ATLAS Silicon Microstrip Tracker Operation and Performance

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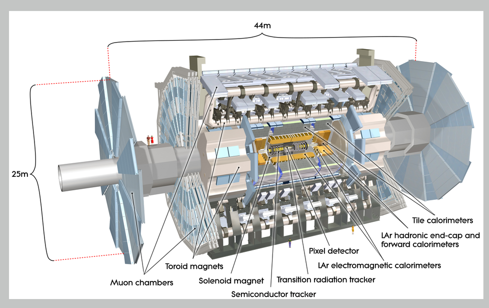
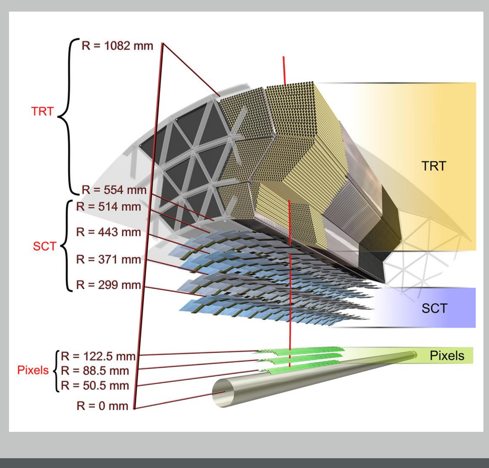
Semi-Conductor Tracker (SCT)

The ATLAS Experiment

ATLAS is one of two general-purpose experiments at the Large Hadron Collider (LHC) at CERN. The detector layout consists of an Inner Detector (ID), Calorimeters and a Muon Spectrometer. The ID is divided into three sub-detectors inside a 2 T solenoidal magnetic field

- Silicon Pixel detector
- Semi-Conductor Tracker (SCT)
- Transition Radiation Tracker



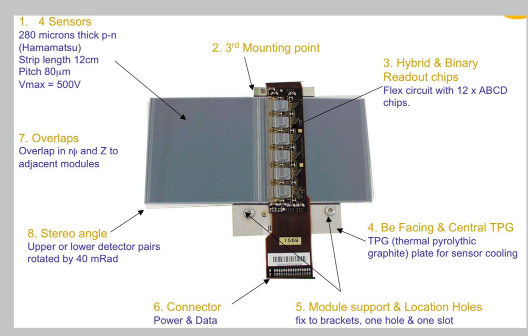


SCT Design

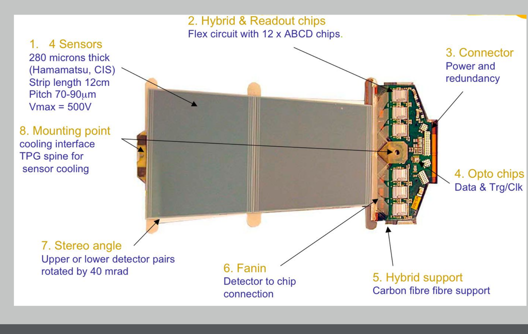
The SCT consists of

- 6.3 million silicon strip channels operated at $-8°$C
- 1536 channels per module (768 on each side)
- 4088 modules
  - 2112 on 4 barrel cylinders
  - 1976 on 18 end-cap disks
- Back-to-back sensors
  - glued to highly thermally conductive substrates for mechanical/thermal stability
  - with a 40 mrad stereo angle between the strips

- Barrel modules



- End-cap modules



Module Specifications

- Binary readout mode
- Optical communication with off-detector electronics
- 5.6W/module (rising to $\sim$ 10W after 10 years LHC)
- Resolution: $r\phi \sim 16\mu$m (bending plane), $z \sim 580\mu$m
- Noise occupancy $< 5 \cdot 10^{-4}$ or $<$ 1500 electrons
- Maximum 1% of non-operational strips
- Hit threshold 1 fC

ATLAS Data Taking

- In 2010 the LHC delivered 47 pb^{-1} and in 2011 5.6 fb^{-1} integrated luminosity of proton-proton collision data at 7 TeV
- During this period the SCT has provided vital tracking information used by almost every analysis in ATLAS
- In stable beam collisions, the SCT recorded good quality data in 99.9% of the luminosity during 2010 and 99.6% during 2011

ATLAS 2011 p–p run

Inner Tracking			Calorimeters				Muon Detectors				Magnets	
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.8	99.6	99.2	97.5	99.2	99.5	99.2	99.4	98.8	99.4	99.1	99.8	99.3

