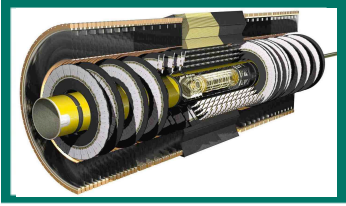
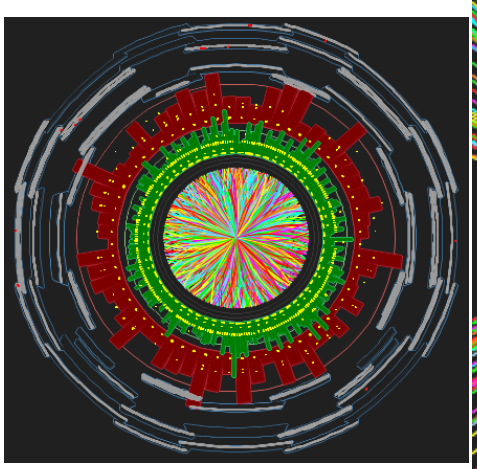
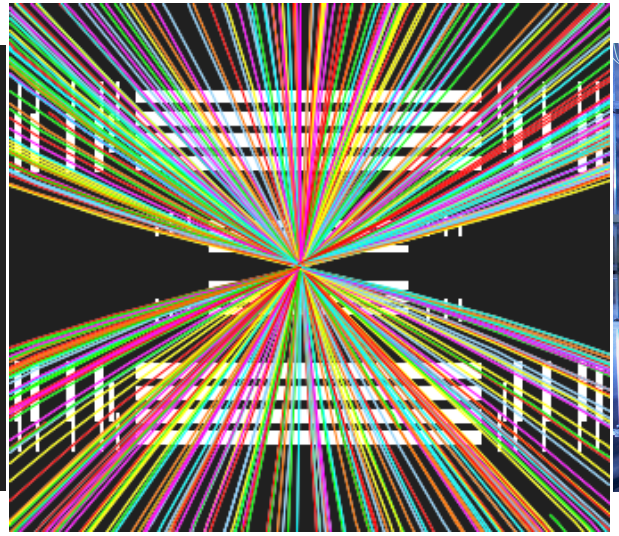
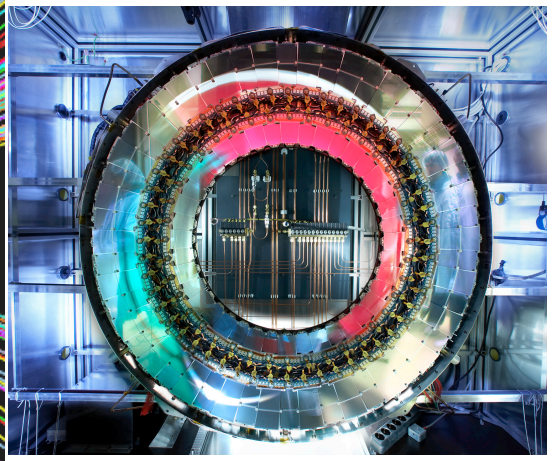


Operation & Performance
of the
ATLAS SemiConductor Tracker

Dr. Petra Haefner

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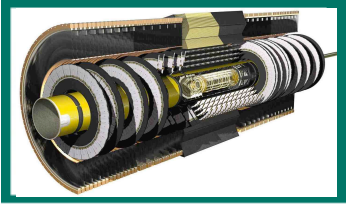
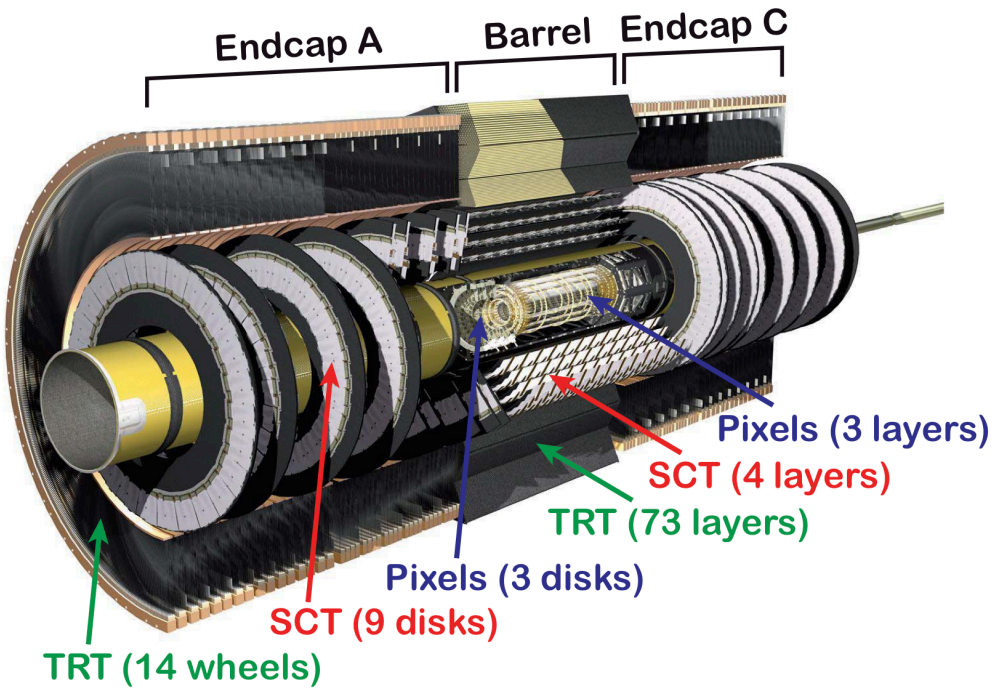


The SCT Detector

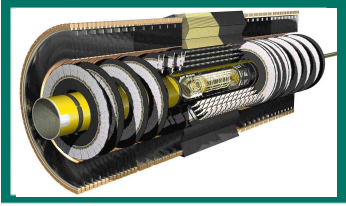


Facts & Figures

Barrel:	4 layers, 2112 modules
Endcaps:	2 x 9 disks, 1976 modules
Coverage:	30 cm < r < 52 cm, $\|\eta\| < 2.5$
Active Material:	61 m^2 silicon
Readout:	6.3 million channels

