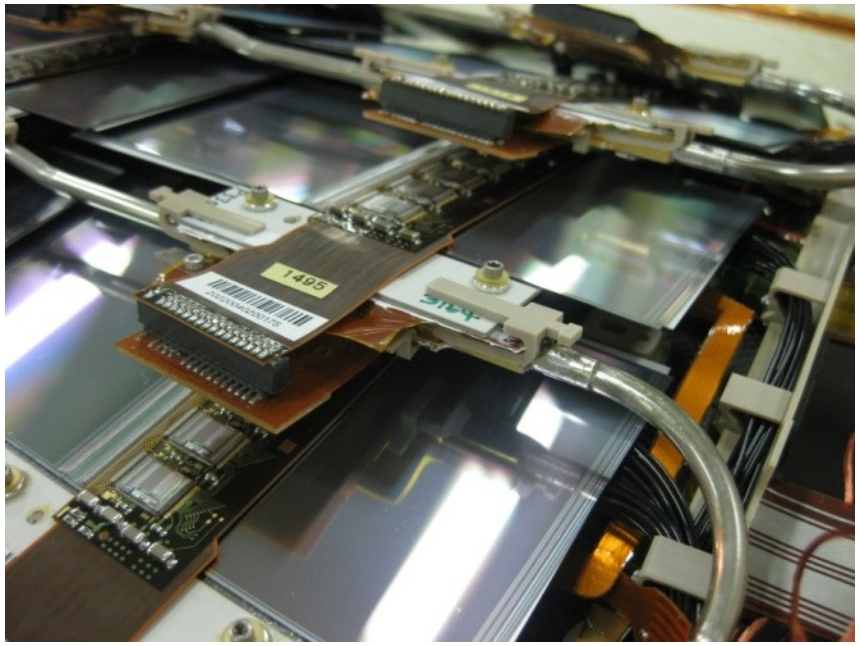


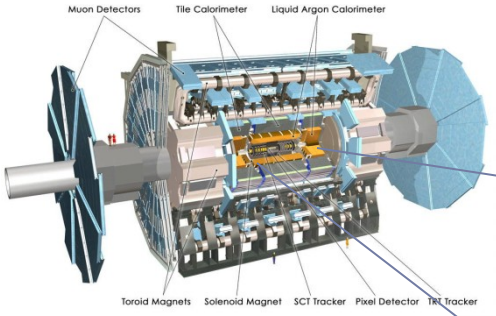
The Data Acquisition System of the ATLAS Semiconductor Tracker

Tom Barber, University of Cambridge, IoP HEPP 2010
On behalf of the entire SCT DAQ Team

Introduction

- The ATLAS Semiconductor Tracker (SCT) DAQ
  - SCT Modules
  - DAQ Hardware and Infrastructure
- Calibration of the SCT
  - Optical tests and results
  - Detector response and calibration
- Results from Physics runs
  - A hardware based monitoring system
    - Cosmic runs
    - LHC single beam splash events
    - First LHC Collisions

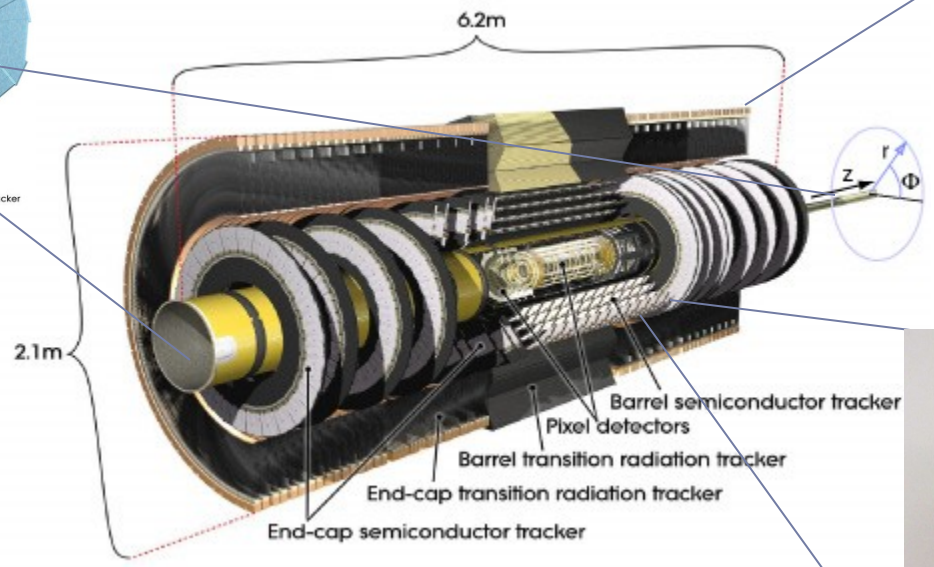
The ATLAS Semiconductor Tracker



The ATLAS Experiment

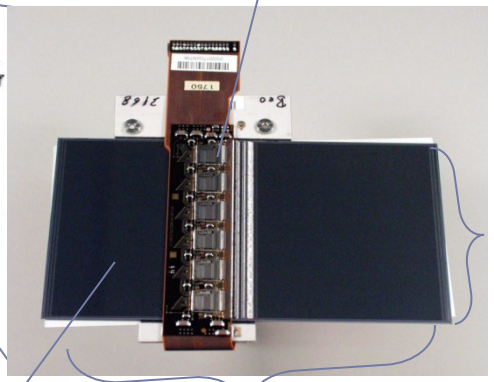
The ATLAS Inner Detector
Diagram: ATL-PHYS-PUB-2009-002

