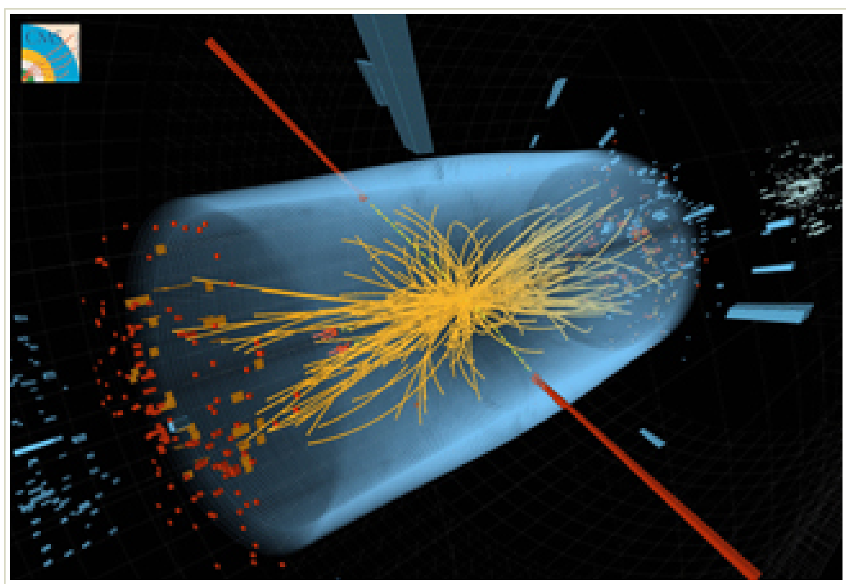
The Missing Piece?

UT physicists are part of the hunt for the elusive Higgs boson

July 4, 2012

In the early-morning hours of America's Independence Day Holiday, scientists announced the latest results from experiments conducted at the Large Hadron Collider, the most powerful particle accelerator in the world located at CERN, the European Organization for Nuclear Research. In a seminar scheduled for 9:00 a.m. Central European Summer Time on July 4 (3:00 a.m. in Knoxville), researchers shared what they've learned from a barrage of new data collected between April and June of this year—more data than they gathered in all of 2011. Of keen interest is whether they have at last discovered the Higgs boson, the elusive subatomic particle that brings the so-called "theory of almost everything" closer to completion. This achievement is shared by physicists all across the world, including UT faculty and students, who joined the search party in 2006.

The Higgs boson plays a critical role in what physicists call The Standard Model: the arrangement of fundamental particles—and the way they influence one another—that make up everything in the universe. While there are some gaps (the theory doesn't take into account gravity, for example, or the dark energy that comprises most of the universe), it has nonetheless proven greatly successful in explaining experimental results and predicting new phenomena since it came of age in the 1970s. The model's architecture includes the 12 building blocks of matter, divided into quarks (which constitute, for example, protons and neutrons) and leptons, the lightest one being the electron. Additional particles carry three of the four fundamental forces that influence quark and lepton behavior (the strong force, weak force, and electromagnetic force). The Higgs particle is a cornerstone of this theory because it's predicted to give all particles their mass by interacting with them. Named for Peter Higgs, one of the scientists who in 1964 proposed its role in fundamental physics, it is the only particle in the Standard Model that has eluded experimental observation so far.



(Image credit: CERN/CMS) A typical candidate event including two high-energy photons whose energy (depicted by red towers) is measured in the CMS electromagnetic calorimeter. The yellow lines are the measured tracks of other particles produced in the collision. The pale blue volume shows the CMS crystal calorimeter barrel.

The High Energy Physics group at the University of Tennessee has been part of the hunt for the Higgs boson for the past six years, working with the international collaboration that built and maintains the LHC's Compact Muon Solenoid detector, or CMS.

The Large Hadron Collider is an underground, 17-mile ring that straddles the French-Swiss border and accelerates protons to enormous energies in opposite directions. Every second, protons collide head-on more than 40 million times at particular locations surrounded by layers of particle detectors. The results of these collisions can be new particles or other phenomena. With multiple layers, the CMS detector can observe these remnants and track their signatures, providing scientists with data to piece together what happened at the heart of a collision.

