

ATLAS Silicon Tracker operation and performance



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on behalf of the ATLAS SCT Collaboration

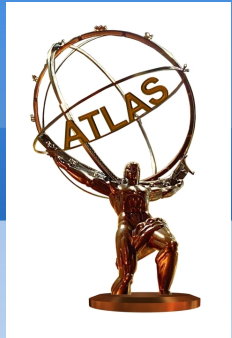
Vertex 2010

19th International Workshop on Vertex Detectors

6th-11th June 2010, Loch Lomond, Scotland



Introduction



This talk is about **ATLAS SCT**:
operation experience, efficiency, occupancy,
noise, timing, Lorentz angle, cooling, etc.

It is *not* about tracking, vertexing, alignment,
physics results.

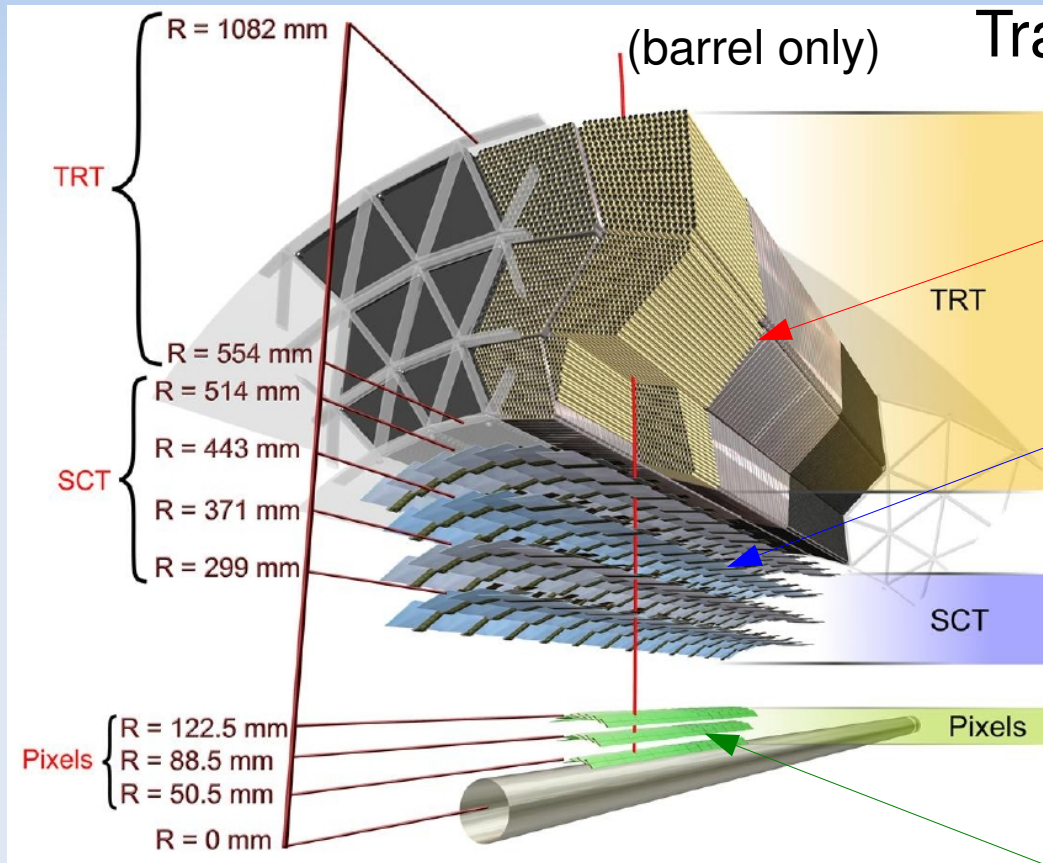
(See Giacinto Piacquadio's talk later today.)

ATLAS Inner Detector



ATLAS Inner Detector

Located in $B = 2\text{ T}$ solenoidal field
Tracking coverage up to $|\eta| = 2.5$



Transition Radiation Tracker

SemiConductor Tracker

Dimensions:

