Discovery of GOD Particle

Philosophical view on Higgs Boson Particle

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1. INTRODUCTION

In the early 1960s, a new particle was hyped by several groups when it was used to answer the question of where the masses of elementary particles come from; this particle is usually referred to as the Higgs particle or the Higgs boson. In July 2012, this Higgs particle was finally verified experimentally by the ATLAS collaboration and the CMS collaboration using the Large Hadron Collider at CERN.

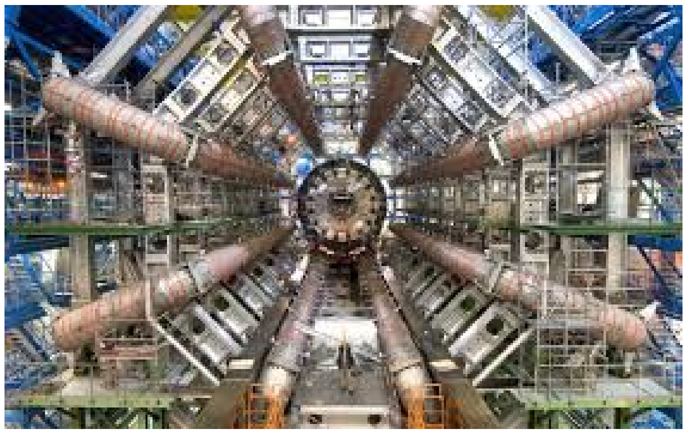

Figure-1: A section of the Large Hadron Collider (LHC) beneath the France–Switzerland border near Geneva

1.1 History of the HIGGS Particle

The Higgs boson is an elementary particle in the Standard Model of particle physics. First suspected to exist in the 1960s, it is the quantum excitation of the Higgs field (the field produced by boson particles). Unlike other known fields such as the electromagnetic field, it has a non-zero constant value in vacuum. The question of the existence of the Higgs field became the last unverified part of the Standard Model of particle physics, and for several decades, was considered "the central problem in particle physics".

Particle physicists study matter made from fundamental particles whose interactions are mediated by exchange particles – gauge bosons – acting as force carriers. At the beginning of the 1960s a number of these particles had been discovered or proposed, along with theories suggesting how they relate to each other, some of which had already been reformulated as field theories in which the objects of study are not particles and forces, but quantum fields and their symmetries, however, attempts to unify known fundamental forces such as the electromagnetic force and the weak nuclear force were known to be incomplete.

The presence of the field, now confirmed by experimental investigation, explains why some fundamental particles have mass, despite the symmetries controlling their interactions implying that they should be massless. It also resolves several other long-standing puzzles, such as the reason for the extremely short range of the weak force.

1.2 Name of Higgs - Boson

The Higgs boson, the subatomic particle that has brought a Nobel Prize to Francois Englert and Peter Higgs, is so small that its discovery took 40 years. Yet, it is so big for physics, that it took on the nickname the "God particle." Although, the name itself have little scientific significance, and was the invention of Leon Lederman, himself a great physicist, who used it as the title of a popular book in 1993. The nickname, though, is a deft little contribution to the communication of science. Because of it, countless more people have heard of the Higgs particle, why it matters, and how much effort went into finding it.

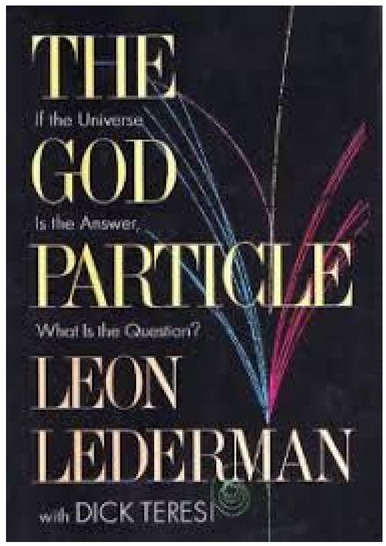

Figure-2: Cover of the original book "The God Particle" by Leon Lederman published in 1993

The name most strongly associated with the particle and field is the Higgs boson and Higgs field. For some time the particle was known by a combination of its PRL author names (including at times Anderson), for example the Brout–Englert–Higgs particle, the Anderson-Higgs particle, or the Englert–Brout–Higgs–Guralnik–Hagen–Kibble mechanism, and these are still used at times.

