



University of
Zurich^{UZH}



First measurement of solar ^8B CE ν NS with the **XENONnT** dark matter experiment

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

EPS-HEP

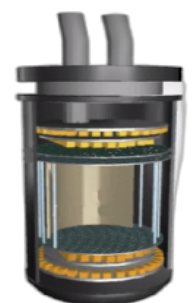
July 8th 2025, Palais du Pharo, Marseille



The XENON Collaboration



XENON10
2005
25 Kg LXe



XENON100
2008
160 Kg LXe



XENON1T
2016
3200 Kg LXe



XENONnT
2020
8500 Kg LXe

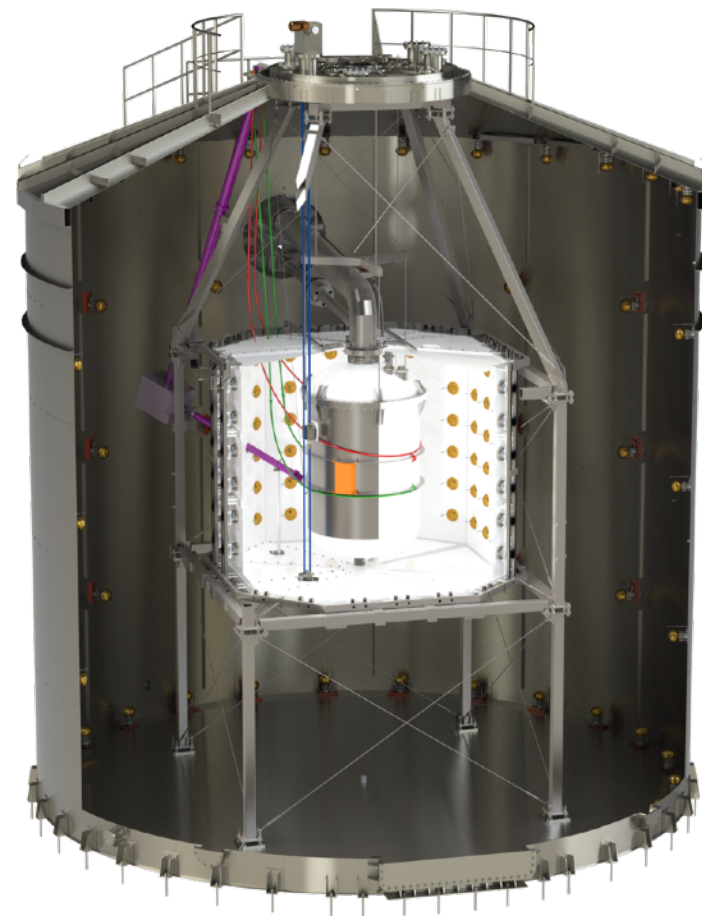


~200 Scientists
30 Institutions
12 countries

The XENONnT Experiment

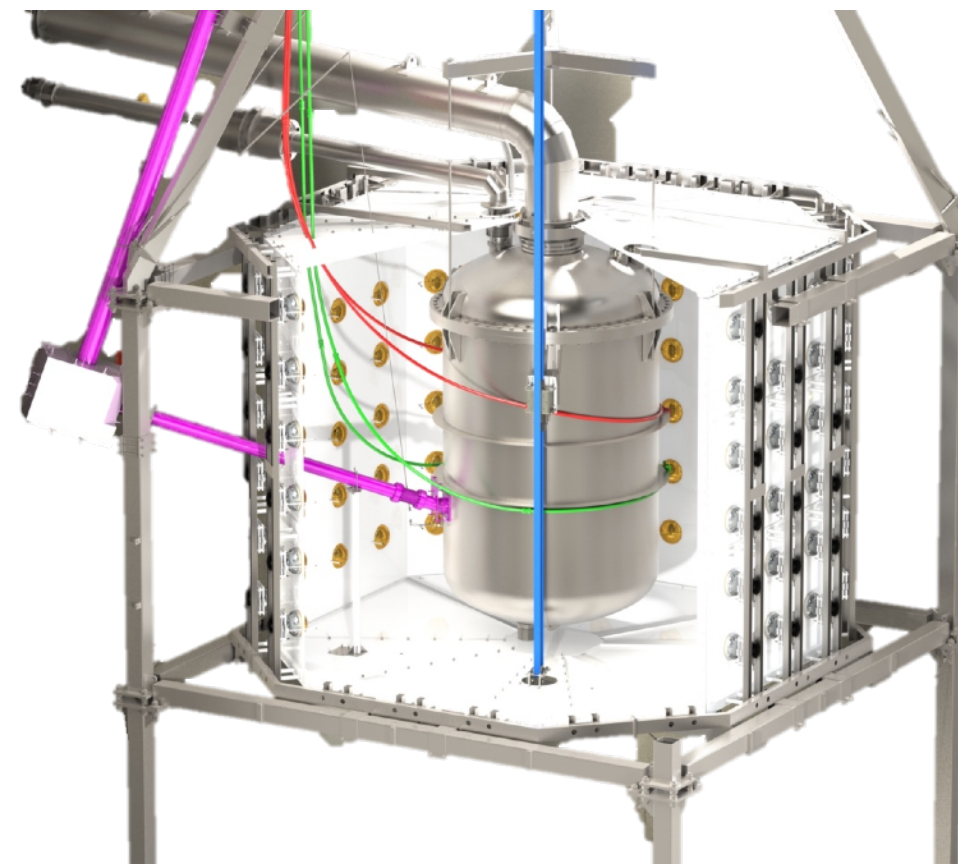


Water Cherenkov Muon Veto (MV)



- **~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)

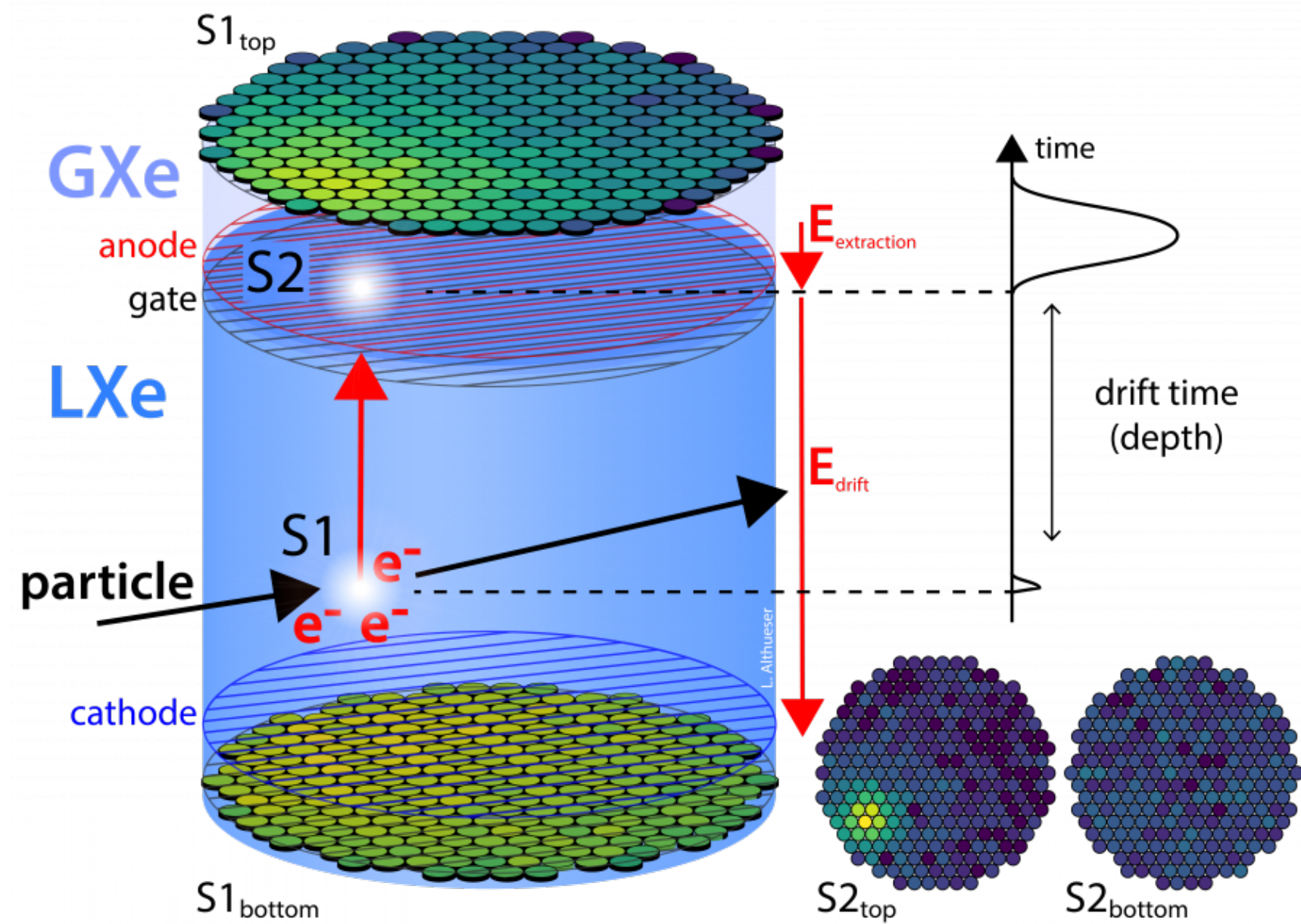


- **5.9 t** active LXe mass
- **1.3 x 1.5 m** diameter × height
- **494** PMTs (3" Hamamatsu R11410-21)
- **23 V/cm** electric drift field
- **2.9 kV/cm** extraction field

Dark Matter Direct Detection with XENONnT



Main detection channel: coherent elastic weakly interacting massive particle (WIMP) - nucleus scattering



Signals:

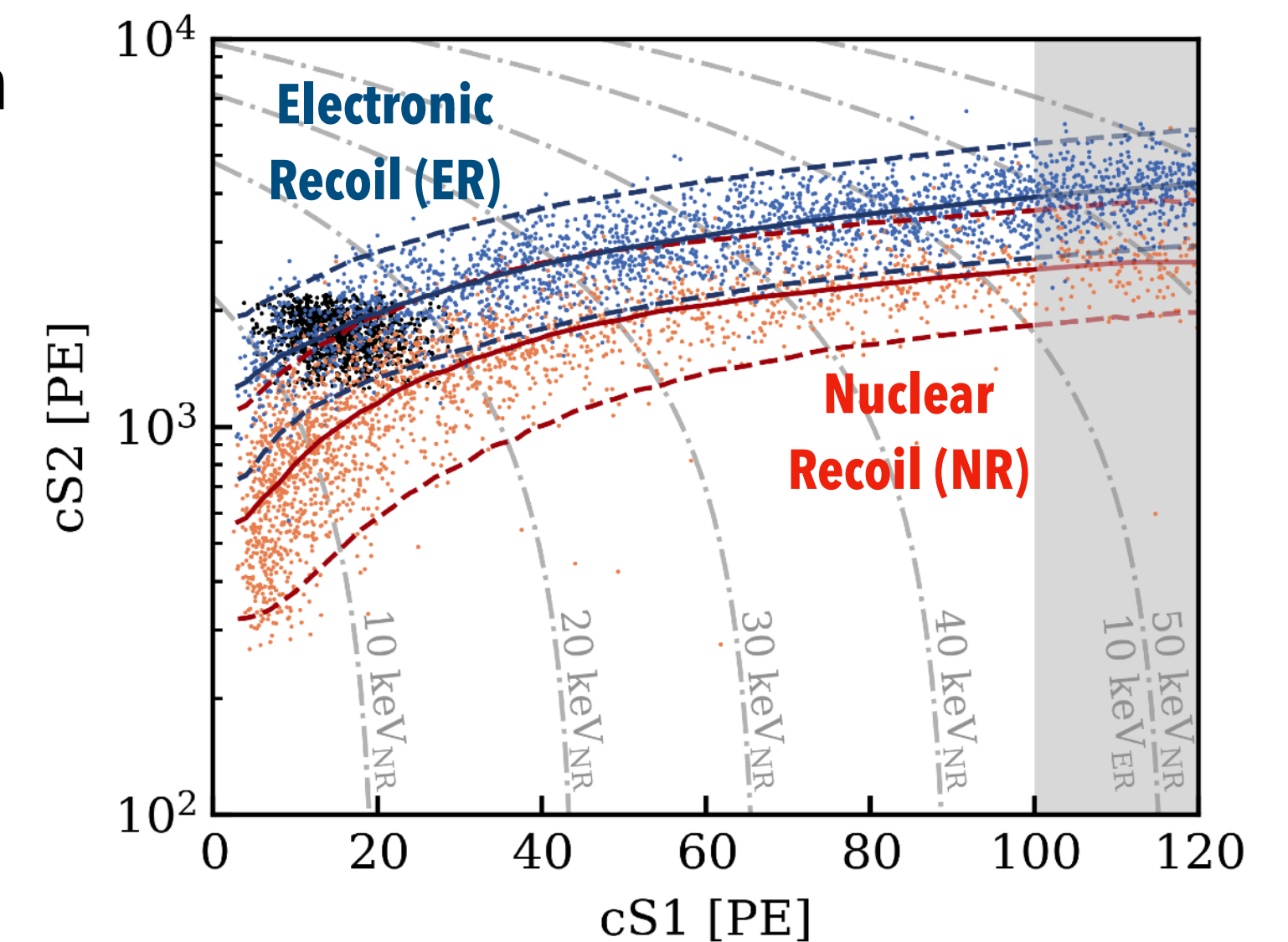
- Prompt scintillation light (**S1**) in liquid xenon (LXe)
- Secondary light (**S2**) in gas xenon (GXe) from ionization charges

Dual-phase 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 first two science runs



- **Data taken between July 2021 and August 2023**

- ~3.5 t x yr exposure
- 4 t fiducial mass

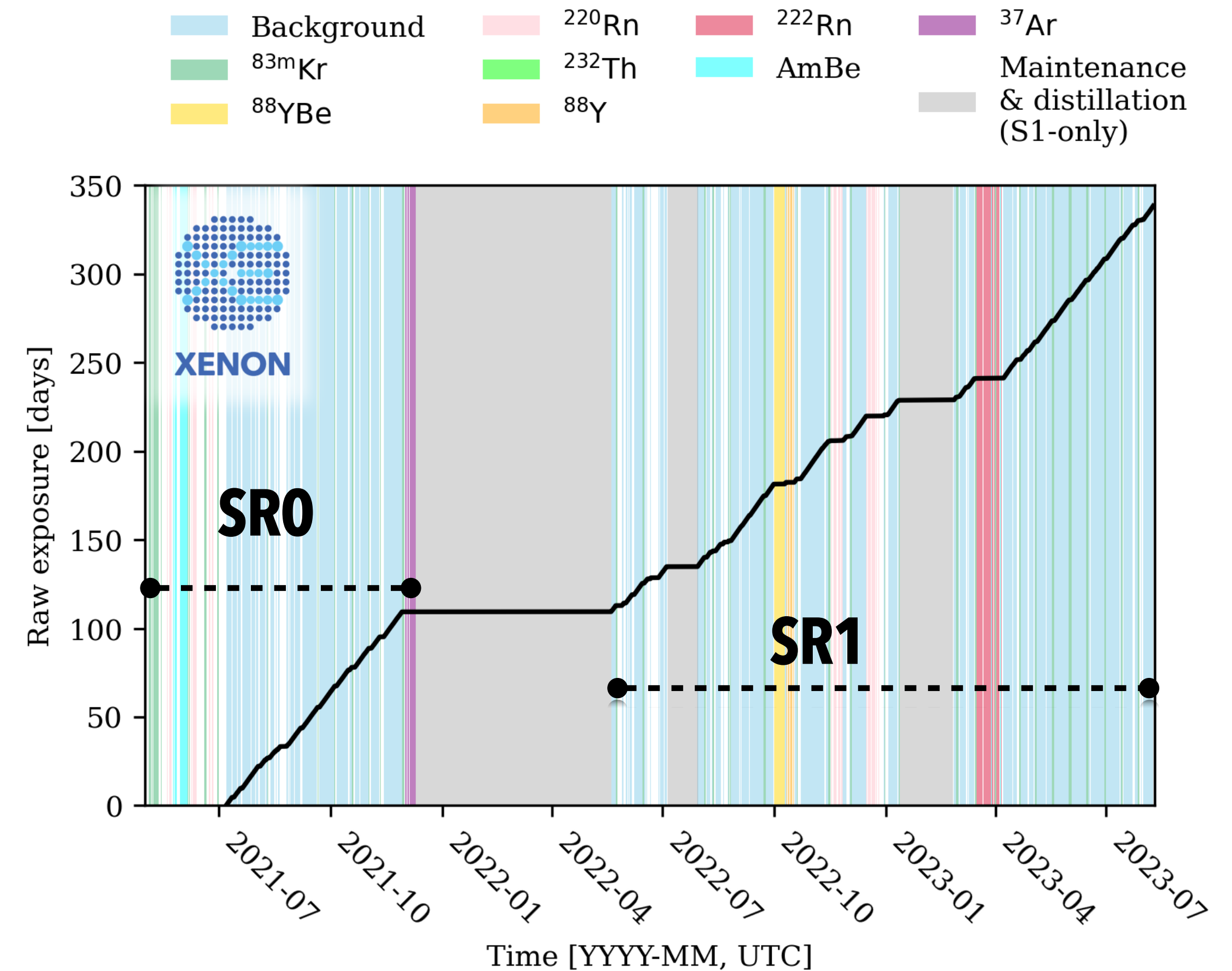
- **Stable detector response**

- 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



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

[arXiv:2502.18005](#) (2025)

