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 various conditions data 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.

The ATLAS detector [1], designed to study the collisions produced by the LHC, is scheduled to start taking data in 2008. ATLAS consists of several subsystems: an inner detector, a calorimeter system and a muon detector. The inner detector measures the trajectories of charged particles. It consists of a pixel detector, a silicon strip detector, and a straw detector. The calorimeter consists of an electromagnetic (EM) part that detects and measures electrons and photons, and a hadronic part that measures jets. The EM calorimeter and the hadronic endcap calorimeters use liquid argon (LAr) as the active medium, while the hadronic barrel calorimeter is based on scintillating tiles. The muon spectrometer surrounds the other subsystems. It contains two types of chambers for triggering on muons: RPCs (Resistive Plate Chambers) in the central region, and TGCs (Thin Gap Chambers) in the forward region. For precision tracking, MDT (Monitored Drift Tube) chambers are used except in the forward region near the interaction point, where CSCs (Cathode Strip Chambers) are used.

The ATLAS detector is currently being commissioned using cosmic rays. While the cosmic muons provide a clean environment to test all the various aspects of the detector, they also introduce some complications for the reconstruction. For example, the cosmic muons arrive at random times, while the default reconstruction software assumes that the particles arrive synchronously with the readout clock. The reconstruction software was modified for the cosmics such that it first calculates the difference between the readout clock and the arrival time of the muon, and then corrects the drift times in the tracking detectors and selects the correct set of coefficients for the energy reconstruction in the calorimeters. Furthermore, the reconstruction software needed to be modified to reconstruct particles that do not point to the region where the LHC collisions will occur. On the other hand, many other parts of the offline software only needed small modifications, such as the detector description and the data decoders. The cosmic ray data is used to provide an initial calibration and alignment of the detector, and to fix problems that cannot easily be spotted using simulated data, such as errors in the cable maps, or missing protections against corrupted data.

The simulation of the cosmic setup is performed using the G4ATLAS application [2]. Cosmic muons are generated at the surface and, after an initial cut on the direction, tracked through the earth towards the pit with the ATLAS detector. The detector description is provided by the GeoModel package, which has several layouts available that are dedicated to the cosmics, since not all the detectors are in their final position yet (see Fig. 1). The tracking through all the various volumes and materials is performed by the GEANT4 package suite. Events where the muon does not reach ATLAS are discarded by a filter. This filter can also be configured to filter on subvolumes within ATLAS instead of the whole ATLAS volume: e.g. the calorimeters or the inner detector. The simulation is used to study the performance of the reconstruction and alignment algorithms. Many different samples were produced: e.g. with different muon energies, with and without magnetic field, and with different layouts, including misaligned layouts. The simulation also allows to estimate the cosmic rate for each subdetector. Fig. 2 shows an example of a simulated event.

All subdetectors in ATLAS have now taken cosmic data, either at the surface or in the pit. Detailed results obtained with these data per subsystem can be found in Refs. [3], [4] and [5]. In June 2007, the first combined data were recorded where the inner detector, calorimeters and muon spectrometer were all present, although not yet with 100% of the available number of channels. The second combined data taking period followed two months later, and at least two more such periods are planned before the LHC starts up. The cosmic trigger is provided by the RPCs, the TGCs and the tile calorimeter. The events are reconstructed on the fly and are monitored and displayed in the control room. So far, the level-2 and level-3 triggers are configured to accept all the events accepted by the level-1 hardware trigger. Nevertheless, some trigger algorithms were run to test their correct functioning in the online environment. Fig. 3 shows the energy reconstructed in the LAr calorimeter in the level-2 trigger. The tail towards higher energies corresponds with the energy deposited by cosmic muons. Fig. 4 shows

Figure 1. Implementation in GeoModel of a layout used for the cosmics. The endcap calorimeters are in the 'garage' position, away from the central barrel.

