35th Rencontres de Blois 2024

Current status of direct dark matter searches with XENONnT

Jaron Grigat
on behalf of the XENON collaboration

Bundesministerium
für Bildung
und Forschung

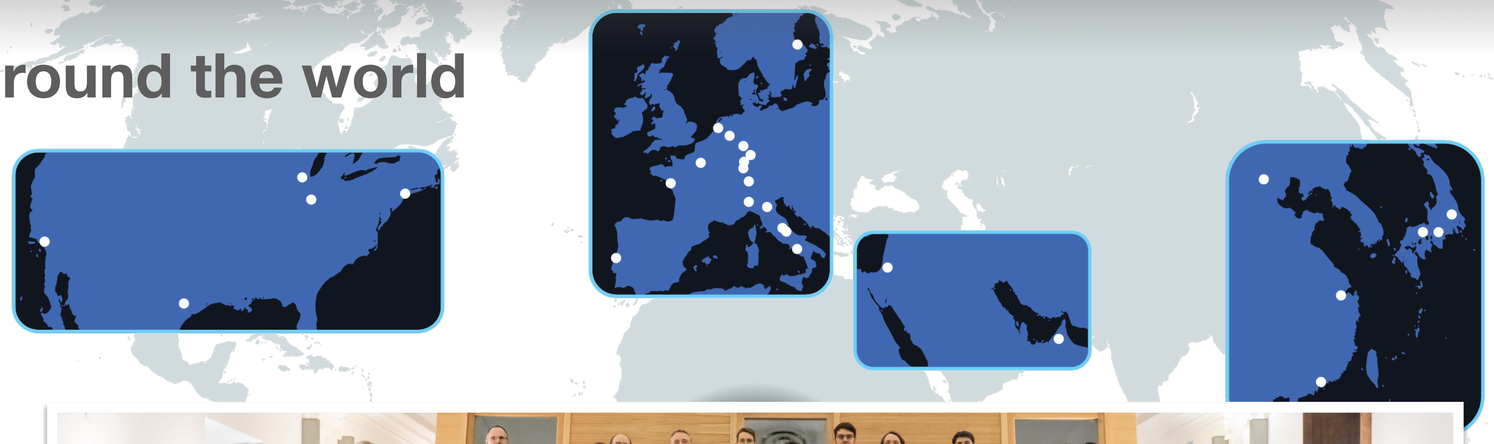
XENON

universität freiburg

23.10.2024, Jaron Grigat, jaron.grigat@physik.uni-freiburg.de

XENON Collaboration

~200 Scientists
29 Institutions around the world



AMERICA

- UC San Diego — San Diego
- Houston
- The University of Chicago — Chicago
- Columbia University in the City of New York — New York City
- Purdue University — Lafayette

EUROPE

- Zurich
- KIT Karlsruhe Institute of Technology — Karlsruhe
- WWU Münster — Münster
- Uni Freiburg — Freiburg
- JGU — Mainz
- Max-Planck-Institut für Kernphysik — Heidelberg
- Nikhef — Amsterdam
- Stockholm University — Stockholm
- Universidade de Coimbra — Coimbra
- Subatech — Nantes
- LPNHE Paris — Paris
- INFN Torino — Torino
- Alma Mater Studiorum — Bologna
- Università degli Studi dell'Aquila — L'Aquila
- INFN LNGS — Assergi
- Napoli

EAST

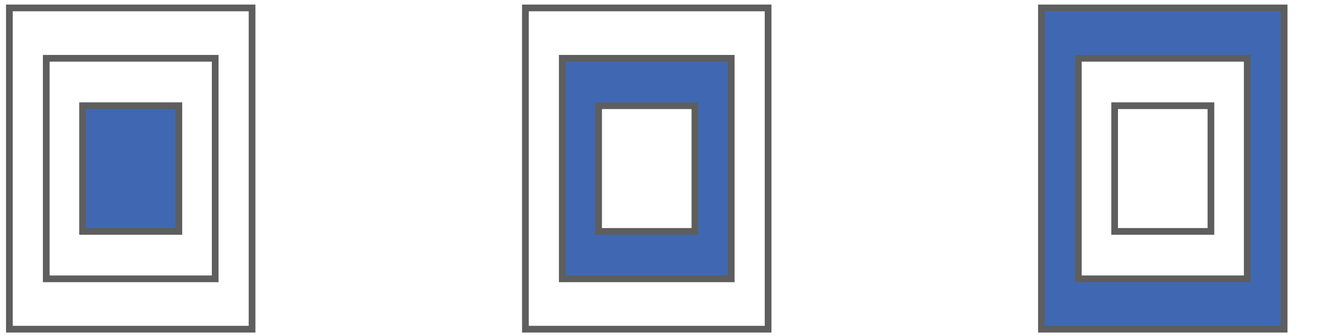
- Weizmann Institute of Science — Rehovot
- NYU Abu Dhabi — Abu Dhabi

ASIA

- Tsinghua University — Beijing
- Westlake University — Hangzhou
- The Chinese University of Hong Kong, Shenzhen — Shenzhen
- The University of Tokyo — Tokyo
- Nagoya University — Nagoya
- Kobe University — Kobe

XENONnT Experiment

- Located at the INFN Laboratory Nazionali del Gran Sasso (LNGS) in Italy
- Main science channel: search for nuclear recoils (NRs) created by Weakly Interacting Massive Particles (**WIMPs**)
- Three nested detectors:

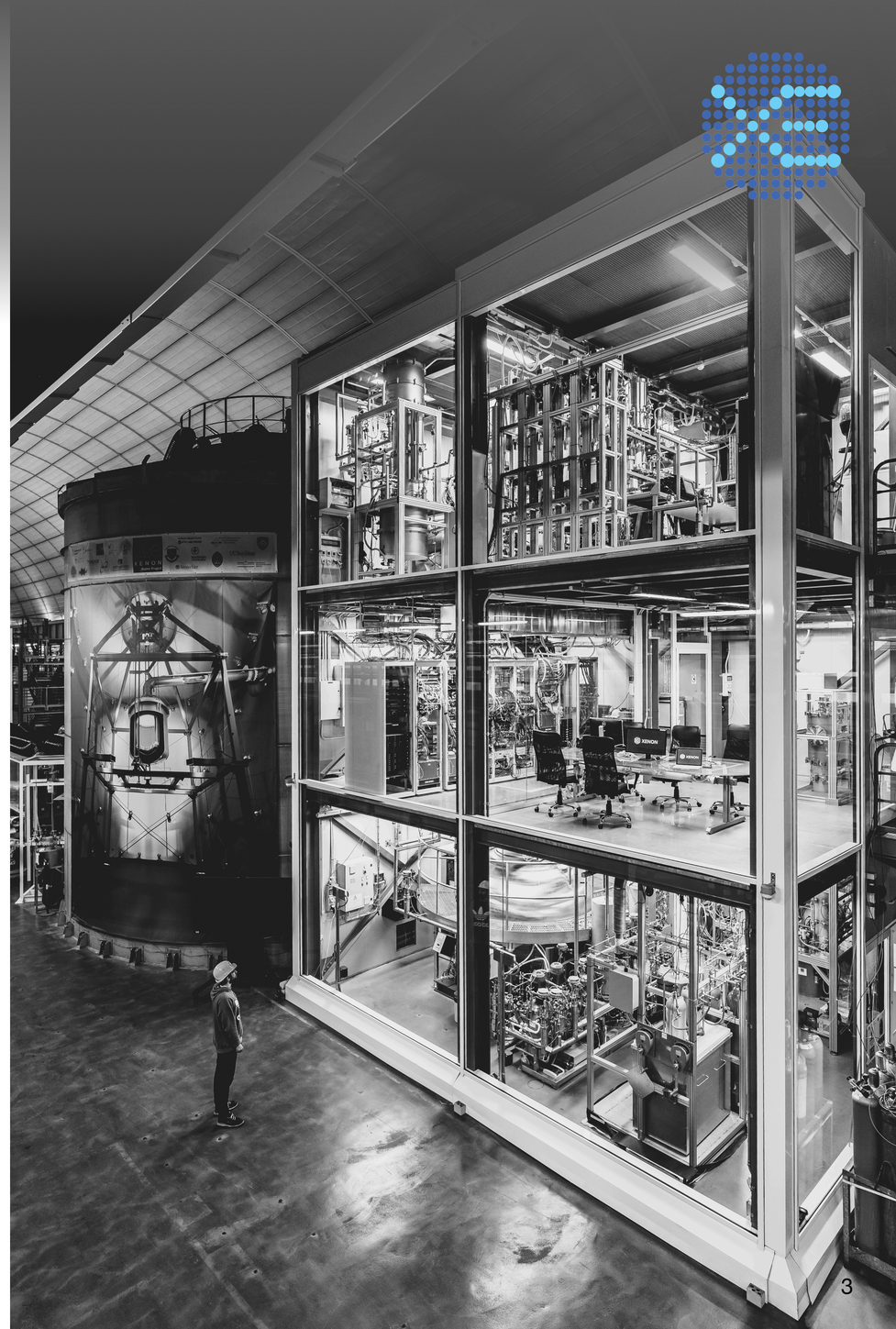


Xenon dual-phase
Time Projection Chamber
(TPC)

