The largest experiment in the world

A 27km circular tunnel in Switzerland called the Large Hadron Collider (LHC) accelerates subatomic particles at close to the speed of light, before smashing them together at incredible force. The collider belongs to the European Organisation for Nuclear Research (Cern) and scientists all over the world use it to conduct experiments to uncover what the universe is made of and how it works. Lucas Tan, who visited the facility, explains Cern's inner workings.

What is Cern?

It is one of the world's leading centres for particle physics research. It has facilities such as the Large Hadron Collider and the Antimatter Factory, which scientists from all over the world use to conduct experiments.

Scientific goals

- Complete the Standard Model, currently the best theory explaining the nature of the universe.
- Solve what dark matter and dark energy consist of. Together, these make up 95 per cent of the universe.
- Determine how matter obtains its mass.
- Discover the mechanism behind gravitational force.
- Investigate the properties of antimatter — matter's counterpart which appears to be identical to matter except for an opposite electric charge — and explain why the universe is dominated by matter rather than antimatter.

Major achievements

The World Wide Web was invented at Cern by British scientist Tim Berners-Lee in 1989.

Modern medical technologies

- Synchrotron light sources, which power medical imaging.
- Accelerator technologies, whose applications are used in cancer radiotherapy.

Most of the discoveries of elementary particles in the Standard Model

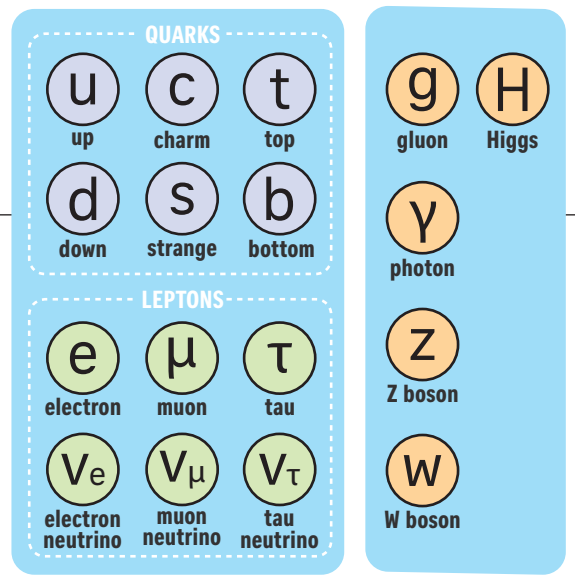
- Notably the discovery of the Higgs boson in 2012, the long sought-after particle responsible for the origin of mass.

What is the Standard Model?

The Standard Model is a theory that aims to classify all elementary particles of matter and describe all forces completely. Elementary particles are indivisible subatomic particles that are not composed of other particles. There are two types of elementary particles described in the Standard Model: bosons and fermions.

Fermions

- Classified into quarks and leptons, these make up atoms and are involved in subatomic reactions.
- **Quarks** are bound together by the strong force to form protons and neutrons in the nucleus of an atom.
- **Leptons** consist mostly of light particles, including the electron. They are not affected by the strong force, and are mainly involved in nuclear reactions.



Bosons

These are force carrying particles, with each particle being associated with one of the four types of forces:

- Electromagnetic force carried by the photon.
- Strong force carried by the gluon.
- Weak force carried by the W and Z bosons.
- Gravitational force carried by the graviton, which has not been discovered yet.
- The Higgs boson is a special boson that provides matter with mass.

CERN'S GIANT LABORATORY

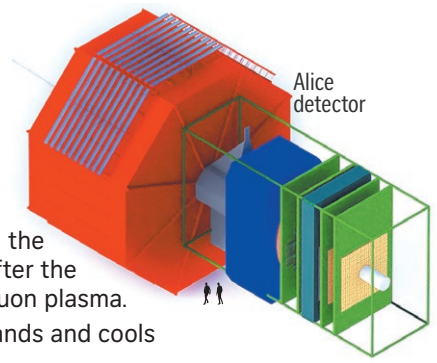
What's happening in the LHC?

Cern is best known for its experiments involving proton-proton collisions.

