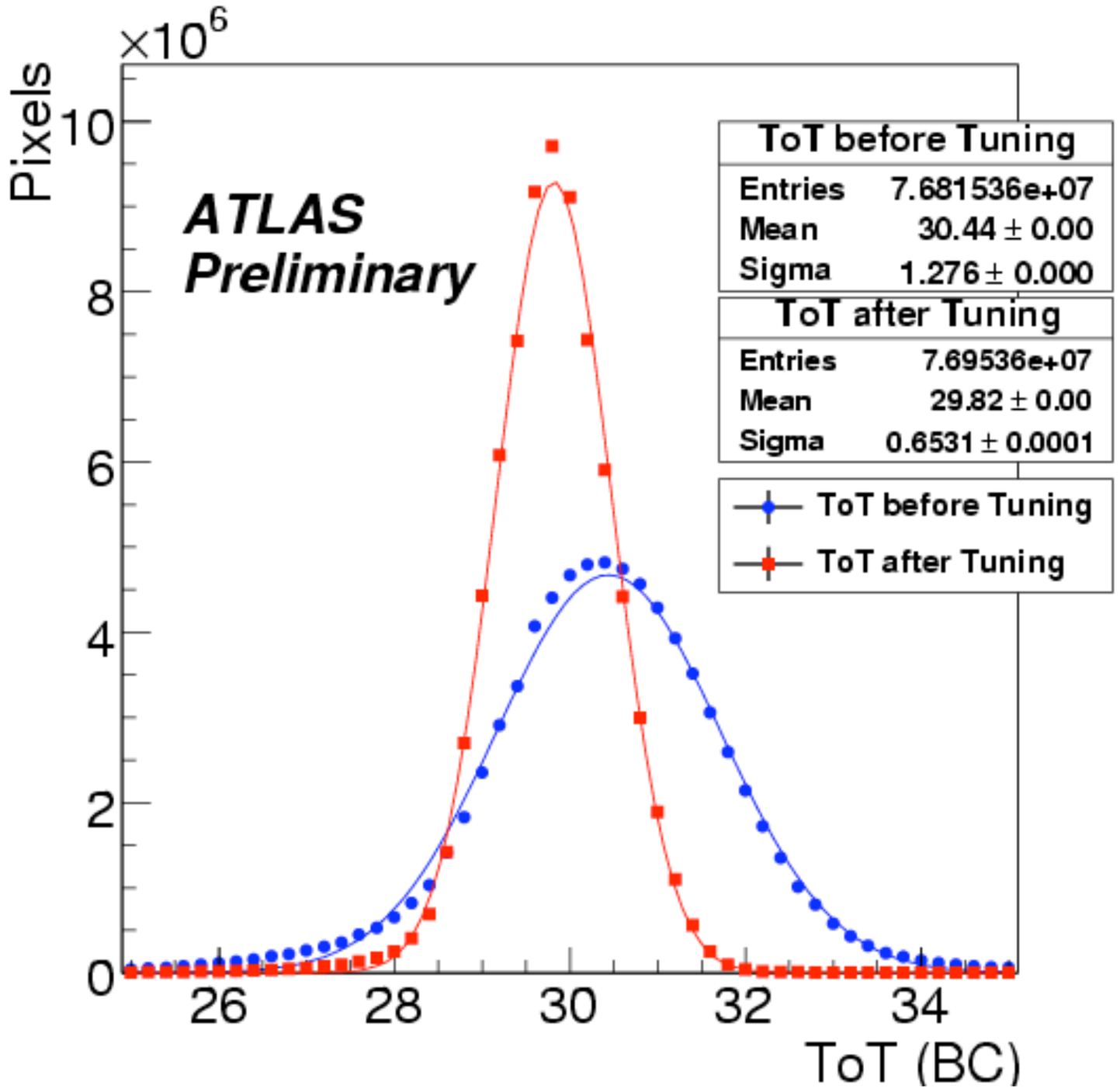
  - threshold/noise ~25
    with noise ~170 e^-



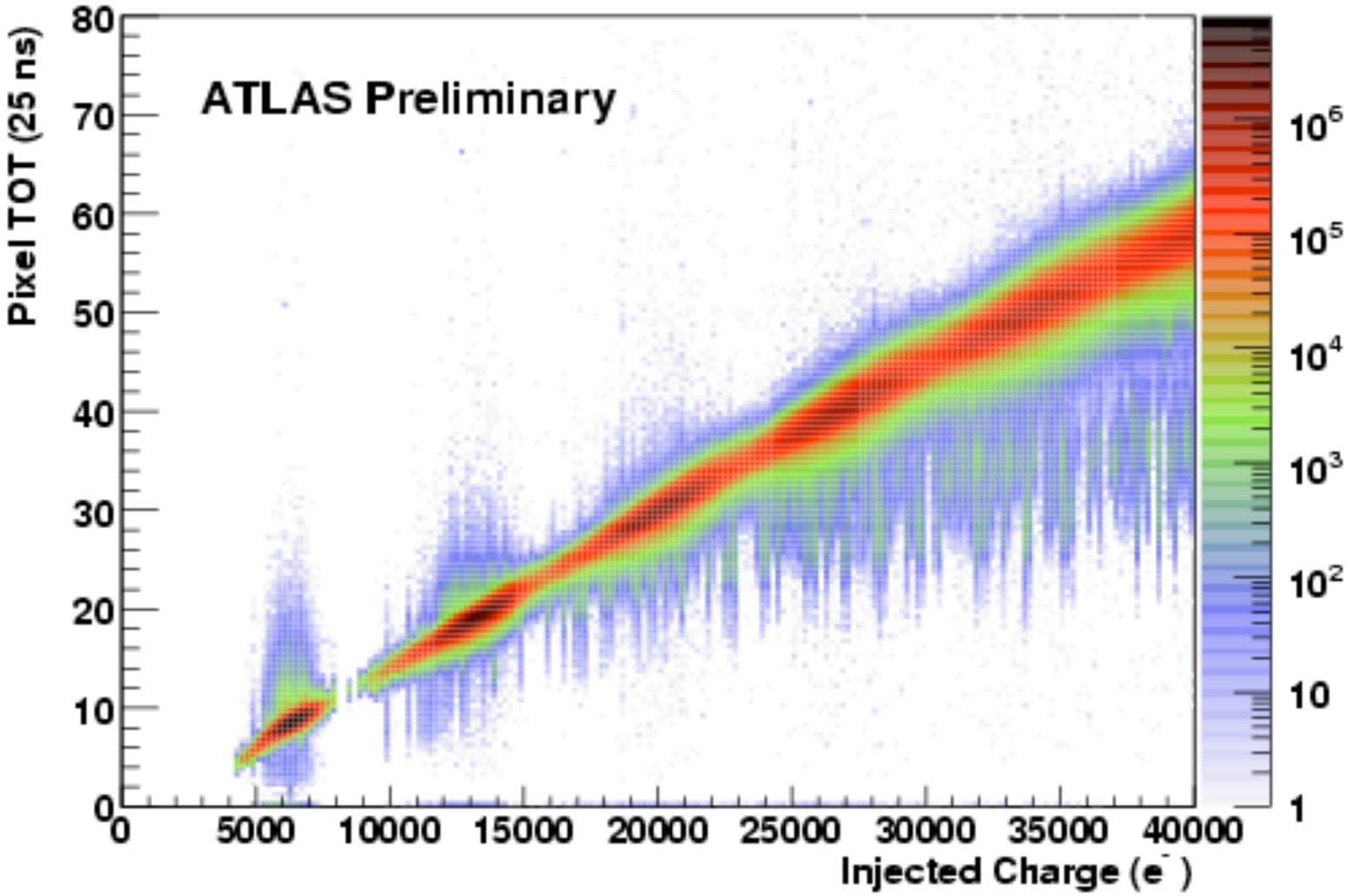
Time over Threshold

- The comparator translates the pre-amplifier output into a time over threshold (ToT) information
  - the shape of the signal at the comparator is altered by changing the feedback current
  - a signal length of 30 bunch-crossings (BC) at a deposited charge of 20,000 e^- is targeted
    - 1 BC = 25 ns
  - uniform response after tuning



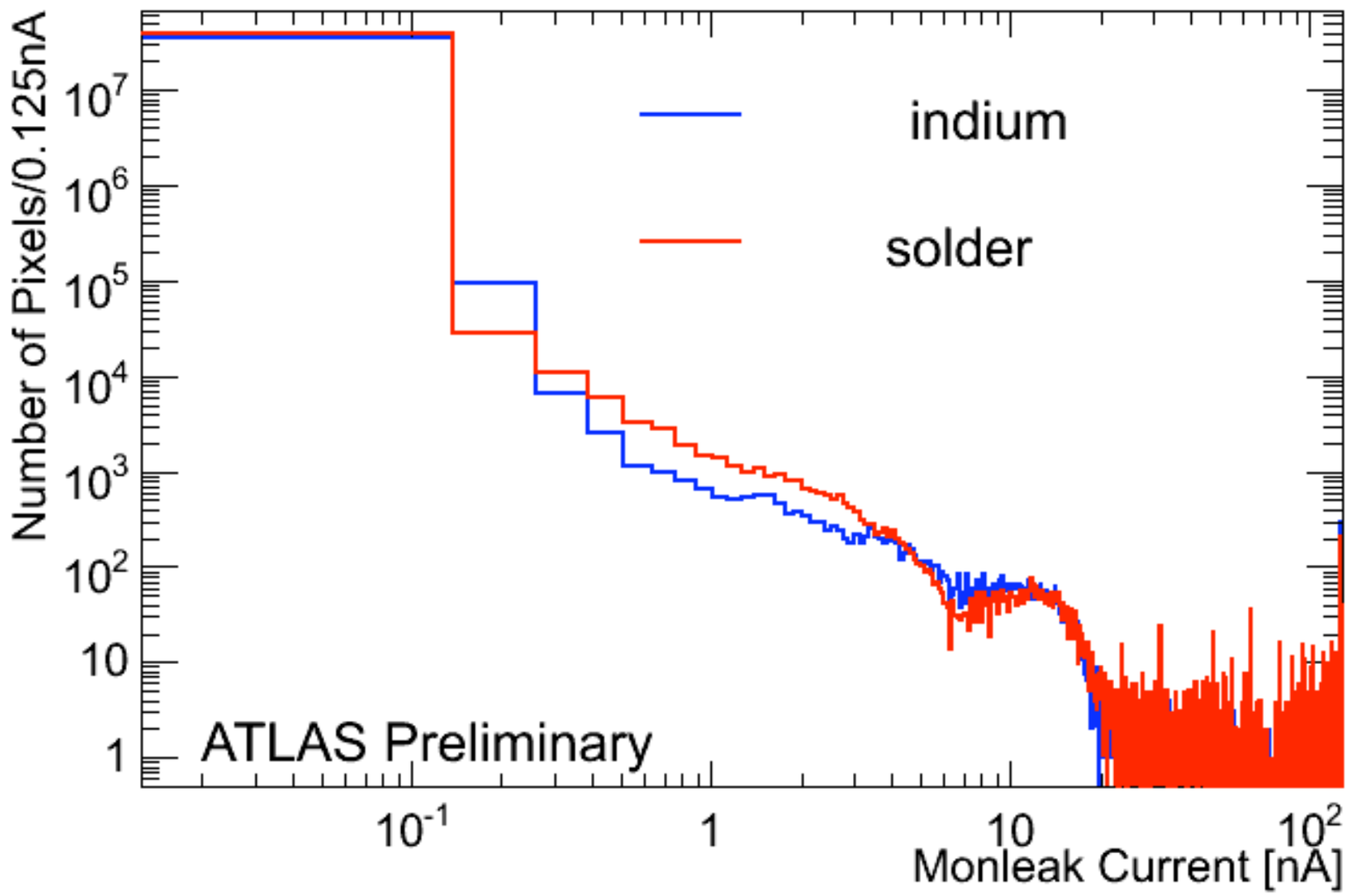
ToT Calibration

- Dependance of ToT measured by varying the injected charge
  - approximately linear, confirms expected behavior
  - biased spreads at high injected charges (but note the logarithmic scale)
  - this measurement does not correspond to a physics requirement of the Pixel Detector (energy loss)



