Latest Results and Status of PandaX Experiment

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Outline

❖**WIMP search result with PandaX-II full exposure data (131.7 ton-day)**

❖**Preliminary result of Axion search from low energy ER events**

❖**Status of next generation PandaX-4T experiment**

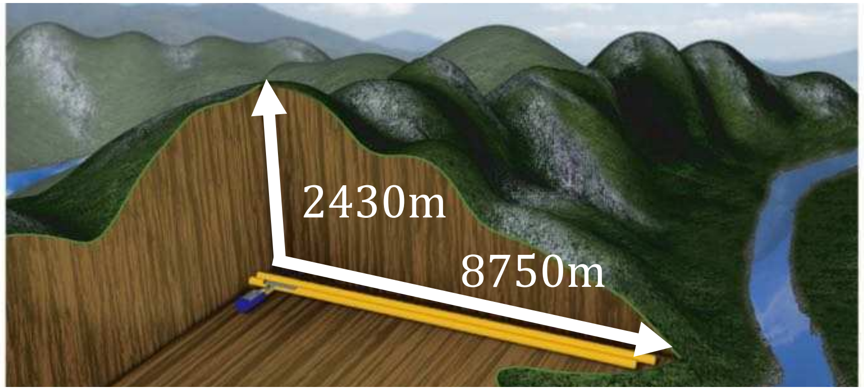
PandaX Collaboration

❖Particle and Astrophysical Xenon Experiment

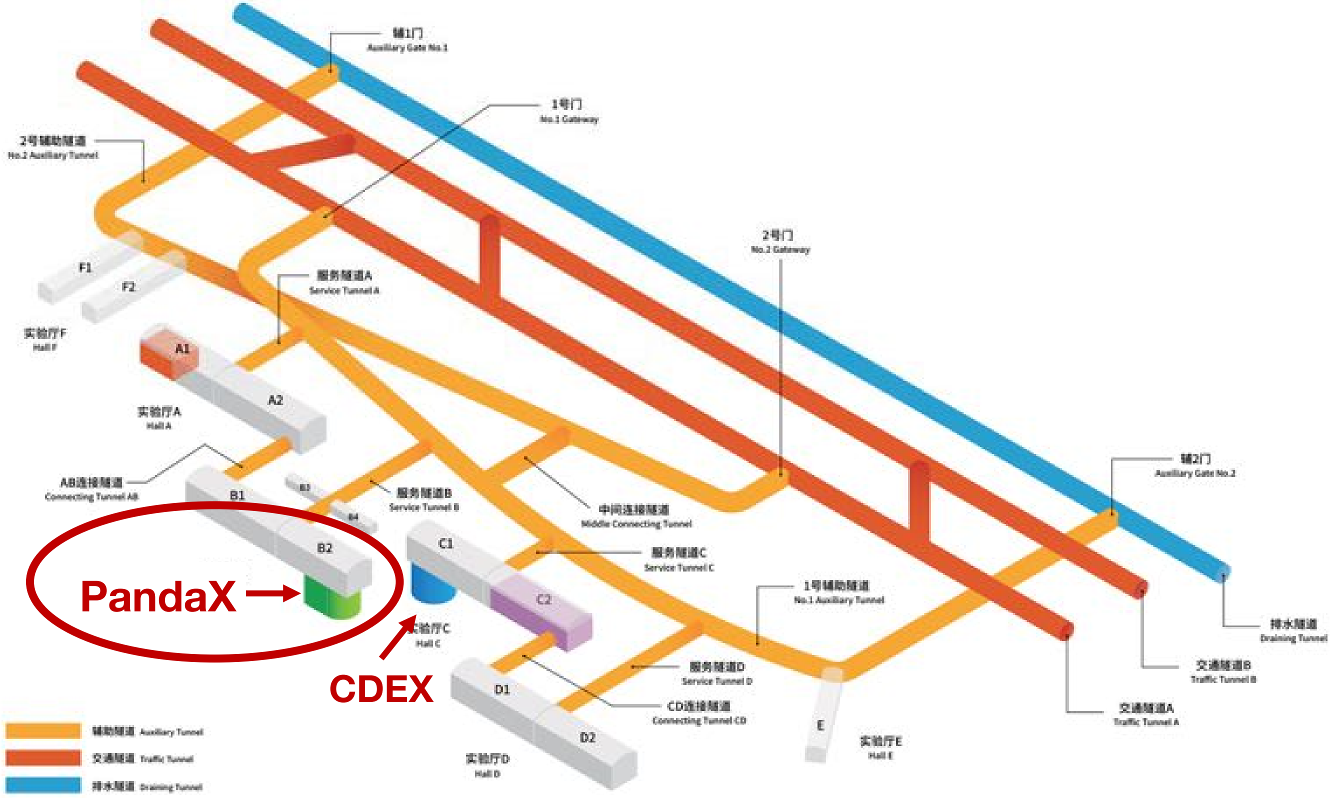
- Formed in 2009

China Jinping Underground Laboratory

- ❖Deepest (6800 m.w.e): < 0.2 muons/m^2/day
- ❖Horizontal access: 9 km long tunnel
- ❖CJPL-II: new experiment halls



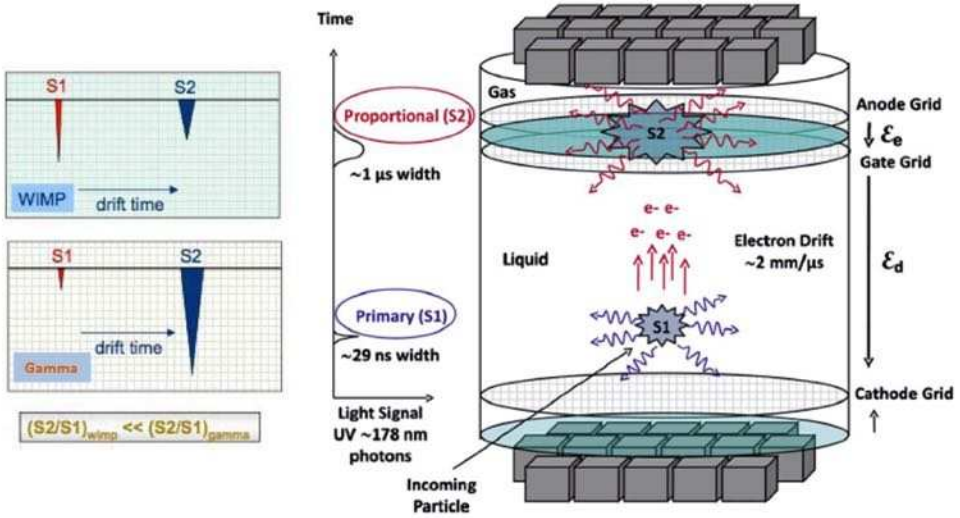
Kick-off of CJPL-II facility construction project, July 20, 2019



PandaX Dark Matter Experiment

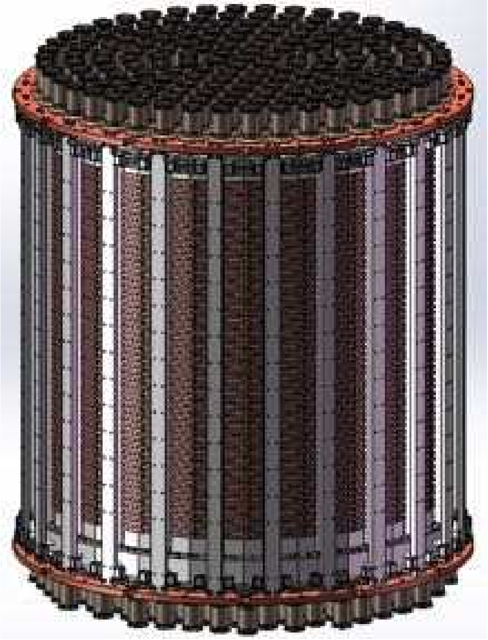
❖Dual-phase Xenon TPC

- Prompt S1 (scintillation)
- Delayed S2 (ionization)
- 3-dimensional position reconstruction
- Electron recoil vs nuclear recoil discrimination



PandaX-I: 120 kg
2009-2014

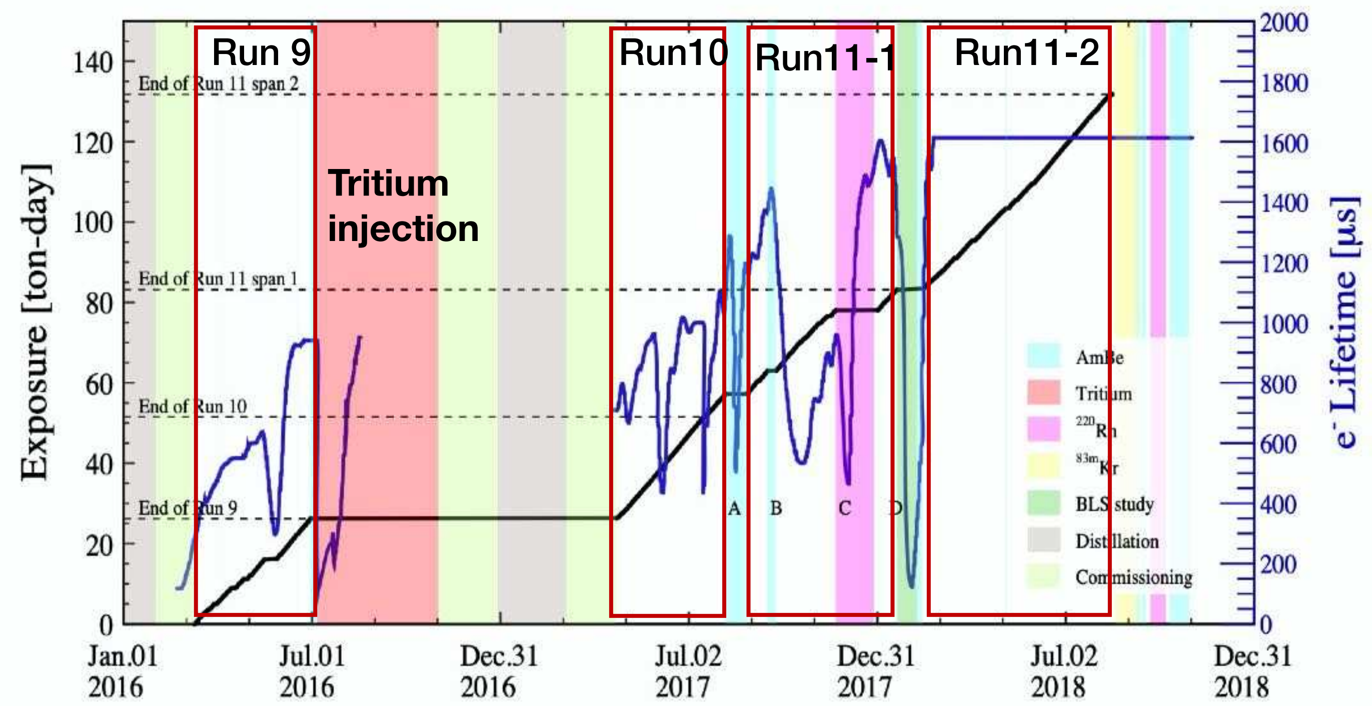
PandaX-II: 580 kg
2014-2019



PandaX-4T: 4 ton
2019-

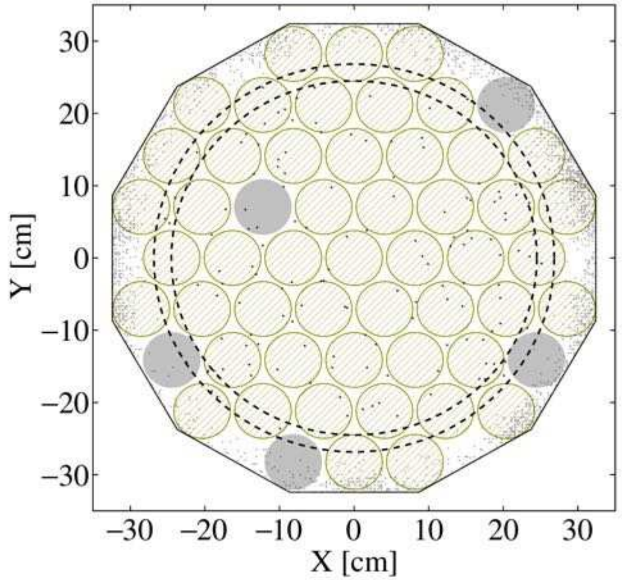
PandaX-II Full Exposure Data

- **2019.06 "End-of-Run" completed**
- **Total exposure: 131.7 ton-day**
  - Run 9: 79.6 days (published)
  - Run 10: 77.1 days (published)
  - **Run 11, span 1: 96.3 days**
  - **Run 11, span 2: 147.9 days**

