

# First measurement of weak mixing angle in direct detection

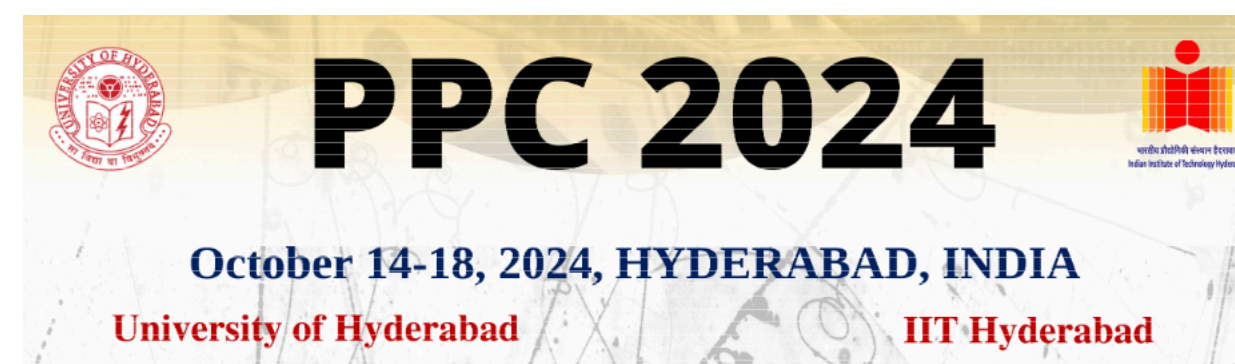
Tarak Nath Maity  
University of Sydney

Based on:

[TNM](#), C Boehm; 2409.04385



THE UNIVERSITY OF  
SYDNEY



# What are we doing?

Have we ever **tested** the **Standard Model** of particle physics in **sub-MeV energy regime** before?

**Perhaps not!**

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Weak mixing angle

$$A^\mu = B_0^\mu \cos \theta_W + W_0^\mu \sin \theta_W$$

$$Z^\mu = W_0^\mu \cos \theta_W - B_0^\mu \sin \theta_W$$

$$\sin^2 \theta_W = \frac{g'^2}{g^2 + g'^2}$$

$g$  : SU(2)<sub>L</sub> gauge coupling

$g'$  : U(1)<sub>Y</sub> gauge coupling

Quantum correction



Running of weak mixing angle

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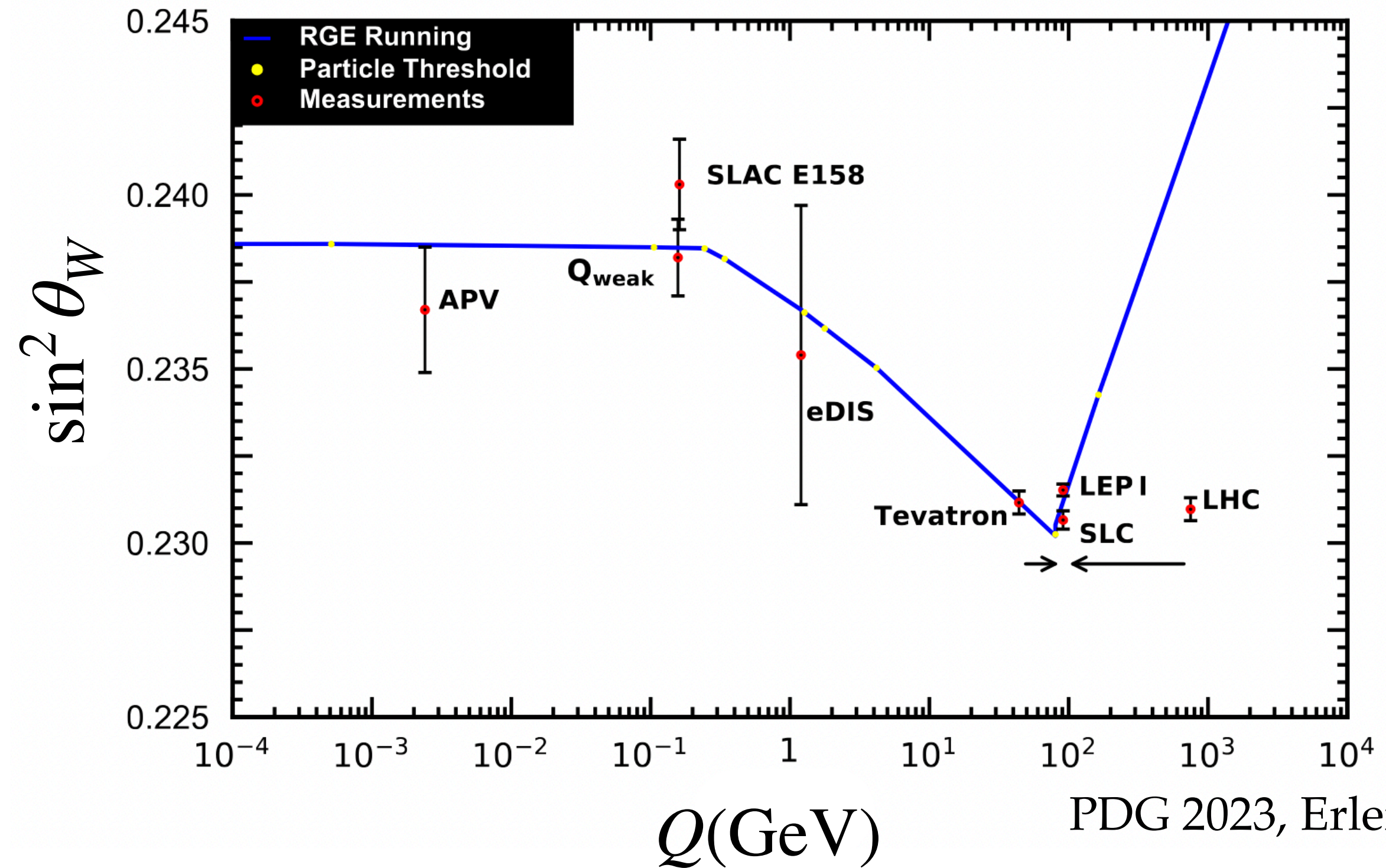
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PDG 2023, Erler+ 1712.09146



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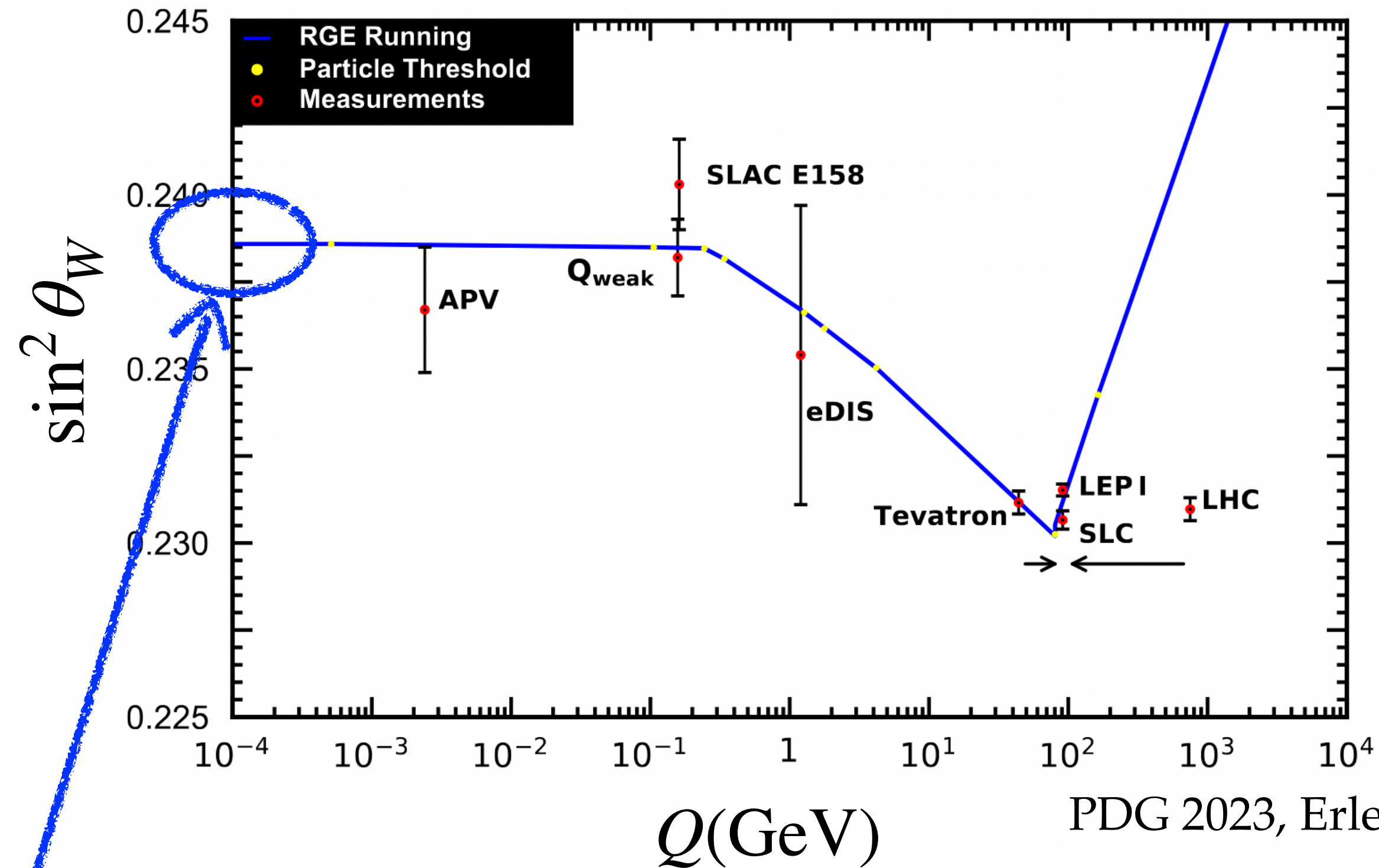
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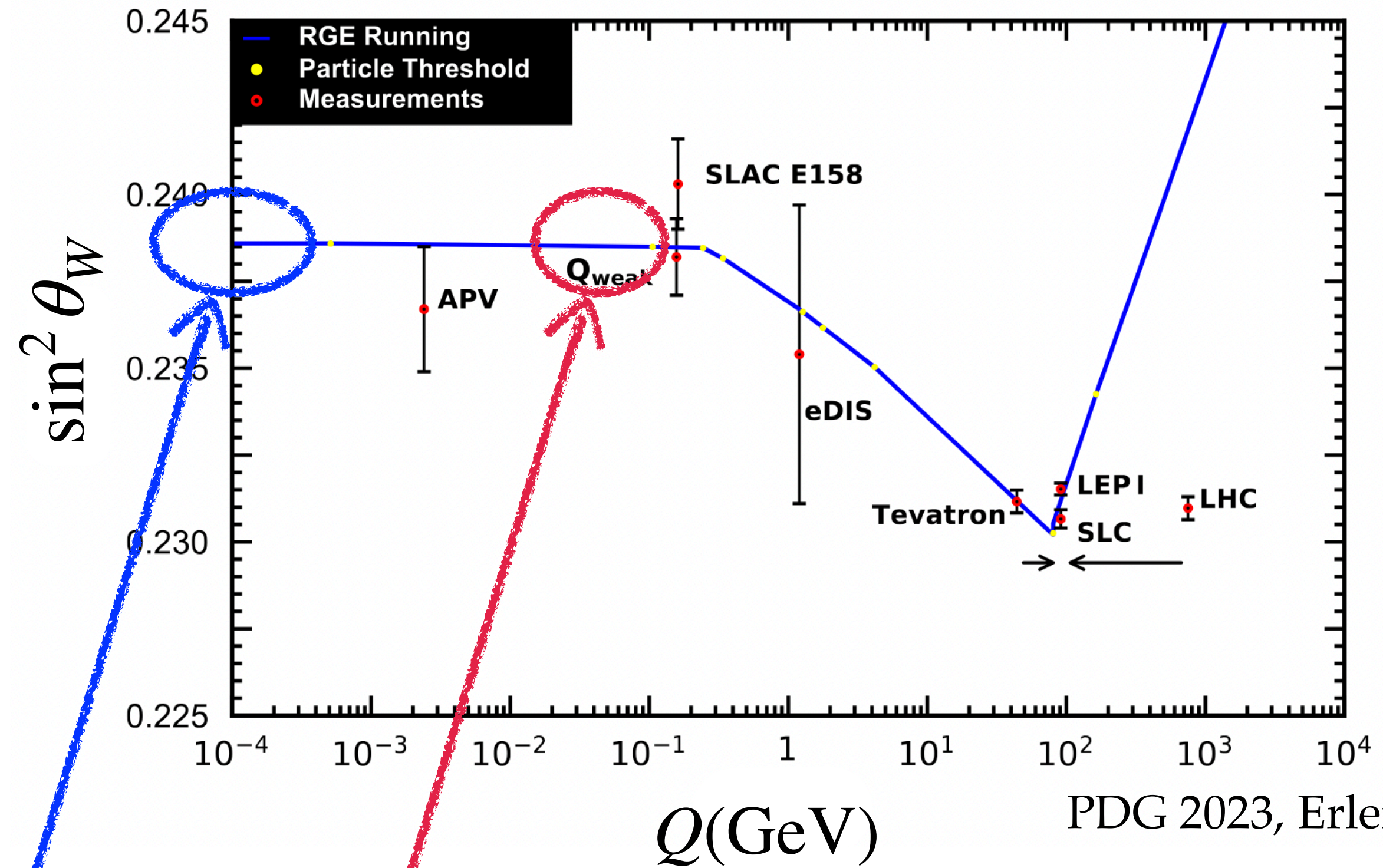
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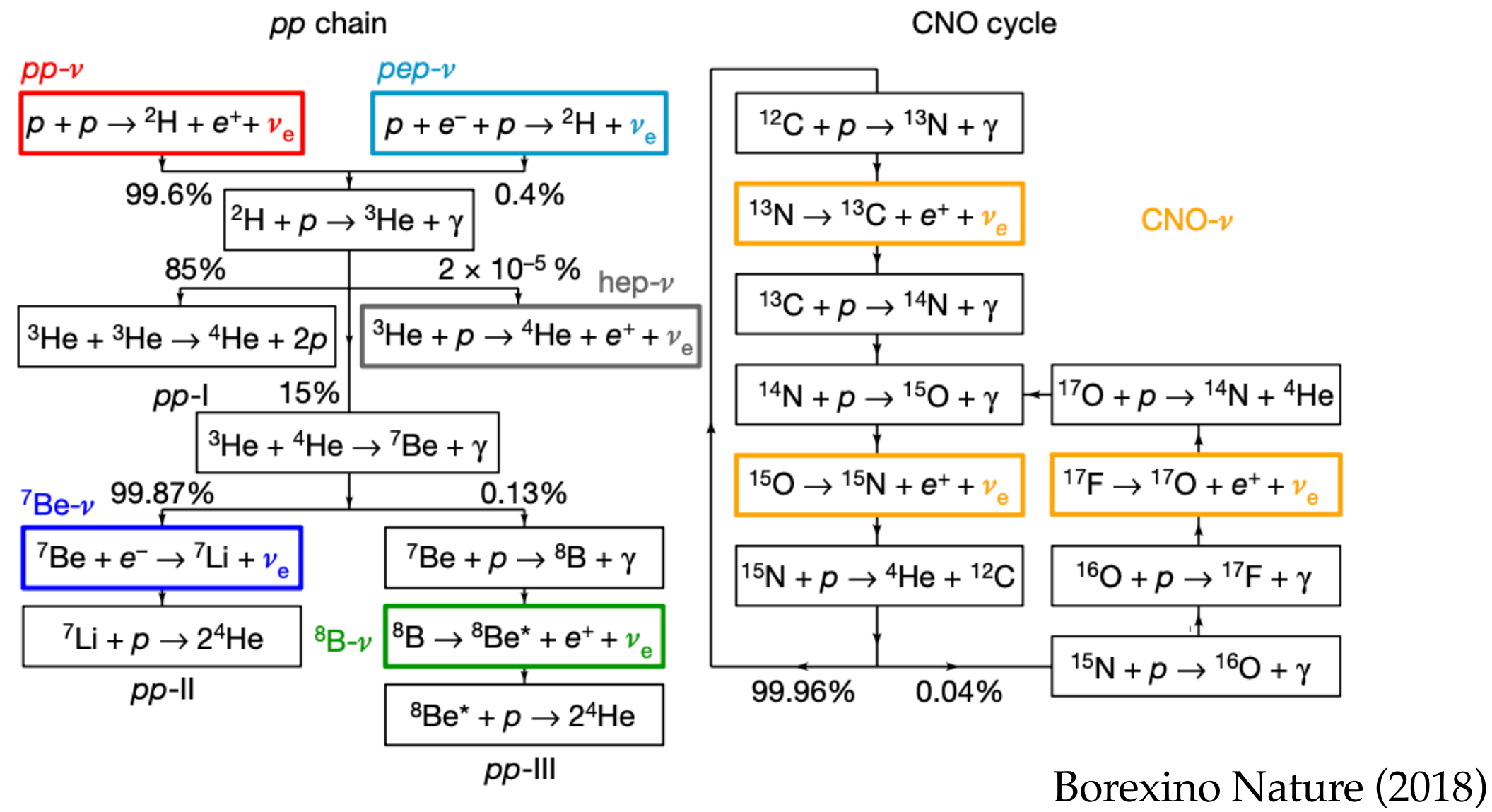
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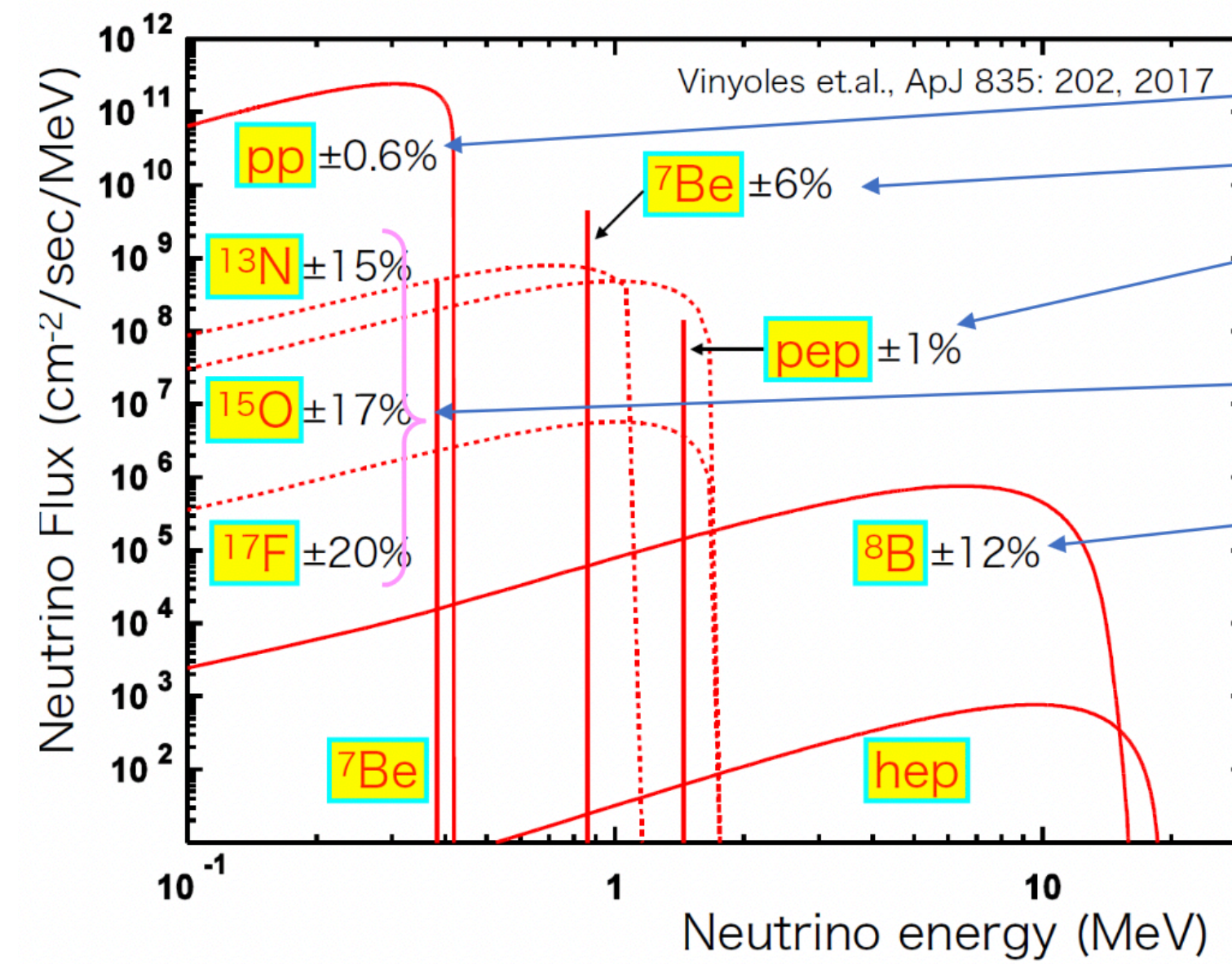


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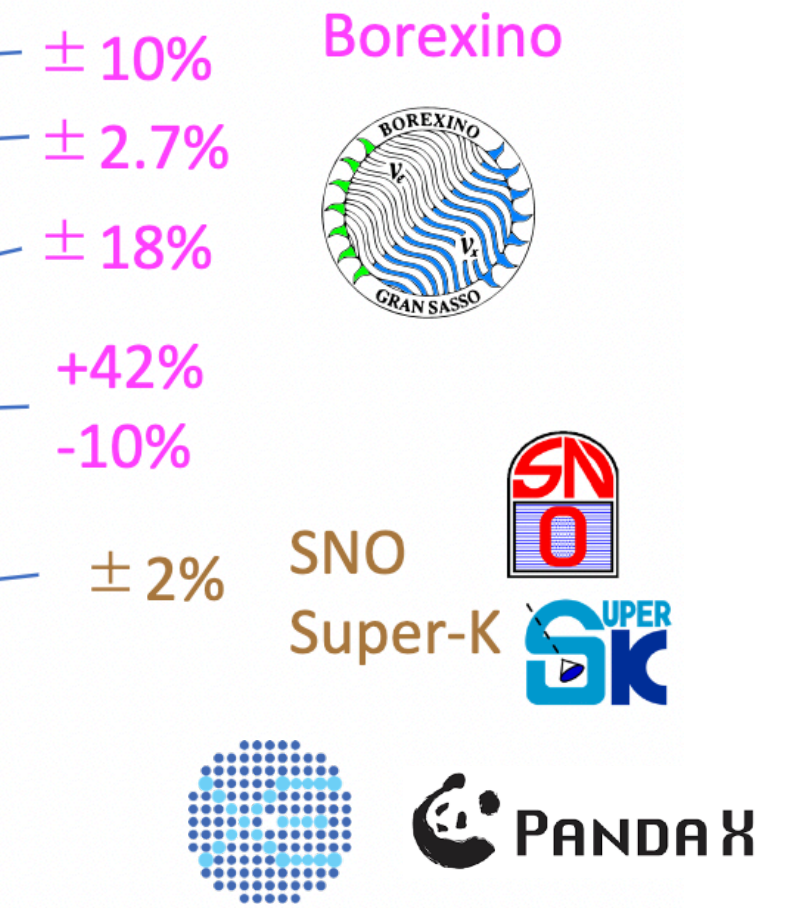
By observing Solar neutrinos