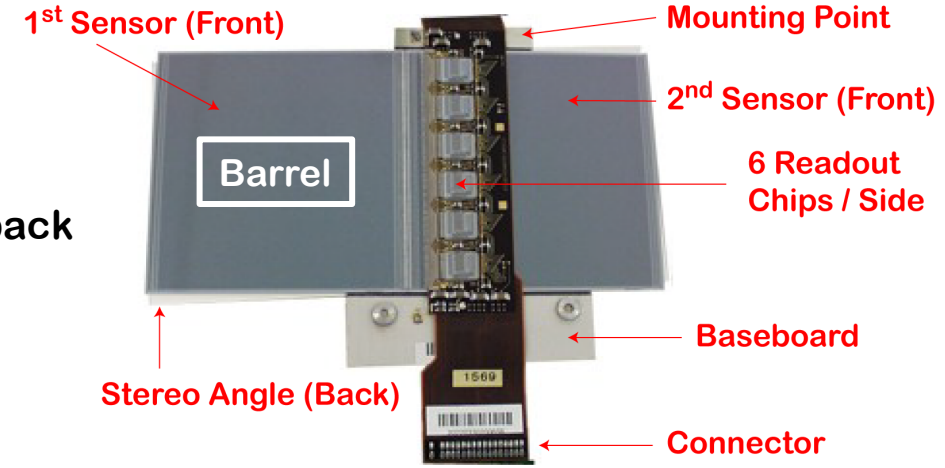
Operating Points

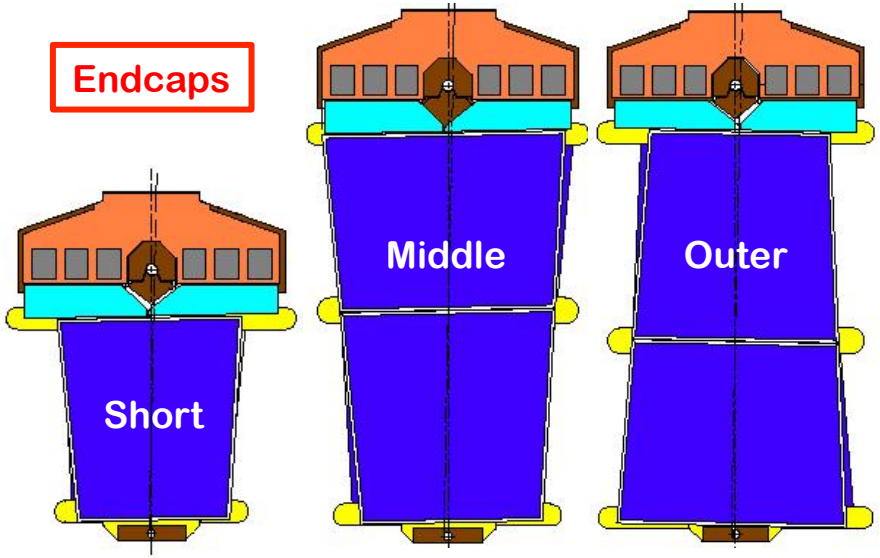
- 150 V reverse bias voltage ($U_{standby}$ = 50 V, U_{max} = 500 V)
- 1 fC hit threshold (binary readout)
- 3 time bin readout (25ns / bin = LHC clock)
- C_3F_8 cooling: -7°C to +4.5°C

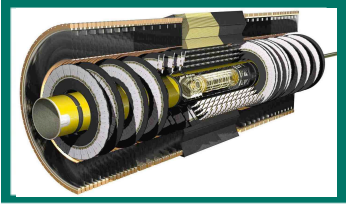


The SCT Modules

- **Sensor Setup**
  - 768 p-strips on n-type silicon
  - Pitch: 80 μm (B), 57-94 μm (EC)
  - 285 μm thick
  - 2 single-sided sensors glued back-to-back
  - Stereo angle of 40 mrad
  - 83 % Hamamatsu, 17 % CiS
- **Sensor Length**
  - 13 cm (B), 6-12 cm (EC)
- **Resolution**
  - ~17 μm(rφ, bending plane), ~580 μm (z)
- **Baseboard**
  - Mechanical & thermal structure
  - Thermal Pyrolitic Graphite
- **Readout**
  - Radiation-hard front-end readout chips (ABCD3TA)
  - 6 chips/side, 128 channels/chip
  - 48 modules served by 1 ROD
  - 11 (12) RODs send data to 1 ATLAS ROS
  - TIM provides trigger signal & clock

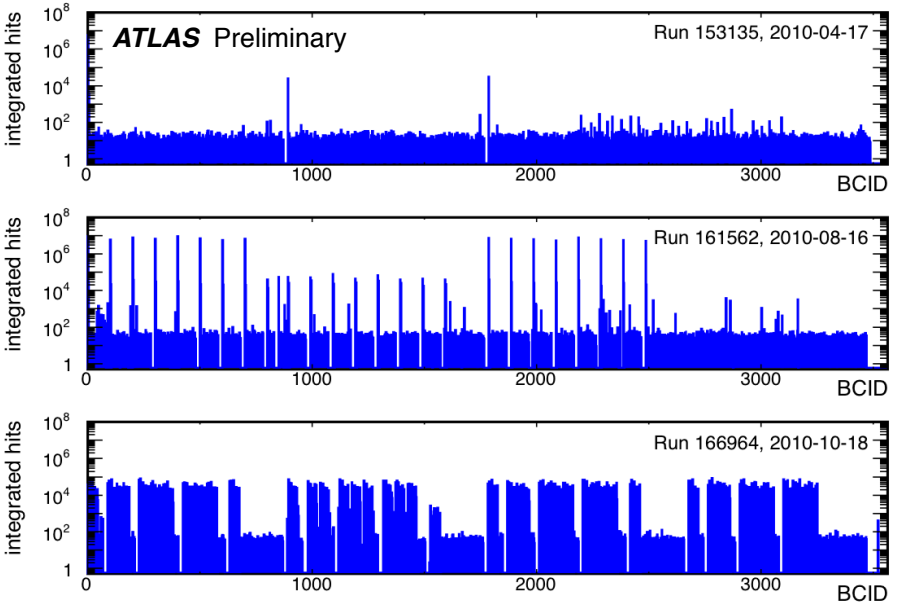


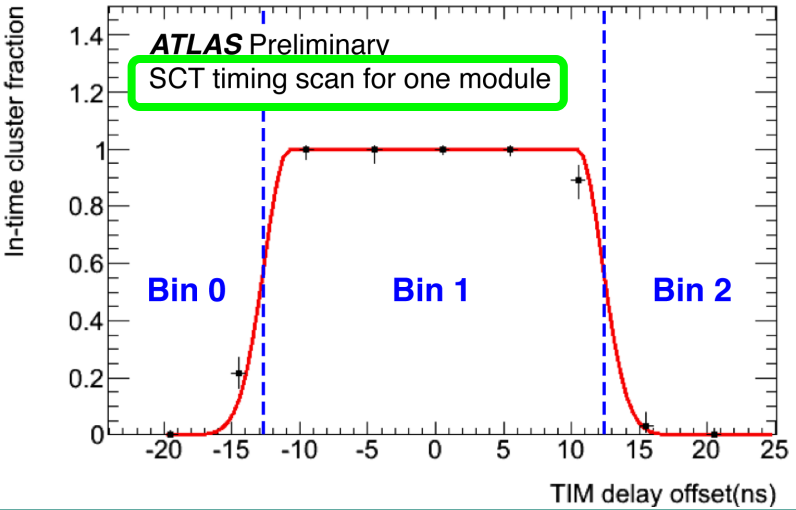


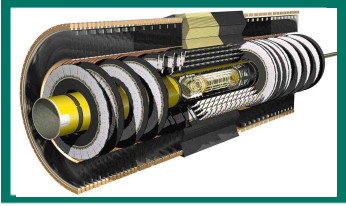


SCT Readout & Timing

- 3 time bins of 25 ns (LHC clock) around trigger accept signal
- 3 different timing modes:
  - XXX: no hit requirement
    2010: ≥75 ns bunch distance
  - X1X: bin 1 hit required
    2011: 50 ns bunch trains
  - 01X: bin 1 hit required, no hit bin 0
    2012(?): 25 ns bunch trains
- Timing scans done for all modules
  - Account for fiber lengths
  - Account for TOF from IP to module
- SCT very well timed in

