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ATLAS Silicon Microstrip Tracker Operation and Performance

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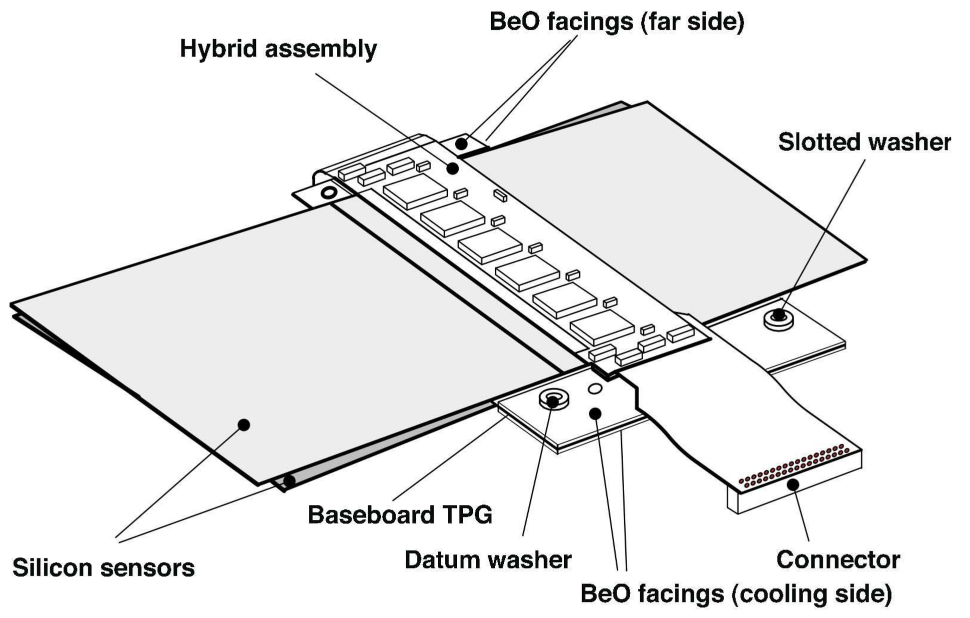
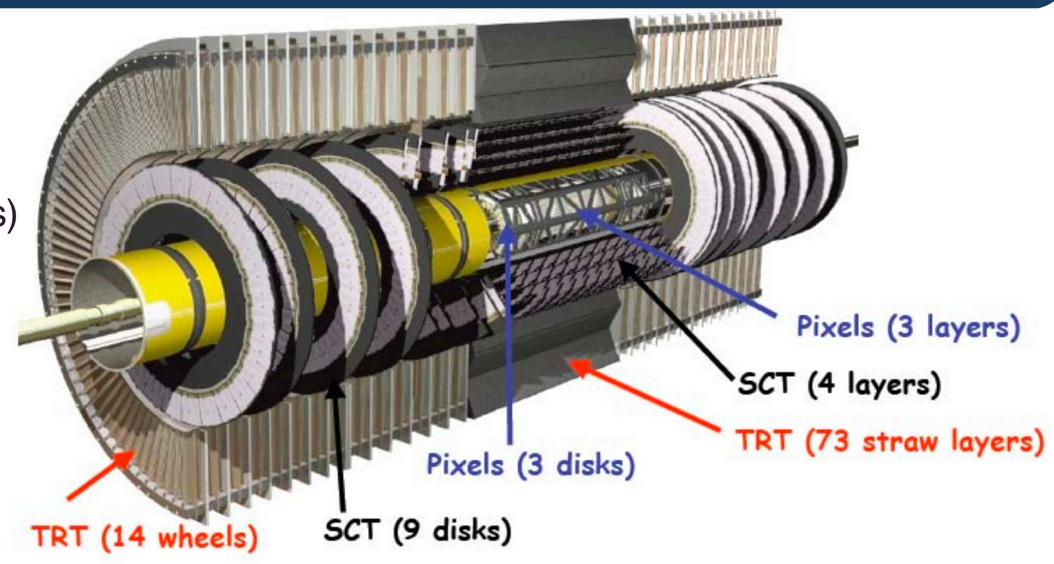
On behalf of the ***ATLAS*** Collaboration

The Silicon Microstrip Tracker

- **The Atlas Silicon Microstrip Tracker** (SCT) consists of [1]:
  - 61 m² of silicon with 6.2 million readout channels
  - 4088 silicon modules
    - 4 Barrel layers and 18 Disks (9 in each of the two Endcaps)
      - Barrel: 2112 modules (1 type) with coverage $|\eta| < 1.1$
      - Endcaps: 1976 modules (4 types) with coverage $|\eta| < 2.5$