Energy spectra w/ SSM uncertainties



Measured flux errors

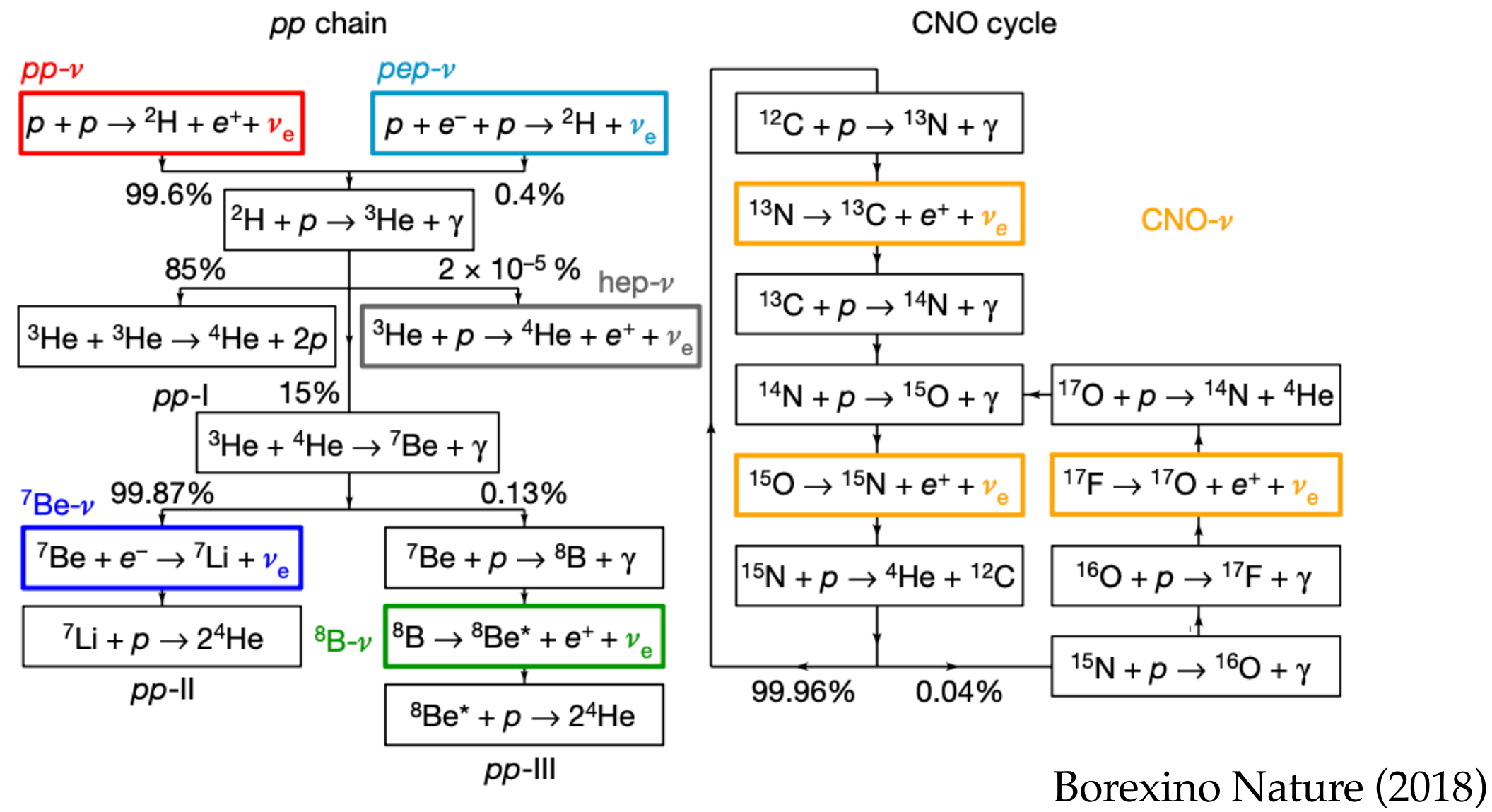


Sekiya TAUP 2023  
SNO nucl-ex/0204008  
Bergstrom+ 1601.00972

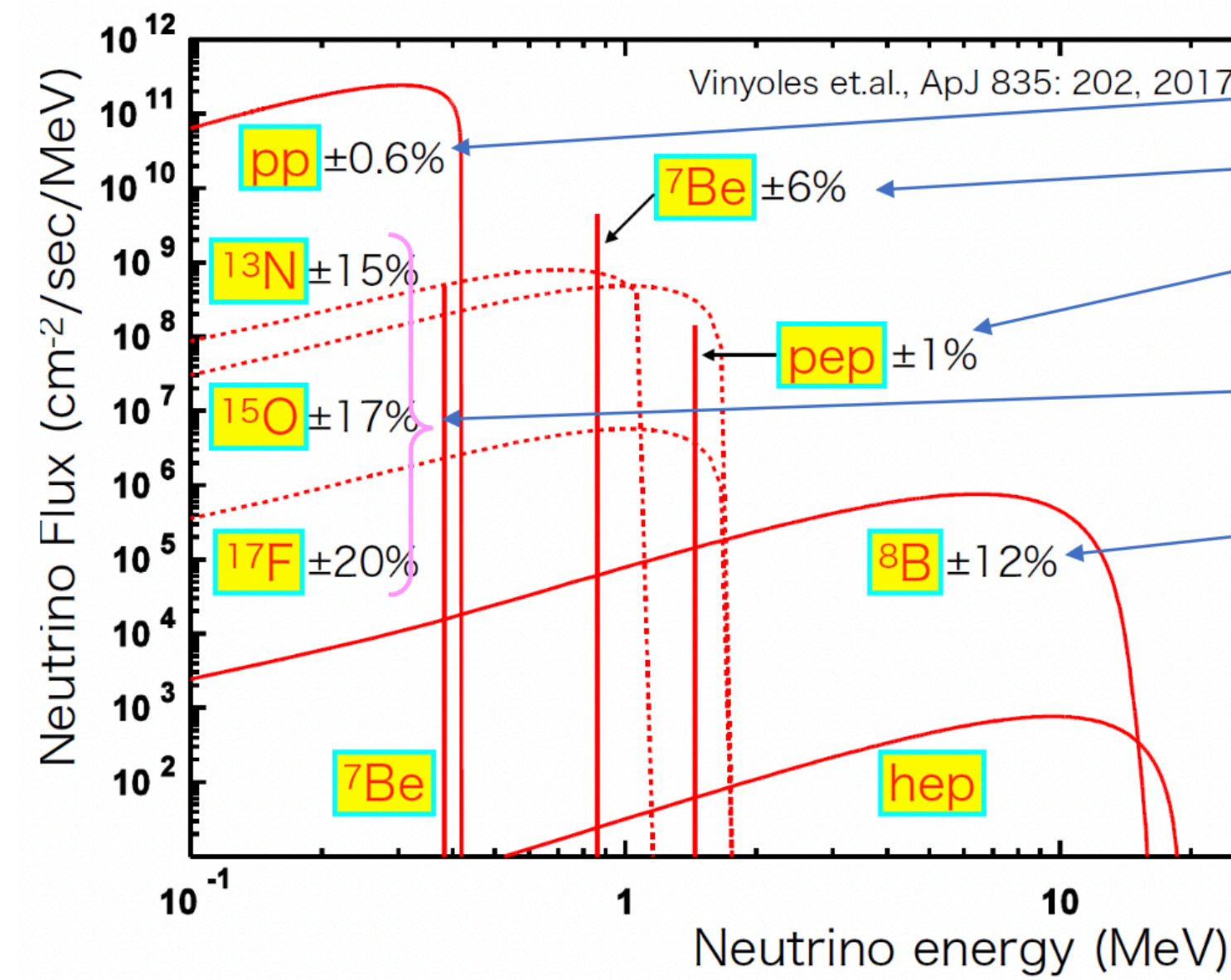


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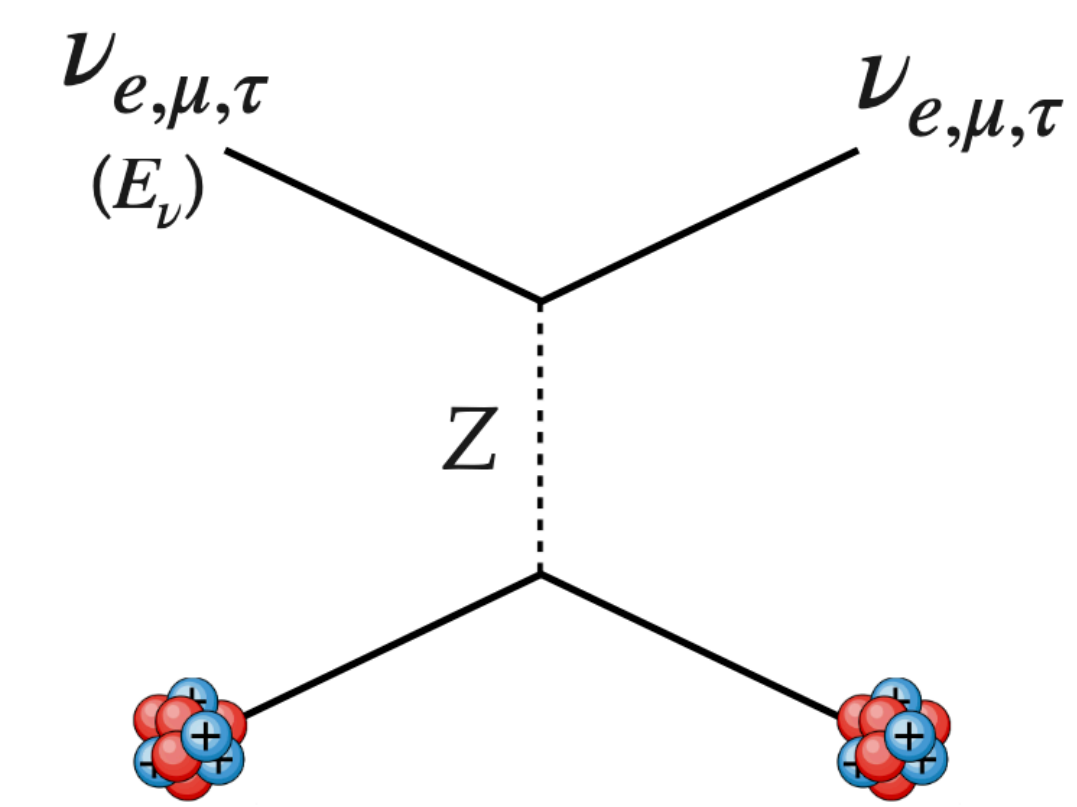
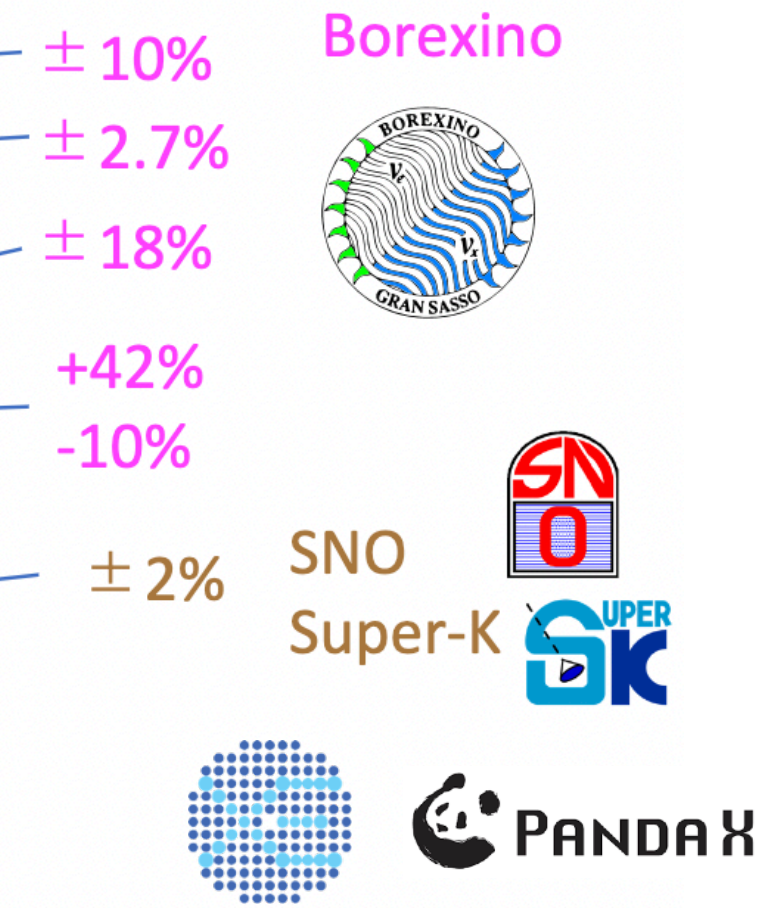
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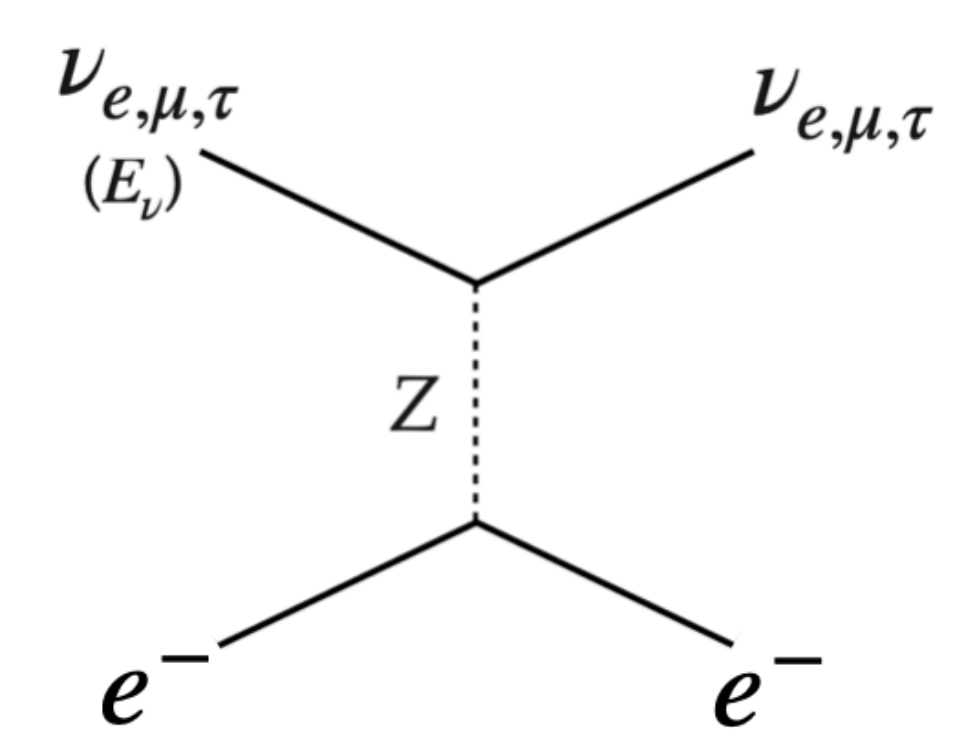
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Coherent elastic neutrino-nucleus scattering (CEvNS)



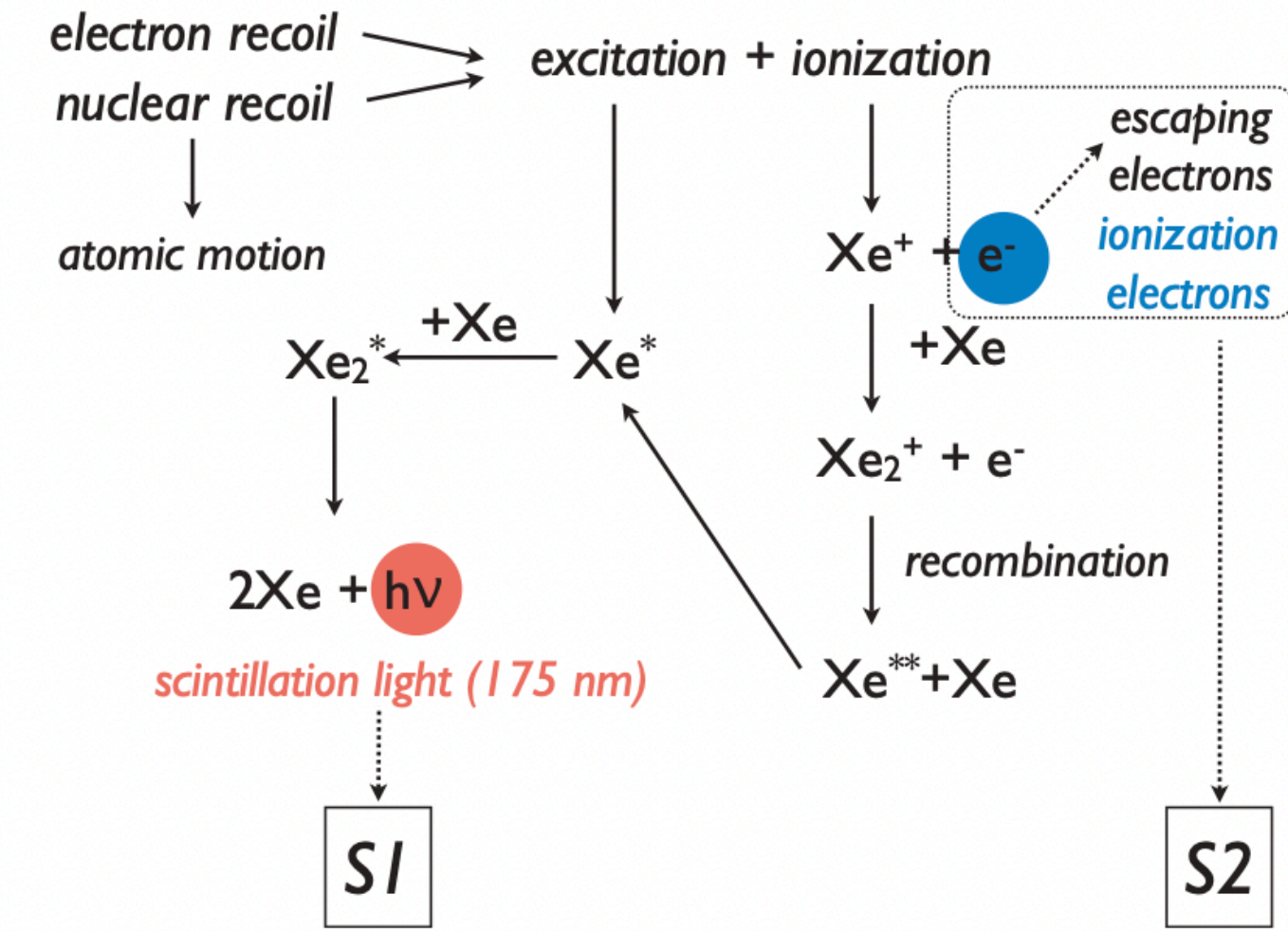
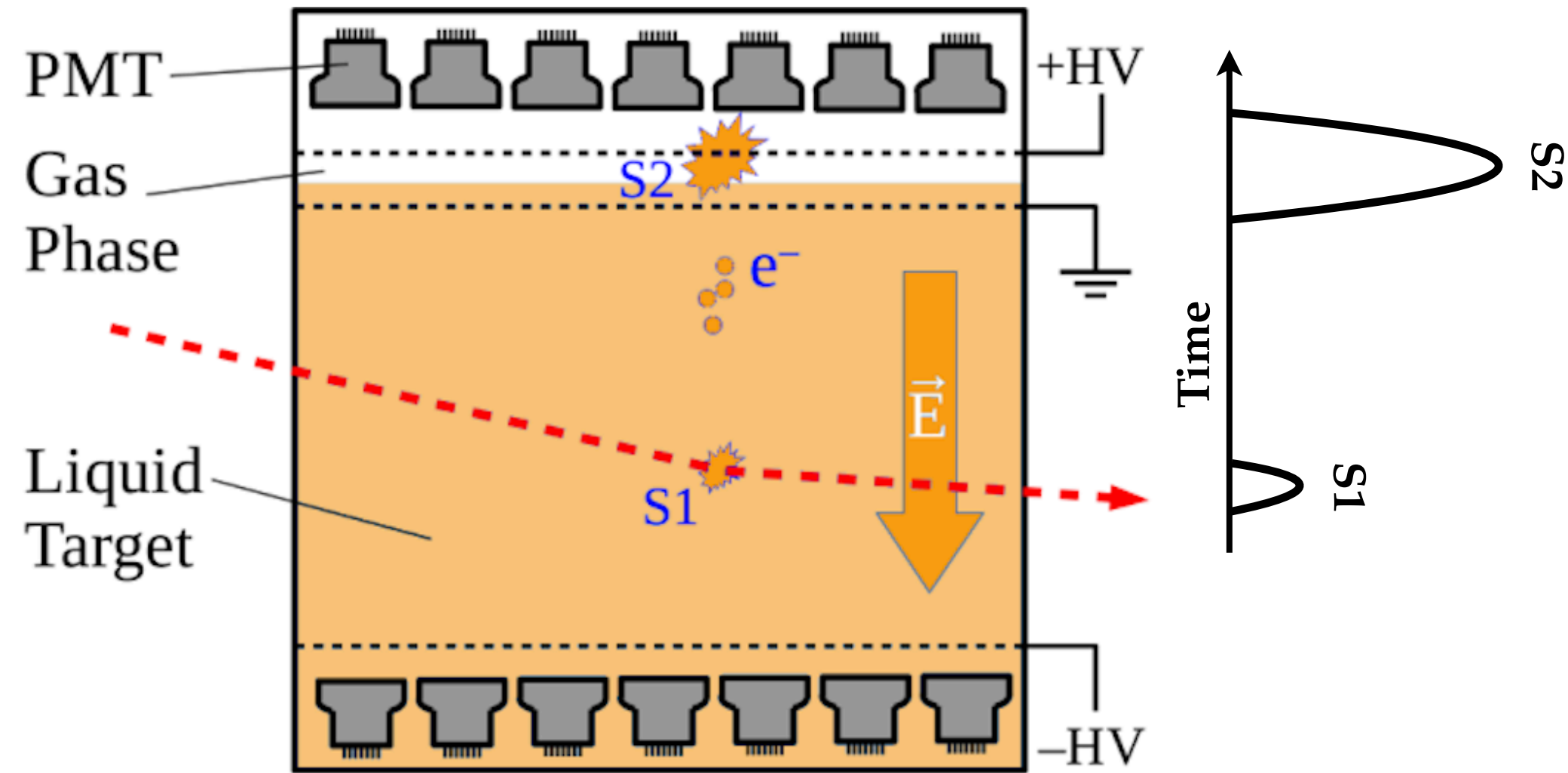
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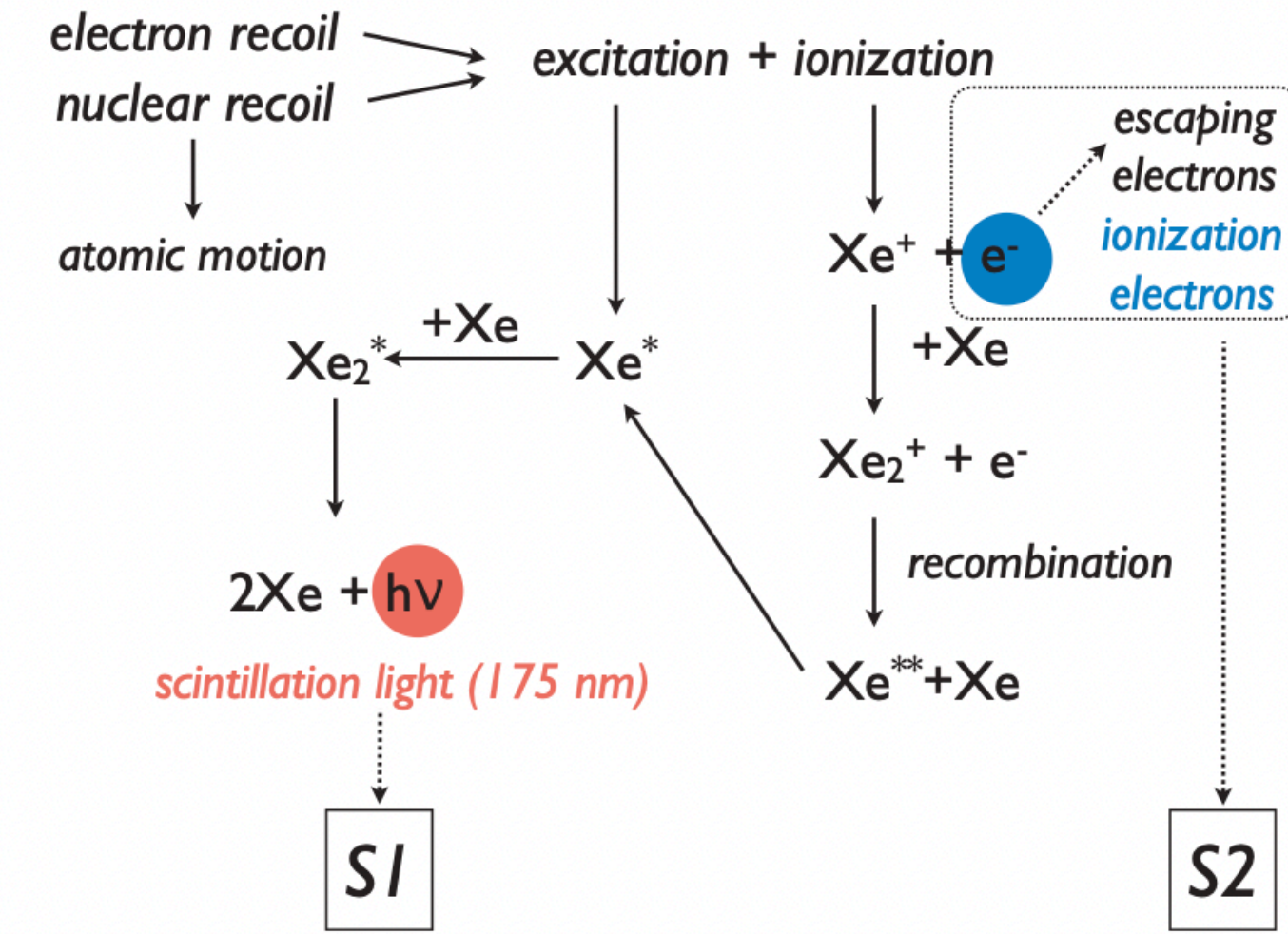
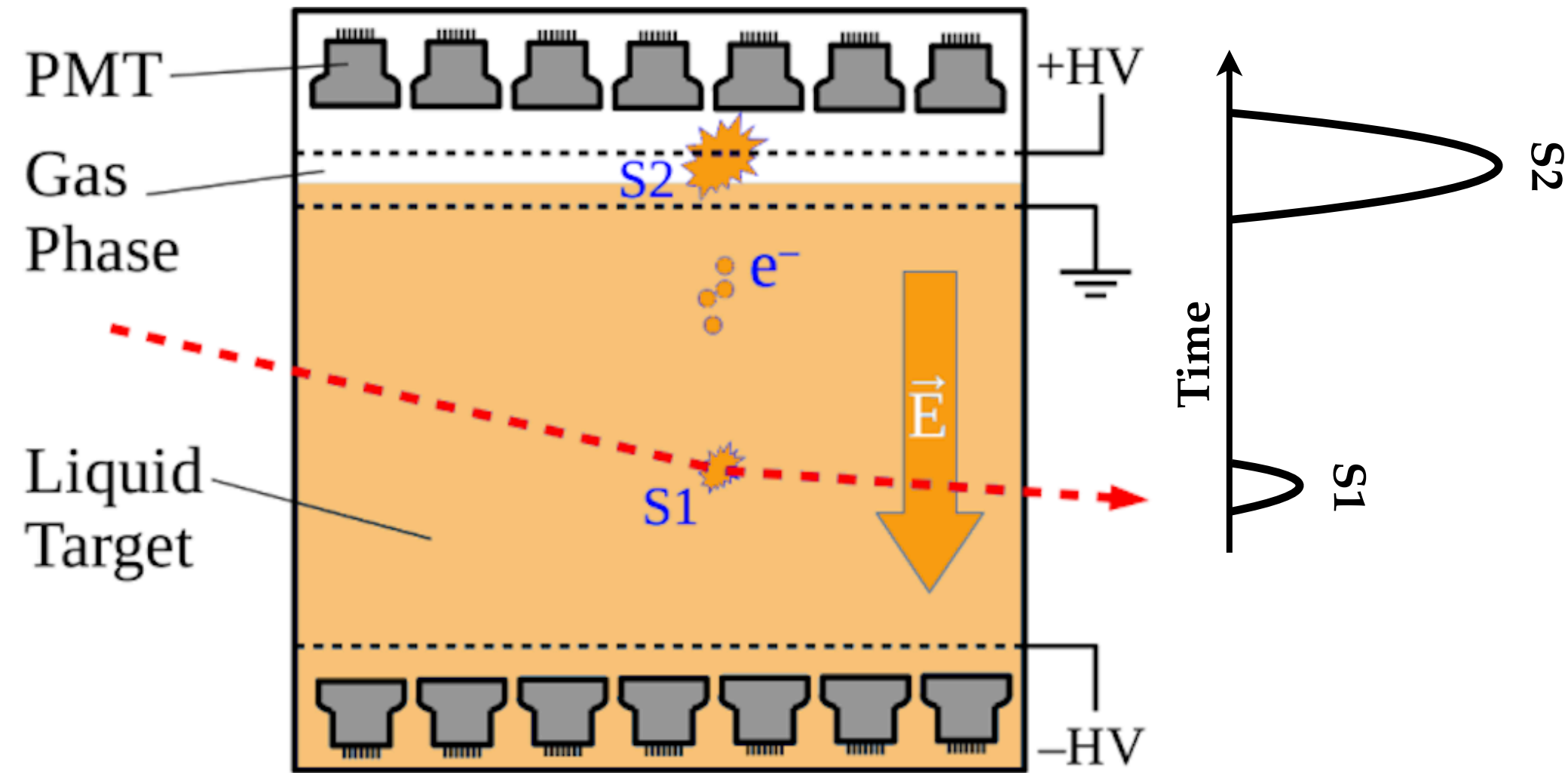
# Observing neutrinos in DD(Xe)

XENONnT, PandaX-4T, LZ ...



