The ATLAS Detector – a Status Report[1]

Werner Witzeling, CERN, Geneva, Switzerland
For the ATLAS Collaboration

1. Introduction and overview

ATLAS is one of the two general purpose detectors under construction for the Large Hadron Collider (LHC). This paper gives a brief description of the different sub-systems that form the ATLAS detector and describes the status of the project.

LHC is the new proton-proton collider presently under construction at CERN [1]. This new machine will be located in the existing LEP tunnel replacing the elements of the LEP machine. LHC will provide proton-proton collisions at a centre of mass energy of 14 TeV and at a luminosity of 10^{34} $cm^{-2}sec^{-1}$. With its unprecedented performance this machine will open the window to a yet unexplored range of particle physics.

The ATLAS Collaboration is formed by about 1800 physicists and engineers from 146 different institutions located all around the world. Commensurate with the size of the ATLAS Collaboration is the detector that is now under construction. Figure 1 shows an overview of the detector, it is 46 m long, 22 m high and weighs some 7000 tons.

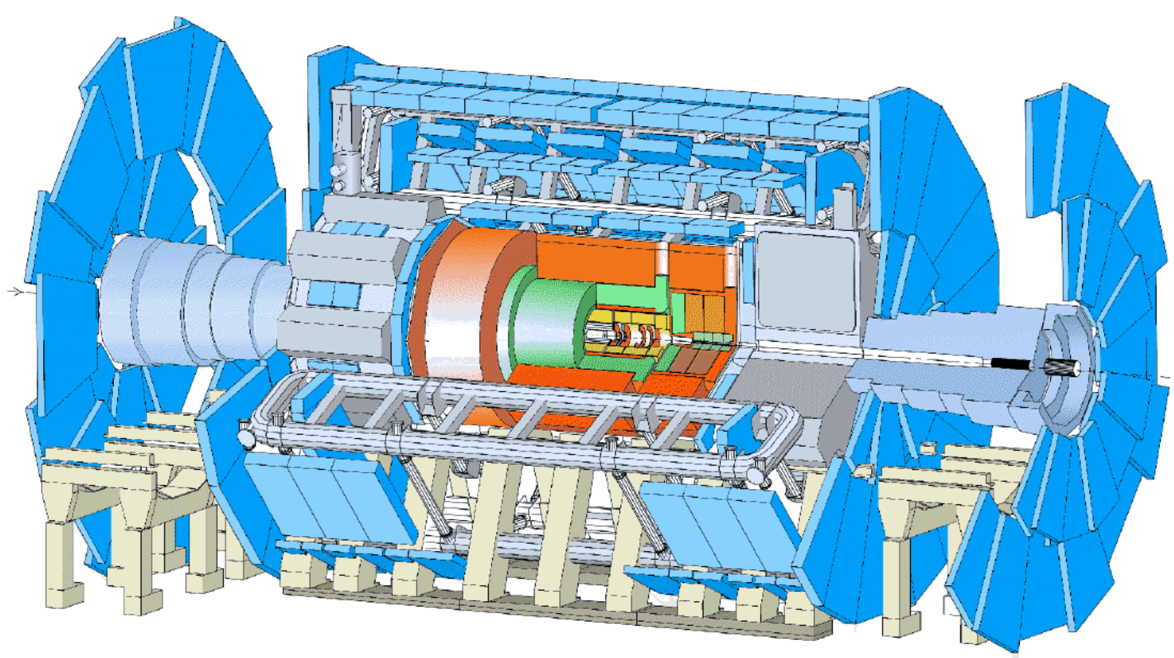

Figure 1: Overview of the ATLAS detector

The ATLAS detector [2] is designed as a general purpose detector with a powerful discovery potential based on following features:

[1] Presented at the XIVth International Workshop on High Energy Physics and Quantum Field Theory, Moscow, Russia, 27 May – 2 June 1999.

- Efficient tracking with measurement for high-p_T leptons, with identification of electrons and photons and aiming for full event reconstruction capability at low luminosity;
- Very good electromagnetic calorimetry for electron and photon identification and measurement;
- Full coverage hadronic calorimetry with accurate jet and missing transverse energy measurements;
- High-precision muon momentum measurement with the capability to measure accurately at the highest luminosity using the external muon spectrometer in stand-alone mode;
- Large acceptance in azimuth and pseudorapidity;
- Triggering and measurement of particles at low-p_T threshold.

