ATLAS Semi Conductor Tracker Operation and Performance

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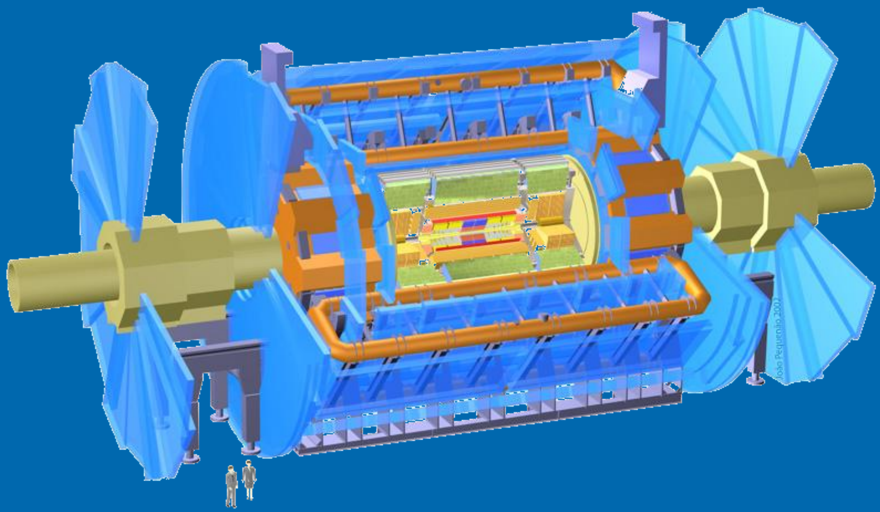
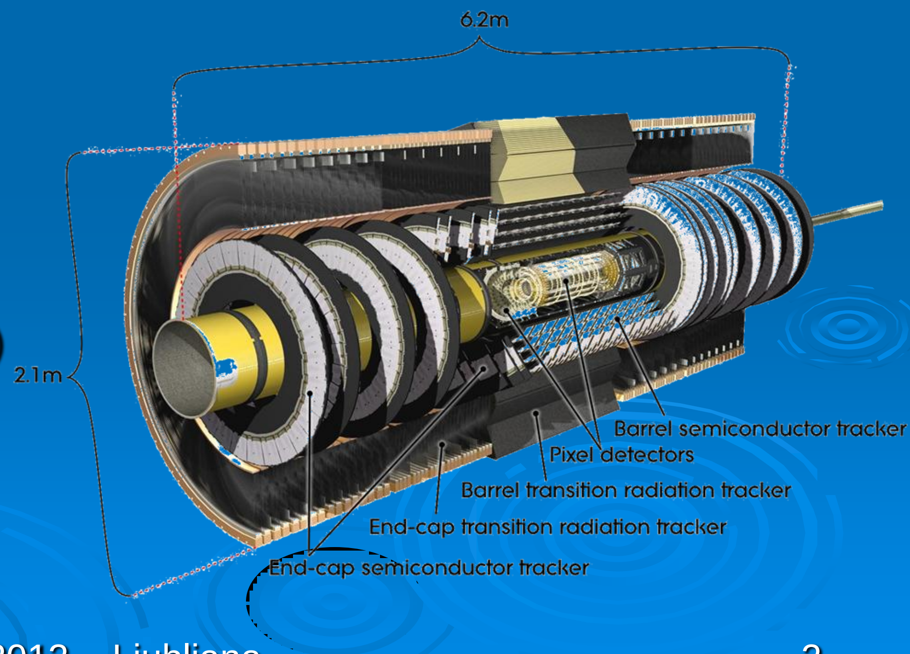
On behalf of the ATLAS SCT Collaboration

7th Trento Workshop
Ljubljana, 29th of Feb – 2nd of Mar

ATLAS and the SCT



- The ATLAS Detector
  - Muon Spectrometer
  - Calorimeters
  - Inner Tracking System
- Looked at √s = 7TeV pp collisions delivered by the LHC in 2010 and 2011. √s rises to 8TeV in 2012 and in the future to even higher energies

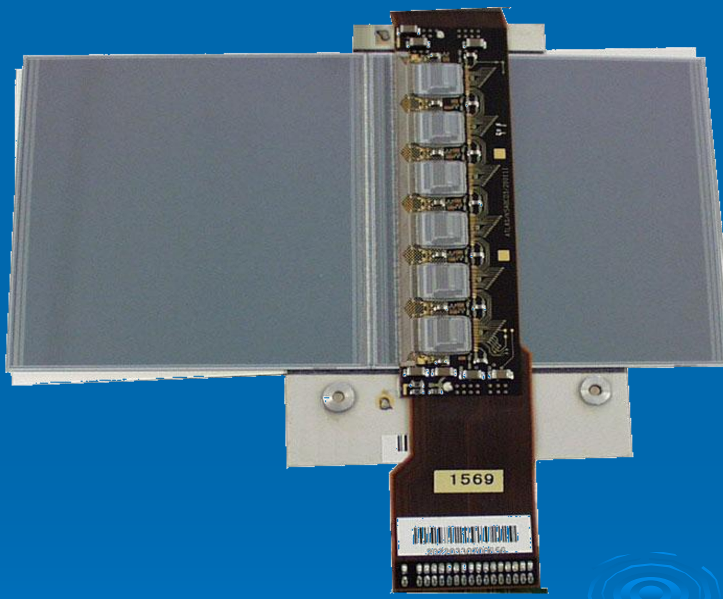


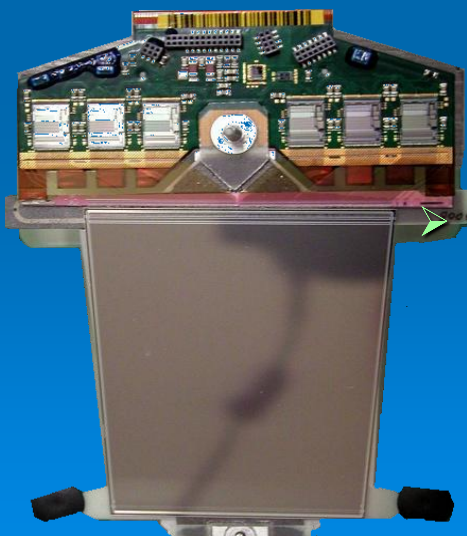
- The Inner Detector of ATLAS:
  - Pixel Detector
  - SemiConductor Tracker (SCT)
  - Transition Radiation Tracker (TRT)
- Operating in a 2 Tesla magnetic field

The SCT

- 6.3 million silicon strip channels
  - a total of 61 m^2 of silicon
  - cooled to -8~+5ºC with C_3F_8
- 4088 modules
  - 2112 on 4 barrel cylinders
  - 1976 on 18 end-cap disks, 9 on each end
- Consists of back-to back planar sensors, glued to a thermally-conductive baseboard
  - with a 40 mrad stereo angle

