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LARGE HADRON COLLIDER

The ultimate test

In an interview just prior to the first beam of the Large Hadron Collider, Jon Butterworth tells Matt Williams how the experiment could change our fundamental theories of physics

Deep underground at the laboratories of the European Organization for Nuclear Research (CERN), physicists are preparing to launch one of the most ambitious scientific projects ever constructed. The Large Hallidron Collider (LHC) is a 27km underground circular tunnel, at an average depth of 100m, made up of superconducting magnets through which protons will be fired together at a higher energy than ever before. The LHC, which will be switched on for its first beam on 10 September, will break several records as it will also be the coldest place in the universe, colder than outer space and colder than the cosmic microwave background, a temperature of 1.9 Kelvin (-271.2 degrees Celsius). As such, it is the biggest single cryogenic project in the world. The superconducting magnets ensure that the protons being fired around the LHC are kept on the right track in order to be able to collide together. Jon Butterworth, a professor of physics at University College London, explains why these proton collisions are a central part of the experiment.

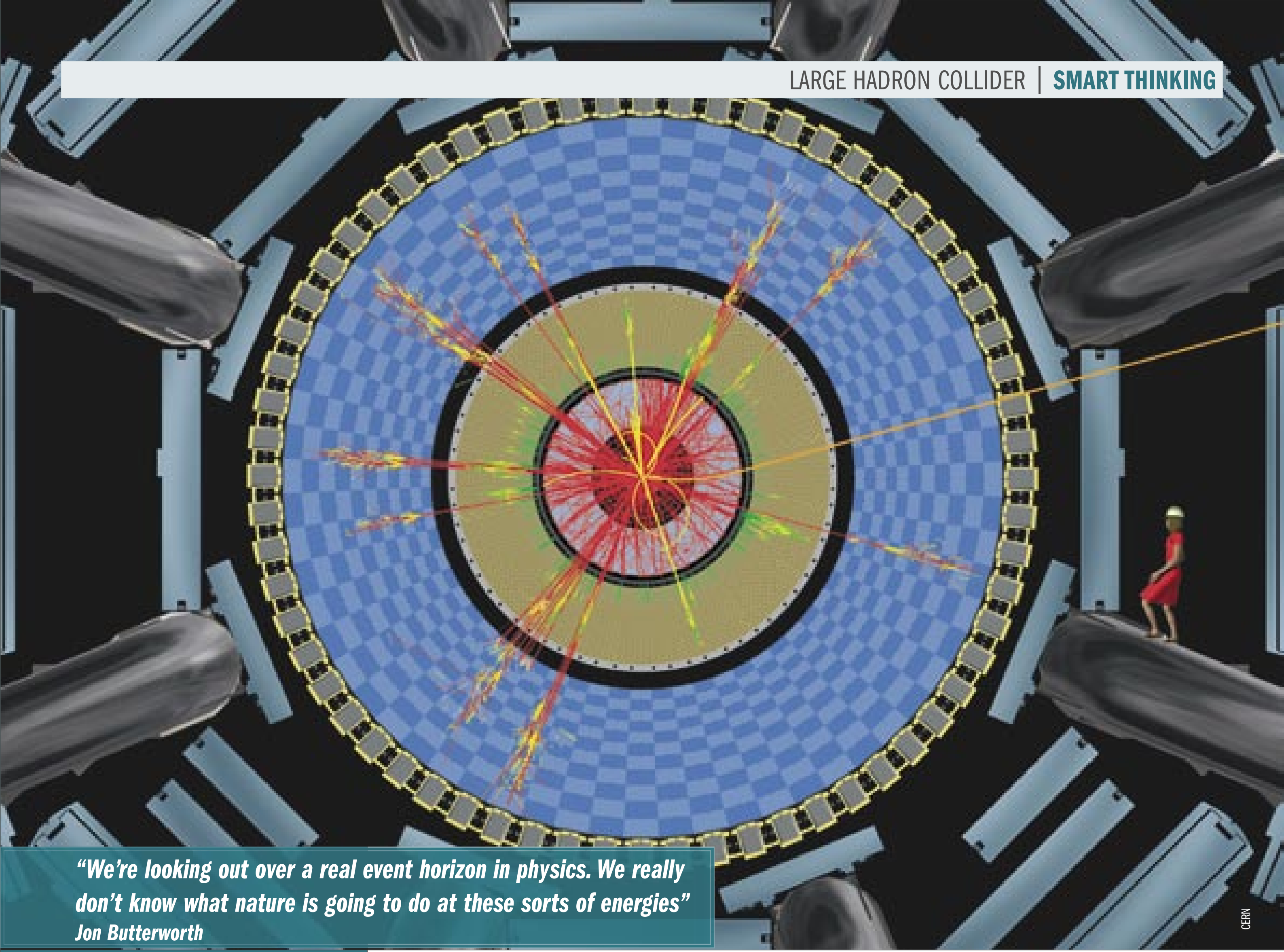
"A group of protons collide with each other every 25 nanoseconds, or every 25 billionth of a second. There are four detectors on the ring, which are there to try and work out what happens when these protons interact. We really don't know what nature is going to do at these sort of energies and we want to be prepared for everything. These contain all the smart tricks you can think of, with the aim of telling us everything we think we can know about these collisions."

