Calibration of ATLAS Resistive Plate Chambers

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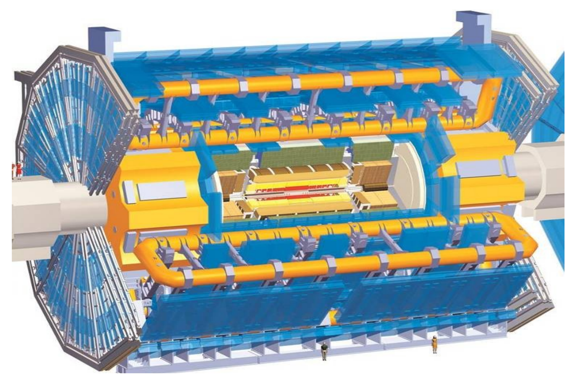
ATLAS detector [1]



Precision Track Reconstruction:

- 1150 Monitored Drift Tube Chambers (MDTs)
- 32 Cathode Strip Chambers (CSCs) in the region closest to the beam pipe

Trigger and 2nd coordinate measurement of trajectories:

- 605 Resistive Plate Chambers (RPC, Barrel region)
- 3588 Thin Gap Chambers (TGC, End Cap region)

Magnet System:

- Toroidal field geometry, 8 (Barrel), 2x8 (End Cap) superconducting coils, bending power up to 7.5 Tm

Constraints and requirements

The challenging LHC environment and the ATLAS physics programme, call for severe requirements on the muon trigger detector:

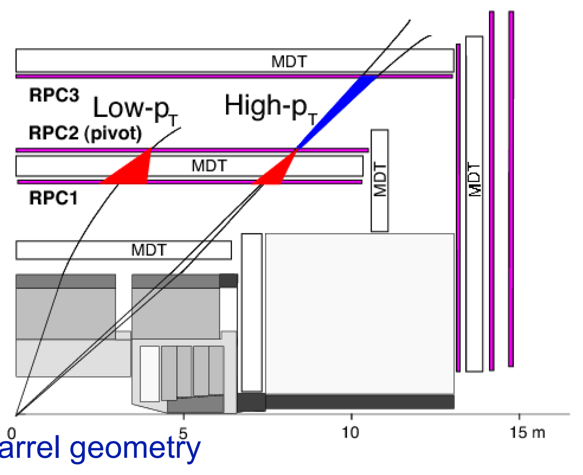
Rate capability → 100 Hz/cm^2 expected rate including a safety factor of 5

High trigger selectivity → 2D readout needed

ATLAS precision muon tracking is available only in the bending view, ***the second coordinate is obtained from the trigger detector***

Trigger efficiency robustness: 3 trigger doublets chambers (6 tracking planes), as shown in the plot; 3/4 majority on the lowpt trigger + 1/2 majority for the high pt trigger.

Comfortable bunch crossing (25 ns) ***identification*** well achieved with a nanosecond time resolution.



Maximum geometrical coverage: 26 different unit formats to match with the barrel geometry

The RPC system is a ***3D tracker*** with a cm resolution matched with a ns timing

In order to fully exploit its potentialities, such a complex system needs to be fine-tuned, adjusting all operating parameters in order to achieve the best possible (homogeneous) performance over the full barrel region.

This leads to the necessity of a ***dedicated software suite***, to extract from all available data sources (detector control system, detector readout, data from other detectors) the needed information.

Computing challenges

- The high number of readout channels (~350000) calls for severe requirements on the analysis tools to be developed.
  - high-statistics data samples will have to be used as input, if granularity up to the strip level has to be achieved. We estimate about 10 million muon tracks will be needed for a *very minimal*, *rough* estimation of performances of the single readout channels.
  - the results would be unmanageable without a proper interface to some database technology. Considering one full calibration per week, we estimate an amount of data of about 1.6GB/year, to be archived in such a way that it can be used to track back in the past the behavior of each readout channel
  - the CPU power needed for the analysis makes it necessary to use distributed computing resources. A dedicated farm at Naples has been setup and is being used for the most CPU-intensive tasks
- In addition to the information extracted from the read-out data, detector control system (gas flow, power settings, gap currents,...) and environmental parameters (temperature, pressure,...) must also be taken into account, to provide a complete frame for RPC calibration.

