

DARK MATTER GROUP

PATRICK DECOWSKI



DM Group Members

- **Faculty Members:**

- Jelle Aalbers '23
- Auke-Pieter Colijn
- Patrick Decowski [PL]
- Tina Pollmann '20

- **Postdocs:**

- Maxime Pierre '23
- James Mead '23

- **PhDs:**

- Pravita Hallur '24 [with GRAPPA]
- Anna Hurhina '25
- Maricke Flierman '21
- Carlo Fuselli '22
- Pranati Kharbanda '23
- Saad el Morabit '23 [with Theory]
- Marjolein van Nuland-Troost '22 [with Neutrino Phys]
- Kelly Weerman '22

'xx → hired in 20xx

- **MSc:**

- Ezra de Cleen [UvA/VU]
- Joost van Dijk [UvA/VU]
- Conor Ford [RUG]
- Damian van Leeuwen [UvA/VU]
- Nina Oskam [UvA/VU]
- Felix Semler [RUG]
- Kristie Wesdrop [TUD]

- **HBO (technical) students:**

- Rovana Plet [Haagse Hogeschool]

- **BSc students**

- Stella Halstead [Wheaton College, USA]
- Rijk Martin [UvA/VU]
- Gileesa McCormick [UvA/VU]
- Sake Meuleveld [UvA/VU]
- Leo Sahlen [AUC]

- **Goodbyes:**

- Peter Gaemers (PhD finished in May'24)

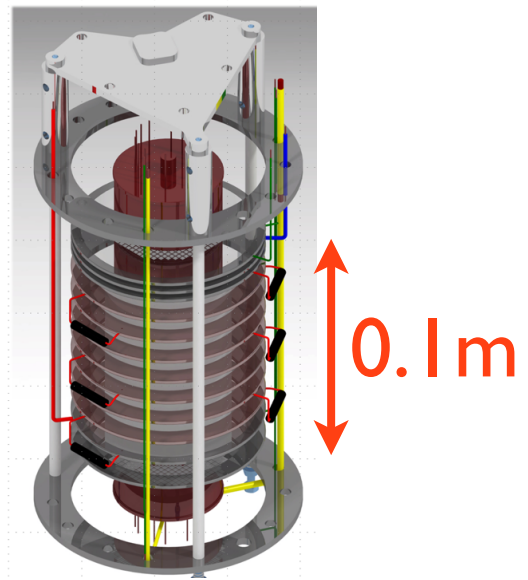


Our Activities

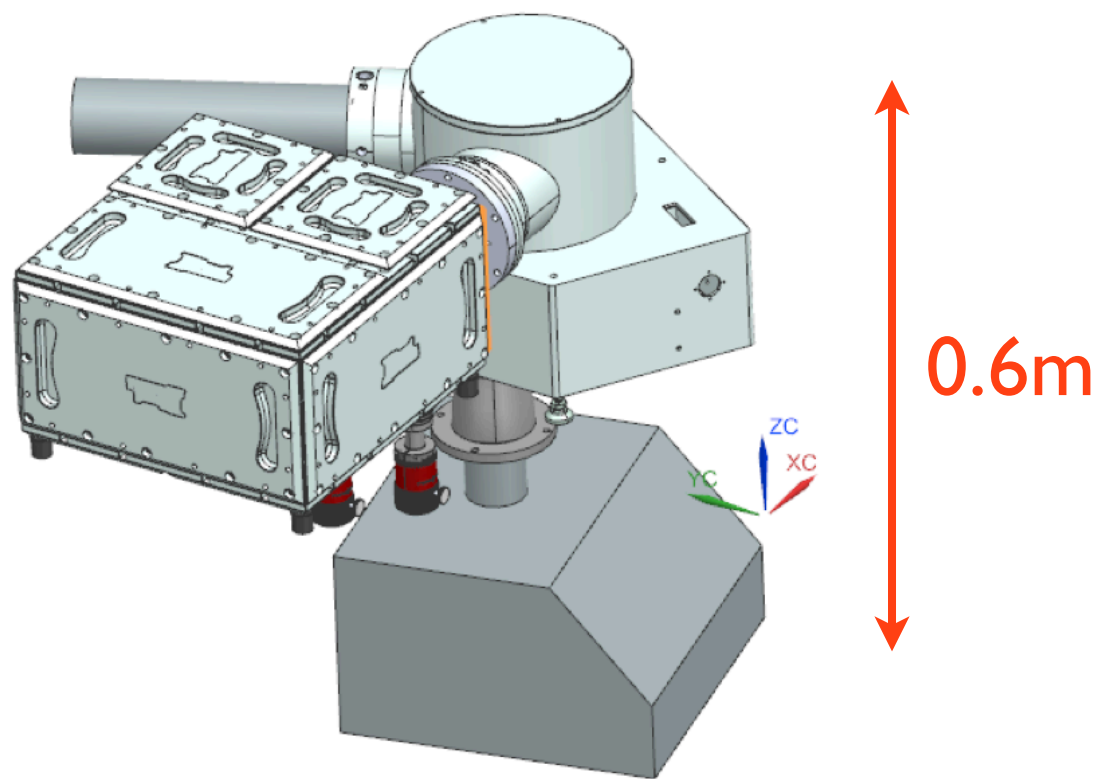
Main: liquid xenon based rare event experiments

