

THE SEARCH FOR DARK MATTER

Proton collisions within the LHC might have enough energy to create dark matter. Although they won't be able to see them directly, scientists might be able to get some clues about the properties of this mysterious, invisible substance

1 When protons are collided in the LHC, the energy released is converted into new particles

At the heart of this is Einstein's famous equation $E=mc^2$. This states that mass and energy are equivalent to each other. It is the energy released by a proton collision that allows new particles to form.

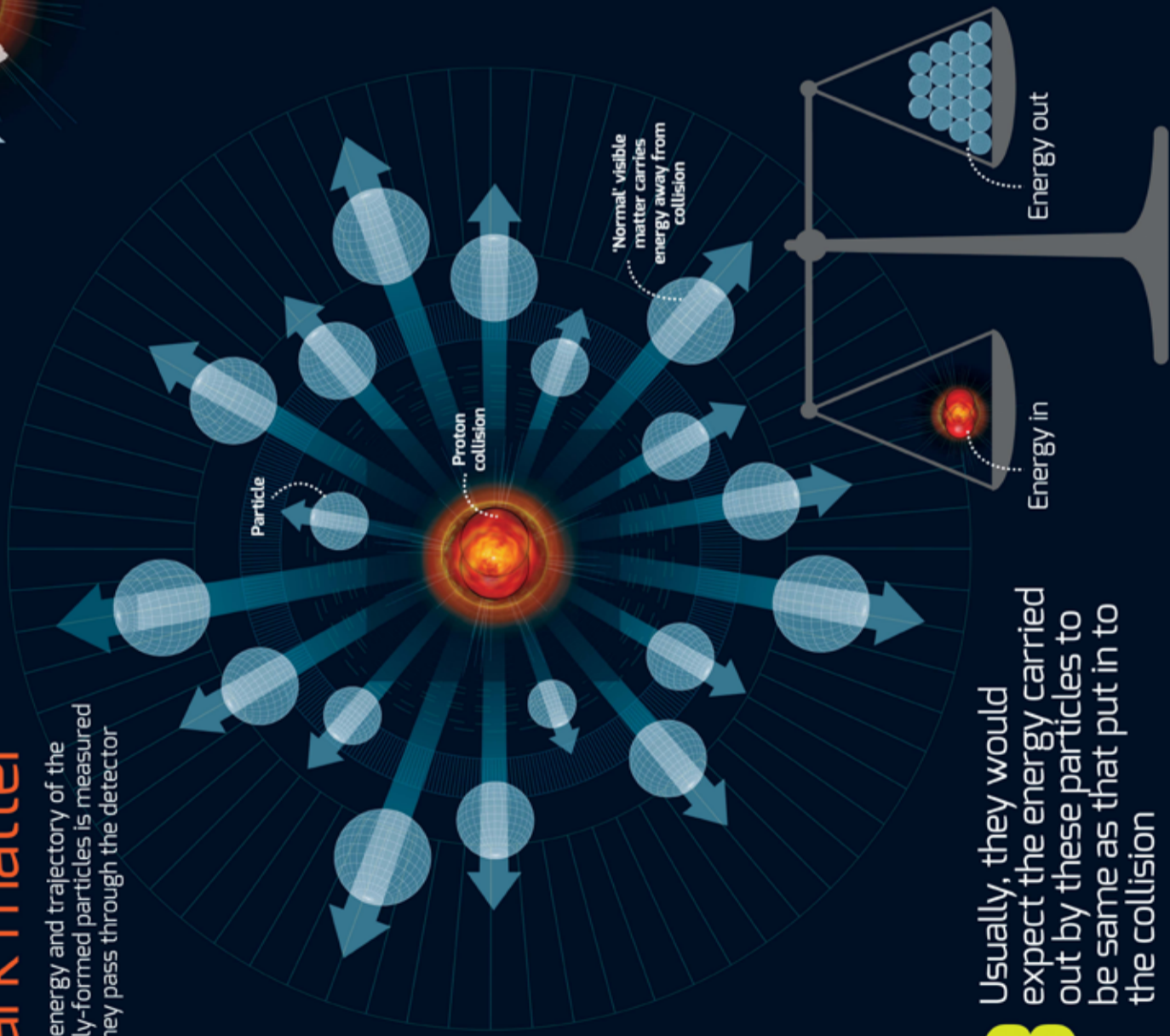
Energy is transformed into mass in the form of new particles. Because the LHC will collide protons with more energy than ever before, the particles created will have more mass than ever before

