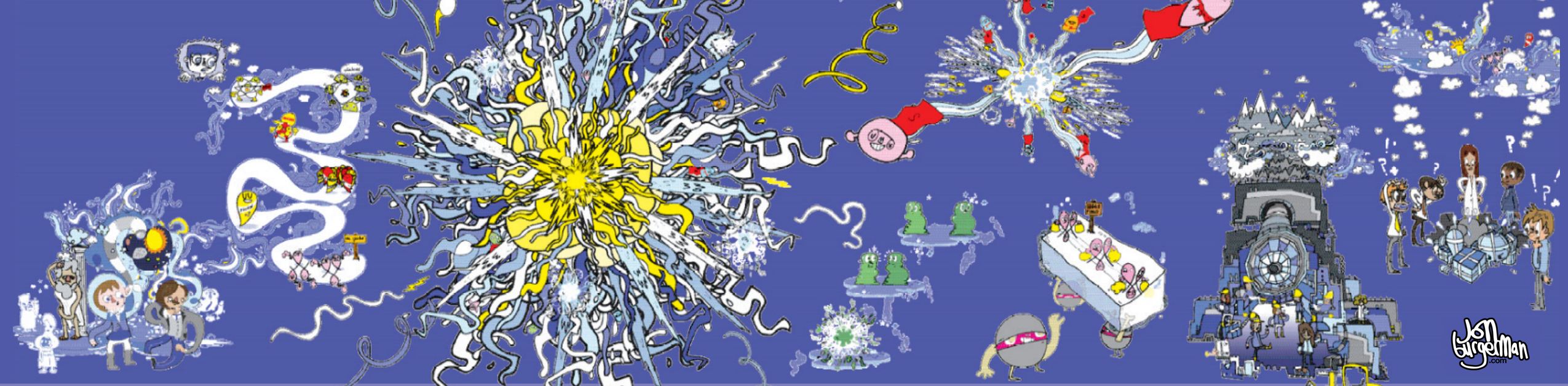


Questions, questions, questions...

Throughout history, curiosity has been a driving force for humans. We constantly ask how and why things are the way they are. How did the Big Bang give birth to our universe? There are still many unanswered questions.

To explain the unknown, scientists must push the boundaries of what they understand. And to do this they start with ideas.

What makes up our world?

To understand the biggest thing, the universe, it helps to look at the smallest things. Scientists discovered that all the stuff around us is made up of atoms.

By delving inside the atom, they found the nucleus, and inside the nucleus protons and neutrons. When they looked closer they found that protons and neutrons are made up of quarks, particles that scientists think are some of nature's smallest building blocks.

But how do these smallest particles shape our world?

How did the universe begin?

Over 13 billion years ago the Big Bang gave birth to the universe creating space, time, energy and matter.

To understand the laws of our universe now, scientists must work out how particles behaved at its high-energy beginning. They imagine what the universe was like then, but base their ideas on how our world behaves today.

Now, to test their theories, they've built a machine to recreate the conditions of our universe just after the Big Bang began.

What are the big questions?

There are lots of things that scientists are yet to discover about our universe.

Why are we here?

What is our universe made of?

Why does anything have mass?

To solve these fundamental questions, scientists have imagined possible answers and have built the biggest ever particle physics experiment to put their ideas to the test.

Where did the antimatter go?

Why are we here? It's all down to matter and antimatter. During the Big Bang matter and antimatter were created equally... but everything we can find today is made of only matter.

When matter and antimatter meet they destroy each other, turning into energy. If you met your anti-you, you would both annihilate, releasing a huge burst of energy. But luckily you're still here because there's no antimatter in our world.

So where did it go?

What's missing in our universe?

Scientists can only see 5% of the stuff that makes up the mass of our universe. They call the rest dark matter and dark energy. Scientists know something about how these 'missing' bits behave but they don't know what they are actually made of.

One idea involves new types of particles that are heavier versions of existing particles. Some scientists think they can create these 'supersymmetric' particles – 'sparticles' – at very high energies.

Do sparticles make up the missing matter?

What gives things mass?

How and why do particles get mass?

Scientists think it's down to the Higgs field. This field acts like invisible treacle spread throughout the universe, but instead of slowing particles down it gives them mass. Some particles 'feel' this field more than others, and get more mass. Experts predict that the Higgs field is carried by a particle called the Higgs boson.

The hunt for Higgs is on...

How do you test an idea?

To find the answers to the big questions, engineers and scientists have built the biggest ever underground experiment – the Large Hadron Collider. It will smash particles together to produce the highest ever controlled energy on Earth.

Scientists hope this incredible machine will enable them to find out if their ideas about the universe are correct.

Where next?

Scientists are standing at a new frontier for physics. But one of the most exciting things about the Large Hadron Collider is that it might find totally unexpected stuff.

