New observatory studies universe's most energetic phenomena

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A recently completed observatory on the slopes of Mexico's Volcán Sierra Negra will play a major role in helping scientists, including Los Alamos National Laboratory researchers, see objects and events far outside our own galaxy and gain a deeper understanding of some of the most energetic phenomena in the known universe: supernovae, neutron star collisions and active galactic nuclei.

The newly constructed facility sits 13,500 feet above sea level and after four years of construction and partial operation along the way will soon begin collecting data at full capacity.

The project is a joint collaboration between the United States and Mexico and carries the fancy name High Altitude Water Cherenkov (HAWC) Gamma-Ray Observatory, because each of HAWC's detectors is a huge tank containing 50,000 gallons of ultrapure water with four light sensors anchored to the floor. When gamma rays or

cosmic rays reach Earth’s atmosphere, they set off a cascade of charged particles, and when these particles reach the water in HAWC’s detectors, they produce a cone-shaped flash of light known as Cherenkov radiation. The particles are traveling slightly faster than the speed of light in ultrapure water and cause an effect much like a supersonic jet’s sonic boom.

The light sensors record each flash of Cherenkov radiation inside the detector tanks. By comparing nanosecond differences in arrival times at each light sensor, scientists can reconstruct the angle of travel for each particle cascade. The intensity of the light indicates the primary particle’s energy, and the pattern of detector hits can distinguish between gamma rays and cosmic rays. With 300 detectors spread over nearly three football fields, HAWC is able to “see” these events in relatively high resolution.

The Department of Energy's Office of Science, Los Alamos National Laboratory and the National Science Foundation provided funding for the United States’ participation in HAWC.

“The HAWC observatory will detect the highest-energy photons ever observed,” said Brenda Dingus, the principal investigator for the U.S. Department of Energy’s funding for HAWC and a research fellow at Los Alamos National Laboratory. Dingus also is a Fellow of the American Physical Society and in 2000 was a recipient of the Presidential Early Career Award for Scientists and Engineers.

What if your computer keyboard were a detector array?

To envision how the detectors work, Jordan Goodman, professor of physics at the University of Maryland and principal investigator for the National Science Foundation’s funding for HAWC, suggests imagining your computer keyboard as a detector array, with each key representing one tank. Now, approach the keyboard with an open hand at an angle. This represents the cascade of charged particles. The heel of your hand will strike a few keys first, followed by more keys in a defined order as you flatten your palm across the keyboard.

“HAWC truly is the only observatory of its kind, and will give us a clearer picture than ever before of the high-energy wonders of the universe,” Goodman said.

HAWC has been collecting data since August 2013 when it had only 111 detector tanks. Even then, HAWC was much more capable than its predecessor, an observatory known as Milagro that operated near Los Alamos and ceased taking data in 2008. In eight years of operation, Milagro found new sources of high-energy gamma rays, detected diffuse gamma rays from our own Milky Way galaxy and discovered that the cosmic rays hitting earth had an unexpected non-uniformity.

“HAWC will be more than 10 times more sensitive than Milagro was, and it will detect many new astrophysical accelerators,” Dingus explained. “These accelerators push our understanding of physics because they involve the highest gravitational and electromagnetic fields.”

“Los Alamos also studies these phenomena through complex computer simulations to determine how the physical mechanisms can accelerate particles to such high energies and to compare these predictions with the gamma ray observations,” said Alan Bishop, Principal Associate Director for Science, Technology and Engineering at Los Alamos.

From its perch atop the highest accessible peak in Mexico, HAWC will have 15 percent of the sky within its sights at any given time. As the earth rotates, so too will HAWC's field of vision, meaning that HAWC will see up to two-thirds of the sky every 24 hours. The team's major science goals include studying active galactic nuclei—the bright outputs of energy associated with the growth of supermassive black holes at the center of some galaxies—as well as tracking gamma ray bursts and other large explosions. In addition, the researchers will try to determine the enigmatic nature of cosmic rays themselves.

In the past year and half, HAWC has gathered high-energy images of objects near and far, including the Crab Nebula, multiple sources in the Milky Way and the active galactic nucleus Markarian 421.