Luminosity weighted relative detector uptime and good quality data delivery during 2011 stable beams in pp collisions at √s=7 TeV between March 13th and October 30th (in %), after the summer 2011 reprocessing campaign

Operation and Performance

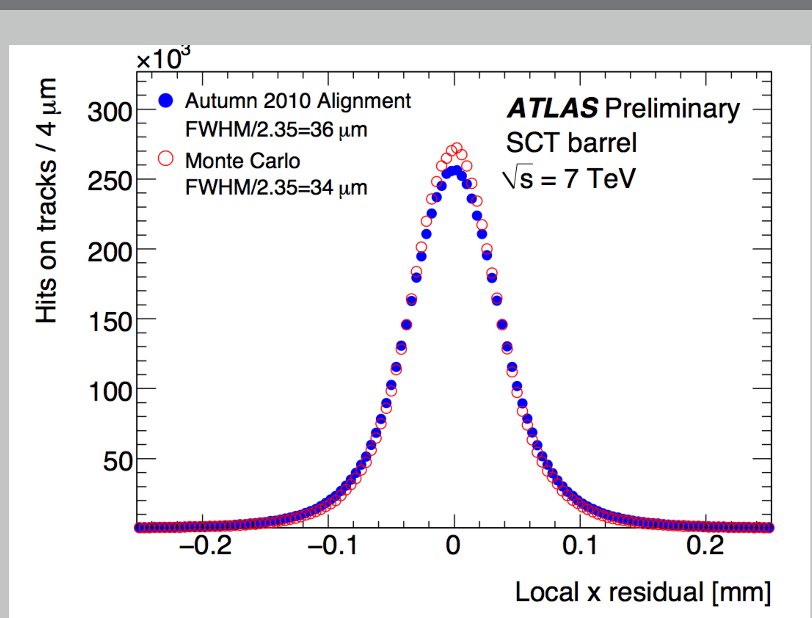
Alignment

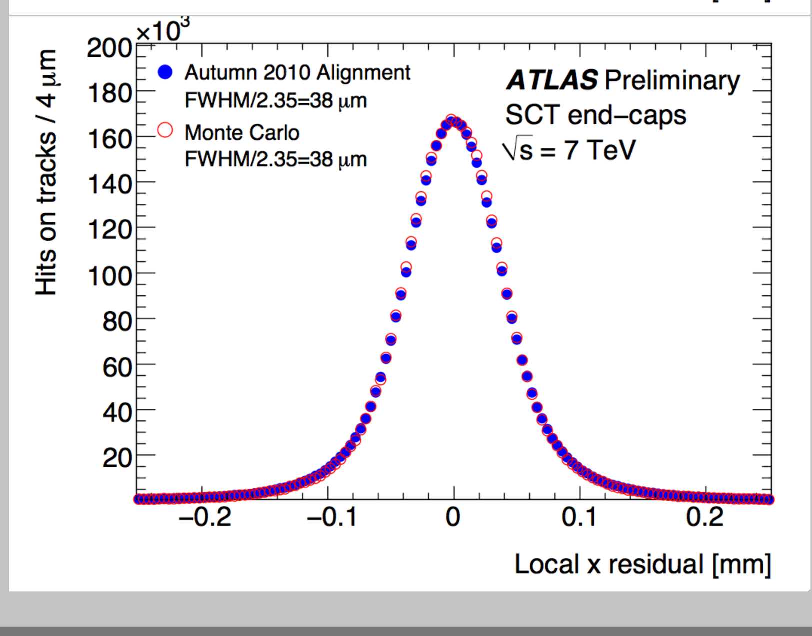
- The alignment of the SCT modules is based on χ^2 of fitted tracks using hits in the Pixel, SCT and TRT detector
  - Using reconstructed tracks with $p_T > 2$ GeV from minimum bias events
- The residuals in the local x coordinate are derived as the distance from the measured point to the track extrapolation
- The alignment is constantly improving with time

