PandaX:

A Deep Underground LXe Observatory in China

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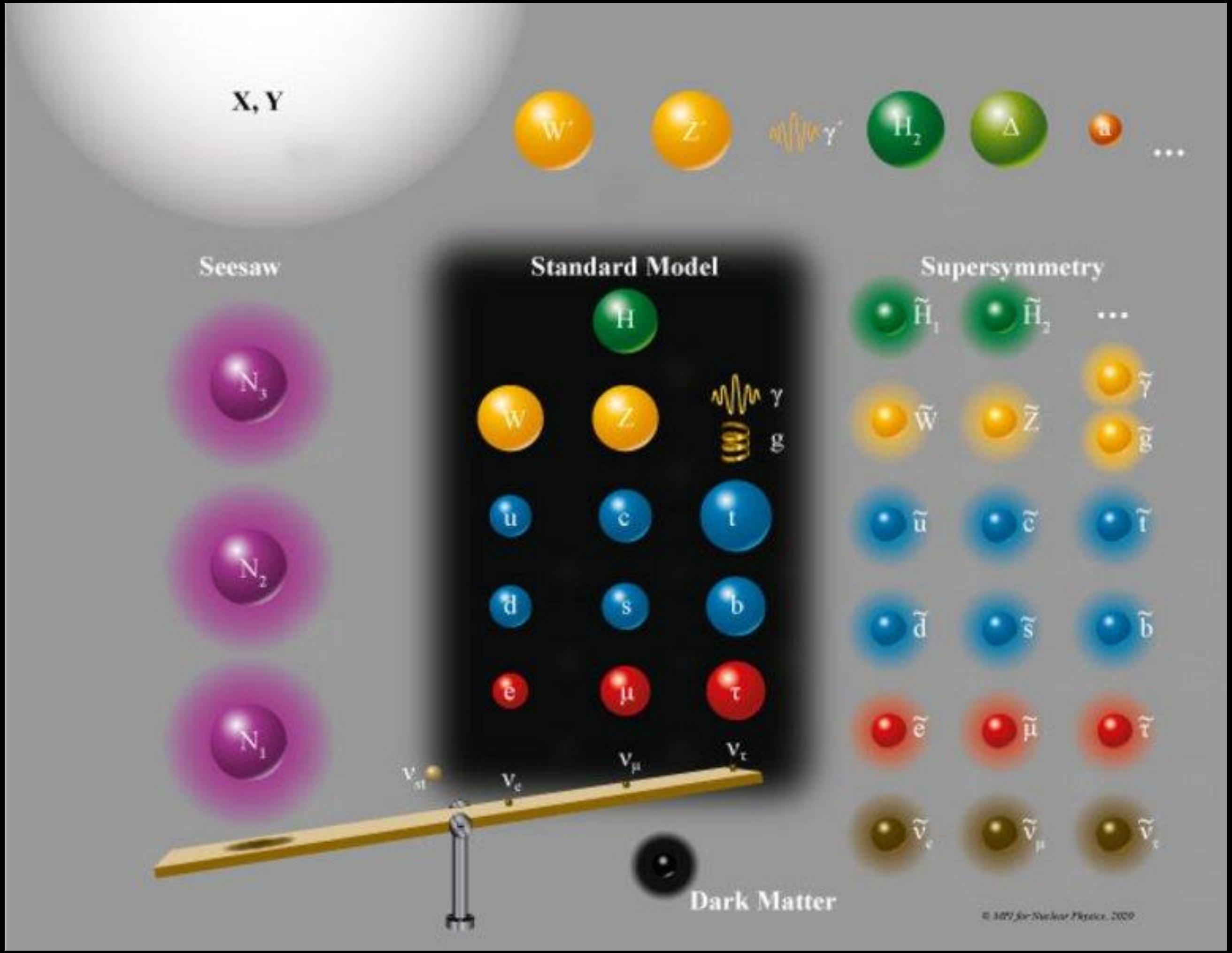
Shanghai Jiao tong university

1/3 proton mass/cm^3, v ~1/1000c

Elementary particles?



Particle scattering

Chadwick 1932: discovery of neutron

- alpha + Be9 -> C + x (production)

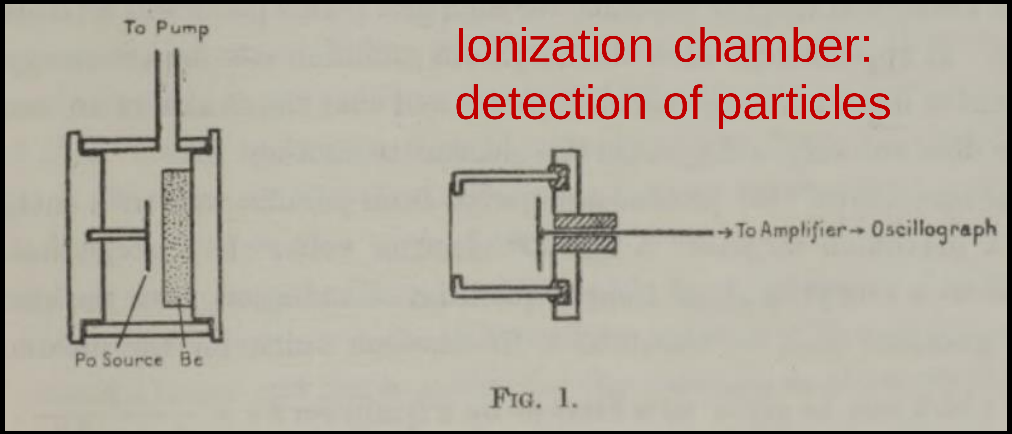
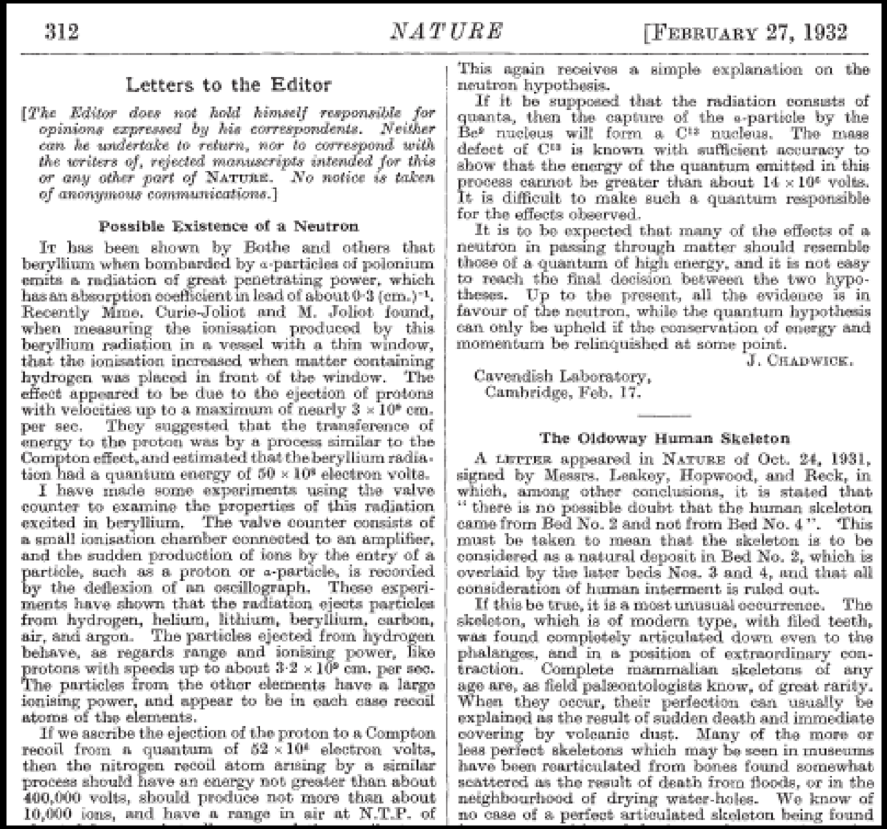


Fig. 1.


Nobel prize 1935



Letters to the Editor

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Possible Existence of a Neutron

It has been shown by Bothe and others that beryllium when bombarded by α-particles of polonium emits a radiation of great penetrating power, which has an absorption coefficient in lead of about 0·3 (cm.)$^{-1}$. Recently Mme. Curie-Joliot and M. Joliot found, when measuring the ionisation produced by this beryllium radiation in a vessel with a thin window, that the ionisation increased when matter containing hydrogen was placed in front of the window. The effect appeared to be due to the ejection of protons with velocities up to a maximum of nearly 3 × 10^9 cm. per sec. They suggested that the transference of energy to the proton was by a process similar to the Compton effect, and estimated that the beryllium radiation had a quantum energy of 50 × 10^6 electron volts.

I have made some experiments using the valve counter to examine the properties of this radiation excited in beryllium. The valve counter consists of a small ionisation chamber connected to an amplifier, and the sudden production of ions by the entry of a particle, such as a proton or α-particle, is recorded by the deflexion of an oscillograph. These experiments have shown that the radiation ejects particles from hydrogen, helium, lithium, beryllium, carbon, air, and argon. The particles ejected from hydrogen behave, as regards range and ionising power, like protons with speeds up to about 3·2 × 10^9 cm. per sec. The particles from the other elements have a large ionising power, and appear to be in each case recoil atoms of the elements.

If we ascribe the ejection of the proton to a Compton recoil from a quantum of 52 × 10^6 electron volts, then the nitrogen recoil atom arising by a similar process should have an energy not greater than about 400,000 volts, should produce not more than about 10,000 ions, and have a range in air at N.T.P. of

This again receives a simple explanation on the neutron hypothesis.

If it be supposed that the radiation consists of quanta, then the capture of the α-particle by the Be^9 nucleus will form a C^{13} nucleus. The mass defect of C^{13} is known with sufficient accuracy to show that the energy of the quantum emitted in this process cannot be greater than about 14 × 10^6 volts. It is difficult to make such a quantum responsible for the effects observed.

It is to be expected that many of the effects of a neutron in passing through matter should resemble those of a quantum of high energy, and it is not easy to reach the final decision between the two hypotheses. Up to the present, all the evidence is in favour of the neutron, while the quantum hypothesis can only be upheld if the conservation of energy and momentum be relinquished at some point.

J. Chadwick.

Cavendish Laboratory,
Cambridge, Feb. 17.

The Oldoway Human Skeleton

A letter appeared in NATURE of Oct. 24, 1931, signed by Messrs. Leakey, Hopwood, and Reck, in which, among other conclusions, it is stated that "there is no possible doubt that the human skeleton came from Bed No. 2 and not from Bed No. 4". This must be taken to mean that the skeleton is to be considered as a natural deposit in Bed No. 2, which is overlaid by the later beds Nos. 3 and 4, and that all consideration of human interment is ruled out.

If this be true, it is a most unusual occurrence. The skeleton, which is of modern type, with filed teeth, was found completely articulated down even to the phalanges, and in a position of extraordinary contraction. Complete mammalian skeletons of any age are, as field palæontologists know, of great rarity. When they occur, their perfection can usually be explained as the result of sudden death and immediate covering by volcanic dust. Many of the more or less perfect skeletons which may be seen in museums have been rearticulated from bones found somewhat scattered as the result of death from floods, or in the neighbourhood of drying water-holes. We know of no case of a perfect articulated skeleton being found

- x + A -> x + A (detection)

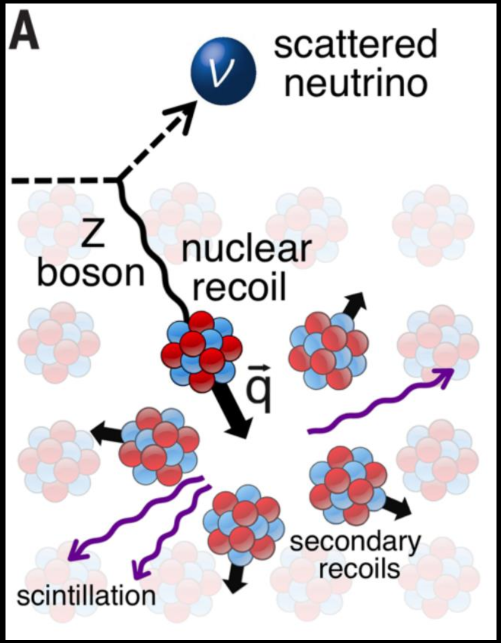
$1 GeV/c^2 * 0.1\ c \sim 10\ fm$

and (coherent) strong interaction!

Coherent elastic neutrino-nucleus scattering (CEvNS)

Quantum mechanics: 200 MeV ~ 1 fm
So MeV neutrino cannot resolve nucleons in nucleus

N=num neutrons



Coherent effects of a weak neutral current

Daniel Z. Freedman
Phys. Rev. D **9**, 1389 – Published 1 March 1974

Article | References | Citing Articles (412) | PDF | Export Citation

ABSTRACT

If there is a weak neutral current, then the elastic scattering process $\nu + A \to \nu + A$ should have a sharp coherent forward peak just as $e + A \to e + A$ does. Experiments to observe this peak can give important information on the isospin structure of the neutral current. The experiments are very difficult, although the estimated cross sections (about 10^{-38} cm^2 on carbon) are favorable. The coherent cross sections (in contrast to incoherent) are almost energy-independent. Therefore, energies as low as 100 MeV may be suitable. Quasi-coherent nuclear excitation processes $\nu + A \to \nu + A^*$ provide possible tests of the conservation of the weak neutral current. Because of strong coherent effects at very low energies, the nuclear elastic scattering process may be important in inhibiting cooling by neutrino emission in stellar collapse and neutron stars.

$$\sigma = \frac{G^2}{16\pi} N^2 \Delta_{\max}{}^2 = \frac{G^2 N^2}{4\pi} E^2 .$$

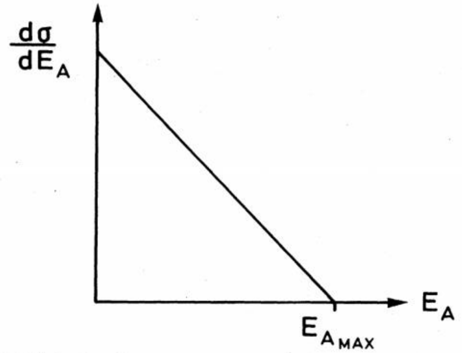


FIG. 1. Recoil-energy spectrum of the struck nucleus A in elastic neutrino scattering.

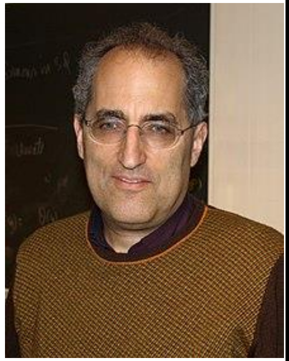
$$\bar{E}_A = \frac{2}{3A} (E/1\ \mathrm{MeV})^2\ \mathrm{keV}$$

“Application”

PHYSICAL REVIEW D VOLUME 31, NUMBER 12 15 JUNE 1985

Detectability of certain dark-matter candidates

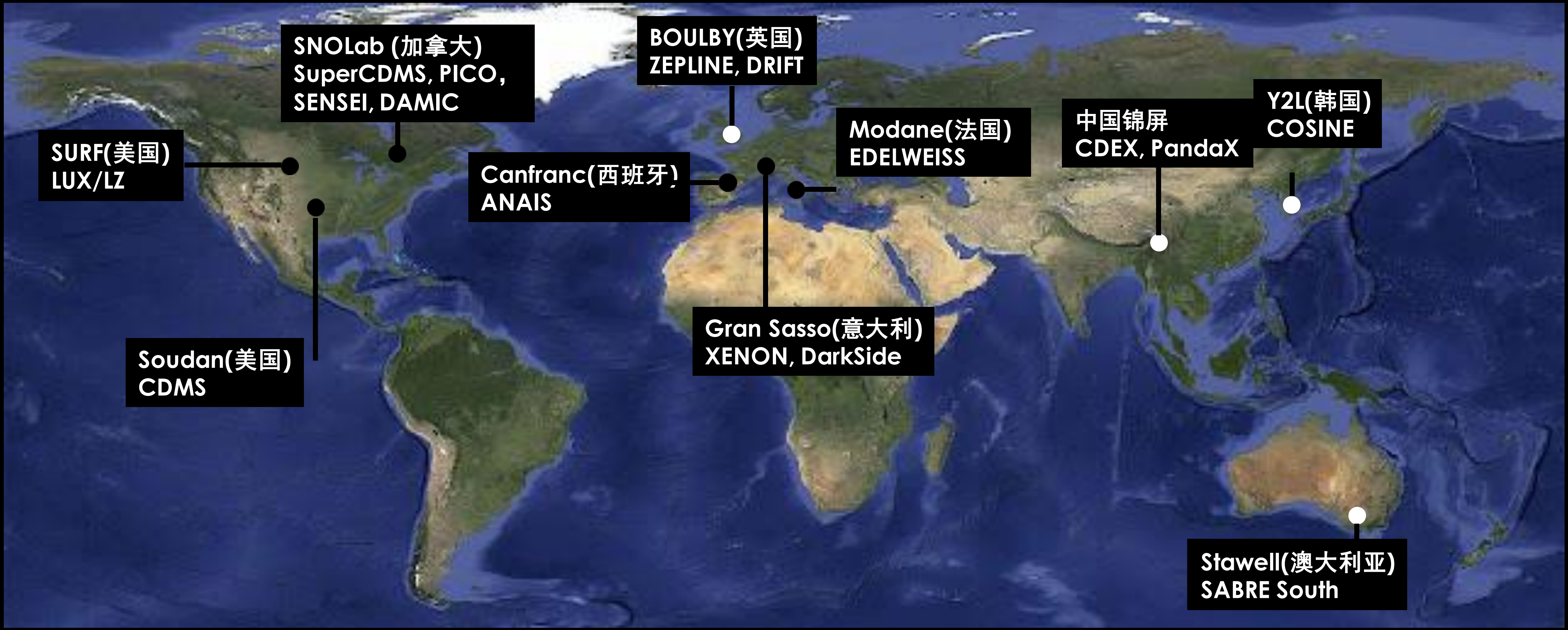
Mark W. Goodman and Edward Witten
Joseph Henry Laboratories, Princeton University, Princeton, New Jersey 08544
(Received 7 January 1985)



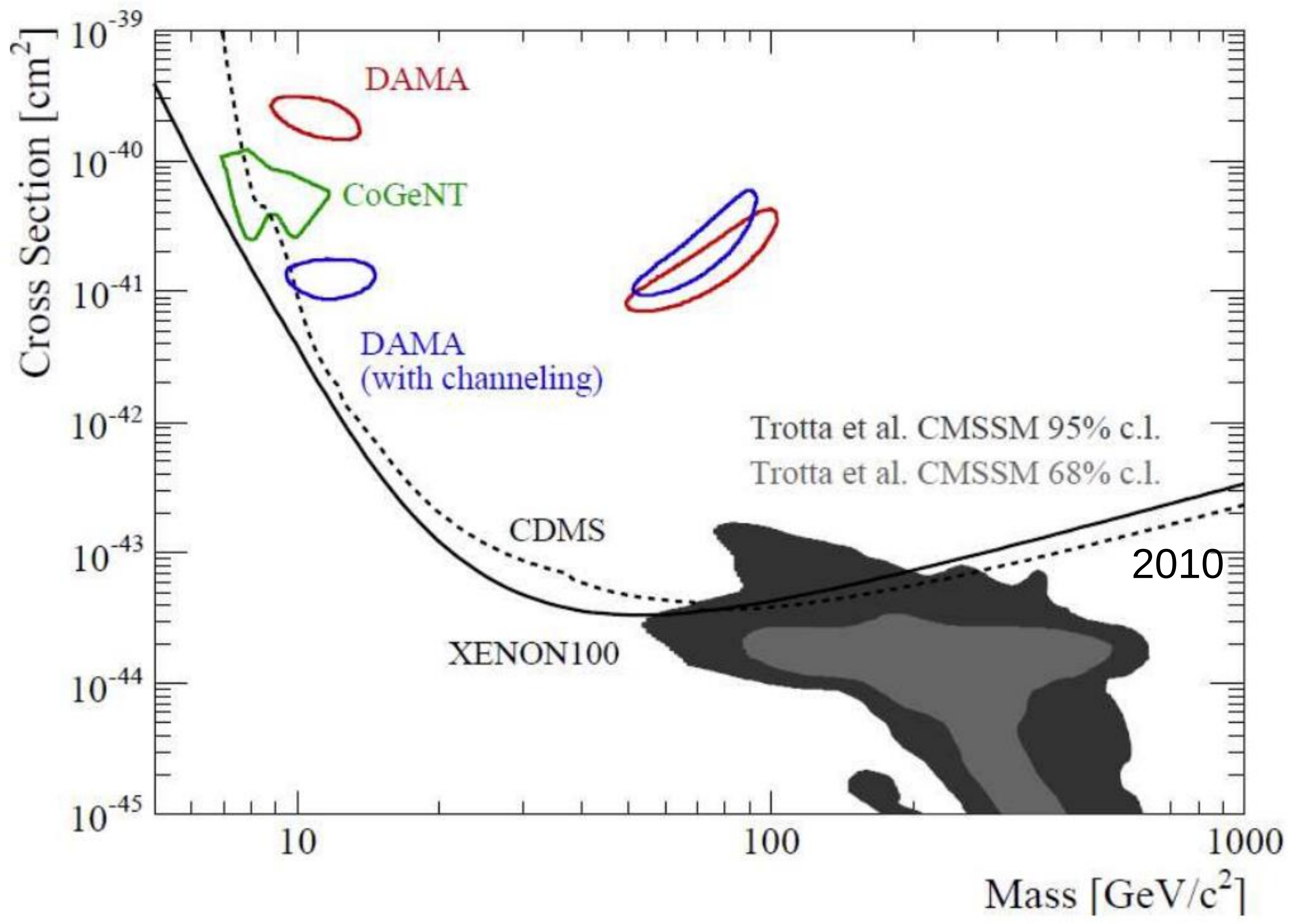
We consider the possibility that the neutral-current neutrino detector recently proposed by Drukier and Stodolsky could be used to detect some possible candidates for the dark matter in galactic halos. This may be feasible if the galactic halos are made of particles with coherent weak interactions and masses $1-10^6$ GeV; particles with spin-dependent interactions of typical weak strength and masses $1-10^2$ GeV; or strongly interacting particles of masses $1-10^{13}$ GeV.

