



清华大学
Tsinghua University



XENON



1926 - 2026
TSINGHUA PHYSICS

百年
物理

中国物理学会高能物理分会

第十二届全国会员代表大会暨学术年会

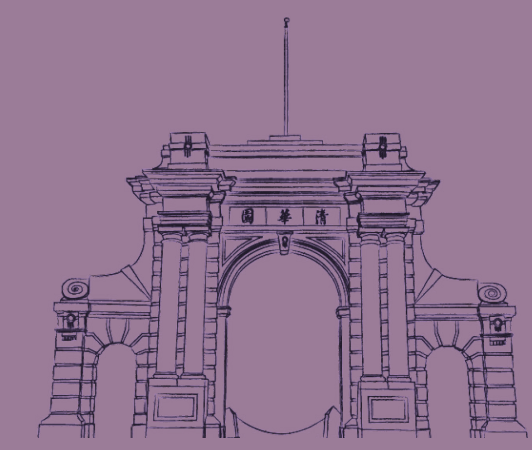
Probing the Solar ^8B Neutrino Fog with XENONnT

CEvNS, light WIMPs, and BSM $-\nu$ Physics

arXiv:2604.06002 (accepted by PRL)

刘可欣 清华大学物理系

XENON合作组



XENON Collaboration



AMERICA



UC San Diego

San Diego 



Houston 



Chicago 



New York City 



Lewisburg 



EUROPE



Zurich 



Karlsruhe 



Münster 



Freiburg 



Mainz 



Heidelberg 



Heidelberg 



Amsterdam 



Stockholm 



Coimbra 



Nantes 



Paris 



Torino 



Bologna 



L'Aquila 



Assergi 



Napoli 

~200 SCIENTISTS
31 INSTITUTIONS
12 COUNTRIES

MIDDLE EAST



Rehovot 



Abu Dhabi 

ASIA



Beijing 



Hangzhou 



Shenzhen 



Tokyo 



Nagoya 



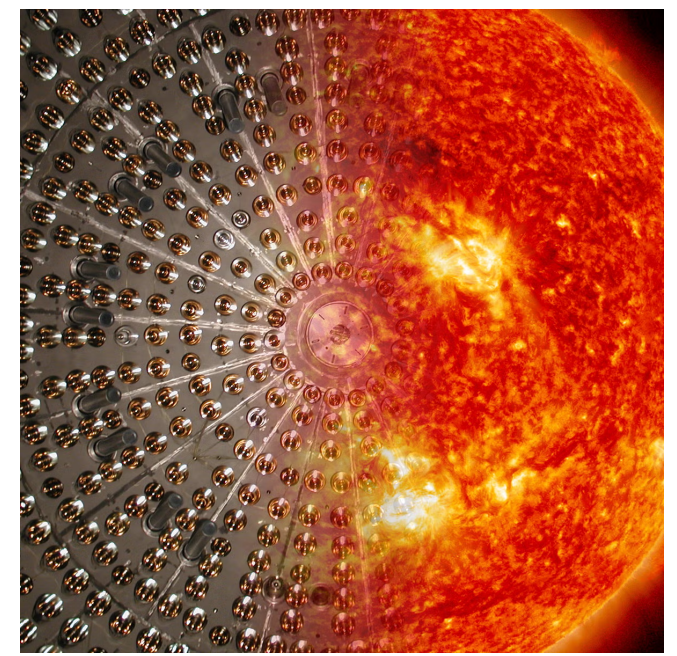
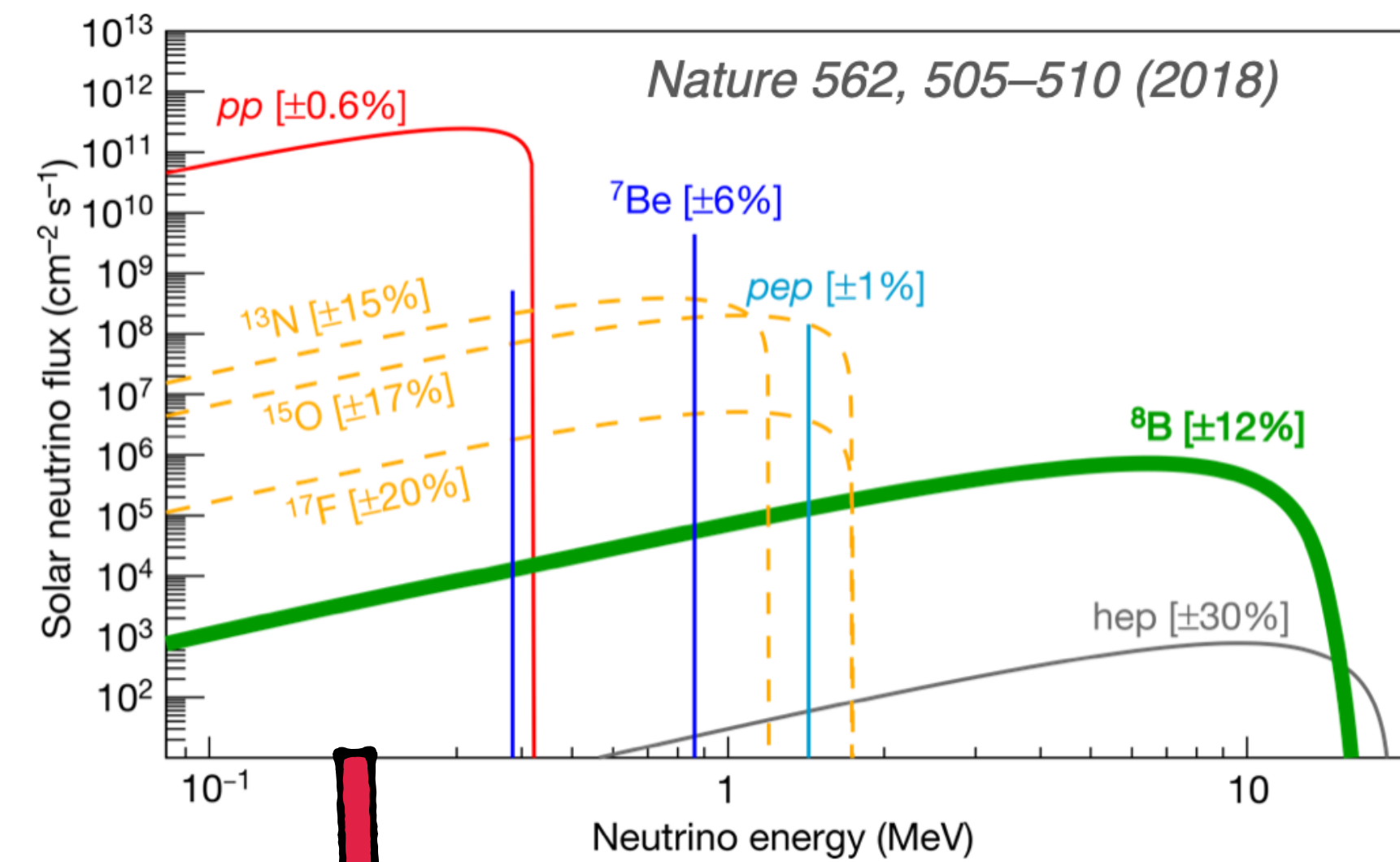
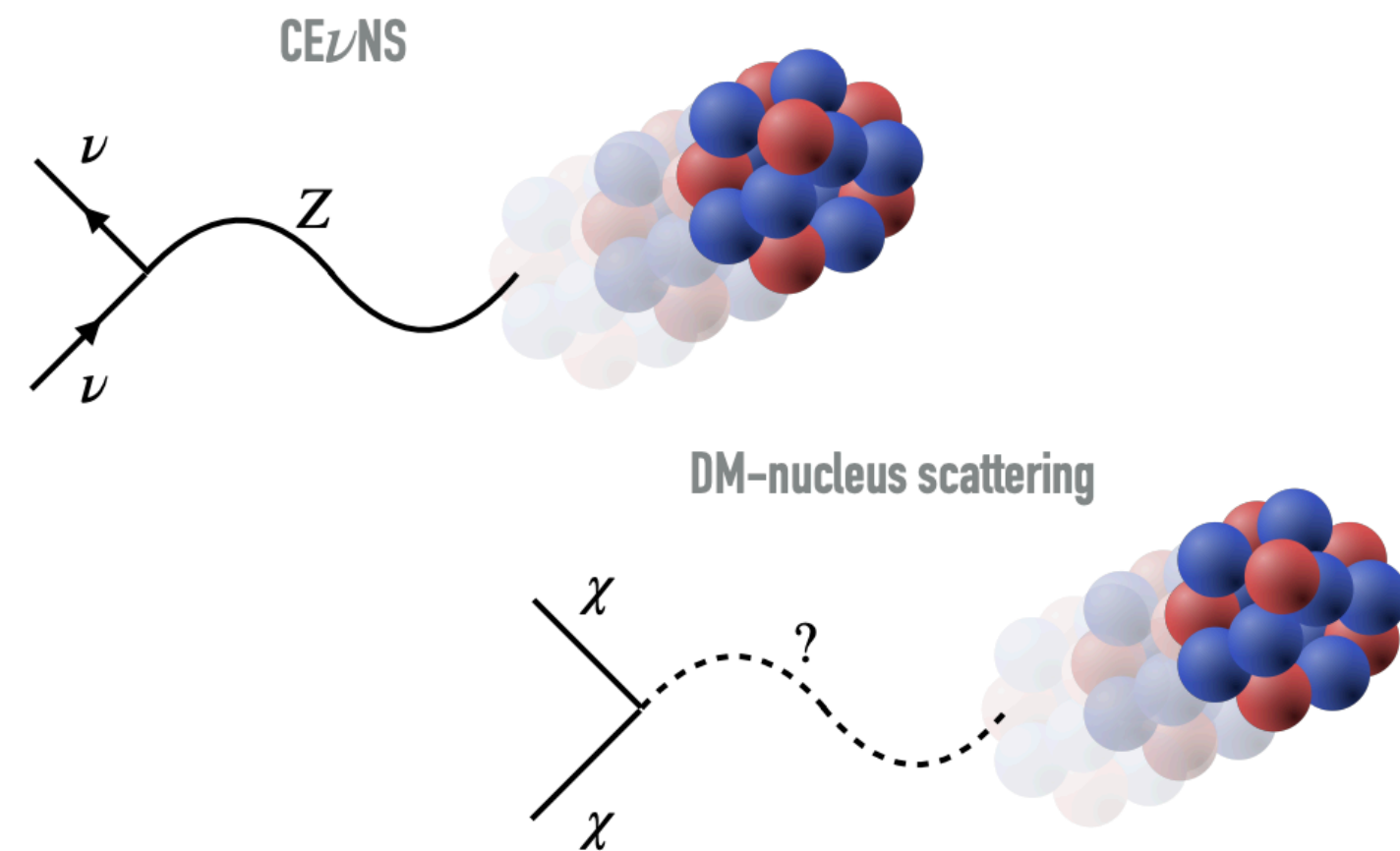
Kobe 



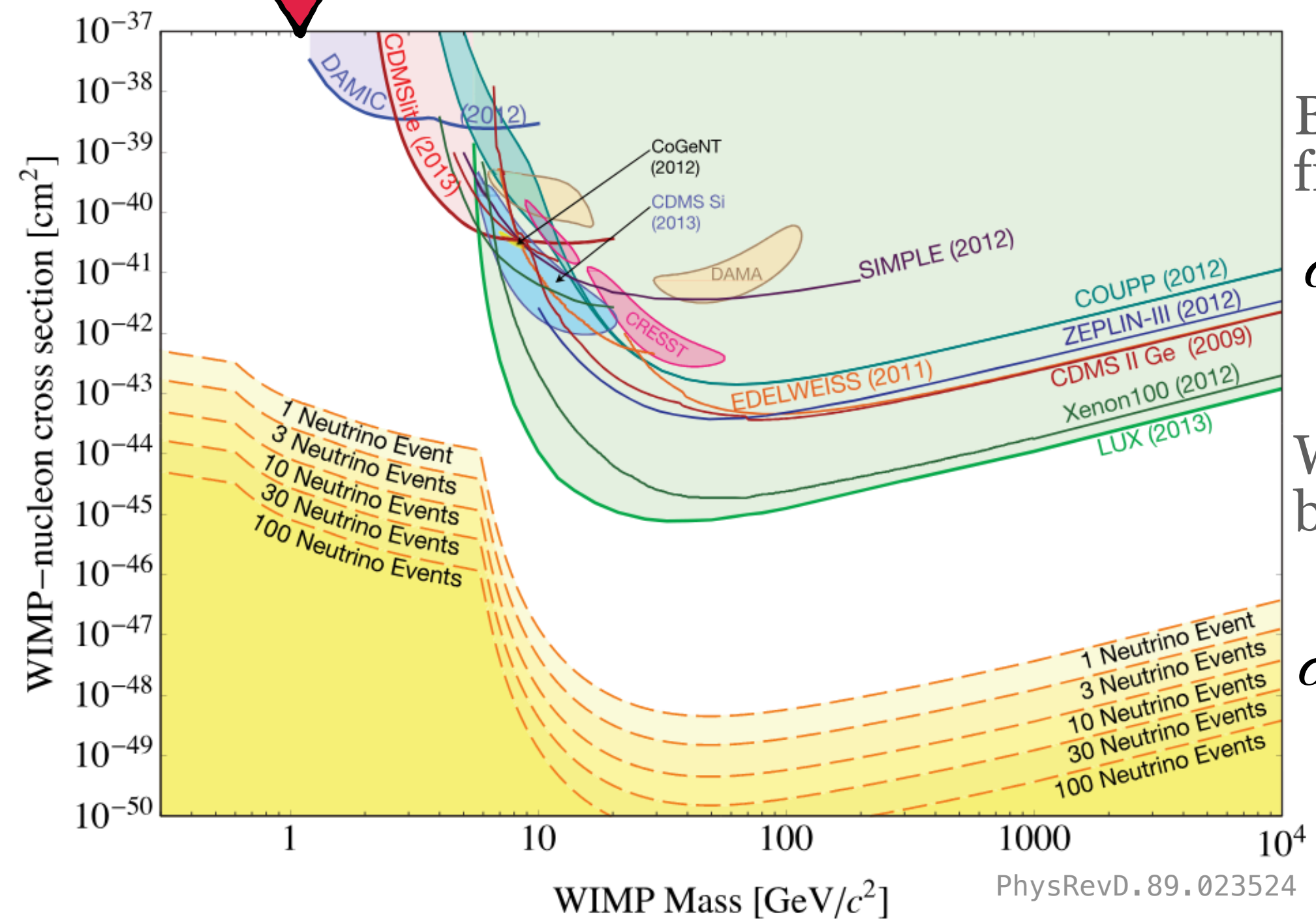
Tokyo 

The Solar Neutrino Fog

$$\nu_{\alpha} + {}^A_Z\mathcal{N} \rightarrow \nu_{\alpha} + {}^A_Z\mathcal{N} \quad \sigma \propto N^2$$



Borexino
(In LNGS Sala A)



Background free:

$$\sigma \propto \frac{1}{M \times T}$$

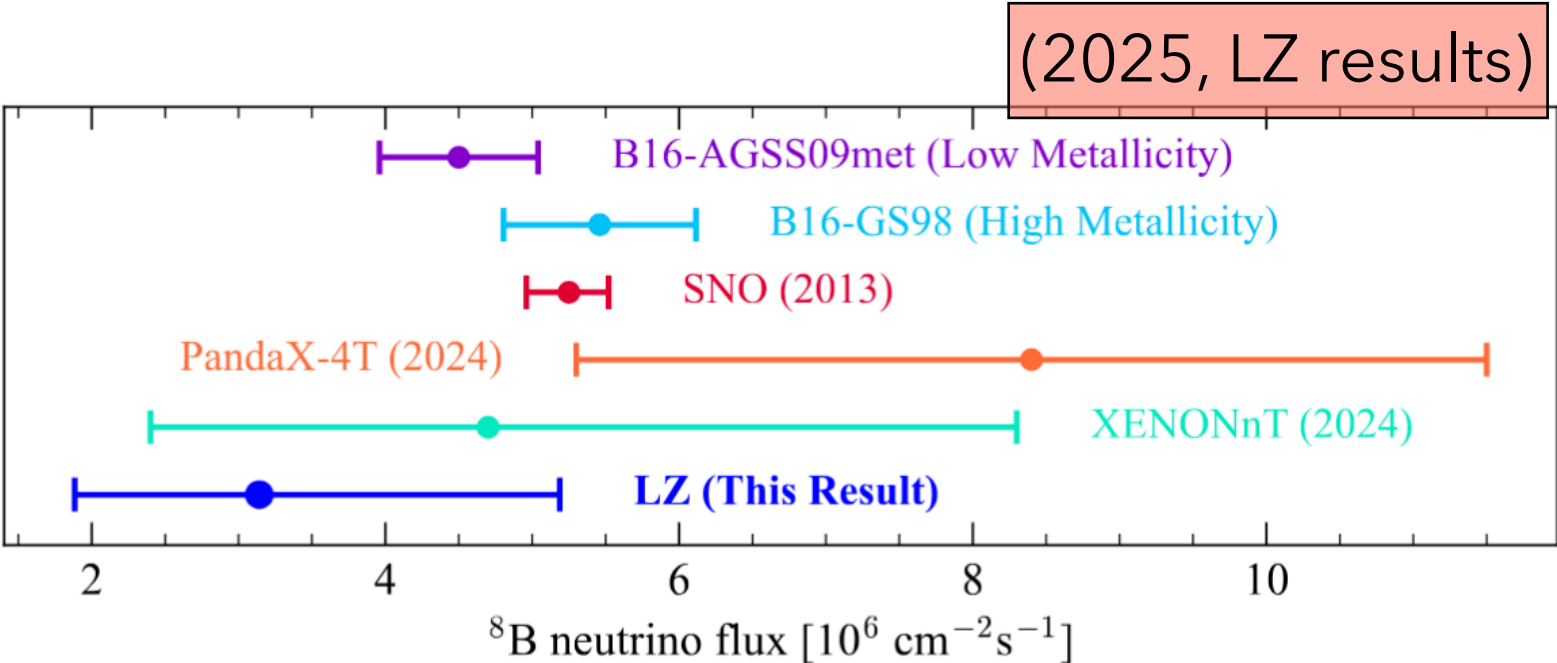
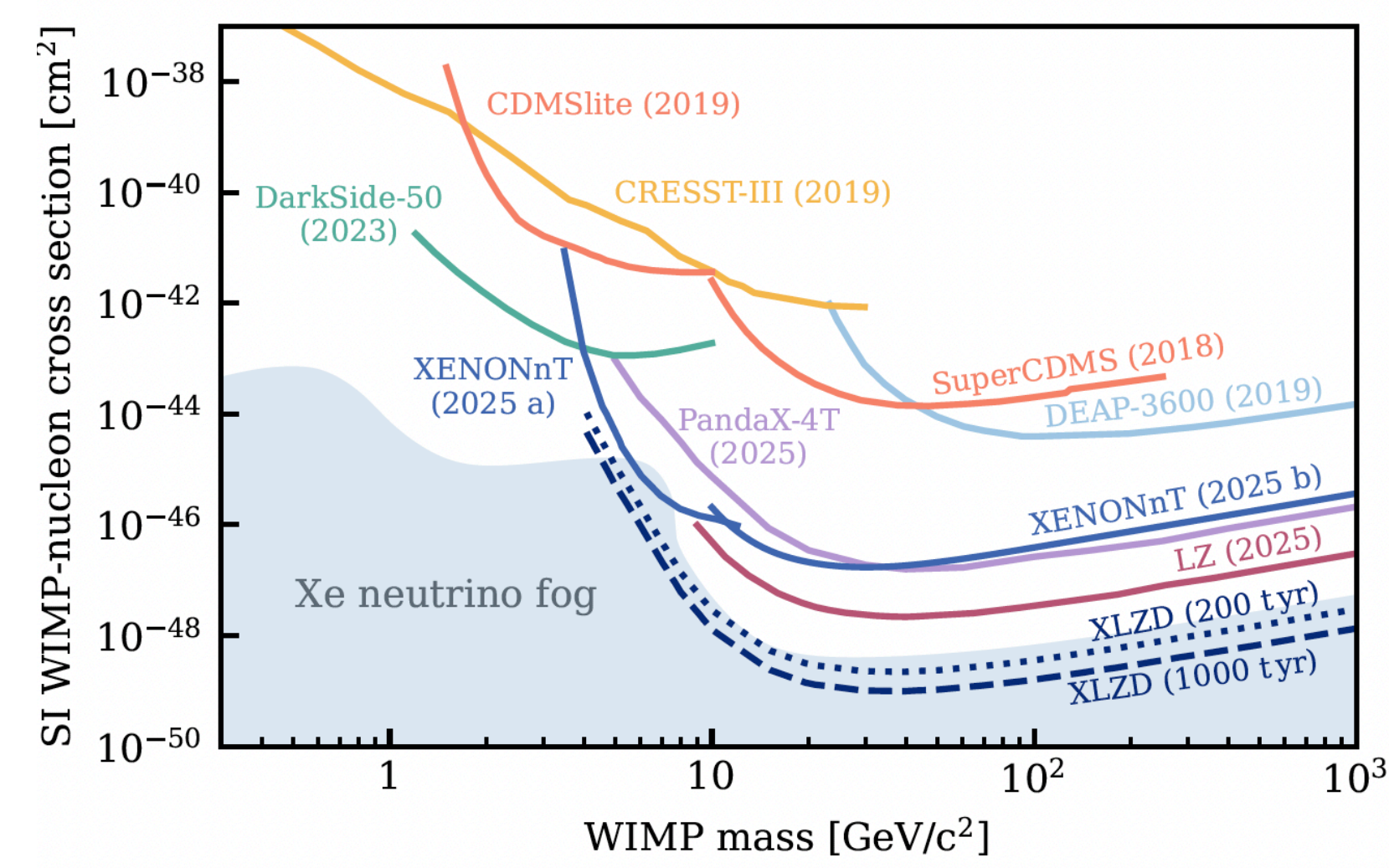
With background:

$$\sigma \propto \frac{\sqrt{b}}{\sqrt{M \times T}}$$

- Coherent elastic neutrino-nucleus scattering (**CEvNS**)
- Similar signature with WIMPs: nuclear recoils (NR)
- The “neutrino fog”: irreducible background; difficult to improve the sensitivity

2024: First glimpse of the neutrino fog

“This year also marked the point when searches for **dark matter** became sensitive enough to detect a potentially bedeviling background: **neutrinos streaming from the Sun.**”

