

The ATLAS Inner Detector operation, data quality and tracking performance.

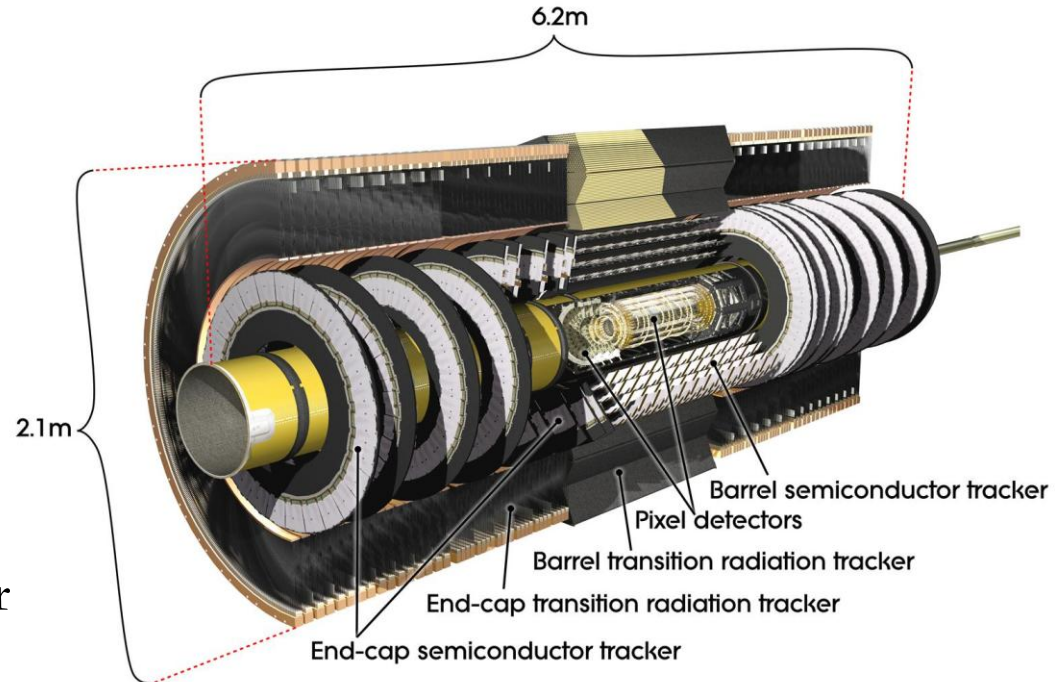
Ewa Stanecka on behalf of ATLAS ID
collaboration

INP PAS Cracow



The ATLAS Inner Detector

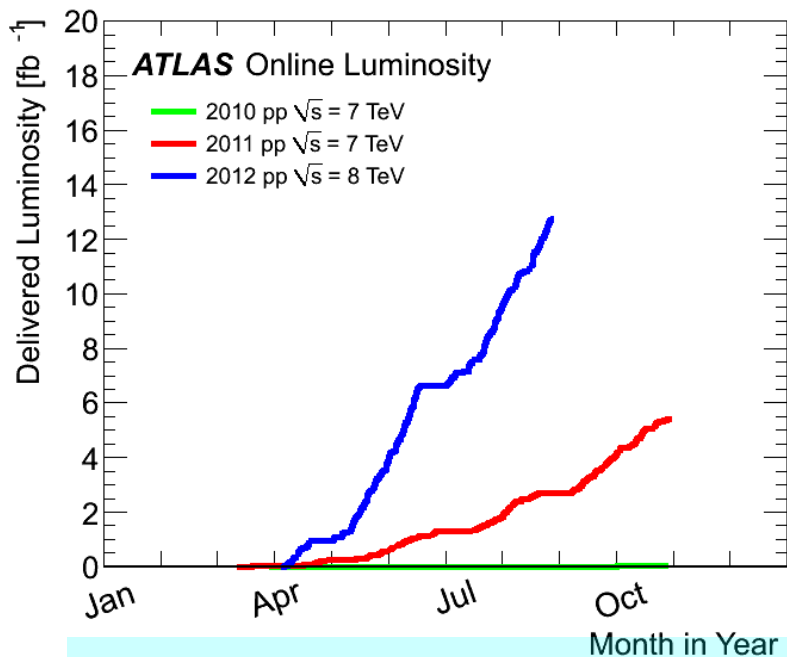
- Precision tracking at LHC luminosity over 5 units in η
- Precise primary/secondary vertex reconstruction
- Excellent b-tagging in jets
- Electron, muon, tau, b- and c-hadron reconstruction
- Transition radiation in the TRT for electron identification
- covers : $|\eta| < 2.5$ (2.0 for TRT)



