This month and next month mark two important anniversaries in the field of particle physics—the 50th anniversary of the inauguration of Fermilab (the Fermi National Accelerator Laboratory, just outside of Chicago, Illinois) and the 5th anniversary of the Higgs boson discovery at CERN (the European Organization for Nuclear Research, in Geneva, Switzerland). These two institutions have been united in their commitment to elucidate the laws that govern the physical universe. Their main achievements (the discovery of bottom and top quarks at Fermilab, and of the W, Z, and Higgs bosons at CERN) reflect how Fermilab and CERN, with other laboratories around the world, have joined forces throughout these 50 years to prove right the “standard model”—the theory that describes the fundamental components of matter that we know of—or, to challenge it. Our quest to understand the makeup and behavior of the world, to answer fundamental questions about the past and future of our universe, and to explore the possible existence of an ultimate “theory of everything” should continue to be a worldwide effort.

Coincidentally, 50 years have also passed since American physicist Steven Weinberg implicitly opened the hunt for the Higgs particle by making it the keystone of the unified theory of weak and electromagnetic interactions, necessary to give a mass to the known particles. That theory, which by 1973 evolved into what today is called the standard model, condenses in a few lines of mathematical formula all that is known about the elementary components of matter (quarks and leptons), their interactions, and how they shape the world around us. Among other successes, it describes how the elements of the periodic table formed during the “Big Bang” and during the lifetime of stars, and explains the measured properties of the electron with a precision better than one part in a billion. The existence of the Higgs boson represented, until 2012, the last remaining untested prediction of the standard model.

Five years after the discovery, the study of the Higgs boson’s properties is just entering the precision phase required to further challenge the standard model. Why should physicists be eager to detect cracks in what appears as a perfect theory? The mechanism by which the Higgs boson gives masses to particles relies on ad hoc assumptions about its dynamical behavior. Today’s evidence is that those assumptions are correct, but will they be challenged by future, more precise, data? What is their origin? Is there a more fundamental theory that dictates them?

Furthermore, the standard model does not account for dark matter, neutrino masses, and the abundance of matter over antimatter in the universe. Is there a connection between these phenomena and the deep structure of the Higgs? What new theory will take us beyond the standard model, to explain all of that? Whatever emerges, the standard model will stand as one of humanity’s most profound intellectual achievements, much like Newton’s law of gravity: Einstein’s theory of general relativity did not disprove it, but found its deeper origin and went beyond, thus opening new perspectives on our world, from black holes to the expansion of the universe.

As we celebrate their achievements, CERN and Fermilab look ahead together and with other laboratories to identify the origin of the Higgs mechanism, neutrino masses, and dark matter. Such ambitions will continue to require farsightedness, determination, and patience. As we discover new particles, interactions, and phenomena, answering the “What?” and fortifying our understanding of “How?” will move us ever closer to addressing the most difficult question: “Why?”

–Michelangelo Mangano

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