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How the Large Hadron Collider Works

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Large Hadron Collider (LHC) is the world's most powerful particle accelerator. The LHC was constructed by the European Organization for Nuclear Research (CERN)). This machine deserves to be labelled 'large', it not only weighs more than 38,000 tonnes, but runs for 27 km in a circular tunnel located 50–175 meters below ground, on the border between France and Switzerland. The LHC was shut down several times. In February 2013 it was shut down to fix the problem with the design of a superconducting wire. The second long shut down, during which the LHC's equipment would be upgraded, began in December 2018 and is scheduled to end in late 2021 or early 2022 [1]. In an attempt to understand our universe, including how it works and its actual structure, scientists proposed a theory called the Standard Model. This theory tries to define and explain the fundamental particles that make the universe what it is. It combines elements from Einstein's theory of relativity with quantum theory.

The Standard Model makes several predictions about the universe, many of which seem to be true according to various experiments. But there are other aspects of the model that remain unproven. One of those is a theoretical particle called the Higgs boson particle. The Higgs boson particle may answer questions about mass. Why does matter have mass? Some scientists hope the events created by the LHC will also uncover evidence for the existence of the Higgs boson particle. Others hope that the events will provide hints of new information we haven't even considered yet.

Another question that scientists have about matter deals with early conditions in the universe. During the earliest moments of the universe, matter and energy were coupled. Just after matter and energy separated, particles of matter and antimatter annihilated each other. Fortunately, there was a bit more matter than antimatter in the universe. Scientists hope that they'll be able to observe antimatter during LHC events. [2]. One goal of the LHC project is to understand the fundamental structure of matter by re-creating the extreme conditions that occurred in the first few moments of the universe according to the big-bang model. In the 1960s British physicist Peter Higgs postulated a particle that had interacted with other particles at the beginning of time to provide them with their mass. The Higgs boson had never been observed—it should be produced only by collisions in an energy range not available for experiments before the LHC [1].

After a year of observing collisions at the LHC, scientists there announced in 2012 that they had detected an interesting signal that was likely from a Higgs boson with a mass of about 126 gigaelectron volts (billion electron volts). Further data definitively confirm those observations as that of the Higgs boson. Second, the standard model requires some arbitrary assumptions, which some physicists have suggested may be resolved by postulating a further class of supersymmetric particles; these might be produced by the extreme energies of the LHC. Finally, examination of asymmetries between particles and their antiparticles may provide a clue to another mystery: the imbalance between matter and antimatter in the universe [1].

The LHC is truly global in scope because the LHC project is supported by an enormous international community of scientists and engineers. Working in multinational teams all over the world, they are building and testing equipment and software, participating in experiments and analyzing data. The UK has a major role in the project and has scientists and engineers working on all the main experiments [3].

The principle behind the LHC is pretty simple. First, you fire two beams of particles along two pathways, one going clockwise and the other going counterclockwise. You accelerate both beams to near the speed of light. Then, you direct both beams toward each other and watch what happens. The equipment necessary to achieve that goal is far more complex. The LHC is just one part of the overall CERN particle accelerator facility. Before any protons or ions enter the LHC, they've already gone through a series of steps [2].

With 15 petabytes of data gathered by the LHC detectors every year, scientists have an enormous task ahead of them. CERN's solution to this problem is the LHC Computing Grid. The grid is a network of computers, each of which can analyze a chunk of data on its own. Once a computer completes its analysis, it can send the findings on to a centralized computer and accept a new chunk of data. As long as scientists can divide the data up into chunks, the system works well.

One challenge with such a large network is data security. CERN determined that the network couldn't rely on firewalls because of the amount of data traffic on the system. Instead, the system relies on identification and authorization procedures to prevent unauthorized access to LHC data [2].

So, researchers have used the LHC to find the Higgs Boson. The discovery of the Higgs Boson is just the beginning. Researchers hope to find other types of bosons and other elementary particles and to use the LHC to begin testing the theory of supersymmetry.

The LHC is also scheduled to receive an upgrade to high luminosity somewhere after 2022, which will increase the spectrum within which results are visible. In simple terms, this means researchers will be able to observe tests better, as the tunnels will be better lit [4].

This is important for obvious reasons, but the main concern is the LHC may be running out of potential discoveries given its current luminosity. In the early life of a collider, the number of discoveries is vastly greater than later on, as the number of things which can be seen at a given luminosity is finite. The only way to increase the number of potential discoveries is to upgrade the facility's luminosity or the strength of its instruments. The upgrade should allow for even more puzzling aspects of particle physics to be examined [4].

References:

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