CERN-RRB-2013-025
5 April 2013

ATLAS Progress Report for the April 2013 RRB

1. Introduction

The period since the last RRB meeting in October has seen the completion of the more than three-year long running period of the LHC and ATLAS ("run-1"), with the completion of pp data taking in December and a very successful p-Pb and lower energy pp run this year. In total ATLAS has recorded 27 fb^{-1} of pp collision data at 7-8 TeV centre-of-mass energy in run-1. Since mid-February the LHC has entered the first long shutdown (LS1), and ATLAS has started an extensive programme of maintenance and consolidation at the detector site.

Throughout run-1, including the last six months, the ATLAS detector performed with high efficiency and data quality: for the 2012 pp data more than 95% of the recorded total is usable in all physics analyses. This excellent performance continued along the computing chain, through reconstruction, data reduction and to final analysis. The computing resources available to ATLAS on the WLCG during this last year were an essential ingredient in producing a substantial number of results based on the full data set within 3 months of the end of pp data collection.

Many results including already 13 fb^{-1} of 2012 data were shown at the HCP conference in November, followed by first results with the full 2011-plus-2012 dataset already by the Moriond and Aspen conferences in March. A key focus has been to make rapid progress in elucidating the nature of the Higgs-like boson co-discovered by ATLAS and CMS in July 2012. Full updates of the boson channels were available by March with the full dataset, analysing not only the mass and signal strengths, but also the spin-parity of the new boson, finding evidence for vector-boson production, and deriving constraints on coupling strengths. In addition to the Higgs measurements, a range of searches for other new particles have also been reported based on the full, or large parts of the, run-1 data sample, as have measurements of other known processes such as diboson production.

In total, 240 journal articles have been submitted or published, based on collision data, by 3 April. Forty-seven have been submitted since 1 October 2012. In addition, ATLAS has now released 480 conference notes. This productivity demonstrates that the Collaboration is able to deliver a large wealth of physics results very quickly, thanks also to the smooth and effective operation of the computing grid infrastructure based on the WLCG backbone.

ATLAS has an extensive and carefully planned programme of work at the experiment for the 2013-2014 long shutdown (LS1), including the installation of a new inner-detector cooling plant, replacement of the liquid-argon and tile calorimeter low voltage power supplies, completed installation of staged muon chambers, expanding readout systems to cope with a 100 kHz first-level trigger rate, improvement of the magnet cryogenic system, and additional consolidation work. The so-called "Insertable B-layer" (IBL) will be installed in the Pixel detector with a new beam pipe. It was decided in January to remove the Pixel detector from ATLAS during LS1 in order to install the support tube for the IBL, and to allow replacement of much of the Pixel detector services.

Away from the detector, significant work is planned on the software and computing systems of the experiment: after three very intensive and almost continuous years of operation and analysis, there is now time to make improvements based on the accumulated experience, which will provide substantial technical performance improvements, enhancing the physics possibilities after LS1.

All of these accomplishments have required very considerable operational effort. Operation Tasks (OTs), defined as all activities essential to the operation of ATLAS, from central shifts and on-call tasks at Point-1 to computing and data preparation tasks, require ~650 FTE, plus shifts. Responsibility for OTs is shared among the Institutions in proportion to their number of authors. Effort on ATLAS-specific WLCG operation, at the level of approximately 180 FTE, is in addition. During LS1, OTs related to operation of the detector at point-1 (mainly shifts) are dropping to a low level, but the requirement for offline activities is increasing a little due to the large computing development and test programme.

Substantial progress has been made in establishing detector upgrades, building on earlier R&D activities. Several milestones are being reached in 2012/3. The Collaboration Board (CB) has now approved four “Phase-1” projects to be installed on the timescale of the second long LHC shutdown in 2018 (LS2): the new small wheels (NSW) upgrading the muon triggering and providing improved tracking in the forward region; the fast track trigger (FTK) providing track information very early in the high-level trigger processing; new liquid-argon (LAr) digitised trigger outputs; and a range of improvements to the trigger/DAQ (TDAQ) system, including new first-level calorimeter trigger processor units. Technical Design Reports are being written for all four projects, for submission to the LHCC later this year. A Letter of Intent (LoI) for the second tranche of “Phase-2” upgrades, planned for installation in 2022-2023 (LS3), was submitted to the LHCC prior to their March meeting, and was very well received.

The ATLAS Collaboration consists today of 177 institutions from 38 countries with approximately 3000 active scientists, of which 1800 with Ph.D. (hence considered for M&O cost-sharing) and about 1200 students. At its February 2013 meeting, the ATLAS CB admitted Louisiana Tech University, USA as a new member institution.

ATLAS is extremely grateful to the Funding Agencies for their continuing support over two decades. This support has enabled the success of the collaboration in making the Higgs boson discovery and starting to elucidate its nature, already in this early phase of the physics exploitation of the LHC.

2. Detector Operations

Proton-proton data taking for run 1 of the LHC was completed in December with a total integrated luminosity delivered to ATLAS of 23.3 fb^{-1} at 8 TeV centre-of-mass energy, of which 21.7 fb^{-1} were recorded in stable beam conditions (see fig. 1).

