

**XENON**

 **COLUMBIA UNIVERSITY**  
IN THE CITY OF NEW YORK



**清华大学**

Tsinghua University

# First Measurement of Solar $^8\text{B}$ Neutrinos via Coherent Elastic Neutrino-Nucleus Scattering with XENONnT

**XENONnT 实验上测量太阳硼-8中微子与原子核相干弹性散射**

徐大成，哥伦比亚大学/清华大学

2024/08/15

第十四届全国粒子物理学术会议

- 200+ 成员
- 29 研究单位
- 12 国家

# XENON 合作组



## AMERICA

- UC San Diego  
San Diego, USA
- Houston, USA
- THE UNIVERSITY OF CHICAGO  
Chicago, USA
- COLUMBIA UNIVERSITY  
IN THE CITY OF NEW YORK  
New York City, USA
- PURDUE UNIVERSITY  
Lafayette, USA

## EUROPE

 Zurich, Switzerland	 Karlsruhe Institute of Technology Karlsruhe, Germany	 Münster, Germany	 Freiburg, Germany	 Mainz, Germany	 Heidelberg, Germany	 Amsterdam, Netherlands	 Stockholm, Sweden
 Coimbra, Portugal	 Nantes, France	 Paris, France	 Torino, Italy	 Bologna, Italy	 L'Aquila, Italy	 Assergi, Italy	 Napoli, Italy

## MIDDLE EAST

- מכון ויצמן למדע  
WEIZMANN INSTITUTE OF SCIENCE  
Rehovot, Israel
- جامعة نيويورك أبوظبي  
NYU | ABU DHABI  
Abu Dhabi, UAE

## ASIA

- 清华大学  
Tsinghua University  
Beijing, China
- 西湖大学  
WESTLAKE UNIVERSITY  
Hangzhou, China
- 香港中文大学(深圳)  
The Chinese University of Hong Kong, Shenzhen  
Shenzhen, China
- 東京大学  
THE UNIVERSITY OF TOKYO  
Tokyo, Japan
- 名古屋大学  
NAGOYA UNIVERSITY  
Nagoya, Japan
- 神戸大学  
KOBE UNIVERSITY  
Kobe, Japan

# 中微子或一些暗物质候选粒子与氦原子核弹性散射

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)

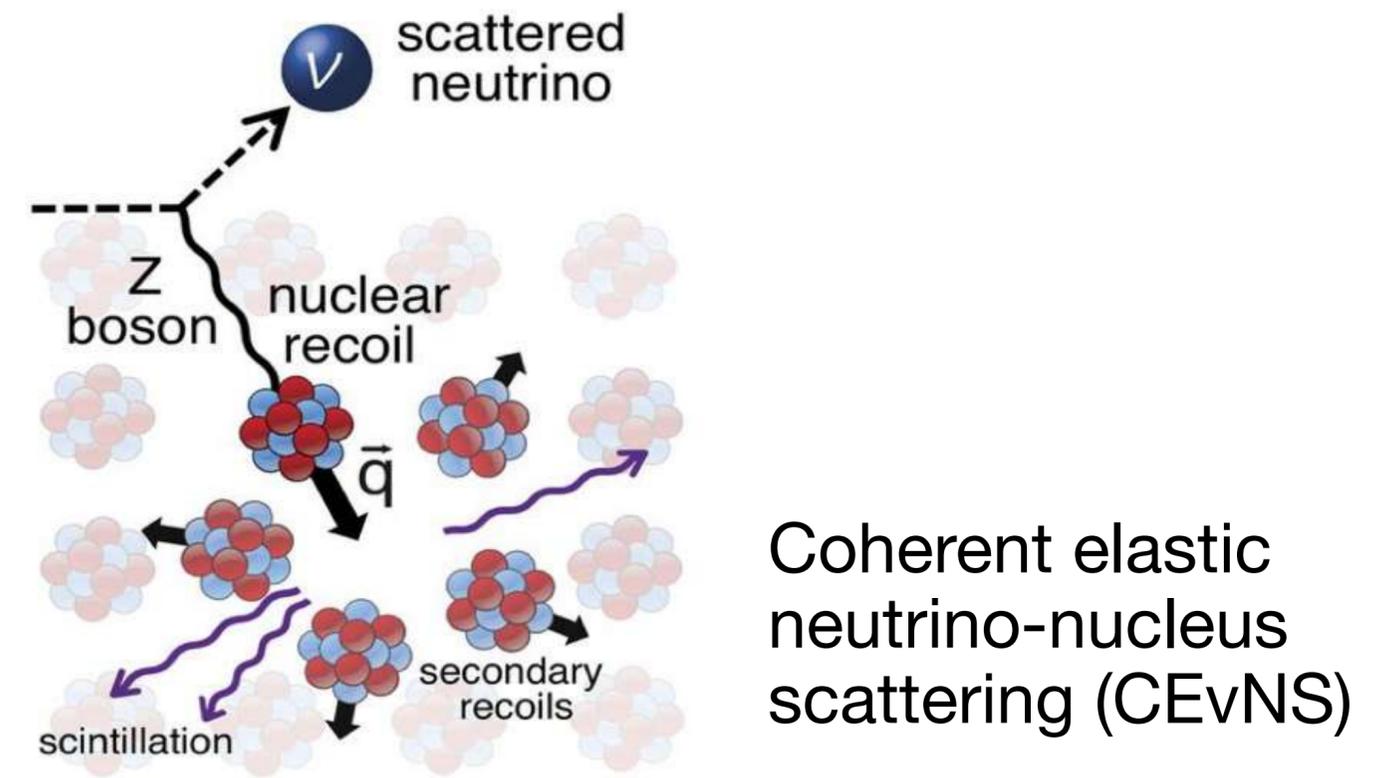
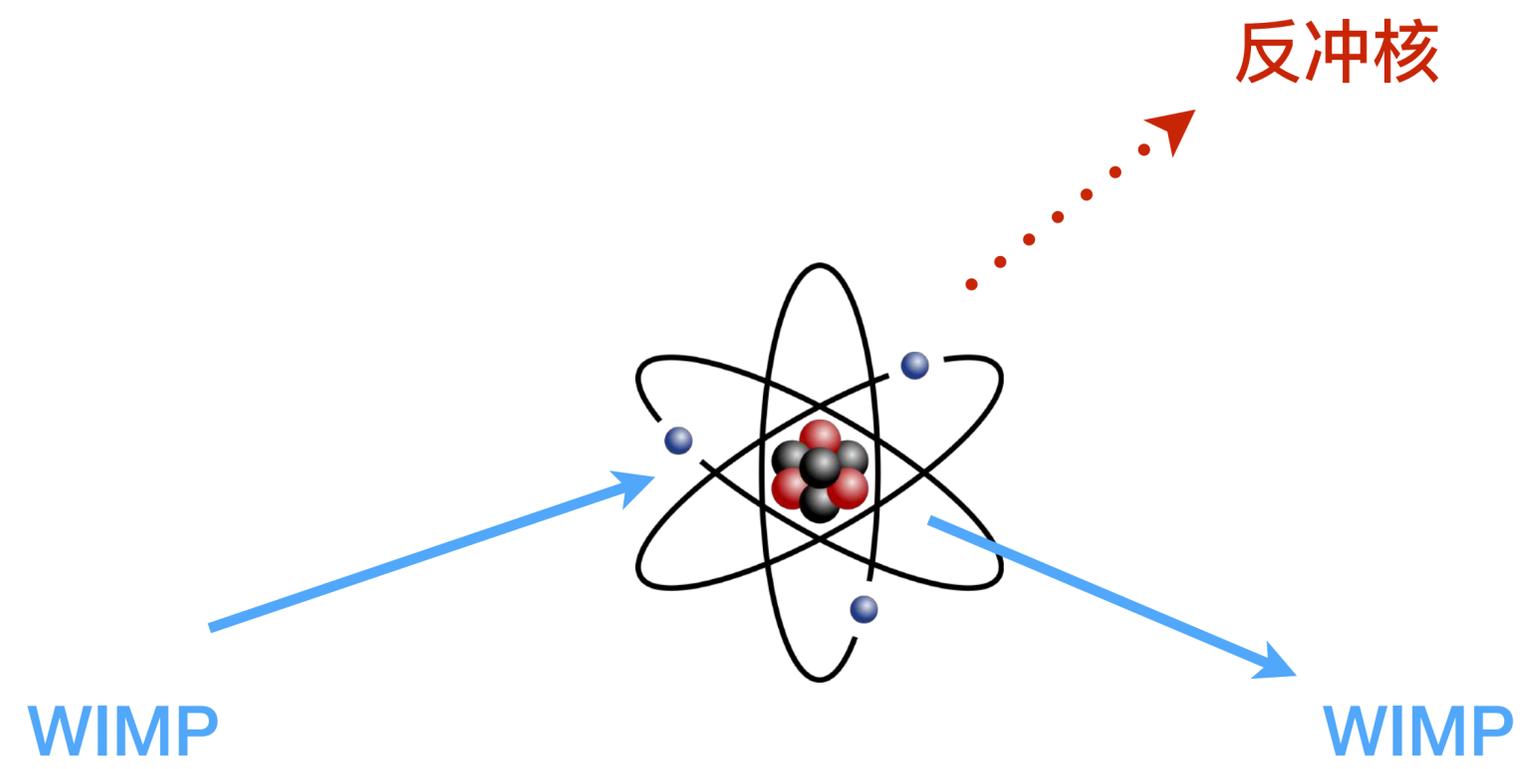
We consider the possibility that the neutral-current neutrino detector recently proposed by Drukier and Stodolsky could be used to detect some possible candidates for the dark matter in galactic halos. This may be feasible if the galactic halos are made of particles with coherent weak interactions and 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**

