University of Zurich[UZH]

Latest results from the XENONnT dark matter experiment

Paloma Cimental (University of Zurich) on behalf of the XENON Collaboration

Swiss Physical Society Meeting
September 13th 2024, ETH, Zurich

The XENON collaboration

XENON10
2005
25 Kg LXe

XENON100
2008
160 Kg LXe

XENON1T
2016
3200 Kg LXe

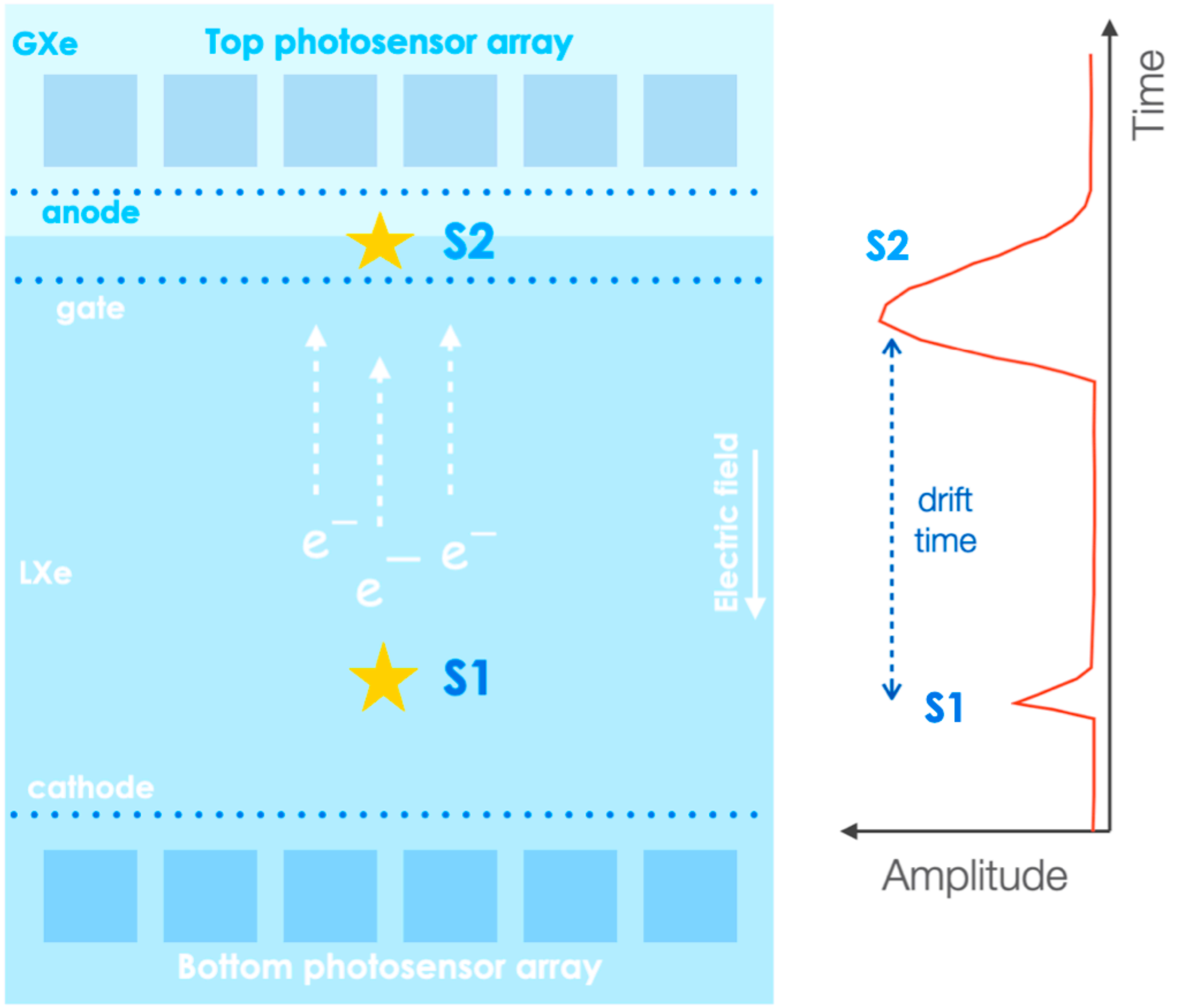
XENONnT
2020
8500 Kg LXe

~170 Scientists

29 Institutions

12 countries

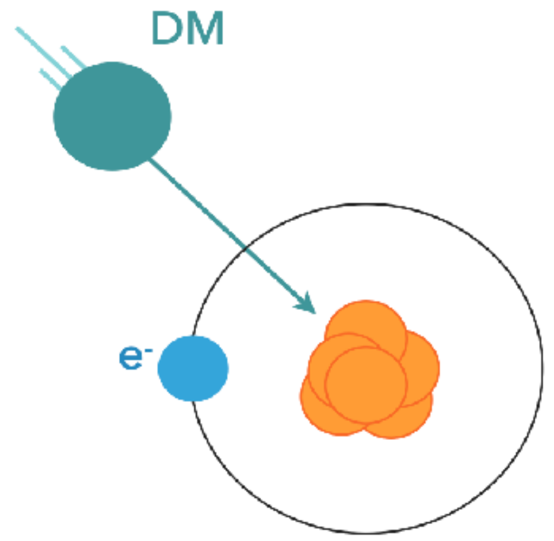
Direct dark matter detection



Main detection channel: coherent elastic WIMP - nucleus scattering

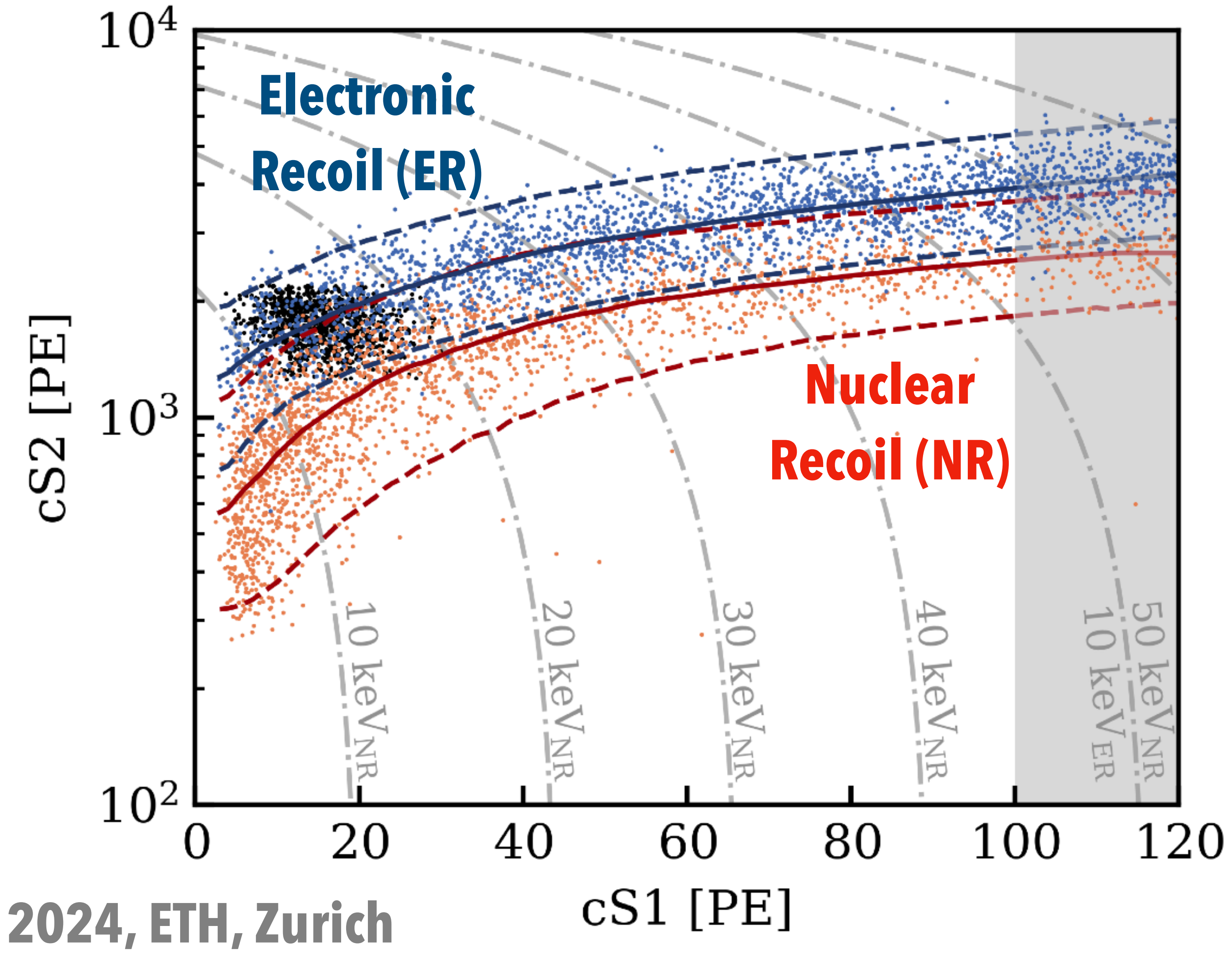
Signals:

- Prompt scintillation light (**S1**) in liquid xenon (LXe)
- Secondary light (**S2**) in gas xenon (GXe) from ionisation charges



Dual-phase Time Projection Chamber (TPC) technology provides:

