ATLAS Silicon Microstrip Tracker Operation and Performance

Vicki Moeller

University of Cambridge

on behalf of the ATLAS Collaboration

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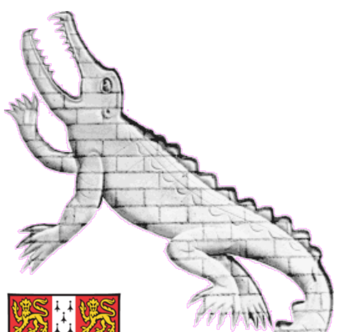
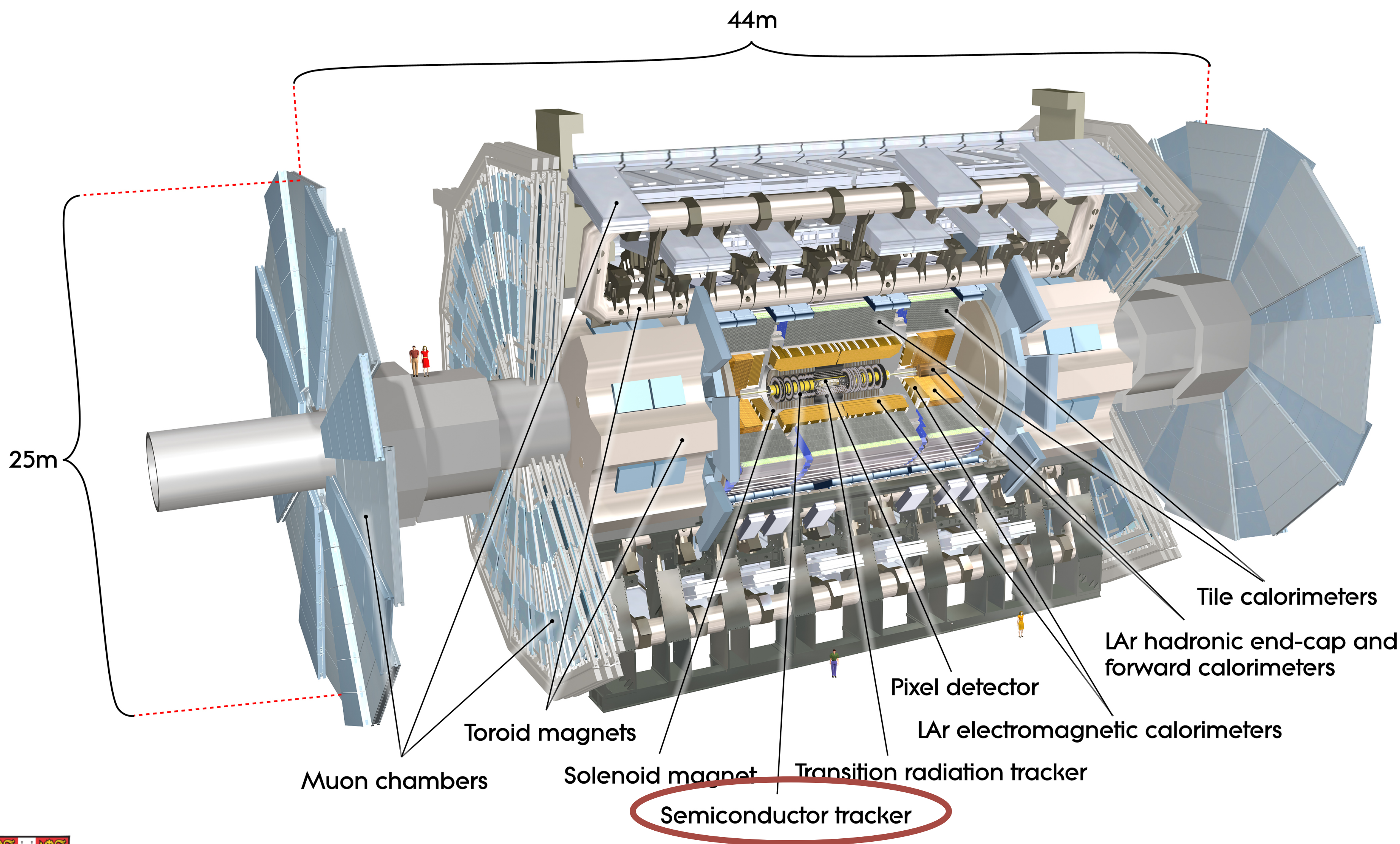
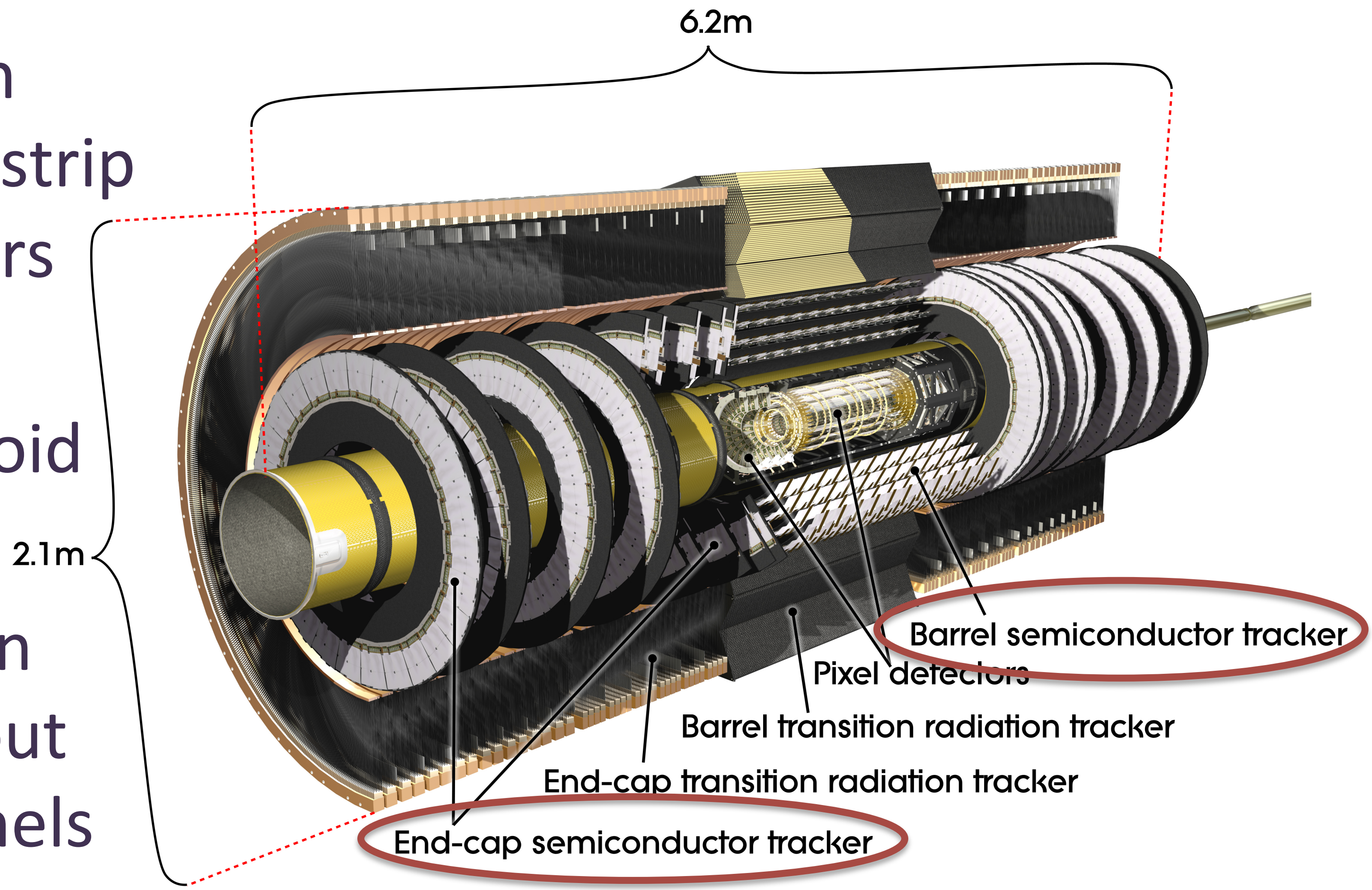