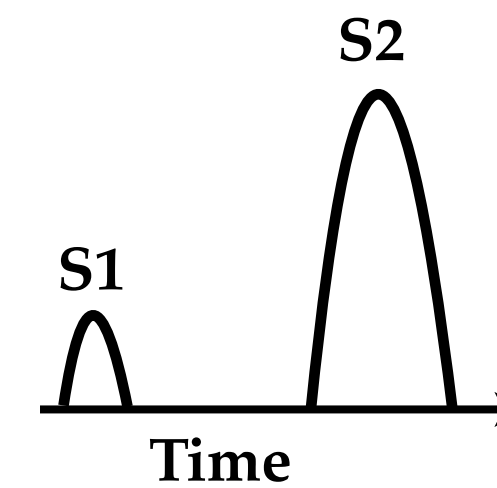
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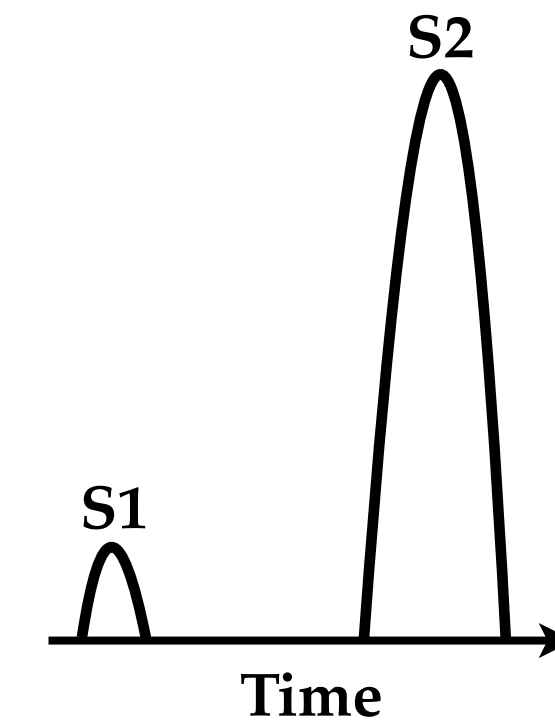


## S1-S2 only analysis

Nuclear recoil



Electron recoil



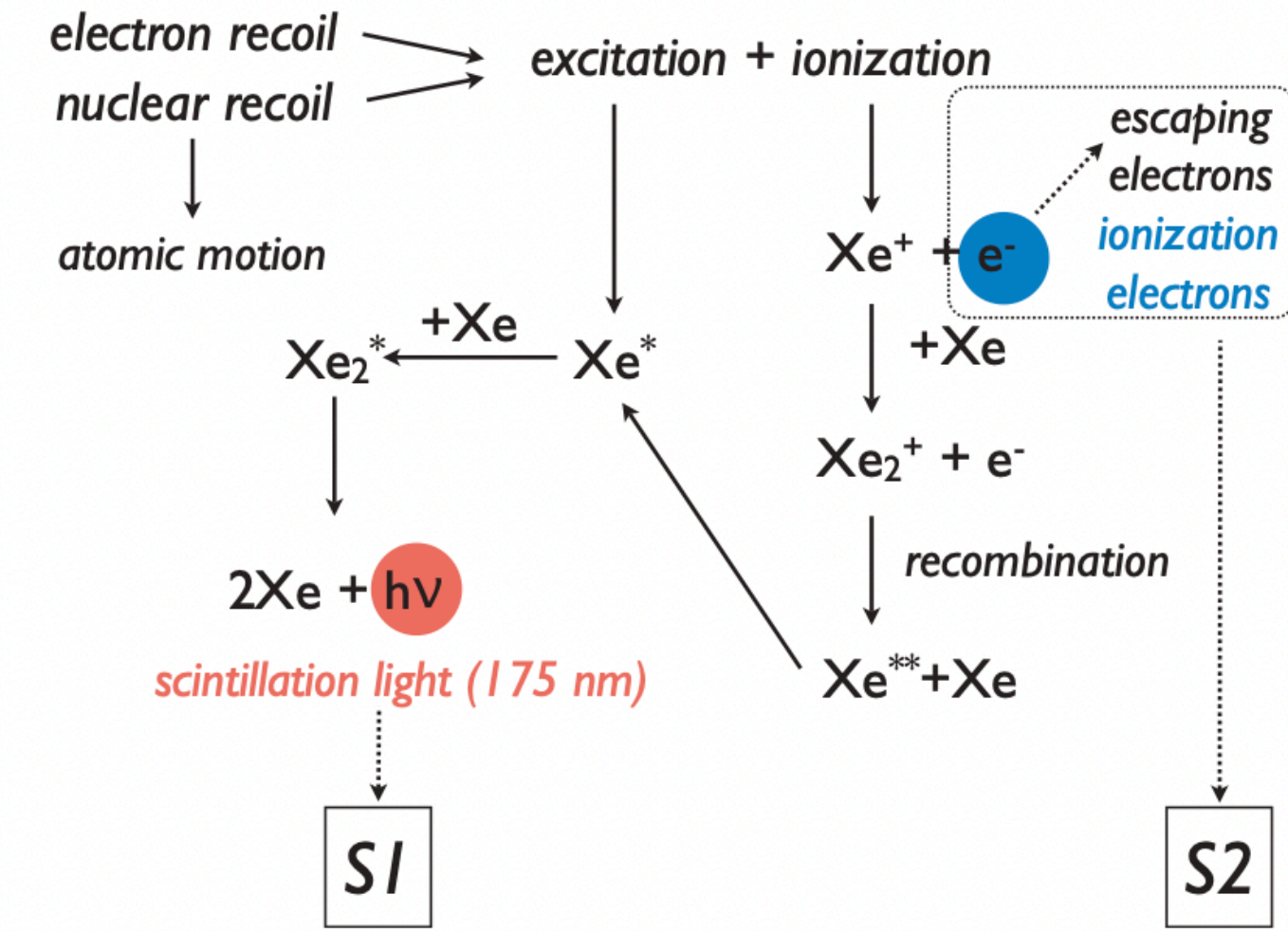
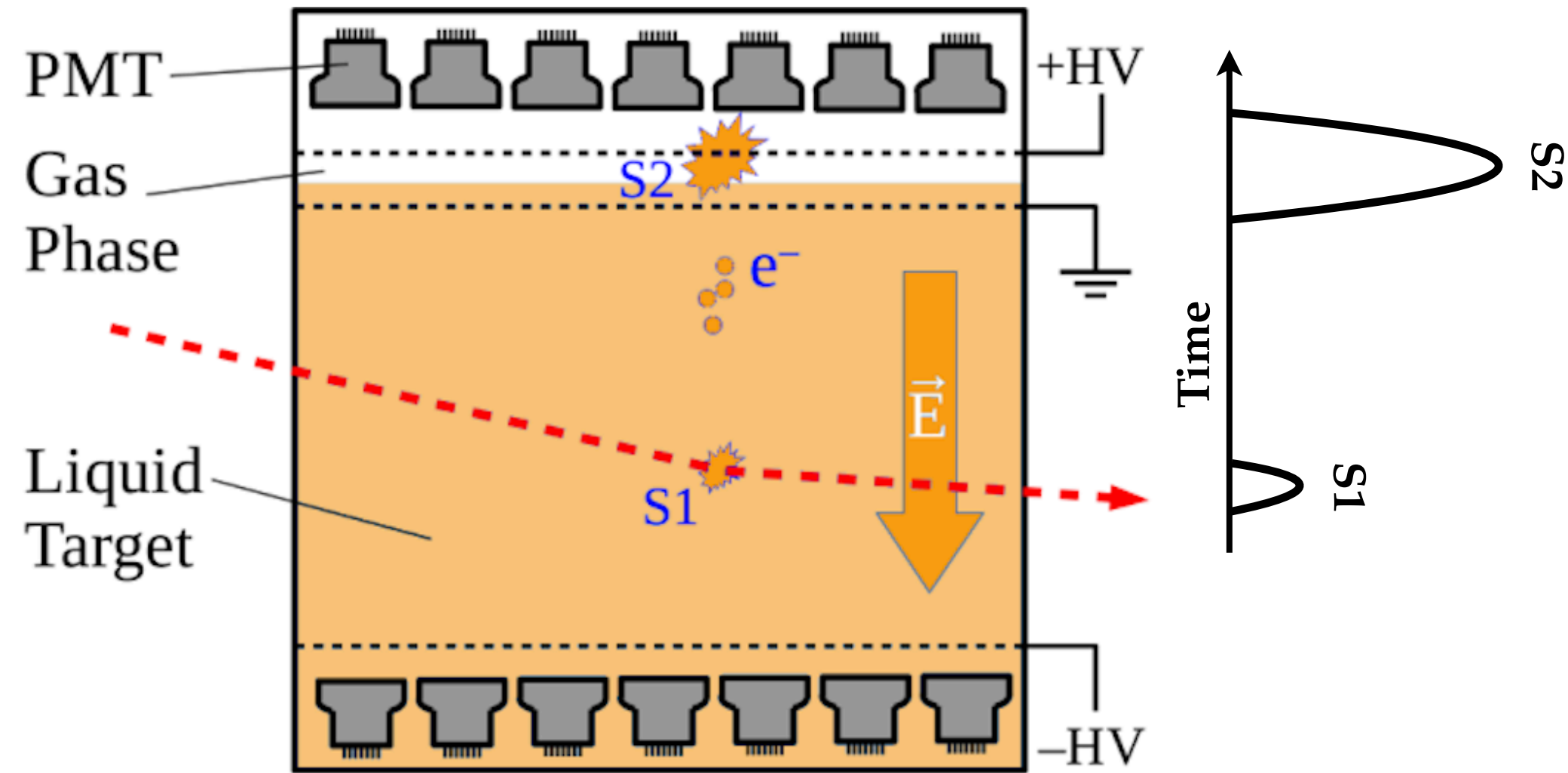
S2/S1 ratio - can distinguish - nuclear and electron recoil

$$E_{\text{recoil}} \gtrsim 0.5 \text{ keV}$$



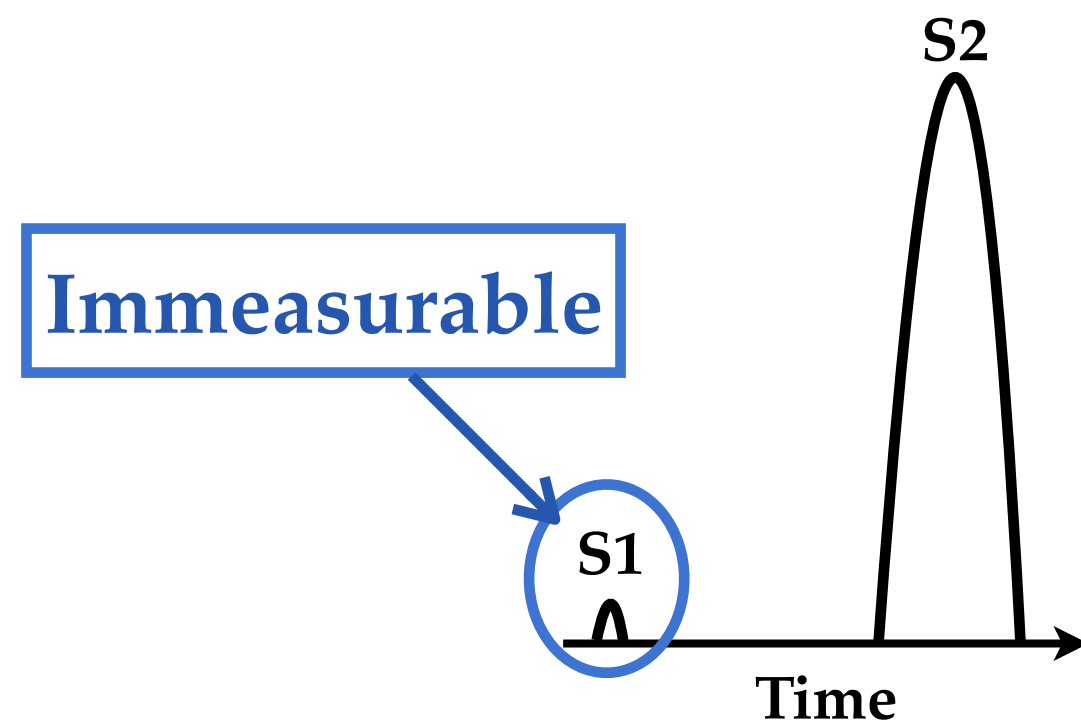
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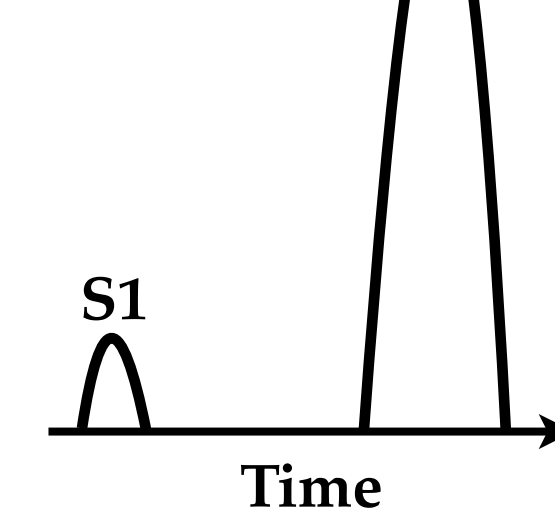
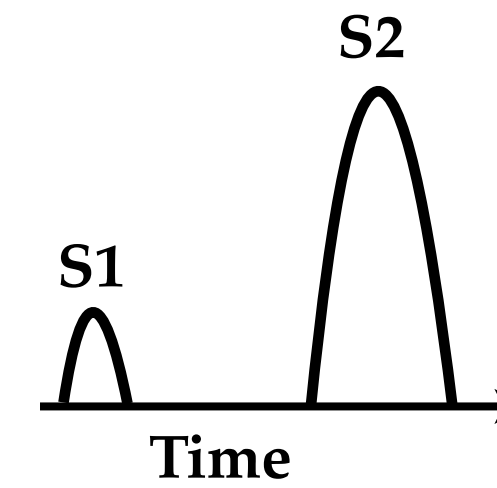
S2 only analysis

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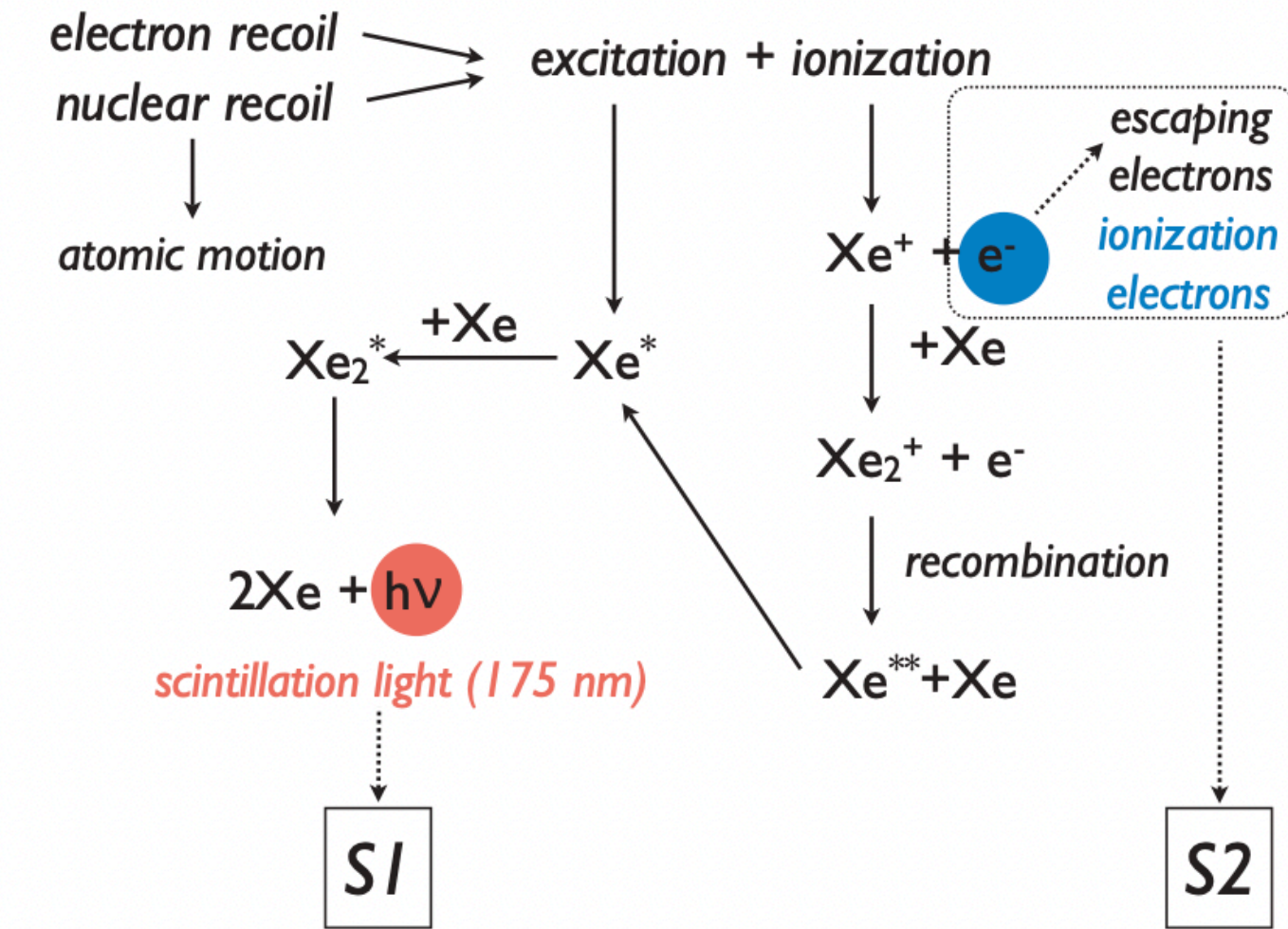
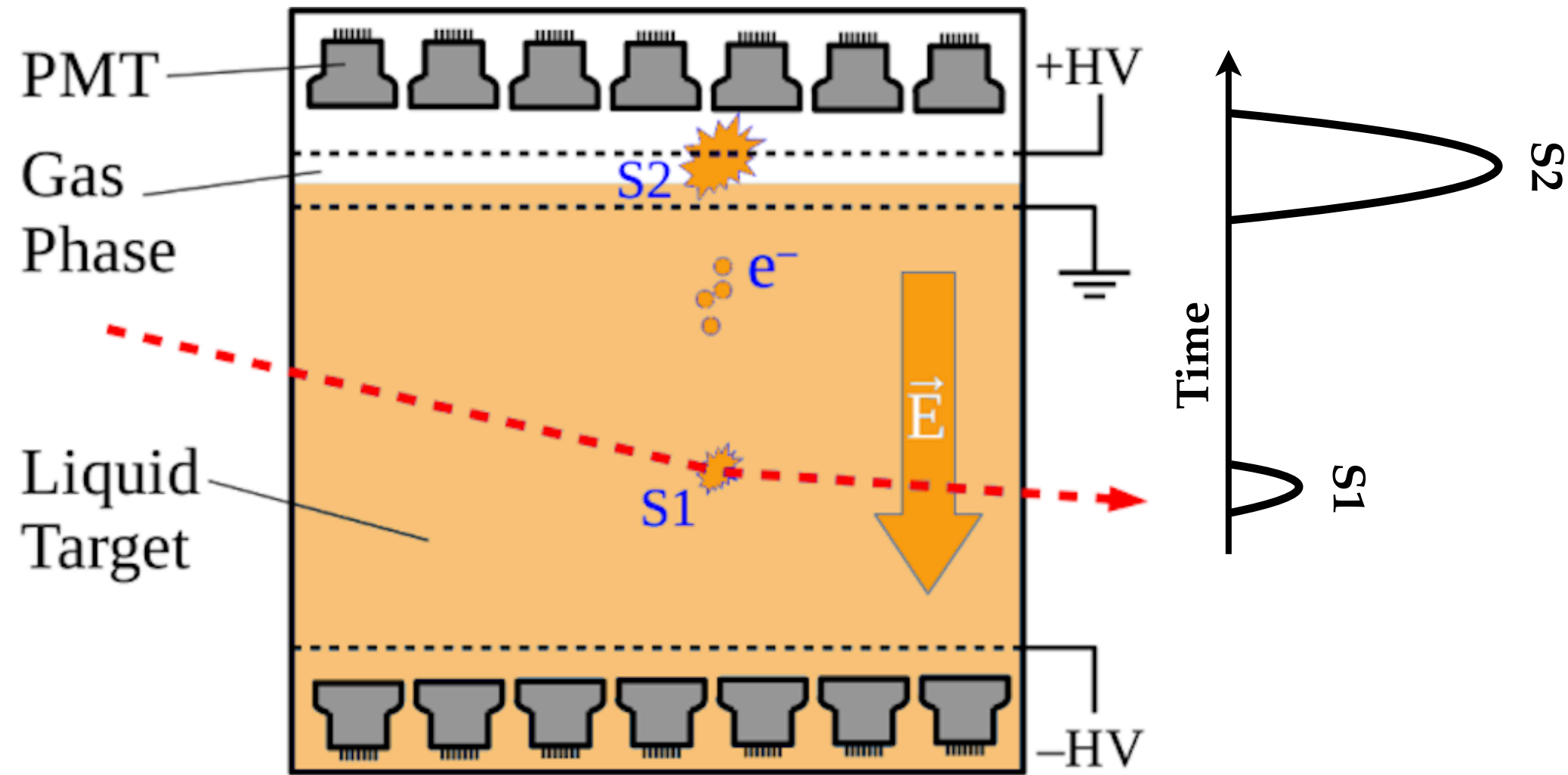
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$$E_{\text{recoil}} \lesssim 0.5 \text{ keV}$$

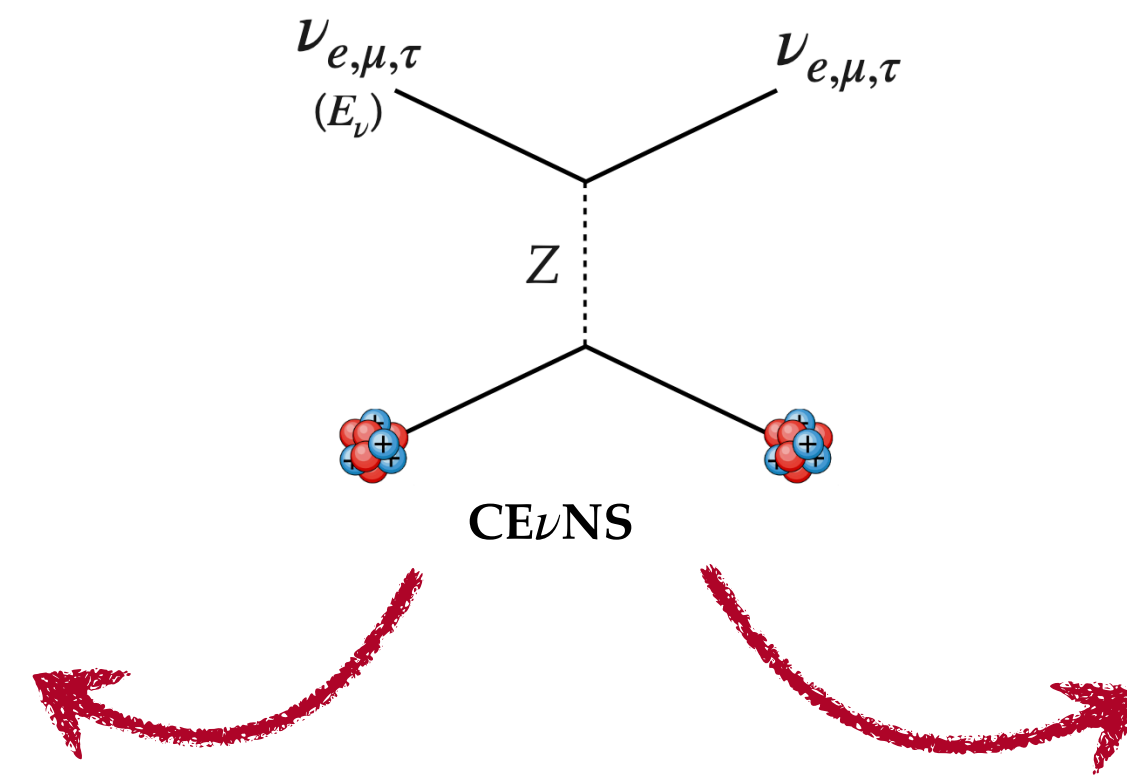
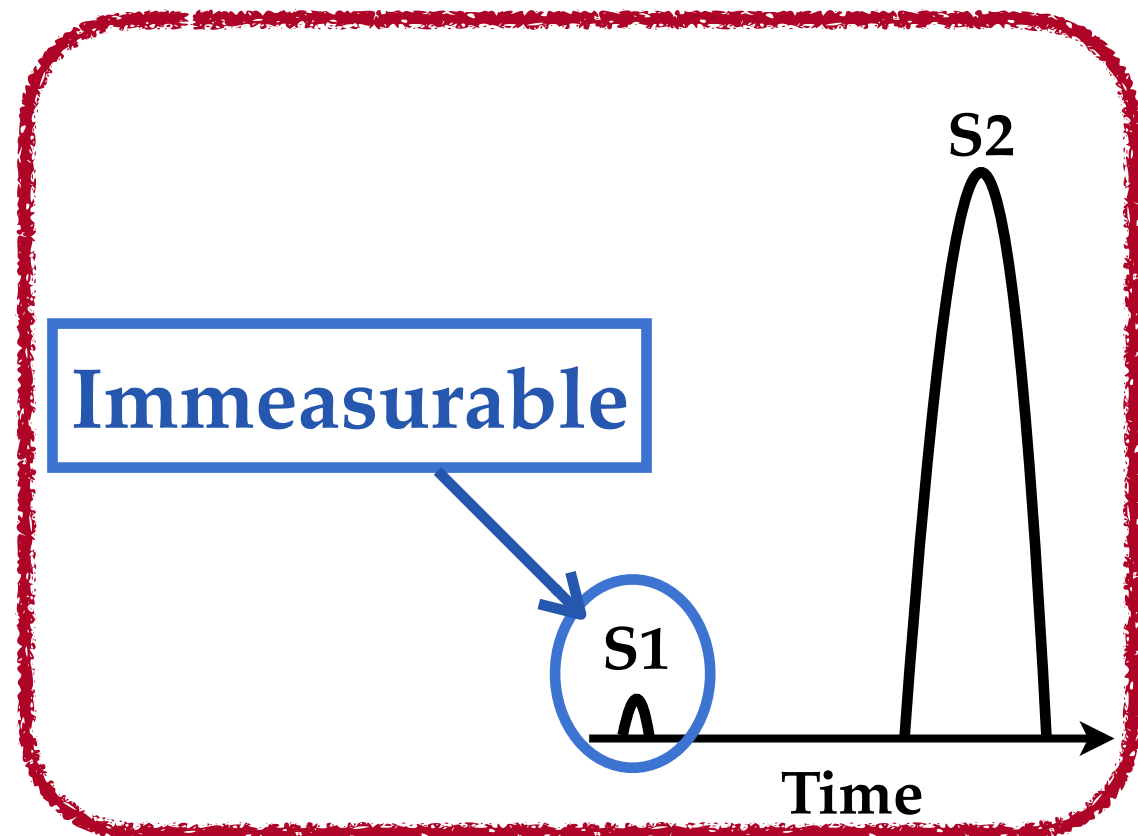
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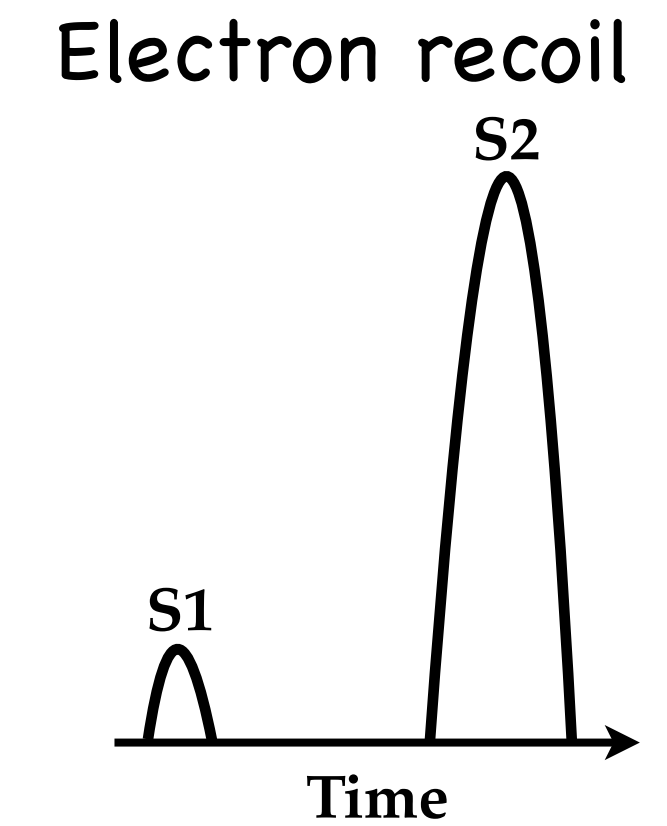
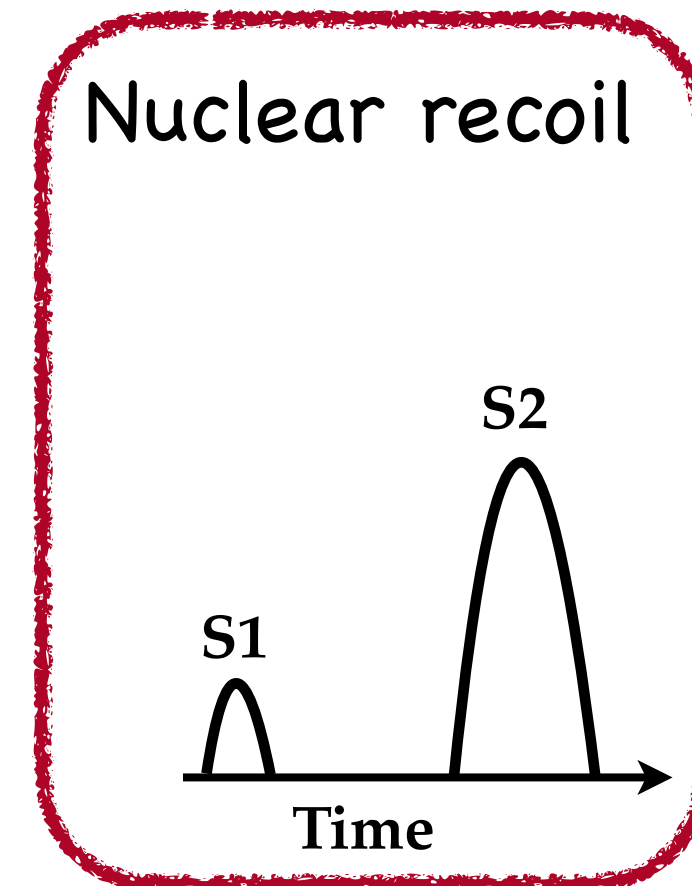
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S2 only analysis



