

World's largest particle accelerator begins operations

Scientists to gain greater understanding of the mysteries of the universe

Dan Conway
25 September 2008

On September 10, scientists at CERN, the European Laboratory for Particle Physics, successfully sent a beam of protons around a 17-mile ring overlapping the borders of France and Switzerland. This marked the beginning of the largest, most ambitious science experiment in all of human history, the Large Hadron Collider. It is the product of the cumulative effort of over ten thousand scientists and engineers from more than 80 countries and 500 universities.

The Large Hadron Collider (LHC) is an engineering marvel in the most awesome sense of the term. The collider is located 100 meters underground, and is designed to smash subatomic particles together at extremely high speeds to reveal the existence of even more fundamental particles. The LHC will accomplish this by accelerating two separate beams of protons—small positively charged particles found in the nucleus of atoms—and in certain cases, lead ions, in opposite directions around the large ring.

Before entering the large ring, however, the protons are prepared to achieve the speeds required in four separate stages.

First, hydrogen atoms, which normally consist of a single electron and proton, are stripped of their electrons and accelerated through a linear accelerator known as the LINAC 2, and then further accelerated through a four-ringed structure called the Proton Synchrotron Booster, followed by the 628-meter-circumferenced Proton Synchrotron.

The Proton Synchrotron, built in 1959, was CERN's first particle accelerator, and is still being used today by the Large Hadron Collider, albeit with significant upgrades. The protons' energy is then further increased in a larger ring, the Super Proton Synchrotron, before entering the 17-mile-long main ring.

The entire Large Hadron Collider contains an array of superconducting magnets, each cooled to a temperature of 1.9 Kelvin, which is equivalent to minus 271.25 degrees Celsius, making the LHC the largest cryogenic system ever made. Such extremely cold temperatures, requiring 120 metric tons of liquid helium in total to produce, are necessary to induce superconductivity—that is, zero resistance to the flow of electric current. The strong electric currents in turn produce the extremely powerful magnetic fields required.

To bend the protons around the ring, the accelerator uses 1,232 dipole magnets, and 392 quadrupole magnets are used to focus the beams for collisions. Radio waves push the protons around the ring and “bunch” them together into groups of around 100 billion each.

The protons are accelerated around two adjacent tracks in the main ring, traveling in opposite directions and achieving speeds of 99.999999 percent the velocity of light in the process.

The two main qualities of an accelerator that maximize the speed of

particles are the strength of its magnetic fields and its overall circumference. To that end, the generated power and size of the LHC make it the most powerful accelerator ever completed. The protons accelerating around it ultimately achieve energies of 7 tera electronvolts (TeV). An electron volt is the energy required to move an electron through a voltage difference of one volt, while tera is a prefix meaning one trillion, i.e. 1 followed by twelve 0s.

The protons are then made to collide at one of four points around the ring containing massive detectors. The net energy of the collisions produced will be 14 TeV, twice that of each opposing proton.

One detector, the CMS, or Compact Muon Solenoid, is essentially in the shape of a large cylinder 20 meters long and 15 meters in diameter. The CMS weighs 12,500 metric tons and produces a magnetic field of 4 Tesla, or 100,000 times greater than that of the Earth. Once the protons collide with each other they will create millions of smaller particles that will react to the magnetic field in different ways depending upon their respective properties.

Detectors like the CMS don't actually “see” the particles as if they were giant microscopes. Instead, they employ layers of finely tuned equipment to record various aspects of particles produced as a result of the collisions.

The first layer of the CMS, for example, uses silicon sensors, each millionths of a centimeter wide, to measure the momentum and positions of created particles.

The protons themselves travel into the detectors in bunches of around 100 billion each. Of the 200 billion protons present at the intended collision area, only 20 or so will actually collide due to the protons' small size. The proton bunches, however, travel essentially in pulses at a frequency of one pulse every 25 nanoseconds. This means that collisions inside the detector will actually take place at an average rate of 80 million per second.

The detector must then record the outcomes of these collisions, requiring enormous computer processing and storage capabilities. CERN technicians estimate that the data obtained from the LHC will account for a staggering one percent of all computer data kept on the planet.

To underscore the importance of such a massive information technology operation, some particle physicists believe that the Higgs Boson, the elusive particle that LHC scientists hope to find, has already been created at the Tevatron accelerator at Fermilab near Chicago, Illinois. The facility, however, may not have had computing power sufficiently fast enough to recognize and analyze it, or may not have had storage capacity large enough to record it.

In order to accomplish such a monumental task of data collection and analysis, CERN has created the world's largest computing grid, which

will utilize the power of over 200 computing centers across the globe, spanning a total of 100,000 central processing units (CPUs).

The large computing grid can process data at a rate of 1 gigabyte per second and is expected to add an additional 15 petabytes or 15 million gigabytes of data per year.

It will also contain the largest instance of database clustering technology in the world. Database clustering is an extremely advanced technology that distributes single databases over multiple computers. The Large Hadron Collider's databases will also be replicated at ten separate data sites in ten different countries.

Of all the billions of collisions recorded, however, only a scant few will be of potential interest to researchers, and only a tiny minority of those will ultimately be of actual scientific import. The oft-used analogy of "finding a needle in a haystack" in this case simply doesn't do justice.

Scientific expectations

The collisions inside the detectors will create temperatures 100,000 times hotter than the core of the sun. The conditions so created will also be similar to the first millionth of a second after the Big Bang, the origin of the known universe. It is under such conditions that scientists hope to confirm the existence of the missing link of the standard model of particle physics, the Higgs Boson.

