A J2EE based server for Muon Spectrometer Alignment monitoring in the ATLAS detector

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Abstract. We describe the software chain for the Atlas muon optical alignment system, dedicated to the measurement of geometry corrections for the Muon Spectrometer chambers positions. The corrections are then used inside the reconstruction software. We detail in particular the architecture of the monitoring application, deployed in a J2EE server, and the monitoring tools that have been developed for the daily follow up. The system has been in production during the whole Run 1 period (2010-2013).

1. The muon spectrometer optical alignment system

The Atlas Muon spectrometer is composed of three cylindrical layers with 624 (barrel) and 578 (end-caps) muon precision chambers (Monitored Drift Tubes and Cathode Strip Chambers). For a 1 TeV p_T muon, the *sagitta* (see figure 1) of the track bent by toroidal magnetic field is $\sim 500 \mu m$. To achieve 10% resolution at that momentum, the relative positions of the chambers have to be known at $30 \mu m$ ($40 \mu m$) in the barrel (end cap) for the combination of coordinates relevant to the sagitta reconstruction. In order to follow chamber displacements, a network of optical sensors has been designed, coupled with a network of temperature sensors to take into account chamber expansion (figures 1 and 2).

The muon spectrometer's optical alignment system is split in two separated sub-systems, one for the barrel detector and another for the two end caps systems. In this note we will refer mainly to the barrel software chain. The system is composed by $\sim$ 12000 optical sensors (5800 in the barrel and 6500 in the two end cap): an optical source (Rasnik[1] mask or BCAM[2] spot) is focused by a lens on a CCD sensor (figure 1). The three elements (source, lens, CCD) are precision-mounted on different chambers on specific devices. The CCD readings are converted online to a set of parameters related to the relative positions of the devices on which the three elements are mounted. The main two parameters are the two translations in the plane orthogonal to the optical axis. Alignment reconstruction software then use the measurements from all the sensors, and determine positions for all ATLAS chambers.

The architecture of the optical alignment monitoring software can then be divided in two areas: the *online* side, consisting of a read-out system performing optical image analysis and database (DB) storage for the output parameters; the *offline* side, made of a monitoring server
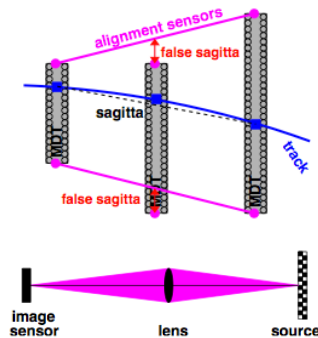
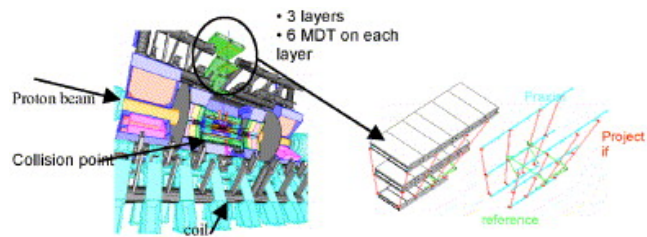**Figure 1.** Sagitta definition and optical line schema.

Figure 2. ATLAS muon spectrometer optical alignment system.

delivering services to the alignment algorithms (and to client applications) in order to compute the chamber positions and deformations to be applied at the level of the reconstruction software.

2. The software chain of the optical Muon Alignment System

The alignment system has to follow muon spectrometer deformations in quasi real time to provide corrections in a few hours after the physics data have been taken. Figure 3 shows schematically the software chain: the online chain is deployed inside the ATLAS private network, while the offline chain is deployed inside CERN GPN (General Public Network).

2.1. The online side: read-out system and optical image analysis

Optical sensor images for the barrel system are collected from the read-out[3] software running on 8 data acquisition PCs; a full read-out cycle is performed every 15 minutes (a similar schema is valid for the end cap system). Optical images are analyzed in order to compute a set of parameters related to displacements and rotations, which are stored in the online Oracle DB cluster (ATONR).

The data are then replicated to the offline Oracle DB cluster (ATLR) inside the CERN GPN every few seconds, using Oracle Streams[4]. The migration to ATLR cluster is needed because alignment algorithms are running on GPN network, outside the private online network.