2T Solenoid Magnet



- 2 x 6 ABCD3T chips
- 128-channel binary readout ASIC
- Readout 3 time bins
- Centred on trigger

SCT Barrel



62mm

120mm

- 4 high-resolution space points
- 4088 modules
- 6.2 M channels
- 61 m^2 active silicon

4 SCT Barrel layers

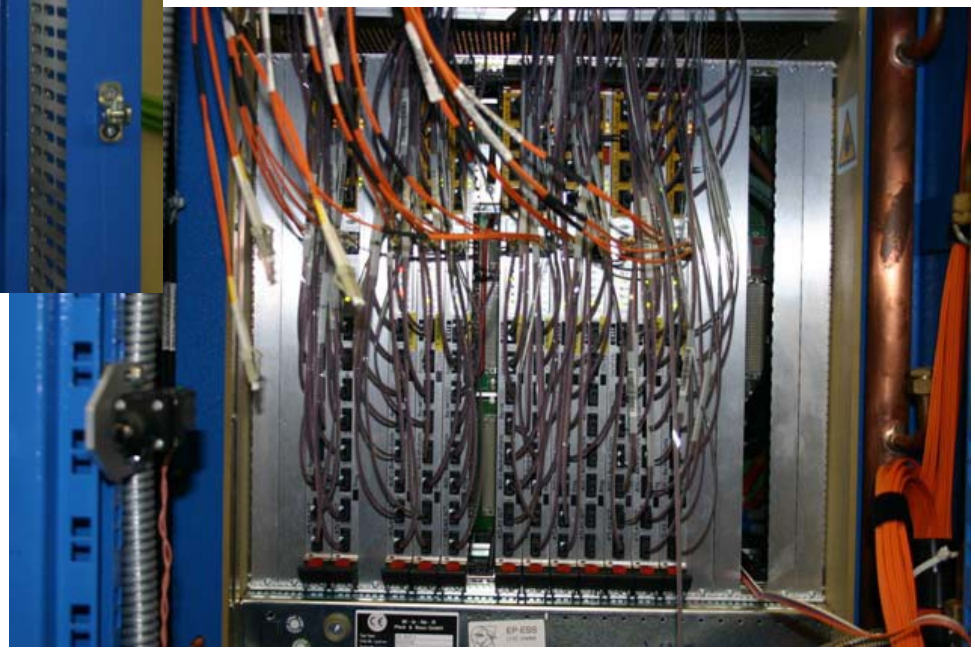
2 x 9 SCT Endcap Discs

- 2 sides of 768 Silicon strips
- Nominal bias 150V
- 40mrad stereo angle between planes provides 3D resolution

Photograph from:
2008 *JINST* **3** S08003

Data Acquisition Hardware

- 8 VME Crates
- Containing 11 pairs of:
  - Readout Drivers (ROD)
  - Back-of-crate (BOC)

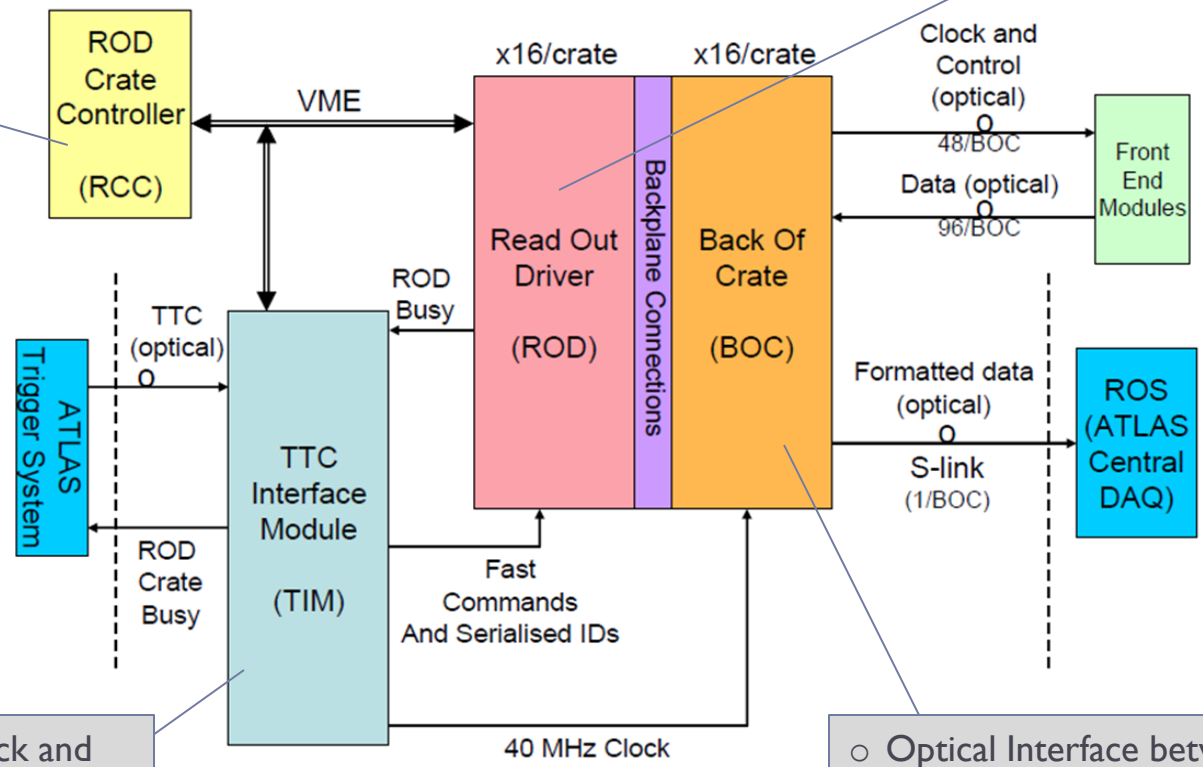


- Triggers and timing distributed by the Timing Interface Module (TIM)
- Each crate controlled by a single board computer (SBC)

