
Property of CERN

Physicists on the

Four OU faculty members are involved in groundbreaking research that delves into the very origins of the universe.

By Don Lincoln

Oklahoma is one of the youngest states in the Union. With even the eponymous "Sooner" land rush occurring only about a hundred years ago, it is fair to call Oklahoma one of the last frontiers to be conquered in the continental United States and to claim that Oklahomans have a little more "pioneer spirit" than many Americans.

It is, therefore, entirely fitting for scientists at the University of Oklahoma to be working at the frontier of knowledge, pushing back the boundaries of mankind's ignorance. Many big questions continue to be pondered, from the origins of life to the source of human consciousness. However, few questions are as grand as the origins of the universe itself: Why is there something and not nothing?

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This photo of the massive Large Hadron Collider (LHC) tunnel shows part of the accelerator at CERN, the next generation facility near Geneva, Switzerland, soon to be the focus for the OU physicists.

Frontier

While people have asked these questions for as long we have written records to tell the tale, over the past few centuries extraordinary strides have been made regarding this question. We now know that the universe was created about 14 billion years ago in a cataclysmic explosion called The Big Bang. Astronomical evidence confirms that the universe was once much smaller and hotter. By staring into the heavens, we can untangle the history of the universe back to only a couple of hundred thousand years after the beginning.

Even this striking achievement leaves a gap in our knowledge. However, we scientists are not done. Using huge circular particle accelerators, literally miles in circumference, we can smash subatomic particles together at prodigious energies and study the early universe. Indeed our best understanding is that modern particle accelerators can recreate the conditions of the universe about a billionth of a second after the Big Bang.

OU professors Brad Abbott, Phil Gutierrez, Pat Skubic and Mike Strauss have devoted their professional lives to pushing back this frontier. The OU experimental particle physics program involves the world's two largest particle accelerators, the Fermilab Tevatron, just outside of Chicago, and the Large Hadron Collider, just outside Geneva, Switzerland.

Until recently, the bulk of their effort was focused at Fermilab. Since 1985, Fermilab has been the highest energy particle accelerator in the world. For the last 20 years, two large experimental collaborations have engaged in a friendly competition, searching for things never before seen. The experiment that provides the data for OU physicists to do their research is called DZero. This experiment involves about 600 physicists, and they have published hundreds of research papers. This research has resulted in several hundred Ph.D. degrees, including seven from OU. In addition, six postdoctoral researchers have started their careers in the OU high energy particle physics group.

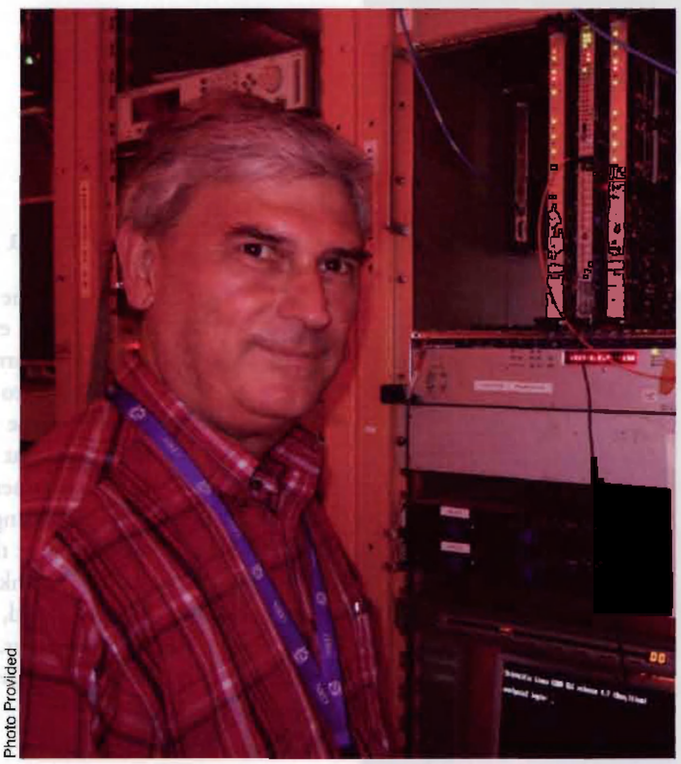

Photo Provided

OU's Phil Gutierrez has spent more than a decade studying 'top quarks.' Quarks are subatomic particles that compose protons and neutrons, which in turn make up the nuclei of atoms.

The research program at the Tevatron is very extensive, involving every type of subatomic physics yet discovered. The OU professors are experts in the studies of subatomic particles called quarks.

