World's largest particle collider may unlock secrets of universe

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The LHC tunnel

The Large Hadron Collider (LHC), the world's largest and highest-energy particle accelerator, could generate astonishing new insights into the Big Bang, the building blocks of the universe, the mysterious properties of dark matter and perhaps even extra dimensions in the universe.

Located at the CERN laboratory outside Geneva, the immense collider, which measures more than 16 miles in circumference, is expected to usher in a new era of particle physics research, enabling scientists to replicate conditions immediately after the Big Bang.

To that end, on March 19, the collider fired beams of protons in both directions, clockwise and counter-clockwise, at a new world-record energy: 3.5 trillion (or tera) electron volts. The LHC will soon collide these proton beams against each other, allowing physicists to analyze the particles produced in the collisions. CERN eventually plans to collide proton beams at a blistering 7 tera-electron-volts in both directions.

Robert Cousins, a UCLA professor of physics who has served as a leader of the Compact Muon Solenoid (CMS) experiment at CERN — one of the LHC's four main experiments — is hopeful the collider will lead to extraordinary discoveries about the nature of the universe.

"We're going to study the Big Bang as far back as we can take it," said Cousins, whose research group is supported by the U.S. Department of Energy and who is principal investigator on a CMS grant funded by the National Science Foundation.

"The fundamental questions," he said, "were asked by the ancient Greeks: Where did we come from, what are we made of? How did the universe evolve and what are the forces of the universe?

"We think there are undiscovered forces. The history of physics is one of unification of ideas. Isaac Newton discovered that the same force that makes apples fall also holds the Earth to the sun and holds the moon to the Earth. When I teach Newton's universal law of gravity, the key word is 'universal.' One law of gravity accounts for apples falling and the relationship between the moon and the Earth. Historically, optics, electricity and magnetism were three different fields; now there is one theory of electromagnetism.

"Nature likely contains extra forces that we have not found yet," Cousins said. "Any successful attempt to unify the known forces of nature will almost certainly unify some unknown forces of nature at the same time. The job of experimental physicists is to go find those forces. I am most excited about finding new forces that shed light on unification. If you're going to paint the complete picture, you need to know what the other forces are."

The LHC is one of the most complex scientific instruments ever built. Funding for it comes from many sources, including the U.S. Department of Energy's Office of Science and the NSF. Ten thousand people from 60 countries helped design and build the collider and its experiments, including more than 1,700 scientists, engineers, technicians and students from more than 90 U.S. universities and laboratories supported by the DOE's Office of Science and the NSF. Participating U.S. universities include strong research groups from UCLA and seven other UC campuses.

Physicists may make dark matter at the LHC by colliding protons at high energy, which will make new types of unknown particles that decay down to the particles that make up dark matter, Cousins said.

The LHC will recreate conditions that existed less than one-billionth of a second after the Big Bang, and will do so repeatedly in a controlled way. Collisions of protons at energies as high as existed just after the Big Bang will be recorded by giant digital cameras. Eventually, there will be nearly 1 billion collisions per second.

Historically, high-energy particle physics has addressed the smallest pieces of matter and the forces between those objects.

"In the last few decades, an enormous amount of progress has been made in cosmology, which addresses very large questions, such as how the universe evolved from the Big Bang," Cousins said. "If you run the equations of general relativity for cosmology back to the Big Bang, you also need to know what the smallest objects in nature are and what the forces are between them in order to get close to the Big Bang.

"[UCLA professor of physics and astronomy] Edward Wright's cosmology measurements highly constrain the speculation of what the forces are between particles, what the smallest particles are and what dark matter can be. There is much speculation about what dark matter might be if it is not ordinary matter."

With a few exceptions, the particles that the scientists make will decay into lighter particles — some are common matter, like electrons; others are particles that are well understood, such as muons, a heavy version of an electron that decays after one-millionth of a second; and still others will be completely unknown, according to Cousins.

CMS is designed to measure the momentum, direction and energy of the particles that remain when the new particles decay. A second experiment at CERN called ATLAS will use different techniques to answer the same key questions.

CMS weighs more than 13,000 tons and contains 75 million silicon sensors. It has a detector, "a fantastic device," Cousins says, that is like a digital camera with 65 million pixels and the ability to take 40 million photographs per second.

"My thesis experiment 30 years ago had seven channels to detect photons and electrons," Cousins said. "The experiment I did after my thesis had a couple hundred. CMS has more than 75,000. The technology is incredible.

"We're going to find out what nature has in store for us," he said. "We'll see and measure the particles that come out of the region where the clouds of protons collide."

The research is scheduled to continue for more than a decade. Thousands of researchers from dozens of countries are participating in the LHC project, and more than 2,500 scientists and engineers from 38 countries work on the CMS experiment.

"I'm among many people who see this as absolutely the highlight of their career," Cousins said. "I cannot imagine doing anything else."

Seven UCLA physics professors and their research groups have contributed to CMS, beginning with David Cline, who was one of the founders of CMS some two decades ago and who is still an active collaborator. Jay Hauser has devoted all his research time to CMS for many years and is currently a member of the CMS management board. Many other UCLA physicists and engineers, including professors, researchers, postdoctoral scholars and graduate students, have contributed significantly to the research over many years.

Cousins, a member of UCLA's faculty since 1982, began working on CMS in 2000. He has been teaching when not in Geneva. His UCLA courses in the academic quarter just completed included a graduate course and Physics 10, or Conceptual Physics, often referred to as "physics for poets," which he first taught in 1988.

CERN's member states include Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, the Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom. The United States, India, Israel, Japan, Russia, Turkey, the European Commission and UNESCO have observer status.

More information:
Cousins to deliver free public lecture March 31

Cousins will present a free public lecture on the Large Hadron Collider and its physics at UCLA on Wednesday, March 31, at 7 p.m. The lecture, intended for a general audience, will be held in the Grand Horizon Room at Covel Commons. Seating is limited, and registration is required at events.pna.ucla.edu/lhc .

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