The ATLAS SemiConductor Tracker Operation and Performance

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On behalf of the ATLAS Collaboration
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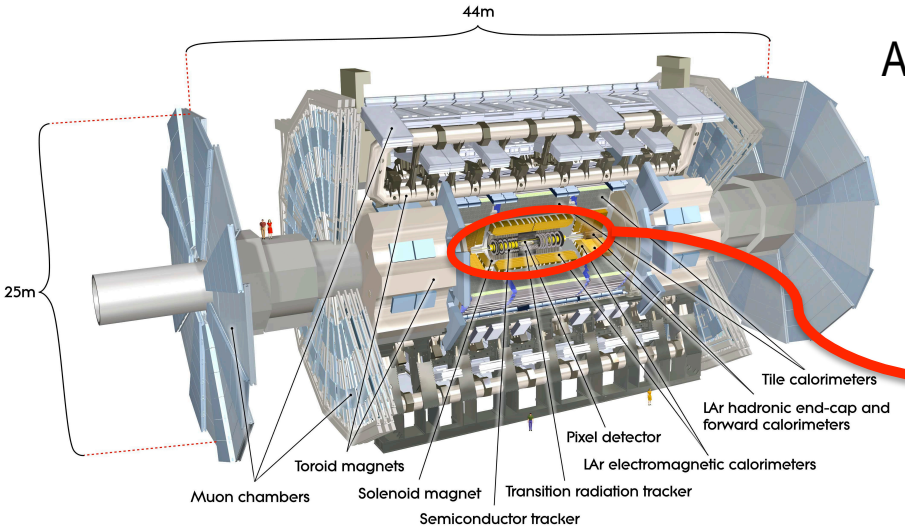
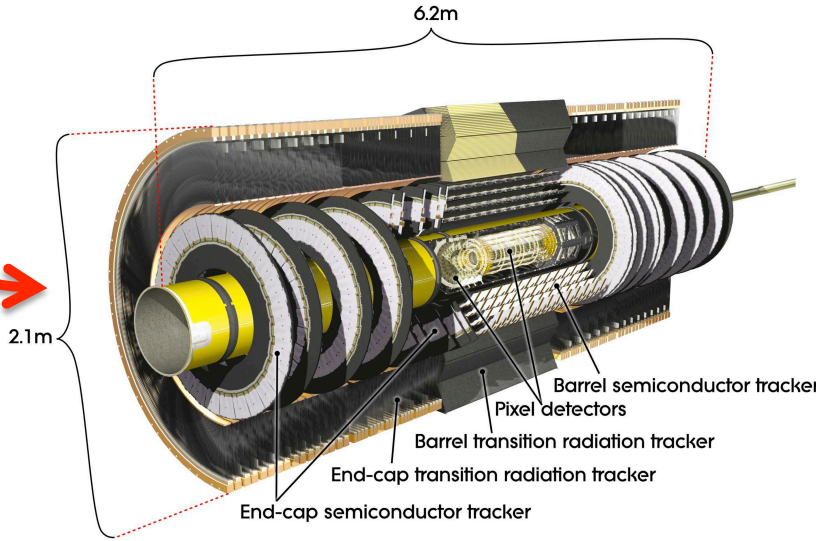
The ATLAS SemiConductor Tracker



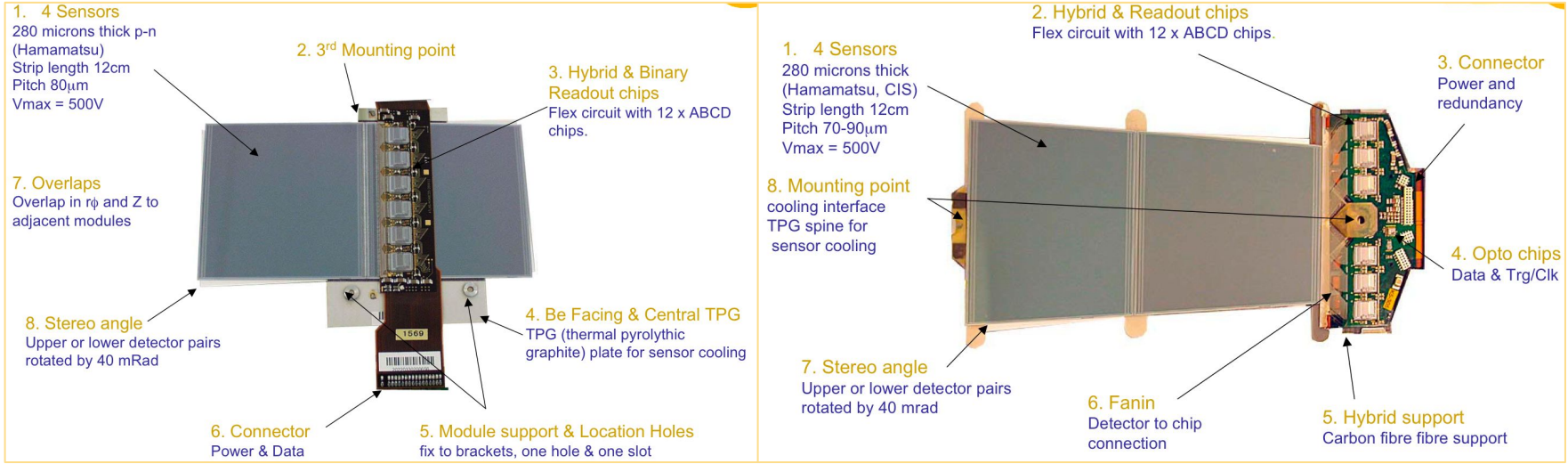
ATLAS Inner Detector = Pixels + SCT + TRT



