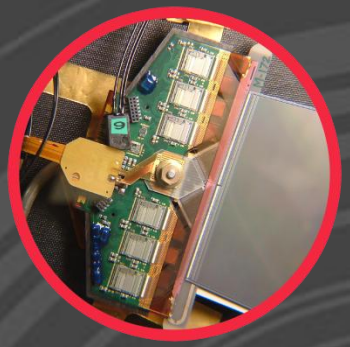


SCT and ID : construction, installation and status

Carmen García (IFIC)

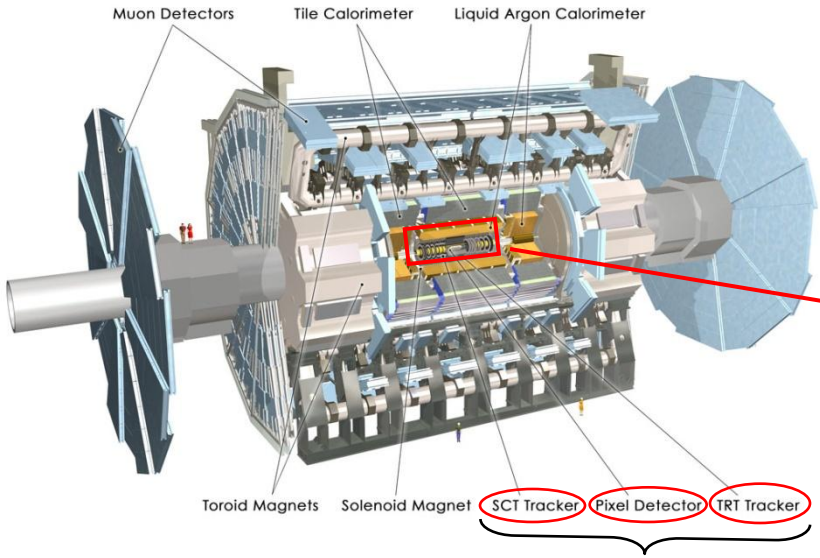
Granada 2009 (28-30 de octubre) Primera reunión de la red LHC

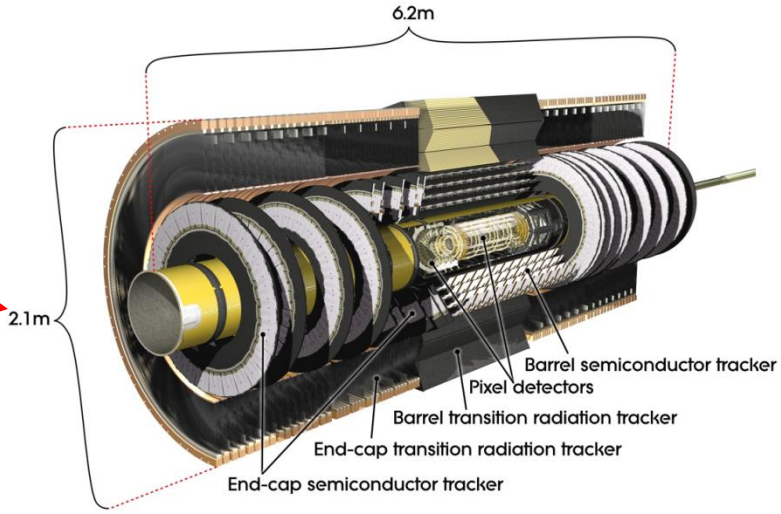
Outline

- Introduction to Inner Tacker
- The properties of the SemiConductor Tracker (SCT) and module description.
- Detector assembly and installation.
- Current status
- Detector performance:
  - Hit efficiency.
  - Noise Occupancy.
  - Alignment.
  - Lorentz angle studies.
- Summary and conclusions

More detail in M. J. Costa talk about ATLAS commissioning

The Inner Detector (ID)

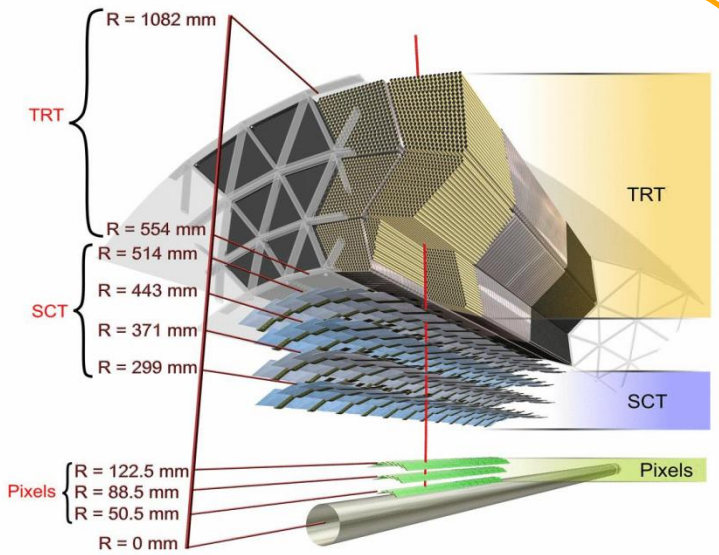




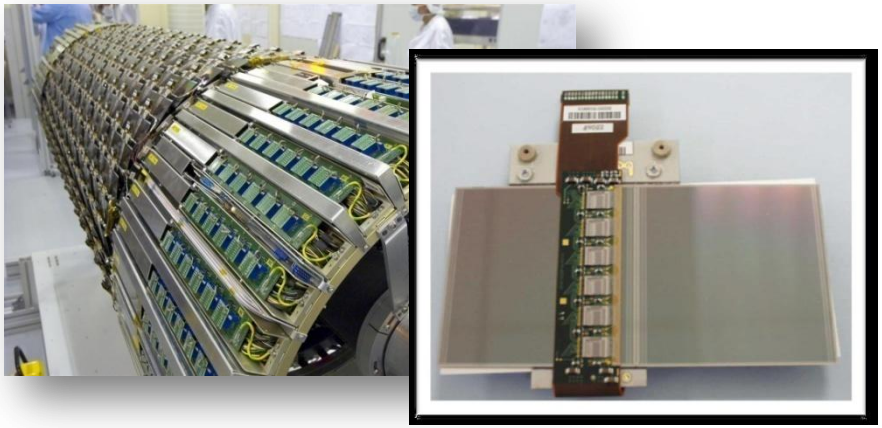
The commitments of the IFIC and CNM-IMB, can be quantified as:

- 1.5% of the Inner Detector project,
- 2.7% of the SCT project, or
- 10% of the SCT End-caps.

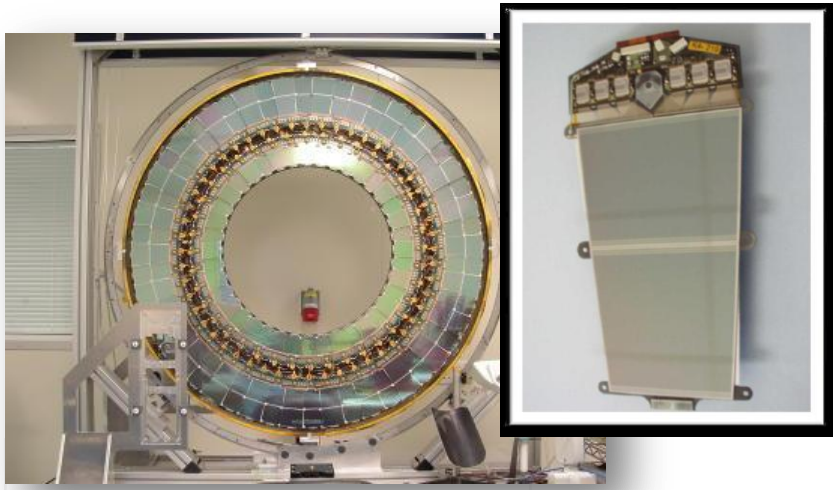
- **Pixels**: 80M readout channels.
- **SCT**: 6M readout channels
- **TRT**: 350k readout channels.
- **2 T solenoidal magnetic field**.



The Semiconductor Tracker (SCT)



- 4 layers (2112 Modules)
- Coverage up to |η| = 1.4.
- Each module has two sides, each with 768 strips (120 mm).
- Stereo angle 40 μrad between strips on each side, enables detection of 3D “space points”.
- Strip pitch 80 μm (barrel).
- 6 ABCD readout ASIC chips per side with binary readout (1 fC threshold).
- 150 V bias voltage (before irradiation).
- Evaporative cooling system with C_3F_8 at -25 C, design operation at -7 C

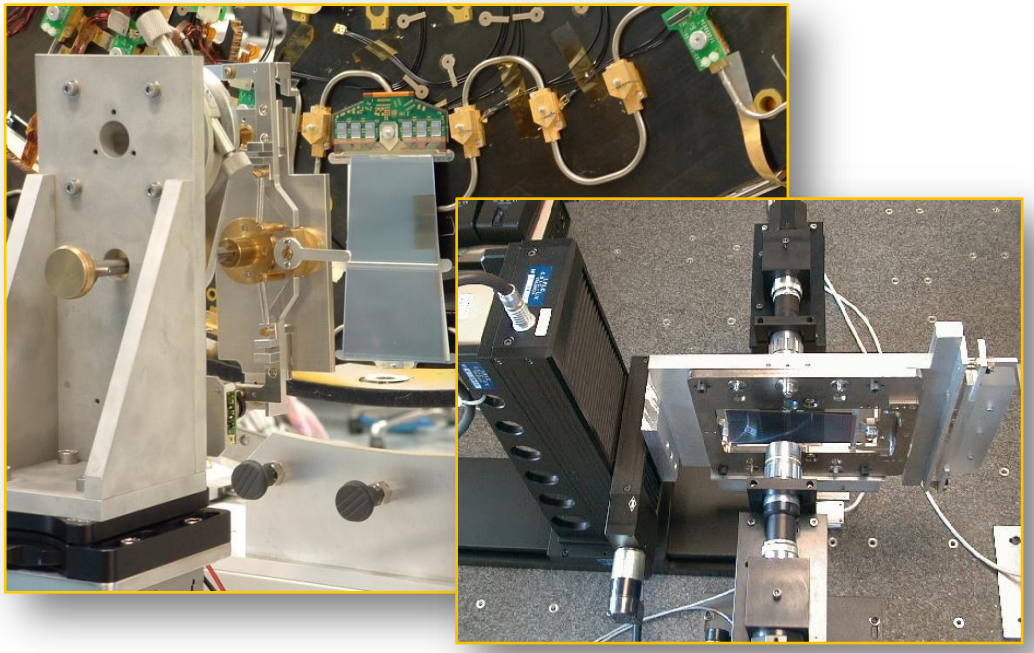


- 9 disks on each side with four layouts - inner, middle, short middle, outer. (1976 Modules)
- Coverage up to |η| = 2.5.
- Strip pitch varies from 57-94 μm.
- Strip length varies from 55 mm to 120 mm

IFIC-CNM contribution:

- Assembly and full QA of 282 modules.
- Fabrication a delivery of pitch adaptors for the endcap modules

Tolerances and requirements on the SCT



- **As-built tolerances per module**
  - < 8 μm in-plane, achieved RMS: 2 μ m
  - < 70 μ m out-of-plane (bowing and thickness), achieved: ~ 40 μ m
- **SCT assembly**
  - Mounting precision: ~50 μ m
  - No survey for the barrel.

