The Largest Running Dark-matter Experiment has Its First Result: No Finding Yet with the World Best Sensitivity

The PandaX-II experiment, a half-ton scale dual-phase xenon experiment at the China JinPing underground laboratory (CJPL), has recently published the dark matter search results by combining the data from their commissioning run (19.1 live-days) and the first physics run (79.8 live-days). No trace of dark matter was observed with an exposure of 33,000 kg·day of liquid xenon, providing the newest and tightest published constraints on the existence of dark matter. The letter was published in 16 September 2016, as the cover letter of Volume 117, Issue 12 of the Physical Review Letters. It is also highlighted as one of the "Editor's Suggestion" article. This result was first announced to the world by Xiangdong Ji, Spokesperson and Project Leader of the PandaX, during the 2016 International Identification of Dark Matter conference on July 21.

Fig. 1: Picture of the PandaX collaboration.

PandaX (Particle AND Astrophysical Xenon) collaboration was founded in 2009 by Prof. Ji who splits his time between Shanghai Jiao Tong University and University of Maryland, USA. The collaboration consists of a numbers of institutions in China, including Shanghai Jiao Tong University, Peking University, Shandong University, Shanghai Institute of Applied Physics, Sun Yat-Sen University, University of Science and Technology of China, China Institute of Atomic Energy and Yalong Hydropower Company. Scientists from the University of Maryland and University of Michigan also joined the collaboration. The experimental hall of PandaX is located in CJPL, which has been developed by the Tsinghua University and the Yalong Hydropower Company in 2010.

Dark matter comprises of 85% of the matters in the universe according to the observations from astronomy and cosmology. Lack of electromagnetic interactions to ordinary matter makes the dark matter impossible to be "seen" with common methods, acting like "ghosts". Many scientists believe that between the dark matter particle and ordinary matter there exists a weak interaction. Such interaction makes it possible for detection of dark matter with detectors in the satellites, such as "WuKong" launched in the end of 2015 in China, or with particle colliders, such as the large hadron collider at CERN (LHC), or with the deep underground dark matter detectors such as PandaX. However, the detection is far from a trivial task due to the extreme weakness of the interaction.

PandaX experiment uses xenon atoms as the detection target. It searches for extremely tiny signals caused by possible collisions between the xenon atoms and billions of dark matter particles around the earth. Recoiling energy from collisions produces photons and electrons, signals of which can be recorded by sensitive photomultiplier tubes (PMTs) in one single event. PandaX experiment, for the first time, makes use of 110 new type 3-inch PMTs to collect these signals. The latest result

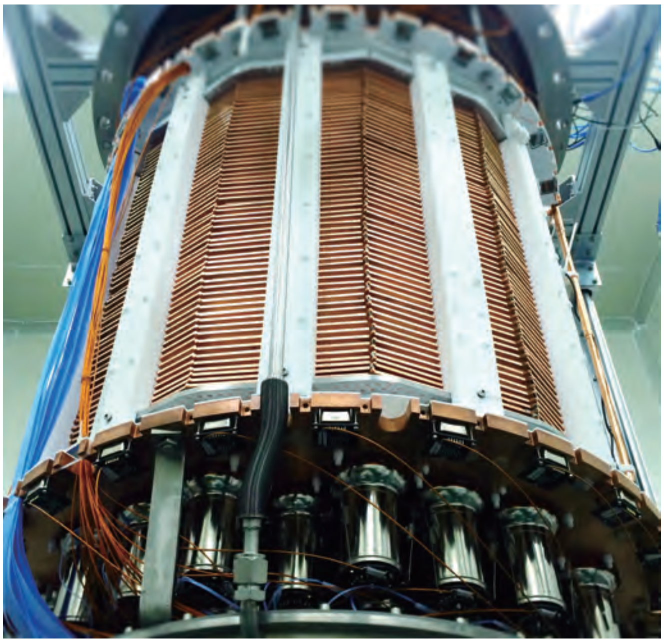

Fig. 2: A picture showing the detector sensitive volume before being installed into the cryostat.

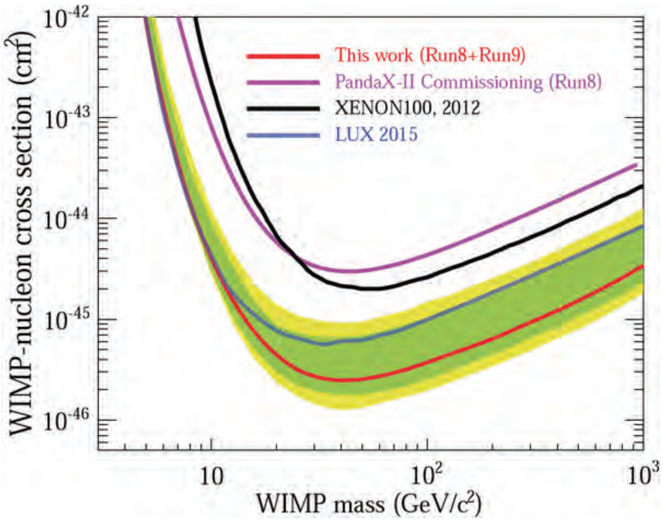

Fig. 3: First results from PandaX-II in comparison to the world data. The solid red curve is the upper limit from PandaX-II for the spin-independent dark matter-nucleon cross sections vs. the dark matter mass. Overlaid limits are: PandaX-II commissioning run (magenta), XENON100 experiment 2012 (black), and LUX experiment 2015 results (blue). The 1 and 2-σ sensitivity bands are shown in green and yellow, respectively.

is equivalent to the fact that there is no single collision between these dark matter particles and 33000 kg of xenon atoms in one day or 1 kg of xenon atoms in 33000 days. This fact sets unprecedented stringent constraints for possible dark matter particles and provides vital inputs for theoretical research on dark matter. As a matter of fact, previous dark matter detection results have excluded many dark matter theories. The most popular theory, the supersymmetric dark matter theory, is also constrained more tightly by the latest PandaX-II data.

The most challenging part of the experiment is that background particles such as gamma rays can also produce photon and electron signals. Despite the fact that the PandaX detector is installed underneath the 2400 m of mountain rocks and is surrounded by hundreds of tons of high purity materials (they stop environmental background but not dark matter), the detector recorded approximately 24 millions of events in total. All these events are processed and scrutinized by the data analysis. In the end, all events were attributed to radioactivity in the detector but not from dark matter collisions. This high rejection power for background interferences demonstrates the great potential of detecting dark matter particles with the PandaX detector.

CJPL is in the middle of a 17-km long tunnel through the JinPing Mountain. The collaborators from the PandaX Collaboration had stationed there since 2012. In 2014, the collaboration completed the first phase experiment (PandaX-I) with a 120-kg liquid xenon target, which was the first large-scale xenon dark matter detector in China. Shortly after this, the upgraded 500 kg PandaX-II detector was constructed in CJPL. This detector is capable of detecting a single photon or electron with high sensitivity. Being the largest running dark matter detector and with the lowest background level in the world to date, it has the highest sensitivity for dark matter detection. After this first run, it will continue to operate until a total of 2-year exposure. In the future, the collaboration is planning to develop a multi-ton multi-purpose liquid xenon experiment, PandaX-xT, to push further the dark matter search. In addition, the collaboration has just announced the conceptual plan (arXiv:1610.08883) for a 200-kg (upgradable to ton-scale) high pressure gas detector project, PandaX-III, to search for the so-called neutrinoless double-β decay in ^{136}Xe in order to test if neutrinos are their anti-particles.

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