Data Acquisition System

- Generates commands and parses data
- Hybrid architecture
  - FPGAs implement data path
  - DSPs for control and calibration

- SctApi provides interface with hardware
- Software for configuration, and calibration on separate servers



- Distributed 25ns clock and triggers from ATLAS
- Veto fixed-frequency triggers

- Optical Interface between crate and modules
- Sends data fragments to ATLAS central DAQ

Diagram from:
A Abdesselam *et al* 2008 *JINST* **3** P01003

SCT DAQ Infrastructure

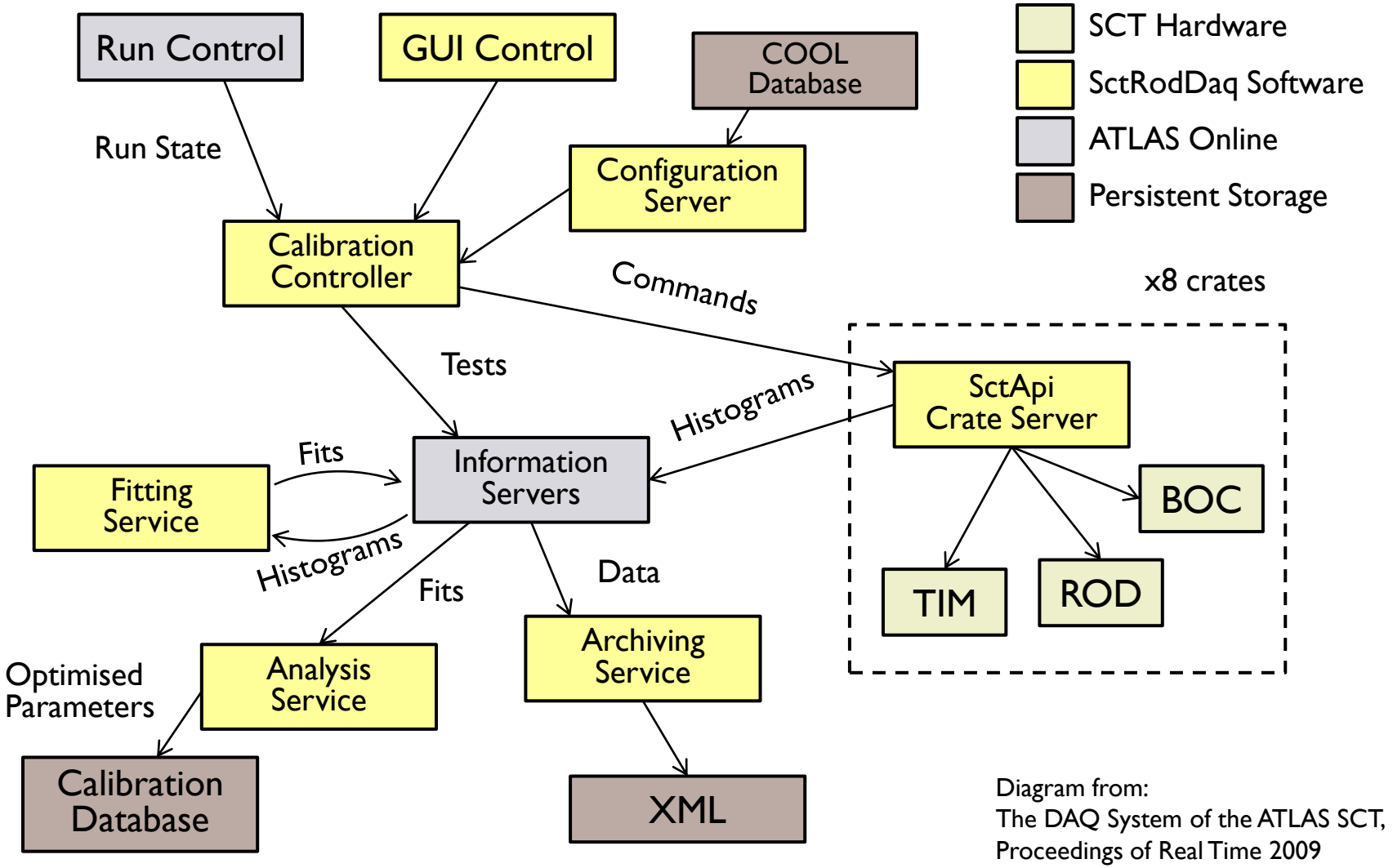
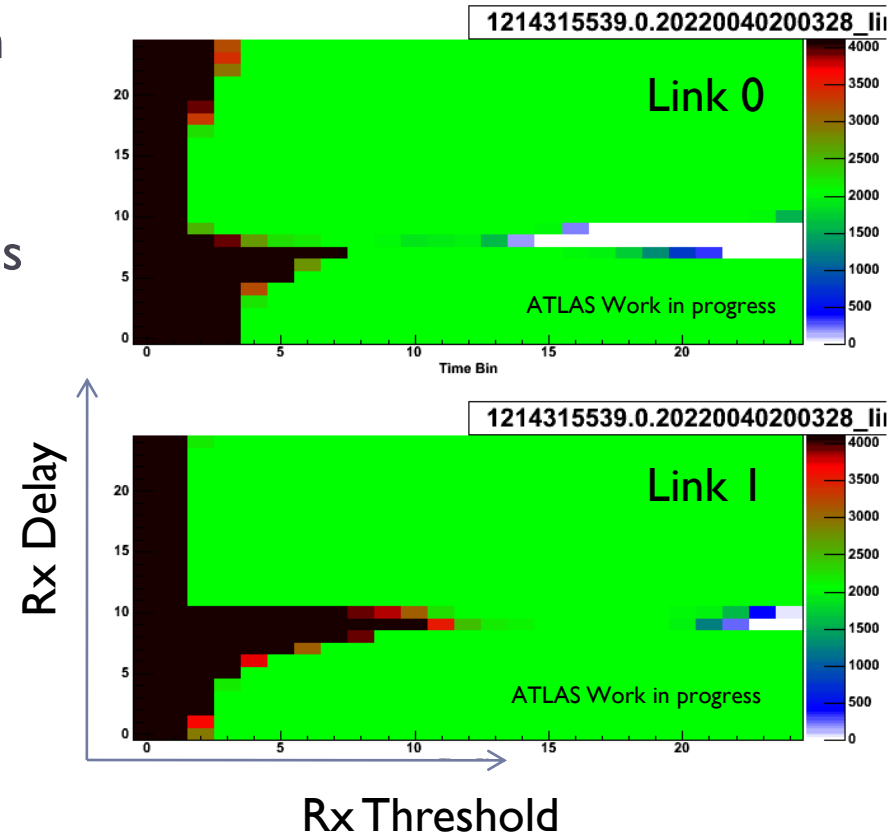