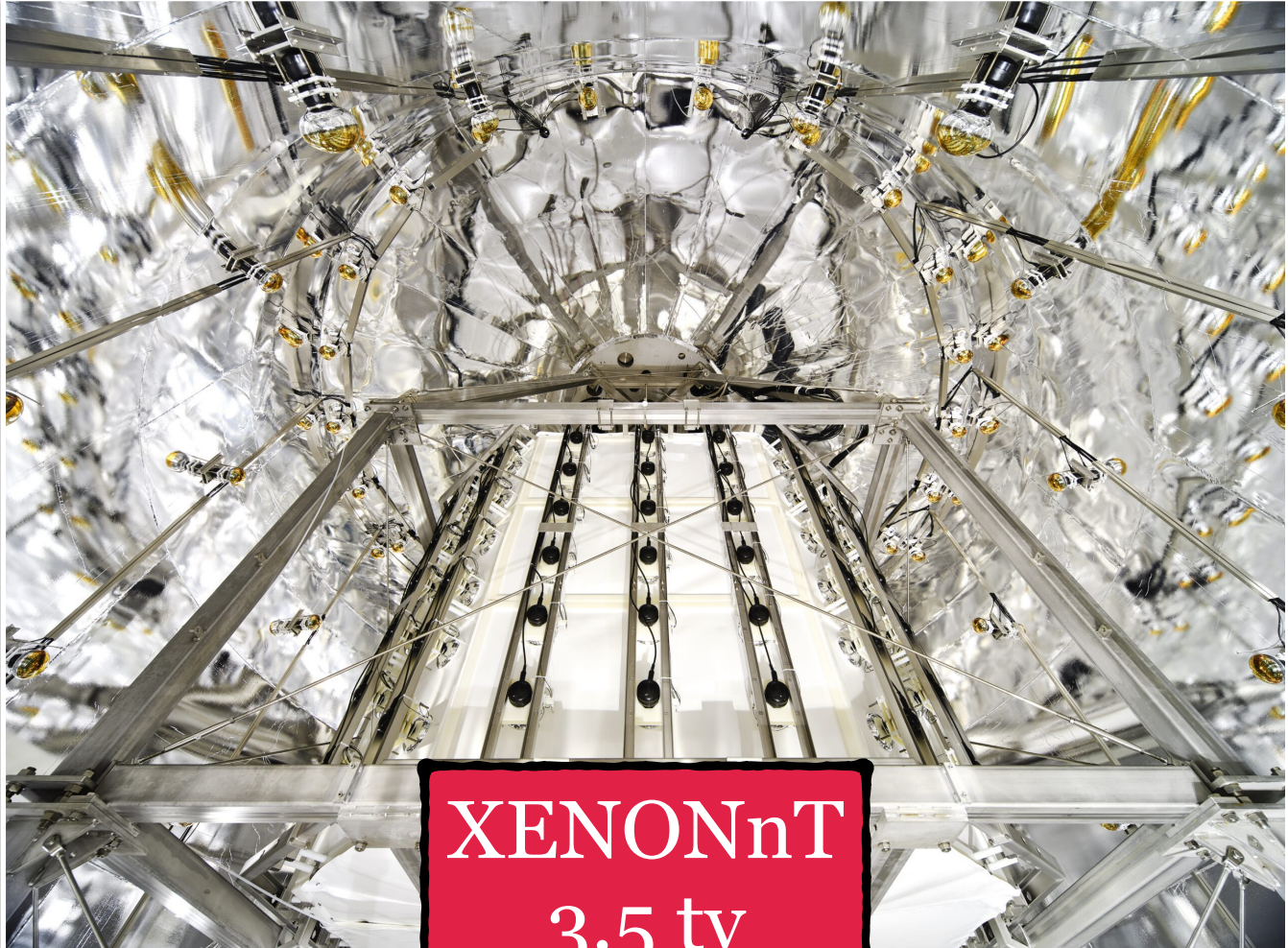


PhysRevLett.133.19100



PandaX-4T 1.20(1.04) ty
paired(US2)
2.64 σ

PhysRevLett.133.191002



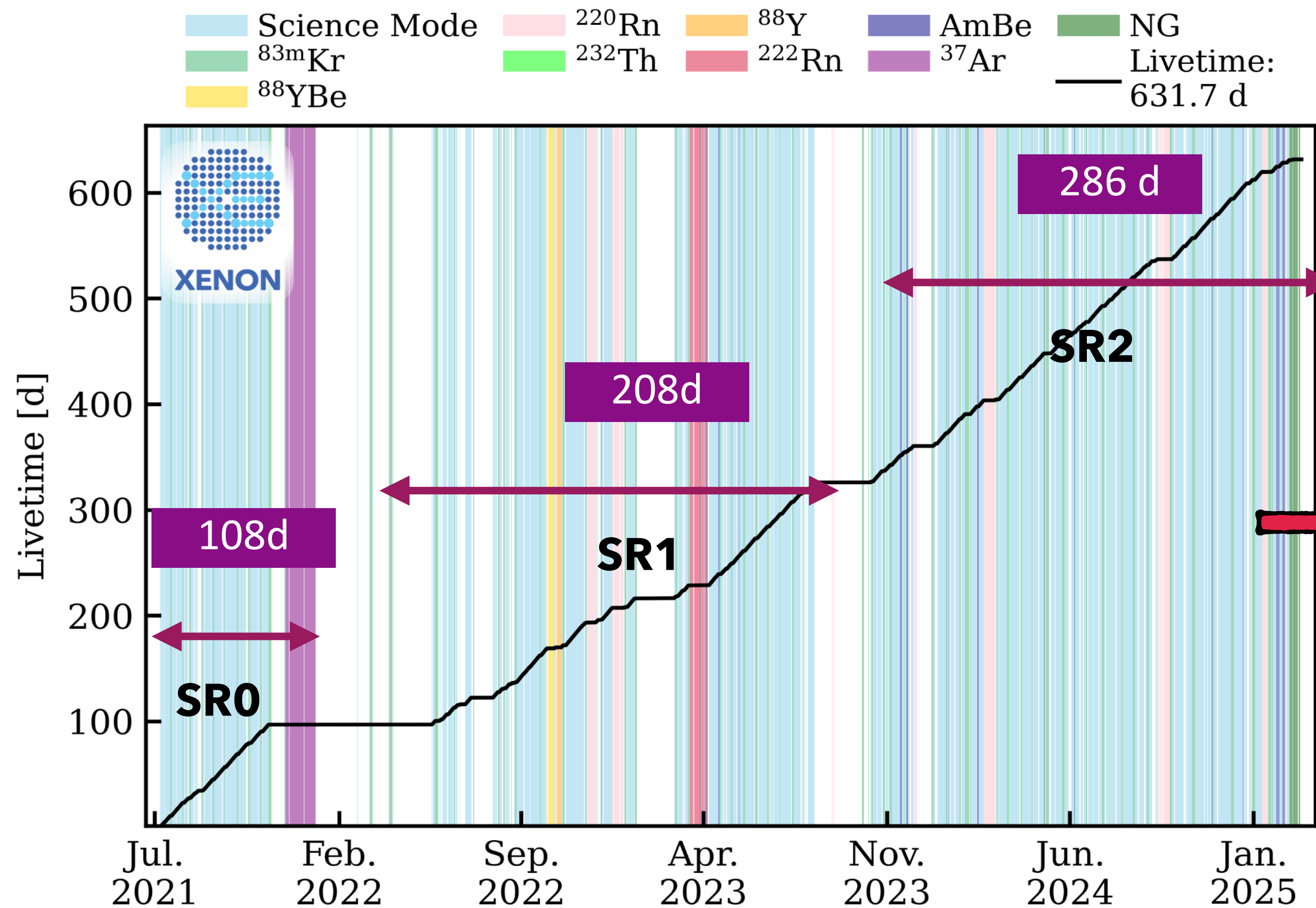
XENONnT
3.5 ty
2.73 σ

arXiv:2512.08065

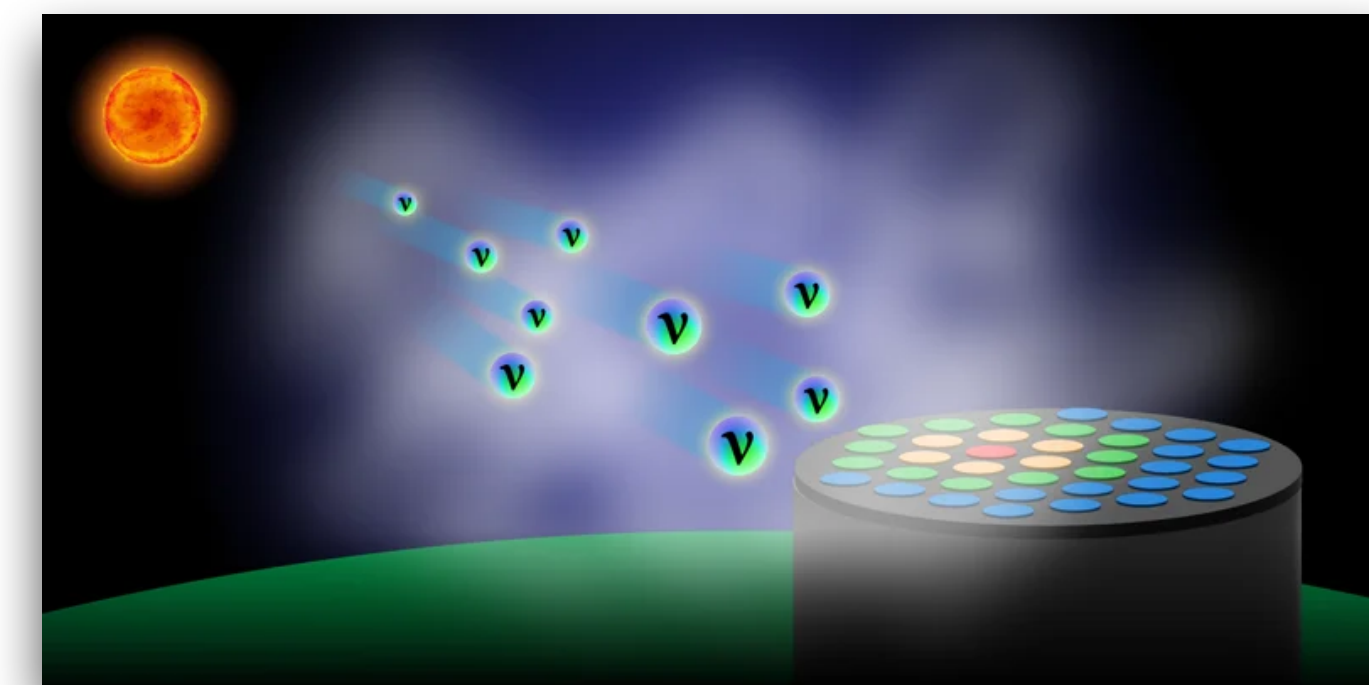


LZ
5.7 ty
4.5 σ

XENONnT Exposure



➡ Today's **3** : What's next?



Today's **1** : “First indication” quick recap

○ Phys. Rev. Lett. 133, 191002

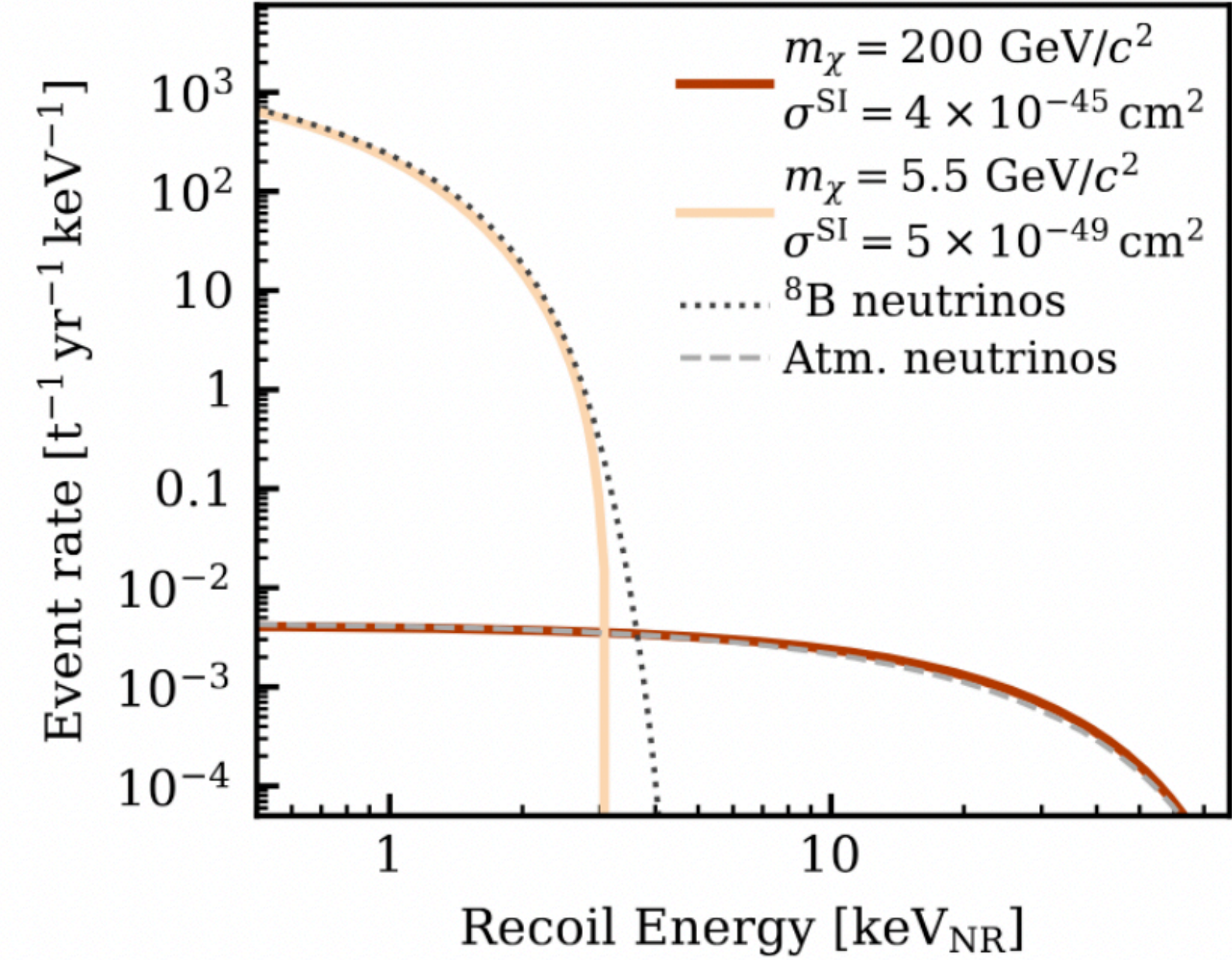
Today's **2** : New results!

○ arXiv:2604.06002(accepted by PRL)

^8B CEvNS: sub-keV NR

^8B neutrino spectrum

CEvNS Cross-section



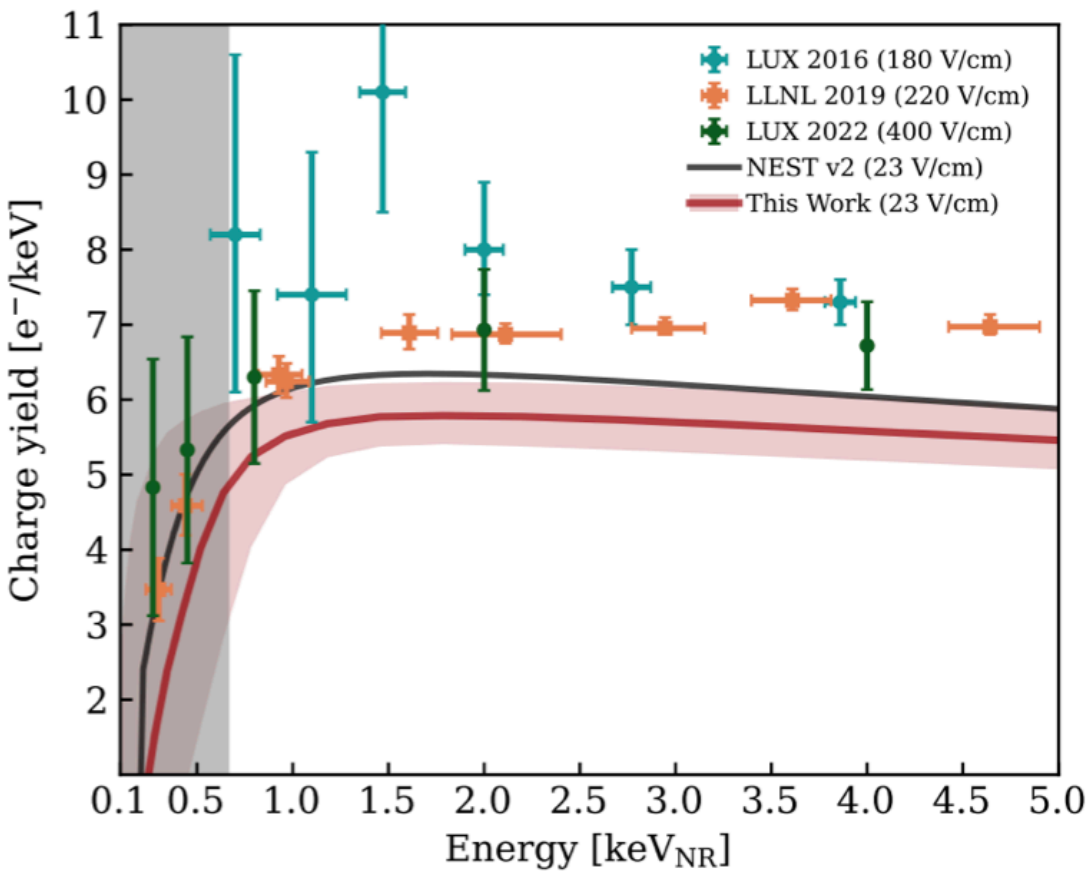
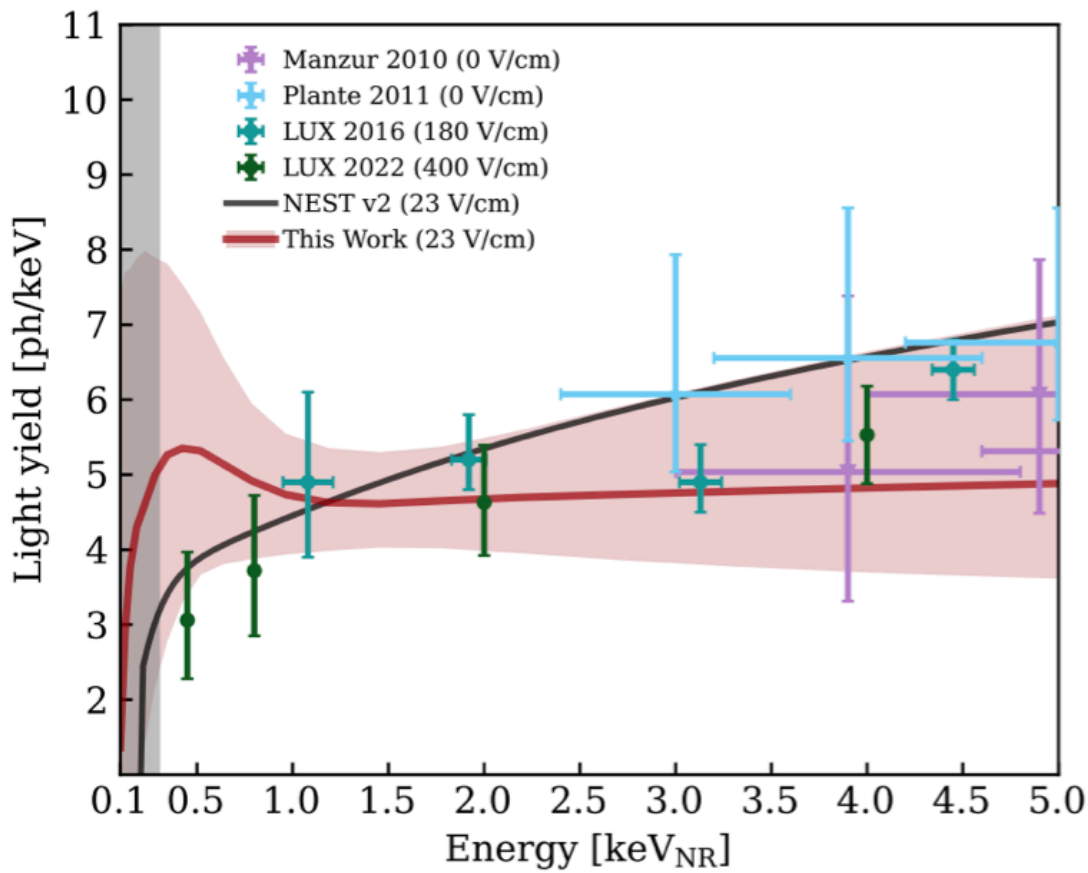
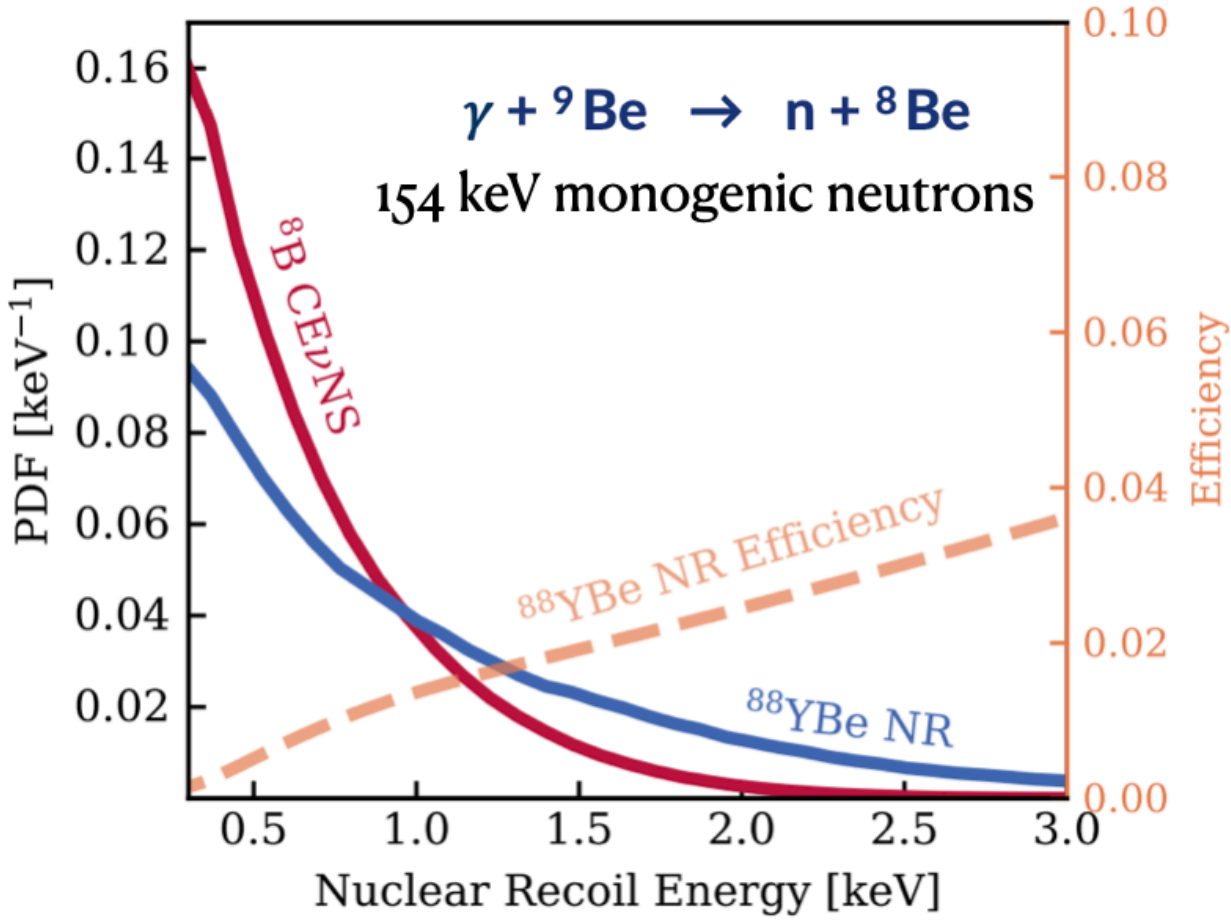
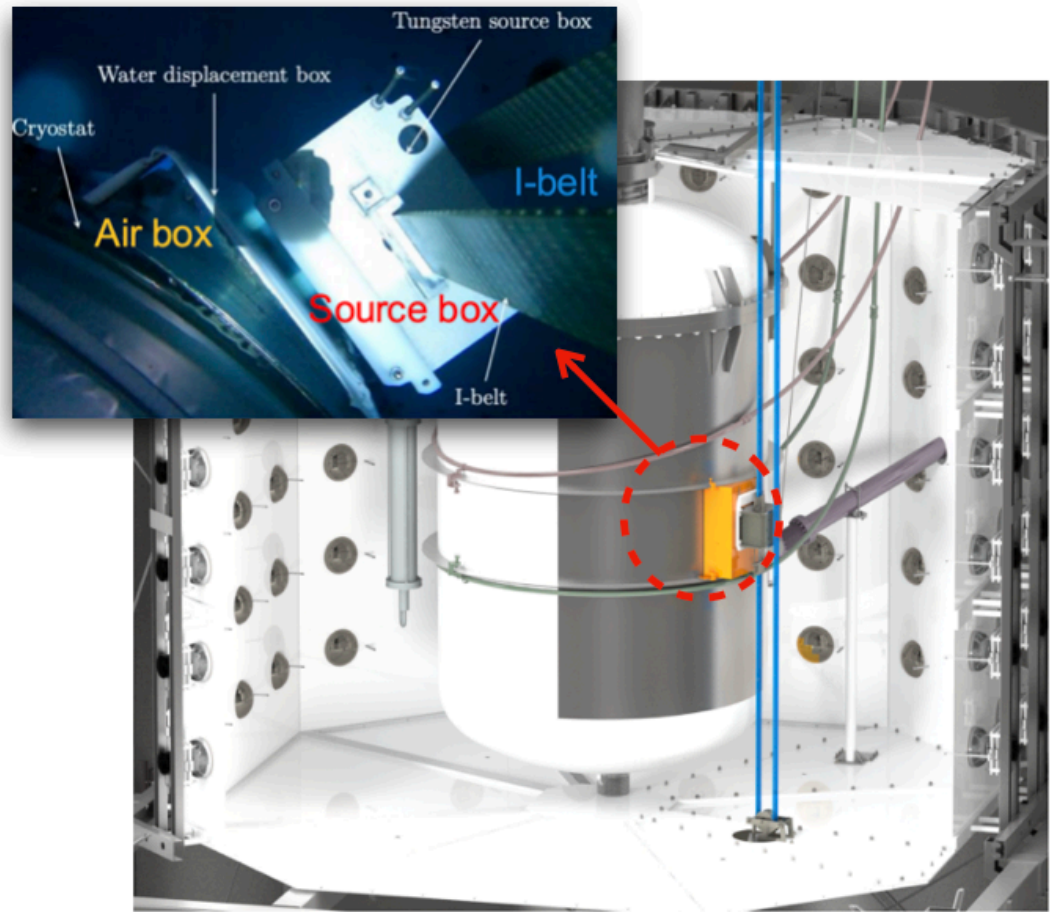
Scattering rate: ★
600 /ty