2

Because they know how much energy they have put into the protons, scientists know how much energy the collision will release

Collision without dark matter

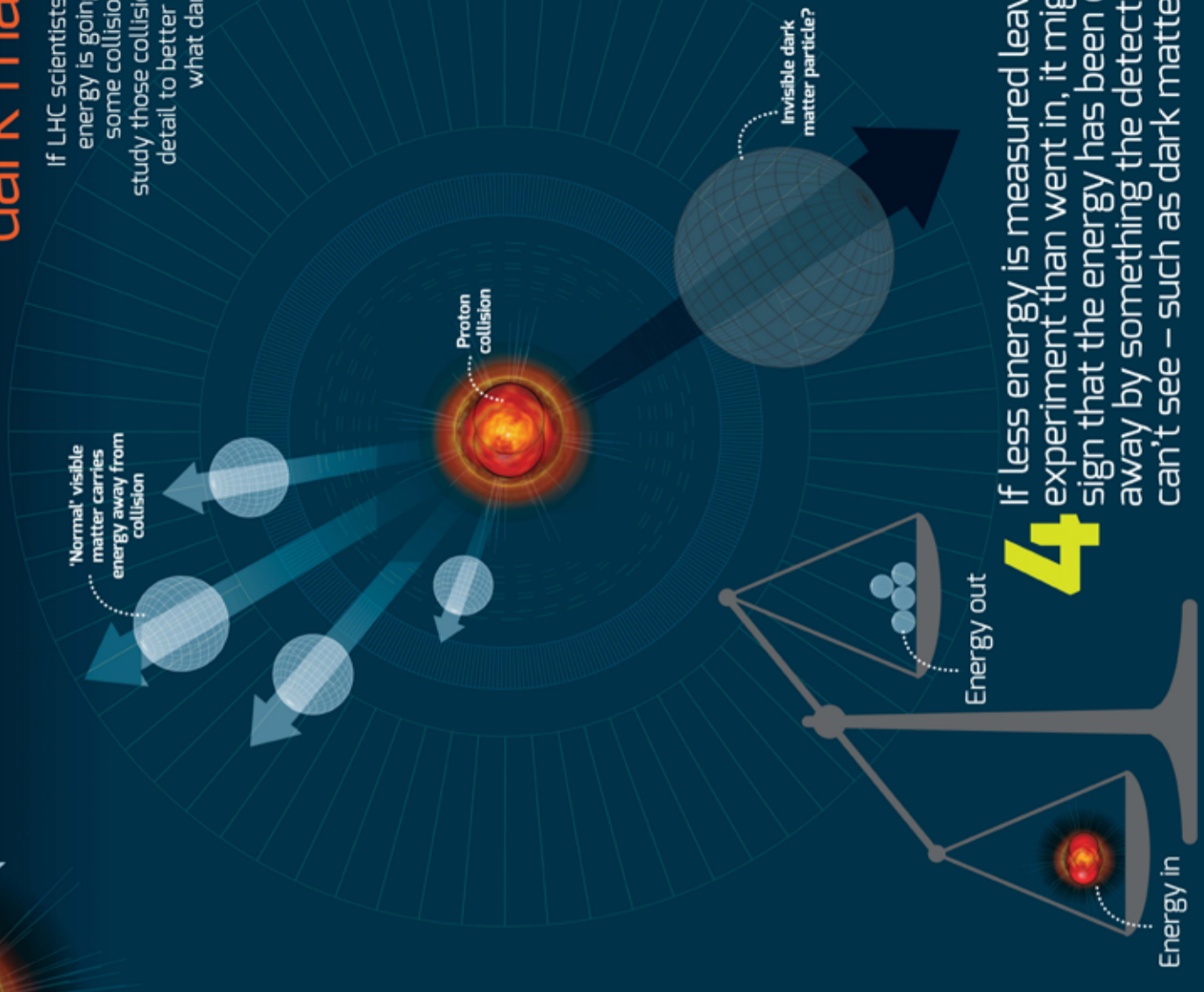
The energy and trajectory of the newly-formed particles is measured as they pass through the detector