Diagram from:
The DAQ System of the ATLAS SCT,
Proceedings of Real Time 2009

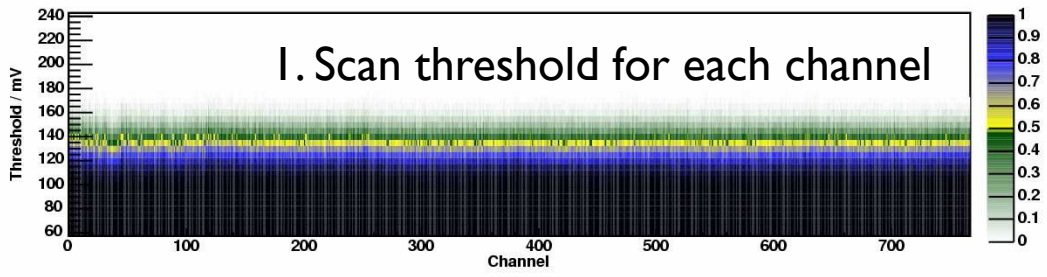
Calibration of Optical Links

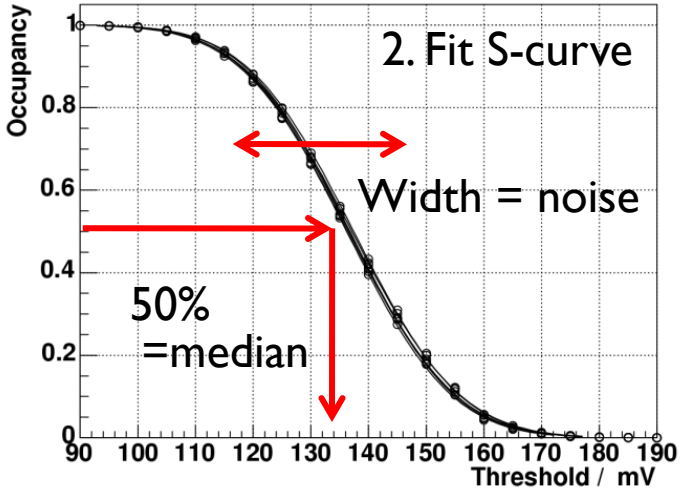
- Optical Links
  - Need reliable communication
  - between modules and crates.
- Each module has:
  - 1 Tx link to receive commands
  - 2 Rx Links to send data
  - Built-in redundancy
- Need to Calibrate:
  - Tx Current
  - Tx shape (Mark Space Ratio)
  - Rx Threshold
  - Rx Delay
- Extensive optical calibration
  - Only 3 modules excluded due to readout problems (March 2010)