2023, 2025

SR0, SR0 + SR1

ν

^8B solar neutrinos

Phys.Rev.Lett. 133 (2024) 19, 191002

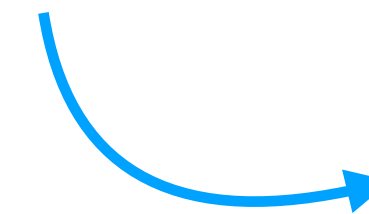
2024

SR0 + SR1

Physics Results so far



This talk



ν

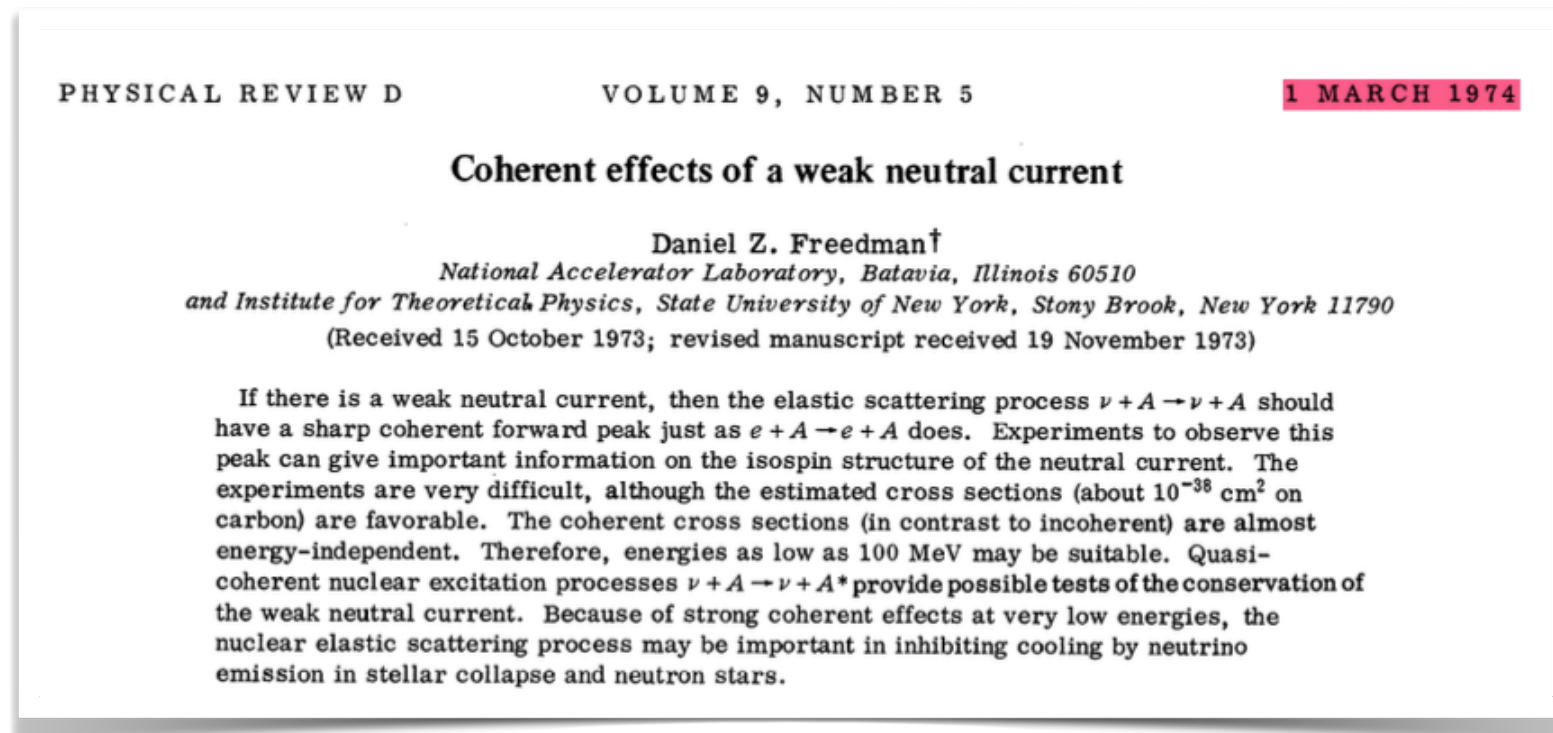
⁸B solar neutrinos

Phys.Rev.Lett. 133 (2024) 19, 191002

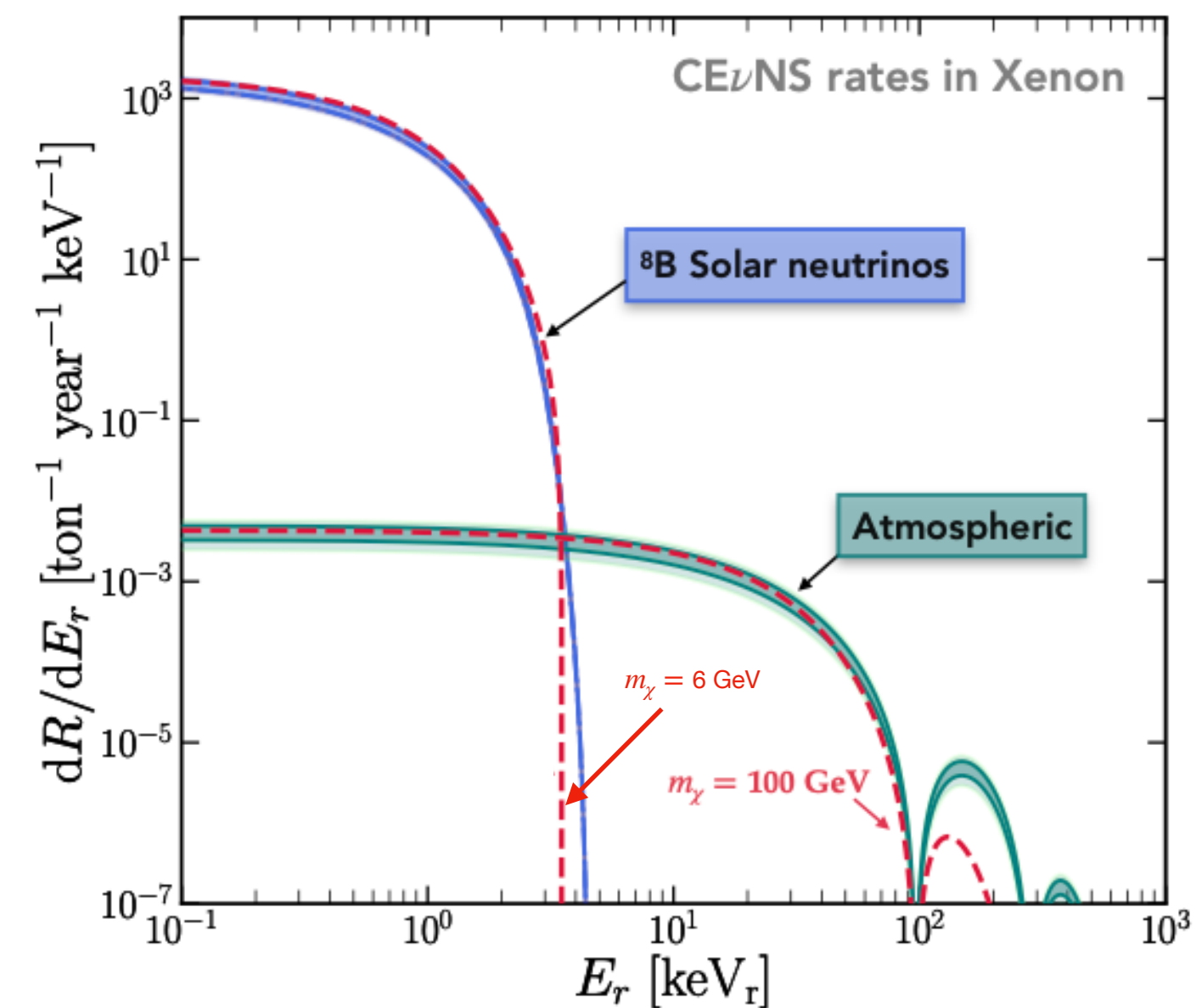
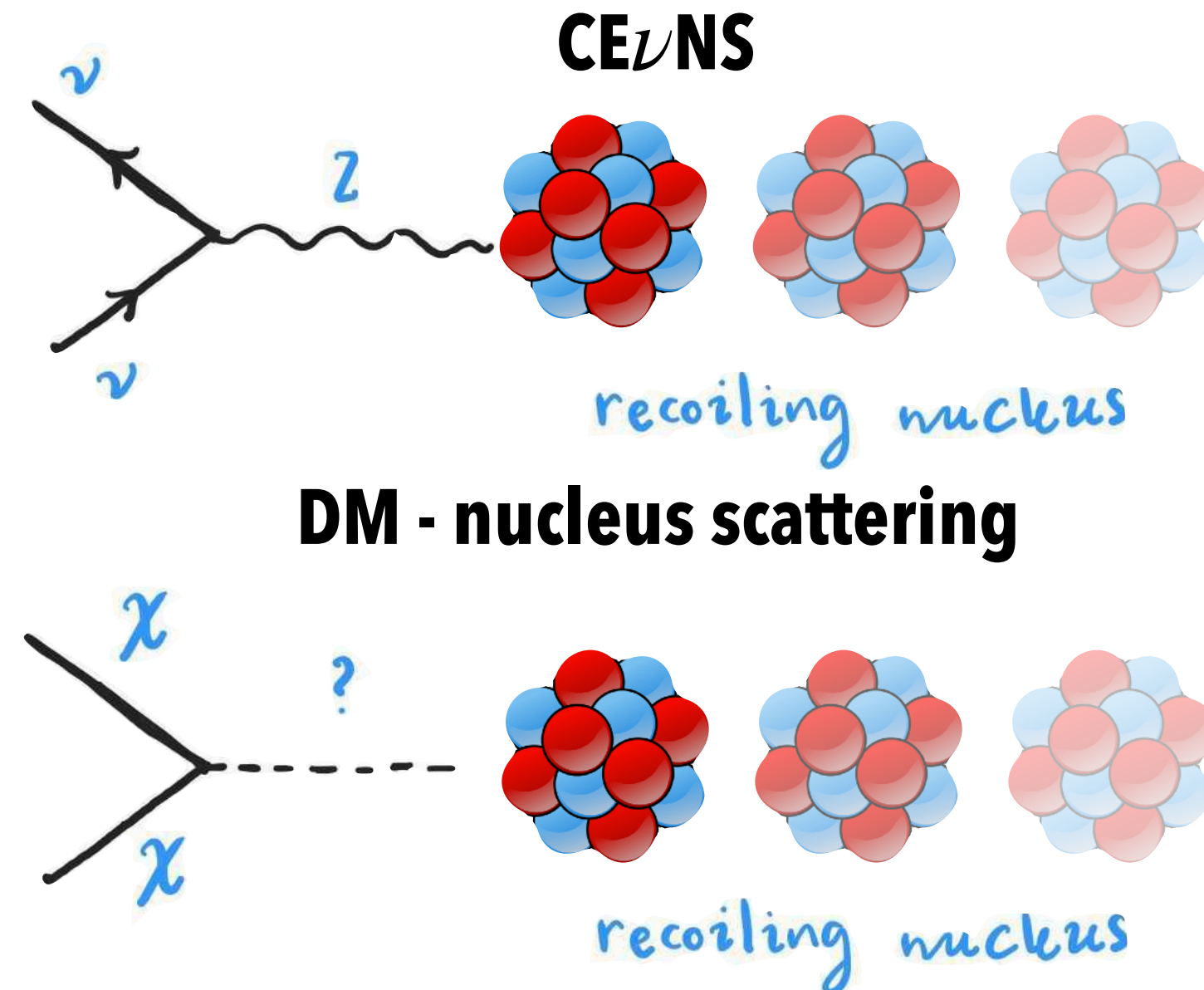
2024

SR0 + SR1

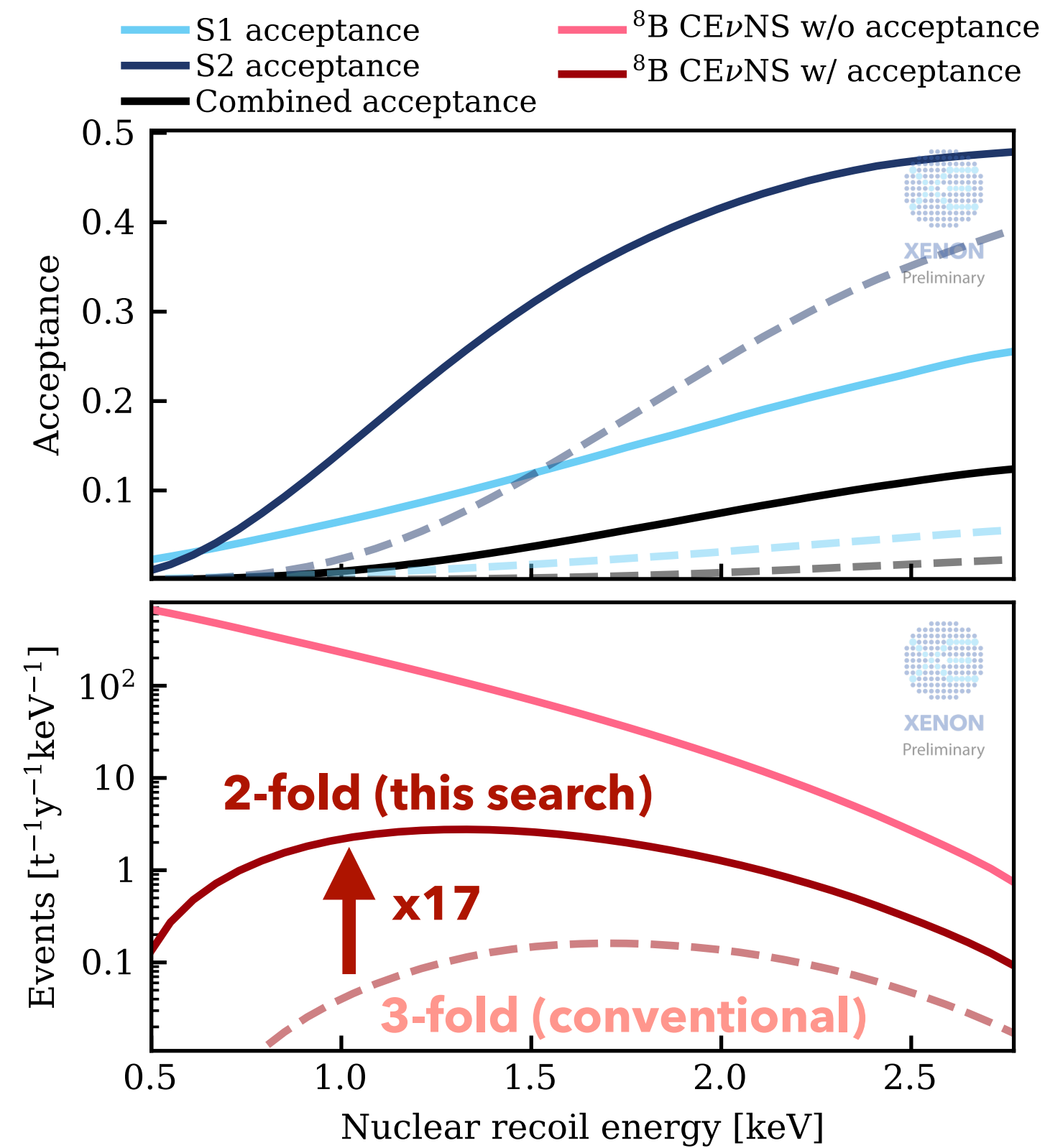
Elastic Scattering of Dark Matter and Neutrinos



- **CE ν NS**: Coherent Elastic Neutrino - Nucleus Scattering
 - First measured by COHERENT (2017) with spallation neutron source
- ^8B CE ν NS typical recoil energy ≤ 1.5 keV_{NR}
- Mimics single scatter NR signals expected from WIMPs



Lowering the Threshold



- 0.2 ^8B events expected in 3-fold conventional analysis
- PMT coincidence requirement reduced from 3 to 2 hits*

Region of interest for ^8B CE ν NS search:

- S1: [2, 3] hits
- S2: [120, 500] photoelectrons $\simeq$ [4, 17] electrons

~17 times larger ^8B CE ν NS rate!

