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Track Based Alignment of the ATLAS Inner Detector: Implementation and Performance

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The Large Hadron Collider (LHC) at CERN is the world's largest particle accelerator, which collides proton beams at an unprecedented centre of mass energy of 7 TeV.

ATLAS is a multipurpose experiment that records the products of the LHC collisions. In order to reconstruct the trajectories of charged particles produced in these collisions, ATLAS is equipped with a tracking system (Inner Detector) built on two different technologies: silicon planar (pixel and microstrip) sensors and drift-tube based detectors.

The goal of the Inner Detector alignment is to determine accurately the position and orientation of its sensors with a precision better than 10 micrometers, such the tracker performance is not degraded far beyond its intrinsic resolution. This requires the determination of over 700,000 degrees of freedom (DoF) with high accuracy.

The implementation of the track based alignment within the ATLAS software framework unifies different alignment approaches and allows the alignment of all tracking subsystems together.

The alignment specific classes are directly linked with the track reconstruction software, which provides tools for computation of specific quantities (residuals, pulls, track derivatives, covariance matrices, ...). The detector specific classes inherit from a common base allowing for a unified definition of the alignment geometry.

As the alignment algorithms are based on minimization of the track-hit residuals, one has to solve a linear system with large number of DoF. The solving itself poses a real challenge as it involves inversion or diagonalization of a large matrix that may be dense. Fast solving algorithms as well as full diagonalization have been implemented to calculate the results for the alignment.

The alignment software also has the ability to constrain the system either with constraints on the tracks (beam spot, primary vertex, momentum from the ATLAS muon system, E/p, ...) or constraints on the alignment corrections.

The alignment is executed on a run by run basis at the ATLAS calibration loop using the CERN Analysis Facility with ~200 CPUs running Scientific Linux CERN 5.

For these purposes, two independent data streams are selected online by the event filter (at a 50 Hz rate).

The first one consists of a collection of high momentum and isolated tracks.

The second is a set of cosmic-ray tracks triggered during the LHC empty bunches.

Detailed alignment runs on the GRID, where data corresponding to many data periods is analysed, allowing for thousands of CPU to be utilised simultaneously.

We will present an outline of the track based alignment approaches, their implementation within the ATLAS software framework and their performance when aligning the ATLAS detector.

Summary

The alignment of the Inner Detector of ATLAS poses a real computing challenge. There are more than 700 thousand degrees of freedom to align with high accuracy. Therefore many millions of tracks are needed.

Besides the computing resources are a key ingredient for the alignment procedure. The ATLAS ID alignment has been adapted to run on the GRID. Several thousand jobs are submitted in parallel to the ATLAS tier 2 centers. There the data is processed and the output is collected in form of alignment matrices and vectors, plus monitoring histograms. The whole alignment procedure is run iteratively till convergence is found. In each iteration, before solving the alignment, all the matrices and vector of individual jobs have to be added together. In order to obtain the alignment corrections one needs to solve a linear system with many thousands degrees of freedom. Thus the computing represents also a challenge. Fast matrix inversion with matrix conditioning and diagonalization of the full matrix are used. In the second case and in order to obtain sensible alignment corrections, one has to identify the singular and the near-singular modes of the alignment.

The whole alignment chain can also be run quasi-online in the calibration loop, where alignment constants are required to be derived run by run. There is also a limit of 36 hours to obtain the corrections, prior the bulk processing starts.

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