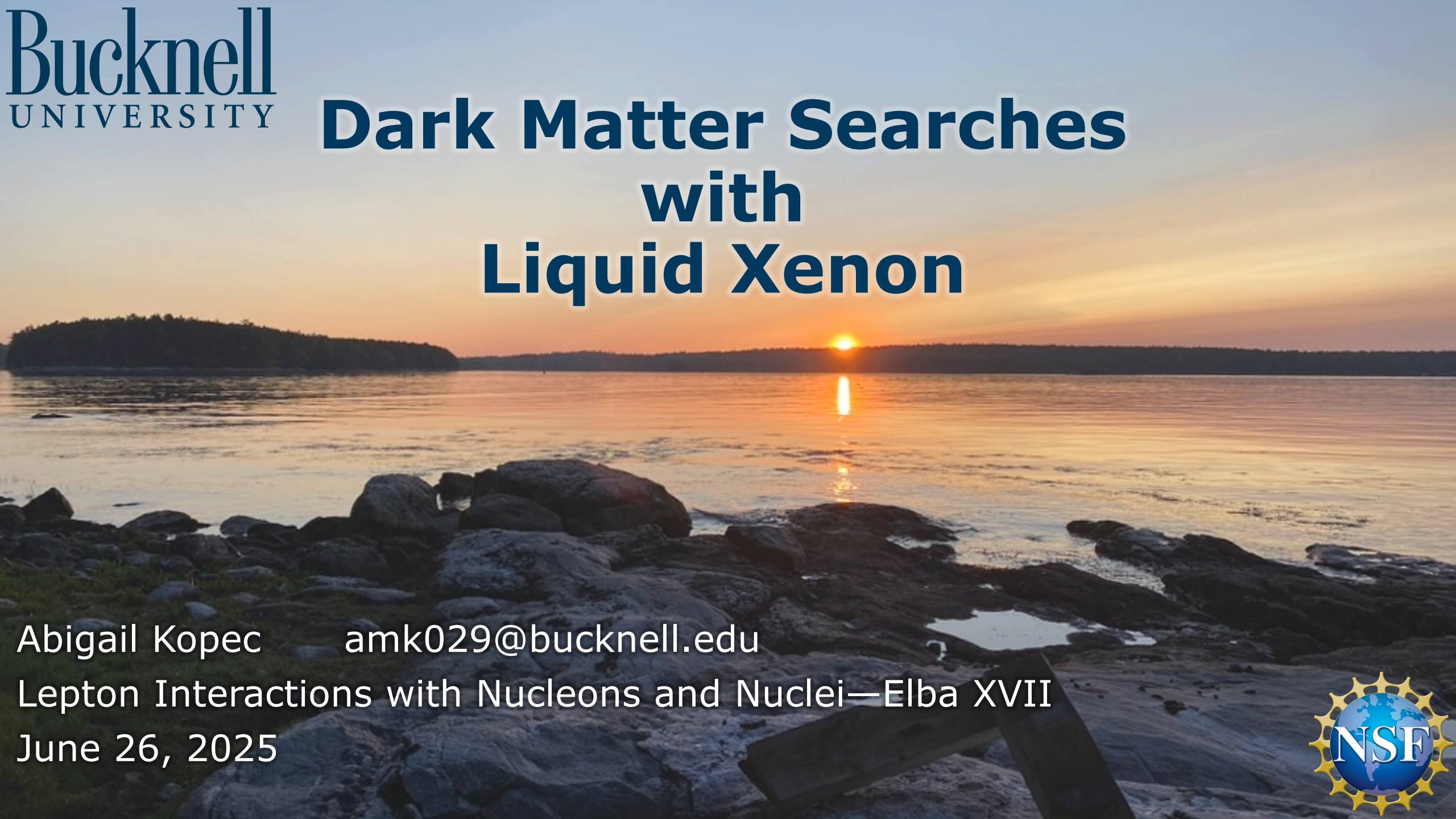
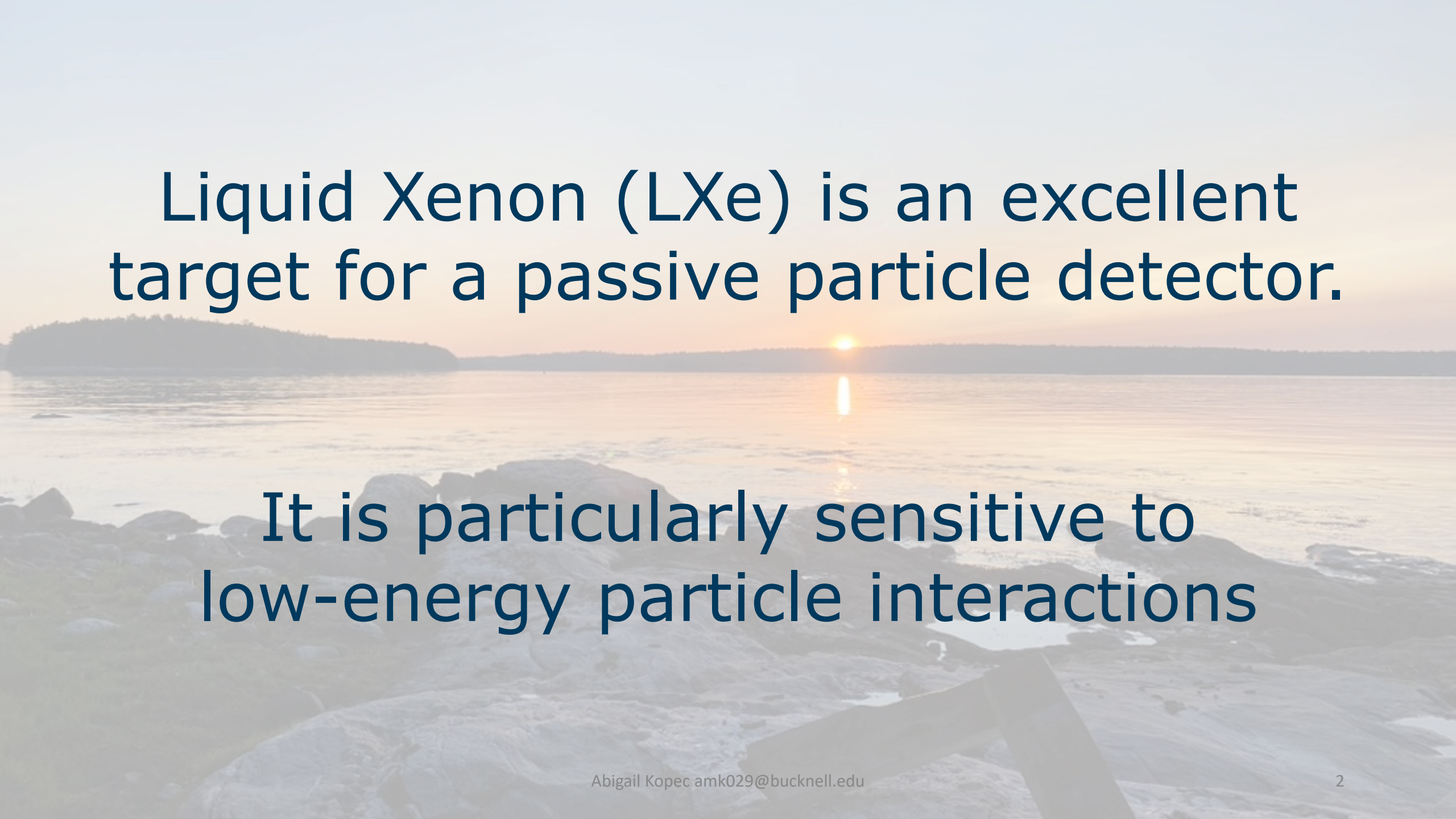


Dark Matter Searches with Liquid Xenon

Abigail Kopec amk029@bucknell.edu

Lepton Interactions with Nucleons and Nuclei—Elba XVII

June 26, 2025



Liquid Xenon (LXe) is an excellent target for a passive particle detector.

It is particularly sensitive to low-energy particle interactions

Why Xenon? - Scintillator

54
Xe
xenon

- Mean electronic excitation value:
  W ~ 11.5eV

Baudis, Sanchez-Lucas, Thieme. Eur. Phys. J. C 81, 1060 (2021)

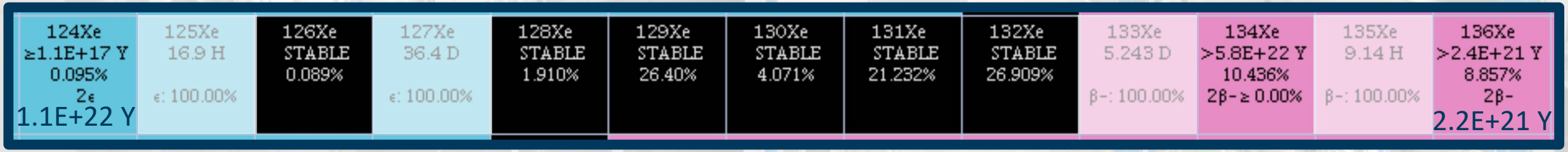
- 174.8 nm scintillation:
  PMTs with ~30% QE
  Teflon ~100% reflectance

Cichon, Eurin Jörg, Marrodán Undagoitia, Rupp. JINST 15 09, P09010 (2020)