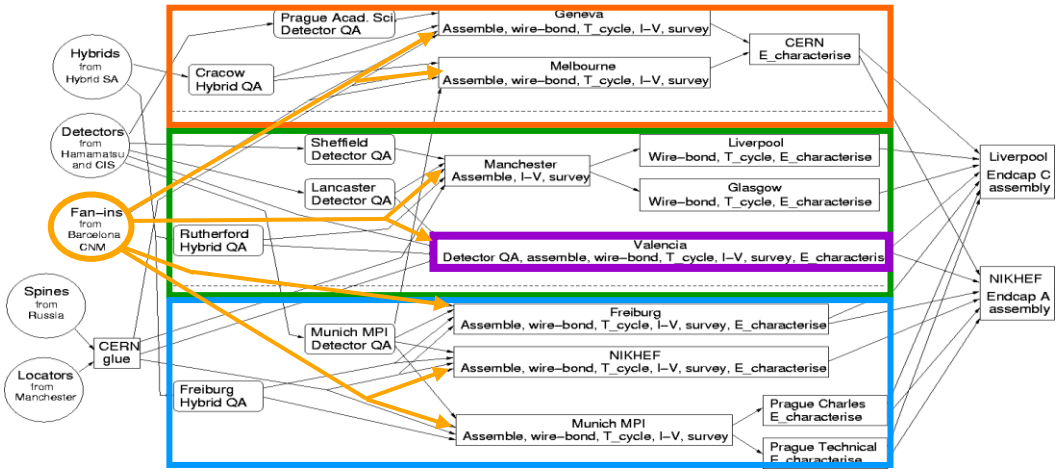
Physics requirements

- 4 space-point measurements
- Spatial resolution: σ(rΦ)~16 μm, σ(rz)~560 μm
- High efficiency: >99% @1fC
- Noise occupancy: $< 5 \times 10^{-4}$ @1fC
- Radiation hard detectors and electronics: ~2×10^{14} 1-MeV-neq/cm^2 over 10 years

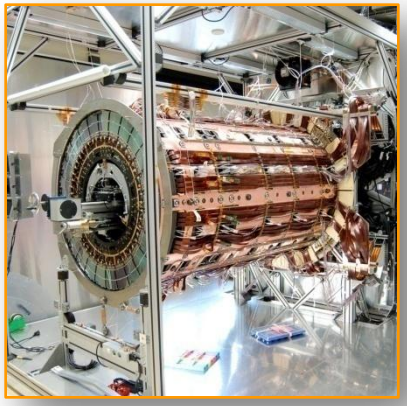
The tracking detector must performed high-precision measurements in order to provide satisfactory **patter recognition**, primary and secondary **vertex recons-truction** as well as exceptional **momentum reconstruction**.

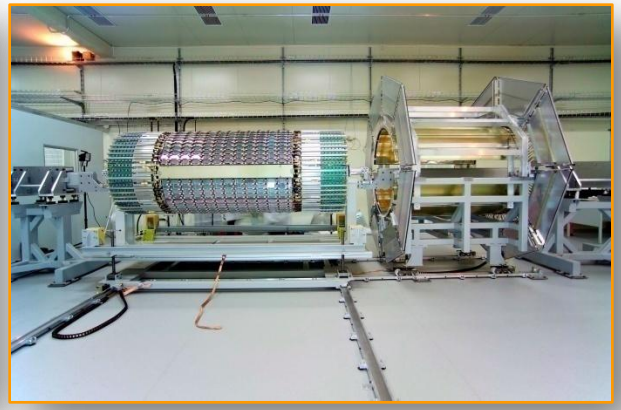
SCT Macro-assembly and integration

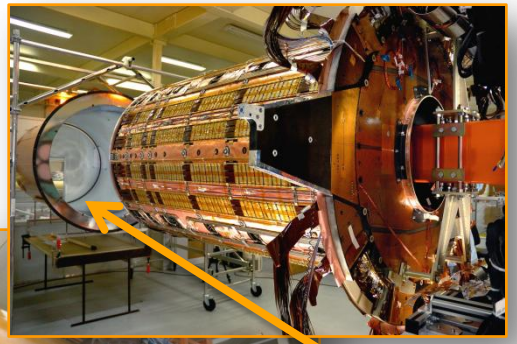
- **SCT module production & QA** diversified around the world:
  - Barrel: Japan, US, UK, Sweden, Norway
  - End-caps: UK, Spain, Switzerland, Germany, the Netherlands, Poland, Czech Republic, Australia

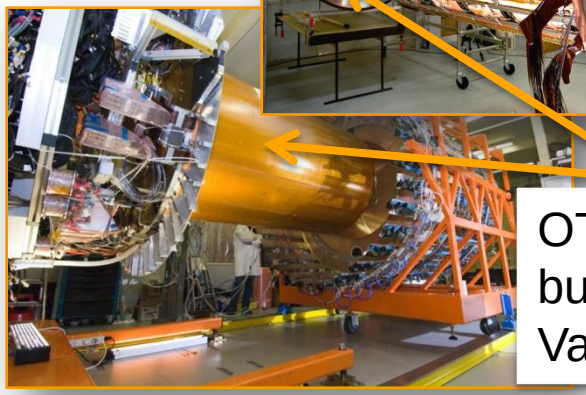


- Module integration (**macro-assembly**) and testing:
  - Oxford (Barrel), Nikhef (End-cap A), Liverpool (End-cap C)
- Macro-assembly (Barrels) and **final integration** @CERN



