

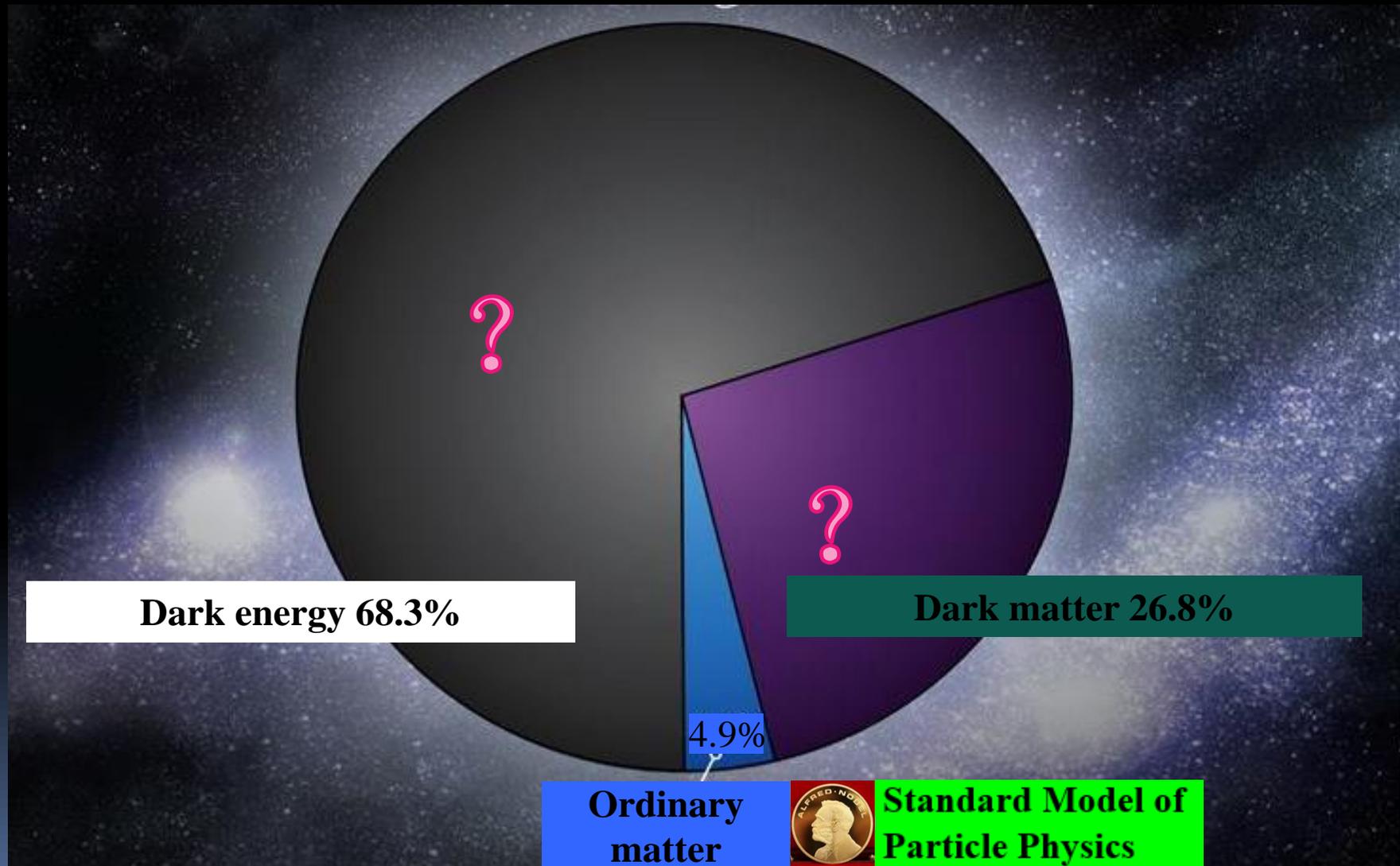
The PandaX Experiments and Recent Results from PandaX-II

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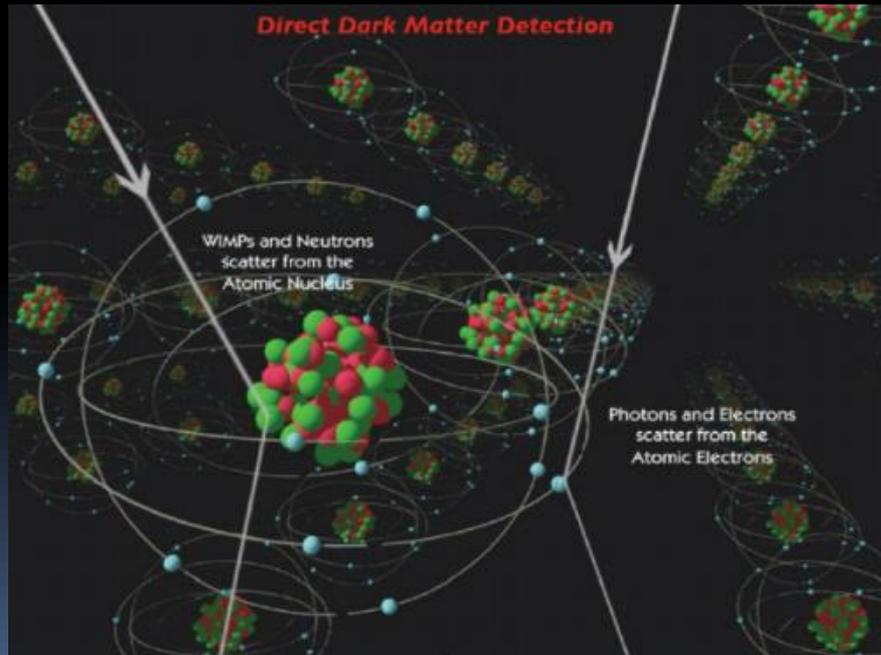
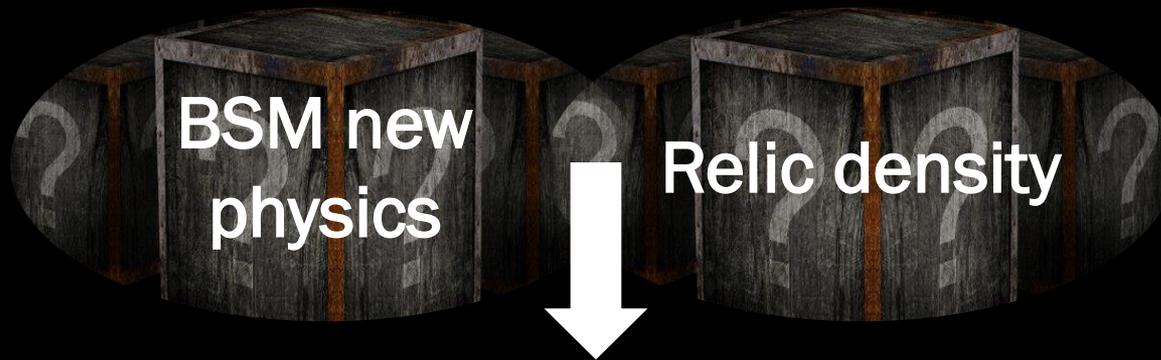
On behalf of the PandaX Collaboration



Composition of the universe

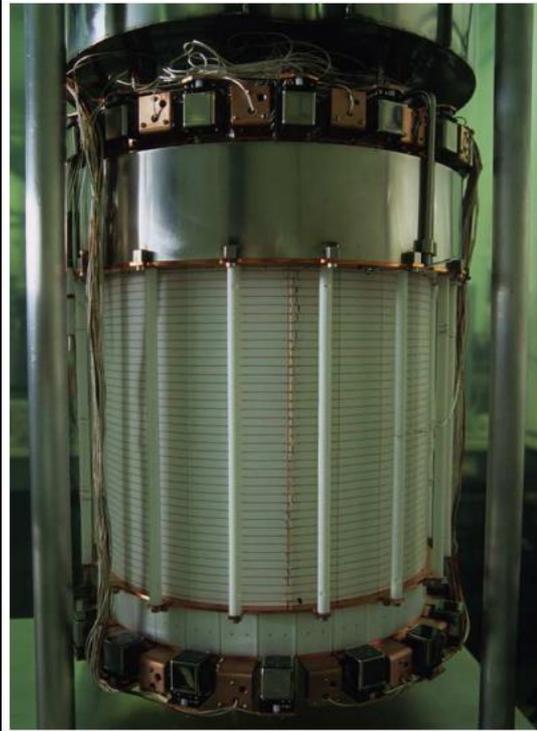


WIMP, the miracle, and the detection



DM direct detection:
wait for DM interacting
atomic nucleus in the
detector, and detect its
recoil (Goodman &
Witten, 1985)

