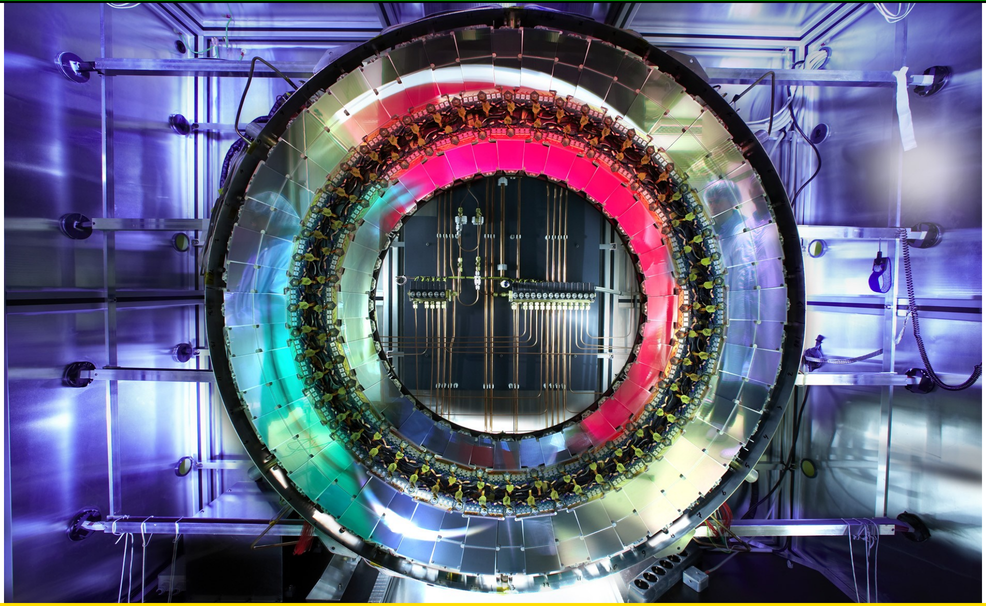
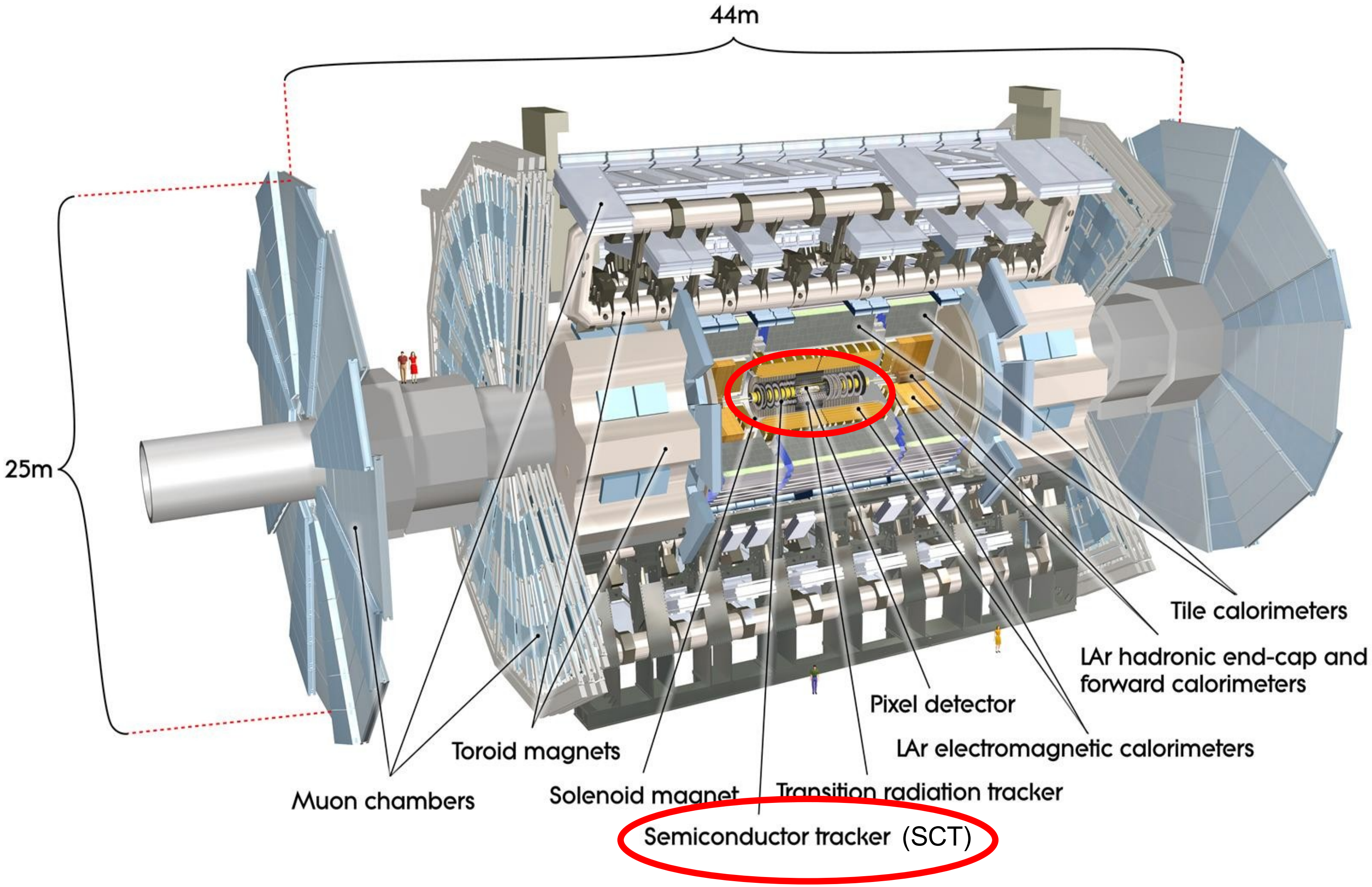
ATLAS strips: Running Experience



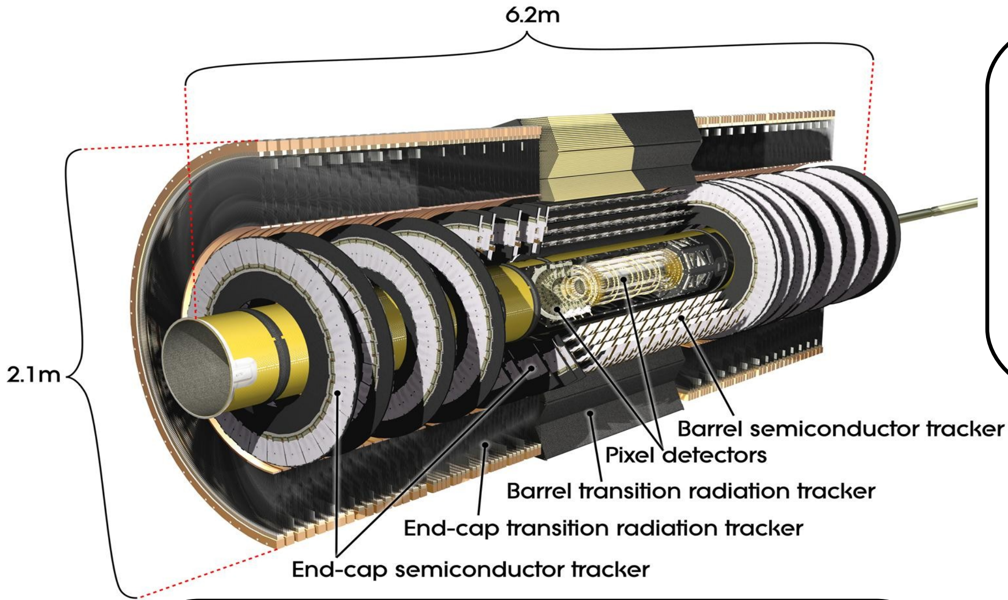
VERTEX 2009 – Mooi Veluwe
14th September 2009