In this paper, we will calculate the sensitivity of the detector considered in Ref. 5 to various dark-matter candidates. Although this detector is not very sensitive to

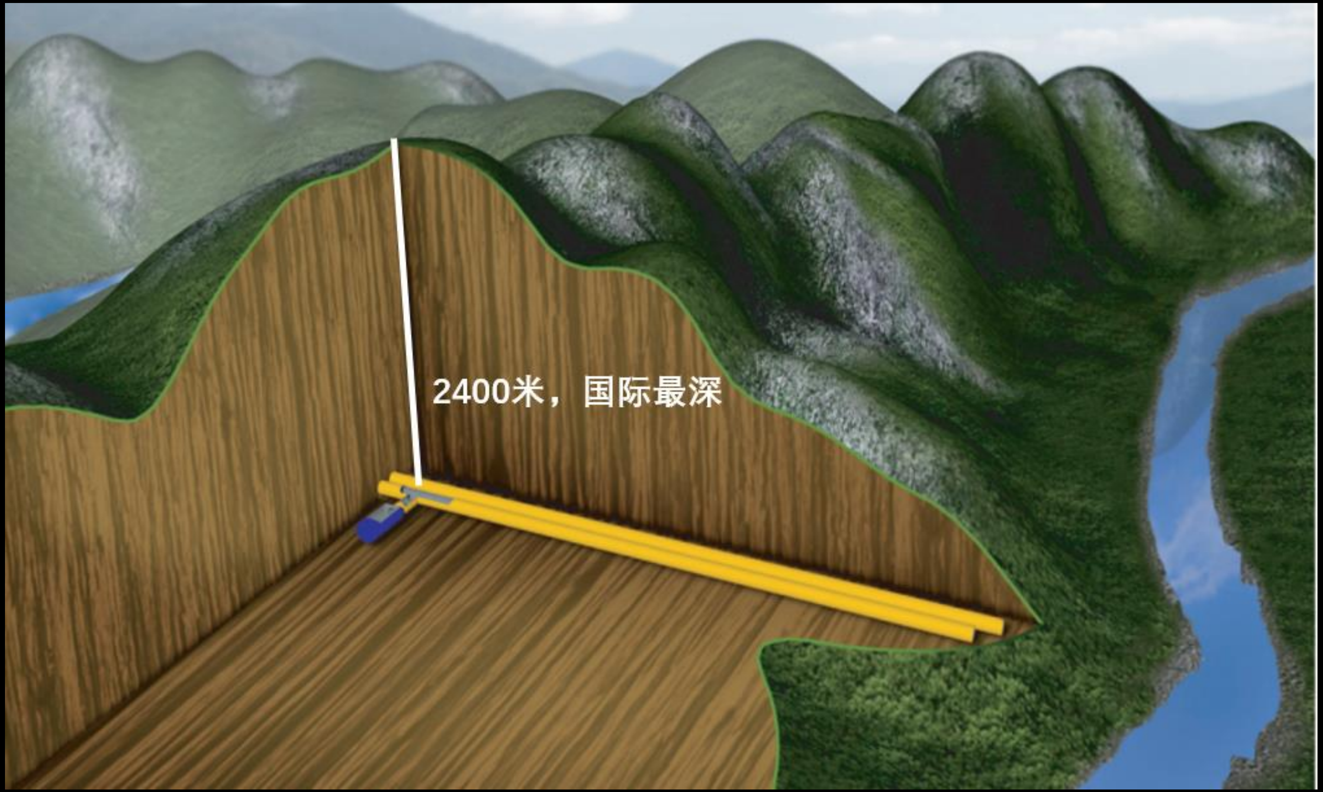
For a 100 GeV dark matter, v=1/1000c, p=100 MeV/c, λ~10 fm
So coherent scattering with nucleons inside nucleus!


SNOLab (加拿大)
SuperCDMS, PICO,
SENSEI, DAMIC
BOULBY(英国)
ZEPLINE, DRIFT
SURF(美国)
LUX/LZ
Canfranc(西班牙)
ANAIS
Modane(法国)
EDELWEISS
中国锦屏
CDEX, PandaX
Y2L(韩国)
COSINE
Soudan(美国)
CDMS
Gran Sasso(意大利)
XENON, DarkSide
Stawell(澳大利亚)
SABRE South

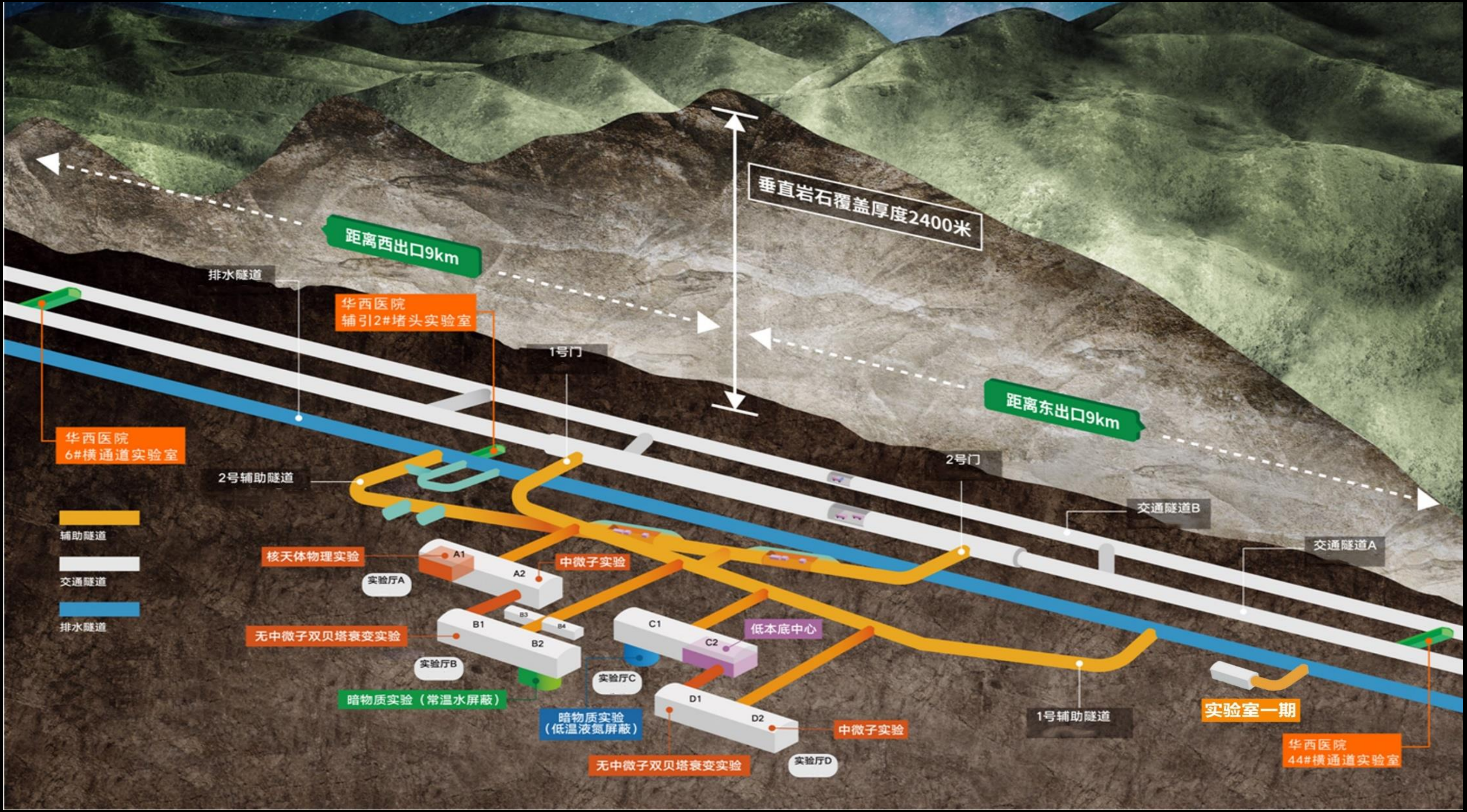
Low Hanging Fruit?



China Jinping Underground Laboratory (CJPL)



CJPL-II: National Major Facility (2024-now)



Particle and Astrophysical Xenon observatory

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

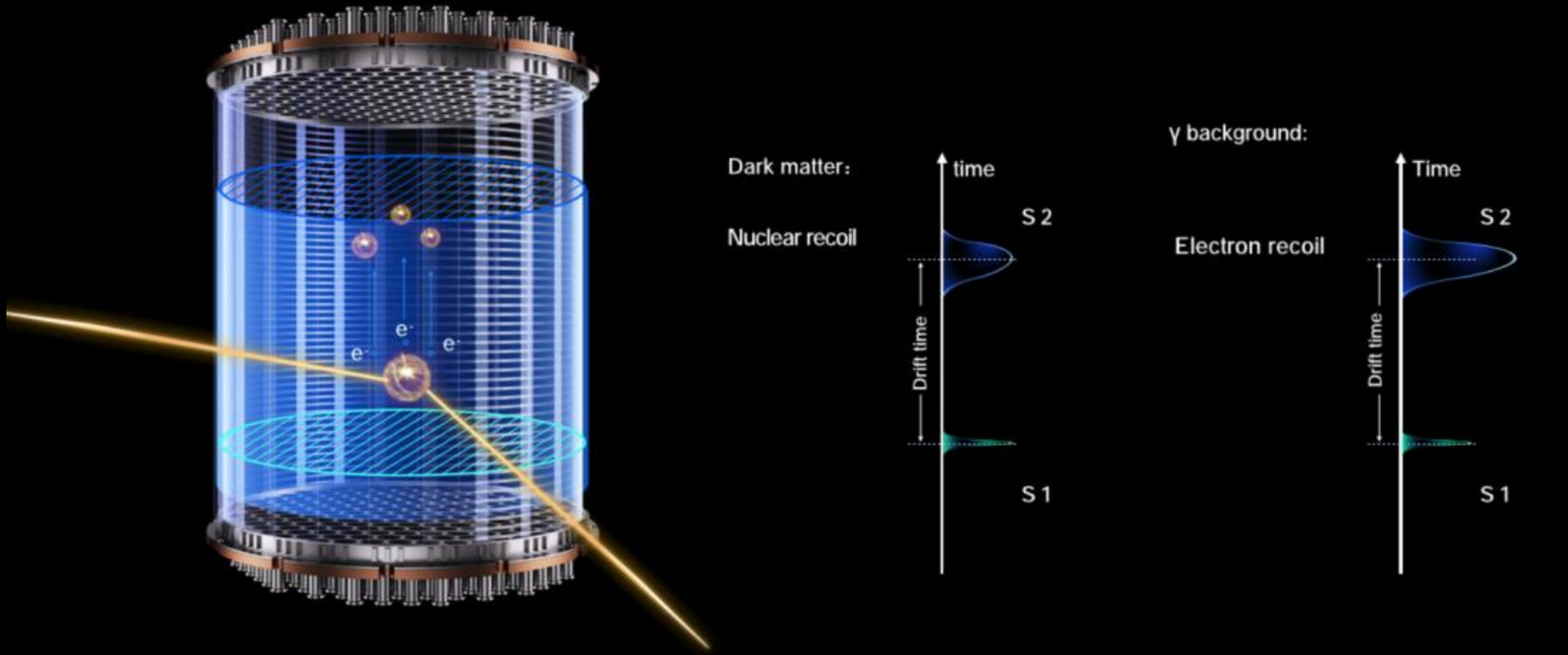
2019.8-

PandaX-4T moved to CJPL-II

PANDA X

Particle and Astrophysical Xenon observatory

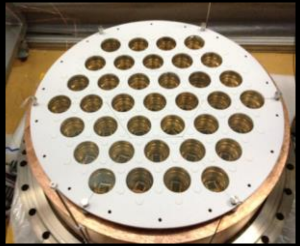
Dual-phase xenon time projection chamber (TPC)



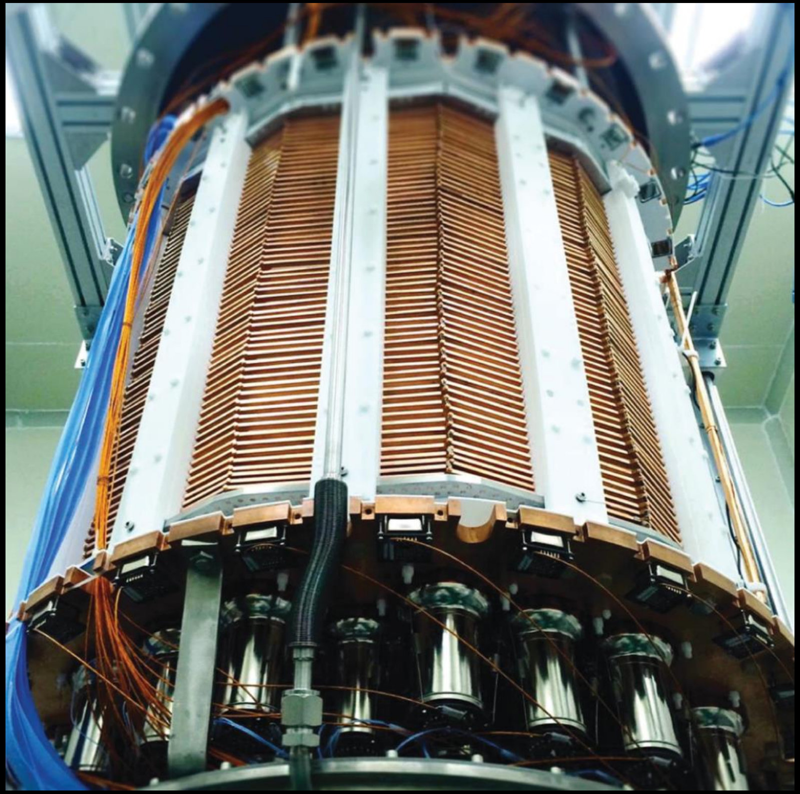
Detector capability:

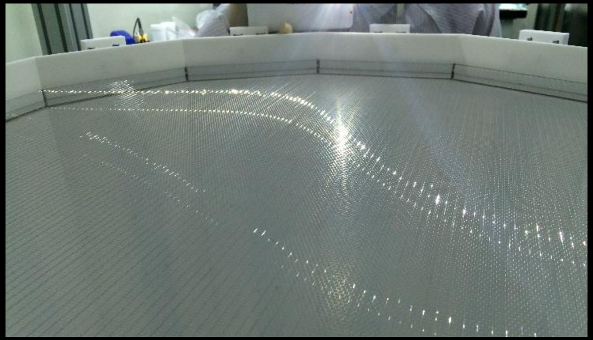
- 3D reconstruction and fiducialization
- Good ER/NR rejection
- Calorimeter capable of seeing a couple of photons/electrons

PandaX-I（2009-2014），120 kg



PandaX-II (2015-2019)





580kg

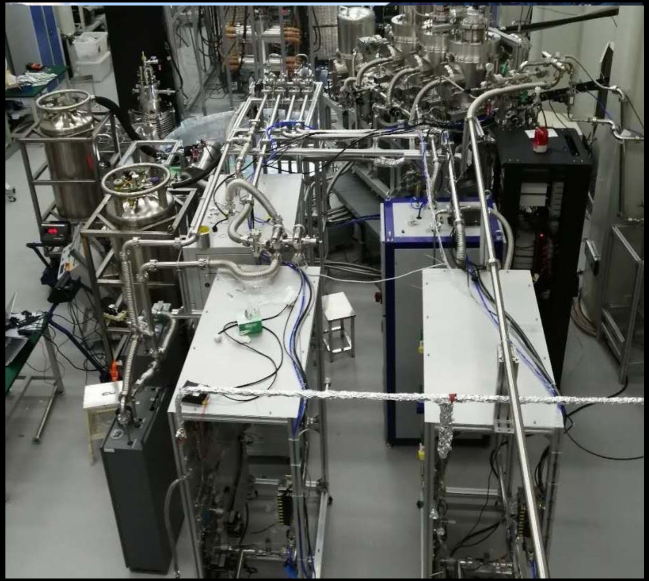
120kg

2018.4 water tank construction

2019.8 PandaX-4T instllation

2020.5 liquid xenon filling

2020/6-2020/11 integration tests



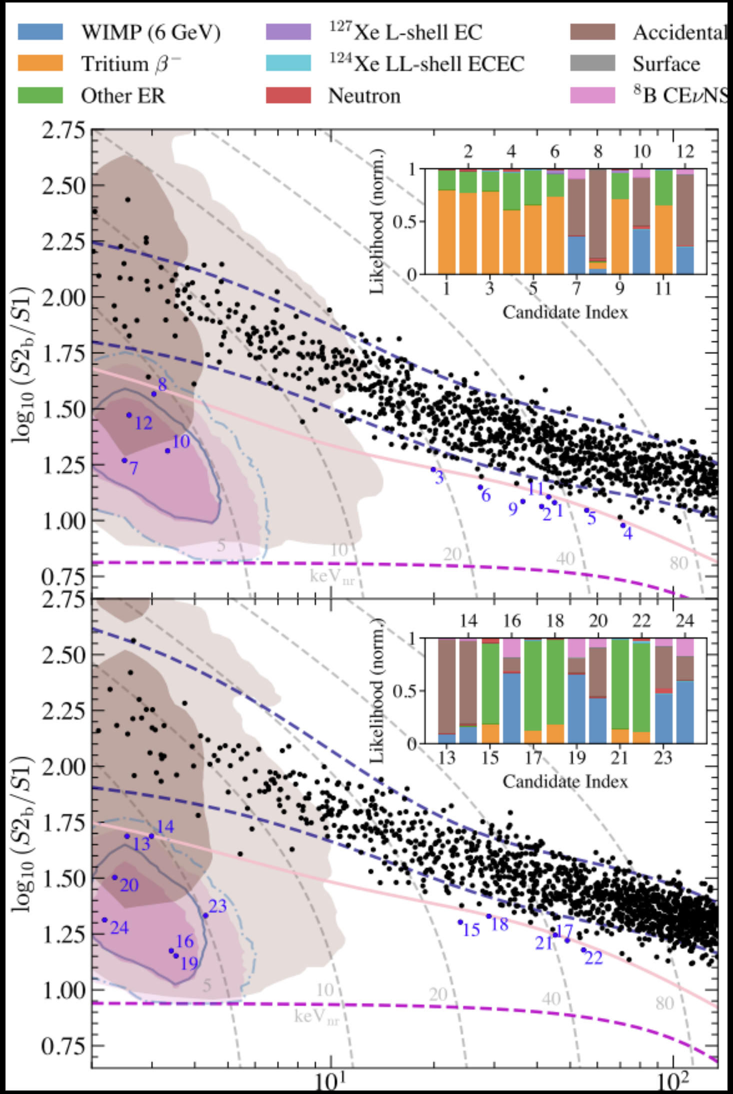
Data taking interleaved with surgeries and lab construction

