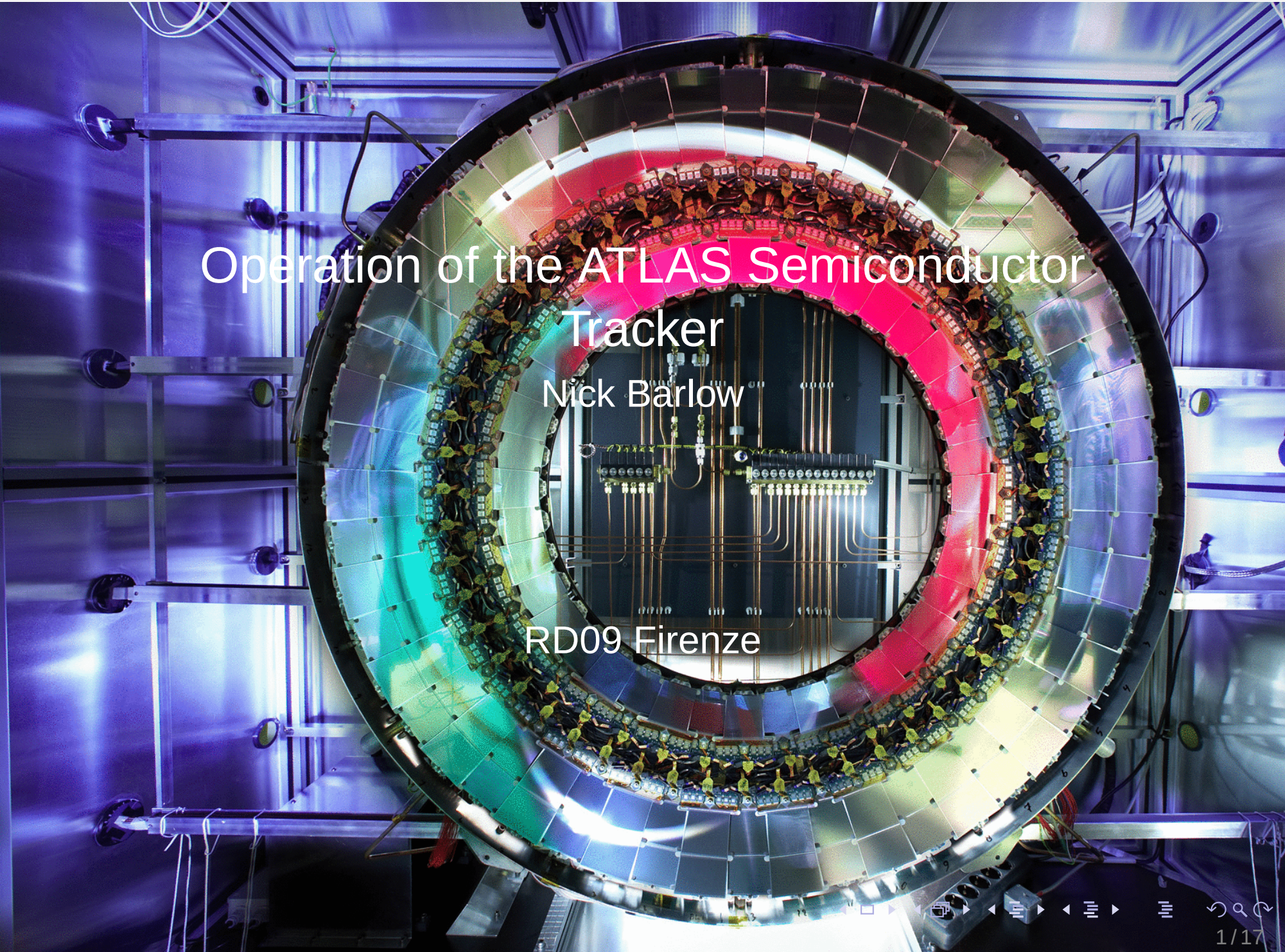
