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

International Joint Workshop on the Standard Model and Beyond 2024
& 3rd Gordon Godfrey Workshop on Astroparticle Physics

ARC CENTRE OF EXCELLENCE FOR DARK MATTER PARTICLE PHYSICS

What are we doing?

Have we ever tested the weak sector of the Standard Model in sub-MeV energy regime before?

Perhaps not!

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Weak mixing angle

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

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

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

g : SU(2)$_\mathrm{L}$ gauge coupling

g' : U(1)$_\mathrm{Y}$ gauge coupling

Quantum correction

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Running of weak mixing angle

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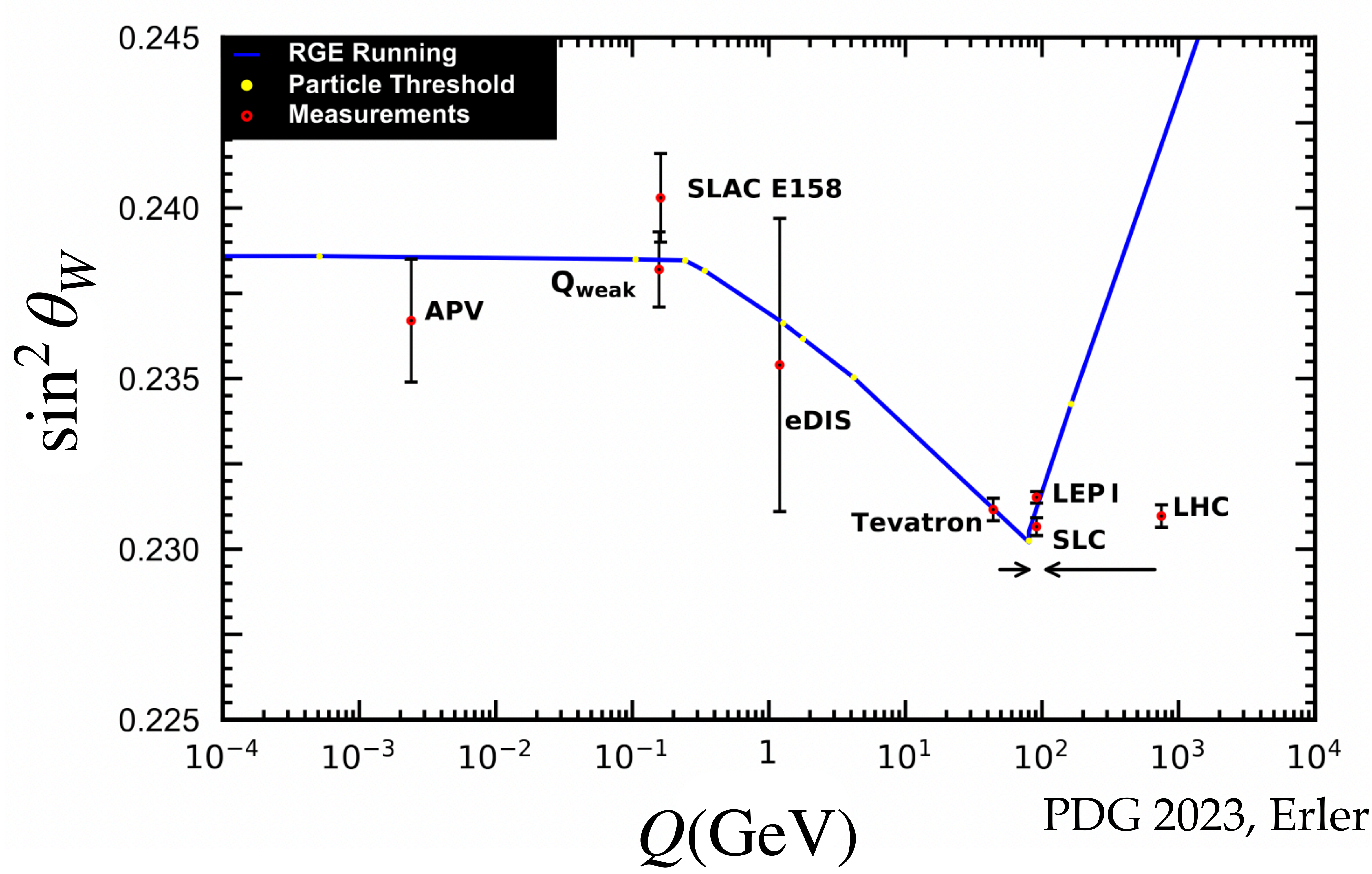