The ID is composed of three Sub-detectors, of different technologies:

- **Transition Radiation Tracker (TRT)**
- **Semi-Conductor Tracker (SCT)**
- **Pixel detector:**

Data Taking and Data Quality



| ATLAS p-p run: April-June 2012 | | | | | | | | | | |
|---|------|-----|--------------|------|-------------------|------|-----|-----|----------|-----|
| Inner Tracker | | | Calorimeters | | Muon Spectrometer | | | | Magnet | |
| Pixel | SCT | TRT | LAr | Tile | MDT | RPC | CSC | TGC | Solenoid | ... |
| 100 | 99.6 | 100 | 96.2 | 99.1 | 100 | 99.6 | 100 | 100 | 99.4 | ... |
| All good for physics: 93.6% | | | | | | | | | | |
| Luminosity weighted relative detector uptime and good quality data delivery during 2012 stable beams in pp collisions at $\sqrt{s}=8$ TeV between April 4 th and June 18 th (in %) – corresponding to 6.3 fb ⁻¹ of recorded data. The inefficiencies in the calorimeter will partially be recovered in the future. | | | | | | | | | | |

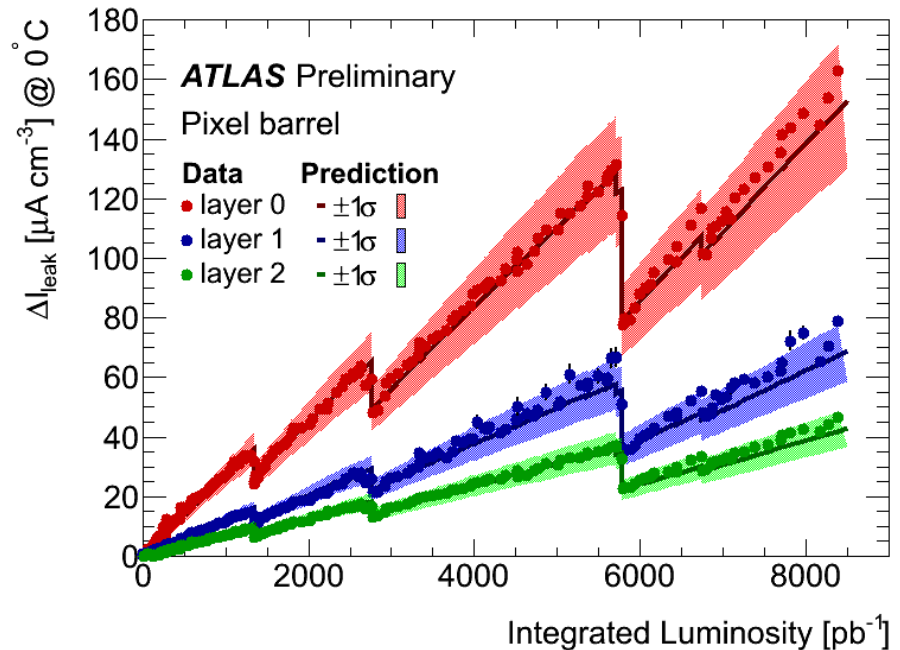
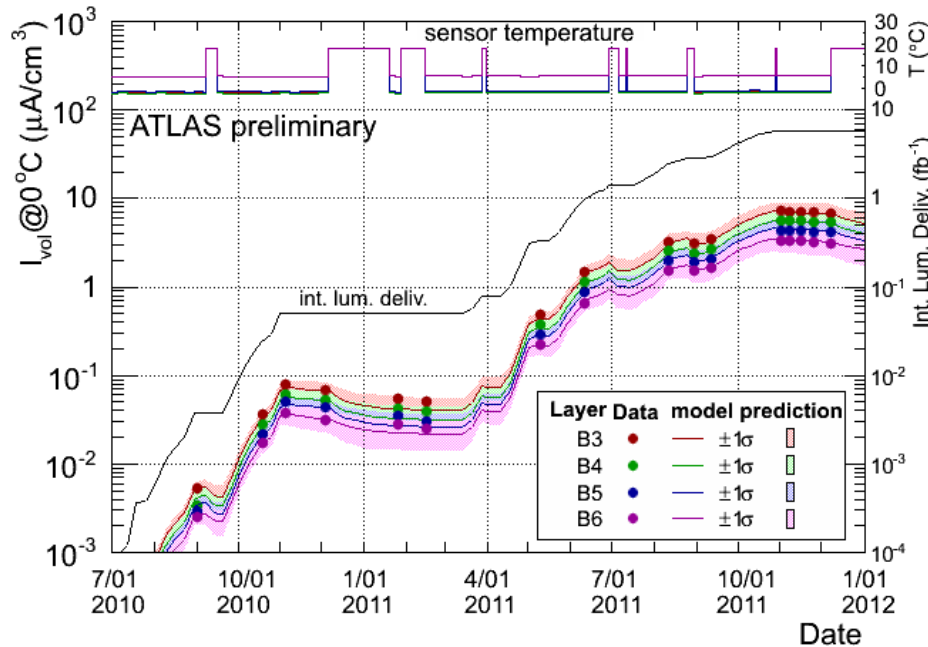
Excellent data taking performance, for all ID detectors during 2010, 2011 and 2012. Close to 100% availability.