A considerable amount has been written on how Higgs' name came to be exclusively used. One main explanation is that Higgs undertook a step which was either unique, clearer or more explicit in his paper in formally predicting and examining the particle. Of the PRL papers' authors, only the paper by Higgs explicitly offered as a prediction that a massive particle would exist and calculated some of its properties. He was therefore "the first to postulate the existence of a massive particle" according to Nature.[161]

1.3 Summary and impact of the PRL papers

The three papers written in 1964 were each recognised as milestone papers during Physical Review Letters's 50th anniversary celebration. Their six authors were also awarded the 2010 J. J. Sakurai Prize for Theoretical Particle Physics for this work. Two of the three PRL papers (by Higgs and by GHK) contained equations for the hypothetical field that eventually would become known as the Higgs field and its hypothetical quantum, the Higgs boson. Higgs' subsequent 1966 paper showed the decay mechanism of the boson; only a massive boson can decay and the decays can prove the mechanism. In the paper by

Higgs the boson is massive, and in a closing sentence Higgs writes that "an essential feature" of the theory "is the prediction of incomplete multiplets of scalar and vector bosons".[62]

2. SIGNIFICANCE OF HIGGS BOSON

Evidence of the Higgs field and its properties has been extremely significant for many reasons. The importance of the Higgs boson is largely that it is able to be examined using existing knowledge and experimental technology, as a way to confirm and study the entire Higgs field theory. Conversely, proof that the Higgs field and boson do not exist would have also been significant. Here, we mention some of the most significant contribution to the science by this discovery.

2.1 Validation of the Standard Model

The Higgs boson validates the Standard Model through the mechanism of mass generation. As more precise measurements of its properties are made, more advanced extensions may be suggested or excluded. As experimental means to measure the field's behaviours and interactions are developed, this fundamental field may be better understood. If the Higgs field had not been discovered, the Standard Model would have needed to be modified or superseded.

Related to this, a belief generally exists among physicists that there is likely to be "new" physics beyond the Standard Model, and the Standard Model will at some point be extended or superseded. The Higgs discovery, as well as the many measured collisions occurring at the LHC, provide physicists a sensitive tool to parse data for where the Standard Model fails, and could provide considerable evidence guiding researchers into future theoretical developments.

2.2 Symmetry breaking of the electroweak interaction

Below an extremely high temperature, electroweak symmetry breaking causes the electroweak interaction to manifest in part as the short-ranged weak force, which is carried by massive gauge bosons. This symmetry breaking is required for atoms and other structures to form, as well as for nuclear reactions in stars, such as our Sun. The Higgs field is responsible for this symmetry breaking.

2.3 Particle mass acquisition

The Higgs field is pivotal in generating the masses of quarks and charged leptons (though Yukawa coupling) and the W and Z gauge bosons (though the Higgs mechanism).