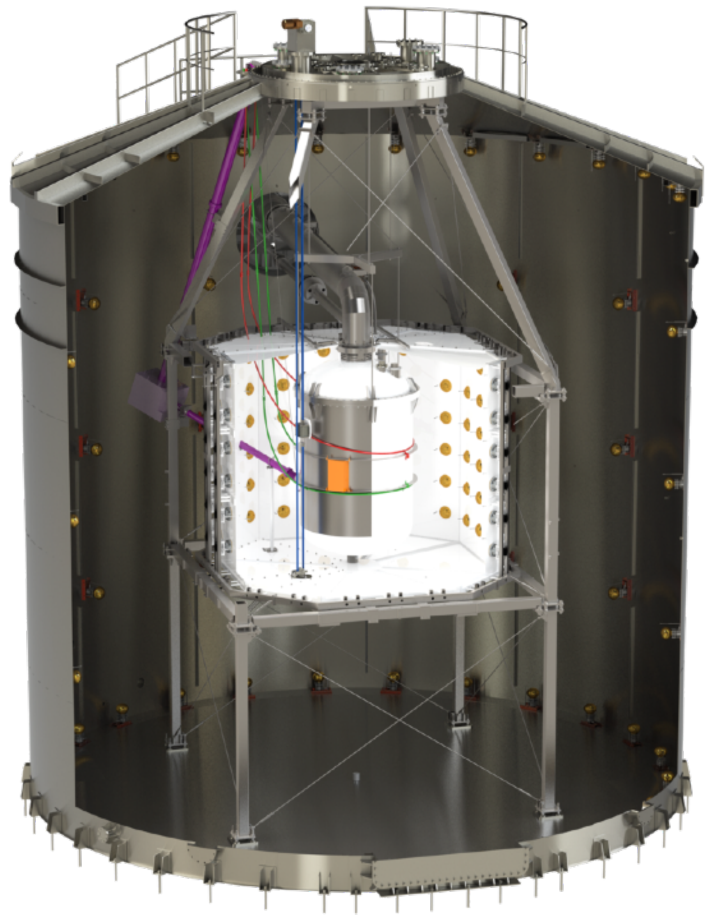
- 3D position reconstruction
  - x - y from **S2** top photosensor pattern
  - z from **S1**-**S2** time delay



- Energy reconstruction from: $E \propto \left(\frac{S1}{g1} + \frac{S2}{g2}\right)$
- Discrimination of electronic and nuclear recoils using the **S1**/**S2** signal ratio

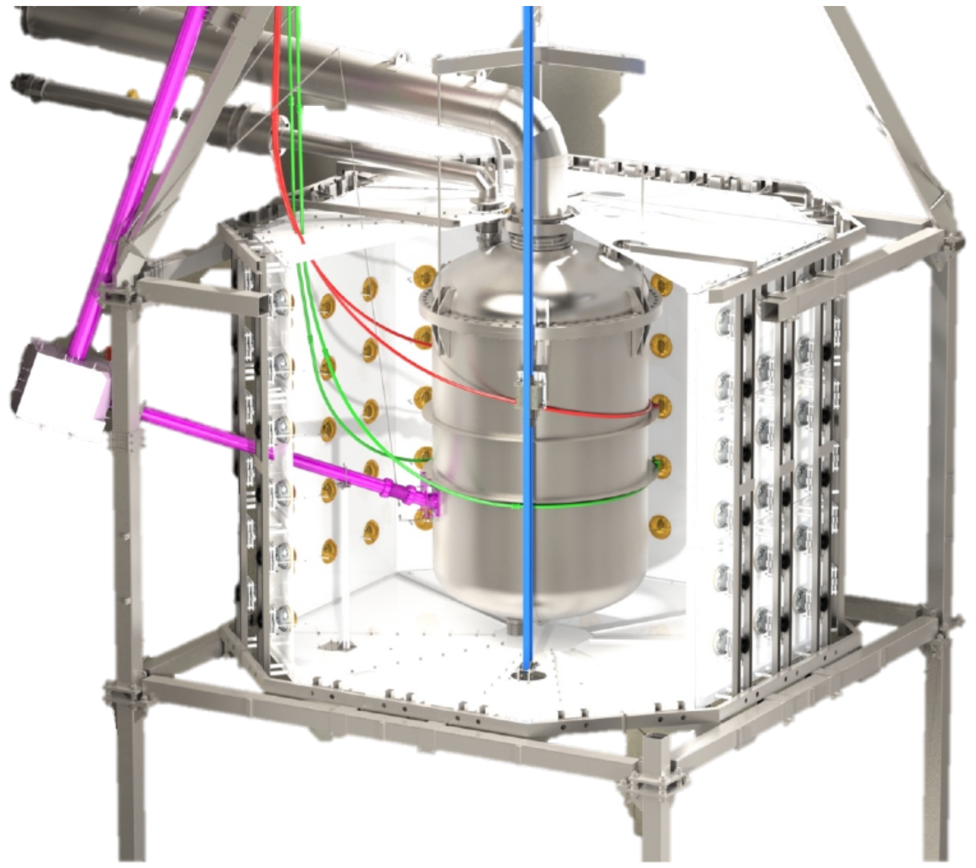
The XENONnT experiment

Water Cherenkov Muon Veto (MV)



- **~10 x 10 m** diameter ⨯ height
- **84** PMTs (8″ Hamamatsu R5912-ASSY)

Gd-loaded water Cherenkov Neutron Veto (NV)



- **~2 x 3 m** radius ⨯ height
- **120** PMTs (8″ Hamamatsu R5912)
- **0.05%** GdSO concentration (since 2023)

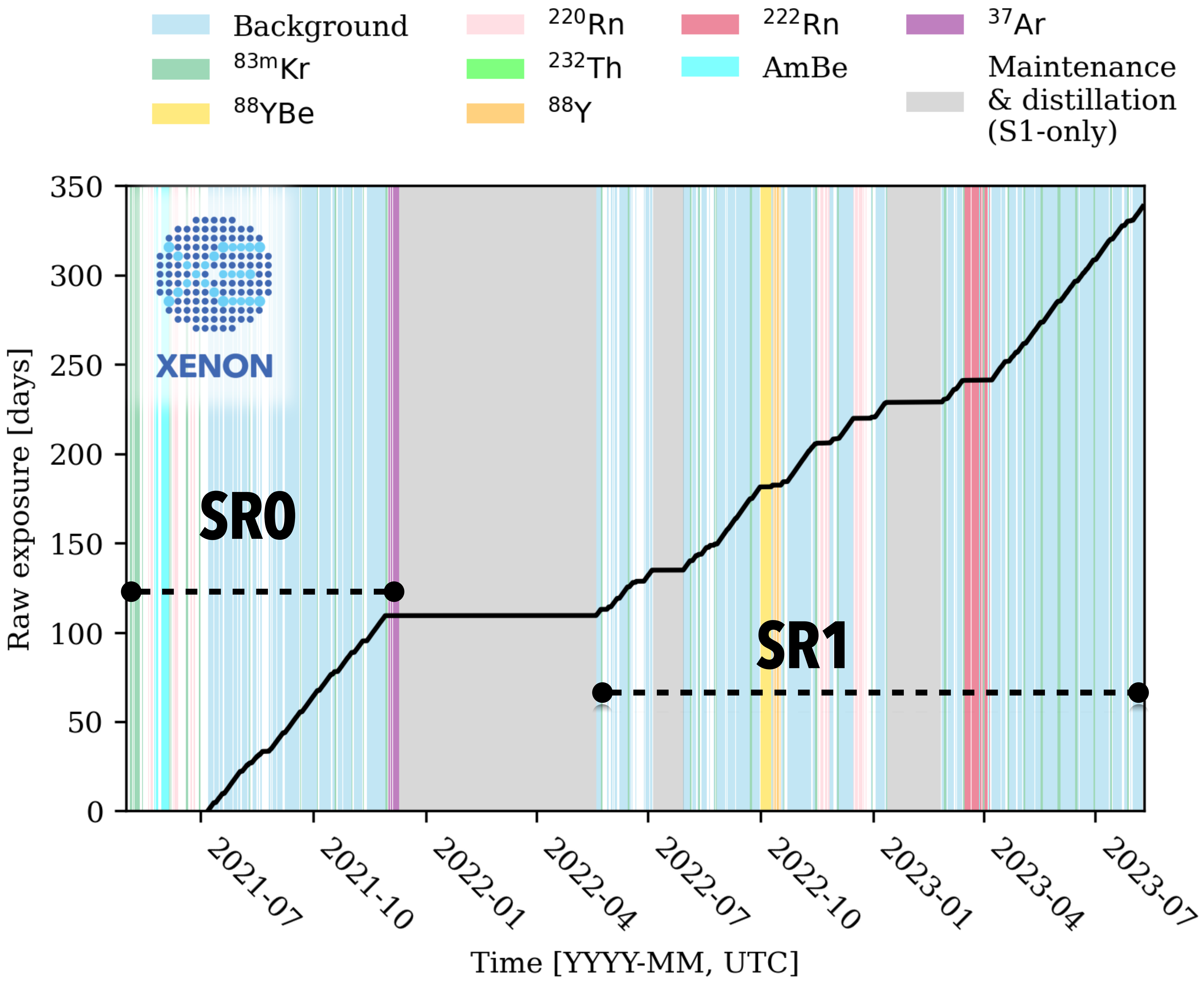
LXe Time Projection Chamber (TPC)

- **5.9 t** active LXe mass
- **1.3 x 1.5 m** diameter ⨯ height
- **494** PMTs (3″ Hamamatsu R11410-21)
- **23 V/cm** electric drift field
- **2.9 kV/cm** extraction field

The first two science runs

- **Data taken between July 2021 and August 2023**
  - ~316 days of exposure
- **Stable detector response**
  - Light yield <1 % variation
  - Charge yield <3 % variation
- **High liquid xenon purity**
  - Electron survival probability > 90% at the maximum drift length
- **Regular calibrations** to study detector response and light/charge gains

Science Run	g1 [PE/ph]	g2 [PE/e]
SR0	0.1515 ± 0.0014	16.45 ± 0.64
SR1	0.1367 ± 0.0010	16.85 ± 0.46