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

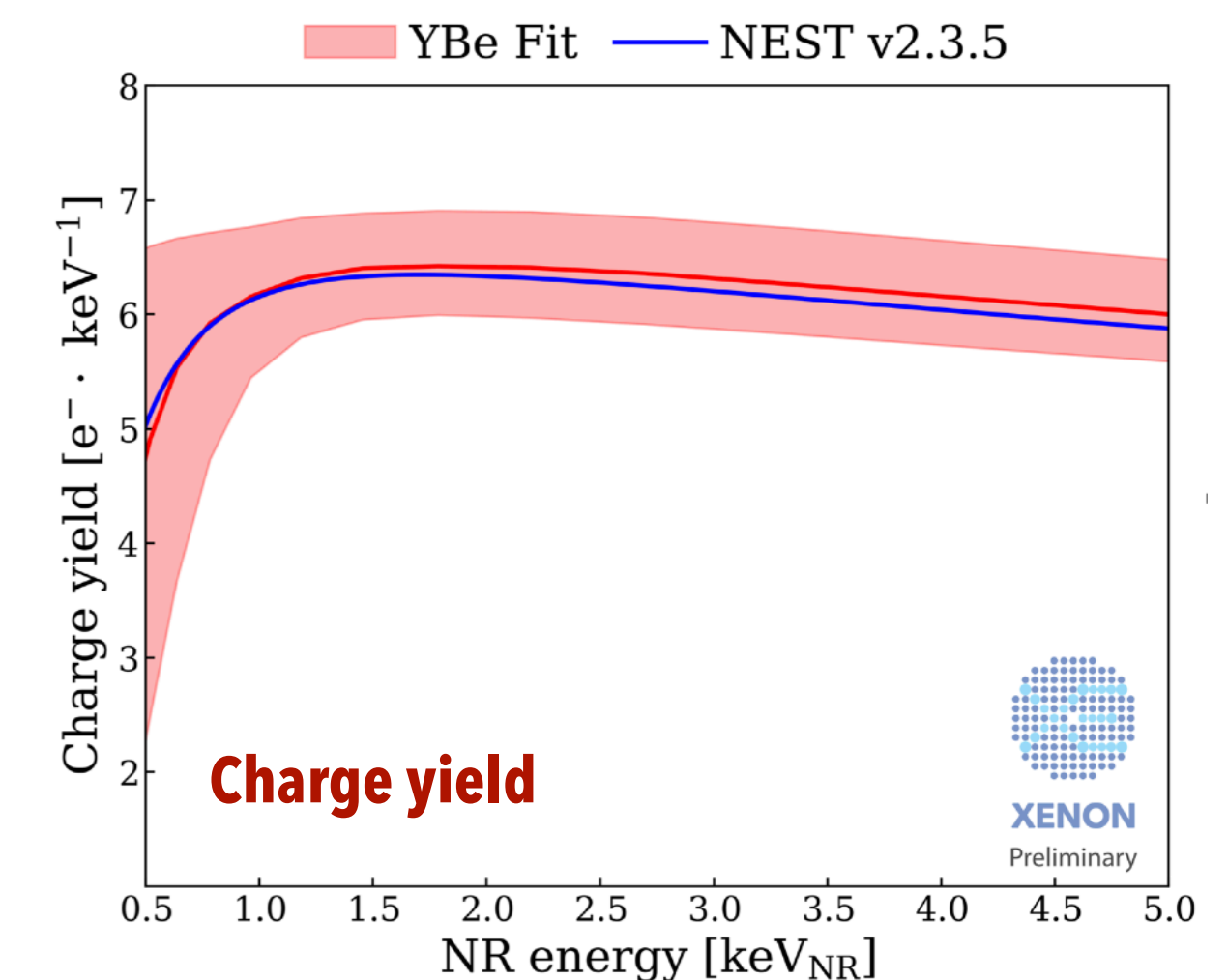
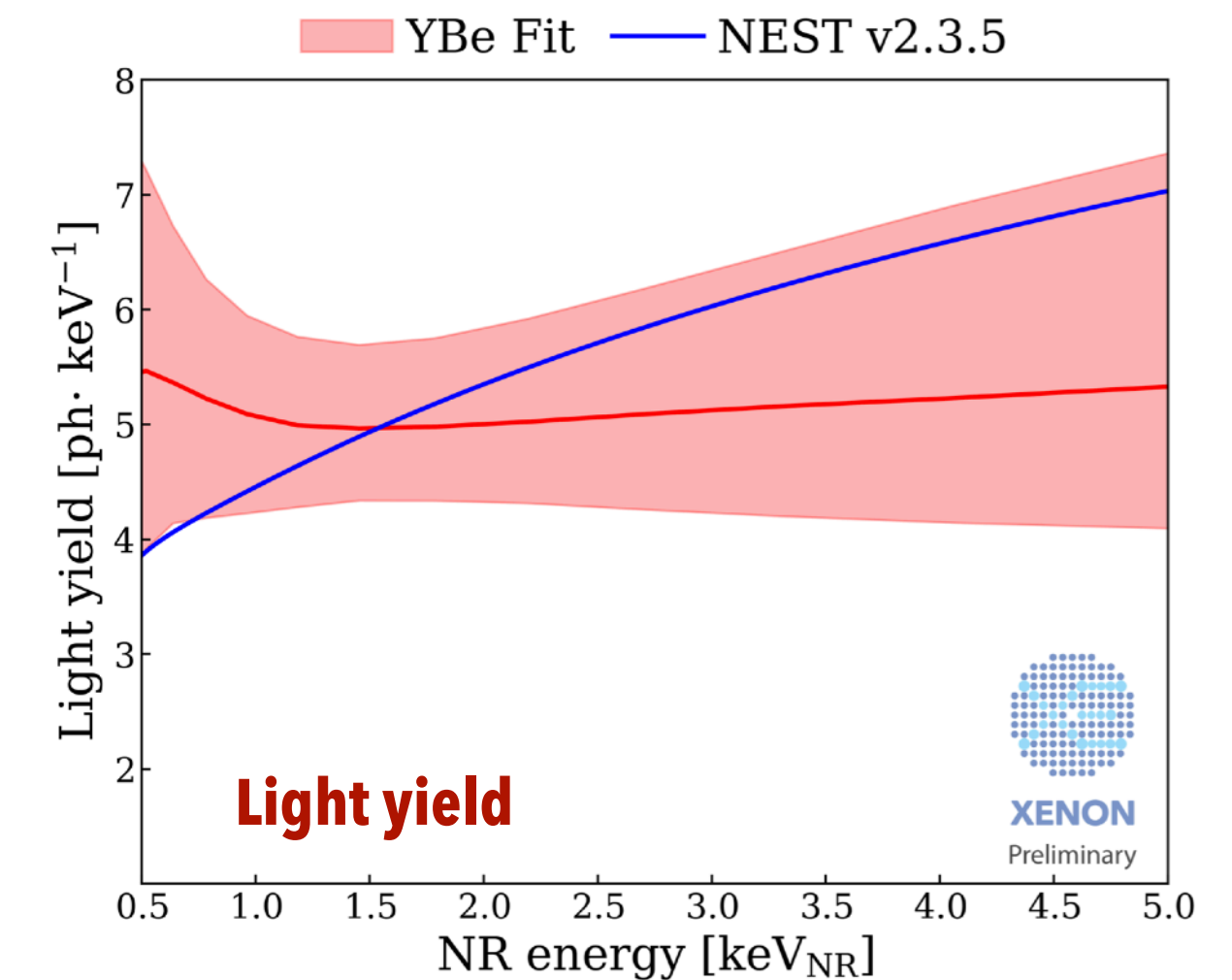
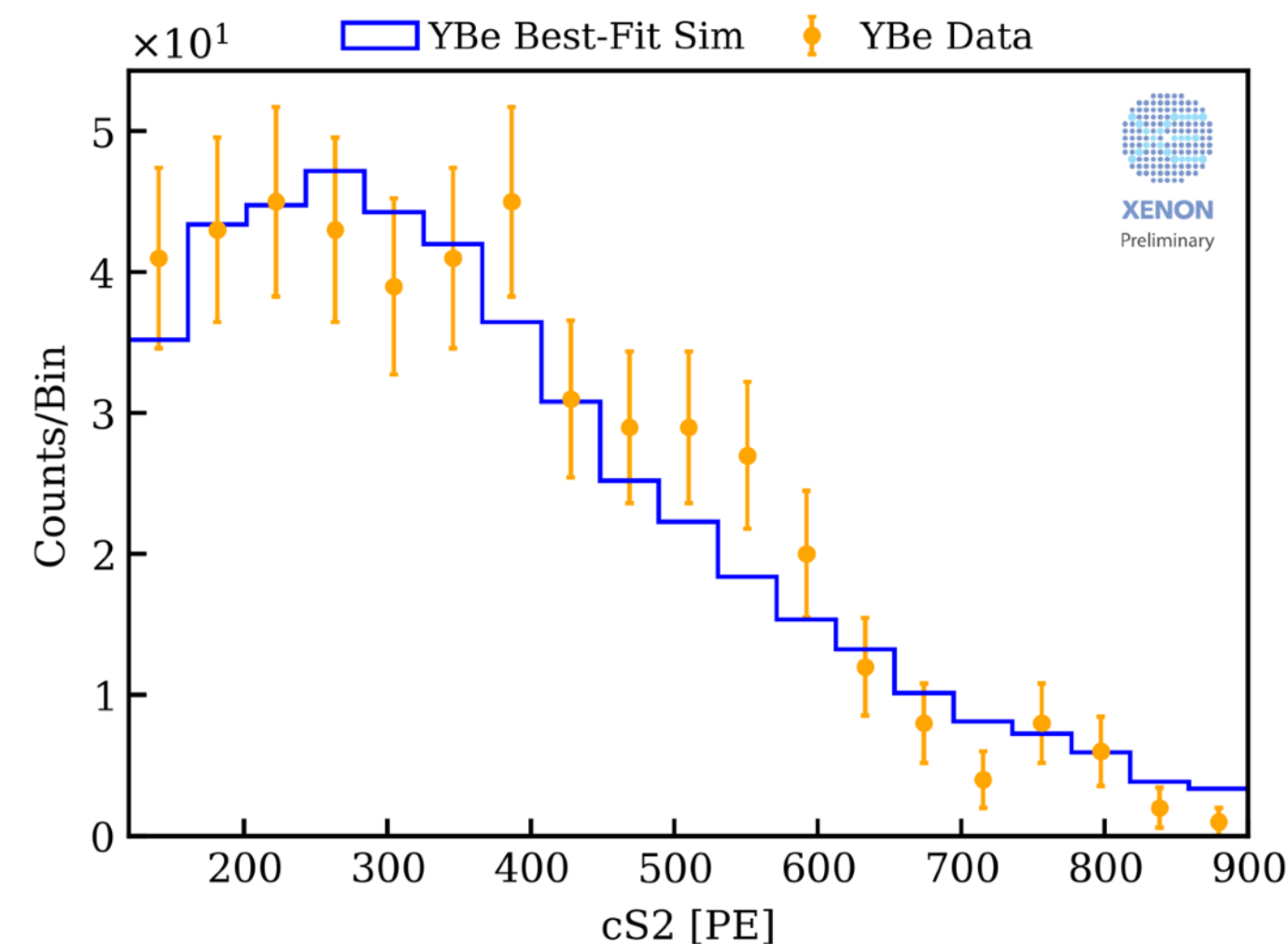
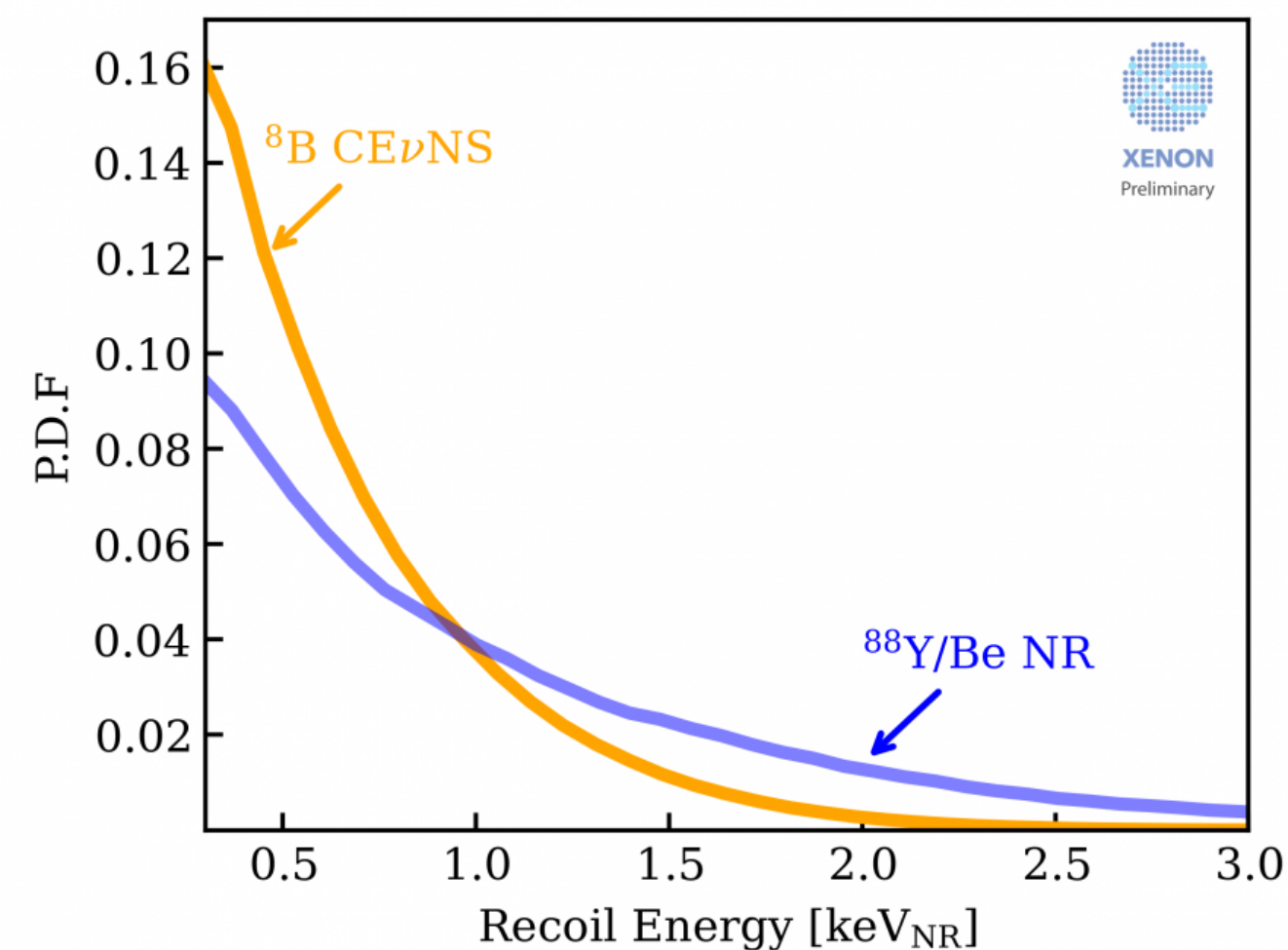
*PMT hit corresponds to a detected photon