Why Xenon? - Clean

54
Xe
xenon

- Noble atomic element
  - Easy Purification
  - Unreactive
- Stable



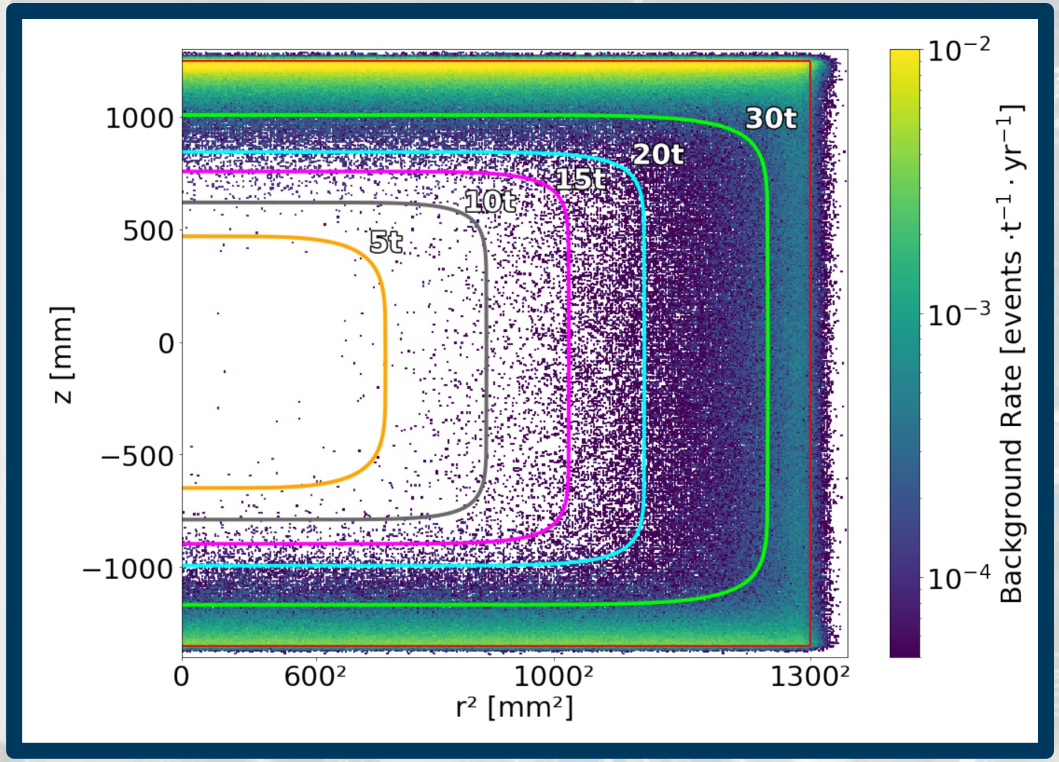
XENON Collaboration. Nature 568, p.532-535 (2019)

EXO-200 Collaboration. Phys. Rev. C 89, 015502 (2014)

Why Xenon? – 131 GeV

- Elastic Scattering
  Dark Matter - 100GeV WIMP
- Coherent enhancement
  Neutrinos CEvNS
- Self-shielding

54
Xe
xenon

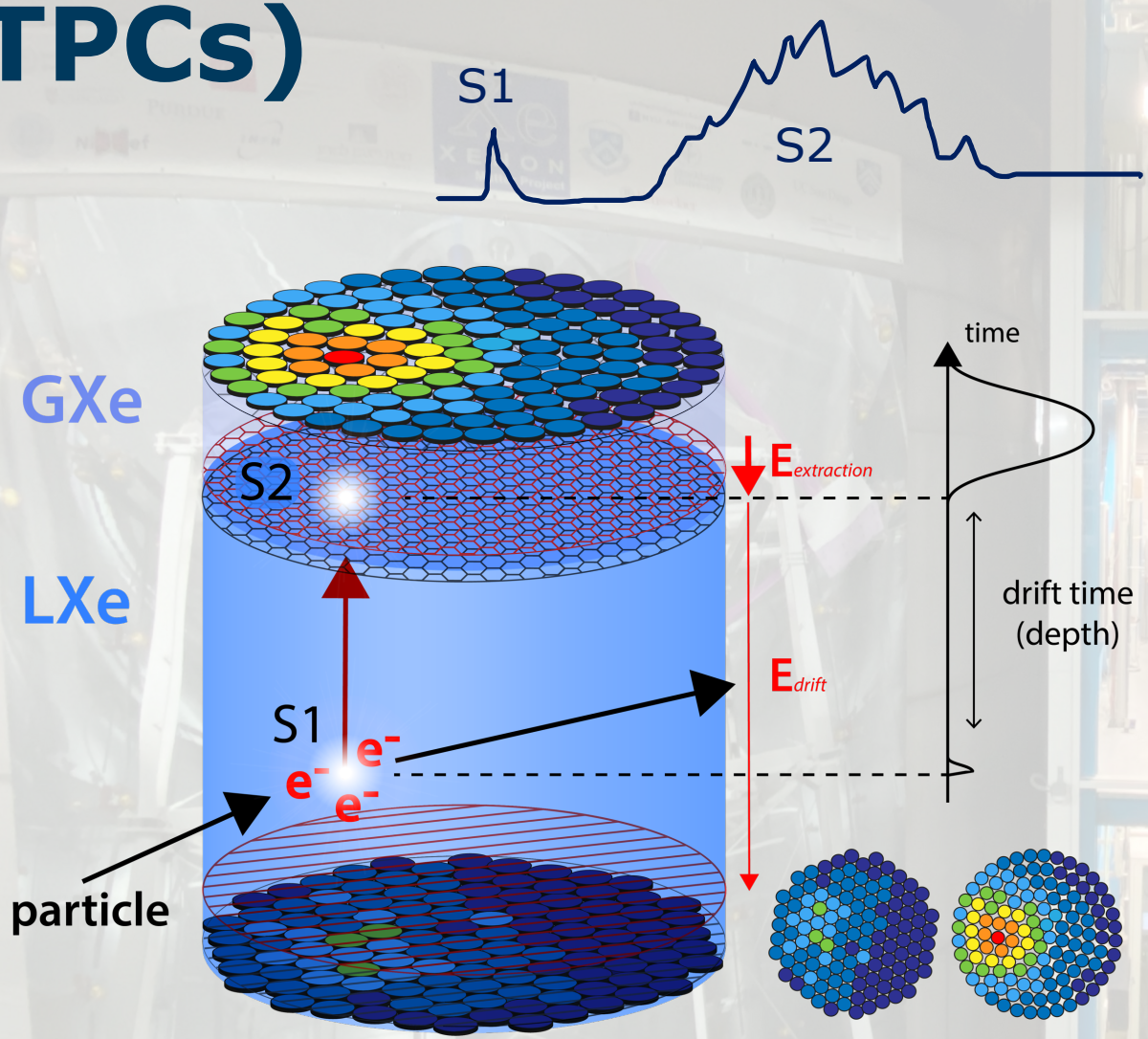


DARWIN Collaboration. Eur. Phys. J. C 80, 808 (2020)

LXe Dark Matter Experiments

- XENONnT
- LUX-ZEPLIN
- PANDAX-4T

Dual-Phase Time Projection Chambers (TPCs)



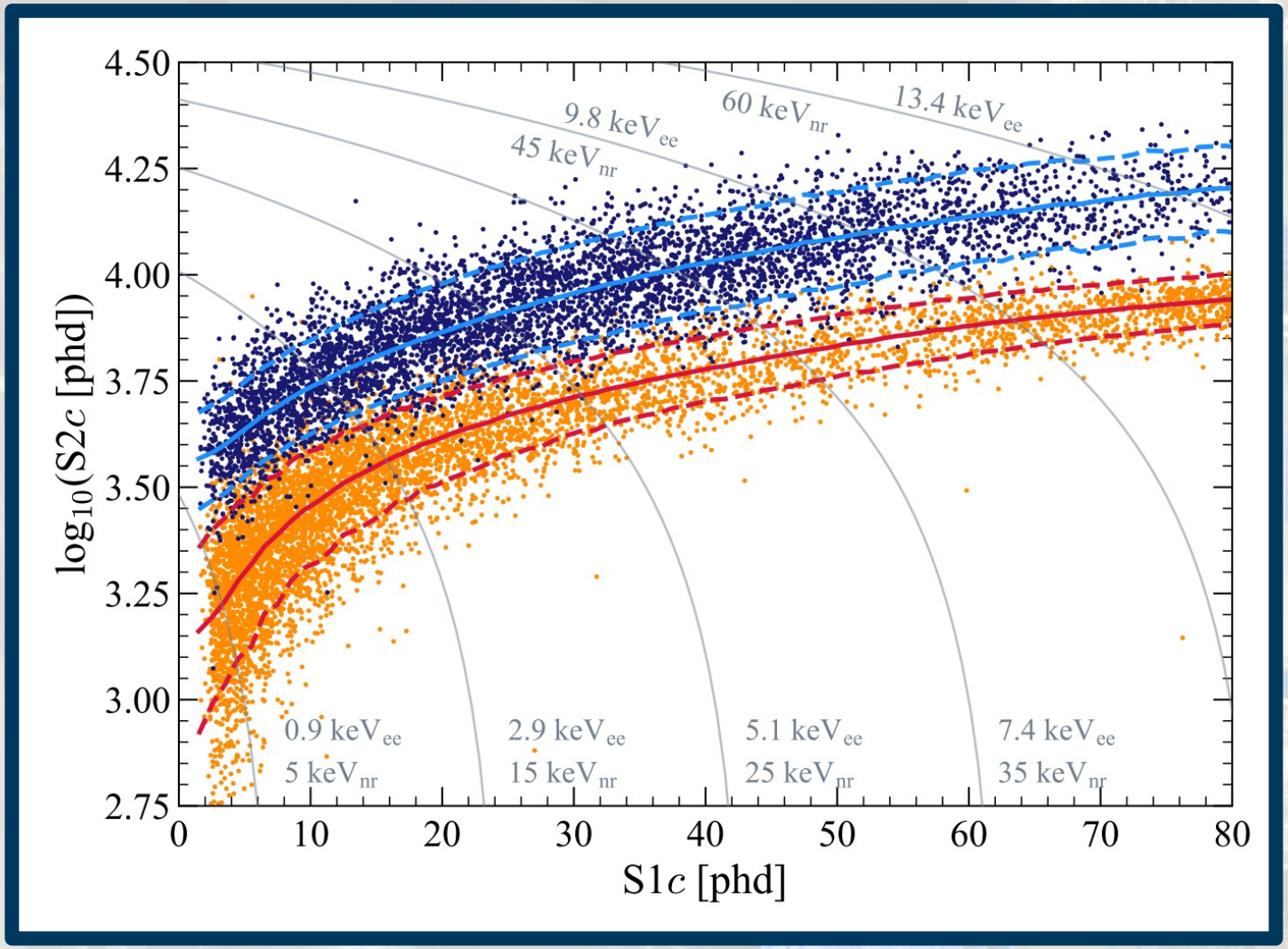
Particle interactions give two signals:

- Prompt Scintillation (S1)
- Delayed Ionization (S2)

(x,y,z) Position Reconstruction

Nuclear and Electronic Recoil Differentiation (NR/ER)

Nuclear Recoils & Electronic Recoils



- ER: An electron is scattered from an atom, leads to more ionization.
- NR: A nucleus is scattered in an atom, leads to more recombination.