SCT:

- 61 m^2 of silicon strips: 30cm < R < 52cm, hermetic coverage for $|\eta| < 2.5$
- Immersed in 2-T solenoidal B field
- Barrel: 2112 rectangular modules on 4 layers
- Endcaps: 1976 wedge-shaped modules on 18 disks (9 each end)
  → Tracks with $p_T > 1$ GeV/c pass through at least 4 layers
- Total of 6.3 million readout channels
- Cooled to -7°C with C_3F_8

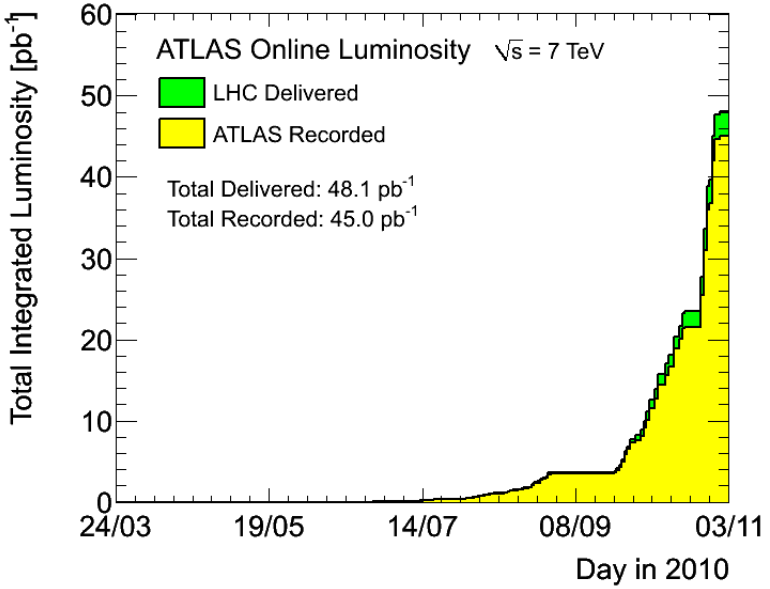
SCT Modules

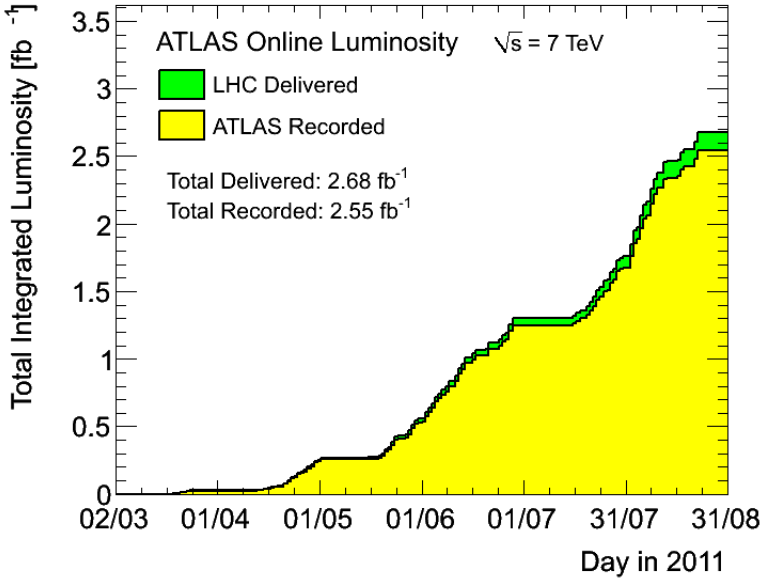


- Back-to-back p-in-n planar sensors, 285μm thick, 40mrad stereo angle
- Glued to thermally-conductive baseboard
- Bias voltage 150-500V (~65V/~85V depletion Hamamatsu/CiS)
- Strip pitch 80μm (barrel), 70-90μm (endcaps – constant phi) → 17μm resolution in bending plane
- Binary readout via ABCD3TA
  - Rad-hard DMILL technology
  - 12 ASICs per module, mounted on Cu-kapton flex hybrid
- Optical communication with off-detector readout electronics:
  - 1 TX (clock/command) fibre, 2 RX (data) fibres per module
  - Redundancy between neighbor modules.
- 4 types of endcap modules for hermetic coverage of disks

Operational History

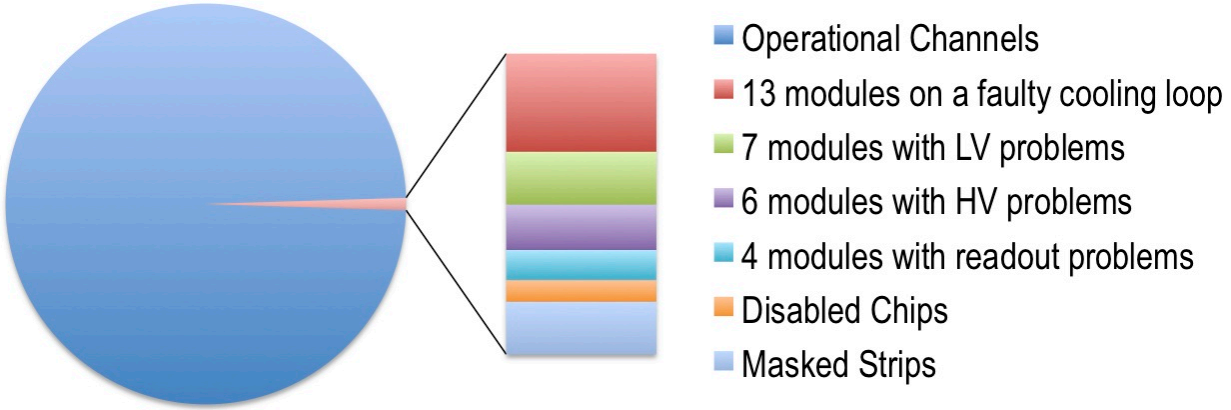
- Commissioned from 2007 with cosmic rays
- First LHC collisions at $\sqrt{s}$ = 900 GeV December 2009
- $\sqrt{s}$ = 7 TeV collisions in March 2010
- Increased LHC luminosity in 2011





