

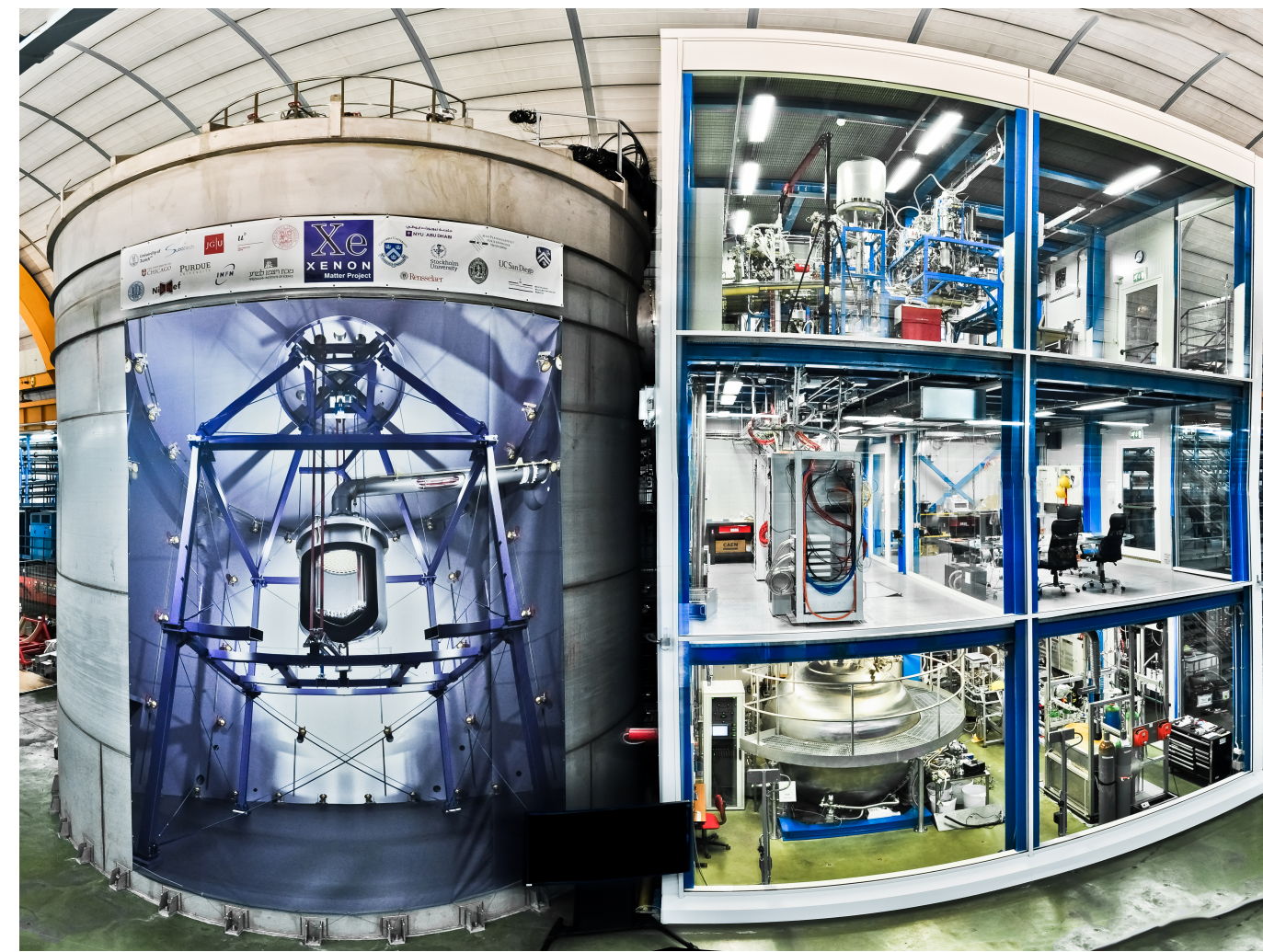
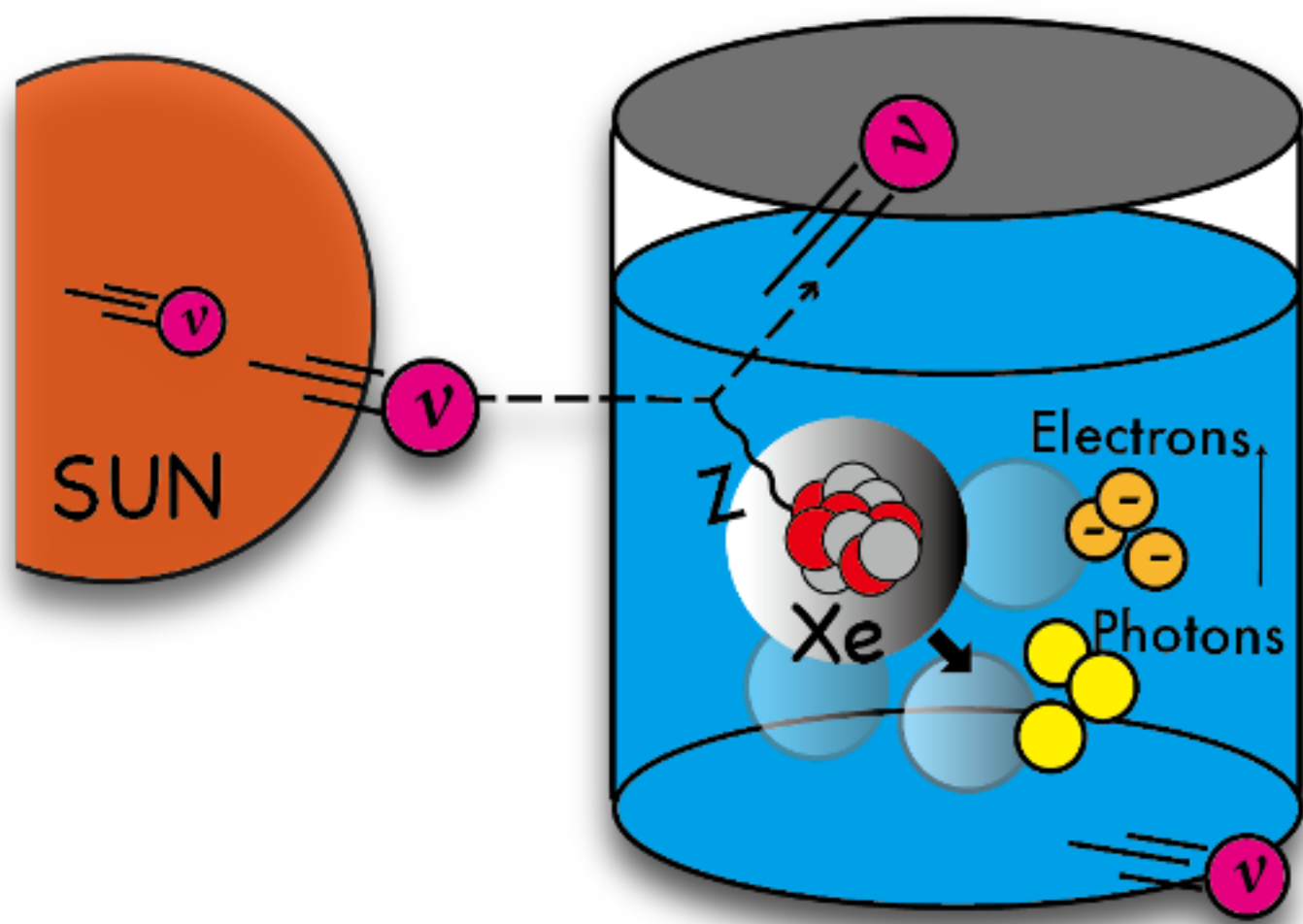


清华大学
Tsinghua University

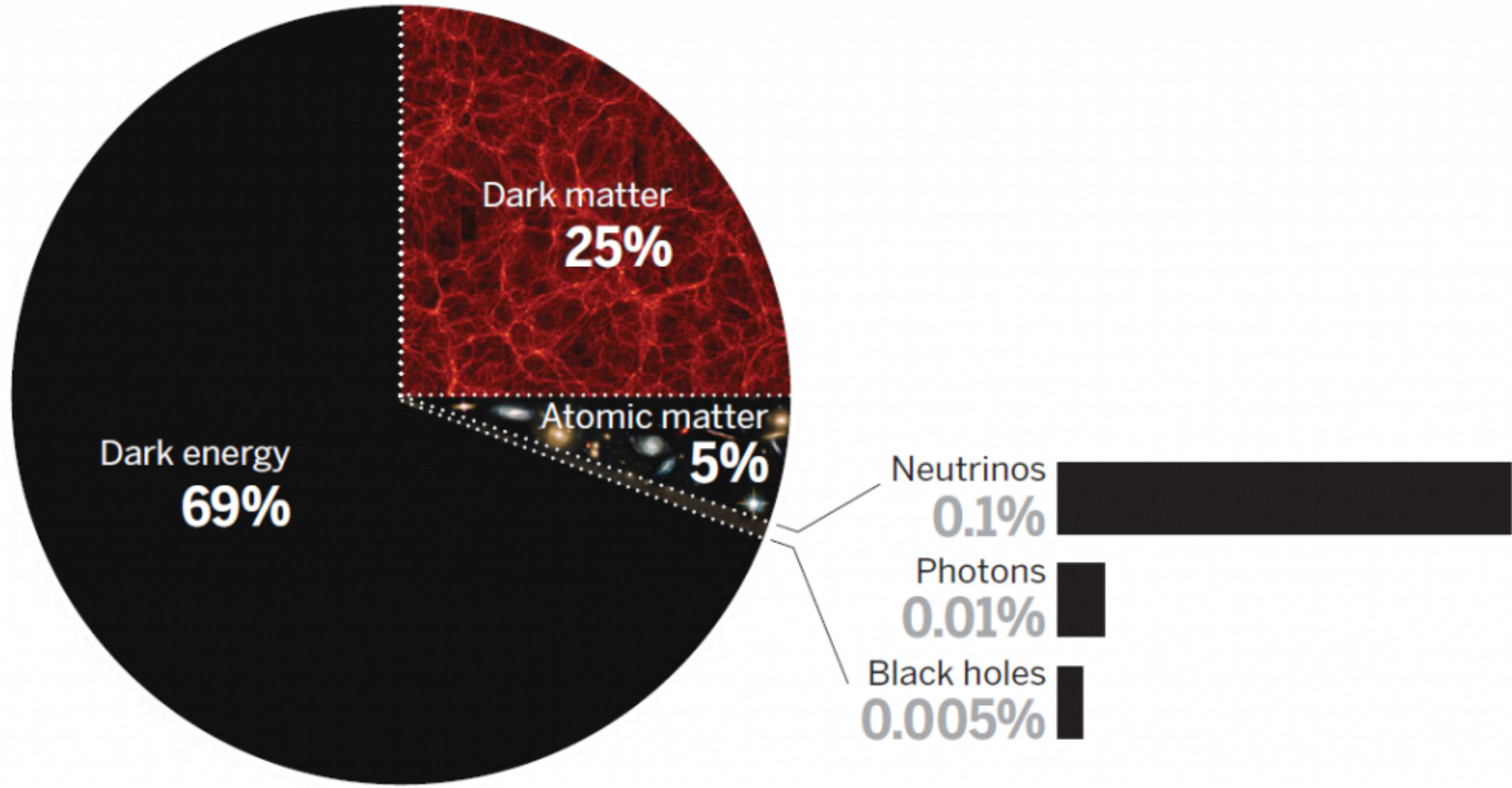
PPC 2026 and 4th Gordon Godfrey
Workshop on Astroparticle Physics
Aug 31-Sep 4, 2026, Sydney

Dark Matter Search with Liquid Xenon Time Projection Chambers

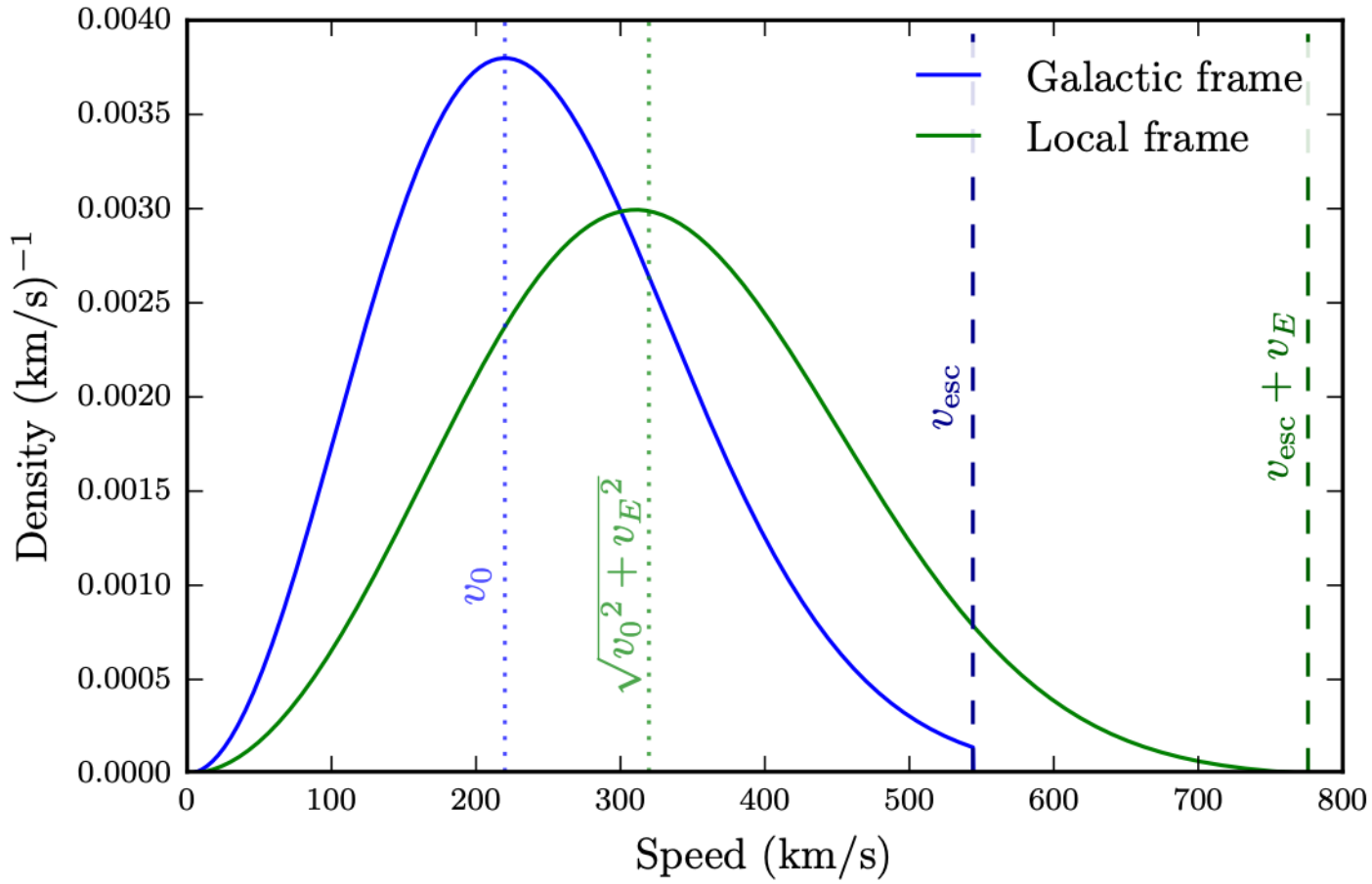
Fei Gao
Tsinghua University



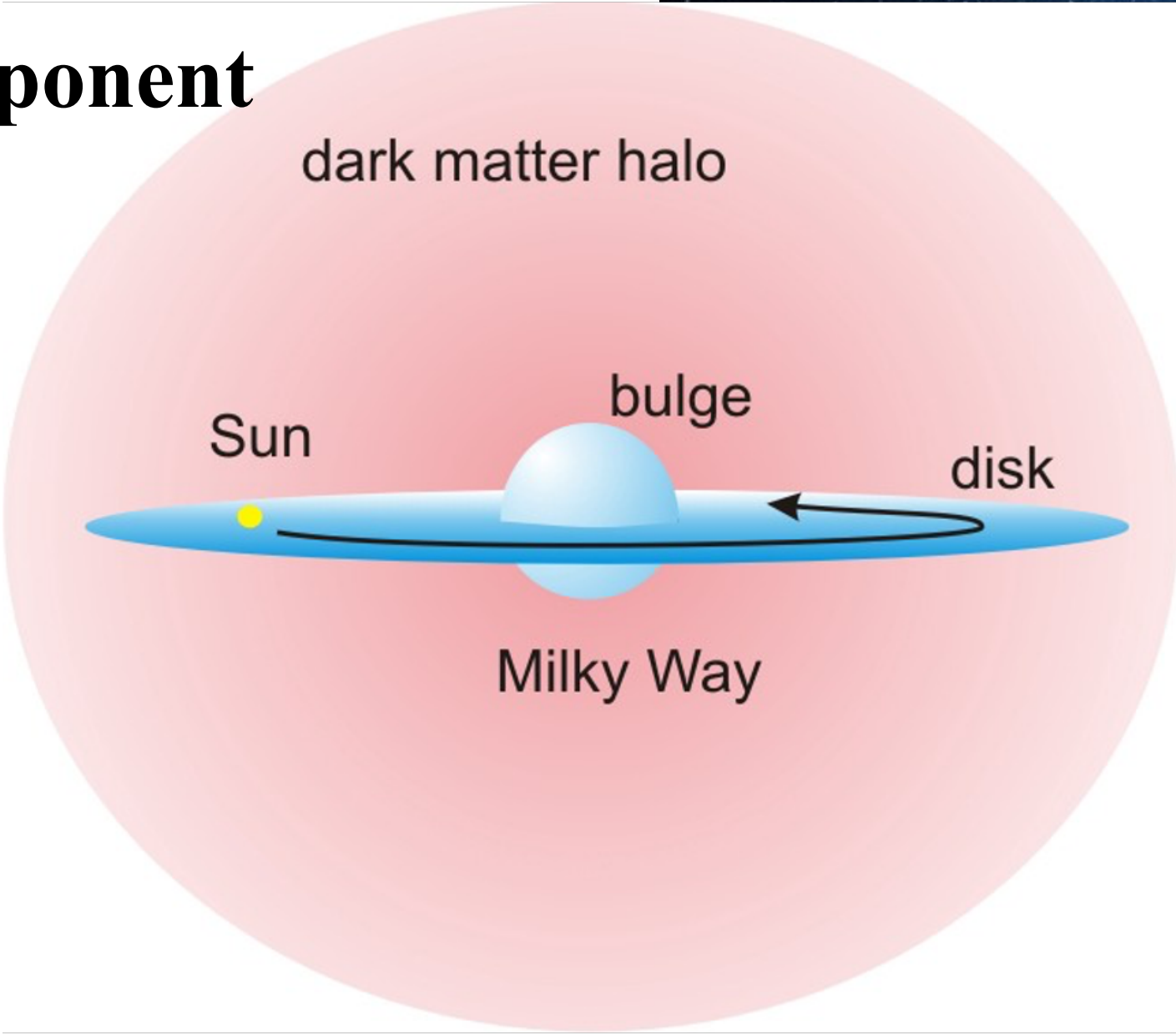
Dark Matter



Constant flux of dark matter.



Dark Matter is a Major Component of the Universe



The local dark matter density is around 0.3 GeV/cm³

Direct Detection of Dark Matter

PHYSICAL REVIEW D

VOLUME 9, NUMBER 5

1 MARCH 1974

Coherent effects of a weak neutral current

Daniel Z. Freedman†

National Accelerator Laboratory, Batavia, Illinois 60510

and Institute for Theoretical Physics, State University of New York, Stony Brook, New York 11790

(Received 15 October 1973; revised manuscript received 19 November 1973)

If there is a weak neutral current, then the elastic scattering process $\nu + A \rightarrow \nu + A$ should have a sharp coherent forward peak just as $e + A \rightarrow e + A$ 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} cm² 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 $\nu + A \rightarrow \nu + A^*$ 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.

PHYSICAL REVIEW D

VOLUME 31, NUMBER 12

15 JUNE 1985

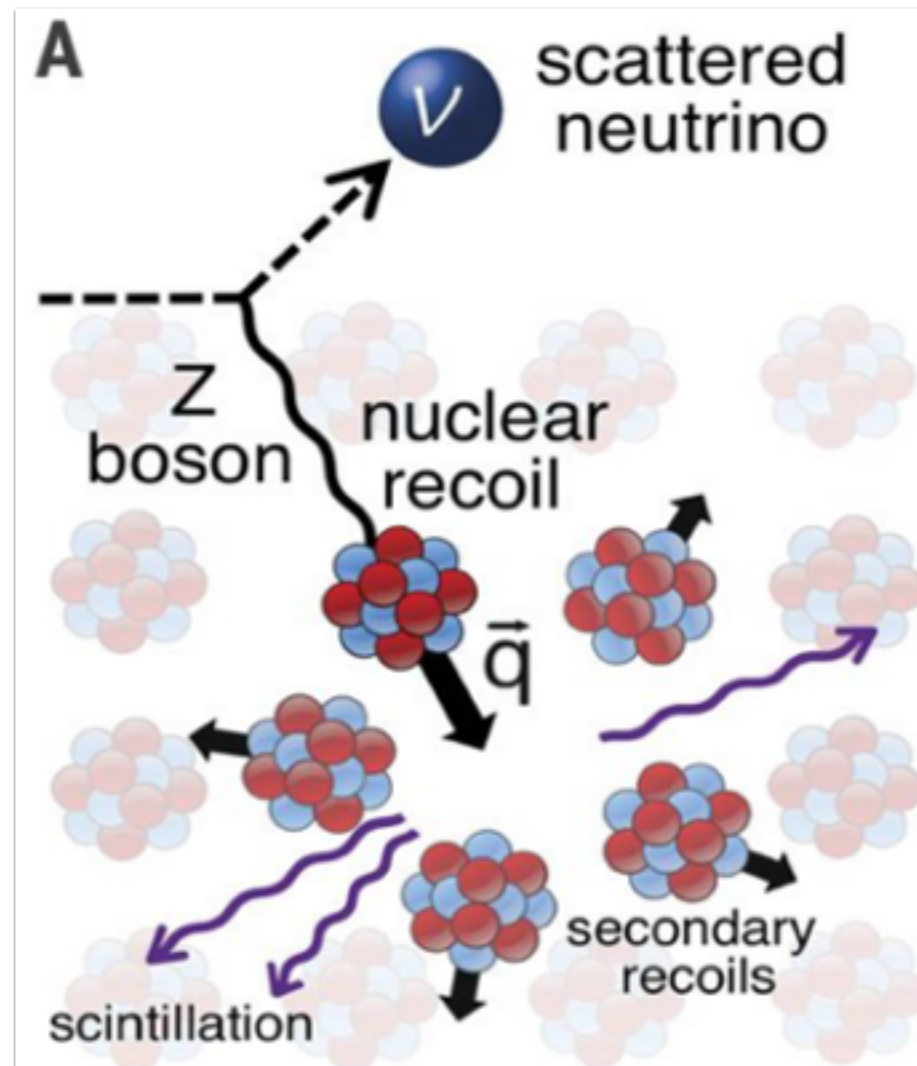
Detectability of certain dark-matter candidates

Mark W. Goodman and Edward Witten

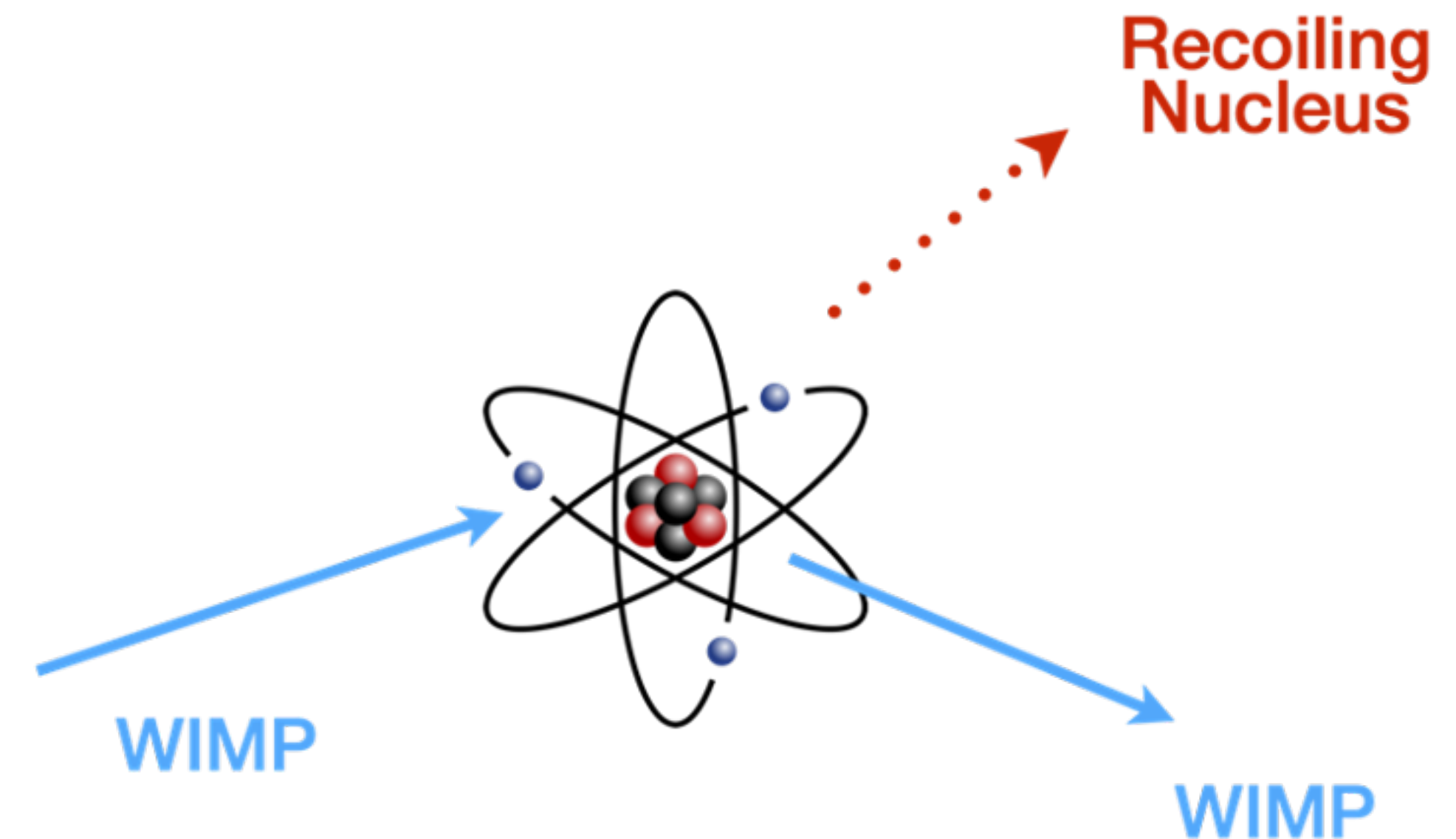
Joseph Henry Laboratories, Princeton University, Princeton, New Jersey 08544

(Received 7 January 1985)

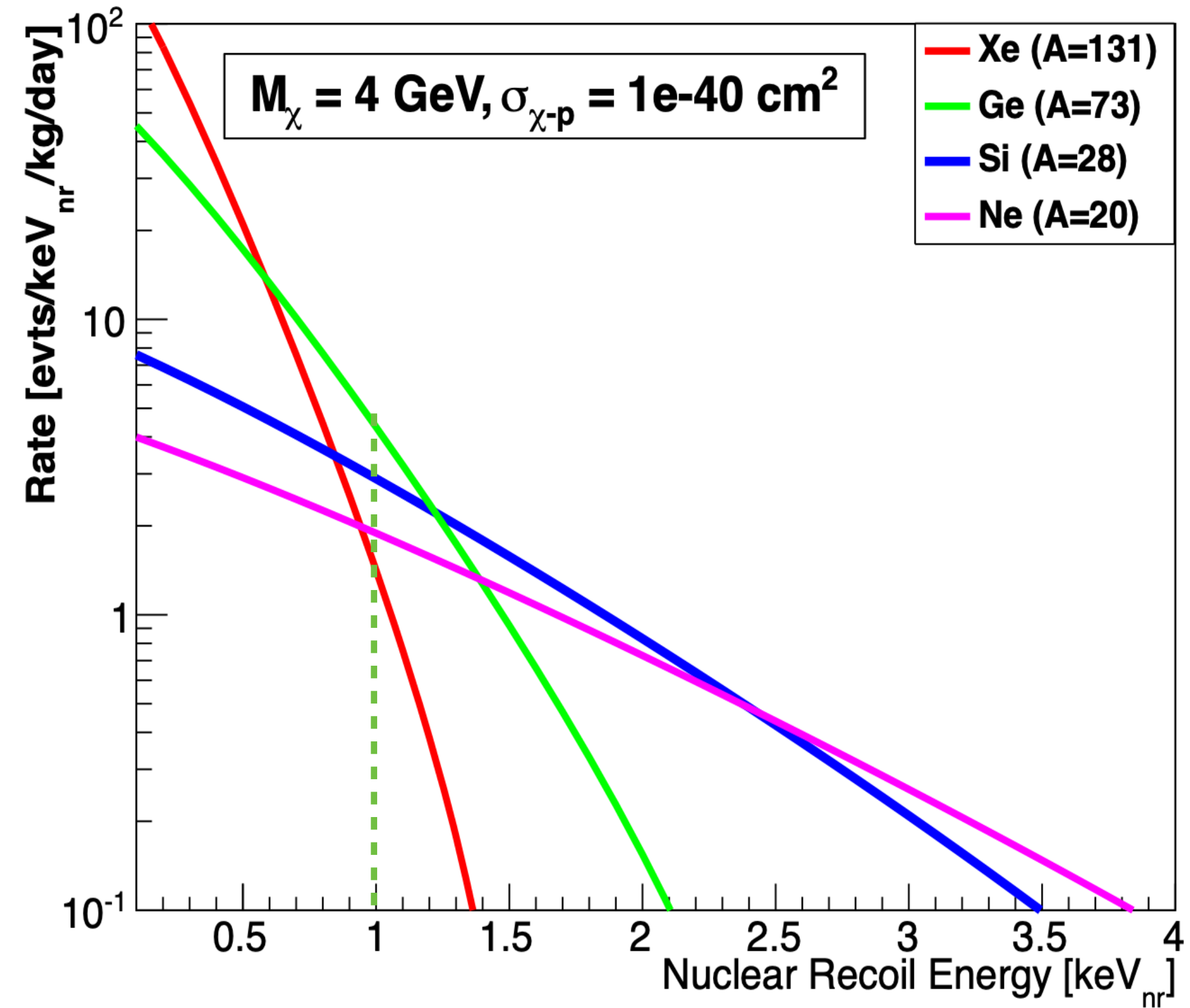
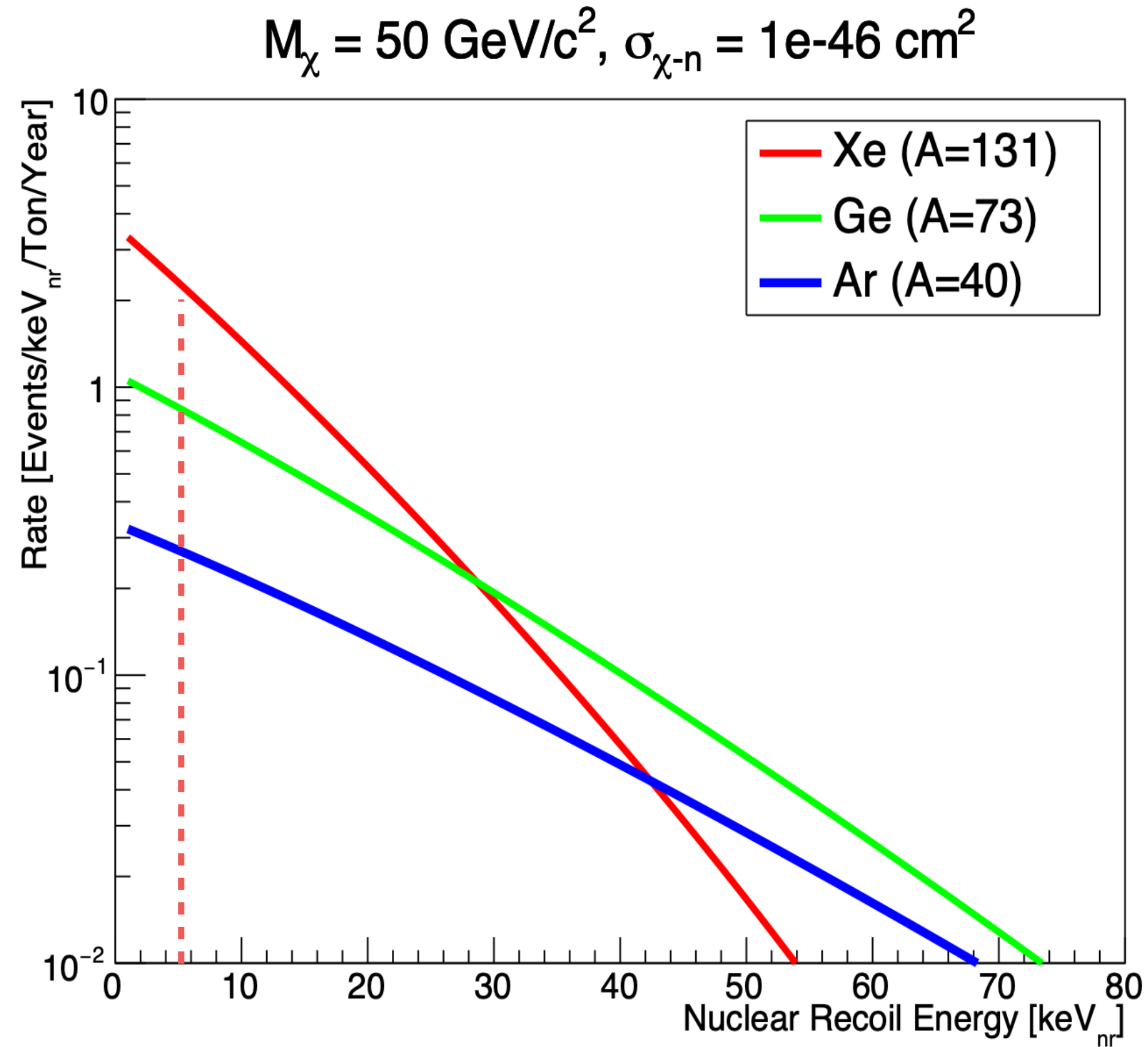
We consider the possibility that the neutral-current neutrino detector recently proposed by Drukier and Stodolsky could be used to detect some possible candidates for the dark matter in galactic halos. This may be feasible if the galactic halos are made of particles with coherent weak interactions and 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.



D. Akimov et al, Science 357 (2017)



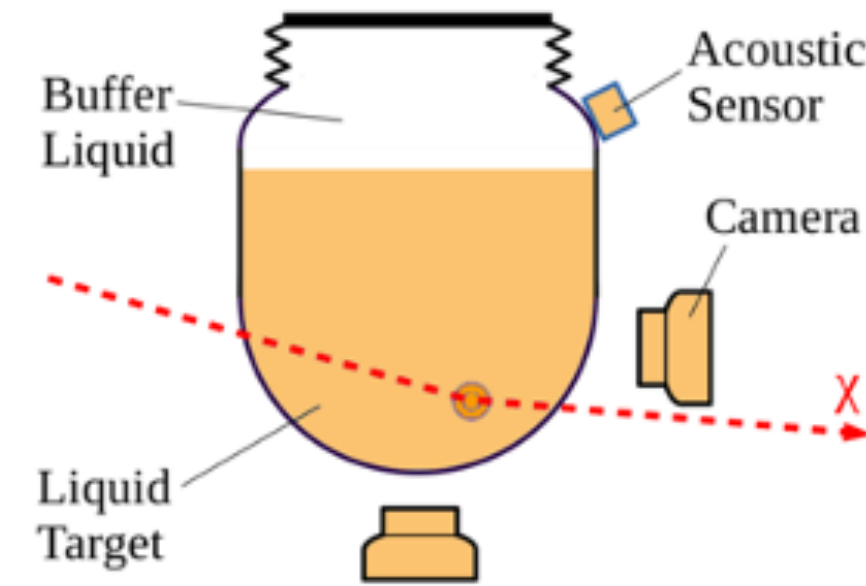
Signatures of Dark Matter Interactions



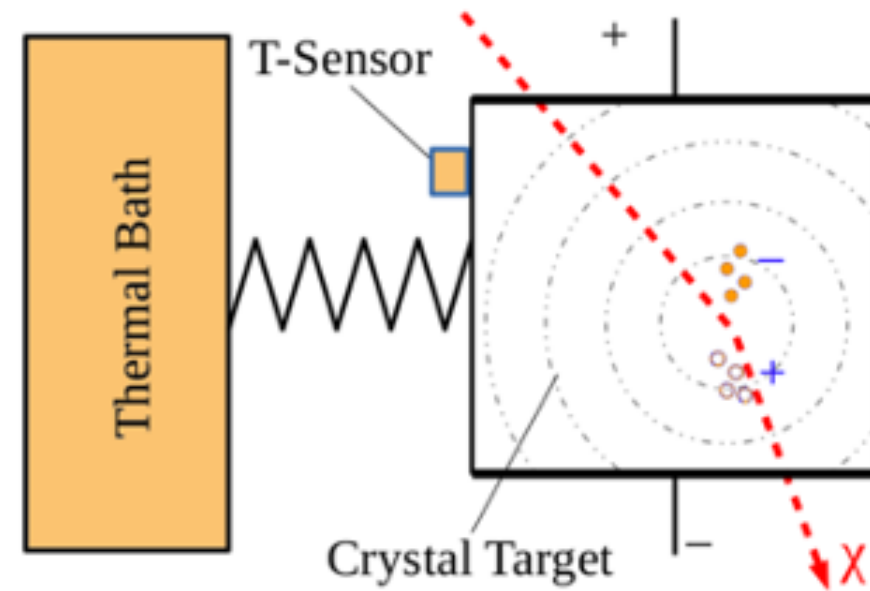
Exponentially falling nuclear recoil energy spectrum

Detection Techniques

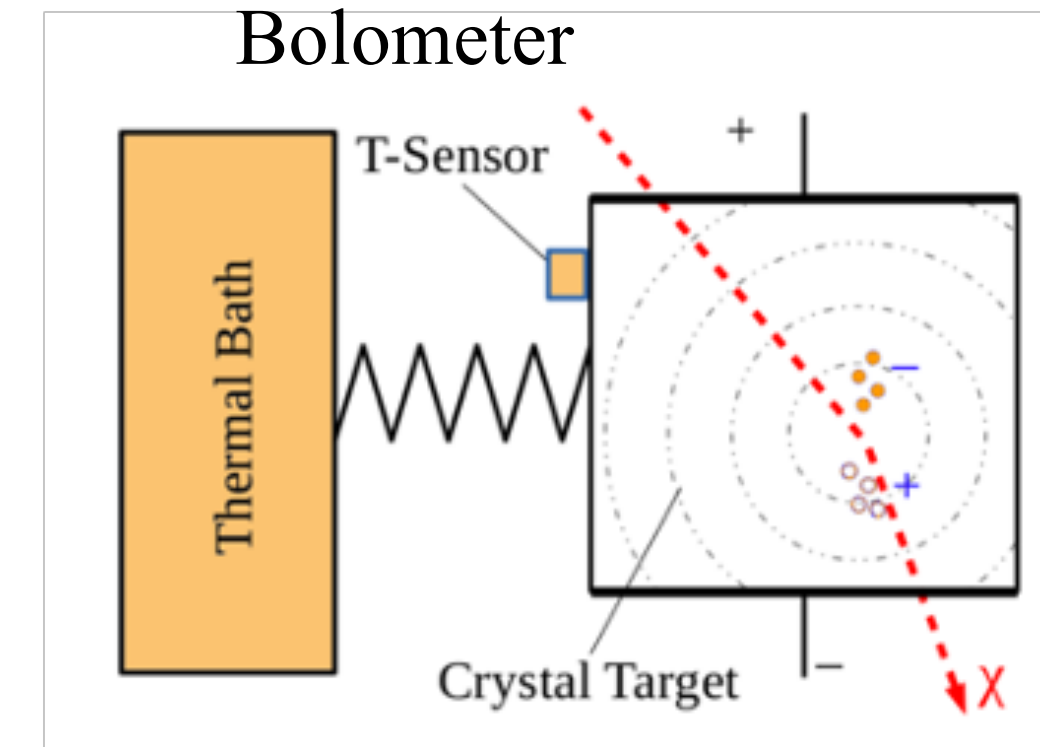
Bubble Chamber



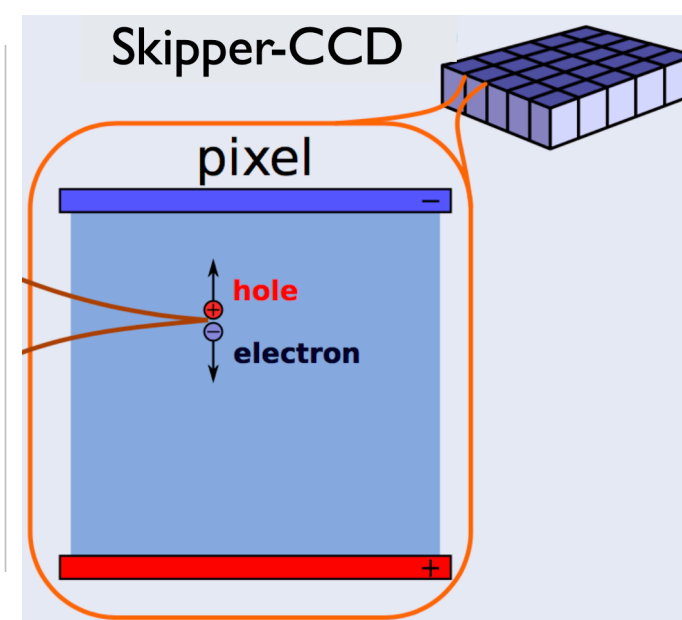
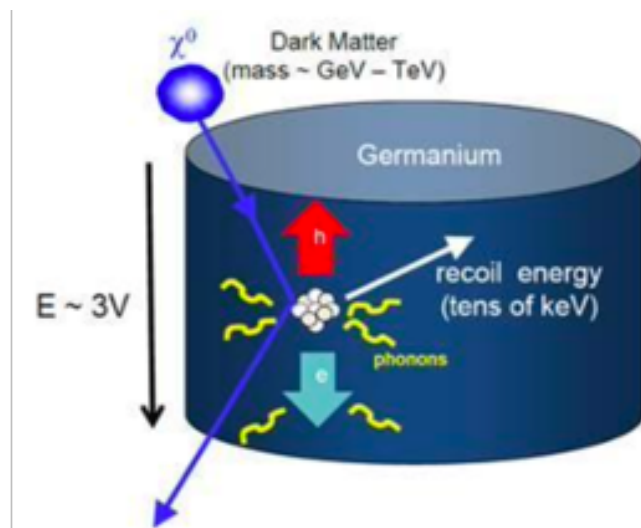
Bolometer



Bolometer



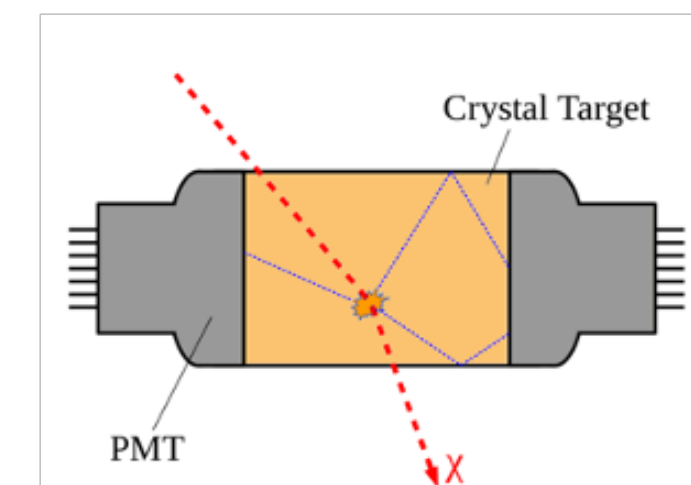
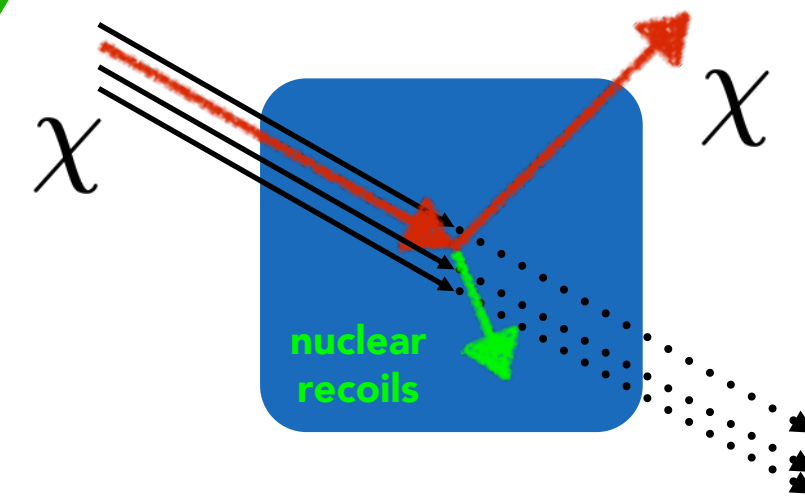
Point Contact Ge



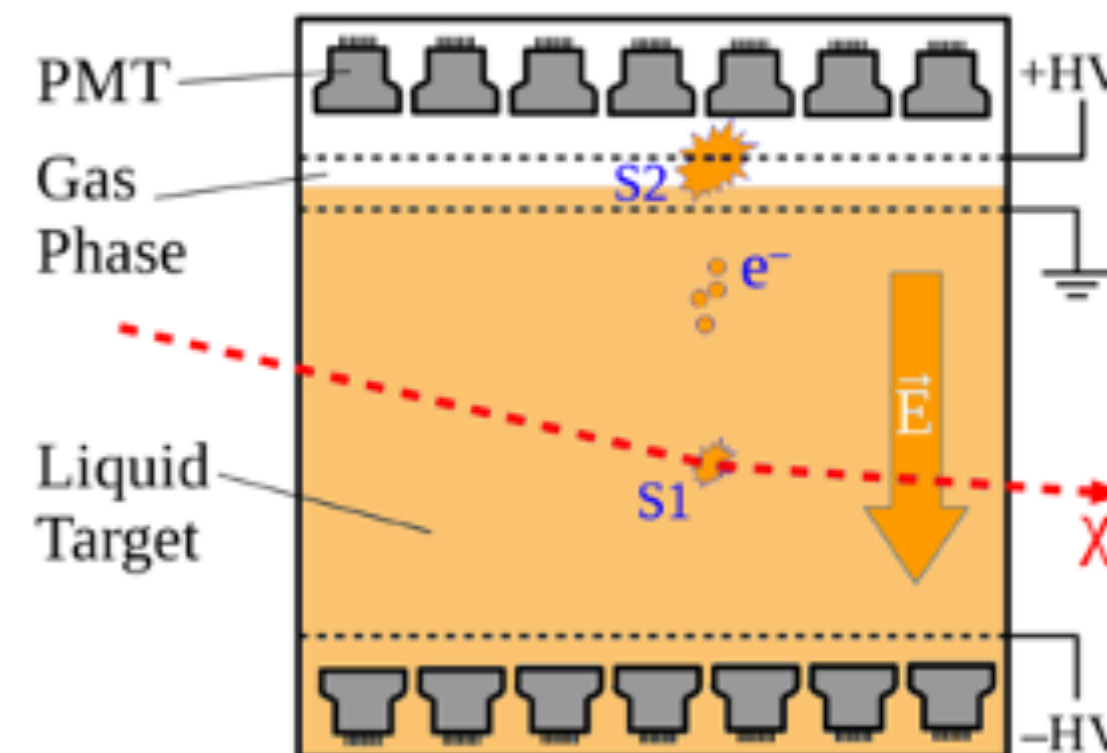
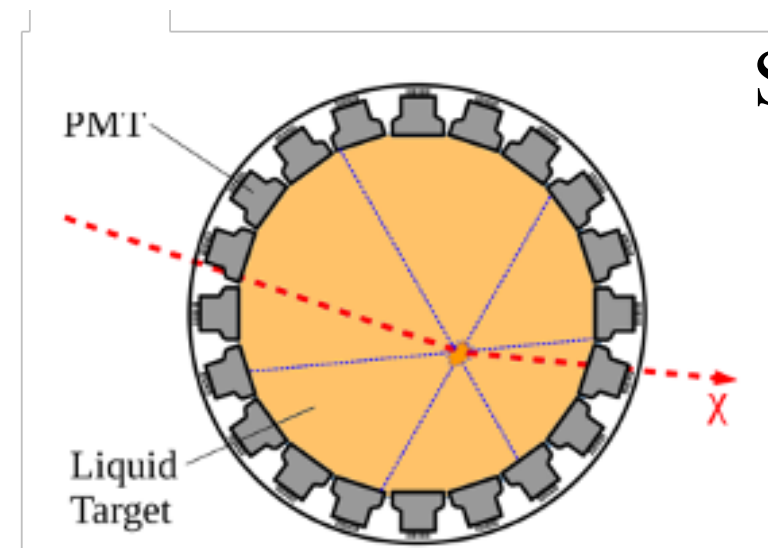
Charge

Heat

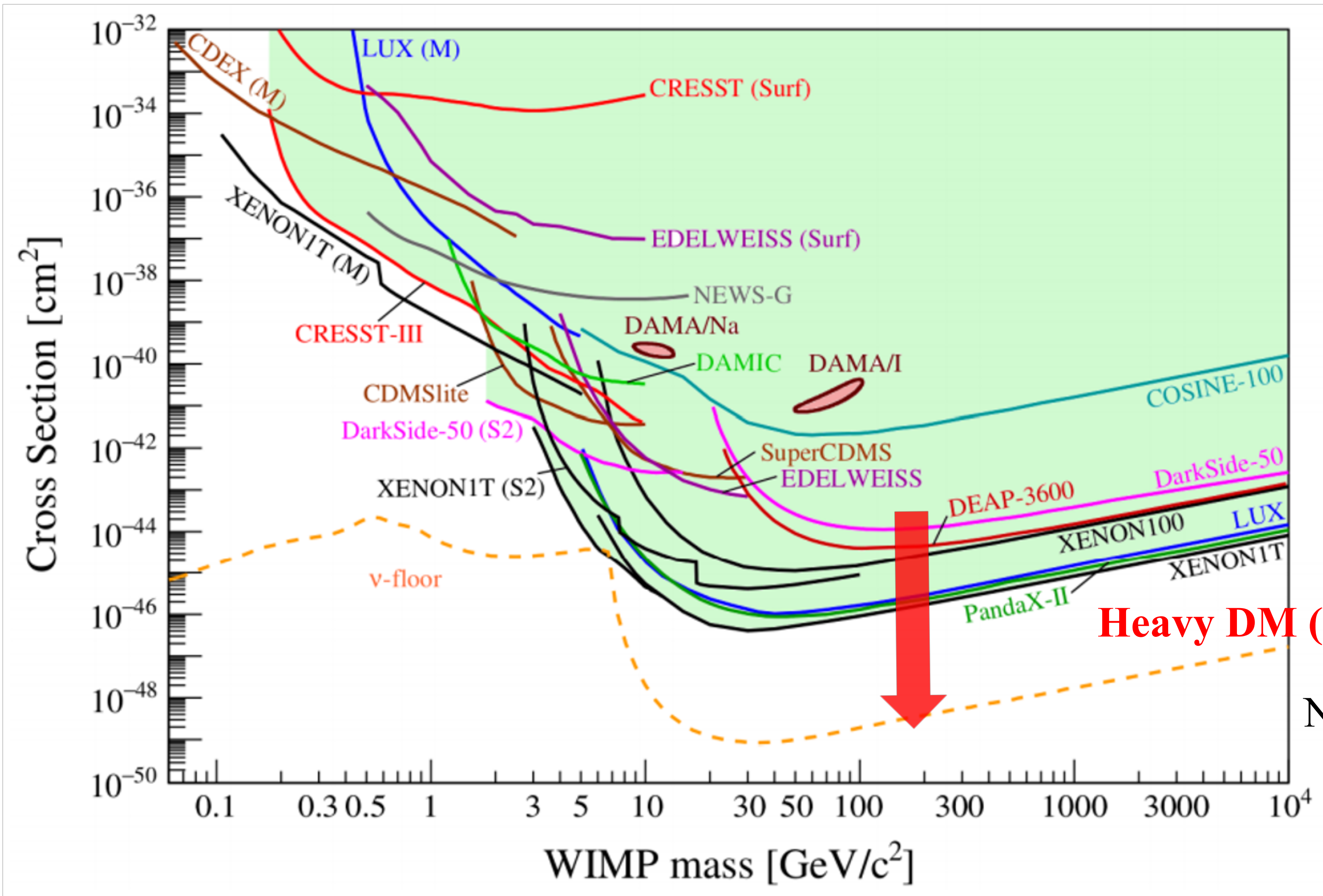
Light



Scintillator



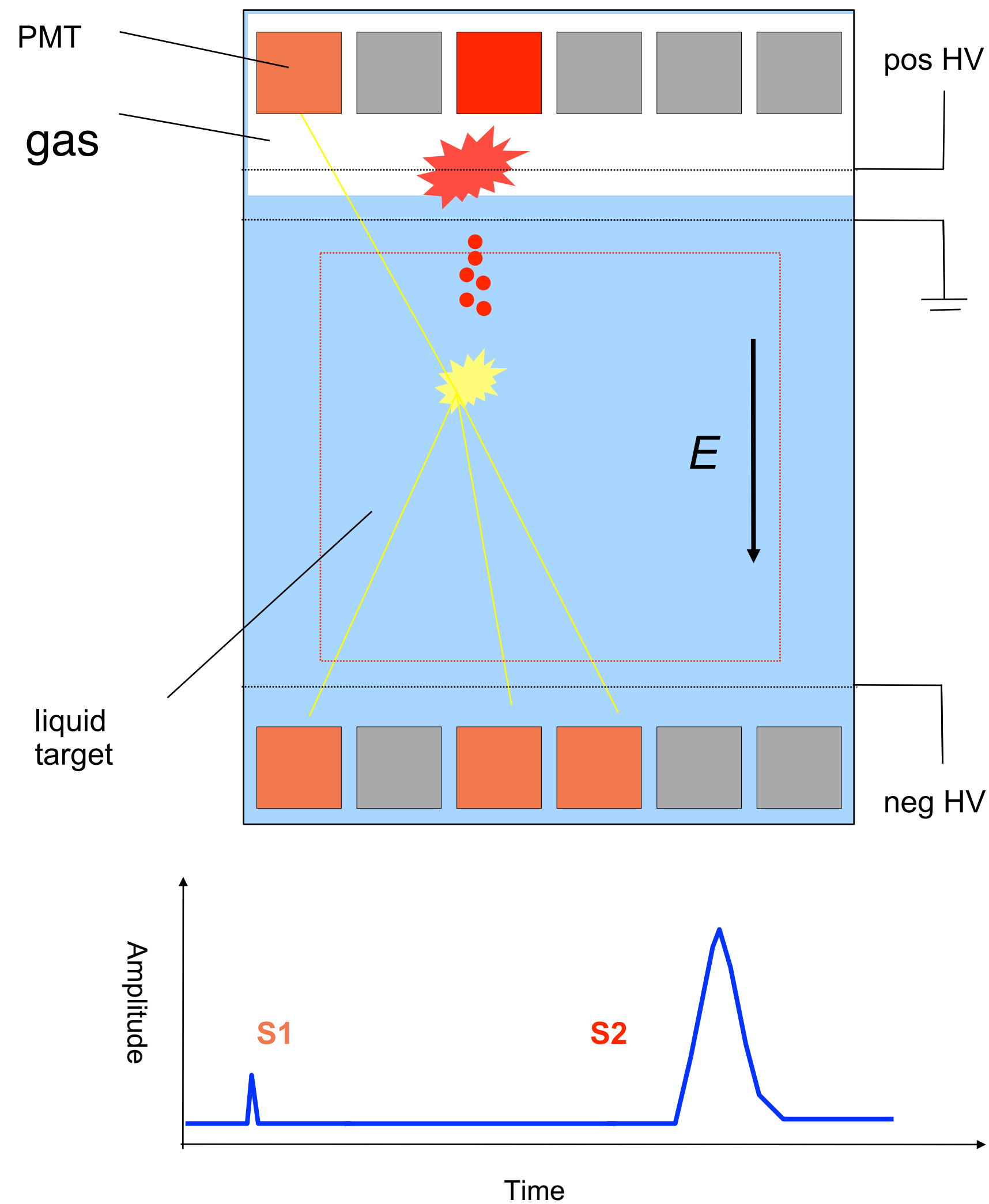
Status of Dark Matter Searches



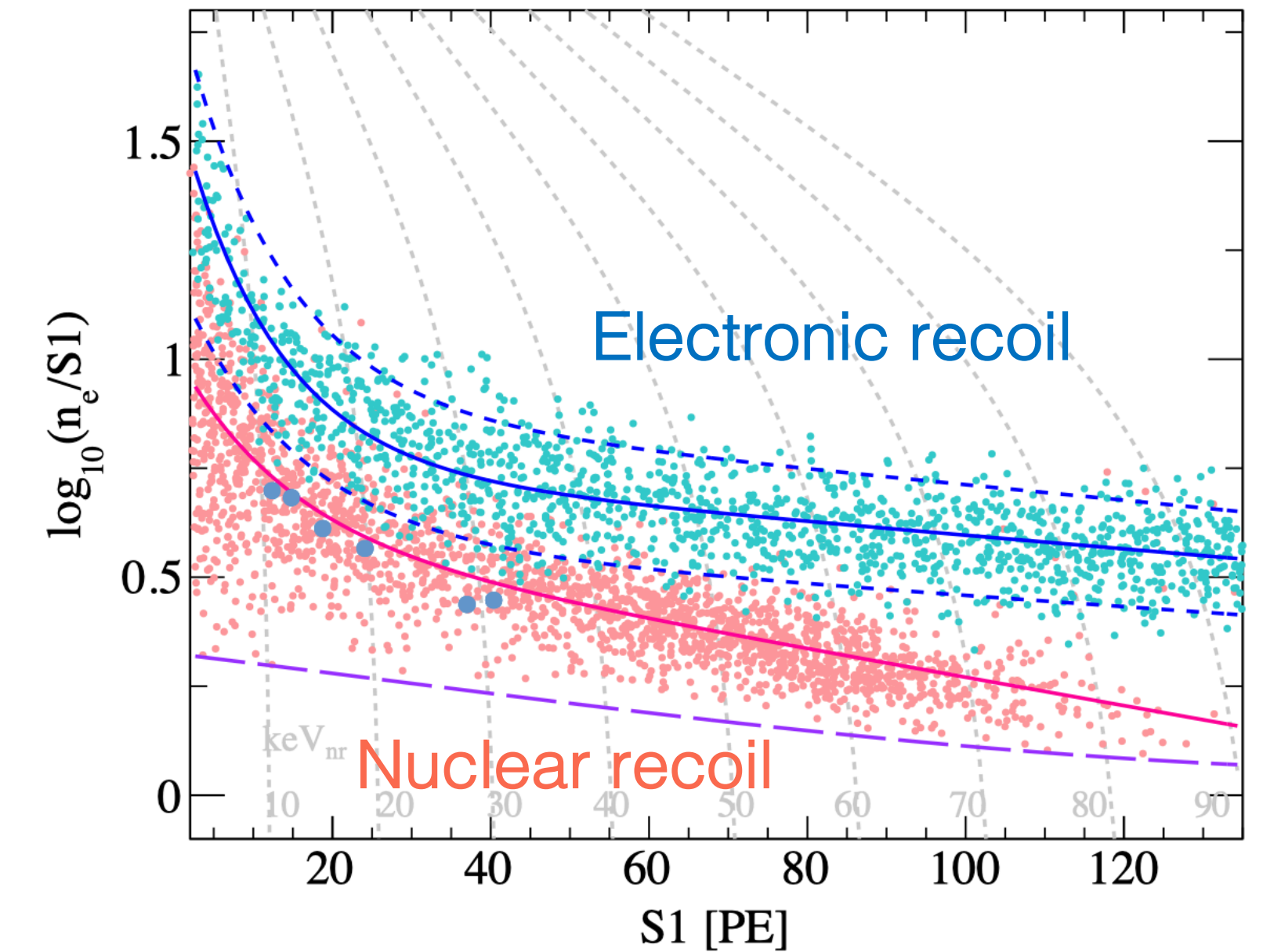
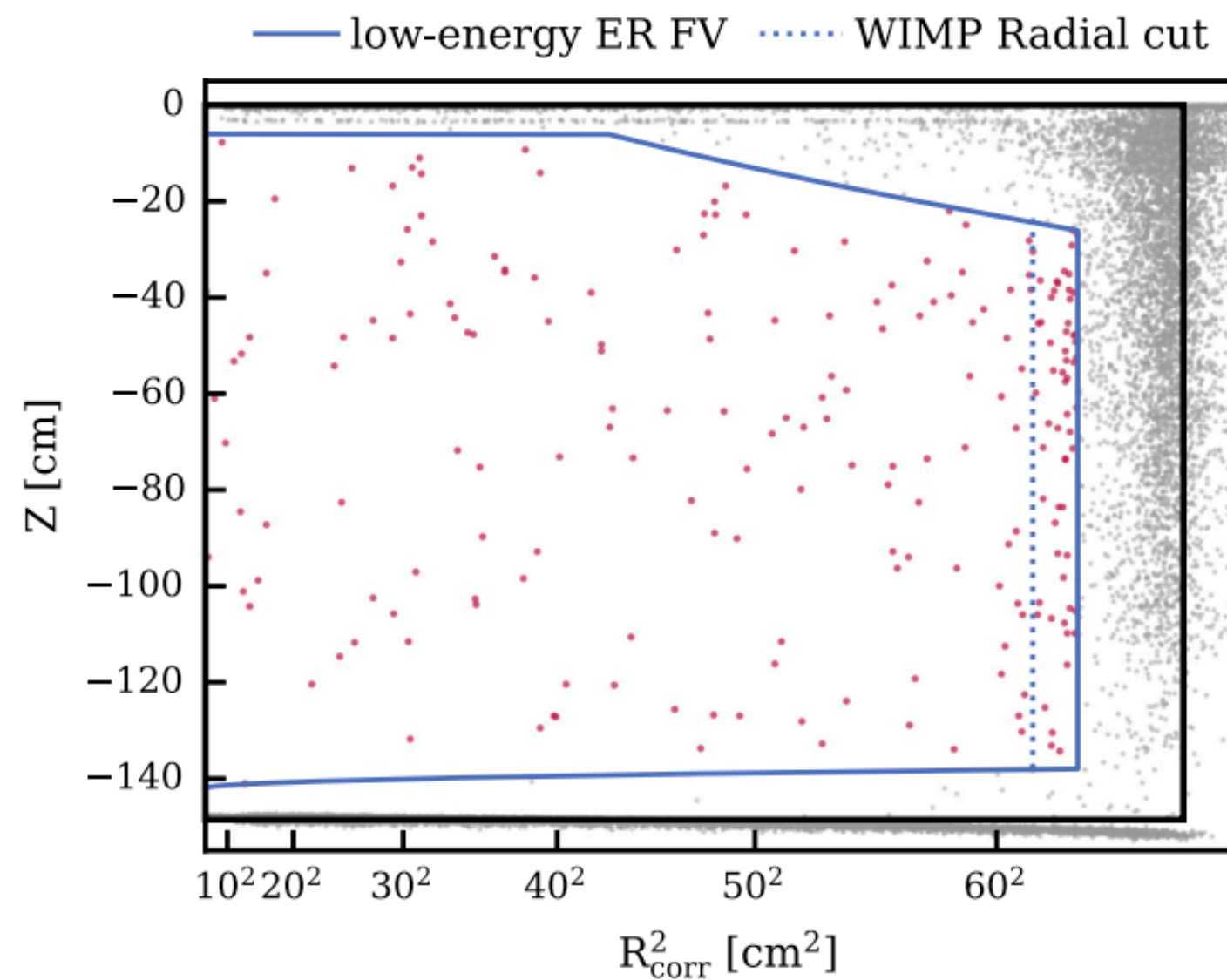
Heavy DM (WIMPs)

Noble Liquid TPC

Dual-phase Noble Liquid Time Projection Chambers

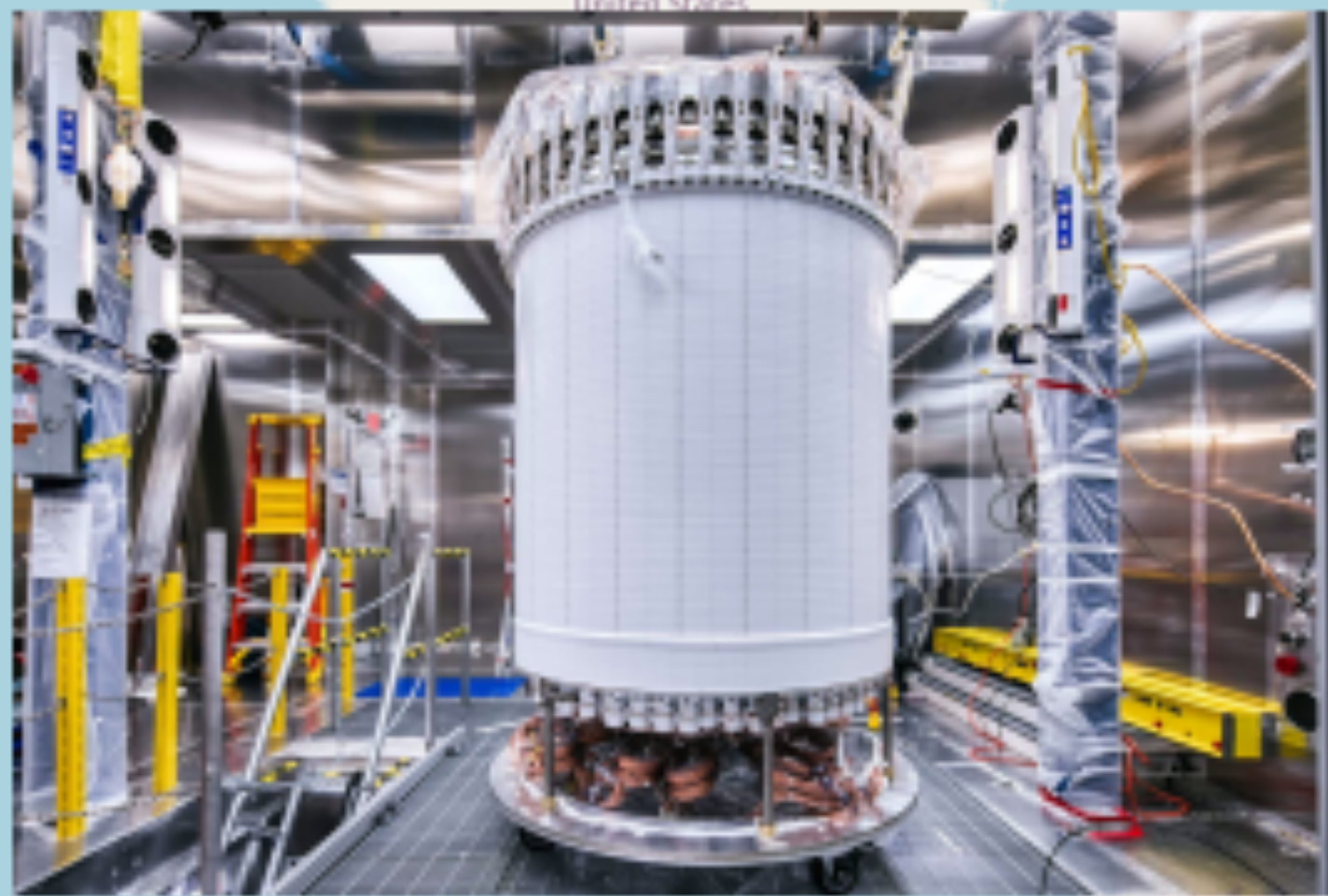


- two signals for each event:
 - 3D event imaging: x-y (S2) and z (drift time)
 - Recoil type discrimination from ratio of charge (S2) to light (S1)



“G2” LXeTPCs for Dark Matter Search

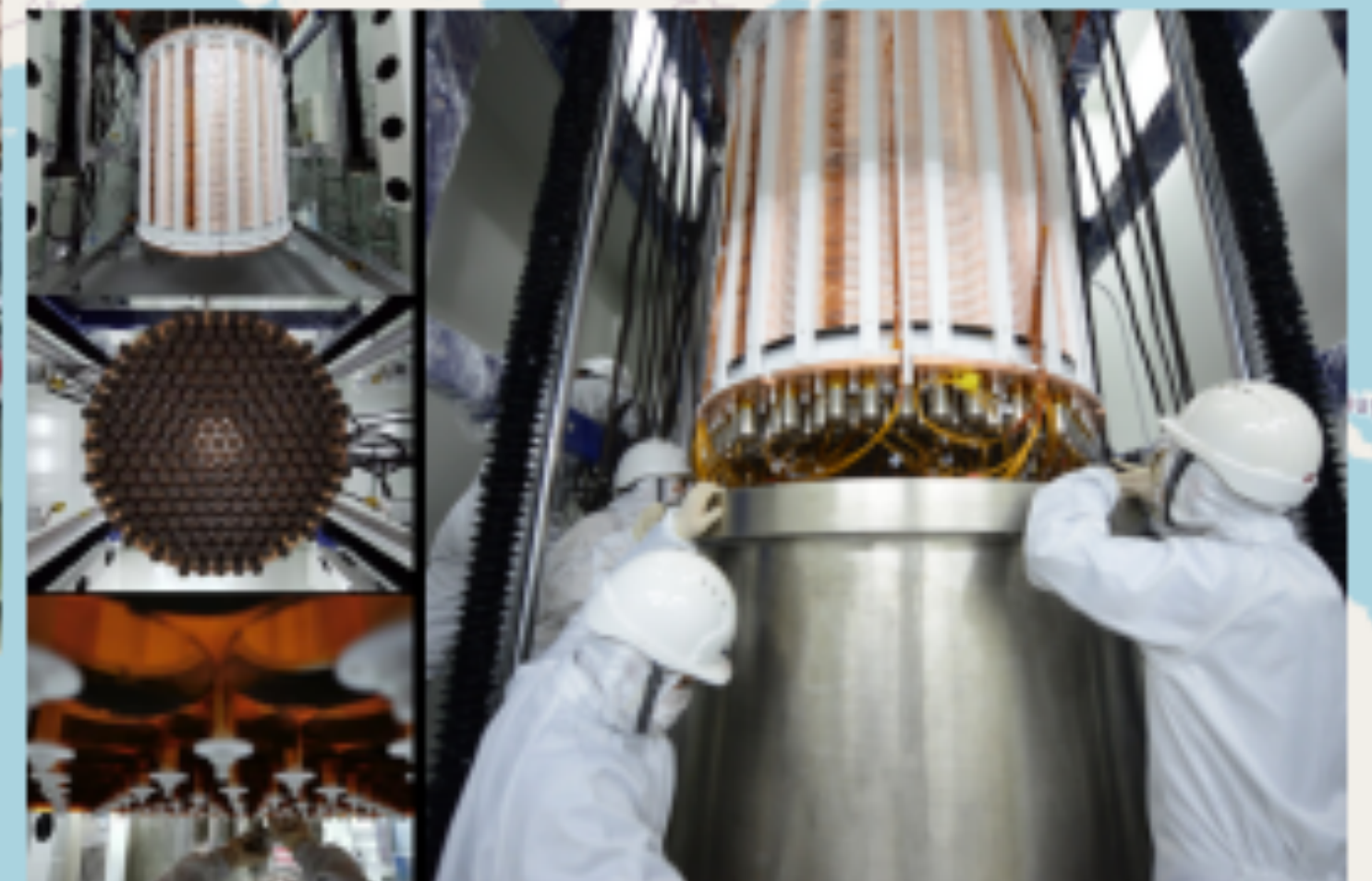
Sanford Lab, LZ, 7 ton



LNGS, XENONnT, 6.5 ton

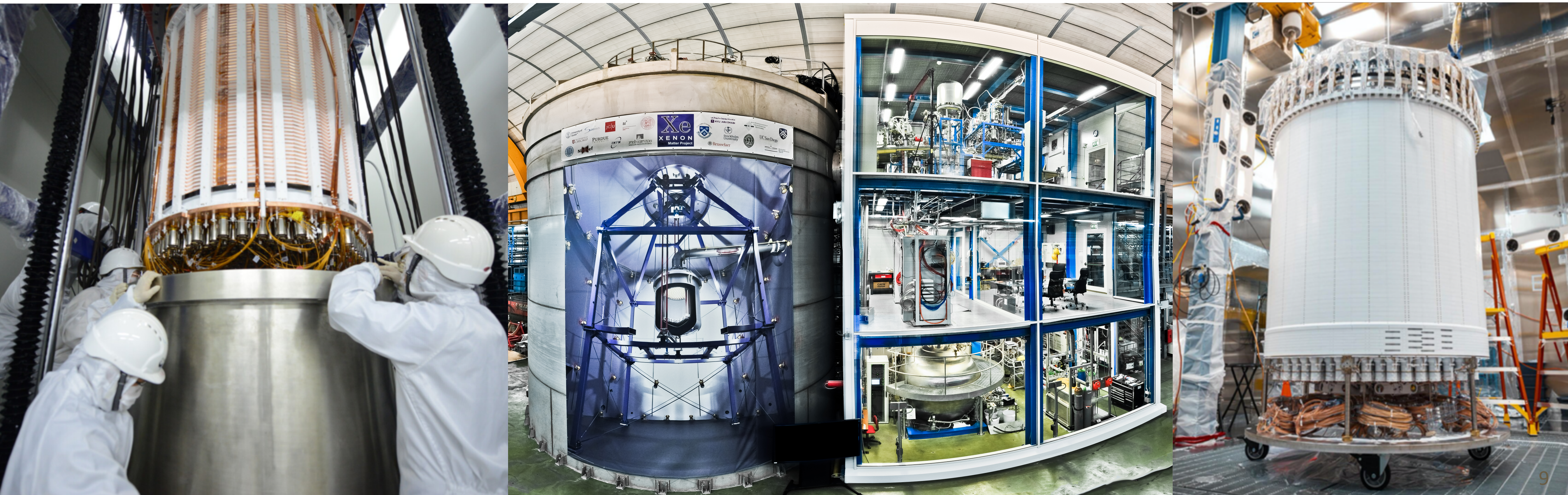


CJPL, PandaX-4T, 3.7 ton

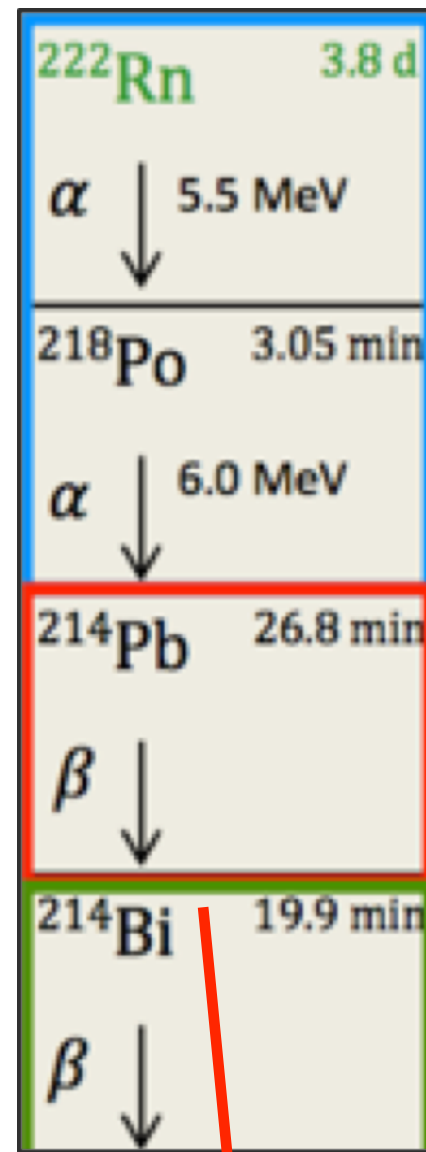


“G2” LXeTPCs for Dark Matter Search

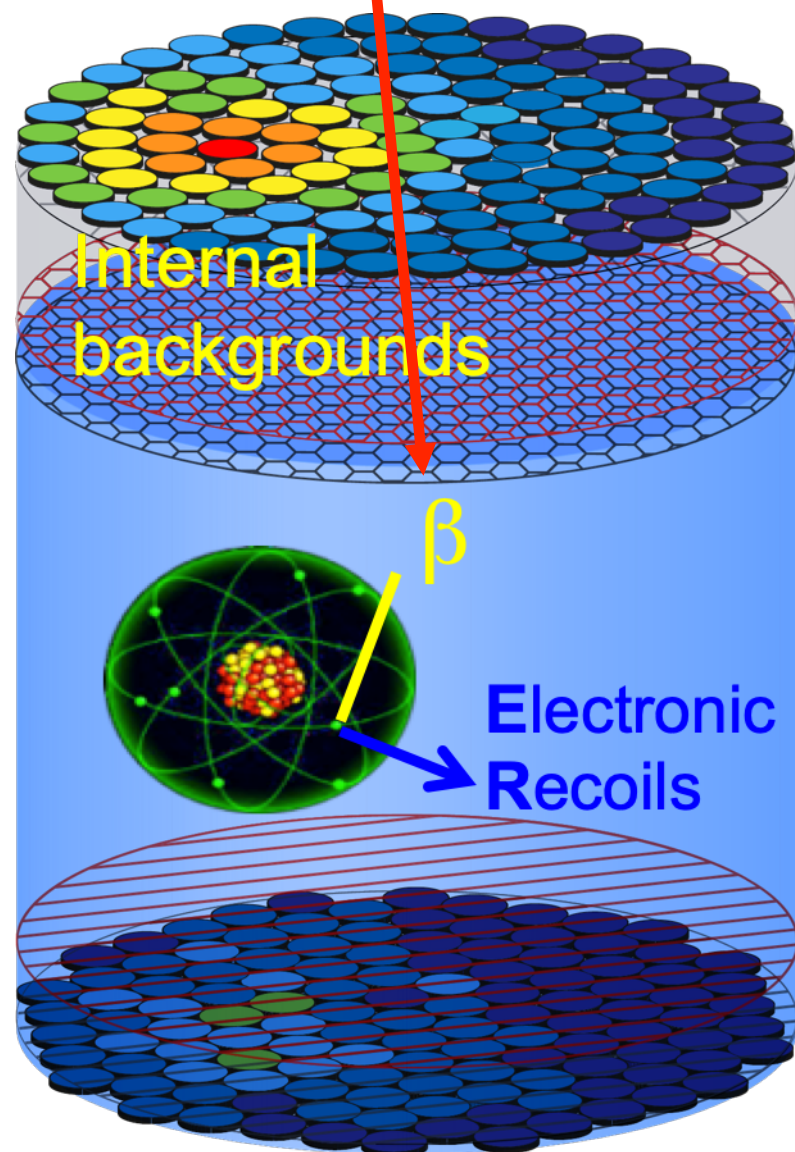
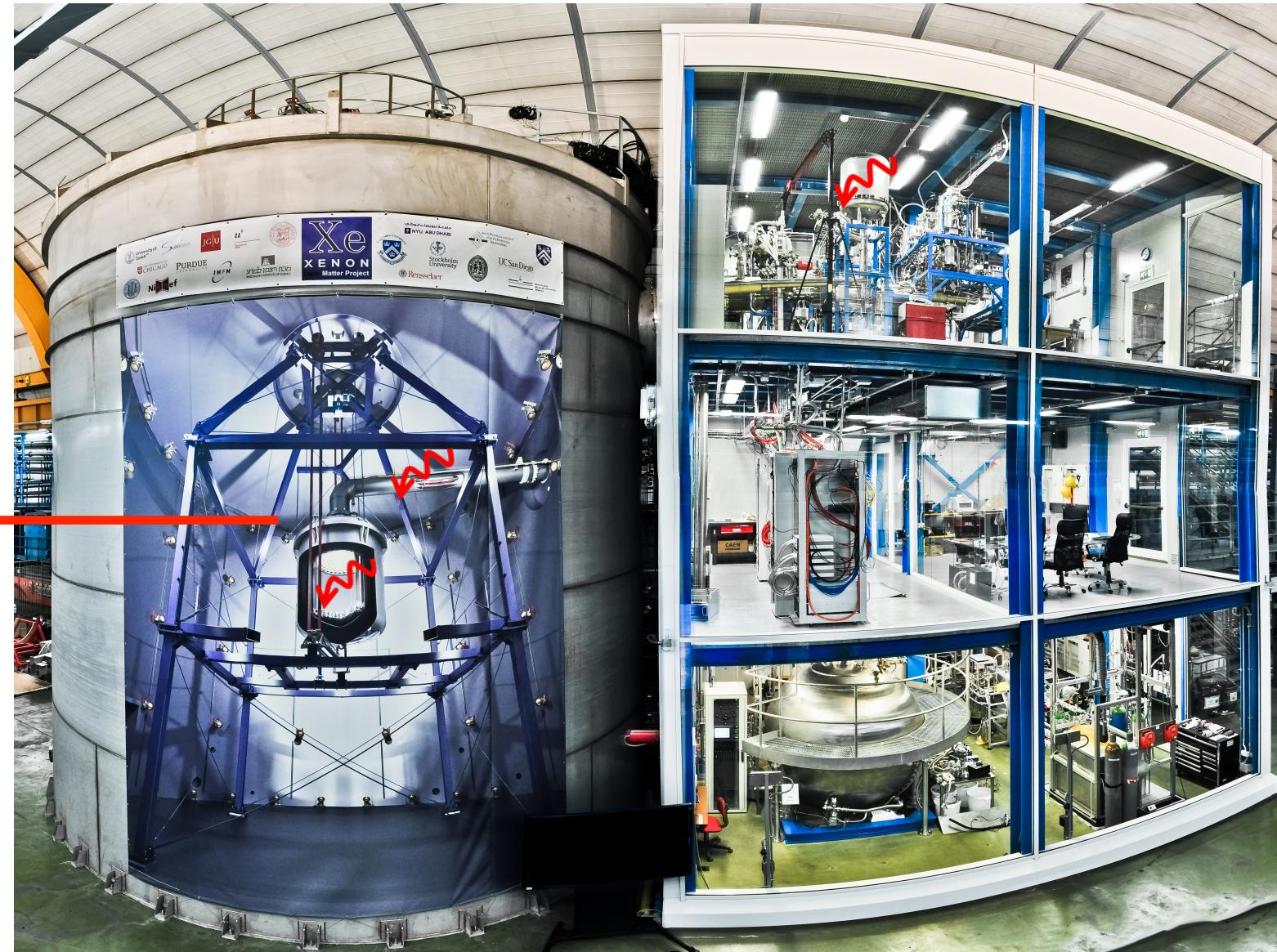
Experiments	Location	Sensitive Mass [t]	Fiducial mass [t]	Radon reduction	Neutron veto	Published Exposure [t-y]
PandaX-4T	CJPL (China)	4.0	2.8	Distillation	Pure water	1.5
XENONnT	LNGS (Italy)	5.9	4.0	Distillation	Gd-loaded Water	6.8
LZ	SURF (US)	7.0	5.6	Software Veto	Gd-loaded Scintillator	5.7



Background Challenge: Kr and Rn

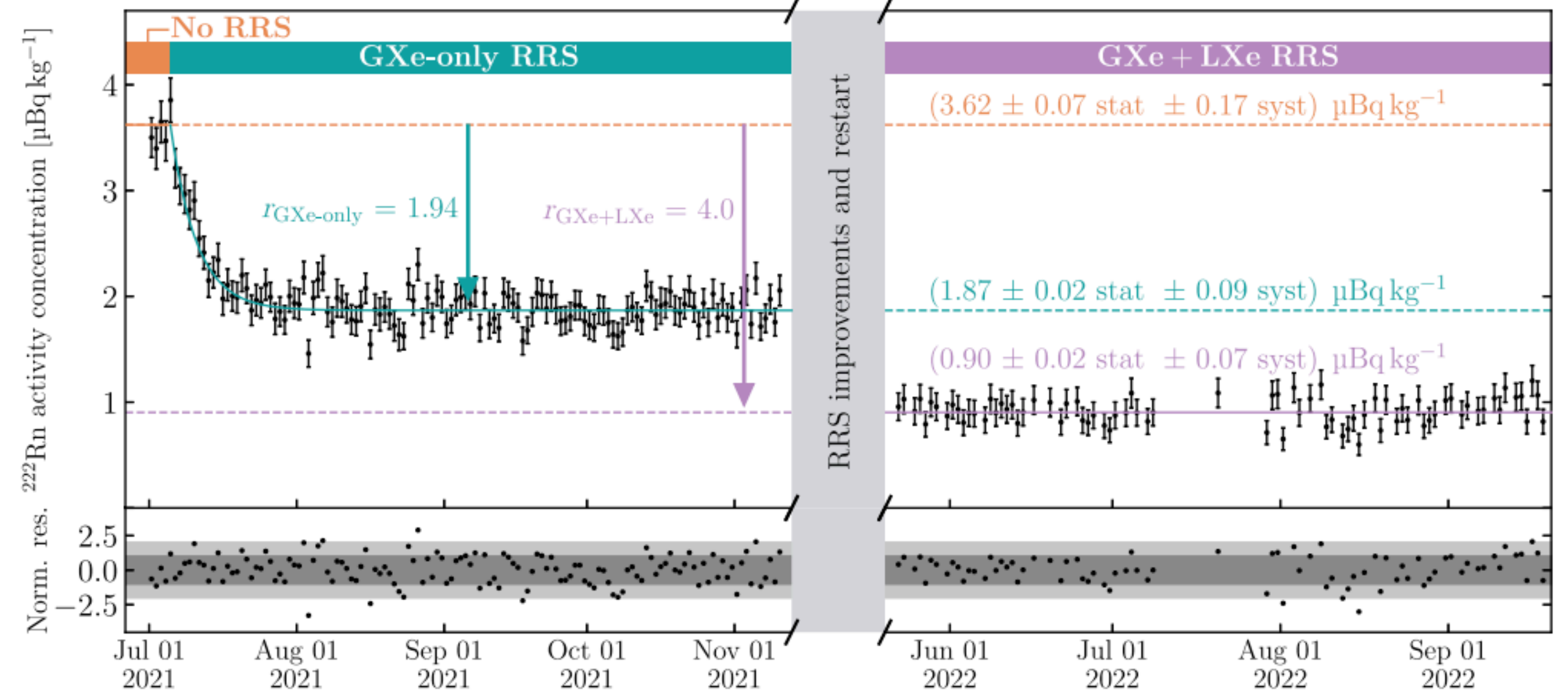
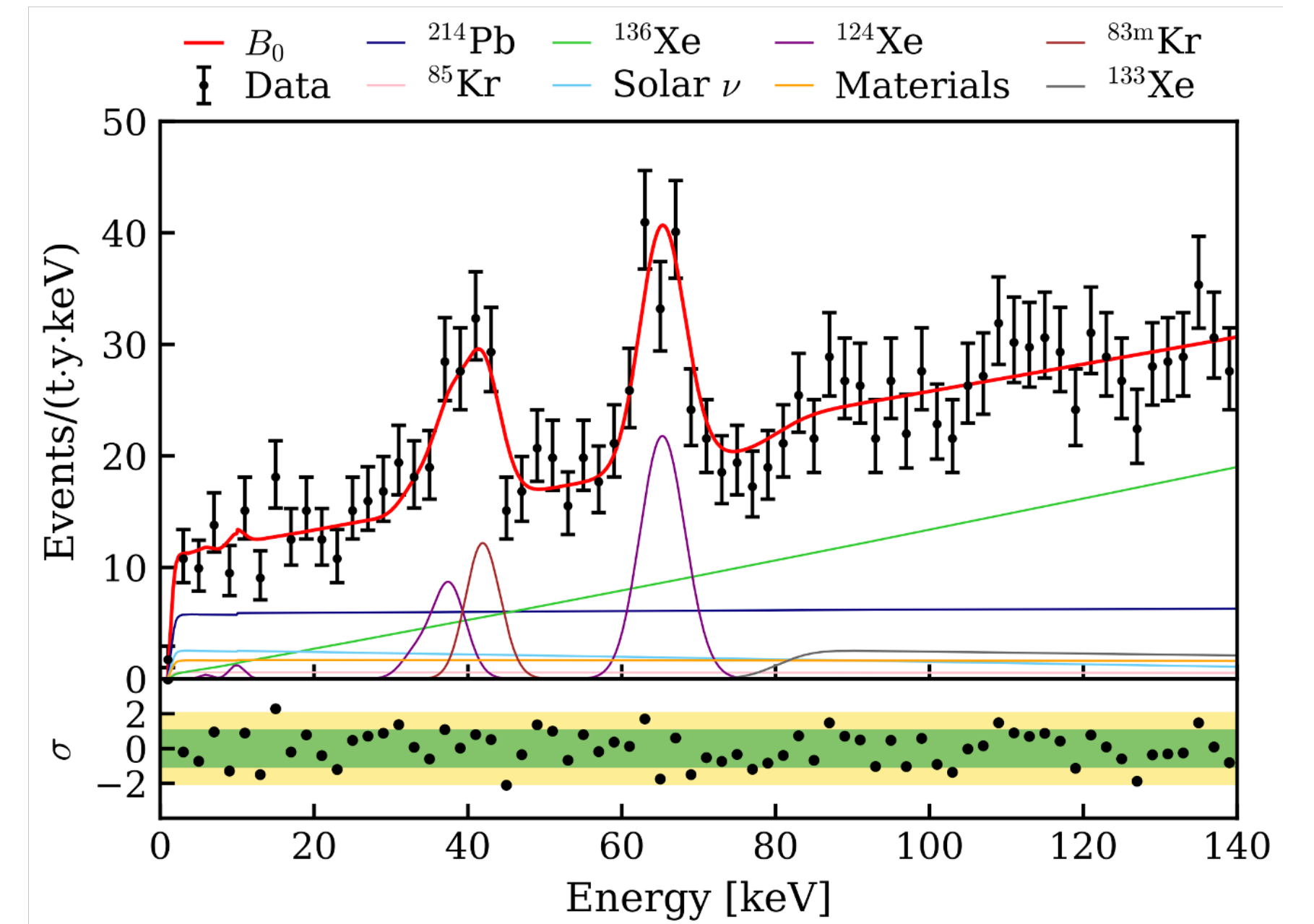


^{222}Rn

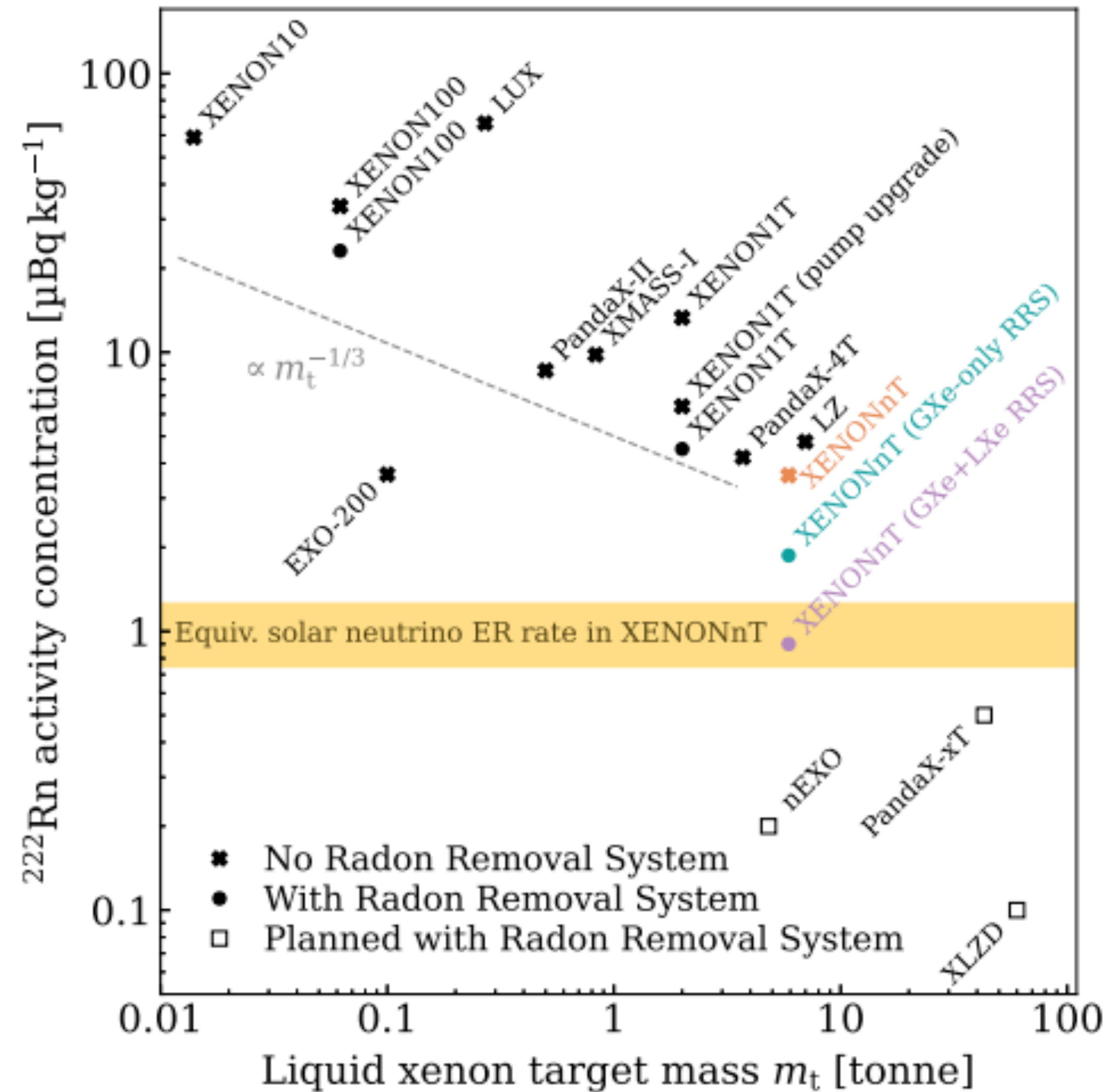


Xe

Rn

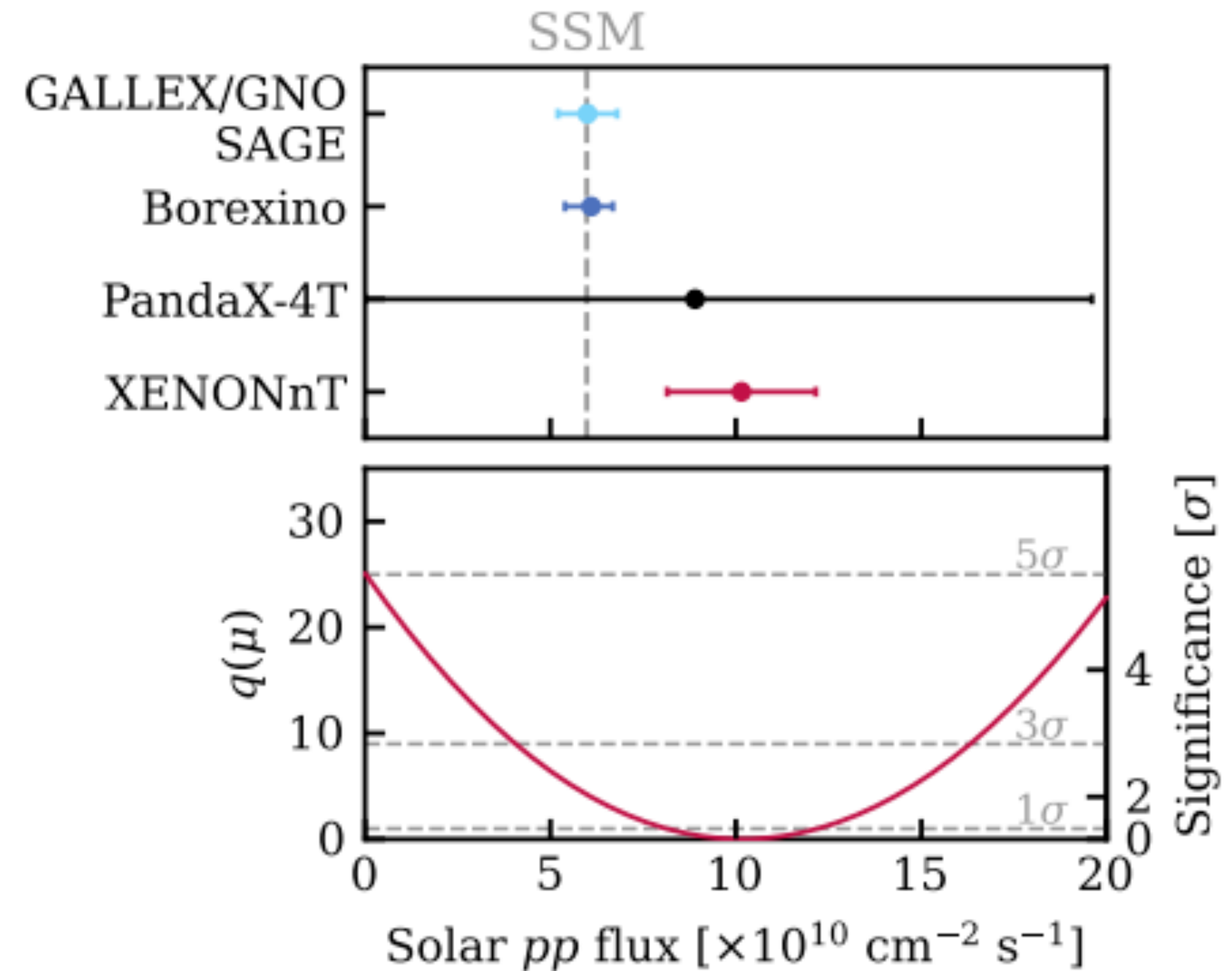


Background Challenge: Kr and Rn



[PRX 15, 031079, 2025](#)

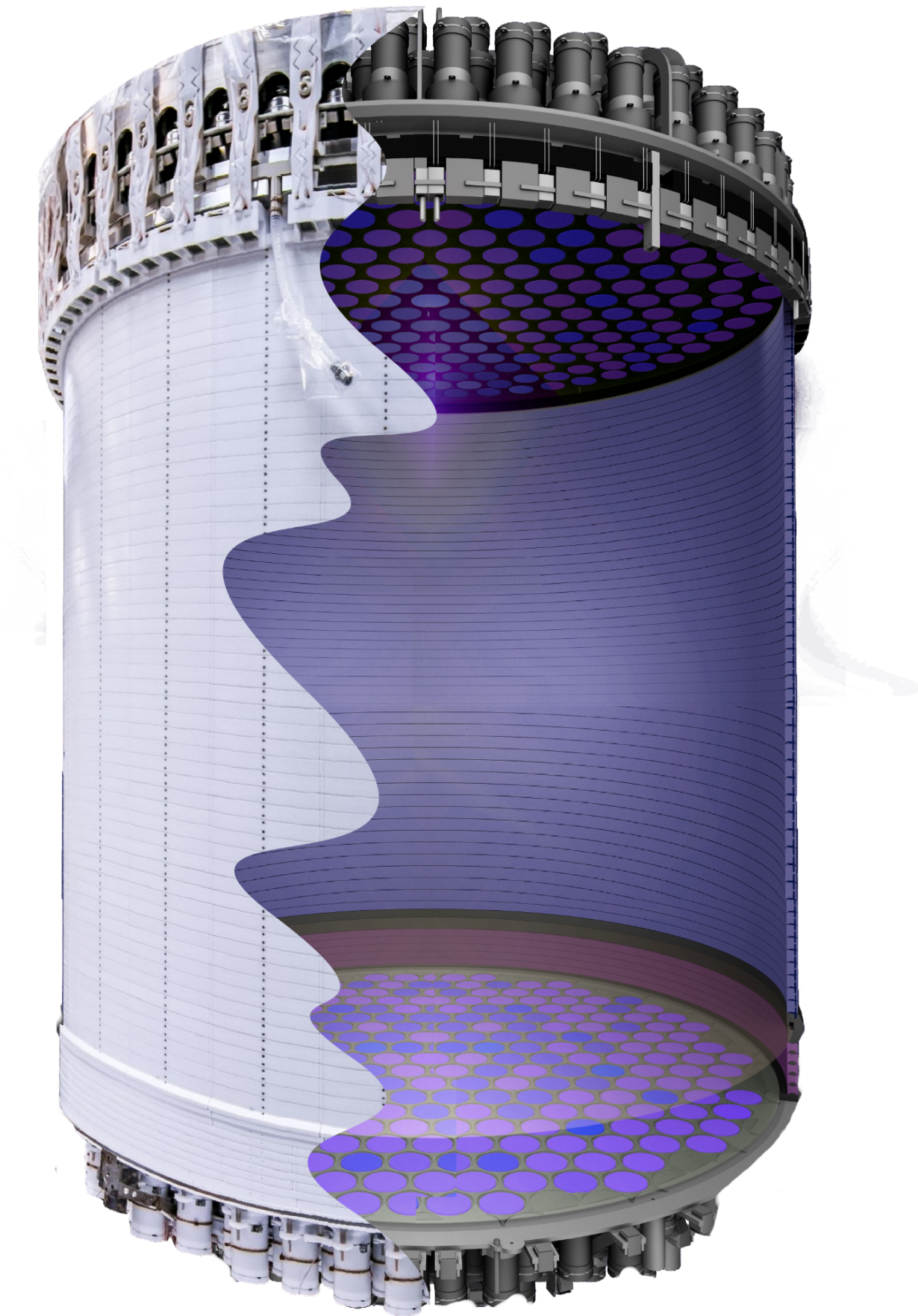
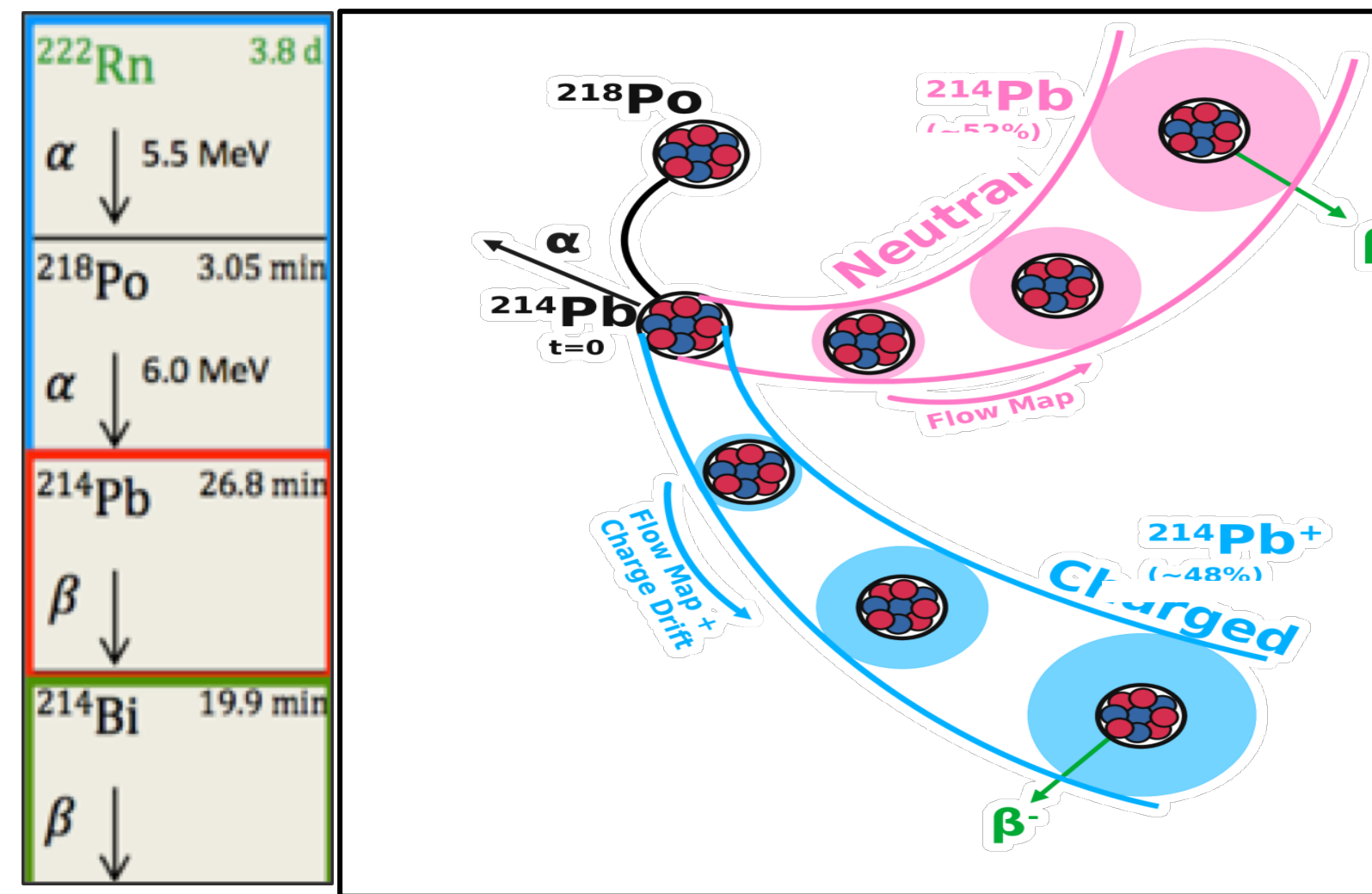
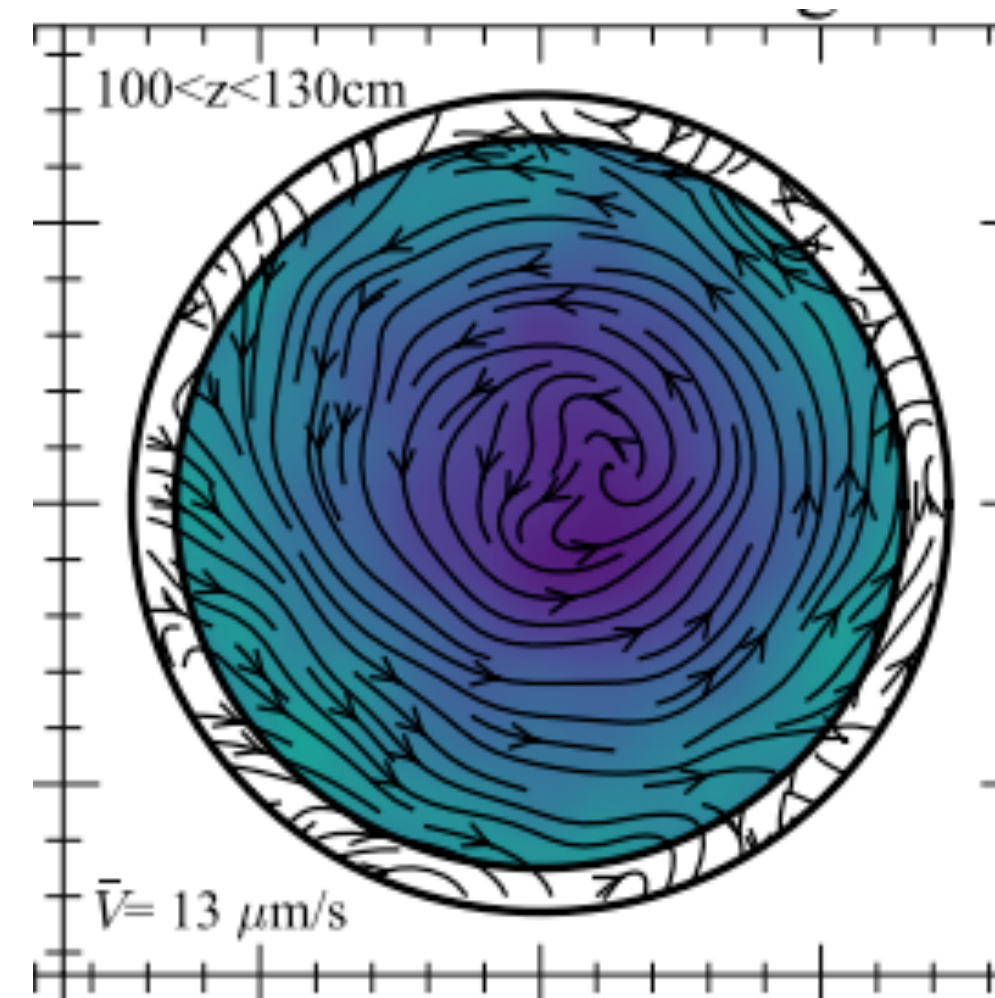
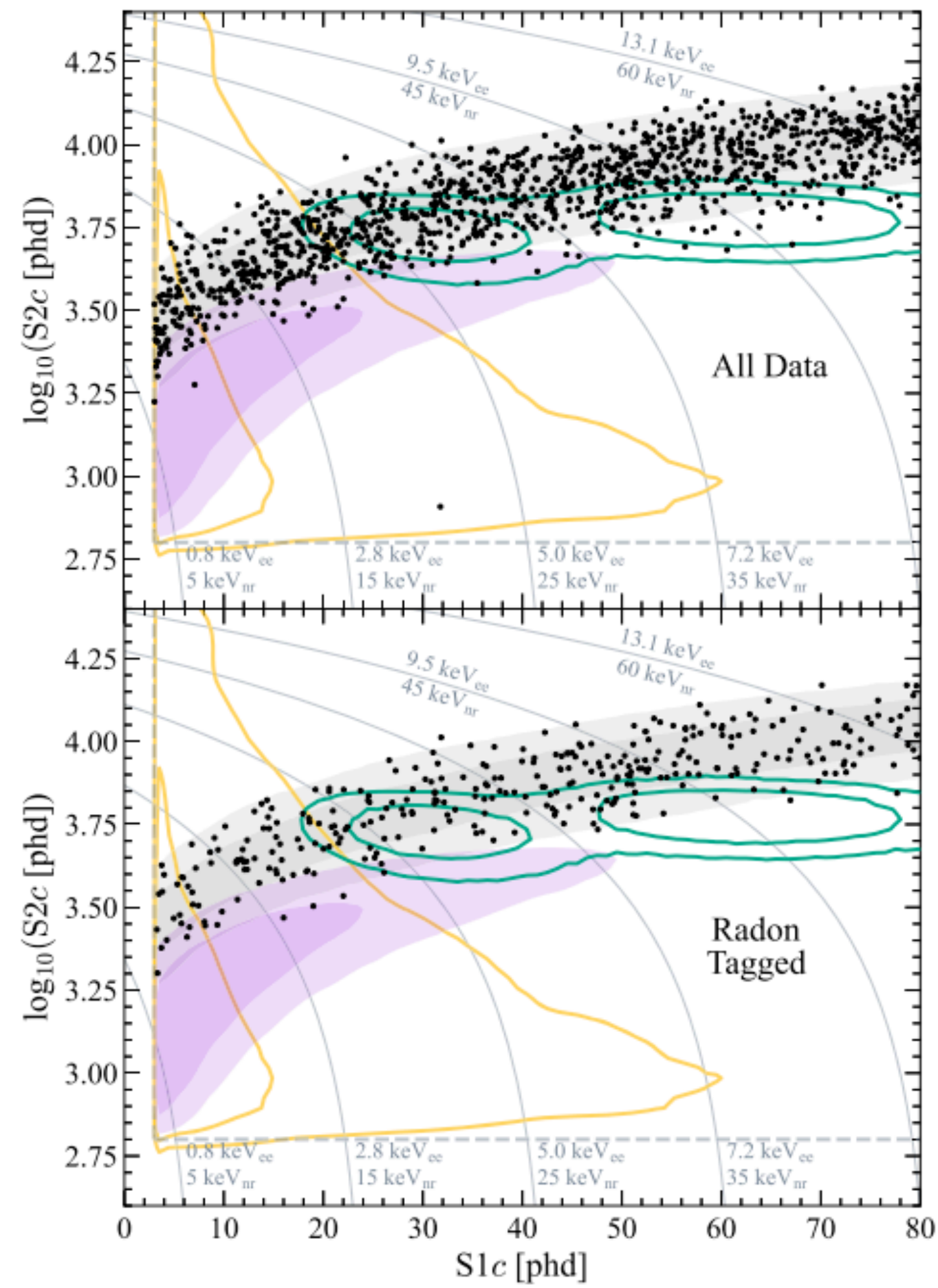
The contribution of the Pb-214 background is comparable to that from solar pp neutrinos.



[arXiv: 2608.29450](#)

LXe TPC starts to be very sensitive to solar pp neutrinos.
See [J. Ye's talk at this conference](#).

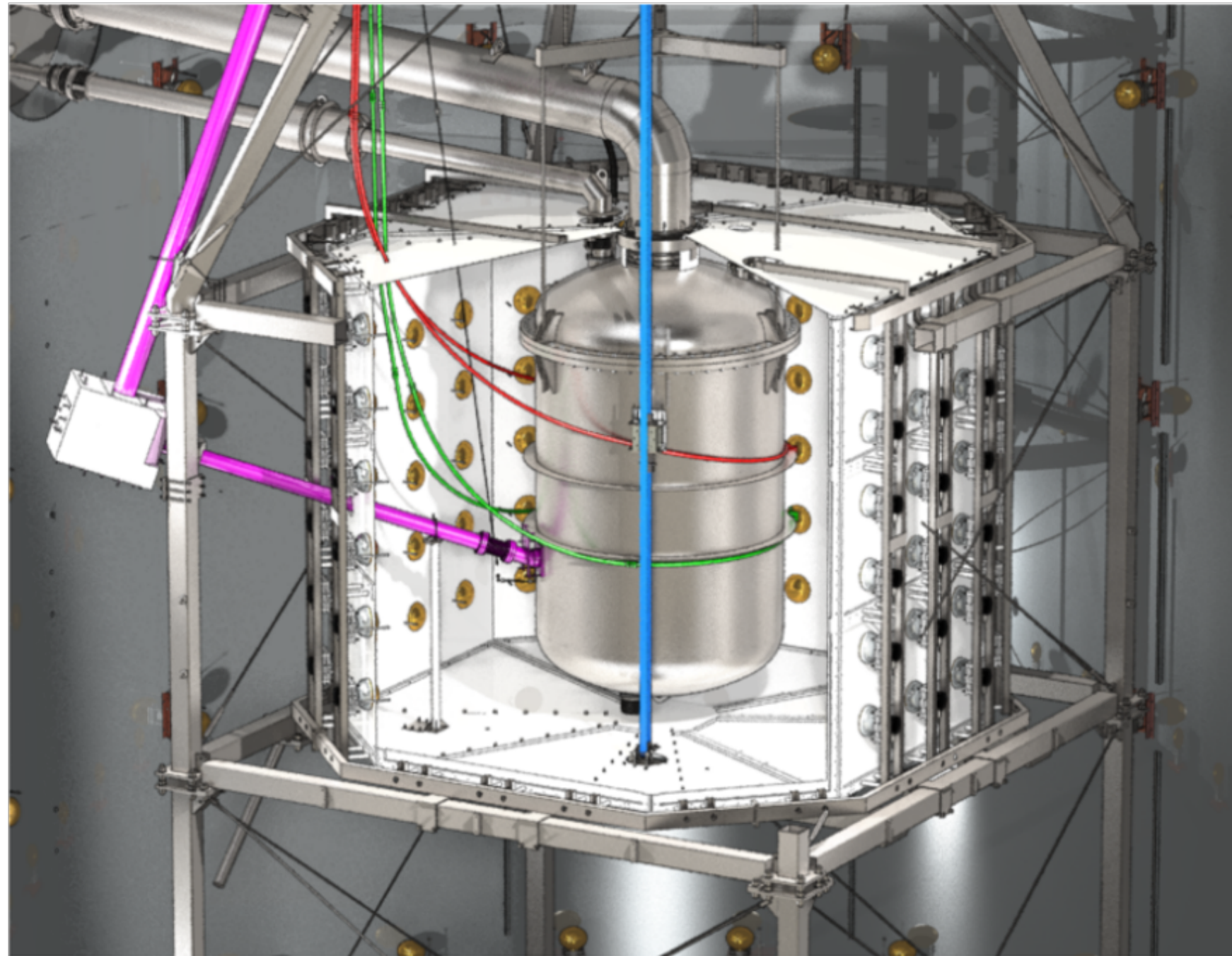
Background Rejection for Pb214



arXiv: 2508.19117

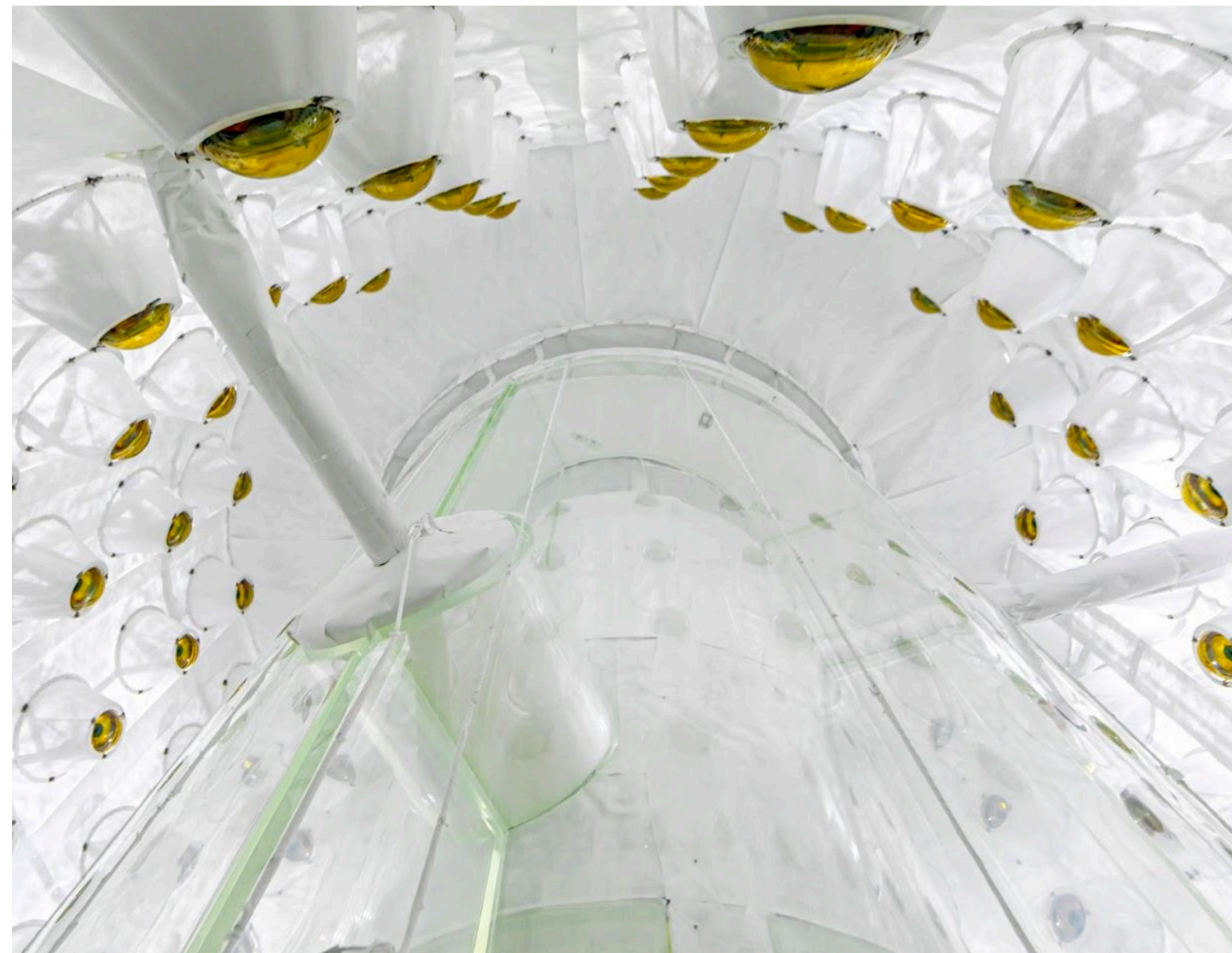
With 9% of exposure, LZ can identify 63% of the Pb214 background

Background Challenge: Neutrons

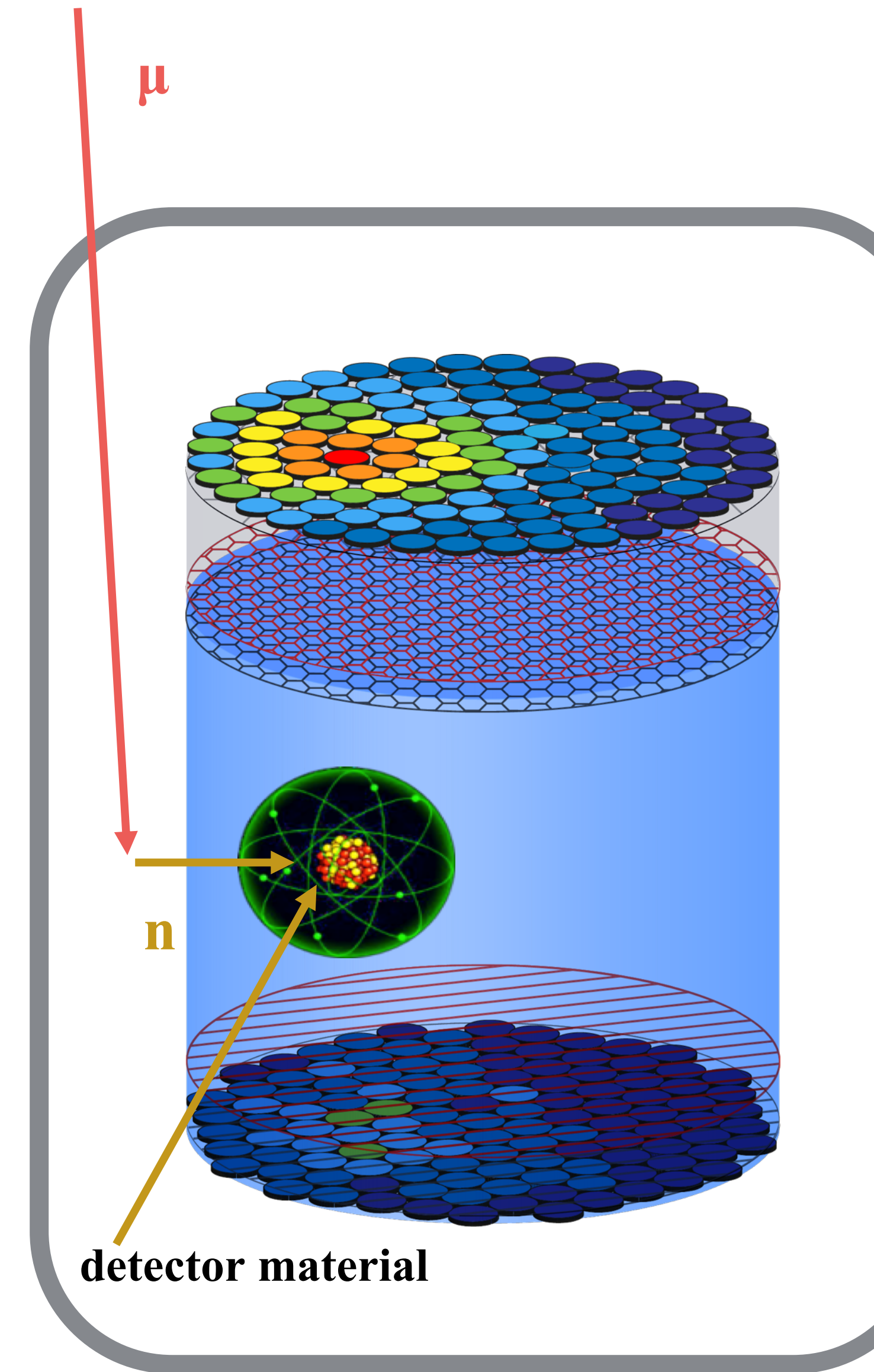


XENONnT, PandaX-4T

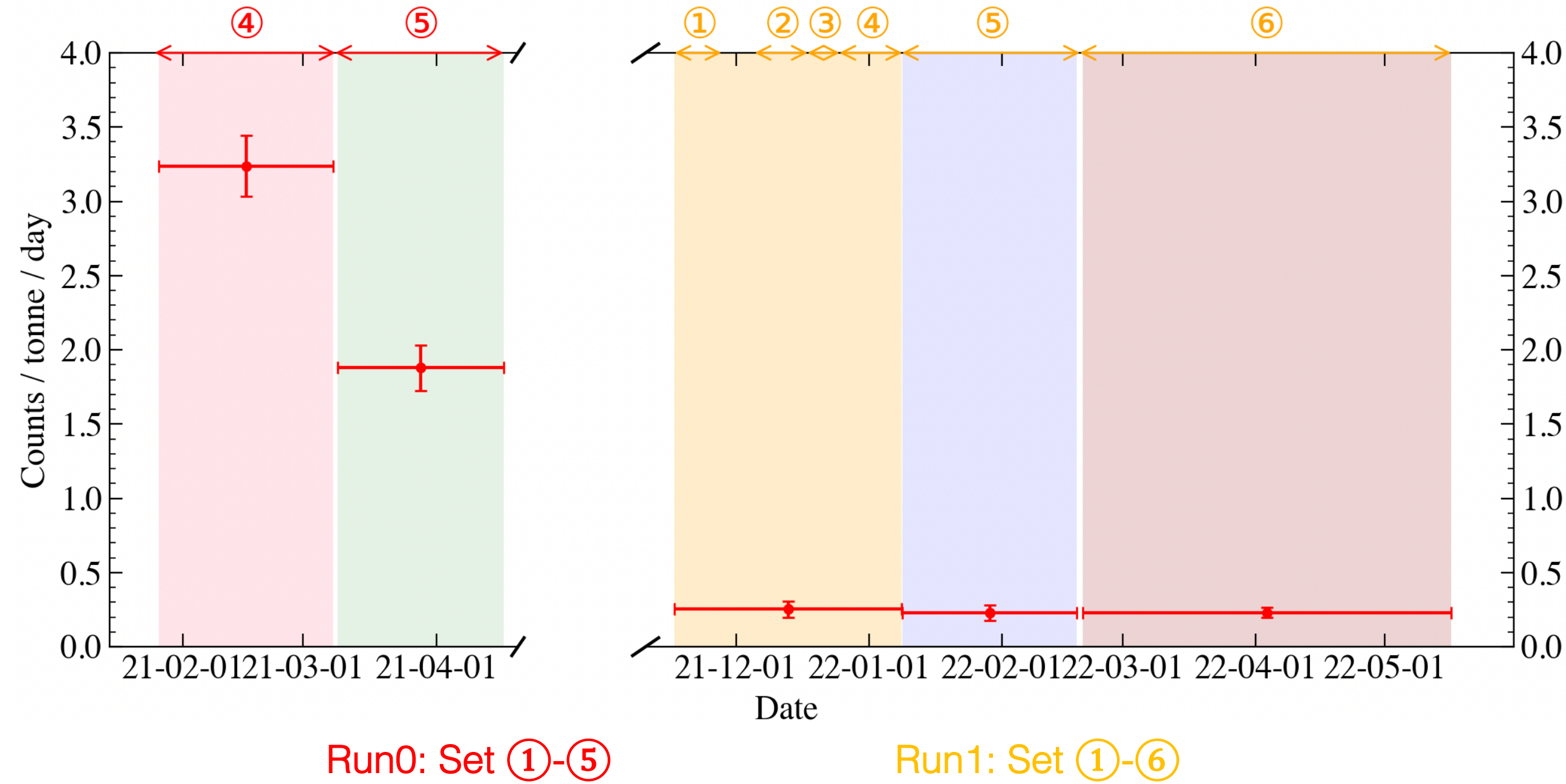
LZ



Neutron background reduced to < 1
events / (20 tonne-year)



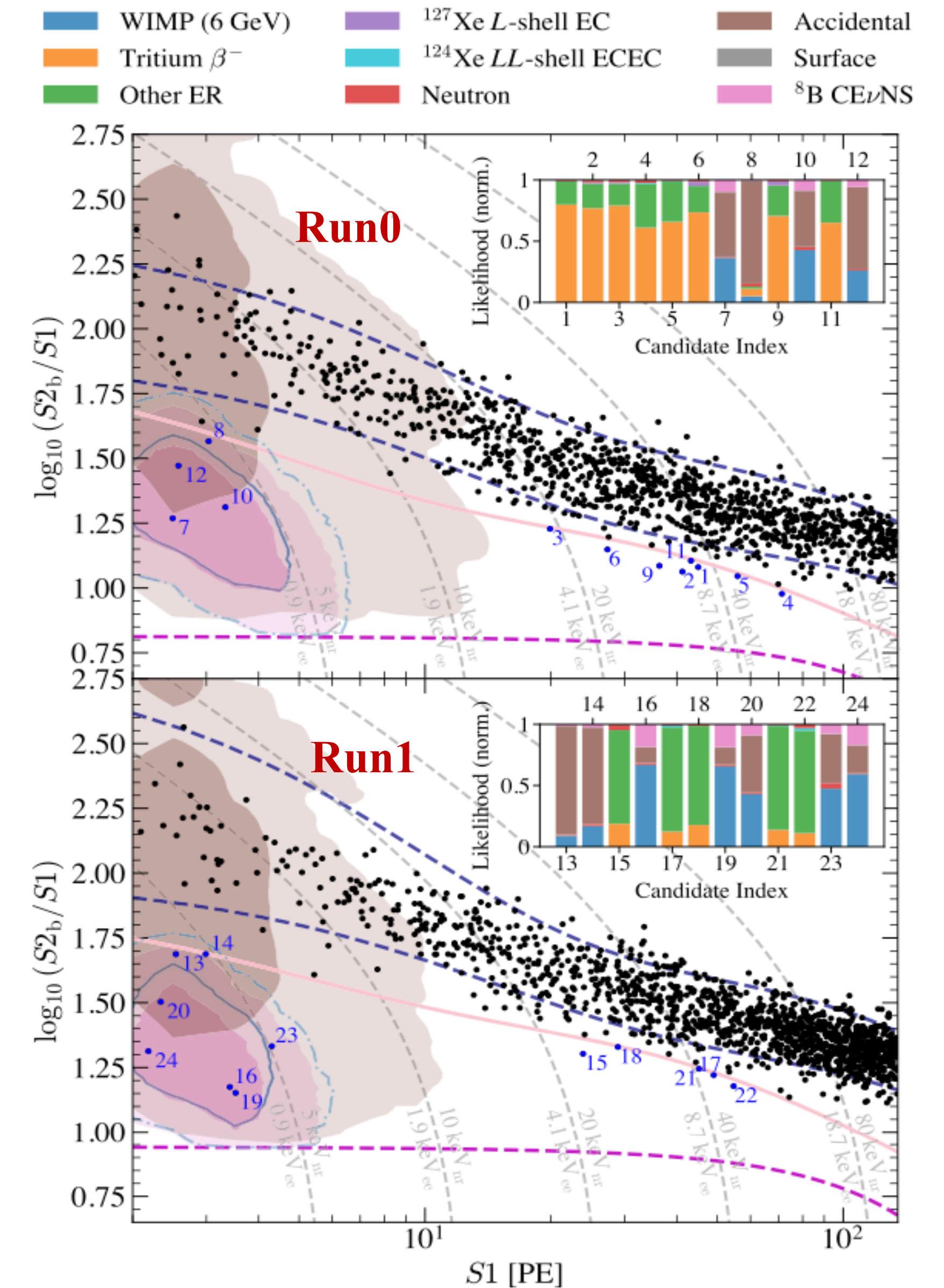
Dark Matter Search Results – PandaX-4T



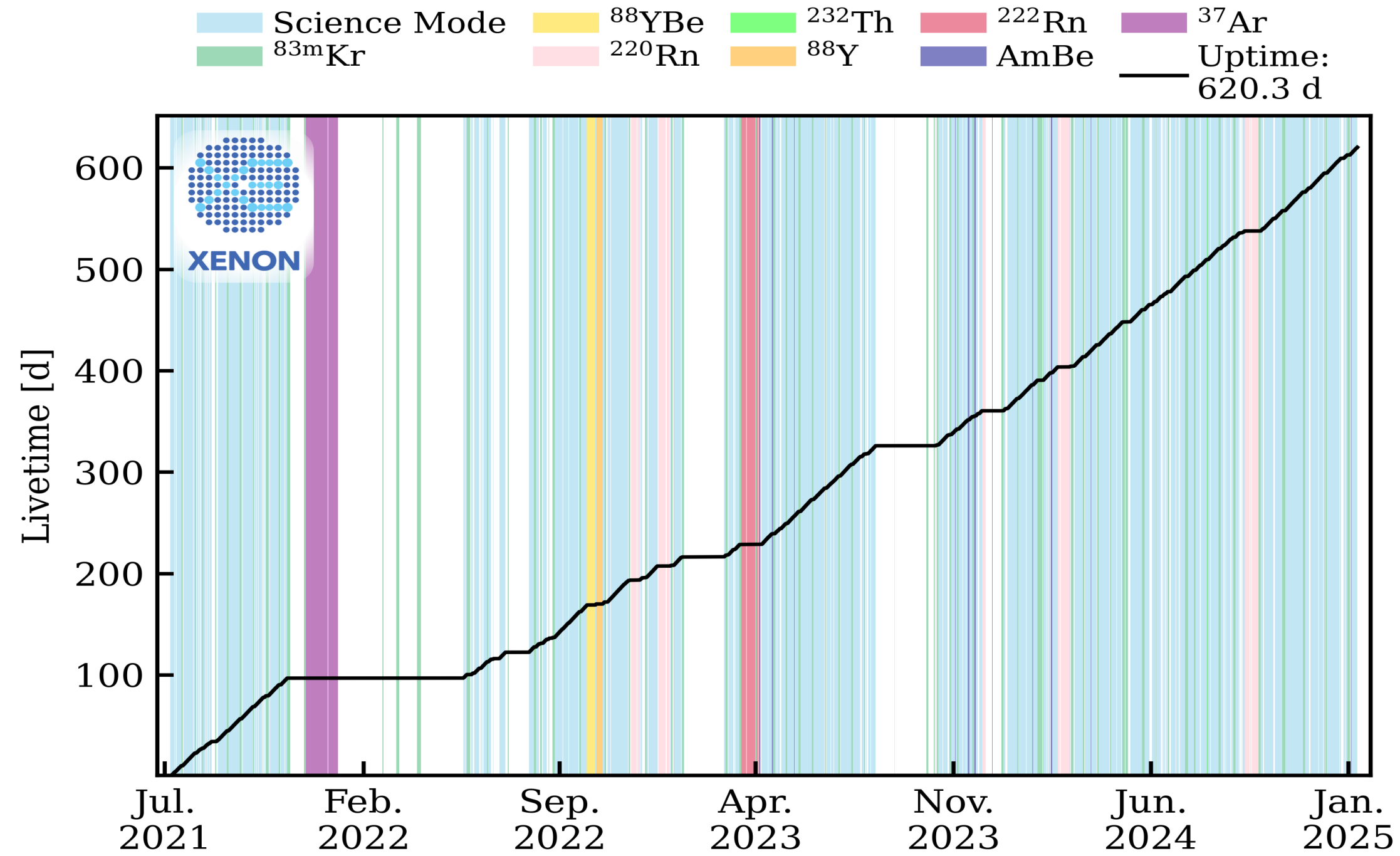
Background data taking: 2021-2026

Published exposure for WIMP search: 1.54 t-y

Tritium background has been significantly reduced in Run-I



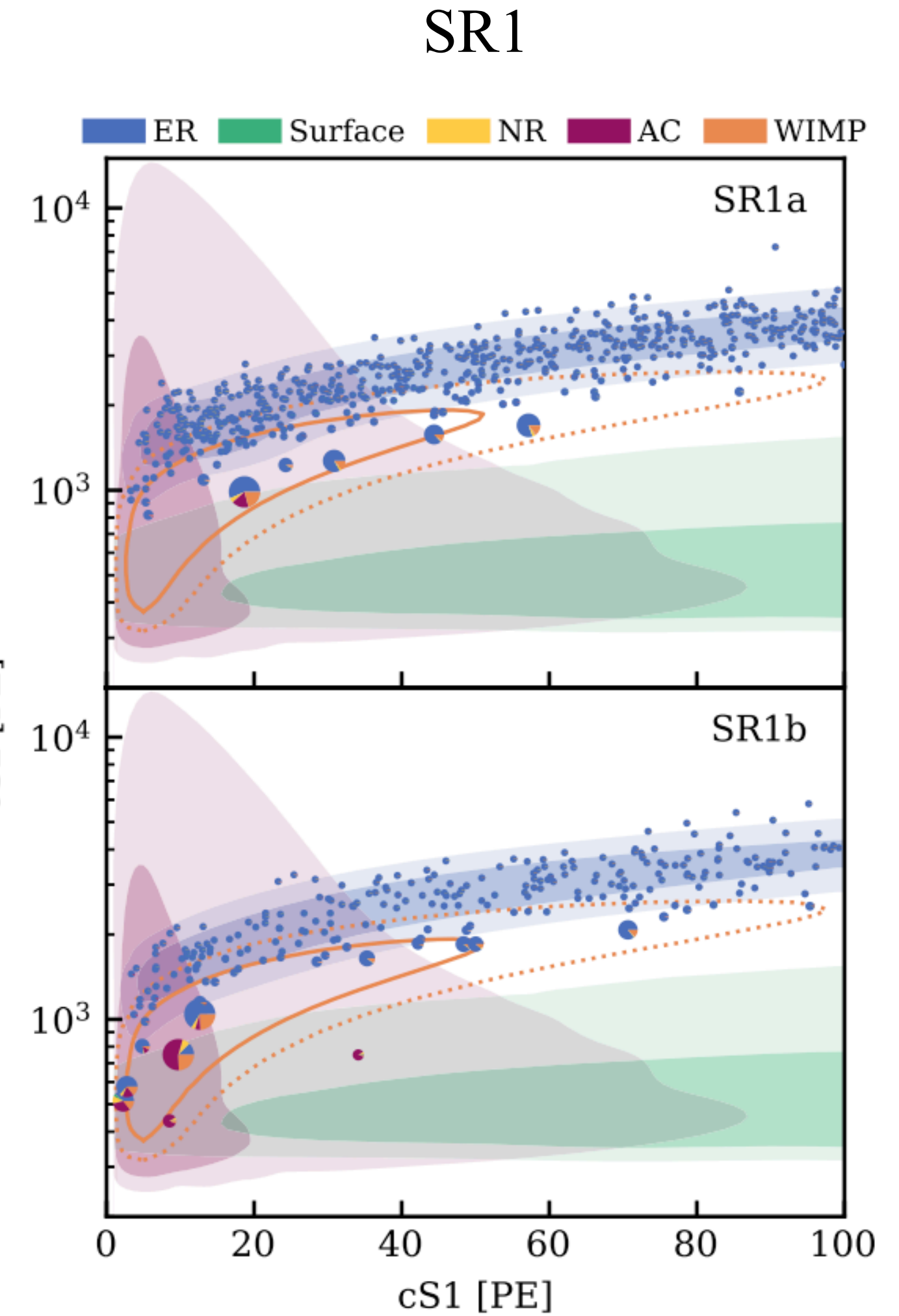
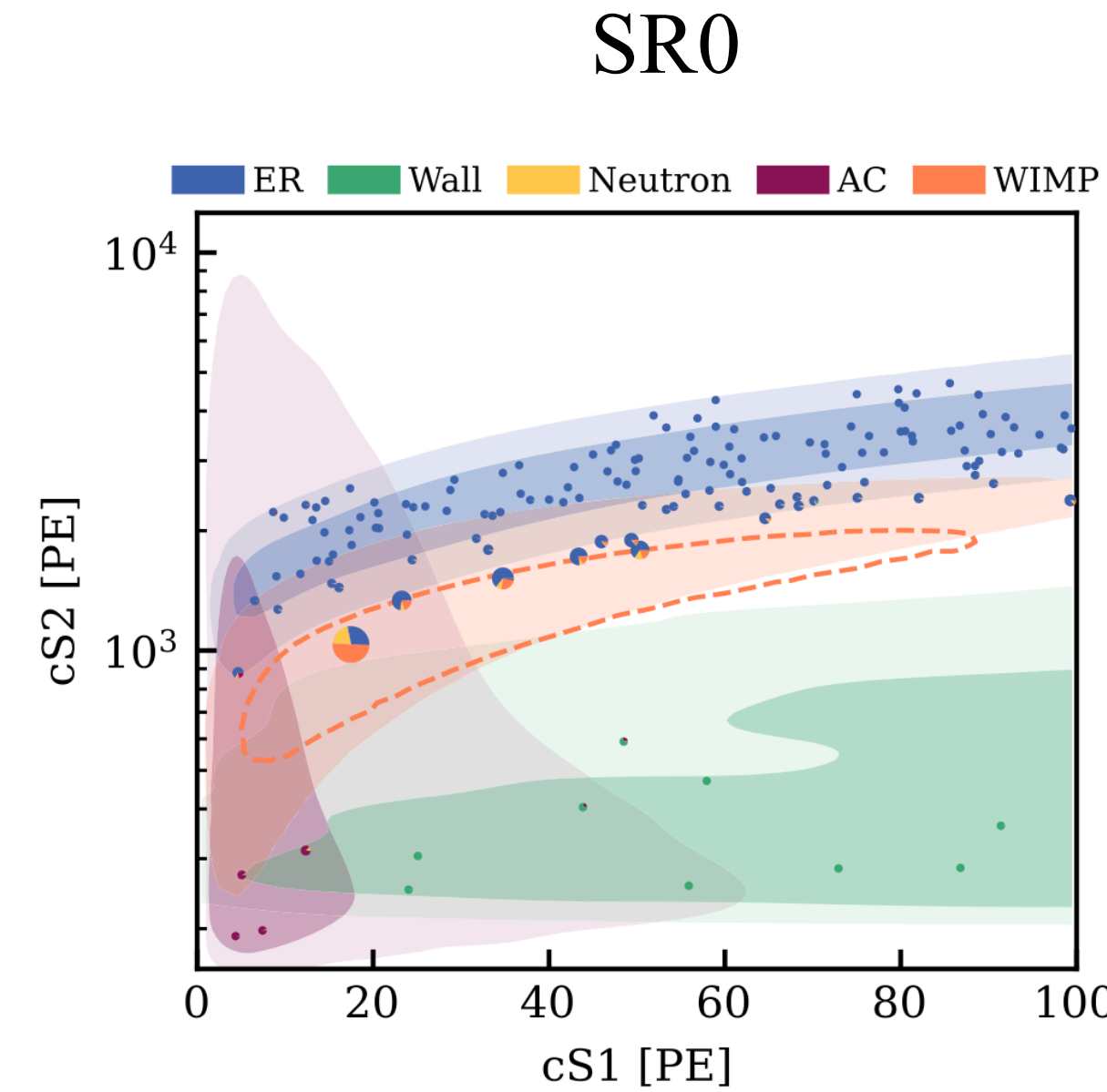
Dark Matter Search Results – XENONnT



SR0

SR1

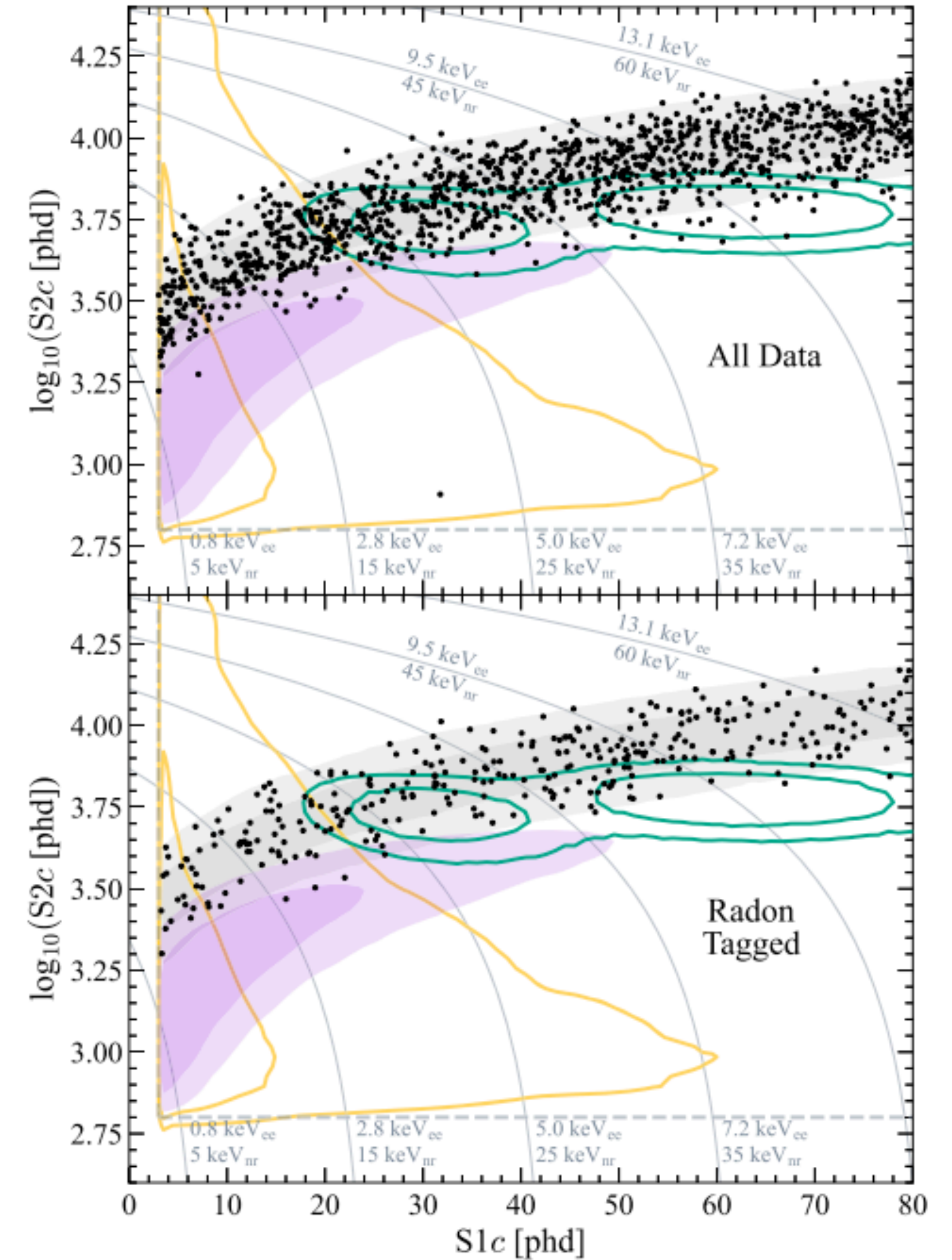
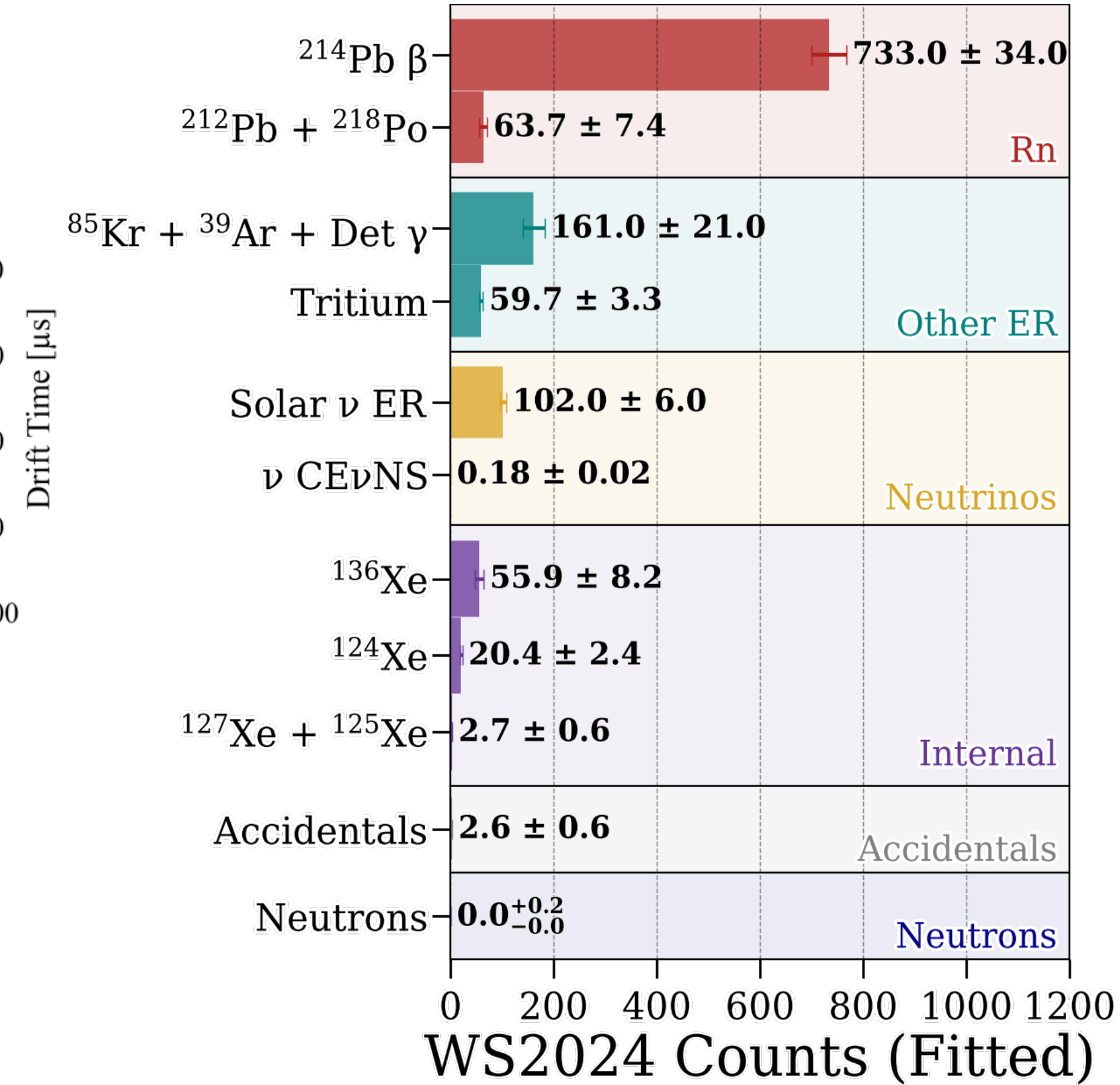
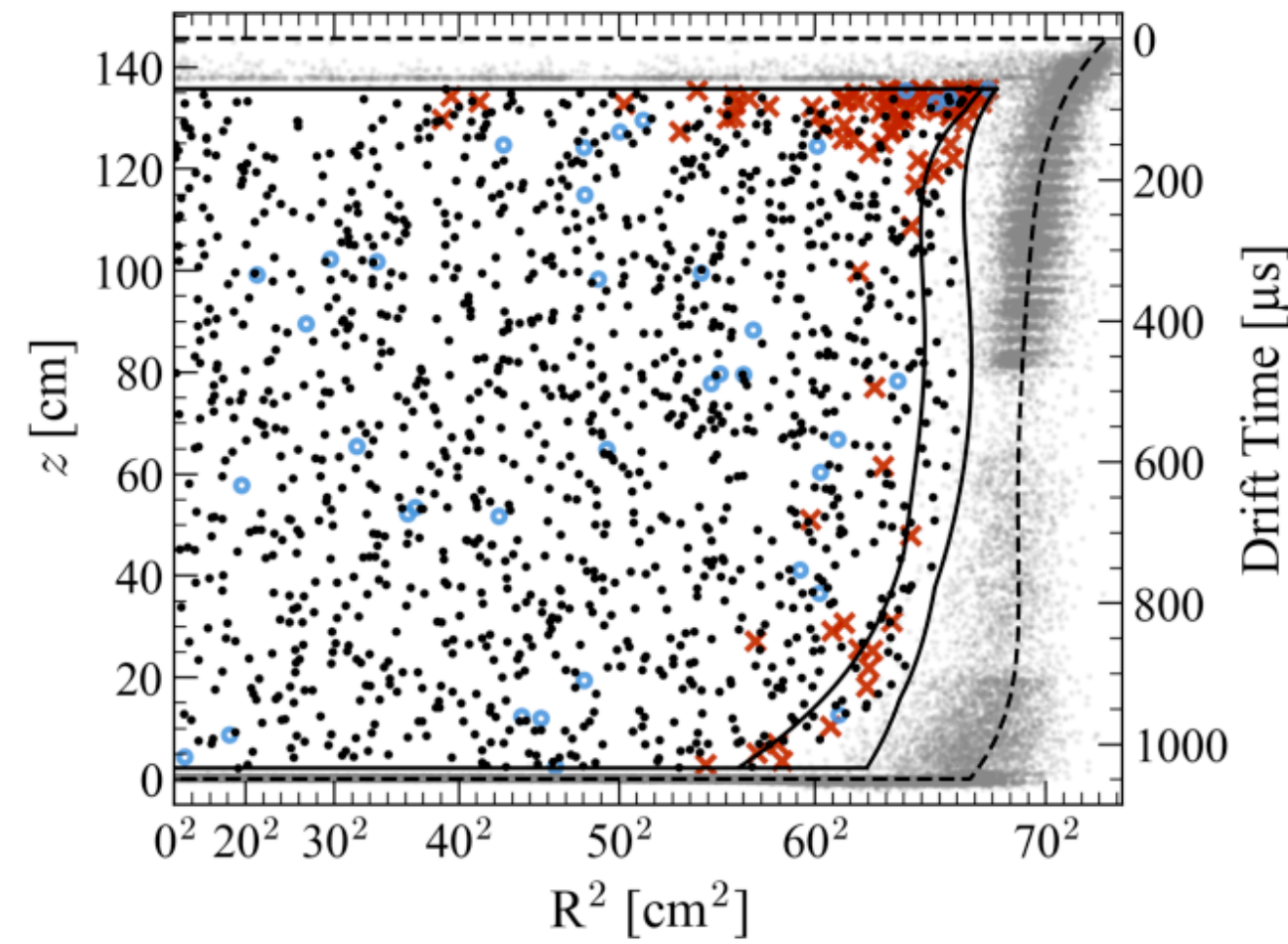
SR2



Background data taking: 2021-2025

Published exposure for WIMP search: 3.1 t-y (SR0+SR1)

Dark Matter Search Results – LZ

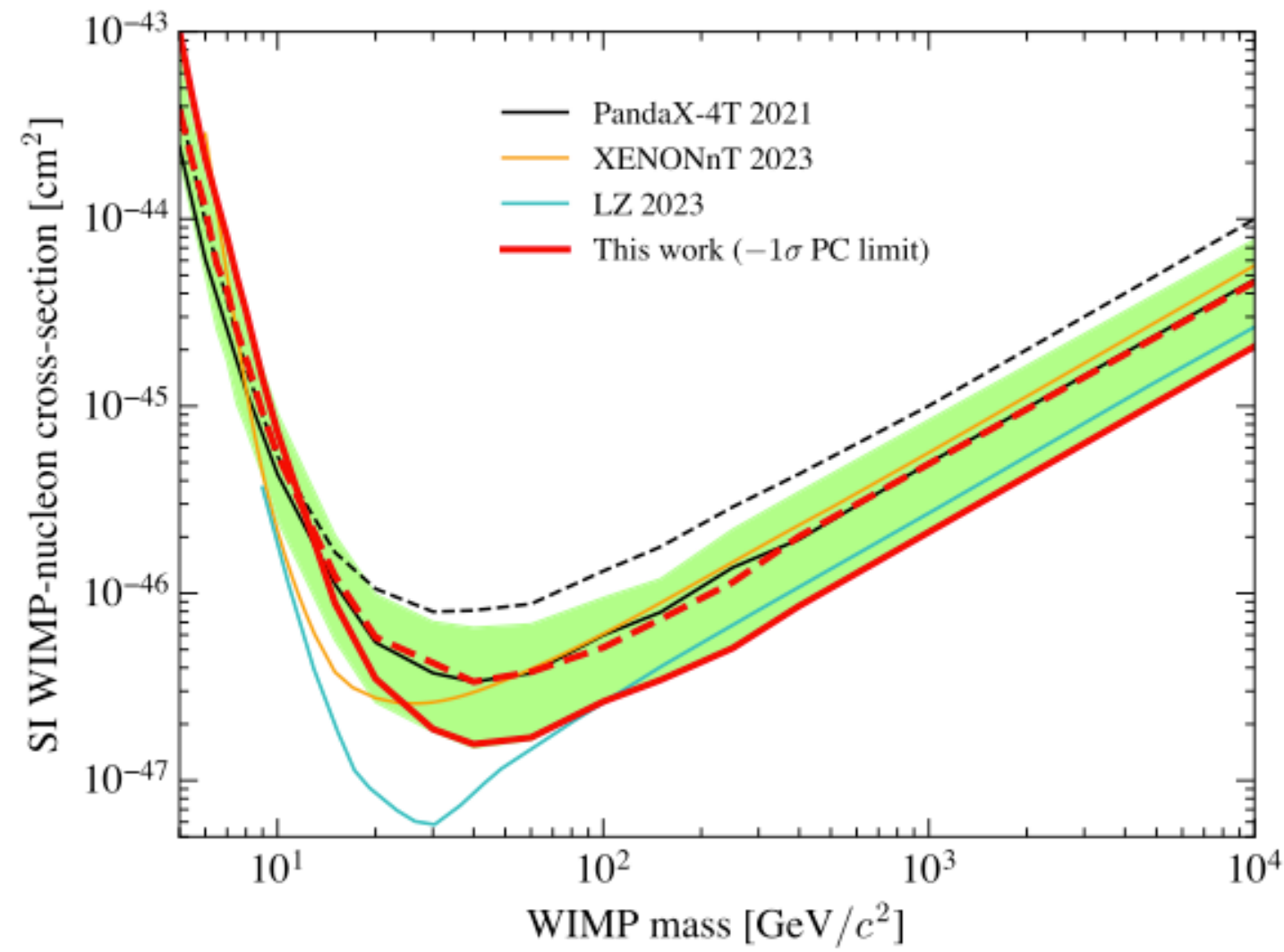


LZ has the largest fiducial mass among the three.

Published exposure for WIMP search: 4.2 t-y

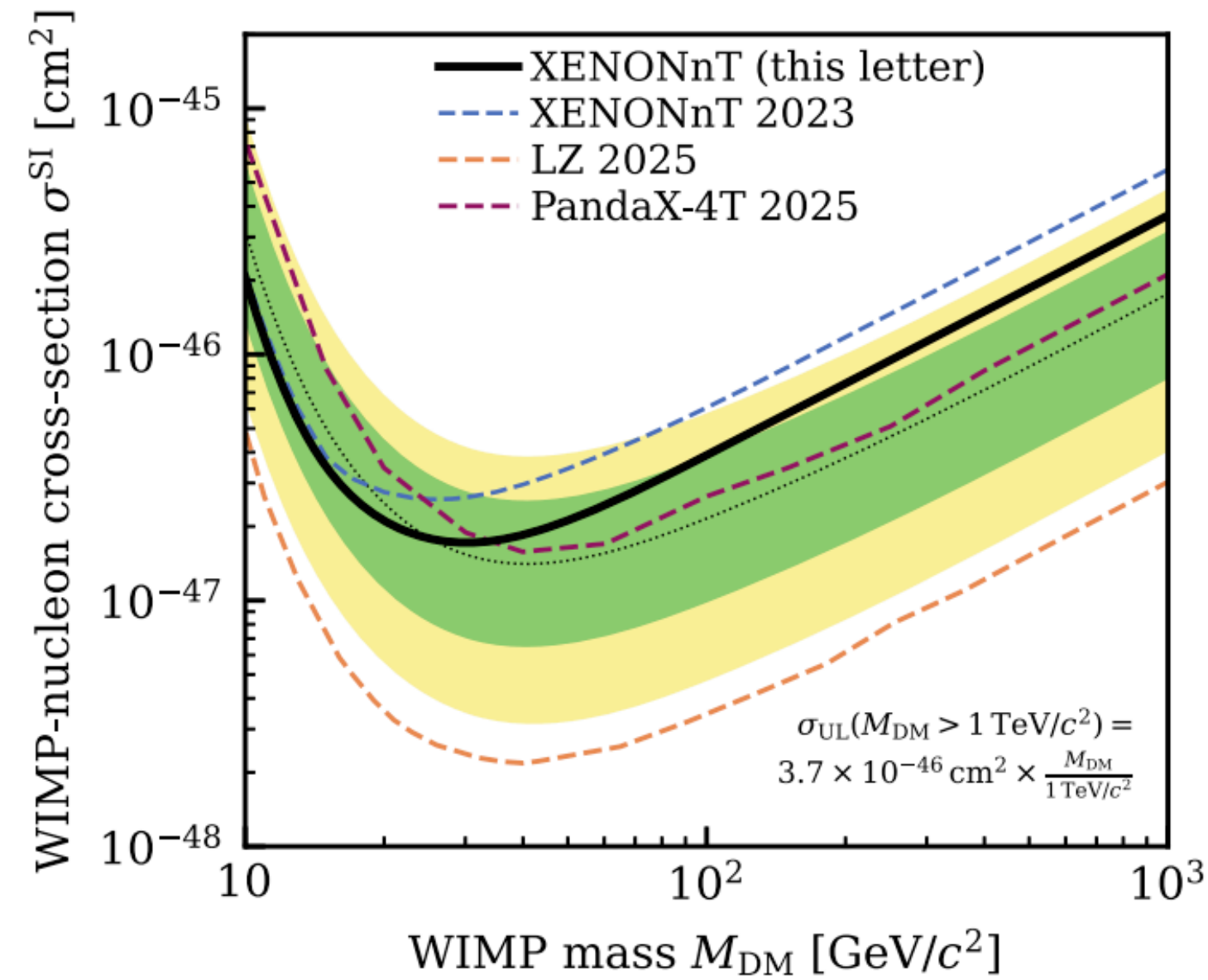
Dark Matter Search Results

PandaX-4T



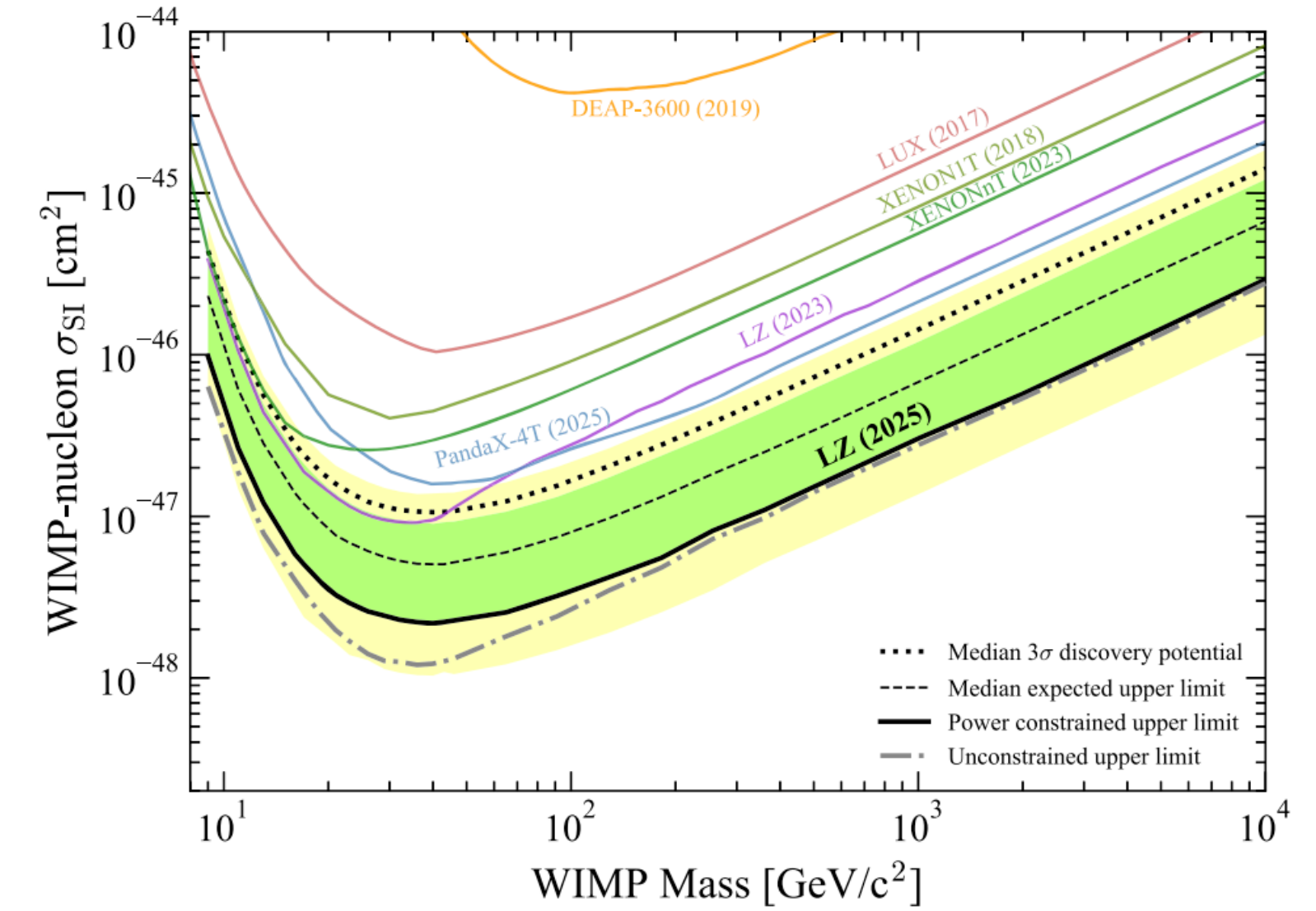
PRL 134, 011805, 2025

XENONnT



PRL 135, 221003, 2025

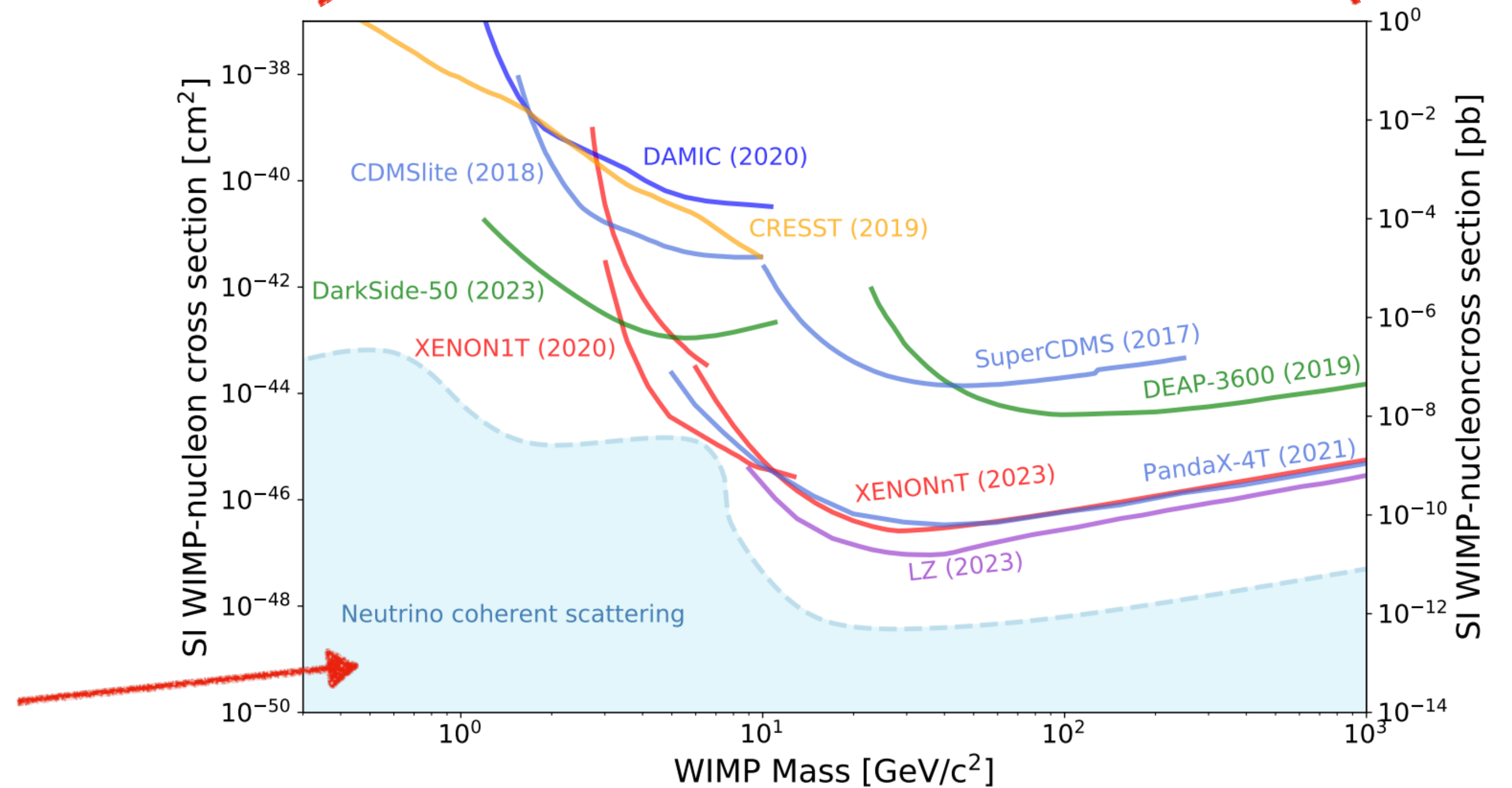
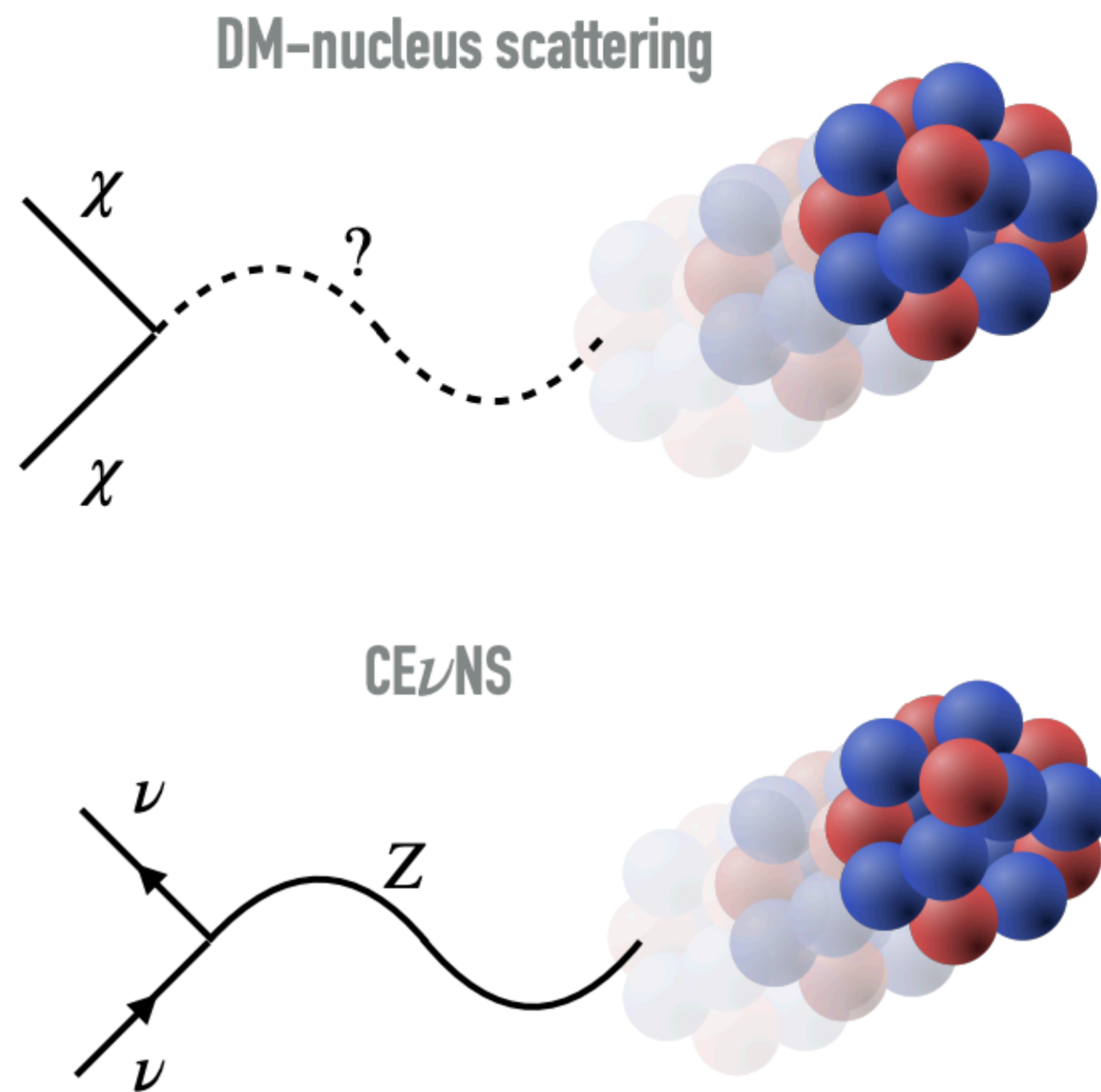
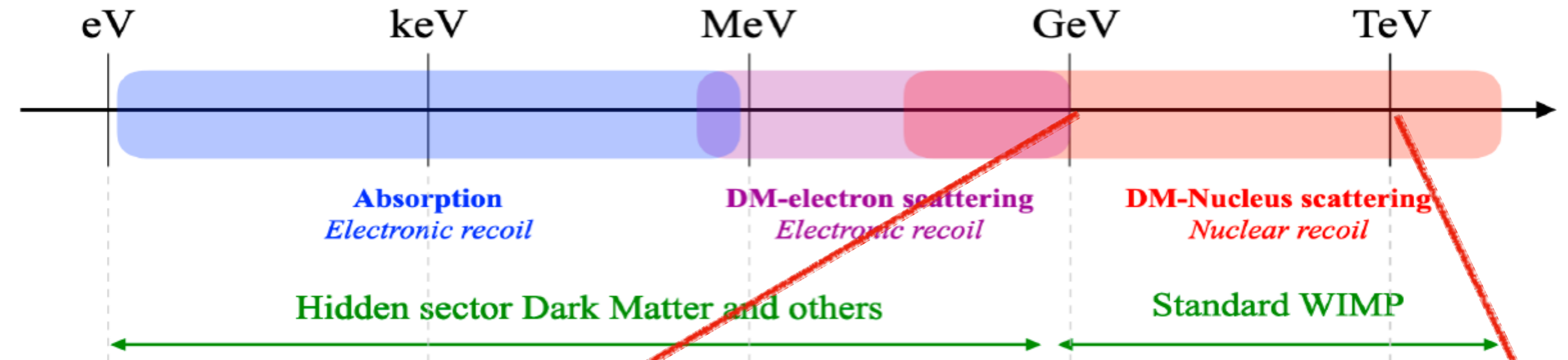
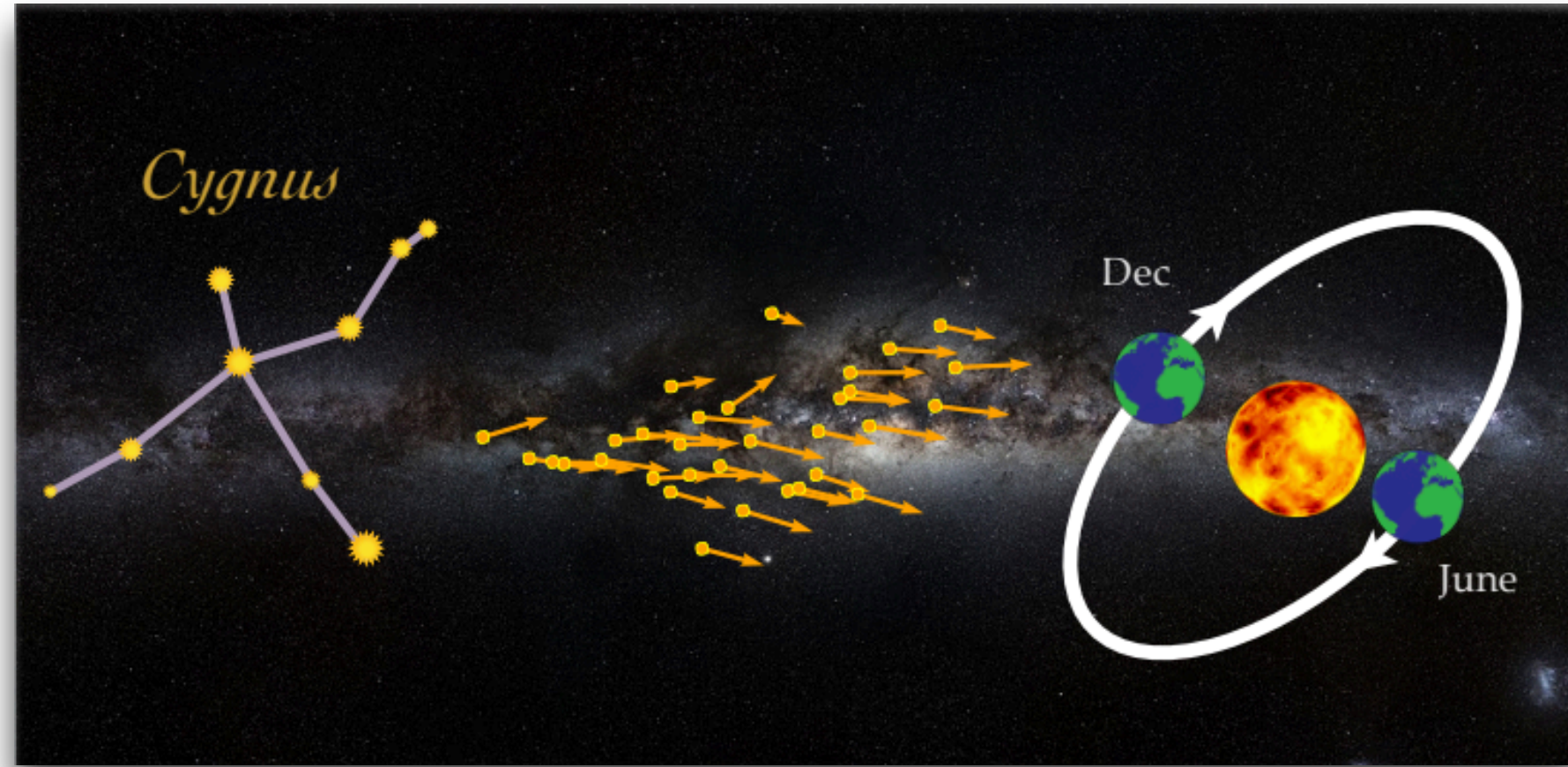
LZ



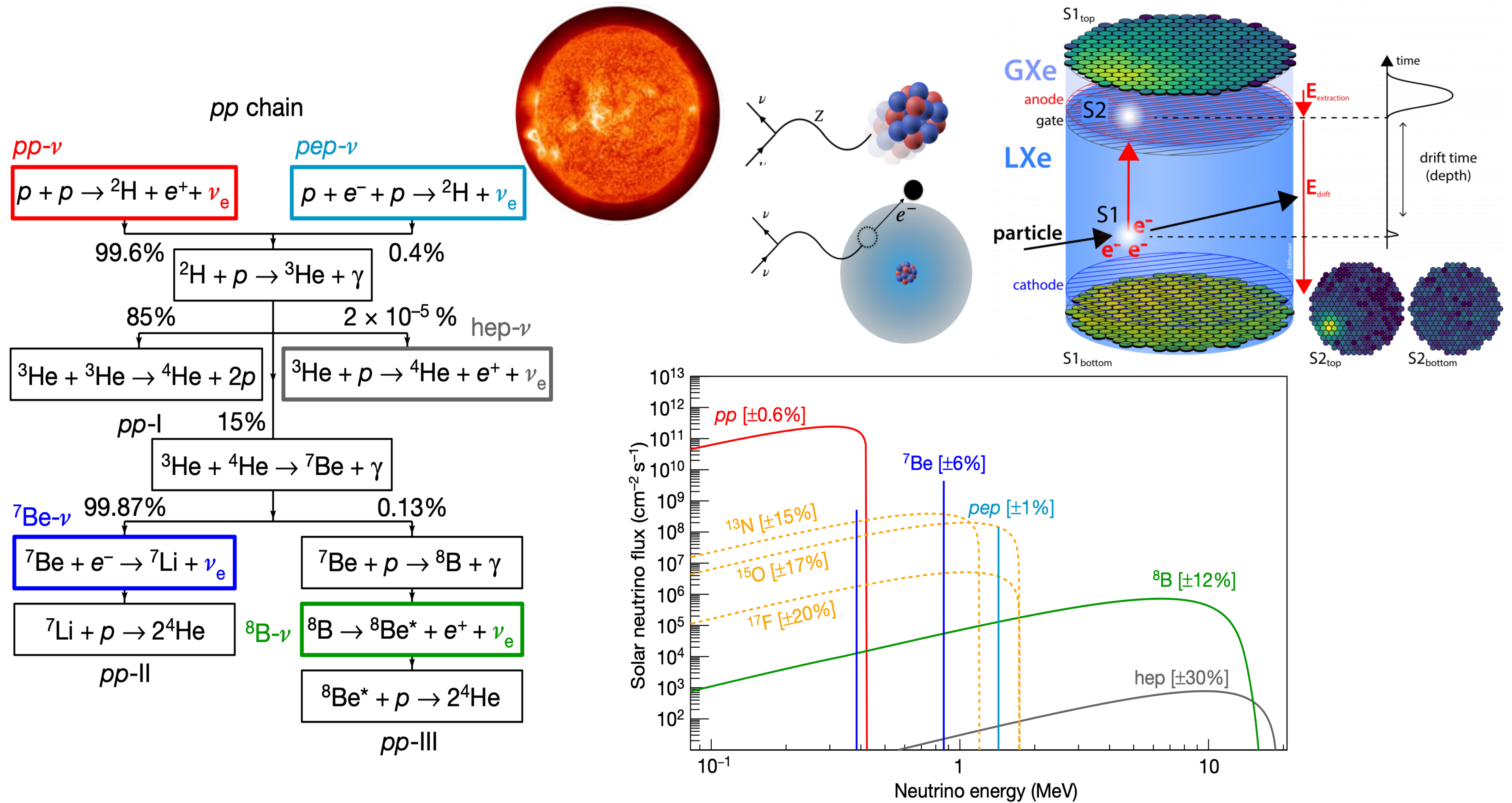
PRL 135, 011802, 2025

LXeTPCs continue to lead the sensitivity to WIMPs for masses above 10 GeV

The “Neutrino fog”

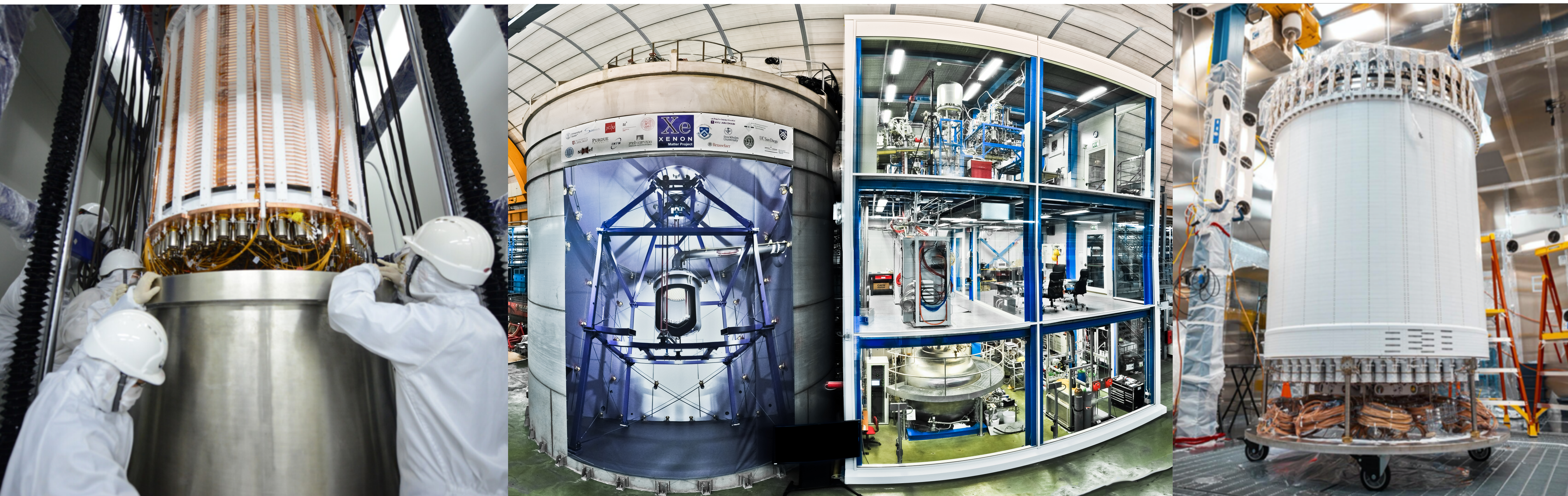


Detection of Solar neutrinos with LXeTPC

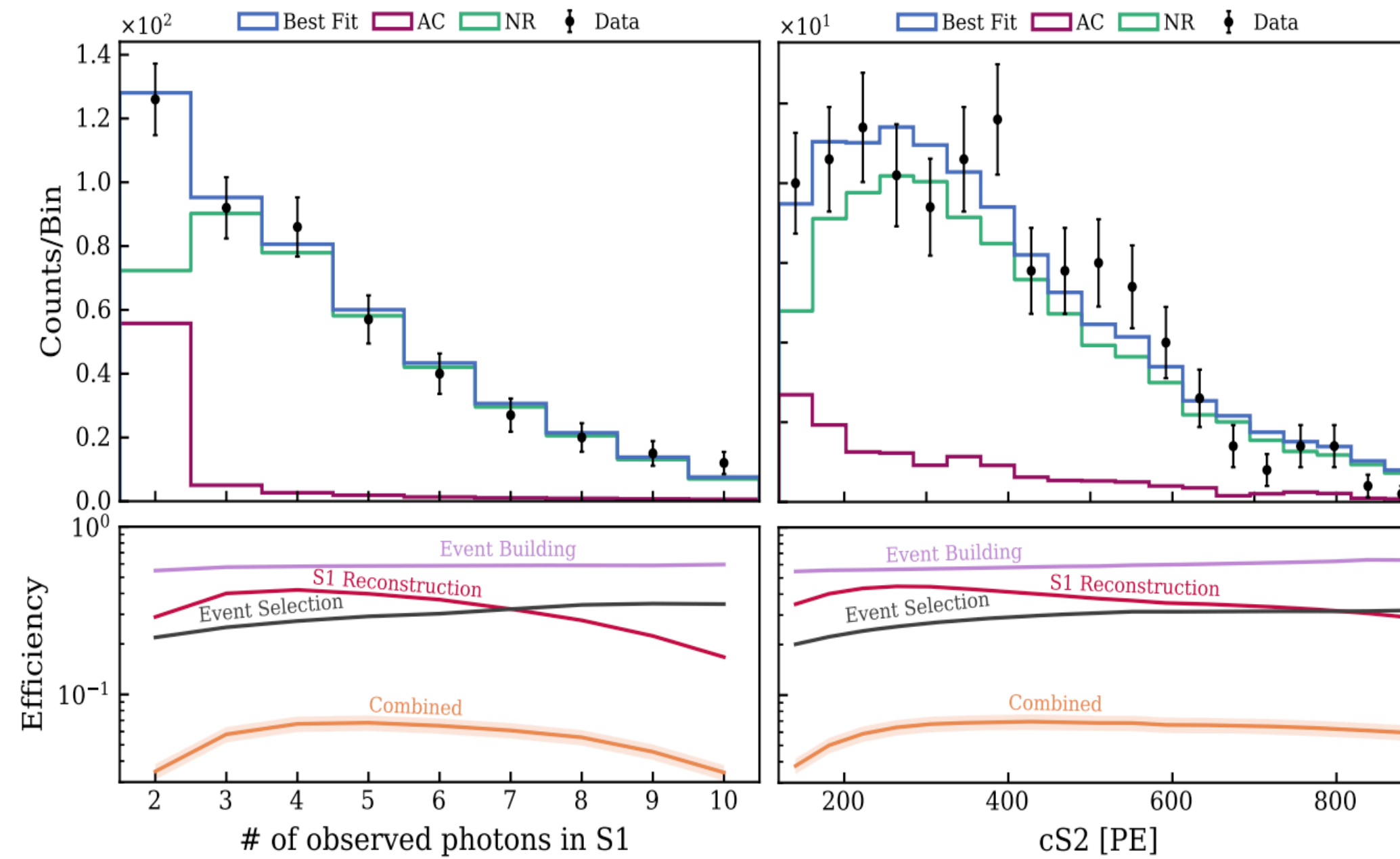
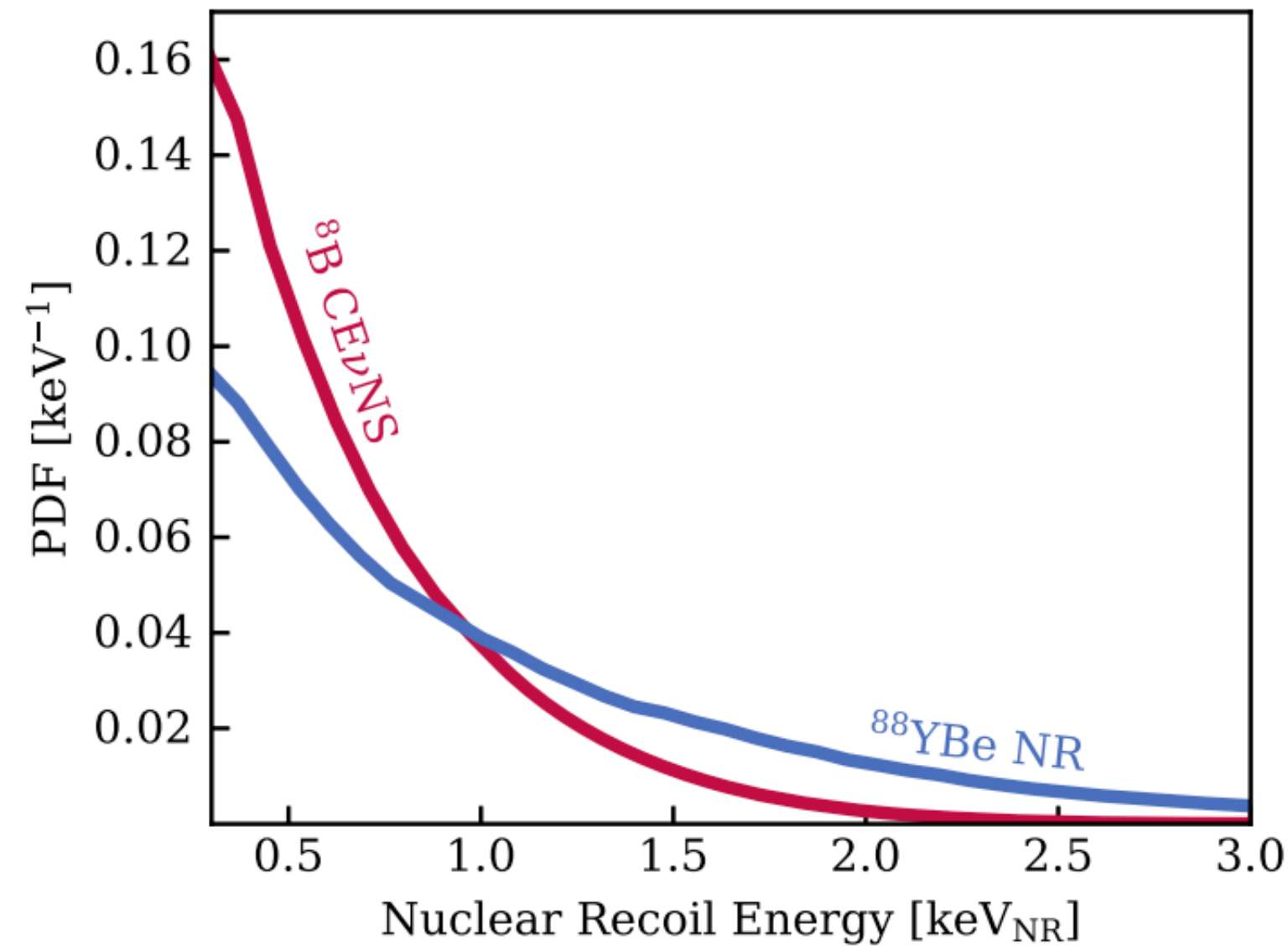


Detection of Solar ^8B neutrinos with LXeTPC

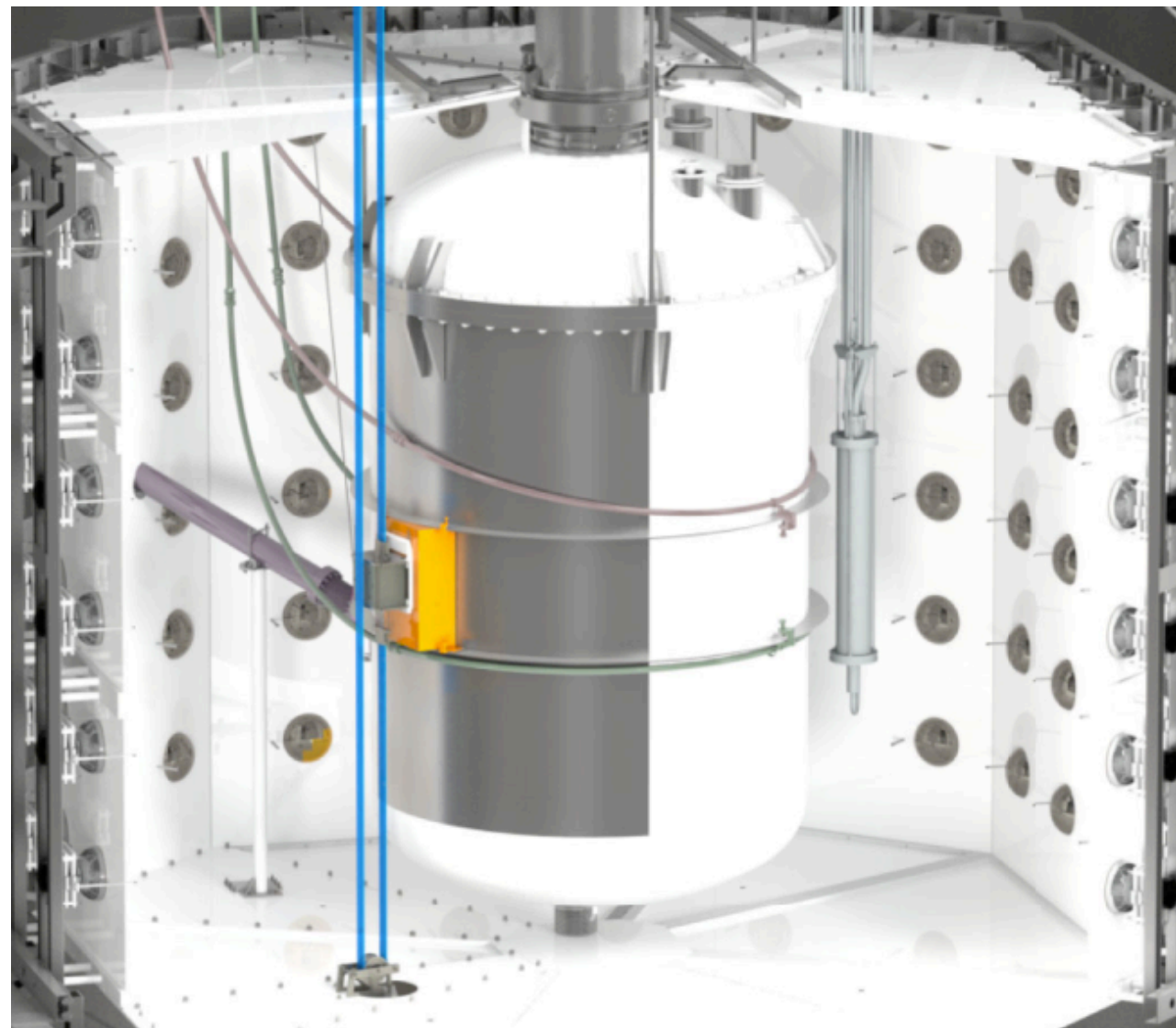
Experiments	Exposure [t-y]	S1 [ph]	S2 [e-]	Background	Expected Signal	Statistical significance
PandaX-4T	1.0	any	≥ 4.0	251 ± 32	43 ± 7	2.6
XENONnT	6.8	2 or 3	≥ 4.0	42.1 ± 1.9	16 ± 4.5	3.3
LZ	5.7	≥ 3	≥ 3.5	6.6 ± 0.3	20.6 ± 7.9	4.5



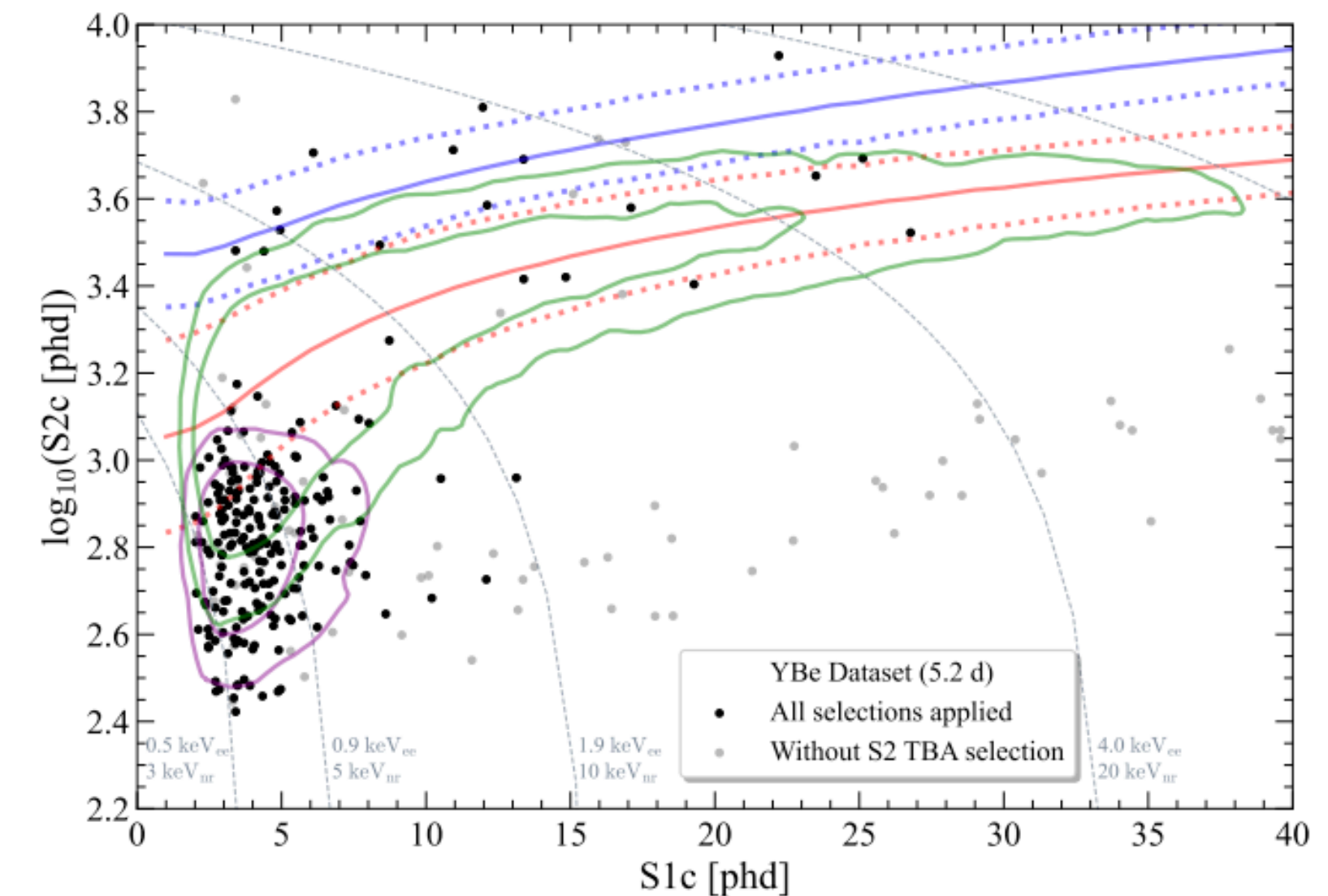
Calibration of XENONnT and LZ for solar ^8B detection



XENONnT:
PRD 113, 112017, 2026

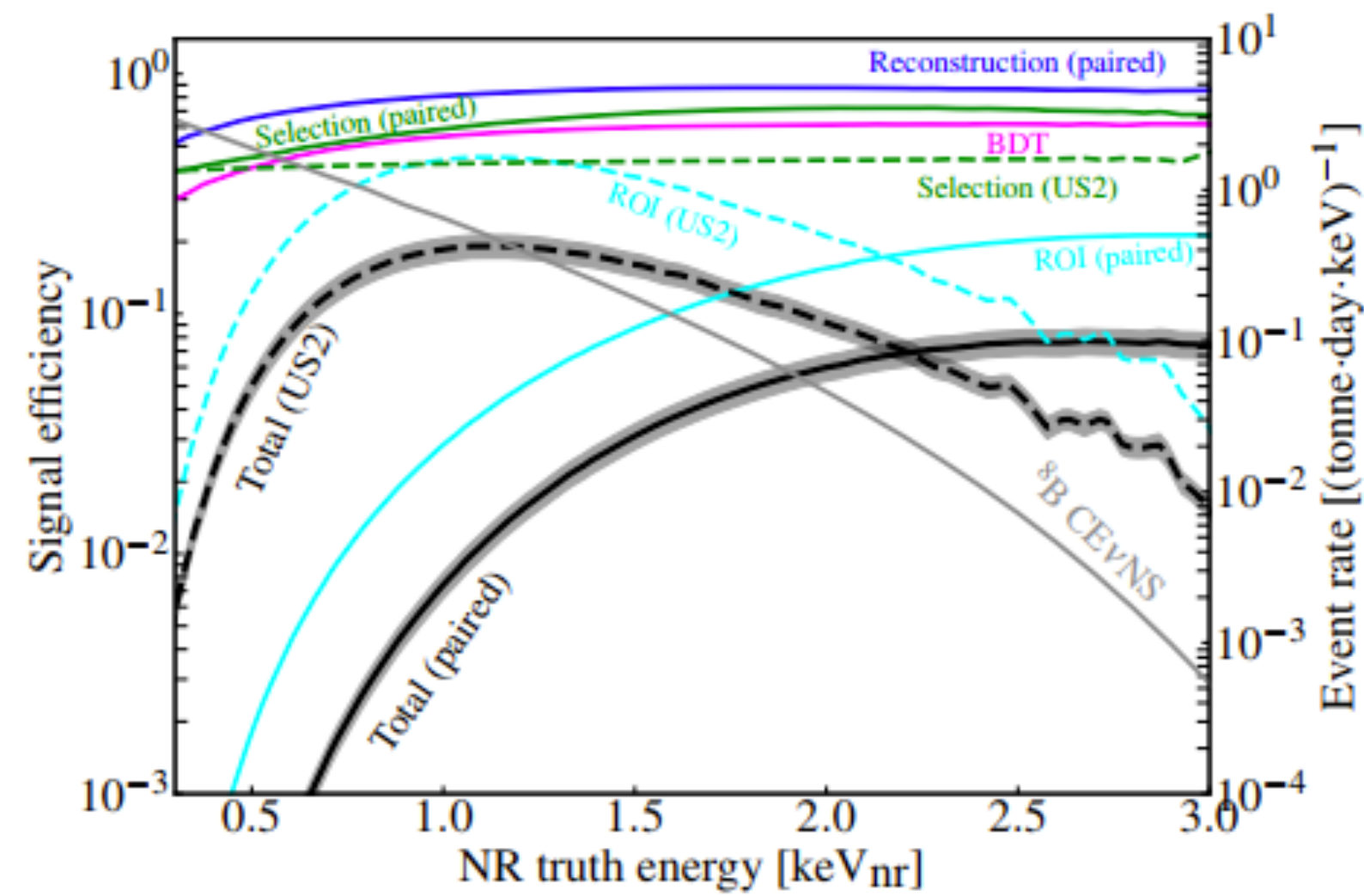


LZ:
arXiv 2509.16281

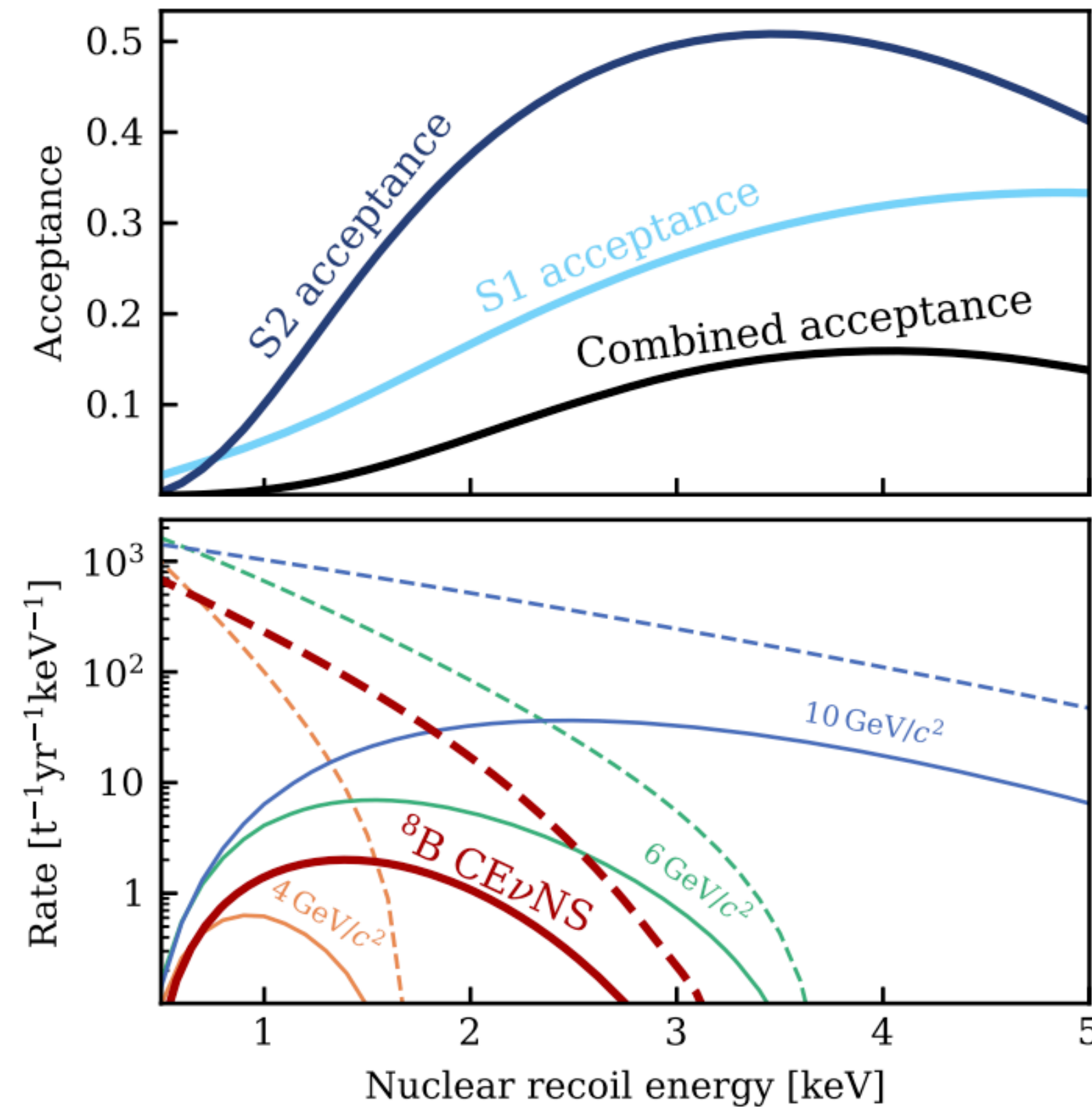


Detection efficiencies

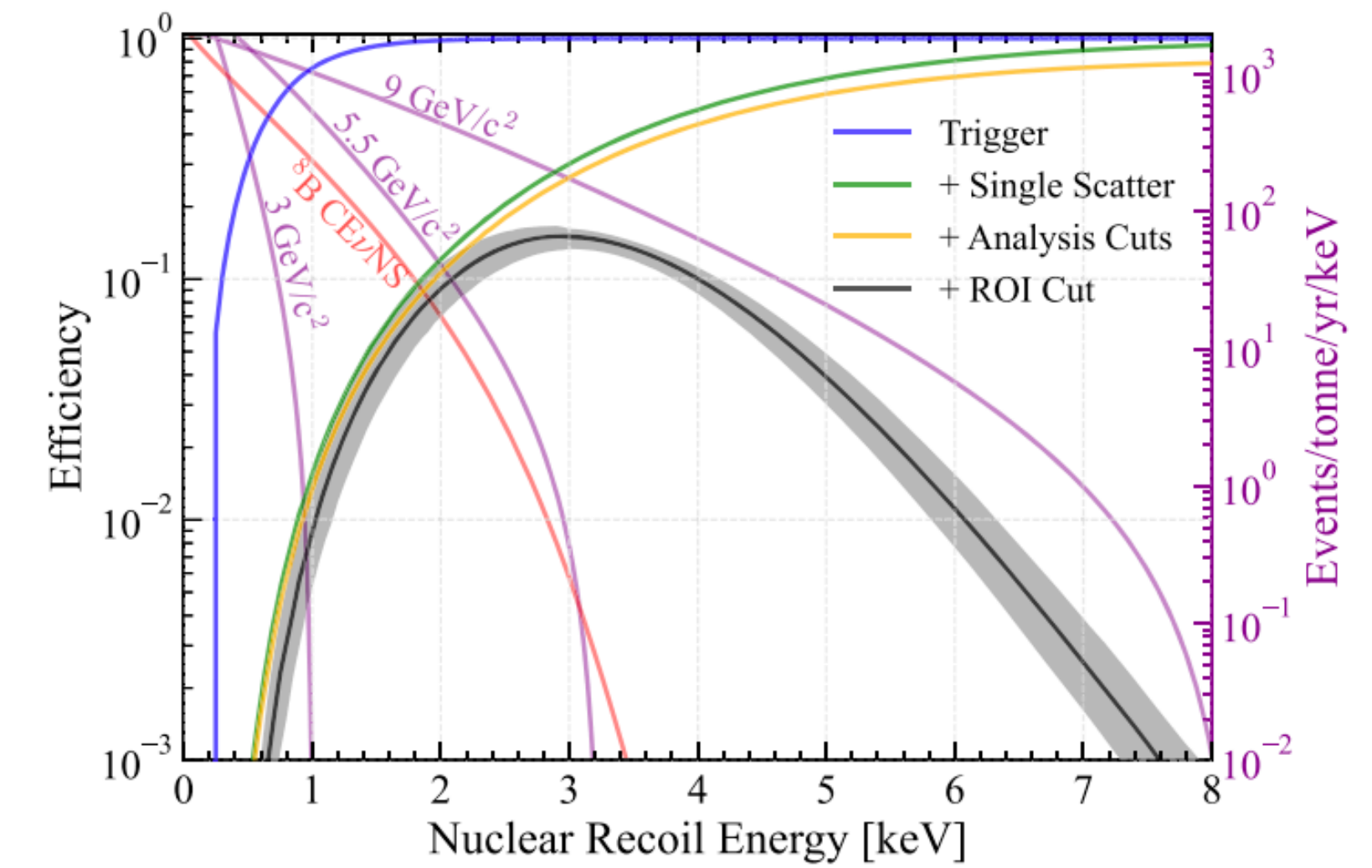
PandaX-4T



XENONnT

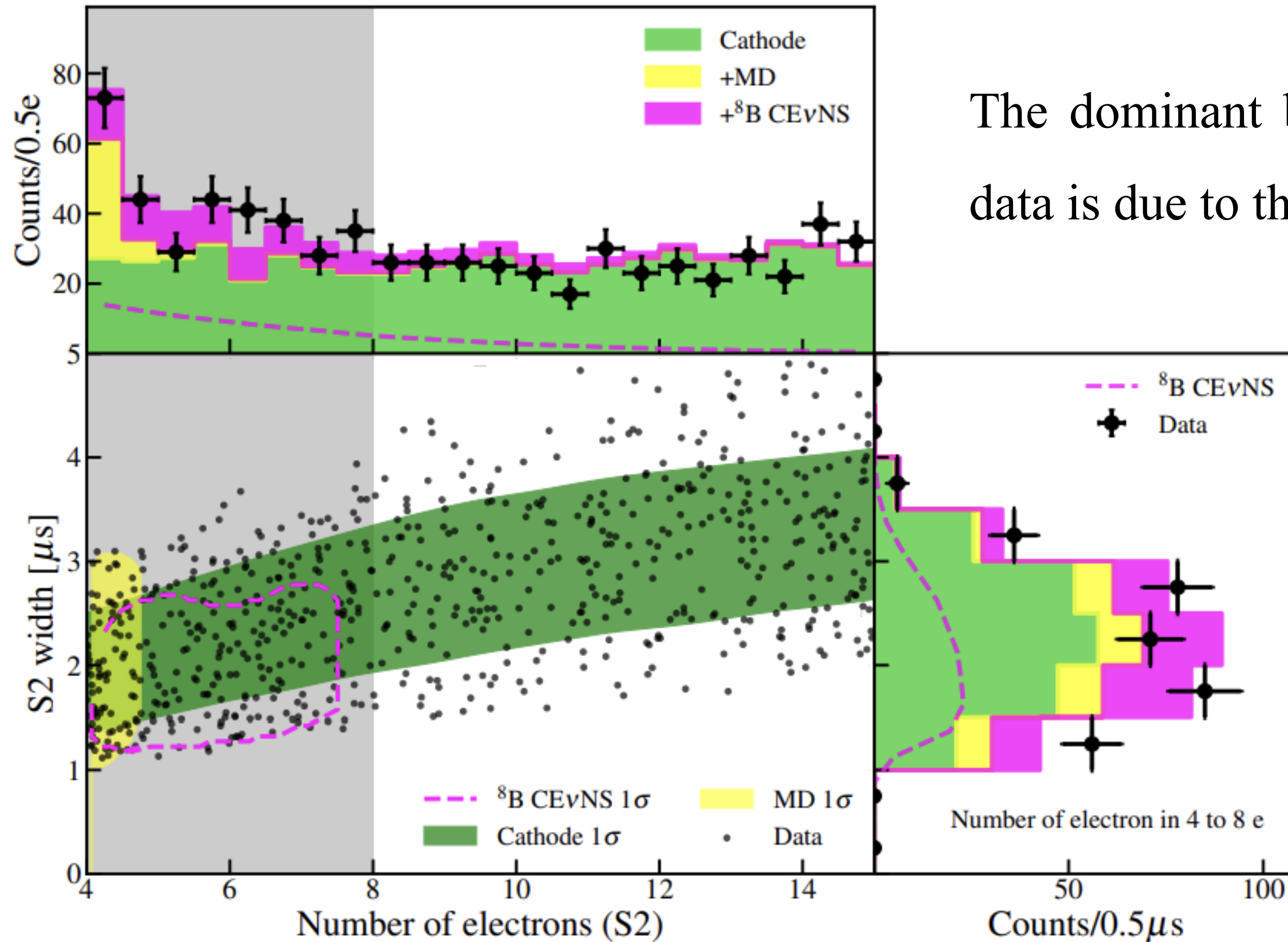


LZ



Detection Efficiency in PandaX is the largest with an S2-only analysis

Solar ^8B CEvNS search with PandaX-4T



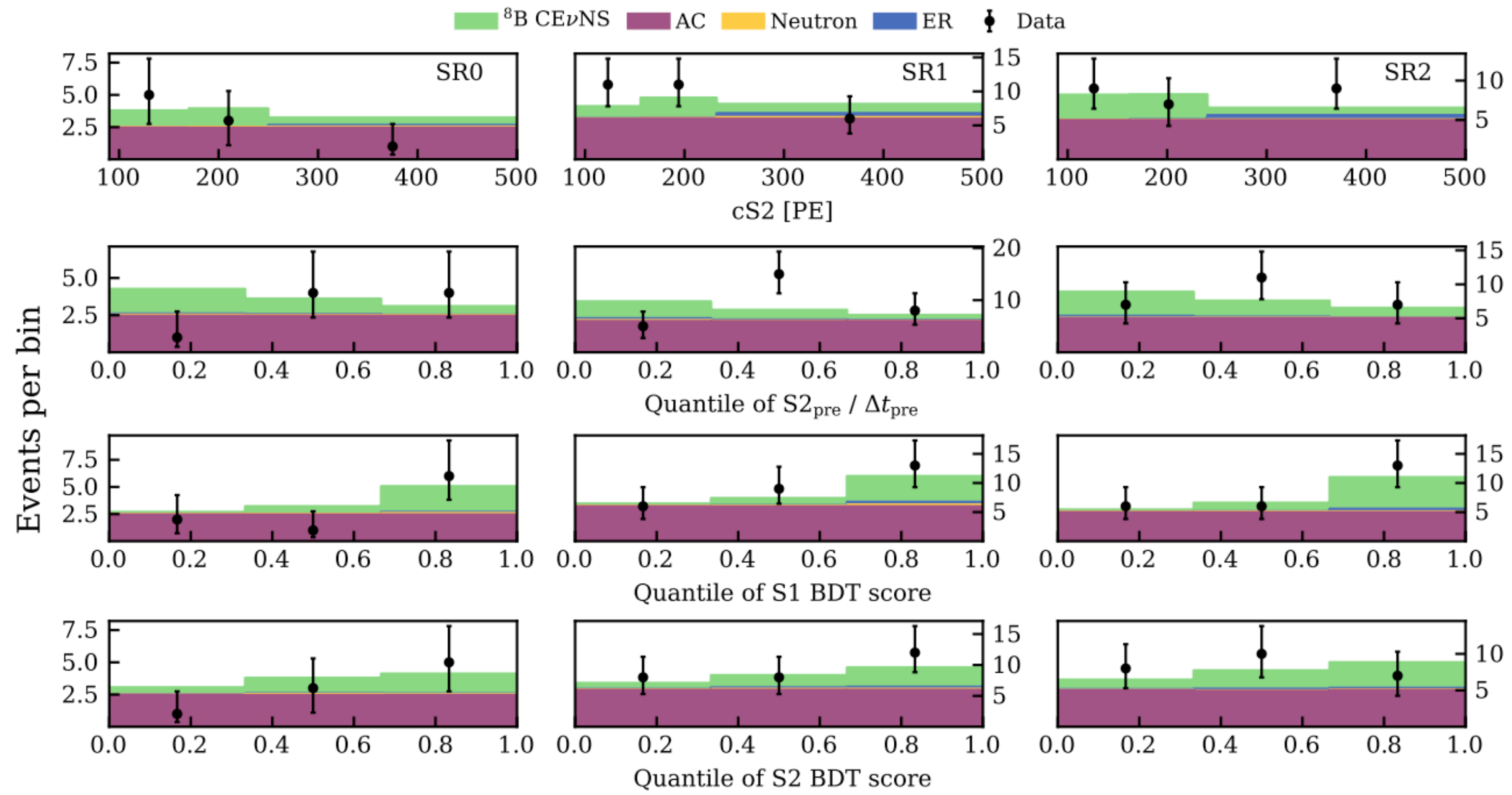
The dominant background in the S2-only analysis of PandaX data is due to the radioactivity on the cathode.

Best-fit ^8B yield:
 Paired: 3.5 ± 1.3 evts
 S2only: 75 ± 28 evts

Statistical significance: 2.6-sigma

Solar ^8B CEvNS search with XENONnT

成分	预测	本底 + ^8B best fit
AC – SR0	7.5 ± 0.7	7.4
AC – SR1	17.8 ± 1.0	17.9
AC – SR2	14.9 ± 0.7	14.9
ER	1.2 ± 1.2	1.4
Neutron	0.8 ± 0.4	0.8
总本底	42.1 ± 1.9	42.4
^8B – SR0	3.2 ± 1.0	3.3
^8B – SR1	5.9 ± 1.8	6.1
^8B – SR2	7.2 ± 2.2	7.3
^8B Total	16 ± 4.5	17
观测	9 (SR0) + 28 (SR1) + 25 (SR2) = 62	

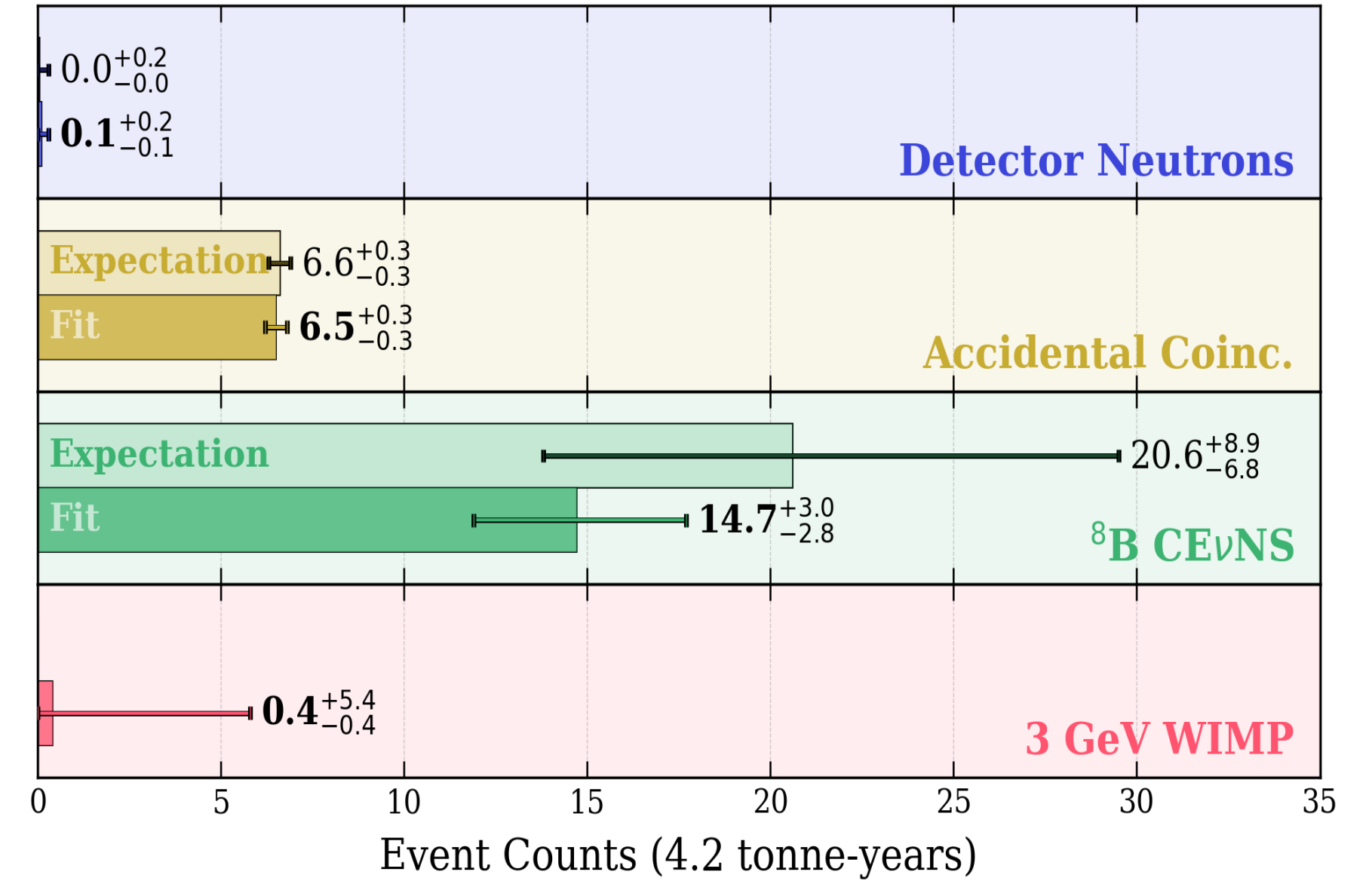
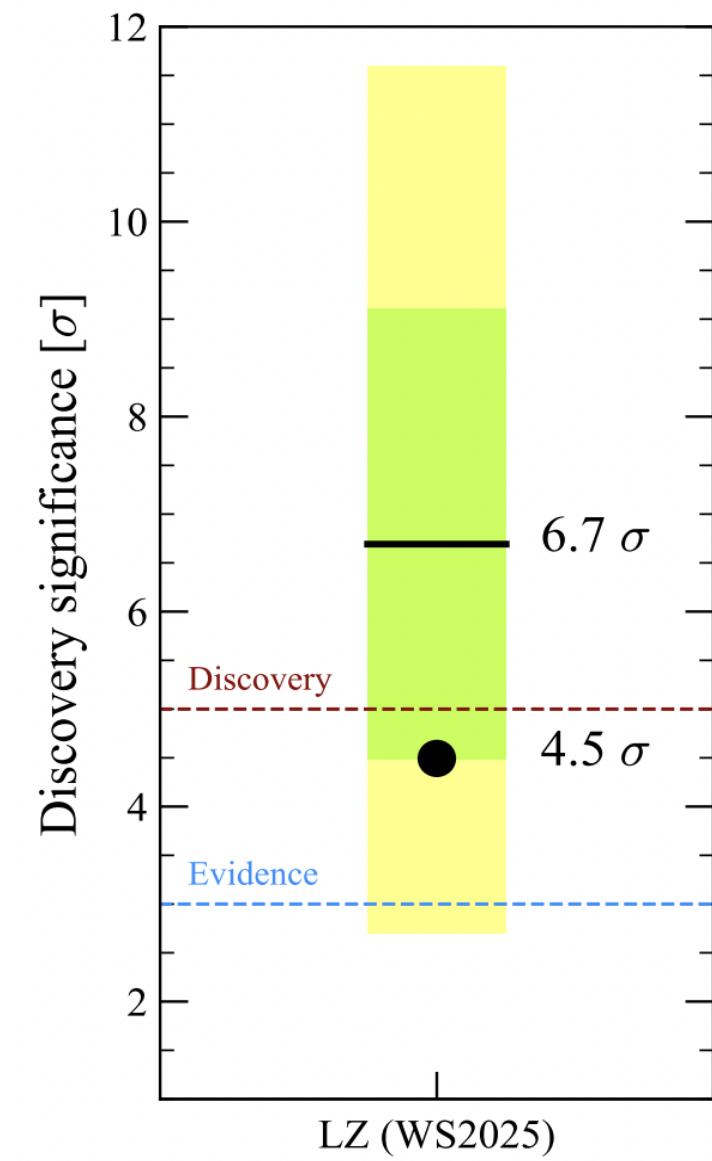
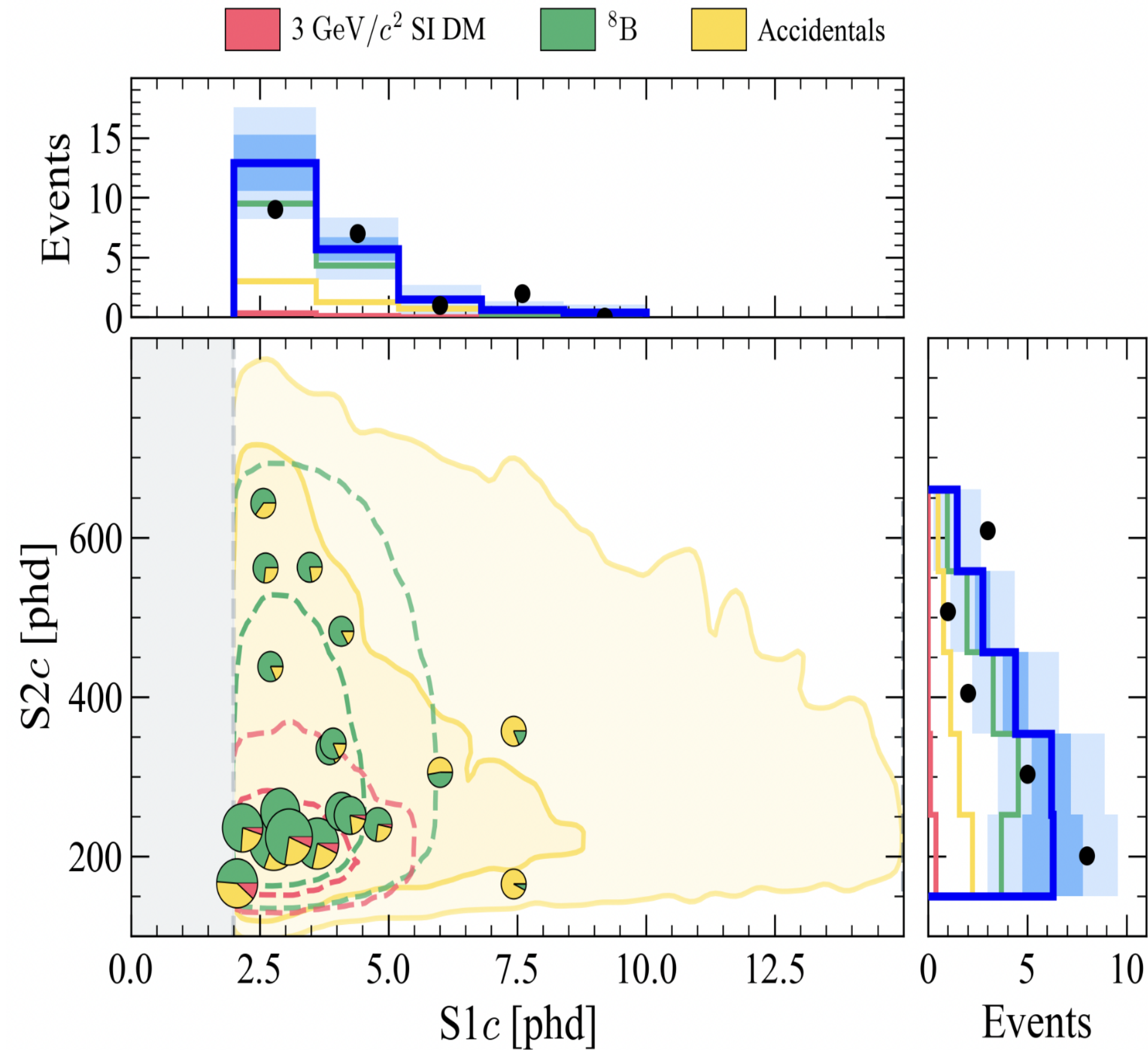


The dominant background in the standard analysis with S1 and S2 combined is the accidental coincidence background.

Statistical significance: 2.7-sigma and 3.3-sigma

PRL 133, 191002, 2024
PRL 137, 091807, 2026

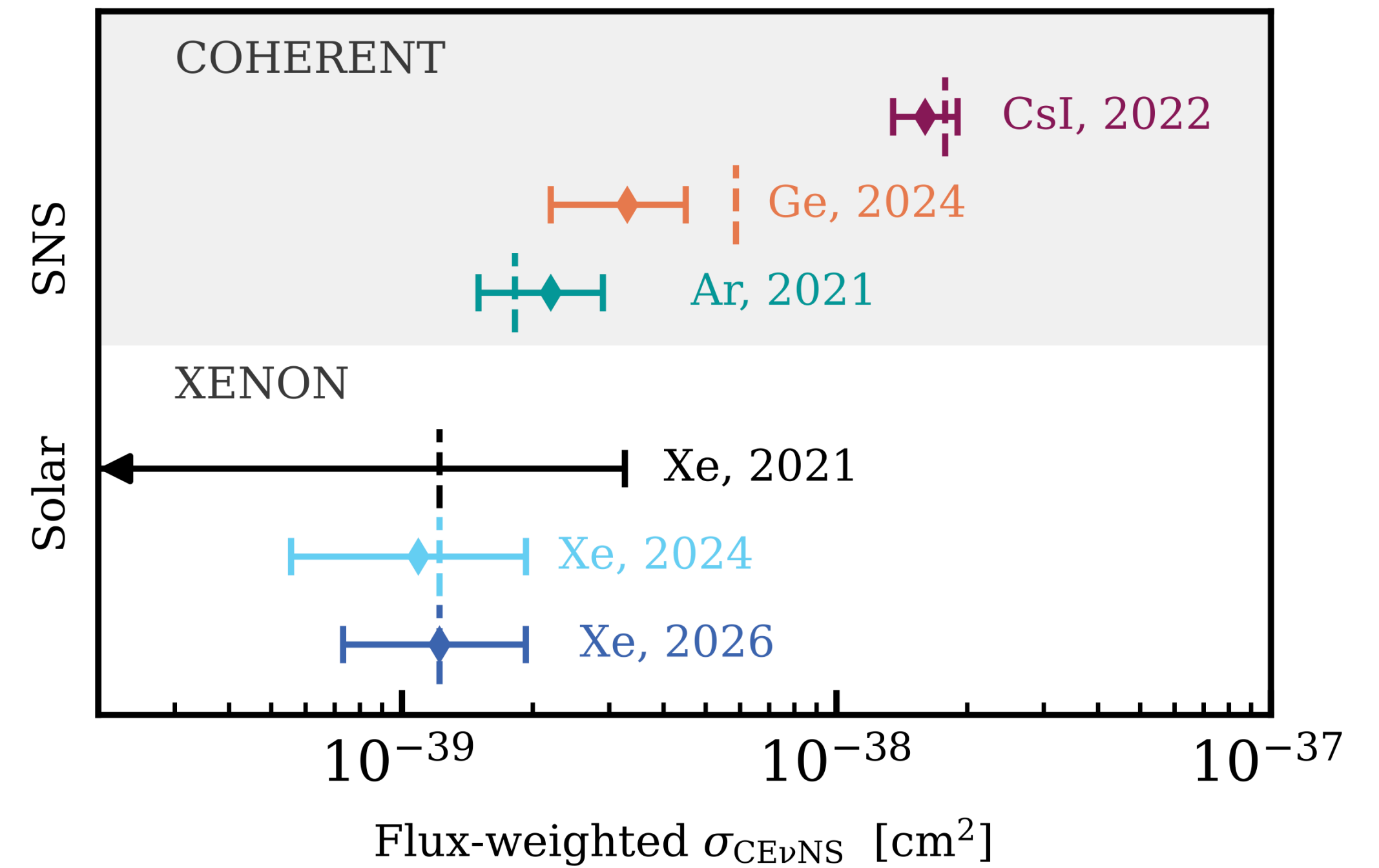
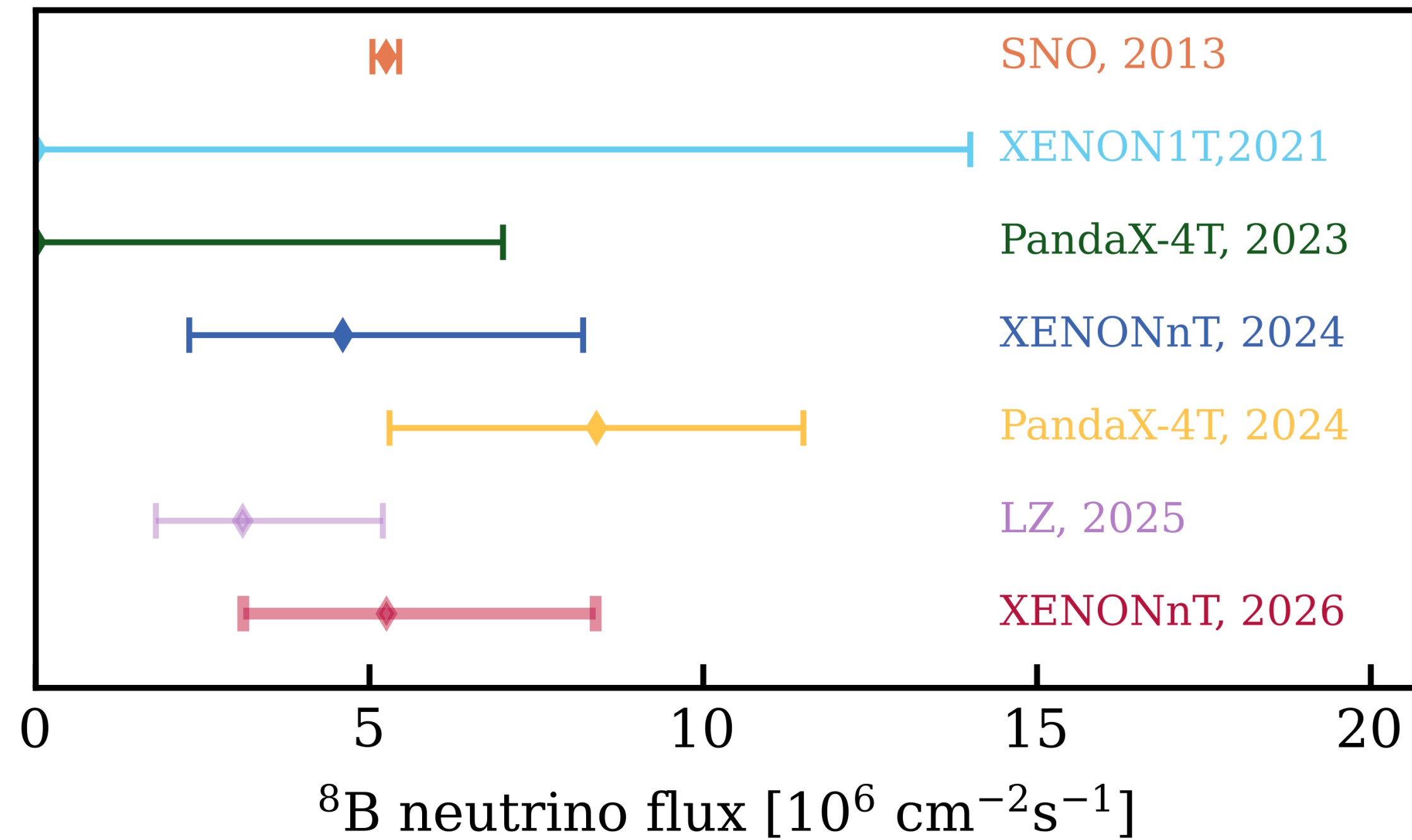
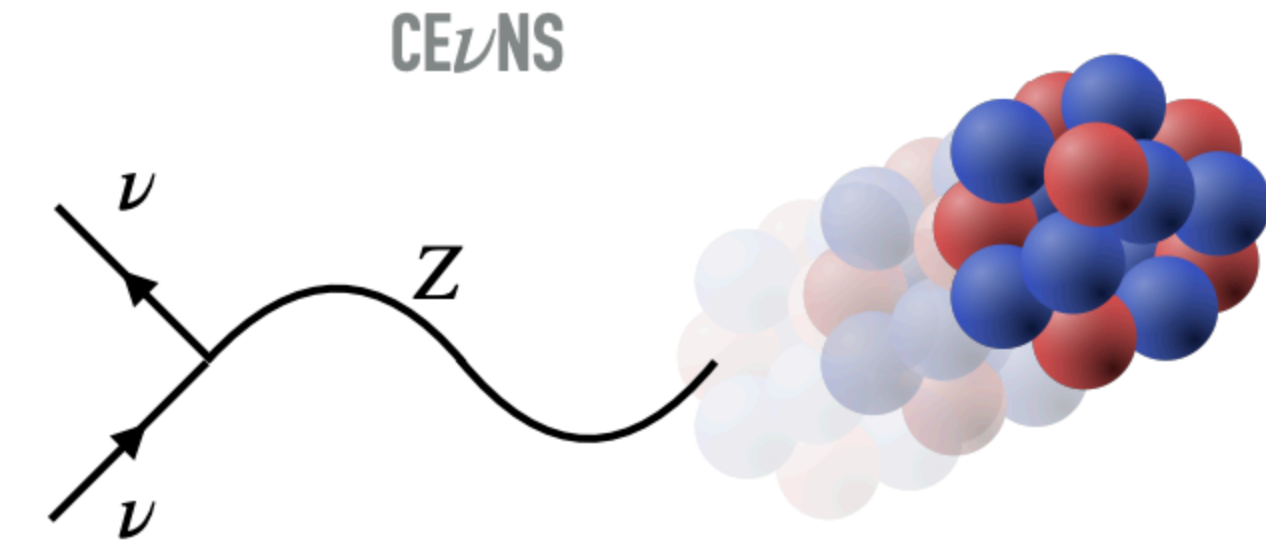
Solar ^8B CEvNS search with LZ



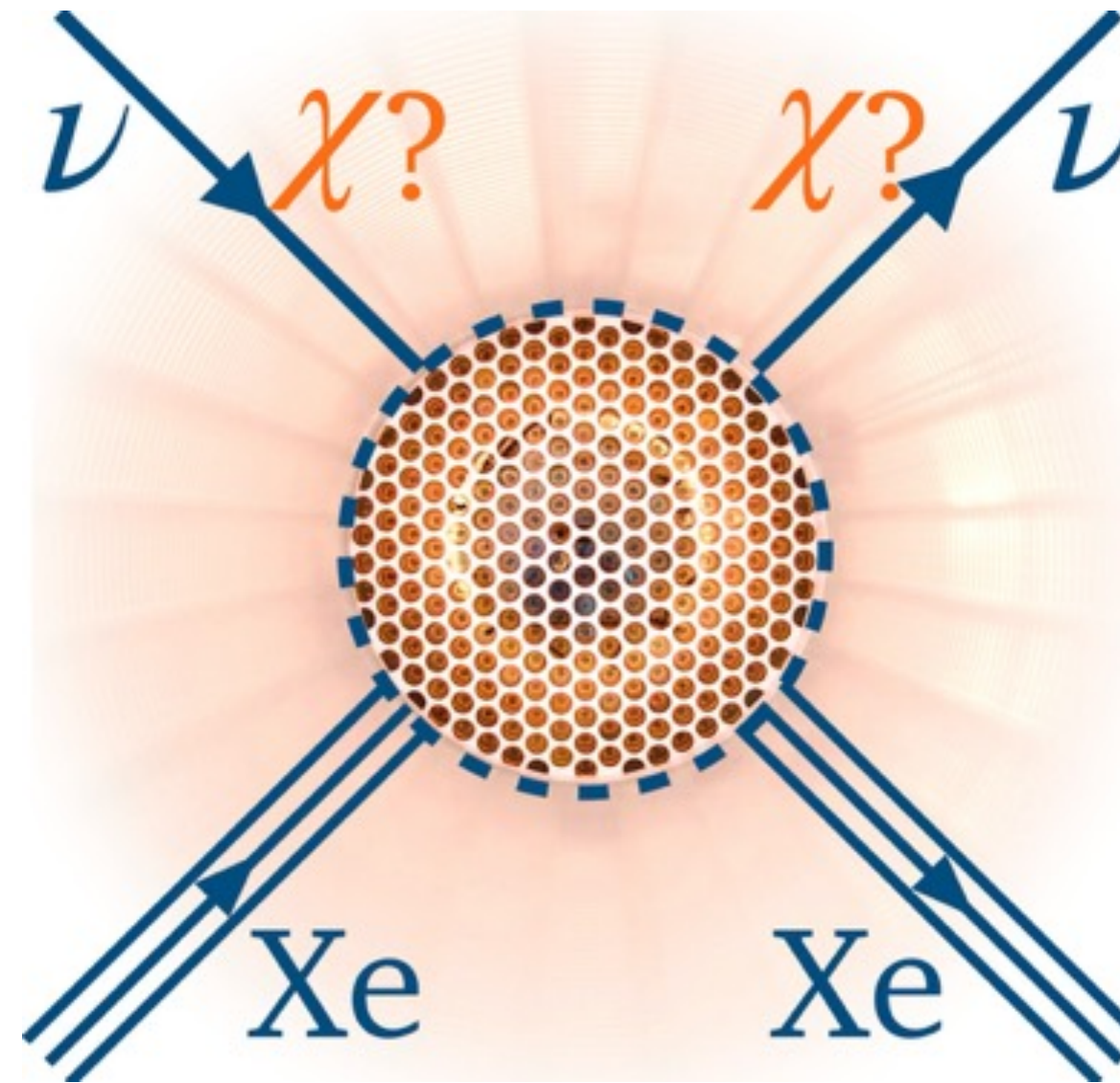
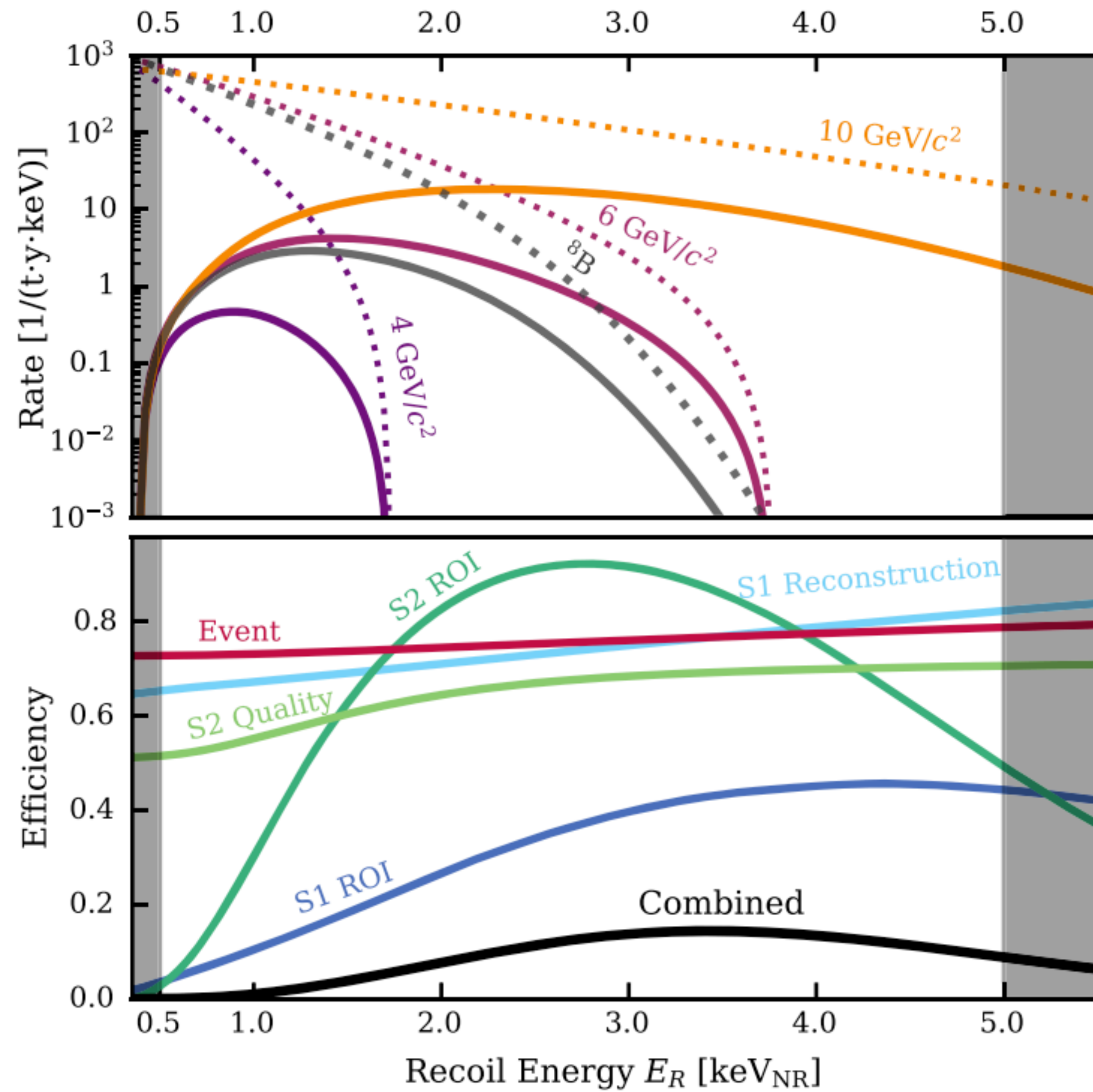
The dominant background in the standard analysis with S1 and S2 combined is the accidental coincidence background.

Statistical significance: 4.5-sigma

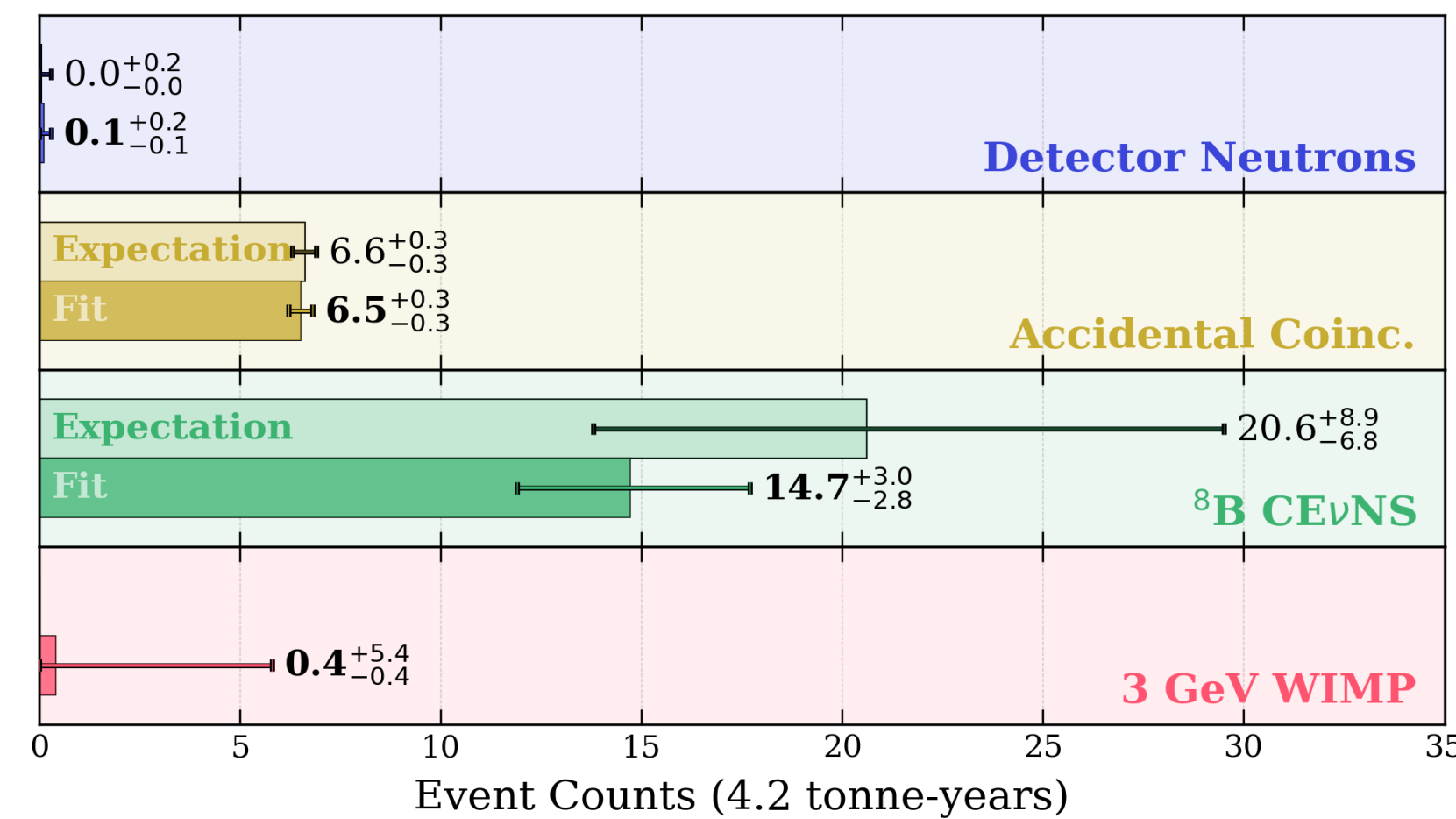
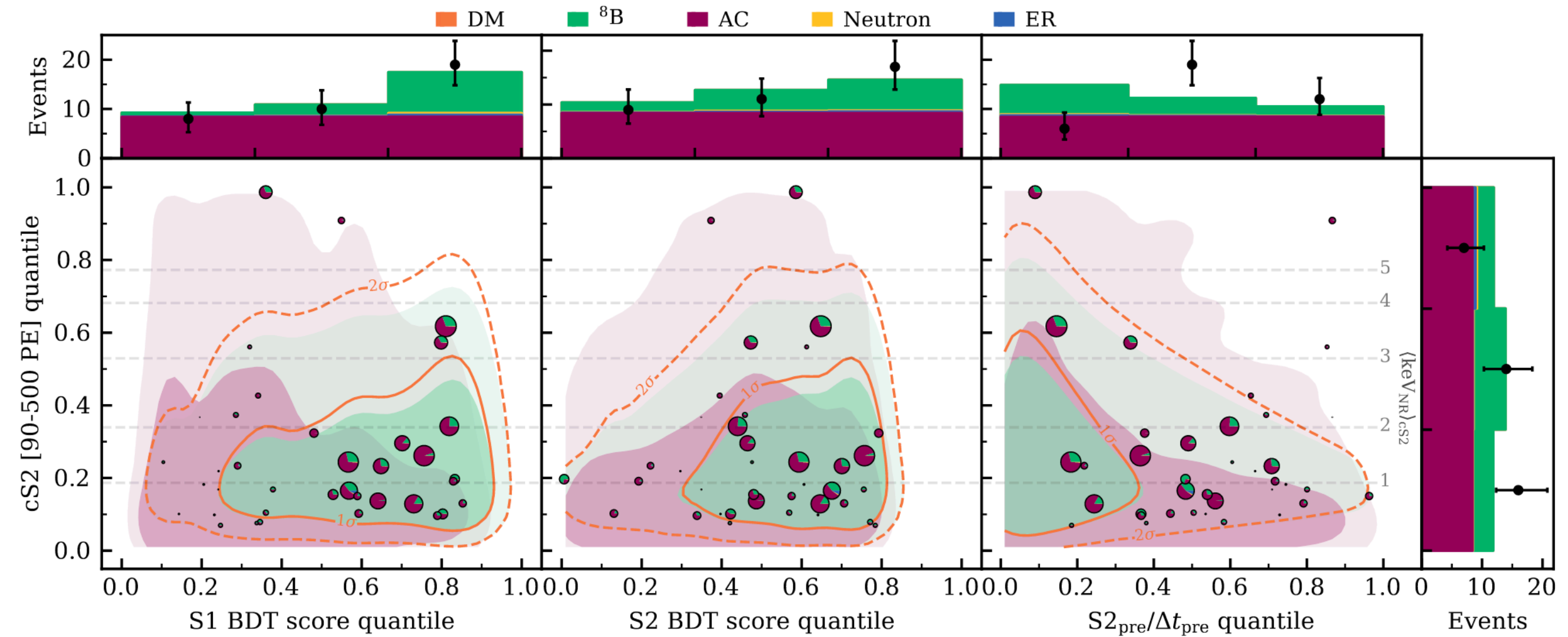
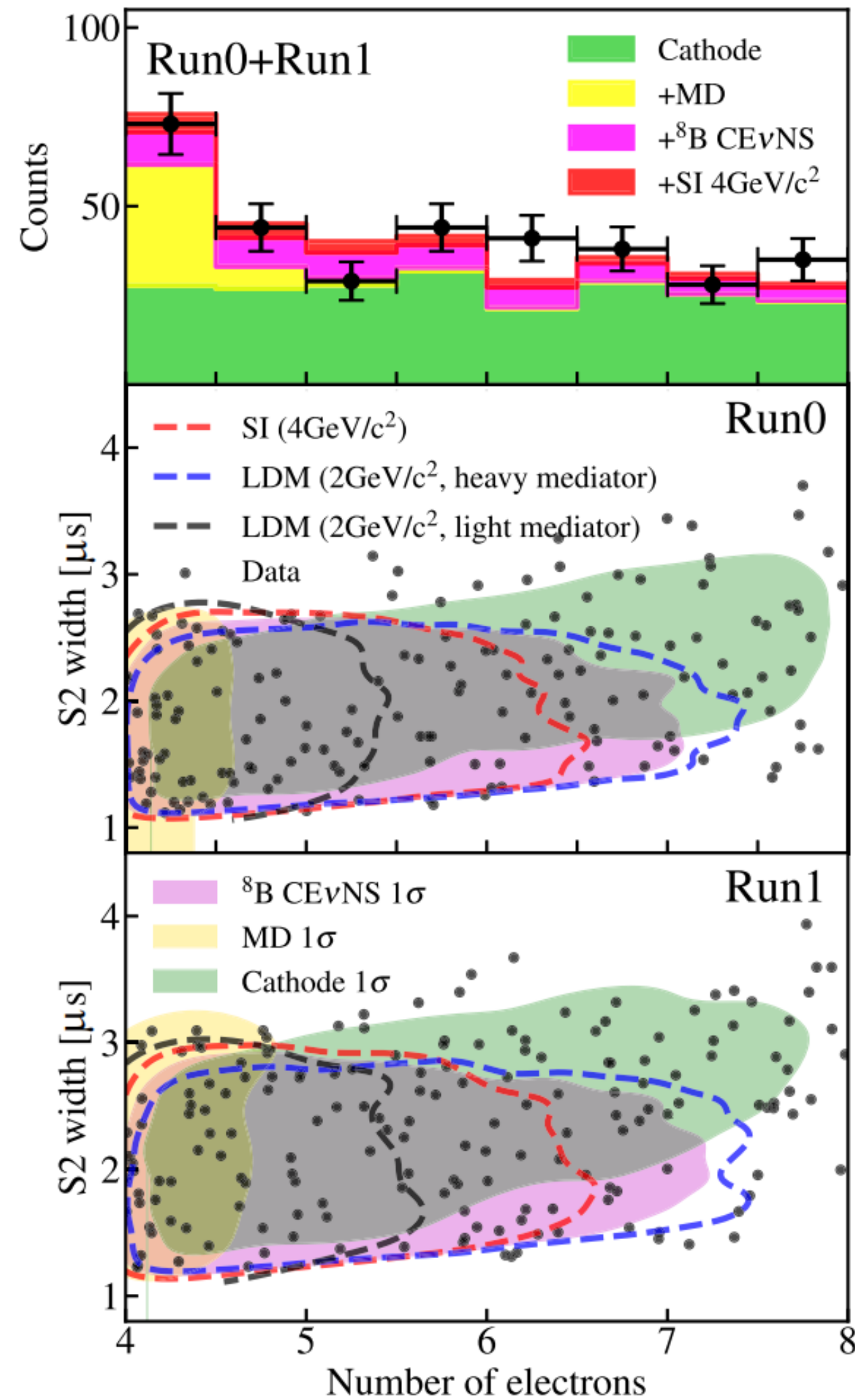
Measurements of the Solar ^8B neutrinos



Search for dark matter in the “neutrino fog”



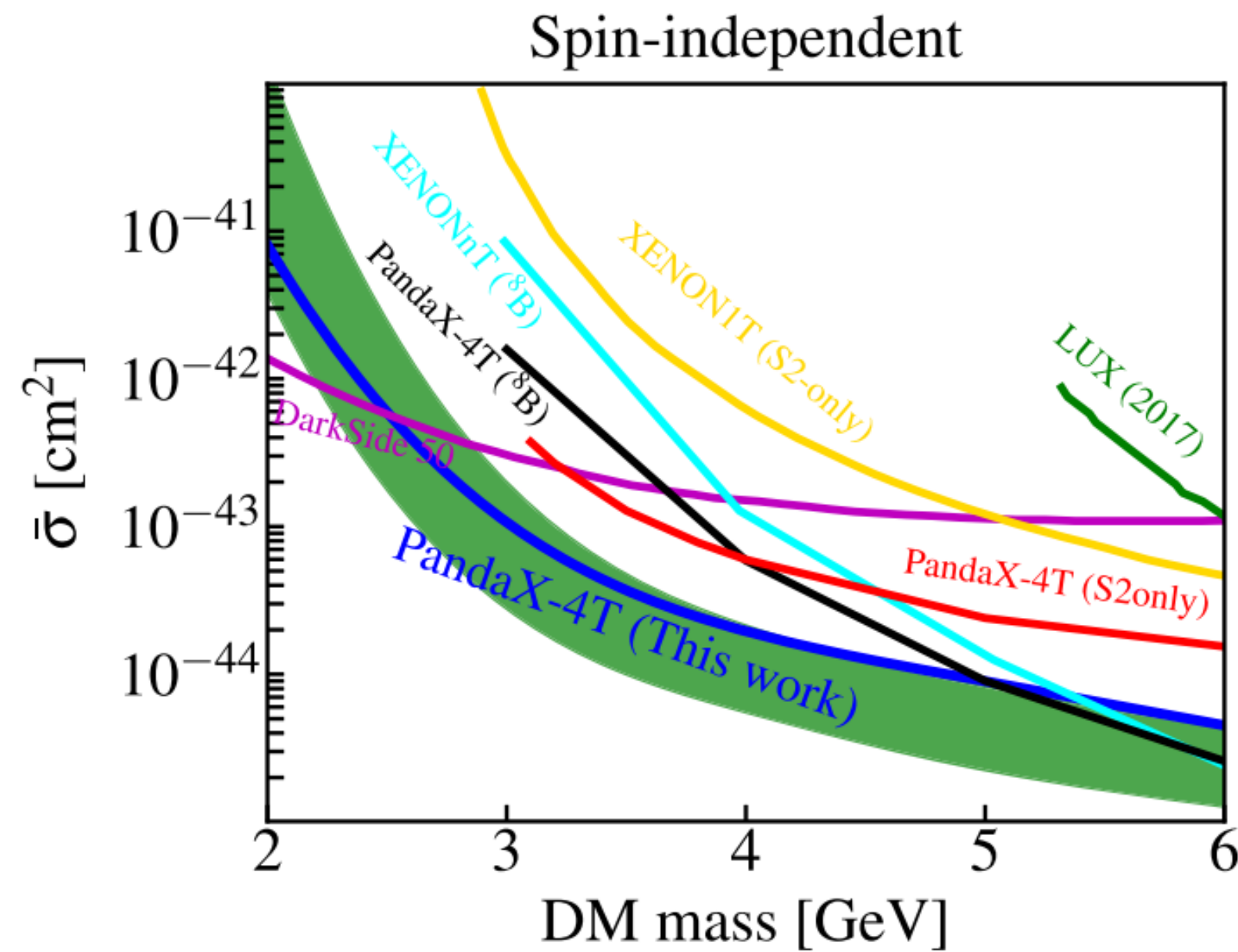
Search for dark matter in the “neutrino fog”



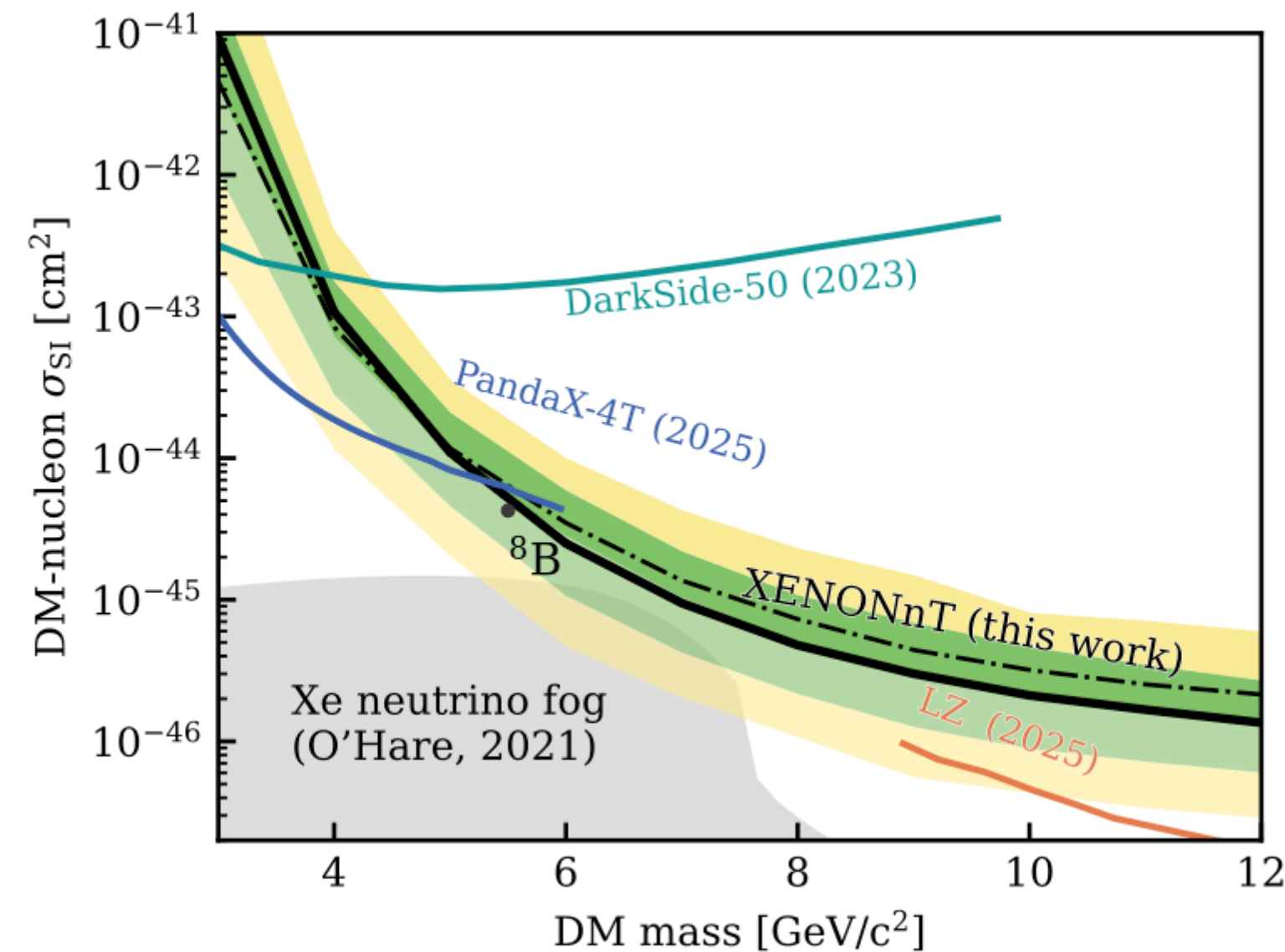
Due to the similarity between nuclear recoils from WIMPs and neutrinos, the WIMP search sensitivity is significantly affected by the “neutrino fog”

Search for dark matter in the “neutrino fog”

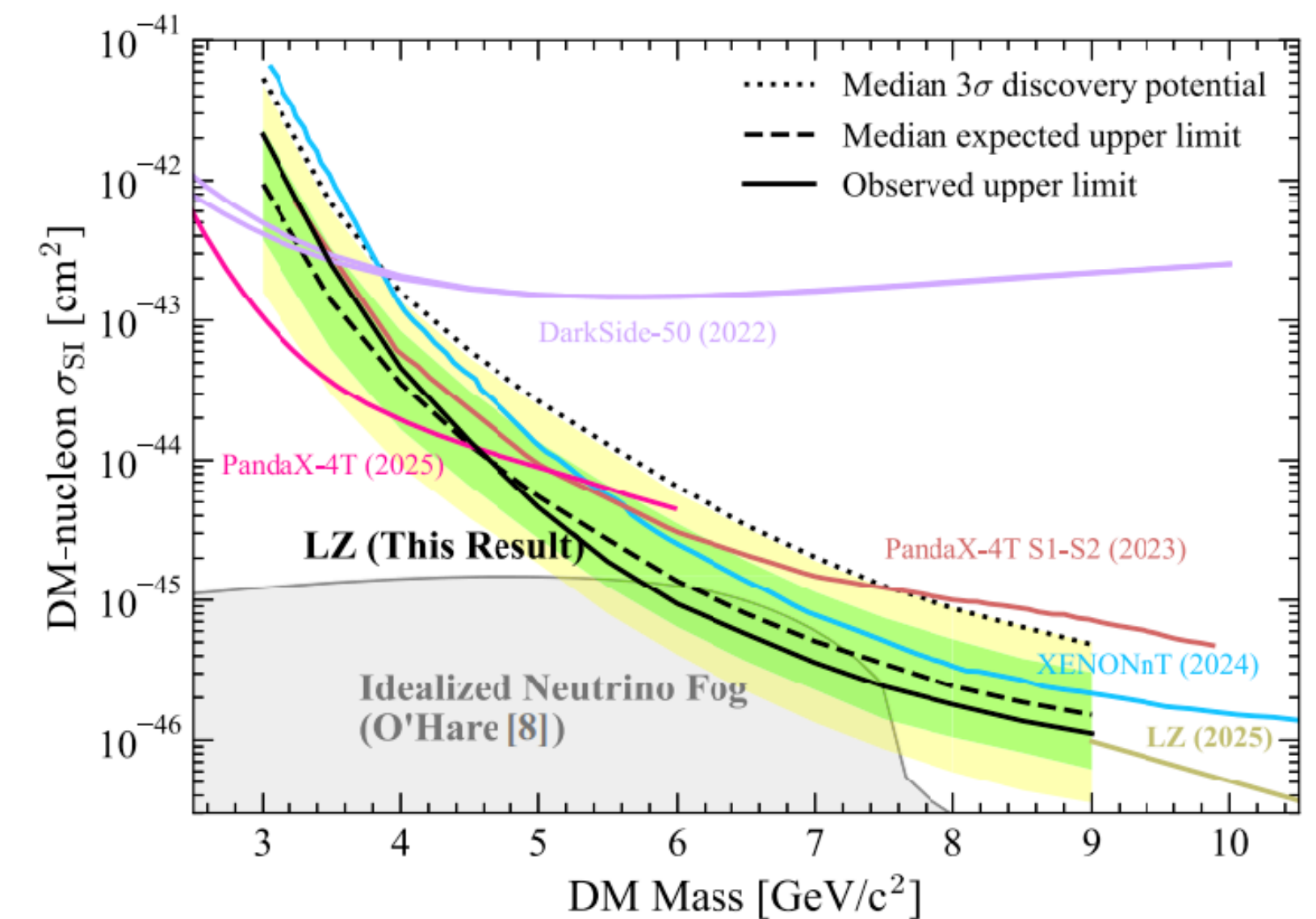
PandaX-4T



XENONnT

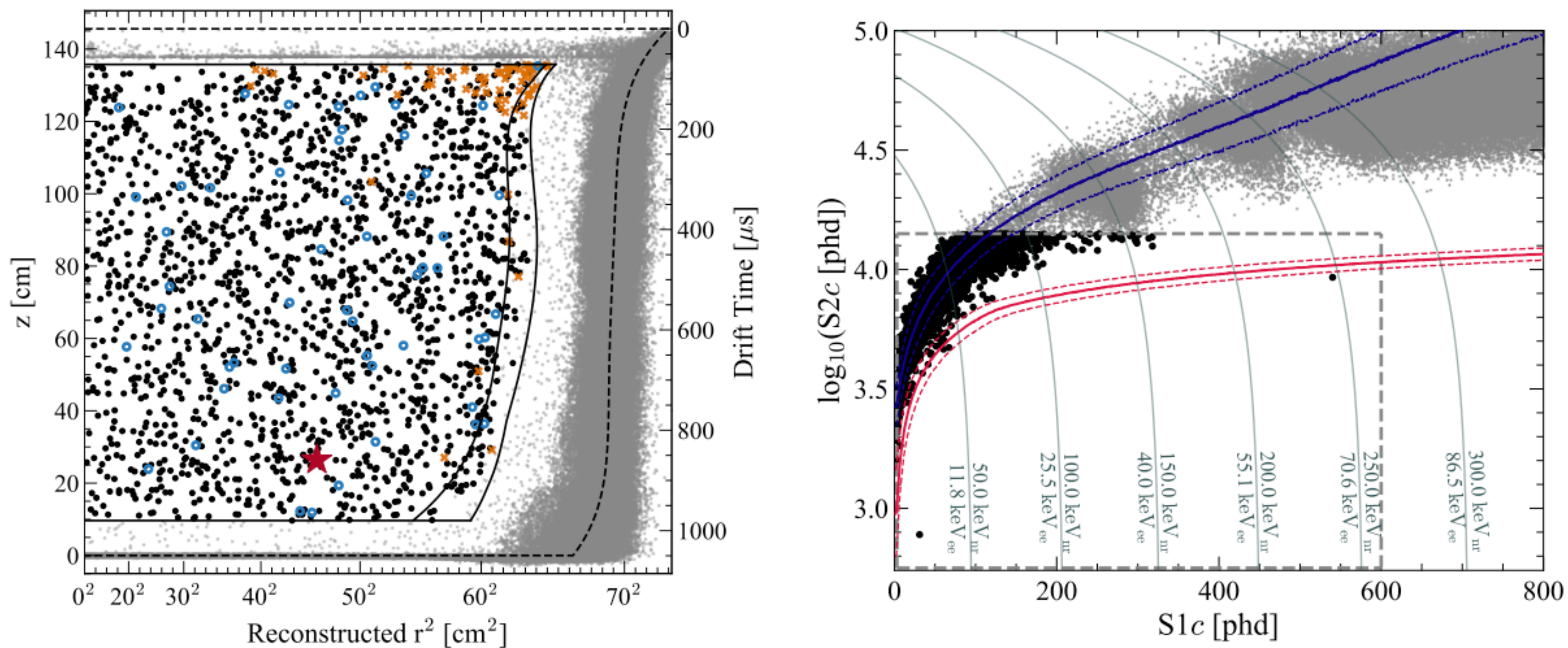


LZ



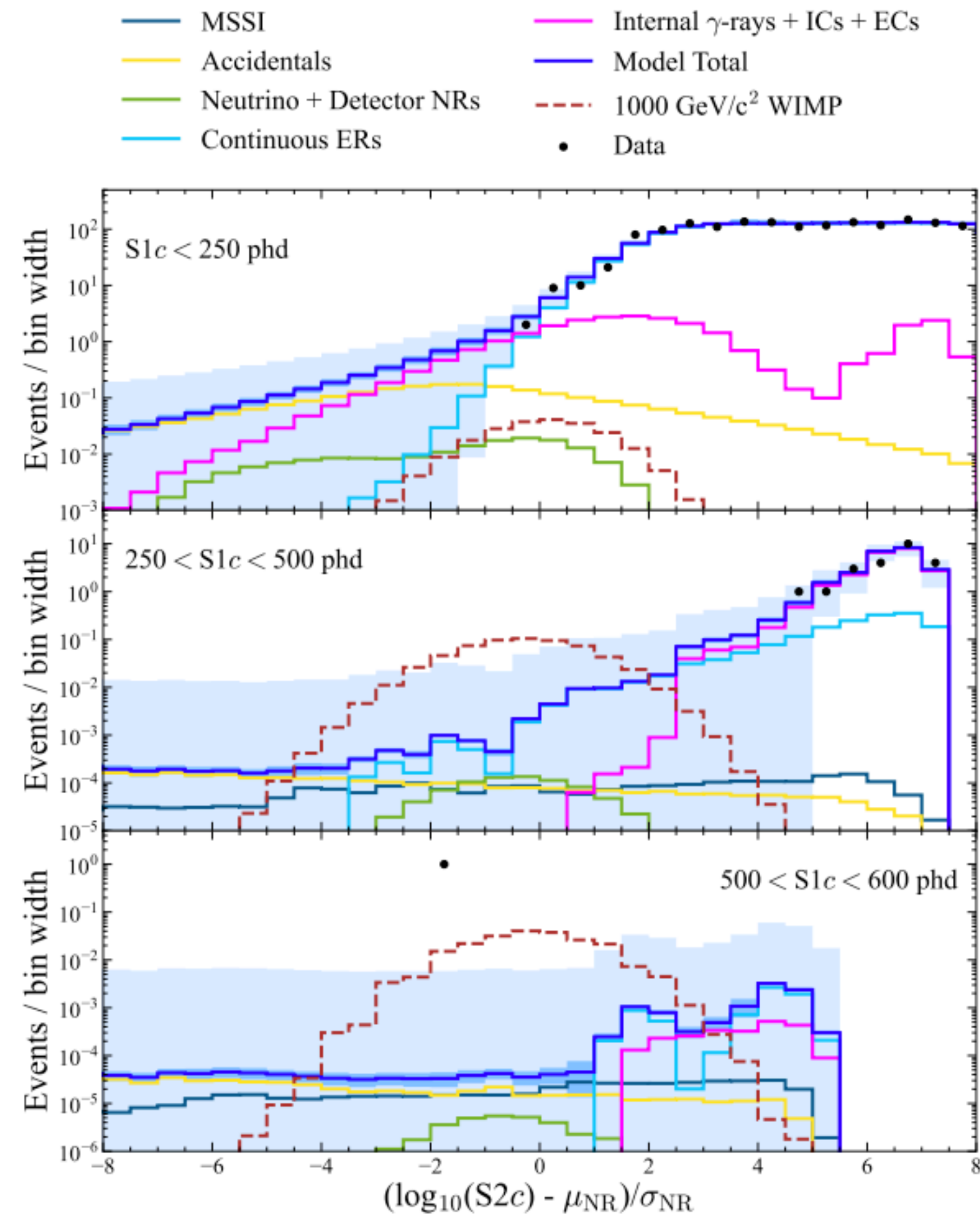
Due to the similarity between nuclear recoils from WIMPs and neutrinos, the WIMP search sensitivity is significantly affected by the “neutrino fog”

The New Event found in LZ



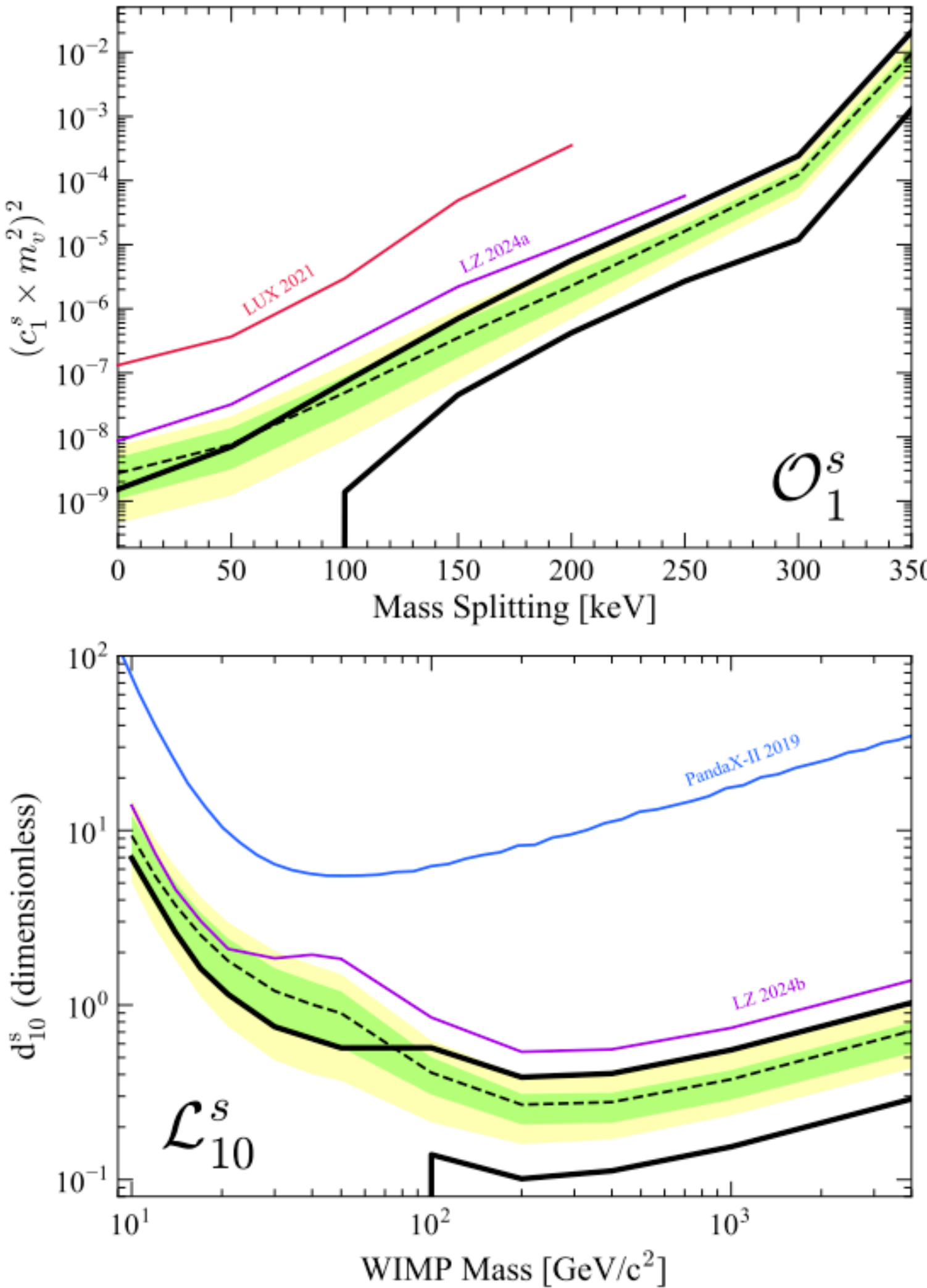
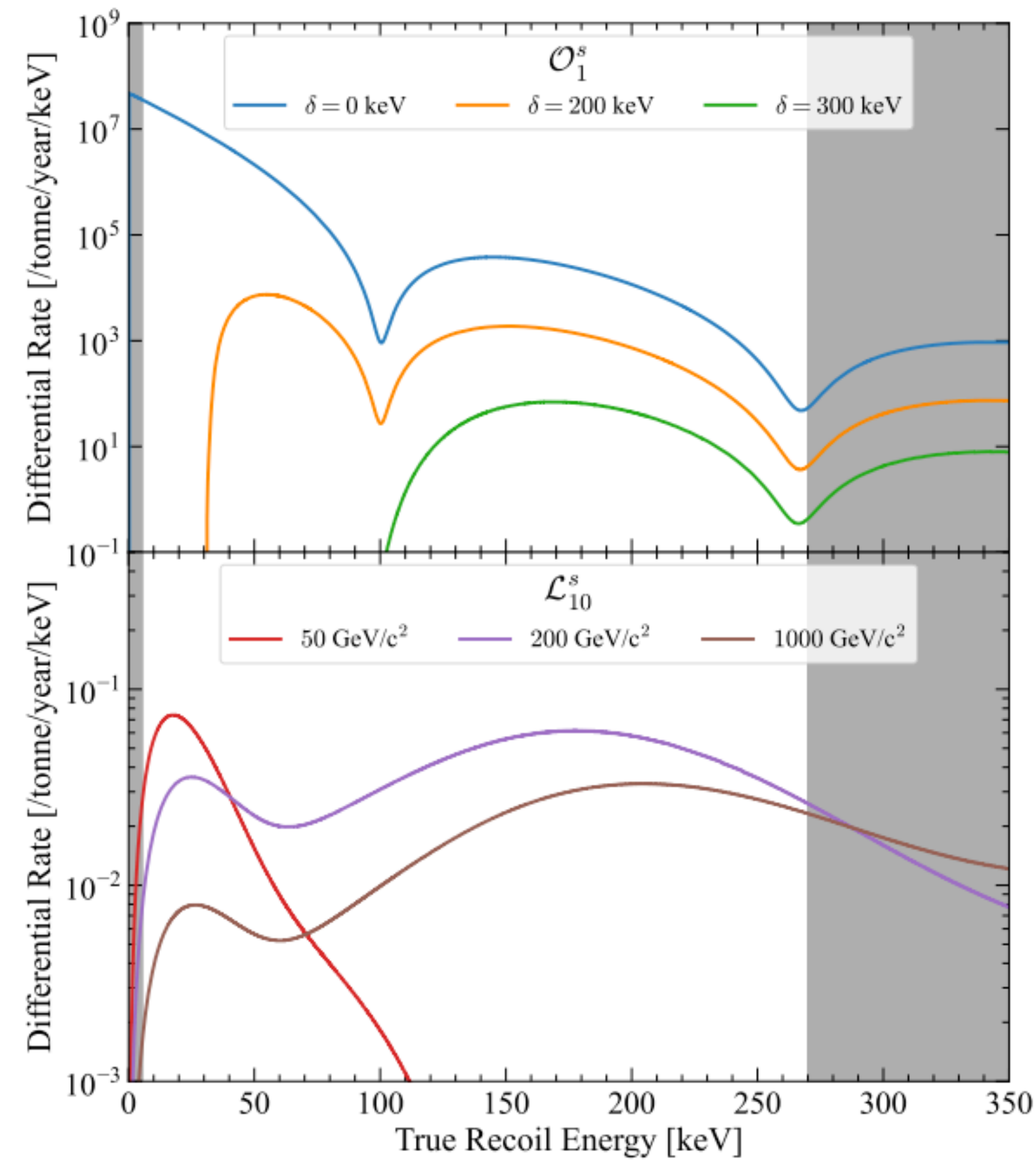
LZ observed an NR-like event with an NR-equivalent energy of ~ 250 keV, with 2.8 t-y of exposure

The event behaves well in the parameter spaces like position, and can hardly be accounted for by the known background



Statistical significance: 2.6-sigma (global) / 3.4-sigma (local)

The New Event found in LZ



The large and unexplored exposure from PandaX-4T, XENONnT, and LZ will be a powerful validation of this event

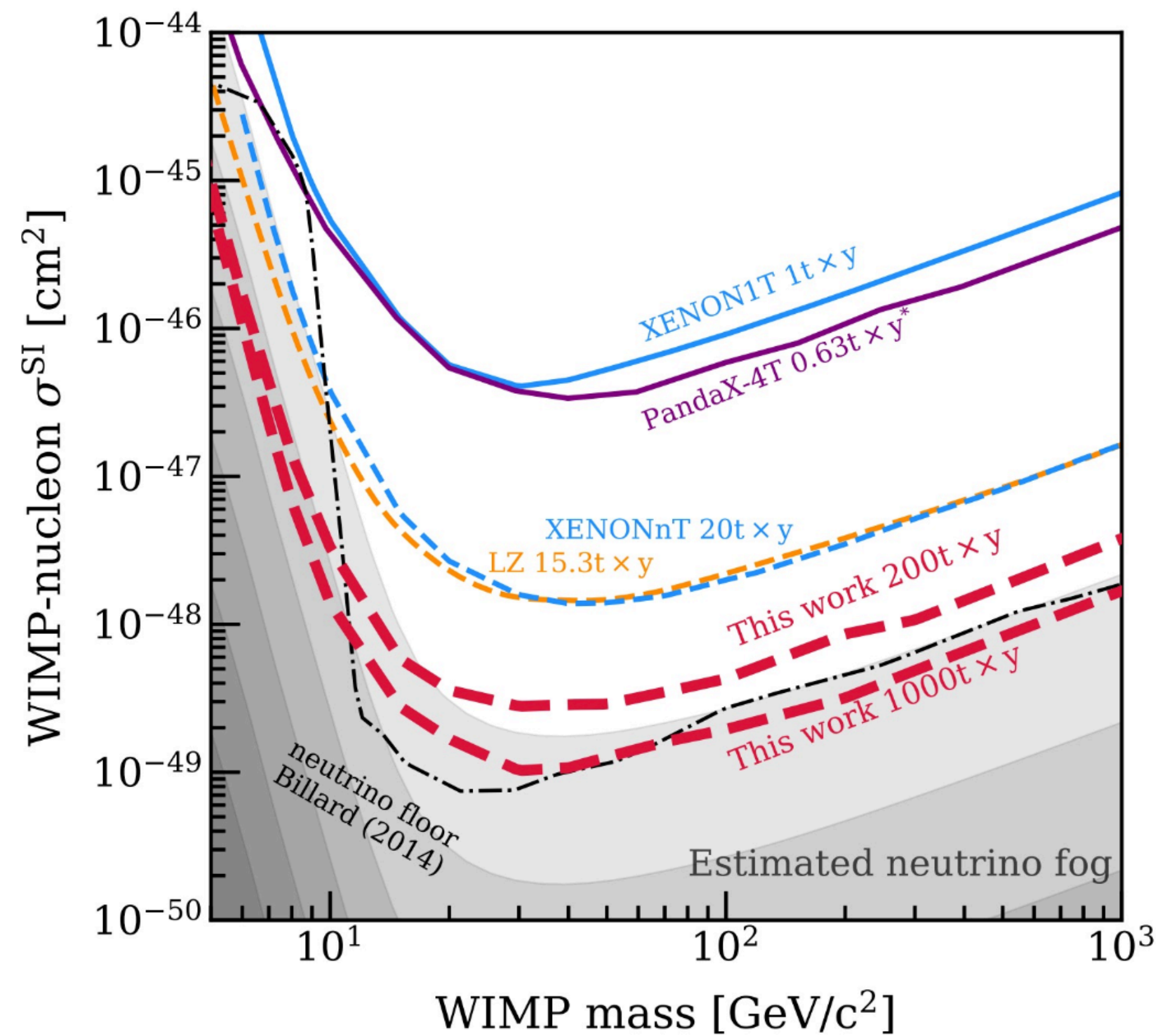
Experiments	Published Exposure [t-y]
PandaX-4T	1.5
XENONnT	6.8
LZ	2.8 (used) / 5.7

The event can be better described within the EFT framework, in which the rate at the lowest recoil energy is suppressed.

More information from LZ will be shown in [Theresa Fruth's talk](#) this afternoon.

Future LXeTPCs

J. Phys. G: Nucl. Part. Phys. 50 (2023) 013001

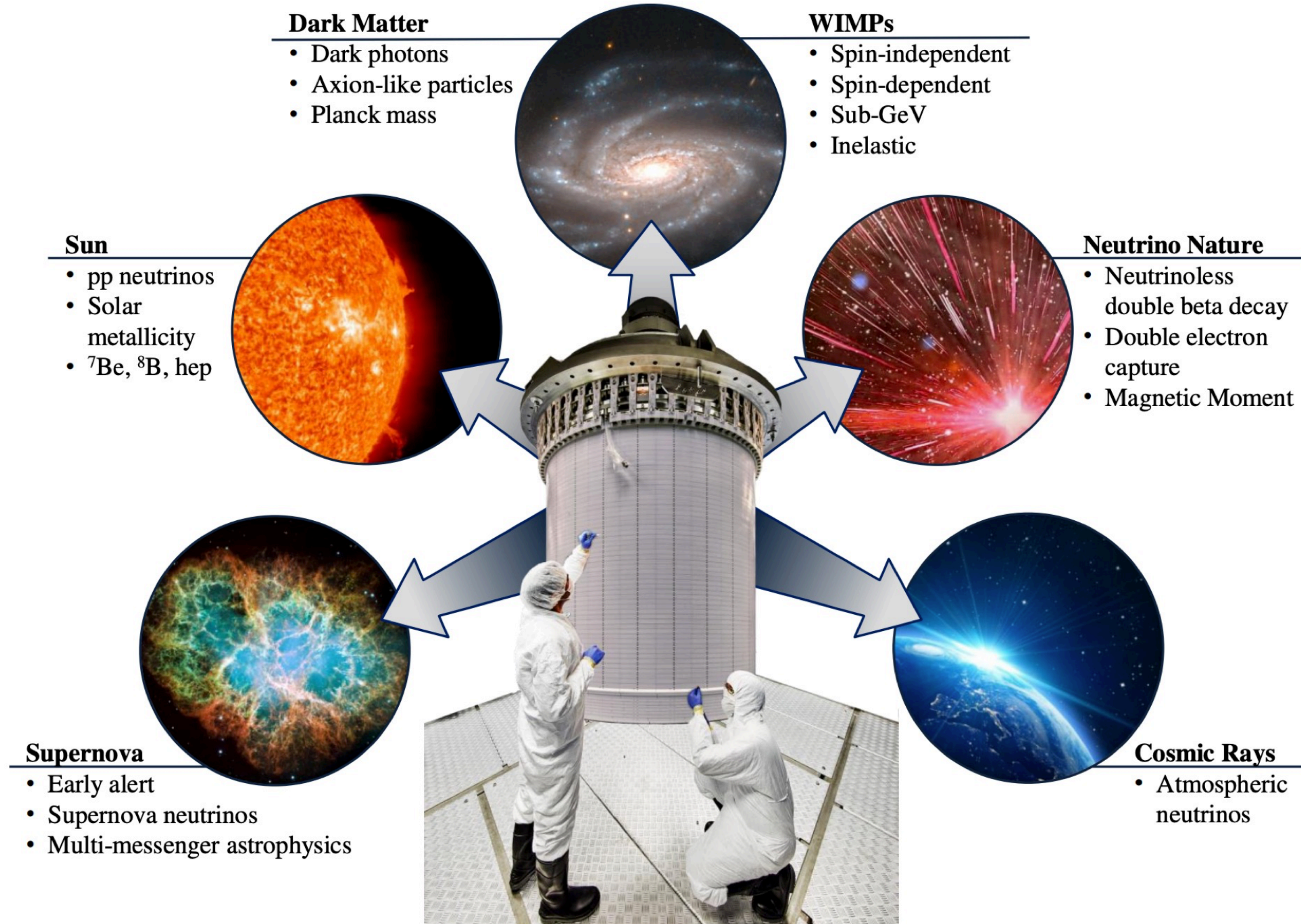


PandaX-xT: ~50t @ CJPL

The first step with 20 t is expected to arrive in 2027

XLZD: ~60t @

A lot of key R&D ongoing



Summary and highlight of this talk

- Scalability and low backgrounds in LXe experiments have made them the most favorable targets for heavy WIMPs.
- Over the past years, PandaX-4T, XENONnT, and LZ/XENONnT have significantly improved WIMP search sensitivity.
- Solar “neutrino fog” has been reached! LXeTPC has become the smallest solar neutrino observatory (also for pp).
- The interesting NR-like event observed in LZ will be investigated by all LXeTPCs.
- PandaX-xT / XLZD will go even further on the path to the atmospheric “neutrino fog”.
- We will finally find Dark Matter, or learn what it is not.

Thanks for your attention!

I would also like to thank the colleagues from PandaX-4T
and LZ for providing the materials used in this talk!