Alignment of the ATLAS Inner Detector Tracking System

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On behalf of ATLAS Collaboration

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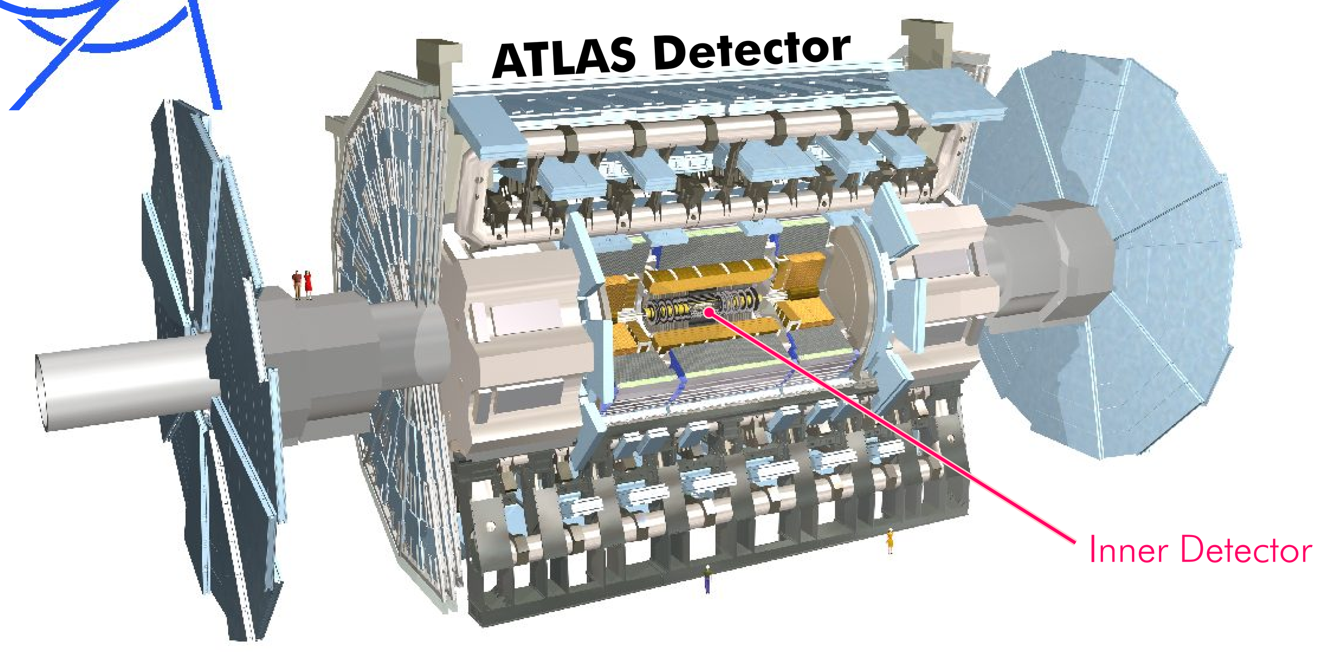
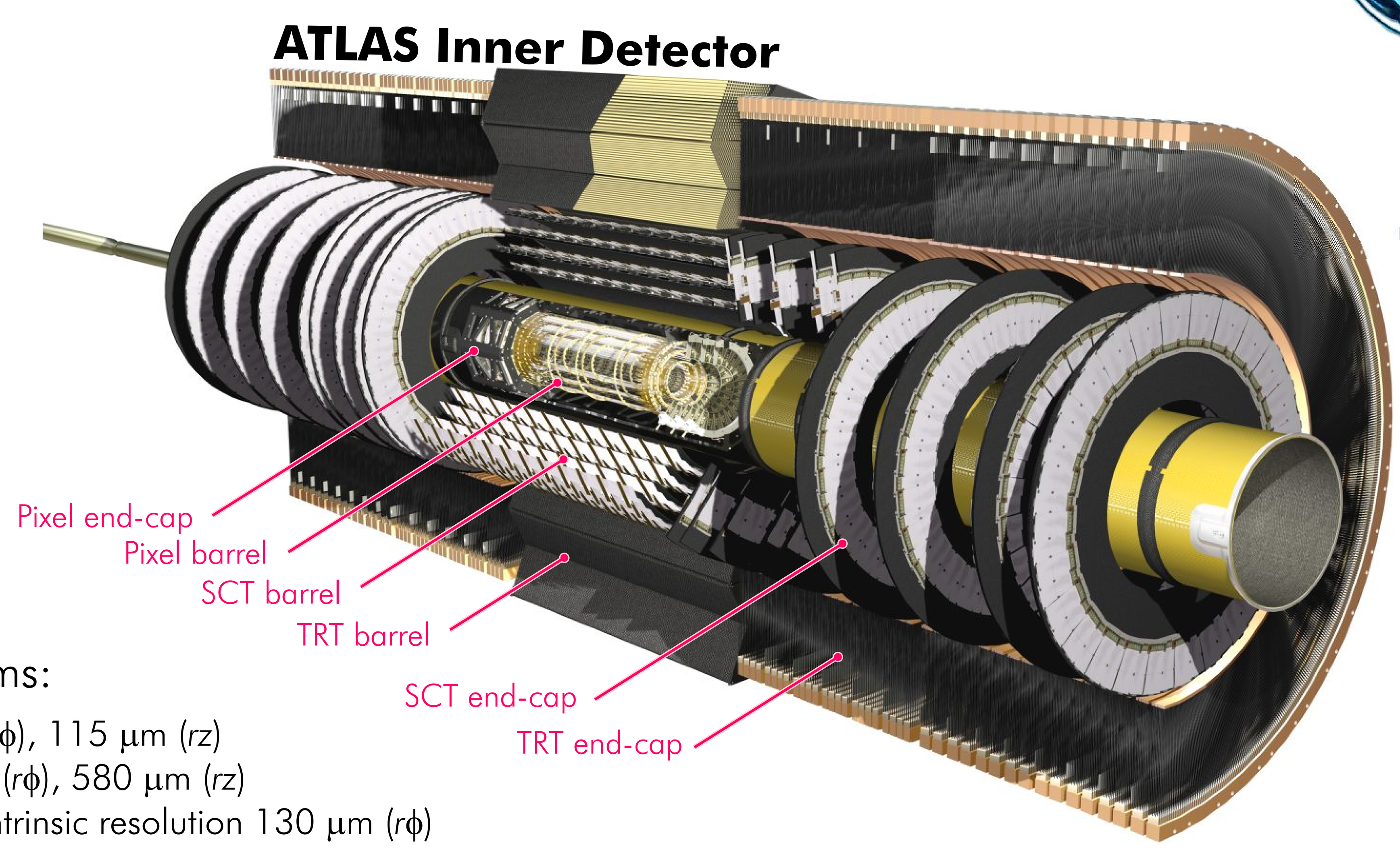




