Dark matter search results from the PandaX-II experiment

Mengjiao Xiao
University of Maryland, College Park
(On behalf of the PandaX-II collaboration)

2017-06-21

PandaX Collaboration

PandaX = Particle and Astrophysical Xenon Experiments

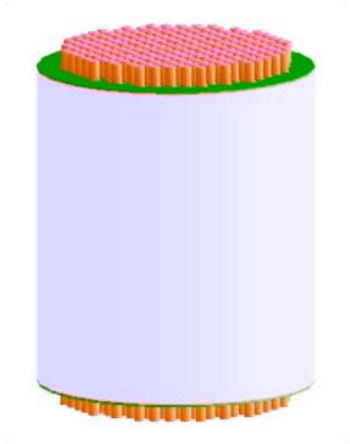
PANDA X ~ 50 people

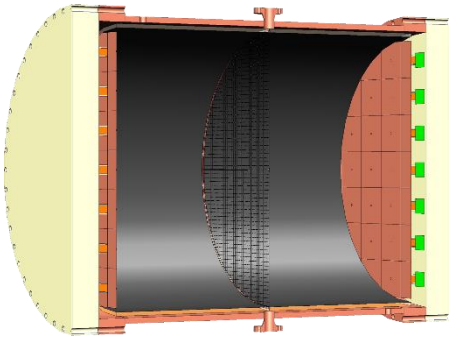
Started in 2009:

- Shanghai Jiao Tong University (2009-)
- Peking University (2009-)
- Shandong University (2009-)
- Shanghai Institute of Applied Physics, CAS (2009-)
- University of Science & Technology of China (2015-)
- China Institute of Atomic Energy (2015-)
- Sun Yat-Sen University (2015-)
- Yalong Hydropower Company (2009-)
- University of Maryland (2009-)
- Alternative Energies & Atomic Energy Commission (2015-)
- University of Zaragoza(2015-)
- Suranaree University of Technology(2016-)

PandaX Experiments

PANDA X = Particle and Astrophysical Xenon Experiments





PandaX-I: 120 kg DM experiment
2009-2014

PandaX-II: 500 kg DM experiment
2014-2018

PandaX-xT: multi-ton (~4-T) DM experiment
future

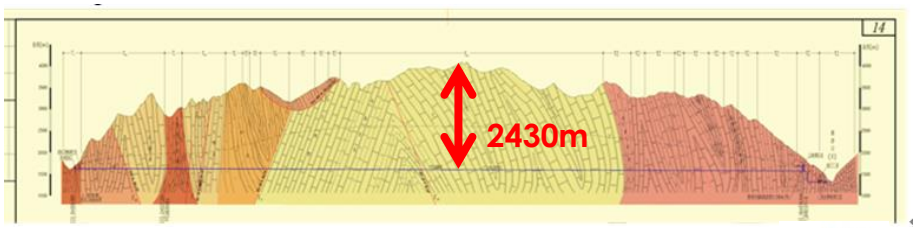
PandaX-III: 200 kg to 1 ton HP gas ^{136}Xe 0vDBD experiment
future

