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Status and startup for physics with the ATLAS experiment

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Abstract

The LHC accelerator is going to produce the first proton-proton collisions in one year from now. The ATLAS experiment at the LHC entered in a new phase, dedicated to the detector commissioning. This paper is focused on the ATLAS physics commissioning, which will proceed through four different stages. We describe here the strategy which will be followed to understand the detector and undertake the first physics measurements, from beam tests to cosmic run and from pre-collision to collision events.

1. LHC and ATLAS

The LHC machine, which will collide protons against protons at the never before reached energy in the center of mass of 14 TeV, is constructed in the former LEP tunnel at CERN [1]. The 27 km ring will host 1232 superconducting dipole magnets, 15 m long, providing a 8.33 T bending magnetic field for the 7 TeV proton beams. To achieve the design luminosity of 10^{34} cm^{-2} s^{-1}, 2808 bunches of 10^{11} protons each have to be stored. The bunch crossing interval will be 25 ns and the total energy stored per beam will be around 350 MJ.

At the LHC, four interaction regions are constructed and two of them will host the general purpose experiments ATLAS [2] and CMS [3], designed for pp collisions at high luminosity. A specialized detector for heavy ion collisions (ALICE) and a spectrometer for B-physics (LHCb) are also under construction. ATLAS is a typical multi-component collider detectors. Charged particle detection consists of silicon pixel vertex detectors (Pixels), silicon strip detectors (SCT) and a straw tube transition radiation tracker (TRT). A 2 T solenoid magnet surrounds the tracking detectors in front of the calorimeter. A fine-grained liquid Argon (LAr)–lead electromagnetic calorimeter is surrounded by a scintillator-iron Tile-Calorimeter and LAr–Cu calorimeters in the forward region. Muon detection in the barrel proceeds through a huge air-core toroid magnet consisting of eight superconducting coils instrumented with monitored drift tubes (MDT) and cathode strip chambers (CSC) for momentum measurement and resistive plate chambers (RPC) for triggering.

2. Status of machine and experiment at the end of Summer 2006

All key objectives of the LHC machine have been reached by the end of 2005. After initial problems with the production of superconducting cables, and more recent problems in the installation of the cryogenic support lines have been overcome, the completion of LHC is now progressing very well. The production of the dipoles is finished and their moving into the tunnel is progressing. Three quarters of the machine have been liberated for the installation of the magnets. Interconnect work is proceeding in two octants in parallel. Quadrupoles production is also proceeding smoothly.

The magnet installation is now steady at the rate of 25 magnets/week. Already 1000 cryo-magnets are in the tunnel. According to the latest schedule (June 2006) [4], the last magnet will be delivered on October 2006, and tested on December 2006. The installation then will be completed on March 2007, and after that, on August 2007, the machine will be closed. The first collisions should take place on November 2007, but they will not be at the full energy of 7 TeV per beam, since the full commissioning of the machine will be only up to the field needed for de-Gaussing (1.2 TeV). Initial operation will be then at 900 GeV with a static machine (no ramp, no squeeze) to debug machine and detectors.

The full commissioning up to 7 TeV will be done during the Winter 2008 shutdown. LHC should deliver every year about 140-160 days of physics (including the activity of ALICE and TOTEM). This leaves 100-120 days for proton luminosity running. If one assumes an efficiency for physics of about 50%, this means 1200 hours, or about $4 \cdot 10^6$ s of proton luminosity running/year.
This is a somewhat new scenario with respect to the ones presented before, and therefore it makes sense to be conservative and assume that by the end of 2008, the integrated luminosity will be more near to 1-2 fb^{-1} rather than to the previously expected 10 fb^{-1}, per experiment.
For what concern the ATLAS experiment status, the construction of most sub-detectors is now finished and they are being assembled in the underground hall. The installation is proceeding smoothly.

At the moment we are writing this paper (September 2006), the situation is as described in the following. The Solenoid map has been completed at the end of July. The cool down of the Barrel Toroid (BT) started in April and is now completed. The first full current excitation will happen by the end of the year. The BT current tests took place in August. The End-Cap Toroids are taking more and more their final shape, but some last mechanical 'details' need still to be solved. Certainly, to know (and measure) the magnetic fields to the ambitious accuracies ATLAS has set as its goals will be a serious business.

The barrel SCT has been inserted into the barrel TRT at the end of February: the system is now installed in the pit. Each of the four silicon layers of the SCT has been tested: 99.7% of the channels turned out to be fully functional. One end-cap of the TRT has been fully assembled, together with two completed end-cap pixel disks with 2.2 M channels. The Inner Detector End-Caps will go into the pit at the beginning of 2007.
The complete Barrel Calorimeter is already in the final position at z=0, and the cooling down of the electromagnetic section has been completed. Both the Barrel and End-Cap LAr calorimeters have been tested at cold on the surface, finding less than the 1% of dead channels.