The ATLAS Detector



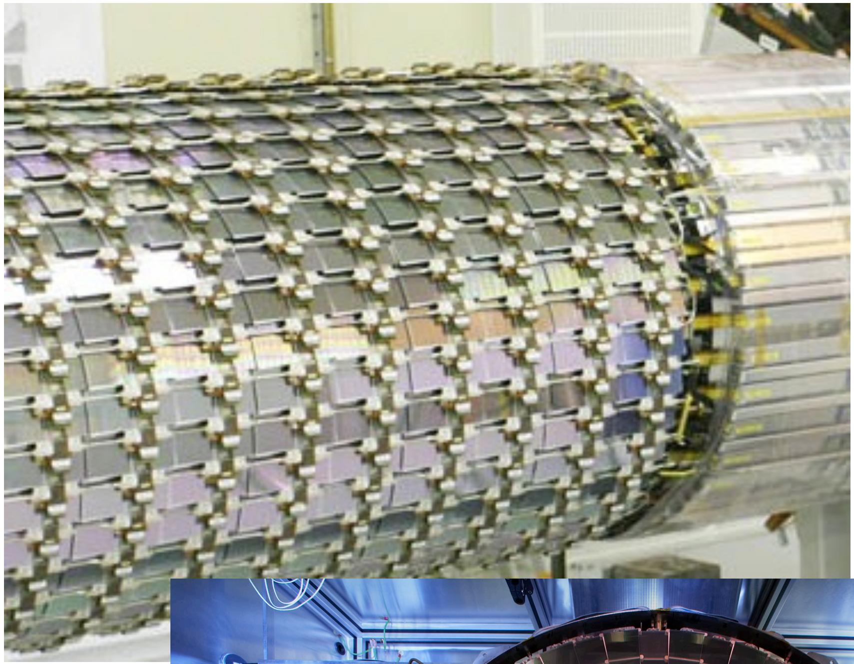
ATLAS Semiconductor Tracker (SCT)

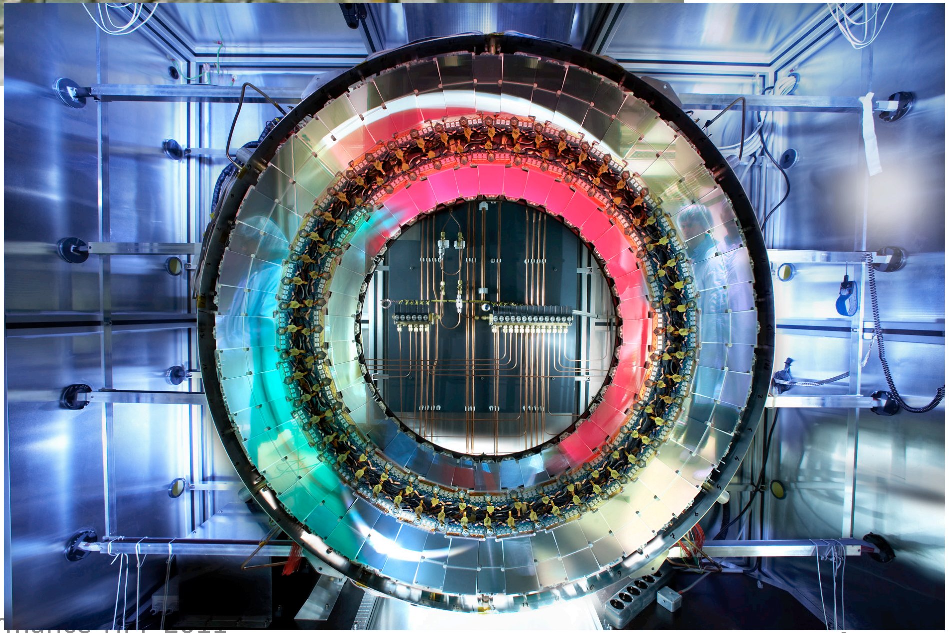
- 61 m^2 silicon microstrip sensors
- B=2T solenoid
- 6.27 million readout channels