Associate Professor of Physics Stefan Spanier leads UT's CMS work, which includes postdoctoral researcher Zongchang Yang, graduate students Grant Riley and Andrew York, and recently graduated students Giordano Cerizza and Matthew Hollingsworth. Typically two undergraduate students participate in projects at CERN during the summer and are involved with the campus laboratory or with data analysis during the fall and spring semesters. The group's involvement started with the design and implementation of additional detectors based on artificial diamonds. These detectors are located close to the high-intensity LHC beam and act as sentries: they can detect any radiation the beam creates that is hazardous for the CMS detector. In a worst-case scenario, the protection system can shut off the proton beams, protecting the 66 million individual readout channels of the nearest detector: the same detector for which UT students provided software and helped to commission. Graduate students York and Riley, in fact, have just returned from CERN, where during the past few weeks they analyzed information from this and other sub-detectors to guarantee that the CMS is running smoothly.

Far from Over

While speculation surrounding the July 4 announcement has already generated a great deal of excitement, there is still much work to be done. With a signal for the Higgs particle, scientists will need to conduct further analysis to determine its properties.

Spanier explained that for the Higgs hunt, it is critical to identify reactions that can fake a Higgs signal and determine the rate at which they contribute. To do so, scientists measure and count particle tracks at a high rate very close to the beam where they actually present a radiation hazard. Evidence for the Higgs, he said, would be a signal close to the expected mass; but to confirm the discovery of the elusive particle, researchers will need to establish the different ways it falls apart and compare that data against the predictions of the Standard Model.

"As there are many different ways for the Higgs particle to decay and the number of Higgs particles produced in proton-proton collisions is small, many more collisions with higher and higher intensities of the proton beams have to be measured to arrive at significant comparisons," he continued. "And after all, the Standard Model does not yet incorporate the physics of dark energy or the full theory of gravitation as described by general relativity. But even the mass of the Higgs, though well constrained by theory, appears a bit like an accident unless there are other force particles involved that still need to be discovered. This means the hunt is far from over."

In this vein, the UT group is studying pixelated artificial diamond detectors with particle beams. In collaboration with Fermilab; Rutgers University; the University of Colorado, Boulder; and Princeton University, the group is exploring whether this radiation-hard technology can replace particle detectors inside the CMS detector to prepare for even higher beam intensities. Such ramped-up power would be required to test any Higgs candidate for further compliance with predictions of the Standard Model and searches for rare signals. Of particular interest is the functionality of diamond detectors after they have been exposed to substantial amounts of neutrons. A prototype detector has already been installed to support data-taking for this year, and undergraduate students from UT are involved in gathering and analyzing data from this new device. The group also plans to study diamond detectors after they have been exposed to large amounts of neutrons in a nuclear reactor.

Strong computing support is required to analyze the huge amount of data recorded with the CMS detector, and the UT group has a 10-gigabit network connected directly to Fermilab (which receives data from CERN), as well as a computer cluster based on the shared computing concept that has been developed for high energy physics, called GRID. This setup has translated into broader benefits for UT as well: the Newton cluster of the Office of Information Technology uses these concepts to provide shared computing resources for researchers across the university.

Whatever the news from CERN on Wednesday, one thing is certain: UT's physicists will continue their research to answer fundamental questions about why things work the way they do.

See more coverage from the Knoxville News-Sentinel.

Related Sites

- Learn more about the High Energy Physics Group at UT: http://hep.phys.utk.edu/ and the Compact Muon Solenoid: http://public.web.cern.ch/public/en/lhc/CMS-en.html
- Watch the CERN Webcast at: http://webcast.web.cern.ch/webcast/ or learn more about CERN and the LHC at: http://public.web.cern.ch/public/Welcome.html
- Read the U.S. Press Release on the latest LHC results at: http://www.fnal.gov/pub/presspass/press_releases/2012/Higgs-Search-LHC-20120704.html, and the CERN press release at: http://press.web.cern.ch/press/PressReleases/Releases2012/PR17.12E.html