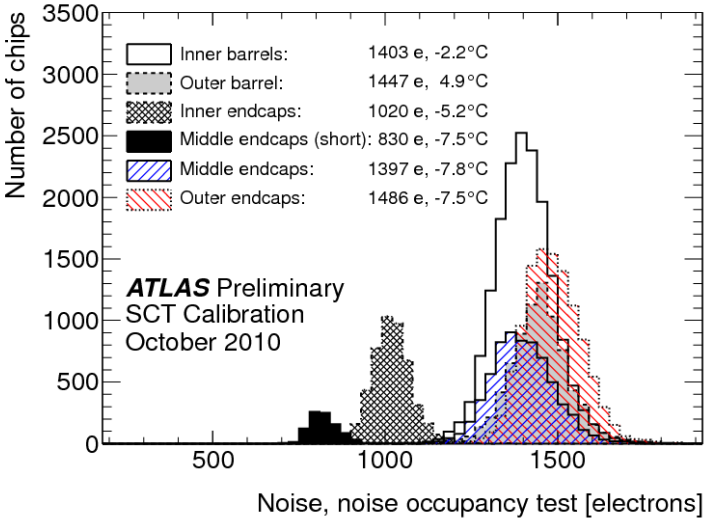


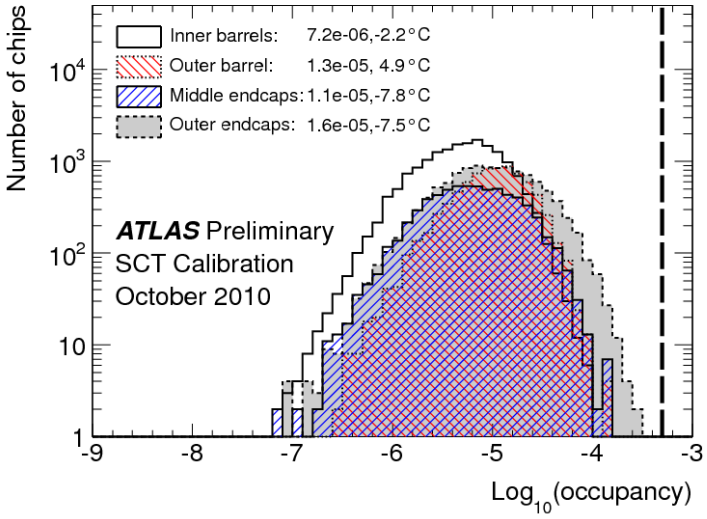


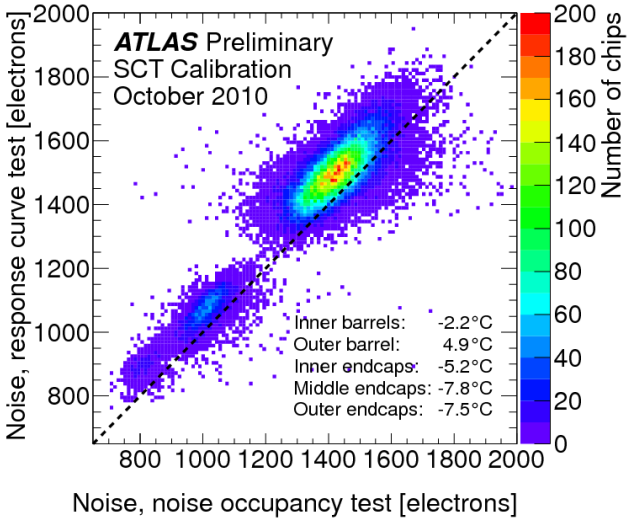


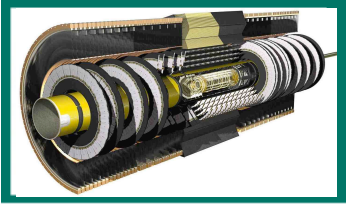
Noise Occupancy

- **Calibration Measurement**
  - Charge injection circuit in readout chip 0-16 fC
  - Measure hits vs. threshold (S-curve)
  - Fit by complementary error function
  - Width characterizes noise
  - SCT noise < 1500 e
  - Hit threshold ~ 6200 e
- **Online Measurement**
  - Count hits in random triggers (empty bunches)
  - SCT noise occupancy ~ 10^{-5}
  - Design requirement < 5 * 10^{-4}
- **Both methods in good agreement**
- **Less than 0.2% disabled noisy strips**



