The Higgs Boson: A Theory, An Observation, A Tool

With her firm belief in the standard model, physicist Manuella Vincter was confident that the Higgs boson would be seen at the Large Hadron Collider (LHC). She's less sure about what might come next.

By **Marric Stephens**

This article is part of a series of pieces that Physics Magazine *is publishing to celebrate the 10th anniversary of the Higgs boson discovery. See also: **Poem: Higgs Boson: The Cosmic Glyph**; **Research News: A Particle is Born: Making the Higgs Famous**; **News Feature: The Era of Higgs Physics**; **Podcast: The Higgs, Ten Years After**; and **Collection: The History of Observations of the Higgs Boson**.*

A high-energy physicist at Carleton University, Canada, and a deputy spokesperson for the ATLAS experiment at the Large Hadron Collider (LHC) at CERN in Switzerland, Manuella Vincter has spent her whole career working on high-energy-physics problems. She started in high-energy physics in the early 1990s, when, as a master's student, she joined CERN's Large Electron-Positron Collider (LEP) and began what she calls an ongoing "love affair" with *W* and *Z* bosons.

Credit: CERN

Vincter's early research focused on the symmetry-breaking process by which *W* and *Z* bosons, carriers of the weak force, acquire mass. LEP had been designed to probe the limits of the standard model of particle physics—the theory that classifies all the known particles— by testing such processes with unprecedented precision. Researchers also thought that LEP had a reasonable chance of spotting another boson that fascinated Vincter—the Higgs boson—although that wasn't to be.

In 1998, Vincter moved to the ATLAS experiment, which was conceived with the Higgs boson firmly in its cross hairs. There, she helped assemble and test one of ATLAS's particle detectors. She was part of ATLAS's Canada team when the Higgs boson was discovered and has remained with the ATLAS Collaboration ever since. *Physics Magazine* spoke to Vincter about the searches for the Higgs boson at LEP and at ATLAS, and her hopes for the next major milestone in particle physics.

All interviews are edited for brevity and clarity.

How optimistic were researchers that they would find the Higgs boson at LEP?

At that time, we didn't know for sure that the Higgs existed, and if it did exist, we didn't know what its mass was. But LEP was thought to be a place where we might see the particle.

There are two ways physicists can detect the Higgs boson. One is to measure it directly like we did at the LHC; it just appeared in the experiment. The other way is to spot it indirectly by measuring other processes sensitive to interactions with the Higgs boson. Both approaches were tried at LEP. When LEP was dismantled in 2001 to make way for the LHC, we knew that if the standard-model Higgs boson existed, then its mass was, unfortunately, in a range beyond the reach of LEP.

Interestingly, just when data-taking was finishing at LEP, there were calls by some members of one of the teams to delay the shutdown by a year or so because they had seen a little excess signal at a certain energy that might have indicated the Higgs. That delay didn't happen. Instead, we put all our energies into finishing the LHC, because if the Higgs was there, we thought we'd see it, no question. It was a no-lose scenario.

So you were sure that the Higgs boson existed and would be found by the LHC?

I've always been a true believer in the standard model. It's been tested extensively, and every time it comes up against a new challenge it ends up winning. So by the time LEP was over, I could tell you where the Higgs should be within about 50 GeV.

With the knowledge that you have now, do you think that LEP did spot the Higgs boson?

No, the excess events were at the wrong energy—they didn't match what we know now to be the Higgs boson mass. Particle collisions are probabilistic, so we do occasionally see small deviations from what we expect. If you flip a coin five times in a row, there's a small chance that you'll get five heads, but when that happens, it doesn't necessarily mean anything.

What was the atmosphere like at the LHC when the Higgs boson discovery was announced?

Everyone was absolutely delighted. People were crying with joy when the discovery was shared.

If the Higgs had not been found where it was, then we would have had a big challenge, because there would have been no firm theoretical guidance as to where to look for it. We could have kept looking at higher and higher energies, but we'd have been searching without the firm backing of the standard model. But, of course, we did see the Higgs.

How have experiments with the Higgs evolved in the ten years since its discovery?

Ten years ago, the Higgs boson was just a theoretical construction; then it became something we could measure; now it's a precision tool that physicists can use to look for "new" physics—that is, particles and interactions that aren't predicted by the standard model.

Just like LEP, one of the goals of the LHC is to make incredibly precise measurements of the standard model. When you compare these precise measurements to theoretical predictions, any deviations mean that either you've made a mistake in the measurement or your prediction is wrong. And if your prediction is wrong, it may mean that you need to add new physics to the model. Now that the Higgs boson's properties have been measured so precisely, they can be worked into our predictions.

With the Higgs now part of the high-energy-physics tool kit, what other discoveries do you think are possible with the LHC?

Since the LHC's first operational run, we have nearly doubled the energy at which we can collide particles. This energy determines the mass of the particles that a collision can create, with higher energies producing heavier particles. Some of the measurements that we made in the previous observational run were barely confirmations of processes predicted by the standard model. We hope that the recent LHC upgrade, which we just finished, will allow us to take these observations from "we think we can see something" to "this thing exists, we can measure it precisely, and we can use it to look for other things."

One of those "things" is dark matter. Just like in the LEP days, when I knew the Higgs boson existed because the standard model predicted it, I know that dark matter exists because it has been indirectly observed in the cosmos. Dark matter could be produced in the LHC; for example, via the decay of a Higgs boson, or through processes involving particles predicted by an extended version of the standard model known as supersymmetry. Supersymmetry is a beautiful and elegant theory that answers a lot of weird questions about nature, including dark matter. But whether supersymmetry is correct is an open question. It could very well be that the answer will be found in the large swaths of LHC data still to come.

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