XENON

清華大學

Tsinghua University

First Measurement of Coherent Elastic Neutrino Nucleus Scattering of Solar ^{8}B Neutrinos in XENONnT

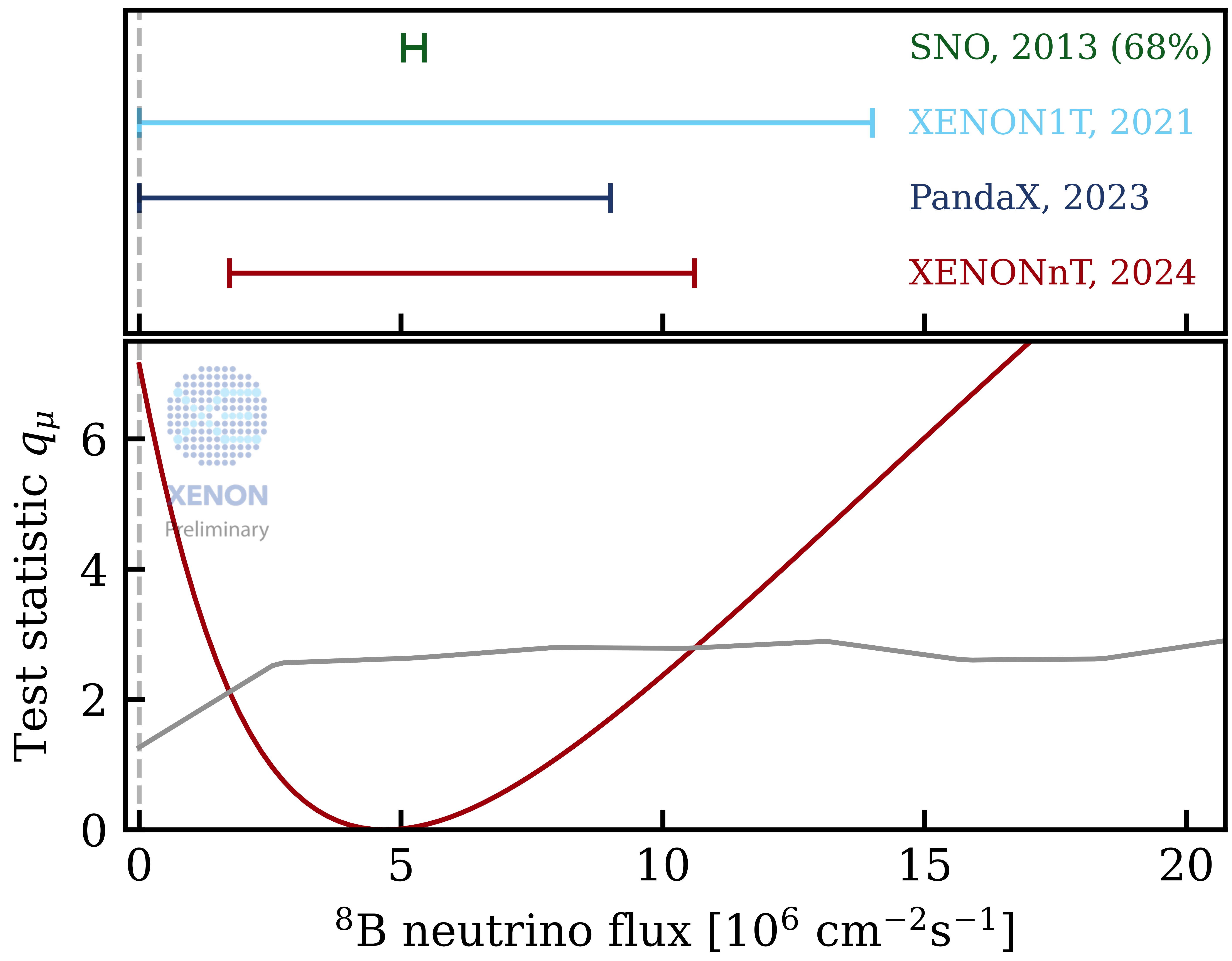
Fei Gao, Tsinghua University

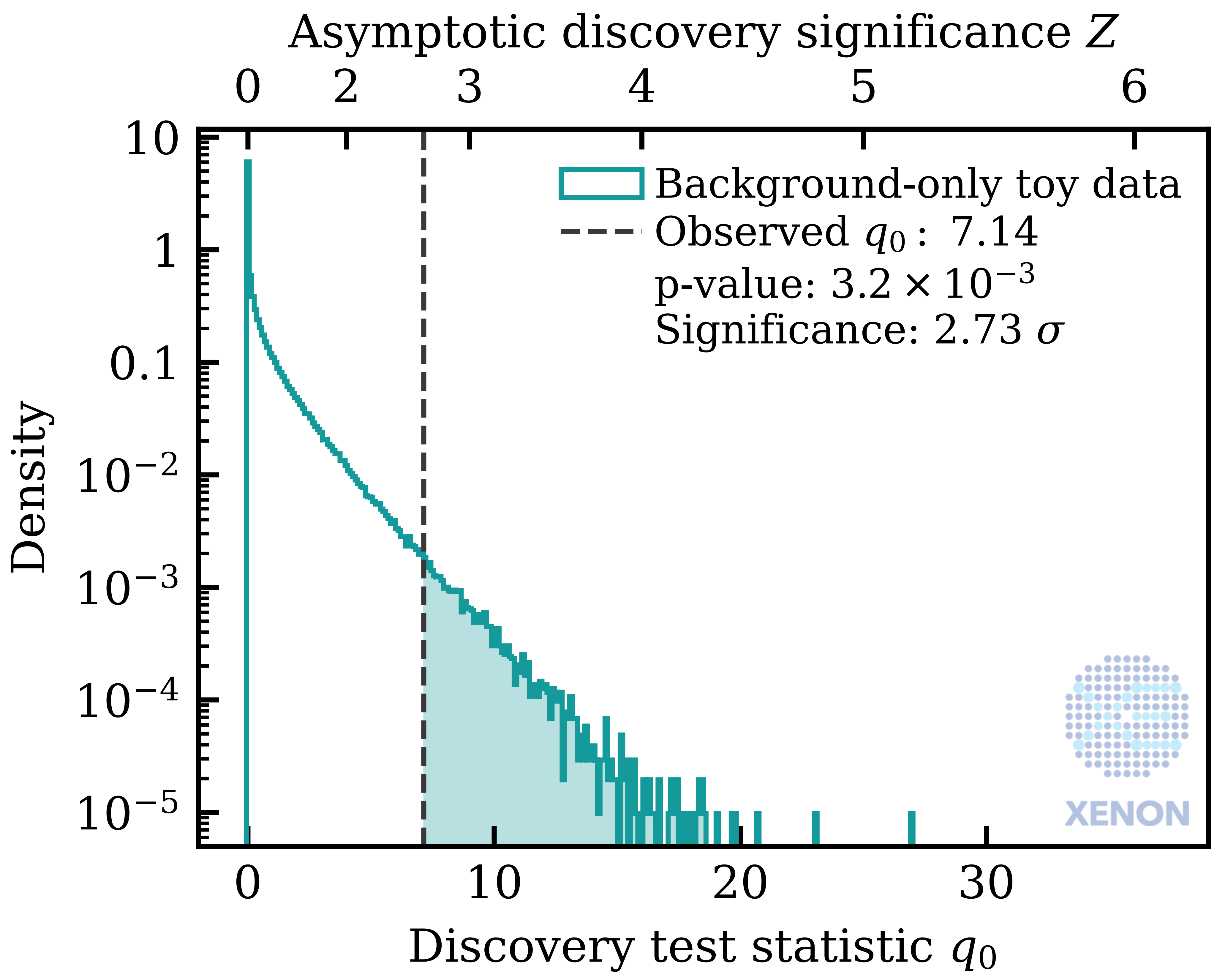
on behalf of the XENON Collaboration

15th International Workshop on the Identification of Dark Matter

July 8-12, 2024, L'Aquila

XENONnT Solar ^{8}B CEvNS Search Results





- We have measured the solar ^{8}B neutrinos via CEvNS in XENONnT at 2.73σ
- The first CEvNS measurement with Xe!
- The first astrophysical neutrino measurement via CEvNS

XENON Collaboration

- 200+ scientists
- 29 institutions
- 12 countries

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
- JG|U — Mainz
- Max-Planck-Institut für Kernphysik — Heidelberg
- Nikhef — Amsterdam
- Stockholm University — Stockholm
- University of Coimbra — Coimbra
- Subatech — Nantes
- LPNHE Paris — Paris
- INFN Torino — Torino
- Alma Mater Studiorum A.D. 1088 — Bologna
- Università degli Studi dell'Aquila — L'Aquila
- INFN LNGS — Assergi
- Napoli

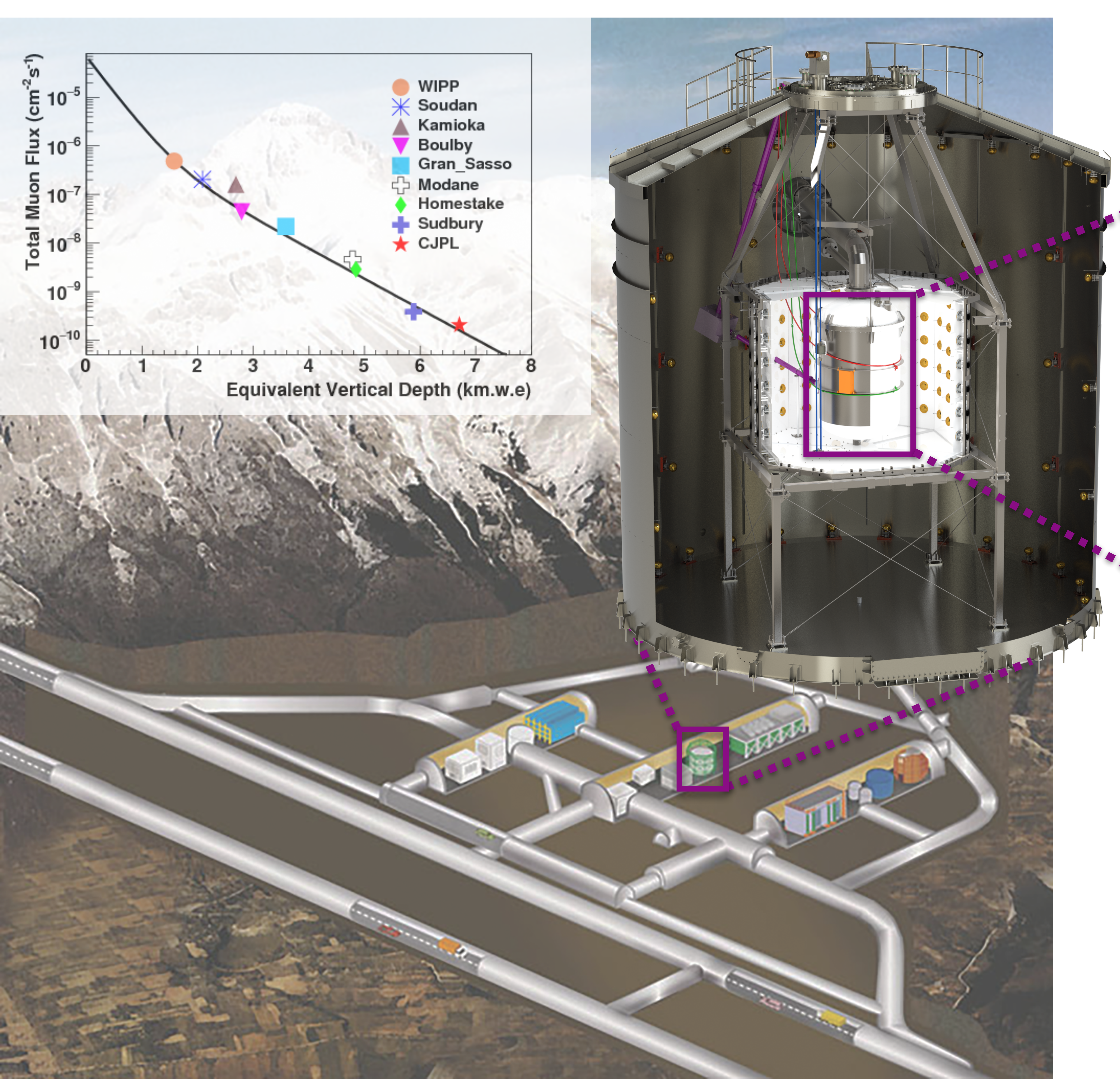
MIDDLE EAST

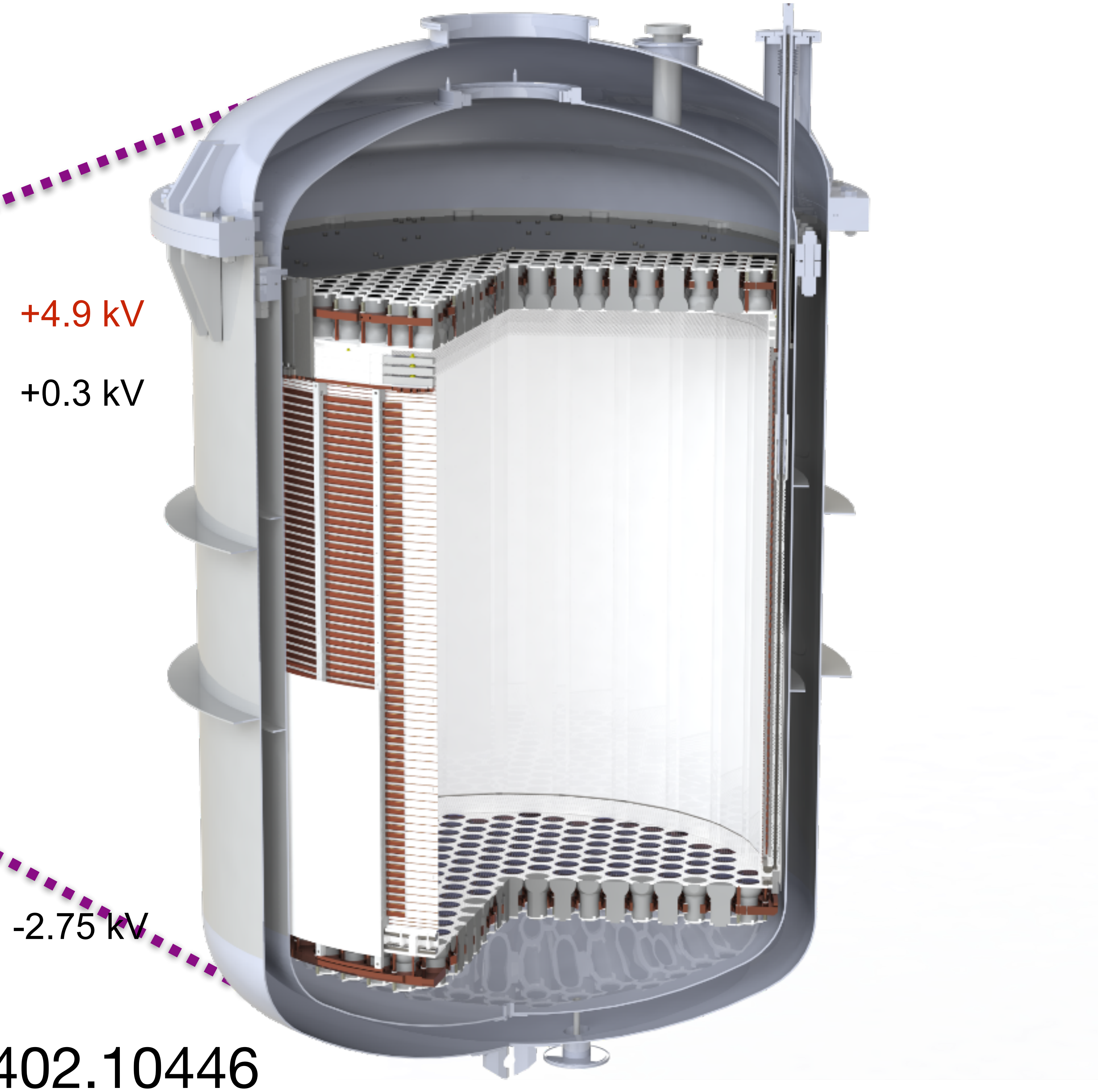
- מכון ויצמן למדע Weizmann Institute of Science — Rehovot
- جامعة نيويورك أبوظبي NYU ABU DHABI — Abu Dhabi

ASIA

- 清華大学 Tsinghua University — Beijing
- 西湖大學 Westlake University — Hangzhou
- The Chinese University of Hong Kong, Shenzhen — Shenzhen
- 東京大学 The University of Tokyo — Tokyo
- Nagoya University — Nagoya
- Kobe University — Kobe

XENONnT Under the Gran Sasso Shield





arXiv: 2402.10446

Drift Length	Diameter	Sensitive Target	Drift Field
1.5m	1.32m	5.9 tonne	23 V/cm

Elastic Scattering of Dark Matter and Neutrinos

PHYSICAL REVIEW D VOLUME 31, NUMBER 12 15 JUNE 1985

Detectability of certain dark-matter candidates

Mark W. Goodman and Edward Witten
Joseph Henry Laboratories, Princeton University, Princeton, New Jersey 08544
(Received 7 January 1985)

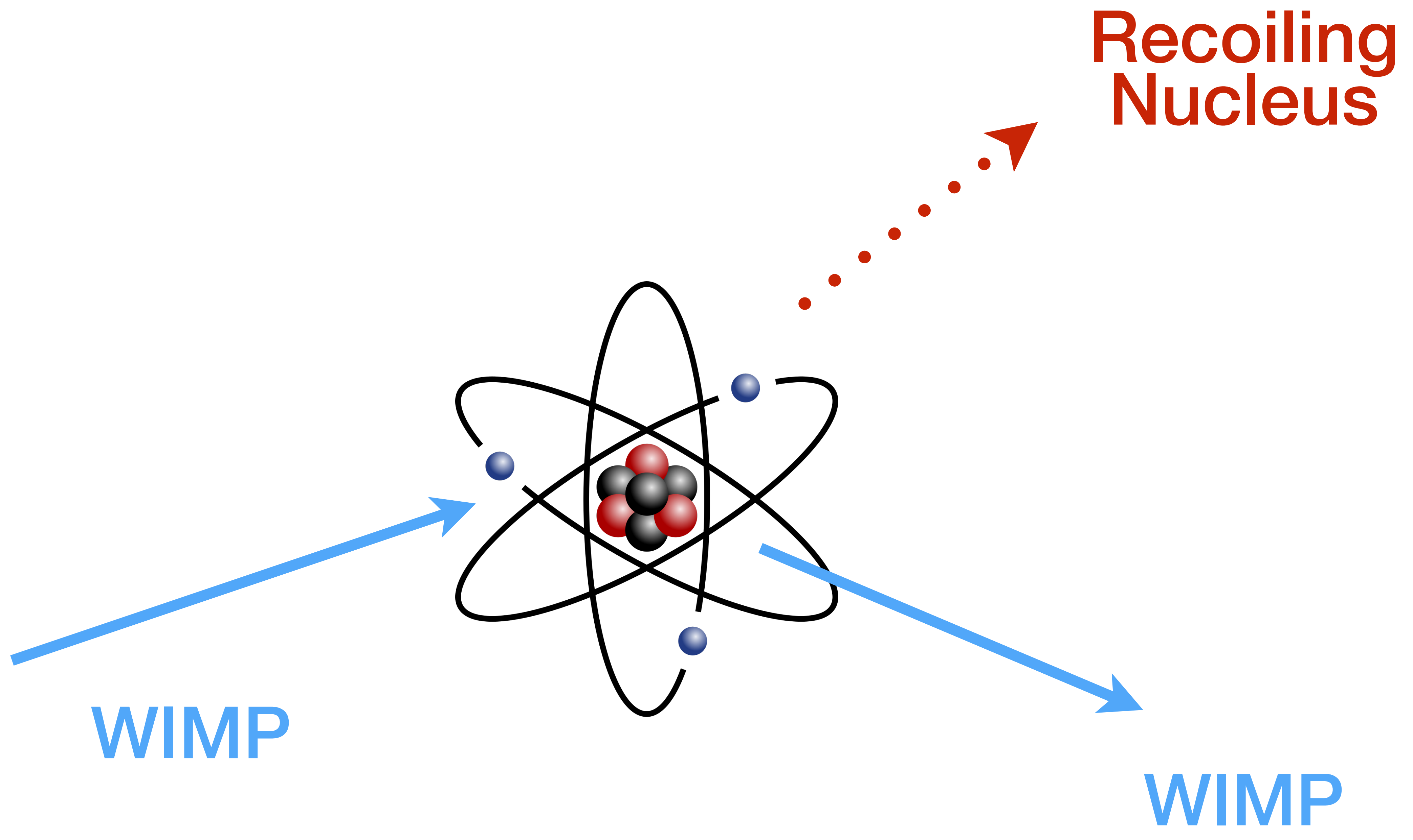
We consider the possibility that the neutral-current neutrino detector recently proposed by Drukier and Stodolsky could be used to detect some possible candidates for the dark matter in galactic halos. This may be feasible if the galactic halos are made of particles with coherent weak interactions and masses 1—10^6 GeV; particles with spin-dependent interactions of typical weak strength and masses 1—10^2 GeV; or strongly interacting particles of masses 1—10^{13} GeV.