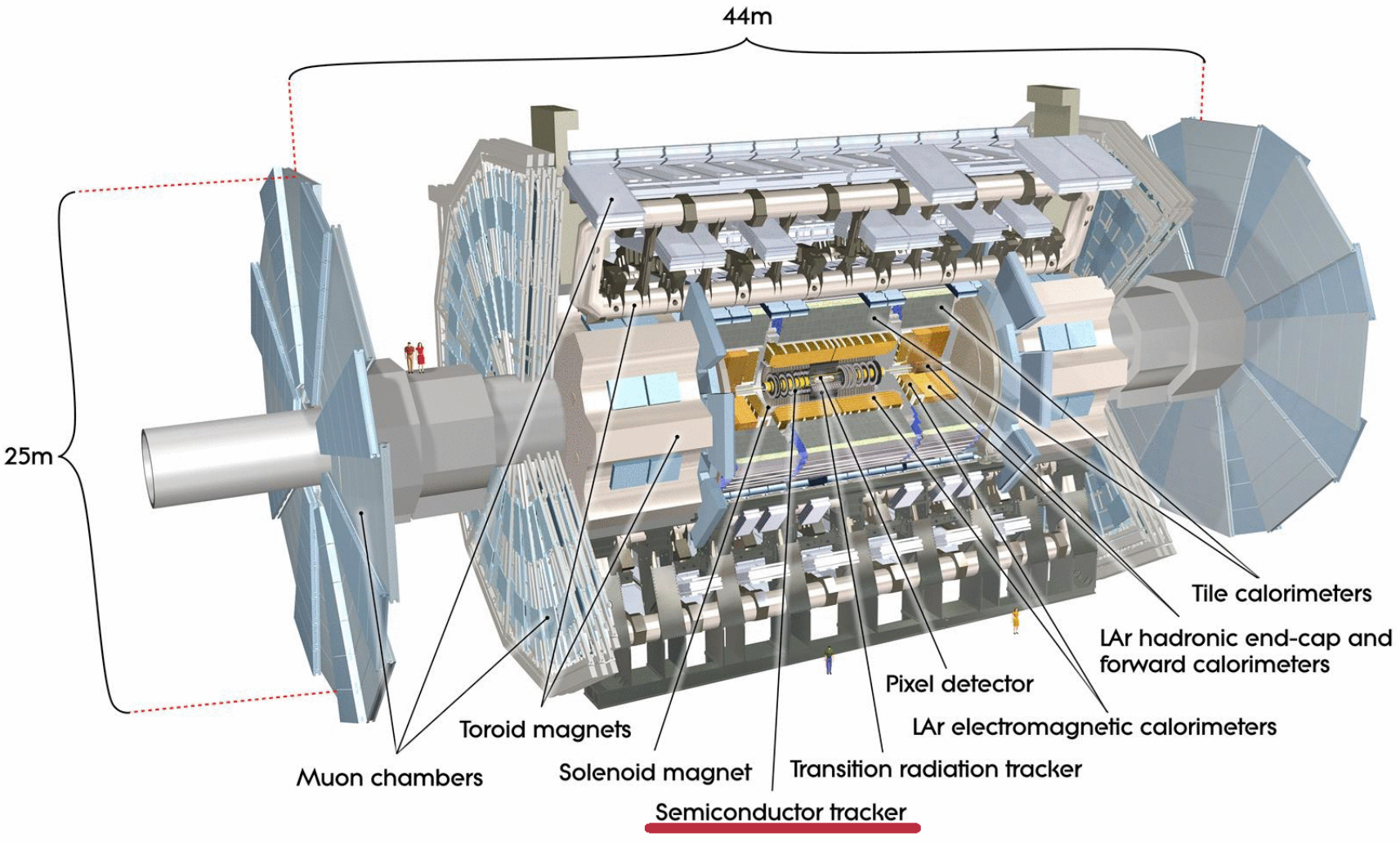