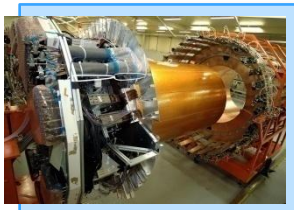






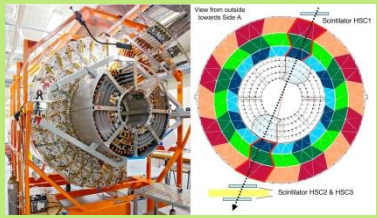
OTEs buldt @ Valencia

ID integration and Instalation



SCT + TRT
Endcap test
@ SR1
Fall-2006

SCT+TRT
Endcap
installed with
in ATLA
April-2007



SCT + TRT
barrel test @
SR1
June-2006

SCT+TRT Barrel
Installed with in
ATLAS
Agust-2006

2005 2006 2007 2008 2009

Cosmics Cosmics Cosmics

Barrels macro-assembly

Endcaps @ SR1

ROD installed

M6-data taking
March-2008

First beam
in ATLAS

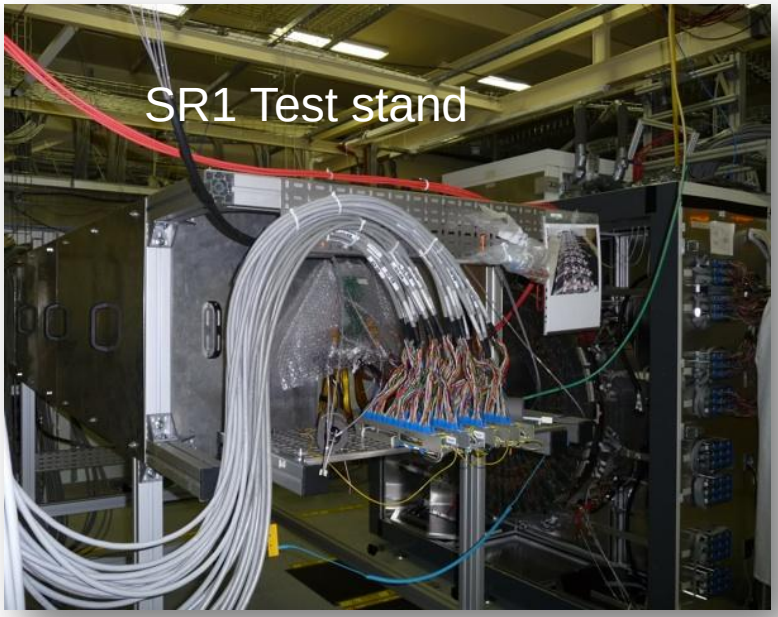
Cosmics run and
preparation for
data taking

SCT service installation @ ATLAS pit

Pixels with
in ATLAS
June-2007

SR1 test stand

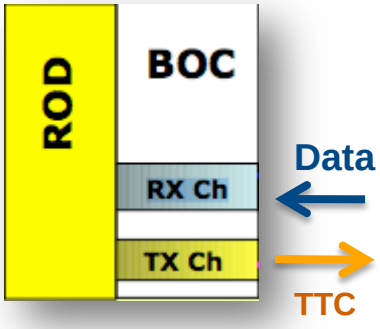
- Barrel sector: 48 modules.
- Endcap ¼ disk : 3 rings, 33 module.
- One cooling loop each
- Good opportunity for students and new post-docs to learn about SCT.
- Used for training and DAQ developments.



Issues Encountered

Cooling

- SCT modules (and Pixels) are cooled by an evaporative cooling system, using C_3F_8 in order to minimize the radiation damage.
- 3 out of 6 compressors of the plant failed in May 2008.
- 100 kg of C_3F_8 lost and 900 kg contaminated (detector not affected)
- **The cooling plat was repaired and upgrade** by August 2008 and has been running relatively stable since.
- **Only one cooling loop is off** due to a more permanent leakage problem, affecting 13 modules.

