

Commissioning with cosmic rays of the Muon Spectrometer of the ATLAS experiment at the Large Hadron Collider

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Abstract. The Muon Spectrometer of the ATLAS experiment is made of large toroidal magnets, arrays of high-pressure drift tubes for precise tracking and dedicated fast detectors for the first-level trigger. All the detectors in the barrel toroid have been installed and commissioning has started with cosmic rays. These detectors are arranged in three concentric rings and the total area is about 6000 square meters. During the installation and commissioning of the detectors, data are usually taken with the magnet off, but a dedicated run took place with the magnetic field of the barrel toroid turned on. We present the procedure to control the response of the single detectors installed in the barrel toroid, Monitored Drift Tubes and Resistive Plate Chambers, and results of the first tests done with cosmic rays triggered by the first-level processor and read-out through the ATLAS data acquisition. Details on the installation and commissioning schedule will be given in view of the completion of the instrumentation of the muon spectrometer for the first period of data taking with proton-proton collisions.

1. The Muon Spectrometer: status of the installation

The Muon Spectrometer of the ATLAS experiment [1] has been designed to identify and precisely measure muon tracks over a wide range of transverse momentum, pseudorapidity, and azimuthal angle. The required momentum resolution is better than 10% up to 1 TeV. The spectrometer is based on three air-core magnets, a barrel and two end-caps, each made of eight superconducting coils that form an octagonal structure and generate a toroidal field of bending power $\int Bdl \sim 3 \text{ T m}$ in the barrel and $\sim 5 \text{ T m}$ in the end-caps. The muon trajectories are measured in three stations (called inner, middle and outer). In figure 1, a transverse view of the barrel muon spectrometer shows the magnet coils and the muon stations. The tracking detectors are Monitored Drift Tubes ([2] MDT in the following) and Cathode Strip Chambers (CSC) in the very forward regions. Each MDT chamber provides six to eight measured points in the bending plane with an average precision of $\sim 80 \mu\text{m}$ per point. A stand-alone muon trigger system [3] relies on dedicated chambers which measure space points in both projections, r - z and r - ϕ , with lower accuracy. Resistive Plate Chambers (RPC) and Thin Gap Chambers (TGC) are the trigger chambers in the barrel and end-caps regions respectively. To obtain the required muon momentum resolution, an optical alignment system is used to continuously monitor the chamber misalignment and deformation. This information is used off-line to correct for misalignments at the level of $\sim 30 \mu\text{m}$ in the track reconstruction.

The barrel toroid magnet installation was completed and it was tested in November 2006. The nominal current value of 20.5 kA was reached at the first cool down. Almost all the ~ 700 muon barrel stations have been installed. Only few stations in the lower sectors are missing to permit end-caps opening and access to the inner part of the detector. Both end-cap toroids have been installed in the cavern in June and July 2007 respectively. The installation of the middle part of the end-cap spectrometer is well advanced. The inner part of both end-caps will be ready in November while the support structures for the outer parts are still missing but all chambers are ready to be mounted.

2. Commissioning the detector

For the commissioning of the detector, a three-level strategy has been adopted. At first level each muon station was tested on surface before installation. MDT chambers were tested for high voltage and gas leak tightness, the functionalities of the Detector Control System (DCS, [4]) were checked and the read-out electronics was tested via test pulse runs. RPC chambers were also tested for gas-leak tightness and noise level. Moreover, the Level-1 trigger electronics was read-out via test pulses. At the second level each station is tested with provisional services after its installation in the cavern. This phase has been completed for most of the installed stations. The third level of the commissioning foresees the final test of each station and a sign-off procedure test of complete sectors. It is done with final services, power supplies and read-out electronics. The goal of the final phase is a general test up to a cosmic ray run. The test includes high voltage and gas tightness, the completion of a list of dead and noisy channels and the commissioning of the DCS and alignment systems sector by sector. Left over problems should be fixed and the configuration Data Base should be filled with the information for later use with proton-proton collisions. The sector commissioning of the spectrometer already started with the aim of having the largest part of the spectrometer ready for the closure of the experiment in March 2008.

