



A Boson Named Higgs

Gabriele Veneziano



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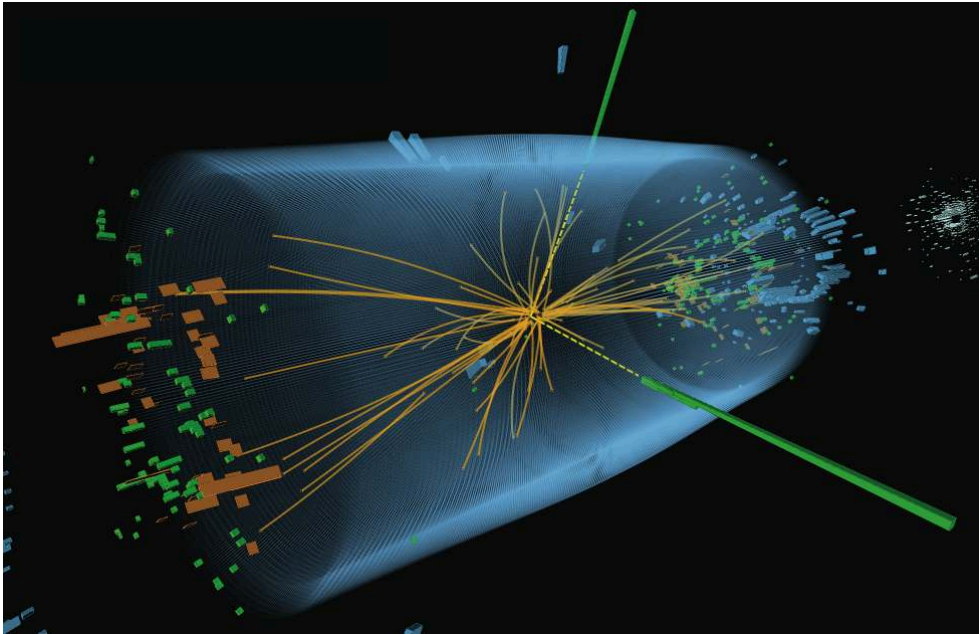
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EDITOR'S NOTE

Source: La lettre, no. 38, June 2014

- 1 **On 24 May 2013 the Collège de France Chair of Elementary Particles, Gravitation and Cosmology, created in 2004, organized a closing symposium entitled: “A Boson Named Higgs”. The origin of this initiative can be found in the Chair’s Inaugural Lecture in February 2005, when it was planned that the future discoveries of the CERN’s Large Hadron Collider (LHC), located near Geneva, would soon be the topic of an annual lecture series.**



An event in the CMS detector interpretable as the disintegration of a Higgs boson into two photons (tracks in green)

© Guido Tonelli

- 2 Unfortunately, due to several delays in the launch of the accelerator, these discoveries took longer than expected. The discovery of the “Higgs boson” only happened in July 2012, when the Chair’s last annual lecture series had just been completed. To make up for this “shortcoming”, the Chair organized a symposium entirely dedicated to this fundamental discovery, which was rewarded a few months later with the Physics Nobel Prize awarded to François Englert and Peter Higgs.
- 3 The existence of the “Higgs boson” is the “cherry on the cake” of what is called the Standard Model (SM), the different aspects of which the Chair presented for eight years. According to the SM, all known matter (that is, excluding the still mysterious dark matter) is made of a small number of so-called elementary particles. These constituents of matter are all “fermions”, particles characterized primarily by their inability to cohabit with a second identical fermion (Pauli’s exclusion principle). The most familiar example of a fermion is the electron. The exclusion principle implies that the electrons orbiting around an atom’s nucleus must be in different states (or orbits) – which explains the periodic table of elements remarkably well.
- 4 On the other hand, in the SM the different interactions between fermions stem from their exchanging “bosons” among themselves. Unlike fermions, bosons like to cohabit with other bosons of the same kind. When a very large number of such bosons gather together, they form a macroscopic field. Here the most famous example is the photon. The field produced by a large number of photons is none other than the widely known electromagnetic field.
- 5 The Higgs boson is no exception to this rule: like the photon, it can also generate a field, called the Higgs field. But unlike an electromagnetic field, the Higgs field does not have a direction in space. It is what is called a “scalar” field, which bears more resemblance to a density or temperature field. The originality of the Higgs field lies in the fact that, according to the SM, it already exists in the absolute vacuum, since, by properly choosing its value, it is possible to lower the energy with respect to the one

which would have prevailed in its absence (whereas an electromagnetic field can only increase the energy).

- 6 The presence of this field has a spectacular effect on (almost) any other particle living in it: the given particle, which would have no mass without the Higgs field, acquires a mass proportional to its “charge” (the analogue of the electric charge but for the Higgs field). Essentially, only the photon (that does not have this charge) remains massless. The other elementary particles, particularly the fermions that form all visible matter, have a non-zero mass in agreement with observations.
- 7 Although this was all very nice from a theoretical point of view, until then no experimental proof existed that elementary particle masses are linked to the existence of this field in the “vacuum” and therefore, ultimately, to the existence of the boson that produces it. Its discovery at CERN spectacularly confirmed what theorists had expected for over fifty years! Without any doubt the event warranted a celebration worthy of the Collège de France.
- 8 The closing symposium sought to include all the ingredients that contributed to the discovery of the boson in question.
- 9 After a brief introduction by the Chair, theorist Jean Iliopoulos (ENS Paris) recalled the ideas, which, in the 1960s, had led to proposals for the BEH (Brout-Englert-Higgs) mechanism and the existence of a boson associated with it.
- 10 Fabiola Gianotti (CERN) and Guido Tonelli (Pisa) presented the developments in particle detectors stemming from their experimental collaborations (ATLAS and CMS respectively) which, through billions of collisions, allowed for particle detectors to single out those containing the precious boson. At the same time, they reviewed the data analysis.
- 11 Jorg Wenninger and Frederic Hemmer (respectively a physicist and a systems engineer at CERN) discussed the technological challenges (building the LHC) and the challenges in informatics (data processing) that were so crucial to the LHC’s success.
- 12 Riccardo Barbieri (ENS Pisa) then discussed possible theoretical spin-offs of the discovery. To conclude, a roundtable moderated by the Chair considered some possible post-Higgs scenarios.

Videos of the symposium are available at www.college-de-france.fr, on the professor’s page.

Programme

Introduction

Gabriele Veneziano, Collège de France

From Design to Discovery

Jean Iliopoulos, ENS Paris

ATLAS

Fabiola Gianotti, CERN

CMS

Guido Tonelli, INFN, Pisa

The Road towards High-Power LHC

Jorg Wenninger, CERN

The Worldwide LHC Computing Grid

Frédéric Hemmer, CERN

Implications and Theoretical Perspectives

Riccardo Barbieri, SNS, Pise

After Higgs, What's Next?

Gabriele Veneziano, Collège de France

AUTHOR

GABRIELE VENEZIANO

Emeritus Professor, Elementary Particles, Gravitation and Cosmology (2004-2013)