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ATLAS Progress Report for the October 2009 RRB

1. Introduction and Collaboration Composition

In anticipation of LHC colliding beams data taking later in 2009, ATLAS activities have focused on readiness to record quality data and to process and analyze the data. To this end, the current LHC shutdown period has been used for routine repairs and maintenance of the detector, trigger, and data acquisition and to continue commissioning of the detectors and of ATLAS as a whole. During this period, work is ongoing to exercise and optimize the software, computing, and grid infrastructure both through processing and analysis of cosmic ray commissioning data and through rigorous, dedicated testing.

The ATLAS detector 'as built' and its basic performance have been documented in a comprehensive publication in the Open Access journal JINST. It can be briefly recalled that the detector concept uses a superconducting magnet system with a Central Solenoid around the Inner Detector and large air-core Toroid Magnets for the Muon Spectrometer. Between the two are the Liquid Argon (LAr) and Tile Calorimeters. A hierarchical 3-level Trigger and Data Acquisition system collects the data for the collaboration-wide computing and physics analysis activities. The initial staged detector configuration, now operational, corresponds to the financial framework which was defined in the Completion Plan as presented and approved at the October 2002 RRB (CERN-RRB-2002-114rev1) and updated at the October 2006 RRB (CERN-RRB-2006-069). An extensive report (*Expected Performance of the ATLAS Experiment - Detector, Trigger and Physics*, CERN-OPEN-2008-020, arXiv:0901.0512v3) summarizes recent evaluations of the detector performance and of the experiment's physics potential.

The ATLAS Collaboration consists at the time of the writing of this report of 169 Institutions from 37 countries with roughly 2800 scientific authors (including 800 students). No new institutions have joined the Collaboration since the April RRB. The Collaboration Board will be asked at its meeting on 9th October 2009 to endorse the withdrawal of Hiroshima University (Japan) and Ritsumeikan University (Japan), and the admission of Tokyo Institute of Technology (Japan), Waseda University (Japan), University of Edinburgh (U.K.), University of Sussex (U.K.), and University of Iowa (U.S.).

On 1st July 2009, Dave Charlton (University of Birmingham) became Deputy Spokesperson, completing the ATLAS management team of Fabiola Gianotti (Spokesperson), Marzio Nessi (Technical Coordinator), Markus Nordberg (Resources Coordinator), and Andy Lankford (Deputy Spokesperson). On 1st January 2010, Gregor Herten (Albert-Ludwigs-Universität Freiburg) will succeed Kerstin Jon-And as Collaboration Board Chair. Professor Jon-And will become Deputy Collaboration Board Chair for 2010.

2. Maintenance of the Magnet System

The ATLAS superconducting magnet system comprises the Central Solenoid (CS), the Barrel Toroid (BT), two End-Cap Toroids (ECT), and their common services.

Status: Many improvements were made to the magnet services during the shut-down in order to enhance robustness, reliability, and ease of operation. Following the maintenance period and closure of the detector in early June, the full magnet system was tested at nominal current and then operated during cosmic ray commissioning data taking.
Changes: Improvements to magnet services systems.
Concerns: None.
Plans: Routine maintenance and operations of magnet system and services.

3. Commissioning and Maintenance of the Inner Detector

The Inner Detector (ID) combines three concentric sub-systems, from inside to outside the Pixel detectors, the Silicon strip detectors (SCT), and the Transition Radiation Straw Tracker (TRT).