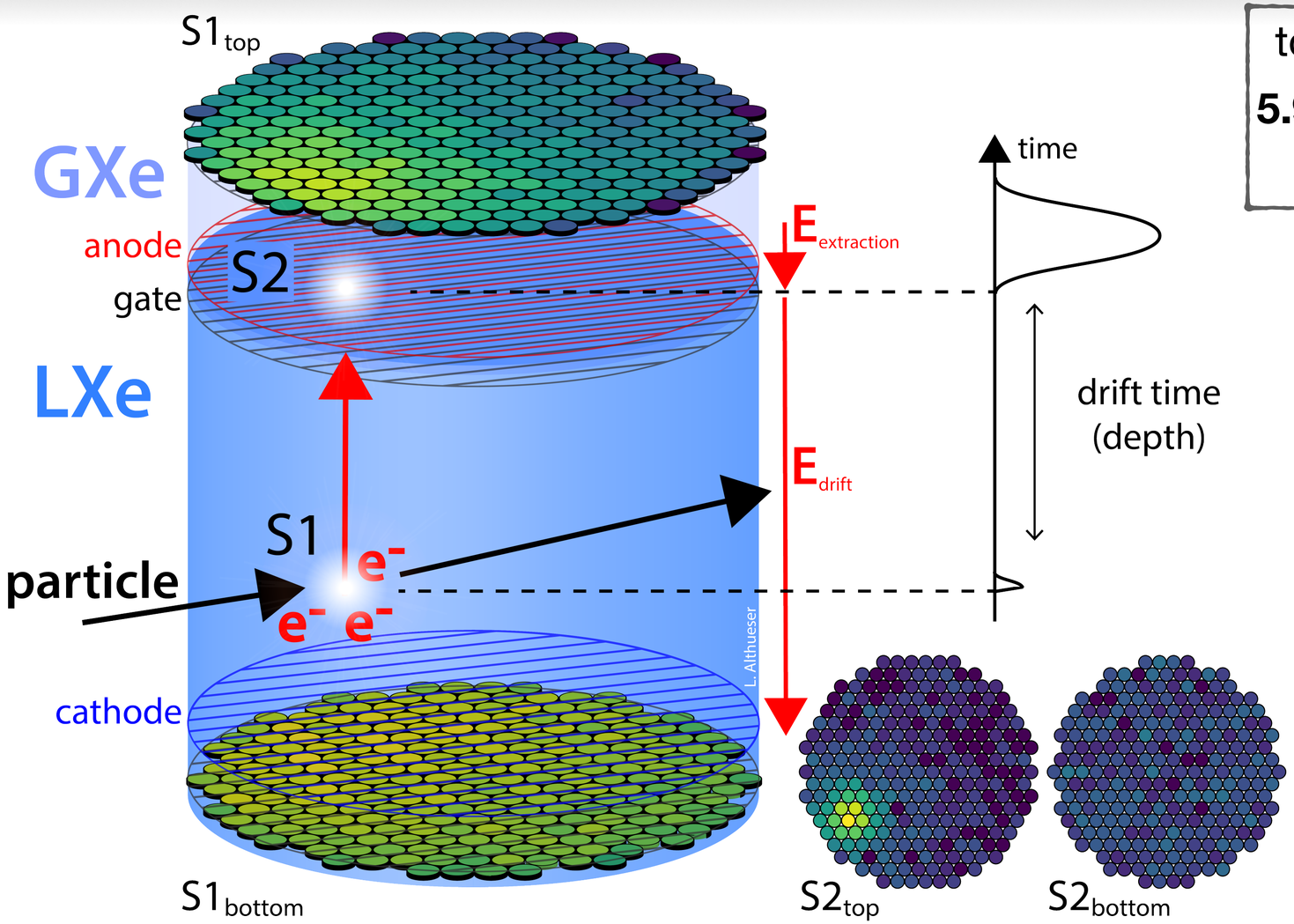
Neutron Veto
(Gd-salted) Water
Cherenkov detector

Muon Veto
Water Cherenkov
detector

700 t Water tank
Passive shielding



Time Projection Chamber (TPC)



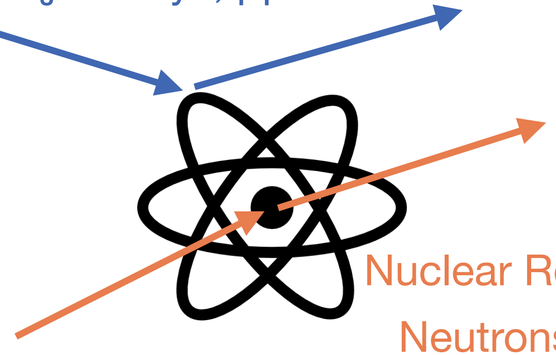
total mass: **8.5** tonne ultra pure liquid xenon

5.9 tonne active mass observed via **494** PMTs

height = **1.5m**, diameter = **1.3m**

Electronic Recoils (ERs)

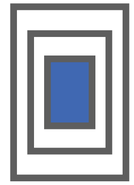
e.g.: β- & ɣ-decays, pp-neutrinos



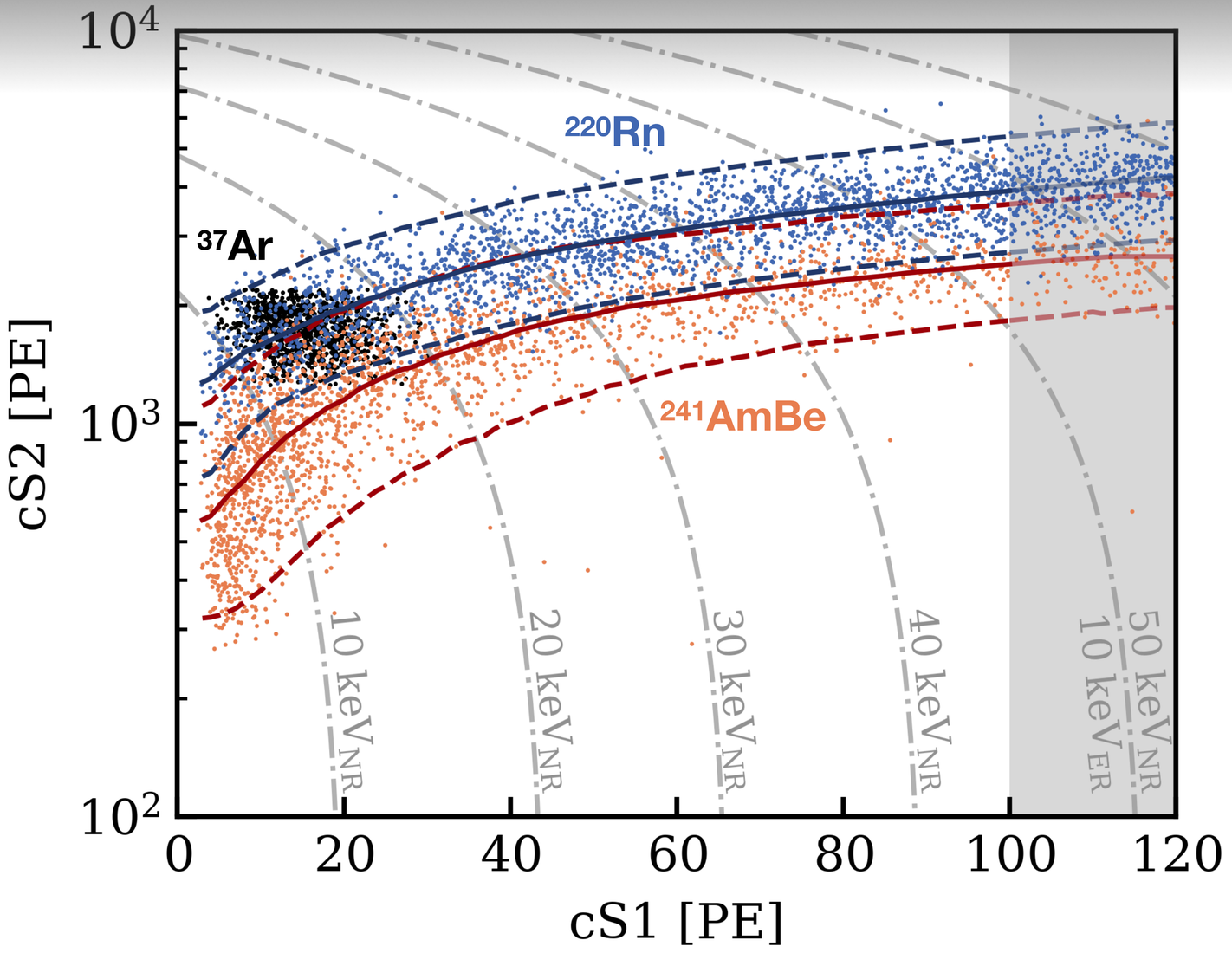
Nuclear Recoils (NRs)

Neutrons, CEvNS, WIMPs

$$\left(\frac{S2}{S1}\right)_{NR} < \left(\frac{S2}{S1}\right)_{ER}$$



ER vs. NR discrimination

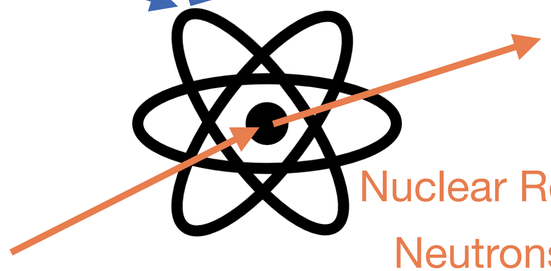


cS1, cS2 signals **corrected** for detector effects

Calibration sources: ^{37}Ar, ^{220}Rn, ^{241}AmBe

Electronic Recoils (ERs)

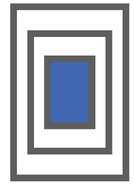
e.g.: β- & ɣ-decays, pp-neutrinos



Nuclear Recoils (NRs)

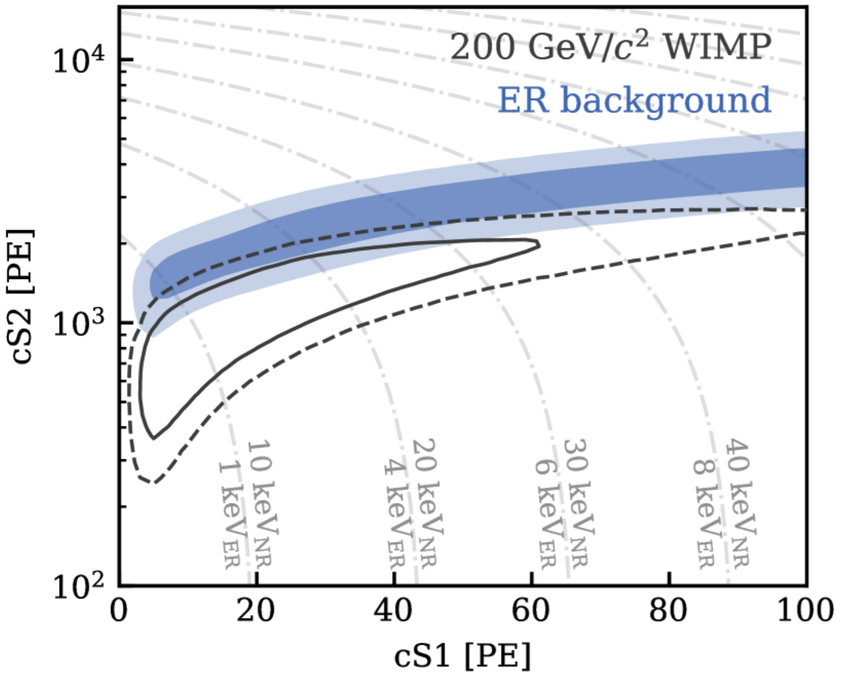
Neutrons, CEvNS, WIMPs

$$\left(\frac{S2}{S1}\right)_{NR} < \left(\frac{S2}{S1}\right)_{ER}$$

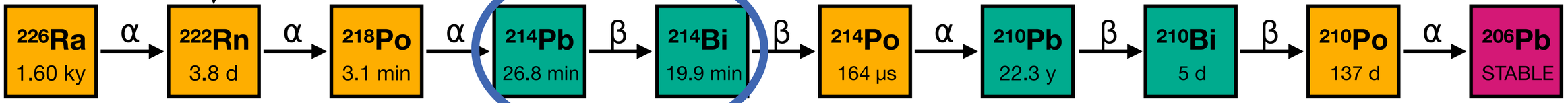


ER background

- ER leakage into signal region → keep total ERs as low as possible
- ER spectrum in WIMP ROI dominated by ^{214}Pb β-decays to ground state
- Reduced by
  - A. Careful selection of low-bkg. construction materials Eur. Phys. J. C 82, 599 **(2022)**
  - B. Detector Design Eur. Phys. J. C 84, 784 (**2024**)
  - C. On-site Krypton removal system Eur. Phys. J. C 77, 275 **(2017)**
  - **D. Online Radon removal** Eur. Phys. J. C 82, 1104 (**2022**)