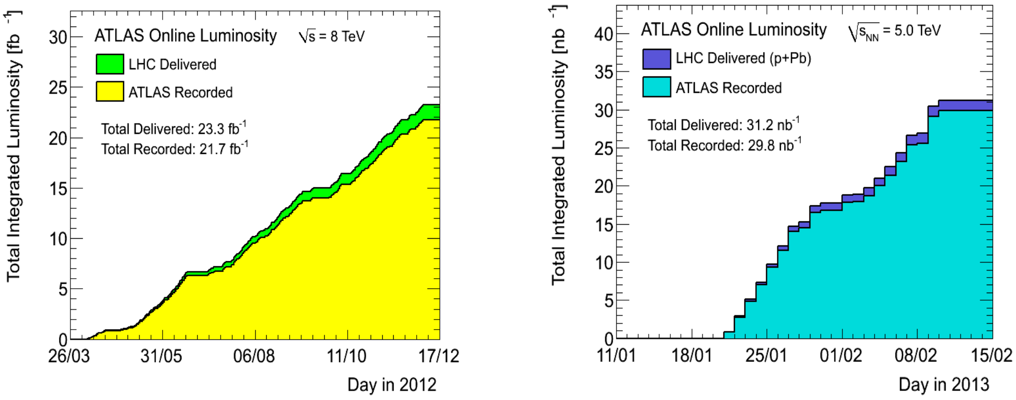


Figure 1: ATLAS integrated luminosity in 2012 for proton-proton collisions at 8 TeV and in 2013 for p-Pb collisions.

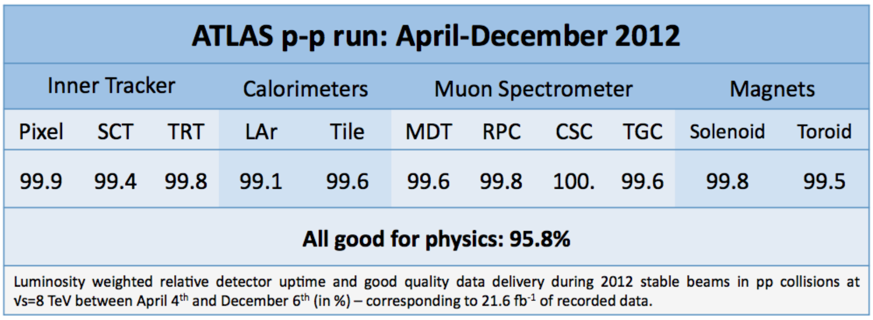
With peak luminosities at the start of a fill reaching routinely 7.5x10^{33} cm^{-2} s^{-1} and above, ATLAS readout and bandwidth resources were used to their limits. Both spare and redundant systems were successfully brought into operation to cope with the high rate and high pile-up. The overall ATLAS data taking efficiency, while stable beams were declared by the LHC, is 93.5% over all 2012, essentially the same as in 2011, despite the increased luminosity last year.

As in the first half of 2012, the high data taking efficiency relied on continuous maintenance of infrastructure such as cooling, cryogenics, electricity, gas systems and ventilation, as well as of subdetector components. The short technical stops interspersed with data taking were crucial in this regard, and made use of to the fullest. In addition, continuous improvements and work was ongoing on the trigger and DAQ system, in particular to cope with the gradually increasing peak rates and bandwidth requirements, and on the detector control, to allow a more and more autonomous operation of the detector.

Reliable and prompt responses of on-call experts was a crucial asset, as was having a well-trained shift crew, supported by intuitive shift and expert tools. Tuning of the ATLAS “shifter assistant” expert system, as well as more and more sophisticated handling of recoveries of faulty detector elements, have continued throughout the data taking, with very positive results.

The proton-proton data taking was followed by a very successful p-Pb run in 2013, in which the LHC delivered 31.2 nb^{-1} to ATLAS, of which 29.9 nb^{-1} were recorded. Finally, ATLAS took data with protons at an intermediate centre-of-mass energy of 2.76 TeV, including performing a van der Meer scan for luminosity calibration, this data sample being crucial as reference for the analysis of the 2011 Pb-Pb collision data.

The quality of data collected with protons at 8 TeV continued to be excellent, as shown in Table 1. Data taken before 10 November has been reprocessed, recovering in particular a few runs with previously bad conditions data. After reprocessing, 95.8% of all recorded data is good for all ATLAS analysis, eliminating the need to use different definitions of good data quality in different analyses.



ATLAS p-p run: April-December 2012										
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.9	99.4	99.8	99.1	99.6	99.6	99.8	100.	99.6	99.8	99.5
All good for physics: 95.8%										
Luminosity weighted relative detector uptime and good quality data delivery during 2012 stable beams in pp collisions at $\sqrt{s}$=8 TeV between April 4th and December 6th (in %) – corresponding to 21.6 fb^{-1} of recorded data.										

Table 1: Luminosity weighted relative fraction of good quality data delivered per sub-detector, after reprocessing for data taking before November 2012.

For the p-Pb run, the overall good data quality fraction is 86.9%. This is lower than for the pp data due to a readout hardware problem with the Cathode Strip Chamber (CSC) system over a period of two days, which due to the short duration of p-Pb data taking has a fractionally significant impact. For most p-Pb analyses, the forward muon system is not critical, and data will be used when the CSC was not fully operational; in such analyses 94.8% of data is usable.