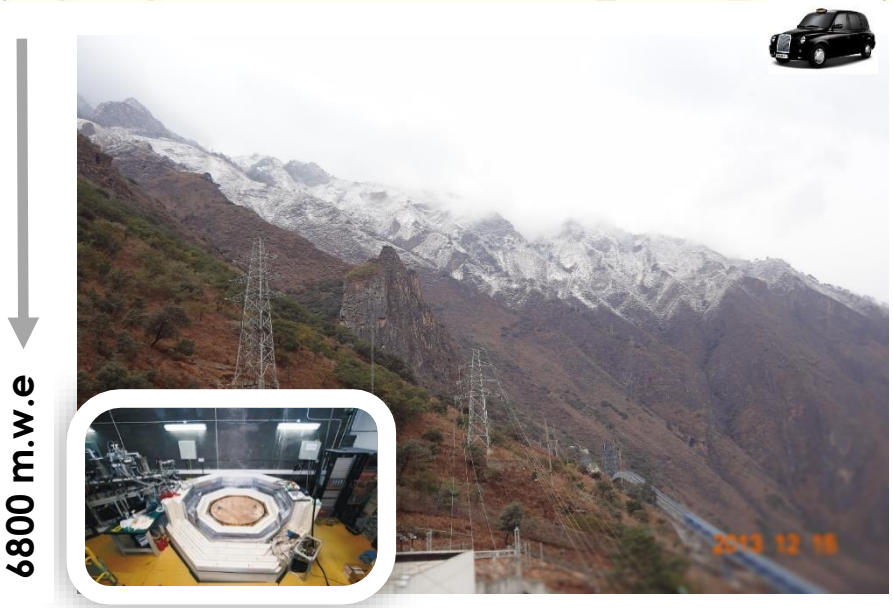
CJPL-I

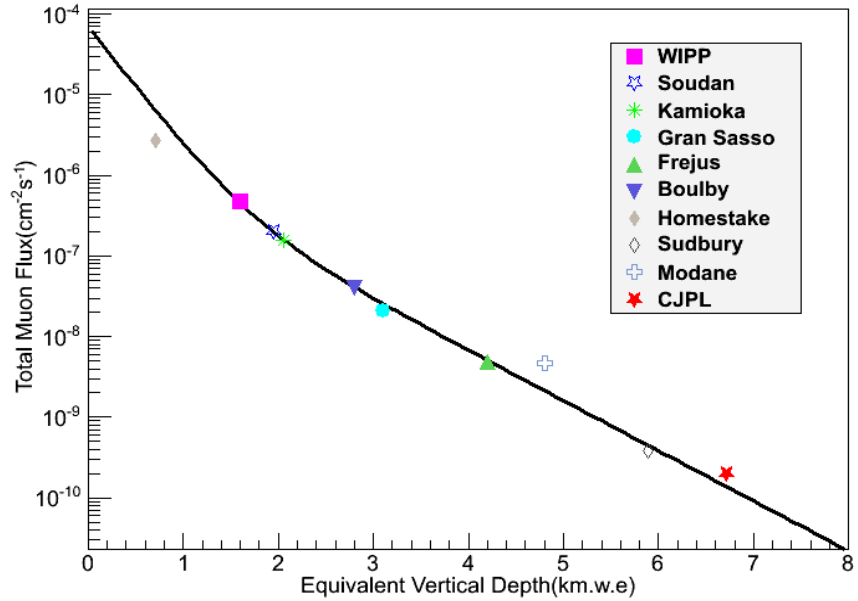
CJPL-II

Location of PandaX experiments

CJPL = China Jin-Ping Underground Laboratory

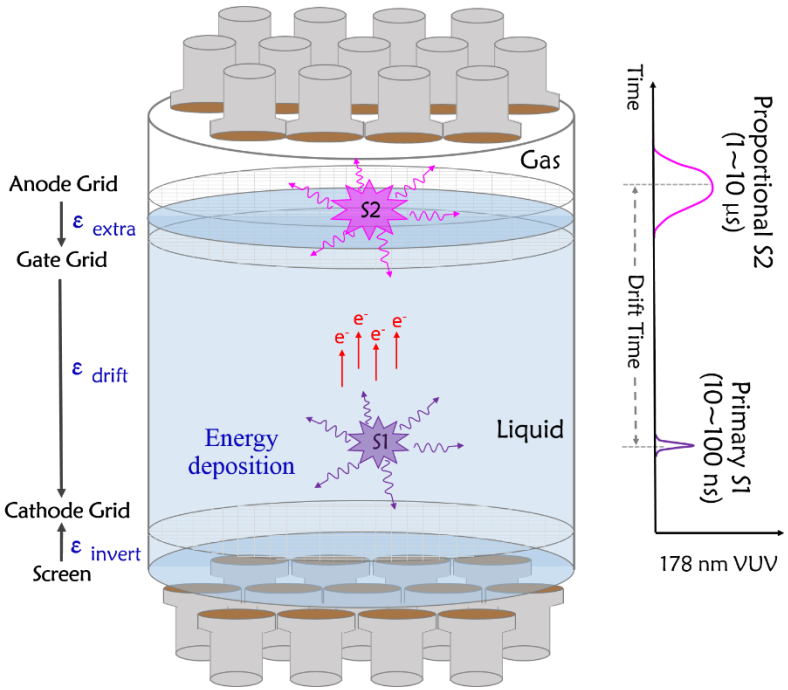


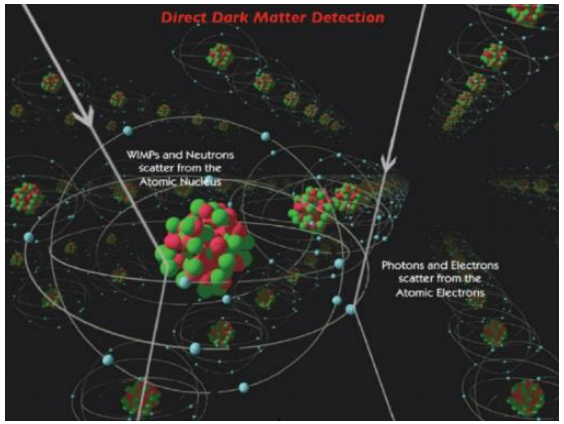


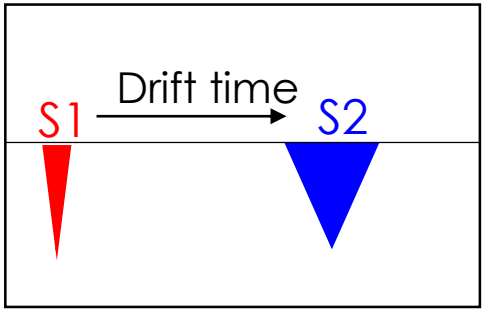


- Deepest in the world, muon flux ~1 μ/week/m^2;
- Horizontally access, Drive in!

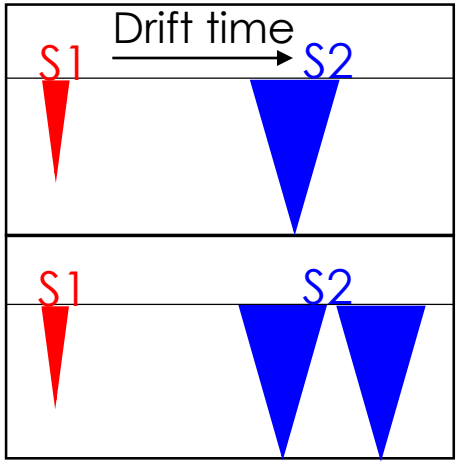
Dark matter searches with dual-phase TPC







Dark matter:
nuclear recoil (NR)



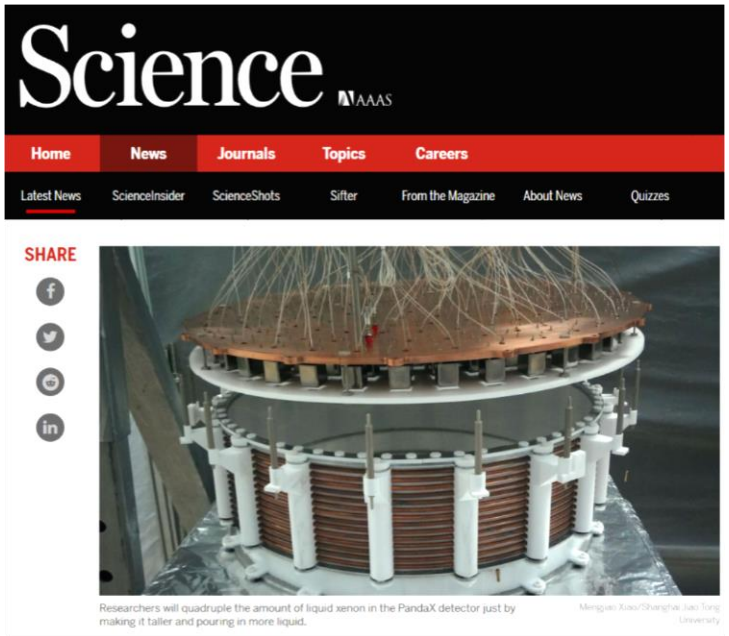
Gamma background:
electron recoil (ER)

$(S2/S1)_{NR} << (S2/S1)_{ER}$

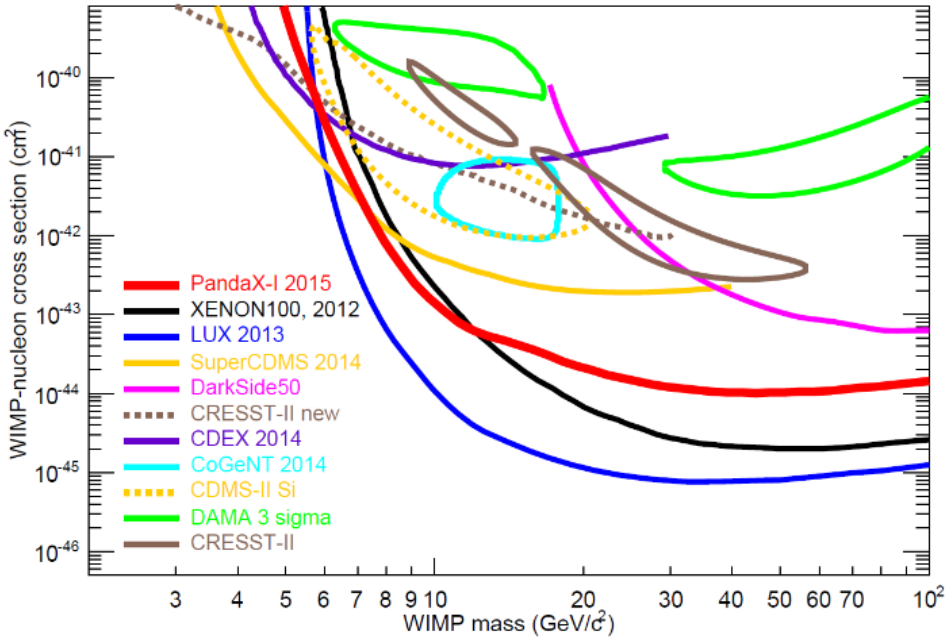
Final DM search results of PandaX-I experiment

Chinese team is catching up in hunt for dark matter

By Adrian Cho | Aug. 26, 2014 , 6:00 PM



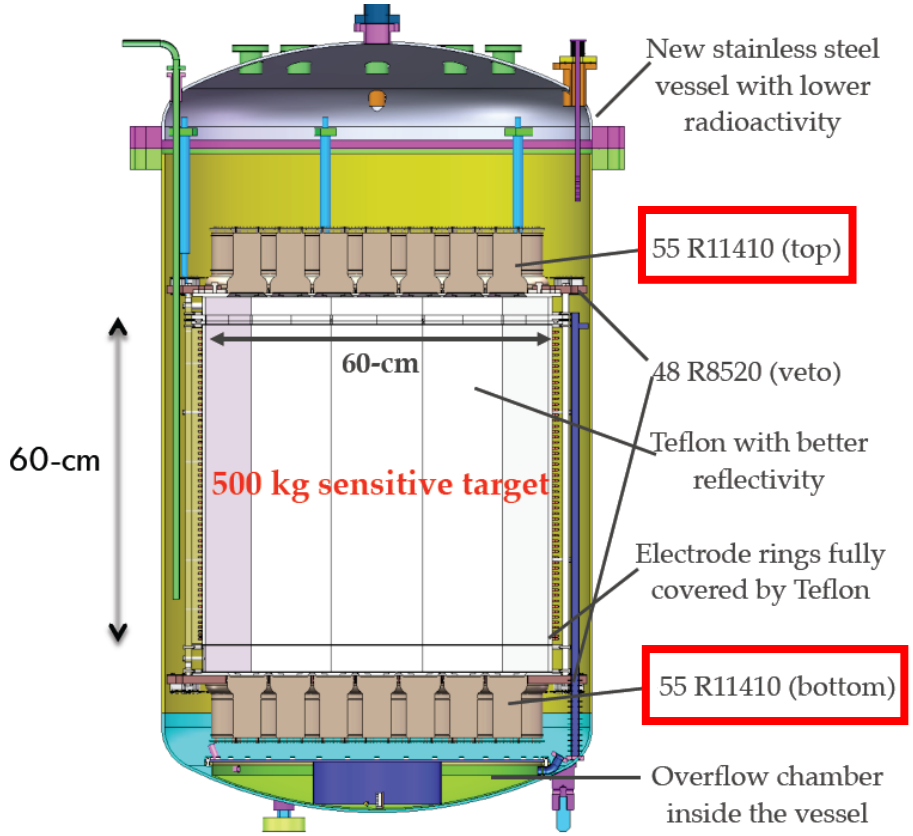
Phys. Rev. D 92, 052004(2015)