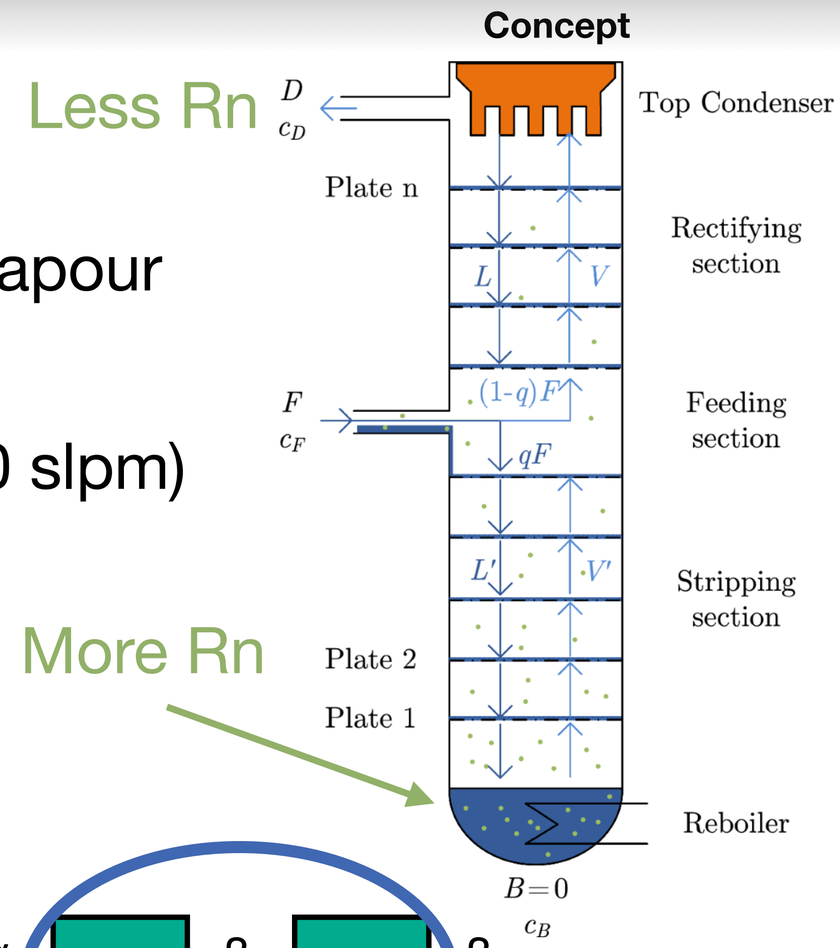


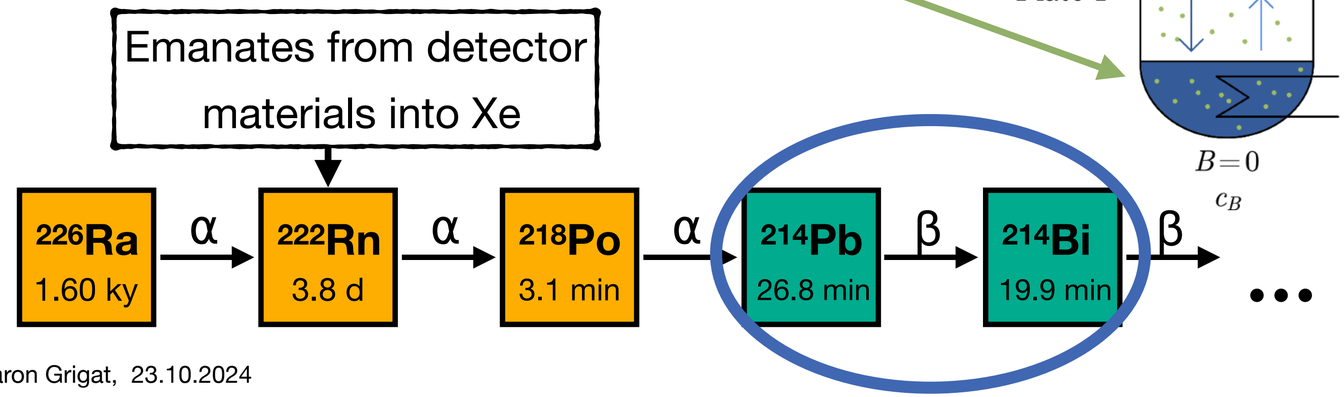
Emanates from detector materials into Xe

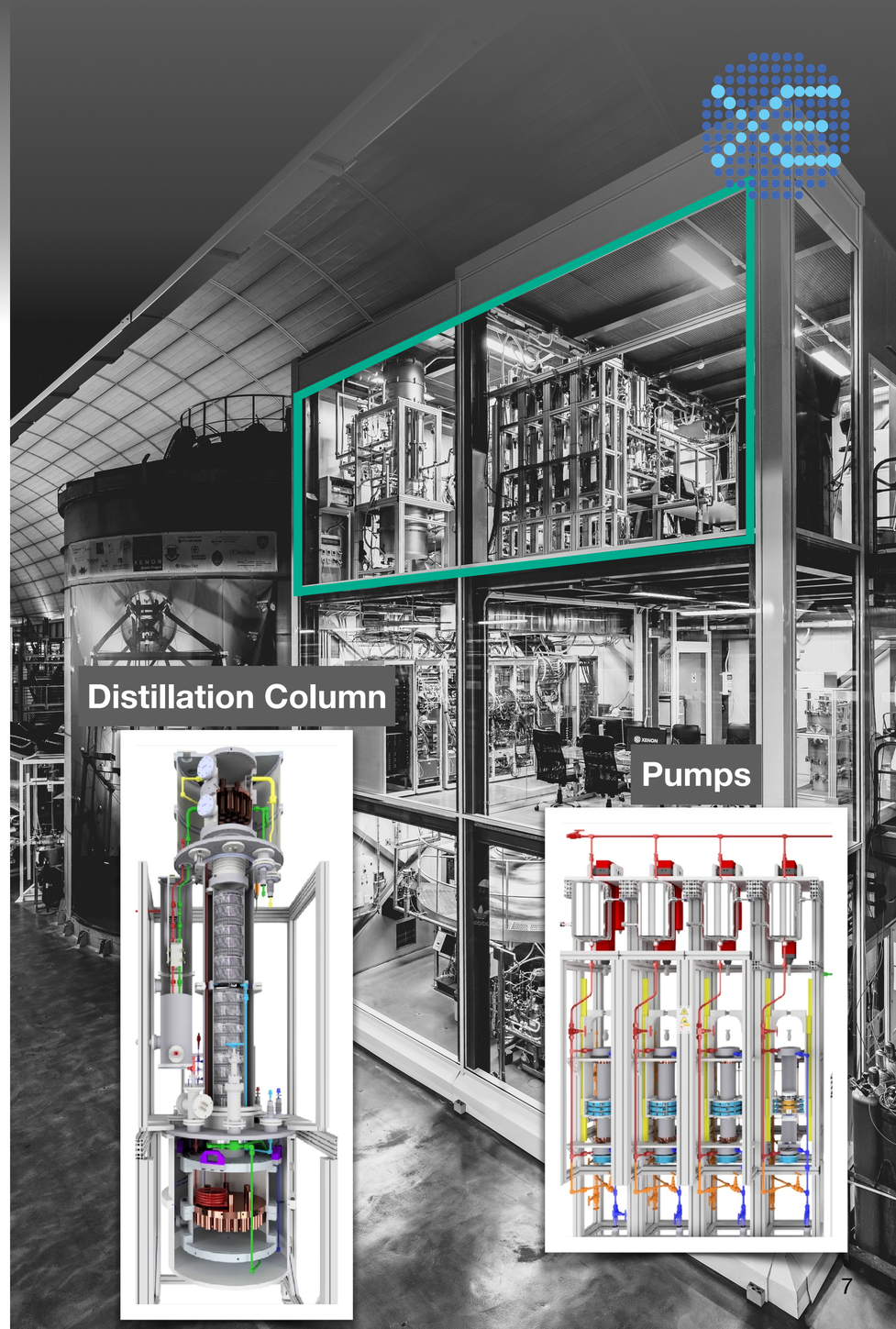


Online Radon Removal

- Exploits difference in vapour pressure of Xe and Rn
- High flow: 71 kg/h (200 slpm)