Radial: 30 cm to 52 cm

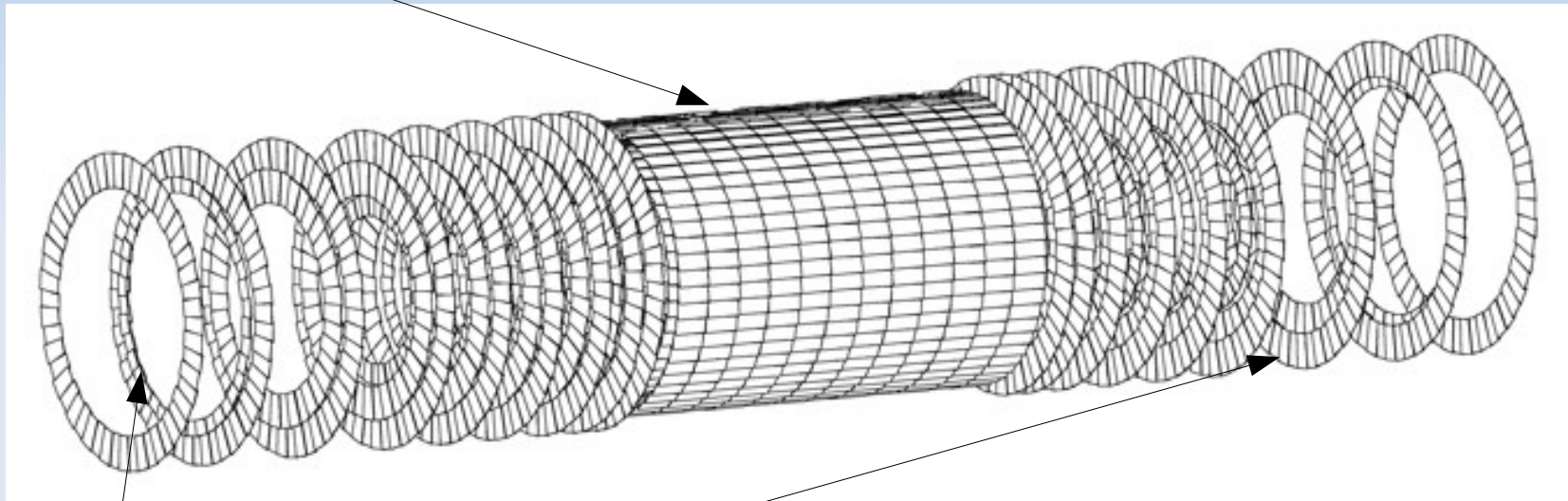
Longitudinal: -2.7 m to +2.7 m

Pixel detector

SCT layout



Barrel: 1.5 m long, $|\eta| < 1.1-1.4$, 4 layers, 2112 modules

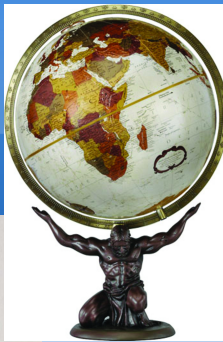


Endcaps: 9 discs, 988 modules, $1.1-1.4 < |\eta| < 2.5$

Total: $2112 + 2 \cdot 988 = 4088$ modules

61 m² of silicon

SCT Modules



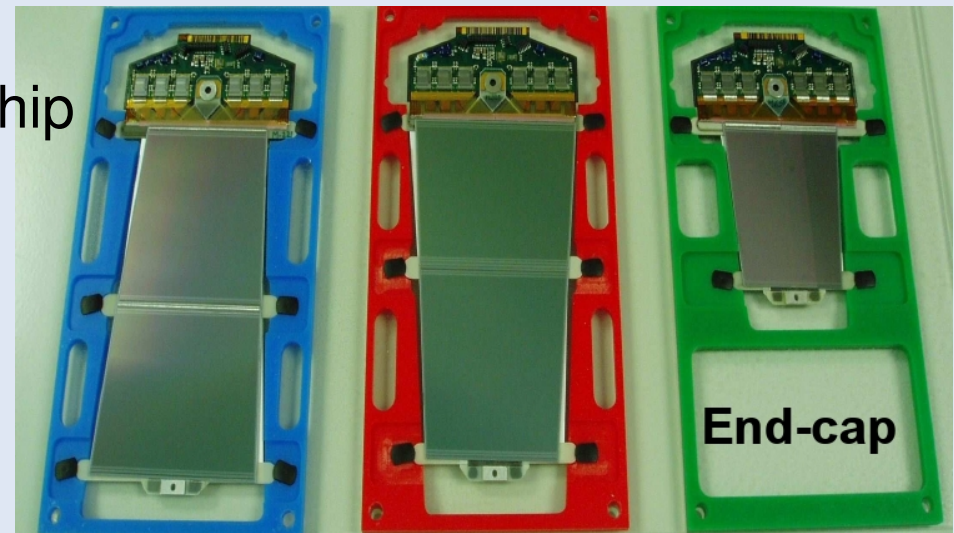
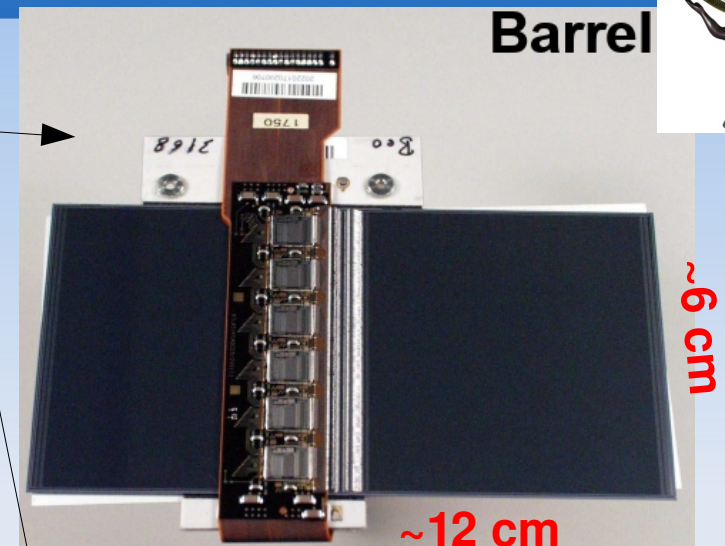
Barrel: 1 layout

Endcap: 3 layouts

- p strips in n-type Si
- pitch: 80 μm (barrel), 57-94 μm (endcap)
- typical depletion voltage: 65 V
- operation: 150 V reverse bias
- currently 5.5 W power per module
(at the end expected up to 9 W)
- double-sided (40 mrad stereo angle)
- 6 chips per side, 128 channels per chip
 $\rightarrow 4088 \cdot 2 \cdot 6 \cdot 128 = 6,279,168$ readout channels

Spacepoint resolution:

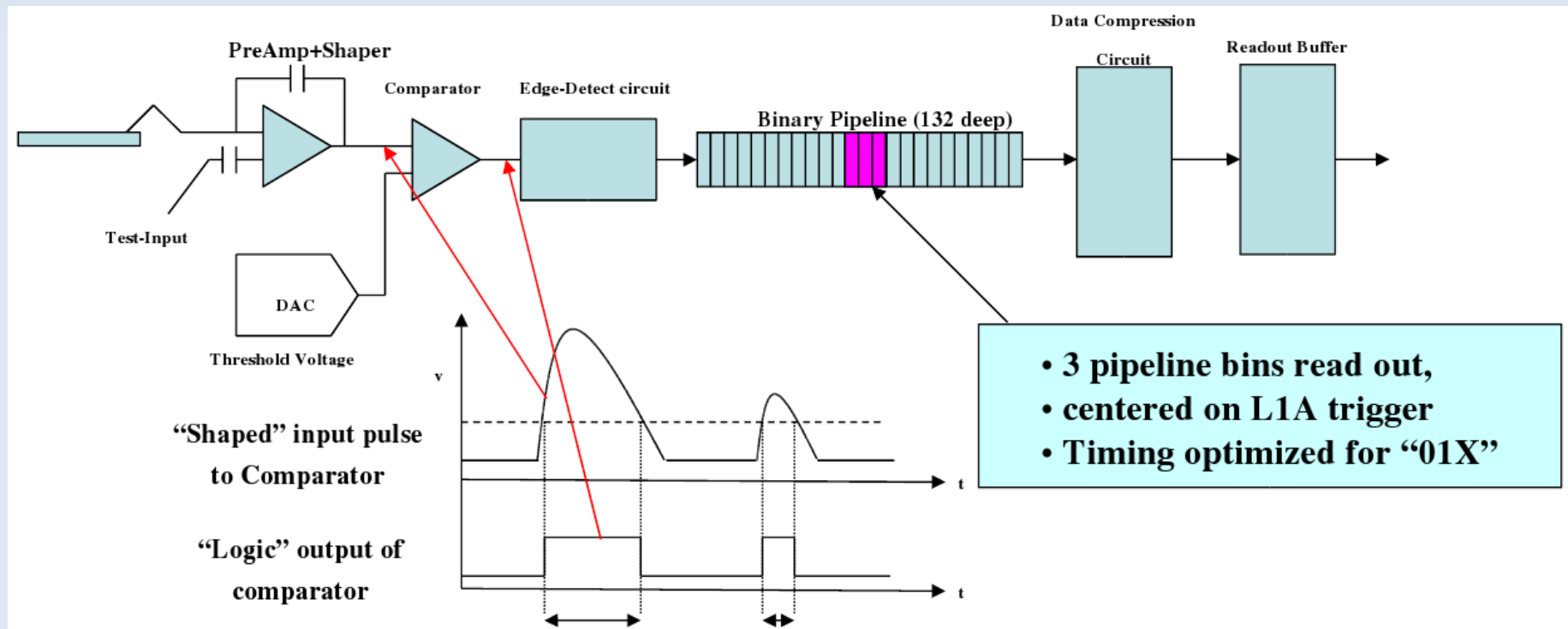
- $r\phi \sim 17 \mu\text{m}$ (the bending plane)
- $z \sim 580 \mu\text{m}$