Manuel Kayl on behalf of the ATLAS SCT Collaboration

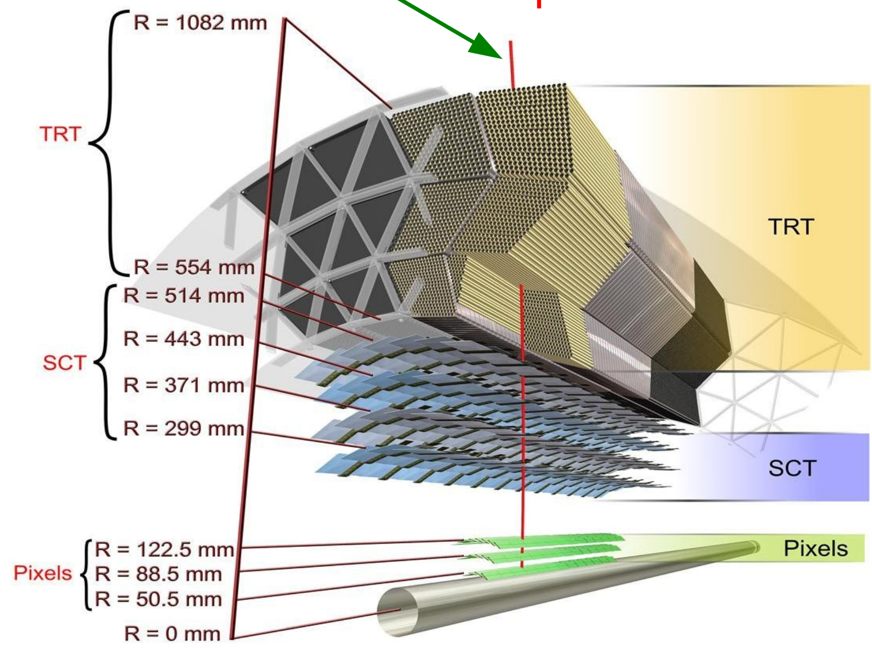
The ATLAS detector



The ATLAS Inner Detector



- Located in 2 T solenoidal field
- Tracking coverage of up to |η| = 2.5
- Consists of Pixel, SCT and TRT



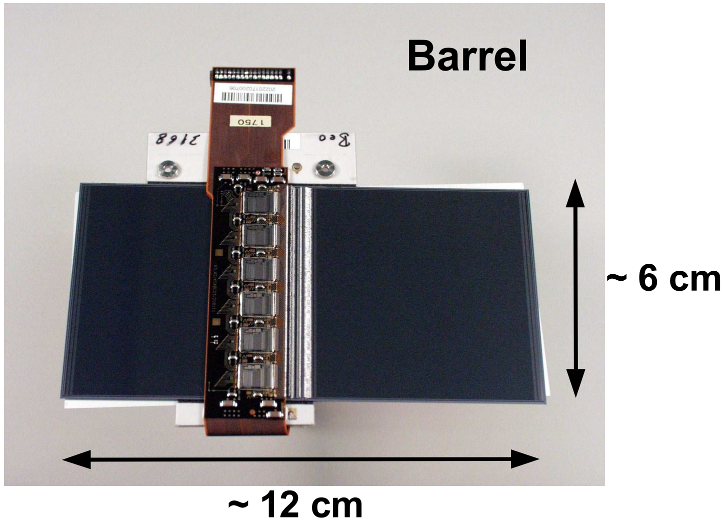
- Dimensions of SCT:
  - Radial : 300 mm – 520 mm
  - Longitudinal : up to +/- 2700 mm
- SCT barrel (4 layers)
  - Covers up to |η| = 1.4
  - 2112 modules
- SCT end-caps (9 disks each)
  - Cover up to |η| = 2.5
  - 1976 modules in total

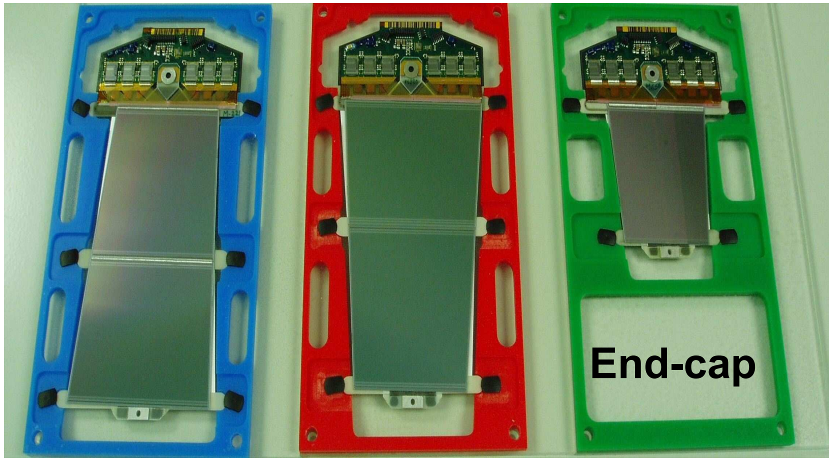
The SemiConductorTracker (SCT)

- Silicon sensors
  - Four layouts (one barrel, three end-cap)
  - Two sensors glued back-to-back
  - 40 mrad stereo angle
  - p-in-n sensors (p strips on n Si)
  - Strip pitch: 80 μm (barrel),
    57 – 94 μm (end-caps)
  - 768 active readout channels per side

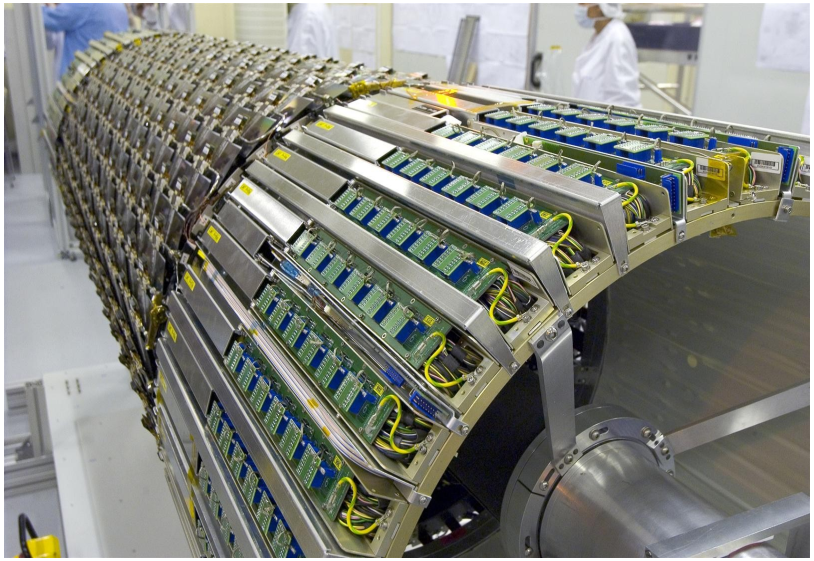
- Signal read out
  - Three bunch crossings of 25 ns at a time
  - Six ABCD chips per side
  - Binary readout (default threshold: 1fC)

- Operation conditions
  - 150 V reverse bias before irradiation
  - Up to ~ 10 W power per module
  - Evaporative cooling system with C_3F_8 at -25° C, design operation at -7° C





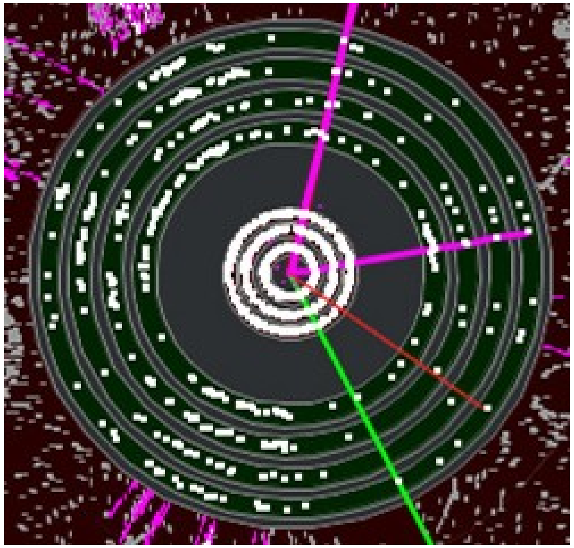
Tolerances and requirements on the SCT



- As-built tolerances per module
  - < 8 µm in-plane, achieved RMS: 2 µm
  - < 70 µm out-of-plane (bowing and thickness), achieved: ~ 40 µm
- SCT assembly
  - Mounting precision in z : 60 µm
  - No survey in r-phi

Physics requirements

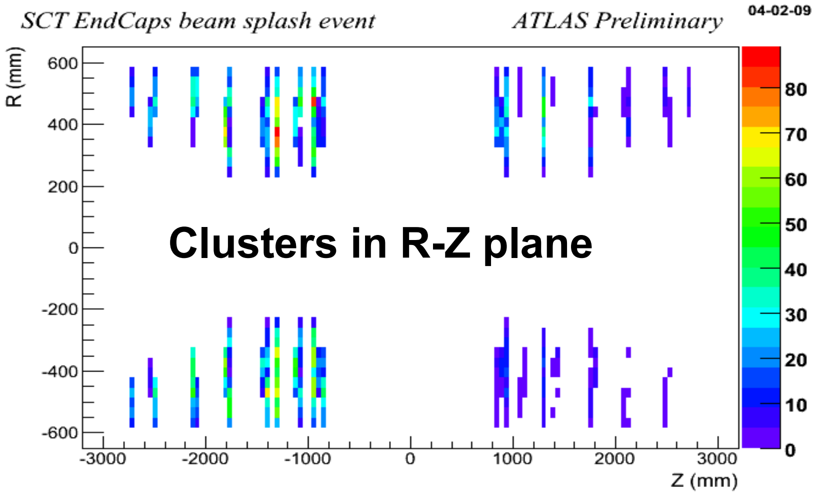
- **Resolution (x* y): 17 µm * 580 µm**
- **Alignment tolerances (x*y): 12 µm * 50 µm**
- **Noise occupancy: < 5 * 10^{-4}**
- **Efficiency: > 99%**
- **Radiation : ~ 2 * 10^{14} Neq cm^{-2} over 10 years**