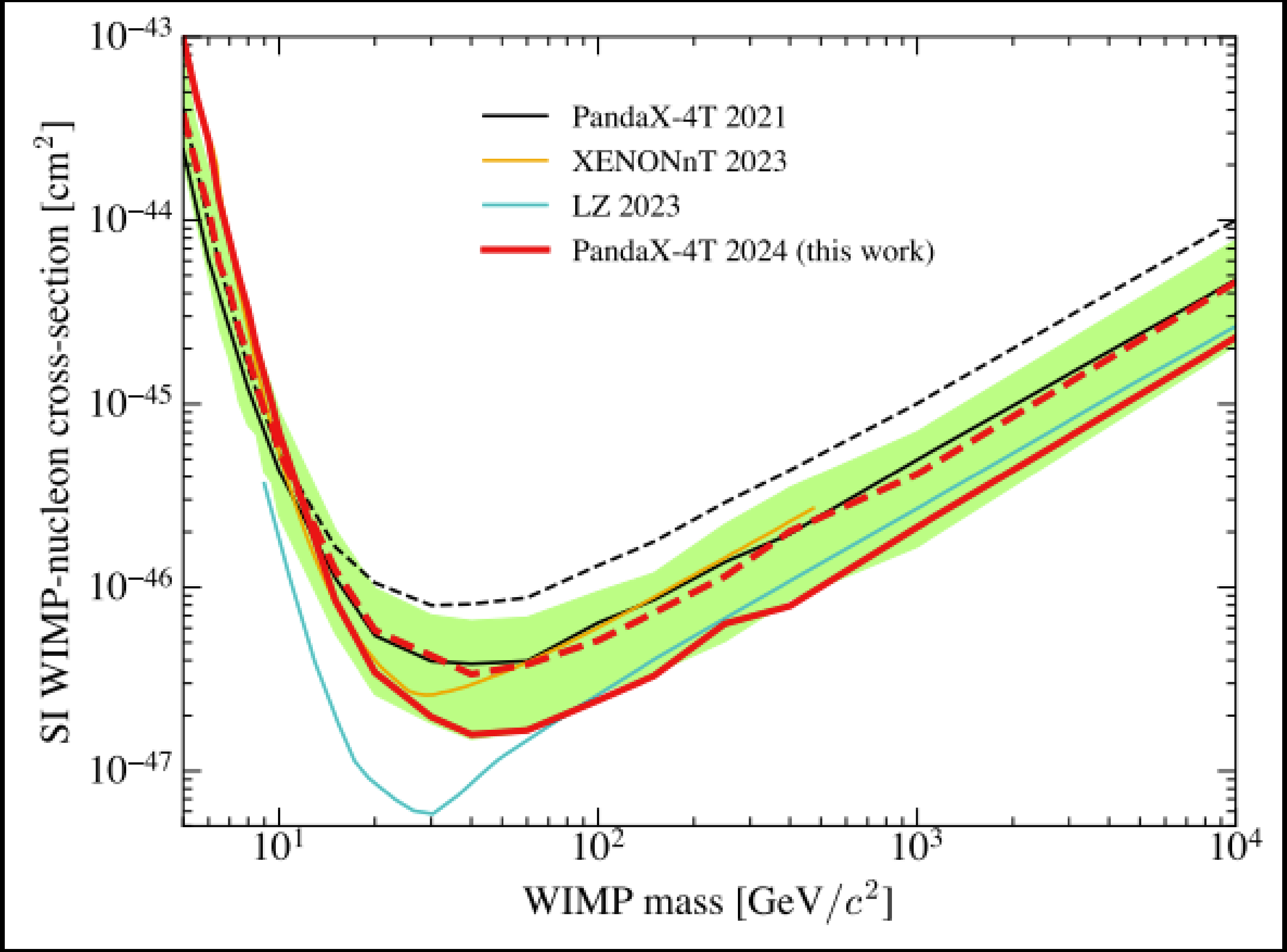
Time	Activity
2020/11-2021/04	commissioning (Run0) 95 days
2021/07-2021/10	tritium removal xenon distillation, gas flushing, etc.
2021/11-2022/05	physics run (Run1) 164 days
2022/09-2023/12	CJPL B2 hall renovation xenon recuperation, detector upgrade
2024/01-2024/07	resuming operation
Current status	Shutting down on April 15, 2026 (Run2)

Background: toughest battle

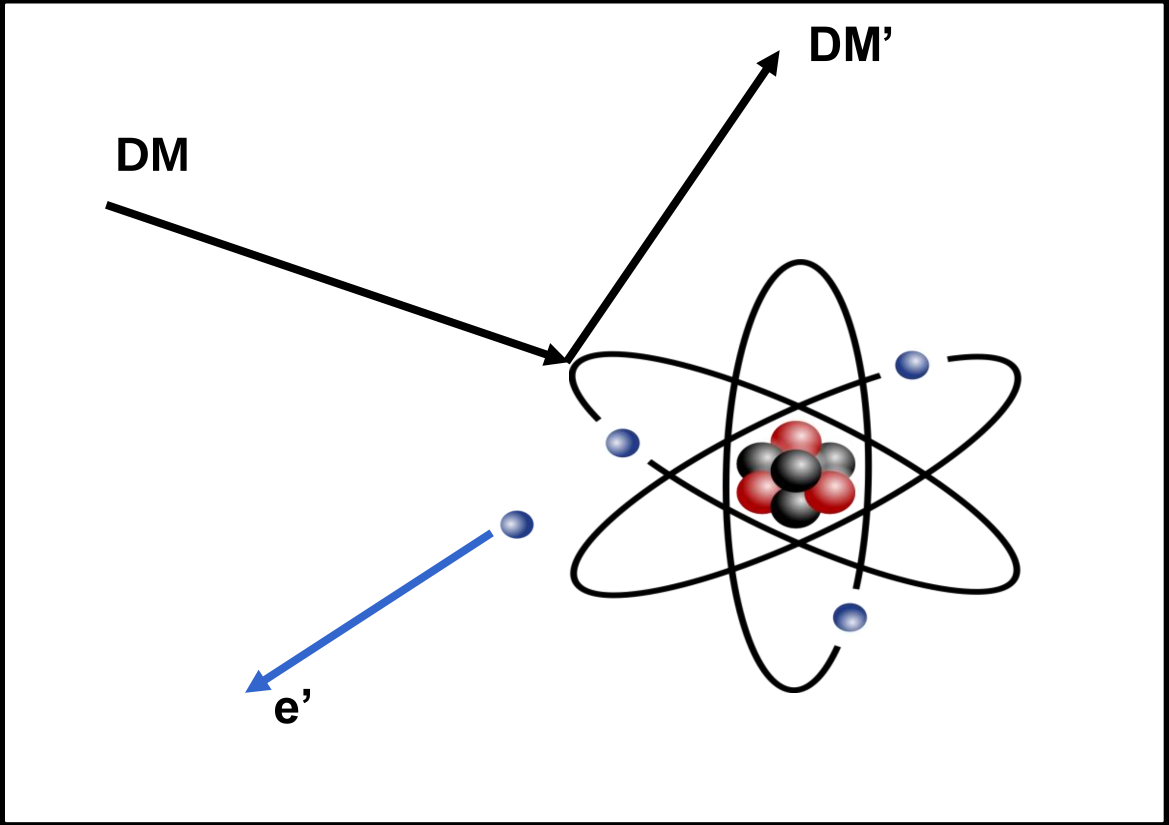
Similarly: ^{85}Kr ~ 10 atom/kg, ^{222}Rn ~ 1 atom/kg in xenon

1.5 ton*year Exposure

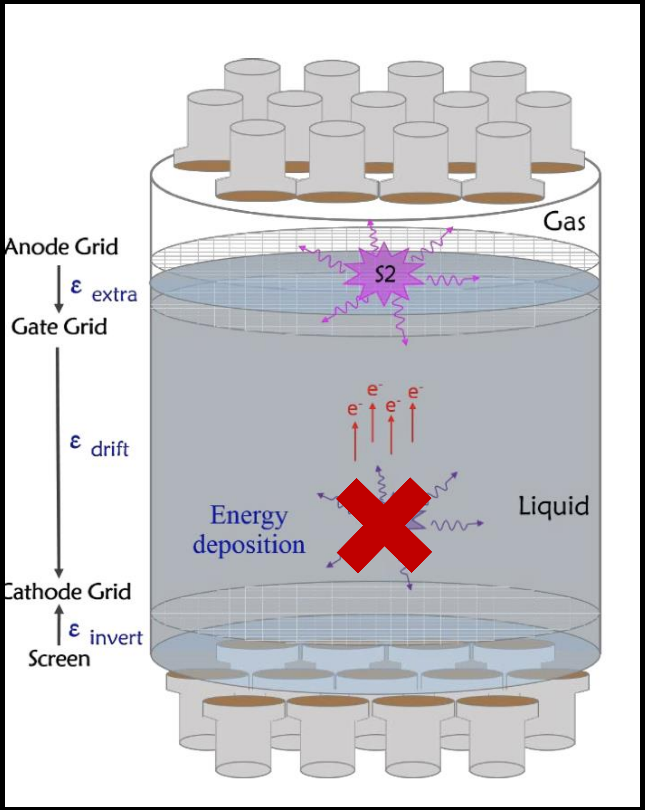




Low mass DM detection techniques



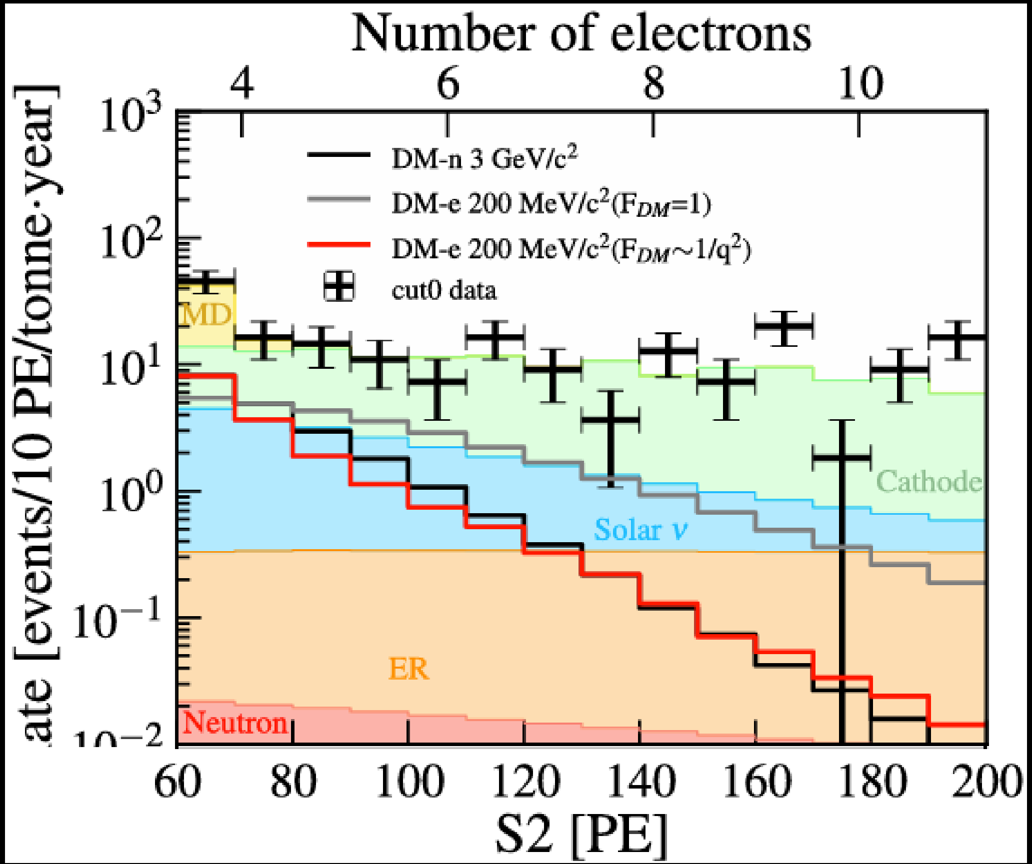
+

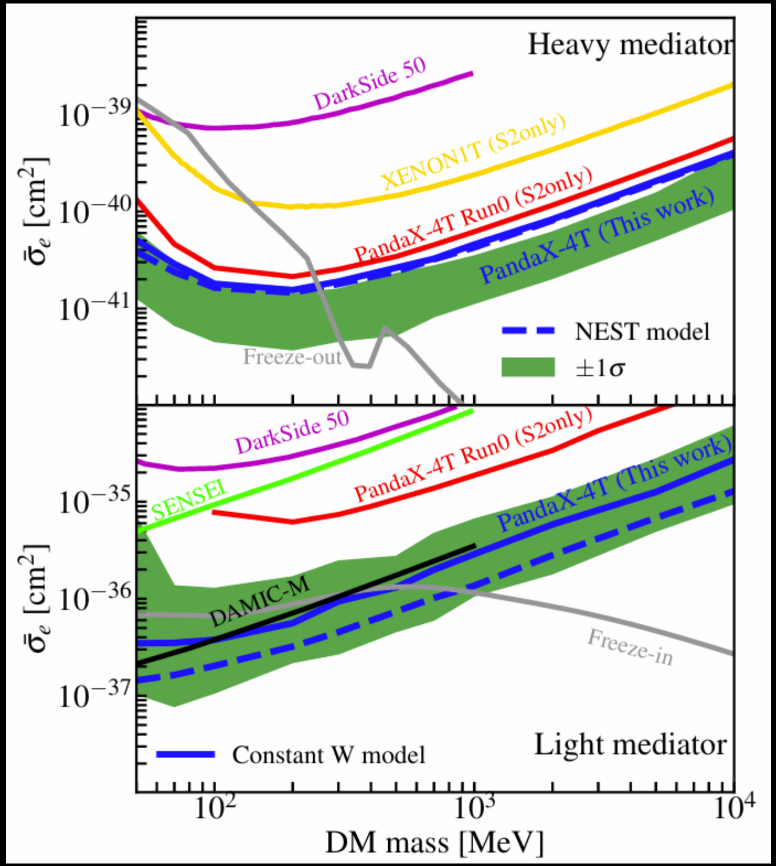


Atomic inelastic scattering: accessing full DM KE-binding. Essig, Mardon, Volansky, PRD 85, 076007 (2012)

Ionization-only (S2-only in LXe)

S2-only approach

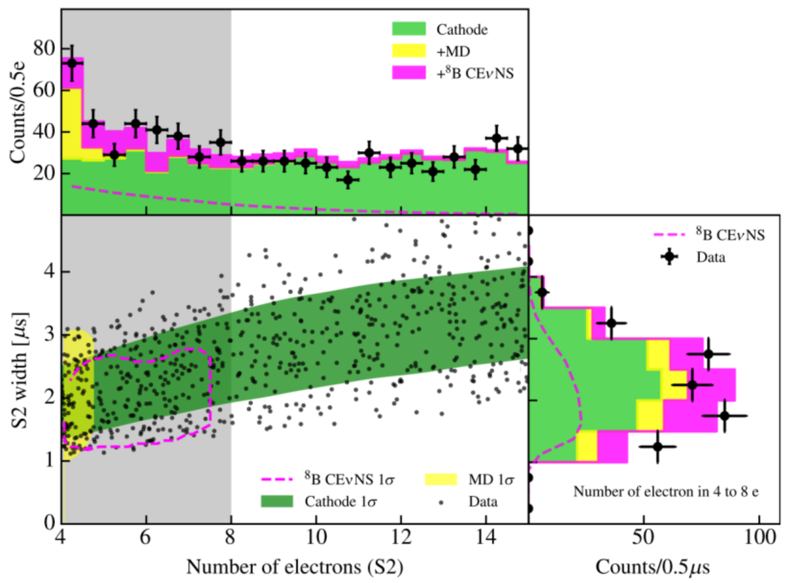


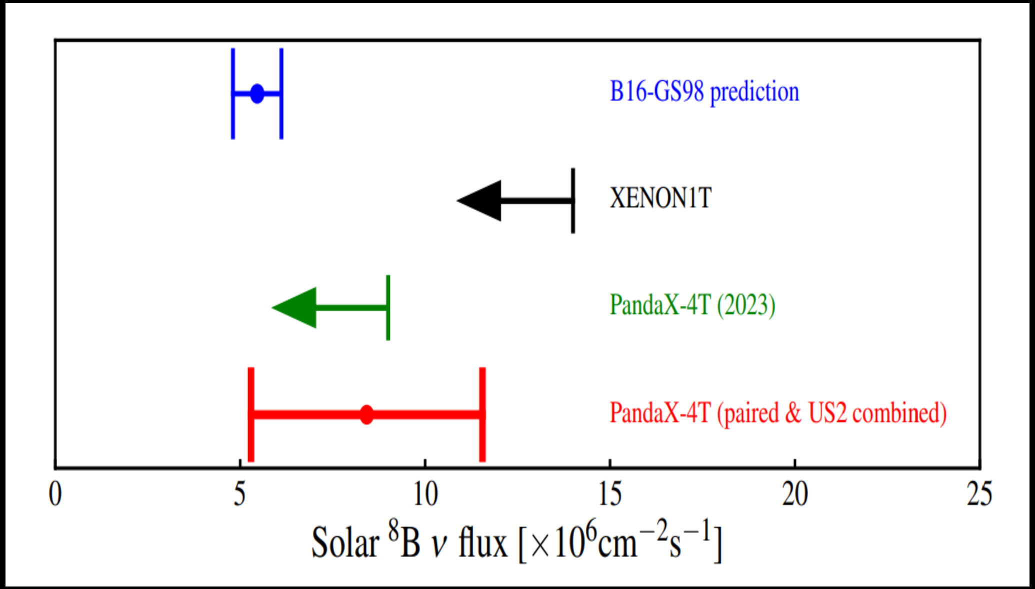


PRL 130, 261001 (2023)
PRL 135, 211001 (2025)