Operation of the ATLAS Semiconductor Tracker

Nick Barlow

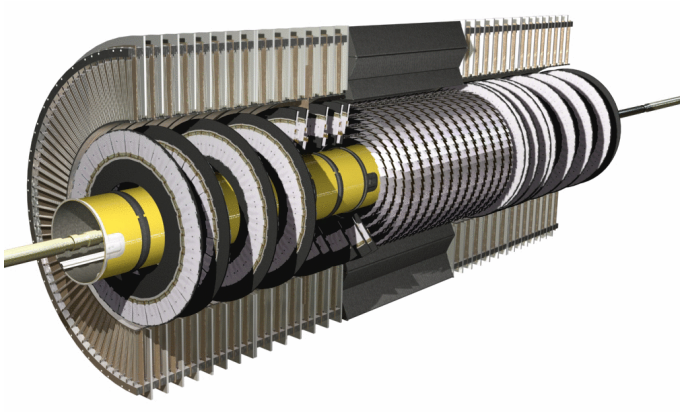
RD09 Firenze

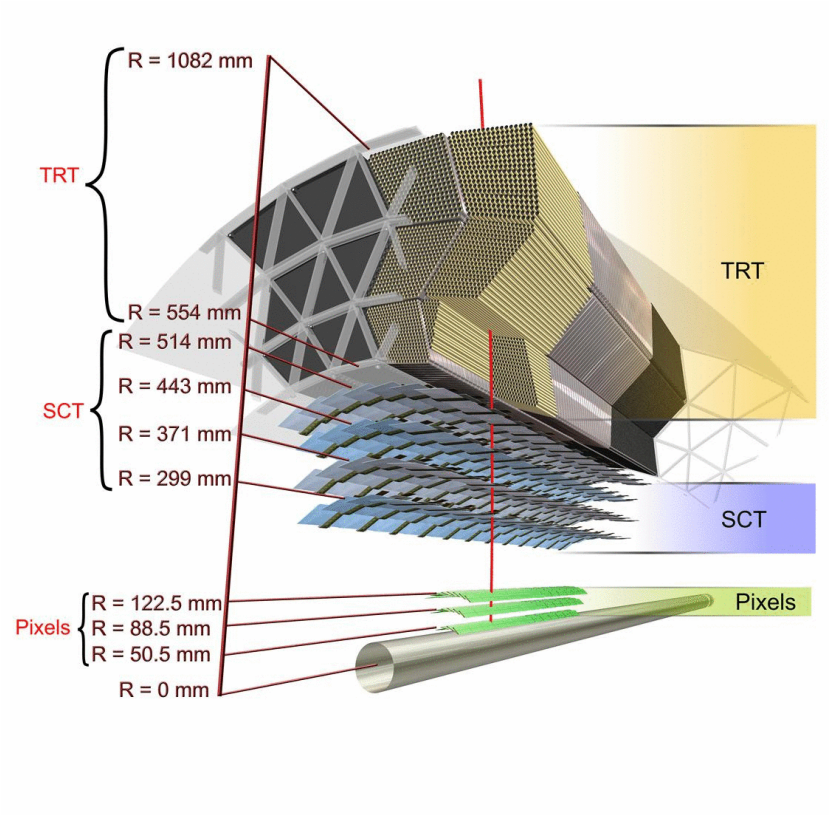
The ATLAS detector



The ATLAS inner detector

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



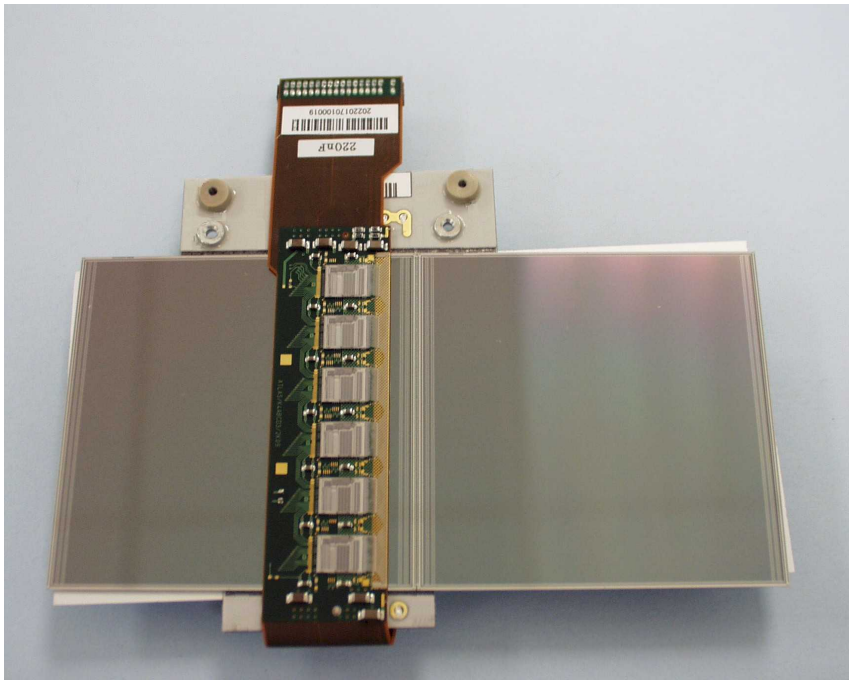


- SCT Barrel:
  - 4 Layers
  - 2112 Modules
  - $|\eta| < 1.4$ coverage
- SCT Endcaps:
  - 9 disks on each side
  - 1976 Modules
  - $|\eta| < 2.5$ coverage