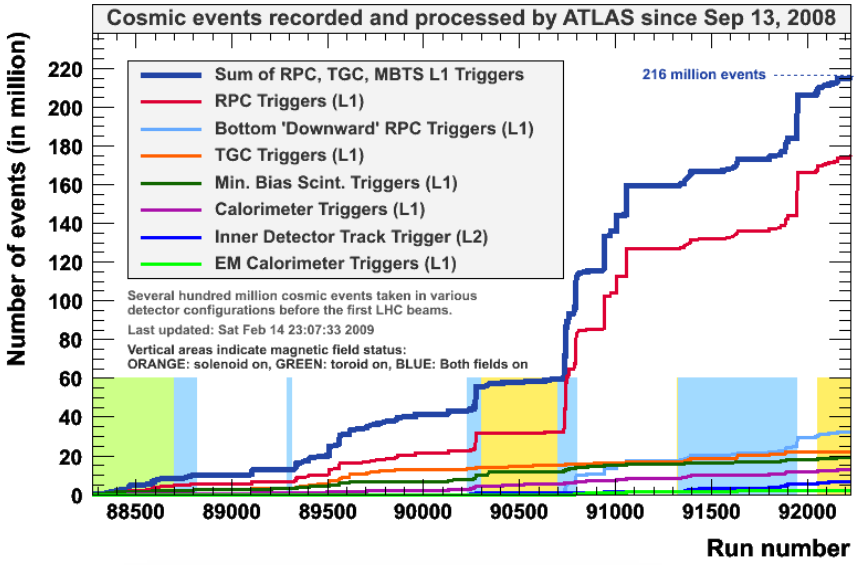


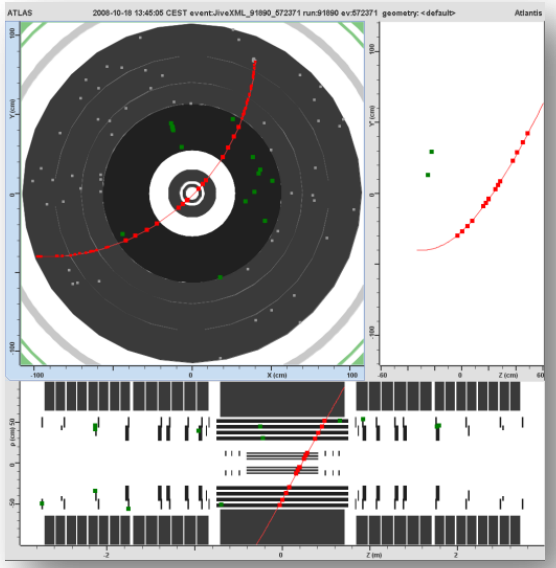
Optical communication

- Fiber optic links provide communication between the front-end and the off-detector DAQ electronics.
- The TX link send clock and commands to the modules while the RX link receives the module data.
- In 2008 and early 2009 TX s were failing at a high rate due to electrostatic discharges damage of the VCSELs during manufacturing.
- Improved TX plug-ins were **produced and installed in summer 2009**. Amongst those, only four channels have failed to date

Cosmic ray events

- September-October 2008, continuous data-taking with whole ATLAS detector.
- **More then 2 millions of tracks with SCT hits were registered**
- June-July 2009, semi-continuous data-taking with all ATLAS inner detector.
- From the 12th of October a semi-continuous combined ATLAS run is taking place with continuous running starting three weeks prior to LHC beam.

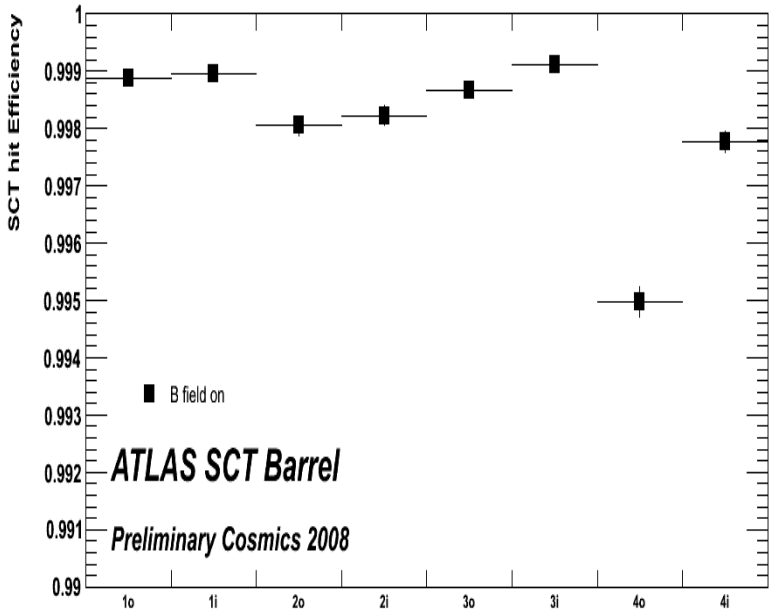




Atlantis display of a cosmic event with solenoid B-field on

Hit efficiency

- The hit efficiency is measured through expected hits-tracks passing trough an active region of silicon without a hit being read out.
- The muon tracks were required to have:
  - 10 SCT hits, 30 TRT hits
  - Chi2/DoF below 2.
  - The intersection with the modules had to be within 40 degrees of normal incidence.
  - There had to be a hit of some kind on the track before and after the module being studied
  - A guard region around the edge of the active silicon was excluded.

