Large Hadron Collider could reveal our origins

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Large Hadron Collider. Image courtesy of CERN.

The biggest science machine ever built has begun churning out the smallest known bits of matter in the universe. Its goal is to uncover some of the deepest, long-hidden secrets of nature.

This enormously ambitious device is the Large Hadron Collider, or LHC, a 17-mile-long ring-shaped tunnel 300 feet under the Swiss-French border near Geneva. It began operations on March 30 and has been called the greatest scientific undertaking since the Manhattan Project, which created the atomic bomb during World War II.

Some scientists regard the LHC as nothing less than a "time machine" that may let them go back billions of years to study the origins of the universe. They hope it will shed light on such profound questions as:

What happened immediately after the birth of the universe 13.7 billion years ago? What does most of the universe consist of? How did matter come to be? Are there more dimensions of space than the three (plus time) that we're familiar with?

The answers to those questions may have no immediate practical applications, but history has shown repeatedly that advances in fundamental science usually lead to useful things such as telephones, radios, computers, improved manufacturing, nuclear energy, global positioning satellites and so on.

"Since World War II, science and technology have been responsible for half of America's economic progress," said Alan Leshner, the president of the American Association for the Advancement of Science in Washington.

Here are some common questions and answers about the new collider:

Q: What does the name Large Hadron Collider mean?

A: The LHC is "large" because it's the biggest assemblage of scientific tools ever gathered in one place. It works with "hadrons" -- physicist jargon for protons and neutrons that make up the nucleus of an atom. It's a "collider" because it smashes protons -- tiny subatomic particles -- together so that scientists can peer at their shattered innards.

Q: Just how big is it?

A: The underground ring is lined with 1,232 50-foot-long magnets, each weighing 35 tons. The tunnel also contains four gigantic particle detectors, as big as apartment buildings, plus two smaller ones, all crammed with scientific instruments. The whole complex is chilled by 120 tons of liquid helium to almost absolute zero, colder even than outer space.

Q: Who runs the LHC?

A: The builder and operator is the European Organization for Nuclear Research, known as CERN, an acronym for its original, slightly different French name. CERN began as a collaboration of 12 nations in 1952 and now has 20 members. The U.S. joined as an observer, not a full member, in 1997, but hundreds of Americans work there, along with a rotating cast of more than 10,000 scientists, engineers and technicians from around the world.

Q: How does the LHC work?

A: Bunches of protons, the nuclei of hydrogen atoms, are injected into the tunnel by a series of accelerators that boost their speed to 99.9999991 percent of the speed of light. The magnets steer the protons around the ring 11,245 times a second in concentrated beams. They zip through the tunnel in two parallel pipes, half of them running clockwise, half counter-clockwise. At four locations the beams cross each other, crashing protons into each other head on.

Q: What happens then?

A: The proton collisions produce a spray of even tinier particles, mostly "quarks," which are the smallest, most fundamental building blocks of matter so far discovered. According to CERN, protons are 100,000 times smaller than the simplest atom, hydrogen, and quarks are 10,000 times smaller than protons. For comparison, if a hydrogen atom were six miles across, a quark would still measure less than four-thousandths of an inch.

Q: How powerful are the collisions?

A: Physicists measure a collider's energy in "electron volts," which is the tiny force required to move one electron from one side of a one-volt battery to the other side. The LHC collider produces 7 trillion electron volts -- abbreviated as 7 TeV -- of energy. That sounds like a lot, but protons are so small that a little energy goes a long way. To a human, 1 trillion electron volts would feel like a mosquito hitting your skin.

Even so, the LHC is the most powerful proton collider in the world. The current record is 2 TeV at the Fermi National Accelerator Laboratory in Batavia, Ill. In a few years, if all goes well, the LHC's power will be doubled to 14 TeV.

Q: What do scientists hope to learn from all this?

A: By slamming subatomic particles together, they aim to recreate the conditions that existed in the first moments after the Big Bang, the theoretical beginning of the universe.

At that time, the infant universe was so hot that it consisted only of a hot soup of quarks and another breed of particles called gluons. Unlike quarks, gluons have no mass and aren't constituents of matter, but they carry the force that holds quarks together. After a few seconds, the primeval quark-gluon soup, or plasma, cooled enough to allow quarks and gluons to form protons and neutrons, which eventually combined with electrons to make atoms, molecules, stars, chairs and people.

Q: Will the LHC help explain how quarks combined to create matter?

A: That's one of the major goals of the project. Scientists hope they will find in the debris of the collisions evidence of an as yet undiscovered subatomic particle called the "Higgs boson," named after a Scottish physicist who predicted such a particle in 1964. Like the gluon, bosons are particles that have no mass but carry a force. Scientists think the

Higgs boson, if it exists, is the particle that allows energy to turn into mass. The theory is that Higgs bosons are spread throughout the universe, like flowers in a field. Particles acquire mass -- in other words become matter -- by interacting with the Higgs field. That's why physicist Leon Lederman called the Higgs the "God Particle" in a 1993 book of that name.

Q: What about those theoretical extra dimensions?

A: Many physicists suspect that space contains more dimensions than the familiar up-down, left-right, forward-back trio. These extra dimensions, if they exist, are said to be rolled up so tightly that they're invisible to human eyes, like a garden hose seen from a space satellite. It's possible that the LHC might detect evidence of one or more such dimensions.

Q: Could the LHC solve the puzzles of "dark matter" and "dark energy" that make up most of the contents of the universe?

A: The collider's detectors might find evidence of other undiscovered particles that are believed to form dark matter, an invisible substance that accounts for 23 percent of the universe, and whose gravity holds galaxies together.

Dark energy is an even more mysterious force that's driving the galaxies apart at an accelerating pace. It apparently makes up 73 percent of the universe, leaving only 4 percent for ordinary matter, the stuff we can see and feel. It's unlikely, however, that the LHC will find a satisfactory explanation for dark energy.

Q: How about anti-matter, the so-called "evil twin" of ordinary matter?

A: Anti-matter is just like ordinary matter, except its electric charges are reversed. Anti-protons carry a negative charge, while anti-electrons, also known as positrons, have a positive charge. When matter and anti-matter meet, they annihilate each other. Scientists believe equal amounts of matter and anti-matter were created in the Big Bang, but almost all the anti-matter is gone. The LHC may provide clues as to why this happened.

Q: What happens to the data generated by the LHC?

A: CERN estimates the collider produces about 700 megabytes of data per second, enough to fill a 12-mile-high stack of CDs per year. The material will be distributed worldwide over the Internet.

Q: How much does the LHC cost?

A: About $5 billion so far for design, construction and operation.

Q: Is it possible that the LHC might blow up the world?

A: No, scientists say. The proton collisions produce tiny "fireballs" thousands of times hotter than the sun, but they last only microseconds and scientists say they aren't dangerous. According to CERN, the fireballs' energy is much weaker than the cosmic rays from outer space that have bombarded Earth harmlessly for billions of years.

The LCH played a fictional role in Dan Brown's bestselling novel "Angels & Demons." Brown wrote that the LCH created enough anti-matter to blow up the Vatican. CERN commissioned two studies that declared this impossible. The American Physical Society, an association of U.S. physicists, agreed.