- Barrel module
  - One shape
  - 80 µm pitch



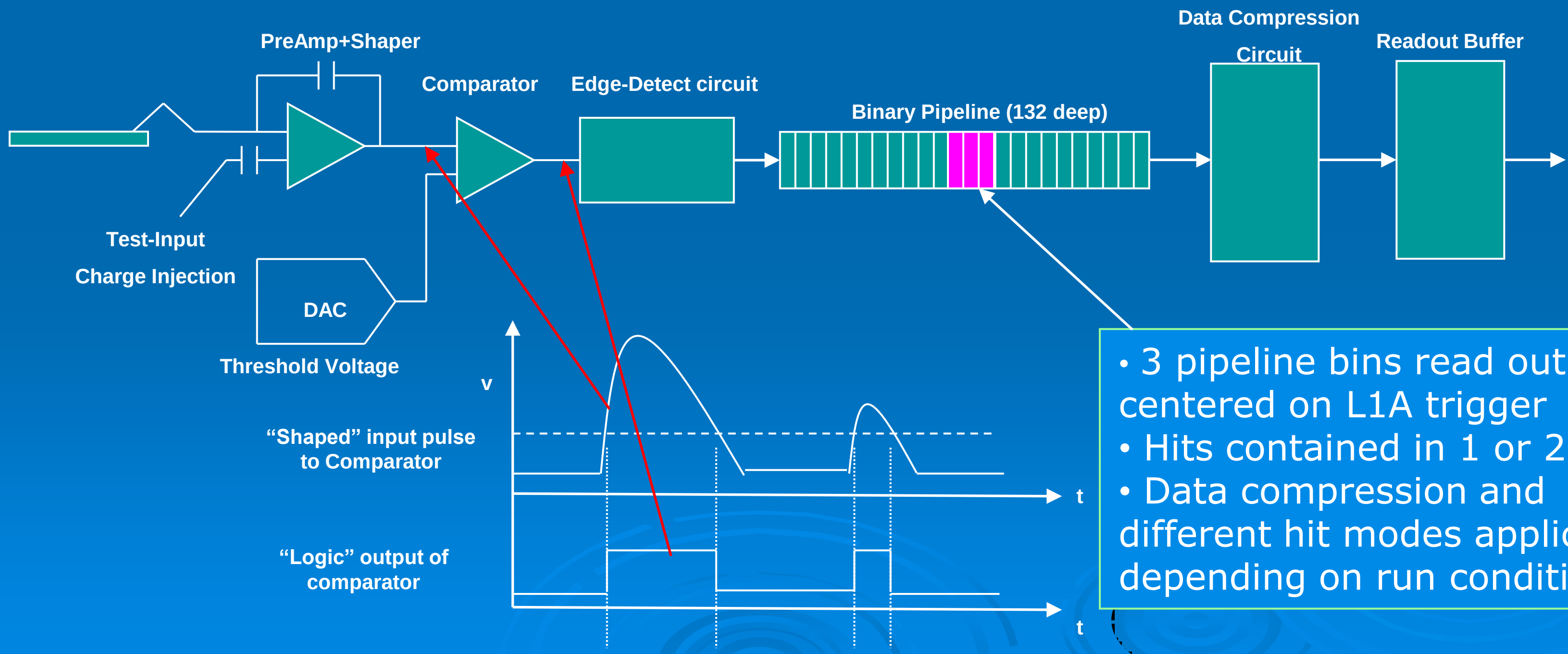


- End-cap module
  - One of the five different shapes
  - 57-90 µm pitch

- 1536 channels per module
- Up to 500 V bias voltage
- Optical communication
- 5.6W/module (->10W after 10y)

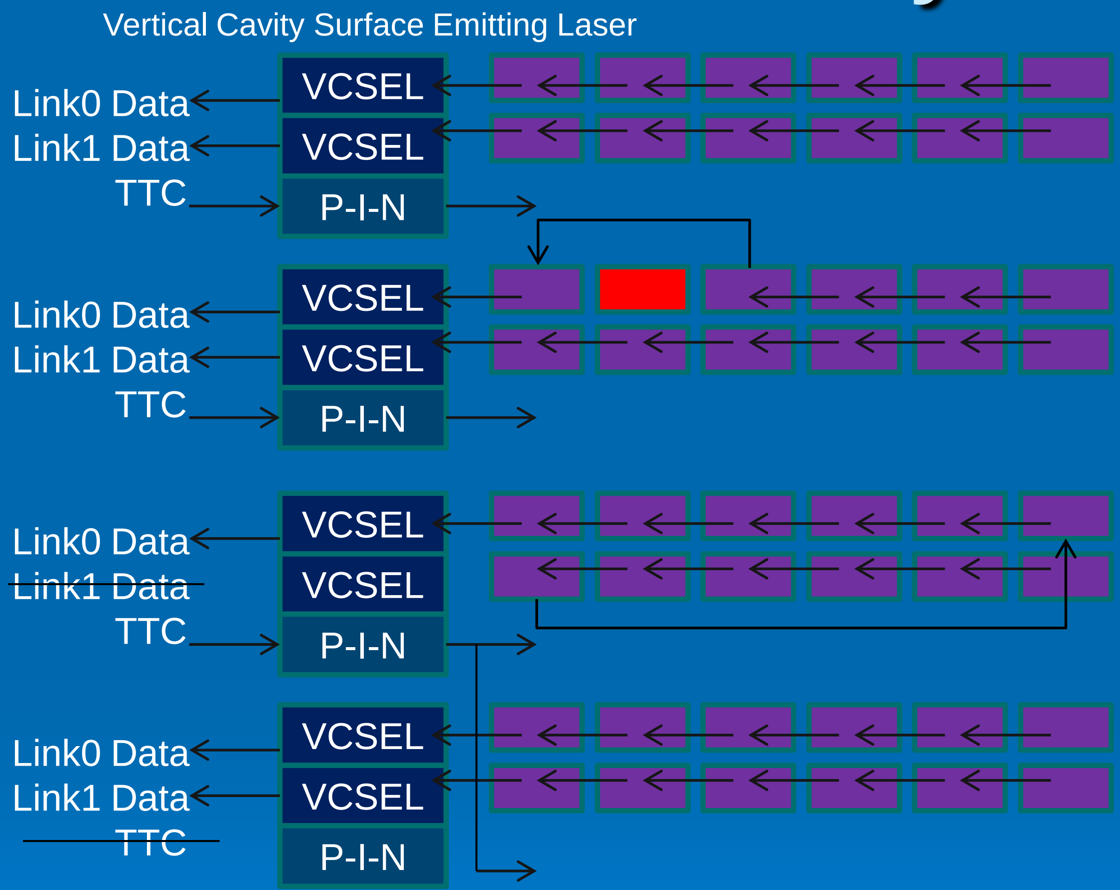
SCT Front-End Electronics

- 12 ABCD ASIC front-end chips (6 per module side)
  - 128 channels per chip
  - Binary read-out scheme with a 132 bit deep buffer
  - 40 MHz (25 ns) clock
  - 20 ns front-end shaping time



- 3 pipeline bins read out, centered on L1A trigger
- Hits contained in 1 or 2 bins
- Data compression and different hit modes applicable depending on run conditions