SCT Status

- >99% operational channels



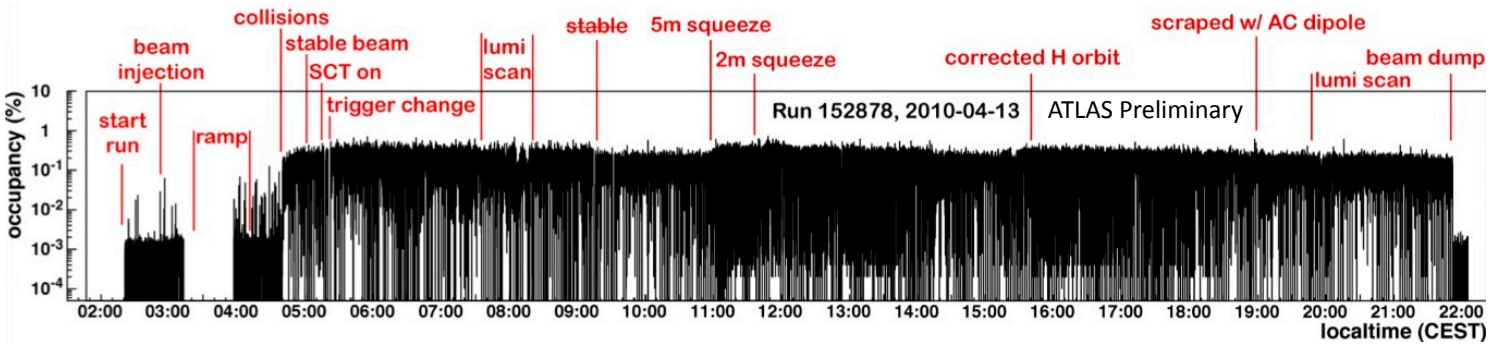
- Stable since 2009
- Operational channels are 99.9% efficient:

Inner Tracking Detectors			Calorimeters				Muon Detectors				Magnets	
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.9	99.9	100	90.0	91.3	94.8	98.2	99.5	99.7	99.9	99.6	99.6	99.4

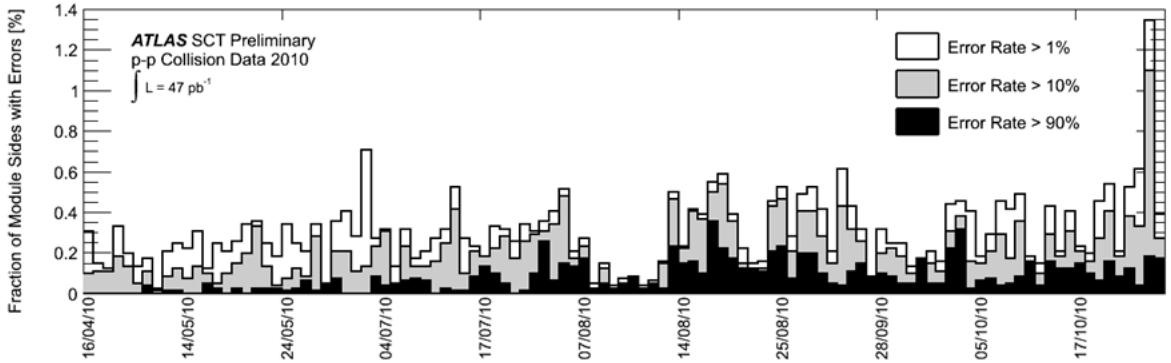
Luminosity weighted relative detector uptime and good quality data delivery during 2011 stable beams in pp collisions at $\sqrt{s}$=7 TeV between March 13th and August 13th (in %). The inefficiencies in the LAr calorimeter will largely be recovered in the future.

SCT DAQ stability

- 'Warm start' procedure:
  - Bias at 50V standby; near depletion so ~fully efficient
  - To nominal (150V) when beams are stable