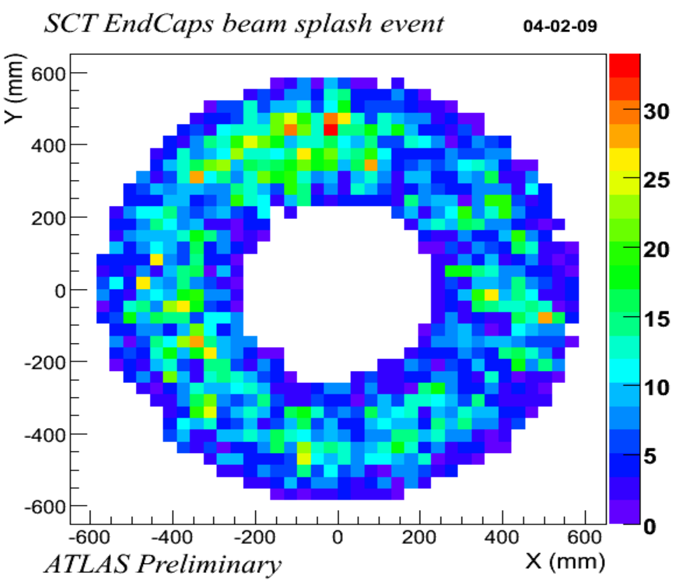
LHC beam and the SCT: Beam splash

First LHC beam as seen by SCT (10/09/2008)

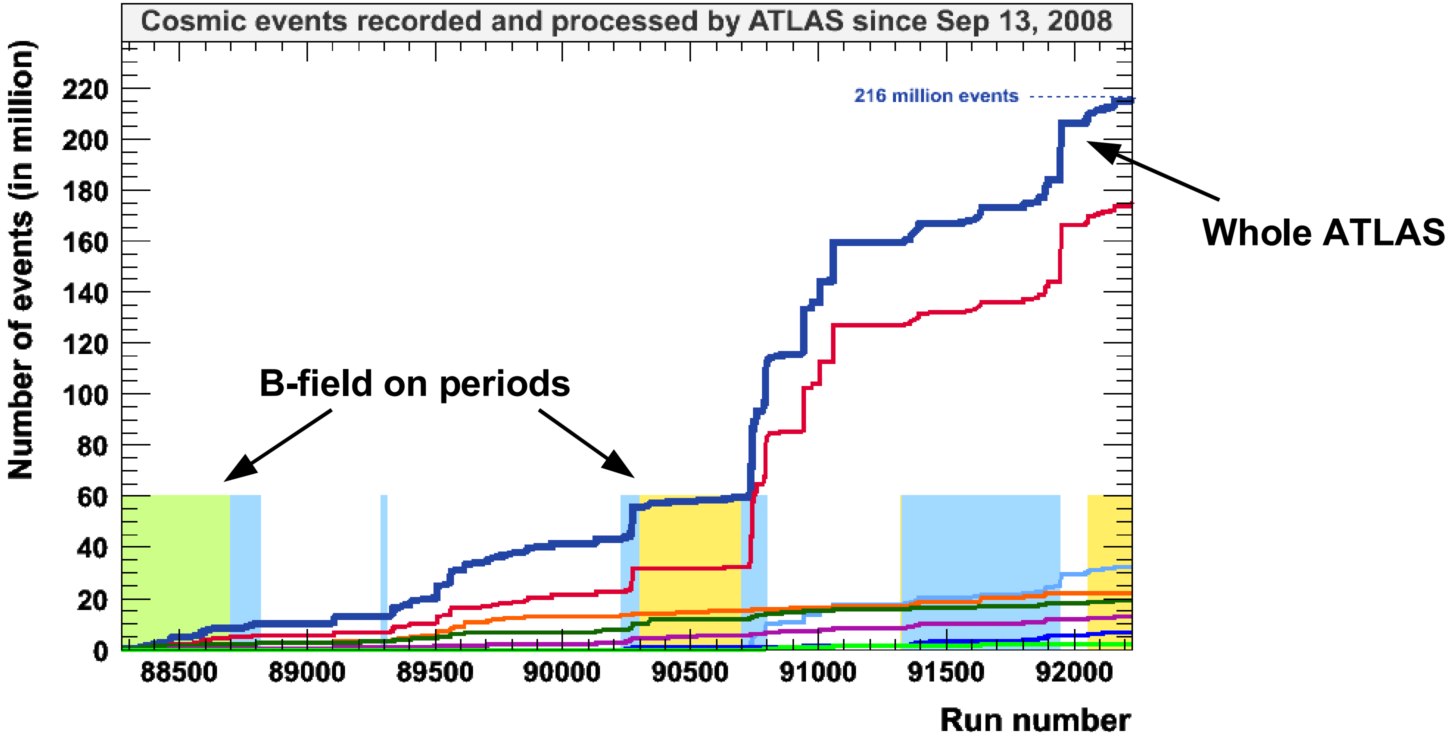
- Beam at injection energy (450 GeV) hit collimators close to ATLAS
- SCT operating at 'safe' conditions: only end-caps, bias voltage 20 V, threshold 1.5 fC
- Timing with LHC clock was studied



Clusters in X-Y plane

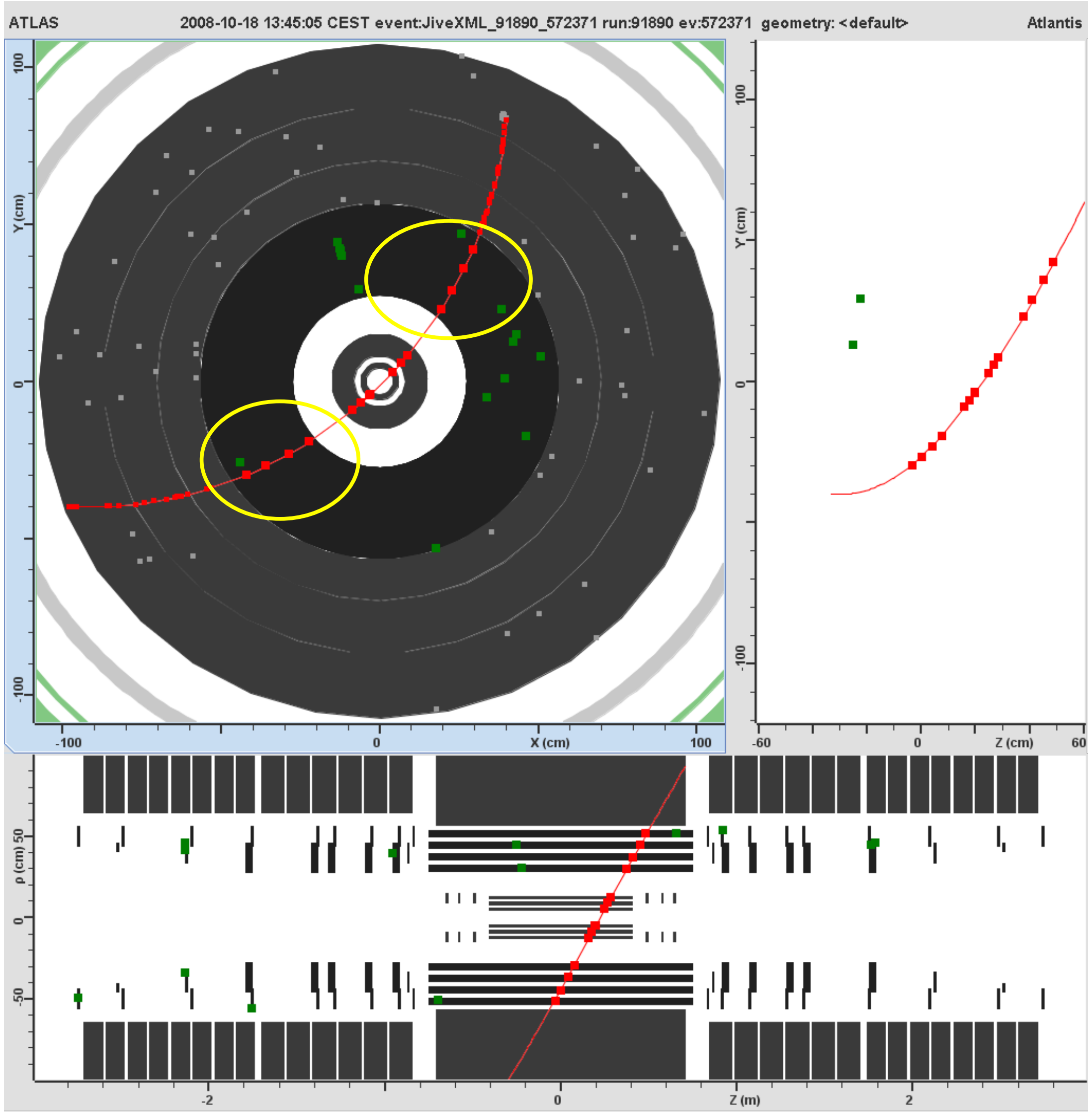


Running the SCT: cosmic data taking



- By far largest amount of real data
- Useful for calibration, trigger, alignment and tracking performance
- ~ 2M tracks recorded with SCT in 2008 (B field-on and B field-off)
- Extensively analysed, cross-checked with 2009 cosmic data
- Differences from collision tracks:
  - Low statistics in end-caps
  - Track parameter spectra

