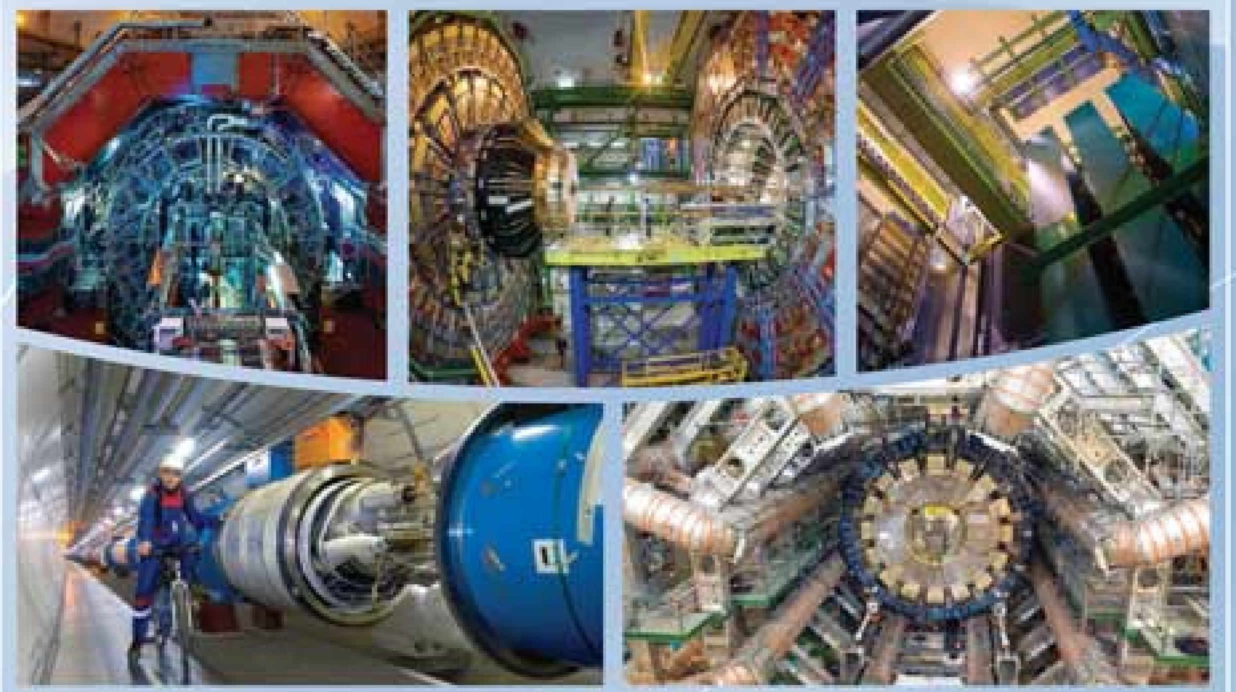
About the LHC

The LHC is the biggest scientific experiment in the world. It accelerates two beams of protons in opposite directions around a 27km underground tunnel, until they approach the speed of light. The particles are then collided together, generating ultra high energies that recreate in the laboratory the conditions experienced less than one billionth of a second after the Big Bang.

When the protons collide, four detectors (ATLAS, CMS, ALICE and LHCb) analyse the collisions in great detail. This allows physicists to test their fundamental theories of matter – and, if past experience repeats itself, may throw up some unexpected results!



FURTHER INFORMATION

If you would like to know more about the Large Hadron Collider, CERN or Particle Physics in general, try the following resources:

Websites

www.cern.ch
www.stfc.ac.uk/particlephysics
http://durpdg.dur.ac.uk/lbl/particleadventure
www.schoolscience.co.uk
www.collidingparticles.com
www.tes.co.uk/
www.nationalstemcentre.org.uk/
http://ippog.web.cern.ch/

Books

Collider - the search for the world's smallest particles
Paul Halpern, John Wiley & Sons, 2009

The Quantum Frontier - The Large Hadron Collider
Don Lincoln, Johns Hopkins University Press, 2009

The Large Hadron Collider a Marvel of Technology
edited by Lyndon Evans, EPFL, 2009

A Zeptospace Odyssey
A journey into the Physicsof the LHC)
Gian Giudice, OUP Oxford, 2010

Present at the Creation
(Story of CERN and LHC)
Amir Aczel, Crown, 2010

Massive - The Hunt for the God Particle
Ian Sample, Virgin Books, 2011

The Infinity Puzzle
Frank Close, OUP Oxford, 2011

Knocking on Heaven's Door
Lisa Randall, Vintage, 2012

Higgs Force
Nicholas Mee, Lutterworth, 2012

Science & Technology Facilities Council

The Science and Technology Facilities Council operates world-class, large-scale research facilities; supports scientists and engineers world-wide; funds researchers in universities and provides strategic scientific advice to government.