SCT Module Geometry

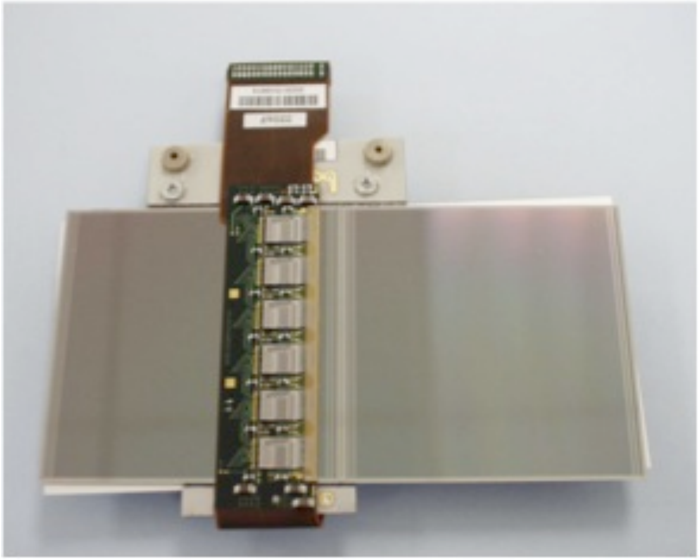
- 2112 identical **barrel** modules
  - 4 cylindrical layers (0,1,2,3)
  - |η| < 1.4
- 1976 modules in 2 **endcaps** (A and C)
  - 9 disks per endcap, |η| < 2.5
  - Inner, Middle, Short Middle and Outer
    - Strip pitch varies 57-94 μm
    - Strip length varies 55-120 mm

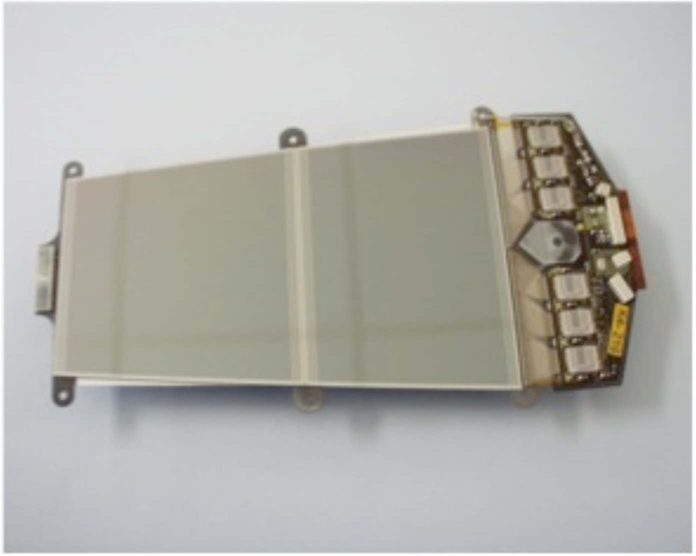


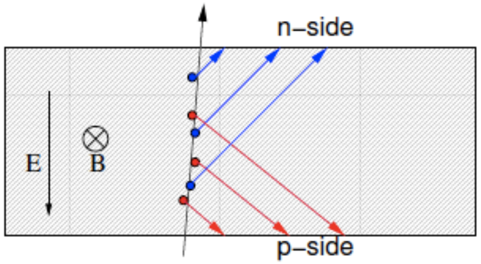


SCT Module Specs

- 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_{Φ}~16µm / Z~580µm
- Binary Readout on p side
  - 150V Bias Voltage (before irradiation)
  - ~65V Depletion Voltage
  - 1 fC threshold for 'hit'

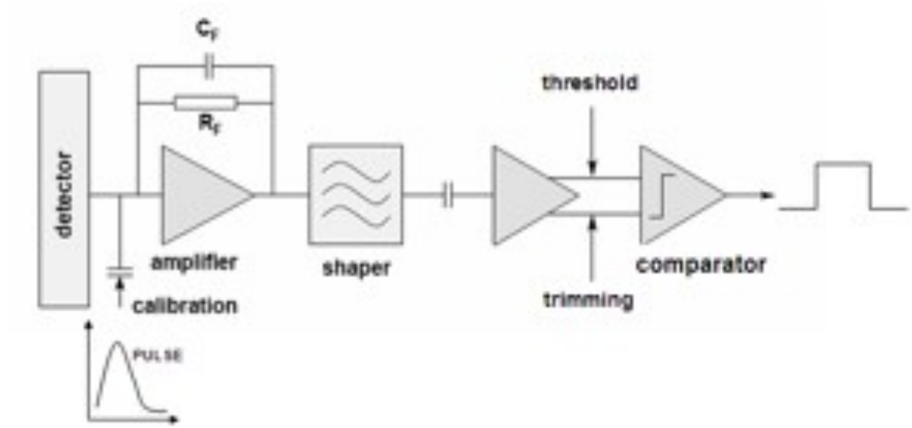






Read Out

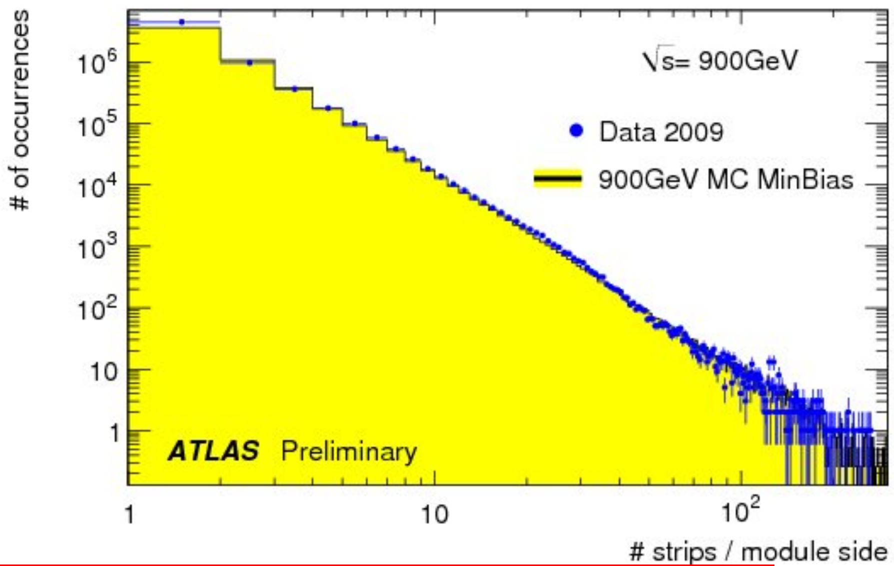
- Signals from the strips are processed in 128-channel front-end ASICS
- 12 ABCD3TA chips per module, 6 per side
  - Mounted on a Cu/polyimide flex circuit

