ATLAS Muon Calibration Framework

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Abstract. Automated calibration of the ATLAS detector subsystems (like MDT and RPC chambers) are being performed at remote sites, called Remote Calibration Centers. The calibration data for the assigned part of the detector are being processed at these centers and send the result back to CERN for general use in reconstruction and analysis. In this work, we present the recent developments in data discovery mechanism and integration of Ganga as a backend which allows for the specification, submission, bookkeeping and post processing of calibration tasks on a wide set of available heterogeneous resources at remote centers.

1. Introduction

The ATLAS detector is optimized for muon identification with an efficiency greater than 95% and a fractional momentum resolution better than 3% over a wide transverse momentum (p_T) range. The primary detector system built to achieve this is the muon spectrometer. The spectrometer covers the pseudorapidity range $|\eta| < 2.7$ and allows identification of muons with momenta above 3 GeV/c and precise determination of p_T up to about 1 TeV/c. The muon spectrometer comprises three subsystems:

- Superconducting coils provide a toroidal magnetic field whose integral varies significantly as a function of both η and ϕ (azimuthal angle).
- Precision detectors are located in three widely-separated stations at increasing distance from the collision region. Each station includes multiple closely-packed layers measuring the η - coordinate, the direction in which most of the magnetic

field deflection occurs. Monitored Drift Tubes (MDT) provide these measurements everywhere except in the high-η ($|\eta| > 2.0$) region of the innermost station where cathode strip chambers are used. The measurement precision in each layer is typically better than 100 μm.

- Resistive Plate Chambers (RPC) in the barrel region and Thin Gap Chambers (TGC) in the endcap region are used as trigger chambers.

Figure 1 shows different contributions to the muon momentum resolution as a function of p_T as expected from Monte Carlo simulations [1]. At low momentum, the resolution is dominated by fluctuations in the energy loss of the muons traversing the material in front of the spectrometer. Multiple scattering in the spectrometer plays an important role in the intermediate momentum range. For $p_T > 300$ GeV/c, the single-hit resolution, limited by detector characteristics, alignment and calibration, dominates. The target resolution can be achieved provided the single hit chamber resolution is kept near the 80 μm of the intrinsic resolution. The alignment and calibration should then be known with an overall accuracy better than 30 μm.

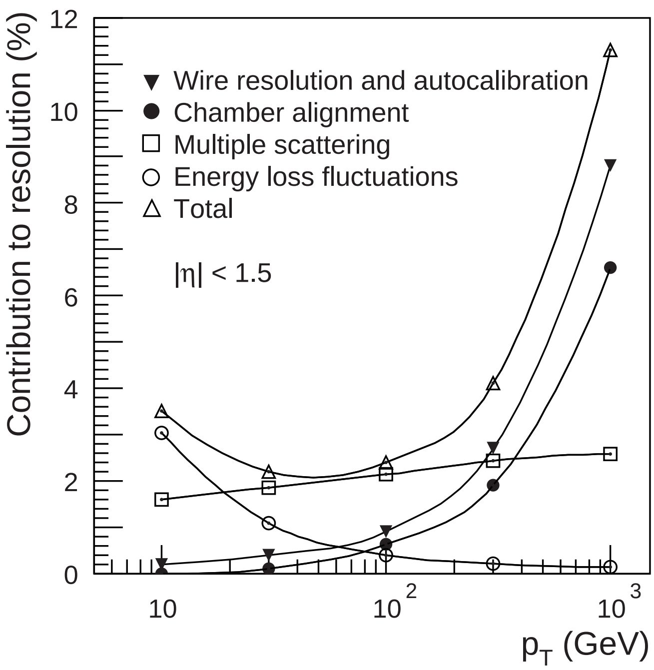

Figure 1. Contributions to the momentum resolution for muons reconstructed in the muon spectrometer as a function of p_T as expected from Monte Carlo simulations for $|\eta| < 1.5$.

This paper describes the calibration in context of MDT chambers. Section 2 deals with several steps which are needed for MDT calibrations. The procedure to collect muon triggered events and architecture of remote calibration center is mentioned in section 3 and 4. Section 5 shows the inherent latency involved in calibration framework.

2. Calibration task

The calibration of the muon drift-tube chambers is performed in several steps. In the first step the drift-time measurements of the tubes are synchronized. An offset for the drift time (t_0) can be obtained by different procedures, for example by fitting the leading edge of the drift time spectrum with a Fermi-function. It is subsequently subtracted from the measured drift time to compensate for signal propagation times in cables and electronics.

The space drift-time relation $r(t)$ is derived from the data. An initial space-time relationship to seed the procedure is obtained by integrating the drift-time spectrum. The achievable accuracy of about 200 μm is sufficient for initial track segment fits in a chamber. The optimal r-t relation is then found with an iterative procedure based on the minimization of the difference between the distance of the segment to the wire and the drift radius (residual). This is repeated iteratively. For the measurement of the momentum of the muons in the TeV-range, the $r-t$ precision is one of the limiting factors for the resolution [2]. A $r-t$ precision of 20 μm is required to reach 10 % relative transverse momentum resolution at $p_T = 1$ TeV/c.

In order to have enough statistics for the calibration, one $r-t$ relation per chamber is determined. At least 30×10^6 muon tracks are required for a single calibration of the drift parameters in the whole spectrometer. The calibration should be repeated frequently (possibly every day) to follow time variations.