Low-Energy Calibration with ^{88}YBe

arXiv:2412.10451



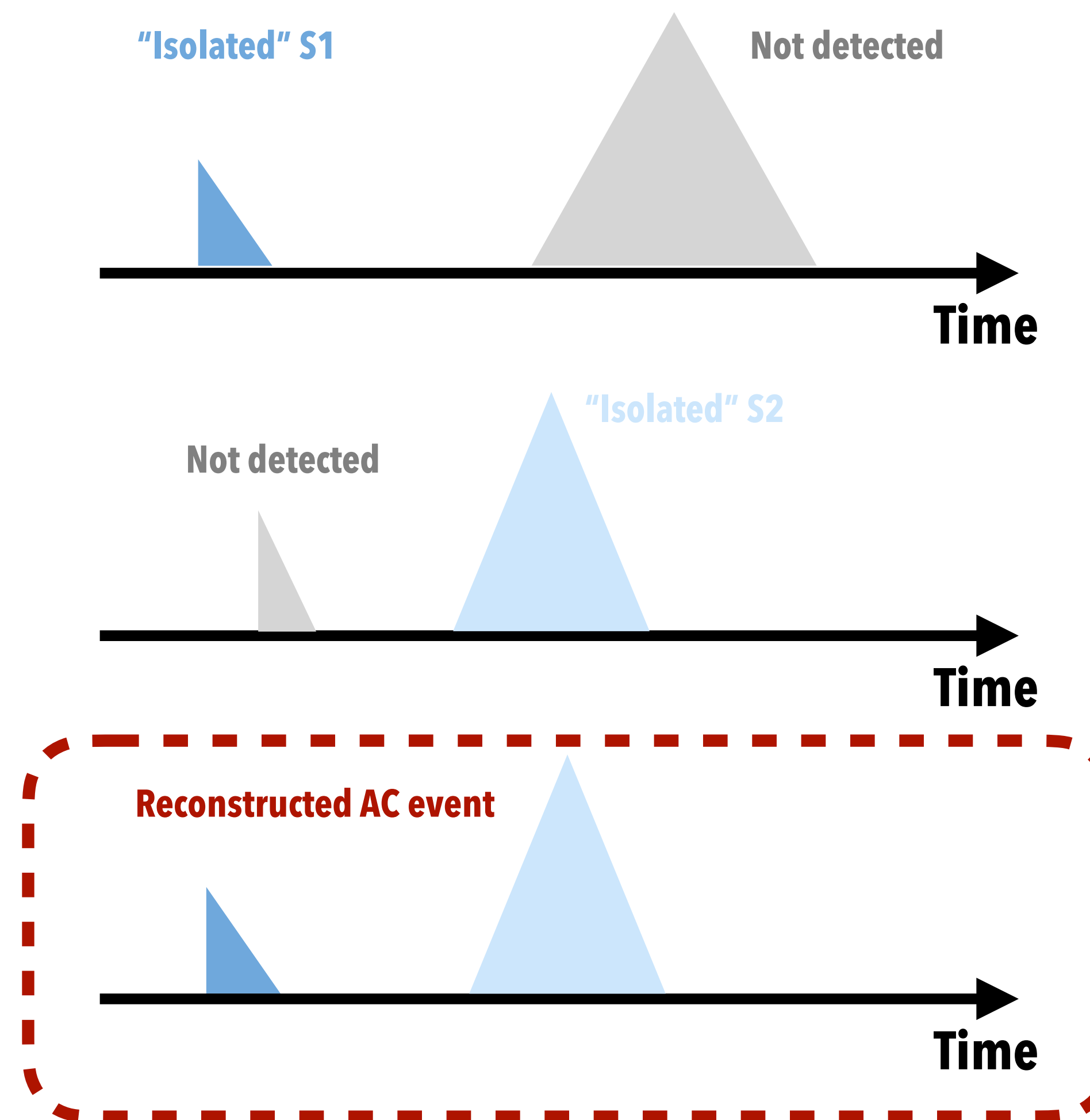
- External ^{88}YBe source: $\gamma + {}^9\text{Be} \rightarrow n + {}^8\text{Be}$
 - $\sim$ quasi-monoenergetic 152 keV neutrons
 - Nuclear recoil spectrum similar to ${}^8\text{B}$
- Excellent match between simulations and calibration data
- Fit to NEST model to ^{88}YBe data to predict light and charge yields at the XENONnT drift field



Dominant Background: Accidental Coincidence



- Random unphysical pairing of **isolated S1** and **S2**
- Dominant background close to the threshold
- Rate before mitigation:
 - **"Isolated" S1**: ~ 15 Hz
 - **"Isolated" S2**: ~ 0.15 Hz
 - With max. Drift time of 2.25 ms $\rightarrow \sim 400$ AC events per day
- Mitigation techniques include:
 - S1 and S2 Boosted Decision Tree (BDT) classifiers using waveform shape properties
 - S2 time shadow selection

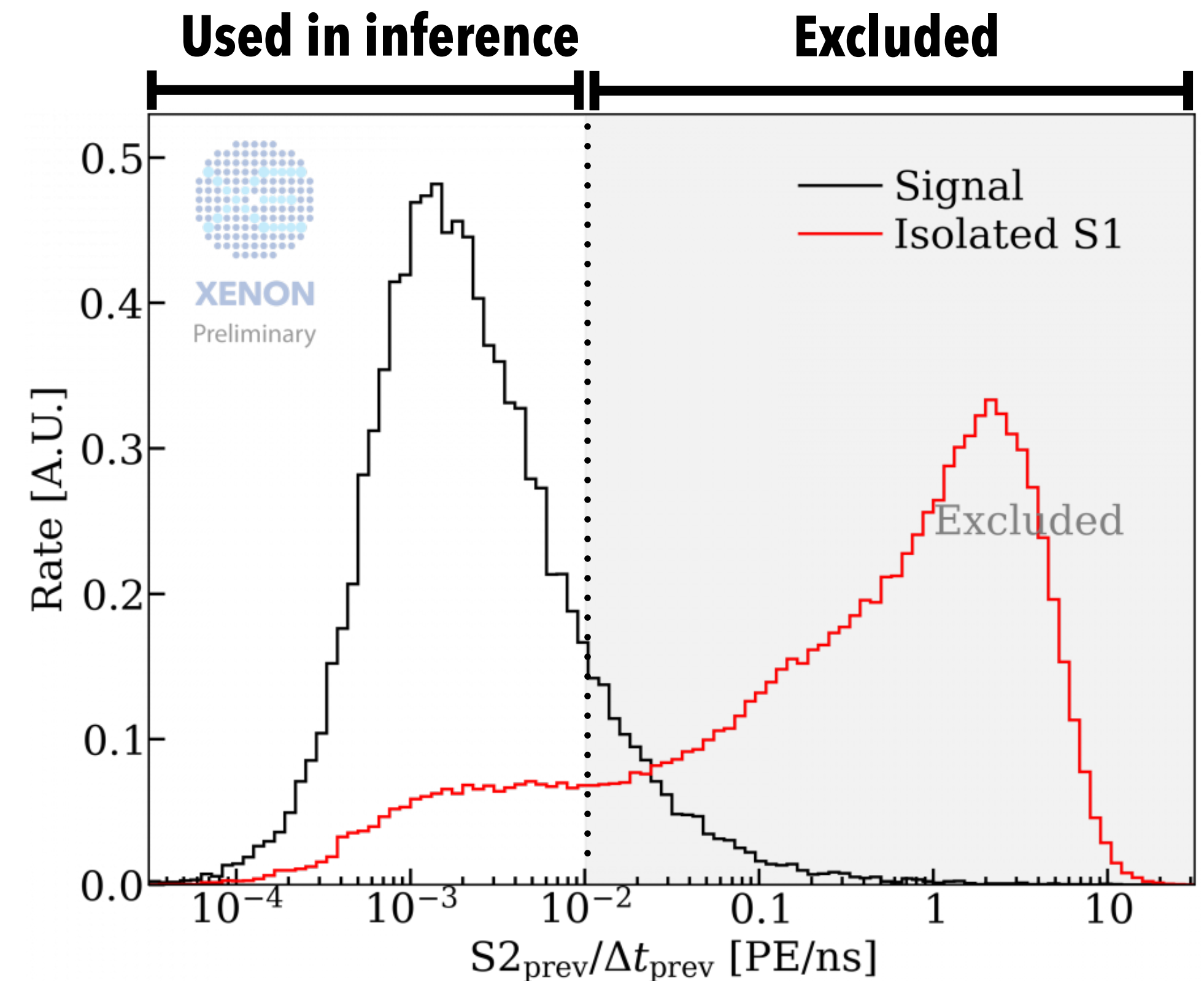
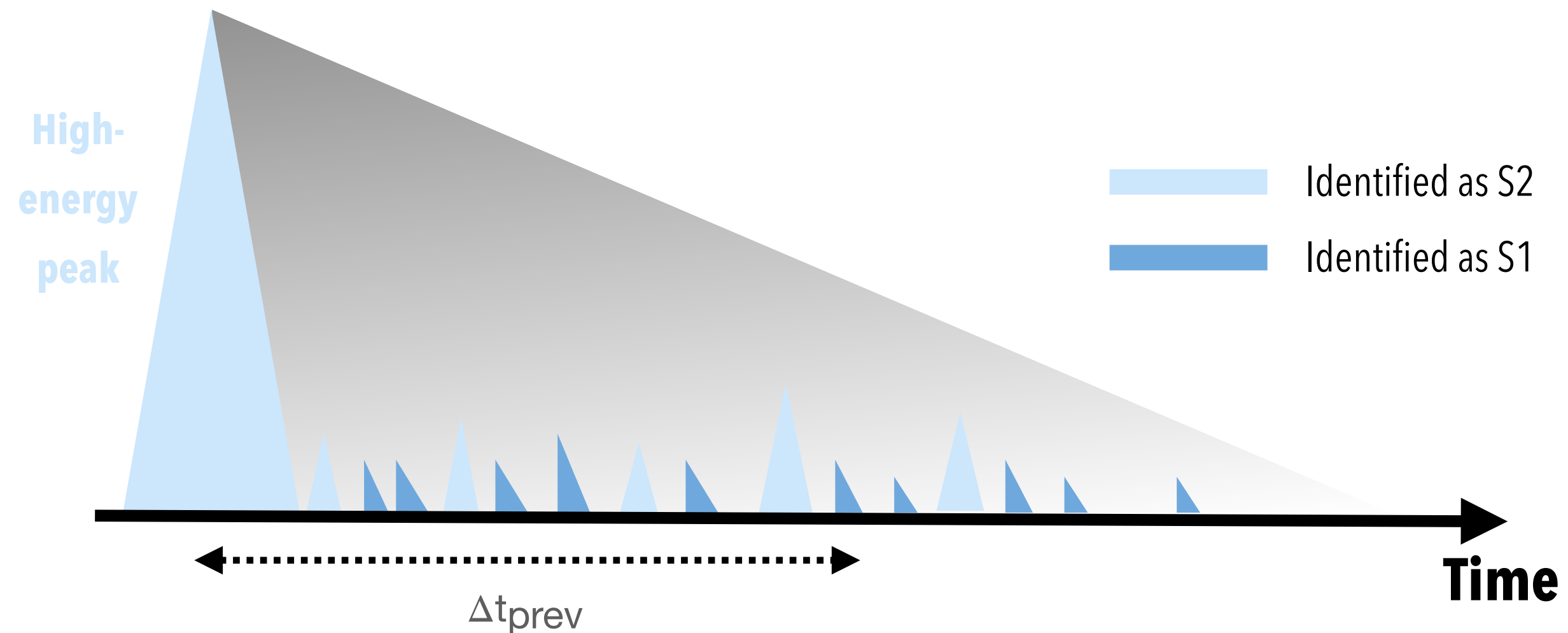


AC Background Suppression



- Mitigated utilizing selections based on time and position correlation to their preceding high-energy S2 peak

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

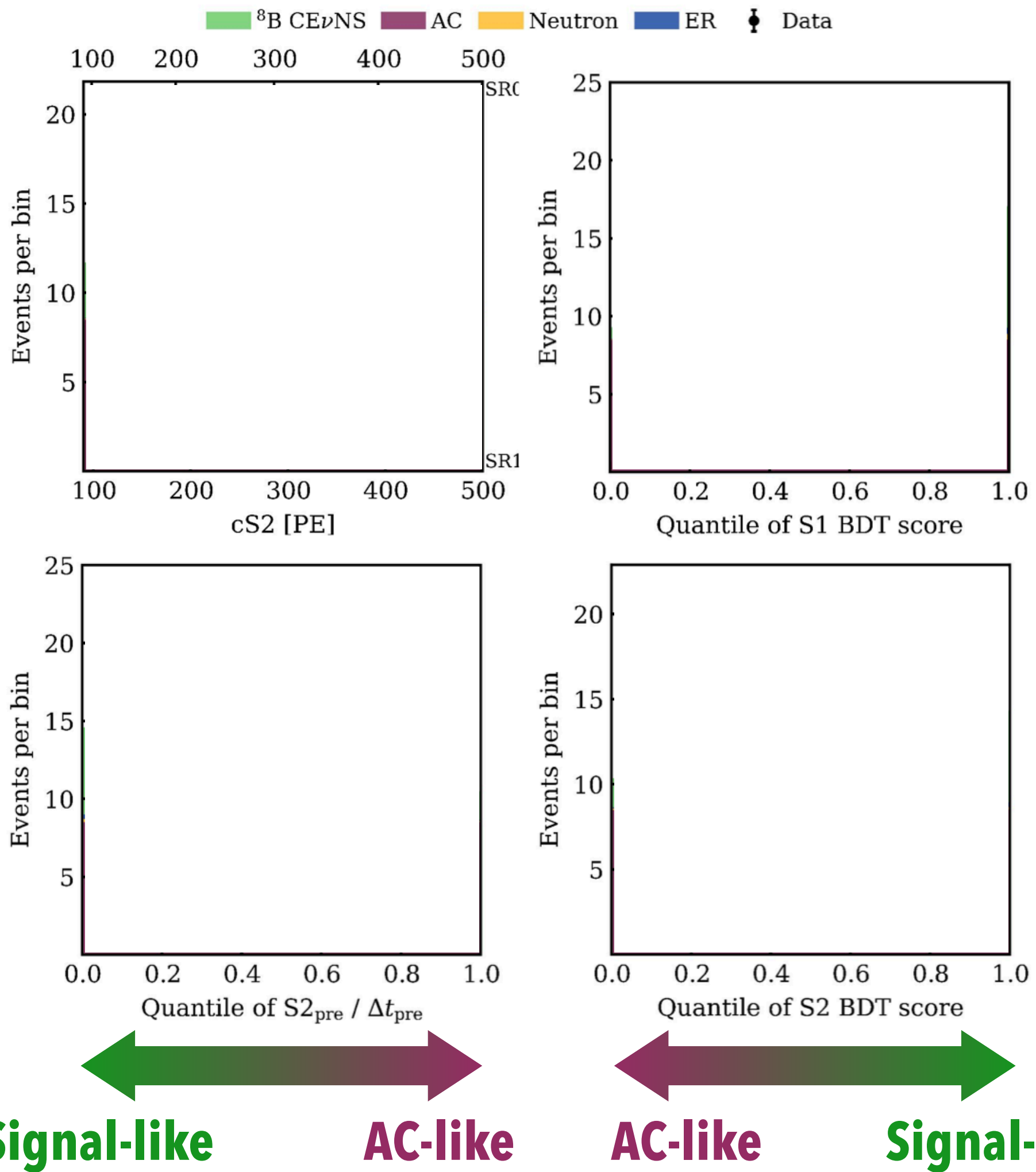


Signal & Background Prediction



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	$26.4^{+1.4}_{-1.3}$
^8B	$11.9^{+4.5}_{-4.2}$