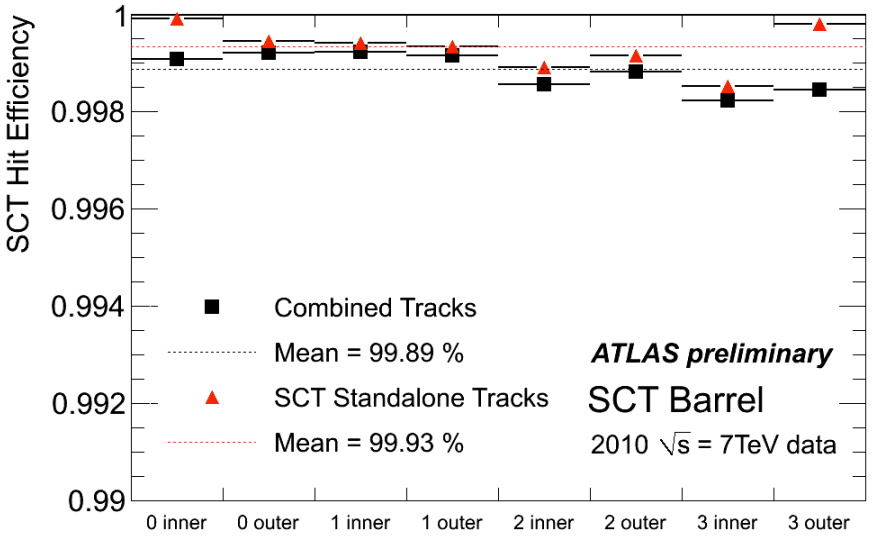


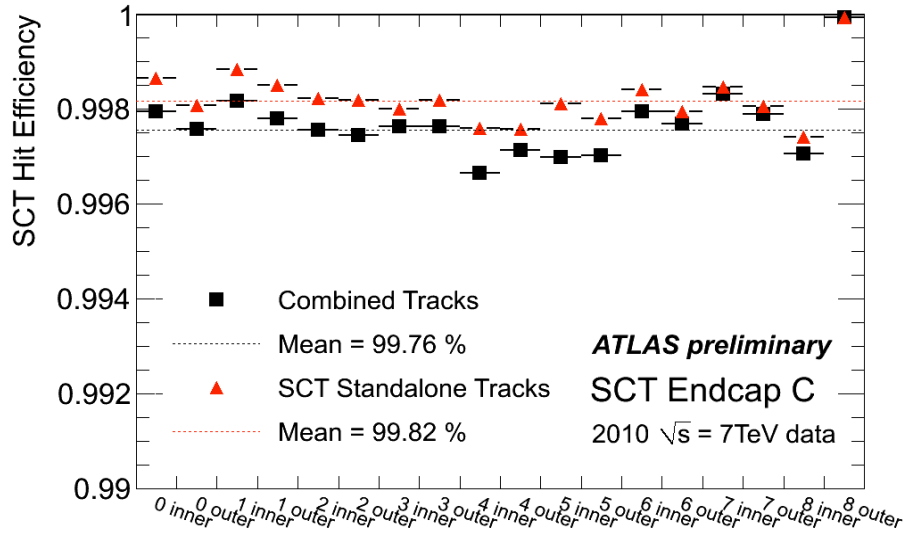


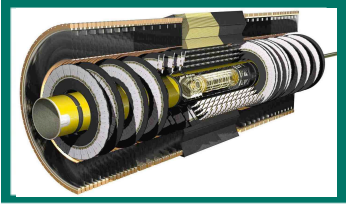


Hit Efficiency

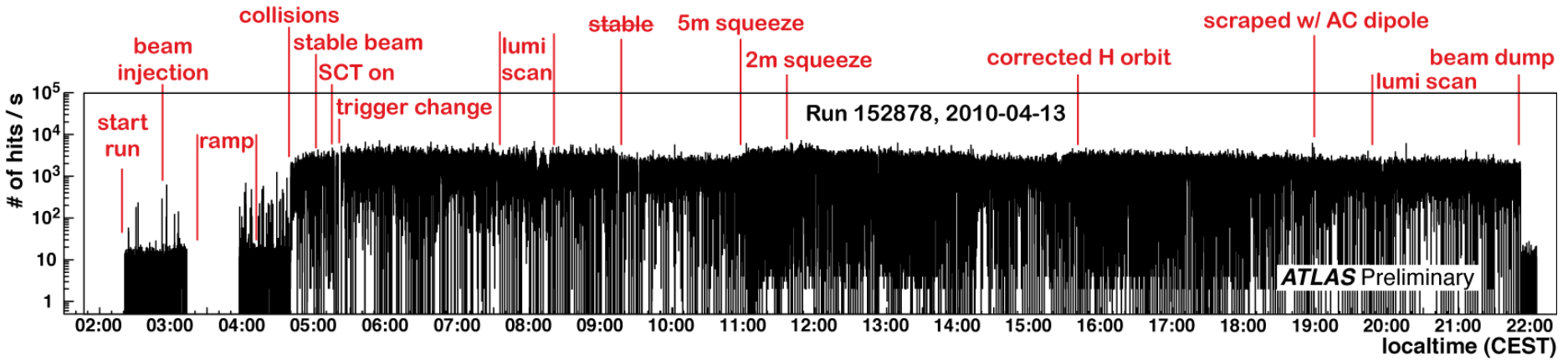
- **Efficiency** = # of hits / # of possible hits (on reco. tracks)
  - Dead modules & chips accounted for
- **Barrel**
  all layers > 99.8 % efficiency
- **Endcaps**
  all disks > 99.6 % efficiency
- **Time stability**: ± 0.1 %
- **Well above design of 99.0 % efficiency**



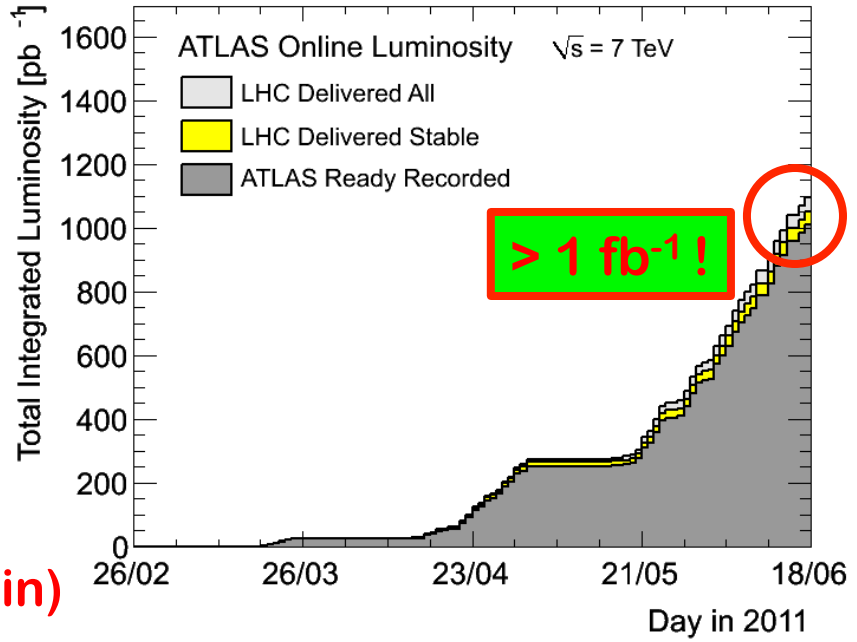


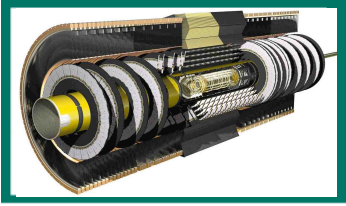


SCT Operation



- Very low noise detector
- Well timed in, good time resolution
- Efficient even at standby voltage (50 V)
- Excellent beam conditions monitor
- Allows safe & efficient warm start O(min)



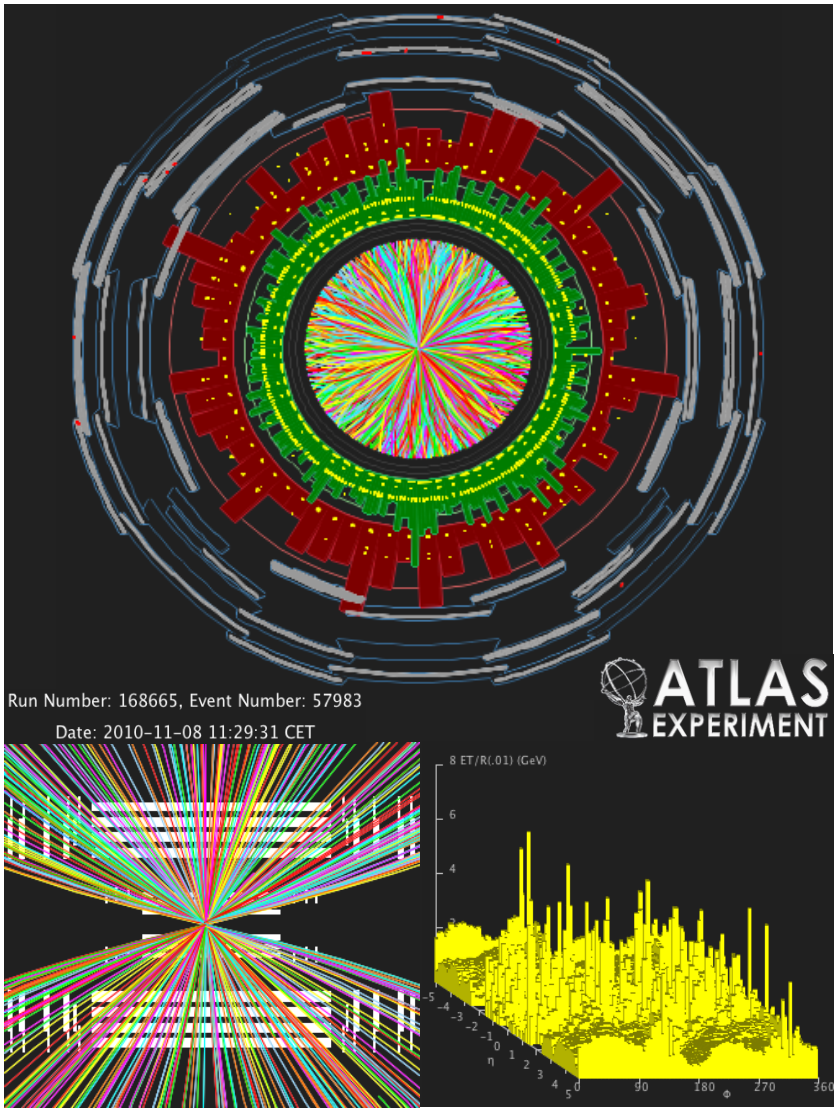


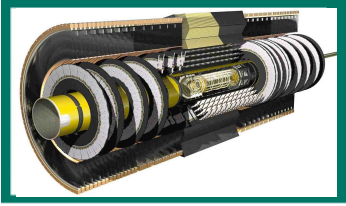
Occupancy

- ROS event size limit: 65 kB (configured)
- Event truncation at ~ 46 % occupancy
- Avg. occ. for 10 vertices is 0.7 %
- Predicted mean occupancy at design luminosity ~ 1 %
- Maximal occupancies observed:

Beam Type	Single Module	Avg. of all Mod.
Proton	20 %	8 %
Heavy Ion	37 %	16 %

- SCT is not limiting ATLAS Level 1 rates





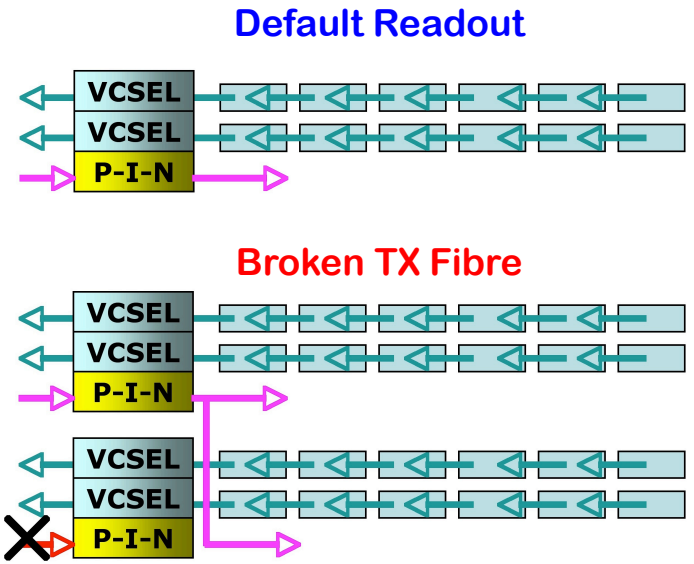
Operation Issue – TX Deaths

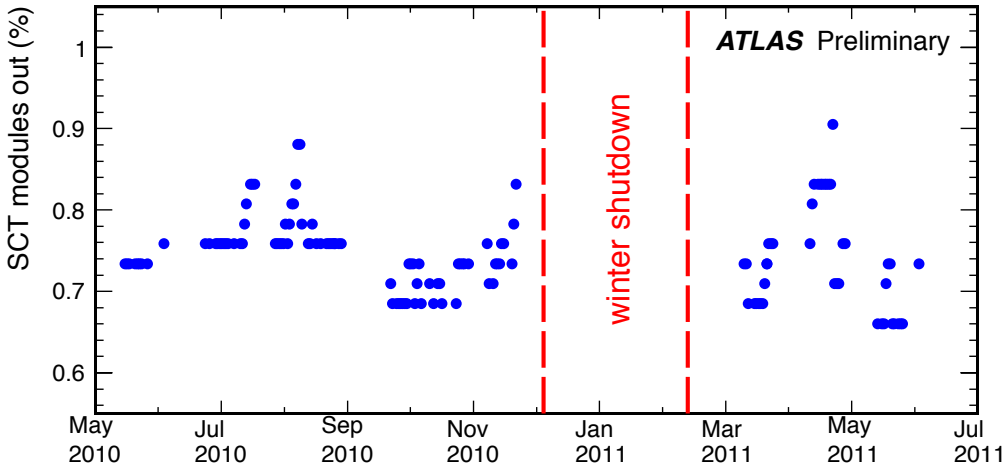
- 360 off-detector TX arrays, 12 VCSELs / TX
- Started dying (again) in May ‘10
- O(10) deaths per week
  - (most) SCT modules have redundancy
    → change configuration after run end
  - Modules w/o redundancy
    → replace TX, O(days)

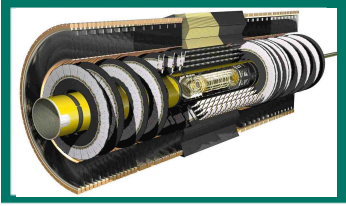
- Allows stable operation with < 10 mod. out

- Cause of failure: humidity
- Supply racks with dry air

- Spare situation
  - ~200 old type available
  - Production of new TXs with better humidity resistance started, ~2*1000





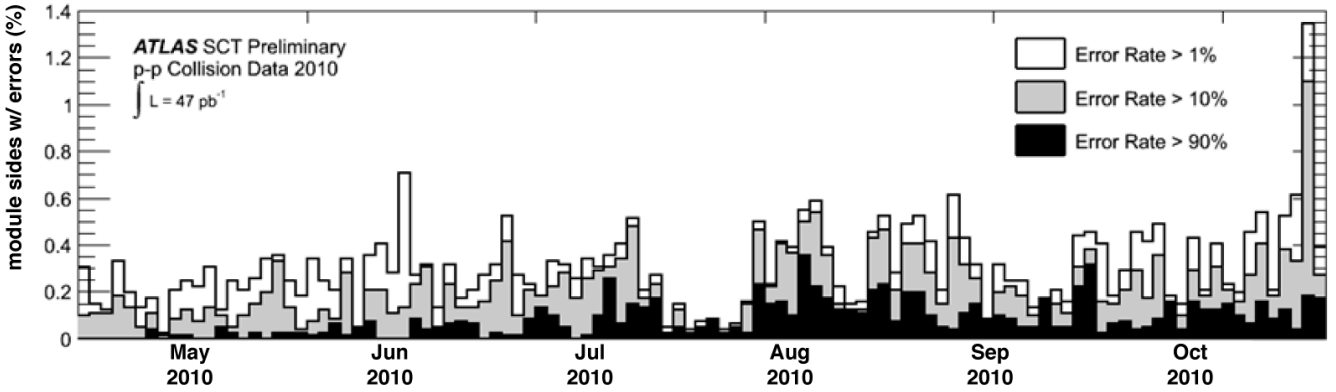


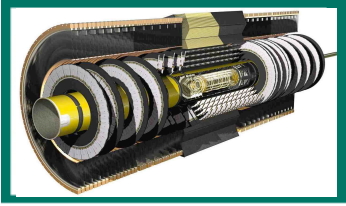
Data Taking Stability

- Module Issues (Average 2010-11)
  - 0.75 % modules out of DAQ
  - 0.18 % modules with errors
- Only 11 / 196 runs with SCT issues in 2010
  - 6 runs where data quality was not affected
  - 5 runs with ROD busy
    - ηφ-region affected in tracking
    - 2010: ROD stopless removal
      48 modules taken out of the run
      O(h) for recovery (need to restart run)
    - 2011: ROD stopless recovery
      Reconfigure ROD during run
      O(min) for full recovery of all modules
- **Data taking efficiency > 99.4 %**

Disabled Modules	#	%
Cooling	13	0.32
LV	7	0.17
HV	6	0.15
Readout	4	0.10
Total	30	0.73

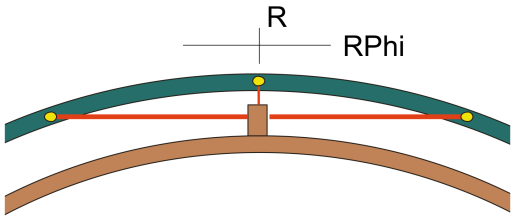
Eff.	PIX	SCT	TRT
2010	99.1%	99.9%	100%
2011	99.5%	99.4%	100%

