Seeing the Universe through the Large Hadron Collider

By Yi-Ling Hwong, PhD candidate at the Australian Centre for Astrobiology, UNSW

When I was a little girl one of the things I used to do with my family was to take walks after dinner in the big rice field behind our house. I grew up in Malaysia, a country where light pollution wasn't a problem, and starry night skies stretched as far as the eye could see.

For many years I thought the skies looked the same everywhere in the world. In my childish mind, the universe was a sacred thing, only to be admired, not understood. But I also wondered, what if I am wrong?

A growing desire to understand the universe took me from Malaysia to Germany, and eventually to the European Organisation for Nuclear Research, or CERN, in Geneva, Switzerland. Hosting more than 10,000 physicists and engineers from around the globe, it is the biggest physics research centre in the world.

Some of the most brilliant minds of our time – driven by the same desire to understand the universe – came together in 1956 and founded the organisation with the mission of studying the fundamental building-blocks of the cosmos. The tools of the trade in particle physics are accelerators and detectors. We build some of biggest machines ever made by humankind in order to study the smallest constituents of matter.

After completing an engineering degree in Germany, I was very fortunate to win a European Union funded Marie Curie Fellowship in 2008 to study and work at CERN for three years. This scheme provides a valuable opportunity for researchers of any nationality to work on international projects and advance their careers.

During my time there I completed my Master's thesis, developing a control system for the liquid helium production plant, created software for the CMS particle detector, and worked as a science communicator.

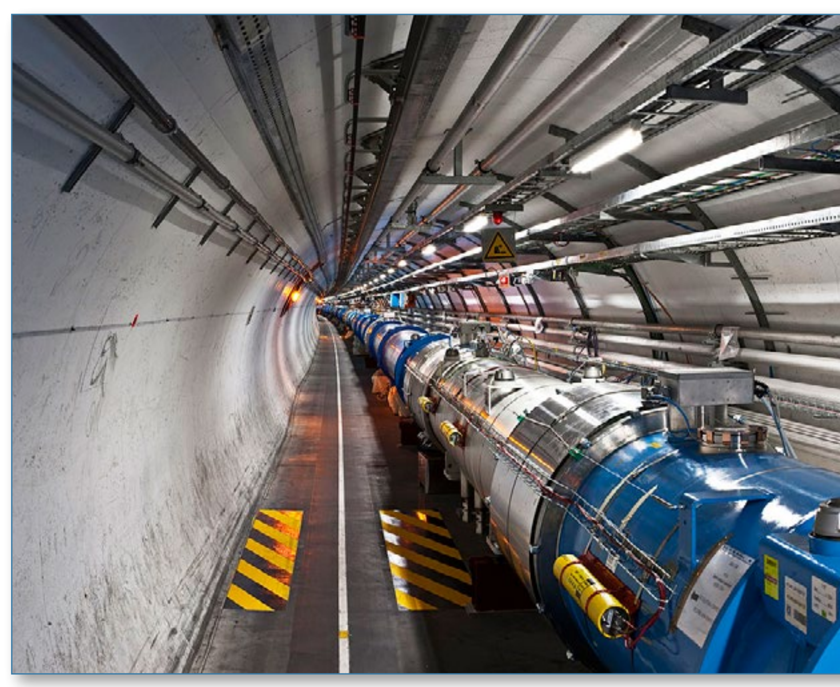
I was given the opportunity to lead, to take initiative, to teach and to learn. Instead of being given orders, I was encouraged to expand my potential and manage my own goals. I got to meet people from all over the world, and was challenged to think, wonder, doubt and explore.

Although CERN started out concentrating on particle physics, it has branched into many other fields, including engineering, computing, environmental studies, space and medical science. It employs mathematicians, computer scientists, lawyers, accountants, communications professionals and many others.

It is the place where the World-Wide Web was invented. However, not everything there is state-of-the-art. It still has some quirks, such as randomly numbered buildings, and creaky stairs, and windows that do not close!

The flagship accelerator at CERN – the now-famous Large Hadron Collider, or LHC – represents the culmination of rigorous scientific investigation, extraordinary engineering ingenuity, and many years of hard work. It's control centre looks like a scene out of *Star Trek*.

