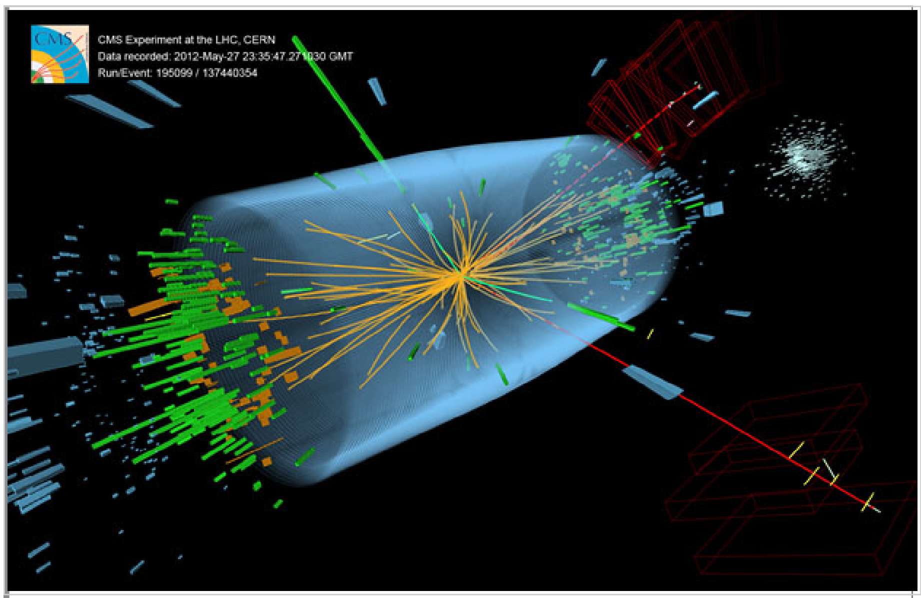
It is a Higgs!

UT's particle physics group makes ongoing contributions to LHC research

April 8, 2013

On July 4th, 2012, the ATLAS and CMS experiments at the Large Hadron Collider (LHC) of CERN in Geneva, Switzerland, announced the discovery of a new particle that could likely be the long searched for Higgs boson, also known as the "god" particle. In recent conferences new preliminary results were presented on two and a half times more data than was available for the discovery. These latest findings from the collision of protons at somewhat higher energy in the LHC now show an even more significant signal! This is good news for the so-called Standard Model of particle physics. The model assumes that all elementary particles start out massless. Most particles that we observe in our detectors, on the other hand, clearly have mass (the photon is massless). In 1964 the physicist Peter Higgs and others suggested that all particles are subjected to an omnipresent force that generates their mass and hence completes this theory. The particle associated with this force is the Higgs particle. An observation of this particle can be considered a great triumph of our approach to a deeper understanding of the Universe, which is based on very fundamental principles and mathematical rules. Therefore, a definite absence of this particle has wide-ranging consequences for this otherwise unprecedented successful theory.

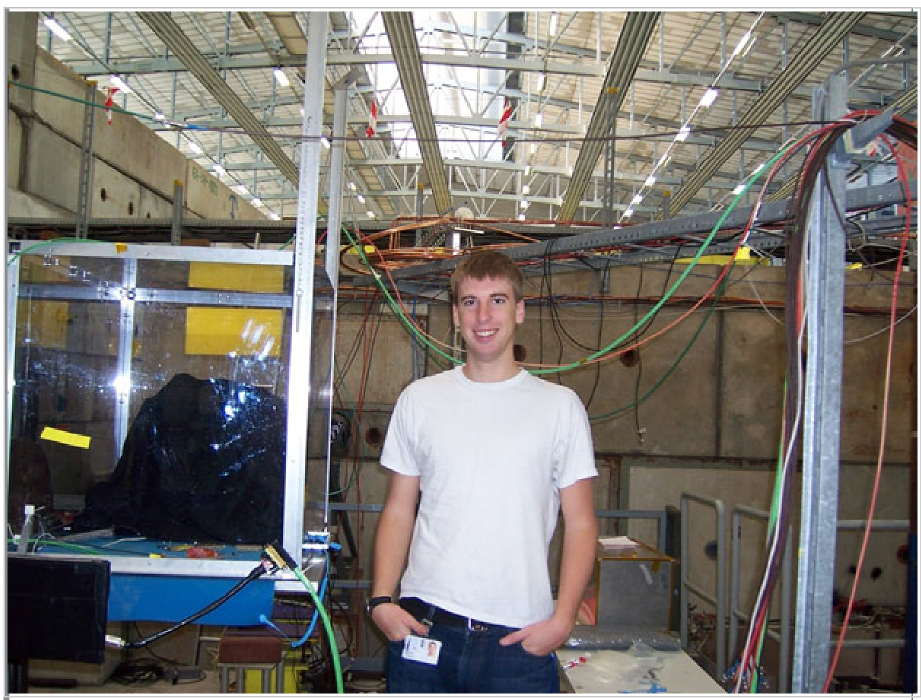


Event recorded with the CMS detector in 2012 at a proton-proton centre-of-mass energy of 8 TeV. The event shows characteristics expected from the decay of the SM Higgs boson to a pair of Z bosons, one of which subsequently decays to a pair of electrons (green lines and green towers) and the other Z decays to a pair of muons (red lines). The event could also be due to known Standard Model background processes.