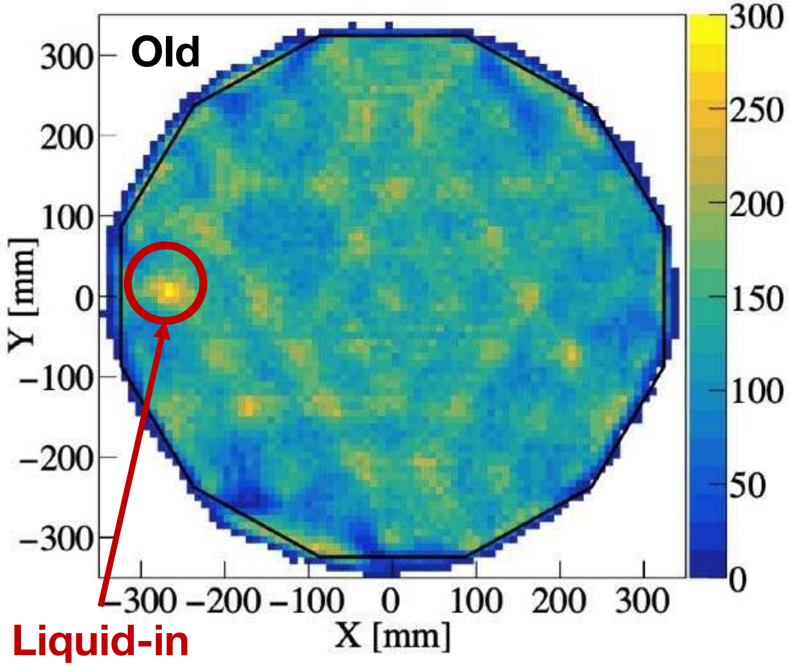


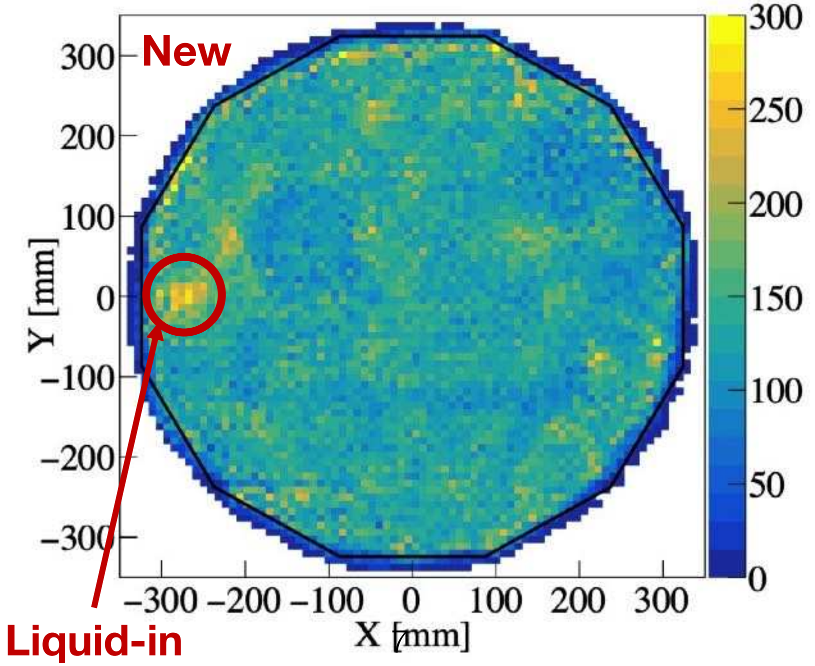
- **Full data analysis**
  - New position reconstruction
  - New detector response model
  - Improved background evaluation

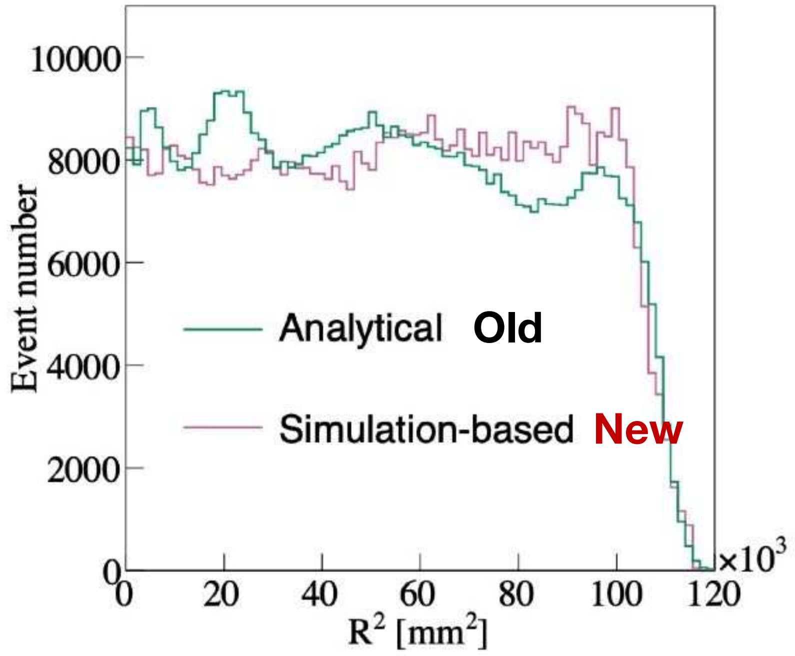
New Position Reconstruction



- ❖ **Turn off 7 malfunctioned PMTs**
  - 5 top and 2 bottom
- ❖ **Simulation-based position reconstruction**
  - Optical simulation of the detector
- ❖ **Trained with evenly distributed ^{83m}Kr calibration events**







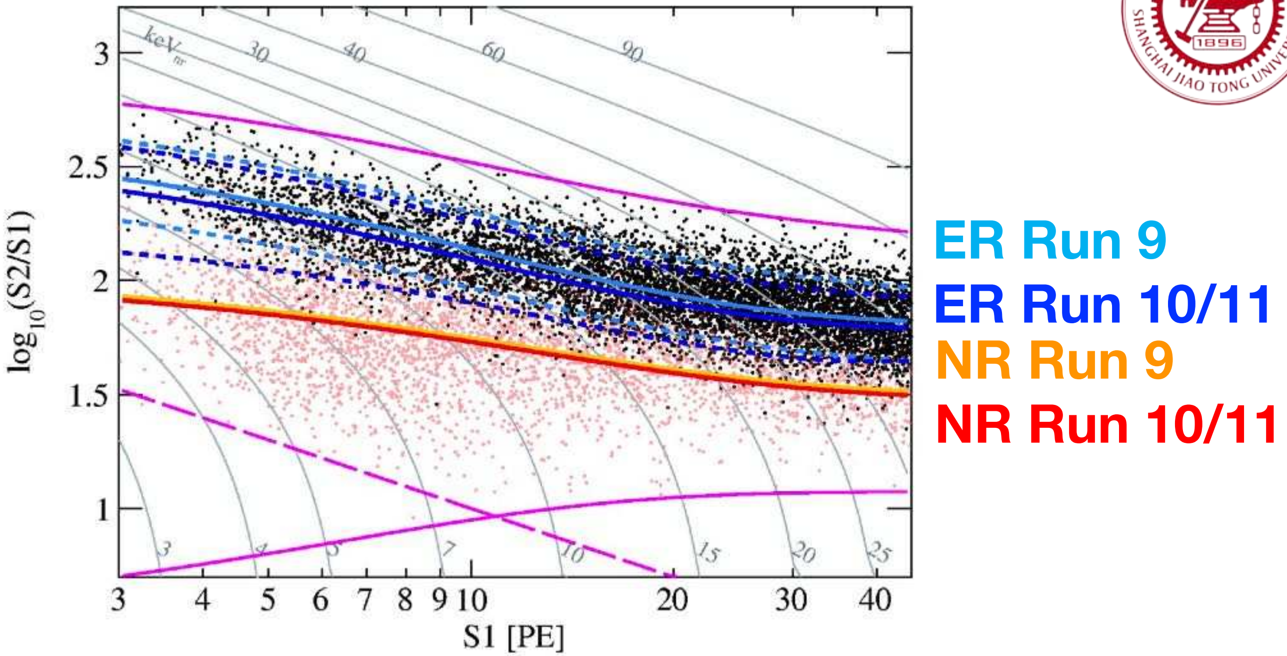
New Response Model

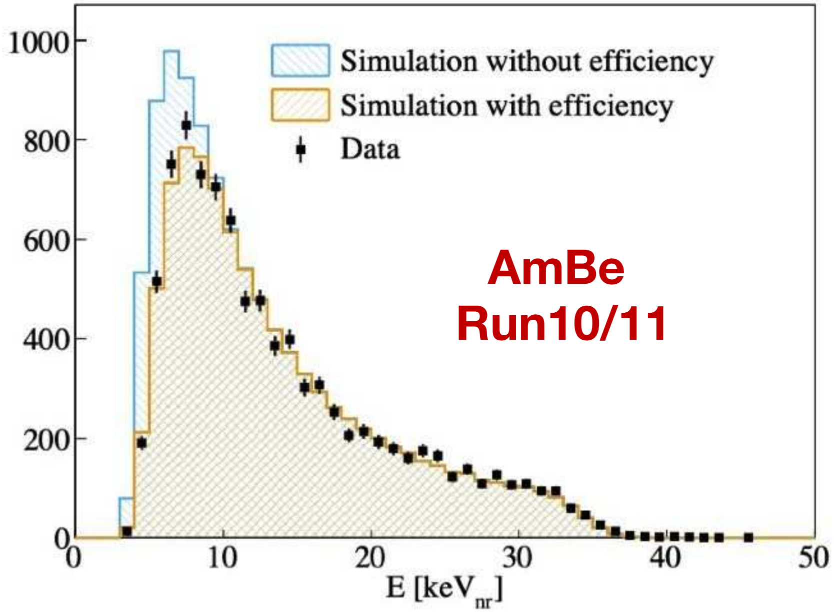
❖Calibration data

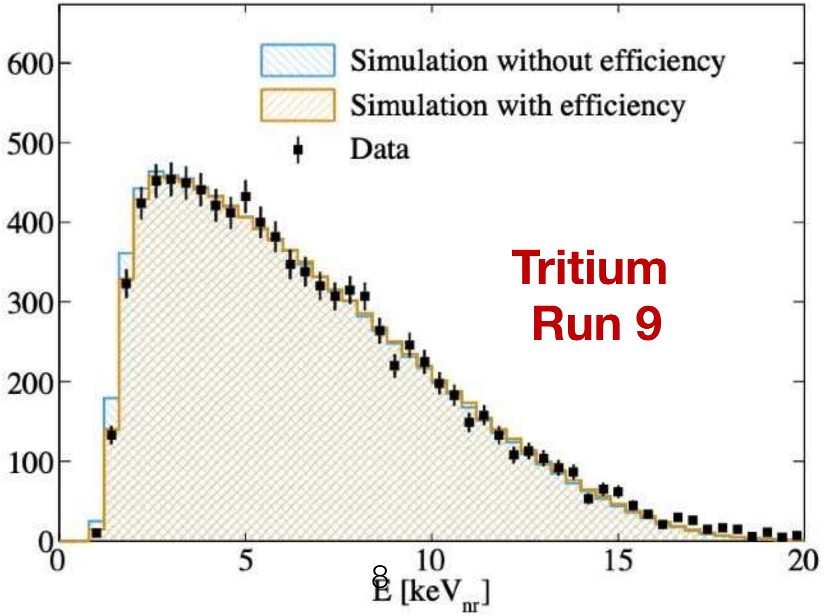
- ER events: tritium and ^{220}Rn
- NR events: AmBe