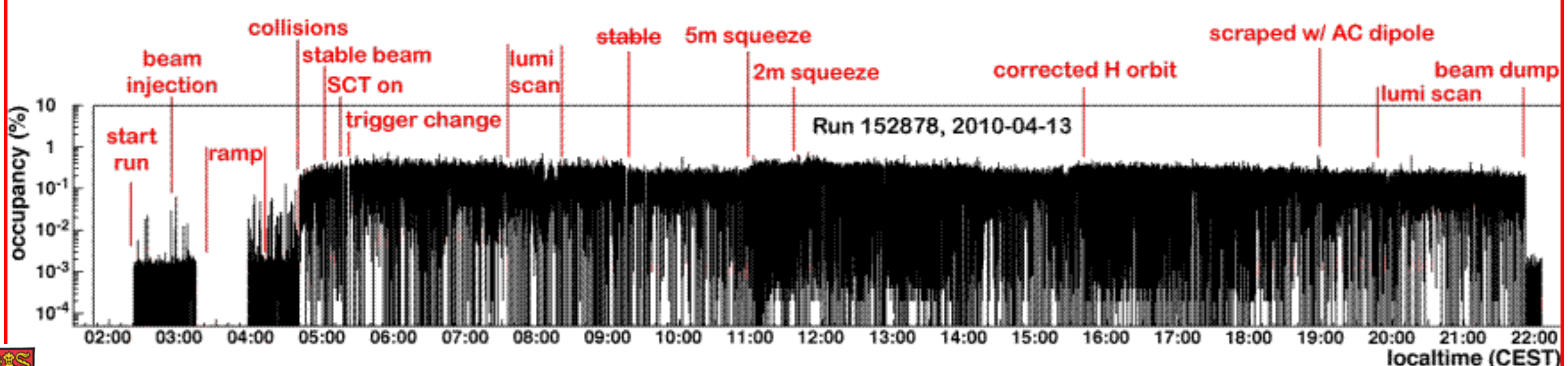


- Data is transferred to the off-detector readout electronics via optical fibers
  - One clock and command (TX) fiber per module
  - Two data-readout (RX) fibers per module

SCT Modules Sensor Performance

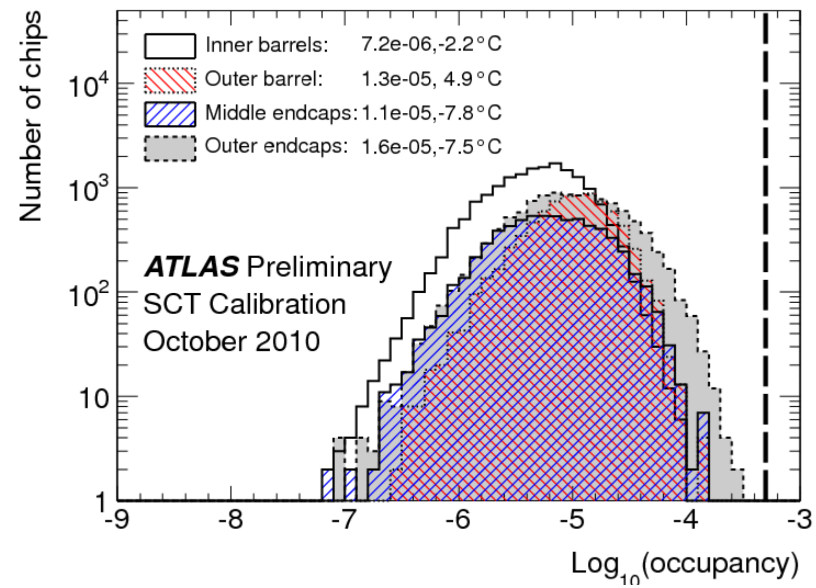
- Occupancy
  - 900GeV run compared with a 900GeV minimum bias MC sample and solenoid on
  - Good agreement is obtained for a wide range of number of strips