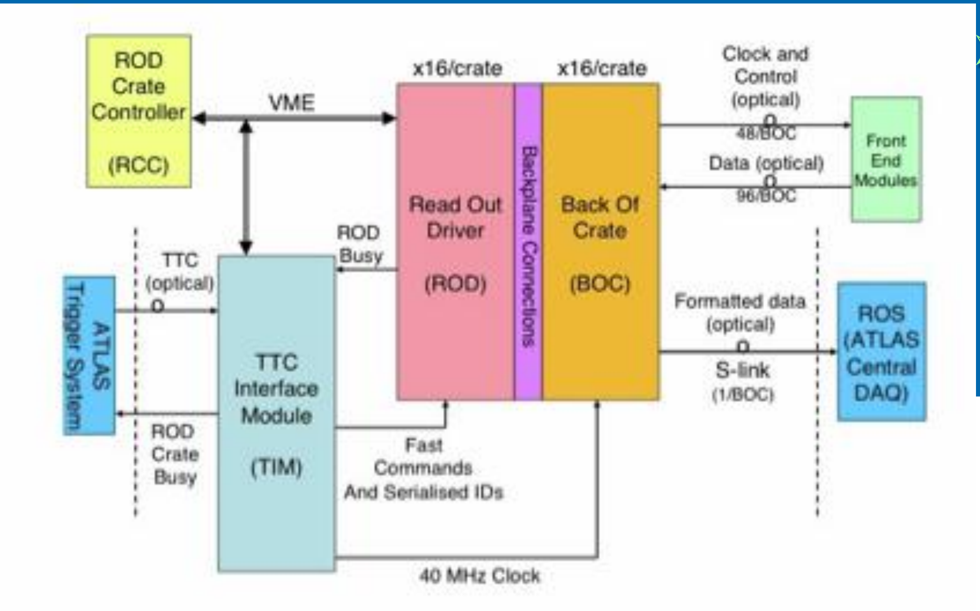
Redundancy Schemes



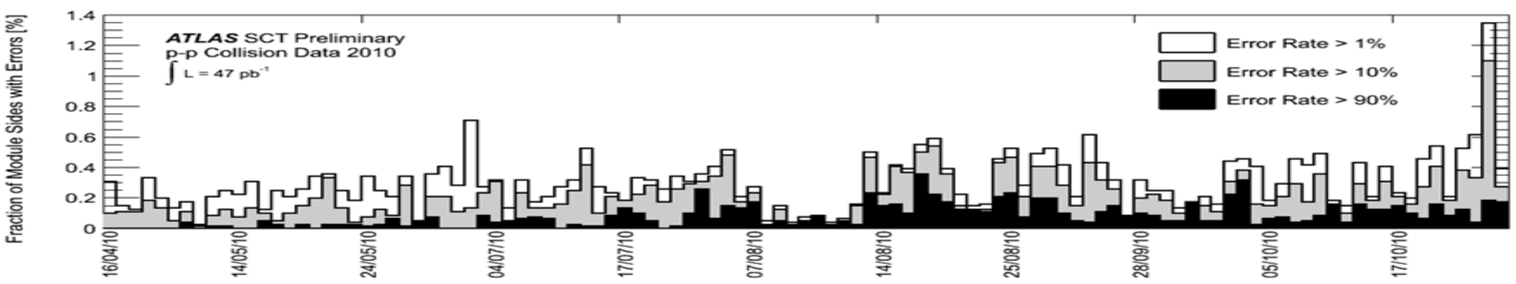
- Standard operation
  - All chips, VCSELs and fibres ok
- Dead chip bypassed
  - VCSELs and fibres ok
- Broken RX fibre or dead RX VCSEL
  - For barrel modules, lose master chip of lost link
- Broken TX fibre or dead TX VCSEL
  - Clock/control signals taken from neighbouring module
- Typical snapshot of optical readout status in SCT

Faulty Readouts	Barrel	Endcap A	Endcap C	SCT	Fraction [%]
Link 0	13	21	14	48	1.17
Link 1	16	30	10	56	1.37