Photons, electrons

S1, S2

Efficiency

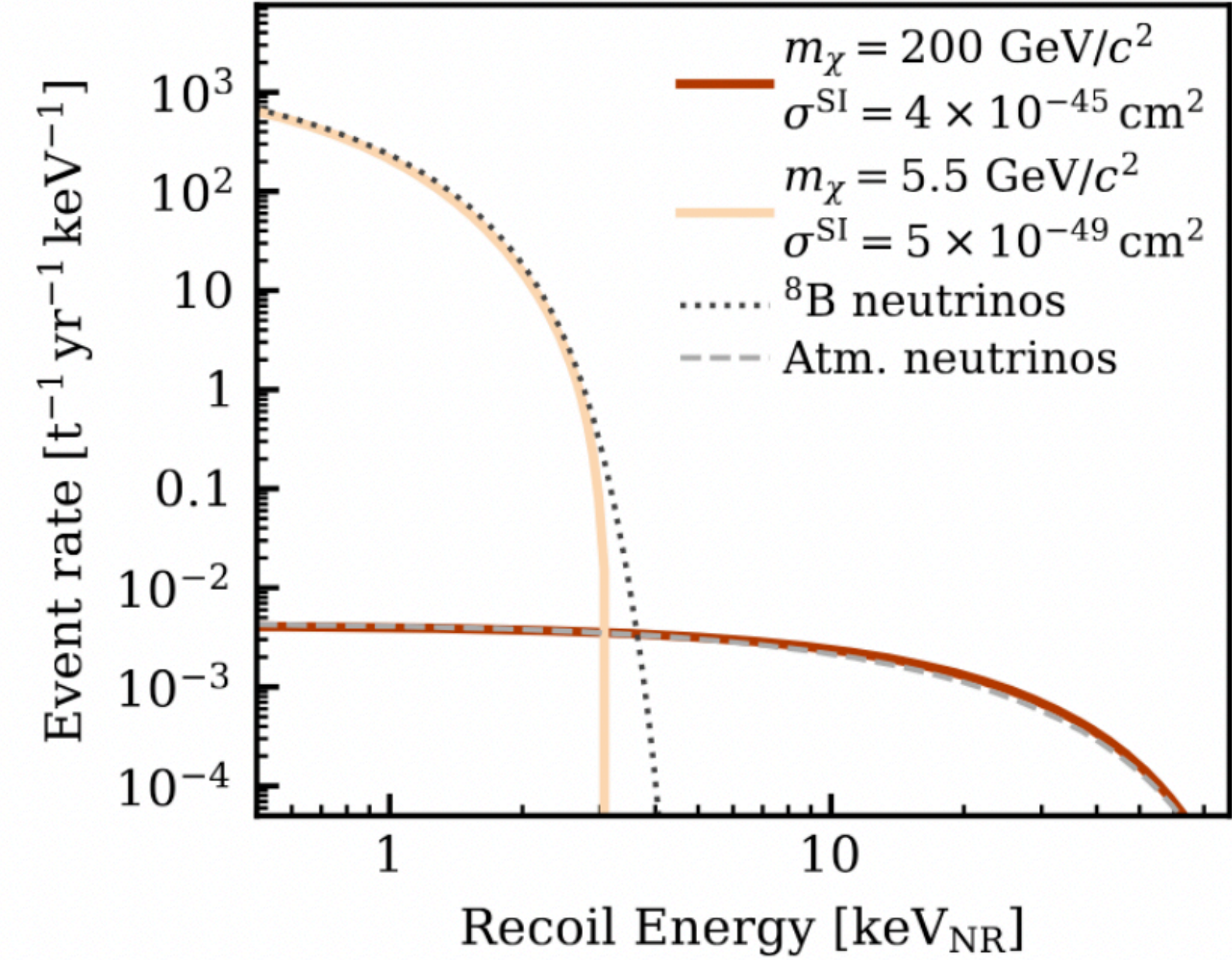
Signal



^8B CEvNS: sub-keV NR

^8B neutrino spectrum

CEvNS Cross-section



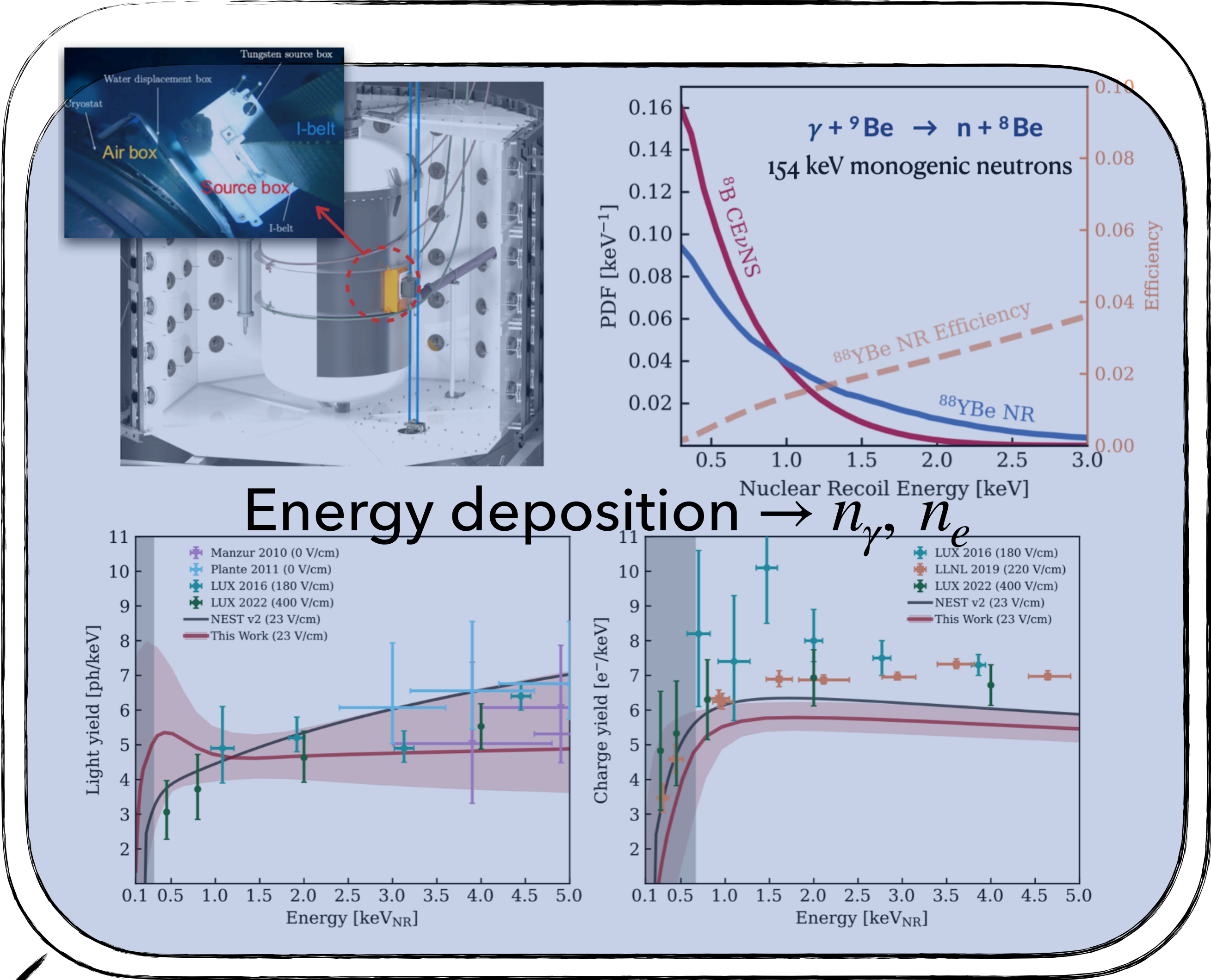
Scattering rate: ★
600 /ty

Photons, electrons

S1, S2

Efficiency

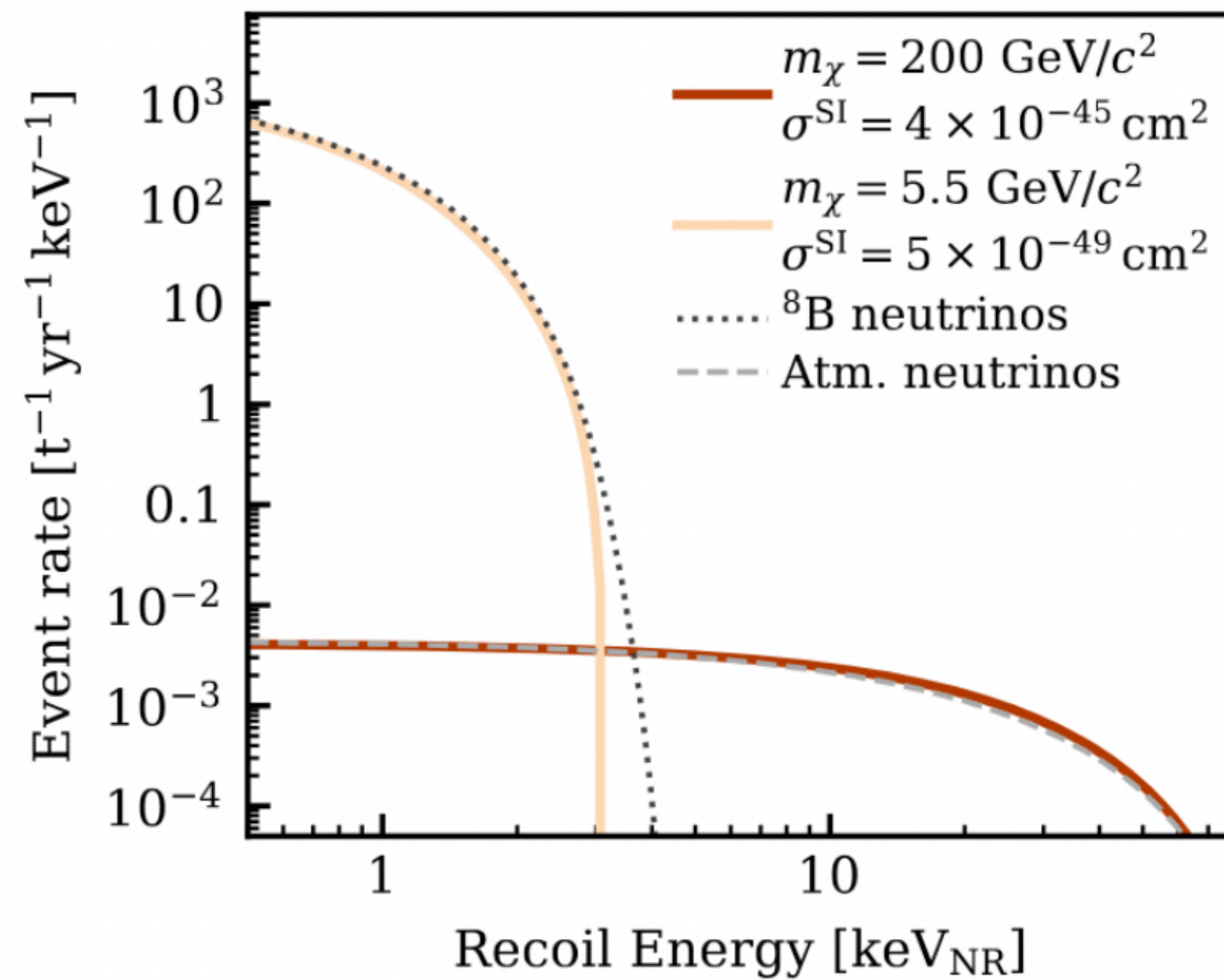
Signal



^8B CE ν NS: sub-keV NR

^8B neutrino spectrum

CE ν NS Cross-section



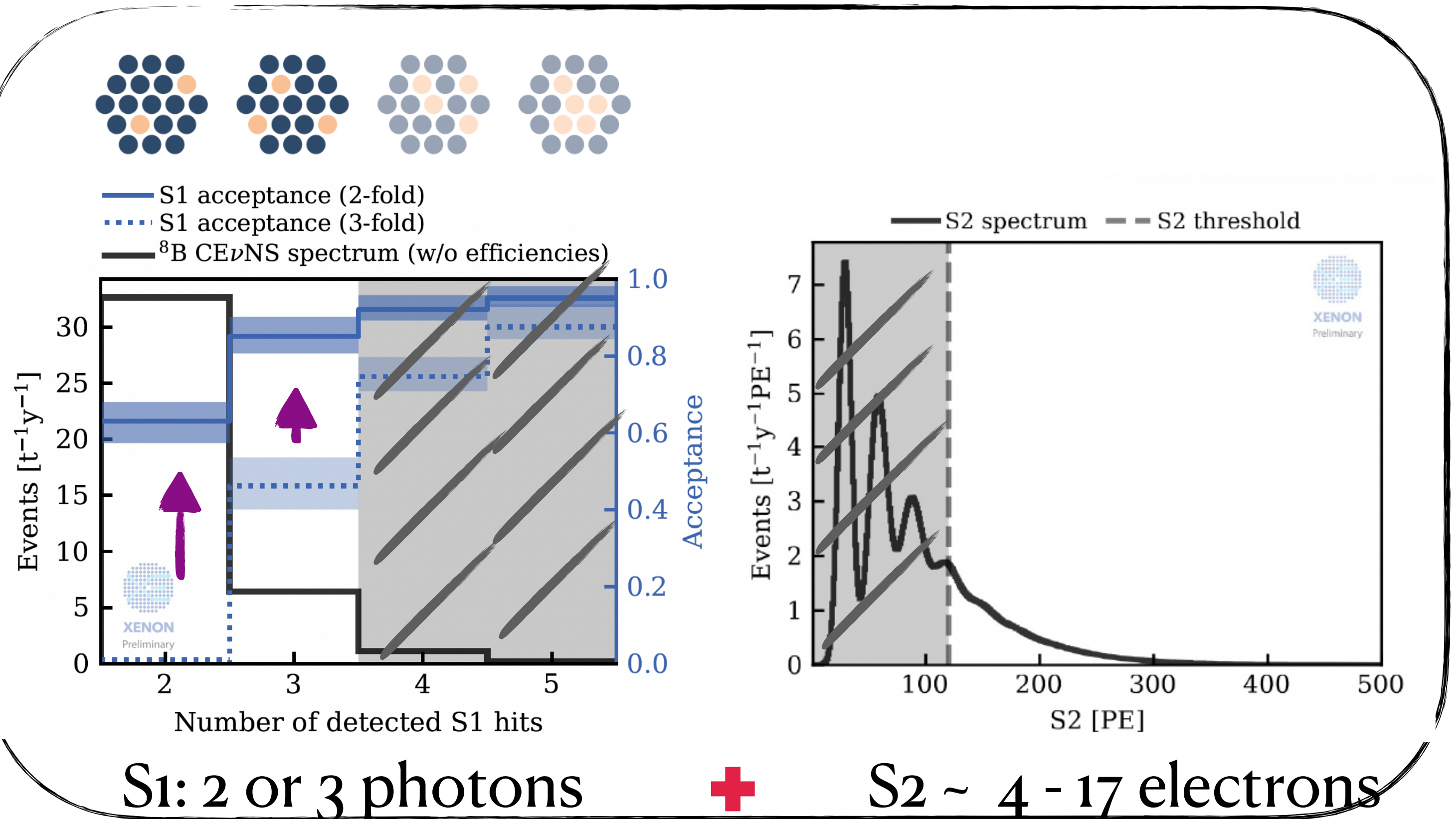
Scattering rate:
600 /ty

Photons,
electrons

S1, S2

Efficiency

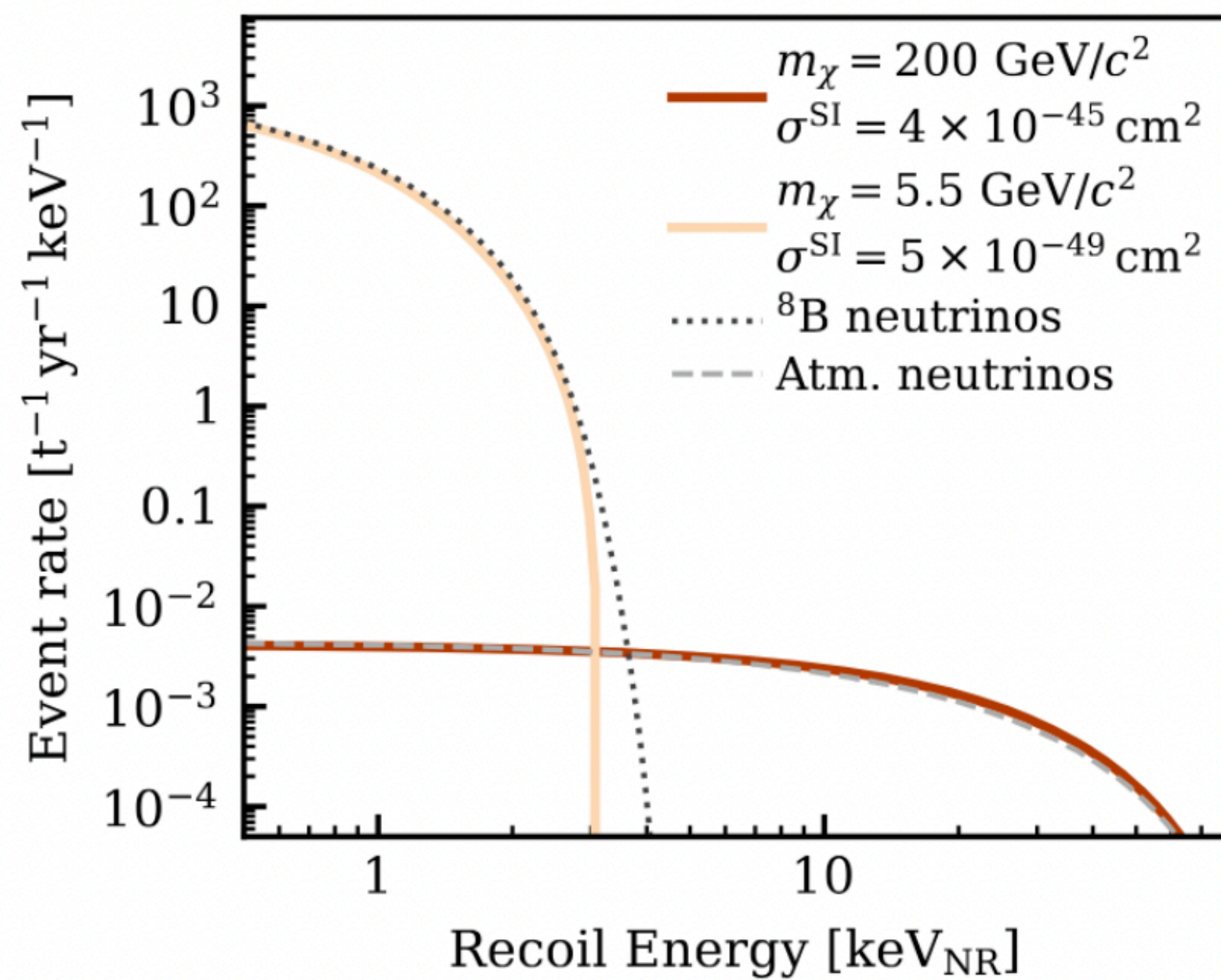
Signal



^8B CE ν NS: sub-keV NR

^8B neutrino spectrum

CE ν NS Cross-section



Scattering rate:
600 /ty

Photons,
electrons

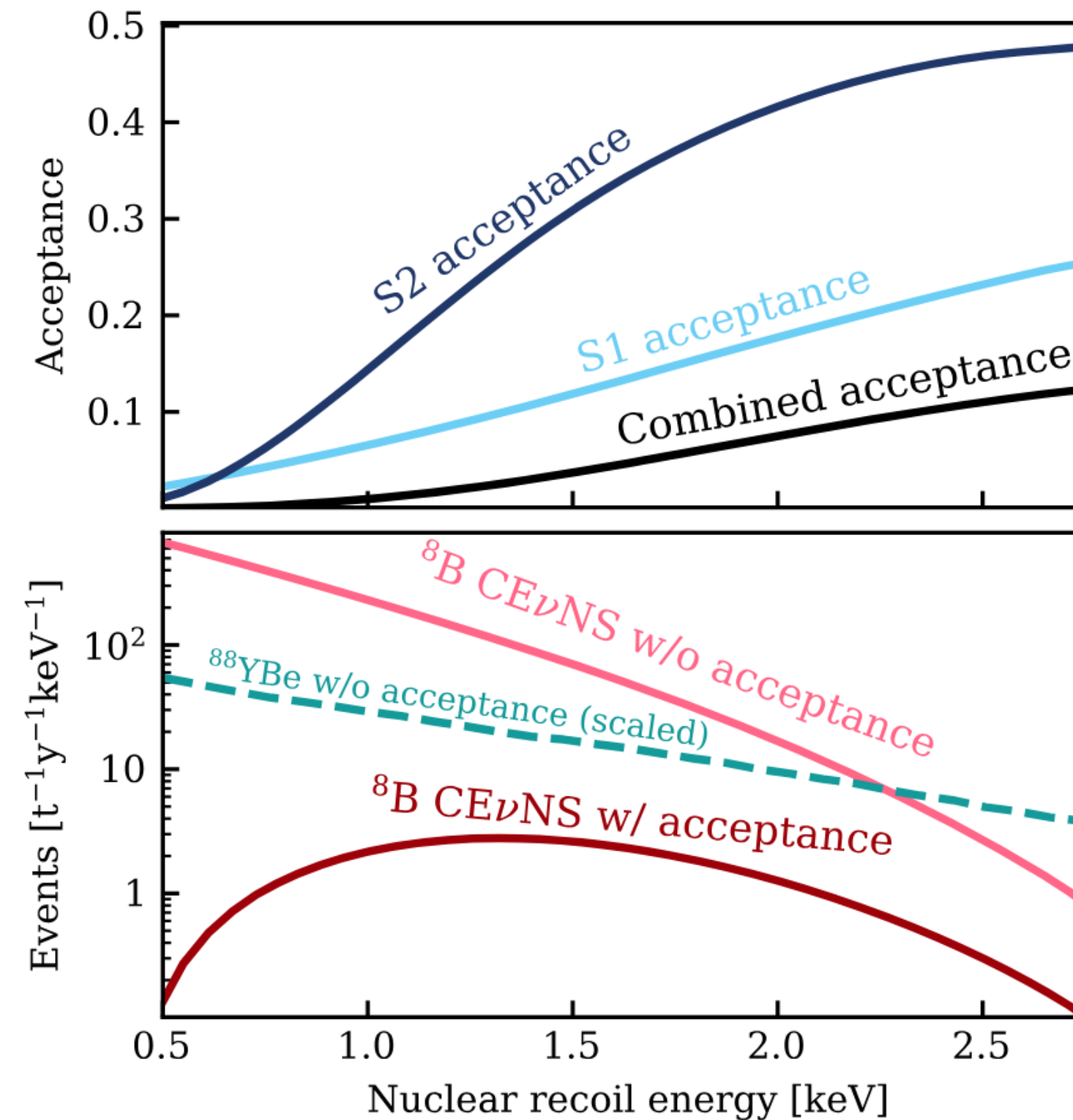
S1, S2

Efficiency

3 /ty

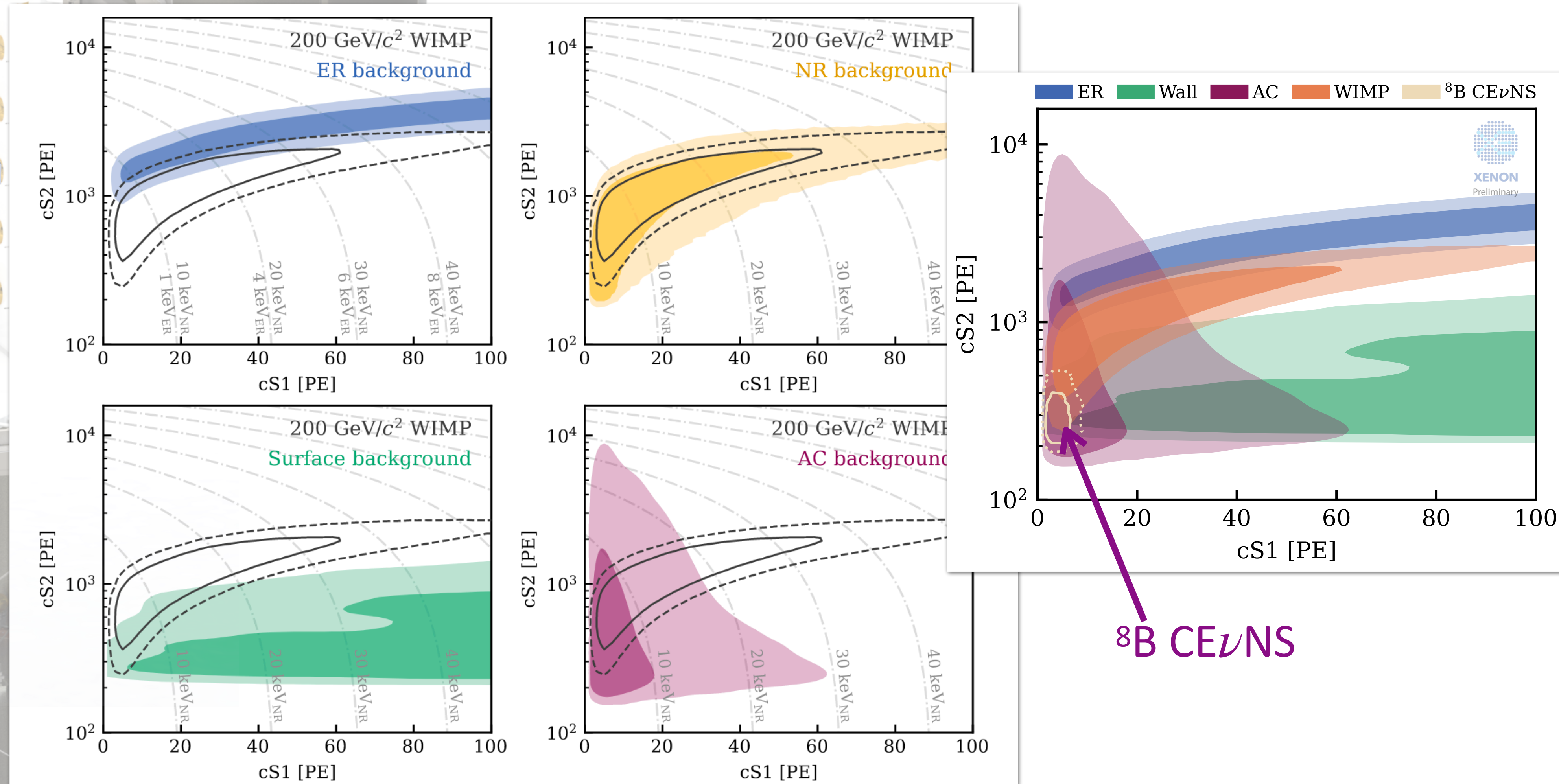
Signal

Expected signal rate:



Background landscape in the dark matter search

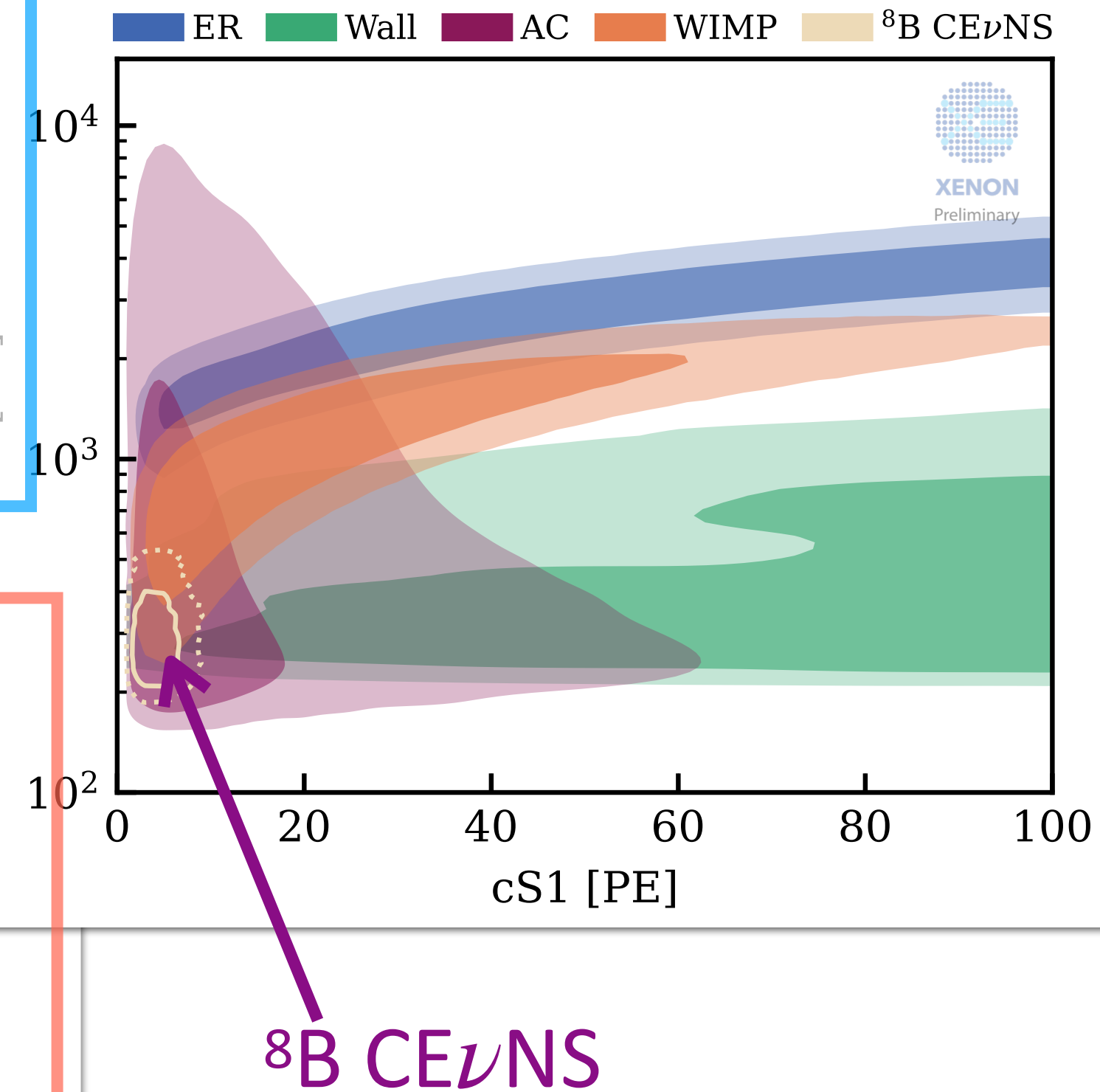
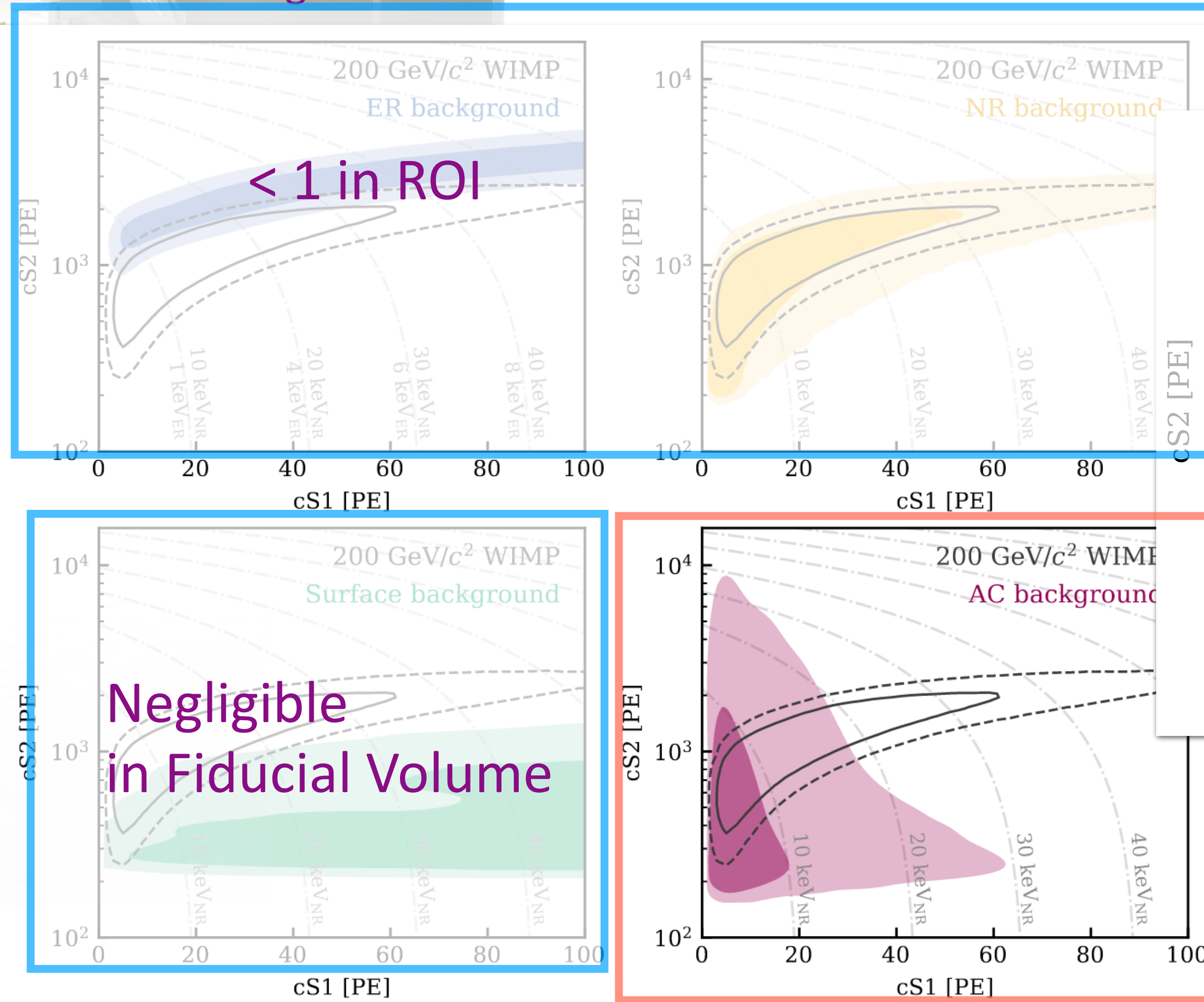
Background models in XENONnT WIMP search



Phys. Rev. D 111, 103040

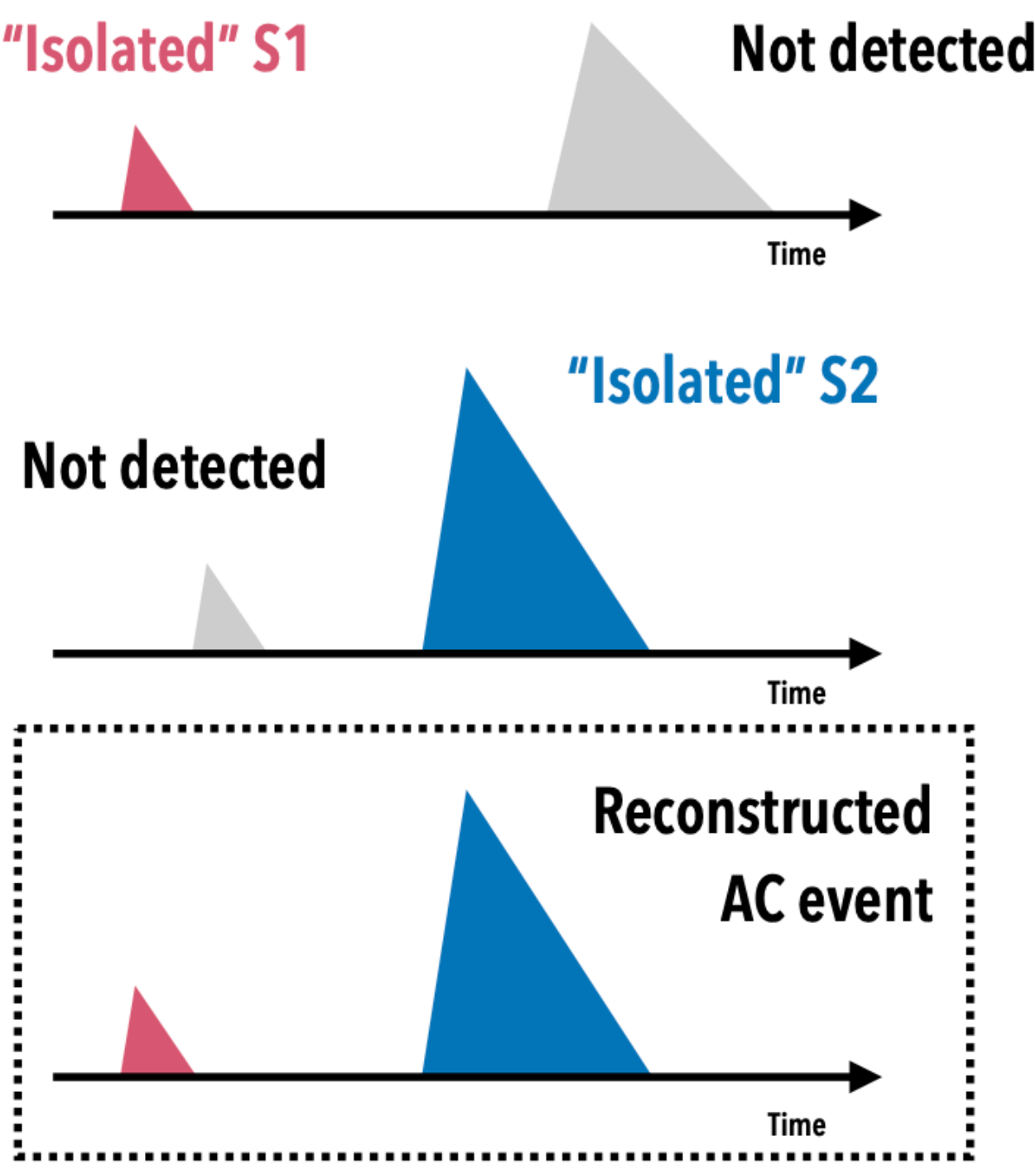
Background landscape in the dark matter search

Background models in XENONnT WIMP search



Phys. Rev. D 111, 103040

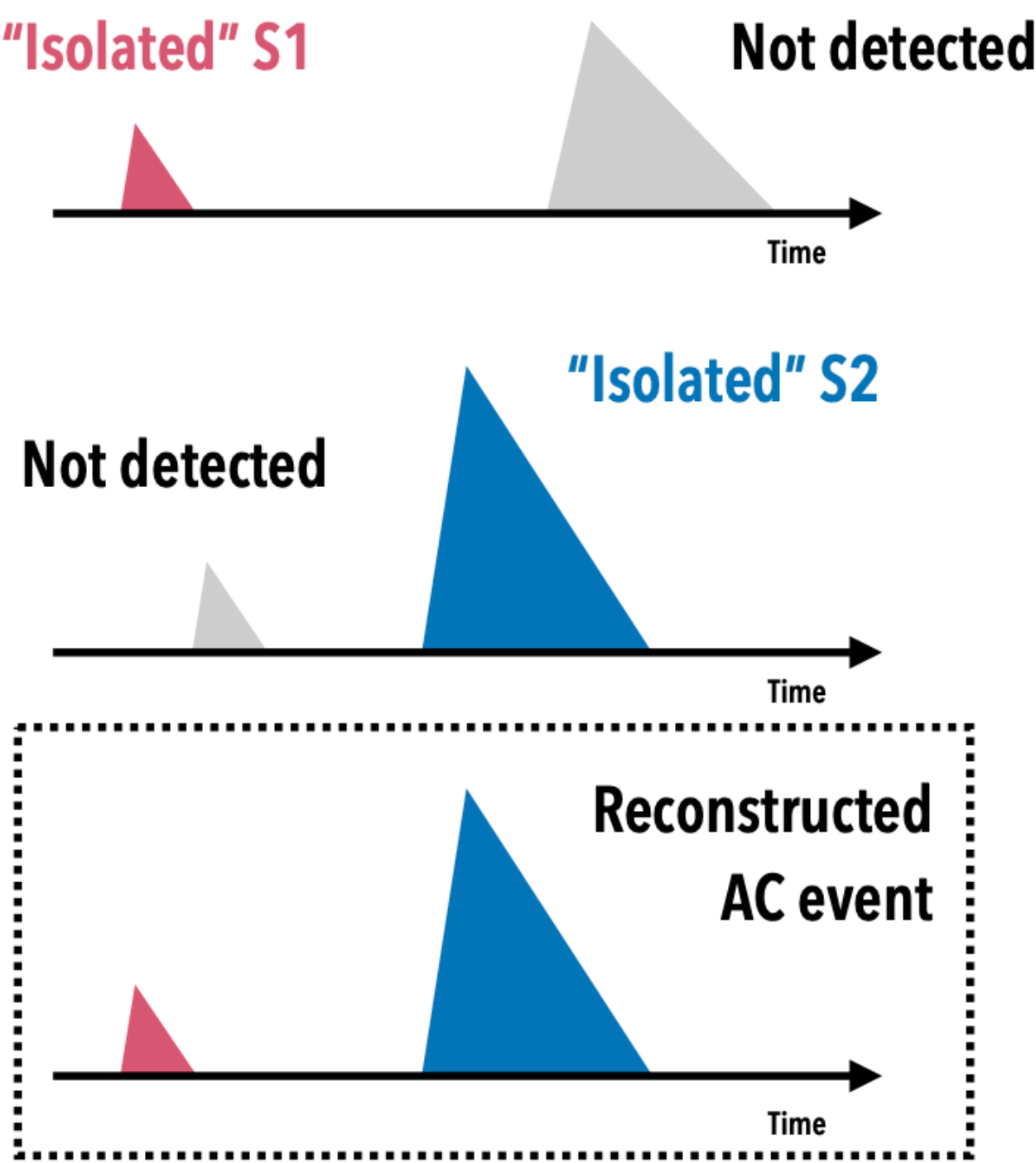
Dominant Background: Accidental Coincidence



$$N_{AC} = \int_{t_0}^{t_1} R_{S1}(t) \cdot R_{S2}(t) \cdot T_{max} dt$$

IsoS1 Rate	IsoS2 Rate	T _{max}	Raw AC Rate
~ 15 Hz	~ 0.15 Hz	2.2 ms	~ 400/day

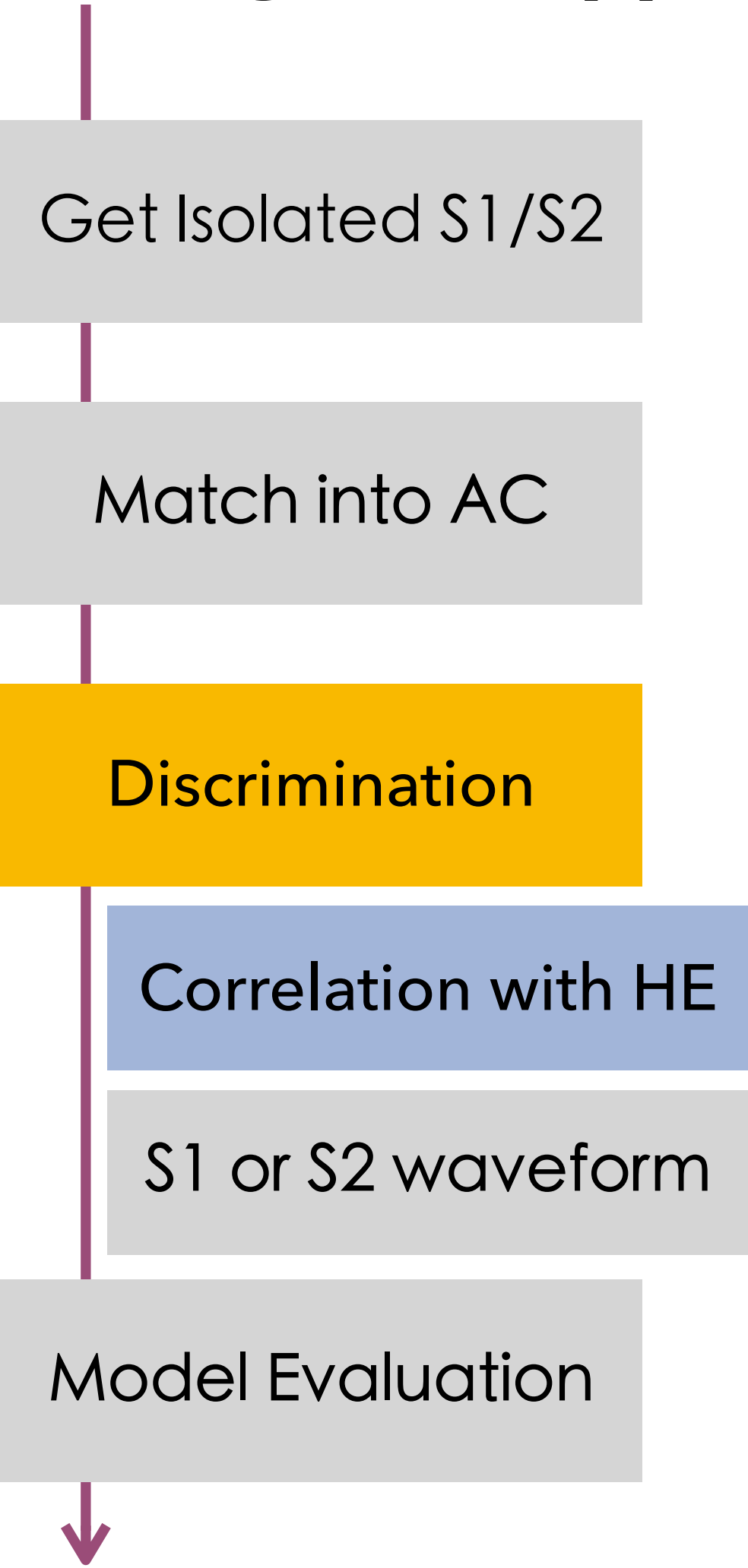
Dominant Background: Accidental Coincidence



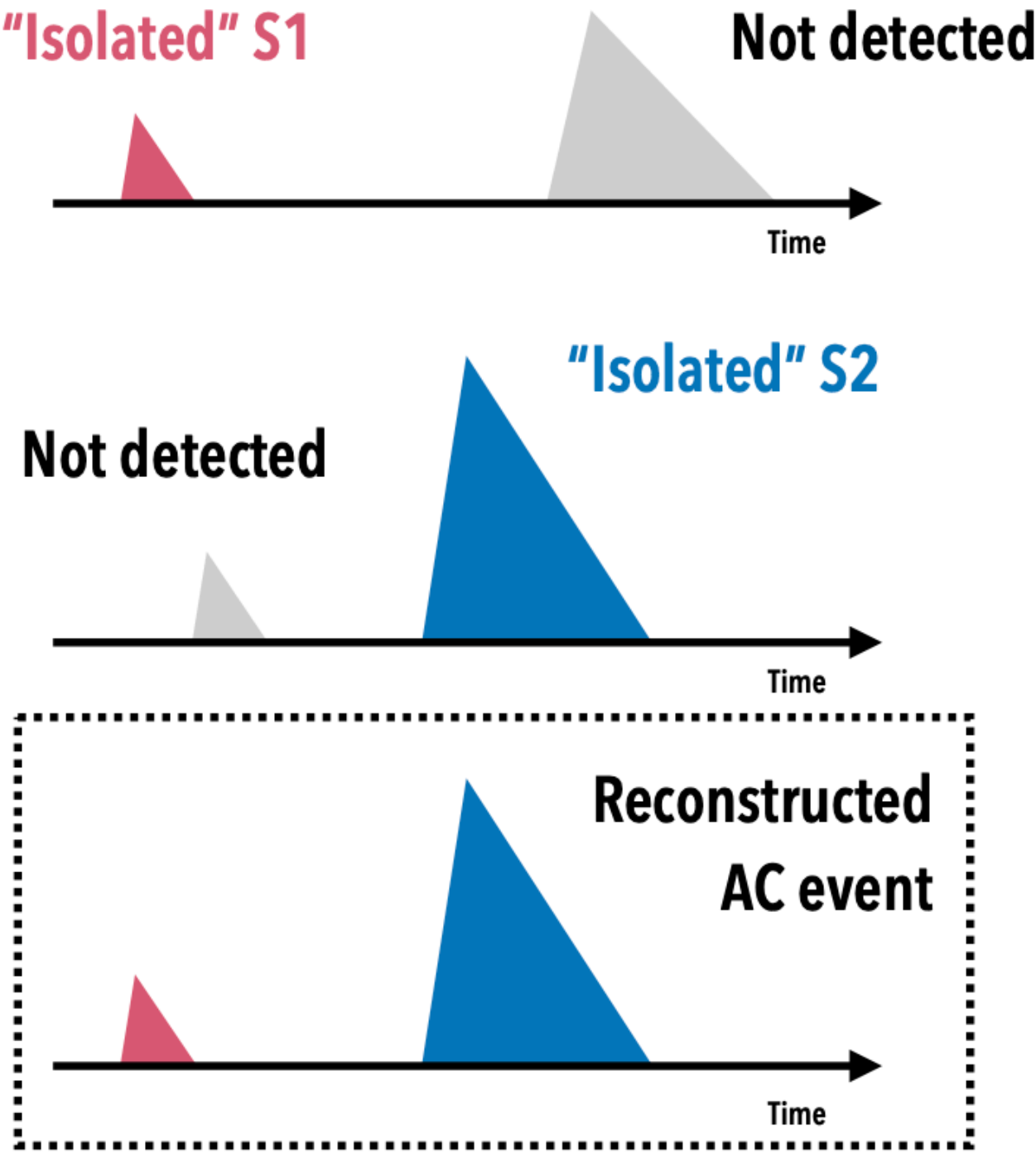
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Modeling and suppression