3 Usually, they would expect the energy carried out by these particles to be same as that put in to the collision

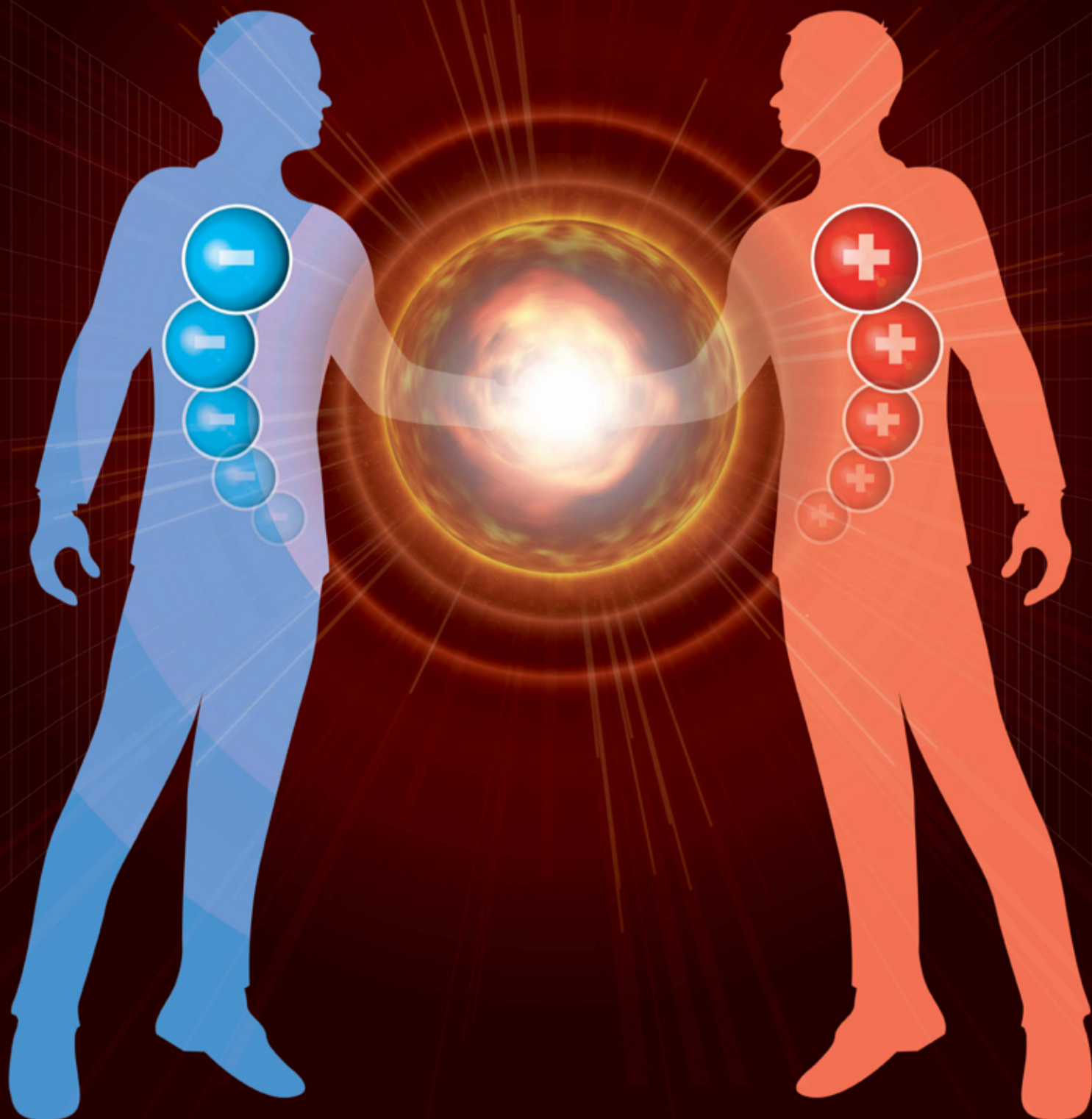
Collision makes dark matter

If LHC scientists notice that energy is going missing in some collisions they can study those collisions