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All Signs Point to Higgs, but Scientific Certainty Is a Waiting Game

By DENNIS OVERBYE

In their bones, physicists feel it is the long-lost Higgs boson, but in science, feelings take second place to data. So these same physicists admit that it will take more work and analysis before they will have the cold numbers that clinch the case that the new particle announced on July 4 last year is in fact the exact boson first predicted by Peter Higgs and others in 1964 to be the arbiter of mass and cosmic diversity. "Personally, I have no problems calling this *a* Higgs boson," said Joe Incandela, a professor at the University of California, Santa Barbara, and spokesman for the leader of one of the teams, known as CMS, that reported the new particle last July. "If it's not, I won't mind eating my words, because it would be so much more interesting."

He spoke on the eve of the Moriond workshop in La Thuile, Italy, where on Wednesday CERN physicists will present the latest analysis of some 2,000 trillion collisions recorded by the Large Hadron Collider. There could still be surprises, but so far, physicists say, the particle is on target with the predictions of the Standard Model, the current reigning theory in physics. Which is a triumph for the theorists who invented the boson, but might be a disappointment for those who dream of revolution.

"We are in post-discovery depression," said Eilam Gross, one of the CERN physicists on the Atlas team. "What happens when you search for something and then it turns out to be exactly what you are looking for?"

What happened in the first instant of the Big Bang? What happens at the middle of a black hole where matter and time blink in or out of existence? What is the dark matter whose gravitational influence, astronomers say, shapes the structures of galaxies, or the dark energy that is forcing the universe apart? Why is the universe full of matter but not antimatter?

And what, finally, is the fate of the universe? These are all questions that the Standard Model, the vanilla-sounding set of equations that ruled physics for the last half century, does not answer. Some of them could be answered by the unproven theory called supersymmetry, which among other things is needed to explain why whatever mass the Higgs has is low enough to be discovered in the first place and not almost infinite. It predicts a whole new population of elementary particles — called superpartners to the particles physicists already know about — one of which could be the dark matter that pervades the universe. If such particles exist, they would affect the rate at which Higgs bosons decay into other particles, but the CERN teams have yet to record what they consider a convincing deviation from the Standard Model predictions for those decays. Supersymmetry is still at best a beautiful idea.

One thing that has hampered progress is that physicists still do not agree on how much the new particle weighs. Eyebrows were raised in December when the Atlas team reported that their two different methods of measuring the boson's mass do not agree. They get a mass of 126.6 billion electron volts by watching for it to decay into a pair of gamma rays, and 123.5 billion electron volts when they look for a signature of four charged particles. The spread of more than three billion electron volts means the error bars for the two measurements do not overlap. The results from the rival CMS are closer together, in the middle, consistent with a mass of 125.8 billion electron volts.

Atlas physicists say the effect is most likely a statistical fluctuation that will be cured eventually with more data.

What does it matter how much a Higgs boson weighs? It could determine the fate of the universe.

In December 2012, shortly after CERN teams first declared that they had seen signs of the famous boson with a mass of 125 billion electron volts, Gian Giudice, a CERN theorist, and his colleagues ran the numbers and concluded that the universe was in a precarious condition and could be prone to collapse in the far, far future.

The reason lies in the Higgs field, the medium of which the Higgs boson is the messenger and which determines the structure of empty space, i.e., the vacuum.

It works like this. The Higgs field, like everything else in nature, is lazy, and, like water running downhill, always seeks to be in the state of lowest energy. Physicists assume that the Higgs field today is in the lowest state possible, but Dr. Giudice found that was not the case. What counts as rock bottom in today's universe could turn out to be just a plateau.

Our universe is like a rock perched precariously on a mountaintop, he explained, in what physicists call a metastable state. The Higgs field could drop to a lower value by a process known as quantum tunneling, although it is not imminent.

Dr. Giudice's calculations suggest that it would take much longer than the age of the universe; the whole Milky Way galaxy could disappear into a black hole long before then. Which is good.

If that should happen — tomorrow or billions of years from now — a bubble would sweep out through the universe at the speed of light, obliterating the laws of nature as we know them.

Reports of this work caused a flurry in the press. As Jeremy Bernstein, the noted physicist and author, wrote in a recent e-mail after reading the news, “Help!!!”

But it’s not time to dial up a Mayan priest for guidance yet. The calculations assume that the Standard Model is the final word in physics, good for all times and places and energies — something that no physicist really believes. Theories like supersymmetry or string theory could intercede at higher energies and change the outcome.

The calculations also depend crucially on the mass of the top quark, the heaviest known elementary particle, as well as the Higgs, neither of which have been weighed precisely enough yet to determine the fate of the universe. If the top quark were just a little lighter or the Higgs a little heavier, 130 billion electron volts, Dr. Giudice said, the vacuum would in fact be stable.

It’s a puzzle, he said, why the universe exists in such a critical state. In an e-mail, Dr. Giudice wrote, “Why do we happen to live at the edge of collapse?”

He went on, “In my view, the message about near-criticality of the universe is the most important thing we have learned from the discovery of the Higgs boson so far.”

Guido Tonelli of CERN and the University of Pisa, said, “If true, it is somehow magic.” We wouldn’t be having this discussion, he said, if there hadn’t been enough time already for this universe to produce galaxies, stars, planets and “human beings who are attempting to produce a vision of the world,” he said.

“So, in some sense, we are here, because we have been lucky, because for this particular universe the lottery produced a certain set of numbers, which allow the universe to have an evolution, which is very long.”

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