Journal of Physics: Conference Series **119** (2008) 032010 doi:10.1088/1742-6596/119/3/032010

Implementation of Chamber Misalignments and Deformations in the ATLAS Muon Spectrometer Simulation

N Benekos[1], L Chevalier[2], S Goldfarb[3], R Harrington[4], J F Laporte[2], I Logashenko[4], J Miller[4], A Ouraou[2], D Rebuzzi[5], M Schott[6], S Spagnolo[7], N van Eldik[8], M Verducci[9] and S Willocq[8]

[1] Univ. Illinois at Urbana-Champaign, Department of Physics
[2] DAPNIA, Centre d'Etudes de Saclay, France
[3] High Energy Physics, Harrison M. Randall Laboratory, University of Michigan, USA
[4] Department of Physics, Boston University, USA
[5] Dipartimento di Fisica Nucleare e Teorica, Università di Pavia and INFN Pavia, Italy
[6] Ludwig-Maximilians Universität, München, Germany
[7] Dipartimento di Fisica, Università del Salento and Sezione INFN di Lecce, Italy
[8] Department of Physics and Astronomy, University of Massachusetts, USA
[9] Conseil Européen pour la Recherche Nucléaire (CERN), Geneva, Switzerland

E-mail: `daniela.rebuzzi@pv.infn.it`

Abstract. The implementation of run-time dependent corrections for alignment and distortions in the detector description of the ATLAS Muon Spectrometer is discussed, along with the strategies for studying such effects in dedicated simulations.

1. Introduction

The Atlas Muon Spectrometer [1] is designed to achieve precise transverse momentum resolution for muons in a p_T range extending from 6 GeV/c up to 1 Tev/c and pseudo-rapidity (η) below 2.7, by exploiting an air-core toroidal magnetic field. A muon track typically crosses three measurement stations separated by about 5 m, each providing a measurement of the corresponding super-point with precision of 50 μm.

The Muon System consists of about 1700 stations, with individual mechanical supports, organized in Large and Small sectors around the eight toroid coils, and made of four detector technologies: Monitored Drift Tubes (MDT) and Cathode Strip Chambers (CSC) (at $2 \leq |\eta| \leq 2.7$) for precision tracking in the bending plane ($\mathrm{R-z}$) and Resistive Plate Chambers (RPC) at $|\eta| \leq 1$ and Thin Gap Chambers (TGC) at $|\eta| \geq 1$ for triggering and coarse tracking in the transverse plane.

The most demanding design goal is an overall uncertainty of 50 μm on the sagitta of a muon with p_T =1 TeV/c which, to be achieved, requires obtaining the following constraints: a single MDT resolution of 80 μm, uncertainty from MDT auto-calibration below 30 μm, wire position known within 20 μm, and chamber positions determined within 30(40) μm in the barrel (end-caps). For high p_T muons (above $\sim$ 100 GeV/c) the dominant contributions to the momentum resolution are MDT auto calibration and residual uncertainty in the detector geometry.

The MDT chambers ($\sim$ 1200) are made of two arrays of staggered aluminium drift tubes, $1-6$ m long, 3 cm diameter, 400 μm thin Al wall, leading to a global thermal expansion coefficient of 25 μm/m/°C. In order to meet the design performance of the spectrometer, the absolute alignment of more than 1000 MDT chambers, along with their deformations induced by temperature gradients and mechanical stress, have to be known and appropriately handled by the Detector Description Software at run-time.

2. Non Ideal Geometry in the Detector Description

For each station, three angles, three shifts and eight deformation parameters (tube plane twist, sagging or elongation of the support plates separating the two multi-layers), will be provided by a sophisticated optical alignment system [2], based on laser beams and CCD cameras, in addition to offline alignment procedures. The parameters will be stored in a Condition Database, implemented in Oracle, using the LCG COOL API [3], with an appropriate Interval of Validity for use in reconstruction applications.

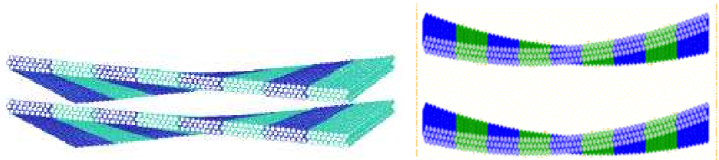

Figure 1. MDT Chamber deformations. Here displayed two possible effects, exaggerated for illustration.

The specific ATLAS software (`MuonGeoModel`), describing the geometry of both the active and inert components of the Muon Spectrometer is based on the ATLAS-wide package `GeoModel`[4]. This software is used to construct a transient description of the ATLAS detector that is easily translated into a `GEANT4` representation, but which is also used by offline applications, such as reconstruction. The spectrometer layout is represented as a hierarchy of volumes of a given material, provided with identification tags and relative transforms. The deepest levels in the tree correspond to active gas volumes (of MDT tubes or RPC/TGC/CSC gaps).

Volumes corresponding to Detector Elements hold cached absolute transforms. Some transforms are *alignable*, i.e. they consist of a nominal and a Δ transform, the latter allowing to be updated at run-time. At any update, all cached full transforms beneath the aligned node in the tree are automatically re-calculated. A set of classes, representing the `Readout Geometry`, accessed via a Detector Manager, and linked to nodes corresponding to Detector Elements, provides information with the readout granularity: i.e. strip position, read-out side, etc.

