A software and computing prototype for CMS muon system alignment

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A software and computing prototype for CMS Muon System alignment

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Abstract. A precise alignment of Muon System is one of the requirements to fulfill the CMS expected performance to cover its physics program. A first prototype of the software and computing tools to achieve this goal has been successfully tested during the CSA06, Computing, Software and Analysis Challenge in 2006. Data was exported from Tier-0 to Tier-1 and Tier-2, where the alignment software was run. Re-reconstruction with new geometry files was also performed at remote sites. Performance and validation of the software has also been tested on cosmic data, taken during the MTCC in 2006.

1. Introduction

Since the early stages of design and development, it was well understood that a precise knowledge of the position of the different elements of CMS (Compact Muon Solenoid at LHC) Muon Spectrometer was necessary. To achieve this goal, different hardware, software and computing solutions were developed. We discuss in this article the present situation of the later two, covering diferent issues: the calculation of alignment constants from data, and implementation of the constants obtained by this or other methods into the track reconstruction, and the workflow and dataflow in a grid environment, including remote access to the alignment database. The existing tools were tested during two major challenges in 2006 for CMS, the CSA06 (Computing, Software and Analysis Challenge, described in [1]) and the MTCC06 (Magnet Test and Cosmic Challenge, where a fraction of the detector was operated taking cosmic data [2]).

2. Workflow at CSA06

As part of the general CSA06 challenge, the Muon System Offline Alignment was tested, emulating at smaller scale the expected situation during the real data taking, starting in 2008. After data processing at CERN a new stream known as ALCARECO was produced, selecting the muon track information relevant for alignment, reducing the size of the sample by two orders of magnitude. This data was then transferred to the Tier-2 where the analysis was to be performed. Full samples were also transferred for validation jobs. In all the cases the CMS schema for data transfers was followed.

Different type of jobs were run at the Tier-2 as the data arrived. Initially basic magnitudes were plotted, checking the quality of the data. Then, alignment jobs were executed using misaligned geometries and producing new geometry databases. The time interval between sample availability at CERN Tier-0 and first results was about 24 hours.

Finally re-reconstruction was performed on full validation samples, comparing its performance for different algorithms, samples and tunings.

3. Computing infrastructure at CSA06

The alignment analysis was mainly run in a computer cluster situated at IFCA (Instituto de Física de Cantabria) which is part of the Spanish Federated Tier2 for CMS [4]. A total of 90 CPUs (Xeon at 3.2 GHz, 1 GB RAM) were available during the CSA06 challenge. All of them could be fully dedicated to the alignment exercise during significant periods of time. The standard LCG [3] software was deployed in the site.

The storage system was based on DPM [5] with a total disk space of 12 TB. An important part of this space was reserved for the data samples associated to the alignment exercise. Data was moved from CERN with PhEDEx [7], which is a CMS tool that provides an efficient data placement and file transfer system based on FTS and SRM.

On the other hand, the alignment and calibration (Alicali) tasks need access to remote databases located at CERN where Alicali constants are stored and retrieved. Since many of these queries may take place concurrently and their values are unlikely to change so often a caching proxy system based on Squid was developed by CMS. Access is then performed using a local proxy server with the FroNTier [6] package installed so the load on the central CERN database is lowered.

Standard CMS software (CMSSW) was initially installed manually, and centrally at later stages once a procedure was developed within the collaboration. For this exercise a software installation area shared among WNs was used.

4. Alignment Software

The strategy defined for the alignment in CMS software (CMSSW) consists in reading a geometry file in the format of an ORACLE DB (that could be local or remote at Tier-0, with access through FroNTier), incorporating the corrections during track reconstruction, keeping local coordinates of detectors unchanged, and applying the corrections in the transformation to the global frame. The same tools are used to simulate misalignment, providing distorted geometry files also introduced during reconstruction. One of the advantages of this method is that fully simulated samples with a misaligned geometry are not required (samples are produced with the nominal geometry, and changes take place afterwards at reconstruction level).

In particular different misalignment scenarios were designed to provide a realistic picture of the expected situation in the detector. The ShortTerm scenario represents a detector not yet aligned, when a compresion of CMS due to the magnetic field, and an elliptical deformation induced by the weight of the detector are expected. And the LongTerm scenario refers to the situation of the detector after the expected alignment precision (from both hardware and software alignment systems) has been achieved. A specific software package known as MuonAlignment was developed in order to create and manage alignment databases inside the CMS software framework. The package supports a logical structure of components following the mechanical design of the detector, in order to allow correlated misalignments of many subdetectors. The description of each scenario is provided through configuration files, providing a fast and flexible access and modification procedure.

A package called MuonStandaloneAlgorithm (figure 1) implementing a track-based alignment algorithm following Blobel's method [8] has also been developed inside the framework.