The Muon Spectrometer system construction is completed, and now assembly, integration, and installation are undergoing.
In parallel with these progresses, some issues remain critical, like the power supplies for most of the systems, the Barrel Muon chambers installation (very near to the 75% mark now), and the Big Wheels (the first TGC wheel now is installed).
For what concern the data acquisition (DAQ), the pre-series of the final Trigger-DAQ system, consisting in 8 racks (10% of the final data flow) is now in operation at the pit site and is used to take cosmic data (see paragraph 5.1).
The main emphasis underground now, is on installation of cabling and services, as well as on installation of infrastructure and electronics in the two adjacent counting rooms. The whole chain from the pit (USA15) to the surface HLT/DAQ farm (SDX1) to the Tier-0→Tier-1s→Tier-2s starts to take shape and operate.

It is reasonable to assume that ATLAS will be ready at the time of the machine start-up. However, because of missing resources, several components will not be complete at the beginning of data taking.

ATLAS will start with three pixel layers (if the Pixel delay will be recovered and the detector will be inserted) and without the TRT in the region $2<|\eta|<2.4$. In addition, part of the high level trigger and data acquisition processors will be deferred, with the consequence that the output rate of the level-1 trigger will be limited to 35 kHz instead of the initially planned 75 kHz.. The part of the physics program which will be mostly affected by this de-staging is of course the B-physics one, since, due to the reduced level-1 bandwidth, the threshold of the single muon triggers will have to be raised from the originally foreseen few GeVs, to P_T =14-20 GeV. All other studies should not be particularly affected by this [5].

3. Commissioning

The deadline of the first proton-proton collision is approaching fast, and ATLAS is nowadays fully committed in the detector commissioning. This will be a major enterprise, and the past experience of even smaller and simpler detectors teaches us that is crucial to have an efficient and well organized program in order to bring the experiment from the completion of the installation to the data taking phase. For this reason, a very detailed plan has been developed [6], divided in four phases. The first three phases cover mainly the commissioning of the individual sub-detectors (for example electronic calibration, alignment etc.). The fourth phase (Phase D), which started already this year, is focused on the commissioning of the detector as a “whole” with physics events, and can also be divided in four stages:

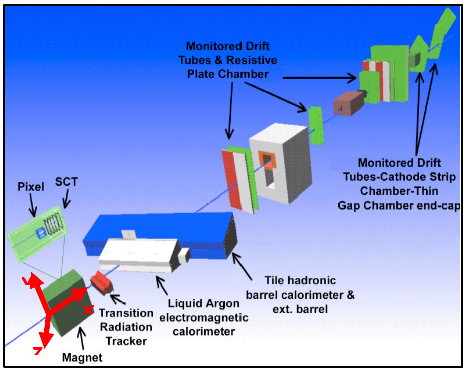
- Cosmic runs
- Single-beam periods
- First pp collisions
- Physics commissioning

In addition, the Combined Test beam performed by ATLAS in 2004 represents a significant progress towards the understanding of the complete detector and hence first physics.
In this paper we outline the chosen strategy to understand the detector and undertake the first physics measurements in the early period of the LHC operations.

4. The ATLAS combined test beam

From May to November 2004, a full vertical slice of the ATLAS detector has been tested on the CERN H8 and H6 beam lines. This corresponds to about a 1% of the total detector acceptance. In most cases, production modules have been part of the setup (shown in a schematic and real view in fig. 1a) and 1b) respectively).

In this occasion, all ATLAS sub-detectors (and the level-1 trigger) have been integrated and have ran all together adopting a common DAQ and monitoring, as well as the “final” electronics and slow control systems. In six months of data taking, about 90 millions of events have been collected, corresponding to 4.5 TB of data.
Different particles at different energies, ranging from few GeV up to 350 GeV, have been used to test, calibrate and align the inner tracking detector (Pixel, SCT and TRT), the calorimetric system and the muon system (MDTs, RPCs and CSCs).



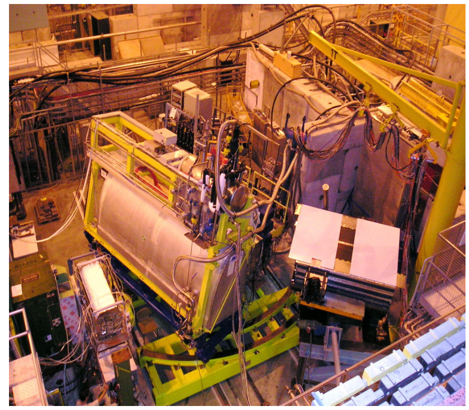


Figure 1: a) Scheme of the experimental setup (GEANT4). b) A real view of the combined setup in the H8 line.

During the tests, many configurations have been tried, for example varying the magnetic field (from 0 to 1.4 T), the material in front of the Inner Detector, or running with a beam separation of 25 ns etc.

Figure 2: Preliminary results from the ATLAS combined test beam. Charge/momentum measured by the SCT and Pixel detectors as reconstructed using simulation (higher histogram) and test beam data (lower histogram).

Lot of experience in running the whole detector has been gained: all the sub-detectors have been integrated and synchronized, and even the data analysis has been performed using the official common ATLAS framework. Several papers are going to be prepared summarizing the obtained results, which include e.g.: pion tracks reconstructed in all the three tracking systems, the correlation of the z-coordinate muon tracks in the inner detector with that of the muon system and finally, correlations of pion energy losses in the electromagnetic and hadronic calorimeter [7].