- Completed in **Oct. 2014**, with 54.0×80.1 kg-day exposure.
- Data strongly disfavor all previously reported claims.
- Competitive upper limit for low mass WIMP among xenon experiments.

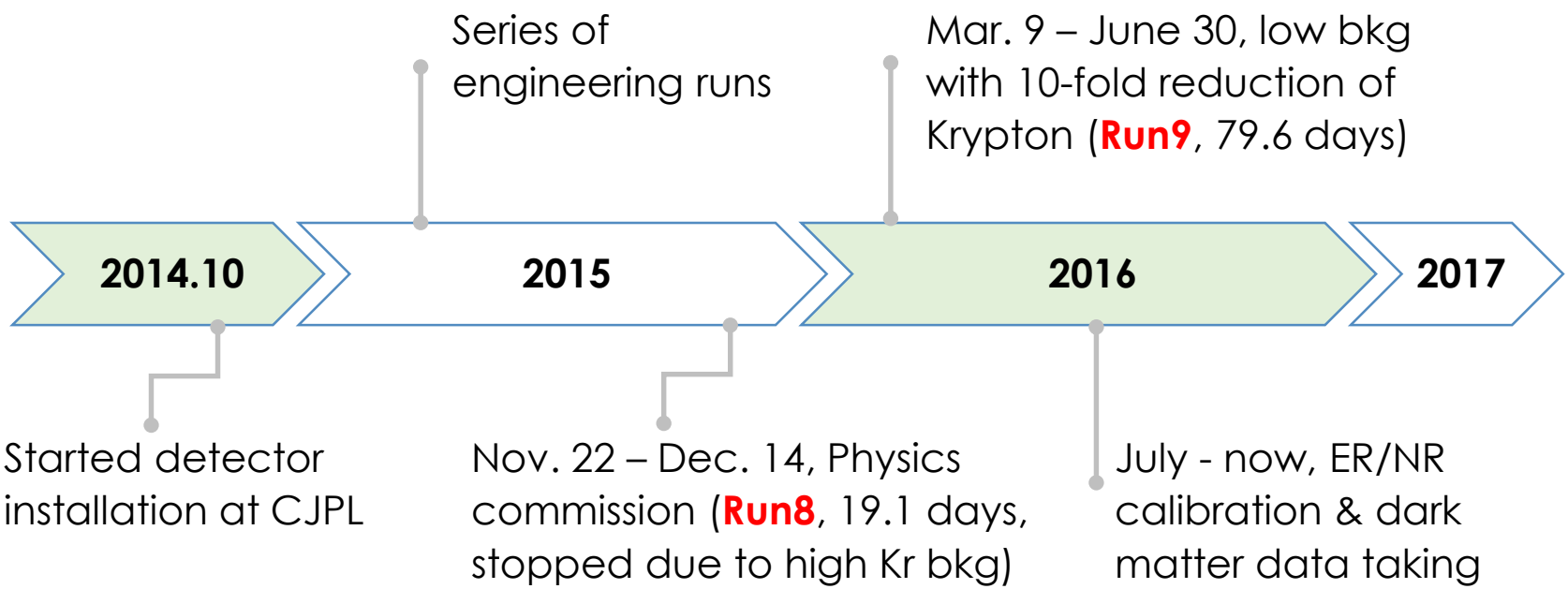
PandaX-II new TPC

- **H=60 cm, ∅ = 60 cm**
- **More than Larger Volume:**
  - New IV: inner vessel with clean low radioactive Stainless steel
  - New PMTs: 55+55, 3-inch high QE (R11410) and improved base with split ±HV power.
  - New Veto: PMTs in skin region
  - Better Reflector: improved reflectivity of PTFE, etc.



Assembly of PandaX-II detector

Run history of PandaX-II

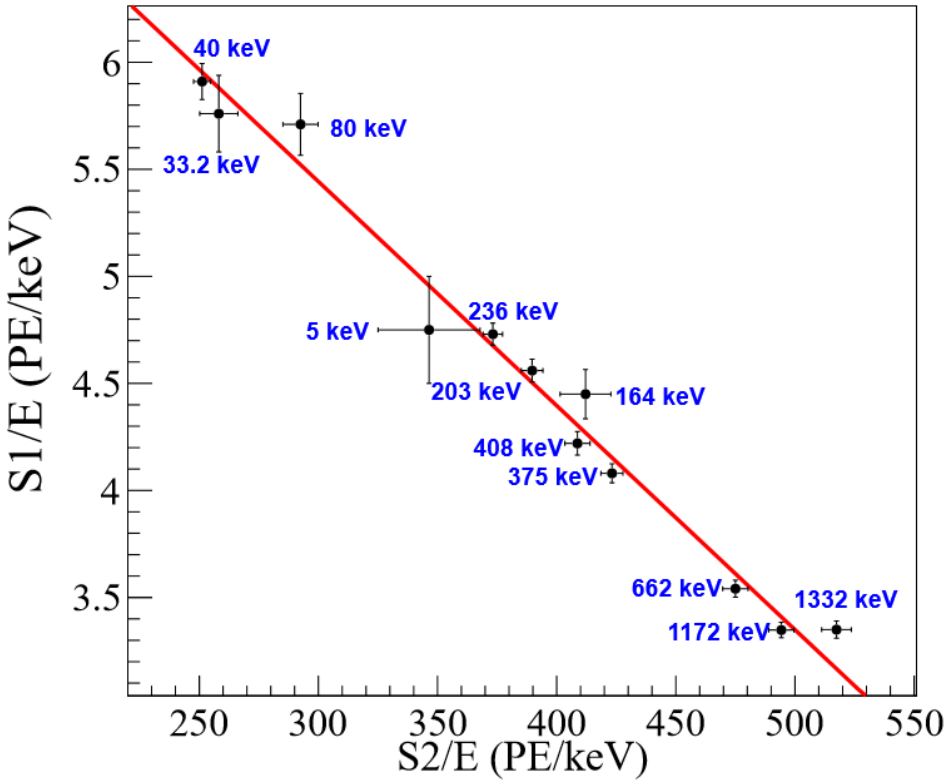


Major updates in Run9

Items	Status in Run9
Krypton level	Reduced by ×10
Exposure	Increased by ×4 (79.6 vs 19.1 days)
ER calibration	Using tritium calibration
NR calibration	Statistics ×6
Analysis	• Improved position reconstruction; • Used BDT to suppress accidental background by more than ×3