in more detail to better understand what dark matter is

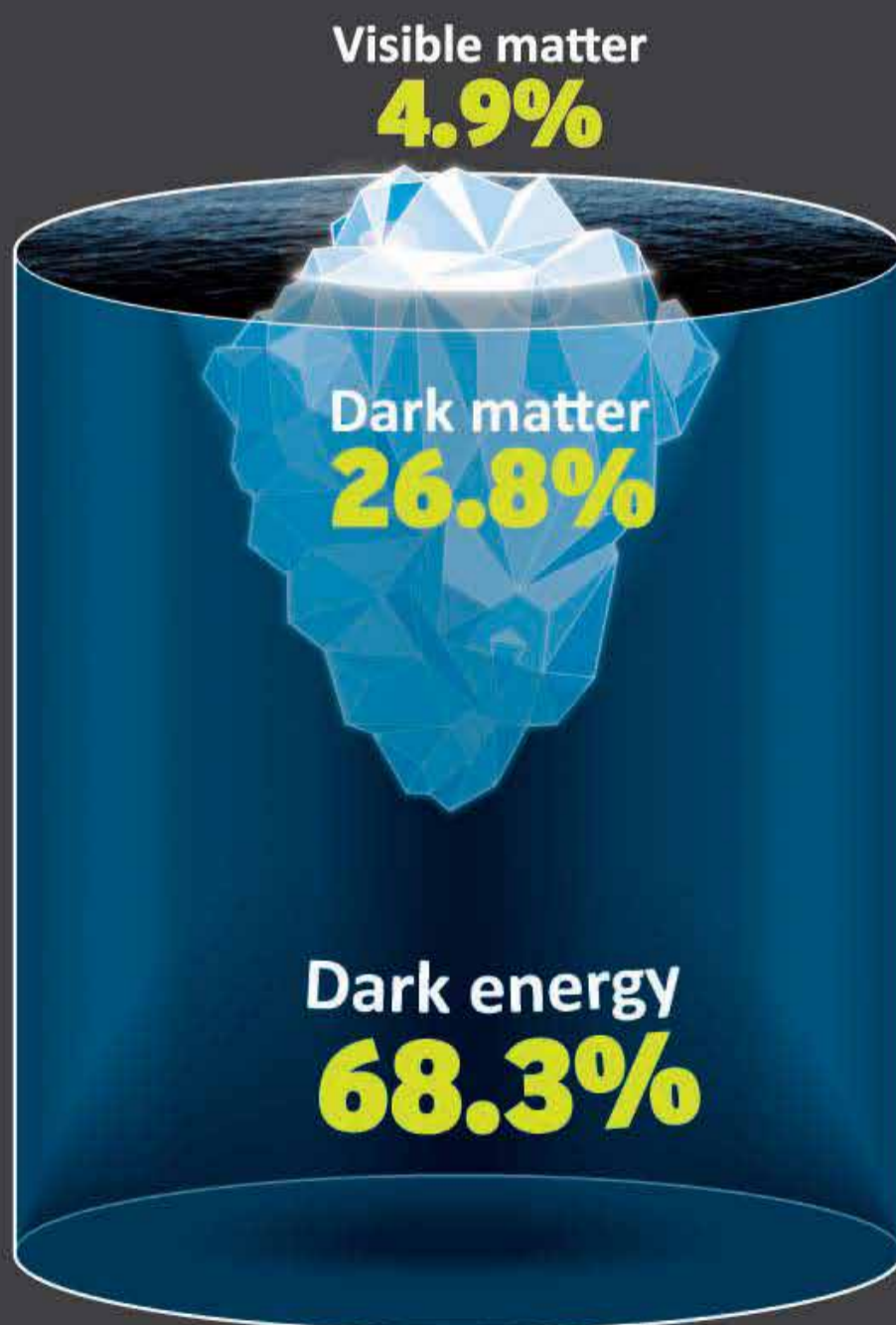


4 If less energy is measured leaving the experiment than went in, it might be a sign that the energy has been carried away by something the detectors can't see – such as dark matter