Quarks are among the smallest subatomic particles we have found. In our normal world, they are found ensconced in the center of atoms—the building blocks from which all matter is made. Atoms look a bit like microscopic solar systems, with a nucleus at the center and orbiting electrons serving the role of planets. The nuclei of atoms are made of subatomic particles called protons and neutrons.

In the 1960s and 1970s, physicists were able to show that these protons and neutrons were composed of particles called quarks. We now believe that there exist six types of quarks, with whimsical names: up, down, charm, strange, top and bottom. Only the up and down quarks are found in the nucleus of atoms. To study the other kinds of quarks, we must make them in our large accelerators. However, these other quarks were common in the first fractions of a second of the universe, so understanding the instant of creation requires that we understand the quirks of all the quarks. Accordingly, the OU particle physics professors have become quark experts. In fact, Abbott and this article's author were part of the group that co-discovered the top quark in 1995.

For reasons that still remain mysterious, these additional quarks are heavier than the two found in ordinary matter. For instance, the top quark weighs about 100,000 times more than the up quark. This huge disparity in mass strongly suggests that the top quark is a fascinating object to study. Gutierrez has spent more than a decade studying this enigmatic particle. He, along with his students and postdoctoral assistants, has made major contributions to the DZero collaboration's top quark research program, culminating in the spring 2009 observation of top quarks produced individually. (This is to be contrasted with

Property of Fermilab

This aerial view of the Fermilab facility near Chicago, a complex consisting of a series of particle accelerators, each feeding the next, shows the Tevatron, Fermilab's highest energy particle accelerator and the location of the DZero experiment involving four OU physicists.

the 1995 discovery of top quarks produced in tandem with their antimatter partners, the anti-top quarks.) Single top quarks are produced very rarely, and there are many collisions that can mimic their signature. This study was akin to looking for a few diamonds mixed into a bucket of cubic zirconia, and yet find them they did.

Abbott and Strauss have focused more on the behavior of the much lighter up and down quarks and the mysterious bottom quark. Collisions between up and down quarks involve the strongest force we know—the nuclear force. The strength of this force allows us to look at the very highest energy collisions possible. In these collisions, physicists hope they might find particles even smaller than quarks. If they succeed, just as atoms were found to contain protons and neutrons, which in turn contain quarks, finding something inside quarks will reveal another layer in the subatomic onion.

Property of CERN

OU professor Mike Strauss, left, and research scientist Horst Severini stand in front of the ATLAS detector at CERN in Geneva, Switzerland.

Strauss was primary author of a paper publishing his most recent graduate student's Ph.D. thesis result, which holds the world record of most precise measurement of this kind. "I'm very grateful for my time at OU working with my adviser," that former graduate student, Mandy Rominsky, says. "It was very cool to make a measurement that is twice as accurate as the next best one. I'm sure the measurement helped me win one of the handful of Fermilab postdoctoral research positions awarded each year."

Then there are bottom quarks, which are especially interesting. Because of the weird principles of quantum mechanics, particles containing bottom quarks can morph from matter to antimatter and back to matter again. Since we believe that matter and antimatter were made in equal quantities in the early universe, the fact that our universe is made wholly of matter is a pressing mystery. It is hoped that studies of these chameleon particles might lead to an answer to the question of where all the antimatter went.