Detector Operation

Continuous work in the **Detector Control System (DCS)** and **Data Acquisition (DAQ)** in order to maximize data taking efficiency.

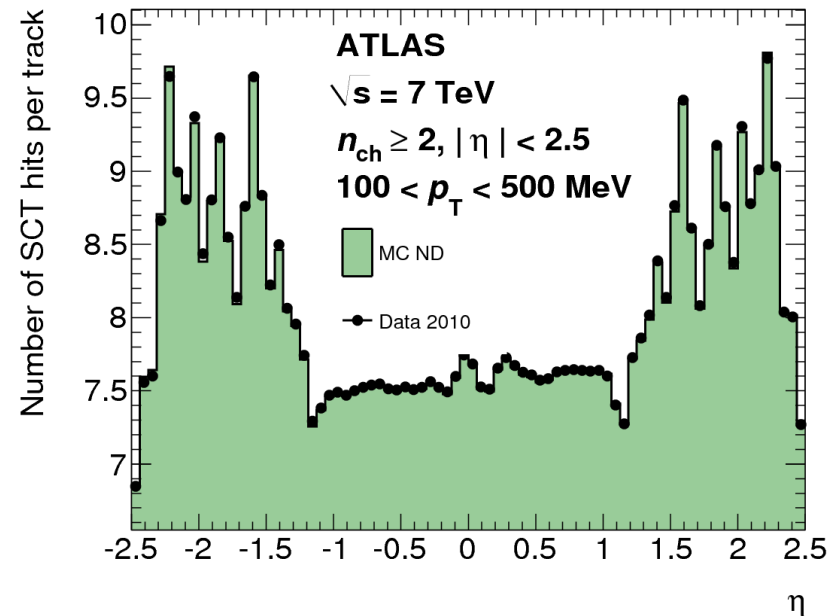
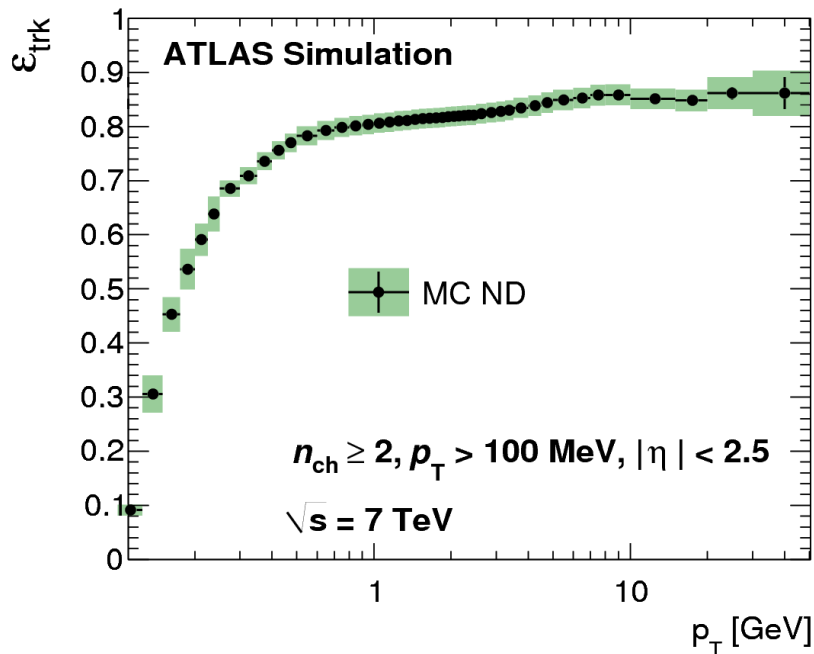
Radiation Damage