S1-S2 only analysis



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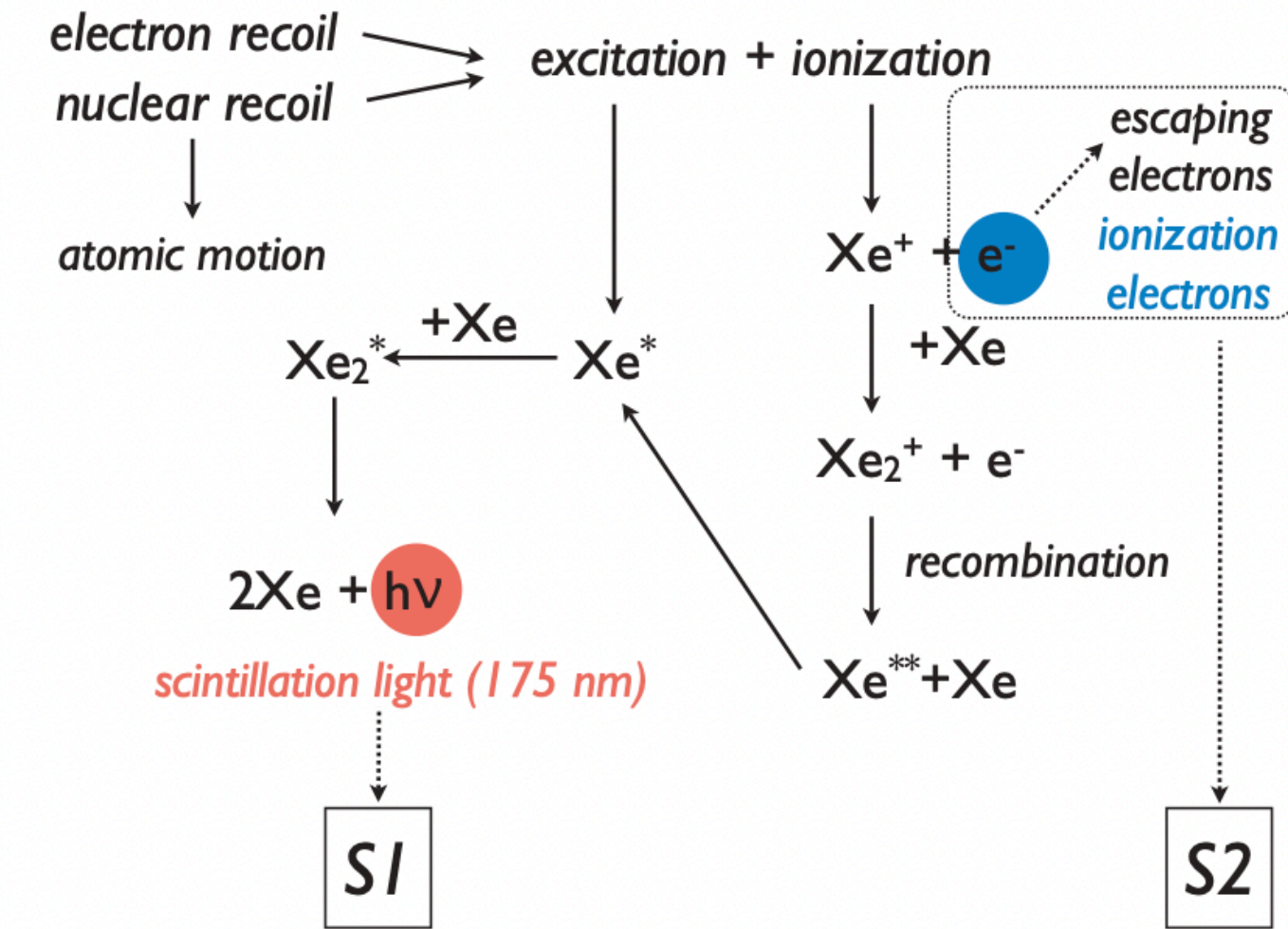
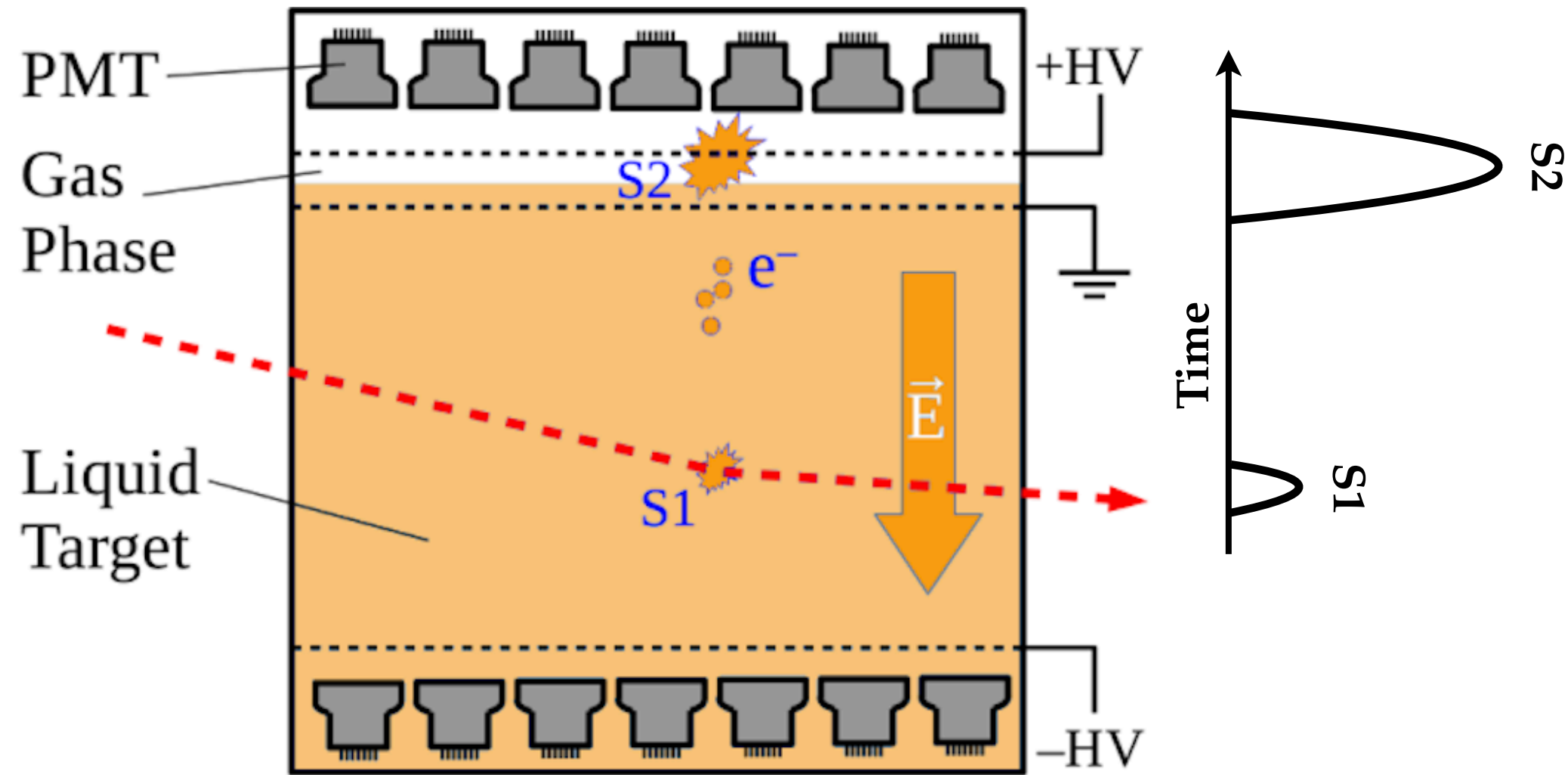
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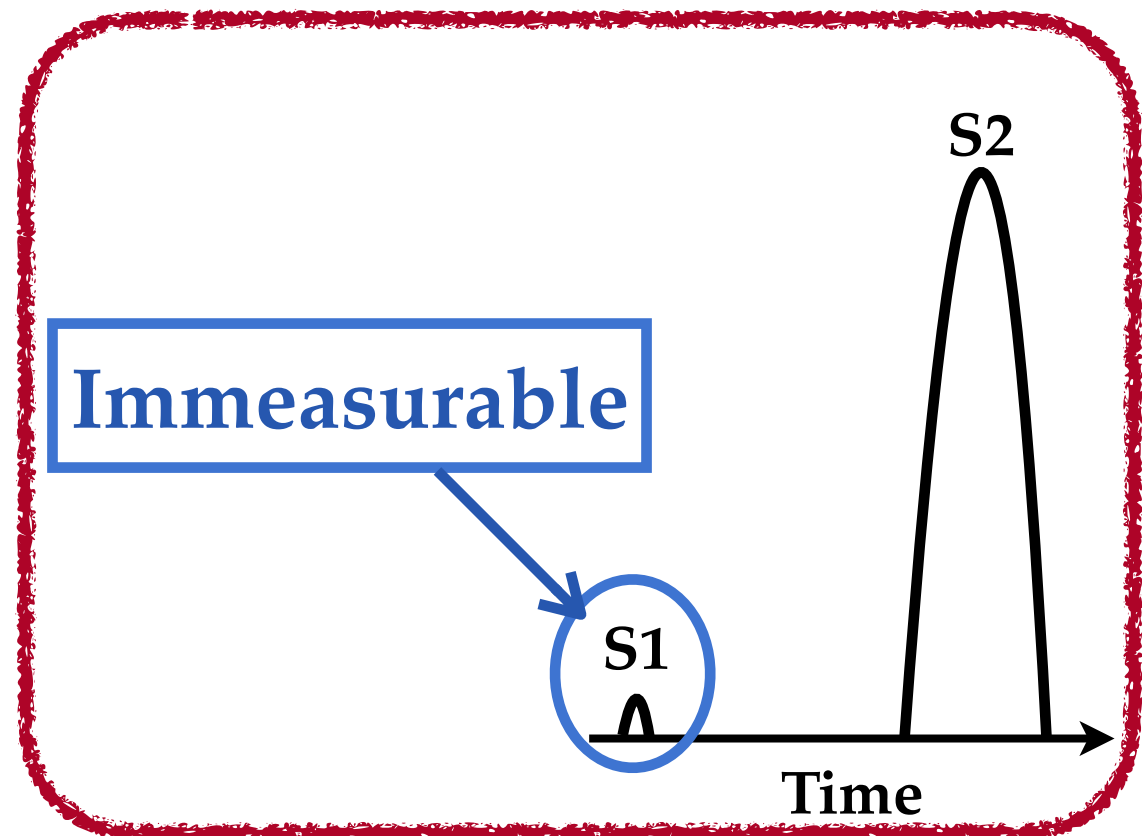


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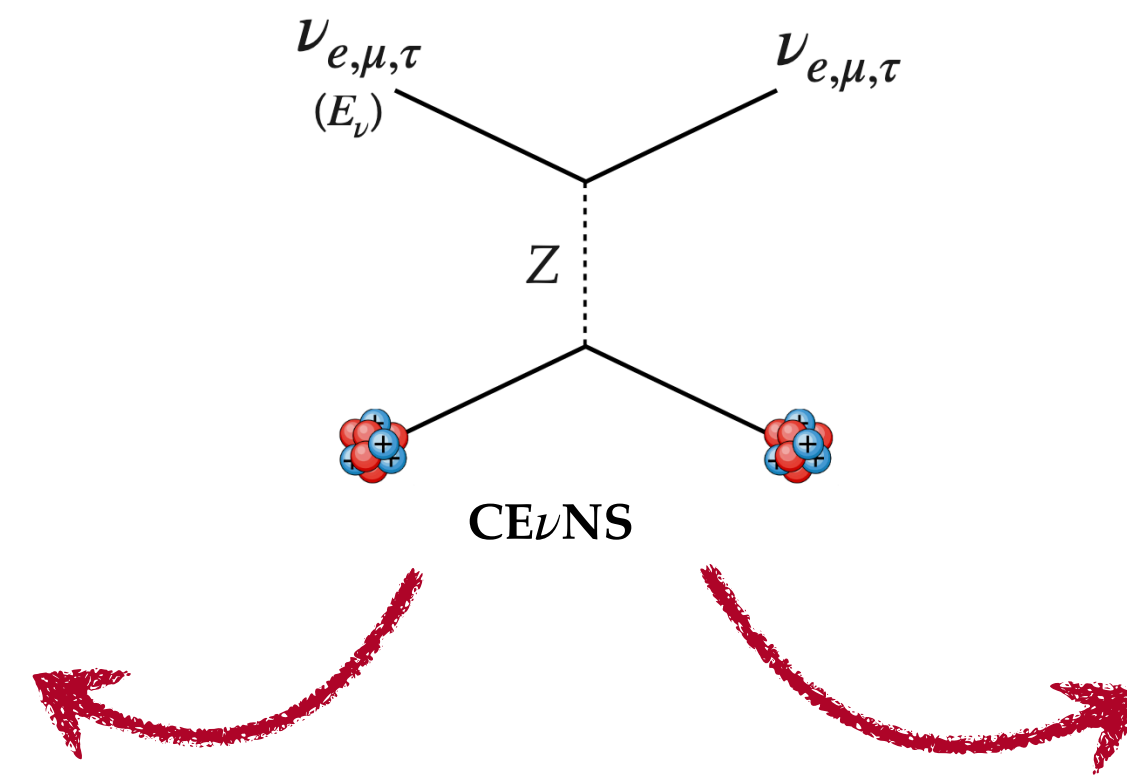
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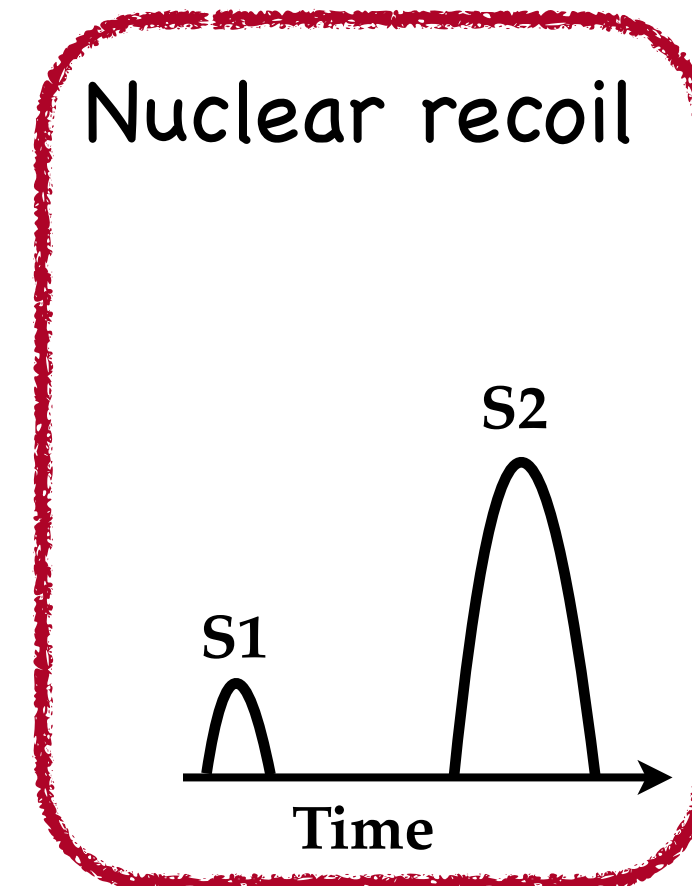
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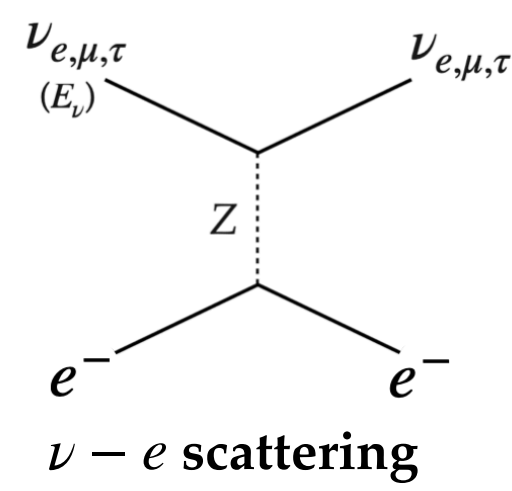
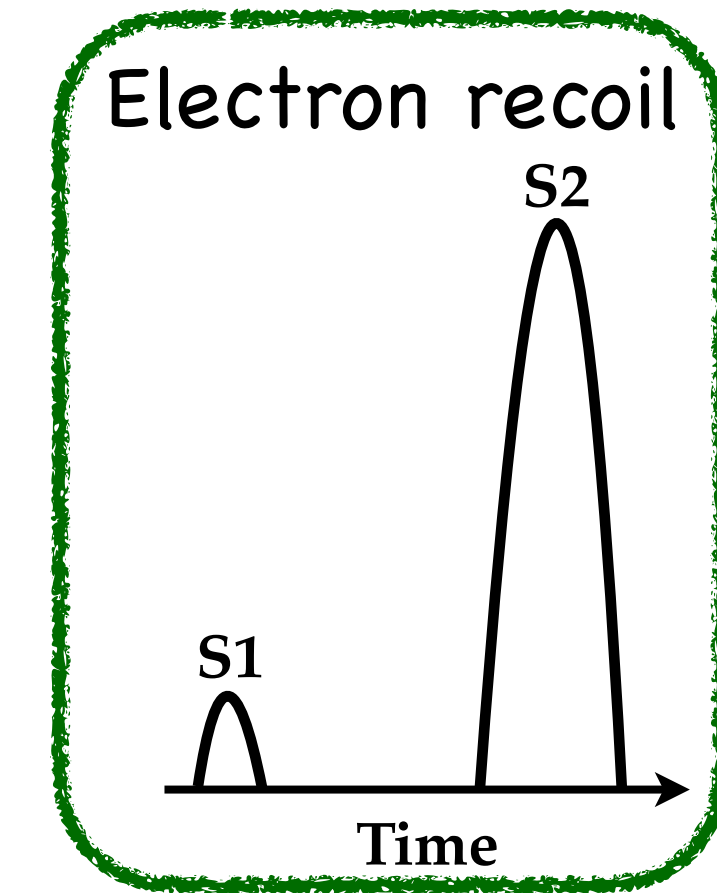
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**S1-S2 only analysis**



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# Neutrino events at DD? nuclear recoil

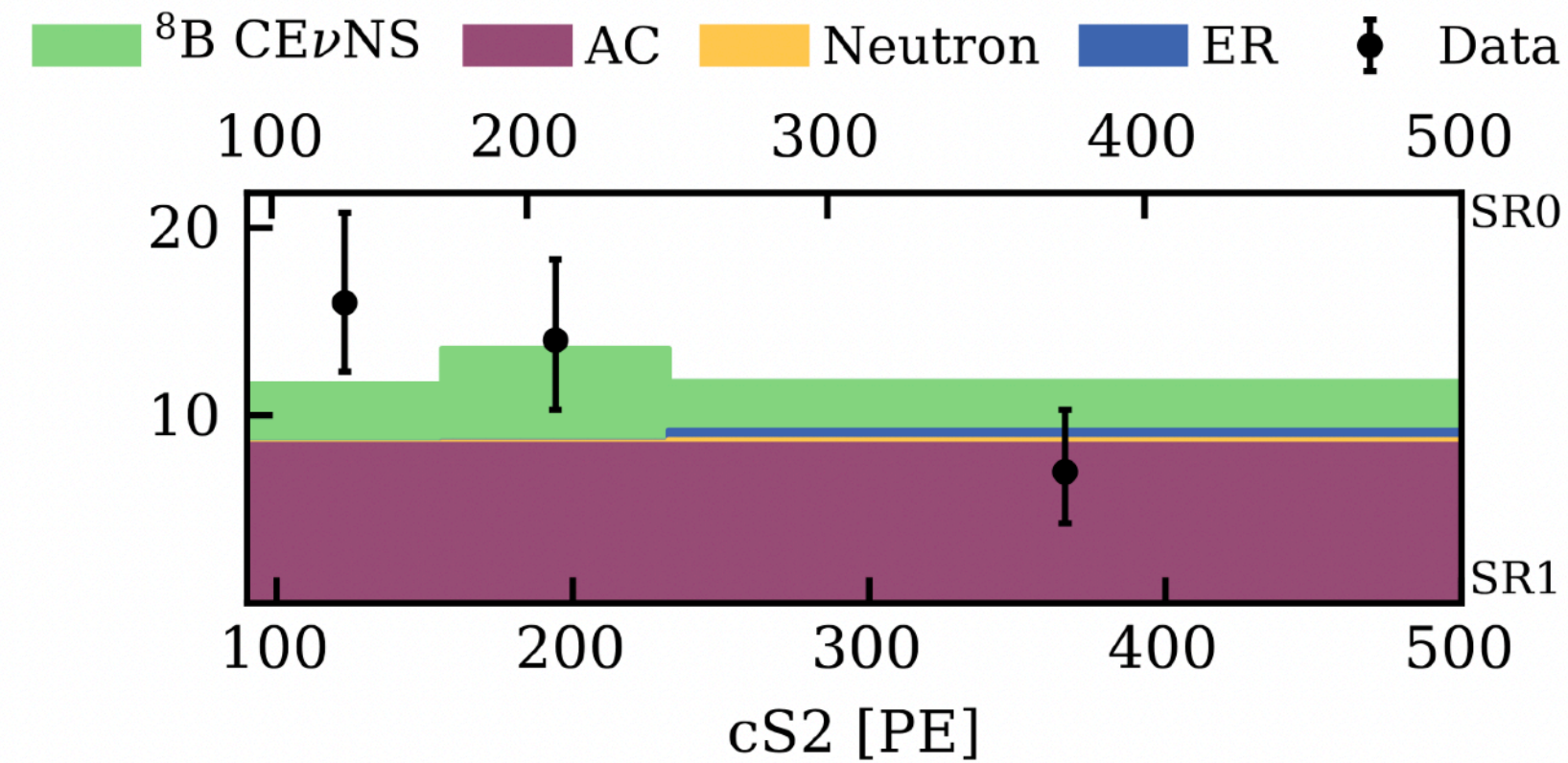
## XENONnT

arXiv > nucl-ex > arXiv:2408.02877

Nuclear Experiment

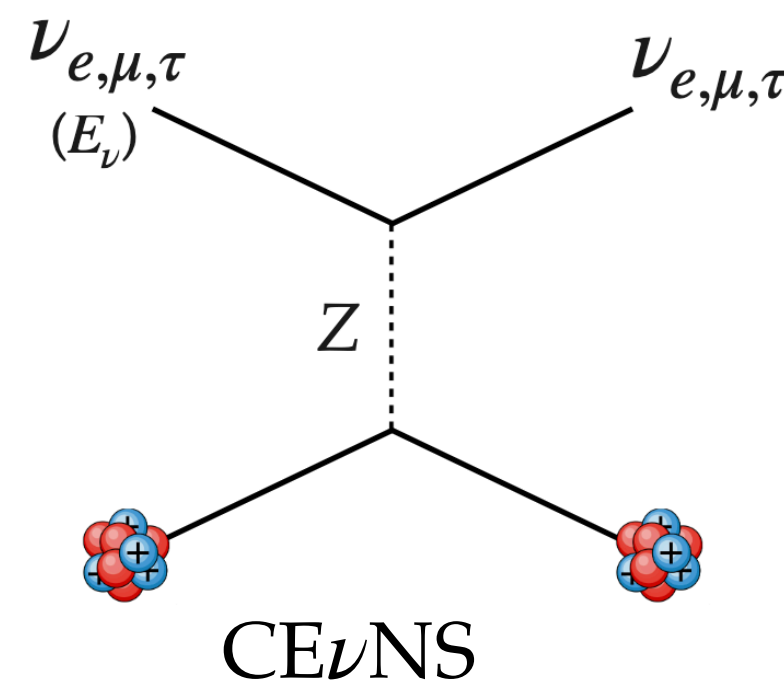
[Submitted on 6 Aug 2024]