Design requirements

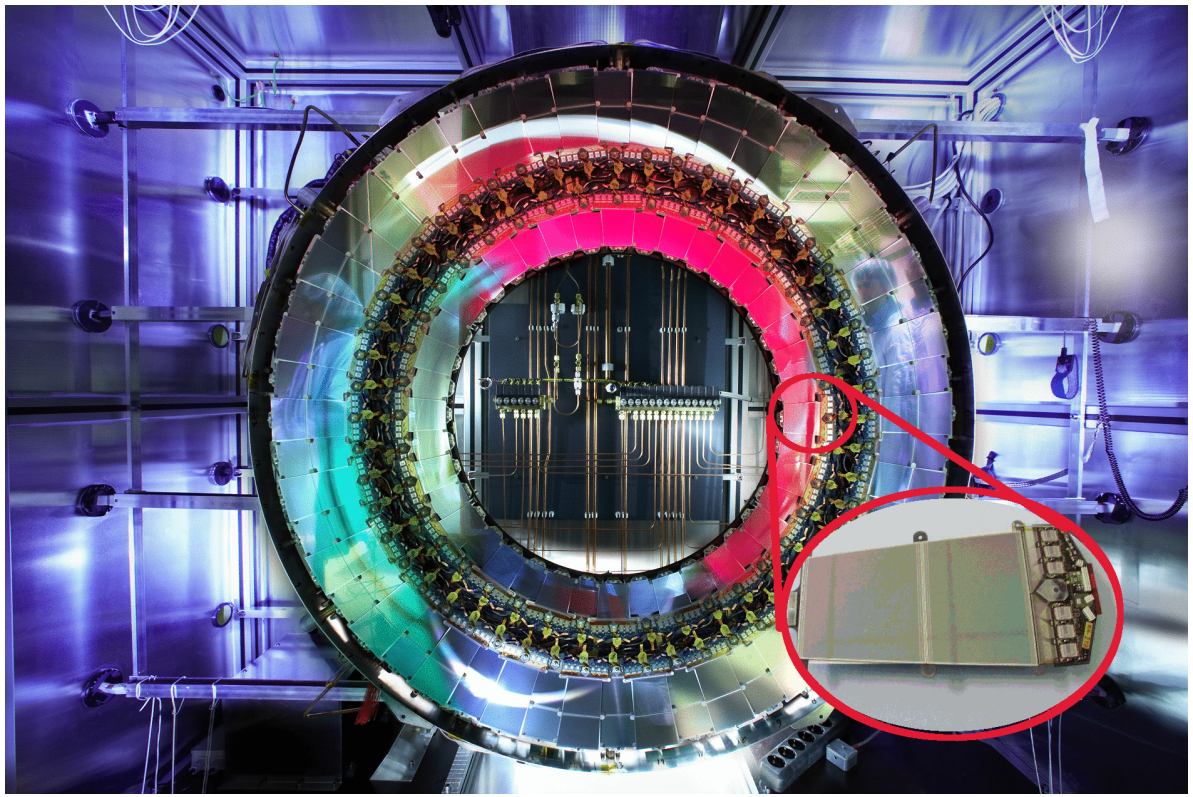
- Reconstruct isolated leptons with $p_{\mathrm{T}} > 5\ \mathrm{GeV}$ with 95% efficiency out to $|\eta| < 2.5$.
- Measure momentum with better than 30% precision even at $p_{\mathrm{T}} = 500\ \mathrm{GeV}$.
- Track back to the vertex z-coordinate with better than 1mm precision.
- Two track resolution better than 200 $\mu\mathrm{m}$ at 30 cm radius.
- Material should be no more than 20% X_0 in total.
- Assuming 3 years of LHC operation at $10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ and 7 years at $10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, including 50% uncertainty, innermost barrel must be able to withstand fluence of $2 \times 10^{14}\mathrm{n}/\mathrm{cm}^2$ 1 MeV neutron equivalent.

SCT barrel modules



- Each module has two sides, each with 768 strips.
- Stereo angle 40 mrad between strips on each side, enables detection of 3D “space points”.
- Strip pitch 80 μm (barrel).
- 6 ABCD readout ASIC chips per side.
- Binary readout (1 fC threshold).
- 150 V bias voltage (before irradiation).

Endcap modules



Same as barrel modules, except:

- Four layouts - inner, middle, short middle, outer.
- Strip pitch varies from 57-94 μm.
- Strip length varies from 55 mm to 120 mm

Cooling

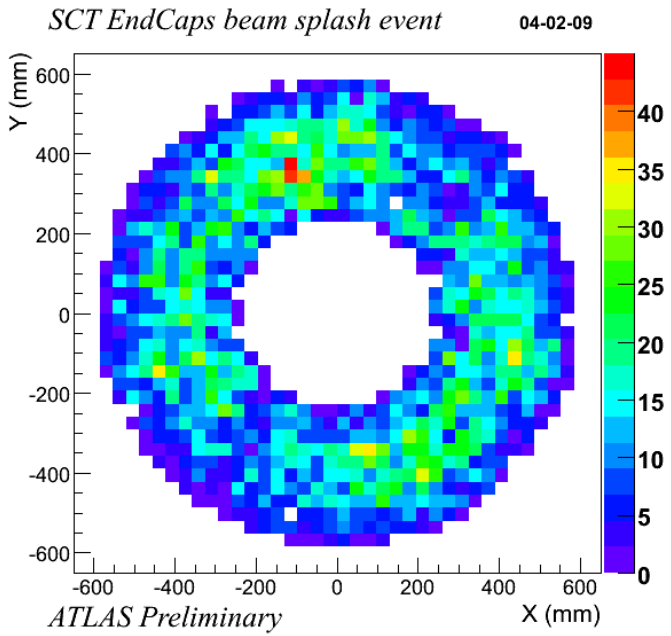
- In order to minimize the effects of radiation damage, need to operate SCT modules as cold as possible.
- Use evaporative cooling (C_3F_8) system, shared with pixel detector.
- In May 2008, three compressors in cooling plant malfunctioned due to failure of a magnetic clutch system.
  - Plant repaired and refurbished, slip sensors fitted to magnetic clutches.
- Further refurbishment and improvements were carried out in summer 2009.
  - Mitigate problems caused by vibration of the compressors.
  - Larger tank for cooling fluid.
- Cooling plant now running relatively stably 24/7.

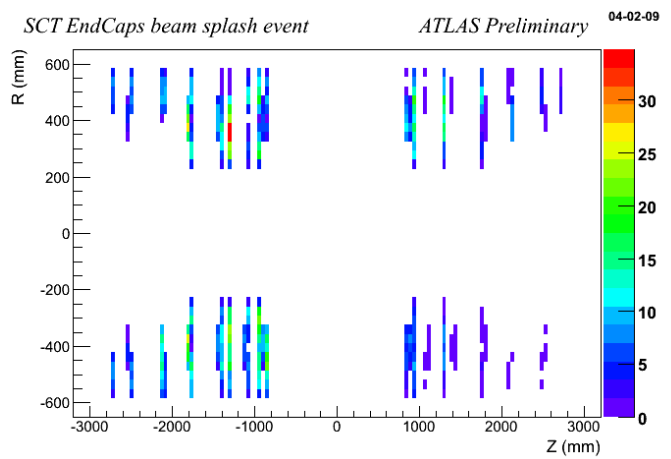
Optical communications.

