AN INVESTIGATION OF ATLAS EXPERIMENT AT THE CERN LHC

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ABSTRACT

The ATLAS experiment is one of the multi-purpose experiments at the Large Hadron Collider (LHC) at CERN, constructed to study elementary particle interactions in collisions of high-energy proton beams. Twelve different sub detectors as well as the common experimental infrastructure are controlled and monitored by the Detector Control System (DCS) using a highly distributed system of 140 server machines running the industrial SCADA product PVSS. Higher level control system layers allow for automatic control procedures, efficient error recognition and handling, manage the communication with external systems such as the LHC controls, and provide a synchronization mechanism with the ATLAS data acquisition system.Different databases are used to store the online parameters of the experiment, replicate a subset used for physics reconstruction, and store the configuration parameters of the systems. This contribution describes the computing architecture and software tools to handle this complex and highly interconnected control system.

Keyword: - *ATLAS detector, Detector Control System (DCS), Iinner detector, Muon spectrum, Magnet System, Calorimeter, Solenoid, Forward Calorimeter, End cap toroid etc.*

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1. INTRODUCTION

ATLAS is the largest general-purpose particle detector experiment at the Large Hadron Collider (LHC), a particle accelerator at CERN (the European Organization for Nuclear Research) in Switzerland.The experiment is designed to take advantage of the unprecedented energy available at the LHC and observe phenomena that involve highly massive particles which were not observable using earlier lower-energy accelerators. ATLAS was one of the two LHC experiments involved in the discovery of the Higgs boson in July 2012.It was also designed to search for evidence of theories of particle physics beyond the Standard Model.The experiment is a collaboration involving 6,003 members, out of which 3,822 are physicists (last update: June 26, 2022) from 257 institutions in 42 countries.

The ATLAS detector is 46 metres long, 25 metres in diameter, and weighs about 7,000 tonnes; it contains some 3,000 km of cable.At 27 km in circumference, the Large Hadron Collider (LHC) at CERN collides two beams of protons together, with each proton carrying up to 6.5 TeV of energy – enough to produce particles with masses significantly greater than any particles currently known, if these particles exist. When the proton beams produced by the Large Hadron Collider interact in the center of the detector, a variety of different particles with a broad range of energies are produced. ATLAS is the largest general-purpose particle detector experiment at the Large Hadron Collider (LHC), a particle accelerator at CERN (European Organization for Nuclear Research) in Switzerland. The experiment is designed to take advantage of the unprecedented energy available at the LHC and to observe phenomena involving extremely massive particles that previously could not be observed using low-energy accelerators. ATLAS was one of two LHC experiments involved in the discovery of the Higgs boson in July 2012. It was also designed to search for evidence of theories of particle physics beyond the Standard Model.

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The first cyclotron, an early type of particle accelerator, was built in 1931 by Ernest O. Lawrence, with a radius of only a few centimeters and a particle energy of 1 megaelectronvolt (MeV). Since then, there has been a huge increase in accelerators in the quest to produce new particles of greater mass. As accelerators have grown, so has the list of known particles that can be used to probe them. Atlas is one of two general purpose detectors at the Large Hadron Collider (LHC). It investigates a wide range of physics, from the Higgs boson to extra dimensions and particles that could make up dark matter. Although its scientific goals are similar to those of the CMS experiment, it uses different technical solutions and a different magneto-system design.

Beams of particles from the LHC collide with the center of the ATLAS detector, creating collision debris in the form of new particles that fly in all directions from the collision point. Six different detection subsystems arranged in layers around the collision point record the particles' path, speed and energy, allowing them to be identified individually. A giant magnet system bends the path of charged particles so that their momentum can be measured.

The interactions in the ATLAS detectors create an enormous stream of data. To digest the data, ATLAS uses an advanced "trigger" system to tell the detector which events to record and which to ignore. Complex data-acquisition and computing systems are then used to analyze the recorded collision events. At 46 meters long, 25 meters high and 25 meters wide, the 7000-tonne ATLAS detector is the largest volume particle detector ever built. It is located in a cave 100 meters below ground near the main CERN site, close to the village of Mayrin, Switzerland.

2. Literature Review

The researcher pictured for scale in the famous ATLAS detector image is Roger Ruber, a researcher from Uppsala University, Sweden. Ruber, one of the researchers responsible for the ATLAS detector's central cryostat magnet, was inspecting the magnets in the LHC tunnel at the same time Maximilien Brice, the photographer, was setting up to photograph the ATLAS detector. Brice asked Ruber to stand at the base of the detector to illustrate the scale of the ATLAS detector. This was revealed by Maximilien Brice, and confirmed by Roger Ruber during interviews in 2020 with Rebecca Smethurst of the University of Oxford.