- Radiation damage effects in SCT and Pixel became visible in 2011 and they are increasing with luminosity and time.
- Monitoring of radiation damage via the increase of sensor leakage current



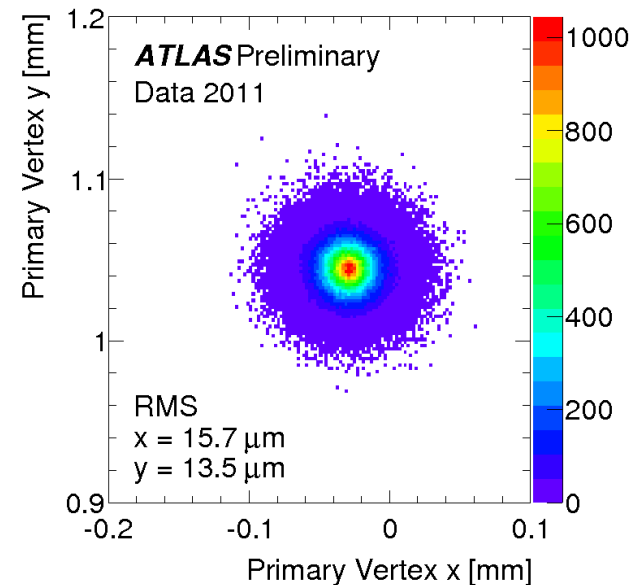
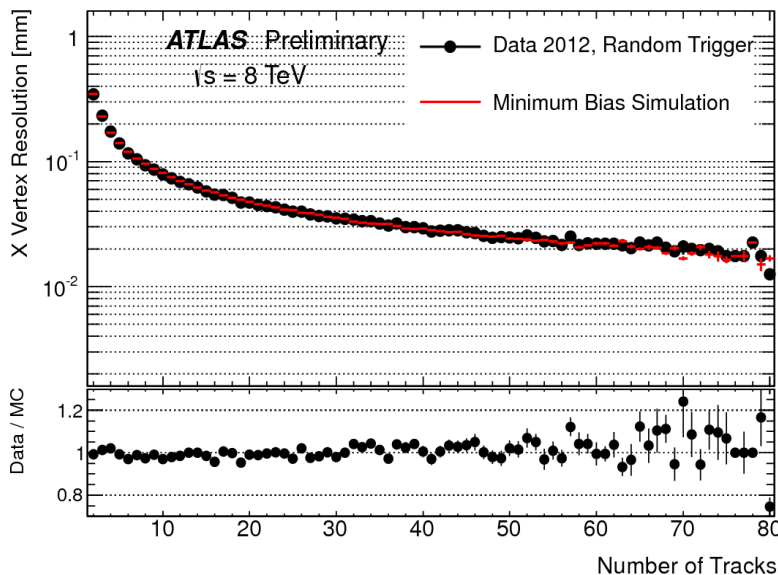
Track and Vertex Reconstruction Performance I