PDG 2023, Erler+ 1712.09146

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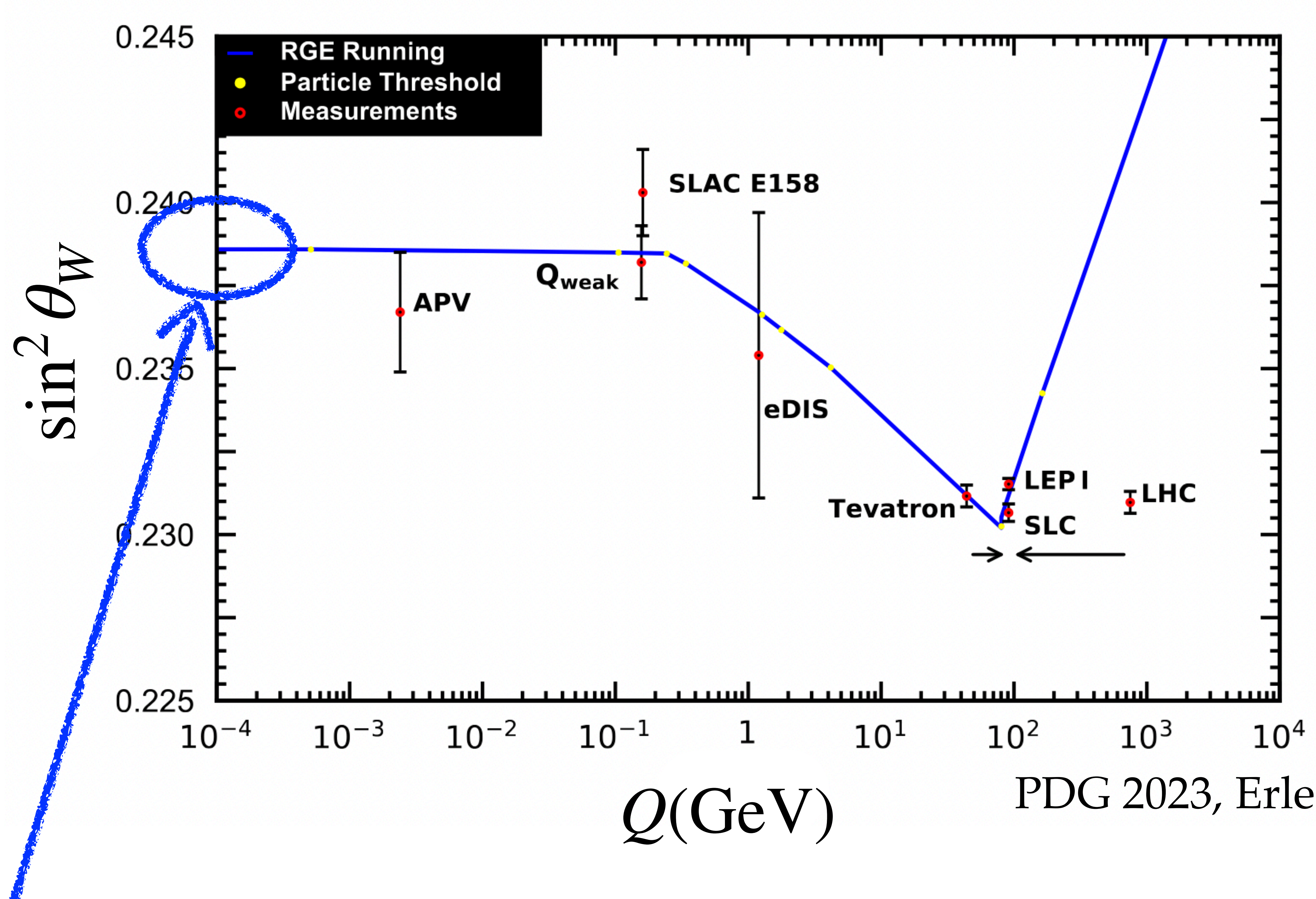

