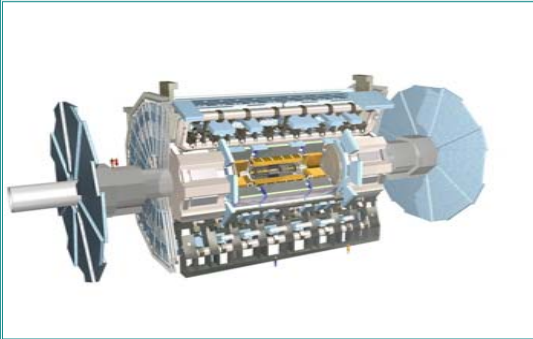


ATLAS and the LHC



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Birmingham Masterclass
Tuesday 24 April 2007



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- Why build the LHC ?
- About the accelerator
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- Update on progress (current!)

Why build the LHC ?

- To further our knowledge on how the universe is constructed and works:
 - **Understand the origin of particle mass** (Search for the standard model Higgs boson and supersymmetry)
 - **Look for physics beyond the standard model** (Grand Unification Theories, supersymmetry and theories of everything)
 - **Answer existing open questions** (Are quarks and leptons elementary particles, are there other families of quarks, leptons and gauge bosons, why is there a matter – antimatter asymmetry in the universe etc.)
 - **Perform precision measurements** (eg. Top quark mass)
 - **Anything else in addition !**

What is the LHC (Large Hadron Collider) ?

- The largest (and most expensive) 'atom smasher' ever built.
- LHC - the aim of the exercise: To smash protons moving at 99.999999991% of the speed of light into each other and so recreate conditions a fraction of a second after the big bang. The LHC experiments try and work out what happened.
- Very high energy is needed to produce massive new particles, while very high intensity is needed as some of the interesting processes are very rare

The LHC



Constructed within the 27km circumference tunnel formally used by the LEP and LEP II electron – positron colliders from 1989 until 2000

Will collide counter rotating bunches of 7TeV energy protons every 25ns at the centre of each of the four LHC detectors

Each proton goes around the 27km ring over 11 000 times a second.

A nominal proton beam in the LHC will have an energy equivalent to a person in a Subaru driving at 1700 kph.

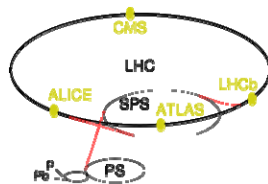
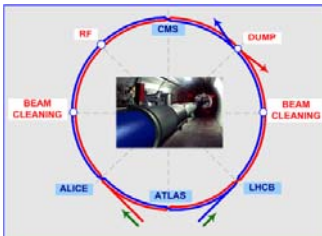
(The world land speed record held by Andy Green in Thrust SSC stands at 1227.985kph)

The LHC



- Proton – proton collision centre of mass energy of 14TeV is a factor of 7 larger than the largest current machine
- Design luminosity is a factor of 100 greater than previous colliders
- Should allow new particle searches up to ~ 5TeV mass (From $E = mc^2$)

How the LHC works

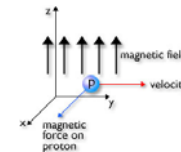


- 50MeV protons are created by the linac2 linear accelerator and are accelerated by a chain of synchrotrons before entering the LHC at 450GeV
- The protons are boosted to 7TeV within the LHC before focusing magnets force the beams to collide at each of the four LHC experiment points



How the LHC works

- The protons are accelerated using strong electric fields and are forced to travel around the LHC ring using powerful bending magnets.



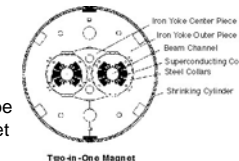
- The beam energy possible is limited by the bending power needed to keep protons circulating in the tunnel

- The higher the beam energy, the larger the magnetic field strength required (**Building a bigger tunnel is not a realistic option !**)

- 1232 main superconducting dipoles produce a field of 8.4 Tesla needed to get to 7TeV proton beam energy

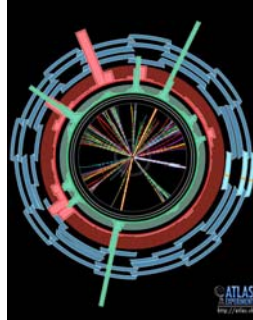


- Magnets have been designed so that two oppositely moving beams of protons can be dealt with in one magnet with a double yoke