5. The pre-collisions period

Even before the LHC will have delivered proton-proton collisions, the first exposure of ATLAS to high energy particles from cosmic rays and also beam-halo and beam-gas events during single beam running, can be used for the detector commissioning. The event rates have been estimated with full simulation studies and they have been found to be significant and useful for this purpose [6]. A high level of alignment is required within the Inner Detector system: for example, the tracker module positioning on supports should be guaranteed to a precision of 17-100 μm, the supports themselves should be positioned to 20-200 μm and the Inner Detector will have to be positioned to ±3 mm with respect to the beam axis, with a precision on the rotation with respect to the solenoid axis of better than 1 mrad. Thanks to the cosmic rays, it should be possible to align some of the Pixel and SCT modules, those exposed to the largest cosmic flux, to a precision of 20 μm**.**

The information collected at this pre-collisions time will also be precious for the detector timing. Cosmic and halo muons are long lever arm tracks that should allow adjustments of the sub-detector relative timing across the whole detector. Beam halo and beam-gas events are expected in time with the beam and should therefore allow adjustments between the ATLAS and the LHC clocks.

1. *Cosmic rays*

Full simulation of the cosmic ray runs in ATLAS show that the expected particle rates (including shafts, shieldings etc…) are of the order of about 30 Hz. The advantage of using cosmic rays as a tool for commissioning the detectors is manifold, since it allows testing the final system and discovering problems before collisions data appear.

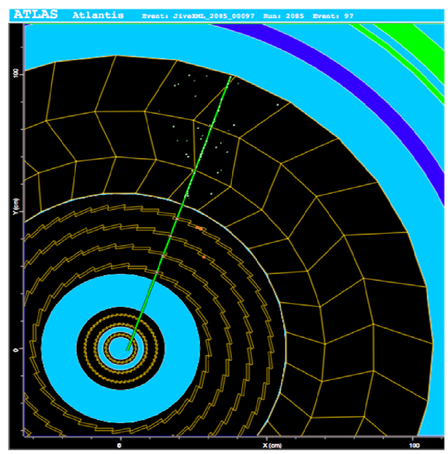


Figure 3: a) Display of a cosmic ray (the first one taken in the ATLAS pit) crossing the Tile Calorimeter , 42b) Display of a cosmic muon crossing the SCT and TRT detectors.

A milestone in the commissioning of ATLAS was reached on June 21, 2005, at 18:30, when the first cosmic rays were observed in the Tile calorimeter, already positioned underground. Data were read out using final electronics both on the detector and in the underground counting room, and the final offline software was used for the reconstruction and analysis of the events.

Based on this success and on the experience gained in this exercise, the cosmic rays program is continuing, first with the commissioning of the other individual sub-detectors, and later with combined runs. In this way, for example, other cosmic runs took and will take place in 2006, with the Inner Detector components. In Summer 2006 there has been a combined cosmic run involving the Tile and the LAr calorimeters.

2. *Beam-halo*

Machine-induced secondary particles, expected as soon as the first beam circulates, potentially provide a second means of preliminary commissioning of the detector. These particles are mainly due to elastic and inelastic scattering of the beam protons on the residual gas in the vacuum pipe, beam cleaning inefficiency and elastic beam-beam scattering at the high luminosity insertion regions. The vacuum in the pipe is indeed not perfect, and one can assume an average value of $3 \cdot 10^{-8}$ Torr.

The halo particles cross the detector from side to side, leaving signals essentially in the end-cap regions: they are therefore complementary to the cosmic muons discussed above. They can be used, for example, to look for dead cells, energy, alignment etc. The expected rate of muons is equivalent to 105 kHz (for $E_\mu > 10$ GeV 16 kHz, for $E_\mu > 100$ GeV 1kHz). Fig. 4a) shows a simulated beam halo event crossing the ATLAS detector (as for the number quoted before, with reference to a luminosity of 10^{-34} $cm^{-2}s^{-1}$).

3. *Beam-gas*

During the single beam period, the beam-gas collisions occurring directly inside the Inner Detector cavity might also be a potentially useful source of data. Close to the nominal interaction point (±20 cm) one expects a rate of ~25 Hz of reconstructed tracks with $P_T > 1$ GeV. This corresponds to $>10^7$ tracks in two months of single beam. These events (with the available statistics) could be used, for example, for the Inner Detector alignment, since they resemble proton-proton interactions. However, using the standard triggers, it looks difficult to trigger on these events which are essentially boosted minimum-bias. ATLAS will install minimum bias trigger scintillators. This, since the transverse energy of the outgoing particles is very small. Fig. 4b) shows an event display of a beam gas event in the ATLAS detector.

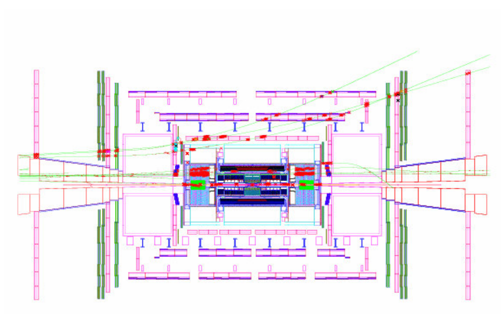


Figure 4: a) Simulated beam halo event in the ATLAS detector b) Simulated beam-gas event.