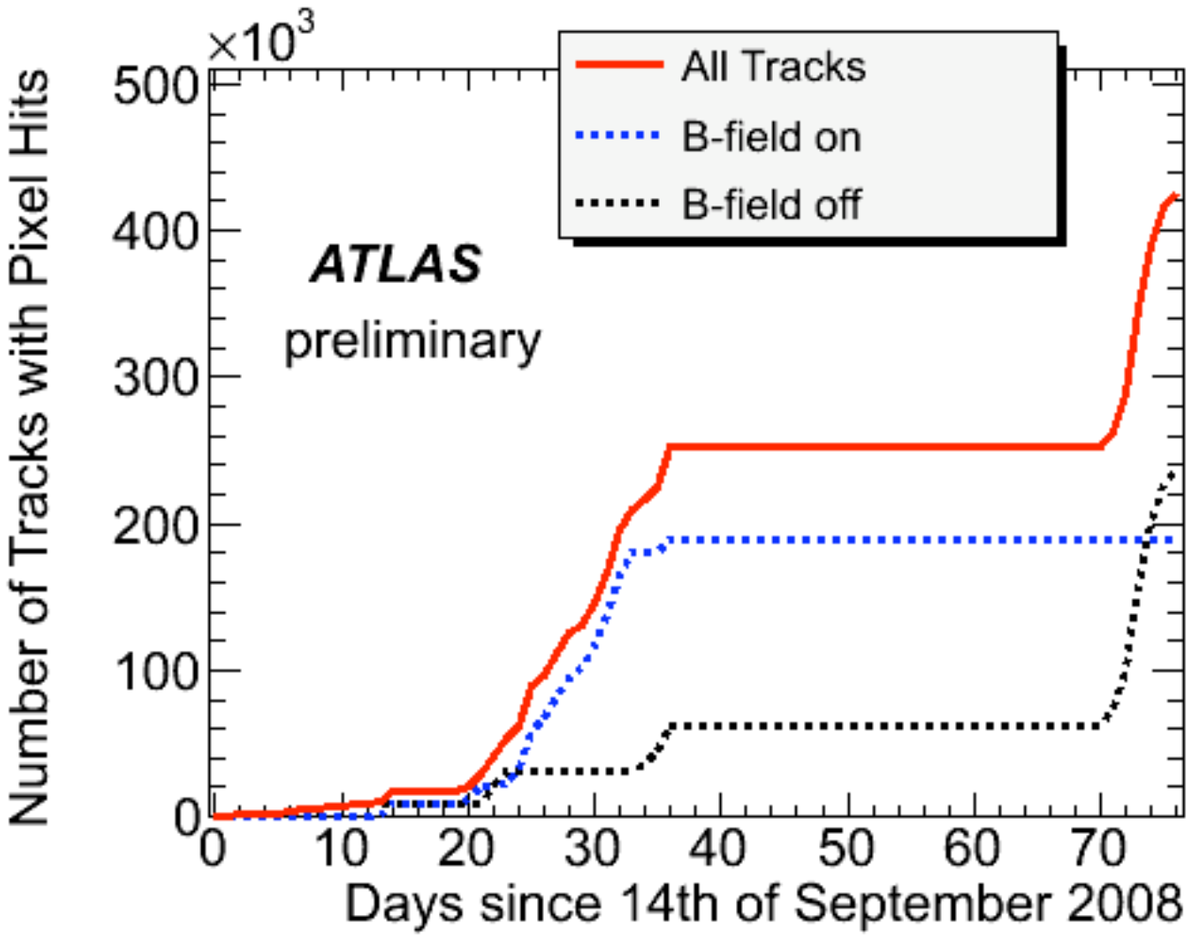
Monitoring of the Sensor Status

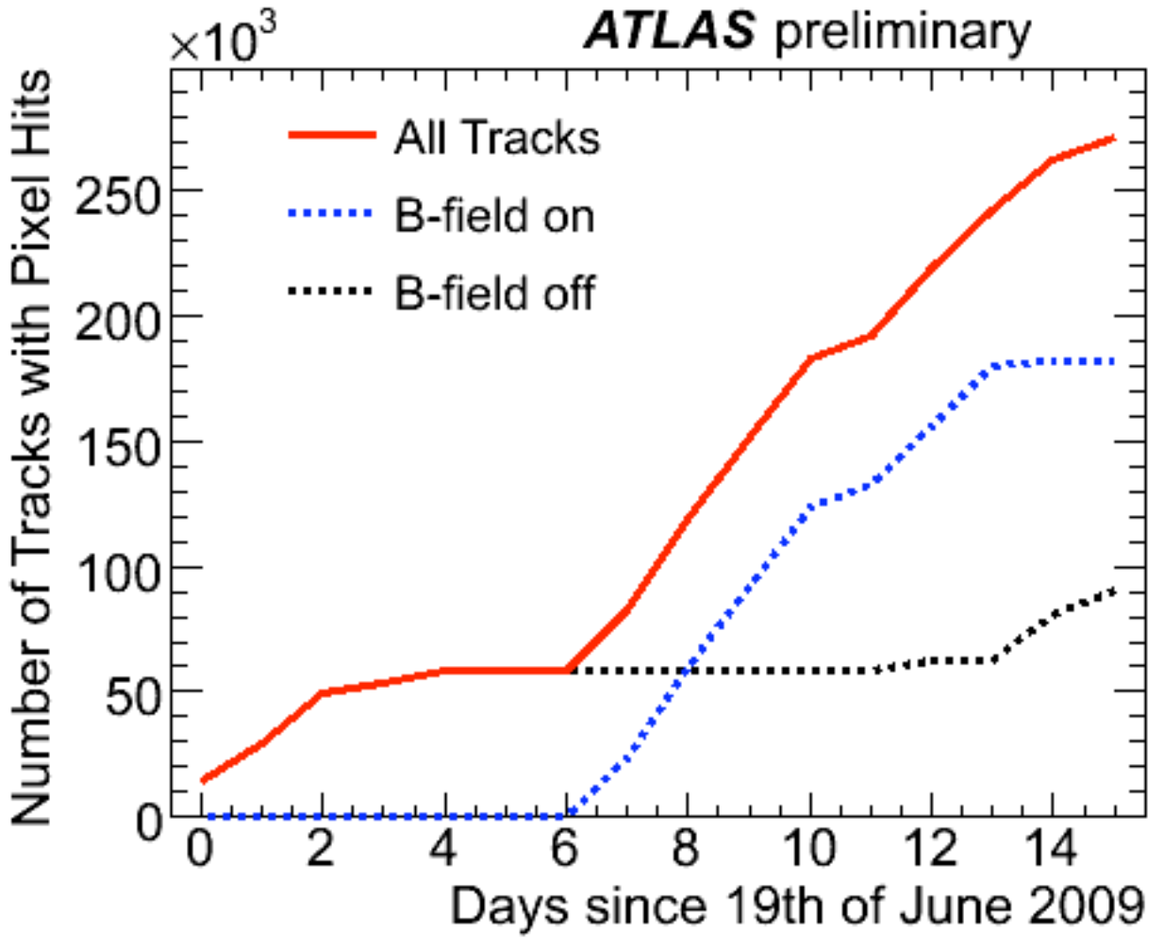
- Quantities that change with radiation damage have been assessed
  - the residual leakage current through the sensor will rise over time
  - at this point, the leakage current for most pixel is below the measurement accuracy of 125 pA
    - this also adds to the noise



Cosmic Ray Data Taking

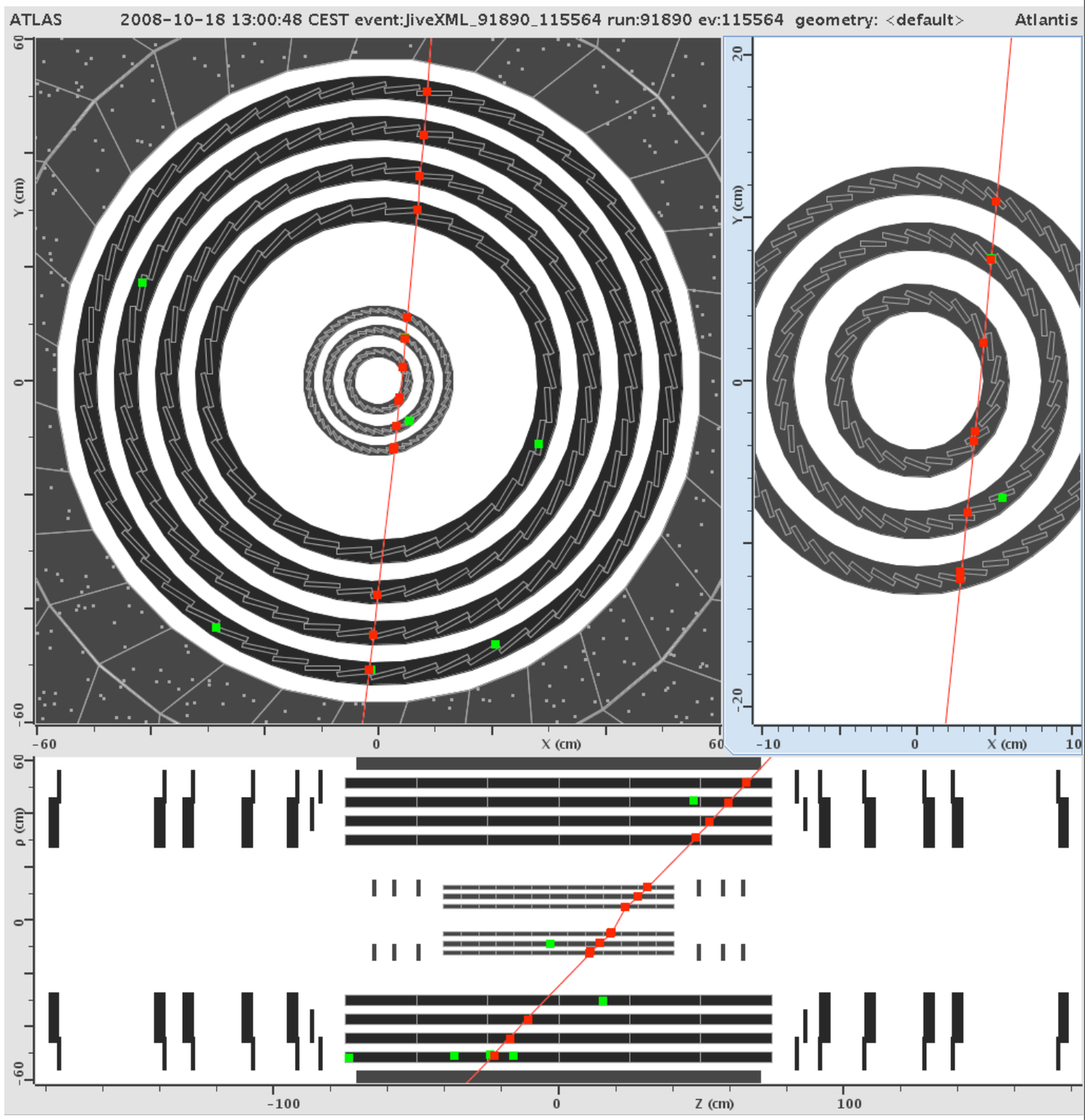
- During the run periods in 2008 and 2009 a total of 700,000 tracks was collected
  - 310,000 tracks with magnetic field





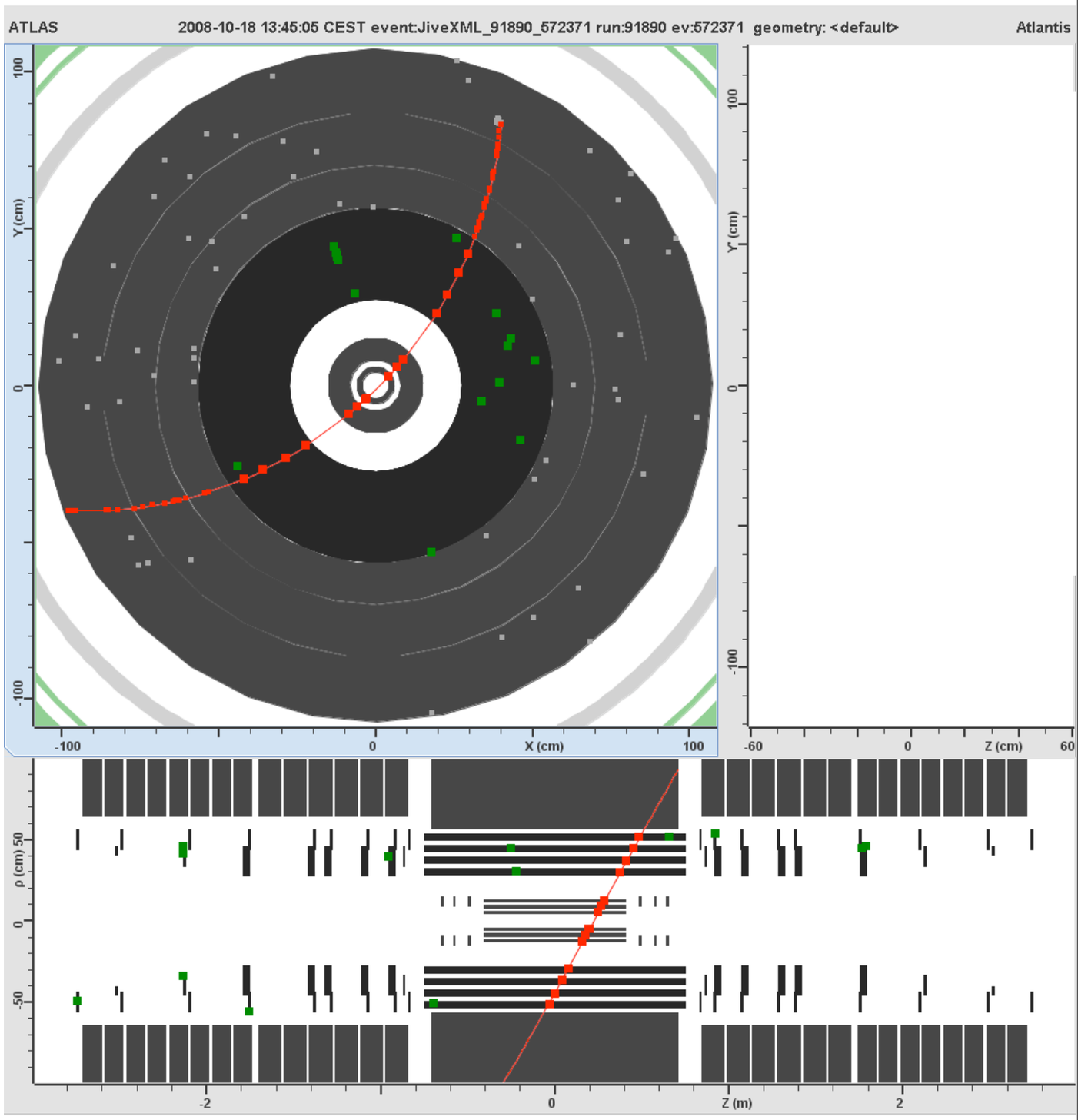
Example Track

- Event display with reconstructed track
  - magnetic field off
  - 8 pixel hits are registered, the additional hits are due to overlapping modules
  - displayed red are hits on track, green are noise hits
  - one noise hit in the Pixel Detector