Status: The major shutdown work for the Inner Detector was a refurbishing of the 6 compressors of the evaporative cooling plant, the installation and commissioning of a new spare compressor, and the upgrading of the cooling distribution racks in UX15. The total number of compressors is now 7, where 4-5 are needed for normal operation. The problem of fatigue cracks has been fixed, but there are still leaks developing in the cooling plant, for example when screw threads work loose. Wear of the piston rings in the compressors also requires monitoring. The UPS powering distribution has been upgraded so that any of the 7 compressors can act as the master (on UPS, while the rest are on normal power). The leak rates of the refurbished distribution racks are within specification, and extra sensors allow more frequent leak down measurements to track the evolution of leaks inside the detector volume. Since the plant was restarted in June, 203 of 204 cooling loops have been operating. Only one SCT circuit is not being run (the one with the very large leak that developed in the last days of installation, affecting just 13 of 4088 SCT modules). For the longer term there is a concern that pressure drops for the SCT barrel cooling circuits are too large to achieve a sufficiently low temperature, which is further complicated by a new problem with the thermal enclosure heater pads. These are large-area copper-kapton heaters that should ensure thermal neutrality of the silicon volumes compared to the TRT, and of the Inner Detector volume compared to the outside. Last year, only the heater pads on the outer cylinder of the SCT end caps were operated. This year, the Pixels and SCT are running at a lower temperature, and the heater pads on the outer cylinder of the SCT barrel were put into operation. These pads are physically glued to the inner cylinder of the TRT. Three of eight barrel pads failed during the June/July cosmics run, and reflection measurements on the cable indicate that the failure is inside the Inner Detector volume. A thermal configuration that will work for the next few years, without causing over-cooling of the TRT, can be established by running the outer barrel of the SCT at a higher temperature than the three inner barrels. However, there are concerns for the longer term, when the SCT modules have seen significant radiation and need to be kept cold even during shutdowns. A risk analysis, along with more refined studies of bias voltage and leakage current evolution as a function of radiation dose and temperature, is in progress. A replacement of the heater pad power supplies to prevent further failures is under consideration.

The off-detector opto-transmitter plug-ins, used in both the Pixels and SCT, have all been replaced with new units made with very strict electro-static discharge (ESD) protection procedures. Immediately after installation, a small number of these units were found to have failed, consistent with an anticipated 1% infant mortality. The opto-transmitter light output is rigorously tracked, and it is encouraging there have been no new failures after several weeks of running.

Improvements have been made to the cavern ventilation to allow safe access when CO_2 is flowing in the TRT and in the Inner Detector volume.

Changes: Completion of evaporative cooling system upgrades. Replacement of off-detector opto-transmitter plug-ins.
Concerns: Pixel cooling system leak rates may lead to inoperability of some pixel modules, and leaking C_3F_8 refrigerant may lead to long-term damage of detectors. Maintenance of the compressor plant remains at a high level. Barrel thermal enclosure heater pad failures may affect long-term thermal management and hence silicon detector lifetime.
Plans: Closely monitor proper operation of new opto-transmitter plug-ins and leak rates of pixel cooling circuits. Study effects of C_3F_8 refrigerant on the detector. Develop alternative technologies to replace compressor plant. Refine models for silicon radiation damage as a function of temperature.

4. Commissioning and Maintenance of the Calorimeters

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

Status: All calorimeter systems performed well in cosmic muon and single beam running in 2008 and 2009. Three main actions were successfully completed during the 2008-2009 shutdown: refurbishment of the Tile Calorimeter electronics; the second refurbishment of the 58 (+8 spare) low-voltage power supplies (LVPS) powering the LAr front-end electronics; and repair of approximately 30 LAr Front End Boards (including 10 with a failed optical transmitter). The calorimeters were fully operational when the detector was closed in May 2009; nonetheless, a small number of problems have occurred since access to the calorimeters became no longer available. Four LAr LVPS are now operated in redundant mode, and LAr optical transmitters are continuing to fail at the rate of approximately one per week (16 have failed since May affecting 1.2% of all channels). As the medium- and long-term reliability of the retrofitted LAr LVPS is a concern, development of backup solutions for installation at the end of 2010 are underway at two vendors. The cause of the LAr optical transmitter failures is being studied. A correlation with the shape of the light spectrum of the electro-optic component (VCSEL) prior to failure suggests electrostatic discharge (ESD) damage during circuit fabrication. A backup solution for possible future installation is in development. One of 256 Tile Calorimeter low-voltage power supplies has malfunctioned, affecting approximately 0.5% of the cells. Careful survey of the medium- and long-term stability of Tile Calorimeter low-voltage supplies is being carried out. The Tile Calorimeter goal is to keep the number of inoperable channels to less than 1% during the 2010 data-taking

A wealth of cosmic ray data is being used for the tuning of the calorimeters and for the measurement of their performance. For example the uniformity of response inside the LAr barrel calorimeter has been measured with minimum-ionizing muons to 1% (limited by statistics) and an upper limit for the response variation due to the LAr barrel calorimeter gap variation to 0.3%. The noise and electronic gains are measured regularly. The electronic stability is at the level of 0.2%.

