# Compact Muon Solenoid

CMS is a world wide collaboration comprising 1889 physicists and engineers from 150 institutions in 31 countries

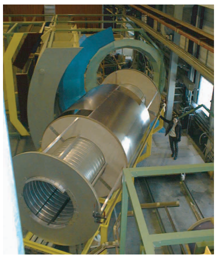
CMS is a general purpose proton-proton detector designed to run at the highest luminosity at the LHC

## Silicon Tracker

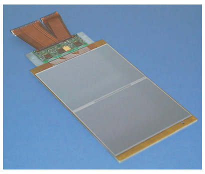
**Purpose:** measure momentum ($p$) of charged particles (e.g. electrons, positrons, pions...)

**Method:** Many concentric layers of thin, finely-segmented sensors made of silicon. A charged particle traversing a sensor will produce a "hit". Join-the-hits to make a "track", from which you can measure $p$

**Trivia:** ~70 million individual detector segents; the segments are about as thin as a human hair!



A model of the CMS tracker



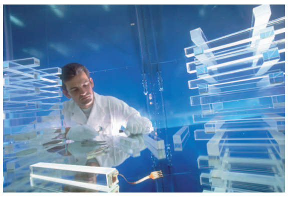
Two silicon sensors bonded together. Each detector is 16cm wide and 11cm long, and each contains 512 strips that are 0.14mm wide.

## Electromagnetic Calorimeter (ECAL)

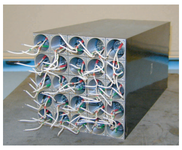
**Purpose:** measure energy of electrons, positrons and photons

**Method:** 80000 crystals of lead-tungstate absorb the particles and produce light; the amount of light produced is proportional to the energy of the particle

**Trivia:** Each crystal is ~98% metal - but is completely transparent!



Inspecting some crystals - each weighs around 1.5 kg



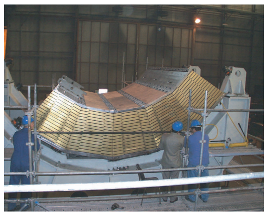
An endcap "SuperCrystal" (5x5 crystals) weighs around 50kg and is supported by carbon fibre of 0.4mm thickness!

## Hadronic Calorimeter (HCAL)

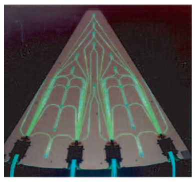
**Purpose:** measure energy of "hadrons" - protons, neutrons, pions.....

**Method:** Particles deposit energy in layers of brass. This energy is measured by interleaved layers of light-producing plastic tiles (scintillators).

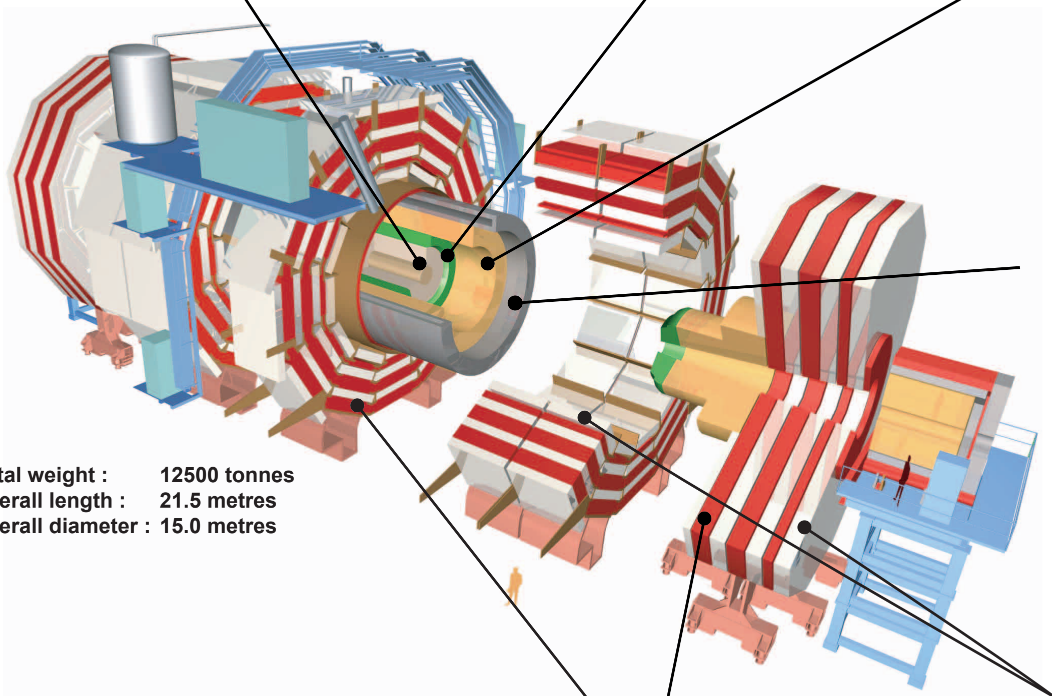
**Trivia:** The brass for the endcap HCAL comes from recuperated artillery shells from Russian warships