Total exposure: **3.51** ton·year
Expect ^8B CE ν NS: **$11.9^{+4.5}_{-4.2}$** events

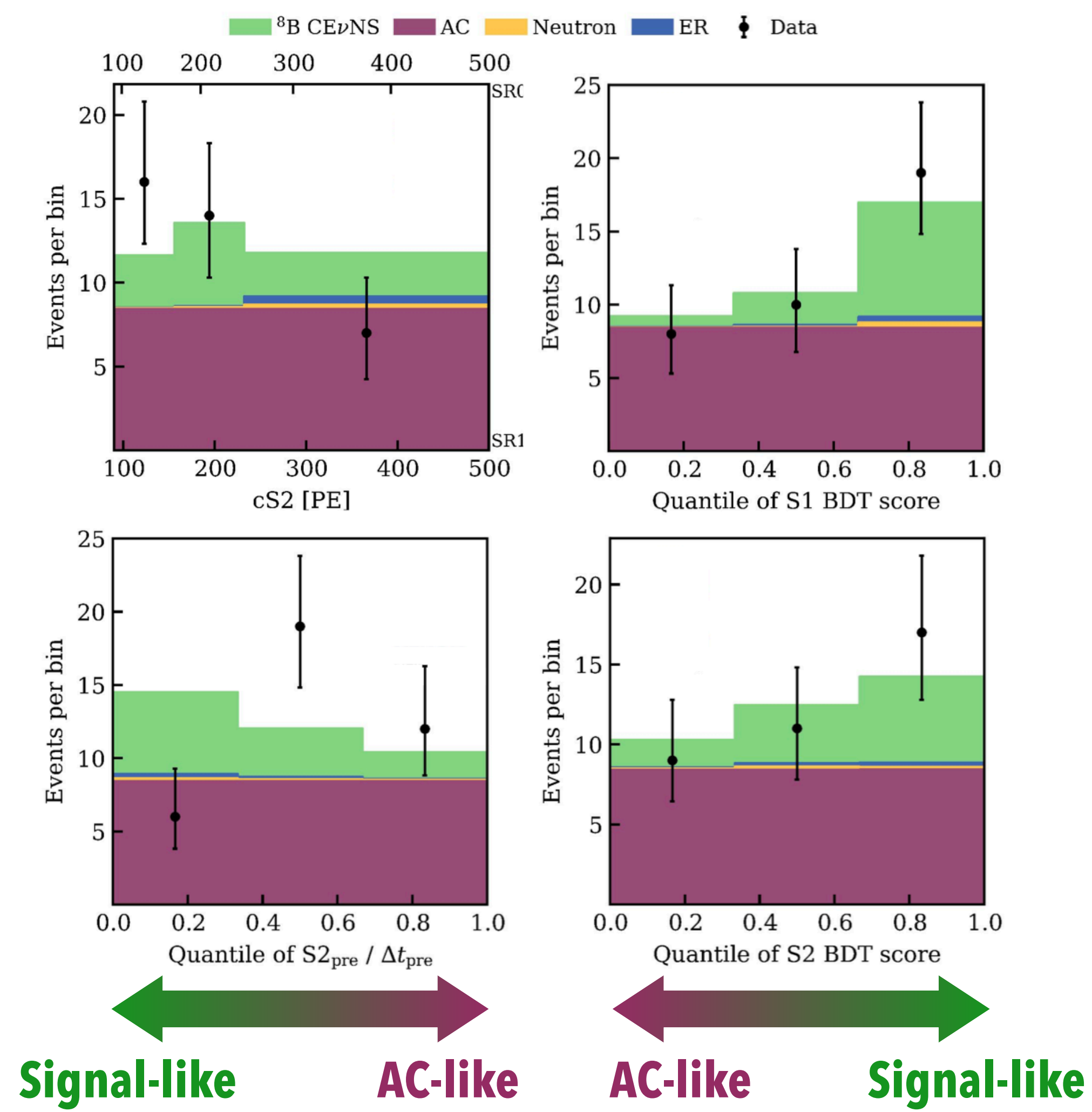


Unblinding Results



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
^8B	$11.9^{+4.5}_{-4.2}$	$10.7^{+3.7}_{-4.2}$
Observed	37	

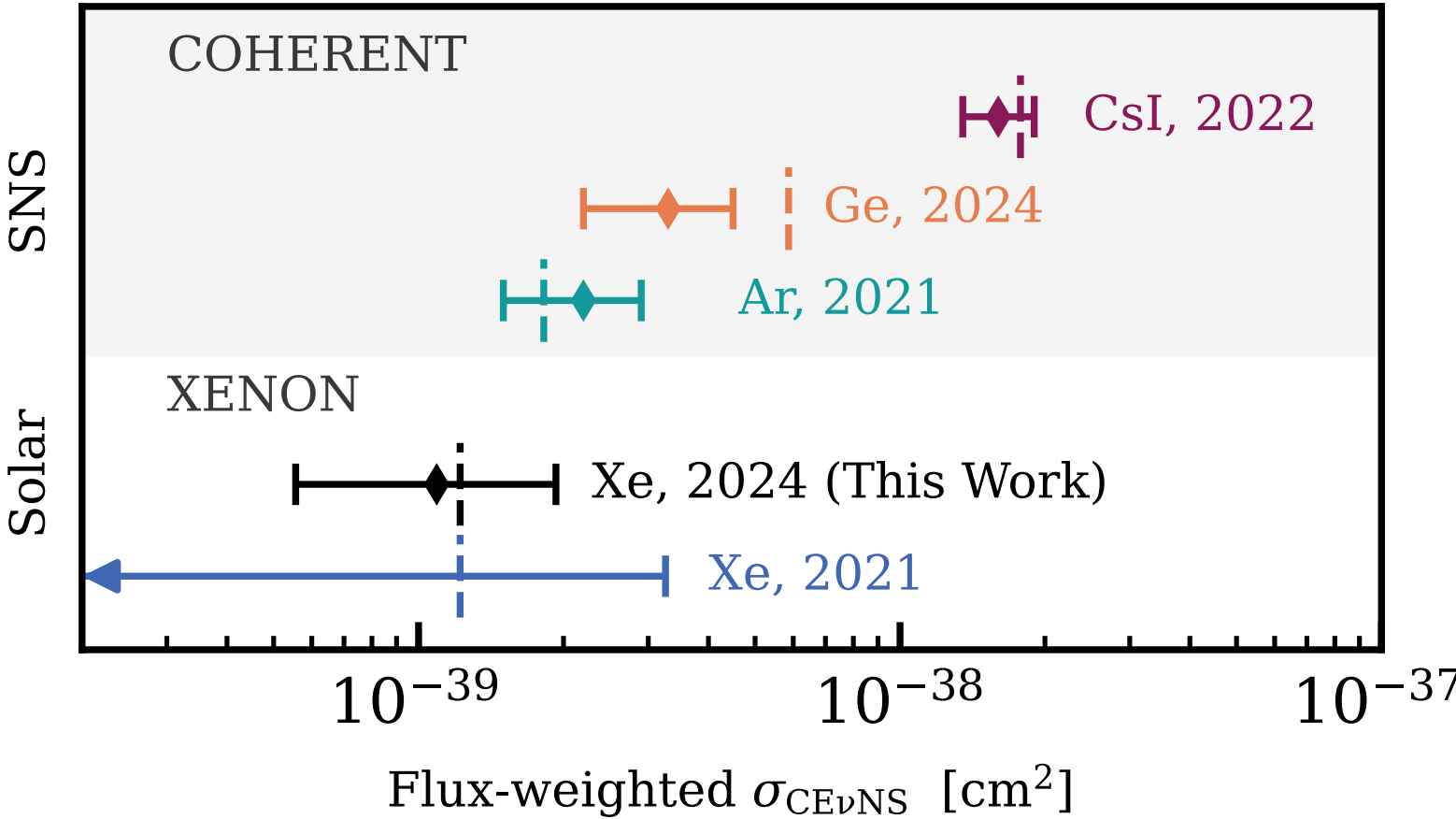
- Overall data agrees with the signal + background expectation in the four-dimension analysis
- Tension in the time shadow dimension is under investigation



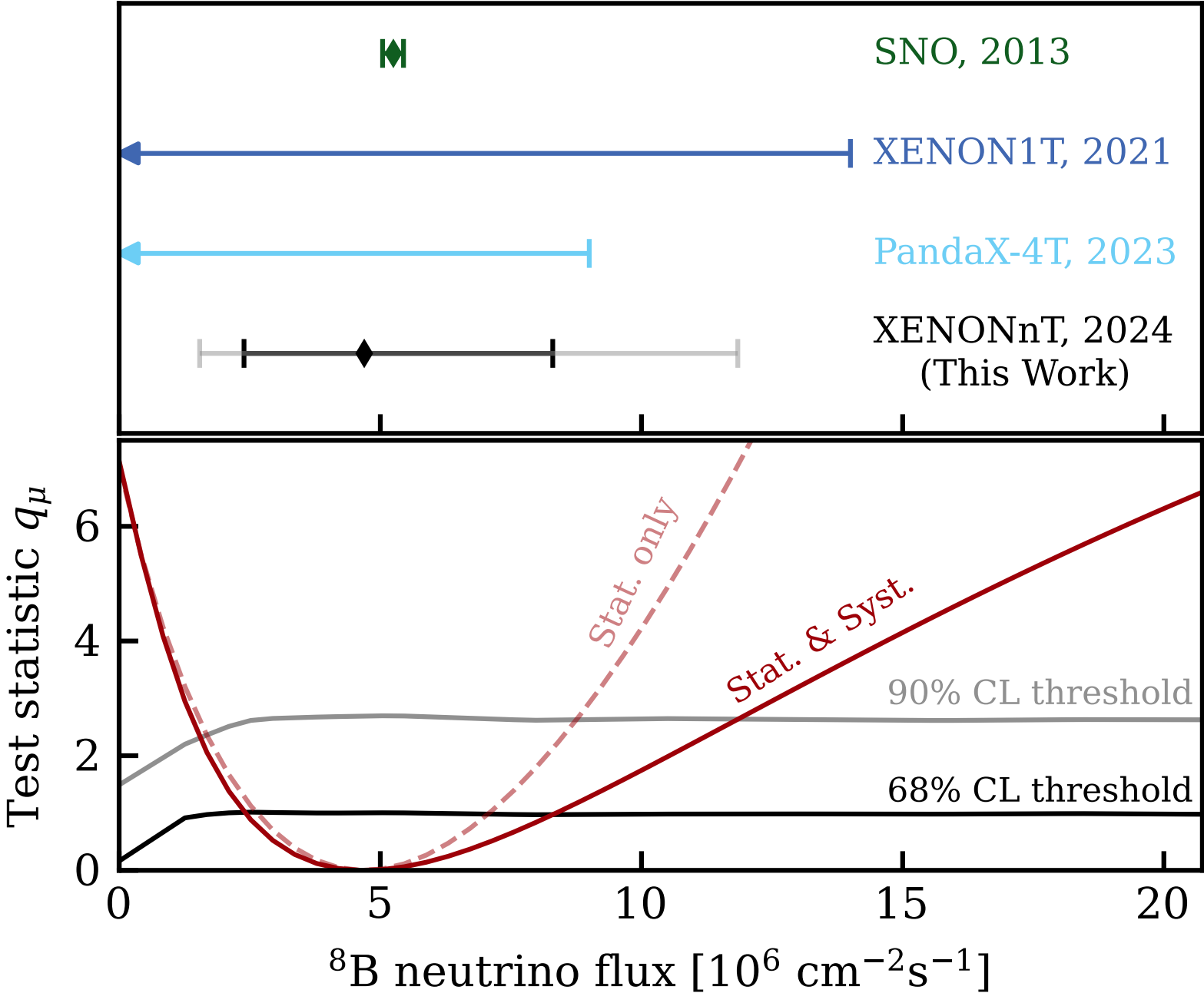
Statistical Inference



- The background-only hypothesis is disfavored at 2.73σ
- Measured ^8B neutrino flux: $(4.7^{+3.6}_{-2.3}) \times 10^6 \text{ cm}^{-2} \cdot \text{s}^{-1}$
- Flux measurement in agreement with SNO (2013)

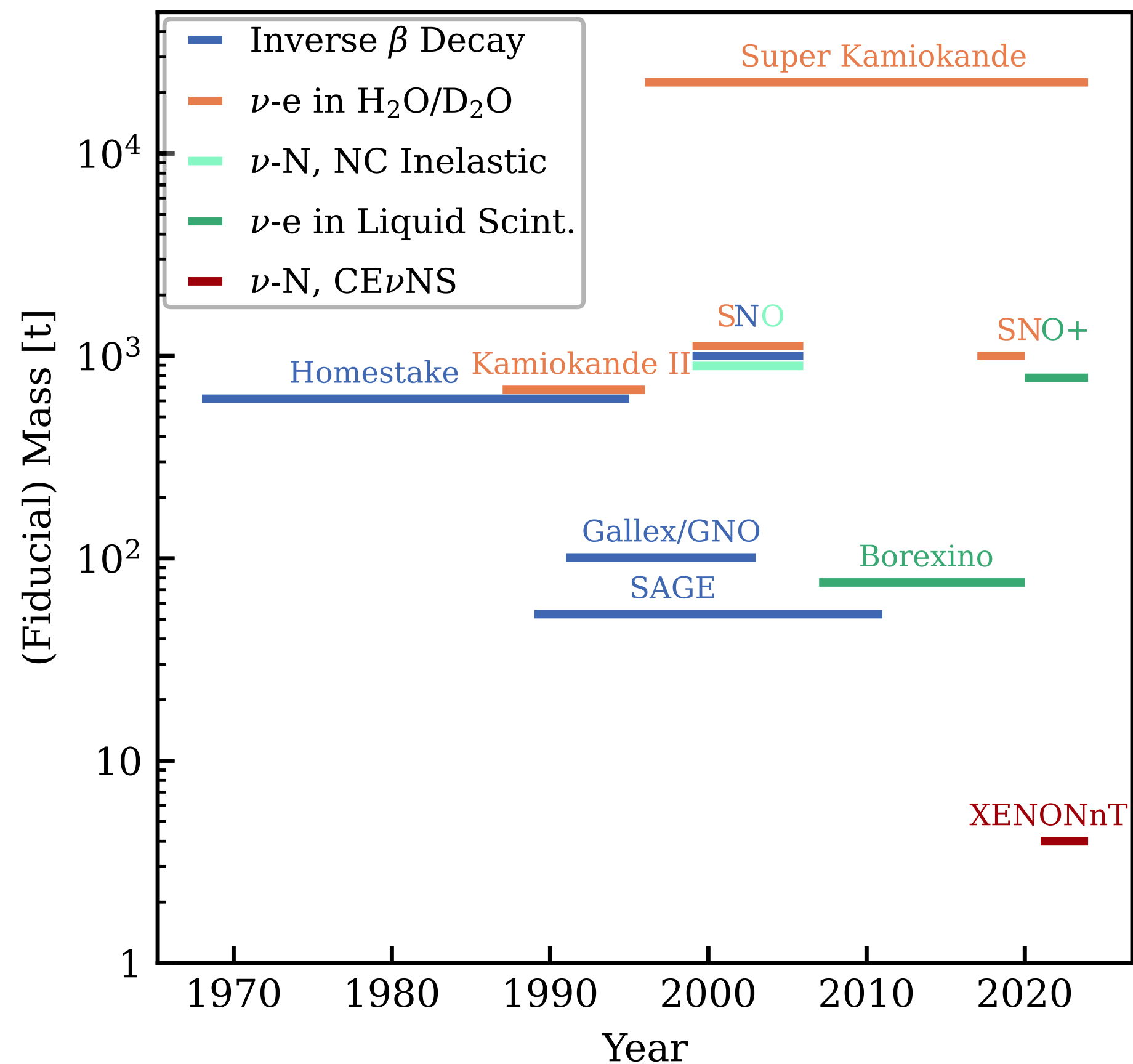


Similar results by Panda-X-4T
Phys. Rev. Lett. 133, 191002 (2024)