Physics results so far

a

ER channel

Phys.Rev.Lett. 129 (2022) 16, 161805

2022

SR0

χ

NR WIMP dark matter

Phys.Rev.Lett. 131 (2023) 4, 041003

2023

SR0

ν

^{8}B solar neutrinos

arXiv:2408.02877

2024

SR0 + SR1

Physics results so far

α

ER channel

Phys.Rev.Lett. 129 (2022) 16, 161805

2022

SR0

χ

NR WIMP dark matter

Phys.Rev.Lett. 131 (2023) 4, 041003

2023

SR0

This talk

ν

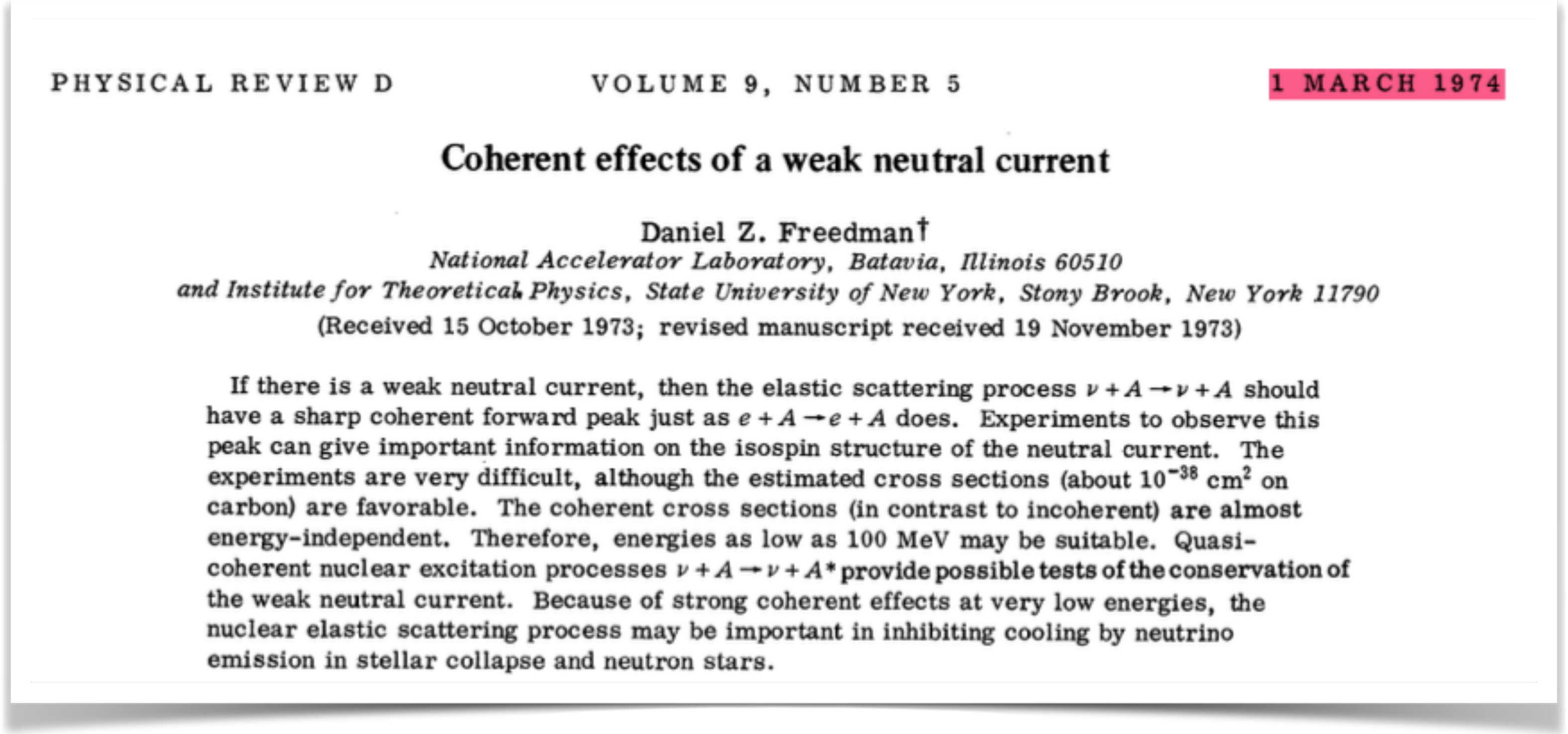
^{8}B solar neutrinos

arXiv:2408.02877

2024

SR0 + SR1

Elastic Scattering of Dark Matter and Neutrinos


PHYSICAL REVIEW D VOLUME 9, NUMBER 5 1 MARCH 1974

Coherent effects of a weak neutral current

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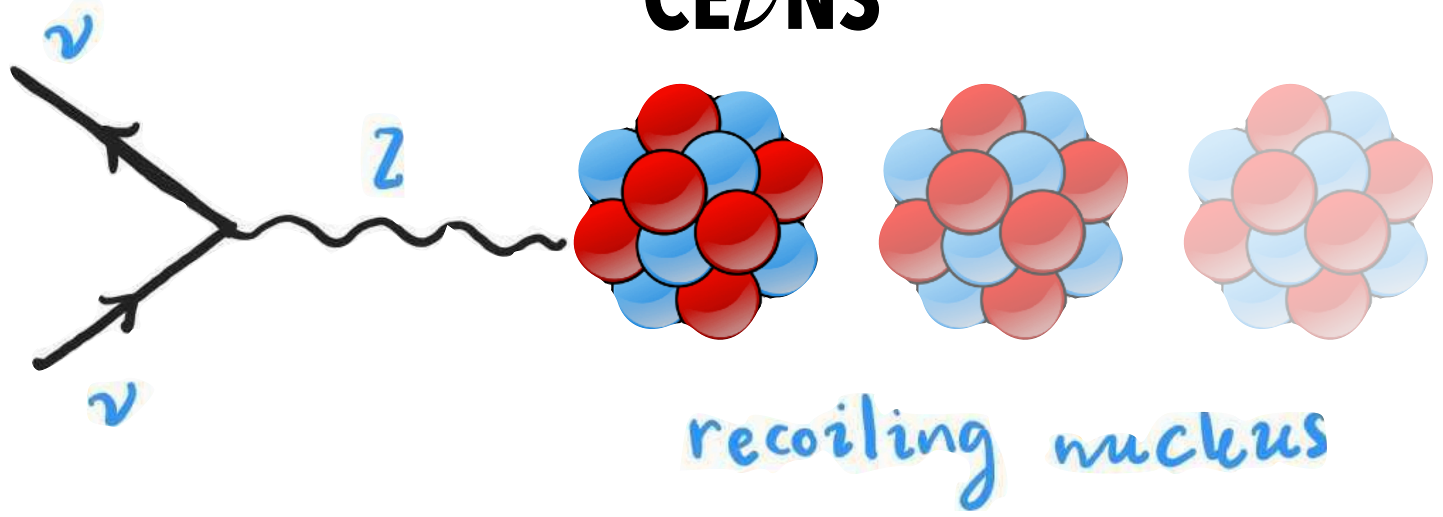
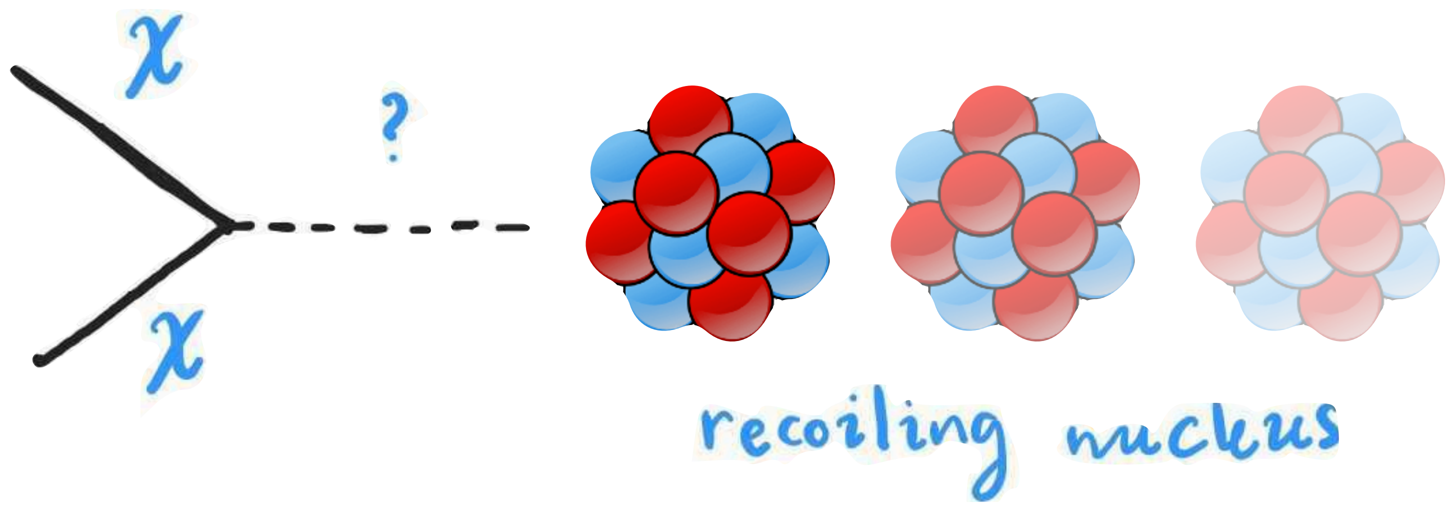
(Received 15 October 1973; revised manuscript received 19 November 1973)

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.

