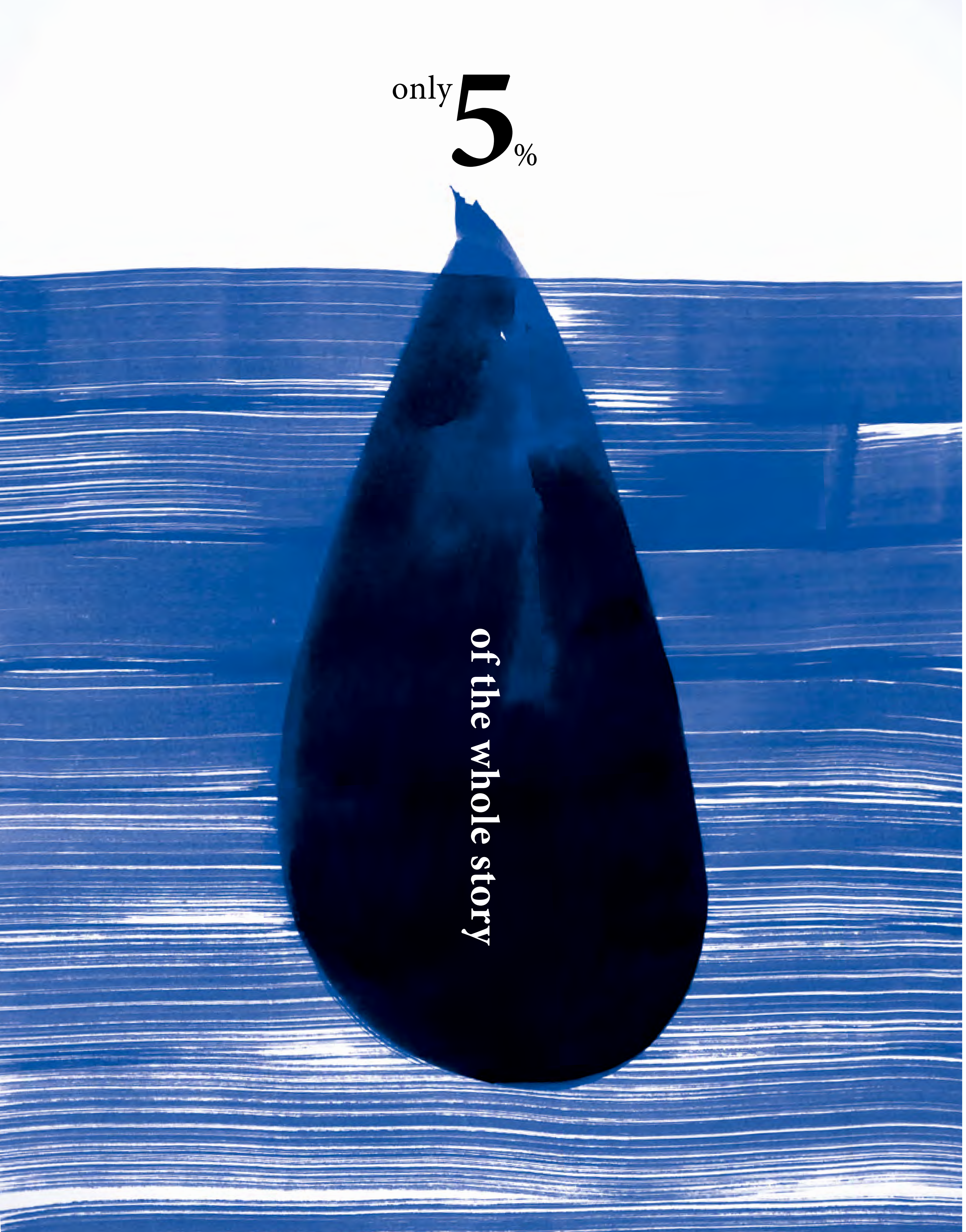

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From God's Particle to Dark Matter

Investigating the universe: Getting the big picture by colliding small particles

This article is about curiosity and why we would not be human if we were not curious. If people were not curious, we would not be able to fly around the world to be here, keep in touch with family and colleagues at home via video conference or share the things we find fascinating with the rest of the world through tweets and 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 many are still open.