Dual phase xenon experiments



XENON100, 60 kg,
completed 2012, Gran
Sasso
XENON1T commissioning



LUX, 250 kg, running, Sanford
Lab
LZ(multi-ton) in preparation

Dual phase xenon
detector is

Large target



Low energy
calorimeter



3D camera



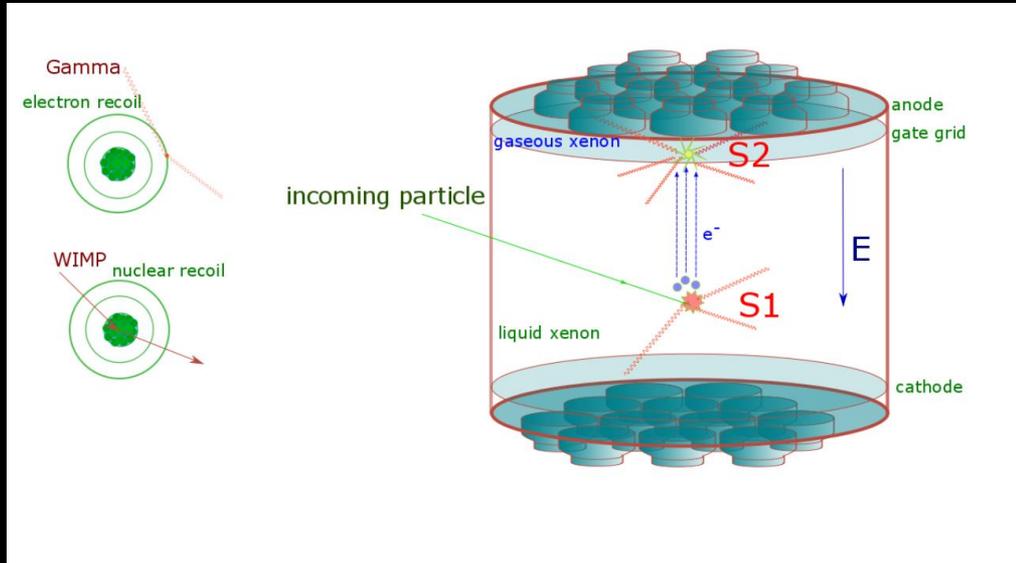
Signal/bkg
discriminator



Self-shielding body

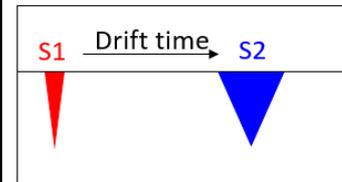


Dual phase xenon experiments

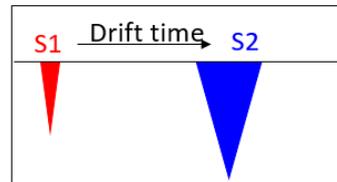


DM direct detection: recoil of atomic nucleus in the detector (Goodman & Witten, 1985), $<10 \text{ keV}_{ee}$ energy

Dark matter: nuclear recoil (NR)

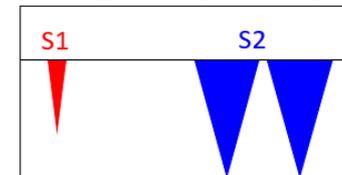


γ background: electron recoil (ER)



$$(S2/S1)_{NR} \ll (S2/S1)_{ER}$$

Multi-site scattering background (ER or NR)

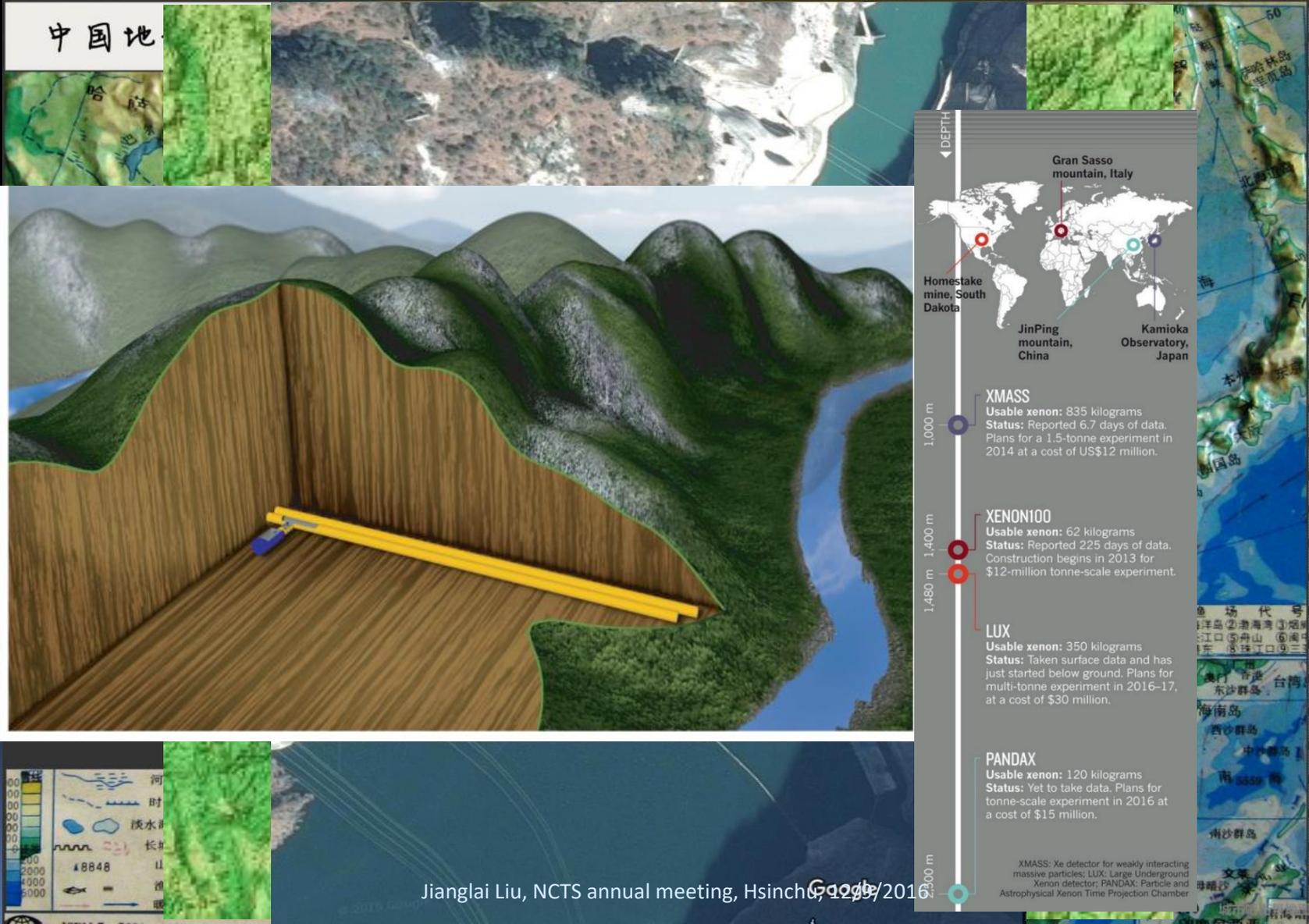


Underground experiments

- Every second there are 10^8 dark matter passing through us
- Our body has 10^{29} atoms
- Less <1 nucleus is hit per year!
- But our body is hit 10^8 /day by environmental background radiation!
- Hide detector in deep underground lab, and put massive shield



China Jinping Underground Lab



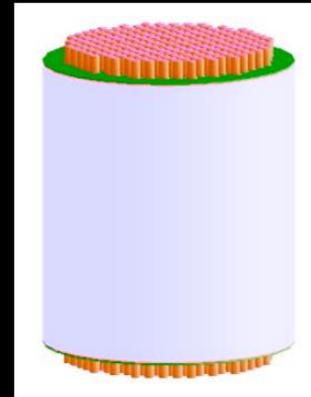
PandaX Experiments



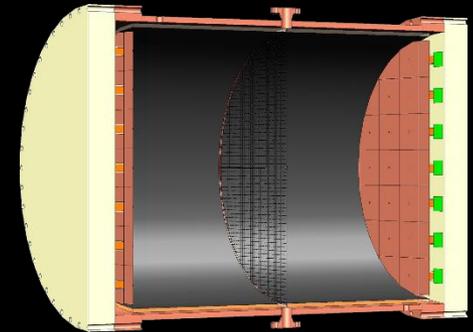
PandaX-I: 120 kg
DM experiment
2009-2014



PandaX-II: 500 kg
DM experiment
2014-2018



PandaX-xT:
multi-ton (~4-T)
DM experiment
2018-



PandaX-III: 200 kg to
1 ton HP gas ^{136}Xe
0vDBD experiment
2016-



PANDA X = Particle and Astrophysical Xenon Experiments

PandaX collaboration

Started in 2009, ~50 people



- 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-)

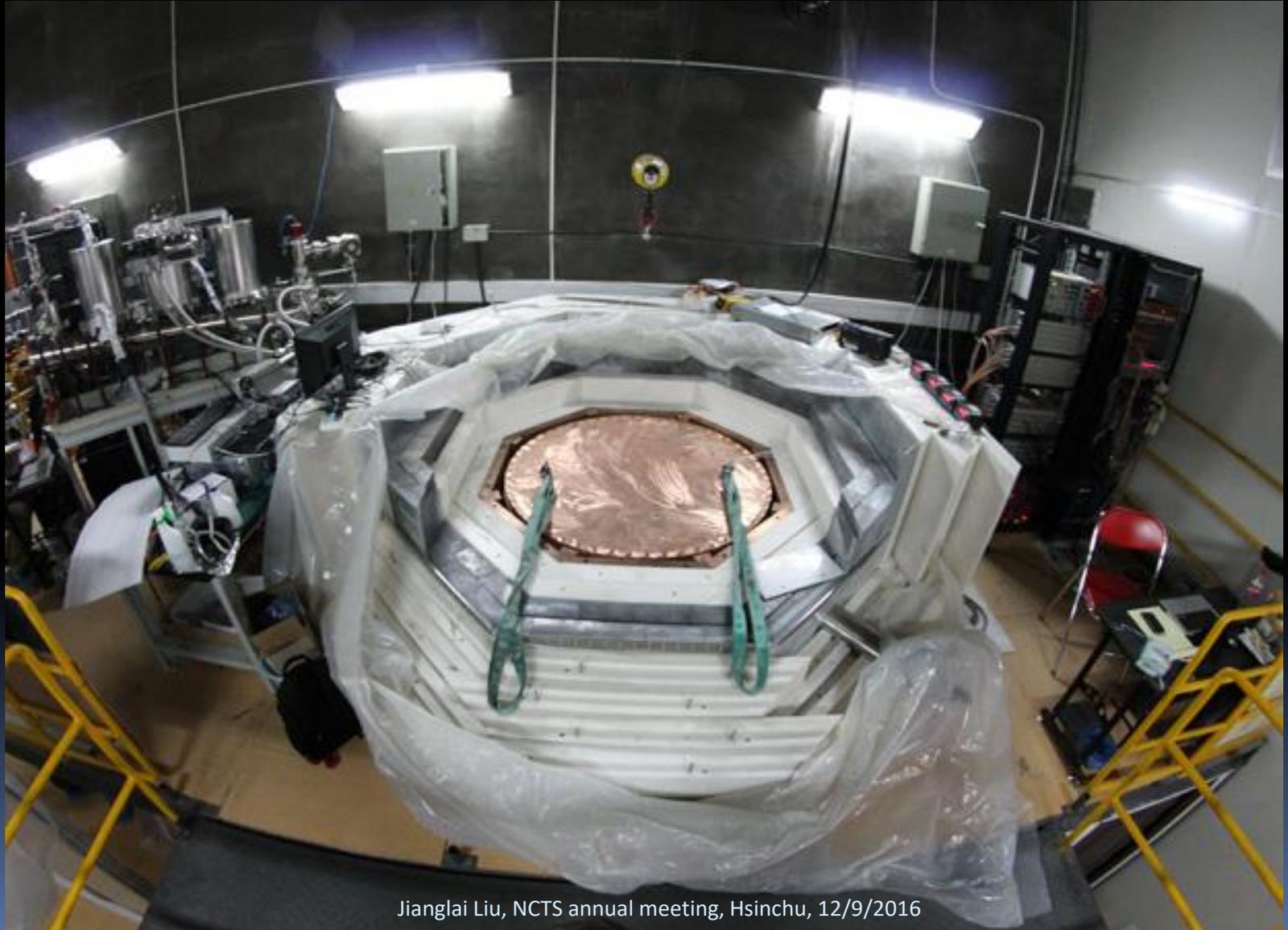
First delivery of PandaX equipment to Jinping