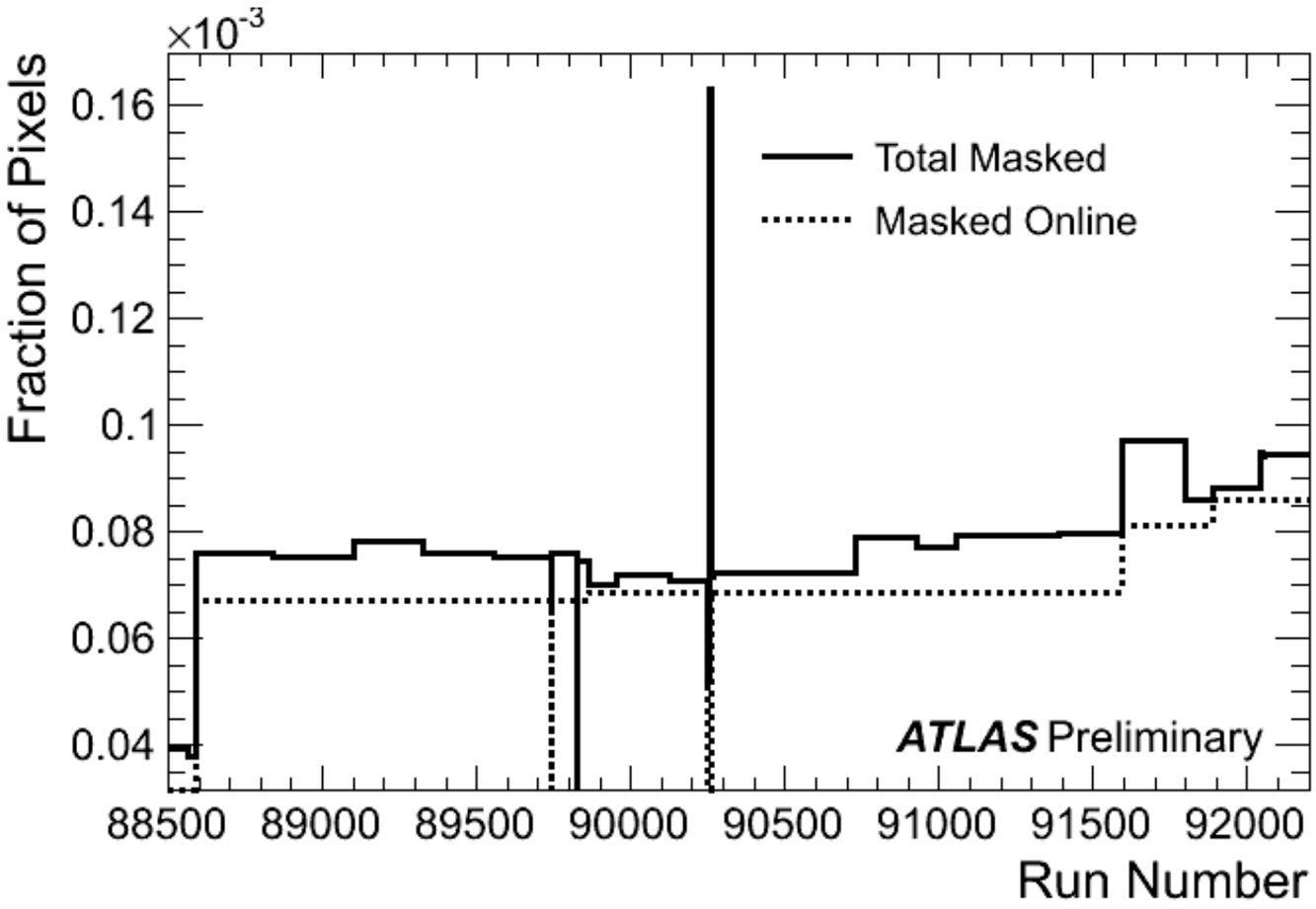
Example Track

- Another event display with reconstructed track
  - magnetic field on
  - TRT hits are also visible
  - no noise hits in the Pixel Detector



Noise and Masked Pixels

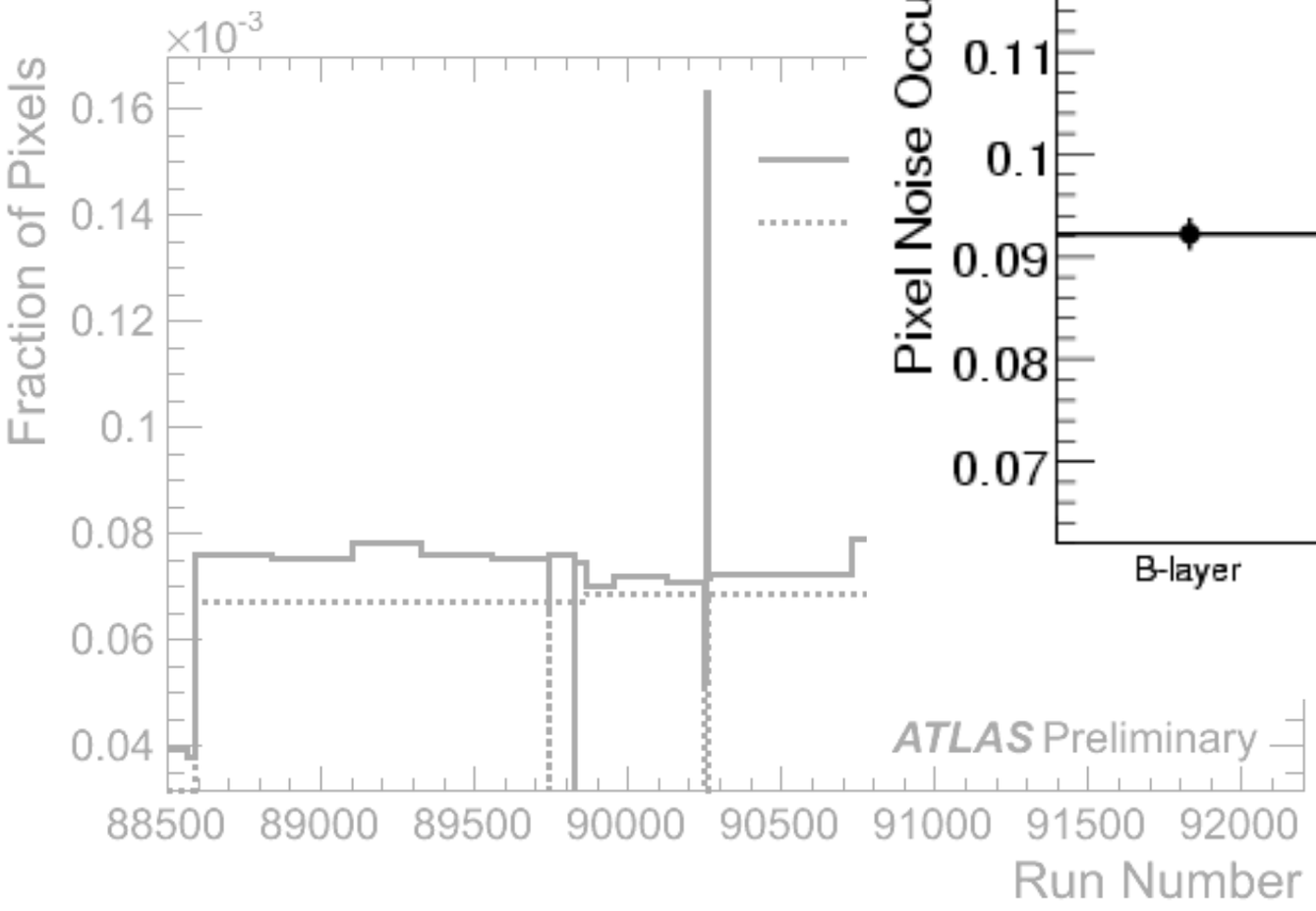
- Dedicated random trigger runs are taken to collect "noise data"
  - a noise mask is generated from this data
  - pixels with a hit occupancy exceeding a threshold are masked from data-taking

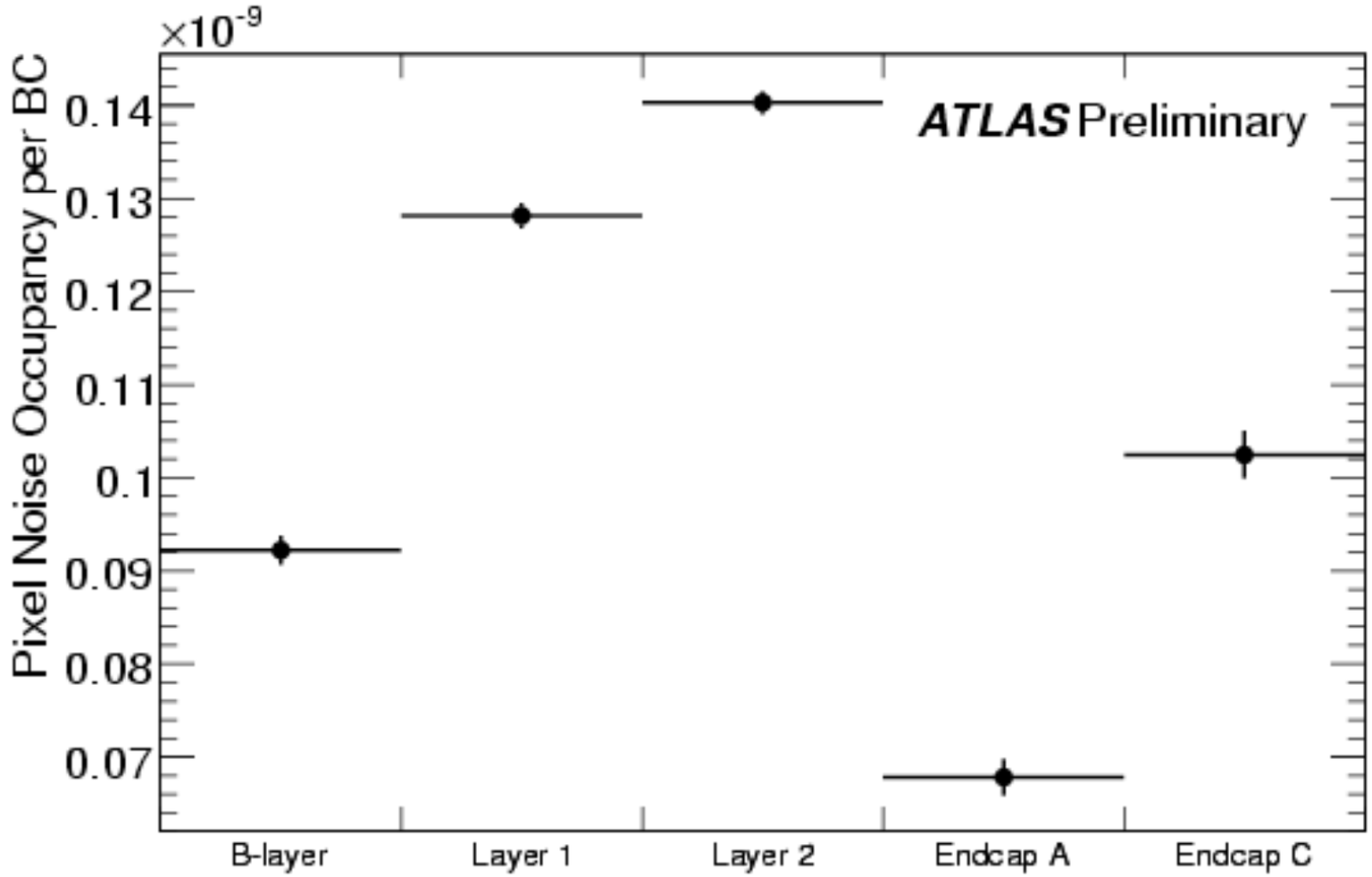


fraction of masked pixels
~ 10^{-4}

Noise and Masked Pixels

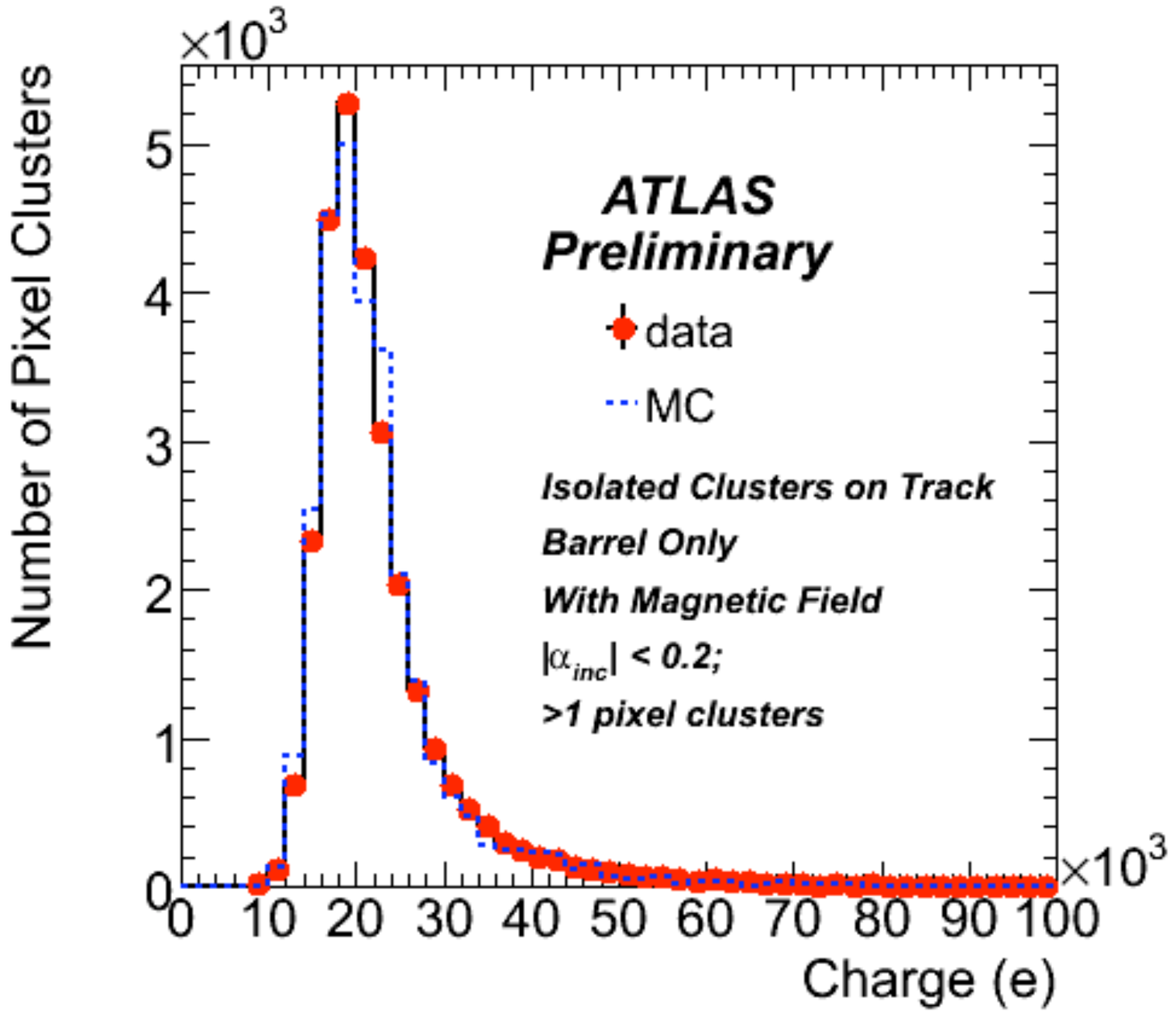
- Noise occupancy
  ~10^{-10} hits/pixel/BC