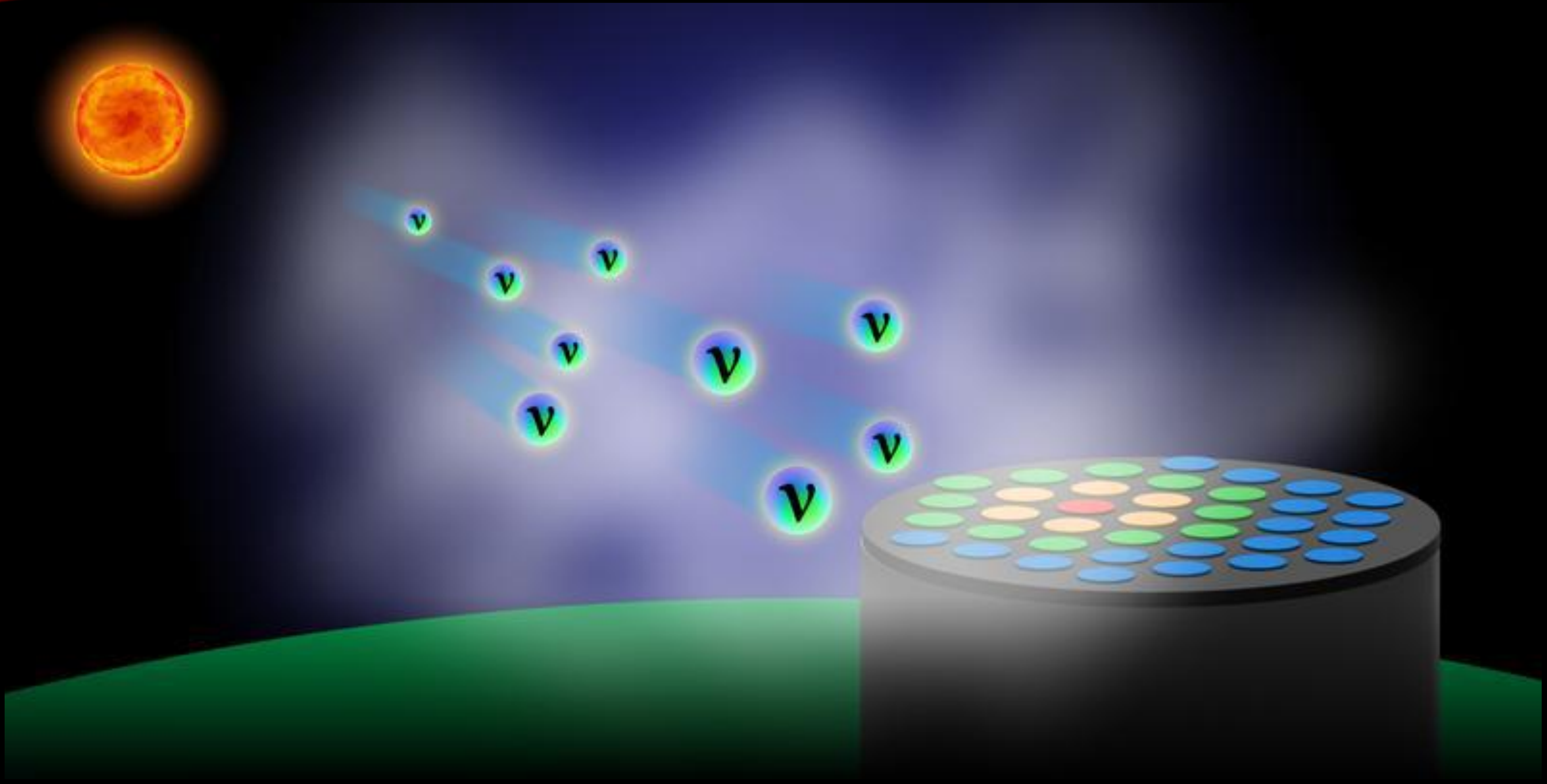
B8 neutrino CEvNS

- Greatly benefit from S2-only data (~ton×year)
- Best-fit B8 events: 75±28 (S2 only) and 3.5±1.3 (S1-S2 paired)
- Reject background-only hypothesis with significance of 2.64σ
- PRL 133, 191001 (2024), Editors' Suggestion
- XENONnT result in the same issue of PRL (191002), similar significance



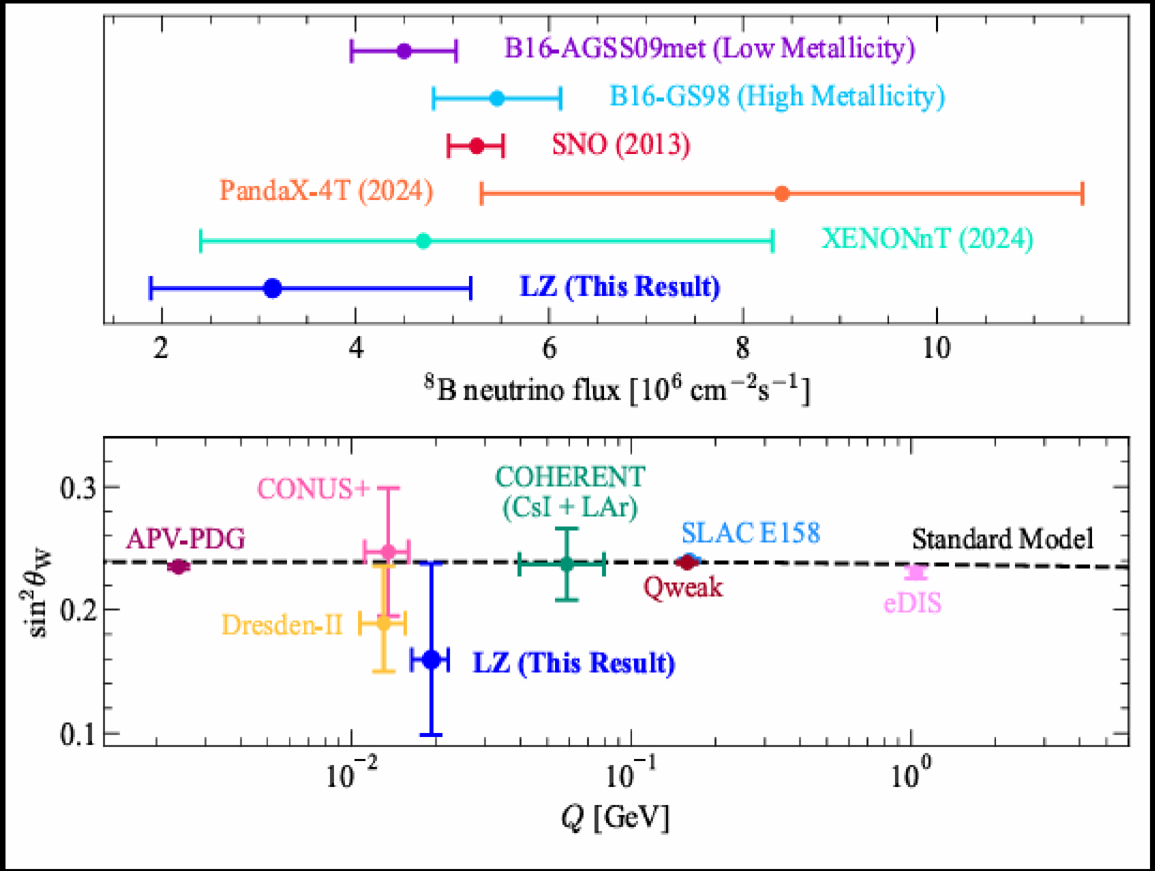


Physics Magazine highlights of the year 2024

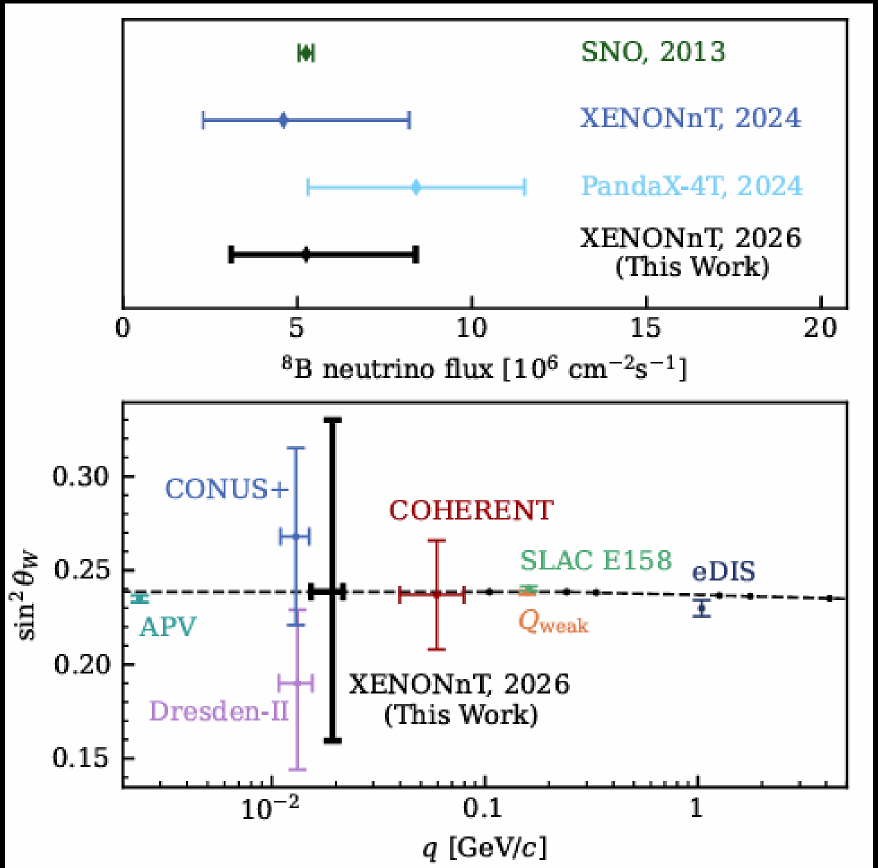


LZ/XENON latest results

LZ: 2512.08065

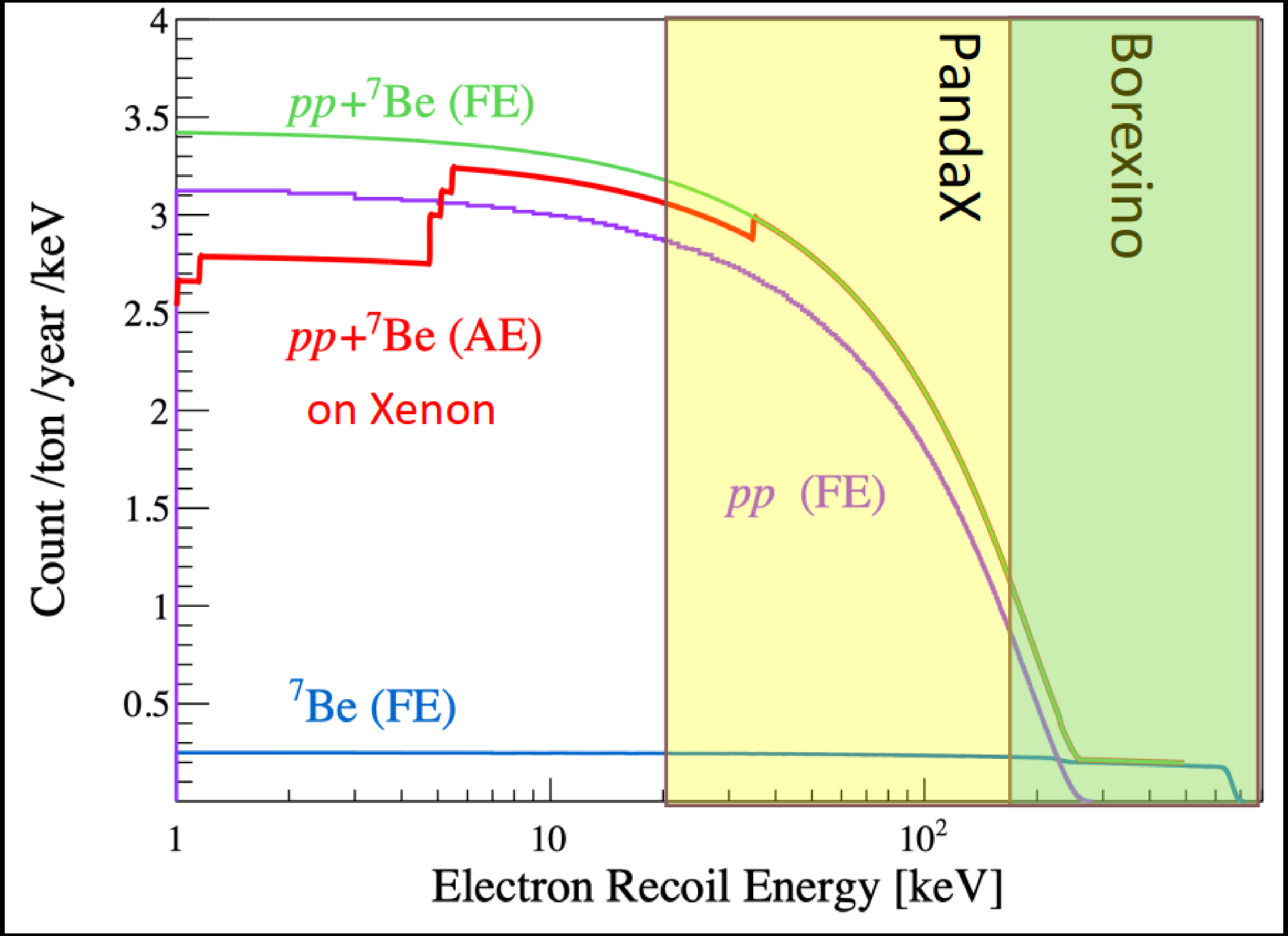


XENON: 2604.06002



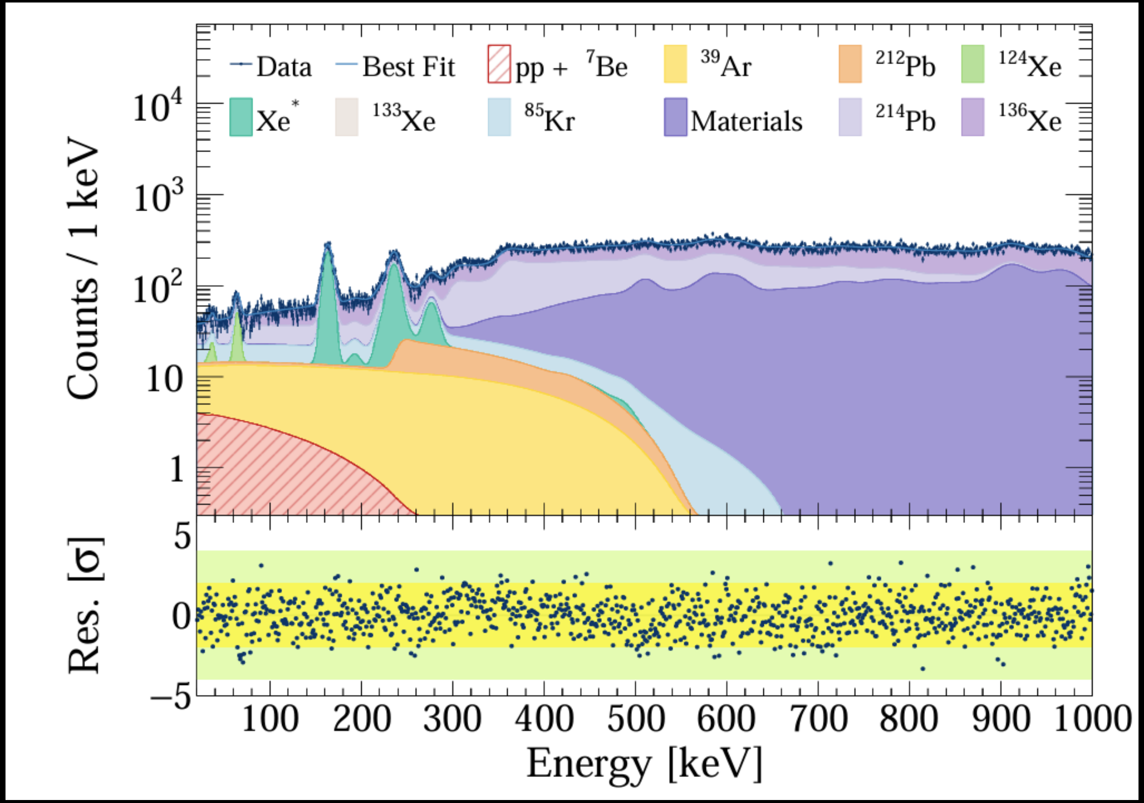
A platform to study neutrino interactions + astrophysical neutrino observatory

Solar pp neutrino – unique low E window



Recent release @ Neutrino 2026

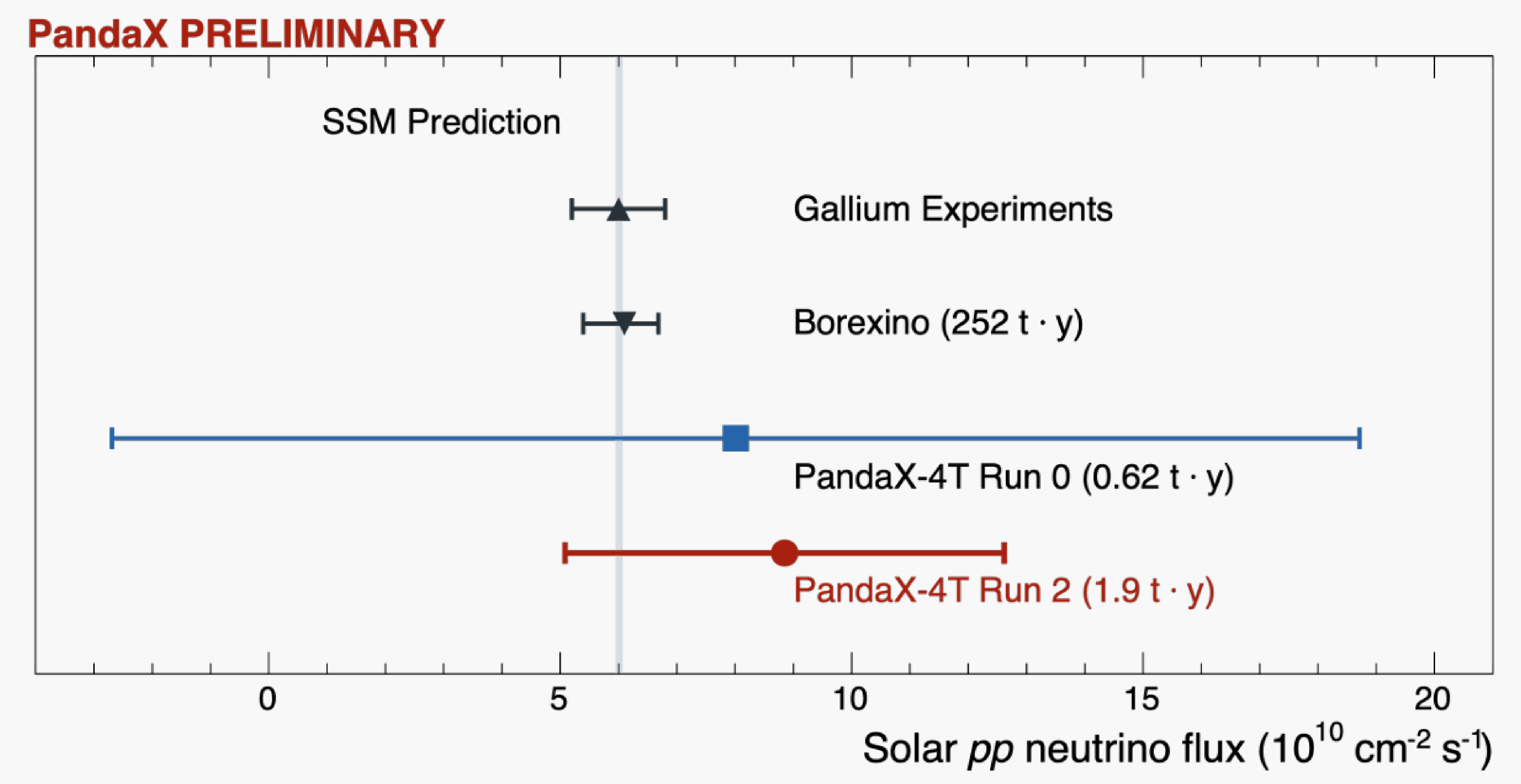
- 1.9 ton*year data (Run 2)
- Blind analysis with multi-step unblinding procedure
- arXiv:2607.02405