The combined energy of the two protons colliding is 14 teraelectronvolts, the equivalent of 14 million million electron volts, with an electron volt being the energy an electron gets when it accelerates through one volt. This is seven times higher than any collision that has taken place before and the ability to monitor what happens when protons collide at such high energies should, Butterworth says, help answer some of the fundamental unsolved questions of physics.

"The reason this particular energy is interesting is because we're looking out over a real event horizon in physics. We have what's known as a standard model in particle physics, which is the most precise theory that we have about nature and how accurate our calculations are. An integral part of this theory is something known as the Higgs Boson. This plays a very critical role in the standard model, and without it we can't make very precise predictions. However, no evidence exists for this particle apart from the fact that we need it to make these predictions. We haven't actually ever seen a Higgs particle."


CERN

The Higgs Boson or 'God' particle, in the standard model of



"We're looking out over a real event horizon in physics. We really don't know what nature is going to do at these sorts of energies"
Jon Butterworth

physics, is what allows particles to have mass. Some of the particles to which the Higgs Boson gives mass are those that carry a weak nuclear force, the force that drives the reactions in the sun and which is therefore a vital part of nature. At very high energies, these particles have a strength similar to electromagnetic forces such as light and electricity, and the high levels of energy operating in the LHC will, for the first time in the history of physics, provide the conditions far beyond the point at which these forces become unified.

"At this level of energy, the Higgs will be doing what the Higgs has to do. If the Higgs is really there, not only should we be able to 'see' the Higgs particle in operation, but we should be able to produce Higgs particles ourselves and see them. This is basically what the LHC is built for."

In simple terms, then, the outcome of the experiment will be either that the Higgs Boson particle is able to be detected and created, or else the experiment will prove that the Higgs particle does not exist, in which case the standard model theory will be wrong. Butterworth says the latter outcome will have serious consequences for the world of physics.

"It would mean that we've been doing all our calculations on a false premise, that the theory that we have at the moment as our best theory is wrong. It's not completely wrong, because the calculations work…but what it would show is that although our theory is fine at low energies, at high energies it's wrong. We would have to go back to square one."

A good analogy, says Butterworth, is that of Einstein and the theory of relativity. Einstein did not show that Newton was wrong, but that Newton was an approximation, and that as you go to high speeds then it would be wrong. Newton was right at low speeds, but wrong at high speeds. The implications for the world of science, and the uncertainty of the outcome, is what makes the LHC such an exciting project.

"Whatever happens, this is going to rewrite the textbooks," says Butterworth. "It may remove a lot of question marks about the Higgs, and the Higgs will be there as a real thing…but in a way, I'm dreading that it will be found. I hate the idea of the theories being ahead of the experiments all the time. It would be really nice if the experiment could find something completely new.

"If the Higgs is there, I'm sure a lot of theorists will be over the moon. Many experimental physicists, however, might be a bit annoyed that all we've done is confirm the theory, when actually we'd like to rip it up." ★