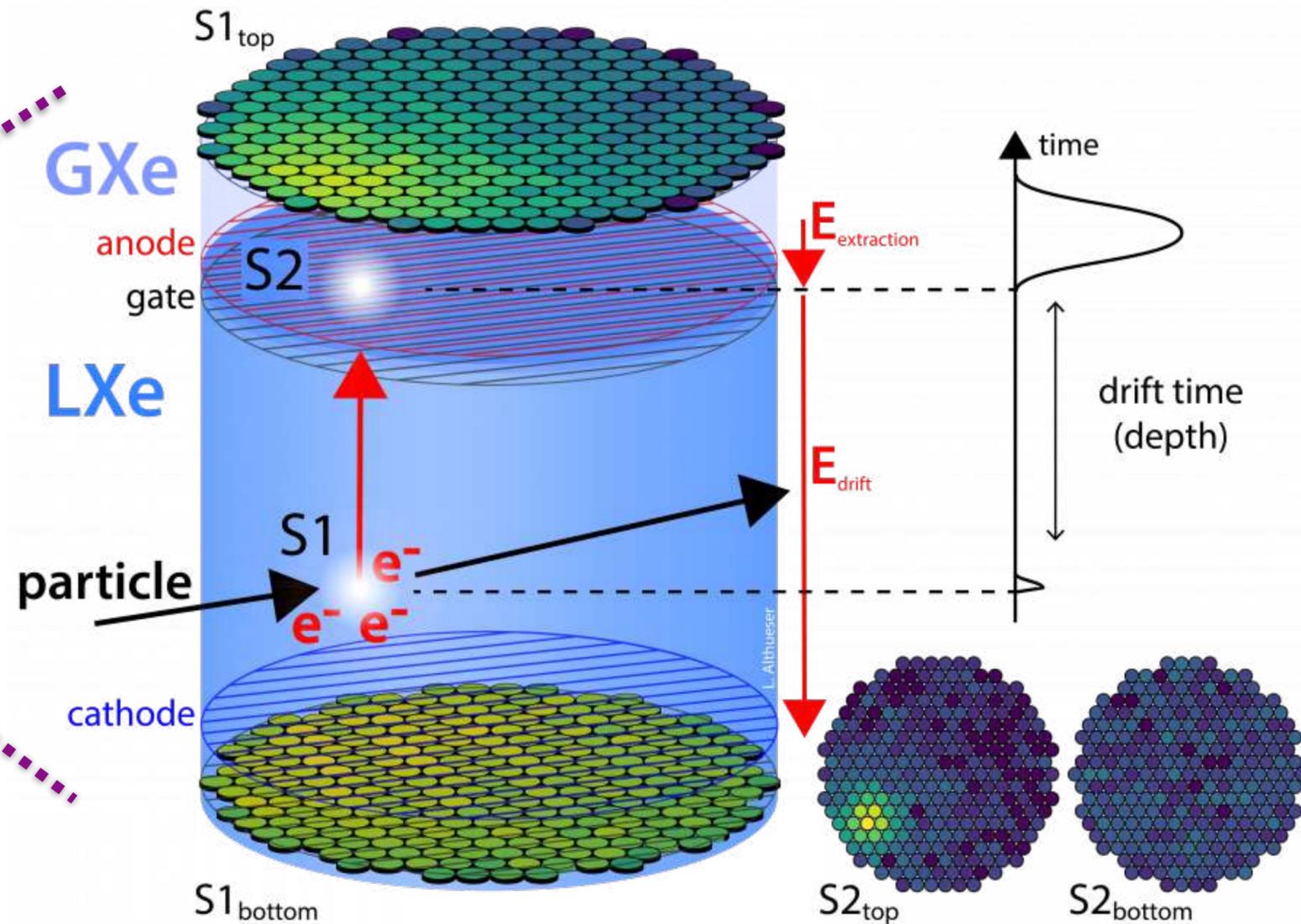
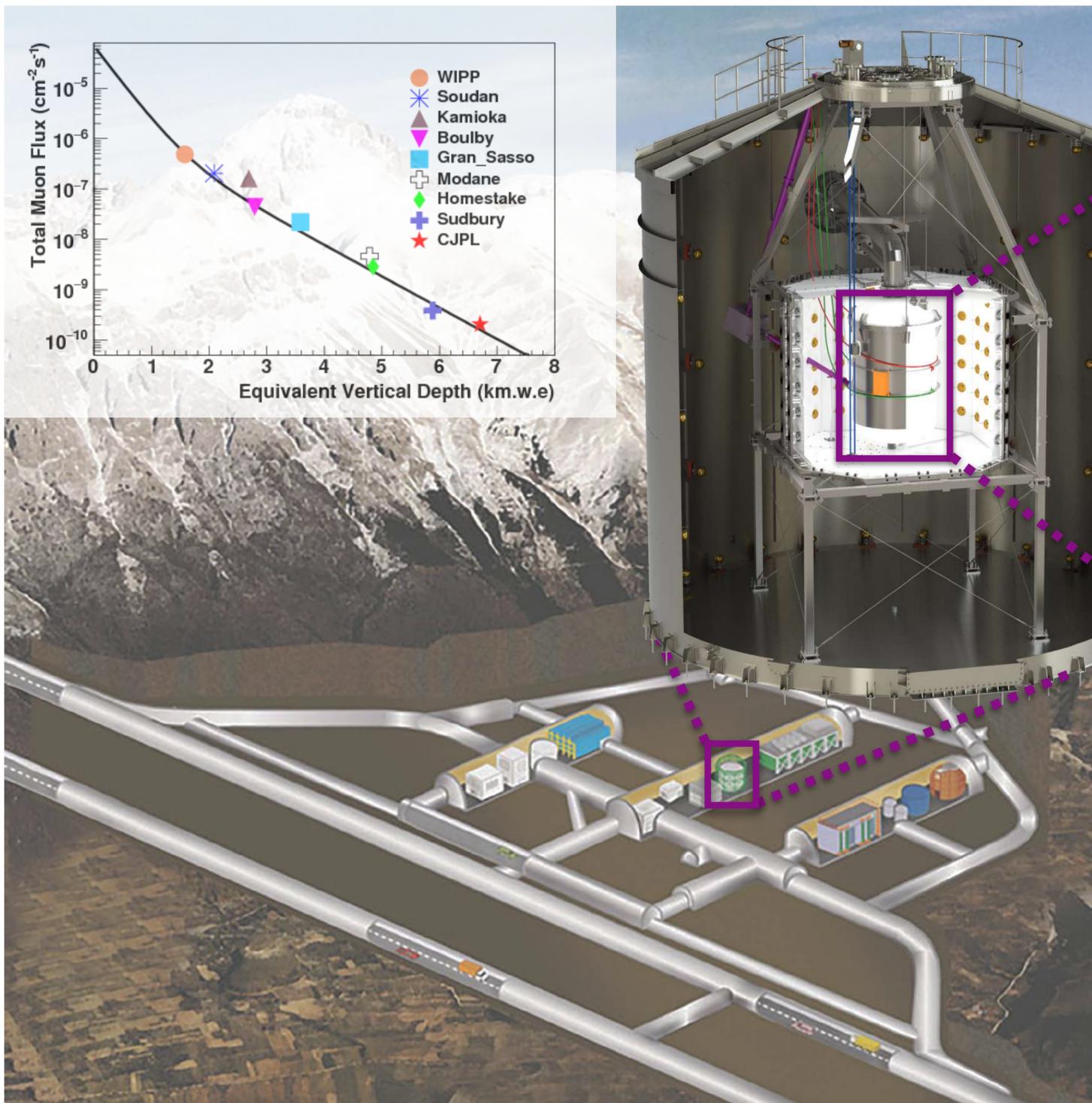
Daniel Z. Freedman†  
*National Accelerator Laboratory, Batavia, Illinois 60510*  
*and Institute for Theoretical Physics, State University of New York, Stony Brook, New York 11790*  
 (Received 15 October 1973; revised manuscript received 19 November 1973)

If there is a weak neutral current, then the elastic scattering process  $\nu + A \rightarrow \nu + A$  should have a sharp coherent forward peak just as  $e + A \rightarrow e + A$  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<sup>2</sup> 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  $\nu + A \rightarrow \nu + A^*$  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 位于 LNGS 的双相氙时间投影室