These considerations lead to a concept using semiconductor detectors and straw tubes for the so-called Inner Detector, surrounded by an electromagnetic calorimeter based on the liquid argon technique. The hadronic calorimeter uses scintillator read-out in the major part and again the liquid argon technique for the calorimeters in the forward region. An special feature of the ATLAS Detector is the large muon spectrometer with an open toroidal magnetic field configuration.

2. The Inner Detector

The Inner Detector [3] is composed of three detector systems covering the pseudorapidity range to $|\eta| \leq 2.5$. Figure 2 shows a schematic view of the Inner Detector.

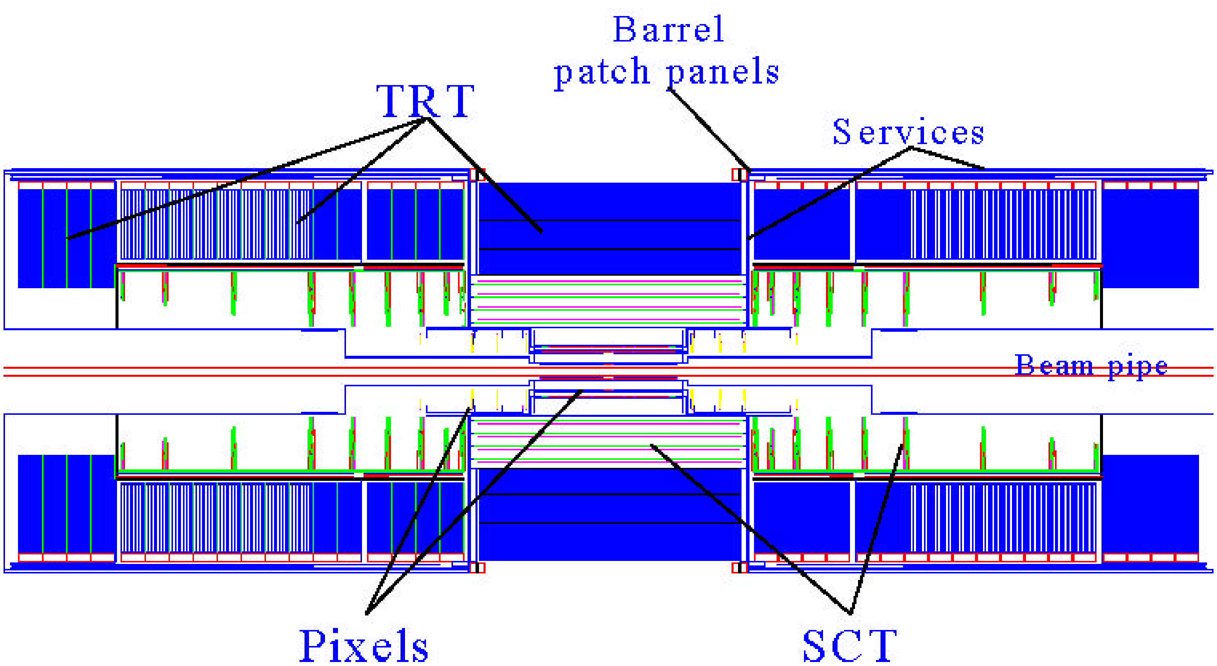

Figure 2: Schematic view of the Inner Detector

In the centre is located the **Pixel Detector** providing three space points per track. The barrel section consists of three layers with the innermost layer being located at a radius of 4 cm. The two forward sections (one on each side) contain five layers of disks. The resolution of these pixel detectors is about 10 μ in $r\varphi$ and about 50 μ in θ. They have to operate in an extremely hostile environment of radiation. Test beam results show that detectors irradiated to full LHC fluence survive with acceptable performance. Indium bump bonding of the FE electronics has been successfully shown and the development of radiation hard front-end electronics is proceeding.

The Pixel Detector is surrounded by the **SemiConductor Tracker (SCT**). It consists of four concentric barrel layers and 9 disks on either side. Each layer consists of a double layer of Silicon strip detectors with a small stereo angle between them. This detector provides typically four space points per track with a resolution in rφ of ~16μ and ~580 μ in the z-direction. The design of the detectors (p-on-n technology) is finalised, and the production orders are to be placed in the 4^{th} quarter of 1999. In order to reduce radiation damage, the pixel and SCT detectors will be kept at an operating temperature of lower than –5 °C. The cooling is achieved by evaporative cooling using Fluorcarbons as coolant.