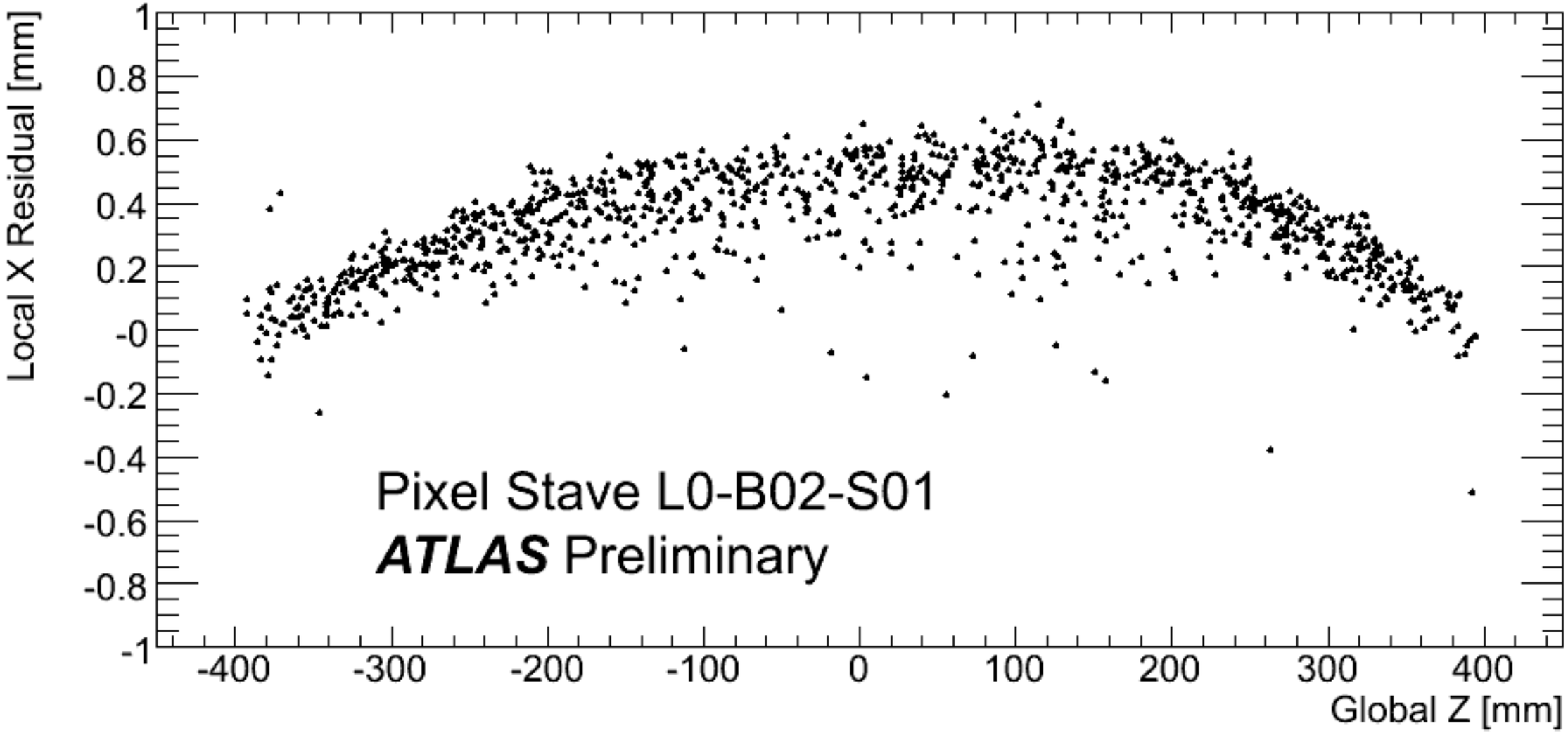
ToT Resolution

- The detector response was simulated with a MIP deposition of 19,000 e^-
  - The data shows a Landau peak at 18,700 e^-
- This verifies the ToT - charge calibration



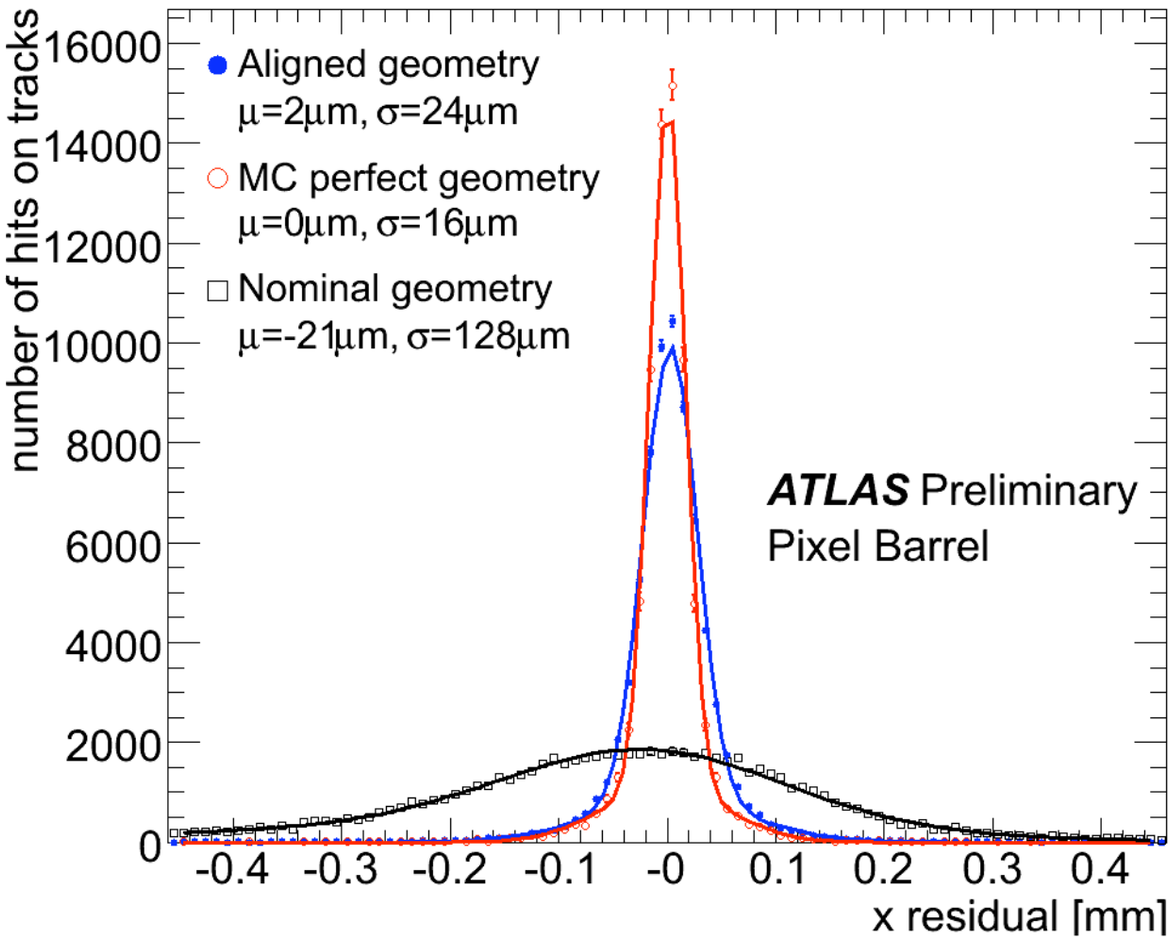
Alignment

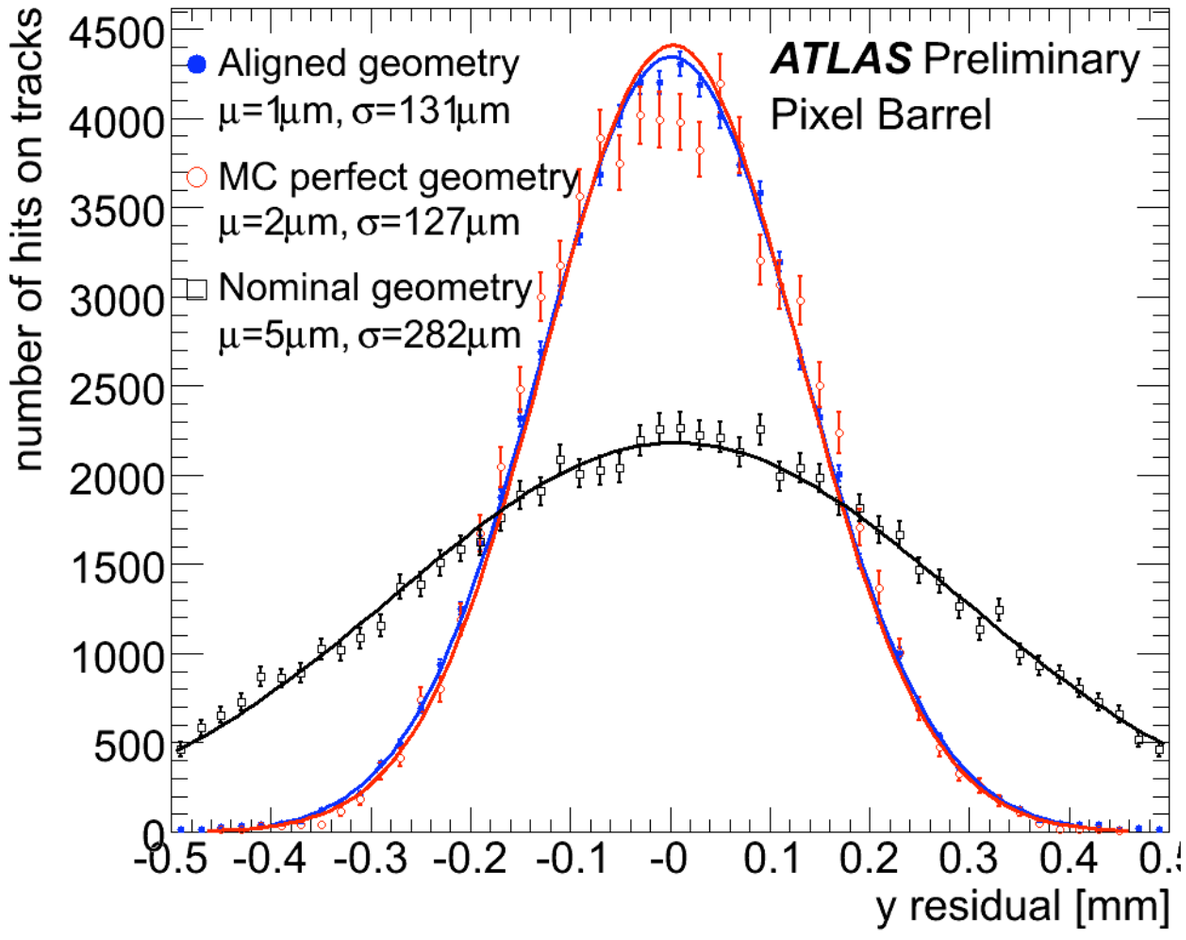
- Alignment can spot mechanical features of the detector