Changes: Refurbishment of the Tile Calorimeter electronics. Refurbishment of the LAr low-voltage power supplies. Repair of LAr Front End Boards.
Concerns: Medium- and long-term reliability of the LAr and Tile Calorimeter low voltage power supplies and long-term reliability of LAr optical transmitters may require future replacement.
Plans: Fully integrate with ATLAS for combined cosmic running in Autumn and be ready for beam running. Continue development of long-term backup solutions in areas of concern.

5. Commissioning and Maintenance of the Muon Detectors

The Muon Spectrometer is instrumented with precision chambers for the momentum measurement (Monitored Drift Tube chambers, MDTs, and for a small high-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 end-caps).

Status: The complete muon chamber instrumentation for the initial detector configuration was available for the LHC start-up in 2008. Installation of additional chambers in the region between barrel and endcaps was started during the current shutdown and will be completed during subsequent shutdowns. Six large sectors (EEL) were installed this year out of a total of 16 large sectors. The mechanical supports for most of the small sectors on one end of the detector and half of the small sectors on the other end were also installed this year. The shutdown was used to repair problematic chambers, where very few residual problems now exist. Broken RPC gas inlets were repaired, and studies found that a small admixture of water in the MDT gas mixture reduces the probability of cracking of gas jumpers. For 2009/2010 running, the MDTs and TGCs will be greater than 99.5% active, and the CSCs and RPCs will be greater than 97% active. Because of redundancy, the trigger coverage for both the RPCs and TGCs will be almost complete. Radiation-hard readout fibres have been installed on the ‘Big Wheel’ end-cap MDT chambers on both ends of the detectors. Repair of the unexpected readout limitation with the Readout Drivers (RODs) of the CSCs is progressing steadily. The CSC readout system was successfully integrated with the other muon readout systems in August. Rate improvements are expected to be complete for 2009 beam running. All four component systems of the Muon Spectrometer will be available for the first LHC collisions.

Cosmic ray muon data recorded in 2008 and in 2009 is being used for commissioning and alignment and to improve the understanding of the performance of the muon spectrometer. Chamber resolutions and efficiencies have been measured and agree with expectations. The absolute optical alignment of the End Cap muon spectrometer is at the 40 micron level. Using track-based alignment plus optical relative alignment, a large part of the barrel sectors are aligned to better than 100 microns. The MDT calibration procedure is operational and performing to specifications.

Changes: Installation of 6 MDT EEL sectors. Installation of radiation-hard readout fibres on both MDT Big Wheels. MDT Barrel Chamber Service Modules upgraded to run at higher rates. Large improvements in timing and coverage of the barrel trigger, now reaching almost full coverage. Replacement of the TGCs that were damaged by last year’s pressure accident.
Concerns: High ambient temperature in the top barrel RPC sectors may lead to RPC ageing. Required CSC readout rate for the initial phase of the run has not yet been demonstrated. RPC gas inlets are fragile, and a batch of RPC high voltage connectors is fragile. Cracking on a few gas jumpers of the EO MDT chambers has been observed.

Plans: Provide additional cooling to reduce ambient temperature in the top barrel RPC sectors. Complete improvements to CSC readout rate. Monitor condition of RPC gas inlets, and replace broken inlets if necessary during maintenance periods. Monitor failure rate of RPC high voltage connectors, and replace all connectors during future shutdown if necessary. Monitor condition of MDT gas jumpers. Finish commissioning work, particularly on the RPCs and CSCs. Continue study of detector performance, calibration, and alignment with cosmic muon data. Make improvements in the operability of the detector and on assessment of data quality. Establish final muon trigger timing in the barrel region using first beams.

6. Forward Detectors

The forward detectors for the first phase of ATLAS 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), of a Zero Degree Calorimeter (ZDC) placed in the absorber structure TAN where the beams join separate beam pipes at 140 m away from the IP, and of an Absolute Luminosity for ATLAS (ALFA) detector in Roman Pots at 240 m from the IP. A proposal for an ATLAS Forward Physics project (AFP) is being considered by an ongoing internal review.

Status: LUCID is in an advanced stage of commissioning. ZDC commissioning continues, including commissioning with cosmic rays. ALFA detectors are still in development. Installation of the ALFA mechanics in the LHC tunnel was initiated, with completion planned for the next shutdown period.
Changes: Installation of part of ALFA mechanics.
Concerns: None.
Plans: Complete preliminary commissioning of LUCID and ZDC before LHC beams. Complete development of ALFA detectors for installation, along with remaining mechanics, in the next shutdown period. Install the electromagnetic part of the ZDC when the LHCf experiment is removed.