The so-called **Transition Radiation Tracker (TRT)** occupies the remainder of the Inner Detector volume, it consists of about 50 000 straw tubes in the barrel section and about 320 000 straw tubes - arranged in wheels - in the two end-cap sections. Because of the small diameter of the straws, this type of gas detector offers a high rate capability and by employing xenon gas, electron identification capability is added using the transition radiation photons created in PE radiator foils interleaved with the straws. The TRT will provide typically 36 measurements per track. A barrel module-0 and a four plane wheel prototype have been completed. The design is being finalised now and the radiation hard front-end electronics is ready for submission of the pre-series.

The combination of the three detectors will provide a robust tracker with balanced performance, the overall resolution of the Inner Detector is shown in figure 3.

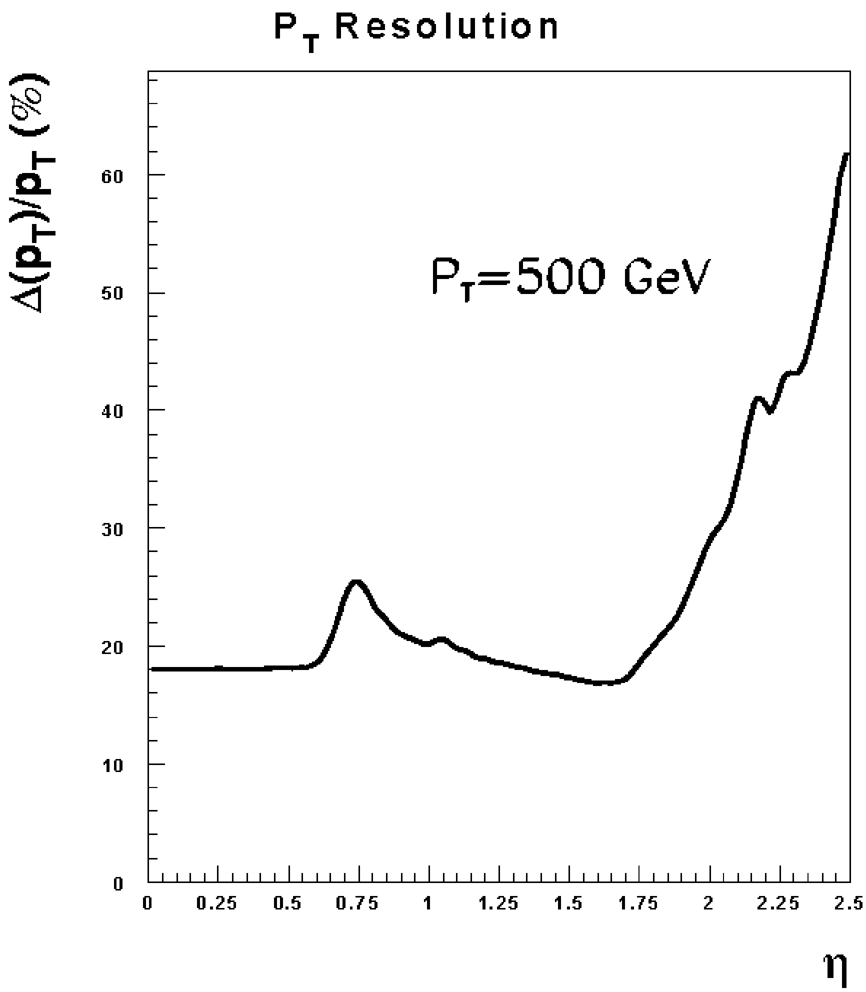

Figure 3: Overall resolution of the Inner Detector

3. Calorimetry

The calorimetry consists of an electromagnetic calorimeter covering the region of pseudorapidity up to $|\eta| < 3.2$, a hadronic barrel calorimeter covering $|\eta| < 1.7$, hadronic end-cap calorimeters covering $1.5 < |\eta| < 3.2$ and forward calorimeters covering $3.1 < |\eta| < 4.9$. Figure 4 shows a schematic view of the calorimeter system [4, 5, 6].