LUX-ZEPLIN Collaboration. Phys. Rev. Lett. 131, 041002 (2023)

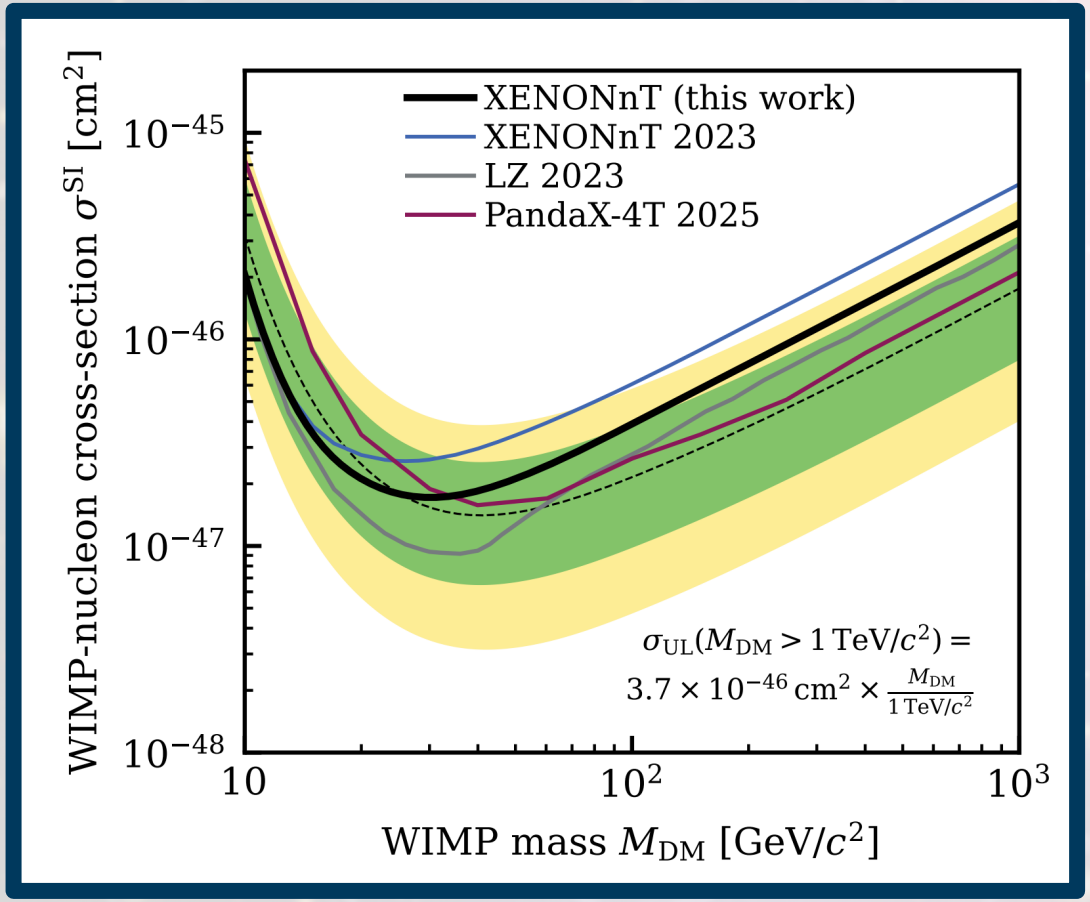
Dark Matter

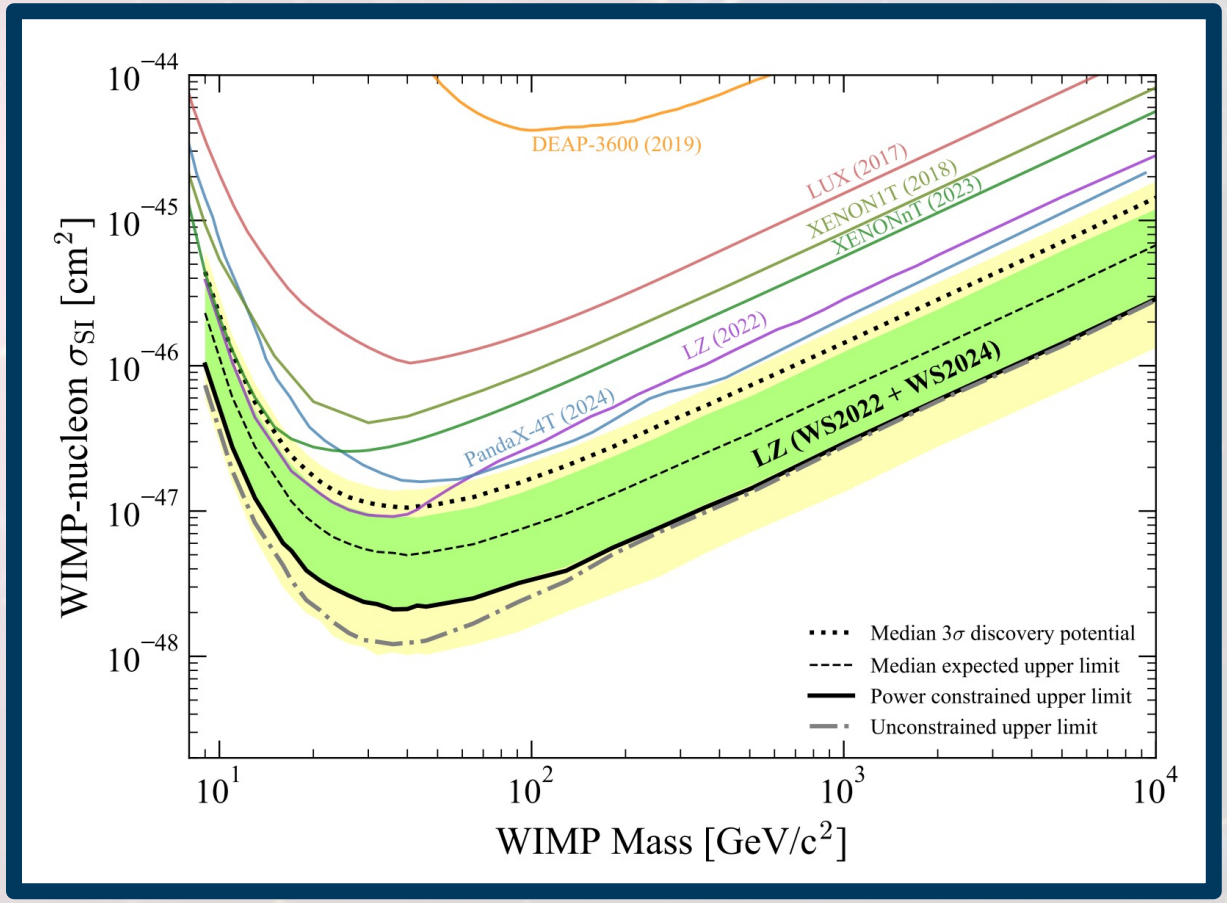
~90 Orders of Magnitude in Mass

LXe TPCs are sensitive to a broad range of dark matter models

Dark Matter – Nuclear Recoils

Spin-Independent WIMPs