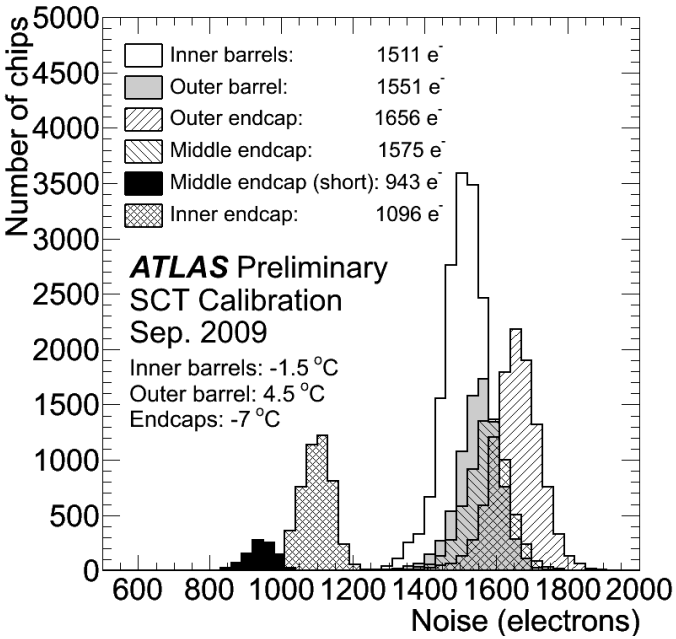


Efficiency for each layer of the SCT barrel, measured from cosmic 2008 data

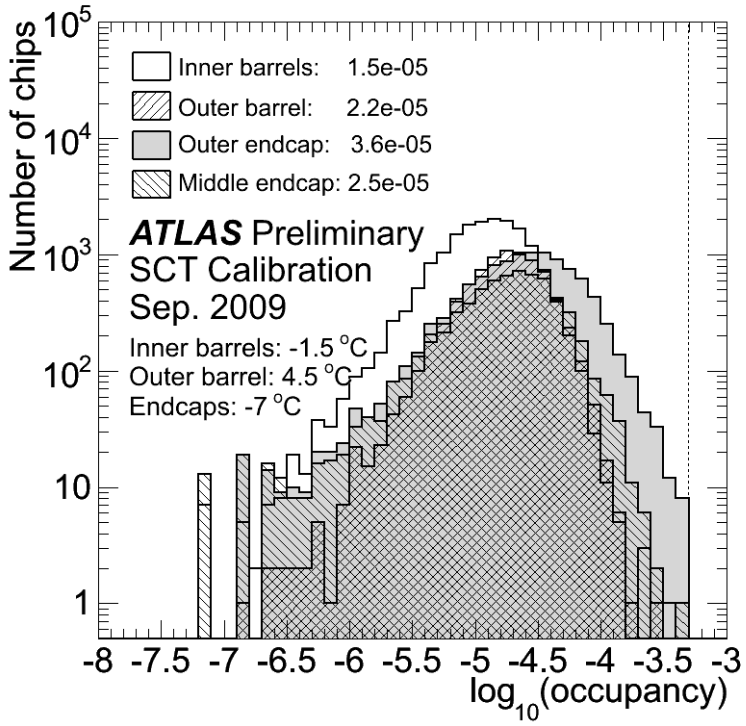
The silicon efficiency was found to be > 99%

Noise Occupancy

- Noise occupancy can be measured in data-taking runs using random trigger or during standalone calibrations
- The noise occupancy per channel in the SCT has been established to be well **below the design specification** of 5 x 10^{-4}



Input noise to ABCD chips measured in response curve calibration.



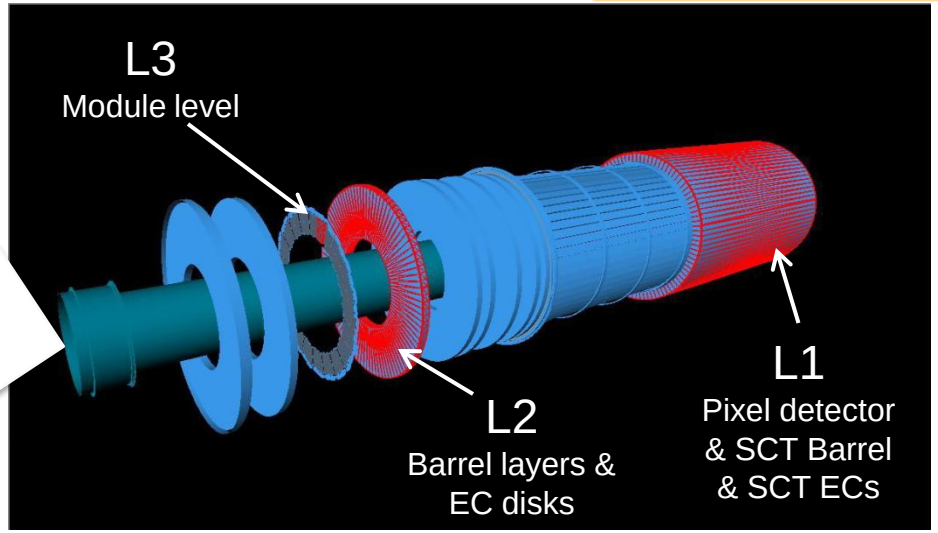
Noise occupancy measured in 2008 cosmics data.

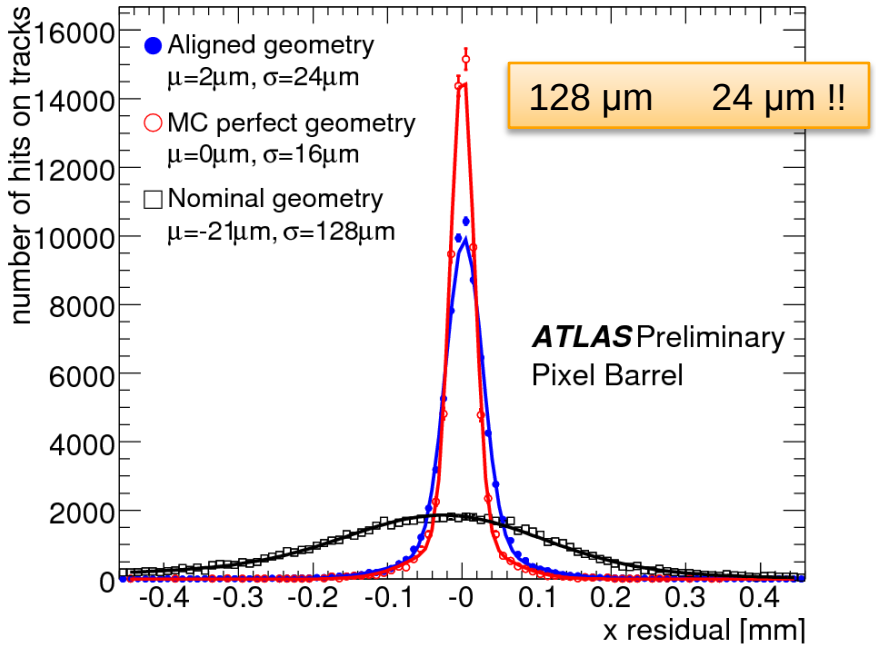
Alignment

- Hardware-based alignment (FSI) under test
- Use of track-based alignment algorithms
- Silicon (Pixels+SCT) alignment, then TRT
- Different approaches (silicon):
  - **Global χ2 (Valencia-Oxford meth.)**
    - full correlations taken into account
    - inversion 6Nx6N matrix
  - **Local χ 2**
    - ignore correlations (iterations)
    - inversion of N 6x6 matrices
  - **Robust**
    - centre and overlap residuals
    - - dofs, no rotations around