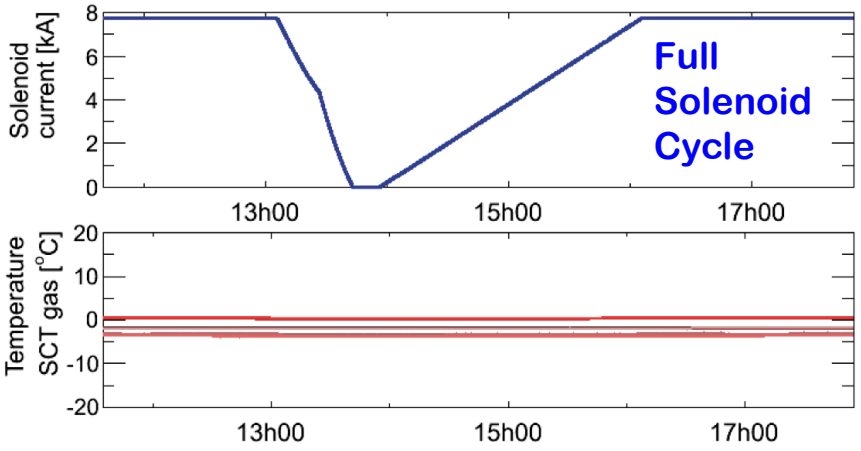


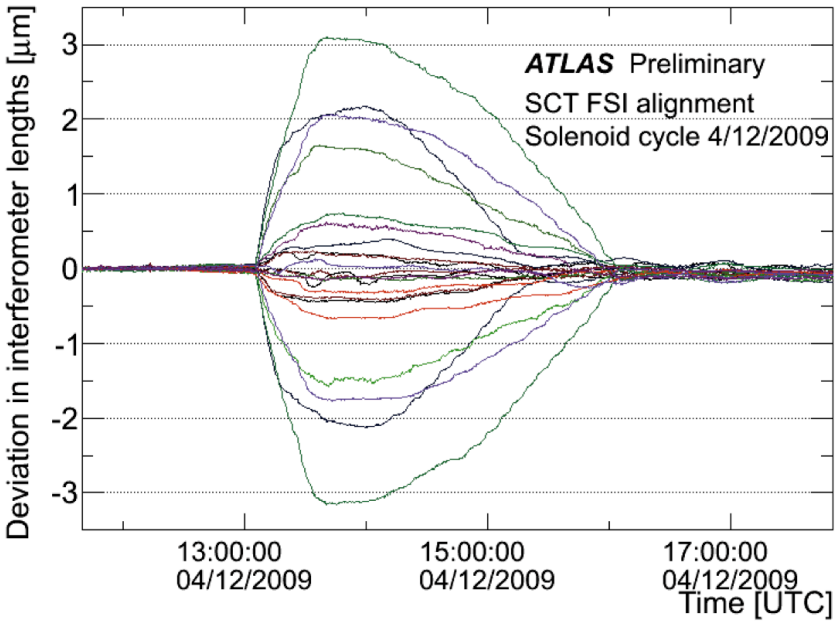


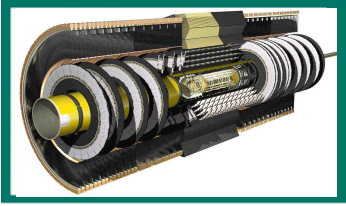
Geometric Stability

- Monitor long term stability of SCT geometry
- Optical alignment system using Frequency Scanning Interferometry
- 842 interferometers form geodetic grid of distance measurements
- Detected movements
  - Before magnet ramp down: position deviations $\sigma \sim 11$ nm
  - During solenoid ramp: movements ≤ 3 μm
  - After full magnet cycle: position deviations $\sigma \sim 49$ nm
- SCT geometry extremely stable



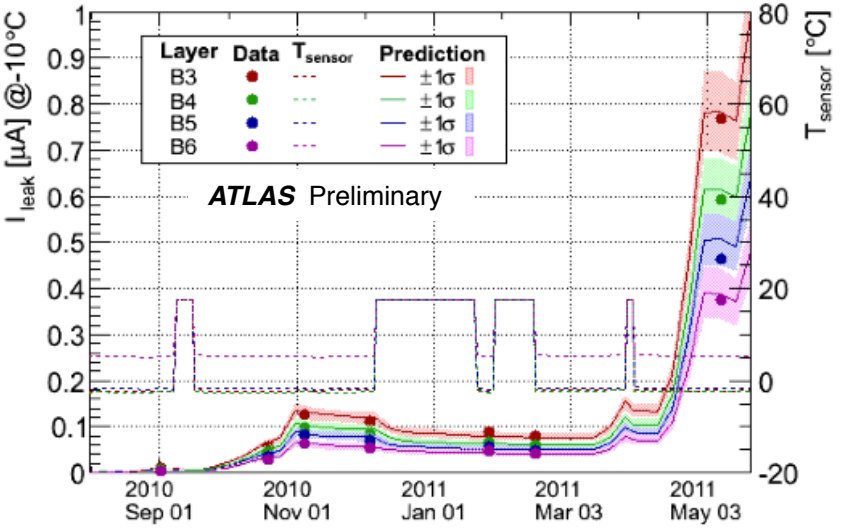


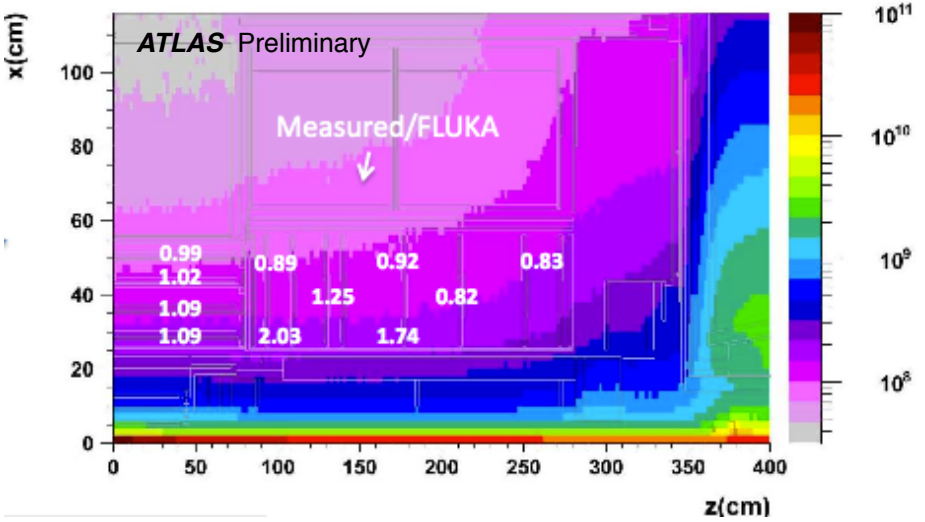


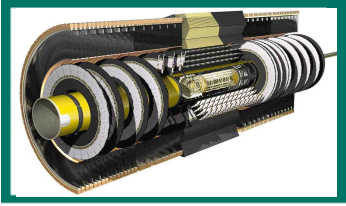


Detector Irradiation

- Radiation damages detector & electronics
- Monitoring needed to predict future performance of current & upgrade SCT
- Linear relation between leakage current & fluence (if T, V = const)
- Measure fluence on-detector
  - Barrel: Excellent agreement with simulation
  - Endcaps: Good agreement in outer / middle rings
  - Inner Rings: Radiation larger than in simulation
  - Need to understand the difference
- Trip limits increased in June 2011
- Safety factor of 1.5 seems still sufficient for upgrade R&D