Whether or not a particle is a Higgs boson is demonstrated both by how it falls apart into other particles and its quantum properties. This requires reconstructing it from the many different ways it can decay and comparing the rates at which they occur. The main observation of the Higgs was in its decay into two photons and two Z particles (bosons that help mediate weak interactions); the observed rates are close to Standard Model predictions. To work as predicted the Higgs boson should also show no preference in the direction it interacts with other particles –in other words, it should have the same quantum mechanical properties as the vacuum. This can be measured from angular distributions of the decay into two Z articles. The CMS experiment published a study that the observed Higgs candidate particle is indeed consistent with this requirement [**Phys. Rev. Lett. 110, 081803 (2013) (http://prl.aps.org/abstract/PRL/v110/i8/e081803)**].

So is it THE Higgs particle? First of all, the detection of the boson is very rare - it takes around 1 trillion (10^{12}) proton-proton collisions for each observed event. To characterize all of the decay modes will require much more data from the LHC. And then, the even more exciting perspective is actually that discrepancies with detailed predictions show up. 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 particle, though well constrained by the Standard Model, appears a bit like an accident unless there are other force particles involved that still need to be discovered. If present, they will at some level modify the appearance of the Higgs particle. This includes the possibility that there are other Higgs particles, which means the hunt is far from over. And to mention how gravity might come into play: several theories predict the possibility of the creation of micro black holes in proton-proton collisions at the LHC.

Since 2006, the University of Tennessee High Energy Physics group has been part of the hunt for the Higgs boson, working with the LHC of the particle physics laboratory CERN. The group collaborates with the international CMS collaboration that has built and maintains the Compact Muon Solenoid detector. At present, the group has one faculty member (Stefan Spanier), two postdoctoral researchers, three graduate students, and typically two undergraduate students who participate in projects at CERN during the summer and are involved in the laboratory on campus or data analysis with computers during the semester. The group made substantial contributions to the particle tracking detectors needed to study the decay properties, particularly the angular distributions of the Higgs boson. For future applications of this device at much higher beam intensities the group studies pixelated artificial diamond detectors in the laboratory and particle beams. The detectors are radiation hard and will be used for measurements of particle trajectories in the ongoing hunt for rare signals. Any particle rate measurement with the CMS detector depends crucially on the knowledge of the overall particle production rate in proton-proton collisions. Therefore, the University of Tennessee group, together with U.S. university collaborators from Rutgers, Vanderbilt, and Princeton, is implementing a new instrument based on diamond pixel detectors deep inside the CMS detector. Prototypes are tested in test beams and the installation is scheduled for next year.



UT graduate student Grant Riley in a laboratory area at CERN, Geneva, Switzerland, where a prototype detector made of artificial diamonds is tested with beams of high energetic particles.

Another very fundamental question in the quest for new particles is: how often are particles produced in a single proton-proton collision? Since protons consist of smaller constituents they are the ones that actually collide, and in principle this can happen more than once, each time with the potential to create, for example, the Higgs particle. Assuming there is only one collision results in a miscounting of the Higgs production rate. Fortunately, there are certain particle production processes also happening that are very sensitive to this phenomenon, and our graduate student Andrew York found one of those and a way to count those occurrences.

Strong computing support is required to analyze the huge amount of data recorded with the CMS detector. We have a 10 GBit network with a direct connection to Fermilab, where data from CERN are shipped, and a computer cluster based on the shared computing concept called GRID. The Newton cluster of OIT, a spin-off of this involvement, uses these concepts to provide shared computing resources for researchers across the UT campus.

More Information

- **The Compact Muon Solenoid (CMS) detector at the Large Hadron Collider (LHC) (http://home.web.cern.ch/about/experiments/cms)**
- **CERN Press Release (March 14, 2013) on the Higgs boson (http://press.web.cern.ch/press-releases/2013/03/new-results-indicate-particle-discovered-cern-higgs-boson)**
- **UT physicists are part of the hunt for the elusive Higgs boson (July 2012) (http://www.phys.utk.edu/news/2012/news_higgs_07042012.html)**