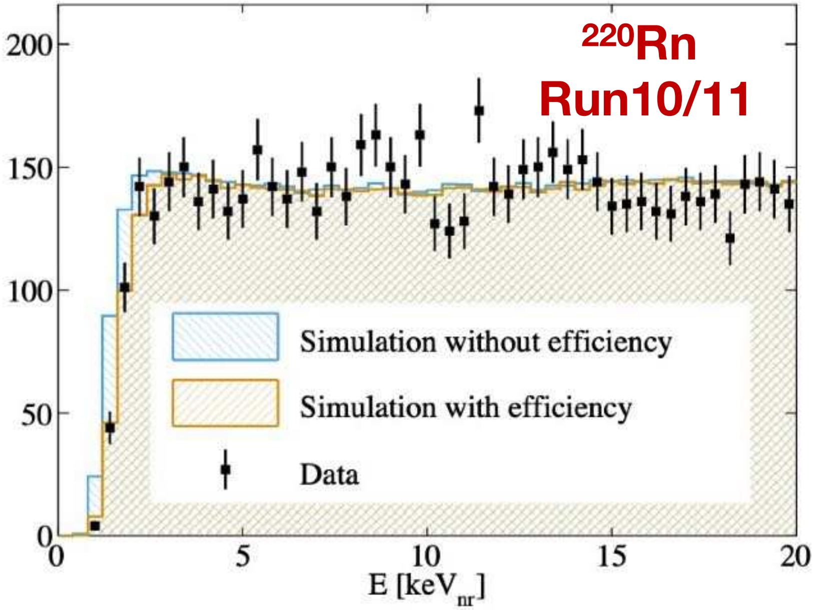
❖Nest 2.0 based response model

- with data quality cut efficiency









Background Sources

❖

Source	Evaluation
^{127}Xe	35.5 day lifetime, decay away in Run 11
^{3}H	Introduced after Run 9, fitted from data, see later
^{222}Rn	Depletion effect from measurement
^{85}Kr	Not a constant due to air leakage in Run 11
neutrons	Data-driven estimation
surface events	Data-driven extrapolation
accidental events	Newly trained BDT discriminator

^{222}Rn Background

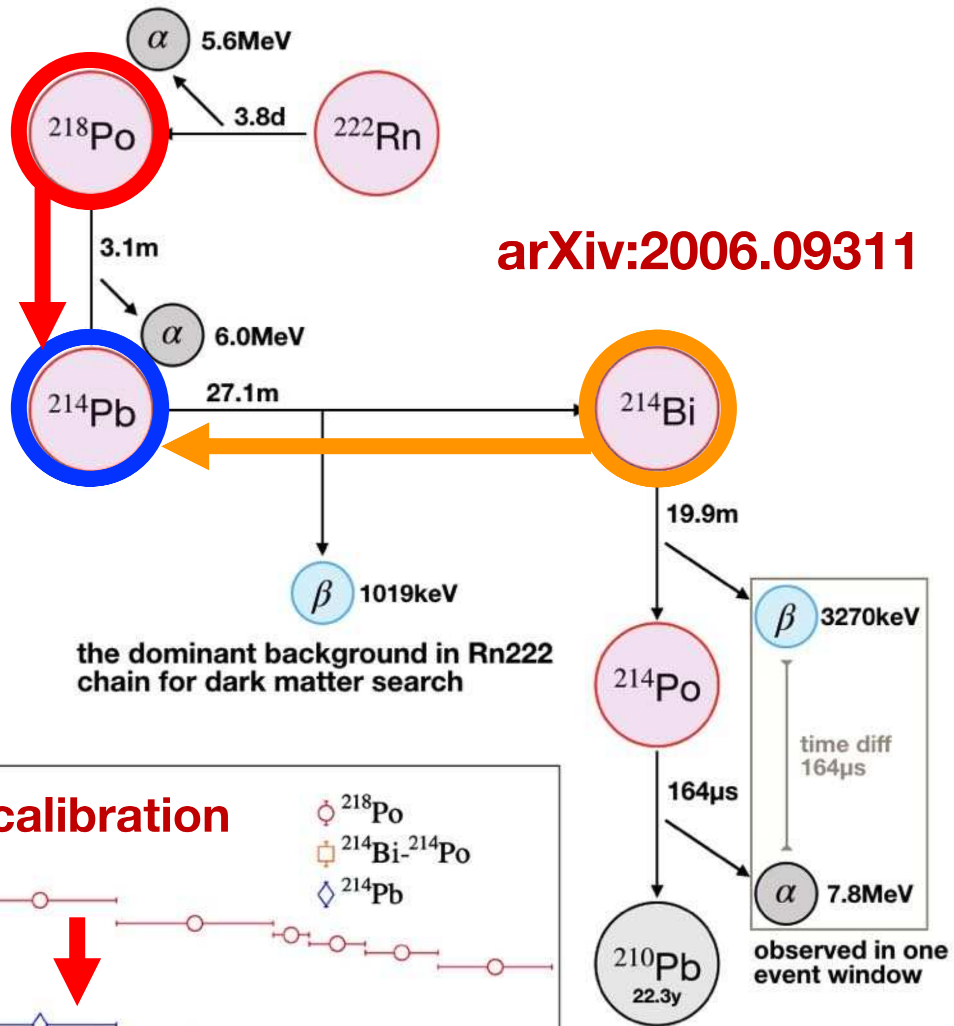
❖**Major ER contribution from ^{214}Pb**

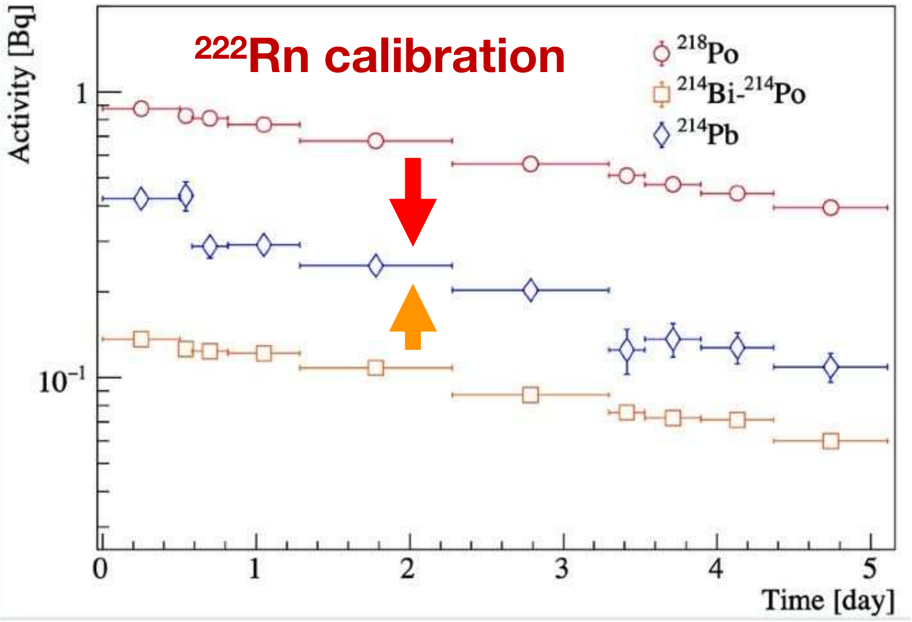
- Charged Rn progenies attracted to the cathode with negative HV
- Less contribution in fiducial volume: "depletion effect"

❖**New method to evaluate ER event rate from ^{214}Pb**

- Interpolation from ^{218}Po and ^{214}Bi
- The depletion ratio measured from ^{222}Rn calibration (end-of-run)

❖**PandaX-II ^{214}Pb level: 10μBq/kg**

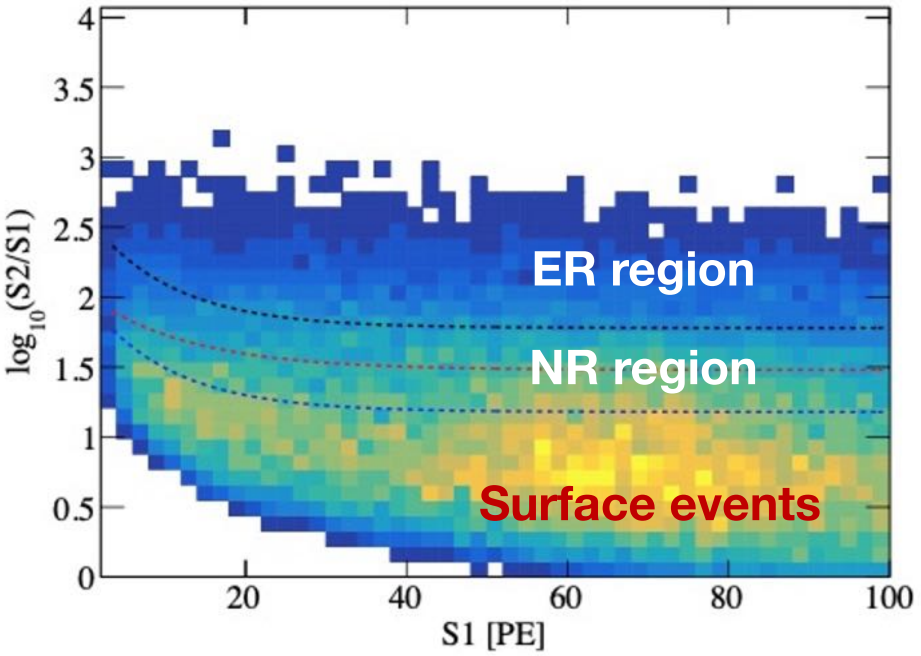




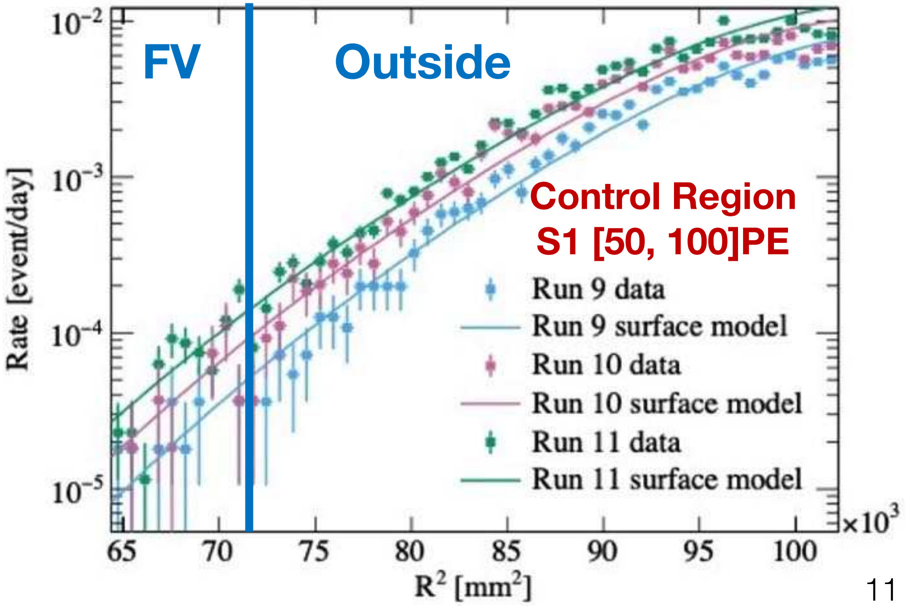
Surface Background

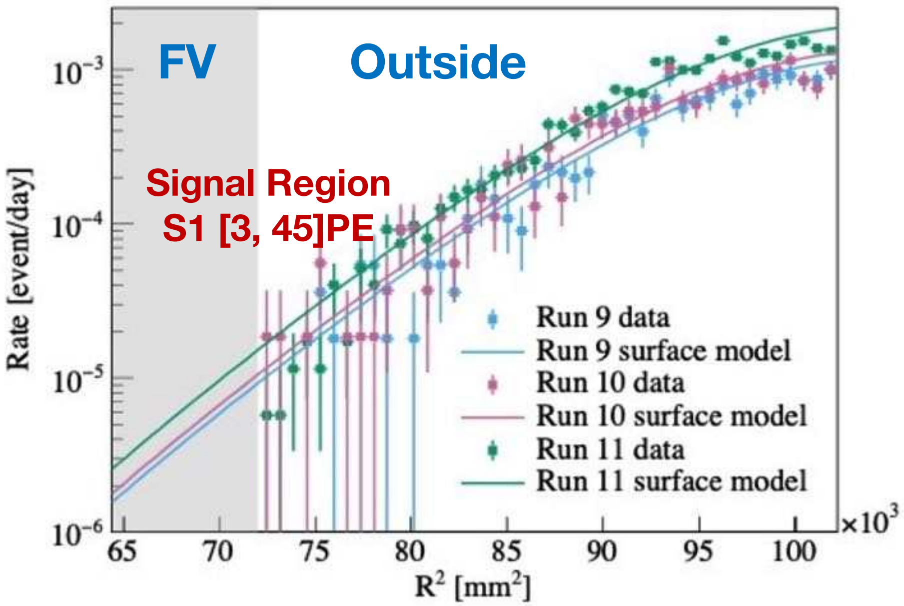
❖Surface events

- Mostly ER events from Rn plate-out
- Losing S2 on the surface, shifting below ER region



❖Data-driven extrapolation from outside FV region





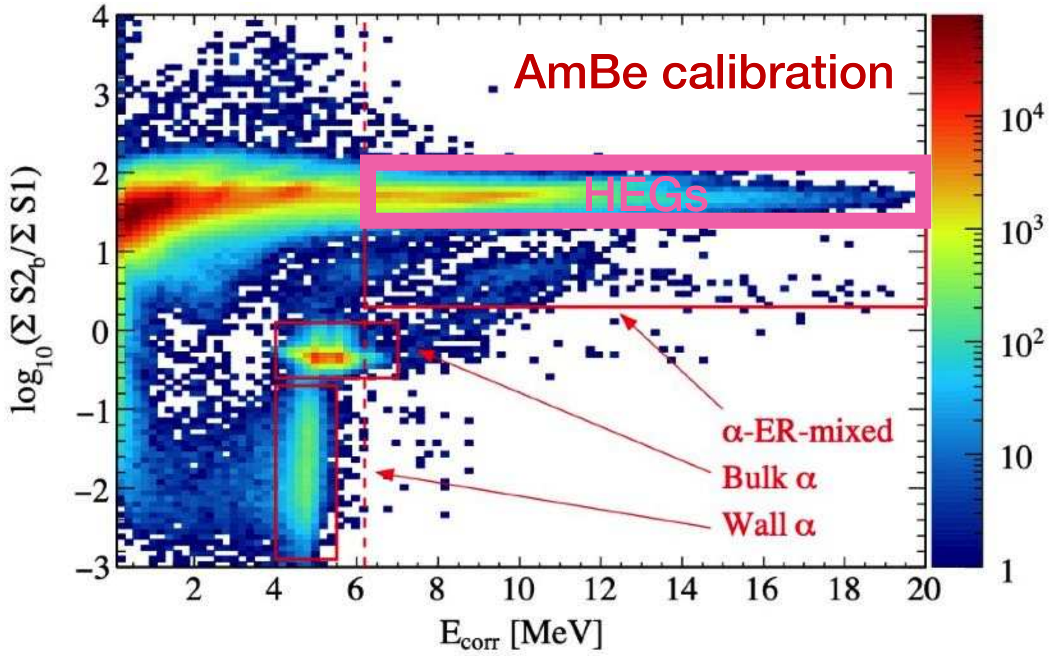
JINST 14 (10): C10039, 2019

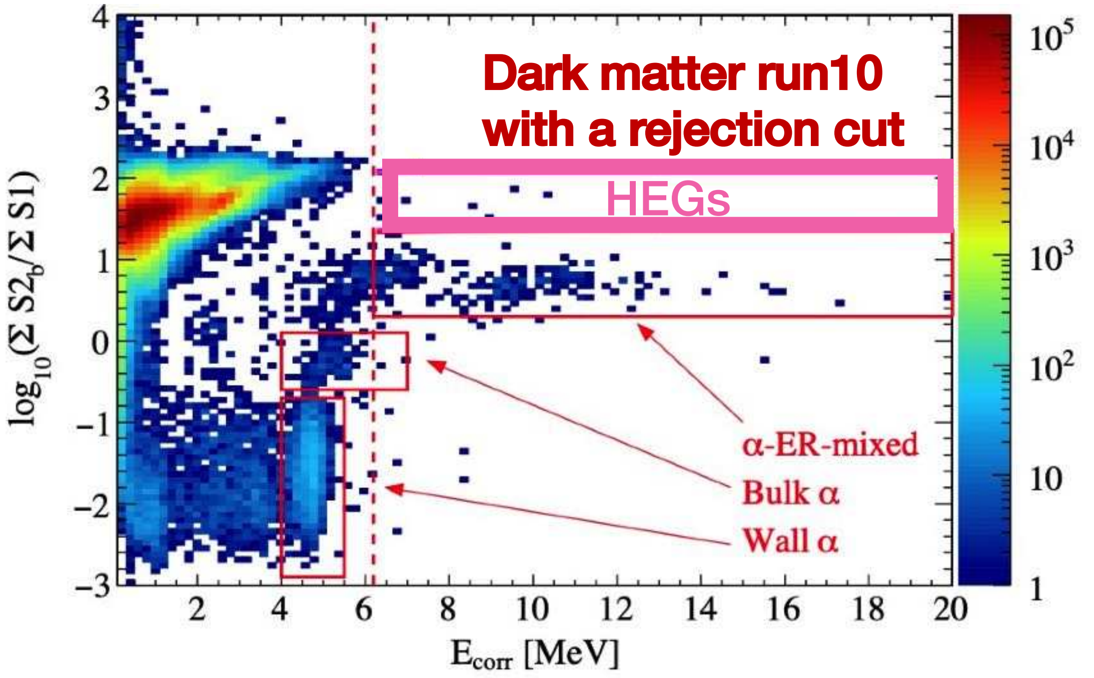
Neutron Background

❖New evaluation based on high energy gammas (HEGs)

- Neutron events associated with HEGs (neutron capture, nuclear de-exciation)
- Scale factor (neutron events / HEGs) from MC simulation with HEGs included
- Tested in AmBe calibration data

SCIENCE CHINA Physics, Mechanics & Astronomy(2019)





❖PandaX-II full exposure: 3.0±1.5 events in WIMP signal region

Background Budget for Low Energy Events

❖ **Compared with Run 10, more background contributions in Run 11**

- ^{85}Kr and tritium

Preliminary

Item		Run 9	Run 10	Run 11, span 1	Run 11, span 2
Flat ER (mDRU)	^{85}Kr	1.19 ± 0.2	0.18 ± 0.05	0.20 ± 0.06	0.40 ± 0.07
	^{222}Rn	0.19 ± 0.10	0.17 ± 0.02	0.19 ± 0.02	0.19 ± 0.02
	^{220}Rn	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01
	ER (material)	0.20 ± 0.10	0.20 ± 0.10	0.20 ± 0.10	0.20 ± 0.10
	Solar ν	0.01	0.01	0.01	0.01
	^{136}Xe	0.0022	0.0022	0.0022	0.0022
Total flat ER (mDRU)		1.61 ± 0.24	0.57 ± 0.11	0.61 ± 0.12	0.81 ± 0.12
^{127}Xe (mDRU)		0.14 ± 0.03	0.0069 ± 0.0017	< 0.0001	
^{3}H (mDRU)		0	0.17		
Neutron (mDRU)		0.0022 ± 0.0011			
Accidental (event/day)		0.014 ± 0.004			
Surface (event/day)		0.041 ± 0.008		0.063 ± 0.0013	

WIMP Search

❖S1 [3, 45] PE and Fiducial volume 329 kg

❖Blinded analysis for Run 11

❖Total 1220 events, 38 below NR median

- Consistent with background expectation

Preliminary

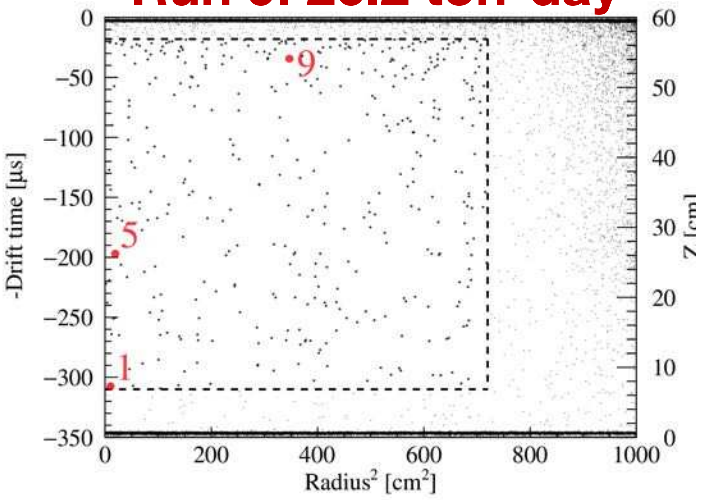
	ER	Accidental	Neutron	Surface	Total fitted	Total observed
Run 9	381.1	2.20	0.77	2.13	387 ± 23	384
Below NR median	2.3	0.46	0.36	2.12	5.3 ± 0.5	4
Run 10	145.6	1.07	0.47	2.66	150 ± 14	143
Below NR median	1.3	0.23	0.22	2.65	4.4 ± 0.6	0
Run 11, span 1	219.4	1.03	0.59	6.23	227 ± 19	224
Below NR median	3.7	0.32	0.32	6.20	10.5 ± 1.1	13
Run 11, span 2	451.0	1.60	0.91	9.68	464 ± 30	469
Below NR median	7.5	0.50	0.49	9.64	18.2 ± 4.2	21
Total	1197.2	5.9	2.72	20.7	1227 ± 51	1220
Below NR median	14.9	1.51	1.39	20.6	38.4 ± 6.0	38

Event Distributions

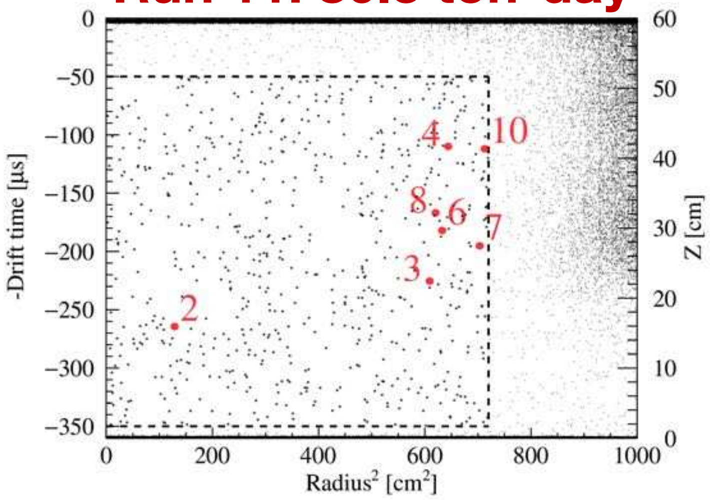
❖Distribution of events with high WIMP hypothesis likelihood

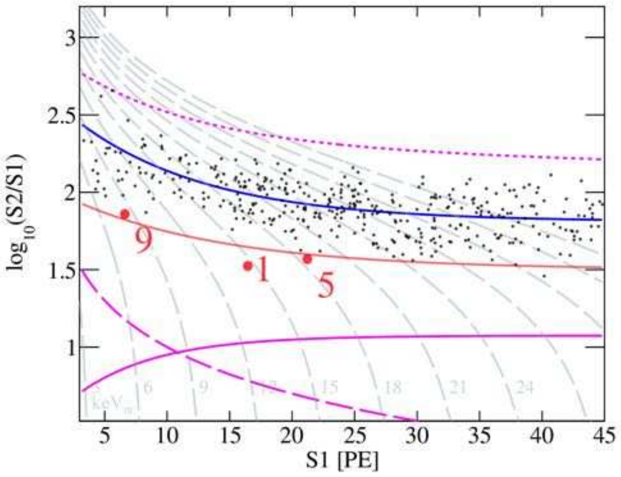
- 3 events in Run 9 and 7 events in Run 11

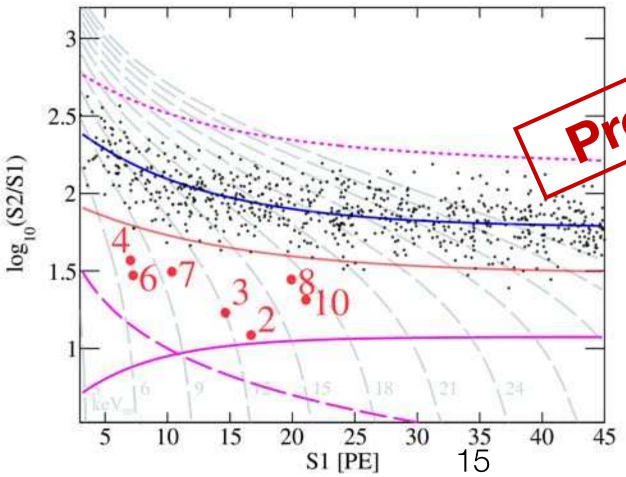
Run 9: 26.2 ton-day

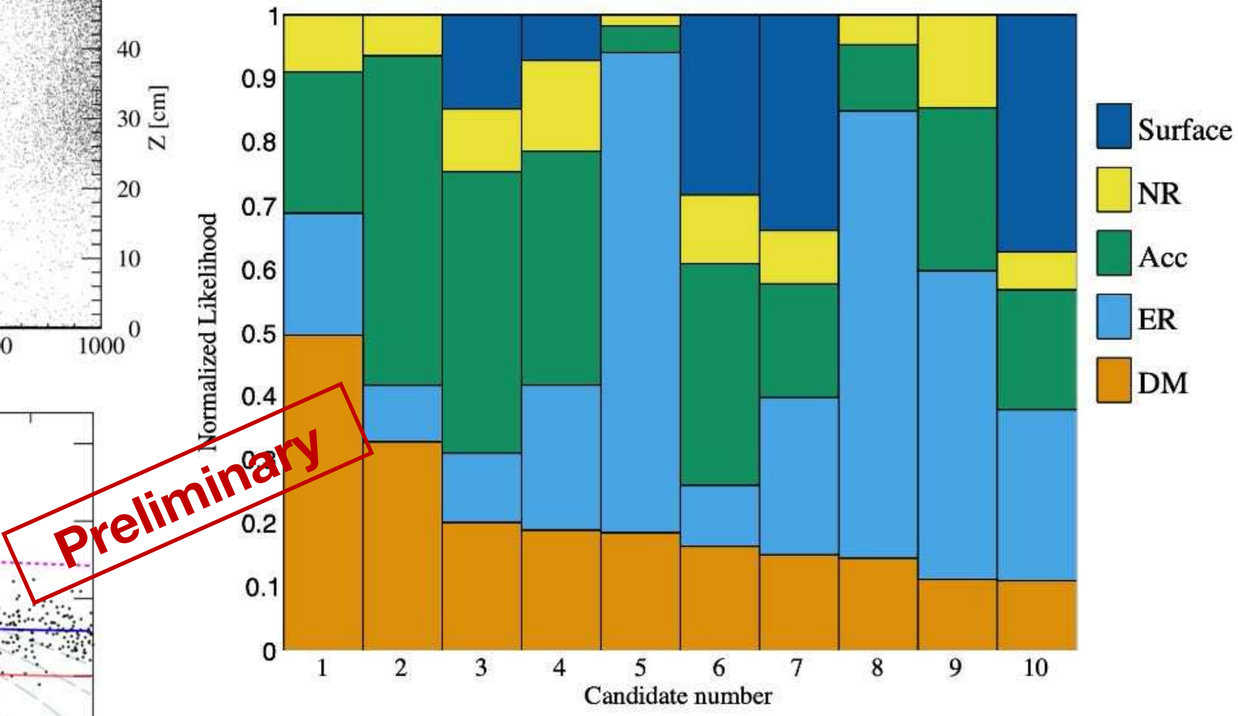


Run 11: 80.3 ton-day









Constraints on WIMP Model

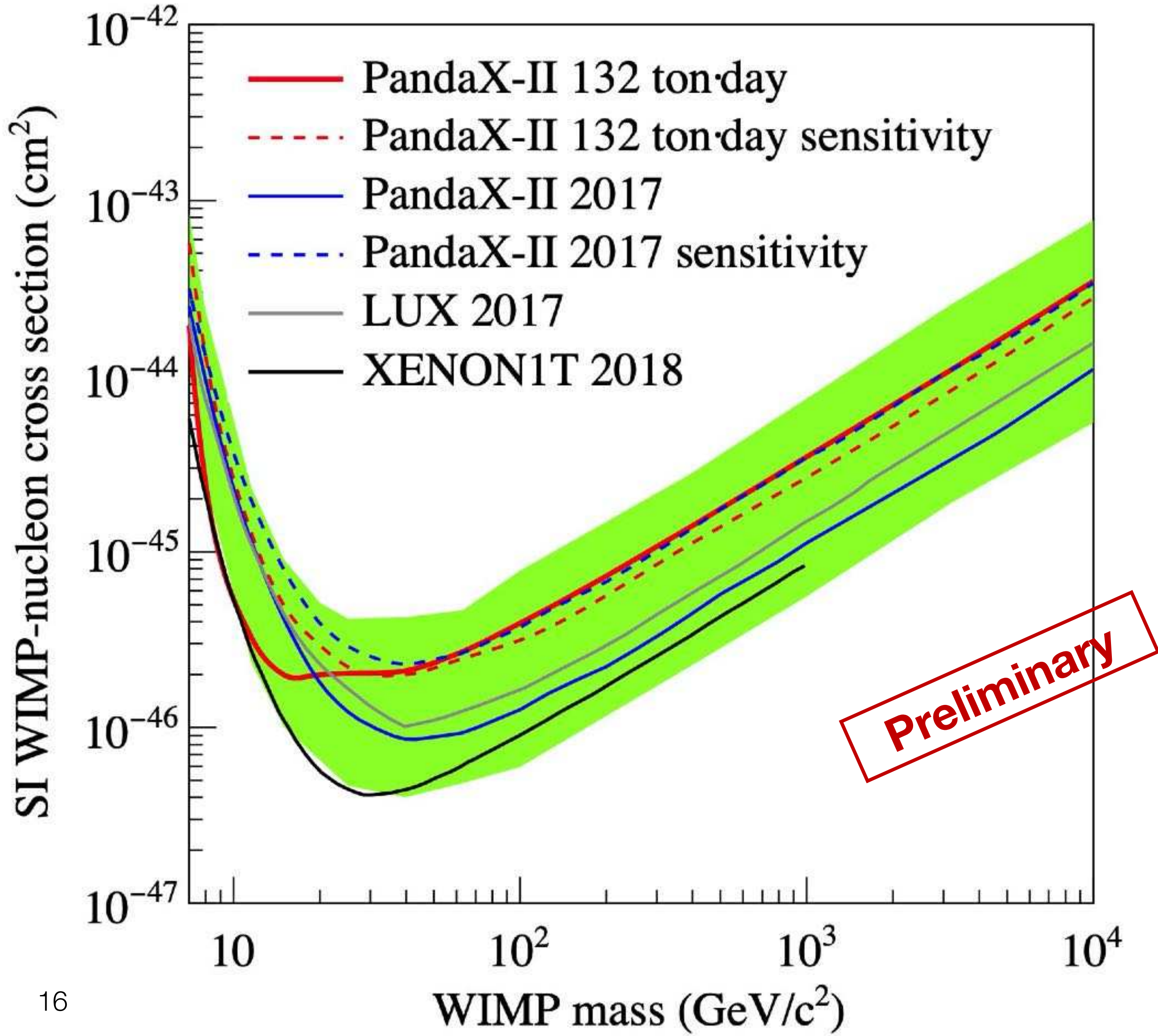
❖Spin-independent Interaction

❖Exclusion limits on SI

- 2.1×10^{-46} cm^2 for 40 GeV
- 1.4×10^{-45} cm^2 for 400 GeV

❖Will submit tomorrow

Best-fit for m_c=400 GeV
4.2 events -> $\sigma_{\chi n}=3.2 \times 10^{-46}$ cm^2
p-value of 0.19 -> 0.92 σ



Axion Search

❖ **Axion signal in xenon detector: low energy ER events**

❖ **With full exposure**

- Expand the energy window to 25 keV
- Reduce the FV to 250 kg

❖ **Dominant background: Spectrum fitting to the data**

- ^{127}Xe: decay away in Run 11
- Flat ER: ^{85}Kr, ^{222}Rn, materials
- Tritium: appearing since Run 10

❖ **Critical background spectra obtained from calibration**

Background Spectrum

❖ Tritium spectrum

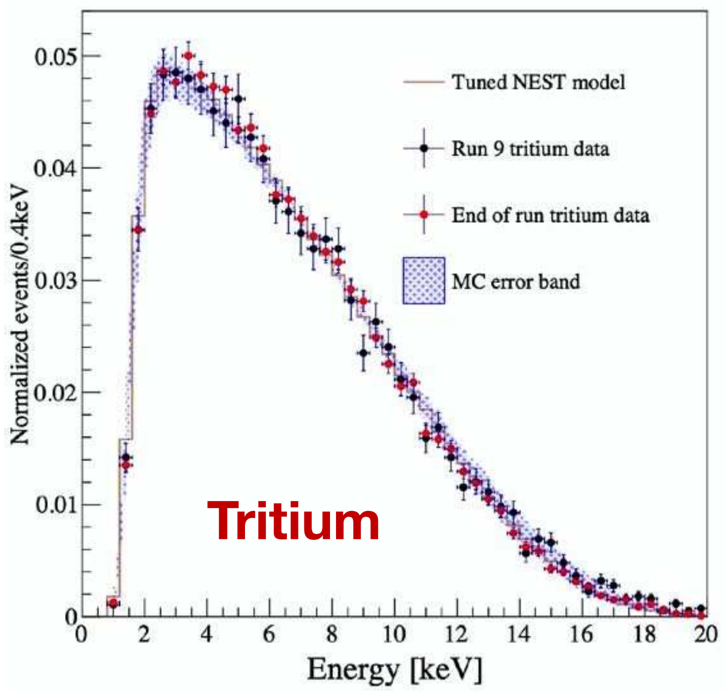
- Two injection calibrations
- T1(Right after Run 9) and T2 (End of run)

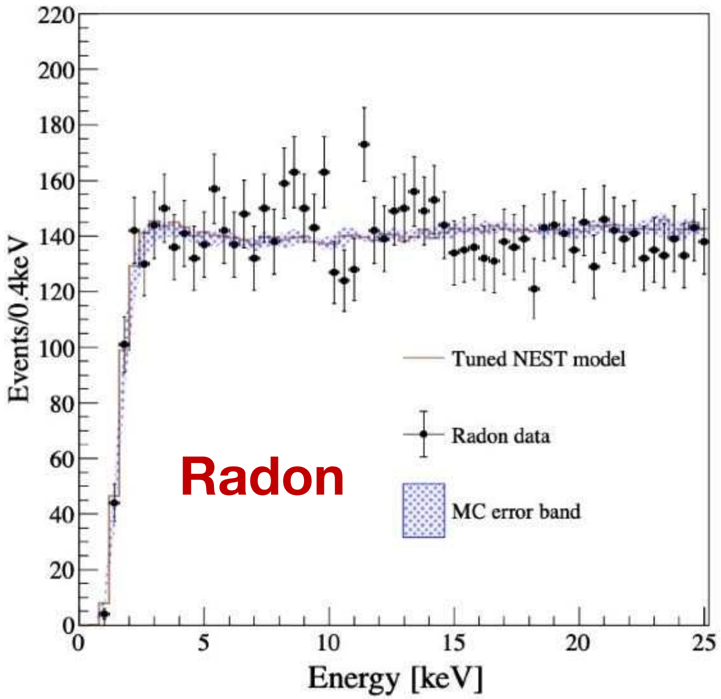
❖ Flat ER spectrum

- Estimated from ^{220}Rn calibration after Run 10

❖ Systematic uncertainty

- Detector response model parameters
- Non-linearity of data-taking baseline suppression
- Theoretical uncertainty





Tritium Background

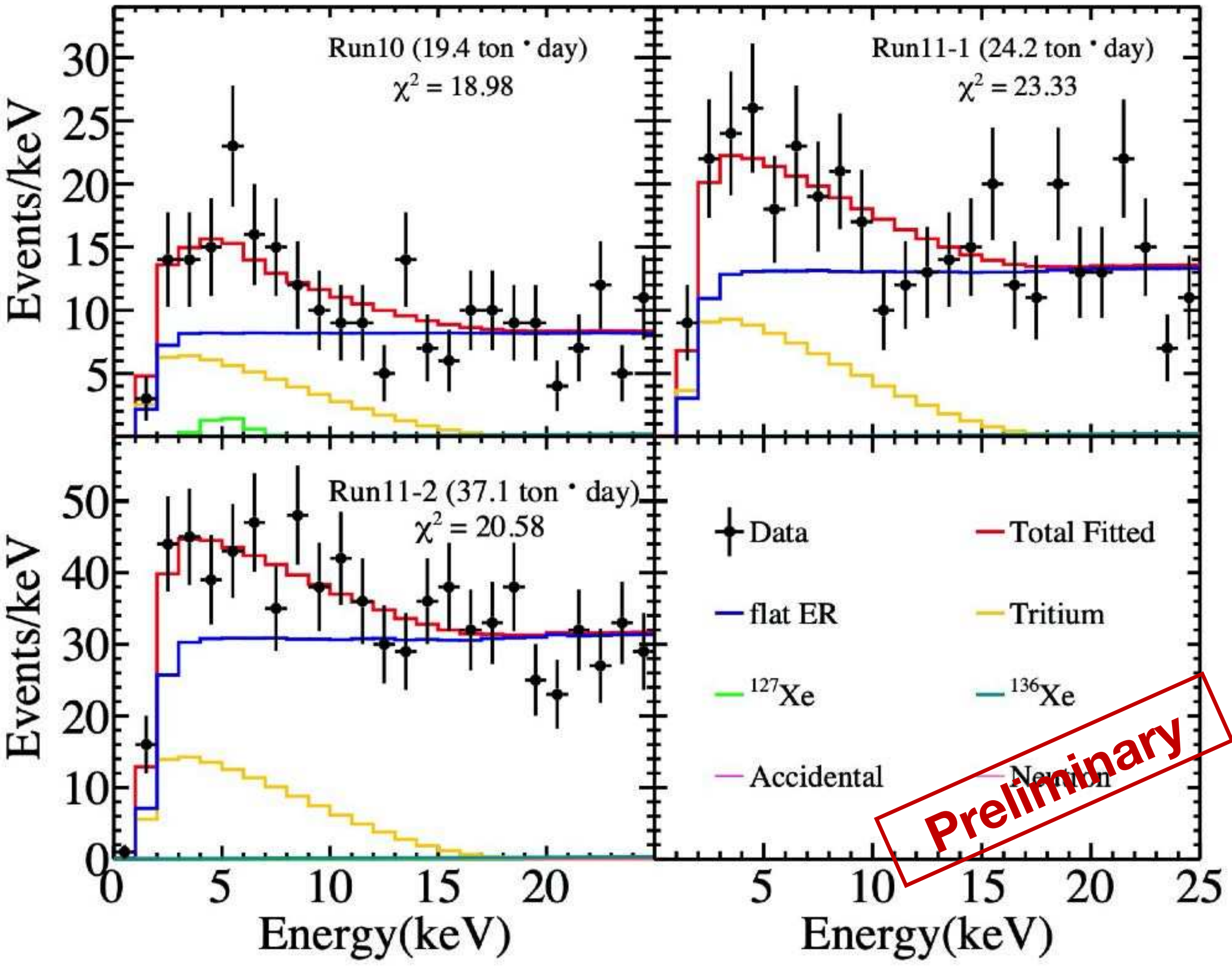
❖ No direct measurement

❖ Unbinned likelihood fit on Run 10, 11-1, 11-2 independently

Run	Tritium level
10	0.044±0.008 μBq/kg
11-1	0.050±0.010 μBq/kg
11-2	0.050±0.009 μBq/kg

❖ Consistent with a constant rate

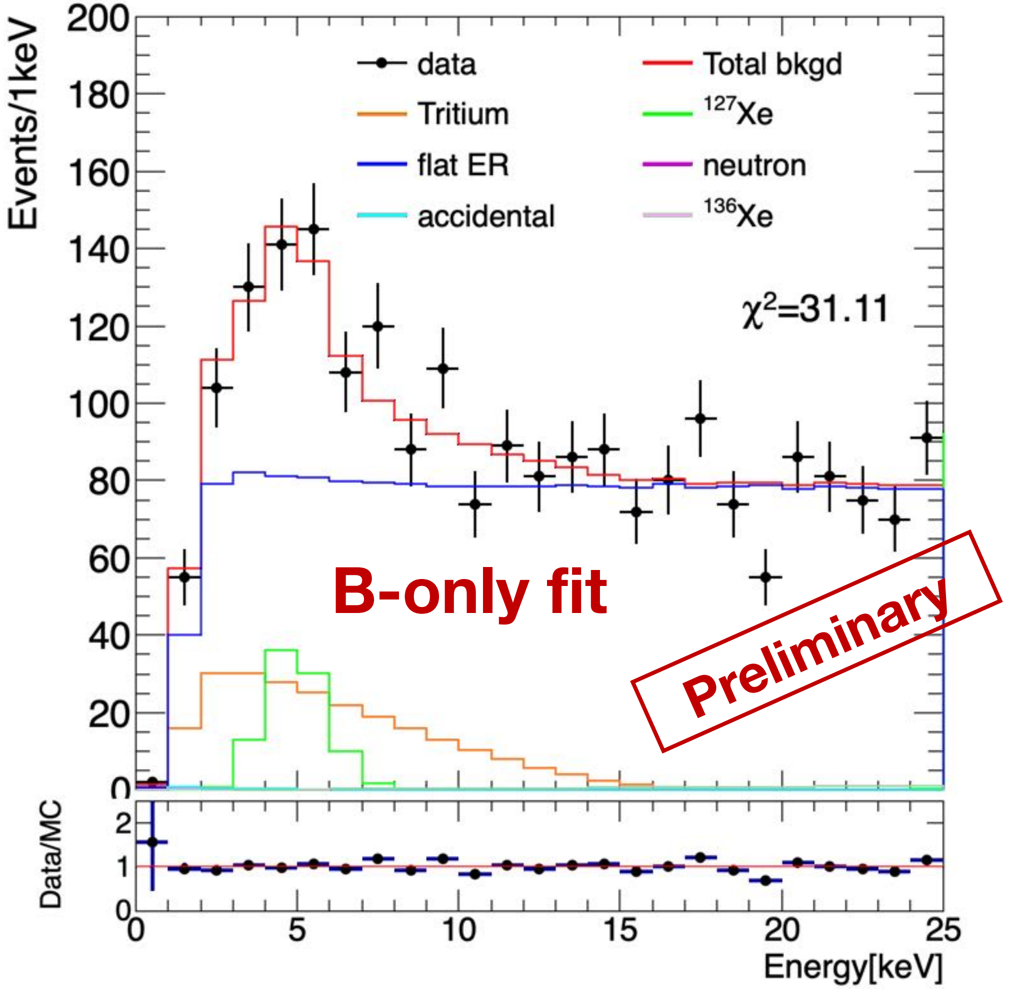
- Total fitted 0.049±0.005 μBq/kg



Background-only Fit

- ❖ **Fit the data energy spectrum with tritium contribution floating**
- ❖ **Total data 2200 events**
- ❖ **Estimated background 2209.3±46.3**
  - Consistent with data within 1σ

Events	Run 9	Run 10	Run 11-1	Run 11-2
^{127}Xe	81.2	3.7	0	0
tritium	0	60.4	73.3	113.9
accidental	1.3	0.6	0.6	1.0
neutron	0.6	0.4	0.5	0.7
^{136}Xe	2.6	2.5	3.1	4.9
flat ER	574.5	196.6	325.3	761.7
Total	660.2 ± 23.5	264.2 ± 14.8	402.8 ± 19.4	882.1 ± 31.6
Data	658	259	401	882



Background plus Signal Fit

❖ **With tritium and axion contribution floating**

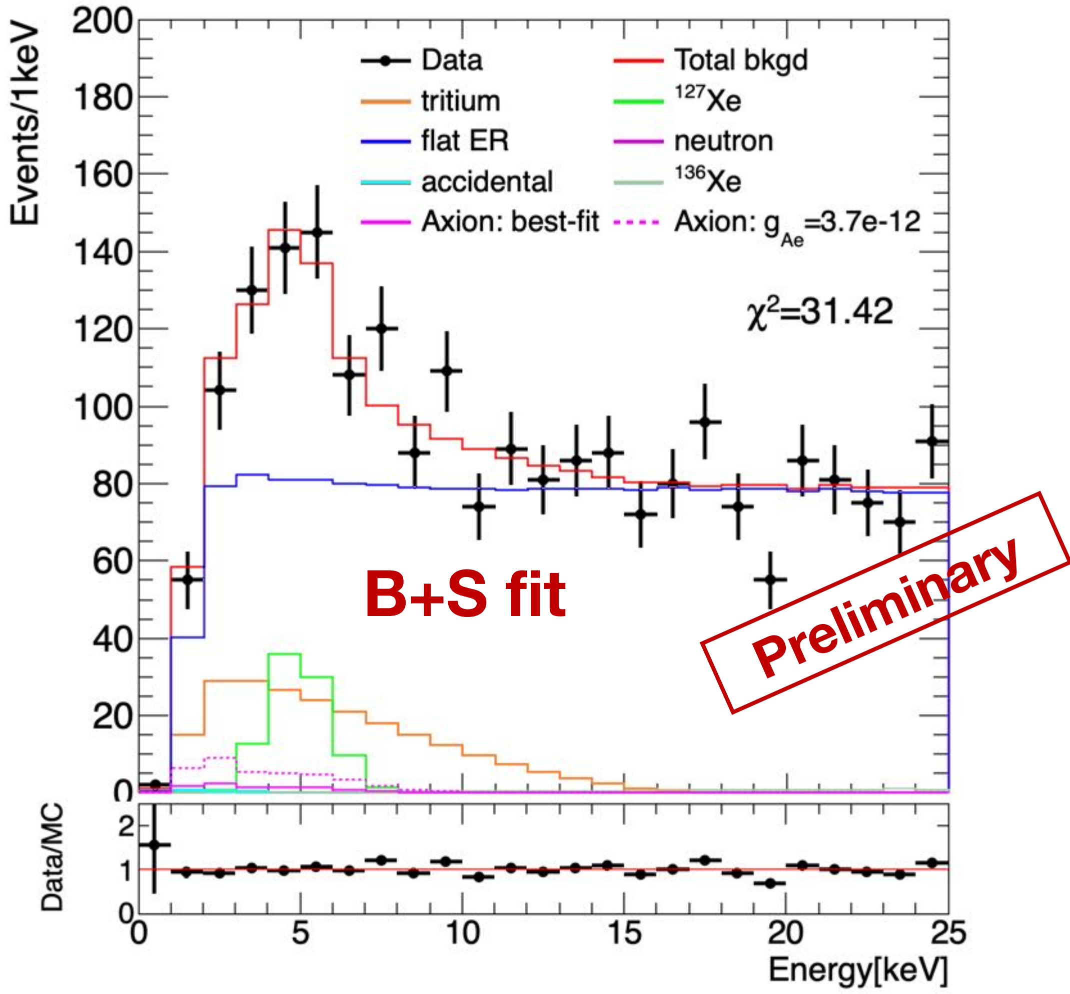
- Degeneracy confirmed due to similar shapes

❖ **No significant best-fit signal yield**

❖ **Similar fitting quality to bkgd-only fit**

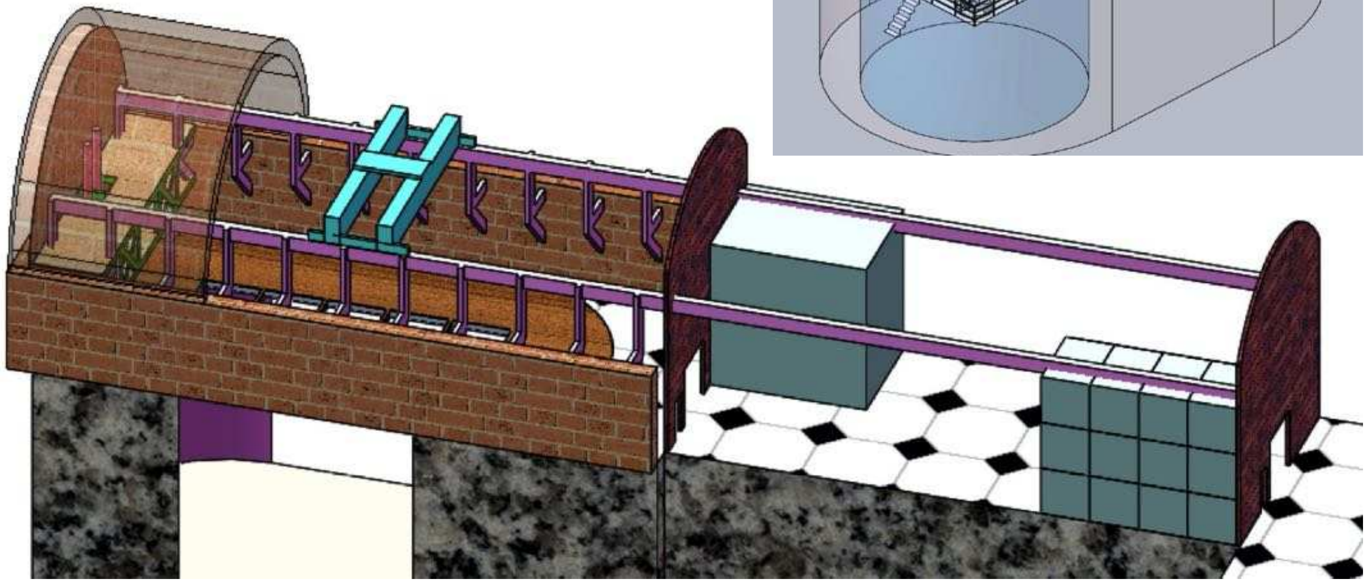
- Indicating limited sensitivity from our data

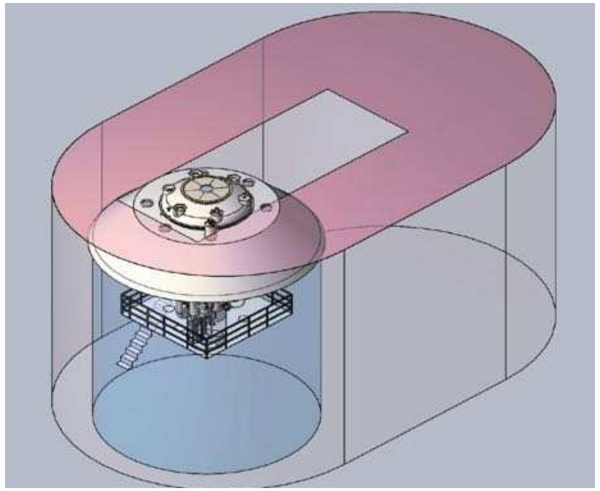
❖ **Analysis is work-in-progress**



New Experimental Hall at CJPL-II

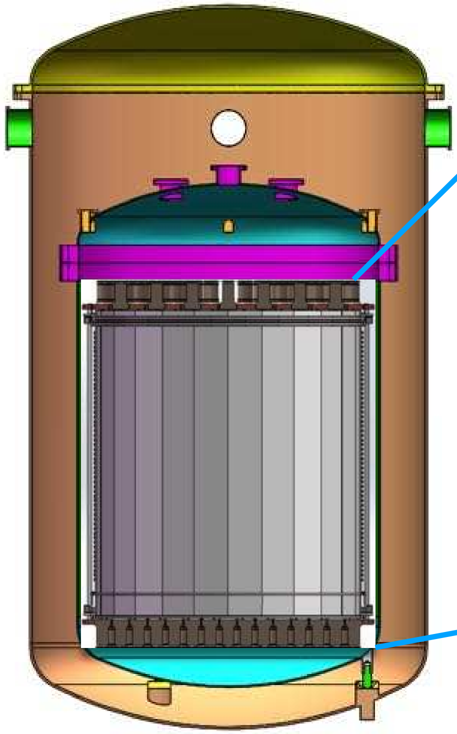
❖ A general facility containing an ultrapure water shield of 4500 m^3 to host large scale DM and $0\nu 2\beta$ experiments

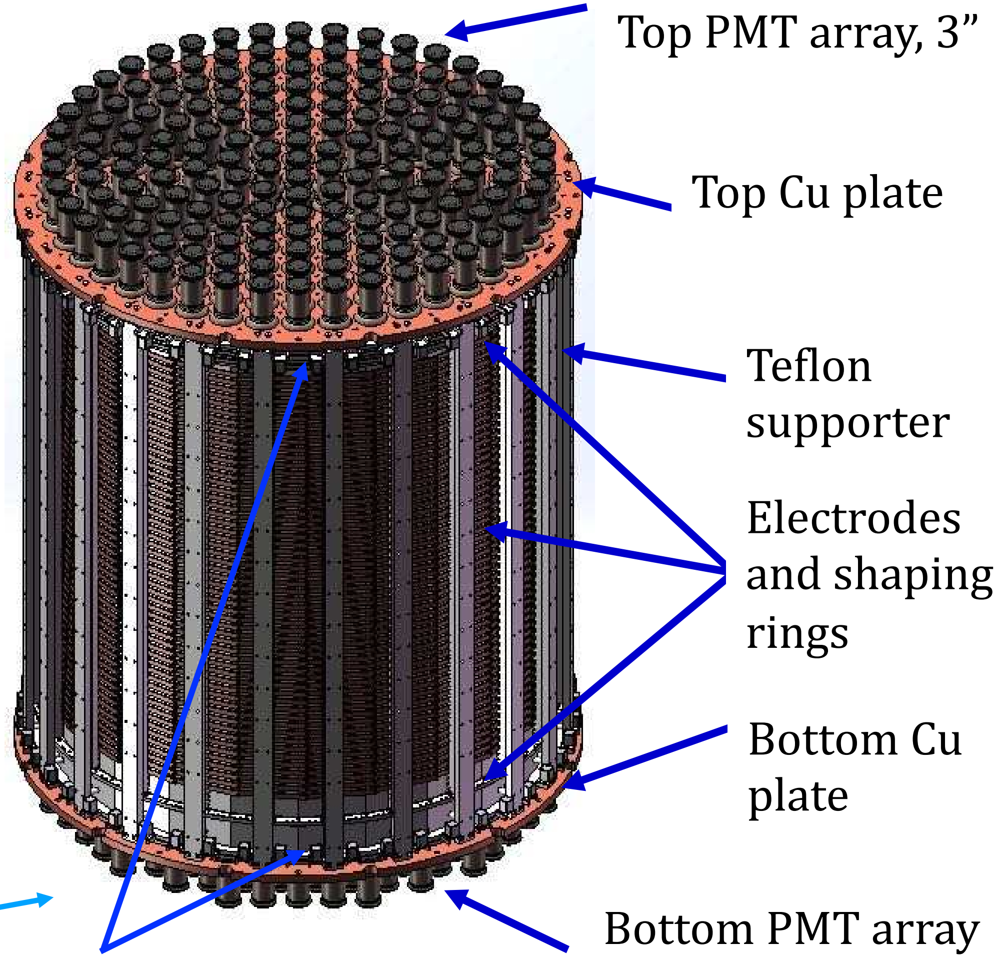




PandaX-4T Experiment

- ❖4-ton liquid xenon in sensitive volume
- ❖Drift region: 1.2m(H) x 1.2m(D)
- ❖3-in PMTs, 169 top/199 bottom
- ❖1-in veto PMT 126

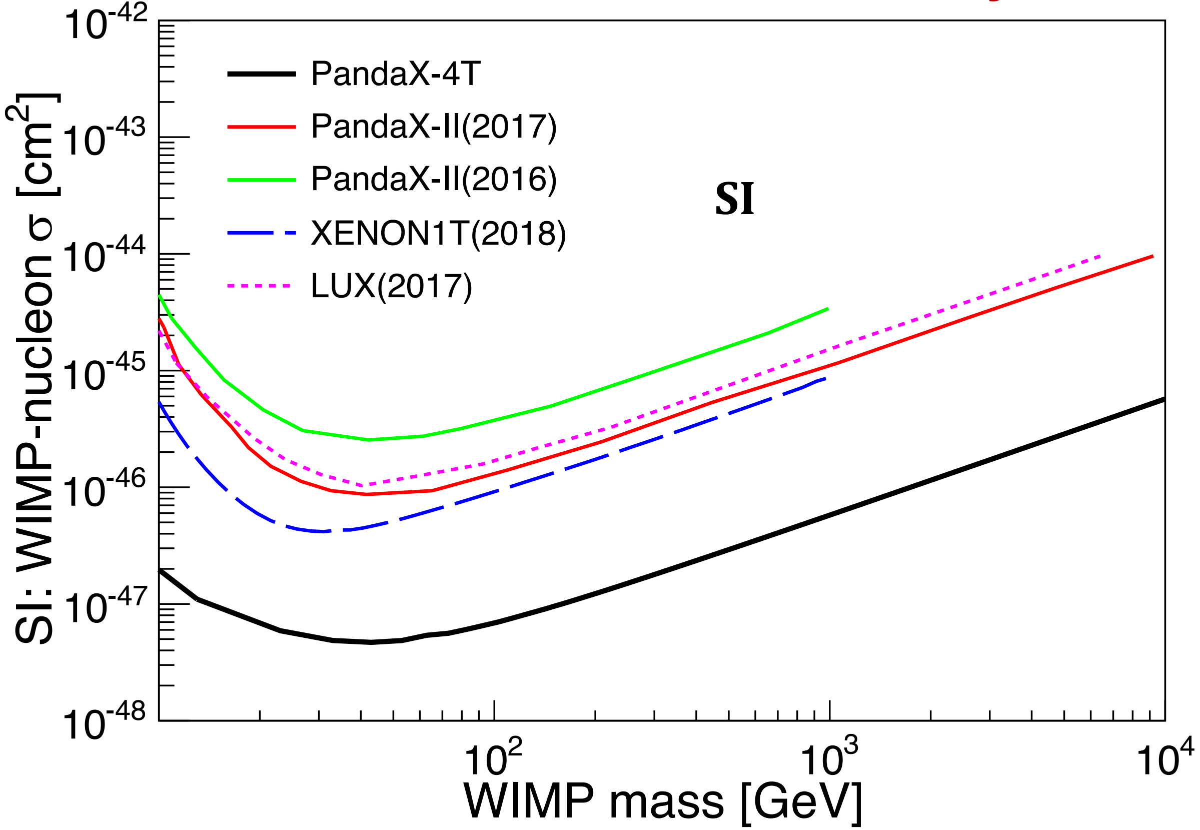




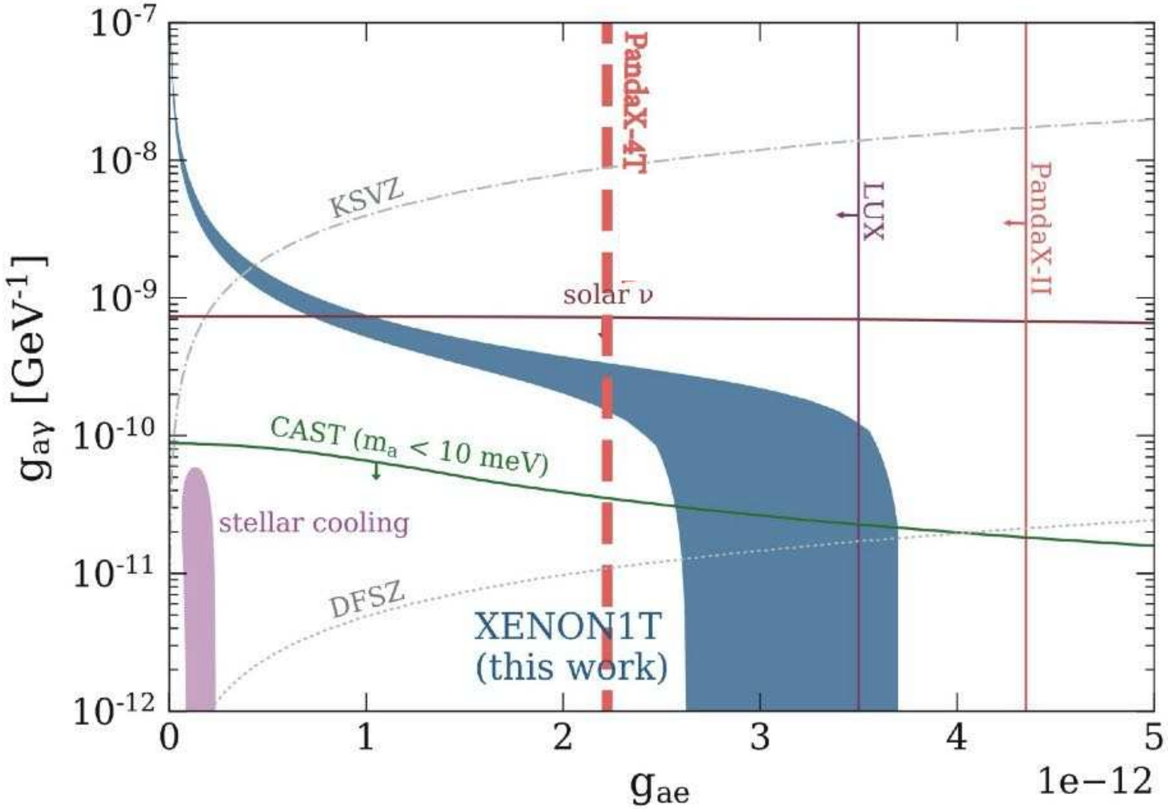
Expected Sensitivity

- ❖6-ton-year: expecting 10x more sensitive than PandaX-II
- ❖1-ton-year: definitive test of the XENON1T low energy ER result

PandaX-4T 6 ton-year



PandaX-4T 1 ton-year



Under Construction


10k Clean Room


Ultra-pure water system


Detector


Distillation Tower


Cooling Bus

Summary and Outlook

- ❖PandaX-II has completed successfully in 2019
- ❖PandaX-4T experiment, x10 more sensitive than PandaX-II, is the next generation
- ❖Temporary infrastructure construction in B2 hall of CJPL-II recently completed
- ❖Onsite detector assembly is work-in-progress
- ❖Expected commissioning of PandaX-4T: end of 2020
- ❖Stay tuned!

Thank You!

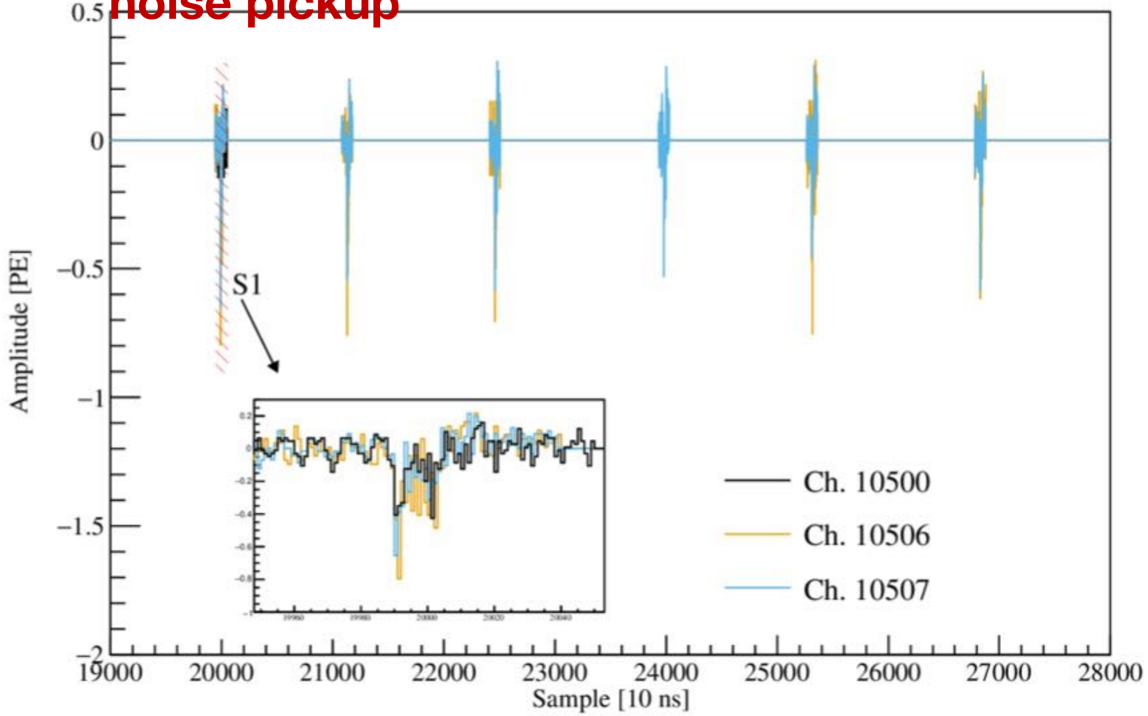
Backup

Post-unblinding cut

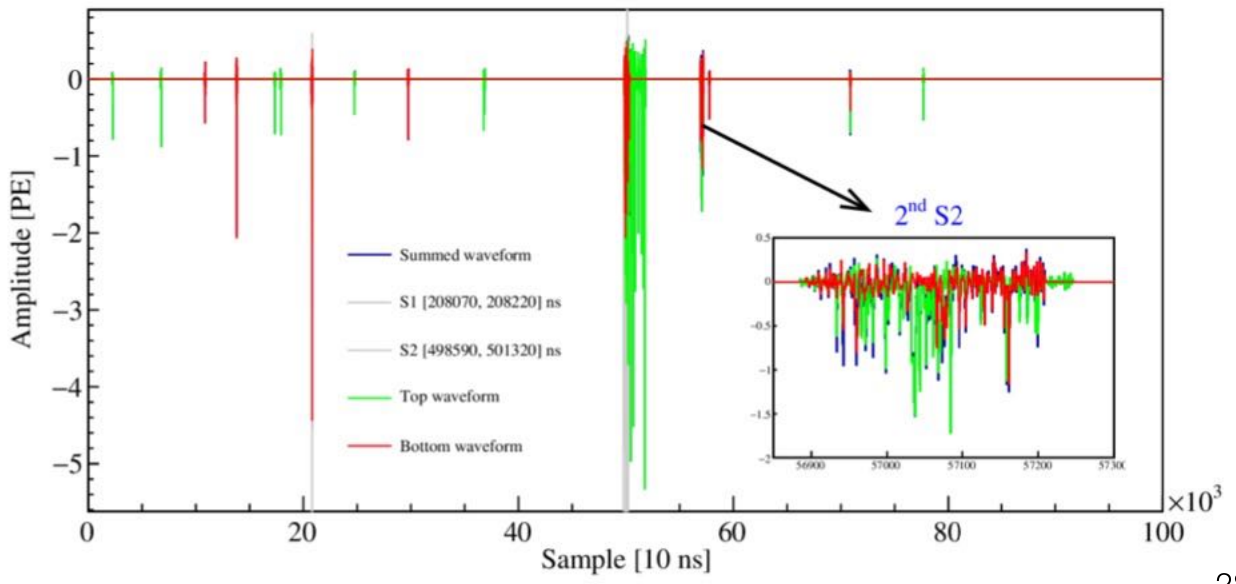
❖

Cut	Run 9	Run 10	Run 11
All triggers	24502402	18369083	49885025
Single S2 cut	9806452	6731811	20896629
Quality cut	331996	543393	2708838
DM search window	76036	74829	257111
FV cut	392	145	710
BDT cut	384	143	695
Post-unblinding cuts	384	143	693

Wrongly rconstructed S1 due to coherent noise pickup



2nd S2 wrongly identified as multiple S1



Light Yield and Charge Yield

❖ **Fitted from our calibration events**

❖ **Consistent with world data**