We report the WIMP dark matter search results using the first physics-run data of the PandaX-II 500 kg liquid xenon dual-phase time-projection chamber, operating at the China JInPing underground Laboratory. No dark matter candidate is identified above background. In combination with the data set during the commissioning run, with a total exposure of $3.3 \times 10^4$ kg-day, the most stringent limit to the spin-independent interaction between the ordinary and WIMP dark matter is set for a range of dark matter mass between 5 and 1000 GeV/c$^2$. The best upper limit on the scattering cross section is found $2.5 \times 10^{-46}$ cm$^2$ for the WIMP mass 40 GeV/c$^2$ at 90% confidence level.

Weakly interacting massive particles, WIMPs in short, are a class of hypothetical particles that came into existence shortly after the Big Bang. The WIMPs could naturally explain the astronomical and cosmological evidences of dark matter in the Universe. The weak interactions between WIMPs and ordinary matter could lead to the recoils of atomic nuclei that produce detectable signals in deep-underground direct detection experiments. Over the past decade, the dual-phase xenon time-projection chambers (TPC) emerged as a powerful technology for WIMP searches both in scaling up the target mass, as well as in improving background rejection [1][3]. LUX, a dark matter search experiment with a 250 kg liquid xenon target, has recently reported the best limit of $6 \times 10^{-46}$ cm$^2$ on the WIMP-nucleon scattering cross section [4], with no positive signals observed.

The PandaX-II experiment, a half-ton scale dual-phase xenon experiment at the China JInPing underground Laboratory (CJPL), has recently reported the dark matter search results from its commissioning run (Run 8, 19.1 live days) with a 5845 kg-day exposure [5]. The data were contaminated with significant $^{85}$Kr background. After a krypton distillation campaign in early 2016, PandaX-II commenced physics data taking in March 2016. In this paper, we report the combined WIMP search results using the data from the first physics run from March 9 to June 30, 2016 (Run 9, 79.6 live days) and Run 8, with a total of $3.3 \times 10^4$ kg-day exposure, the largest reported WIMP data set among dual-phase xenon detectors in the world to date.

The PandaX-II detector has been described in detail in Ref. [5]. The liquid xenon target consists of a cylindrical TPC with dodecagonal cross section (opposite-side distance 646 mm), confined by the polytetrafluoroethylene (PTFE) reflective wall, and a vertical drift distance of 600 mm defined by the cathode mesh and gate grid located at the bottom and top. For each physical event, the prompt scintillation photons (S1) and the delayed electroluminescence photons (S2) from the ionized electrons are collected by two arrays of 55 Hamamatsu R11410-
tributions for individual PMTs using low intensity (<178 nm photons in xenon [6], we measured the PE multiple PE production in R11410-20 by the approximately pulses transmitted into the detector. To study the mul-

crived fields while avoiding spurious photons and elec-

teract fields while avoiding spurious photons and elec-

tron emission from the electrodes. In each period, cali-

different TPC field settings were used at different running

ger on the S2 vertical uniformity correction was performed for every data
taking unit, typically lasting for 24 hours, based on the
electron lifetime obtained therein.

The PMT gains were calibrated using the single photo-

electron lifetime is given in the table, although the S2 vertical

The analysis reported in this paper follows the pro-

ey energy and position. A skin liquid xenon region

20 photomultiplier tubes (PMTs) located at the top and

During the data taking period in Run 9, a few dif-

event energy and position. A skin liquid xenon region

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TABLE I: Summary of four settings in Run 9 where $E_{\text{drift}}$ and $E_{\text{extract}}$ are the drift field in the liquid and
electron extraction field in the gaseous xenon,