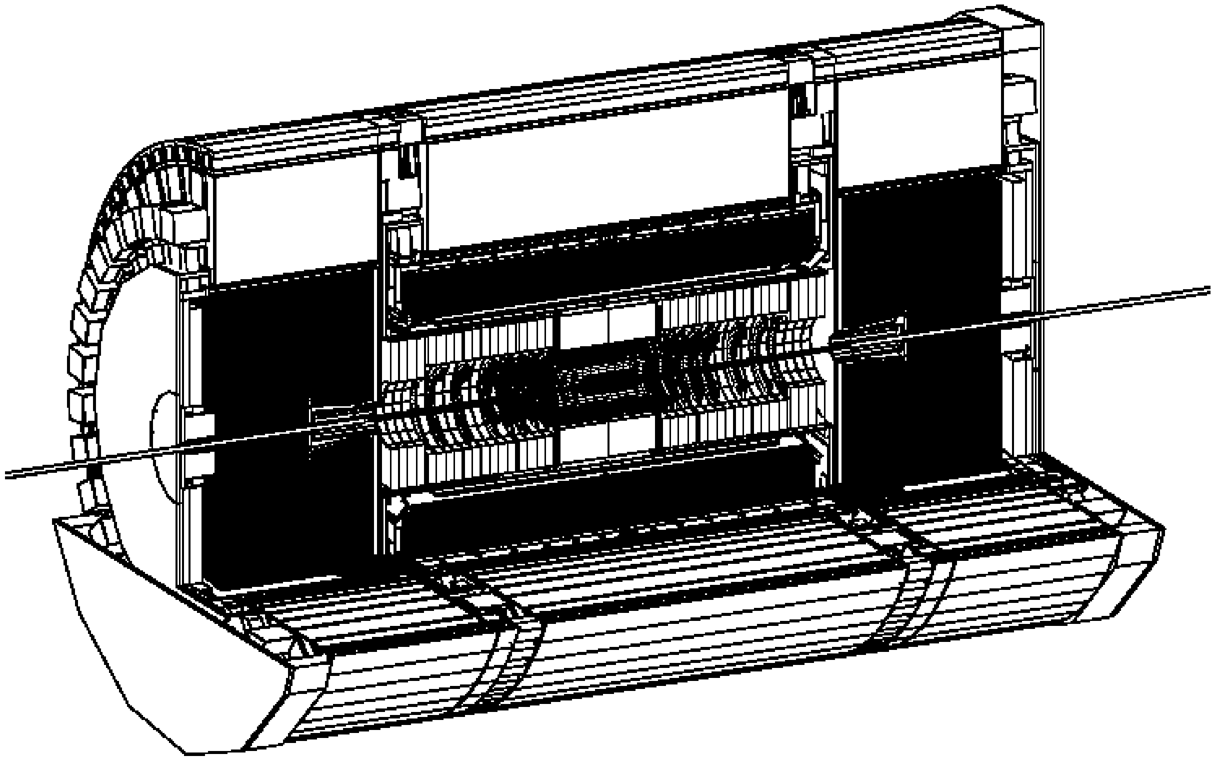

Figure 4: Schematic view of the Calorimeter System

The **electromagnetic calorimeter** is a lead/liquid argon sampling calorimeter with accordion shaped absorber plates and interleaved readout electrodes. The accordion calorimeter combines hermeticity with excellent energy and position resolution, it covers the region of pseudorapidity up to |η| < 3.2 and has 3 longitudinal samplings. It is equipped with a presampler in the range of |η| < 1.8 to allow for energy correction, if the particle shower starts in the Inner Detector or in the solenoid. The EM calorimeter is composed of three parts, a barrel section and two forward sections. The barrel cryostat also houses the superconducting solenoid. Figure 5 shows the energy resolution of an end-cap prototype module obtained in a test beam.

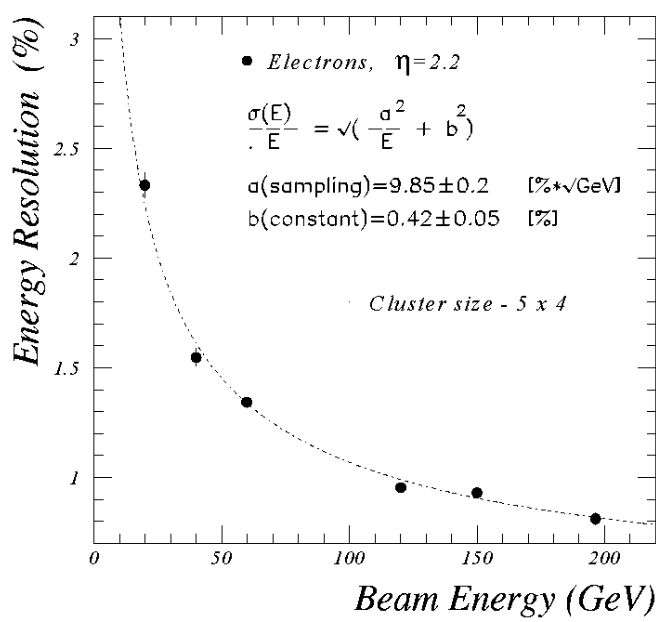

Figure 5: Energy resolution of the electromagnetic end-cap module as function of energy (best fit superimposed)

The **forward part of the hadronic calorimeter** and the forward calorimeter are also based on the liquid argon technique, they share the end-cap cryostats with the EM calorimeters. The hadron calorimeter covers the pseudorapidity range of 1.5 < |η| < 3.2, it is composed of copper plates forming wheels with readout electrodes in between and has a fourfold longitudinal segmentation. Figure 6 shows test beam results for pions obtained with a prototype module.