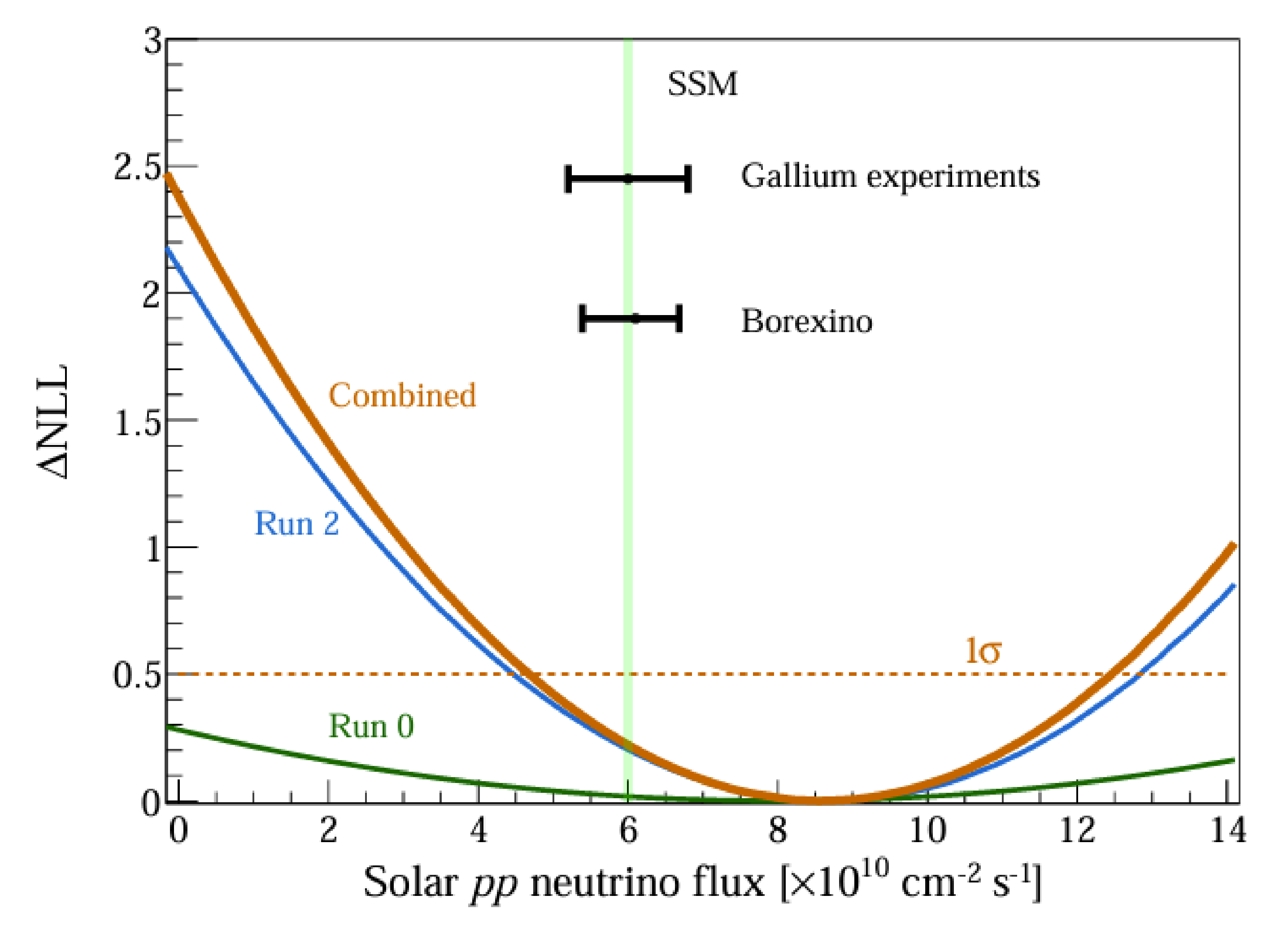
Systematic uncertainty table (on μ)

Component		Contribution
Overall efficiency		0.26
Signal selection		0.04
Detector response		0.13
Background	^{39}Ar	0.39
	^{85}Kr	0.38
	Material	0.36
	^{136}Xe	0.20
	^{124}Xe	0.15
	^{212}Pb	0.14
	^{133}Xe	0.09

Recent release @ Neutrino 2026



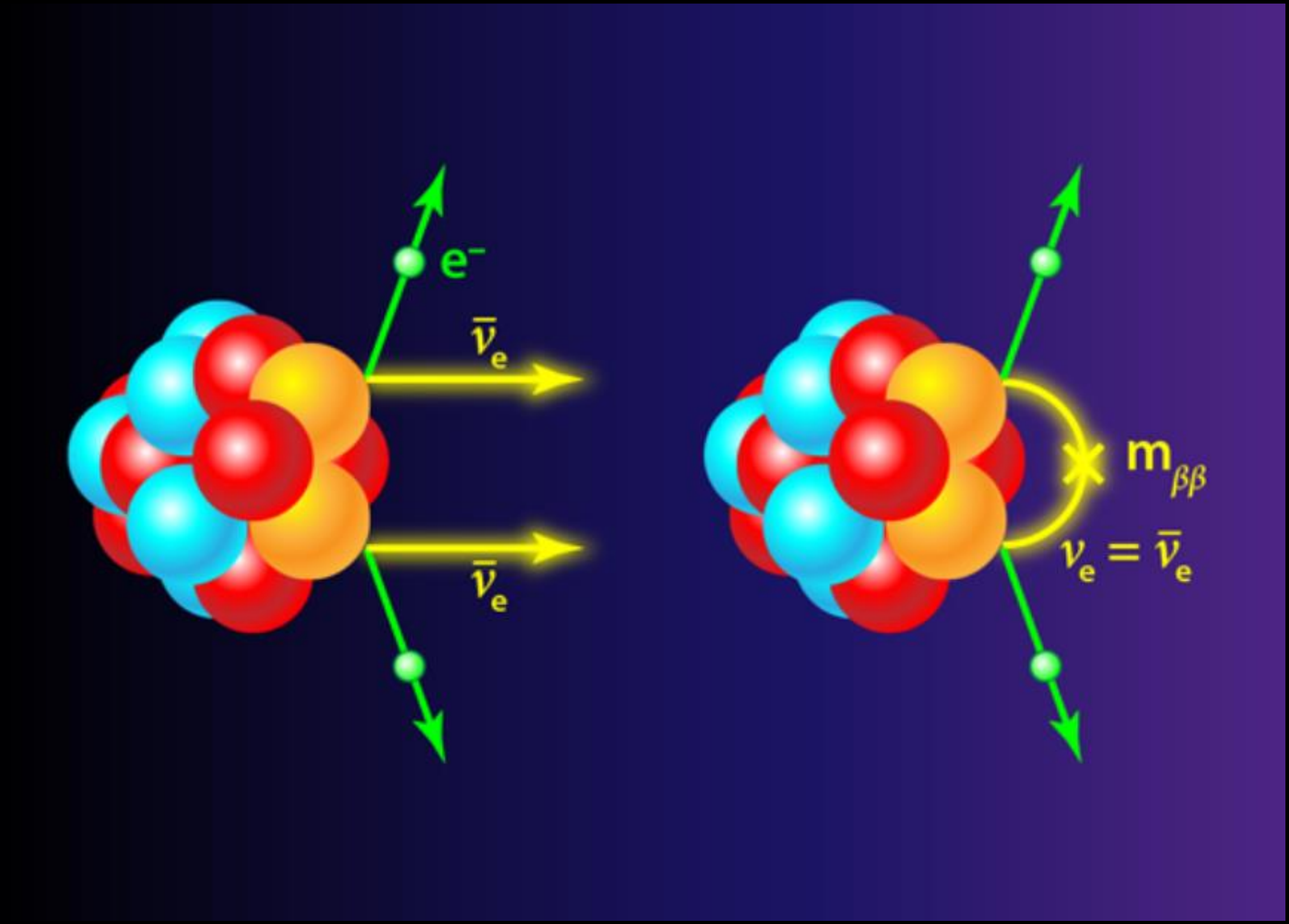
Recent release @ Neutrino 2026



“Bigger fish”: Majorana neutrinos

1937, Majorana

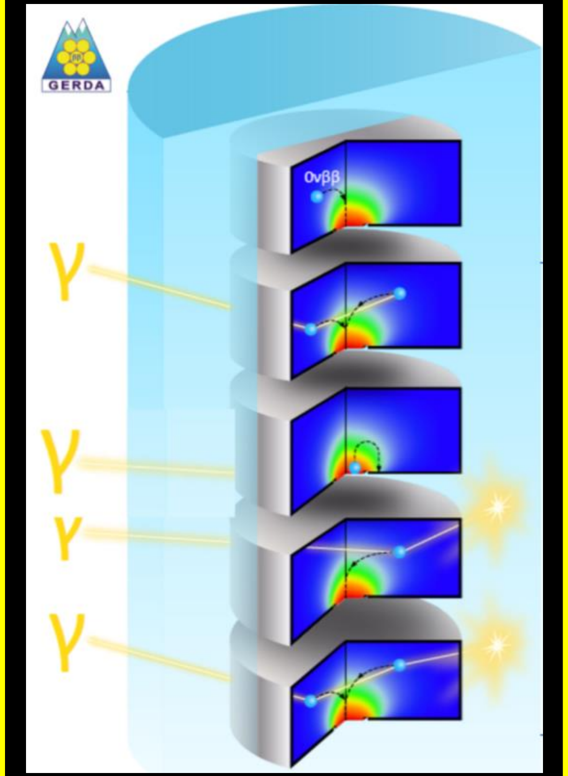
$$\bar{\nu} = \nu$$



$^{130}Te/^{100}Mo$

CUORE

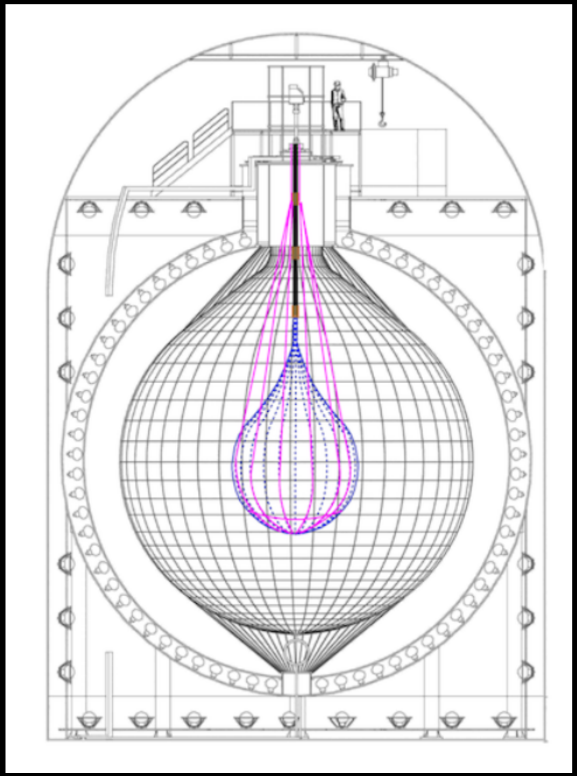
CUPID



^{76}Ge

LEGEND family

CDEX



^{136}Xe (8.9% natural abd.)