2.2. The offline side : alignment algorithm and monitoring server

The data collected by the online read-out system are used as input to alignment algorithms (called *Asap* for barrel, *Aramys* for the end-caps). These programs retrieve optical sensors data from Oracle and compute the corrections to nominal chamber positions over a given IOV (Interval Of Validity). The corrections are validated and uploaded to the ATLAS condition database (COOL [5]), for use by muon reconstruction software.

As we can see in figure 3, the offline chain is made of several software components:

1) The alignment monitoring server: Java software running inside a J2EE [6] compliant application server, providing access to the Oracle DB to persist configurations, bookkeeping of alignment corrections and monitoring data.

2) Alignment reconstruction software: Asap and Aramys.

3) Client libraries to access remotely the monitoring server for visualization and data monitoring.

4) A python based web server, CherryPyCool [7]: a Restful service accessing COOL data via the COOL API, making that data available via standard GET, PUT ad POST HTTP methods.

5) Oracle Database for the alignment monitoring tables, optical sensors data and conditions data, maintained centrally by CERN IT.

The usage of a server delivering methods to retrieve, update and insert data in Oracle allows common DB access methods for Aramys and Asap. Remote clients can connect to the server by means of different protocols (HTTP, IIOP) in order to manage all the data stored in Oracle. The server runs regular monitoring tasks to provide fast feedback on the system status.
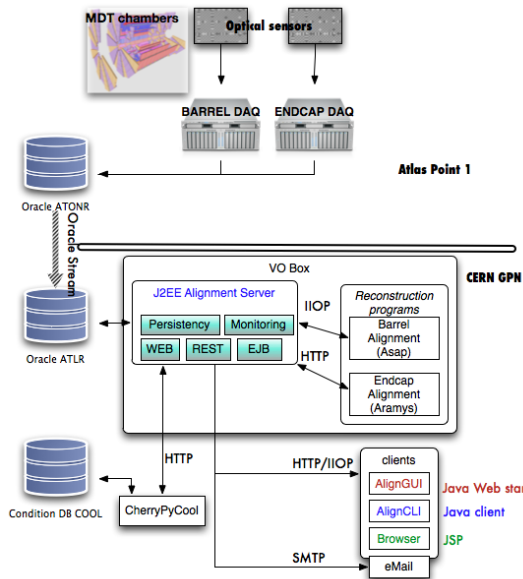

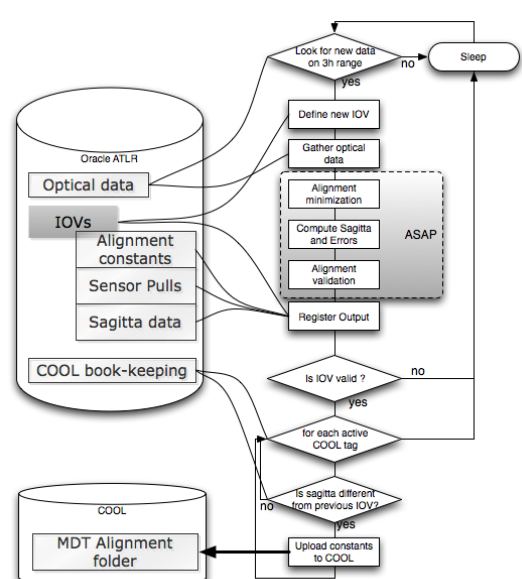**Figure 3.** General view of the software chain

Figure 4. Barrel alignment flow chart

Alignment algorithm flow chart: the alignment algorithm fits 6 positional parameters of the precision chambers and 11 deformation parameters, for a total of 21K degrees of freedom, via a minimization process that provides as output a set of geometry corrections to apply to every chamber in the muon spectrometer. The Asap alignment algorithm is written in C++ and makes (extensive) use of the ROOT[8] framework for the input and output data (ROOT trees).

The alignment monitoring is a Java application deployed inside a J2EE server[9] and relies on standard APIs for data persistency, DB connections management, authorization and authentication (among others). The server sits between the client software and the DB (multi-tier model architecture). The alignment reconstruction is managed by schedulers (fig.4): the server seeks new optical sensor data every few hours (the frequency can be configured), and the correspondent IOV found is recorded in a table. It retrieves then the data inside the IOV time ranges, starts the alignment reconstruction (calling Asap as an external library via the CORBA IIOP protocol) and stores all output parameters for that IOV in Oracle. The new corrections are validated and uploaded to the conditions database if different from the previously stored data (a cut on maximum sagitta over all sectors is used).

