ATLAS Silicon Microstrip Tracker
Operation and Performance

Vicki Moeller
University of Cambridge
on behalf of the ATLAS Collaboration
TIPP 2011
The ATLAS Detector
ATLAS Semiconductor Tracker (SCT)

- 61 m$^2$ silicon microstrip sensors
- B=2T solenoid
- 6.27 million readout channels
SCT Module Geometry

- 2112 identical **barrel** modules
  - 4 cylindrical layers (0,1,2,3)
  - $|\eta| < 1.4$
- 1976 modules in 2 **endcaps** (A and C)
  - 9 disks per endcap, $|\eta| < 2.5$
  - Inner, Middle, Short Middle and Outer
    - Strip pitch varies 57-94 μm
    - Strip length varies 55-120 mm
SCT Module Specs

- 2 sensor planes glued back-to-back
  - 768 AC-coupled strips per plane
  - 285 μm thick p-in-n strips
  - 80 μm strip pitch in barrel
  - 40 mrad stereo angle between planes
    - 3-D Space Points $r_\phi \sim 16\mu m / Z \sim 580\mu m$

- Binary Readout on p side
  - 150V Bias Voltage (before irradiation)
  - $\sim 65V$ Depletion Voltage
  - 1 fC threshold for ‘hit’
Read Out

• Signals from the strips are processed in 128-channel front-end ASICS

• 12 ABCD3TA chips per module, 6 per side
  – Mounted on a Cu/polyimide flex circuit

• Data is transferred to the off-detector readout electronics via optical fibers
  – One clock and command (TX) fiber per module
  – Two data-readout (RX) fibers per module
SCT Modules Sensor Performance

- Occupancy
  - 900GeV run compared with a 900GeV minimum bias MC sample and solenoid on
  - Good agreement is obtained for a wide range of number of strips
Noise in the SCT

- Measured occ < spec
- Noise measured per chip
  - Response curve test
  - Noise occupancy test
Intrinsic Module Efficiency Barrel

- Hit efficiency = number of hits per possible hit
  - Dead modules and chips are taken into account
  - $p_T$ track $> 1$GeV
- For stand-alone tracks we demand at least 7 SCT hits (not including the hit under test for efficiency)
- For combined tracks at least 6 SCT hits
- Module specification $\geq 99\%$

ATLAS SCT Performance TIPP 2011
06/12/2011
Intrinsic Module Efficiency Endcaps

SCT Hit Efficiency

- **Combined Tracks**
- **SCT Standalone Tracks**

**ATLAS preliminary**

- Mean = 99.75 %
- SCT Endcap A
- Mean = 99.81 %
- 2010 $\sqrt{s} = 7$ TeV data

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Module Errors

• Overall, the error rate is very low
• The total fraction of data with errors in the run period was less than 0.25%
Trigger and Timing

- The SCT reads out 3 25ns time bins (BCs) around LVL1 accept
  - Trigger is delayed to account for length of optical fibers and time of flight from IP
  - Hits should arrive in the middle bin (010 or 011)
  - In 2010 running SCT was in XXX mode
  - In 2011 we have moved to X1X
  - In 25ns operation (compressed mode) we will run 01X
2010 Data-Taking

• In 2010, the SCT was 99.4% efficient in ATLAS data-taking, 99.9% w/o ‘warm start’

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Luminosity weighted relative detector uptime and good quality data delivery during 2010 stable beam in pp collisions at \( \sqrt{s} = 7 \text{ TeV} \) between March 30th and October 31st (in %). The inefficiencies in the LAr calorimeter will partially be recovered in the future.

• Typically, 99.3% of the total of 4088 modules were operational
  • There is a cooling leak on a very forward endcap disk, affecting 13 modules
  • Problems with the off-detector optical system sending clock and control signals to modules (TXs)
  • Some scattered HV/LV line issues
Heating and Cooling Challenges

- SCT ideally cooled to -7° C by C$_3$F$_8$ evaporative cooling to limit sensor radiation damage
- TRT ideal temperature is ~12° C
- Some heating pads used to keep environments isolated failed
- Solution: 3 Inner SCT barrels at -2°C
- Outer SCT Barrel layer acts as thermal shield operated at 4.5° C
TX Saga

• In 2008 and early 2009, we were losing individual TX channels
• Evidence pointed to ESD damage on VCSEL arrays during manufacturing
• New batch of TX plug-ins ordered, with increased ESD precautions
• In Summer 2009 all of the TXs were replaced
• At the end of the summer greater than 99% of the SCT modules were functional
• Unfortunately, TX deaths began again in 2010 operation due to ingress of humidity in the VCSELs
SCT Track-Based Alignment

