Future plan of the PandaX Experiment

- report at the CJPL International Advisory Committee meeting

PandaX Collaboration, 9 Nov., 2016

The PandaX (Particle and astrophysical Xenon) observatory uses xenon as target and detector to search for WIMP particles as well as neutrinoless double beta decay (NLDBD) in ^{136}Xe. At present, the PandaX-II experiment is in operation in CJPL-I. The future PandaX program will pursue the following three main directions:

1. Continue the operation of PandaX-II until a total of 2-year exposure;
2. Develop and operate a multi-ton multi-purpose liquid xenon experiment, PandaX-xT, to push further the dark matter search;
3. Develop and operate a 200-kg (upgradable to ton-scale) high pressure gas TPC (HpgTPC), PandaX-III, to search for NLDBD in ^{136}Xe.

Each direction is elaborated below.

PandaX-II operation

PandaX-II has published the world leading WIMP limit with a 99-day exposure, reaching an upper limit to spin-independent WIMP-nucleon cross section of 2.5×10^{-46}cm^2 [1]. The current plan is to maintain stable operation until we have data with a 2-year total live time. Calibration runs will be interleaved to monitor the detector response. The wealth of low background data will allow us to pursue many different physics analyses (in additional to the standard WIMP-nucleon elastic scattering), including constraints to generic WIMP-nucleon operators, light WIMPs, inelastic WIMPs, limits to solar and galactic axions, etc.

We will also use the PandaX-II detector to test new technologies for a future multi-ton detector, e.g. online Kr removal, upgrade of the trigger/electronics system to achieve a lower threshold and a higher data bandwidth, alternative electron recoil and nuclear recoil calibrations, etc.

PandaX-xT

We are developing a proposal for PandaX-xT, with the ultimate target of reaching the so-called neutrino-floor [2] at a sensitivity to ~10^{-49} cm^2 for the spin-independent WIMP-nucleon cross section. For the immediate next phase, we envision a detector with a sensitive target of 4-ton. The design will be based on our experience with the PandaX-II experiment. The scientific case for the 4-ton experiment is compelling. With a 6 ton-year exposure, the sensitivity to spin-independent WIMP-nucleon cross section limit is expected to reach 10^{-47}cm^2, more than one order of magnitude lower than the current PandaX-II limit. The sensitivity of the 4-ton experiment, together with current leading exclusion limits, the mSUSY contour [3], and the ultimate neutrino "floor" (Billard et al. [2]), is shown in Fig. 1. This experiment will also be a critical technology demonstrator for the next stage PandaX-xT detector.