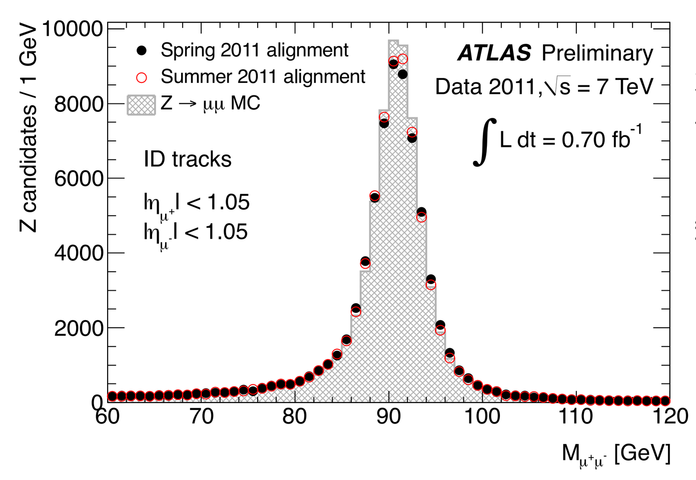
- Two pairs of identical single-sided p-on-n silicon micro-strips sensors (80 µm strip-pitch) which are glued back-to-back.
- Stereo angle of 40 mrad between sides
  - 3D space point information
- Space point resolution $r_\varphi \sim 16$ µm / $r_Z \sim 580$ µm

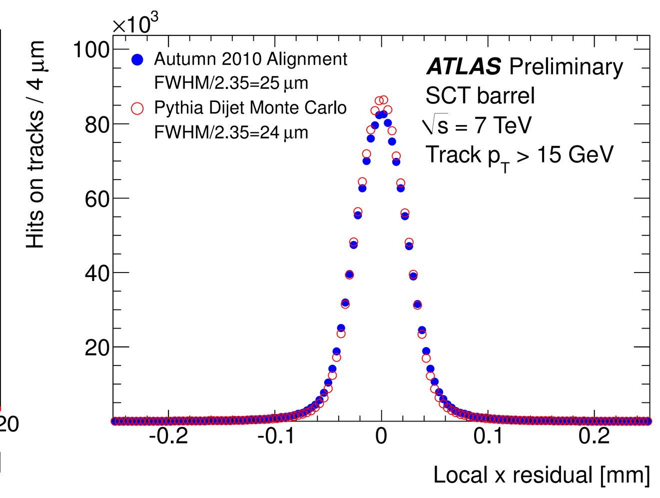
Operations

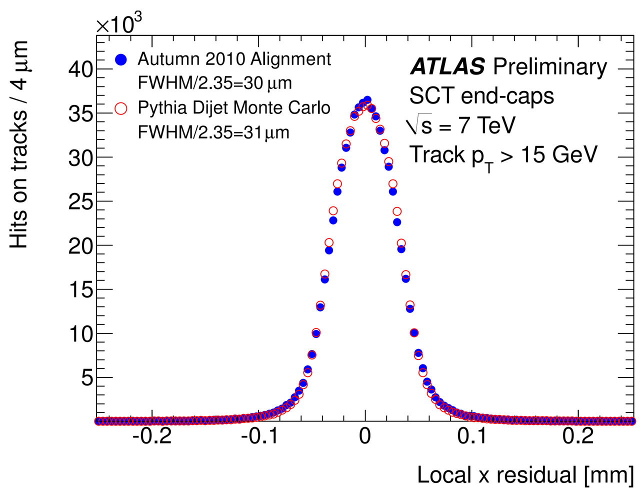
- **During the past three years** data taking the SCT achieved a high operating efficiency with 99 % of operational strips.
- **The SCT Data Acquisition System** also achieved a high performance. Sources of inefficiencies were studied and reduced to the minimum among which the main ones were module desynchronization and data corruption due to single-event upset in the chips.
  - **Error Rate** was monitored online and typically it was found to be ~0.2 % of the total number of readout links. An error rate reduction was achieved by:
    - Single module automatic reconfiguration
    - Global reconfiguration every 30 minutes of data taking
  - **SCT ROD busy** can inhibit all data taking, hence an automatic recovery system was put in place:
    - A busy ROD is automatically excluded from the run and then re-introduced back into data taking after all modules have been reconfigured reducing the impact on data quality.