Alignment

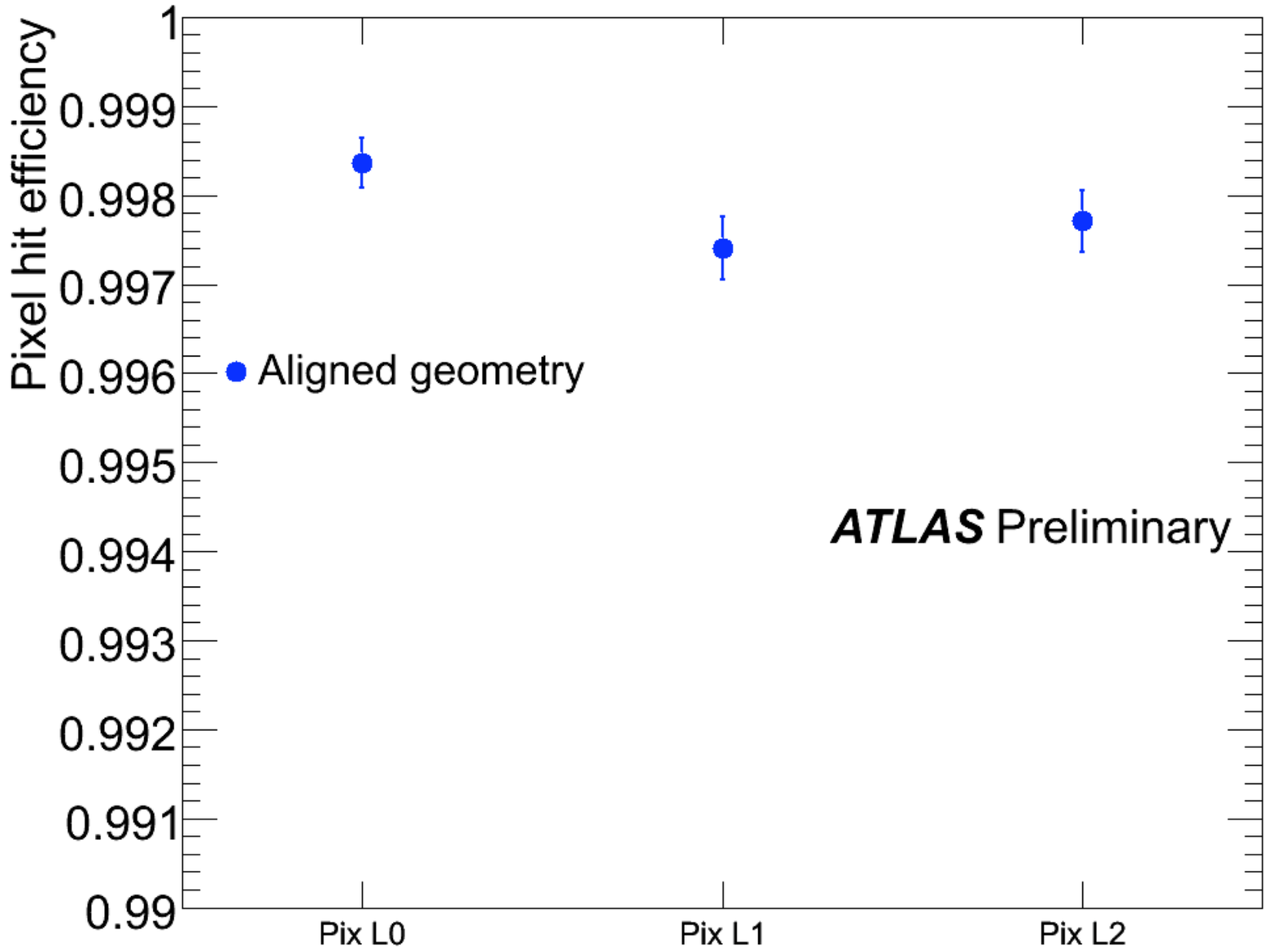
- Effect of alignment on residuals
  - clear proof of principle for alignment algorithms
  - residuals in precision direction ~24 μm





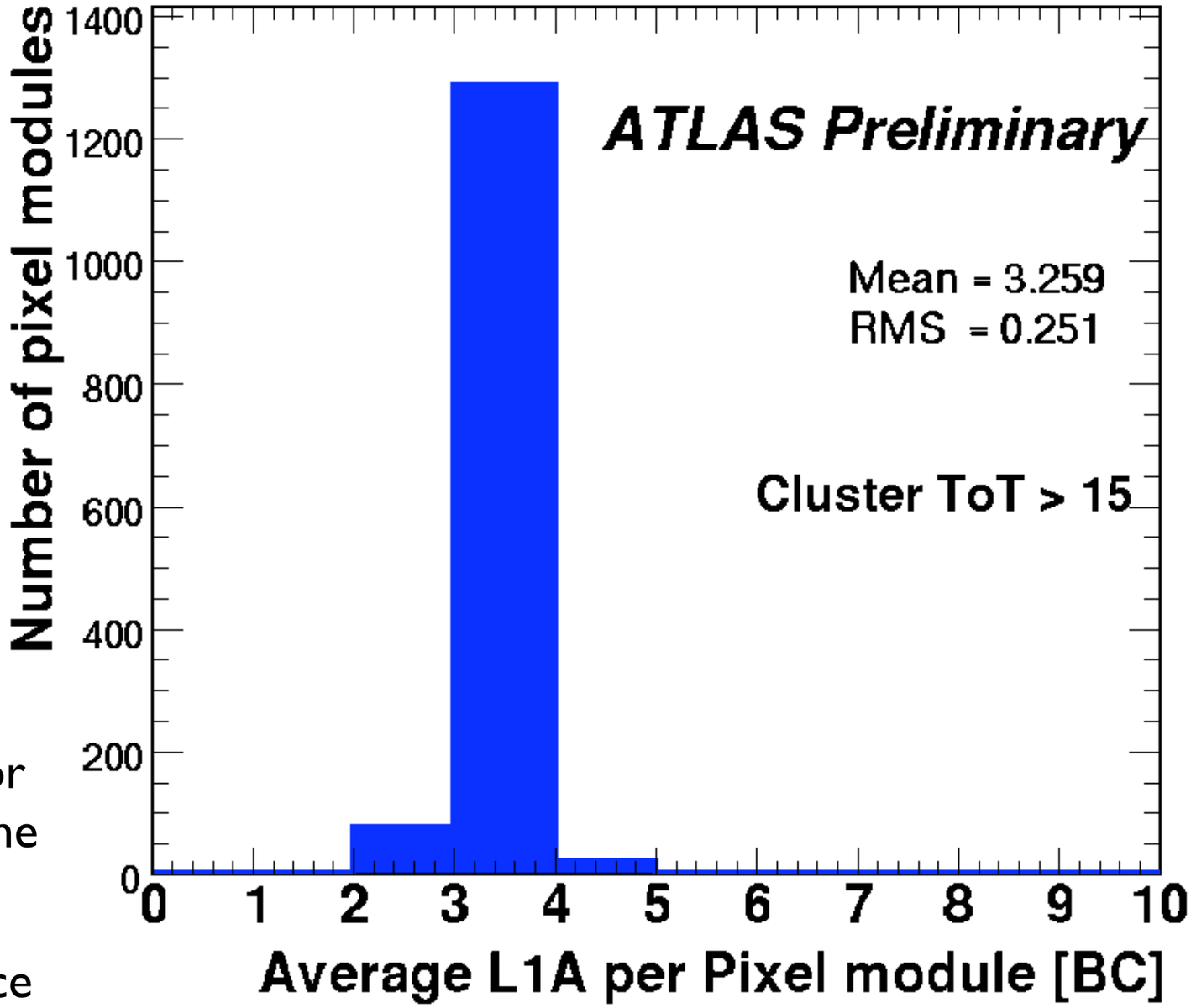
Efficiencies

- Efficiency for attaching hits to tracks (for the barrel)
  - well above 99.5%, therefore exceeding the requirement of 97%
  - after masking noisy pixels
  - disabled modules are not considered



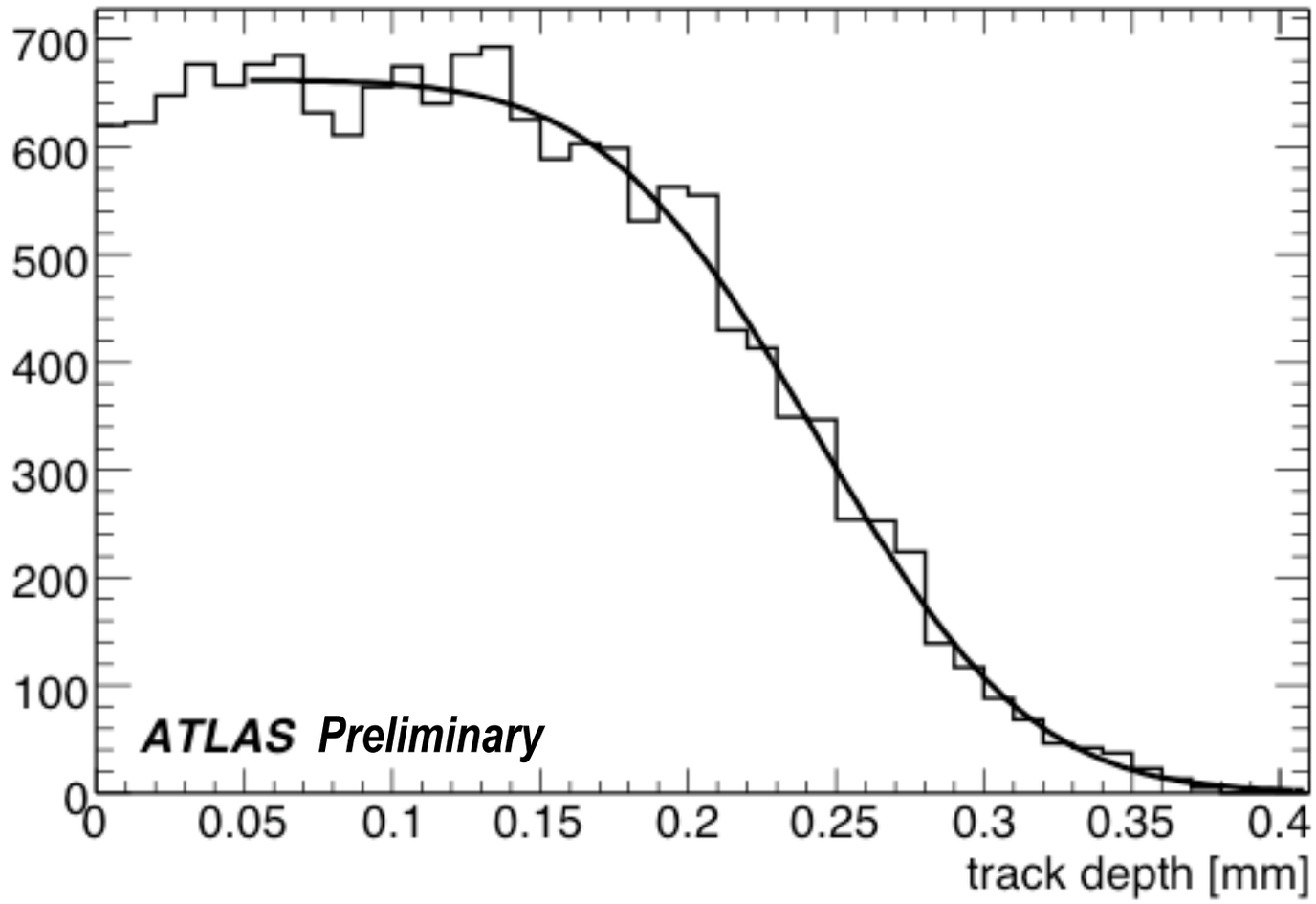
Timing

- The Pixel Detector has to be synchronous with the ATLAS clock
  - for cosmic ray data-taking, more than one BC is read out per trigger
  - the timing of the modules was calibrated to have a hit in BC 3 after the trigger, for signal events
  - main effects like cable lengths are corrected, remaining effects are, for example, signal shape details like the "timewalk"
  - start with 5 BC readout and reduce to 1 BC later



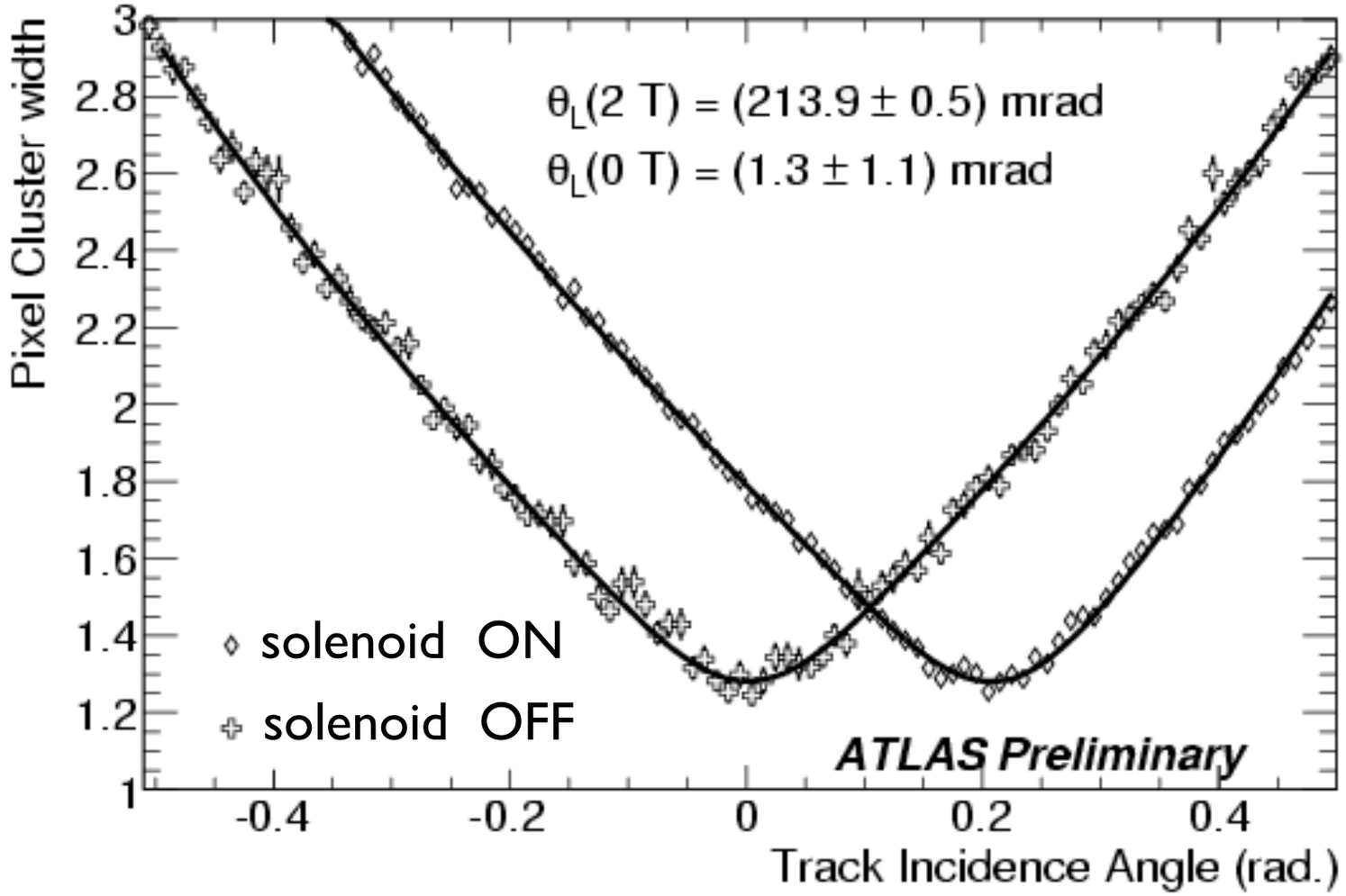
Depletion Depth Measurement

- Tracks can be used for different studies of sensor related quantities
  - the track depth in the last pixel of a hit cluster can be used to calculate the depletion depth of the module
  - result: (251.2 ± 9.5) µm
    - good agreement with the sensor thickness of ~250 µm
  - the depletion depth can be monitored while radiation damage increases



