}essentials{

Michael Hauschild

Exploring the Large Hadron Collider – CERN and the Accelerators

The World Machine Clearly Explained

Springer

essentials

Springer essentials

Springer essentials provide up-to-date knowledge in a concentrated form. They aim to deliver the essence of what counts as "state-of-the-art" in the current academic discussion or in practice. With their quick, uncomplicated and comprehensible information, essentials provide:

- an introduction to a current issue within your field of expertis
- an introduction to a new topic of interest
- an insight, in order to be able to join in the discussion on a particular topic

Available in electronic and printed format, the books present expert knowledge from Springer specialist authors in a compact form. They are particularly suitable for use as eBooks on tablet PCs, eBook readers and smartphones. *Springer essentials* form modules of knowledge from the areas economics, social sciences and humanities, technology and natural sciences, as well as from medicine, psychology and health professions, written by renowned Springer-authors across many disciplines.

More information about this series at http://www.springer.com/series/16761

Michael Hauschild

Exploring the Large Hadron Collider—CERN and the Accelerators

The World Machine Clearly Explained

Springer

Michael Hauschild
CERN – Physics Department, Geneva,
Switzerland

ISSN 2197-6708 ISSN 2197-6716 (electronic)
essentials
ISSN 2731-3107 ISSN 2731-3115 (electronic)
Springer essentials
ISBN 978-3-658-32725-5 ISBN 978-3-658-32726-2 (eBook)
https://doi.org/10.1007/978-3-658-32726-2

The translation was done with the help of artificial intelligence (machine translation by the service DeepL.com). A subsequent human revision was done primarily in terms of content.

Responsible Editor: Lisa Edelhaeuser
This Springer imprint is published by the registered company Springer Fachmedien Wiesbaden GmbH part of Springer Nature.
The registered company address is: Abraham-Lincoln-Str. 46, 65189 Wiesbaden, Germany

What You Can Find in This *essential*

- Who is doing research here?—A brief history of the European Research Center for Particle Physics (CERN)
- Matter and forces!—A small overview of the Standard Model of elementary particle physics
- Particles, very heavy!—How CERN won its first Nobel Prize
- Faster and faster!—Very small and very large particle accelerators
- The world machine!—The way to the LHC, the greatest machine ever built

Preface

The world machine, the Large Hadron Collider (LHC) at CERN, the European Organization for Nuclear Research near Geneva, is the largest particle accelerator in the world. The first ideas and concepts for the LHC were already made in the early 1980s. From these beginnings, however, it took more than a quarter of a century until the LHC was finally completed, a ring-shaped particle accelerator with a circumference of 27 km, 100 m below ground. When particle beams circulated in the LHC for the first time on September 10, 2008, the excitement among scientists was boundless. The launch of the LHC with live transmission from the LHC control room was in the top news media worldwide. The physicists were in each other's arms.

Only a few days later, on September 19, 2008, came the great disillusionment. It happened during a test: One of over 10,000 cable connections could not withstand the stress of the high electric current and melted. Nobody was hurt, but the LHC was massively damaged and it took more than a year until finally, in November 2009, operations could be resumed.

In the accident investigations, the cable connections turned out to be a potential weak point. It would have taken far more than a year to check and repair or even renew all connections. CERN's management, therefore, decided to operate the LHC at half power for the time being in order not to put too much stress on the connections.

But even half the energy was enough to announce the discovery of a new elementary particle on July 4, 2012 using the two large particle detectors ATLAS and CMS. And the LHC continued to run. In March 2013, the physicists from ATLAS and CMS were finally certain that the newly discovered particle was indeed the long-sought Higgs particle.

More than 50 years ago, in 1964, theoretical physicists Robert Brout, François Englert, and Peter Higgs, among others, published ideas on how elementary particles can obtain mass, that is, become heavy. One consequence of their theories is the existence of a new particle, the Higgs particle, named after Peter Higgs. For a long time, this particle was searched for at various particle accelerators and detectors around the world, until the physicists finally found it at the LHC. Brout had already died in 2011 and could not live to see the triumph, but Englert and Higgs were awarded the Nobel Prize in Physics in autumn 2013, with great jubilation and sympathy from the physicists involved at CERN.

But this is not the end of research at the LHC, it is only the beginning. The newly discovered Higgs particle must be measured, its properties determined and compared with the theoretical predictions. More new particles may just be waiting to be found in the next few years, and every newly discovered particle could trigger a revolution in the understanding of our world and the universe.

Since the beginning of 2013, the LHC and the particle detectors have, therefore, been made fit for the new challenges. In a break of more than 2 years, all weak points in the cable connections were eliminated, new safety systems were installed and the detectors were improved in order to unravel even more of nature's secrets with now higher energy.

As more than 5 years earlier, the first circulating particle beams were eagerly awaited in March 2015 and the LHC was put back into operation. Finally, after a further 2 months, the accelerator physicists were ready: On June 3, 2015, the first collisions took place at almost twice the energy as before: 13 TeV, comparable to the energy of two colliding mosquitoes, but highly concentrated on two tiny particles, and once again a new world record.

The world machine is running again! In the coming months and years, particle physicists will look even more intensively than before into their collected data from the countless collisions to see if there are any indications of new particles and new phenomena beyond the so-called Standard Model.

This *essential* is part of a series on the LHC relaunch in spring 2015 and takes you back to the very beginnings of CERN, one of the most fascinating research centers ever, its history, its people and its accelerators. You will learn about how particle accelerators work and how the first ideas were used to build the LHC, the world's largest machine today.

In other *essentials* of this series you will learn more about the experiments and detectors at the LHC, the discovery of the Higgs particle, the current restart, and