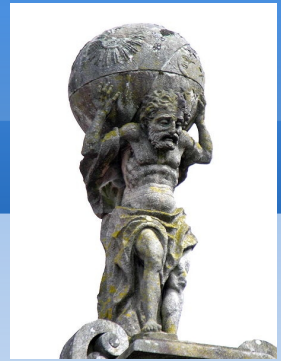
SCT module readout



- binary readout: a strip is hit or is not hit (1 or 0)
- operates at LHC bunch crossing frequency - 40 MHz (25 ns)
- front end shaping time of 20 ns
- default threshold: 1 fC

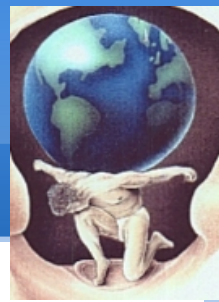


SCT design requirements



- intrinsic strip efficiency $> 99\%$
- noise occupancy $< 5 \cdot 10^{-4}$ per read-out
- maximum 1% strips un-operational

Status of Active Channels



Total SCT:
4088 modules

Excluded:
+ 30 modules
+ 33 chips
(~2.75 modules)
+ 10,673 strips
(~7 modules)

**99.03% of
ATLAS SCT
is ON**

ATLAS SCT Configuration May 2010

Disabled Readout Components	Endcap A	Barrel	Endcap C	SCT	Fraction (%)
Disabled Modules	5	10	15	30	0.73
Disabled Chips	5	24	4	33	0.07
Masked Strips	3,364	3,681	3,628	10,673	0.17
Total Disabled Detector Region					0.97

more info

ATLAS SCT Disabled Modules May 2010

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

All on one leaking cooling loop

Taking collision data!



7 TeV collision event

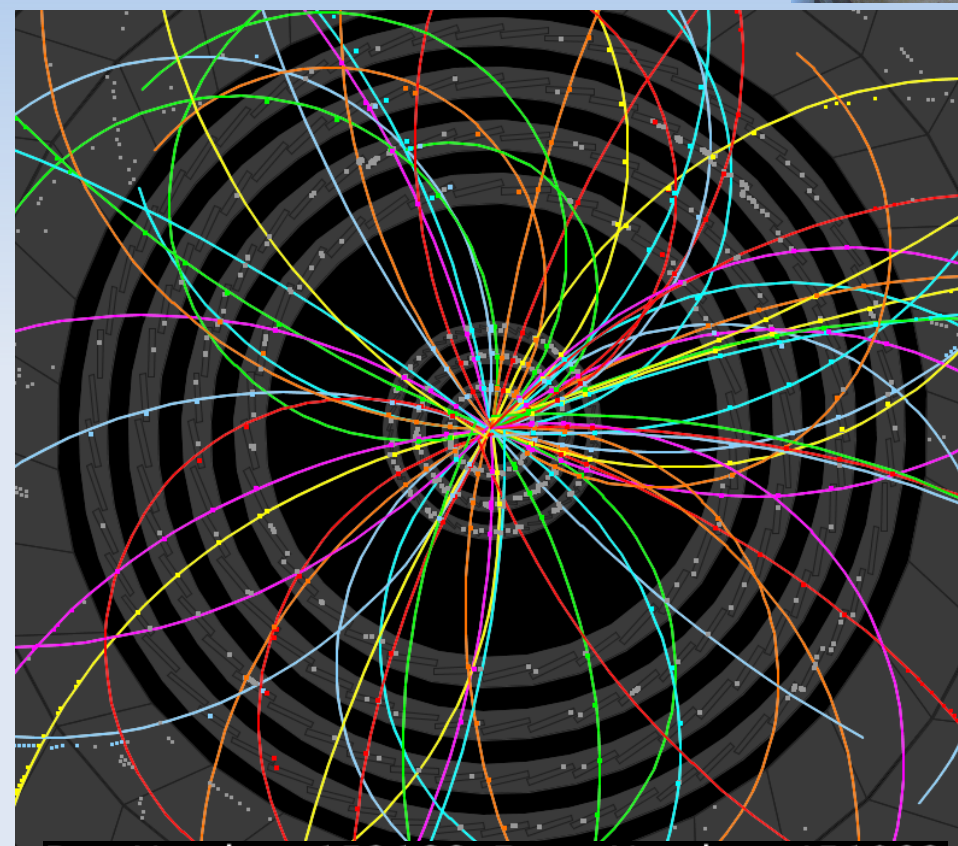
After many years of preparation and commissioning with cosmics **finally taking collision data:**

23.11.09: first 900 GeV collisions, solenoid off

6.12.09: 900 GeV collisions, solenoid on

30.3.10: 7 TeV collisions

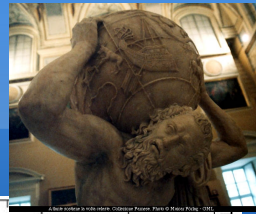
If no stable beam flag → running in stand-by mode (20V)



