The ATLAS experiment: status report and recent results

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1 Introduction

The ATLAS experiment was designed to explore a broad variety of phenomena that may arise at the high energies accessible at the Large Hadron Collider (LHC), and was optimized for the search of the Higgs Boson in the largest possible mass range and for the search of very heavy objects as for example new heavy Gauge bosons (W', Z') or supersymmetric particles. The detector consists of two magnetic spectrometers with cylindrical geometry and electromagnetic and hadronic calorimeters covering a very large fraction of the solid angle as can be seen in Figure 1 [1]. Charged particle tracks and vertices are reconstructed with silicon pixel and silicon strip detectors covering $|\eta| \leq 2.5$ and transition radiation detectors covering $|\eta| \leq 2.0$, all immersed in a 2 T magnetic field provided by a superconducting solenoid. This tracking detector is surrounded by a finely-segmented, hermetic calorimeter system that covers $|\eta| \leq 4.9$ and provides three-dimensional reconstruction of particle showers. It uses Pb-liquid argon for the inner electromagnetic compartment followed by a hadronic compartment based on Fe-scintillating tiles in the central region ($|\eta| \leq 1.7$) and additional Cu-liquid argon for higher η. Outside the calorimeter, there is a muon spectrometer with air-core toroids providing an average magnetic field integral of about 3 Tm. Three stations provide precision measurements of the η-coordinate for $|\eta| \leq 2.7$ using drift tubes except for the inner station for $|\eta| \geq 2.0$ where cathode strip chambers are used. Triggering capability and measurement of the non precision ϕ-coordinate are provided by resistive-plate chambers for $|\eta| \leq 1.05$ and by thin-gap chambers for 1.05 $\leq |\eta| \leq 2.4$.

2 ATLAS operations and data taking

During the first half of 2011 the LHC was operated at a center of mass energy of 7 TeV, achieved a maximum instantaneous luminosity of $1.3 \times 10^{33} cm^{-2} s^{-1}$ and delivered an integrated luminosity of about 700 pb^{-1}. The ATLAS data taking efficiency was higher than 95% and the fraction of operational channels was very close to 100%

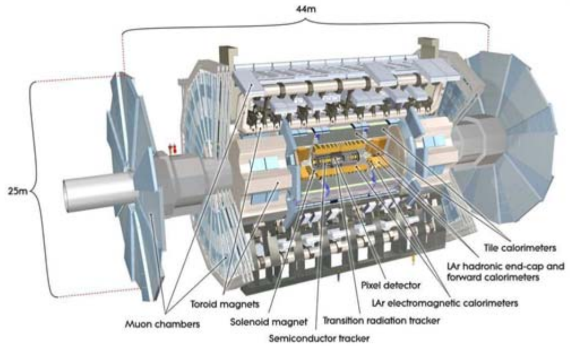

Figure 1: The ATLAS detector.

for all the subsystems. In Table 1 a detailed account of the fraction of good data usable for analysis for the different subsystems is given. As an example the fraction of collected luminosity used in the *top* analysis, which requires good data from all the ATLAS subsystems, is about 83%.

Inner tracker	Calorimeters	Muons	Magnets
Pixel SCT TRT	LAr LAr LAr Tile EM Had FWD	MDT RPC CSC TGC	Solenoid Toroid
99.5 99.4 100	87.5 92.4 94.5 100	100 99.0 99.9 99.8	96.8 95.1

Table 1: Good data quality fraction for the different ATLAS subsystems.

The trigger system in ATLAS is organized in three levels. The level 1 (LVL1) is based on hardware processors and selects events containing high momentum objects (leptons or jets) from the 10^8 proton interaction per second producing an output rate of about 50 KHz. These events are then processed by the second level trigger (LVL2), based on a PC farm which analyze the Regions Of Interest (ROIs) indicated by the LVL1 and refine the selection arriving at an output rate of about 4 KHz and finally the Event Filter (EF) applies the full offline reconstruction to the event and produces the final output rate of about 300 Hz which is then written to disk for further analysis. The trigger thresholds varied during the first half of 2011 following the ever increasing instantaneous luminosity delivered by LHC, and in the last period of operations the main triggers selected events containing electrons with transverse momentum above 20 GeV, muons above 18 GeV, jets above 180 GeV and missing E_T greater than 60

GeV.

