Chinese scientists search for evidence of dark matter particles with new underground PandaX detector

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The new PandaX facility, located deep underground in the southwestern Chinese province of Sichuan, hosts a large liquid-xenon detector designed to search for direct evidence of dark matter interactions with the nuclei of xenon and to observe 136Xe double-beta decay.

The detector's central vessel was designed to accommodate a staged target volume increase from an initial 120 kg (stage I) to 0.5 t (stage II) and ultimately to a multi-ton scale.

The technical design of the PandaX facility and detector is outlined in a new paper co-authored by Ji Xiangdong, of the Institute of Nuclear and Particle Physics, Astronomy and Cosmology at Shanghai Jiao Tong University, and published in the Beijing-based journal *SCIENCE CHINA Physics, Mechanics & Astronomy*.

While noting that cosmologists generally agree that 80 percent of the matter in the universe is made up of some form of "dark matter," these researchers also acknowledge that so far, no physicist has ever produced experimental data that provides convincing evidence for the existence and structure of dark matter.

"The standard model of particle physics, which has been very successful in explaining the properties of ordinary matter, can neither explain dark matter's existence nor its properties," Professor Ji and co-authors across China and the United States write in the new study. "Yet the discovery and identification of dark matter would have a profound impact on cosmology, astronomy, and particle physics."

"A leading dark matter candidate consistent with all astrophysical data is a weakly interacting massive particle (WIMP)," they add. "WIMPs could be studied in standard particle physics through either observations of ordinary matter particles produced through DM [dark matter] annihilations in the halo of the Milky Way, production of DM particles through high-energy collisions in accelerators such as the Large Hadron Collider, or WIMPs could be detected through their interactions with atomic nuclei in specially designed detectors."

Direct detection experiments are deployed in underground laboratories around the world. When WIMPs interact with nucleons in a detection medium, it is predicted they will recoil and generate kinetic motion of atoms (heat), ionization (free electrons) and scintillation (de-excitation of excited electrons).

Direct detection experiments measure one or two or even possibly three of these signatures, depending on the choice of material.

In the case of noble liquid detectors, a light signal is measured by photo multiplier tubes; ionization electrons drifting in an external electric field are either detected through their charge or through electroluminescence. For heat measurements, the detector has to be kept at very low temperature, typically at tens of milli Kelvin, which is a cryogenic challenge, particularly for large masses.

Among all the direct detection experiments, the xenon dual-phase technology appears to be particularly promising. Over the last 3–4 years, the XENON100 experiment, using liquid xenon (LXe), has produced the best limits over a wide range of WIMP masses.

The new PandaX liquid-xenon facility is likewise aimed at the detection of both prompt scintillation and ionization electrons in a dual-phase mode, which allows for discrimination between nuclear recoils and electron recoils.

"Xenon does not have long-lived radioactive isotopes and can be highly purified," explains the team of researchers. "Xenon has a large atomic mass, which entails a large WIMP scattering cross section."

"Xenon liquefaction temperature is around 100°C," they add, "and thus cryogenics is relatively easy to manage."

A crucial property of xenon as a WIMP detector is its outstanding background discrimination. A particle interacting with liquid xenon produces both xenon excitation states and electron-ion pairs. The decay of excited states to the ground state results in scintillation light (S1) at a vacuum UV wavelength of about 175 nm.

The ionization signal is detected via its electroluminescence signal (S2).

The nuclear recoil signal from a WIMP elastic scattering event in liquid xenon differs from that of electron recoils. Most of the energy of the nuclear recoil is transferred to atomic motion and cannot be detected, leaving only about 10%–20% observable energy relative to electron recoils of the same energy.

"The ionization density for nuclear recoils is much higher than that for electron recoils and therefore more electron-ion recombination takes place for nuclear recoils," the researchers state. "This leads to a smaller ratio of ionization/scintillation (S2/S1), and provides 99.9% electron recoil background discrimination."

Collaboration on the Particle and Astrophysical Xenon (PandaX) experiment started in 2009 involving physicists at Shanghai Jiao Tong University, Shandong University and the Shanghai Institute of Applied Physics, Chinese Academy of Sciences. Researchers at the University of Maryland, Peking University, and the University of Michigan joined two years later.

Most of the PandaX Dark Matter Experiment's sub-systems were developed in the particle physics laboratory of Shanghai Jiao Tong University, and were transported to the China Jinping Deep Underground Laboratory in August 2012. After successful installation, two engineering runs were carried out in 2013. The system has been collecting science data since late March 2014. A small prototype for PandaX was developed and is running in the particle physics laboratory at Shanghai Jiao Tong University.

In the new paper, these researchers describe the goals and the technical structure of the PandaX detector system.

Initial results from the PandaX Dark Matter Experiment could be released late this year.

More information: Cao Xiguang, Chen Xun, Chen Yunhua, et al. "PandaX: a liquid xenon dark matter experiment at CJPL." Sci China-Phys Mech Astron, 2014, 57(8): 1476-1494 phys.scichina.com:8083/sciGe/E … abstract509023.shtml

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