Example of a 2D Optical Scan

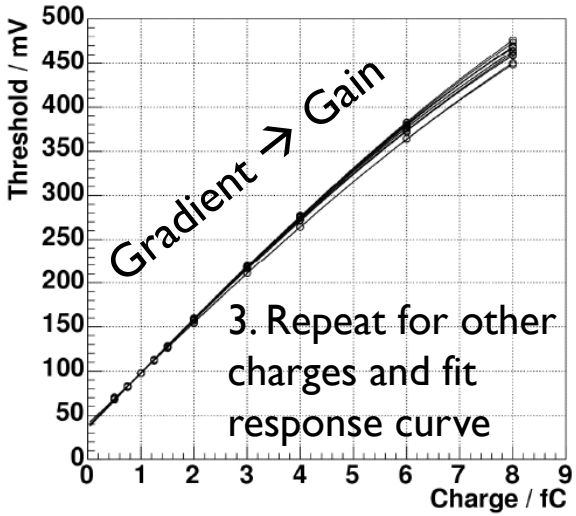


Front End Calibration





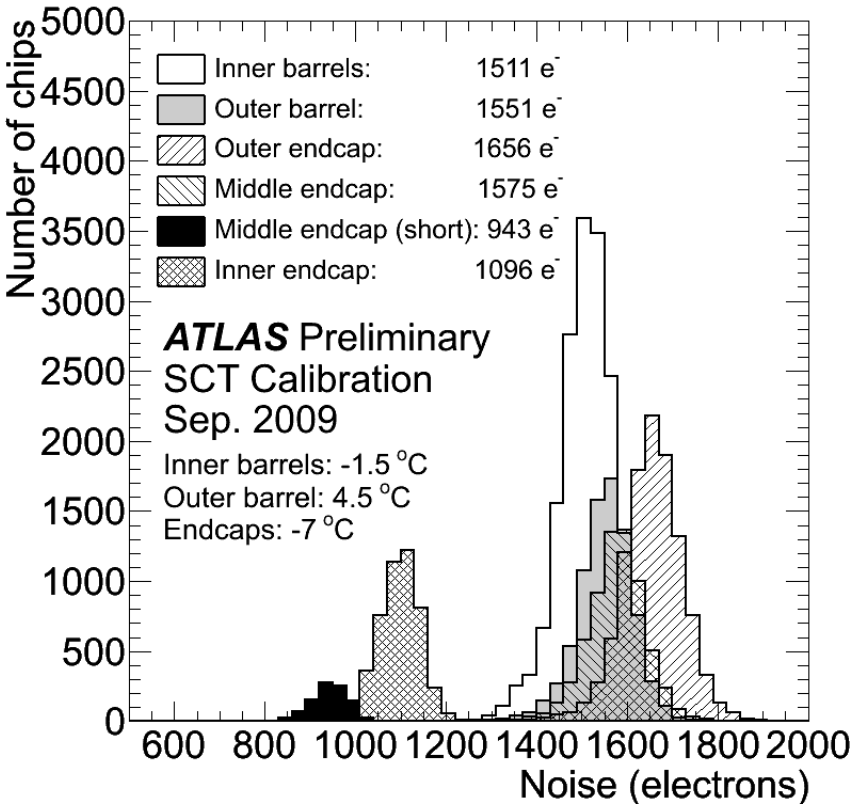
- Also calibrate silicon strip response to charge.
- Fixed charge injected by capacitors on modules.
- For each injected charge:
  - Create histogram of occupancy versus threshold for every channel.
  - Fit a complementary error function
    - Threshold at 50% occupancy gives median
    - Width gives the noise
- Threshold calibrated by starting scans for several different values of injected charge.
- Fitted *response curve* gives threshold for any charge.
- Threshold scan with no injected charge
  - Noise Occupancy Test



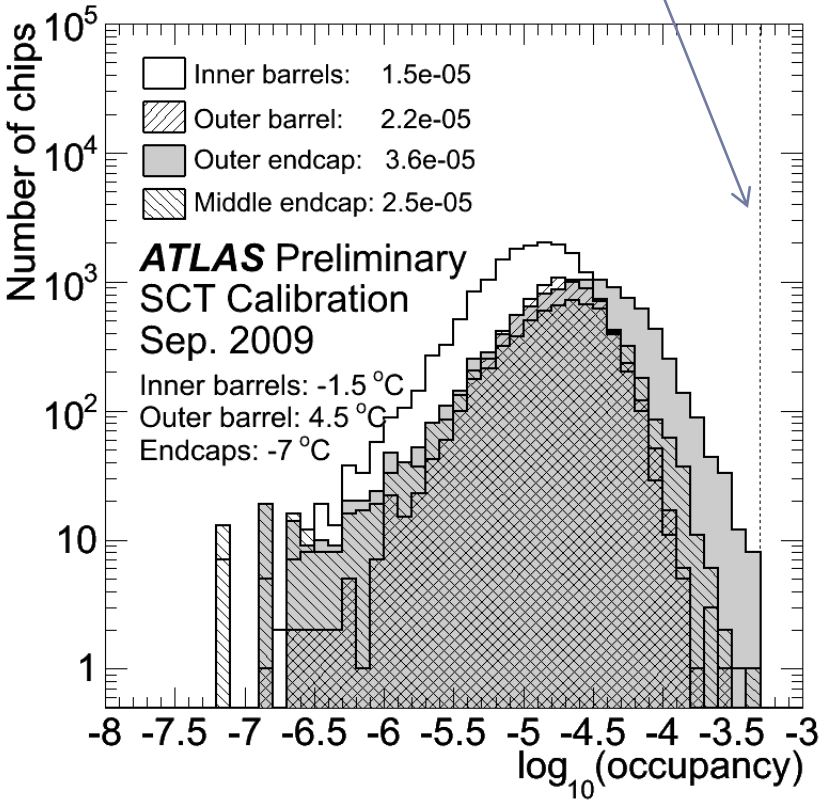
Plots taken from: A Abdesselam *et al* 2008 *JINST* **3** P01003