6. Commissioning with physics: the first 30-100 pb^{-1}

1. *Detector commissioning and simulation tuning*

The ATLAS detector performances expected at the time the first proton-proton collisions will take place are shown on Table 1. These estimates are based on the detector construction quality, on the known precision of the hardware calibrations and alignment systems, on test beam results, on simulation studies and on the experience gained in the pre-collision period [6]. These initial numbers should improve significantly once the first data will be collected in

2008. Due to the high event rates expected at the LHC, a large statistics should be reached already after a few weeks of data taking. Very soon therefore, ATLAS will only be limited by the systematic errors.

	Expected performance day-1	**Physics samples to improve**
ECAL uniformity	~1%	Minimum Bias, $Z \to ee$
e/γ scale	~2%	$Z \to ee$
HCAL uniformity	~3%	Single pions, QCD jets
Jet scale	<10%	$Z \to (ll)$ +1j, $W \to jj$ in ttbar
Tracking alignment (μm)	20-200 in $R\phi$?	Generic tracks, isolated μ, Z

Table 1: Expected ATLAS performance on "day-one", based on detector construction quality, test beam results, cosmic runs, simulation studies.

The first data will be used to understand and calibrate the detector, trigger and software in situ using well known physics samples [7]. For example, due to the high cross section for the production of top events (1 pair per second at a luminosity equal to 10% of the design value), one can study the jet energy scale using the $W \to jj$ mass peak, where the W is from the top decay.
Similarly, reconstructed decays like $Z \to ee$, $\mu\mu$, will be used to commission the tracker, the electromagnetic calorimeter and the muon systems.
Taking into account the misalignment initially foreseen for the ATLAS tracking system, tracks will be reconstructed with efficiency of the order of 40-60%. In just one day of data taking it will be possible to collect a statistics of data to align the Pixels to 1-2 μm and the SCT to 2-3 μm. As already mentioned, at this point one will be dominated by the systematic errors involved (i.e.: below a precision of 100 μm, thermal instability becomes relevant). A constant and detailed monitoring of the detector will be crucial to understand and reduce the sources of systematic.

2. *Early physics goals and measurements*

The next step will be to understand the basic Standard Model (SM) processes at LHC, since they will take place at a completely new center of mass energy never reached previously, and perform the first checks and tunings of the Monte Carlo simulations. This includes measuring the basic cross sections, for events as minimum bias, QCD jets, W, Z and top. It has to be underlined that the statistical error on all these measurements will be practically negligible after having collected about 10 pb^{-1} of data.

Fig. 6 shows[1] the number of events expected to be recorded, for three different SM processes ($W \to l\nu$, $Z \to ll$, $tt \to l\nu+X$) as a function of the integrated luminosity. The assumed selection efficiencies for W and Z are 20% and 5% for the tt (no b-tag, inside the mass bin). An integrated luminosity of 10 pb^{-1} corresponds to about one month of data taking at an instantaneous luminosity of 10^{30} cm^{-2} s^{-1}, and to less than two weeks at 10^{31} cm^{-2} s^{-1}, assuming a machine efficiency of 50%. With the same assumption, 100 pb^{-1} will be taken at a luminosity of 10^{32} cm^{-2} s^{-1} in just a few days and will give more or less the present statistics collected up to now by the CDF and D0 experiments.

[1] Thanks to F. Gianotti.

To these events of course one has to add a lot of minimum bias and jet events (about 10^7 in two weeks of data taking if 20% of the trigger bandwidth is allocated).

Figure 5: Number of events expected in ATLAS vs. integrated luminosity.

In the following, few specific early analyses are described, namely: minimum bias (MB), PDFs and top studies.

a. Minimum Bias

Minimum bias (MB) studies implies the analysis of different types of scattering processes contributing to the hadron-hadron cross-section. The four largest contributions are: non diffractive, single diffractive, double diffractive and elastic. In any case, MB events are dominated by soft partonic interactions. A MB event is what one would see with a totally inclusive trigger. The experimental definition depends in fact on the experiment trigger: MB is usually associated to non single-diffractive events (NSD), as done for example by the ISR, UA5 and CDF. The NSD cross section at the LHC ranges from ~65 to 74 mb (depending on the chosen model, PYTHIA or PHOJET). MB events therefore are expected to contribute significantly (more than 65%) to the total scattering process at the LHC.
MB events are important in order to describe background processes to any signal event and since, by definition, they occur all the time (especially with respect to rarer events like Higgs), they turn out to be useful also to predict the radiation damage to the detector due to the scattered protons. In terms of physics, the study of MB events can improve for example our understanding of QCD effects, of the total and jet cross sections. But it can be useful also to evaluate the occupancy, pile-up and backgrounds for the detector.
Finally, these events are worthy of scientific study in their own right, as they provide an insight into the internal structure of protons.
At the LHC, studies on MB events should be done early on, at low luminosity, to remove the effect of overlapping proton-proton collisions. A MB event at the LHC would look like the one simulated in fig. 6a). The tracks are quite soft (P_T^{peak} ~250 MeV), with an approximate flat distribution in η (up to $|\eta| = 3$) and in ϕ[8]. The mean number of charged tracks at $|\eta| <2.5$ is around 30.
The obvious first measurements one will do at the LHC are $dN_{ch}/d\eta$ and dN_{ch}/p_T, since they only require several thousand events. MC predictions have been compared with data from ISR, SPS and Tevatron experiments, and then extrapolated to the LHC energy. If one looks at the distribution of charged particles as a function of the pseudo-rapidity η, at $\eta = 0$, different models make different predictions for the LHC case. The multiple interaction model in

PHOJET predicts a ln(s) rise (s being the energy in the cms of the collisions) while PYTHIA suggests a rise dominated by the $\ln^2(s)$ term (see fig. 7b)).

