ATLAS

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A proposal for the calibration and alignment of the ATLAS muon spectrometer

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Abstract

A proposal for the computation of the MDT drift parameters and the chamber positions is presented using a dedicated data stream created at the on-line level and transferred to dedicated calibration computer centers. The calibration parameters are computed on these centers, validated and then loaded into the ATLAS database. The muon groups of Michigan, Munich (LMU and MPI), Roma ("La Sapienza" and "Roma Tre") and Saclay propose to the ATLAS collaboration to assume the responsibility of these operations.

Subject to the approval of the respective funding agencies

1 Introduction

The full physics reach of the ATLAS muon spectrometer requires precise determination of the calibration and alignment parameters. The test beam and laboratory experience shows that in order to reach the ultimate precision of the spectrometer, the drift parameters of the MDT tubes have to be updated frequently. The muon community via the MDT calibration group has produced a detailed model for this procedure [1]. In addition, some of the alignment parameters which cannot be determined with sufficient precision from the optical systems have to be derived from reconstructed tracks [2]. These procedures require the extensive collection of data, possibly in a separate, dedicated calibration data stream, and the use of large computing facilities for analysis. Both these operations – data collection and analysis – require manpower and experience in data acquisition, computing, software, detector physics and analysis.

This note expresses the intention of some of the muon groups to produce the calibration parameters using their local computing facilities (the so-called *tier-2* computing centers), and then to provide these constants to the whole ATLAS community. Due to the large amount of work required, the groups which sign the present proposal are open to discussion to enlarge the calibration group to other ATLAS institutions as well as individual experienced physicists from the muon community. The proposal is subject to the demonstration of its technical feasibility and detailed tests are in progress for this purpose. The proposal is also subject to the approval of the respective funding agencies which must provide the necessary computing and manpower resources.

This note does not contain a full technical description of the project, which in part is available [1, 3] and in part will be produced when the tests in progress will be concluded. In the next sections the main aspects will be reviewed. Section 2 summarizes the data requirements and section 3 is devoted to the data collection. Section 4 describes the data transfer and the calibration computations and section 5 the data validation. Finally, section 6 contains a list of milestones, which have to be successfully passed to validate the project.

2 Data requirements

This section is a summary and an update of the ATLAS muon calibration document [1] (and references therein), which justifies the values presented in this proposal. Here, the following requirements are assumed :

- the t_0 computation has to be repeated at least every week using $\sim 20,000$ muon hits per tube;
- therefore, a total of $\sim 10^8$ muon tracks have to be collected for each day of running, uniformly distributed in the full spectrometer;
- the *r*-*t* function calculation has to be performed daily;
- the number of *calibration regions* (i.e. the regions of the spectrometer with similar drift properties and which use same *r*-*t* function) is of the order of some thousands; a conservative estimate of this number is $\sim 10,000$ regions in the barrel and $\sim 5,000$ regions in the end-caps;
- the same data sample collected for the t_0 computation can be used for the *r*-*t* determination.

Below we discuss data collection from the on-line DAQ system and the resources for the data analysis and validation.

For the alignment the following tasks have to be completed by means of reconstructed high-p_T tracks:

- small barrel chambers with respect to large barrel chambers;
- *BEE* chambers with respect to endcap *EC* chambers;
- *EC* with respect to barrel spectrometer;
- *BIS8* with respect to *BIS7*.

The target precision transverse to the track direction in the bending plane is 30 μm. The alignment parameters have to be updated with a frequency of 2 to 4 hours to follow the expected day-night variation. Each task requires special track selection in specific ($\Delta\eta$,$\Delta\phi$) regions. To reach the required precision, a total number of 2×10^6 muon tracks have to be collected per day.

3 Data collection

From the figures above, it is estimated that the muon calibration requires a peak acquisition rate of the order of 2.5 KHz, a number exceeding the output of the ATLAS Event Filter.

Fortunately, the calibration does *NOT* require the complete information of a standard ATLAS event. Only the muon spectrometer data (MDT, trigger chambers and DCS information) are used by the calibration programs. It is estimated that the size of a single "event" (i.e. a single muon in the spectrometer) can be reduced to $\sim$ 1 KByte, if only the hits in the triggered region of interest (ROI) are transferred along with the associated hits in the trigger chambers. This solution requires the collection of $\sim$ 100 GB per day, which is feasible with the present ATLAS on-line computing facilities.

A model for the data selection and collection in agreement with these criteria has been recently developed [3]. It consists in creating a separate "muon calibration data stream" from the Level 2 processors, with some capability of track selection based on momentum and geometrical parameters. The data collection runs in parallel with normal physics data taking.

The ATLAS DAQ community is well aware of the muon group requirements and is presently evaluating the model. In this note it is assumed that the model, or an equivalent one, will be implemented and normally run in the standard ATLAS DAQ.

4 Calibration strategy

This section shows the proposed solution for the computation of the calibration and alignment constants. The main requirement is to build a reliable and robust system, able to cope with the huge amount of data required to produce a validated calibration on a daily basis.