Armed with new evidence, the scientists would dream up new theories to test. It is this cycle of thinking and testing that powers our quest to understand nature.

The theories are ready, now it's time to start testing.

3

Universal answers – and amazing advances

Scientists need to understand why and how the very smallest particles behave to answer some of the very big questions about our universe. And the Large Hadron Collider (LHC) will **help them find those answers**.

But that's not all the LHC will do. The experiment is **pushing technology to its limits**, which should lead to advances in many areas. For instance, the LHC needs fabulously fast computers that can track the particles as they travel through the detectors.

This is a challenge equivalent to reading 10,000 copies of *Encyclopaedia Britannica* a second...

Processing prowess

Not all collisions will create something interesting, so the LHC's **computers have to choose the most promising ones** for scientists to examine. Of the billions that will occur, only a few hundred per second will be saved.

The LHC needs so much computing power that its IT experts are using the Grid – an international network that allows computers to reach out and 'borrow' spare processing power from all over the world.

Dizzying data
One year's particle-collision information would fill a stack of CDs 20 km high – and that's just the stuff the computer decides is 'interesting' enough to keep. This tower represents just an hour's worth of data, so scientists use high-capacity tapes for storage instead.
Source: London Recycling Ltd Inv. No. E2007.69.1

computing
video

Asking three big questions

So what are the big questions that scientists are looking to answer?

- What is the unexplained matter and energy that makes up **95% of our universe**?
- Why didn't matter and antimatter **destroy each other** at the beginning of our universe?
- Why do some things have mass and others don't?

The LHC should help us get some answers.

CIP

Answering lots more questions

The LHC should help scientists answer lots of questions – **even ones they haven't thought of yet**. As they put their theories to the test, they should be able to fill in some gaps in their ideas.

To find out why some things have mass scientists are hunting for something called the Higgs particle.

'Searching for Higgs will be equivalent to looking for one needle in 20 million haystacks.'

Tara Shears, a physicist working on the LHCb detector

Pushing technology to its limits

Scientists have built the collider to test their theories – and hopefully find new questions to inspire future thinking.

But we'll get even more out of the collider. The LHC is pushing technology to its limits and beyond, **giving us new knowledge** about magnets and cryogenics.

'In a project like the LHC, technological spin-offs are likely. Personally I just work for the pleasure of knowledge.'

Gian Giudice, a theoretical physicist working on the LHC

Hunt Higgs
Game

2

Back to the Big Bang

The Large Hadron Collider (LHC) will let scientists really have a smashing time. Tiny particles will be **zipping round the ring** at nearly the speed of light.

Each time a pair of particles collide, a cascade of **different particles** will be created, shooting off in all directions. To track them, the scientists have to use super-speedy hi-tech detectors.

When the particles smash together they will have seven times more energy than in any previous experiment.

This is the key to finding out what happened in the instant after the Big Bang...

When beams collide...

Imagine the energy of a speeding train, packed into a narrow beam of particles. When two of these beams cross inside the LHC, they'll produce tiny bursts of **extremely high energy**.

'These high-energy collisions will replicate the conditions that occurred in the moments after the Big Bang, about 14 billion years ago.'

Patrick Koppenburg, a physicist working on the LHCb detector

This is the first time scientists have created such high-energy collisions. But don't worry, experts are sure the Earth won't explode.

'The "explosion" will be confined to a minuscule amount of space, and only last for a tiny instant in time.'

David Evans, a physicist working on the ALICE detector

Particle burst

Not all the particles travelling towards each other will collide. But when two particles do meet head on the results are amazing – scientists go so far as to call it an 'event'.

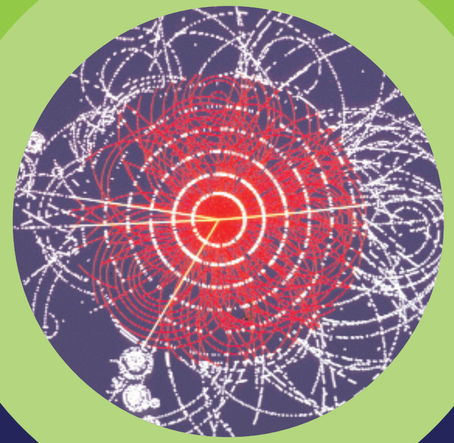
Each event produces a burst of different particles that shoot off in all directions. And with **600 million collisions a second** there's an awful lot to keep tabs on – but scientists have top-of-the-range detectors to record it all.

Dedicated detectors

Four huge detectors – ALICE, ATLAS, CMS and LHCb – are positioned around the ring at the collision sites. The **detectors have several layers**, each on the hunt for a different bit of information. As each newly produced particle darts through the detector it will be recognised and logged.

'Only some particles can be detected directly – others will quickly disappear, so the detectors have to spot the trail that's left behind.'