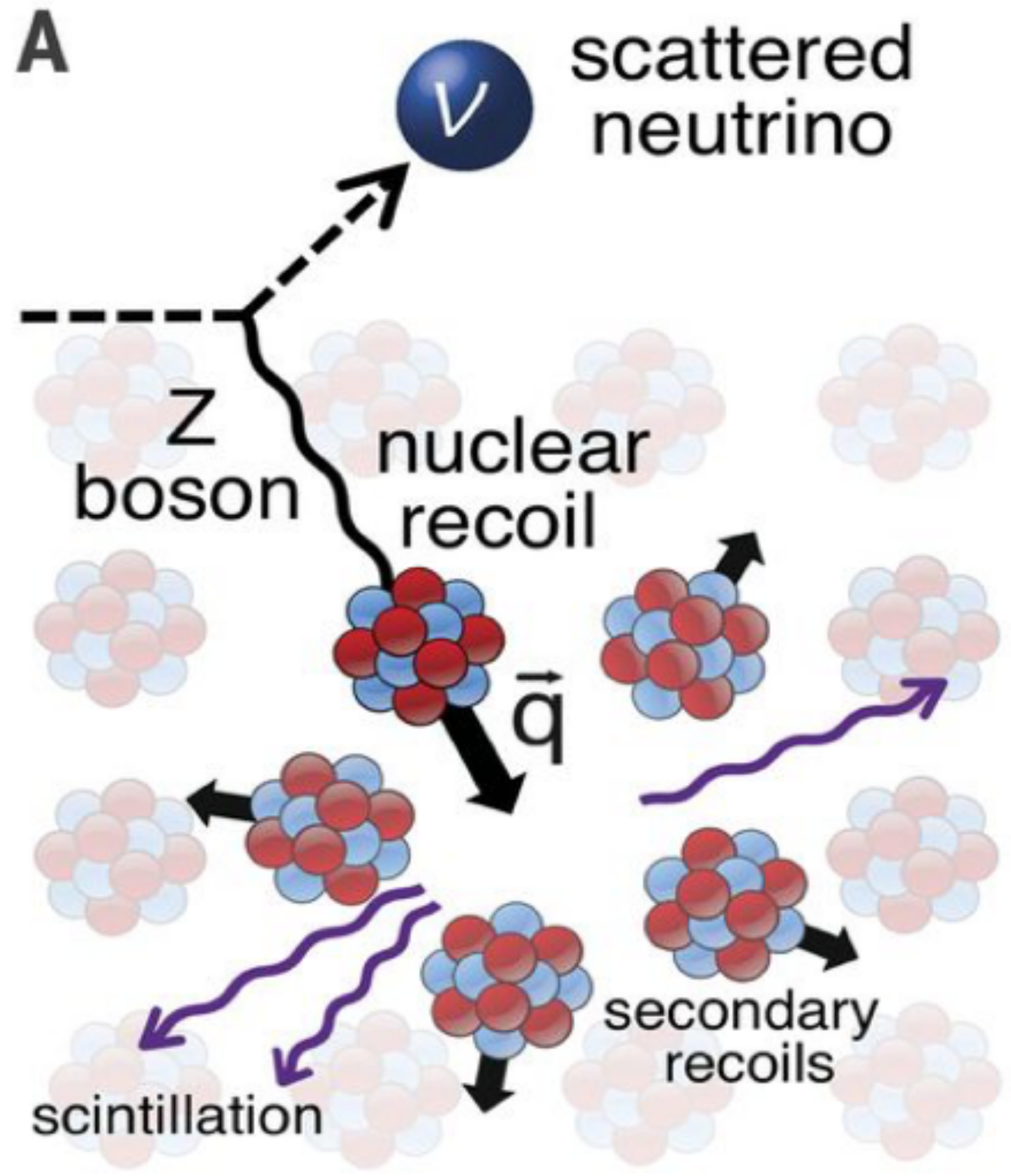
PHYSICAL REVIEW D VOLUME 9, NUMBER 5 1 MARCH 1974

Coherent effects of a weak neutral current

Daniel Z. Freedman†
National Accelerator Laboratory, Batavia, Illinois 60510
and Institute for Theoretical Physics, State University of New York, Stony Brook, New York 11790
(Received 15 October 1973; revised manuscript received 19 November 1973)

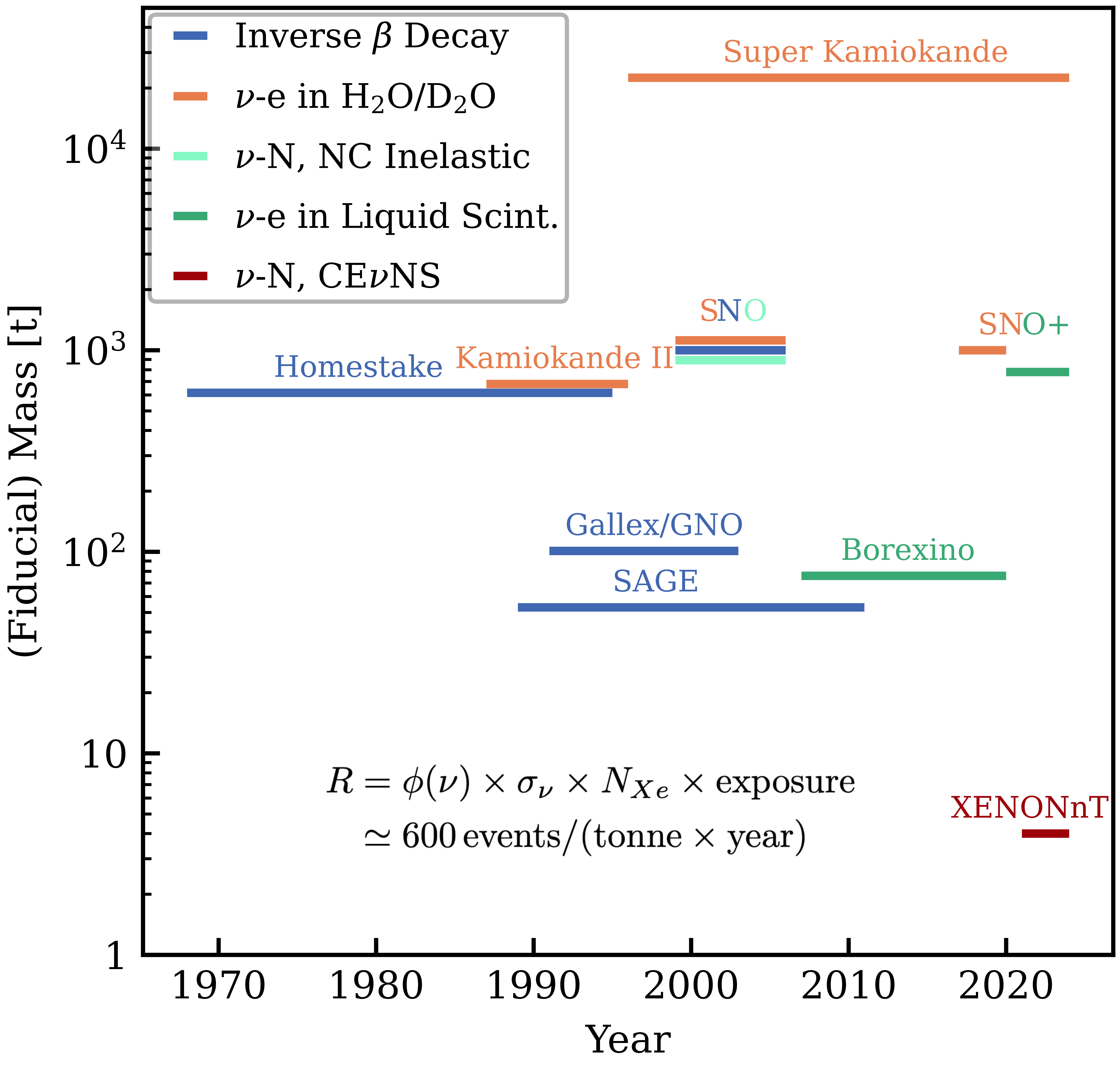
If there is a weak neutral current, then the elastic scattering process $\nu + A \to \nu + A$ should have a sharp coherent forward peak just as $e + A \to e + A$ does. Experiments to observe this peak can give important information on the isospin structure of the neutral current. The experiments are 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.



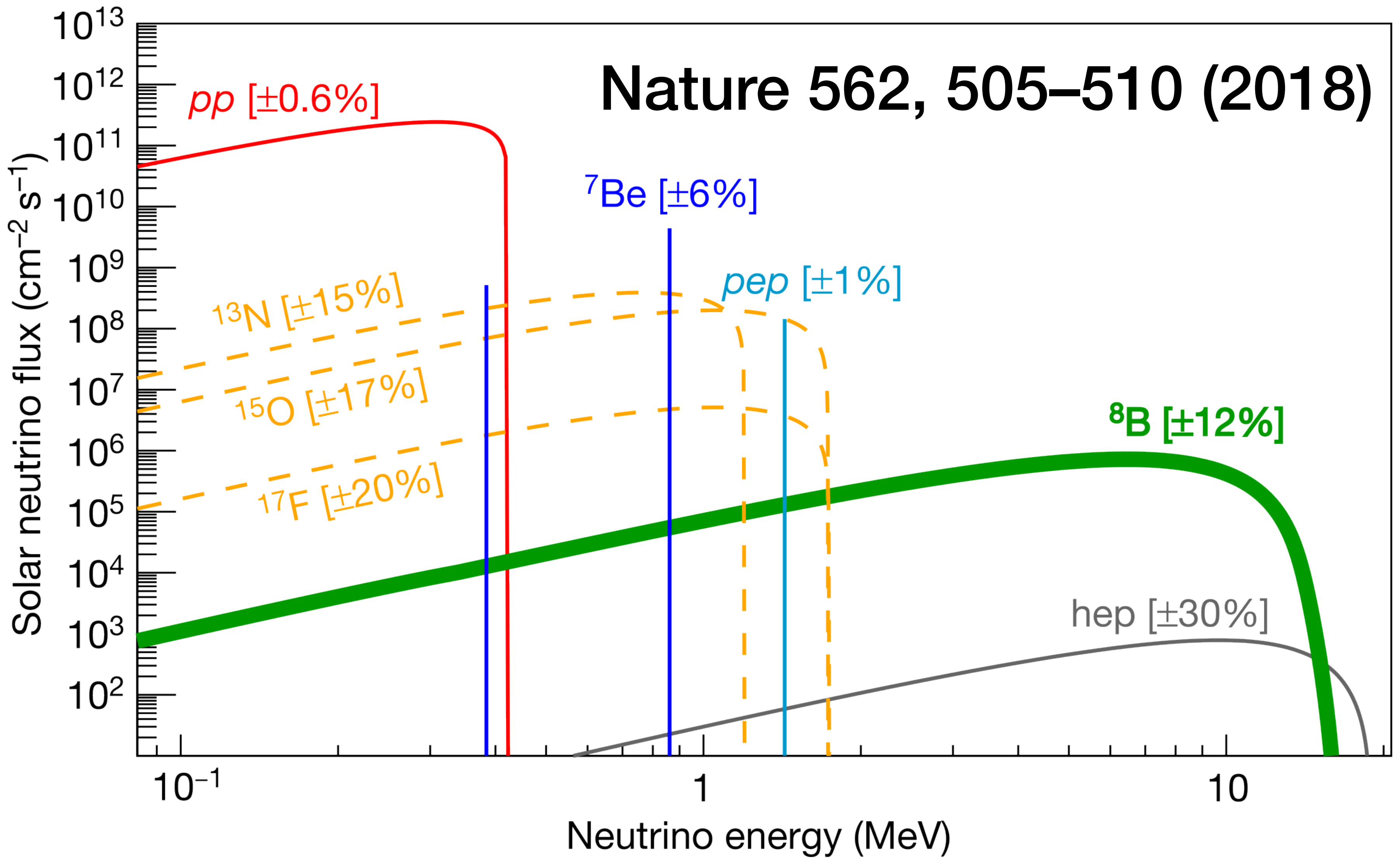


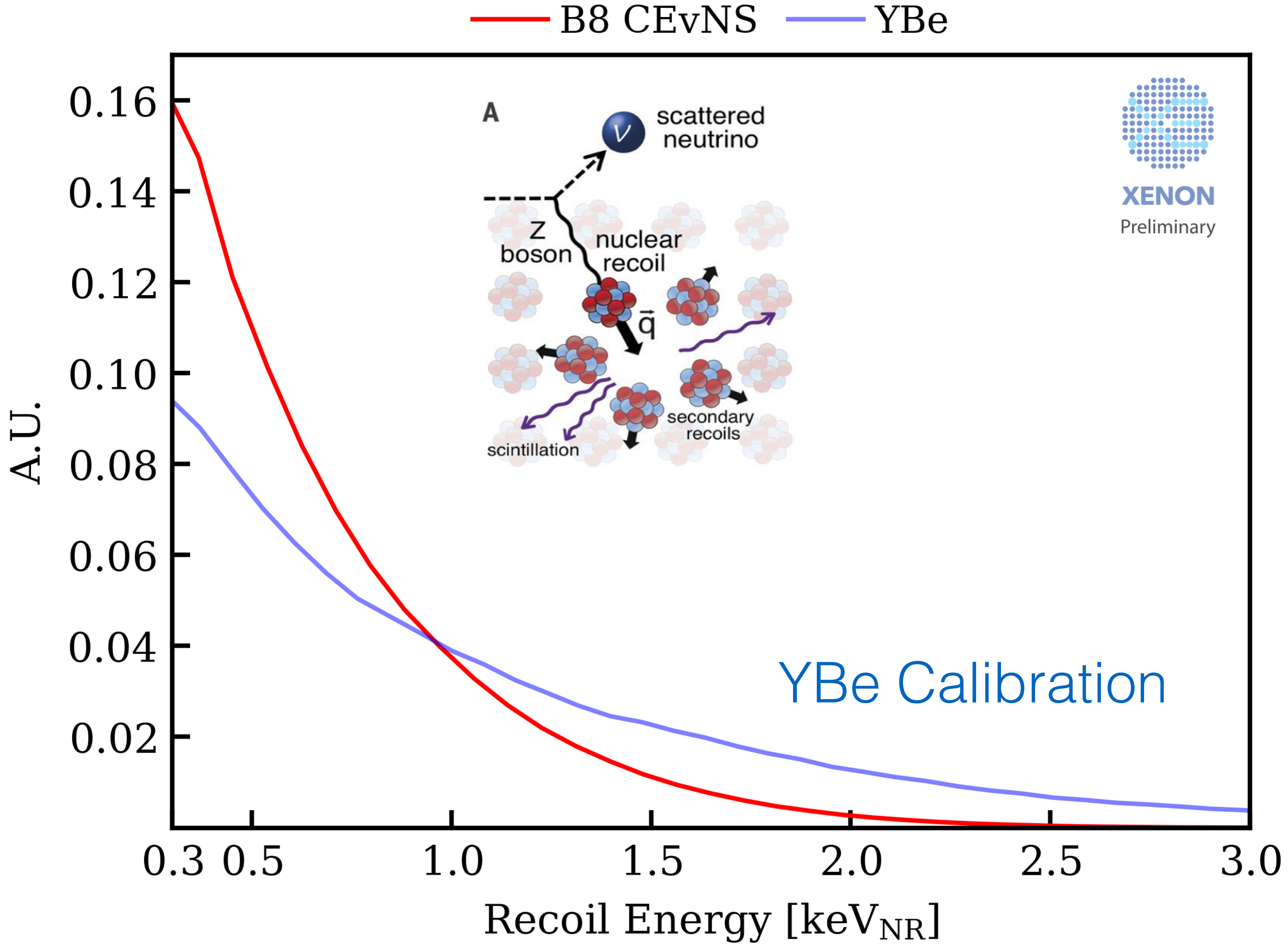
D. Akimov et al, Science 357 (2017)

XENONnT as a Solar Neutrino Detector via CEvNS



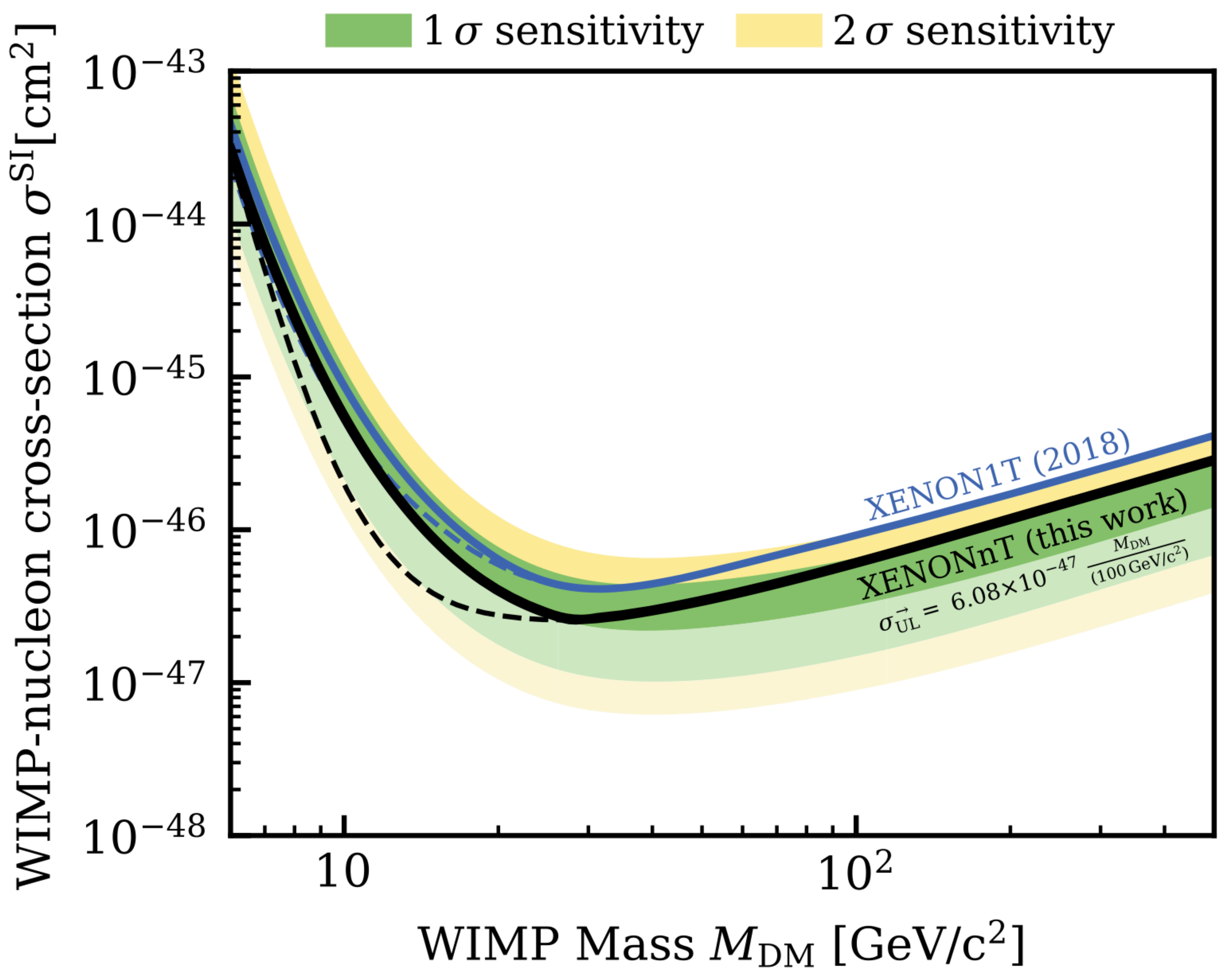
$$R = \phi(\nu) \times \sigma_\nu \times N_{Xe} \times \text{exposure}$$
$$\simeq 600\,\text{events}/(\text{tonne} \times \text{year})$$





Science Data

PRL 131, 041003 (2023)



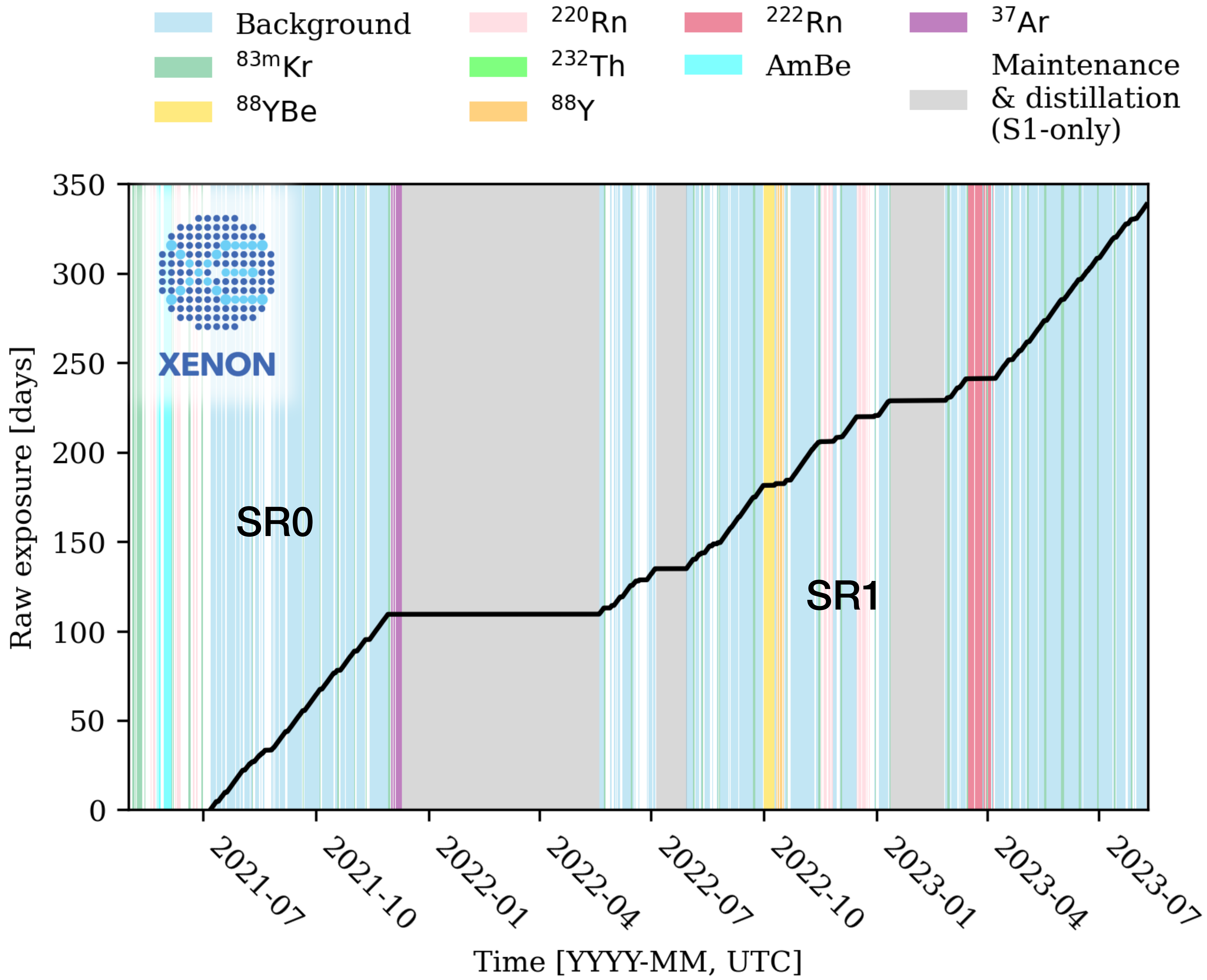
WIMP Dark Matter searches with the XENONnT experiment

Jul 8, 2024, 2:20 PM
20m
Palazzo dell'Emiciclo, Sala Ipogea

Parallel talk
Direct detection

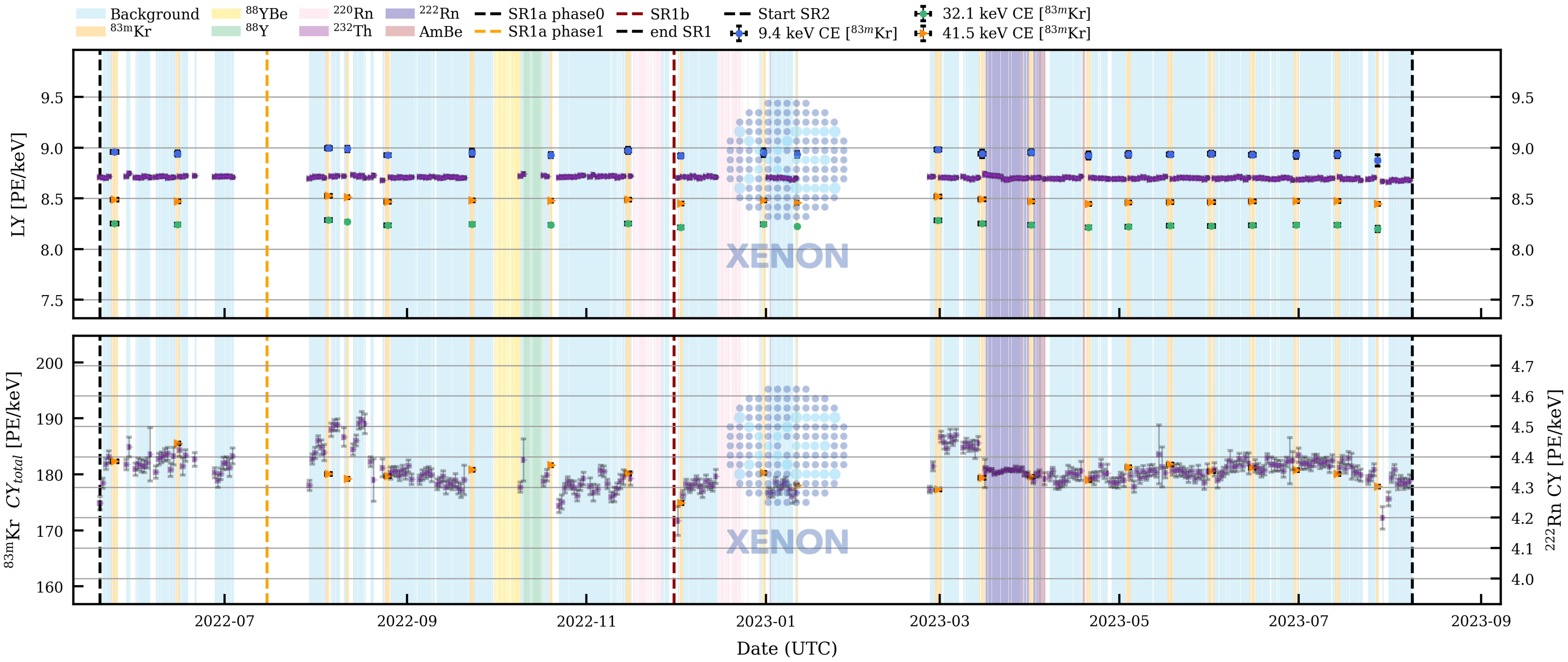
Speaker

Henning Schulze Eißing



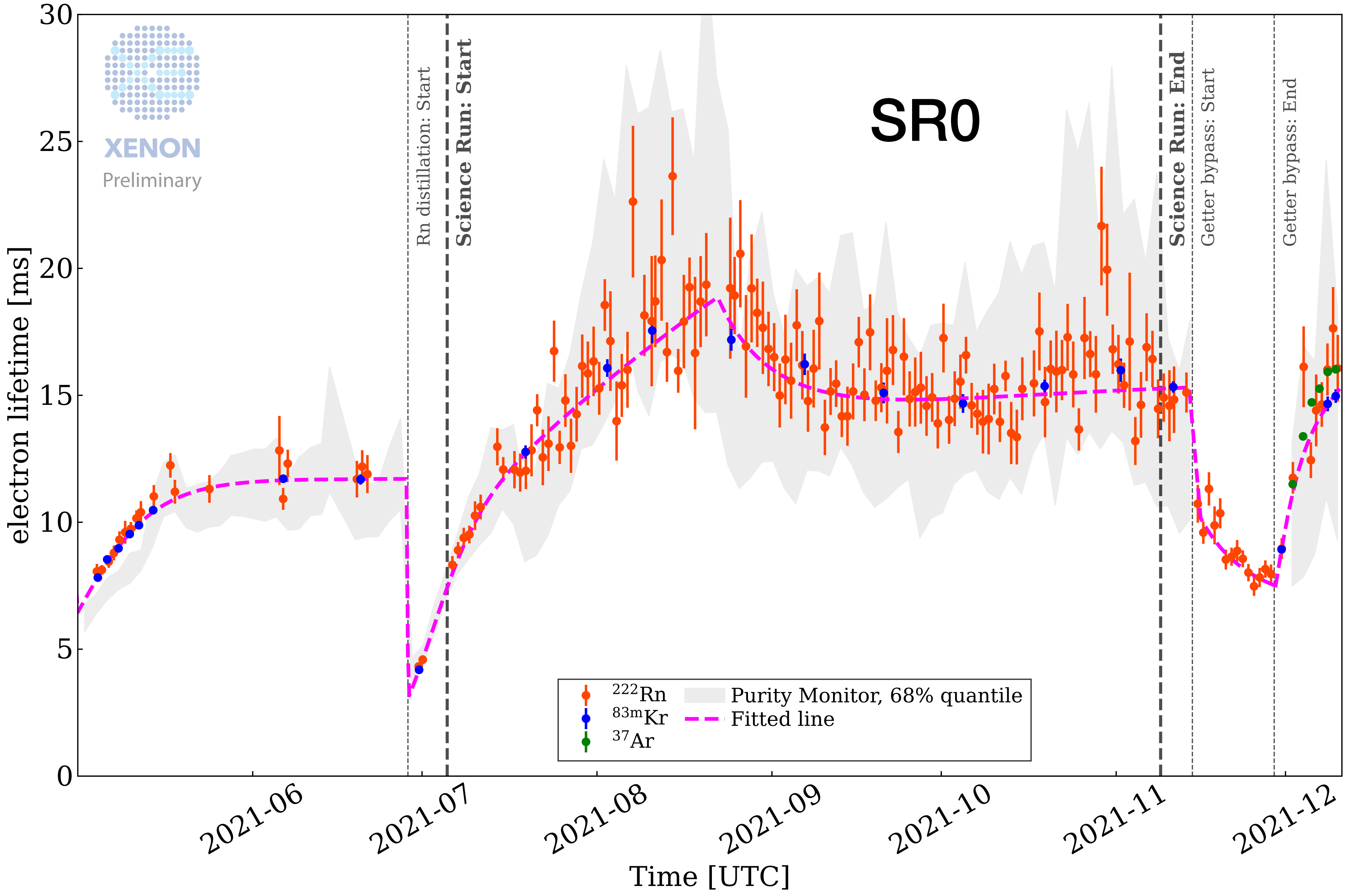
Both SR0 and SR1 data are used to search for solar ^{8}r CEvNS and WIMPs Dark Matter, etc

