LAPP-EXP-2006-11

Commissioning of the ATLAS detector and combined beam test results

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Abstract

The ATLAS detector is a large and complex experiment. Commissioning of the various components, both separately and together, is a challenging task which requires a methodology and a sustained and detailed plan of work. The commissioning stages of ATLAS will be described, together with an overview of results obtained during the construction and the integration so far. Once installed and functional the various parts of the detectors are operated with cosmic particles in several combinations. The performance of the detector components, both individually and in combination, has been also measured in a series of test beam data taken over the last years.

Presented at Xth Pisa Meeting on Advanced Detectors,
La Biodola Isola d'Elba (Italy) May 21-27, 2006

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1. Introduction

The ATLAS experiment is a multi purpose detector currently being built at the future LHC at CERN. Its physics goals consist firstly in finding a possible Higgs boson rather indicated by indirect data to sit in the low mass region (~120 GeV) but also to have the capability to cover a wide range of possible new phenomena (super-symmetry, high mass gauge bosons, extra-dimensions,...).

The main parts of the detector are at present time almost completed and the collaboration is in the full swing for the installation phase. In parallel is growing the activity of integrating all parts of the detector as well as the detector control system (DCS), the data acquisition (DAQ) and the trigger system, level 1 (L1) and high level (HLT) triggers. The commissioning effort organized around the construction will be reported here for its current and next stages.

The integration phase has already started in 2004 when a test beam combining all parts of the ATLAS (about 1% of the total size) has being run [2]. The enterprise has allowed starting this integration as far as DAQ and offline code are concerned. It has also allowed undertaking combined analysis to check the performances of the detector in a context much closer to the final one. Some of the results are quoted here, first to demonstrate the performance and as indication of the interest of running with cosmic events in the pit to debug and commission the final detector before the first collisions arrive.

2. Status of the construction

The description of the experiment can be found elsewhere [1]. The detector is currently in construction on its final underground location.

The barrel air toroid magnet has been fully assembled as well as its services (cryogenics, vacuum system and power supply). It is being pumped and will soon starts cooling down. The central solenoid hosted by the barrel liquid argon calorimeter cryostat is also in place and being cooled down.

The calorimeter system, composed of the liquid argon electromagnetic (accordion), hadronic end cap and forward calorimeters are all in place, surrounded by the hadronic iron scintillator tile calorimeter also completed. All the front end electronics for the barrel part is in place except most of the low voltage power supplies. The back end readout electronics in the counting room is in place and already tested.

Along the barrel calorimeter barrel takes place a massive cabling campaign concerning the inner detector services including the piping for the three central trackers.

In parallel the barrel silicon tracker (SCT) and transition radiation tracker (TRT) are being assembled and tested on surface [4] before being brought underground as a unique object. A fair fraction of the electronics to readout and operate the detector is already used on surface and will be moved to the cavern later on. The test and installation of the barrel tracker will be followed by the two end caps. Finally the pixel detector is being assembled separately [4] and will be integrated much later.

The barrel muon chambers (MDT and RPC stations) are being installed in the central region (about 800 chambers). A very limited amount of readout and cables are available so far. The end cap wheels (MDT and TGC) are integrated on surface as large sectors and fully tested before being brought down into the pit soon.

More details on the detector construction status can be found in [3].

3. Strategy for commissioning

The commissioning process in ATLAS has been divided in four main phases. The phase I consists in commissioning each sub-detectors or sub-systems by its own. There is a list of well defined work packages to be completed for various parts of a sub-detector (e.g. LV, HV, slow control). This way of proceeding is based on the fact that the hardware arrives in time and fully tested. In practice it is far to be the case and a lot of pre-debugging occurs during this phase for clear planning reasons. The second phase consists in integrating two or more parts together: a sub-detector and the DAQ, the DCS, the configuration databases, etc... One aim is to obtain e.g. a functional DAQ with good operational capability in order to run e.g. a full electronic calibration and fully analyze it. The third phase consists in taking cosmic runs with a dedicated trigger (based here on the signal from the TILE calorimeter and later the barrel RPCs). The goals are similar to phase 2 but with particles. This allows checking more deeply the detector, the full reconstruction chain, starting to build a map of the bad channels and starting organizing the shift, the control room and the operation of the detector. In practice the phases 2 and 3 deeply interfere. Finally the phase 4 will starts with the first beam(s) with beam gas events first to study the end-cap region which cannot be well covered with cosmics and then to very first collisions.