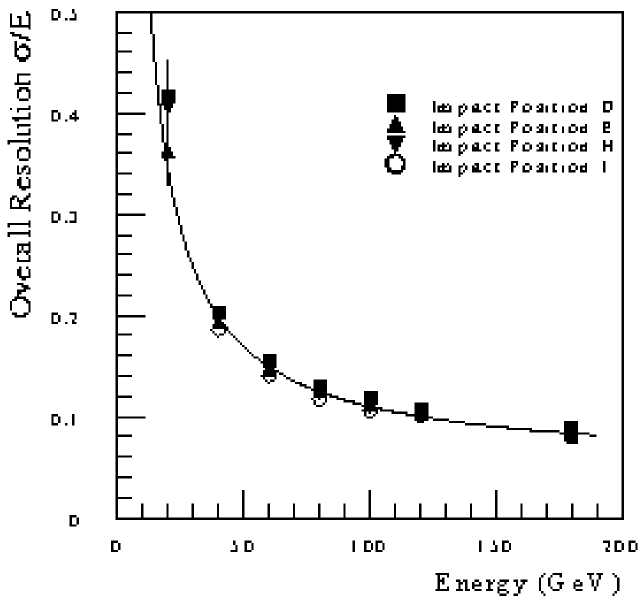

Figure 6: Energy resolution of the hadronic end-cap module
as function of energy for pions

The series production of the modules is well under way. Inside the hadron calorimeter is inserted the **forward calorimeter** covering the pseudorapidity range 3.1 < |η| < 4.9, this detector has to work in a hostile environment of very high radiation. It consists of a high density metal matrix, one copper and two tungsten sections. The metal matrix has longitudinal channels in which are inserted tubes and rods. The gap in between is filled with liquid argon.

The major part of the **hadronic calorimeter** is the so-called Tile Calorimeter, an iron/scintillator sampling calorimeter. It is divided into three parts, the barrel and two extended barrel calorimeters

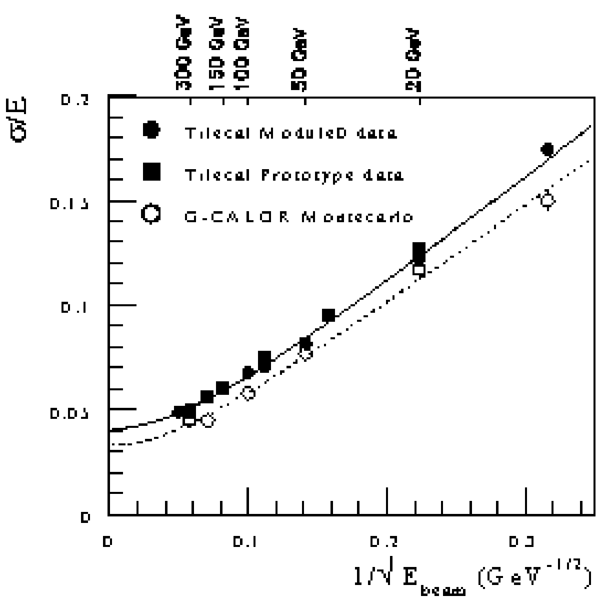

Figure 7: Energy resolution for pions for incident pion energies
Between 10 and 400 GeV.

surrounding the three liquid argon cryostats. Each part is subdivided into 64 modules, The scintillator is read out by means of photomultipliers and wavelength shifting fibres that are grouped in such a way to obtain a pseudo projectivity of the read-out. The series production of modules has started in three laboratories. Figure 7 shows the energy resolution for pions obtained with a prototype module in a test beam.

4. Magnets [7]

The magnetic field of 2 Tesla for the Inner Detector is provided by a **superconducting solenoid** that is integrated into the cryostat of the barrel liquid argon calorimeter. The design aims to minimize the material in front of the calorimeter. The total thickness of the solenoid amounts to 0.67 radiation lengths. The solenoid is currently being manufactured in Japan.

One of the salient features of the ATLAS detector is the large **superconducting air core toroid** that provides the magnetic field for the muon spectrometer. Figure 8 shows a schematic view of the arrangement, it consists of a large barrel toroid and two end-cap toroids. The overall length is 26 meters and the diameter is 20 meters. The total stored energy in the toroid system amounts to 1500 MJoule. The design of the system is being finalised, first final production lengths of the superconductor have been produced by co-extrusion of aluminium and the NbTi superconducting cable, a large prototype coil (called B-zero) is presently under construction.