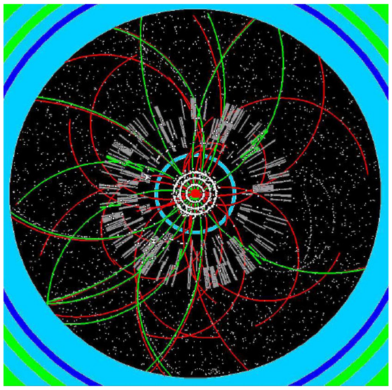


Figure 6: a) Display of a minimum bias event in the ATLAS detector. b) PHYTIA and PHOJET prediction for the distribution of the differential number of charged particles at η=0 as a function of the collision cms energy.

Preliminary studies showed that the tracking is characterized by a limited acceptance in η and P_T. Only the region $|\eta| < 2.5$ is covered (as shown in fig. 7a)) and the charged track reconstruction at low P_T has to be better understood. For the moment only tracks with $P_T >$ 500 MeV, i.e. which crosses all the three components of the ID) have been considered for reconstruction (see fig. 7b)).

Figure: 7 a) Number of charged tracks vs η. In black (higher histograms) the Pythia generated tracks are represented. In blue and red (lower histograms) the tracks are reconstructed with two different algorithms. b) Number of charged tracks as a function of the transverse momentum of the track. In black (higher histograms) the Pythia generated tracks are represented. In blue and red (lower histograms) the tracks are reconstructed with two different algorithms.

However, recent studies are trying to assess with more precision what is the real tracks momentum limit in ATLAS, developing new and more sophisticated reconstruction algorithms. The first indications allow us to be optimistic: the tracker is in principle sensitive even to very soft tracks. A track with P_T of 400 MeV reach the end of the TRT (fig. 8a)), a track with P_T of 150 MeV reaches the last SCT layer (fig. 8b)), a track with only 50 MeV cross all the three Pixel layers (fig. 8c)).

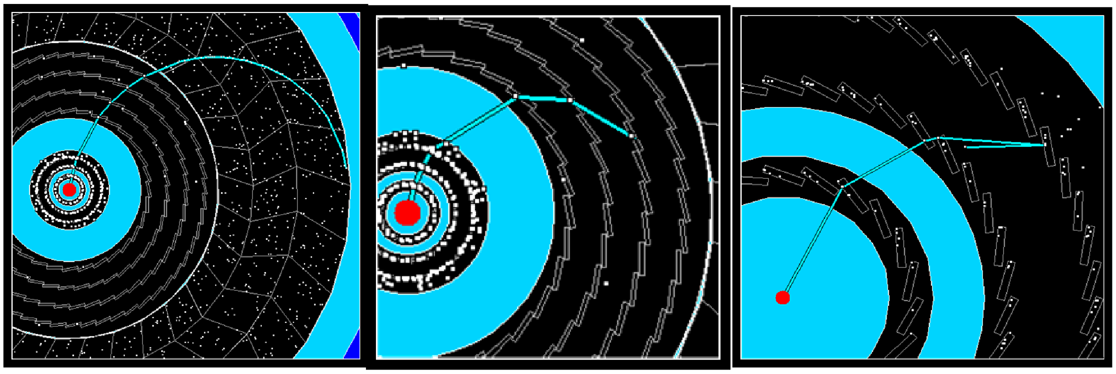


Figure 8: Simulated track of a) 400 GeV, b) 150 GeV and c) 50 GeV in the ATLAS Inner Detector.

b. PDFs

As for all the hadron colliders, at the LHC every cross section calculation is a convolution of the cross-section at parton level and of the parton distribution function (PDFs). These last ones are crucial to get reliable predictions for new physics signals (like Higgs, SUSY, Extra Dimensions etc.) and background cross sections. The x-dependence (where x is the fraction of the proton momentum carried by the parton) is determined by fit to data from experimental observables (DIS processes at fixed target and HERA), Drell Yan lepton pair production, high E_T jets at CDF and D0, W rapidity asymmetry at CDF, νN di-muon at CCFR and NuTeV etc..). The Q^2 (transferred momentum)-dependence is instead determined by conventional LO, NLO, NNLO QCD evolution in the DGLAP formalism. The most recent PDF sets provide uncertainties, which only make sense at NLO (or higher), since only in this case normalization is believable. Which situation LHC will find at its start? In most of the relevant x-regions accessible at LHC, HERA data are an important source of information in the determination of the PDFs (low x-sea and gluon PDFs).
The DESY experiment now is in a second stage of operation (HERA-II [9]) characterized by an important increase in luminosity and by the possibilities to perform new measurements. This brings a reduction of the high-x PDF uncertainties, which is going to be relevant for the high scale physics at the LHC, where one expects new physics to appear. In particular, there should be a significant reduction of the valence-quark uncertainties over all-x, and of the sea and gluon uncertainties at mid-to-high-x. Less significant should be instead the improvement to the sea and gluon uncertainties at low-x. Said this, the kinematics regime which LHC will be able to explore is in any case much broader than the one currently explored. At the TeV scale the cross section predictions are dominated by high-x gluon uncertainty, while at the EW scale (W and Z masses), the theoretical predictions are dominated by low-x gluon uncertainty. But how will it be possible to constrain the PDFs at LHC? One way is to look at the rapidity distribution (y) of the lepton from the W-boson decay [10]. The W-boson production over $|\eta| < 2.5$, at LHC involves $10^{-4}<x_{1,2}<0.1$. This region is dominated by gluon splitting $g \rightarrow qq$.
At y=0 the PDF uncertainty is ~±5.2% from ZEUS-S, ~±3.6% from MRST01E and ~±8.7% from CTEQ6.1M. The central value difference from ZEUS-S to MRST01E is of about 5%, while from ZEUS-S to CTEQ6.1 is ~3.5%. The ATLAS goal therefore will be to reach a systematic experimental error of 4 % about, in order to distinguish between different sets of structure functions.