With the start of LS1, there will be no physics data taking for up to 2 years. It is nevertheless crucial to maintain the expertise and competence in detector operations. In particular, work on shifter and expert tools will continue, automating as much as possible recoveries of failed readout elements, or tripped power supplies. More advanced monitoring tools are also being developed. This operations-related development will complement the work on the detector hardware during LS1.

An important goal after LS1 for the experiment is to increase the rate at which the first-level trigger can be operated. Currently this reaches a maximum close to 75 kHz: action is being taken in several systems to allow this to be increased to the original ATLAS goal of 100 kHz.

2a. Magnet System

The ATLAS superconducting magnet system comprises the central solenoid, the barrel toroid, two endcap toroids, and their service systems for cryostat vacuum insulation; cryogenic plant for helium supply and proximity cryogenics for enforcing helium circulation among the cold masses; power converters and their electrical circuits including switches, bus bars to deliver current to the various coils and diode-resistor units to absorb the stored energy in the case of slow dumps; and controls and safety systems to guarantee reliable and safe operation. Most of the magnet system services for vacuum, cryogenics and controls have been operational since 2006 and must be maintained and upgraded in view of ATLAS running for many more years.

In view of the first long shutdown and after three and a half years of nominal operation since September 2009 it can be concluded that the system has performed remarkably well. In the year 2012 no serious interruptions of services during data taking took place other than power cuts due to thunderstorms. In all cases, the magnet system responded as expected. With some 19000 magnet running hours only 0.1% of the time the magnet was off during data taking. In 2012, the causes of the four unplanned magnet discharges were power glitches in the external electrical network, a failing cryogenic sensor, a filter cleaning requirement in cryogenics, and power converter faults.

Advance preparation for changes to the magnet system in LS1 has provided a list of consolidation improvements. The modifications mainly concern cryogenics. An extra powerful booster compressor was installed in 2012, and a second main compressor for the 4K refrigerator was installed in early 2013, both to increase compressor redundancy and protect ATLAS from a 12 month downtime in case a compressor would break down. A second investment is the new installation of helium dryers in the compressor stations of shield and main refrigerators in order to avoid 2-3 day stops sometimes required for system cleaning and purging. A third investment ensuring robust data taking is the installation of a new 10000 liter helium storage dewar that will be incorporated in the solenoid cooling circuit. The new dewar makes it possible to continue data taking with the solenoid on, while the toroid is in fast dump recovery, which takes 4 days. Other LS1 works on the magnet system concern a complete check and re-commissioning of all electrical systems, power converters, switches, re-tightening of bolts on the widely spread bus bars systems, and removing some hot spots. One of the two redundant magnet safety systems will be replaced by a new, industrial and much cheaper, unit. The second redundant unit would be replaced during LS2. Modifications to the vacuum systems are being made, again with the aim to reduce the risk of down time and to make the system less vulnerable to possible damage due to accidental interventions in the cavern.

2b. Inner Detector

The Inner Detector (ID) combines three concentric sub-systems: the Pixel detector, the silicon strip detectors (SCT), and the transition radiation tracker (TRT), listed from inside to outside.

The off-detector optical transmitter plug-ins (TXs) used in both the Pixel and SCT detectors continued to be problematic. The existing plug-ins use humidity-resistant VCSEL arrays (humidity ingress was identified as the cause of failures of previously installed batches from a different vendor). Nonetheless, the existing plug-ins exhibited a small but significant rate of channel deaths, and have shown a ~10% drop in optical power during the past year of operation. Given the severe concerns for the longevity of these units, a new TX design has been developed which incorporates a commercially available optical sub-assembly with proven robustness and reliability. Tests by ATLAS on a sample of the new TXs are so far very encouraging, and we hope to procure sufficient numbers of the new TX in LS1 to meet all SCT and Pixel needs.

In preparation for the increased pile-up and trigger rates anticipated after LS1, the SCT will expand their data acquisition system during LS1 and also apply an improved data compression algorithm. These steps will significantly improve existing bandwidth limitations arising from the S-Link to match or exceed the limit from the front-end chips. For the SCT, an additional 38 readout drivers and 38 back-of-crate cards are being fabricated, to supplement the 90 cards of each type that are currently installed. Production of the new hardware is on schedule and the cards will be installed in Summer 2013; the expanded DAQ will be commissioned when the SCT is cooled and powered again from October 2013.

The pixel detector performed stably and with high efficiency during 2012. At the end of the run the decision was made to extract the pixel detector during LS1 in order to equip it with new service quarter panels and integrate the 4th pixel layer, the IBL. The decision was made based on careful risk evaluation for an in-situ IBL installation and the benefits of new and accessible opto-components for long-term maintenance of the future 4-layer pixel detector. The new service quarter panels will provide increased readout speed for the second and third pixel layers, and facilitate the recovery of known failures, e.g. failed communication links. The extraction also allows the surface integration of the support tube for the IBL which minimizes risks of B-Layer damage.

Over the last year the TRT has developed several leaks, resulting in a loss of xenon gas. In the last months of operation the total loss of Xe was about 170 liters per day. The number of leaks is quite large, and ten of them are significant. All leaks are in the exhaust pipes of the detector. The working hypothesis is that the leaks are caused by the corrosion of the PEEK pipes in places which are under significant mechanical stress. This corrosion is initiated by ozone produced in the gas avalanche in the straw. Leaks in the barrel TRT are not accessible but a leak repair technique for the endcaps is under development. A campaign to try to access and to repair the leaks will start in April and will last a few months. Steps to improve the gas system performance to minimize gas losses will be implemented during LS1.

