SAE./No.65/October 2016

Studies in Applied Economics

FROM GOD'S PARTICLE TO DARK MATTER

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Global Health, and Study of Business Enterprise

From God's Particle to Dark Matter

Investigating the Universe: Getting the Big Picture
by Colliding Small Particles[1]

by Joachim Mnich

About the Series

The *Studies in Applied Economics* series is under the general direction of Prof. Steve H. Hanke, Co-Director of The Johns Hopkins Institute for Applied Economics, Global Health, and the Study of Business Enterprise (hanke@jhu.edu).

About the Author

Joachim Mnich is the Director for Particle and Astroparticle Physics at the Deutsches Elektronen-Synchrotron (DESY) and Professor of Physics at the University of Hamburg. He is currently Chair of the International Committee for Future Accelerators (ICFA), a panel working under the auspice of the International Union of Pure and Applied Physics (IUPAP) to promote international collaboration in all phases of the construction and exploitation of high energy accelerators. He is also a member of numerous national and international strategy and advisory boards.

Prof. Joachim Mnich has a graduate degree in electrical engineering and obtained a PhD in particle physics, both from Aachen University. In the past, he has worked on large particle physics experiments at DESY and CERN. His interest is experimental particle physics, particularly precision tests of the electroweak interaction, and the design, development, and construction of modern tracking detectors. Since 2000, he has been a member of the CMS experiment at the Large Hadron Collider at CERN and contributed to the construction of the silicon-based central tracking detector as well as to studies to test the Standard Model of particle physics. Prof. Joachim Mnich is also involved in studies to prepare the next large collider project (International Linear Collider (ILC)) that will be able to examine the recently discovered Higgs particle with unprecedented precision. In this context, between 2005 and 2009, Prof. Mnich initiated and led the EU-funded EUDET research project aimed at developing advanced detectors for the ILC.

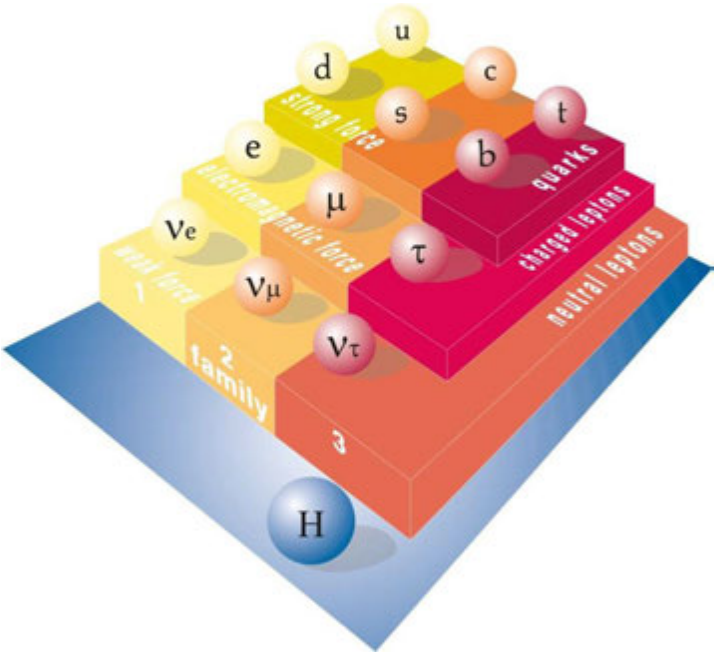
[1] This paper was delivered at the Stern Stewart Annual Summit, which was held at Schloss Elmau, Bavaria on 17 September 2016. I wish to thank Barbara Warmbein (DESY) for her help in preparing this article.

This paper is about curiosity and its crucial role in human nature.

If people weren't curious, we wouldn't be able to fly around the world, connect instantly and realistically with family and colleagues around the globe, or share what we find fascinating with the rest of the world through Tweets, links, and posts.

Humankind has always wanted to find out how things work: How do you make fire? How could you conquer the oceans? Where does the world end? What is the smallest thing that exists in the universe? We've answered many of these questions, but so many are still left unanswered.

We've come quite far, but all the things we have learned about our world – the Earth, our solar system, our galaxy, and the universe – are only 5 percent of the whole story.



https://media.desy.de/DESYmediabank/?l=de&c=2156&r=19388&p=1

(Today's picture of the fundamental building blocks of matter replacing the view of the 19th century based on the periodic table of elements; credit DESY)

95 percent of the Universe is still unknown. We think it's probably a mixture of what we call **Dark Matter** and a hypothesized **Dark Energy**. How did we find this out, and how can we catch the dark stuff?

There is an intimate connection between the smallest (elementary particles) and the largest things (like galaxies) in our universe. Therefore, studying the fundamental building blocks of matter and the way those building blocks interact provides insight into our universe's origin from the **Big Bang** to its development into what we observe today. Understanding how these building blocks interact can help us forecast the future.

