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The Communication, Collaboration and Scientific Development of the CERN Large Hadron Collider

Introduction:

CERN's Large Hadron Collider (LHC), a 6.84 billion AUD project, has inspired significant milestones in particle physics as one of the greatest scientific feats of this century (Jamieson, 2019). A challenging design and engineering accomplishment, dissimilar to any previous project, the LHC has inspired communication and collaboration from scientists and engineers all over the world. Despite significant public backlash regarding safety and environmental impact, prior to the opening of the collider, the LHC has allowed physicists to answer questions related to models in quantum physics. This research has then been applied to the development of new technology in a range of fields including medicine and information technology. Despite only having completed a small portion of its aimed research thus far, the LHC has already influenced significant development in particle physics.

Background on the Large Hadron Collider Project:

CERN's LHC operates at energy levels seven times greater than any particle accelerator previously made. The collider allows physicists to reproduce conditions existing a billionth of a second after the Big Bang by colliding high-energy protons and ions (Jamieson, 2019). Weighing more than 38,000 tonnes, the LHC consists of a 27-kilometre circle, set one-hundred metres below ground-level (CERN, 2008).

Within this ring, two beams of particles travel in opposite directions in separate beam pipes (two tubes maintained at ultra-high vacuum). They are guided by the strong magnetic fields of superconducting magnets to reach a frequency of 11,000 circuits of the ring per second - close to the speed of light. The paths are then crossed, causing a portion of the particles to collide (CERN, 2008). The electromagnets are made using coils of electrical cable designed to operate in a superconducting state, leaving minimal energy lost due to resistance. This is achieved by refrigerating the magnets, using liquid helium, to a temperature of -271° Celsius, less than that of outer space. In addition to this, a range of over two-thousand other magnets between five and fifteen metres long are utilised to bend, focus and squeeze the beams to increase chances of collision (CERN, 2019).

Development and Physics Applications:

A primary goal of the LHC, the observation of the Higgs Boson, was achieved in 2012. First described by Higgs and Englert in 1964, the Higgs boson is an elementary particle in the Standard Model of particle physics, as displayed in *Figure 1* below (New Scientist, 2018). A part of the Standard Model is the unification of the weak and electromagnetic forces to describe them as a single electroweak force. The theory further describes the electroweak force-carrying particles (the photon, W and Z Bosons). However, a bizarre phenomenon occurred when the equations to describe the particles were written. There was no indication as to how the particles could have mass but the equations only worked when the particles were given mass. Hence, the Higgs field was introduced to explain this phenomenon. Particles are thought to acquire mass by interacting with this field. Higgs proposed that when particles move through the Higgs field, a form of resistance, equal to the mass of the particle, gives particles their mass. The Higgs Boson is the visible manifestation of the Higgs field; by supporting its existence, this flaw in the Standard Model was able to be resolved (CERN, 2020).