It cannot be excluded that some parts of the detector will need to be operated in future with a cheaper argon-based mixture instead of the more expensive xenon mixture. The impact on TRT performance with an Ar mixture is under study. A few modules of the TRT were operating with different Ar-based mixtures during the p-Pb run. Preliminary results indicate that the tracking properties of the TRT will not be affected by a change of the active gas mixture, although electron identification will be impacted. The effect on the overall ATLAS physics performance for different scenarios of operation with an Ar-based mixture is under study.

Among many upgrade activities which are planned for LS1 the TRT ROD firmware upgrade is important for operation in 2015. Significant effort will be required to reach stable operation at L1 trigger rate of 100 kHz at high luminosity (hence occupancy).

The ID evaporative cooling system operated with high efficiency in 2012, though the compressors required frequent maintenance primarily due to filter clogging. The thermosiphon-based replacement evaporative system is on schedule, and will be exercised first with a bypass system in August, and then with the SCT from October 2013.

2c. Calorimeters

The calorimeter system includes a liquid argon (LAr) electromagnetic calorimeter, a barrel and two extended barrel Tile hadronic calorimeters, liquid argon end-cap hadronic calorimeters (HEC), and liquid argon forward calorimeters (FCal).

The frequency of high voltage trips in the LAr calorimeters, which was an issue in the past, remains low (1 per 10 hours), and its effect on data quality has been minimised through automatic recovery. Sporadic noise occurs in the LAr presampler. This effect has been mitigated by reducing the applied high voltage. In summary, the LAr calorimeters achieved a remarkable data quality efficiency of 99.1% during the 2012 proton run.

While the original low voltage power supplies (LVPS) on the Tile calorimeter tripped very frequently (~14000 trips in 2012), the forty (out of 256) redesigned LVPS installed during the technical stop at the end of 2011 have been operating well, with only one trip in 2012. The remaining 216 new supplies, which also have better noise performance, will be installed in the upcoming long shutdown, as will the remaining 46 (out of 58) redesigned LAr LVPS. On top of that a small number - about 15 - LAr front-end boards will be repaired. During LS1 the Tile calorimeter electronics will also be consolidated with reinforced connectors and the missing 1/16 crack scintillators will be installed.

2d. Muon Detectors

The muon spectrometer is instrumented with precision chambers for momentum measurement (Monitored Drift Tube chambers, MDTs, and for a small higher-radiation forward area Cathode Strip Chambers, CSCs) and with fast chambers for triggering (Resistive Plate Chambers, RPCs, in the barrel, and Thin Gap Chambers, TGCs, in the endcaps).

During the latter part of the 2012 run, and the subsequent 2013 p-Pb run, the muon system continued to perform remarkably well both in terms of percentage of operational channels (no relevant change with respect to the last report) and in terms of high data quality, delivering well-understood physics performance.

During LS1, a large number of consolidation and maintenance activities will be performed, both on the detector and on the read-out and control systems.

The detector will be completed by installing the remaining EE chambers on side A, four large sectors and eight small sectors. The feet region acceptance will be increased, both in terms of trigger and high precision tracking, by installing four new stations (each with MDT and RPC) in sector 13, covering the two elevator holes. The trigger acceptance in sector 12 and 14, which is hindered by the presence of the feet will be recovered by instrumenting an additional layer of RPC already installed in the outer barrel layer with trigger electronics.

In the EO MDT chambers, leaking gas jumpers will be replaced improving on the gas tightness of the system.

The small wheel on side-C has been lifted to the surface, to allow sufficient clearance in the cavern for the pixel removal/reinstallation, and the IBL installation. Two CSC chambers, in which two layers out of four are damaged, will be repaired while the small wheel is on the surface.

The RPC will perform repairs on the gas inlet of the chambers, which are prone to breakage, using a new technique involving the use of a sealing varnish. The grounding of many chambers (in particular in the feet region) will be improved, and improvements in the monitoring of the gas pressure at the inlet of the chambers are foreseen. This latter operation will allow to spot immediately the formation of micro-cracks in the gas inlet of the chambers allowing a much easier maintenance of the system.

About 30 new TGC chambers will be installed on the big wheels, replacing the chambers that showed permanent trips under high-luminosity operation. The alignment system will be improved by including the BEE chambers in the endcap alignment and by improving the system in the sectors 12 and 14 using special alignment frames to be installed between the BMF chambers.

All the DCS PCs will be renewed, together with the CanBus interfaces, and the DCS software framework will be updated.

In the running period after LS1, the peak first-level trigger rate will be 100 kHz. To cope with this, a new CSC ROD is needed. This will be designed and produced during LS1.

2e. Forward Detectors

The ATLAS forward detectors consist of a Luminosity Cerenkov Integrating Detector (LUCID) placed around the beam pipe inside the forward shielding at ± 17 m from the Interaction Point (IP), a Zero Degree Calorimeter (ZDC) placed in the TAN absorber structure where the beams enter separate beam pipes at ±140 m from the IP, and an Absolute Luminosity for ATLAS (ALFA) system based on fiber detectors located in Roman Pots at ±240 m from the IP.