Aug 16, 2012



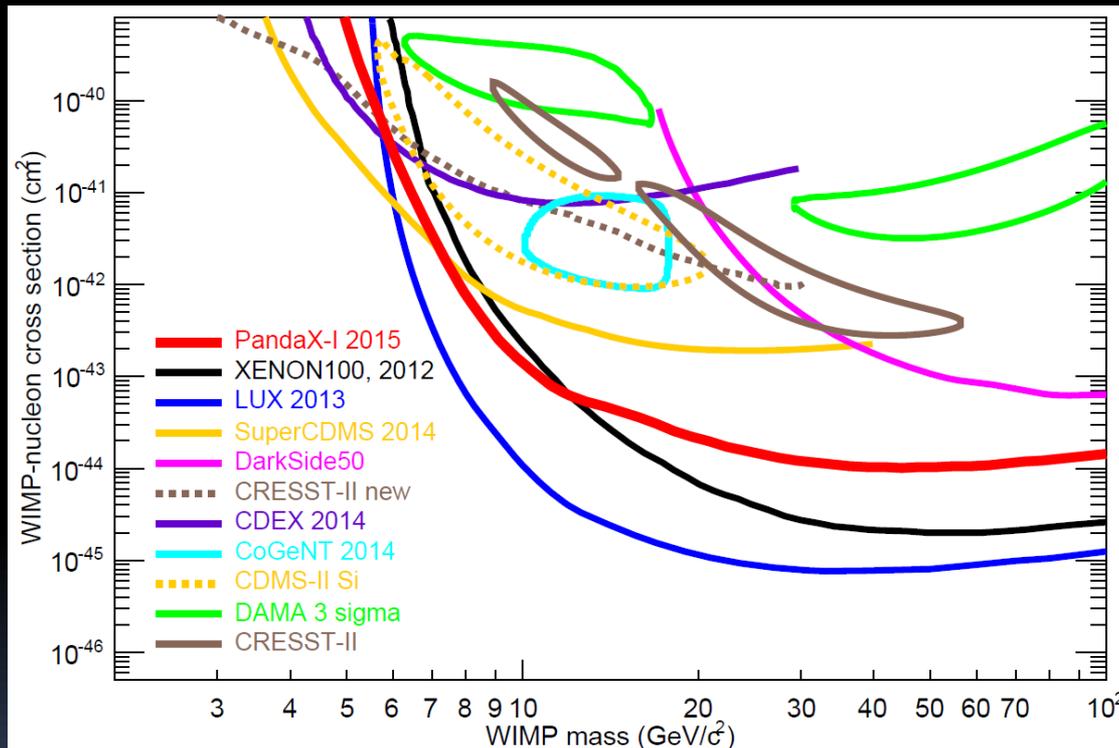
Jianglai Liu, NCTS annual meeting, Hsinchu, 12/9/2016

PandaX apparatus



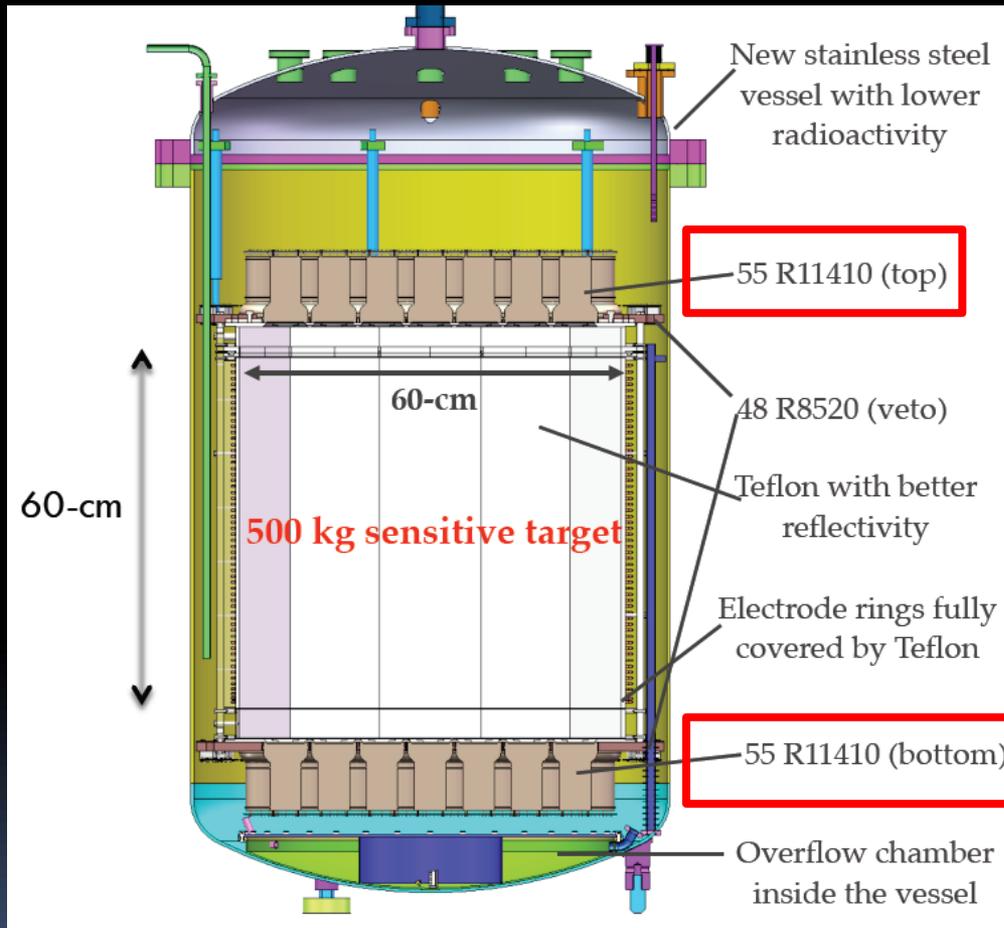
PandaX-I results

Phys. Rev. D 92, 052004(2015)



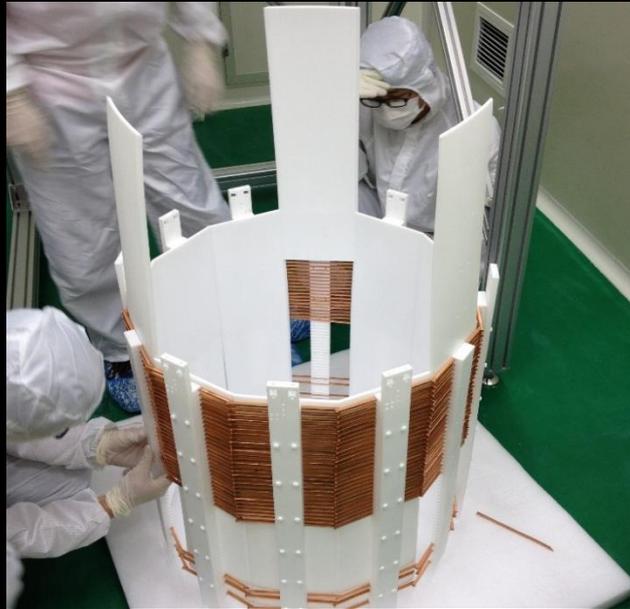
- Completed in **Oct. 2014**, with 54.0 x 80.1 kg-day exposure
- Data strongly disfavor **all** previously reported claims
- Competitive upper limit for low mass WIMP among xenon experiments

PandaX-II

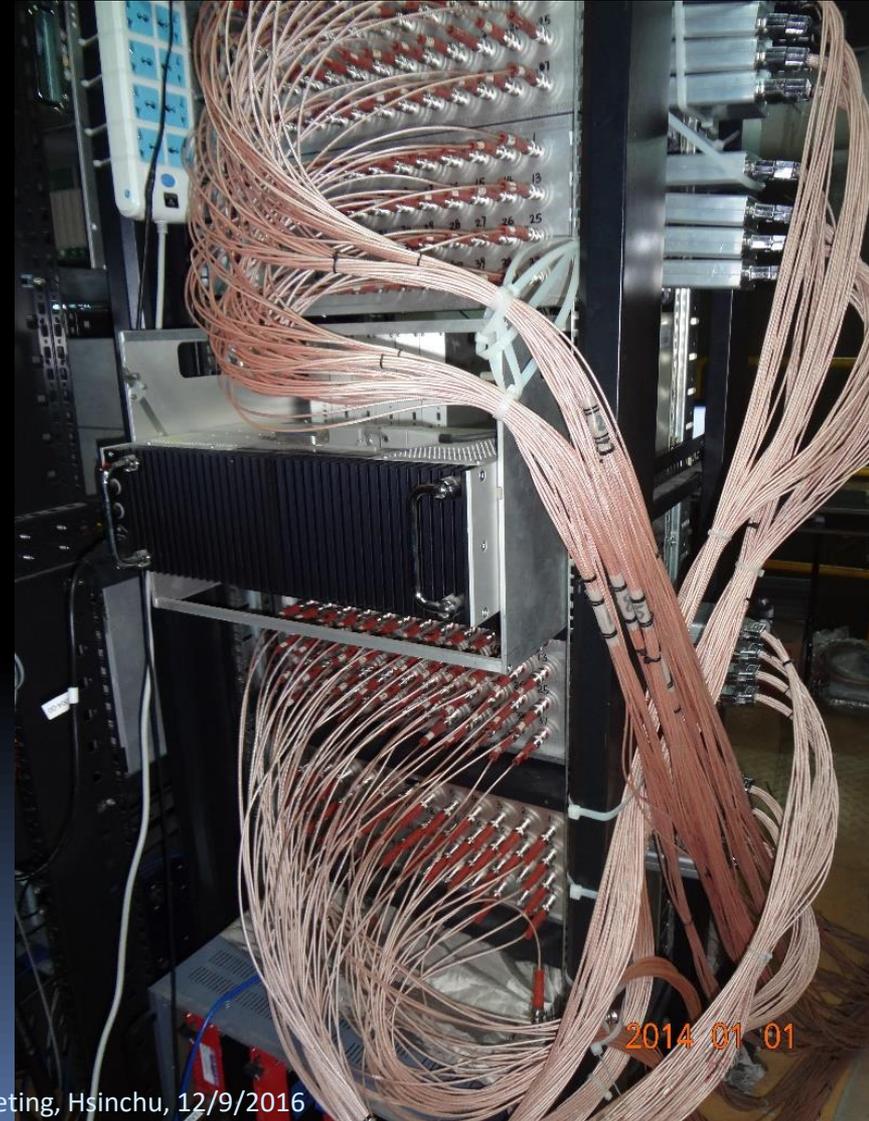
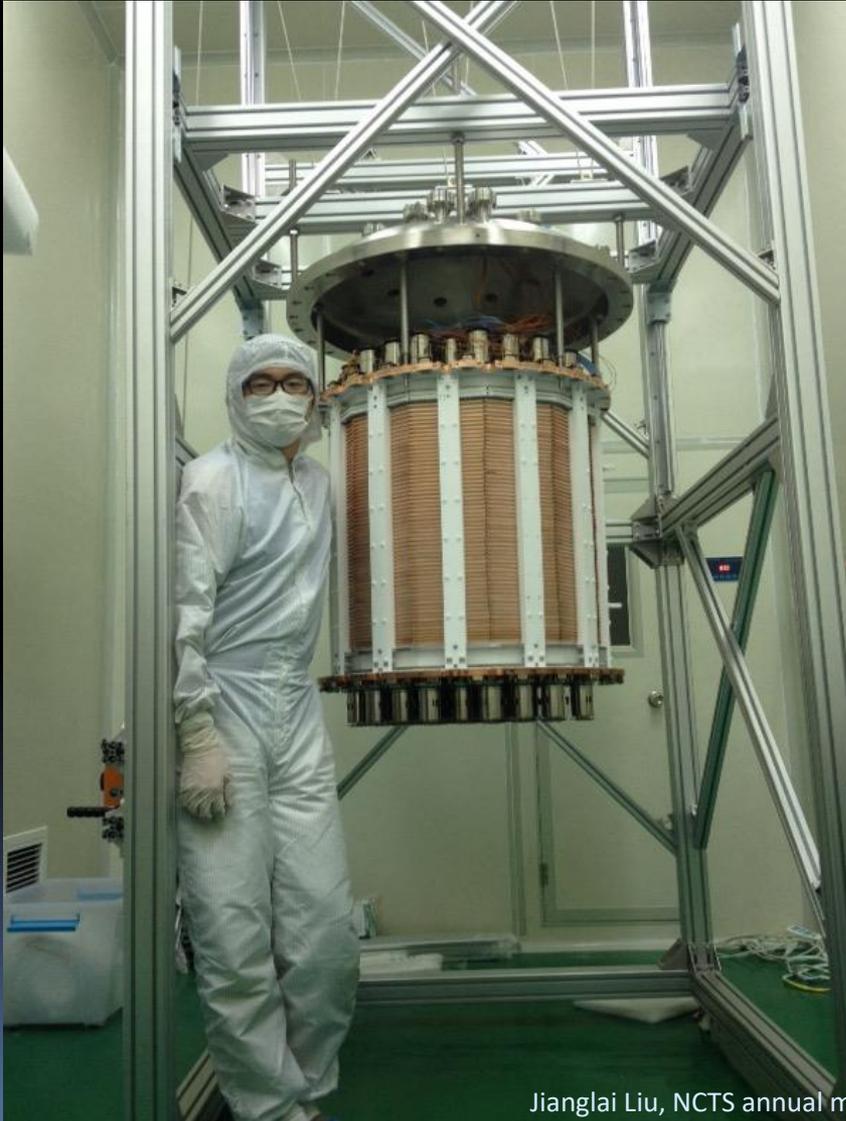


- New inner vessel with clean SS
- New and taller TPC
- More 3" PMTs and improved base design with split -ve and +ve HV
- New isolated skin veto region

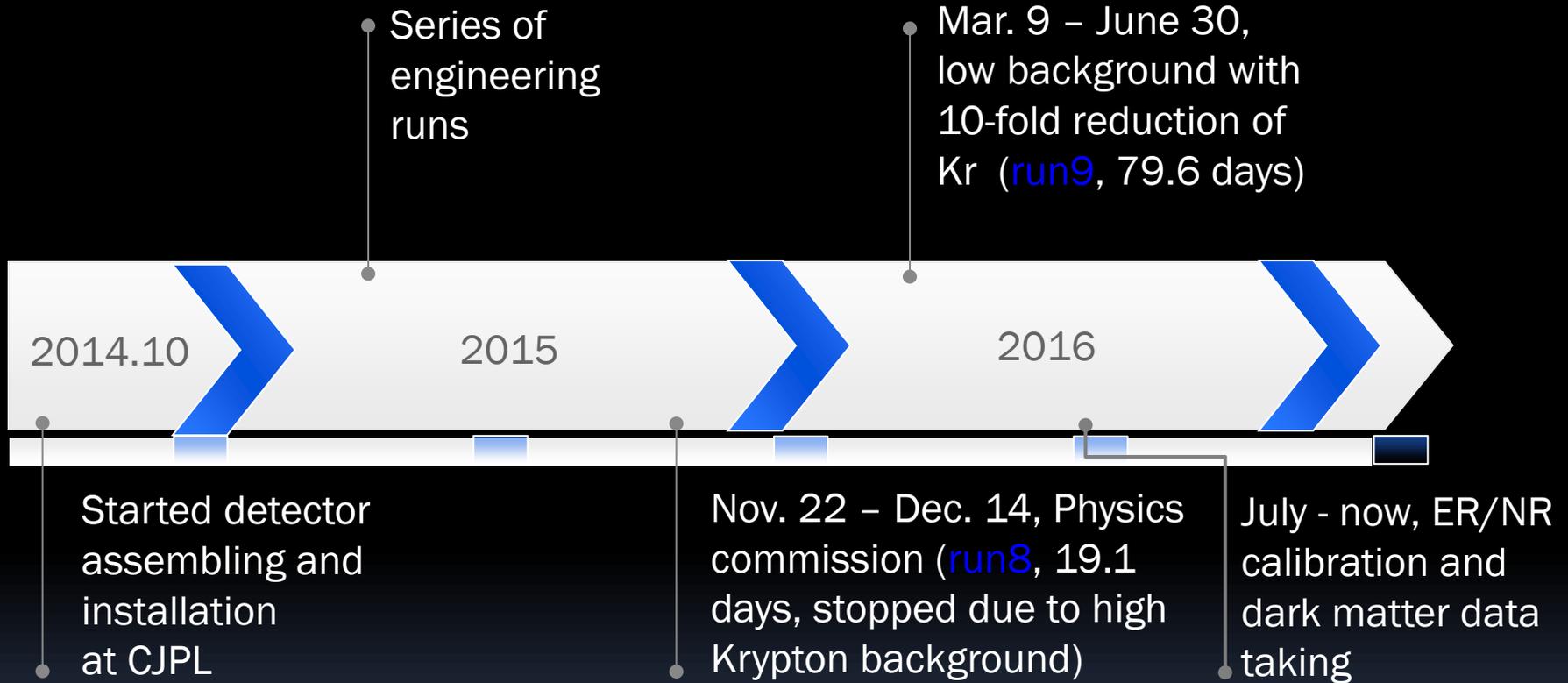
Detector construction



Putting all together



Run history



- Run8+run9=98.7 days, exposure: 3.3×10^4 kg-day
- Largest dual phase xenon experiment producing science data

Major upgrade in run 9

Items	Status in Run 9
Krypton level	Reduced by x10
Exposure	Increased x4 (79.6 vs 19.1 day)
ER calibration	Using tritium calibration
NR calibration	Statistics x6
Analysis	Improved position reconstruction
Background	Accidental background suppressed more than x3 using BDT

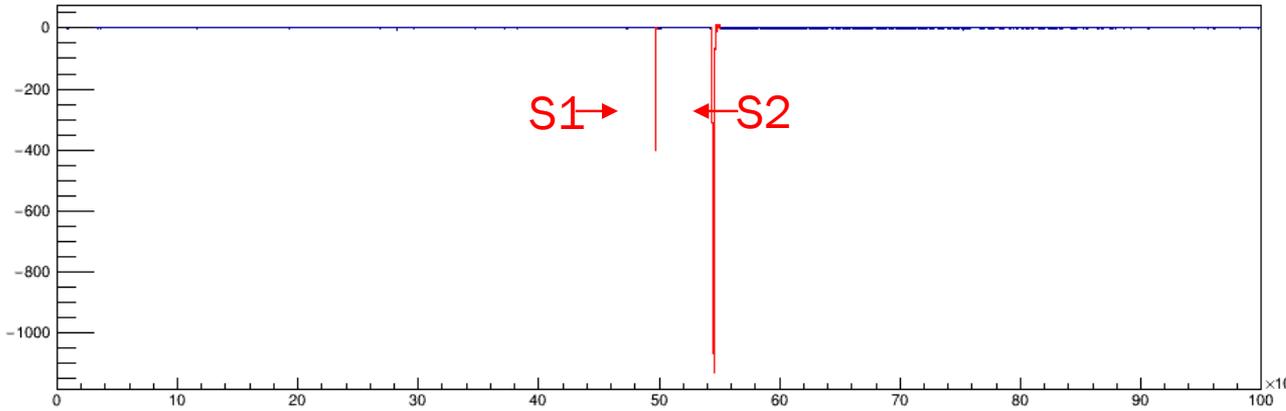
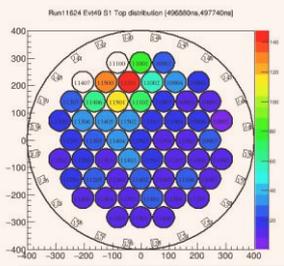
Typical single scattering event

S1

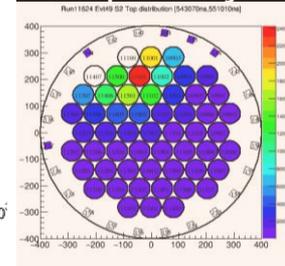
Soft Esum Waveform run 11624, event 49, Bottom Array

S2

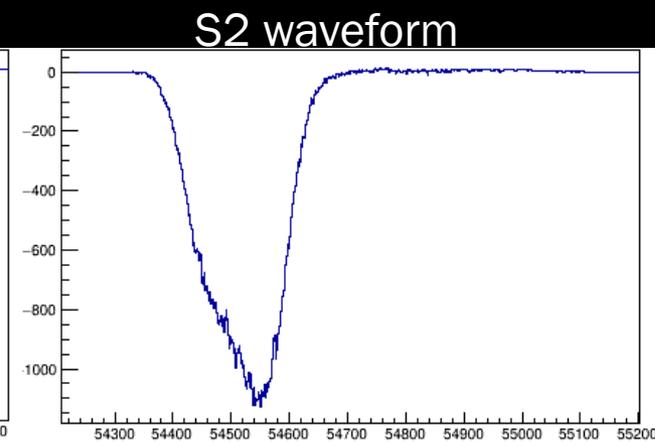
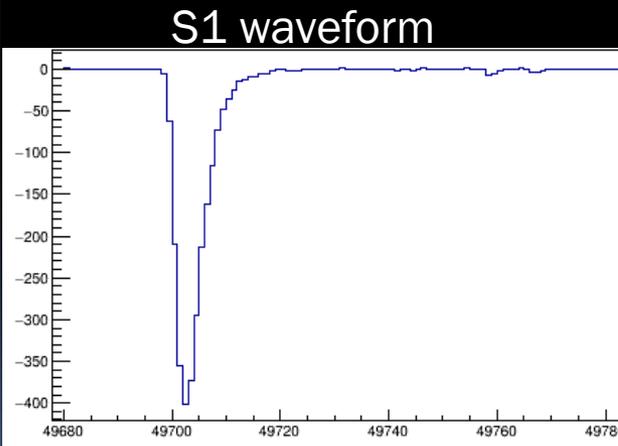
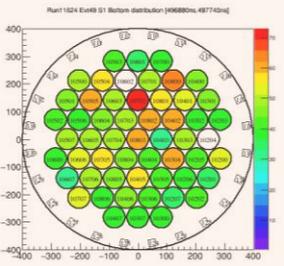
Top Array



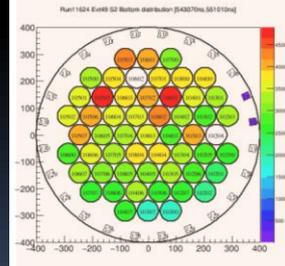
Top Array



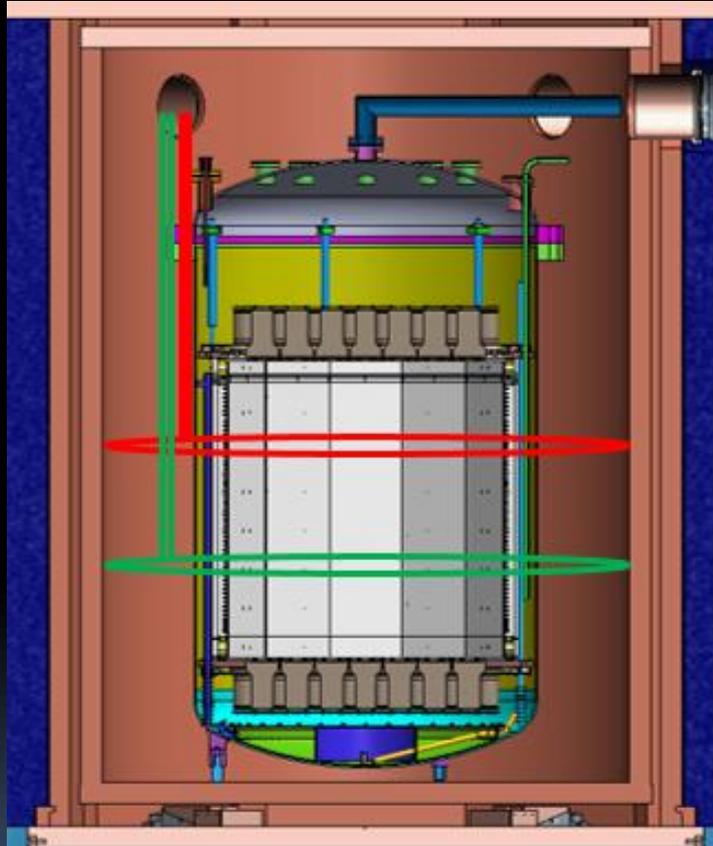
Bottom Array



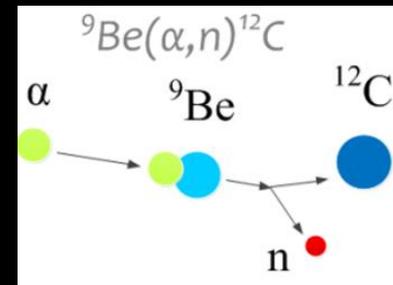
Bottom Array



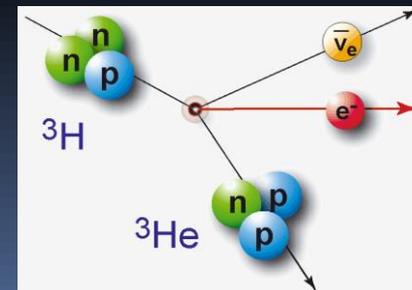
Extensive calibration program



- Low rate AmBe neutron source
⇒ Simulate DM NR signal

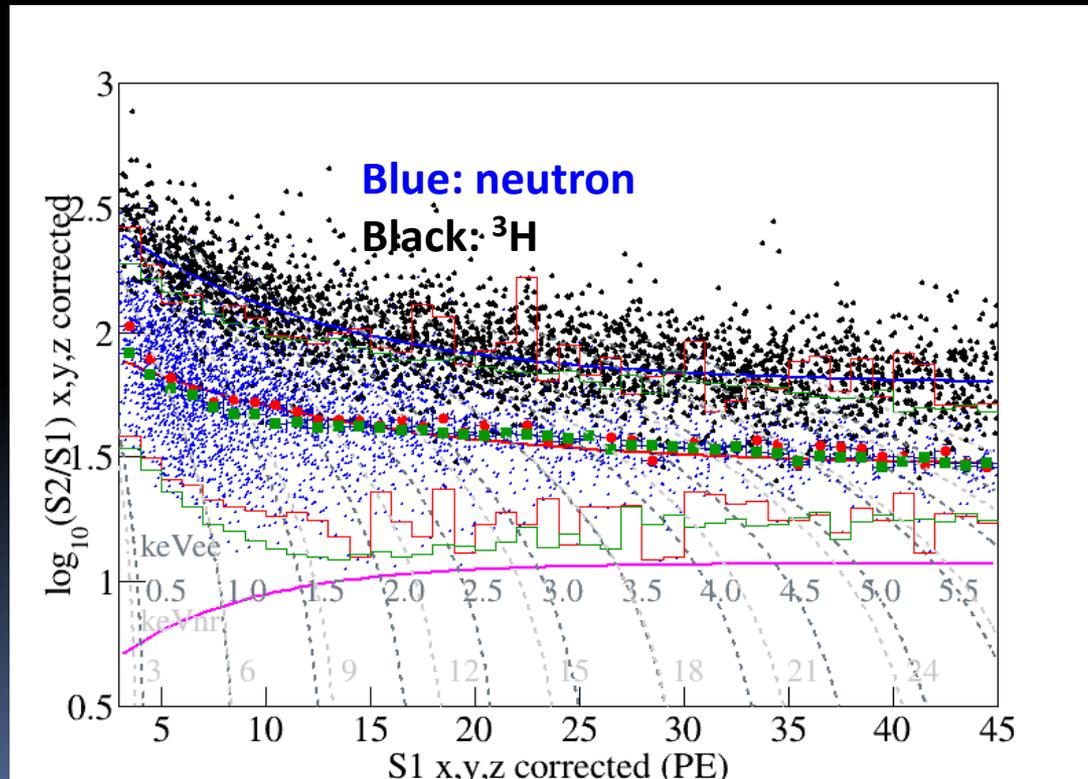


- CH_3T injection: tritium beta decays
⇒ Simulate ER background

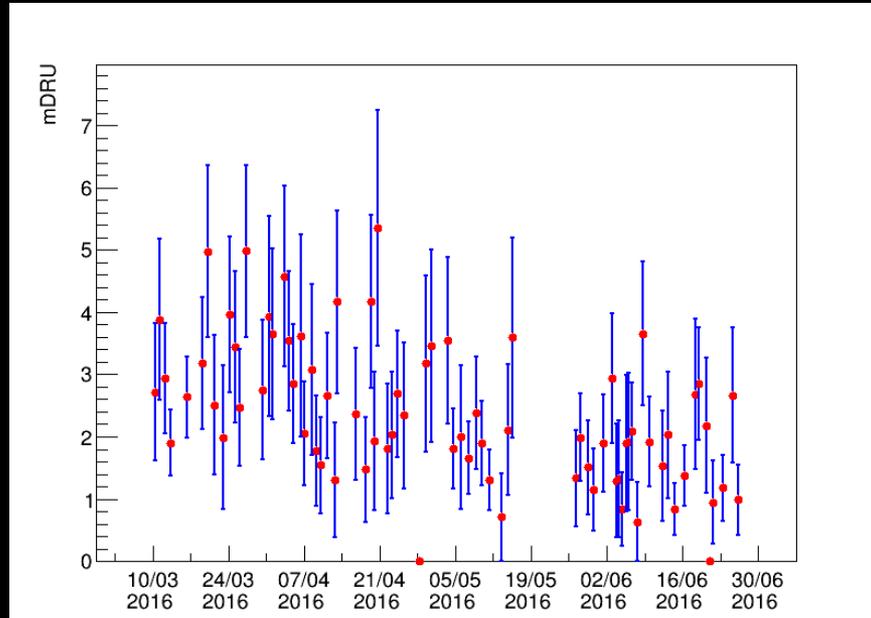


ER/NR separation

- Separating electron-recoil background from nuclear recoil signal by using known sources



Low energy rate in run 9



- Events selected in the FV with energy $<10 \text{ keV}_{ee}$
- ~ 2 mDRU in the FV on average, **world lowest reported background level.**
- Decrease over time due to ^{127}Xe decay

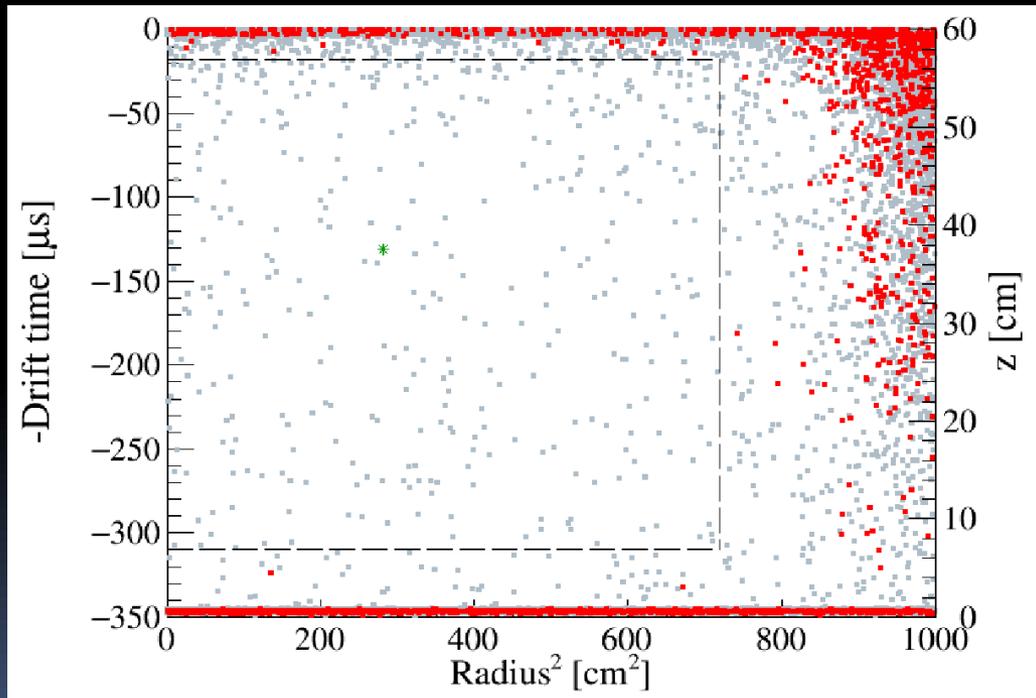
Item	Run 8 (mDRU)	Run 9 (mDRU)
^{85}Kr	11.7	1.19
^{127}Xe	0	0.42
^{222}Rn	0.06	0.13
^{220}Rn	0.02	0.01
Detector material ER	0.20	0.20
Total	12.0	1.95

Final candidates (run 9)

Gray: all

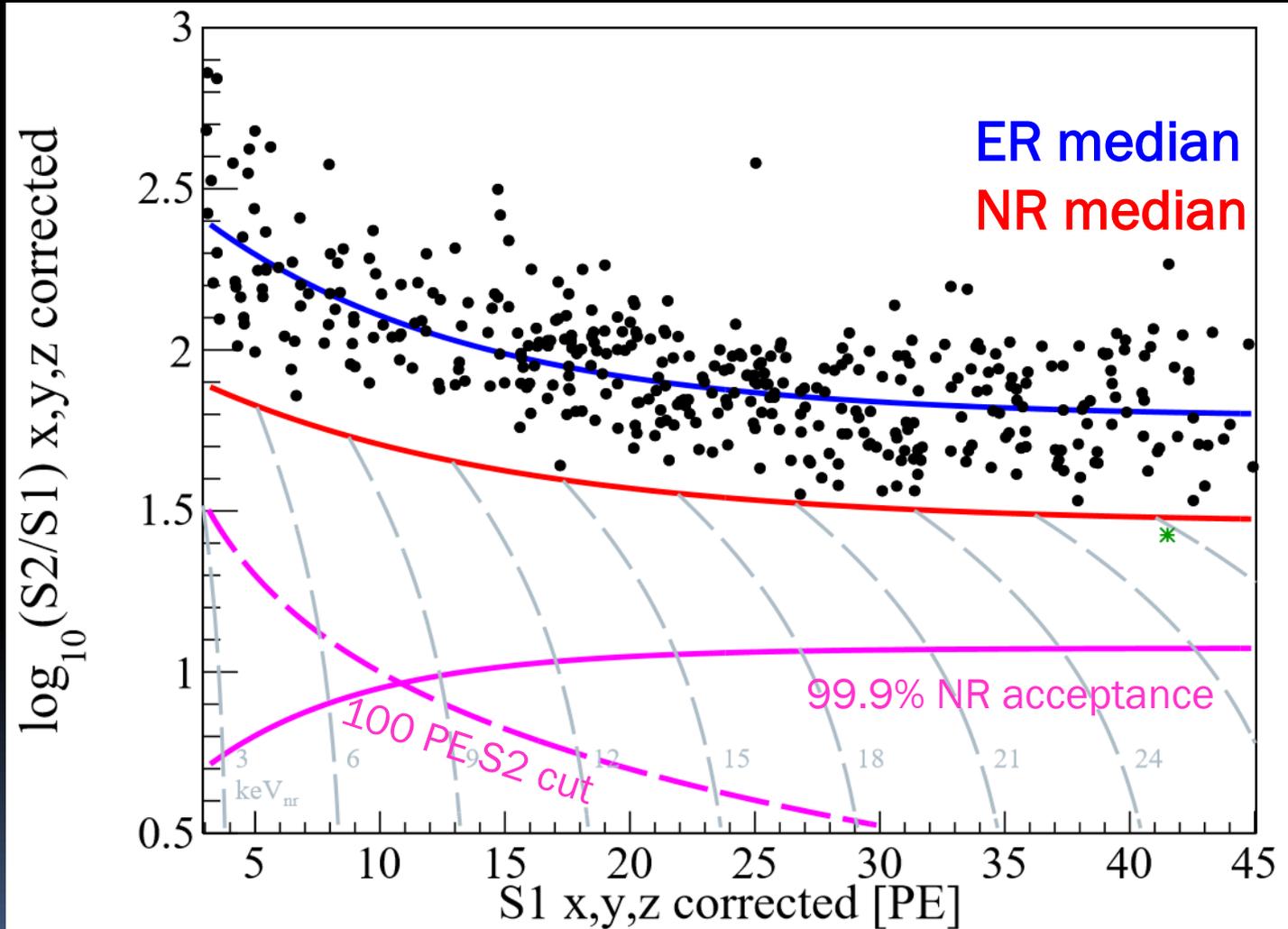
Red: below NR median

Green: below NR median and in FV

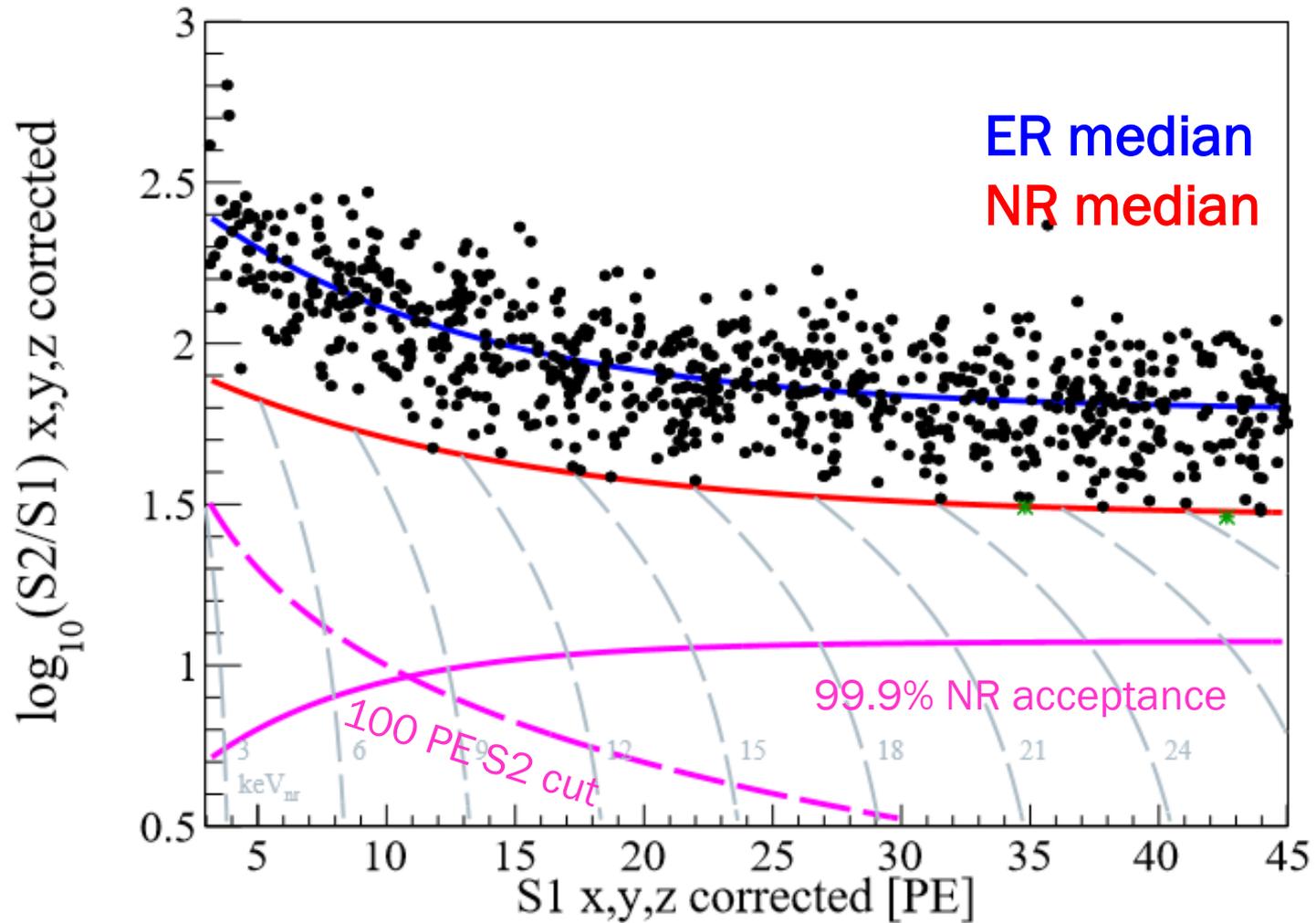


- 389 total candidates found in the FV (329 kg)
- 1 below NR median
- Outside FV, edge events more likely to lose electrons, leading to S2 suppression

Final candidates (run 9)



Final candidate (run 8)



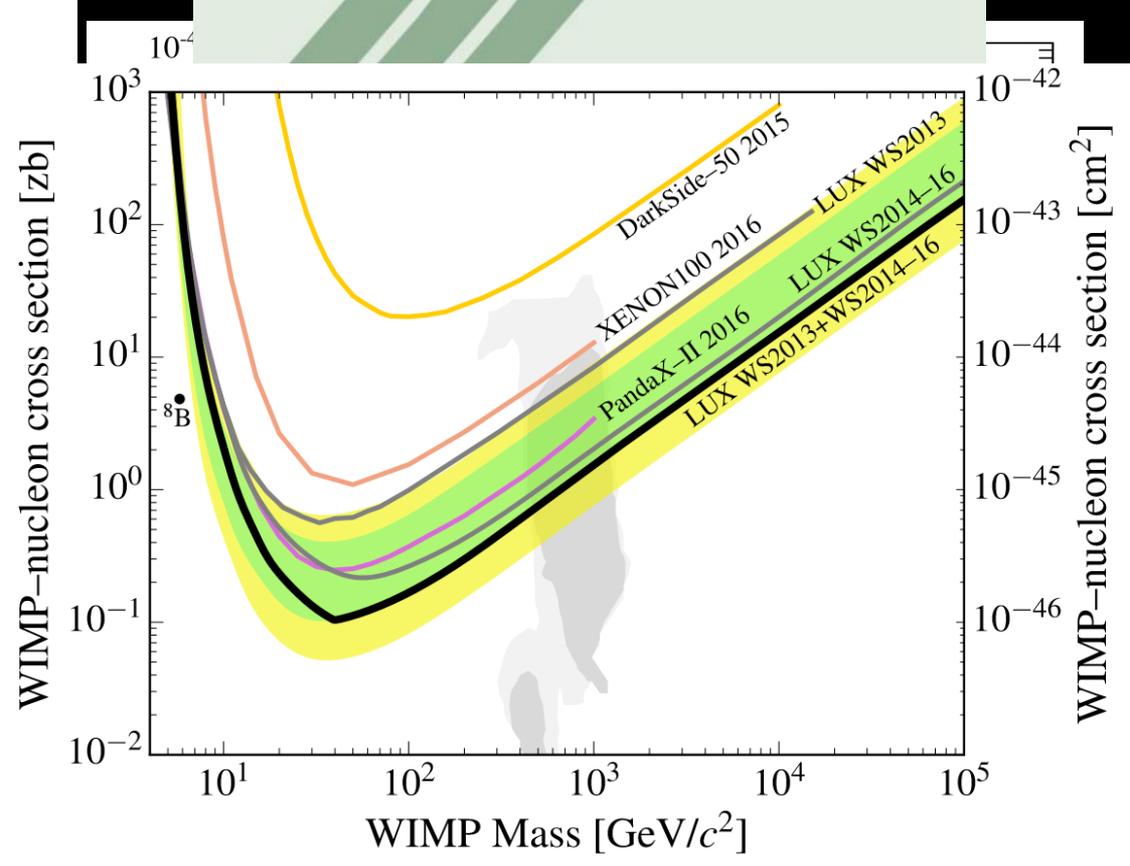
Summary of final candidates

	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

Combined exposure: 33000 kg-day

Spin-independent cross section limit

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



- Minimum exclusion: $2.5 \times 10^{-46} \text{ cm}^2$ @ 40 GeV/c^2 , improved x10 from run 8, >x2 from LUX 2015
- LUX 95+332 day results had a limit at $1.1 \times 10^{-46} \text{ cm}^2$ @ 50 GeV/c^2 , not published yet
- This is the **first** low background result from PandaX-II, a long life (~500 live-day) ahead of this!

2016

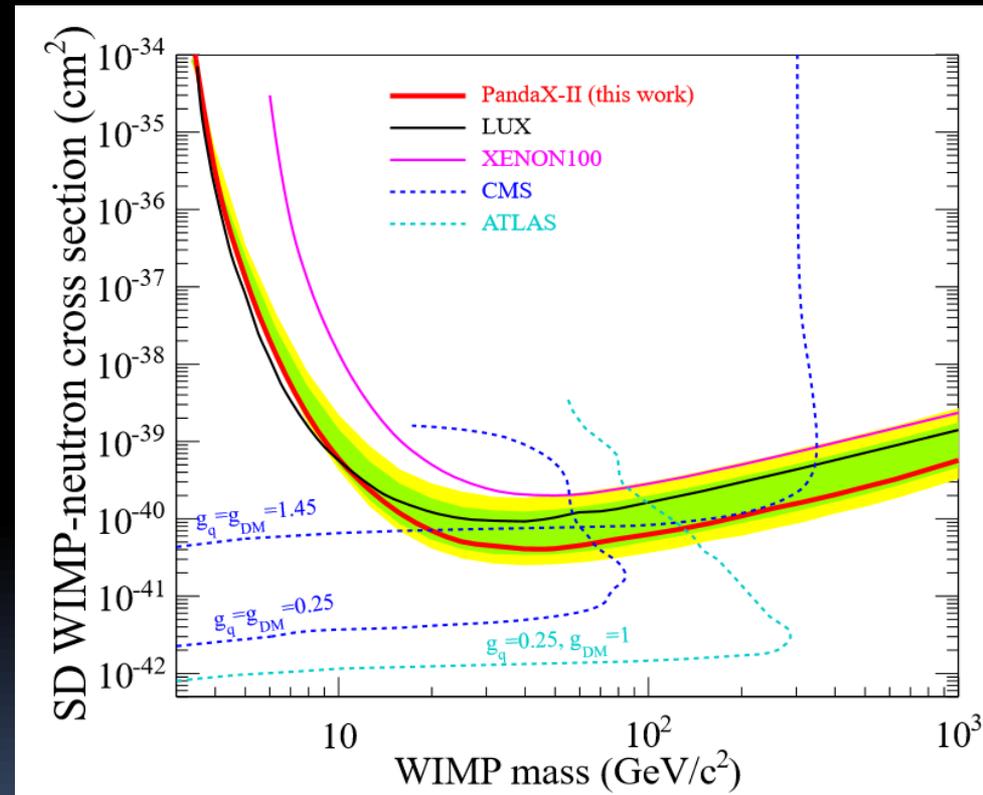
American Physical Society



Volume 117, Number 12

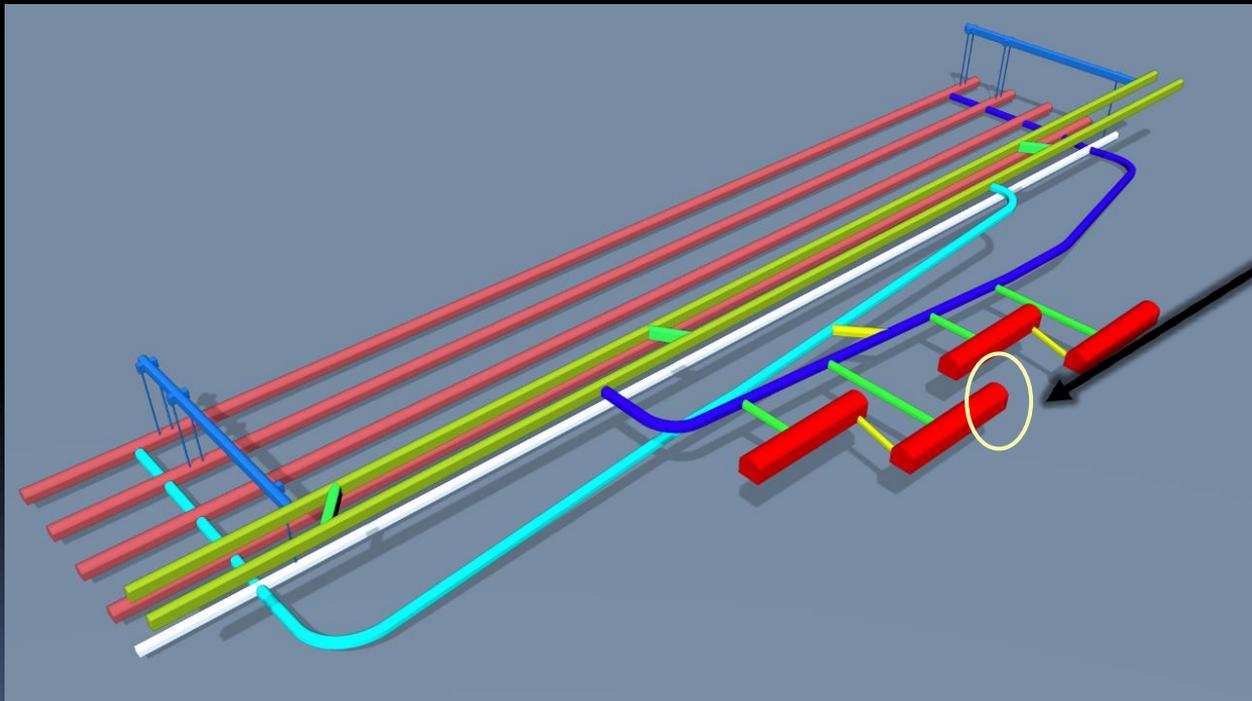
Spin-dependent limit

- ^{131}Xe and ^{129}Xe has unpaired neutrons (non-zero spins)
- WIMP could have spin, and could interact with nuclear spin via axial coupling
- arXiv:1611.06553, world best SD-neutron limit from direct detection



PandaX new home: CJPL-II

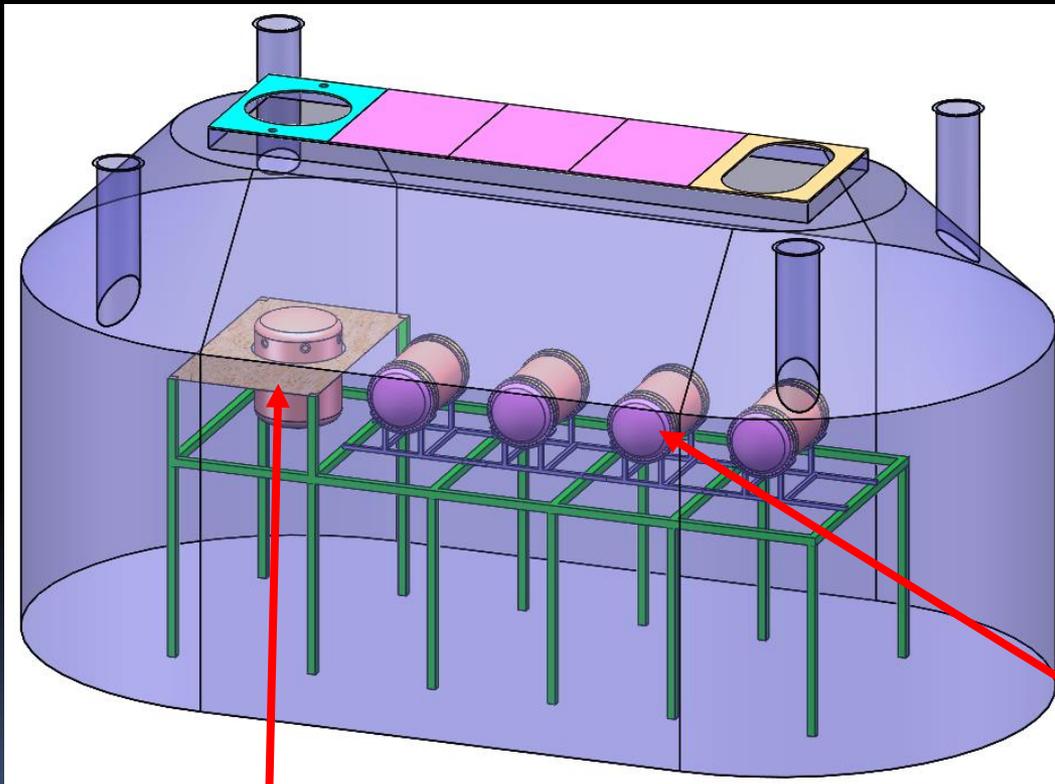
8 experimental Halls, 14(H)x 14(W)x65(L) m each.



B4, PandaX site!

PandaX in CJPL-II

A large experimental infrastructure to host multiple dark matter and double beta detectors



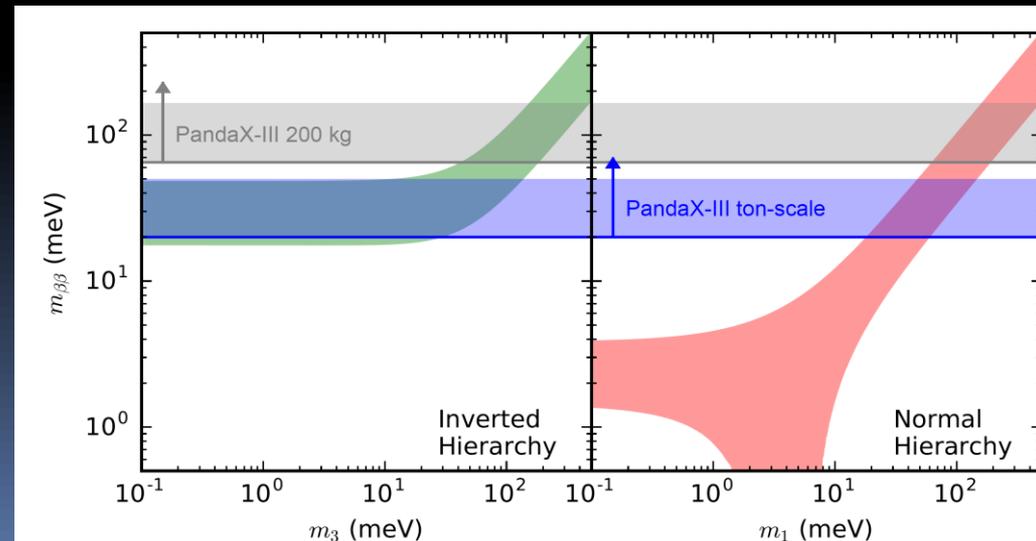
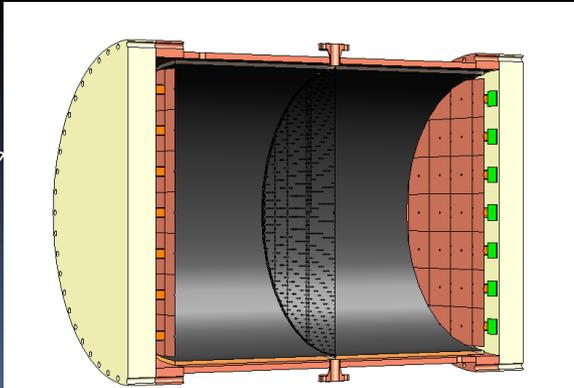
To achieve an extremely low background environment, use ultrapure water contained in a large SS water tank with 25(l)x13(w)x13(h), 3400 ton capacity

3-40 ton LXe DM experiment

HP Xe136 experiment (multiple detectors)

PandaX-III: High pressure ^{136}Xe TPC

- $0\nu\text{DBD}$ signal: two electrons emitting from the same vertex with a summed energy at the Q value (tracking essential)
- TPC: 200 kg, 10 atm, symmetric, double-ended charge readout plane with micromegas module with cathode in the middle
- Four more upgraded modules for a ton scale experiment
- Published CDR recently: [ArXiv:1610.08883](https://arxiv.org/abs/1610.08883)



Experimental hall



Summary and outlook

- Many exciting physics opportunities in PandaX at the world deepest CJPL
- PandaX-II has reached the forefront of the DM search, and will continue PandaX-II data taking till end of 2018
- The collaboration is going forward in preparation for PandaX-xT and PandaX-III!
- We love to discuss with theorists where and what to look for!