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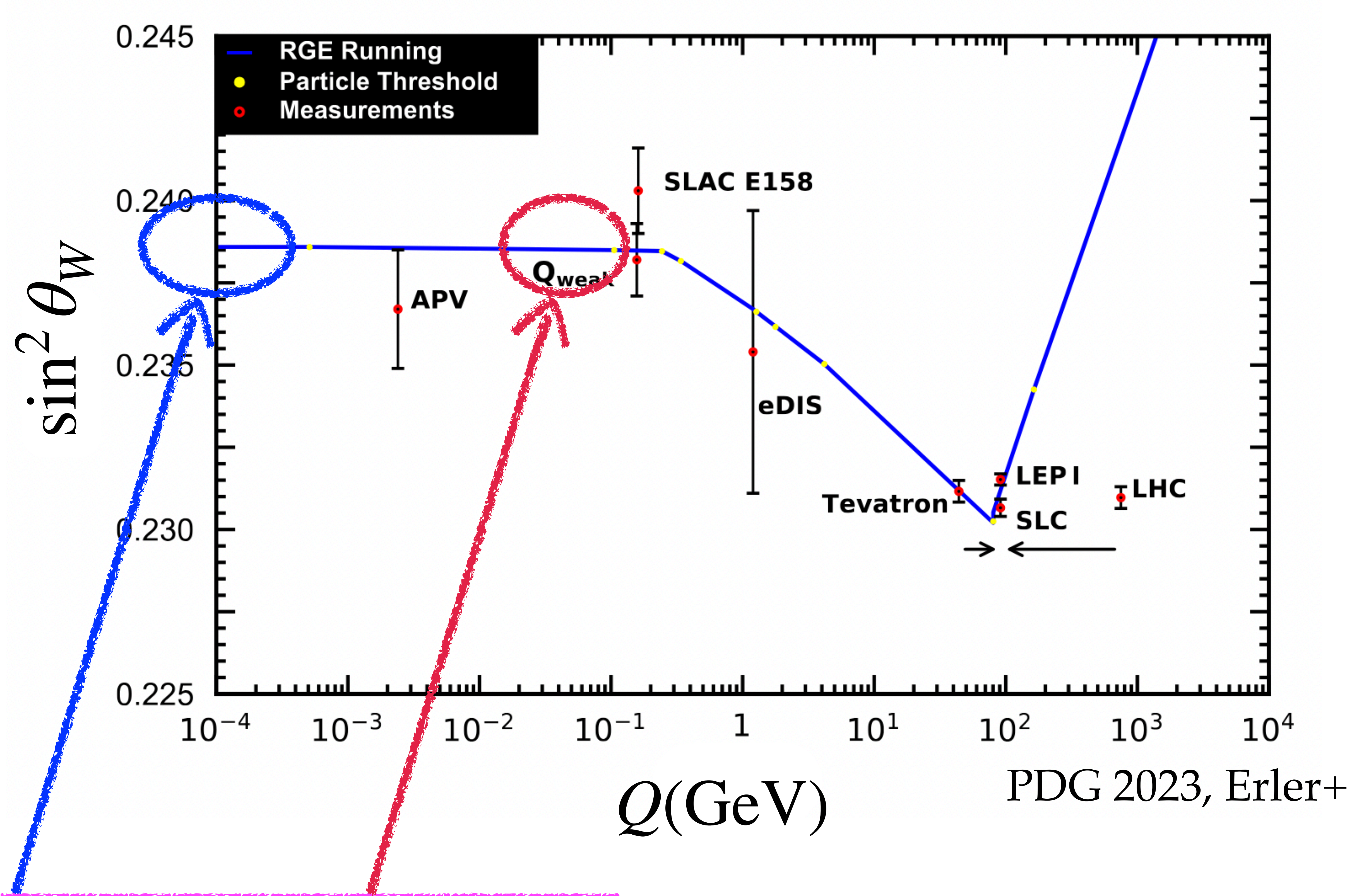