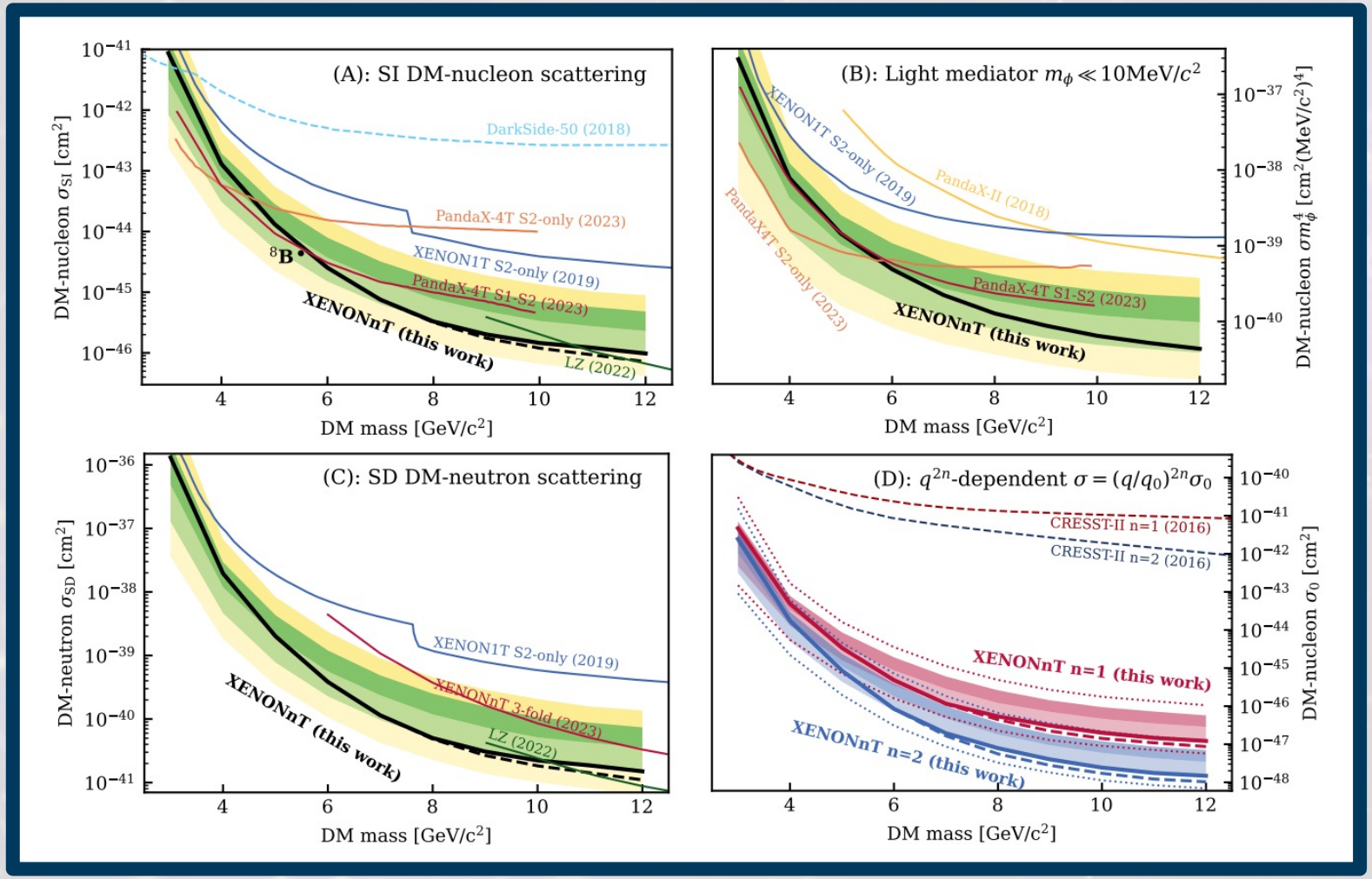


XENON Collaboration.
arXiv: 2502.18005

LUX-ZEPLIN Collaboration.
arXiv: 2410.17036

Dark Matter – Nuclear Recoils

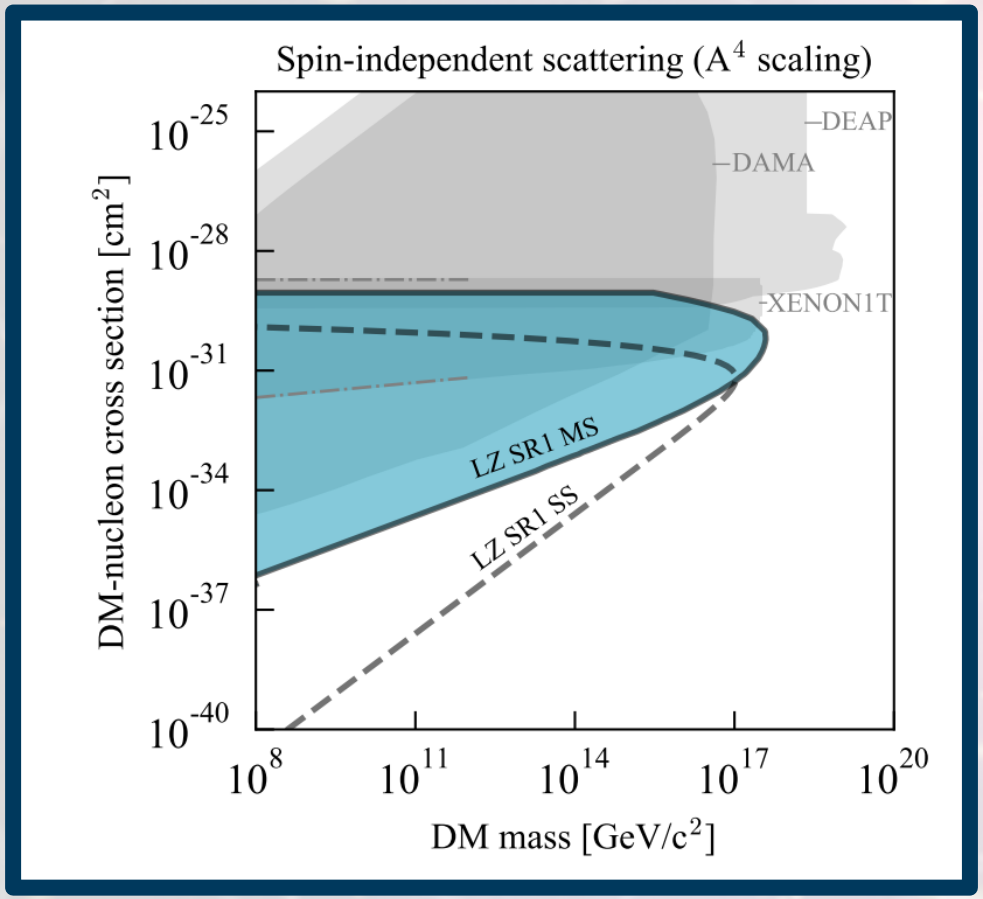
Light WIMPs despite Neutrinos

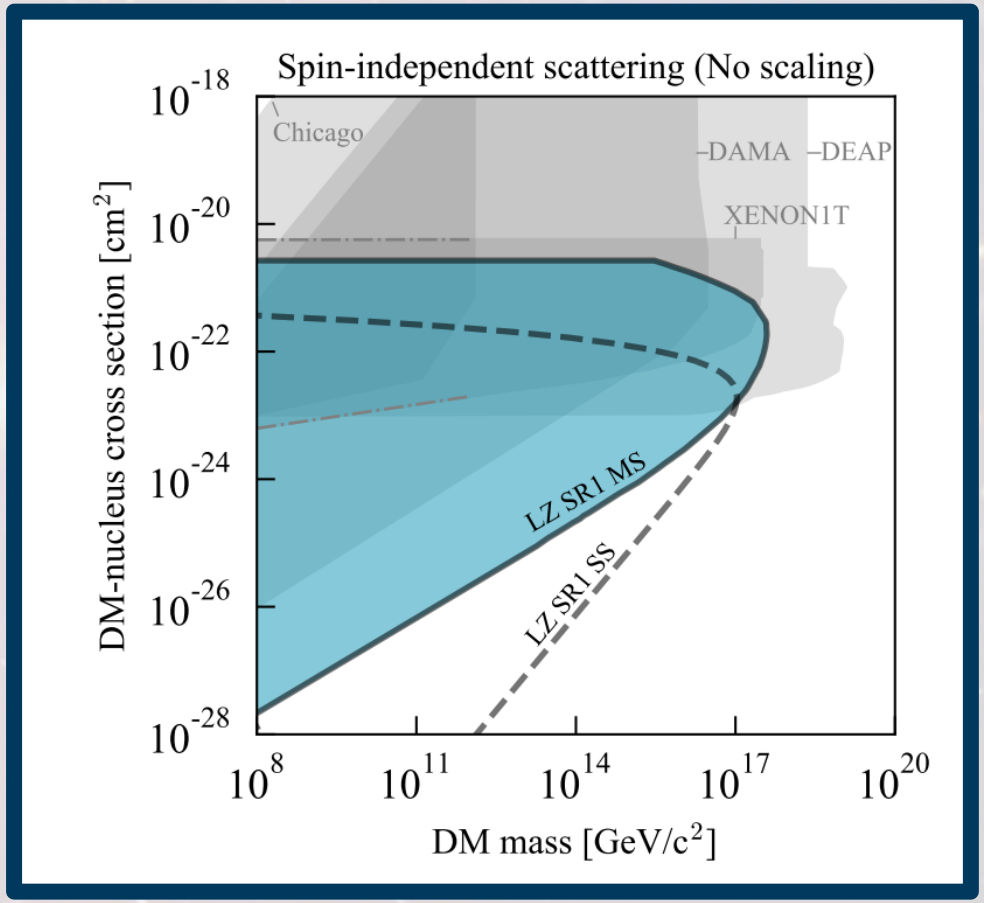


XENON Collaboration.
Phys. Rev. Lett. 134, 111802 (2025)

