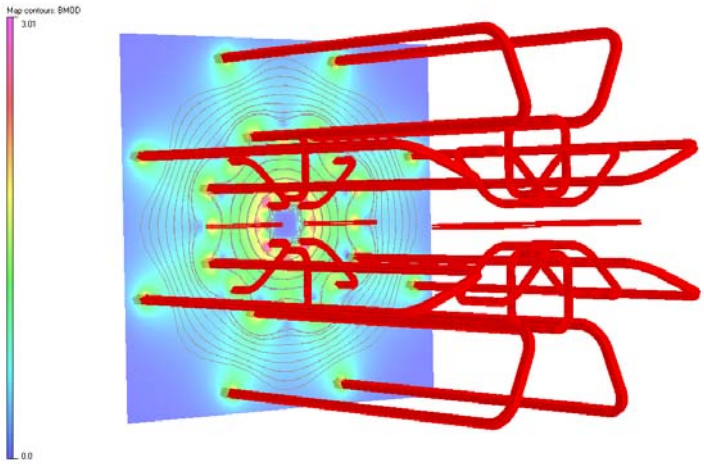
End-Cap Toroid

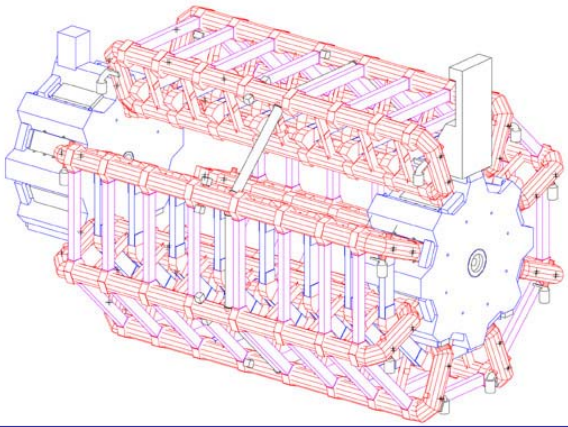
Two End-Cap Toroids are positioned inside the Barrel Toroid, one at each end of the Central Solenoid. They provide the magnetic field in the forward regions of the ATLAS detector across a radial span of 1.7 to 5 meters. The eight coils of each End-Cap Toroid are assembled as a single unit inside one large cryostat. The castellated cryostat vacuum vessel makes it possible to retract the End-Cap Toroids from the operating position to allow access to the centre of the detector. The coils of the End-Cap Toroids are rotated by 22.5 degrees with respect to the Barrel Toroid coils which allows a radial overlap and the optimisation of the magnetic bending power in the interface region of the toroids.



Main Parameters (per End-Cap):

Peak magnetic field:	4.1 T
Operating current:	20,500 A
Operating temperature:	4.8 K (-268 °C)
Axial length:	5 m
Inner diameter:	1.7 m
Outer diameter:	11 m
Stored energy:	250 MJ
Weight:	240 tonnes
Conductor length:	13 km

Each coil consists of two double pancakes wound directly in an aluminium coil casing and is about 4 by 4.5 meters large with a weight of roughly 13 tonnes. One complete End-Cap Toroid has a diameter of 11 meters, a width of 5 meters and a weight of almost 240 tonnes. The End-Cap Toroids are electrically connected in series with the Barrel Toroid and likewise operated at a current of 20,500 amperes providing a peak field of 4 tesla.

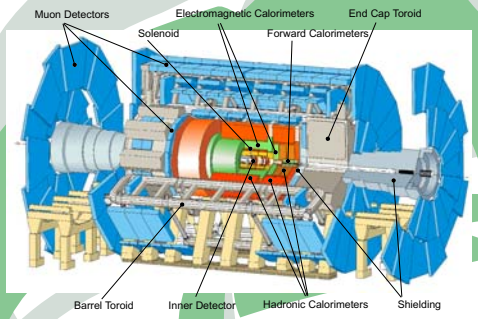


Cryogenics

The magnet system assembly weights 1300 tonnes and is cooled by liquid helium at 4.8 kelvin (-268 °C). It takes some 30 days to cool down to this temperature. The approximate cryogenic cooling power requirement is 2.3 kilowatt at 4.5 kelvin and 11.5 kilowatt at 60 to 80 kelvin. The energy of 1600 megajoule stored in the magnet system is equivalent to the energy of a 4100 tonnes (820 meters long) freight train racing at a speed of 100 km/h.