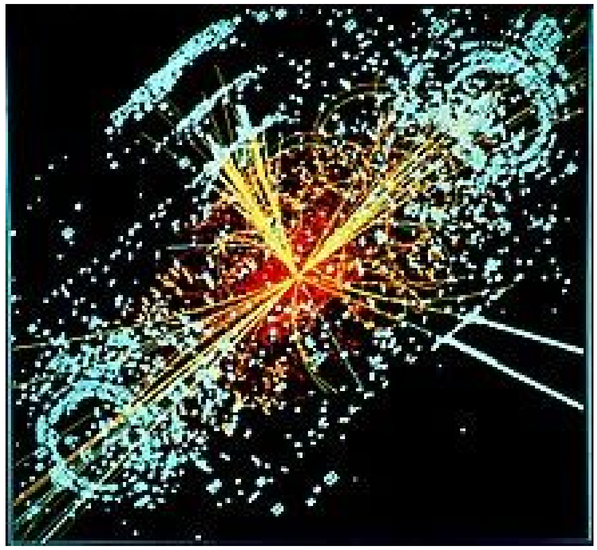

Figure-3: Simulated Large Hadron Collider CMS particle detector data depicting a Higgs boson produced by colliding protons decaying into hadron jets and electrons

It is worth noting that the Higgs field does not "create" mass out of nothing (which would violate the law of conservation of energy), nor is the Higgs field responsible for the mass of all particles. For example, approximately 99% of the mass of baryons (composite particles such as the proton and neutron), is due instead to quantum chromodynamics binding energy, which is the sum of the kinetic energies of quarks and the energies of the massless gluons mediating the strong interaction inside the baryons. In Higgs-based theories, the property of "mass" is a manifestation of potential energy transferred to fundamental particles when they interact ("couple") with the Higgs field, which had contained that mass in the form of energy.

2.4 Scalar fields and extension of the Standard Model

The Higgs field is the only scalar (spin 0) field to be detected; all the other fields in the Standard Model are spin ½ fermions or spin 1 bosons. According to Rolf-Dieter Heuer, director general of CERN when the Higgs boson was discovered, this existence proof of a scalar field is almost as important the Higgs' role in determining the mass of other particles. It suggests that other hypothetical scalar fields, from the inflaton to quintessence, could perhaps exist as well.

3. IS IT A GOD PARTICLE

The Higgs boson is often referred to as the "God particle" in popular media outside the scientific community. The phrase "God Particle" was plastered across the front pages of news outlets everywhere when the discovery of the particle was announced in 2012. But contrary to popular belief, the scientific community disregard this name. Many scientists feel the name is inappropriate since it misleads readers; the particle has nothing to do with God. It leaves open numerous questions in fundamental physics, and does not explain the ultimate origin of the universe.

4. THE CMS EXPERIMENT

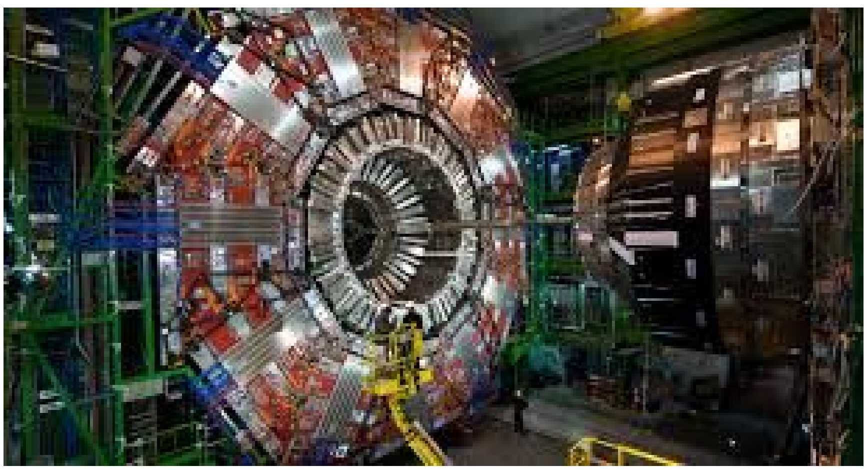

Figure-4: Setup of the Compact Muon Solenoid (CMS) experiment at a research institute in Cessy, France