- Multi-stage track identification algorithms:
 - **inside-out** algorithm, reconstructs most primary tracks.
 - **outside-in**, reconstructs secondary tracks eg. conversions, hadronic interactions, V^0 decays



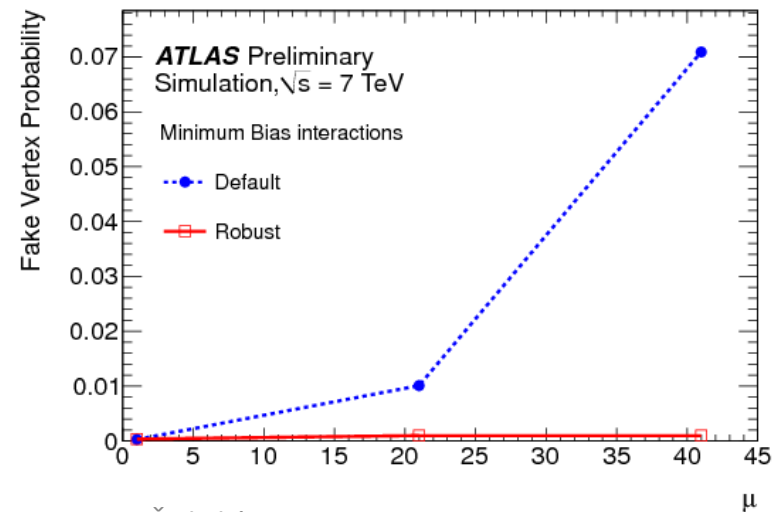
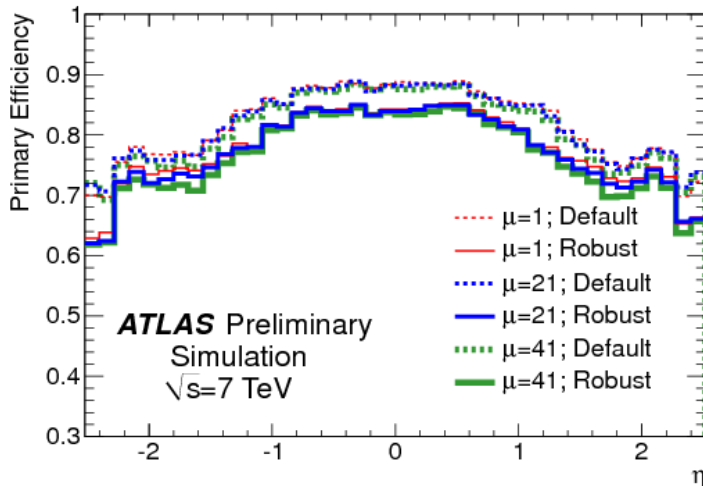
Track and Vertex Reconstruction Performance II

- Current vertexing algorithm: iterative vertex finder, adaptive vertex fitter
- Routinely determine the beam spot from average vertex position over a short time period.
- The beam spot position is used as a three-dimensional constraint.
- Vertex resolution determined from data using split vertex technique