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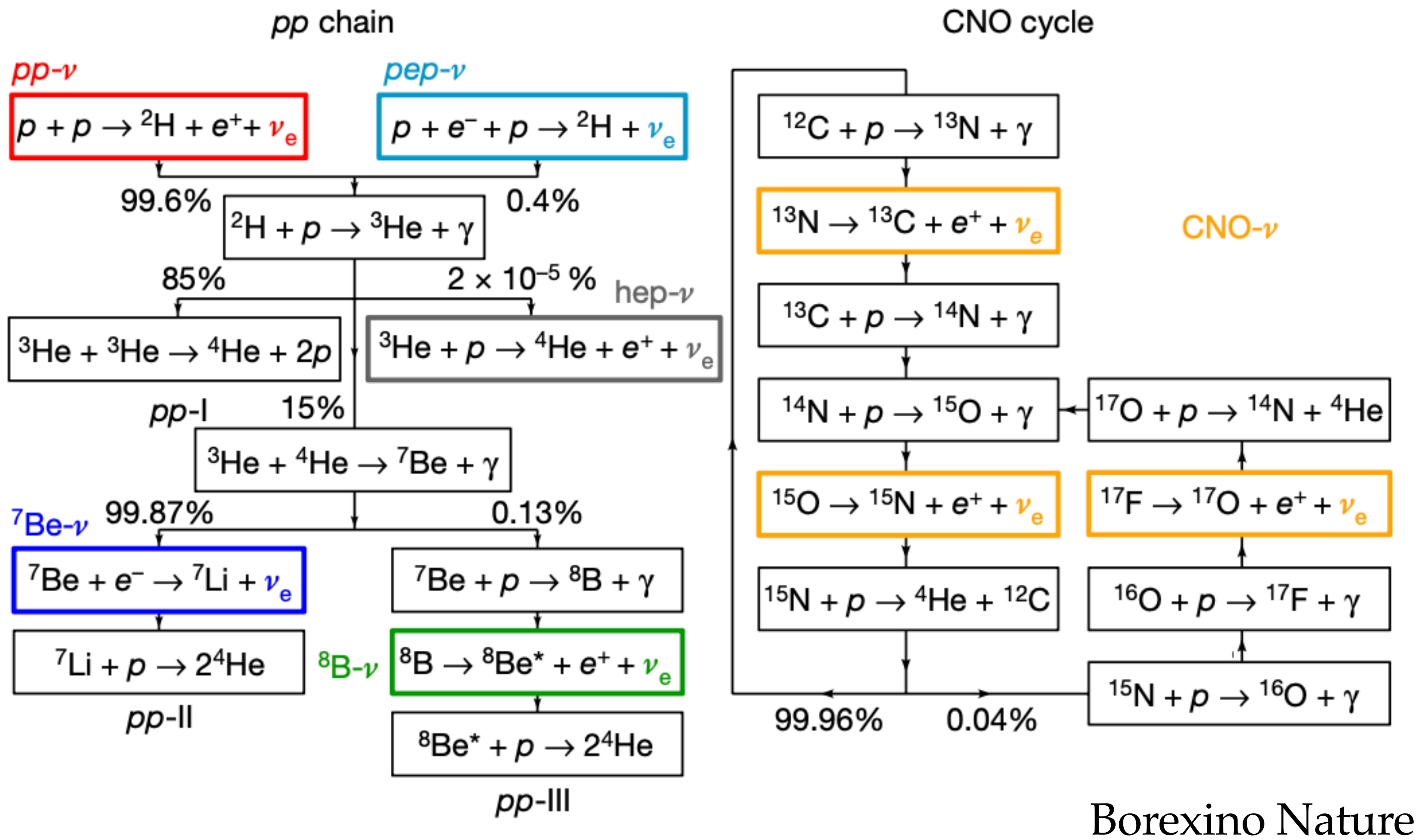
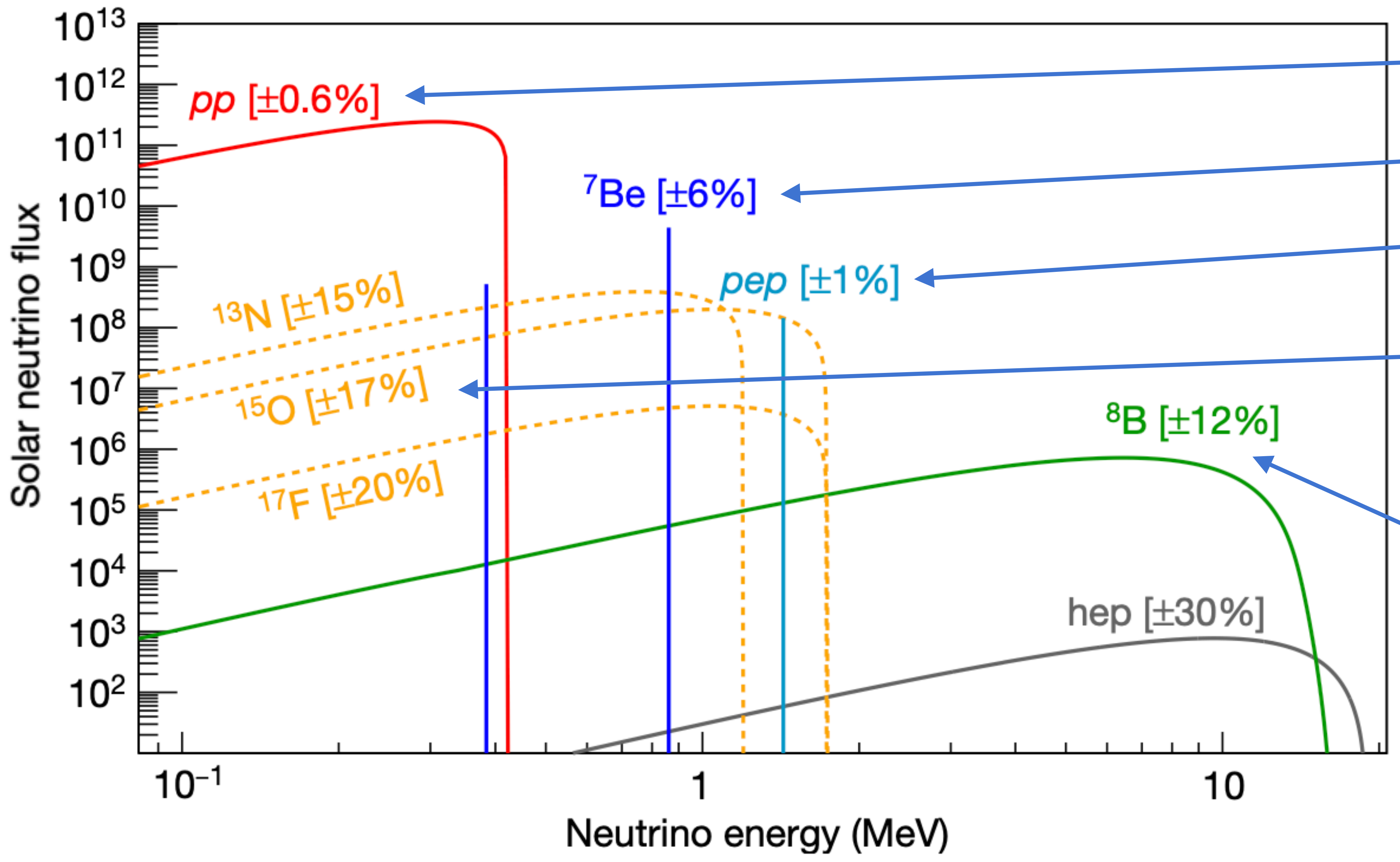
By observing Solar neutrinos