Dave Barney, a physicist working on the CMS detector



Capturing collisions
Each time the particle beams smash together this is what happens. The red line that is a particle shooting out from the point of impact. Scientists decide the pattern to figure out whether it's hiding the secrets of the universe.

Image: CERN

World's most massive onion
Here you can see the huge structure of CMS, one of the massive particle physics hunting experiments. It's built like an onion; each layer is packed with hi-tech detectors looking for a different bit of information about the particle collisions.

Image: CERN

Big Bang Video

CIP

1

The world's largest physics experiment...

Engineers have built one of the **biggest, fastest, coldest** experiments on Earth. At four locations inside a 27 km ring, scientists will **smash particles together** to try and answer some fundamental questions about our universe.

These collisions need to be very high energy if the scientists are to find what they are looking for – which means that the particles need to be travelling at almost the speed of light, whizzing round the ring **11,000 times** a second.

The inside of the ring also has to be the coldest, emptiest place in the universe...

Hidden from view
The red line shows where the LHC is buried, 100 metres beneath the quiet countryside of France and Switzerland. The huge circular tunnel is about the same length as London Underground's Circle line.
Image: CERN

Inspiring experiment

The Large Hadron Collider (LHC) will smash particles together at **almost the speed of light**. It is one of science's most awe-inspiring projects.

The LHC has been built at CERN, the European particle physics laboratory. Thousands of scientists, engineers and technicians from over 50 countries have spent 10 years and €3 billion building it, including a strong team from the UK.

'The UK is involved in all the experiments at the LHC, so whenever discoveries are made British physicists will be there.'

Helen Heath, a physicist working on the LHC

CIP

A smashing time

Within a 27 km ring-shaped tunnel, two beams of particles will whizz round at incredibly high speed in opposite directions. Then in four **colossal caverns** – some as big as a five-storey building – scientists cross the beams, smashing particles together head on.

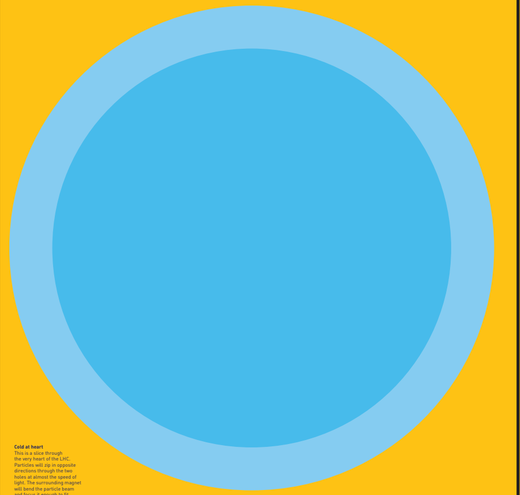
Each collision creates a cascade of different particles. But all the particles are far too small to be seen, so scientists will use hi-tech detectors to capture the tell-tale tracks they leave behind.

Super-cool magnets

The LHC uses over a thousand special magnets – chilled to a temperature **even colder than outer space** – to create a powerful magnetic field that curves the particles around the tunnel.

Scientists need to control which particles are colliding inside the ring. So they suck everything out of the tube, creating a vacuum, and then add only the particles they want. There are so few particles left inside the ring that it is the **emptiest place in the universe**.

Cathedrals of science
The LHC will smash particles together inside massive detectors. ATLAS is the biggest – Westminster Abbey could fit inside its underground chamber. Check out the size of the detector compared to the man standing in the foreground.
Image: CERN



Cold at heart
This is a section through the beam pipe of the LHC. Particles will zip in opposite directions through the two holes at almost the speed of light. The surrounding magnet will bend the particle beam and keep it enough to fit comfortably here as a 20 pence coin.

Source: CERN
Inv. No: LSDG7-4012

Particle-packed pencil
Everything in the universe is made from particles and they're incredibly small. The proton – one of the particles used in the LHC – is normally found inside atoms. It took roughly 0.05 g of pencil graphite to create this drawing – a tiny amount of graphite, but it contains an astounding 15,000,000,000,000,000,000,000 protons!

Source: Science Museum
Inv. No: E2007.70.1

scientists can now explore their BIG BANG dreams...

BIG BANG!

Particle proof

Deep underground, scientists have built a huge experiment to study the **smallest particles** that exist – to help them answer some of the **biggest questions** about our universe.

Scientists have spent over 10 years developing their latest theories about how the universe works. But until now they haven't had a powerful enough experiment to test their ideas.

All this will change with the Large Hadron Collider. The huge amounts of energy this can produce will recreate the conditions that occurred less than a billionth of a second after the Big Bang.

The Science Museum finds out how this super-cool, high-energy experiment will help us understand how our universe works...

This exhibition is supported by

Science & Technology Facilities Council