The Little Book of the Big Bang: A Big Scientific Adventure

Everything you always wanted to know about the Large Hadron Collider but were afraid to ask

www.stfc.ac.uk
How did the universe get to be as it is, when it could all have been so very different?

Nature doesn’t just sit there. Nature DOES things. And that requires interactions, or forces, such as gravity and electromagnetism. We don’t understand a lot of what Nature does. So far, for example, there is no single and complete theory that can describe all of the forces (gravity, electricity and so on) together. When we have such a theory we will know Nature better. That is one aim of the Large Hadron Collider.

The Large Hadron Collider will change the way we think about the Universe.

A boring Universe smoothly, evenly, boringly the same everywhere.

An interesting Universe

A very interesting Universe, and the more closely we look at it the more interesting it gets.

True!

Most of your body is empty space - very roughly 99.999 999 999 999% nothing by volume. The REST is made of quarks and electrons.
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The LARGE HADRON COLLIDER is changing the way we think about the Universe.

TRUE!
The LARGE HADRON COLLIDER concentrates energy so much that it is as intense as it was one billionth of a second after the start of the Universe, in the BIG BANG.

Some people are so fascinated by the Universe that they’re creating a big scientific adventure called the LARGE HADRON COLLIDER.

It simulates the Universe almost at the beginning of time.
It accelerates beams of **hadrons**. Hadrons are particles made of quarks. Protons are one kind of hadron. Mostly the Large Hadron Collider will accelerate protons so that scientists can take a really close look at how Nature does things.

The Large Hadron Collider is at the CERN research centre near Geneva.
It accelerates beams of **hadrons**.

There are still very big questions about existing theory says that there were equal amounts of **matter** and **antimatter** at the Big Bang. But nobody knows why we live in a matter universe. The Large Hadron Collider will test some ideas.

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So that it can accelerate particles until they have very high energy.

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The next train to arrive will be... oh, too slow... you've missed it, and again, and again, and again, and again, and again, and again, and again, and again, and again, and again, and again, and again, and again.

The tunnel that holds the Large Hadron Collider is about as long as the Circle Line on the London Underground. A proton takes about 0.1 milliseconds for one circuit of the tunnel. (Not an ordinary rush hour experience.)

Many hospitals have their own small accelerators for producing beams of particles for radiation therapy.

The vacuum inside the LARGE HADRON COLLIDER is as empty as outer space. Creating the vacuum is equivalent to pumping all of the air out of a cathedral.

**True!**

Particle accelerators are also used for drying the ink on soft drinks cans.
There are still very big questions about **STUFF**

**WHY** is the world made of **matter** and not antimatter?

Nobody knows. BUT the LARGE HADRON COLLIDER will put some ideas to the test.

Existing theory says that there were equal amounts of **MATTER** and **ANTIMATTER** at the **BIG BANG**. But nobody knows why we live in a **MATTER** Universe. The LARGE HADRON COLLIDER will test some ideas.

I am matter. YOU are antimatter

It’s hard to tell what’s matter and what’s antimatter until they meet. Then they annihilate each other, with a bang.

**DO WE** LIVE IN A WYSIWYG UNIVERSE?

Tasty to look at... but if I get the wrong one I’m down to my last 8

We are conscious of space & time, a total of four dimensions. But there could be **EXTRA DIMENSIONS** that we can’t see directly. Maybe the LARGE HADRON COLLIDER will tell us if they exist.
There's a lot of STUFF out there that exerts gravitational pushes and pulls on other STUFF. But it's invisible and NOBODY KNOWS WHAT IT IS. So it gets to be called DARK MATTER. The LARGE HADRON COLLIDER will test predictions about the possible nature of dark matter.

Matter, aka STUFF

It takes up space. It can store energy. It affects other matter by means of forces.

If all of nature's forces are just different versions of a single type of interaction then it's likely that for every kind of particle there is a 'SUPERSYMMETRIC' or SUSY partner.

Maybe 'dark matter' is made of SUSY particles. If SUSY particles do exist then the Large Hadron Collider should find them. That might be one mystery solved.
Try it and see. That’s something that science does. It uses ideas to develop predictions about expected observations.

Then it sets up experiments to test the ideas.

Try 2

Any scientific theory has to stand ready to be questioned and tested. That’s what makes scientific theory so strong. Only the best can survive test after test.

A lot of new ideas have to be thrown out because they do not produce good predictions. But some survive repeated testing.

The Large Hadron Collider is set up to test ideas. It is based at CERN – the world’s largest laboratory dedicated to fundamental science.

TRUE!
The flexings of the Earth’s crust due to the Moon’s gravity and to the weight of snow on nearby mountains is detectable at CERN’s particle accelerator tunnels.
Hi

Forces

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SEE

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A MASSIVE problem required a BIG PREDICTION

The best ideas about matter, so far, have all had a big failing. They did not predict the existence of MASS as we know it.

So in the 1960s there was an extra IDEA that MASS happens because of the action of a particle that had not yet been detected.

British scientist Peter Higgs had the IDEA and the predicted HIGGS particle was named after him.

To test the PREDICTION that scientists used the LARGE HADRON COLLIDER and in July they found a Higgs-like particle.

Further LHC experiments continue to take place aimed at making certain that the particle is a HIGGS.

