Student 4: High Achieved

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Is high-energy particle physics worth the cost?

Particle physics and the LHC

The Large Hadron Collider (LHC) is the world's largest and most powerful particle accelerator with the fundamental purpose of increasing our knowledge of the universe. It was built between 1998 and 2008 by the European Organization for Nuclear Research (CERN) and is the latest addition to CERN's accelerator complex. The LHC consists of a 27-kilometre ring located 100 meters under the border of France and Switzerland near Geneva, Switzerland. Once it is switched on, semiconducting electromagnets within are used to help hurls beams of protons in opposite directions around the LHC at speeds up to 99.9999991% the speed of light. Once up to speed, they are made to collide, releasing energy and creating new particles. Analysis of the debris gives us a glimpse of the subatomic world and the laws that govern it. Through these events, scientists have been able to recreate the conditions that would have been present milliseconds after the Big Bang. During this first moment, time, space, the particles and forces that shape our Universe came into existence, so understanding this event would unlock many mysteries of the universe. This research into high-energy particle physics is exciting and brings us one step closer to understanding the world around us. It has allowed physicists to test different theories of particle physics, in particular the existence of the theorized Higgs Boson. ①

Findings from the LHC

The Higgs Boson is part of the Standard Model and is thought to be responsible for giving matter its mass. The Standard Model is a theory proposed as an attempt to understand our universe. This theory is important because it tries to define and explain the fundamental particles and basic forces that make up the universe. It proposes 12 particles that are divided into two groups, the quarks and leptons. It includes 3 forces, the electromagnetic, strong, and weak forces (the theory excludes the force of gravity). There are also force- carrying particles called bosons. The W and Z boson cause the weak force, photons are responsible for the electromagnetic force, and gluons create the strong force. All of these particles have been confirmed by the experiments at the LHC. Particles can be extremely hard to detect because they only exist for fractions of a millisecond before they decay into or join together with other subatomic particles so the only way to confirm their presence is by analysing the by-products. Thankfully, each particle has a unique decay signature that can be distinguished by software. The Z boson, that has a neutral charge for example, decays into two leptons (e- and e+ or p - and p +). Electrons show up as two yellow lines on the detector software and the direction the electron's path bent is used to determine its charge. Muons show up as a long red line also bending depending on their charge. The W boson (either w- or w+) decays into a single electron or muon plus a neutrino. The neutrino is undetectable but missing momentum in the system accounts for this and shows up as a yellow arrow, whose length is proportional to the amount of missing momentum. The theorized Higgs boson has several possible decays. The most popular is the decay into two Z bosons or into two photons. The Higgs boson is the missing piece to the Standard model and is the main focus of the LHC collisions. The groundbreaking discovery of a Higgs like particle at the LHC in July of 2012 was a huge step forward towards completing the Standard model. It would take its place as the third boson and could also be responsible for being the force- carrying particle for gravity. On the other hand, the results of the high-energy particle physics taken place at the LHC could blow the whole theory apart. If the Higgs particle that has been discovered turns out not to be the one that we expect, this would open the doors for an addition to the standard model or the need to rewrite the whole theory. Scientists are also looking for evidence of dark matter, antimatter, dark energy and super symmetry to support other theories. These discoveries could make the existence of other dimensions possible. No matter what the outcome, this high-energy particle physics will expand our knowledge of the universe and may even give us a different view on looking at reality. The research conducted at the LHC has an obvious beneficial place in our society, but at what cost? ②

How much does it cost?

Both the building and running of the LHC comes with enormous costs. It took a decade to construct that costed a total of over 6 billion dollars. The LHC requires a colossal amount of energy to accelerate and smash beams of protons together. It consumes an estimated 800,000 megawatt hours (MWh) of electricity that costs almost 30 million dollars annually. "Taking all of those costs into consideration, the total cost of finding the Higgs boson ran about $13.25 billion (1)." Although this seems like a lot of money, there are over 50 billionaires on the Forbes List worth more than that. It's not like the money isn't going to a good cause and understanding our universe is priceless.

Are the high-energy particle collisions at the LHC safe?

The LHC can create higher energy than any other particle accelerator for more effective proton collisions but has been a subject of many claims of safety. Groups such as 'Citizens Against The Large Hadron Collider' is a non-profit organization established for the purpose of preventing the operation of the LHC until further safety tests are conducted. It is a website where concerned citizens around the world can protest against the operation of the LHC. The best-known opposition of the LHC came in the form of a lawsuit filed in America by Wagner and science writer Luis Sancho. The LHC Safety Assessment Group (LSAG) has published a review analysing the risks and has concluded the LHC presents no danger. A key focus of the critics' argument has been the creating of black holes. Black holes typically occur when certain stars collapse on themselves at the end of their lives, concentrating a large amount of matter in a very small space, creating such a strong gravitational pull that even light can't escape. In theory, a black hole doesn't have to occur on a planetary scale but at any size. The claim of a microscopic black hole being created in the LHC when protons disintegrate is purely theoretic and LSAG claim that even if such a black hole were created, it would be so instable and evaporate in one-trillionth or one-millionth of a second.