Input data / analysis strategy

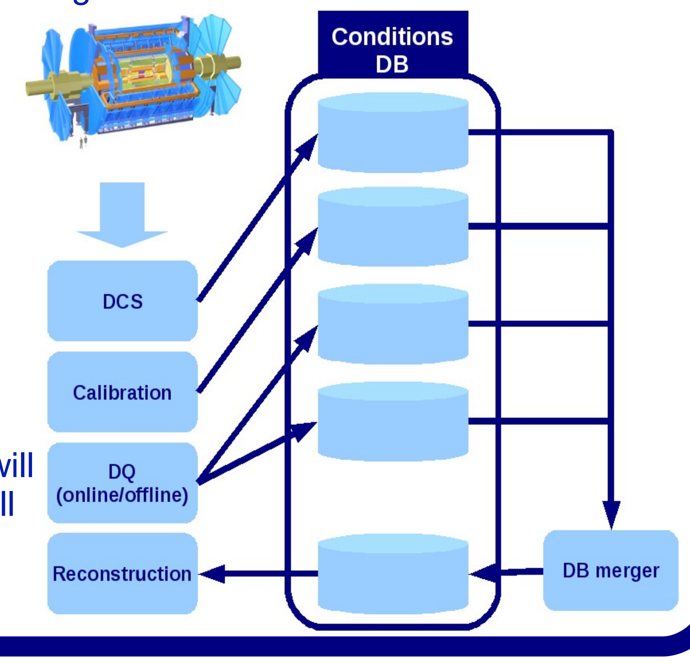
- ATLAS data is divided into different *streams*. They can correspond, for example, to different trigger menus (calorimeter trigger, muon trigger, minimum bias trigger, etc). An *express stream* is also foreseen, to be used for detector monitoring (but also including the most promising topologies for discovery channels), which will have the highest priority in the data processing. All these streams contain full events, and can be used, to some extent, to estimate the detector behavior by means of Data Quality applications.
- However, in order to achieve a detailed and reliable measurement of the detector response up to the level of the individual strips, a significant number of muon tracks must be analyzed, which is not achievable in a reasonable time with the normal data streams. A dedicated stream has been foreseen to answer to this kind of necessities, called *muon calibration stream.* It contains the output of the Level 2 muon trigger, hence it comes at a much higher rate than the events selected by the full trigger chain. Each event contains *only hits from the muon spectrometer*, in a region where a muon trigger occurred, i.e. a two-muons event would be split in two calibration stream events
- The main advantage of the calibration stream is its high statistics. Its simplified event format, which contains only muon hits in only one part of the spectrometer, allows a relatively easy and fast reconstruction of the muon tracks. This is much useful, given the high number of events to be processed. On the other hand, the fact that it does not contain full events, means that it cannot be used in a straightforward way for a reliable measurement of the noise rate.
- From the point of view of the analysis algorithms, there are two main issues in our case: first, RPCs are actually providing the muon trigger and, second, RPCs are also used in reconstruction; in particular, they are the only source of space measurements in the non-bending direction. Both these effects tend to introduce a bias on efficiency measurements if not adequately treated
- As far the the reconstruction bias is concerned, one simply has to exclude from pattern recognition and track fitting one given layer, whose efficiency can thus be measured with no bias at all. On the other hand, removing the trigger bias is less trivial. Knowing the trigger configuration (in particular its majority) one can extract from the data an unbiased sample for a given layer. For example if the trigger is requiring a coincidence of at least 3 RPC layers out of the 4 in the inner station one can have an unbiased efficiency measurement for layer 1, by using only events where layers 2, 3 and 4 had a hit. This approach is particularly good for monitoring during normal data taking, and has been already implemented in the analysis. One could also run with dedicated trigger configurations where a given layer is excluded from the trigger decision. This second possibility is a better choice in dedicated calibration runs, since higher statistics can be achieved
- In order to ensure redundancy and robustness, a twofold strategy is used for RPC detector studies:

1) Exploiting the precision of the muon tracking detector:	2) Using stand alone, RPC-only tracking:
•☺Tracking and extrapolation to RPC layers takes into account materials and magnetic field •☺precise extrapolation allows to determine spatial resolution and to study small local effects •☹applicable only to runs where tracking chambers are on •☹presently all RPC hits are used in reco, hence a bias is introduced in efficiency measurement. This will be fixed in a more refined version of the analysis which is in preparation.	•☺Does not depend on tracking detector at all •☺Dedicated tracking algorithm avoids reconstruction bias on efficiency (by not using hits of a given layer) •☹Interoperability with other reconstruction tools is missing •☹Magnetic field and material effects not implemented yet •☹Extrapolation precision limited by RPC granularity

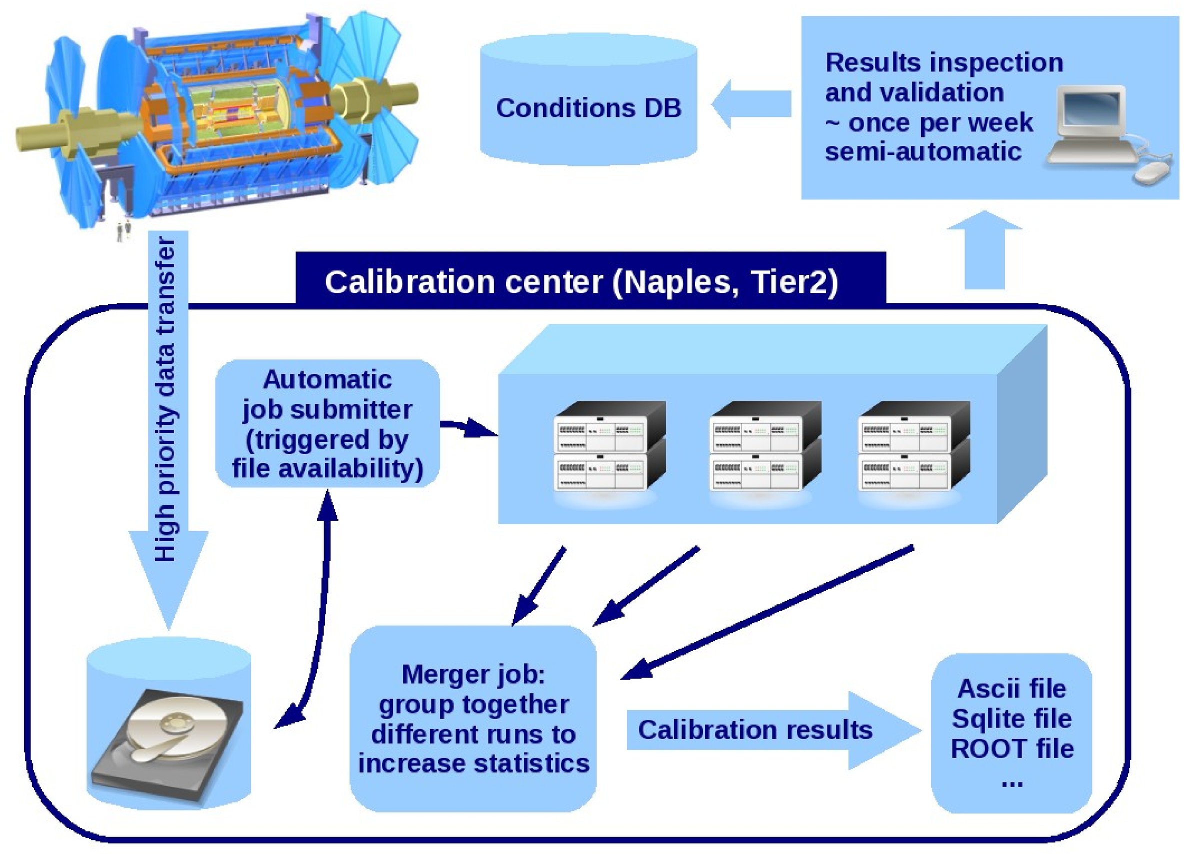
- The baseline strategy is to exploit the possibilities given by both our analysis techniques and both the data sources:
  - Data Quality applications, running on the full streams, measure all relevant quantities using standalone RPC tracking. This is done mainly at CERN's computing facilities.
  - Different analysis jobs perform high statistics analysis on the calibration stream, using the full tracking capabilities of the muon spectrometer. A computing farm has been foreseen at Naples for this kind of studies, where calibration stream data is replicated
- Other possibilities are of course available (running DQ-like analysis at Naples on the calibration stream or running precise tracking on the full streams) and, even though they would not add any new information to what already obtained by the previous ones, they play an important role as fall-back solution in case any of the baseline measurement fail.