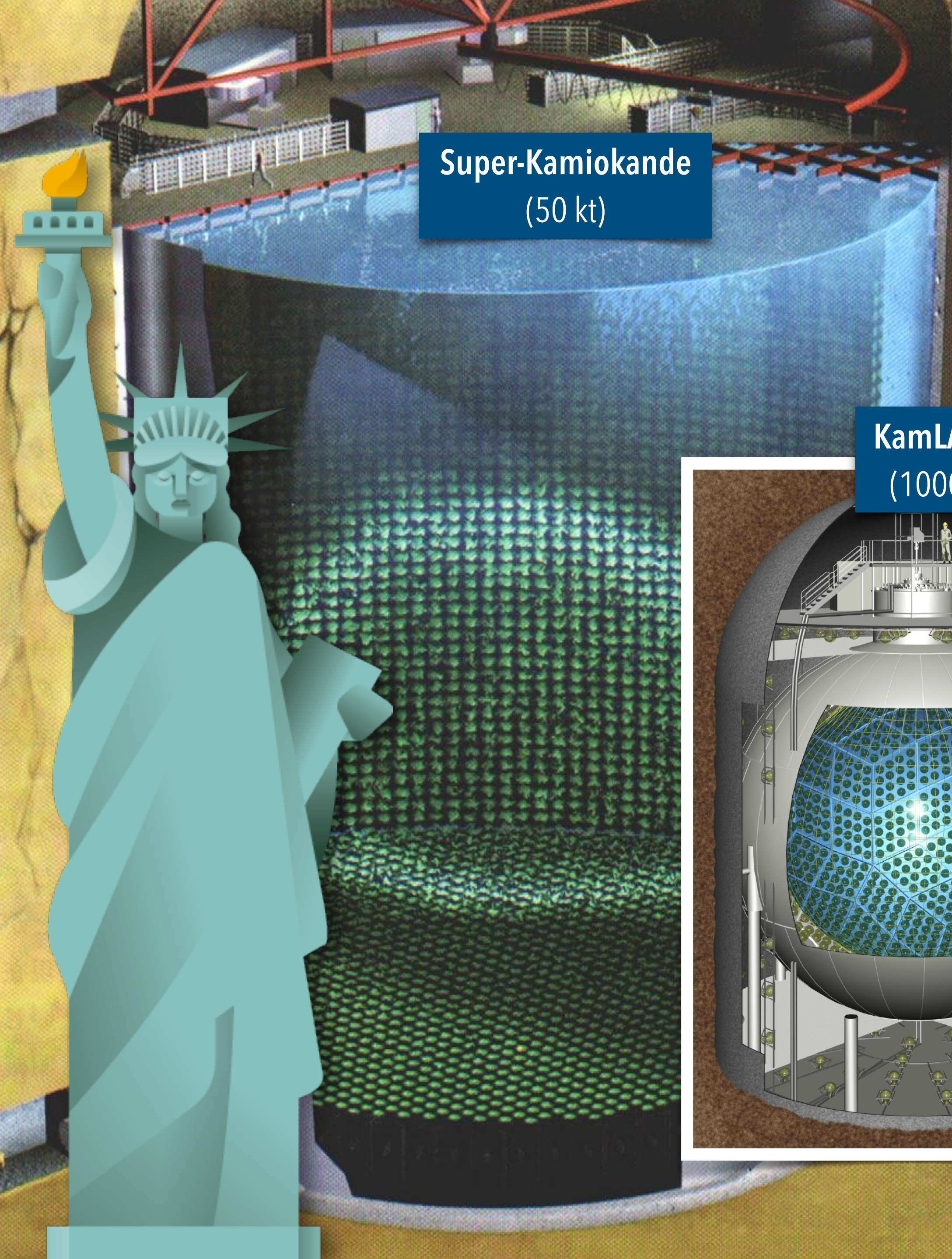


- $\sigma_{\text{CE}\nu\text{NS}}$ in agreement with standard model prediction

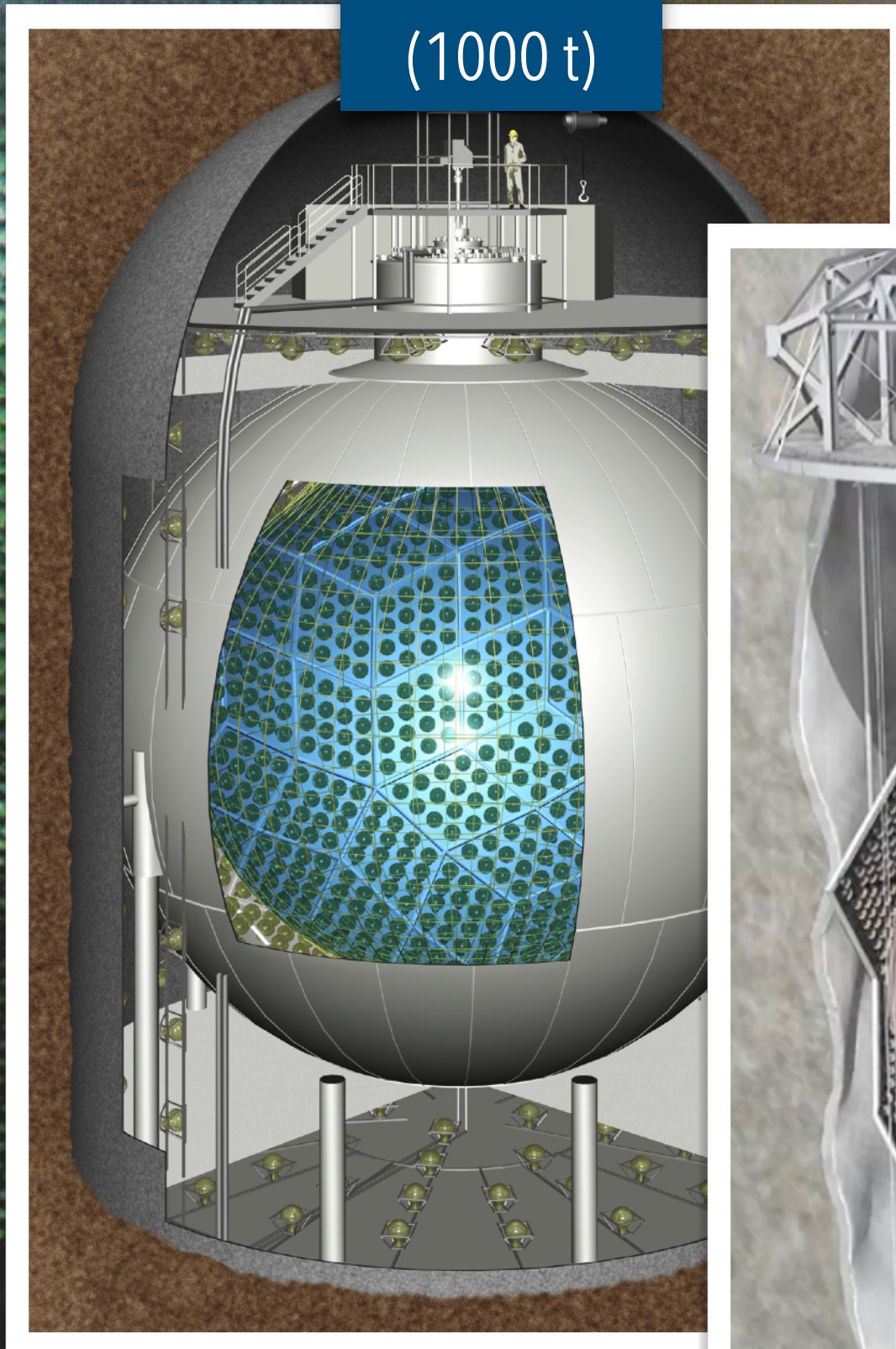
Summary



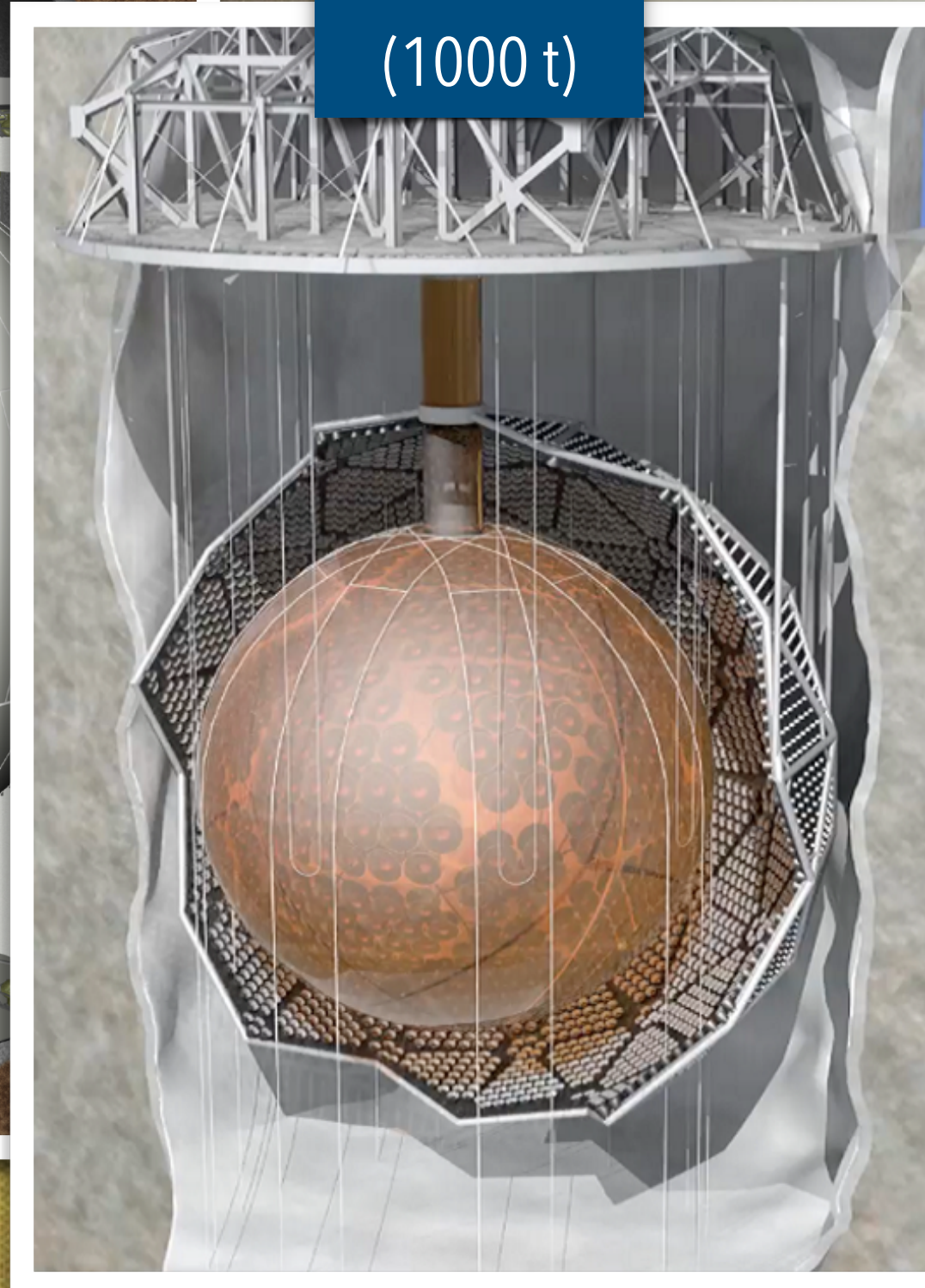
- **XENONnT performed a blind search for ^8B CE ν NS**
 - 2.73σ discovery significance
 - Measured ^8B neutrino flux: $4.7^{+3.6}_{-2.3} \times 10^6 \text{ cm}^{-2} \cdot \text{s}^{-1}$
- **First** detected astrophysical ν in a dark matter detector
- **First** measured CE ν NS from astrophysical ν source
- **First** measured CE ν NS with a Xe target
- XENONnT already finalized the third science run (SR2):
stay tuned for more results...



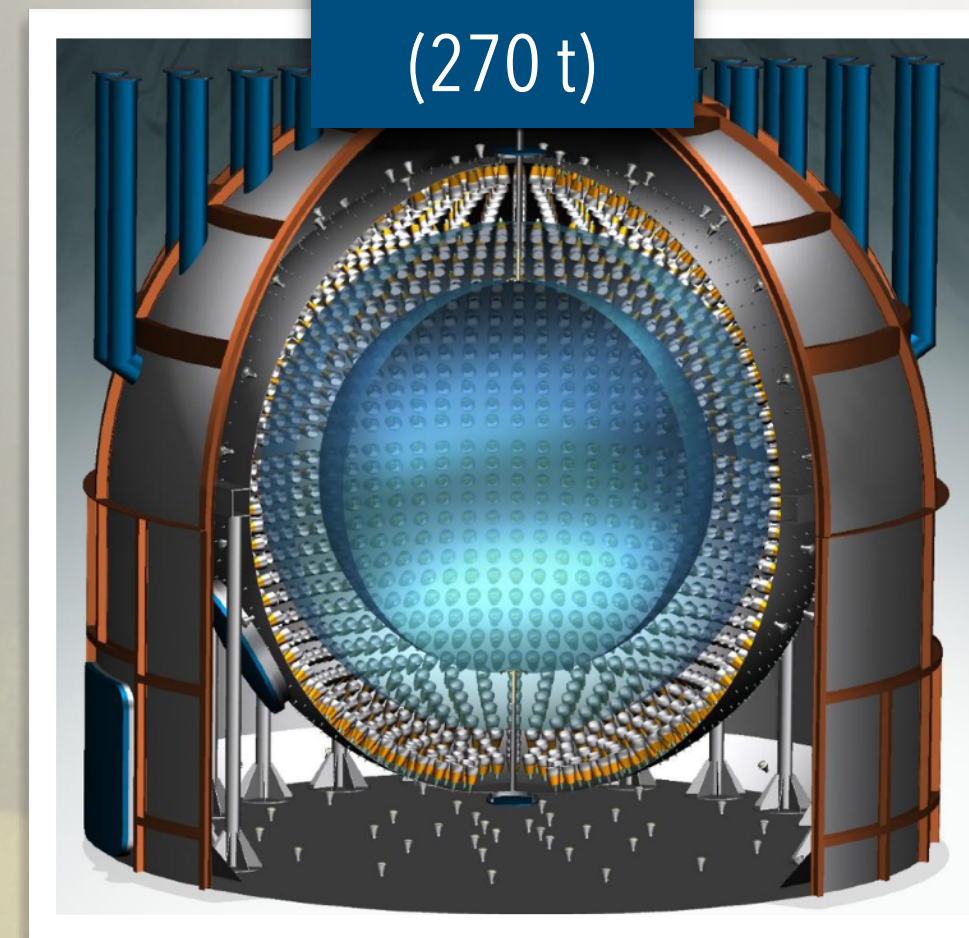
Super-Kamiokande
(50 kt)



KamLAND
(1000 t)



SNO
(1000 t)



Borexino
(270 t)

**XENONnT: The Smallest
Solar Neutrino Detector**

XENONnT
(5.9 t)