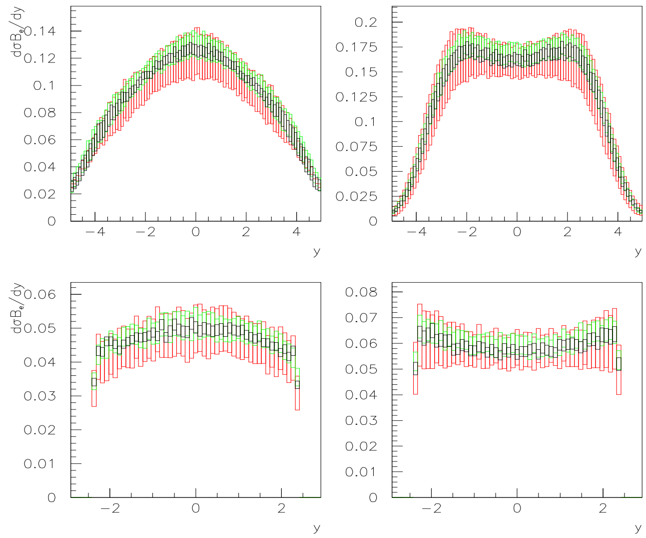


Figure 9: a) PDFs kinematics regime at the LHC. b) e^+ (left) and e^- (right) rapidity distribution for events at generator level (upper plots) and at ATLAS detector level (lower plots). The error boxes are the full PDF uncertainties. The events have been generated with the Herwig MC simulations with NLO corrections.

The effect of including the ATLAS data on PDF fits, have been evaluated simulating real experiment conditions, and finding that the central value of the ZEUS PDF prediction shifts, while its uncertainty is reduced. It has been found that with few days of statistics at LHC at low luminosity, the error on the low-x gluon shape parameter λ ($xg(x) \sim x^{-\lambda}$) is reduced by 41%. The systematics involved in this study (e.g. e^+/e^- acceptance vs y) can be controlled to few % by using a sample of Z→ee (about 30000 events can be collected with an integrated luminosity of 100 pb^{-1}).

c. Top mass and cross section

At the LHC we expect about six millions of top pair events to be produced in one year at a luminosity of 10^{32}. Given this huge statistics, this process is very valuable for the in-situ calibration of the ATLAS detector at the commissioning stage. According to the SM each top quark decays in a W and a b-quark. We select the events in which one of the Ws decays in two jets and the other one decays in a charged lepton and a neutrino. The large cross section and the large S/B ratio for this so-called single lepton + jets channel, allow to produce high purity samples with large statistics in a short time period. The understanding of the experimental signatures for top events involves most parts of the ATLAS detector and is essential for claiming potential discoveries of new physics.

Top-quark decay products include one or more jets originated from a b-quark. Thus, the b-tagging performance of the ATLAS detector has an important role for top analysis. Indeed, top events themselves can be used to evaluate the b-tagging efficiencies directly from the data. It can be done, for example, by selecting a pure sample with tight kinematical cuts and counting then the number of events with at least one tagged jet. The number of events with 0, 1 and 2 b-tagged jets can then be compared and the tagging efficiency be evaluated. An efficient b-tagging needs precise alignment of the trackers of the Inner Detector, which will be reached only after few months of data taking. But at the very beginning, during the commissioning stage, will it be possible to perform top physics? ATLAS explored the

possibility of reconstructing top events in production by assuming the absence of b-tagging. The study has been performed at fast simulation level [11] and afterwards repeated with the full ATLAS detector simulation [12].
In this scenario, without b-tagging, the aim is to reconstruct the top in the “single lepton” channel using extremely simple and robust selection criteria. We selected the events by requiring four jets, one high P_T isolated lepton and missing E_T.
The (hadronic) top mass is reconstructed as follows: all four permutations of three jets (out of the four selected jets) are considered. For each permutation the jets are added together and the P_T of the system is determined.
The permutation which results in the highest P_T value is taken as the set of jets that correspond to the decay of the top quark. The top mass itself is then simply reconstructed as the invariant mass of the three selected jet. The selection efficiency for this study is 5.3% (trigger efficiency not being included). The W-boson which decays in two jets is also reconstructed, by choosing the two jets with highest momentum in the reconstructed three-jets c.m. frame. Even with such a simple selection and mass reconstruction, both the top and hadronic W-mass peak are clearly visible, even with only 300 pb^{-1} of data collected (corresponding to one week at low luminosity).
The most dangerous background (characterized by a large uncertainty) is due to W+jet events from QCD, and it has been simulated with the Alpgen Monte Carlo. If one applies an additional cut to constrain the W mass, the top peak improves.
Fig. 10a) and 10b) show the reconstructed hadronic top mass before and after applying the selection on the W-mass.