Calibration output

- The aim is to measure with enough precision all the quantities sensitive to the working point. This includes for example the panel efficiencies and the gap efficiencies (a good estimation of the latter is already achievable by looking at efficiency of any of the two readout panels corresponding to a given gap).
- The average size of RPC clusters (i.e. two or more adjacent strips with hits in time coincidence) is also a very important parameter, being very sensitive for example to front-end threshold settings, in particular when measured at working point. Moreover, one characteristic of RPCs is that a cluster with size 2 is more precise than a cluster with size 1, being the former in general only possible when a particle crosses a small region between two neighboring strips. This means that, when using a precise enough tracking detector, one can measure the different space resolution for clusters of size 1 and 2, and give this information back to the reconstruction algorithms for proper error handling.
- Counting rates per panel and per gap are also crucial in understanding the evolution of the status of the detector in time
- All these quantities, with granularity up to the strip level, are presently stored in a dedicated structure in a database (ATLAS Conditions DB [2]). In addition to this, a separate structure keeps track of all the detector control system and environmental parameters. Two more structures are presently used by the DQ applications (online and offline) to store their results.
- For performance reasons, reconstruction algorithms will need to access only one, smaller structure, with reduced granularity. This will be created by a dedicated algorithm (still to be prepared), which will extract relevant information from the other structures and merge them into a table to be exposed to reconstruction clients.



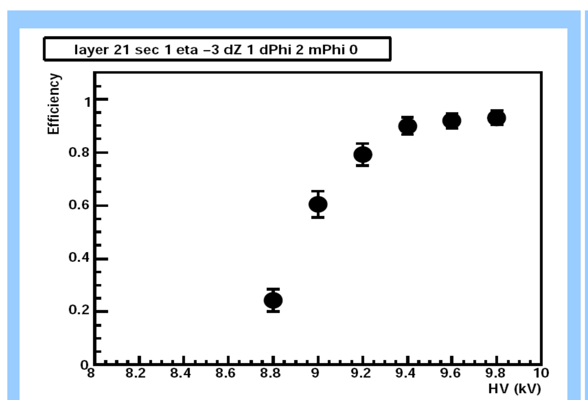
Calibration data flow



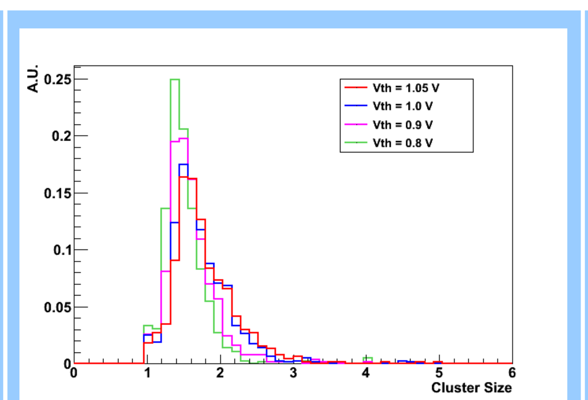
- Plot shows a schematic view of the RPC calibration flow
  - Using precise tracking, and calibration stream
- Muon calibration stream will be copied at calibration center with high priority
- Data arrival will trigger job submission
- The ganga [3] tool is used for job submission and monitoring
- The details of the merging process may vary, depending on the granularity (i.e. statistics) ones wants to achieve
- All steps are presently working, but automation (in particular the job submitter) still has to be implemented

Results with cosmics

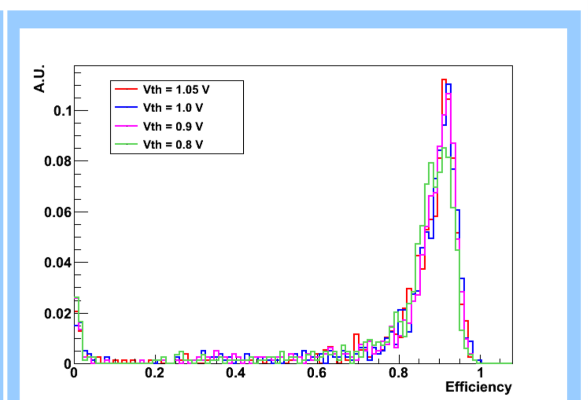
- Several dedicated calibration runs were taken in the last months in order to test the apparatus and to exercise the software tools for DQ/Calibration
  - We show here some results just to give an idea of the functionality of the software we have put in place.
  - They must be intended as PRELIMINARY
- Since for technical reasons the muon calibration stream was not available for those runs, results shown here were obtained with the full stream, with granularity up to the panel level.
  - Tests with muon calibration stream were performed on different runs (less relevant for the detector calibration), and the software chain was proved to be functional