Run Number: 152166, Event Number: 451982

Date: 2010-03-30 13:28:15 CEST

Lorentz Angle



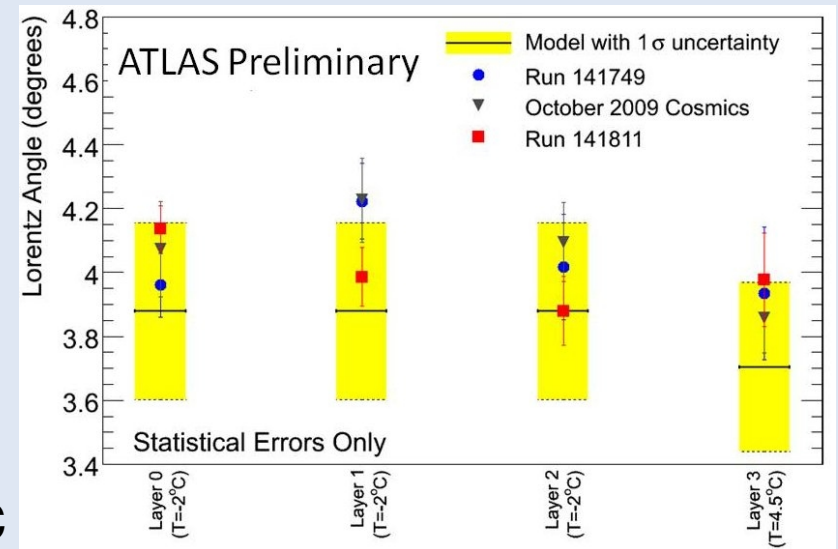
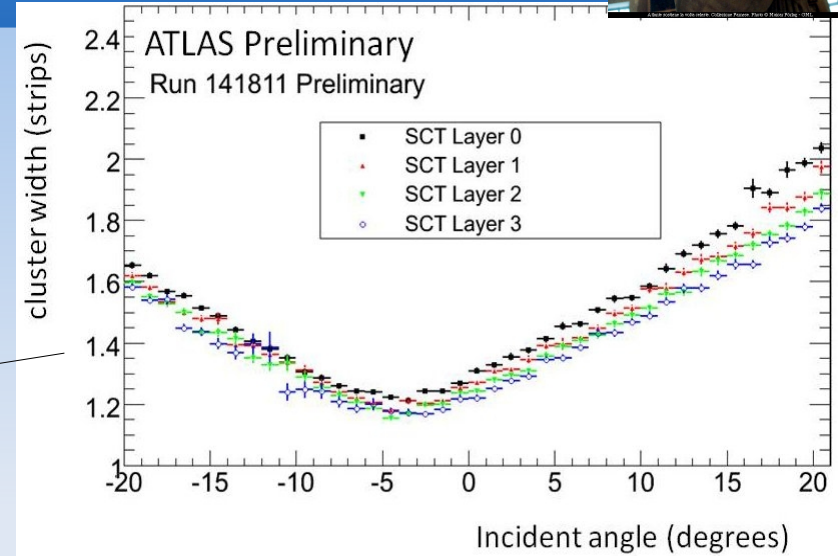
- Lorentz angle θ_L : Drift angle of holes in magnetic field
- depends on magnetic field and hole mobility
- Fit with

$$[d(\tan\theta_L - \tan\theta) + \delta/\cos\theta] \otimes \text{Gauss}(\theta)$$

geometry
diffusion
resolution

θ : particle's incidence angle

- result: $\theta_L \sim 4$ degrees
- consistent between different layers, data taking periods and model prediction



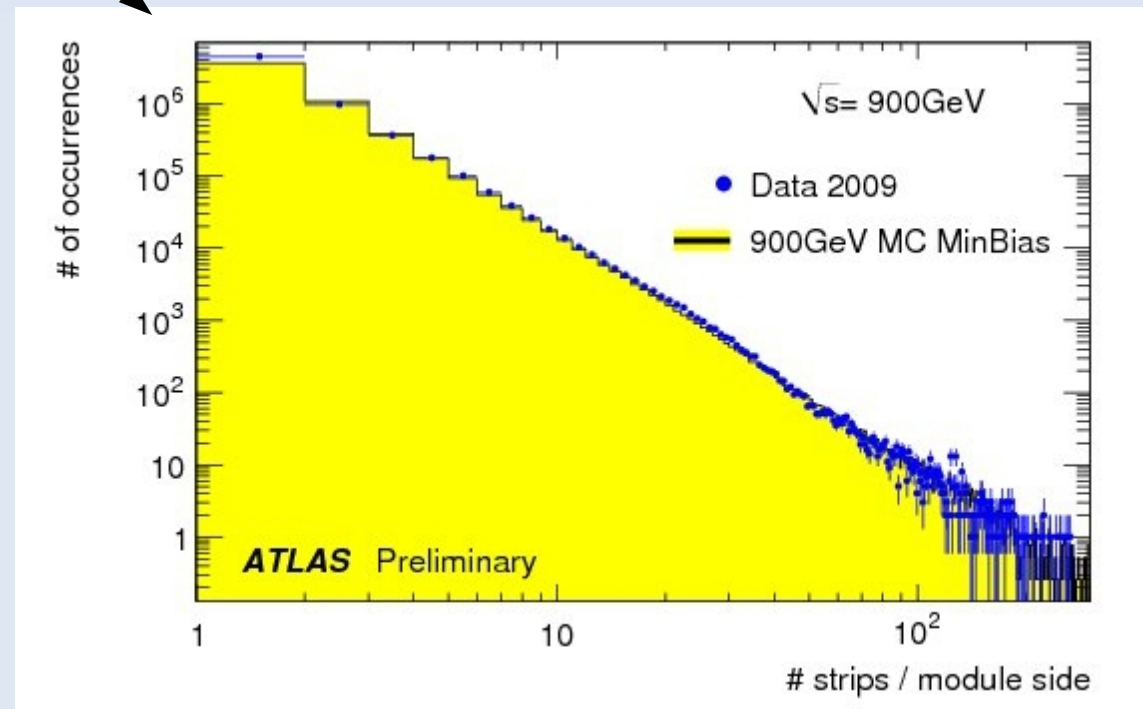
Barrel 0,1,2: -2°C

Barrel 3: $+4.5^\circ\text{C}$ (the TRT needs a higher temperature)

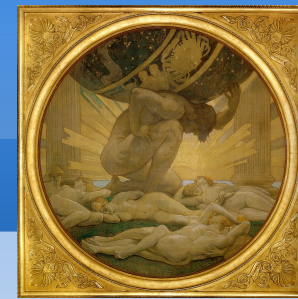
Occupancy



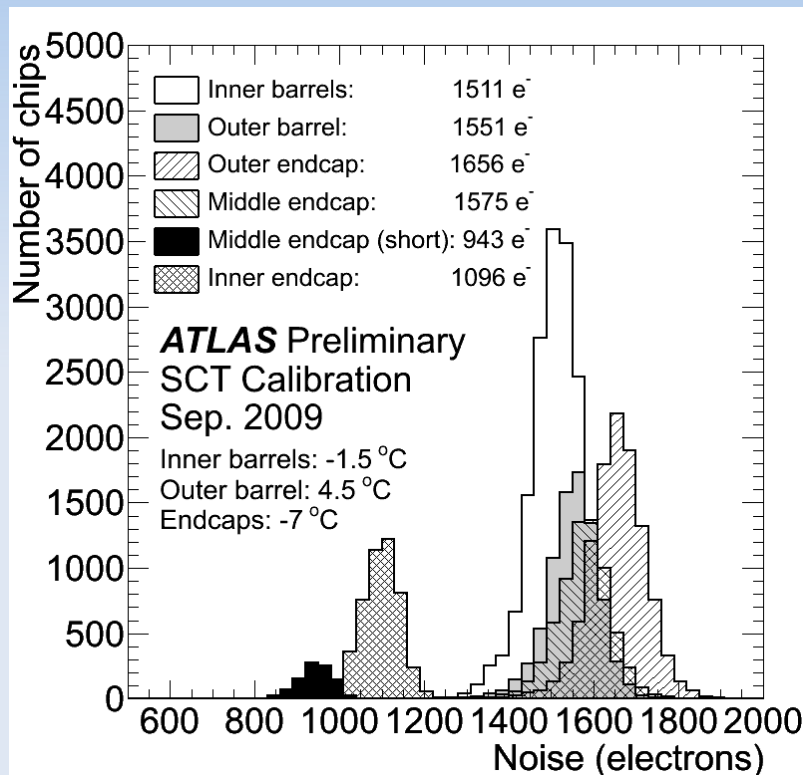
- Average SCT occupancy is very low.
- Number of hits per module side; normalised to the same number of events.
- A very good agreement (over six orders of magnitude) between data and simulation!