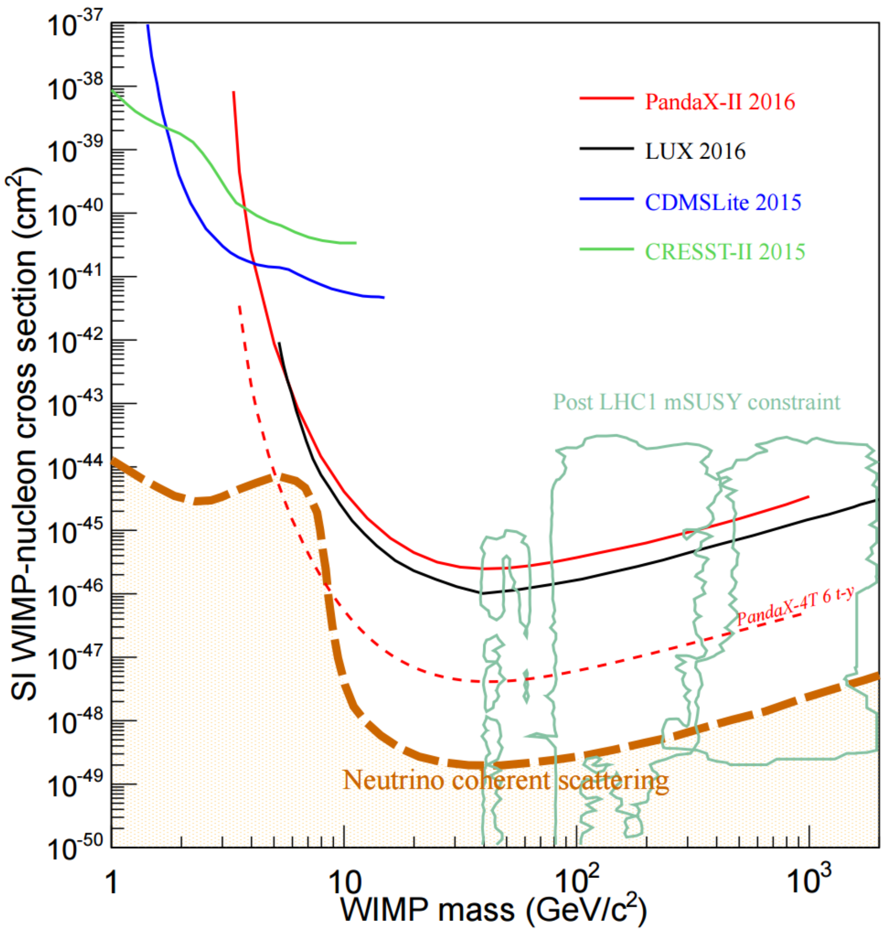

Figure 1 The projected median sensitivity (dashed curves) on the spin-independent WIMP-nucleon cross section for PandaX-4T with 6 ton-y exposure. The currently leading exclusion limits (see legend), the neutrino "floor" (Billard et al. [2]), and the post LHC mSUSY allowed contours (Bagnaschi et al. [3]) are overlaid in solid curves for comparison.

The 4-ton experiment will contain a TPC with a diameter of 1.2 m and a height of 1.2 m. The TPC size is approximately doubled in every dimension from PandaX-II, presenting a few technological challenges. We will perform realistic assembly and tests of the electrodes before the final detector assembly. Additional high quantum efficiency 3-inch PMTs will be employed to maintain the high photon detection efficiency. The new electronics design aims for high data bandwidth in order to achieve a trigger-less readout. The 4-ton experiment needs to handle around 5-ton of liquid xenon, including cooling, storage, filling and recovery. The current system for PandaX-II can handle 1-2 tons of xenon. We plan to build multiple such mature systems and run them in parallel. The reliability can be easily achieved with redundancy.

To achieve lower level of background, we will continue to improve the HPGe counting station at CJPL to reach a detection sensitivity of 0.1 mBq/kg. We are constructing a new krypton distillation tower in CJPL aiming to suppress the Kr concentration to 0.1 ppt. Operating the column underground avoids xenon being exposed to cosmic radiation.

The PandaX-xT detector will be housed in a large ultrapure water pool in the CJPL Hall B2 (Fig. 2). The inner part of the experimental hall is a clean room of class 10000. A dedicated radon-free clean room will be set up for detector assembly. At present, the experimental hall and water pool civil work is completed. Furnishing work is ongoing and the hall is expected to be ready for beneficial occupancy by the beginning of 2018.