Dark Matter – Nuclear Recoils

Multiply Interacting Massive Particles

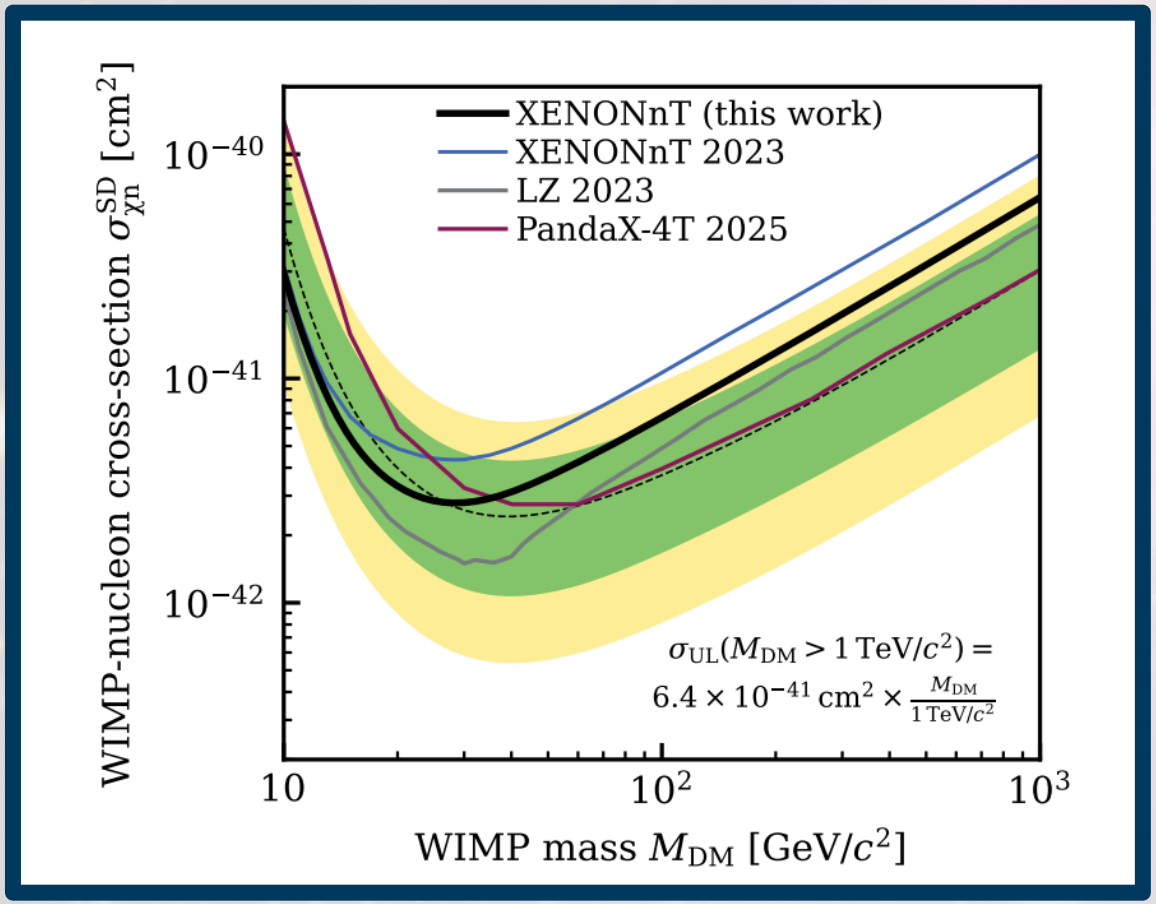


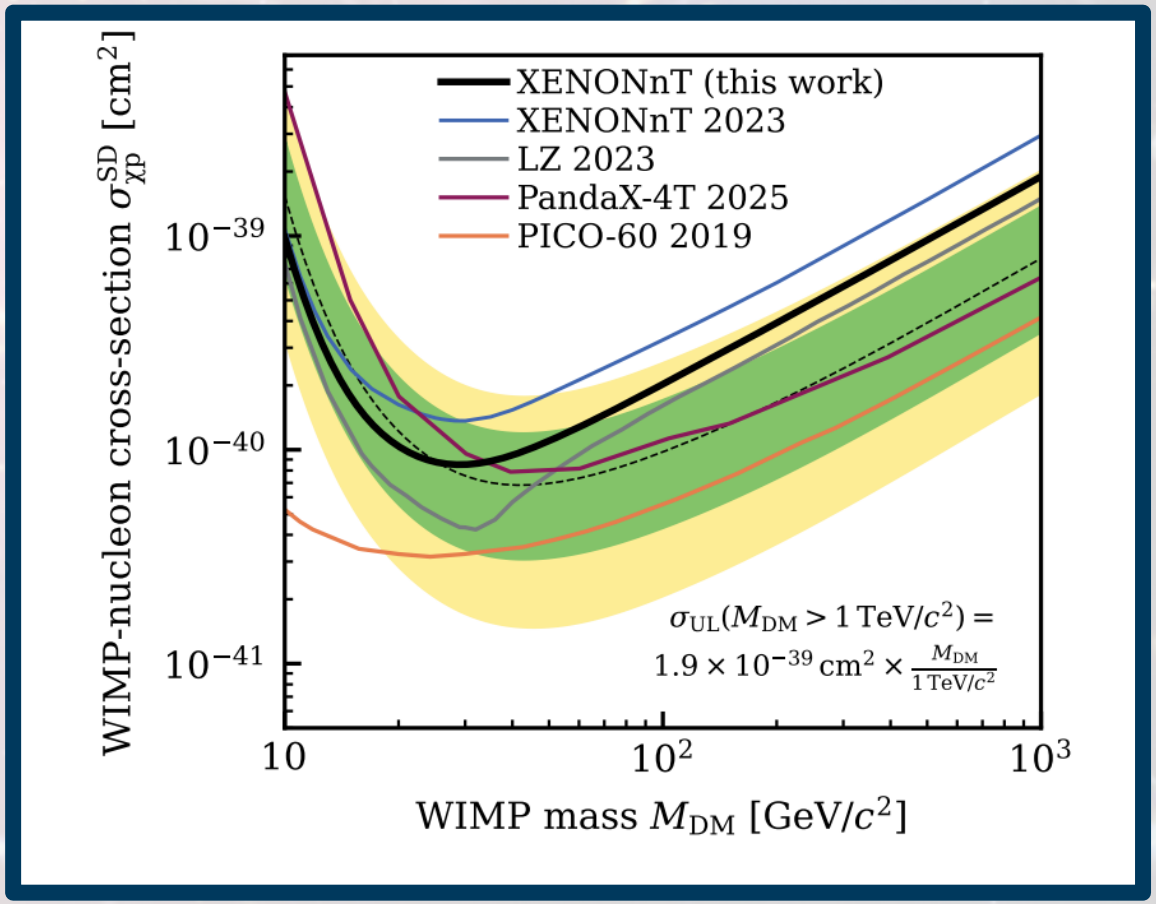


LUX-ZEPLIN Collaboration.
Phys. Rev. D 109, 112010 (2024)