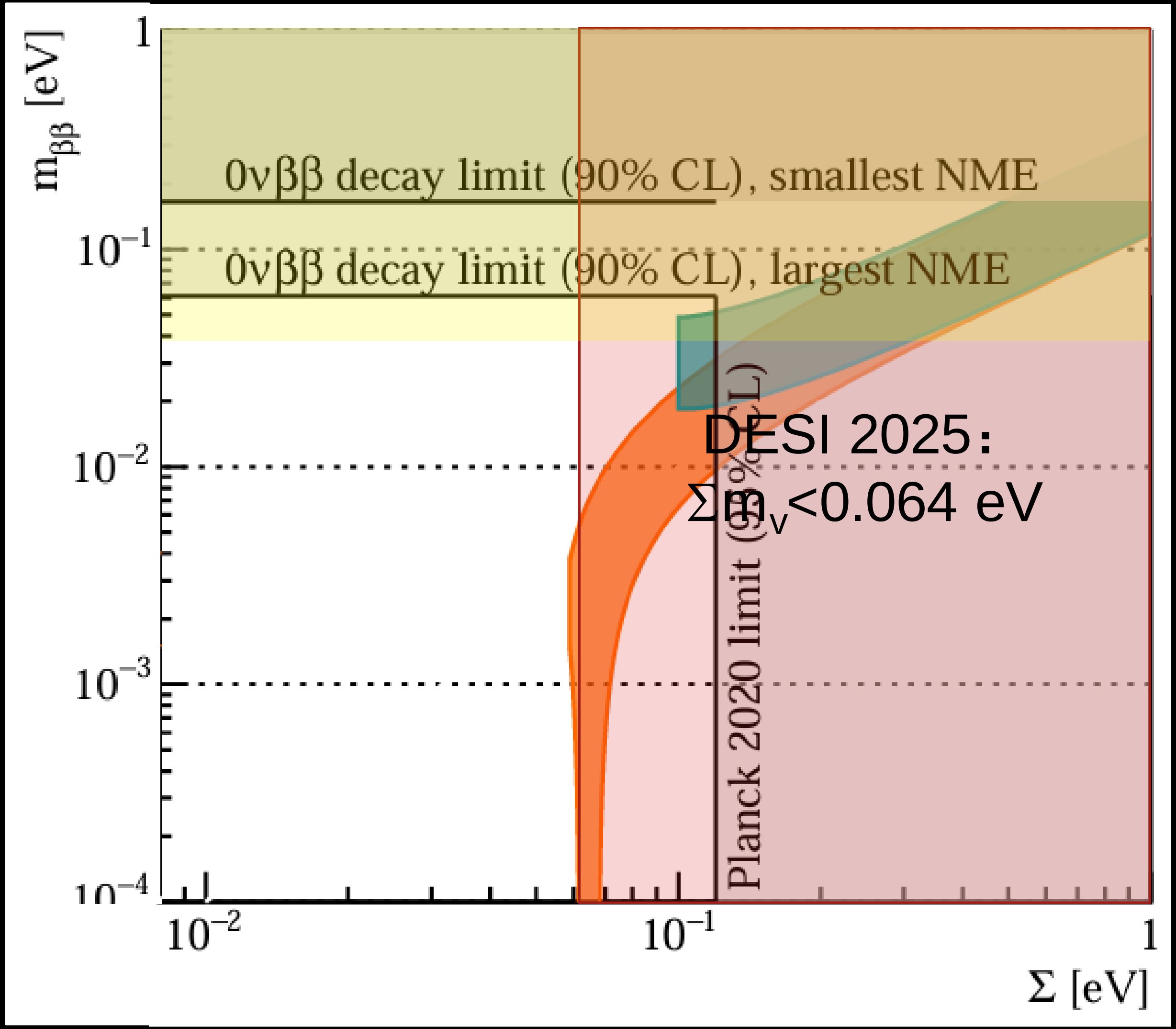
KamLAND-ZEN

Doped LS

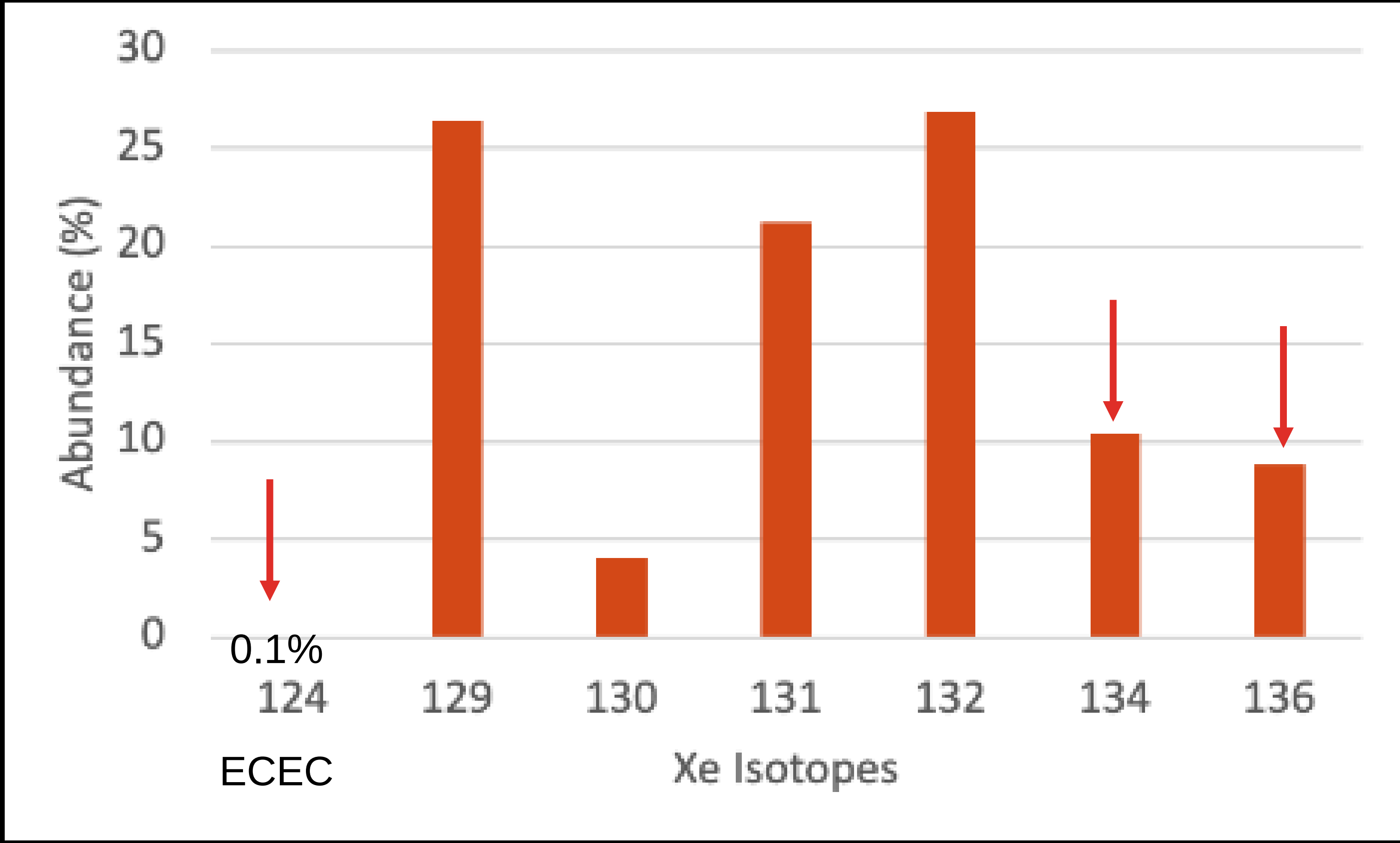
EXO/nEXO

LXe TPC

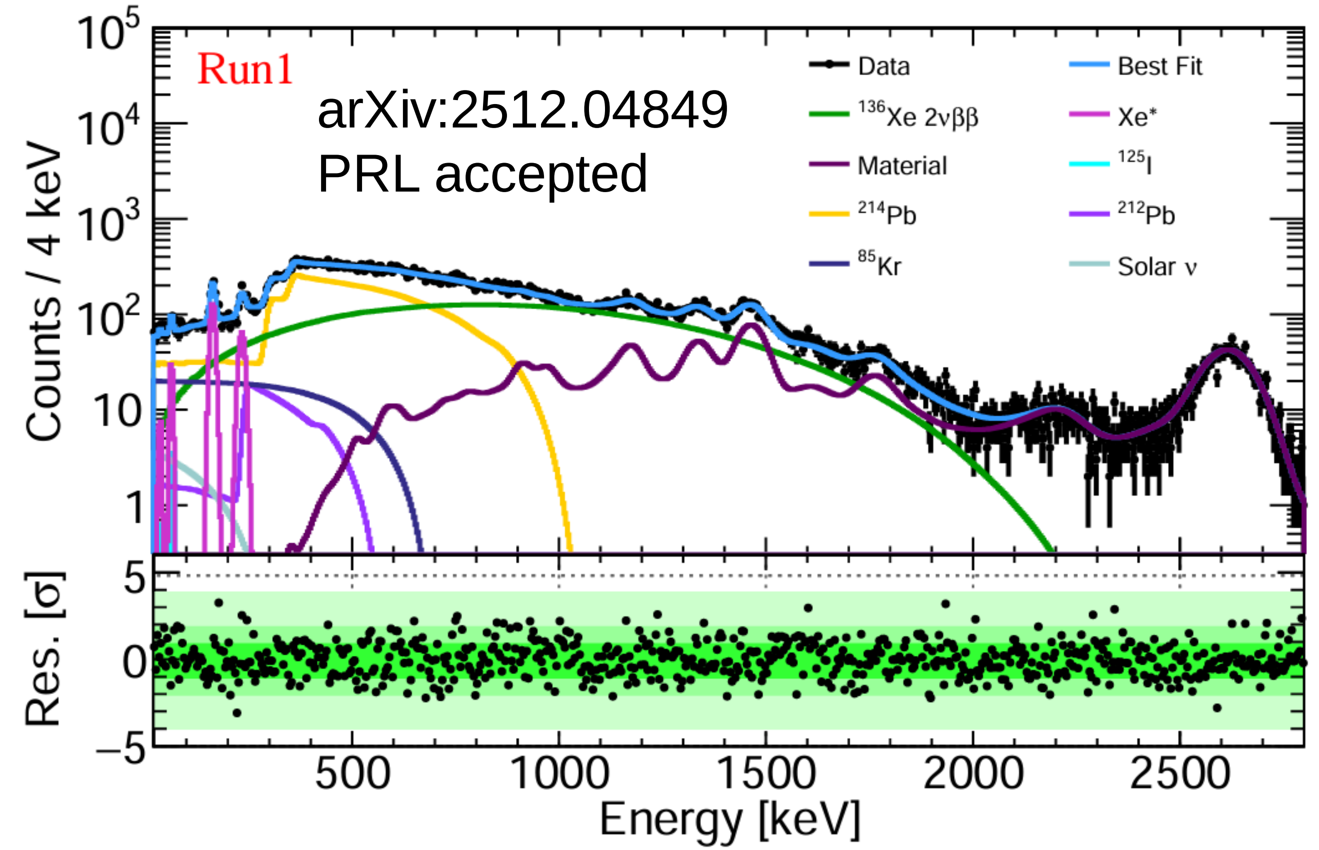
Particle Experiments vs Cosmology

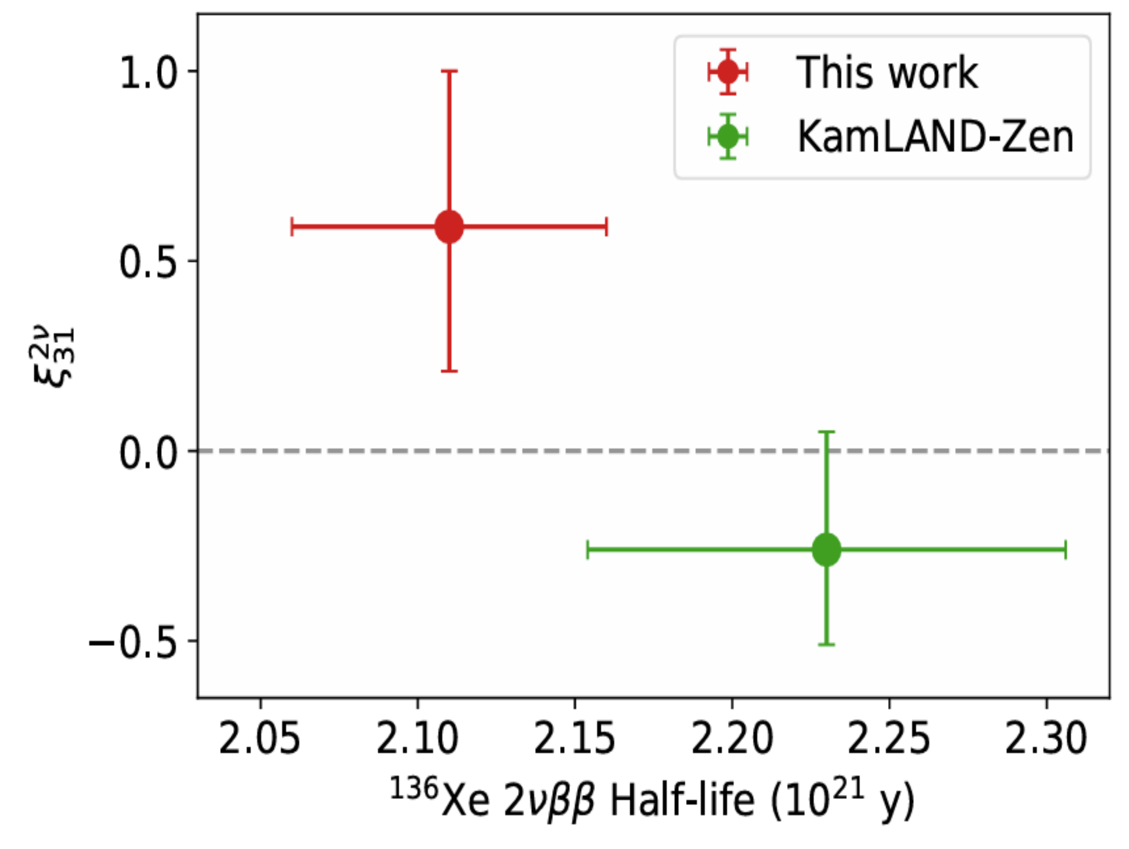


Feature of Natural Xenon



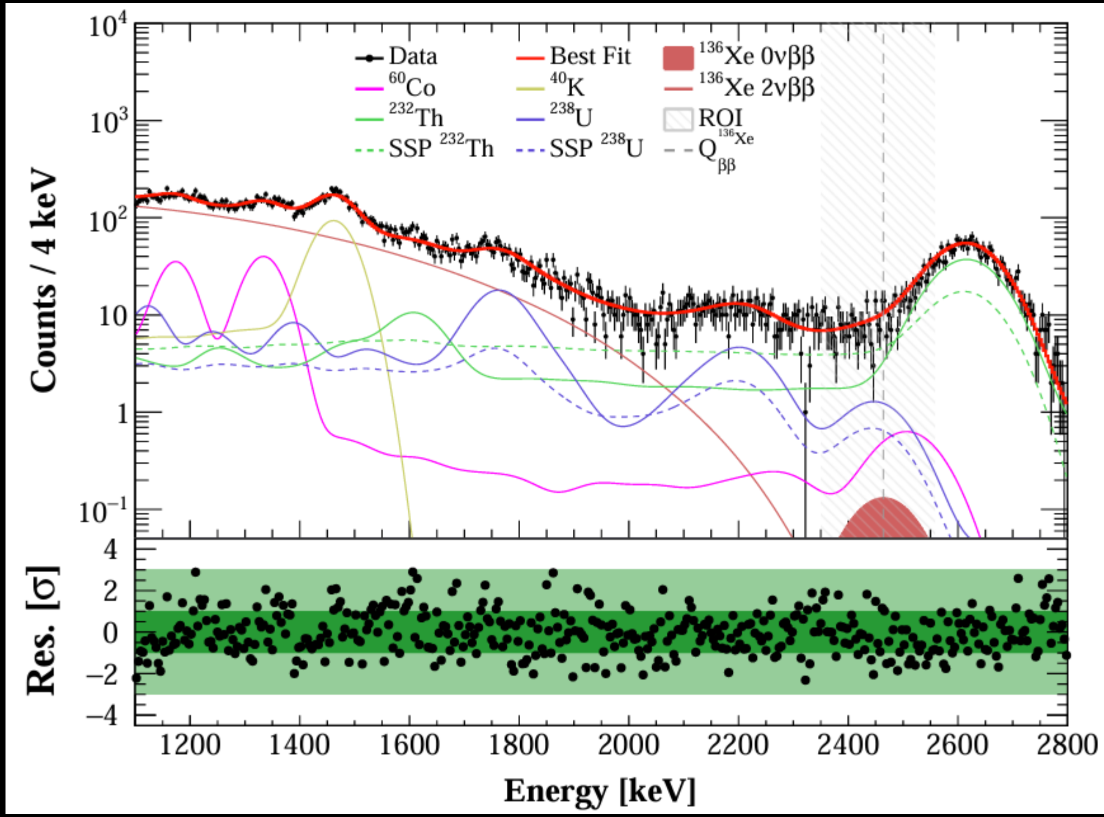
Most accurate Xe136 2vbb (rate/spec)!

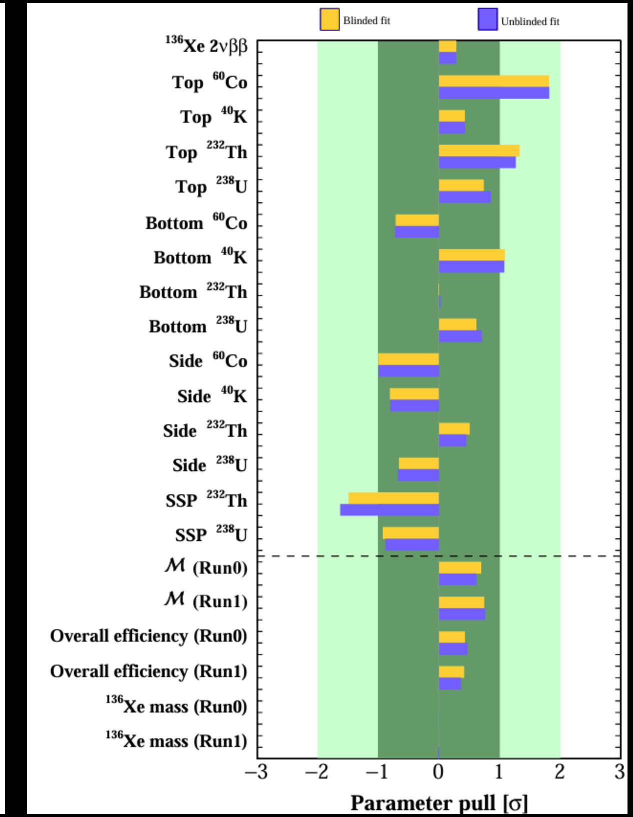




39.1 kg×year of Xe136, best fit: 54k events!

Search for Xe136 0vDBD





arXiv:2412.13979

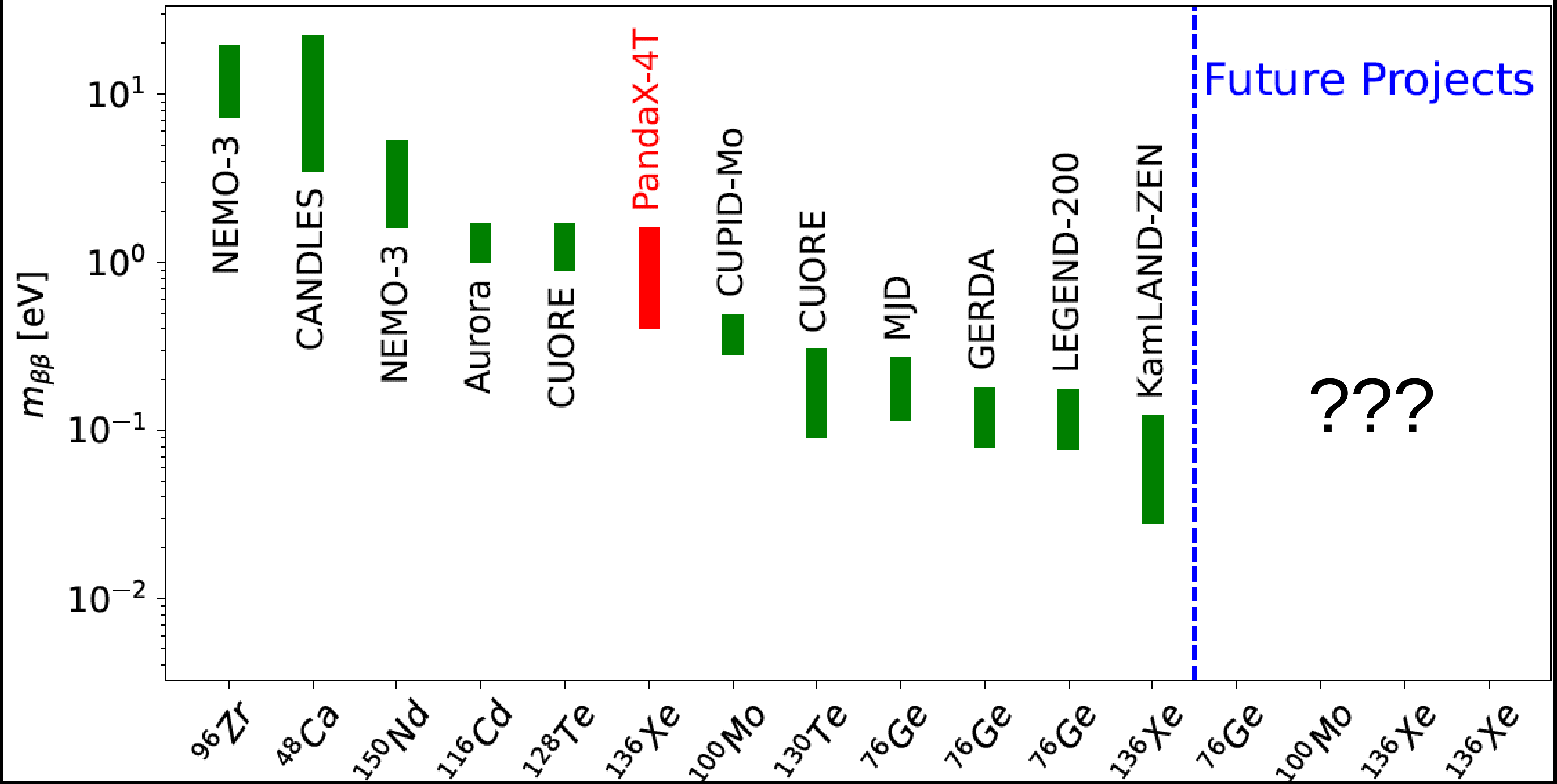
Lifetime

$> 2.1 \times 10^{24}$year 90% CL

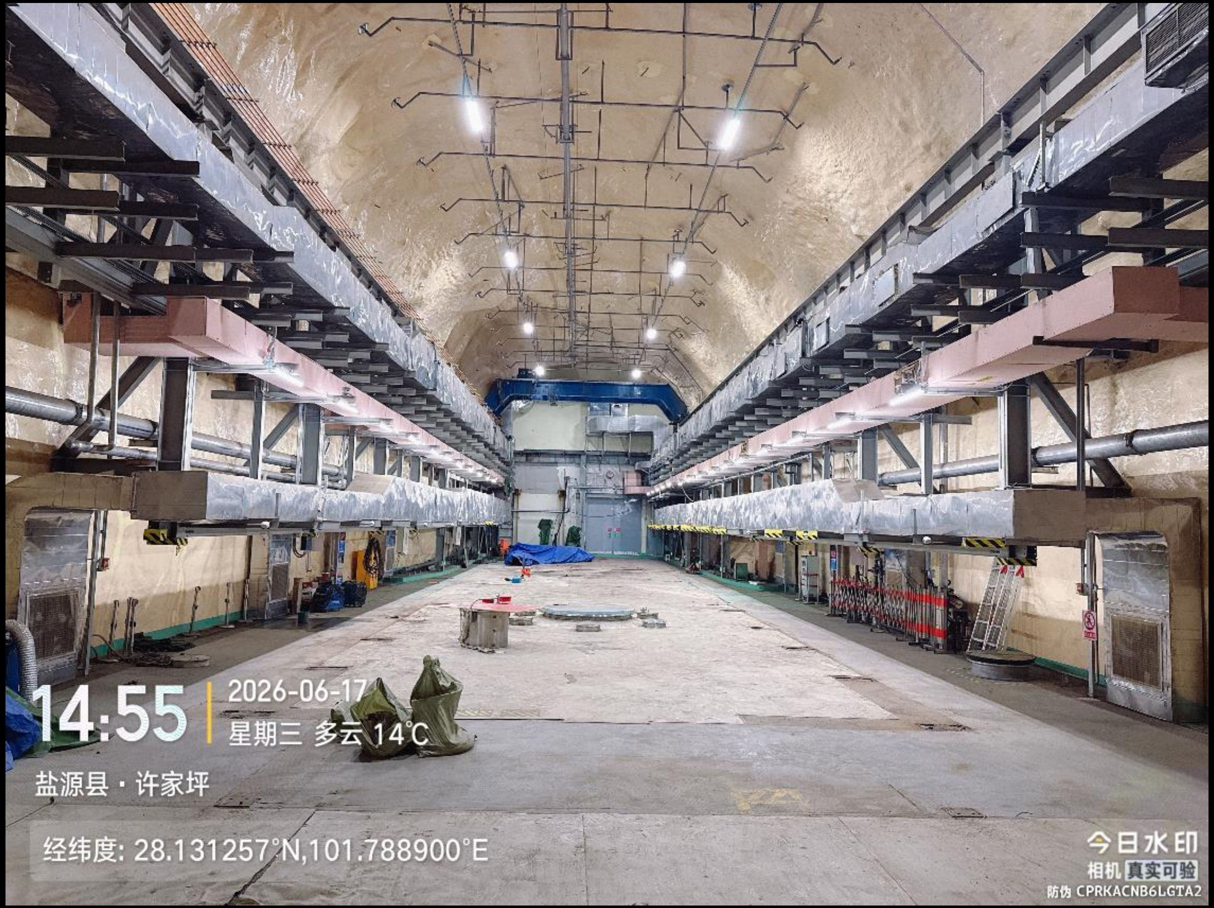
Median sensitivity

2.7×10^{24}year

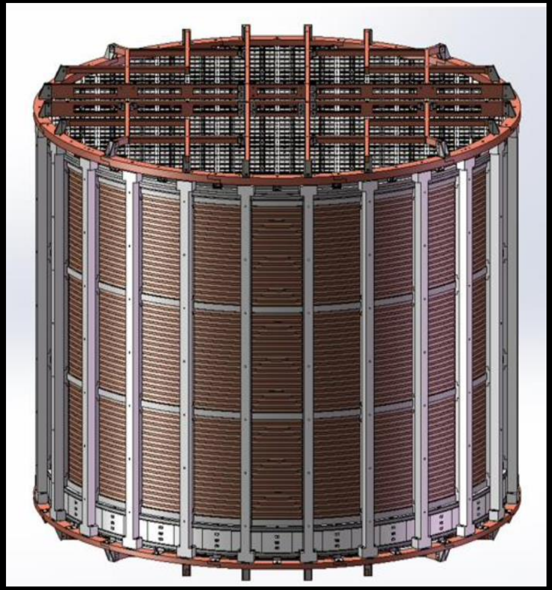
Race of Majorana neutrino mass



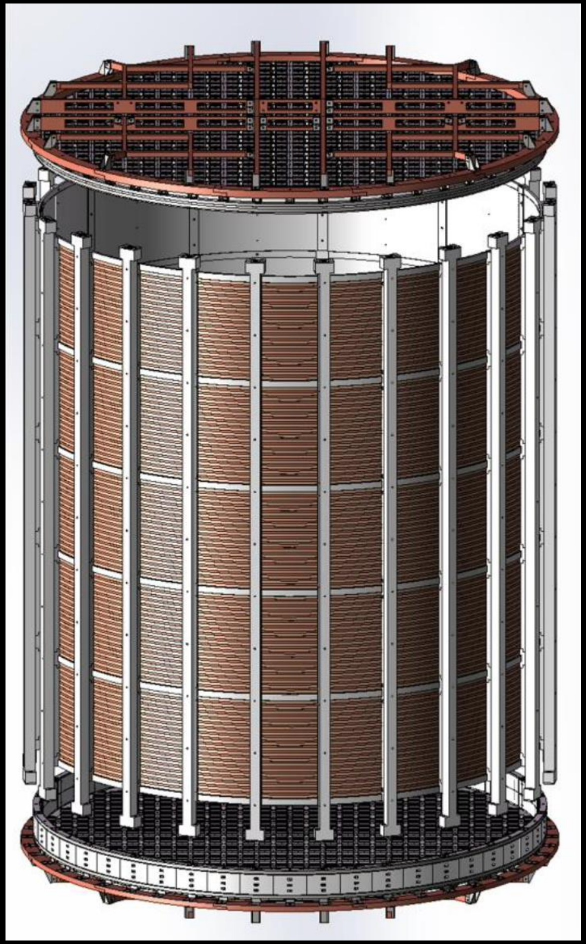
Bye bye PandaX-4T!



