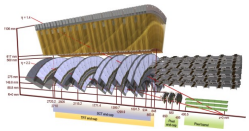
LHCC Poster Session - CERN, 23 March 2011

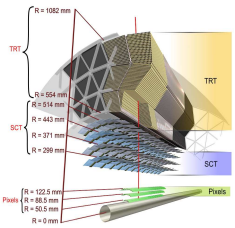
Alignment of the Inner Detector Tracking System

The Atlas Inner Detector

The Inner Detector (ID) is the main tracking system of ATLAS. The ID consists of 3 different subsystems:

- Pixels (3 hits/track)
- SCT (8 hits/track)
- TRT (30 hits/track)





Sensor dimensions and resolutions:

Subdetector	Element size	Resolution	Channels
Pixel (Silicon Pixels)	50 μm * 400 μm	10 μm * 115 μm	80 Millions
SCT (Silicon Strips)	80 μm * 12 cm (40 mrad stereo)	17 μm * 580 μm	6 Millions
TRT (Straw Tubes)	4 mm (diameter)	130 μm	0.4 Millions

Track Based Alignment Algorithm

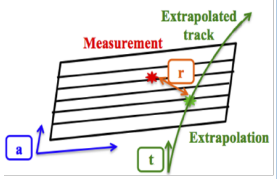
Track based alignment algorithms rely on a track-hit residual χ^2 minimization.

$$\chi^2 = \sum_{trk} [\mathbf{r}^T(\mathbf{t},\mathbf{a}) V^{-1} \mathbf{r}(\mathbf{t},\mathbf{a})]$$

$$\mathbf{t} = (d_0, z_0, \phi_0, \theta, q/p)$$

$$\mathbf{a} = (T_x, T_y, T_z, R_x, R_y, R_z)$$

$$V \equiv \text{Hit covariance matrix}$$



Minimization condition $\frac{d\chi^2}{d\mathbf{a}} = 0 \rightarrow \sum \left[\mathbf{r}^t V^{-1} \left(\frac{\partial \mathbf{r}}{\partial \mathbf{t}} \frac{d\mathbf{t}}{d\mathbf{a}} + \frac{\partial \mathbf{r}}{\partial \mathbf{a}} \right) \right] = 0$

Taylor expansion and keeping up the linear term:

$$\sum \left[\left(\frac{d\mathbf{r}}{d\mathbf{a}} \right)^T V^{-1} \left(\frac{d\mathbf{r}}{d\mathbf{a}} \right) \right] \delta\mathbf{a} + \sum \left(\frac{d\mathbf{r}}{d\mathbf{a}} \right)^T V^{-1} \mathbf{r} = 0$$

$N_{DoF} \times N_{DoF}$ matrix — N_{DoF} vector

Alignment Goals

The module nominal positions do not correspond with the "real" locations. The goal of the alignment is to determine the module positions in order to describe accurately the real detector geometry.

- Baseline goal: Module misalignments should not contribute more than 20% to the degradation of the track parameters with respect to the intrinsic resolution.
- Therefore alignment tolerances should be:

	Pixel		SCT		TRT
	Barrel	Endcap	Barrel	Endcap	All
rφ (μm)	7	7	12	12	30
z (μm)	20	100	50	200	-

- Higher accuracy is required for precision physics measurements.

Alignment Levels

The alignment is performed in a sequence of several levels of detector granularity following the assembly hierarchy:

- Level 1: Pixel as a whole, SCT barrel and end-caps, TRT barrel and end-caps, 6 degrees of freedom (DoFs) per structure.
- Level 2: Pixel barrel half-shells and disks, SCT barrel layers and end-cap disks, TRT barrel modules and end-cap wheels.
- Level 3: Silicon modules (6 DoFs) and TRT straws (2 DoFs).

	# Structures			# DoFs		Typical correction (μm)
	Pix	SCT	TRT	Silicon	TRT	
Level 1	1	3	3	24	17	1000
Level 2	12	22	96	204	960	100
Level 3	1744	4088	350848	34992	701696	10

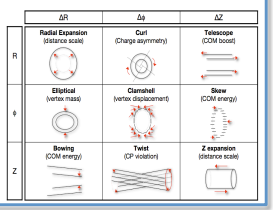
Weak modes

Systematic deformations of the detector geometry that leave the χ^2 of the tracks almost invariant:

• With weak mode distortions the helicoidal path of the track is preserved but the track parameters may suffer a bias.

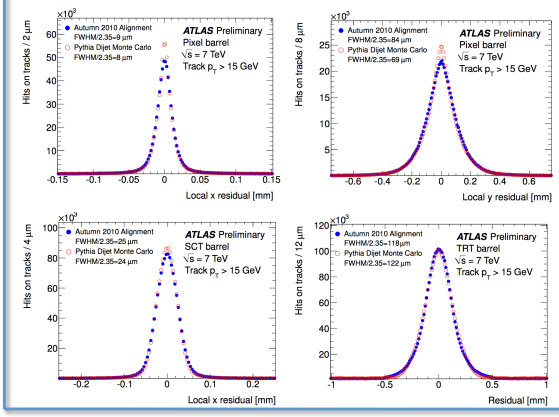
How can weak modes be detected and constrained?

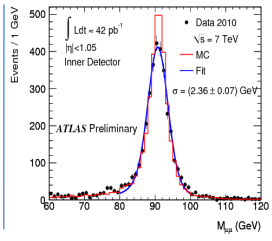
• Use external constraints:
  - On track parameters.
  - On the geometry (survey).
• Use of different samples of data:
  - Cosmic tracks.
  - Collision tracks.
• Look at the physical observables:
  - Resonance masses, …



Alignment Performance with 7 TeV data

Residual distributions of the 3 sub-detectors comparing real data with a Monte Carlo sample with perfect alignment.





Physics performance with $Z \rightarrow \mu^+\mu^-$

• Muon tracks tagged with the Muon Spectrometer.
• $M_{\mu\mu}$ computed from Inner Detector tracks only after they have been identified as muons.

The ATLAS Inner Detector tracking system has been aligned using the LHC √s = 7 TeV data taken during 2010. The input data consisted of two samples: one of high pT and isolated collision tracks, while the second is a sample of cosmic-ray tracks collected between LHC proton-proton collisions. This poster presents the alignment procedure, its results and performance with the LHC collision data. Results from real data are compared with a Monte Carlo sample simulated with a perfectly aligned detector.

The estimated residual misalignment of silicon modules is shown in the table (statistical errors only).

(μm)	Pix x	Pix y	SCT
Barrel	4	18	10
End-caps	7	35	11

Vicente Lacuesta, for the ATLAS Collaboration

ATLAS EXPERIMENT