Detector performance

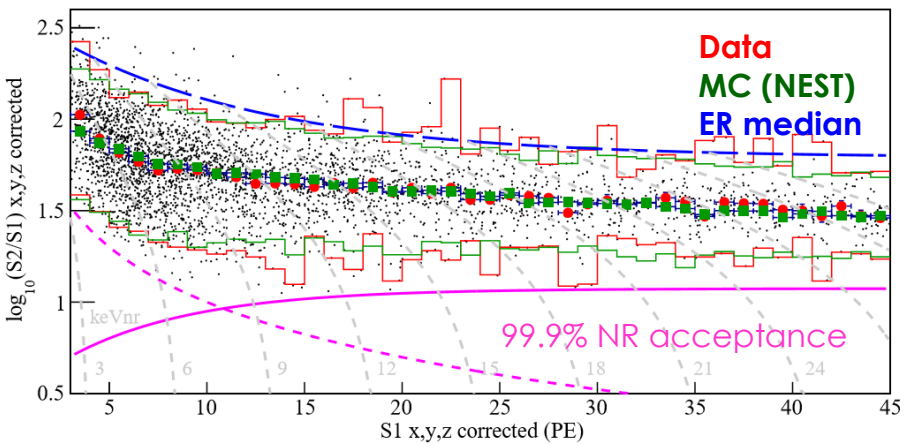
$$E_{ee} = W \times \left(\frac{\mathrm{S1}}{\mathrm{PDE}} + \frac{\mathrm{S2}}{\mathrm{EEE} \times \mathrm{SEG}}\right)$$



- W = 13.6 eV (global fit)
- Gaussian fits to all ER peaks in data
- Uncertainty on each data point estimated using energy nonlinearity
- Linear fit in S1/E vs S2/E to extract PDE and EEE

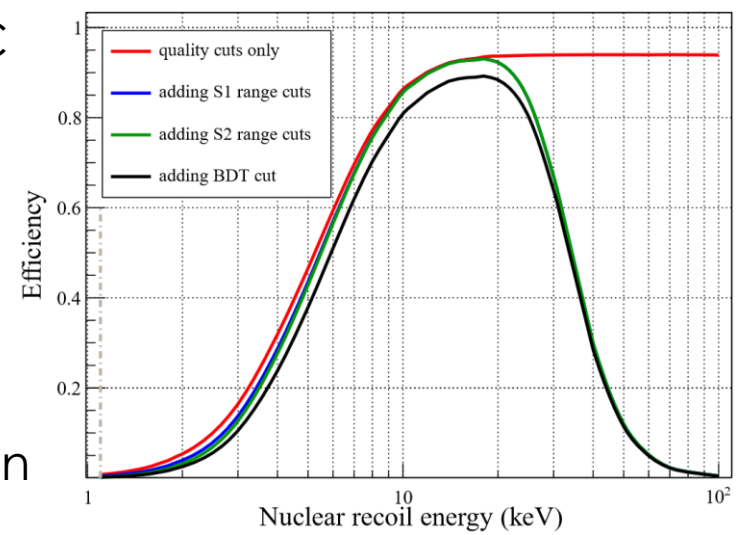
Setting	Live time (day)	E_{drift} (V/cm)	E_{extract} (kV/cm)	PDE (%)	EEE (%)	SEG PE/e	τ_e (μs)
1	7.76	397.3	4.56	11.76	46.04	24.4	348.2
2	6.82	394.3	4.86	11.76	54.43	26.9	393.1
3	1.17	391.9	5.01	11.76	59.78	26.7	409.0
4	63.85	399.3	4.56	11.76	46.04	24.4	679.6

NR calibration

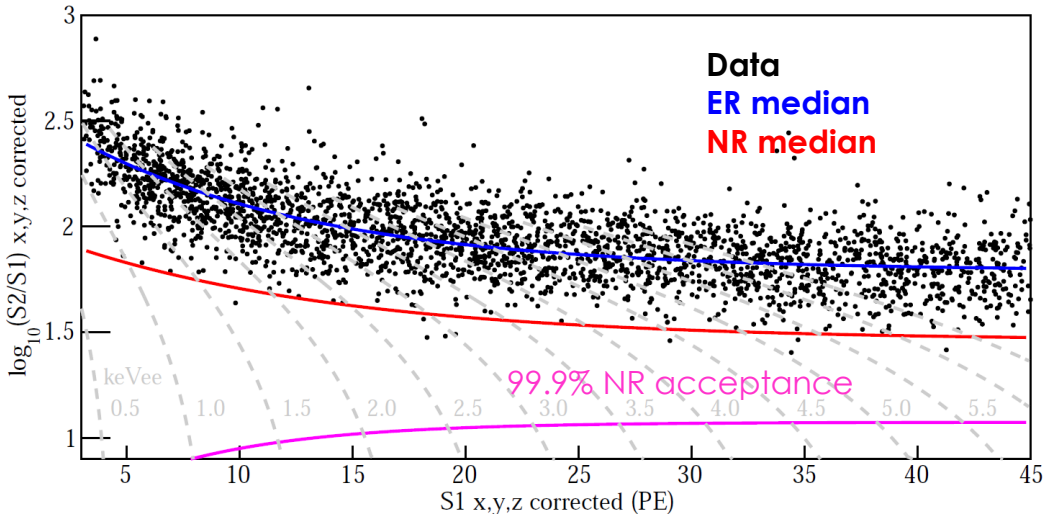


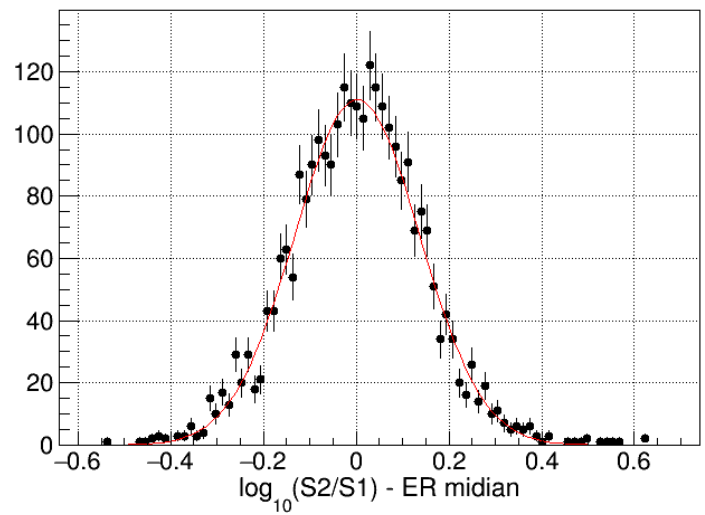
- 162.4 hours of AmBe data taken, with ~3400 low energy single scatter NR events collected
- NR median curve agreed well with MC (NEST-1.0-based)

- NR efficiency obtained by data/MC ratio
- S1 [3,45] PE, S2 [100_{raw},10000_{corr}] PE
- Adopted 1.1 keV_{nr} threshold
- NR efficiency function agrees with that obtained in tritium ER calibration