The coordinates of a hit in a misaligned geometry can be expanded in a Taylor's series as a function of the increment of the track and alignment parameters. Provided that the value of these alignment parameters is small enough (and this is always true because of a first alignment

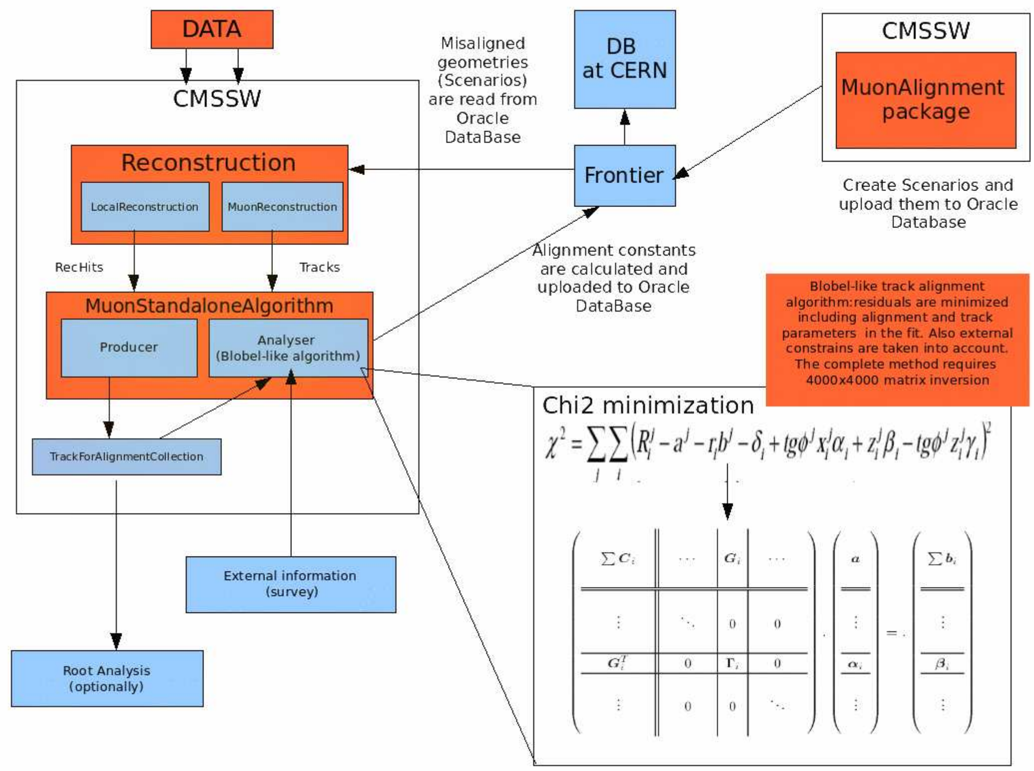
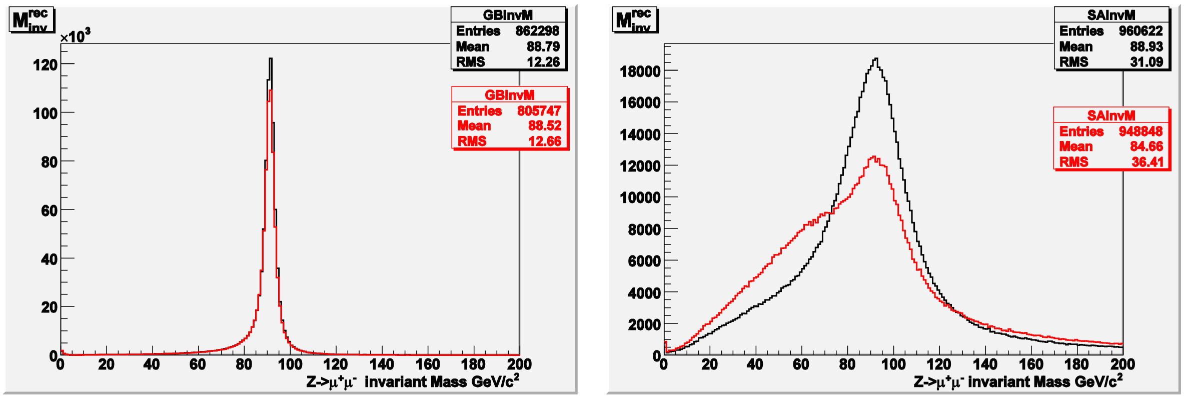