SCT DAQ and stability

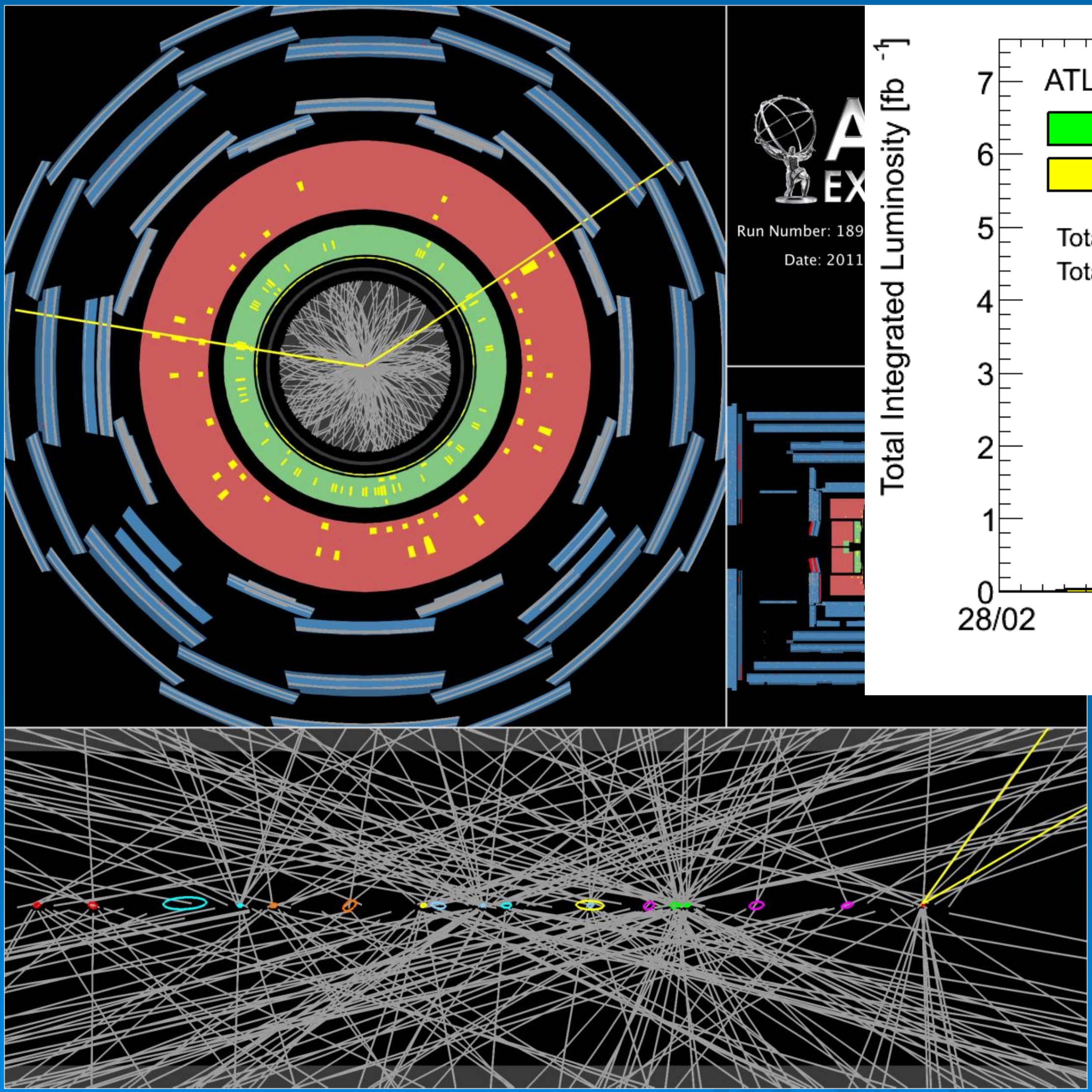


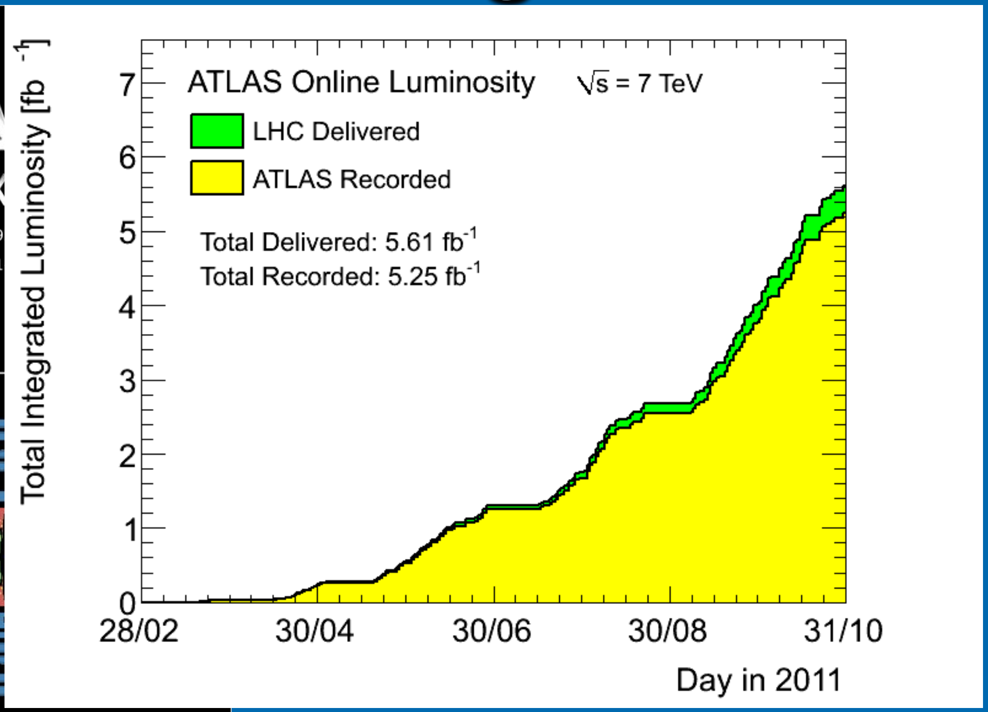
- The SCT DAQ was improved with several enhancements during the last couple of years to maximise data taking efficiency
  - "stopless" reconfiguration/reintegration of RODs in case of BUSY (rare)
  - Auto reconfiguration and recovery of modules which shows errors
  - Auto reconfiguration of the entire SCT to counter Single Event Upsets



Fraction of module sides reporting errors as function of time during the 2010 data taking period
The error rate is very low

ATLAS data taking





The above figure shows the cumulative luminosity versus day delivered to and recorded by ATLAS during 2011

The event display shows a Z candidate in a di-muon decay with 20 reconstructed vertices

ATLAS data taking efficiency

Inner Tracking Detectors			Calorimeters				Muon Detectors				Magnets	
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.8	99.6	99.2	97.5	99.2	99.5	99.2	99.4	98.8	99.4	99.1	99.8	99.3

Luminosity weighted relative detector uptime and good quality data delivery during 2011 stable beams in pp collisions at √s=7 TeV between March 13th and October 30th (in %), after the summer 2011 reprocessing campaign

SCT data taking efficiency is excellent

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.

SCT Configuration in ATLAS

Typical SCT configuration status (May 2010)

Disabled readout component	Barrel	Endcap A	EndCap C	SCT	Fraction %
Modules	10	5	15	30	0.73
Chips	24	5	4	33	0.07
Strips	3681	3364	3628	10673	0.17