### Table I: Summary of four settings in Run 9

| Setting | Live Time (day) | $E_{\text{drift}}$ (V/cm) | $E_{\text{extract}}$ (kV/cm) | PDE (%) | EEE (%) | SEG (%) | PE/e (μs) |
|---------|----------------|---------------------------|-----------------------------|---------|---------|---------|----------|
| 1       | 7.76           | 661.3                     | 4.56                        | 11.76   | 45.04   | 24.4    | 348.2    |
| 2       | 6.82           | 664.3                     | 4.86                        | 11.76   | 54.43   | 26.9    | 393.1    |
| 3       | 1.17           | 391.9                     | 5.01                        | 11.76   | 59.78   | 26.7    | 409.0    |
| 4       | 63.85          | 399.3                     | 4.56                        | 11.76   | 46.04   | 24.4    | 679.6    |

PMTs located close to the PTFE wall, the PAFs took

The ER and NR calibration events through tritiated

Most of external background events are located close
to the detector boundary, therefore a powerful background
rejection demands good position reconstruction. In addi-
tion to the template matching (TM) algorithm in Ref. [9],
a new algorithm was developed based on an iterative fit-
ting of the position-dependent PAF for each PMT. For
PMTs located close to the PTFE wall, the PAFs took into account effects due to photon reflections. In each
iteration, the position was reconstructed by maximizing
the charge likelihood according to the PAF obtained from
the previous iteration, and the new position entered into
the determination of the next PAF. Using this recon-
struction, the Kr events in Run 8 and the tritium cali-
bation events in Run 9 yielded good uniformity in the
horizontal plane.

The ER and NR calibration events through tritiated
methane and AmBe sources are shown in log$_{10}$(S2/S1)
vs. S1 in Fig. 1 after the dark matter selection cuts
(Table IV). The AmBe calibration was carried out in-
between the dark matter running periods. A full Monte
Carlo (MC) simulation based on Geant4 [10, 11] (v10.2)
including neutron-gamma correlated emission from the
source, detailed detector geometry, neutron propagation
in and interactions with the detector (following the rec-
ommended physics list [12]), and S1-S2 signal production
(NEST-1.0-based [13]) was developed to compare to the
data. According to the simulation, less than 10% of the
low energy events are contaminated with multiple scat-
tering in the dead region (“neutron-X”). The data qual-
ity cuts mentioned above further suppress the neutron-X
events, therefore the final sample was considered as a
pure single-scatter NR sample at this stage. 3447 such
events were collected for 6.8 days in total, with less than
1% contamination from the ER background. In the bot-
omy panel of Fig. 1 the medians and widths of the NR
data were compared to those obtained from the NEST-
1.0 NR model [13] with detector parameters (PDE, EEE,
SEG, and DPF) taken into account, and a good agree-

### Table I: Summary of four settings in Run 9

| Setting | Live Time (day) | $E_{\text{drift}}$ (V/cm) | $E_{\text{extract}}$ (kV/cm) | PDE (%) | EEE (%) | SEG (%) | PE/e (μs) |
|---------|----------------|---------------------------|-----------------------------|---------|---------|---------|----------|
| 1       | 7.76           | 397.3                     | 4.50                        | 11.76   | 45.04   | 24.4    | 348.2    |
| 2       | 6.82           | 394.3                     | 4.86                        | 11.76   | 54.43   | 26.9    | 393.1    |
| 3       | 1.17           | 391.9                     | 5.01                        | 11.76   | 59.78   | 26.7    | 409.0    |
| 4       | 63.85          | 399.3                     | 4.56                        | 11.76   | 46.04   | 24.4    | 679.6    |
ment is observed. The distributions in S1 and S2 were also compared to the MC, a small discrepancy was observed in detailed shape for small S1 and S2. A tuning of the NEST model could improve the comparison (see Fig. 11 in Supplemental Material [14]) but worsen the agreement for medians of log_{10}(S2/S1) at low energy, which warrant further investigation. Following the standard practice, untuned NEST is used when reporting the official results. The corresponding efficiencies as functions of NR energy are shown in Fig. 2 which are later applied to calculate the dark matter detection efficiency.

