

Commissioning of the ATLAS Offline Software with Cosmic Rays

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Abstract. The ATLAS experiment of the LHC is now taking its first data by collecting cosmic ray events. The full reconstruction chain including all sub-systems (inner detector, calorimeters and muon spectrometer) is being commissioned with this kind of data for the first time.

Specific adaptations to deal with particles not coming from the interaction point and not synchronized with the readout clock were needed. Data decoders and the infrastructure to deal with conditions data as those coming from the data acquisition configuration, detector control system, calibration and alignment corrections were developed and validated as well.

Detailed analyses are being performed in order to provide ATLAS with its first alignment and calibration constants and to study the combined muon performance. Combined monitoring tools and event displays have also been developed to ensure the good data quality.

A simulation of cosmic events according to the different detector and trigger setups has also been provided to verify it gives a good description of the data.

1. Introduction

As a first step towards preparation for collisions, ATLAS [1] is using cosmic ray data to commission its offline reconstruction software. Commissioning of the offline software is an integral part of understanding the detector in the early stages of an experiment. Detectors rely on reconstructed information to determine noisy channels, calibration and alignment constants, trigger timing between detectors, etc. During detector commissioning periods, ATLAS has also integrated the use of offline software to receive prompt information about the data. This information is presented by event displays, monitoring histograms, or data quality checks of monitoring histograms. The preparation leading up to the commissioning periods is essential for successfully integrating all systems in a usually tight timescale. The following document will discuss the steps taken for preparation and results from recent commissioning runs.

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2. ATLAS Detector

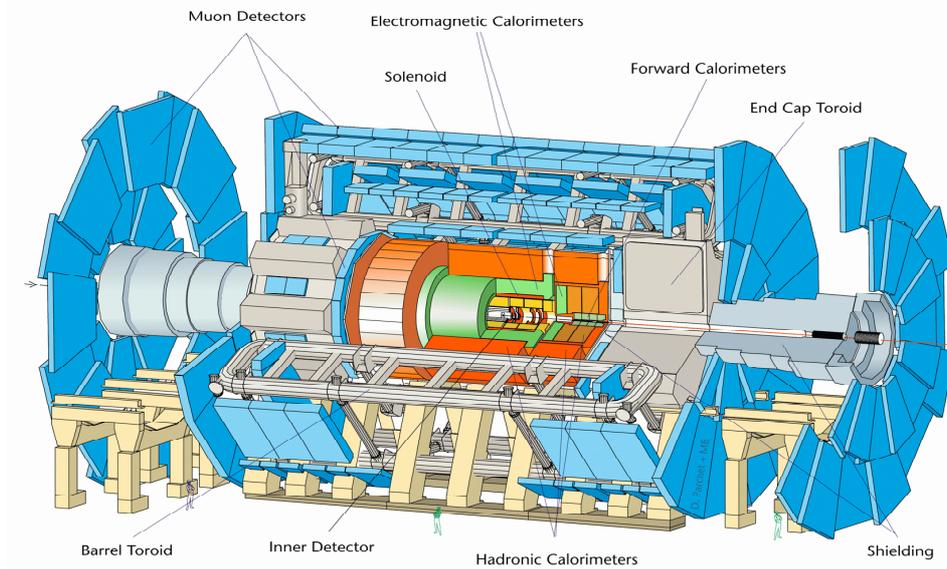


Figure 1. Schematic of ATLAS detector.

ATLAS detector has about 140 million electronic channels and detects particles at 40 MHz bunch crossing rate which is then reduced by 3 trigger levels to the 200 Hz of recorded event rate. It consists of three tracking detectors, hadronic and electromagnetic calorimeters, and four muon spectrometers.

The three tracking detectors include the Silicon Pixel Detector, the Semiconductor Tracker (SCT), and the Transition Radiation Tubes (TRT). The detector consists of a Hadronic and electromagnetic calorimeter. The hadronic calorimeter is either a Liquid Argon (LAr) sampling calorimeter or an Iron/Scintillator (Tile) sampling calorimeter. The electromagnetic calorimeter is made of LAr sampling accordion shaped absorber plates.

