Coordinate frames for ATLAS offline software

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Abstract

This document defines the coordinate frames to be used in the various phases of event processing in ATLAS offline software, and the methods necessary to implement them.

1 Introduction

Several different conventions exist for defining the coordinate systems in ATLAS offline software, and they may not all be the same, given the finite precision with which the different parts of ATLAS will be assembled and positioned together in the pit. Different systems may also be appropriate at different stages during the software processing, due to the various needs of the different stages. This note attempts to enumerate all the coordinate systems, and makes a proposal of how they should be related.

The current draft results from discussions at the BNL software week in May 2003 [1], and still contains several open question.

2 Coordinate frames

This section enumerates the various coordinate systems used in different parts of the ATLAS offline software, and defines the relationships between them. Note that these systems are logically different (in that they are used for different purposes) but may not be physically different (we may choose to make some of them the same).

2.1 ATLAS global frame

The ATLAS global frame is defined by Technical Coordination in [2] (referred to there as the 'Detector axis system') and is the global coordinate frame with respect to which the main parts of the ATLAS detector will be surveyed. In this coordinate system, the z axis follows the nominal beam direction (with positive z towards Geneva and LHC point 8) and negative z towards the Jura and LHC point 2. Side A of ATLAS has $z > 0$ and side C $z < 0$. The z axis is inclined by 1.25 % with respect to the horizontal plane to follow the slope of the LHC ring; the gradient is downhill towards point 8. The x axis is horizontal and points towards the centre of the LHC ring, and the y axis points almost vertically upwards. The origin is the nominal interaction point.

This coordinate frame also defines the nominal beamline. Objects in the cavern will be surveyed with respect to this system, and their absolute positions will be known to precisions of around 1 mm, depending on their positions in the cavern and the parts of the cavern survey network which are directly visible. Depending on the positioning and movement systems, the detector pieces may actually be positioned several mm from their nominal positions, and may also be slightly rotated.

2.2 Event generation frame

Most event generators work in a frame with z along the direction of the incident protons, corresponding to the centre-of-mass system of the p-p collision. This frame will not be coincident with the ATLAS global frame. The actual beamline is expected to be within ± 3 mm of its nominal position, and to be stable to within ± 1 mm on the medium term. The displacement with respect to the nominal beamline may also be different on the two sides of ATLAS, leading to a slight rotation between the two frames (hence the proton beam will not follow the ATLAS global z axis). For example, if the beam is displaced by ± 1 mm in opposite directions at the two ends of the ATLAS cavern, this will lead to a rotation of 0.04 mrad between the centre-of-mass system and the ATLAS global frame.

There is also expected to be a crossing angle between the two beams of about 150 μrad, which will give a global transverse event boost of ~ 1 GeV (corresponding to $\beta = 0.75 \times 10^{-4}$) and contribute to a transverse missing energy which is on average non-zero.

2.3 Simulation global frame

This frame is used to position the overall envelope volumes of the various parts of ATLAS for simulation, and to perform the associated particle tracking.

2.4 Reconstruction local frames

The detector subsystems may wish to use subdetector local frames to perform subdetector-specific reconstruction, rather than using a global frame. One example is the inner detector, where it may make sense to perform track reconstruction in a frame where the z axis coincides with the axis of symmetry of the solenoid, allowing track propagation algorithms to be simpler and faster. The solenoid axis is expected to differ from the global axis by several mm and up to 1 mrad [3]. However, the sharing of EDM and tracking information by the inner detector and muon reconstruction may require that the two systems use a consistent frame, which would make the choice of the solenoid frame more problematic. Choosing a separate frame for the inner detector reconstruction would also introduce additional complexity between the subsystem and combined reconstruction [1].

2.5 Reconstruction global frame

The reconstruction global frame should be used for all combined reconstruction involving the linking of objects reconstructed by the various subdetectors. Thus if subdetectors use their own specific local frames, their output should be transformed into the global frame before combining with other subdetectors, implying that the final reconstructed objects from subdetectors should be expressed using the reconstruction global frame coordinate system.

2.6 Physics analysis frame

The physics analysis frame should in principle correspond to the event generation frame, where the initial collision is between two protons moving along the z axis, and the missing transverse energy from all final state particles is zero. This implies transforming the event

[1] In some cases, frames local to individual sensitive detectors (*e.g.* a silicon module) might be useful, but this should have no impact on reconstruction output objects and is not discussed here.

from the reconstruction frame to compensate for the difference between nominal and actual beamline positioning, and applying a small transverse boost to compensate for the beam crossing angle, such that the reconstructed physics event is in the centre-of-mass system.

3 Coordinate frames proposal

The following proposal attempts to minimise the number of different frames being used, whilst still keeping the necessary realism and flexibility.

- Simulation and combined reconstruction will be done a in single frame, corresponding to the ATLAS global frame defined in [2]. Thus, the global 'envelope volumes' of detector pieces will be positioned in the simulation according to the survey measurements made in the cavern, and the coordinate system will correspond to the nominal beamline.
- Event generation will be done in the 'natural' event generator centre-of-mass frame, with the colliding protons on the z axis. A small boost, translation and rotation will be applied to the four-vectors before simulation, in an extension of the current procedure where the event origin is shifted to simulate the beamspot position and spread.
- Subdetectors may perform subdetector-specific reconstruction in local frames not coincident with the ATLAS global frame, but all finished objects for combined reconstruction must be expressed in the ATLAS global frame.
- Although the reconstruction events could be transformed back to a physics frame with no net transverse momentum, the effects of this are felt to be sufficiently small that this can be neglected, apart from a few specific studies. This boosting would also not be sufficient to fully correct for the effect, since E_{T} thresholds (for trigger or reconstruction) and η acceptance boundaries would still be defined in the reconstruction rather than the physics frame. Therefore, it is preferred to do physics analysis in the reconstruction/global frame rather than introduce a separate physics frame.

This leaves open the question of whether any subdetectors will actually implement a reconstruction local frame—only the inner detector has currently expressed interest, and the current thinking is not to do this, due to the difficulties of then sharing tracking code and data with the muon system.

4 Practical considerations

As defined above, the only transformation tools which will be needed are those necessary to transform generated physics events into the ATLAS global frame. The necessary offsets, rotations and boosts may vary with time (depending on what data period is being simulated), so these data should naturally be put in the conditions database. If necessary, similar tools could also be provided to transform standard objects (three- and four-vectors) back to the physics frame at the end of reconstruction.

If only a single reconstruction frame is used, GeoModel and related services would always provide detector positions in the reconstruction/global frame, and no ambiguity or translation needs would arise. Similarly the magnetic field services would provide the field in terms of the global frame (meaning it would not in general be symmetric about the z axis).

5 Actions

Several actions were agreed at the BNL meeting [1]:

- The physics community will investigate the possible effects of the rotation of physics events with respect to the reconstruction coordinate system, and the boost due to the crossing angle. This will be done with some example physics processes, to evaluate whether the effects are significant in practice, and what is the best way to take them into account.
- The inner detector community will investigate further the consequences of reconstructing in a coordinate system which is not aligned with the solenoid axis, and compare this with the complexity of introducing an extra reconstruction local coordinate system for the inner detector.

References

[1] Discussion at ATLAS BNL software week, 25/5/04.

[2] Co-ordinate axis systems, G. Bachy, ATL-GE-QA-2041.

[3] Survey of the ATLAS ID, R. Hawkings, ATL-IC-IN-0001.