Calibration Results

Nominal threshold set to 1.0 fC

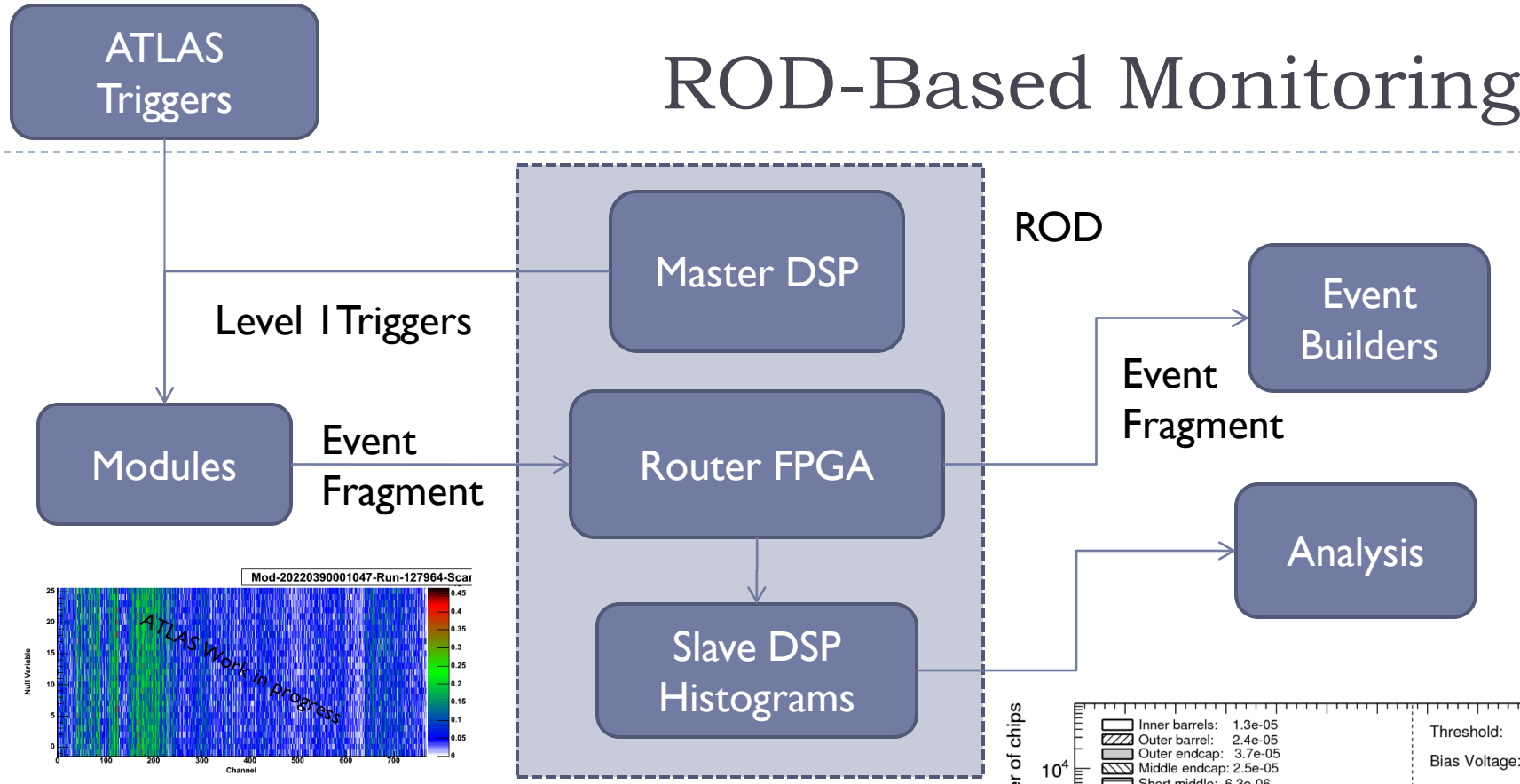


Well within 2.10^{-4} specification

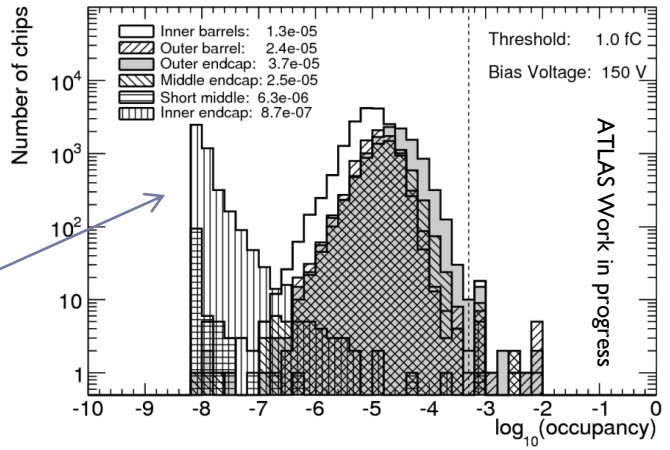


SCT well calibrated: currently ~0.7% modules excluded from data taking (March 2010)