The ATLAS Inner Detector consists of three detector systems:

Pixel: Silicon Pixel detectors - 1774 modules - with intrinsic resolution 10 μm ($r\phi$), 115 μm (rz)
SCT: Silicon micro-strip detectors - 4088 modules - intrinsic resolution 17 μm ($r\phi$), 580 μm (rz)
TRT: Transition Radiation Tracker with Polyamide drift tubes - 992 modules - intrinsic resolution 130 μm ($r\phi$)

Inner Detector Alignment

Goal of the alignment is to obtain corrections to nominal positions of modules in order to accurately describe the real detector. This is necessary condition for efficient track reconstruction, precise momentum measurement and vertex determination and has big impact on ATLAS physics performance. The degradation of resolution of track parameters should not exceed 20%.

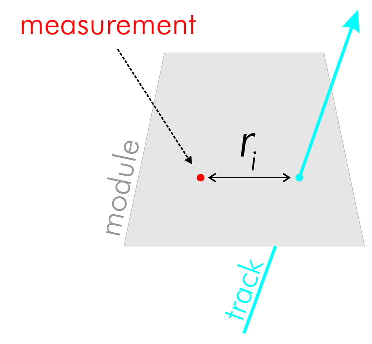
Ultimate alignment precision can be reached using track based algorithms. Algorithms used in ATLAS are based either on the minimization of the χ^2 of the track w.r.t. both track parameters and alignment parameters – Global χ^2 algorithm and Local χ^2 algorithm – or on track-hit residuals in the overlap regions between modules – Robust alignment.

Global χ^2 Alignment

This is the baseline alignment algorithm used in ATLAS. The χ^2 minimization involves solving system of N linear equations of N parameters where N is the number of degrees-of-freedom (DoF) of the system. Considering 3 translations and 3 rotations, 6 DoF per module results in huge system of ~40000 DoF for the ATLAS Inner Detector.

$$\chi^2 = \sum_{tracks} r^T V^{-1} r \longrightarrow r_i = r_i(\pi, \alpha)$$

Depending on the granularity of the alignment (whole barrel/end-cap → barrel shells/end-cap disks → modules) different solving techniques are used:
→ CLHEP, LAPACK/SCALAPACK
→ fast solving for sparse symmetric matrices, etc.