Total of 0.97%

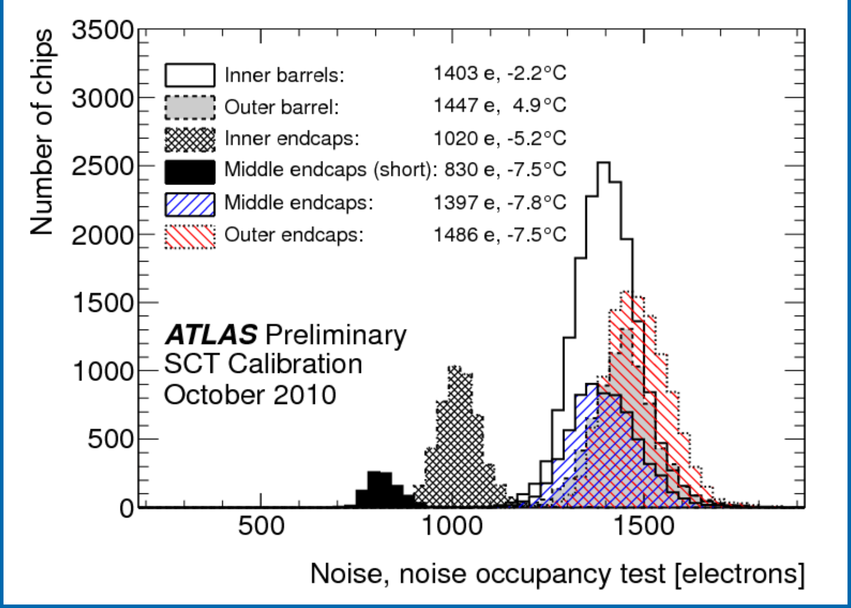
Disabled Module details

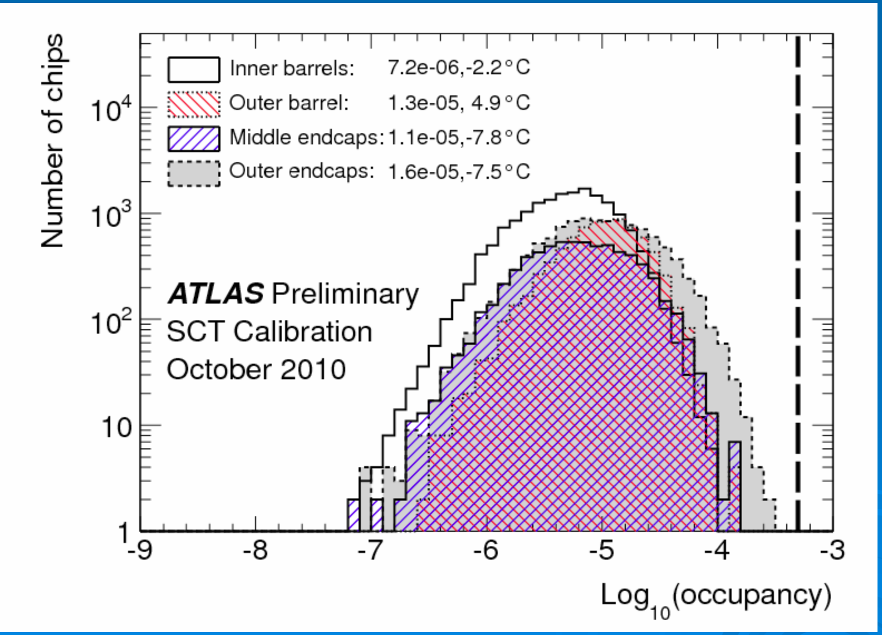
	Barrel	Endcap A	Endcap C	SCT	Fraction %
Total	10	5	15	30	0.73
Fraction %	0.2	0.5	1.5	0.7	
Cooling	0	0	13	13	0.32
LV	6	0	1	7	0.17
HV	1	4	1	6	0.15
Readout	3	1	0	4	0.10

The 13 disabled modules on Endcap C is due to one faulty cooling loop on disk 9

SCT Calibration

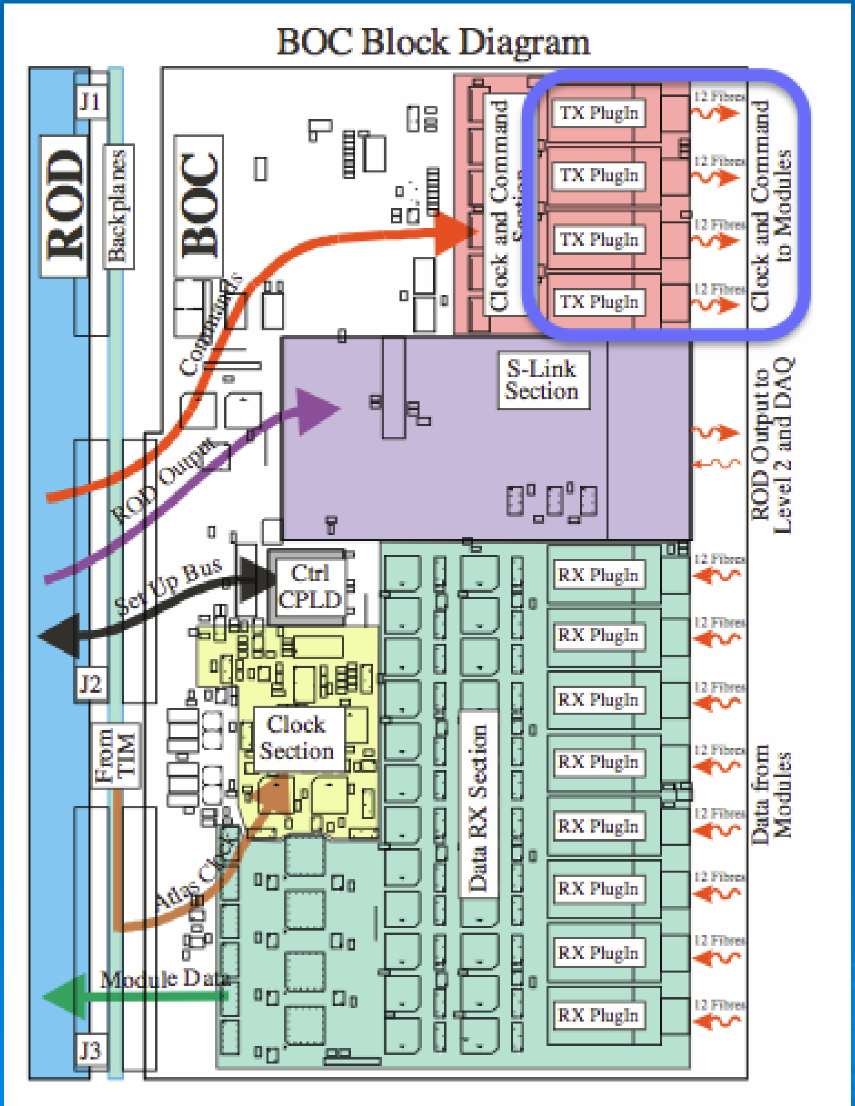
- Noise distribution per chip measured from a response curve test
  - Charge injection from FE chips
  - Measures hits vs. threshold (S-curve)
  - Noise extracted from fit of S-curves
- Noise < 1500 electrons
  - Which is the design criteria
  - Hit threshold 1fC





- Noise Occupancy per chip
  - Measures noise occupancy as a function of threshold and extract the input noise
- Noise Occupancy about 10^{-5}
  - Design criteria < $5x10^{-4}$

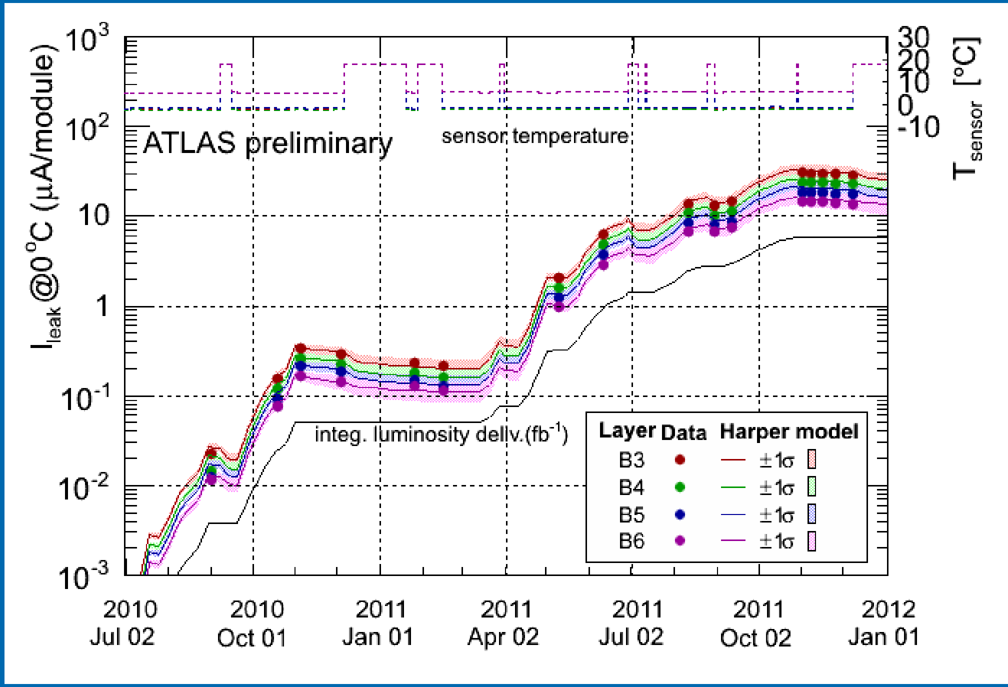
TX VCSEL issues



- The major operational issue has been failure of the optical TX VCSEL arrays used to send command signals to the modules
- Initially attributed to ESD damage due to poor precautions in the factory
- New production batch installed in 2009 improved lifetimes
- However started to fail again soon after, this time attributed to humidity
- Being gradually replace with TX'es from new vendor with improved humidity tolerance
  - Also now operated in lower humidity
- Redundancy schema has minimized impact on operational efficiency