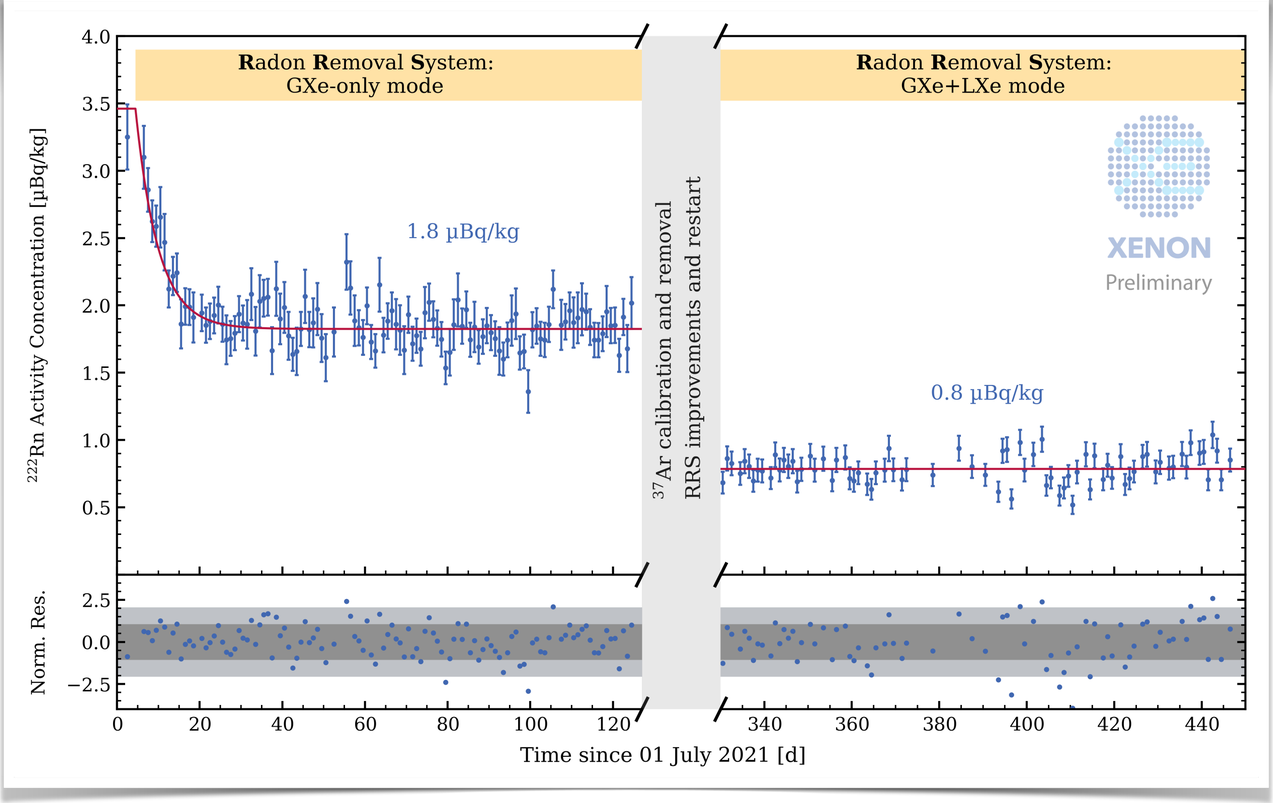


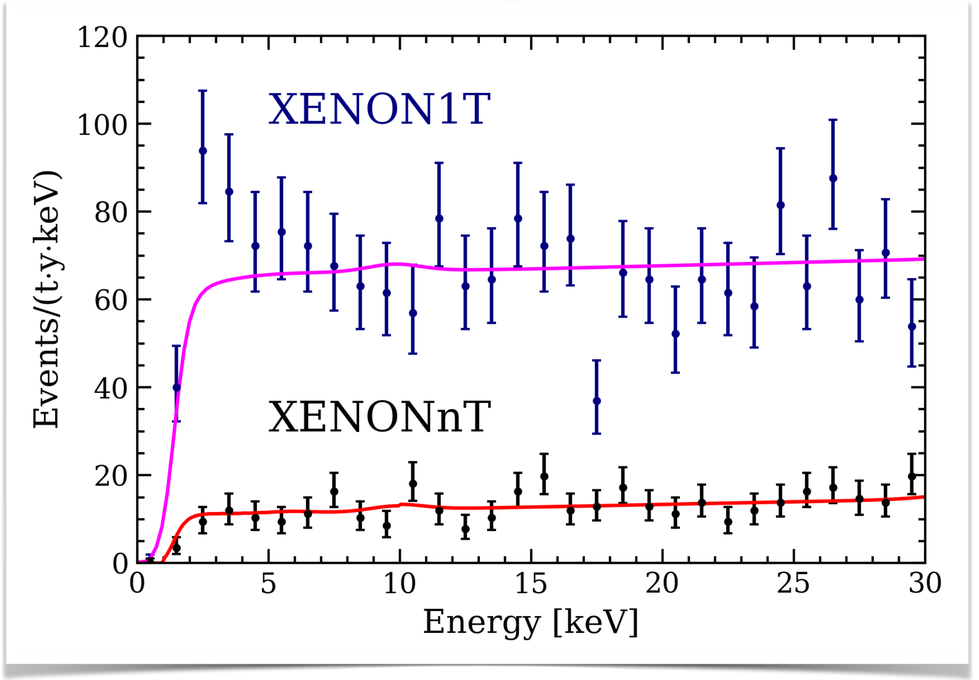




Online Radon Removal

Search for New Physics in Electronic Recoil Data
Phys. Rev. Lett. 129, 161805 (**2022**)



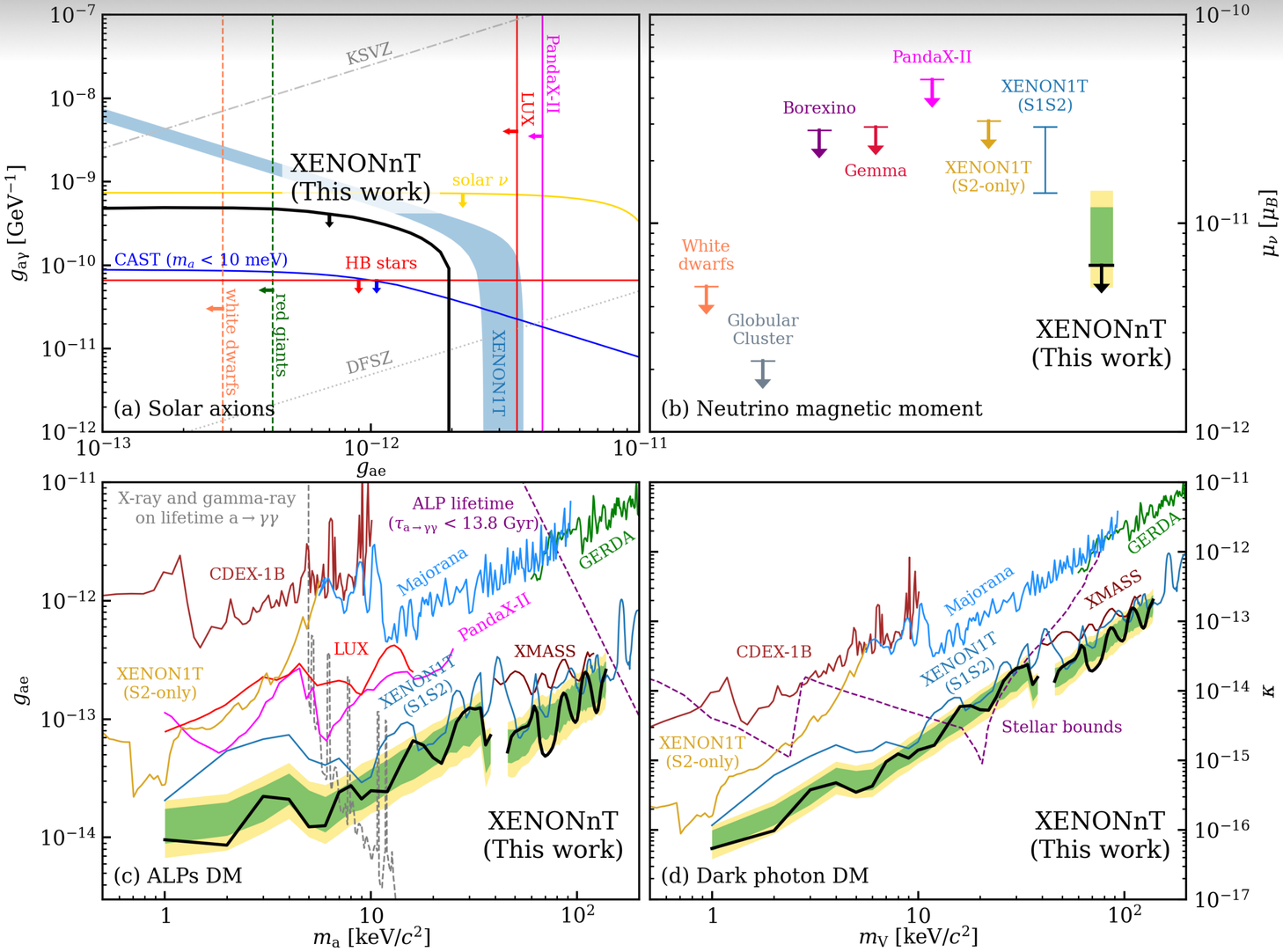


- Unprecedented low ER background at **(15 ± 1.3) (t · y · keV)$^{-1}$** in the **(1, 30) keV** search region
- Factor **~5x** compared to XENON1T
- Another factor **2.3x** reduction in ^{222}Rn activity in upcoming searches!

ER Results

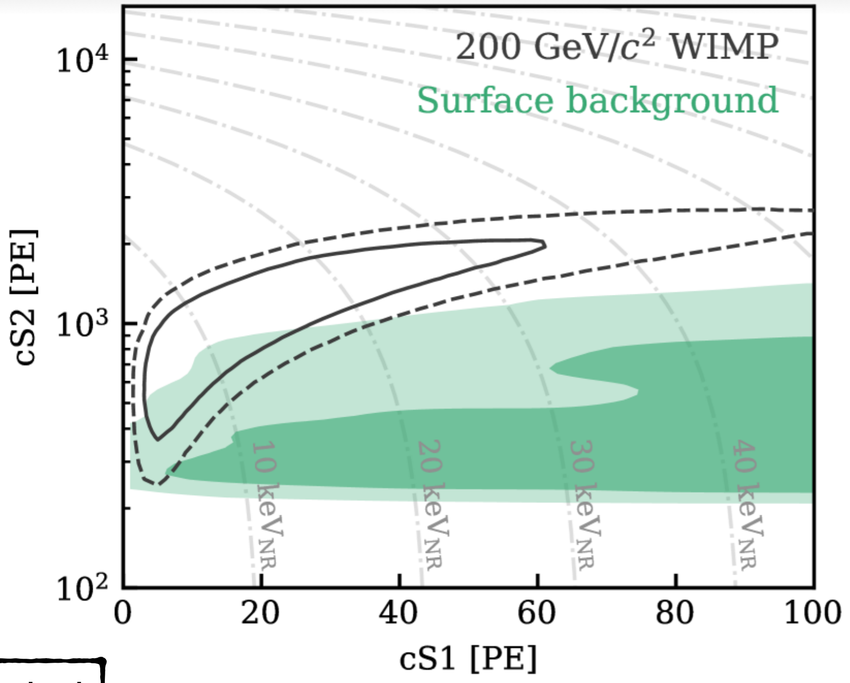
Search for New Physics in Electronic Recoil Data
Phys. Rev. Lett. 129, 161805 (**2022**)