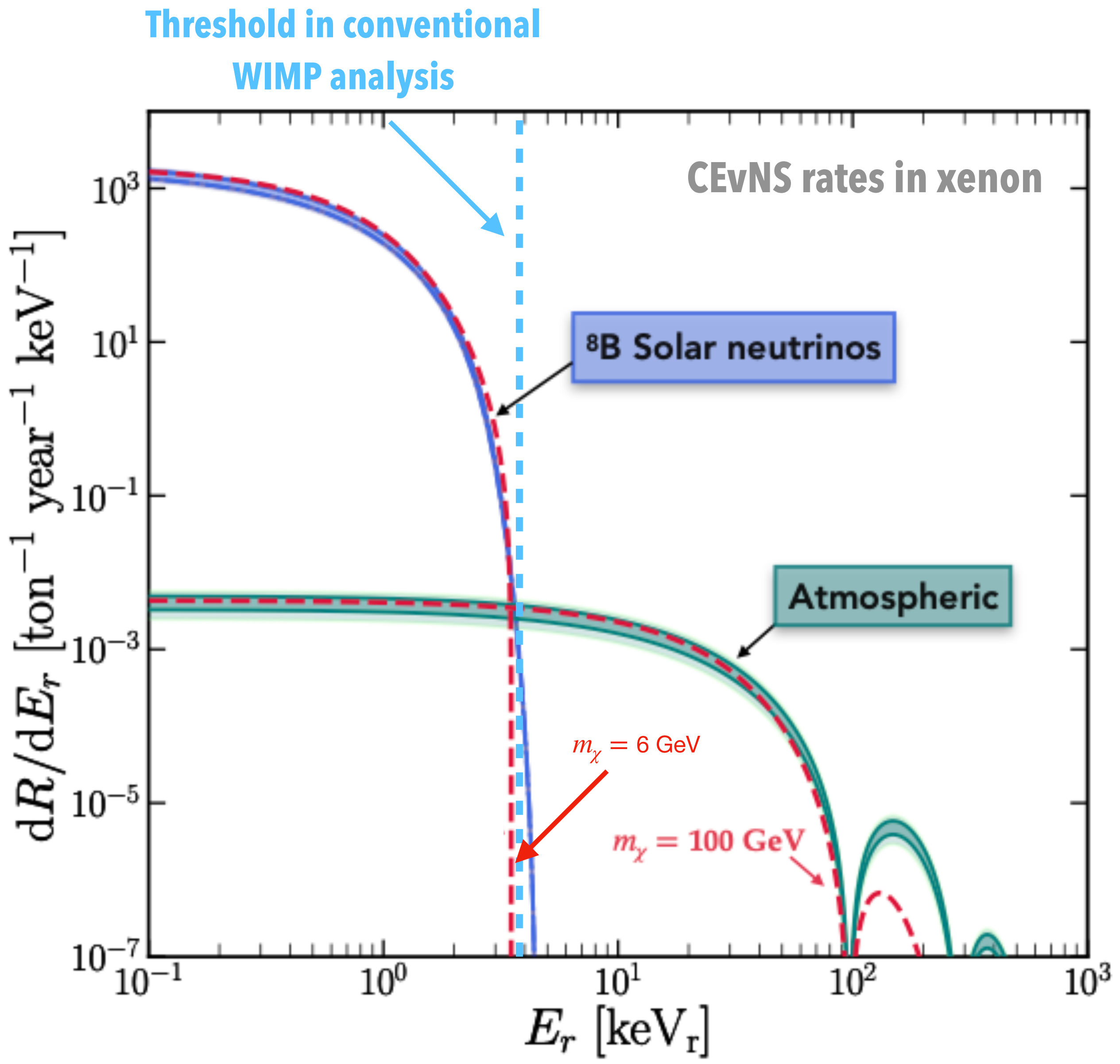
CEνNS



DM - nucleus scattering



- **CEνNS**: **C**oherent **E**lastic **N**eutrino - **N**ucleus **S**cattering
  - First measured by COHERENT (2017) using a spallation neutron source
- ^{8}B CEνNS typical recoil energy $\lesssim$ 1.5 keV$_{NR}$
  - Almost indistinguishable signature from 5.5 GeV/c^2 WIMP

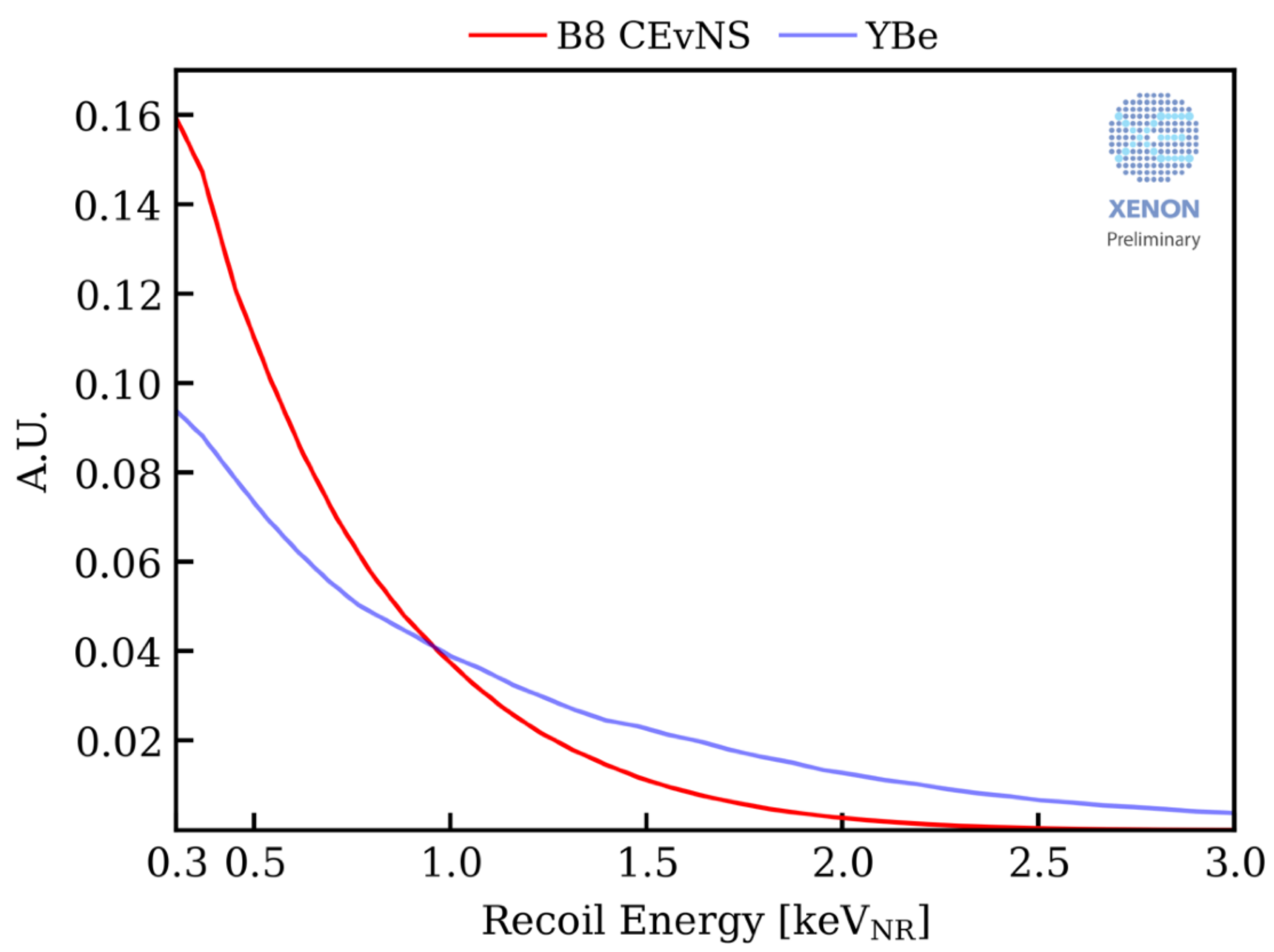


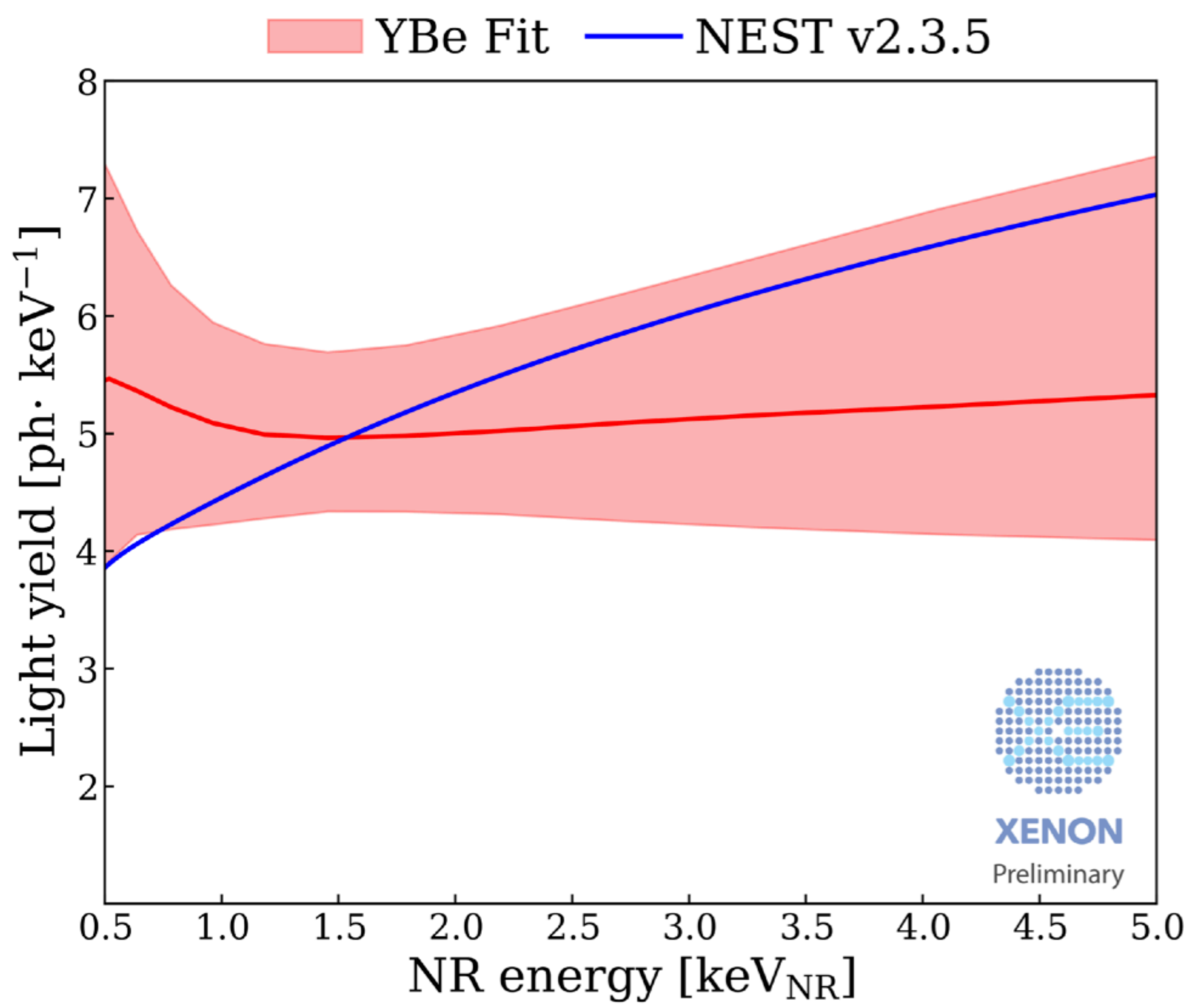
- **Lowering the energy threshold is essential to increase the signal acceptance**
  - Model detector response to low-energy NRs
  - Suppress and constrain increased background