A range of relative luminosity estimators is used by ATLAS, including LUCID, the beam condition monitor system (BCM) and calorimetric measurements. While LUCID and the BCM measure the luminosity separately for each beam crossing the calorimeter integrate over many beam crossings. Cross-comparisons between these detectors provide valuable checks of the stability of the individual luminosity measurements. At the end of 2012, LUCID data was taken with reduced HV and with quartz fibers. This data will be used to develop new methods for measuring the luminosity with LUCID after LS1. One of these methods is a luminosity measurement based on integration of the signal charge from quartz fibers during each bunch-crossing. The present photomultipliers will also be replaced with smaller ones in LS1 to improve the accuracy of the luminosity measurement at high pile-up..

In October 2012 data was taken successfully with the ALFA Roman Pots (RP) with dedicated LHC optics (beta* = 1km). About 300 000 elastic-like events, and many million diffractive triggers, have been collected. The Roman Pot detectors were moved very close to the LHC beams, to about 3 sigma (1mm). This close distance allows an analysis in the Coulomb-nuclear interference region. The ALFA detector was also used for data taking in the p-Pb runs. In these runs the detectors on the proton side were at 13 sigma (about 4.5 mm) from the beam. In the final intermediate pp run at 2.76 TeV a special run with the ALFA trigger was performed.

A goal during the LS1 shutdown period is to overcome the heating of ALFA by RF (radio-frequency) losses. Different options of active cooling and RF protection by improvement of the impedance by special RP or beam pipe fillers are under investigation. In April-May 2013 the technical solution will be selected and mass production launched after series of validation tests.

The ZDC was improved in preparation for the 2013 p-Pb run: a new, more precise calibration/monitoring system exploiting the Tile calorimeter laser system has replaced the old one based on LEDs; all photomultipliers used for triggering and energy measurements were replaced with new ones with higher gain; and all the quartz rods, with the exception of the position sensing ones, were replaced with new ones of the same type (the old ones having been degraded by radiation). The ZDC was re-installed and commissioned during the end-of-year break and it provided triggers and took data during the p-Pb run. Additional consolidation work is foreseen during LS1: the readout system will have to cope with 50/100 ns bunch spacing in heavy-ion collisions, and the quartz rods will be replaced by quartz fibers that are more radiation resistant.

2f. Trigger and DAQ System

The major sub-systems of the trigger and data acquisition system (TDAQ) are the Level-1 trigger (with calorimeter, muon, and central trigger processor, CTP, subsystems), the high-level trigger (HLT – comprising the Level-2 trigger and the event filter), the data acquisition (DAQ), and the detector control system (DCS).

The DAQ and HLT infrastructure operated at the performance limits of the hardware installation foreseen for 2012 operations, dealing with a peak Level-2 accept rate of 6.5 kHz and a physics throughput to mass storage of 600 Mbyte/s. The latter was achieved by increasing the size of the part of the system that handles the output to mass storage. The system also operated successfully during the p-Pb running in 2013. During LS1, a rolling replacement of the DAQ networks and the readout system will be undertaken so as to ensure that the system will operate at the same level of efficiency post-LS1.

Work is also underway to be able to configure and operate the HLT computer farm as a local grid site during LS1, providing a significant CPU resource to offline computing. The HLT farm should be ready for production of simulated data during the second quarter of 2013. The DAQ/HLT software is also undergoing changes during LS1, building on the operational experiences gained to-date and leading, in some areas, to simplifications of the overall software system. The computing capacity of HLT will also be increased during LS1 in preparation for higher energy and higher luminosity conditions post-2014.

The trigger selections (“menu”) defined for the 2012 run have demonstrated the flexibility required to handle the evolving LHC high-luminosity conditions. Optimisation of the selections, and increased pile-up robustness, have allowed data to be taken with similar trigger thresholds as in 2011 for the main physics objects (*e.g.* leptons and photons) in spite of the higher energy and luminosity. In addition, an improved selection has been implemented for physics channels of particular interest, such as certain Higgs decay modes. The strategy of giving full bandwidth to high-priority triggers at the start of each LHC fill and, as their rate decreases, allocating some bandwidth to lower priority triggers has allowed ATLAS to maximize its physics coverage. Peak trigger rates in high luminosity pp running were 70 kHz at Level 1, 6.5 kHz at Level 2, with a mean physics output rate averaged over the LHC fill of 400 Hz. In addition, an average of 150 Hz of lower priority “delayed” triggers were written directly to storage for offline reconstruction and analysis during LS1. Experience gained in the 2012 p-Pb pilot run enabled a new menu to be deployed for the 2013 p-Pb run which allowed the collection of almost 30 nb^{-1} with very high efficiency.

A major programme of improvement and upgrade of the trigger system is under way during LS1. Hardware upgrades are being made to the Level-1 calorimeter and central trigger, and a new topological triggering capability will be added at Level-1. Extensive changes are also being planned to the HLT steering and algorithmic software to simplify the selection flow and also improve the selection efficiency. The HLT software is also being prepared to capitalize on track segments provided by the new fast track trigger (FTK). Work has started to define the principal elements of a trigger menu for start-up after LS1. This will also provide important input to the forthcoming Phase-1 TDAQ TDR.