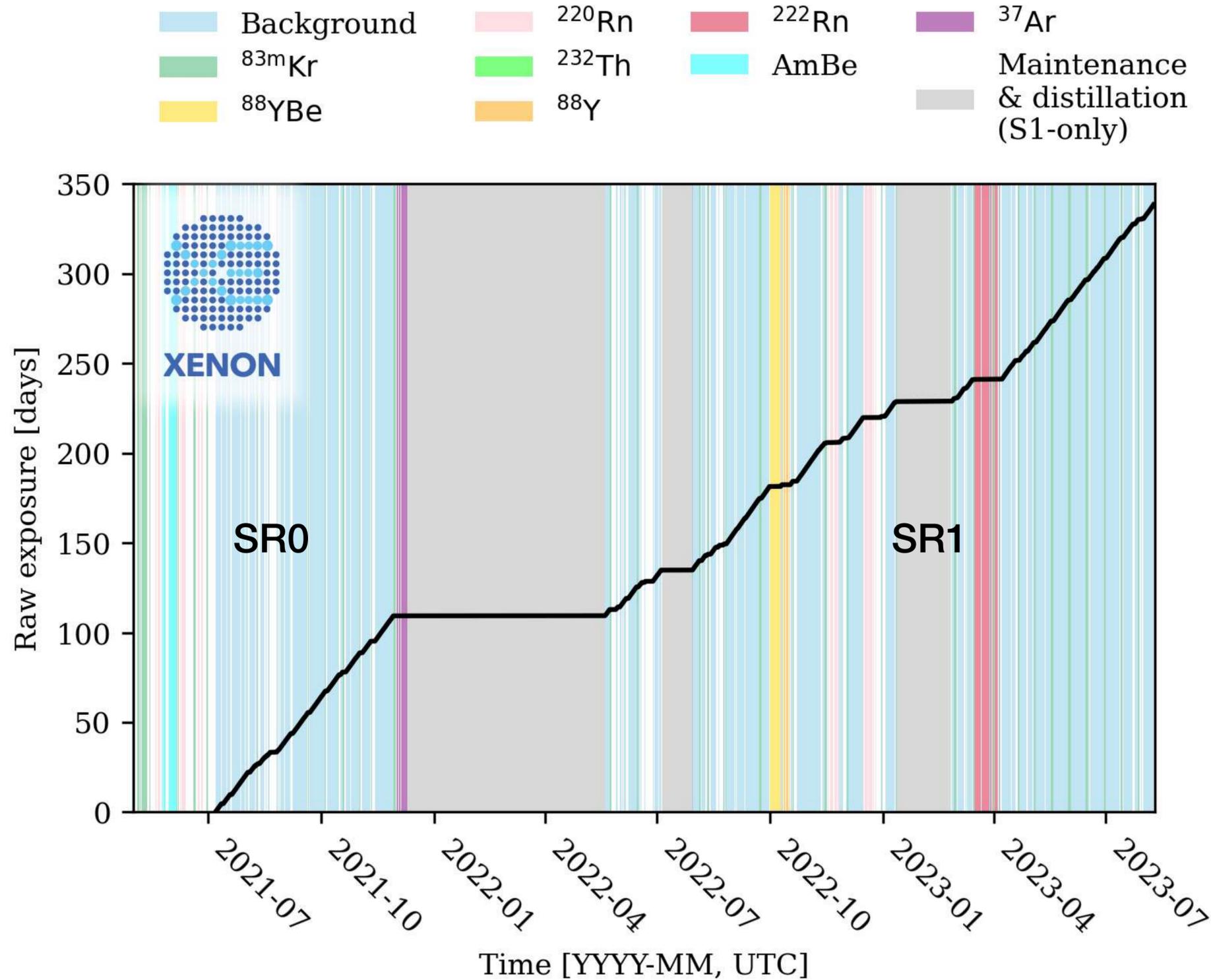


arXiv: 2402.10446

漂移长度	直径	灵敏质量	漂移电场
------	----	------	------

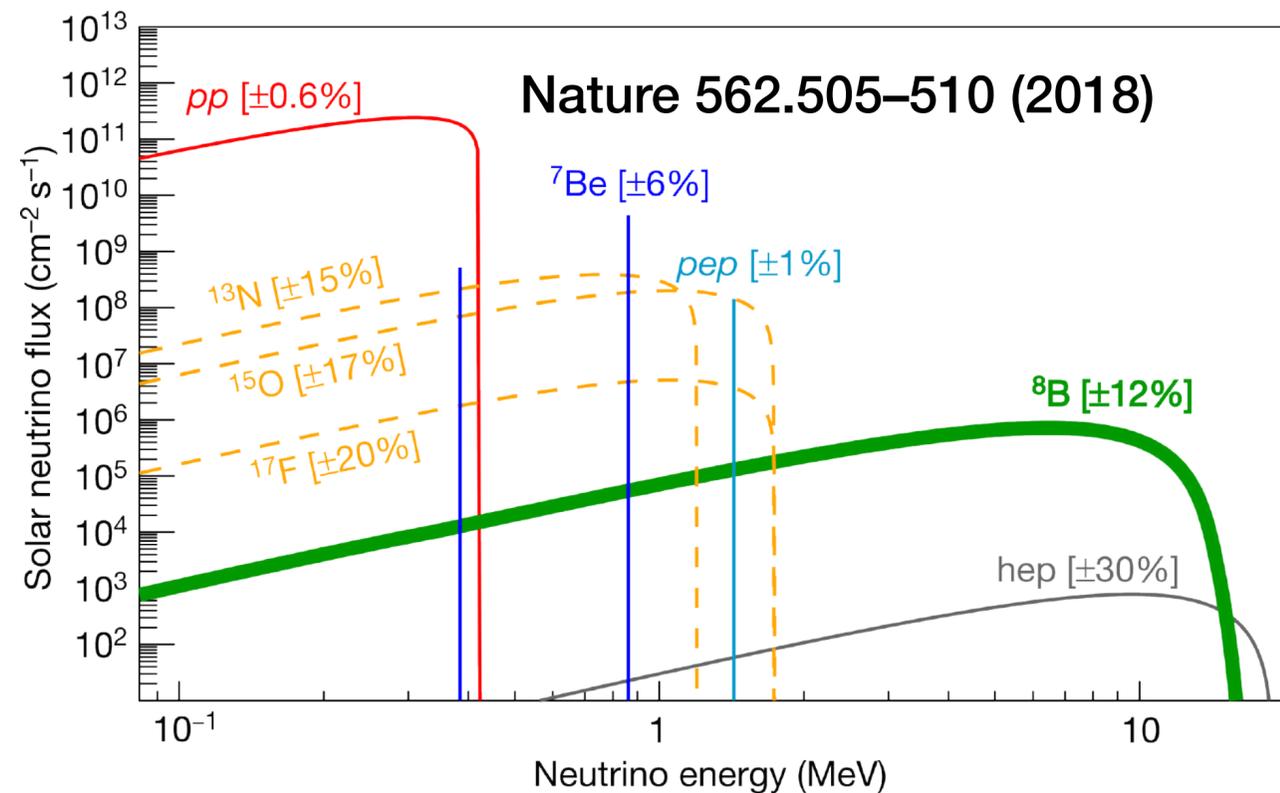
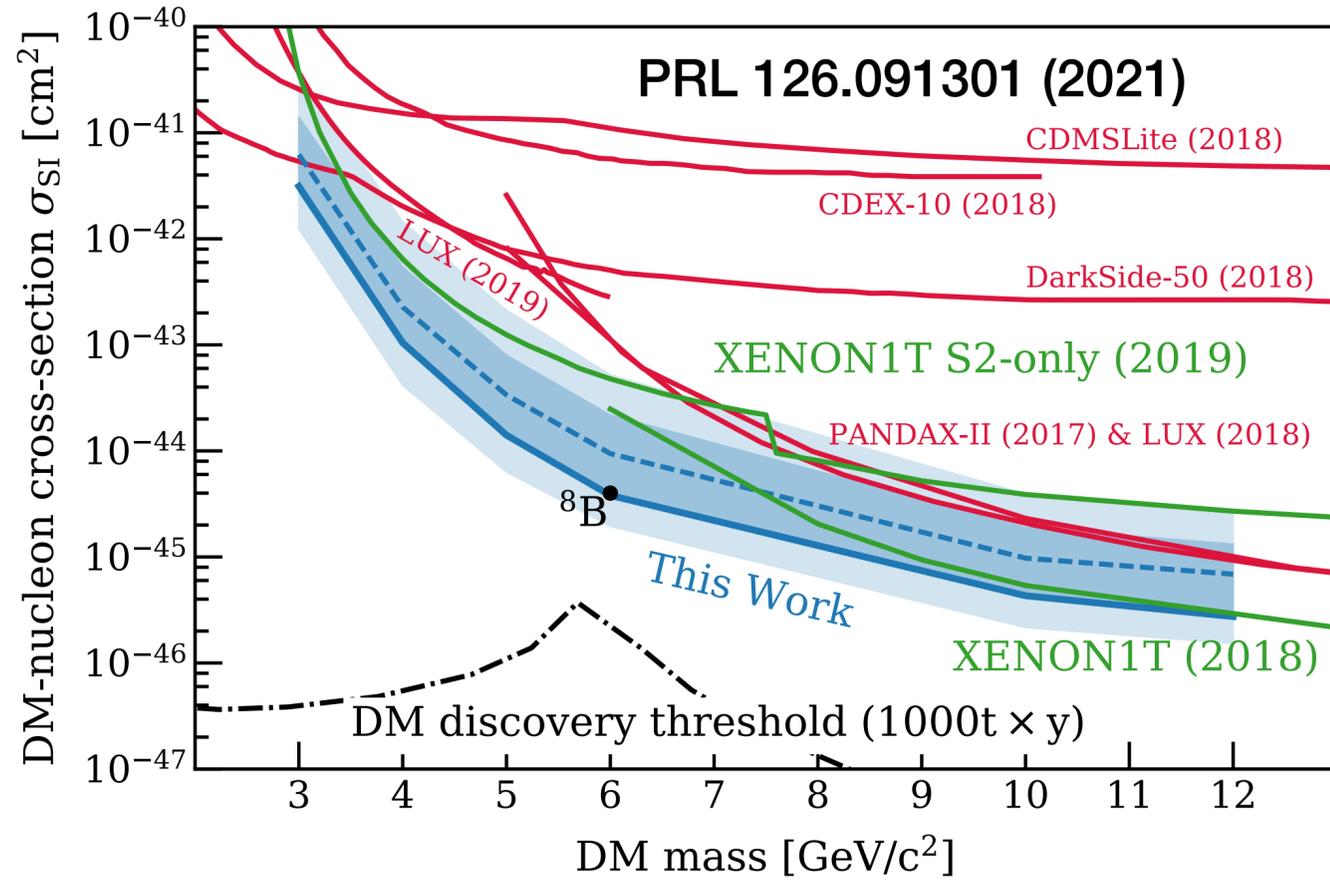
1.5m    1.32m    5.9 tonne    23 V/cm

# XENONnT 运行情况

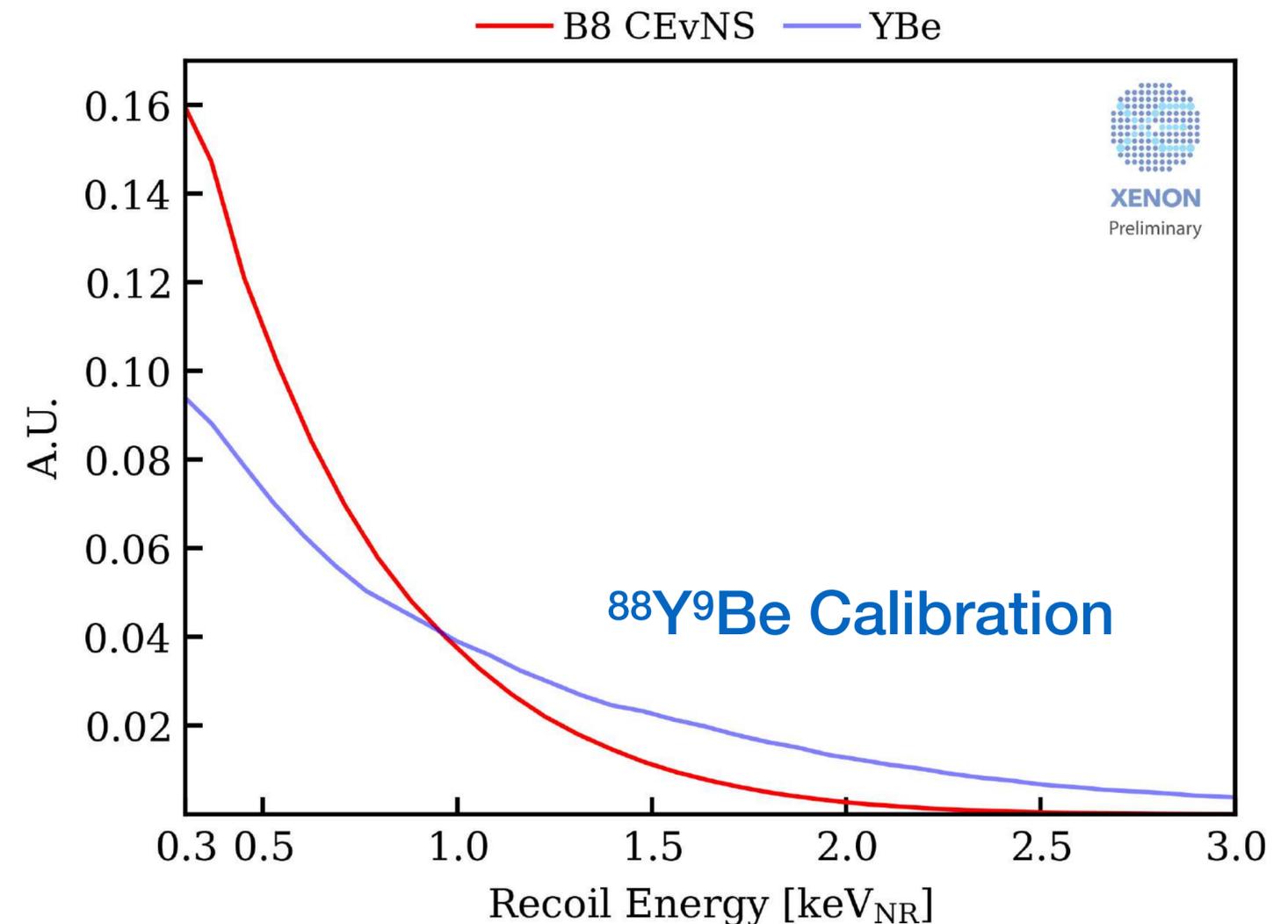


- SR0 的数据已经在低能电子反冲对应的物理和新物理和 WIMP 搜索中被揭盲 (unblind)
- XENONnT  $^8\text{B}$  CEvNS 分析中首次使用了 SR0+1 运行两年的数据 (3.5ty)

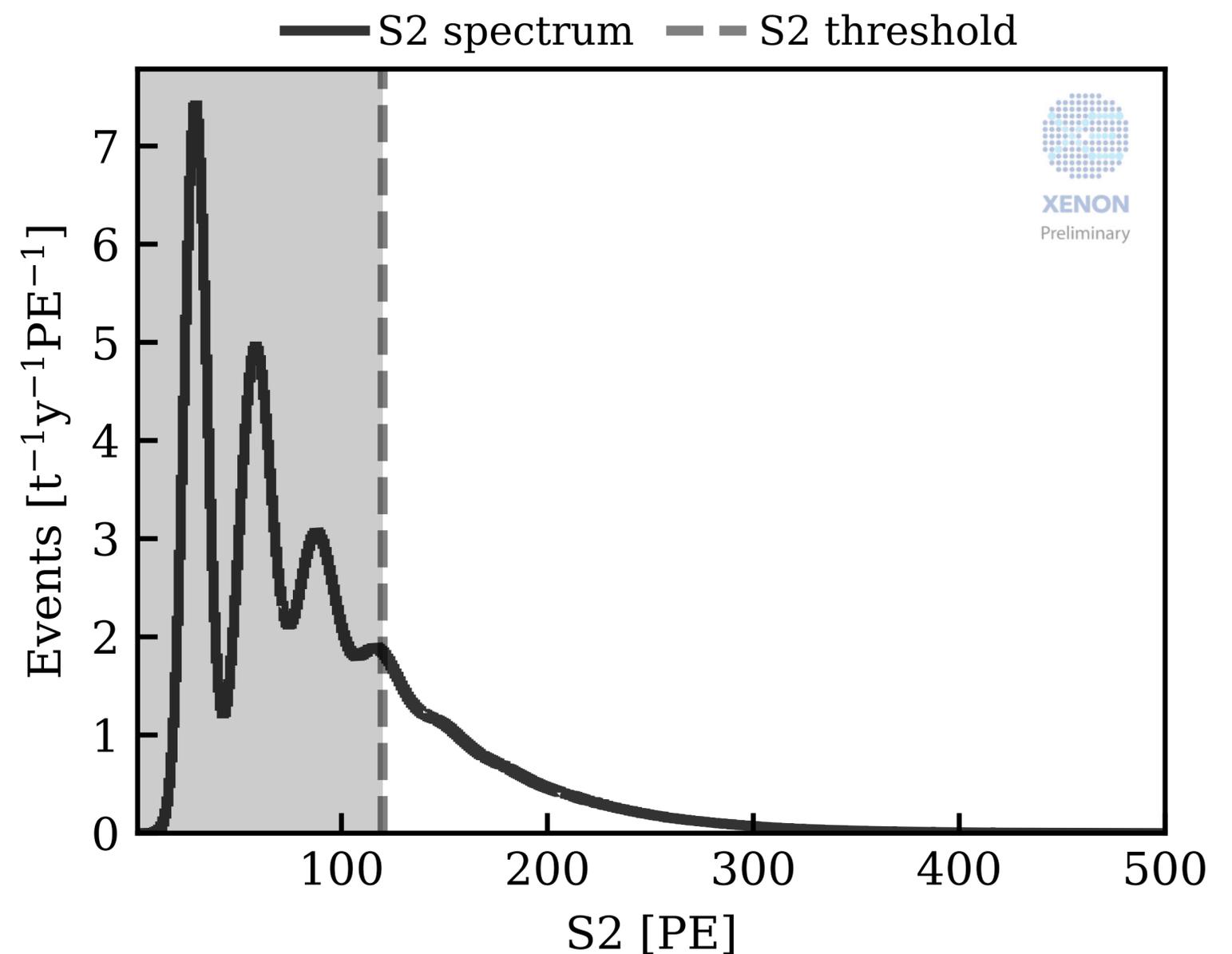
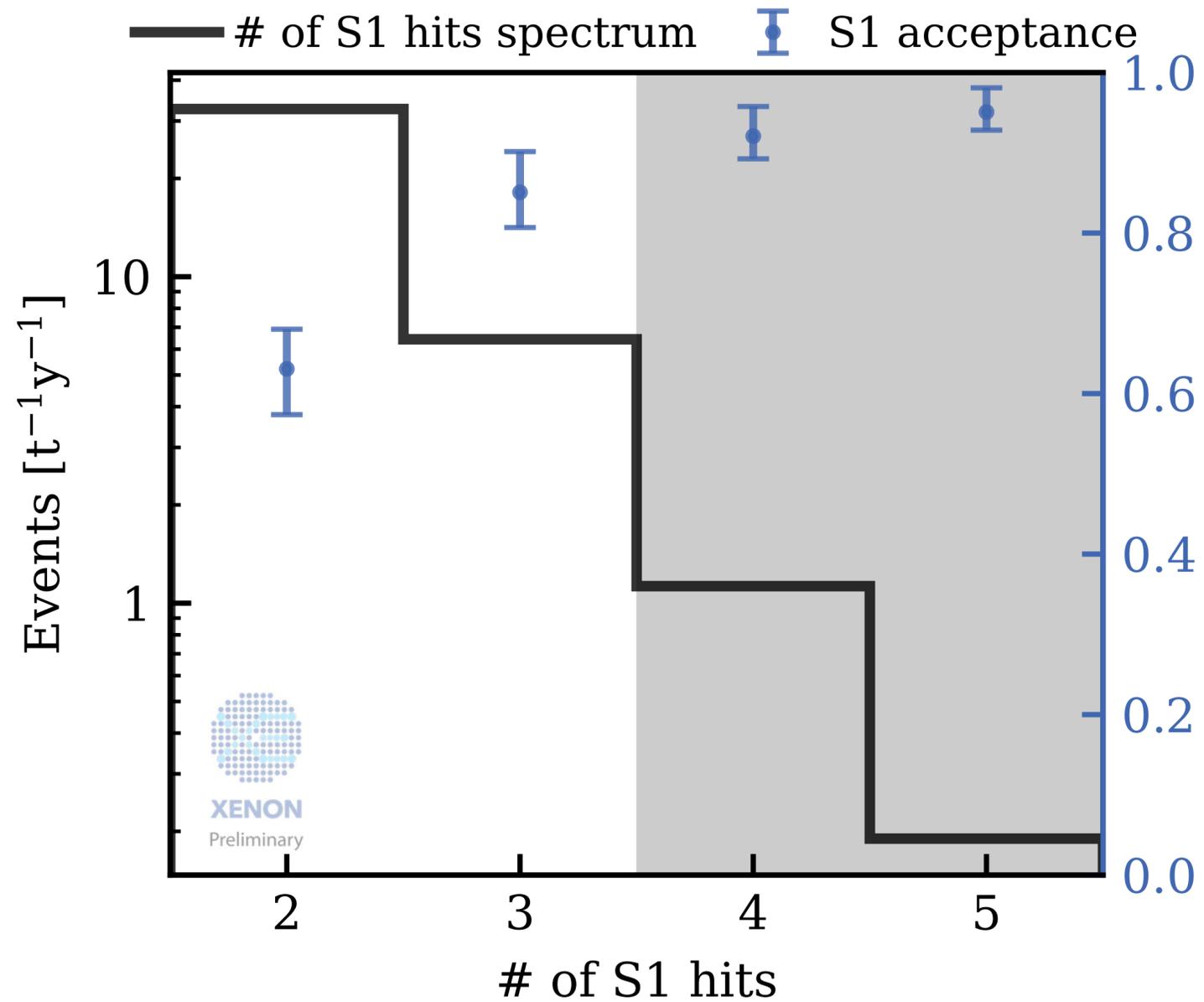
# WIMP 搜索中的中微子本底与 $^8\text{B}$ CEvNS 能谱