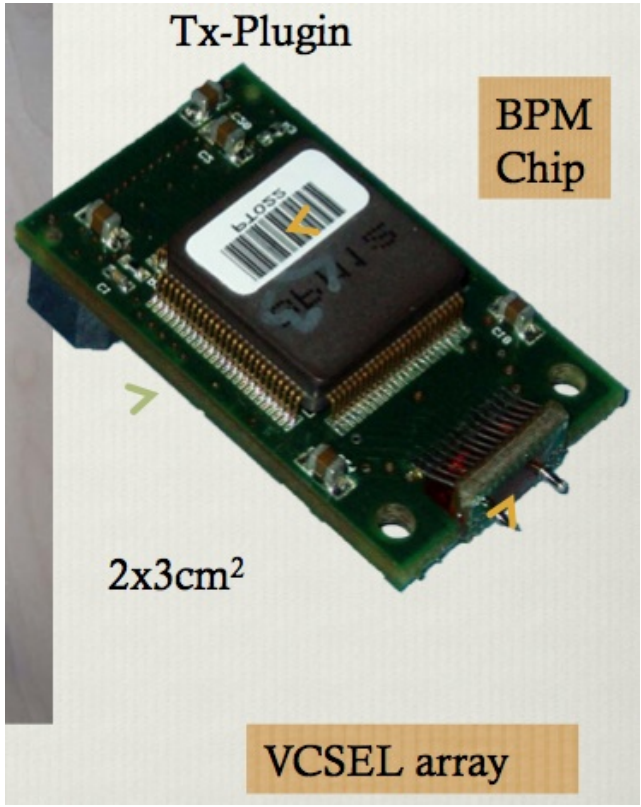


- Consistently low error rates



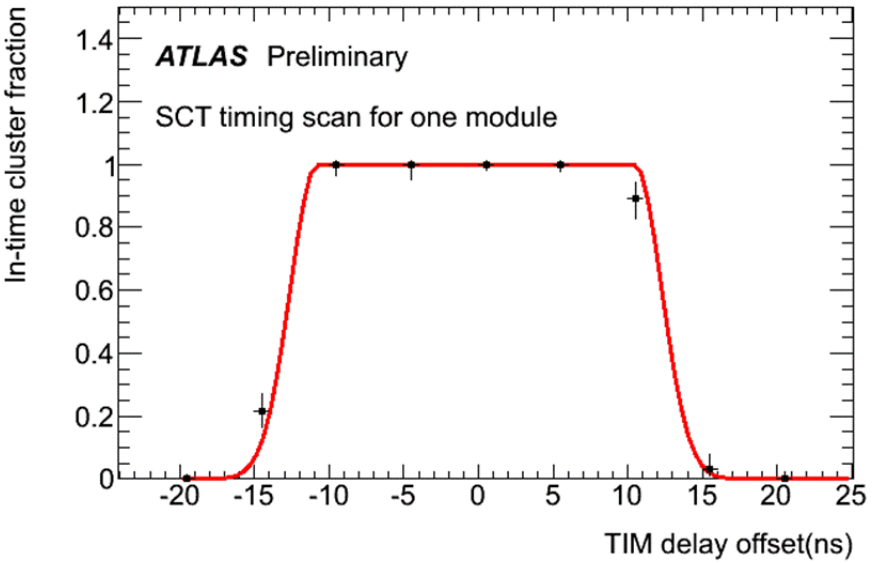
Optical Transmitter Problems

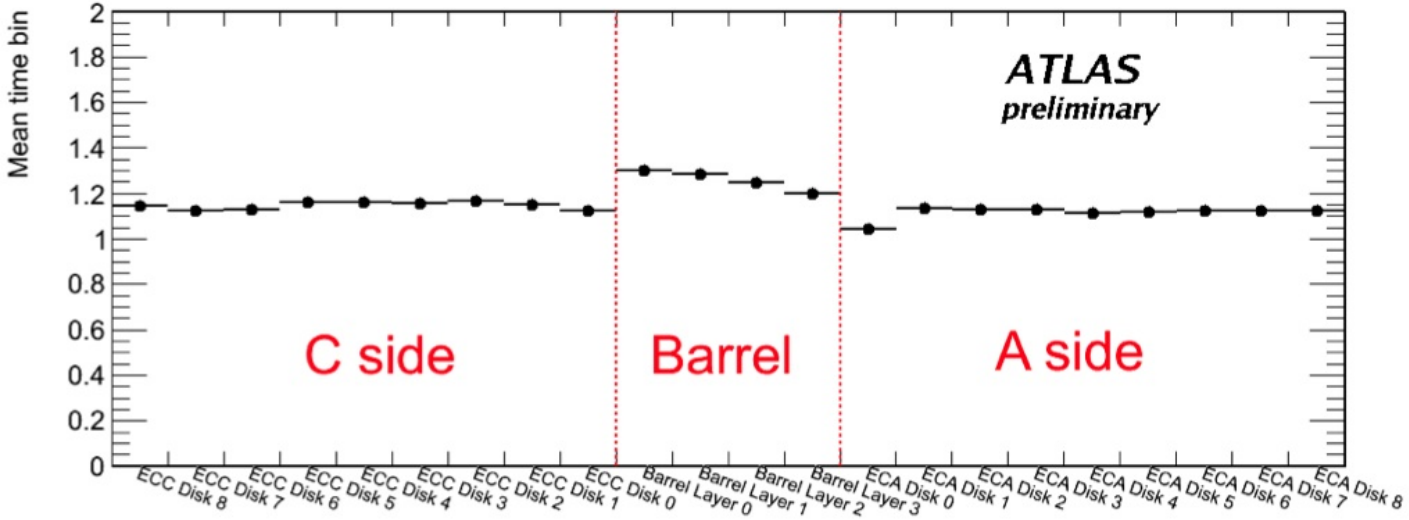
- 'TX plugin' = optical transmitter unit for RODs (off-detector)
  - Holds 12 VCSELs
- In 2008 these VCSELs begin dying
  - ESD damage during manufacture
  - sensitivity to humidity
  - Peak failure rate was ~3/day
- Temporary fixes:
  - Utilise module redundancy
  - Replace plugins with spares
  - Flush crates with dryer air
- Long term fix: replacing plugins with new units with better humidity resistance:
  - 3/8 crates have new units installed
  - Rest will be replaced by end of 2011