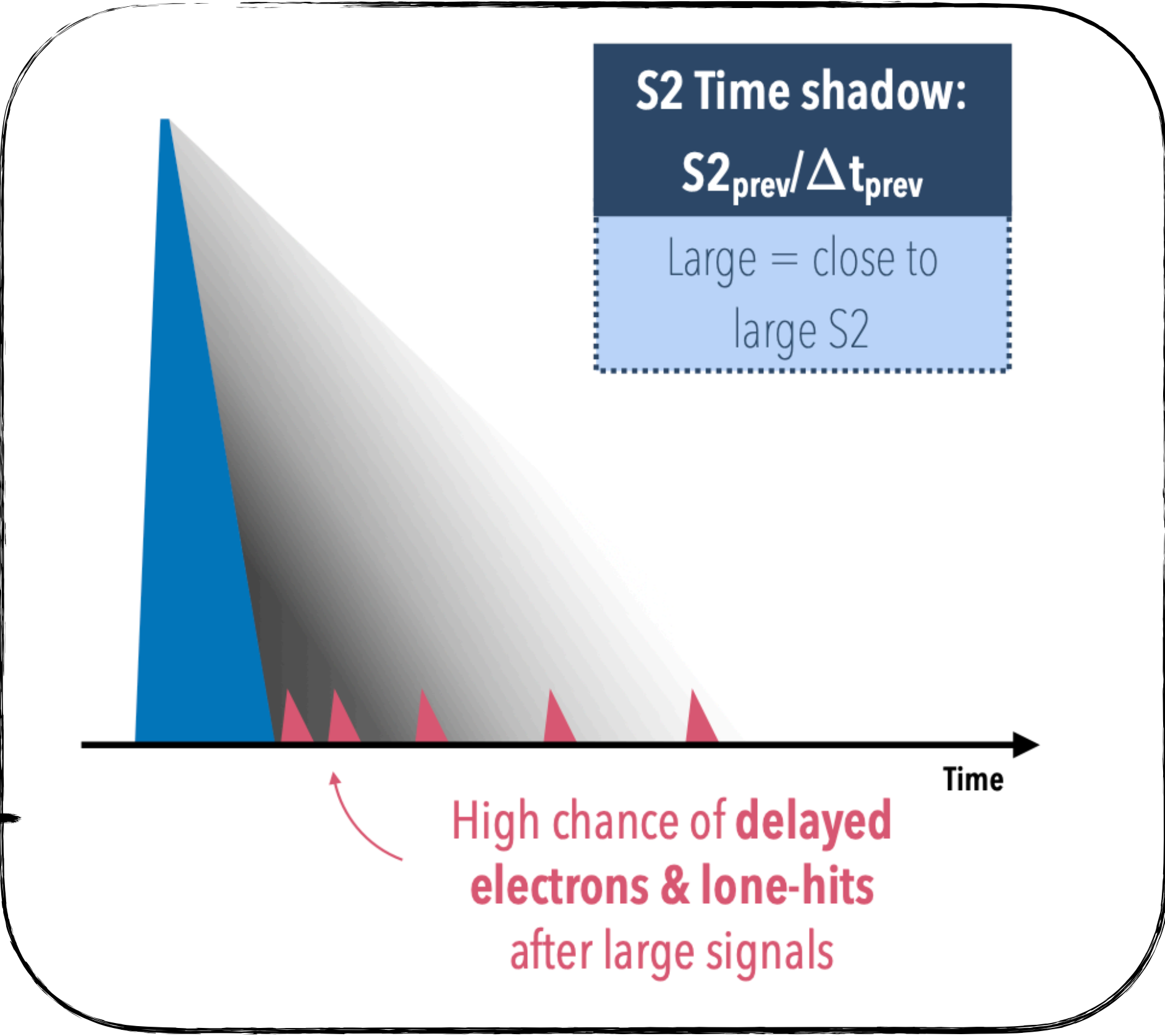
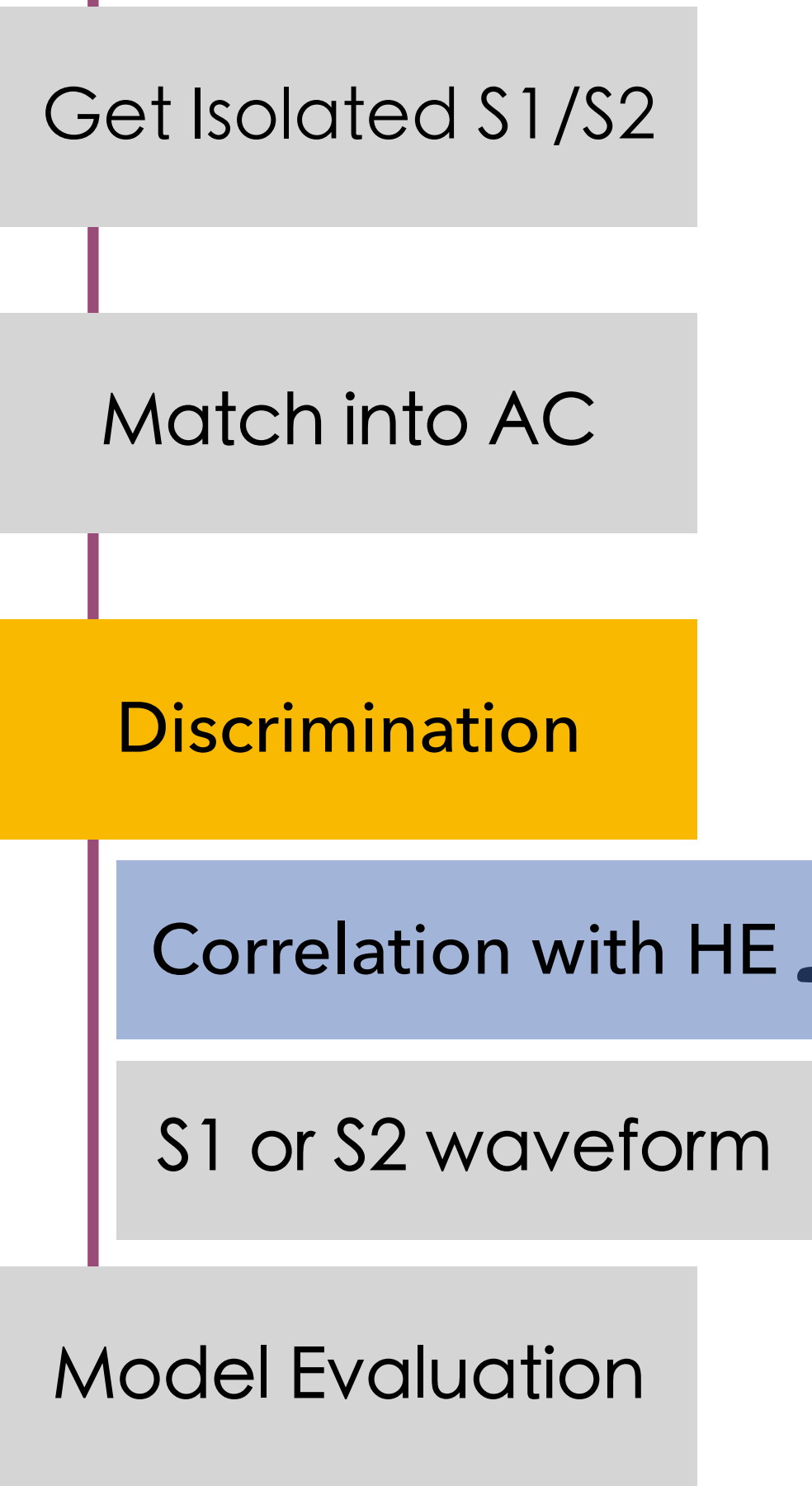
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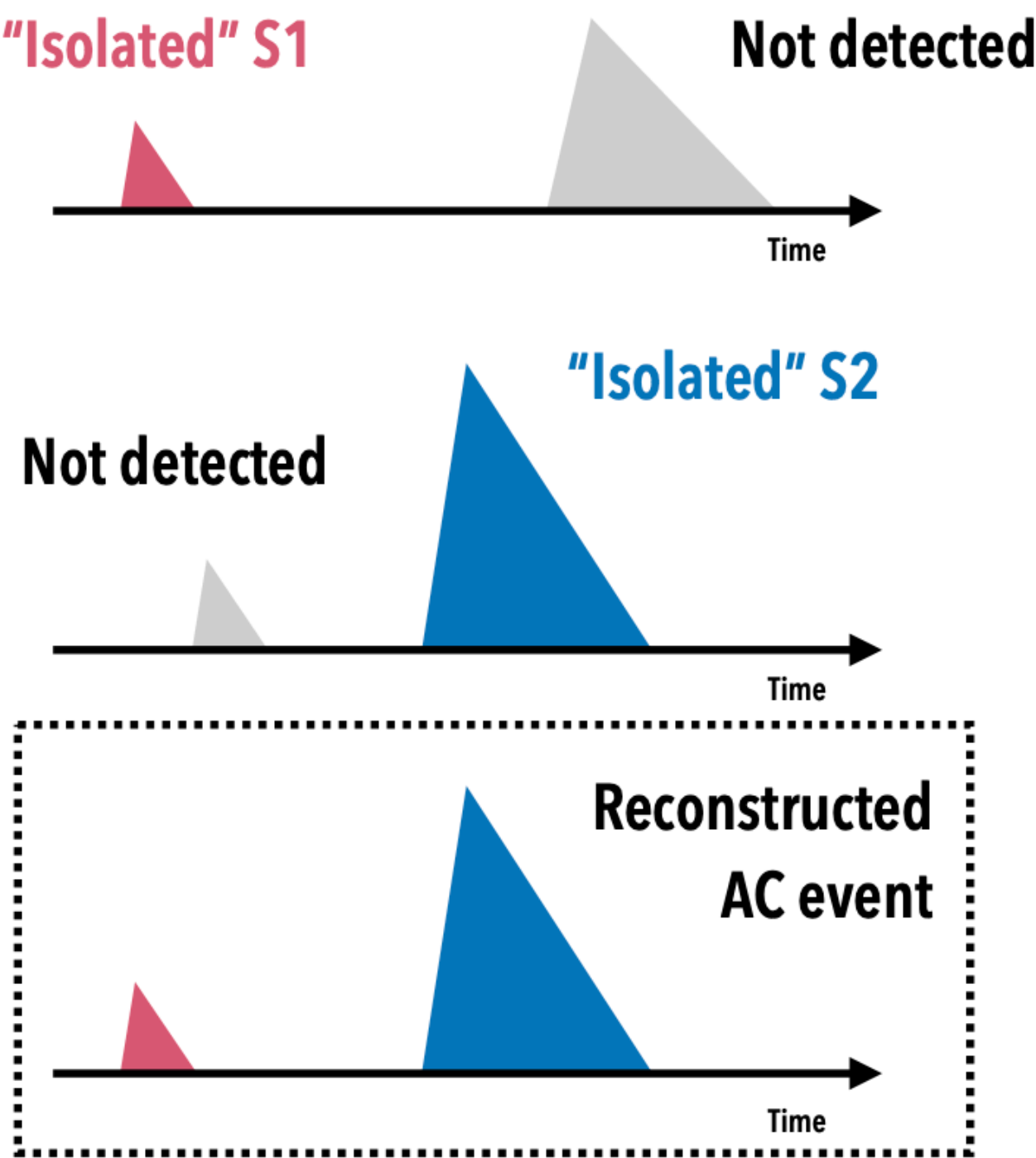
IsoS1 Rate	IsoS2 Rate	T _{max}	Raw AC Rate
~ 15 Hz	~ 0.15 Hz	2.2 ms	~ 400/day

Modeling and suppression



- Using time and position **correlation with high energy peaks**: reduce the AC by **2 order of magnitude** at **80%** signal acceptance

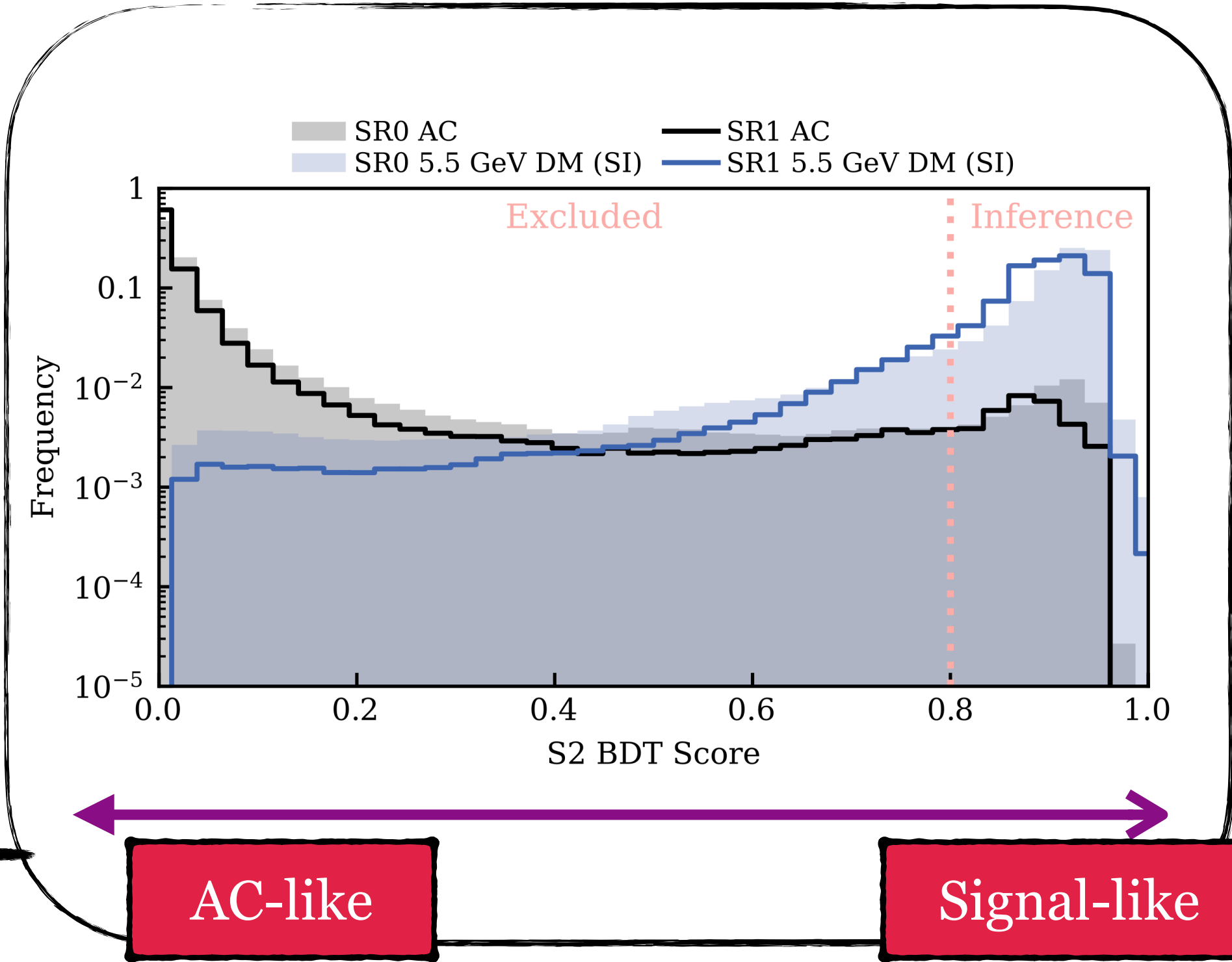
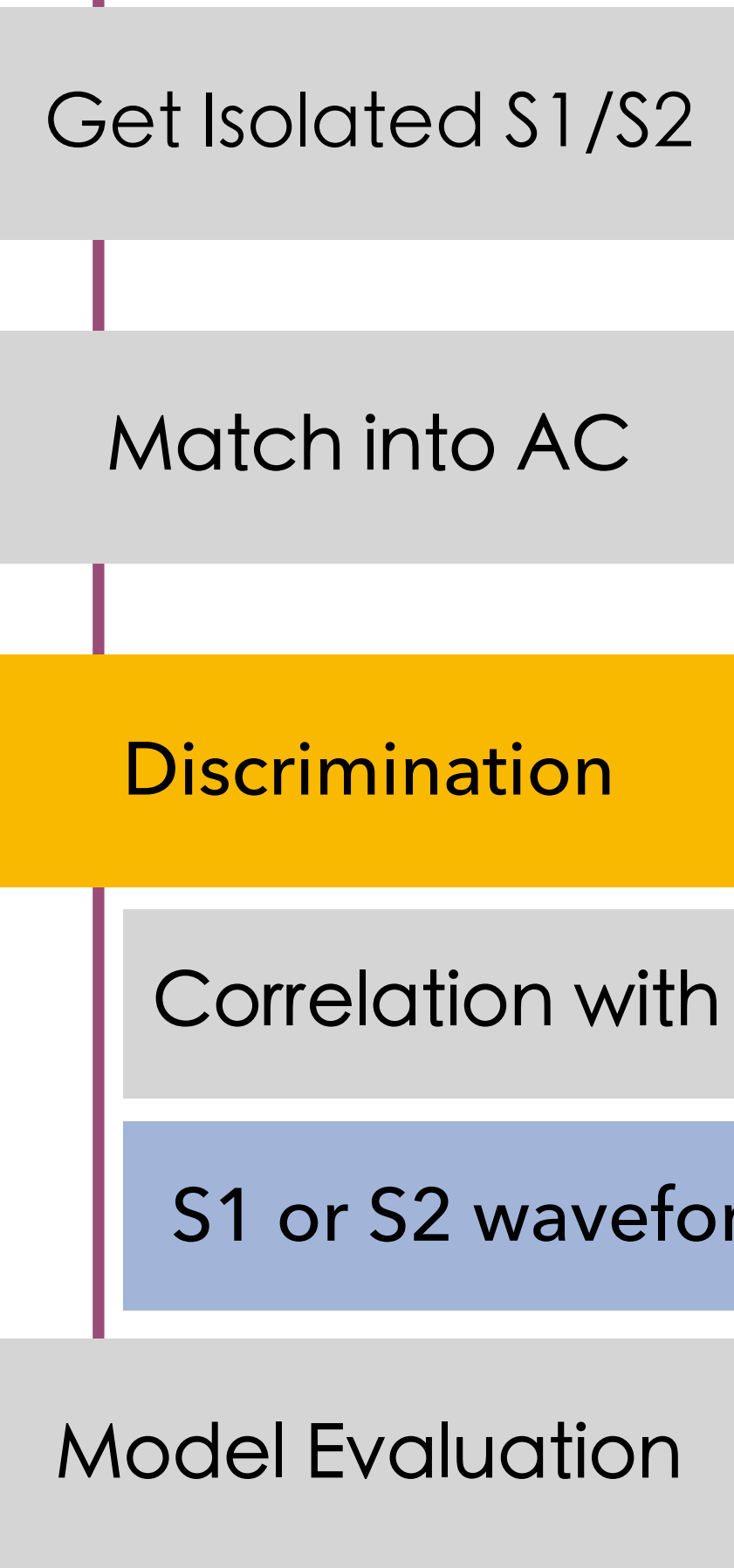
Dominant Background: Accidental Coincidence



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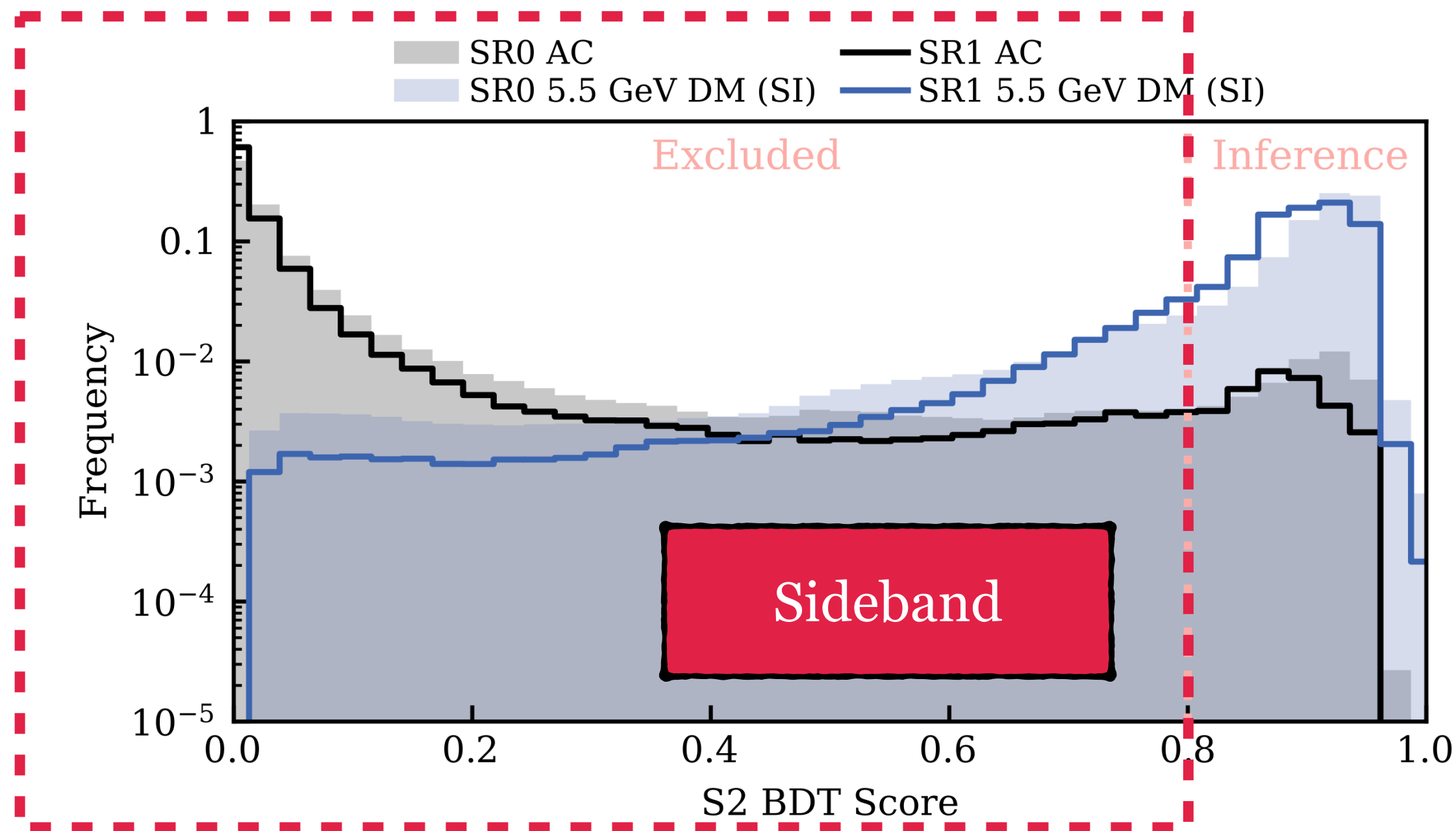
IsoS1 Rate	IsoS2 Rate	T _{max}	Raw AC Rate
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Modeling and suppression