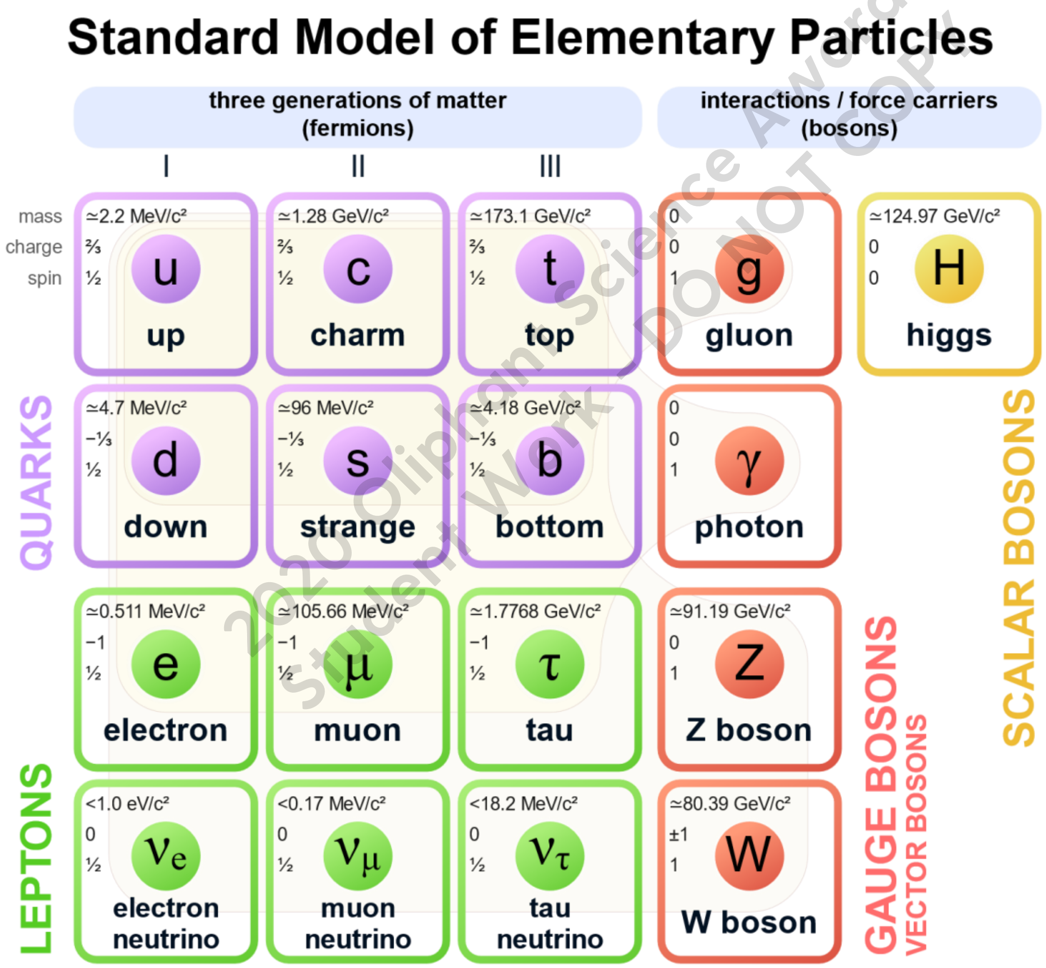

Figure 1: The place of the Higgs Boson in relation to the Standard Model theory (CERN, 2020).

Another study was undertaken at the LHC by Jon Butterworth, a physics professor at University College London who worked on the ATLAS experiment. This study, undertaken in 2017, provided a revolutionary development to fundamental understandings of physics. As described by a paper written by Albert Einstein in 1905, light is known to exist with properties similar to both particles and waves in small packages (quanta) known as photons. Since the times of Einstein, the question of 'what actually are light quanta' has perplexed the scientific world. This study at the LHC in which light was observed colliding, and then bouncing off in an elastic collision (one where the kinetic energy is conserved by the particles) provides the first significant development to this theory since its proposal by Einstein. According to the ATLAS physics coordinator, Dan Tovey, of the University of Sheffield, 'this phenomenon is impossible in classical theories of electromagnetism'. Hence, this unexpected behaviour of light quanta provides a new perspective of the behaviour of photons, one that is yet to be described mathematically by scientists (Butterworth, 2017).

