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The Large Hadron Collider
The world's most complicated machine.

Dr Dan Faircloth, Rutherford Appleton Laboratory, UK.
This is the the most complicated machine that humanity has ever built

Dr Stephen Serjeant, Department of Astrophysics, Open University.

It's like taking two watches, and smashing them to pieces against each other and looking at the bits, and then trying to find out how the watches work from the bits.

Dr Bruce Kennedy, Rutherford Appleton Laboratory, UK.

There have been many times over the past 15-20 years when a lot of us have probably thought that what we're trying to do was probably not possible because it's such a huge step forward from what's ever been done before.

Deep beneath the Swiss-French border at the Central European Centre for Nuclear Research lies the LHC, a particle accelerator designed to begin the next era of research into the nature of the universe. Particle physicist Dr Bruce Kennedy is part of a team at the UK's Rutherford Appleton Laboratory that made one of the LHCs massive detectors.

Its sometimes thought to be rather crude that the way you find out what's happening inside particles is to smash them together and look at the debris. But, there's a basic physical reason for this, you can think of it as a microscope, and if you want to resolve very small structures in a microscope, the size of structures you can see is controlled by the wavelength of the beam that you're firing in. The price you pay for that is that at a certain point, and the proton is about that point, the energy of the object you are firing in is equivalent to the mass energy of the particle you are actually investigating. And then you find that there's so much energy going in, you basically blow the thing apart, and the only way you can get an idea of what's going on is to look at the debris that comes out of that collision.

The LHC is stepping into uncharted scientific and engineering territory, but it won't be uncharted collision territory. Dr Stephen Serjeant is senior lecturer in Astrophysics at the Open University,

It's not widely recognised in the press but particle collisions like these are happening all the time. Cosmic rays are coming in and being funnelled along the magnetic field lines of the Earth and hitting the Earth with just as much energy, in fact more than you get in the Large Hadron Collider so what we're doing in the Large Hadron Collider is controlling which ones we're seeing so we can diagnose what's going on, which you wouldn't be able to do if you just stuck a detector on the North Pole and waited for the Northern Lights.

In the LHC, the chaotic explosion of fundamental particles exists for just a fraction of a second. At the UK's ISIS accelerator, Dr Dan Faircloth describes how they use detectors to capture what happens.

We don't actually see particles being created. We see the paths that they leave behind. So it's a bit like looking for footprints in the snow, trying to work out what animals were there, that is essentially what you see in the detectors, the paths that the particles took. And then using these paths, you can understand a little bit about the nature of these new particles, and when you understand about the nature of the particles, that tells you how they interact, and that tells you why everything is here, what is stuff made of, what is matter.

The analysis relies on what's known as the 'standard model'.

The standard model is our current best explanation for how stuff works, how particles work, the basic properties of matter. And there's a big piece missing – mass. What gives particles, things, mass? Where does this actually come from?

Professor Peter Higgs, came up with a solution. His theory is that a mechanism, called the Higgs field, gives everything in the universe mass. And it works through a particle called the Higgs Boson.

We theorise that there's this particle called the Higgs Boson which gives particles and matter, like you and I, mass. The theory says it should exist, this particle, so we want to try and detect it because no one's seen one yet, and that's because we haven't yet built a machine that's big enough to produce one of these things.

Dr Stephen Serjeant, believes that the Higgs Boson is not the only discovery the LHC may make. Evidence for a generation of heavier particles called supersymmetric particles is also on the cards.

There's lots of things that the Large Hadron Collider will be able to do. Another thing it might constrain is super symmetry, to look for a new generation of particles, some of which may explain dark matter in the Universe. It would be marvellous to understand dark matter particles, to know what they are, how they interact with other particles, whether they interact with themselves at all, that would be very fundamental to cosmology. This is one of the marvellous things you can do with particle accelerators is to probe conditions that happened very, very early in the history of the Universe.

Dr Bruce Kennedy of the Rutherford Appleton Laboratory hopes the LHC can take scientists one step closer to a grand theory of everything.

If we discover evidence of super symmetry that really is a huge advance from what we call the Standard Model. That then means we're in a whole new region of physics, a whole new set of questions come up, trying to understand what supersymmetry means. But, the prospect , if we can understand that, of going far beyond the theory we have now to bring in all four forces in universe and to understand the properties of a whole host of new particles which are guaranteed to exist if we have supersymmetry, and really get a much more detailed and basic understanding of the fundamental nature of the universe is really very exciting. And the LHC is really the first time that we will have the chance to get the kind of data that can actually throw light on these very fundamental questions. So, to be so close to it now is really a great moment to be working in particle physics.