

# CMS

## The Compact Muon Solenoid Experiment

**Protons and heavy ions collide with unprecedented energies in the centre of CMS**

**To create**

localised conditions similar to those that existed a fraction of a billionth of a second after the Big Bang

**To look for**

new particles such as the Higgs boson, supersymmetric particles and gravitons, and new phenomena such as micro black holes and new states of very hot and dense matter...

**To understand**

why the world is the way it is  
why some particles weigh more than others  
what constitutes the dark matter in the Universe  
if there are more dimensions of space  
how hot, dense matter behaved in the early Universe  
if we can progress towards a unified theory that underlies all physical phenomena

Experiments are essential for understanding the nature of the Universe. CMS is such an experiment.

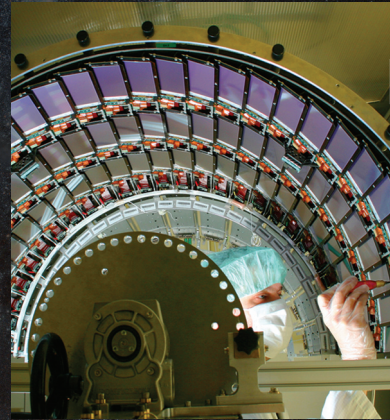


<http://cms.cern.ch>



# The Detector and Detectives

CMS is a large technologically advanced detector comprising many layers, each designed to perform a specific task. Together these layers allow CMS scientists to identify and precisely measure the energies and momenta of all particles produced in collisions at CERN's Large Hadron Collider (LHC).



## Electromagnetic Calorimeter

Nearly 80 000 crystals of lead tungstate ( $\text{PbWO}_4$ ) are used to measure precisely the energies of electrons and photons. A 'preshower' detector, based on silicon sensors, helps particle identification in the endcaps.



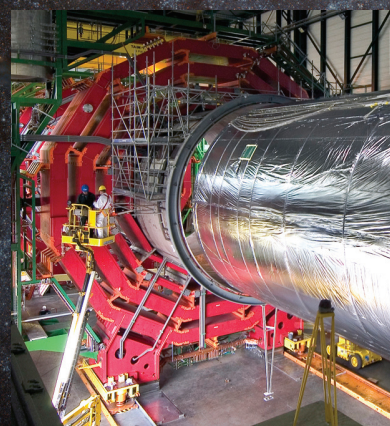
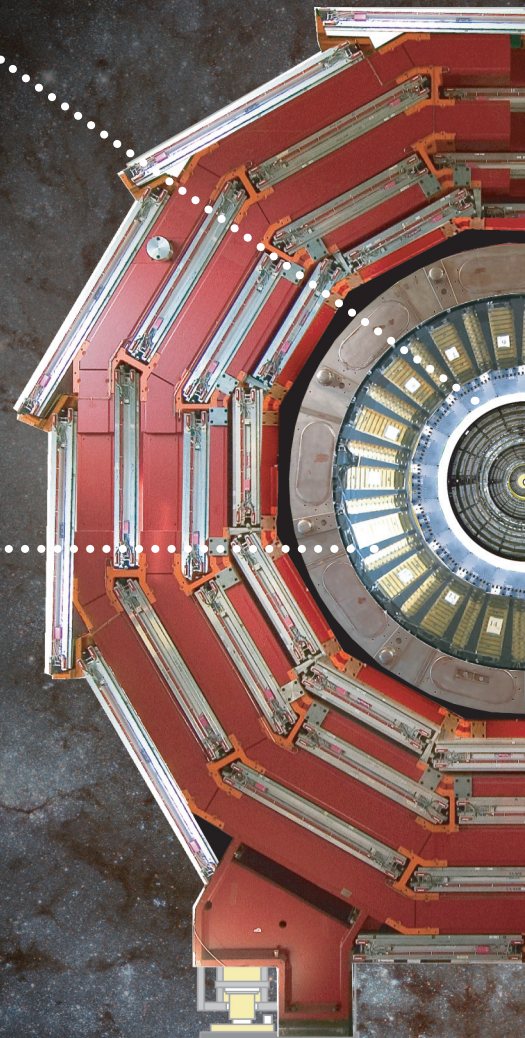
## Hadron Calorimeter

Layers of dense material (brass or steel) interleaved with plastic scintillators or quartz fibres allow the determination of the energy of hadrons, that is, particles such as protons, neutrons, pions and kaons.