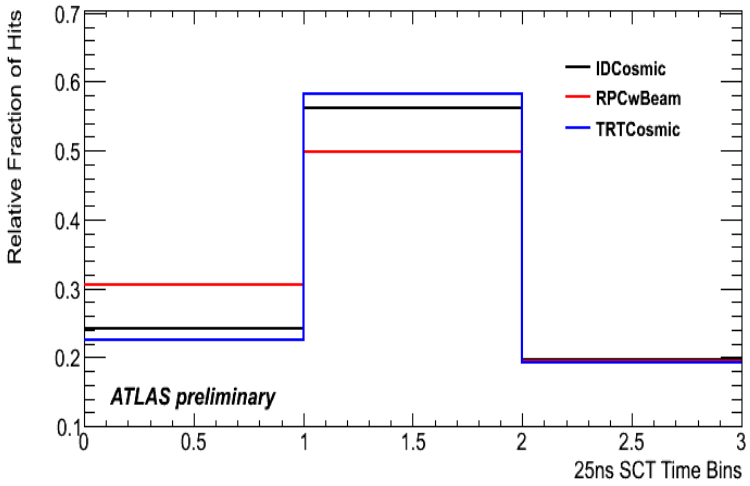
Running the SCT: cosmic event

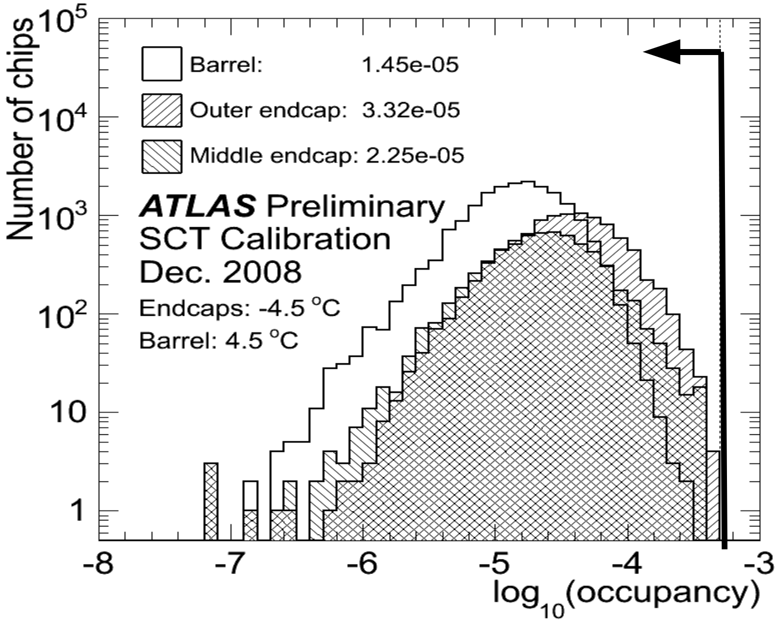


SCT in operation: timing and occupancy

Timing studies

- SCT reads out three bunch crossings
- Hits should arrive in middle bin (X1X pattern)
- Detector well timed in, contribution from trigger jitter visible





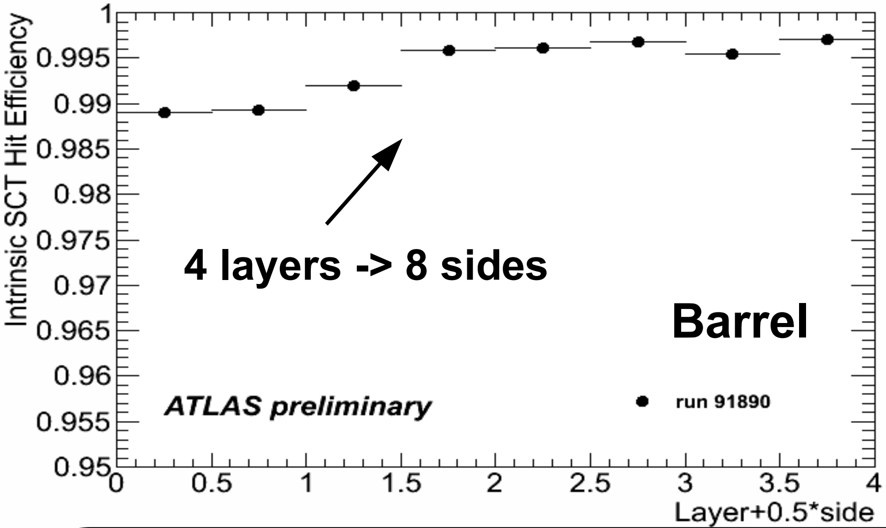
Noise occupancy

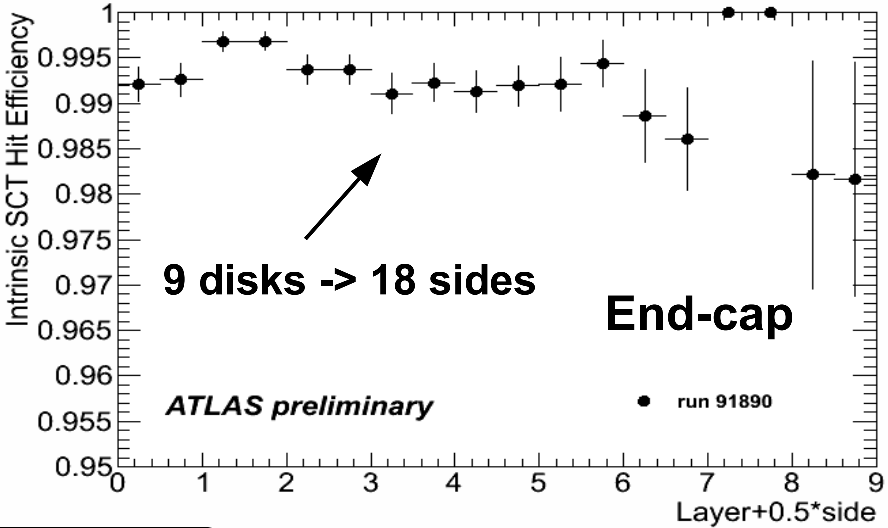
- Noise occupancy per strip (physics mode)

$$N_{\text{strip}} = \frac{N_{\text{hits}} - N_{\text{SpacePointHits}}}{N_{\text{events}} - N_{\text{SpacePointHits}}}$$

- Well below specification of $5 * 10^{-4}$
- Dependence on strip length, temperature visible

SCT performance: hit efficiencies



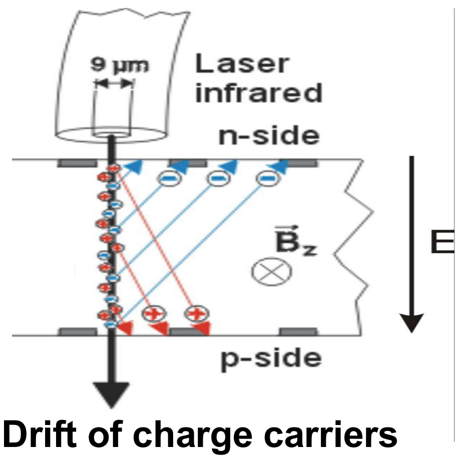


- Benchmark number for understanding the detector, many effects to be considered:
  → dead channels, calibration, alignment, tracking
- Unbiased hit efficiencies (hit removed from track), comparison of expected and actual hits
- Limited statistics in end-caps
- **Hit efficiency meets requirements (> 99%)**

Non-operational modules (in 2008)