Borexino Nature (2018)

SSM uncertainties



Measured error

±10 %

±2.7 %

±18 %

+42 %
−10 %

±2 %

Borexino

SNO
Super-K

Sekiya TAUP 2023
SNO nucl-ex/0204008
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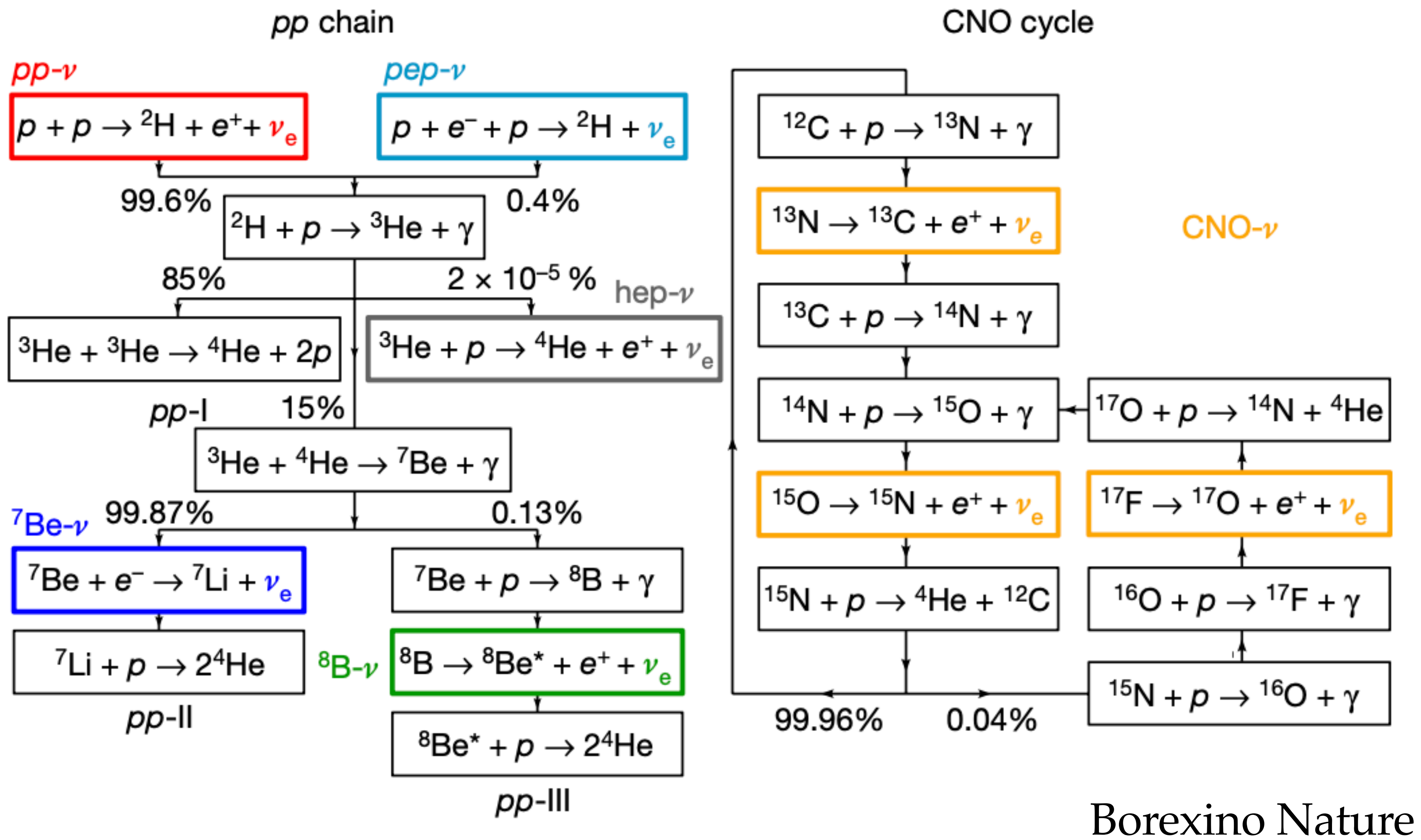