3. Computing and Software

The entire ATLAS and WLCG computing and software chain has continued to perform in an outstanding fashion in 2012. The computing model and the operations team have demonstrated the flexibility and capacity to accommodate higher trigger rates and higher event pile-up than anticipated, very large scale simulation of Monte Carlo samples, and demands of the physics analysis effort. Intense efforts to optimise both the technical and physics performance of the software, particularly with respect to high pile-up, have also been successful.

The large integrated luminosity collected in 2012, reflecting also the extension of proton-proton running, has produced a dataset of considerable size. Data analysis, reprocessing, and simulation activities associated with this dataset will continue through the long shutdown.

An ambitious plan for the upgrade of the ATLAS software and computing during the long shutdown has been defined and is being implemented. It is being undertaken in order to improve further the use of the computing resources requested for the LHC re-start in 2015. A key consideration for efficient use of resources after LS1 will be the level of event pile-up: LHC operation with 25 ns bunch spacing will be very important in managing the computing resource requirements, in addition to the big programme of software improvements. Considerable effort is being invested in developing a new simulation framework (ISF), which will enable mixing fast (parameterized) and full simulation options, selectable at the particle level, and in speeding up the pileup simulation (digitization). The target for data reconstruction is to achieve a speed-up factor of two to three compared with the current software performance. The envisaged improvements are to be achieved by targeted algorithmic improvements as well as introducing (auto) vectorisation into as many areas of ATLAS code as possible, thereby utilising modern CPU architectures better. The plan is to collaborate on this with other LHC experiments. Substantial work is also ongoing revising the analysis model to optimize the number of data formats and their content, as well as the CPU needed in producing them. In addition, ATLAS is developing a new distributed data management system and new job and task management systems, introducing a simplified and scalable handling of data replicas (thereby optimising disk space usage), and speeding up the job processing sequence.

The core computing infrastructure and services tasks, defined as M&O Category A, continue to play a crucial role for the smooth operation of the software and computing chain. They enable ATLAS to exploit the large investments of computing resources made worldwide by the WLCG collaboration partners.

4. Physics

During the last RRB reporting period ATLAS reported the observation of a new boson with a mass of ~126 GeV, at the special CERN seminar held on July 4th. The observation was published in August 2012 and has by now received more than 800 citations. A very high priority for the data analysis since that time were to assess if this new boson is consistent with the Standard Model Higgs boson.

For the HCP conference in November new results on the fermionic decay channels (bb and tautau) were presented based on the full 2011 data and 13.8 fb^{-1} of 2012 data, both consistent with the SM Higgs expectation but not yet sensitive. Updated measurements of the three di-boson decay modes were presented at Moriond/Aspen in March, based on the full 2011 and 2012 dataset. The ratio of the observed signal strength to the one predicted by the SM is consistent with the expectation in all decay modes as shown in Fig. 2. With this large dataset detailed analyses of the angular spectra of the decay products were made, supporting the hypothesis that the boson has indeed the quantum numbers of the vacuum as predicted for the SM Higgs boson, i.e. no spin and positive parity. First investigations of the Higgs boson production modes were made, and the data show evidence for the production via the vector-boson fusion (VBF) process as shown in Fig. 2, where a value of zero for VBF production is excluded at more than 3σ. The mass of the new boson has been measured precisely: 125.5 ± 0.2 (stat.) $^{+0.5}_{-0.6}$ (syst.) GeV. ATLAS was also able to search for, and constrain for the first time, the so-called “invisible” decay modes of the Higgs boson, e.g. the decay to two neutralinos (which are among the best candidates for explaining the dark matter in the Universe). ATLAS was able to exclude a branching ratio >65% to invisible particles at 95% C.L. using 13.8 fb^{-1} of the 2012 data.

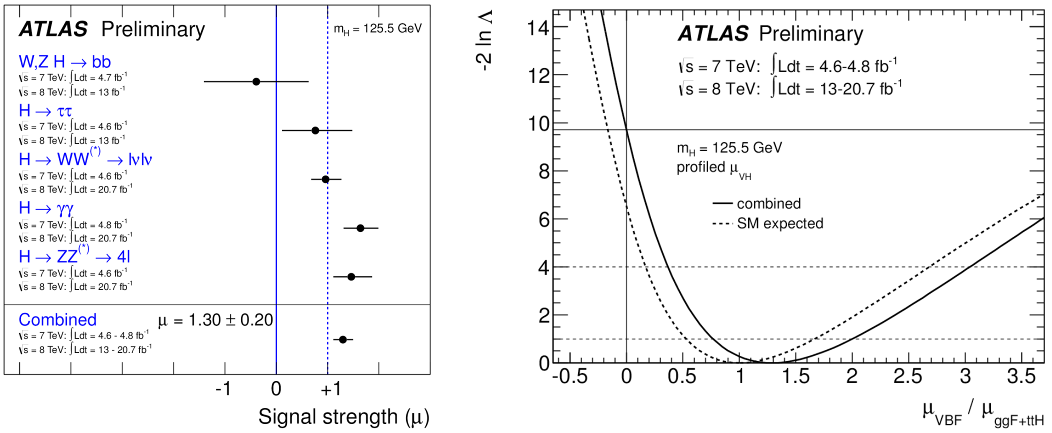


Figure 2: Left: the observed signal strength in five Higgs boson decay modes compared to the Standard Model prediction. Right: likelihood versus the relative signal strength in vector-boson-fusion (VBF) production over top related production (ggF+ttH) for a Higgs boson mass hypothesis of 125.5 GeV. The dashed horizontal lines show the 1σ, 2σ and 3σ values of the likelihood.

