

Updates from the PandaX-II experiment

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Abstract. The PandaX is a series of xenon-based experiments searching for dark matter candidates in the China Jinping Underground Laboratory (CJPL). PandaX-II, a 580-kg liquid xenon time projection chamber (TPC), has recently finished its data taking, with a total exposure of more than 400 live-days. New improvements have been made for better signal reconstruction and background estimation. And also, PandaX-II has shown the potential in neutrino-less double beta decay (NLDBD) research of ^{136}Xe .

1. Introduction

PandaX-II is a dual-phase xenon direct dark matter detector located at CJPL. The cylindrical TPC contains 580 kg liquid Xe in the sensitive volume and 110 3-inch PMTs (55 in top array close to the anode electrode and 55 in bottom array close to cathode) monitoring all the signals coming from the sensitivity region. From 2016 to 2018, the detector has collected up to 400 days of DM search data divided into 3 Runs (Run9, 10 & 11). Following the scientific data taking, a series of R&D tests were carried out until the mid of 2019 when the liquid xenon recuperation started.

For now, using the data taken from Run9 and Run10, several searches of dark matter particles have been done on different topics [1–7]. For the final results covering all the Runs, we are developing a new reconstruction algorithm and have made significant improvements as shown below. The background budget has been updated based on more detailed research. We want also to point out that 9% of natural xenon is ^{136}Xe , which is a good candidate for the NLDBD search. We will also introduce the first NLDBD result from PandaX-II.

2. Improvements in reconstruction and background estimation

Three major improvements in energy reconstruction, vertex reconstruction and estimation of background budget have been achieved.

2.1. Energy reconstruction

We have several low-gain PMTs whose gain values were biased based on the traditional single photon electron fitting method. We need to find another source to calibrate these PMTs. The typical high energy α events were believed evenly distributed in the detector, so the α events charge spectrum from every single PMTs at the symmetric positions should be the same as each other. The average profile of normal PMTs was chosen to be a benchmark for the low-gain one. In that way, the gain could be tuned to a more precise level.

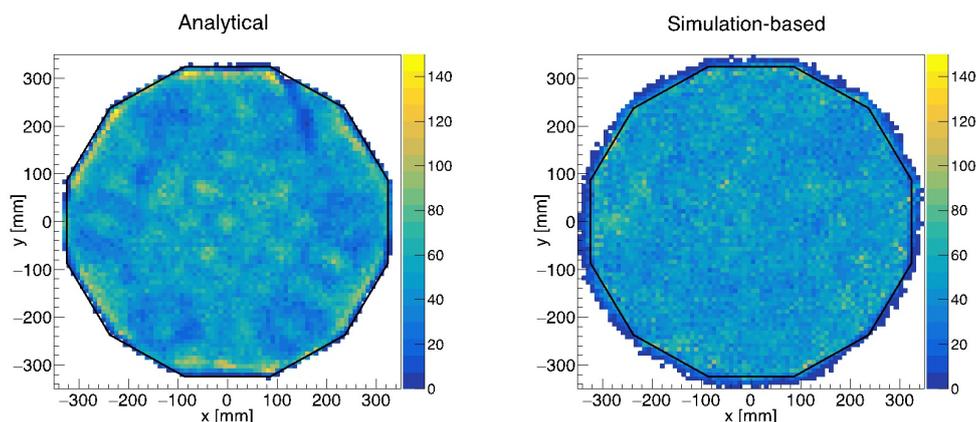


Compared to the bottom PMT array, S2's charge distribution on top PMTs was usually clustered and position-dependent. So we will use S2's charge information from the bottom array to derive the energy information for every event. Furthermore, this method will also relieve the high energy events from the saturation effect.

2.2. Vertex reconstruction

The vertex reconstruction in published researches of PandaX-II was mainly based on the photon acceptance function (PAF) method, which still shows some PMT correlated clustering effect, like Fig.1(a). We suspect that the analytical function may not describe the truth. So we build a new non-analytical PAF using a tuned Monte Carlo(MC) simulation.