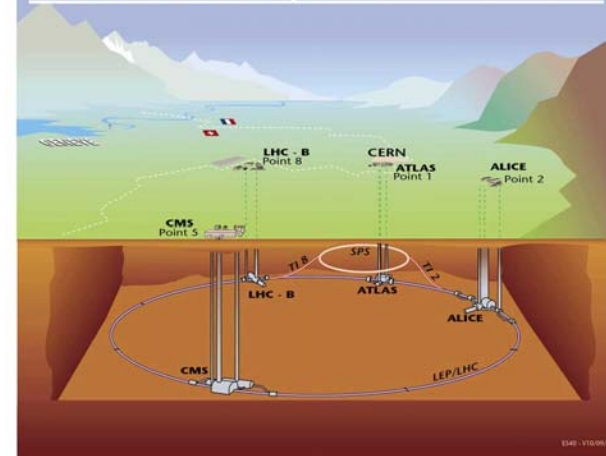


LHC proton – proton collisions

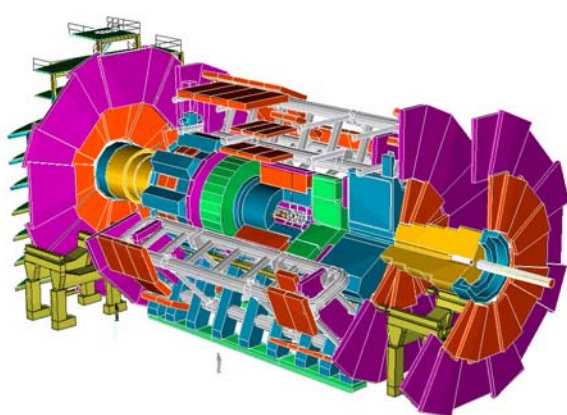
- Come in two types:
 - 'Soft collisions': where the momentum transfer between the two colliding protons is small
 - 'Hard scattering' where quarks or gluons from the two incoming protons collide head on. Massive particles may be formed and products are formed at large angles to the beam pipe.
- The hard interactions are the interesting ones but the soft interactions are much more frequent.
- Separating out the interesting events from the background is one of the biggest challenges faced by the LHC detectors
- Only ~10 of the 1 billion events are produced by hard scattering



Overall view of the LHC experiments.



ATLAS (A Toroidal LHC Apparatus)



The ATLAS Physics Programme

- Search for the standard model Higgs boson from the LEP II / TeVatron limit up to theoretical limit of 1TeV
- Search for supersymmetry and beyond standard model physics (particles up to a mass of ~5TeV; limited by momentum fraction carried by the quarks and gluons which make up the proton)
- Precise measurements of the W boson, top quark and associated interactions

Search for the Higgs boson

- Within the standard model, it is currently believed that particles obtain their observed masses via the Higgs mechanism
- When a particle moves through the Higgs field, the strength of the coupling to the field determines the mass of the particle

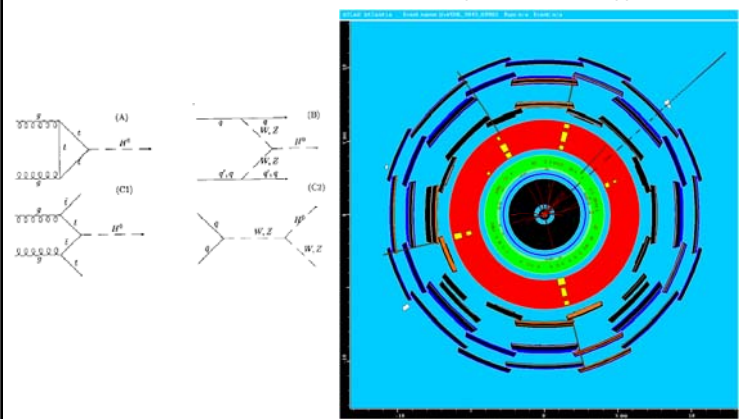


- The mechanism requires that a real Higgs particle should exist coupling strongly to heavy particles
- The SM Higgs H^0 **will be seen at the LHC if it exists**
- To see the Higgs look for its decay products:
 - For example look for $H \rightarrow ZZ \rightarrow 4$ charged leptons