Time variation of residuals

	Barrel	End-cap
May 2010	42μm	44μm
Oct 2010	36μm	38μm
Ideal	34μm	38μm

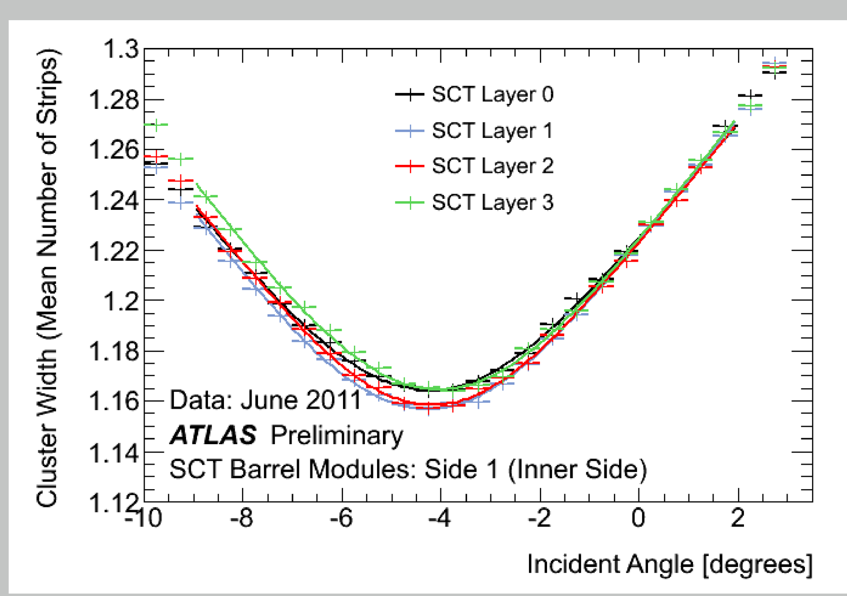
- The residuals for both end-cap and barrel modules obtained from data in Autumn 2010 are in excellent agreement with simulations of a perfectly aligned detector

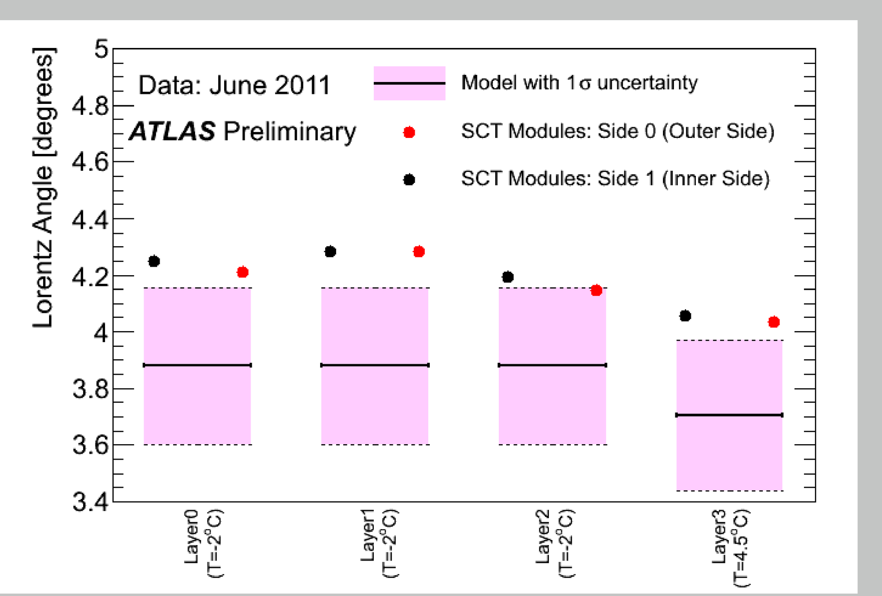




Lorentz Angle

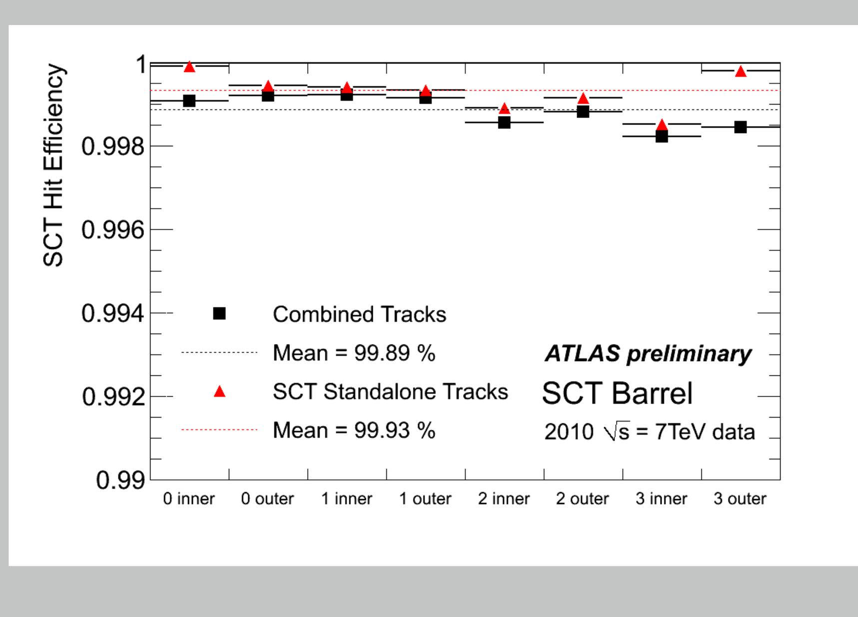
- The Lorentz force affects the drift direction of the charge carriers
- Lorentz angle depends on both the magnetic field strength, module temperatures and bias voltage.
  - Hence important to monitor for SCT operation
- Extracted from minimum of cluster size vs. track incident angle
- Model prediction sensitive to digitisation used in the simulation
- Measurements from both cosmics and collision data are consistent with simulations

