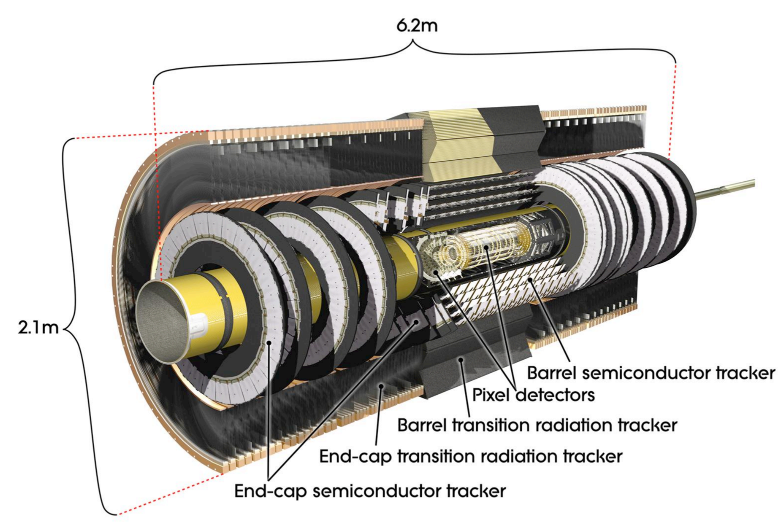
Alignment of the ATLAS Inner Detector Tracking System

V. Lacuesta-Miquel*, R. Moles-Valls
* Insíuto de Física Corpuscular, IFIC (CSIC-UVEG) – Vicente.Lacuesta@ific.uv.es
SUSSP65

The ATLAS Inner Detector

The **ID** (*Inner Detector*) is the inner most 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 composed by three sub-detectors: **Pixel**, **SCT** (*SemiConductor Tracker*) and **TRT** (*Transition Radiation Tracker*).

	Pixel Detector Pixel	SCT Detector SemiConductor Tracker	TRT Detector Transition Radiation Tracker
Measurement	Discrete space-point	Stereo pairs of silicon micro-strip	Average of 30 hits per track
Detector type	Pixel detector	Micro-strip silicon detectors	Gaseous straw tube elements
Detector Size	Pixel size: 50x400 μm^2 All modules equals	Micro-strip pitch: ~ 80 μm 6 different types	Diameter: 4 mm Length: 144 cm barrel, 37 cm EC
Resolution	14x115 μm^2 (*)	23μm (Rφ) , 580 μm (z)(*)	130 μm (*)
Modules	1744	4088	176
Layout	3 layers (barrel) 2x3 discs (end-cap)	4 layers (barrel) 2x9 discs (end-cap)	73 layers in 3 rings (barrel) 2x160 straw planes in 40 four-plane assembly units (end-cap)

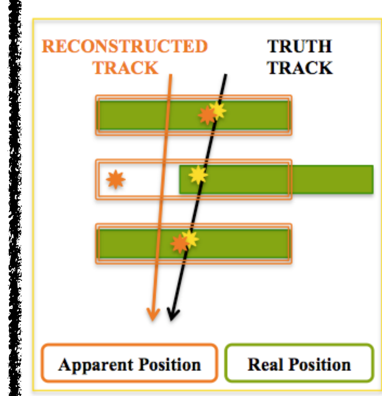


Inner Detector

(*) The ATLAS Experiment at the CERN Large hadron Collider, JINST3 S08003

Alignment Problem and Requirements

The detector misalignments affect the track parameters resolution.



The strategy to solve the alignment problem has different steps:

- **Assembly and survey measurements**: External measurements of the as-built detector.
- **Frequency Scanning Interferometry**: A laser alignment monitoring system of the SCT.
- **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%).

Required precision

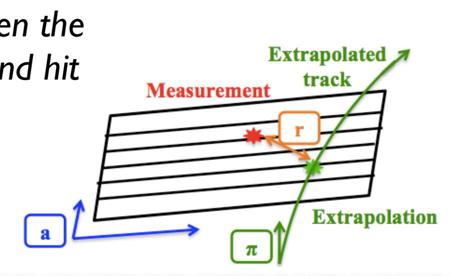
Direction	Pixel's Barrel	Pixel's End-Cap	SCT Barrel	SCT End-Cap
Rφ (μm)	7	7	12	12
Z (μm)	20	100	50	200

Track Based alignment algorithms

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

residuals : $r = hit_{measured} - hit(\pi,a)_{extrapolated}$

distance between the hit measured and hit extrapolated



χ^2 definition:

$$\chi^2 = \sum_{Tracks} r^T(\pi,a)V^{-1}r(\pi,a)$$

Where **r** are the residuals that depend on track parameters (π) and **alignment parameters (a)**.

χ^2 minimization:
The algorithms use the χ^2 minimization with respect alignment parameters to find the real geometry.