- Communication between front-end and off-detector Data Acquisition (DAQ) electronics is done via fibre optic links.
  - "TX" link sends clock and command signals to the modules (one fibre per module).
  - "RX" link receives data from the modules (one fibre per module side).
  - Redundancy scheme - modules can receive clock and command signals electrically from neighbouring module in case of dead TX. Both sides of a module can be read out through one link in case of bad RX.
- In 2008 and early 2009, we were losing individual TX channels at an unacceptable rate.
  - Evidence pointed to ESD damage on VCSEL arrays during manufacturing.
  - New batch of TX plugins ordered, with increased ESD precautions.
- All TX plugins now replaced. Two channels dead, consistent with expectations of infant mortality based on pre-production tests.

LHC beam splash events

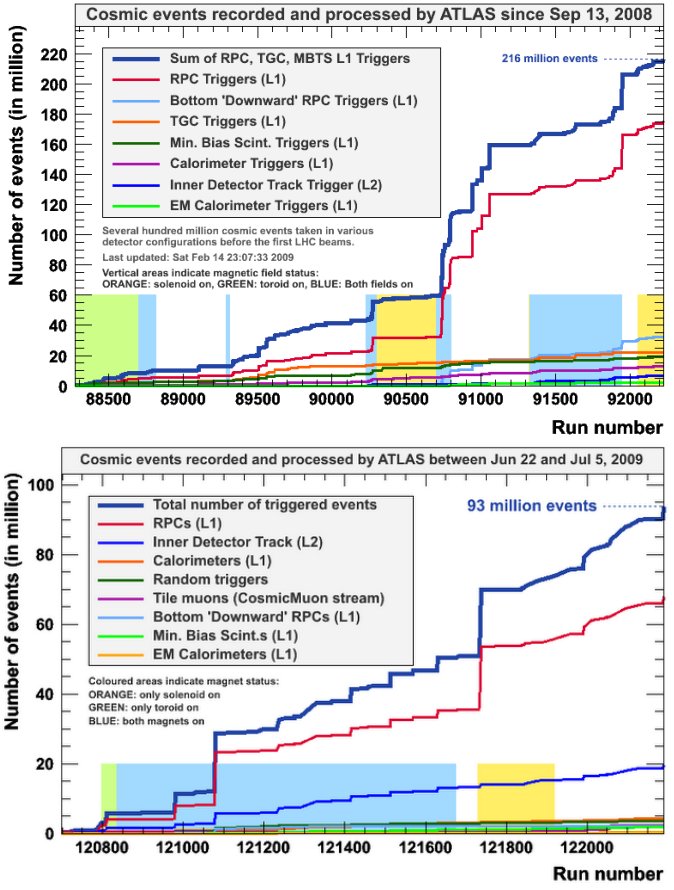
- September 10th 2008, day of first LHC beam, included periods where beams were fired into collimators 140 m upstream of ATLAS.
- For detector safety, SCT barrels were off, SCT endcaps were on but with 20 V bias voltage.
- Triggered using Minimum Bias and Beam Pickup triggers.