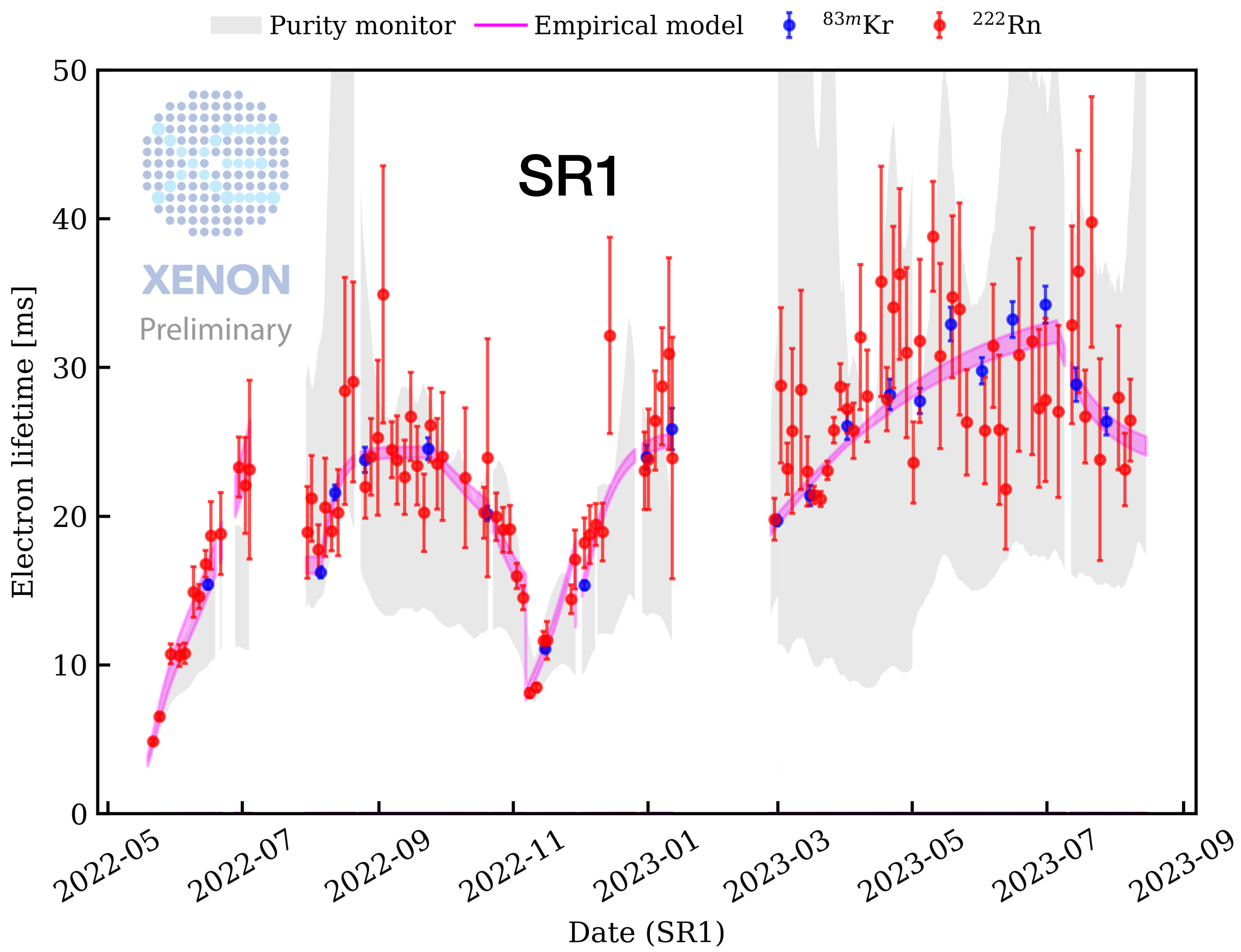
Stability of XENONnT During Science Runs

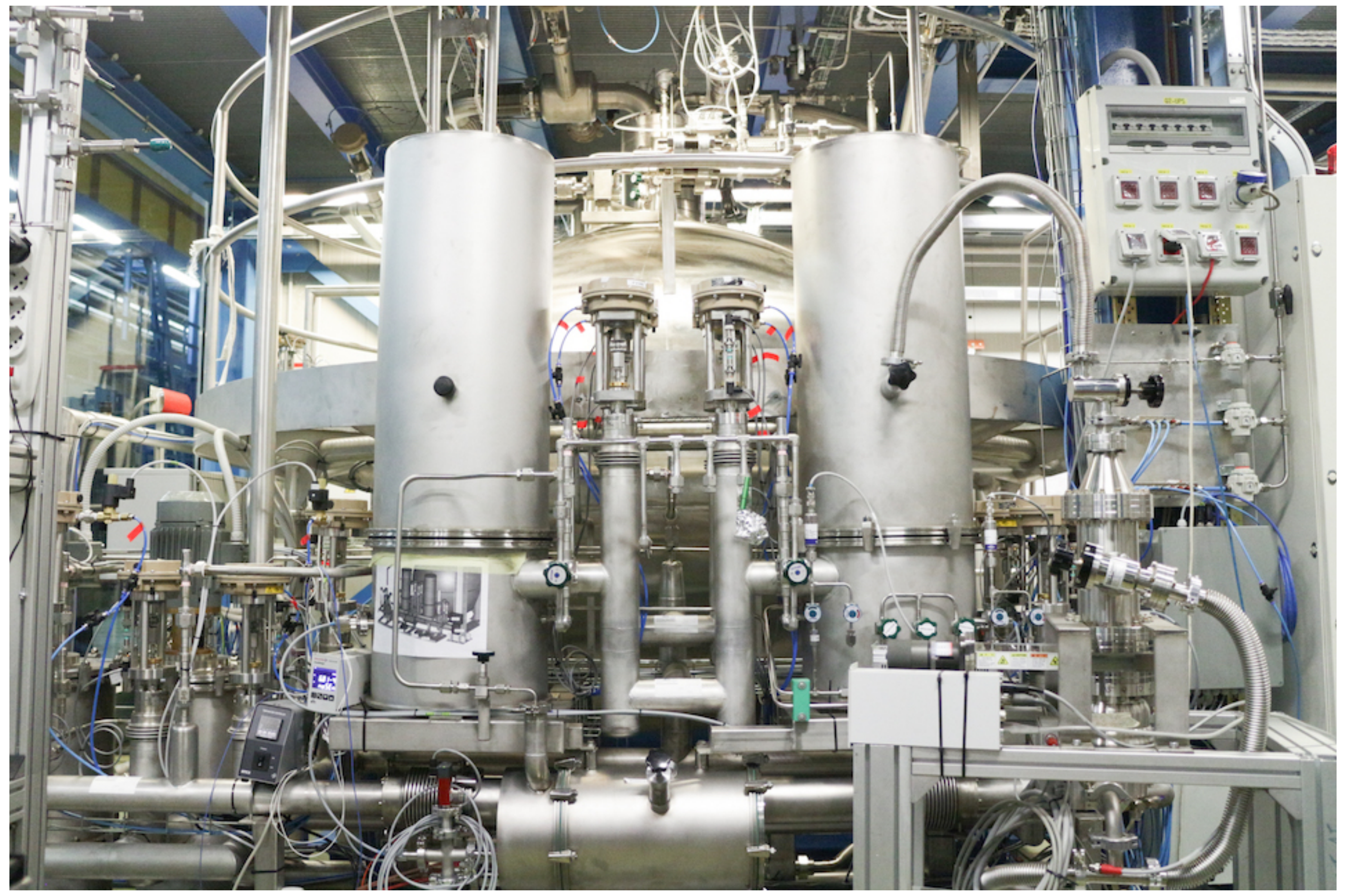


The stability of XENONnT is well established in both SR0 and SR1

Liquid Xenon Purity During Science Runs



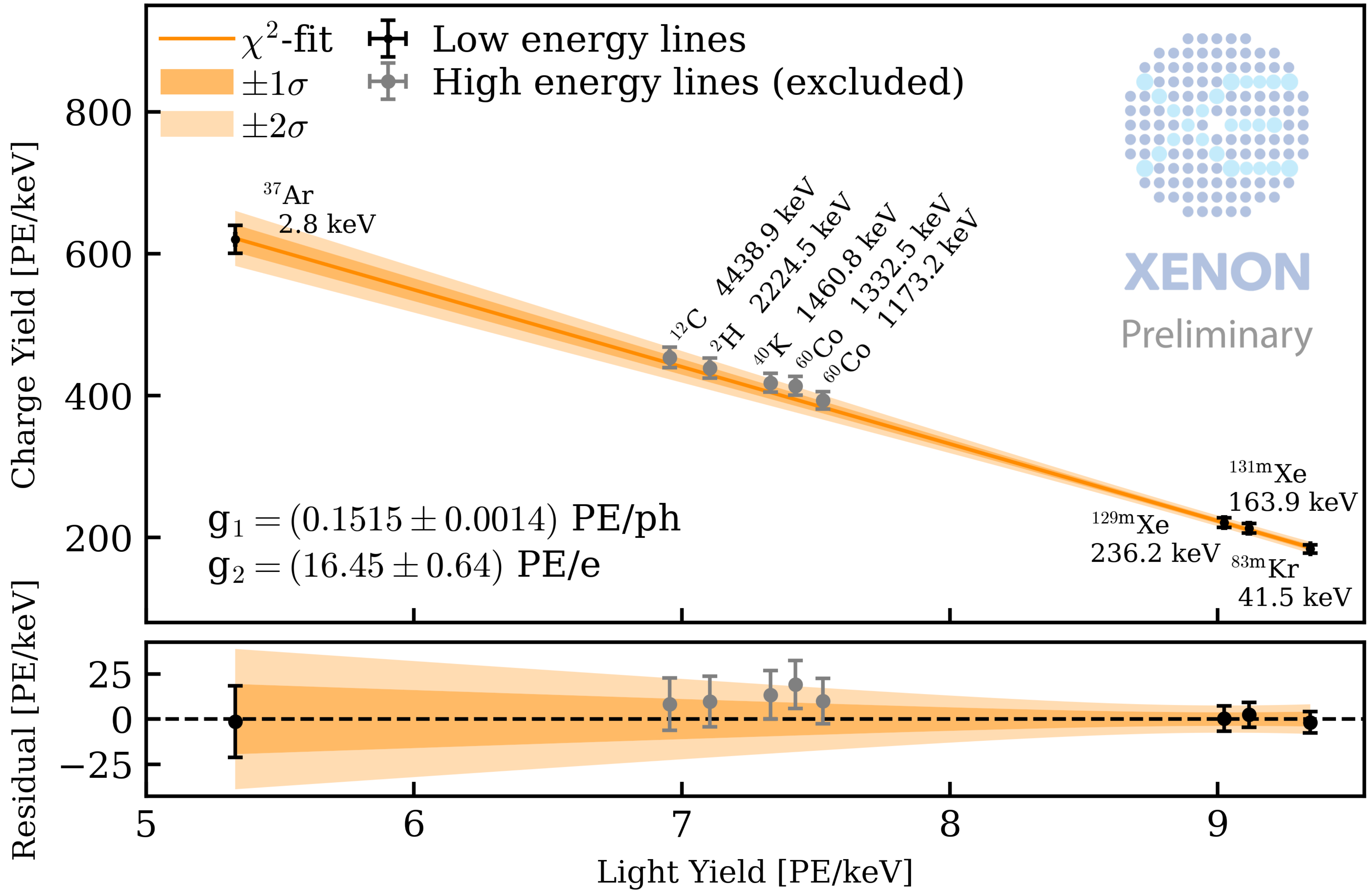




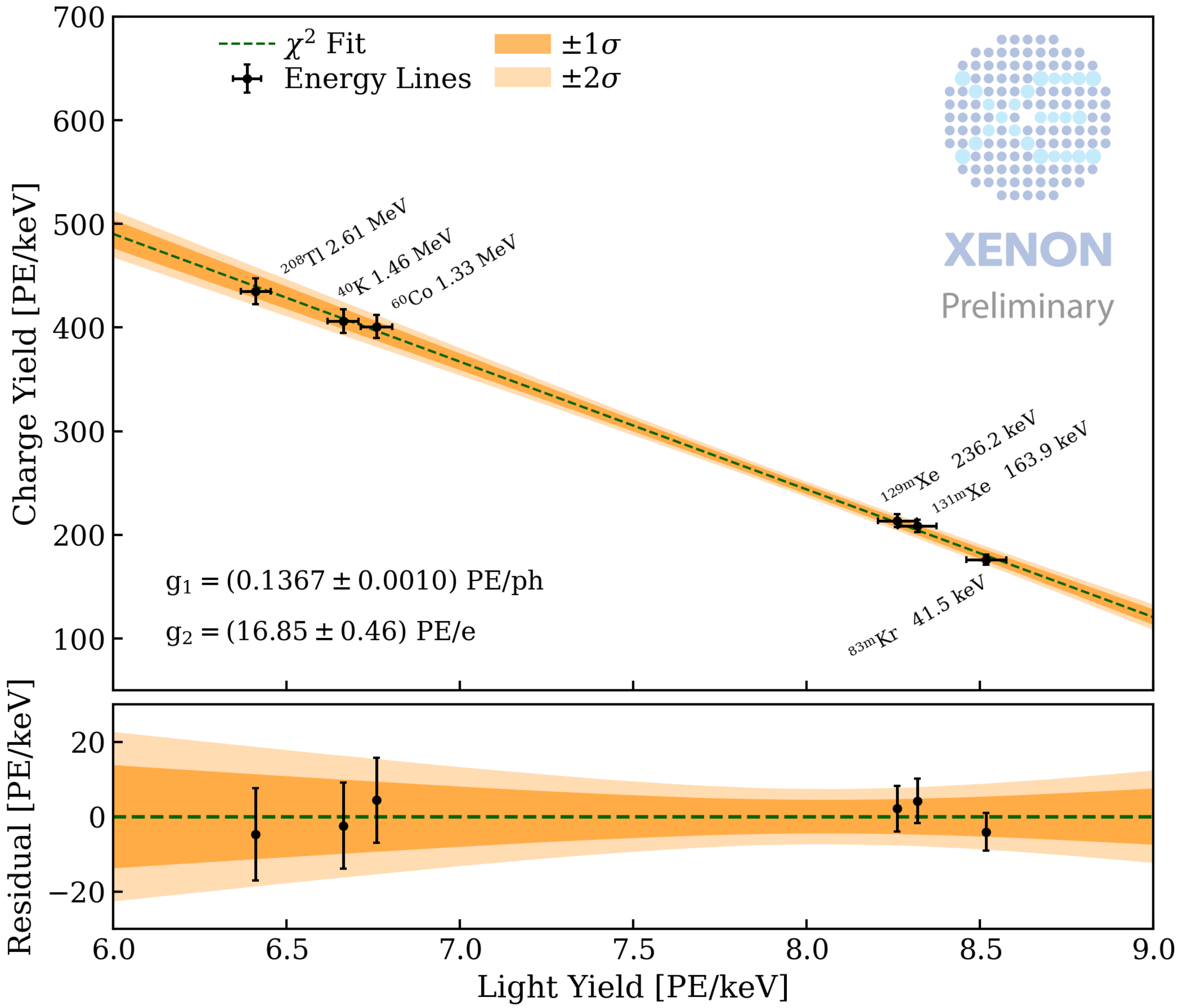
XENONnT maintains high electron lifetime thanks to its novel liquid phase purification