The ID has 6008 modules to align. Most of the modules have 6 DoFs. There are several alignment algorithms working in the ID detector:

SILICON SYSTEM

GlobalChi2:

- Based on the χ^2 minimization.
- Uses biased residuals.
- Inter module correlation and Multiple Coulomb Scattering is taken into account.
- Huge symmetric matrices are created (34992 DoFs)

LocalChi2:

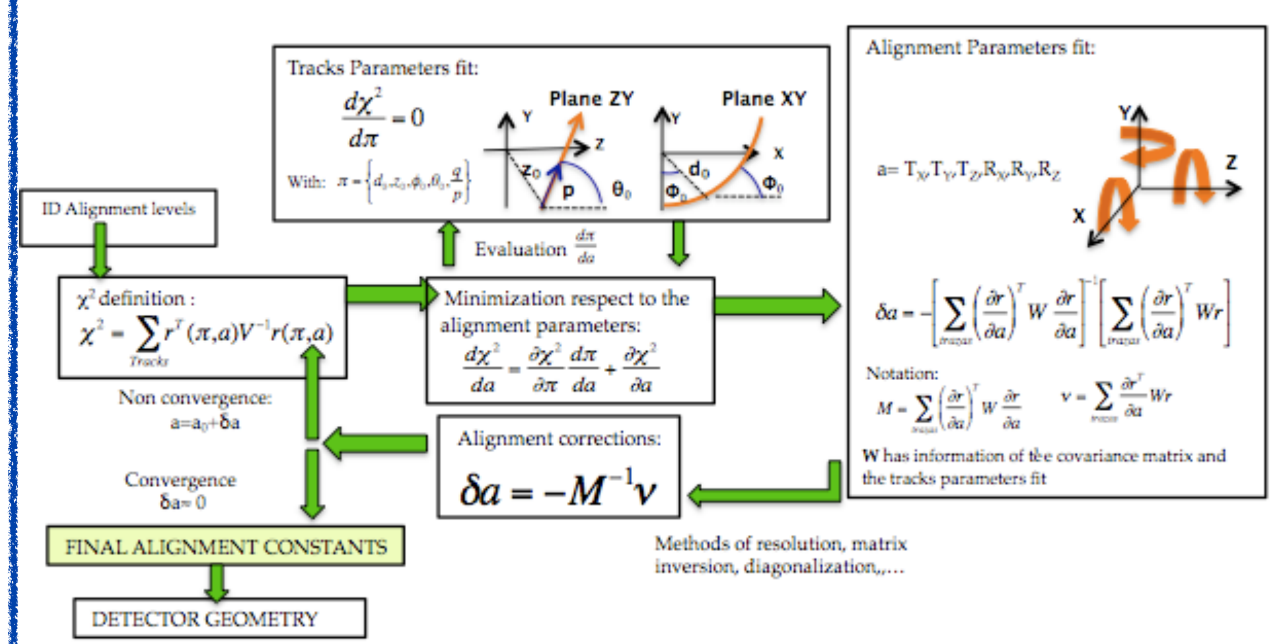
- Same principle as the GlobalChi2 algorithm.
- Unbiased residuals.
- No dependence with respect to the track parameters.
- No Multiple Coulomb Scattering.
- Needs to solve 6x6 matrices (6 DoFs per module).

Robust:

- Uses centre residuals and overlap distributions.
- Uses local x and y residuals.
- Overlap residuals for adjacent modules.
- 3 DoFs per module (plane parameters: Tx, Ty, Rz)

TRT SYSTEM

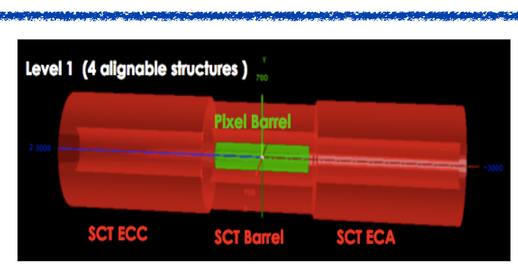
- Based on the the χ^2 minimization.
- Inter module correlation .
- TRT with respect to silicon system.



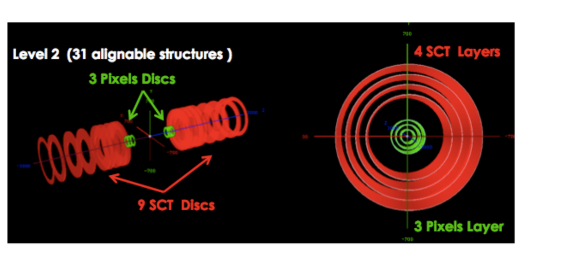
GLOBAL CHI2 ALIGNMENT ALGORITHM

Silicon alignment levels

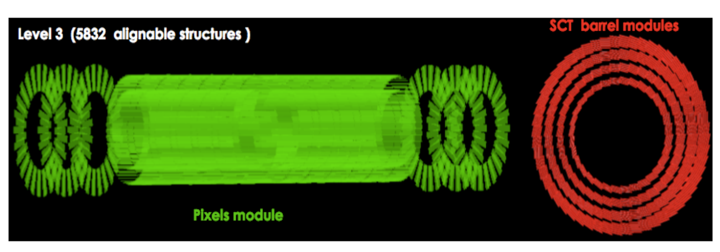
The ID alignment is done on several levels corresponding to different granularity of the detector.