Barrel	**~ 1%**
End-cap	**~ 3%**

SCT in magnetic field: Lorentz Angle

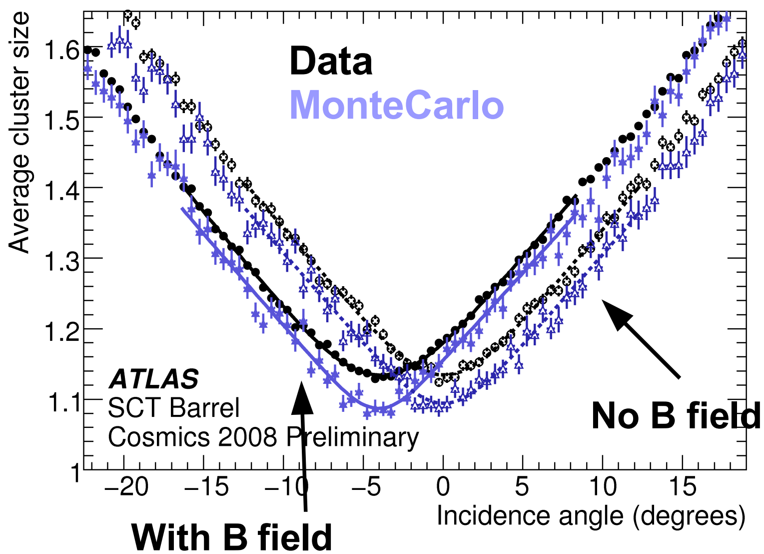


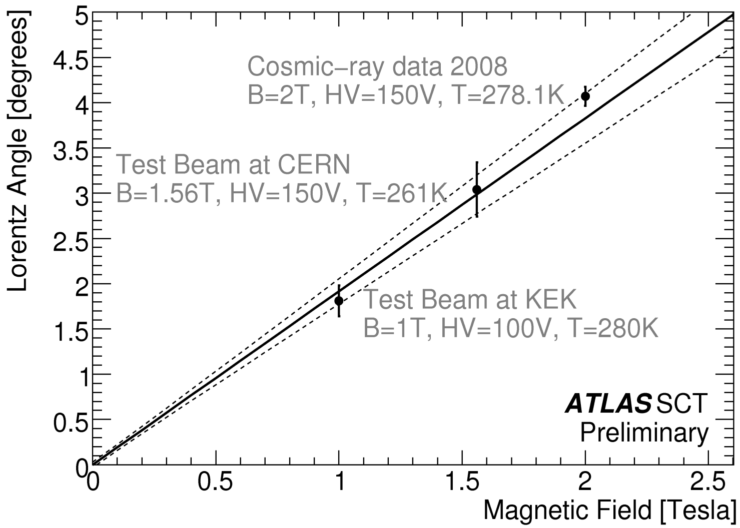
- Drift angle of electrons/holes in magnetic field
- Depends on magnetic field, charge mobility
- P-strip readout → holes collected
- Obtained by fitting the function

$$[e \tan|\Theta_L - \Theta| + \delta/\cos\Theta] \oplus G(\Theta)$$

geometrical term — diffusion term — gaussian resolution

- **Data: ThetaL = 3.93 ± 0.03 (*stat.*) ± 0.09 (*syst.*)**
  MC : ThetaL = 3.69 ± 0.26 (*syst.*)
- Consistent measurements obtained

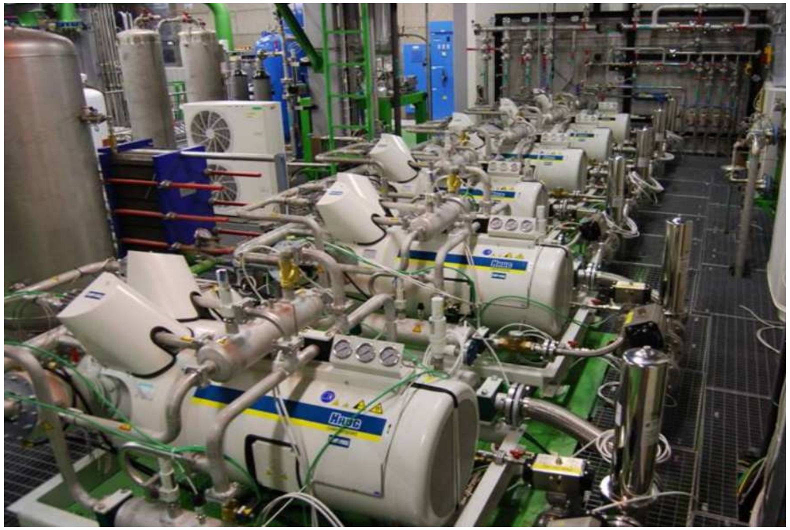




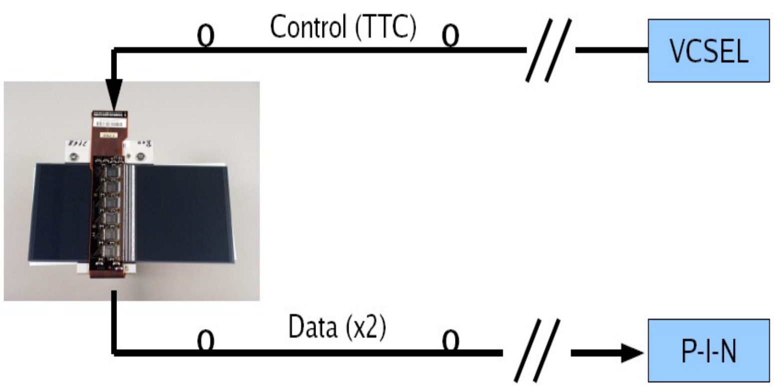
SCT operation: room for improvements

Cooling

- Shared system with Pixel detector
- Problems occurred: leaks in cooling pipes and failures of compressors, design temperature will not be reached
- Talk by Koichi on Thursday

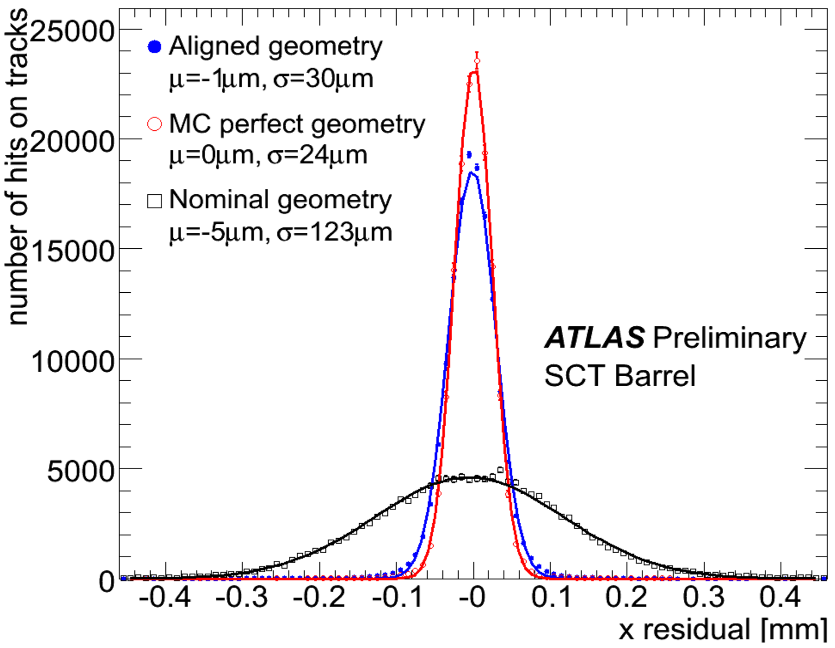


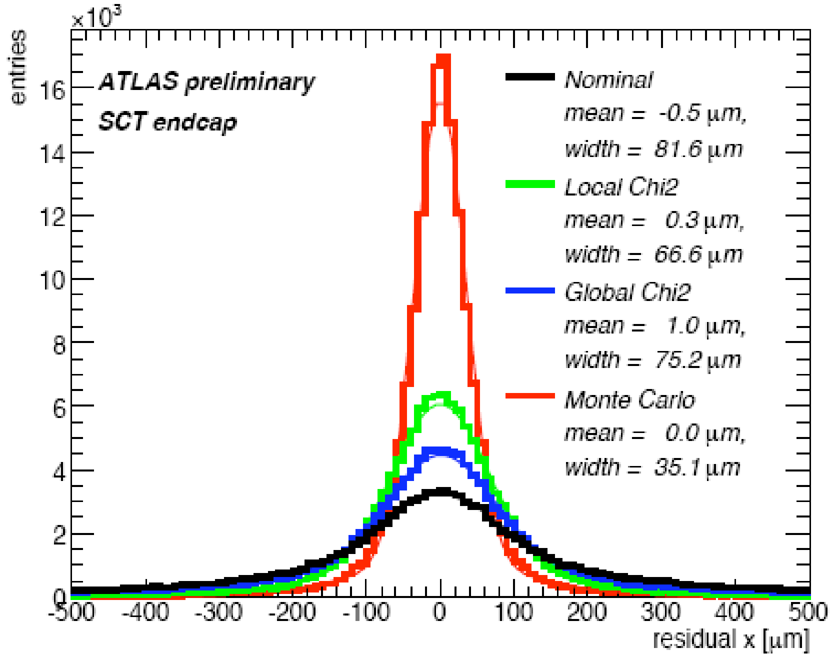
Off-detector system



- Optical transmission system for module communication
  → Failure of VCSELs in data acquisition rack
  → Accessible, all links replaced in May and August 2009
- Several HV trips during operation, needs reset of modules during operation