Radiation damage

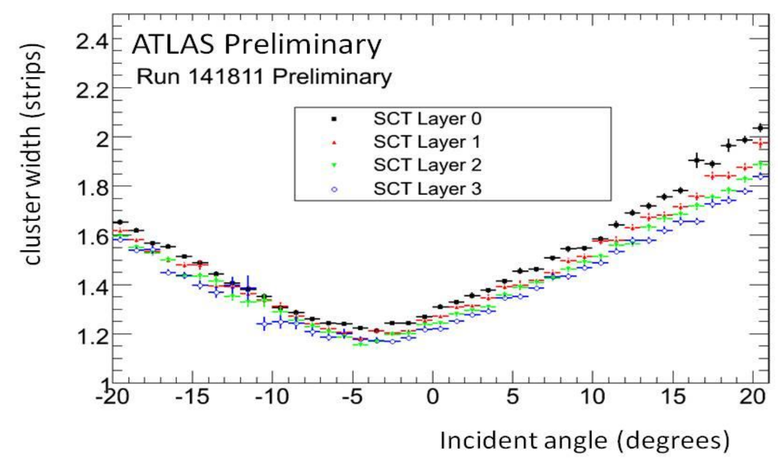
- The collisions at ATLAS give rise to radiation background which damage sensors and electronics
- The effects are being monitored through the sensor leakage current
- The measured fluency and predictions are shown in the plot and are in excellent agreement

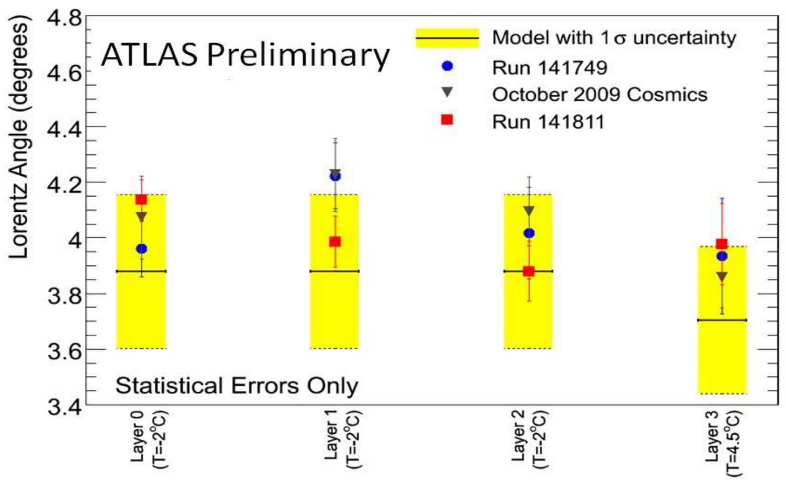


- The measured leakage currents of the modules are slowly increasing, both at 50V (standby state) and 150V (on state)
  - Current trip limits has been increased appropriately, from 5μA to 50μA
- So far expect negligible effects on depletion voltage

Lorentz Angle measurements

- The Lorentz force affects the drift direction of the charge carriers
- The Lorentz angle is extracted from the minimum of the distribution of the cluster size versus the track incidence angle
- It depends on the magnetic field strength, module temperature, bias voltage and radiation damage
- Model prediction sensitive to digitization model used in simulation
- Measurements of both cosmic and collision data in agreement with model predictions