At the end of Run 9, tritiated methane with a specific activity of 0.1 mCi/mmol was administered into the detector through a liquid-nitrogen cold trap, a leak valve, and a 100 mL sample chamber under vacuum, which was flushed with xenon gas in the detector. We collected a total of 2807 tritium β-decay events. Among these, 9 leaked below the median of the NR band, leading to a leakage fraction of (0.32±0.11)%.

During the krypton distillation campaign in early 2016, 1.1-ton of xenon was exposed to about one month of sea level cosmic ray radiation, leading to the production of 127Xe, which then decayed via electron capture (EC) to 127I producing characteristic ER energy deposition in the detector. The 127Xe level was identified by the 33 keV K-shell X-ray (following EC), with a decay rate of about 1.1±0.3 and 0.1±0.03 mBq/kg at the beginning and end of Run 9, respectively. In the low-energy region, M-shell and L-shell vacancies of 136I can produce 1.1 keV and 5.2 keV ER events in the detector, respectively. The background was estimated to be 0.37±0.05 mDRU (1 mDRU = 10^{-3} events/day/kg/keV_{ee} where keV_{ee} represents “electron equivalent” energy) below 10 keV_{ee} based on the MC by scaling the measured K-shell X-ray rate, in good agreement with 0.42±0.08 and 0.40±0.13 mDRU obtained from the spectrum fit and time-dependence fit of the low energy events. We chose 0.42 mDRU as the nominal value with a systematic uncertainty of 25%.

The krypton background level was estimated in-situ using the β-γ delayed coincidence from 85Kr decay. In total, 52 candidates were identified in Run 9 within 329 kg of FV (discussed later) and no time dependence was observed, leading to an estimate of 44.5±6.2 ppt of Kr in xenon assuming a 85Kr concentration of 2×10^{-11} in natural Kr. This represents a factor of ten reduction compared to the Kr level in Ref. 9.

The backgrounds due to radio-impurity of detector components shall be the same as those in Ref. 10, and so is the neutron background. The ER background due to Rn was estimated in-situ using the β-α delayed coincidence events. The 222Rn and 220Rn decays were estimated to be 8.6±4.6 and 0.38±0.21 µBq/kg, respectively, consistent with the results in Ref. 10. We also estimated the background from the 136Xe double-β decay events and neutrinos (see Ref. 15 and references therein). The former produces an ER background of 0.10±0.01 events per 10000 kg-day. The neutrino ER

FIG. 1: Top: tritium calibration data in log_{10}(S2/S1) vs. S1, and fits of medians of ER (blue) and NR (red) data. Bottom: AmBe calibration data in log_{10}(S2/S1) vs. S1, together with medians from the data (red solid circles) and MC (green squares), and the fit to ER medians (blue dashed). The 2.3- and 97.7-percentiles circles) and MC (green squares), and the fit to ER vs. S1, together with medians from the data (red solid circles) and MC (green squares), and the fit to ER medians (blue dashed). The 2.3- and 97.7-percentiles circles) and MC (green squares), and the fit to ER medians (blue dashed). The 2.3- and 97.7-percentiles circles) and MC (green squares), and the fit to ER medians (blue dashed). The 2.3- and 97.7-percentiles circles) and MC (green squares), and the fit to ER medians (blue dashed). The 2.3- and 97.7-percentiles circles) and MC (green squares), and the fit to ER medians (blue dashed). The 2.3- and 97.7-percentiles circles) and MC (green squares), and the fit to ER medians (blue dashed). The 2.3- and 97.7-percentiles circles) and MC (green squares), and the fit to ER medians (blue dashed). The 2.3- and 97.7-percentiles circles) and MC (green squares), and the fit to ER medians (blue dashed). The 2.3- and 97.7-percentiles circles) and MC (green squares), and the fit to ER medians (blue dashed). The 2.3- and 97.7-percentiles circles) and MC (green squares), and the fit to ER medians (blue dashed). The 2.3- and 97.7-percentiles circles) and MC (green squares), and the fit to ER medians (blue dashed).