No concluyentes

Ready for data acquisition



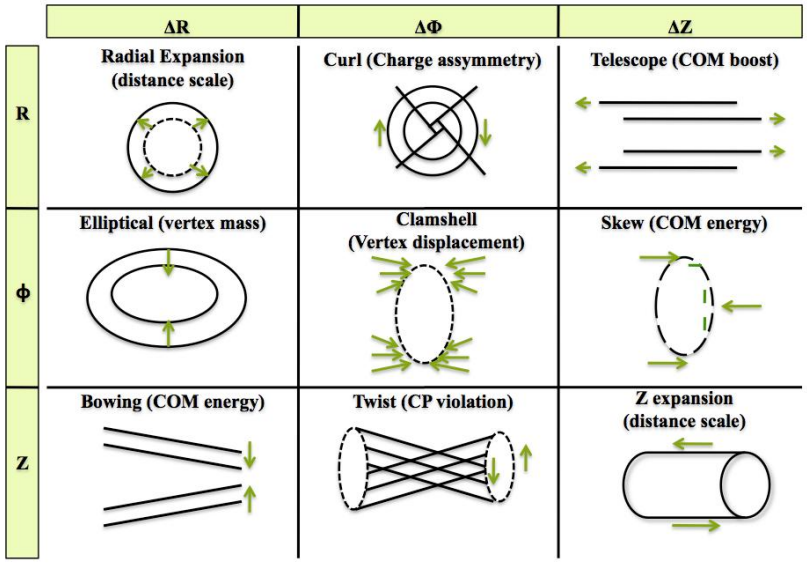


Already approaching ideal alignment in barrels. Less statistics in endcaps, but will be improved with first collisions data.

Alignment (waiting for interactions)

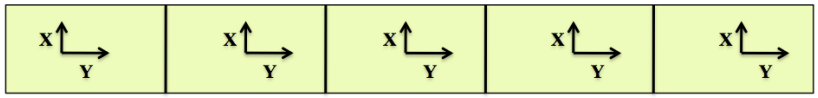
The **Weak Modes** are deformations that leave the track χ^2 almost unchanged. There are some tools to determine these weak modes:

- Combine interaction, cosmic rays and beam halo data
- Vertex and beam spot constraint
- External surveys
- Use FSI Information

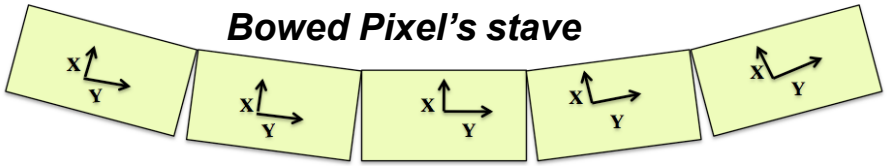


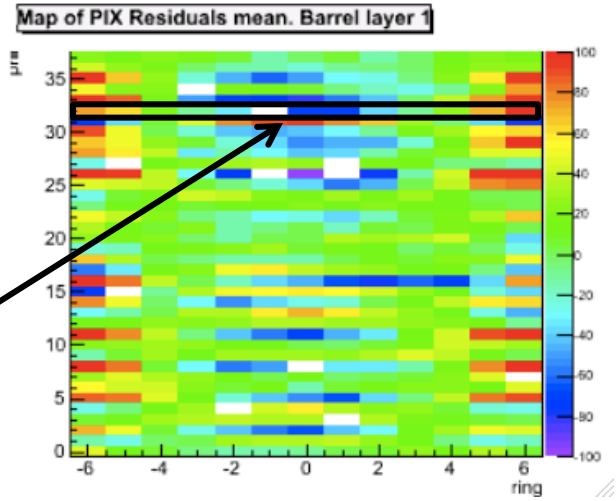
Pixel's BOWING: Has been observed bowing pixel staves in the modules local x direction