Monitoring and Performance

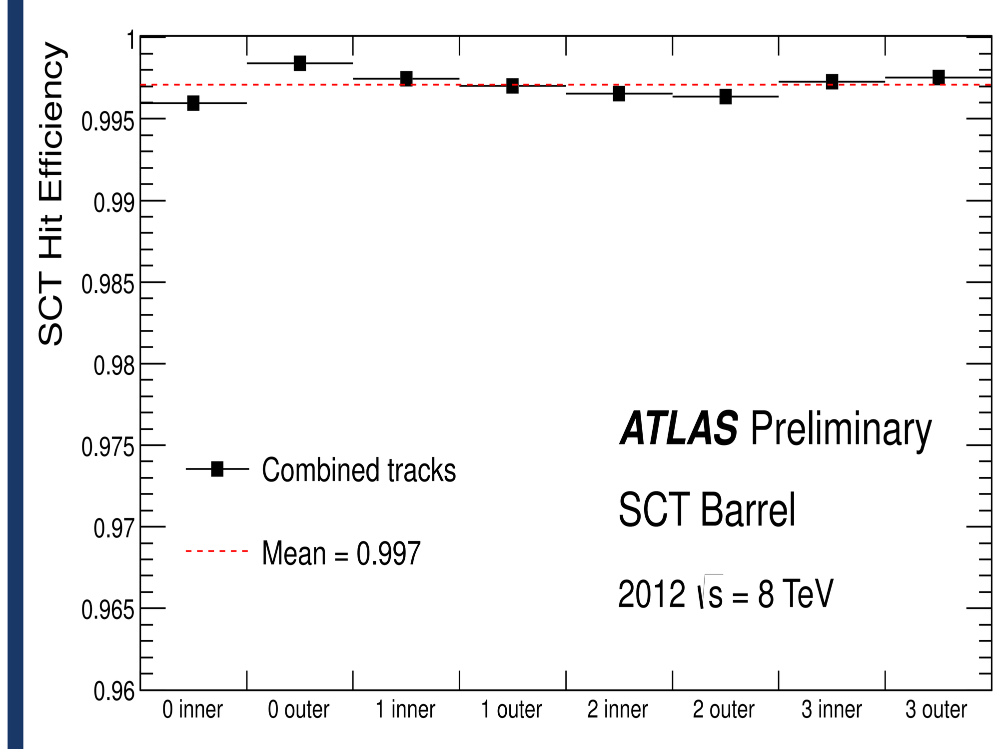
- **Data Quality** needs to be ensured during operations. The SCT has its own monitoring tool developed as an analysis software algorithm that it can be run both online and offline.
  - Online: by running the full track reconstruction it ensures tracking and DAQ quality fall within the accepted range. It also allows for rapid investigation of problems during data taking.
  - Offline: the monitoring tools ensure that, after every run, only the portion of data that satisfy strict quality criteria are selected (99.6 % in 2011 and 99.3 % in 2012)