SCT Alignment results



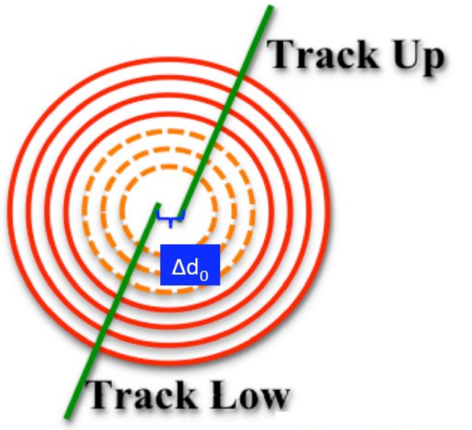


- Obtained with mixed B field on and off data
- Barrel resolution improves from 123 μm (nominal) to 30 μm (aligned)
- End-cap alignment difficult (not on module level)
  → still considerable improvements achieved
- Width of residual distributions consistent with random misalignment of O(20 μm)
- More on alignment in Tuesday afternoon session

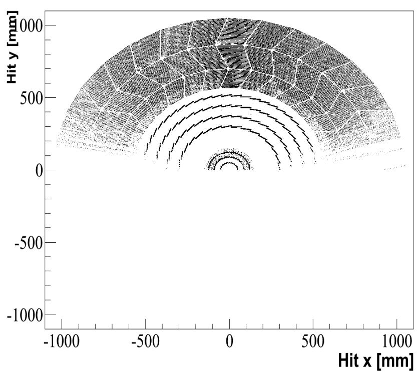
Readiness for physics: tracking performance

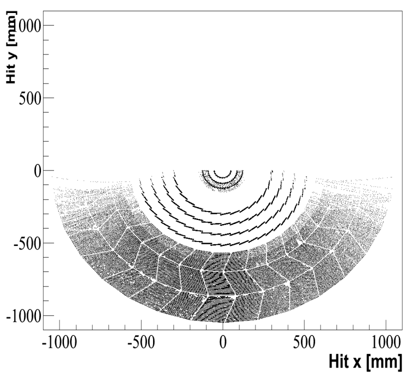
- Tracking performance variables like impact parameter resolution can be studied using cosmic tracks split up in upper and lower half tracks
  - → Two separate "collision-like" tracks
  - → Constrain tracks close to interaction region
  - → Estimate track parameter resolutions from distributions of difference in track parameters T:

$$\sigma_T = \frac{T_{upper} - T_{lower}}{\sqrt{2}} = \frac{\Delta T}{\sqrt{2}}$$

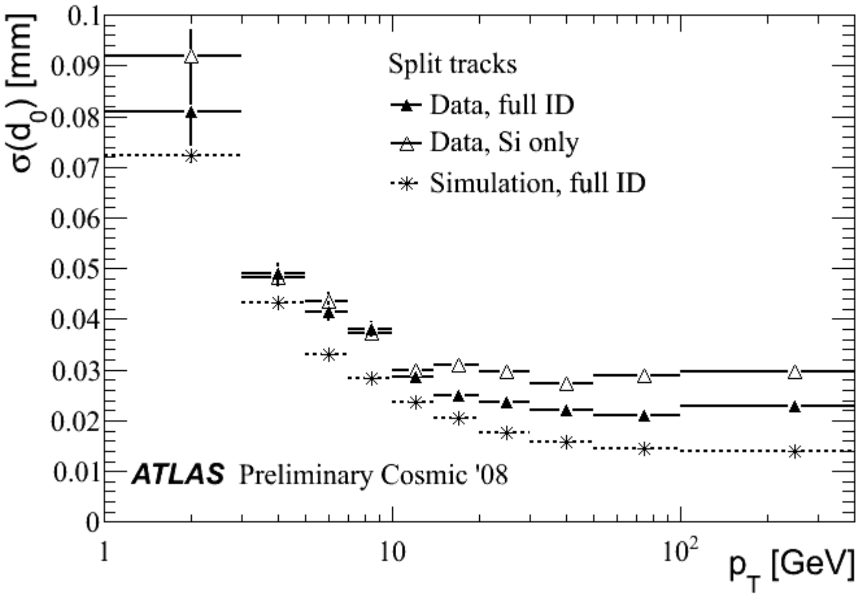


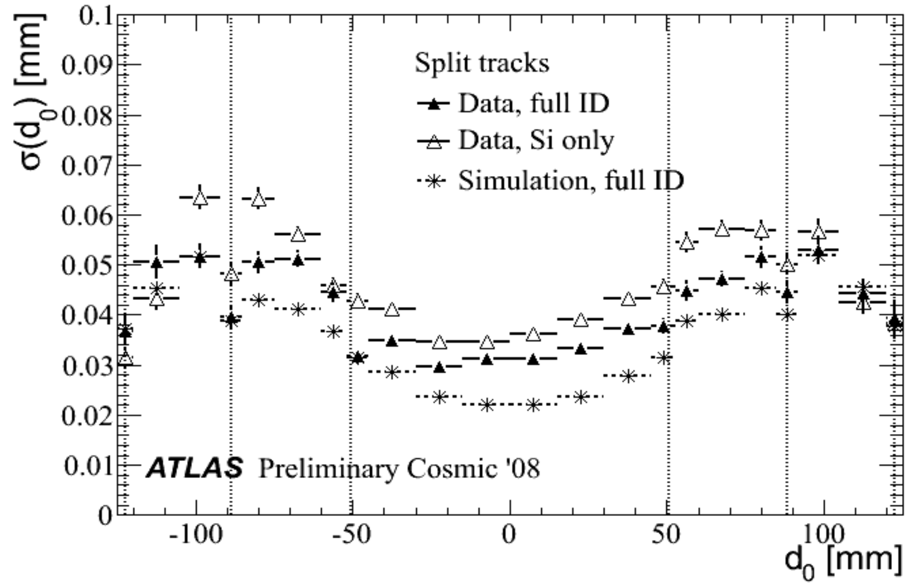
Hit distributions in x-y plane for tracks split in upper and lower half





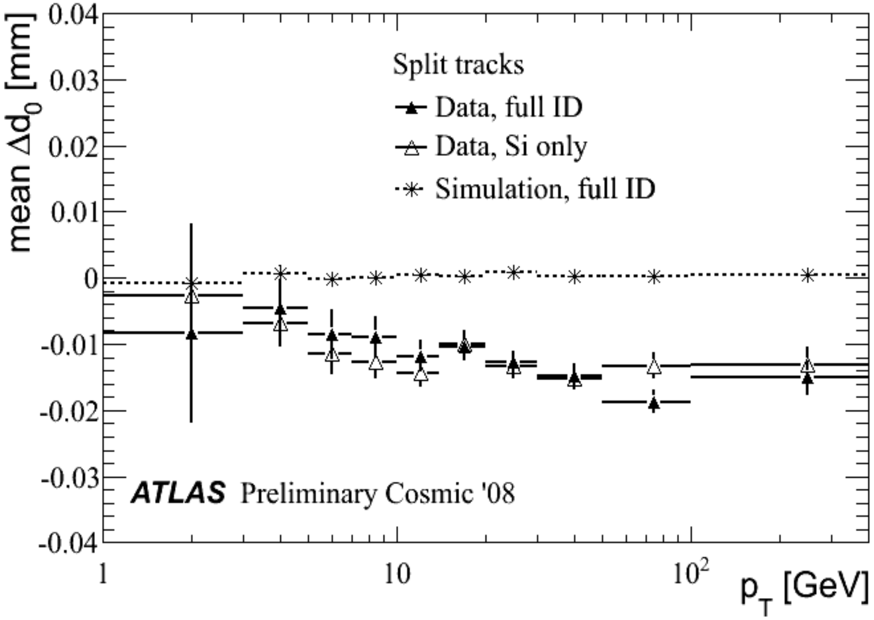
Transverse impact parameter resolution

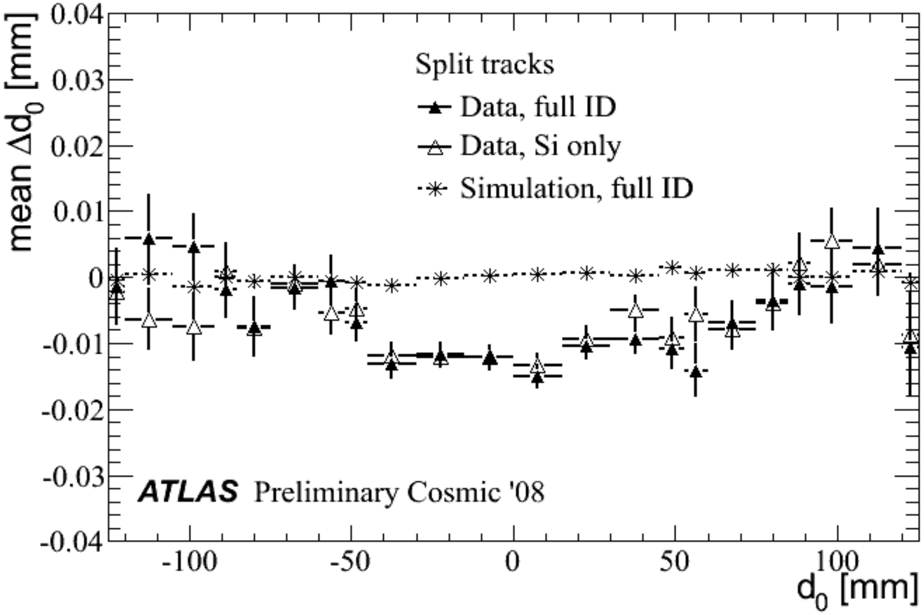




- Transverse impact parameter resolution versus p_T and d_0 itself
- Comparison of Si-only, full ID (incl. TRT) tracks with full ID simulation
- At low p_T dominated by multiple scattering, at high p_T by intrinsic detector resolution (left plot)
- Dips in resolution if d_0 equals radii of Pixel layers (right plot)
  - → short extrapolation distance to perigee point
- Understood in great detail, difference to simulation indicates remaining misalignments