Our Tools

Our telescopes are huge particle accelerators within which we smash some of the smallest particles, such as electrons and protons, into each other, and study the debris. Our flagship is the **Large Hadron Collider (LHC)** at CERN, close to Geneva in Switzerland.

https://cds.cern.ch/record/1295244?ln=en

(Schematic overview of the Large Hadron Collider. The circle indicates the tunnel 100 m underground. Image: CERN)

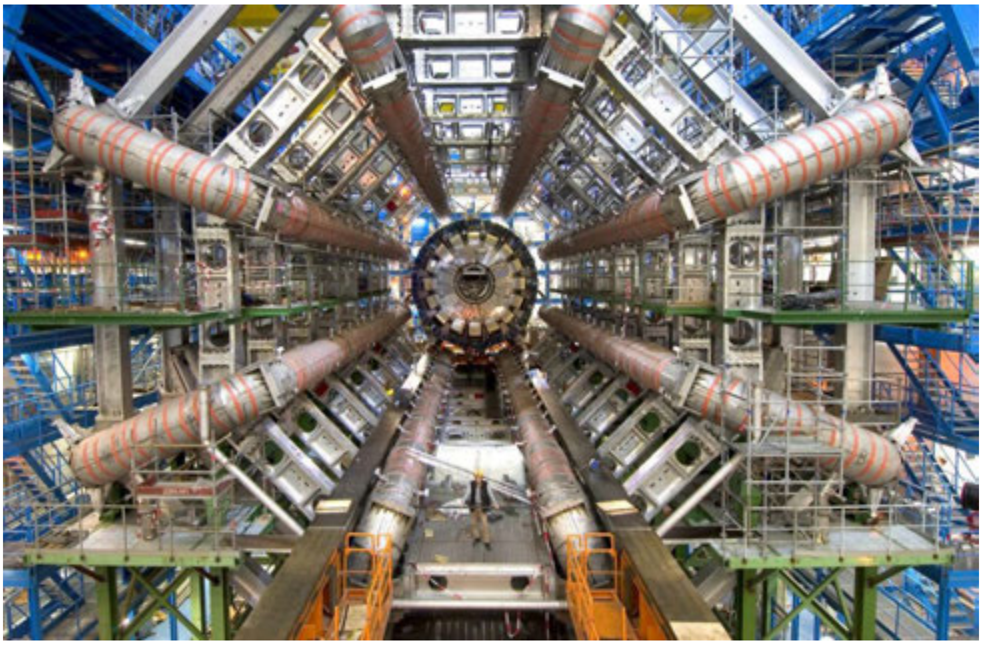
CERN, the European Organization for Nuclear Research, is an intergovernmental organization that was established in 1954 as one of Europe’s first scientific joint ventures. It currently has 22 member states.

More than 10,000 scientists from research institutes and universities from about 100 countries work on the experiments at CERN. In its 60 years of existence, CERN has become a laboratory for both Europe and the world alike.

My laboratory, Deutsches Elektronen-Synchrotron DESY, is one of CERN’s key partners. In the past, we operated our own particle smashers. We have now joined the experiments at the LHC.

What is this LHC anyway?

The Large Hadron Collider (LHC) is a 27-kilometre particle accelerator that sits in a circular tunnel some 100 metres underground, straddling the border between France and Switzerland. In the ring, protons are accelerated in both directions around the ring and collide at four points. Planning for this new collider started in the 1980s. Construction began in the 90s, and it was first used in 2009. In 2012, the LHC found the Higgs particle, and now the accelerator has generated the highest energy ever reached in man-made accelerators: 13 TeV, i.e. thirteen thousand billion electron volts.



https://mediastream.cern.ch/MediaArchive/Photo/Public/2005/0511013/0511013_01/0511013_01-A4-at-144-dpi.jpg

*(This is **the** iconographic image of the LHC project. It doesn't show the collider itself, but it does show the ATLAS detector during construction. Image: CERN)*

Accelerating particles doesn't tell us anything about the laws of the universe, but colliding them does. The collisions are recorded by huge detectors built and operated by thousands of physicists from all over the world[2]. The detectors are a bit like digital cameras – only 40 metres long, some 25 metres high, and stuffed with advanced technology able to catch every single particle that appears in the collisions via a frame rate of 40 million frames per second.

Detectors are marvels of both technology and cooperation. Thousands of scientists, students, engineers, and technicians from different countries and cultures come together to design, construct, and operate these detectors and to analyze the data.