## Muon Detectors

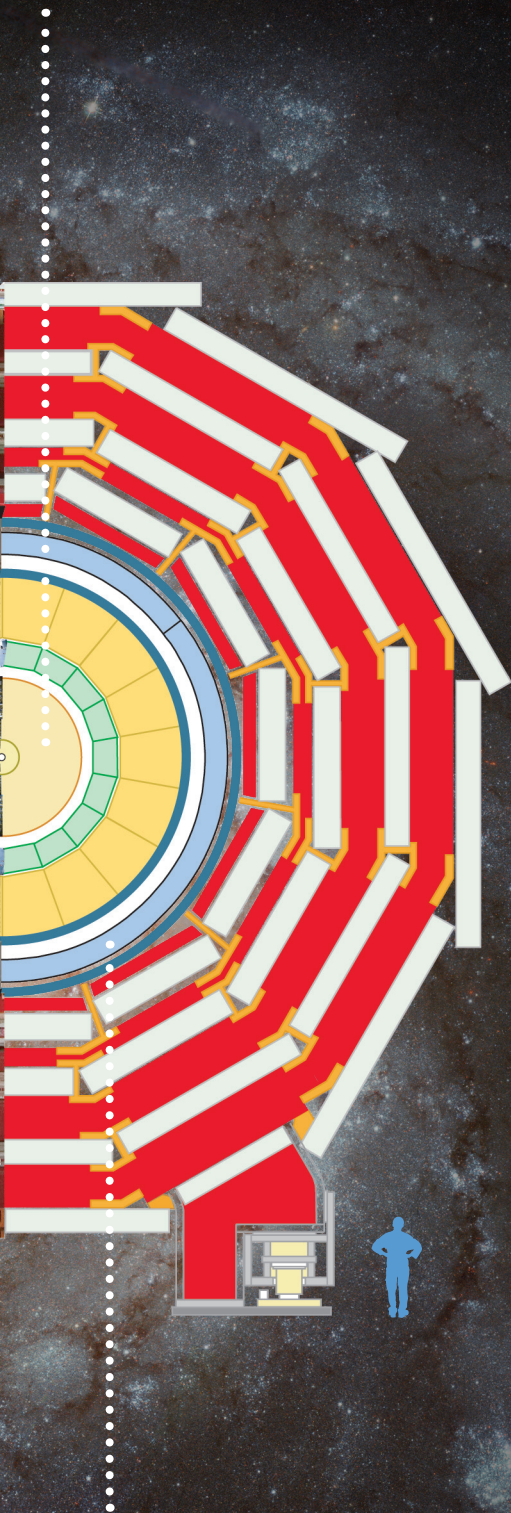
To identify muons (essentially heavy electrons) and measure their momenta, CMS uses three types of detector: drift tubes, cathode strip chambers and resistive plate chambers.





Tracker

Finely segmented silicon sensors (strips and pixels) enable charged particles to be tracked and their momenta to be measured. They also reveal the positions at which long-lived unstable particles decay.

