**THE ID IN A N G L E T R A C K S Y S T E M**

The ID (Inner Detector) is the innermost system tracker of ATLAS (A Toroidal LHC Apparatus). It is designed to provide hermetic and robust pattern recognition, excellent momentum resolution and both primary and secondary vertex reconstruction for charged tracks. The ID is made of three sub-detectors: Pixel, SCT (Semi-Conductor Tracker) and TRT (Transition Radiation Tracker).

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<th>Pixel Detector</th>
<th>SCT Detector</th>
<th>TRT Detector</th>
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<tr>
<td>Pixel</td>
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**Measurement**
- Discrete space point
- Stacked pairs of silicon micro-strips
- Average of 30 hits per track

**Detector Size**
- Pixel detector: 15x15 µm²
- Micro-strip pitch: 80 µm
- All modules equal: 6 different types
- Length: 144 cm barrel, 37 cm EC
- Resolution: 14x115 µm²

**Layout**
- Pixel: 3 layers (barrel)
- SCT: 2x6 disc (end-cap)
- TRT: 2x10 disc planes

**Requirements**
- No dependence with respect to the track parameters
- The weak modes with respect to the track parameters are found with a precision of ~5 µm.

**GlobalCh2**
- Based on the $\chi^2$ minimization
- Use biased residuals
- Inter module correlation and Multiple Coulomb scattering is taken into account
- The weak modes are left unchanged and are measured simultaneously each arm survey and more standards tools.

**SIDE CHALLENGES**

- The alignment algorithms work with a track $\chi^2$ sensitive to misalignments. The $\chi^2$ is built from the track residuals.
- It is an implicit function of the alignment parameters and it has a minimum in the aligned geometry.

**RESIDUALS**
- $r = \text{hit}_\text{measured} - \text{hit}_\text{theory}$
- Distance between the hit measured and hit extrapolated

**X² DEFINITION**

$\chi^2 = \sum (n_i - \text{hit}_\text{theory})^2$

Where $n_i$ are the residuals that depend on track parameters ($n$) and alignment parameters ($a$).

**X² MINIMIZATION**

$\frac{\partial \chi^2}{\partial a} = 0$

The algorithms use the $\chi^2$ minimization with respect alignment parameters to find the real geometry.

**SILICON ALIGNMENT LEVELS**

**LEVEL 1 structures (24 DoFs):**
- Whole pixel detector
- SCT barrel
- SCT end-cap A and B

**LEVEL 2 structures (186 DoFs):**
- Layers in Pixel’s and SCT barrel
- Discs in Pixel’s and SCT end-cap

**LEVEL 3 structures (34992 DoFs):**
- Module level in Pixel’s and SCT detector

**ID ALIGNMENT PROCEDURE**

The full alignment chain runs in parallel on the CAF (CERN Analysis Facility) using 100 CPUs. All the steps have been automated using python scripts.

**SURVEY INFORMATION**

Several surveys and measurement methods are used to determine the final installation position: optical survey, robotic arm survey and more standards tools. It’s a difficult task due to the large quantity of ID services and limited space between sub-detectors.

**WEAK MODES**

The Weak Modes are deformations that leave the track $\chi^2$ almost unchanged.
- Cosmic rays and beam halo
- Vertex and beam spot constraint
- External surveys
- Use FSI information

**Alignment Problem and Requirements**

The detector misalignments affect the track parameters resolution. Resolution strategy to solve the alignment problem has different steps:
- Assembly and survey measurements: External measurements of the as-built detector
- Frequency scanning interferometry: SCT is equipped with a laser alignment monitoring system
- Track based alignment algorithms: To achieve the ultimate precision (µm)

** REQUIREMENTS**
- The knowledge of the alignment constants should not lead to a significant degradation of the track parameters beyond the intrinsic tracker resolution to achieve the ATLAS physics goals. (Degradation of tracking resolution less than 20%).

**Alignment Algorithms**

- Track based alignment algorithms
- Cosmical data based alignment algorithms
- Measurement and alignment algorithms
- Pixel’s Bowing
- SCT’s Bowing
- Pixel’s and SCT’s Bowing

**Alignment of the ATLAS Inner Detector Tracking System**

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