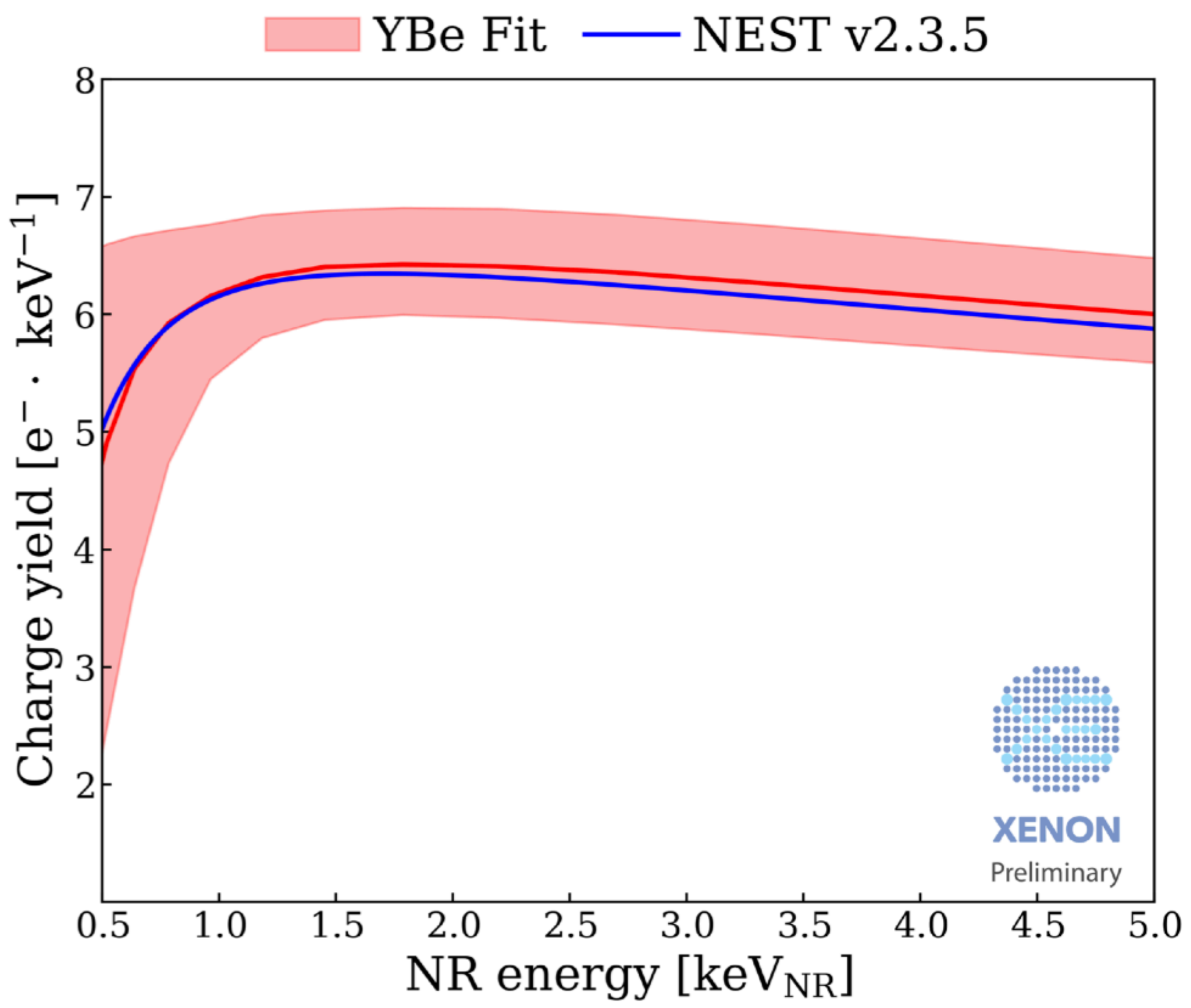
Search for solar ^{8}B CEνNS

^{88}YBe Low energy NR calibration

- 152 keV neutrons from ^{88}YBe source
- Excellent match between simulations and calibration data
- Models to predict the light and charge yield in the ^{8}B CEνNS energy range at the XENONnT drift field