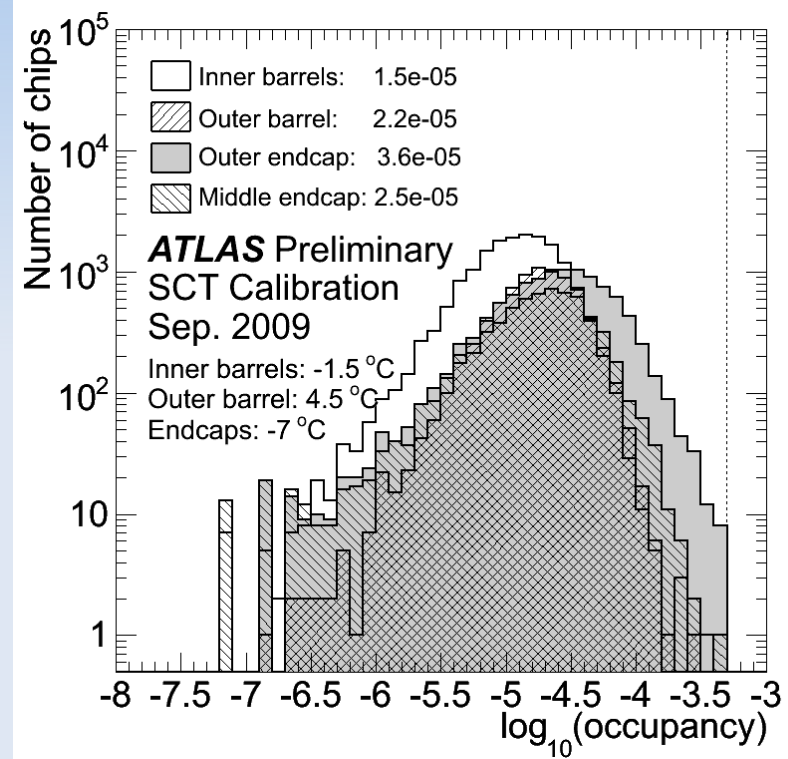
Noise



NOISE from response curve test:



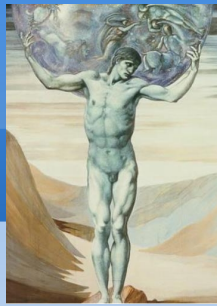
NOISE OCCUPANCY using random trigger:



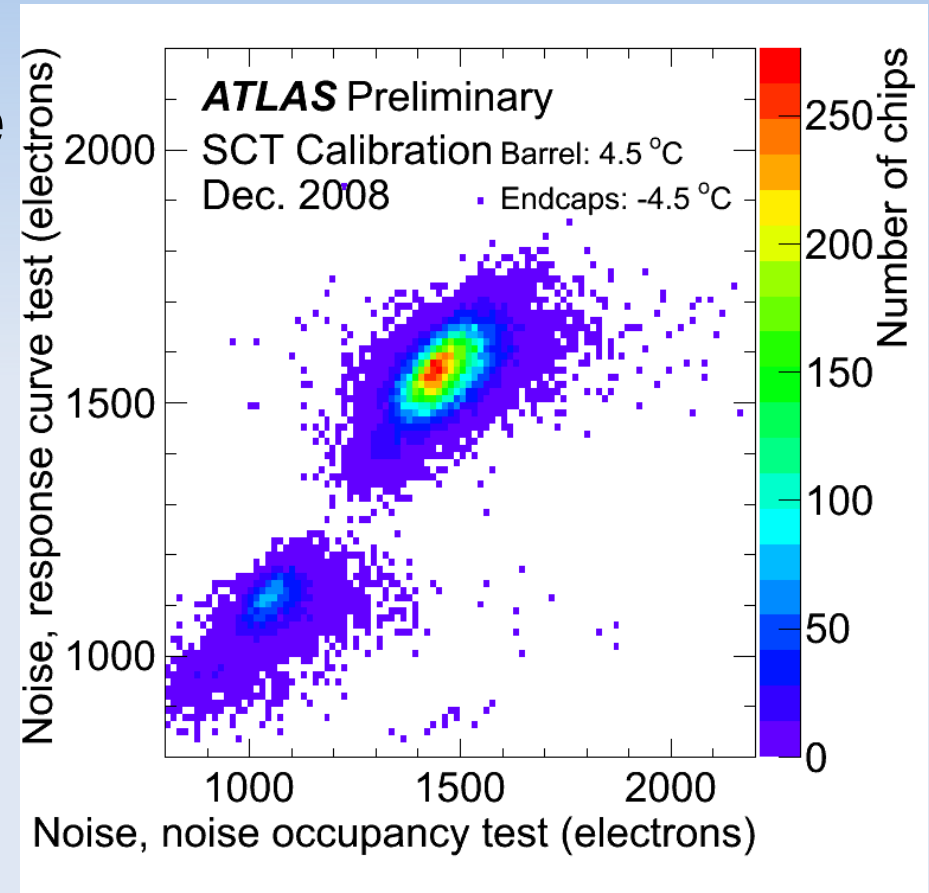
LEVEL SENSING MODE, 3 READ-OUT TIME BINS

- strips with $N > 5 \cdot 10^{-4}$ are masked (0.17%).
- noise about 1500 e⁻, well below the typical threshold of 1fC (6,240 e⁻)
- noise occupancy significantly lower than the requirement of $5 \cdot 10^{-4}$