3. First results from the commissioning in the pit

Up to now, there have been two main data taking periods. The first was in November 2006. Data were taken with the barrel toroid at full field. Thirteen muon stations in sector 13 were operated; the trigger was given by the RPC chambers. The muon barrel alignment system was active. In June 2007 there was another data taking period in which 85 muon stations were involved: 71 barrel stations in sector 5 and 14 end-cap MDT in sectors 10,11 and 12. Approximately 27000 MDT tubes were read-out. The trigger was given by the RPC in one side of the barrel sector and by the TGC in one end-cap sector. Some of these runs were taken in combination with the calorimeters. This allowed to profit of the trigger from the tile hadronic calorimeter and to test the combined muon track reconstruction. We had a fully operational alignment system and the services (including the gas, high voltage and low voltage systems) were in the final configuration. The RPC trigger rate was ~ 70 Hz. Cosmic muons enter the ATLAS cavern mainly from the two access shafts. This is observed both from the detector illumination and from the angle of the tracks reconstructed in the chambers. In the runs with the magnetic field on, it was possible to separate μ^+ and μ^- tracks from the different curvature as well as measure the momentum. The relative rate of μ^+ and μ^- tracks was ~ 1.5 [5] in agreement with montecarlo calculations.

A study of the MDTs drift parameters was performed on all the chambers under operation. The drift time spectrum length (t_{max}) depends on the operating conditions and should be the same for all the chambers. The t_{max} distribution for the tested chambers is shown in figure 2; the width of the distribution can be easily explained taking into account, for example, small (less than $2^\circ C$) temperature differences among the different chambers. In order to achieve the required muon momentum resolution, the space-time relation ($r(t)$ in the following) for MDT chambers should be known with an accuracy of about $20 \mu m$. $r(t)$'s are computed with an auto-calibration procedure [6]; for all the chambers in operation they resulted to be within $30 \mu m$.

A measurement of the effect of magnetic field on $r(t)$ relations has been performed during the runs with the magnet on and is in agreement with expectations.

The correlation between RPC and MDT chambers was tested for both triggering and tracking purposes. This can be done by simply comparing tracks in the bending plane. A more refined study is going on to measure RPC efficiency with two independent methods: using only RPC information or extrapolating MDT tracks in the RPC. Although systematics are under investigation, the two methods are consistent and a good correlation between the two detectors is reported.

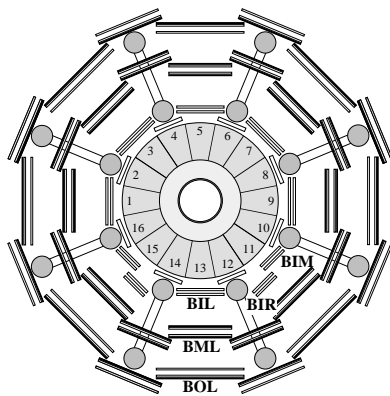


Figure 1. Transverse view of the ATLAS barrel muon spectrometer showing the MDT tracking chambers and the RPC trigger chambers (in black in the Middle and Outer stations). Sector numbering and stations naming convention for the barrel is also shown.

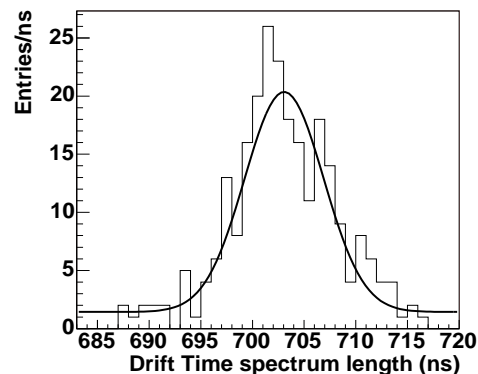


Figure 2. Distribution of the drift time spectrum length as measured for groups of 24 MDT tubes for the chambers under operation in a run with the magnetic field off. The gaussian fit to the distribution has a mean value of 703 ns and a σ of 4 ns.

Acknowledgments

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