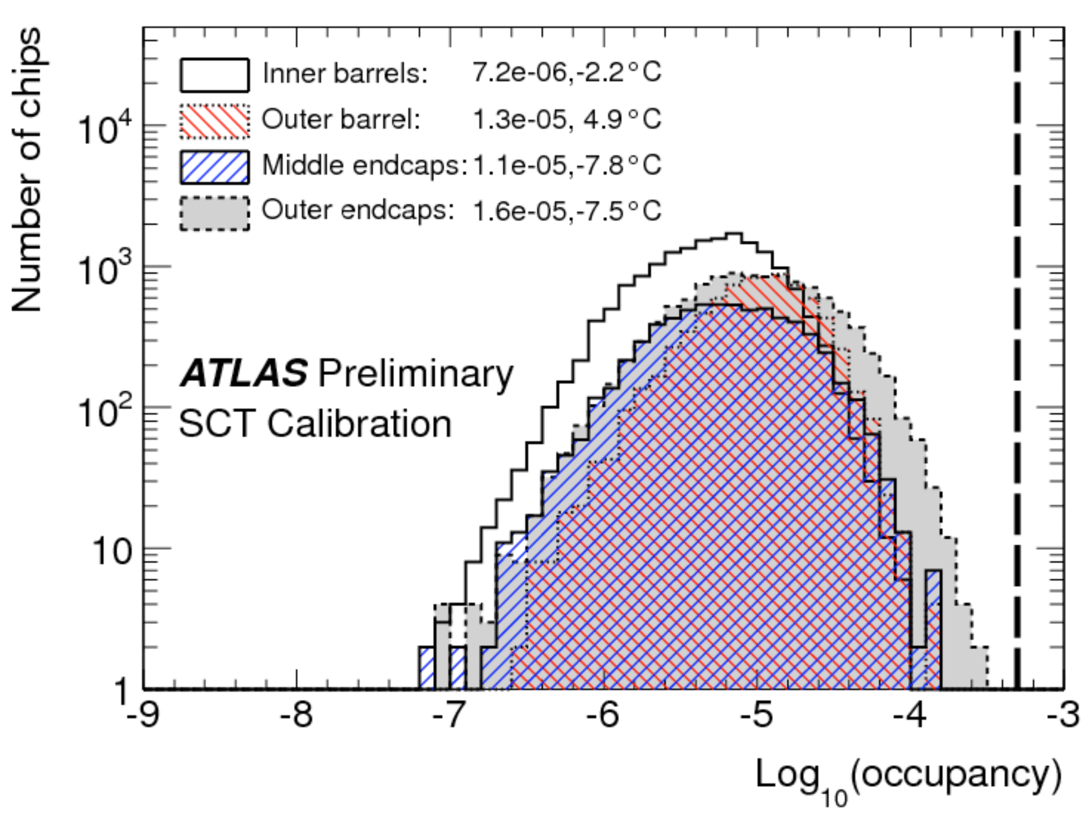






- **Alignment** is performed with cosmic and collision data by minimizing the χ² of track hit residuals.
  - For collision data, tracks with $p_T > 15$ GeV are selected from a jet trigger to minimize multiple scattering effects.
  - From the comparison of hit residuals and reconstructed track parameters (transverse momentum, impact parameters) between data and a perfectly aligned MC simulation, misalignment effects can be assessed. Excellent agreement was found in the residual distributions for both Barrel and Endcap [5]. The resolution in the $Z \rightarrow \mu\mu$ invariant mass distribution, from tracks reconstructed with the full Inner Detector, is very close to the expectation from MC [6].





- **The Efficiency** is constantly monitored. The intrinsic hit efficiency, ε, defined as the ratio of the number of hits on any given track, with transverse momentum higher than 1 GeV, over the sum of holes and hits [4]:

$$\varepsilon = \frac{N_{\rm hits}}{N_{\rm hits}+N_{\rm holes}}$$

A hole on track is defined as track point where a hit is expected but not actually recorded. As expected a small decrease in the hit efficiency was observed in 2012 with respect to early data taking. The higher track multiplicity increases the probability of tracks sharing hits, reducing artificially the efficiency. It is shown that the SCT hit efficiency, for all barrel layers (and sides), is above 99.7 % for combined tracking (requiring at least 7 silicon hits)[2].