- Beams of protons are first accelerated through a series of accelerators, before they are injected as two opposing beams into the LHC.
- The collider has more than **1,500 magnets**, which focus and steer the beam along its **27km tunnel**.
- Meanwhile, electric fields generated from charged plates accelerate the beam close to the **speed of light**.
- The collisions occur at **four sites**, and can create new particles which are analysed by the particle detectors.

Alice

- A Large Ion Collider Experiment (Alice) is a detector designed to study a new state of matter, quark-gluon plasma, theorised to exist just after the Big Bang, an event that is believed to be the start of the universe.
- Collisions in the LHC can generate temperatures up to 100,000 times hotter than the core of the sun, similar to conditions shortly after the Big Bang, allowing for the creation of quark-gluon plasma.
- Scientists are studying how the plasma expands and cools to give rise to the particles today.



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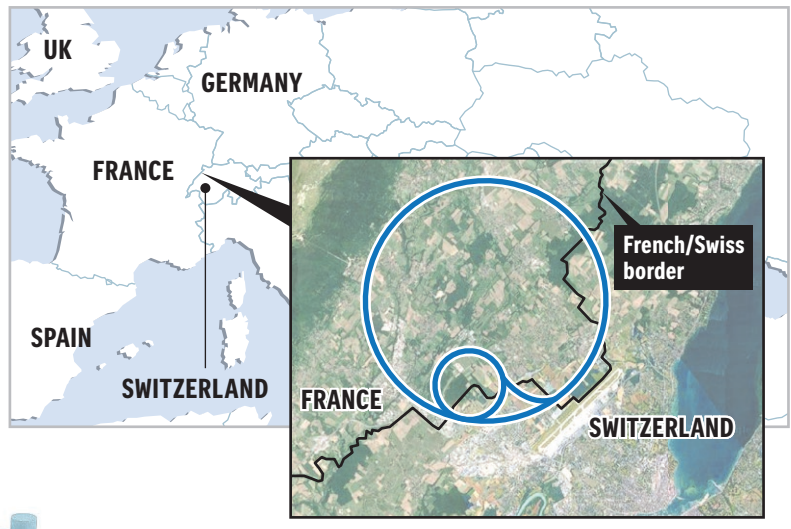
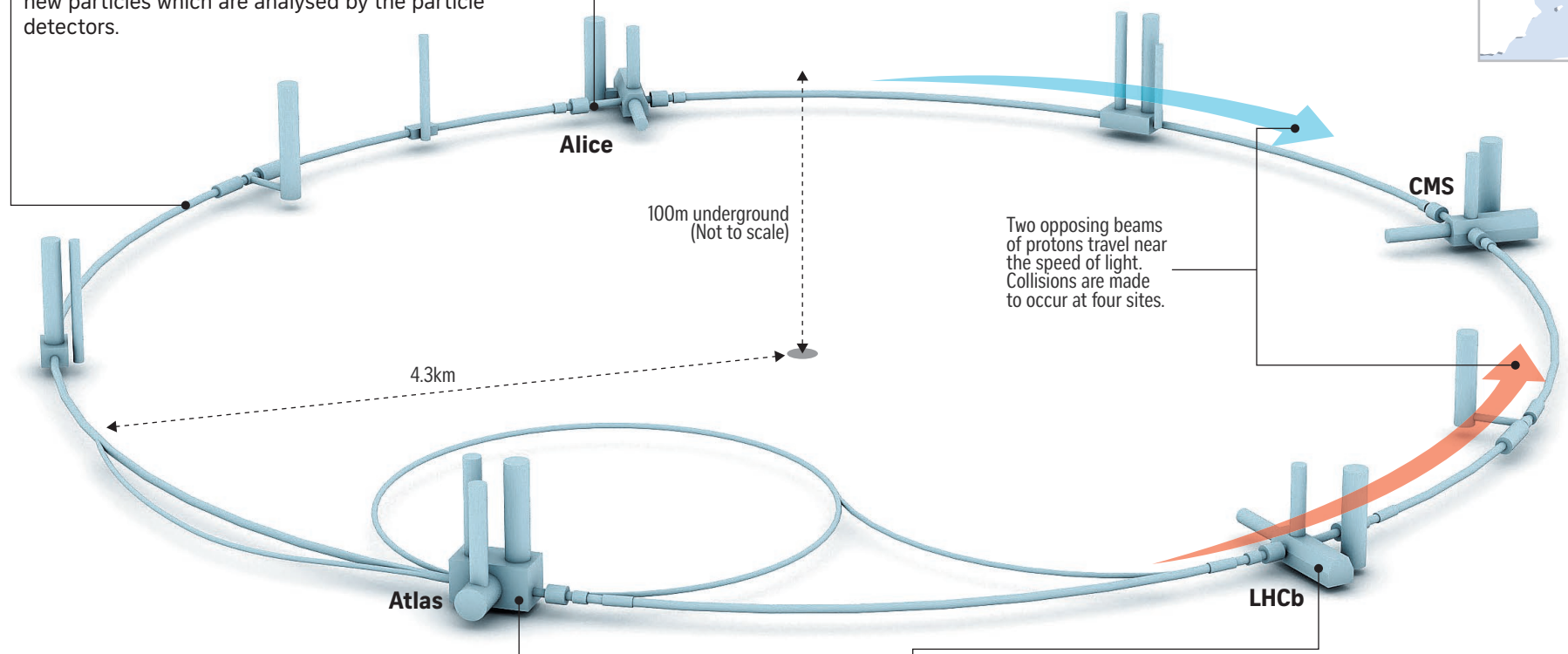
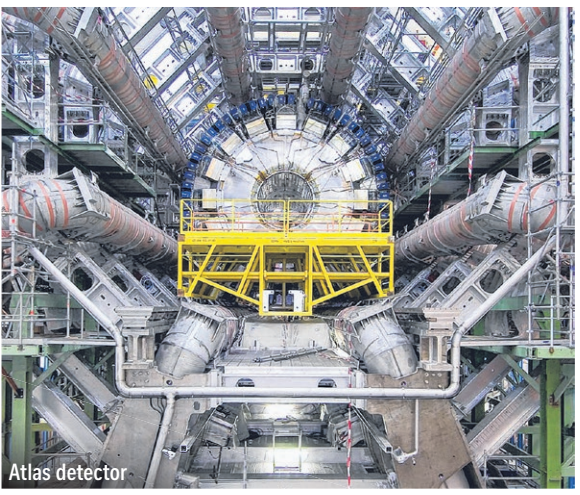