Our R&D Lab @Nikhef

XAMS



VULCAN

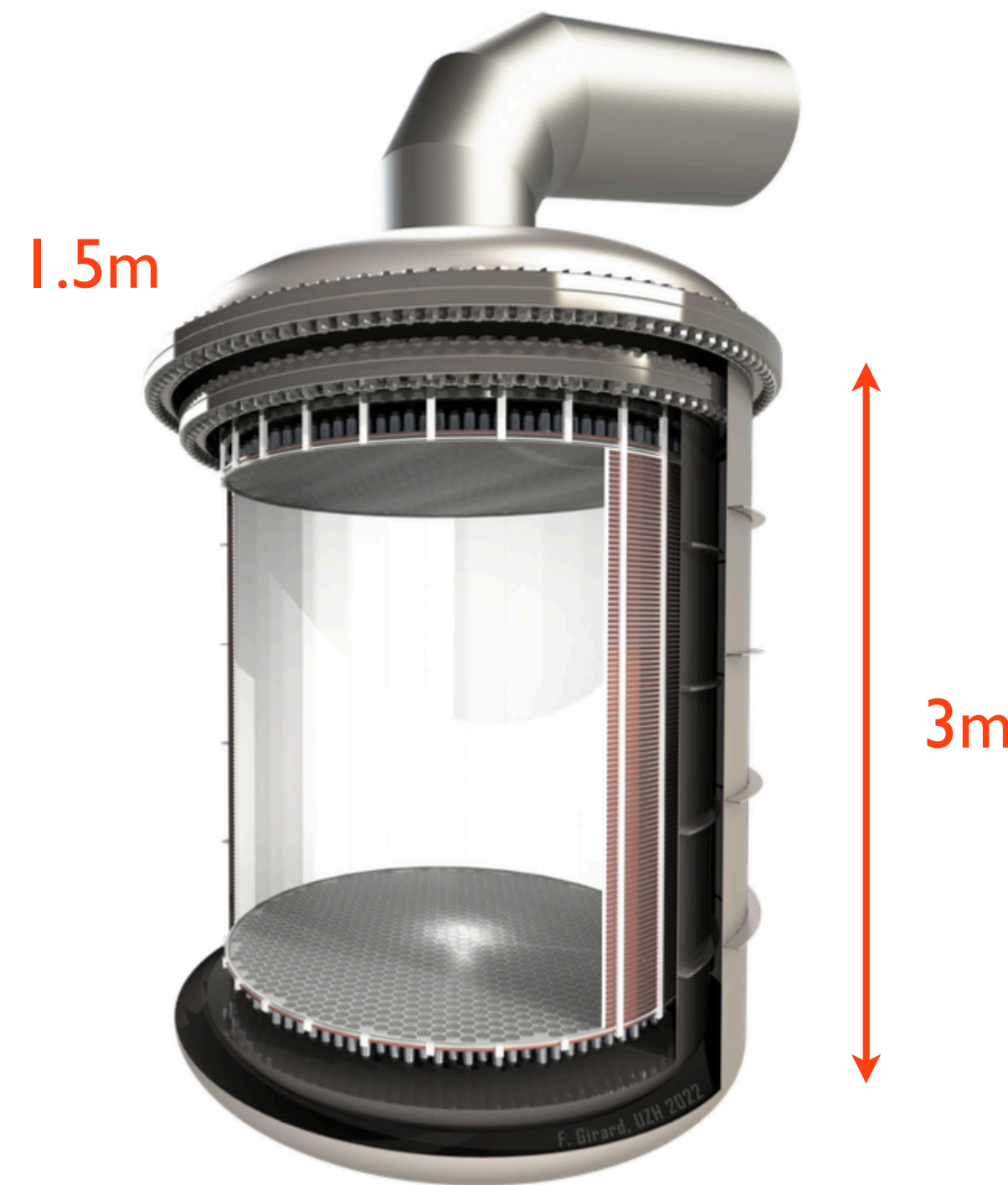


Current and future experiments

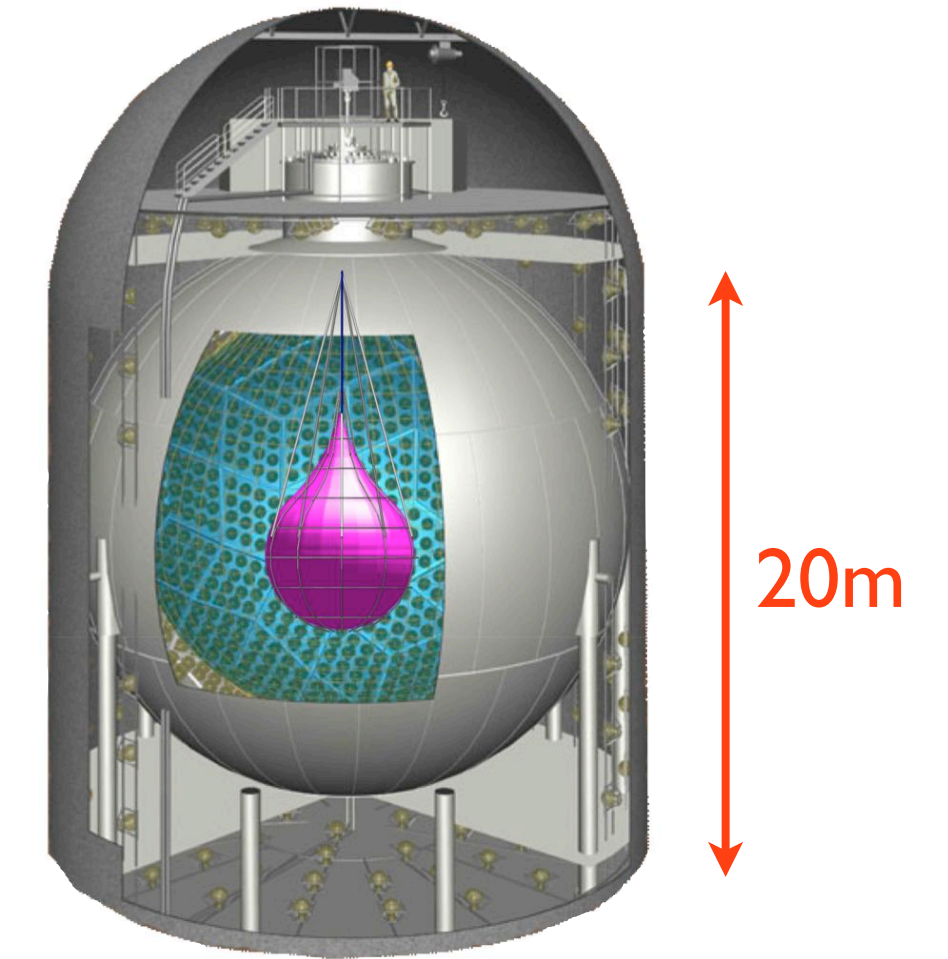
XENONnT



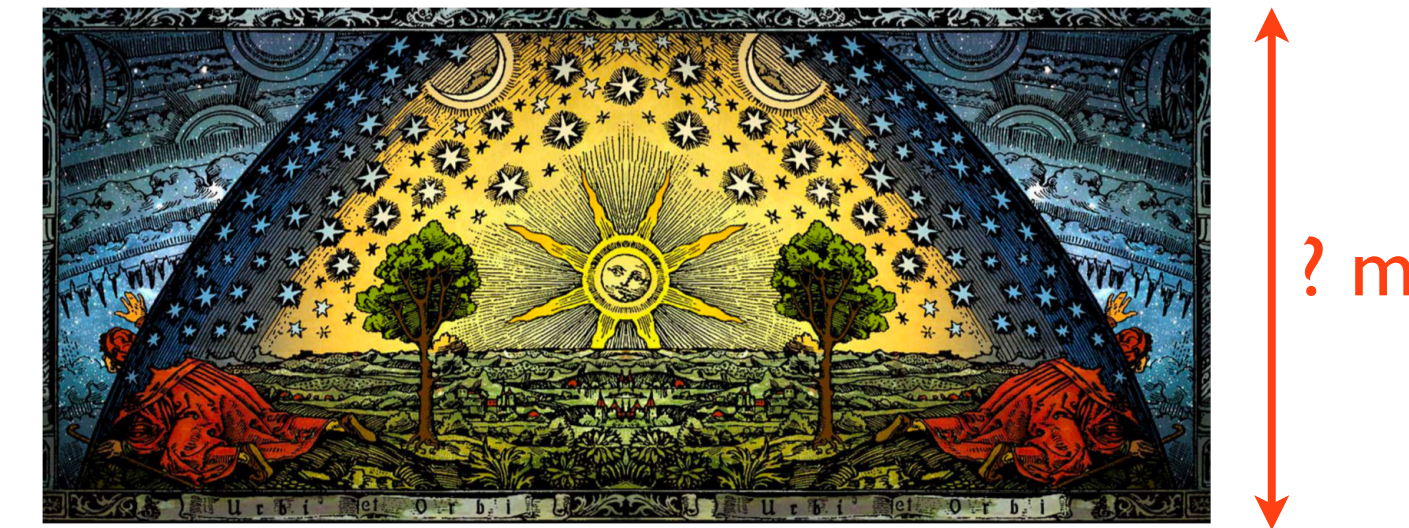
XLZD



KamLAND-Zen



PTOLEMY R&D



DUNE [with Neutrino Physics Group]



Current Roles of Nikhef DM Group

- **Roles in XENON**

- A.P. Colijn: Technical Coordinator XENONnT
- M.P. Decowski: Chair/Member Publication Board, Collaboration Board
- M. Pierre [PD]: Physics Analysis Coordinator

- **Roles in XLZD**

- A.P. Colijn: Siting Committee
- M.P. Decowski: Executive Board
- T.R. Pollmann: Work Group Leader Science & Sensitivity

- **Funding**

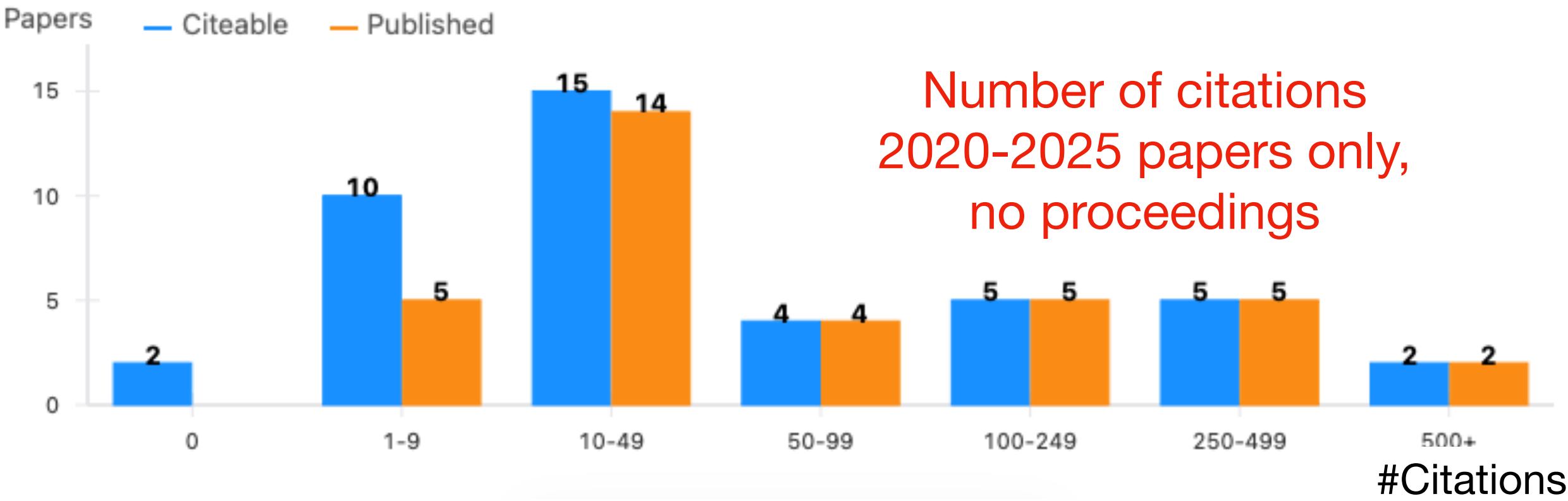
- NWO-VP “The Hidden Universe” [2018-2025, 1.8 MEu with Neutrino Program]
- NWO-M2 “Searching for dark matter in the XENON waste” [2019-2024, 700 kEu]
- NWA-ORC “One second after the Big Bang” [2021-2026, 1.1 MEu]
- 3x NWO-WGS “Computing for the XENONnT Rare Event Search” [2019-2025, 500 kEu]
- Internal UvA funding for PhDs [2020, 2022, 2023, 2024]

- **Our detector contributions in XENONnT**

- New DAQ system
- Overall SW reconstruction framework
- Cryostat support & alignment structure
- Cryostat design
- Computing Resources [with PDP and SURF]
- Machining TPC parts

XENON Papers past 5 years

~150 collaborators



Papers with major Nikhef analysis / paper writing contributions:

WIMP Dark Matter Search using a 3.1 tonne × year Exposure of the XENONnT Experiment

XENON Collaboration • E. Aprile (Columbia U. and Columbia U., Astron. Astrophys.) et al. (Feb 25, 2025)

e-Print: 2502.18005 [hep-ex]

pdf cite claim reference search 10 citations

First Search for Light Dark Matter in the Neutrino Fog with XENONnT

XENON Collaboration • E. Aprile (Columbia U. and Columbia U., Astron. Astrophys.) et al. (Sep 26, 2024)

Published in: Phys.Rev.Lett. 134 (2025) 11, 111802 • e-Print: 2409.17868 [hep-ex]

pdf DOI cite claim reference search 12 citations

XENONnT analysis: Signal reconstruction, calibration, and event selection

(XENON Collaboration)++ and XENON Collaborations • E. Aprile (Columbia U. and Columbia U., Astron. Astrophys.) et al. (Sep 13, 2024)

Published in: Phys.Rev.D 111 (2025) 6, 062006 • e-Print: 2409.08778 [hep-ex]

pdf DOI cite claim reference search 11 citations

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

XENON Collaboration • Elena Aprile (Columbia U.) et al. (Aug 5, 2024)