The Compact Muon Solenoid (CMS) experiment is one of two large general-purpose particle physics detectors built on the Large Hadron Collider (LHC) at CERN in Switzerland and France. The goal of CMS experiment is to investigate a wide range of physics, including the search for the Higgs boson, extra dimensions, and particles that could make up dark matter. The search for the SM Higgs particle played a crucial role in the design of the CMS detector. Because the mass of the Higgs was not predicted by theory and because the production cross section and width vary widely across the allowed mass region the detector had to be quite flexible. The fact that the detector had to be able to detect multiple decay modes also entered into the design. "The central feature of the CMS apparatus is a superconducting solenoid of 6 m internal diameter, which provides a magnetic field of 3.8 T [123]. Within the field volume are a silicon pixel and strip tracker, a lead tungstate crystal electromagnetic calorimeter (ECAL), and a brass/scintillator hadron calorimeter (HCAL).Muons are measured in gas-ionization detector embedded in the steel flux-return yoke. Extensive forward calorimeters complement the coverage provided by barrel and end cap detector.

5. PHILOSOPHICAL VALUE OF HIGGS BOSON

The discovery of the Higgs particle in Summer 2012 marked a milestone in high energy physics. It concluded the search for standard model particles that had been a main goal of experimental high energy physics since the early 1970s. It may also lead towards indications for new physics and therefore could emerge as the first step beyond standard model physics. This crucial point in the evolution of experimental high energy physics offers a fitting basis for philosophical reflections on the empirical status of high energy physics. Recent decades have brought about considerable changes in the layout and character of collider experiments. In a number of ways, empirical testing in contemporary high energy physics differs from the classical understanding of experimental testing. New conceptual issues have emerged that are philosophically significant and must be of concern for a philosophy of physics that aims at being at the height of its time. Those issues are intensely discussed among experimental high energy physicists themselves, which offers a good opportunity for interaction between the philosophy of physics and one of the leading fields of physical research. Moreover, those issues can also have repercussions for the general philosophy of science by raising substantial philosophical questions with respect to the relation between theory and experiment, the epistemic status of theoretical statements and the notions of empirical confirmation and discovery.

The Higgs discovery is not only the culmination of a long quest, but also the start of a new era in particle physics. The verification of a key prediction of the mechanism of mass generation is, indeed, a landmark, but now the challenge is to understand the dynamics that underlie it, and its possible connection with issues in other areas of science, such as astrophysics and cosmology.

One viewpoint is that the Higgs boson may be a particle that is as elementary as the electron or photon, in which case it may be accompanied by many other as-yet-undiscovered particles as in the supersymmetric theories discussed in the paper by Allanach [8], which may also provide the dark matter postulated by astrophysicists. Alternatively, as suggested by Grojean [9], the Higgs boson may be a manifestation of some novel strong interactions that could have interesting implications for future experiments on the Higgs boson as well as other possible new particles. The possible connections between the Higgs boson and cosmology are reviewed in the paper by Shaposhnikov [10]. Puzzling aspects of conventional Big Bang cosmology include its size and the fact that Euclidean geometry is so successful. One possible way to resolve these puzzles may be via an epoch of cosmological inflation, perhaps driven by energy in 'empty' space related to the Higgs, a suggestion that is now being challenged by measurements of the cosmic microwave background radiation.

One another aspect of this discovery is that even though the Standard Model Higgs Mechanism forms part of the Standard Model as a renormalizable quantum field theory, which, to the current date, describes all phenomena observed at particle colliders to very high precision, physicists have searched for alternatives to a fundamental Higgs field already early on. Evidently, until very recently one of the main motivations for this was the lack of direct experimental evidence for the Higgs boson. However, even now after the recent discovery of a Higgs-like particle, many particle physicists would consider the confirmation of this particle being the Higgs boson with properties exactly as predicted by the SM as a disappointment. The paper by S. Friederich et.al. [987] examine the "physicists' charge of ad hocness against the Higgs mechanism in the standard model of elementary particle physics". They argue that even though this charge never rested on a clear-cut and well-entrenched definition of “ad hoc”, it is based on conceptual and methodological assumptions and principles that are well-founded elements of the scientific practice of high-energy particle physics.

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