The method consists of creating a pool of *calibration centers* (associated with ATLAS tier-2 centers), where the data of many adjacent trigger towers are analyzed. Up to now, the following groups have expressed their intention to create a calibration center :

- The University of Michigan, for the spectrometer end-caps;

- Munich (LMU and MPI), for the spectrometer barrel and the alignment tasks;
- Roma ("La Sapienza" and "Roma Tre"), for the spectrometer barrel.

These groups have independently proposed to their funding agencies to locate a tier-2 in their laboratory (at Michigan, Munich MPI and Roma "La Sapienza" respectively).

The calibration centers will agree on a recipe for the data splitting, possibly containing some overlaps for operational checks. For the system commissioning, the data will be independently calibrated in each center, and the results compared to validate the procedure. In case of a major failure of a single tier-2, the task assignment among the centers will be temporarily revised to allow for a fast analysis of the data.

4.1 Computing requirements

From the figures quoted in section 2 and the conservative estimate of 0.2 s/track for calibration and 1 s/track for alignment on a present-day CPU (2.5 GHz, 100% efficiency), an overall requirement of 6,000 CPU hours/day is needed, corresponding to $\sim$ 300 processors of the present type. Although this rough estimate deserves refinement, it clearly shows the feasibility of the system provided that the calibration computing centers, associated with tier-2 centers, are well-equipped and able to devote a significant fraction of their computing capability to this task.

4.2 Data splitting and transfer

A possible model for the data transfer is :

1. from the ATLAS experiment to the CERN tier-0; the calibration data represent a small fraction of the total data of ATLAS (100 GB per day, corresponding to few $\times 10^{-3}$ of the total ATLAS standard data stream [4]);
2. in the tier-0 the data are split by trigger towers or alignment tasks into many separate sub-streams;
3. each sub-stream is sent to a different tier-1; in normal conditions, the data are *NOT* stored in the tier-0;
4. in each tier-1 the data are copied to tape, for further analysis and backup, and then sent to different tier-2 centers; the data are *NOT* stored in the tier-1 disks in normal conditions;
5. in this way each calibration computing center receives a fraction of the total data, corresponding to an integer number of trigger towers.

Tests are currently in progress on these issues. Also alternative solutions, not using the tiers, are being considered.

The data stored on tape, as well as all the results of the analysis will be fully available for the ATLAS collaboration. In future they could be used for other purposes such as further calibrations, alignment or physics studies.

4.3 Data analysis

Within each tier-2 the data are again split among different CPU's so that a single processor analyzes only one (or a small number of) trigger tower(s) or only one type of alignment task. The calibration analysis program computes both the t_0's and the r-t's in a single step with the method described in [1]. In this way tracks from the same ROI are analyzed by a single CPU and the analysis process is highly efficient.

The present methods allow the computation of the drift parameters without a precise knowledge of the chamber position, using (if necessary) the information of the inplane optical sensors only. Therefore the calibration can be performed before the alignment procedure. For the alignment analysis, the alignment parameters derived from the optical systems have to be used as a reference for the positions of the chambers with precise optical monitoring and as a starting point for those with a less precise optical measurement. These parameters are stored in the DCS conditions database and are accessible at the tier-2 centers. As alignment does not require very accurate r-t relation, the calibration parameters of the previous iteration can be used.

After the validation (see next section) the calibration parameters are stored in the ATLAS conditions database and made public for the whole Collaboration. This part of the procedure consists in the transfer of a small amount of data ($\sim$ 25 MB / day) from the calibration centers to the conditions database.

The calibration groups will make frequent reports to the ATLAS Collaboration on the calibration and alignment diagnostics (failure rate, performances, accuracy, and similar figures) and the resources used in the operations (number of CPU's, computer time, number of physicists and technicians involved, etc.)

4.4 Human resources

The operations described in the previous paragraph require substantial human resources. The work necessary to set-up and commission the system is not considered here since it involves the expertise of the full muon community and includes all the work already produced in the field. The following labor estimates show instead the maintenance and running of the system, including the validation step. The people need to be recruited in the proponent groups (or in the groups with large expertise in the MDT calibration) with the help of the respective funding agencies. The following list constitutes a preliminary estimate of such resources, in the standard units of full time equivalents, *FTE* (a single FTE can be composed by a fraction of the work of many real people) :

- the maintenance and delivery of the DAQ for the calibration data stream will be delivered by the HLT/DAQ groups; it is highly relevant (and appreciated), but it is outside the scope of the present estimate;

- in standard conditions the data transfer process and the storage at tier-0 and tier-1 do not require additional manpower; the supervision of the operations, the functioning of the transmission links and the prompt reaction to errors are estimated to 0.5 FTE per calibration center (i.e. a computing expert on call, high priority);

- the program running and prompt debugging of the calibration software will require 0.25 FTE for each calibration center (software or detector expert on call, high priority); for the center responsible for the alignment tasks, an additional 0.20 FTE should be devoted to running and debugging of the alignment software;

- the long term maintenance and update of the calibration software requires 0.5 FTE in total[1] (software or detector expert, normal priority); the alignment part will also require 0.5 FTE;
- the calibration and alignment analysis and validation requires 2-3 FTE for each calibration centers (detector or analysis experts); they will probably run with a shift system to ensure 24-hour coverage of the operations. After some experience is gained these estimates will likely be relaxed and the human resources can be replaced by automated systems. However, the first phase of the LHC will require a large effort for ATLAS physicists.