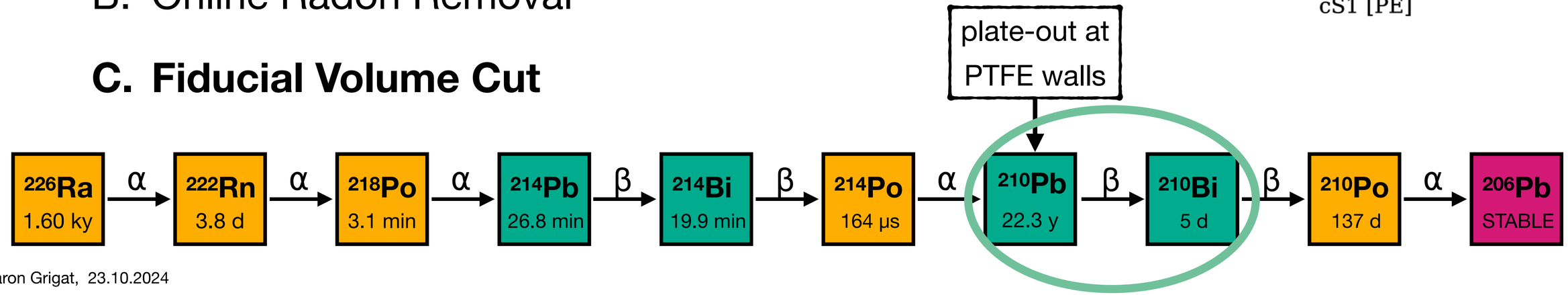
- No significant excess over background found
- World leading limits on several New Physics models



Surface Background

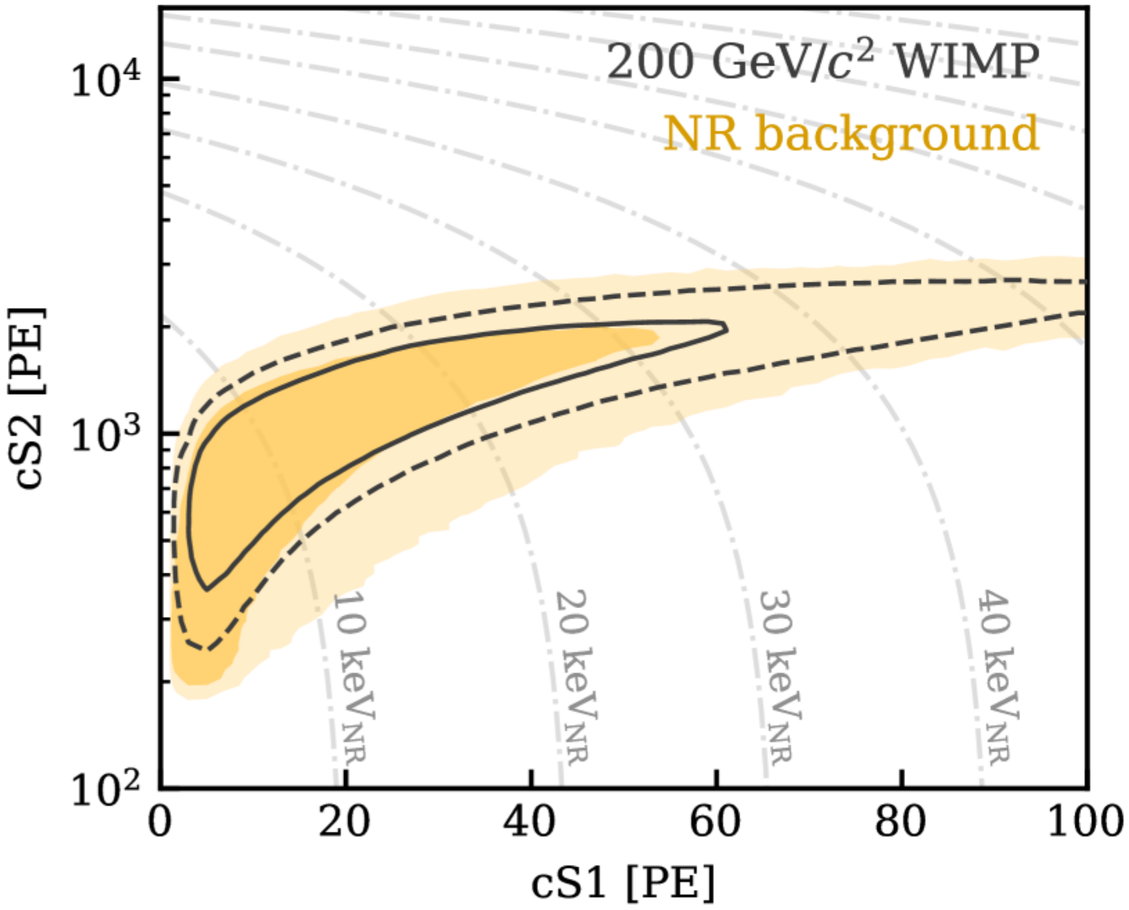
- ^{210}Pb plates-out due to long half-life
- ^{210}Pb decays to ground state with partial charge loss
- Reduced by
  A. Material Selection
  B. Online Radon Removal
  C. Fiducial Volume Cut





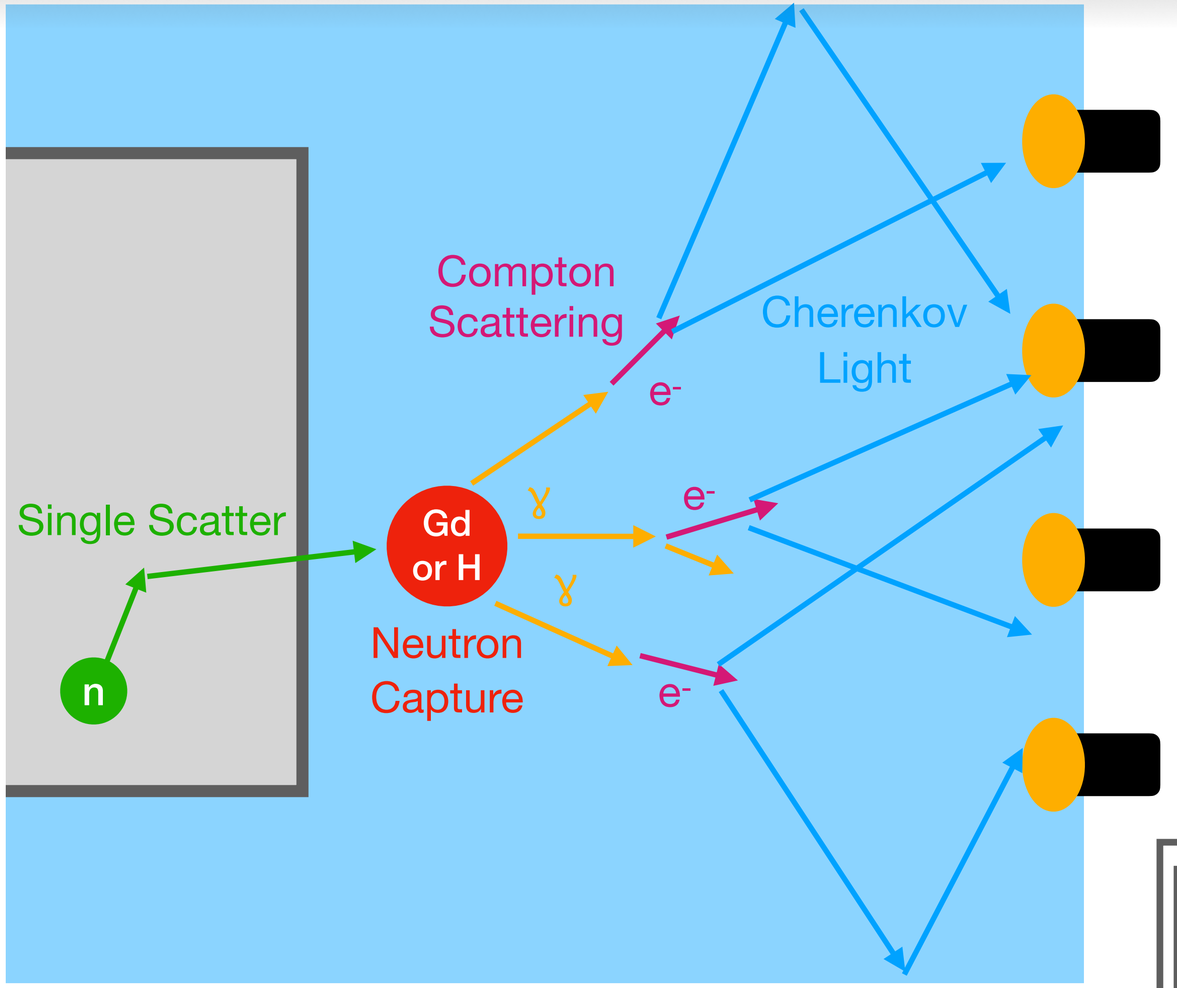
NR Background

- Dominated by neutrons
- Reduced by
  - A. Material Selection
  - B. Fiducial Volume Cut
  - **C. Single Scatter Cut**
  - **D. Neutron Veto**