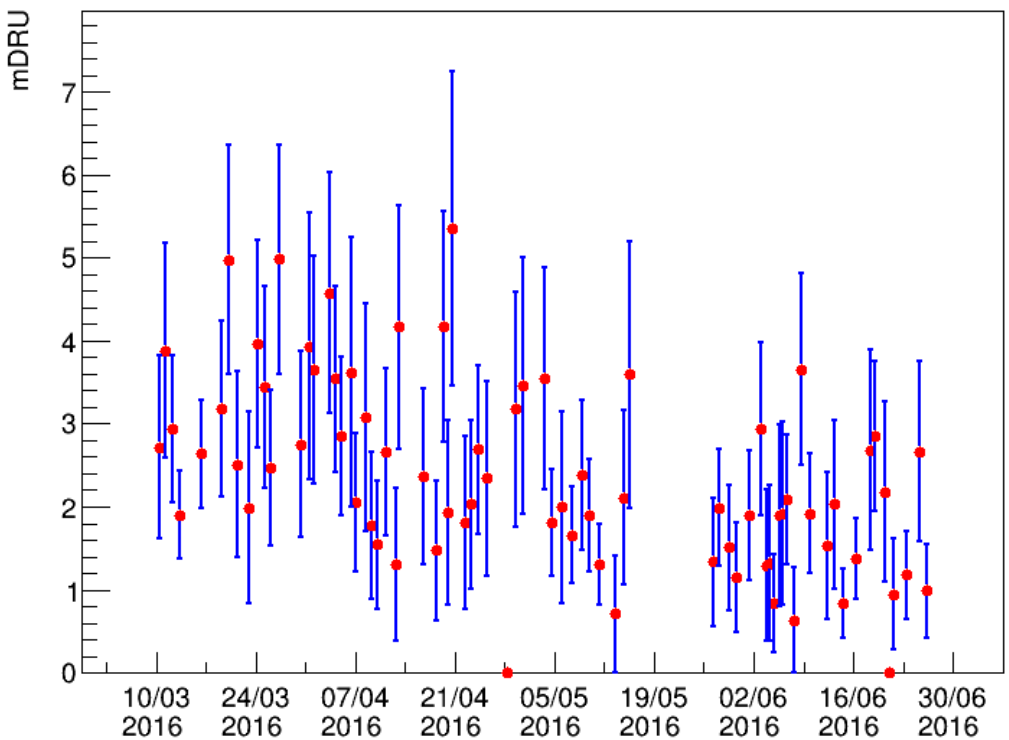
ER calibration with CH_3T





- 18.0-hour data, ~2800 low energy ER events in fiducial volume.
- 9 events below NR median, leakage fraction (0.32±0.11)%
- Consistent with Gaussian expectation

Low-energy rate in Run9

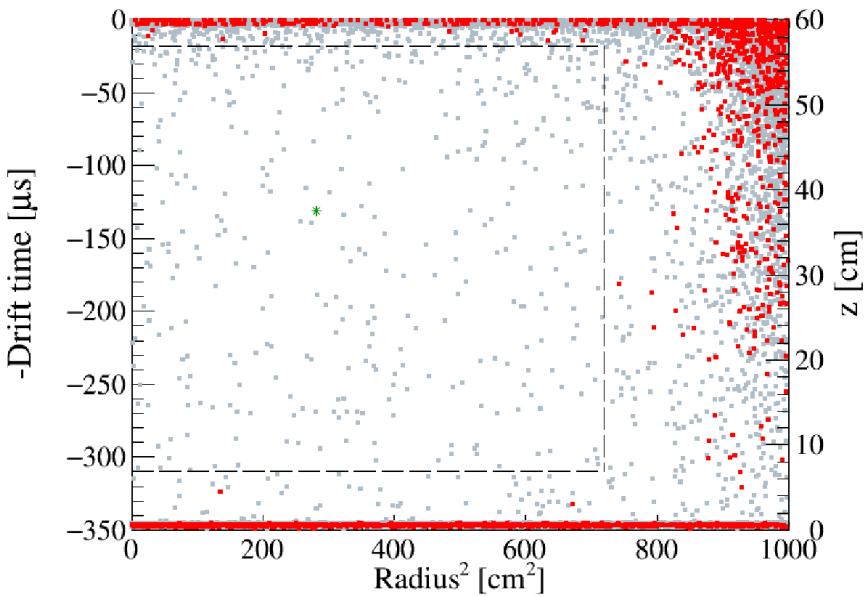


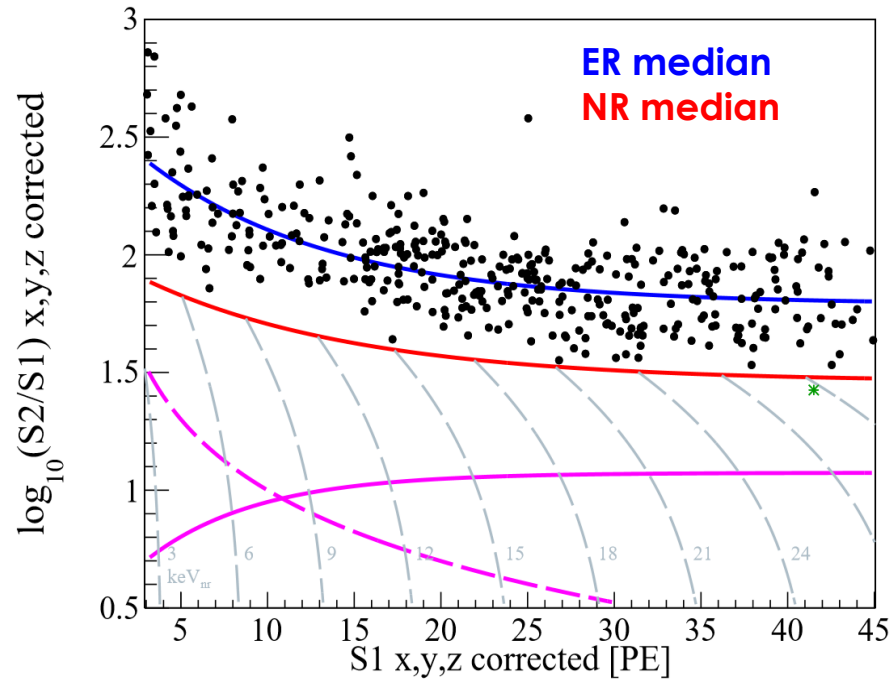
Item	Run 8 (mDRU)	Run 9 (mDRU)
^{85}Kr	11.7	1.19
^{127}Xe	0	0.42
^{222}Rn	0.06	0.13
^{220}Rn	0.02	0.01
Detector material ER	0.20	0.20
Total	12.0	1.95

- Events selected in the FV with energy less than 10 $\mathrm{keV_{ee}}$
- ~2 mDRU in the FV on average (15.3 mDRU in Run 8)
- Decrease over time due to ^{127}Xe decay

Final candidates in Run9

Gray: all
Red: below NR median
Green: below NR median and in FV





- 389 total candidates found in the FV (329 kg), 1 below NR median.
- Outside FV, edge events are more likely to lose electrons leading to S2 suppression.

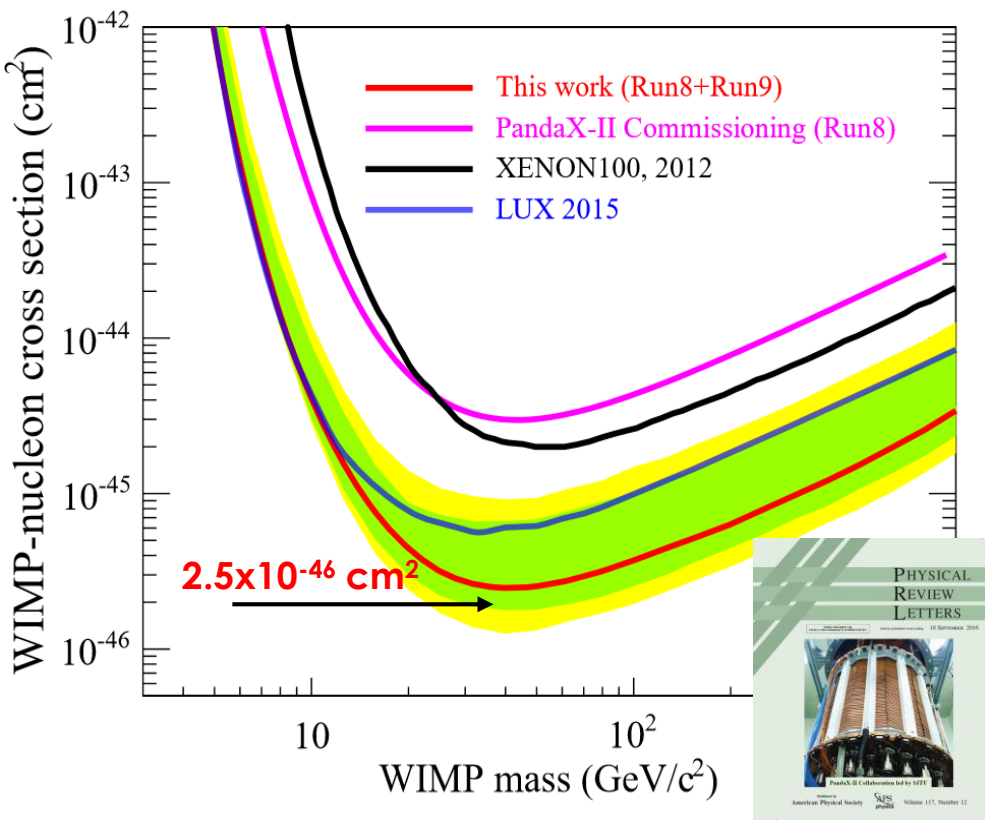
Final candidates in Run8+Run9

	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

- No excess was found compared to the expectation.
- Data in run 8 and run 9 were combined in the final analysis, 15 time bins taking into account the time dependent factors
- A likelihood approach is used to obtain a new WIMP search limit.