Another argument against the operation of the LHC is the production of potentially harmful cosmic rays (high-energy radiation). However, nature has created these rays some of which have much higher energy than the LHC, which is in a controlled laboratory environment. According to the LSAG, "the Universe as a whole conducts more than 10 million million LHC-like experiments per second. The possibility of any dangerous consequences contradicts what astronomers see - stars and galaxies still exist (2)." Concerned citizens have put forward more small worries about the operation of the LHC that the LSAG have addressed and concluded that the LHC is safe to operate. From their conclusion, it is safe to say that the chance that the LHC will destroy the planet is minimal and the results of experiments at CERN are worth the risk.

Is it worth the cost?

The experiments conducted at the LHC are scientific. The whole point of science is creating theories and then testing them. So far, we have had masterminds such as Albert Einstein and Werner Heisenberg proposing theories about the universe such as the 'standard model' and 'string theory'. Before the LHC, there were no ways of testing these theories. With this new technology, we can scientifically test these hypotheses. The LHC and standard model is a perfect example of the essence of science. While there is no practical application of the discoveries scientists have made at present, we will most likely find some in the future. This isn't the only reason hundreds of scientists and engineers built the LHC though, it is also to further our knowledge. Being humans, we are driven by curiosity and thrive with discovery; so naturally, we have built a device to do just that. When we are so close to unlocking essential secrets of the universe, it seems that the cost doesn't matter. This may seem selfish of the Western World to invest a huge amount of money into smashing protons together but furthering our knowledge of the universe will not only benefit the scientists but the whole world. Teleportation and extra dimensions could mean ending poverty, uniting our planet and maybe even discover extraterrestrial life. Some people argue that until the LHC proves anything it is just wasting money. This is simply not true and work at CERN has already created advancements in our lives. Building the LHC forced engineers to come up with new technologies and designs for large constructions that will benefit our ever-expanding society. The LHC is unique in that it is 100m underground so the builders had to find fast and reliable ways of drilling down and around 27km underground. This advancement is important particularly for the mining industry and allows us to mine more effectively. Another problem that engineers had to solve was constructing the huge circular concrete tubes underground that encased the tubes that the proton beams race through. These types of new innovations could lead to the creation of underground cities in the future if needed. The World Wide Web is another development thanks to the LHC. The amount of data that CERN had to transfer meant new methods of computing had to be created to keep up. The LHC Computing Grid was CERN's innovation to overcome the challenge of transmitting the masses of information to other locations around the world and is now used predominantly by large companies. It combined both fibre optic cables and high-speed Internet connections to allow data transfers of over 10 Gbs/s. this technology is now used to provide superfast Internet to homes around the world. New software methods were developed to analyse the massive amounts of data called midware. There was also the need for them to operate simultaneously to process the data faster, which has allowed computing companies to produce machines that can run much faster. Thirdly, the LHC project requires a lot of staff on the job. This creates much more jobs for people that would otherwise contribute to Switzerland's large unemployment rate.

So what is the next step?

Considering all of the benefits the LHC has already given us, the decision whether to operate it again in September 2014 seems obvious. We should continue the operation of the LHC and possibly even build another one to speed up the process. People around the world and particularly those who live near the particle accelerators should be shown the document by the LSAG showing that the operation of the LHC will not destroy the world and assured that no harm will come of them. (3)

Reliability of sources

- The Forbes website is usually a reliable source because it shows the author and the date. The price of running the LHC is may not be so reliable because the breakdown of cost doesn't quite add up. Also the currency can't be verified- although being an-American Press it is assumed that they are in US dollars.
- The safety article is directly from the CERN website that gives it credibility. There isn't an author or date but it is likely to be written by the CERN press that would include a group of people. The information is updated from 2003, which is a sign of authenticity although it doesn't specify how up to date it is. The source does provide links that of the LSAG report up to 2008 and other detailed information, which overall makes this a reliable source.
- Howstuffworks is a reliable source that shows the author and date but is written in layman's terms that could decrease its reliability. It does reference the information presented in the article that makes it a reliable source.

Websites

- https://www.forbes.com/sites/alexknapp/2012/07/05/how-much-does-it-cost-to-find-a-higgs-boson/#27af3a763948
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