The Council's Public Engagement unit offers a wide range of support for teachers, scientists and communicators to facilitate greater engagement with STFC science which includes astronomy, space science, particle physics and nuclear physics:

For schools

- Free resource guides suitable for teaching ages 10-18. Go to www.stfc.ac.uk/teachers
- STFC educational publications dealing with many aspects of fundamental physics. Go to www.stfc.ac.uk/pepublications
- Funding schemes for projects and school visits. Go to www.stfc.ac.uk/pefunding
- A Moon rock and meteorite loan scheme. Go to www.stfc.ac.uk/moonrocks
- Visits to STFC's UK laboratories in Cheshire, Oxfordshire and Edinburgh plus CERN in Geneva. Go to www.stfc.ac.uk/seethescience

For scientists

- Communication and media training courses; funding schemes and Fellowships for public engagement. Go to www.stfc.ac.uk/pefunding

For further information telephone 01793 442175 or email Neville.hollingworth@stfc.ac.uk

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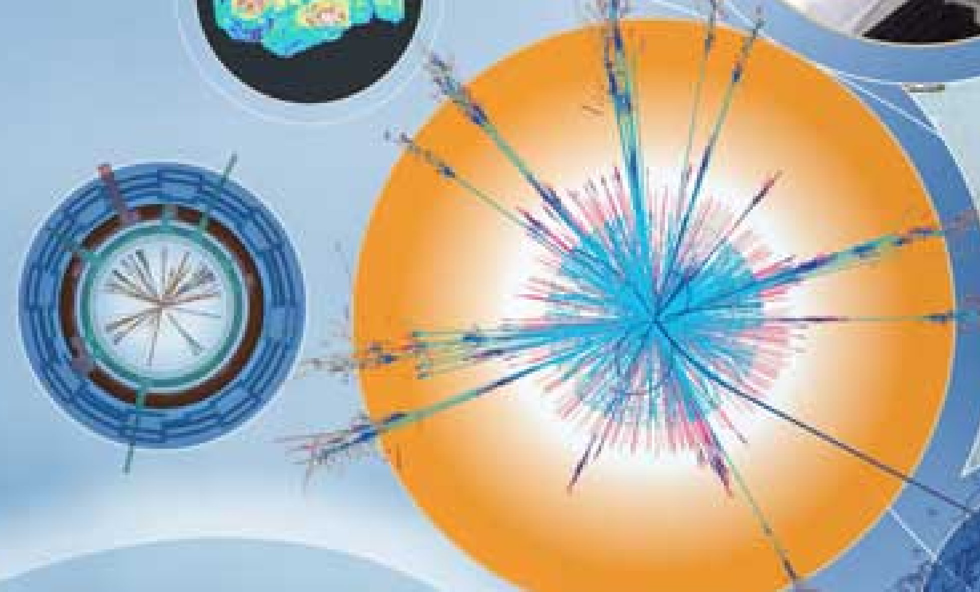
The UK contribution

The UK is playing a leading role in the LHC and its experiments. The project leader during the construction of the LHC was Welshman Lyn Evans, and groups from 19 British universities and research laboratories are taking part. They have designed, manufactured and assembled detector modules and developed new computing techniques to analyse unprecedented amounts of experimental data.

Technology benefits

To build the LHC, engineers have had to push technology to new levels. This has led to advances in many fields including the design of superconducting magnets and the systems which cool them to near absolute zero. Particle Accelerators are already used in hospitals to treat cancers. Novel sensor designs developed for use in detectors have led to safer and better medical imaging.



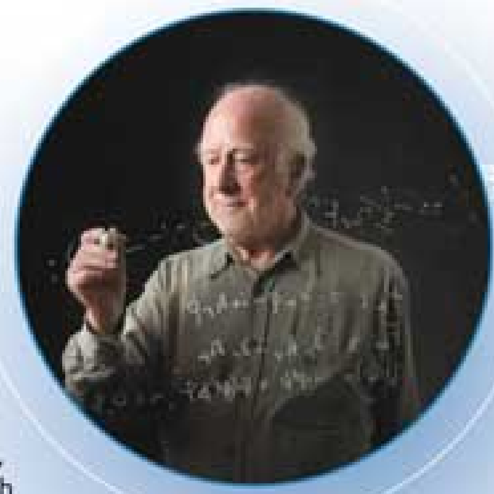
BIG QUESTIONS: BIG EXPERIMENT

THE LARGE HADRON COLLIDER, CERN

Science & Technology Facilities Council

Nobel Prize

In 1964, Peter Higgs and others predicted the existence of an all-pervading field that gives mass to matter particles. Excitation of this field gives rise to the long searched for Higgs particle. In 2013 the Nobel Prize for Physics was awarded to Professor Peter Higgs and Professor François Englert for this theoretical discovery.