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



Observed events:  $10.7^{+3.7}_{-4.2}$  (S1-S2 analysis)

Statistical significance:  $2.73 \sigma$



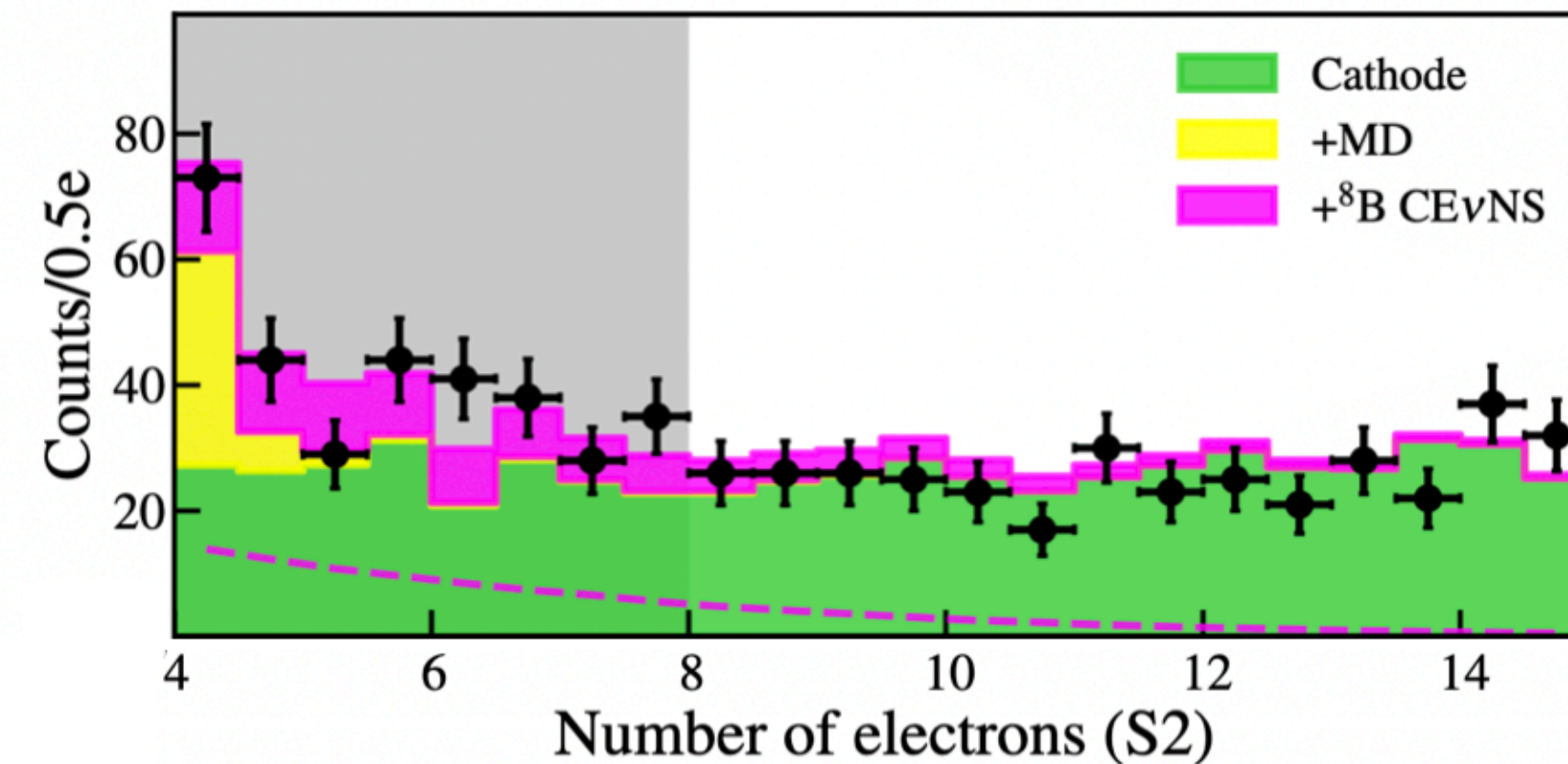
## PandaX-4T

arXiv > hep-ex > arXiv:2407.10892

High Energy Physics - Experiment

[Submitted on 15 Jul 2024 (v1), last revised 13 Sep 2024 (this version, v3)]

First Indication of Solar  $^8\text{B}$  Neutrino Flux through Coherent Elastic Neutrino-Nucleus Scattering in PandaX-4T



Observed events:  $3.5 \pm 1.3$  (S1-S2 analysis)

Observed events:  $78 \pm 28$  (S2-only analysis)

Statistical significance:  $2.64 \sigma$



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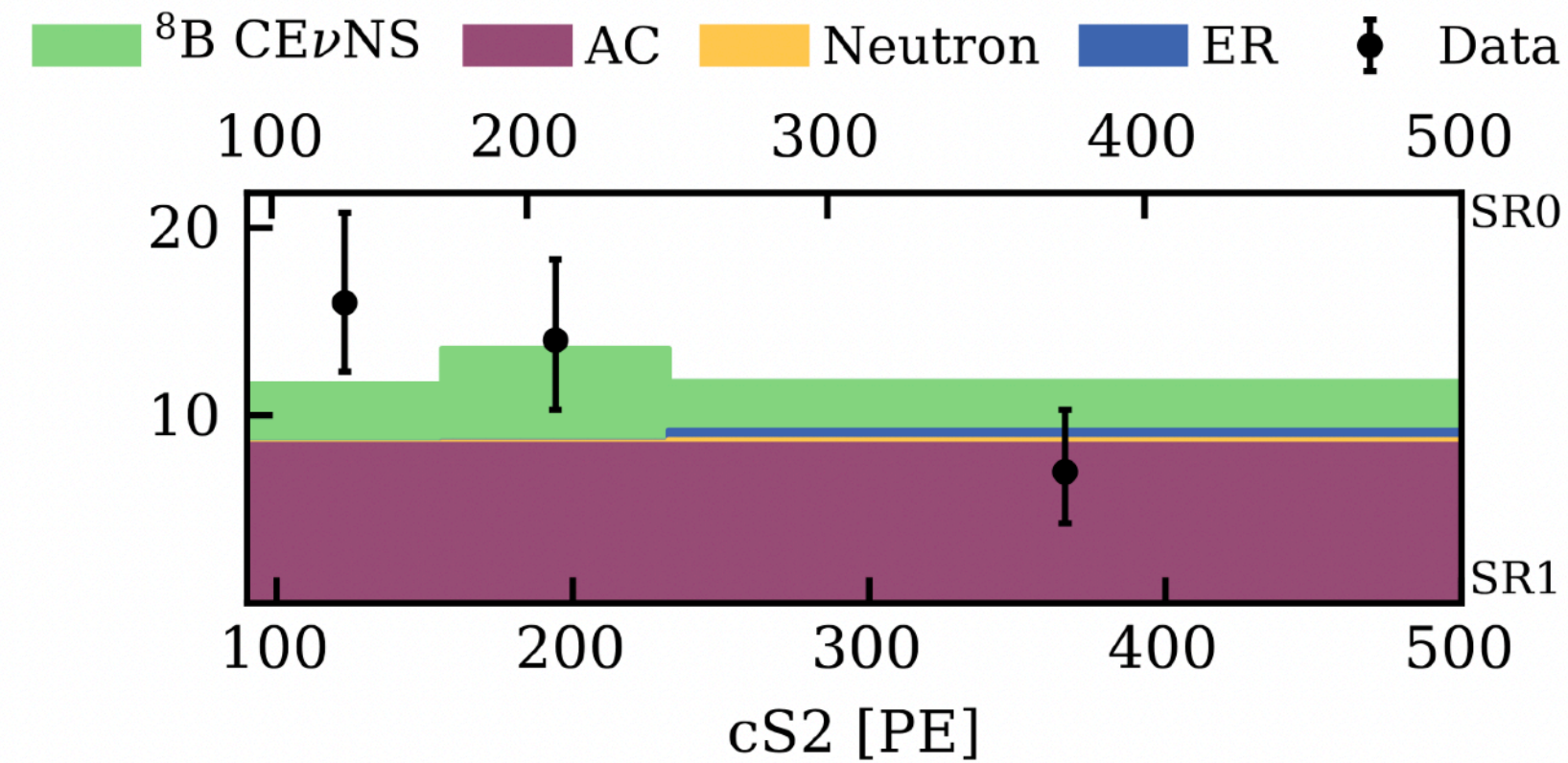
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Nuclear Experiment

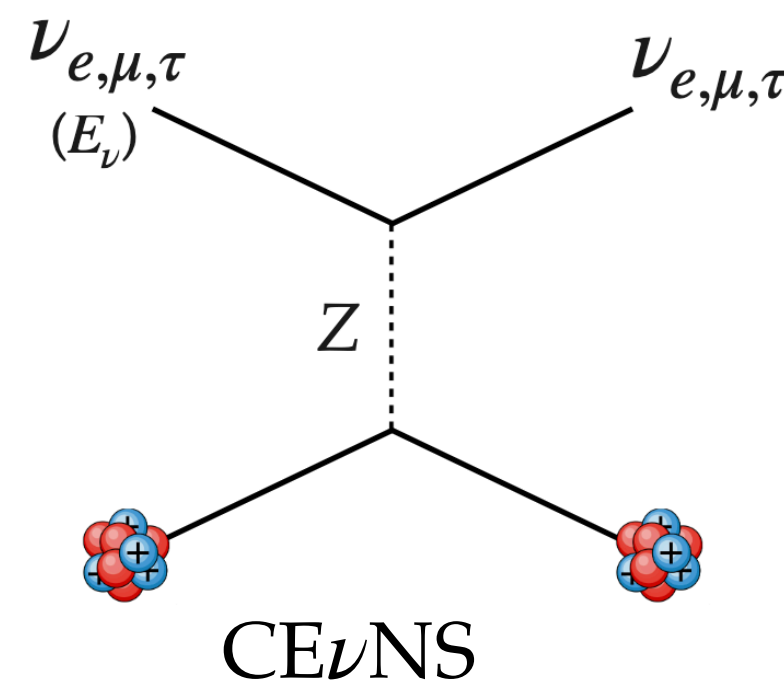
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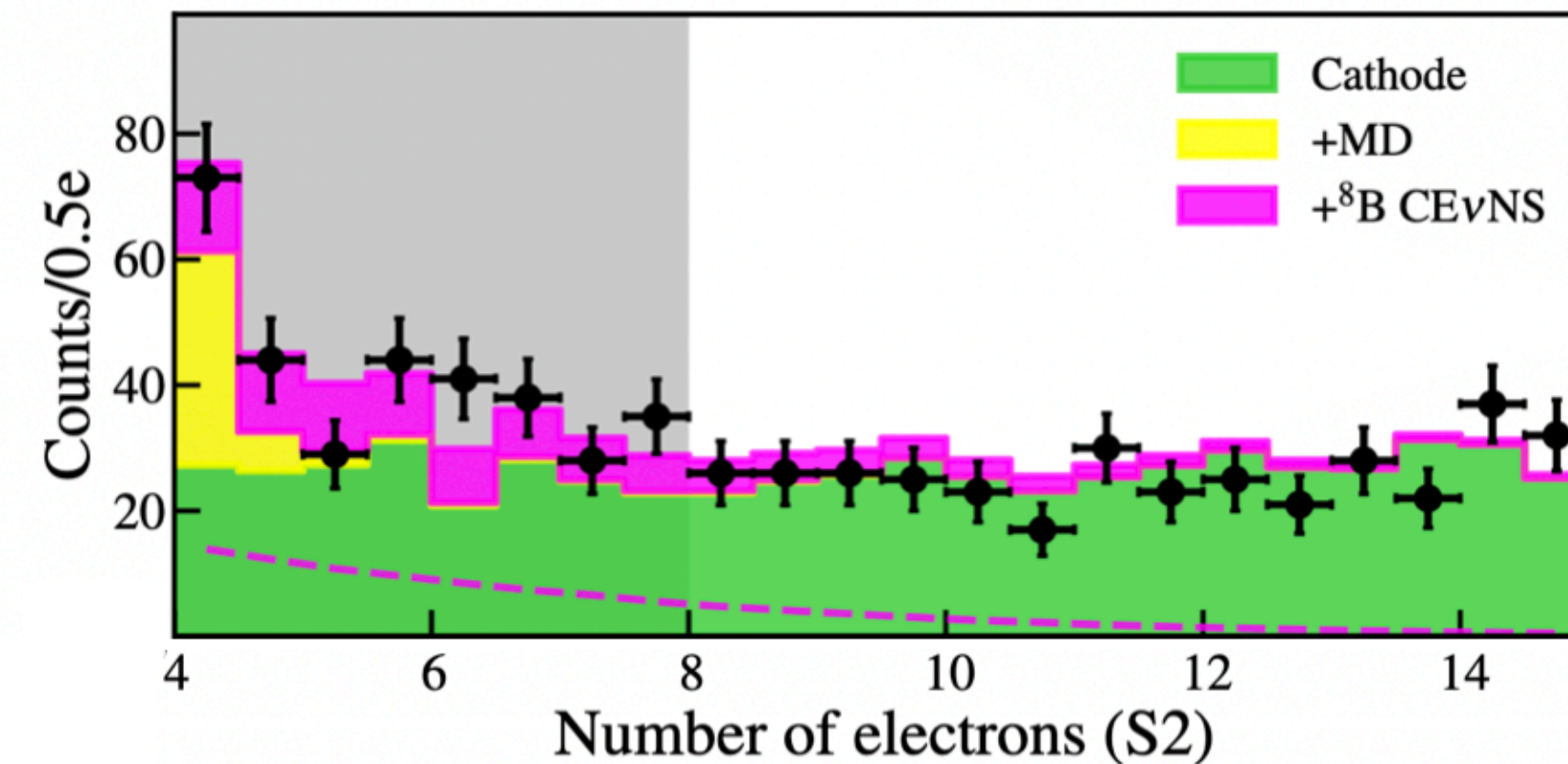
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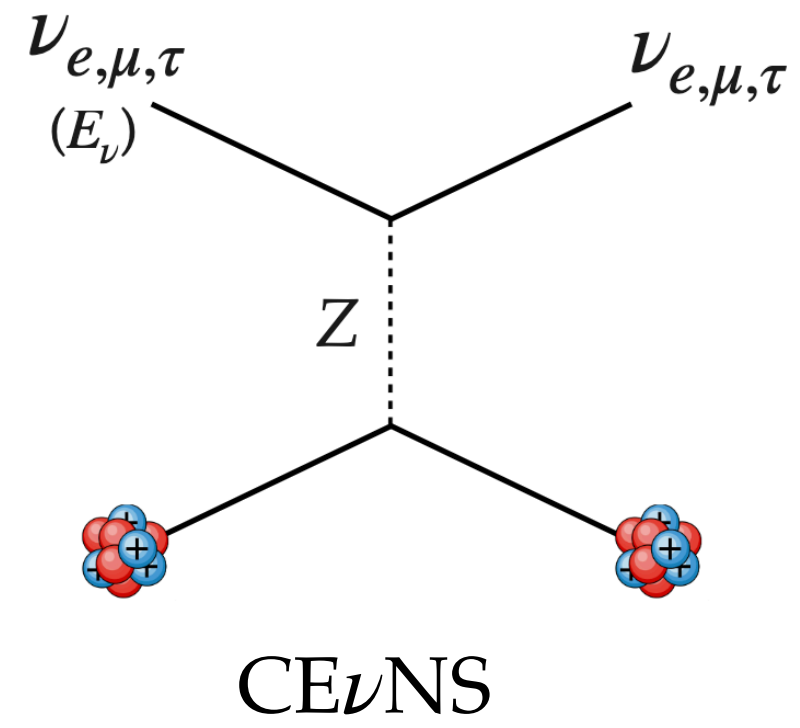
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Observing essentially the Standard Model process, can we say something new?

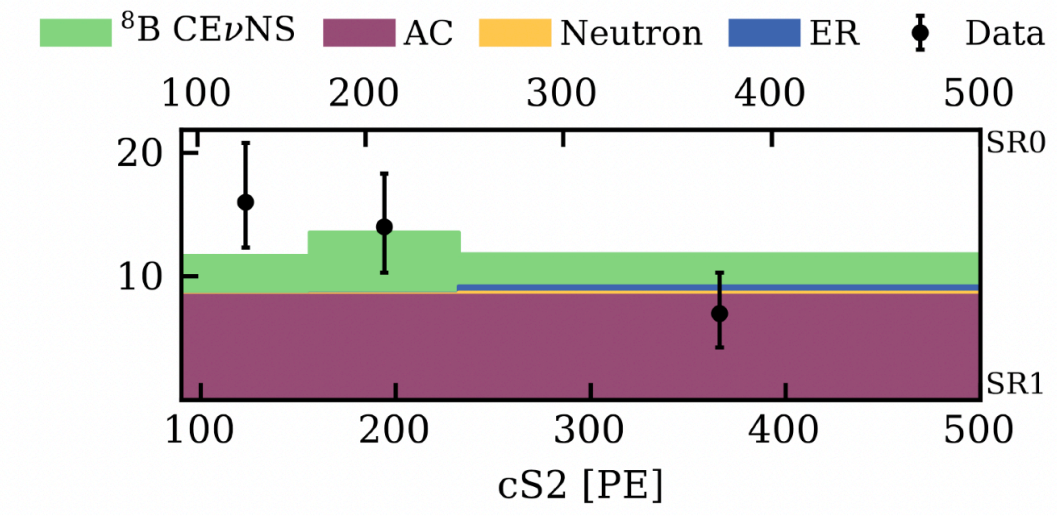


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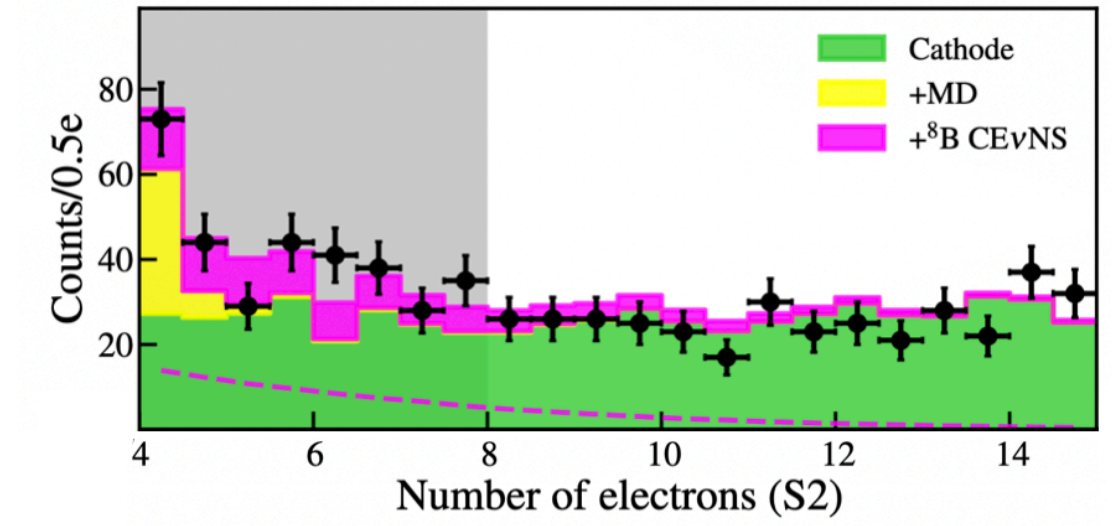


$$\frac{d\sigma}{dE_N} \propto f(\sin^2 \theta_W)$$

XENONnT

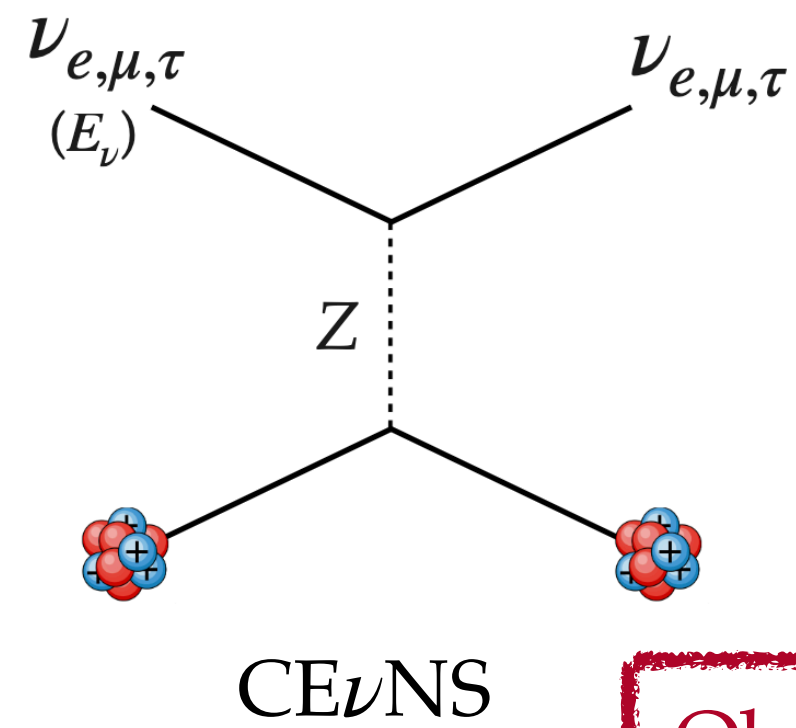


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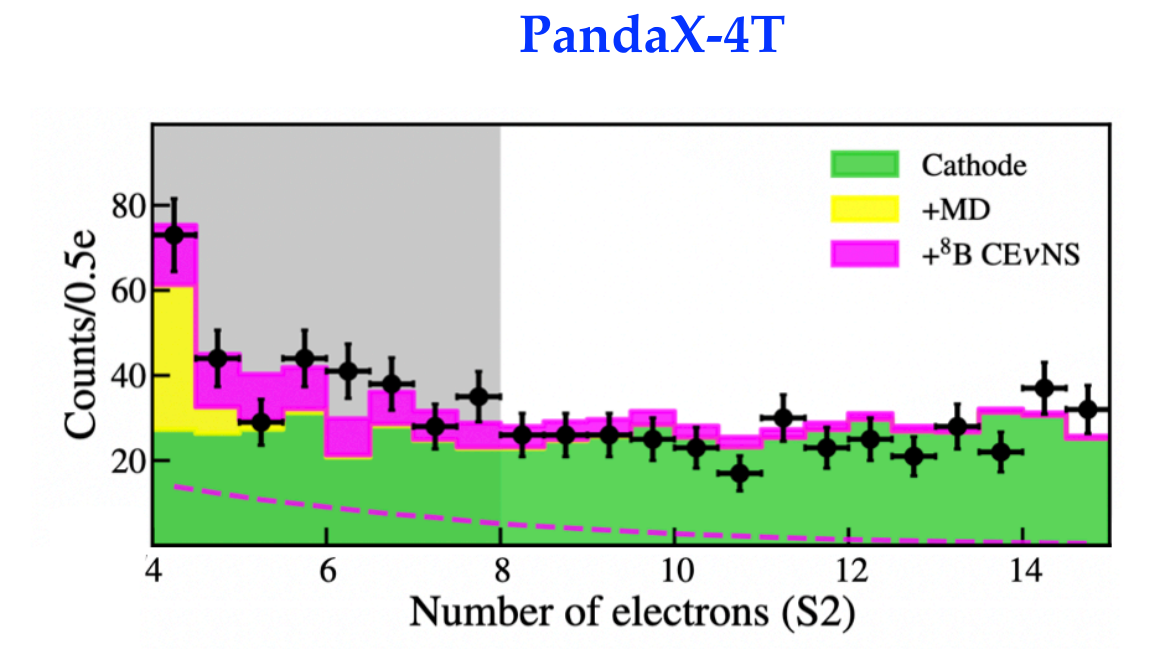
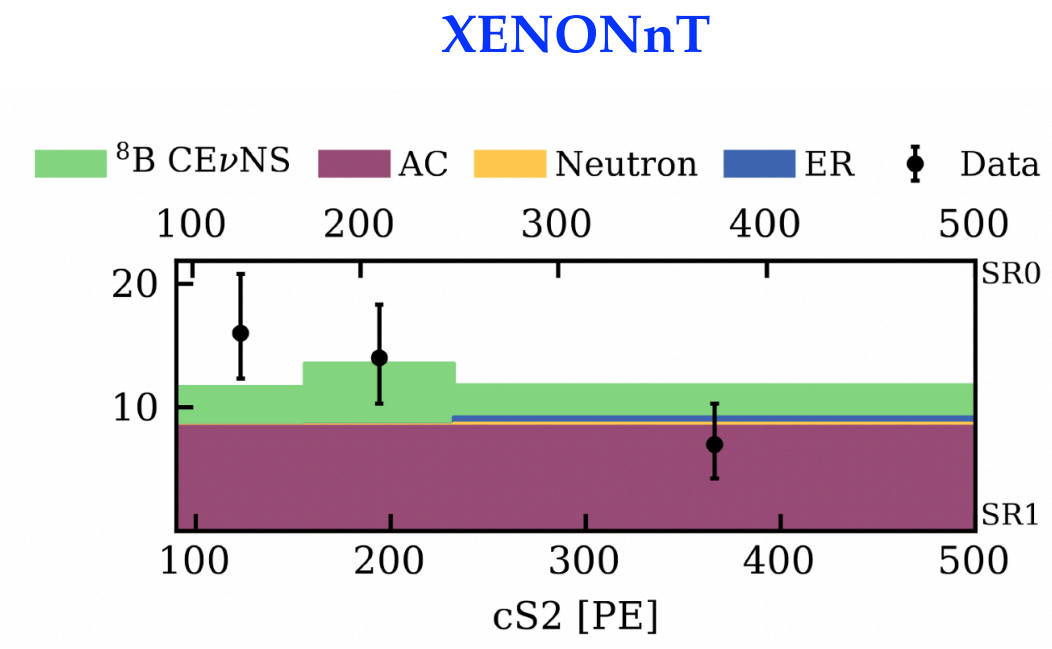


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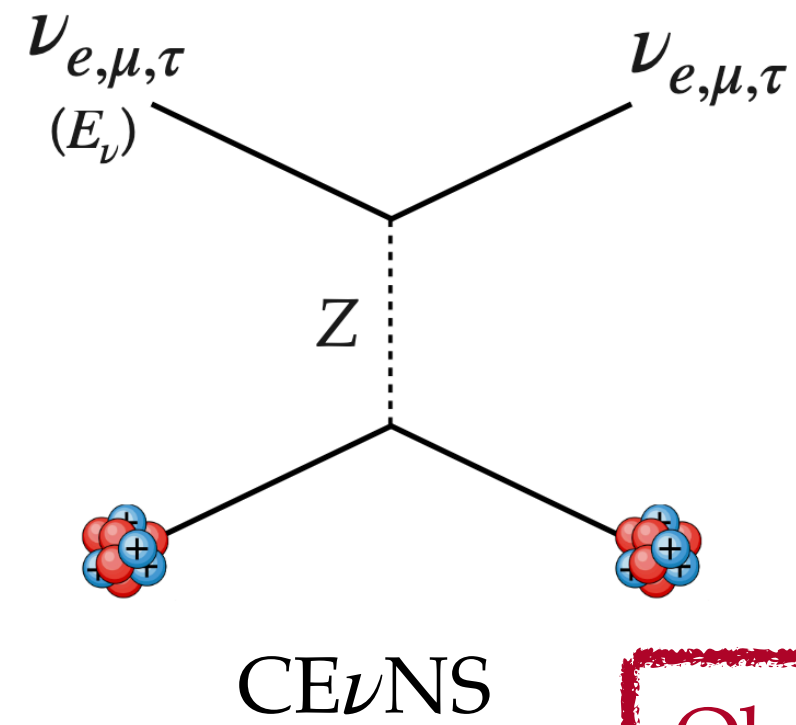
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Observed solar  $^8\text{B}$  events depends on  $\sin^2 \theta_W$