We've come very, very far. But everything we know about our world including the Earth, our solar system, our galaxy, the universe, what they are made of and the rules they play by amount to only five percent of the whole story.

A total of 95 percent of the universe is still unknown. We think it is 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 they interact provides insight into our universe such as its beginning with the Big Bang, its development into what we observe today and the ultimate fate.

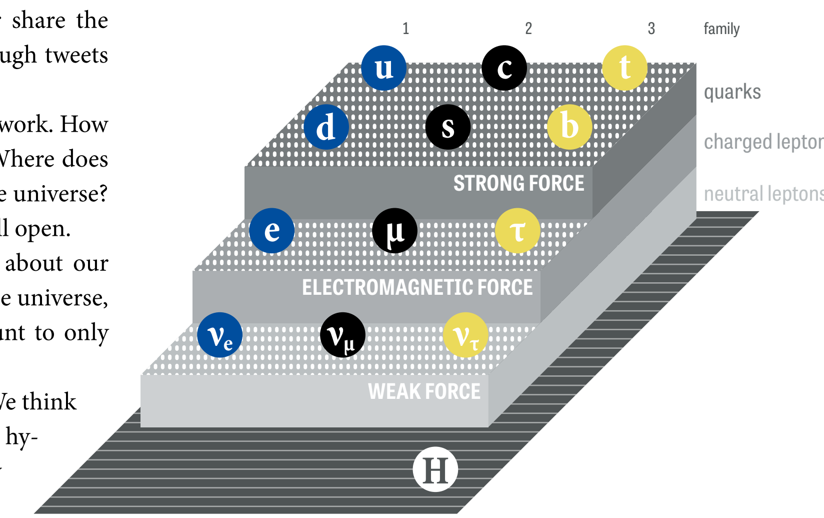


Figure 1: Today's picture of the fundamental building blocks of matter replacing the view of the 19th century based on the periodic table of elements.
Source: DESY

Our tools

Our telescopes are huge particle accelerators in which we smash the smallest particles like 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.

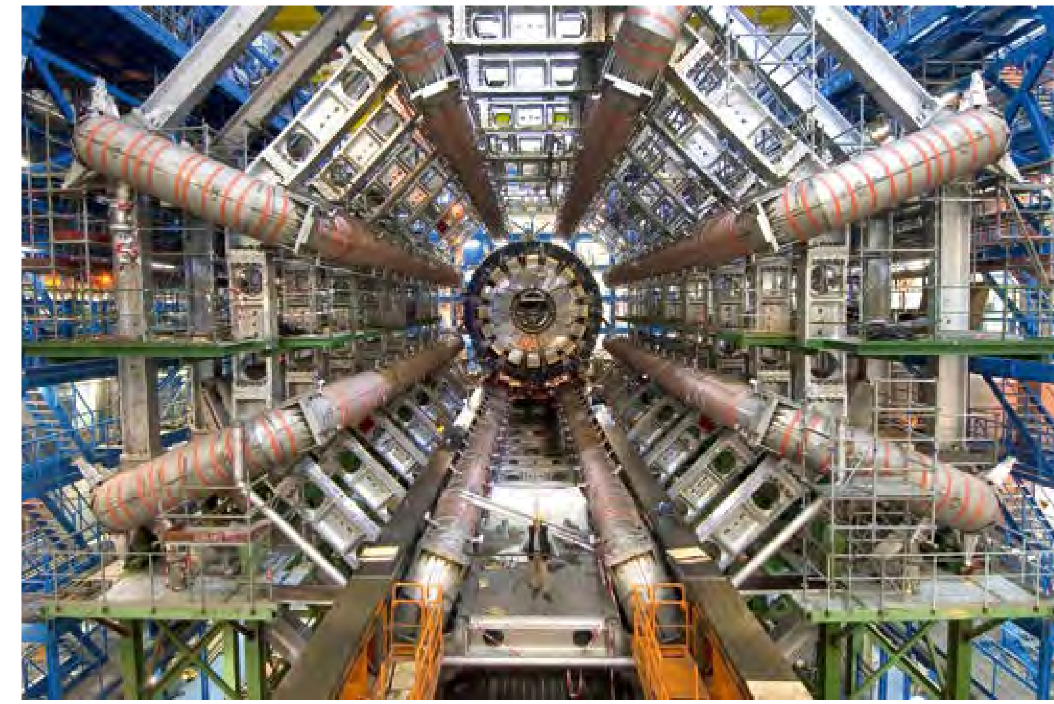
CERN, the European Organization for Nuclear Research, is an intergovernmental organization established in 1954 as one of Europe's first scientific joint ventures. Currently it has 22 member states.

