ATLAS Silicon Microstrip Detector Operation and Performance

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ATLAS

ATLAS is one of two large, general-purpose detectors at CERN's Large Hadron Collider (LHC) with the aim of searching for new particles and processes, such as Supersymmetry or the elusive Higgs boson. ATLAS has been designed to be sensitive to as wide a range of potential new physics as possible.

The detector consists of several layers. Starting from the interaction point and moving outwards:

- The Inner Detector, which in turn consists of
 - The Pixel detector
 - The Semi-Conductor Tracker (SCT)
 - The Transition Radiation Tracker (TRT)
- The Electromagnetic Liquid Argon Calorimeter
- The Hadronic Tile Calorimeter
- The Muon Spectrometer

After years of installation, commissioning and data-taking with cosmics, we are finally **taking real collision data!**

Collisions at the LHC:

23/11/2009: First collisions at the LHC (900 GeV)

8/12/2009: Collisions at 2.36 TeV (world record)

30/3/2010: Collisions at 7 TeV!

Plan to collect 1 fb⁻¹ in 2010-2011

SCT

The second layer of the Inner Detector, the Semi-Conductor Tracker occupies the region from 30 to 52 cm radially from the interaction point and reaching to ± 2.7 m in the z-direction, providing tracking coverage up to $|\eta|=2.5$. Located inside a 2 T field, provided by a solenoidal magnet, it consists of 4088 p-in-n silicon strip modules (described below), arranged into 4 barrel layers and 9 endcap disks at either end.

Design Requirements:

- Intrinsic strip efficiency > 99 %
- Noise occupancy < $5 \cdot 10^{-4}$ per read-out
- Maximum 1% of strips non-operational

SCT Modules

The SCT modules consist of two pairs of identical single-sided sensors (p strips in n-type Si) glued back-to-back on a thermal pyrolytic graphite (TPG) baseboard, at a 40 mrad angle to provide a two-dimensional position measurement. The baseboard transfers the heat generated by the readout electronics and the sensors to the cooling pipe.

Each pair of sensors is wire-bonded, forming 126 mm long strips.

- 768 strips/side $\rightarrow$ 1536 channels/module
- Typical Depletion Voltage: ~ 60 V
- Operated at 150 V reverse bias

Space-point resolution:

- $\sigma_p \sim 17 \mu\text{m}$ (bending plane)
- z $\sim 580 \mu\text{m}$

Module Readout:

- Strips read out by radiation-hard front-end circuits (ABCD3T)
- 6 read-out chips/side $\rightarrow$ 128 strips/chip
- Binary readout: strip considered “hit” (1) if signal amplitude higher than predefined threshold (default: 1 fC), else “no hit” (0)

Barrel Module

Endcap Module

Timing

SCT reads out 3 time-bins (25 ns) around the trigger Accept signal. If well timed-in, hits should be in the middle bin (left plot – for three different triggers). The mean of these histograms, for a well timed in detector is a value between 1 and 2 (right plot).

Noise

Noise determined from response curve test (left) and noise occupancy using random triggers (centre). The few strips (<0.2%) with occupancy > $5 \cdot 10^{-4}$ are disabled. Results from the two methods agree well (right)

SCT Status

ATLAS SCT Configuration May 2010

Disabled Readout Components	Number	%
Disabled Modules	30	0.73
Disabled Chips	33	0.07
Masked Strips	10673	0.17
Total Disabled Detector Region		0.97

details $\rightarrow$

Disabled Modules Details May 2010

	Number	%
Total	30	0.73
Fraction (%)	0.7	
Cooling	13	0.32
LV	7	0.17
HV	6	0.15
Readout	4	0.1

99.03% of the detector is ON!

All 13 on one leaking cooling loop

Intrinsic Silicon Strip Efficiency

Number of hits per possible hit. Disabled modules and chips taken into account. Efficiency for two types of tracks shown: SCT stand-alone and combined Inner Detector tracks.

Efficiency $\sim 99.8\%$: Higher than requirements!

Lorentz Angle Measurement

Lorentz angle: Angle by which charges in a silicon sensor drift, due to the magnetic field. Can be obtained by determining the track incidence angle yielding the minimum average cluster width (distribution on left plot). Results within 1 σ of model prediction (right plot)

Occupancy

Number of hit strips per module side. A good agreement (over 6 orders of magnitude!) can be seen between data and MC.

The discrepancy in the first bin is understood to be due to the lower levels of noise in the MC simulation: the data is collected over 3 time-bins (see section on Timing), whereas the simulation assumes only one – thus leading to lower noise levels, by approx. a factor of 3.

Alignment

Unbiased residual distribution in x, for MC perfect alignment (red) and 7 TeV collision data using current best alignment (blue). Residual defined as measured hit position minus expected hit position from track extrapolation.

Conclusions

The SCT is operating smoothly and successfully, collecting 7 TeV collision data at the LHC and contributing to the first physics results. It is performing excellently, achieving and surpassing the design requirements, with **more than 99% of the detector being fully functional**, an **intrinsic hit efficiency of $\sim 99.8\%$** and a typical **noise occupancy well below $5 \cdot 10^{-4}$** . Measurement of quantities such as the occupancy or the Lorentz angle demonstrate the **understanding of the detector**, and allow the **fine-tuning of its MC simulation**. Finally, combination of the information from cosmics and collisions has **allowed the alignment to already start approaching the ideal**.

References / More Information

- ATLAS Collaboration, G. Aad et. al., *The ATLAS Experiment at the CERN Large Hadron Collider*, JINST 3 (2008) S08003.
- <https://twiki.cern.ch/twiki/bin/view/Atlas/SCTPublicResults>
- <https://twiki.cern.ch/twiki/bin/view/Atlas/InnerDetPublicResults>