Published in: Phys.Rev.Lett. 133 (2024) 19, 191002 • e-Print: 2408.02877 [nucl-ex]

pdf links DOI cite claim reference search 79 citations

The XENONnT dark matter experiment

XENON Collaboration • E. Aprile (Columbia U. and Columbia U., Astron. Astrophys.) et al. (Feb 15, 2024)

Published in: Eur.Phys.JC 84 (2024) 8, 784 • e-Print: 2402.10446 [physics.ins-det]

pdf DOI cite claim reference search 59 citations

First Dark Matter Search with Nuclear Recoils from the XENONnT Experiment

XENON Collaboration • E. Aprile (Columbia U. and Columbia U., Astron. Astrophys.) et al. (Mar 26, 2023)

Published in: Phys.Rev.Lett. 131 (2023) 4, 041003 • e-Print: 2303.14729 [hep-ex]

pdf DOI cite claim reference search 479 citations

The triggerless data acquisition system of the XENONnT experiment

XENON Collaboration • E. Aprile (Columbia U. and Columbia U., Astron. Astrophys.) et al. (Dec 21, 2022)

Published in: JINST 18 (2023) 07, P07054 • e-Print: 2212.11032 [physics.ins-det]

pdf DOI cite claim reference search 16 citations

Search for New Physics in Electronic Recoil Data from XENONnT

XENON Collaboration • E. Aprile (Columbia U. and Columbia U., Astron. Astrophys.) et al. (Jul 22, 2022)

Published in: Phys.Rev.Lett. 129 (2022) 16, 161805 • e-Print: 2207.11330 [hep-ex]

pdf DOI cite claim reference search 342 citations

Double-Weak Decays of ¹²⁴Xe and ¹³⁶Xe in the XENON1T and XENONnT Experiments

XENON Collaboration • E. Aprile (Columbia U.) et al. (May 9, 2022)

Published in: Phys.Rev.C 106 (2022) 2, 024328 • e-Print: 2205.04158 [hep-ex]

pdf DOI cite claim reference search 55 citations

Material radiopurity control in the XENONnT experiment

XENON Collaboration • E. Aprile (Columbia U. and Columbia U., Astron. Astrophys.) et al. (Dec 10, 2021)

Published in: Eur.Phys.JC 82 (2022) 7, 599 • e-Print: 2112.05629 [physics.ins-det]

pdf DOI cite claim reference search 47 citations

Excess electronic recoil events in XENON1T

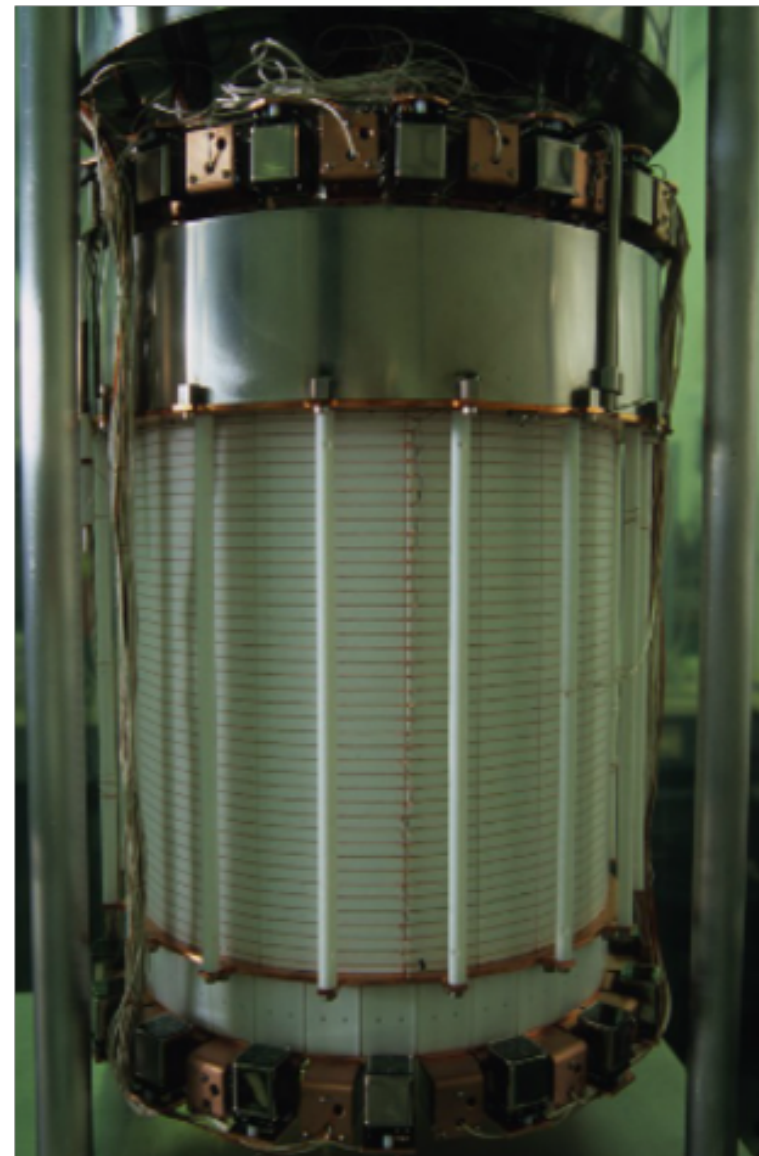
XENON Collaboration • E. Aprile (Columbia U.) et al. (Jun 17, 2020)

Published in: Phys.Rev.D 102 (2020) 7, 072004 • e-Print: 2006.09721 [hep-ex]

pdf links DOI cite claim reference search 715 citations

LXe Series of Experiments

Every few years we build more sensitive experiments, with lower radioactive backgrounds, more xenon target.
The XENON collaboration recently joined with our LZ competitors in the US to form the XLZD collaboration.