After the Big Bang, **matter** and **antimatter** should have formed in equal measure. When they meet, matter and antimatter **annihilate** each other on contact...



There must have been a subtle **difference**, that allowed matter to survive and dominate the Universe today



Visible matter

This is the stuff that makes up everything we can see and touch – all the dust, asteroids, comets, planets, stars, galaxies and you and me

Dark matter

The dark side of matter doesn't interact with light, so it is invisible. We can detect how its gravity affects visible matter. It is a bit like visible matter's invisible friend – helping to hold the galaxies and clusters of galaxies together

Dark energy

While dark matter holds stuff together, dark energy is pushing everything apart. It is causing the Universe's expansion to speed up. The more space expands, the more dark energy there is

THE HIGGS BOSON



THE HUNT
CONTINUES...

Although we have now found the **Higgs boson**, there's still a lot we **don't know** about it. The only way to find out those things is to make more Higgs bosons and examine them.

We do know

NO spin
NO charge



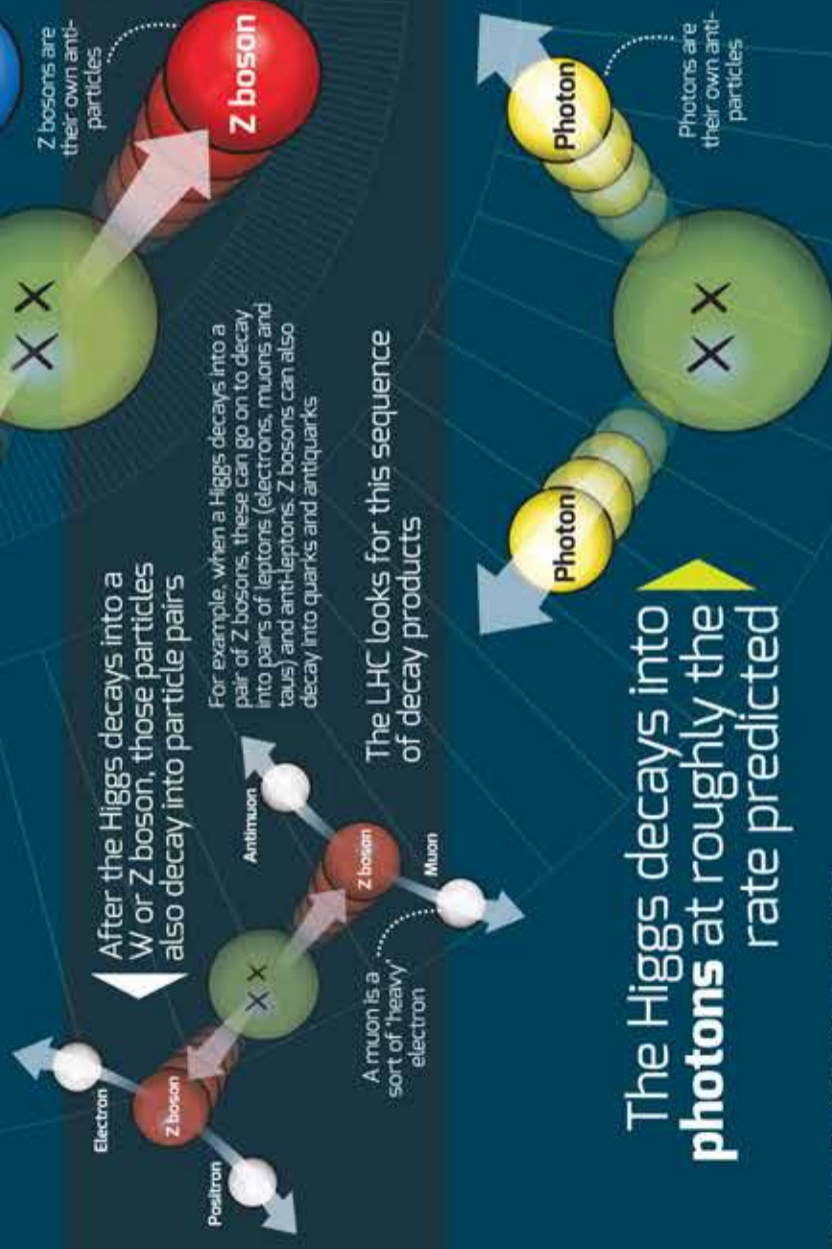
The Higgs is its **own** antiparticle

Most particles have an antimatter version. Some other bosons, such as the photon and Z boson are also their own antiparticles

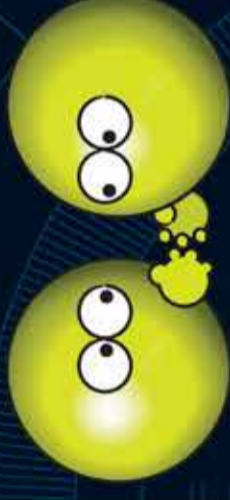
It has **zero** electric charge and **zero** spin

The Higgs decays into **W** and **Z bosons** at roughly the rate predicted by the Standard Model

This is important because it shows that the Higgs gives the bosons their mass



We would like to know



How long does the Higgs 'live' before it decays?

Does it decay into **quarks** and **leptons** at the rate we expect?

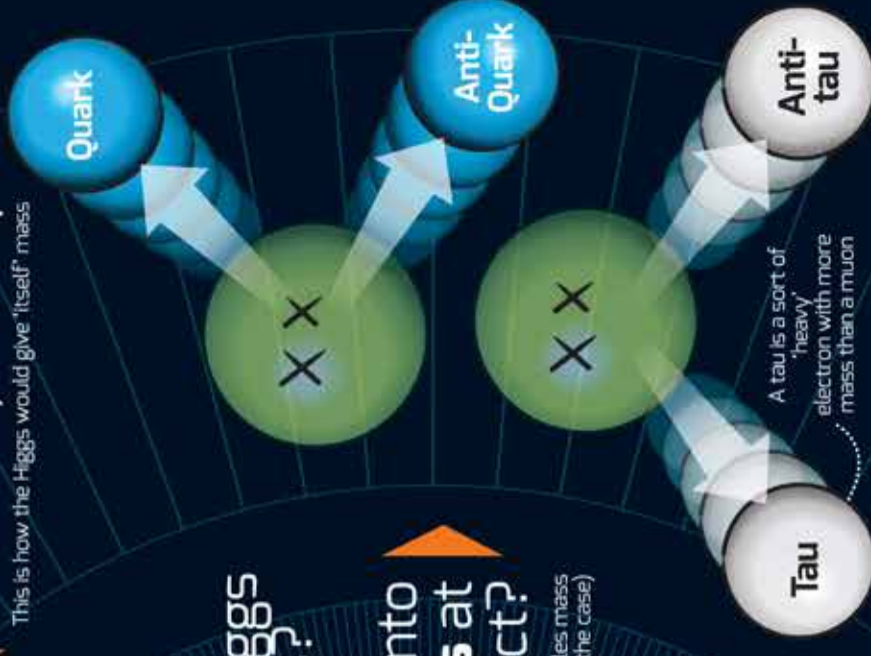
This would tell us whether the Higgs gives these particles mass too (there is some evidence that this is the case)