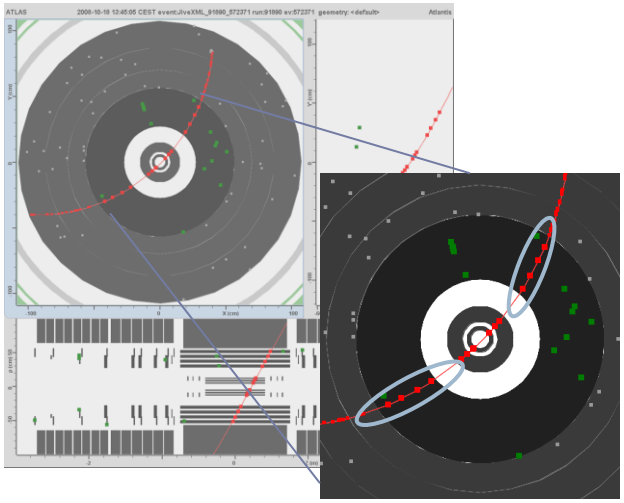
ROD-Based Monitoring

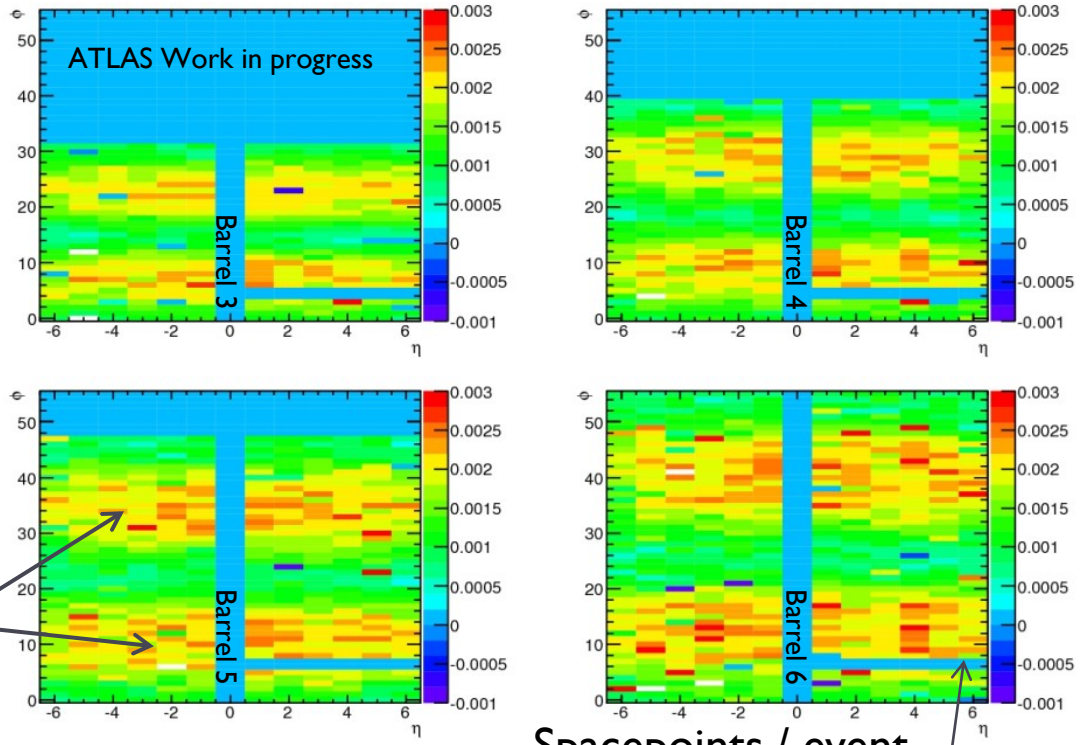


- Histogramming infrastructure from calibration mode
  - Modified for monitoring during physics runs
  - Semi-continuous data-collection
- Online analysis data at module level of:
  - occupancy, spacepoints, timing
- High statistics noise measurements possible
  - Inner endcaps now visible!



Cosmic Data Taking





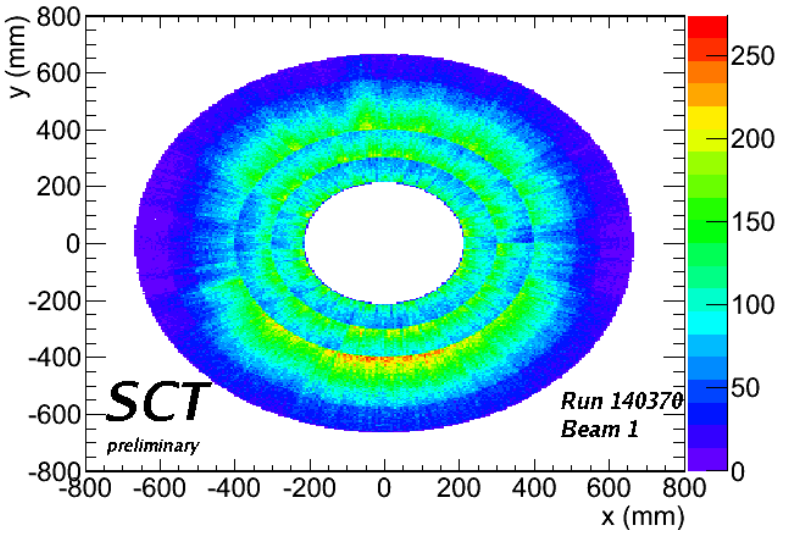
Top/Bottom of barrels seen in ROD monitoring

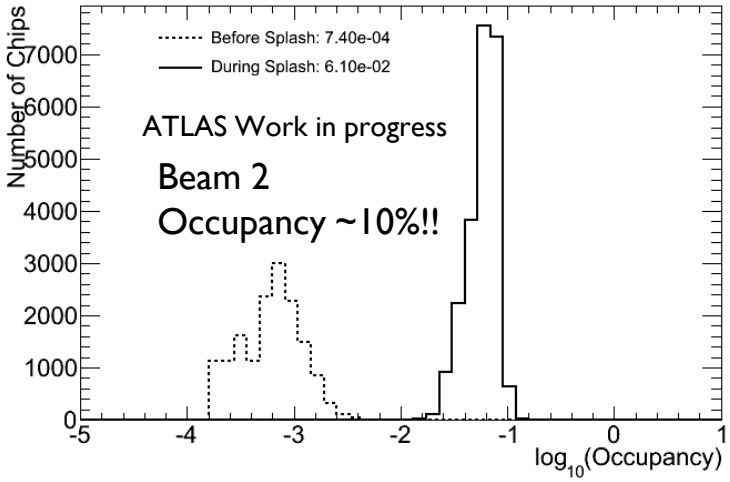
- Extensive cosmic data taking in 2008-09
- Efficiency of SCT barrel modules ~ 99.8% at 1.0fC
- In 2008, SCT Recorded ~2 million cosmic tracks
  - 1.1 million B-field off, 900,000 B-field on

Events from ROD not histogrammed if a single module on that ROD is returning errors.

