Alignment of the ATLAS Inner Detector Tracking System

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1 Introduction

The ATLAS experiment [1] is a multi-purpose particle detector at the Large Hadron Collider (LHC) at CERN, designed to analyse high energy proton-proton and heavy ion collisons. The innermost detector subsystem of ATLAS is the Inner Detector (ID), which is embedded in a 2 T axial magnetic field surrounding the interaction region. Its purpose is to reconstruct trajectories of charged particles and precisely measure their momentum and interaction vertices. As the intrinsic resolution of the ID exceeds the achievable assemply precision by two orders of magnitude, an accurate description of the detector geometry is vital to perform high precision physics measurements. To determine the position and orientation of each detector module, a track based alignment procedure is applied.

2 Track Based Alignment of the ATLAS Inner Detector

The ID consists of two silicon detectors (Pixel and SCT) and a transition radiation tracker (TRT) constructed of gas filled straw tubes. The Pixel has 1744 modules with an intrinsic resolution of $10 \times 115\,\mu m^2$ in RΦ and z directions respectively. The SCT consist of 4088 silicon strip modules with an intrinsic resolution of $17\,\mu m$ in RΦ and $580\,\mu m$ in z direction. The TRT has 176 modules composed of straw tubes with a diameter of $4\,mm$ and achieves an intrinsic resolution of $130\,\mu m$.
The alignment is performed at different levels of granularity motivated by the mechanical layout of the detector. A full alignment procedure contains several iterations at each level starting with larger structures going to smaller ones, where each alignable structure has six degrees of freedom (DoF). At the most detailed alignment level individual modules and straw tubes are aligned with a total of more than 700k DoF.
The ATLAS track based alignment algorithms rely on the minimization of a χ^2 constructed from track-hit residuals. A track-hit residual is the difference between the

reconstructed track and the actual hit in the detector. The alignment χ^2 is defined as [2]

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

where $\mathbf{r}$ is the vector of track-hit residuals, $\mathbf{t}$ are the track parameters, $\mathbf{a}$ are the alignment parameters and V is the covariance matrix of the hit measurements. The alignment corrections are obtained by minimization of this χ^2.

3 Alignment Performance with 7 TeV Collision Data

The alignment has been performed [2] using well isolated high p_T tracks selected with the ATLAS high level trigger during proton-proton collisions with $\sqrt{s} = 7\,TeV$ at the LHC in 2010. In addition cosmic-ray tracks collected by the ATLAS cosmics-ray trigger in between collsion runs were used as input for the alignment. Figure 1 shows the results of the jet trigger data reconstructed with the Autumn 2010 Alignment compared to the perfectly aligned dijet MC simulation sample.

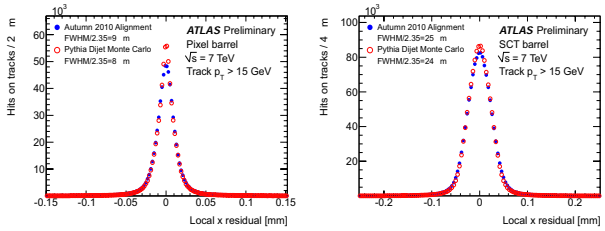

Figure 1: The Pixel and SCT local x residual distributions for the jet trigger data sample reconstructed with the Autumn 2010 Alignment (full circles), compared with the dijet MC simulation sample (open circles). The distributions are integrated over all hits-on-tracks in barrel modules and tracks are required to have $p_T > 15\,GeV$.

References

[1] ATLAS Collaboration, The ATLAS Experiment at the CERN Large Hadron Collider, J. Instrum. 3 (2900) S08003.

[2] ATLAS Collaboration, ATLAS-CONF-2011-012, `http://cdsweb.cern.ch/record/1334582`