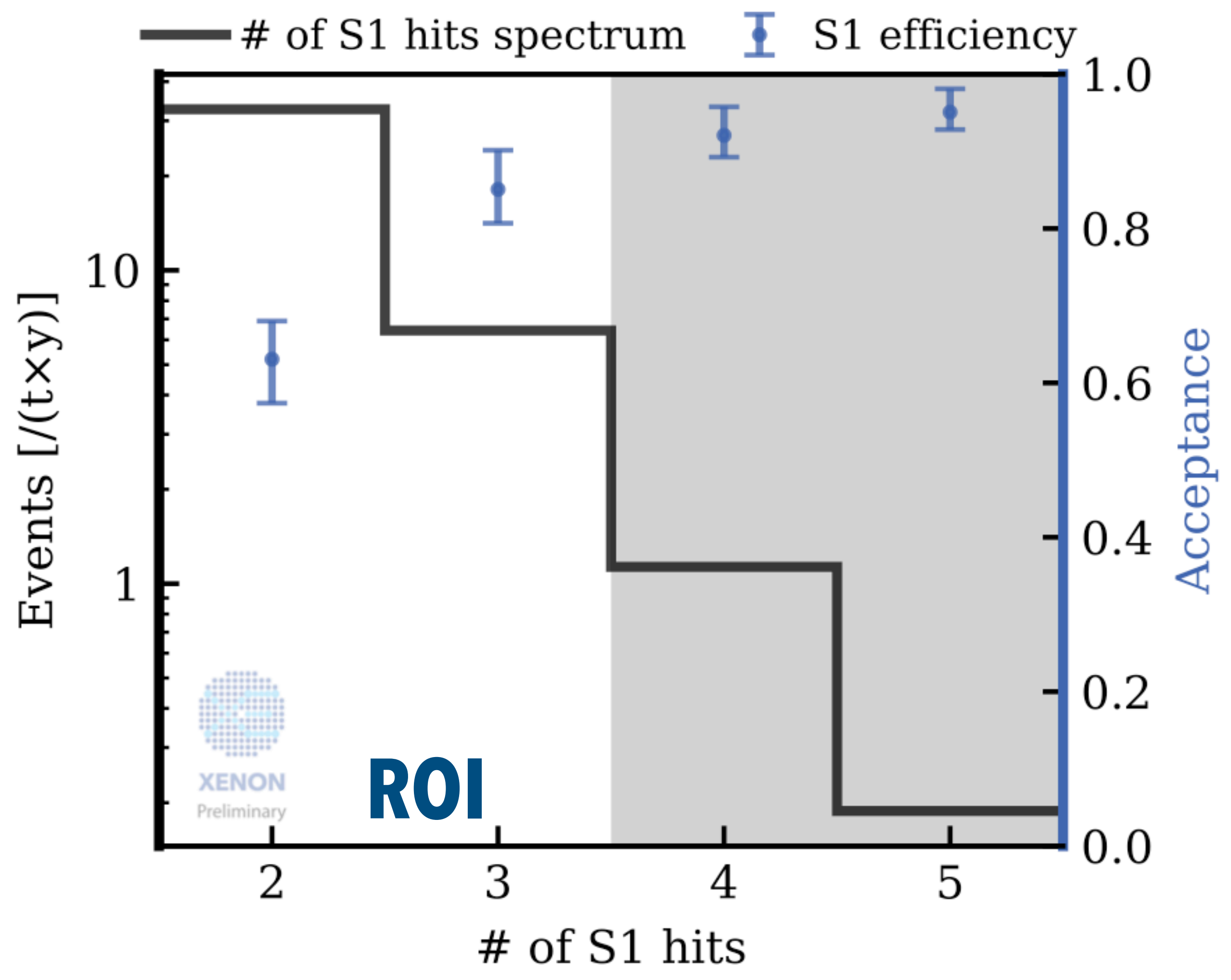


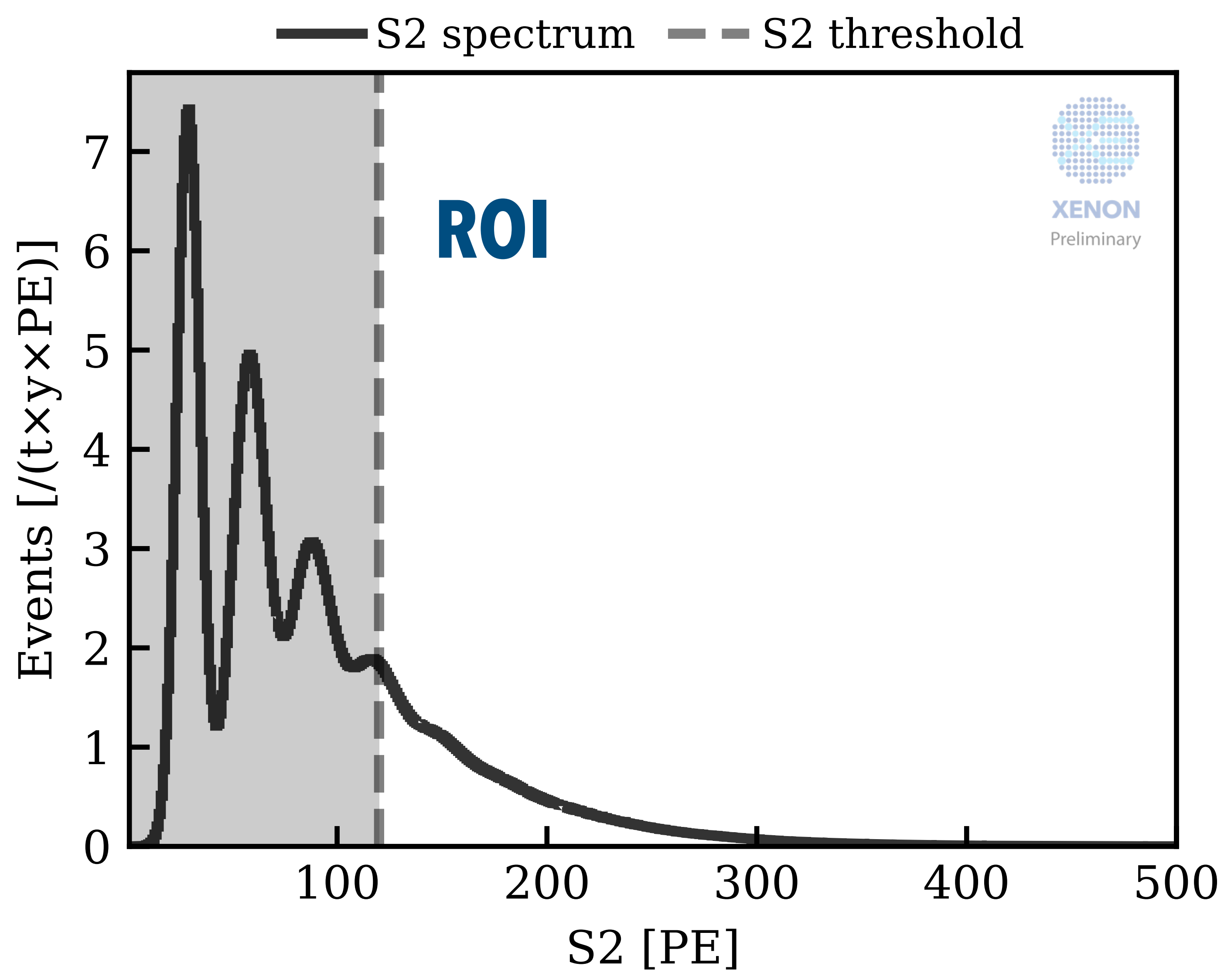




Search for solar ^{8}B CEνNS

Regions of interest and energy threshold





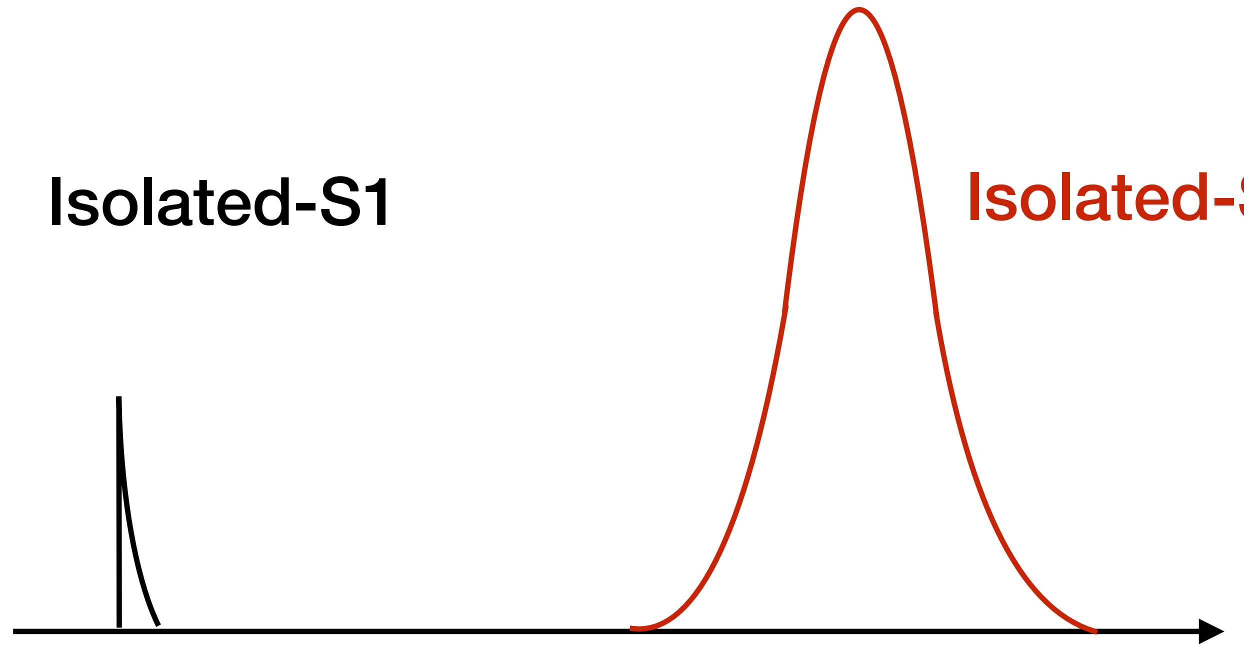
- S1 signal ROI: [2, 3] hits
  - An S1 hit corresponds to a detected photon
  - ^{8}B CEνNS rarely produces signals with over 3 hits

- S2 signal ROI: [120, 500] photoelectrons (PE)
  - Corresponds to 4 - 16 extracted electrons
  - Upper threshold to remove ER background from β and γ radiation

S1 and S2 lower threshold reduced to increase detected ^{8}B CEνNS by ~17 times compared to conventional analysis

Search for solar ^{8}B CEνNS

Main background: Accidental Coincidence (AC)