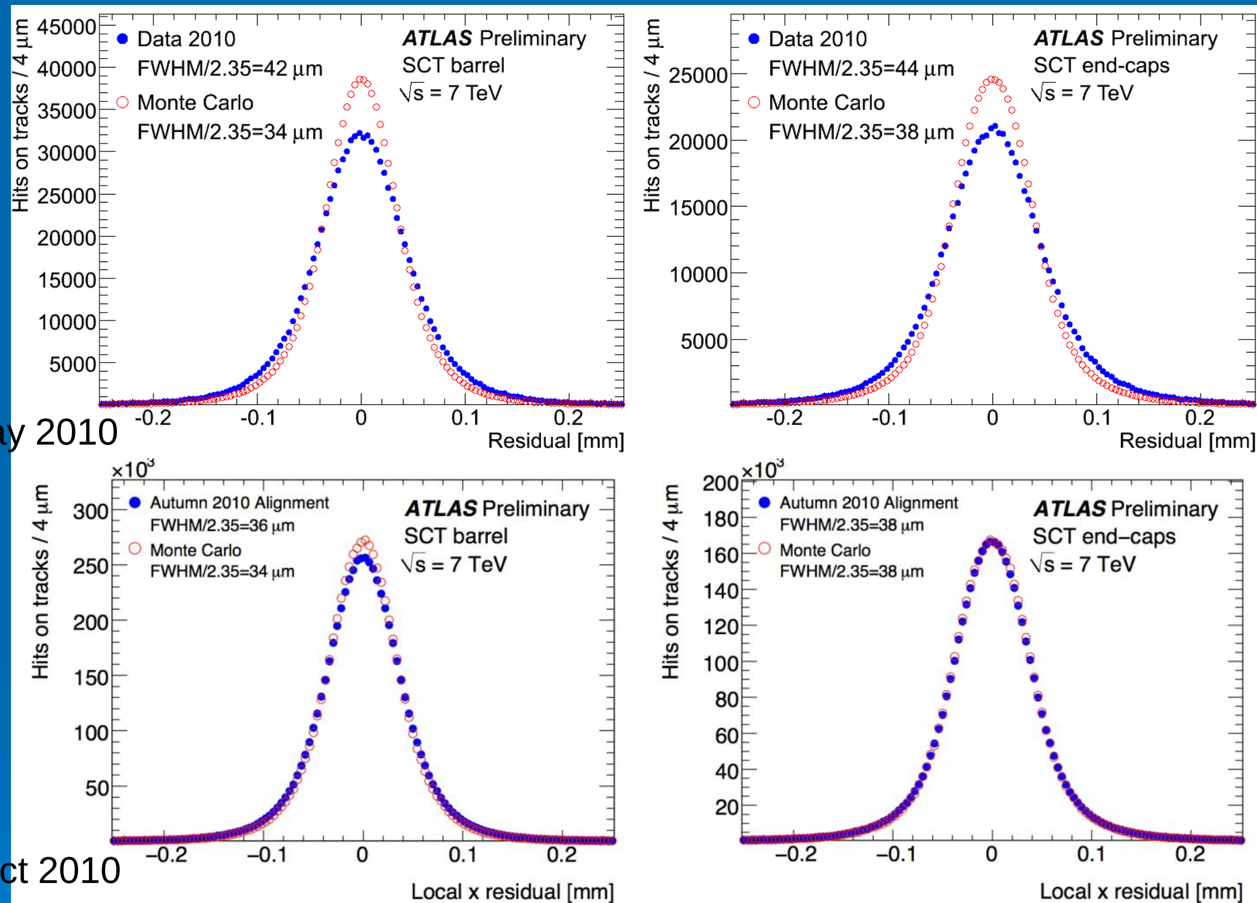




Alignment

- The alignment was derived using track based global χ^2 algorithm
- The residual is defined as the measured hit position minus the expected from the track extrapolation
- The projection of the residual onto the local x co-ordinate is shown
- The alignment continues to improve with time

May 2010

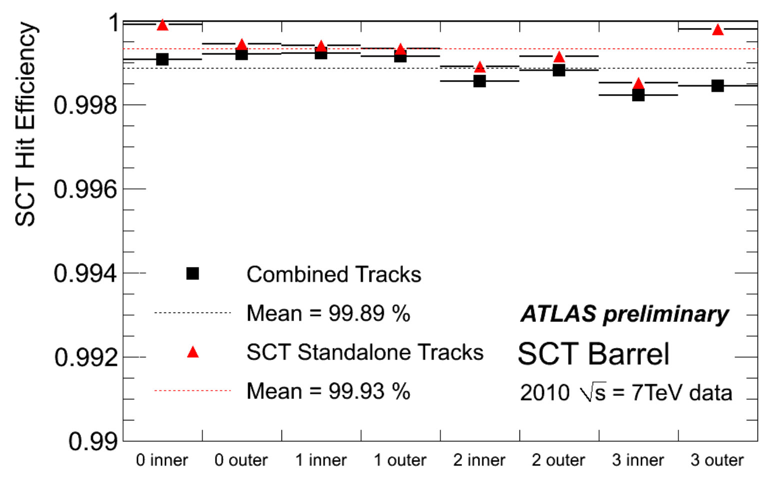


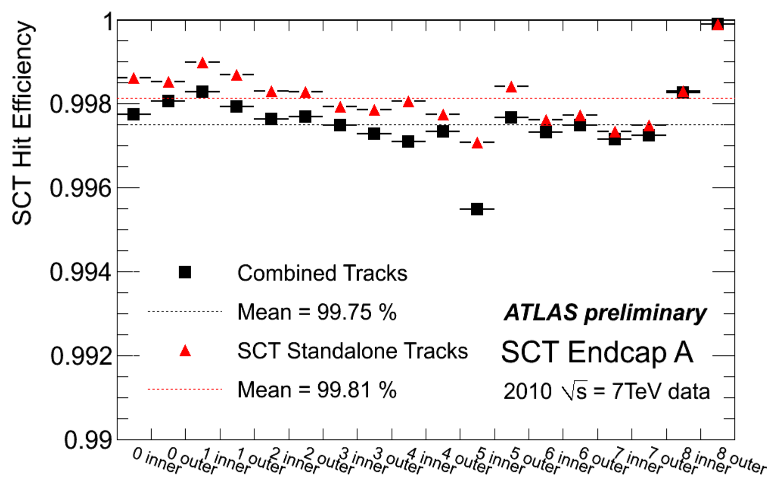
Oct 2010

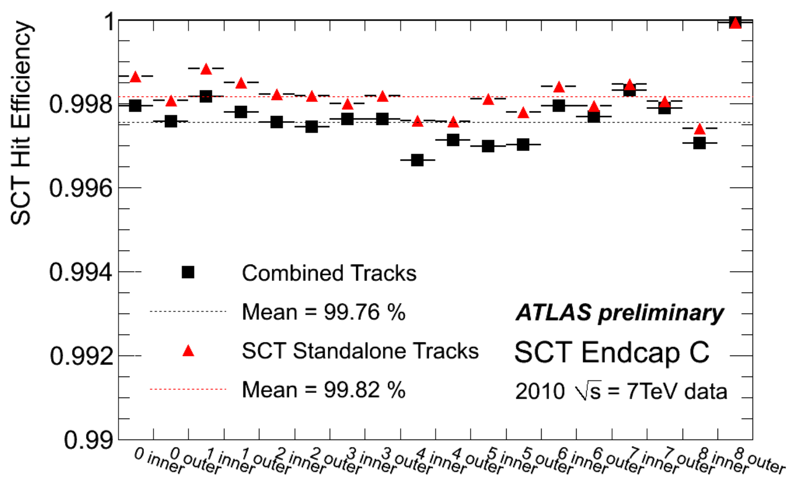
Barrel		End-Caps	
May 2010:	42µm	May 2010:	44µm
Oct 2010:	36µm	Oct 2010:	38µm
Simulation:	34µm	Simulation:	34µm

Hit Efficiency

- Intrinsic Hit Efficiency:
  - # of hits/# of possible hits on tracks
- Requirements:
  - P_T > 1 GeV/c
  - ≥ 7 Hits for SCT standalone
  - ≥ 6 Hits for ID combined
- Hit Efficiency >> 99%
  - > 99% design criteria







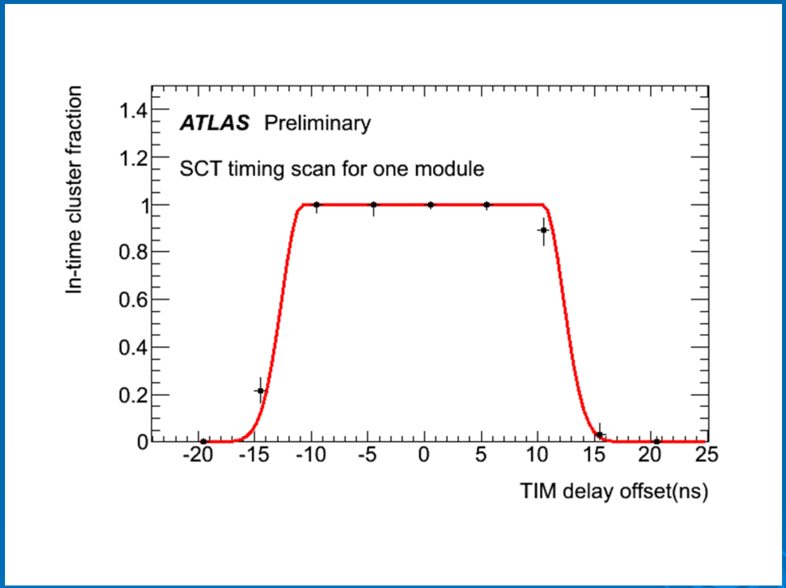
Summary

- SCT shows an excellent performance during the first two years of physics data taking
  - With an overall data taking efficiency of **99.6%** in 2011
  - **99.0%** of the 6 million channels operational
  - All design criteria as noise, efficiency, tracking and alignment has been fulfilled
- The evolution of the leakage currents are in good agreement with expectations from radiation damage
- No significant operational issues besides TX VCSEL deaths
  - Small impact on physics data taking due to the very important redundancy schema
- The SCT is ready for renewed data taking at higher energy and luminosities