Higgs $\rightarrow 4$ leptons is the GOLDEN CHANNEL as experimentally very clean

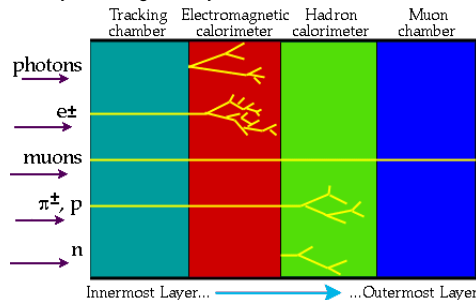
Higgs boson production

ATLANTIS image of simulated Higgs $\rightarrow 4$ leptons



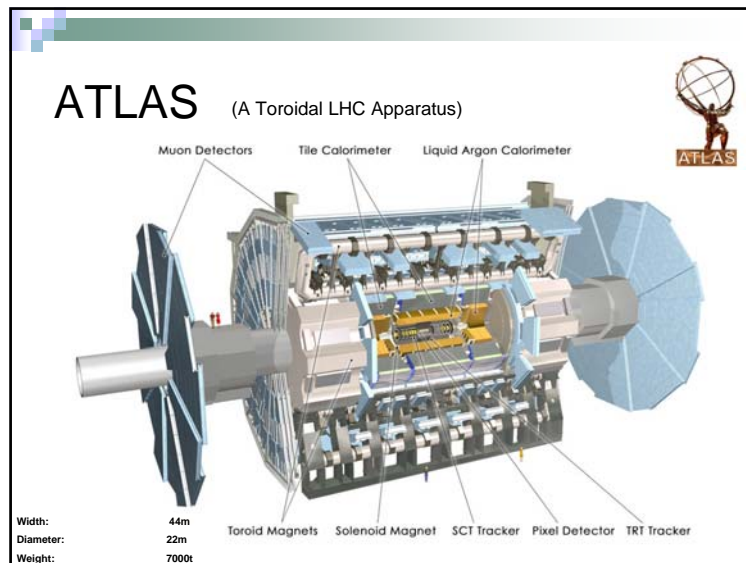
The ATLAS Detector Principle

- ATLAS is multipurpose detectors designed to allow precision measurement of electrons, muons, taus, (neutrinos), photons, jets, b – jets etc (ie everything in a particular event)
- It consists of cylindrical layers outwards from the collision point with a symmetrical cylindrical geometry

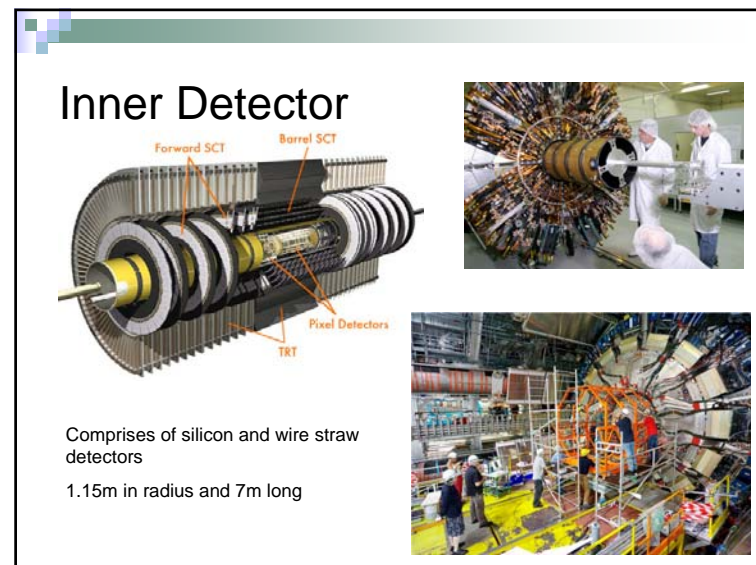
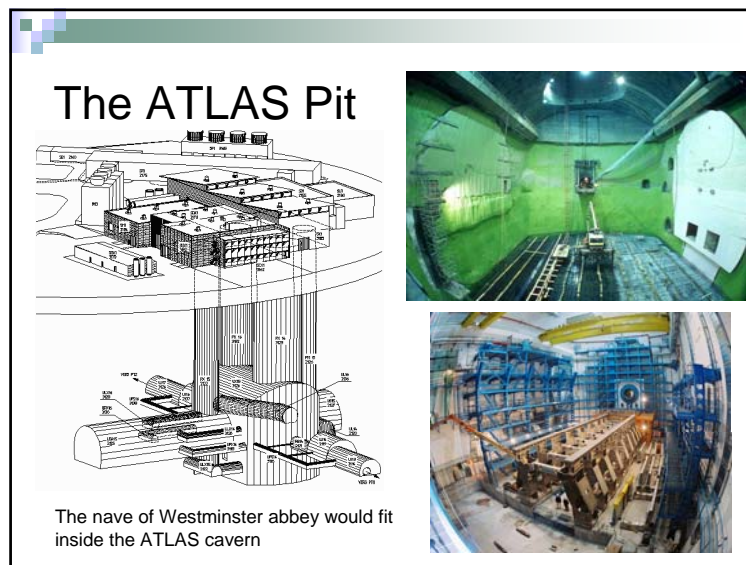