Calibration with Mono-energetic Electronic Recoils

SR0

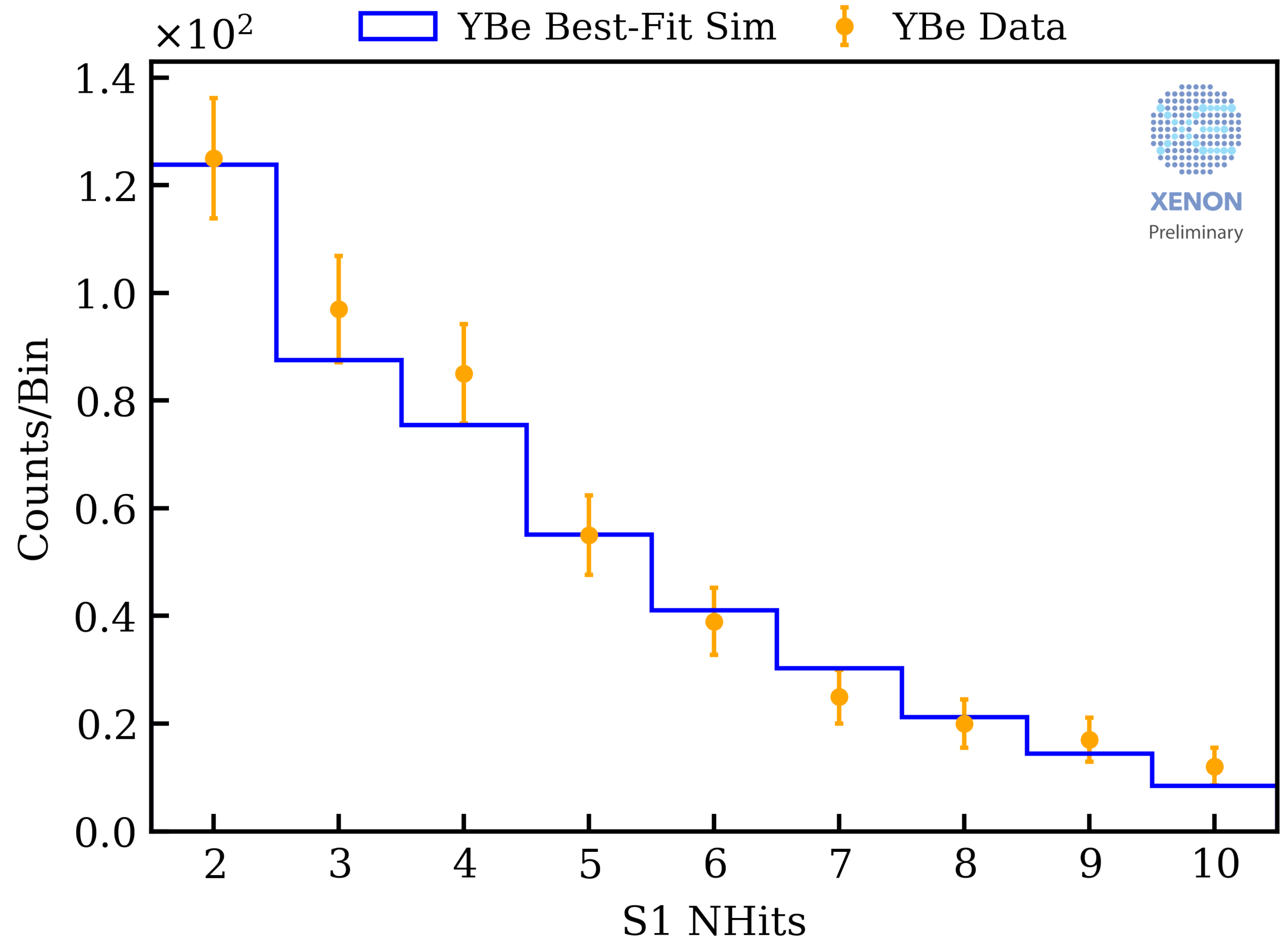


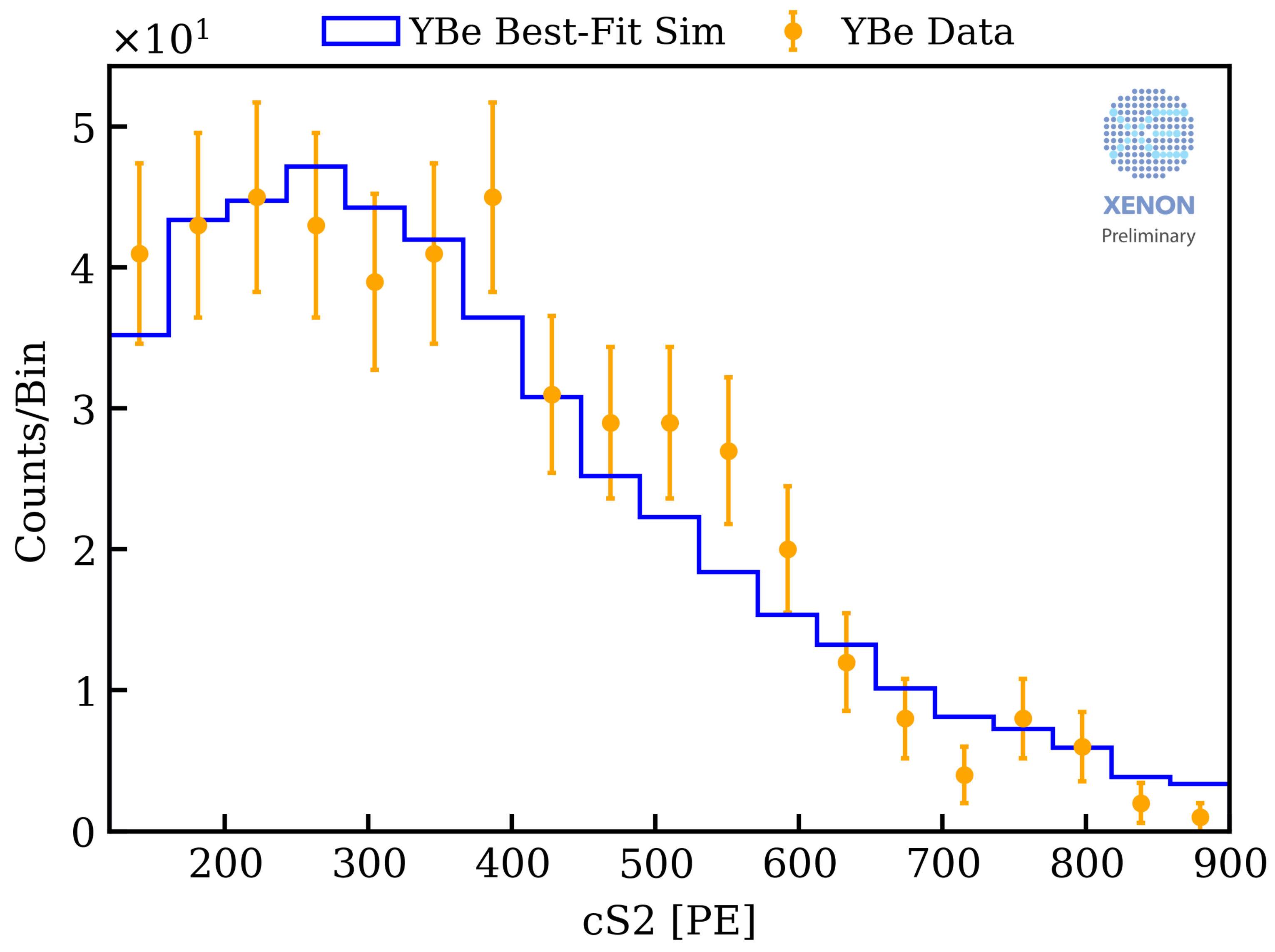
SR1



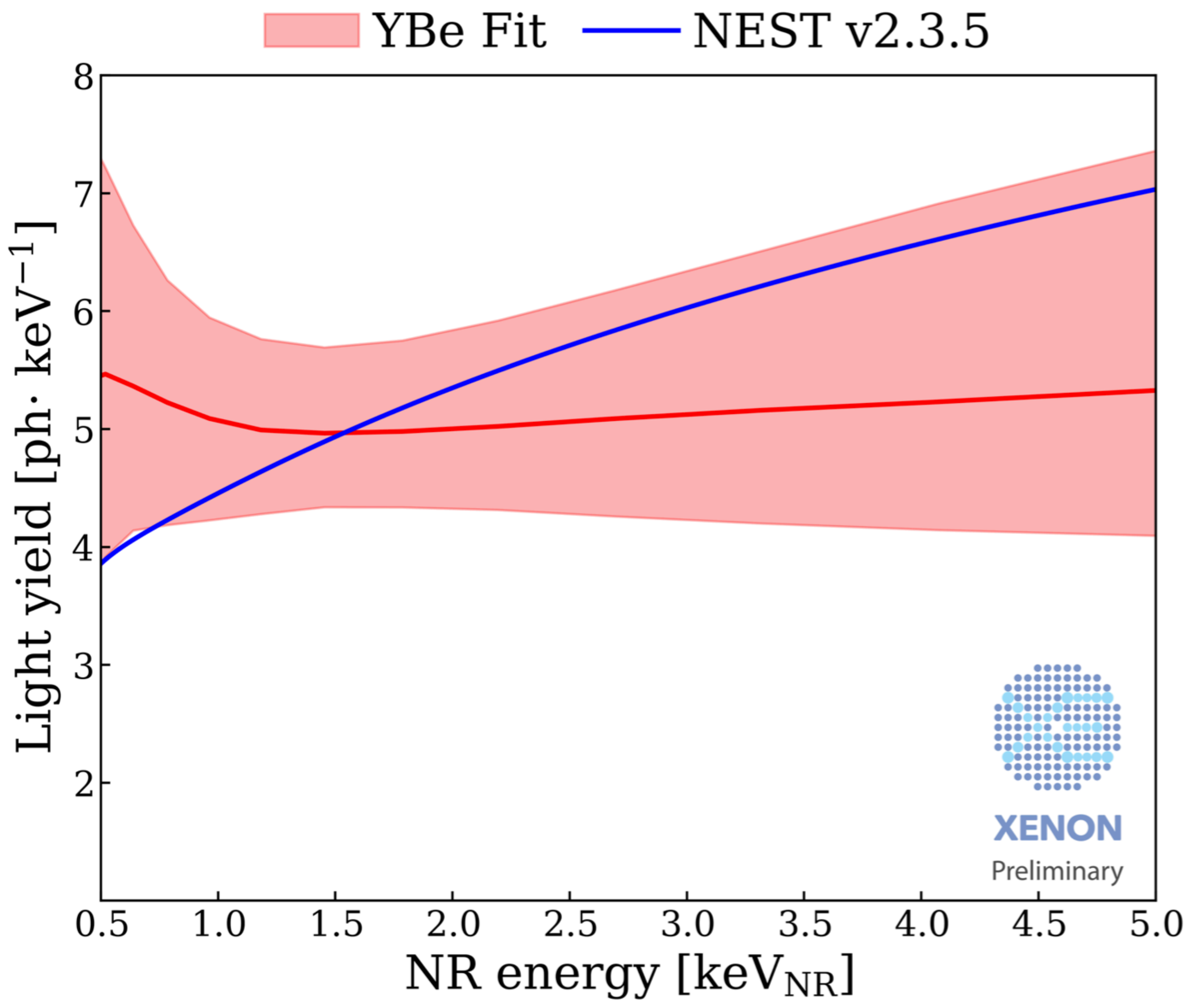
Science Run	g1 [PE/ph]	g2 [PE/e]
SR0	0.1515 ± 0.0014	16.45 ± 0.64
SR1	0.1367 ± 0.0010	16.85 ± 0.46

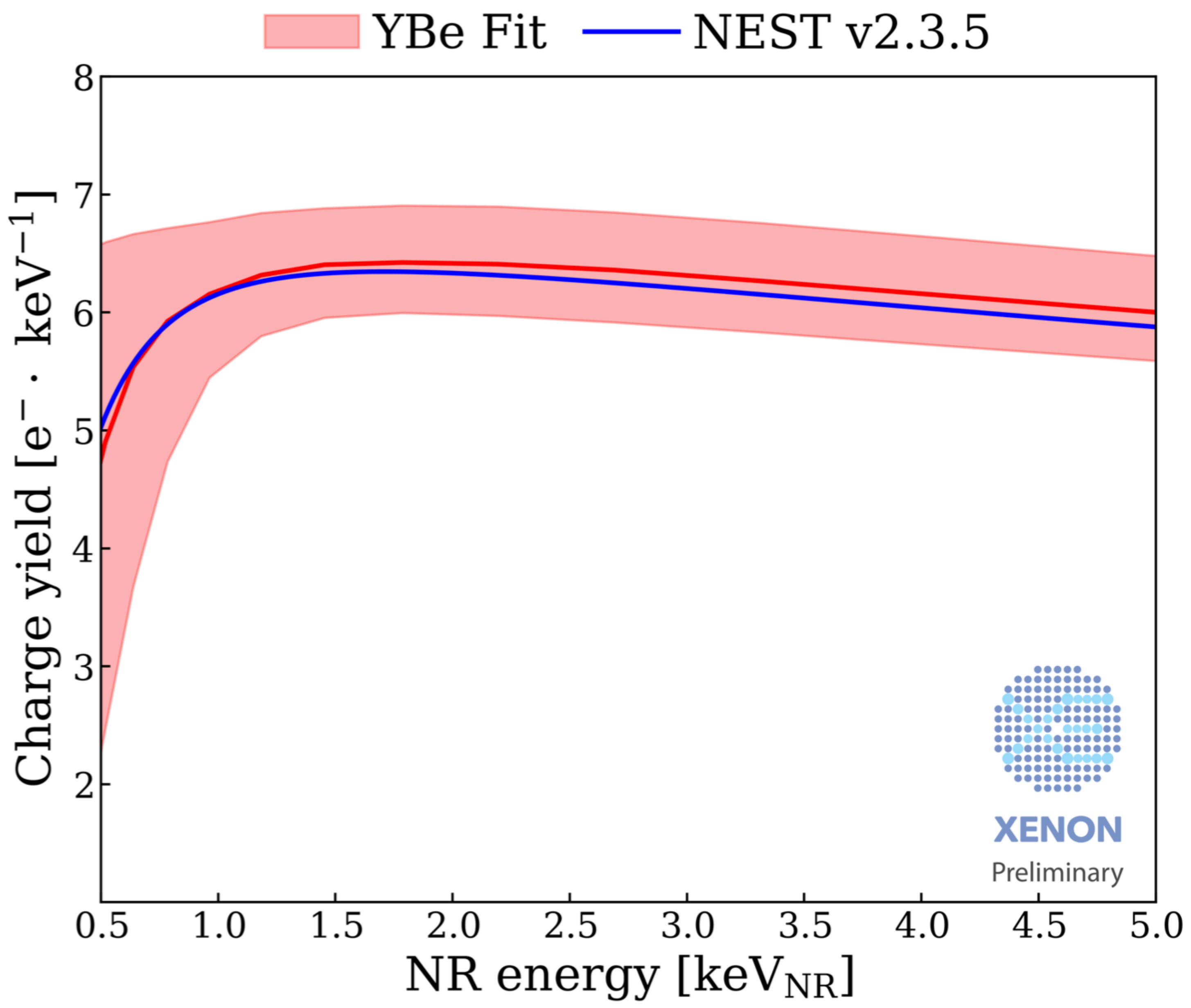
Calibration with YBe Neutron Source





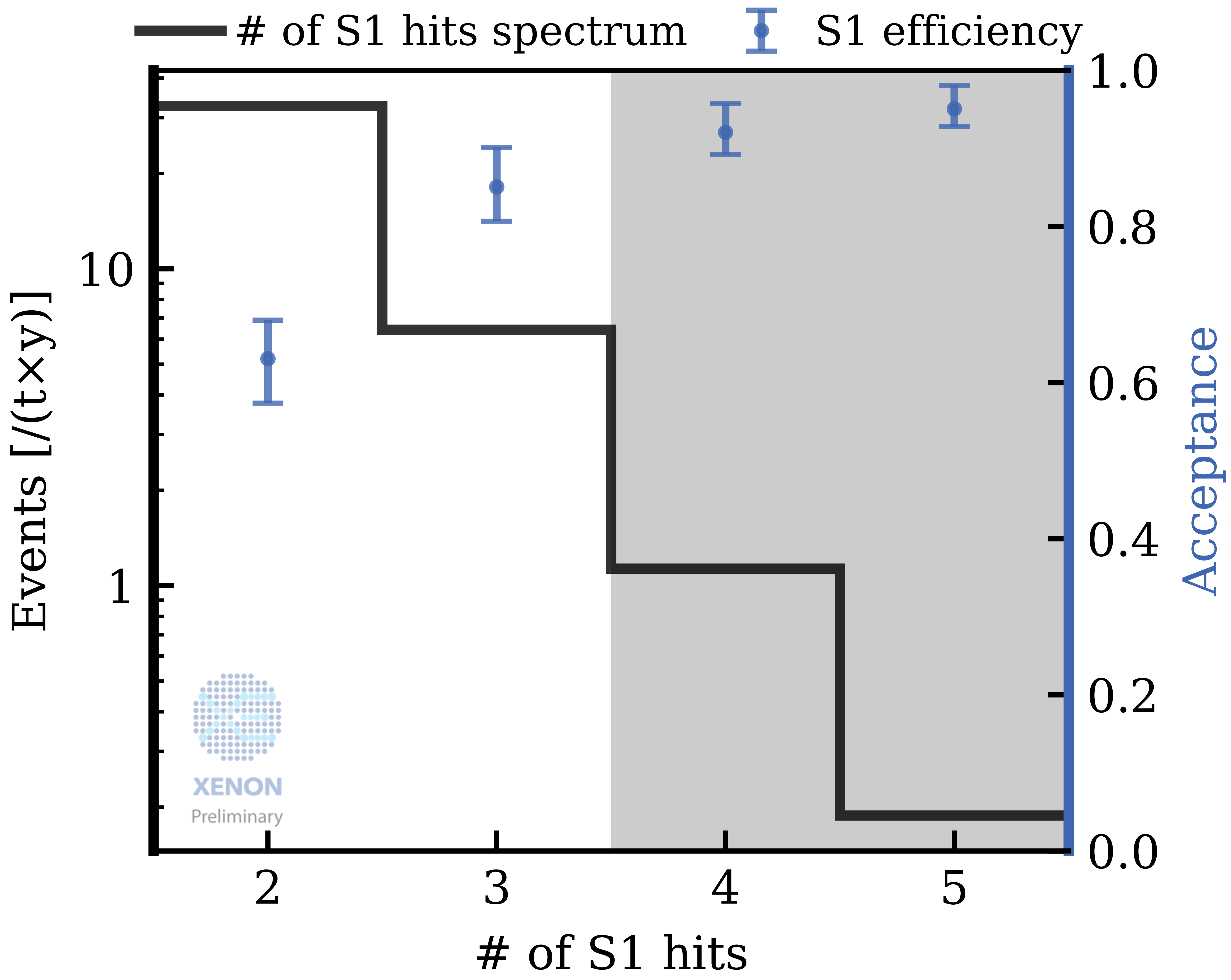
Excellent match between Data and Model



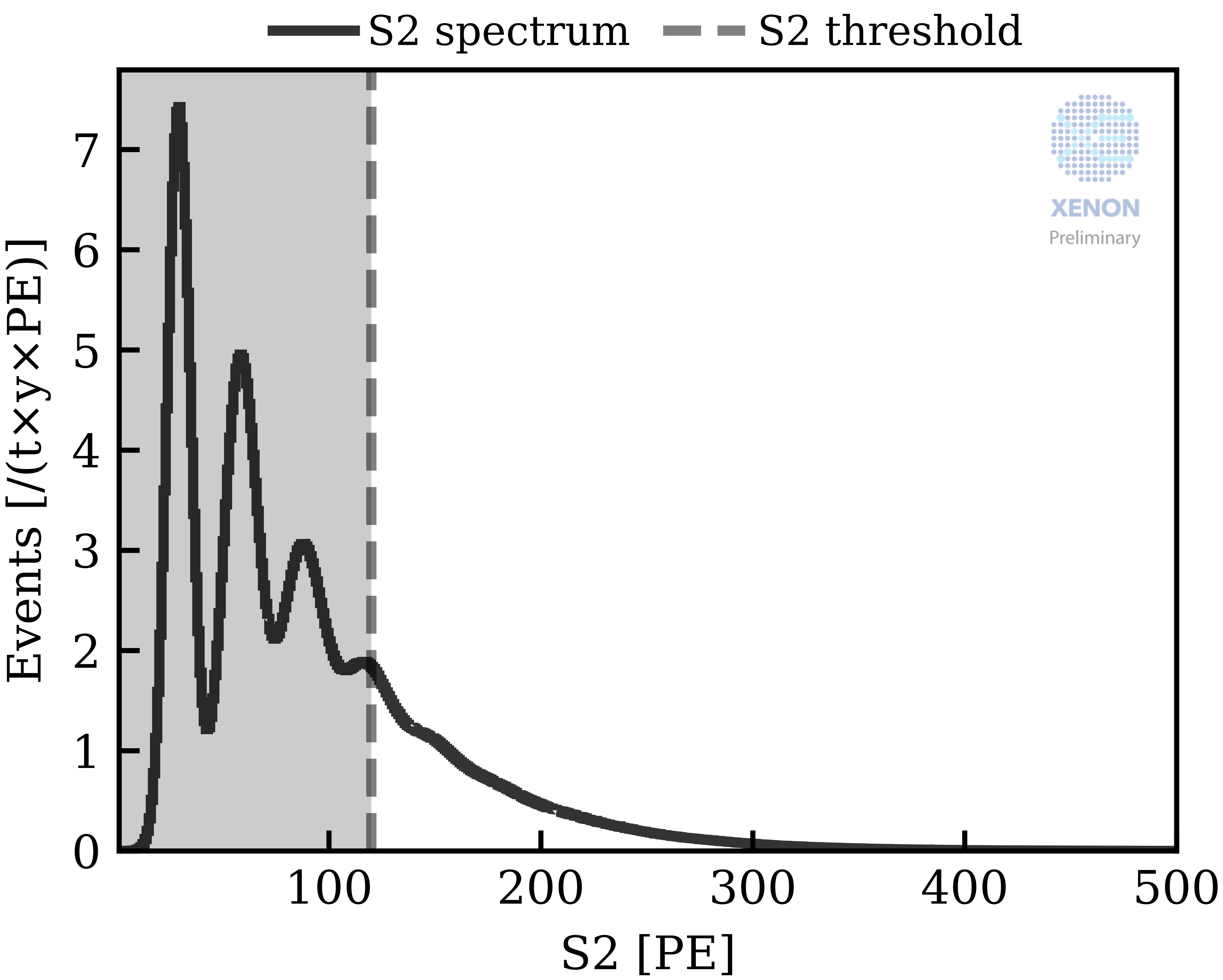


NEST model is constrained by YBe data to predict the light and charge yield in the ^{8}B CEvNS energy range at the XENONnT drift field