In the ATLAS 2007 Computing System Commissioning, aiming at the production of the ultimate physics and performance studies before LHC collisions, most data samples have been simulated and successfully reconstructed with a MS layout described by a set of primary numbers stored in the static geometry database which include some realism: broken cylindrical symmetry and random displacements of all MDT chambers (rms of shift and tilt parameter distributions are 1 mm and 1 mrad).

More recently, in the context of the Condition Data Challenge, the data describing the chamber random misalignments have been stored in the Condition Database. Software tools for accessing them, on the basis of their Interval of Validity, have been developed. The ability of `MuonGeoModel` to represent the correct spectrometer geometry by initializing the geometry representation with primary numbers corresponding to the nominal layout and updating such transient model afterwords with alignment data extracted from the Condition Database has been demonstrated.

3. MDT Deformations in the Simulation

GeoModel itself does not provide built-in functionality for describing chamber deformations. In addition, it is necessary to use mechanisms, such as parametrization and volume sharing, in order to keep memory usage reasonable. Treatment of individual tube deformations in GEANT4, for example, would require the usage of separate tube volumes or other techniques that would explode the memory size well beyond the current limitations of the computing model. To avoid this problem, tube deformations and wire sag are both introduced at the level of the Readout Geometry with tubes shifted and tilted with respect to their nominal location in the multilayer.

A first implementation of MDT deformations, based on this concept, is in place and exhibits the expected functionality. The full transform of any MDT tube is derived from a sequence of logical steps, which makes available the realistic chamber geometry to any reconstruction application: nominal positioning of the tube in its multilayer, corrections for shifts and tilt angles as determined by deformation parameters, nominal positioning of the multilayer in the station frame, correction of the station transform in the nominal local frame according to alignment data, nominal location of the station frame in the ATLAS global reference frame.

4. Validation of the Deformation Code

In order to validate the description of deformation effects on simulated data, the following approach is under test: particles are simulated in GEANT4 making use of the nominal geometry then, at digitization level [5], the local hit position is transformed to the global frame and relocated back into the sensitive volume by using the MuonGeoModel interfaces that account for deformations; the correctly positioned hit is finally digitized.

To validate this procedure, drift radii obtained from the digitized hits are compared to the distance between the track point of closest approach to the tube wire and the wire itself (*residuals*).

Results are shown in Figure 2 where the configuration, including the deformations as above described, is compared to the ideal geometry one. The track-wire distance is in reasonable agreement with the drift radius, within the single tube resolution (80 μm).

The deformation parameters used here are dummy numbers hardcoded in the MuonGeoModel code. They will be read from the ATLAS Condition DataBase, in the final design. Here the emphasis is put on the deformation procedure and its validation.

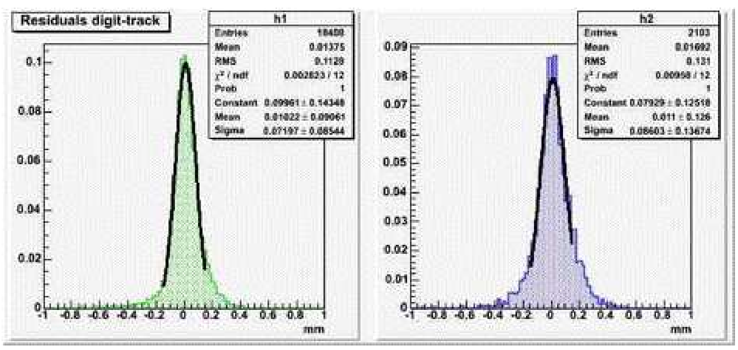

Figure 2. ATLAS preliminary: Distributions of the difference between the track-wire distance and the drift radius (residuals) obtained from the digitised MDT hit.
Left plot: no deformations in the MDT chamber description. Right plot: deformations considered. Both distribution widths are in agreement with the single MDT tube resolution.

5. Conclusions and Outlook

We presented the first implementation of the chamber deformations in the GEANT4 simulation. Since GeoModel itself does not provide functionality for describing them, we implemented a method which takes into account the deformations at the digitization level. The hit position is modified according to deformation parameters before the digit creation procedure.

The procedure has been validated by means of studies which compare the geantino track point of closest approach to the tube wire to the wire itself and the residuals have been found to be compatible with the intrinsic tube resolution. These studies should be repeated once the deformation parameters will be available from the chamber alignment monitoring system, and they will be stored in the ATLAS Condition DataBase.

References

[1] ATLAS Collaboration, *ATLAS Muon Spectrometer Technical Design Report*, CERN/LHCC/97-22, 1997.
[2] C. Amelung, *The alignment system of the ATLAS muon spectrometer*, Eur.Phys. J. **C33**, 2004, 999-1001.
[3] The LCG COOL Conditions Database API is described and documented at https://cern.ch/twiki/bin/view/LCG/COOL.
[4] J. Boudreau at al. *ATLAS detector simulation : status and outlook*, CERN-ATL-SOFT-PUB-2005-004, 2005.
[5] D. Rebuzzi, K. A. Assamagan, A. Di Simone, N. Van Eldik, Y. Hasegawa, "Geant4 Muon Digitization in the Athena Framework", ATL-SOFT-PUB-2007-001, 2007.