Professor Peter Higgs, University of Edinburgh

International collaboration

The LHC is at CERN, the European Laboratory for Particle Physics, in Geneva. Thousands of physicists and engineers from over 113 countries across the world work on various aspects of the project, both at CERN and in their home countries. The experiments require carefully planned cooperation between many multinational teams. Many components of the detectors were constructed in one country, then assembled and tested in another, before being sent to CERN. UK industry was involved in making many of the components and still contributes to on-going experiments and upgrades.

QUARKS

up	u	d	down
charm	c	s	strange
top	t	b	bottom

LEPTONS

electron	e	ν_e	electro neutrino
muon	μ	ν_μ	muon neutrino
tau	τ	ν_τ	tau neutrino

FORCE	ELECTRO MAGNETIC	STRONG	WEAK	GRAVITY
CARRIER	γ	g	W,Z	GRAVITON ?
ACTS ON	CHARGED PARTICLES	QUARKS GLUONS	QUARKS LEPTONS	ALL

The Standard Model

This is the best description of matter we have – although physicists know that it is incomplete. We know that there are two sets of six elementary matter particles called quarks and leptons, and three fundamental forces that are carried between the quarks and leptons by other particles called 'carriers': electromagnetism and the weak and strong nuclear forces. Gravity is a fourth force, thought to be carried by a particle called the graviton, but physicists do not understand how it fits in with the standard model. The LHC will help us find the missing pieces of the standard model, like the Higgs particle – the key to why some particles have mass.

What happened in the big bang?

QUARKS, GLUONS AND THE BEGINNING OF THE UNIVERSE

At the earliest moments of the Big Bang, the Universe consisted of a searingly hot soup of fundamental particles - quarks, leptons and the force carriers. As the Universe cooled to 1000 billion degrees, the quarks and gluons (carriers of the strong force) combined into composite particles like protons and neutrons. The LHC is able to collide heavy nuclei so that they release their constituent quarks, taking us back to the time before the protons and neutrons formed, and re-creating the conditions when quarks and gluons were free to mix without combining. The ALICE experiment studies the debris of these collisions to investigate this early state of matter.

Why do particles have mass?

MYSTERIOUS MASS

Particles of light (known as photons) have no mass. Fundamental particles (such as electrons and quarks) do – and we're not sure why. British physicist Peter Higgs proposed the existence of a field which pervades the entire Universe and interacts with these particles to give them mass. This field should reveal itself as a particle – the Higgs Particle. The discovery of a Higgs-like particle was announced on 4th July 2012 by the ATLAS and CMS teams.

Where's the antimatter?

MATTER AND ANTIMATTER

Every fundamental matter particle has an antimatter partner with equal but opposite properties such as electric charge (for example, the negative electron has a positive partner known as the positron). Antimatter was created, along with matter, in equal amounts in the Big Bang, but we see mostly matter in the Universe today - so what happened to the antimatter? Experiments have already shown that some particles decay at slightly different rates from their anti-particles, which could explain this. The LHCb experiment studies the subtle differences between matter and antimatter particles.

What's the Universe made of?

DARK MATTER, NEW PARTICLES AND SUPERSYMMETRY

The theory of 'supersymmetry' suggests that all known particles have, as yet undetected, 'superpartners'. If they exist, the LHC should find them. These 'supersymmetric' particles may help explain one mystery of the Universe – dark matter. Astronomers detect the gravitational effects of large amounts of matter that can't be seen. This dark matter is estimated to make up about 85% of the total matter in the Universe and we don't know what it is! One possible explanation of dark matter is that it consists of supersymmetric particles.

What kind of universe do we live in?

EXTRA DIMENSIONS AND MINI-BLACK HOLES

Gravity does not fit comfortably into the current descriptions of forces used by physicists. It is also very much weaker than the other forces. One explanation may be that extra unobserved dimensions exist in our Universe and that gravity can "leak out" across the dimensions, making it appear weaker. The LHC may enable us to observe some evidence of these extra dimensions – for example, the production of mini-black holes which exist for just a tiny fraction of a second.