^{8}B CEvNS: Signal Region of Interest



S1 Range: 2 & 3 hits

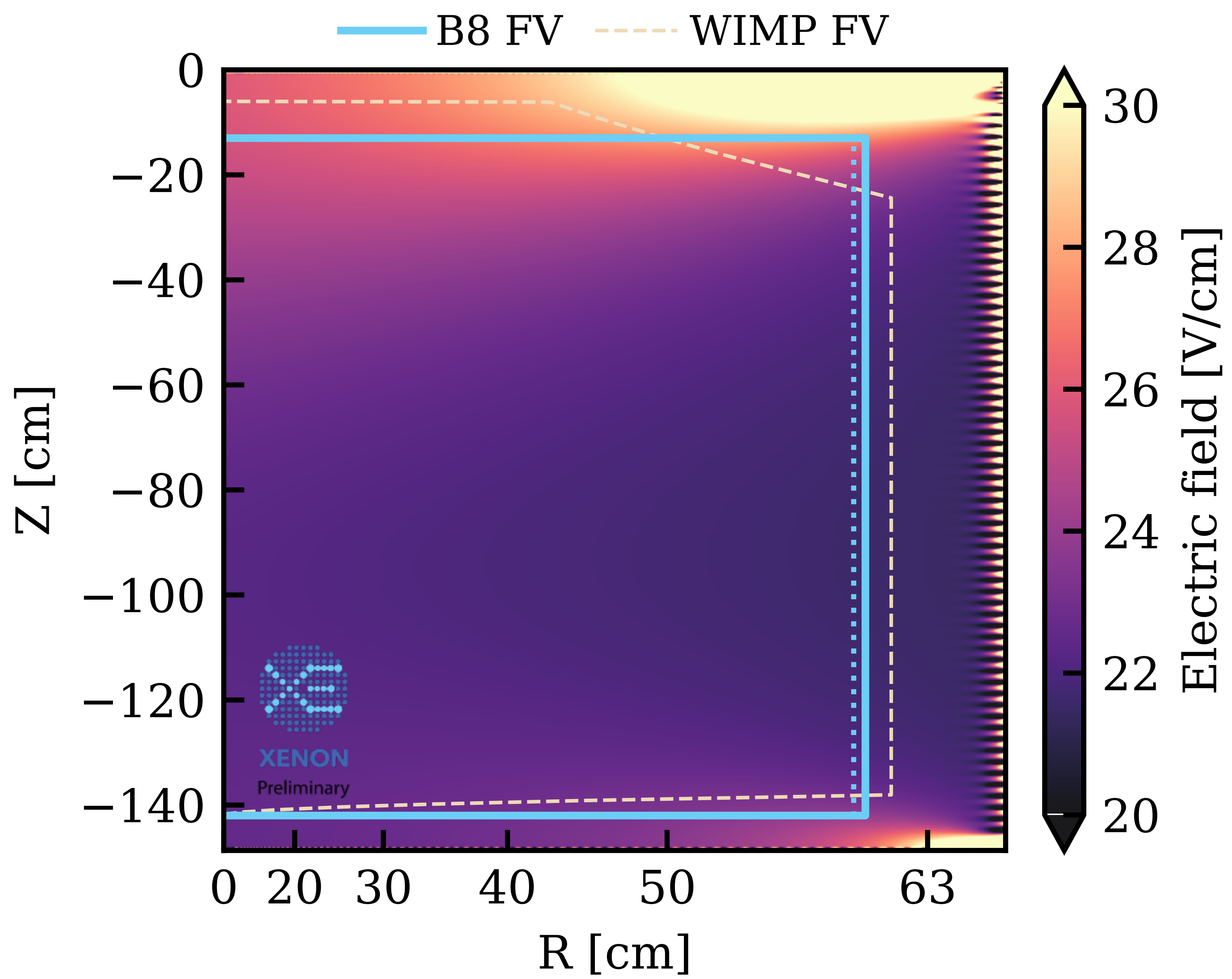


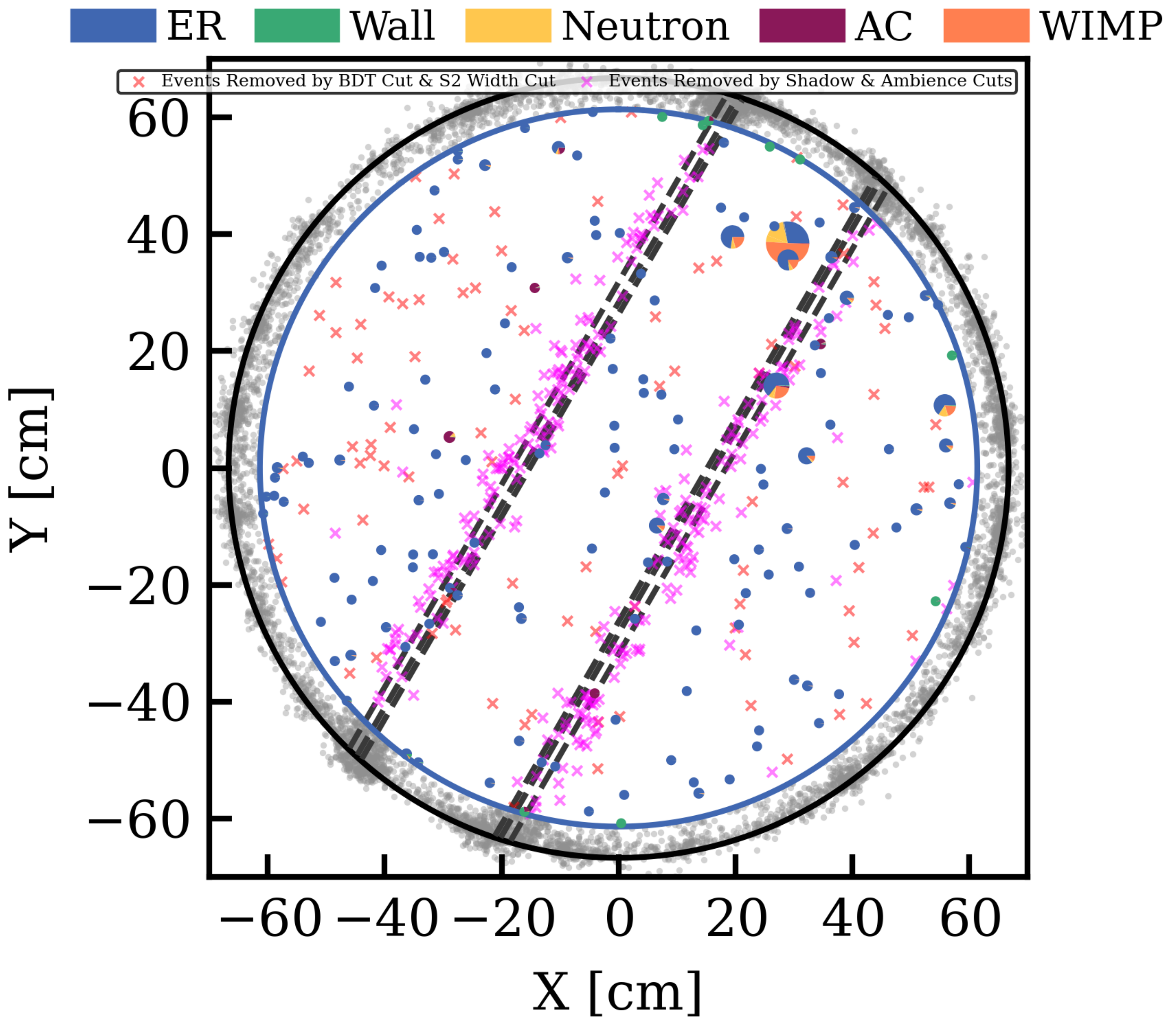
S2 Range: 120 - 500 PE

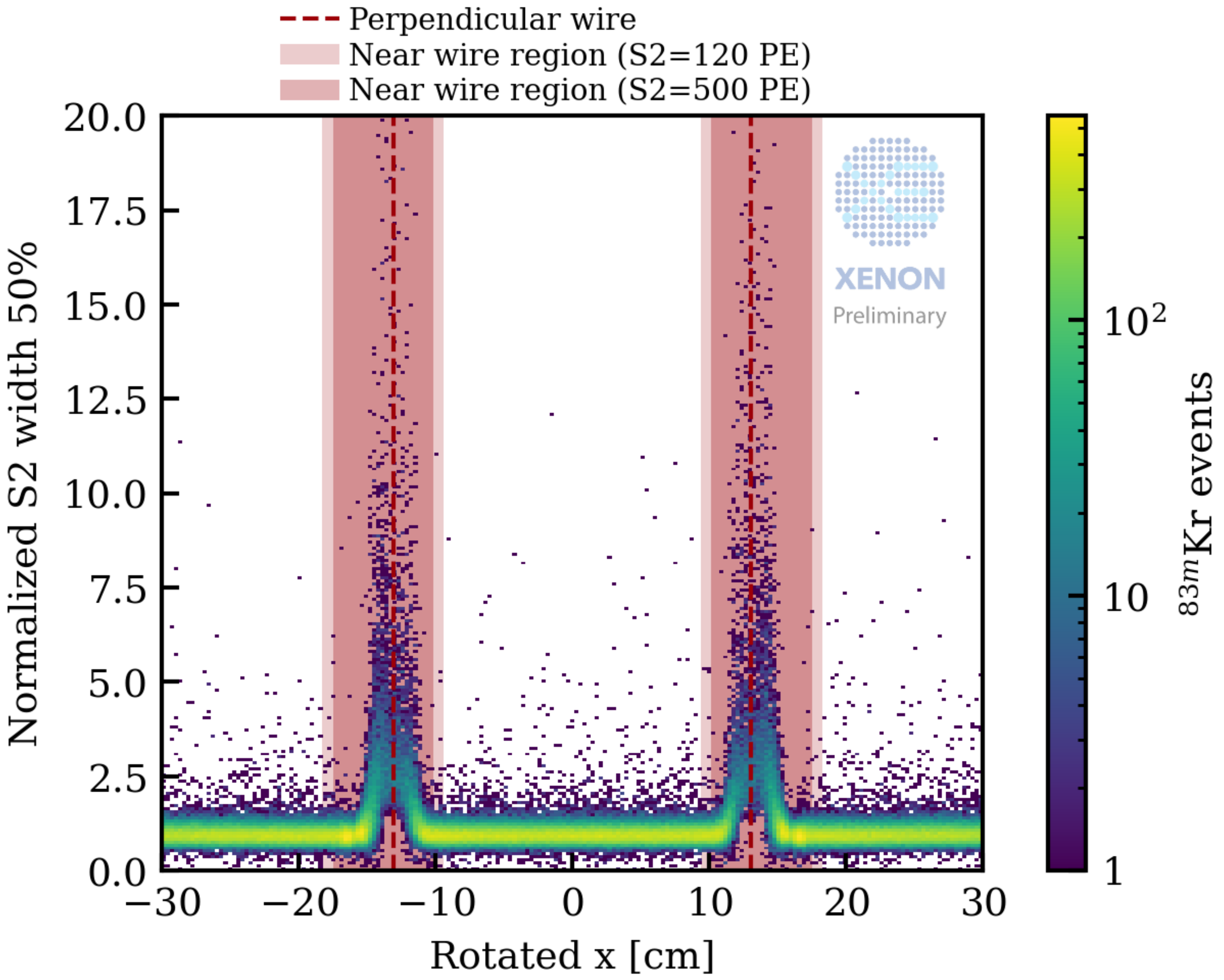
A hit usually corresponds to a photon hitting the PMT and is recorded by our DAQ and software

S2 threshold of 120PE is used to reject high isolated S2 background below it.

Fiducial Volume and Exposure





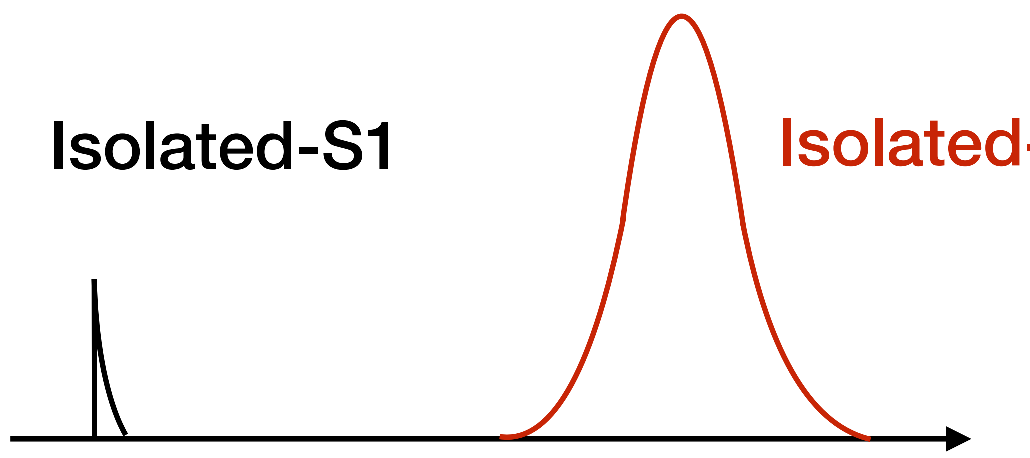


Science Run	Livetime [Years]	Fiducial Mass [Tonne]	Exposure [Ton-Year]
SR0	0.296	3.97	1.17
SR1	0.571	4.10	2.34
SR0+SR1	0.867		3.51

Events around the supporting wires are removed due to:

- high Background rate
- Insufficient modeling of S2

Accidental Coincidence (AC) Background



Accidental Coincidence Background in XENONnT for Low Energy Nuclear Recoil Search

Jul 8, 2024, 3:00 PM
20m
Palazzo dell'Emiciclo, Sala Ipogea

Parallel talk
Direct detection

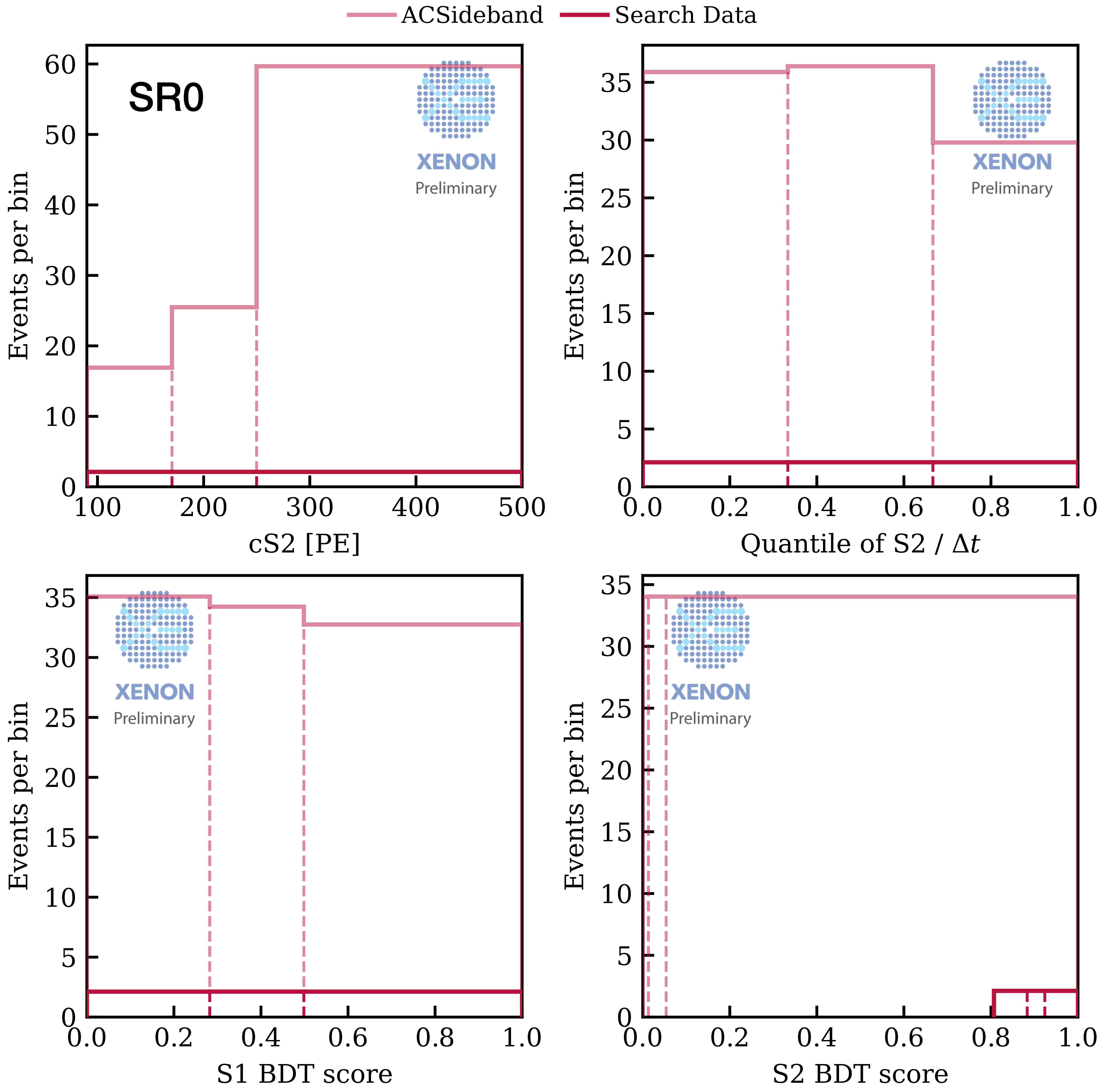
Speaker

Kexin Liu (Tsinghua University)

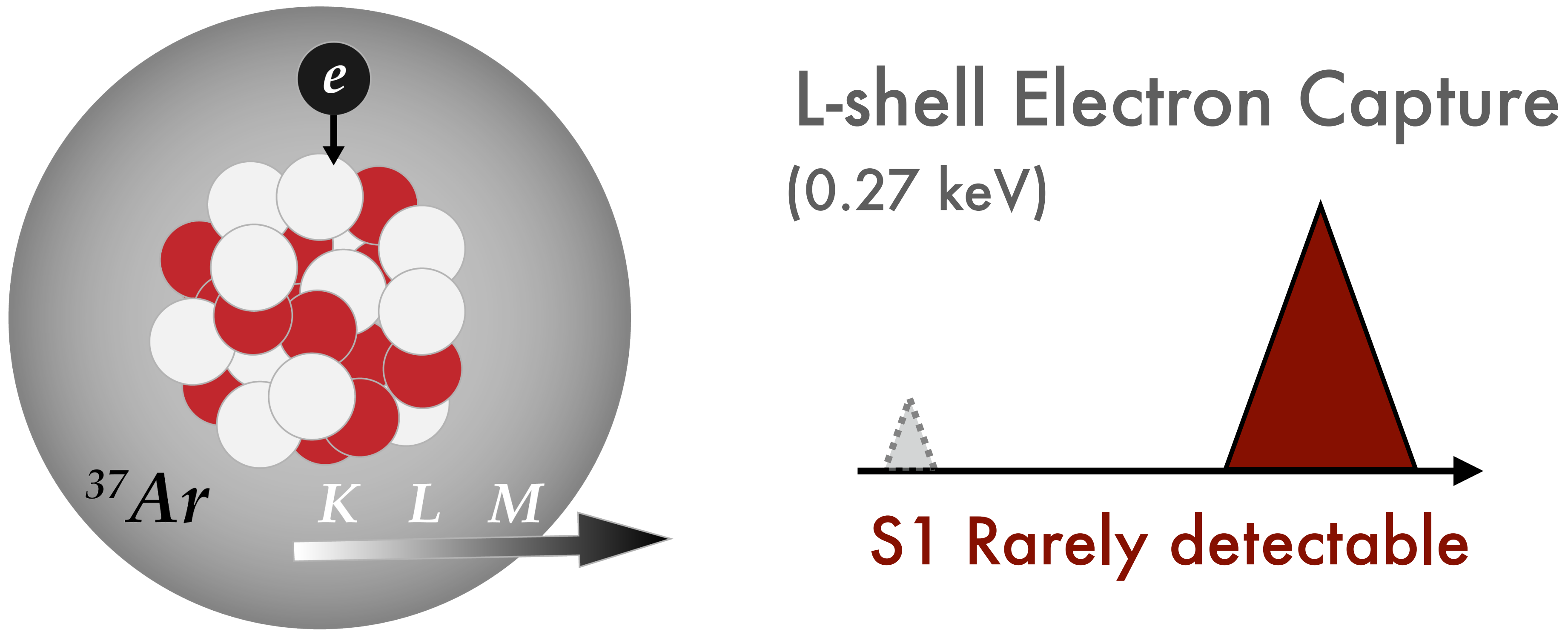
Component	Sideband Data	Search Data
AC - SR0	123.7	7.48
AC - SR1	350	17.77
^{8}B	< 2	11.93

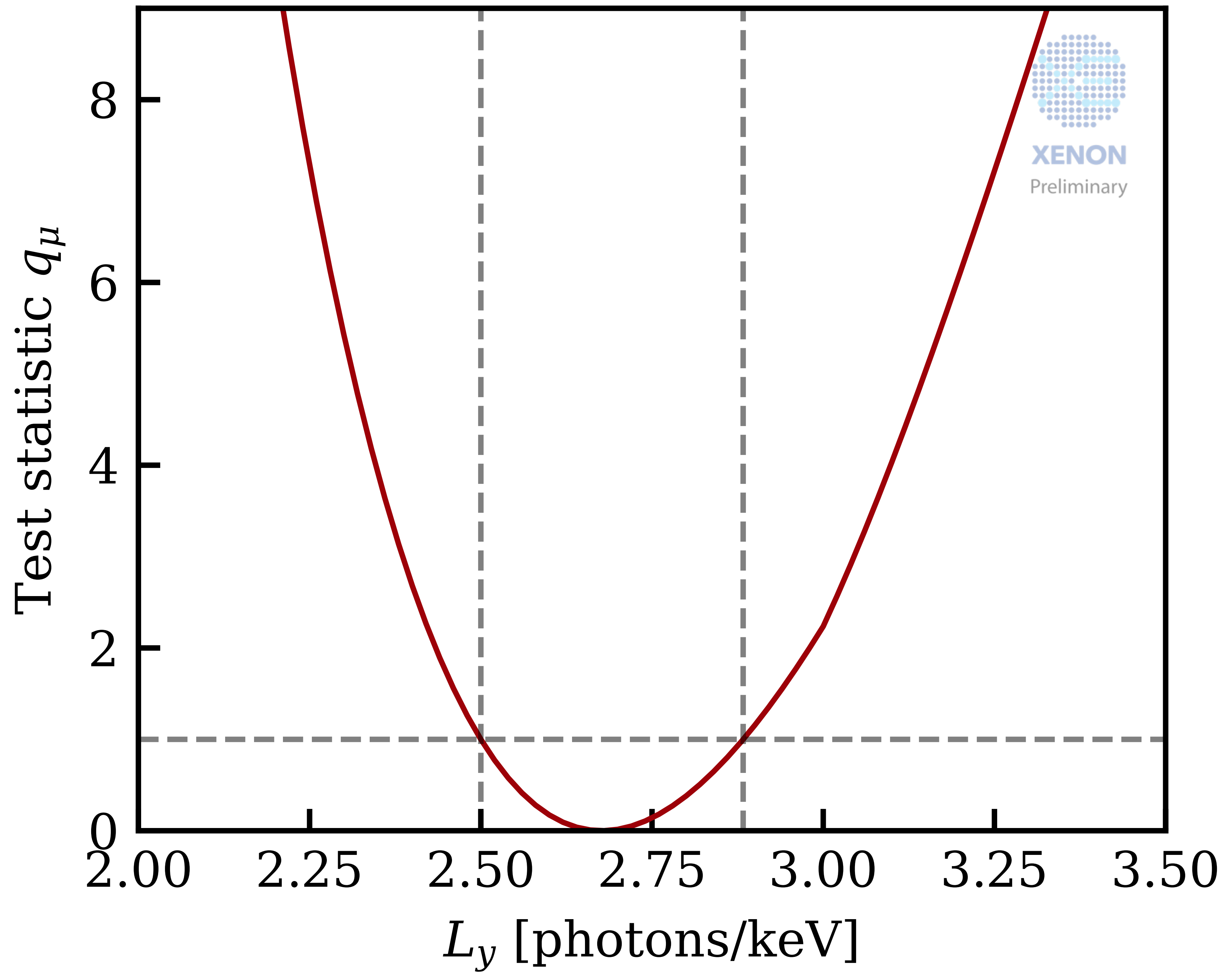
The final likelihood analysis includes:

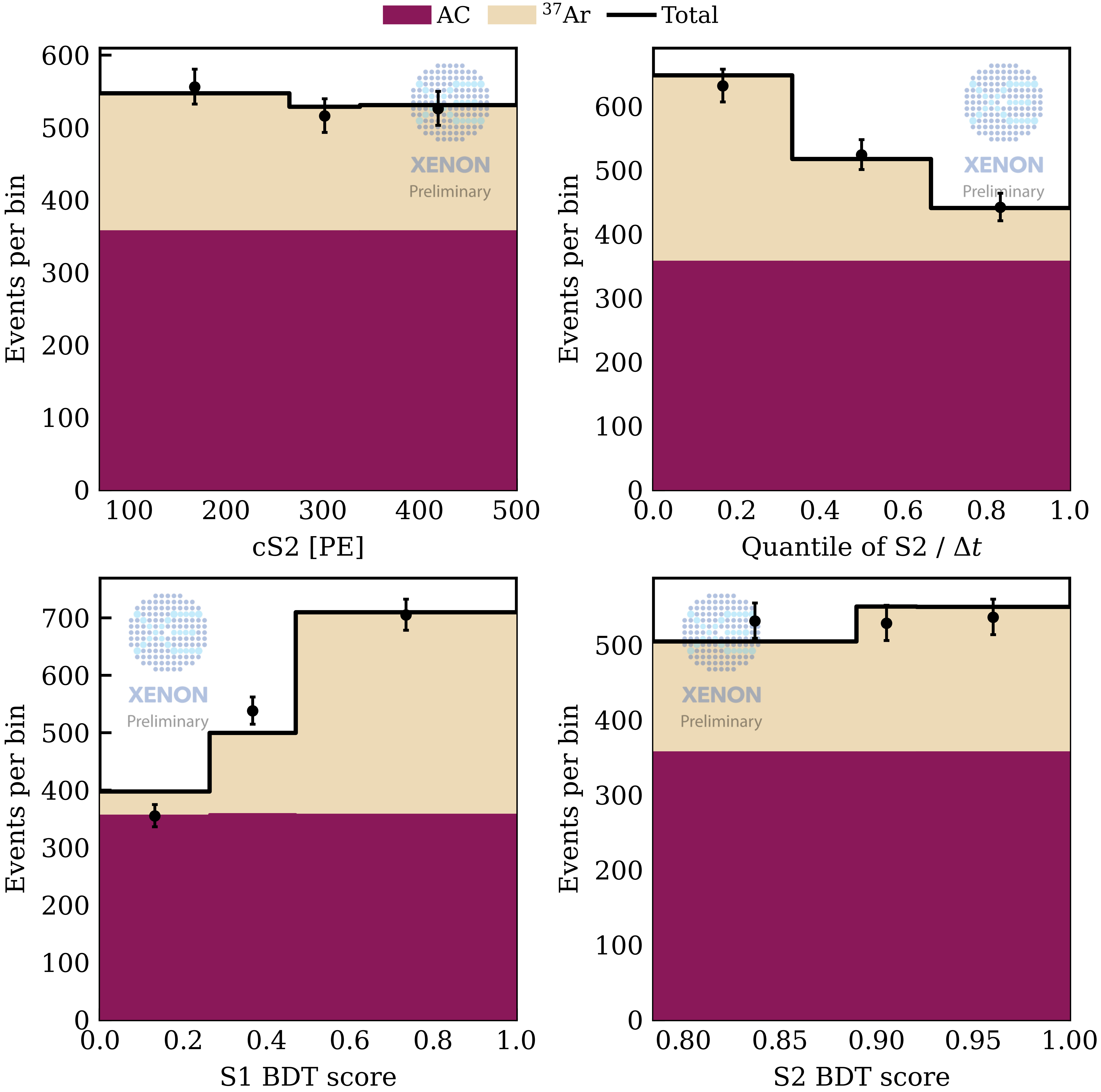
- 4D space (81 bins) for AC discrimination
- 2 Science Runs