- Precision alignment allows on-line track reconstruction and invariant mass determination.
  - Residual = Measured hit position – expected position from track extrapolation.
  - Track $p_T > 2$ GeV and more than 6 Si hits.
Conclusions

• In LHC p-p collisions the SCT has been very efficient
• The SCT is operating beyond design expectations
• Humidity-sensitive VCSELs in the optical system and temperamental temperature systems have been some of our biggest challenges
• The SCT is a key precision tracking device in ATLAS and we are taking more and more good physics data every day

• Questions?
Backup
Data Acquisition

• **Back Of Crate Card**
  – Optical interface between crate and modules
  – RX and TX connections

• **Read Out Driver**
  – Generates commands and parses data
  – FPGAs implement data path
  – Communicates via VME backplane
  – Event fragments sent to ATLAS via S-Link

• **Timing Interface Module**
  – Distributes Clock and Triggers from ATLAS central trigger processor
  – Generates counters for event synchronization
  – Vetoes fixed-frequency triggers (lesson learned from Tevatron)

• **SCTApi interfaces with hardware**
  – Produces scans for calibration and monitoring
  – Implements redundancy actions
Optical System

• An opto-package connects to each module
  – Allows communication between the module and the off-detector electronics

• A PIN diode receives encoded timing, trigger and commands signals down the RX line

• The DORIC “master” chip decodes the clock and command signals and sends them to all 12 ABCD chips

• To read out the modules
  – Electrical signals generated by the 2 DORIC chips are converted to optical signals for transmission to the control room by 2 vertical-cavity surface-emitting lasers (VCSEL)
TX Humidity Problem

• Measured spectral width of a number of TXs operating at room temperature in air and nitrogen
  – The samples in air degrade
  – The cause of TX failure is the ingress of humidity beyond a reasonable doubt!
• Plans to install a dry air compressor in ROD racks
• Two new sources of TXs on the way
Powering the SCT

- Each detector module is served by its own independent power supply
- Low voltage (LV) cards supply
  - Detector Module ASICs (ABCD chips)
  - On-detector optical communication components (VPIN and VCSEL)
- High voltage (HV) cards provide
  - Bias voltage (up to 470V) for the module sensors
- 88 power supply crates in 22 racks
  - Each holds 12x 4-channel LV cards and 6x 8-channel HV cards serving up to 48 modules
Evaporative Cooling

- $C_3F_8$ in liquid phase is delivered at room temperature from the condenser to the capillaries located immediately before the detector structures.
- The fluid expands through the capillaries and then remains in saturation conditions (boiling) along the cooling circuit on the detector structure.
- Heaters at the exhaust of the detector structures evaporate the residual liquid and raise the temperature of the vapour above the cavern dew point.
- The fluid in superheated vapour phase is brought back to the compressor and then to the condenser.
- In early 2009, a damaged cable in the cooling system was repaired on disk 1 in endcap C, recovering 23 modules.
Heating and Cooling Challenges (Cont.)

- In May 2008, 3 compressors in the cooling plant malfunctioned due to failure of a magnetic clutch system
  - Solution: Plant repaired and refurbished, slip sensors fitted to magnetic clutches
- Further refurbishment and improvements were carried out in summer 2009
  - To mitigate problems caused by vibration of the compressors
  - Added larger tank for cooling fluid to protect system based on latent heat
Material Budget

**ATLAS Preliminary**

\[ |\eta^{\text{tracks}}| < 1.2 \]

- **Data**
- **Simulation**
- **Fit**

\[ \mu = 497.6 \pm 0.1 \text{ (stat) MeV} \]

\[ \sigma_{\text{core}} = 6.8 \pm 0.1 \text{ (stat) MeV} \]

Minimum Bias Events (\(\sqrt{s} = 900 \text{ GeV}\))

**ATLAS Preliminary**

\[ |\eta^{\text{tracks}}| > 1.2 \text{ or } |\eta^{\text{tracks}}| < -1.2 \]

- **Data**
- **Simulation**
- **Fit**

\[ \mu = 498.2 \pm 0.1 \text{ (stat) MeV} \]

\[ \sigma_{\text{core}} = 10.5 \pm 0.1 \text{ (stat) MeV} \]

Minimum Bias Events (\(\sqrt{s} = 900 \text{ GeV}\))

**ATLAS Preliminary**

- Simulation

**ATLAS Preliminary**

- 20% \(X_0\) sample
- 10% \(X_0\) sample
- nominal

**ATLAS Preliminary**

- Simulation

**Ratio to nominal**

**ATLAS Preliminary**

- 20% \(X_0\) sample
- 10% \(X_0\) sample