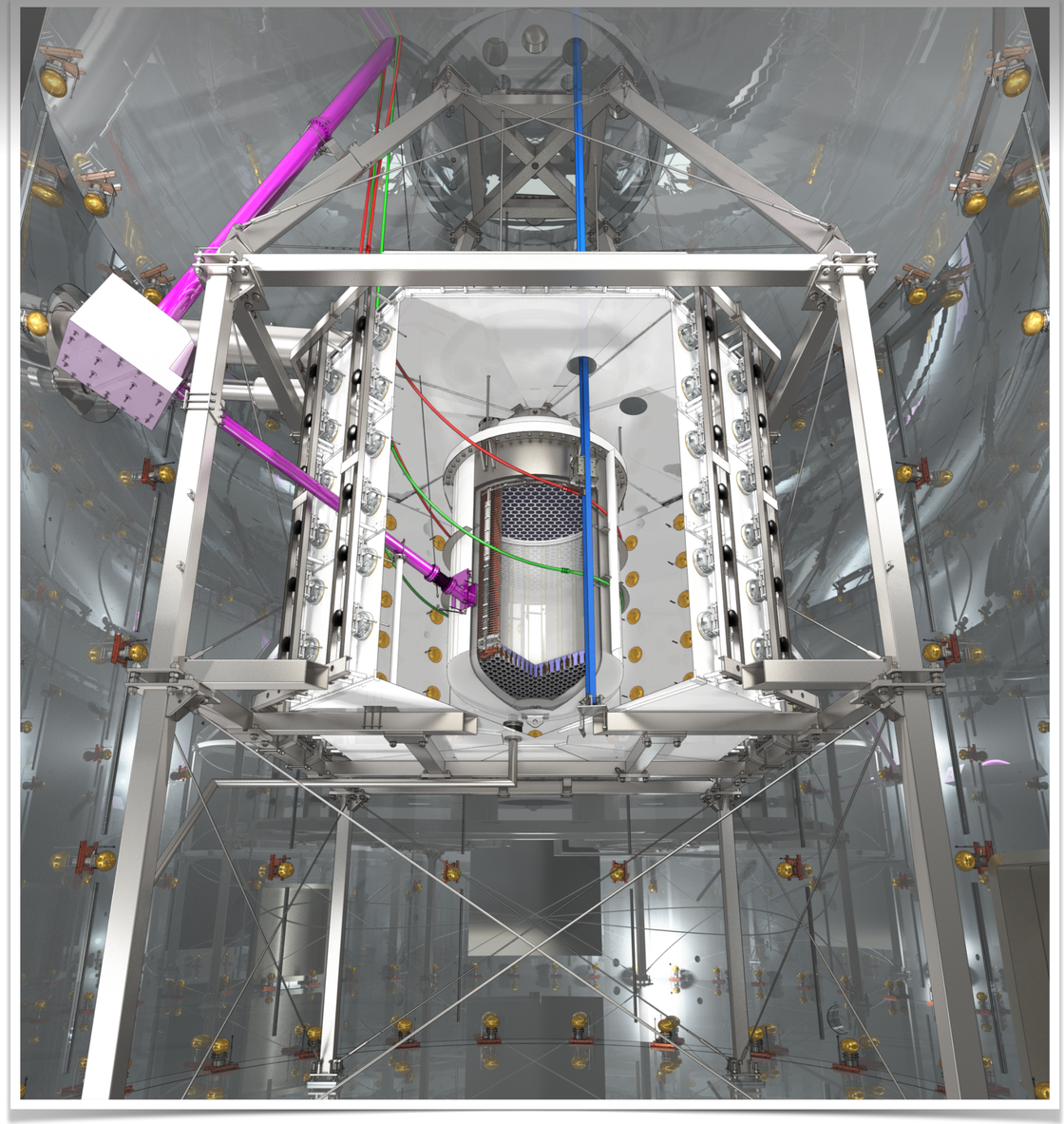
Neutron Veto

- Neutron capture inside veto subsequently creates Cherenkov light
- 120 8” PMTs inside enclosure of reflective panels
- Tagging efficiency **53%** with pure water
- Since fall 2023: added Gadolinium salt to water tank (**0.02%** concentration of Gd) → **~77%** tagging efficiency
- End goal: **~0.2%** Gd concentration →**~90%** tagging efficiency



Neutron Veto

- Neutron capture inside veto subsequently creates Cherenkov light
- 120 8” PMTs inside enclosure of reflective panels
- Tagging efficiency **53%** with pure water
- Since fall 2023: added Gadolinium salt to water tank (**0.02%** concentration of Gd) → **~77%** tagging efficiency
- End goal: ~**0.2%** Gd concentration →**~90%** tagging efficiency



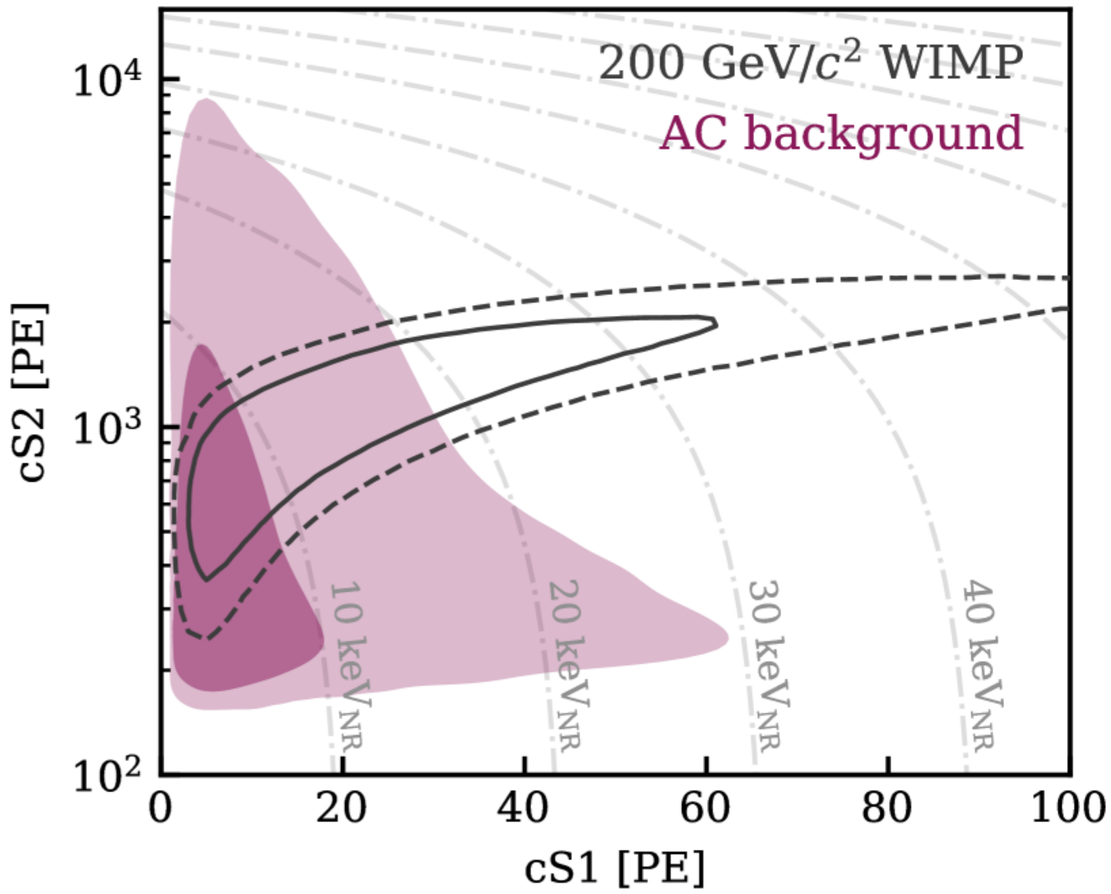
Accidental Coincidence (AC) Background

- Accidental pairing of isolated S1s and S2s within max. drift time window
- Reduced by multiple analysis cuts

More details in Dacheng Xu's talk

Tomorrow 16:35

First Indication of Solar ^{8}B Neutrinos via
Coherent Elastic Neutrino-Nucleus Scattering with XENONnT



Status and Exposure

1st Science Run (SR0)

Search for New Physics in Electronic Recoil Data
Phys. Rev. Lett. 129, 161805 (**2022**)

First Dark Matter Search with Nuclear Recoils
Phys. Rev. Lett. 131, 041003 (**2023**)

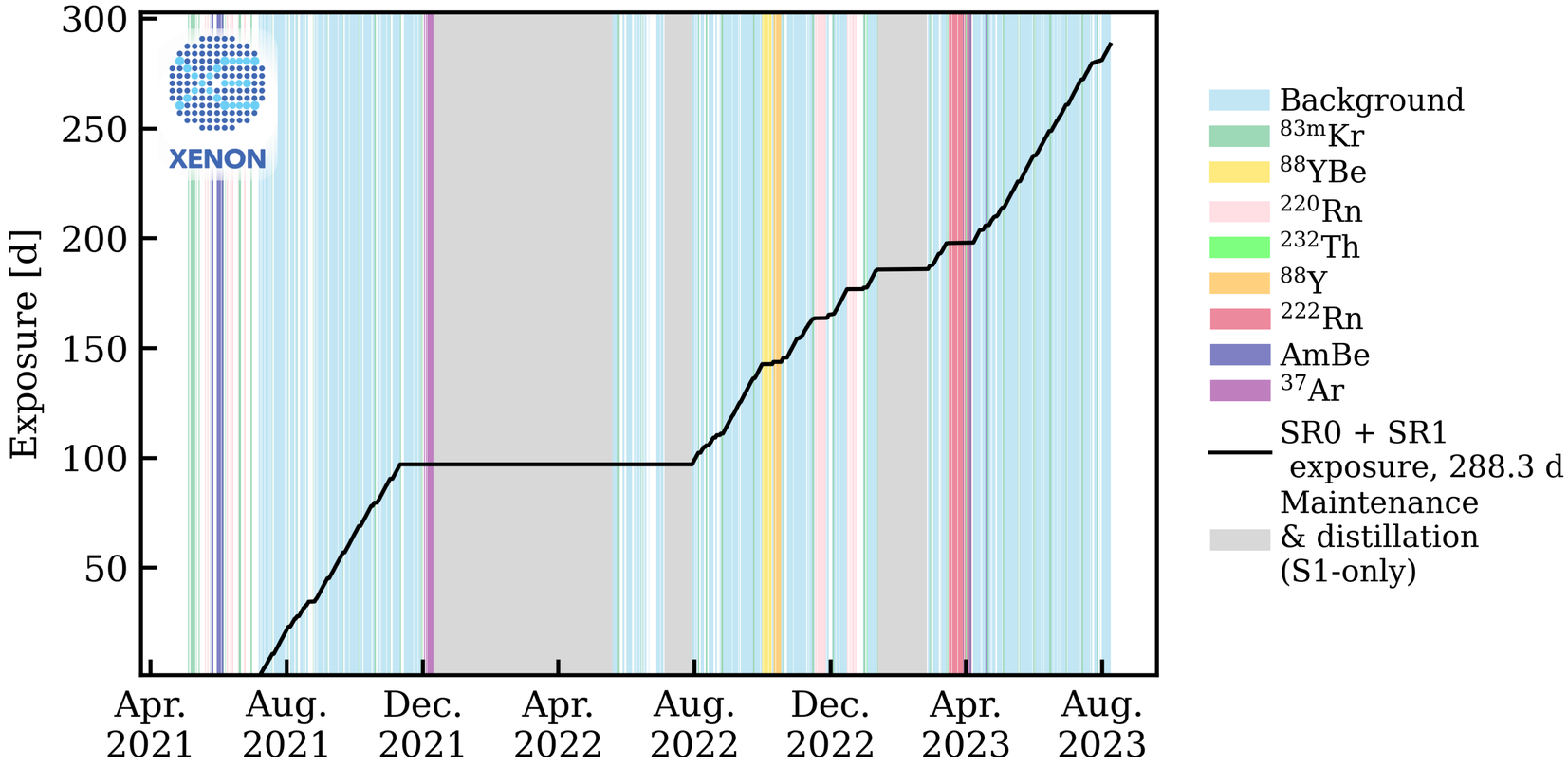
→ **Next slides** ←

2nd Science Run (SR1)

First Indication of Solar ^{8}B Neutrinos via CEvNS
arXiv:2408.02877 (**2024**)

First Search for Light Dark Matter in the Neutrino Fog
arXiv:2409.17868 (**2024**)