Analysis Validation with ^{37}Ar





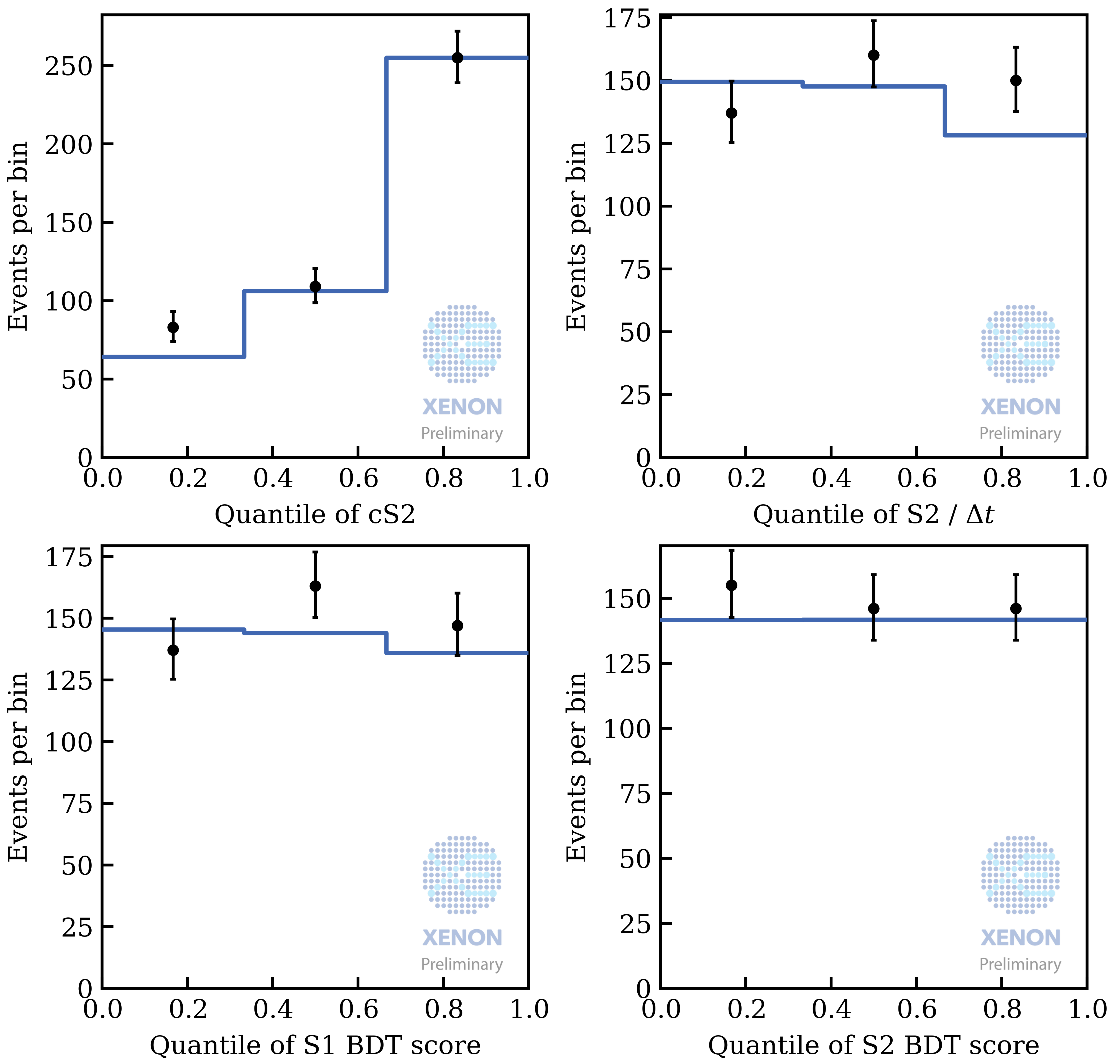


AC-Sideband Unblinding

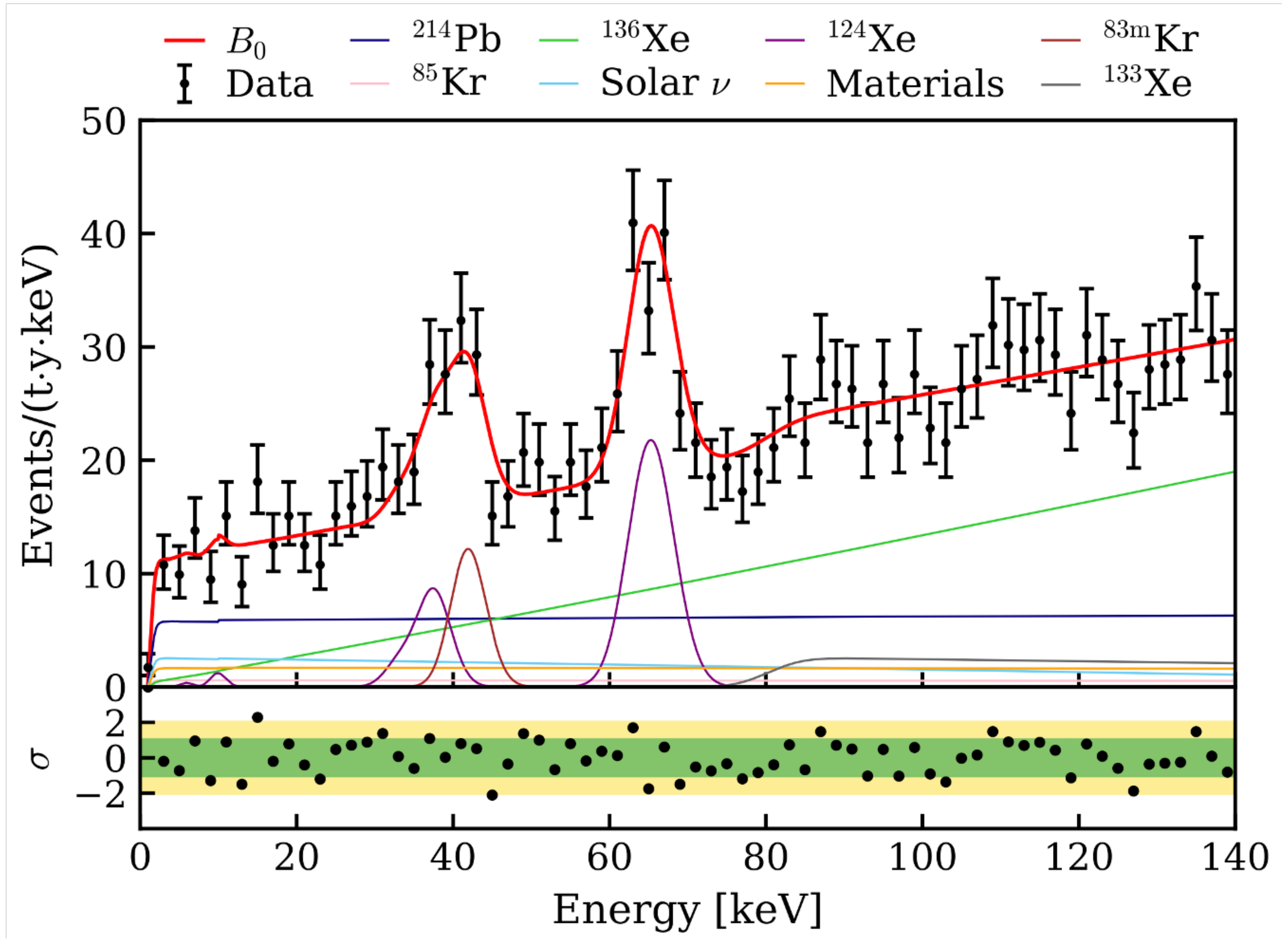
The S2 threshold is increased to 120 PE after sideband unblinding!

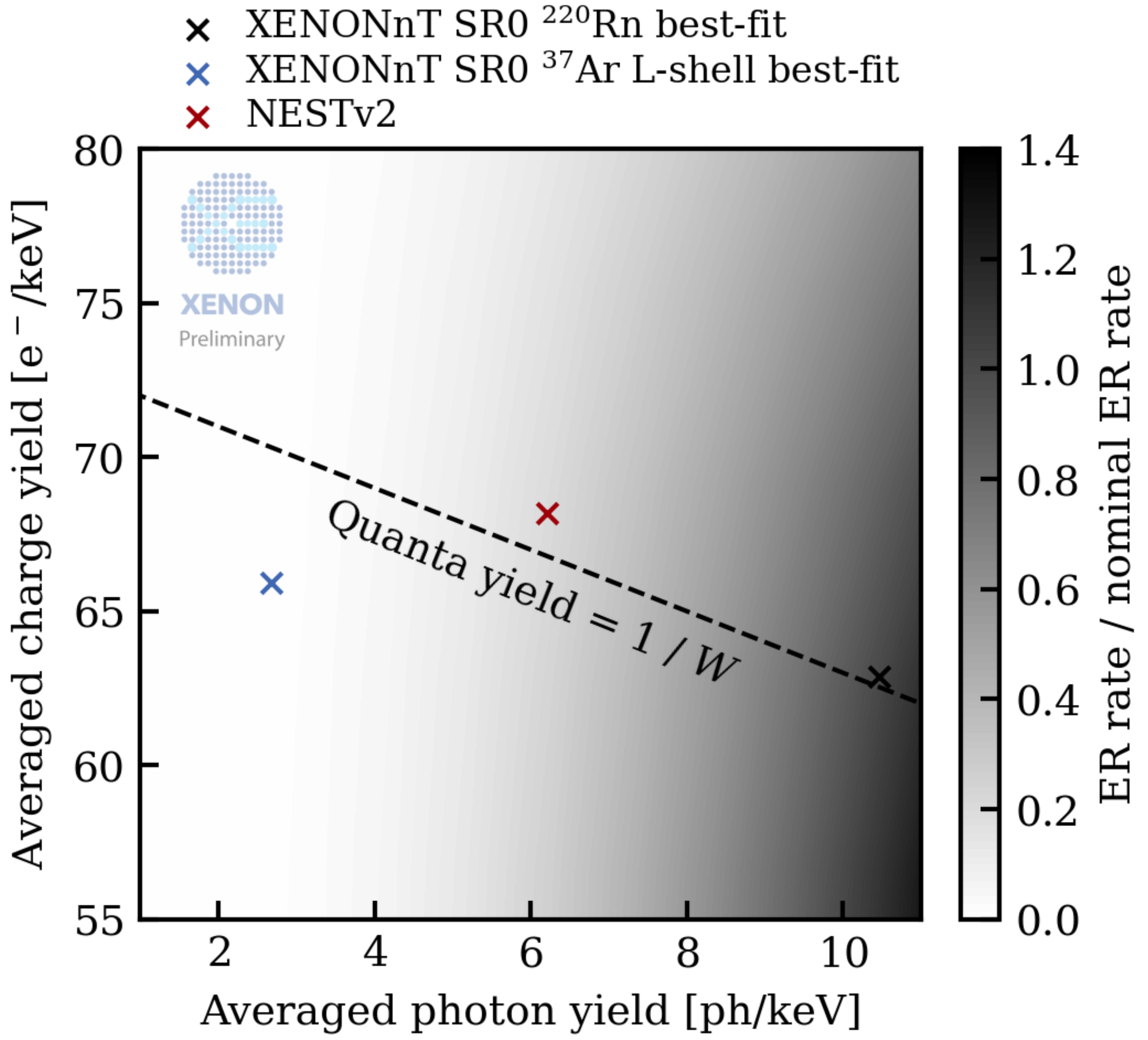
Science Run	Expectation	Observation	P-value (4D)	Deviation from expectation
SR0	122.7	121	0.33	-0.15 sigma
SR1	290.0	310	0.252	1.17 sigma

The remaining differences are considered potential systematical uncertainties! (<10%)



Electronic Recoil Background



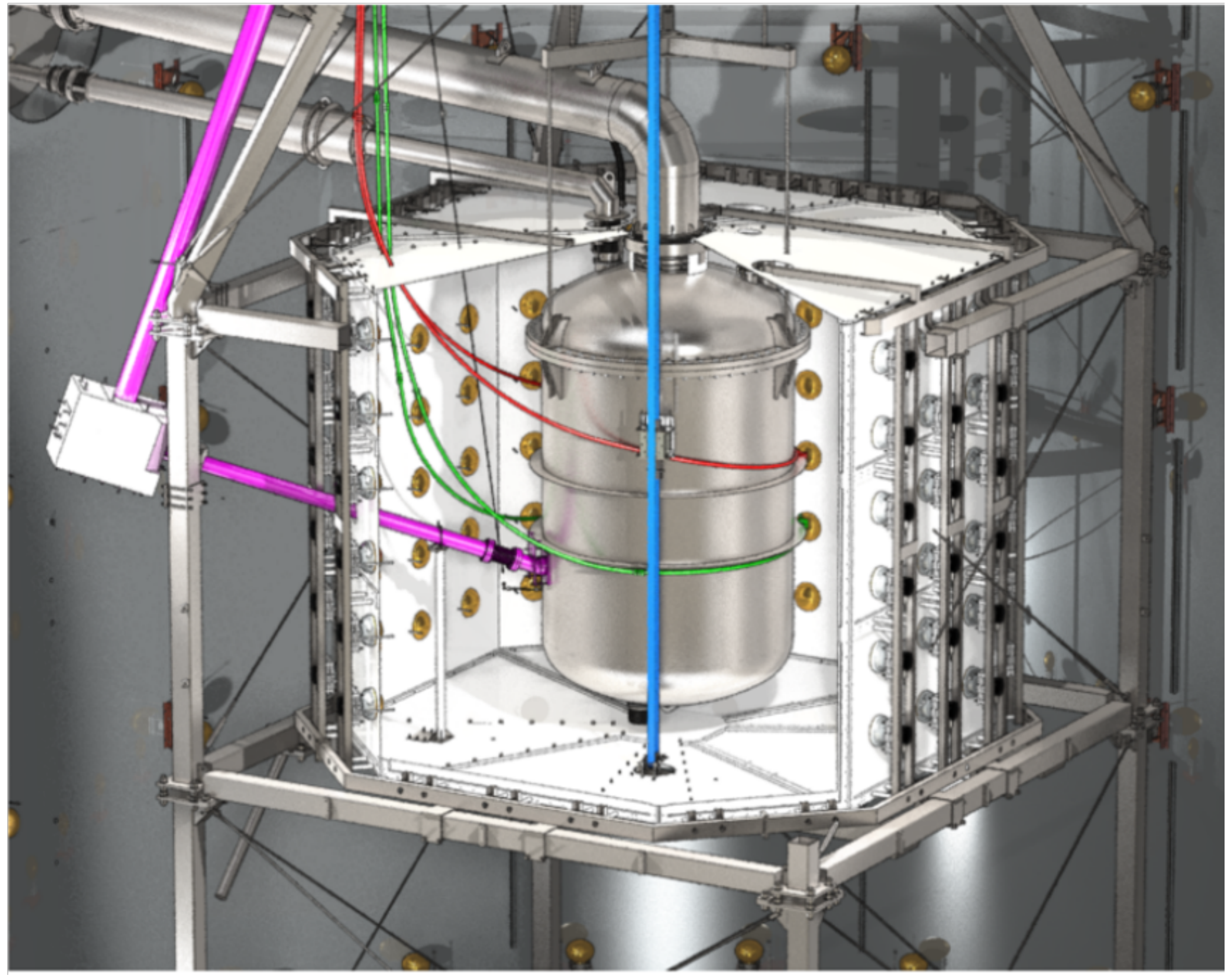


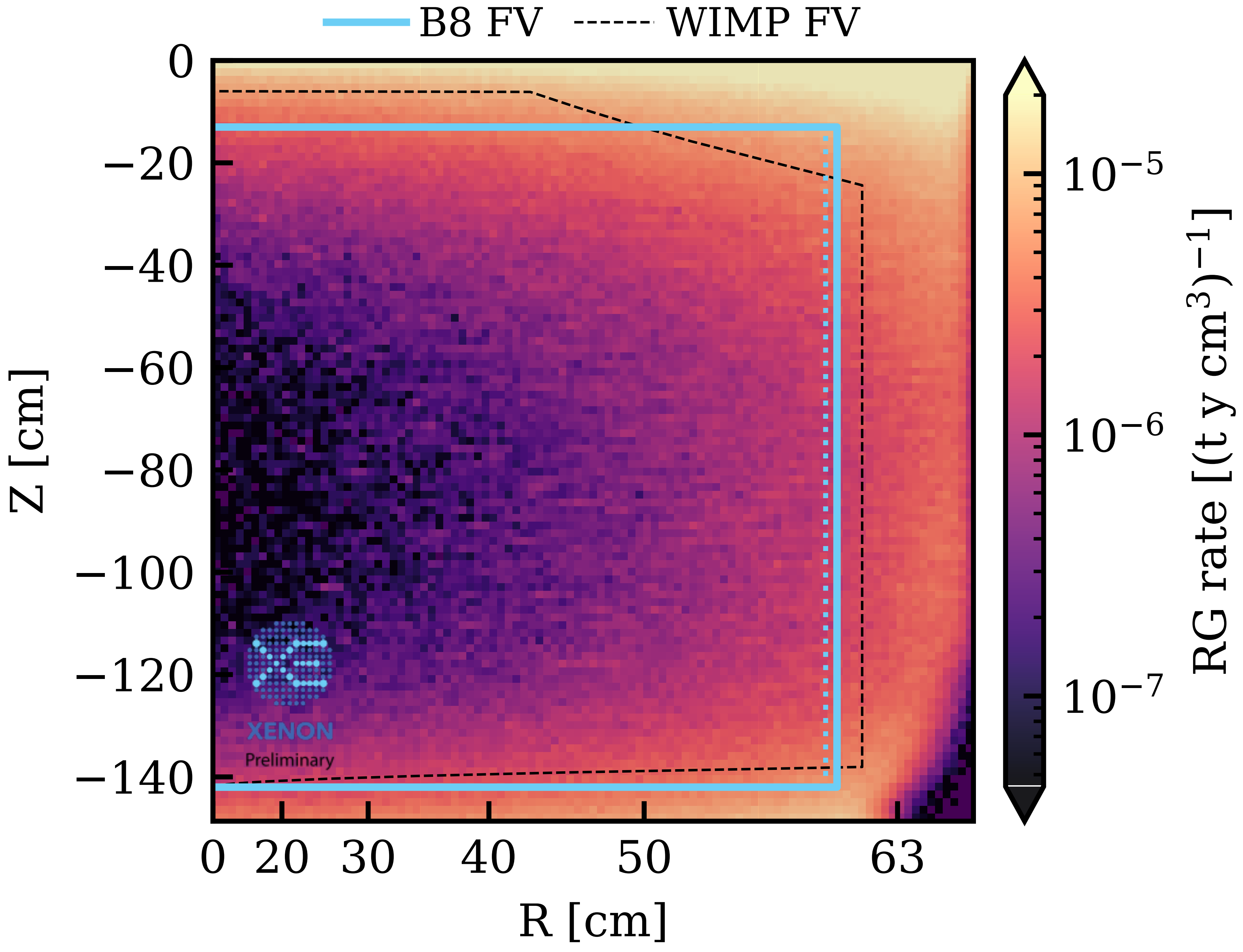
Science Run	CEvNS ROI (^{220}Rn Model)	CEvNS ROI (NESTv2 Model)
SR0	0.13	~0
SR1	0.56	~0

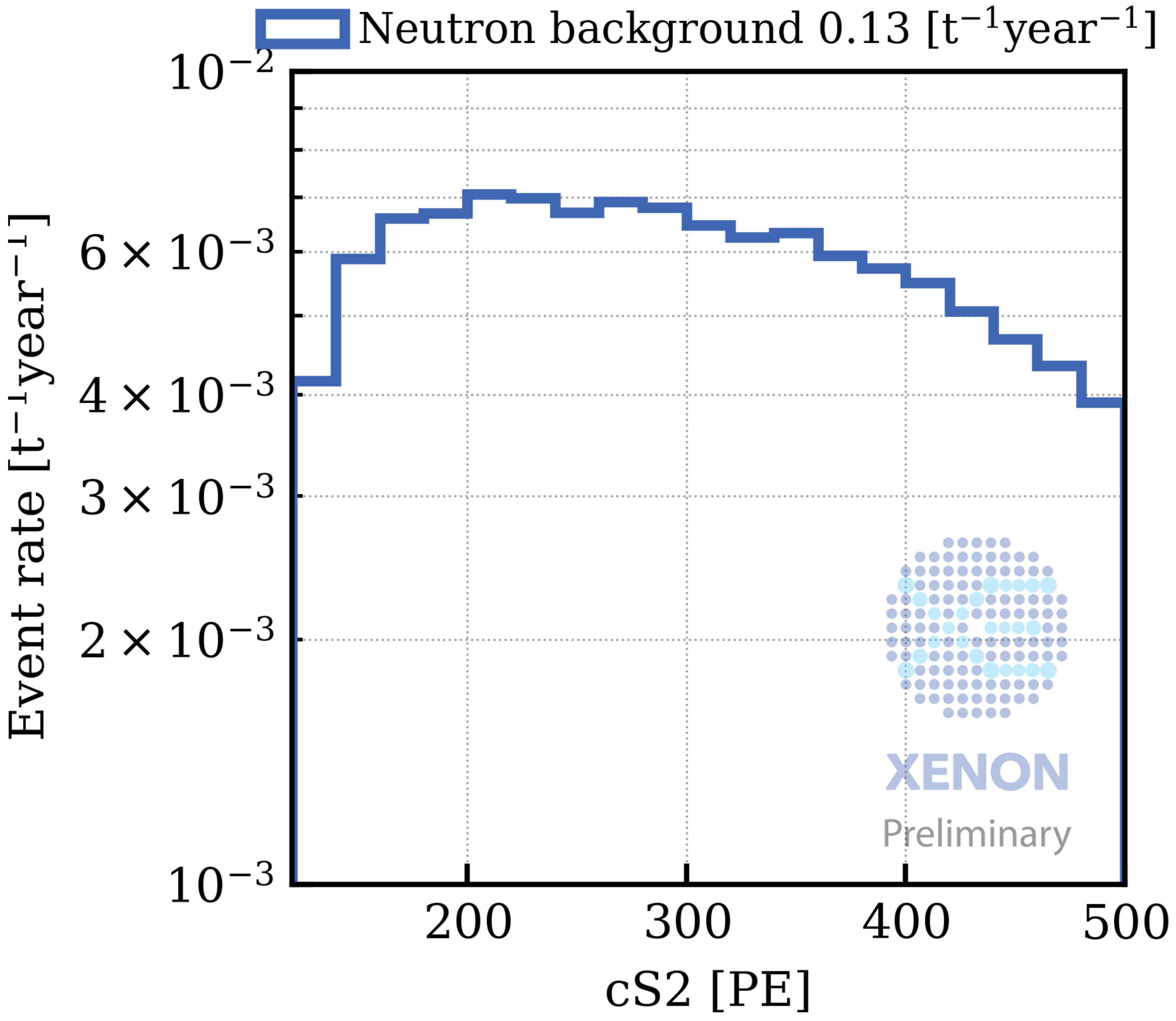
Final background prediction (conservative):

- SR0: 0.13 ± 0.13 Events
- SR1: 0.56 ± 0.56 Events

Neutron Background







The XENONnT Neutron Veto: performances without and with Gd-doping.

Jul 8, 2024, 5:10 PM

20m

Palazzo dell'Emiciclo, Sala Ipogea

Parallel talk | Direct detection

Speaker

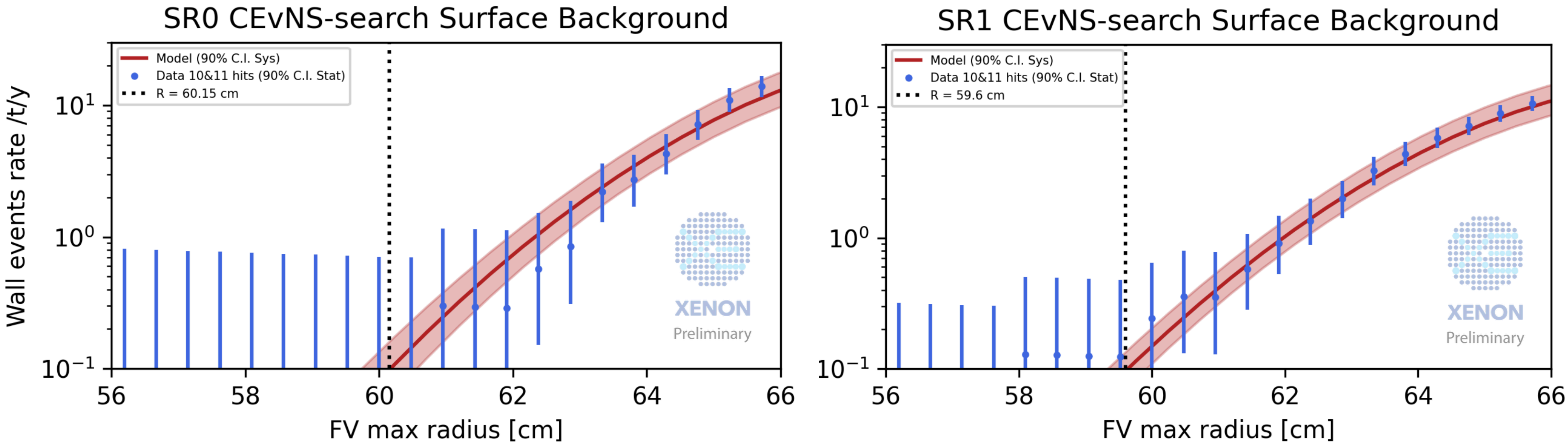
Marco Selvi (Istituto Nazionale di...