- 未来中微子将会是低质量 WIMP 探测的主要本底
- 为了建立信号模型，我们首次在双相氙时间投影室中进行了  $^8\text{B}$  CEvNS 中子核反冲刻度



# $^8\text{B}$ CEvNS 信号所处的可观测量 (S1 & S2) 区间



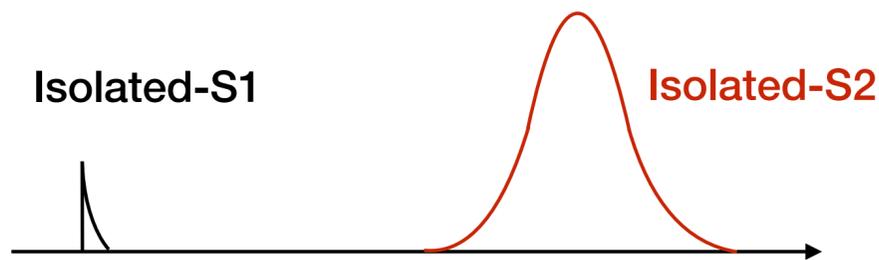
S1: 2 & 3 光子“击中”数 (hit)

S2: 120 - 500 PE

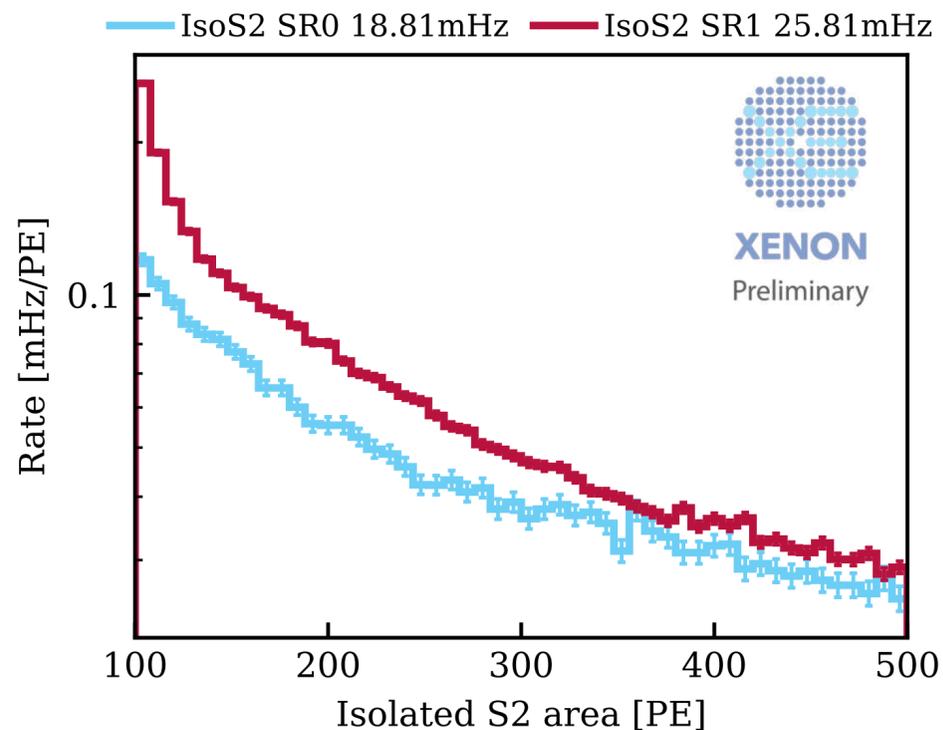
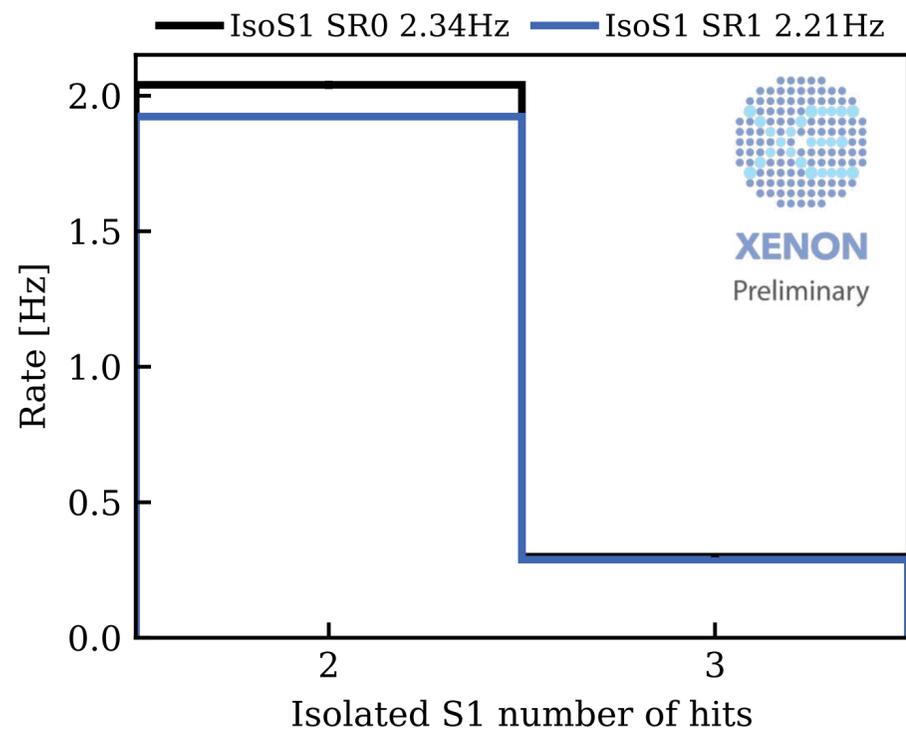
光子“击中”数指被 PMT 收集、采数系统记录且软件重建出的光子