4. Commissioning of the sub-detectors

The phase 1 of the commissioning process has started for all sub-detectors: inner detector (SCT+TRT barrel) on surface [4], the liquid argon and TILES barrel calorimeter and the barrel muon stations (MDT and RPC). As an example the later is shortly described here with more details in [6].

The Muon commissioning is divided in 3 stages. First the stations are tested on surface near to one cavern shaft. The MDT are tested for: broken wires (HV test), gas leak tightness, DCS functionality, read-out capability via noise measurements and electronic test pulse runs. The RPC are on their side tested for: gas leak tightness, noise behavior and level 1 trigger signal read-out via electronic test pulse runs. It has turned out that this step is extremely useful. Many small problems were fixed at this level and also more severe ones not detected before and which would have been very difficult to solve underground. The usefulness of this stage shows also the difficulty to install a delicate apparatus in and quite hostile environment dominating by large infrastructure work (like cabling work or piping installation). More than 200 chambers have been tested up to now (about 20% of the barrel).

Once installed in the cavern the station are again but simply tested. The MDT high voltage and gas leak tightness are tested; for RPC only gas leak tightness is. The main reason of this simplicity of is due to the non availability of services (cables, pipes and electronics) by the time the stations are installed. This will unfortunately increase the complexity of the commissioning when the stations will be finally connected to the final readout and services. Repairs and corrections have to be foreseen in a environment with difficult access.

Nevertheless two stations in the lower sector of the barrel have been successfully combined together with a temporary readout system and have taken cosmics data triggered by an external scintillator (see Fig 1). Analysis can be then performed with the use of all analysis tools (see later). This will be pursued with a higher number of chambers and the use of RPC for trigger generation.

5. Commissioning of the DAQ and DCS systems

The ATLAS DAQ system is based of 3 trigger levels. The L1 decides to push the selected events from the front end electronics to the first level of computing (ROD) and to Read Out Systems (ROS). Then a second level, based on region of interest information pulls the events from the ROS to the L2 farm. Selected events are then transferred to the event filter farm for the third selection level leading to a 100Hz rate.

The ROS system, made of about 150 PCs is currently being commissioned. This is achieved for the liquid argon barrel part as well as the TILE calorimeter. The next detectors will be the inner detector (barrel) and the muon spectrometer. The tests are centered on the functionalities of the Optical links between the RODs and the ROS.

In parallel a real test of the DAQ has been done will about 10% of the final system, including all the functionalities. The ROS to SFI communication was tested, with the L2 system and then including the switch and the event filter. This was firstly done with dummy events and algorithms but also with simulated events and the official EF code. Various performances have been compared with a simulation model. All the results obtained agree well with the later (see Fig. 2). In addition stability tests have shown satisfactory operation. The DAQ is then ready to grow in size with the installation of the final switch and 30 % of the volume for the end of 2006.

6. Toward integration and cosmic runs

The integration of the various pieces of the detector proceeds by steps, integrating the full chain of on line configuration databases, the trigger, DAQ, slow control, HLT, on-line monitoring, event display, control room concretized by shifts. The operational procedures and associated DAQ performances will be fully tested as well as the calibration procedures. The treatment of the bad channels has also to be elaborated.

Cosmics run will be very useful to push and motivate the work and studies. It has been shown that 100 muons per liquid argon medium layer cell can be enough to understand the timing of the calorimeter within 0.6 ns. It is also possible to learn about the detector uniformity and bad channels using these events.

The trigger will be provided by the TILES calorimeter with special L1 boards allowing triggering on quasi projective (0.05 Hz) and non projective (0.15 Hz) events. The timing of the TILES calorimeters can this way be understood at the level of 1.7ns. Finally the liquid argon-TILES inter calibration can be envisaged considering the understanding of the TILES response to MIP at a 3% level.

As far as rates are concerned the liquid argon calorimeter produces 5 TB of raw calibration data or 42GB in averaged mode. The TILES calorimeter expects around 1GB per day. Considering a cosmic rate of 10 Hz, 1.4MB/s for the TILES calorimeter and 15MB/s for the barrel liquid argon seems feasible with only one PC to record the events. The barrel muon spectrometer in a first step is expected to produce only 2kB/event. Later with the end cap parts the final event building capabilities will be needed.

