

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



Science & Technology
Facilities Council

**HOW
DID THE
UNIVERSE
GET TO BE
AS IT IS,**
when it could
all have
been so very
different?



Dear Everybody,
Nothing much
ever happens
here. x Dr H

POST CARD
Everybody
The Earth
The Solar System
The Milky Way
The Universe

A **BORING** Universe
smoothly, evenly, boringly
the same EVERYWHERE



POST CA
Dear Everybody,
The stars are
pretty but it's
a bit lonely.
x Dr H

Greetings
from the Universe

An **INTERESTING** Universe



POST C
Wow! You
should see
this place.
x Dr H

Greetings
from the 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.

**NATURE
DOES THINGS...**

TADAAA!

Nature doesn't just sit there. Nature **DOES** things. And that requires 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.

Doctor
Ron Head

TRUE!

The **LARGE HADRON COLLIDER** will concentrate energy so much that it will be 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 will simulate the Universe almost at the beginning of time.

THE LARGE HADRON COLLIDER...



LARGE
It's so that it can accelerate particles until they have very high energy.

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.

It makes the hadrons
COLLIDE.

The Large Hadron Collider is at the CERN research centre near Geneva.



Geneva



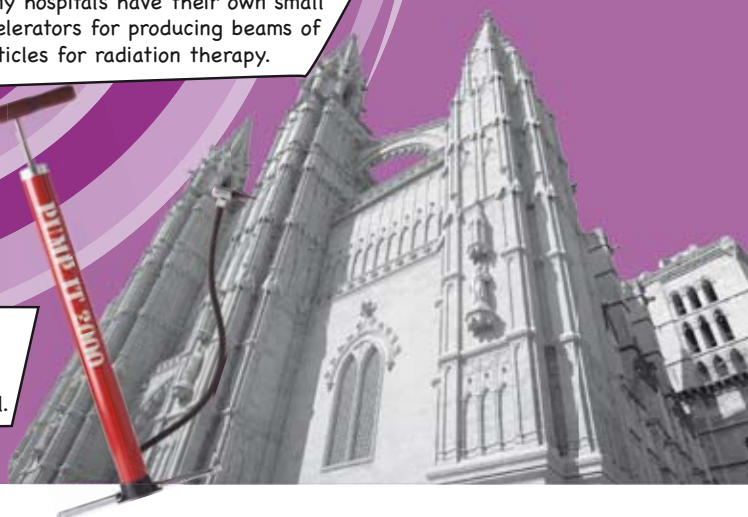
"The next train to arrive will
be ...oh, too slow...you've
missed it, and again, and
again, and again, and again,
and again, and again, and
again, and again, and again, and
again, and again, and again, and

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.

Particle accelerators are also used for drying the ink on soft drinks cans.

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.



TIME, SPACE, ENERGY, FORCES AND STUFF

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



**BUT HOW
BIG IS IT?**

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.



WHAT is dark energy?

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

It takes up

It can store

It affects other matter by means of

STUFF SPACE ENERGY FORCES

Super!

AND symmetric!

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.

I'm in heaven!

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

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.

Experiment No.6

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.

2. Jill tries to catch donkey in a coffee cup
«sigh»
another slow day at the lab

FAILED!

A MASSIVE PROBLEM REQUIRES A BIG PREDICTION

WHY is there stuff at all?

MASS seems to be a pretty basic feature of matter.

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

The best ideas about matter, so far, have a big failing. They don't predict the existence of MASS as we know it.

So there is an extra IDEA that MASS happens because of the action of a particle that hasn't been detected yet.

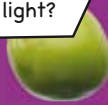
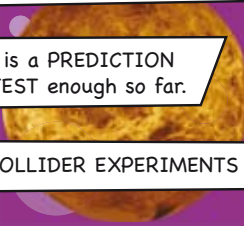
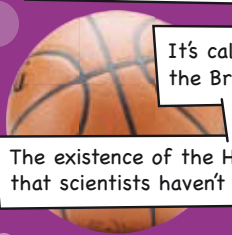
It's called the HIGGS particle after Peter Higgs, the British scientist who had the idea.

The existence of the HIGGS particle is a PREDICTION that scientists haven't been able to TEST enough so far.

But the LARGE HADRON COLLIDER EXPERIMENTS will provide new tests.



Hi



THE LARGE HADRON COLLIDER IS A PEOPLE THING



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.



LYN EVANS

Lyn, from Aberdare in Wales, has worked on accelerators at CERN for over 30 years and has been the project leader for the Large Hadron Collider since it was first planned in 1983. He is responsible for co-ordinating the efforts of 2500 scientists and engineers and a £1 billion budget.



DAVE BARNEY

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."

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!"



LILY ASQUITH

Lily is a PhD student at University College London about to move to CERN for 6 months to work on the ATLAS Detector. She is one of many people who will be looking for the Higgs particle.

"I'm a single mother with one kid, Jessie, who is 8. 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



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

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.

TRUE!

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

wow
wow
wow
wow



FROM THE BIKE

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!)

... 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



I go faster than that

TO THE WEB

... now, and for the future

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

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

TRUE!

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 ...

... BUT BECAUSE THEY ARE CLEVER, DETERMINED AND FUNDED BY THEIR GOVERNMENTS THEY ARE ABLE TO GENERATE NEW TECHNOLOGIES.

TO THE GRID



FURTHER INFORMATION

If you would like to know more about the LHC and the science behind it, try the following resources:

WORLD WIDE WEB SITES

www.lhc.ac.uk

www.cern.ch

www.particlephysics.ac.uk

www.stfc.ac.uk/SciProg/PP/Projects/LHC.aspx

www.schoolscience.co.uk

Books

The New Cosmic Onion:

Quarks and the Nature of the Universe

Frank Close CRC Press, 2006

The Particle Garden:

Our Universe as Understood by Particle Physicists

Gordon Kane Addison-Wesley, 1996

The Particle Odyssey

Frank Close, Michael Marten and Christine Sutton

Oxford University Press, 2002

The Quark Machines:

How Europe Fought the Particle Physics War

Gordon Fraser Institute of Physics Publishing, 1997

Quarks, Leptons and the Big Bang

Jonathan Allday Institute of Physics Publishing, 2001

CREDITS

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