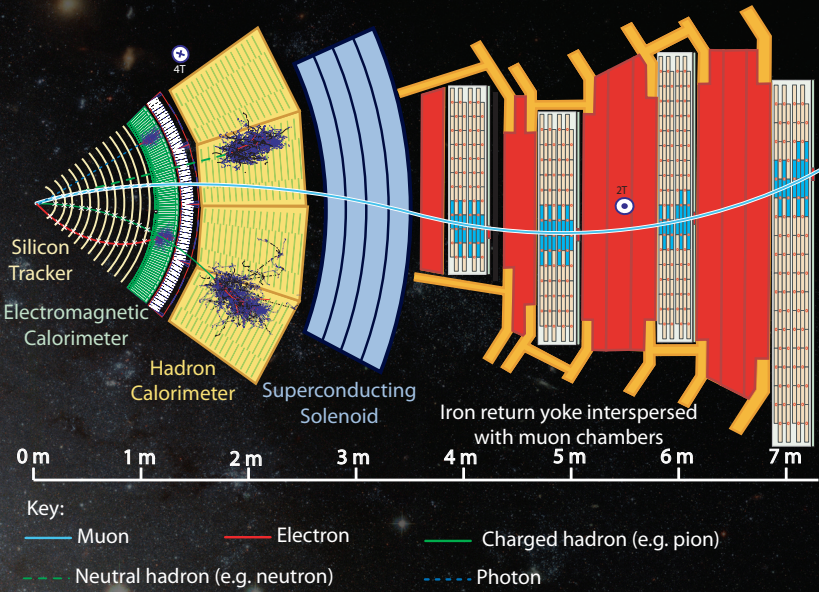


Superconducting Solenoid

Passing 20 000 amperes through a 13 m long, 6 m diameter coil of niobium-titanium superconductor, cooled to  $-270^{\circ}\text{C}$ , produces a magnetic field of 4 teslas (about 100 000 times stronger than that of the Earth). This field bends the trajectories of charged particles, allowing their separation and momenta measurements.

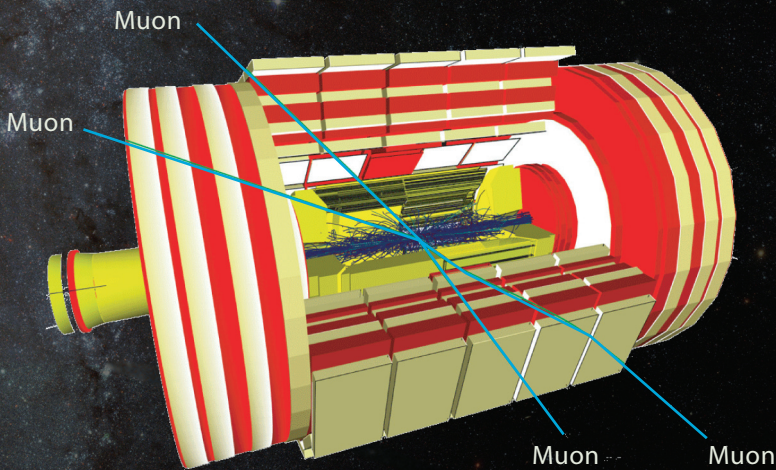
Pattern Recognition

New particles discovered in CMS will be typically unstable and rapidly transform into a cascade of lighter, more stable and better understood particles. Particles travelling through CMS leave behind characteristic patterns, or 'signatures', in the different layers, allowing them to be identified. The presence (or not) of any new particles can then be inferred.

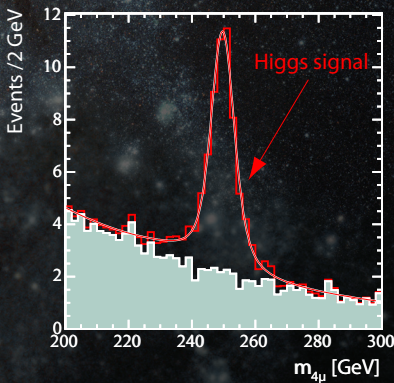


Trigger System

To have a good chance of producing a rare particle, such as a Higgs boson, the particle bunches in the LHC collide up to 40 million times a second. Particle signatures are analysed by fast electronics to save (or 'trigger on') only those events (around 100 per second) most likely to show new physics, such as the Higgs particle decaying to four muons in the figure below. This reduces the data rate to a manageable level. These events are stored for subsequent detailed analysis.



Simulated 250 GeV Higgs decaying to 4 muons



Data Analysis

Physicists from around the world use cutting-edge computing techniques (such as the Grid) to sift through millions of events from CMS to produce plots like the one on the left (a simulation) that could indicate the presence of new particles or phenomena.



