The ATLAS Conditions Database Architecture for the Muon Spectrometer

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Abstract. The Muon System, facing the challenge requirement of the conditions data storage, has extensively started to use the conditions database project 'COOL' as the basis for all its conditions data storage both at CERN and throughout the worldwide collaboration as decided by the ATLAS Collaboration. The management of the Muon COOL conditions database will be one of the most challenging applications for Muon System, both in terms of data volumes and rates, but also in terms of the variety of data stored. The Muon conditions database is responsible for almost all of the 'non event' data and detector quality flags storage needed for debugging of the detector operations and for performing reconstruction and analysis. The COOL database allows database applications to be written independently of the underlying database technology and ensures long term compatibility with the entire ATLAS Software. COOL implements an interval of validity database, i.e. objects stored or referenced in COOL have an associated start and end time between which they are valid, the data is stored in folders, which are themselves arranged in a hierarchical structure of folder sets. The structure is simple and mainly optimized to store and retrieve object(s) associated with a particular time. In this work, an overview of the entire Muon conditions database architecture is given, including the different sources of the data and the storage model used. In addiction the software interfaces used to access to the conditions data are described, more emphasis is given to the Offline Reconstruction framework ATHENA and the services developed to provide the conditions data to the reconstruction.

1. Introduction
The complexity of the Muon system requires taking into account a huge amount of the information for the understanding of the detector response and the event analysis.

The challenge performance resolution of ~60 μm per muon track can be obtain by a good knowledge of the detector, including a systematic check of the performance quality for each run.

The monitoring of the detector response and the parameters defining the detector conditions for each run form the conditions “non-event” data, the use and the analysis of those data will require a huge effort in terms of data storage management and development of software tools.

2. The Muon Spectrometer
The ATLAS Muon Spectrometer is the outer part of the ATLAS detector and is designed to detect charged particles exiting the barrel and endcap calorimeters and to measure their momentum in the
pseudorapidity range $|\mu|<2.7$. It is also designed to trigger on these particles in the region $|\mu|<2.4$ [1], in figure 1 there is the Muon Spectrometer layout in the Rz plane.

The quality of the muon measurement has been one of the guiding design criteria for the ATLAS experiment, the performance goal is a standalone transverse momentum resolution of approximately 10% for 1 TeV tracks. This concern is reflected by the choice of the main components of the muon spectrometer: a system of three large superconducting aircore toroid magnets, precision tracking detectors with ~60\(\mu\)m intrinsic resolution, and a powerful dedicated trigger system. Muon chamber planes are attached to the toroids to measure the muon trajectories. In the barrel, the natural layout consists of three layers of chambers: at the inner and outer edges of the magnetic volume and in the midplane to measure the sagitta. In the forward direction the chambers are placed at the front and back faces of the toroid cryostats, with a third layer against the cavern wall, to maximize the lever arm of the point angle measurement. The high precision chambers are complemented with an independent fast trigger chamber system.

![Figure 1. The ATLAS Muon Spectrometer layout in Rz plane](image)

The precision momentum measurement is performed by the Monitored Drift Tube chambers (MDT’s) and the Cathode Strip Chambers (CSC’s).

The MDT chambers cover the pseudorapidity range $|\eta|<2.7$ (except in the innermost endcap layer where their coverage is limited to $|\eta|<2.0$). These chambers consist of three to eight layers of drift tubes, operated at an absolute pressure of 3 bar, which achieve an average resolution of 80 mm per tube, or about 35 mm per chamber. In the forward region ($2<|\eta|<2.7$), CSC chambers are used in the innermost tracking layer due to their higher rate capability and time resolution.

The precision tracking chambers have therefore been complemented by a system of fast trigger chambers capable of delivering track information within a few tens of nanoseconds after the passage of the particle. In the barrel region ($|\eta|<1.05$), Resistive Plate Chambers (RPC) were selected for this purpose, while in the endcap ($1.05<|\eta|<2.4$) Thin Gap Chambers (TGC) were chosen.

3. The ATLAS Condition Database

The conditions data will be used during the ATLAS data taking, reconstruction and subsequent processing to describe the environments in which the events have been taken. These data have many different origins, and are stored in many different types of databases: configurations database and a conditions database see [2].

The configuration database will store all the data needed at the start of the run, including subdetector hardware and software configuration. The conditions database will store all the parameters describing run conditions and logging, all the data which will be accessed offline, i.e. by the reconstruction or analysis software.
3.1 The Conditions Database Technology

The ATLAS conditions database is based on Oracle DB, with additional implementation done using COOL technology [3].

COOL, an LCG product is a library to manage conditions data in terms of Interval of Validity (IoV), versions and tags, storing the info in simplified tables and accessing to those via C++ code.

COOL uses CORAL as backend, as relational abstraction layer, providing functionality for accessing data in relational databases using a C++ removing at the same time the need to submit directly SQL commands. CORAL allows database applications to be written independently of the underlying database technology (this means that COOL databases can be stored in Oracle, SQLite or MySQL), see for more details [3].