Dark Matter – Nuclear Recoils

Spin-Dependent WIMPs

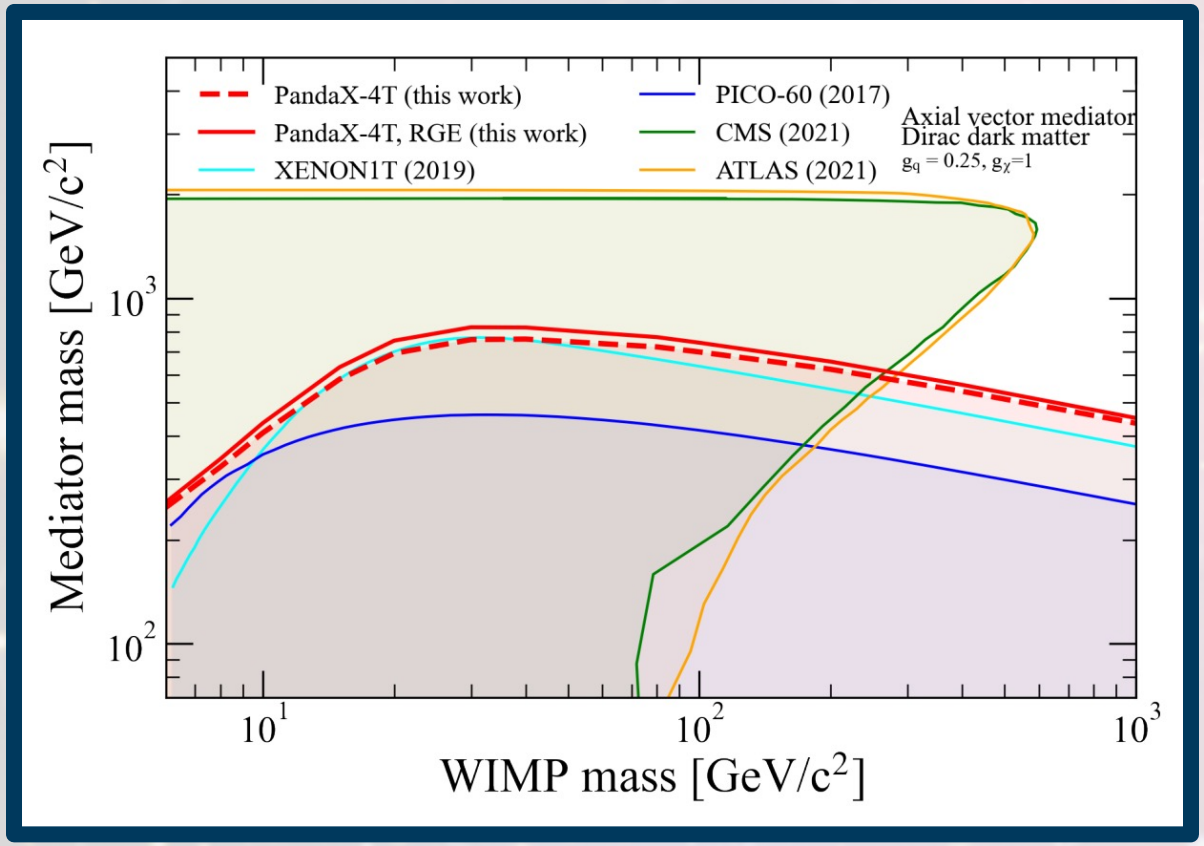


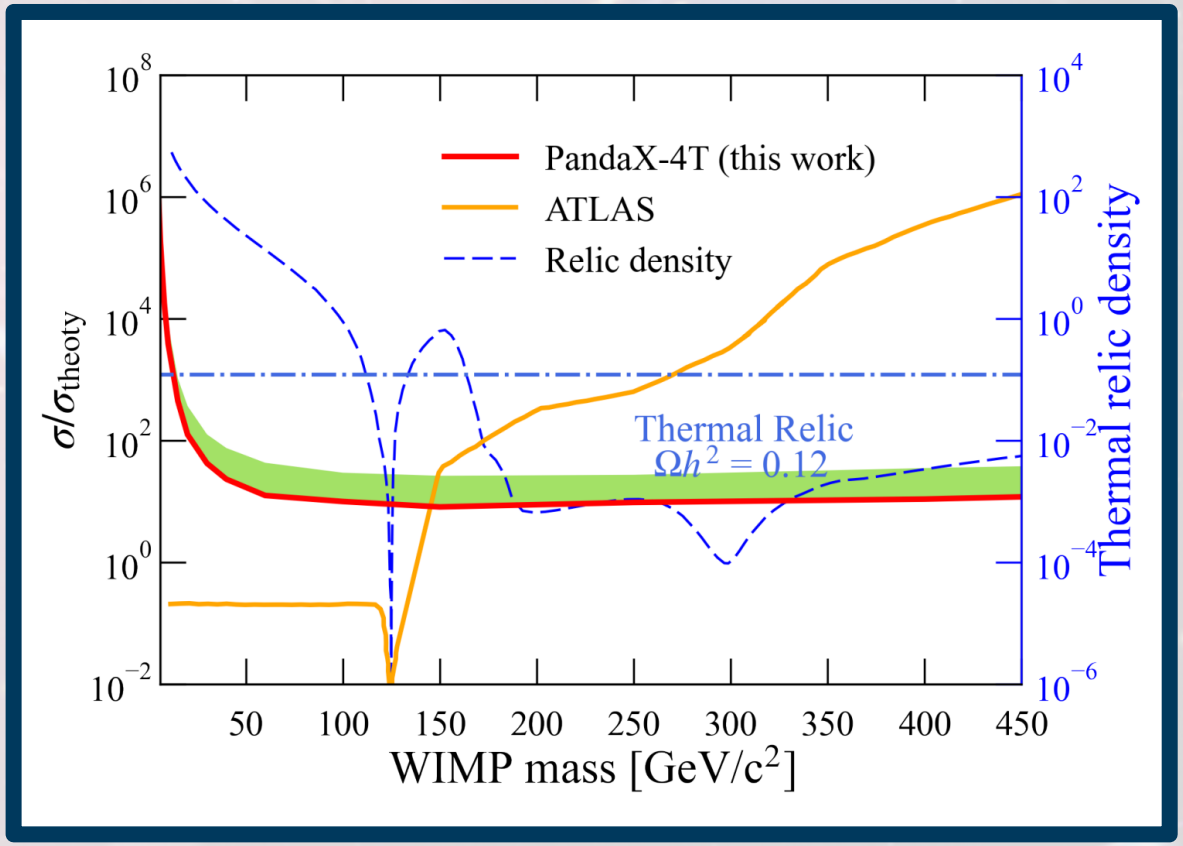


XENON Collaboration.
arXiv: 2502.18005

Dark Matter – Nuclear Recoils

Axial-vector and pseudo-scalar mediated WIMPs

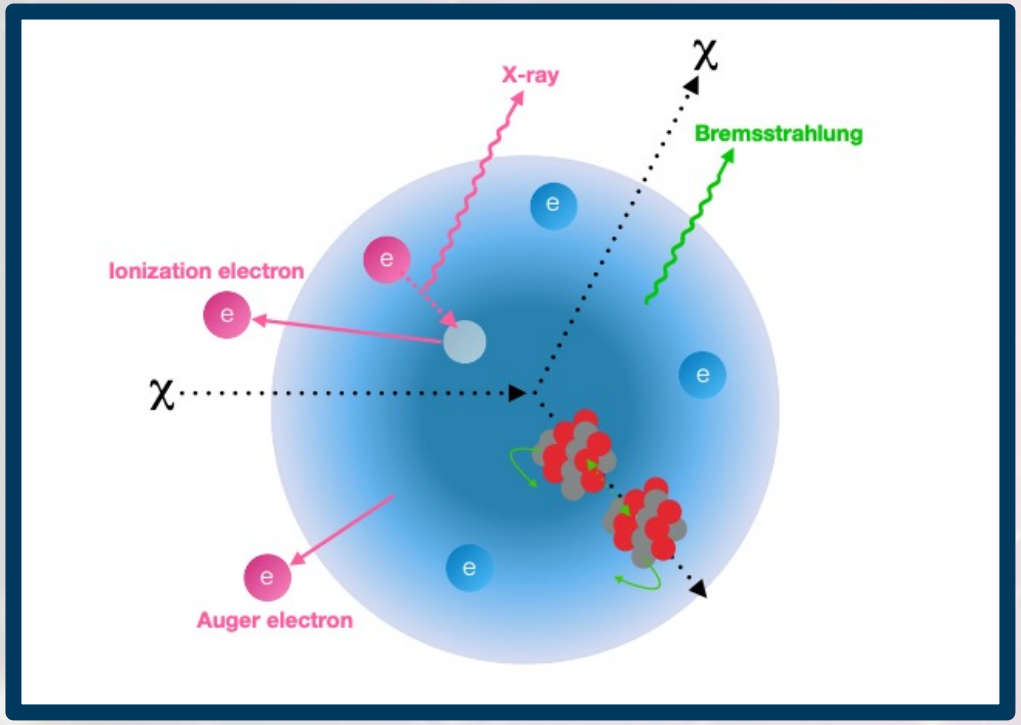


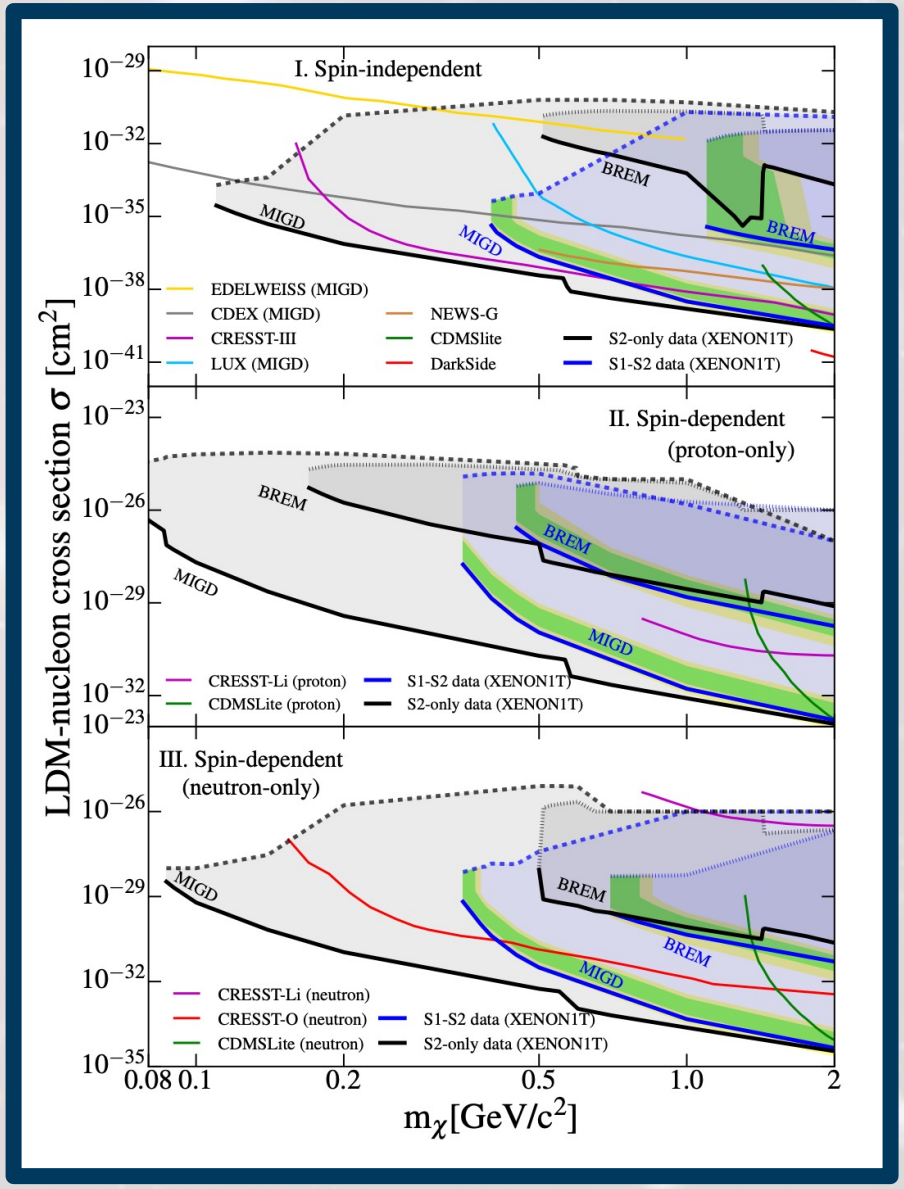


PandaX Collaboration.
Phys. Lett. B 834 137487 (2022)