In parallel to the extensive Higgs physics programme, ATLAS has continued to search for other new particles as predicted by theories such as supersymmetry (SUSY) or other models of new physics. Results have been presented using the full 2012 dataset. In particular, the so-called “natural” SUSY model spectra were targeted, where the partner of the top quark, the stop, is relatively light. Stringent constraints on the mass of the stop have been placed extending up to ~660 GeV, depending on the mass of the lightest supersymmetric particle (which is assumed to be stable and thus provide a dark matter candidate). A large number of other SUSY searches were carried out (in many cases with the full 2012 dataset) and have set stringent limits on the SUSY parameter space, as can be seen in Fig. 3.

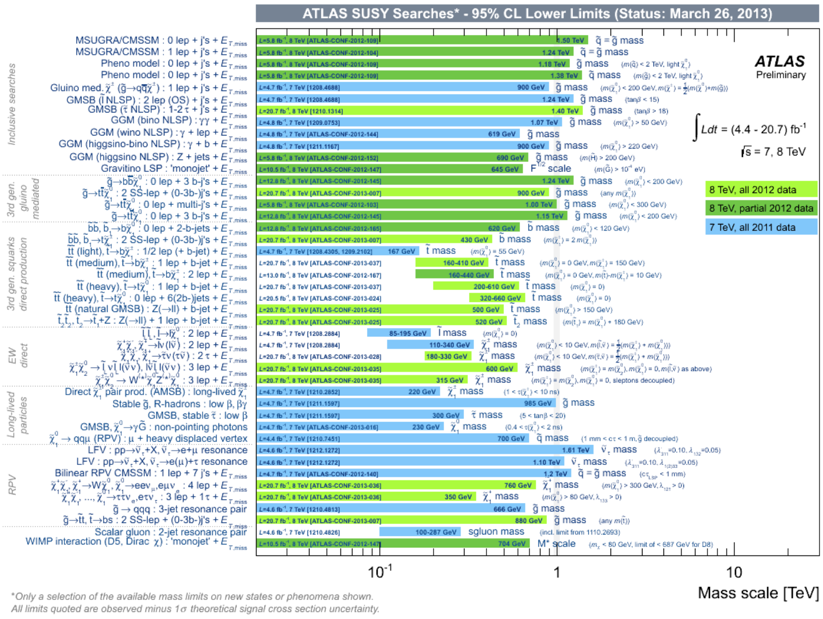


Figure 3: Summary of searches for supersymmetric particles. The different colours indicate which dataset has been used.

Other exotic models of new physics are also investigated vigorously. For example, the classic search for a Z' has been completed in the dielectron and dimuon decay modes with the full 2012 dataset, and sequential SM-like Z' masses below 2.86 TeV are excluded at 95% CL. Other recent results using more than half of the 2012 data include searches for vector-like quarks, searches for anomalous Higgs boson decays to lepton jets, resonances decaying to WZ, high mass dijet resonances, monojets and searches for excited leptons.

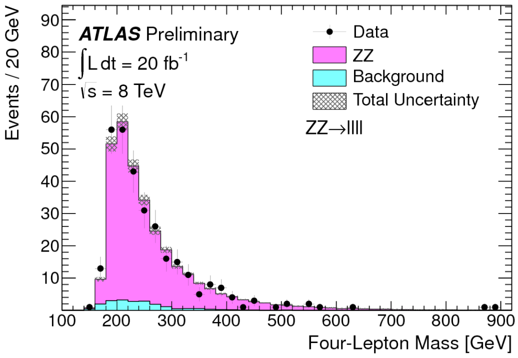


Figure 4: Four-lepton invariant mass spectrum for ZZ candidate events using the full 2012 dataset. The data are compared to the sum of the background estimate and the expected ZZ SM contribution.

In addition to this broad range of searches for new physics a detailed programme of Standard Model measurements is carried out both at 7 TeV and at 8 TeV centre-of-mass energy. A highlight is the cross-section measurement of ZZ production at 8 TeV using the full 2012 dataset in the 4-lepton decay channel. Fig. 4 shows the invariant mass spectrum of the four leptons. In total 309 ZZ candidate events are observed compared to a background estimate of 20.4±5.8 events. The measured cross-section of 7.1±0.5 (stat.)±0.4 (syst.) pb agrees well with the SM expectation of 7.2±0.3 pb. The cross-sections at 8 TeV have also been measured for WZ and top quark pair production.

Many precision measurements continue to be made with the 7 TeV data. An important highlight is the measurement of jet production in association with top quarks, which is of particular importance in view of further improving the theoretical understanding and Monte Carlo modeling of top production, as required for both precision measurements and searches for new physics in the top sector.

In 2012 and 2013 LHC collided for the first time protons with Pb ions. Based on just 1 μb^{-1} of 2012 p-Pb data, ATLAS has already published two papers on the striking observation of the presence of a long-range correlation between charged particles suggestive of final-state collective effects previously observed in Pb-Pb collisions. The analysis of the much larger p-Pb dataset taken in 2013, corresponding to about 30 nb^{-1}, is under way to study these and other phenomena in detail.