The ATLAS Detector

- The inner detector within a magnetic field measures momenta and charge of charged particles and is also used for secondary vertex finding (Pixel, SCT and TRT detectors plus solenoid magnet)
- EM Calorimeter: Measures the energy and position of electrons and photons and also aids particle identification (Liquid argon calorimeter)
- Hadronic calorimeter: Measures the energy and position of hadrons and jets, plus allows derivation of the total missing transverse energy in an event (used to deduce neutrino energy) (Liquid argon and tile calorimeters)
- Muon spectrometer: Identifies muons and measures momentum, combined with the inner tracker (Muon detectors and toroid magnets)



ATLAS Under Construction



Solenoid Magnet



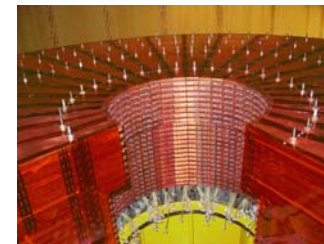
Surrounds the inner detector and is contained in a cryostat

Produces a 2T nominal magnetic field

Calorimeter (EM)



Barrel in cryostat



Endcap



Calorimeter (Hadronic)

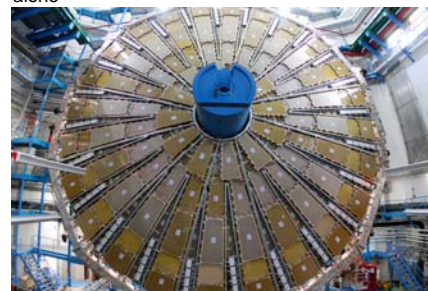


The calorimeters fill the gap between the outside of the inner solenoid and the muon system



Muon Spectrometer

Muons are the only charged particles which can pass through the calorimeters. The muon system therefore acts like the inner tracker but outside the calorimeters to measure the muon properties alone



Toroid Magnets (Barrel toroid)

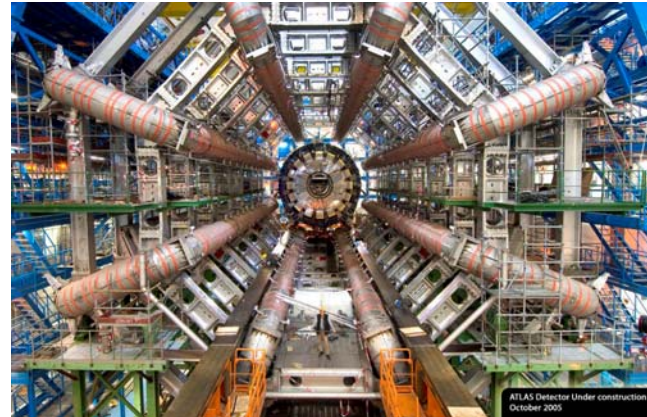


The largest toroid magnet ever built !

Outer diameter 20.1m (inner diameter 9.4m) and 25.3m long

Together with the muon chambers it defines the overall size of ATLAS

The most famous image of 'ATLAS'



ATLAS Yesterday!



Status of progress

- ATLAS detector and LHC are both nearing completion
- Switch on at full energy is scheduled for mid 2008
- A low energy test run may take place later this year