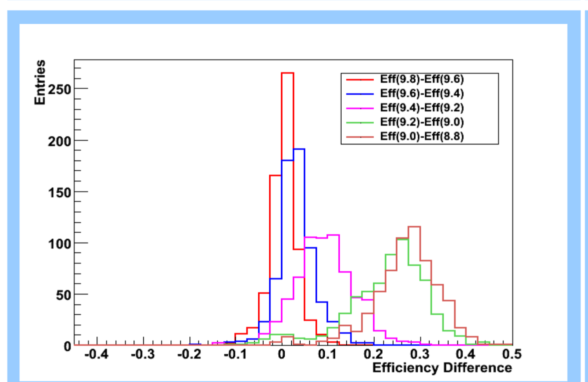
Typical panel efficiency curve as a function of the High Voltage.



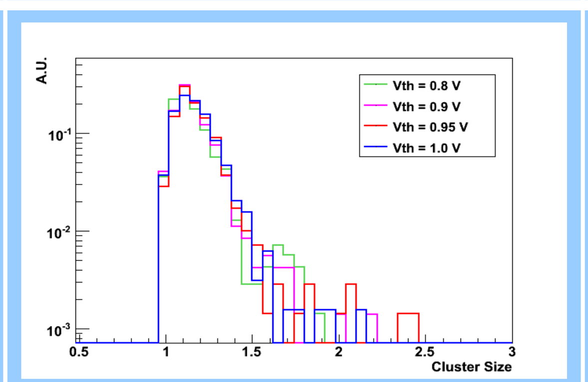
Panel average cluster size for all panels under test, at different front-end threshold values. HV was set at its reference value (9.6kV). As expected, cluster size at working point ***has*** a dependency on the applied front-end threshold



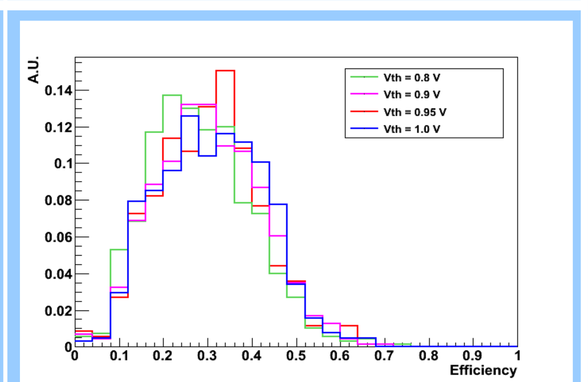
Panel efficiency for all panels under test, at different front-end threshold values. HV was set at its reference value (9.6kV). As expected, efficiency at working point ***has no*** dependency on the applied front-end threshold. Tails at lower values are due to known problems on some panels.



Efficiency increase when increasing the operating High voltage value. Average efficiency values per panel are shown, for all panels under test. The typical plateau behavior is clearly visible, with fermi-like raise around 9.0kV, and the plateau starting from around 9.4kV.



Panel average cluster size for all panels under test, at different front-end threshold values. HV was set at 9.0kV (around the center of the fermi-like raise). As expected, cluster size at this HV value ***has no*** dependency on the applied front-end threshold.



Panel efficiency for all panels under test, at different front-end threshold values. HV was set at 9.0kV (around the center of the fermi-like raise). As expected, efficiency at this HV value ***has a*** dependency on the applied front-end threshold.

References

[1] *The ATLAS Experiment at the CERN Large Hadron Collider*, ATLAS collaboration, 2008 JINST 3 S08003

[2] *Computing Technical Design Report*, ATLAS collaboration, CERN-LHCC-2005-022

[3] *Ganga: a tool for computational-task management and easy access to Grid resources*, F. Brochu et al., arXiv:0902.2685v1