Figure 1. Alignment software framework for the offline alignment exercise during CSA06. The software is fully integrated inside CMSSW and makes use of standard reconstruction and database packages

picture is given by photogrammetry measurements), the series can be truncated leaving only linear terms, and hence, the residuals (the difference between measured and expected spatial coordinates of a hit) are a linear function of both track and alignment parameters. A fit is then performed over the residuals in order to estimate these parameters. This minimization yields to a linear equations system with a number of unknowns equal to the number of alignment parameters plus the number of track parameters multiplied by the number of tracks. The size of this system is huge as the number of tracks is a large quantity. Fortunately, after some algebra and focussing only on the alignment parameters, the dimension of the system can be reduced to the number of alignment parameters. The matrix associated to this system is intrinsically non-invertible due to some degenerated degrees of freedom. External measurements are then added as constrains to the fit to fix an absolute reference and make the system regular. Additional terms added to the tracks-only χ^2 produce new terms that must be added to the linear system.

5. CSA06 Offline Muon alignment exercise

The software tools, the computing infrastructure and the algorithms described in the previous sections, were tested during the CSA06 with different samples. Most of the tests were done with 2 million proton-proton simulated collisions, in which a Z^0 was produced, and forced to decay to muon pairs. Two different exercises were performed. The first exercise emulated a prompt analysis so Global Muons (using both Muon and Tracker detector) and Standalone Muons (using only Muon detector) Muons were reconstructed for Z^0 decaying to dimuon samples



(a) Global Reconstruction

(b) Standalone Reconstruction

Figure 2. Di-muon invariant mass for Global (left) and Standalone (right) Muon Reconstruction, using the nominal geometry (black) and the ShortTerm scenario (red)

(figure 2), running locally at IFCA, and using different geometries, obtained via FroNTier from the DB at CERN. Global Muon reconstruction is not significantly affected by the Muon detector misalignment since nominal (ideal) Tracker detector geometry was considered for this test. On the other hand, Standalone reconstruction shows the expected P_T degradation for the ShortTerm scenario.

As a second exercise, a simple version of the track-based alignment algorithm was applied by considering only the displacement in the more sensitive coordinate (Rϕ). External measurements were mimicked to avoid the problem of degenerated degrees of freedom. The procedure followed was to perform the reconstruction over a geometry containing (simulated) corrections from photogrammetry, in such a way that external measurements in the algorithm were set to 0, and only the errors had to be included in the external associated matrix.

Once the algorithm has calculated the alignment corrections, a geometry database is created, and a track fit is performed using this new geometry in the so called re-reconstruction. Invariant Z^0 dimuon mass distribution for Standalone muons was obtained in order to see the performance of misalignments and corrections (figure 3). After the corrections are applied degradation in the mass dissapears.

6. Magnet Test and Cosmic Challenge

The Magnet Test and Cosmic Challenge took place during the summer and autumn of 2006. CMS magnet was switched on for the first time, and CMS performance was checked detecting muons from cosmic radiation. Cosmic data was made available for analysis using the Grid, with a selected collection of runs transferred from CERN to IFCA (about 10 TB).

The exercise was divided in two different sub-analysis. The first one was dedicated to the alignment of the internal layers inside every DT chamber, using pre-MTCC commissioning cosmic muons and external measurements obtained from the construction sites and survey measurements. A version of the alignment algorithm was successfully applied to the $R\phi$ layers, taken into account all the degrees of freedom. Misalignments found were of the order of 80 μm for displacements and 30 μrad for rotations, but also some outliers appeared with displacements up to 600 μm. Databases with the calculated corrections were created using again standard tools and validation was performed over cosmic muons taken during the MTCC for the DT chambers. The performance of reconstruction was studied with and without corrections, observing a clear centering of the residuals, as can be seen in figure 4, and an improvement of the local reconstruction χ^2.

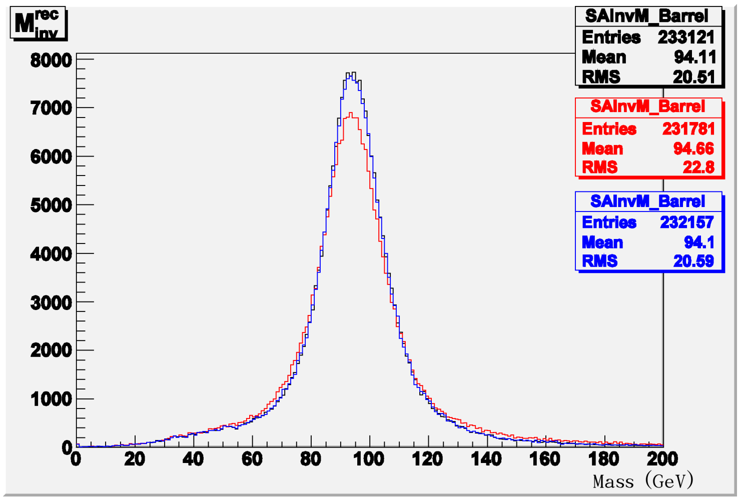


Figure 3. Di-muon invariant mass for muons contained in the region $|\eta| < 1.04$ (barrel), for the nominal geometry (black), using a simplified scenario (red) and after applying the corrections measured by the muon alignment algorithm (blue)