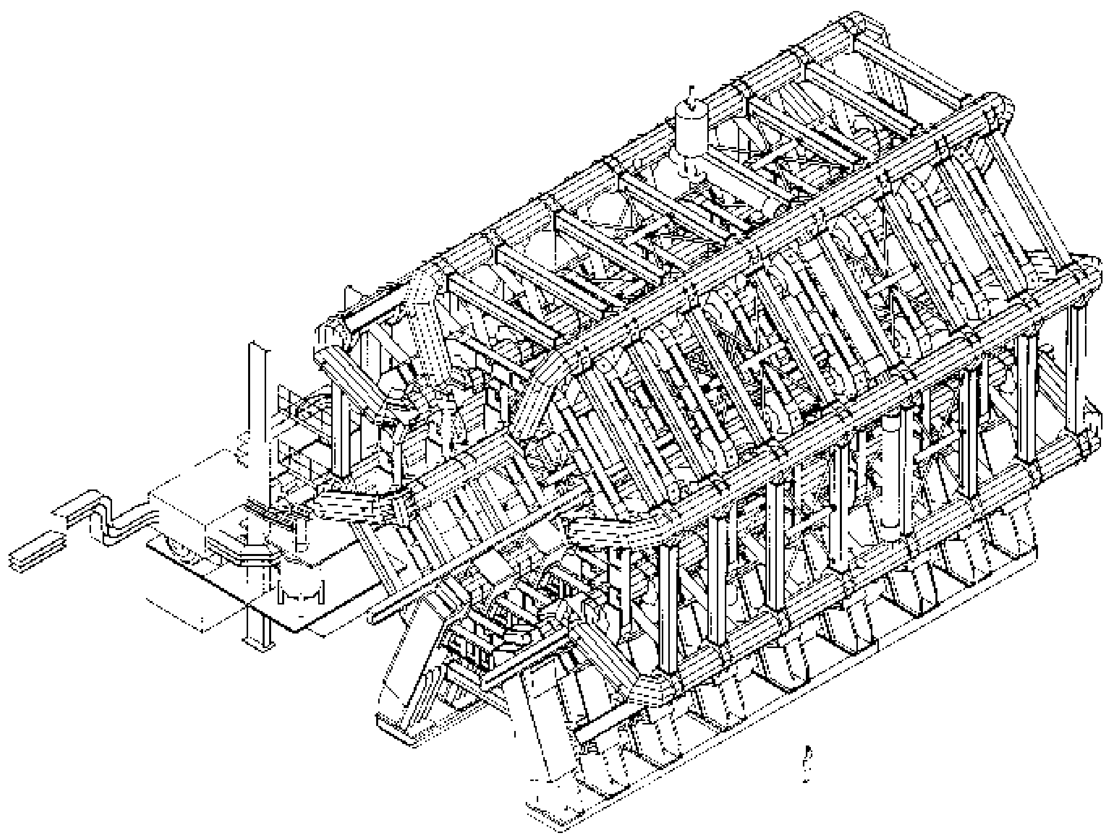

Figure 8: Schematic view of the toroid system

5. Muon Spectrometer

The concept of the muon spectrometer [8] aims an excellent momentum resolution over all pseudo-rapidities, taking advantage of the open air core geometry of the toroid. The muon detector consists of three layers of measuring stations using four different types of chambers. The overall layout is shown in figure 9. The precision measurement is performed by the so-called **Monitored Drift Tube chambers** (MDT) covering most of the acceptance, supplemented by **Cathode Strip Chambers** (CSC) in the very forward region. Each of the MDT chambers consists of two assemblies of three or four layers of high pressure drift tubes, separated by supports in which are integrated optical alignment systems monitoring the geometrical deformations of the large (up to 6 meter long) chambers. The resolution of the individual drift tube (thin walled aluminium tubes filled with 93% Ar-7%CO_2 at 3 bar) is ~80 μ. Construction of prototypes has demonstrated that a precision of ~30 μ is achievable in the mechanical assembly. About 1200 MDT chambers are required to cover the large area of 5500 m^2, some ten production sites are being set up now and construction of the pre-production modules has started on several sites.