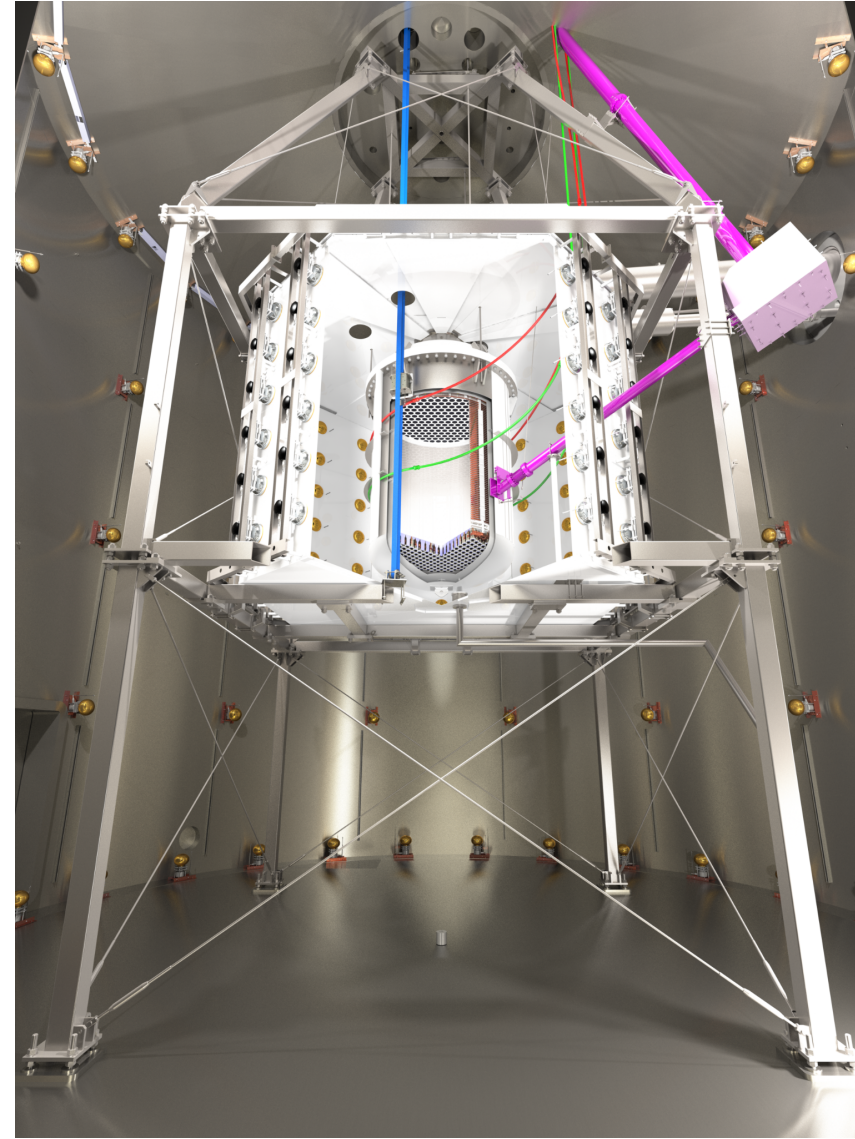
XENON100

160 kg



XENON1T

3.5 ton

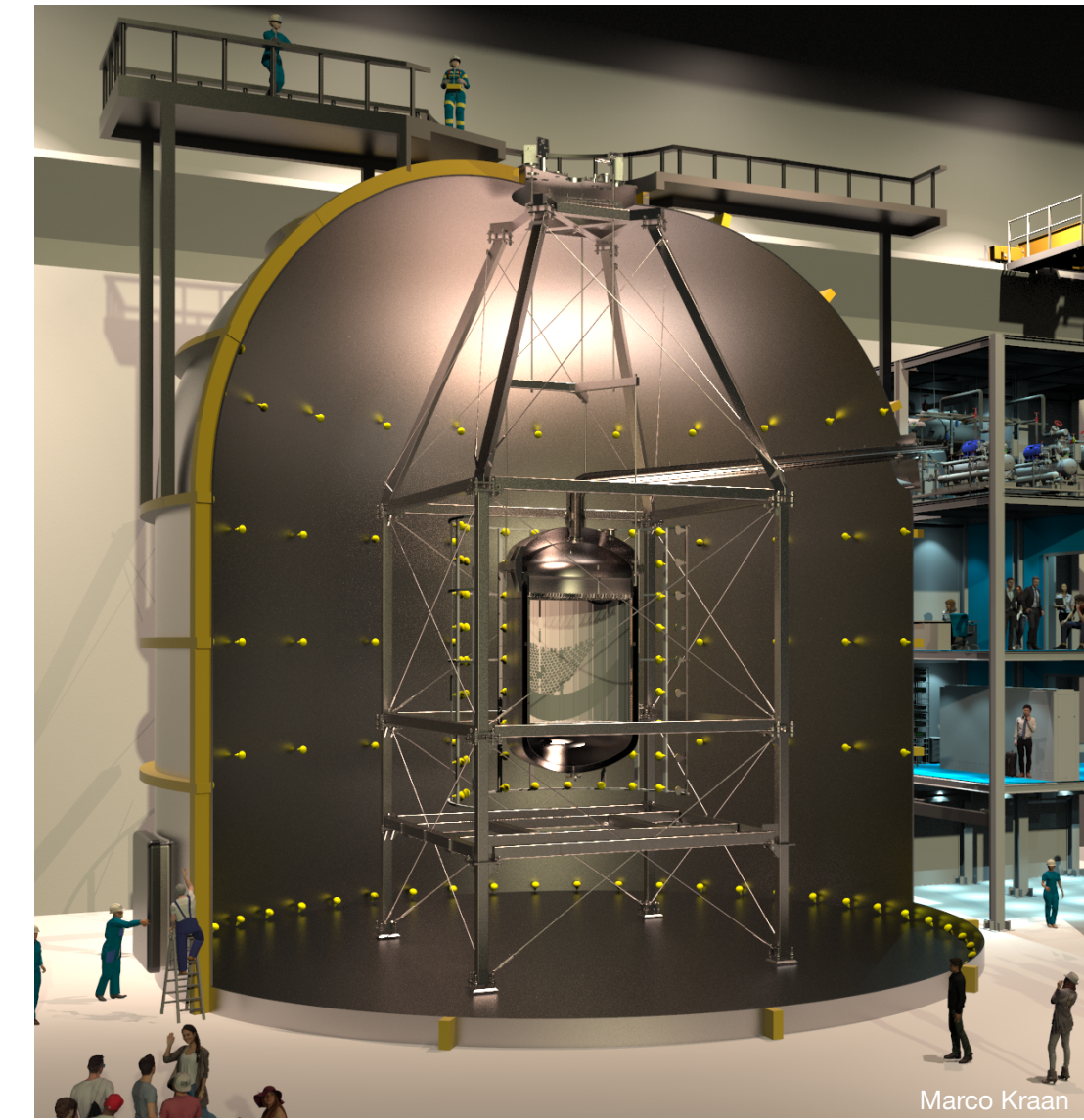


XENONnT

8.5 ton xenon

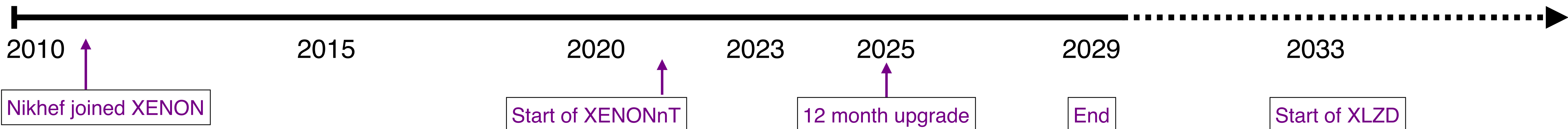
XENONnT Upgrade

Data w/ Better Sensitivity



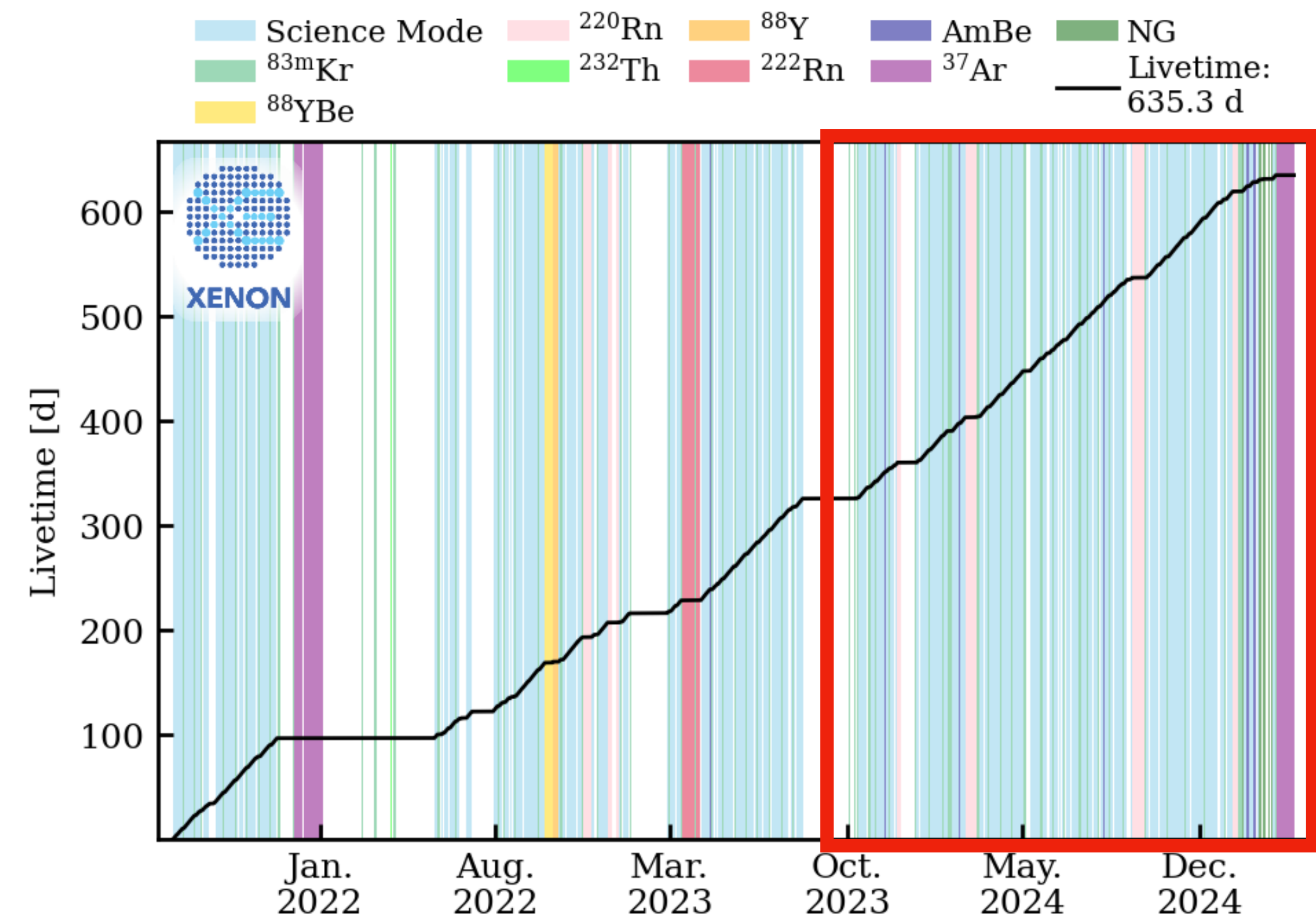
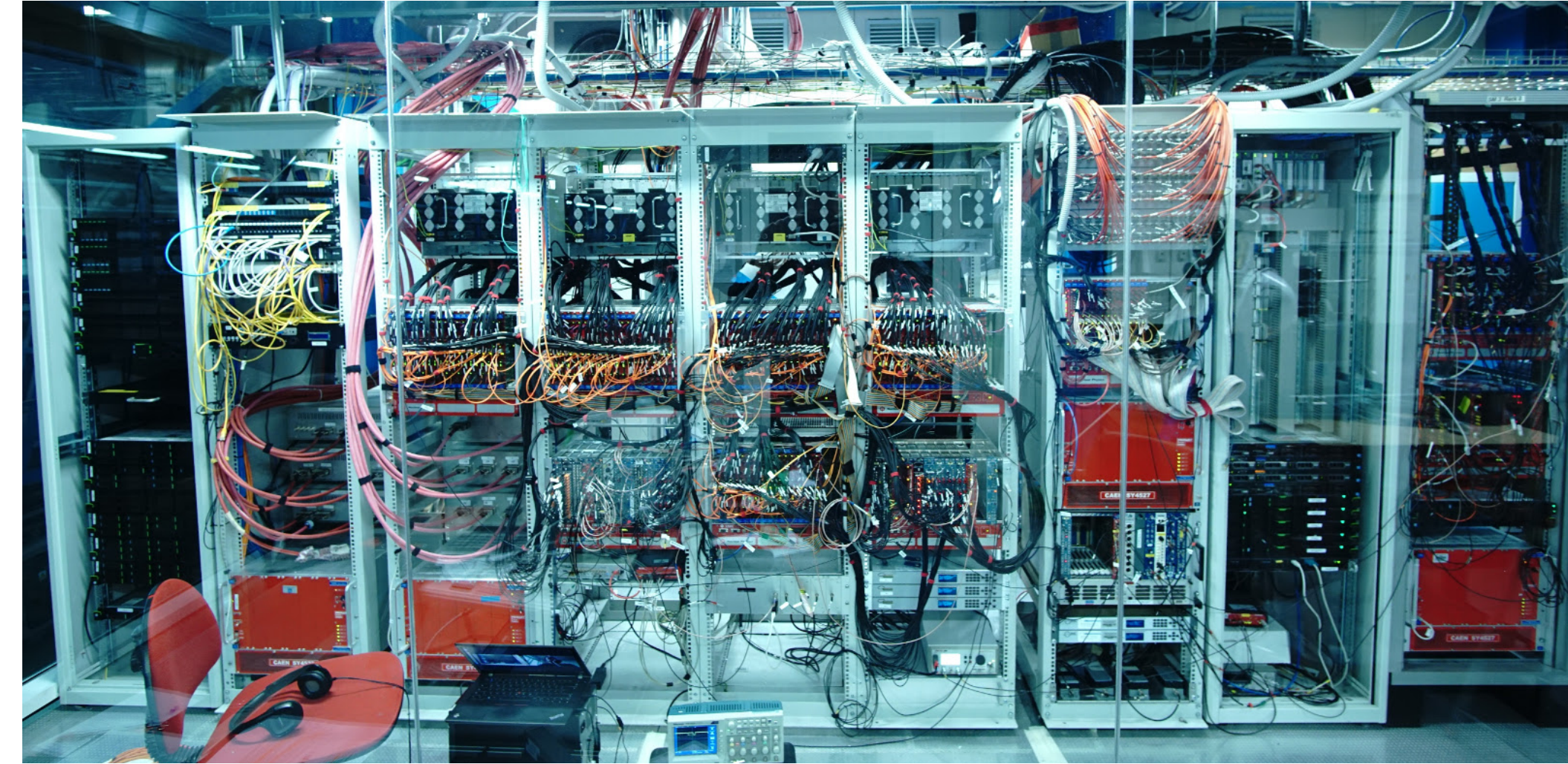
XLZD