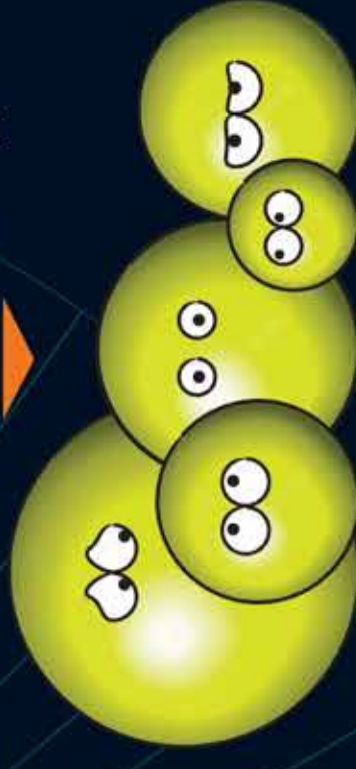
Is the Higgs really a **fundamental particle**, or is it made of something we haven't seen yet?

Does the Higgs **self-interact** in the way it is expected to?

This is how the Higgs would give 'itself' mass



Is it the **only** Higgs boson, or are there other types?



Does the Higgs particle give mass to **Dark Matter**?



SUPERSYMMETRY

THE SEARCH FOR A HIDDEN WORLD OF SUPER PARTICLES

All the matter that makes up the visible Universe is made up of particles that, in turn, are made up of smaller elementary particles...
...but, what if each of these particles has a super-secret super alterego?



The super particles will have similar properties to their normal versions, but their mass and 'spin' will be different.

Each super particle will have **more mass** than its 'normal' version. So, for every **quark**, there will be a heavier 'super quark', called a **squark**, hidden from view

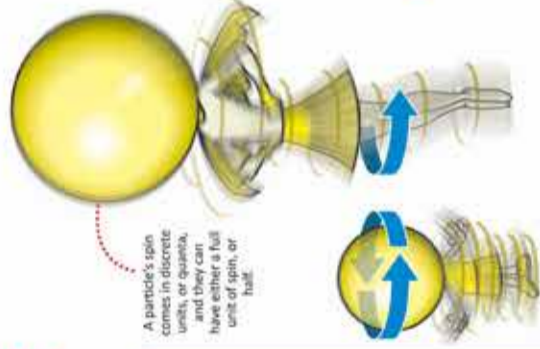
A super particle will have a half unit less 'spin' than its normal counterpart.

As well as having mass and electric charge, particles have a property called 'spin', which is really just a way to describe how they move in an electric field.



In the weird world of particle physics, spin isn't much like spin as you might know it. For example, although a spin-one particle only needs to make one revolution to get back to its starting point, a spin-half particle has to make two revolutions to get back to where it started. So, if you were a spin-half particle facing your friend, and you made one full revolution, when you came to a stop, your friend would still be looking at the back of your head!

A particle's spin comes in discrete units, or quanta, and they can have either a full unit of spin, or half.



PHOTONS ARE SPIN-ONE PARTICLES

PHOTINOS ARE SPIN-HALF PARTICLES



ELECTRONS ARE SPIN-HALF PARTICLES

SELECTRONS HAVE NO SPIN AT ALL

NORMALS



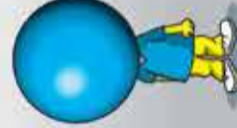
NEUTRINO

This is a particle ninja. It has no electric charge and barely interacts with other particles.



PHOTON

This is a particle of light. It has no mass and carries the electromagnetic force.



QUARK

The protons and neutrons that make up an atom's nucleus are made of quarks.



ELECTRON

This negatively-charged particle orbits an atom's nucleus and allows atoms to bond to form molecules.



HIGGS

The Higgs is responsible for giving the other elementary particles their mass.



GLUON

This carries the strong nuclear force. It is the particle glue that holds quarks together to make protons and neutrons.



Z BOSON & W BOSON

These carry the weak nuclear force. They are responsible for allowing atoms to decay into lighter chemical elements.

SUPERS



PHOTINO



SQUARK



SELECTRON



HIGGSINO



GLUINO



ZINO & WINO

The massive SUSY particles could provide some of the missing 'dark matter' that scientists are searching for.