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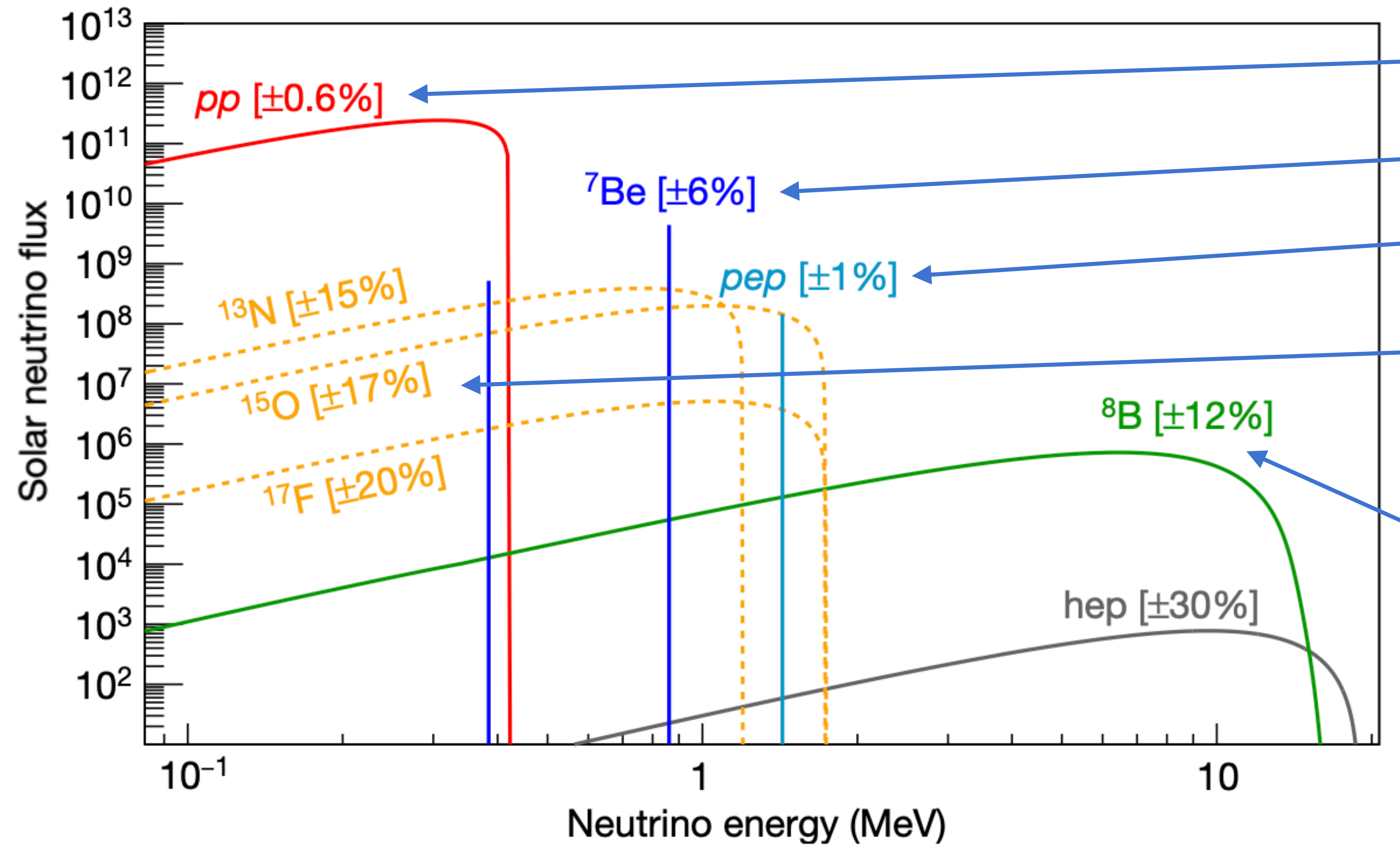