The ATLAS experiment at the LHC relies on selective triggers to capture events containing b-hadroninitiated jets (b-jets), which are associated with a variety of physics processes. Within the Standard Model these processes range from frequently occurring top quark production (predominantly decaying into a b-quark and a W boson) to rare processes like associated production of a Higgs boson with top quark pairs (where all particles decay hadronically), or Higgs pair production (where at least one of the Higgs bosons decays into a $b\bar{b}$ pair [1, 2]). Beyond the Standard Model many theories feature decays of hypothetical new particles into final states containing b-quarks [3, 4].

3. Research Objective

1. To find the ATLAS Experiment in the LHC Machine.
2. The main characteristics of ATLAS detector And Construction work began at individual institutions, with detector components then being shipped to CERN and assembled in the ATLAS experiment pit starting in 2003.
3. A determination of the jet energy scale is presented using proton−proton collision data with a centre-of-mass energy of $\sqrt{s}=13$ TeV, corresponding to an integrated luminosity of 140 fb^{-1} collected using the ATLAS detector at the LHC.

4. Result Analysis

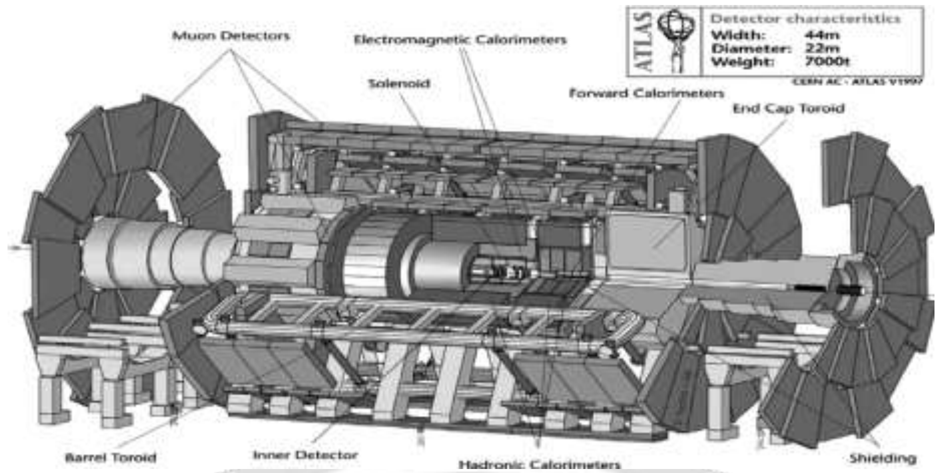
ATLAS permanently records more than 10 petabytes of data per year. [1] Offline event reconstruction is performed on all permanently stored events, which transforms the pattern of signals from the detector into physics objects, such as jets, photons and leptons. gives. Grid computing is being used extensively for event reconstruction, allowing the parallel use of university and laboratory computer networks around the world for the CPU-intensive task of reducing large amounts of raw data into a form suitable for physics analysis. permission is granted. Software for these tasks has been under development for many years, and has continued to be improved since data collection began. Individuals and groups within the collaboration are continually writing their own code to further analyze these objects, searching for patterns of particles that have been discovered for particular physical models or hypothetical particles. This activity requires processing 25 petabytes of data per week.[1]

Let us discuss the full explanation of the ATLAS Detector:

The ATLAS detector consists of a series of ever-larger concentric cylinders around the interaction point where the proton beams from the LHC collide. Maintaining detector performance in the high radiation areas immediately surrounding the proton beams is a significant engineering challenge. The detector can be divided into four major systems:

1. Muon Spectrum
2. Magnet System
3. Inner Detector
4. Calorimeter

The picture of ATLAS Detector is:



Let's discuss all parts of ATLAS Detector one by one with full explanation:

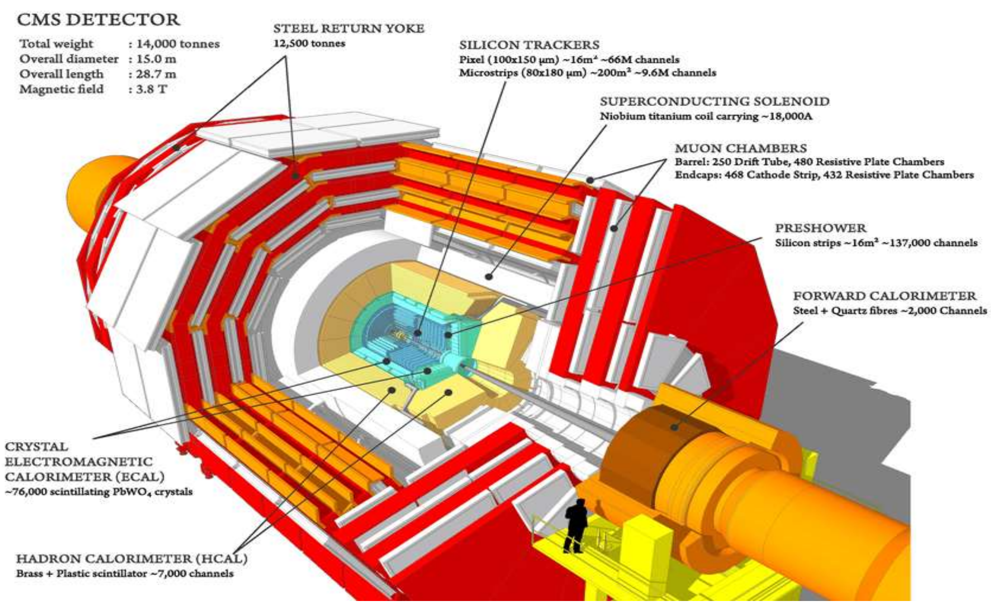
1.4.1 Muon Spectrum : The Muon Spectrometer is an extremely large tracking system, consisting of three parts:

A magnetic field provided by three toroidal magnets;

A set of 1200 chambers measuring with high spatial precision the tracks of the outgoing muons;

A set of triggering chambers with accurate time-resolution.

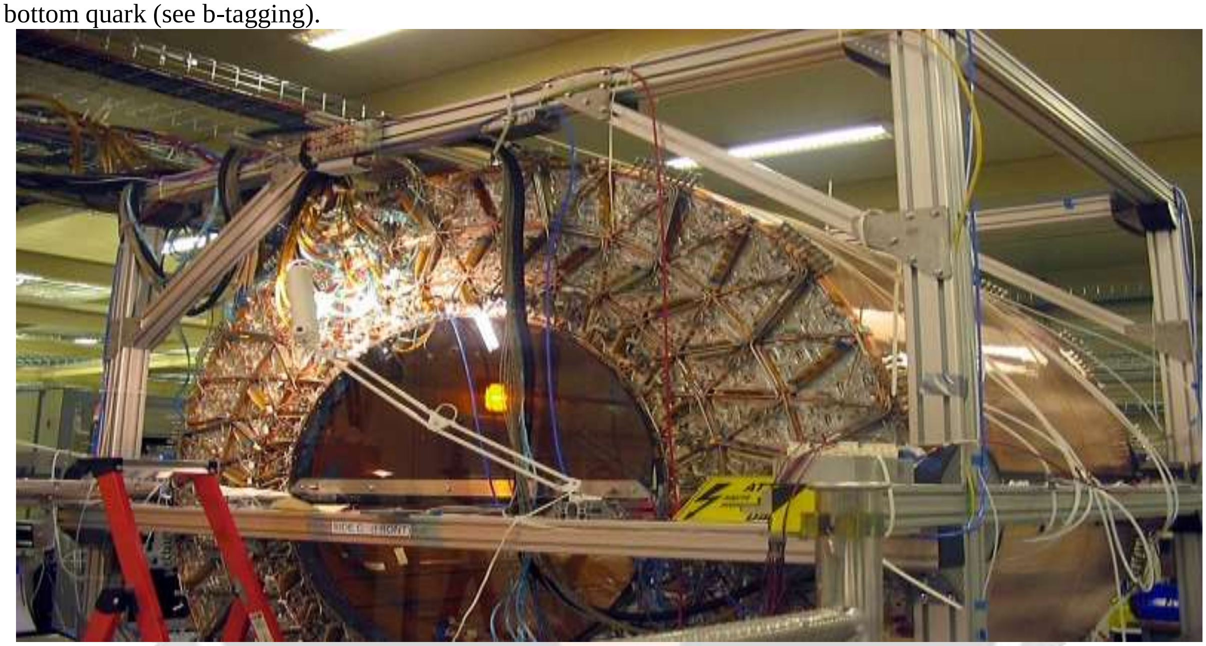
The extent of this sub-detector starts at a radius of 4.25 m close to the calorimeters out to the full radius of the detector (11 m). Its tremendous size is required to accurately measure the momentum of muons, which first go through all the other elements of the detector before reaching the muon spectrometer. It was designed to measure, standalone, the momentum of 100 GeV muons with 3% accuracy and of 1 TeV muons with 10% accuracy. It was vital to go to the lengths of putting together such a large piece of equipment because a number of interesting physical processes can only be observed if one or more muons are detected, and because the total energy of particles in an event could not be measured if the muons were ignored. It functions similarly to the Inner Detector, with muons curving so that their momentum can be measured, albeit with a different magnetic field configuration, lower spatial precision, and a much larger volume. It also serves the function of simply identifying muons – very few particles of other types are expected to pass through the calorimeters and subsequently leave signals in the Muon Spectrometer. It has roughly one million readout channels, and its layers of detectors have a total area of 12,000 square meters.