First, the events reconstructed around the PMTs centers were picked out as seeds. Then the charge patterns on top PMT array of these events were extracted as the reference for MC tuning. The only tuning parameter is the photon emission height (z) in gaseous xenon. The best tuning can give us the relationship between z and (x, y) . Then the $z(x, y)$ was smoothly interpolated to the whole plane and was fed back into the MC program to get the non-analytical PAF. After applying the improved PAF, the vertex reconstructions of evenly distributed ^{83m}Kr events were much better than the previous one, as shown in Fig.2.



(a) old analytical PAF method.

(b) new non-analytical PAF method.

Figure 1. ^{83m}Kr distribution based on different reconstruction methods.

2.3. Background estimation

For a deeper understanding of the background components of PandaX-II, several updates were finished with new methods.

- We constrained single-site nuclear recoil (SSNR) background via neutron-induced high energy gamma (HEG) signals [9]. The neutron background level in Run 10 was 0.47 ± 0.25 , consistent with the old value of 0.83 ± 0.42 but with a smaller error.
- A ^{222}Rn injection test was carried out to study the performance of ^{222}Rn whose daughter ^{214}Pb will contribute to the major electron recoil background in PandaX-4T [10]. The ^{222}Rn level in Run10 and Run11 were updated with 10.0 ± 1.1 and 11.1 ± 1.4 separately.
- Three methods were applied to estimate the isolated S1 rate, which will contribute to the accidental background combined with isolated S2.
- The model of surface events was also finished [11].

3. First NLDBD result

There is 51.6 kg of ^{136}Xe in the PandaX-II sensitive region. Processed with a new dedicated reconstruction algorithm and data selection criteria, the whole scientific data sets were involved in the NLDBD search [8]. Not competitive as typical NLDBD detectors, but as the first published NLDBD result from noble gas based dark matter detection experiments, it has shown the excellent capability in NLDBD research of similar xenon based projects.

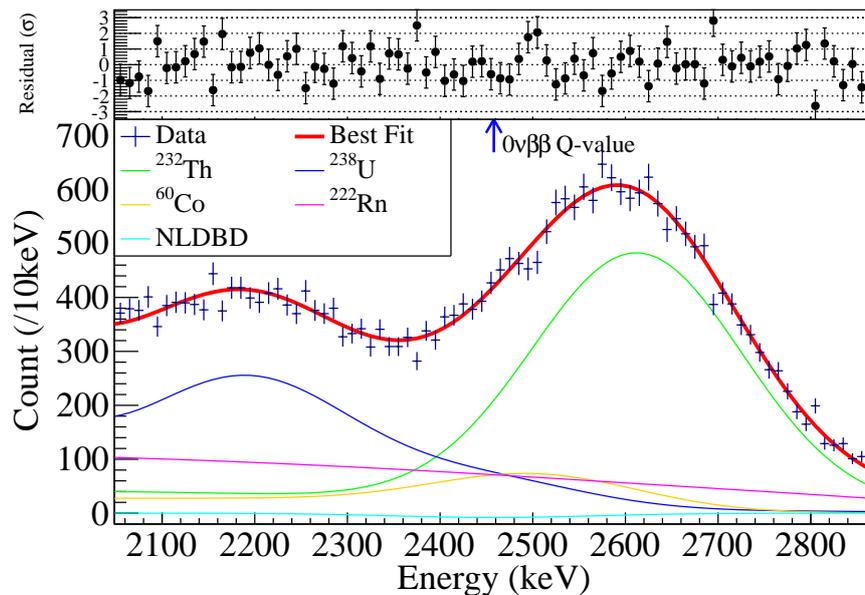


Figure 2. The spectrum of all the data fitted with all background components involved and a floated NLDBD contribution. The NLDBD rate of the best fitting result is $-0.25 \pm 0.21 \times 10^{-23}\text{yr}^{-1}$.

4. Summary

PandaX-II, as one of the most sensitive dark matter detectors, just finished all the scientific tasks this June with many outstanding research topics achieved. We are still making steady progress on the final analysis with entire exposure.

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