In 2011 the LHC proton bunch spacing was 50 ns and, at a luminosity of $10^{33}cm^{-2}s^{-1}$, there were on average 6 collisions per bunch crossing. These pile-up events increase the complexity of the events to be reconstructed. The inner detector track reconstruction, the determination of the missing energy and of the et energy scale and calorimetric isolation have been optimized to cope with these new running conditions. As an example Figure 2 shows the reconstruction of an event containing 7 vertices one of which contains a Z candidate.

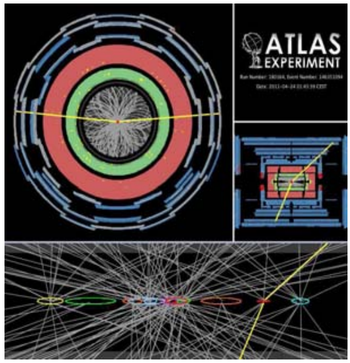

Figure 2: A collision event containing 11 reconstructed vertices and a Z candidate shown with two yellow tracks.

The overall performance of the ATLAS detector on the most relevant physics objects (leptons, jets and missing transverse energy) have been measured using the 2010 and 2011 data. In general the measured performances, some of which are shown in Table 2, are very close to the design values after only one year of running.

Z$\rightarrow e^+e^-$ mass res.	Z$\rightarrow \mu^+\mu^-$ mass res.	Jet energy scale sys.	E^T_{mis} res.
1.9 %	2-3%	$\leq 3\%$	$0.48 \times \sqrt{\sum E_T}$

Table 2: Relative resolutions for the most relevant physics objects

3 Physics results

The ATLAS collaboration performed a very large number of measurement and searches with data samples ranging from 40 to about 200 pb^{-1} and only a summary of some selected results is given here. The first data collected allowed for the $re-discovery$ the Standard Model by measuring the production cross section and the properties of known particles as W, Z and *top* and to gain confidence in the understanding of the detector response. These early measurements were soon followed by searches of new heavy particles as new heavy gauge bosons or supersymmetric particles, quark compositness and of course the first searches of the Higgs in many different decay channels.

3.1 Standard Model

The amount of data collected at 7 TeV center of mass energy allowed detailed and precise measurements on the production cross section of standard model processes as the production of W and Z, *top* and di-bosons.

The W and Z are produced by quark antiquark annihilation and the ratio of the W to Z cross section is very sensitive to the proton Parton Density Function (PDF) at low x. The measured total cross section times leptonic branching ratio for W/Z production, shown in Table 3, is in remarkable agreement with the theoretical predictions, see Figure 3, and represents a success of pQCD and of the present knowledge of the proton PDFs which can be improved measuring the W charge asymmetry. The cross section measurement is performed selecting leptonic decays of the gauge bosons and searching for isolated high P_T leptons ($\geq$ 20 GeV). The kinematical distributions of the selected events are in very good agreement with Monte Carlo expectations, showing a very good control of the instrumental effects [2].

$\sigma_W^{tot} \times BR(W \to l\nu)$	10.391 $\pm$ 0.022 (stat) $\pm$ 0.238 (sys) $\pm$0.353 (lum) $\pm$ 0.312 (acc)
$\sigma_{Z\gamma*}^{tot} \times BR(Z/\gamma* \to ll)$	0.945 $\pm$ 0.006 (stat) $\pm$ 0.011 (sys) $\pm$0.032 (lum) $\pm$ 0.038 (acc)

Table 3: Total cross sections times leptonic branching ratios for W and Z at 7 TeV

The *top* cross section has been measured in ATLAS using many different signatures including single and double leptons final states in conjunction with jets with or without b-tagging [3]. The Top quark is predominantly produced in pairs and the decay products are almost always 2 W and 2 b quarks. Top events where at least one of the W decays leptonically can be identified over the very large multijets QCD background by requiring at least one high P_T lepton and missing E_T plus jets. To measure the mass of the *top* quark it is possible to use its decay in three jets, where the invariant mass of the three jet system can be fully reconstructed. The ATLAS measurement of the *top* mass is : $M_T = 169 \pm 4.0 \pm 4.9$ GeV.

The first measurements of the production cross section of di-boson has been possible with the data collected in 2010 (WW, Wγ,Zγ) and in the first half of 2011 (WZ) [4, 5]. The event selection requires the presence of high momentum leptons and missing E_T. A total of 8 candidate WW events in 34 pb^{-1} and 12 WZ candidates in 205 pb^{-1} were selected. The cross section measurement is still clearly statistically limited but increasing the data sample these measurements will allow to measure the triple gauge bosons couplings. A summary of the most relevant Standard Model cross section measured by ATLAS is shown in Figure 3.