Antimatter Factory

- The Antimatter Factory is connected to the LHC, but utilises the LHC uniquely.
- It houses the Antiproton Decelerator, which decelerates antiprotons created in the LHC.
- In the factory, antiprotons are used to investigate the properties of antimatter. For example, the Gravitational Behaviour of Antimatter at Rest (GBAR) experiment studies the behaviour of antimatter during free fall to determine if it differs from ordinary matter.

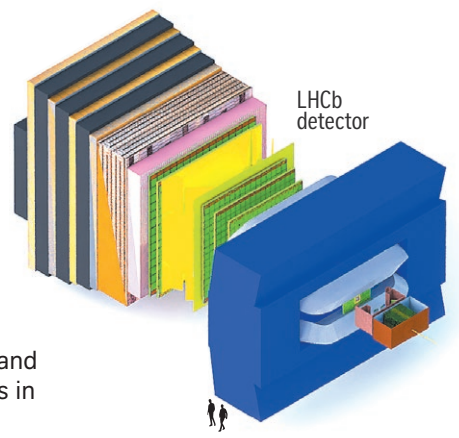

Atlas detector

Atlas and CMS

- The A Toroidal LHC Apparatus (Atlas) and the Compact Muon Solenoid (CMS) are the two biggest detectors in the LHC.
- They are "general purpose" detectors, whose main jobs are to hunt for new particles created in the collisions and investigate new physics, including finding extra dimensions.
- The two detectors allow scientists to independently verify theories with separate experiments.

LHCb experiment

- The Large Hadron Collider beauty experiment (LHCb experiment) is a detector that analyses decay processes involving bottom quarks.
- The experiments here are helping scientists determine the differences between antimatter and matter, and find flaws in the Standard Model.



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