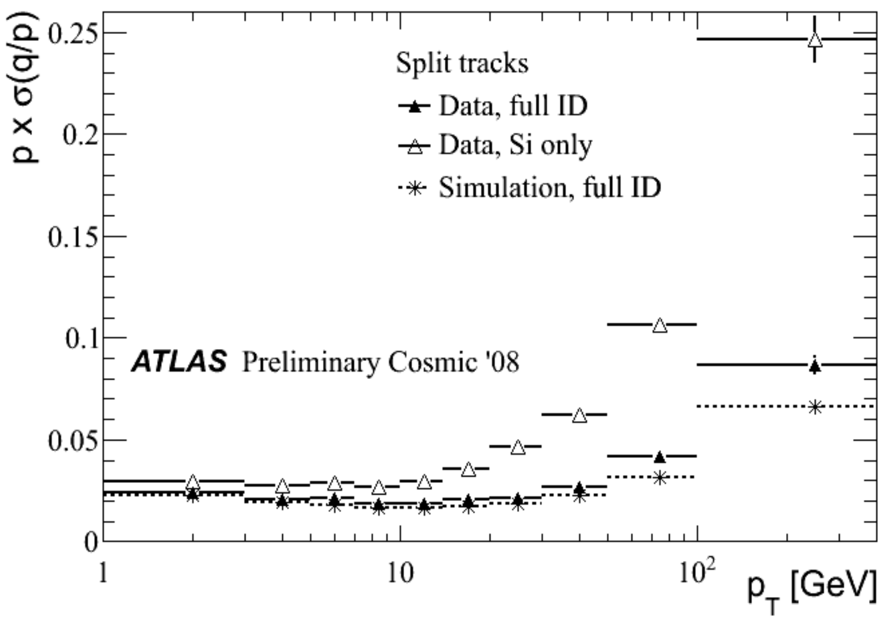
Bias in impact parameter resolution

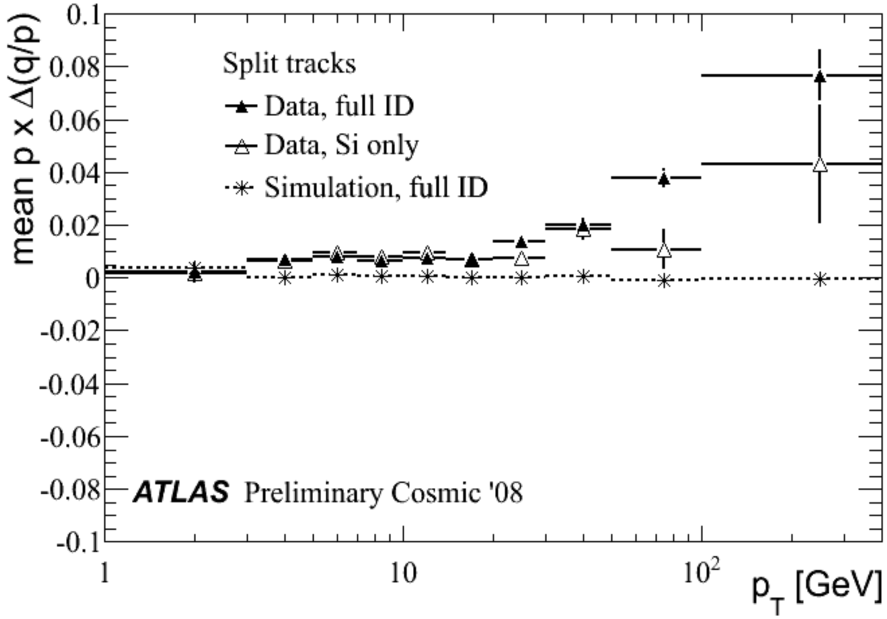




- Mean of the Δd_0 distribution versus p_T and d_0 itself
- Bias of up to 15 µm visible at higher p_T and small d_0
- Not observed in simulation
  - → Real effect, no shortcoming of method
  - → Shows how well detector is already understood
- Possible systematic distortion of detector, crucial for further understanding of interplay between tracking and alignment

Relative momentum resolution





- Relative momentum resolution and mean of the relative momentum
- Comparison of Si-only, full ID (incl. TRT) tracks with full ID simulation
- At high p_T, bigger lever arm with TRT improves the resolution
- Bias at high p_T, not observed in simulation
  - → probably correlated with d_0 bias
- Understood in great detail, difference to simulation indicates remaining misalignments

Conclusions

- Successful operation of SCT in 2008 (and 2009)
- 99% of barrel modules operational, 97% in end-caps (99% barrel and endcap in 2009)
- Problems with evaporative cooling and optical connectors
- In-depth calibration of SCT with cosmic data
  → Lorentz-angle, hit efficiencies, occupancy, ...
- Alignment with cosmic data performed up to module level
- Resolutions of tracking parameters demonstrate readiness for physics measurements of SCT

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 <~ % level.
Cosmic rays detected in conjunction with other detectors
DAQ, DCS and Monitoring tuning up

R… r collisions in a few weeks !

Vertex 2008
Saverio d'Auria

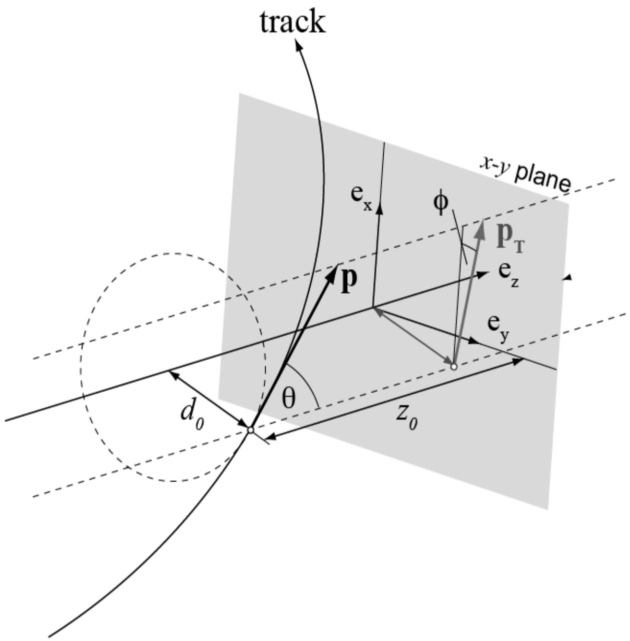
…ria 17th International Workshop on Vertex Detectors, Utö Island, Sweden, 28 July 2008

Gaining experience with a very complex system !

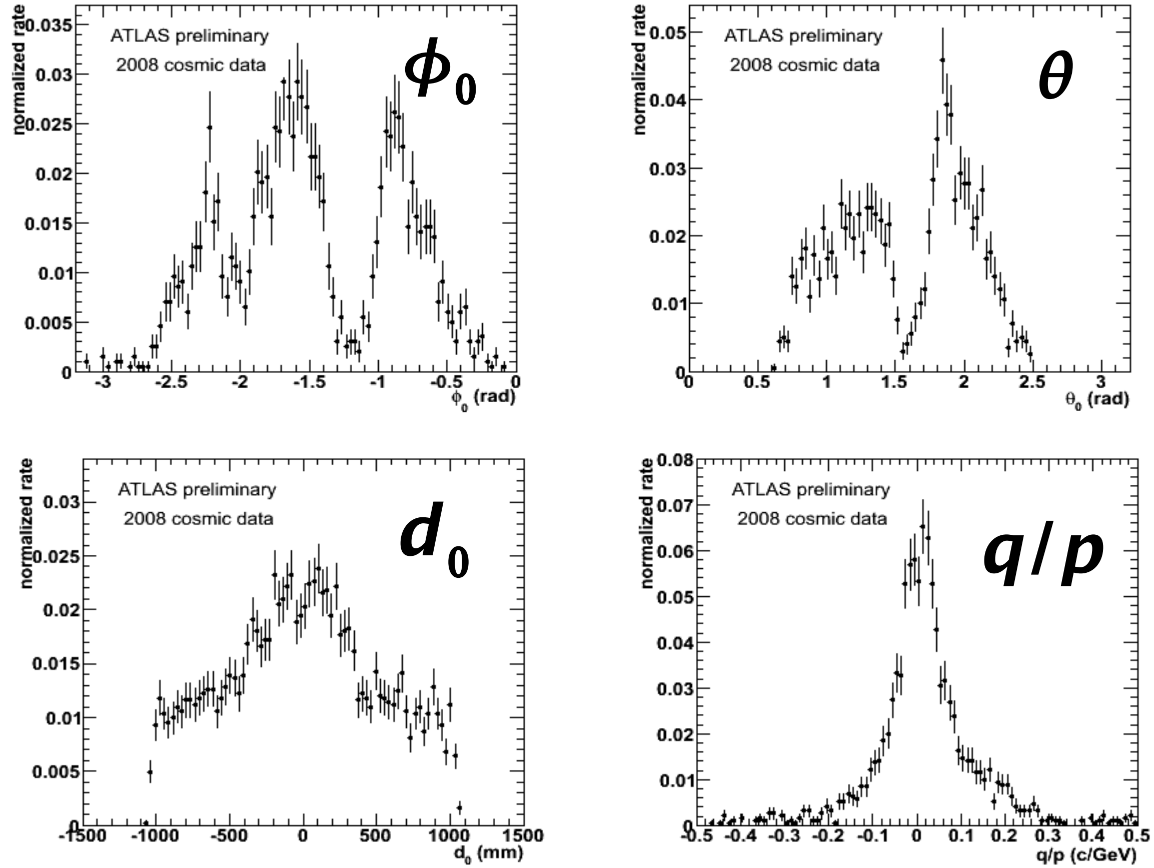
Acquired a lot of experience with a very complex system!