Uncertainty is determined with sideband data tagged with Neutron Veto

Final background prediction:

- SR0: (0.13±0.07) Events
- SR1: (0.33±0.19) Events

Surface Background



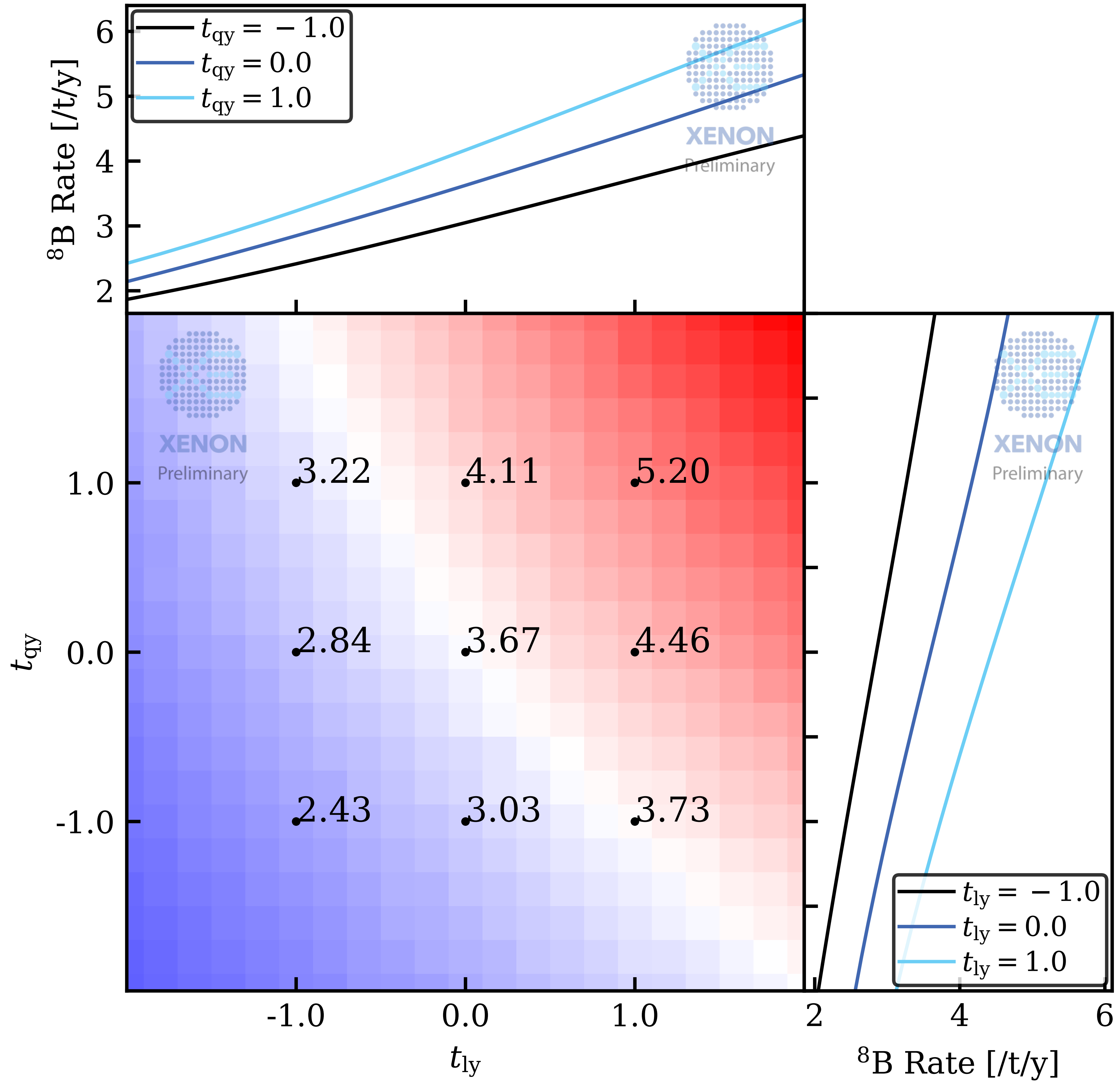
A radial cut is placed to reduce the background on the inner surface of the PTFE panels

Final background prediction:

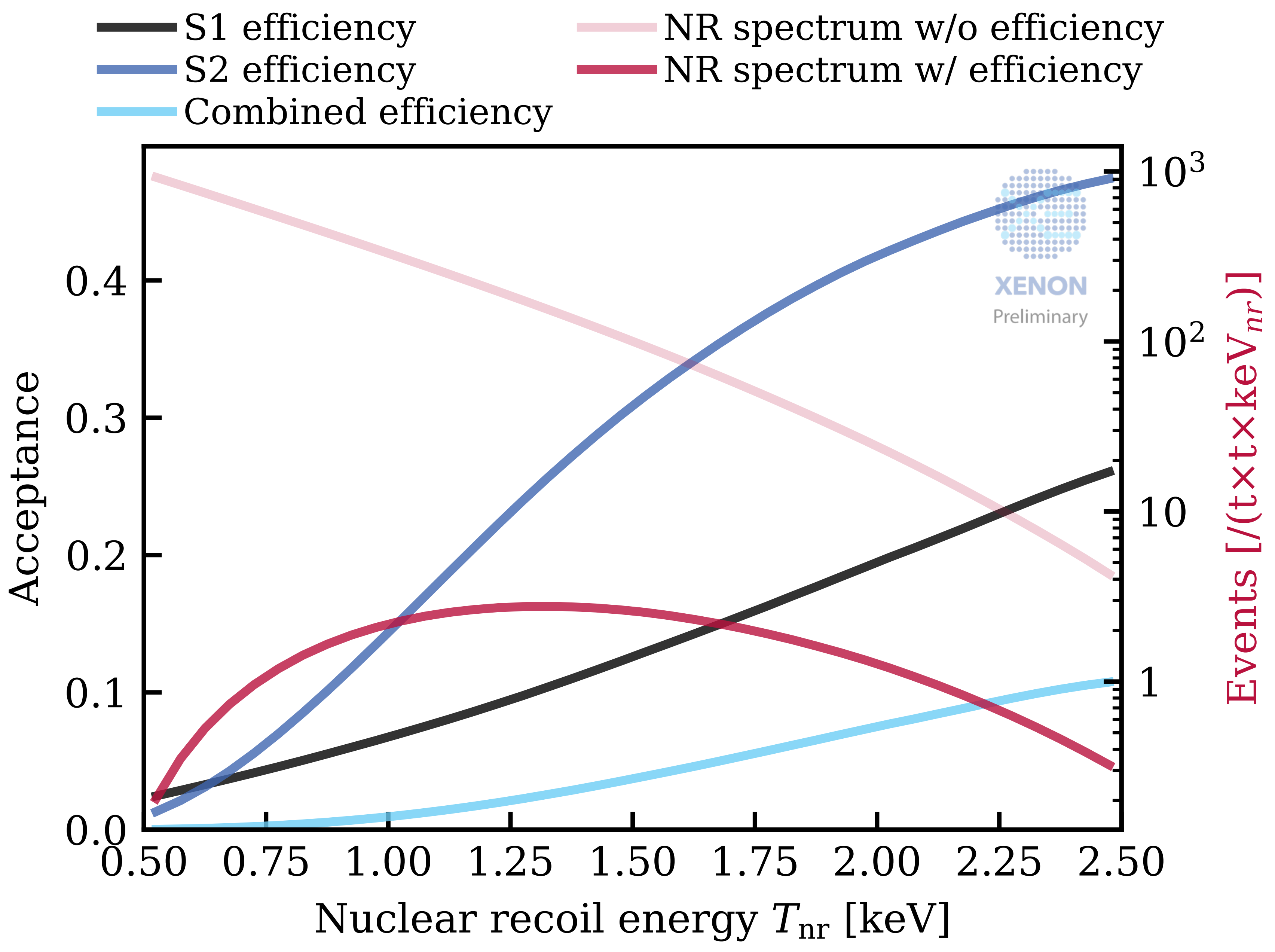
- SR0: < 0.12 Events
- SR1: < 0.23 Events

A negligible component in this analysis

Final Prediction of ^8B Signal and Background

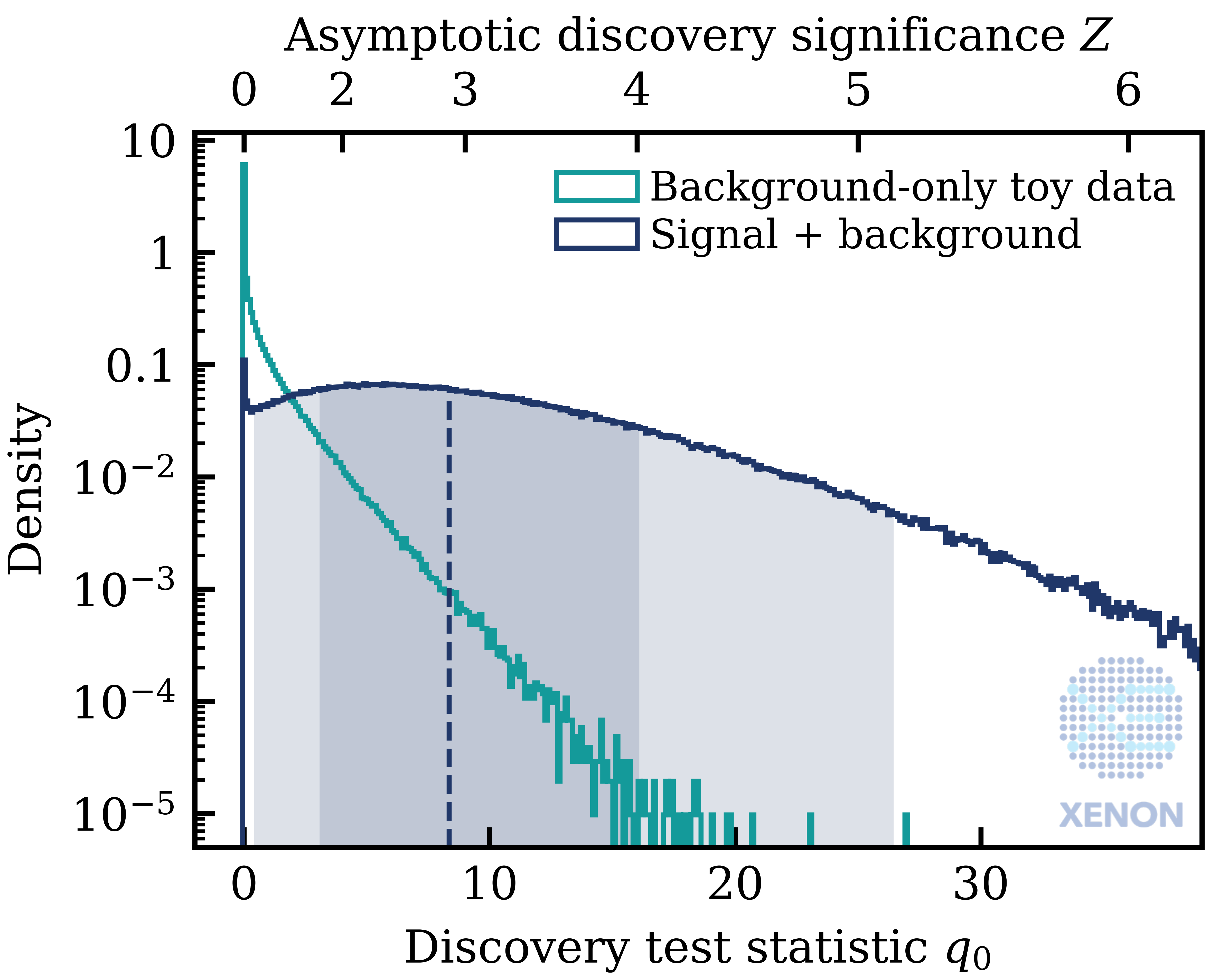


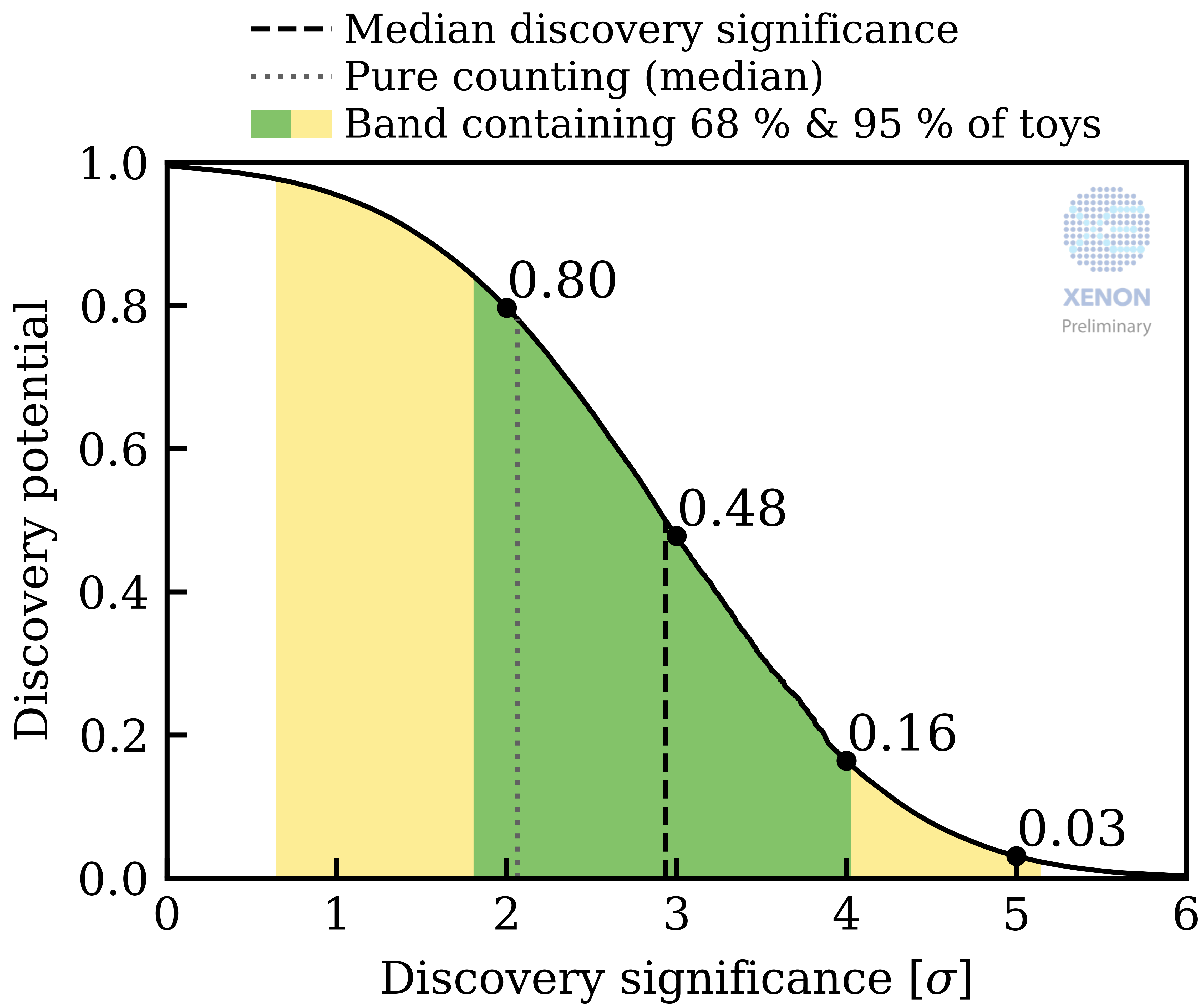
Component	Rate [Events]
AC - SR0	7.48 ± 0.52
AC - SR1	17.77 ± 1.23
ER	0.68 ± 0.68
NR	0.47 ± 0.32
Total Background	26.4 ± 1.5
^8B	11.93 ± 3.1



We expect solar ^8B neutrinos at a median significance of ~2σ, with a counting-only analysis

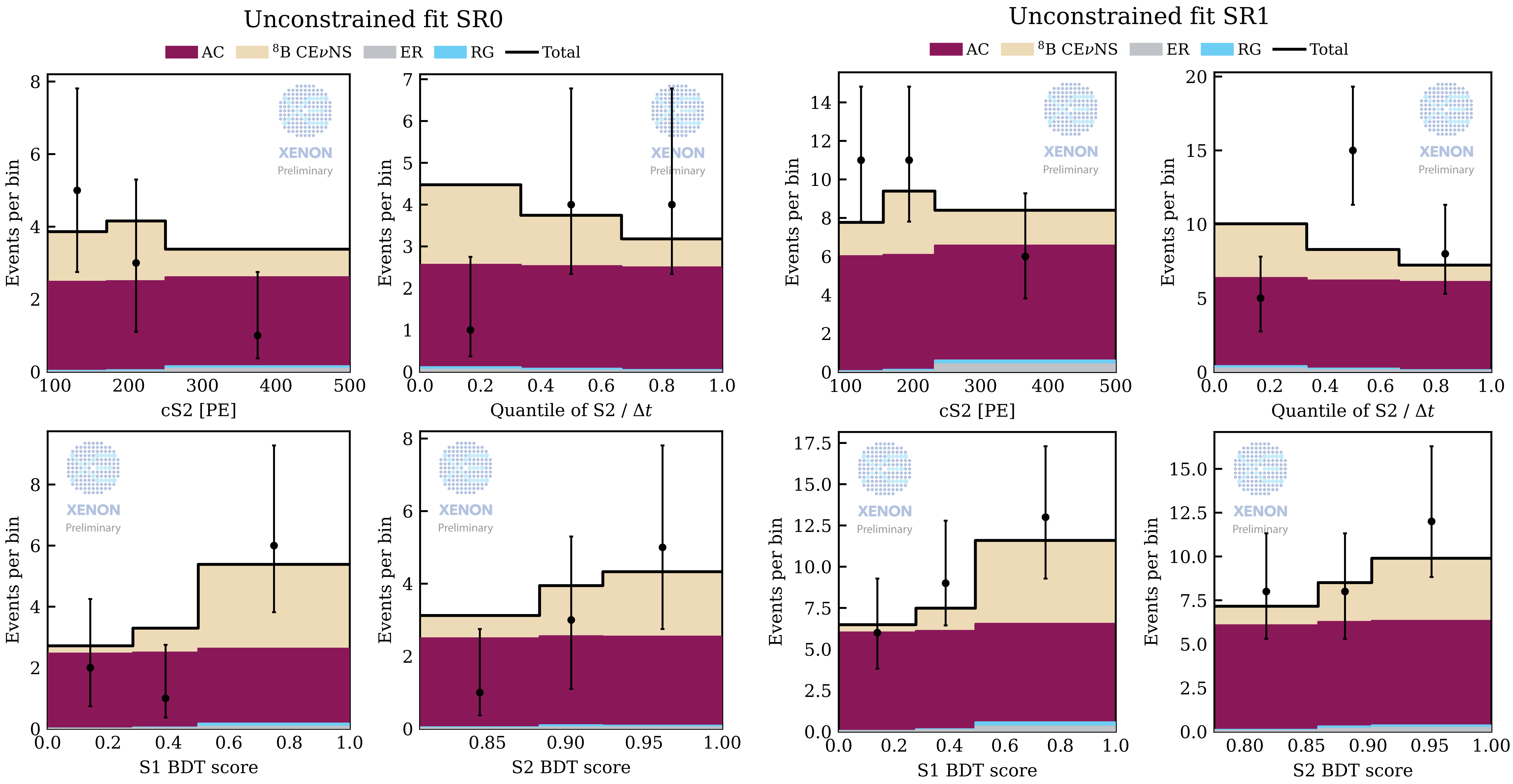
Projected Discovery Potential of ^{8}B Signals





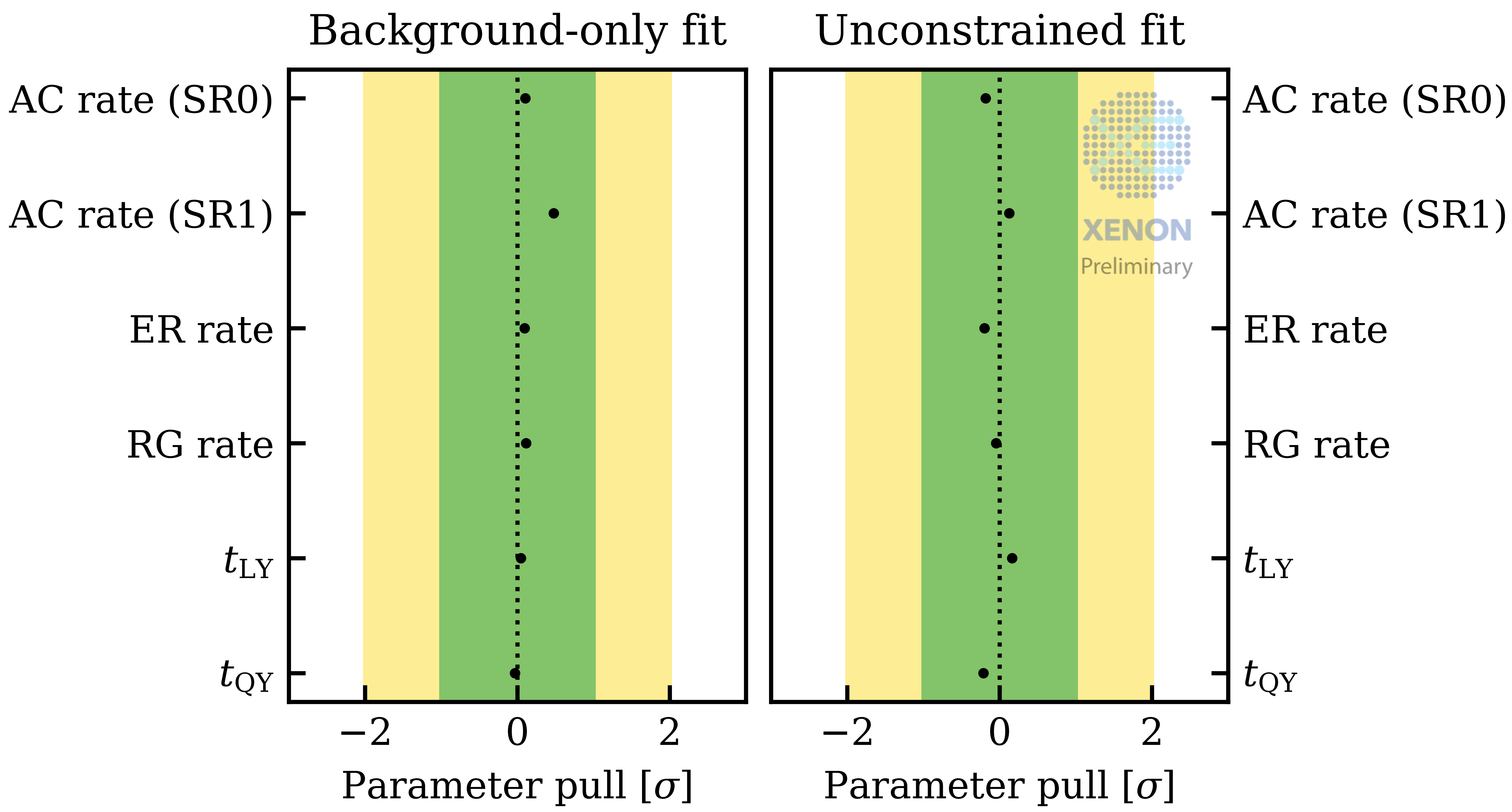
We expect to see solar ^{8}B neutrinos at >3(2) sigma significance with a probability of 0.48 (0.80), with a full 4-D analysis

Results from Unblinding, 07/03/2024



Data agrees with the signal + background expectation!