ATLAS Magnet System

R.J.M.Y. Ruber, 15 March 2005
http://cern.ch/atlas-magnet

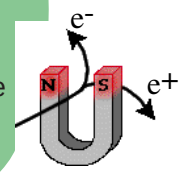


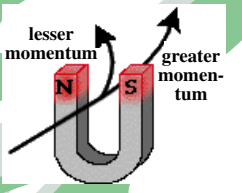
The goal of the ATLAS collaboration is to explore the fundamental nature of matter and the basic forces that shape the universe. The collaboration is preparing a general purpose detector set-up for experiments with proton-proton collisions as provided by the Large Hadron Collider (LHC).

An essential part of the ATLAS detector set-up is the magnet system providing the bending power required for the momentum measurement of charged particle tracks. ATLAS has selected an arrangement of a Central Solenoid servicing the inner detector trackers with an axial magnetic field, surrounded by a system of three large scale air-core toroids generating a tangential magnetic field for the muon spectrometer: one Barrel Toroid and two End-Cap toroids. Each of the three toroids consists of eight coils.

Particles created in a collision can be studied e.g. by using a magnetic field.
For charged particles:

Opposite charges give opposite directions.





Different momenta give different bending radii.

Barrel Toroid

End-Cap Toroid

Central Solenoid

A particular challenge of the ATLAS magnet system is its record-breaking size and the mixed configuration of solenoid and toroid magnets. It also has to accommodate the physics requirements for the ATLAS detector set-up with a light and open mechanical structure. Therefore conduction-cooled superconducting magnets are used in order to reduce material build-up and enhance particle transparency. The magnet system has an overall dimension of 25 meters length by 20 meters in diametre. It has a total weight of 1300 tonnes and stores a magnetic energy of 1600 megajoules.

CERN
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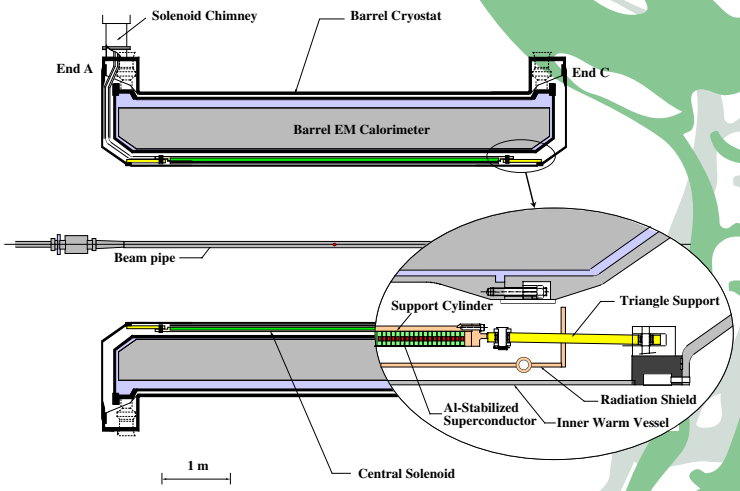
Central Solenoid

The Central Solenoid is designed to provide a 2 tesla strong magnetic field in the central tracking volume. It is a conduction-cooled superconducting solenoid based on a thin-walled construction for minimum thickness to decrease particle scattering effects. In order to reduce material build-up and enhance particle transparency, the solenoid shares its cryostat with the liquid argon calorimeter. The solenoid is made as a single layer coil.

Main Parameters:

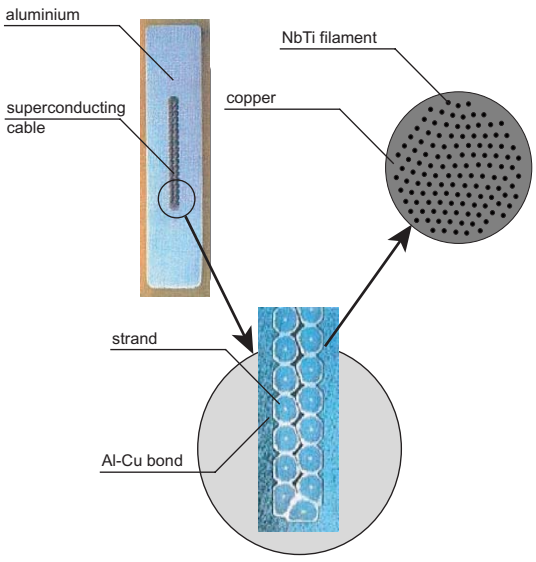
Magnetic field:	2.0 T
Operating current:	7600 A
Operating temperature:	4.8 K (-268 °C)
Coil length:	5.300 m
Coil inner radius:	1.229 m
Coil thickness:	45 mm
Stored energy:	39 MJ
Weight:	5.6 tonnes
Conductor length:	9 km



The solenoid is 5.3 meters long with a bore of 2.4 meters, has a thickness of 45 millimeters, a weight of almost 6 tonnes and operates at a current of 7,600 amperes. All connections are made through a dewar situated on top of a 10 meters long chimney. Twelve triangular glass-fiber supports sustain the coil inside the cryostat. Pure aluminium strips are attached axially along the coil winding to enhance the coil's operation margin by increasing heat conduction.