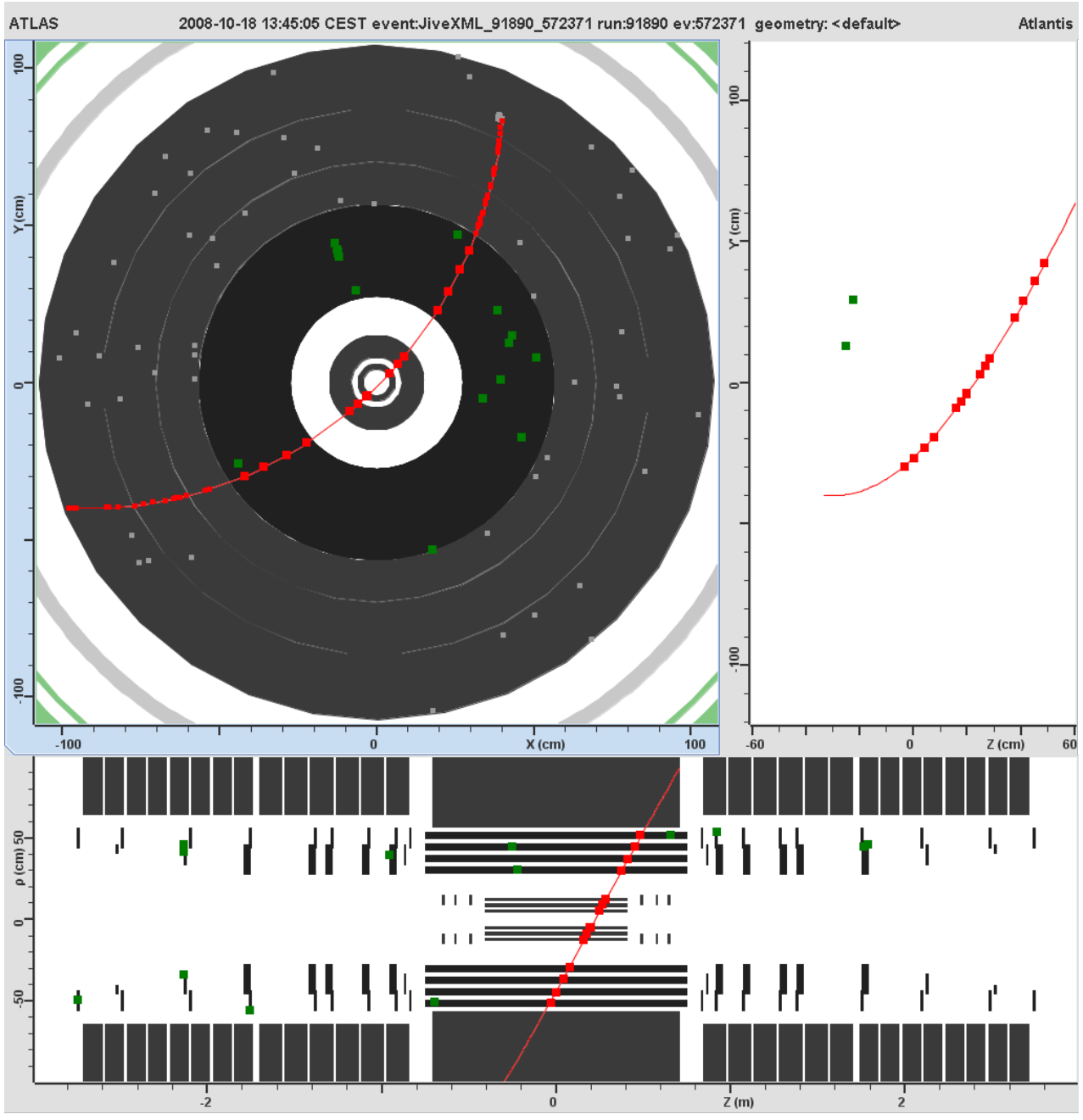


Cosmic ray events

- September-October 2008, continuous data-taking with whole ATLAS detector.
  - Over 2 million tracks with SCT hits recorded!
- June-July 2009, semi-continuous data-taking with all ATLAS inner detector.
- Combined ATLAS cosmics run about to start now, in run-up to LHC beams in November.

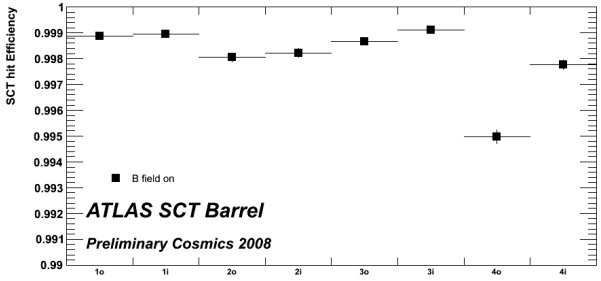


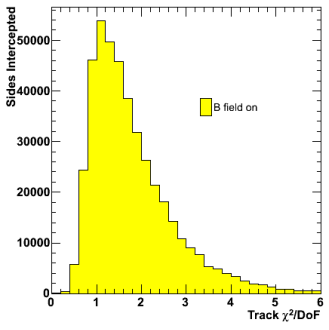
Cosmic ray events

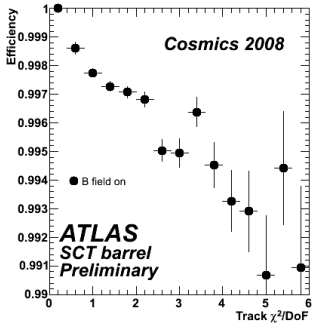


Hit efficiency

- Efficiency defined as “hits per possible hit”.
- Look for occasions where a track passes through an active area of silicon, and no hit is recorded.
- Following cuts applied:
  - Cosmic muons with $\geq$ 10 SCT hits and $\geq$ 30 TRT hits, $\chi^2/\mathrm{DoF} < 2$.
  - Incident angle with wafer $\leq 40°$ from normal.
  - Hits both before and after module under study.
  - Guard region around the edge of the active silicon excluded.