Dark Matter – Nuclear Recoils

Migdal-enhanced WIMPs

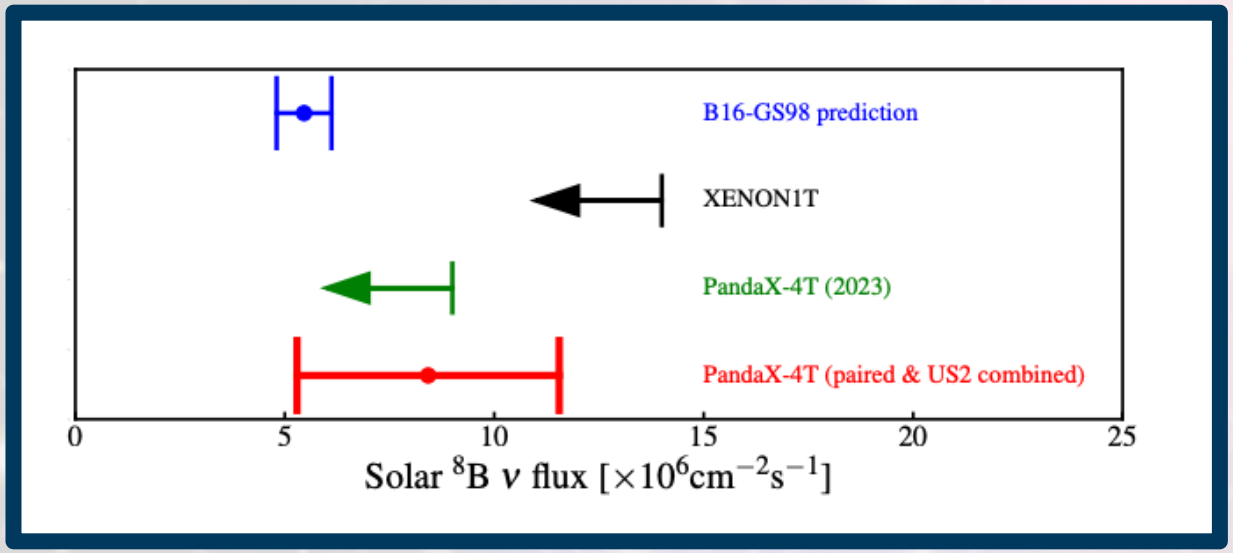


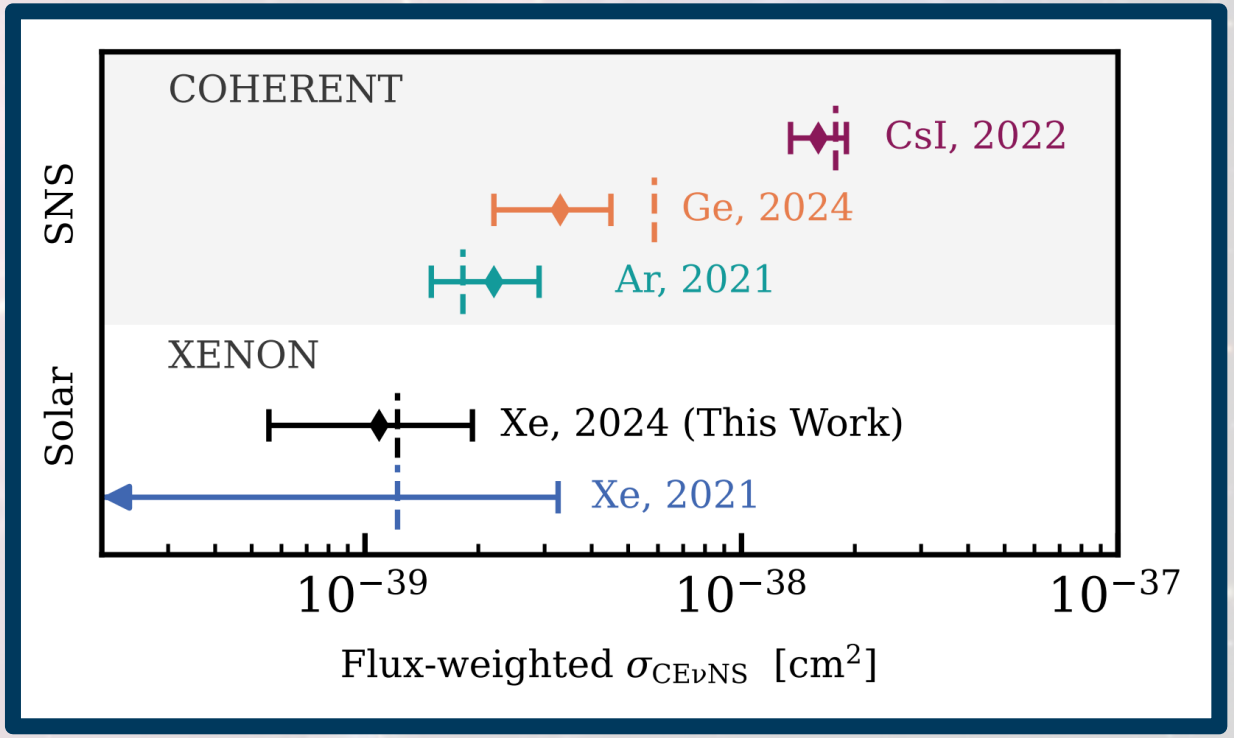


XENON Collaboration.
Phys. Rev. Lett. 123, 241803 (2019)

(Not Dark Matter) – Nuclear Recoils

Coherent-Elastic Neutrino-Nucleus Scattering

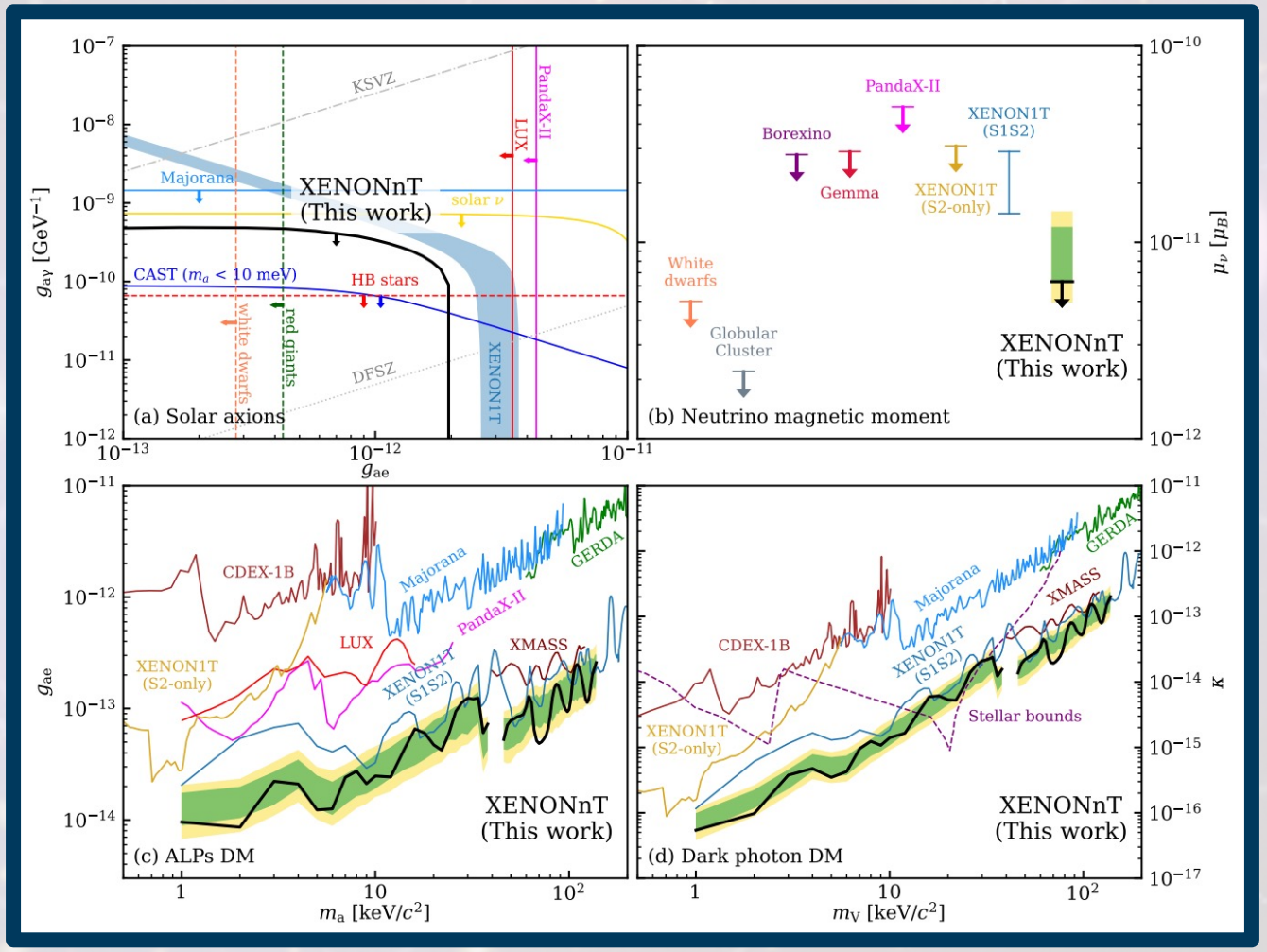




PandaX Collaboration.
Phys. Rev. Lett. 133, 191001 (2024)

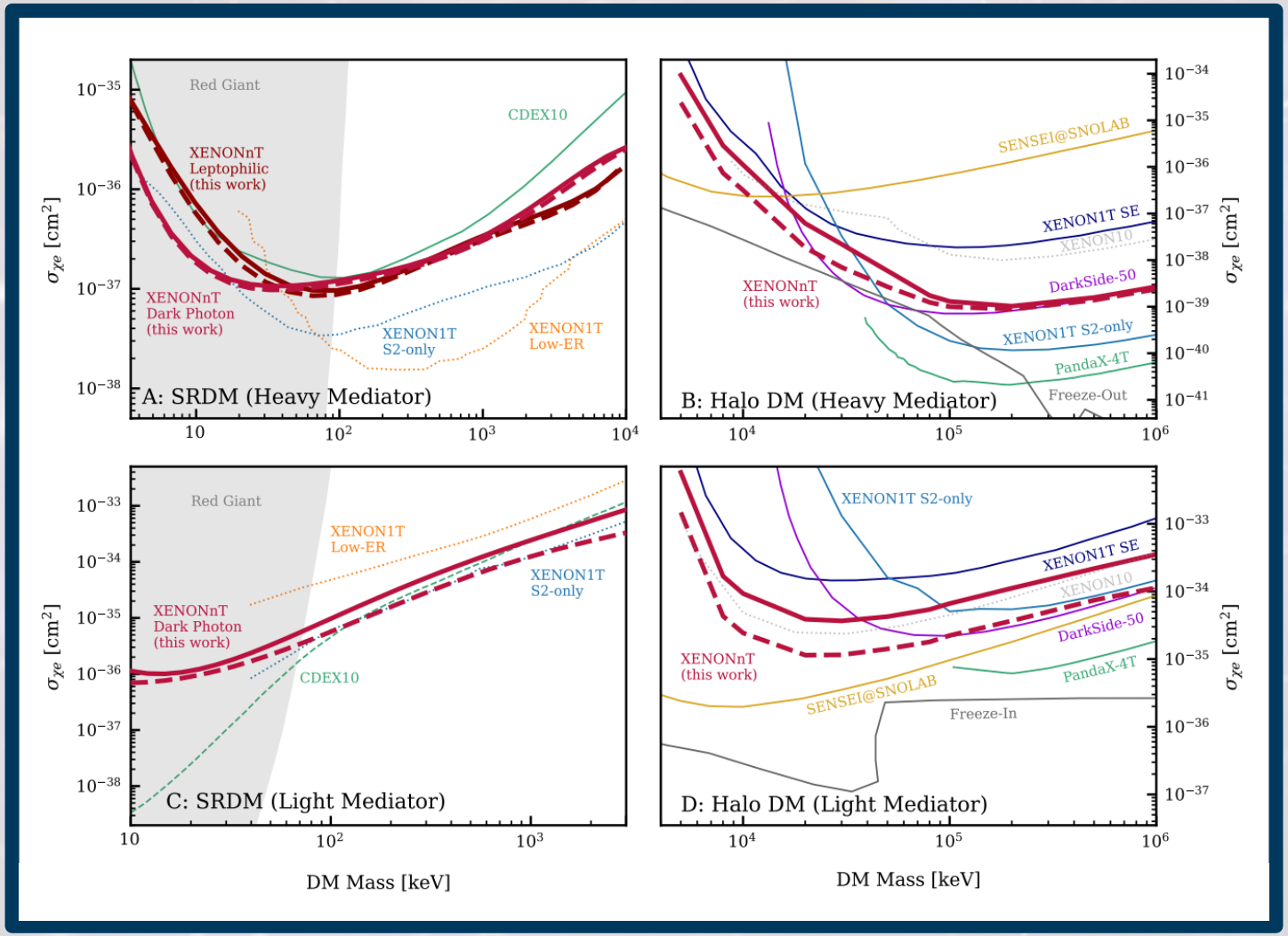
XENON Collaboration.
Phys. Rev. Lett. 133, 191002 (2024)

Dark Matter – Electronic Recoils



XENON Collaboration.
Phys. Rev. Lett. 129, 161805 (2022)