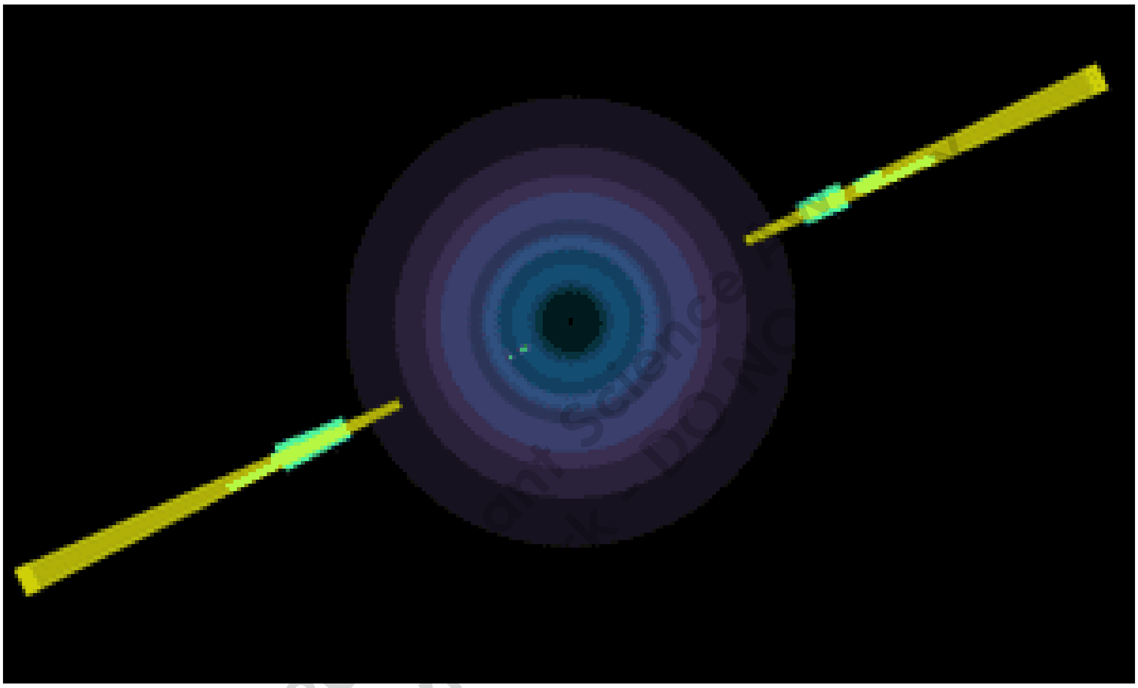

Figure 2: Light scattering data detected by the ATLAS detector (Butterworth, 2017)

Communication and Collaboration:

CERN's LHC has inspired significant global collaboration throughout the process of its engineering and the experimentation it has enabled. Supporting four globally collaborated projects, resulting in over two thousand scientific reports, this particle accelerator has required significant communication across the globe (Lincoln, 2019).

CERN itself, located in Geneva, Switzerland, has sparked significant global effort in the sixty years the organisation has been running (Jamieson, 2019). With twenty-one member countries and seven observers, this organisation has required one of the greatest international efforts for a scientific project. Contribution from physicists from Japan, Eastern Europe, Russia and later all over the globe assisted in the early conceptual designs of the LHC and later in grant pitches (Jenni, 2014).

The LHC relies on a system of computers and software for the processing of the masses of data recorded on its detectors. Known as the Worldwide LHC Computing Grid (WLCG), this system requires significant global collaboration to develop this data to form results (Jamieson, 2019).

The design and engineering of the LHC itself involved contributions from thirty-five countries with each assigned to an aspect depending on their resources and knowledge. The funding of the project was also based upon separate funds, each including a group of countries, to ensure the financial stability of the project. This meant that if a single country was unable to meet their financial or engineering contribution, the project wouldn't be significantly affected (Lucibella, 2014). This effort was reflected in the successful development of the project.

Interaction between Science and Society:

The LHC has provided research and evidence inspiring a range of new technologies and applications in a wide spectrum of areas including medicine and Information Technology. Derived from developments at the LHC, the *Medipix* range of computer chips are an example of a fascinating new technology assisting in the development of smaller ways to store information and new ways to measure and document radiation (Elsevier, 2012). Discoveries at the LHC have also allowed the development of new technology utilised to map and analyse the human brain and its circuitry (Chalmers, 2018). This is improving psychiatric technology to assist in finding treatment for those suffering nervous system related illness or injury (CERN, 2019).

Despite concerns of its power usage in the early stages of the LHC design project, the Collider manages to maintain reasonably low environmental impact. When running, its usage reaches a reasonably efficient 115 MW of electricity which is a small cost when considering its benefits to scientific developments (Gaddi, 2014). A system is currently being developed to utilise heat energy created by the Collider's cooling system to heat the neighbouring city of Geneva, Switzerland. From 2022 onwards, some of the water from the cooling system of the LHC will be redirected to provide heating to over 8000 people's homes with reduced carbon dioxide emissions (Schaeffer, 2019).

In the early stages of the development of the LHC, concerns of its safety inspired debate between the public and scientific community. This stemmed from the collider's ability to produce conditions that had not been created artificially before. Despite the weak scientific basis of this opinion, the public expressed concern of end-of-world scenarios occurring due to collisions in the LHC. These concerns were not supported by the majority of the scientific community with a report by the LHC safety assessment group confirming that 'LHC collisions present no danger and there is no reason for concern.' This was based on the understanding that all conditions created in the LHC have existed on Earth and other astronomical bodies previously and, furthermore, that principles outlined by

Einstein eliminate the possibility of Microscopic Black Holes and therefore vacuums occurring (CERN Accelerating Science, 2019). The LHC has shown no reason for safety concern as is expected for its future.