Noise

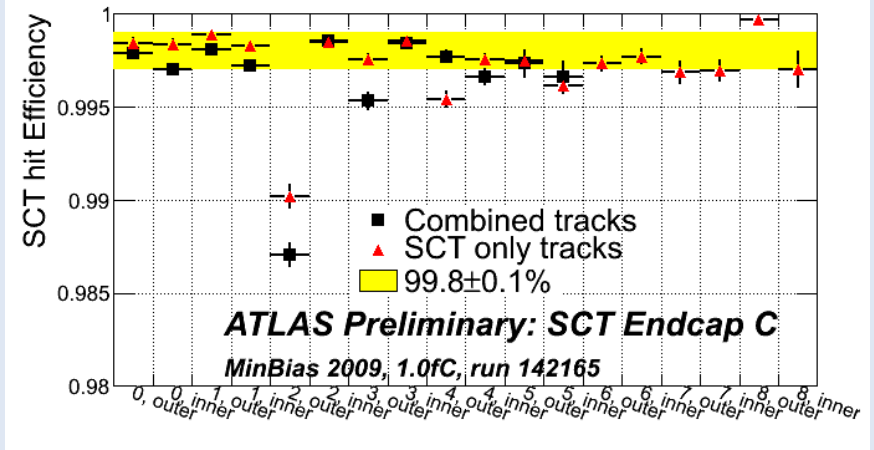
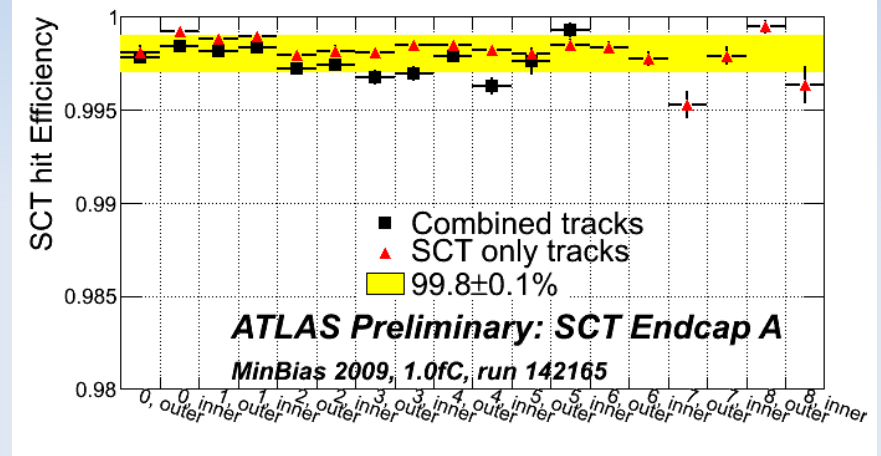
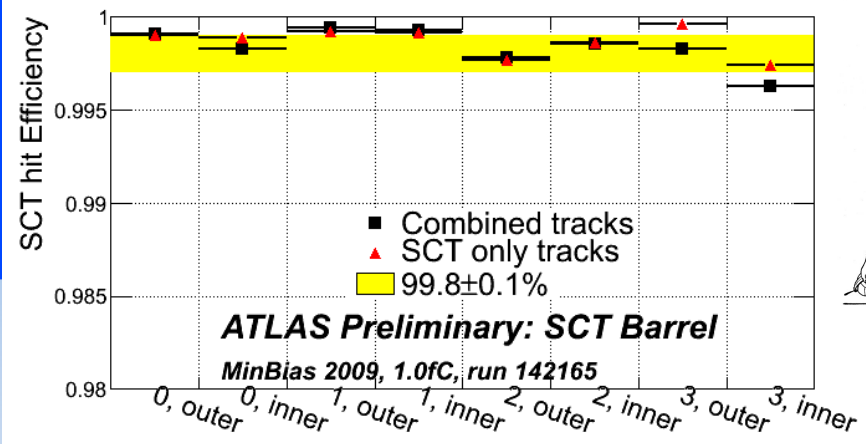


- good agreement between the noise determined from:
 - the random trigger test
 - the response curve test
- will increase with irradiation and moving to the edge sensing mode



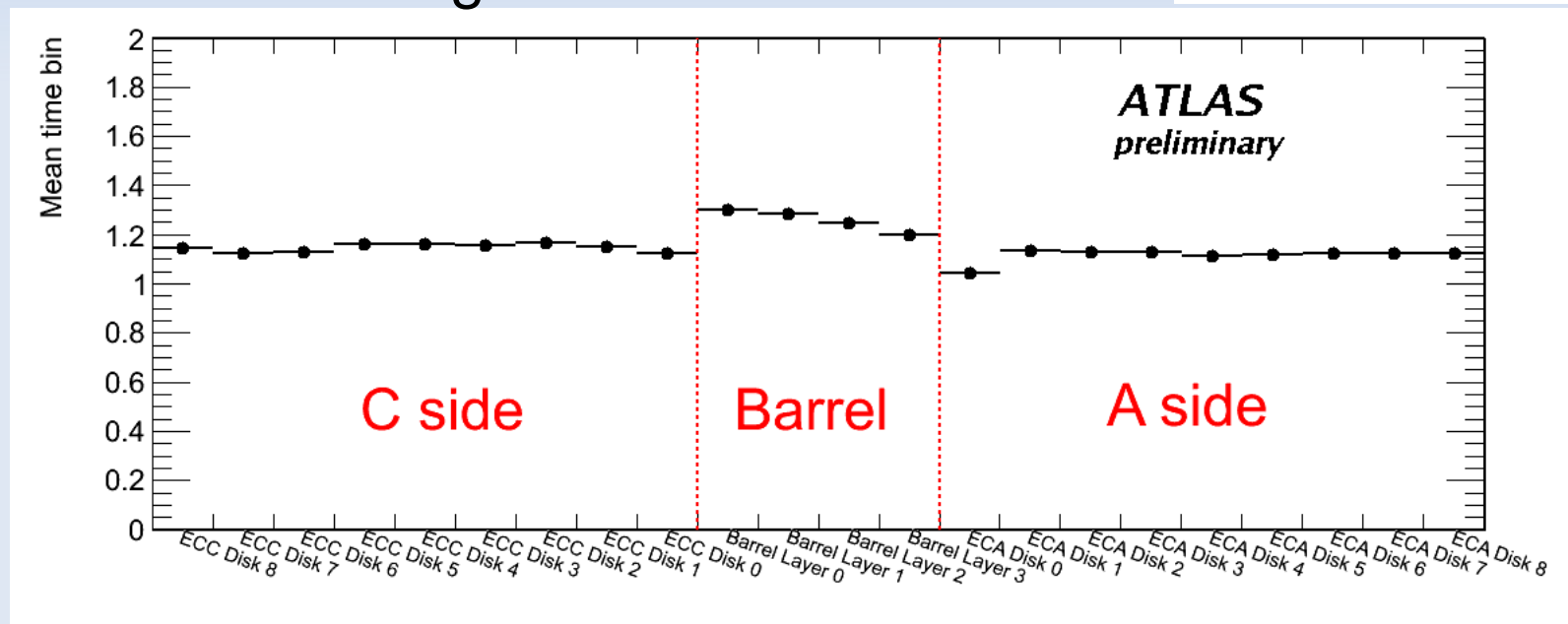
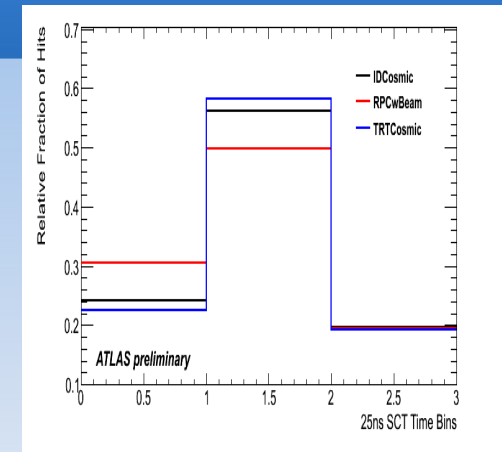
Intrinsic silicon strip efficiency