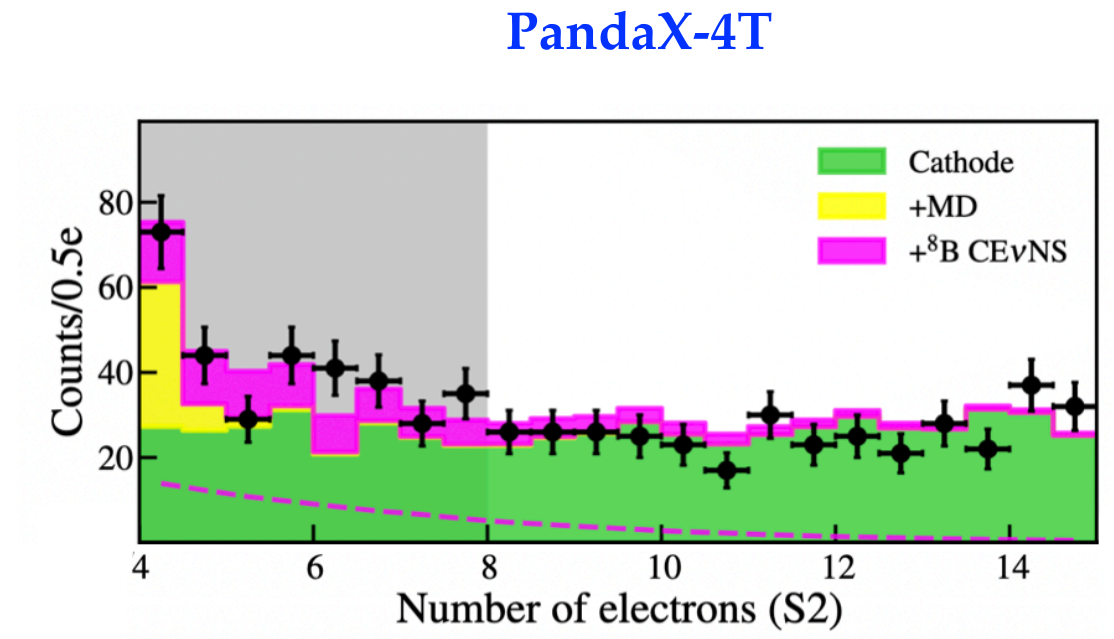
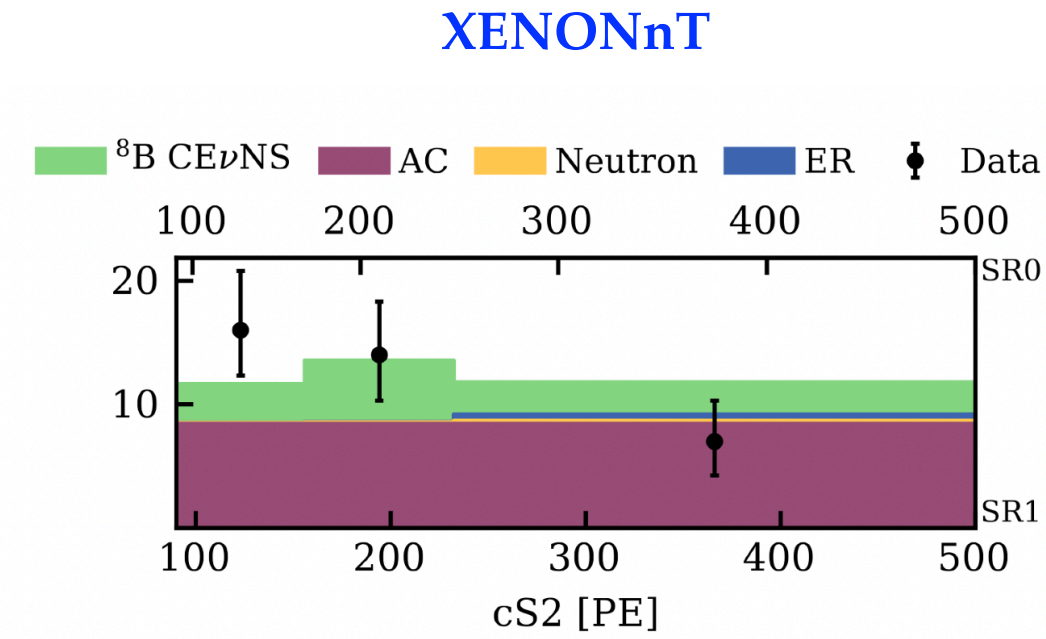
→ One can measure  $\sin^2 \theta_W$  using these data

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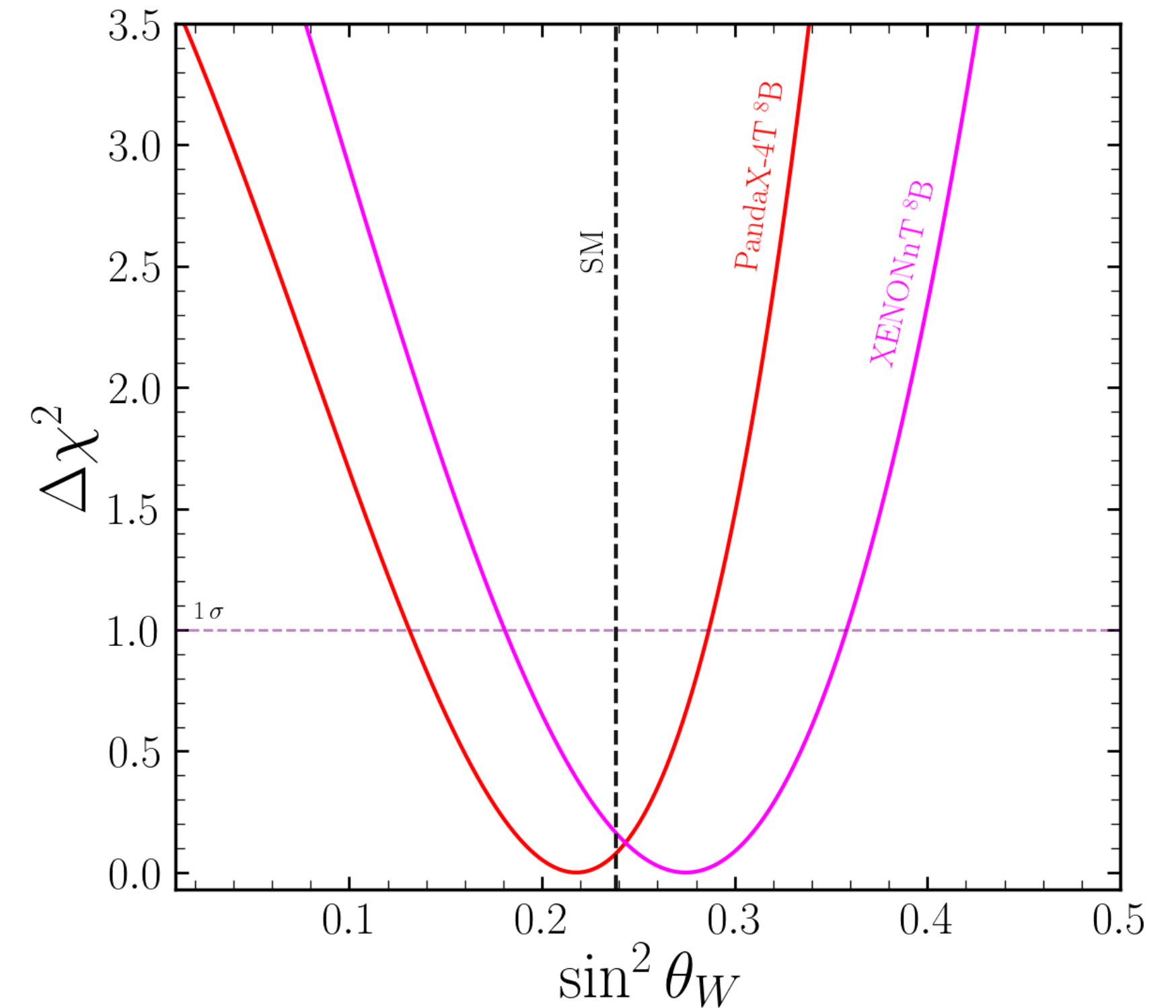


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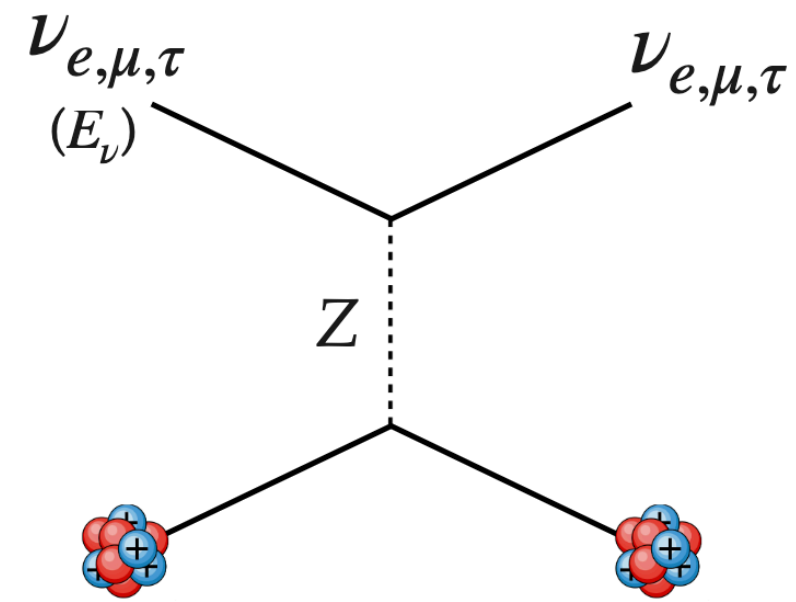


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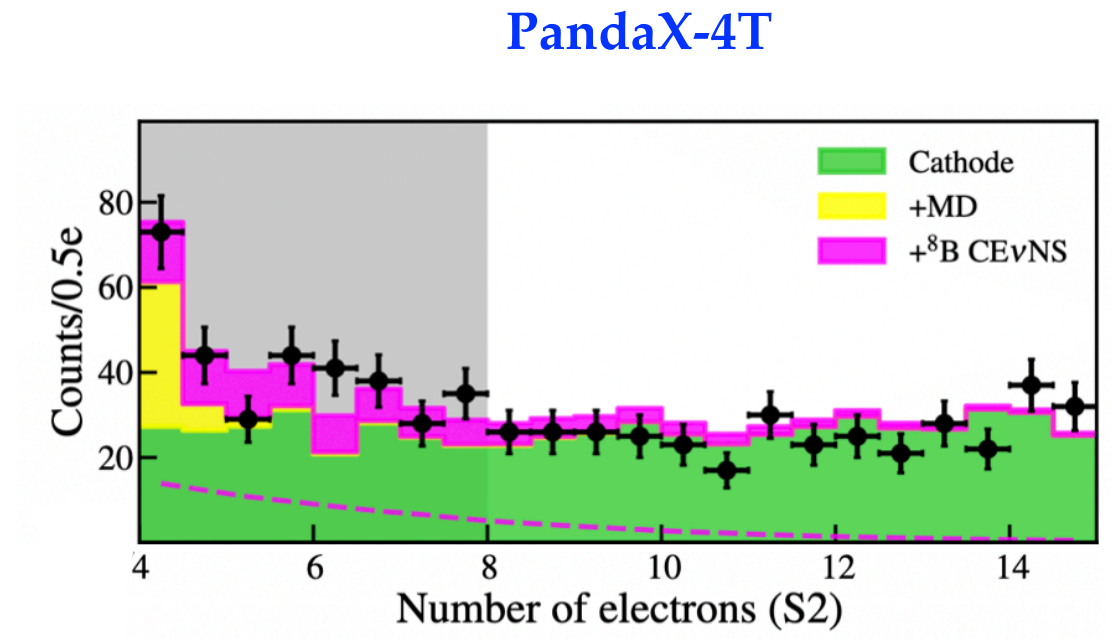
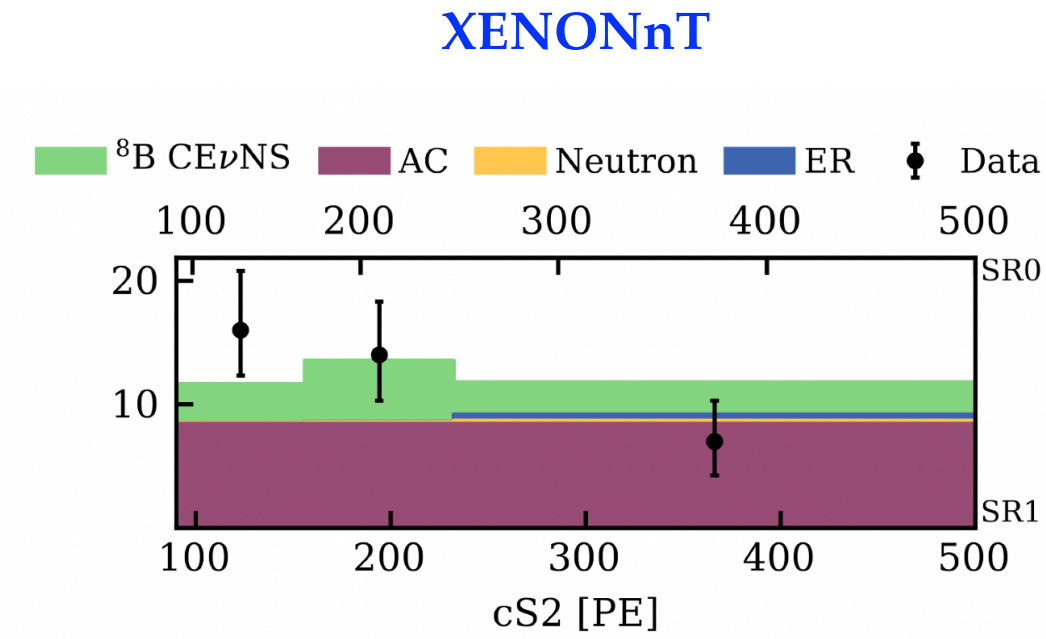
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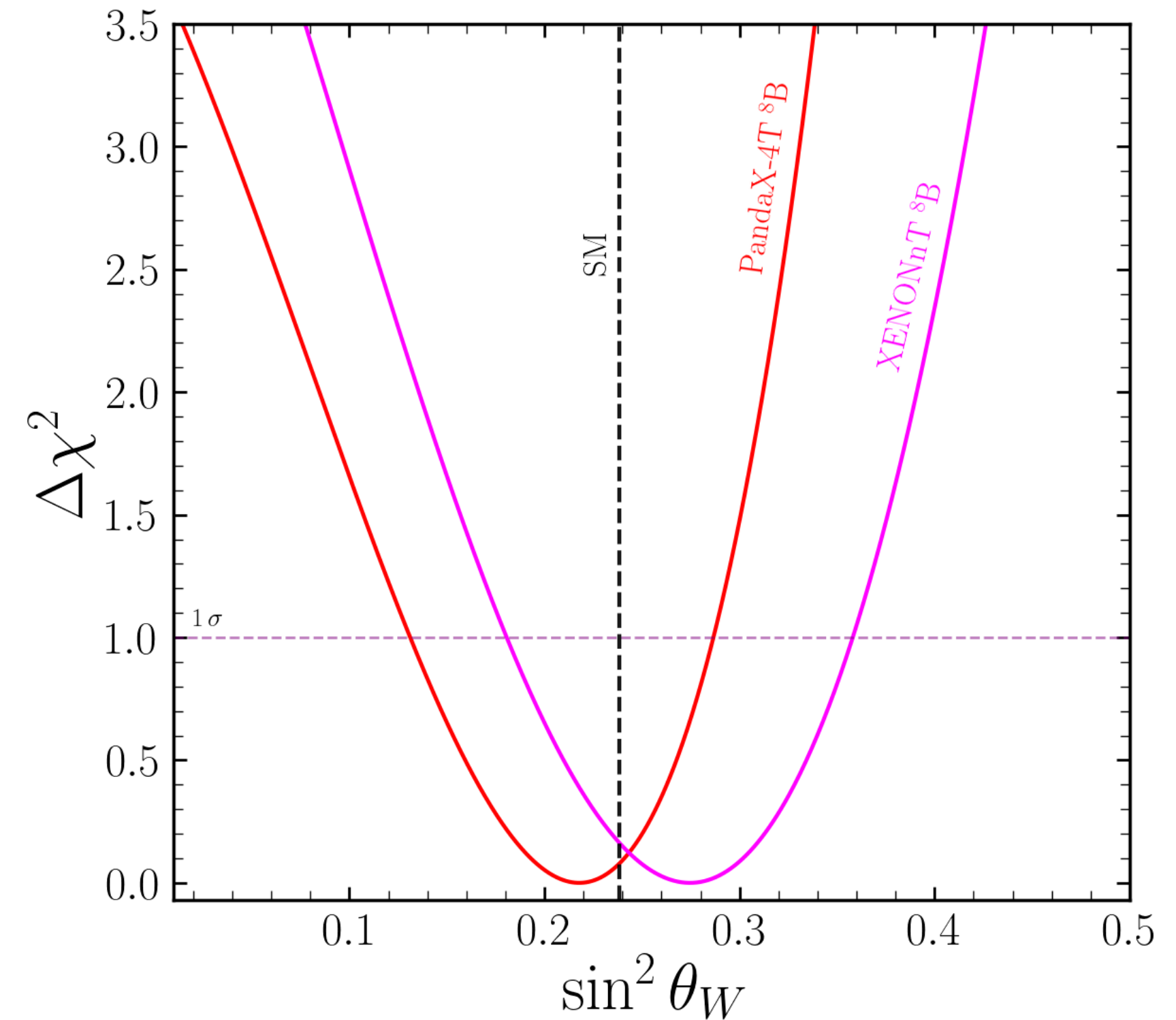
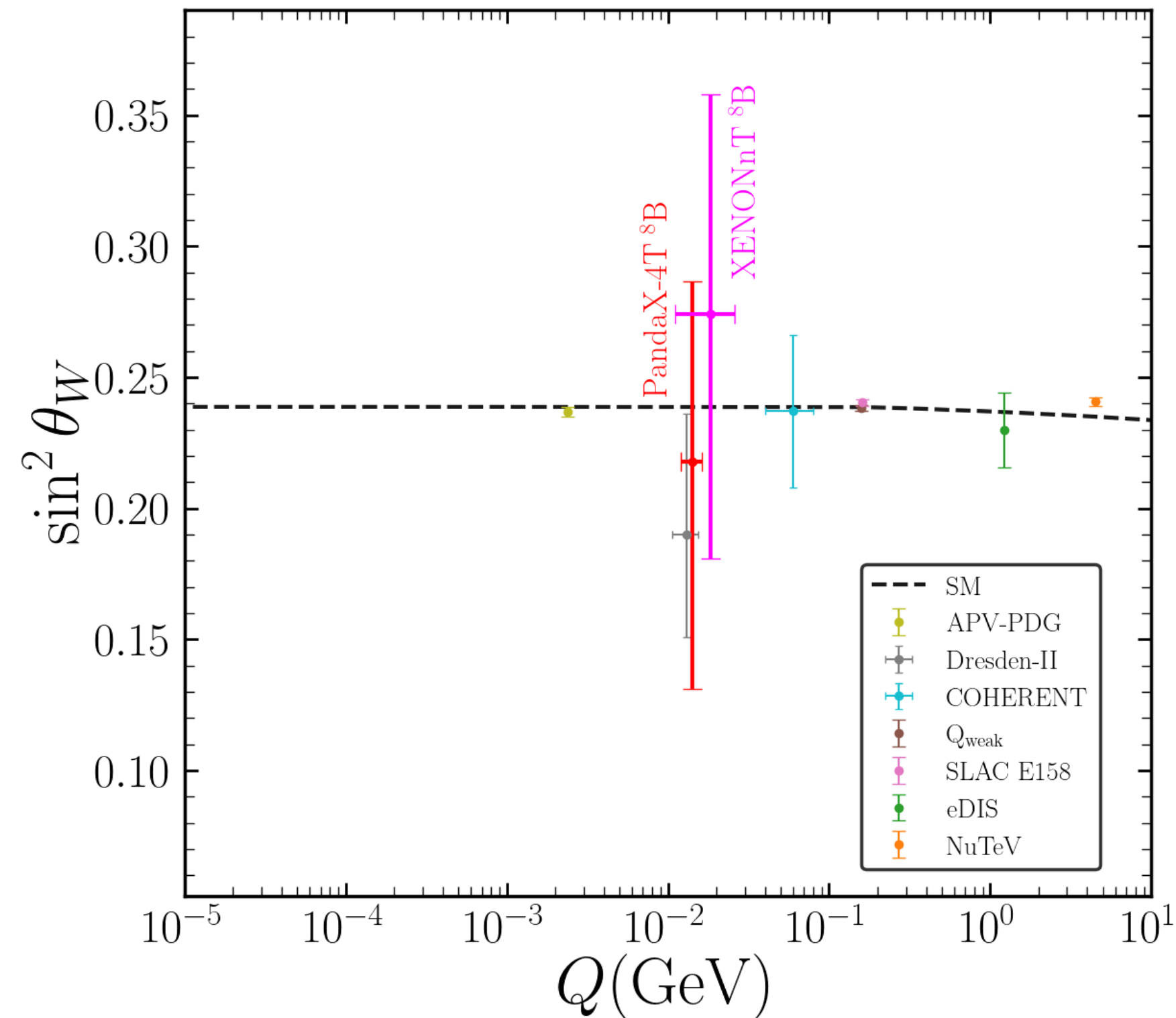
CEνNS

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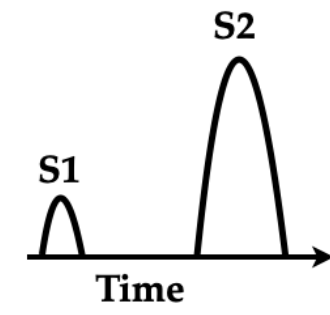


Energy scale determined from recoil energy regime

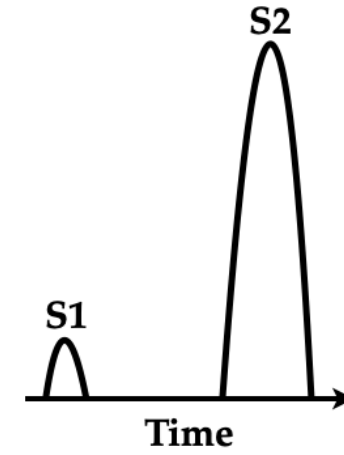
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S1-S2 only analysis

Nuclear recoil



Electron recoil



S2/S1 ratio - can distinguish - nuclear and electron recoil

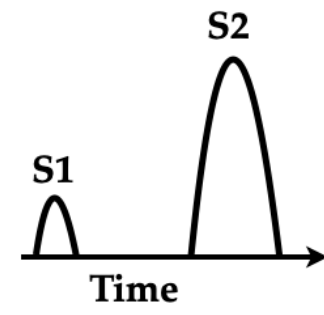
$$E_{\text{recoil}} \gtrsim 0.5 \text{ keV}$$



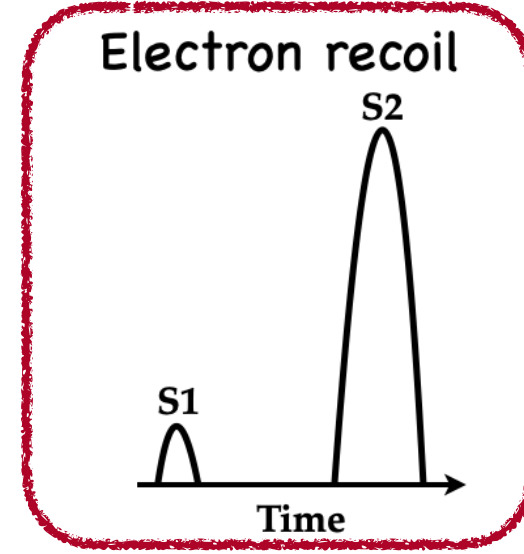
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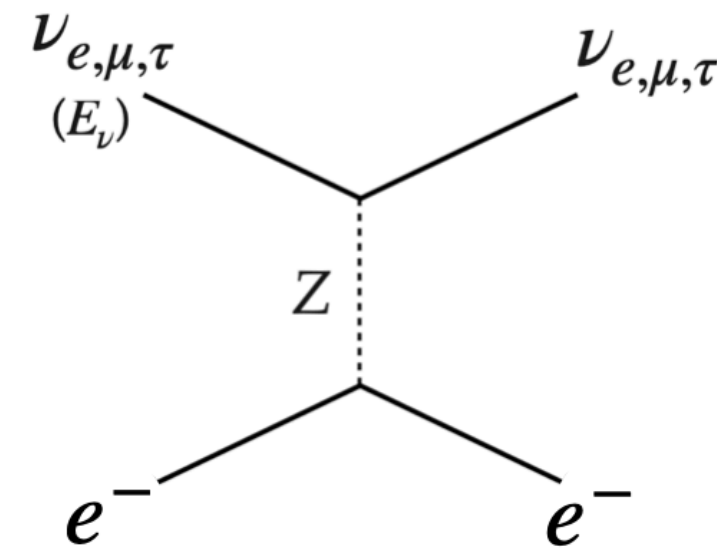


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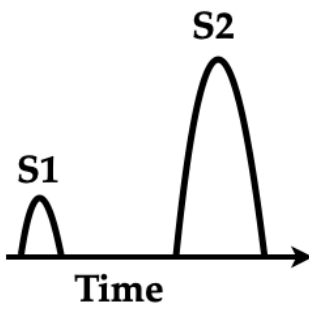