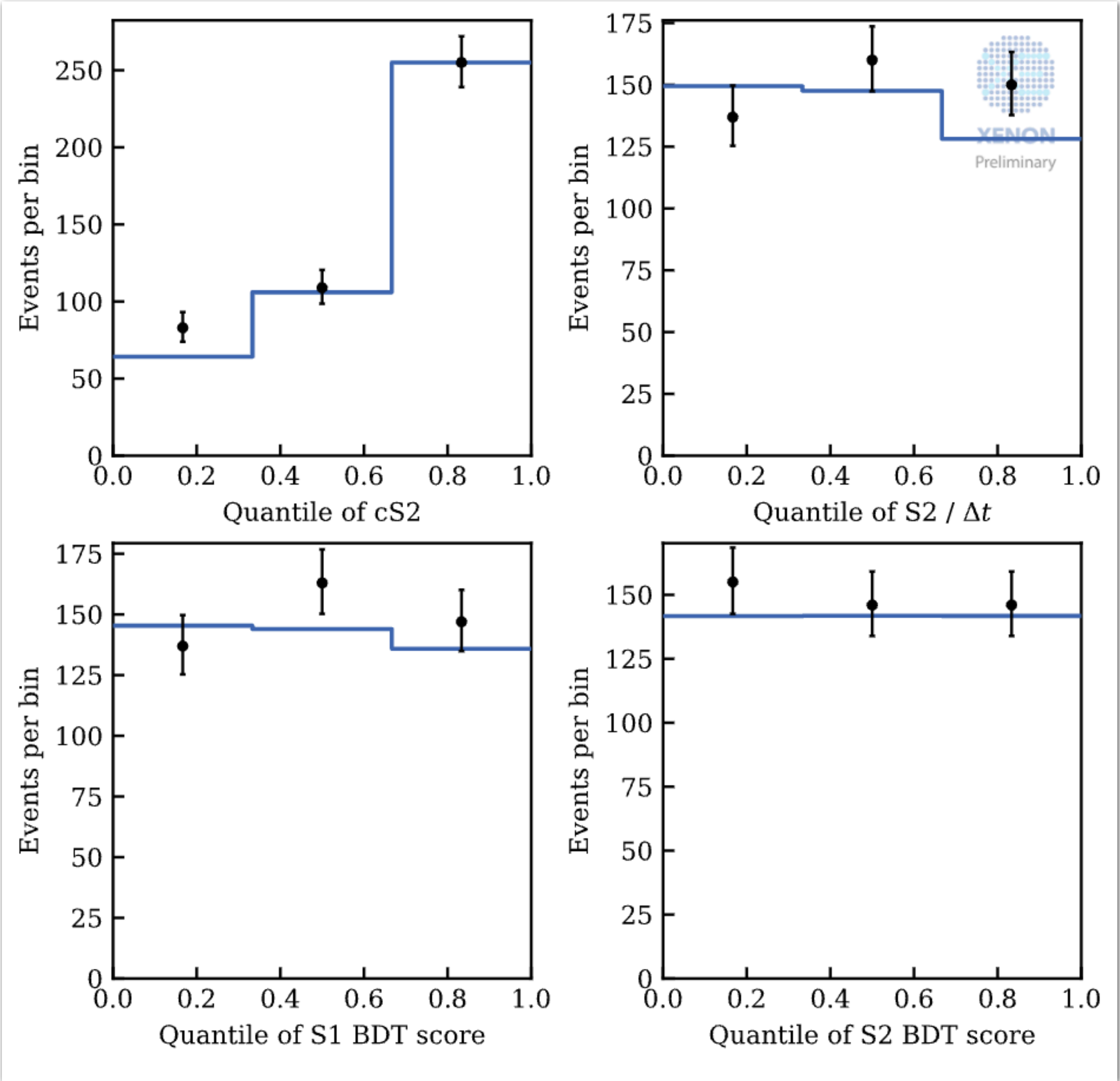


☑ Reduce the AC events by 95% at 80% signal acceptance

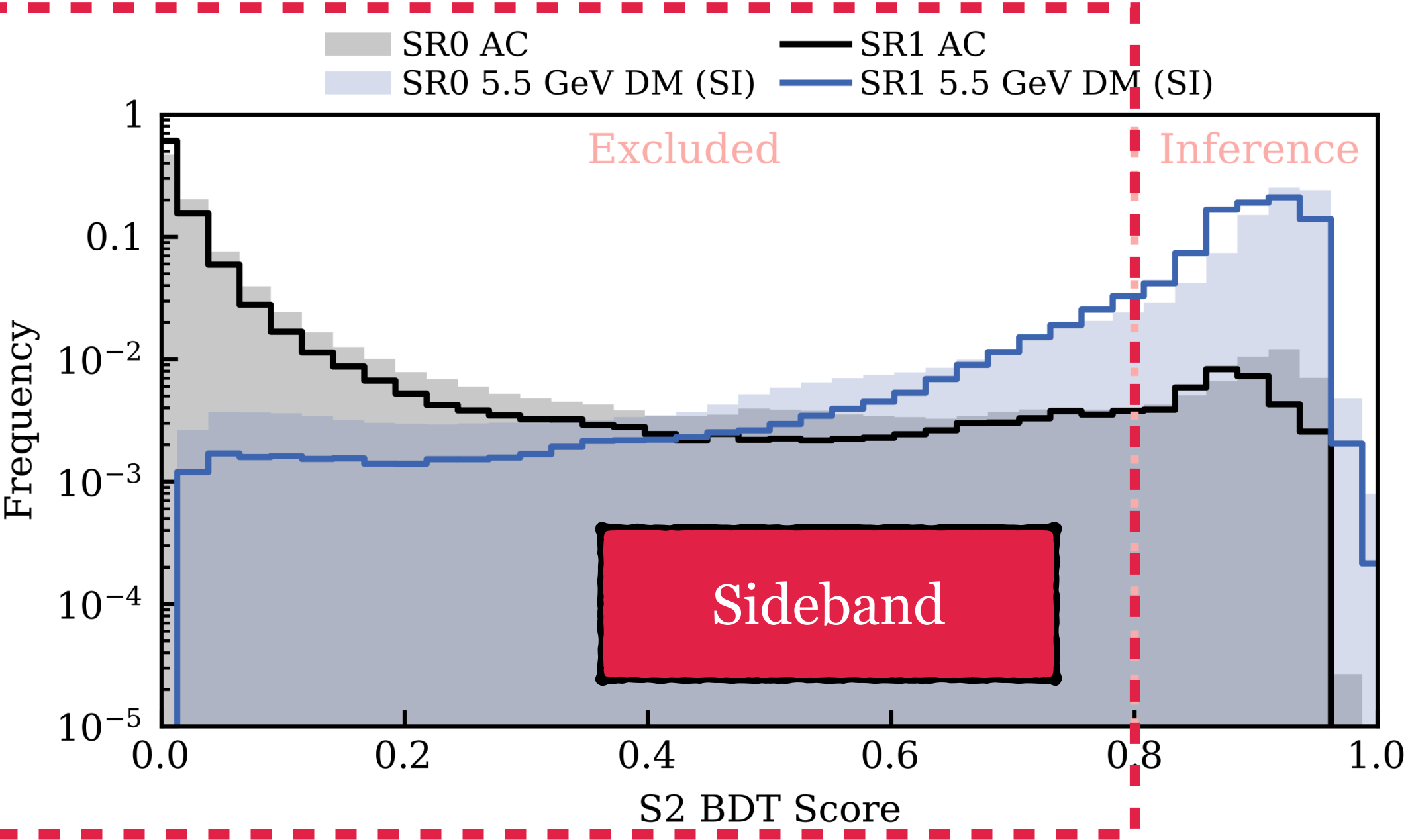
Validation of the AC model



	Prediction	Observation	P-value (4D)	Rel. Uncertainty
SR0	122.7	121	0.33	9.0%
SR1	302.5	326	0.25	5.8%
SR2	417.4	441	0.31	4.9%

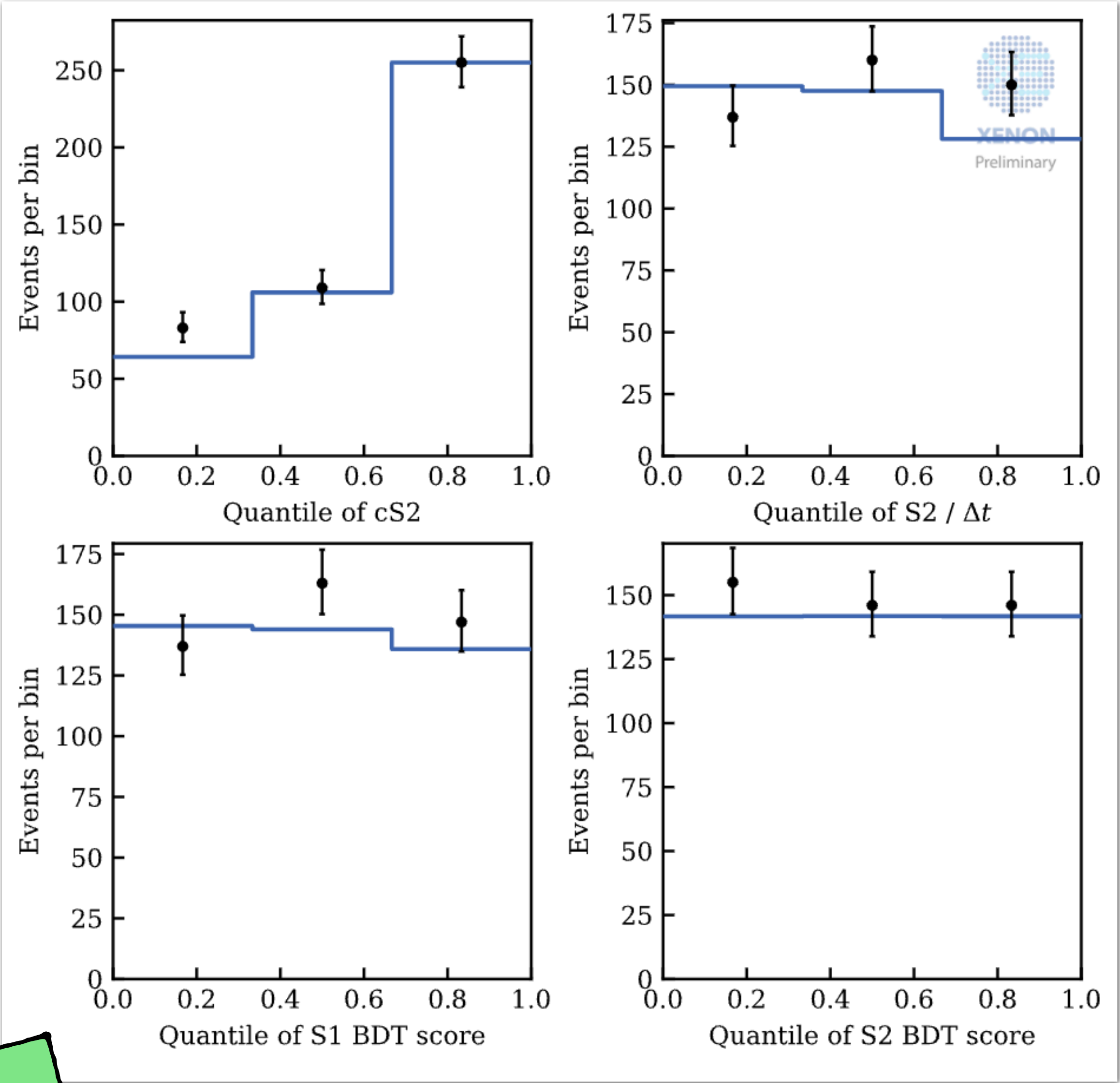


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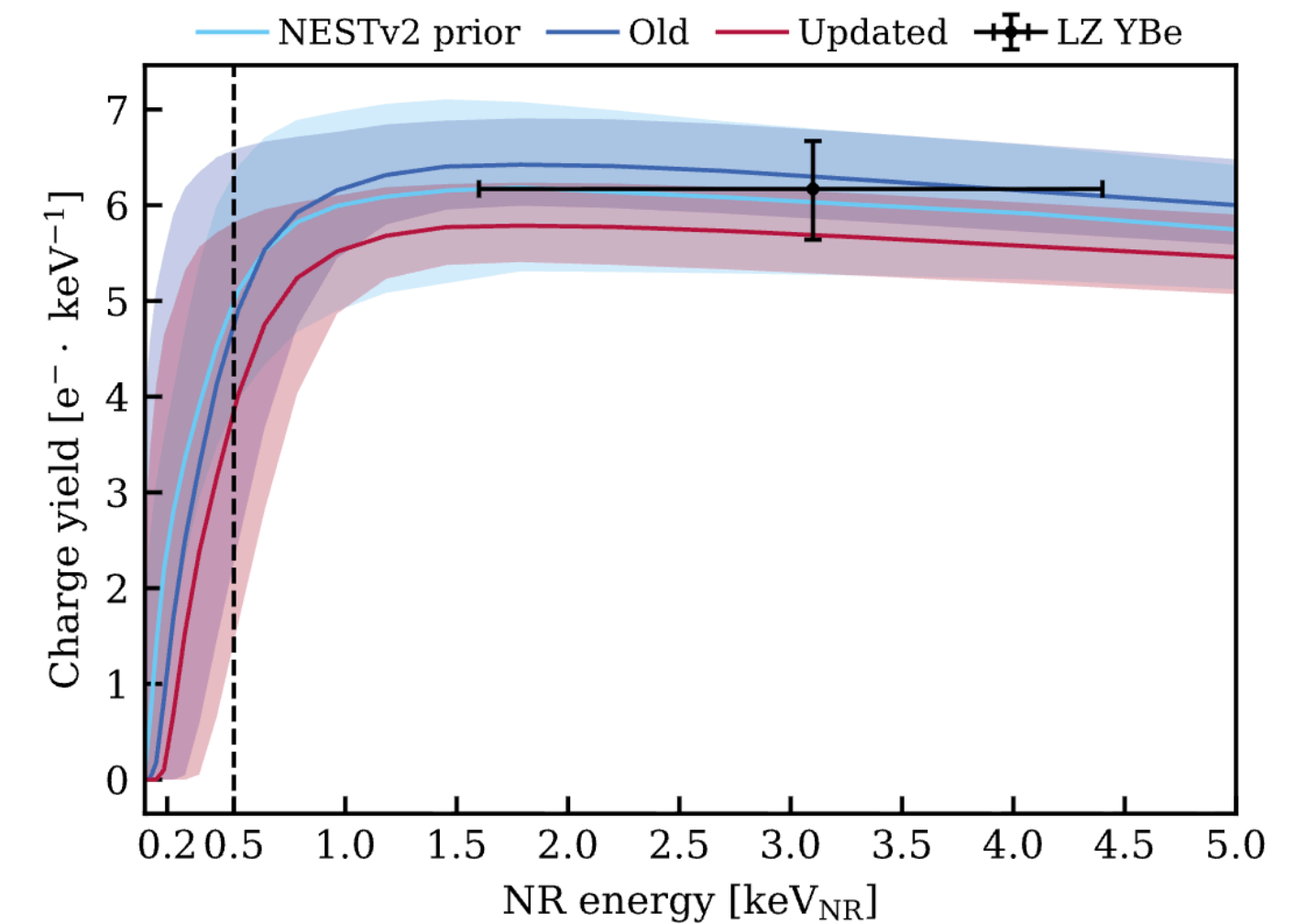
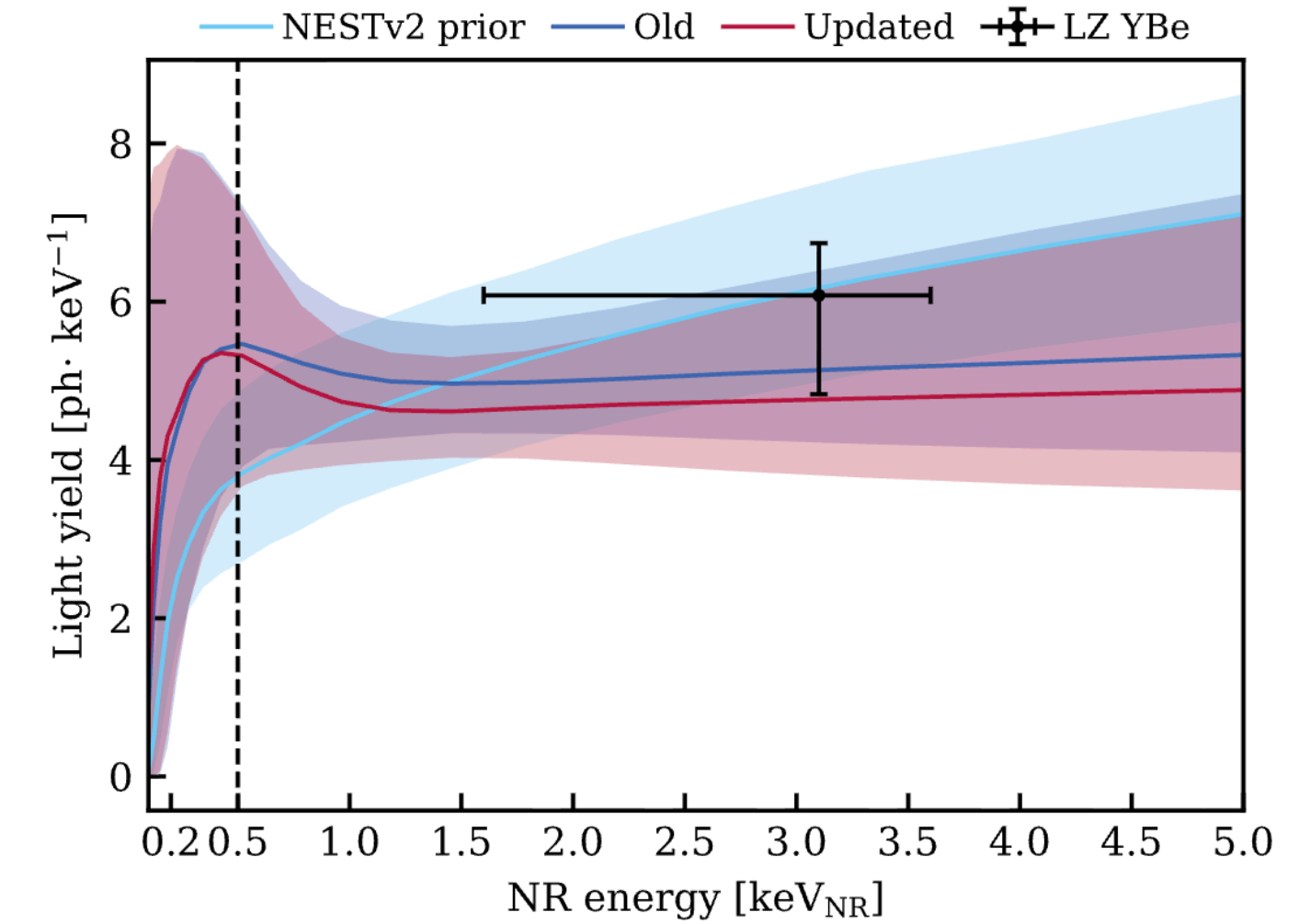
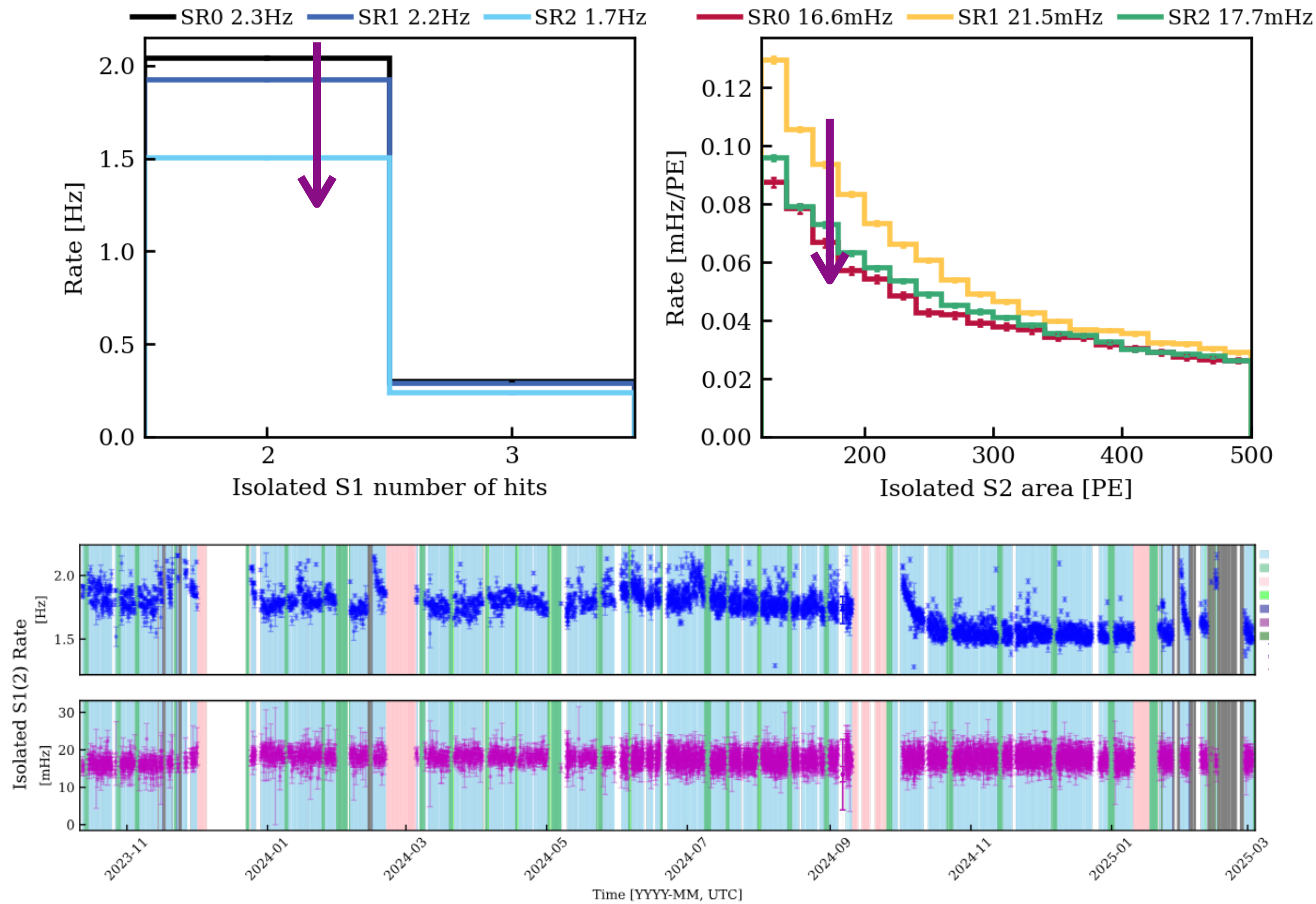
PASS



Enhanced analysis with SR2

Exposure

$$S / \sqrt{N}$$



- Improved event building algorithms:

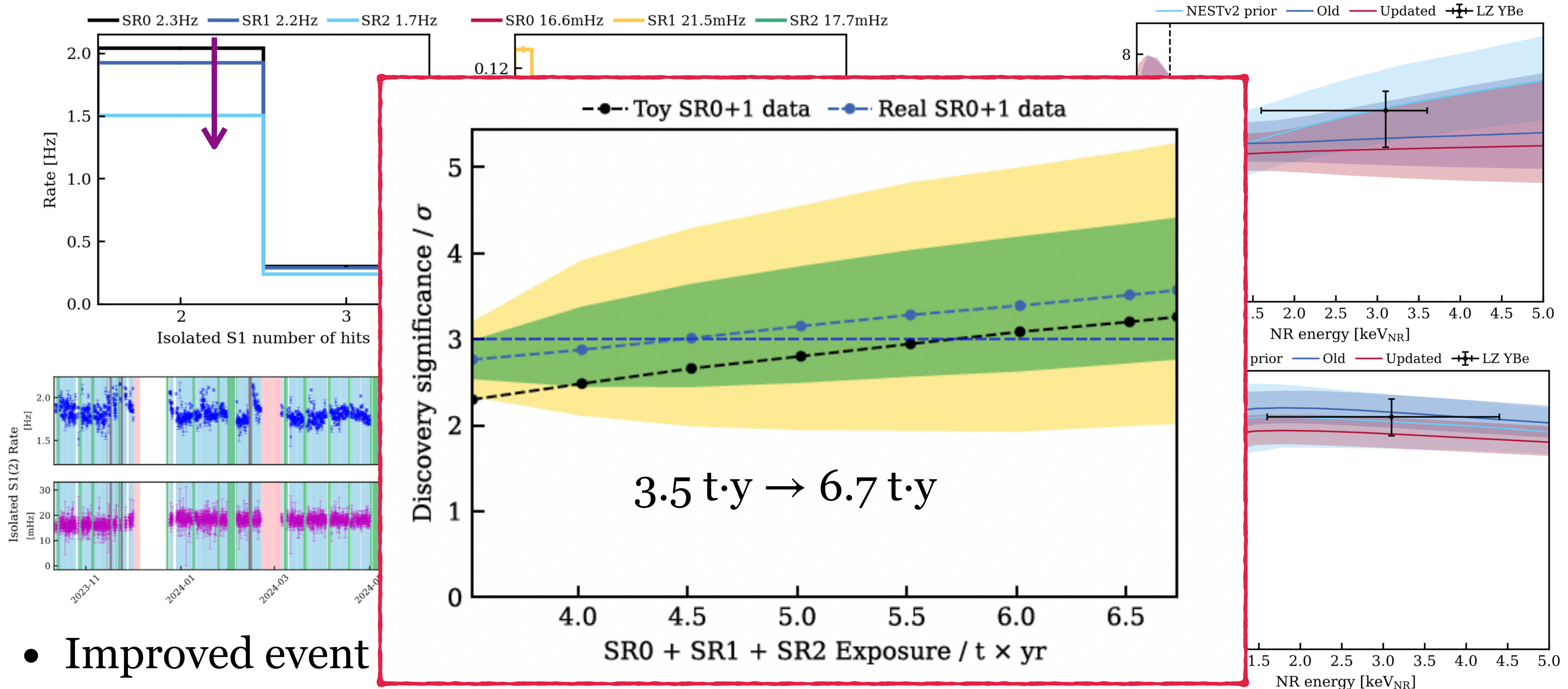
- IsoS2 rate: 10% ↓ Signal efficiency: 5% ↑

- Yields modeling revisited
 - ~ 20% lower yields

Enhanced analysis with SR2

Exposure

$$S / \sqrt{N}$$



- Improved event

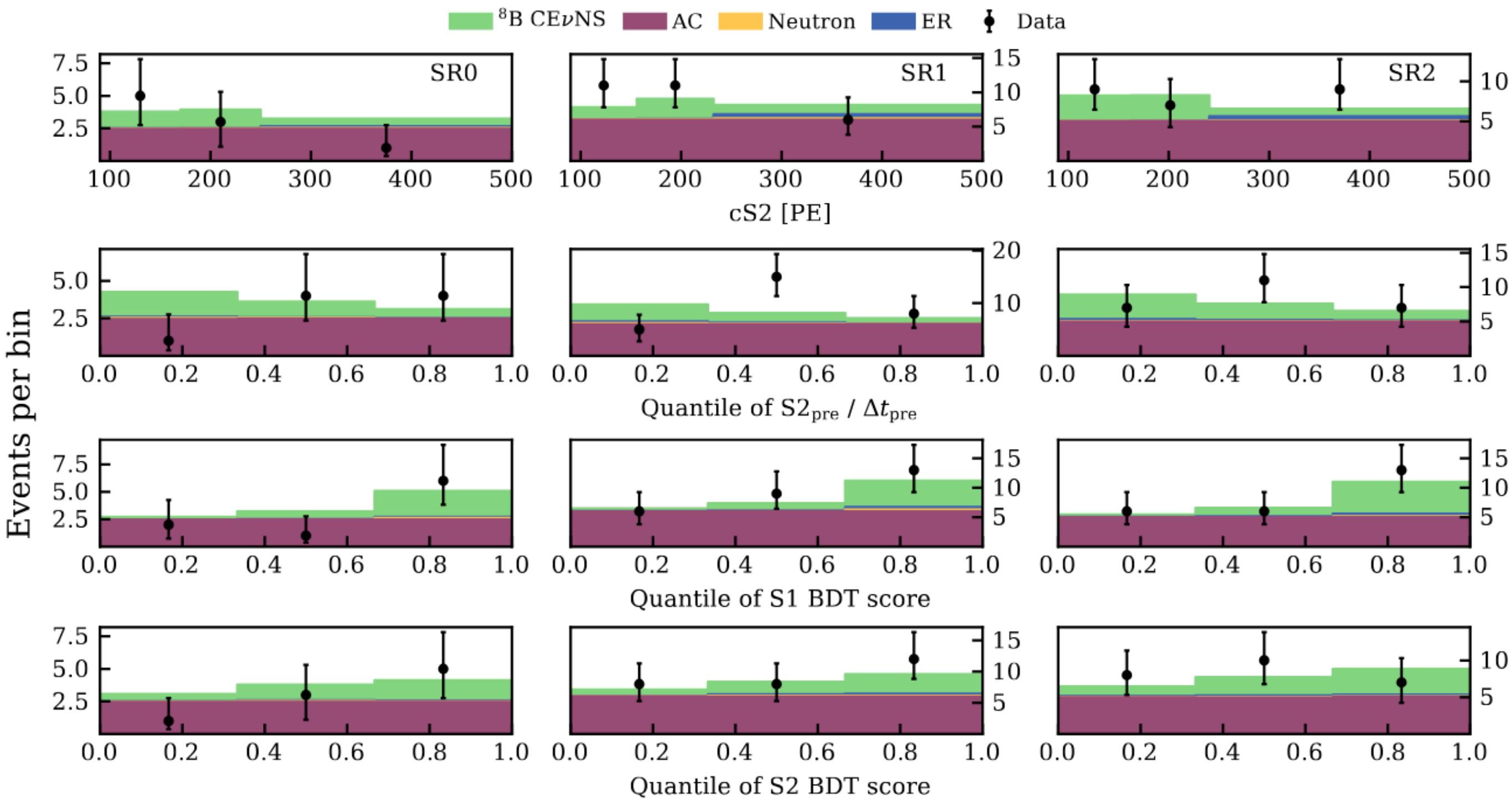
- IsoS2 rate: 10% $\downarrow$ Signal efficiency: 5% $\uparrow$