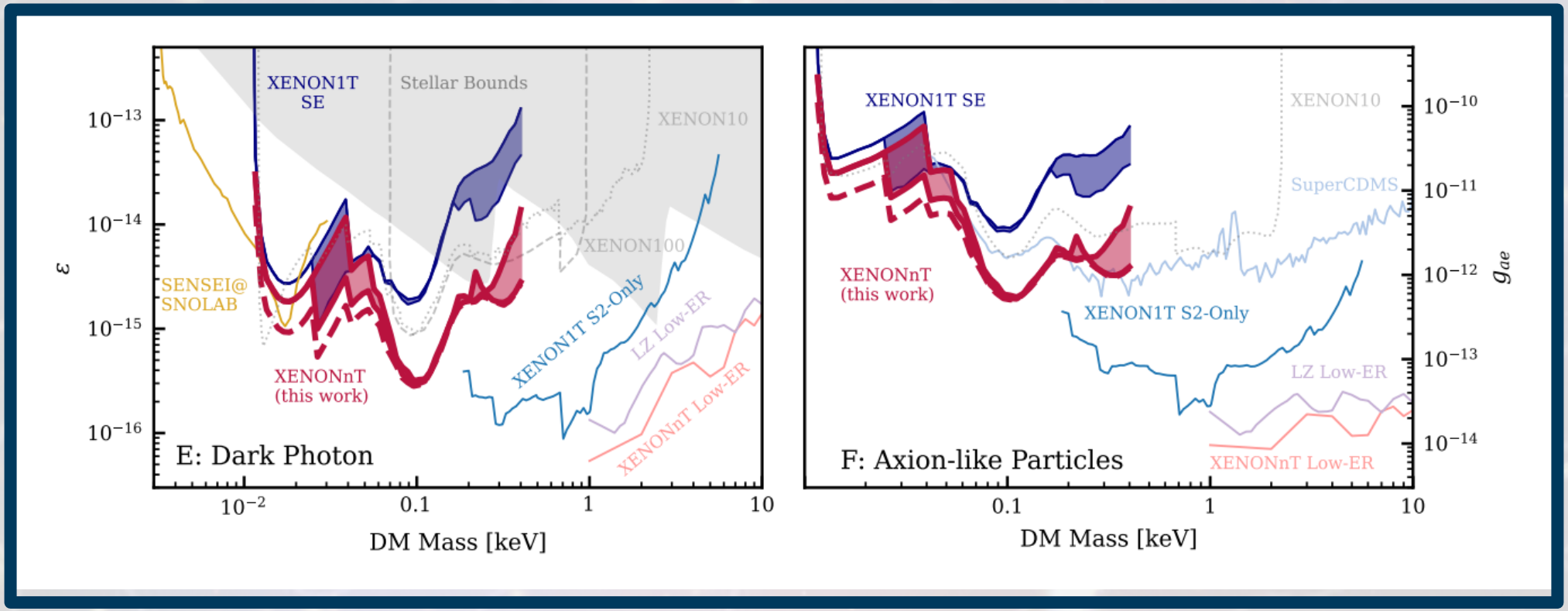
Dark Matter – Electronic Recoils



XENON Collaboration.
Phys. Rev. Lett. 134, 161004 (2025)

Dark Matter – Electronic Recoils

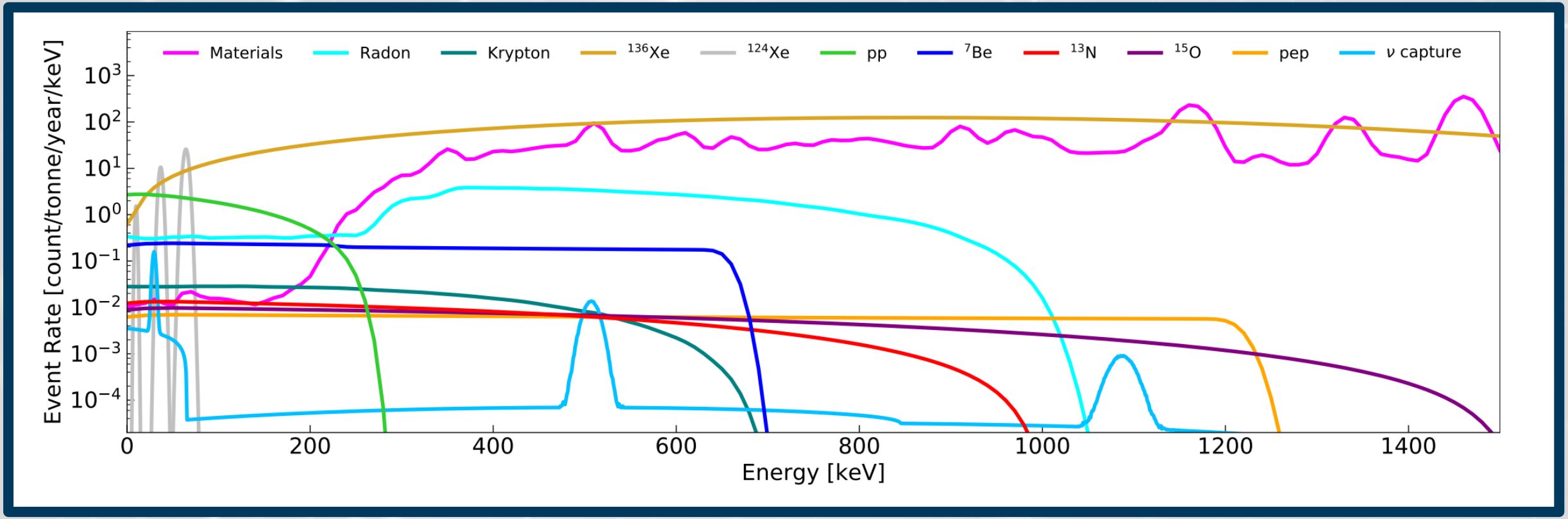
Light Bosons



XENON Collaboration.
Phys. Rev. Lett. 134, 161004 (2025)

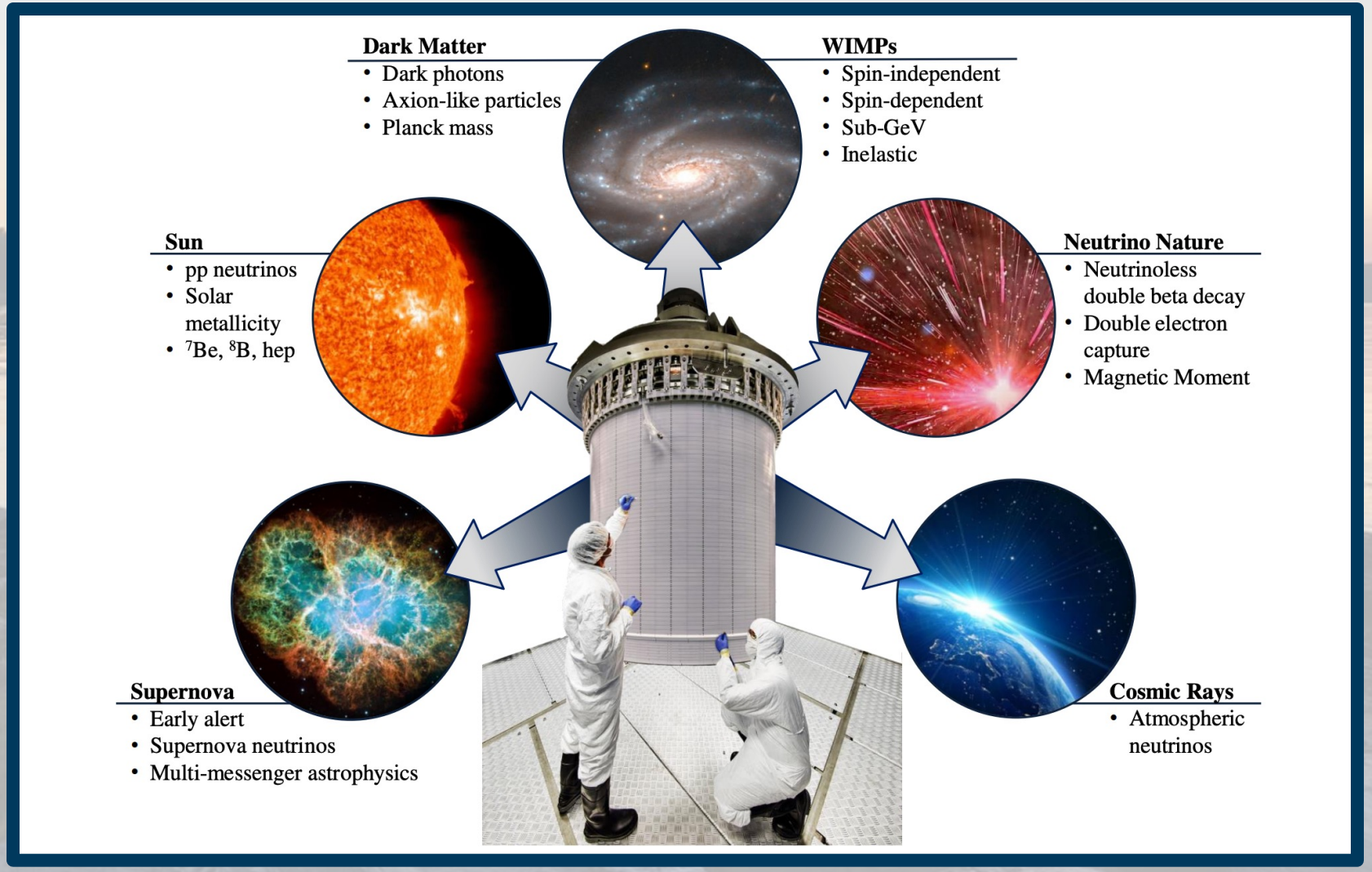
(Not Dark Matter) – Electronic Recoils

Neutrinos soon?



DARWIN Collaboration.
Eur. Phys. J. C 80, 1133 (2020)

XENON-LUX-ZEPLIN-DARWIN Collaboration



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

Summary

LXe-based detectors are versatile observatories for rare particle physics, particularly leading searches for dark matter.

- Primarily detectors for Weakly Interacting Massive Particles
- Sensitive to a wide range of dark matter models, and neutrinos due to low backgrounds (ER and NR).