Backup

Track parameters in cosmic data



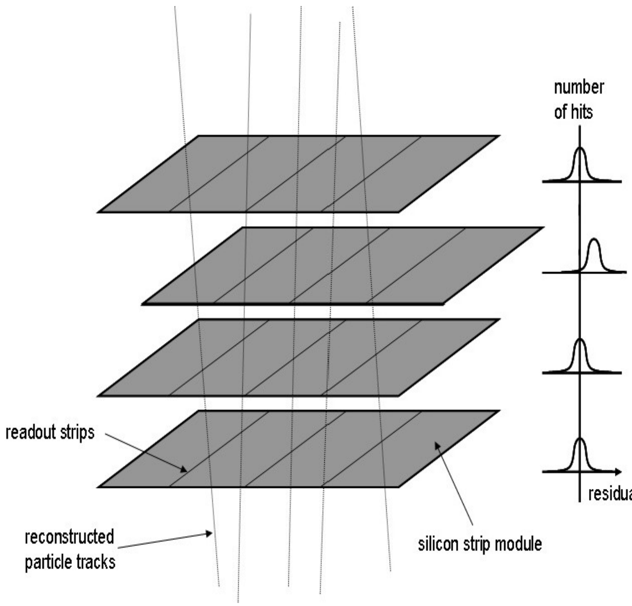
Definition of track parameters



- Typical (asymmetric) distributions for track parameters in cosmics events

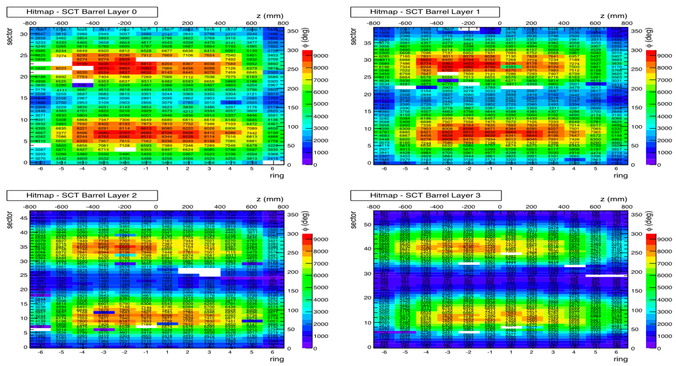
High level commissioning: Alignment

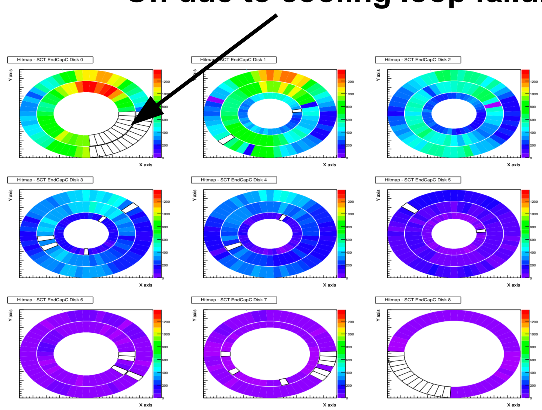
- Detector alignment is the first link from detector operation to performance for physics analyses
  → key role of SCT
- Cosmic muons provide a close-to-reality test-bed
  → will be used to constrain weak modes during collisions data taking
- Alignment strategy:
  - First align silicon detectors, afterwards TRT
  - Different 'levels' of alignment depending on rigid structures, e.g. SCT barrel, SCT layer/disk , SCT module



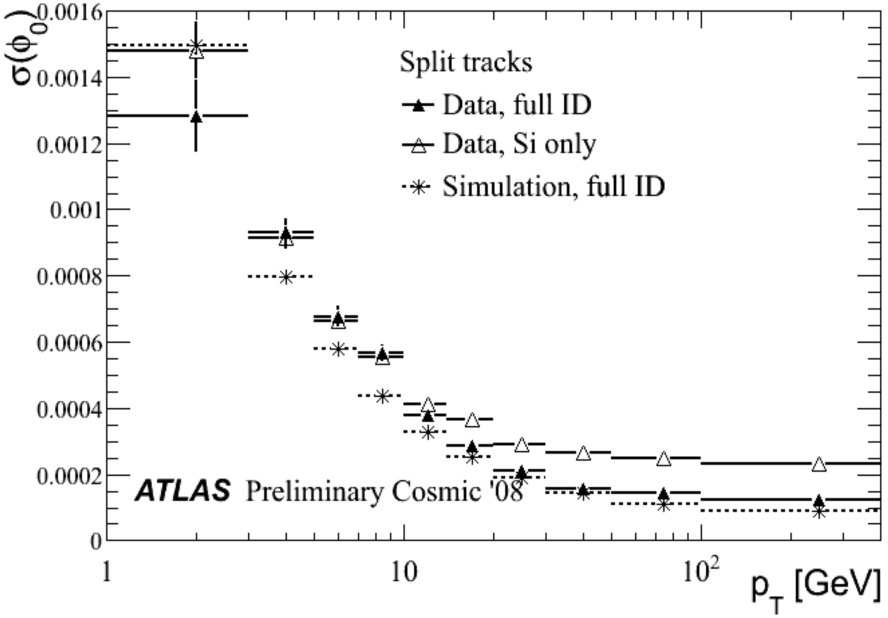
Off due to cooling loop failure

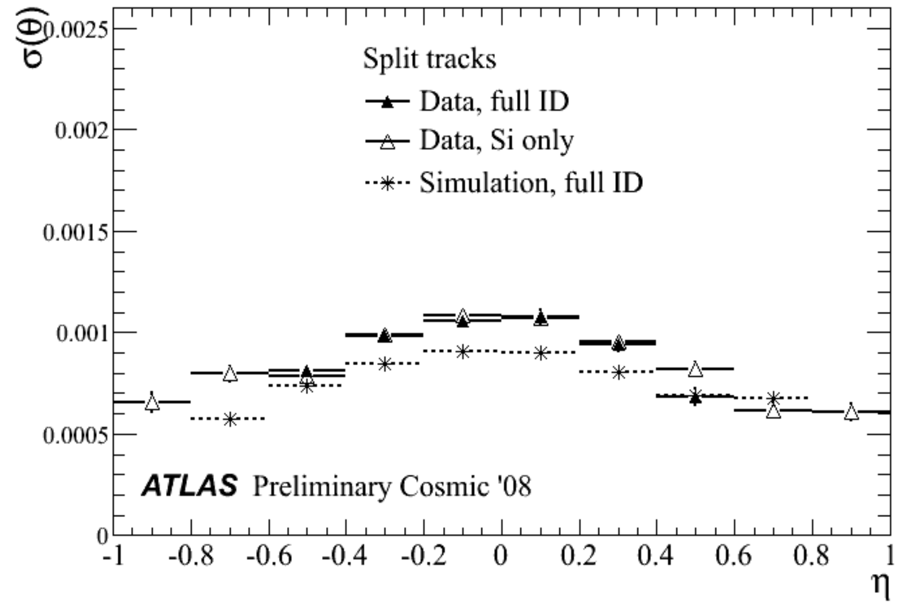
Hit maps of SCT barrel & end-caps





Angular resolutions





- Azimuthal angle resolution versus p_T and polar angle resolution versus η
- Azimuthal angle resolution dominated by multiple scattering at low p_T
- Polar angle resolution improves at larger η due to broader clusters that allow a more precise hit position measurement
- No contribution from TRT due to two dimensional measurement
- Behaviour as expected