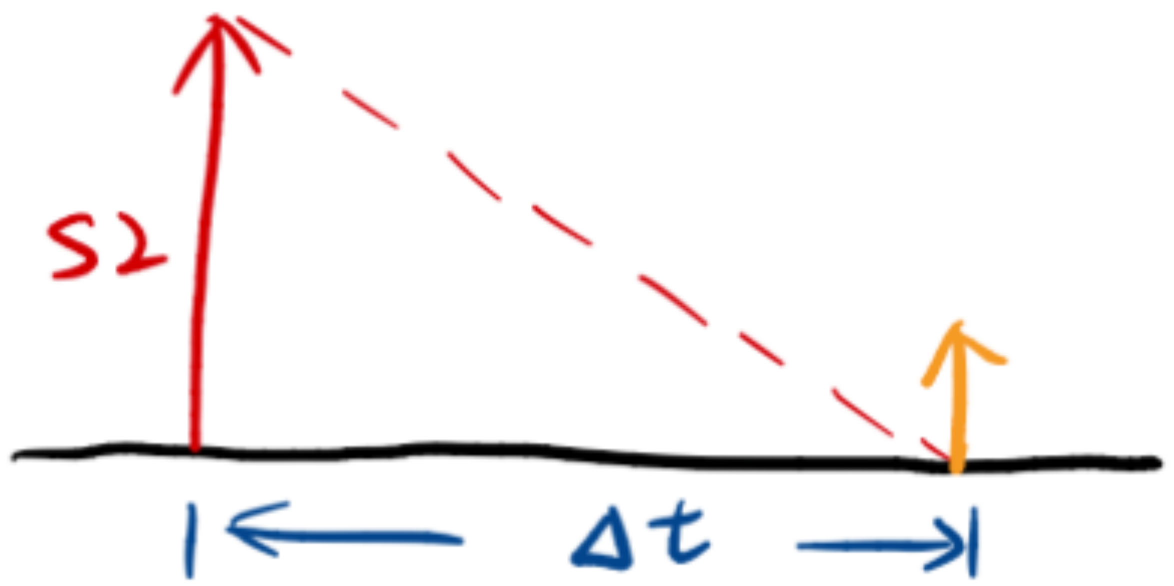


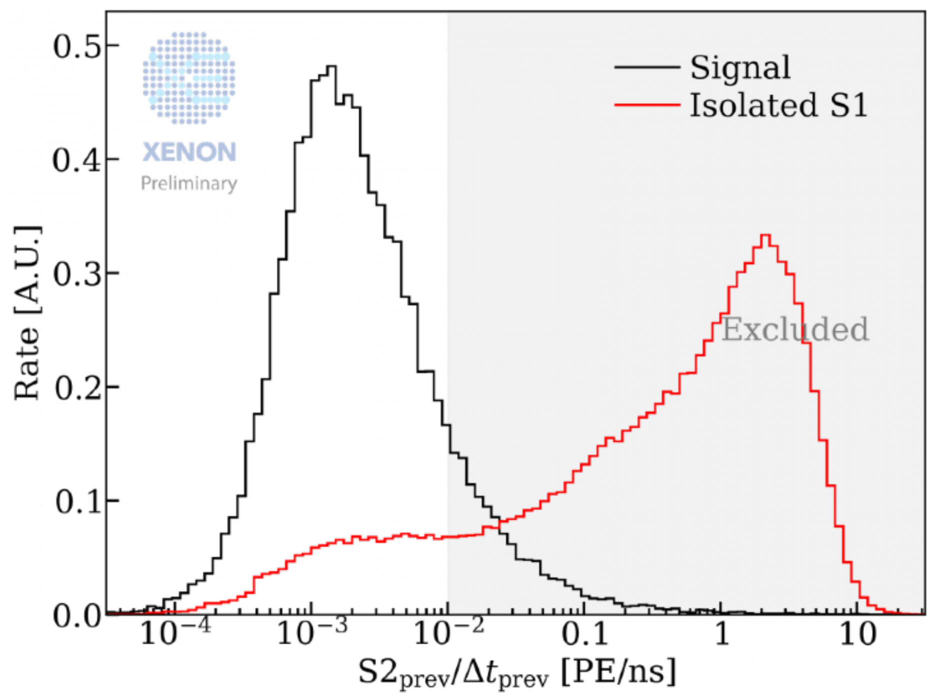
- Random unphysical pairing of isolated **S1** and **S2**
- Isolated S1/S2 are thought to be byproducts of high-energy interactions

Suppression strategy

- Selections based on correlation with their preceding HE peak
- S1 and S2 Boosted Decision Tree (BDT) classifiers using signal shape properties to discriminate signal from ACs
- **4-D space search for better discrimination power in cS2, S1 BDT, S2 BDT, TimeShadow parameters**

$$\textbf{TimeShadow} \equiv \text{Max}\left(\frac{S2_{prev}}{\Delta t_{prev}}\right)$$



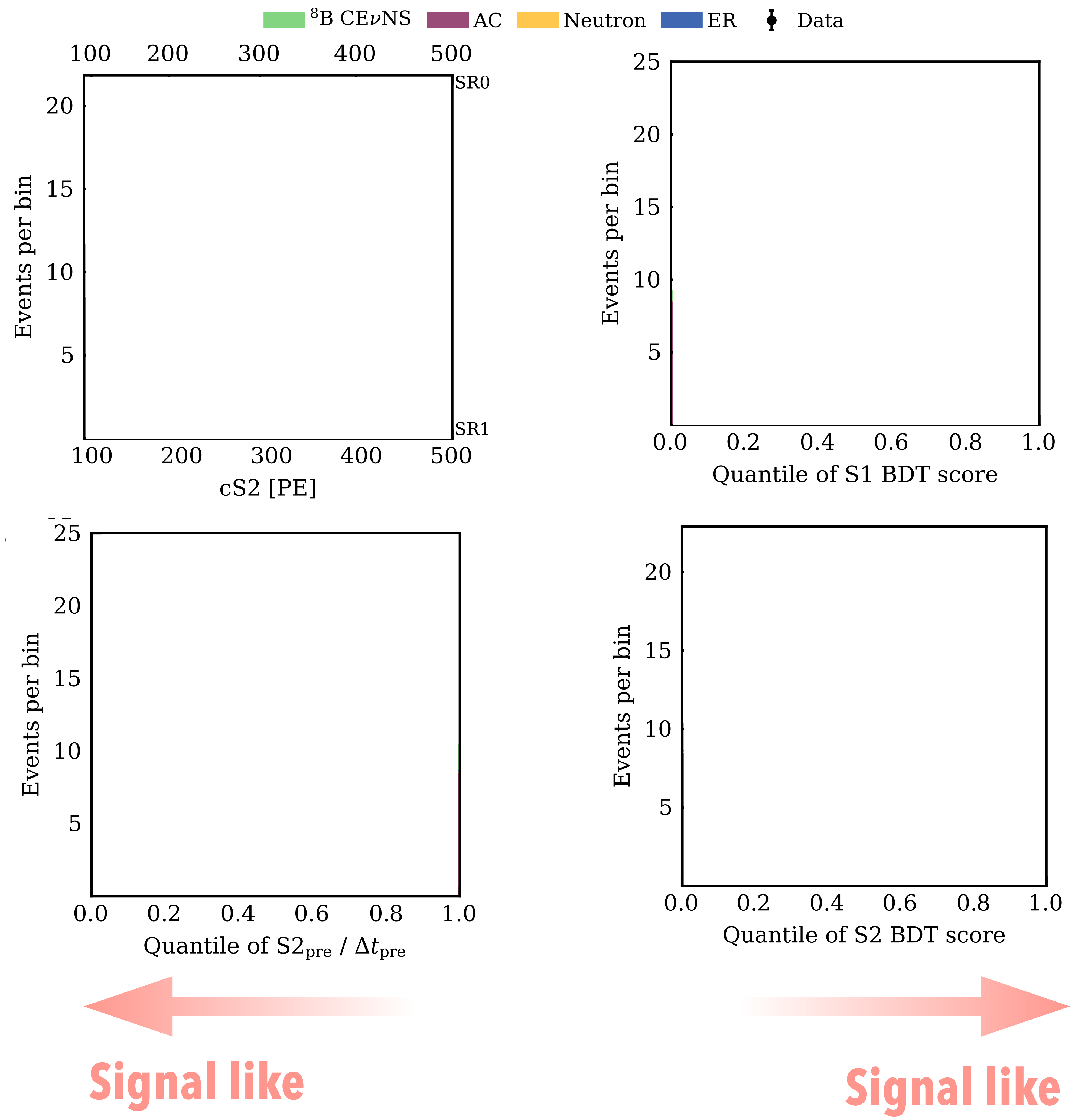


Prediction before unblinding

Component	Expectation
AC (SR0)	7.5 ± 0.7
AC (SR1)	17.8 ± 1.0
ER	0.7 ± 0.7
Neutron	$0.5^{+0.2}_{-0.3}$
Total background	$26.4^{+1.4}_{-1.3}$
^{8}B	$11.9^{+4.5}_{-4.2}$

Total exposure: **3.51** ton·year

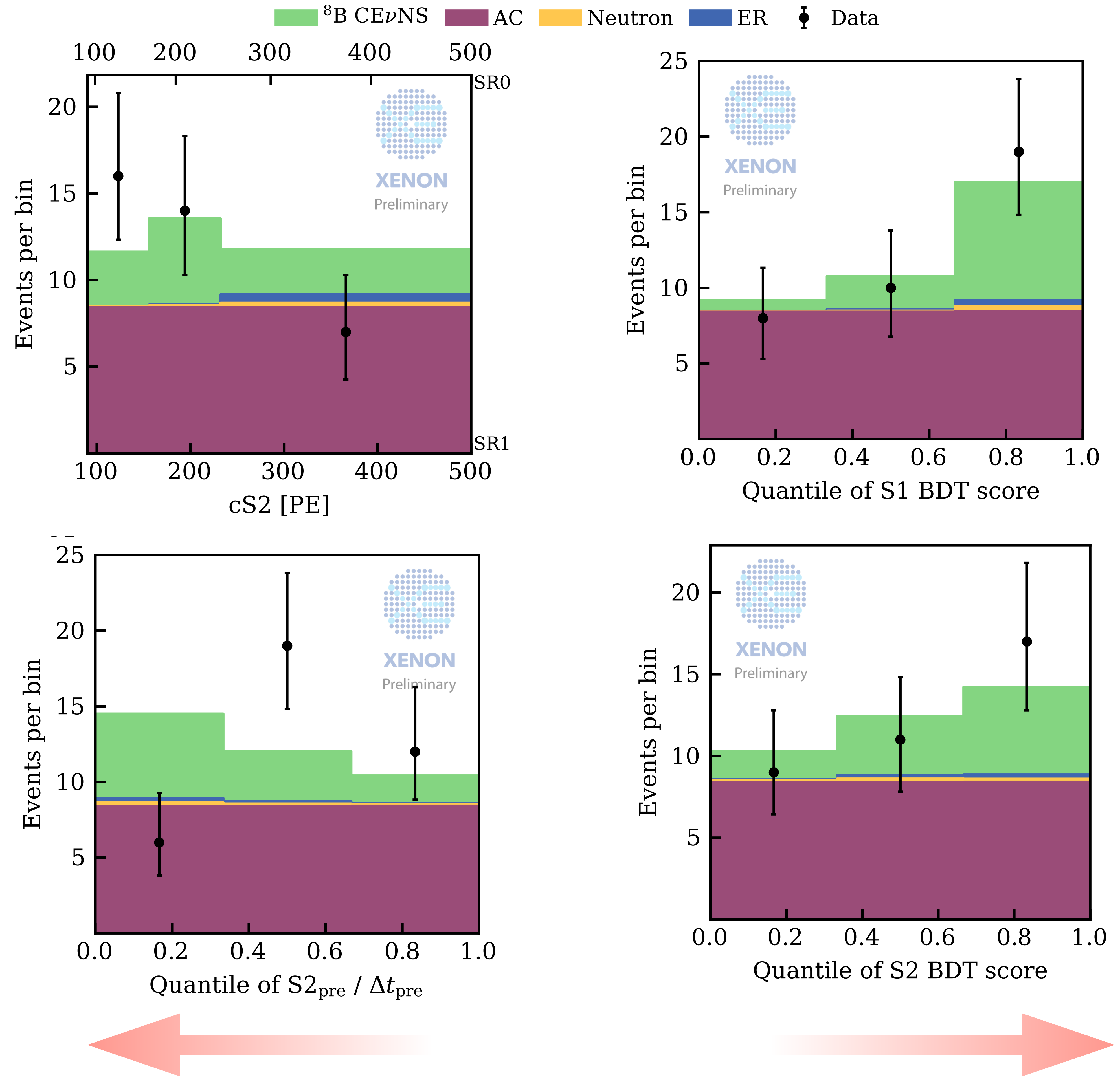
Expect ^{8}B CEνNS: $\mathbf{11.9}^{+4.5}_{-4.2}$ events