Lorentz Angle Measurement

- The charge collection path in the sensor is altered by the solenoid field
  - the Lorentz angle is the effective correction on the particle track compared to the no B-field case
  - measured with cluster size vs. track incidence angle
  - 225 mrad expected, good agreement



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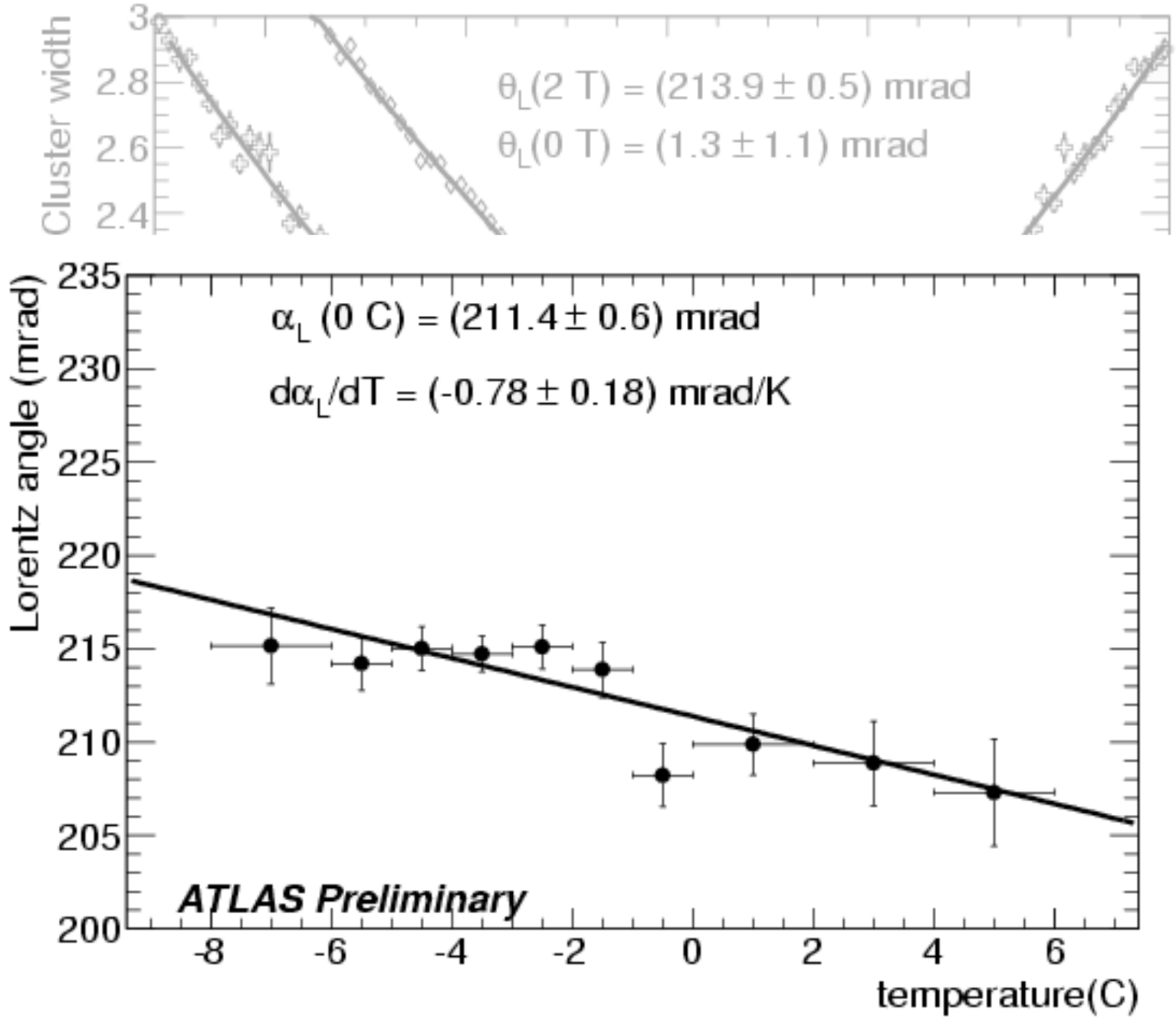
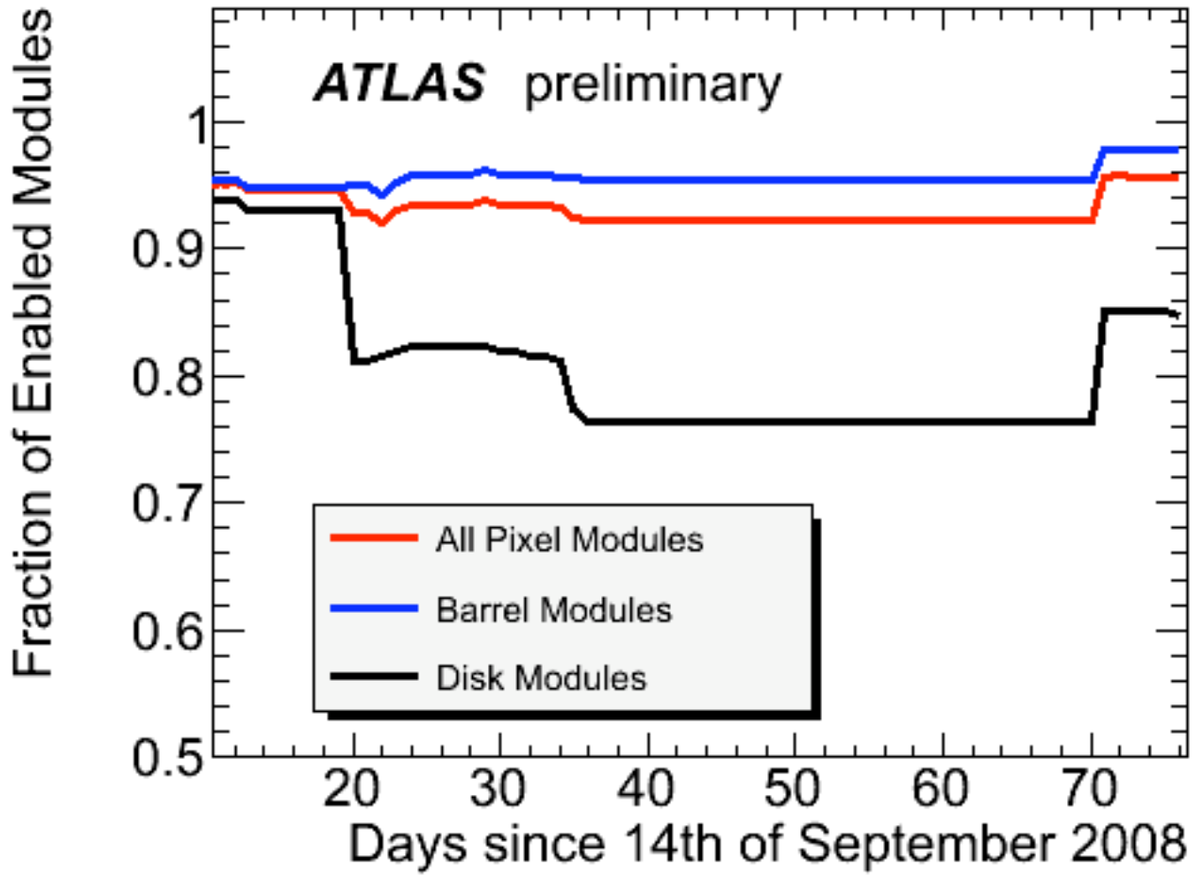
  - decrease of Lorentz angle with temperature also in good agreement with expectation (-0.74 mrad/K)



Detector Evolution

- Detector "evolves"
  - during the commissioning, problematic modules have to be disabled from data-taking
  - recovering and re-integrating them is a main focus of the commissioning periods



Detector Evolution

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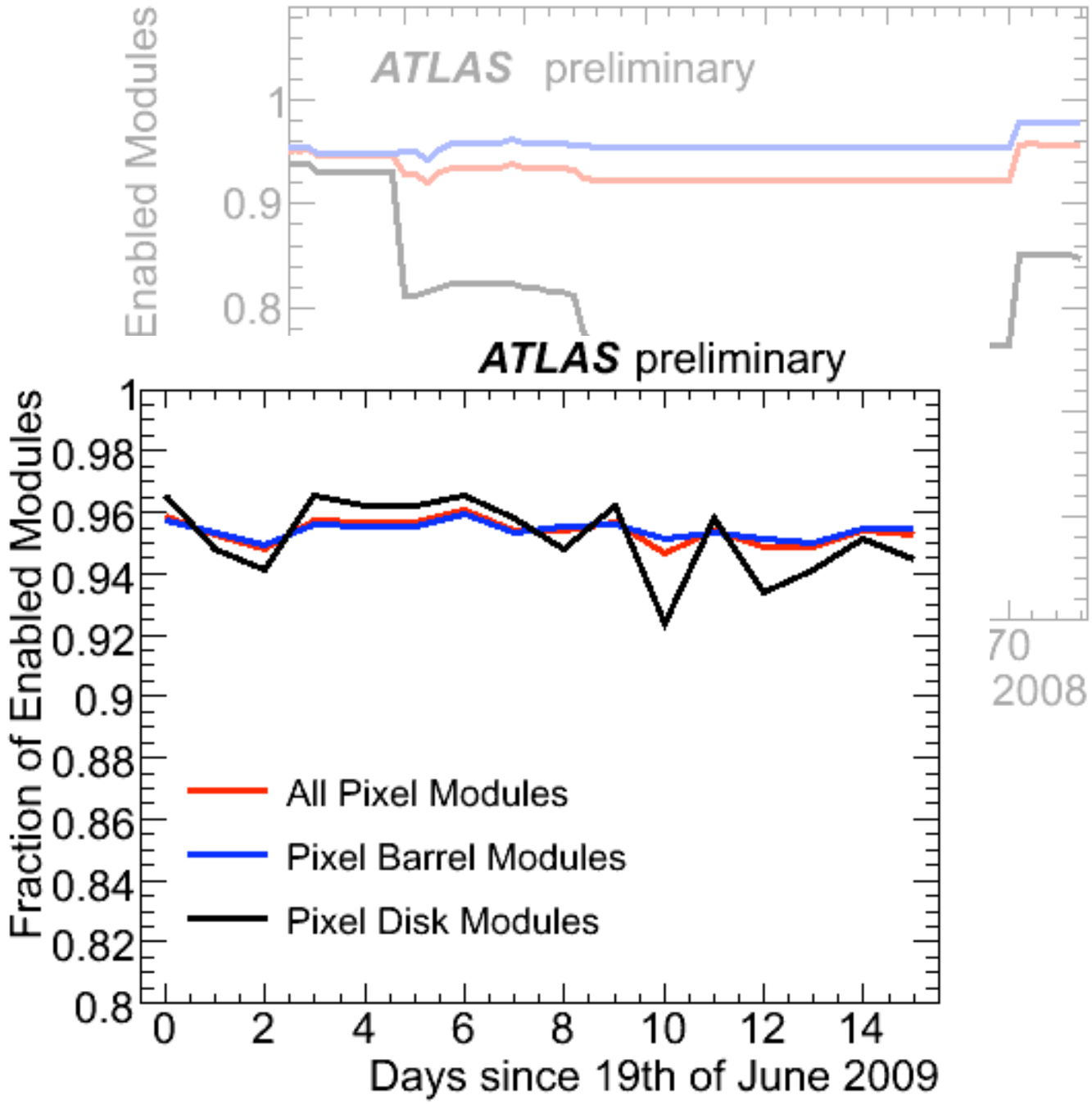
  - during the commissioning, problematic modules have to be disabled from data-taking
  - recovering and re-integrating them is a main focus of the commissioning periods
  - improved understanding of the detector leads to a high fraction of usable modules in the current state
    - more modules operable since June 2009:
      98% currently operable



Current Status and Perspective

- 98% of the pixel detector are usable for data-taking
  - threshold tuning and charge calibration are well understood,
    threshold is at 4000 e^- and noise is ~170 e^- with a threshold/noise of ~25,
    noise occupancy is at ~10^{-10} hits/pixel/BC
  - already good timing will allow a quick reduction of the readout window
  - hit efficiency is well above 99.5% and residuals ~24 μm in precision direction

- Plans
  - tuning at low thresholds is being investigated for future operation phase and for beam pickup studies
  - cosmic ray data taking will continue

