ATLAS Silicon Tracker operation and performance

Urban Bitenc
Freiburg University
on behalf of the ATLAS SCT Collaboration

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This talk is about **ATLAS SCT**: operation experience, efficiency, occupancy, noise, timing, Lorentz angle, cooling, etc.

It is *not* about tracking, vertexing, alignment, physics results.
(See Giacinto Piacquadio's talk later today.)
ATLAS Inner Detector

Located in $B = 2$ T solenoidal field

Tracking coverage up to $|\eta| = 2.5$

Transition Radiation Tracker

SemiConductor Tracker

Dimensions:
Radial: 30 cm to 52 cm
Longitudinal: -2.7 m to +2.7 m

Pixel detector
**SCT layout**

**Barrel:** 1.5 m long, $|\eta| < 1.1-1.4$, 4 layers, 2112 modules

**Endcaps:** 9 discs, 988 modules, $1.1-1.4 < |\eta| < 2.5$

**Total:** $2112 + 2 \times 988 = 4088$ modules

61 m$^2$ of silicon

U. Bitenc: ATLAS strip detector
SCT Modules

Barrel: 1 layout
Endcap: 3 layouts
- p strips in n-type Si
- pitch: 80 μm (barrel), 57-94 μm (endcap)
- typical depletion voltage: 65 V
- operation: 150 V reverse bias
- currently 5.5 W power per module
  (at the end expected up to 9 W)
- double-sided (40 mrad stereo angle)
- 6 chips per side, 128 channels per chip
→ 4088*2*6*128 = 6,279,168 readout channels

Spacepoint resolution:
- rφ ~17 μm (the bending plane)
- z ~580 μm
SCT module readout

- binary readout: a strip is hit or is not hit (1 or 0)
- operates at LHC bunch crossing frequency - 40 MHz (25 ns)
- front end shaping time of 20 ns
- default threshold: 1 fC
SCT design requirements

- intrinsic strip efficiency > 99%
- noise occupancy < 5\times 10^{-4} per read-out
- maximum 1% strips un-operational
## Status of Active Channels

**Total SCT:** 4088 modules

**Excluded:**
- + 30 modules
- + 33 chips (~2.75 modules)
- + 10,673 strips (~7 modules)

### ATLAS SCT Configuration May 2010

<table>
<thead>
<tr>
<th>Disabled Readout Components</th>
<th>Endcap A</th>
<th>Barrel</th>
<th>Endcap C</th>
<th>SCT</th>
<th>Fraction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disabled Modules</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>30</td>
<td>0.73</td>
</tr>
<tr>
<td>Disabled Chips</td>
<td>5</td>
<td>24</td>
<td>4</td>
<td>33</td>
<td>0.07</td>
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<tr>
<td>Masked Strips</td>
<td>3,364</td>
<td>3,681</td>
<td>3,628</td>
<td>10,673</td>
<td>0.17</td>
</tr>
</tbody>
</table>

**Total Disabled Detector Region**

0.97

### ATLAS SCT Disabled Modules May 2010

<table>
<thead>
<tr>
<th>Fraction (%)</th>
<th>Endcap A</th>
<th>Barrel</th>
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<th>SCT</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>30</td>
<td>0.73</td>
</tr>
<tr>
<td>Cooling</td>
<td>0</td>
<td>0</td>
<td>13</td>
<td>13</td>
<td>0.32</td>
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<tr>
<td>LV</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>7</td>
<td>0.17</td>
</tr>
<tr>
<td>HV</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>0.15</td>
</tr>
<tr>
<td>Readout</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>0.10</td>
</tr>
</tbody>
</table>

All on one leaking cooling loop

99.03% of ATLAS SCT is ON
Taking collision data!