Under the standard model, there are two basic types of particles: quarks, which are the building blocks of the protons being shot through the Large Hadron Collider, and leptons. A hadron is another name for a group of quarks bound together. A combination of two "up" quarks and one "down" quark produces the hadron more commonly known as a proton, hence the name Large Hadron Collider.

These particles experience different interactions or forces with one another depending on their various properties. The interpretation of classical physics—meaning physics up until the first years of the twentieth century—was that forces acted between particles through otherwise unexplainable fields present between them. Subsequent discoveries in the branch of physics known as quantum mechanics revealed, however, that fields were instead the material interaction of particles known as gauge bosons.

For example, a proton placed a short distance away from another proton will experience a repulsive electrical force due to the exchange of photons, the particular gauge boson associated with electromagnetism, with the other proton.

Physicists today also understand the universe to be governed by four fundamental forces or interactions: the strong force, which is responsible for binding together quarks and as a residual effect, binding together protons and neutrons in the nucleus of the atom; the weak force, which is responsible for radioactive decay such as that which produces the sun's radiation; the electromagnetic force; and the gravitational force.

Following the standard model, the types of gauge bosons are: gluons for the strong force, photons for the electromagnetic force, and W and Z bosons for the weak force. The standard model does not explain the gravitational force.

The electromagnetic and weak forces are now believed to be different manifestations of the same force, the electroweak force. However, the gauge bosons in these cases are quite dissimilar—photons are massless, and W and Z bosons are extremely heavy.

The Higgs Boson, associated with the so-called Higgs mechanism, has been postulated as the source of mass. The Higgs Boson, however, has never been observed, as the energies required to produce it are so high. It is hoped that the discovery of the Higgs Boson particle in an LHC

collision will help to explain the differences between the W and Z boson and the photon. More generally, the discovery of the Higgs Boson will help explain what accounts for the creation of the masses of all fundamental particles.

The presence of such colossal energies in the detectors of the LHC could shed light on other, equally compelling mysteries, such as the existence of other dimensions of space. It may also establish the nature of dark matter, which is believed to exist in copious quantities throughout the universe but which has never been detected.

The Superconducting Supercollider

While the completion of the Large Hadron Collider represents an exciting leap forward in human understanding, this understanding is, in a sense, ten years overdue. The cancellation of the Texas-based Superconducting Super Collider by the Clinton Administration in 1993, after 14 miles of tunnel had been dug and more than two billion dollars already spent, represented a tremendous blow to the international scientific community and to scientific knowledge in general.

If the SSC had been completed, it would have had a ring circumference of 54 miles and collided particles with a total energy of 40 TeV, more than 3 times what will be produced at the Large Hadron Collider. The site of the SSC has since been sold to a private investment group with no chance of the project being resurrected.

In his book *Science, Money and Politics*, journalist Daniel S. Greenberg writes extensively about the decision to cut funding for the SSC. Greenberg describes the Clinton Administration as "on record in support of the SSC," but in actuality, "the interest in the SSC was negligible and efforts to save the project were perfunctory."

Greenberg also relates an interesting admission by John Gibbons, former Assistant to the President for Science and Technology. In an interview with Greenberg, Gibbons stated that as far as funding for the SSC was concerned, "It was just too little, too late, and Congress wanted some scalps anyhow. This was one. And we didn't fight for that one as hard as we could have. But you have to limit your fights."

Moreover, after the collapse of the Soviet Union, the US Government increasingly saw no reason to further invest in basic scientific research and claimed the Superconducting Super Collider as one of its first victims. The gutting of the SSC was a stark expression of the widespread philistinism of the American ruling class, who will support no project that does not provide an immediate political, military, or economic advantage.

Typical was the outlook of Democratic Senator Tom Harkin of Iowa, who reiterated his reasoning for voting against SSC funding in September 2000: "Are we worse off as a country because we came to our senses in time and did not complete the Superconducting Super Collider? Not at all. We are better off because we saved the money."

While Europe moved forward with CERN and the Large Hadron Collider, the project was still threatened with closure several times. Witnessing the demise of the Superconducting Super Collider, European politicians saw the LHC as a means to rival the US in basic science. Regardless, the collider itself is a testament to the international character of scientific research and its incompatibility with the outmoded nation-state system.

No single nation would have been able to realize such an ambitious scientific undertaking. Furthermore, the results produced by the particle collisions will require the close collaboration of scientists from hundreds of different countries, including the US. Such collaboration has been the hallmark of, and indeed the prerequisite for, scientific advancement for many decades.

The fate of the SSC is one illustration of the constraints placed on the further development of science by a social system that subordinates everything to private profit, geopolitical considerations, and personal wealth accumulation.

It is worth recalling in this regard the difficulties confronting particle physics in an earlier period, during the first decades of the twentieth century. At that time, physicists saw an immense growth in their understanding of the subatomic world. Prior to the outbreak of the Second World War, many discoveries were made as the product of frequent international collaboration. Many of these same scientists found themselves on opposing sides in the war, as their respective capitalist governments scrambled to create the atomic bomb.

This complete and catastrophic change in the role of scientific research was not accidental. The very same technical and productive developments that helped propel enormous scientific advances and international integration were also bringing the different capitalist powers, rooted in the nation-state system, into conflict with each other.

As the achievements at CERN are watched around the world amidst the escalation of geopolitical and economic crisis, such precedents appear prophetic. While science has come a long way, the social organization of mankind still lags terribly behind.

The author recommends the following for those wishing to learn more about CERN and the Large Hadron Collider:

Video of the history of CERN

Brief Overviews of the Higgs Boson, the Standard Model, and other theories

Images of CERN and the Large Hadron Collider

CERN LHC Guide



To contact the WSWS and the
Socialist Equality Party visit:

wsws.org/contact