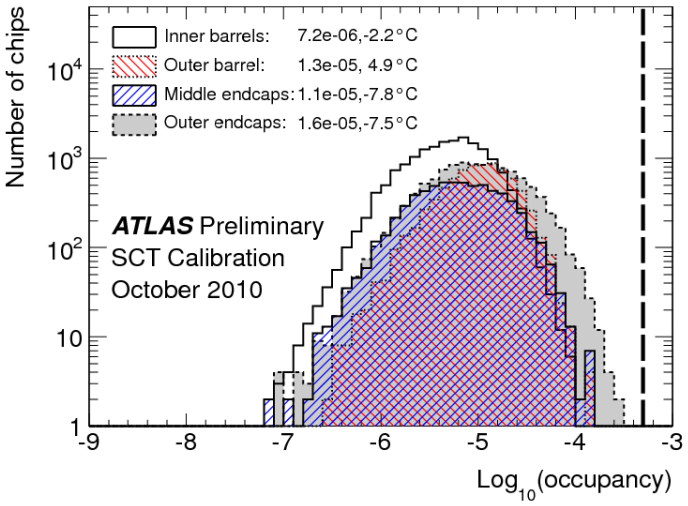
Timing

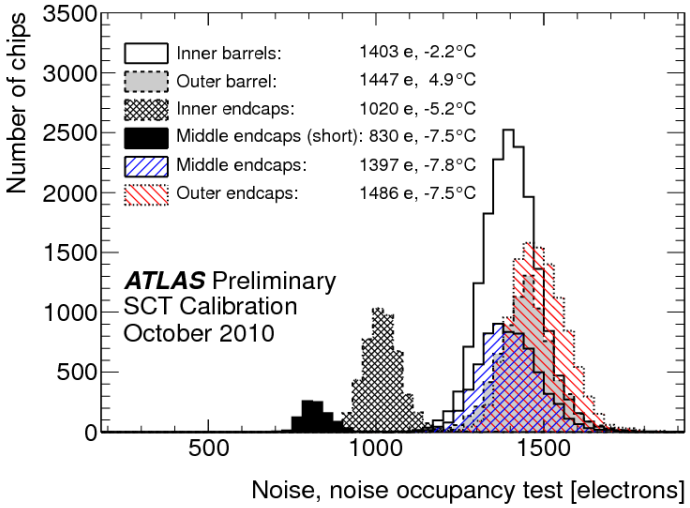
- Three 25ns time bins are read out around the trigger time
- We want the hit to be in the middle bin
  - Early running: "XXX" = accept a hit in any of the 3 bins
  - Now: "X1X" = require a hit in the correct bin
  - Future: "01X"
- Timing scans are done for each module to ensure this
  - Adjustments made for fibre lengths, time-of-flight from IP