7. Commissioning and Maintenance of the Trigger and DAQ System

The major sub-systems of the Trigger and Data Acquisition System are the Level-1 Trigger (with the sub-systems calorimeter, muon and central trigger processor (CTP)), the High Level Trigger (HLT), the Data Acquisition (DAQ), and the Detector Control System (DCS).

Status: The Trigger and Data Acquisition System has been operational at Point-1 for some time. At this stage, the HLT is still in reduced configuration, as available for the initial staged detector, with about 35% of the final HLT CPU capacity presently installed and operational. The full chain is working well and continues to be tested and tuned both in real data-taking conditions of the combined cosmic ray runs and in special technical runs pushing the performance beyond its design limits. Major progress has been made during the shutdown in improving system stability and robustness, in refining data-taking operational procedures, and in providing detailed shifter training including ATLAS-wide training for the Run Control desk. Efficiency improvements include implementation of stop-less exclusion and re-insertion of elements of the detector readout during data-taking, in order to correct errors while minimizing down-time, as well as reduction in the deadtime arising during initialization of the detector systems for data-taking. Detailed plans have been finalized for the commissioning with beam for the LVL1 and HLT.

Changes: Improvements to system stability and operational efficiency.

Concerns: None for the initial system. However, it is reminded that in accordance with the Cost to Completion plans, the initial TDAQ configuration was limited in funds. High-level trigger processors are being added to the initial configuration as deferred funds become available.
Plans: Install a further 13% of the final HLT capacity before the end of 2009, bringing the total installed capacity to roughly 50%, and an additional 25% of the final HLT capacity during 2010. Continue to optimize the full Trigger, DAQ and DCS system in preparation for first collisions and during initial running. Commission the minimum bias trigger rapidly with circulating beam so as to provide the first commissioning data to ATLAS. Commission the LVL1 calorimeter and muon triggers with collision data so that first high transverse energy (E_T) physics samples can be made available quickly. In parallel, commission the HLT in "pass-through" mode before starting to introduce event selection at the HLT level.

8. Shutdown Activities and Global Commissioning of the Detector

Status: Early in the 2008/2009 shutdown, activities focused on routine repairs and maintenance of the magnets, detectors, and trigger and data acquisition, and installation of some additional detector components. Many of these activities are described in the sections above. In order to allow an adequate period of final testing and global commissioning, the detector was closed again at the beginning of June. ATLAS was recommissioned by successive cosmic runs, involving at times the full muon system, the full calorimetry, and the full inner detector separately, and at times the full ATLAS detector. The full ATLAS detector was operated for a total of about 4 weeks, during which approximately 200 million cosmic events were recorded. During the cosmic runs, the emphasis was on detector commissioning, operational efficiency, high-rate operation, and tuning of the detector parameters for optimal performance. These run periods also provided valuable datasets to study the detector and improve the detector timing and calibration. Global cosmics data taking will resume during the second full week of October and will continue until first beam injection in mid-November. In parallel with all of the above activities, operational strategy, for instance trigger and detector commissioning, and as a function of the phase of LHC operations (e.g. single beam, 900 GeV collisions, 7 TeV collisions), is being refined. As a result of the above activities, ATLAS is well prepared for the upcoming long LHC physics run in 2009/2010.

The effort needed for Operation Tasks (OTs) has been estimated for 2009 based upon the experience gained in 2008, particularly during commissioning running, and in consultation with the various project leaders and activity coordinators. Operation Tasks include all activities essential to the operation of ATLAS, from central ATLAS shifts and on-call tasks at Point-1 to the computing and data preparation tasks, some of which can be executed remotely. Responsibility for Operation Tasks is shared among the Institutions in proportion to their number of ATLAS authors (with an increased weight factor for new institutions during their first two years, and with a reduced factor for Ph.D. students). The 2009 review estimated the number of tasks essential to data-taking ('Category 1') required of each ATLAS institution and the number of all other essential operational tasks ('Category 2'). The 2009 estimate is 600-700 FTE, although it is necessarily conservative due to the lack of operational experience with beam. During the last part of 2008, ATLAS operated at the equivalent of 600 FTE. The planning of OTs for 2010 will take into account the experience of the last few months of 2009 and will aim at streamlining certain tasks, in order to reduce the overall FTE requirements, and at enabling more tasks to be performed at remote sites.