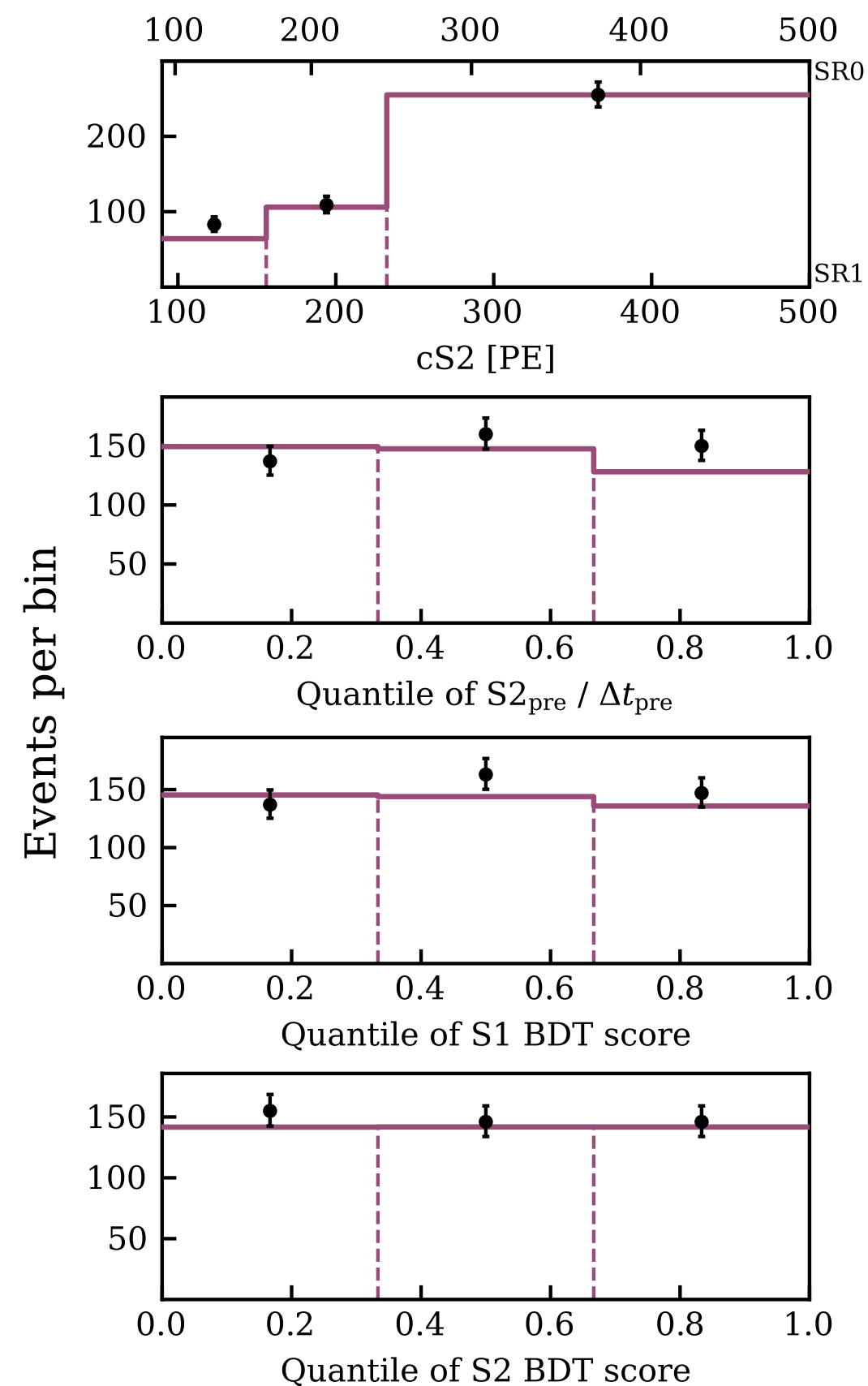


Additional slides

Validation of AC model

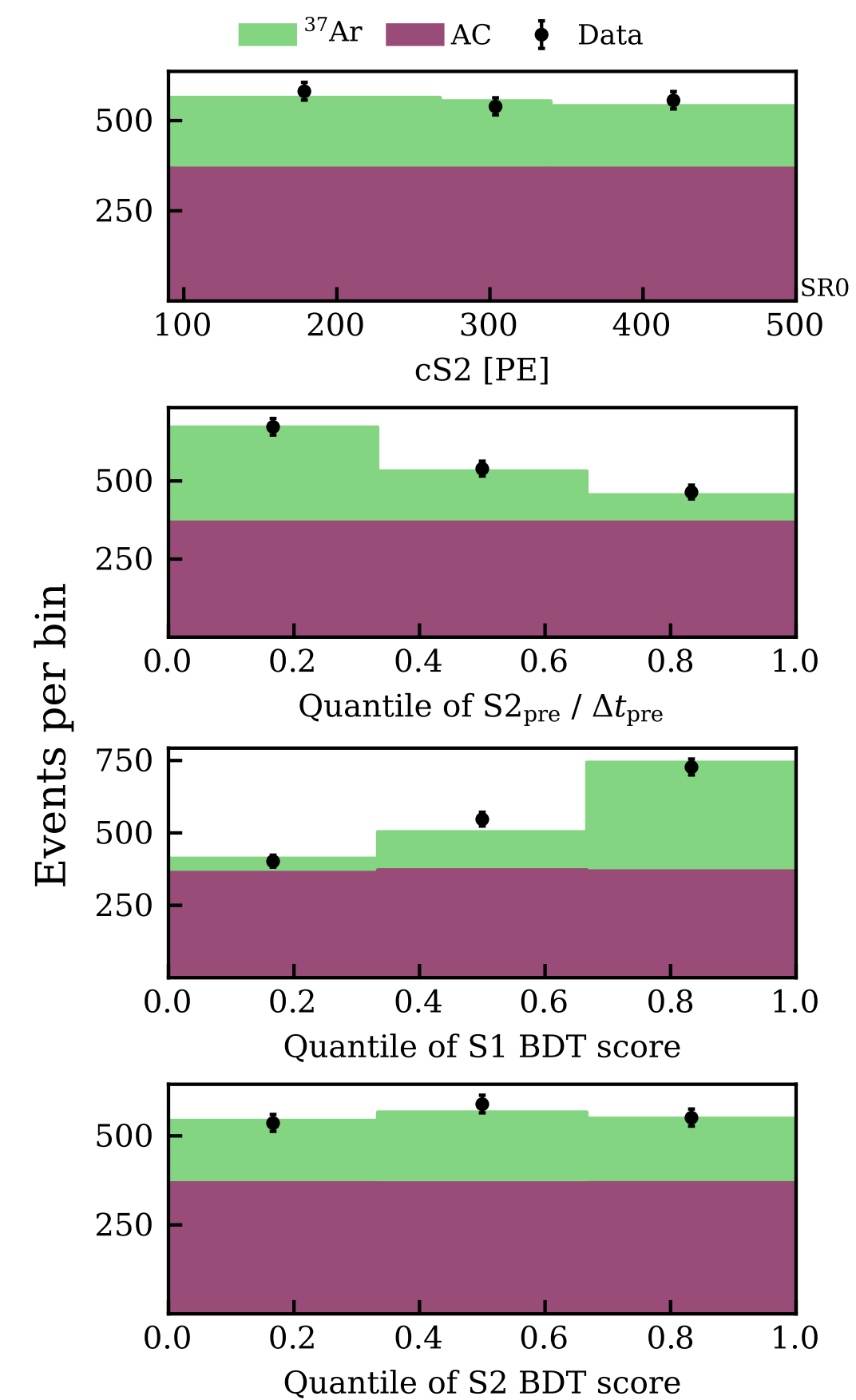


AC SIDE BAND



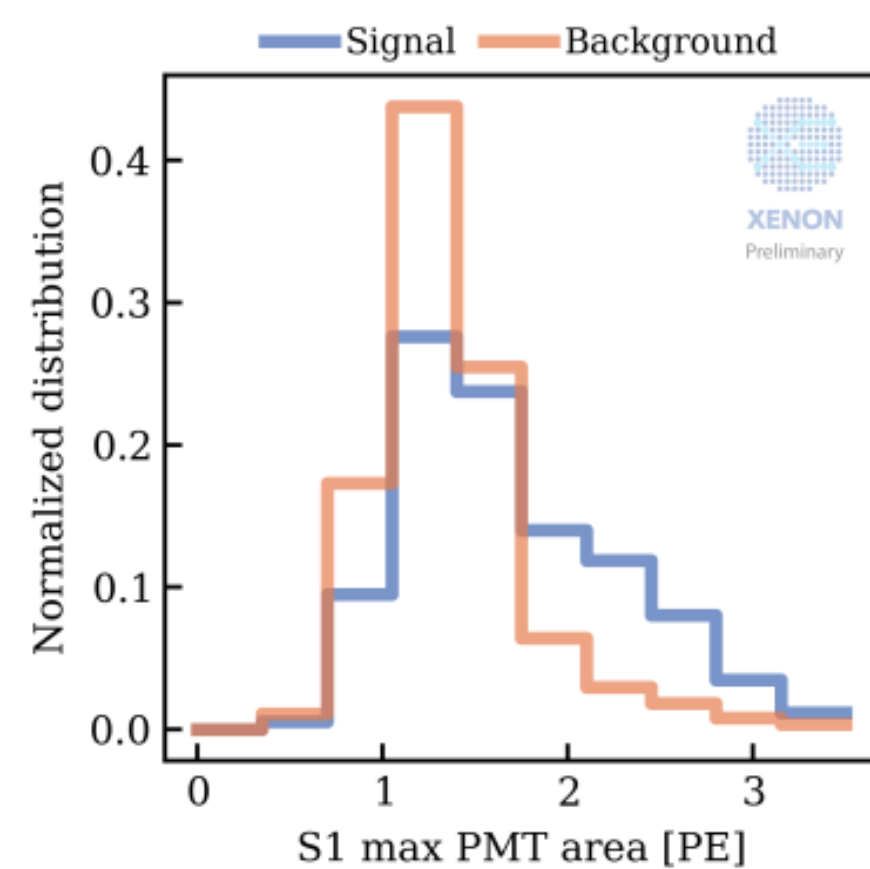
- Validated with AC-rich sideband (events that failed the S2 BDT cut)
- AC model validated with 4D GOF test (p-value = 0.16)
- The difference (< 10%) is propagated as systematic uncertainty to final likelihood

³⁷Ar L-shell EC

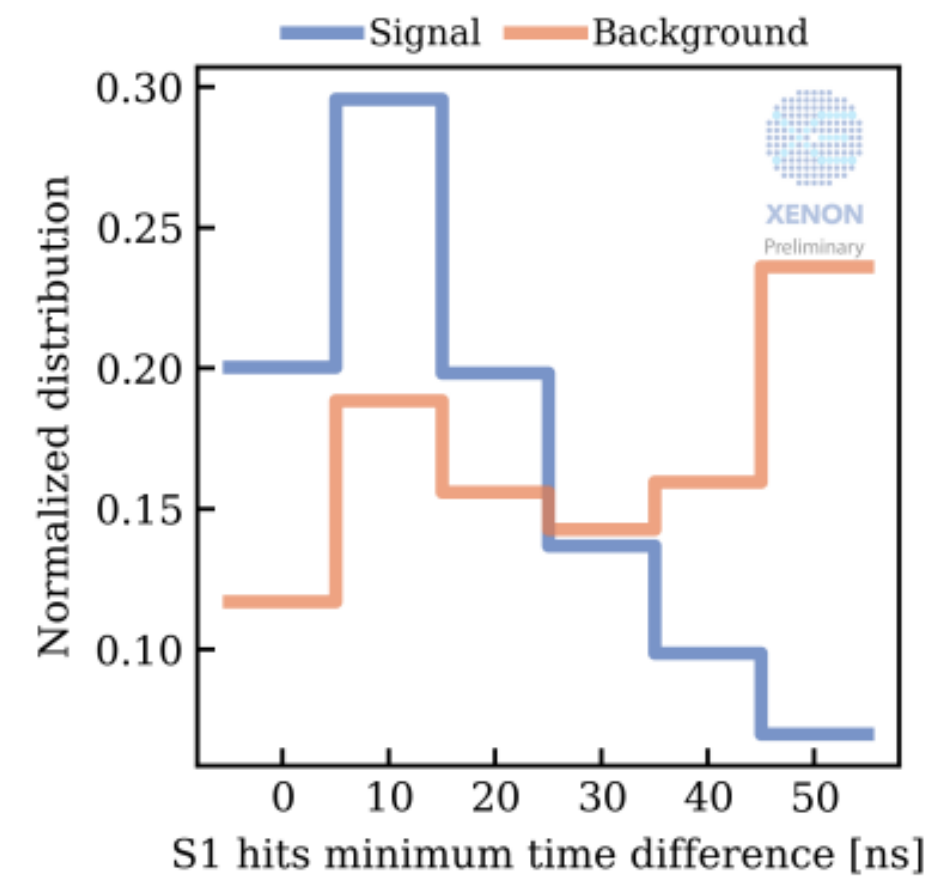


- Validated by ³⁷Ar L-shell 0.27 keV ER calibration data
- Fit match signal + background model
- 4D GOF test: p-value 0.92