3. Alignment Monitoring services

The alignment monitoring server delivers services that are implemented as Java MBeans (Managed Beans). These singleton objects, available inside the application server or via remote

clients, offer a management interface and can be used in combination with Timer services to launch scheduled tasks, like alignment reconstructions and other levels of monitoring (e.g. send email summaries to experts on the server status). The main services of the monitoring server include:

- Reconstruction Manager : used to launch the Asap alignment algorithm.
- Reconstruction Scheduler : checks the time intervals in which the alignment has not yet been performed, launching a reconstruction when needed.
- IntervalMaker Scheduler : runs an Oracle procedure to find dynamically new IOVs, analyzing the stability of the optical sensors readings.
- DAQ Summary Scheduler : checks daily the DAQ status and sends the summary to experts.
- Icaras Errors Scheduler : computes the time jitter variations for every optical sensor. The parameters of a linear regression are stored in Oracle, and used in combination with the intrinsic analysis errors of the optical sensors when performing the alignment reconstruction.
- OLWatcher : once per day, an image for every optical sensor is recorded in the application server from the online read-out system. This allows the image analysis to be rerun in offline mode in case of problems (see 6). This feature has been very useful for the debugging of the online analysis algorithms.

4. The Alignment Data Model

The data model for the alignment database contains all the information needed to configure, run and debug the full software chain of the barrel alignment system, and to handle the geometry corrections for both barrel and end cap systems. The full model is available inside the ATLR cluster, distributed over two different schemas : one for all the tables related to monitoring, the other containing instead the data from optical line systems for the barrel and the end caps. The latter is a replica of the corresponding account on the ATONR cluster. We can summarize the data handled inside the alignment monitoring database in few categories:

- Optical and Temperature sensors data : input data for alignment algorithms.
- Configuration Data : configuration parameters for the algorithms and the monitoring server.
- IntervalMaker Data : data produced by the scheduled task which creates the IOVs over which the alignment software computes corrections.
- Alignment corrections : the output data of the alignment algorithms (fig. 5). Set of intervals are tagged to associate the corrections to a specific version of the alignment software. Bookkeeping of corrections uploaded in COOL DB, and other relevant results of the fit are stored (optical sensors residuals, sagittas, etc.).

5. Alignment Monitoring tools

Several client tools have been developed to monitor the alignment system: command line clients, web applications using JSP (Java Server Pages) and REST, and a java graphical interface (based on Swing and Java Web Start). The latter client application is called AlignGUI, and allows navigation through the whole set of monitoring data from the alignment system as well as to external meta data related to physics runs data taking (see 6). The GUI access remotely the monitoring server using RMI over HTTP, and is used to check the alignment fit stability, monitor the sectors in the spectrometer that have been affected by geometry changes, verify which sensors contributed most to the χ^2.
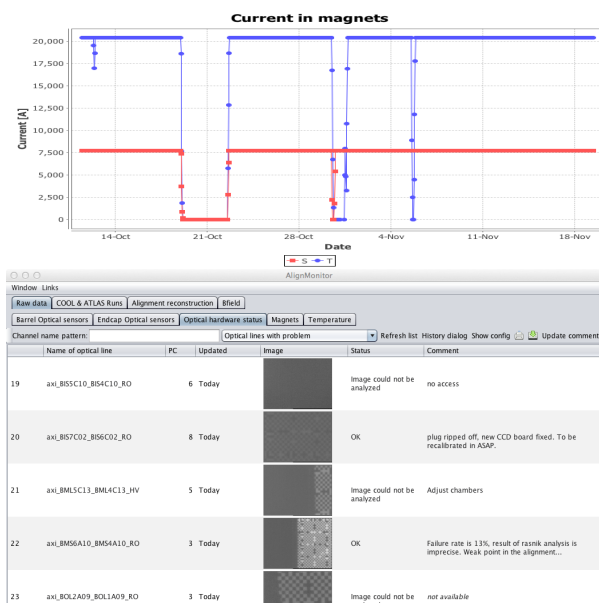
Figure 5. Alignment corrections tables structure.

Figure 6. AlignGUI example functionalities.

6. Summary

The alignment monitoring system has been running smoothly over the whole ATLAS data taking period from 2009 to 2013. The tools developed and the data model implemented in Oracle were very effective in spotting problems during the installation of the optical system, and for the daily follow up by the alignment experts.

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