In parallel the toroid and solenoid magnets will be commissioned. At the same time everything active in the cavern will be exercised to demonstrate the operational aspect of the detectors and their front end electronics in presence of magnetic field. Cosmic event will be of course recorded, particularly to commission the barrel muon spectrometer and later with the central tracker (see Fig. 3). A similar exercise will be done later will the forward muon chambers and the end cap toroid magnets.

7. Conclusions

The integration of the main ATLAS pieces is now starting in the cavern. It proceeds with functional tests as well as successive cosmic runs up to a global cosmic run foreseen for spring 2007 before the LHC starts operating. The aim is to integrate the detectors and systems as they come, when they grow in size, debug the full chain from shifts to data analysis. Beam gas will be used for the end cap regions for timing, alignment and inter calibration as well as DAQ commissioning with high rates.

Very first collisions even with a limited luminosity (10-100 pb^{-1}) can allow via standard processes ($Z \rightarrow ee$, $Z \rightarrow \mu\mu$, $tt \rightarrow bl\nu\ bjj$) to commission then the trackers, calorimeters, muon alignment system, jet energy scale and b-tag for physics.

8. Aknowledgments

I am indebted to L. Chevalier, R. Nikolaidou, L. Pontecorvo, R. Teuscher, G. Unel and Th. Wengler for their helpful material, results plots and some useful discussions.

9. References

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[2] B. di Girolamo et al., ATLAS barrel combined run in 2004. EDMS 406980
[3] N. Hessey, ATLAS Detector Construction Status and Upgrade Plans, Xth Pisa Meeting on Advanced Detectors, May 21-27, 2006
[4] H. Pernegger, Integration and Test of the ATLAS Semiconductor Tracker, Xth Pisa Meeting on Advanced Detectors, May 21-27, 2006
[5] C. Meroni, Overview and Status of the ATLAS Pixel Detector, Xth Pisa Meeting on Advanced Detectors, May 21-27, 2006
[6] L. Pontecorvo, Installation and Commissioning of the ATLAS MUON Spectrometer, Xth Pisa Meeting on Advanced Detectors, May 21-27, 2006

10. Figures

Fig 1: one cosmic event recorded in the ATLAS cavern with two muon stations.
Fig2: comparison of the DAQ preserie behavior with a simulation for various configurations and functioning points.
Fig3: relative alignment of the tracker (Pixels and SCT) with the barrel muon chambers at the combined test beam. A similar analysis will be repeated eventually from data taken in the cavern.