FIG. 2: The detection efficiencies as functions of the NR energy using untuned NEST model after successive applications of selections indicated in the legend. The BDT acceptance shown is determined by applying the BDT efficiency as a function of S1; the acceptance is virtually unchanged if the BDT efficiency is instead applied to S2. The dashed line at 1.1 keV_{ee} indicates the cutoff used in the WIMP limit setting.
background is dominated by pp solar neutrinos, and is estimated to be between 0.2 and 6.0 events per 10000 kg-day where the lower and upper values assume zero or the current experimental limit of the neutrino magnetic moment [10], respectively. The neutrino NR background was estimated to be $1 \times 10^{-3}$ events per 10000 kg-day. The final low energy background composition is summarized in Table II.

| Item       | Run 8 (mDRU) | Run 9 (mDRU) |
|------------|--------------|--------------|
| $^{85}$Kr  | 11.7         | 1.19         |
| $^{127}$Xe | 0.06         | 0.13         |
| $^{222}$Rn | 0.13         | 0.04         |
| $^{220}$Rn | 0.02         | 0.01         |
| Detector material ER | 0.20 | 0.20 |
| Total      | 12.0         | 1.95         |

TABLE II: Summary of ER backgrounds from different components in Run 8 and Run 9. The fractional uncertainties for $^{85}$Kr and $^{127}$Xe are 17% and 0% for Run 8 and 14% and 25% for Run 9, respectively. The uncertainties for $^{222}$Rn and $^{220}$Rn in both runs are taken to be 54% and 55%, respectively. The fractional uncertainty due to detector materials is estimated to be 50% based on the systematic uncertainty of the absolute efficiency of the gamma counting station. Different from Ref. [5], values in the table are now folded with detection efficiency.

Similar to Ref. [9], the accidental background was computed by randomly pairing the isolated S1 (1.8 Hz) and S2 (approximately 1500/day) events within the dark matter selection range. The data quality cuts mentioned earlier suppressed this background to 33%, among which 15% is below the NR median. To optimize the rejection for such background, further cuts were developed based on the boosted-decision-tree (BDT) method [17], in which the below-NR-median AmBe calibration data and randomly paired S1-S2 signals were used as the input signal and background, respectively. The input data were split into two equal statistics sets, one for training and the other for test. The BDT cuts target, for example, events where the drift time and S2-width are inconsistent, or where the S2 shape indicates an S2 originating from the gate or gas regions. 13 variables entered into the training including the charge of S1, S2 and the drift time, the width, 10%-width, rising slope, waveform asymmetry, and top/bottom ratio of the S2, ratio of maximum bottom channel to total and top/bottom ratio of the S1, spikes-within and spikes-around the S1 (indicators of a S2 mis-ID), and the pre-S2 area in a window between 1.5 and 3 $\mu$s (tag of a gate event). After applying the BDT cuts to the accidental background surviving the data quality cuts, events below the NR median were strongly suppressed to 27%, while the overall AmBe NR efficiency was maintained at 93%. The uncertainty on the remaining accidental background was estimated to be 45% using the difference found in Run 8 and Run 9. Similar to Ref. [5], the final S1 range cut was chosen to be between 3 to 45 PE, corresponding to an average energy window between 1.3 to 8.7 keV$_{ee}$ (4.6 to 35.0 keV$_{nr}$), and S2s were required to be between 100 PE (raw) and 10000 PE (uniformity corrected). For all events with a single S2, the FV cut was determined based on the PAF-reconstructed position distribution. The selection criterion in the horizontal plane was taken to be $r < 268$ mm, using data with S1 outside of the dark matter search window (between 50 and 200 PE). The drift time was required to be between 18 to 310 $\mu$s, where the maximum drift time cut was to suppress the below-cathode $\gamma$ energy deposition (so-called “gamma-X") from $^{127}$Xe decays. The liquid xenon mass was estimated to be 329±16 kg, where the uncertainty was estimated based on the position difference between the PAF and TM methods, consistent with other estimates using the tritium event distribution and expected intrinsic resolution from the TM method. The vertical electric field deformation resulting from the accumulations of wall charges in the TPC [4] was estimated using the $^{210}$Po plate-out events from the PTFE wall. The reconstructed positions are 2.4 mm (18 $\mu$s) to 6.3 mm (310 $\mu$s) away from the geometrical wall, a combined effect from reconstruction and field distortion. Therefore we have made a conservative choice of the FV and neglected the field deformation therein. Under these cuts, the final expected background budget is summarized in Table III.