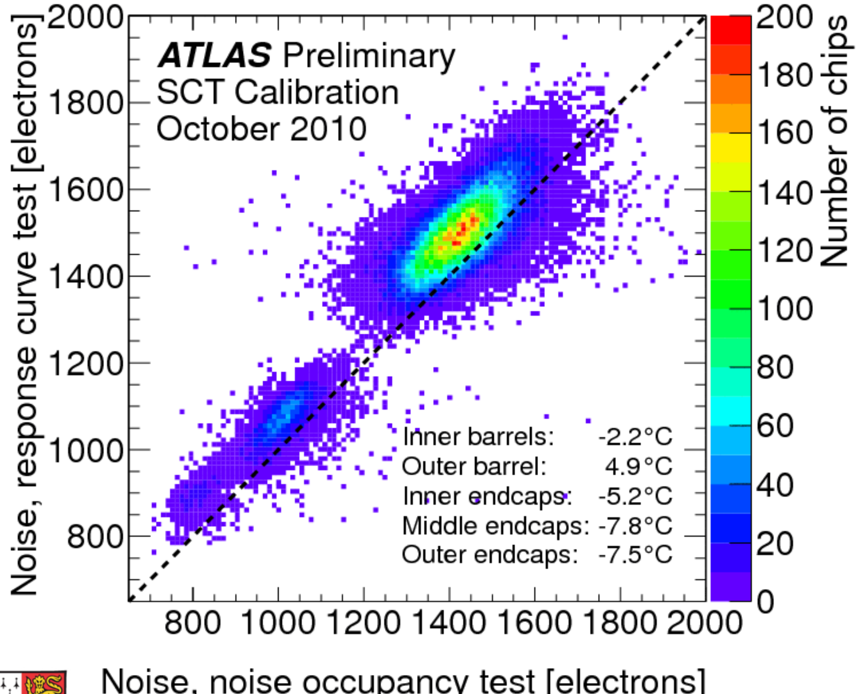


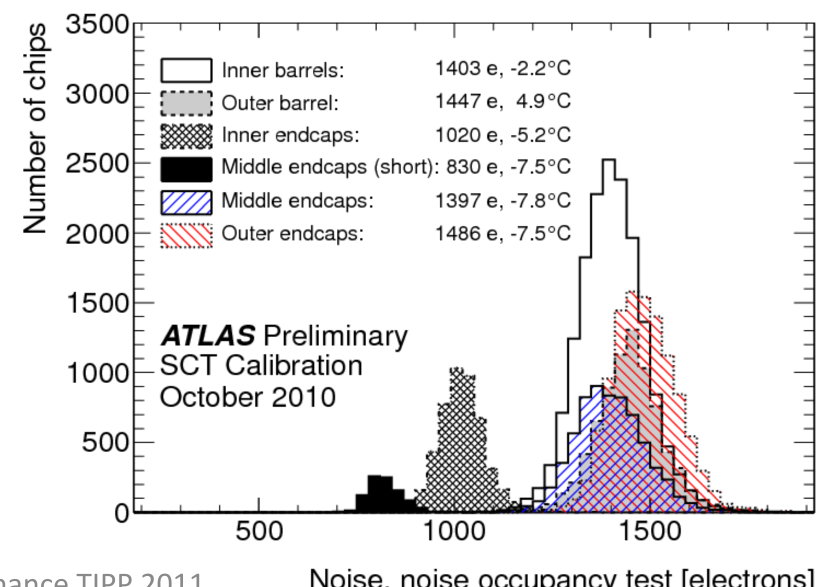


Noise in the SCT

- Measured occ < spec
- Noise measured per chip
  - Response curve test
  - Noise occupancy test

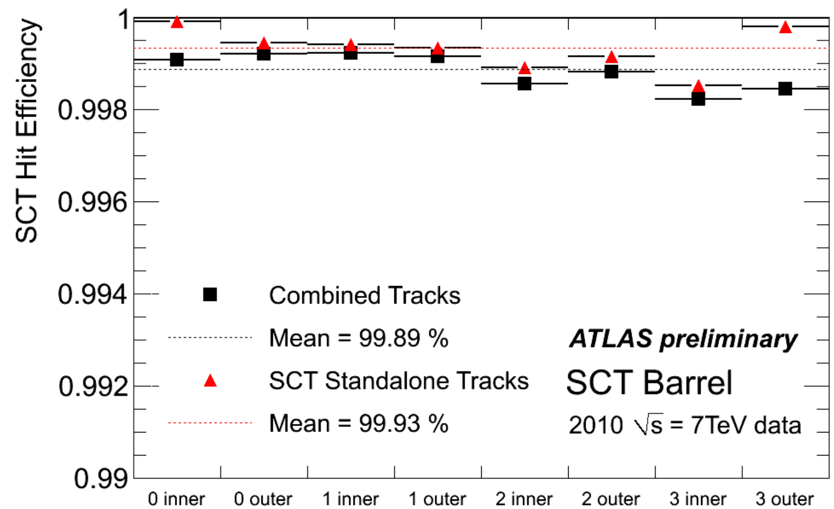




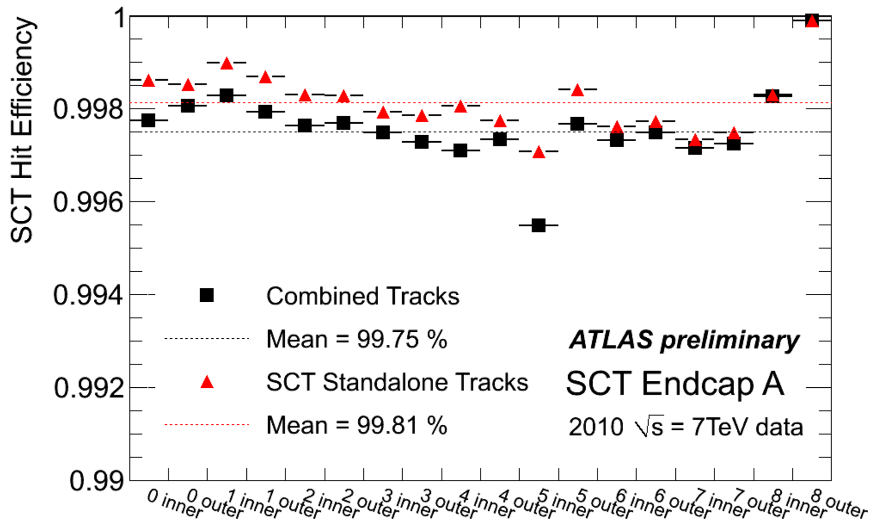


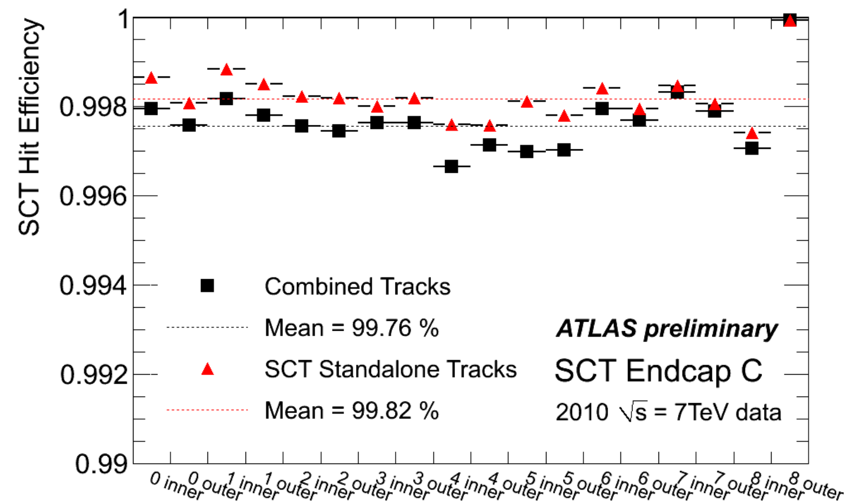
Intrinsic Module Efficiency Barrel

- Hit efficiency = number of hits per possible hit
  - Dead modules and chips are taken into account
  - p_T track > 1GeV
- 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 ≥ 99%