5 Calibration and alignment validation

The validation of the calibration and alignment is an important ingredient of the proposed procedure. This subject is still under study, mainly because of the lack of realistic cases of computation failures. The following discussion is therefore qualitative.

The validation of the calibration will be performed just after the computation in the same calibration centers with two different methods :

- internal consistency of t_0's and r-t functions;
- physical tests with known processes.

The methods are discussed separately in the following sub-sections.

The validation procedure includes the choice of a fallback option, to be used in case of calibration failure (e.g. recompute, use the previous parameters, use a default calibration).

At different calibration centers, it is essential that the calibration procedure be uniform and transparent. After a (hopefully short) period of commissioning the decision process should become automatic whenever possible and should follow precise rules. Therefore, the control procedure will be proposed and updated by a dedicated "task-force" (to be appointed by the muon management), and discussed in the muon meetings.

The validation of the alignment procedure will rely on the track and segment reconstruction quality and on the consistency between the track reconstruction and the optical system in combined fits of tracks and optical data.

5.1 Internal consistency

Some of the checks are discussed in [1]. Essentially they can be divided in two types :

- consistency of t_0's and r-t's;
- time stability.

In the first type we check for the presence of the correct statistics of hits, the convergence of the fits, an acceptable value of the χ^2 probability, the physical meaning of the parameters (e.g. acceptable t_{max}, small uncorrelated noise), the monotonicity and smoothness of the r-t, etc.

The second type of checks compares the newly fitted parameters and those preceding. A sudden and inexplicable change may indicate a possible problem and has to be investigated.

[1]This work will be normally produced by the authors of the calibration software and is independent from the present proposal.

5.2 Physical checks

These checks use both the calibration data stream and a small fraction of the normal ATLAS data stream.

An example of a test with the calibration data stream is the measurement of the muon inclusive cross section as a function of the momentum, angle, spectrometer position. These values need to be both unvarying in time and physically meaningful (e.g. constant in azimuth and symmetric for $\pm\eta$). A more elaborate list of checks will be compiled by the calibration task force mentioned in the previous paragraph.

The physical tests with the normal data stream have been studied in [5]. For these tests, a limited fraction of the standard ATLAS data stream ($\sim 10^5$ events / day) will be transferred to the calibration centers, reconstructed and analyzed for technical results (e.g. presence and width of the Z peak). The selection will be the existence of at least two high-p_T muons of opposite charge at the Event Filter level. Only the inner detector and the muon spectrometer will be fully reconstructed. The CPU time and disk space are estimated to be 100 CPU hours and 200 GB per day. These events do not need to be stored in the calibration centers.

6 Milestones

Although the main features of the project are well-established, many aspects need further study and clarification. A list of such topics is presented here :

- Determination of the number of calibration regions. In the present model it can be changed easily. However, it is a necessary ingredient for all the estimates of the computing and manpower resources. A first approximation can be established using a detailed detector simulation. This study is planned with the data of the *Data Challenge 3* (DC3).

- Frequency of the calibration. It depends on the time variation of the drift parameters. The present understanding relies on test-beam data. More information will come from the cosmics data-taking, but both the low statistics and the low energy of the data will prevent an accurate study.

- Determination of the track selection criteria for each alignment task. This will provide a more precise estimate of the rate of calibration events and the frequency of the alignment procedure which may depend on the collider luminosity if the rate is lower than expected (e.g. for tracks in the overlap of small/large chambers).

- DAQ collection model. A close collaboration with the HLT/DAQ groups is planned. First results are expected before the end of the year 2005.

- Data transfer from ATLAS to tier-0 to calibration centers. Tests are in progress both in Europe and USA. A crucial aspect is the existence of a fallback solution in case of failure of the transfer.

- Computing time in the full ATLAS environment (Athena + full initialization). A preliminary working implementation of the calibration software in the Athena framework is needed. The tests are in progress.

- Data splitting software. Experts are working on the subject. The first tests are foreseen with the DC3 and cosmics data.

- Validation procedure. The subject is discussed in section 5. Given the importance and the complexity of the problem, the work should proceed in collaboration with the whole muon community.

Several "review" sessions, at approximately six month intervals, are foreseen to check the milestones and the readiness of the proposed calibration operations.

In conclusion, the goal of these activities is a working prototype of the calibration operations to be ready at the start of the experiment in the year 2007.

References

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