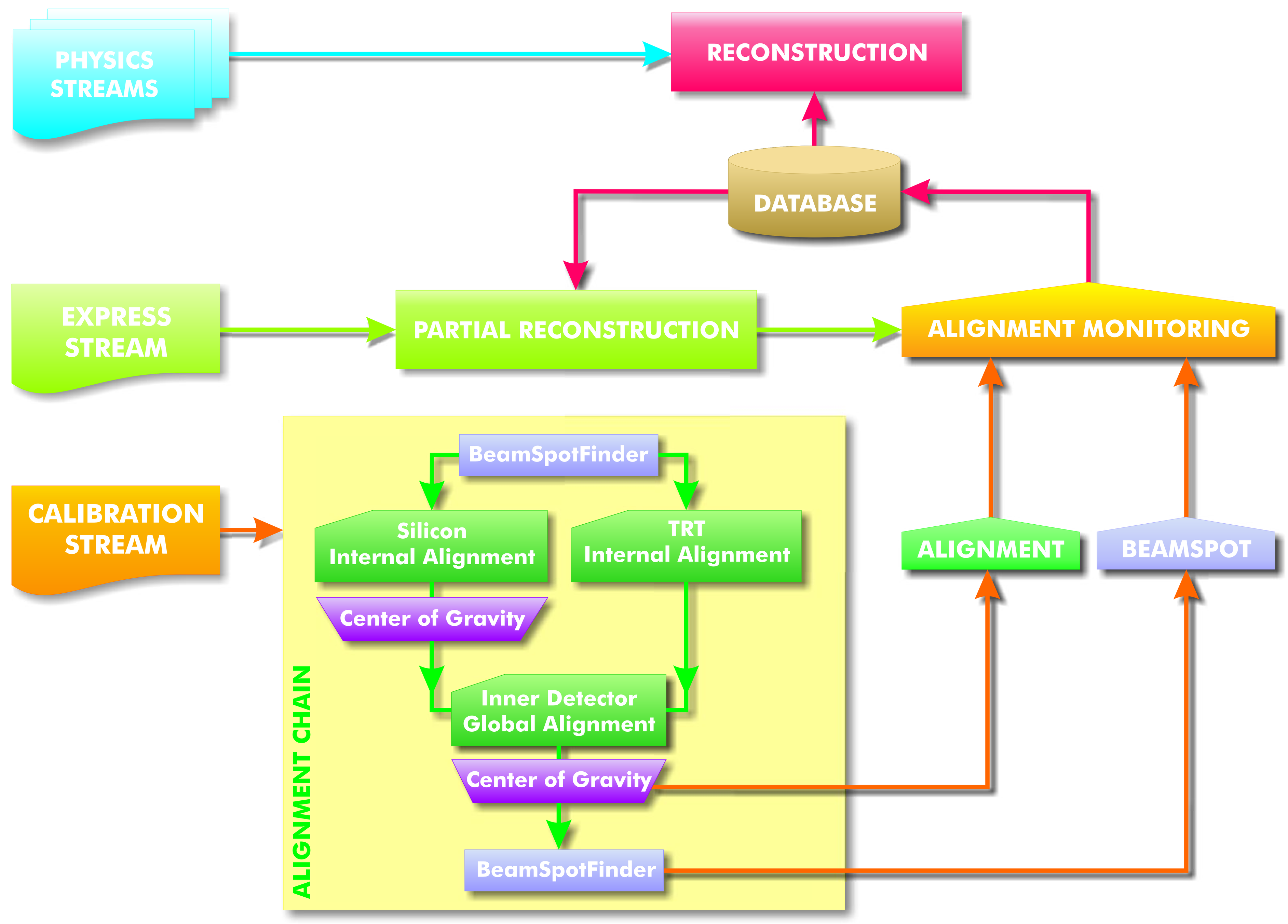


Alignment operation loop

During stable running the alignment of the Inner Detector will be performed on a 24 hour basis using a large number of tracks collected by a dedicated calibration trigger stream. The full alignment chain will be performed on CERN Analysis Facility (CAF) on a dedicated cluster of O(100) CPUs.

In the ALIGNMENT MONITORING the new alignment is compared with the old one using a consistent dataset (Express stream). A decision is then taken on whether the new constants have to be updated in the database and used for the reconstruction of the data from physics streams.

The calibration stream and the automated alignment loop have been successfully tested in a technical run where a special MC sample was used to simulate the expected data-taking conditions.