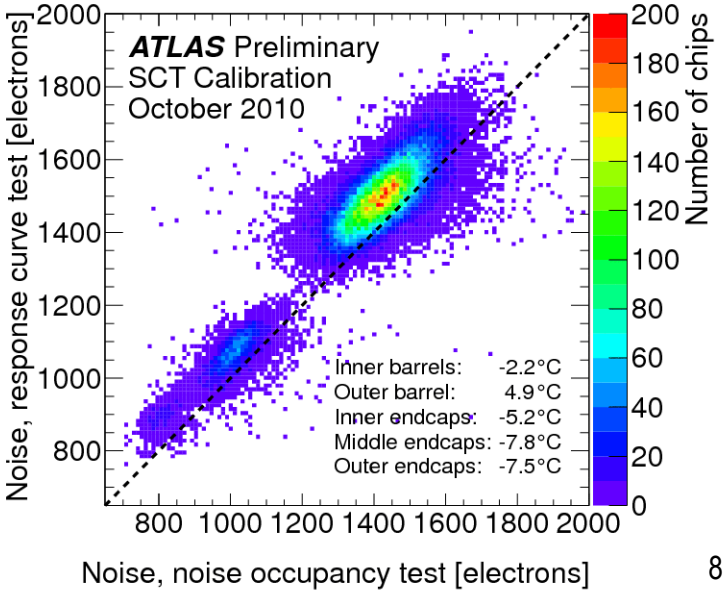


Noise Occupancy

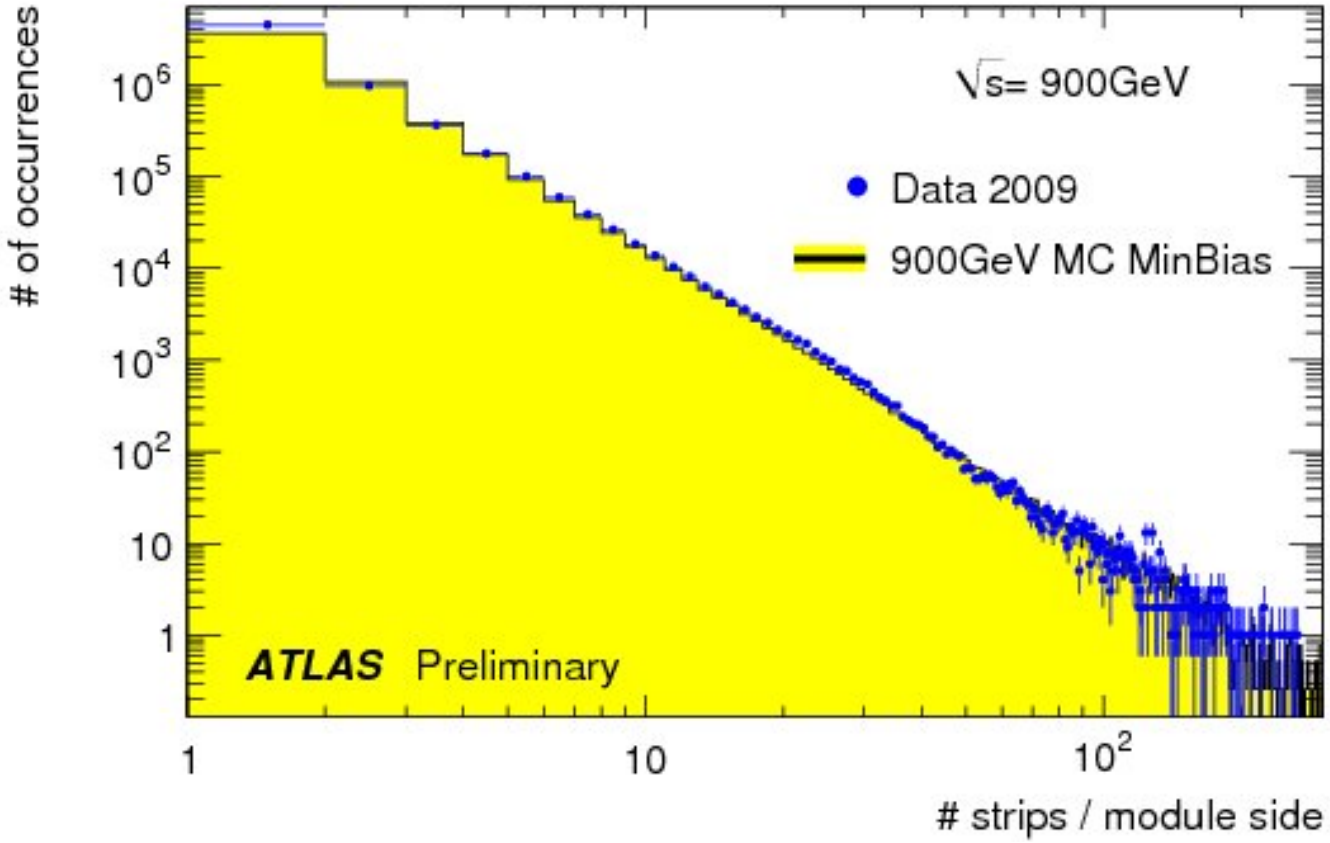




- Noise measured two ways:
  - Calibration pulses injected by the ASIC
    → s-curve fits give measure of noise
  - Measure noise occupancy as a function of threshold
    → Extract input noise
- Results are consistent and below specification:
  Occupancy < 5×10^{-4}, noise < 1500 e-



Strip Occupancy



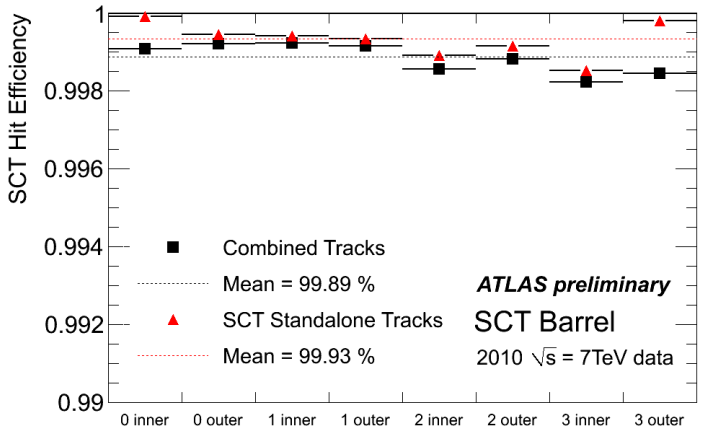
- Plot shows number of strips per module side in a 900-GeV run compared to simulation
- Good agreement MC-data

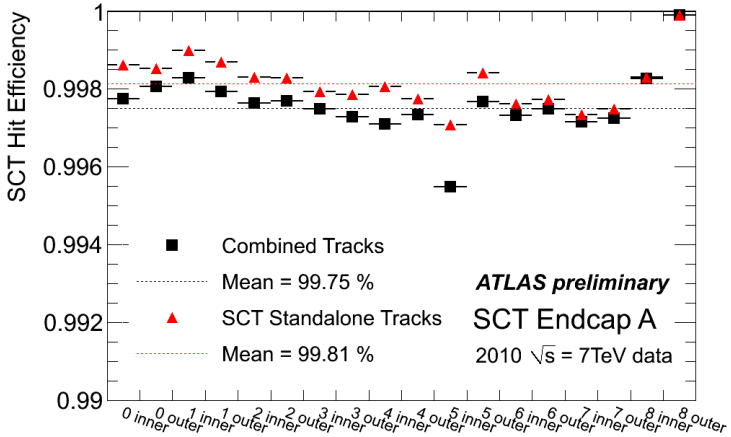
Hit Efficiency from Tracks

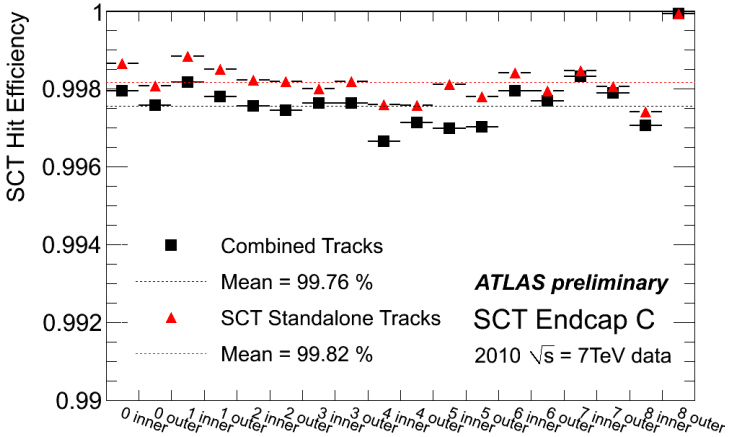
Plots show number of hits / number of possible hits
(dead modules/chips removed)

Track requirements:

- pT > 1 GeV/c
- >7 SCT hits for standalone tracks
- >6 SCT hits for combined tracks





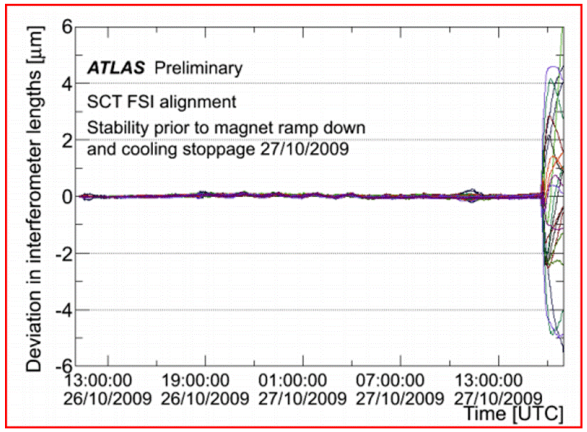


Much better than specification of > 99 %

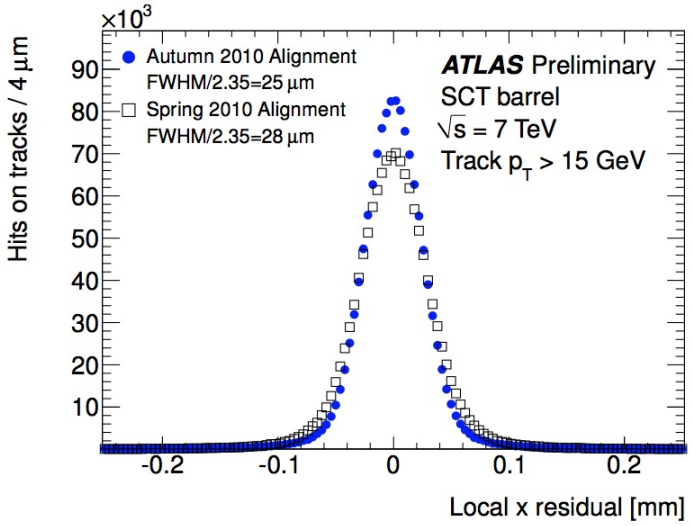
Mechanical Stability and Alignment

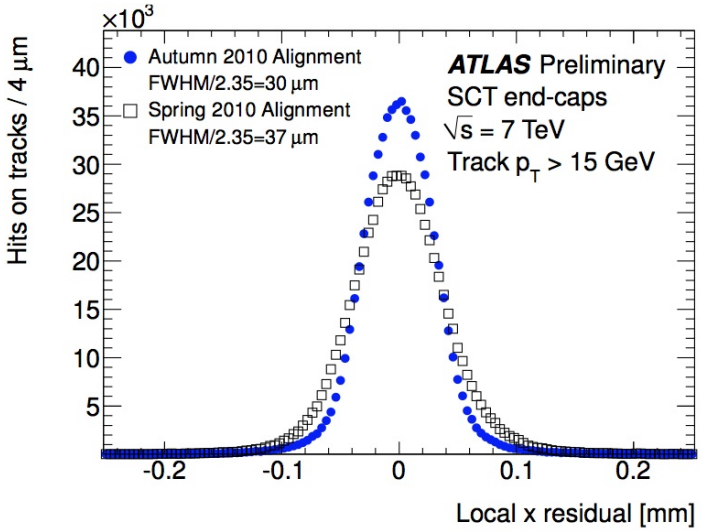
Frequency Scanning Interferometry shows:

- Stability to << 1 μm during runs
- Shifts of 3-5 μm during e.g. temperature, B-field changes



χ^2 minimisation of track-to-hit residuals:



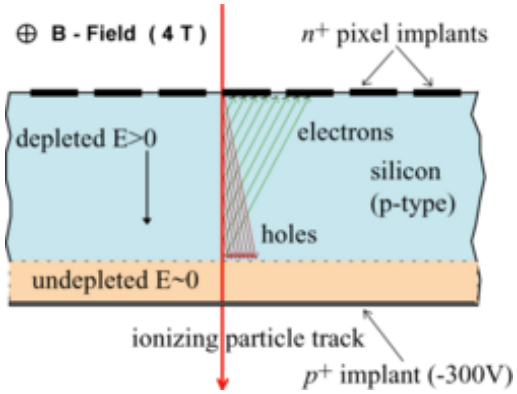


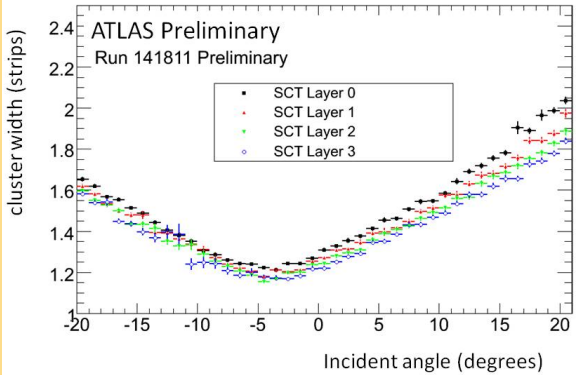
- Approaching design specification value (e.g. 24μm in barrel)
- Time-dependent studies will become possible with more statistics