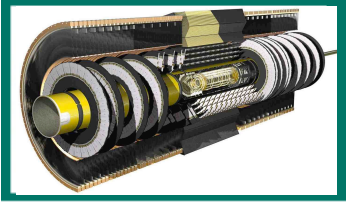




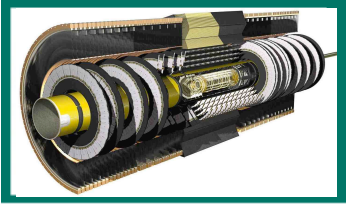


Summary & Outlook

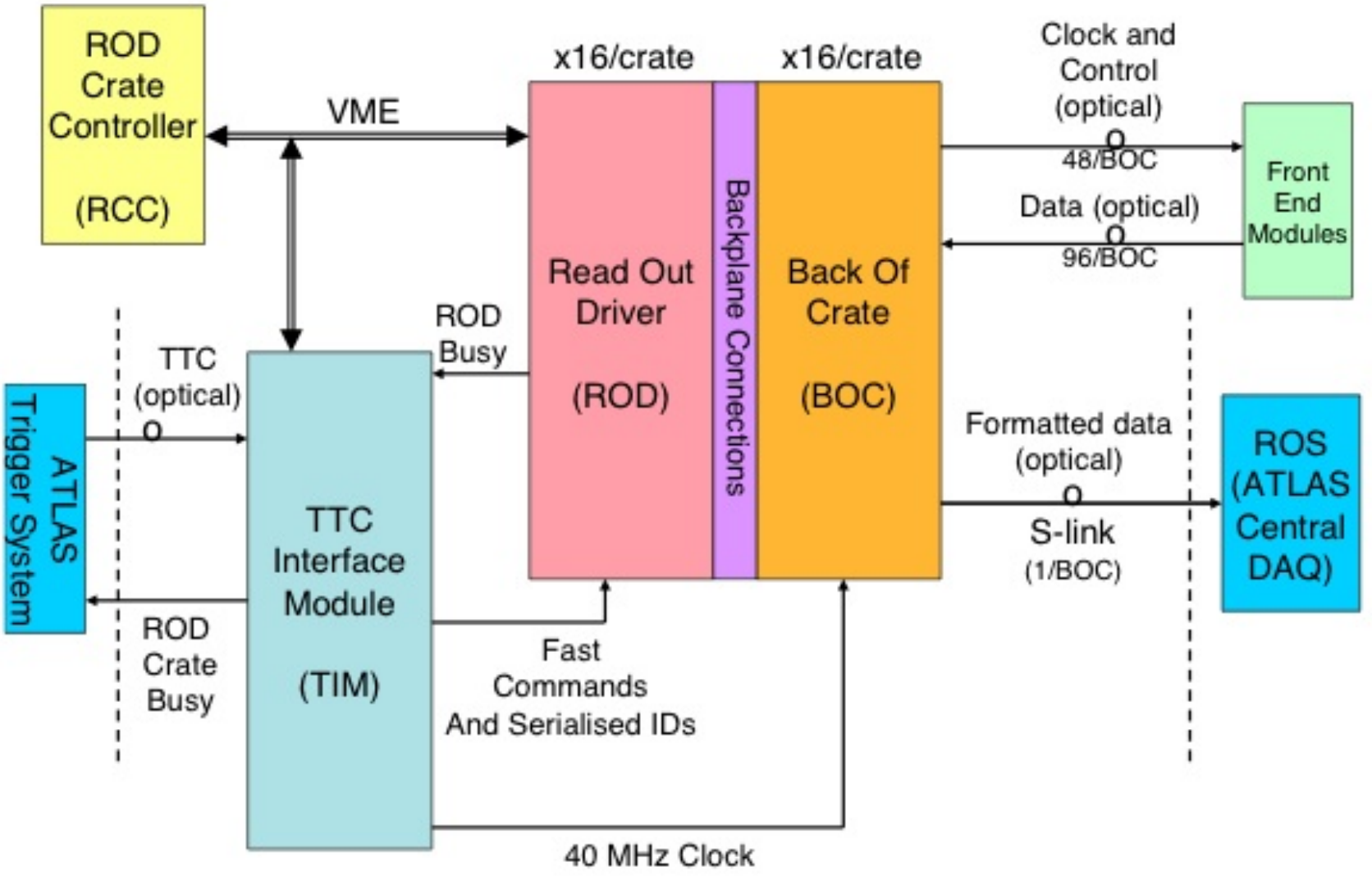
- **SCT is performant and stably operating**
  - Very well timed in detector
  - Number of disabled noisy strips tiny (< 0.2%)
  - Efficiency of 99.6% is higher than design
  - Stopless removal & recovery of RODs working
  - Data Taking Efficiency > 99.4%
- **SCT geometry is extremely stable**
  - Detector Alignment: see talk by Markus Elsing
- **TX death cause understood → humidity**
  - Redundancy scheme very helpful
  - Enough spares available to ensure stable operation
  - New TXs with lifetime > 10 y in preparation
- **First effects of irradiation observed**
  - Increase in leakage current, higher trip limit needed
  - Measurement of fluences agrees well with simulation within safety factor of 50%

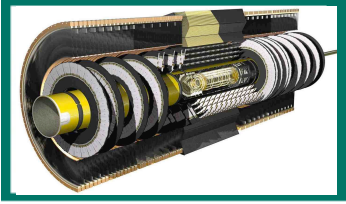


Backup



SCT DAQ Scheme

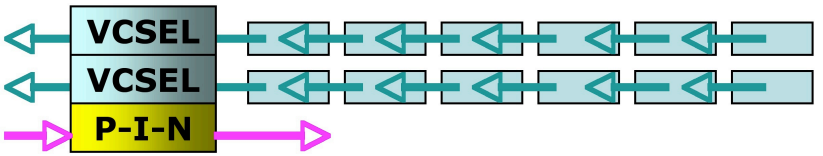




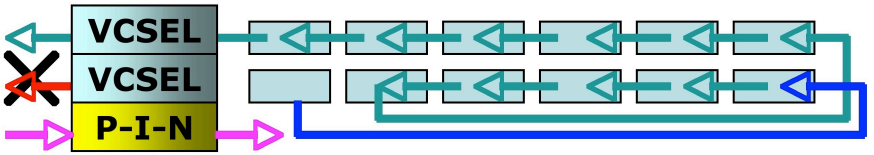
RX Deaths?

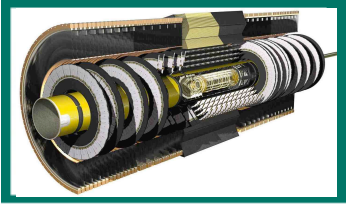
- **On-detector RXs**
  - SCT: different type than TXs
  - Should not be affected
  - Dry nitrogen environment
  - No humidity issue
  - Saw 6 failures in 2010-11