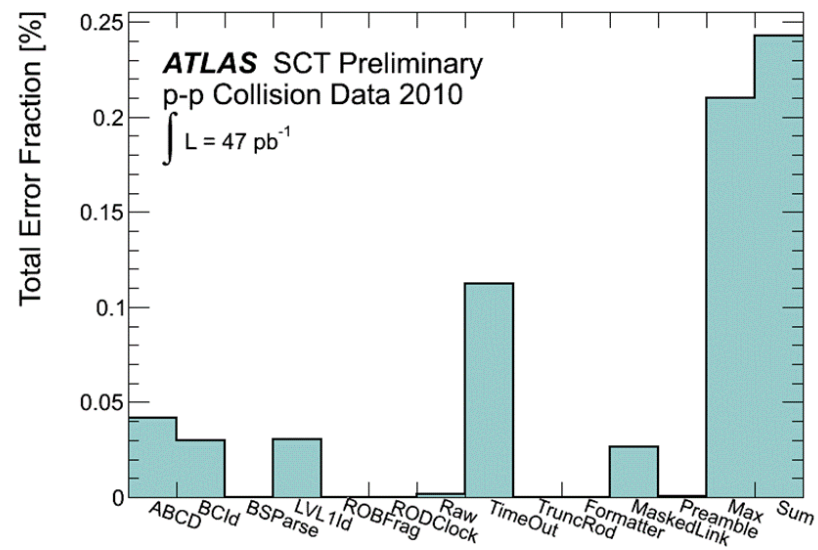
Intrinsic Module Efficiency Endcaps

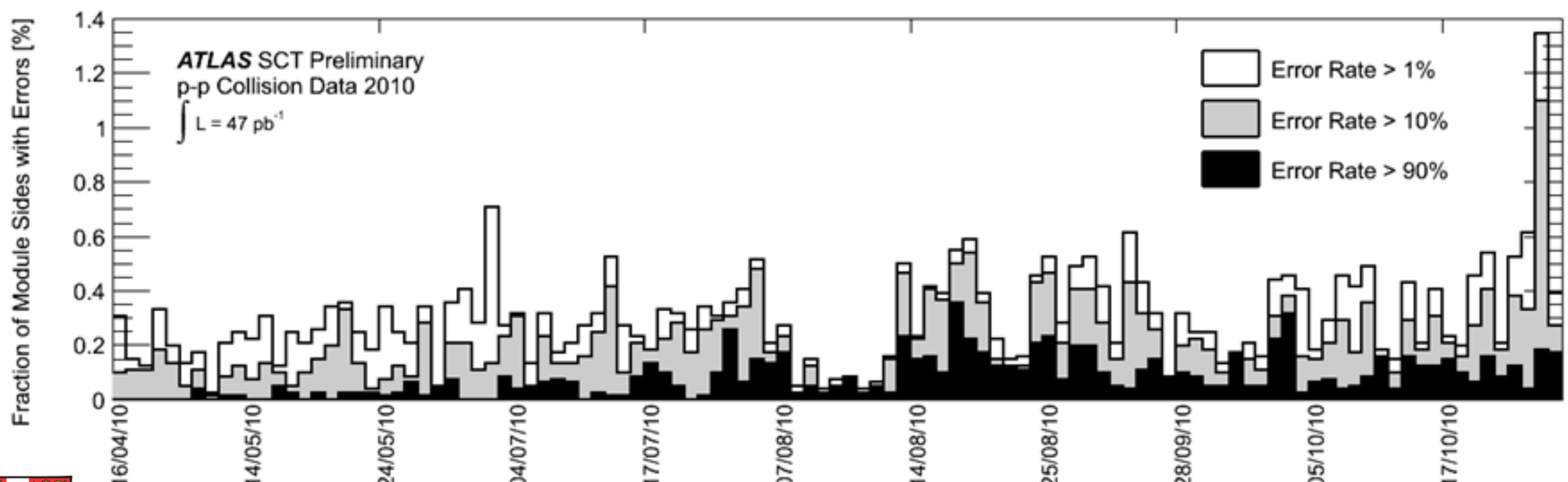




Module Errors

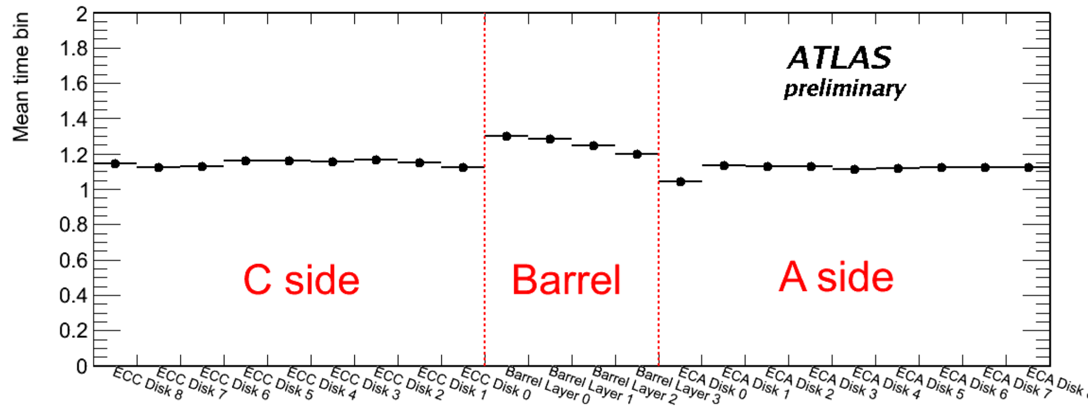
- Overall, the error rate is very low
- The total fraction of data with errors in the run period was less than 0.25%