Concerns: Operation (in the broad sense as specified above) will require significant resources for which Funding Agencies need to plan.
Plans: Run the full ATLAS starting October 12th to finalize the tuning of detector operation in the final weeks prior to beam. Use the first beam and collision data in an optimal way to reach nominal performance for the long LHC physics run at 7 TeV of center-of-mass energy.

9. Commissioning of the Computing and Software

The collaboration-wide distributed computing infrastructure is fully embedded into the framework of the wLCG of which ATLAS is a very active partner. In addition to this Grid infrastructure, there is a very sizable experiment-specific effort required to efficiently interface the ATLAS software suite and analysis framework to the wLCG infrastructure.

Status: The whole ATLAS and wLCG computing and software chain has been operational with real data since ATLAS combined cosmic ray data taking prior to LHC start-up in September 2008. During this year, the computing and software infrastructure has been successfully exercised to reprocess several times approximately 280 million cosmic ray events collected in 2008, exercising a primary function of the Tier-1 centres worldwide. Reprocessing has been performed on RAW data on disk in April, on RAW data on tape in July, and starting from previously processed data (ESDs) in September, thus exercising all normal types of reprocessing. In June, ATLAS participated in the STEP'09 exercise, which was organized through wLCG to stress test the computing infrastructure simultaneously by all experiments. This test covered all aspects of distributed computing operations at nominal rates. Large-scale testing programs of distributed data analysis at Tier-2 centres using simulated data have started in order to prepare optimally for the analysis of real physics data. Some software performance issues related to database access have been addressed. The methods to access database-resident information by analysis jobs running at Tier-2 centres have been defined and the necessary servers (FroNTier servers at Tier-1 sites and Squid servers at Tier-2 sites) have been deployed. Adequate manpower to fully address ongoing software developments in several technical areas is not available, and progress to address this issue has been slow despite efforts. The core computing infrastructure and services tasks, defined as M&O category A, play a crucial role for the smooth operation of the full software and computing chain. They enable ATLAS to exploit the large investments of computing resources made worldwide by the wLCG collaboration partners.
Changes: None.
Concerns: Manpower in some technical software and operation areas.
Plans: Consolidate and further commission the software and computing infrastructure for the collaboration-wide, distributed approach, in full coherence with the wLCG infrastructure backbone.

10. Updates on Due Construction Contributions

At present, the Collaboration still faces an income deficit of 5 MCHF in the total accepted construction costs (CORE+CtC), including open commitments, mainly due to late payments of baseline Common Fund contributions. Due contributions arriving from Funding Agencies are reported elsewhere (CERN-RRB-2009-091).

The Collaboration most strongly urges all Funding Agencies that have not yet committed to their full calculated share of CtC funding, or have not yet financed their baseline Common Fund contributions, to continue their utmost efforts to secure the missing resources. Only a strong solidarity across all funding partners will allow the Collaboration to complete the Full Design Luminosity Detector (FDL) to fully exploit the great LHC physics opportunities as early as possible.

11. Status of FDL Activities

The 2002 Completion Plan reduced the scope of the Full Design Luminosity (FDL) detector as a temporary measure. The staged items included common elements, such as shielding and processors, as well as components of the Inner Detector, Calorimeter systems, and Muon systems. Some of these items have meanwhile been restored; whereas, the fate of other items depends upon the measured performance of the ATLAS detector. It is clear however that the common infrastructure, *e.g.* shielding, environmental monitoring, configuration control, access, and cooling/gas/cryogenic systems, will require improvements. A replacement of the Inner Detector pixel b-layer was envisaged as a part of the FDL detector. A status report on FDL detector activities is provided in CERN-RRB-2009-105.

An Insertable B-Layer (IBL) has been chosen to replace the existing b-layer when the performance of the existing b-layer becomes degraded due to radiation damage. The IBL, along with a new beam pipe, will insert inside the inner radius of the existing b-layer. IBL design is advancing, and an Interim Memorandum of Understanding is being drafted for the IBL project. The draft is planned to be available by the end of 2009, then followed by a Technical Design Report in Spring 2010, to be submitted to the LHCC.