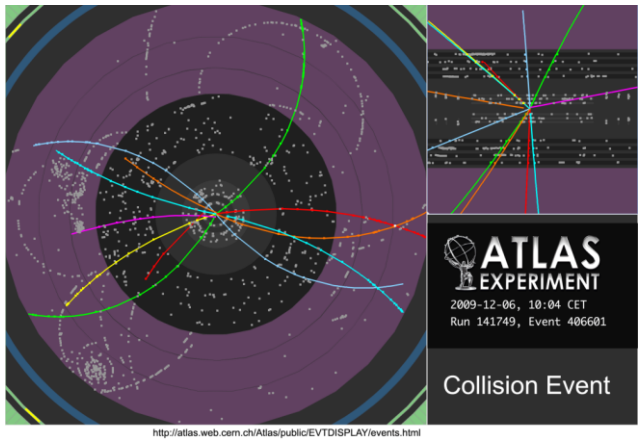
LHC Beam splashes in 2009

- LHC Startup - November 2009
- SCT endcaps were powered
  - 20V, 1.2 fC threshold
  - Barrel excluded for safety
- DAQ performed well under exceptionally high occupancy

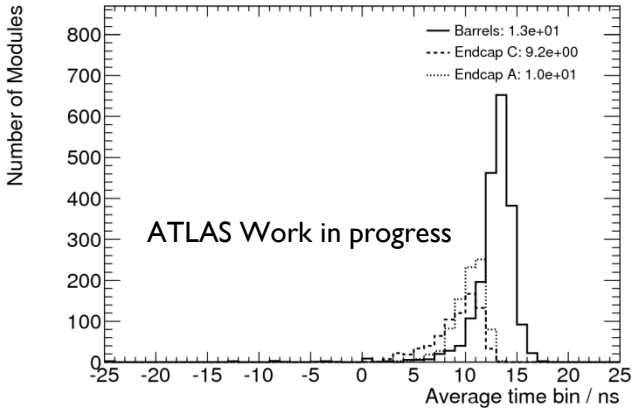


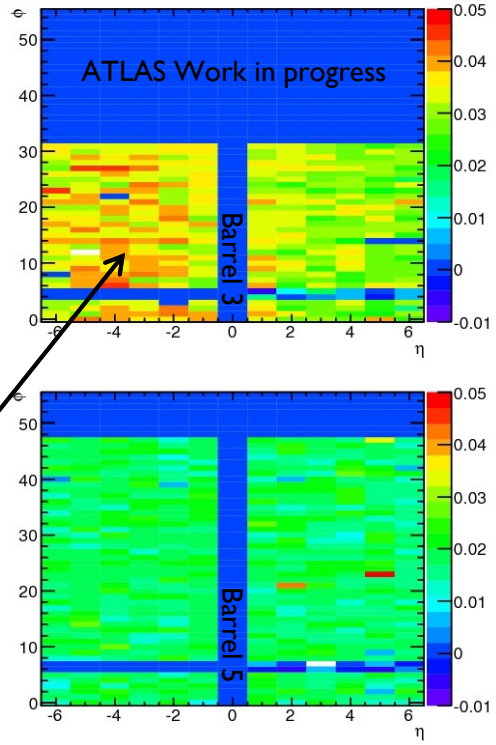


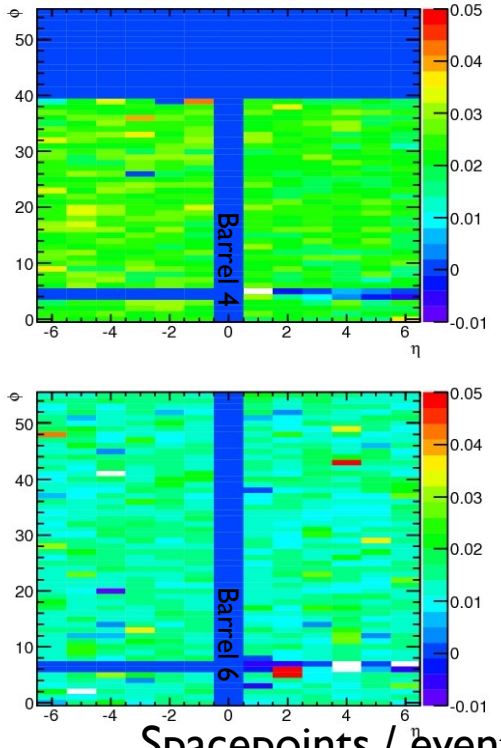
First LHC Collisions in 2009



Beam spot clearly displaced







Spacepoints / event

- LHC Collisions at 450 GeV
  - Since December 2009
- SCT performing very well
  - Track efficiency ~99.8%
  - Timing within ~10ns of trigger

Conclusions

- The ATLAS Semiconductor Tracker
  - Provides 4 high precision spacepoints
  - Consists of 4088 modules in barrel and two end-caps
- Extensive calibration work
  - Optical communications working well
  - Detector response and noise well within specifications
- ROD-based Histogramming
  - Developed into mature monitoring framework
  - Provides accurate, fast feedback of SCT performance
- SCT performed well during 2009
  - First beam splashes and low energy collisions
  - Performed extremely well yesterday for 7 TeV collisions!