1.4.2 Magnet System : The ATLAS detector uses two large superconducting magnet systems to bend the trajectory of charged particles, so that their momenta can be measured.The magnetic force is directly proportional to the product of mass of charged particle , velocity of charge particle and magnetic field of magnets.

1.4.3 Inner Detector : The Inner Detector begins a few centimetres from the proton beam axis, extends to a radius of 1.2 metres, and is 6.2 metres in length along the beam pipe. Its basic function is to track charged particles by detecting their interaction with material at discrete points, revealing detailed information about the types of particles and their momentum.[30] The Inner Detector has three parts, which are explained below.

The magnetic field surrounding the entire inner detector causes charged particles to curve; the direction of the curve reveals a particle's charge and the degree of curvature reveals its momentum. The starting points of the tracks yield useful information for identifying particles; for example, if a group of tracks seem to originate from a point other than the original proton–proton collision, this may be a sign that the particles came from the decay of a hadron with a bottom quark (see b-tagging).



1.4.4 Calorimeter : The calorimeters are situated outside the solenoidal magnet that surrounds the Inner Detector. Their purpose is to measure the energy from particles by absorbing it. There are two basic calorimeter systems: an inner electromagnetic calorimeter and an outer hadronic calorimeter. Both are sampling calorimeters; that is, they absorb energy in high-density metal and periodically sample the shape of the resulting particle shower, inferring the energy of the original particle from this measurement.

Inner Electromagnetic Calorimeter: The electromagnetic (EM) calorimeter absorbs energy from particles that interact electromagnetically, which include charged particles and photons. It has high precision, both in the amount of energy absorbed and in the precise location of the energy deposited. The angle between the particle's trajectory and the detector's beam axis (or more precisely the pseudorapidity) and its angle within the perpendicular plane are both measured to within roughly 0.025 radians. The barrel EM calorimeter has accordion shaped electrodes and the energy-absorbing materials are lead and stainless steel, with liquid argon as the sampling material, and a cryostat is required around the EM calorimeter to keep it sufficiently cool.

Outer Hadronic Calorimeter: The hadron calorimeter absorbs energy from particles that pass through the EM calorimeter, but do interact via the strong force; these particles are primarily hadrons. It is less precise, both in energy magnitude and in the localization (within about 0.1 radians only).The energy-absorbing material is steel, with scintillating tiles that sample the energy deposited. Many of the features of the calorimeter are chosen for their cost-effectiveness; the instrument is large and comprises a huge amount of construction material: the main part of the calorimeter – the tile calorimeter – is 8 metres in diameter and covers 12 metres along the beam axis. The far-forward sections of the hadronic calorimeter are contained within the forward EM calorimeter's cryostat, and use liquid argon as well, while copper and tungsten are used as absorbers.

5. Conclusion

LHC machine gives ATLAS such information as beam and bunch intensities, and other characteristics of the beam such as its position. It also provides the 40.08 MHz bunch clock of the accelerator, needed for the L1 trigger and detector sub-systems. ATLAS provides information on total luminosity and luminosity per bunch obtained from its luminosity detectors, and indications of the quality of the collisions based on information from the detector and from the beam conditions monitors. The ATLAS beam interlock system provides information on whether or not to safely inject or dump the beams, or to move from one mode of operation (e.g. filling) to the next (e.g. ramping). This information is exchanged through the detector control system information server, and dedicated hardware links for such critical information as beam permission signals and timing. In the field of particle physics, ATLAS studies a variety of processes found or detectable in energetic collisions at the Large Hadron Collider (LHC). For already known processes, it is a matter of measuring the properties of the known particles as accurately as possible, or of finding quantitative confirmation of the Standard Model. Processes not yet observed, if detected, would allow for the discovery of new particles or the confirmation of physical theories that go beyond the Standard Model.

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