The second sub-analysis was related to the alignment of DT chambers inside the wheels of CMS. For this exercise only the $R\phi$ coordinate was taken into account. The algorithm made extensive use of external measurements provided by survey of the position and orientation of the chambers inside the wheel. Validation was also done and the performance of reconstruction was again studied. Results revealed misalignments of the order of 1 mm for the MTCC geometry, that were corrected to the 500 μm level using survey measurements, and finally to the 100 μm level using both survey and the alignment with tracks algorithm (figure 5).

In both cases the software chain was successfully completed: reconstruction was performed over real data, the alignment algorithm calculated alignment corrections and created the correspondient geometry databases, and finally re-reconstrucion was performed with the new geometries, resulting in clear improvements.

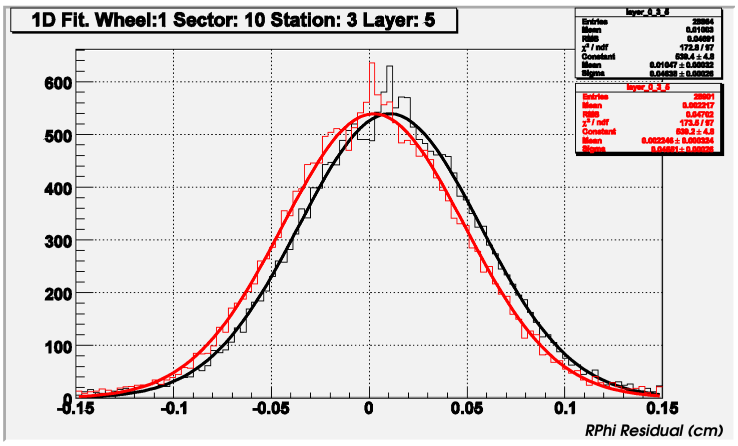


Figure 4. Residual distribution for one internal layer of a drift tube chamber. Black shows the distribution without any correction applied and red with corrections coming from alignment with tracks

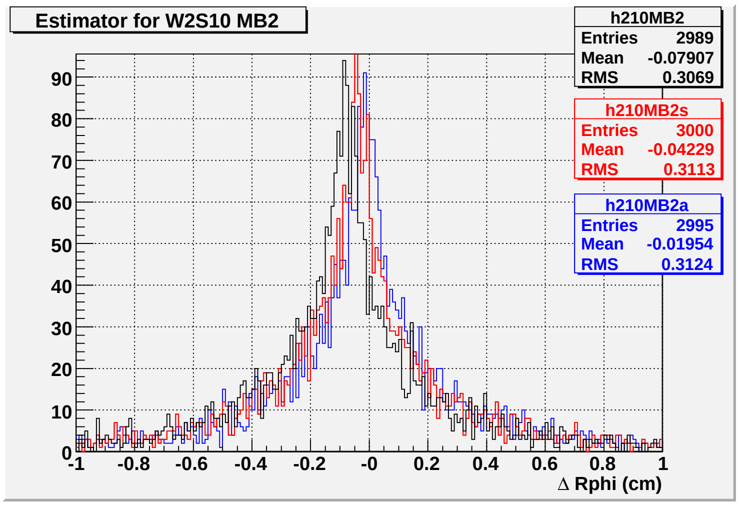


Figure 5. Estimator for the displacement of chambers in the most sensitive coordinate for one of the chambers instrumented in the MTCC. The black histogram shows the estimator when no correction is applied and the red and blue ones when corrections from photogrammetry and track alignment respectively are applied

7. Conclusions

An alignment exercise for the Muon System of CMS was developed and tested successfully during CSA06, at a scale corresponding to roughly 25% of that expected for the real data taking, confirming a correct performance of software and computing resources. The full dataflow was completed in about 24 hours, starting with the alignment and calibration stream availability at Tier-0, followed by data transfers to corresponding Tier-1 and Tier-2, and first prompt analysis and plots at Tier-2. Efficient access to remote databases was also tested, allowing the alignment algorithms to handle alignment constants from the official condition database at CERN without any significant delay.

The performance of a simplified version of the alignment algorithm was validated with simulated data (CSA06). It has also been validated in the MTCC, at a smaller scale, but with real data and realistic data-taking conditions.

Results showed that a significative improvement of muon reconstruction was achieved. A new improved version of the algorithm is now under development and will be tested during CSA07.

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