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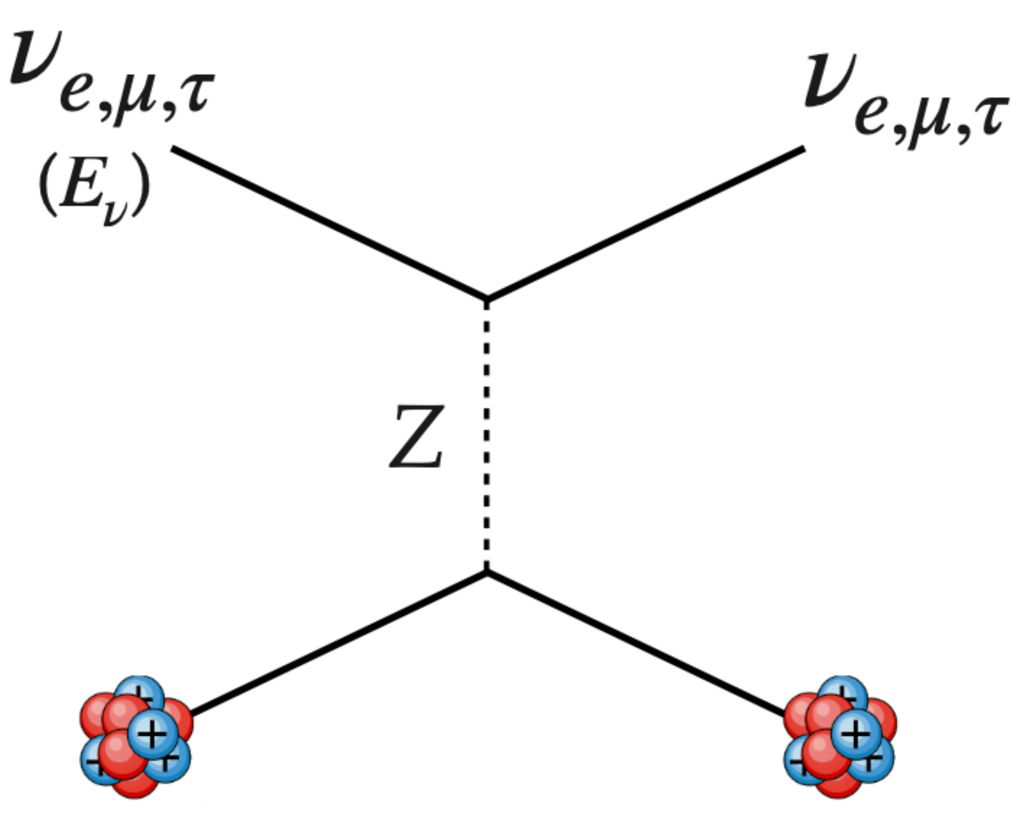
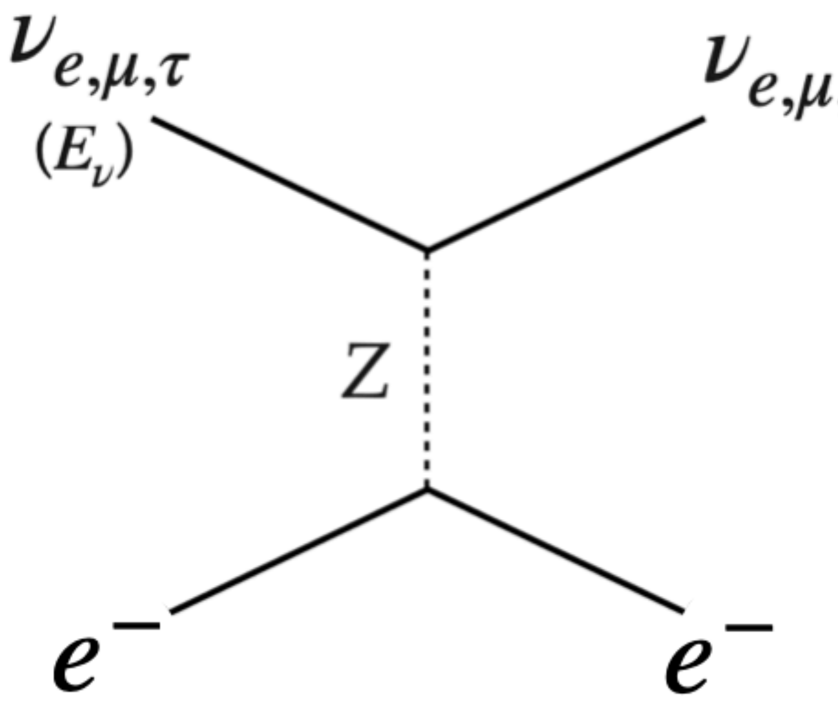


