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Deep Thoughts

Notes from the underground by Communications Director Constance Walter

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The year in particle physics

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This is an excerpt from "2016 year in particle physics" from the Dec. 20 Symmetry Magazine. This excerpt focuses on neutrino and dark matter research. The full article includes the Higgs boson, cosmic acceleration and potential new particles. https://goo.gl/vypsPe

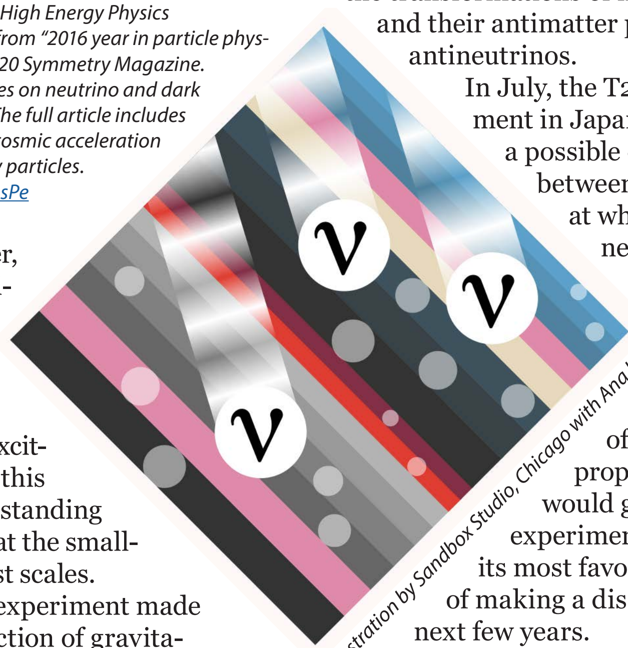

Illustration by Sandbox Studio, Chicago with Ana Kova

Working together, particle physicists from the United States and around the globe made exciting advances this year in understanding the universe at the smallest and largest scales.

The LIGO experiment made the first detection of gravitational waves, originally predicted by Albert Einstein in 1916 in his general theory of relativity. And scientists have pushed closer to the next big discovery at experiments such as those at the Large Hadron Collider and at ultra-sensitive underground neutrino and dark matter detectors.

The pursuit of particle physics is a truly international effort. It takes the combined resources and expertise of partnering nations to develop and use unique world-class facilities and advanced technology detectors.

Physics associated with neutrino mass

In 2016, several experiments studied ghostly neutrinos—particles so pervasive and aloof that 100 trillion of them pass through you each second. A global program of experiments aims to address remaining questions about neutrinos, to discern a neutrino's mass and to understand whether there are differences between the transformations of neutrinos and their antimatter partners, antineutrinos.

In July, the T2K experiment in Japan announced a possible difference between the rate at which certain neutrinos turn into other neutrinos. This hints at a combination of neutrino properties that would give the NOvA experiment in the U.S. its most favorable chance of making a discovery in the next few years.

Also in July, MAJORANA presented preliminary background results based on data collected from Module 1, which began operating in July 2015, to good reviews.

In the longer term, particle physicists aim to definitively determine these answers by hosting the world-class Long-Baseline Neutrino Facility, which would send a high-intensity neutrino beam 800 miles from Illinois to South Dakota. There, the international Deep Underground Neutrino Experiment a mile beneath the surface would enable precision neutrino science.

New physics of dark matter

Indirect evidence indicates that more than a quarter of the mass and energy in the observable universe is made up of dark matter. But little is known about it other than that it interacts through gravity.

To guide the experimental search for dark matter, theorists have studied the possible interactions that known particles might have with a variety of dark matter candidates.

Sensitive detectors, such as the Large Underground Xenon, or LUX, experiment located in Lead, S.D., directly search for the dark matter particles that may be continually passing through Earth. This year, LUX completed the world's most sensitive search for direct evidence of dark matter, improving upon its own previous world's best search by a factor of four.

In addition, data from the Fermi Gamma-ray Space Telescope and other facilities continued to tighten constraints on dark matter through indirect searches.

This sets the stage for a suite of complementary next-generation experiments—including LZ—that aim to significantly improve sensitivity and reveal the nature of dark matter.

Future of discovery science

The world-class facilities and experiments that enable the global program of particle physics are built on a foundation of advanced technology. Ongoing research and development of particle accelerator and detector technology seed prospects for future discovery.

In 2016, researchers continued to make advances in particle accelerator technology in preparation for next-generation machines and possible far-future facilities. At Sanford Lab, for example, CASPAR (Compact Accelerator System for Performing Astrophysical Research) is studying stellar burning in stars to understand the production of elements heavier than iron.

These topics reflect only a small portion of the total scientific output of the particle physics community. But they set the stage for exciting discoveries that will advance our understanding of the universe.