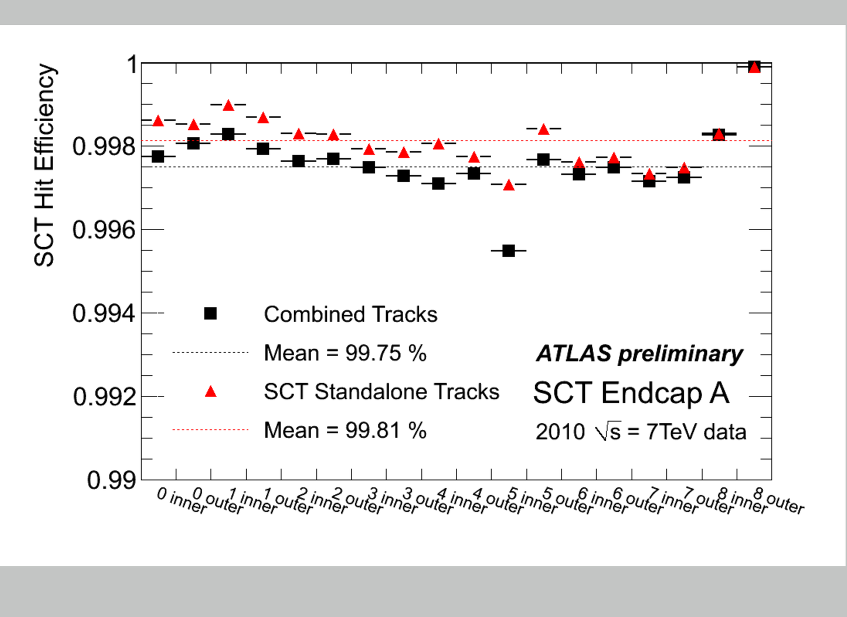




Hit Efficiency

- The intrinsic hit efficiency is measured as the number of hits-on-track per possible hit
  - For both SCT standalone and ID combined tracks
- Only used tracks with
  - $p_T > 1$ GeV/c
  - $\geq$ 7 hits for SCT standalone
  - $\geq$ 6 hits for ID combined
- For both types of tracks, the hit efficiency is well above design criteria of 99% in both barrel and end-caps
- For the SCT standalone tracks, the efficiencies for the innermost and outermost layer are biased as holes before the first measurement or beyond the last are not counted which leads to an artificially high efficiency





Module Status

- The typical configuration of SCT modules with 99.3% of modules in operation
- Only $\sim$30 modules missing because of
  - Leaking cooling loop in end-cap C
  - A variety of HV and LV errors
  - Unexpected failures of off-detector optical transmitters (Tx plugins)