In the barrel region (up to $|\eta|=1$), the trigger function is provided by three station of **Resistive Plate Chambers** (RPC) located on both sides of the middle station and inside the outer station. The chambers have no wires, gas amplification is achieved in the small gap, readout is performed with η and ϕ strips providing a space time resolution of typically 1 cm x 1 nsec. In the forward region, **Thin Gap Chambers** (TGC) are arranged in three stations near the middle station of precision chambers. These chambers are similar to multiwire proportional chambers, the trigger signals are obtained from the wires and read-out strips oriented orthogonal to the wires.

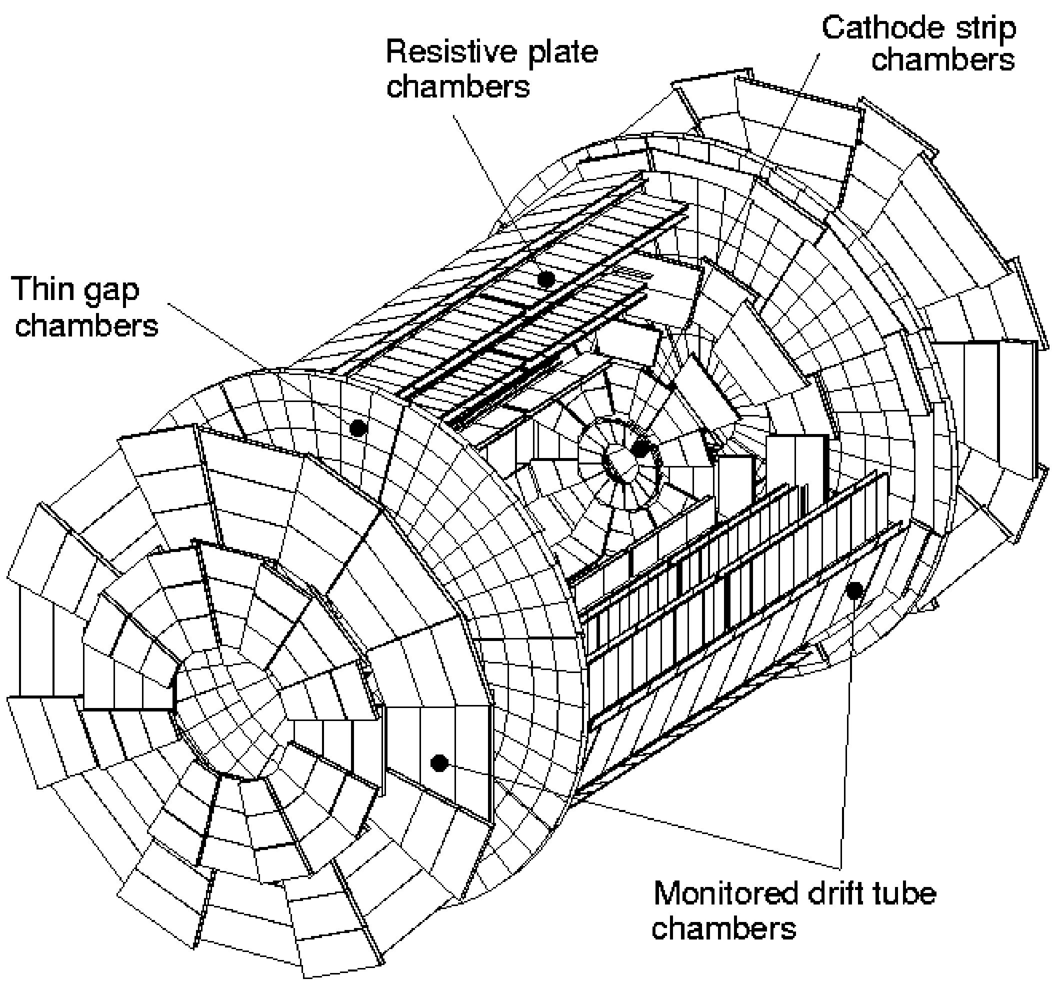

Figure 9: Schematic view of the muon spectrometer

The momentum resolution for muons of the spectrometer in stand alone mode is shown in figure 10 as a function of energy in the pseudorapidity range of $|\eta|<1.5$. The points indicate the simulated resolution and the line gives the calculated value of the momentum resolution, ignoring energy loss fluctuations.