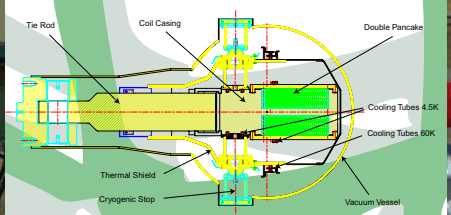
Superconductor

The magnetic field strength of 2 to 5 tesla is perfectly suited for the use of niobium-titanium superconductor in a copper matrix cable co-extruded (or plated) with aluminium. This technique of aluminium stabilisation is applied to handle the large amount of stored energy, to facilitate indirect cooling and to enhance particle transparency. The superconducting cables can operate with currents up to many thousands of amperes when cooled down to 4.8 kelvin (-268 °C). In total some 206,000 kilograms of conductor is required for the ATLAS magnet system.

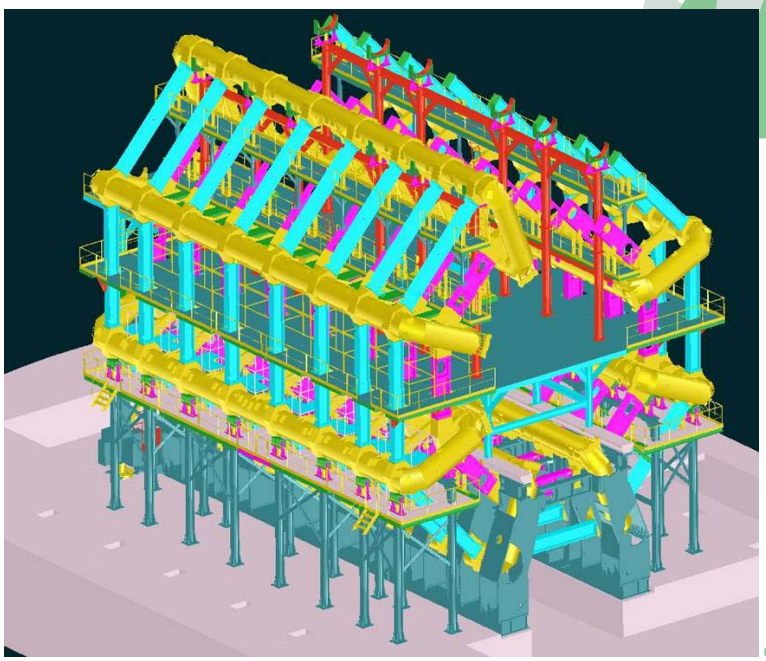


Barrel Toroid

The Barrel Toroid consists of eight flat race-track coils each of them consisting of two double pancake windings housed in a common aluminium casing 25 meters long and 5 meters wide. It generates the magnetic field for the central region of the muon detector. The coils are grouped in a torus shape maintained by a system of 16 supporting rings. All connections are made through a cryogenic ring which combines the eight coils. Each coil is mounted in an individual cryostat and indirectly cooled by liquid helium flowing in tubes attached to the coil casing. A single coil has a weight of some 40 tonnes to which its cryostat adds another 40 tonnes. The total Barrel Toroid assembly has an outer diameter of 20 meters and approaches a weight of 830 tonnes. The toroid is operated at a current of 20,500 amperes and reaches a peak field of 4 tesla.



After integration and test the eight coils are transported to the ATLAS cavern and assembled as a toroid. It is first then that the Barrel Toroid will be operated as a complete system. Due to its exceptional size it was not feasible to assemble and test the integrated Barrel Toroid before underground installation. For the separate tests of the eight coils, a magnetic mirror is used to induce the same level of forces as expected in the full assembly.



Main Parameters:

Peak magnetic field:	3.9 T
Operating current:	20,500 A
Operating temperature:	4.8 K (-268 °C)
Axial length:	25 m
Inner diameter:	10 m
Outer diameter:	20 m
Stored energy:	1100 MJ
Weight:	830 tonnes
Conductor length:	56 km