OFFLINE SOFTWARE FOR THE ATLAS COMBINED TEST BEAM

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Abstract

The ATLAS Combined Test Beam (CTB) is a full slice of the barrel detector of the ATLAS experiment at the LHC and it is being tested this year with beams of pions, muons, electrons and photons in the energy range 1-350 GeV in the H8 area of the CERN SPS. It is a challenging exercise since, for the first time, the complete software suite developed for the full ATLAS experiment has been extended for use with real detector data, including detector description, simulation, reconstruction, online and offline conditions databases, detector and physics monitoring.

INTRODUCTION

The data taking has started this year on May 17th and will continue until mid November 2004: ATLAS [1] is one of the main user of the SPS beam in 2004. The setup spans more that 50 meters and is enabling the ATLAS team to test the detector's characteristics long before LHC starts.
Among the most important goals for this project:

- Study the detector performance of an ATLAS barrel slice
- Calibrate the calorimeters at a wide range of energies
- Gain experience with the latest offline reconstruction and simulation packages
- Collect data for a detailed comparison data-MonteCarlo
- Gain experience with the latest Trigger and Data Acquisition packages
- Study commissioning aspects (i.e. integration of many sub-detectors, test the online and offline software with real data, management of conditions data)

In order to fully exploit the ATLAS trigger mechanism, the SPS will also deliver beams – for two periods of one week each – with bunches of particles at interval of 25ns, namely the LHC frequency.

Important integration issues like combined simulation, combined reconstruction, connection with the online services and management of many different types of conditions data are being addressed for the first time, with the goal of both achieving experience on such integration aspects and of performing physics studies requiring the combined analysis of simultaneous data coming from different subdetectors. It is a unique opportunity to test, with real data, new algorithms for pattern recognition, particle tracking and identification and High Level Trigger strategies. A big fraction of the whole ATLAS collaboration is involved in this effort (physicists, engineers and technicians) with about 40 people in four support groups ensuring the smooth running of the detectors and DAQ.

EXPERIMENTAL LAYOUT

The setup includes elements of all the ATLAS sub-detectors (see Figure 1) :

- Inner Detector: Pixel, Semi-Conductor Tracker (SCT), Transition Radiation Tracker (TRT)
- Electromagnetic Liquid Argon Calorimeter
- Hadronic Tile Calorimeter
- Muon System: Monitored Drift Tubes (MDT), Cathode Strip Chambers (CSC), Resistive Plate Chambers (RPC), Thin Gap Chambers (TGC)

The DAQ includes elements of the Muon and Calorimeter Trigger (Level 1 and Level 2 Triggers) as well as Level 3 farms. A dedicated internal Fast Ethernet Network deals with controls. A dedicated internal Gigabit Ethernet Network deals with the data which are stored on the CERN Advanced Storage Manager (CASTOR). About 5000 runs (50 Millions events) have already been collected so far, corresponding to more than 1TB of data.

CTB OFFLINE SOFTWARE

The CTB Offline Software is based on the standard ATLAS software. About 900 packages exist now in the ATLAS offline software suite, residing in a single CVS repository at CERN. Management of package dependencies, libraries and executable building is performed with CMT.

The ATLAS software is based on the Athena/Gaudi framework [2], which embodies a separation between data and algorithms. Data are handled through an Event Store for event information and a Detector Store for condition information. Algorithms are driven through a flexible event loop. Common utilities (i.e. magnetic field map) are provided through services. Python JobOptions

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scripts allow to specify algorithms and services parameters and sequencing.

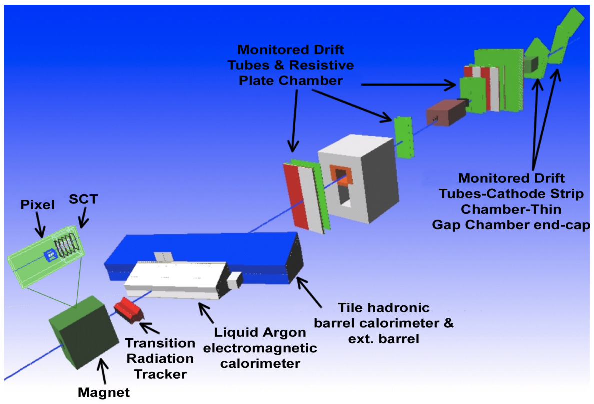

Figure 1: CTB layout as visualized by the Geant4 simulation package.