60 ton



XENONnT Future

- We have only analyzed SR0 and SR1 so far (~280 days)
- Took SR2 data from 2023 → beginning of 2025 (~300 days)
- Upgrade ongoing to replace electrodes to increase drift field from 23 V/cm → 100 V/cm
- Nikhef upgrade contributions:
 - Replace the DAQ machines
 - Fluorescence inspection of the XENONnT TPC
- Analysis:
 - Postdoc Maxime Pierre is Physics Analysis Coordinator
 - Leadership in key analysis groups: MC simulation & Background Modeling
 - Strong expertise in signal reconstruction and corrections
 - Nikhef physics analysis topics: **DM** (high/low DM masses), **neutrino properties** and **rare nuclear transitions**



SR2: Not analyzed yet

Ultra-low BG + new techniques
allow to search for non-WIMP DM

Dark Matter

- Dark photons
- Axion-like particles
- Planck mass

WIMPs

- Spin-independent
- Spin-dependent
- Sub-GeV
- Inelastic

“Ultimate” WIMP DM detector

Sun

- pp neutrinos
- Solar metallicity
- ${}^7\text{Be}$, ${}^8\text{B}$, hep

Low-E complementarity
with DUNE

Neutrino Nature

- Neutrinoless double beta decay
- Double electron capture
- Magnetic Moment

Competitive with
dedicated $0\nu 2b$ exp

Supernova

- Early alert
- Supernova neutrinos
- Multi-messenger astrophysics

Detailed measurements
if/when galactic SN occurs

Cosmic Rays

- Atmospheric neutrinos

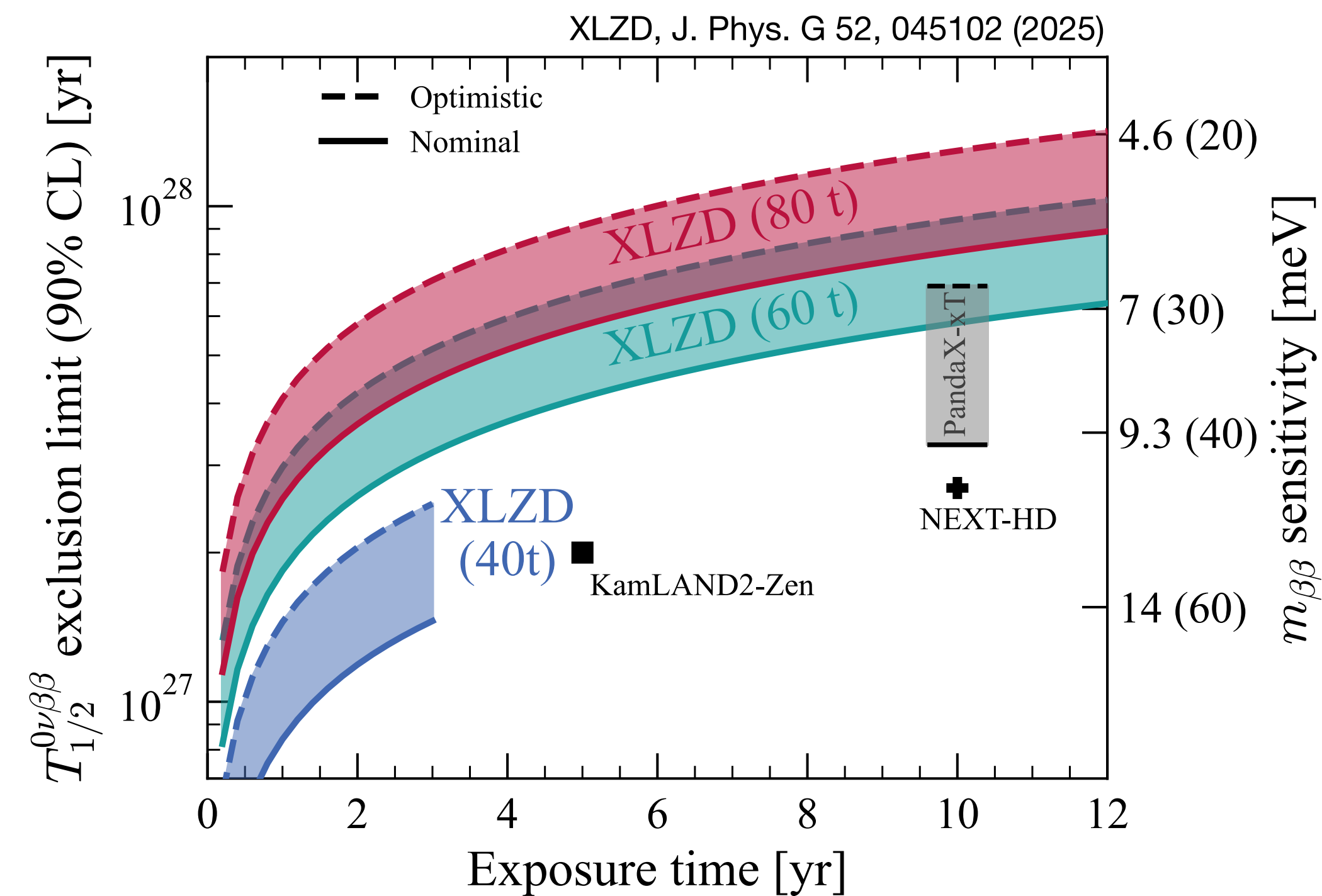
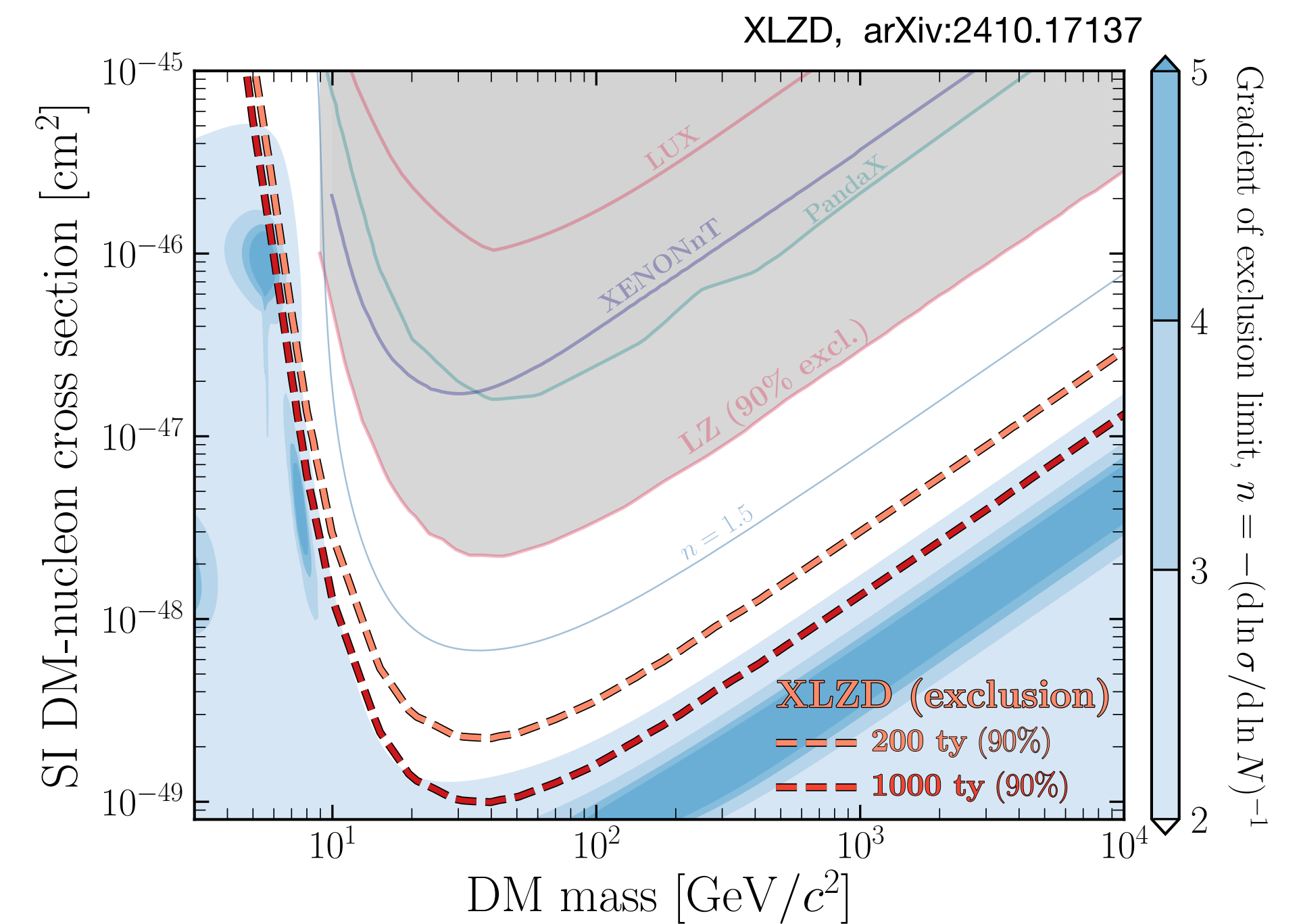
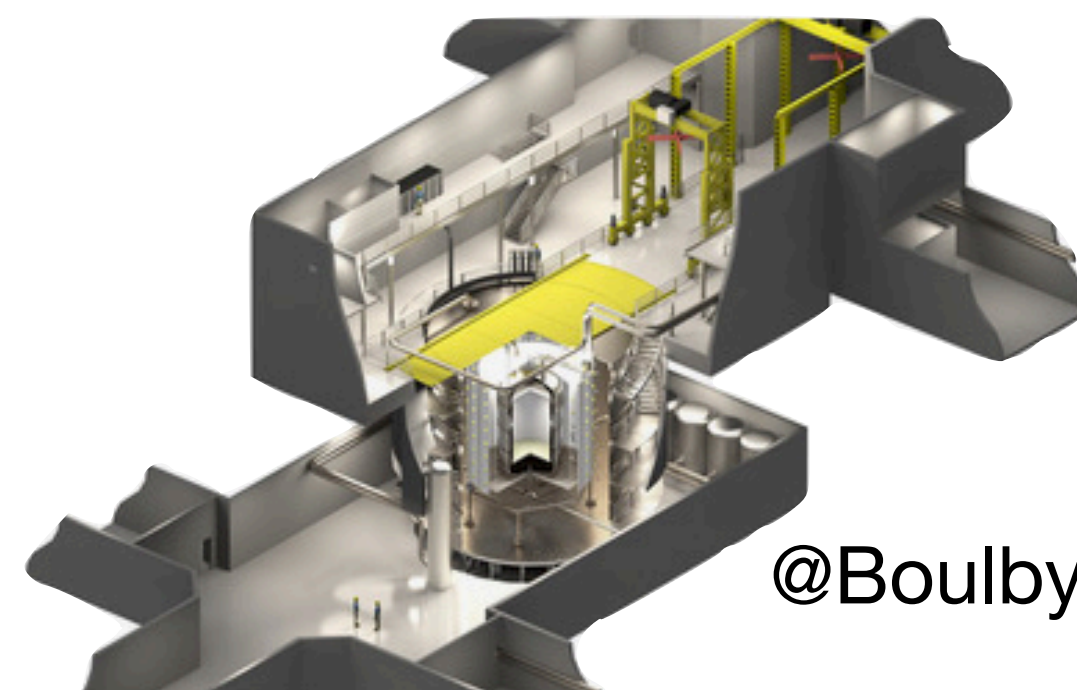
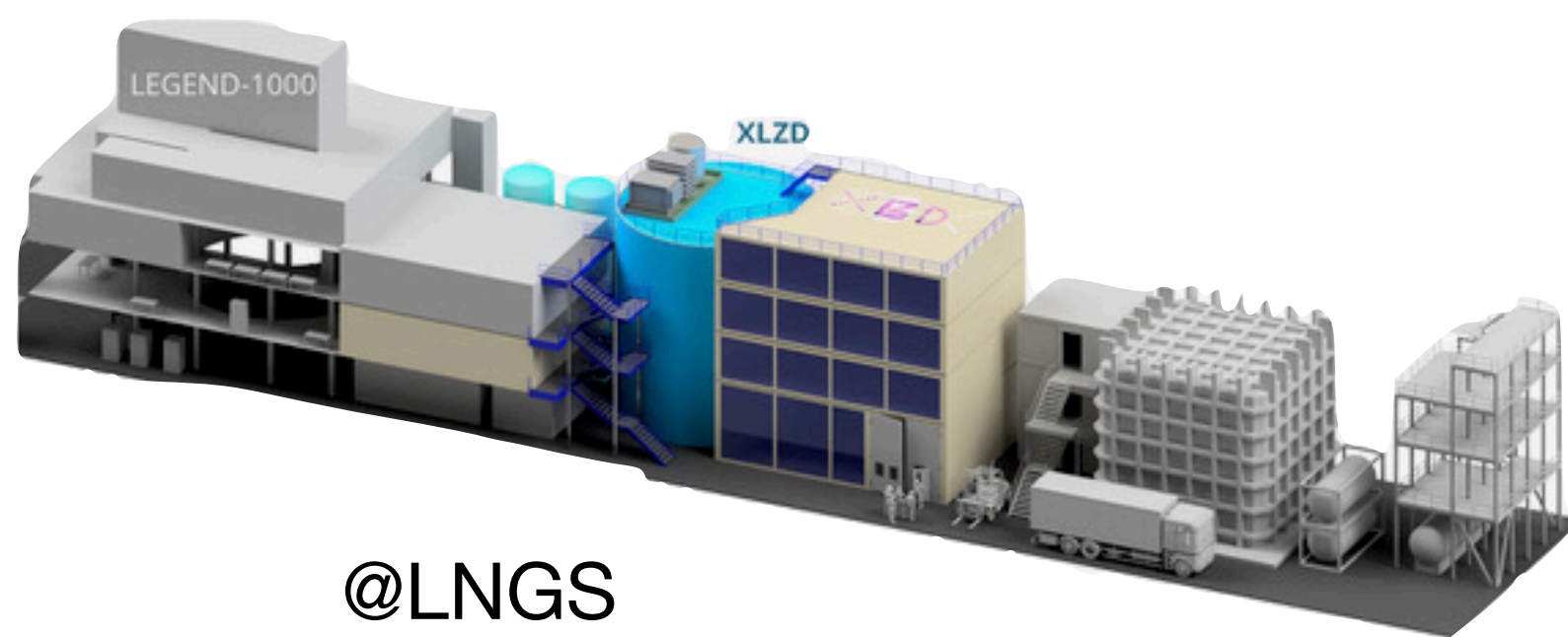
Atmospheric $E_\nu < 100$ MeV

Large liquid xenon mass and ultra-low backgrounds
expand number of available physics channels

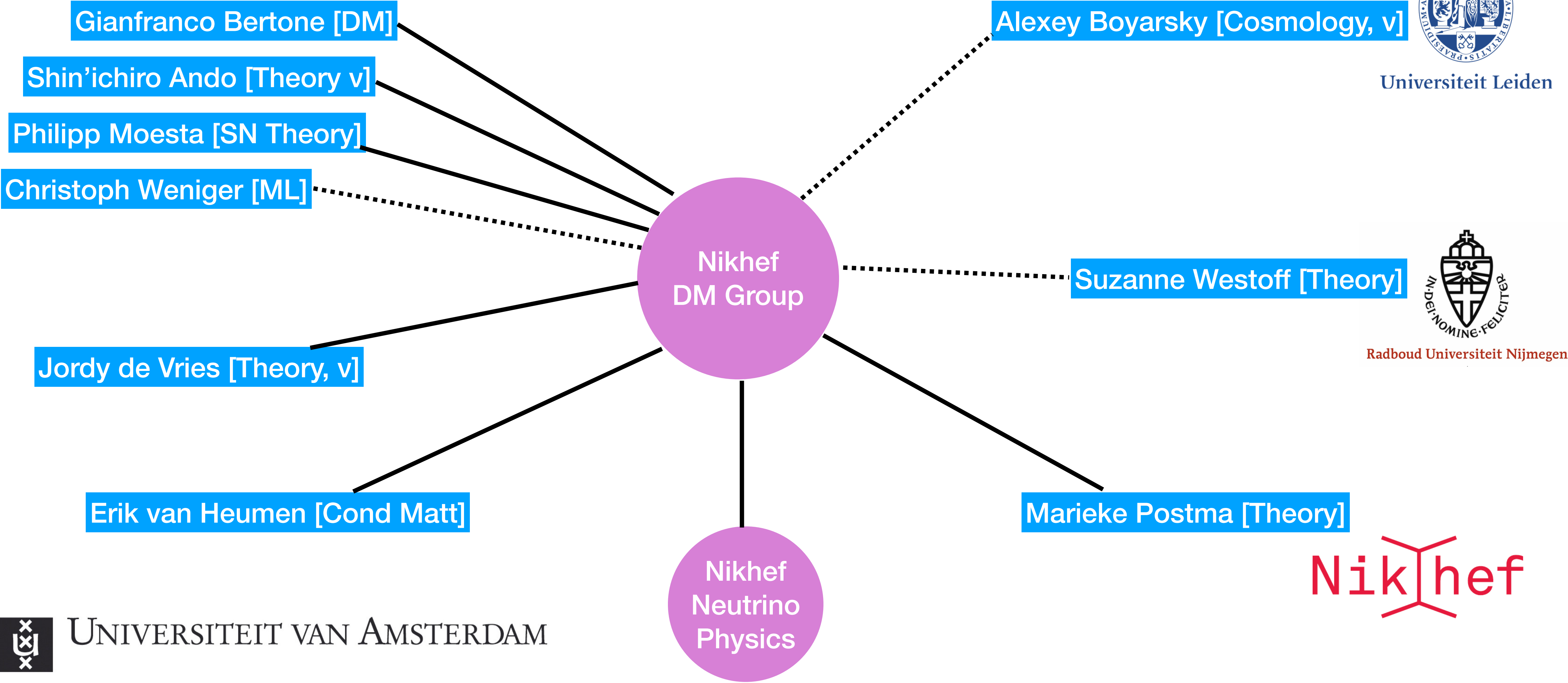


XLZD

- LZ and XENON formed XLZD collaboration in 2024
- 450+ collaborators, ~80 institutions
- Governance established, spokespeople elected
- Decowski elected to Executive Board
- Decowski is candidate for DAQ convener
- Pollmann Science & Sensitivity Work Group convener
- XLZD Input to EPPSU (Decowski, Laura Baudis and Marc Schumann)
- Boulby (UK), LNGS (IT), SNOLAB (CA), SURF (US) possible sites
 - Colijn on siting committee
- Funding strategy discussions EU+ | UK | US | JP