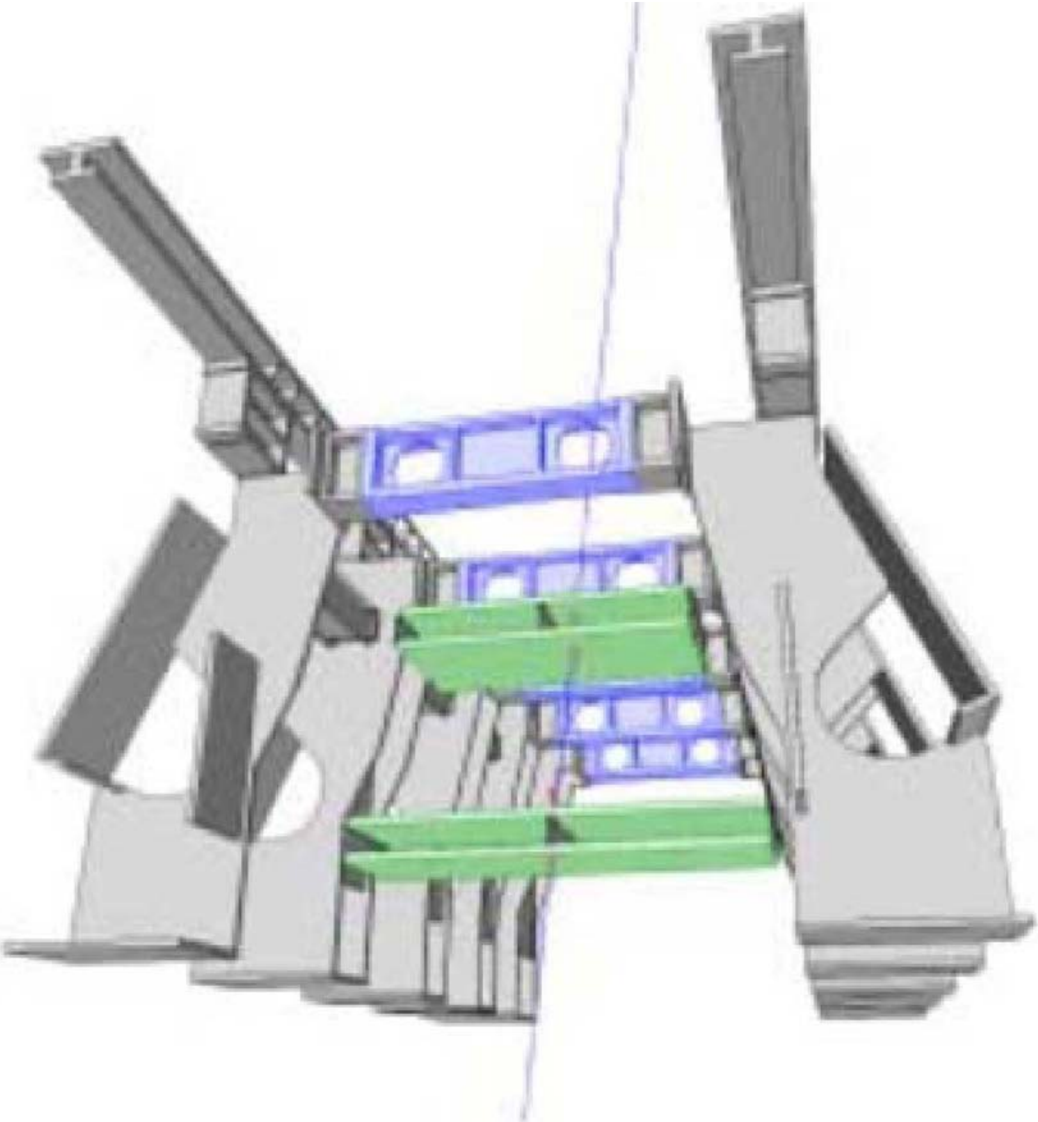
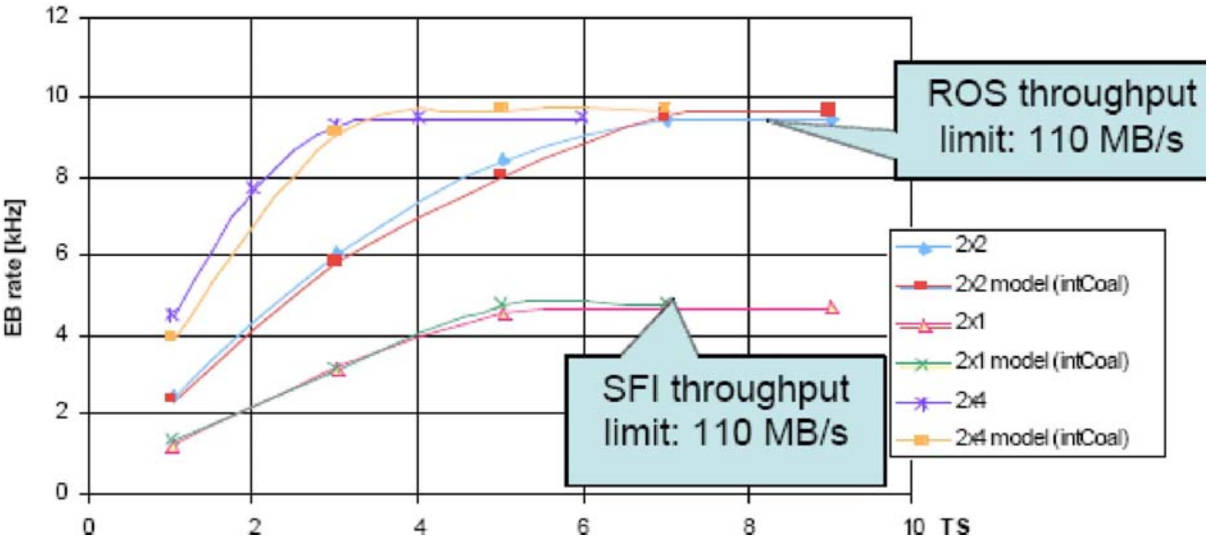
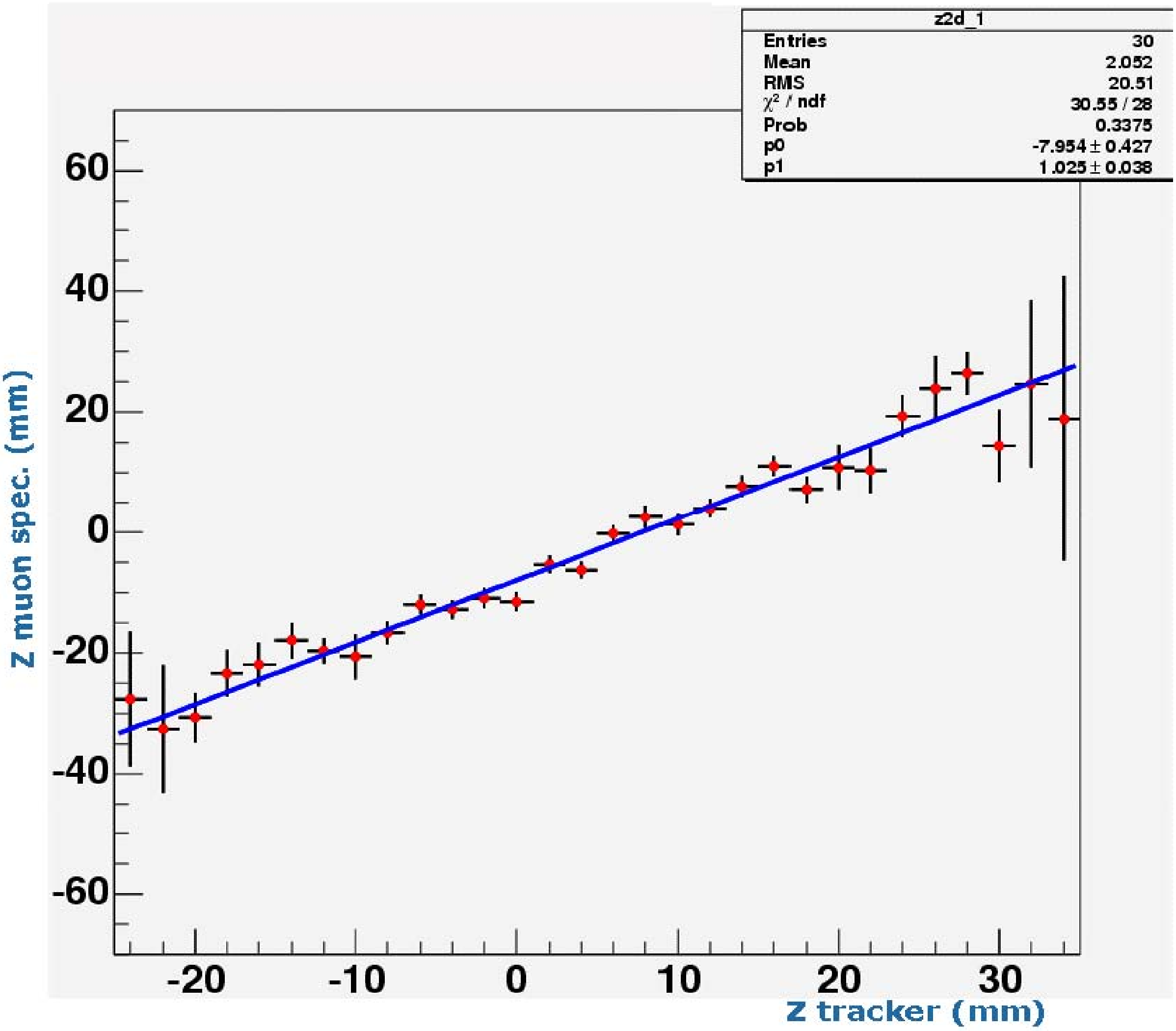


Figure 1



12
10
8
6
4
2
0
EB rate [kHz]
0
2
4
6
8
10
TS
ROS throughput limit: 110 MB/s
SFI throughput limit: 110 MB/s
2x2
2x2 model (intCoal)
2x1
2x1 model (intCoal)
2x4
2x4 model (intCoal)

Figure 2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Mean 2.052
RMS 20.51
χ² / ndf 30.55 / 28
Prob 0.3375
p0 -7.954 ± 0.427
p1 1.025 ± 0.038
60
40
20
0
-20
-40
-60
-20
-10
0
10
20
30
Z muon spec. (mm)
Z tracker (mm)

Figure 3