→ **Dacheng Xu's talk**
Tomorrow 16:35

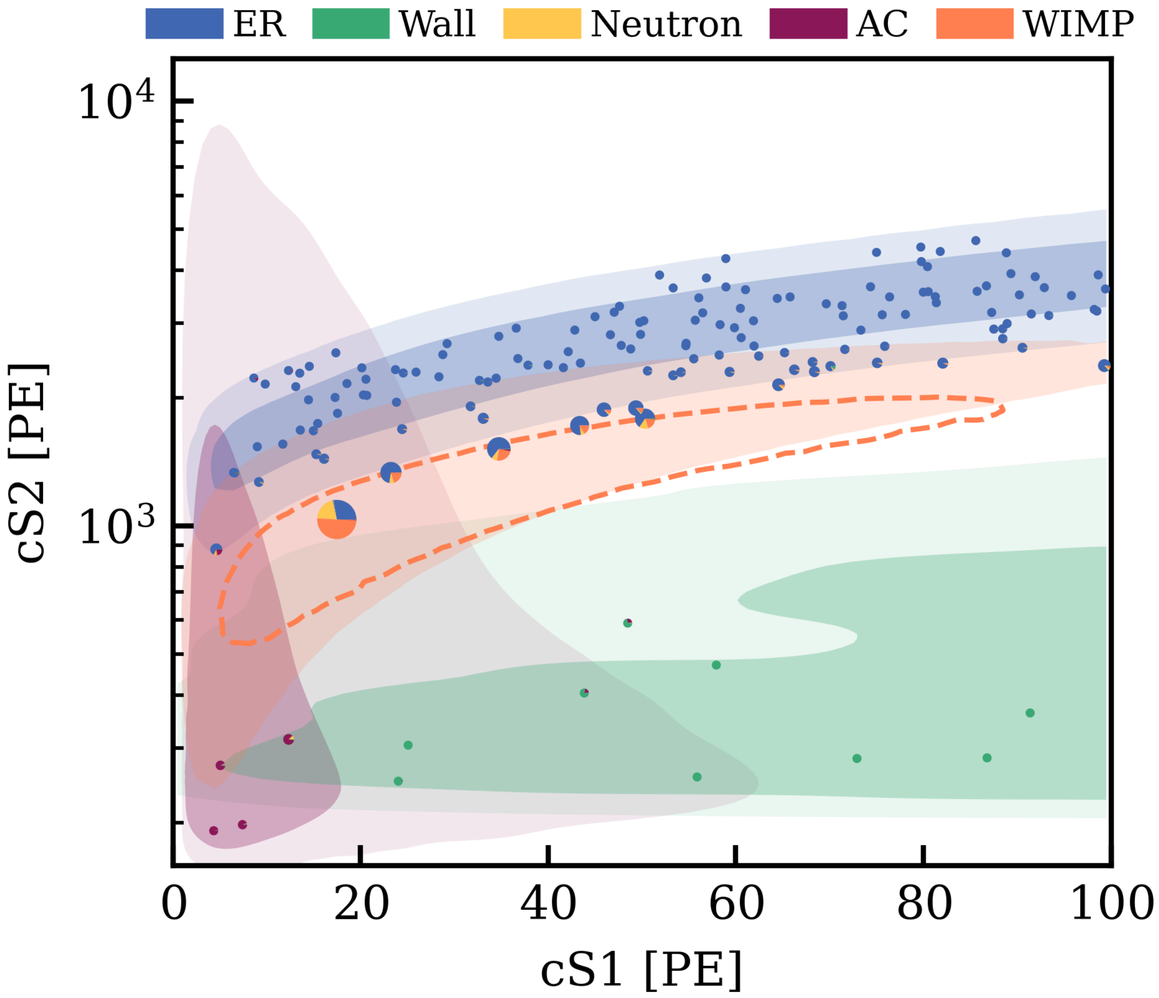


Data taking ongoing

WIMP results (SR0)

First Dark Matter Search with Nuclear Recoils
Phys. Rev. Lett. 131, 041003 (**2023**)

	Best Fit (200 GeV WIMP)
ER	135^{+12}_{-11}
Neutrons	1.1 ± 0.4
CEvNS	0.23 ± 0.06
AC	4.32 ± 0.16
Surface	12^{+0}_{-4}
Total Bkg.	152 ± 12
WIMP	2.6
Observed	152

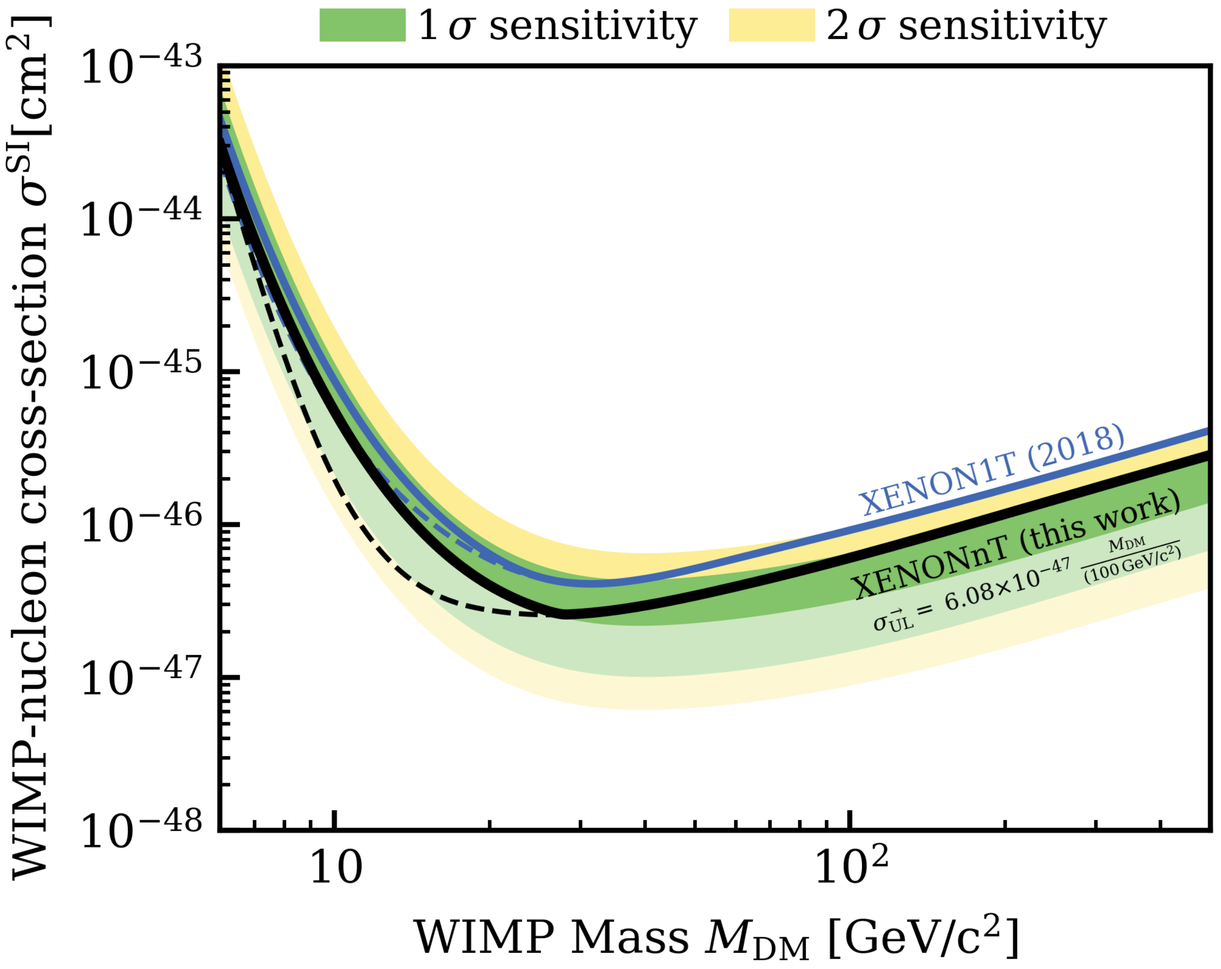


No significant excess over background

WIMP results (SR0)

First Dark Matter Search with Nuclear Recoils
Phys. Rev. Lett. 131, 041003 (**2023**)

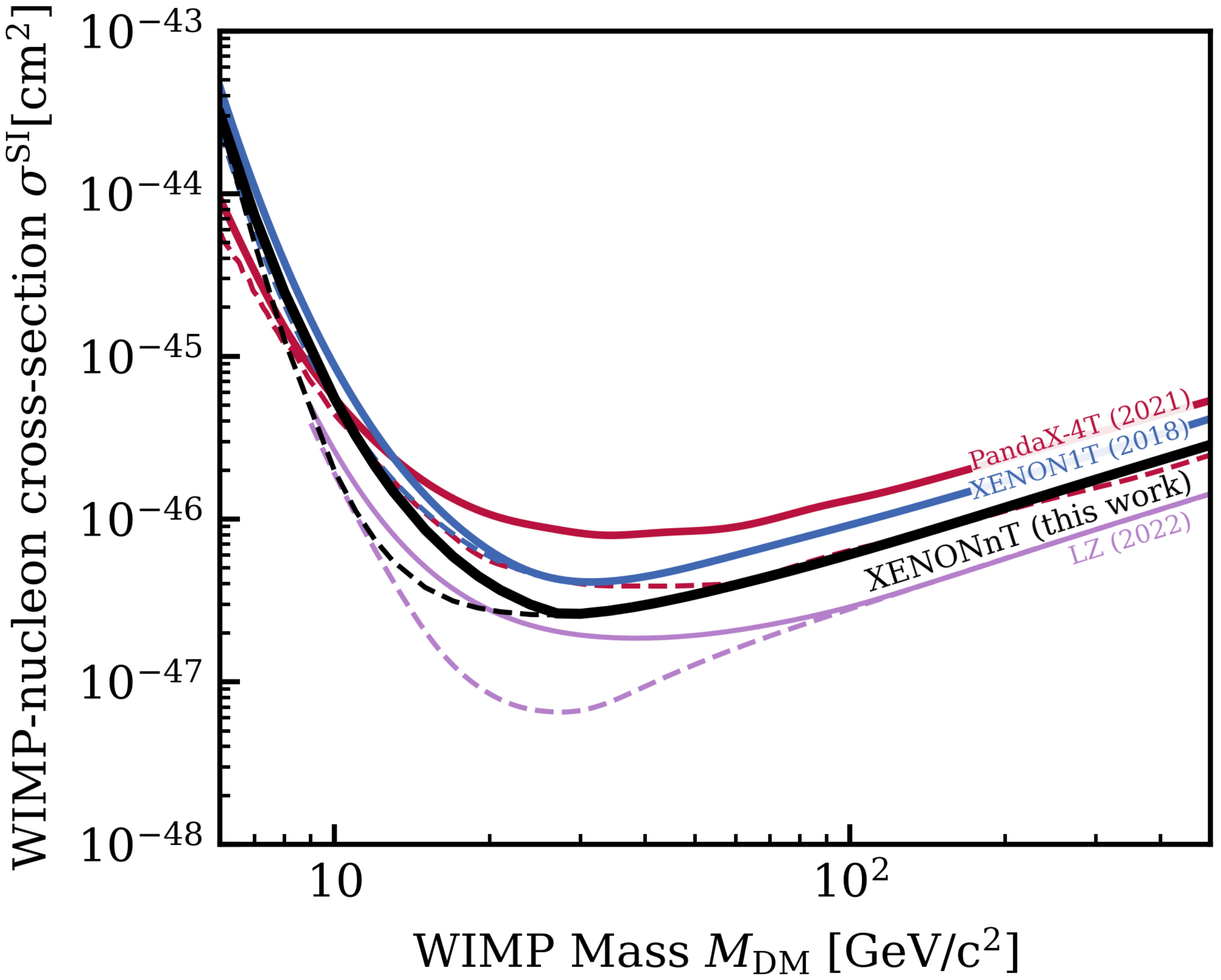
- Blind analysis
- Unbinned maximum likelihood fit
- 90% CL limits
- Power constrained limits (PCL) (solid lines, w/o: dashed lines)