S2下阈选为 120PE, 为了降低偶然符合本底

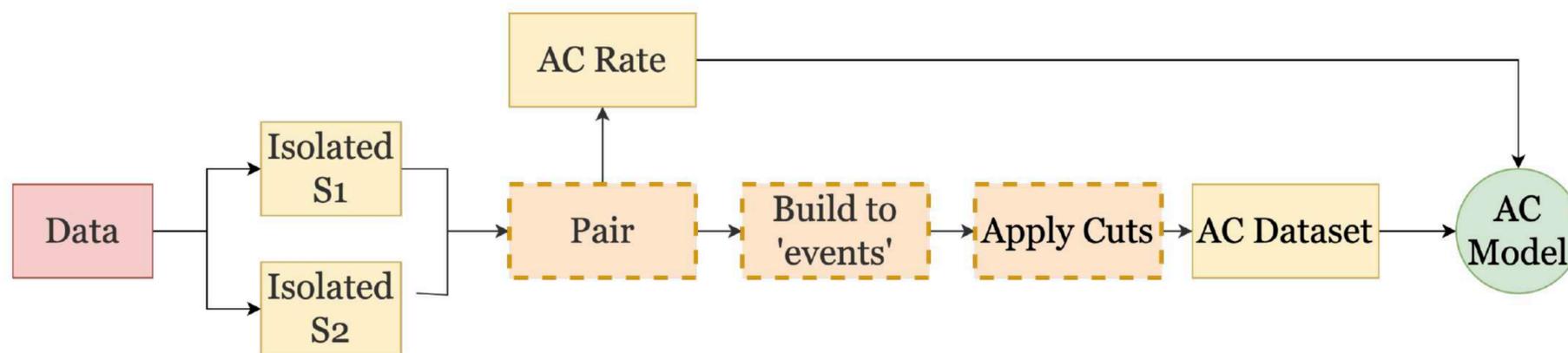
# $^8\text{B}$ 太阳中微子与氙的核反冲能区及低能区相关本底



$$R_{AC} \approx R_{IsoS1} \times R_{IsoS2} \times \Delta t$$



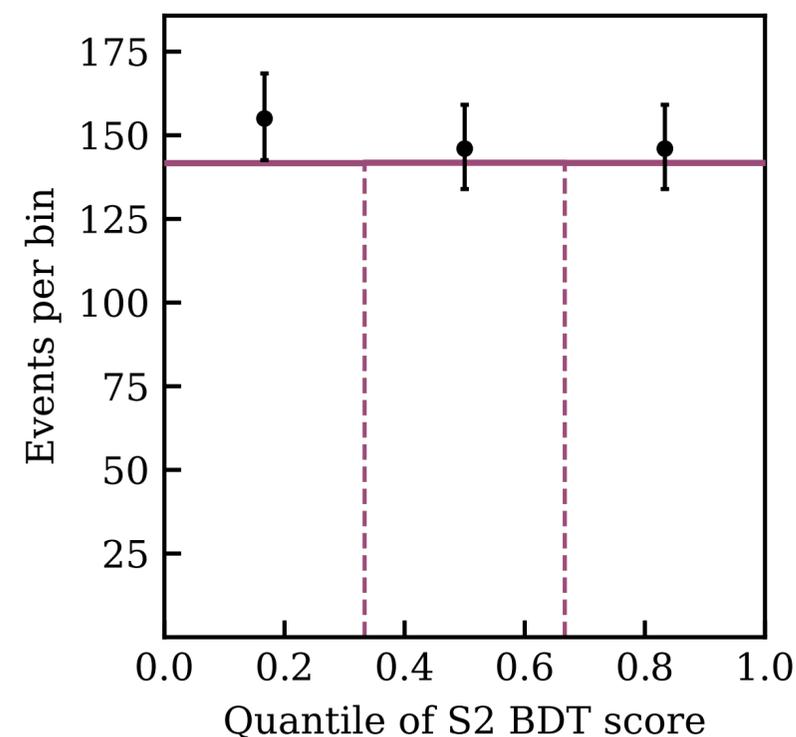
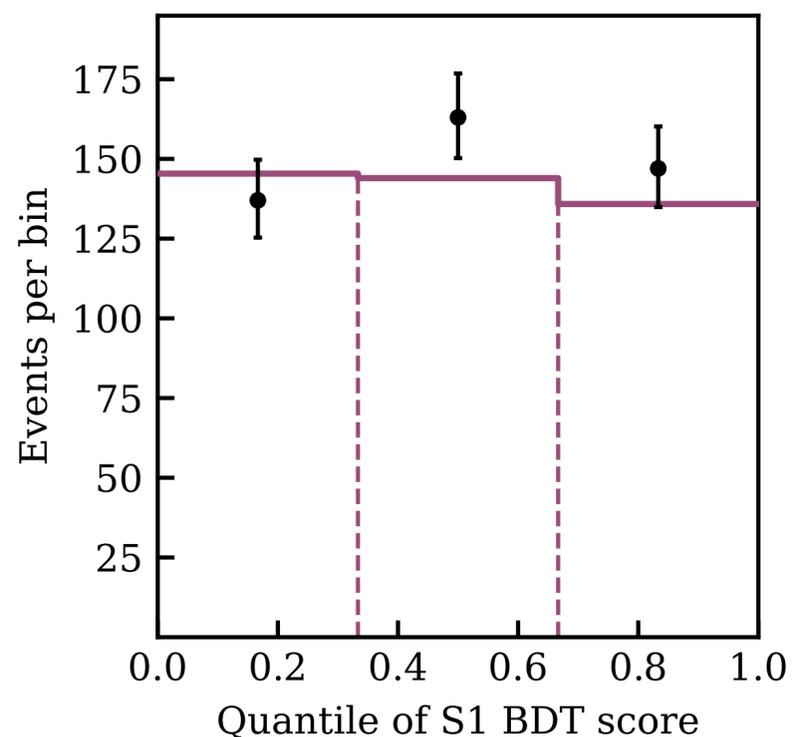
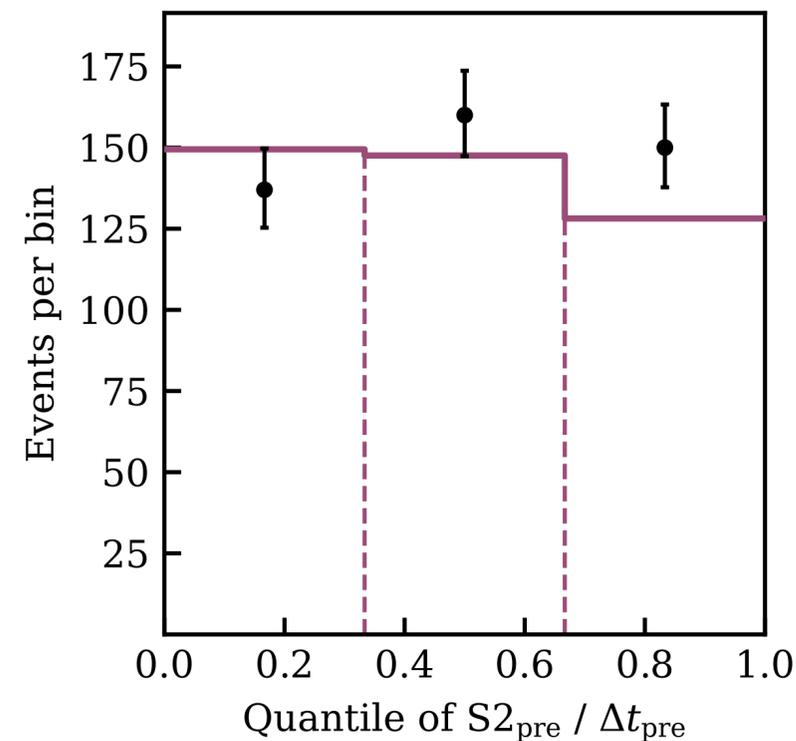
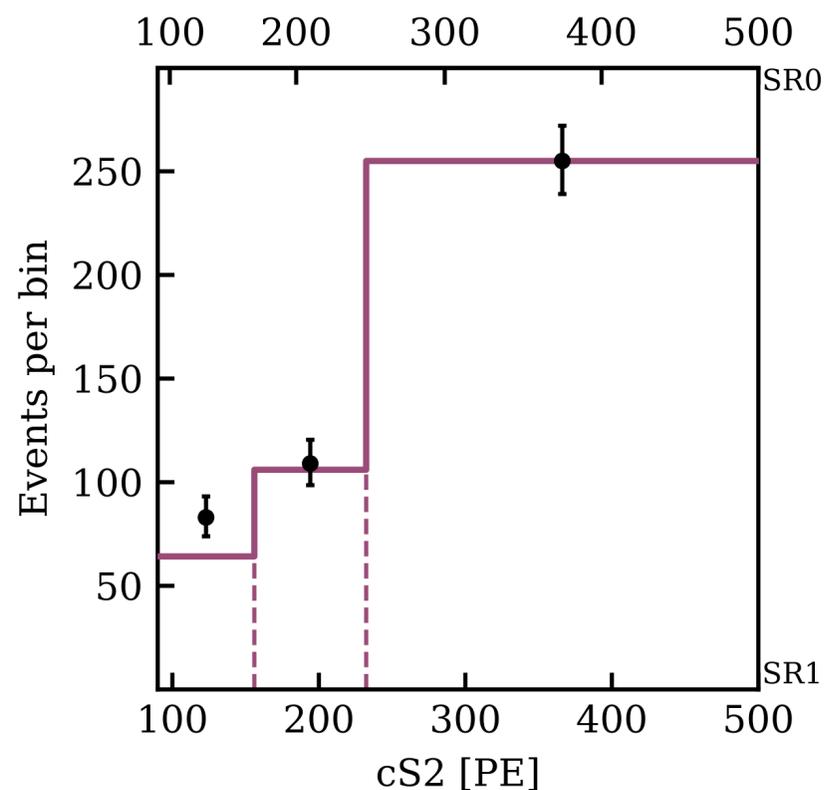
- 我们建立了详细的对偶然符合本底的压低和预测分析框架
- 可以用孤立 S1/2 与能量较大的物理事件（如  $\alpha$  事件）之间的时间和空间关联来压低
- 开发了 S1/2 提升决策树（BDT）综合多种可观测维度（如 S1/2 的波形特征）提升信号和本底的区分能力
- S1/2 BDT 分数也会作为最终统计推断中使用的维度



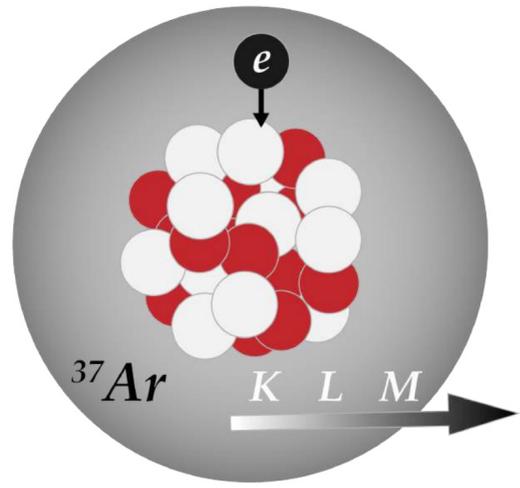
# 偶然符合本底的预测和检验

事件分类	Sideband 数据	物理搜索数据
AC - SR0	122.7	7.5
AC - SR1	302.5	17.8
$^8\text{B}$	< 2	11.9

