Physicists eager to begin analysis of data from new, higher energy run of LHC

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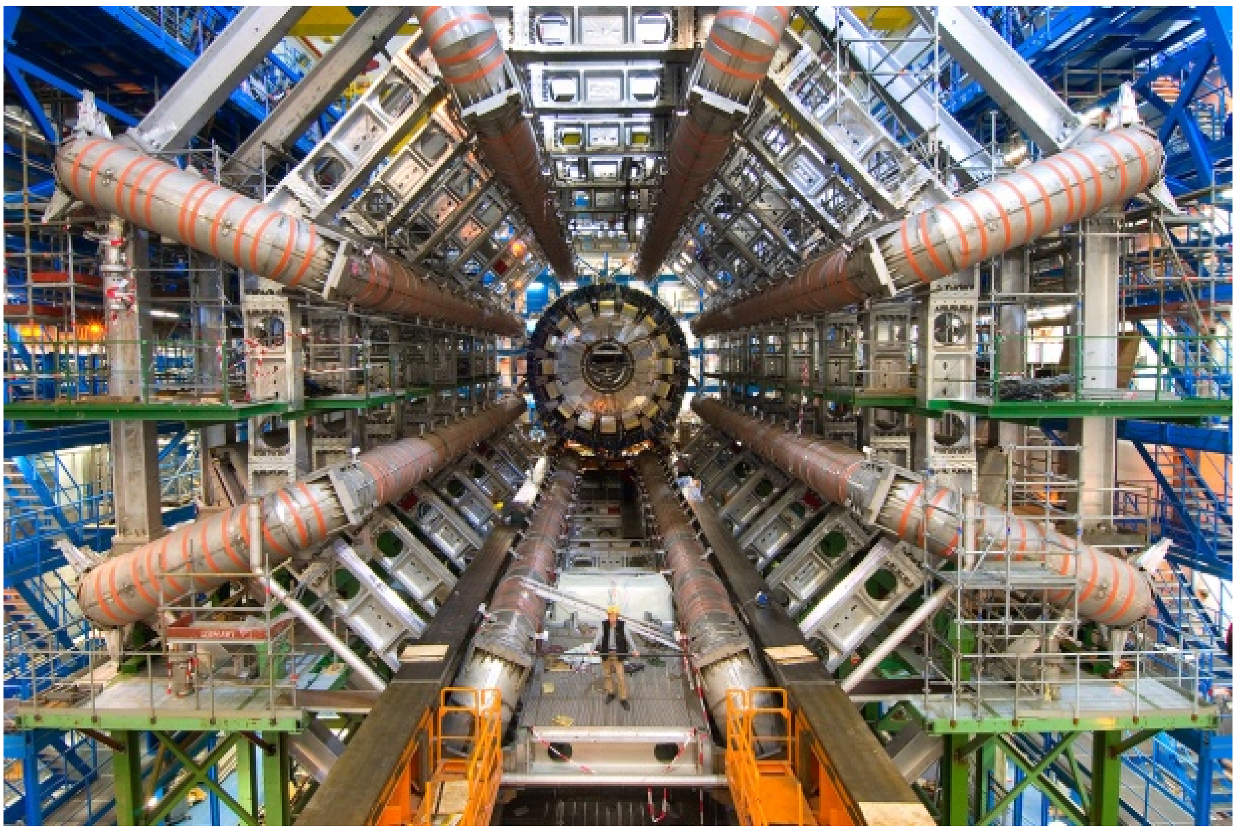

After the discovery of the Higgs boson at the LHC, many people thought its mission over. But the search for new subatomic particles continues in a new phase that begins this week. Credit: CERN LHC

When experiments at the Large Hadron Collider (LHC) in Switzerland start collecting the first 13-teraelectronvolt (TeV) particle collisions data today, a long wait will be over for three University of Massachusetts Amherst physicists, who now begin some of the most exciting years of their careers searching for new subatomic particles, evidence of extra dimensions and the nature of dark matter.