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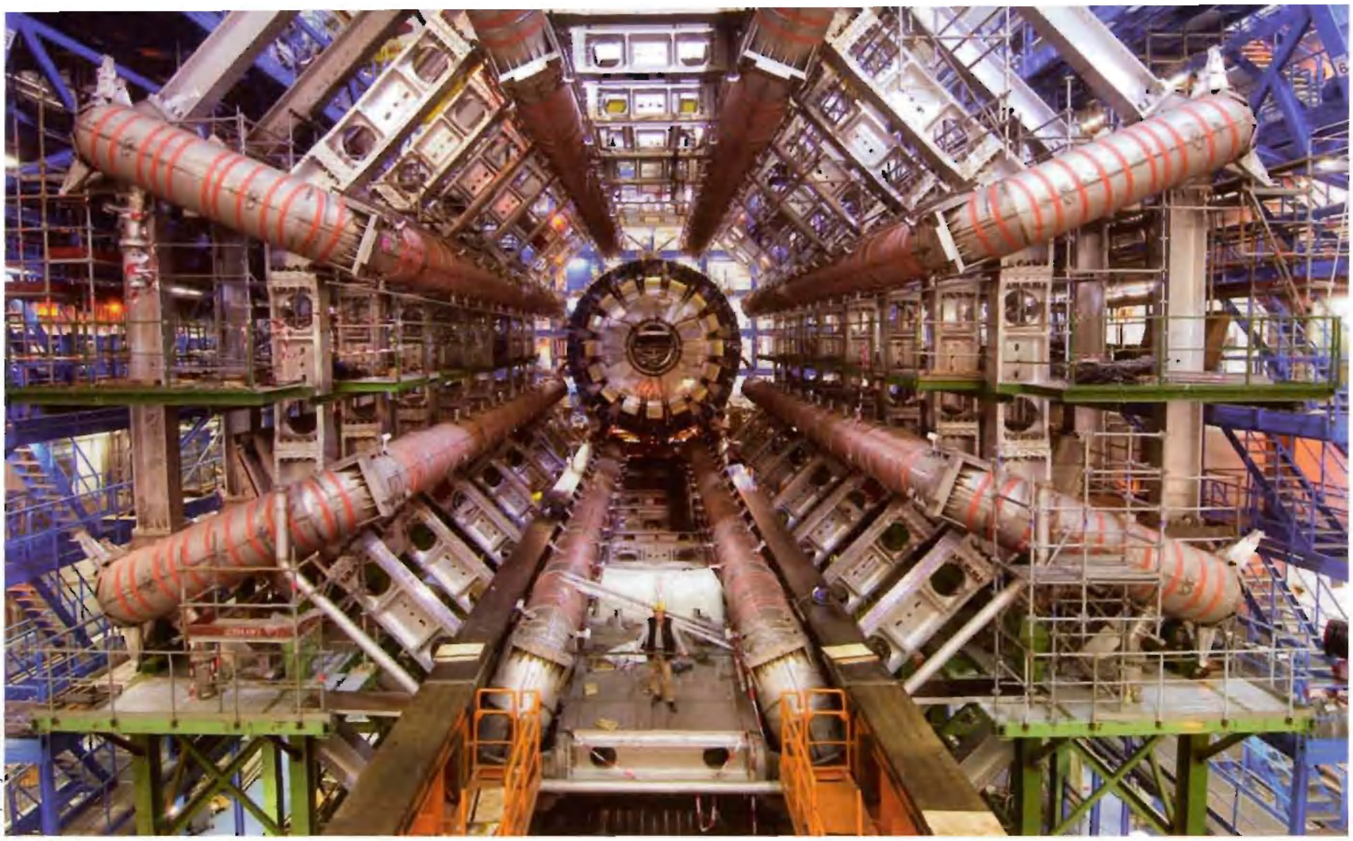

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The enormity of the ATLAS detector at CERN is graphically illustrated by the size of the man standing at the lower center of this photo. OU's Pat Skubic has been paving the way for his OU colleagues' eventual involvement in an experiment to be conducted in Switzerland.

Abbott once led the group of DZero physicists investigating the behavior of bottom quarks. "There are a huge number of questions that can be answered using DZero data," he says. "Given that there are so many opportunities, it's difficult to select only one. However, until we understand how the antimatter disappeared, our theory has a terribly embarrassing gap in it. We physicists don't like gaps, and this is why I study this phenomenon."

While three of the OU faculty have spent the bulk of their research time working at the Fermilab Tevatron, a new facility has commenced operation at the CERN laboratory in Europe. The Large Hadron Collider (LHC) will eclipse the Tevatron as the world's frontier facility, eventually delivering particle beams that are seven times the energy and fifty times more intense. Looking to the future, Skubic has been paving OU's way onto an experiment at the LHC. As the Tevatron ceases operations in a year or two, the entire group expects to shift its attention to the LHC. Their expertise will be most welcome.

The OU experimental particle physics group has a long history working at the cutting edge of knowledge. Between the exciting times at the Tevatron and the bright future at the LHC, these physicists will continue their pioneer heritage, blazing a trail into the quantum frontier.

Robert Taylor

Research being done off-campus significantly enhances the classroom work of professors like Brad Abbott, here in Nielsen Hall with A. A. Hasib, left, and Scarlet Norberg.

Don Lincoln is a senior scientist at Fermi National Accelerator Laboratory and an adjunct associate professor at the University of Notre Dame. He is author of two books about particle physics for the public, including the recently released The Quantum Frontier: The Large Hadron Collider. *His writing on cutting-edge science topics can be found on Facebook at* http://www.facebook.com/pages/Don-Lincoln/10095813788.