Spin-independent cross section Limit

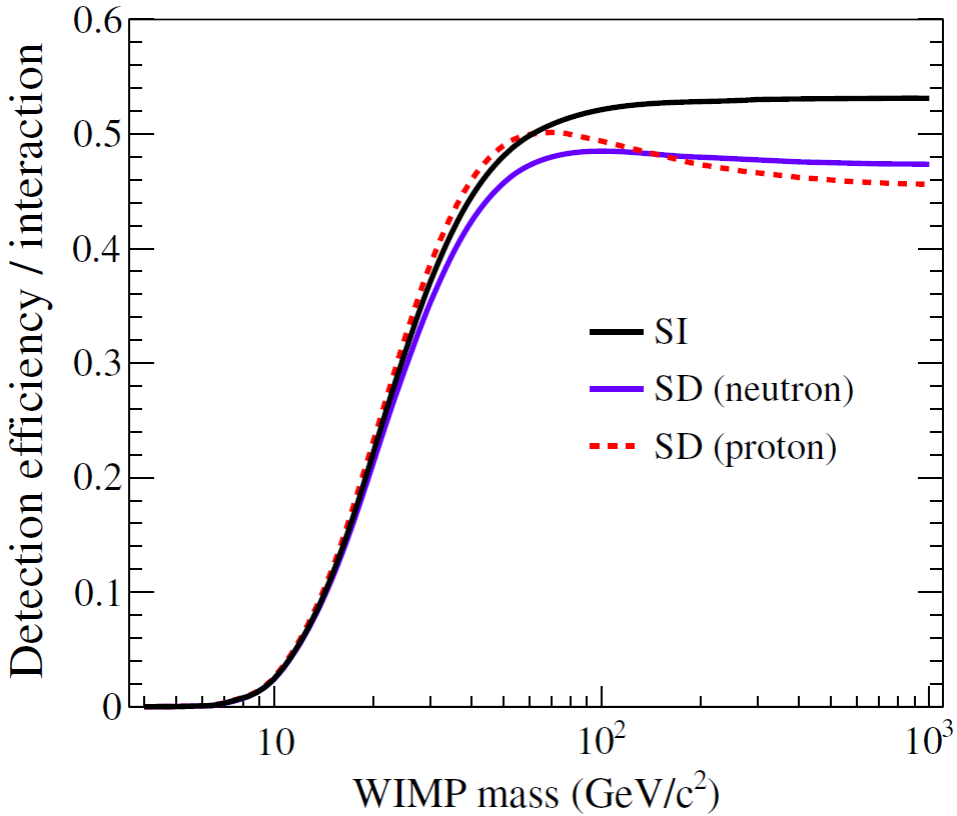
90% limit (PLL, CLs), SI isoscalar elastic DM-nucleon



Phys. Rev. Lett. 117, 121303 (2016)

- First low background run concluded June 2016 with 33,000 kg-day exposure.
- Minimum elastic SI exclusion: 2.5×10^{-46} cm^2 @ 40 GeV/c^2 improved ×10 from run8
- Conservatively used NEST model for official results
- More constraining result could be obtained with a tuned NR model

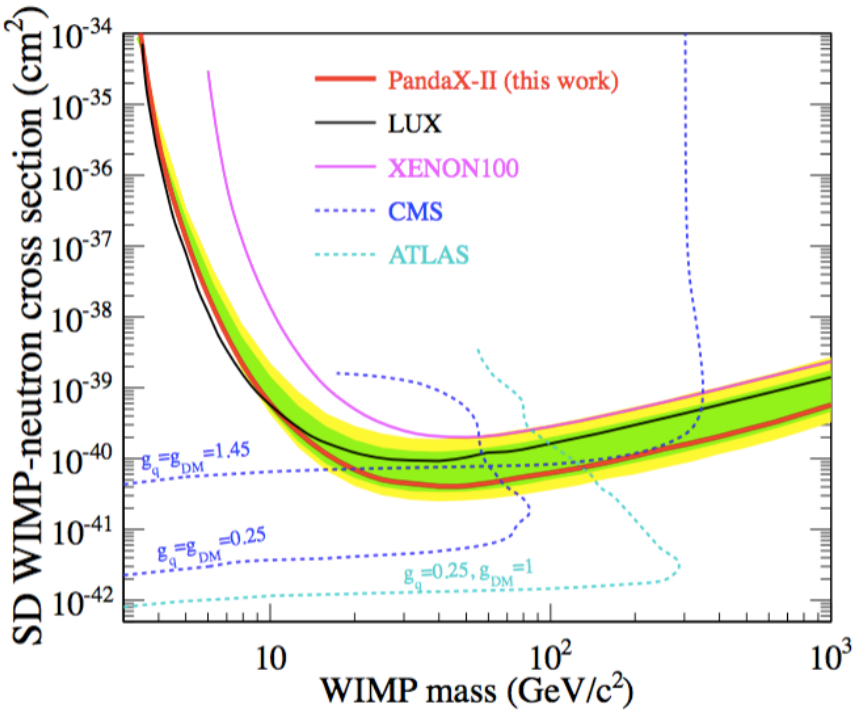
Spin-dependent interaction

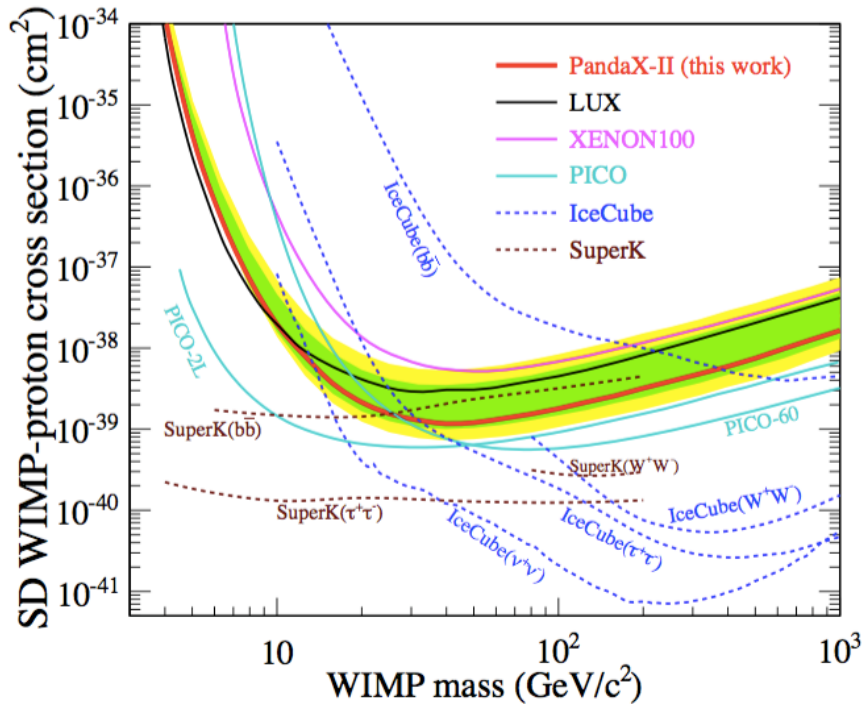


- Same data set to SI study, total exposure of 3.3×10^4 kg·day.
- Updated the detection efficiency for neutron-only and proton-only SD interaction