| ER     | Accidental Neutron | Total Expected | Total observed |
|--------|--------------------|----------------|----------------|
| Run 8  | 622.8              | 5.20           | 0.25           | 628±106 | 734 |
| Below NR median  | 2.0               | 0.33           | 0.09           | 2.4±0.8 | 2   |
| Run 9  | 377.9              | 14.0           | 0.91           | 393±46  | 389 |
| Below NR median  | 1.2               | 0.84           | 0.35           | 2.4±0.7 | 1   |

TABLE III: The expected background events in Run 8 and Run 9 in the FV, before and after the NR median cut. The fractional uncertainties of expected events in the table are 17% (Run 8 ER), 12% (Run 9 ER), 45% (accidental), and 100% (neutron), respectively. Both the uncertainties from the ER rate and leakage fraction, (0.32±0.01)% were taken into account in estimating the uncertainty of ER background below the NR median. Number of events from the data are shown in the last column.

The event rates of Run 9 after successive selections are summarized in Table IV. The skin veto selections are more effective than that in Run 8 since the background was less dominated by the volume-uniform $^{85}$Kr $\beta$-decays. The vertex distribution of all events before and after the FV cut is shown in Fig. 5. Outside the FV, pile-up of events near the cathode, the gate and the wall were observed. After the FV cut, 389 events survived, and event distribution in radius-square agree statistically with a flat distribution, indicating no effects from the
FIG. 3: Position distribution of events that pass all selections (gray points), and those below the NR median (outside FV: red points; inside FV: green star), with FV cuts indicated as the black dashed box.

electric field deformation due to wall charges. One event was found below the NR median curve, with its location indicated in Fig. 3. The log

\[ \log_{10}(S2/S1) \] vs. S1 distribution for the 389 candidates is shown in Fig. 4. Being close to the NR median line, the single below-NR-median event is consistent with a leaked ER background.

| Cut                      | #Events | Rate (Hz) |
|--------------------------|---------|-----------|
| All triggers             | 24502402| 3.56      |
| Single S2 cut            | 9783090 | 1.42      |
| Quality cut              | 5853125 | 0.85      |
| Skin veto cut            | 5160513 | 0.75      |
| S1 range                 | 197208  | 2.87×10^{-2}|
| S2 range                 | 131097  | 1.91×10^{-2}|
| 18 µs FV cut             | 21079   | 3.06×10^{-4}|
| 310 µs FV cut            | 7361    | 1.07×10^{-3}|
| 268 mm FV cut            | 398     | 5.79×10^{-5}|
| BDT cut                  | 389     | 5.66×10^{-5}|

TABLE IV: The event rates in Run 9 after various analysis selections.