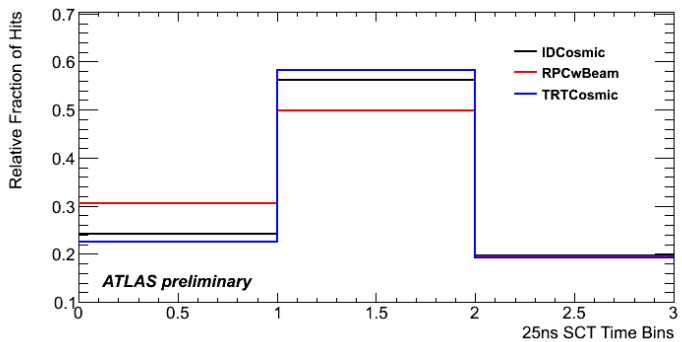




- Efficiency found to be 99.75%

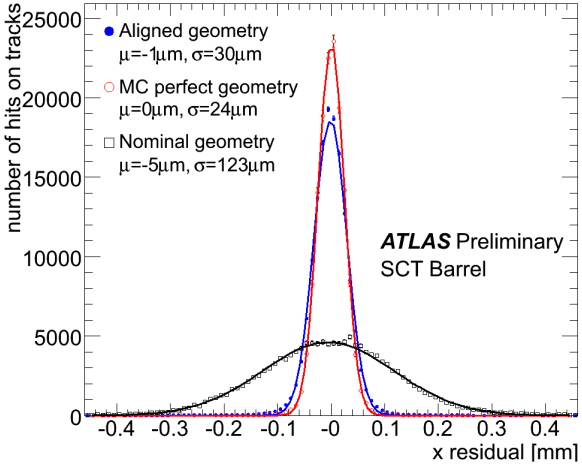
Timing

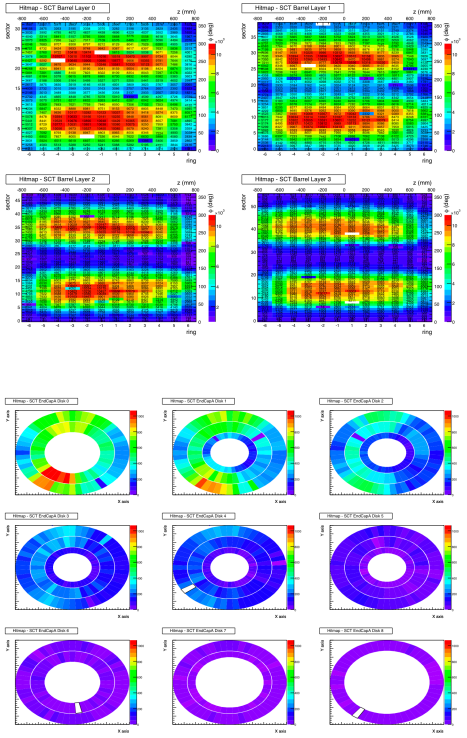
- SCT reads out hits in three 25 ns time bins around the Level-1 Accept (25 ns = LHC bunch crossing period).
- For non-noise hits, expect a 01x pattern of hits in these time bins.
  - Use this to “time in” relative to the trigger by adjusting various delays in the Data Acquisition (DAQ).
  - Will need to revisit this with collisions data, to account for the time-of-flight of particles travelling outwards from the interaction point.



Alignment

- Different “Levels” of alignment:
  - Level 1 treats whole barrel, and each endcap, as one structure.
  - Level 2 treats each barrel layer and endcap disk separately.
  - Level 3 treats each module separately.