ATLAS consists of four muon spectrometers that are categorized as trigger, with a time resolution of 2 ns, or momentum chambers, with a special resolution of 80 microns. The trigger chambers include the Resistive Plate Chambers (RPC) in the barrel and Thin Gap Chambers (TGC) in the endcaps. The momentum measurement chambers include the Monitored Drift Tubes (MDT) in most of the solid angle and the Cathode Strip Chambers (CSC) in the most forward endcap region.

As the ATLAS detector is being assembled the detector geometry changes for each commissioning period. Therefore a realistic detector geometry must be used for reconstruction of cosmic ray commissioning data.

3. Simulation and Reconstruction

Generation of cosmic ray data is done on the surface of the ground and passed through earth 100 m. below where the ATLAS detector lies (see figure 3). The muon tracks are then filtered depending on original position and direction and/or whether they flow within the given detector volume being used for the commissioning period. In general events are digitized using common timing tools except in cases where discrepancy is not resolved between simulation and real data. In order to satisfy different running conditions the data is generated with different detector filter volumes, different energies, magnetic field on and off, and with various misalignments.

There are two approaches taken in reconstructing cosmic ray tracks within the detector. One is to match an inner detector (ID) track with a muon segment (MS) track by using existing combined

algorithms using the cosmic configuration. The other is to perform a global χ^2 fit to ID and MS tracks after applying simple matching criteria.

The calorimeters use regular clustering algorithms with some modifications to increase muon detection. The tile calorimeter uses an algorithm to match clusters in the top (positive ϕ) and bottom (negative ϕ) of the detector with a line that minimizes the sum of orthogonal distances to cells weighted by energy density. The LAr clusters cells in the second sampling of the calorimeter with a seed above 100 MeV and neighbouring cells above 50 MeV.

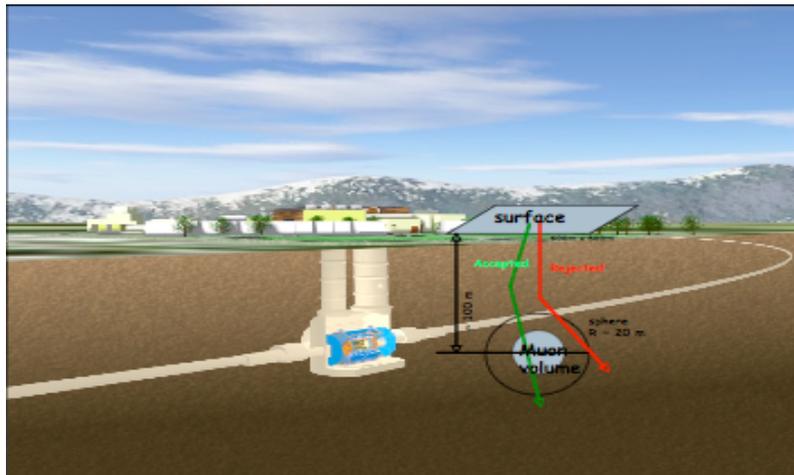


Figure 2. Generation of cosmic rays on the surface passing through earth and hitting detector volume.

4. Testing and Commissioning Running Period

The first pass of testing reconstruction software is using simulated cosmic ray events. Once this has been done successfully, one begins testing the software by reconstructing real data and understanding the discrepancies with respect to the simulated data. During each commissioning period the data is written out with a different version of software and detector setup. Therefore one must determine the compatibility of the software with the latest running conditions and when possible make compatible with reading older commissioning data.