**The CMS Detector** comprises 100 million individual detecting elements, each looking for tell-tale signs of new particles and phenomena—40 million times a second. It is one of the most complex and precise scientific instruments ever constructed. Situated 100 m underground at the French village of Cessy, just across the border from Geneva in Switzerland, it will operate for more than a decade.

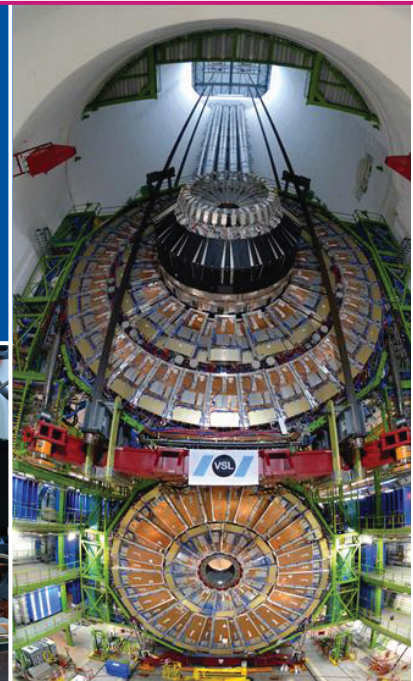


### Physical Parameters

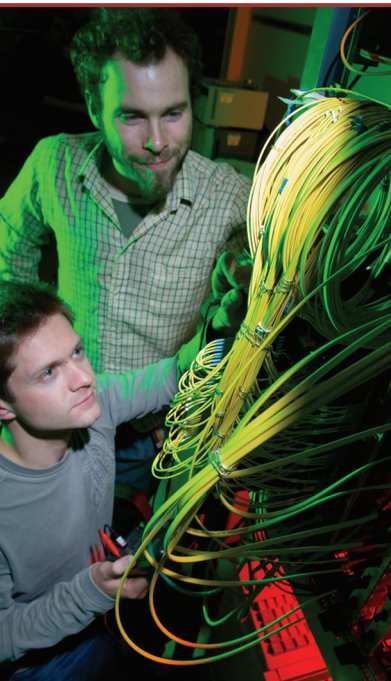
14 000 tonnes  
21 m long  
15 m diameter

The huge size of CMS hides the complexity within. A technician assembles one of the components of the inner tracker using 5-micron thick wires.

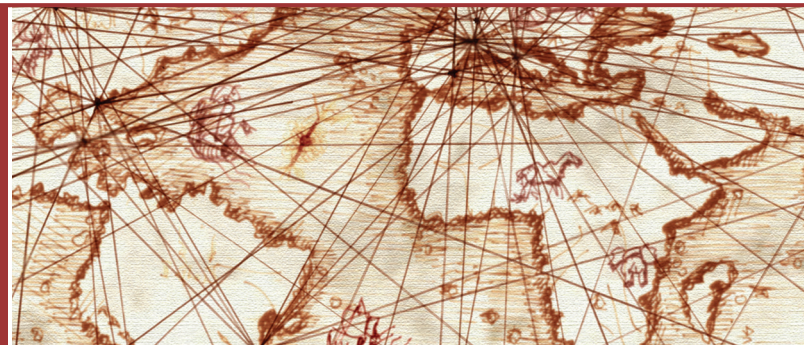
The large pieces of CMS, weighing between 200 and 2000 tonnes each, are lowered 100 m into the cavern before being assembled into position.



**A Worldwide Adventure** Solving some of the mysteries of the Universe is only possible with the involvement of scientists, engineers and students from a multitude of disciplines. Pieces of CMS have been designed and constructed in institutes around the world, as well as in industry, before being brought to CERN for the final assembly. The data analysis will be another worldwide endeavour, made possible through innovations in computing technology such as the Grid.



A researcher and a PhD student work together to cable and test some of the readout electronics of CMS.



Collaborators in the assembly hall celebrating the end of the construction of the initial CMS detector in 2008.

### CMS Collaborators

38 countries, 183 institutes  
More than 2500 scientists, including about 600 students

To find out more about all aspects of CMS, visit our web site at: <http://cms.cern.ch>

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