High Pile-up

- The luminosity delivered by LHC is currently the biggest challenge for ID track and vertex reconstruction
- The increased detector occupancy can result in degraded track parameter resolution due to incorrect hit assignment, decreased efficiency and fake tracks from random hit combinations.
- This in turn impacts vertex reconstruction, resulting in a lower efficiency and an increased fake rate.
- **In order to minimise pile-up impact “robust track selection” was defined**
 - Moderate drop in primary track reconstruction efficiency for significant reduction in fake track fraction
 - Negligible fake primary vertex probability

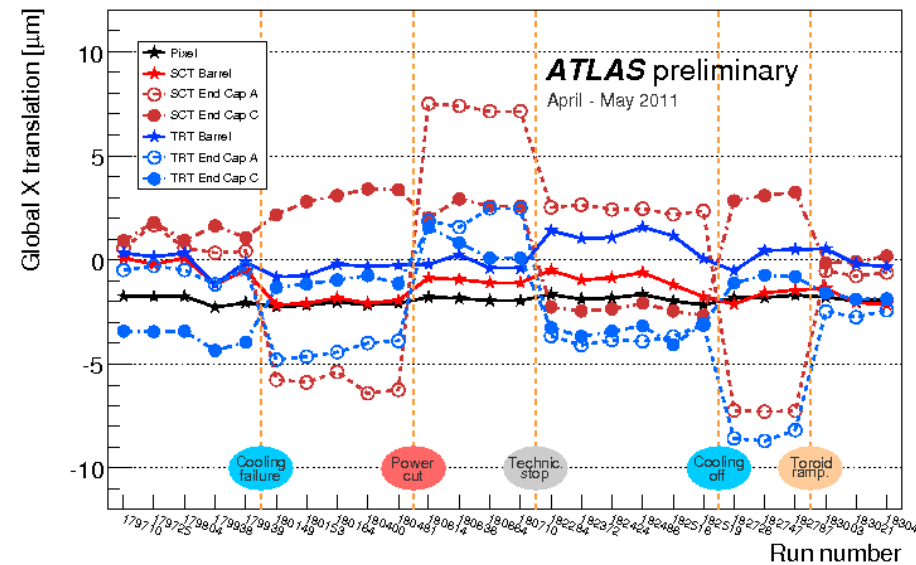


Alignment

Precise detector alignment is required to obtain ultimate track parameter resolution

- Align at different levels of granularity
 - Level 1 (entire sub-detector barrel & end-caps)
 - Level 2 (silicon barrels and discs, TRT barrel modules and wheels)
 - Level 3 (silicon modules, TRT straws $\sim 700,000$ DoF's)
- 2011 data studies show limited movements of Level 1 structures which usually can be correlated to sudden change in detector conditions.
- Advanced alignment using Z resonance and E/p for electrons removes residual biases on momentum reconstruction.

Level 1 alignment





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Summary

- excellent data taking efficiency
- enhancements in DAQ and DCS in order to maximize data taking efficiency
- SCT and Pixel radiation damage agrees with theoretical predictions
- excellent tracking and vertexing performance
- track and vertex reconstruction is robust even in data containing significant pile-up
- the Inner Detector alignment is integrated in ATLAS computing model and uses a combination of advanced techniques in order to achieve the best hit and momentum resolution.

The ATLAS Inner Detector

The ID is composed of four sub-detectors, of different technologies:

- Transition Radiation Tracker (TRT)**
 - Composed of a barrel and end-cap parts
 - 160 MW - beam diameter Kapton streamer tubes with Xe/C₂F₄/CO₂ gas
 - good single proton resolution - 150 μm in 3σ
 - tracking resolution > 30 μm per track
 - high tolerance against radiation doses
- Small Scintillating Tracker (SCT)**
 - 4 barrel layers, 2 end-cap end-caps
 - 40M readout, 5.3M channels (30 Mch)
 - Constant T = 17 μm / 180 μm (3σ)
 - Operational T = 17C - 17C
 - CERN Superconducting Cooling, in resonance with Pixel detector
- Pixel detector**
 - 3 barrel layers, 2 end-cap end-caps
 - 17M readout, 80M channels
 - Constant T = 15 μm / 118 μm (3σ)
 - Cooled in average T = 17C
 - CERN Superconducting Cooling, reliable (having power loss)