- Calculated as
number of measured hits /
number of expected hits
- Dead modules and chips taken
into account (dead strips are not
excluded – would count as
inefficiency)
- Efficiency: ~99.8%
higher than the requirement

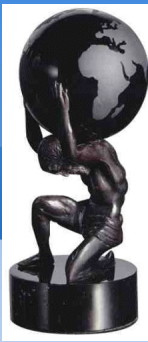


Timing

- SCT currently reads out three bunch crossings (25 ns bins)
- Hits should arrive in the middle bin
- Level sensing mode



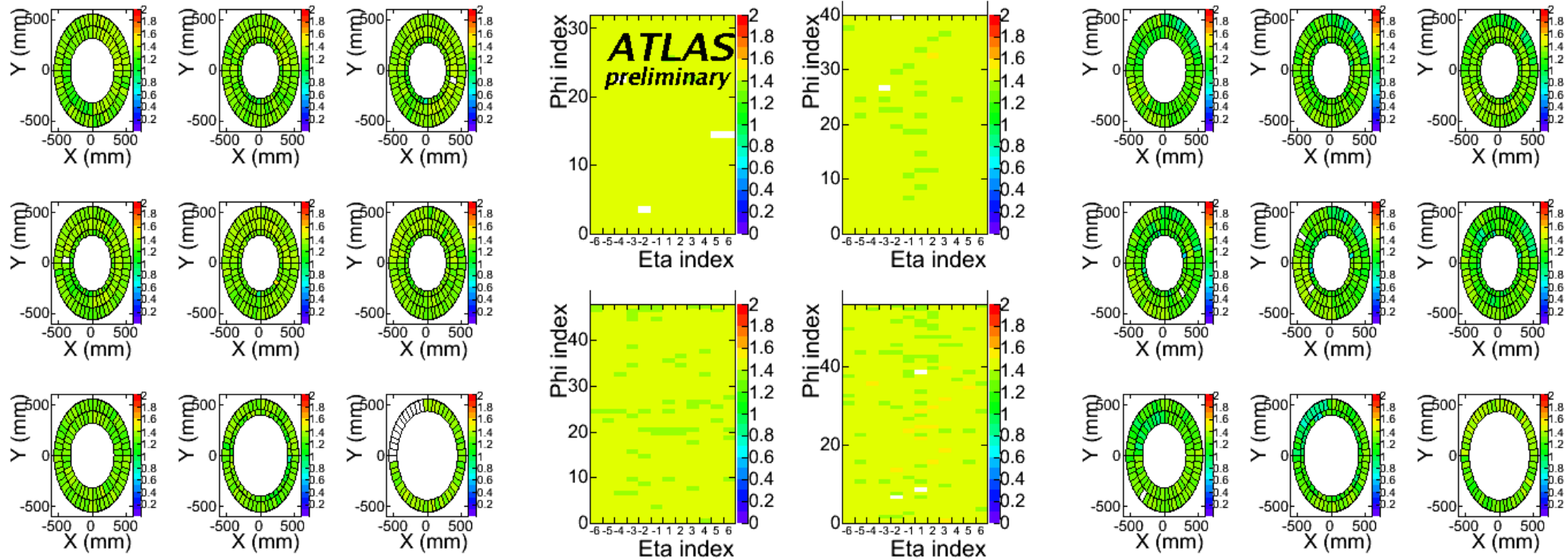
mean close to 1.0: layers and discs are well timed in



Timing

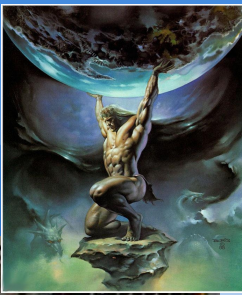


The mean time bin for individual modules:

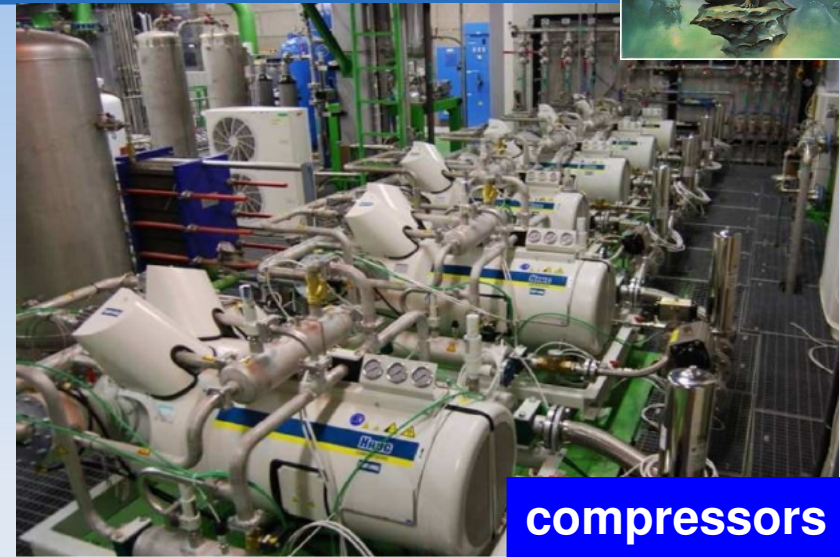


Also individual modules are well timed in.

Cooling



- SCT and Pixel detector share the cooling system.
- Very long history of problems from 2005 to 2008.
- Low level problems persist especially with oil-free, 2-stage, leakless compressors.