The LHC started delivering physics data for the first time in 27 months today, after almost two years offline for re-commissioning. This new LHC run "is a bit special," says elementary particle physicist Stephane Willocq, "because it's not every day that we get to start an accelerator that runs at the highest energy ever achieved. In 2009 we started at 7 and now we're going up to 13 teraelectronvolts. This jump in energy opens up the opportunity to discover heavy new particles. This is probably the last time in our careers for us to have this chance."

As the LHC begins its second run, he and co-investigators Carlo Dallapiccola and Ben Brau, with two postdoctoral researchers, five doctoral students and seven undergraduates on the current ATLAS team (A Toroidal LHC ApparatuS) at UMass Amherst will use its data to explore the most fundamental constituents of matter and laws governing their behavior. ATLAS is one of seven particle-detector experiments at the LHC that is used by thousands of scientists worldwide working on particle experiments.

"We will be searching for new phenomena, looking for the surprise unknown, the signature of something new," says Dallapiccola. "After the discovery of the Higgs boson, many people thought it's over, but the project continues. The Higgs wasn't the only thing, and finding it actually poses new questions. The experiment is not done, it's actually entering a new phase."

The UMass Amherst team brings special expertise in identifying and measuring a class of heavy electrons called muons to the project. Muons are fundamental particles like electrons only 200 times heavier, and are expected to provide tell-tale signs of discovery as decay products of new states of matter. Willocq and colleagues have written much of the particle identification software for a muon spectrometer that reconstructs their trajectories in space and pieces arcs together from raw detector data "like a connect-the-dot game using traces of energy left behind by muons," Willocq says.

In particular, he uses the muon detector to look for a new, short-lived heavy particle called the Z-prime boson, a messenger of a new hypothetical interaction. Discovering it would signal physics beyond the current Standard Model, the theory of the electromagnetic, weak and strong nuclear interactions, plus the subatomic particles and how they interact.

For their part, Dallapiccola and Brau are searching for exotic, long-lived particles whose signatures are also seen using the muon detector. They travel for a long time and pose special identification and detection challenges.

This all will take weeks and months to yield information. Deciding what data are going to be useful and how to extract it is one technical challenge. Further, programming requires some creative and persistent tinkering, says Willocq. "It's not always a linear process. You know where you want to go, but not necessarily how to get there."

Dallapiccola adds, "If nature is very, very kind to us, perhaps by next year's early spring conferences we might have something to report. The worst thing we could do would be to make a big announcement and then have to retract something, even if it's completely honest. So we are extremely cautious. We give ourselves time to sleep on things, to make sure of what we're seeing."

Still, the thrill of being first to discover a new particle inspires each member of the team, the researchers acknowledge.

There are many limitations of the Standard Model of nature at the atomic level, and theorists have been creative in proposing testable solutions to these problems. The LHC is the best tool available to test ideas such as supersymmetry and string theory, Dallapiccola notes. "Certain evidence could come from these new analyses. Were we to find evidence for supersymmetry, string theorists might breathe a sigh of relief because we haven't discovered particles yet that would support it," he says.

Willocq adds, "We must also mention dark matter. It is one of the puzzles that our current understanding doesn't answer. It might be a whole family of new particles, but based on the evidence we have it's a new form of a particle that has not yet been seen in the laboratory. LHC provides a very good opportunity to discover dark matter particles. The experiments starting up this week allow us to push dark matter searches farther than we ever have in the past. It would be very cool if we could discover something in that area."

He also would like to discover why the Higgs boson is so light, its mass rather low compared to theoretical expectation. "Understanding that low mass is a serious challenge," the physicist points out.

Thousands of scientists around the world are welcoming data from the LHC beginning this week that will continue into late fall. It can take up to two years to collect, analyze, review and publish. Dallapiccola sums up, "If we do have a discovery, there's always the question of whether we'll know what it is. That would be a really fun problem to have."

Provided by University of Massachusetts Amherst