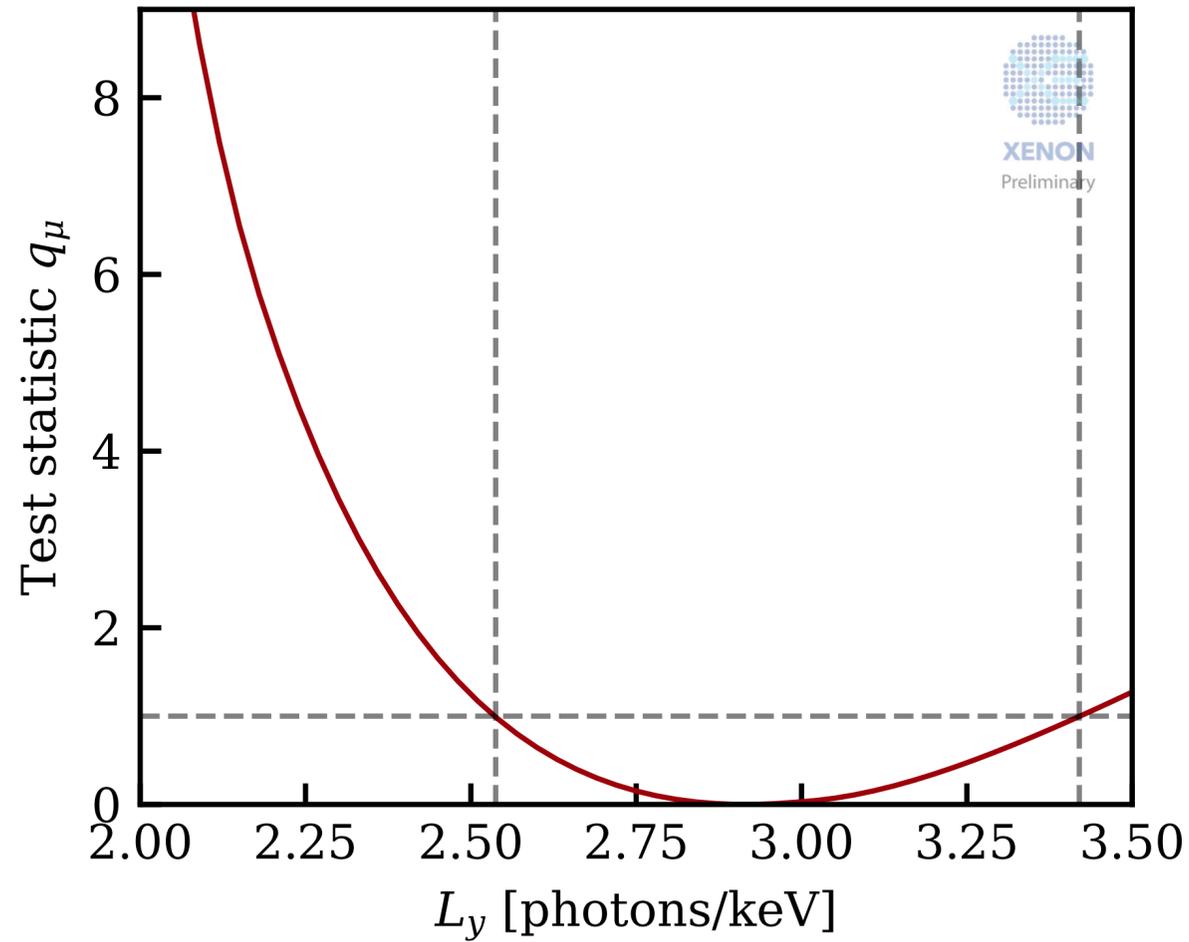
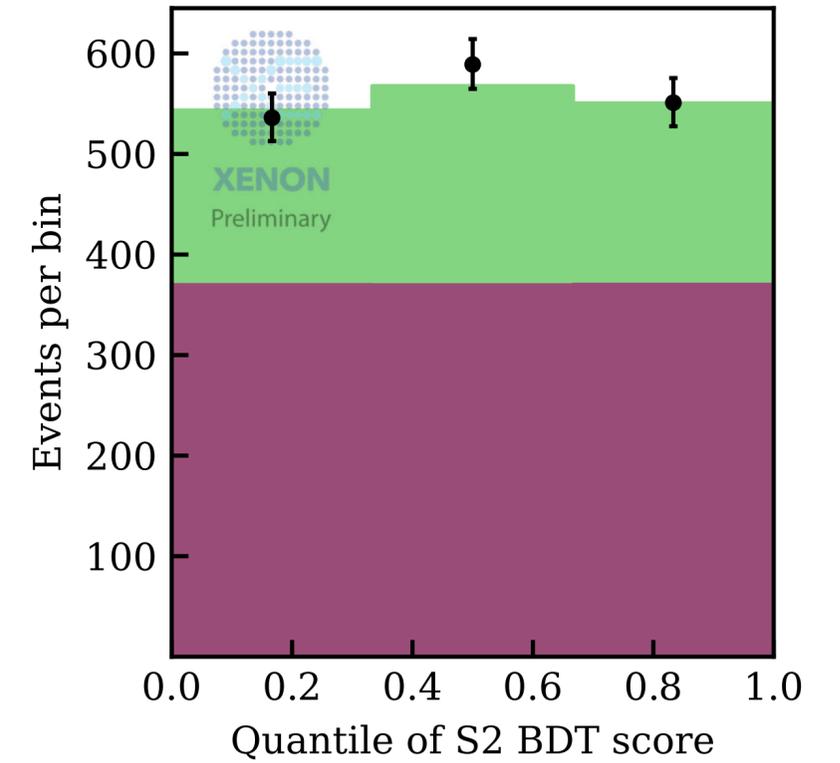
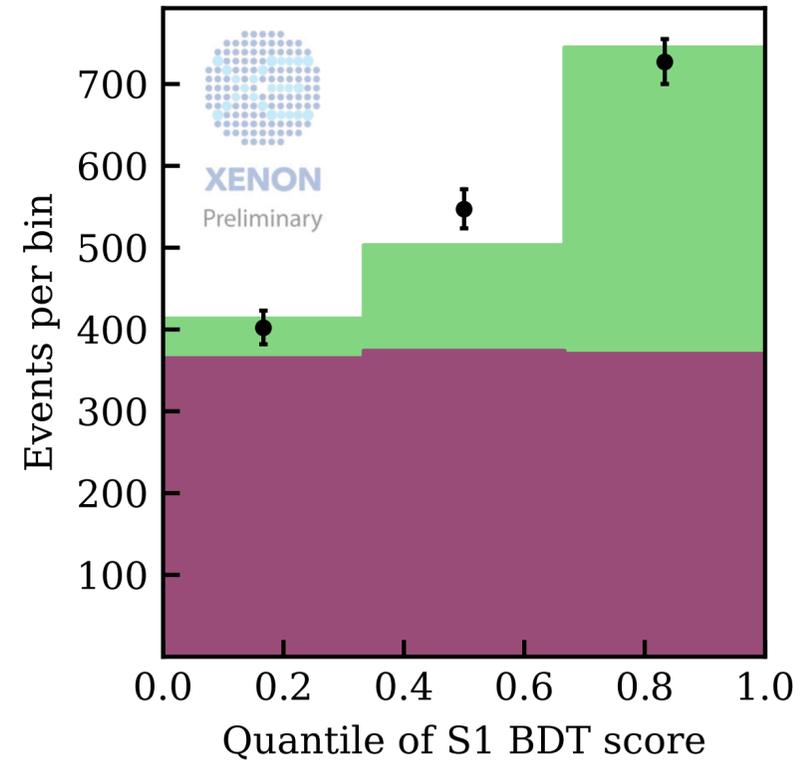
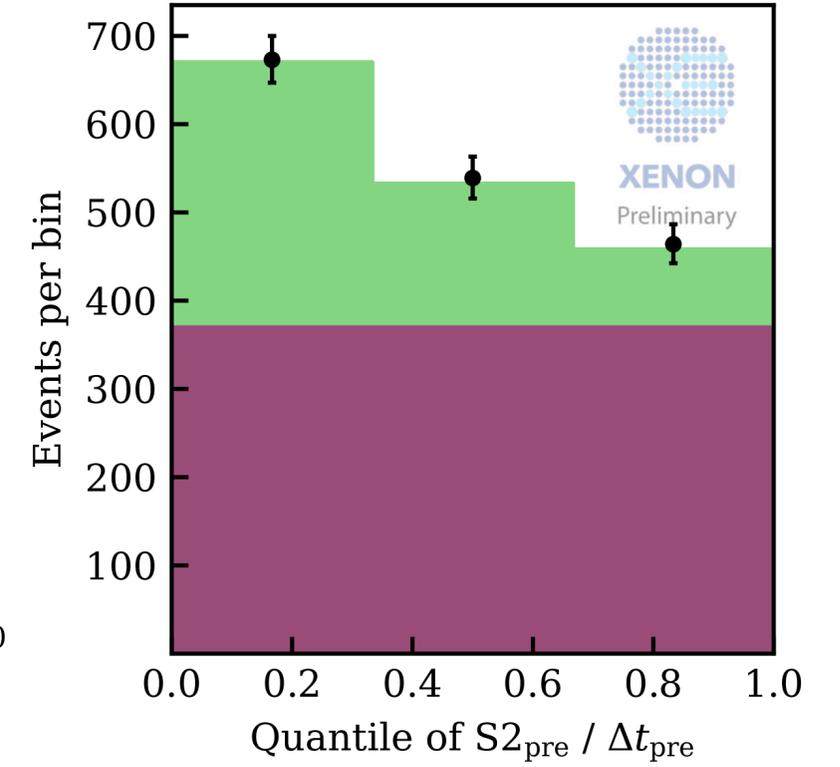
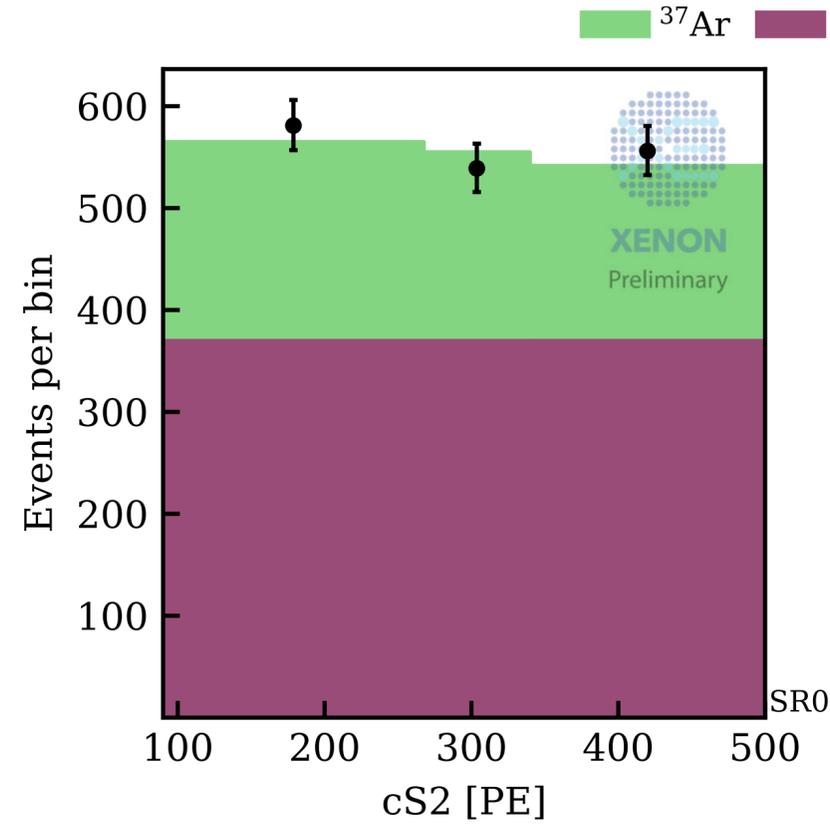
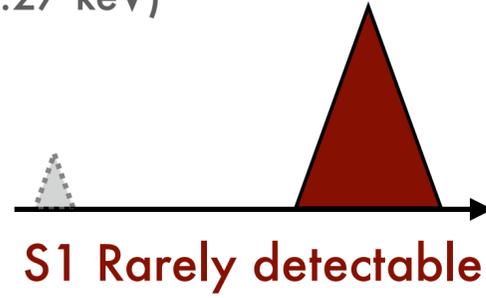
- SR0(1) AC Sideband 中最终观测到 121(326) 个事件，与预期符合
- 最终用于物理搜索的似然函数中包括了 4 个维度： $3^4 = 81$  个 bin。被验证的更多分析维度提供了更强的信号与本底的区分能力。



# 用 $^{37}\text{Ar}$ L shell 事件佐证信号与本底模型

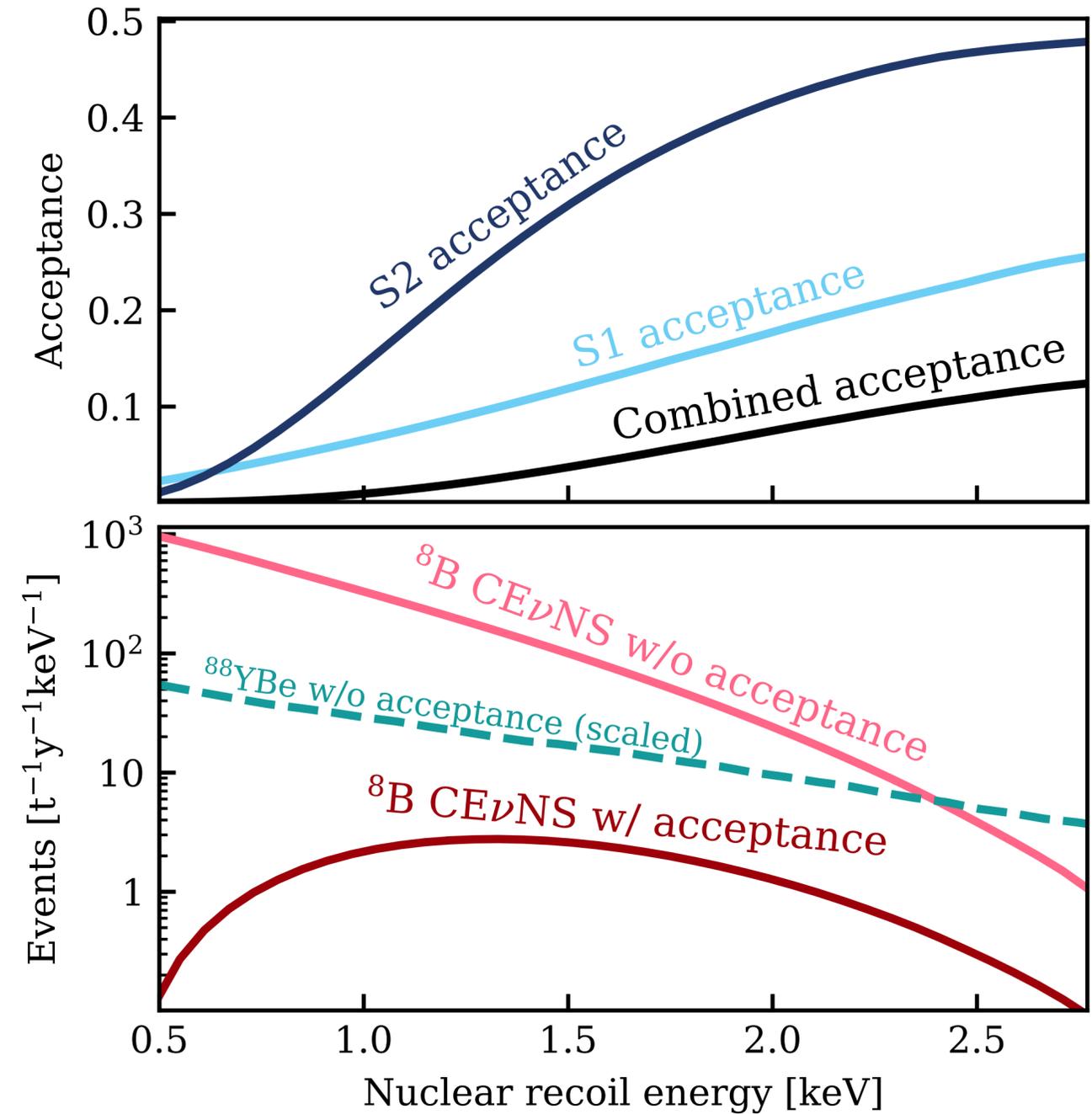


L-shell Electron Capture  
(0.27 keV)