Next future

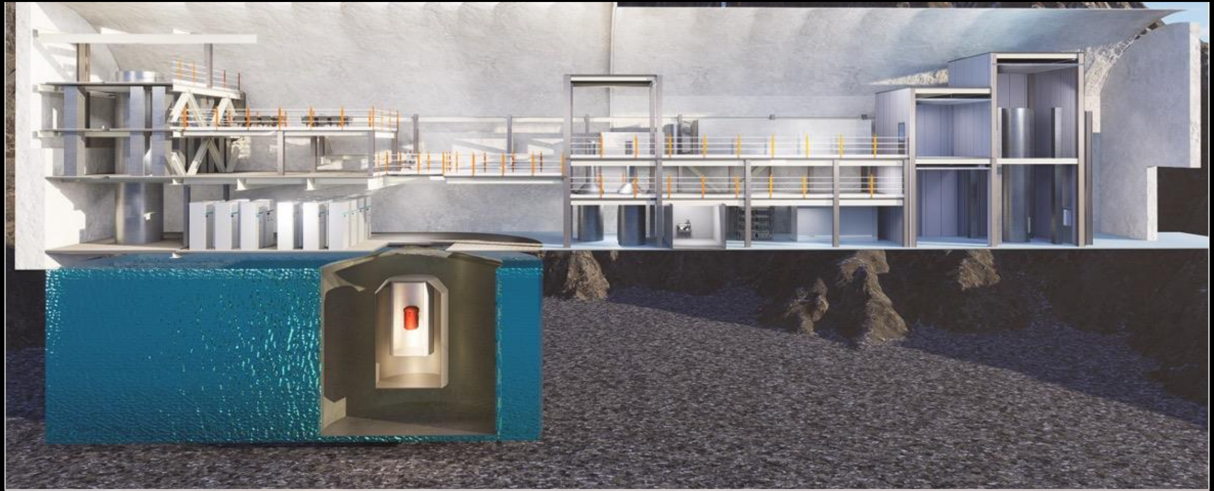


20T



43T

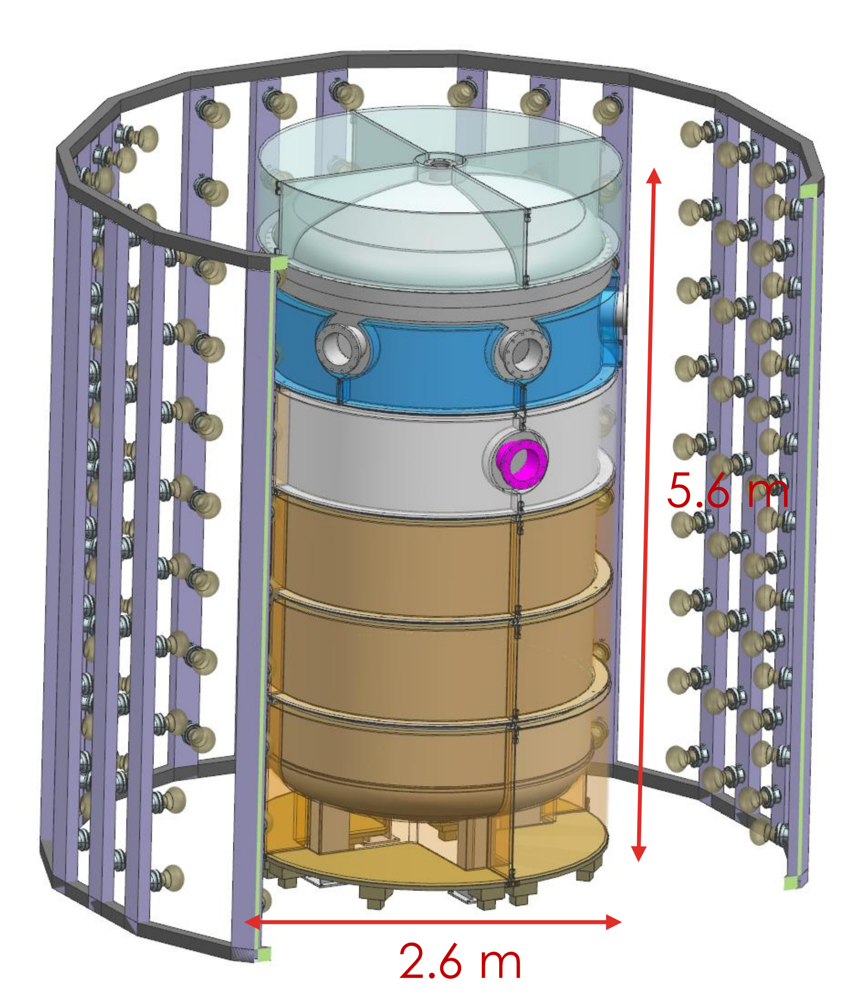
PandaX-20/40T @ CJPL

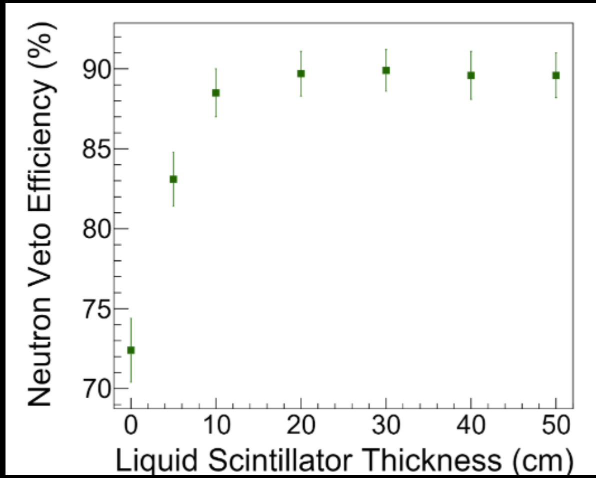


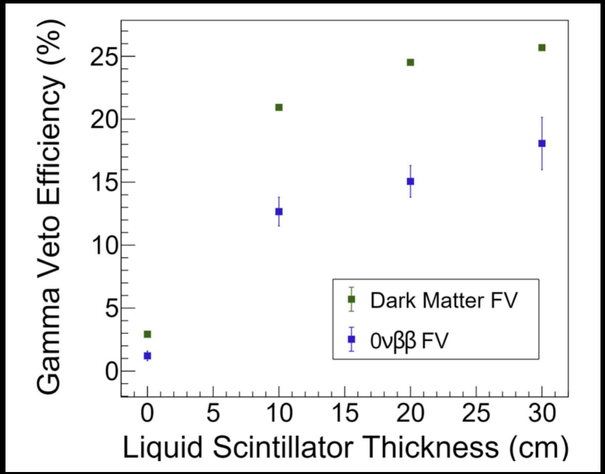
Transporting Xenon to CJPL

In fabrication

Veto detector(s) for PandaX-20T

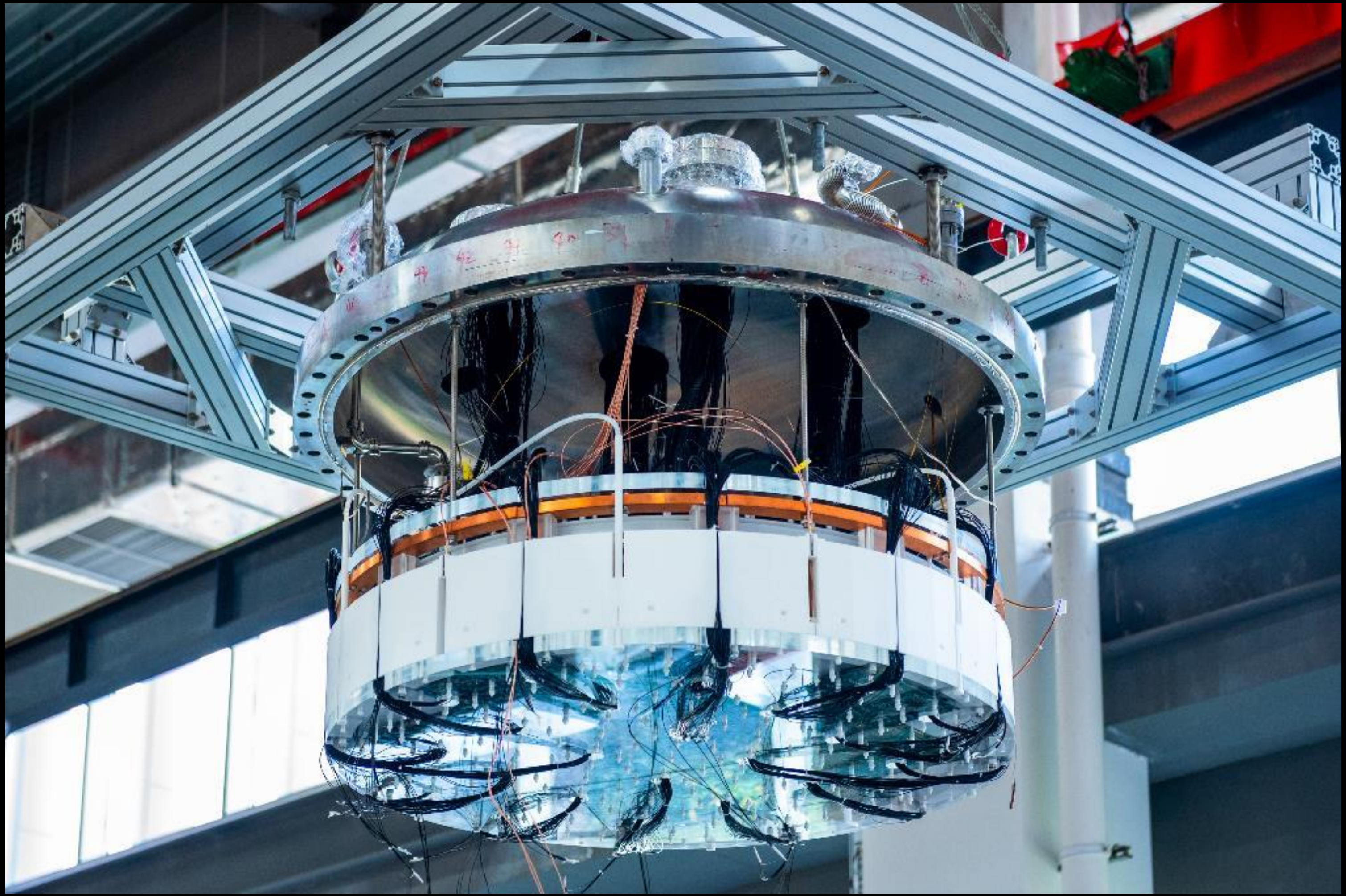




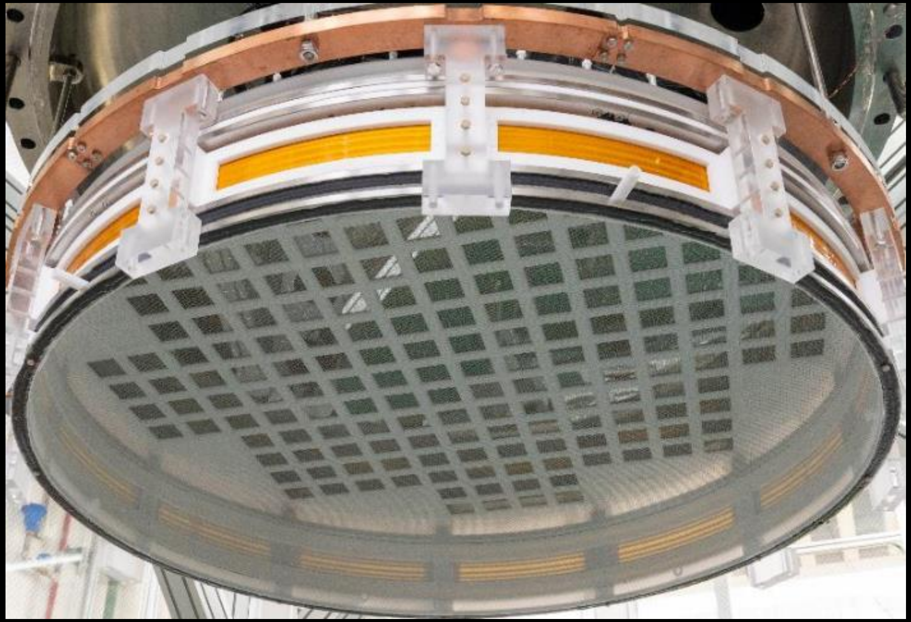


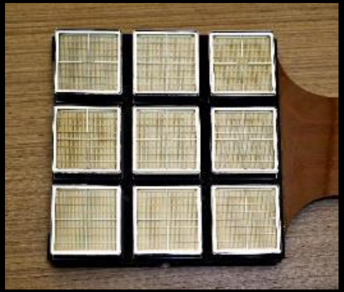
- 10 cm thickness JUNO liquid scintillator（LAB + PPO + bisMSB）in acrylic containers
- optical simulation: close to 90% neutron veto efficiency, about 20% gamma veto efficiency

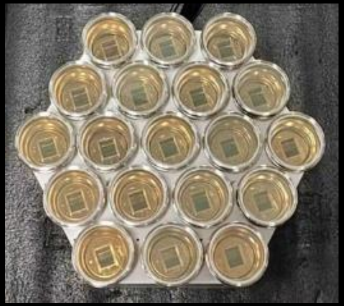
Time projection chamber(s)



Photosensors

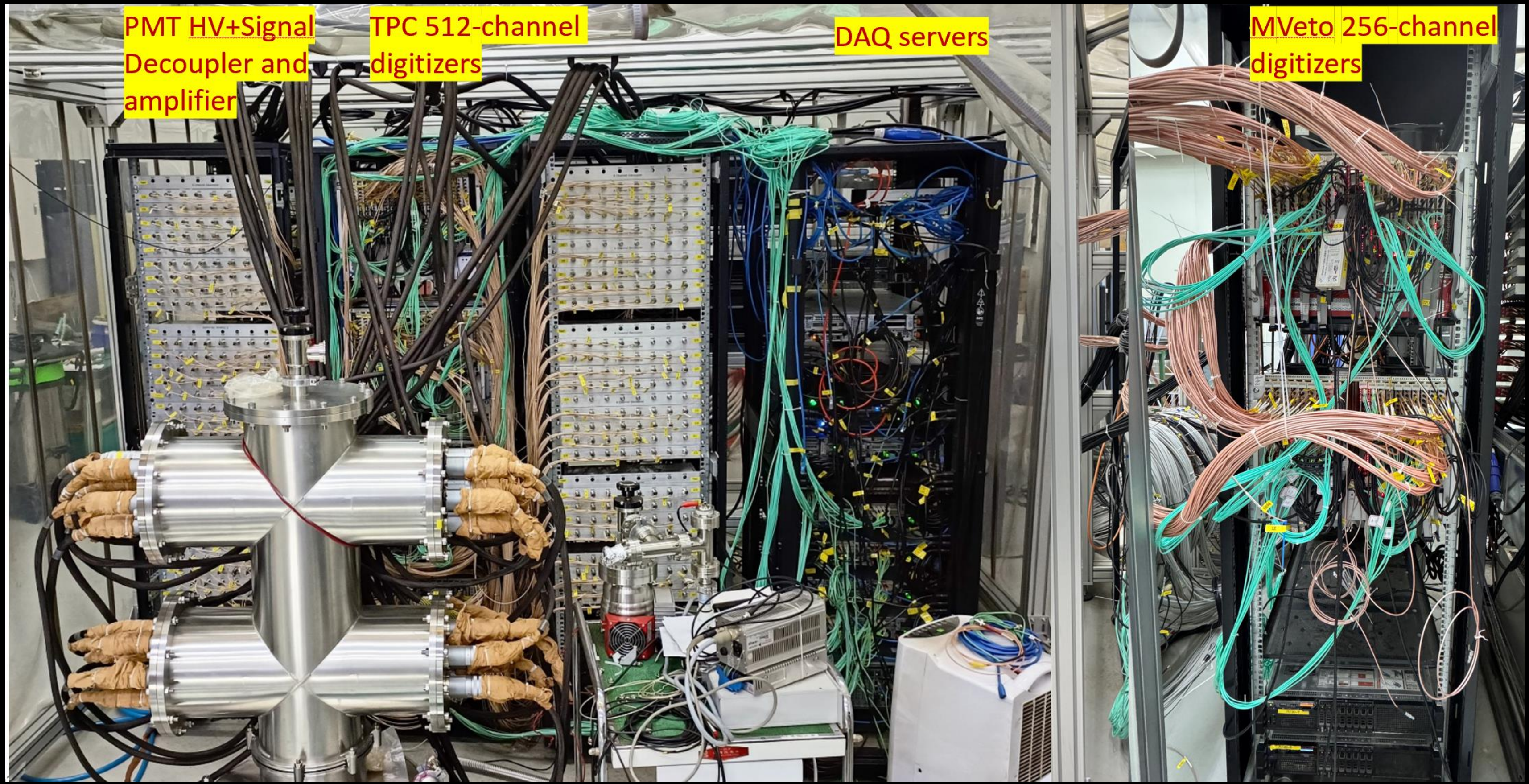






- Top and bottom PMT array design finalized
- Low-radioactivity R12699 PMTs under production, with delivery scheduled for 2026
- Assembly and system-level testing in progress