CTB Software Releases

New ATLAS software releases are built approximately every three weeks, following a predefined plan for software development. New CTB releases are built every week following a CVS-branch of the standard release. In order to cope with the two conflicting needs of having at the same time a stable software release and new functionalities (or bug fixes), we have adopted an "*ad hoc*" strategy for the CTB releases:

- incorporation of new CTB-specific code in the standard ATLAS release is done weekly performing an incremental build which takes into account only selected packages
- the CTB release is then tested and validated for about two days
- the new CTB release is installed and used for CTB operations once per week, during a period in which there is no data taking, preferably during the SPS machine development period, foreseen approximately every Wednesday

Combined Simulation

Simulation of the CTB layout is performed in a flexible way by a package (CTB_G4Sim) similar to the ATLAS G4 Simulation package [3].
Simulation of the three major sub-systems (Inner Detector, Calorimeters and Muon system), including dead material and ancillary detectors, has been carried out mostly by sub-system developers, re-using the existing ATLAS simulation code. The simulation of these sub-systems has then been integrated in the package CTB_G4Sim which takes care also of particle generation and of all the other common tasks.

Python JobOption scripts and macro files allow to select among different configurations (i.e. with and without magnetic field, different positions of the sub-detectors on the beamline, different η values, etc). The detailed comparison data-MonteCarlo is expected to be one of the major outcomes of the physics analysis.

Combined Reconstruction

Full reconstruction is performed in a package (RecExTB) that integrates all the sub-detectors' reconstruction algorithms, through the following steps:

- Access to the detector description data
- Conversion of raw data from the online format to their Object representation
- Access to conditions data
- Access to ancillary information (i.e. scintillators, beam chambers)
- Execution of sub-detector reconstruction
- Combined reconstruction across sub-detectors
- Production of Event Summary Data and ROOT Ntuples
- Production of xml files for event visualization with the Atlantis Event Display

A map of the magnetic field has been computed [4], based on the field measured in the test beam area. The map is loaded as an Athena service at job initialization, both in the simulation and in the reconstruction step.

From the full reconstruction of real data we expect to learn a lot about calibration and alignment procedures and on the performance of new reconstruction algorithms [5]. A very preliminary result on the correlation between tracks reconstructed in the Inner Detector and in the Muon system is shown in Figure 2.

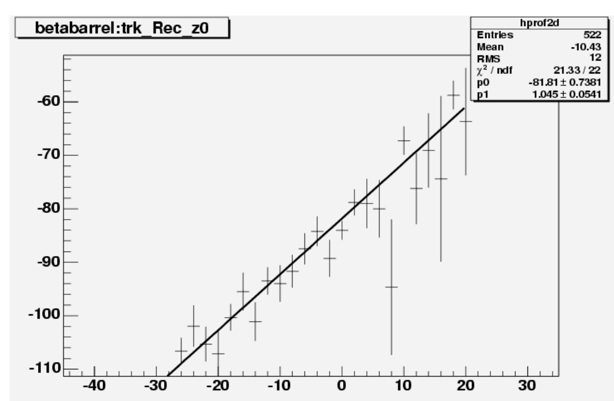

Figure 2 z0 parameter for tracks in the Inner Detector (Pixels+TRT) and in the Muon system . Preliminary results, before alignment corrections.

Detector Description

The detailed description of the detectors and of the experimental set-up is a key issue for the CTB software, along with the possibility to handle in a coherent way different versions of the CTB experimental layouts .

The NOVA MySQL database [6] and ORACLE database are presently used for storing detector description information. The new ATLAS detector description package (GeoModel) [7, 8] has also been extensively used both for simulation and reconstruction. In GeoModel, software components interpret structured data from a relational database and build from that a complete description of the detector. Detector misalignments may also be fed through the model to both simulation and reconstruction.