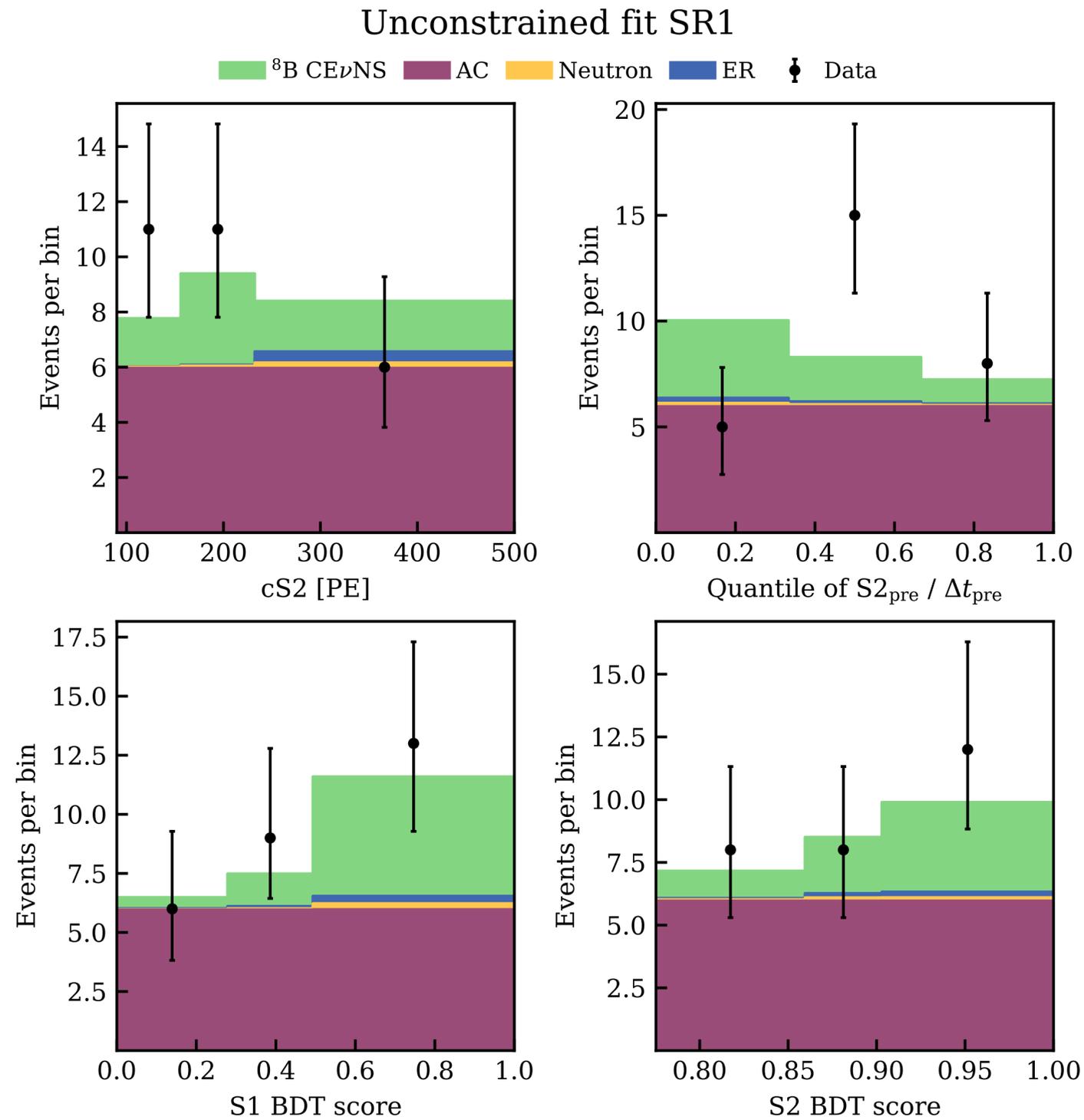
# nT 首次 $^8\text{B}$ CE $\nu$ NS 搜寻中的信号和本底的期望值

事件分类	事件个数期望
AC - SR0	$7.5 \pm 0.5$
AC - SR1	$17.8 \pm 1.0$
ER	$0.7 \pm 0.7$
Neutron	$0.5 \pm 0.3$
<b>Total Background</b>	<b><math>26.4 \pm 1.4</math></b>
$^8\text{B}$	$11.9 \pm 34.5$



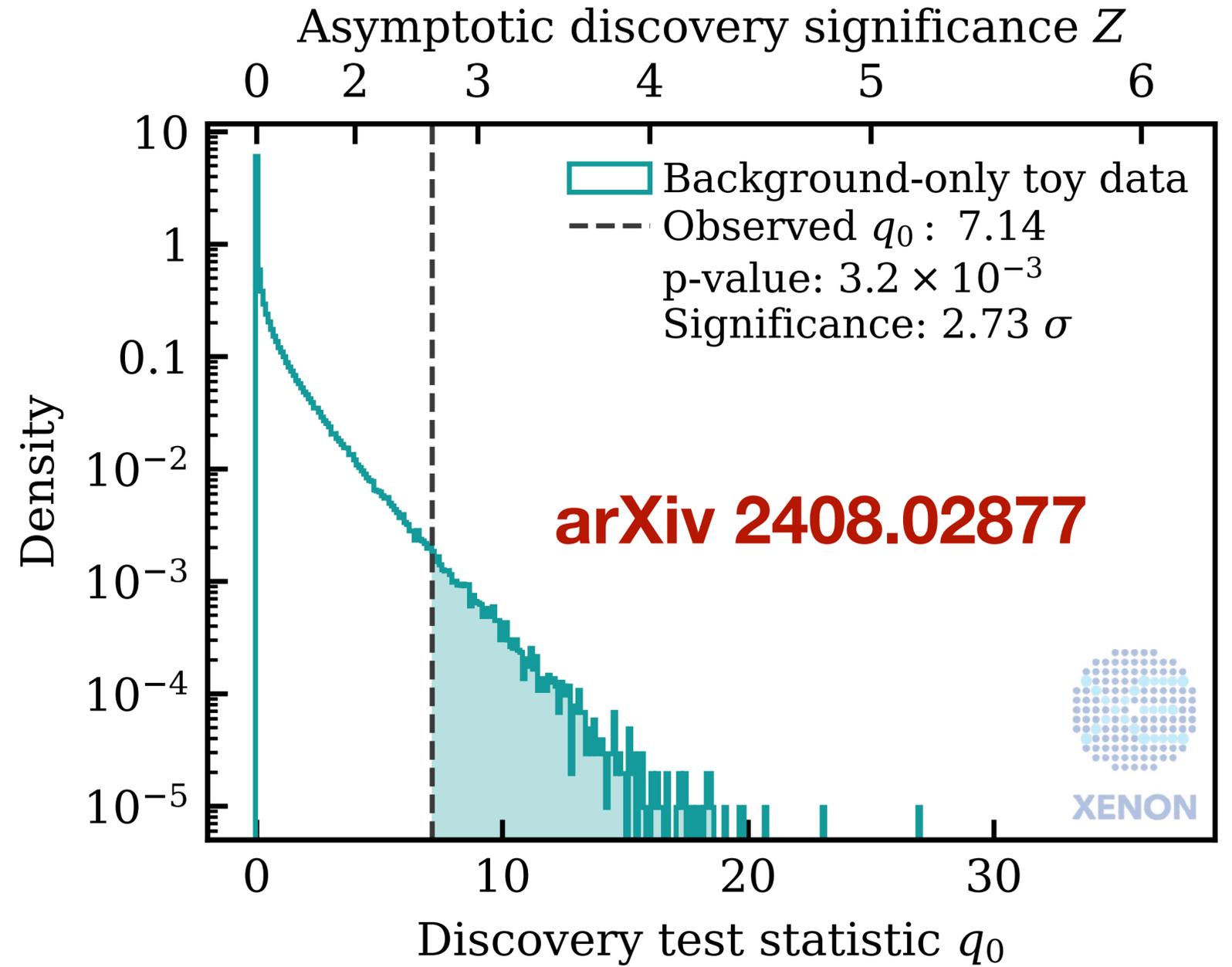
基于最可信的信号模型，我们预期至少看到  $2(3)\sigma$  统计显著度的概率是80%(48%)

# 揭盲(unblind)结果: $2.73\sigma$



数据与本底+信号符合!