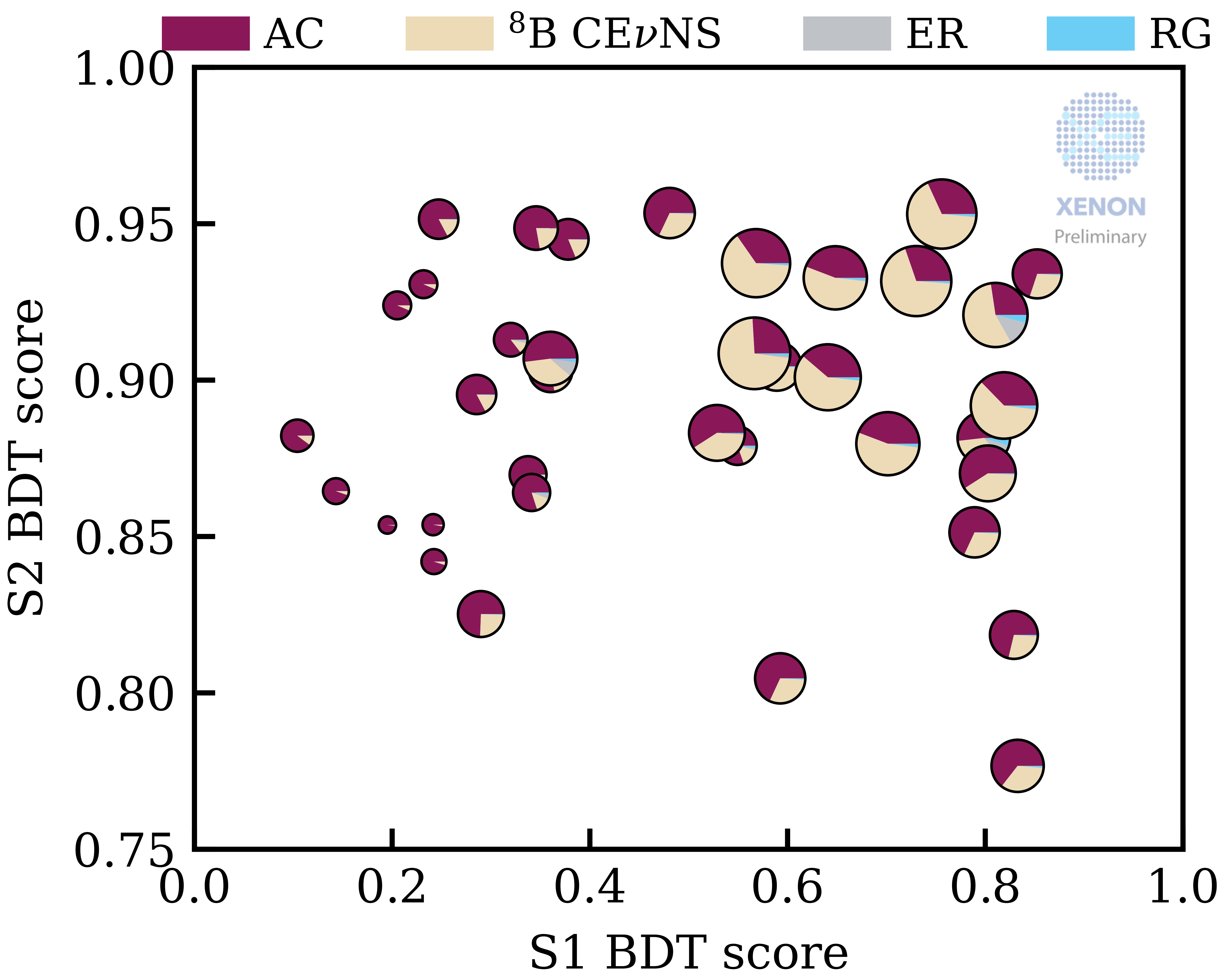
Results from the Unblinding

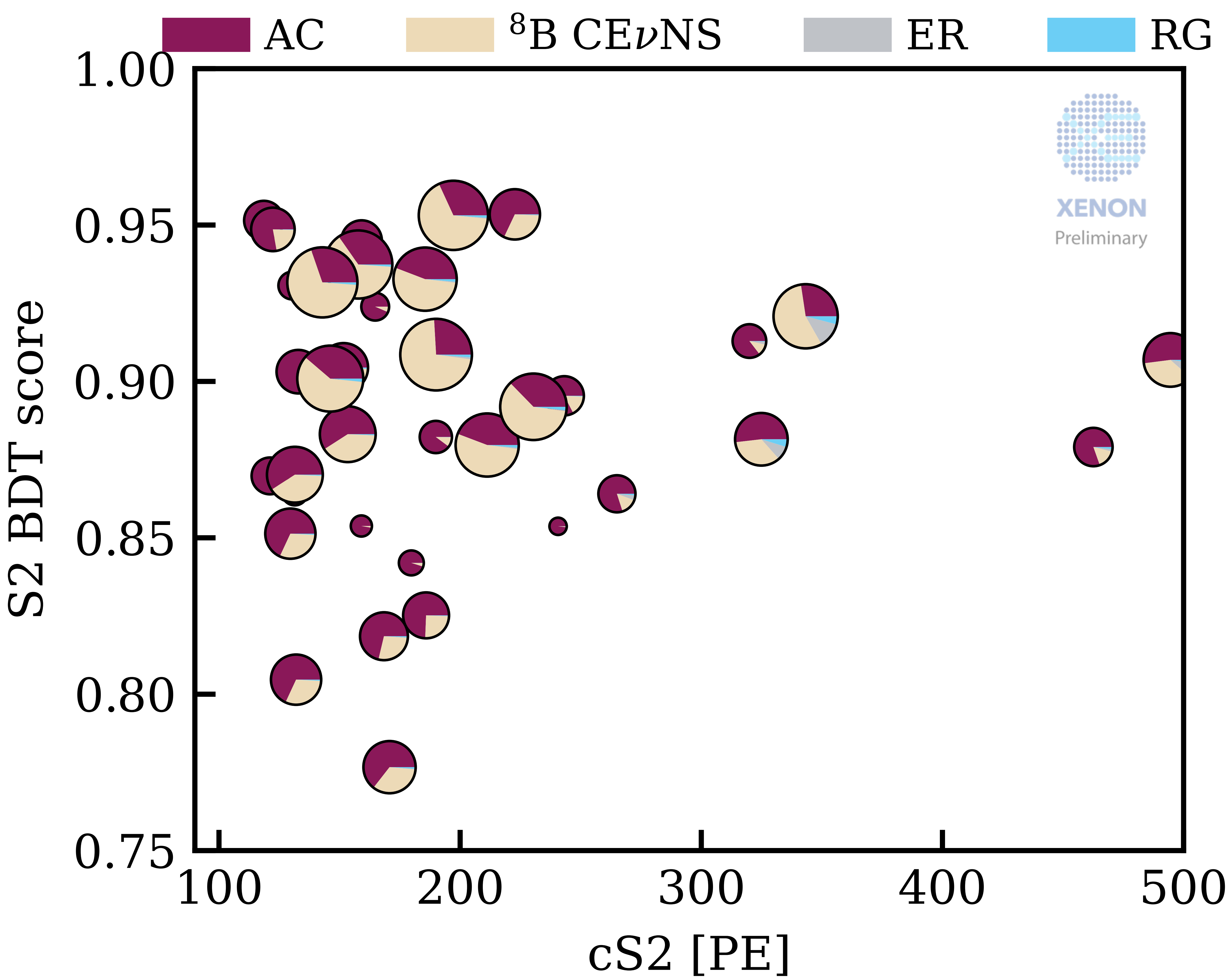


Component	Background only fit	Background + ^{8}B fit	Nominal Expectation
AC - SR0	7.55	7.36	7.48 ± 0.52
AC - SR1	18.26	17.90	17.77 ± 1.23
ER	0.74	0.54	0.68 ± 0.68
NR	0.50	0.45	0.47 ± 0.32
Total Background	27.05	26.24	26.4 ± 1.5
^{8}B	-	10.71	11.9 ± 3.1
Observed		37	

No significant deviation to the background and signal expectation!

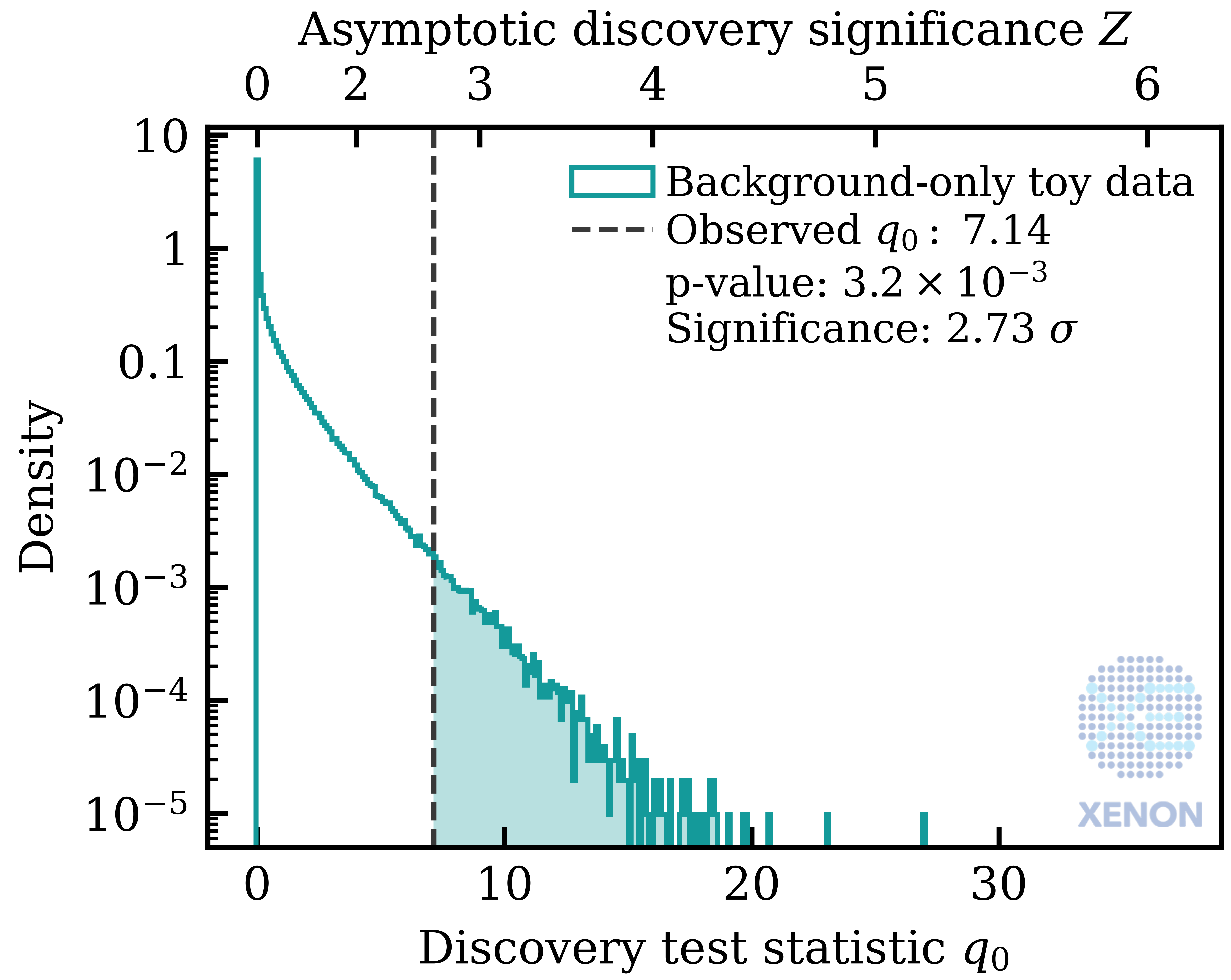
Visualization of Events — Piechart plots





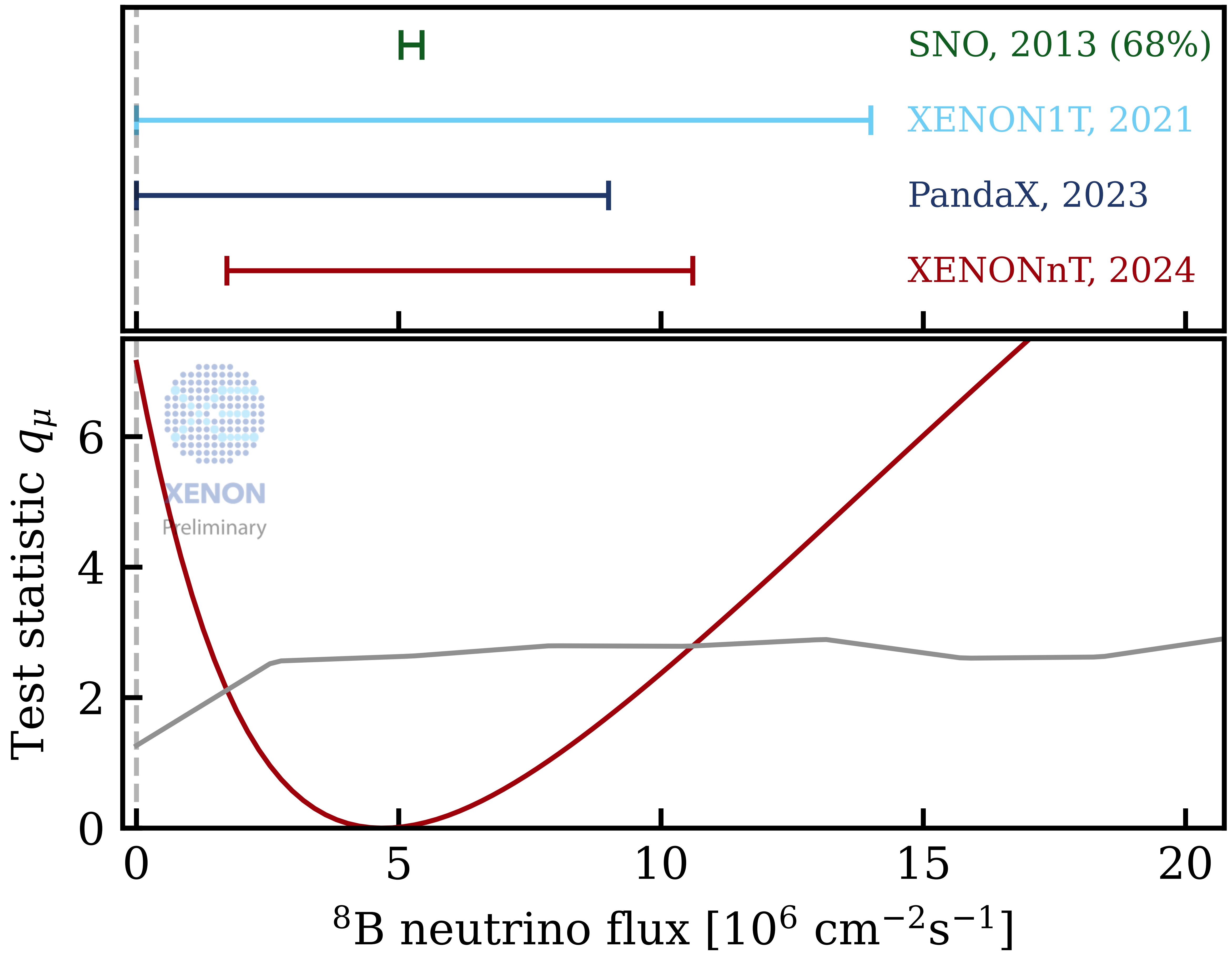
The pie plots show which events occur in a more signal- or background-dominated region from our expectation.

Results from Unblinding



The background-only hypothesis is disfavored at 2.73σ

Publication in preparation



solar ^{8}B flux measurement via CEvNS as [1.72, 10.6] x 10^6 cm^{-2} s^{-1} at 90% C.L.

First Measurement of CEvNS with a Xe Target

$$\sigma \propto Q_W^2 \propto (N - (1 - 4\sin^2\theta_W)Z)^2$$

$$\Longrightarrow \boxed{\sigma \propto N^2}$$

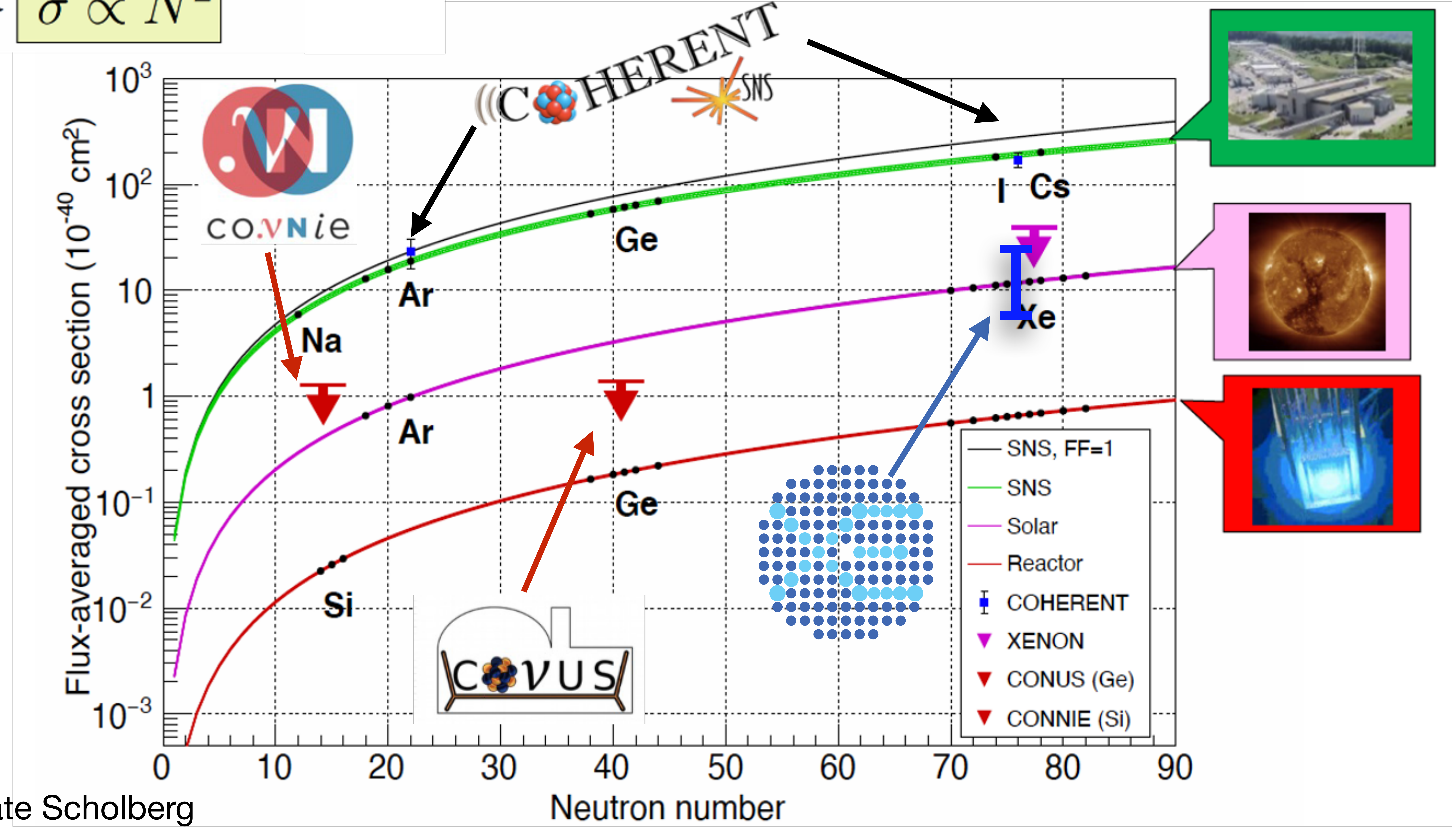
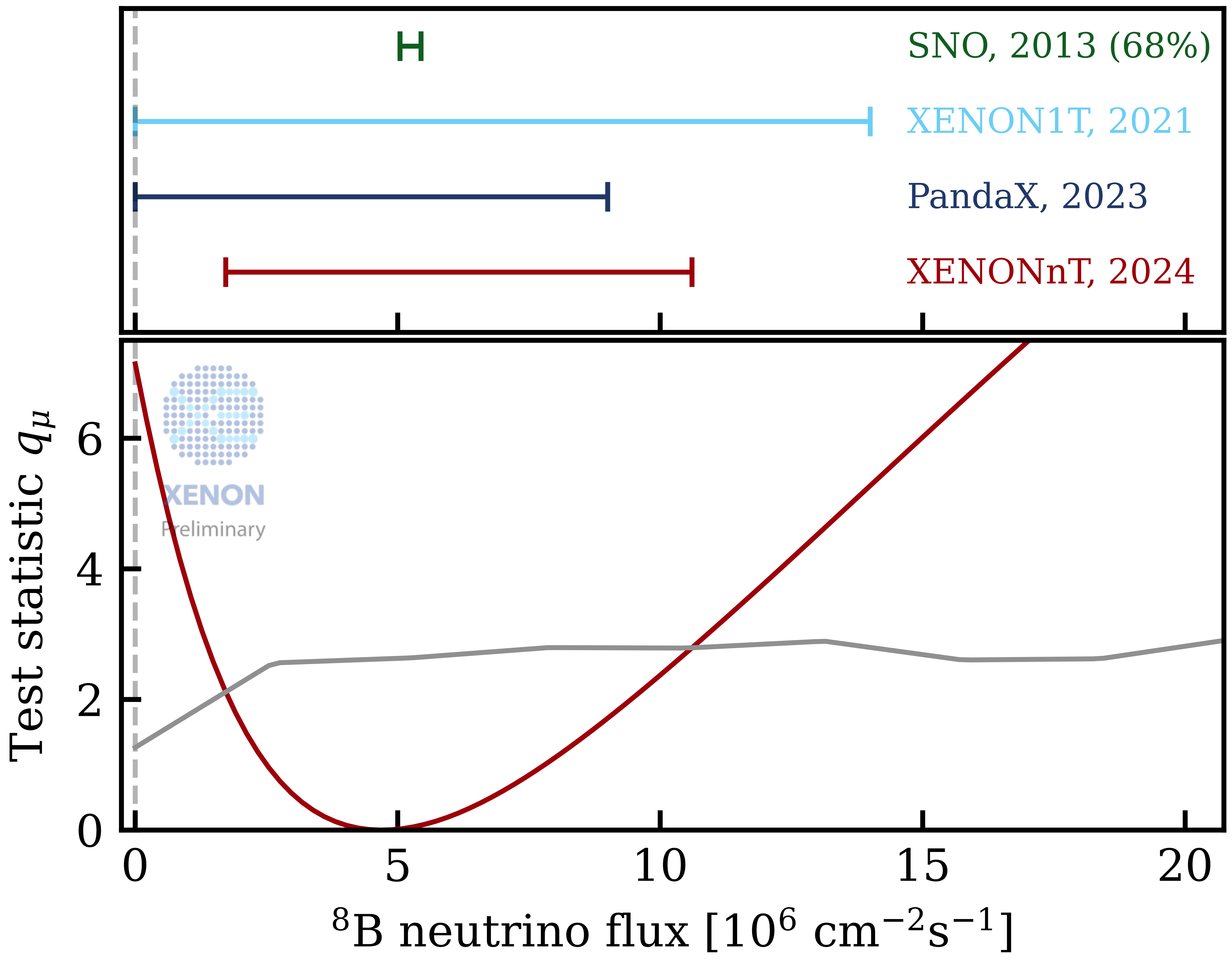
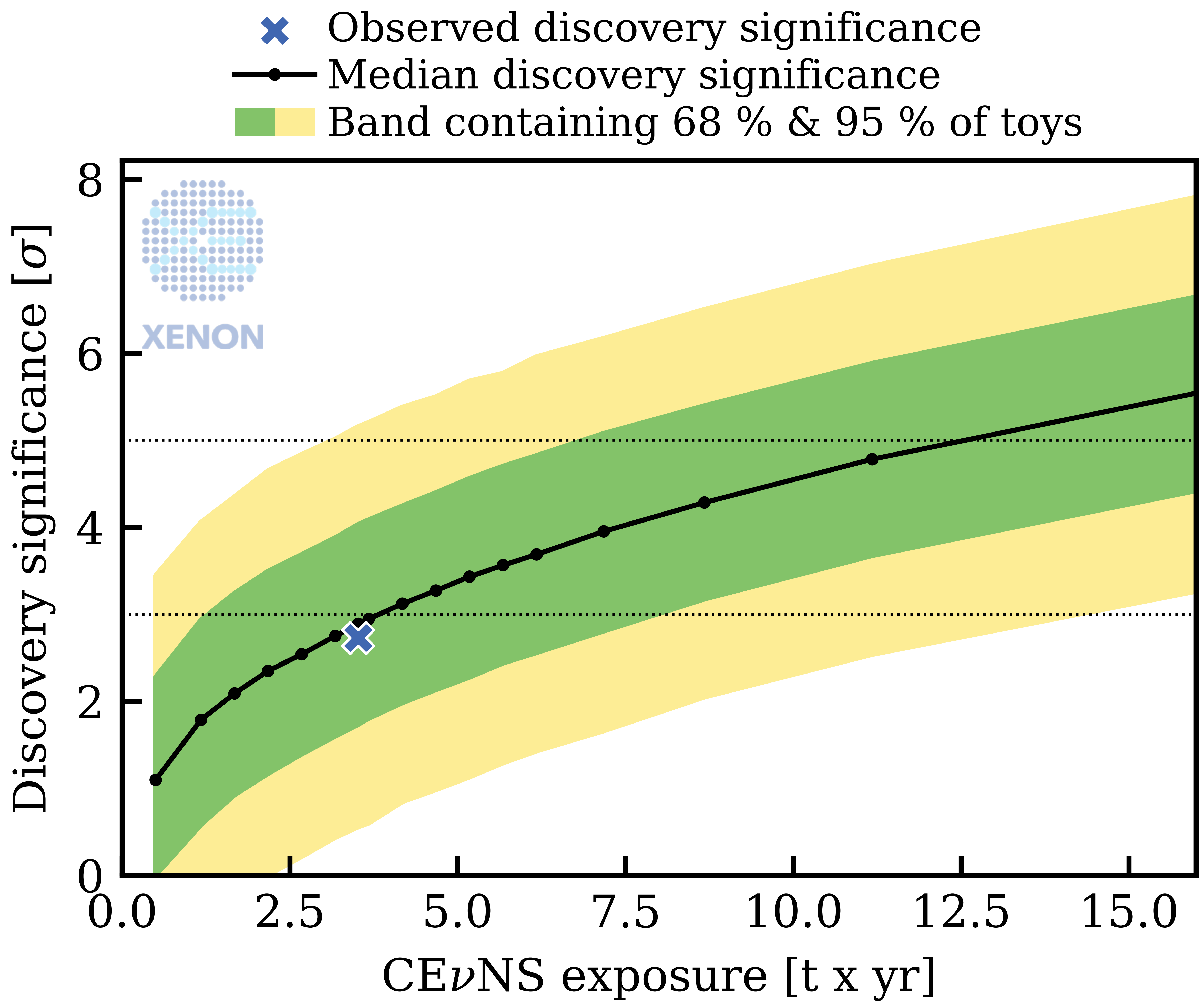


Figure credit: Kate Scholberg

Summary and Outlook

Publication in preparation





XENONnT measures the CEvNS signal in Xe from solar ^{8}B neutrinos for the first time!

With more exposure, we expect to measure the solar ^{8}B neutrino signal at higher significance and to better constrain the ^{8}B neutrino flux