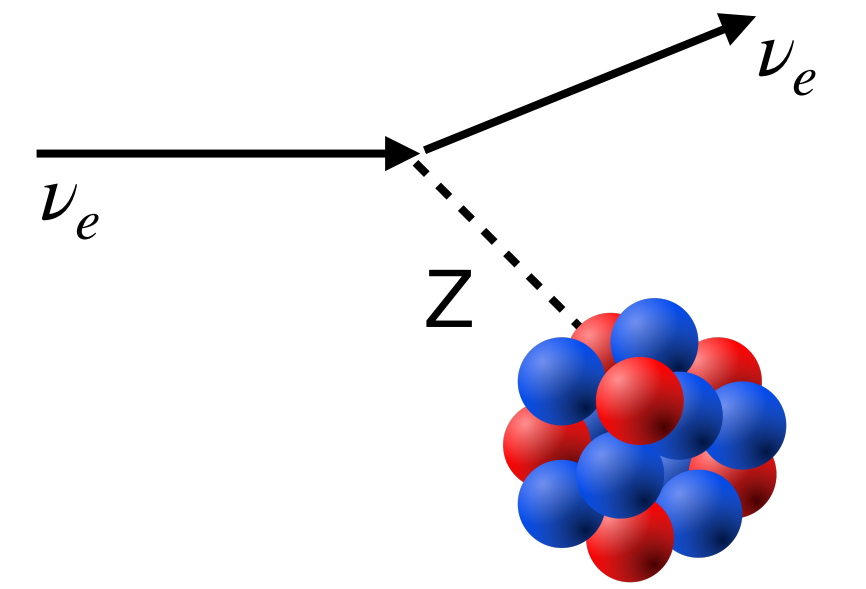
Connections



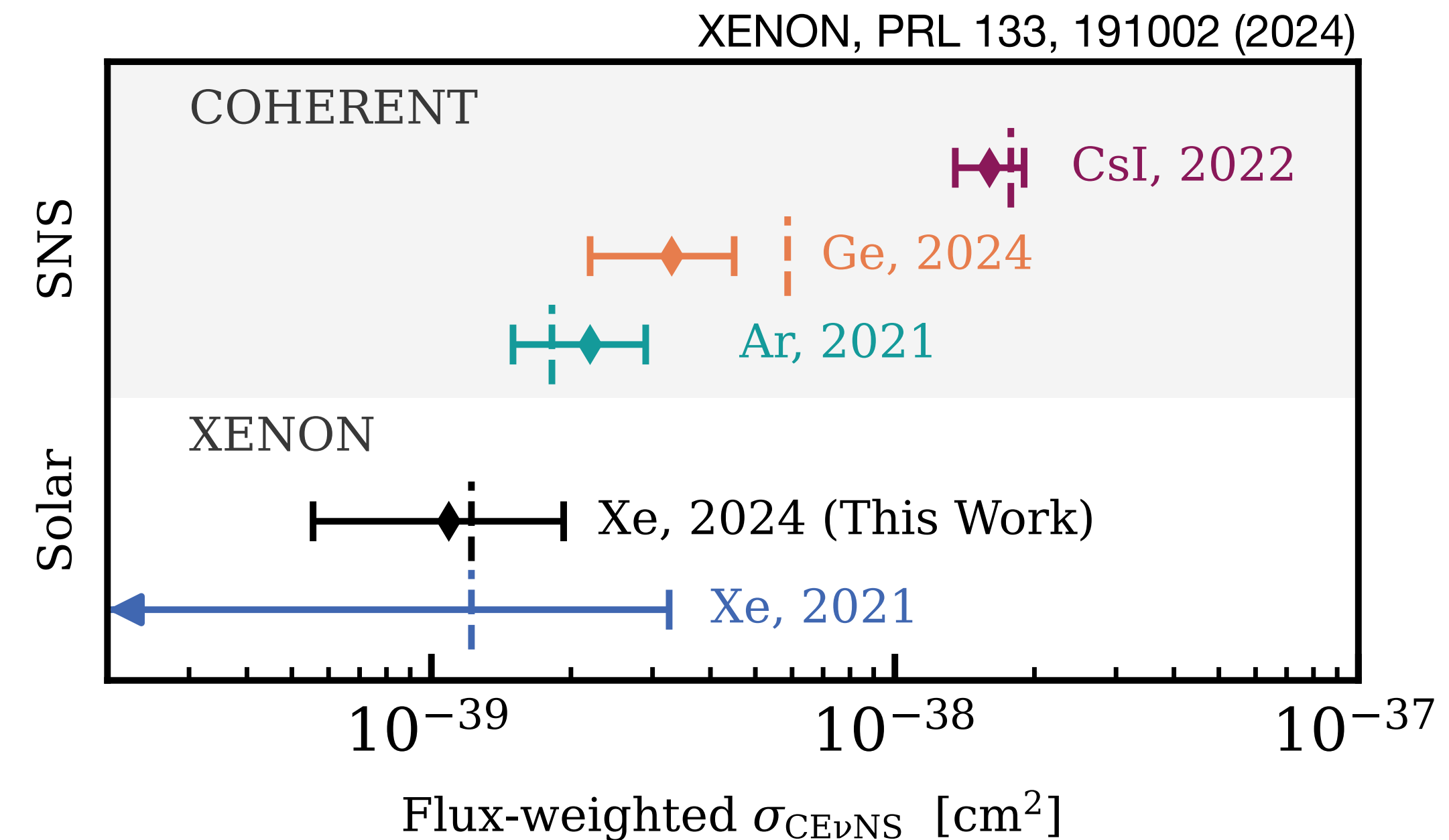
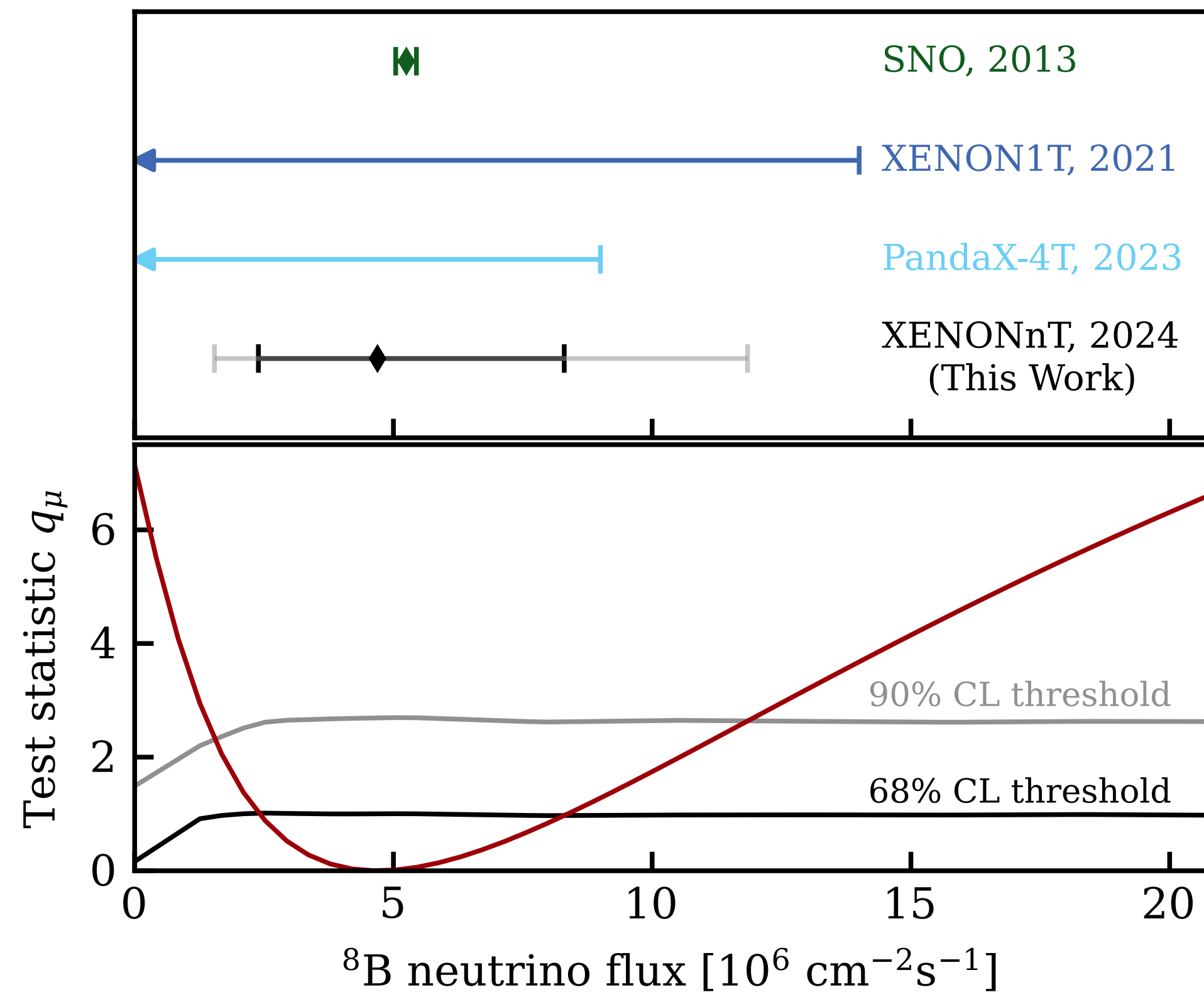
Summary