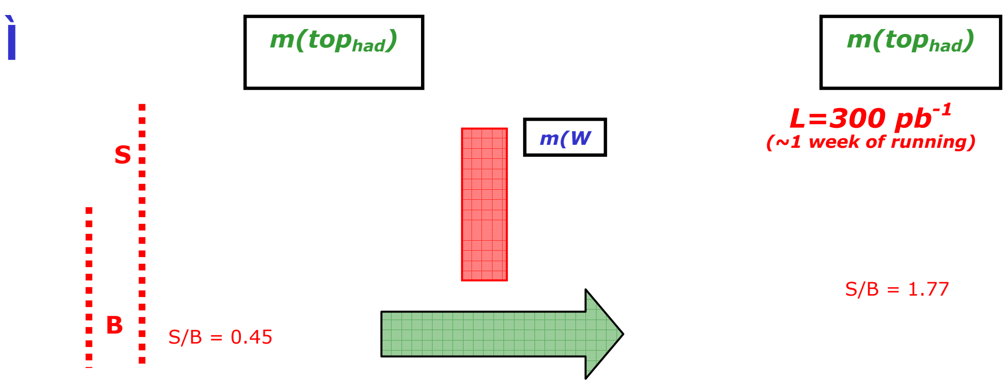


Figure 10: Reconstructed hadronic top mass a) before and b) after applying the selection on the W mass (central small plot)

7. Discoveries?

Once the detector performances will be understood and the main SM processes will be studied, the next step will be to evaluate the background for new physics (like top-anti-top and W/Z + jet events), preparing the road to a possible discovery. In this view, it will be possible also to look at specific “control samples” for each individual discovery channel. For example, ttjj events, with $j \neq b$ can be used to calibrate the ttbb irreducible background for the process $ttH \rightarrow ttbb$.
Only when this last step will be addressed, confidence will be gained to possibly claim a discovery. In the following we make few examples of a new physics signal which can show up relatively soon, at least in terms of statistics collected (about 100 pb^{-1}).

Z' → ee

A particle of mass between 1 and 2 TeV which decays in e^+e^- pairs, like a new gauge boson Z', can be detected at LHC in a relatively easy way, expecially if the lepton coupling is similar to the one predicted by the SM. Even if the branching ratio into leptons is at the percent level as for the Z boson, about 10 events will show up in the ATLAS detector after applying all the analysis cuts to 300 pb^{-1} of data collected, if the Z' mass is around 1.5 TeV. In the TeV region, the Drell-Yan background is quite small (<0.2 events in the region 1.4-1.6 TeV for 100 pb^{-1} of collected data). The signal would appear as a resonant peak on top of a smooth background, and not just as an excess in the total number of events. All this is still true if the calorimeter response is understood to a conservative level of a few percent. Table 2 shows, for different masses of the Z', the expected number of events for 10 fb^{-1} (after having applied all the analysis cuts) and the integrated luminosity needed for a discovery (corresponding to ten observed events)

Mass	**Expected events in 10 fb^{-1}**	**$\int Ldt$ needed for discovery (10 evts observed)**
1 TeV	~160	~70 pb^{-1}
1.5 TeV	~30	~300 pb^{-1}
2 TeV	~7	~1.5 fb^{-1}

Table 2: Expected numbers of Z' events in 10 fb^{-1} of collected data and integrated luminosity needed for a discovery, for different Z' masses.

SUSY

Identification of a SUSY signal implies a very good understanding of the various backgrounds involved in the analysis as well as a good calibration of the detectors.

This of course will require some time, but once it is done, a new signal observation would profit of the huge production cross section for SUSY particles at the LHC and of the quite clear signatures. Looking for final states containing several high P_T jets and large missing E_T, ATLAS should be able to discover squark and gluinos up to masses of about 1.5 TeV in only one month of data taking at low luminosity. A very important detector performance issue for an early SUSY discovery is a robust reconstruction of the event missing E_T. This measurement can be affected by several instrumental effects like calorimeter non-linearities, cracks in the detector, etc.. However, final states faking the presence of missing E_T can be rejected by requiring that the event primary vertex is located close to the interaction centre. This also helps to suppress the background from cosmic ray events and beam-halo muons. Fake missing E_T events can also be eliminated by requiring that there are no jets pointing to detector cracks and that the missing P_T vector is not aligned with any jet. The calorimeter response linearity can be controlled thanks for example to samples of $Z(\rightarrow ll)$+ jet events, where the lepton pair and the jet are back-to-back in the transverse plane, so that the P_T of the lepton which is well measured can be used to calibrate the jet P_T scale over a large dynamic range. For what concern the physics backgrounds ($Z\rightarrow\nu\nu$+jets, $\tau\tau$, QCD multijet events), most of them can be evaluated by using control samples. For example, $Z\rightarrow ee$ events can be used to normalize the $Z\rightarrow\nu\nu$+jets background. Tevatron developed a technique to handle the residual background from QCD. It consists of normalizing the Monte Carlo simulation to the data in the (signal-free) region at low missing E_T and then use the Monte Carlo to predict the background in the (potentially signal-rich) region at large missing E_T. Of course, in all this is crucial the reliability of the Monte Carlo itself.