LEVEL 1, 4 structures (24 DoFs):
Whole pixel detector
SCT barrel
SCT end-cap A and B



LEVEL 2, 31 structures (186 DoFs):
Layers in PIXEL's and SCT barrel
Discs in PIXEL's and SCT end-cap

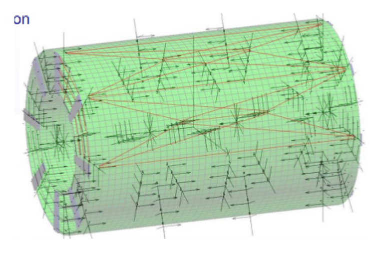


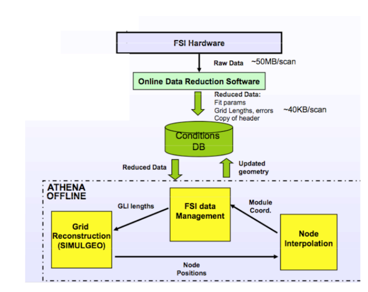
LEVEL 3: 5832 structures (36k DoFs):
Module level in PIXEL's and SCT detector

There are also intermediate levels that combine different substructures as ladders, rings or halfshells.

FSI (FREQUENCY SCANNING INTERFEROMETRY)

A laser alignment system (geodetic grid of length measurement between nodes) is installed in the SCT detector. The FSI provides knowledge about the stability of the detector with time (842 grid line length are measured simultaneously each 10 min). Using FSI, one can achieve a precision <1μm along 1D length (precision in 3D ~5μm). It can measure relative rotations (clocking of barrel) and radial deformation. Will be used intensively in the early runs.

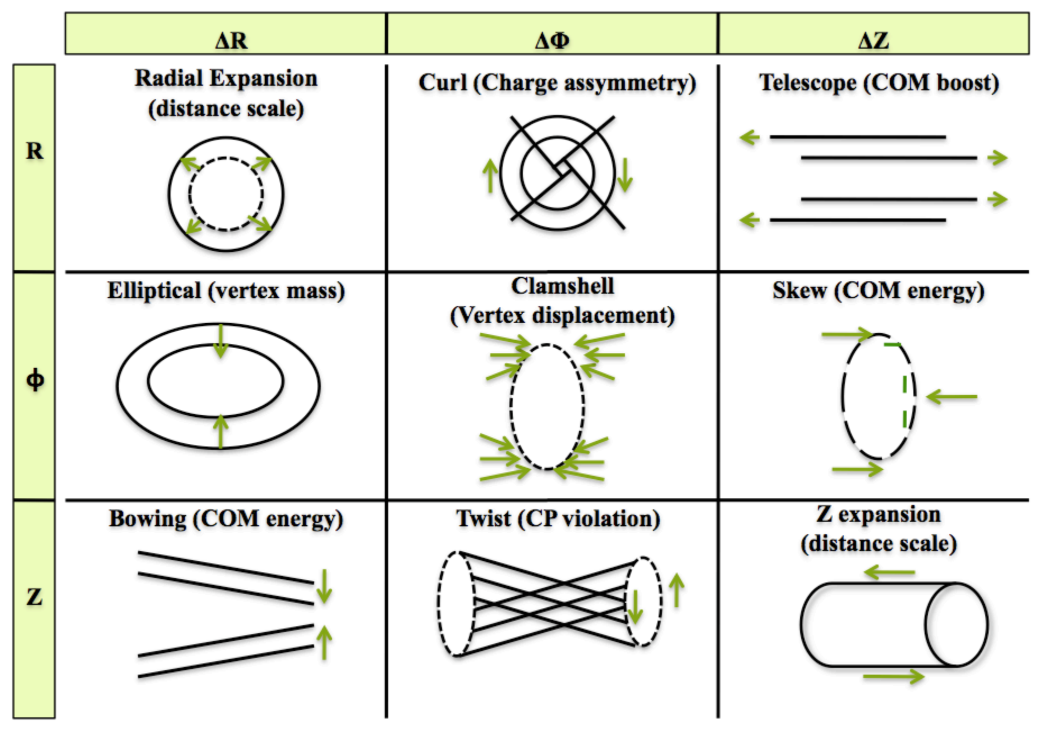

FSI picture system


FSI software chain

Weak modes

The Weak Modes are deformations that leave the track χ^2 almost unchanged.
There are some tools to determine these weak modes:

- Cosmic rays and beam halo.
- Vertex and beam spot constraint.
- External surveys.
- Use FSI Information.



Alignment with real data (M8+ Cosmics)

An alignment was performed using the cosmic rays data obtained in 2008.
The residuals distributions using each silicon algorithm are showed in the plots: