上海交通大學
SHANGHAI JIAO TONG UNIVERSITY

PANDA X

Recent Progress and Plan of PandaX Experiment

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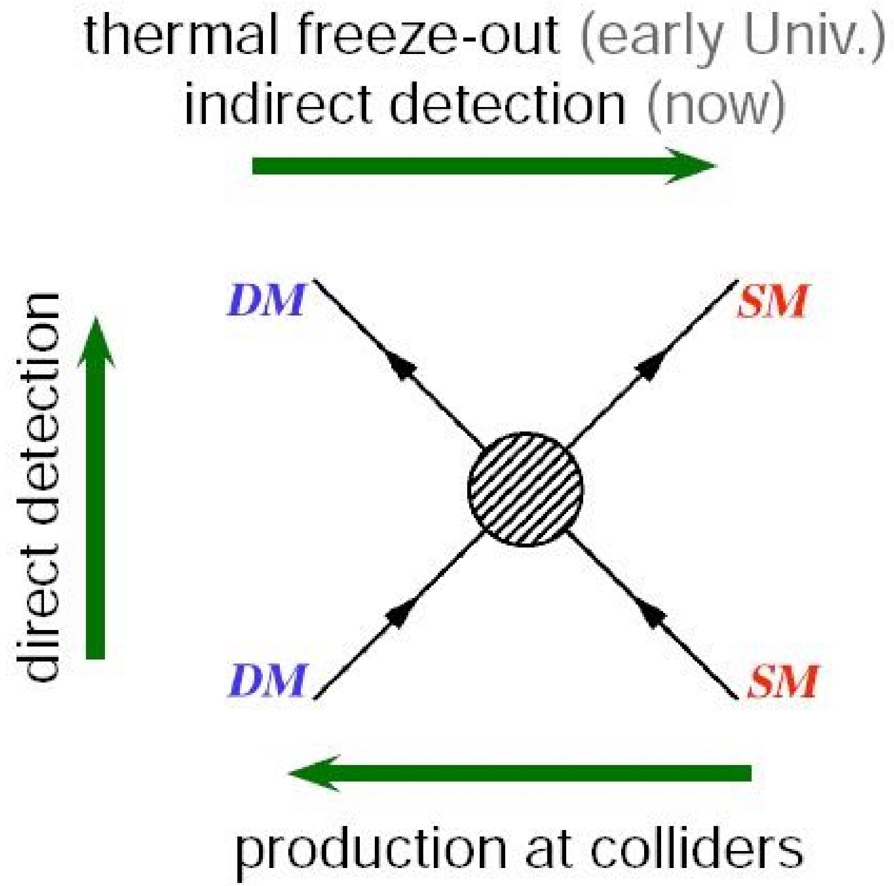
Shanghai Jiao Tong University

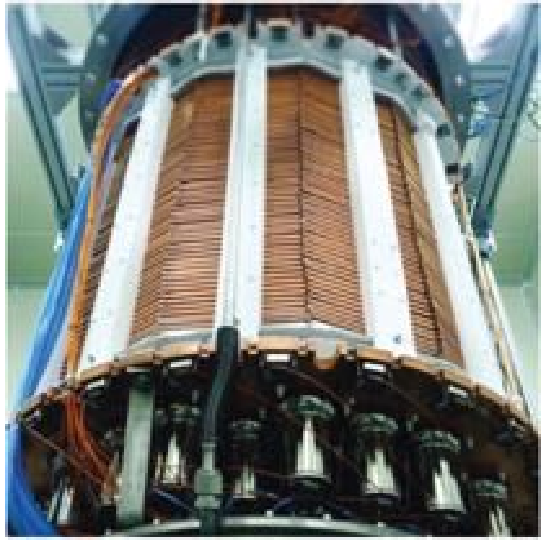
2021-08-26

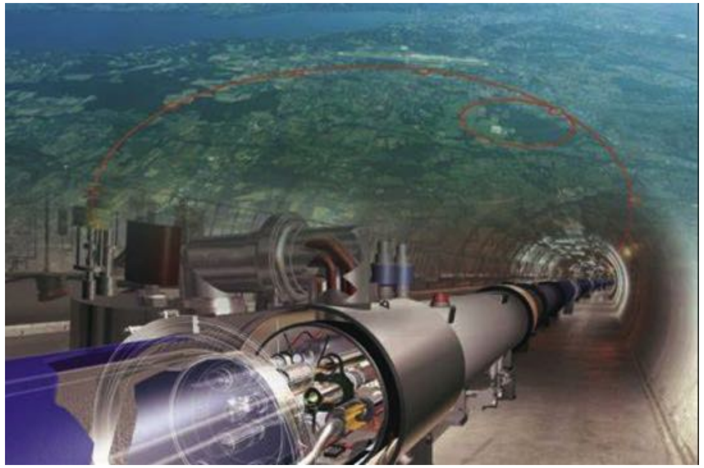
SUSY 2021

Dark matter searches

- Direct detection, indirect detection, collider search

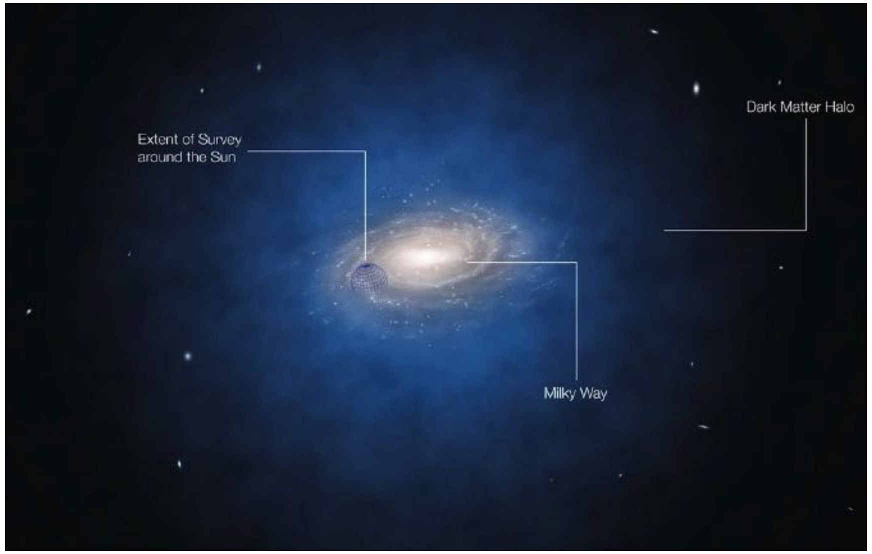




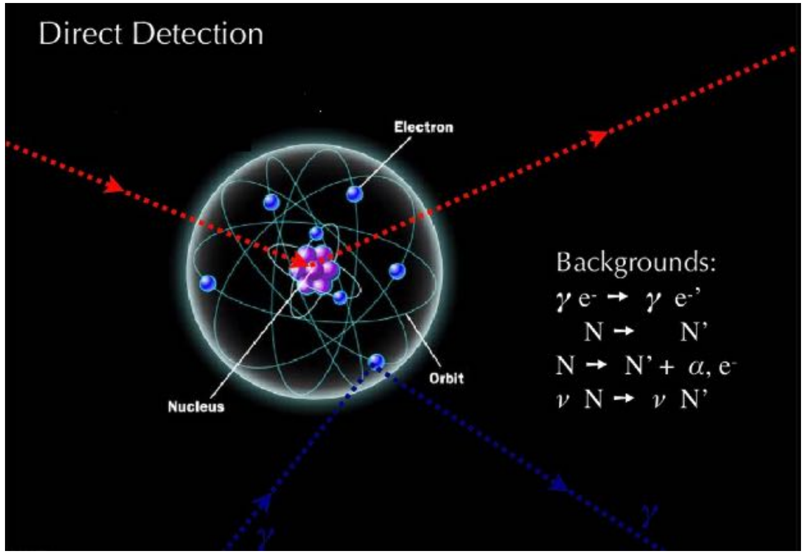


Dark matter direct detection

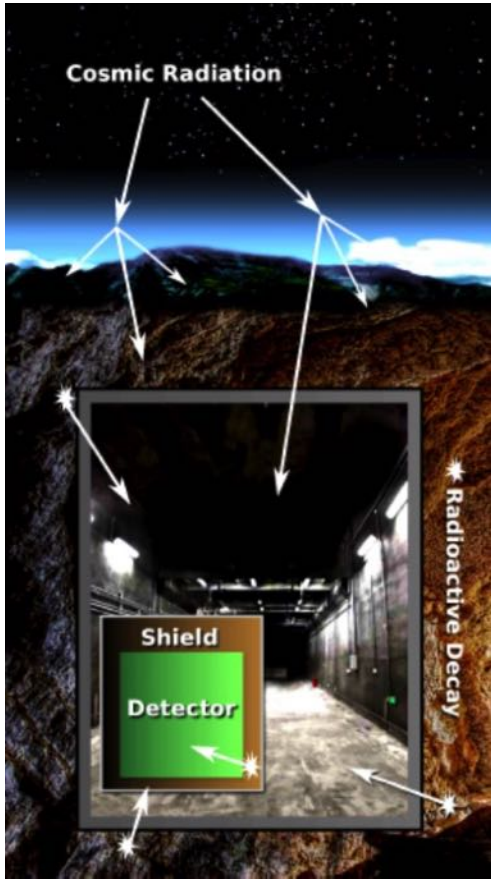
- Solar system in the dark matter halo
- Detection of incoming dark matter scattering off target atom
  - Nuclear recoil (NR) signature
  - Electronic recoil (ER) signature
  - Small and rare signals: underground laboratory



ESO / L. Calçada.



DARK MATTER OVERVIEW: COLLIDER, DIRECT AND INDIRECT DETECTION SEARCHES - QUEIROZ, FARINALDO S. ARXIV:1605.08788

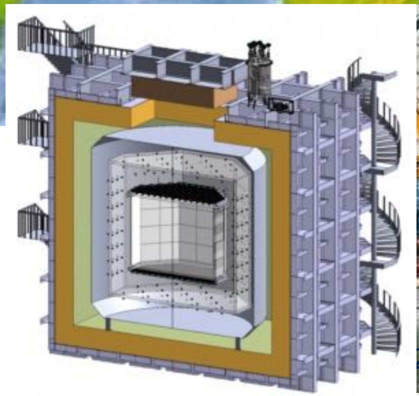


Global efforts

- Multi-tonne scale direct detection experiments

LZ, 7t LXe,
Sanford Lab, US

PandaX-4T, 4t LXe
CJPL, China

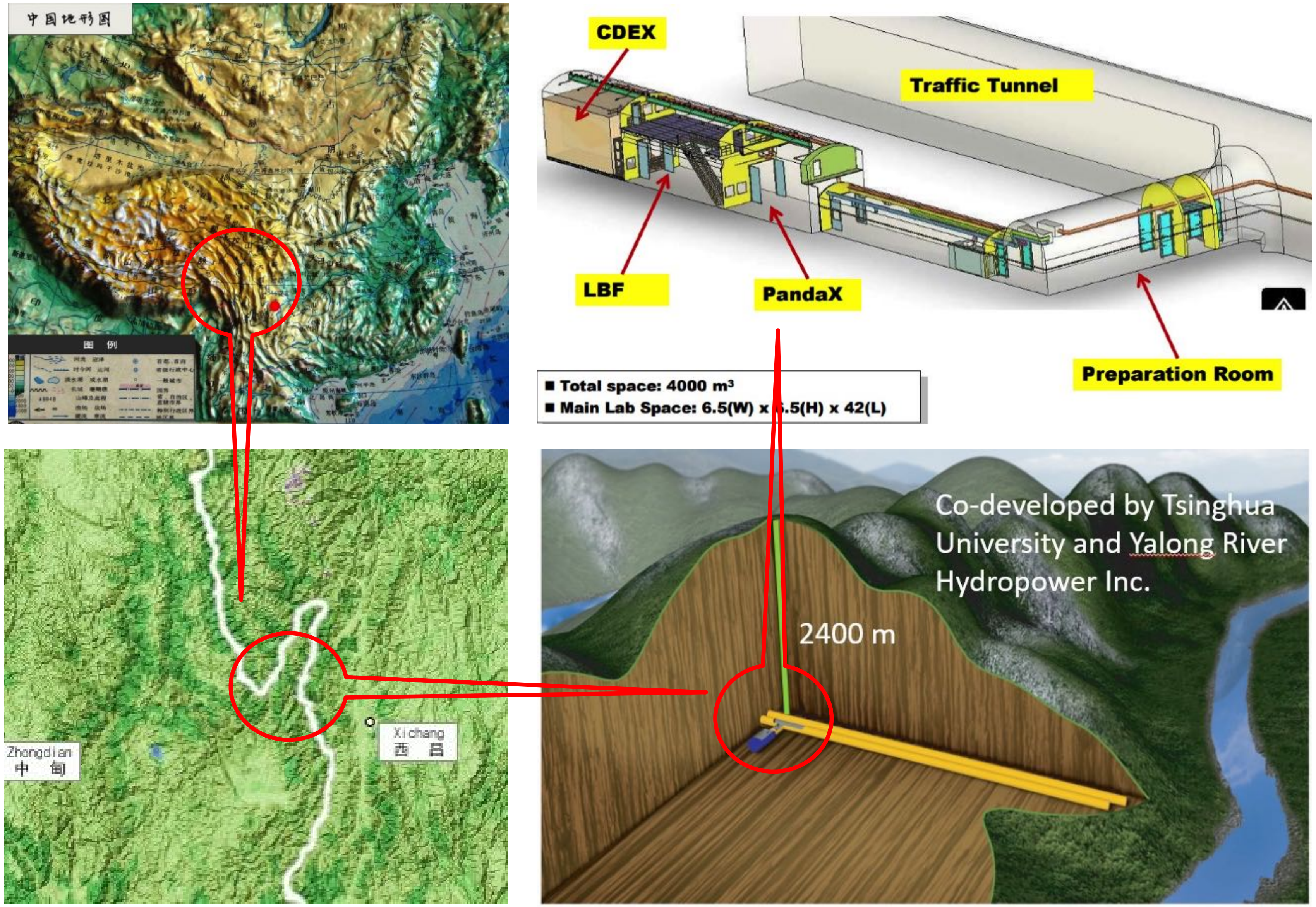


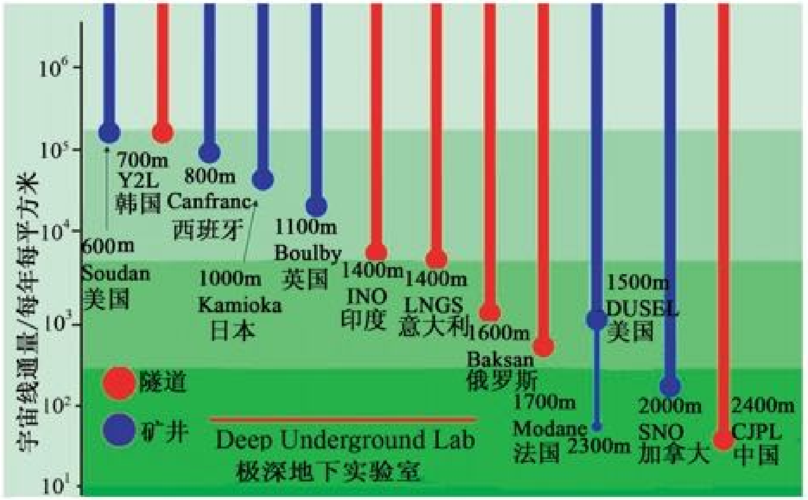
Darkside-20k, 23t LAr
LNGS, Italy

XENONnT, 6t LXe
LNGS, Italy

China Jinping Underground Laboratory (CJPL)

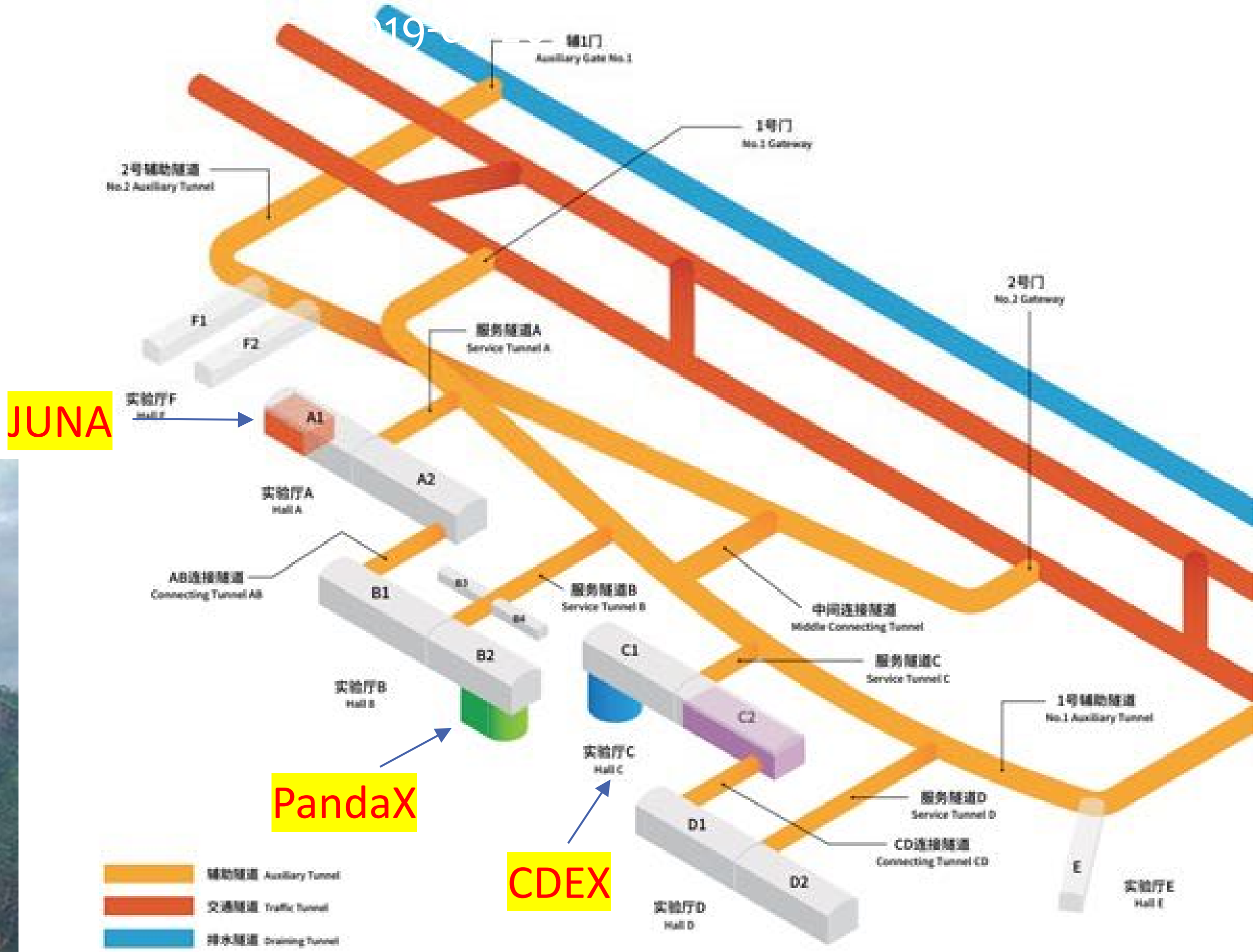
- Deepest
  - 6800 m.w.e.
  - < 0.2 muons/m^2/day
- Horizontal access
  - 9 km long tunnel





CJPL-II

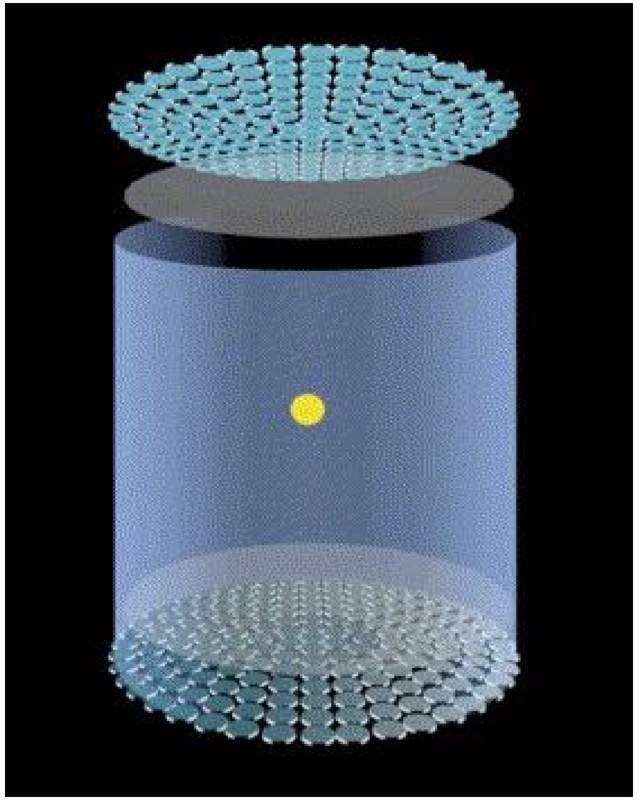
- 8 new experiment halls
  - L: 65m
  - H: 14m
  - W: 14m

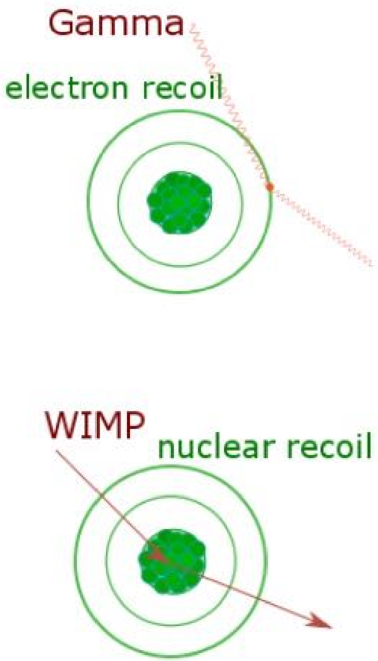


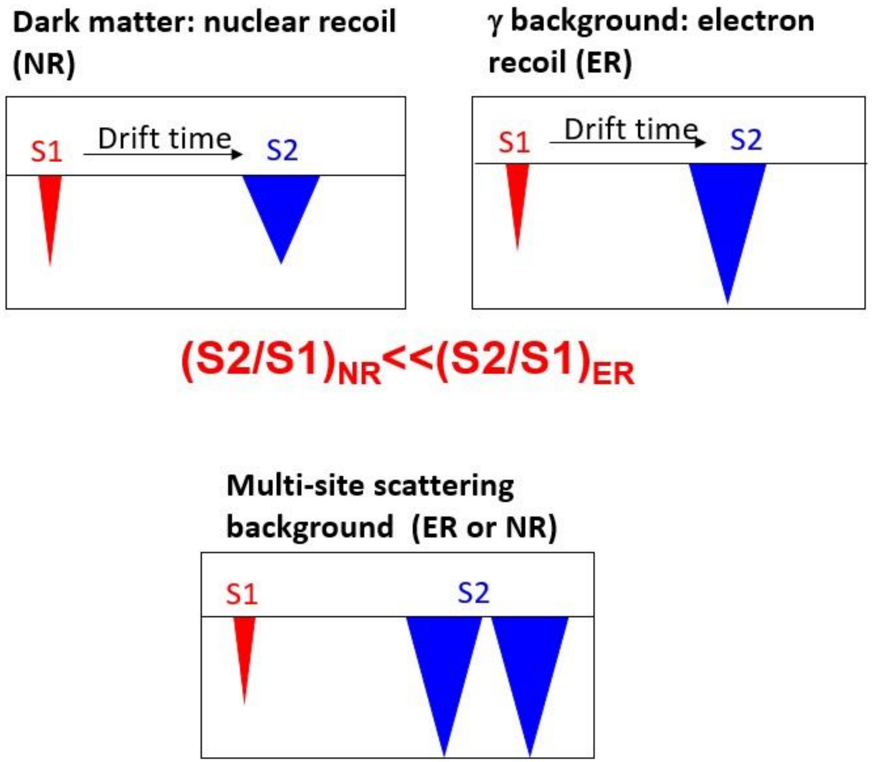
PandaX collaboration

PandaX experiment

- Dual-phase Xenon TPC
  - Large scale target, precise energy and 3D-positon reconstruction
  - Xenon self-shielding, NR and ER discrimination power







PandaX experiment

Collaboration formed

2009.3

2012.7

PandaX-I apparatus moved to Jinping

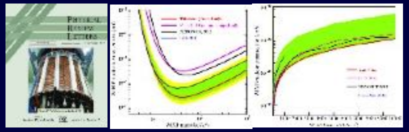
PandaX-I started

2014.3

2014.5-10

PandaX-I, 120 kg operation

PandaX-II, 580 kg operation



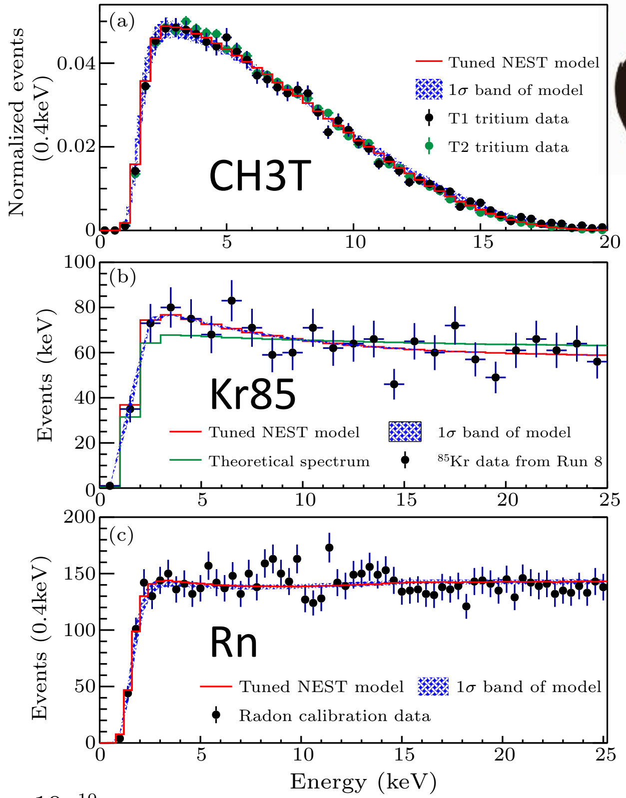
2016.7 -2019.7

2019.8-

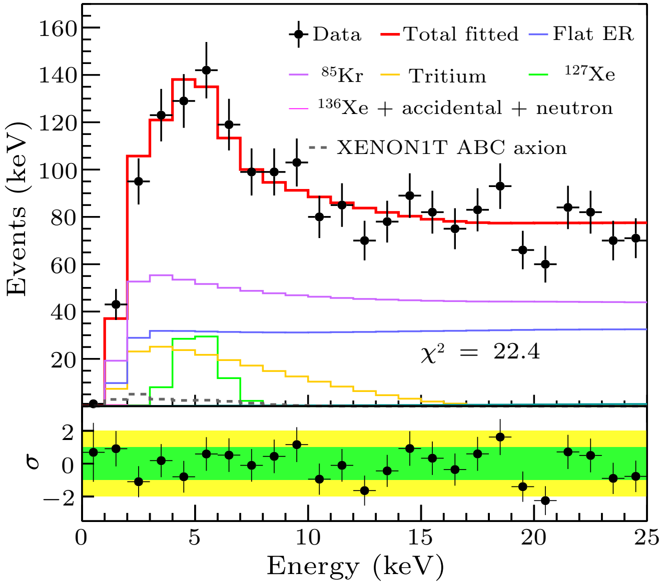
PandaX-4T moved to CJPL-II

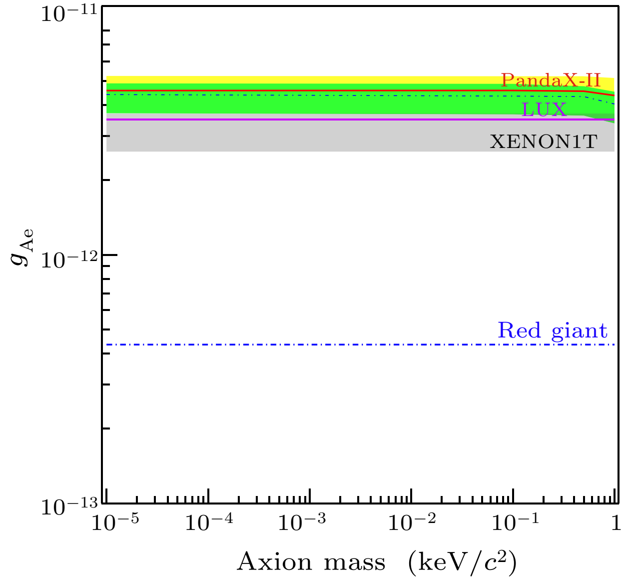
PandaX-II: electron scattering

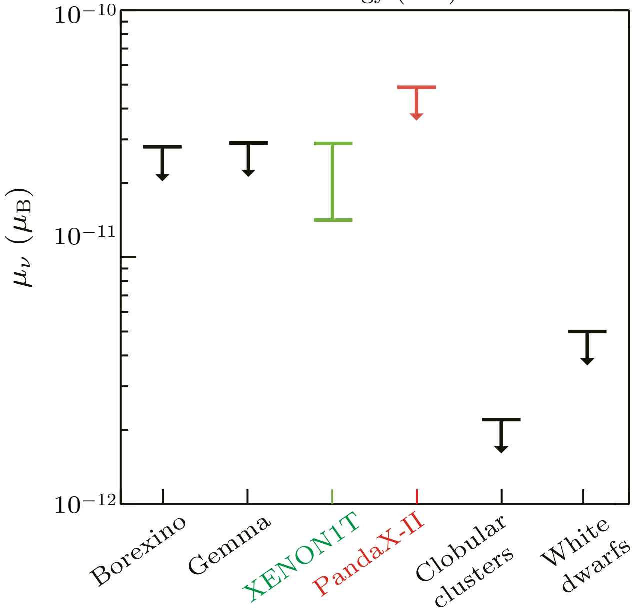
- Signal: axions, neutrino magnetic moment
- Major background spectra obtained from calibration data directly
- Independent check of XENON1T low energy ER excess



CPL Vol 38, No. 1 (2021) 011301

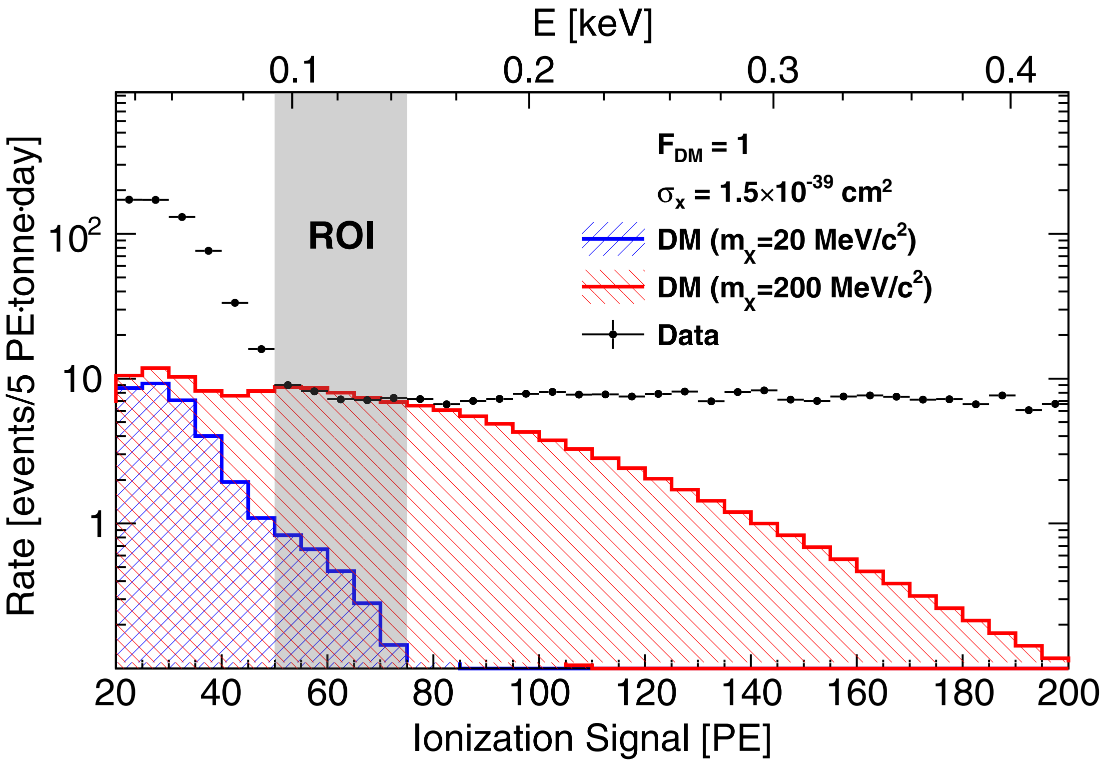




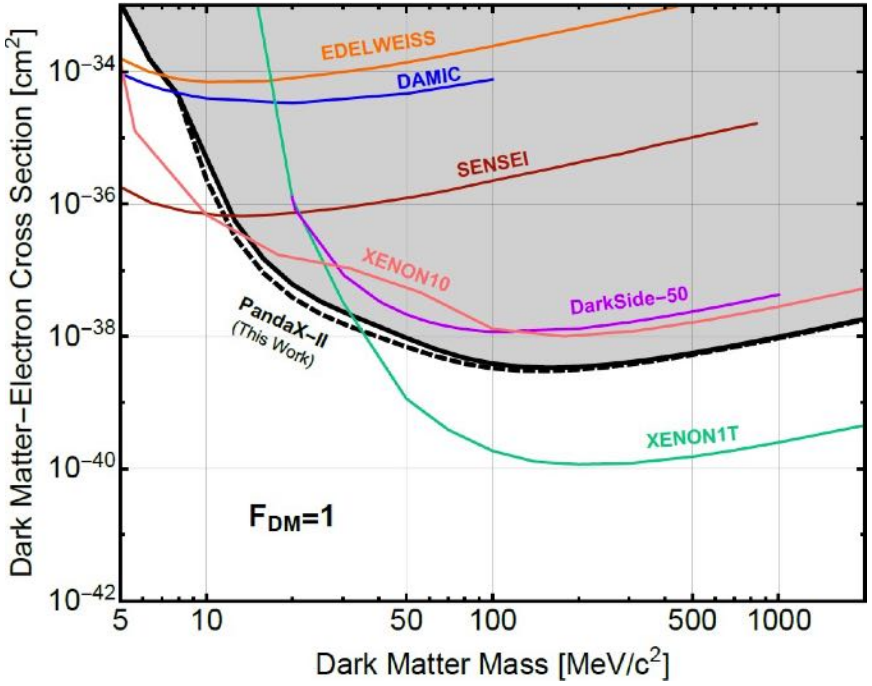


PandaX-II: WIMP-electron scattering

- light WIMP scattering with electrons
- S2-only analysis：effective threshold 80eV
- 15-30 MeV/c^2 WIMP: strongest constraints



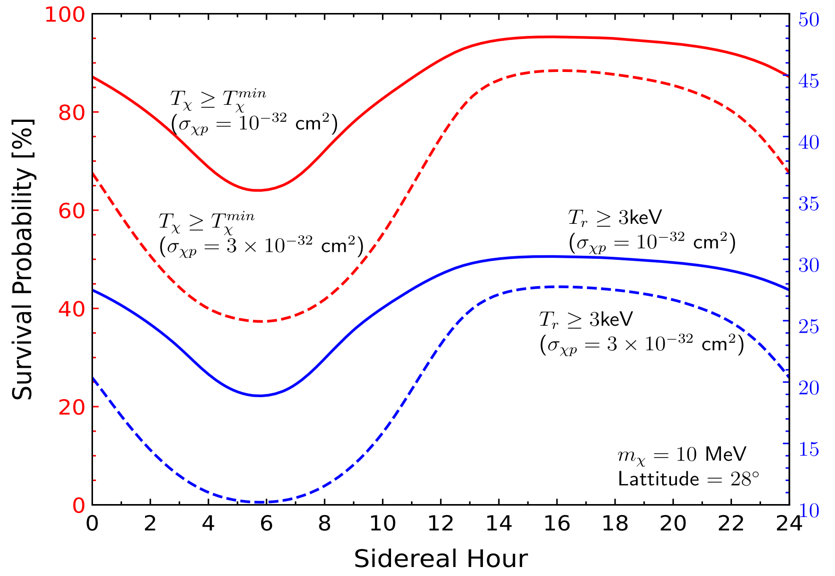
PRL 126, 211803 (2021)

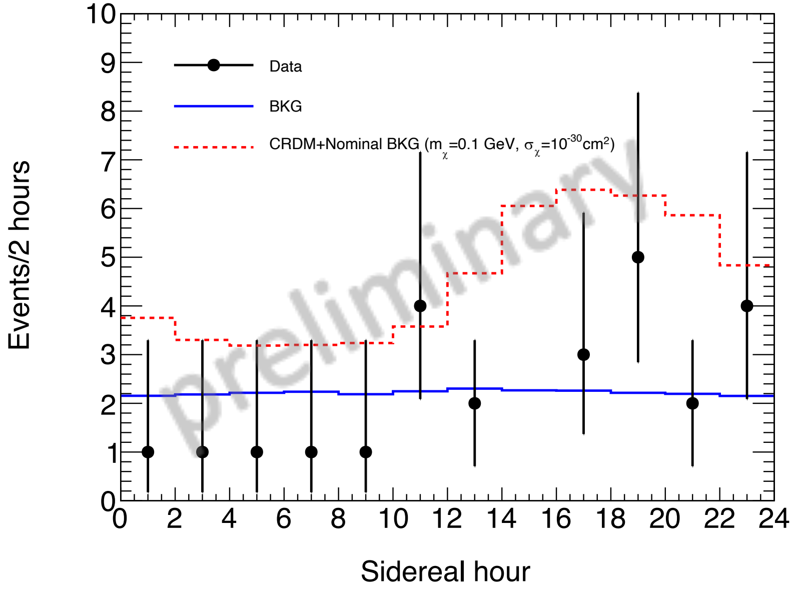


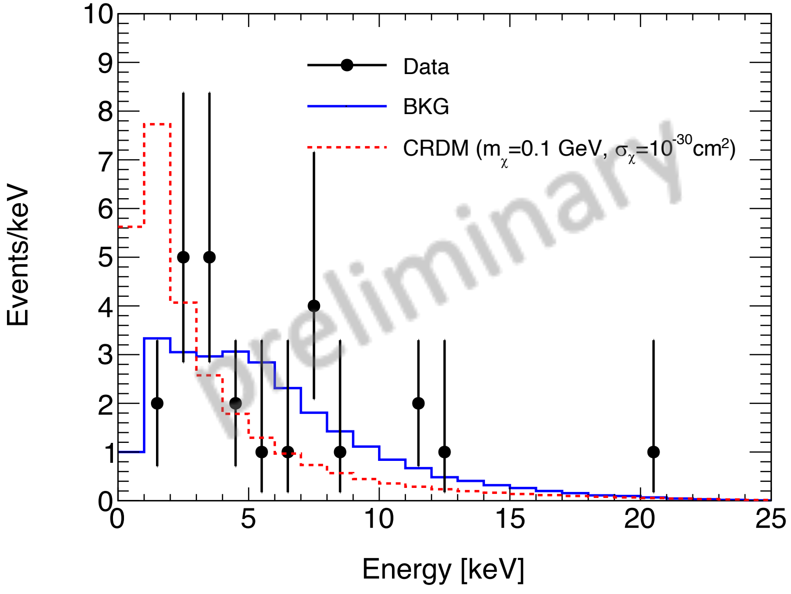
PandaX-II: cosmic ray boosted DM

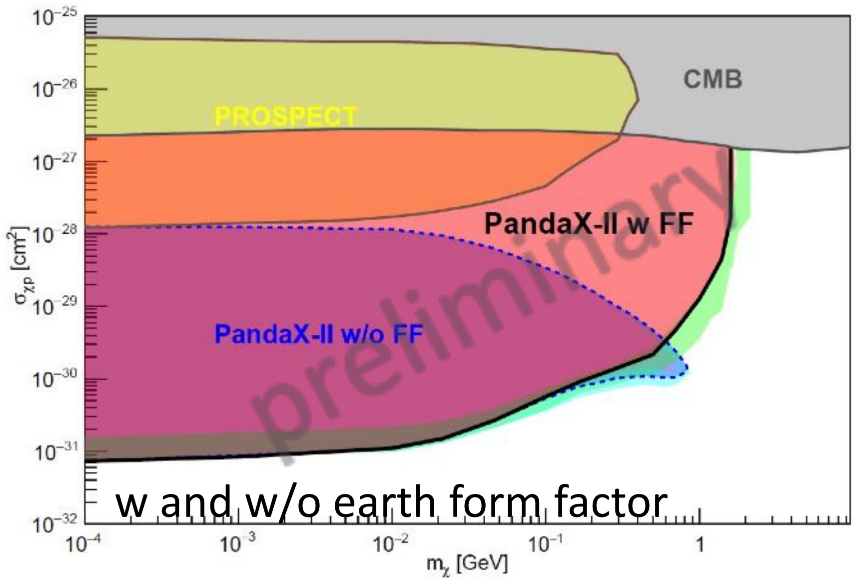
S. Ge, J. Liu, Q. Y, N. Zhou PRL 126 (2021) 9, 091804

- Light DM with cosmic ray boosting
- Signature: **diurnal modulation**
- Using events below NR median
  - 25 events (expected 26.6 background)

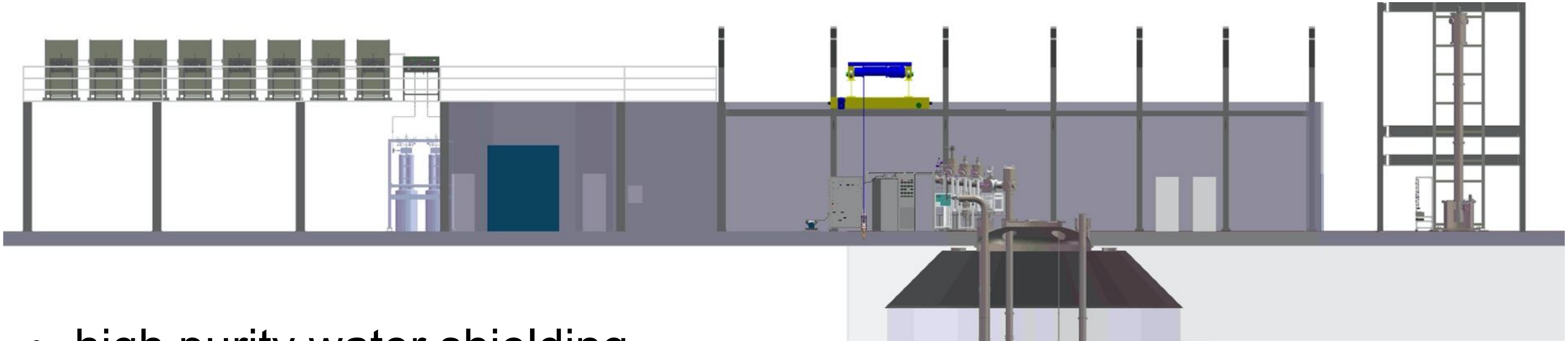


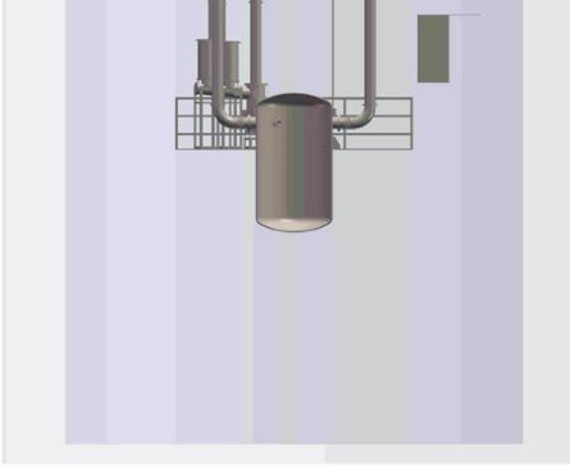




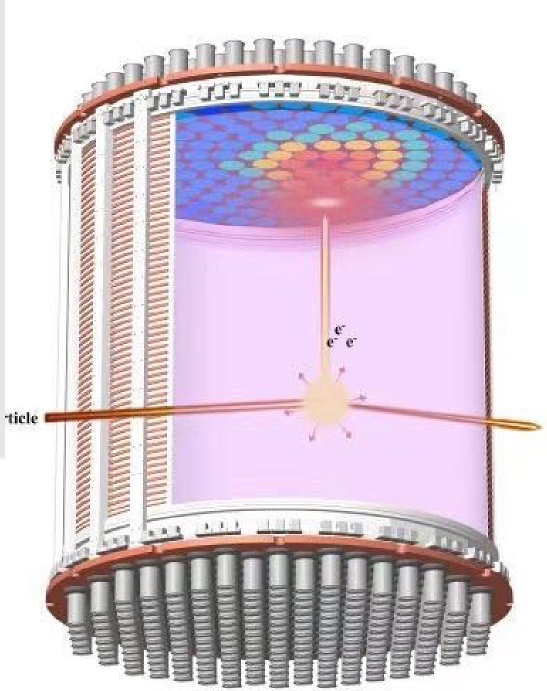


PandaX-4T @ CJPL-II





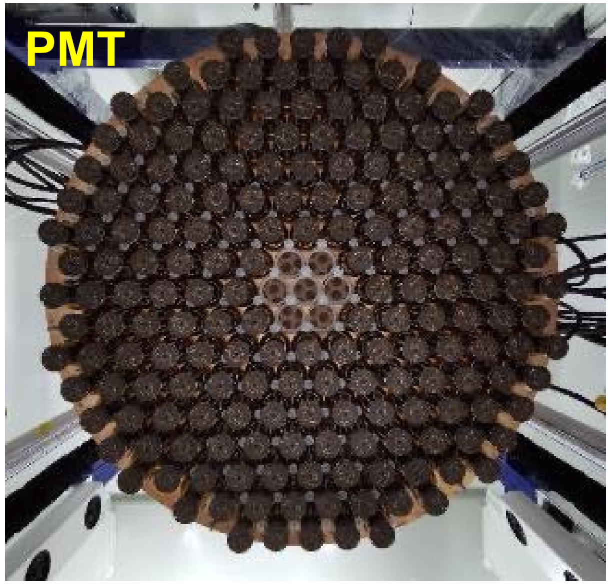
- high purity water shielding
  - 13m H x 10m D ~ 900 m^3
- Sensitive volume: 3.7-tonne LXe
  - 1.2m H x 1.2m D
- 3-inch PMTs: 169 top / 199 bottom

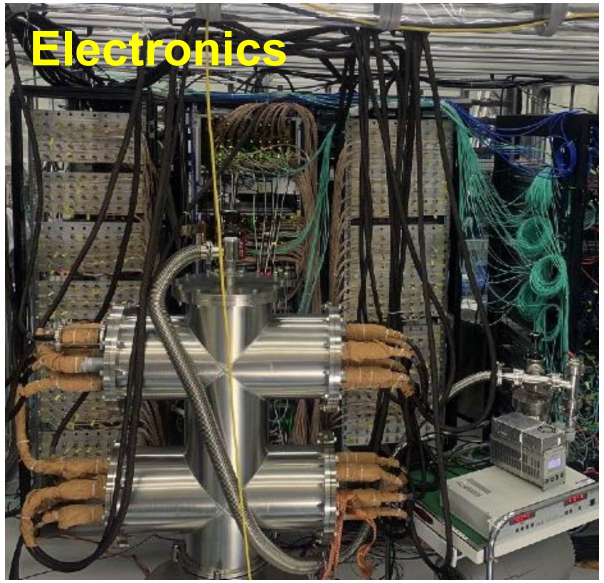


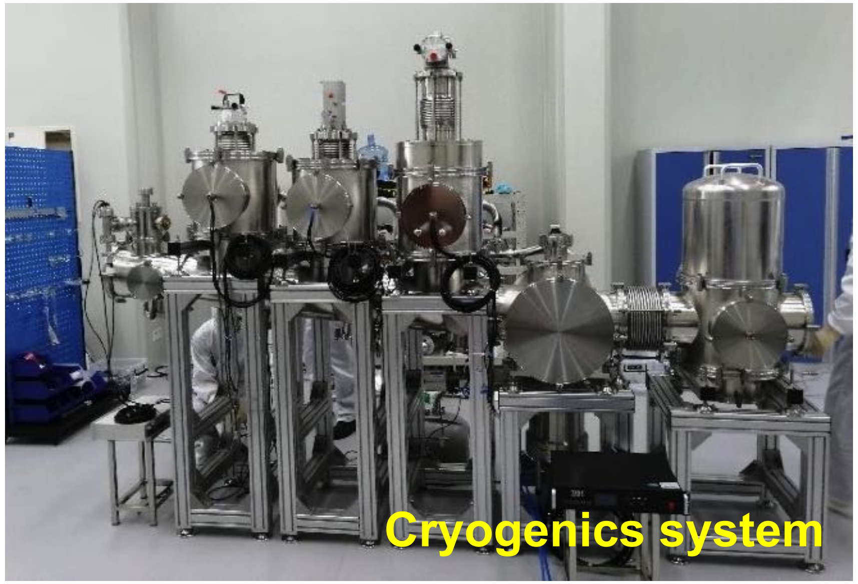
PandaX-4T major milestones

- **2018/04/02**
  - B2 hall construction started
- **2019/08/19**
  - infrastructure completed
  - detector installation started
- **2020/05/06**
  - offline xenon distillation completed
- **2020/05/28**
  - installation completed
- **2020/11/28 – 2021/04/16**
  - commissioning run

PandaX-4T subsystems

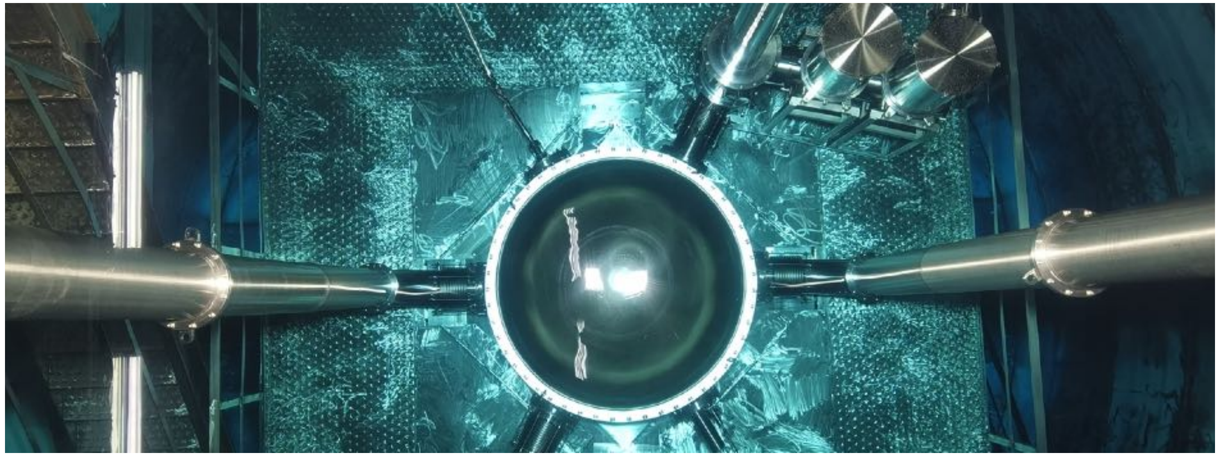


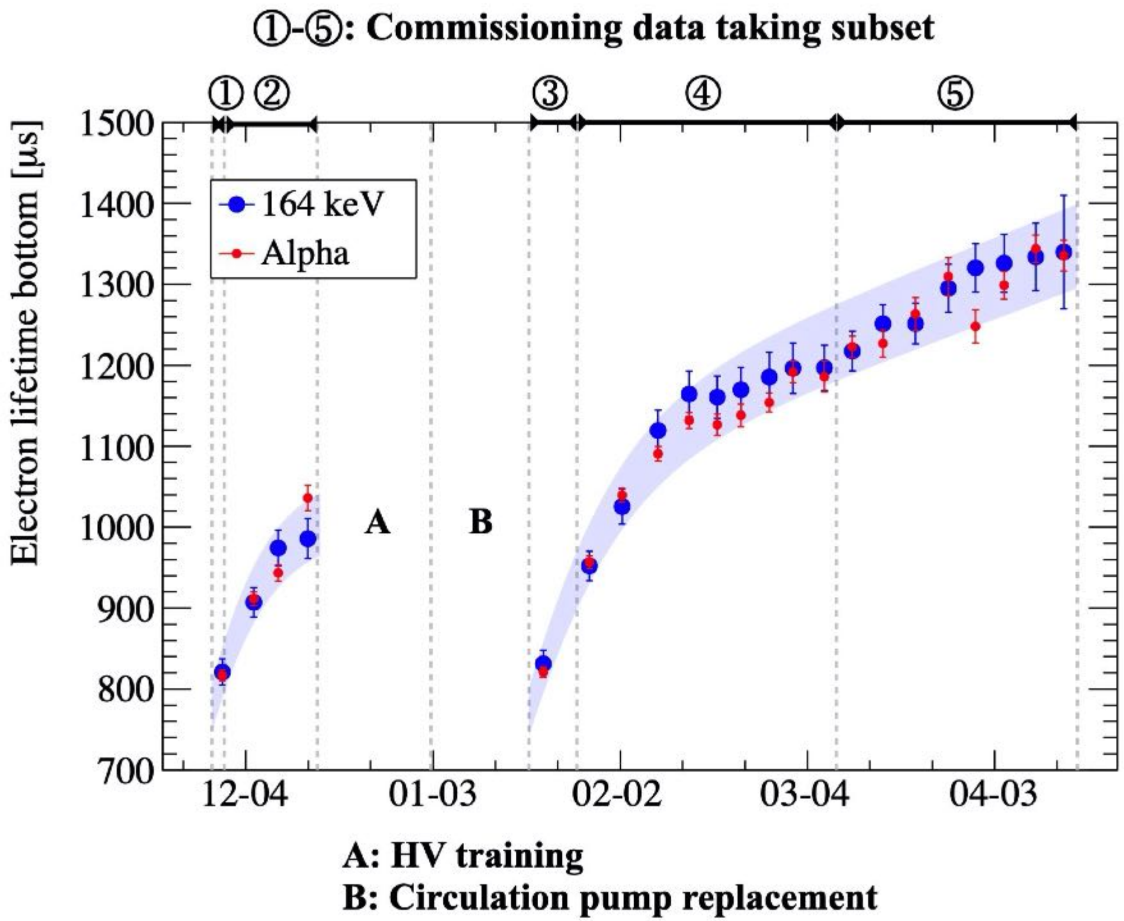




PandaX-4T commissioning

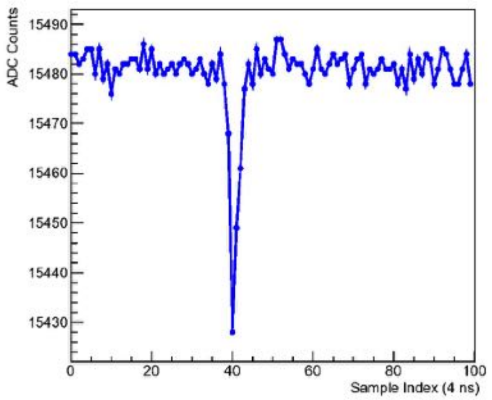
- Stable data running period: 95.0 calendar days





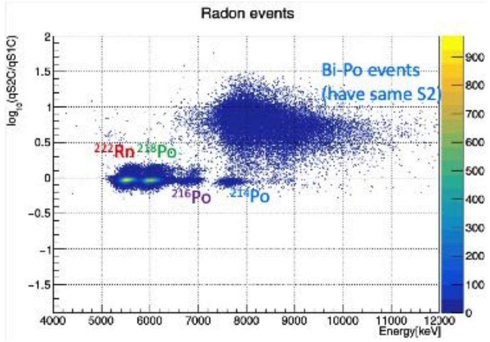
PandaX-4T major improvement

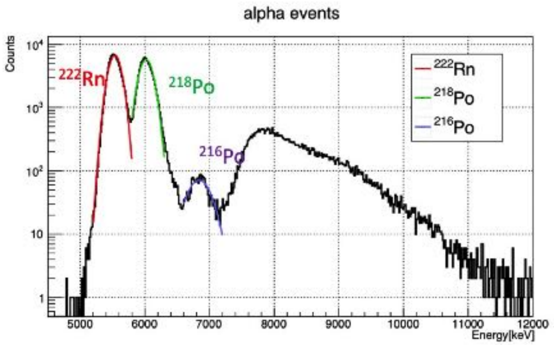
- **Triggerless DAQ**: low threshold
  - – read out pulses above 20 ADC (~1/3 PE)
- **^{222}Rn**: ~ 5 uBq/kg
  - – 1/6 of PandaX-II
- **^{85}Kr**: ~0.3 ppt mol/mol
  - – 1/20 of PandaX-II

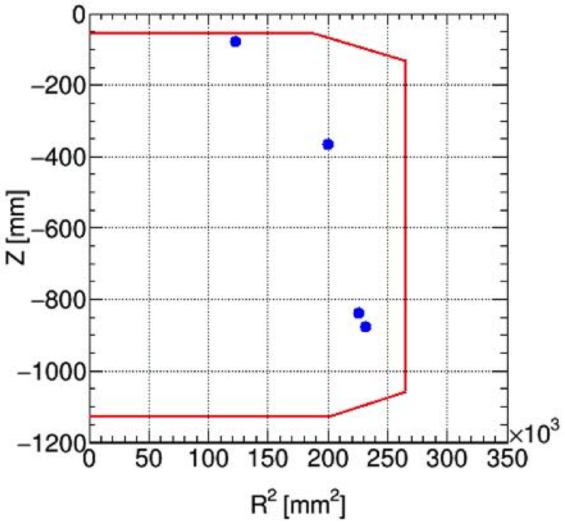


Typical single photon pulse

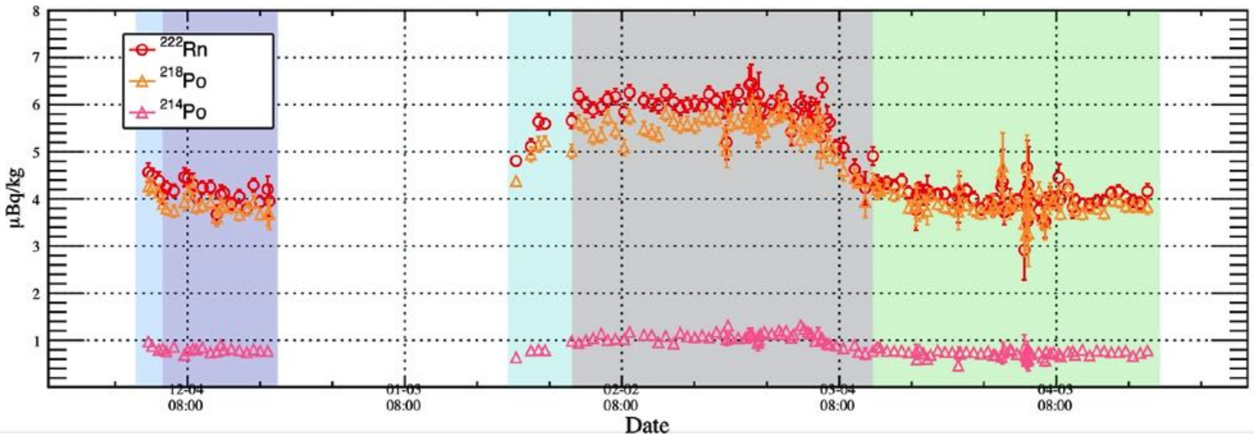
average single photon detection efficiency: 96%.







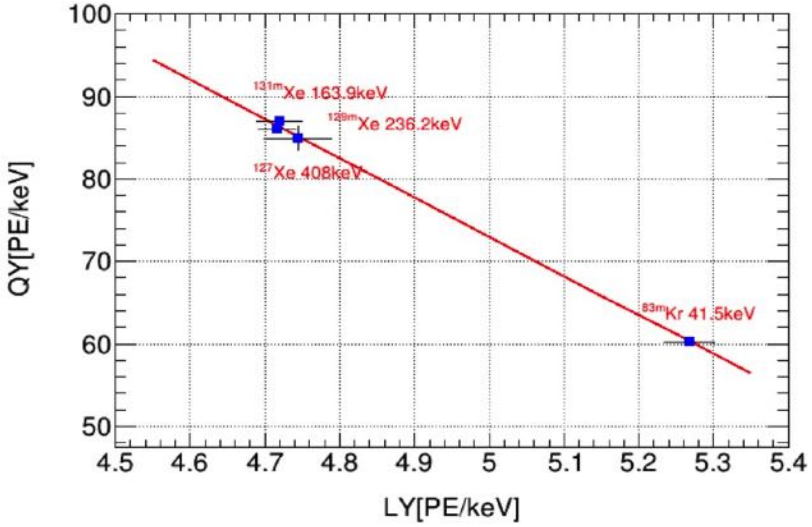
Vertex distribution of β-γ candidates

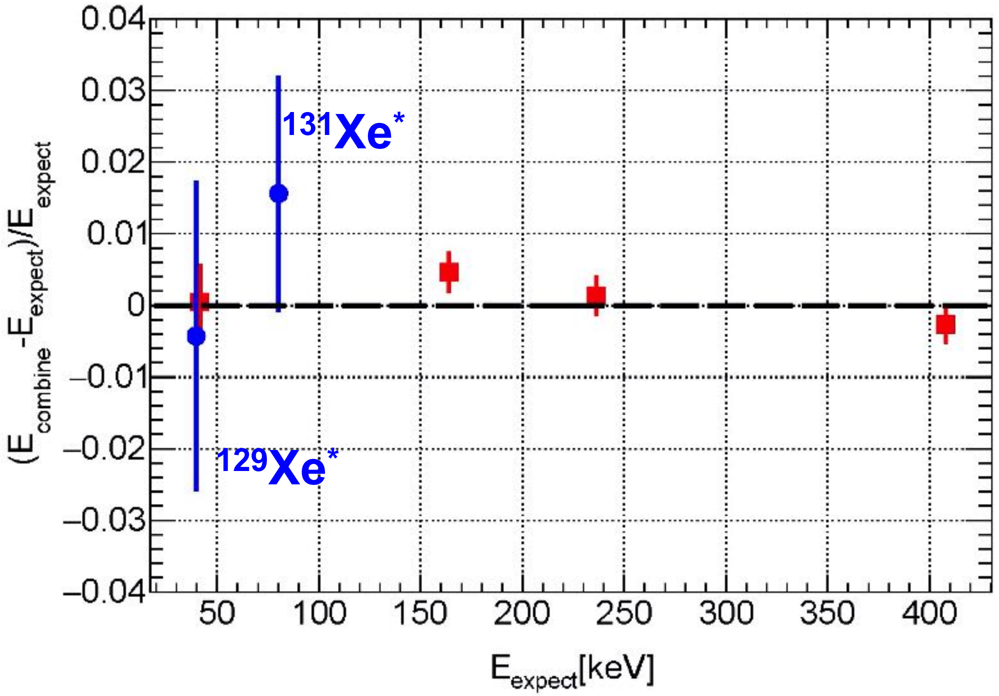


Energy reconstruction

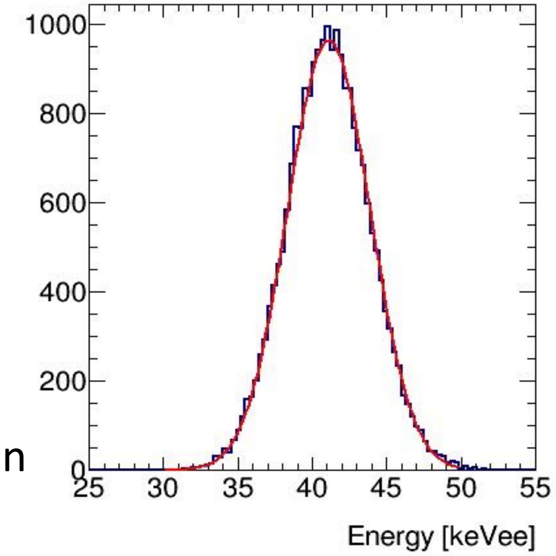
- Energy resolution @ 41.5 keV: 6.8%

$$E = 13.7\text{eV} \times \left(\frac{\text{S1}}{\text{PDE}} + \frac{\text{S2}_\text{b}}{\text{EEE} \times \text{SEG}}\right)$$





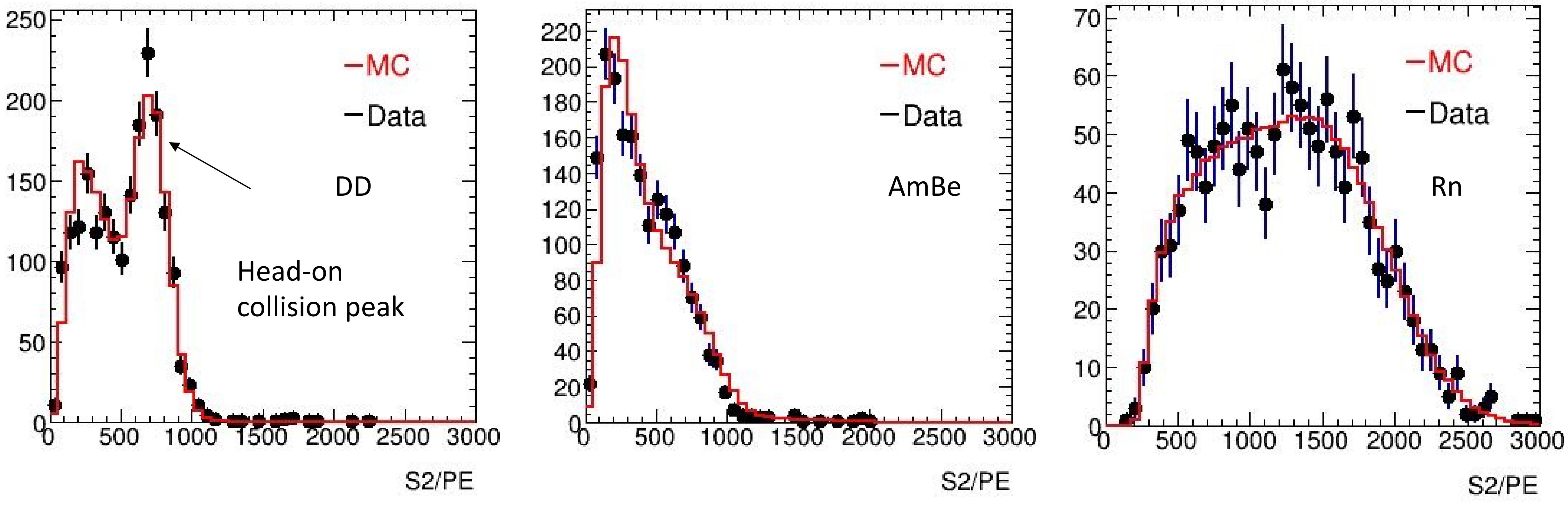
Kr83m calibration



#Set	PDE [%]	EEE [%]	SEGb [PE/e]
1-2	9.0±0.2	90.2±5.4	3.8±0.1
3-5	9.0±0.2	92.6±5.4	4.6±0.1

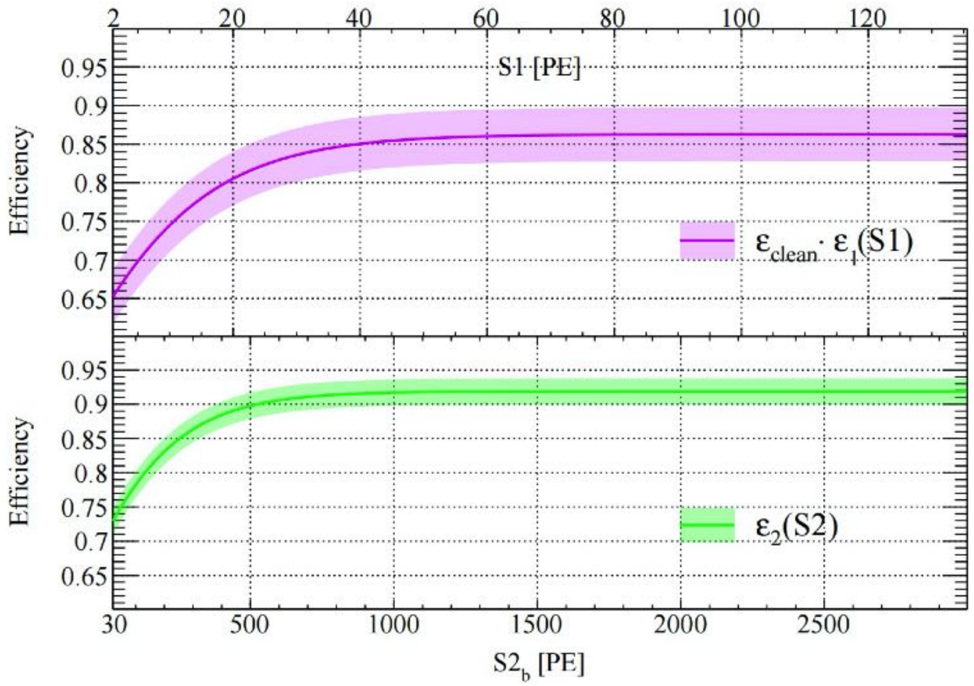
Detector response calibration

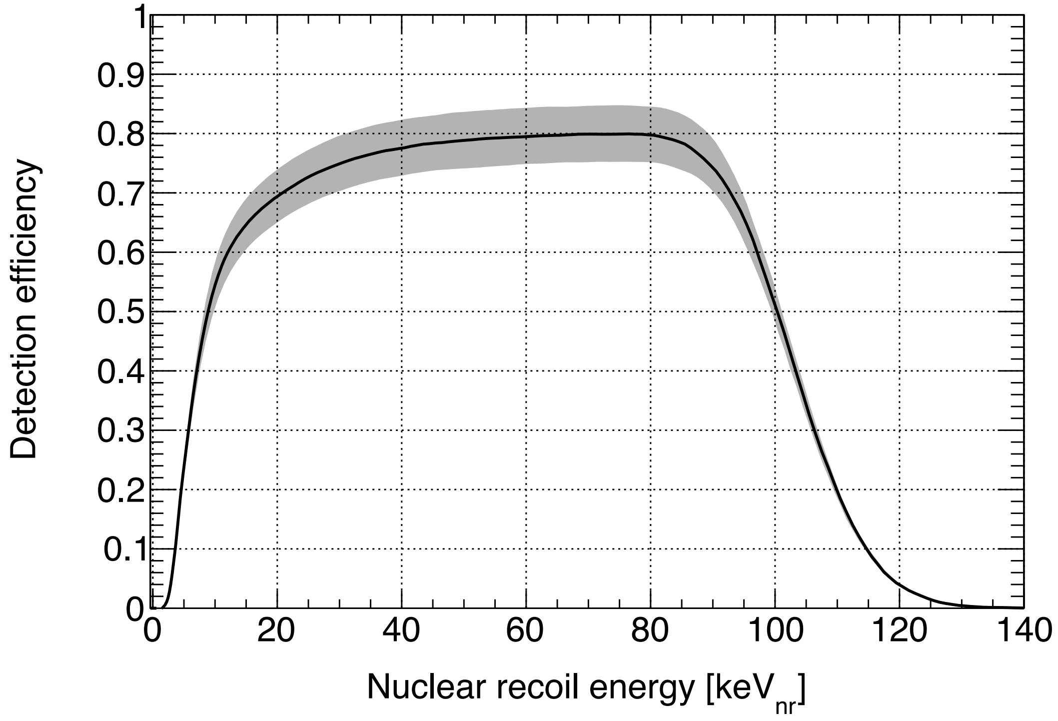
- Light/charge yield, as well as fluctuations
  - Deuteron-deuteron (DD) neutron data used together with AmBe
  - Rn data



Efficiencies obtained from calibration data

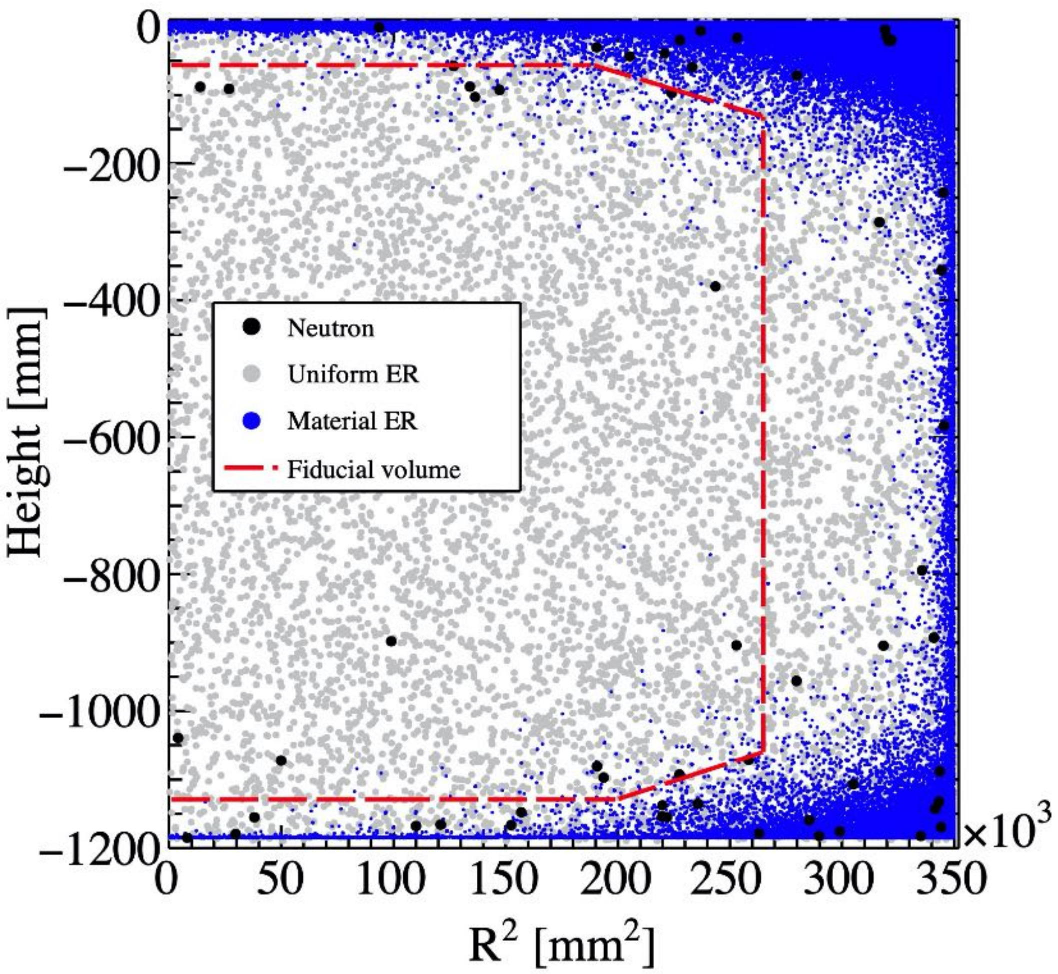
- Same S1 and S2 efficiency obtained from the ER and NR data
- Plateaued efficiency ~ 80%





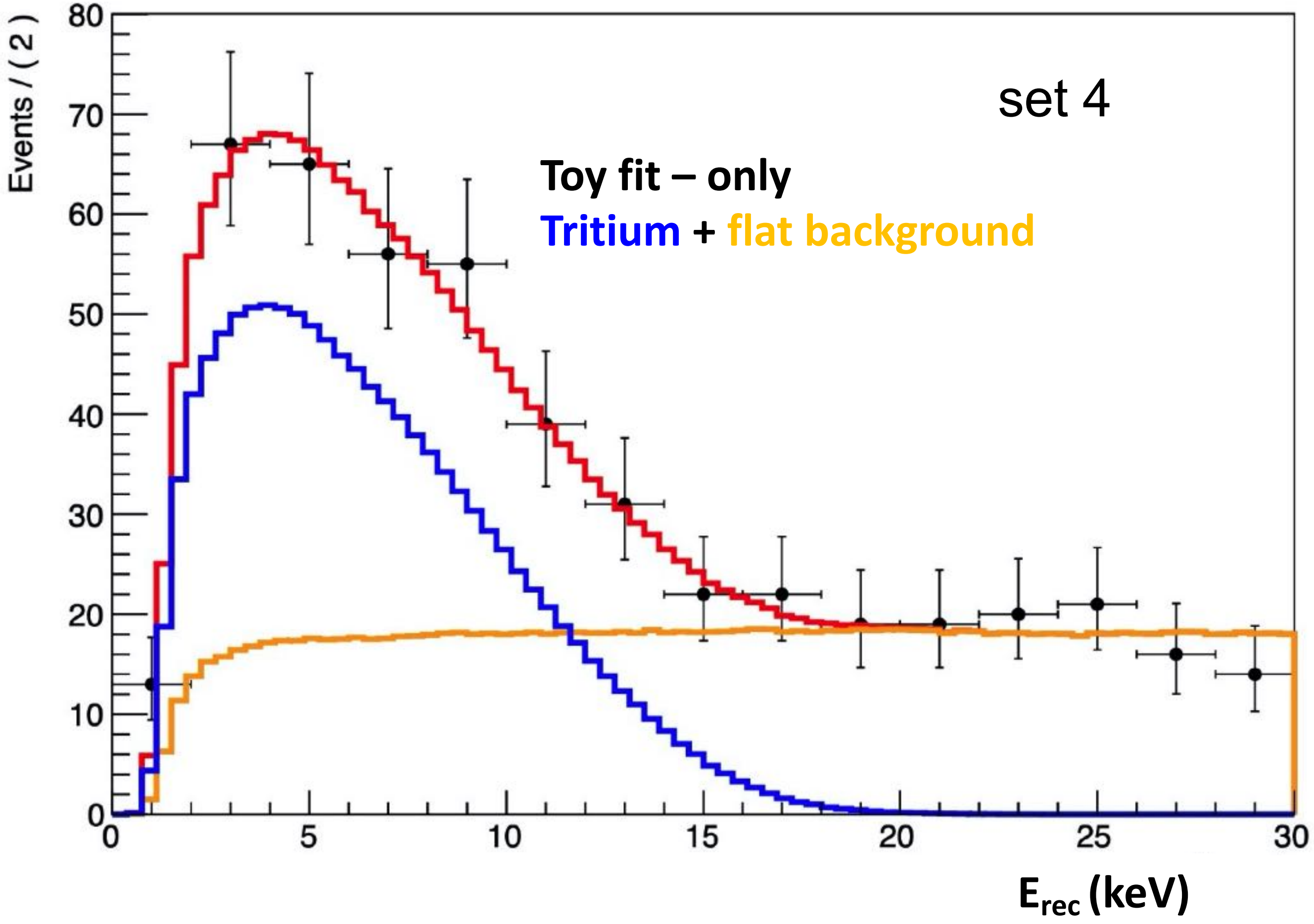
Fiducial volume determination

- Based on background simulation
  - Uniform ER (including tritium) normalization from data
- Define FoM = sqrt(B)/M
- Best FV = 2.67 tonne
- FV cuts in the data maintaining the same FV (correcting for reconstruction bias)



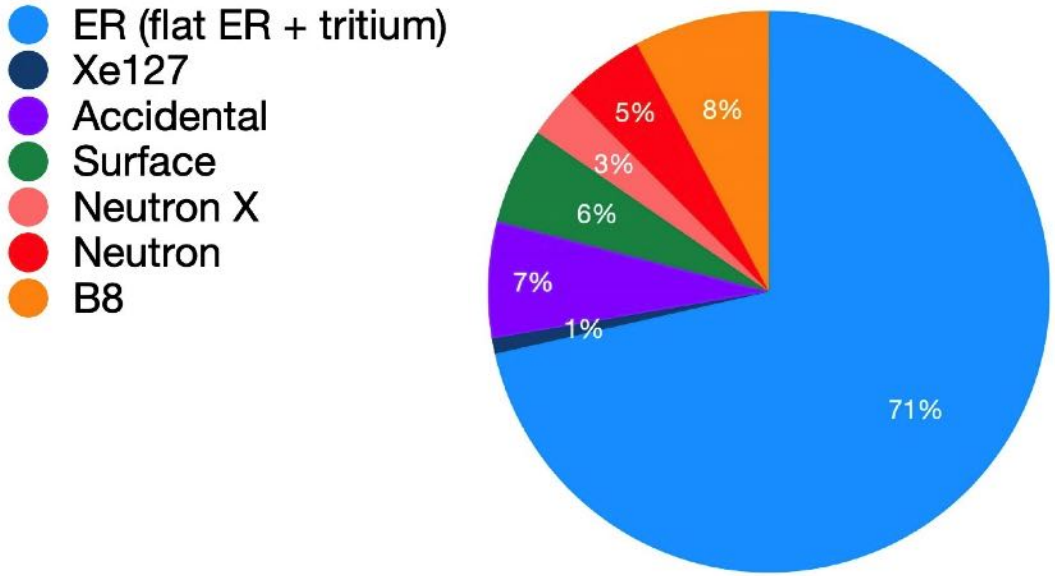
Tritium background

- Tritium spectrum identified in the data
- Likely originated from a tritium calibration at the end of PandaX-II
- Level floating in the final dark matter fit: ~ 5(0.3)x10^{-24} (mol/mol)



Background composition

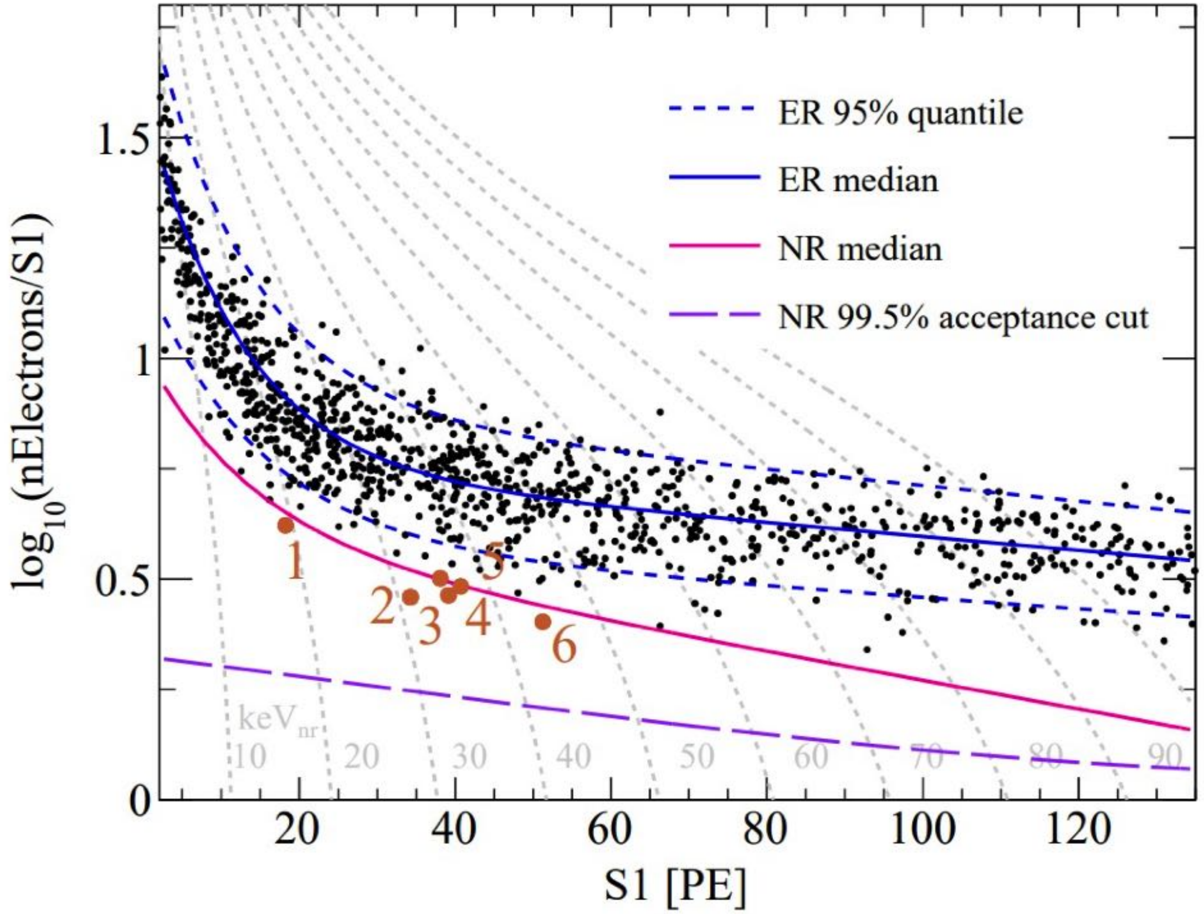
- Background per unit target is improved from PandaX-II by 4 times (<10 keV)
- Expected below-NR-median events: 9.8 (0.6) evts



Component	Nominal (evts)
^{3}T (from fit to data)	532 (32)
Flat ER* (18-30keV side band)	492 (31)
Rn	347 (190)
Kr	53 (34)
Material	40 (5)
pp neutrino	37 (8)
Xe136	31 (6)
Xe127	8 (1)
Neutron	0.9 (0.5)
Neutron-X	0.2 (0.1)
Surface	0.5 (0.1)
Accidental	2.4 (0.5)
B8	0.6 (0.3)
Sum	1037 (45)

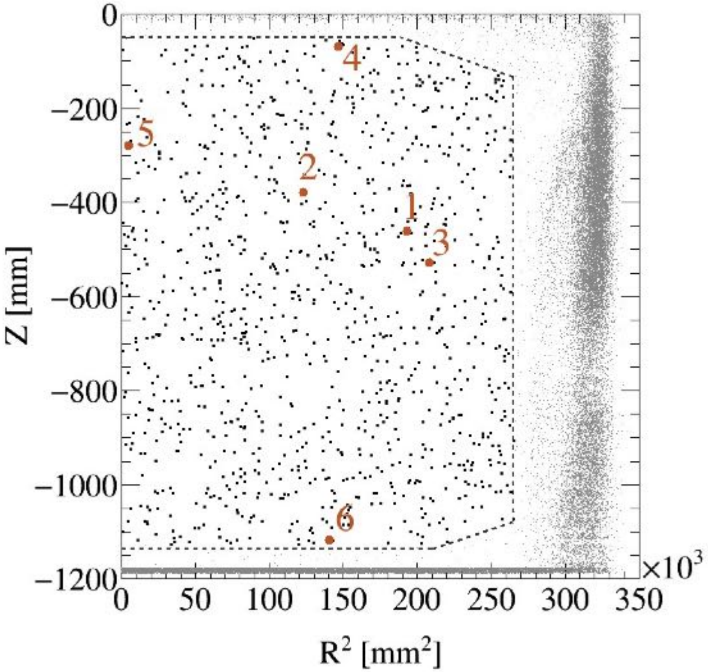
DM candidates

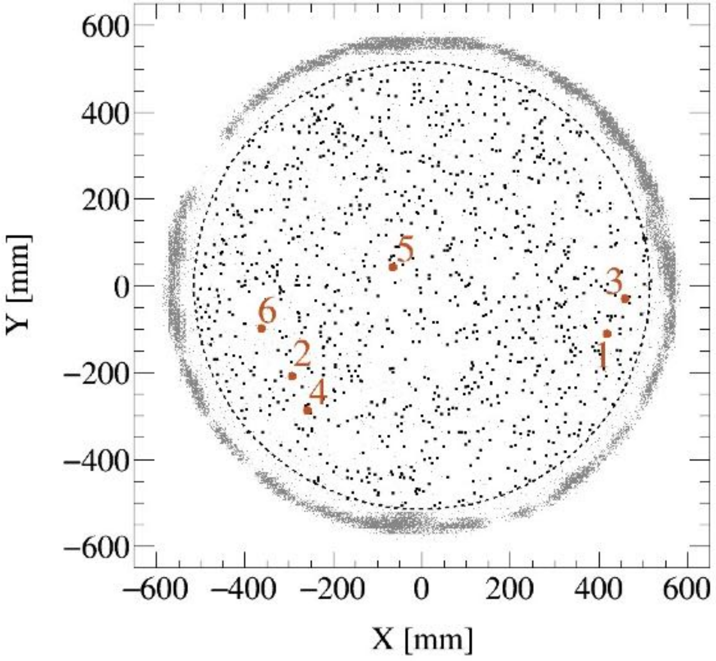
- FV: 2.67 tonne
- Exposure: 0.63 tonne-year
- Selection:
  - S1: 2 – 135 PE
  - S2raw: > 80 PE
  - S2 < 20000
- Candidates
  - **1058 candidates**
  - **6 below NR median line**

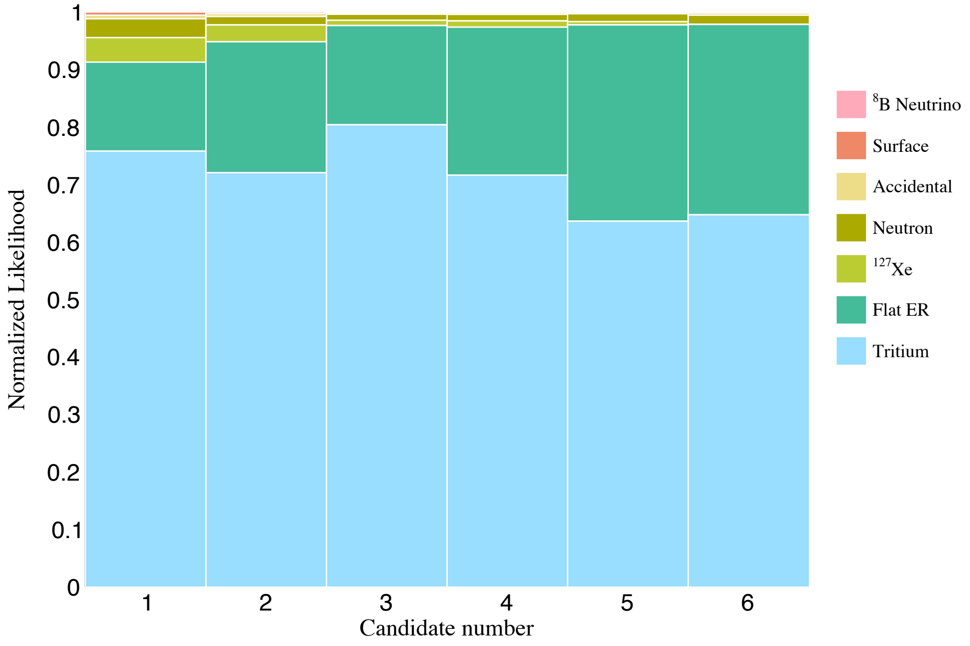


Position distributions

- Events uniformly distributed in the FV, expected if dominated by tritium and radon events.

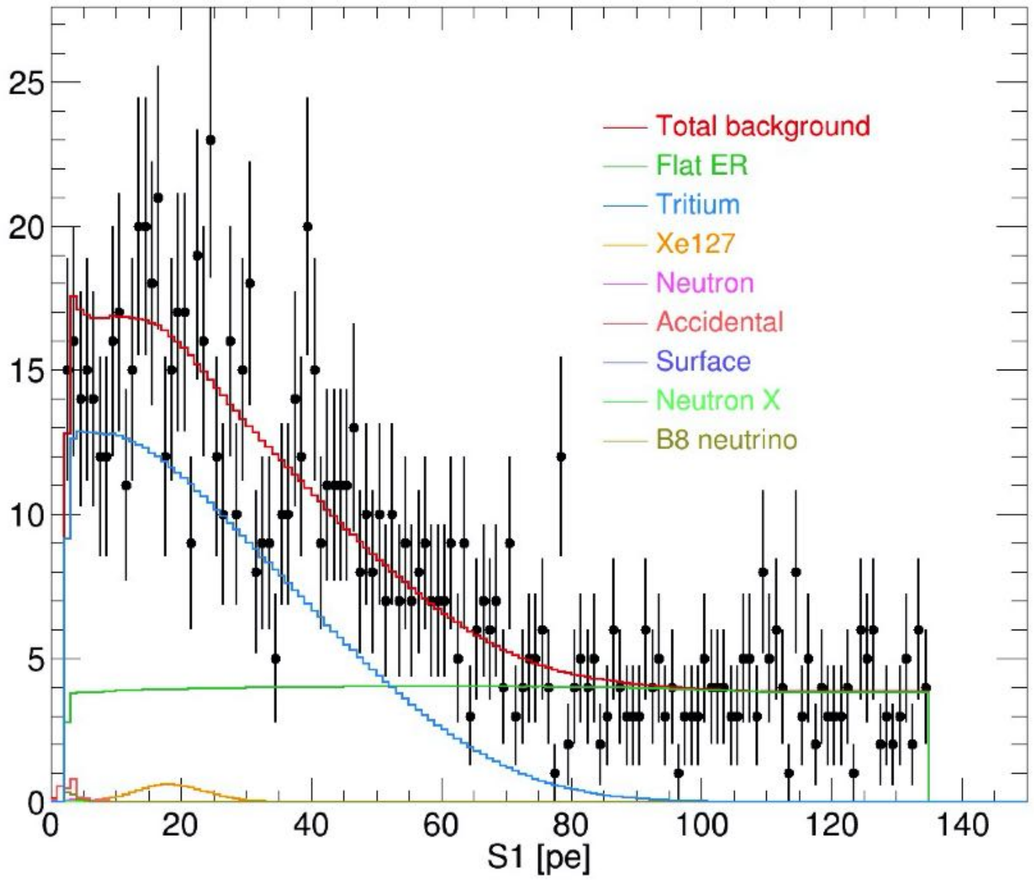






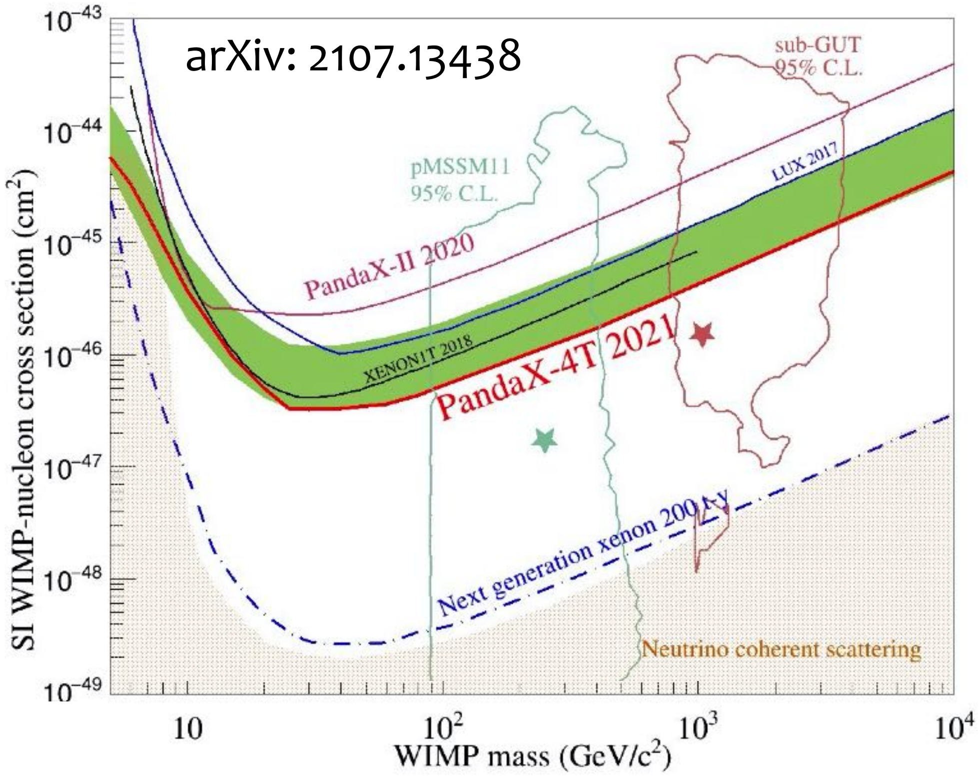
Spectral comparison

- Fit data with unbinned likelihood with all signal/background PDFs in (S1, $S2_b$)
- No excess found, background-only p-value 0.58
- Spectrum agrees with expected background



WIMP-nucleon SI exclusion limits

- Exposure: 0.63 tonne-year
- Sensitivity improved from PandaX-II final analysis by 2.9 times (30 GeV/c^2)
- Our limit is ~1.24 times stronger than XENON1T around 30 GeV/c^2
- Dived into previously unexplored territory!
- Approaching the “low E” neutrino floor

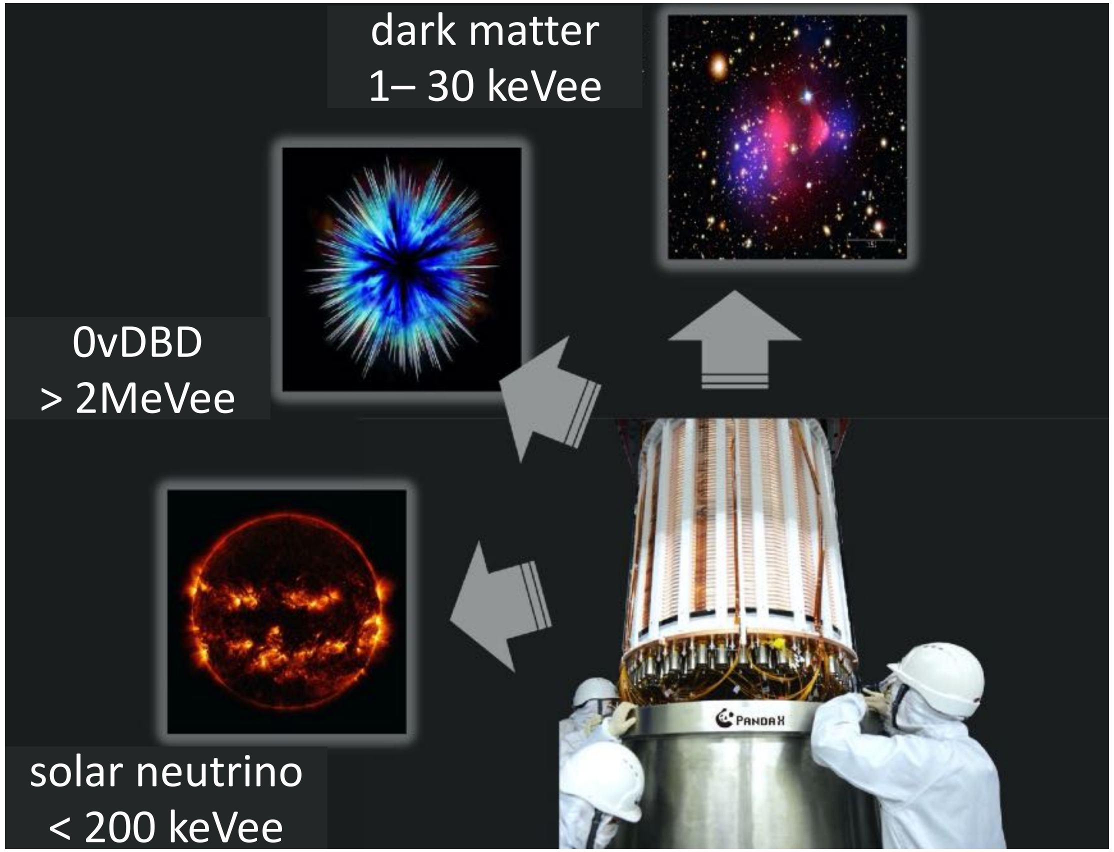


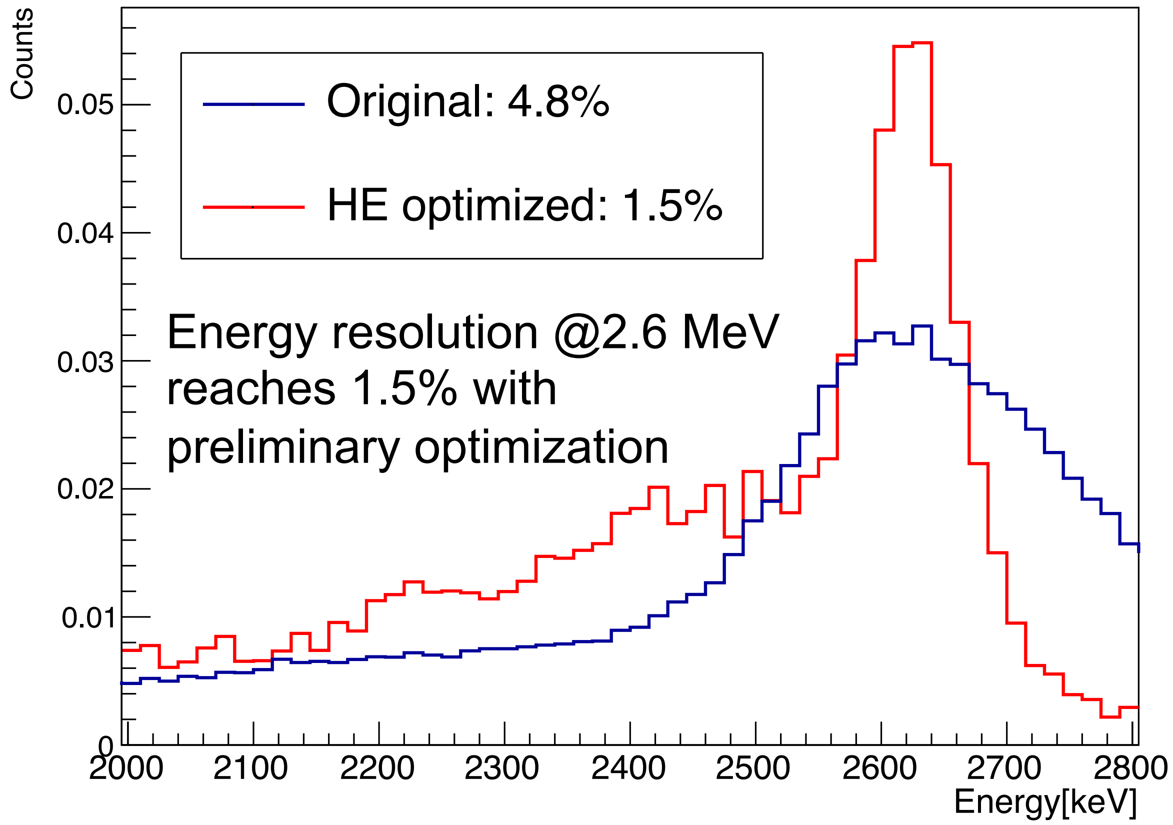
SUSY benchmark contours (MasterCode)

EPJC 78, no.3, 256 (2018), EPJC 78, 158 (2018)

Next plan

- Xenon distillation to remove radioactive impurity like tritium
- Multiple physics tasks: DM, Xe136 0vDBD, solar neutrino, etc

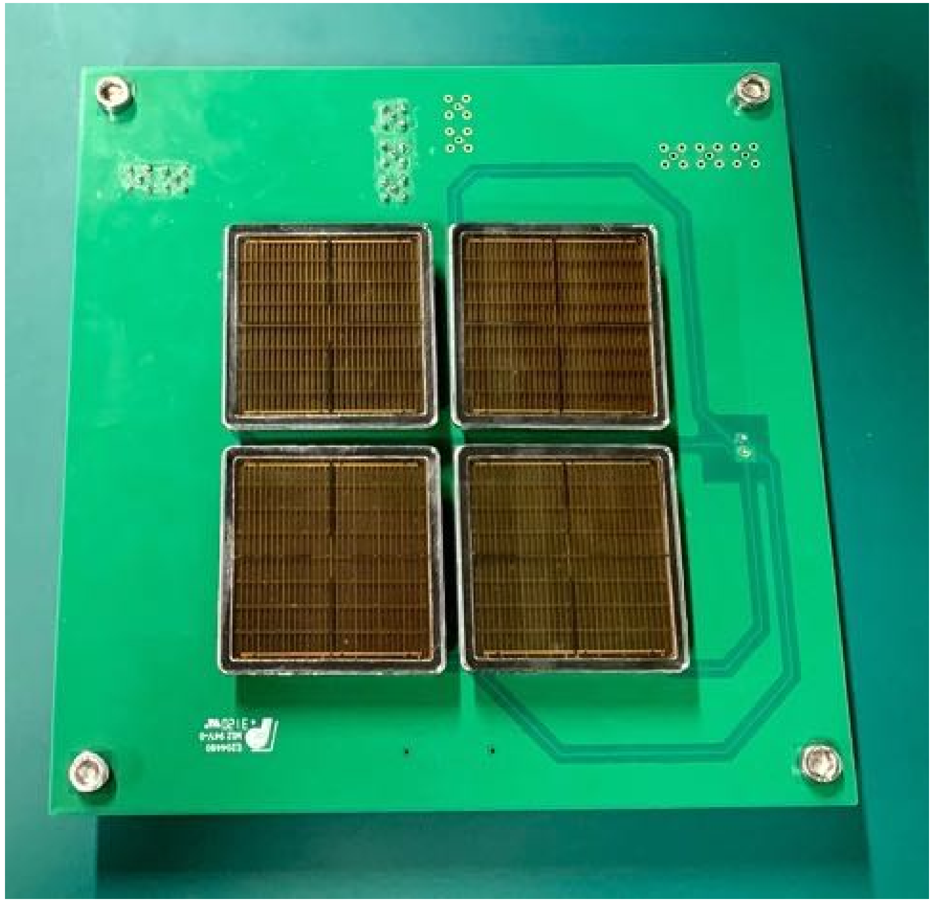




Next-generation detector R&D

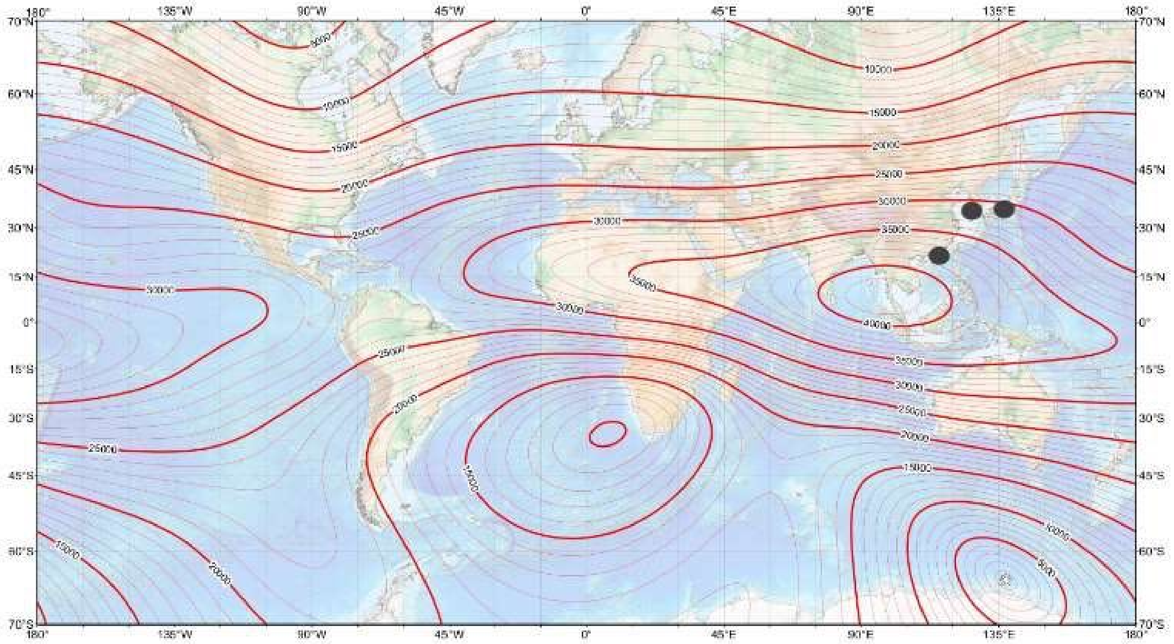
- Low background PMT, xenon isotope separation, etc

Unit: mBq/pc	R12699 (30T)	R11410 (4T)
Co-60	0.76±0.10	1.16±0.72 <2.34
Cs-137	0.02±0.08 <0.16	0.52±0.81 <1.85
K-40	26.42±1.78	8.37±8.47 <22.31
Th-232(early)	0.06±0.25 <0.46	4.33±2.16 <7.88
Th-232(late)	0.00±0.08 <0.12	1.50±0.96 <3.08
U-235	0.00±0.68 <1.11	13.13±8.53 <27.16
U-238(early)	3.32±1.84 <6.35	26.29±16.90 <54.09
U-238(late)	0.60±0.14	2.05±1.18 <3.99



Neutrino floor

- Non-uniform atmosphere neutrinos distribution, due to magnetic field
- CJPL has a unique advantage towards the “neutrino floor”



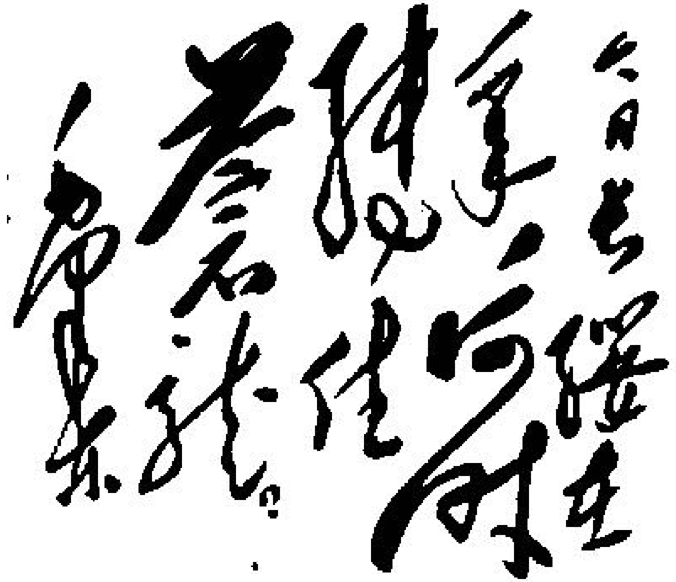
magnetic field

Site	Flux (m^2 sec sr GeV)^-1 [100MeV]
Kamioka	4249
Gran Sasso	7304
Sudbury	11879
Frejus	8215
INO	2554
South Pole	12001
Pythasalmi	12208
Homestake	11774
JUNO	2871

Honda et al. arXiv: 1502.03916 neutrino flux

Summary

- PandaX-II has completed successfully in 2019
- PandaX-4T, x10 more sensitive than PandaX-II
- PandaX-4T commissioning has completed
- Currently, PandaX-4T is performing an offline tritium removal, aiming to reduce the electron recoil background
- In parallel, developing plan for the next generation experiment at CJPL
- Stay tuned!



Today we hold the long cord in our hands，

when shall we bind fast the Grey Dragon?

THANK YOU