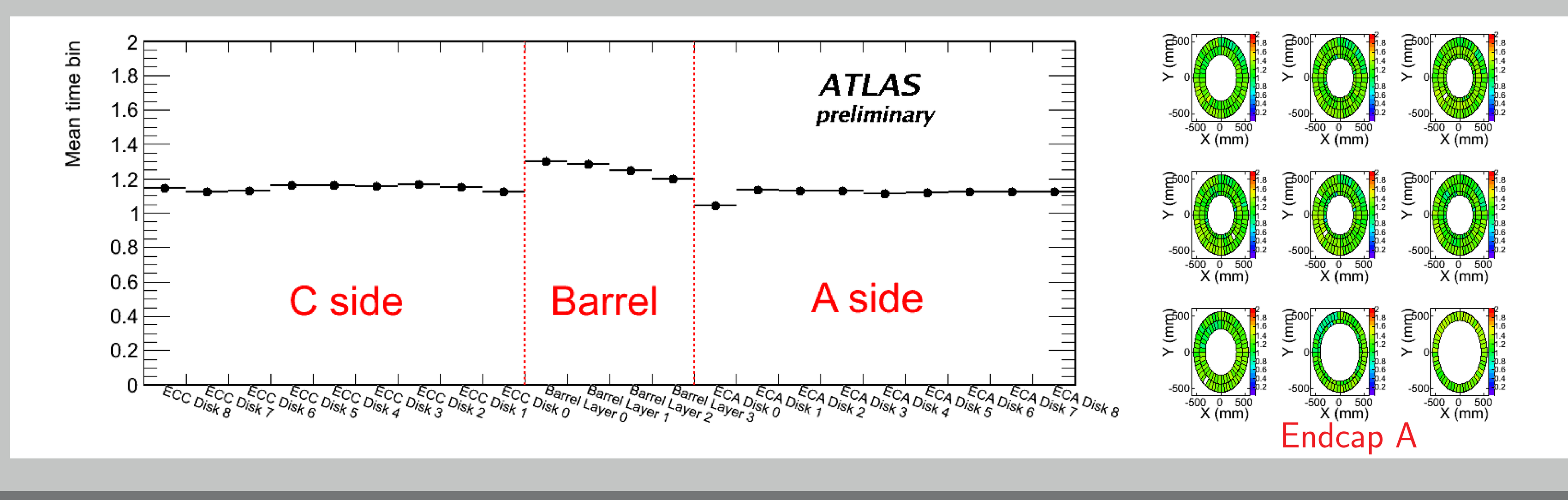
Table 1

ATLAS SCT Configuration May 2010

Disabled Readout Components	Endcap A	Barrel	Endcap C	SCT	Fraction (%)
Disabled Modules	5	10	15	30	0.73
Disabled Chips	5	24	4	33	0.07
Masked Strips	3,364	3,681	3,628	10,673	0.17
Total Disabled Detector Region					0.97