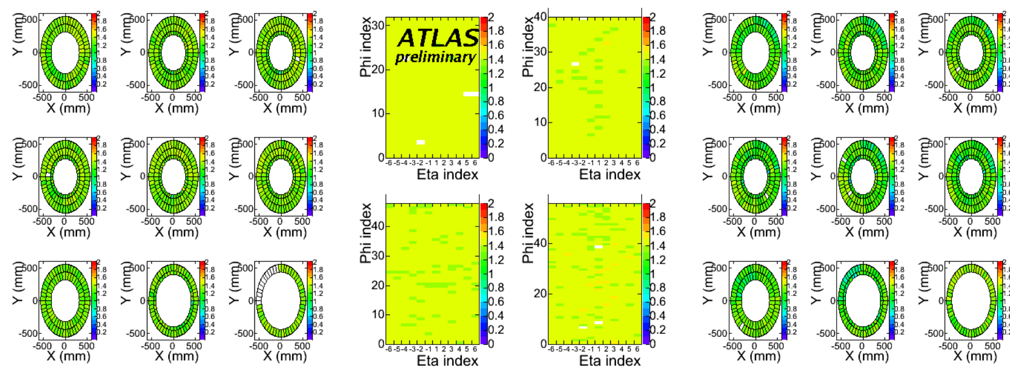




Trigger and Timing

- The SCT reads out 3 25ns time bins (BCs) around LVL1 accept
  - Trigger is delayed to account for length of optical fibers and time o 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'

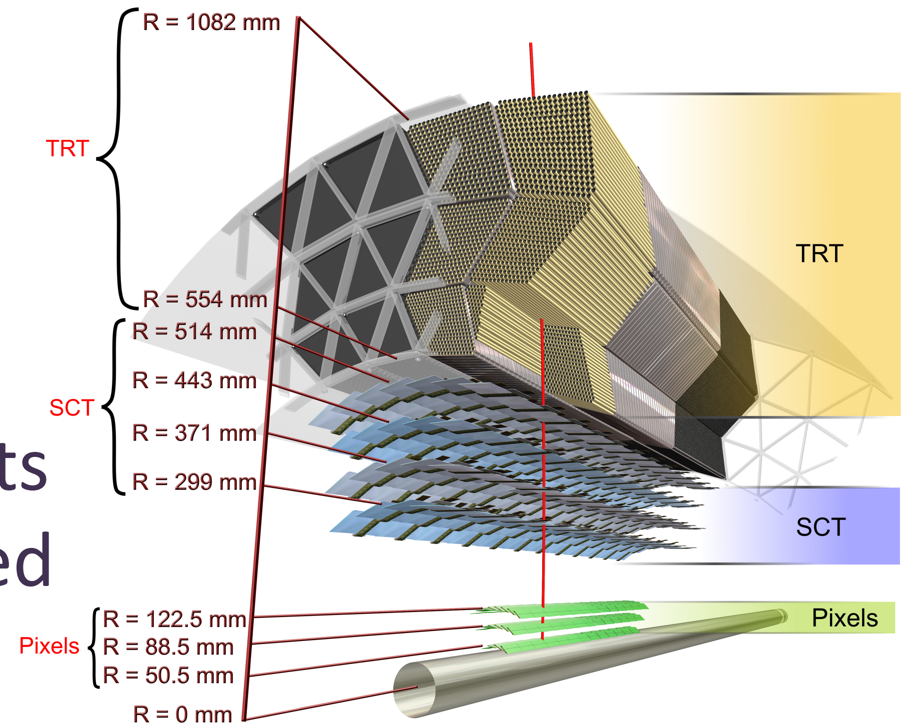
Inner Tracking Detectors			Calorimeters				Muon Detectors			
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	CSC	TGC
99.1	99.9	100	90.7	96.6	97.8	100	99.9	99.8	96.2	99.8

Luminosity weighted relative detector uptime and good quality data delivery during 2010 stable beams in pp collisions at √s=7 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_3F_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