Conditions Database

The management of large volumes of conditions data (i.e. slow control data, calibration and alignment parameters, run parameters) is a key issue for the CTB . We are now using a database infrastructure (Figure 3) whose components are:

- Lisbon Interval-Of-Validity Database (IoVDB, MySQL implementation [9], with data stored internally as XML strings, BLOBS (Binary Large OBjects) or tables or as external references to objects stored in POOL or in the NOVA Database
- POOL for storing large calibration objects
- NOVA for storing Liquid Argon conditions data

Only the MySQL implementation of IoVDB has been used for test beam operations, an Oracle implementation also exists and improvements are expected within the LCG Conditions Database project[10].

The deployment of the present database infrastructure will be of great help in defining the long term ATLAS solution for the conditions database.

A sub-set of the information from the Conditions Database is copied to the bookkeeping database AMI (ATLAS Metadata Interface) [11]: run number, file name, beam energy, etc . Other run information is entered by the Shifter. AMI (Java application) contains a generic read-only web interface for searching, in order to help in the selection of data needed for the various analyses.

Production Infrastructure

In order to cope with the reconstruction of a very large data set, we are using an infrastructure to perform processing and re-processing of the data in short time. To this purpose, the bookkeeping database, AMI, is directly interfaced to AtCom (ATLAS Commander), a tool for automated job definition, submission and monitoring, developed for the CERN LSF Batch System, widely used during the "ATLAS Data Challenge 1" in 2003 [12].

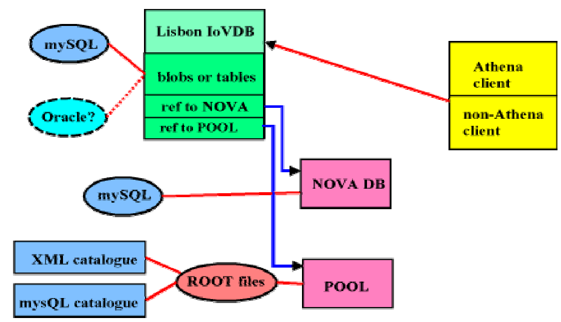

Figure 3: Conditions Database Infrastructure

AMI and AtCom have also been used for the initial production of MonteCarlo data at CERN. The "bulk" MonteCarlo production will be done worldwide, using Grid tools and the production infrastructure developed for the "ATLAS Data Challenge 2" [13].

High Level Trigger (HLT)

The HLT, namely the combination of Level2 and Level3 Triggers, is also playing a role in the CTB, both as a service ands as a client [14].

As a service it provides the possibility to run "high-level monitoring" algorithms executed in the Athena processes running in the Level3 farms. It is the first place, in the data flow, where to establish correlations between objects reconstructed in the separate sub-detectors.

As a client, it is the place where to test complex selection algorithms with the aim to have two full slices (one slice for electrons and photons, one slice for muons) LVL1 -> LVL2 -> LVL3 and producing separate outputs in the Sub Farm Output for the different selected particles [15].

CONCLUSIONS

The Combined Test Beam is the first opportunity to exercise the ATLAS software with real data in a complex setup. All the software has been integrated and is running successfully, including the HLT. Centralized reconstruction has already started on limited data samples and preliminary results are already available, showing good quality.

Calibration, alignment and reconstruction algorithms will continue to improve and to be tested with the largest data sample ever collected in a test beam environment (O 10^7 events).

It has been a first, important step towards the integration of different sub-detectors and of people from different communities (software developers and sub-detector experts).

ACKNOWLEDGEMENTS

The offline software for the Combined Test Beam relies on the effort the whole ATLAS offline software community. A special acknowledgement goes to the people involved in testing and validating the CTB releases, always providing preliminary results for better understanding the quality of the data, for both real data and simulated data. A special acknowledgement goes also to the people providing the detector description for running the ATLAS software on the CTB layout, including the magnetic field map, and to those who have applied significant adaptations to the ATLAS software in order to have it compliant with the CTB layout. Moreover, we should not forget the production group which will be responsible for processing and re-processing of the data in the coming months, in addition to the production of all the MonteCarlo samples needed by the various analyses for a detailed comparison data-MonteCarlo.

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