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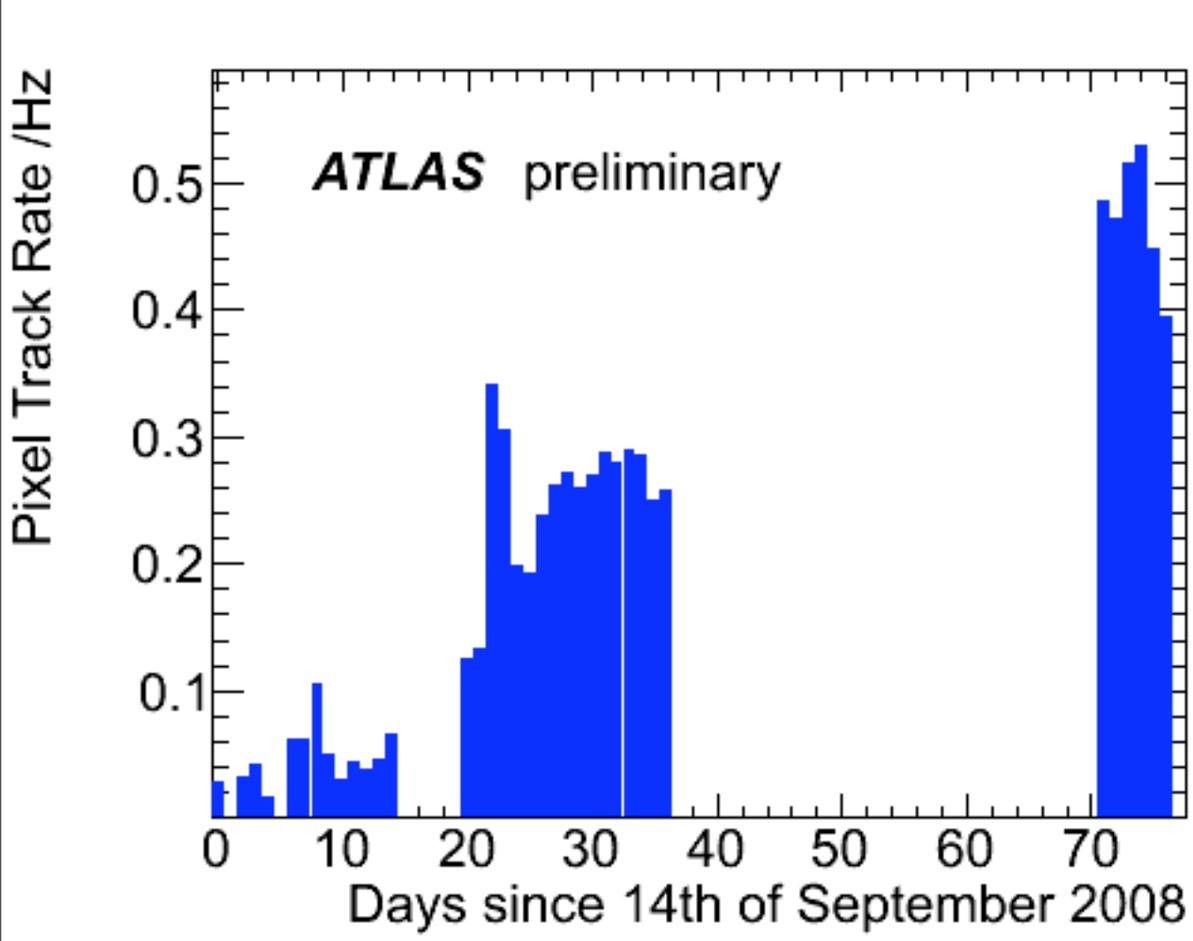
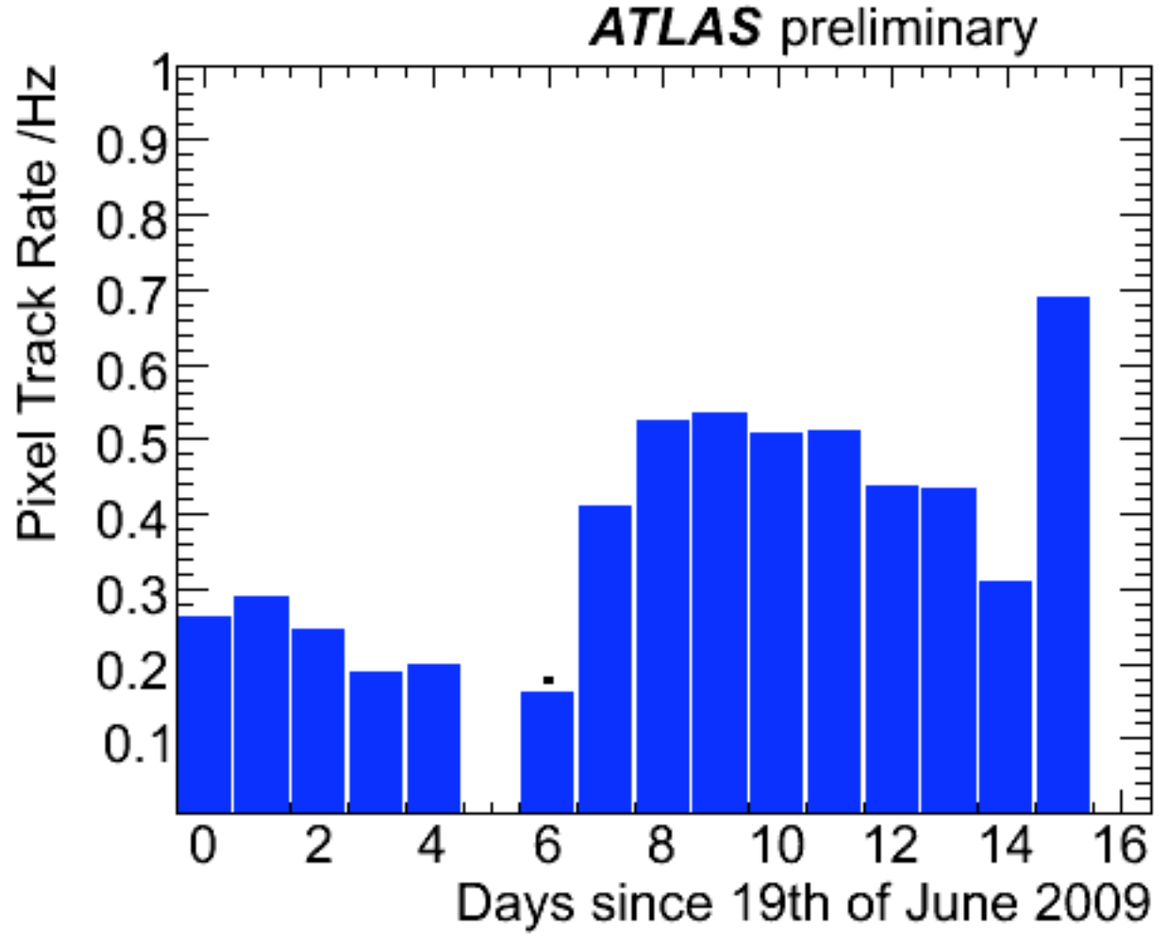
- **The Pixel Detector is ready -**
  for the LHC startup and for first data!