Unblinding results

Component	Expectation	Best-fit
AC (SR0)	7.5 ± 0.7	7.4 ± 0.7
AC (SR1)	17.8 ± 1.0	17.9 ± 1.0
ER	0.7 ± 0.7	$0.5^{+0.7}_{-0.6}$
Neutron	$0.5^{+0.2}_{-0.3}$	0.5 ± 0.3
Total background	$26.4^{+1.4}_{-1.3}$	26.3 ± 1.4
^{8}B	$11.9^{+4.5}_{-4.2}$	$10.7^{+3.7}_{-4.2}$
Observed	37	

Data agrees with the signal + background expectation in the four-dimension analysis



Signal like

Signal like

Unblinding results

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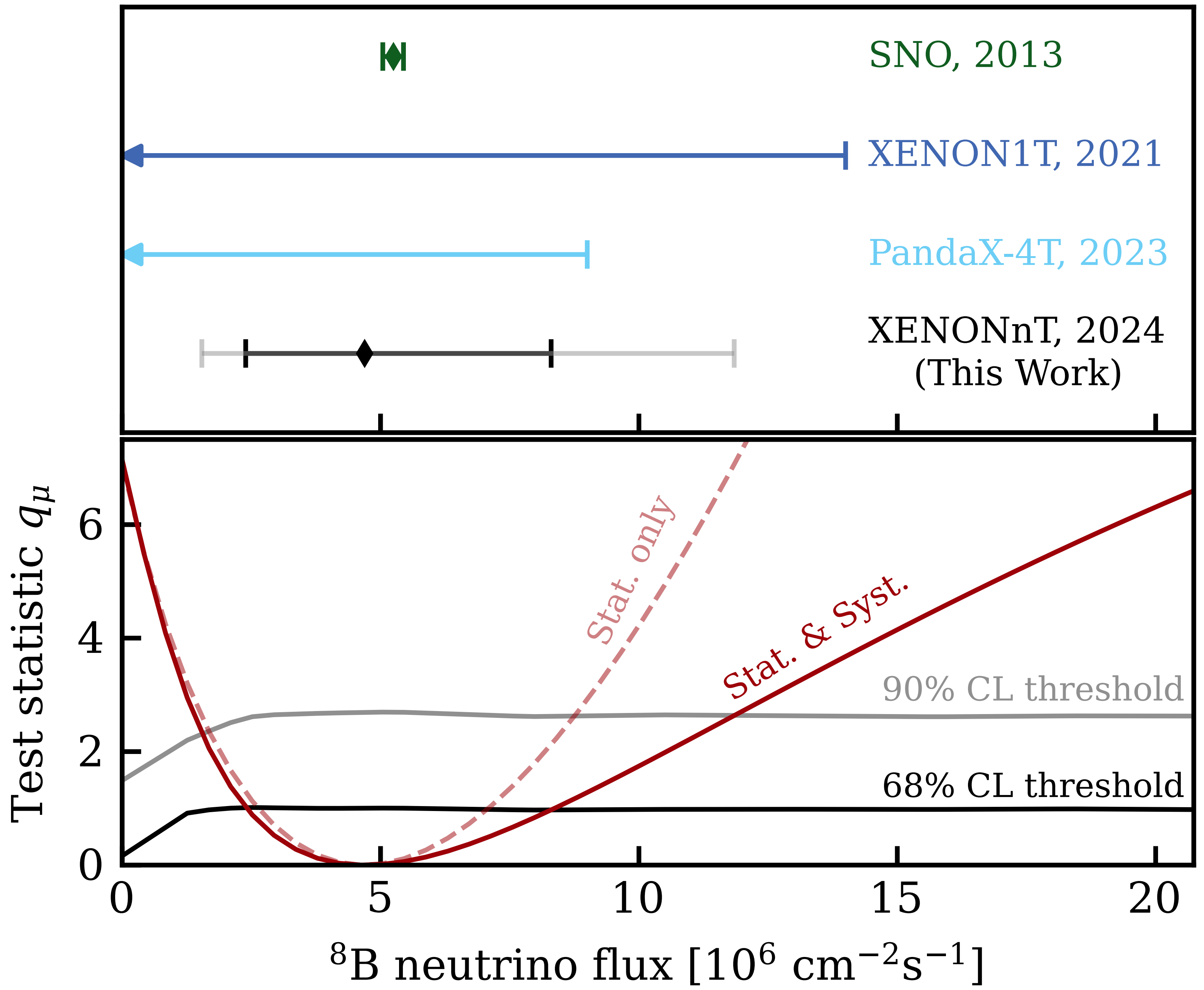
Observed	37	

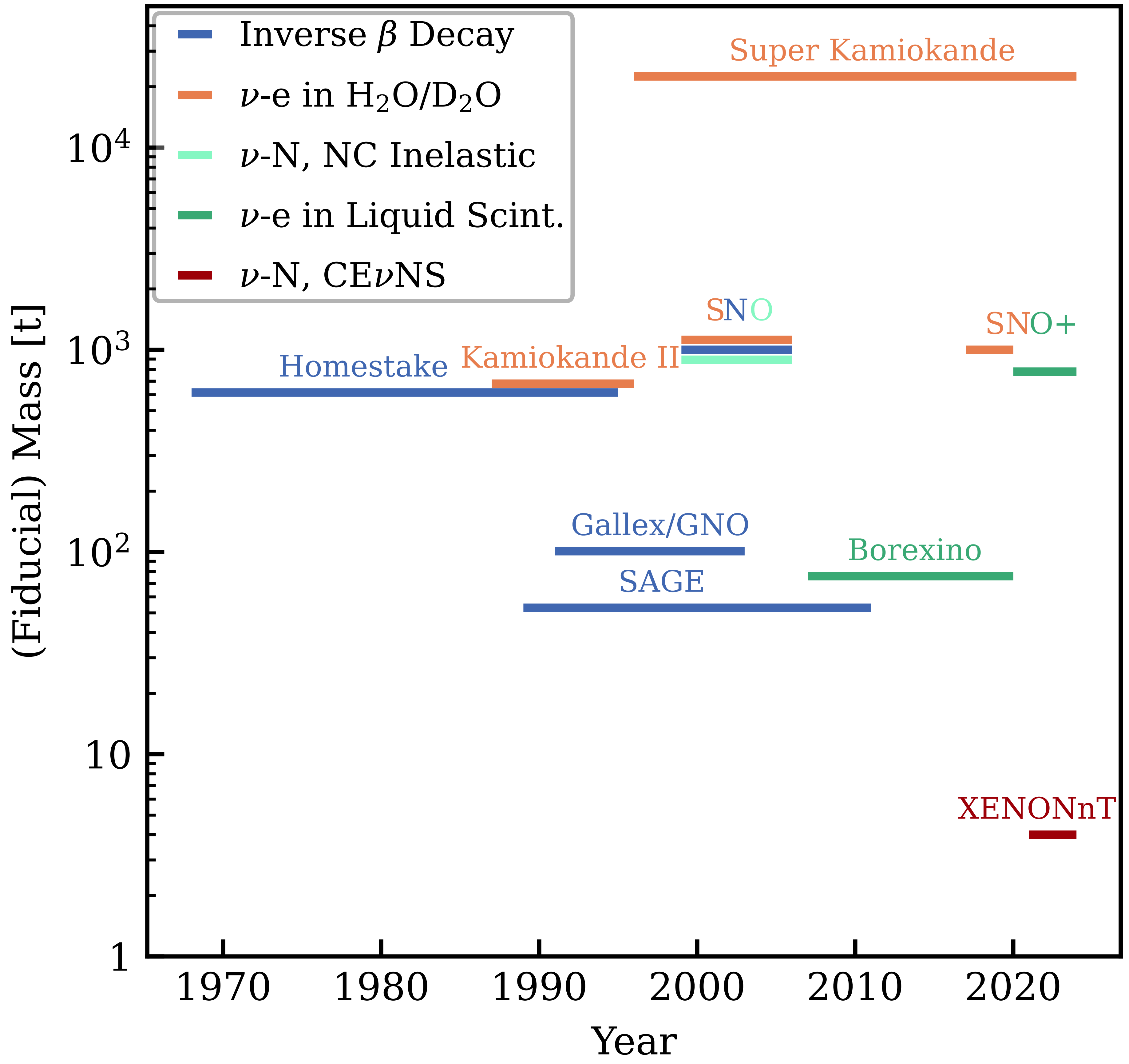
The background-only hypothesis is disfavoured at 2.73σ



- Measured ^{8}B neutrino flux: $4.7^{+3.6}_{-2.3} \times 10^{6}\ \mathrm{cm}^{-2} \cdot \mathrm{s}^{-1}$
- Flux measurement in agreement with SNO (2013)

Phys.Rev.Lett. 92 (2004) 181301

Summary



- **XENONnT performed a blind search for ^{8}B CEνNS**
  - 2.73σ discovery significance
  - Measured ^{8}B neutrino flux: $4.7^{+3.6}_{-2.3} \times 10^6\ \mathrm{cm}^{-2} \cdot \mathrm{s}^{-1}$
- **First** detected astrophysical ν in a dark matter detector
- **First** measured CEνNS from astrophysical ν source
- **First** measured CEνNS with a Xe target

- XENONnT keeps taking data: **stay tuned for more results…**

Thank you.