500 MS/sDigitizers



768-channel in PandaX-4T CJPL

3000-channel in TDLI

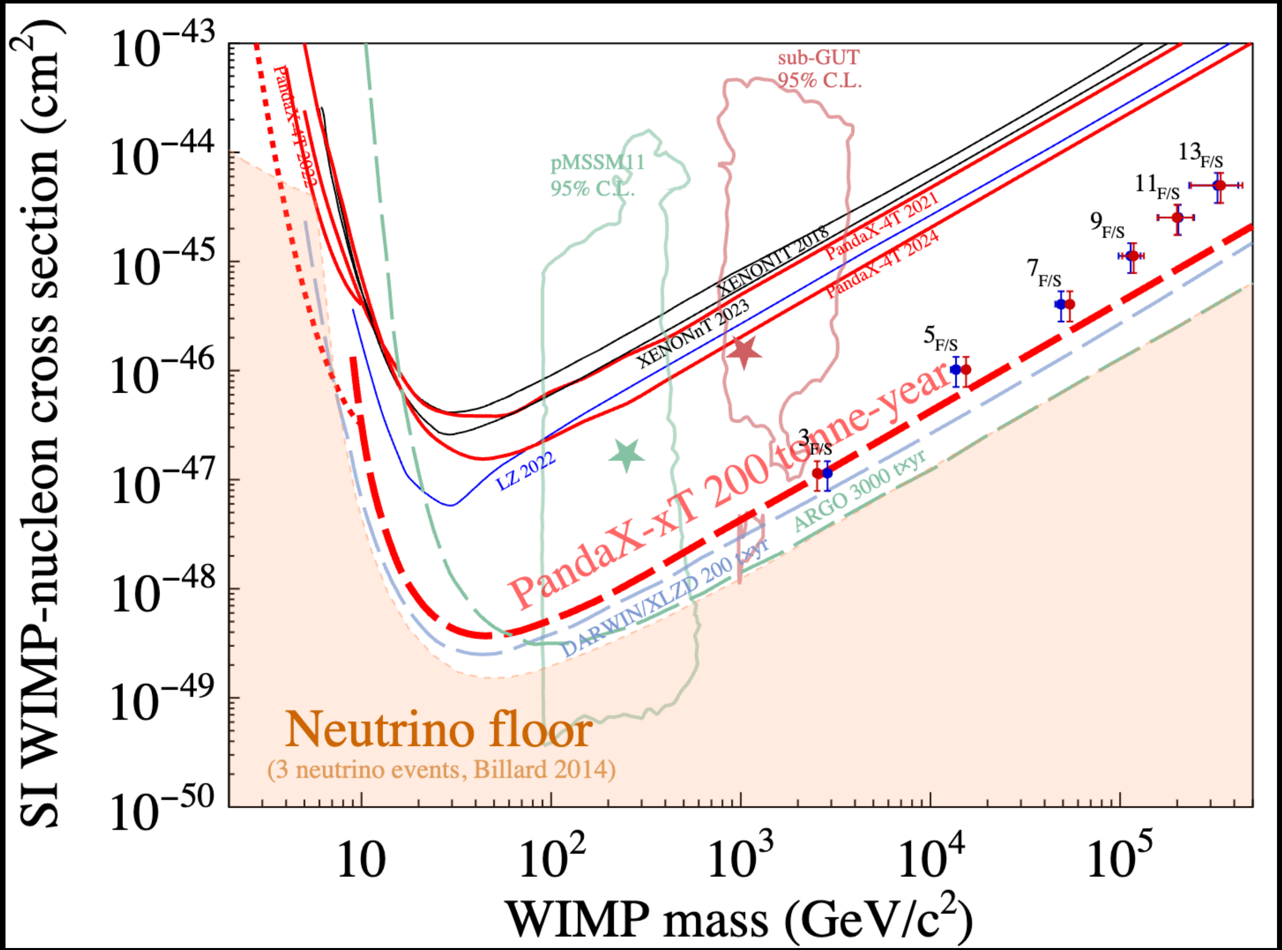
Cryogenics and recirculation

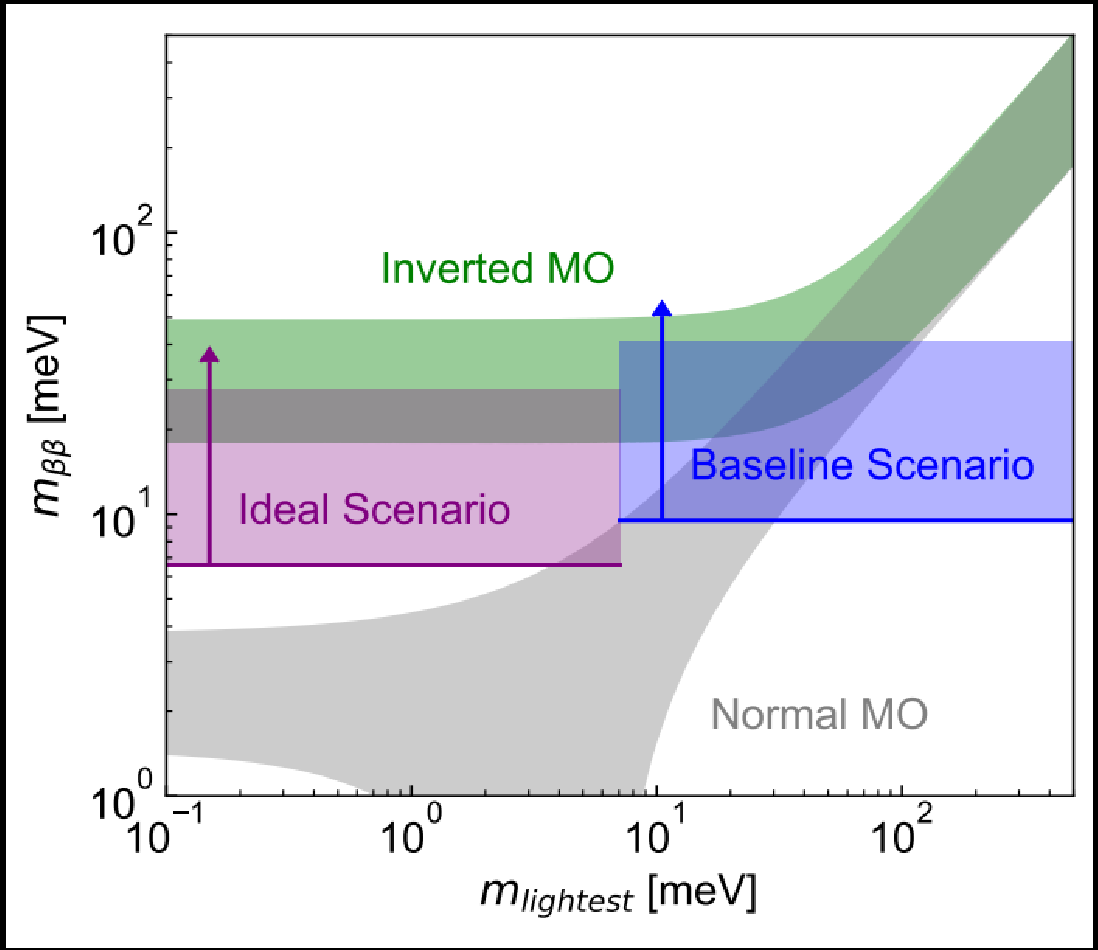
Near future

- 2026.4-6 PandaX-4T decommissioning
- 2026.6-12 PandaX-20T infrastructure construction
- 2027.1-2027.6 PandaX-20T installation
- 2027.7-2027.12 PandaX-20T commissioning
- 2028.1- Physics operation

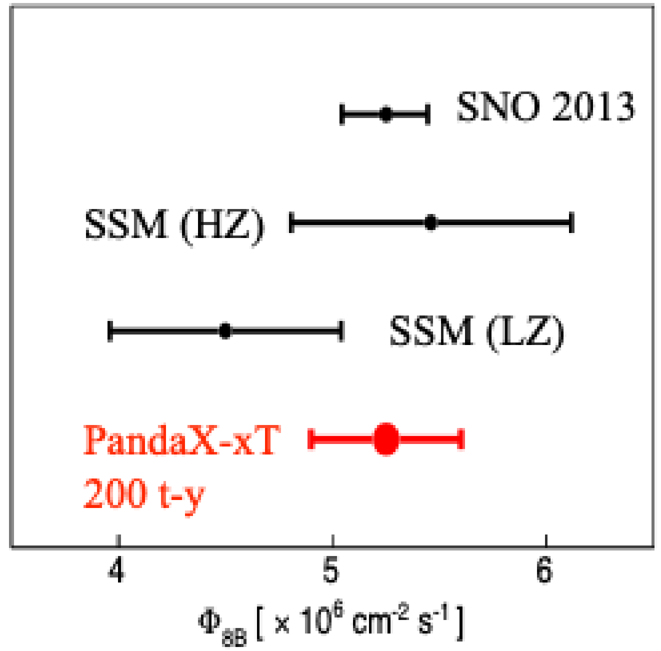
PANDA X
PARTICLE AND ASTROPHYSICAL XENON TPC

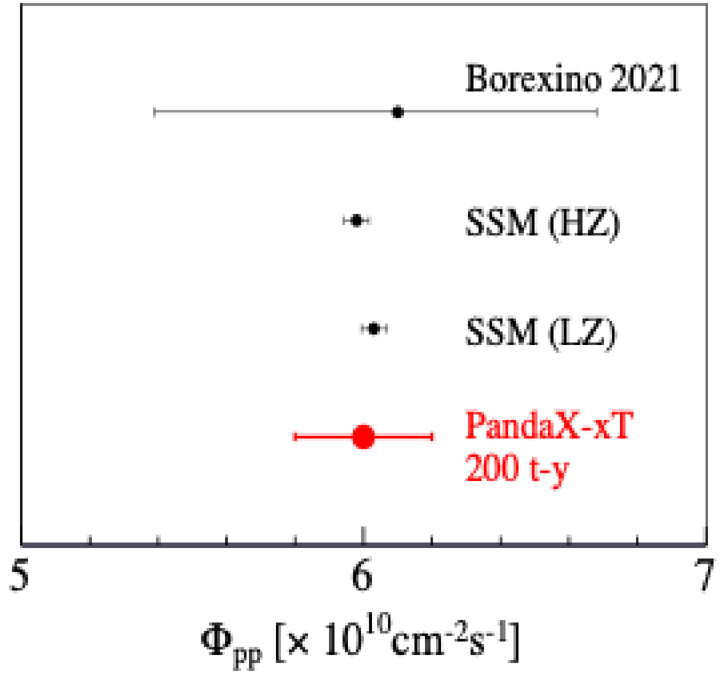
Scientific potentials of a 40T detector

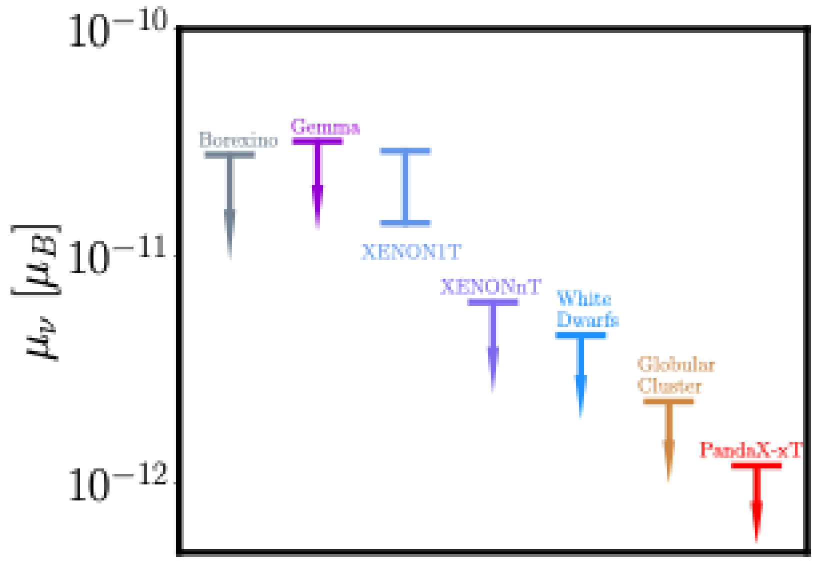




Solar & astrophysical neutrinos





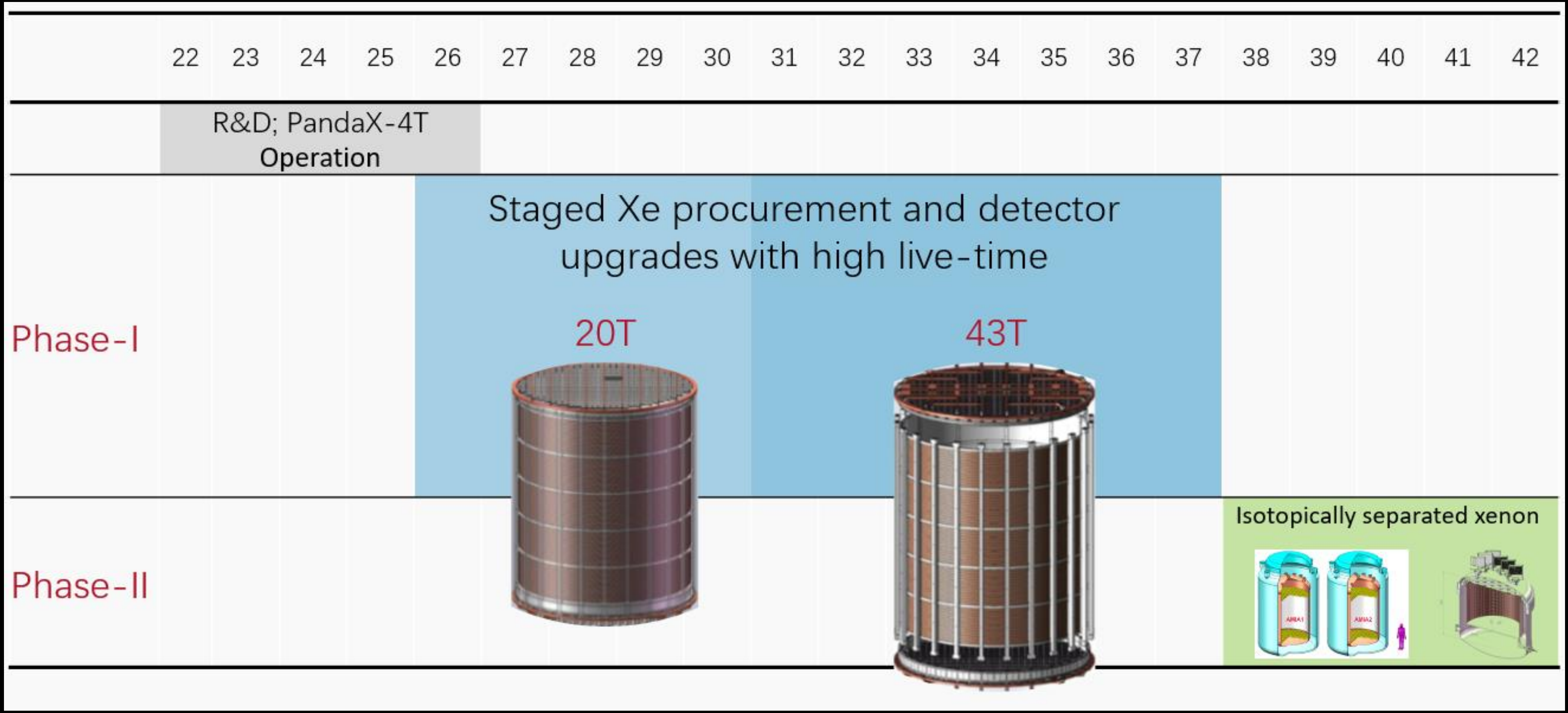


^{8}B neutrino: from indication to precision measurement

pp neutrino: competitive precision with low energy advantage

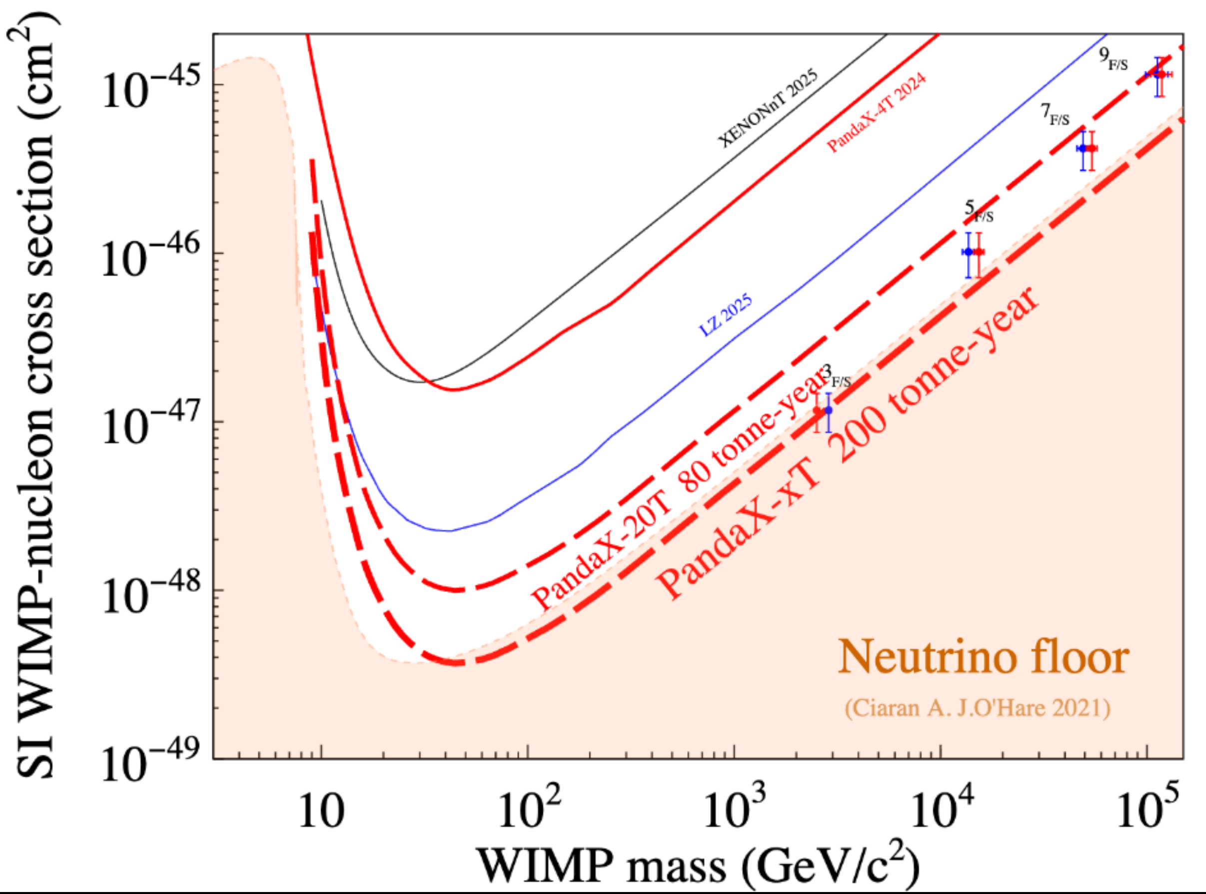
Neutrino magnetic moments: better than astrophysical observations

PandaX-xT timeline

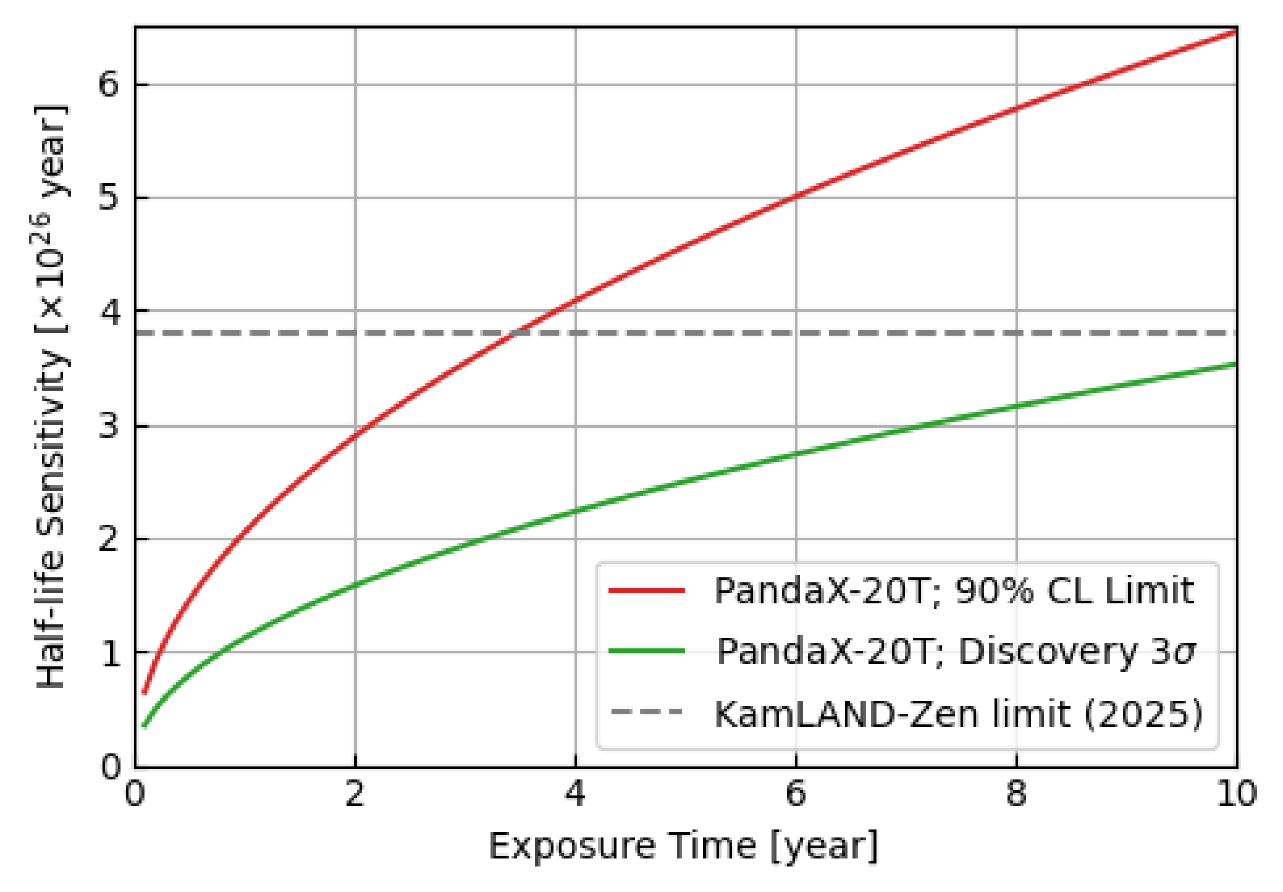


THANK YOU!

Baseline scientific potential of 20T



FV 13 ton, ROI 1-10 keVee, 99.7% ER rejection



FV 2.4 ton natural, 1% resolution