- Nikhef group is deeply involved in dark matter and other rare event searches
 - XENONnT is the scientific focus for the next years. Nikhef group continues to play key roles
- XLZD is a fantastic opportunity for a low background multipurpose detector
 - Several important steps in forming collaboration and initial detector design
- KamLAND-Zen and PTOLEMY are side projects with good synergies
- Four faculty members with healthy balance postdocs / PhDs

Detection of CEvNS

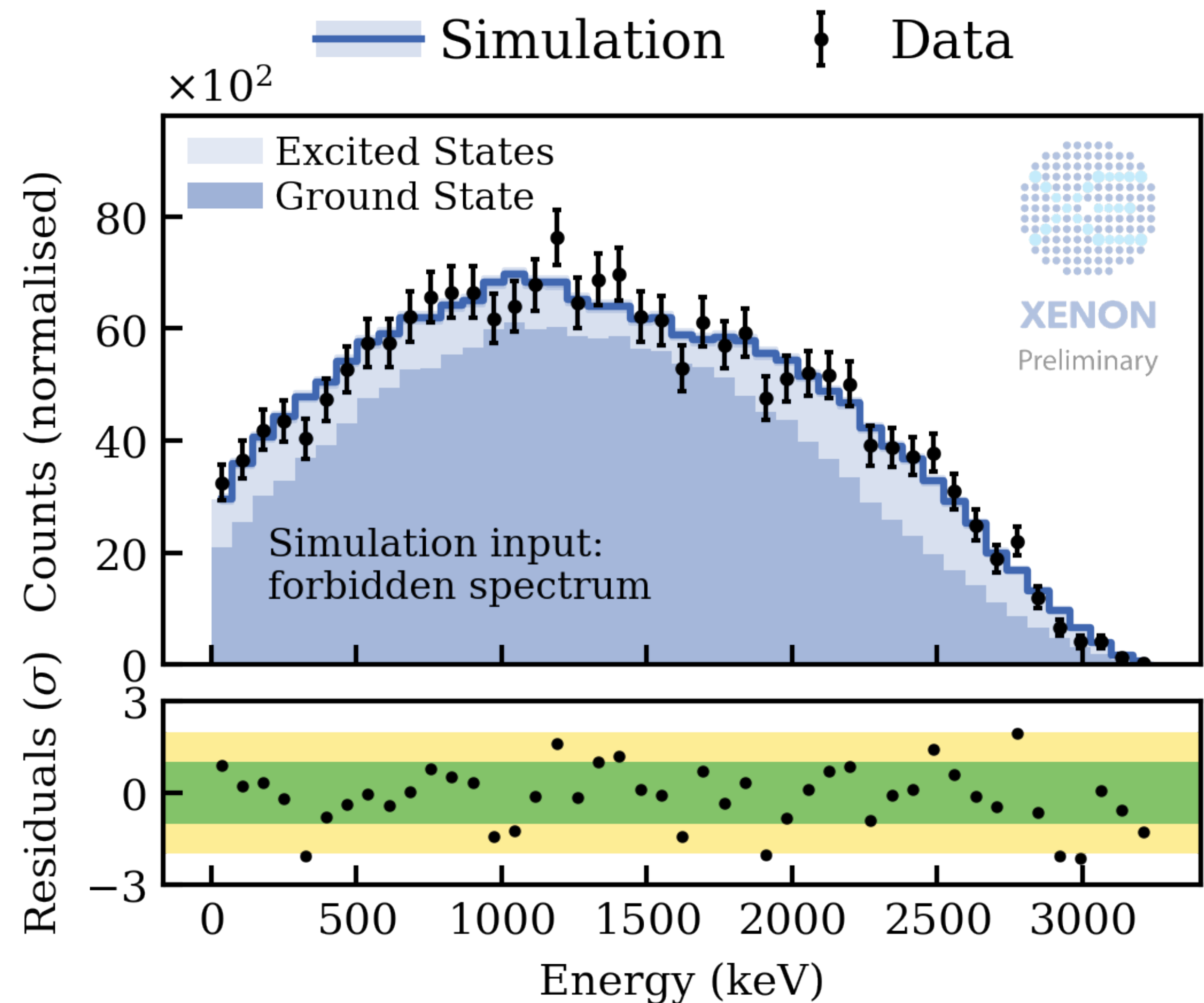
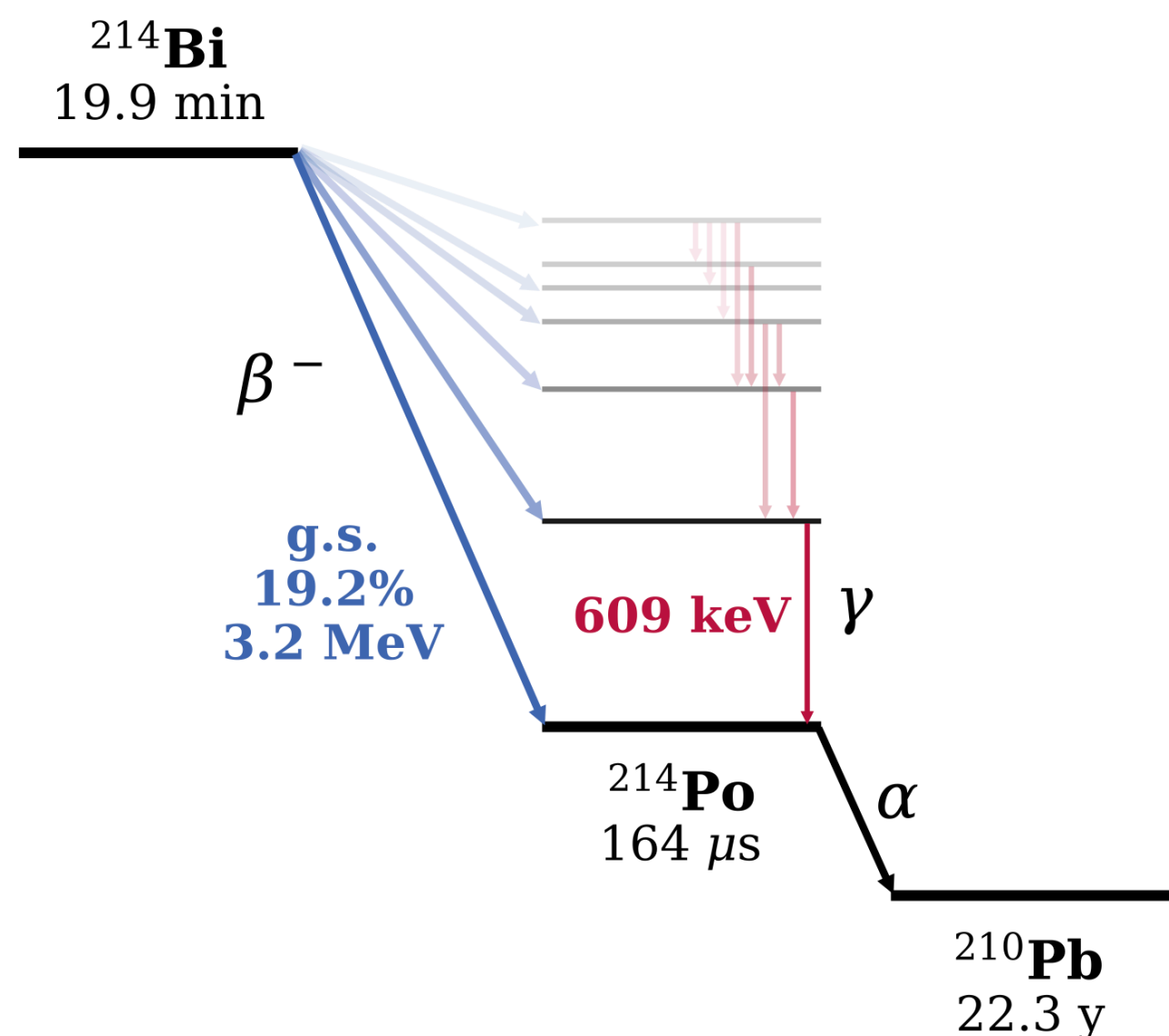


- Solar ^8B neutrino flux: $4.6^{+3.6}_{-2.3} \times 10^6 \text{ cm}^{-2}\text{s}^{-1}$ (no tension with lit)
 - $\rightarrow$ Background-only hypothesis rejected with 2.73σ significance
- With SNO flux $\rightarrow$ Measure the flux-weighted CEvNS cross section: $1.1^{+0.8}_{-0.5} \times 10^{-39} \text{ cm}^2$



Measurement of $^{214}\text{Bi} \rightarrow ^{214}\text{Po}$ G.S.

- Using a ^{222}Rn calibration source to measure the $^{214}\text{Bi} \rightarrow ^{214}\text{Po}$ G.S. decay
- 1st forbidden non-unique beta decay, spectrum unknown
- → Provides insights into nuclear structure
- → Unique ER calibration probe up to 3.2 MeV



New DM Results at high & low masses

- New high-mass (>10 GeV) WIMP result with SR0+SR1
 - arXiv:2502.18005 to PRL
- New low-mass WIMP result near “ ν fog”
 - PRL 134, 111802 (2025)
- “S2-only” $\rightarrow$ lowering threshold
 - PRL 134, 161004 (2025)