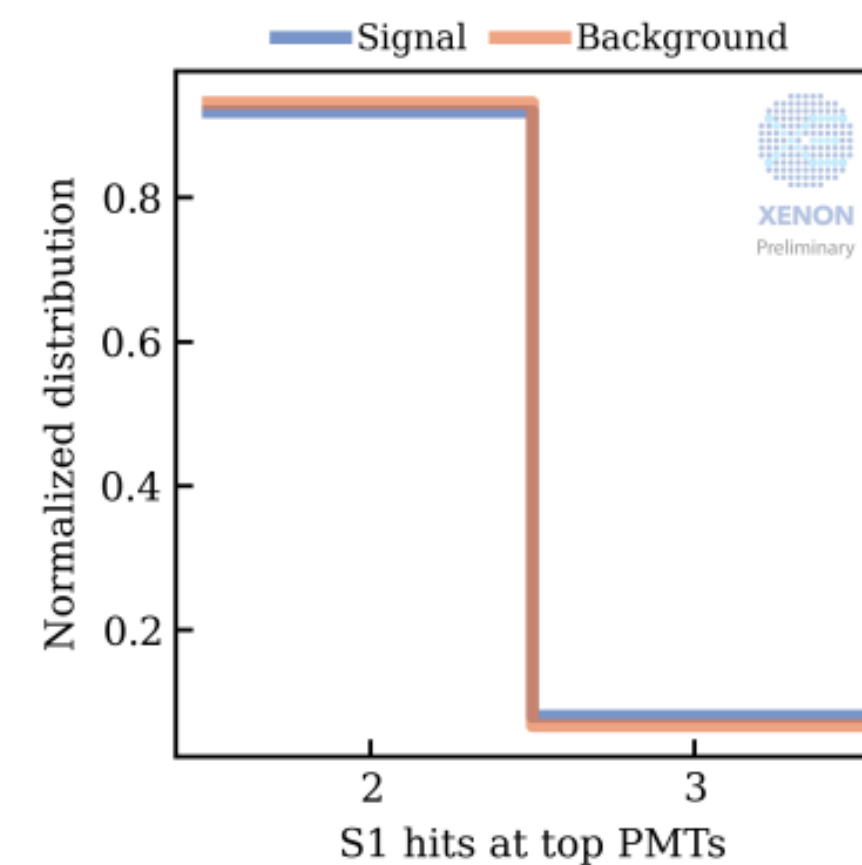
S1 BDT



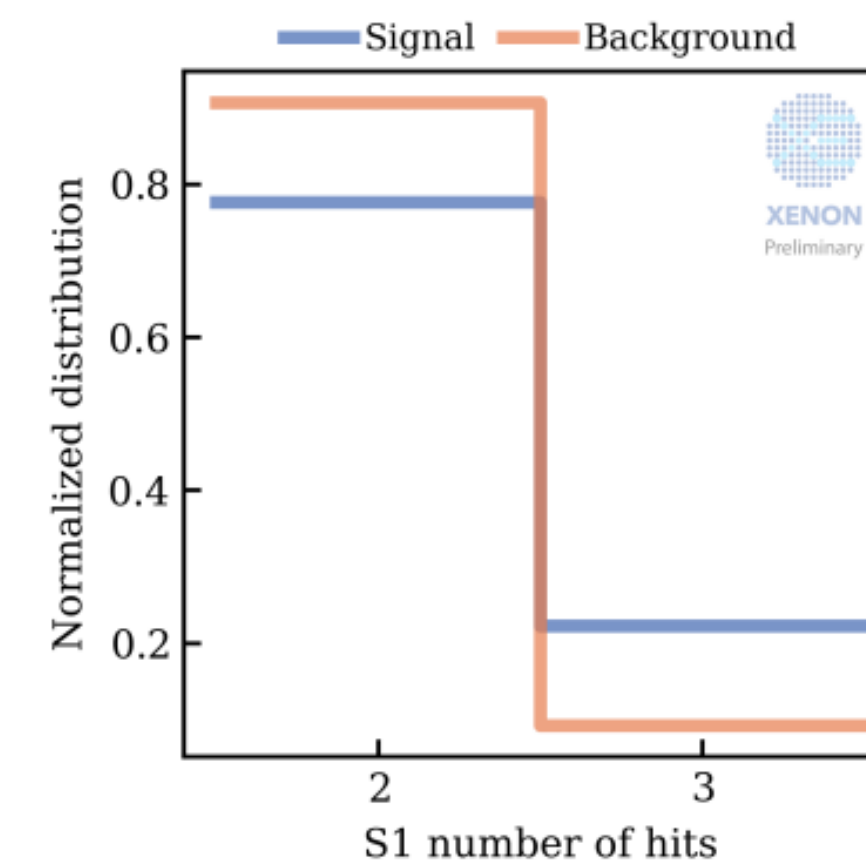
1st: Max hit area



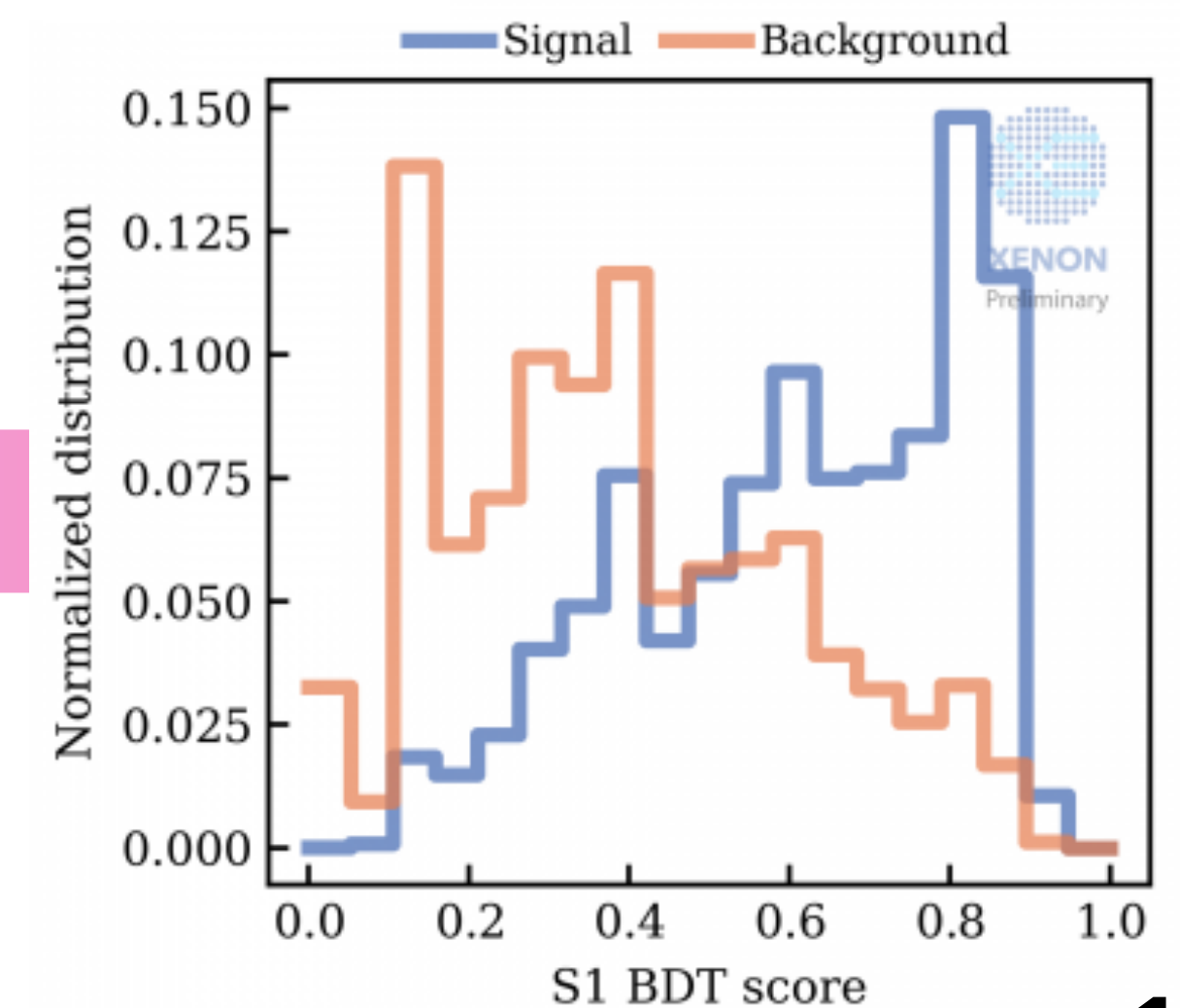
2nd: Minimum time between hits



3rd: Hit count in top photosensor array



4th: Total hit count



S2 BDT

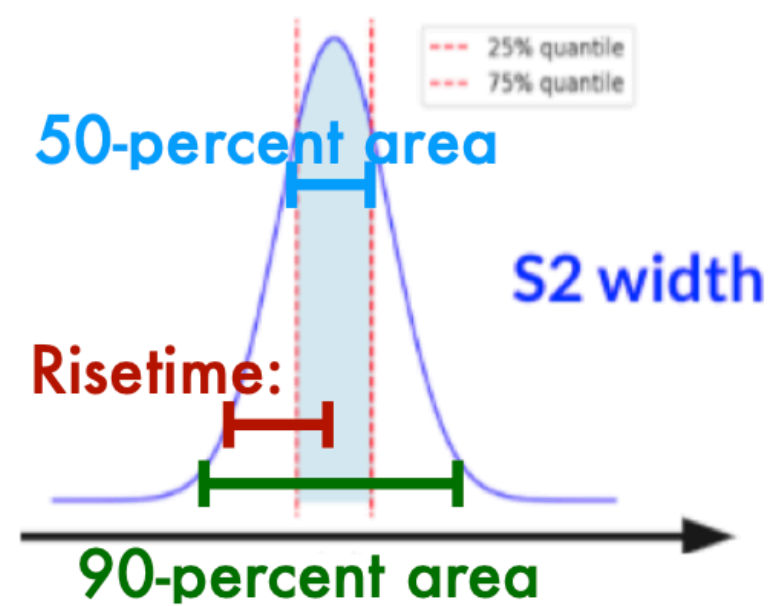
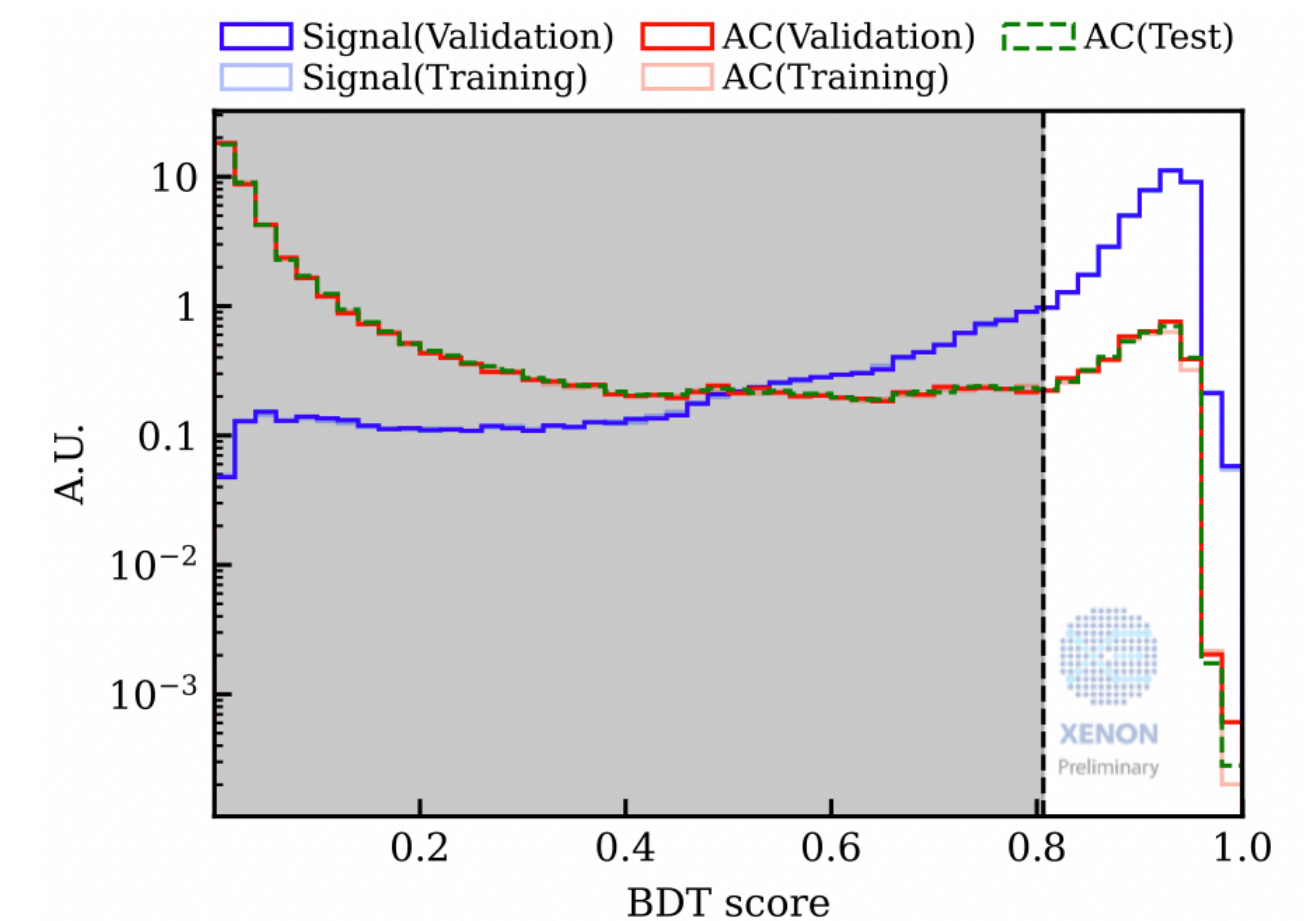
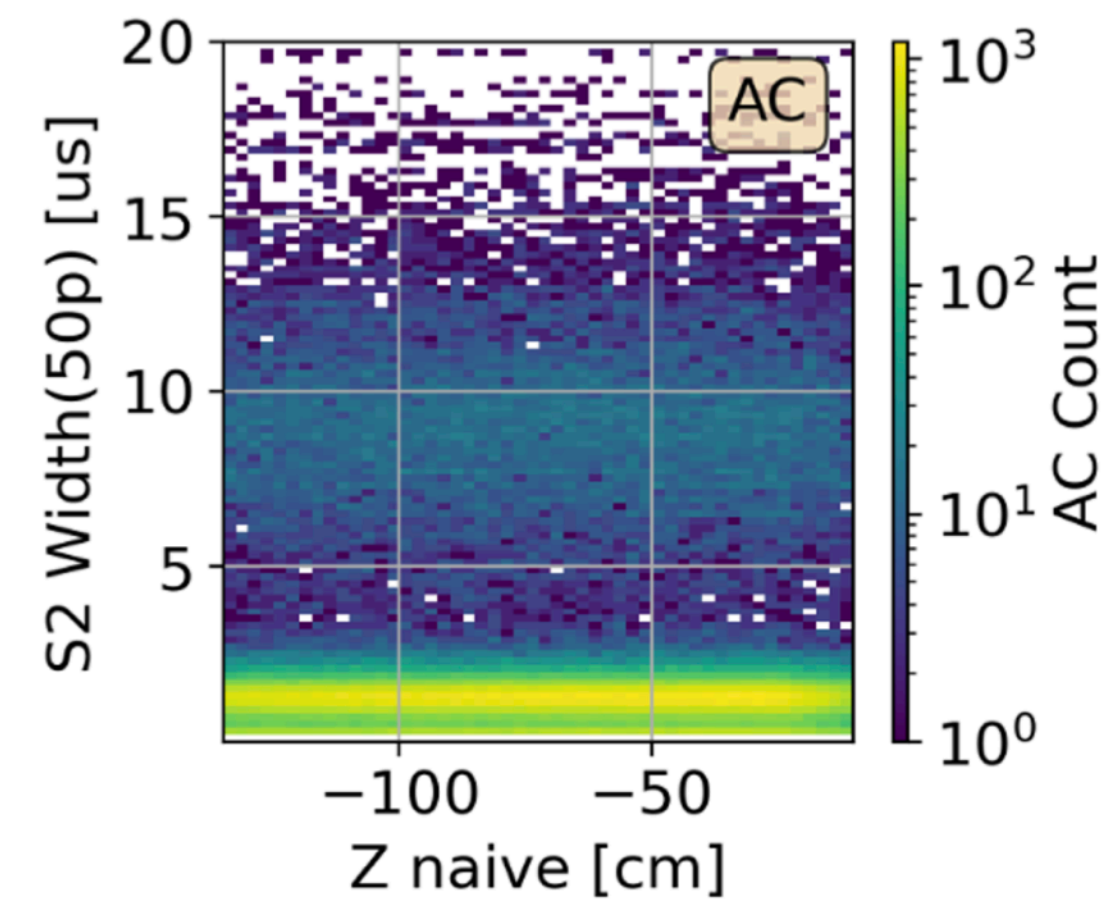
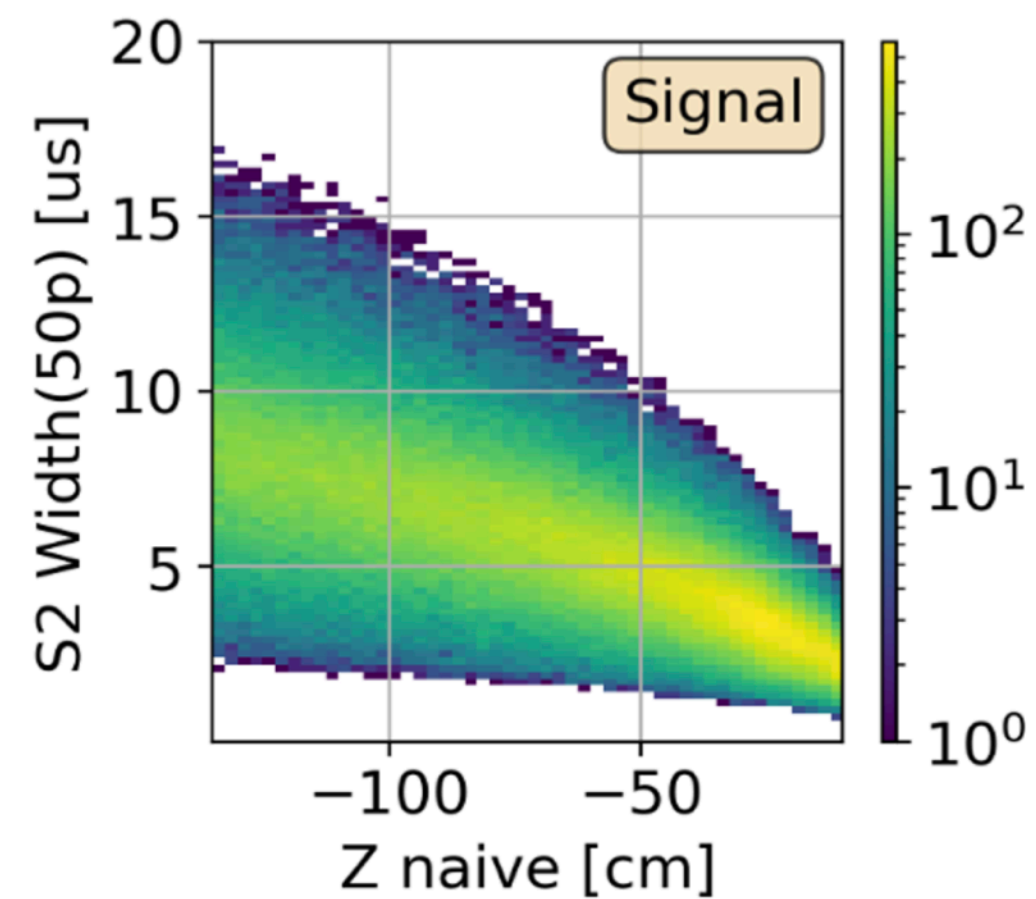


Image from Lanqing Yuang



Reject about 90% AC with 80% signal acceptance

1st: S2 width at 50 %

4th: Drift time

Feature importance

2nd: Rise time

3rd: S2 width at 90 %