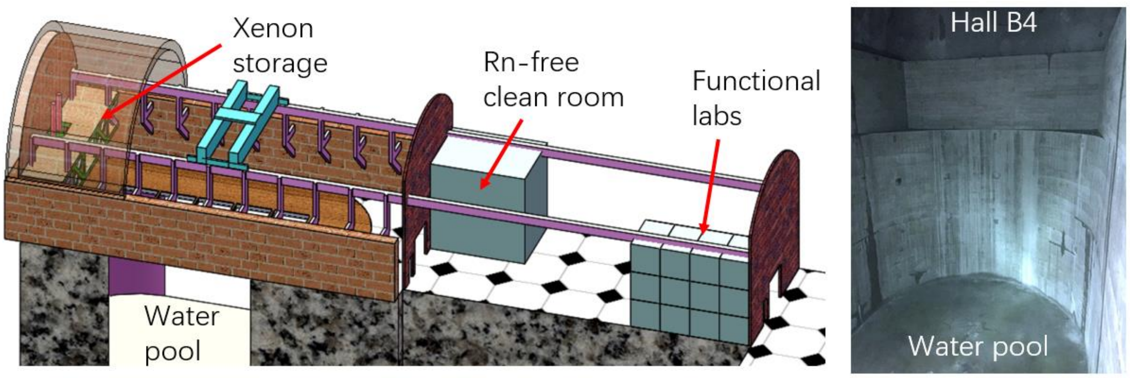

Figure 2: schematic design of Hall B2 in CJPL-II (left), and a picture showing the water pool (right).

PandaX-III

NLDBD, if observed, would confirm that a neutrino is its own anti-particle and provide insights in the origin of tiny neutrino masses. NLDBD violates lepton number conservation and may help explain the matter-antimatter asymmetry in the early universe through leptogenesis. Given the scientific importance, many groups around the world have spent decades on advancing the experimental technologies for making the discovery. It is generally agreed that the immediate goal of the worldwide NLDBD experiments shall be to determine the nature of neutrinos when the neutrino mass spectrum has the inverted hierarchy (e.g. 2015 US nuclear science long-range plan [4]). The current world leading experiment is the KamLAND-Zen in Japan, reaching a lower limit to the half-life of 1.1×10^{26} years [5].

As a natural extension to our liquid xenon dark matter program, we are planning the PandaX-III project at CJPL, which uses ^{136}Xe HpgTPC to search for NLDBD. HpgTPC, with an appropriate charge readout scheme, can achieve percent level (FWHM) energy resolution at the NLDBD Q-value. Moreover, the observed event topology in HpgTPC substantially suppresses background and identifies NLDBD events.

Details of the PandaX-III project can be found in the conceptual design report [6]. This project will take a phased approach. During the first phase, we will build one HpgTPC with 200 kg of 90% enriched ^{136}Xe. Future upgrades will add more HpgTPC modules with improved performance to form a ton-scale experiment. About 200 kg enriched ^{136}Xe at 10 bar will be enclosed in an ultralow background copper pressure vessel of cylindrical shape with a length of 2 m and a diameter of about 1.5 m. The vessel will be located in the same water pool in Hall B4. A symmetrical TPC with ultralow background will be placed in the vessel with the cathode in the middle and two anode planes at the two ends. To reach 3% energy resolution (FWHM) at the NLDBD Q-value, we will use Microbulk Micromegas (MM) [7] with x-y strip readout, which are digitized by a custom ASIC electronics for the first HpgTPC. In addition, a new type of electron readout, called TopMetal [8], has been under development by our collaborators, which has the potential to greatly improve the energy resolution to below 1% FWHM. For the first module, the half-life sensitivity with 3 years live time is 1×10^{26} year at 90% confidence level.

The collaboration has built a prototype, 20-kg scale HpgTPC with Micromegas readout. Commissioning of this demonstrator is currently underway at SJTU. Meanwhile, efforts on high pressure vessels, water shielding, electronics, calibration system, and simulation are being carried out at collaborating institutions.

Collaboration: The PandaX collaboration is led by SJTU, and includes researchers from Peking University, Shandong University, Shanghai Institute of Applied Physics, University of Science & Technology of China, China Institute of Atomic Energy, Sun Yat-Sen University, Yalong Hydropower Company, University of Maryland, Lawrence Berkeley Lab, Alternative Energies & Atomic Energy Commission of France, University of Zaragoza, and Suranaree University of Technology. PandaX-II, PandaX-xT and PandaX-III are all sub-collaborations within PandaX. There is a significant personnel overlap and full information sharing among the three groups.

References:

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