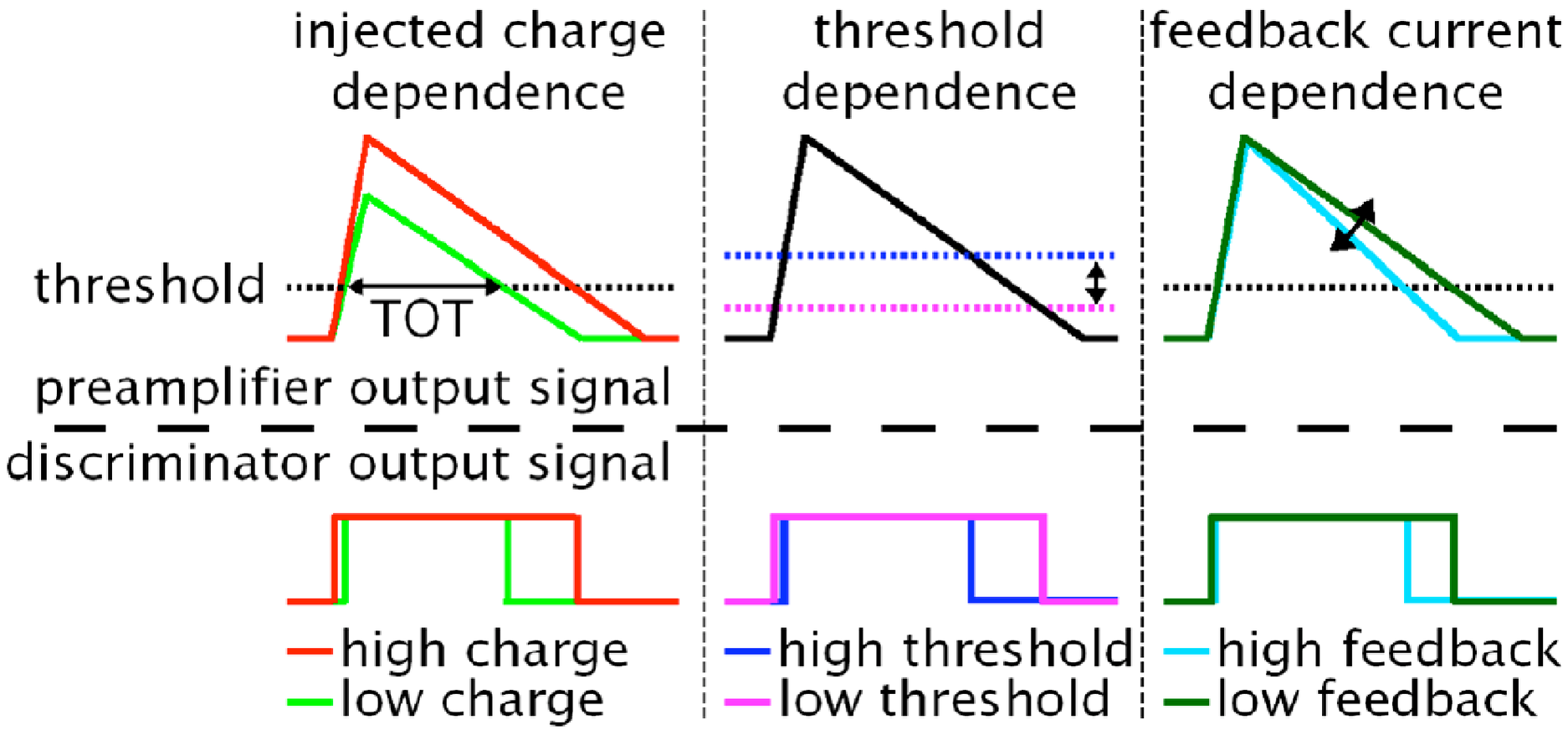
Backup

Track Collection Rate

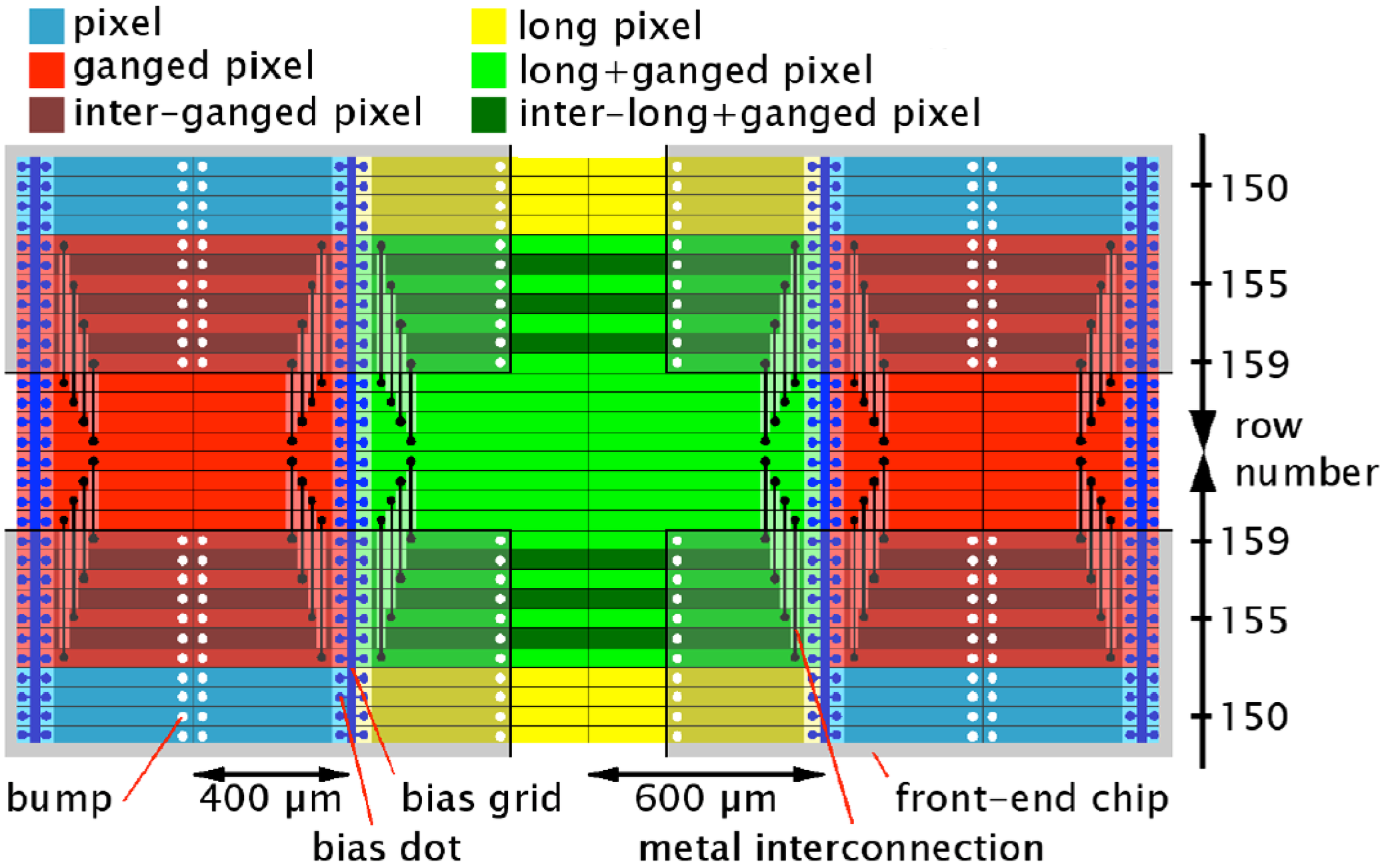




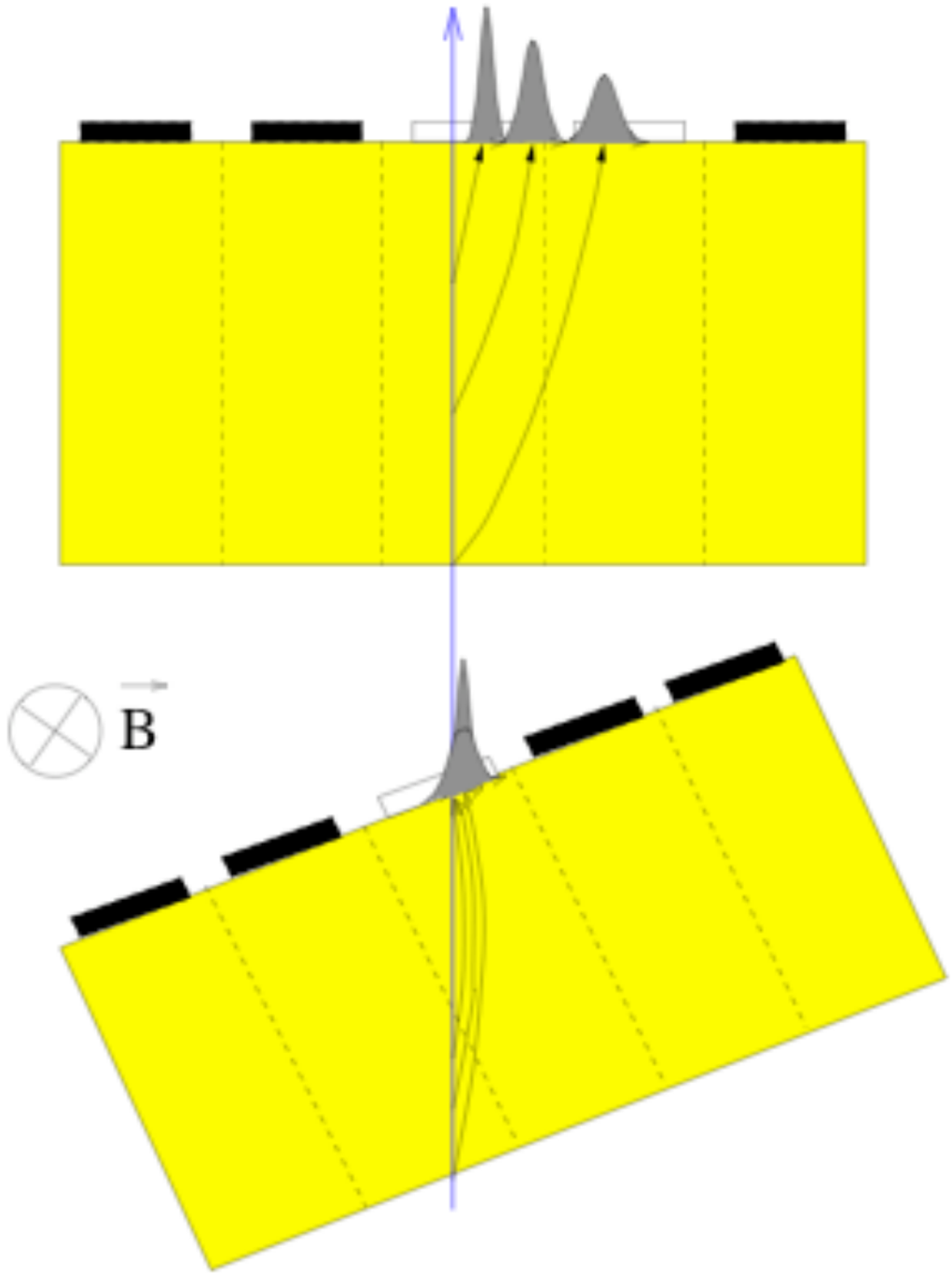
Threshold Principle



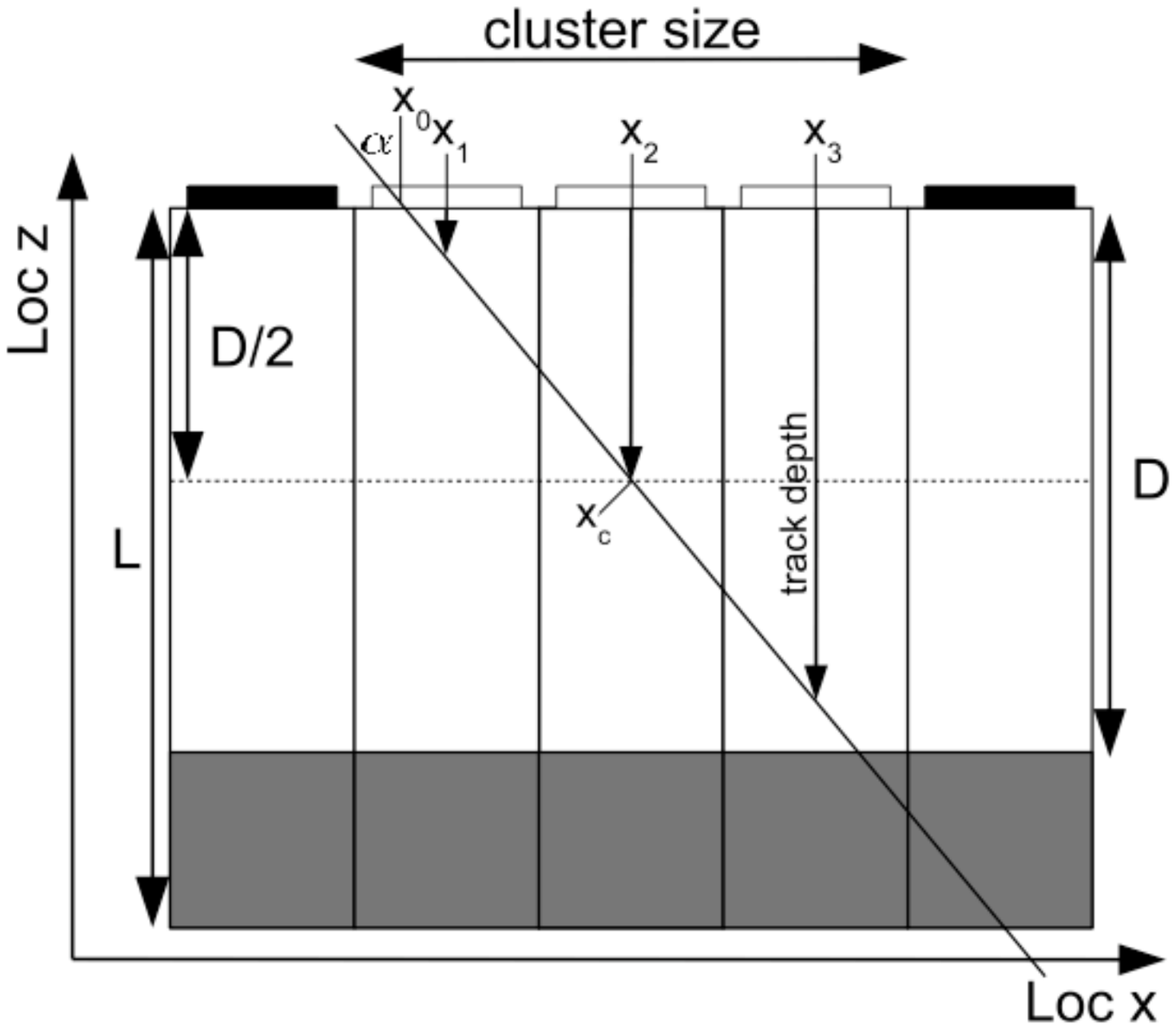
Different Pixel Types

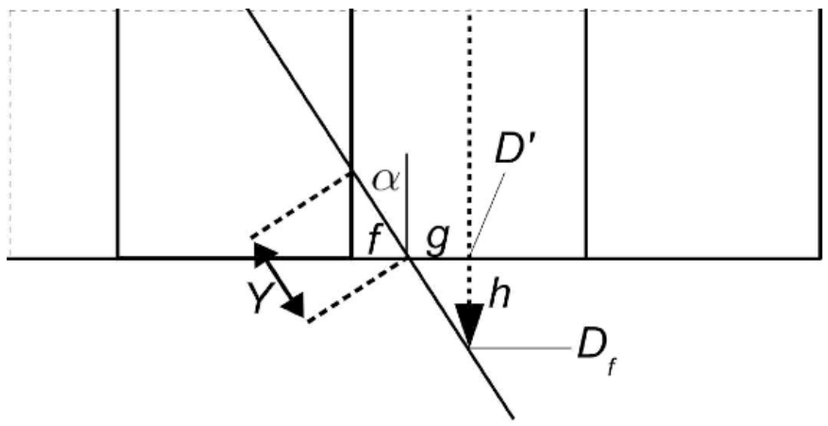


Lorentz Angle

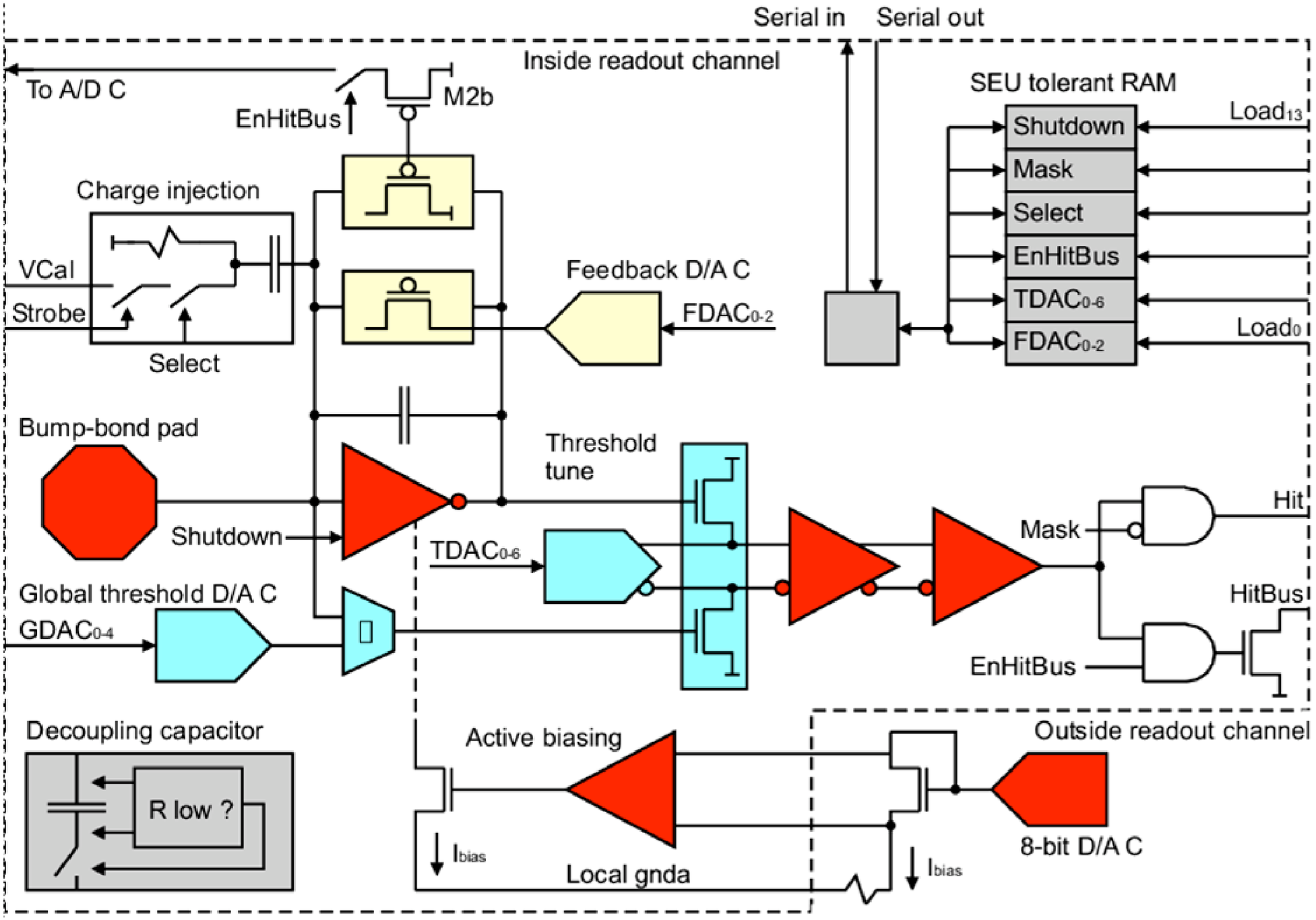


Depletion Depth Principle





Pixel Cell


Serial in
Serial out
Inside readout channel
To A/D C
EnHitBus
M2b
SEU tolerant RAM
Load13
Shutdown
Mask
Select
EnHitBus
TDAC0-6
FDAC0-2
Load0
Charge injection
VCal
Strobe
Select
Feedback D/A C
FDAC0-2
Bump-bond pad
Threshold tune
Shutdown
TDAC0-6
Hit
Mask
HitBus
EnHitBus
Global threshold D/A C
GDAC0-4
Decoupling capacitor
R low ?
Active biasing
Outside readout channel
Ibias
Local gnda
Ibias
8-bit D/A C