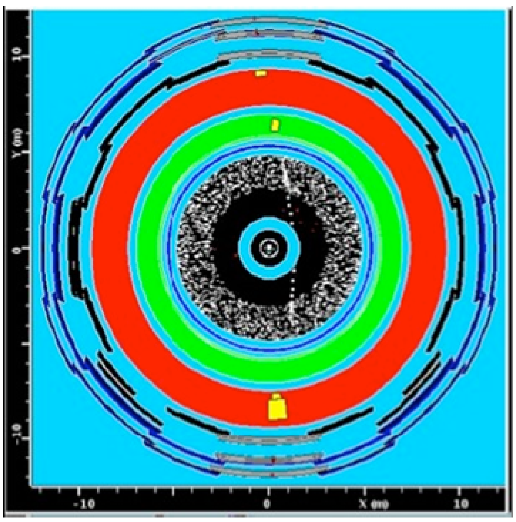

Figure 2. A simulated cosmic event. The track is curved due to the magnetic field in the Inner Detector.

Journal of Physics: Conference Series **110** (2008) 092006 doi:10.1088/1742-6596/110/9/092006

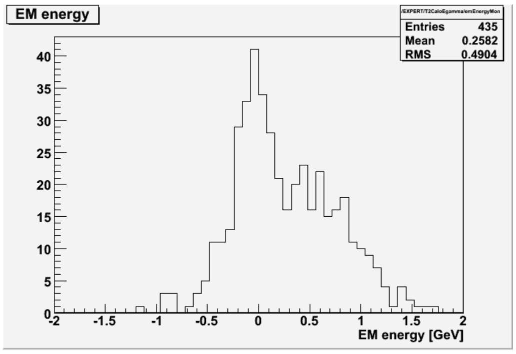

Figure 3. Energy reconstructed in the LAr calorimeter by a level-2 algorithm.

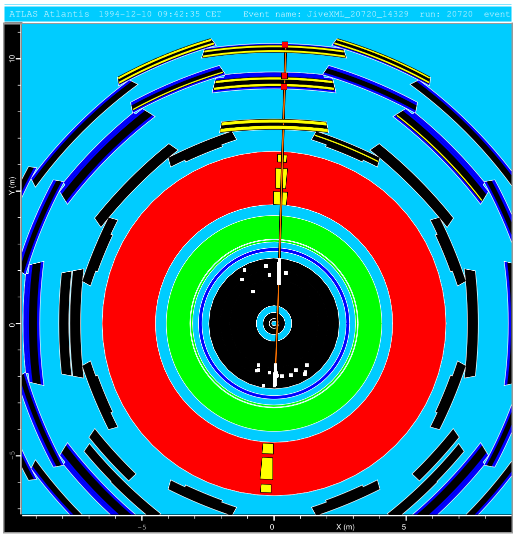

Figure 4. A combined track with hits in the Inner Detector and the Muon Spectrometer.

a combined track reconstructed by the offline software, with hits in the TRT, MDT and RPC detectors. The reconstructed energy deposits in the tile calorimeter can also be seen. The fit quality of the track is $\chi^2/ndf = 380/76$, which is reasonable, given that it is difficult to correct for multiple scattering because the momentum of the track is not known.

Each data file is reconstructed offline at the Tier-0 computer farm at CERN [6]. The output consists of ESDs, ntuples and monitoring histograms, which are typically available within just a few hours after the data has been taken, allowing for prompt feedback about the data quality. Some initial problems with the offline software were quickly spotted and corrected, leading to a job success rate that is now almost 100 %. The files produced at the Tier-0 site have been successfully exported to Tier-1 sites all across the world.

The ATLAS offline software has successfully reconstructed cosmic ray data. The offline analysis has proven crucial to ensure the correct functioning of the detector, e.g. by checking the synchronization between subdetectors. The lessons being learnt with the cosmics data will help greatly to understand the data from collision events when the LHC starts up.

References

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