WIMP results (SR0)

First Dark Matter Search with Nuclear Recoils
Phys. Rev. Lett. 131, 041003 (**2023**)

- Blind analysis
- Unbinned maximum likelihood fit
- 90% CL limits
- Power constrained limits (PCL) (solid lines, w/o: dashed lines)
- Comparison to XENON1T and other published results (non-blind analyses)



Light Dark Matter

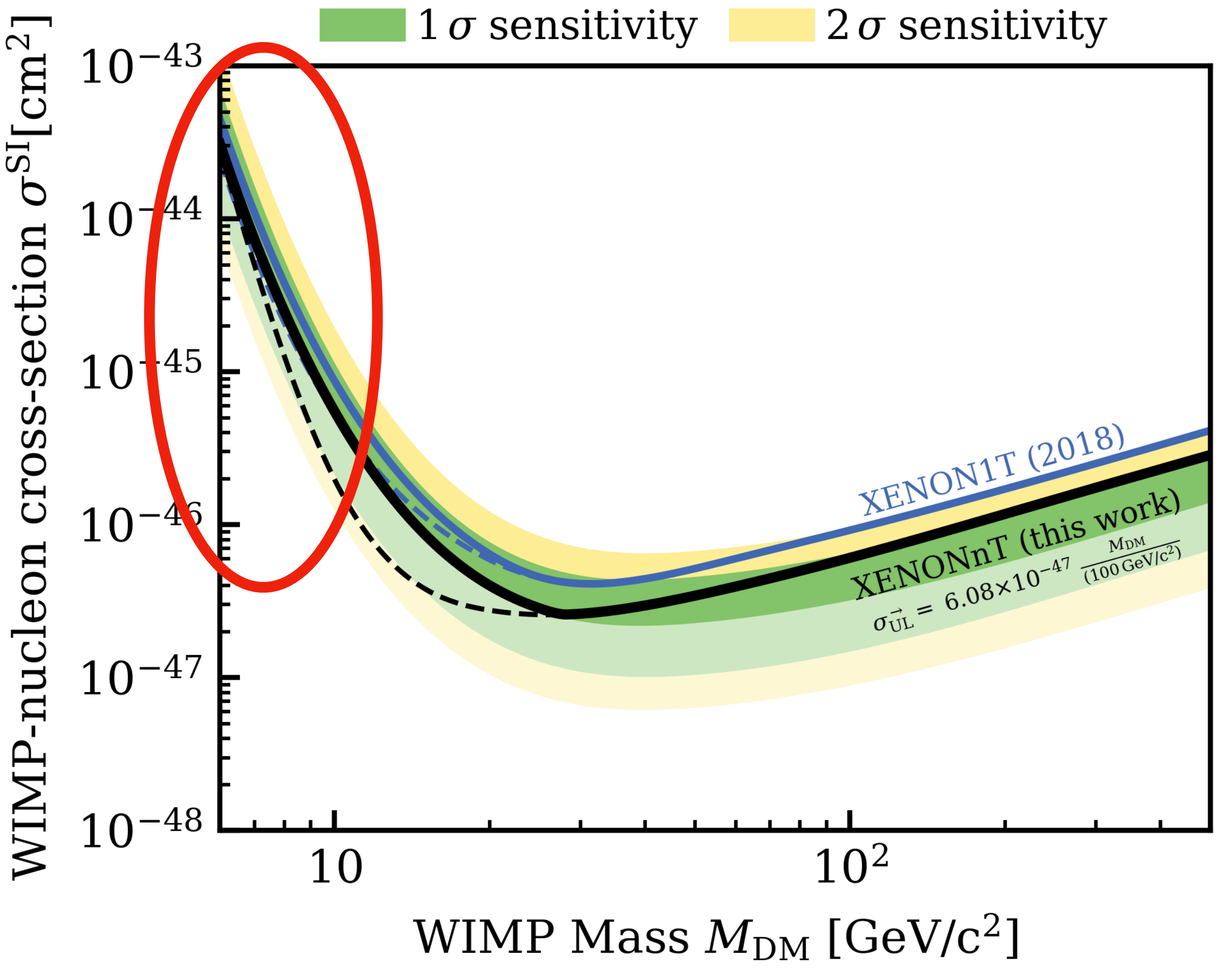
First Search for Light Dark Matter in the Neutrino Fog
arXiv:2409.17868 (**2024**)

- Threshold limits WIMP search for low masses
- S1 PMT coincidence requirement:

3-fold → 2-fold

- Search for [3,12] GeV WIMPs

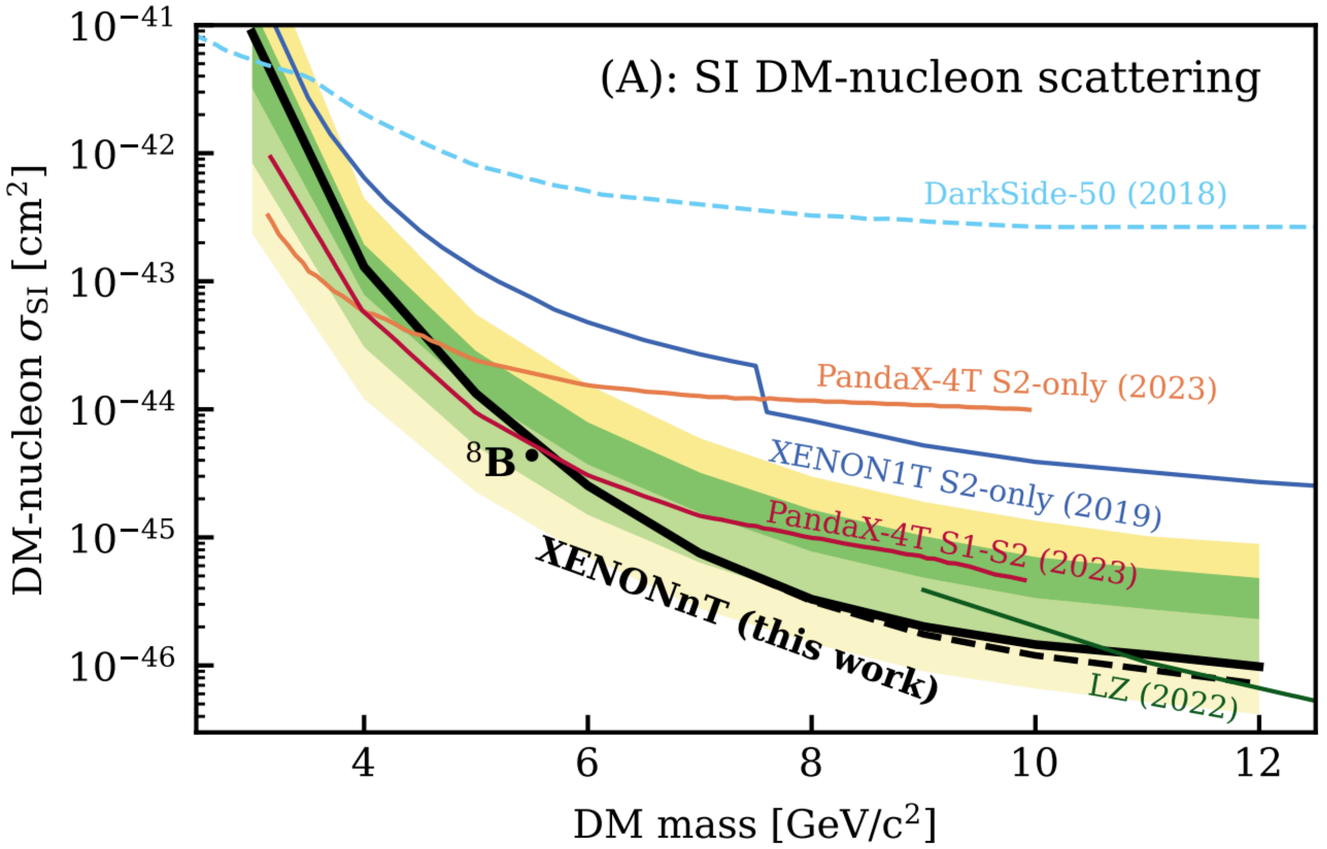
→ Details on analysis in Dacheng Xu's talk Tomorrow 16:35



Light Dark Matter

First Search for Light Dark Matter in the Neutrino Fog
arXiv:2409.17868 (**2024**)

	Best Fit (6 GeV DM particle)
ER	$0.5^{+0.6}_{-0.5}$
Neutrons	0.5 ± 0.3
CEvNS	$11.4^{+2.7}_{-2.6}$
AC	25.3 ± 1.2
Total Bkg.	$37.7^{+3.0}_{-2.9}$
SI DM	0.0
Observed	37



No significant excess over background

Summary and Outlook

XENONnT

- total mass: **8.5 tonne** ultra pure liquid xenon
- Dual-phase Time Projection Chamber with **5.9 tonne** active target
- Several new systems including **online radon removal** and **neutron veto**

First Results (SR0)

- Blinded electronic recoil (ER) and nuclear recoil (NR) searches
- Lowest ER background in the field, **~5x** background reduction w.r.t. XENON1T
- No significant excess over background found

Summary and Outlook

New Results (SR0+SR1)

- First Search for Light Dark Matter in the Neutrino Fog
- First Indication of Solar ^{8}B Neutrinos via Coherent Elastic Neutrino-Nucleus Scattering

→ Dacheng Xu's talk, Tomorrow 16:35

Prospects

- **~2x** lower **^{222}Rn** level
- Improved neutron tagging by **Gd-loaded** neutron veto
- WIMP search with increased exposure in preparation
- Continue to accumulate data. Target exposure: **20 (t · y)**
- Beyond XENONnT? **XLZD**!

→ Maxime Pierre's talk: directly after this

  - Planning stage for detector with [40-60] t active LXe target