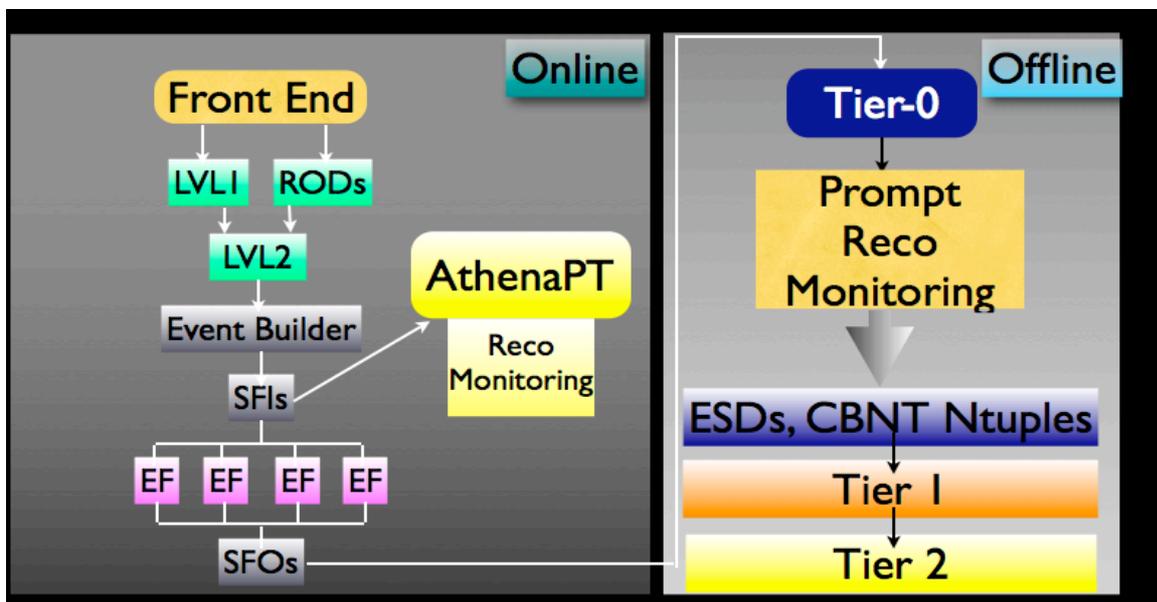


Figure 3. Dataflow setup during commissioning run period.

Figure 4 shows a schematic of the dataflow setup during the latest ATLAS commissioning period in August 2007. The offline software is run in the online environment within the Athena Processing Task (PT) [2] application sampling events from the Sub-Farm Input(s) (SFI) [2]. This allows for prompt reconstruction and monitoring of data as it is read out of the detector. The data is then written out to file by the Sub-Farm Outputs (SFOs) [2] and read in by Tier-0, where the first pass of full reconstruction and monitoring is performed on ATLAS. Finally, Event Summary Data (ESD) [3] and Combined Reconstruction N-tuples (CBNT) [3] are produced and pushed onto Tier-1 and Tier-2 sites [4].

5. Event Displays and Online Monitoring Setup

The ATLAS event display, ATLANTIS [5], is run online receiving reconstructed events over the network from the ATLAS software framework. The software reconstructing the objects being displayed in the event display is run within the Athena-PT framework as mentioned in Section 4. The integration of the offline software into this setup is non trivial since it requires compatibility of underlying software between the online and offline software. It is typically also a challenge to integrate and debug the system due to short timescales of the commissioning periods. The quick response of software experts has made online monitoring with displays and histograms possible during the commissioning runs. Figure 3 shows an event display from a recent commissioning run where one can see hits in the MDT, the calorimeters, and the SCT.