In summary, for the 2013 Moriond/Aspen conferences 28 new preliminary results were presented by ATLAS, and ATLAS has now submitted 240 papers (47 since October 1st 2012). This productive physics output should continue through 2013 and well into 2014. In particular, the full 2012 data sample will allow further direct investigation of the coupling of the Higgs boson to fermions, through the bb and $\tau\tau$ decay modes. A wealth of analyses in progress using these data should result in a bumper year for ATLAS publications in 2013.

5. Status of FDL Activities and Planning for LHC Luminosity Upgrades

The activities during the long LHC shutdown of 2013-2014 (LS1) include a number of items from the 2002 Completion Plan for the Full Design Luminosity (FDL) detector. Improvements and consolidation in infrastructure are undertaken, particularly to shielding, electrical, cooling, gas, and cryogenic systems, as described in the preceding sections. The hermeticity of the muon system is being improved, with the first set of additional chambers already installed. Improvements will be made to the readout systems of several detectors in order to operate with a 100 kHz level-1 trigger rate after LS1. The opening of the detector is proceeding according to plan. The decision was taken to remove the pixel detector in order to prepare it for the planned insertion of the Insertable Pixel B-layer (IBL). The removal of the C-side small muon wheel to the surface required for this operation has already been completed, and the pixel detector is being prepared for extraction. As mentioned above, the pixel detector will also be equipped with new services. The production and assembly of the IBL is progressing on schedule. Initial production issues are being solved, consistent with the tight schedule. Along with IBL installation, which includes a beryllium beam pipe, aluminium beam pipes will be installed in most of the forward regions, with ongoing negotiations for the complete set that would allow to reduce radiation activation problems in future. The various beam pipe sections will be re-assembled in 2014 when the detector will start the closing sequence. A status report on FDL detector activities is provided in CERN-RRB-2013-043.

ATLAS plans two phases of detector upgrades aligned with CERN plans to increase the luminosity of the LHC beyond design value: Phase-1 for installation in the second long shutdown (LS2) in 2018 and Phase-2 (the HL-LHC era) for installation in LS3 planned for 2022. As previously reported, ATLAS is proceeding via Letters of Intent

(LoI) for each upgrade phase, followed by project-specific Technical Design Reports (TDR) and Construction MoU Addenda. The Phase-1 LoI was endorsed by the LHCC at its March 2012 meeting, and the Phase-2 LoI was presented to the LHCC at its March 2013 meeting.

Detector improvements for Phase-I target the integration of ~300 fb^{-1} by the start of the next decade, exploiting peak instantaneous luminosities of 2×10^{34} $cm^{-2}s^{-1}$ and above. Improvements focus primarily on enhancing trigger capabilities in order to maintain good physics selectivity despite much higher data and background rates. Four Phase-I upgrade projects have now successfully completed initial design reviews and gained Collaboration Board approval to prepare Technical Design Reports.

The hardware track finder (FTK) (CB approved 24 June 2011) uses fast associative memory banks for track finding to provide tracking information at the input to the Level-2 trigger. A prototype of an FTK vertical slice was installed in ATLAS and ran successfully in parasitic mode for the last part of the 2012 data taking. The New Small Wheels (NSW) for the muon spectrometer (CB approved 5 October 2012) will be based upon two detector technologies, thin gap chambers with small gaps (sTGC) functioning primarily in a triggering role and micromegas detectors functioning primarily in a precision measurement role, supported by common electronics and infrastructure services. The Technical Design Reports for both FTK and NSW are scheduled for mid-2013. The CB approved the upgrade of the LAr electronics for the first level trigger signals on 8 February, 2013. This upgrade will provide so-called super-cells as input to the trigger decision, splitting the currently used trigger towers into smaller units to provide higher granularity. The upgrades of the trigger and data acquisition (CB approved 8 February 2013) will enable ATLAS to take full advantage of new detector capabilities like the NSW and also provide increased flexibility, for example by employing topological information in order to cope with the environment of the expected post-LS2 performance of the LHC. The Technical Design Reports for the latter two projects are scheduled for autumn 2013. New detectors for ATLAS Forward Physics (AFP) target CB approval and Technical Design Report in 2014.

Detector improvements in preparation for the HL-LHC era target the physics goals attainable with a total of 3000 fb^{-1}, exploiting a levelled instantaneous luminosity of approximately $5x10^{34}$ $cm^{-2}s^{-1}$, with consequent high radiation and event pile-up levels. The requirements and the proposed detector upgrades for this phase of operation have been summarised in the Phase-2 LoI, submitted to the LHCC for its March 2013 meeting. A number of options were presented, and further studies and R&D are planned to narrow the options and to choose technologies. A cross-experiment workshop, supported by ECFA, will be held later in 2013 to help foster commonalities in R&D work between the experiments. Some of the foreseen upgrades, *e.g.* the replacement of the inner detector, are needed to operate ATLAS in the next decade even without the Phase-2 LHC luminosity upgrades.

Examples of the physics potential of ATLAS at the HL-LHC have been reported to the European Strategy Preparatory Group, for instance illustrating the capability to measure the couplings of a Standard Model Higgs boson to between 5% and 25%, depending upon coupling. Rare Higgs boson decay modes and self-coupling measurements would also become accessible with the projected integrated luminosity of about 3000 fb^{-1} by the end of the next decade. Further studies to document a wider range of physics topics, and to assist in detector design optimisation, are in progress.