Standard Model Higgs

The chance to discover a SM Higgs boson at the LHC during the first year(s) of operation depends very much on the Higgs mass, as shown in fig. 11. If the Higgs mass is larger than 180 GeV, discovery may be relatively easy thanks to the gold-plated $H \to 4\ell$ channel which is essentially background-free. The main requirement in this case is an integrated luminosity of at least 5-10 fb^{-1}, since the signal has a cross section of only a few fb.

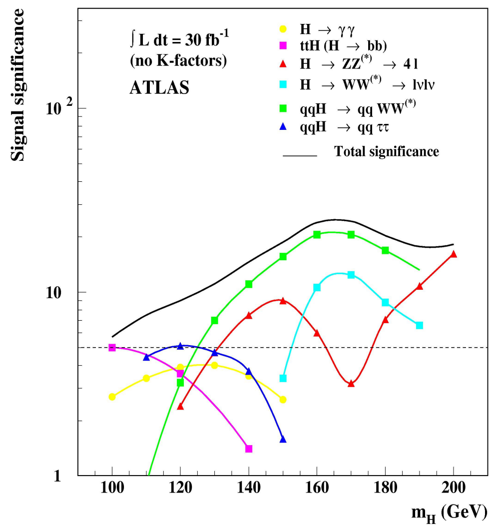


Figure 11: Expected signal significance for a SM Higgs boson in ATLAS as a function of mass, for an integrated luminosity of 30 fb^{-1} and for the various channels. The horizontal line indicates the

A discovery will be much more difficult for a Higgs mass close to the LEP limit. The expected sensitivity for a Higgs mass of 115 GeV and for the first good (i.e. collected with well calibrated detectors) 10 fb^{-1} is summarized in Table 3, which shows the number of signal and background events, as well as the S/B ratio, for three different processes: $H \to \gamma\gamma$, ttH production with $H \to bb$, and Higgs production in vector-boson fusion followed by $H \to \tau\tau$.

	$H \to \gamma\gamma$	$ttH \to ttbb$	$qqH \to qq\tau\tau$ (ll+l-had)
S	130	15	~10
B	4300	45	~10
S/B	2.0	2.2	~2.7

Table 3: Expected sensitivity for a Higgs mass of 115 GeV and for 10 fb^{-1} for three different processes: $H \to \gamma\gamma$, ttH production with $H \to bb$, and Higgs production in vector-boson fusion followed by $H \to \tau\tau$.

The total significance of about 4σ per experiment (4+2.2−1.3 σ including the expected systematic uncertainties) is more or less equally shared among the three channels. These results are quite conservative. For instance, very simple cut-based analyses have been used, and higher-order corrections to the Higgs production cross sections (the so-called K-factors), which are expected to increase for example the $gg \to H \to \gamma\gamma$ rate by a factor of about two compared to leading order, have not been included. Nevertheless the significances of the individual channels for 10 fb^{-1} are small, and an excellent knowledge of the backgrounds is

required. For these reasons, the contribution of both experiments, and the observation of possibly all three channels, will be crucial for an early discovery.
The channels listed in tab. 3 are complementary. They are characterized by different Higgs production mechanisms and decay modes, and therefore by different backgrounds and different detector requirements. A good uniformity of the electromagnetic calorimeters is crucial for the $H\rightarrow\gamma\gamma$ channel. Powerful b-tagging is the key performance issue for the ttH channel, since there are four b-jets in the final state which have to be identified in order to reduce the background. Efficient and precise jet reconstruction over ten rapidity units ($|\eta| < 5$) is needed for the $H\rightarrow\tau\,\tau$ channel, since tagging the two forward jets accompanying the Higgs boson and vetoing additional jet activity in the central region of the detector are necessary tools to reduce the background.

8. Conclusions

While the ATLAS detector installation and integration is proceeding quite smoothly, the experiment has already developed a detailed working plan for the detector commissioning using physics events. This road has been started already in 2004 with the Combined Test beam, with which a full vertical slice of the detector was tested and proved to be functional. From 2005 until present (Summer 2006) many sub-detectors have been placed in the pit and cosmic rays data are being collected This combined cosmic ray commissioning will continue in 2007, until when, at the end of the year, the first collision will appear.
This will provide an additional opportunity to understand the detector in its various parts, and to perform an initial calibration and alignment. The first proton-proton collisions in 2008 will allow to complete the detector commissioning, and finally to observe, understand and measure the well-known Standard Model physics (MB, UE, *W* and *Z*, top events) at a completely new energy, as well as the background expected in the "discovery" channels. At this point, LHC will be ready to enter a completely unexplored territory.

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