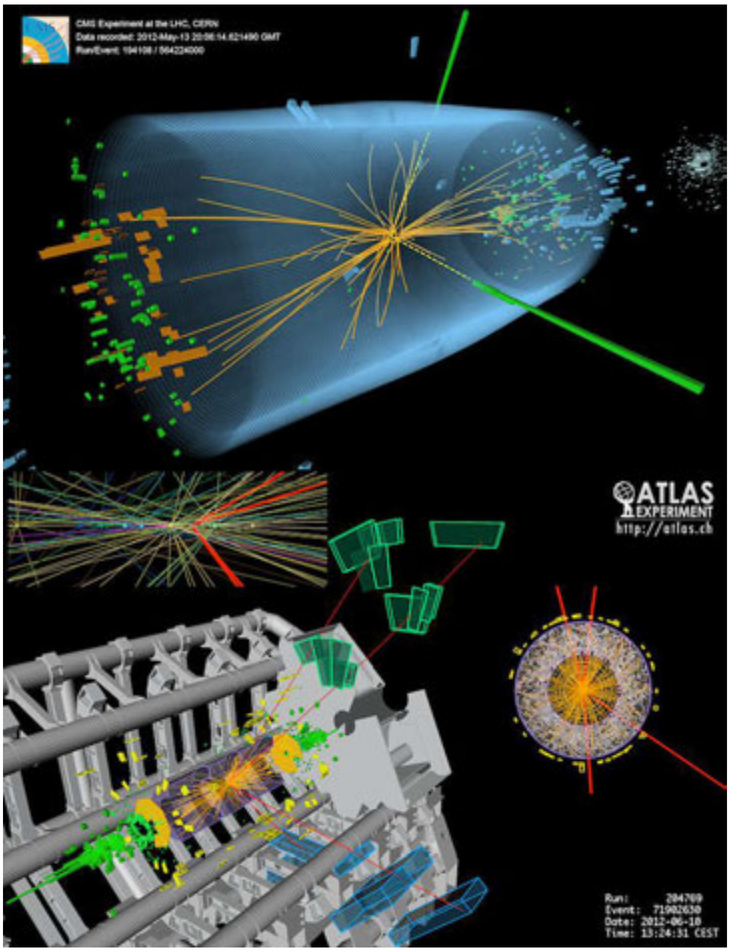
This cooperation exists without any strict hierarchy because everyone is driven by **curiosity** and the common goal to get insight into deeply fundamental questions about mankind.

The Higgs particle (called God's particle by some – but never by physicists)

The first big success of the LHC occurred on 4 July 2012 with an announcement of the discovery of a new particle – **the Higgs!** This particle was predicted almost 50 years earlier by Scottish theorist Peter Higgs (and others, including the Belgian theorist Francois Englert) in 1964. In

[2] You may think that this sounds incredible, but you only realize how incredible it is when you see it for real. I highly recommend a visit to CERN!

2014, Higgs and Englert received the Nobel Prize in physics for their prediction of the Higgs particle.



http://cds.cern.ch/record/1630222

(This computer graphics shows what a particle collision with a Higgs particle looks like in a detector. Image: ATLAS, CERN)

The Higgs is a very important piece in the Standard Model of Particle Physics, our “new periodic system.” It is responsible for giving mass to fundamental particles. Without the Higgs there would be no atoms, molecules, planets, stars, plants, or human beings.

What’s next?

The LHC has discovered the one particle that we had been looking for 50 years, but what’s next?

We believe that the next step to unravel the mystery of the unknown 95 percent of the universe is **Dark Matter** and what it is made of. We have theories that could explain **Dark Matter,** and theories can be quite powerful – Higgs started with just a theory in the 1960s to explain mass. The most popular of these current theories is called **Supersymmetry** – or **SUSY** for short. It predicts a mirror-world of new fundamental particles. Every particle of our known world – the new *periodic system* – would have a supersymmetric partner. It's a bit like the worlds of matter and anti-matter, which we have been exploring since the 1930s.

The LHC will continue to run and collect data for at least the next two decades. Scientists are already looking at bigger, better accelerators to increase the breadth of discovery and to enhance precision. There are ideas and studies for a laser-straight tunnel of up to 50 kilometres in Japan, and even a 100-kilometre ring that would pass right underneath Lake Geneva. We hope that one day there might be political and financial support to turn such visions into reality.

What's in it for me?

Our curiosity makes us build these enormous machines. It lets us develop things that we need for our work, and we only later see how useful these "things" can be for the whole world. For example, Positron-Emission Tomography, better known as PET-scanning, is used to make tumors visible with the help of all the knowledge we have accumulated over the years about the creation, detection, and use of antimatter. Furthermore, did you know that the **World Wide Web** was invented at CERN to make communication between particles physicists around the globe easier? It's hard to think of an innovation that has had a more profound impact on our society.

One more important ancillary benefit is the skills gained by all of the bright, young people who work at CERN for their PhD thesis with high-tech equipment in a highly international environment. Most of them leave academia to work outside science as problem solvers and independent thinkers in intercultural environments.

So what about the Higgs – how is that useful for you? We don't know yet. We don't know whether or not it will have any influence on our lives. The practical uses that may derive from such a scientific discovery are not predictable and sometimes impossible to imagine when the initial research is conducted. At the moment, it is useful because it has widened our knowledge, satisfied some of our curiosity, and sparked new questions – an important part of human culture.

We keep working on new things because there are always more questions that need answers. We continue to develop new technologies for bigger, better, and more efficient colliders that could tell us things the LHC cannot.

So let's stay curious.