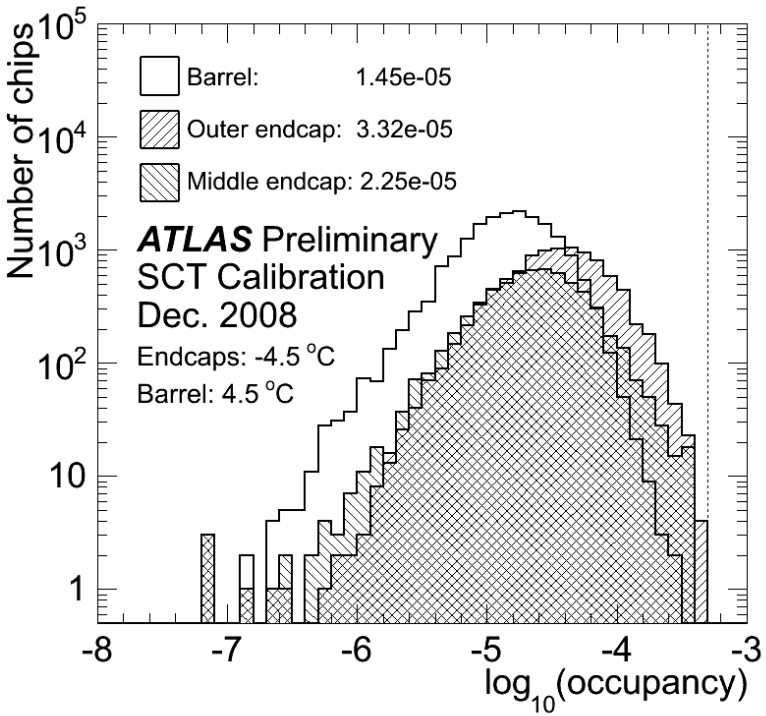




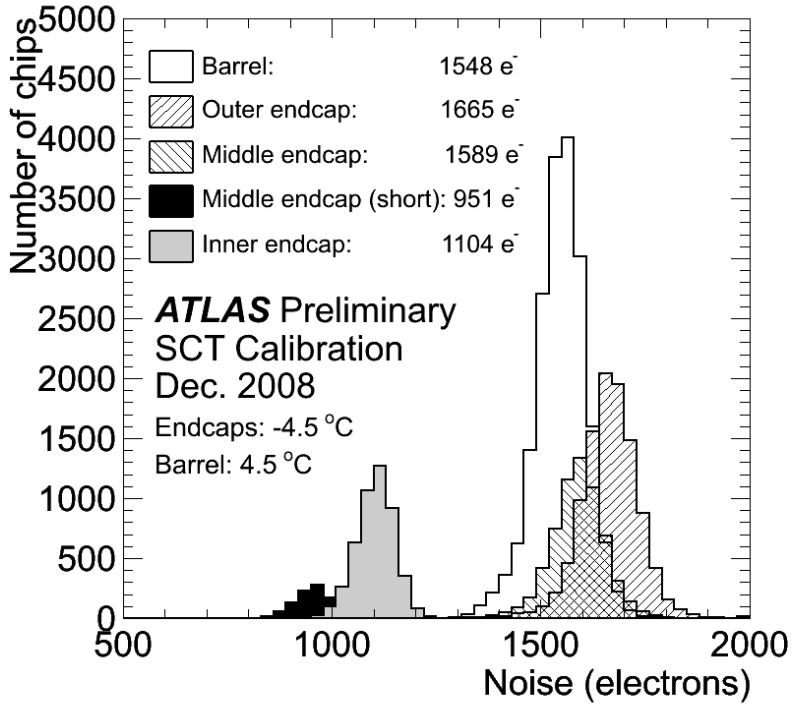
- Already approaching ideal alignment in barrels. Less statistics in endcaps, but will be improved with first collisions data.

Noise

- Design specification requires noise occupancy below 5×10^{-4}.
- Can measure noise in data-taking mode using random triggers, or as part of standalone calibrations.



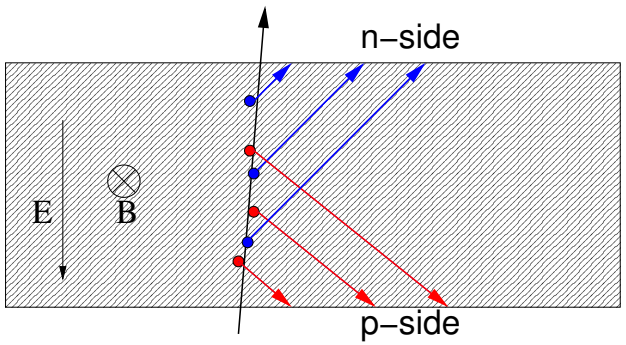
Noise occupancy measured in 2008 cosmics data.



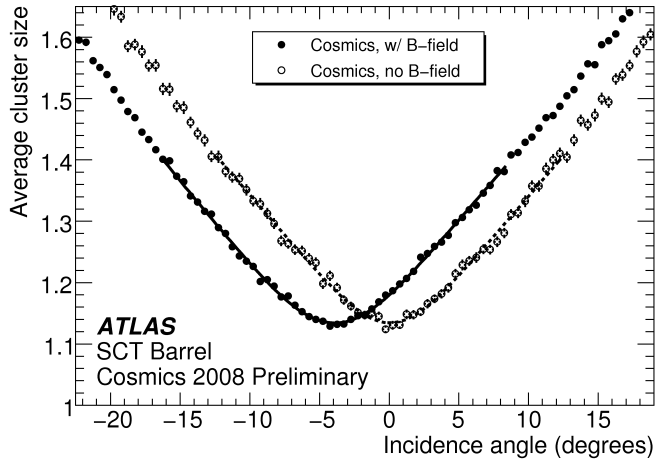
Input noise to ABCD chips measured in response curve calibration.

Lorentz angle measurement

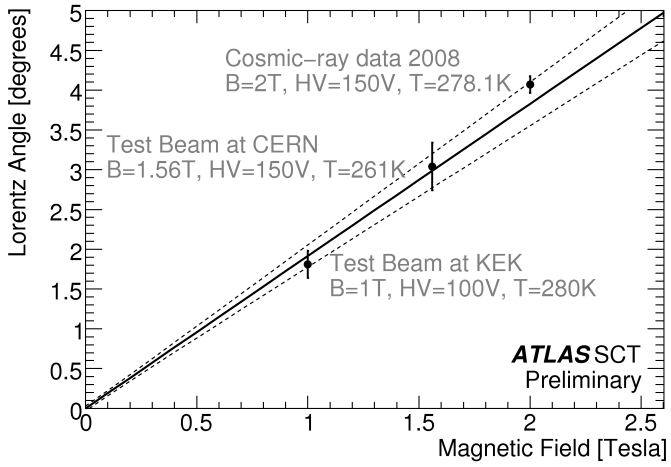
- Drift direction of charge carriers in silicon will be altered by magnetic field.



- *p*-side readout.
- Number of strips with > 1 fC depends on incident angle of ionizing particle.



Measure $\theta_L = 3.93 \pm 0.03 \pm 0.09$, consistent with simulations.



Summary and Conclusions

- 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.
- Problems with opto-transmitters appear to be resolved, but will keep close eye on the situation.
- Cooling system now working reliably.
- SCT is ready for LHC collisions!