Spin-dependent cross section Limit

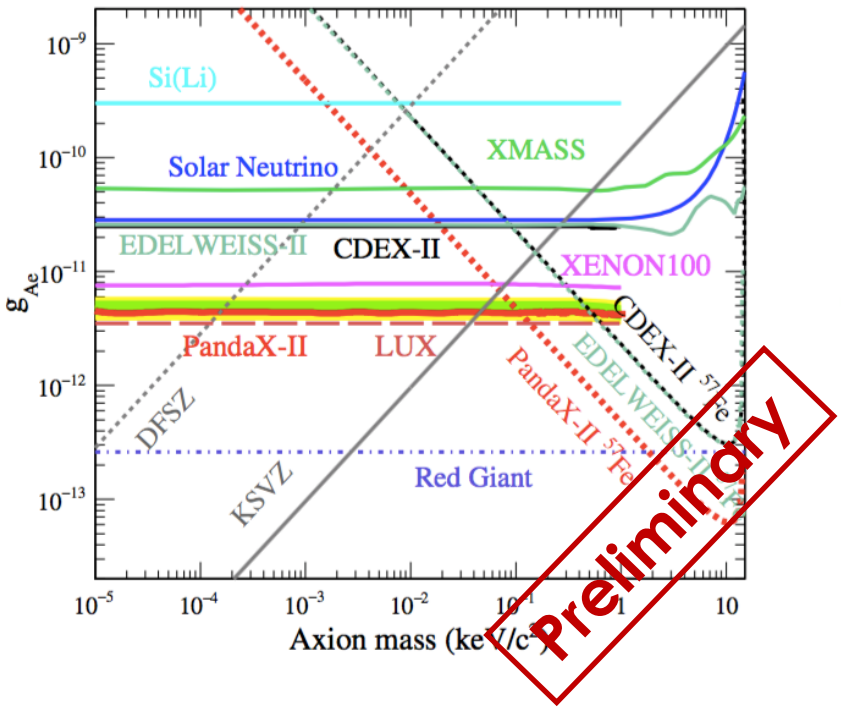
Phys. Rev. Lett. 118, 071301 (2017)

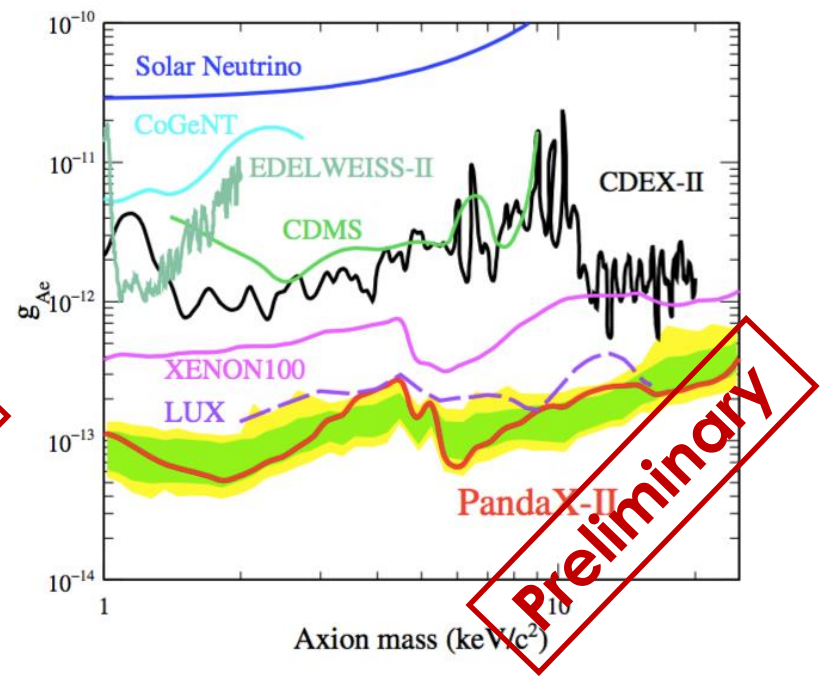




- Leading χ-n limit: PandaX, **4.1×10^{-41} cm²** at 40 GeV/c².
- LUX published a new limit 1.6×10^{-41} cm² @ 35 GeV/c² (*arXiv:1705.03380*).
- Collider search complementary for lower mass.

Limit on Solar Axion and Axion-like Particle



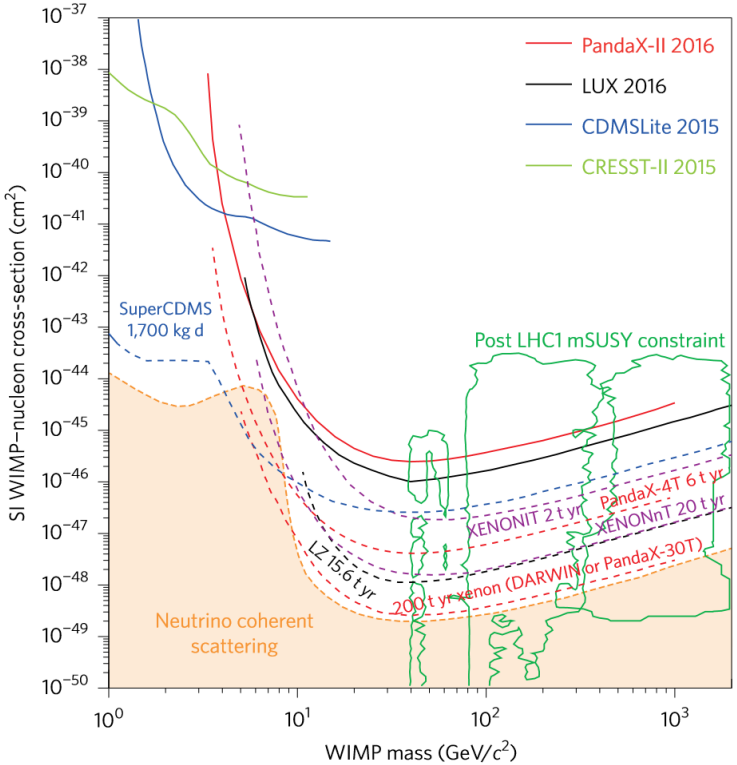


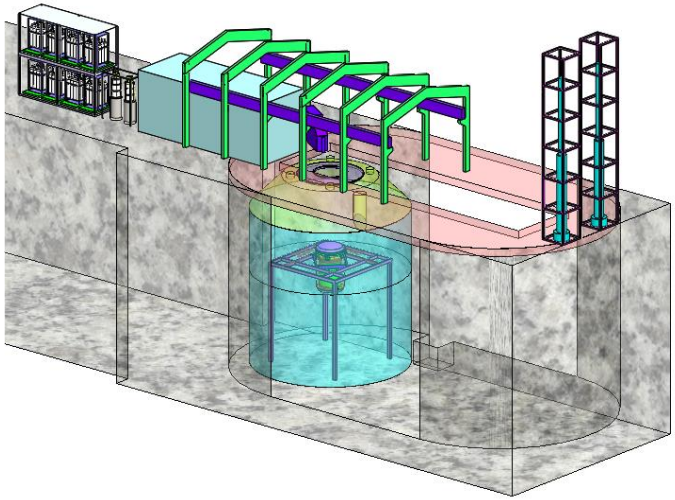
- No Solar or Galactic ALP was founded with PandaX-II first data.
- Leading upper limits are set to Solar and Galactic ALP, paper is coming soon.