Default Readout

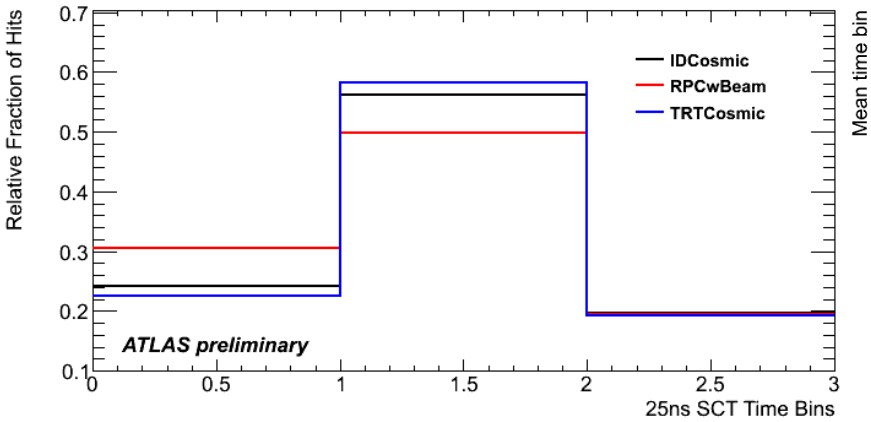


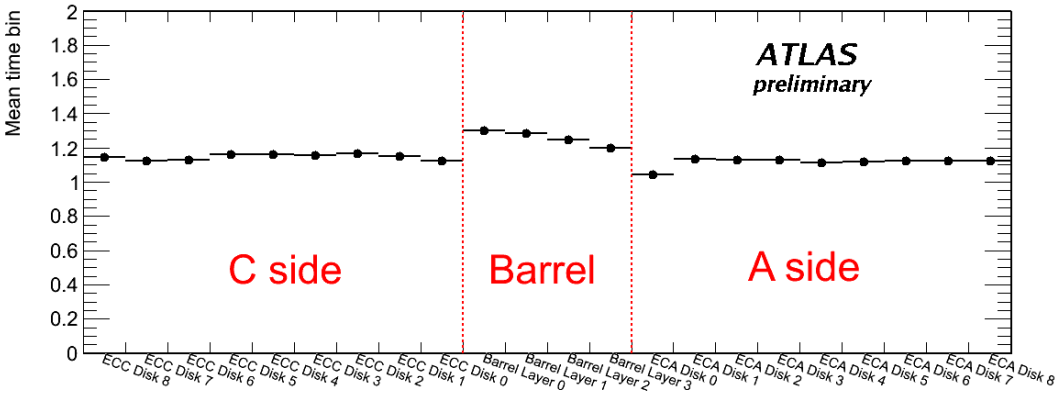
Broken RX Fibre

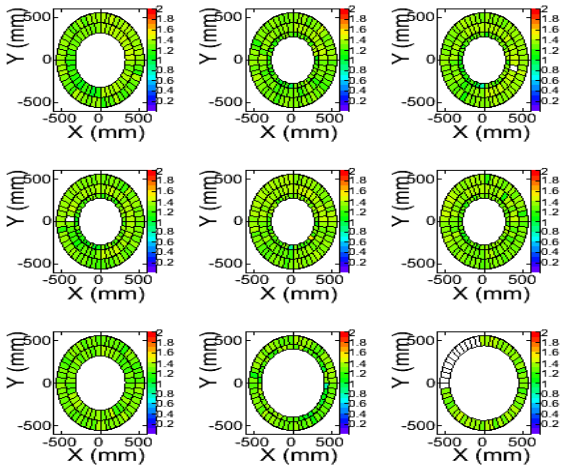


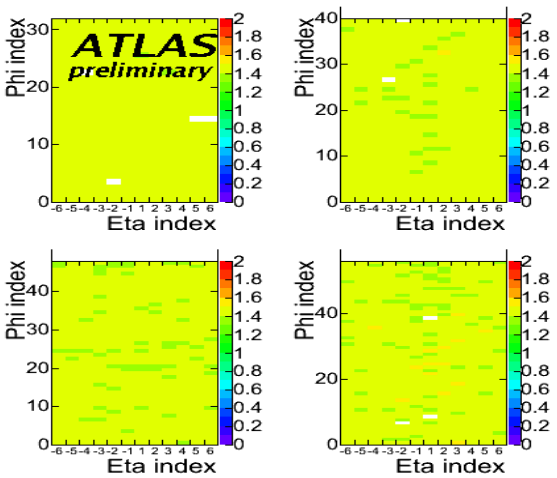


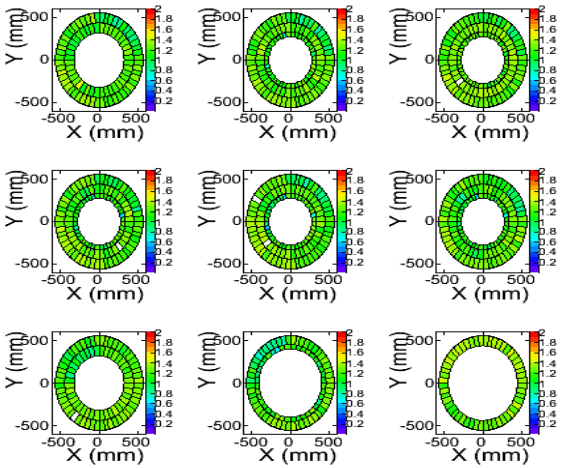
Timing

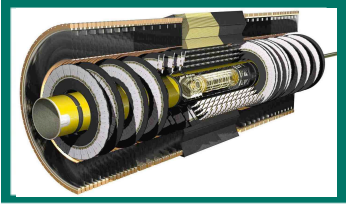

Relative Fraction of Hits
25ns SCT Time Bins
IDCosmic
RPCwBeam
TRTCosmic
ATLAS preliminary


Mean time bin
ATLAS
preliminary
C side
Barrel
A side

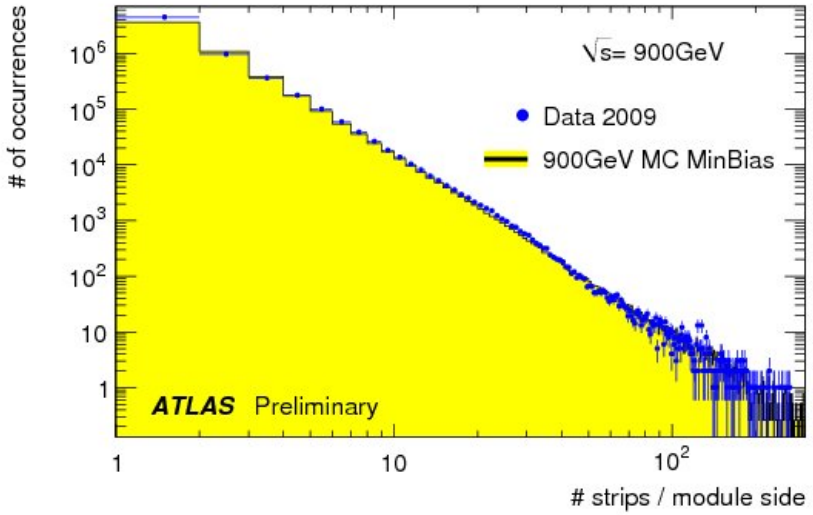

Y (mm)
X (mm)


ATLAS
preliminary
Phi index
Eta index

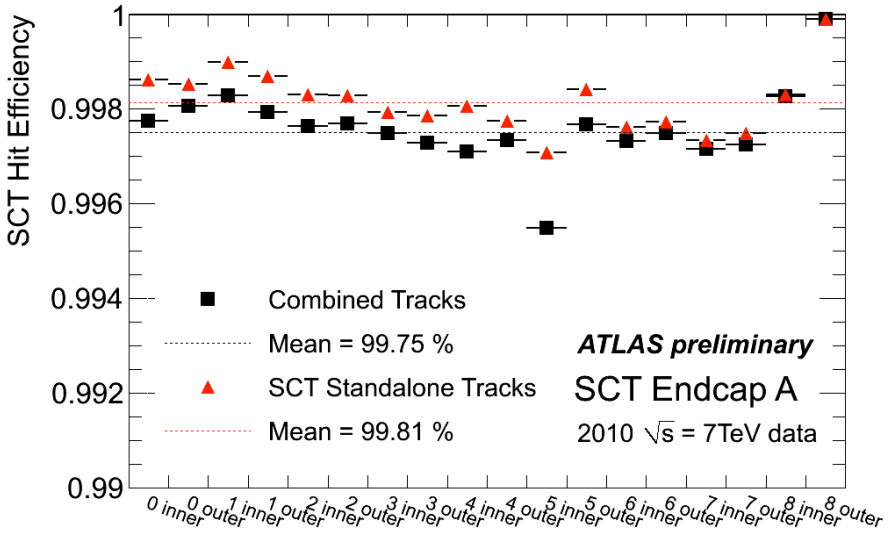

Y (mm)
X (mm)



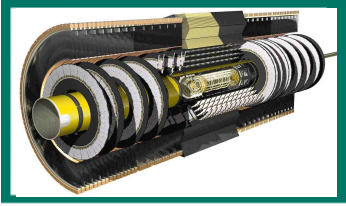
Hit Strips, Efficiency, Occupancy



N(vertex)	Avg. Occupancy (Barrel, innermost layer)
5	0.41 %
10	0.66 %
15	0.89 %



2010	Run Type	Max. Occ.
09. Apr	Cosmics	4%
09. Apr	Beam, non colliding	6%
25. Apr	Squeezed beam, colliding	20%
10. Jun	Single high occ. event	32%
29. Oct	Bunch trains	20%
09. Nov	Heavy Ion	37%



Lorentz Angle

- **Lorentz Angle = Angular drift of charges in silicon sensor due to magnetic field**
- **Dependencies**
  - **Magnetic field**
  - **Temperature**
  - **Bias voltage**
- **Measurement**
  - **Track incidence angle where average cluster width is minimal**