After many years of preparation and commissioning with cosmics finally taking collision data:

- 23.11.09: first 900 GeV collisions, solenoid off
- 6.12.09: 900 GeV collisions, solenoid on
- 30.3.10: 7 TeV collisions

If no stable beam flag → running in stand-by mode (20V)
Lorentz Angle

- Lorentz angle $\theta_L$: Drift angle of holes in magnetic field
- depends on magnetic field and hole mobility
- Fit with
  \[ d(\tan\theta_L - \tan\theta) + \frac{\delta}{\cos\theta} \otimes \text{Gauss}(\theta) \]
  
  $\theta$: particle's incidence angle
- result: $\theta_L \sim 4$ degrees
- consistent between different layers, data taking periods and model prediction

Barrel 0,1,2: $-2^\circ$C
Barrel 3: $+4.5^\circ$C (the TRT needs a higher temperature)
Occupancy

- Average SCT occupancy is very low.
- Number of hits per module side; normalised to the same number of events.
- A very good agreement (over six orders of magnitude) between data and simulation!
- strips with $N > 5 \times 10^{-4}$ are masked (0.17%).

- noise about 1500 $e^-$, well below the typical threshold of $1fC$ (6,240 $e^-$)

- noise occupancy significantly lower than the requirement of $5 \times 10^{-4}$
Noise

- good agreement between the noise determined from:
  - the random trigger test
  - the response curve test
- will increase with irradiation and moving to the edge sensing mode
Intrinsic silicon strip efficiency

- Calculated as number of measured hits / number of expected hits

- Dead modules and chips taken into account (dead strips are not excluded – would count as inefficiency)

- Efficiency: ~99.8% higher than the requirement
Timing

- SCT currently reads out three bunch crossings (25 ns bins)
- Hits should arrive in the middle bin
- Level sensing mode

Mean time bin

C side  Barrel  A side

mean close to 1.0: layers and discs are well timed in
Timing

The mean time bin for individual modules:

Also individual modules are well timed in.
Cooling

- SCT and Pixel detector share the cooling system.
- Very long history of problems from 2005 to 2008.
- Low level problems persist especially with oil-free, 2-stage, leakless compressors.
- 7 compressors in the system, 4 used for the low radiation damage period.
- Future: two possibilities are being studied:
  - a) replace the compressors
  - b) reduce compression ratio by using gravity: take the vapor to the surface, condense it and make use of the hydrostatic pressure of liquid
TDR specification: run SCT at -7°C at the design luminosity

2009: reassessment of cooling requirements and effects of radiation damage

→ Radiation damage ($V_d, I_{LEAK}$) is now expected to be less than predicted at time of TDR.

→ The existing cooling is sufficient to prevent the radiation damage for the foreseeable future.

Current silicon surface temperatures:

- inner three barrel layers: -1.5°C
- the outer barrel layer: 4.5°C
- endcaps: -7°C
Beam background issues

- 2 issues related to significant beam loss incidents:
  - a) voltage potential developed across SiO$_2$
  - b) excess of charge in the front end electronics and services
    - estimated limit: around $10^7$-$10^9$ MIP/cm$^2$ (Minimum Ionizing Particle)
  - BLM protection:
    - internal threshold: $2.5\times10^4$ MIP/cm$^2$
    - 40 μs integration time; all significant accident scenarios are slower (milliseconds)
  - 100% SCT occupancy: 45 MIP/cm$^2$
  - Highest observed occupancy: 30% (~15 MIP/cm$^2$)
Operation, DAQ, DQM

- **Operation:**
  - 1 Atlas Control Room shifter
  - 1 remote (anywhere in the world) DQ shifter
  - N experts on call

- **DAQ:**
  - binary readout, level sensing mode
  - 3 read out bins (bunch crossings)
  - ready to move to 1 read out bin when required

- **DQM:**
  - integrated in the common atlas framework
  - Checking: efficiencies, noise, hit maps, timing, residuals, pulls, ...
G. Piacquadio later today: more about tracking, vertexing, alignment, physics.
Conclusion

- **ATLAS SCT in excellent shape:**
  - more than 99% fully functional
  - 99.8% intrinsic module efficiency
  - low noise
  - well timed in
  - cooling works well
- a very successful period of data taking after restart of LHC
Conclusion

ATLAS SCT proved its excellent performance and contributes to physics measurements.