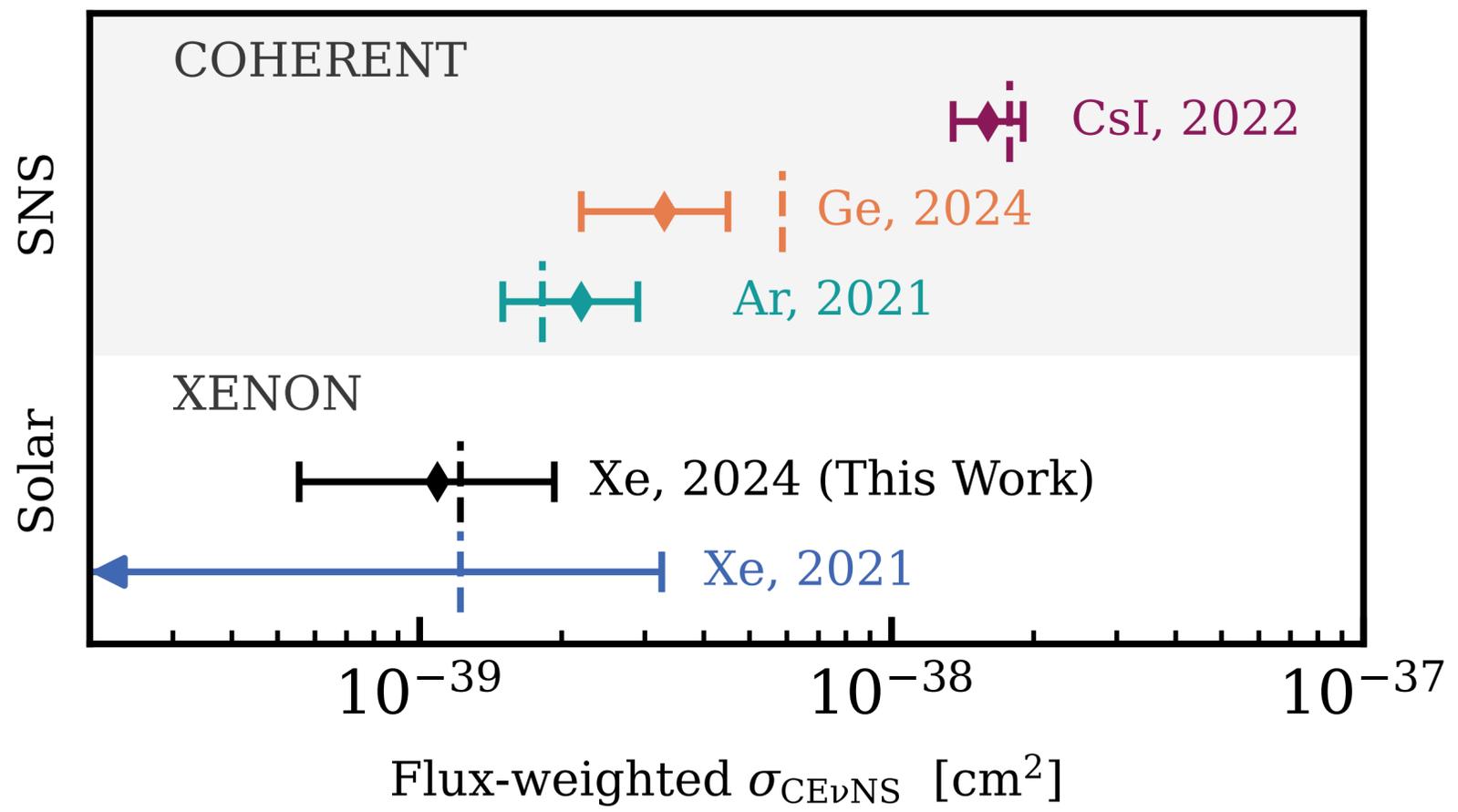
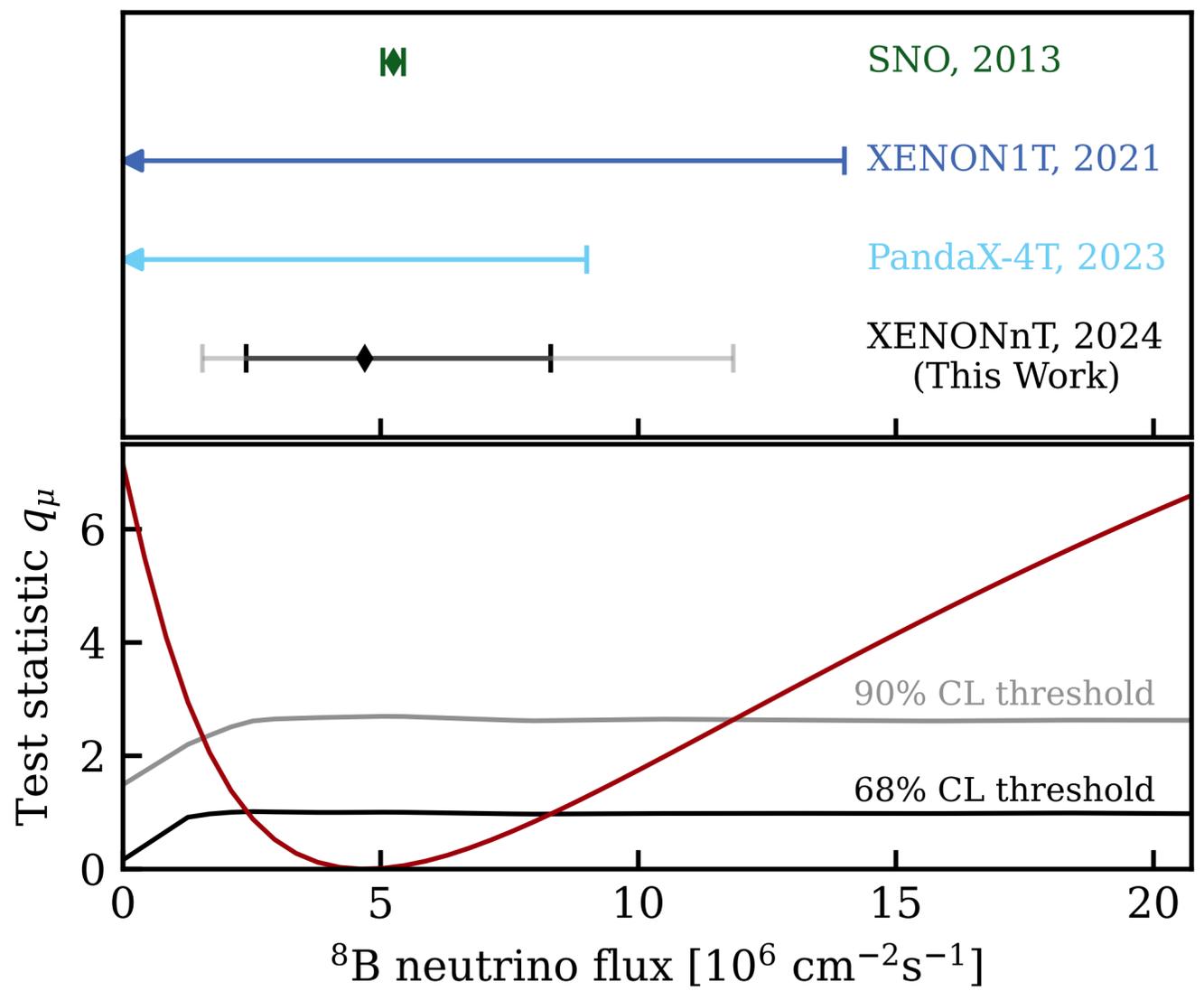
26.4 + 11.9 期望事件数 vs 37 观测事件数



无信号假设被以  $2.73\sigma$  显著度排除

# 对 $^8\text{B}$ 太阳中微子流强与对氙原子核的 CEvNS 截面的限制

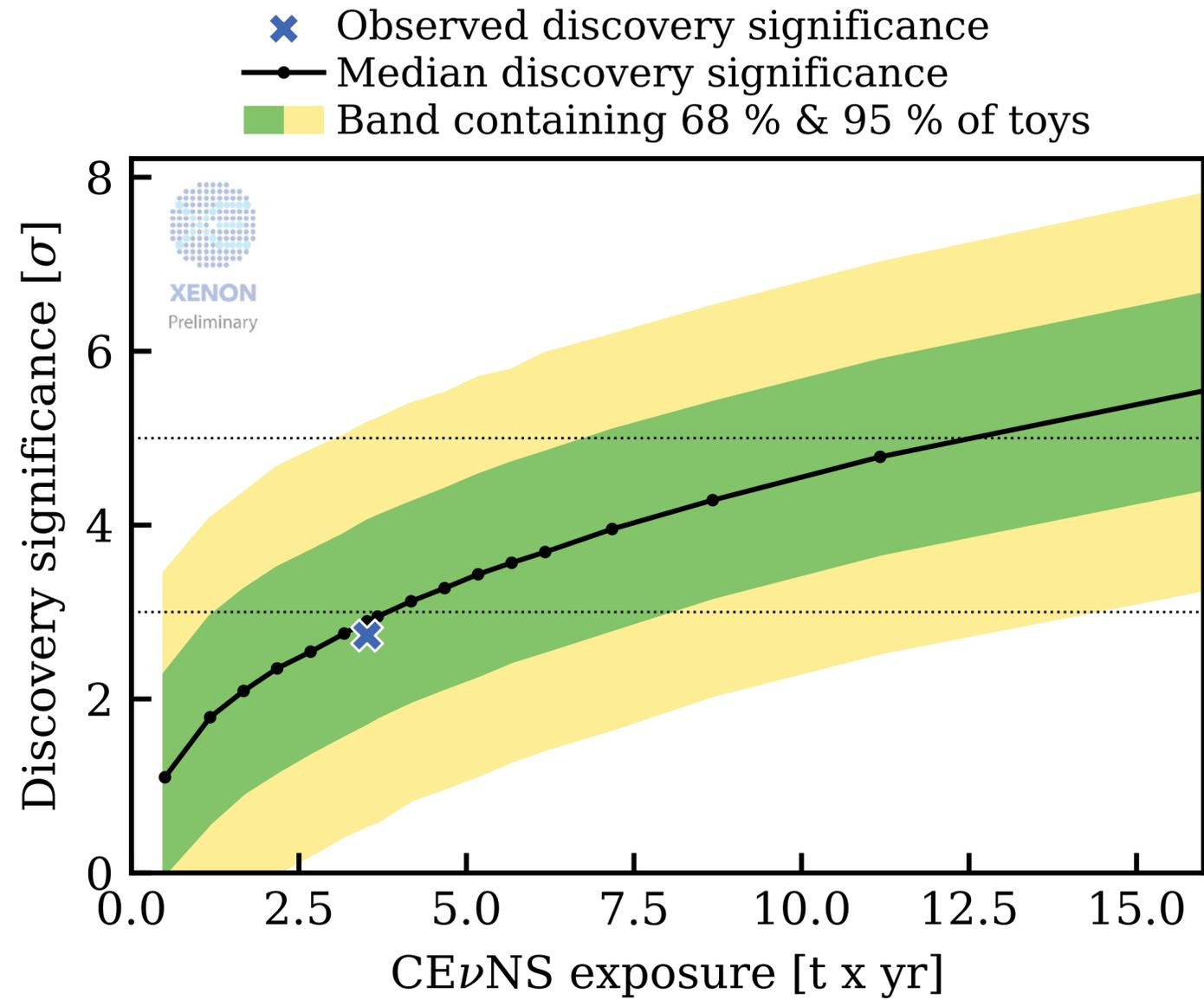
arXiv 2408.02877



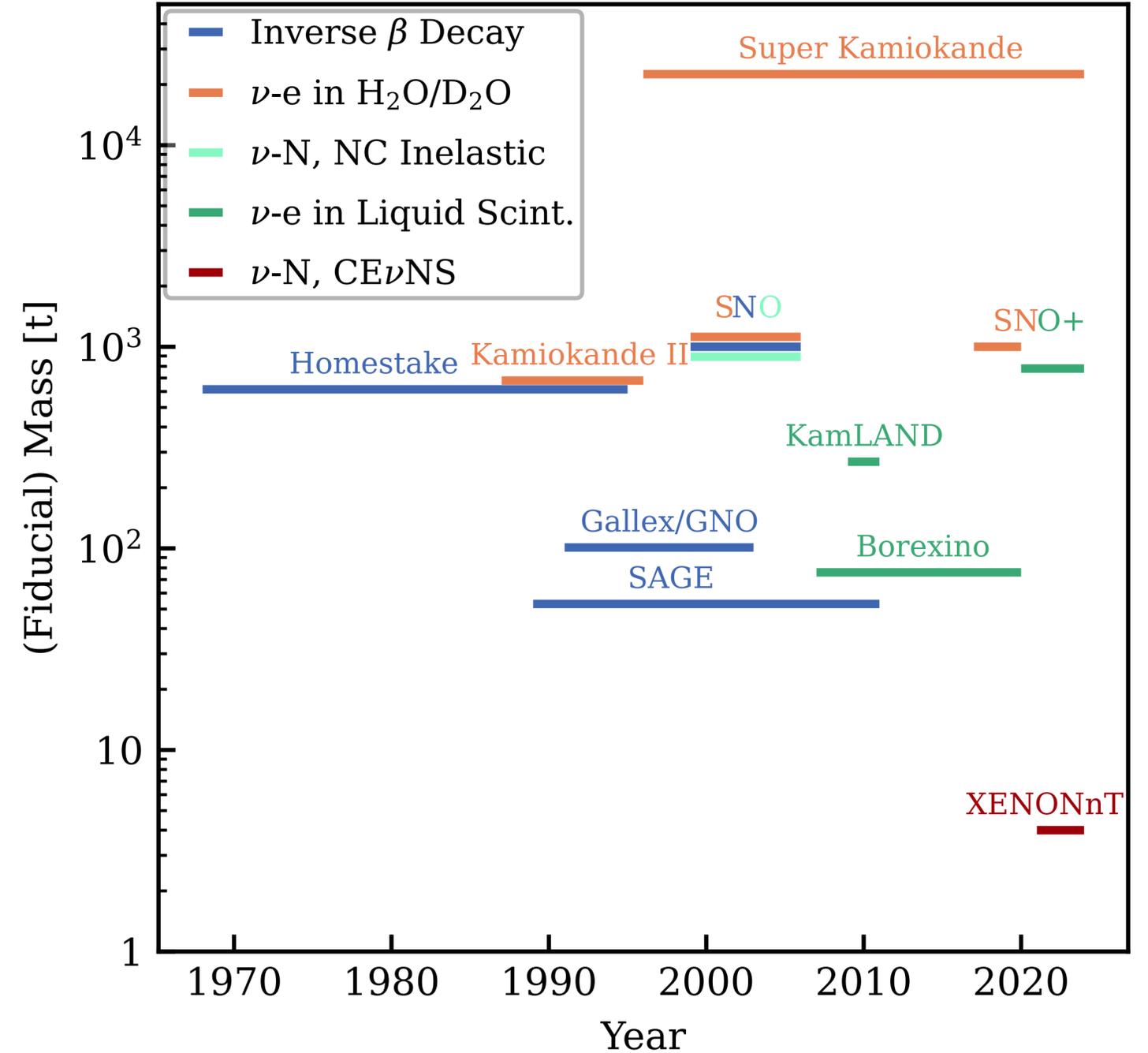
在 68% 置信度上， $^8\text{B}$  太阳中微子的流强被限制为  $[2.4, 8.3] \times 10^6 \text{ cm}^{-2} \text{ s}^{-1}$

在 68% 置信度上，Xe 原子核的 CEvNS 截面限制为在对  $^8\text{B}$  中微子流强加权平均后为  $[0.6, 1.9] \times 10^{-39} \text{ cm}^2$

# 未来计划



随着持续采数，统计显著度的期望将会不断提升



更多的中微子物理搜索正在进行中，敬请期待

**谢谢！**