Limitations:

Despite the LHC's significant achievements, it has not had a flawless mechanical history in the years since its opening. A number of mechanical faults have caused research to cease on multiple occasions. A significant example of this was a leak in a helium tank required to cool the electromagnets in September 2008. Caused by a faulty electrical connection between two of the accelerator's magnets, this incident led to a year-long closure of the collider (CERN, 2008).

Conclusion:

CERN's LHC has allowed significant scientific development in the area of quantum physics with application to technology in society. In its development, it has brought together scientific communities, proving to be a significant engineering feat. Despite initial concerns of its safety and impact on the environment and a number of mechanical issues since its opening, the LHC has and will continue to shape the way humanity understands the quantum world.

<u>Reference List:</u>

Butterworth, J., 2017. *Experiment Reveals Evidence For A Previously Unseen Behaviour Of Light*. [online] the Guardian. Available at: <https://www.theguardian.com/science/life-and-physics/2017/sep/03/experiment-reveals-evidence-for-a-previously-unseen-behaviour-of-light> [Accessed 30 March 2020].

CERN - Accelerating Science. 2008. *CERN Releases Analysis Of LHC Incident*. [online] Available at: <https://home.cern/news/press-release/cern/cern-releases-analysis-lhc-incident> [Accessed 30 March 2020].

CERN Accelerating Science. (2019). *The Safety of the LHC*. [online] Available at: https://home.cern/science/accelerators/large-hadron-collider/safety-lhc [Accessed 24 Sep. 2019].

CERN Accelerating Science. 2020. *The Higgs Boson*. [online] Available at: <https://home.cern/science/physics/higgs-boson> [Accessed 31 March 2020].

CERN. (2019). *Applications of CERN Technologies in Society*. [online] Available at: https://kt.cern/cern-technologies-society [Accessed 24 Sep. 2019].

CERN. (2008). *CERN - How the LHC works*. [online] Available at: https://public-archive.web.cern.ch/en/LHC/HowLHC-en.html [Accessed 22 Sep. 2019].

Chalmers, M. (2018). *Particle physics on the brain*. [online] CERN. Available at: https://home.cern/news/news/physics/particle-physics-brain [Accessed 24 Sep. 2019].

Elsevier, B. (2012). *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*. [online] Science Direct. Available at: https://www.sciencedirect.com/science/article/pii/S0168900212005104 [Accessed 24 Sep. 2019].

Gaddi, A. (2014). *How "green" are we? The environmental footprint of an LHC detector | CMS Experiment*. [online] Compact Muon Solenoid - experiment at CERN's LHC. Available at: http://cms.web.cern.ch/news/how-green-are-we-environmental-footprint-lhc-detector [Accessed 24 Sep. 2019].

Jamieson, C. (2019). *Large Hadron Collider*. [online] Science and Technology Facilities Council - UK Research and Innovation. Available at: https://stfc.ukri.org/research/particle-physics-and-particle-astrophysics/large-hadron-collider/ [Accessed 22 Sep. 2019].

Jenni, P. (2014). *The strength of worldwide collaboration*. [online] CERN. Available at: https://home.cern/news/opinion/accelerators/strength-worldwide-collaboration [Accessed 19 Sep. 2019].

Lucibella, M. (2014). *CERN: 60 Years of Collaboration*. [online] Aps physics. Available at: https://www.aps.org/publications/apsnews/201409/cern.cfm [Accessed 19 Sep. 2019].

Lincoln, D. (2018). *In 10 Years, the Large Hadron Collider Was a Smash — with More Discoveries to Come*. [online] livescience.com. Available at: https://www.livescience.com/64392-large-hadron-collider-discoveries.html [Accessed 18 Sep. 2019].

New Scientist. (2018). *New Scientist Live: why hasn't the LHC found anything new?*. [online] Available at: https://www.newscientist.com/article/2179024-new-scientist-live-why-hasnt-the-lhc-found-anything-new/ [Accessed 18 Sep. 2019].

Schaeffer, A. (2019). *LHC's cooling system, an energy source for CERN's neighbours*. [online] CERN. Available at: https://home.cern/news/news/engineering/lhcs-cooling-system-energy-source-cerns-neighbours [Accessed 24 Sep. 2019].

Siegel, E. (2018). *Five Years After The Higgs, What Else Has The LHC Found?*. [online] Forbes. Available at: https://www.forbes.com/sites/startswithabang/2018/04/11/five-years-after-the-higgs-what-else-has-the-lhc-found/#15bc1c5b552c [Accessed 18 Sep. 2019].