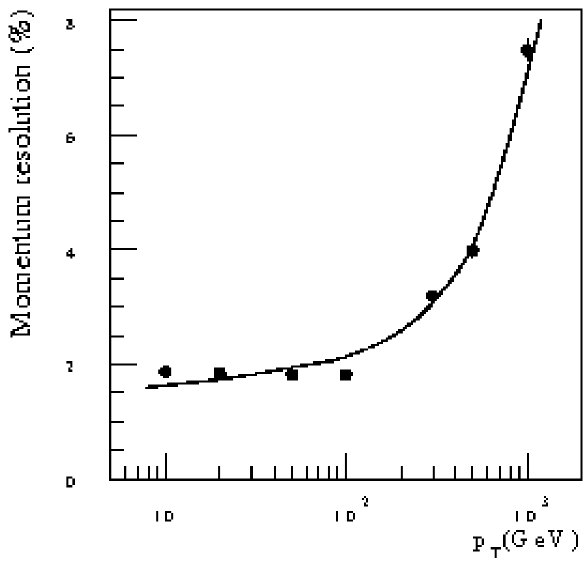

Figure 10: Momentum resolution for muons (see text)

The acceptance has been studied for the precision chamber system and the trigger system using the process H->ZZ*->μμμμ, the acceptance for the trigger system, normalised to the precision chamber system is very close to 1 for two muons, about 0.96 for three muons and about 0.69 for four muons.

6. Conclusion

The ATLAS Collaboration is constructing a powerful detector aimed to fully exploit the new physics at LHC. As an example, figure 11 shows the discovery potential over the full mass range of the SM Higgs particle.

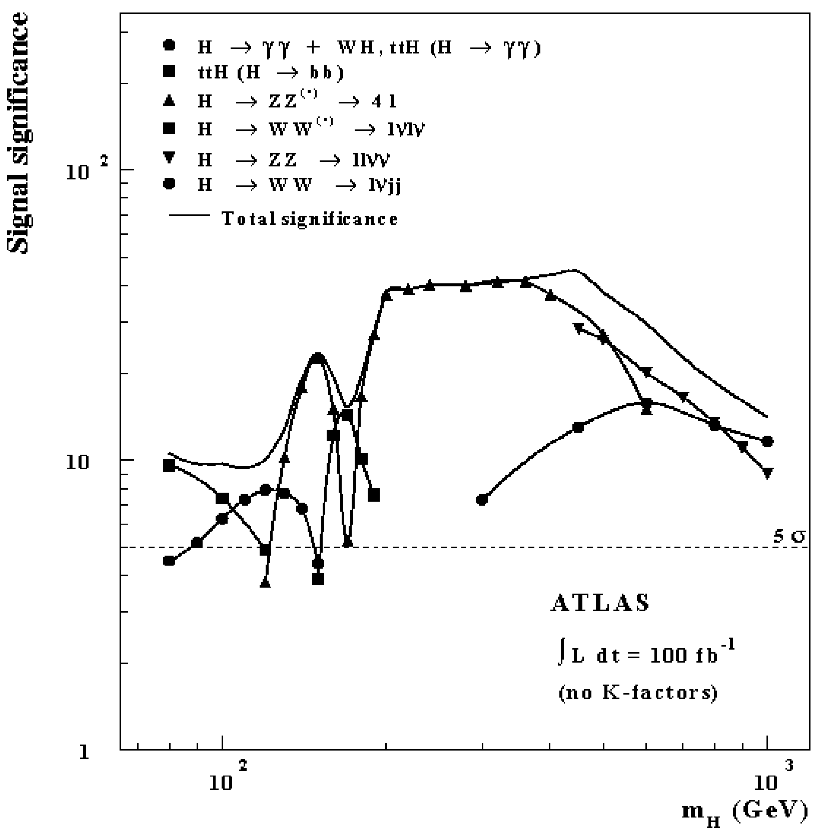

Figure 11: Discovery potential of the ATLAS detector for the Higgs particle

The design work for this large and complex detector is mostly finished, the construction of components has started and great efforts are being undertaken to insure that the experiment will be ready for the first p-p collisions at the turn on of LHC.

References

[1] The Large Hadron Collider, CERN/AC/95-05

[2] The ATLAS Technical Proposal, CERN/LHCC/94-43 (1994)

[3] The ATLAS Inner Detector, Technical Design Report, CERN/LHCC 97-16 and 97-17 (1997)

[4] The ATLAS Liquid Argon Calorimeter Technical Design Report, CERN/LHCC 96-41 (1996)

[5] The ATLAS Tile Calorimeter, Technical Design Report, CERN/LHCC 96-42 (1996)

[6] The ATLAS Calorimeter Performance, Technical Design Report, CERN/LHCC 96-40 (1996)

[7] The ATLAS Magnet System, Technical Design Report, CERN/LHCC 97-18, 97-19, 97-20 and 97-21 (1996)

[8] The ATLAS Muon Spectrometer, Technical Design Report, CERN/LHCC 97-22 (1997)