Neutrino-electron scattering

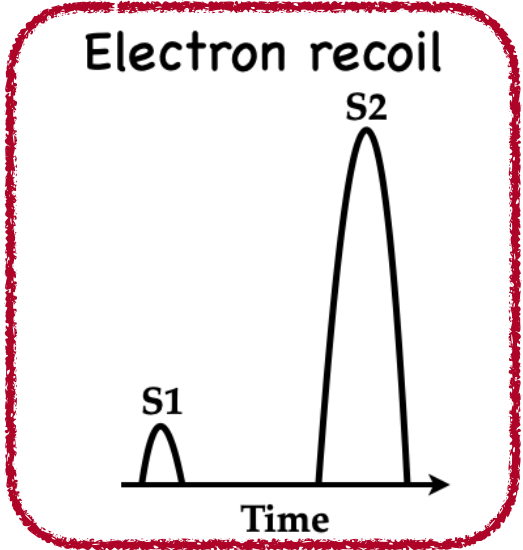
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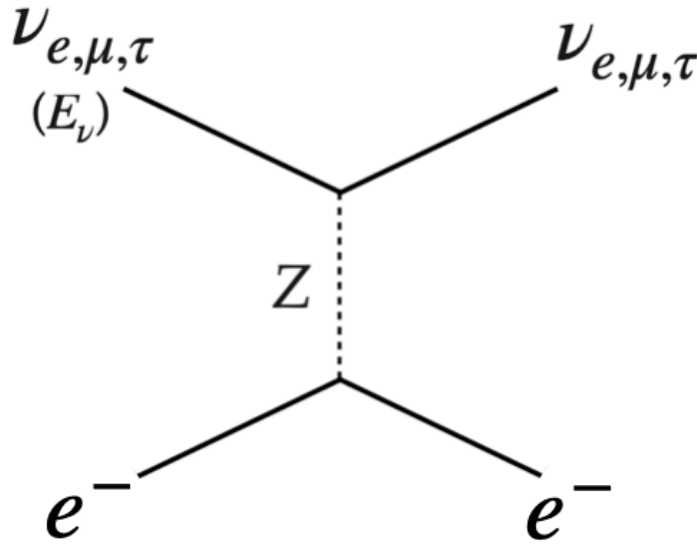


Electron recoil



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Neutrino-electron scattering

Observed  $\nu - e$  events:  $\sim 60$

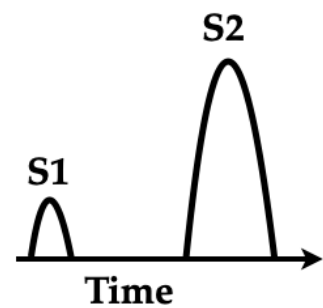
But statistically not significant due to huge background

- XENONnT 2207.11330
- LZ 2307.15753
- PandaX-4T 2408.07641

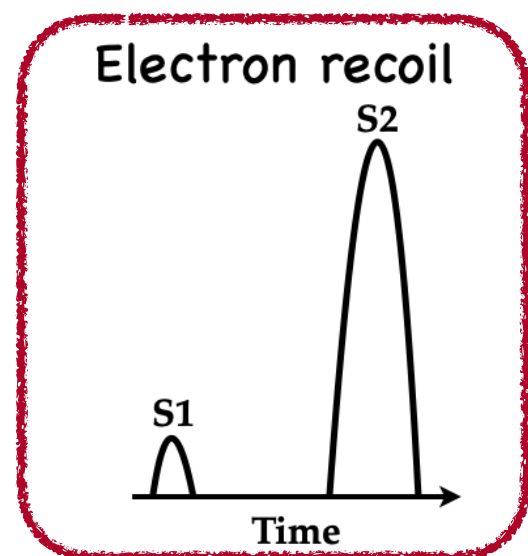
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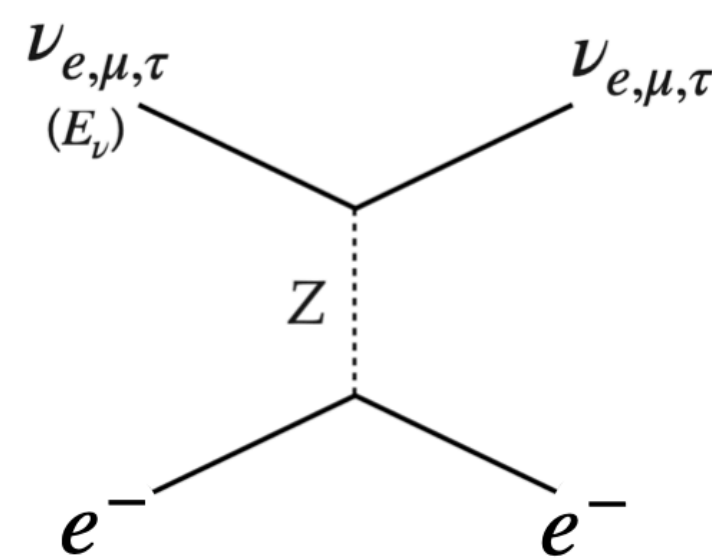


Electron recoil



S2/S1 ratio - can distinguish - nuclear and electron recoil

$$E_{\text{recoil}} \gtrsim 0.5 \text{ keV}$$



Neutrino-electron scattering

Observed  $\nu - e$  events:  $\sim 60$

But statistically not significant due to huge background

XENONnT 2207.11330

LZ 2307.15753

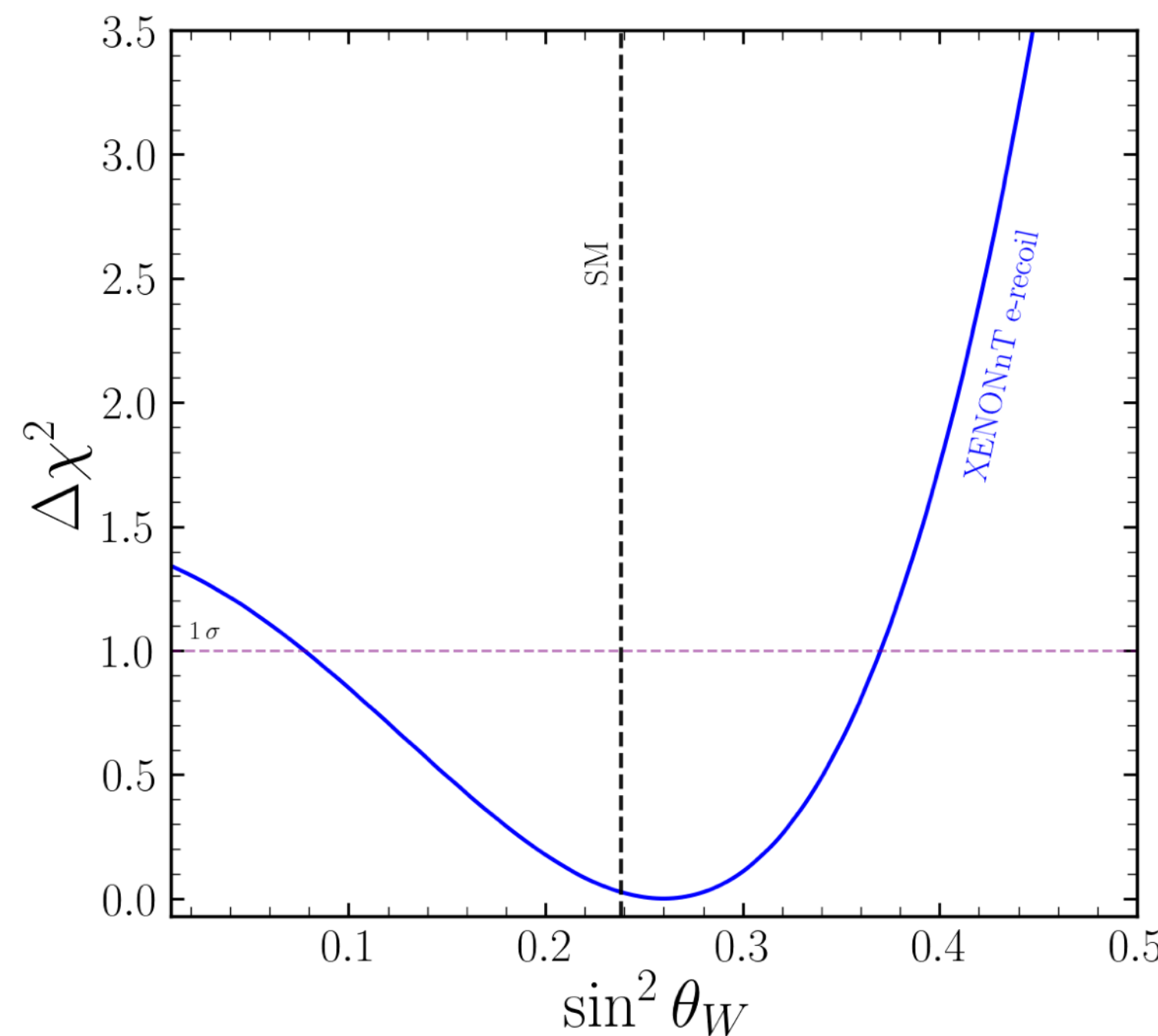
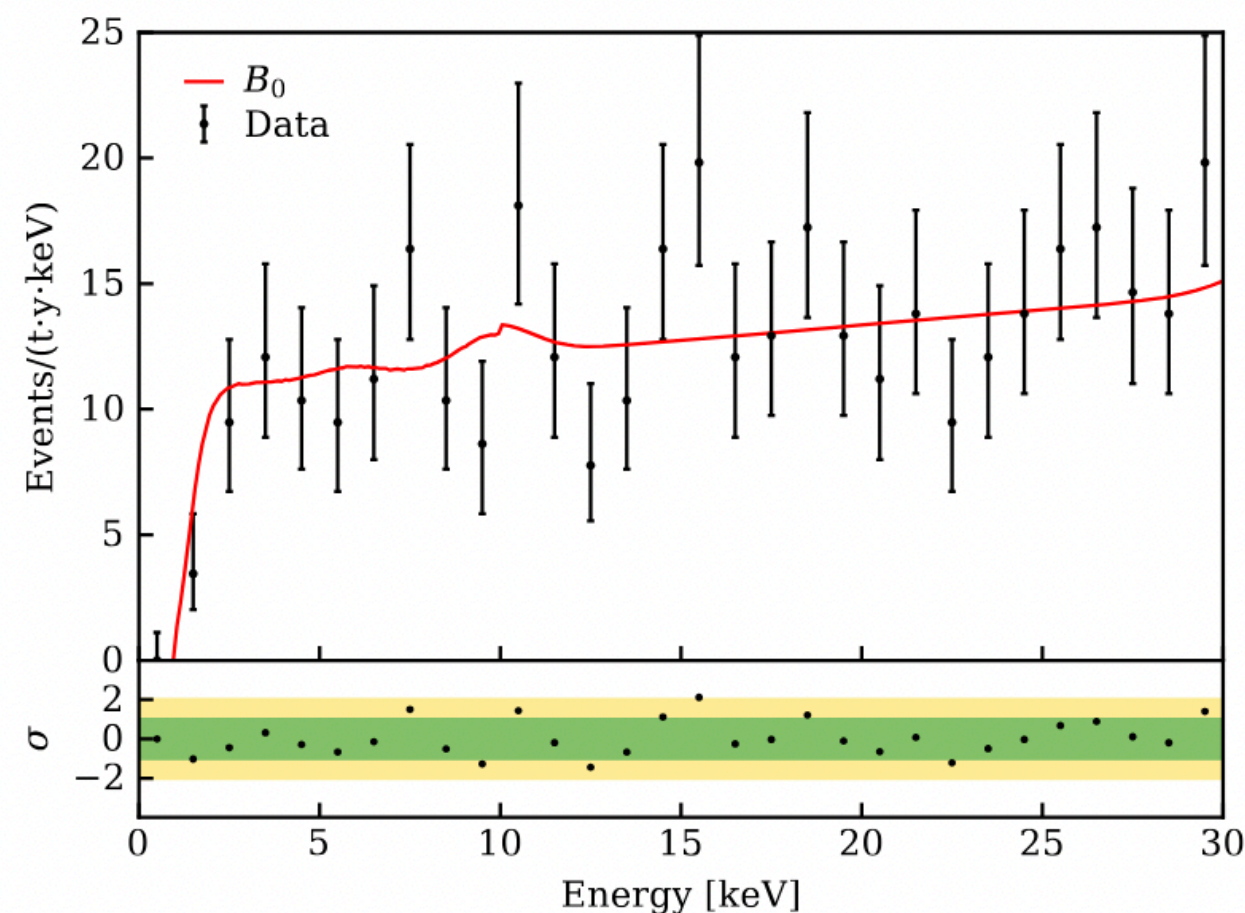
PandaX-4T 2408.07641

arXiv > hep-ex > arXiv:2207.11330

High Energy Physics - Experiment

[Submitted on 22 Jul 2022 (v1), last revised 15 Nov 2022 (this version, v2)]

Search for New Physics in Electronic Recoil Data from XENONnT



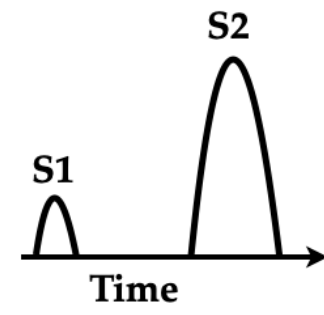
Only upper limits above  $1.16 \sigma$



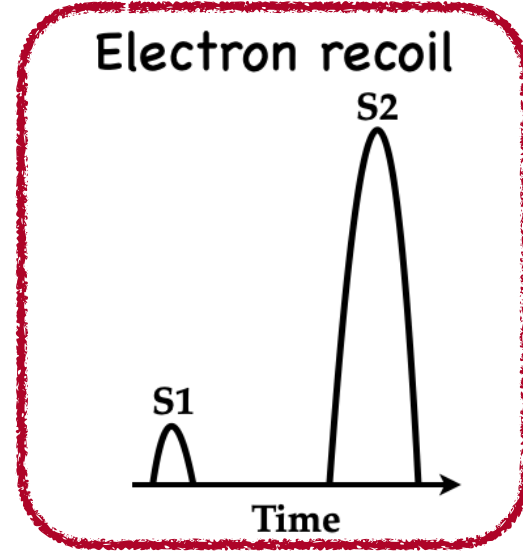
# Our results: electron recoil

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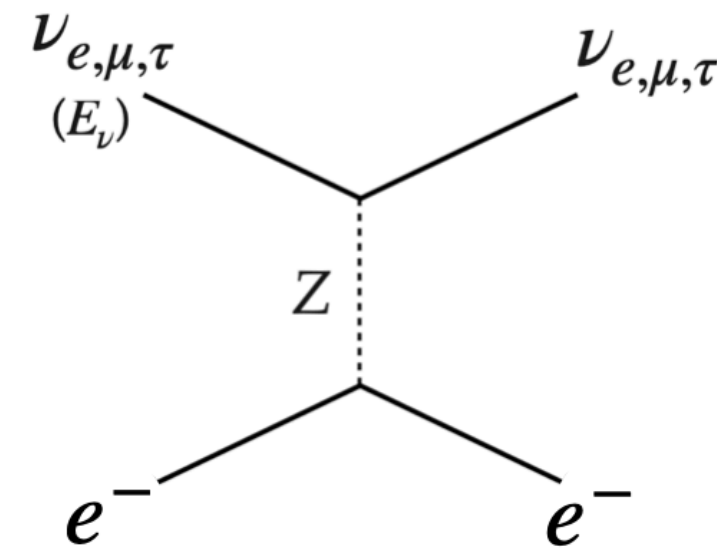


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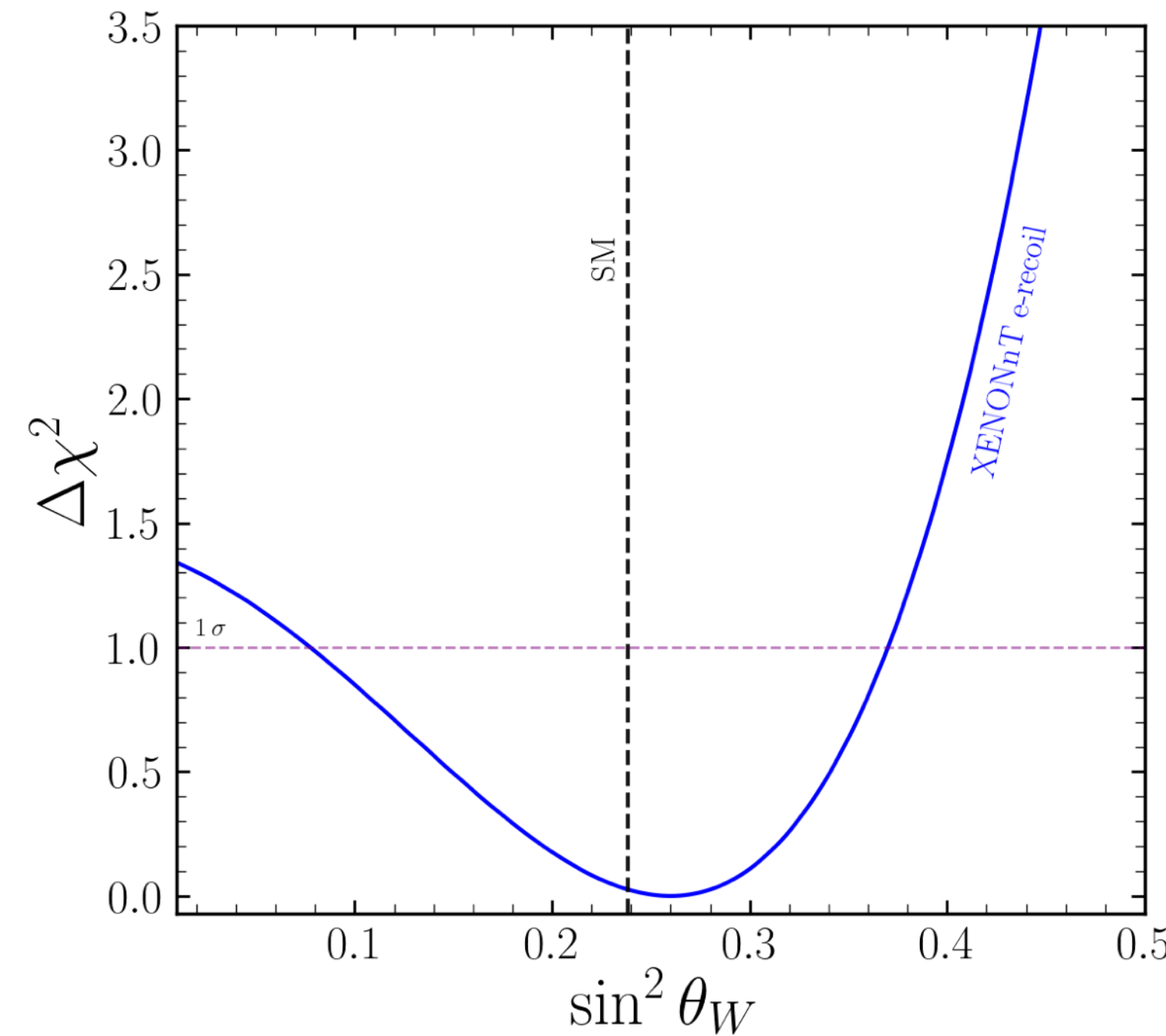
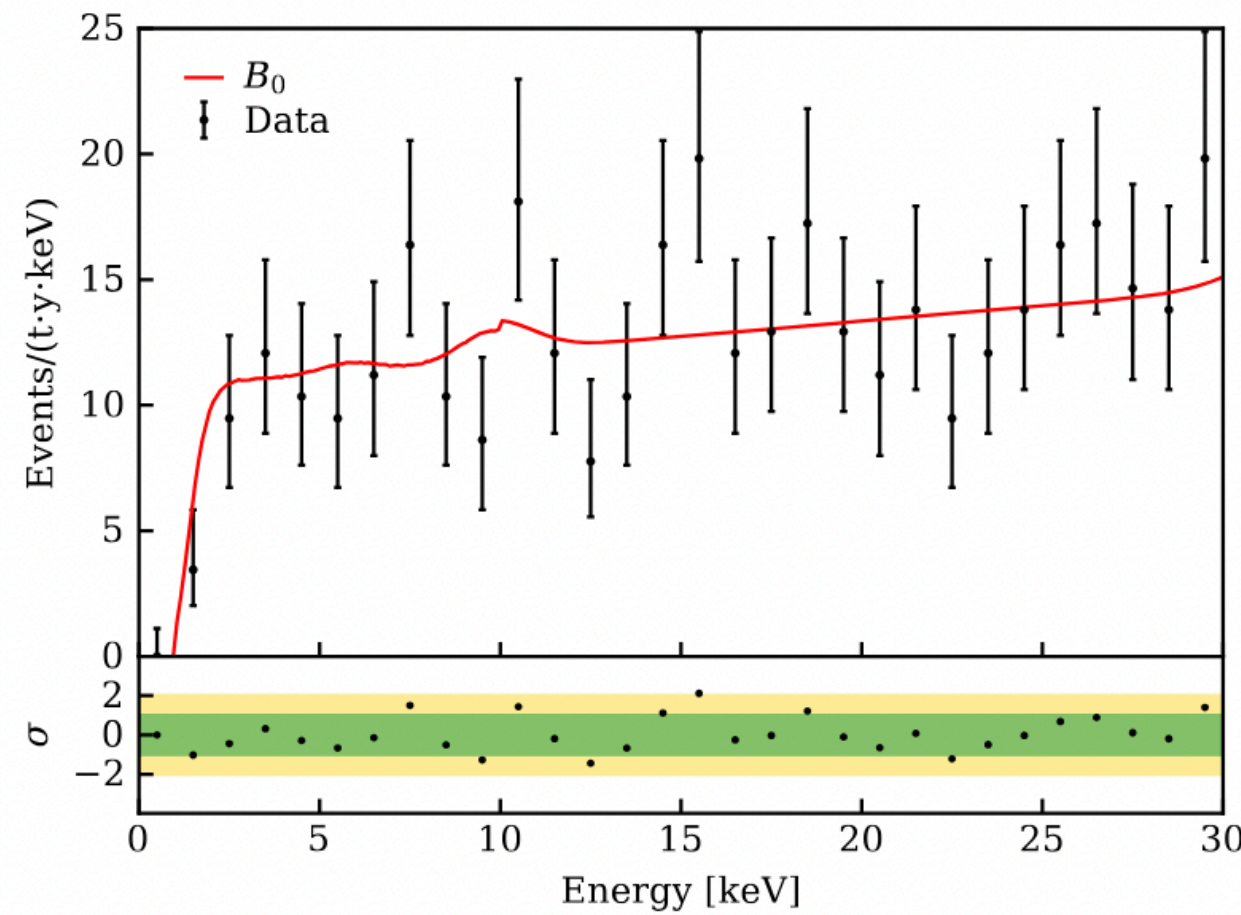
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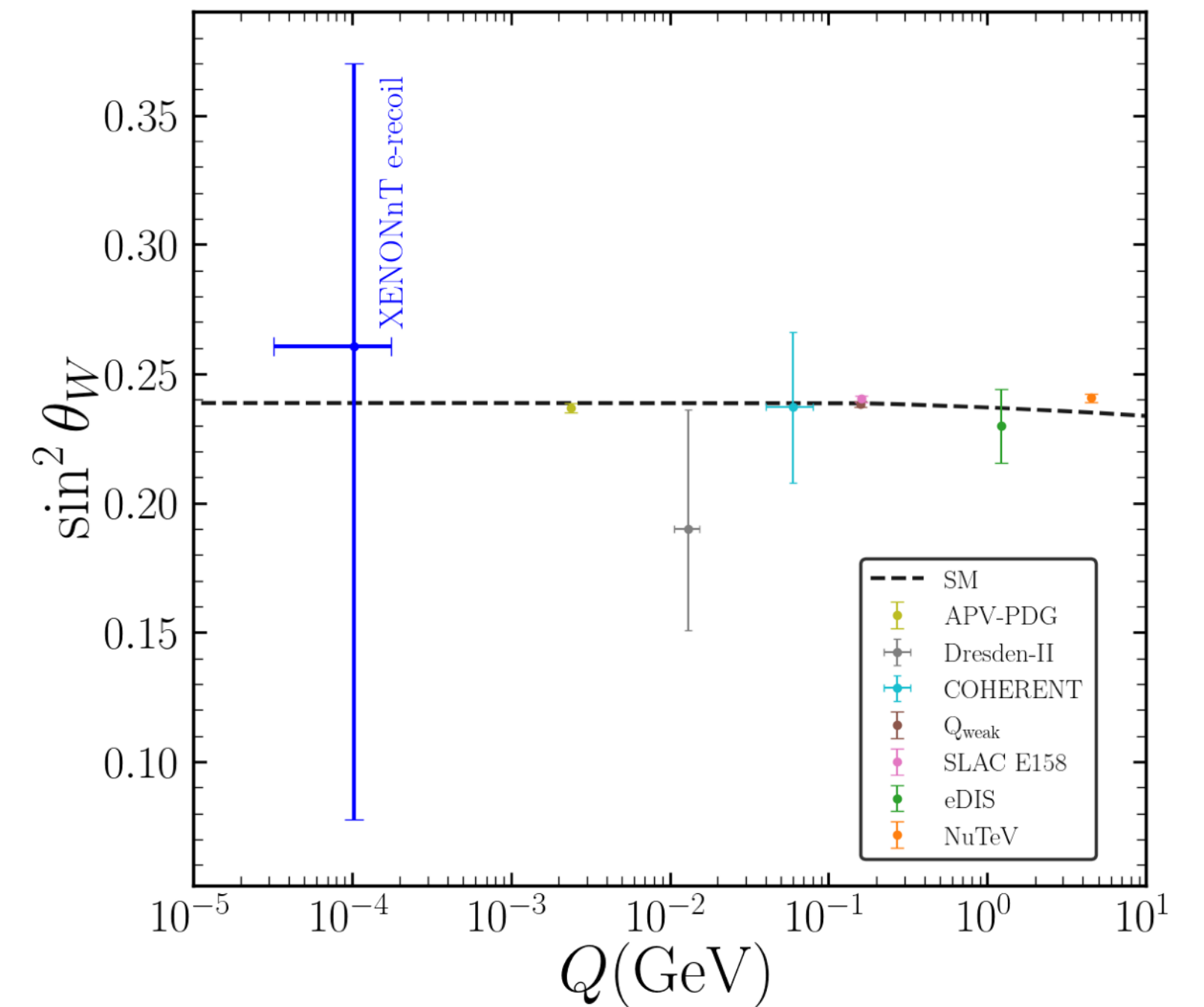
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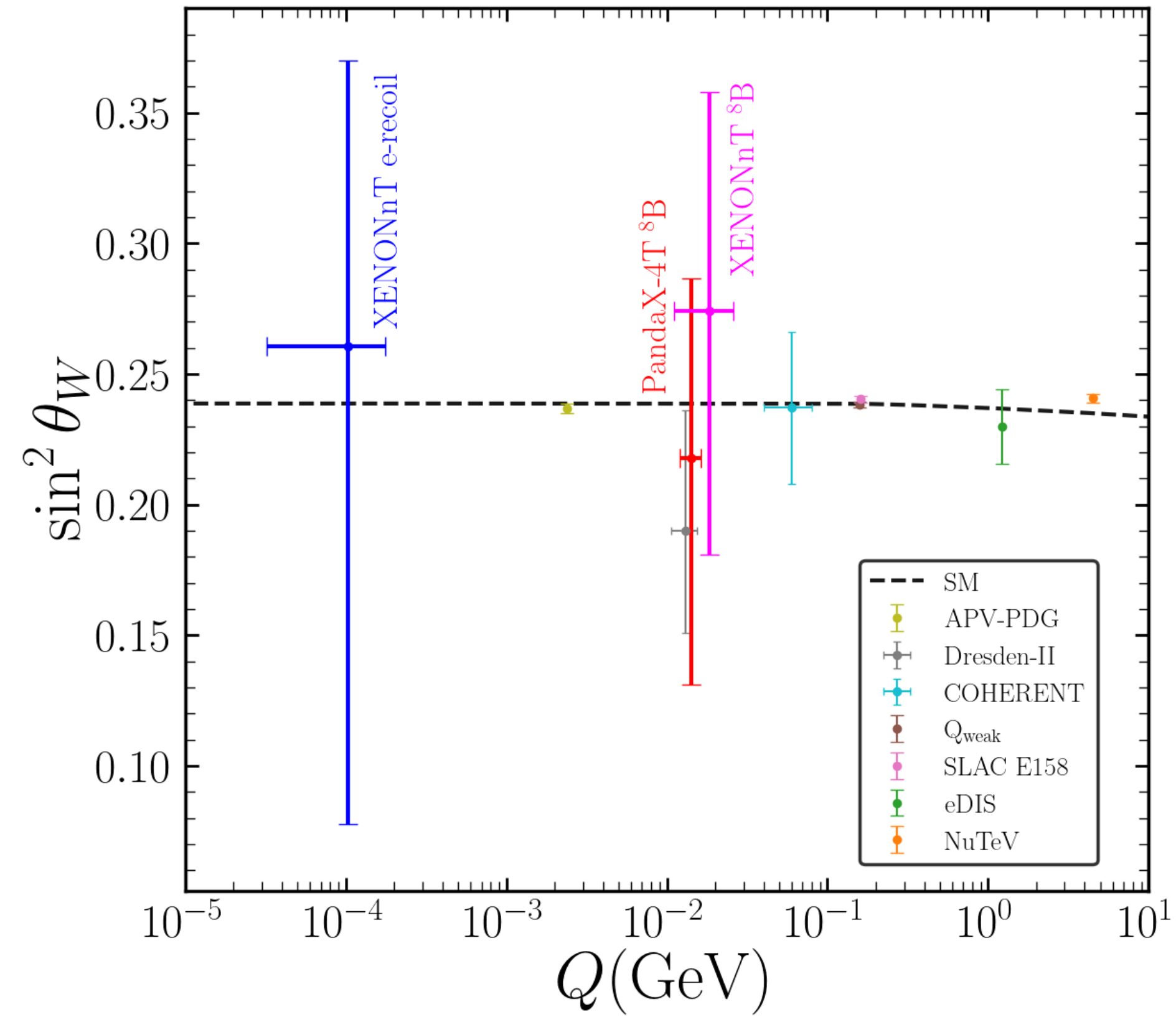
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Probing a SM parameter in an entirely new regime