More than 10,000 scientists from research institutes and universities from about 100 countries work on the experiments at CERN. Since its founding 62 years ago, CERN has become a laboratory not only for Europe, but also for the world.

My laboratory, Deutsches Elektronen-Synchrotron (German Electron Synchrotron) or DESY, is one of the key partners. In the past we operated our own particle smashers and have now joined the experiments at the LHC.

Figure 2: Schematic overview of the Large Hadron Collider. The circle indicates the tunnel 100 meters underground. Source: CERN

Figure 3: This is the iconographic image of the LHC project. It doesn't show the collider itself but the ATLAS detector during construction. Source: CERN



What is this LHC?

The Large Hadron Collider (LHC) is a 27-kilometer particle accelerator that sits in a circular tunnel some 100 meters underground. It straddles the border between France and Switzerland. In the ring, tiny particles called protons fly around in both ways and are made to collide in four points. Planning for this new collider started in the 1980s, construction got underway in the late 1990s and the collider started operation in 2008. In 2012, the Higgs particle was found and now protons collide there at the highest energy ever reached in man-made accelerators which is 13 TeV or thirteen thousand billion electron volts.

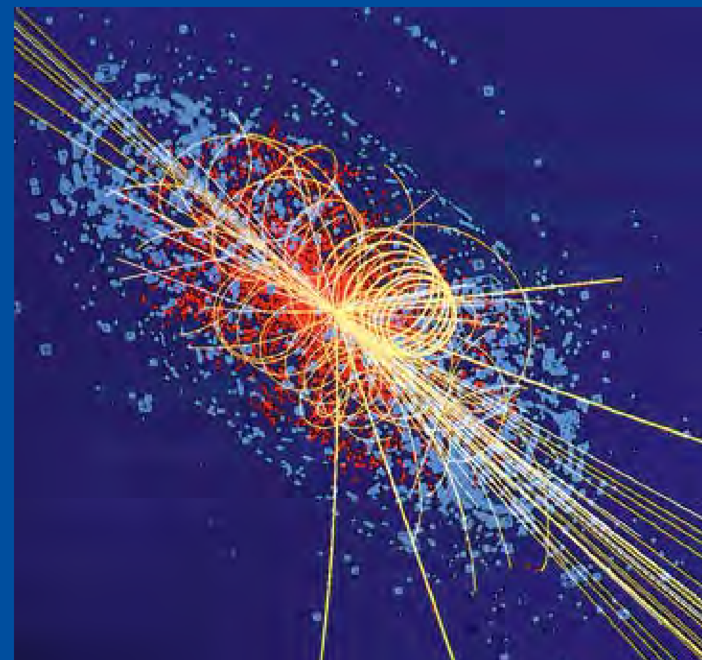
Accelerating particles doesn't tell us anything about the laws of the universe, but colliding them does. The collisions are recorded by huge detectors built and operated by thousands of physicists from all over the world.[1] They resemble digital cameras and are only up to 40 meters long, some 25 meters high and full of state-of-the-art technology to catch every single particle that appears in the collisions at a rate of 40 million images per second.