As its name implies, the LHC collides hadrons – particles that are made up of quarks, one of the fundamental particles in the Standard Model[1] (a mathematical model that describes how the basic building blocks of our universe interact, governed by what are regarded as the four fundamental forces – strong, weak, electromagnetic and gravity).



A view inside the Large Hadron Collider tunnel

The LHC is a ring of magnets 27 kilometres long that straddles the border of France and Switzerland, in a man-made tunnel deep underground. It accelerates two beams of protons travelling in opposite directions to almost the speed of light (99.99991%, to be precise), and then collides them together.

While people can be forgiven for thinking this would be a hot place, the magnets are actually cooled to 2K, or –271.3°C, a temperature colder than outer space.

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Yi-Ling Hwong (left) in the LHC accelerator complex with another CERN computer scientist

The Press Conference when confirmation of the discovery of the Higgs Boson was announced

The collisions result in an enormous amount of energy. According to the famous Einstein equation, $E=mc^2$, energy and mass are equivalent to each other, and can be transformed from one form to the other.

So when you have a huge amount of energy being produced. This energy can be transformed into mass, or 'stuff', and the stuff that particle physicists are interested in is, of course, particles. The massive amount of energy generated by the high-speed collisions in the LHC is transformed into a barrage of subatomic particles, which are then captured by giant detectors.

These cathedral-sized detectors are like cameras, taking pictures of the collisions. Physicists then study the traces of these collisions to try and answer some of the major questions that have fascinated several generations of scientists, such as, "What is the universe made of?" "How did it evolve?" "Where are we going in the future?"

One of the most important discoveries made by the LHC was the discovery of the Higgs boson. First theorised in 1964 by Professor Peter Higgs, a particle physicist from Scotland, it was the final missing piece of the Standard Model puzzle, and was the 'holy grail' of particle physics.

Interaction with the Higgs field is what gives every particle its mass, and Higgs bosons are the ripples of the Higgs field. Since we and everything around us are made of matter, we could say that the Higgs boson is *the* particle that is responsible for our existence, since it gives us mass.

For this reason it has been popularly referred to as the 'God-particle' in the media, albeit to the chagrin of its eponymous predictor and particle physicists everywhere.

After many, many failed experiments to detect this particle, in July 2012, CERN announced that the Higgs boson had been independently observed by two of the LHC's detectors, the ATLAS and the CMS detectors.

As one of the engineers working in the CMS collaboration, I remember that day vividly, and it will forever remain one of the most exciting days of my life. I was with my colleagues outside the CERN auditorium eagerly awaiting the official announcement. We had known about the discovery for months, but had been under a gag order until it was properly confirmed.

Professor Higgs was in the auditorium where the announcement was made, and cameras caught him wiping away tears when the Director General of CERN at that time, Professor Rolf-Dieter Heuer, uttered the words: "I think we have it". The theatre erupted into applause. It was an exhilarating and touching moment for me to witness the joy of the scientists and engineers, some of whom had worked on this for their entire careers. I was also immensely proud to have been part of the team that made the discovery possible.

Professor Higgs was awarded the Nobel Prize in Physics the following year for his theory of the Higgs boson – almost 50 years after he had first predicted its existence.

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To build the LHC and carry out the experiments, scientists and engineers had to push the frontiers of technology, and many innovations were needed. Construction and operation of the LHC has brought about many practical applications. For example, great strides have been made in the fields of medical imaging and hadron therapy for cancer, thanks to advances in accelerator physics. On the clean energy front, the vacuum technology used in the LHC has been applied to develop solar panels that can operate at much higher temperatures than commercially available ones.

There are still many unanswered questions in particle physics, such as where is all the antimatter? What is dark matter and dark energy made of? How many dimensions are there?

The quest for human knowledge is a never-ending one. Meanwhile, for me, the LHC symbolises something much deeper than merely the impressive engineering feat, the discoveries that have been made, and the technologies that have been developed. The fact that it was built with no immediate application in mind but just to help us understand the universe epitomises the true spirit of science. It is a manifestation of the best and quintessential parts of being human: wonder and curiosity.

People rarely do fundamental research for the possible spin-offs, or fame, or money – they do it for the unbridled joy of discovery!

With great fondness I remember my younger self. The girl who dreamt about one day growing up to be a scientist so that she could understand the Universe. Little did I know that the first time I stared up at a starry night sky and wondered what was out there, I was already a researcher.

1 https://www.wikiwand.com/en/Standard_Model