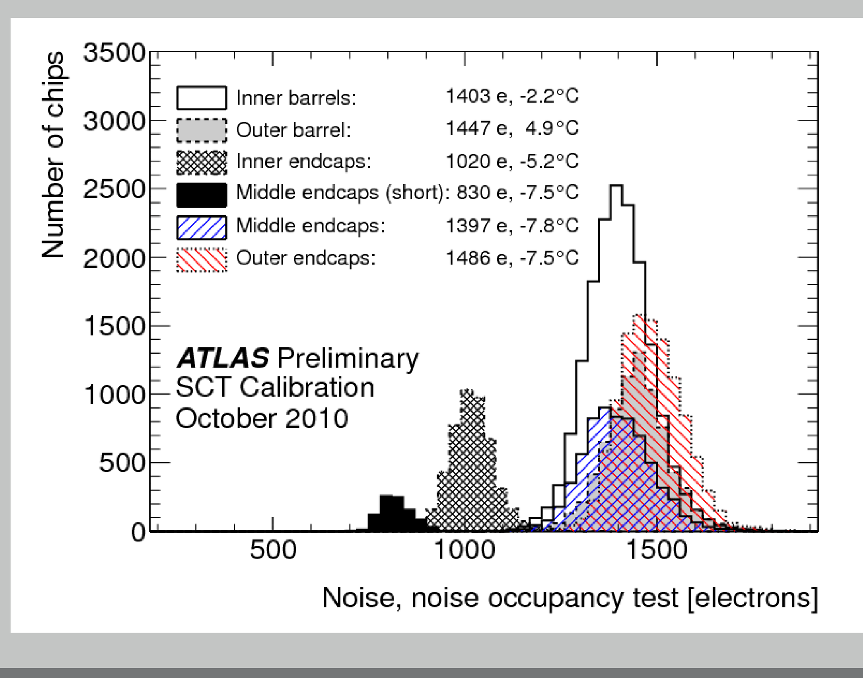
Timing

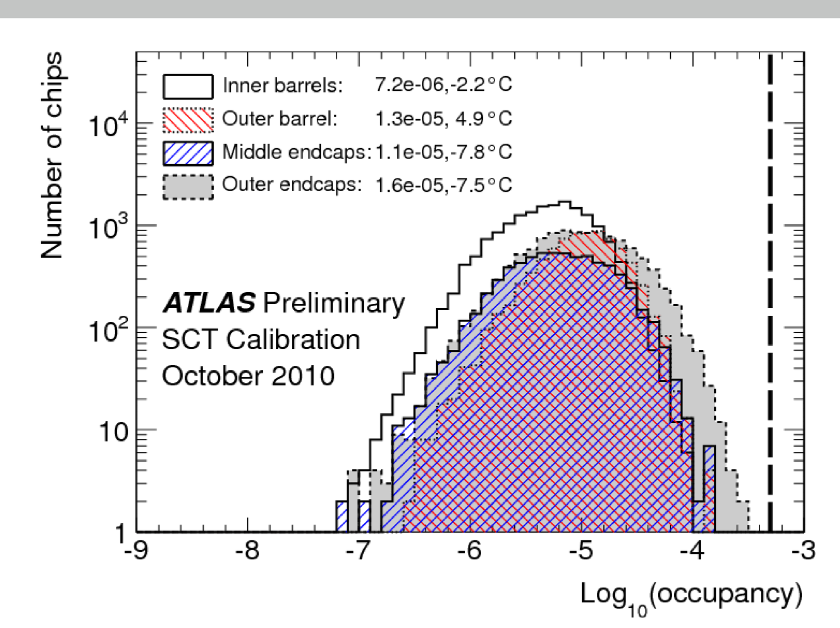
- The SCT read out is done in three 25 ns time bins around the trigger signal
  - Timing of the SCT has to compensate for signal delay due to the length of the optical fibres and for the time-of-flight for particles from the collision to the modules
  - A correctly timed detector should correspond to a 01X hit pattern
- To ensure correct timing, commissioning runs are performed where a hit in any of the three time bins is recorded
  - To measure the timing, the first time bin above the threshold is filled into histograms for all hits-on-tracks
  - For each event, the mean time bin in each SCT layer is stored
  - A perfectly timed detector should give a mean time bin between 1 and 2



Online Calibration

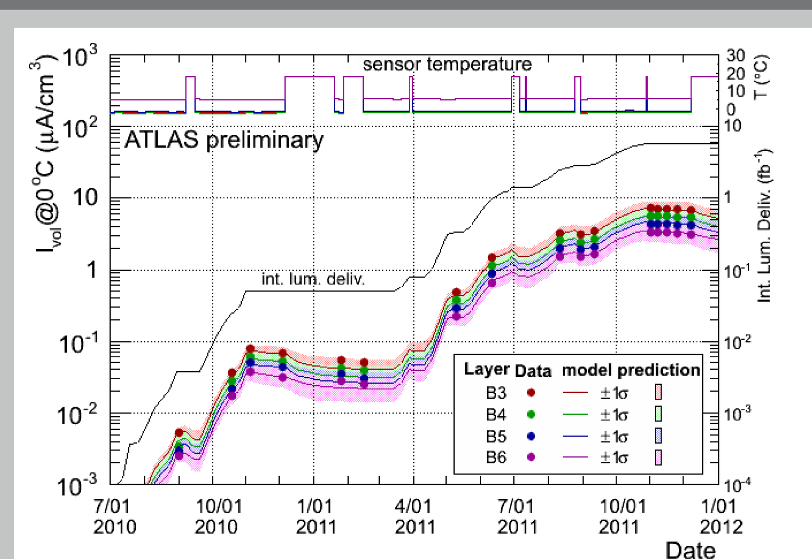
- The SCT online calibration measures the noise level for each chip using two separate methods
  - Response curve test
    - A calibration pulse is injected from the front-end chip
    - Measure hits vs. threshold (S-curve)
    - Obtain noise level from fitting S-curve
  - Noise occupancy test
    - Noise occupancy is defined as fraction of strips with a hit not correlated with activity in the detector
    - Measuring the occupancy in empty bunch crossings
- The two methods give a consistent results of $<$ 1500 electrons or $\sim 10^{-5}$ occupancy
  - Which is well below design criteria





Radiation Damage

- The collisions in ATLAS give rise to radiation which damages sensors and electronics
- The effect is monitored via the module leakage currents, measured in the HV supplies
- The predictions are based on the Hamburg/Dortmund model and simulations of minimum bias events using FLUKA[†]
- Measured and predicted leakage are in good agreement
- Detector needs to be cooled as much as possible to avoid reverse annealing



[†] A. Fasso, A. Ferrari, J. Ranft, and P.R. Sala,CERN-2005-10(2005),INFN/TC.05/11,SLAC-R-773

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