3. Calibration stream

The expected maximum rate of muon triggered events on tape is 40 Hz. A dedicated procedure, allowing the extraction of muon triggered events at a higher rate has been developed in order to achieve enough statistics to be able to follow the possible time variations of the MDT calibrations. We aim at collecting enough statistics to allow a calibration per day with a sample of $\approx 30 \times 10^6$ muon tracks. Considering data taking efficiency, it leads to data acquisition rate of ≈ 1 kHz. The adopted solution, detailed in reference [2], exploits the extraction of a dedicated data stream (the Calibration stream) at the second level muon trigger.

4. Calibration processing

Calibration stream are sampled at a rate of 1 kHz, and sent to the calibration centres in Ann Arbor (University of Michigan), Munich (Ludwig-Maximilians-Universiat, Max-Plank-Institut) and Rome (INFN Roma/INFN Roma Tre). These farms, which are Tier2s in the ATLAS computing system [3], have been equipped with the software packages required by the computation and have agreed to give high priority to the computation of the calibration constants during data taking periods.

The computation model foresees that the data are sent to the Calibration Centers synchronously, in blocks of few GB as soon as they are available from the calibration stream. Therefore the local computation (and the data quality check) starts almost immediately after the beginning of the data taking. Only the second part of the computation, which is much faster than the real processing of all the tracks, is performed at the end of the data taking.

At the end of the computation, the results (i.e. the constants, together with the assessment of the quality of the data) are sent back to the central computing facilities at CERN, checked for overlaps, merged and inserted in the ATLAS main reconstruction database.

4.1. Calibration architecture

The Calibration center [4] have the same components as a standard ATLAS Tier2 center. These components allow for additional services, such as partitioning and allocation of the resources, the dynamic partitioning of the computing resources for the calibration tasks, the partitioning and reservation of the storage resources for the calibration tasks.

Calibration tasks are managed by Local Calibration Data Splitter (LCDS). The LCDS permanently watches for incoming data. As soon as the first data arrives, LCDS starts its operations, and submitting a set of jobs to the calibration batch queue. Job submission and management can be accomplished using computational tool GANGA [5].

GANGA provides a simple and consistent way of preparing, organizing and executing tasks within the experiment analysis frameworks. It allows trivial switching between running test jobs on a local resources and running large-scale calibration tasks on the Grid. The LCDS configuration file specifies input dataset pattern, backend where job should be sent to and the job executable configuration file. The dataset to be processed is queried for its location and contents in the ATLAS experiment DQ2/DDM data management database. Depending on the size of the dataset the Grid job is divided into several sub-jobs that are executed in parallel and are only processing a subset of the input dataset. During execution jobs are monitored. During job completion the results and output files are stored as a output data-set with a reference in the DQ2/DDM data management system database.

At the end of the calibration, when all the relevant data have been properly stored, the data could be in principle released (unsubscribed), and deleted from the Tier2 storage. In case there is a need of reprocessing, the data have to be re-subscribed from the Tier1, although a manual option exists to keep the data for a longer period in the Tier2 storage.

MDT calibration jobs produce a sizeable amount of information ($\approx$ 50 MB/day) that is essential to evaluate the quality of the calibrations. The quality and stability of the individual tube parameters, as well as of the space-time relation, must be continuously monitored. It is important to note that quality checks cannot be performed by the ATLAS online monitoring: not only a high statistics is needed to reach the desired accuracy, but only hits associated to good tracks will have to be used to avoid being overwhelmed by the noise. Validation is therefore a crucial part of the MDT Calibration procedure, and all data needed for it must be accessible from quality checks programs.

A dedicated MDT database (Calibration Database) [6] has been implemented to store the complete calibration information. Validation procedures makes use of the additional parameters to ensure that the calibration constants have been correctly computed. Also, the newly produced constants are compare to those from the previous data taking to decide whether the Conditions DB must be updated. The full information produced at every stage gets store in local ORACLE Calibration databases which is replicated via ORACLE streams to a central database located at CERN: this allows each Calibration site to access the data produced by the others and to eventually provide back-up should one site become unavailable for any reason.

5. Latency

This section describes the latency involved in the MDT calibration framework as described above. The number of subjobs depends on number of files in the calibration stream dataset. Figure 2 shows the distribution of time elapsed between datset creation and when the data has been processed and is available in the remote calibration centres. The latency is peaked around 2 hours. This latency can further be reduced by splitting the job into more number of subjobs.

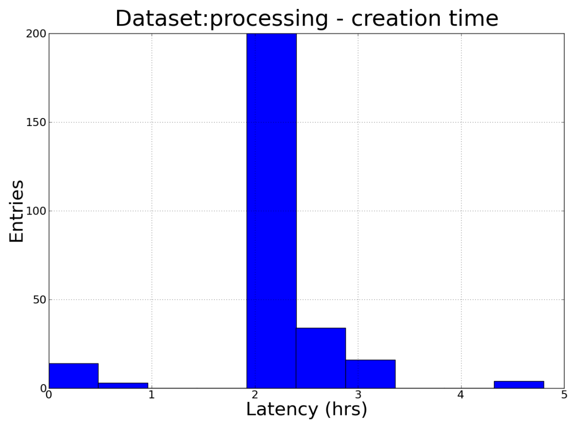

Figure 2. Distribution of time elapsed between dataset creation and processed for tha same period.

6. Conclusion

The Remote Centers used for the calibration of the MDT chambers of the ATLAS Muon Spectrometers have been set up and their functionalities have been tested with real data. The performance are satisfactory and we are looking forward to face the challenge from large amount of data during LHC p-p collisions at higher energy and luminosities.

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