The COOL API has been integrated into the ATLAS online software. Several special purpose higher level interfaces are also being developed, including the Condition Database Interface (CDI) for archiving Information System (IS) data to COOL, the PVSS (Prozessvisualisierungs und Steuerungs-System, a process control engineering software for the read-out of the detector) to COOL interface for archiving Detector Control System (DCS) data, and specialized interfaces for saving monitoring data. In the ATLAS offline reconstruction software is the unique interface used to access to the conditions data.

3.2 The Conditions Database Architecture

COOL data is stored in folders, which are themselves arranged in a hierarchical structure of folder sets. Within each folder, several objects of the same type are stored, each with its interval of validity range (IoV).

These times are specified either as run/event, or as absolute timestamps, and the choice between formats is made according to metadata associated with each folder. The objects in COOL folders can be optionally identified by a channel number (or channel ID) within the folder. Each channel has its own intervals of validity, but all channels can be dealt with together in bulk updates or retrievals.

COOL implements each folder as a relational database table, with each stored object corresponding to a row in the table. COOL creates columns for the start and end times of each object, and optionally the channel ID and tag if used. Several other columns are also created (e.g. insertion time and object ID), to be used internally by the COOL system, but these are generally of no concern to the user. The payload columns (where the data are stored) are defined by the user when the table is created.

Table 4. Example of COOL data for the MDT calibration Data (T0 parameters). The data are stored in one single column (CLOB file of 16M), possibility to add a tag to a set of calibration parameters.

| channel | since  | Until  | payload         | tag       |
|---------|--------|--------|-----------------|-----------|
| 1       | Run1   | Run2   | T0 file1 (CLOB) | Test      |
| 2       | Run1   | Run2   | T0 file2 (CLOB) | Single Beam |

In ATLAS, the payload data can be stored in the three following ways. The payload data can be stored directly in one or more payload columns (inline data), where the columns directly represent the data being stored (e.g. a mixture of float and integer values in the columns representing status and parameter information). In second way, the payload data (in this case a single column) can be used to
reference data stored elsewhere. This reference can be a foreign key to another database table, or a reference to something outside of COOL e.g. a POOL object reference allowing an external object to be associated to intervals of validity.

A third approach involves storing the data as an inline CLOB in the database, i.e. defining the payload to be a large character object (CLOB) which has an internal structure invisible to the COOL database. COOL is then responsible only for storing and retrieving the CLOB, and its interpretation is up to the client code, see table 1.

The retrieving and storing of the data inside a reconstruction job in the Athena framework (offline reconstruction framework) is possible using the IOVService, a software interface between the COOL DB and the reconstruction algorithms via IOV range. The interplay of the Conditions and Configuration databases in the offline reconstruction framework is shown in figure 2.

Figure 2. Data Flow of the Events and Conditions Data in the ATLAS experiment. The Configuration and the Conditions Databases are shown (on the left of the picture) and their links with the Detector Hardware and Software of the experiment.

4. The ATLAS Muon Conditions Data

The Muon Conditions data architecture follows the ATLAS general guidelines.

We have different sources both from the online side and from the offline as the data quality analysis or the calibration and alignment parameters.

The online data primary define the configuration setup of the data taking (DAQ parameters) and of the Detector Control System (DCS), including hardware monitor values as: temperatures, gas pressure, voltage, etc.

Calibration and alignment constants come from analysis algorithms running on a dedicated muon calibration stream coming from the second level of the trigger [4, 5]. Finally, the data quality information, summarizing the quality status flags from the online and offline sides in a common result to be given to the reconstruction analysis. Each subdetector has its own database architecture and its own schema inside the ATLAS conditions servers: ATONR and ATLr, Oracle RAC (Real Application Clusters) running in the CERN computer centre (offline and online servers) and at Tier1s. The folders structures, as the amount of the data, are different due to the different hardware layouts and analysis approaches of the detectors.

The amount of the data for each subdetector depends on the different role and strategy in the tracking
algorithm, the data varies strictly with the time. The access via the offline framework ATHENA is done using a global ATHENA service: the IOVService, which permits to read the correct info at each run per each event number. A cross check event per event between what is stored in the database and what is available at the reconstruction level is done, renewing, in case of differences, the data.

A dedicated package to deal the conditions data exists and has been tested at the reconstruction level.

5. Conclusions

In this paper, a general overview of the Muon conditions database has been given, in particular the database architecture and the software tools have been described in details. The Model has been tested during the Computing and Detector Commissioning; during the Cosmics tests a full chain test has been performed, including the production of the calibration and alignment constant subsequent storage in the COOL folders and later access during a reconstruction job.

The Muon conditions deployment is in line with the entire ATLAS project, the results obtained have been promising, and the Muon conditions schema is now in production, additional features will be implemented in the next months.

6. References

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