Nominal Pixel's stave



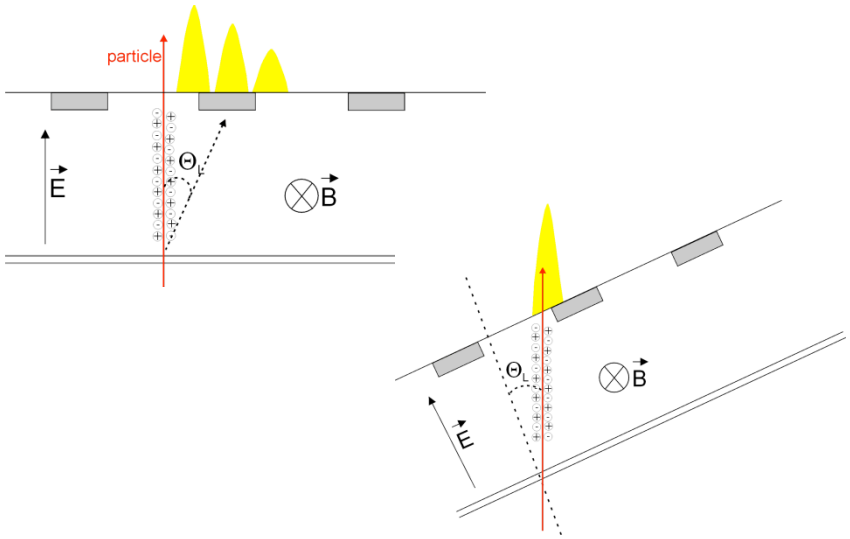
Bowed Pixel's stave



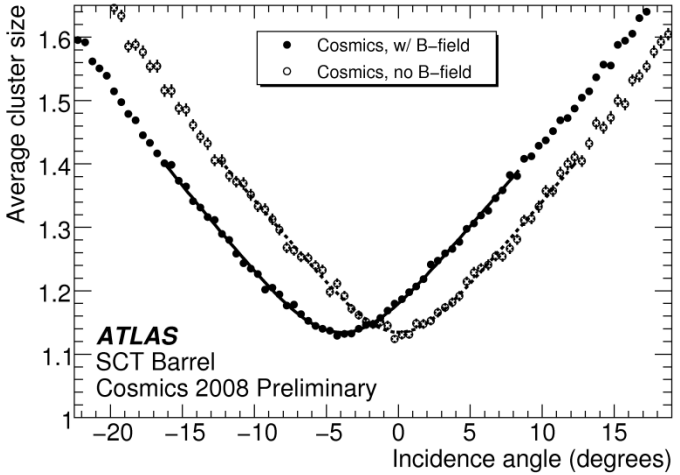


Lorentz angle studies

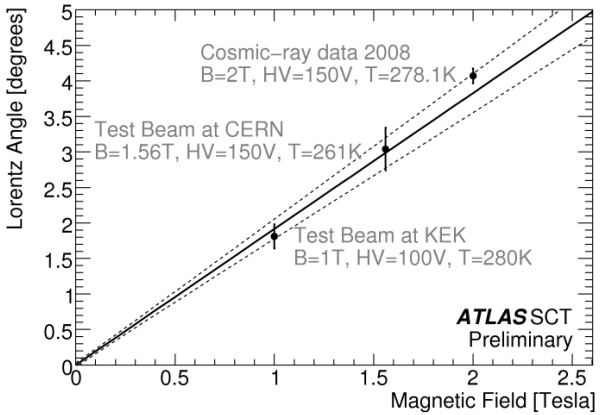
- The drift direction of charge carriers in silicon will differ by **Lorentz angle θ_L** when applying a B-field due to the Hall effect. This angle depends on bias voltage, temperature and solenoid



- The value of θ_L is extracted from the position of the minimum of the mean cluster size .

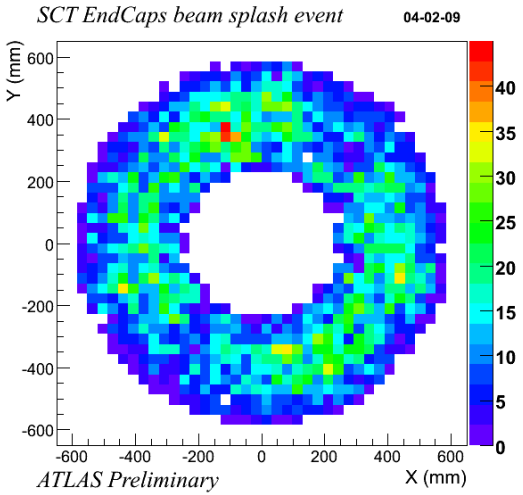


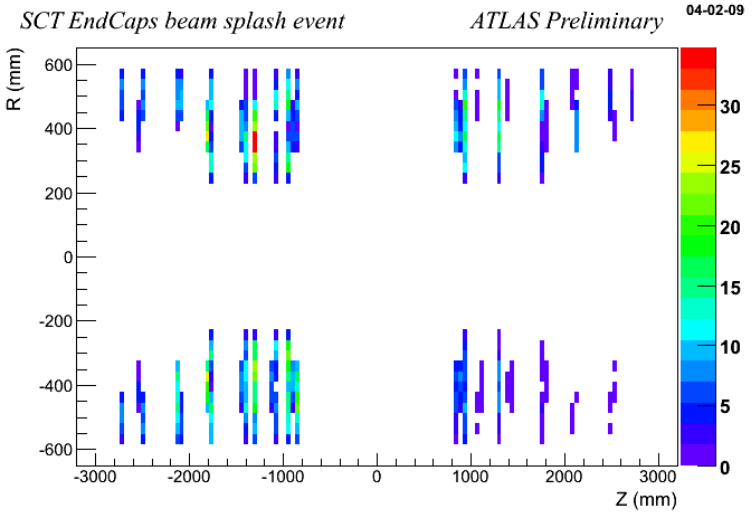
Measure θ_L = *3.93 0.03 (st) 0.09 (sys),*
MC θ_L = *3.69 0.19 (syst)*
consistent with simulations.



LHC beam splash events

- September 10th 2008, day of first LHC beam, included periods where beams were fired into collimators 140 m upstream of ATLAS.
- For detector safety, SCT barrels were off, SCT endcaps were on but with 20 V bias voltage.
- Triggered using Minimum Bias and Beam Pickup triggers.





Summary and Conclusions

- The Semiconducter Tracker has been successfully installed and commissioned within ATLAS.
- Mayor issues such as cooling preoblems and failing optical transmitters have been resolved.
- Just coming to the end of intensive period of calibration and module-by-module debugging.
- 99.7% of barrel modules and 98.8% endcap modules are fully operational.
  - Excluded modules mainly 13 modules on one leaking cooling loop.

SCT is ready for LHC collisions!

Personnel

C. García C. Lacasta (50%) S. Martí J. Fuster (50%) M. J. Costa R. Ros S. Cabrera S. Gonzalez de la Hoz (50%)	Staff (8)
V. Mitsou (RyC) M. Vos (RyC) (50%) A. Wildauer (CPAN)	Postdoc. (3)
J. Bernabeu F. J. Sánchez (50%) R. Marco C. Blanch	Enginiers. (4)
M. Miñano M. T. Perez M. Moreno Llacer A. Irles V. Lacuesta R. Moles E. Torró U. Soldevila	Students (8)
EDP (FTE)	20,5