Photograph of part of the barrel HCAL



Light produced in the scintillators travels down optic fibres



Total weight : 12500 tonnes
Overall length : 21.5 metres
Overall diameter : 15.0 metres

## Magnet

**Purpose:** Cause charged particles to curve - enables the measurement of $p$ (with the tracker)

**Method:** A single superconducting solenoid producing a uniform field along the direction of the beam.

**Trivia:** The CMS magnet is the largest solenoid ever built; the magnetic field produced is ~100000 times that of the earth! When operating at the maximum field, 4 Tesla, the energy stored in the magnet is sufficient to melt 18 tonnes of gold


Artistic impression showing the size of the CMS solenoid

## Trigger and Data Acquisition

**Purpose:** At the LHC, the proton beams cross each other 40,000,000 times each second. At the highest LHC beam intensities there will be roughly 25 proton-proton collisions for each crossing. Recording all the information from these collisions in the CMS experiment requires, for every second of operation, the equivalent of 10000 Encyclopaedia Britannica!
The task of the trigger and data acquisition system is to select, from these millions of "events", the most interesting 100 or so per second.

**Method:** First use information from the calorimeters and MUON detectors and then add information from the TRACKER etc.

**Trivia:** The amount of data transferred from CMS to the data acquisition system is about the same as that handled by the whole world's telecom networks today!

## Computing

**Purpose:** Store the data from the ~100 interesting events per second - each event is around 1 Mbyte. Then process the events to try to find ones containing signs of new physics e.g. the Higgs particle.

**Method:** The data analysis will be a world-wide activity as the processing power required is enormous.

**Trivia:** The number of processors in the first level of analysis is around 4000 - about the same number as present on the whole CERN site in 2001.

## Return Yoke

**Purpose:** Necessary for the solenoid magnet. Also acts as the main structure of CMS.

**Method:** 5 "rings" of iron in the barrel + 2 endcap disks, each comprising 3 layers of iron interleaved with muon chambers. These are the large red structures in the hall.

**Trivia:** The amount of iron used is approximately equal to that in the Tour d'Eiffel in Paris!

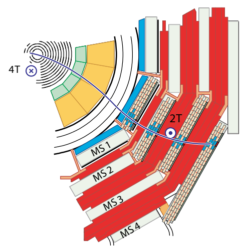
http://cmsinfo.cern.ch

## Muon Chambers

**Purpose:** Detect muons - these particles can signify that "something interesting" has happened

**Method:** Many detector layers placed inside the return yoke. The iron of the return yoke (+the HCAL) absorbs all other particles: only muons (and neutrinos) traverse the muon chambers

**Trivia:** The total area of muon detectors is ~the same as that of a soccer pitch (~6000m$^2$)




Muons are measured 3 times in CMS: in the tracker and the HCAL (inside the magnet, where they bend in one direction) and in the muon chambers (outside the magnet, where they bend in the opposite direction)

Photograph of a full-size endcap muon detector chamber