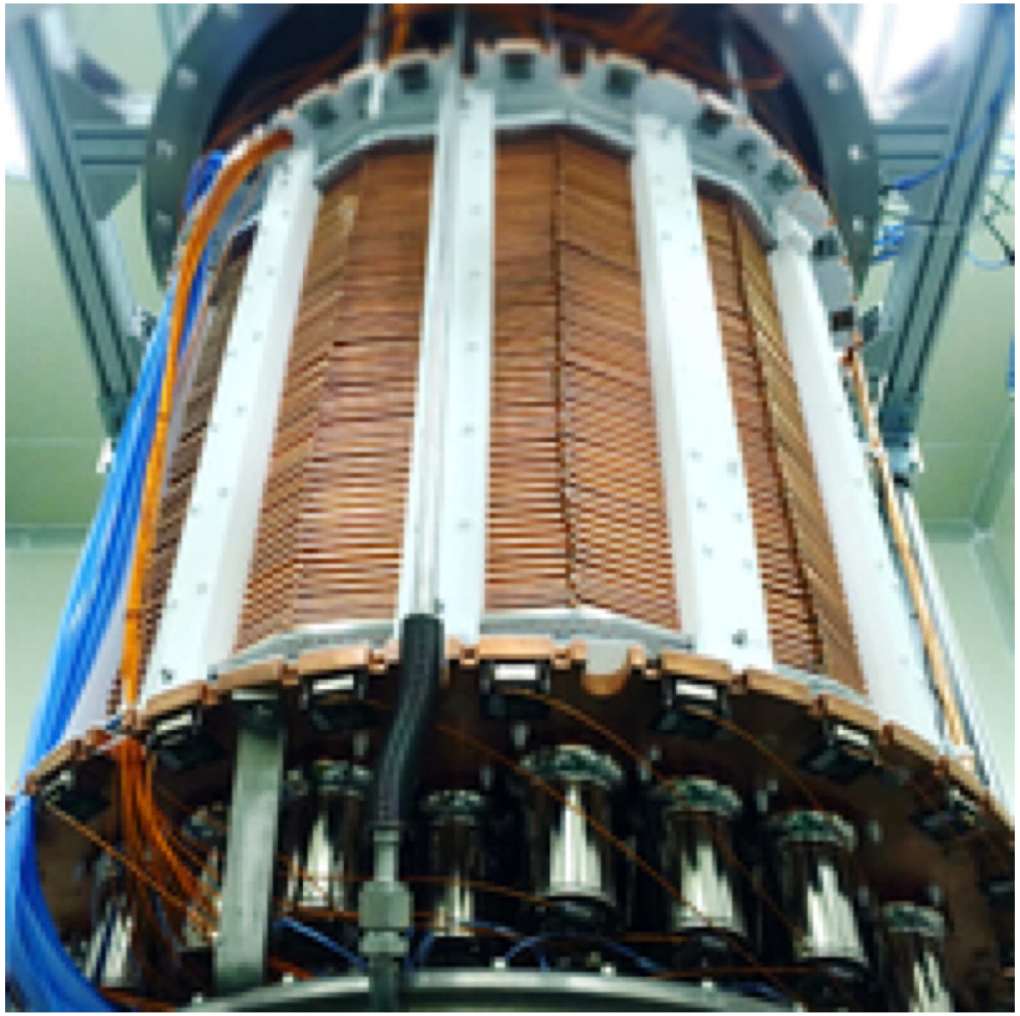
PANDA X
PARTICLE AND ASTROPHYSICAL XENON TPC

上海交通大學
SHANGHAI JIAO TONG UNIVERSITY

UNIVERSITY OF MARYLAND
DEPARTMENT OF PHYSICS



WIMP search with the full PandaX-II exposure

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On behalf of the PandaX collaboration

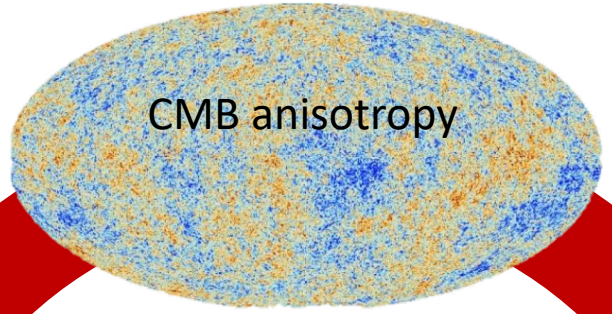
Outline

- Introduction to dark matter and PandaX
- WIMP search with PandaX-II full exposure data
  - Refined algorithms in the analysis
  - Unblinding data and results of the WIMP search
- Summary

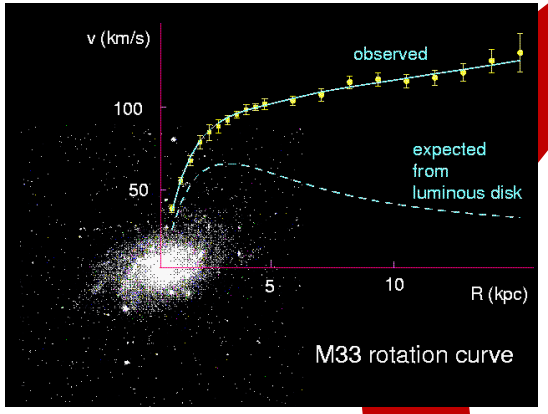
Introduction to dark matter

1930s, F. Zwicky

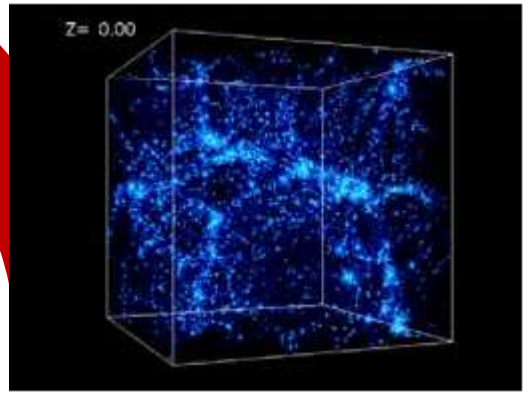
CMB anisotropy



Galaxy rotation curve



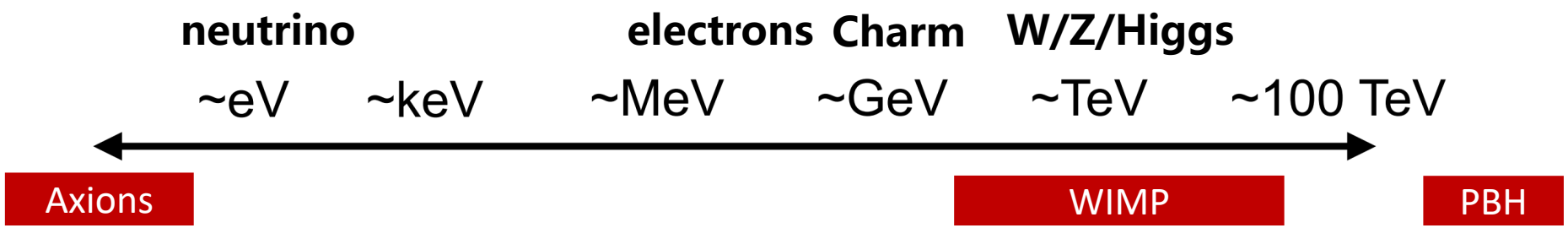
Large-scale structure formation

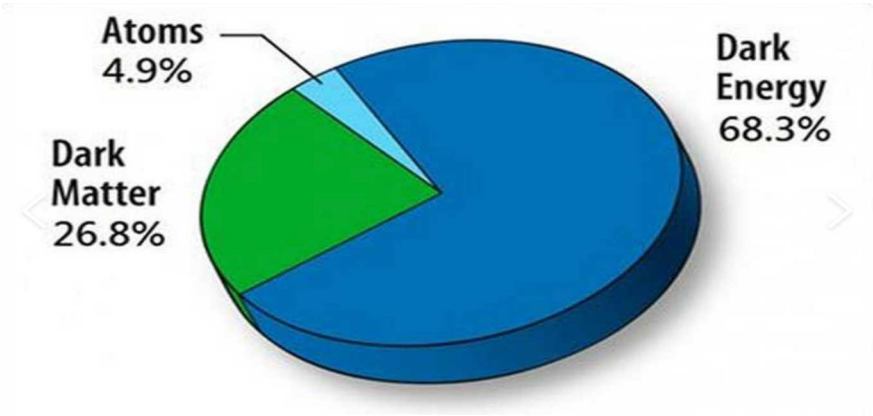


Gravitational lensing

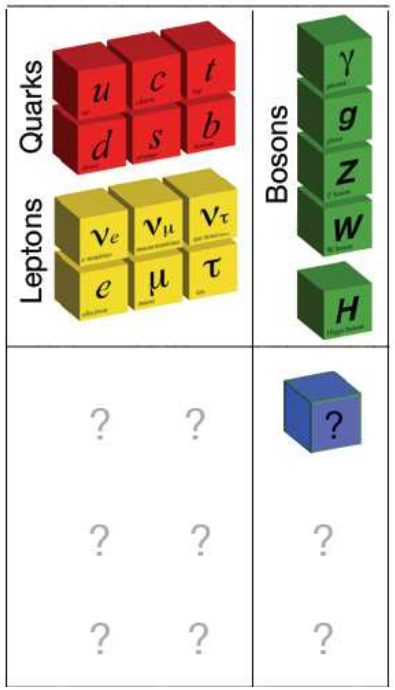
Bullet cluster

Dark matter candidates





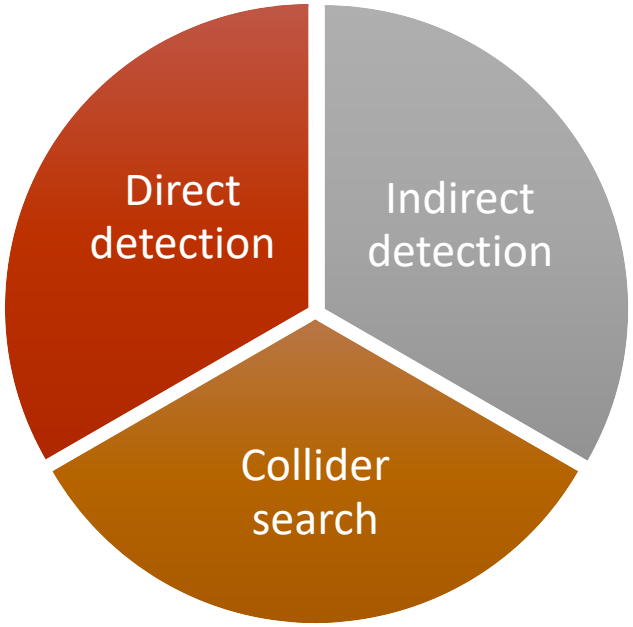
Baryonic acoustic oscillation fitted with standard cosmological model



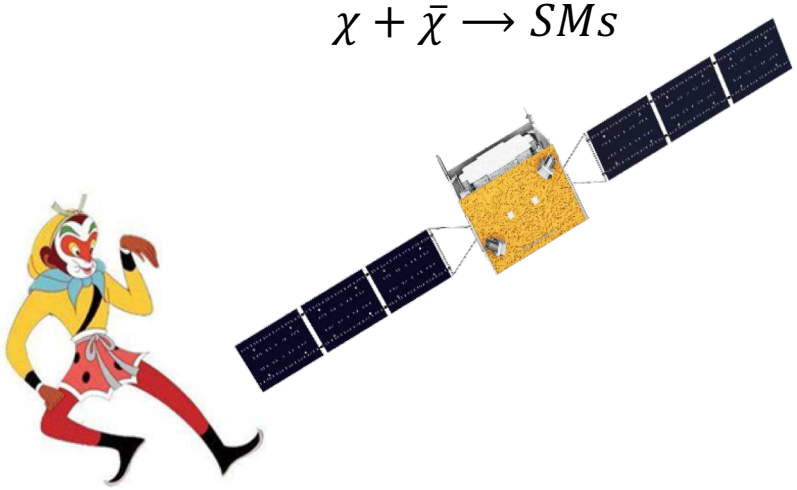
- Weakly interacting massive particles (WIMP), hypothetical particles in the 100 GeV mass range with weak interaction can explain the abundance

Detectability

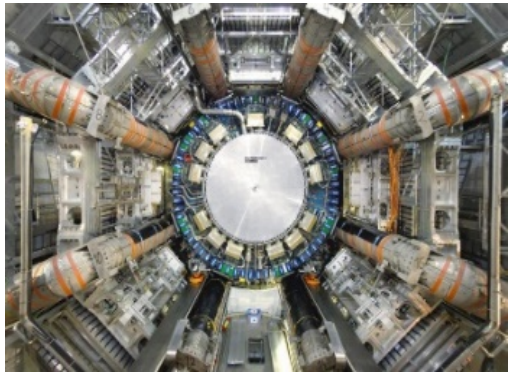
$\chi + SM \longrightarrow \chi' + SM'$



$\chi + \bar{\chi} \longrightarrow SMs$



$SMs \longrightarrow \chi(s)+(SMs)$

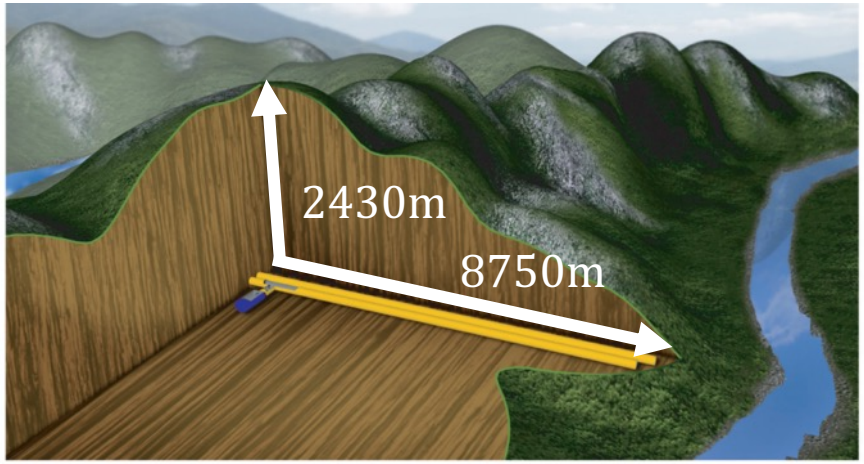


PandaX Collaboration

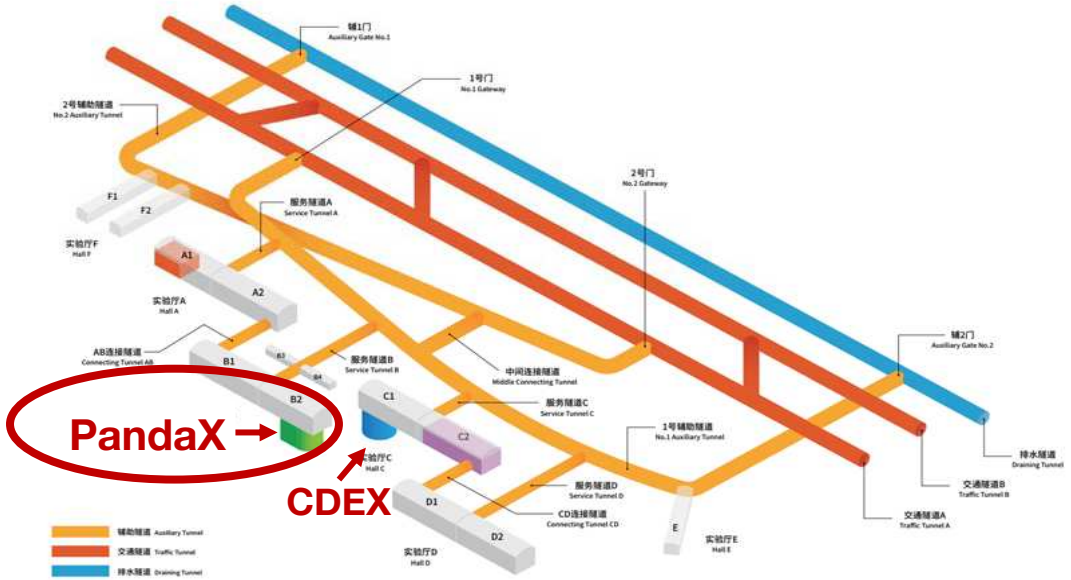
- Particle and Astrophysical Xenon Experiment
  - Formed in 2009

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

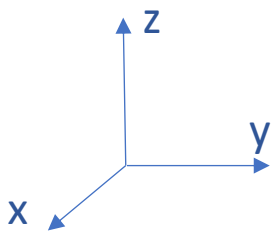


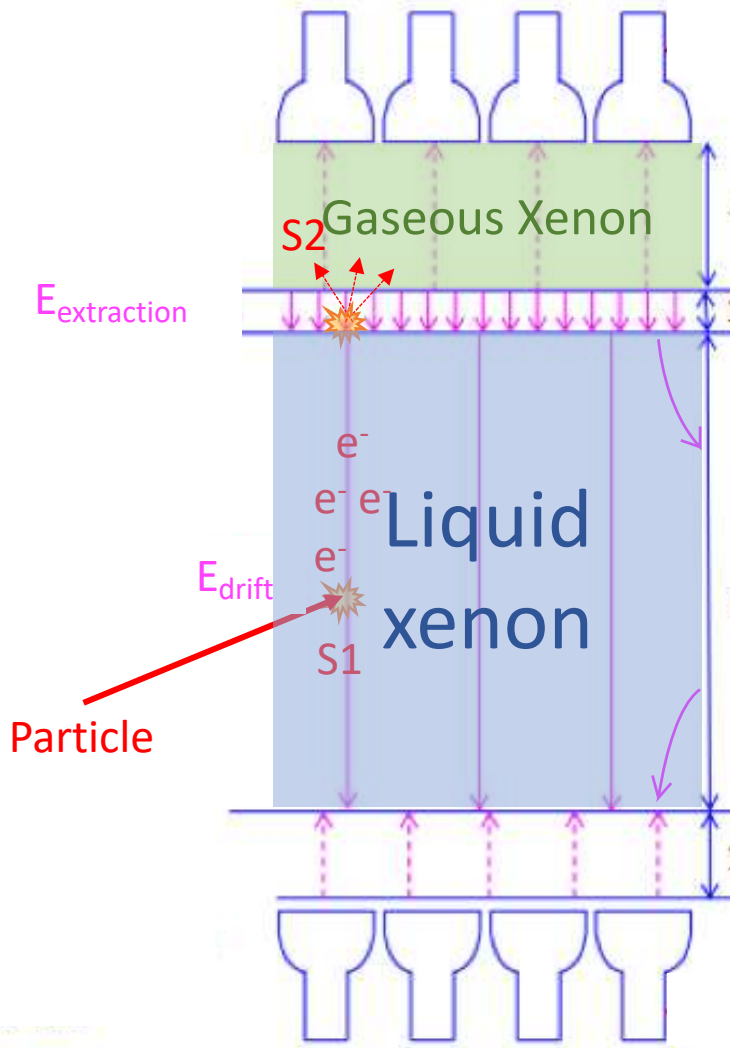
Kick-off of CJPL-II facility construction project, July 20, 2019



PandaX Dark Matter Experiment

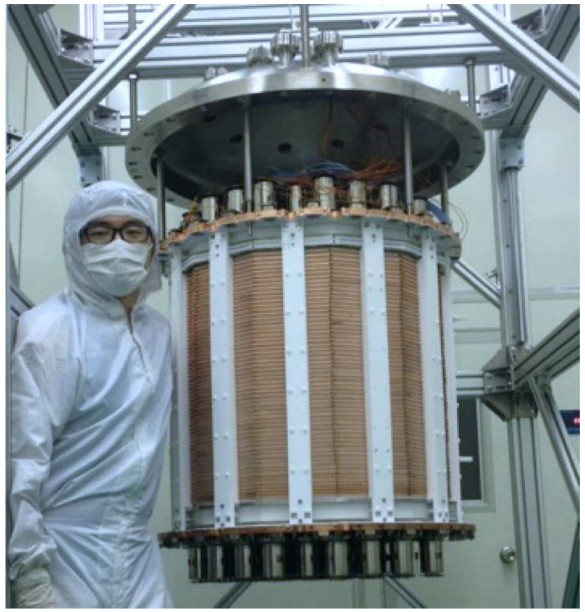
- Dual-phase Xenon TPC
- Origin of an event
  - Nuclear recoils (NR): neutron, WIMPs
  - Electron recoils (ER): gamma, beta
  - Alpha particles
- Energy deposition
  - Excitation, Ionization, Heat
- Signals
  - Prompt light S1 ($\sum_{i=1}^{N_{PMT}} S1_i$)
  - Electroluminance S2 ($\sum_{i=1}^{N_{PMT}} S2_i$)
- Events of interest for WIMP search
  - Single scattering NR with one S1 and S2 in 0-10 keV_{ee}



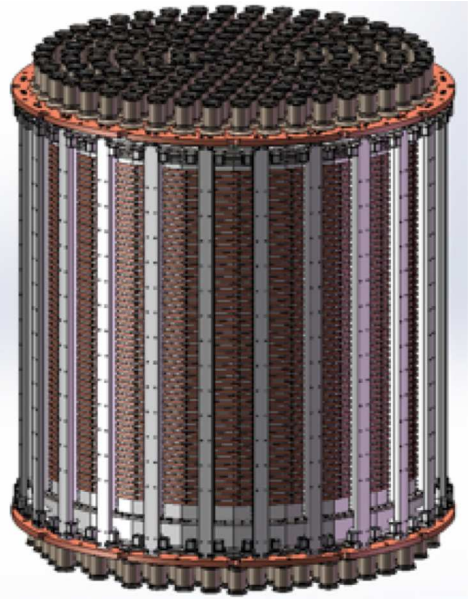


PandaX Dark Matter Experiment

PandaX-I: 120 kg
2009-2014

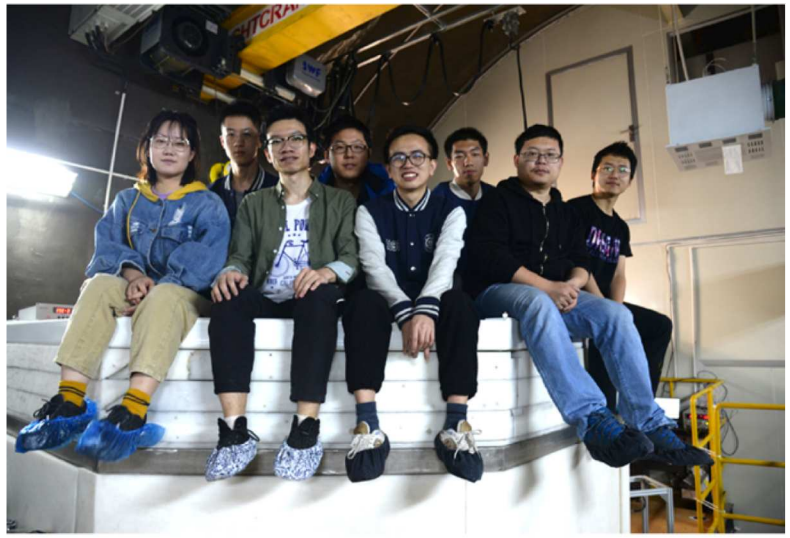


PandaX-II: 580 kg
2014-2019



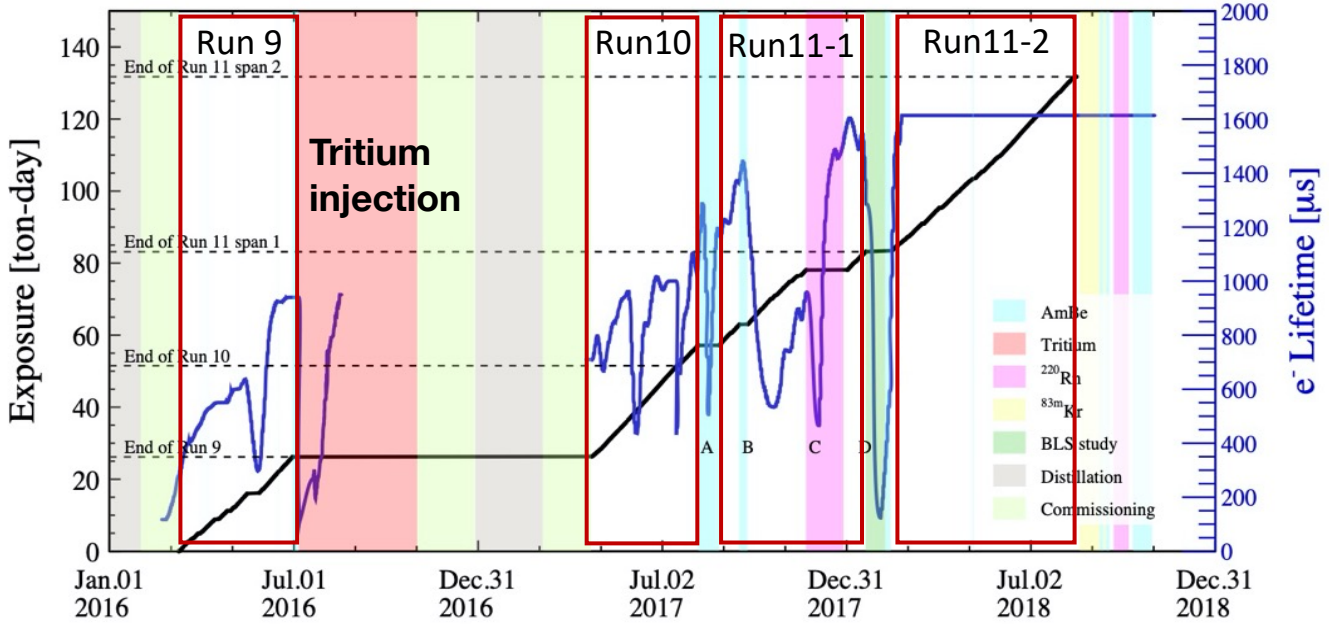
PandaX-4T: 4 ton
2019-

PandaX-II Full Exposure Data



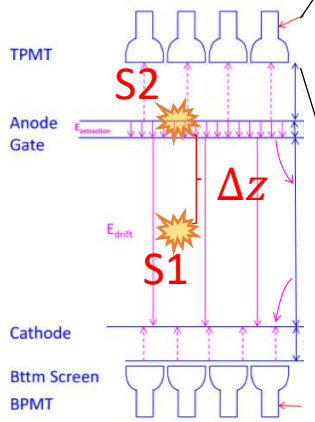
- 2019.06 “End-of-Run” completed
- Total exposure: 131.7 ton-day
  - Run 9: 79.6 days (published)
  - Run 10: 77.1 days (published)
  - **Run 11, span 1: 96.4 days**
  - **Run 11, span 2: 147.9 days**

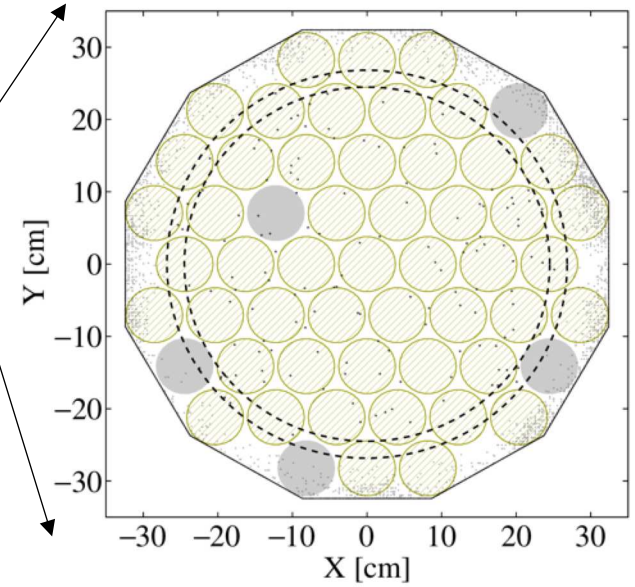
- Refined algorithms
  - New position reconstruction
  - New detector response model
  - Improved background evaluation

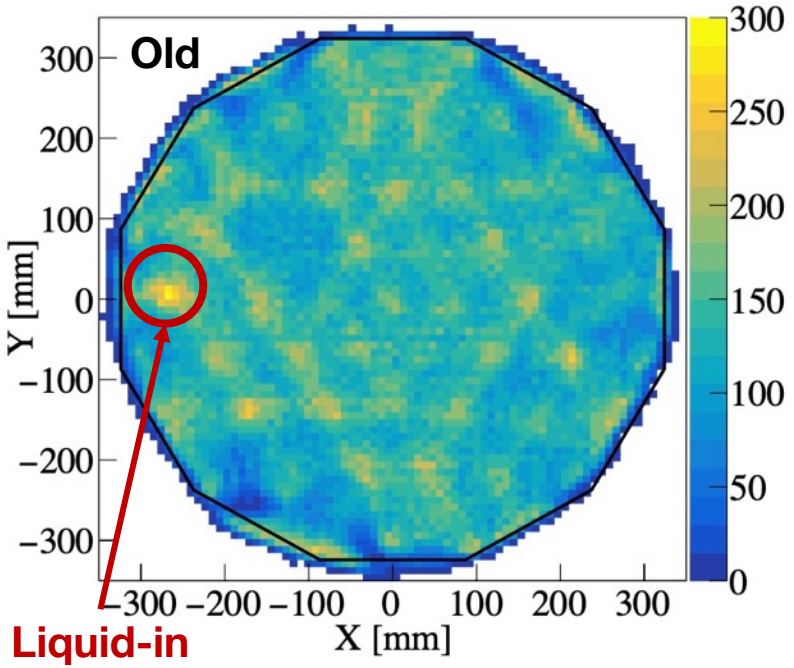


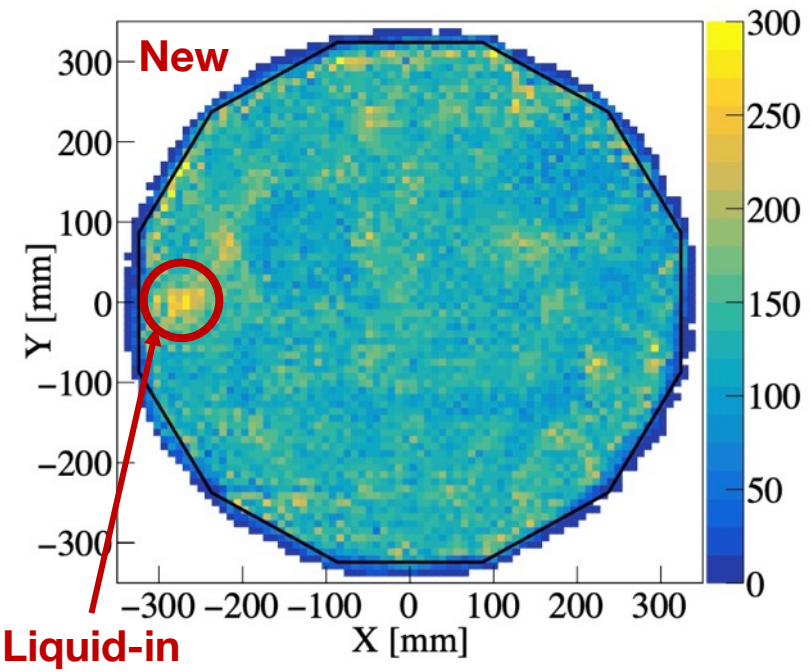
New Position Reconstruction

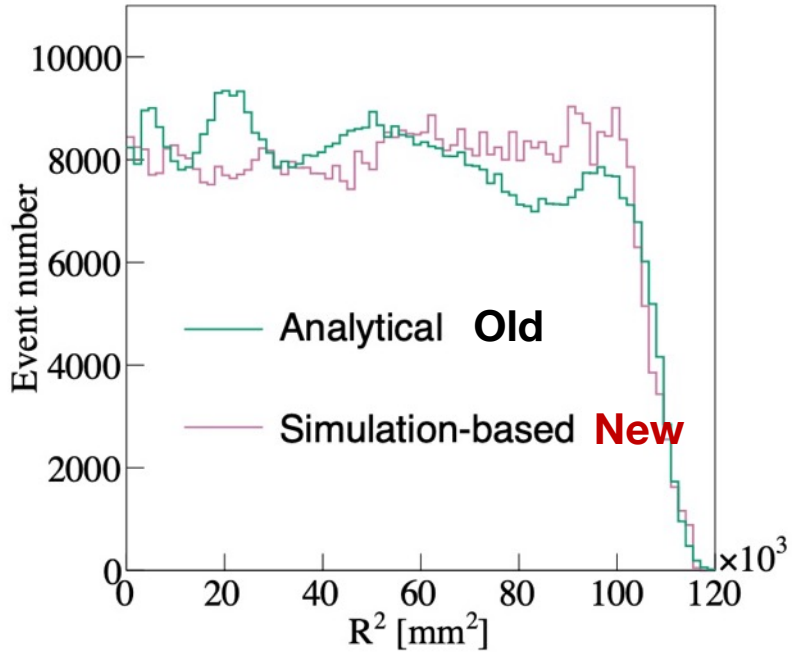
- Trained with evenly distributed ^{83m}Kr calibration events
- Turn off 7 malfunctioned PMTs
  - 5 top and 2 bottom
- Simulation-based position reconstruction
  - Optical simulation of the detector
  - A better construction of photon-response function for each PMT





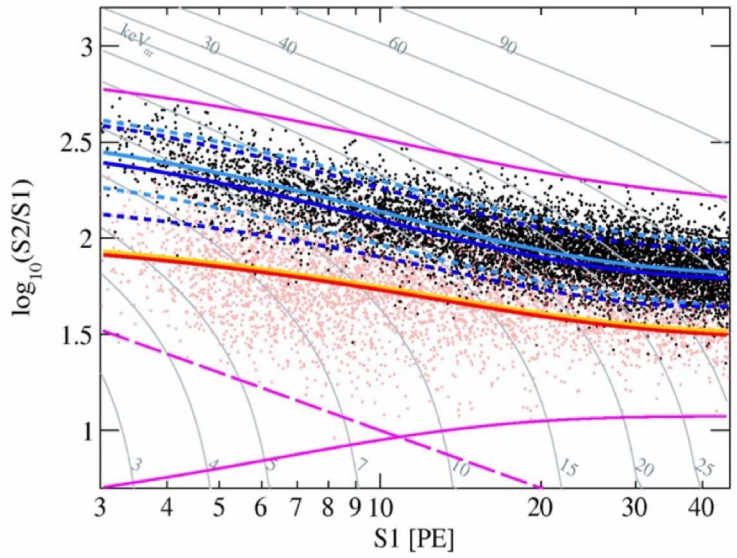




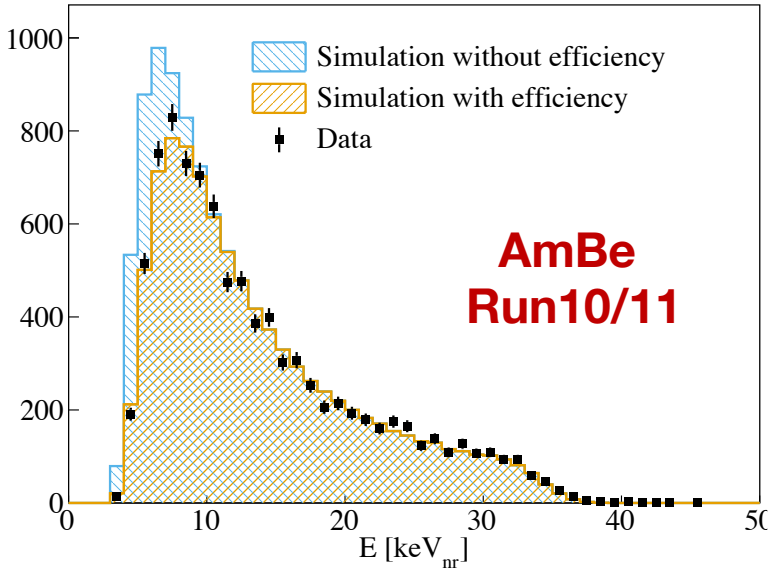


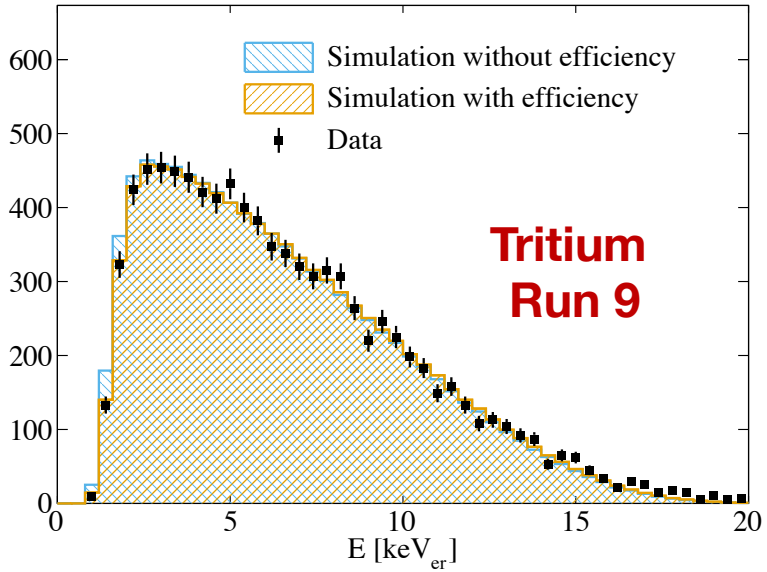
New Response Model

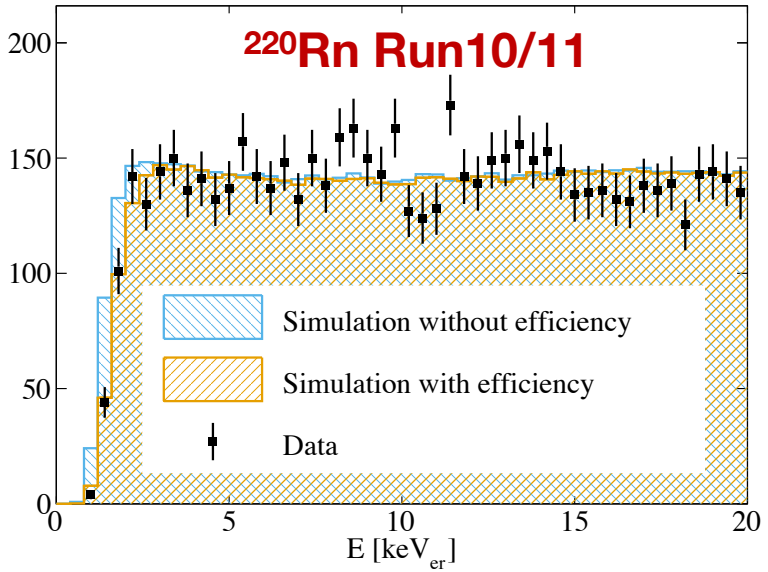
- Calibration data
  - ER events: tritium and ^{220}Rn
  - NR events: AmBe
- NEST 2.0 based response model
  - with data quality cut efficiency



ER Run 9
ER Run 10/11
NR Run 9
NR Run 10/11





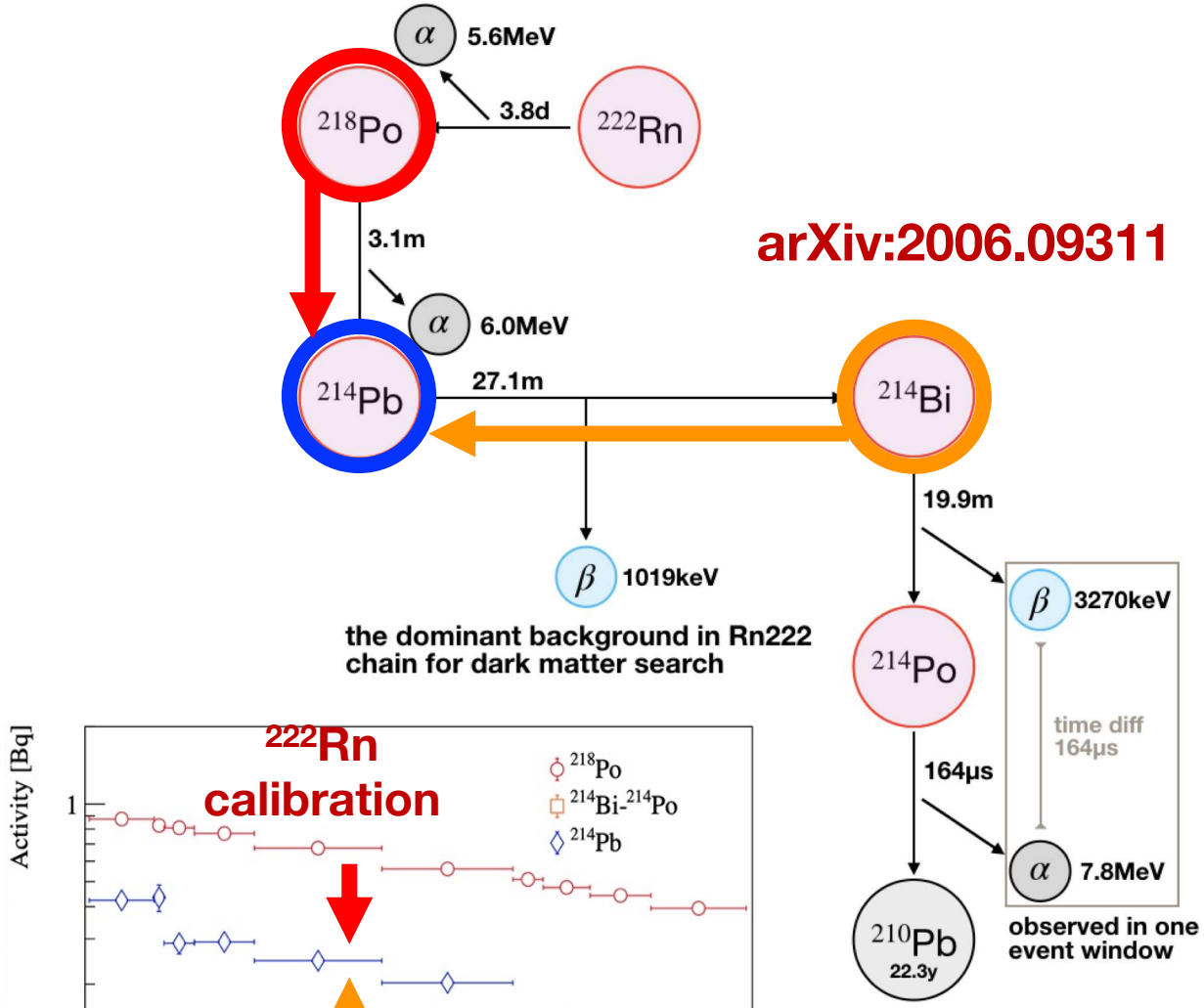


Background Sources

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

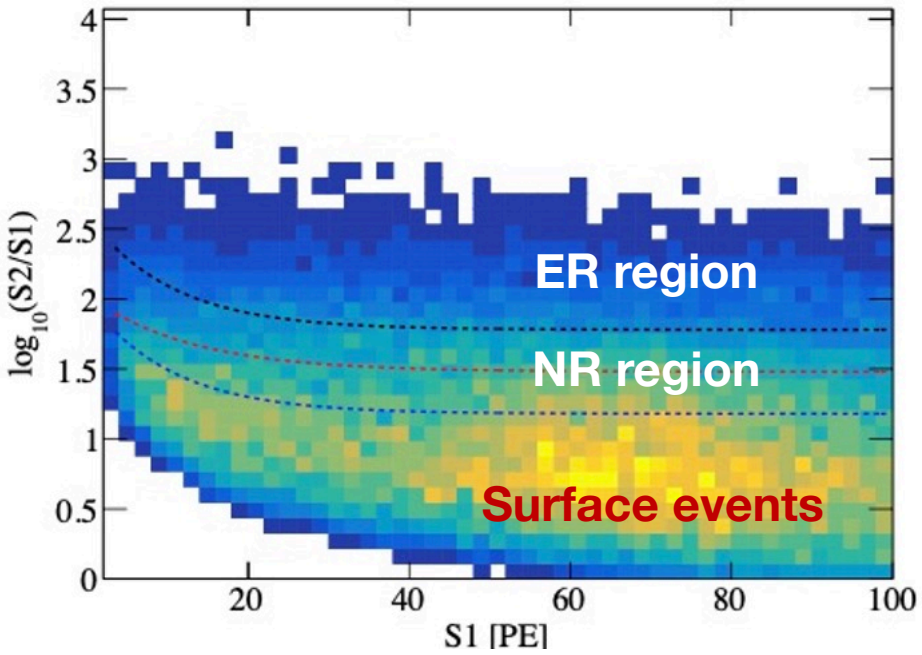
^{222}Rn Background

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



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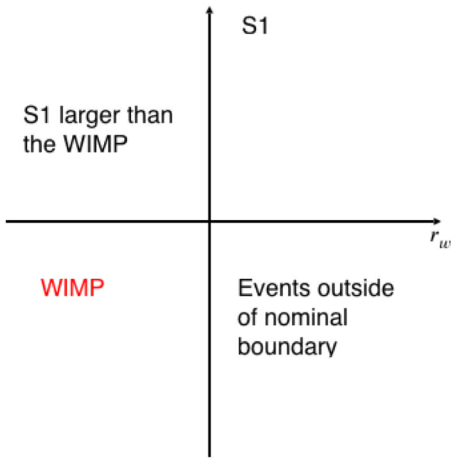

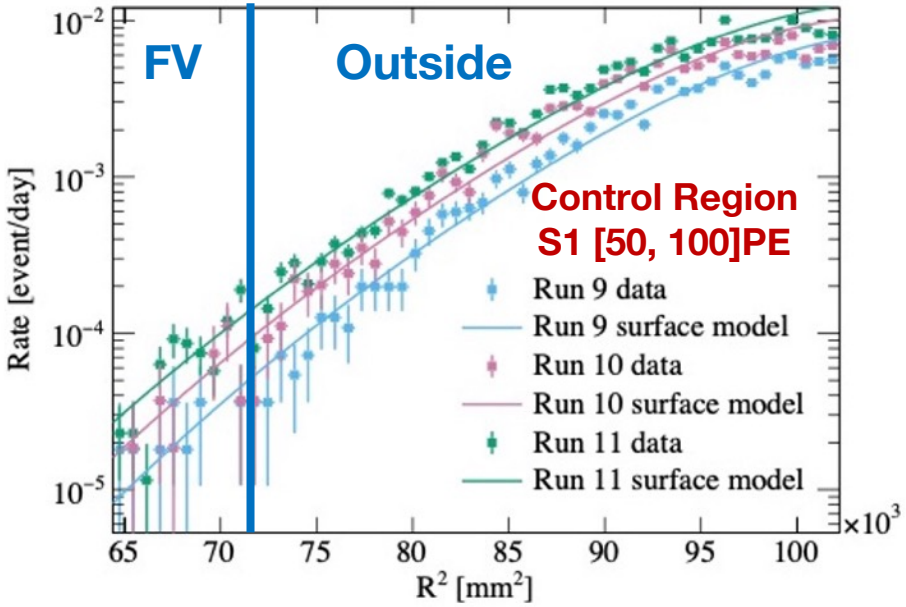

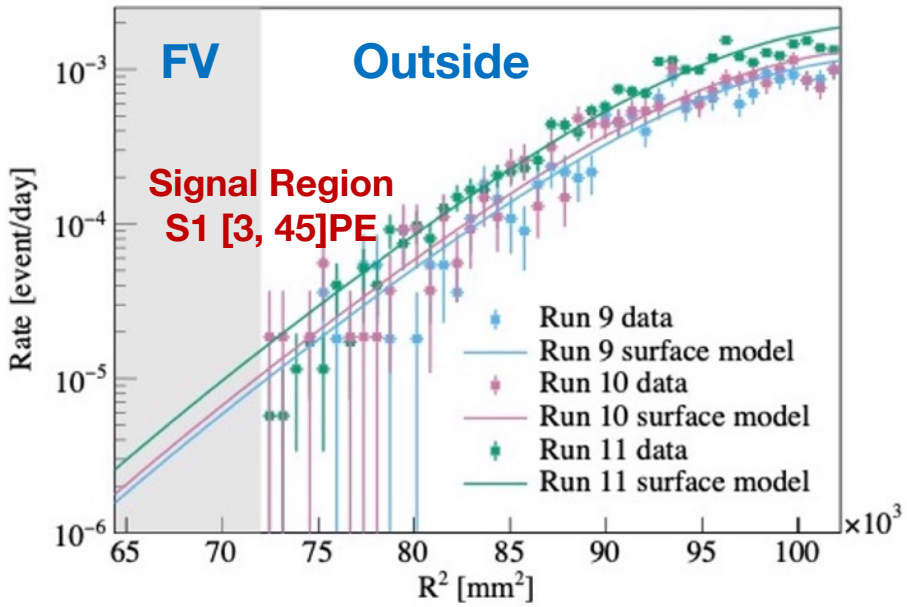

Neutron Background

- 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

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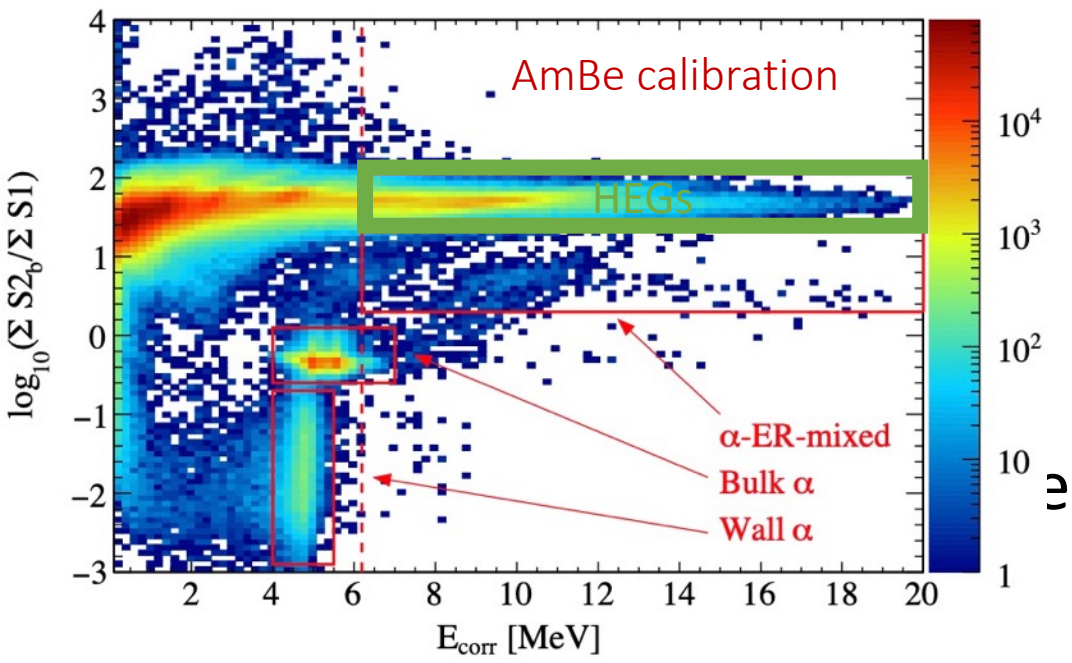

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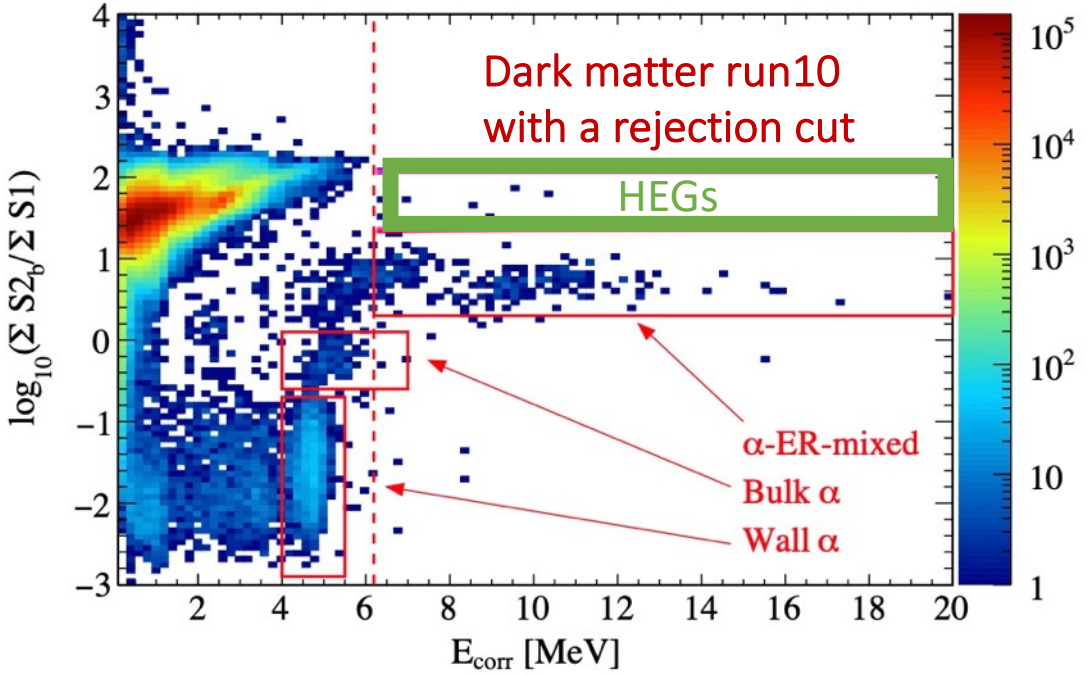


Background Budget for Low Energy Events

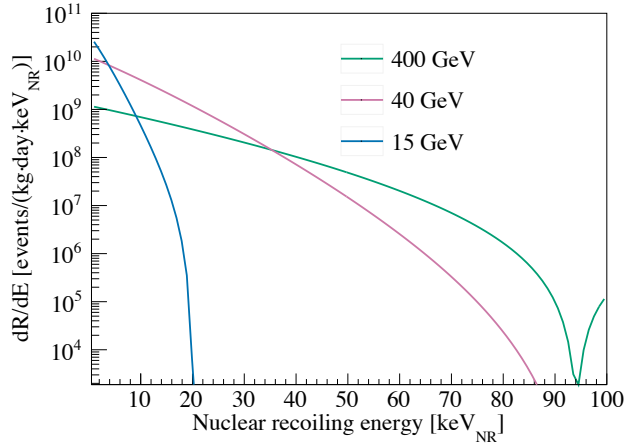
- Compared with Run 10, more background contributions in Run 11
  - ^{85}Kr and tritium

Item		Run 9	Run 10	Run 11, span 1	Run 11, span 2
Flat ER Components (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	0.73 ± 0.08	1.03 ± 0.08
^{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	

Unblinding data and results of the WIMP search

- WIMP
  - NRs, separated from the ER band
- Searching window
  - S1 [3, 45] PE
  - Fiducial volume 329 kg
- Blinded analysis for Run 11
- Total 1220 events, 38 below NR median
  - Consistent with background expectation (best fit with)

dR/dE example with different WIMP masses, $\sigma = 1\times10^{-31} cm^2$



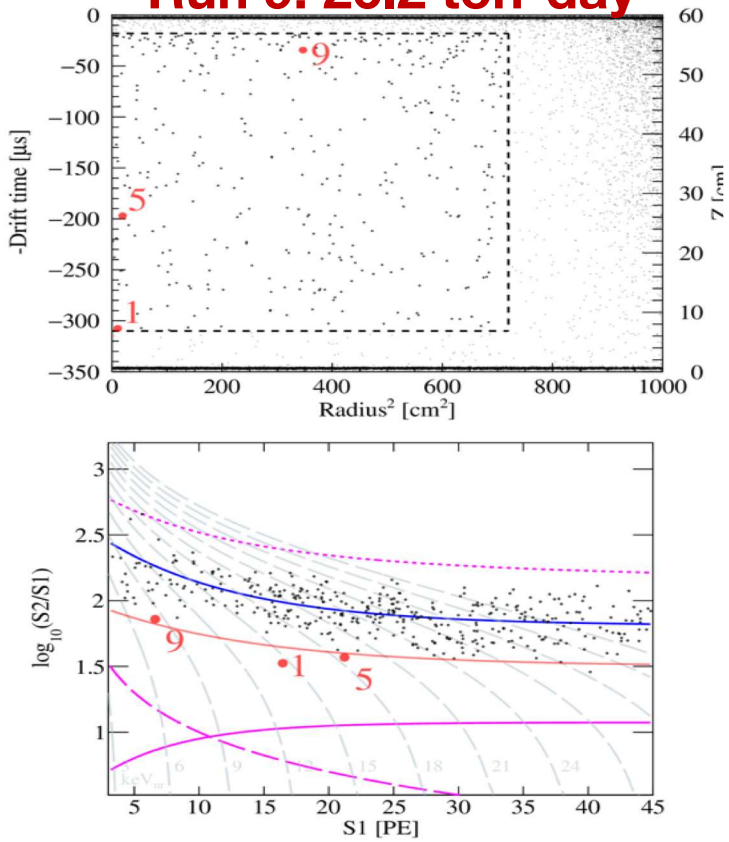
	ER	Accidental	Neutron	Surface	Total fitted	Total observed
Run 9	381.1	2.20	0.77	2.13	387 ± 23	384
Below NR median	2.3	0.46	0.36	2.12	5.3 ± 0.5	4
Run 10	145.6	1.07	0.47	2.66	150 ± 14	143
Below NR median	1.3	0.23	0.22	2.65	4.4 ± 0.6	0
Run 11, span 1	219.4	1.03	0.59	6.23	227 ± 19	224
Below NR median	3.7	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

The best fitting of a 400 GeV WIMP

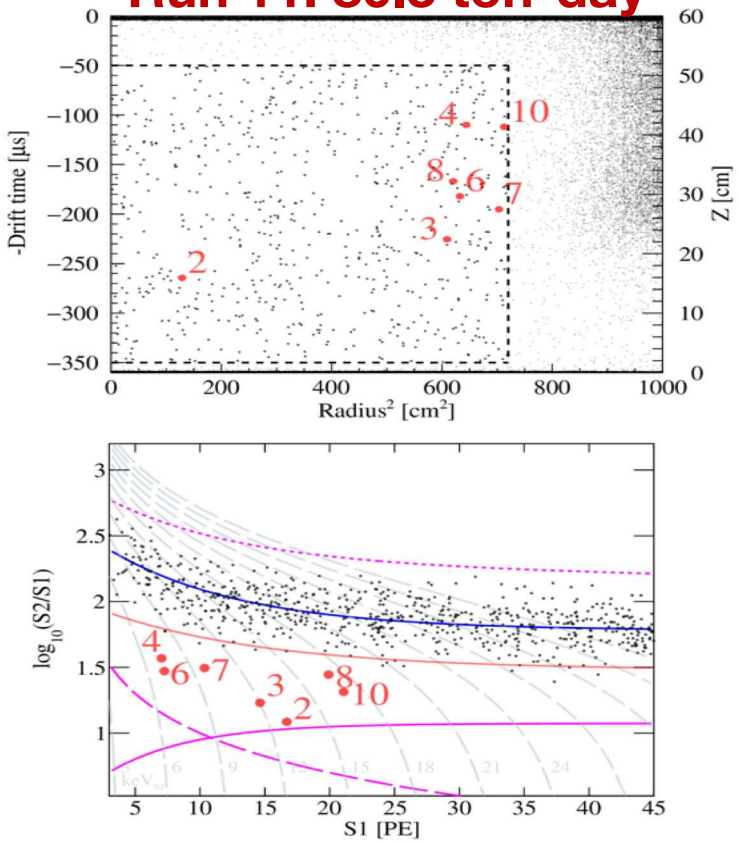
Event Distributions

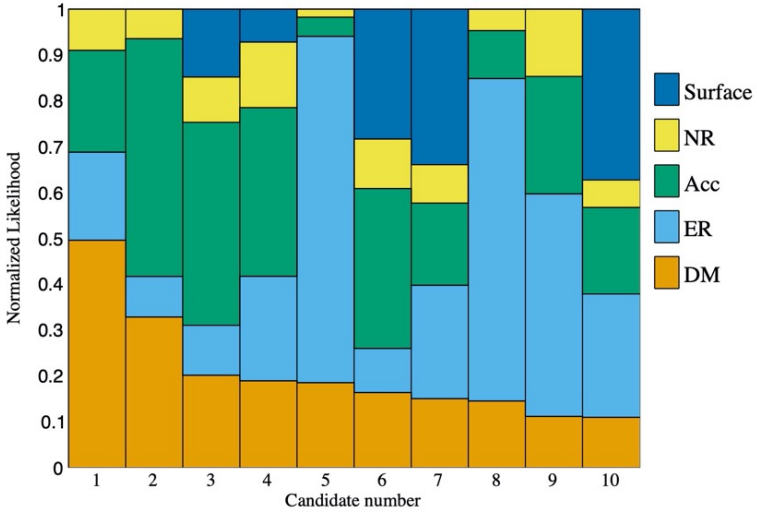
- Distribution of events with high WIMP hypothesis likelihood (400 GeV)
  - 3 events in Run 9 and 7 events in Run 11

Run 9: 26.2 ton-day



Run 11: 80.3 ton-day

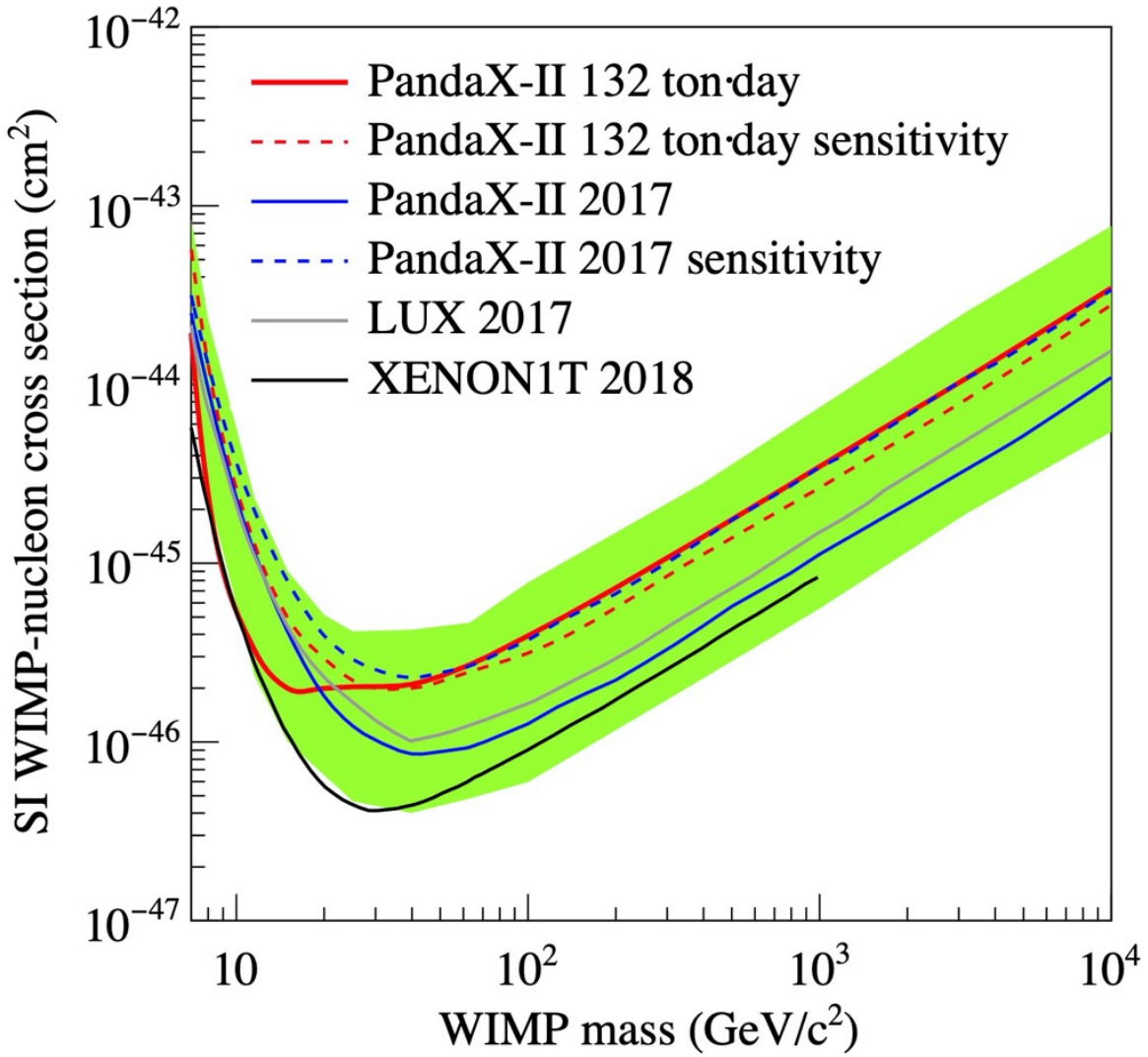




Constraints on WIMP Model

- Spin-independent Interaction

- Exclusion limits on SI
  - 2.0×10^{-46} cm^2 for 15 GeV
  - 2.1×10^{-46} cm^2 for 40 GeV
  - 1.4×10^{-45} cm^2 for 400 GeV



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

Thanks for your attention!

Dr. Xiaopeng Zhou will present the searches on solar axions and neutrinos with enhanced magnetic moment.