The data in Run 8 and Run 9 were combined in the final analysis to obtain a new WIMP search limit. The Run 8 data were reanalyzed with the updated reconstruction and data selection cuts except that the vertical cuts were maintained from 20 to 346 µs (FV = 367 kg), since there was no gamma-X contamination from \(^{127}\)Xe in Run 8. This represents the largest dark-matter-search data set among dual-phase xenon detectors to date with an overall exposure of 3.3×10^4 kg-day. A likelihood approach similar to that in Ref. [9] was used to fit the measured data distribution in S1 and S2. A parameterized tritium event distribution was used to simulate expected distributions for different ER background components, and that for accidentals was obtained from the data. The DM NR signals were simulated with the untuned NEST for different WIMP masses as the expected DM distributions, with the conservative low energy cutoff at 1.1 keV\(_{nr}\) [1]. The entire data set was separated into 15 time bins to take into account the time dependent factors such as the electron lifetime, the background level, and other detector parameters (Table I). The scales of all five background components, \(^{127}\)Xe, \(^{85}\)Kr, other ER background (including Rn and material background), accidental, and neutron background, were defined as global nuisance parameters with their corresponding Gaussian penalty terms constructed based on systematic uncertainties in Tables II and III. The nominal rates for the latter four backgrounds were taken from Table I, and for \(^{127}\)Xe, the nominal rate was derived from the table to include the time dependence. The uncertainties for PDE, EEE, and SEG in the caption of Table II were verified to have small impact to the results and were neglected in the likelihood fit for simplicity.

To obtain the exclusion limit to spin-independent isoscalar WIMP-nucleon cross section, profile likelihood ratio [18, 19] was constructed over grids of WIMP mass and cross section, and the final 90% confidence level (C.L.) cross section upper limits were calculated using the CL\(_s\) approach [20, 21]. The final results are shown in Fig. 5 with recent results from PandaX-II Run 8 [5] and LUX [4] overlaid. Our upper limits lie within the ±\(1\)σ sensitivity band, consistent with statistical expectation based on Table III. The lowest cross section limit obtained is 2.5×10^{-46} cm\(^2\) at a WIMP mass of 40 GeV/c\(^2\), which represents an improvement of more than a factor of 10 from Ref [5]. In the high WIMP mass region, our results are more than a factor of 2 more stringent than the LUX results [4]. Note that we have been gen-

FIG. 4: The distribution of log\(_{10}(S2/S1)\) versus S1 for the dark matter search data. The median of the NR calibration band is indicated as the red curve. The dashed magenta curve represents the equivalent 100 PE cut on S2. The solid magenta curve is the 99.99% NR acceptance curve. The gray dashed curves represent the equal energy curves with NR energy indicated in the figures. The data point below the NR median curve is highlighted as a green star.
erally conservative in officially reporting the first limits in this article. WIMP NR modeling with a tuned NEST could result in an even more stringent limit (see Fig. 10 in Supplemental Material [14]), and a more elaborated treatment of FV cuts would also help.

![Graph showing 90% C.L. upper limits for the spin-independent dark matter candidates were identified above background](image)

**FIG. 5**: The 90% C.L. upper limits for the spin-independent isoscalar WIMP-nucleon cross sections from the combination of PandaX-II Run 8 and Run 9 (red solid). Selected recent world results are plotted for comparison: PandaX-II Run 8 results [5] (magenta), XENON100 225 day results [22] (black), and LUX 2015 results [1] (blue). The 1 and 2-σ sensitivity bands are shown in green and yellow, respectively.

In conclusion, we report the combined WIMP search results using data from Run 8 and Run 9 of the PandaX-II experiment with an exposure of $3.3 \times 10^4$ kg·day. No dark matter candidates were identified above background and 90% upper limits were set on the spin-independent elastic WIMP-nucleon cross sections with a lowest excluded value of $2.5 \times 10^{-46} \text{ cm}^2$ at a WIMP mass of 40 GeV/c$^2$, the world best reported limit so far. The result is complementary to the searches performed at the LHC, which have produced various WIMP-nucleon cross section limit in the range from $10^{-40}$ to $10^{-50}$ (c.f. Refs. [23] and [24]), dependent on the dark matter production models. The PandaX-II experiment continues to take physics data to explore the previously unattainable WIMP parameter space.

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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: 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_{ee} (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 [5] (magenta), XENON100 225 day results [22] (black), and LUX 2015 results [4] (blue). Representative supersymmetric model contours (2σ) after experimental constraints from LHC Run 1 (gold and brown) from Ref. [25] are overlaid for comparison.