Increased in a radial field of 2 Tesla the Inner Detector provides:

- Precision tracking at LHC luminosity over 5 years on p
- Precise primary/secondary vertex reconstruction
- Excellent tracking in pile-up
- Electron, muon, tau, b, and c-baryon reconstruction
- Excellent resolution for the TRT detector

Identification:

- Access < 1.5 ns (2.5 ns for TRT)

Data Taking and Availability

The LHC achieved an integrated luminosity of 6.6 pb⁻¹ in 2011. In 2012 the center-of-mass energy was increased to 8 TeV, and the LHC luminosity was further improved.

ATLAS Data Taking Efficiency

| Year | Efficiency (%) |
|------|----------------|
| 2011 | ~95 |
| 2012 | ~95 |

ATLAS p-p 8 TeV April-June 2012

| Detector | Availability (%) |
|----------|------------------|
| TRT | ~95 |
| SCT | ~95 |
| Pixel | ~95 |

The ATLAS detector is available for data taking for more than 95% of the time during the LHC operation.

Detector Operation

The SCT Data Acquisition (DAQ) infrastructure is a major data taking efficiency:

- "Pipelined" readout architecture of SCT Data Acquisition (DAQ)
- online monitoring of detector status and automatic reconfiguration of modules which shows errors
- Auto reconfiguration of the inner-SCT every 30 minutes as a protection against Single Event Upsets - spontaneous corruption of module reconfiguration

The Detector Control System (DCS) supervises the detector components, provides information about conditions inside the detector, ensures optimal working conditions and provides protection mechanisms. The main DCS subsystems are:

- Superconducting Cooling: to keep silicon detector cooled (-273C)
- Cryo-Pad systems that ensure thermal shield between silicon detector and TRT operating in warm environment. Radiation Monitoring: radiation dose rate inside SCT volume
- In-Pixel and SCT DCS: the automatic status monitoring system that reports the status of the detector to the ATLAS DAQ system

Typical time in ready for data taking is < 1 minute.

Radiation Damage

Radiation damage in the SCT and Pixel detector is a major concern. The radiation damage is monitored and the detector is reconfigured accordingly.

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Track and Vertex Reconstruction

Tracks are reconstructed offline within the full acceptance range:

- $\eta < 2.4$ of the Inner Detector
- Minimum track reconstruction algorithm:
- Inside-out algorithm scans from Pixel ends and adds hits moving away from the interaction point. The track parameters found in the silicon detector are then extrapolated to include measurements in the TRT. Measurements from primary tracks are used to seed secondary tracks.
- Kalman filter algorithm starts from origin and propagates through the TRT and records them directly by adding hits. Measurements from tracks are used to seed secondary tracks.

The tracking efficiency decreases as track length increases. The tracking efficiency is high for short tracks and decreases for long tracks.

Tracking in High Pile-up

The primary track reconstruction efficiency is a major challenge in high pile-up. The ATLAS detector is designed to handle high pile-up.

The primary track reconstruction efficiency is high even in high pile-up conditions. The ATLAS detector is designed to handle high pile-up.

ID alignment

Pixel detector alignment is based on silicon detector track parameter resolution:

- Align at different levels of precision:
- Level 1: detector sub-detectors (barrel & end-caps)
- Level 2: silicon barrel and disk, TRT barrel modules and wheels
- Level 3: silicon modules, TRT streamer tubes (not at TRT)
- Level 4: alignment performed automatically for each run at TRT
- At the module level the detector is stable to better than 1 μm.
- SCT data within three limited acceptance of Level 1 modules which naturally can be recombined to enable change in detector conditions
- Advanced alignment using T-moment and R_z by the detector streamer residual leaves no systematic misalignment.

Bibliography

ATLAS Collaboration, "The ATLAS Inner Detector Alignment Performance in 2011," ATLAS-CONF-2012-012, CERN, 2012.

Please find more details on the poster