- 7 compressors in the system, 4 used for the low radiation damage period.
- Future: two possibilities are being studied:
 - a) replace the compressors
 - b) reduce compression ratio by using gravity: take the vapor to the surface, condense it and make use of the hydrostatic pressure of liquid

Thermal and radiation damage



- TDR specification: run SCT at -7°C at the design luminosity
- 2009: reassessment of cooling requirements and effects of radiation damage
 - → Radiation damage (V_d , I_{LEAK}) is now expected to be less than predicted at time of TDR.
 - → The existing cooling is sufficient to prevent the radiation damage for the foreseeable future.
- Current silicon surface temperatures:
 - inner three barrel layers: -1.5°C
 - the outer barrel layer: 4.5°C
 - endcaps: -7°C



Beam background issues



- 2 issues related to significant beam loss incidents:
 - a) voltage potential developed across SiO_2
 - b) excess of charge in the front end electronics and services
 - estimated limit: around 10^7 - 10^9 MIP/cm² (Minimum Ionizing Particle)
 - BLM protection:
 - internal threshold: $2.5 \cdot 10^4$ MIP/cm²
 - 40 μs integration time; all significant accident scenarios are slower (milliseconds)
- 100% SCT occupancy: 45 MIP/cm²
- Highest observed occupancy: 30% (~ 15 MIP/cm²)



Operation, DAQ, DQM



- **Operation:**

- 1 Atlas Control Room shifter
- 1 remote (anywhere in the world) DQ shifter
- N experts on call

- **DAQ:**

- binary readout, level sensing mode
- 3 read out bins (bunch crossings)
- ready to move to 1 read out bin when required

- **DQM:**

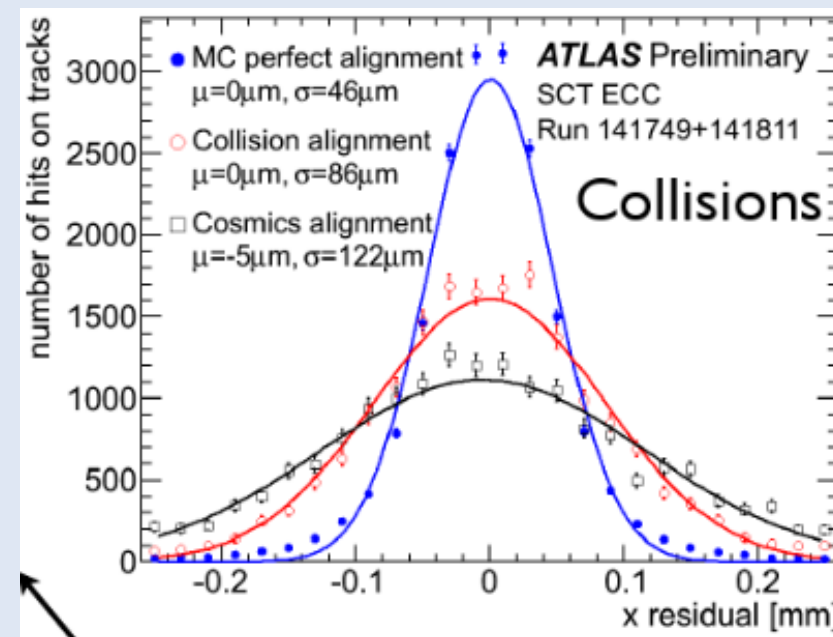
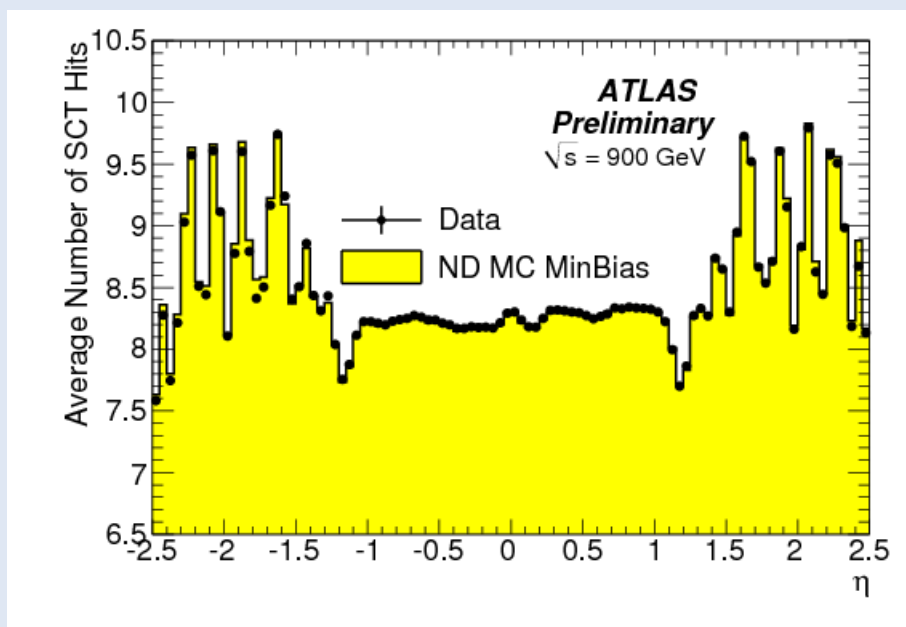
- integrated in the common atlas framework
- Checking: efficiencies, noise, hit maps, timing, residuals, pulls, ...



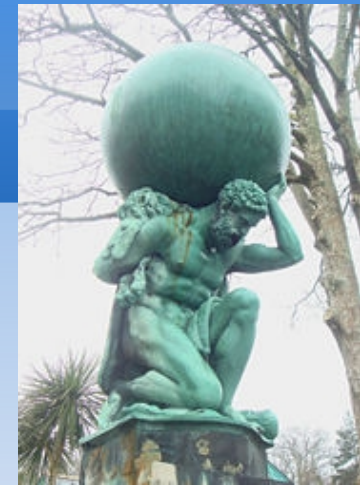
Resolutions, alignment, ...



G. Piacquadio later today:
more about
tracking, vertexing, alignment, physics.



Conclusion



- **ATLAS SCT in excellent shape:**
 - more than 99% fully functional
 - 99.8% intrinsic module efficiency
 - low noise
 - well timed in
 - cooling works well
- a very successful period of data taking after restart of LHC

Conclusion



Conclusions II

Conclusions

The Atlas SCT is being commissioned quite rapidly.
Pace is signed by the evaporative cooling: use any slot available with cooling loops.
Cooling compressor accident delayed commissioning (exp. pixels) and stable running.
Cooling now back, beam pipe bake-out taking place in this moment.
Gaining experience with a very complex system.
Modules seem to behave very uniformly.
Solving initial problems at the e- \bar{e} level.
Cosmic rays detected in conjunction with other detectors
DAQ, DCS and Monitoring tuning up

Start collisions in a few weeks !

Vertex 2008
Saverio d'Auria

17th International Workshop on Vertex Detectors, CERN, Geneva, 28 July 2008

Gaining experience with a very complex system !

Vertex 2009
Manuel Kayl

Acquired a lot of experience with a very complex system!

ATLAS SCT proved its excellent performance and contributes to physics measurements.