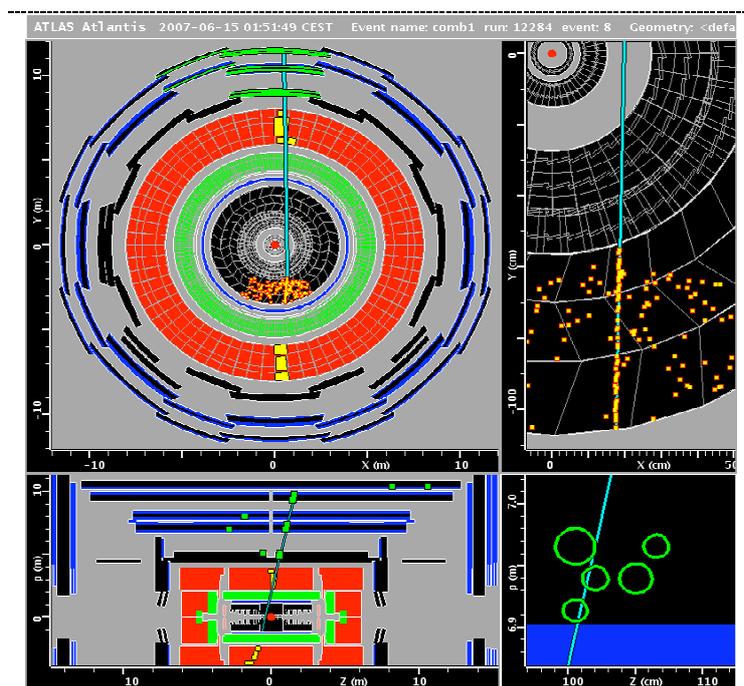


Figure 4.

Event display from recent commissioning run showing SCT, calorimeter, and MDT hits.

6. Monitoring and Analysis

The setup described in the previous sections allows for both online and prompt offline monitoring of data. The monitoring of reconstructed objects is essential for understanding the detector and improving reconstruction algorithms. The histograms produced from the monitoring algorithms can be checked automatically by data quality checking programs. This helps to detect faulty data and amend problems quickly. Examples of the type of quantities monitored are number of tracks

reconstructed in the TRT, calorimeter hits in η/ϕ plane, energy of calorimeter cells and clusters, number of MDT or SCT hits, etc. Figures 5 and 6 show examples of some monitoring histograms that would be monitored.

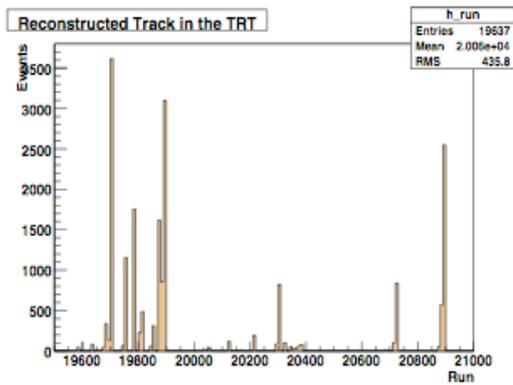


Figure 5. Number of reconstructed muon tracks in the TRT per run.

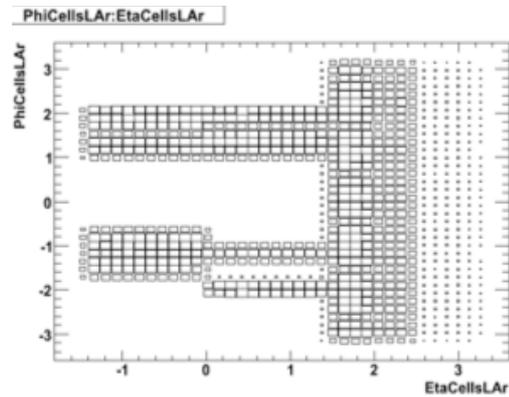


Figure 6. η/ϕ hits of muons in the LAr calorimeter.

7. Conclusions

ATLAS offline software has been commissioned with real cosmic ray data since December 2006. Since then several commissioning periods have been exercised adding more detectors and detector regions. Many steps have been taken in preparation for commissioning with cosmic ray data including generation and simulation of data, determining detector descriptions, reconstruction, integration into online setup, and finally monitoring and analysis of that data. During the latest commissioning run, August 2007, the ATLAS offline software was successfully integrated for reconstructing and monitoring in both the online and Tier-0 environments. Each commissioning period provides valuable experience upon which the whole atlas system can build upon in preparation for collisions.

8. References

- [1] ATLAS Collaboration, “ATLAS detector and physics performance technical design report”, CERN/LHCC/99-14.
- [2] ATLAS Collaboration, “ATLAS DAQ, EF, LVL2, and DCS,” CERN/LHCC/98-16.
- [3] ATLAS Collaboration, “ATLAS Computing Technical Design Report”, CERN/LHCC/2005-022.
- [4] M. Wilson, “Assessment of Data Quality in ATLAS”, see proceedings in this conference.
- [5] Zdenek Maxa, “Event Visualization of the ATLAS experiment – the technologies involved”, CHEP06 Proceedings,