Weak modes

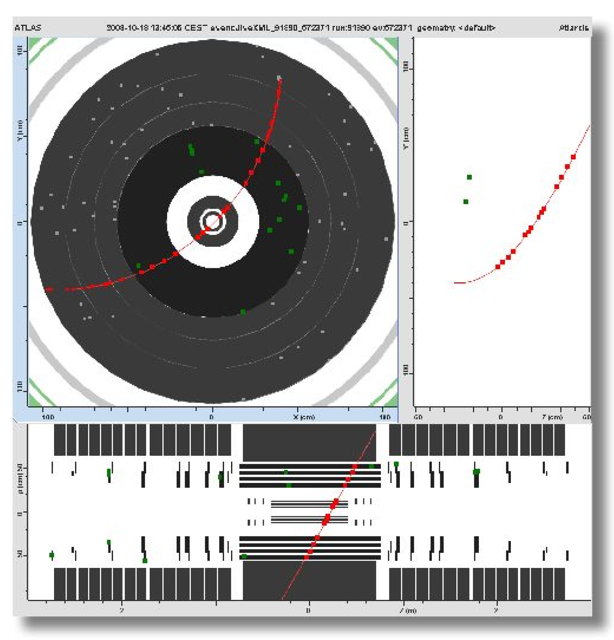
Detector deformations to which the track χ^2 is insensitive ("valley" in χ^2 instead of a single global minimum).

Table shows the classification of weak modes together with their impact on physics measurement. The most dangerous/hardest-to-tackle modes are highlighted.

	ΔR	$\Delta\phi$	ΔZ
R	Radial expansion (distance scale)	Curl (charge asymmetry)	Telescope (CoM boost)
ϕ	Elliptical (vertex mass)	Clamshell (vertex displacement)	Skew (CoM energy)
Z	Bowing (CoM energy)	Twist (CP violation)	Z expansion (distance scale)

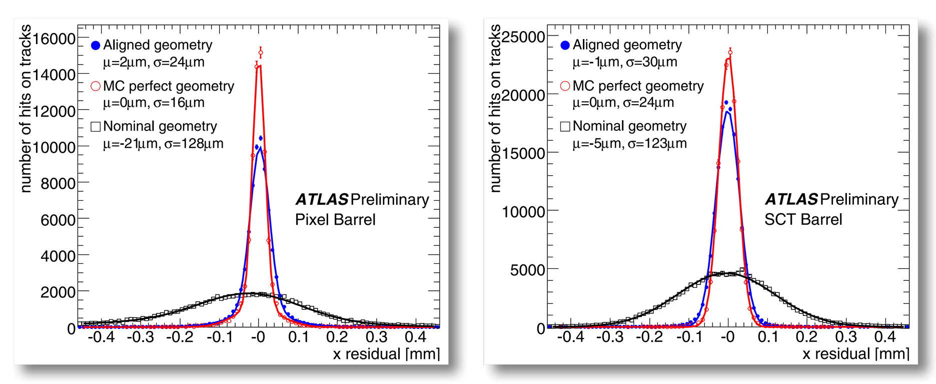
Extra handles are/will be used to deal with weak modes:
cosmic events, beam halo, E/p, survey constraints,
vertex and beam spot constraints, resonant mass constraint, ...

ID alignment with cosmic data

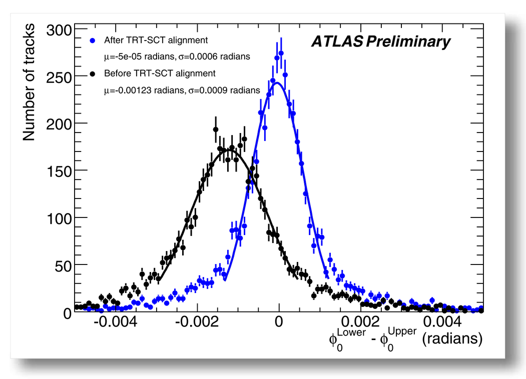


Dedicated global cosmic data taking was performed in the fall 2008. ATLAS collected 7.6M tracks in total. Alignment of the ID was performed using cosmic events at the module level for Pixel barrel, SCT barrel and TRT barrel. Consistent set of alignment corrections was obtained using real data.

Magnetic Field	OFF	ON
All tracks	4.9M	2.7M
SCT tracks	1.2M	880k
Pixel tracks	230k	190k



Residual distributions significantly improve after alignment. Shown are residual distributions for Pixel and SCT.



Difference in ϕ_0 of cosmic tracks split into upper and lower half. Significant improvement is seen after alignment.

ATLAS ID alignment in good shape, getting ready for the first collision data.