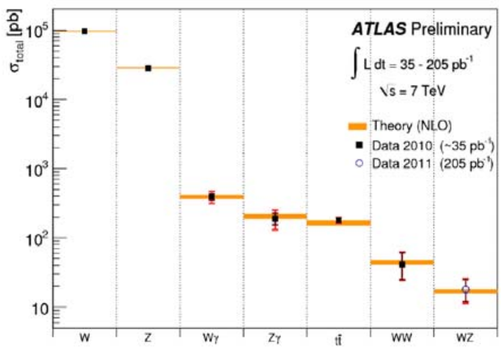

Figure 3: Measured standard model cross sections and comparison with theoretical expectations.

3.2 Exotic searches

One common technique for searching for physics behind the standard model consists in looking for resonant enhancements in the invariant mass distribution of pairs of particle (in general leptons) or jets. This technique has been applied in the search for excited quarks, using 163 pb^{-1}, where the di-jet invariant mass spectrum has been compared locally to the fit of the M_{jj} spectrum over the full range [6]. No significant enhancement has been found at any mass and an upper limit on the visible production cross section of new resonances has been put. Other searches that use the same technique are those aimed at the detection of new heavy gauge bosons. In particular it has been possible to set upper limits on the production cross section times leptonic branching ratio for the production of W like and Z like objects decaying in a lepton, neutrino or in a lepton pair, using between 163 and 241 pb^{-1}. These limits can be interpreted in specific theoretical models and hence translated in mass limits for particles with specific properties. As an example in Table 4 the limits on the mass of excited quarks $q^*$and of the Sequential Standard Model (SSM) W' and Z' bosons are reported [7, 8].

M_{q^*}	$M_{W'}$	$M_{Z'}$
> 2.49 TeV 95% CL	> 1.57 TeV 95% CL	> 1.41 TeV 95% CL

Table 4: Lower limits for the mass of q*, SSM W' and Z'

3.3 Higgs search

The Higgs boson is predominantly produced via gluon gluon fusion at the LHC. Its decay branching ratios are extremely dependent on the Higgs mass, but in general it is possible to identify some broad mass regions where some decay channels are most useful for the search. In the very low mass region (below 125 GeV) the most relevant Higgs decay channel for the Higgs search is $H \to \gamma\gamma$, while for higher masses up to about 200 GeV the the most promising decay channel is $H \to WW$. A very clean channel that is suffering from statistical limitations is $H \to ZZ$ where both the Zs decay in leptons (μ or e). For high mass Higgs ($M_H > 200$ GeV) also the decays of one of the Zs in neutrinos or in jets are considered. ATLAS has explored all of the above decay channels but the available statistics is not yet sufficient to exclude the Standard Model Higgs in any mass range [9, 10, 11]. The limits on the production cross section obtained with the different decay channels have been combined [12] and the observed 95% C.L. upper limit on the cross-section, normalized to the Standard Model cross section is shown in Figure 4.

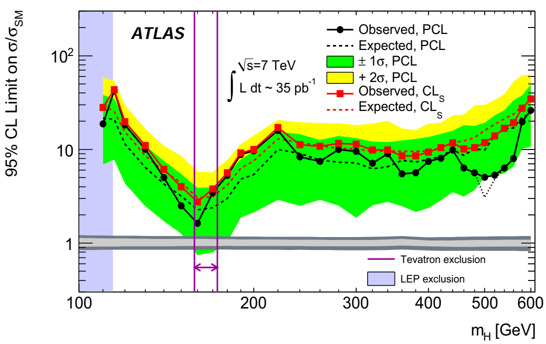

Figure 4: The expected (dashed) and observed (solid) 95% C.L. upper limits on the cross-section, normalized to the SM cross-section, as a function of the Higgs boson mass

4 Conclusions

The first year of data taking and analysis in ATLAS has been very exciting. The detector behaves remarkably well recording with high efficiency high quality data. The achieved performance are already very close to design values and the understanding of the detector response improves steadily. Many physics measurements have been done in the new energy regime, as for example the production cross section of gauge boson pairs and single *top*. Stringent limits on the production of new phenomena as the production of excited quarks states, or of new heavy gauge bosons and supersymmetric particles have been obtained. The search of the Higgs particle has started and the sensitivity is already quite close to the one needed to exclude the presence of this particle in some mass region (close to 160 GeV).

I am grateful to the ATLAS Collaboration that enabled me to present these results and to the whole LHC team that was able to commission and run the accelerator in a spectacular way.

References

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