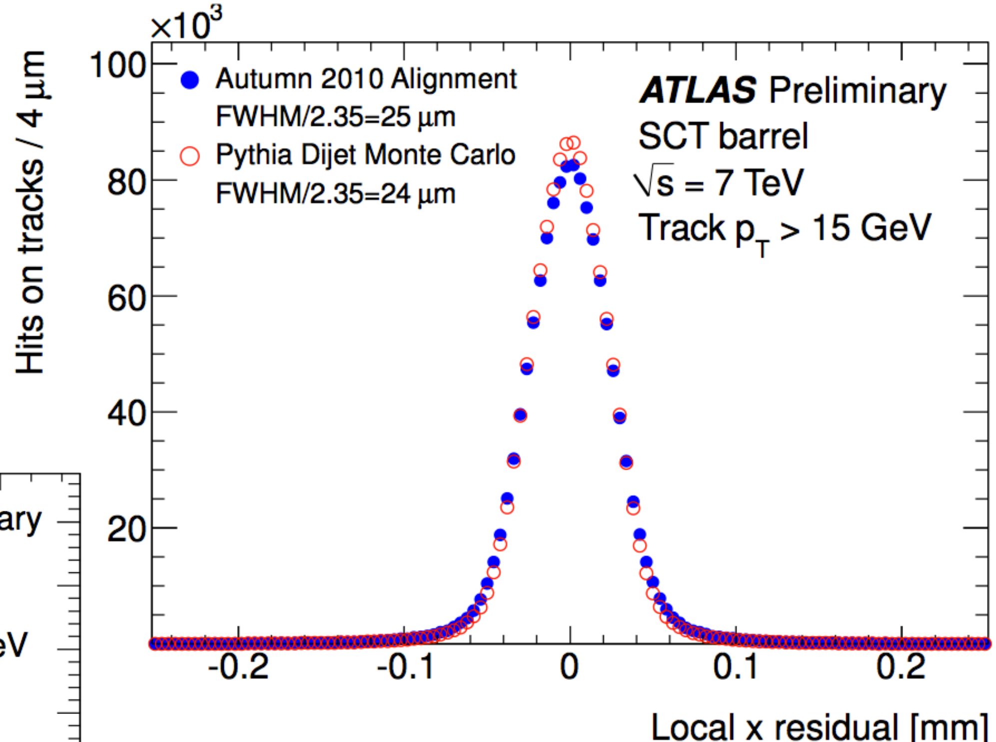


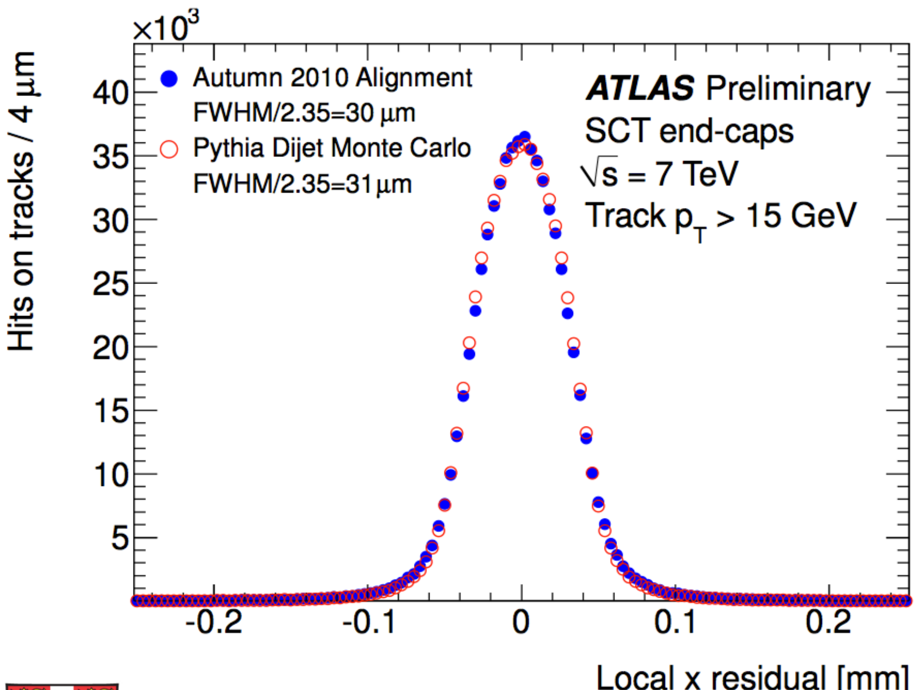
TX Saga

- 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

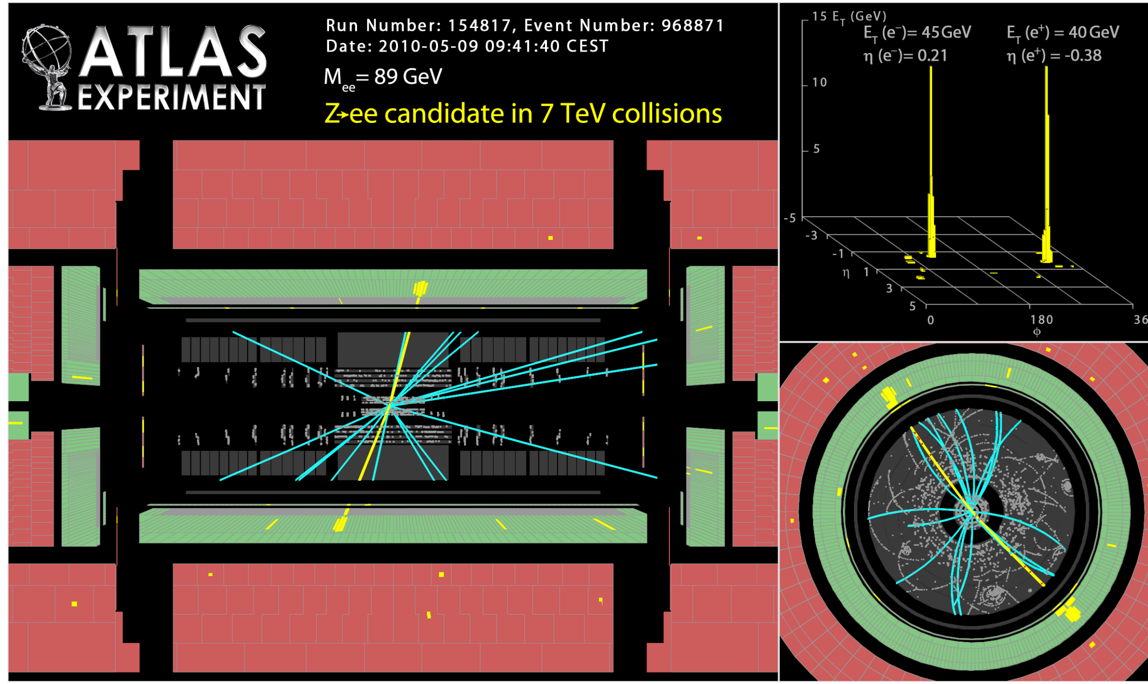
- Precision alignment allows on-line track reconstruction and invariant mass determination





- Residual = Measured hit position – expected position from track extrapolation
- Track pT>2GeV and more than 6 Si hits

Conclusions

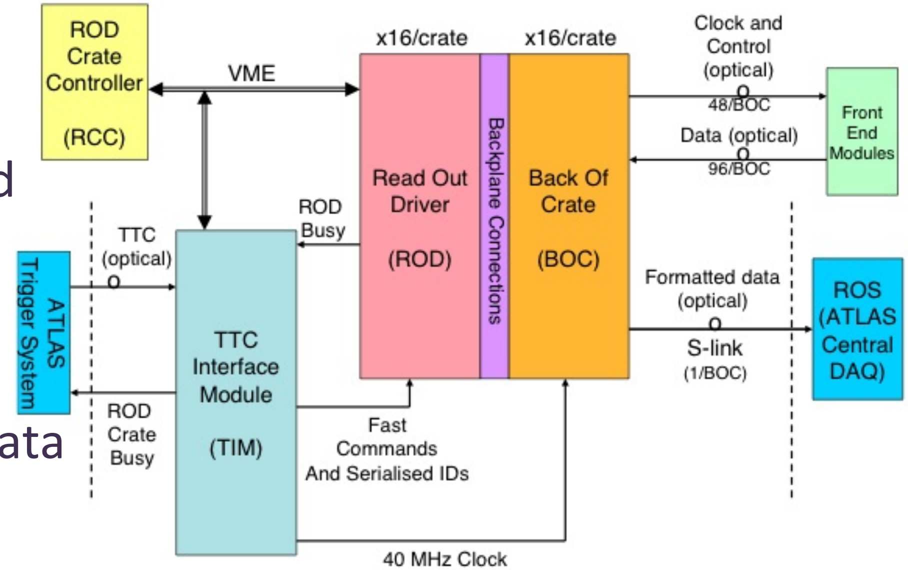


- In LHC p-p collisions the SCT has been very efficient
- The SCT is operating beyond design expectations
- Humidity-sensitive VCSELs in the optical system and temperamental temperature systems have been some of our biggest challenges
- The SCT is a key precision tracking device in ATLAS and we are taking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