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UA Physicists Ready for Science with World's Most Powerful Accelerator

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This artist's graphic shows the underground ATLAS detector along the 17-mile subsurface tunnel, the Large Hadron Collider at the Swiss-Franco border. Protons will smash into each other with unprecedented impact speeds.

The University of Arizona is known for doing Big Science. It partners in the most powerful telescope projects on Earth and in space. It makes the world's largest telescope mirrors. It leads a global center tackling the toughest problems in plant biology. It directs a lander mission to Mars.

When it comes to doing Big Science, or large-scale scientific research usually backed with government funding, UA physics is no exception.

Since the mid-1990s, UA high-energy experimental physicists and their students have been collaborating on the ATLAS experiment, one of two general-purpose particle physics experiments that start when the European Organization for Nuclear Research, or CERN, begins operating the Large Hadron Collider in Geneva later this year.

"The Large Hadron Collider will be the world's highest energy accelerator, the most powerful microscope ever constructed for exploring the subatomic world," UA physics professor John Rutherfoord said. "It will see particles roughly 10 times smaller than the world's current most powerful accelerator, Fermlab's Tevatron, can detect, and that's a tremendous advance. Particle physicists are a huge step closer to understanding the building blocks of nature and discovering how the universe works."

Rutherfoord led development of a new calorimeter technology for ATLAS. UA students, including undergraduate students, in Rutherfoord's campus lab helped build their part of the ATLAS experiment. They developed and built novel liquid argon calorimeters specifically designed to withstand never-before-achieved proton collision rates and measure elementary particle position and energy with excellent accuracy. They tested their prototypes both at CERN and Brookhaven National Laboratory in New York during the peak development phase, 1993-2004.

Rutherfoord is among more than two dozen authors from around the world whose article on the ATLAS forward calorimeter was published recently in a major new scientific journal called the Journal of Instrumentation. Other UA authors on the ATLAS research paper also include Michael Shupe, who is the head of the UA physics department, Peter Loch, Alexandre Savine, Leif Shaver, and Daniel Tompkins.

ATLAS gives real meaning to the idea of Big Science. More than 2,000 participants from 35 nations are involved. These include 420 U.S. physicists, engineers and students from 38 universities and four national laboratories who are funded by the U.S. Department of Energy and the National Science Foundation.

The ATLAS experiment itself is physically enormous. More than 150 feet long and 82 feet across and weighing more than 7,700 tons, the ATLAS detector is the world's largest general-purpose particle detector. The entire detector system sits in its own underground cavern, one of four laboratories along the 17-mile circular underground tunnel that crosses the border between Switzerland and France.

Liquid-helium-cooled superconducting magnets will whip pulsing beams of protons traveling in opposite directions to near-light speeds through the tunnel. It will take individual protons 90 microseconds to travel the entire 17-mile distance. Proton collisions will reach energies of 14 TeV, 15 thousand times the proton's rest mass, where ATLAS' 100 million sensors will measure particle debris that holds answers to long-standing questions in physics.

"ATLAS will allow us to track the path of particles, estimate particle momentum, measure particle energy and position and reconstruct the kinematics of the particle collision," Rutherfoord said.

"One of the most interesting discoveries ATLAS may make before too long is a particle that we anticipate not seeing," he said. The particle might be dark matter, which is invisible but is known by the effects of gravity to make up most of the matter in the universe.

"Dark matter is an extremely weakly interacting particle, so weak that we won't see it directly," Rutherfoord said. "But it will stand out in ATLAS results like a sore thumb."

Physicists will add up the momenta of all the particles they detect, and, according to the law of conservation of momentum, determine how much momentum is missing. They will be able to tell whether weakly interacting particles called neutrinos account for the missing momenta, Rutherfoord said. If the particles are not neutrinos, "we'll know the missing energy is due to something new and different – dark matter particles," he added. "We think it's possible to deduce dark matter particles by the missing momentum."

Particle physicists say ATLAS may help them unravel the origin of mass and other deep mysteries. A more speculative theoretical idea is that the experiments might produce mini-black holes. If that happens, the mini-black holes will evaporate well before leaving the accelerator vacuum beam pipe where they are produced, Rutherfoord said. The ordinary particles produced in the evaporation will signal the brief life of such exotic objects.

Source: University of Arizona

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