Appendix A: Supplementary Materials

This document contains some detailed figures to support the results presented in the main paper, including:

- Fig. 6 the evolution of electron lifetime including the data in Runs 8 and 9;
- Fig. 7 a fit to the anti-correlation between S1 and S2 for the ER peaks to extract the PDE and EEE;
- Fig. 8 comparison of measured ER light yield and charge yield to the prediction by the NEST model.
- Fig. 9 the signal (NR) and background (accidental) efficiencies for the BDT cut in S1 and S2 (below-NR-median);
- Fig. 10 comparison of distributions of two example variables between the signal (NR) and background (accidental) events;
- Fig. 11 data and MC comparison of AmBe distributions in combined energy, S1 and raw S2, with the MC results from the untuned and tuned NEST overlaid;
- Fig. 12 drift time vs. reconstructed radius for the wall $^{210}$Po events;
- Fig. 13 measured energy spectra in the dark matter data below 50 keV$_{ee}$ and below 10 keV$_{ee}$, and the comparison with expected backgrounds;
- Fig. 14 the distribution of final candidates in $\log_{10}(S2/S1)$ vs. S1 from the Run 8 data in this new analysis;
- Fig. 15 the drift time vs. radius-squared and $\log_{10}(S2/S1)$ vs. S1, for the candidates in Run 9, with events removed by the BDT cut highlighted as the blue points;
- Fig. 16 comparison of limits between experiments, and the results from this data using the untuned and tuned NEST model.

![Fig. 6](image_url)  
**FIG. 6:** Evolution of the electron lifetime in Run 8 and Run 9. Each point represent the average in a data taking unit, usually lasted for 1 or 2 days. Only data with electron lifetime longer than 205 $\mu$s were used in the dark matter analysis.
FIG. 7: Linear fit in S2/E vs. S1/E for all ER peaks in data to determine the PDE and EEE. S2 and S1 were obtained from Gaussian fits to each S2 and S1 peak, respectively, and only statistical uncertainties from the fits are shown.

FIG. 8: Comparison of measured ER light yield (left) and charge yield (right) with NEST predictions. Only statistical uncertainties are shown. The systematic uncertainties of PDE and EEE are estimated by the difference between the data and NEST predictions.
FIG. 9: The BDT efficiency for the signal (NR) and background (accidental) events, both are selected below the NR median, projected to S1 (left) and S2 (right).

FIG. 10: Examples of distributions of the input variables used for BDT in the signal and background training samples. Left: S2 pulse shape symmetry, defined as ratio of pre-peak area to the total area of an S2, Right: the width of S2.

FIG. 11: Comparison of distributions between the AmBe data and MC (untuned and tuned, with detection efficiency applied) in combined energy in keV (left), S1 (middle) and raw S2 (right).
FIG. 12: Reconstructed radius vs. drift time for the $^{210}$Po plate-out events from the PTFE wall. The location of the PTFE wall is indicated as the red line.

FIG. 13: Left: combined energy spectrum from 0 to 50 keV in Run 9. Data (black dots) shown include all selection cuts described in Table IV of the main article except that the upper cuts on S1 and S2 are removed. The total background (red) consists of $^{127}$Xe (green), $^{85}$Kr and other ER backgrounds (blue), and neutron background (cyan), all of which are estimated from simulation, as well as accidental background (magenta) estimated from data. When fitting to data, the normalizations of accidental background and NR background were fixed while others were allowed to float. The obtained $^{127}$Xe and $^{85}$Kr rates are consistent with those in Table II of the main article. Right: combined energy spectrum from 0 to 10 keV and individual best fit background components. Data (black dots) shown include all selection cuts described in Table IV of the main article.
FIG. 14: The distribution of $\log_{10}(S_2/S_1)$ versus $S_1$ for DM search data in Run 8 with updated reconstruction and data selection cuts. The median of the NR calibration band is indicated as the red curve. The dashed magenta curve is the equivalent 100 PE cut on $S_2$. The solid magenta curve is the 99.99% NR acceptance curve. The gray dashed curves are the equal energy curves with NR energy indicated in the figure. The two data points below the NR median curve are highlighted as green stars.

FIG. 15: The drift time vs. radius-squared and $\log_{10}(S_2/S_1)$ vs. $S_1$ distributions for candidates in Run 9, with events removed by the BDT cut highlighted as the blue stars.
FIG. 16: The 90% C.L. upper limits for the spin-independent isoscalar WIMP-nucleon cross sections from the combination of PandaX-II Runs 8 and 9 data sets, using untuned NEST (solid red line) and tuned NEST (dashed red line) as the model for dark matter candidate events, respectively. The 1-σ (green) and 2-σ (yellow) sensitivity bands were computed with untuned NEST model. Note that the limit from the tuned NEST is more constraining than that was presented at (http://idm2016.shef.ac.uk/) due to better trained BDT cuts, and is slightly more constraining than what LUX presented at the same conference. More cross checking to this NEST tuning is needed before we present this as an official result. Selected recent world results are plotted for comparison: PandaX-II Run 8 results [1] (magenta), XENON100 225 day results [2] (black), and LUX 2015 results [3] (blue). Representative supersymmetric model contours (2σ) after experimental constraints from LHC Run 1 (gold and brown) from Ref. [4] are overlaid for comparison.