Detectors are not only marvels of technology, but also of cooperation. Thousands of scientists, students, engineers and technicians from different countries come together to design, construct and operate these detectors and analyze the data.

This happens without any strict hierarchy because everyone is driven by curiosity and the common goal of finding answers to questions that are the most fundamental mankind can ask.

1 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.

Figure 5: CMS: Higgs boson decays to four muons. Source: CERN



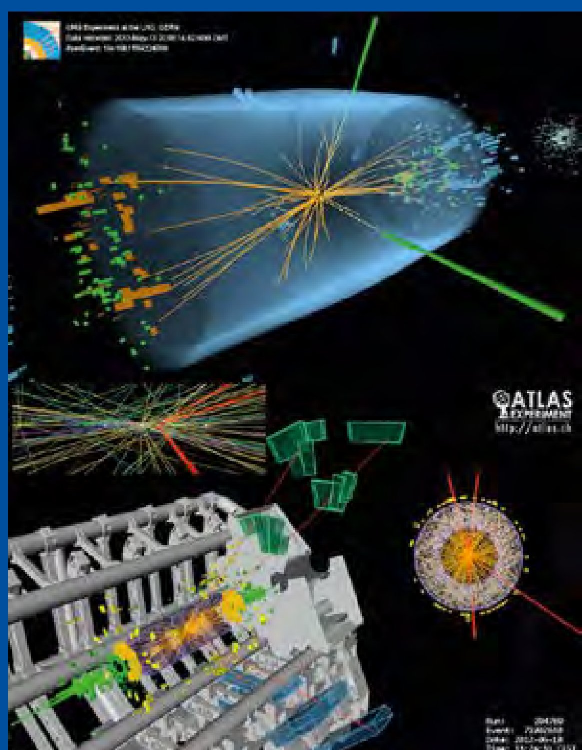


Figure 4: This computer graphic shows what a particle collision with a Higgs particle looks like in a detector. Source: ATLAS, CERN

The Higgs particle (called the God particle by some but never by physicists)

The first big success of the LHC came on July 4th, 2012 with the 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 2013, Higgs and Englert received the Nobel Prize in physics for their prediction of the Higgs particle.

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

What comes next?

The LHC discovered the one particle we had been looking for for 50 years. But what comes 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 which could explain dark matter – remember Higgs also started with a theory in the 1960s to explain mass. The most popular of these theories is called supersymmetry or SUSY. 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 is a bit like the worlds of matter and antimatter which we have been exploring since the 1930s.

The LHC will continue to run and collect data for at least the next two decades, providing ever more proton-proton collisions to be studied. But scientists are already looking at bigger and better accelerators to find more things and look at them more precisely. There are ideas and studies for a laser straight tunnel measuring up to 50 kilometers in Japan and even a 100-kilometer 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 only later do we see how useful it can be for the 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. And did you know that the World Wide Web was invented at CERN to make communication and thus the daily lives of particles physicists spread around the globe easier? It is hard to think of an invention, which by the way was made available to mankind for free, that has had a more profound impact on our society.

All the bright young people working on their PhD thesis at CERN using high-tech equipment in a very international environment are one more important spin-off. Most of them leave academia to work outside of science as problem solvers and independent thinkers who are familiar with working in an intercultural environment.

So, what about the Higgs – how is it useful for us? We don't know yet. We don't know whether one day 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 basic research work is done. At the moment, it is useful because it has broadened 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 are developing new technologies for bigger, better and more efficient colliders that could tell us things the LHC cannot.

So, let's stay curious.

OUR CURIOSITY LETS US DEVELOP THINGS THAT WE NEED FOR OUR WORK AND ONLY LATER DO WE SEE HOW USEFUL IT CAN BE FOR THE WORLD.

I wish to thank Barbara Warmbein (DESY) for her help in preparing this article.