Lorentz Angle

Charges moving through a magnetic field experience Lorentz force

→ Drift is at an angle to the electric field

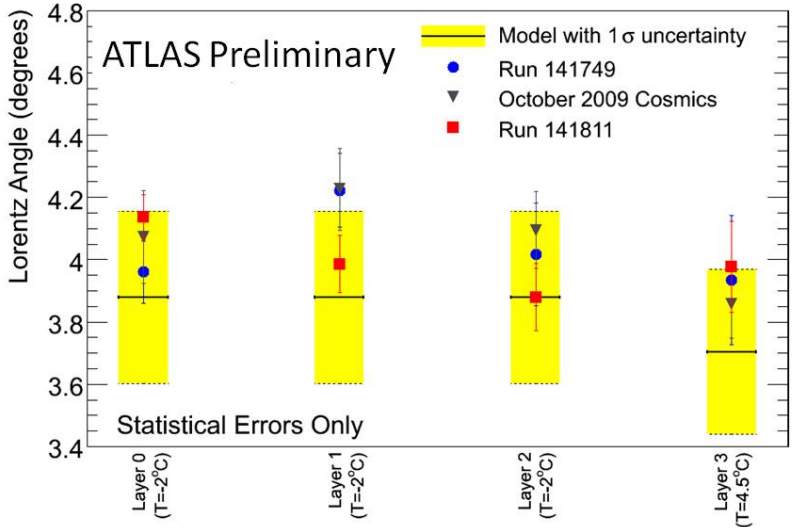




Cluster size is minimised when track-incidence angle equals Lorentz angle

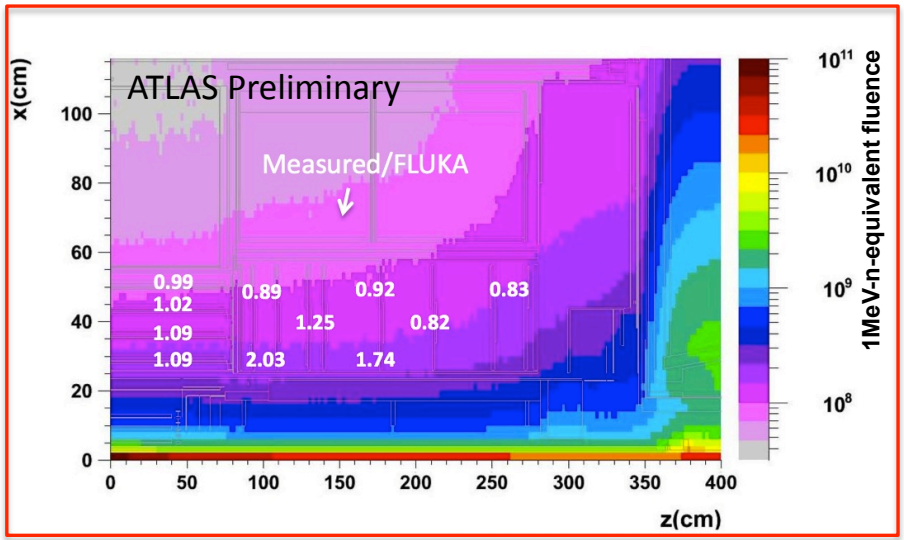
Size of the effect depends upon

- Magnetic field
- Bias voltage
- Temperature
- Radiation damage
  - Long-term monitoring useful



Radiation Damage

Must monitor and understand radiation damage for future

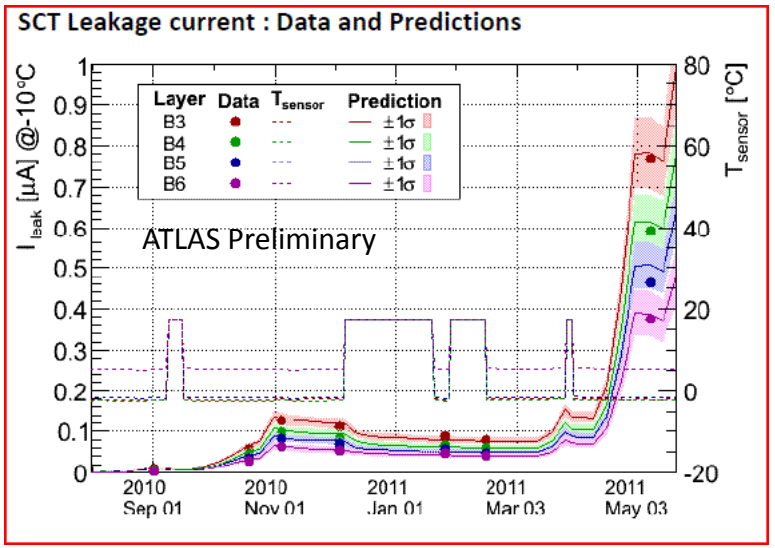


Comparisons with FLUKA predictions:

- Good in barrel region
- Discrepancies in low-R forward region
  - Needs to be understood

Leakage current is a good indicator of radiation damage

- Measurements so far agree well with predictions



Summary

- ATLAS SCT is running very well:
  - Stable
  - Within design specifications
  - Very low inefficiencies.
- Problems encountered with optical readout
  - Spares and redundancy saved us!
- Radiation damage is being monitored and is in reasonable agreement with expectations.
- Looking forward to continued good performance and lots more data.