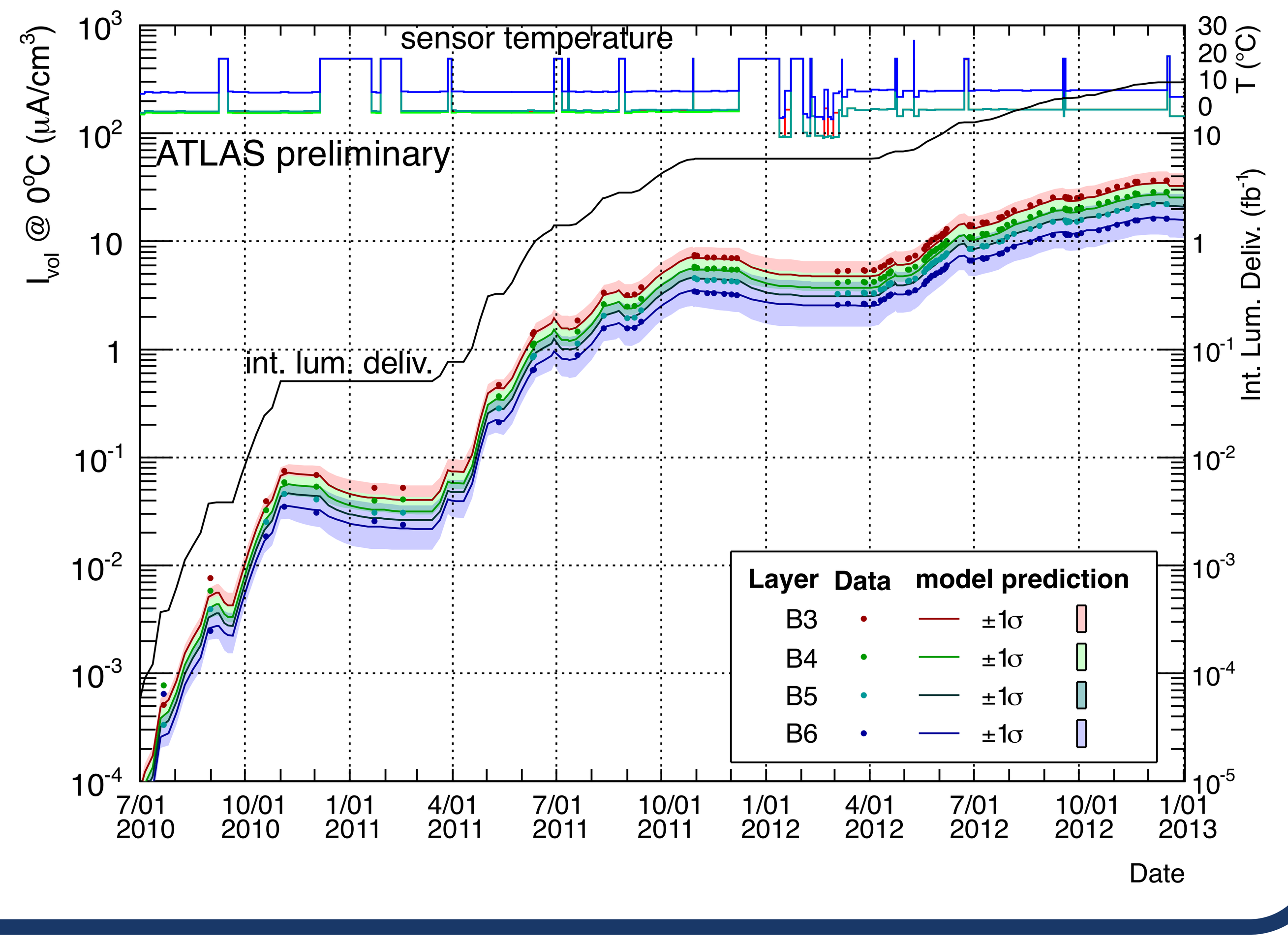
- **Noise occupancy** is defined as the probability to record a hit only due to noise. It is measured both online and offline by the monitoring tool in empty bunches. The dashed line shows the design specification (5×10^{-4}) and no entries are found beyond that threshold [3].

Radiation Damage

- **Irradiation** of silicon sensors results in damage in the bulk silicon and the dielectric layers with main effects:
  - increase in the leakage current of the sensor
  - a change in the effective doping concentration
    - trapping affecting the collected charge
- **The Increase in the Leakage Current**, as expected, was observed to be correlated with the increase in luminosity. It was compared with FLUKA according to the Hamburg/Dortmund model [6]. The variation of leakage current per volume unit has a linear dependance on the fluence ϕ: $I = \alpha\phi$ where α is the actual damage constant. The temperature normalization was chosen to be for all L.H.C. experiments $T_{REF} = 0 \quad ^\circ C$

$$\frac{I_{REF}}{I_{Meas}} = \left(\frac{T_{REF}}{T_{Meas}}\right)^2 \exp\left[-\frac{E_{gen}}{2k_B}\left(\frac{1}{T_{REF}} - \frac{1}{T_{Meas}}\right)\right] \qquad E_{gen} = 1.21 \quad \text{eV}$$

- **Leakage current** of the SCT module has been monitored using HV current in Detector Control System database.
- **Excellent agreement** was found between data and model for the barrel.



References

[1] The ATLAS Experiment at the CERN Large Hadron Collider, 2008 *JINST 3 S08003*
[2] SCT Collision Data Public Plots https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SCTPublicResults
[3] SCT Approved Plots https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ApprovedPlotsSCT
[4] The ATLAS Inner Detector commissioning and calibration *Eur.Phys.J.C70:787-821,2010*
[6] Atlas Collaboration ATLAS-CONF-2011-012 https://cdsweb.cern.ch/record/1334582
[5] Inner Detector Alignment Approved Plots https://twiki.cern.ch/twiki/bin/view/AtlasPublic/InDetTrackingPerformanceApprovedPlots
[6] A. Ferrari, P. R. Sala, A. D. Fasso, J. Ranft, *CERN-2005-010*