MASS seems to be a pretty basic feature of matter.

Or to put it another way, why isn’t everything as insubstantial as light?

Why isn’t there stuff at all?
Alison Bates
Alison, from the University of Glasgow, has spent the last few years based at CERN helping to build the LHCb detector. “LHCb will be looking at the differences between matter and antimatter. It is one of the smaller experiments at the LHC, but certainly not the least exciting. I have really enjoyed the experience of being at CERN and being involved with the LHC, and it has definitely improved my skiing!”

Time
There are still very big questions about

Lyn Evans
Lyn, from Aberdare in Wales, has worked on accelerators at CERN for over 30 years and was the LHC project leader before more recently being appointed to lead the international effort to design the world’s next major particle collider. Lyn is the Linear Collider Director and will lead the Linear Collider organization created to bring two existing large-scale linear collider programs under one governance and build on the work of the LHC.

Scientists explore the fundamental nature of the Universe BECAUSE IT’S THERE and because it makes a COOL JOB

Like astronomers, scientists at CERN are looking for understanding, rather than new technologies. But because their work is so new they develop new skills and technologies nobody ever needed before. That’s how the WORLD WIDE WEB began. It began at CERN.

Who knows what new skills and expertise will emerge in the future.

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Dave joined CERN after completing a PhD at Imperial College, London in 1994. Since then he has worked on the CMS experiment where he is director of outreach CMS. “I’m also the co-ordinator for public outreach. I’m married to Jane and have two young children – Stephanie and Robert. I enjoy playing football (with a local French veterans team!) and skiing.”

Lily Asquith is a physics postdoctoral student at Argonne National Laboratory in Chicago. She works on data from the ATLAS particle detector at CERN’s Large Hadron Collider. She has been actively involved in the search for the Higgs particle. “I love what I’m doing – looking for fundamental truths – and I get to plan my own work and travel all over the place!”
The Large Hadron Collider is a Global Thing.

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People working at CERN come from 98 different countries. People working at CERN come from Portugal to Pakistan, India to Ireland, Morocco to Monaco, Britain to Brazil, Austria to Australia, Portugal, India, Morocco, Britain, Austria, and so on.

The work of CERN is all about international cooperation, not international confrontation.

Every aspect of CERN is international. Countries share the costs, and the benefits.

TRUE!

Every aspect of CERN is international. Firefighters at CERN come from Bulgaria, The Czech Republic, Finland, France, Germany, The Netherlands, Italy, Spain and the UK.
People working at CERN come from 98 different countries.

CERN has a huge global impact.
- It involves a lot of people.
- It develops new technology (like the WORLD WIDE WEB).
- It changes the way we think.
- But it only costs the same to run as one large hospital.

CERN and the LARGE HADRON COLLIDER

CERN began work in 1954, bringing countries of Europe together after the horrors of World War II. Since then, people from 151 different countries have worked there at one time or another.

CERN has a huge global impact.

As well as the WORLD WIDE WEB, X-ray and radiopharmaceutical techniques in medical imaging were developed by particle physicists.
In the early days...

In the 1960s scientists at CERN sent tapes of experimental data to their computer centre by BICYCLE.

NEW improved file transfer speeds (now has 3 gears!)

CERN scientists developed the WORLD WIDE WEB so that they could communicate with each other, all over the world.

In the 1960s scientists at CERN sent tapes of experimental data to their computer centre by BICYCLE.

Later...

CERN scientists developed the WORLD WIDE WEB so that they could communicate with each other, all over the world.

TRUE!

British industry is involved in state-of-the-art technologies – making precision electronic, magnetic and vacuum components for the LHC.

...later...

... but because they are CLEVER, DETERMINED and FUNDED by their governments they are able to generate NEW TECHNOLOGIES.

Working out what's happening in the Large Hadron Collider's huge detecting systems will need a LOT of computer activity.

So scientists have developed THE GRID – a global network of computers becoming one huge interconnected machine.

British taxpayers each contribute the cost of a couple of loaves of bread each year to this world-leading project.

It's a by-product of scientists' searches for understanding of nature ...
... now, and for the future

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... BUT BECAUSE THEY ARE CLEVER, DETERMINED AND FUNDED BY THEIR GOVERNMENTS THEY ARE ABLE TO GENERATE NEW TECHNOLOGIES.
If you would like to know more about the LHC and the science behind it, try the following resources:

**WORLD WIDE WEBSITES**

www.cern.ch  
www.collidingparticles.com  
www.oxfordspark.net/animations/lhc

**TWITTER**

@CERN  
@ATLASexperiment  
@CMSexperiment  
@LHCbExperiment  
@ALICEexperiment

**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 Physics of 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

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 Science in Society 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 Publications and resource guides suitable for teaching ages 7-18.

* Funding schemes for projects and school visits.

* A Moon rock and meteorite loan scheme.

* Visits to STFC’s UK laboratories in Cheshire, Oxfordshire and Edinburgh plus CERN in Geneva.

Go to www.stfc.ac.uk/teachers

**FOR SCIENTISTS**

* Funding schemes and Fellowships for public engagement.

* Communication and media training courses.

Go to www.stfc.ac.uk/pefunding

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

**CREDITS**

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