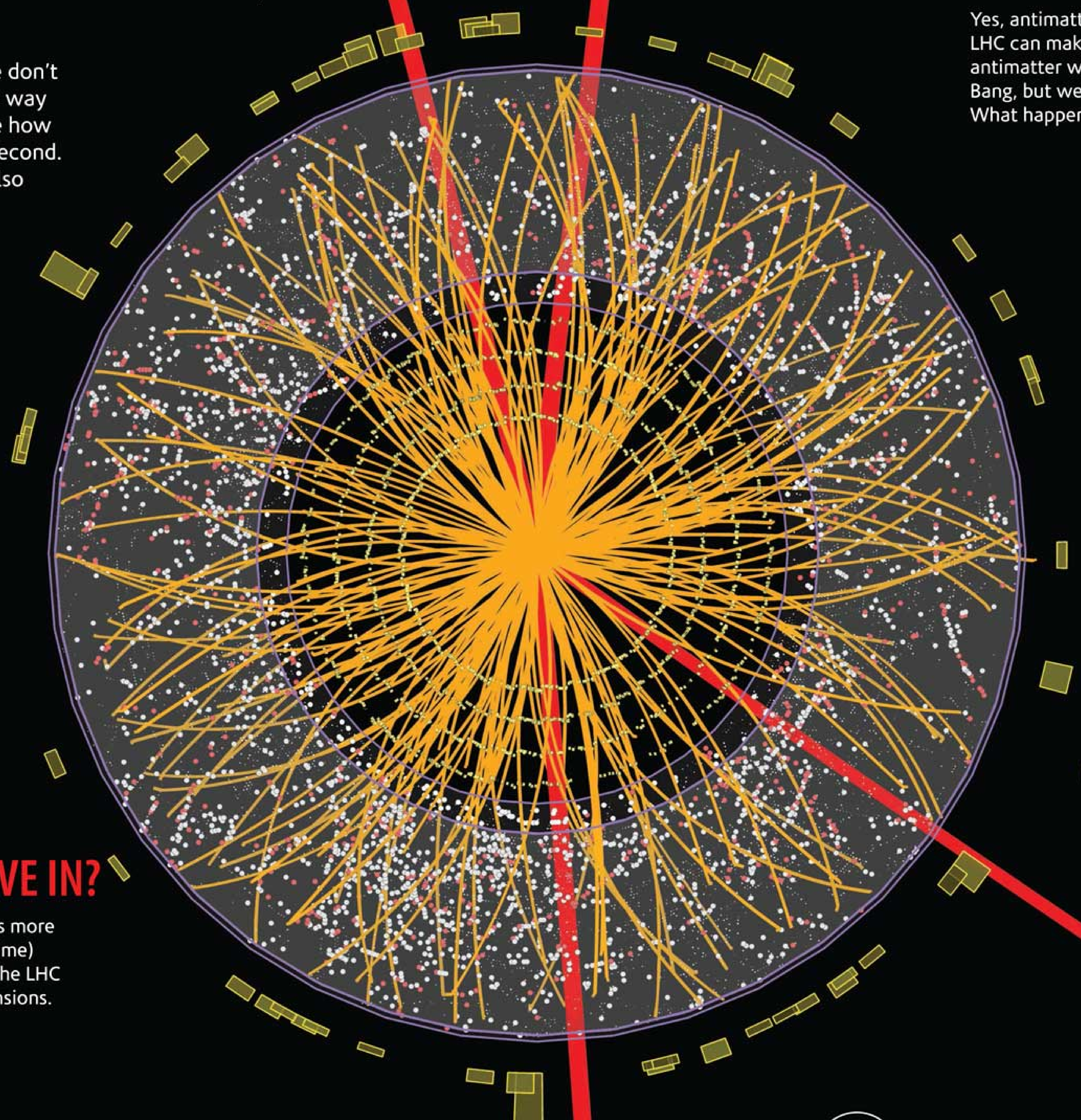
BIG QUESTIONS: BIG EXPERIMENT

THE LARGE HADRON COLLIDER, CERN

ATLAS EXPERIMENT
http://atlas.ch

Run: 204769
Event: 71902630
Date: 2012-06-10
Time: 13:24:31 CEST

The Universe started with a Big Bang – but we don't fully understand how or why it developed the way it did. The Large Hadron Collider allows us see how matter behaved in the first tiny fraction of a second. We have some idea of what to expect – but also expect the unexpected!



WHERE'S THE ANTIMATTER?

Yes, antimatter is real and the LHC can make it! Both matter and antimatter were created in the Big Bang, but we see mostly matter now. What happened to the antimatter?

WHAT HAPPENED IN THE BIG BANG?

What was the Universe made of before the matter we see around us formed? The LHC can recreate the conditions existing during the first billionth of a second after the big bang.

WHY DO PARTICLES HAVE MASS?

Why do some particles have mass while others don't? What makes this difference? The discovery of the Higgs Particle helps us understand this.

WHAT KIND OF UNIVERSE DO WE LIVE IN?

Many physicists think the Universe has more dimensions than the four (space and time) we are aware of. The experiments at the LHC are looking for evidence of new dimensions.

WHAT IS OUR UNIVERSE MADE OF?

96% of our Universe is missing. Some of it may be stuff that scientists call 'dark matter'. Can the LHC find it?

Real event display of a Higgs to 4 muon candidate event. This event was recorded by ATLAS on 10th June 2012. Muon tracks are coloured red

Science & Technology Facilities Council