3 Questions: Physicist Christoph Paus discusses newly discovered particle

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MIT Professor of Physics Christoph Paus

Today CERN, the European Organization for Nuclear Research, announced the most conclusive evidence yet for the existence of the Higgs boson (at 5 sigma), a long-elusive cornerstone of the Standard Model of physics. This subatomic particle, first postulated in the 1960s and widely sought ever since, is thought to underlie the origins of mass.

More than 50 MIT physicists and students were part of the CMS (Compact Muon Solenoid) experiment at CERN's Large Hadron Collider, representing that experiment's largest contingent of physicists from any American university. MIT Professor of Physics Christoph Paus is one of two lead investigators (with Albert De Roeck of CERN) on the CMS Higgs search, which comprises roughly 500 scientists.

Paus spoke with MIT News about the Institute's contribution to this apparent breakthrough in particle physics, as well as the result's significance for our understanding of the universe.

Q. What are the implications of this newly discovered particle? Why should non-physicists care about this?

A. The search for the Higgs boson at the Large Hadron Collider is the culmination of research over the last half-century. This particle is inextricably intertwined with an incredibly mundane-sounding question: "What is the physics of motion?"

Motion ties together the fundamental concepts of space, time and mass: Space and time are linked through velocity, while mass is the resistance to changes in velocity. Explaining motion was important enough that Aristotle sought to do so, and his answer stood for almost 2,000 years. But penetrating more deeply into the mysteries of motion led to the revolutions of Galileo, Newton and Einstein.

In this same tradition, the Higgs boson holds the promise of beginning to finally elucidate the fundamental origins of mass. We cannot yet say whether the phenomenon we are reporting today is indeed the Higgs; that will take much more data to determine. But so far it fulfills our search criteria, and if confirmed, will set an important milestone in our understanding of nature. Should we be observing something other than the Higgs — well, that may be even more important.

Q. What was MIT's contribution to this finding?

A. The MIT group is coordinated by six faculty members and has more than 50 members, including graduate and undergraduate students, making it the largest U.S. university group on the CMS experiment. The group was founded several decades ago by Jerry Friedman and the late Henry Kendall [both of MIT], together with Richard Taylor [of the Stanford Linear Accelerator Center, or SLAC], who demonstrated the existence of quarks in a series of experiments from 1967 to 1973. Today our group analyzes topics as diverse as heavy-ion physics and Higgs searches, which have become our focus since 2009.

The MIT team is deeply involved in four of the five core searches for the Higgs boson. Our group's most prominent contribution in finding this new particle is our work on the analysis of the Higgs's decay to two photons, which represents the lion's share of the observation of the new particle.

Traditionally graduate students and postdocs are the workhorses of such analysis efforts, and in many ways our students and postdocs pioneered the analysis of Higgs bosons' decay into two photons. One outstanding example was the introduction of advanced techniques — the so-called multivariate analyses, or MVA, techniques — into the standard analysis. The MVA has boosted the sensitivity of the two-photon analysis substantially. Through the rigorous application of MVA techniques, we were able to increase the power of the data by more than 50 percent.

Q. What is the next step for this research?

A. To find a particle discovery of similar magnitude, one perhaps has to go all the way back to 1974, and the discovery of the J/psi particle by Samuel Ting [of MIT] and Burton Richter [of SLAC]. At that time the nature of the J/psi particle was not obvious: There was speculation, but it took several years to unravel its nature completely.

In the wake of that event, an entire new family of particles was discovered, which clearly determined the nature of the initially mysterious J/psi particle and changed our view of particle physics forever in the so-called “November Revolution.” The analogy with the present situation is certainly not perfect, but there are some important lessons to be learned.

We do not yet understand the nature of this new particle we have found with the CMS experiment: We have our suspicions that it could be the Higgs boson, as predicted by the Standard Model, but it could also be something else. There is, for example, the theory of supersymmetry, which predicts more such types of particles that we might find in further analyses. Their discovery — or unambiguous identification of the new particle as something other than the Higgs boson — would be even more exciting and would cause another revolution in our understanding of particle physics.

To resolve these issues, it is vital to map out the properties of this new particle, so our MIT research group will now focus on measuring all possible properties of this particle, including its couplings with other particles and its spin. This will require substantially more data and an extension of the analysis to include more ways this new particle might manifest in the detector. In the same vein, we will keep our eyes open for more particles of similar nature, since history tells us if you find one particle there might be more around the corner.

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