- Yields modeling revisited

- $\sim 20\%$ lower yields

⁸B CEvNS search unblinding results

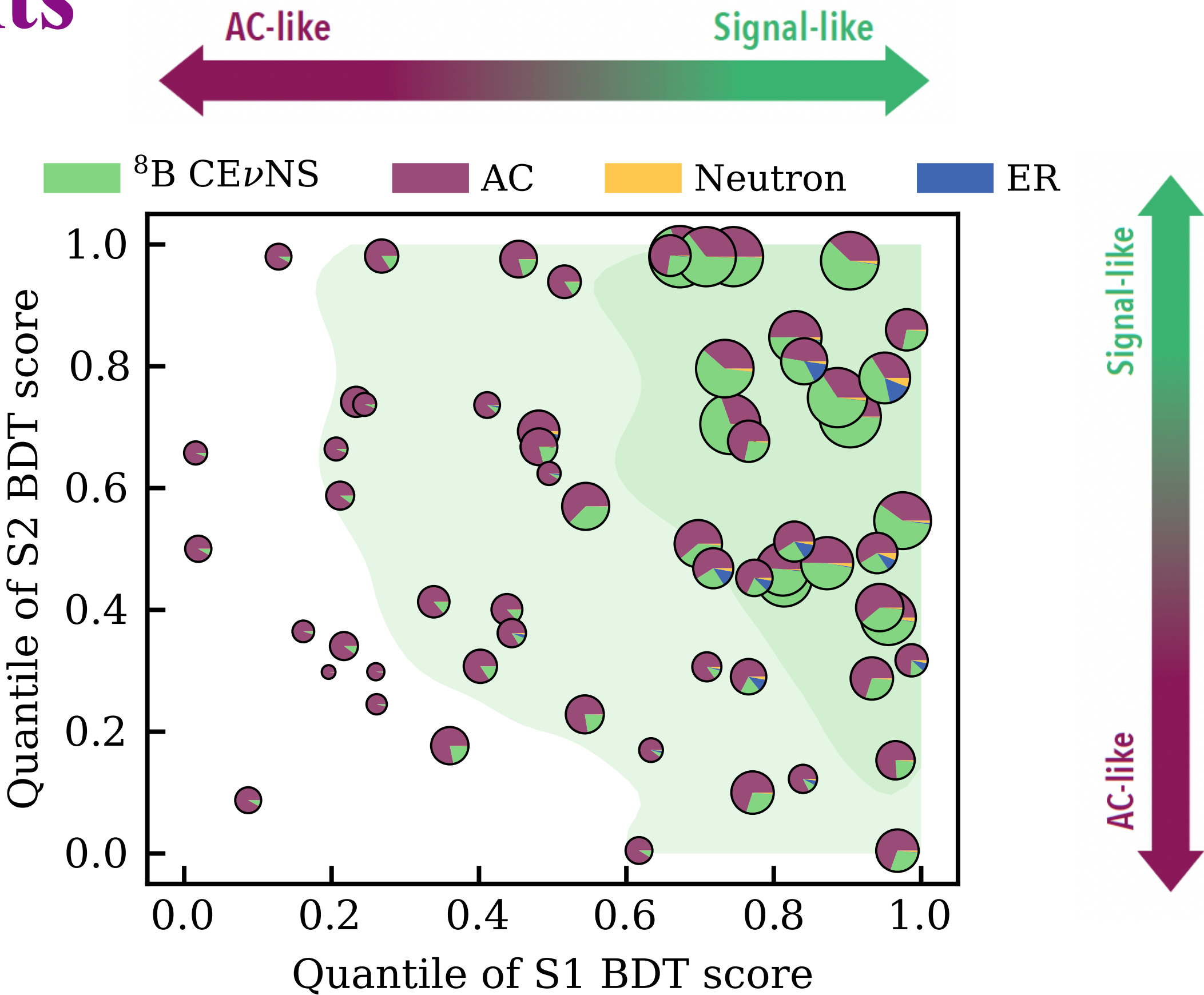
Component	Expectation	Best Fit
AC (SR0)	7.5 ± 0.7	7.4 ± 0.7
AC (SR1)	17.8 ± 1.0	17.9 ± 1.0
AC (SR2)	14.9 ± 0.7	14.9 ± 0.7
ER	1.2 ± 1.2	1.4 ± 1.2
Neutron	$0.8 (-0.5)(+0.4)$	$0.8 (-0.4)(+0.4)$
Total Background	42.1 (-1.7)(+1.9)	42.4 (-1.9)(+1.9)
⁸ B(SR0)	3.2 (-0.9)(+1.0)	3.3 (-1.0)(+1.0)
⁸ B(SR1)	6.0 (-1.6)(+1.9)	6.1 (-1.9)(+1.8)
⁸ B(SR2)	7.2 (-1.9)(+2.3)	7.3 (-2.3)(+2.1)
Total ⁸ B	16.3 (-4.4)(+5.1)	16.7 (-5.3)(+4.8)
Observed	9 (SR0) + 28 (SR1) + 25 (SR2)	



- ✓ **25** new events observed
- ✓ GoF test passed
- ✓ Discovery significance: **3.3 σ**
- ✓ Best fit ⁸B CEvNS: **17 ± 5**

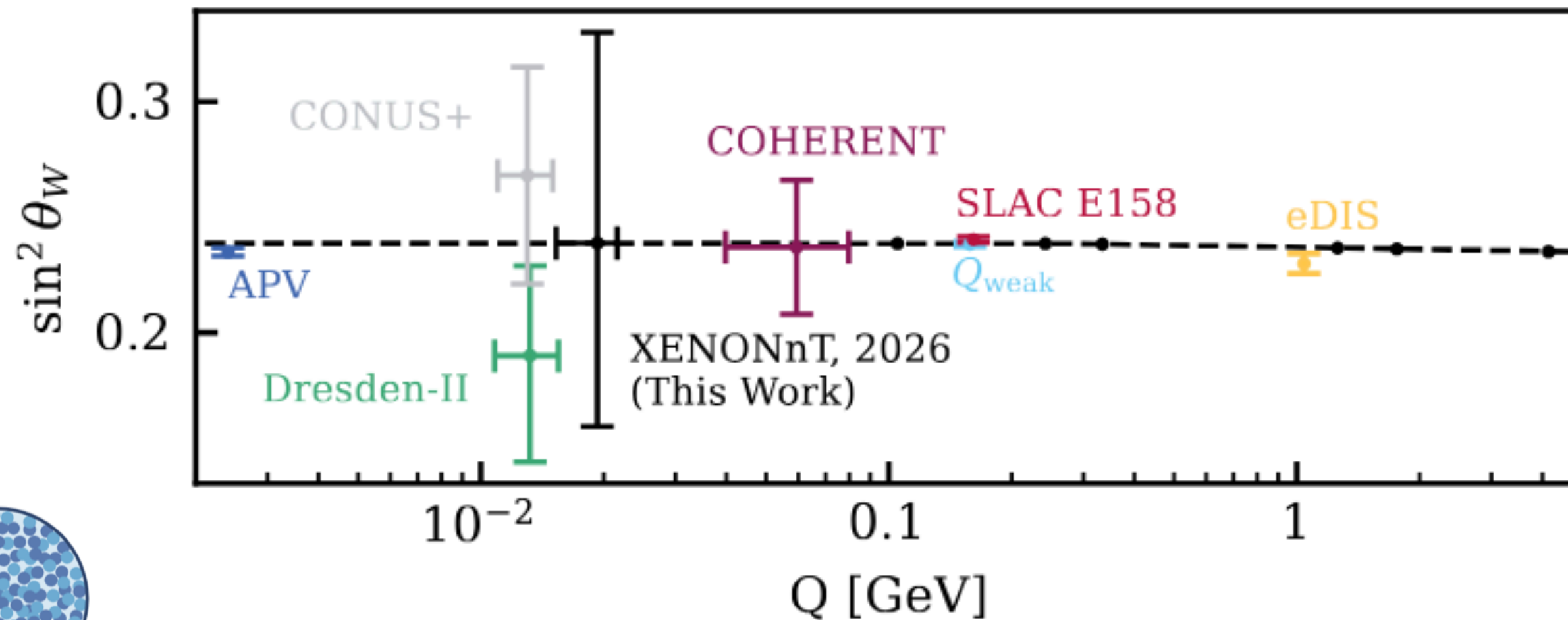
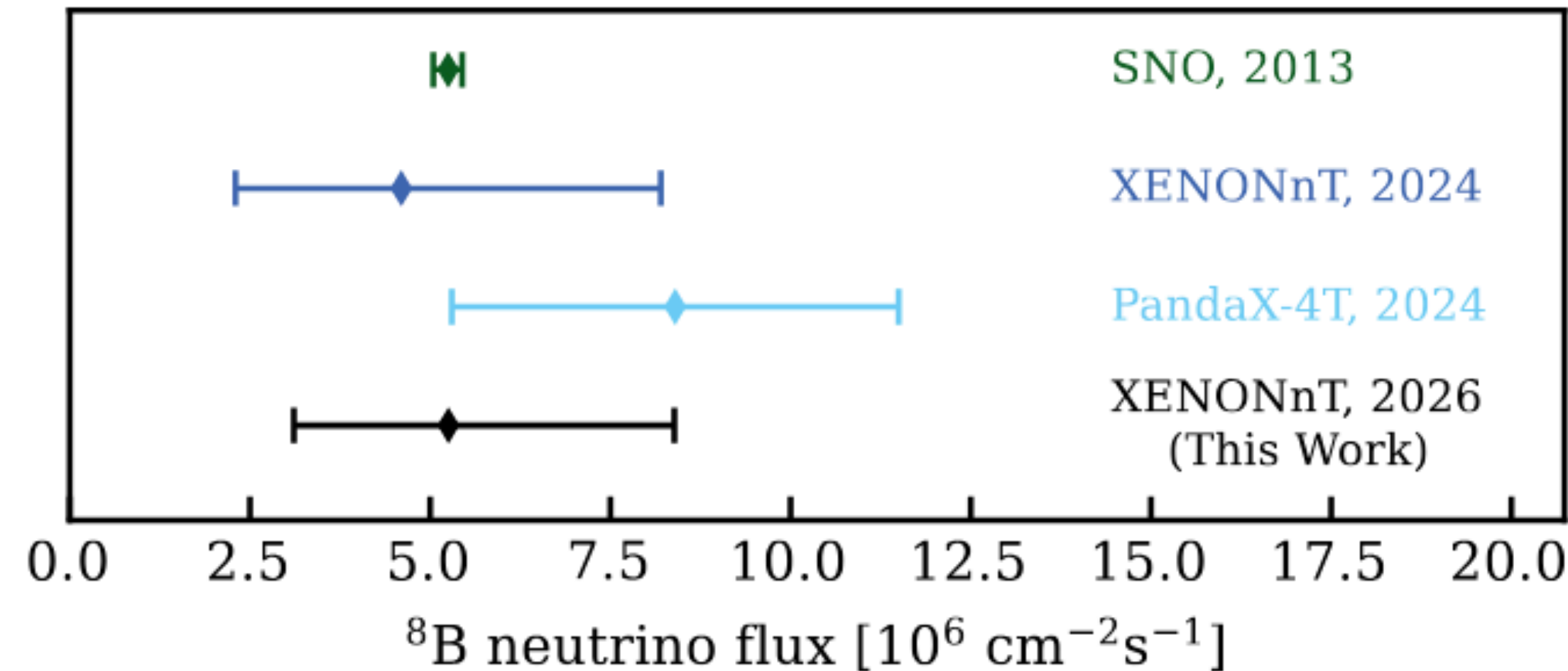
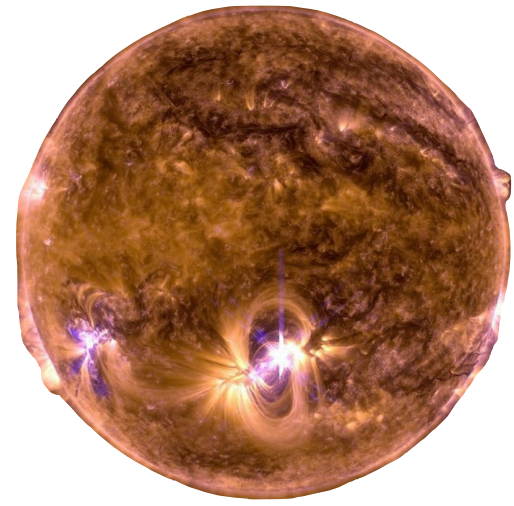
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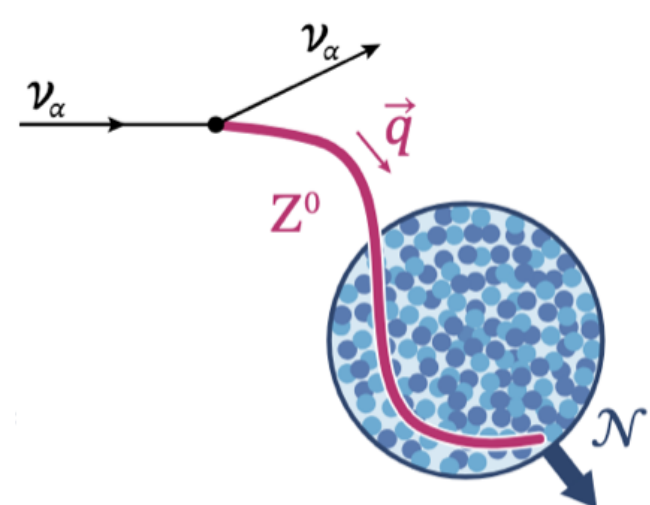


- ☑ **25** new events observed
- ☑ GoF test passed
- ☑ Discovery significance: **3.3 σ**
- ☑ Best fit ⁸B CEνNS: **17 $\pm$ 5**

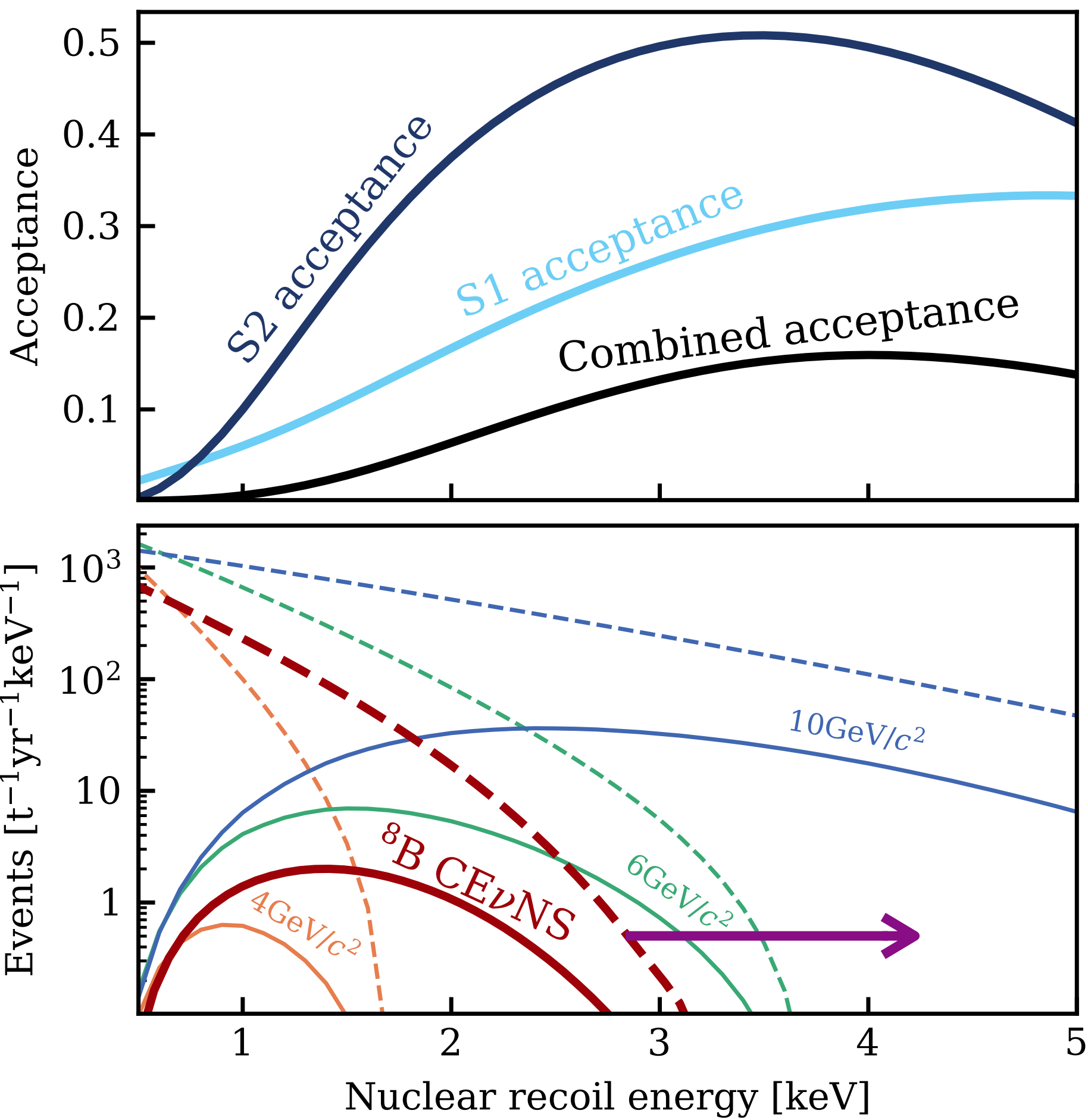
Probe the solar neutrino fog and BSM neutrino physics



- ☑ ^8B rate $(5^{+3}_{-2}) \times 10^6 \text{ cm}^{-2} \text{ s}^{-1}$, consistent with SNO result.
- ☑ Converted the rate (and shape) constraint on ^8B neutrino flux into BSM neutrino physics.
- ☑ sensitivity mainly limited by the uncertainty of light and charge yields.

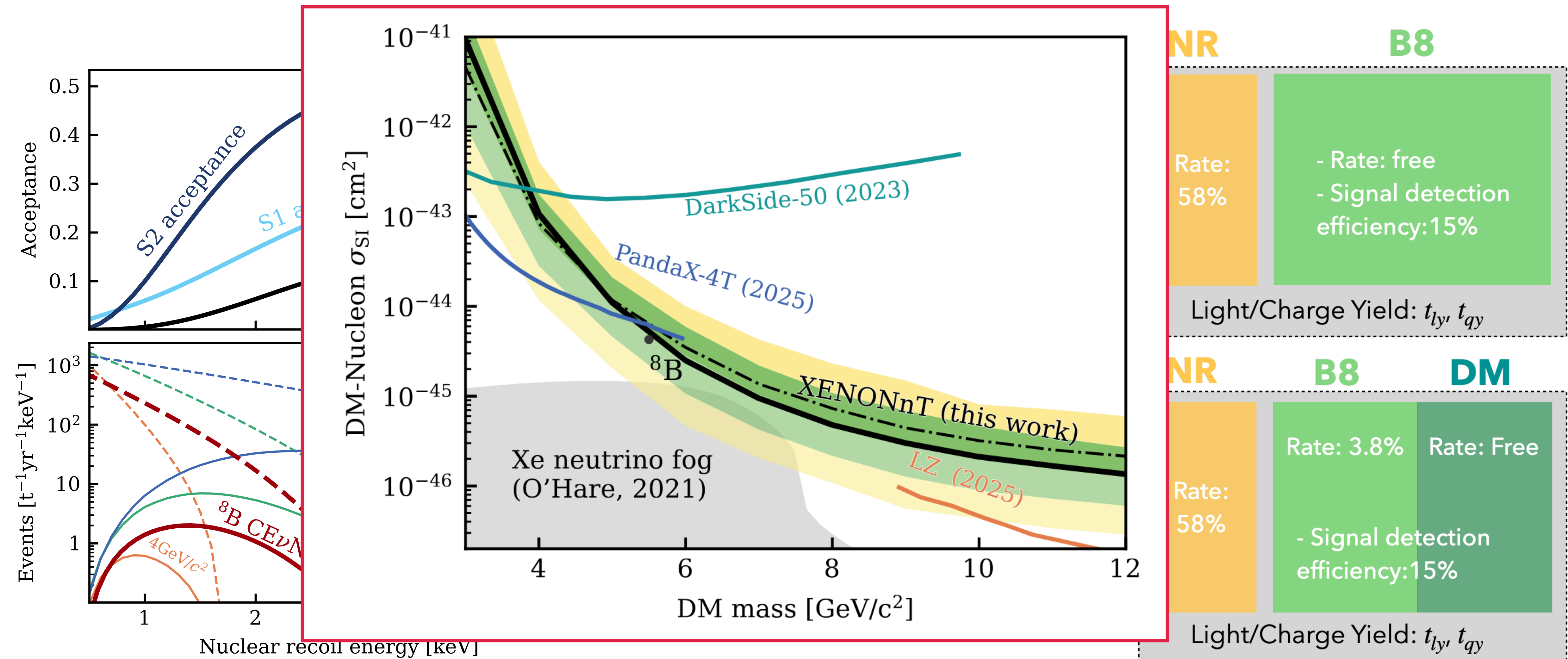


Search for light dark matter in the ‘neutrino fog’



		AC	ER	NR	B8
⁸B CEνNS	Likelihood Terms				
	SR0	9.0%			
	SR1	5.8%	100%		
	SR2	4.9%			
				Rate: 58%	- Rate: free - Signal detection efficiency: 15%
				Light/Charge Yield: t_{ly}, t_{qy}	
Low mass DM	Likelihood Terms				
	SR0	9.0%			
	SR1	5.8%	100%		
	SR2	4.9%			
				Rate: 58%	Rate: 3.8% - Signal detection efficiency: 15%
					Rate: Free
				Light/Charge Yield: t_{ly}, t_{qy}	

Search for light dark matter in the ‘neutrino fog’



- ✓ Doubled exposure → 10% increase in sensitivity @ 5 GeV
- ✓ Officially reached the ‘neutrino fog’!