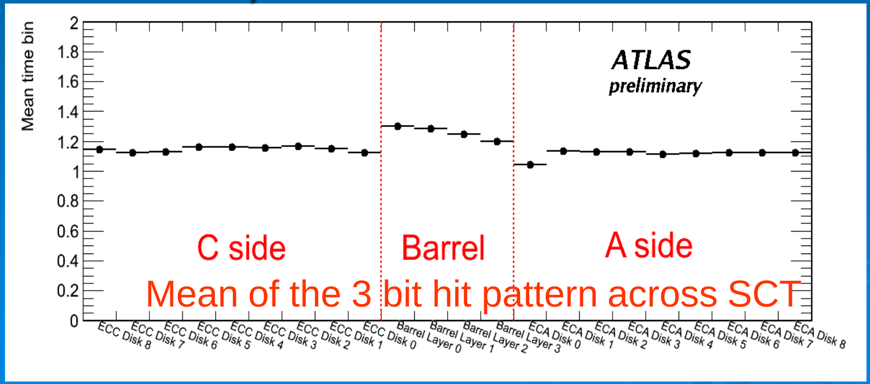
Backup Slides

Timing

- The ABCD chips binary read-out means that it reports “hit” or “no-hit” above the 1fC threshold. It samples hits in 3 consecutive 25 ns bins, and will report a “hit” in the readout depending on the chosen hit mode pattern.

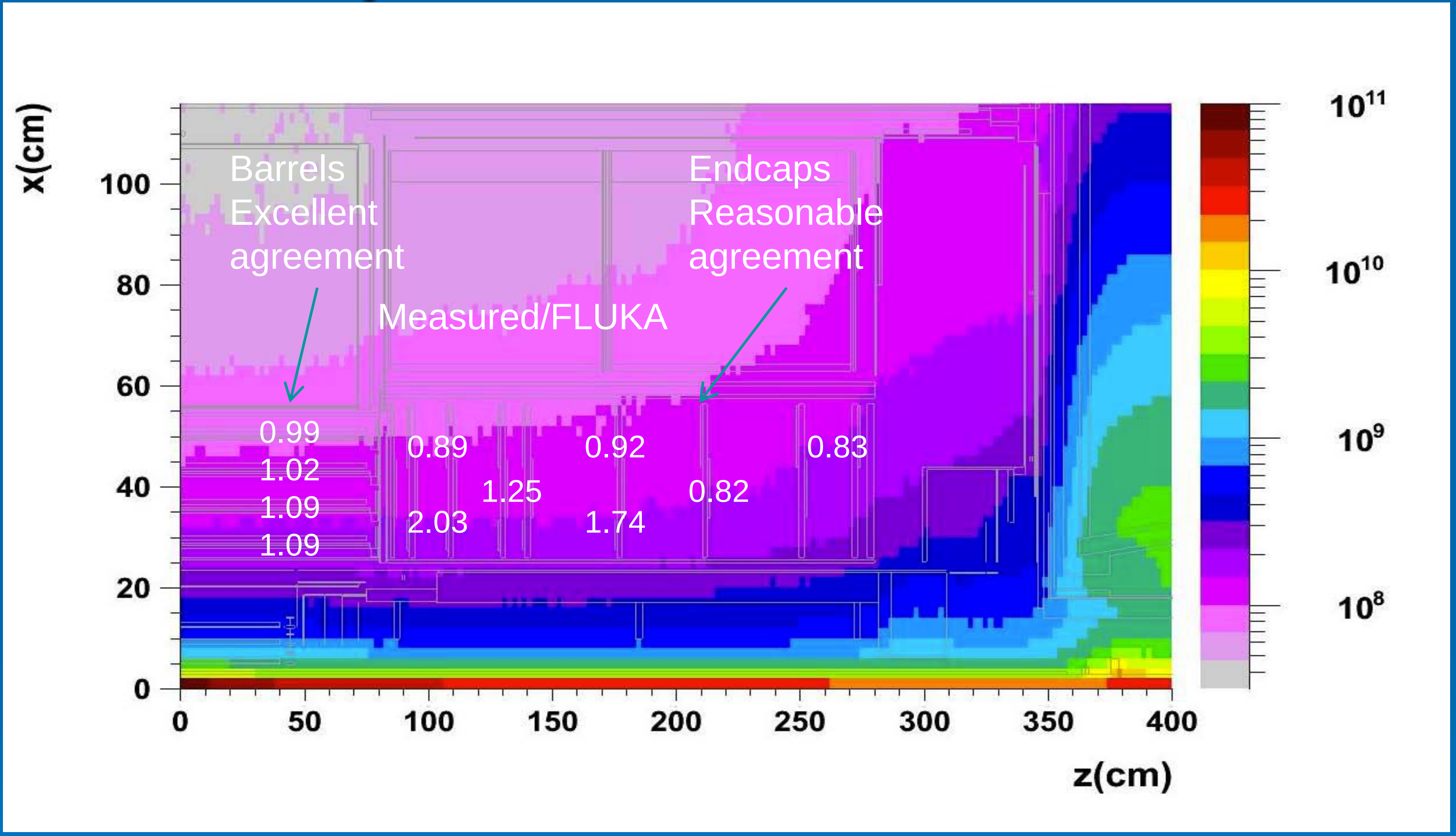


- xxx mode, for timing in, cosmic rays and ≥75 ns bunch trains
- x1x mode, for 50 ns bunch trains (currently used)
- 01x mode, will be used for 25 ns bunch trains (rejection of hits from earlier collisions)



Above plot shows the fraction of in-time clusters on tracks as a function of the delay offset, taken from a timing scan done in 2010. All 4088 modules optimized for 01x (1ns precision)

Comparison of fluences



Comparison of 1MeV neutron equivalent fluences determined from leakage current measurements and FLUKA predictions at 7 TeV
Data from 2010 with a integrated luminosity of $48.6pb^{-1}$

Occupancy and Rate Limitations

Occupancy [%]	Rate Limits [kHz]		Complex DT	Event Size/ROD [kB]
	ABCD	S-links		
0	754	2000	8/53	0.056
1	233	89	8/170	2
10	28	10	8/1395	15.6
20	14.5	5.2	8/2755	31

- The above table demonstrate the various rate limitations for various occupancies.
- At an occupancy of 1%, which is expected for 23 interactions per BX at 14TeV, the rate limit is ~90kHz and imposed by the S-links
  - well above nominal peak trigger rate of 75kHz
- Complex dead time: Maximum number of triggers within a given number of BC. Limited by an ABCD 8-deep event buffer