Outlook: PandaX-xT experiment

- Preparing new experiments in CJPL-II, hall #B2 (civil completed late 2016).
- First stage:
  - PandaX-4T (4-ton target) with SI sensitivity ~10^{-47} cm^2
  - On-site assembly and commissioning: 2019-2020
- Eventual goal: G3 xenon dark matter detector (~30T) in CJPL to "neutrino floor" sensitivity.

Nature Phys. 13 (2017) no.3, 212-216





13m

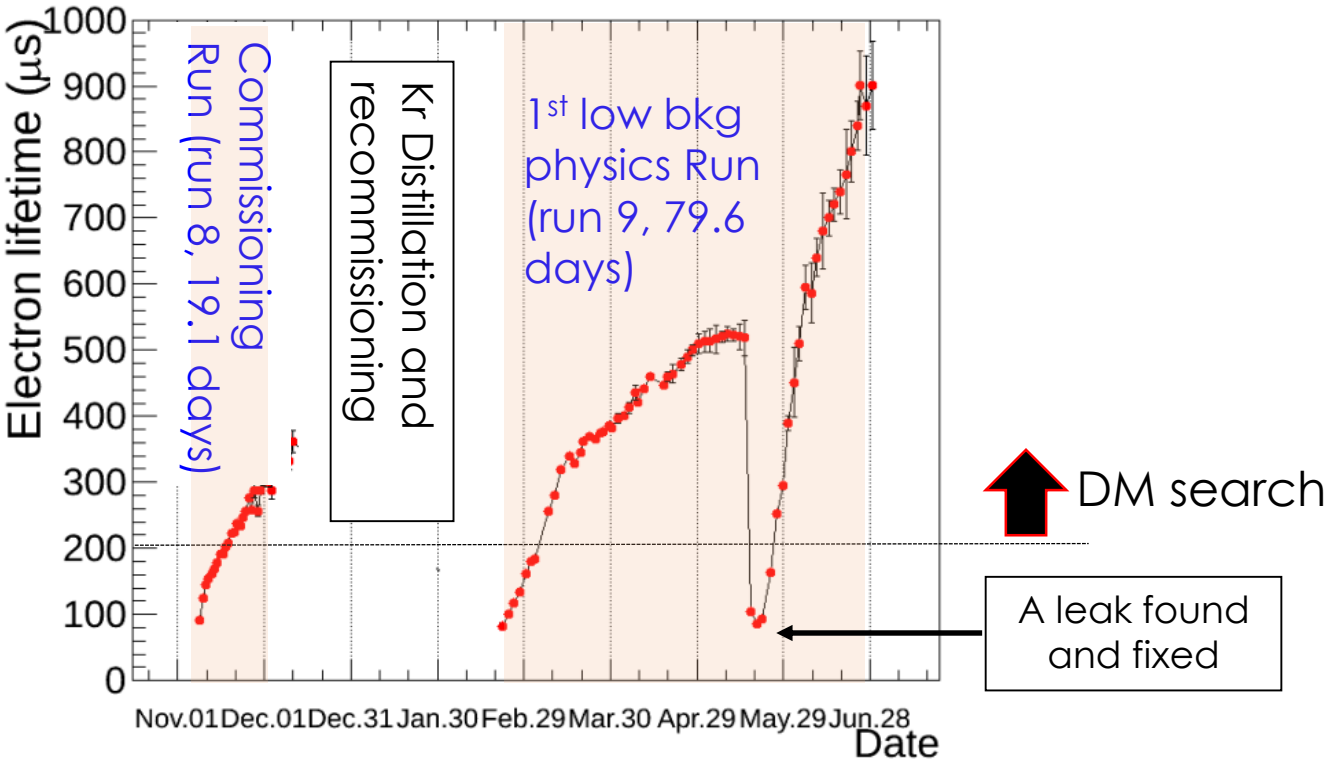
Summary

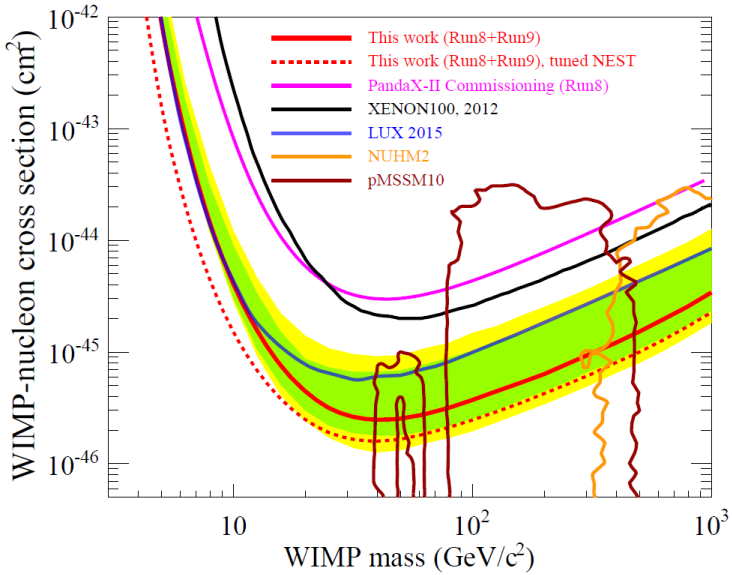
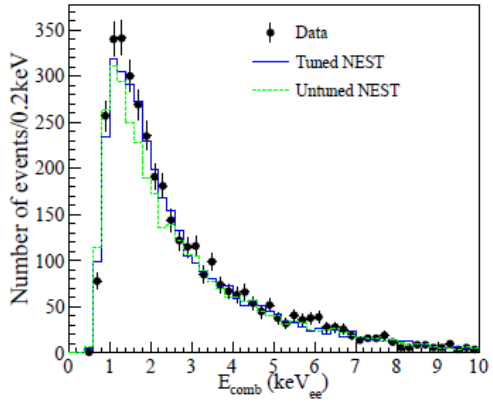
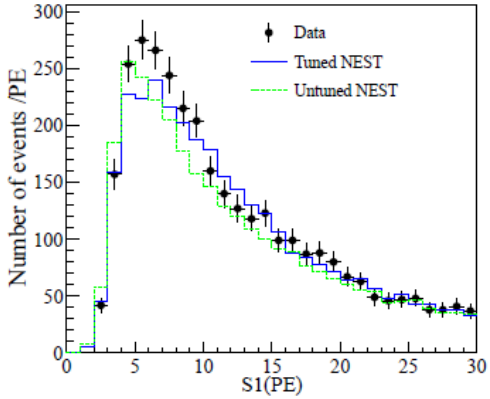
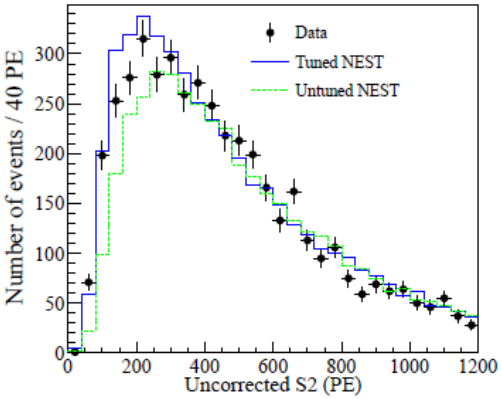
- PandaX dark matter program made rapid progress over the past a few years.
- PandaX-II is a half-ton scale experiment, first 79.6-day low-background data gave competitive upper limits to DM-nucleon coupling.
- Performing many alternative analyses to search for "non-standard" WIMPs.
- Continue PandaX-II data taking till 2018.
- Future plans: PandaX-xT (multi-ton DM) and PandaX-III (HP Gas ^{136}Xe 0vDBD).

Thank you !

Backup slides

Detector performance: electron lifetime



- Max electron drift time in the TPC is 350 μs.
- Data with electron lifetime > 200 μs were selected for the final dark matter analysis.

Comparison of tuned & untuned NEST model