XENONnT Upgrade

	Drift Field [V/cm]	Extraction efficiency	g2 [PE/e]	Maximum drift [ms]
SR0-SR2	23	~50%	16	2.25
Upgrade	100	~80%	30	~1

What if improve the drift field:

- ✓ Signal: improved gain → lowering the energy threshold
- ✓ Background:
 - ✓ Shorter coincidence window
 - ✓ Better discrimination in S2 waveform



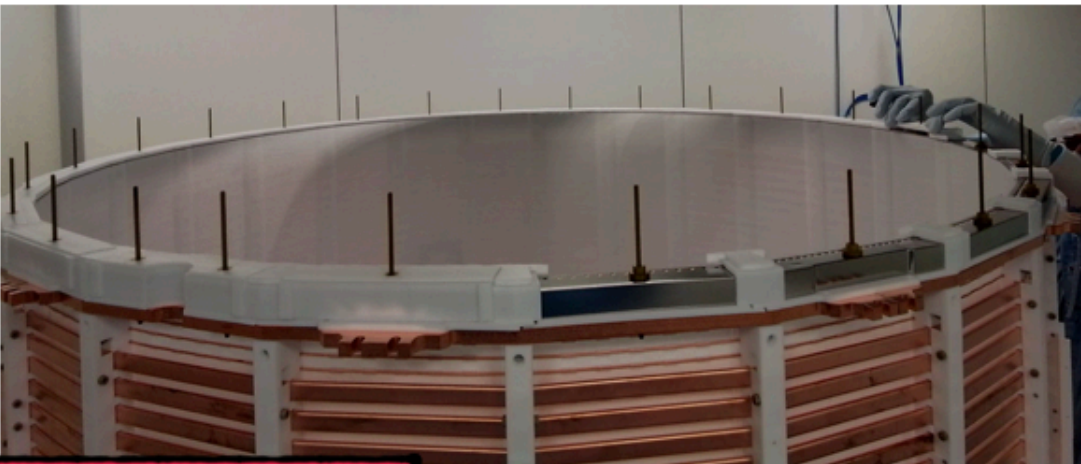
✓ The **broken wire** found



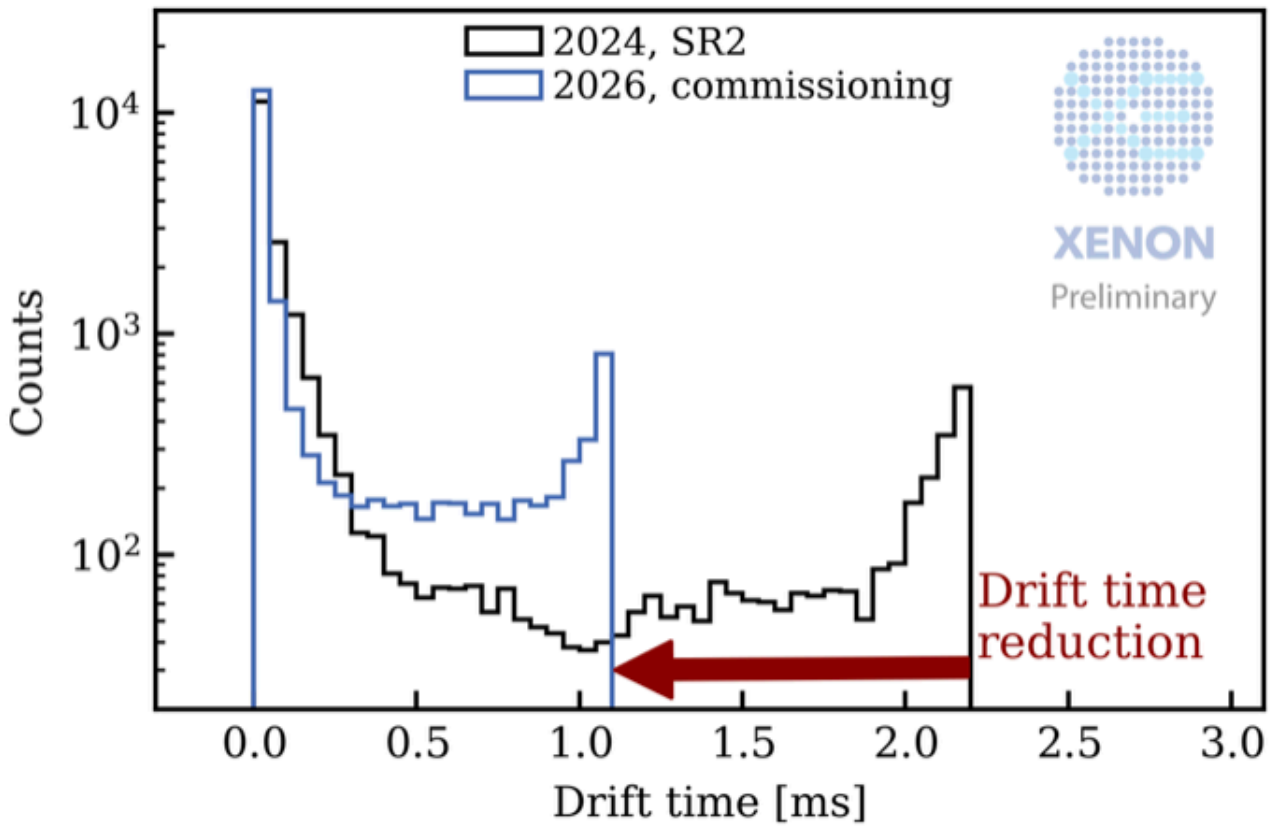
Anode



Cathode



Gate



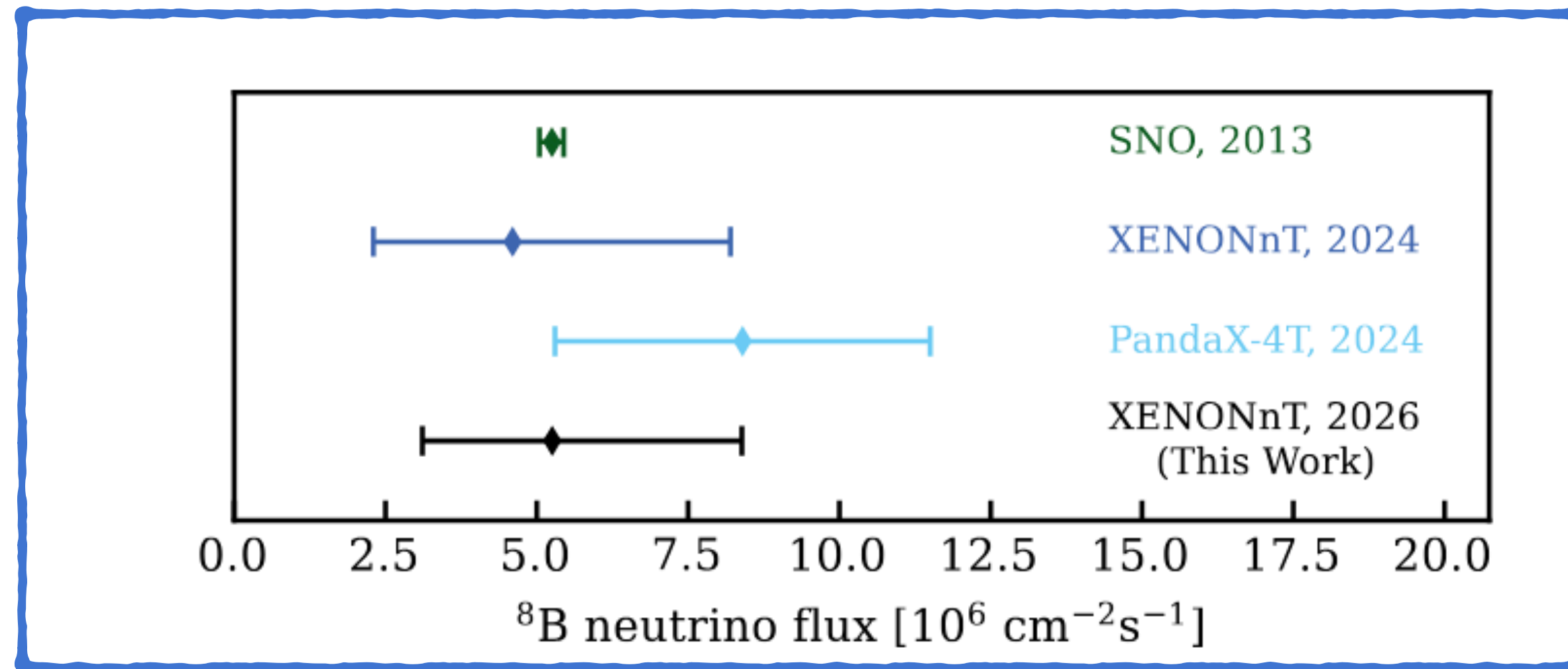
✓ New electrodes installed

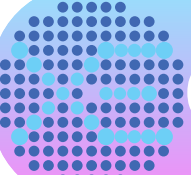
Summary and outlook

- A blind search across three XENONnT SRs yields a **3.3 σ** observation of ^8B CEvNS
- Officially reached the neutrino fog
- **‘XENONnT 2.0’** is now commissioning!

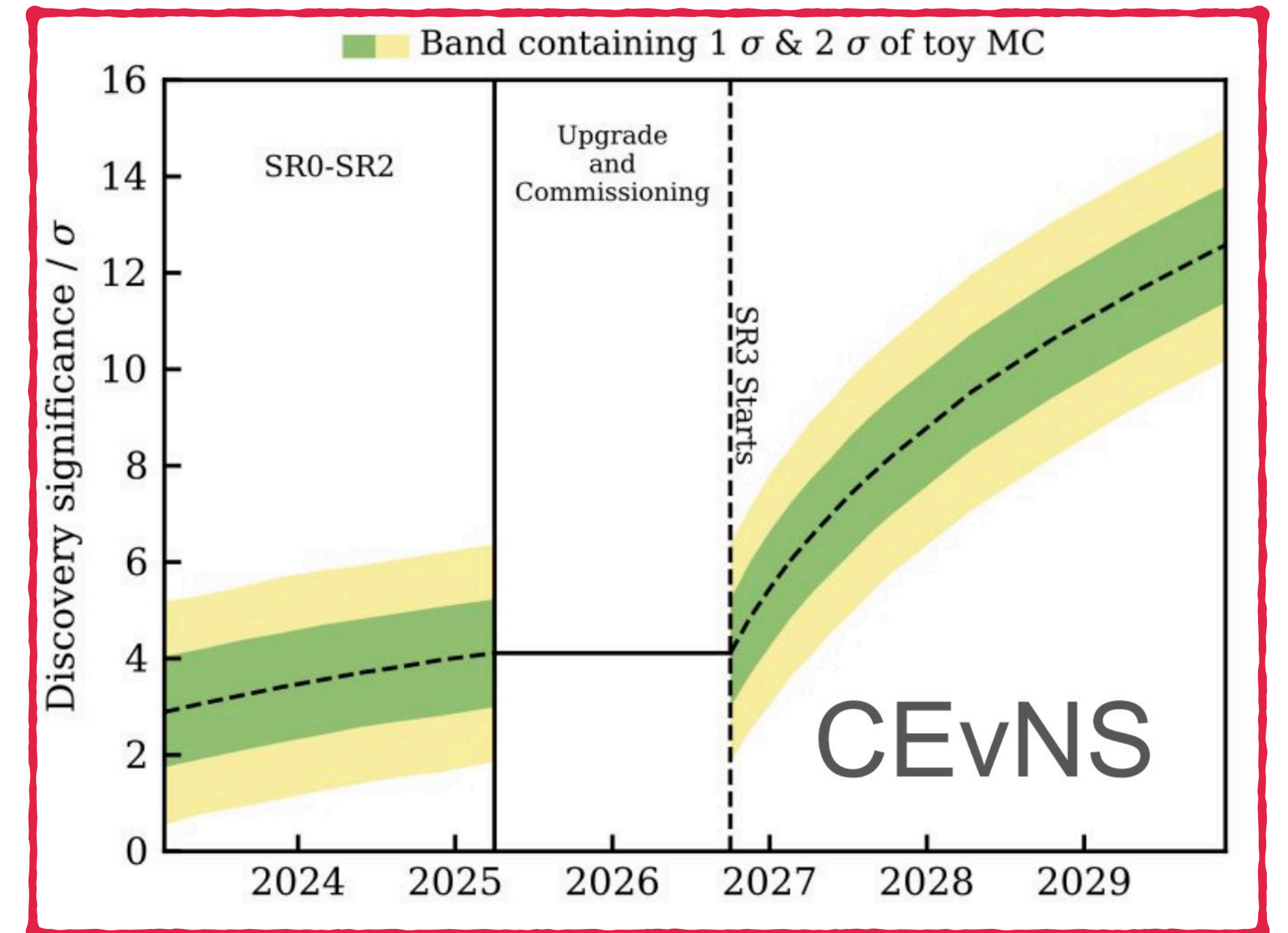


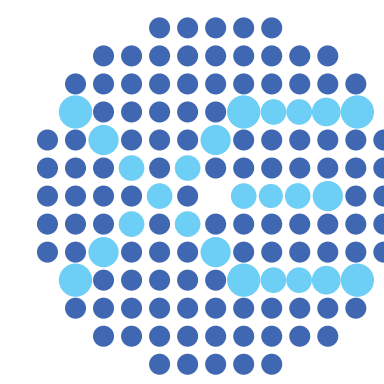
Closing the water tank
(2026.1.6)



 Check out our [Data Release!](#)

arXiv:2604.06002
(accepted by PRL)





XENON



清华大学
Tsinghua University

Thank you for your attention!



lkx21@mails.tsinghua.edu.cn

BSM Neutrino Interactions with CEvNS

CEvNS Nominal Model

$$\frac{d\sigma}{dT} = \frac{G_F^2 M}{\pi} \left(1 - \frac{MT}{2E_\nu^2} \right) G_V^2$$

$$G_V = (g_V^p Z + g_V^n N) F^V(Q^2)$$

$$g_V^p = \frac{1}{2} - 2\sin^2 \theta_W \approx 0.02$$

$$g_V^n = -\frac{1}{2}$$

$$G_V = ((g_V^p + 3\varepsilon_{ll}^{fV})Z + (g_V^n + 3\varepsilon_{ll}^{fV})N)F^V(Q^2)$$

$$\varepsilon_{ll}^{fV} = \frac{g_{Z'}^2}{\sqrt{2}G_F(|\vec{q}|^2 + m_{Z'}^2)}$$

Generalized Neutrino Interaction

$$G_V = ((g_V^p + 2\epsilon_{ll}^{uV} + \epsilon_{ll}^{dV})Z + (g_V^n + \epsilon_{ll}^{uV} + 2\epsilon_{ll}^{dV})N)F^V(Q^2)$$

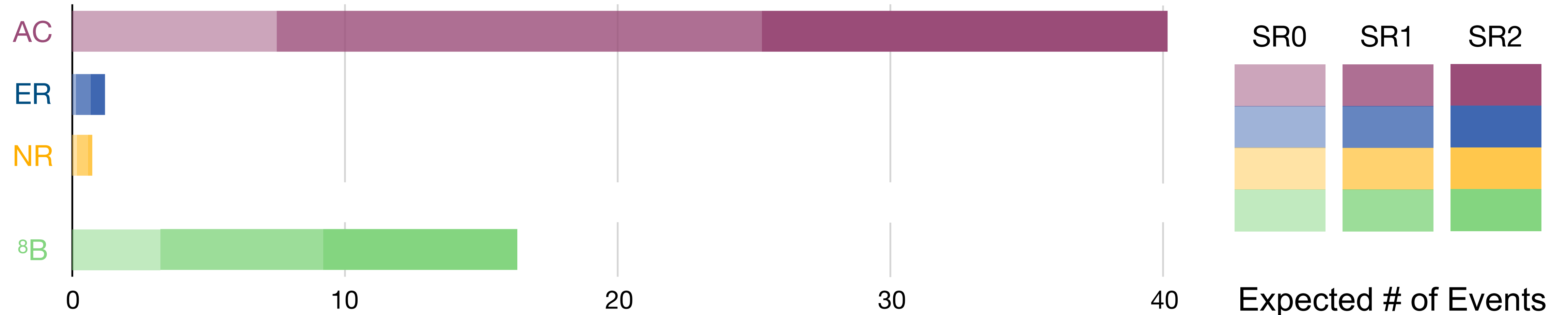
Neutrino Charge Radius

$$\tilde{g}_V^p = g_V^p - \frac{\sqrt{2}\pi\alpha}{3G_F} \langle r_{\nu 1}^2 \rangle$$

Millicharge

$$\tilde{g}_V^p = g_V^p - \frac{2\sqrt{2}\pi\alpha}{G_F q^2} q_{\nu l}$$

Background Components



AC: Accidental Coincidence Background

- Validated by AC-rich sideband
- Uncertainty: 9% (SR0), 6% (SR1), 5% (SR2)

NR: Nuclear Recoil Background

- Estimated using full-chain simulations
- 58% uncertainty from sideband

ER: Electronic Recoil Background

- Flat spectrum at $O(0.1)\text{keV}$
- A conservative 100% uncertainty

^8B : CEvNS Signal

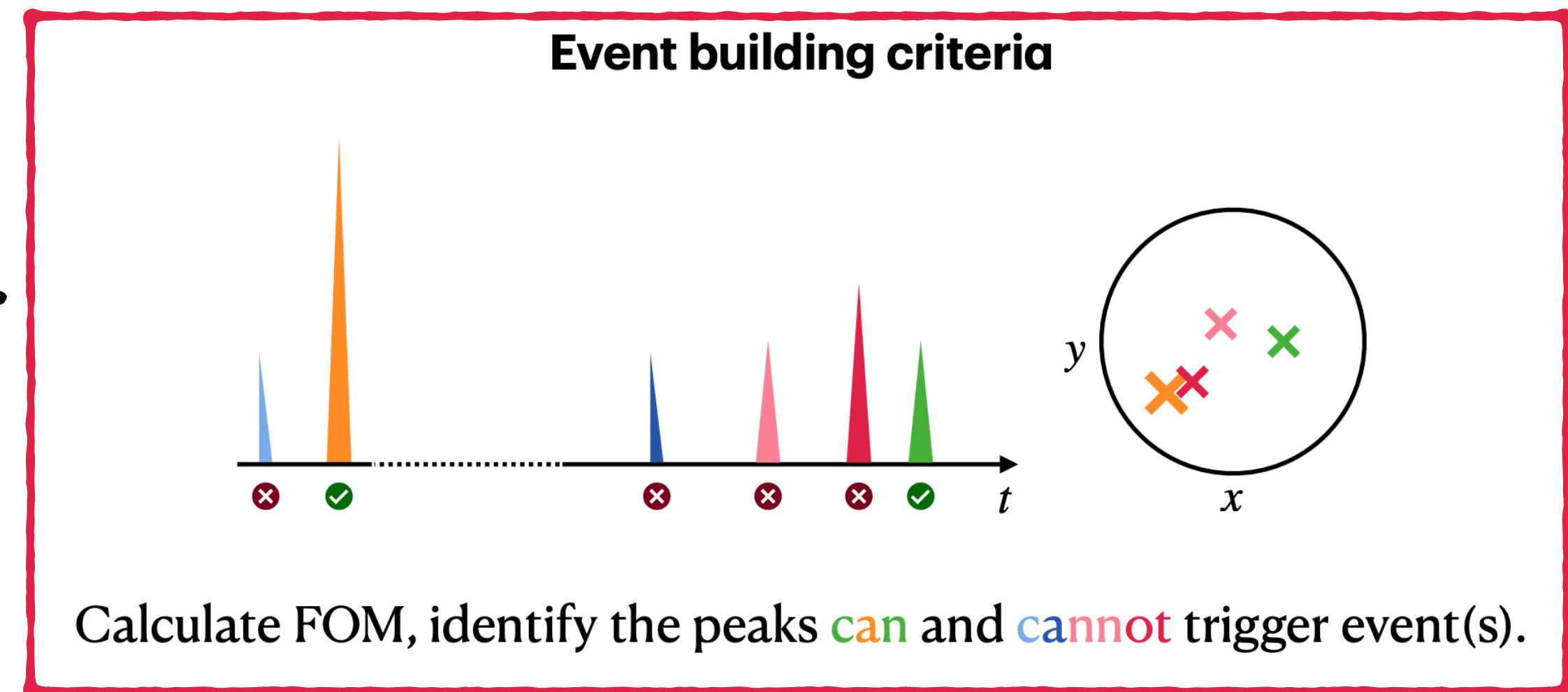
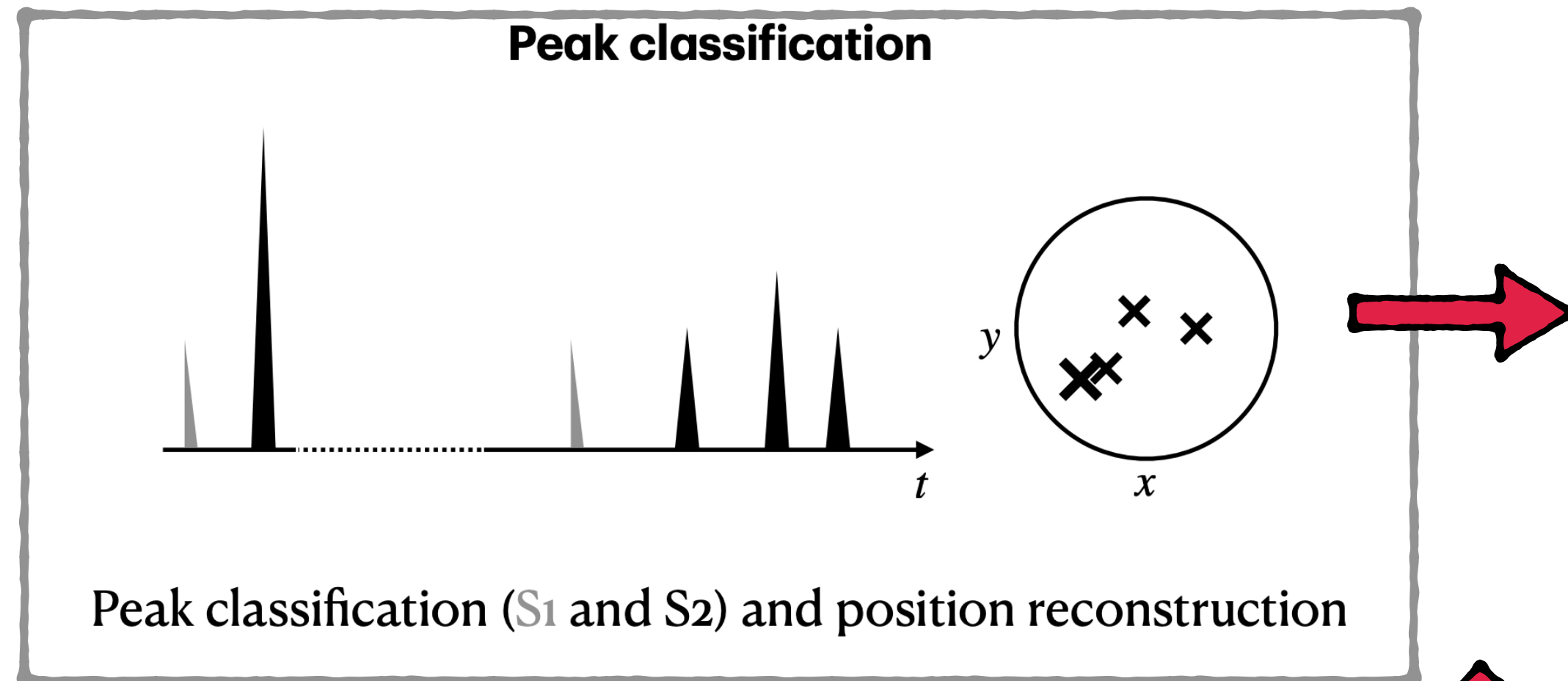
- Yields calibrated using ^{88}YBe neutron source
- ~35% uncertainty from yields and efficiencies

Enhanced search with SR2

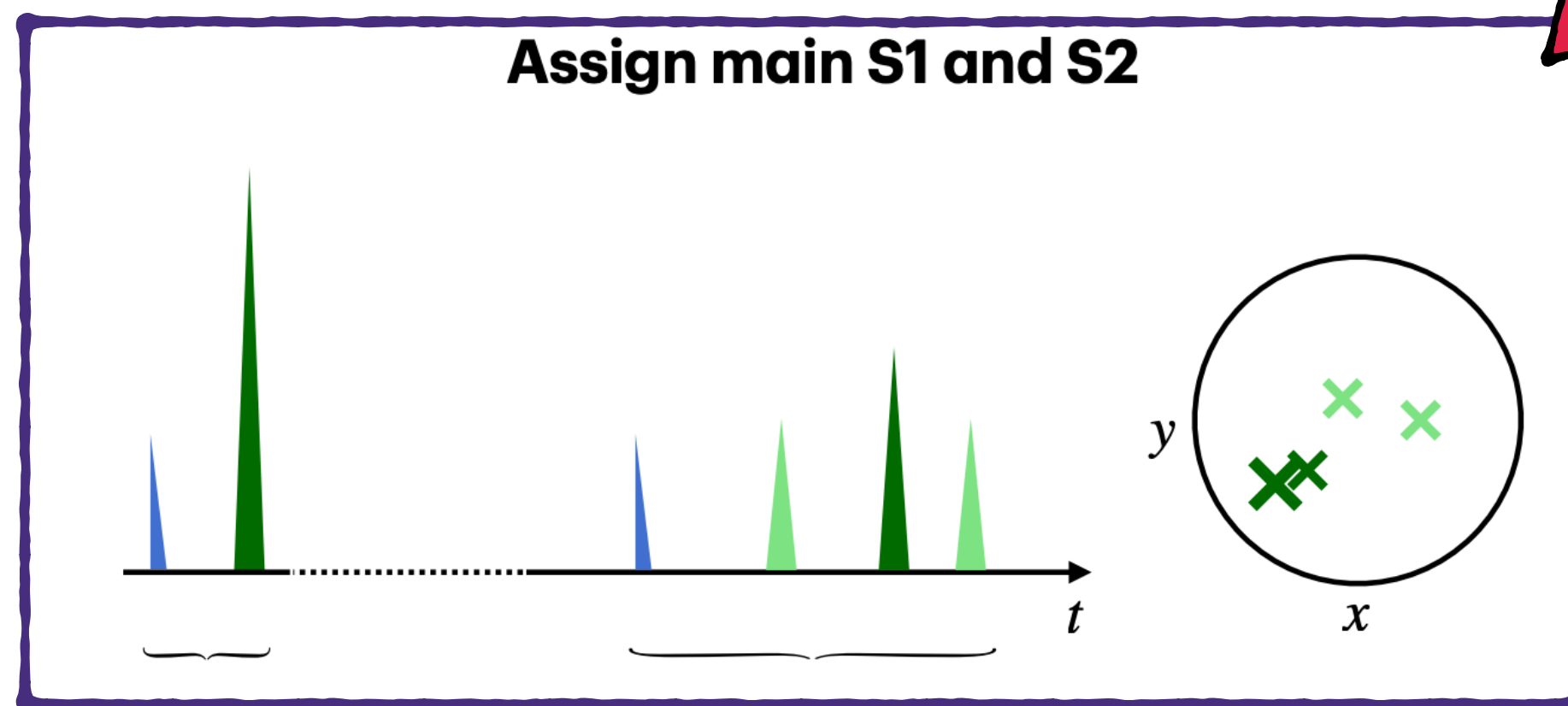
Exposure

$$S / \sqrt{N}$$

- ☑ Bring the AC suppression selections into event building



- Previously, the FOM is mainly **counting the competing peaks**
- Redesign the FoM by combining the **time & position correlation** with HE peaks + small peaks



^8B CEvNS search unblinding results