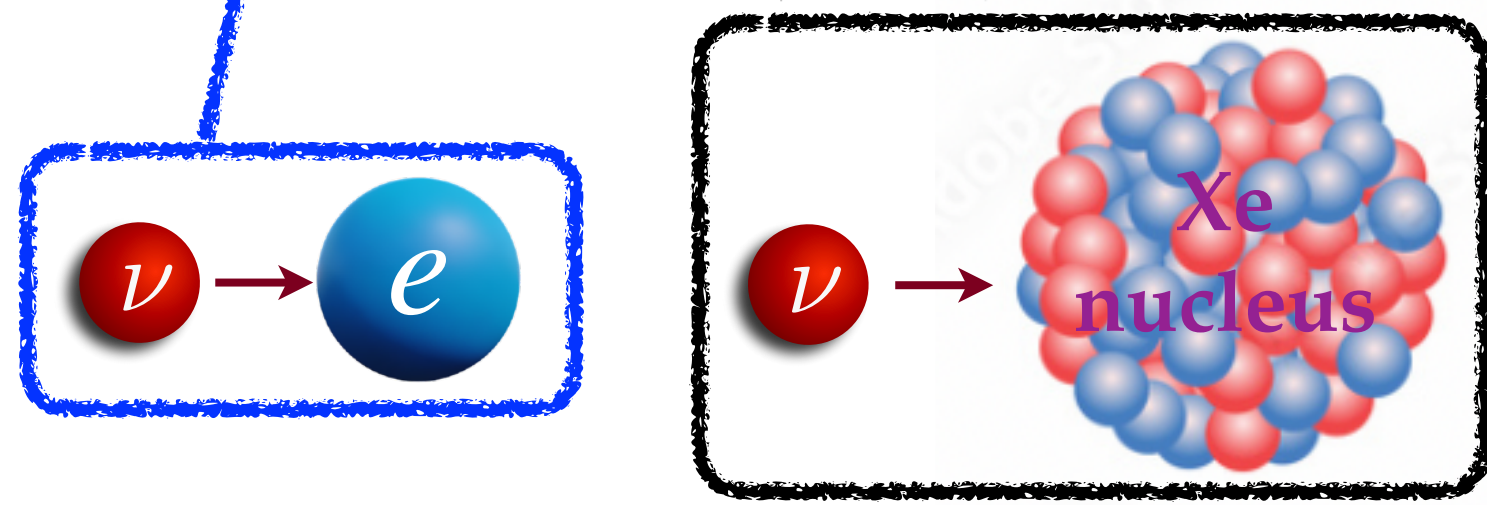
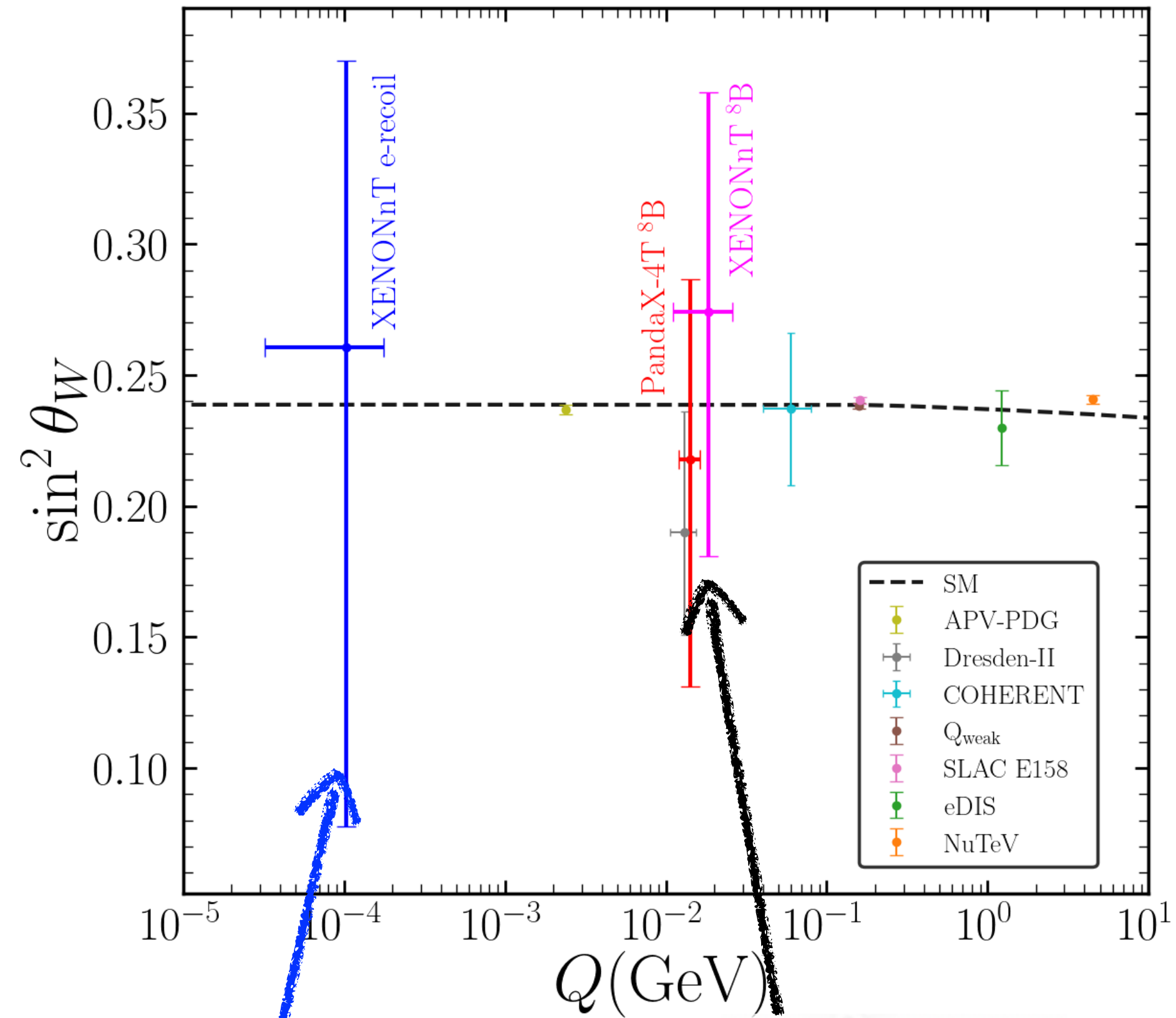
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DD already probing SM in an uncharted territory



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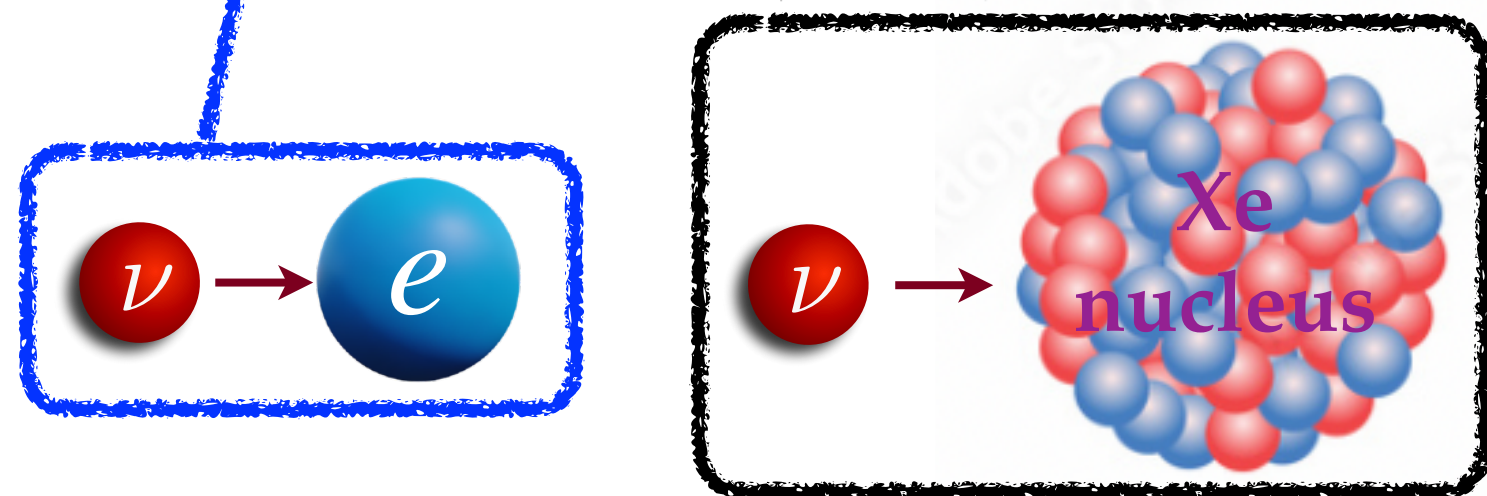
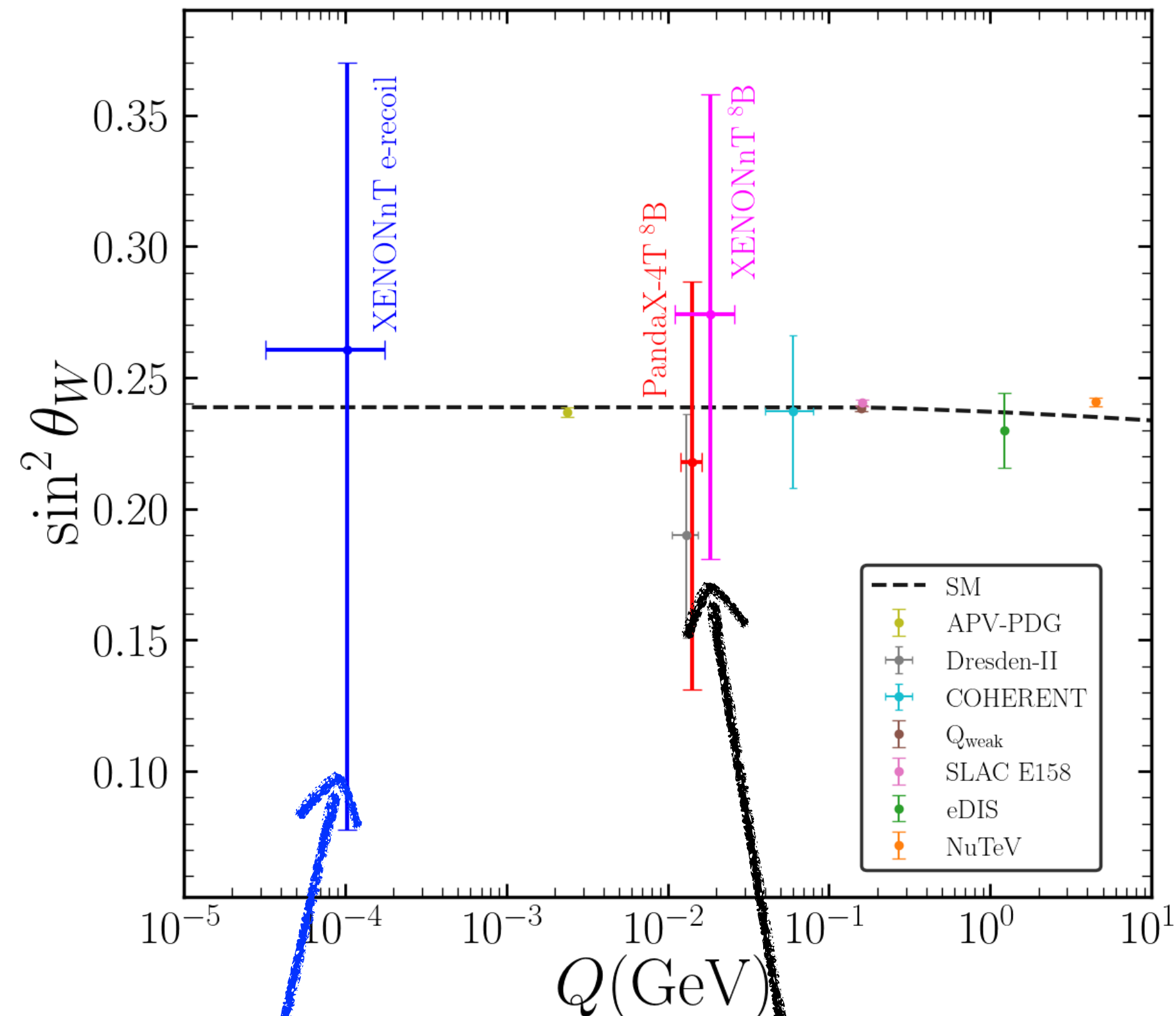
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TNM, Boehm; 2409.04385



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trino observatories. With 300 ty, DARWIN would be able to achieve 0.15% precision in the  $pp$  flux measurement, ap-

DARWIN, 2006.03114

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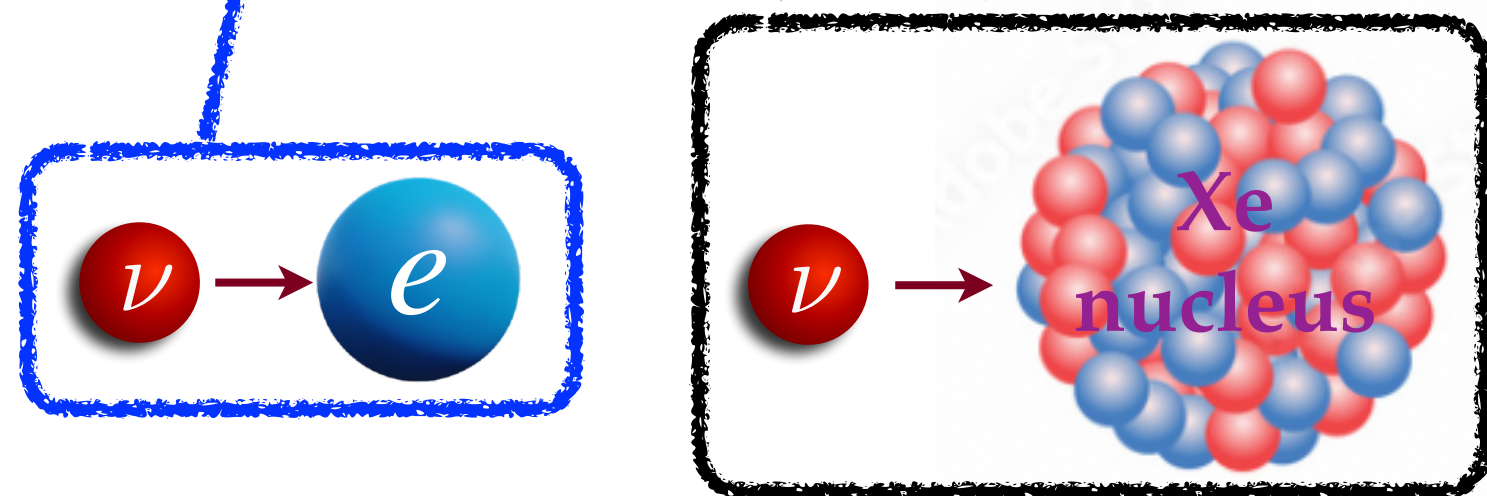
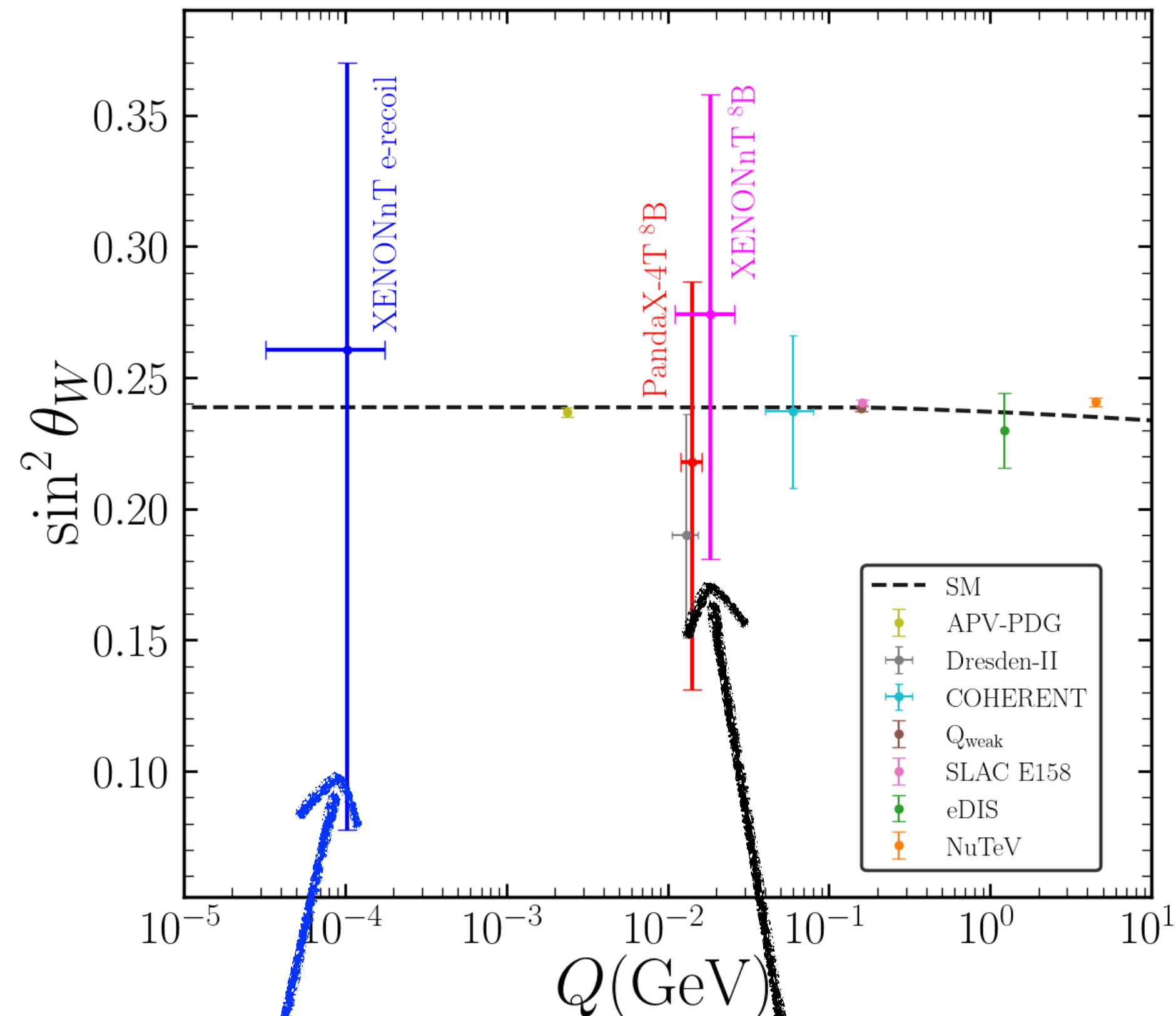
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Expected to see some CE $\nu$ NS events - no detailed analysis yet

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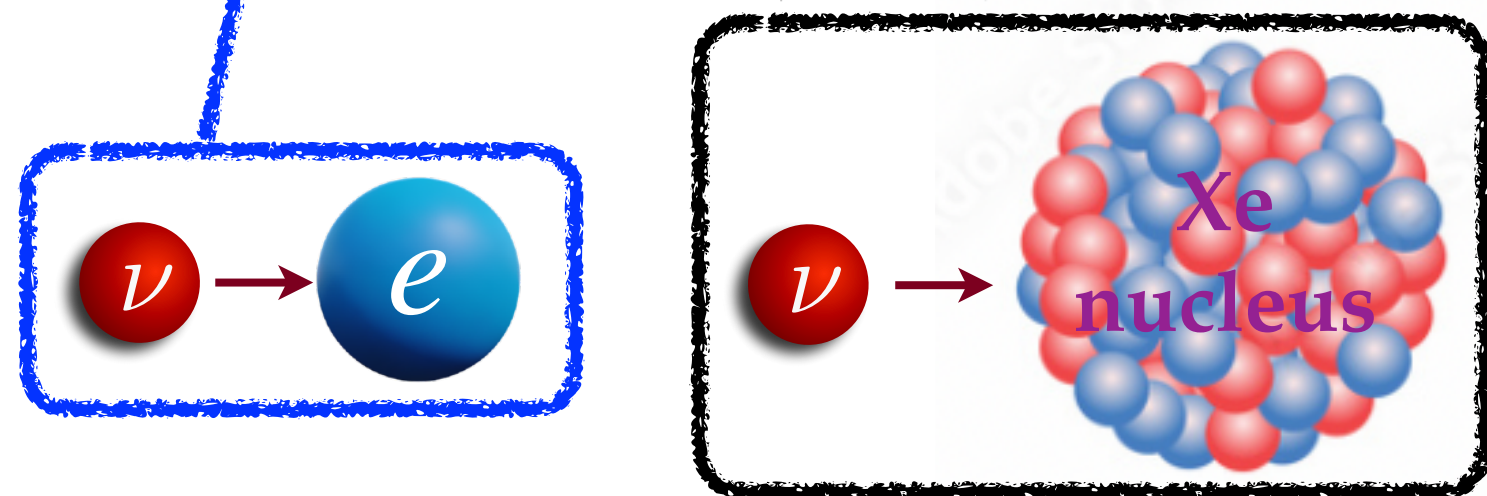
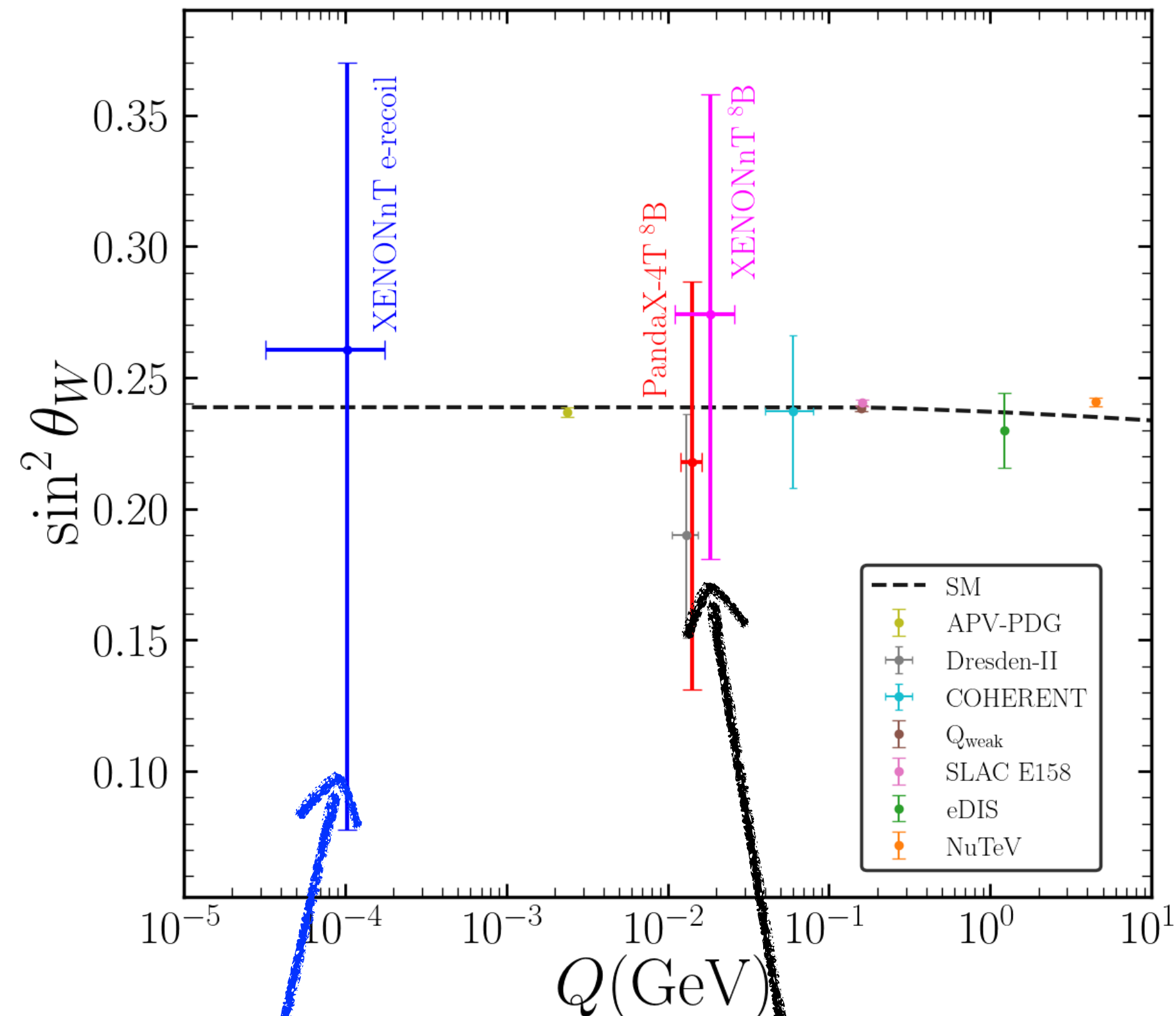
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email: [tarak.maity.physics@gmail.com](mailto:tarak.maity.physics@gmail.com)

Thank you