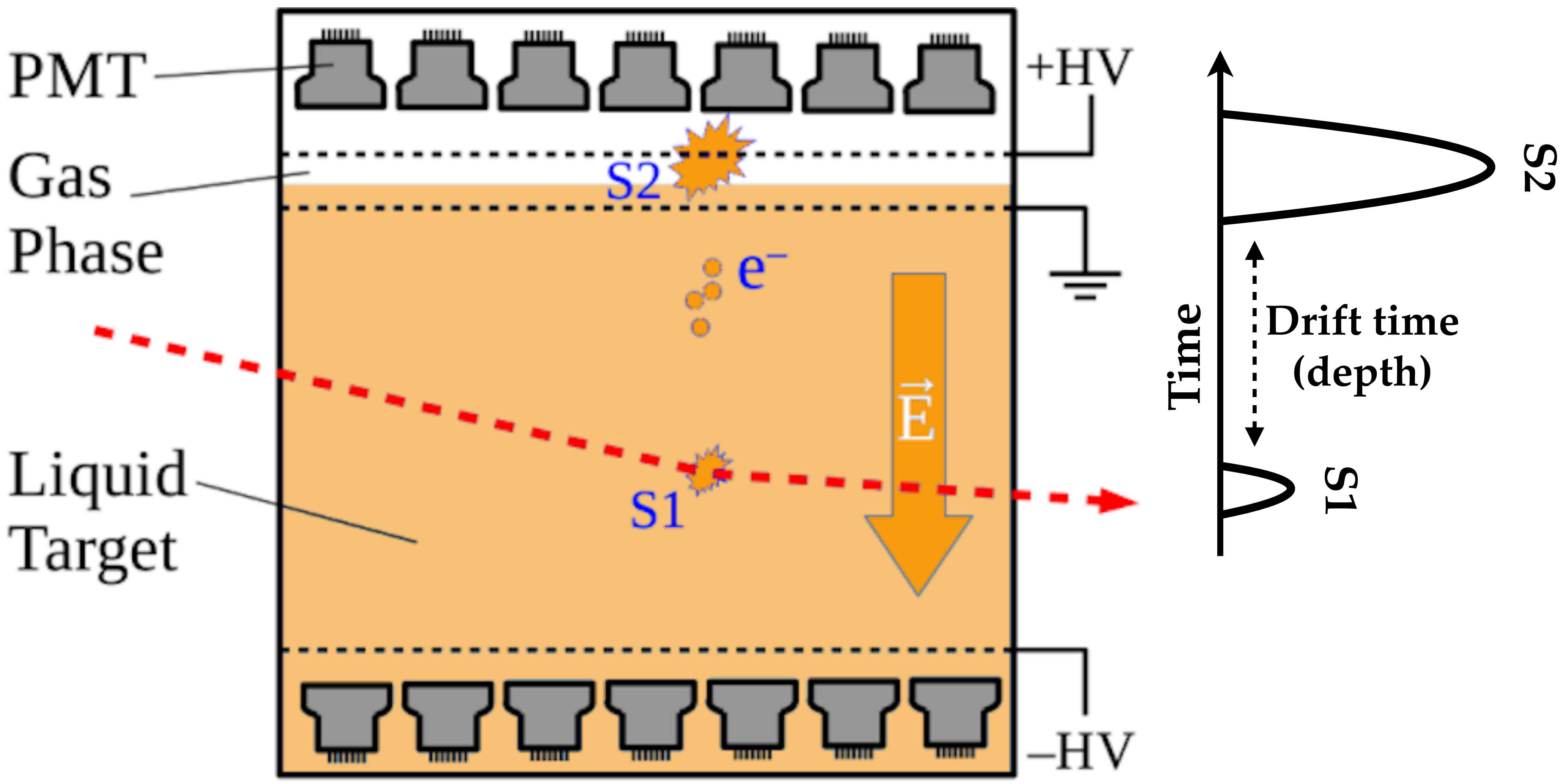
Coherent elastic neutrino -nucleus scattering (CEνNS)



Neutrino-electron scattering

Observing neutrinos in DD(Xe)

XENONnT, PandaX-4T, LZ ...



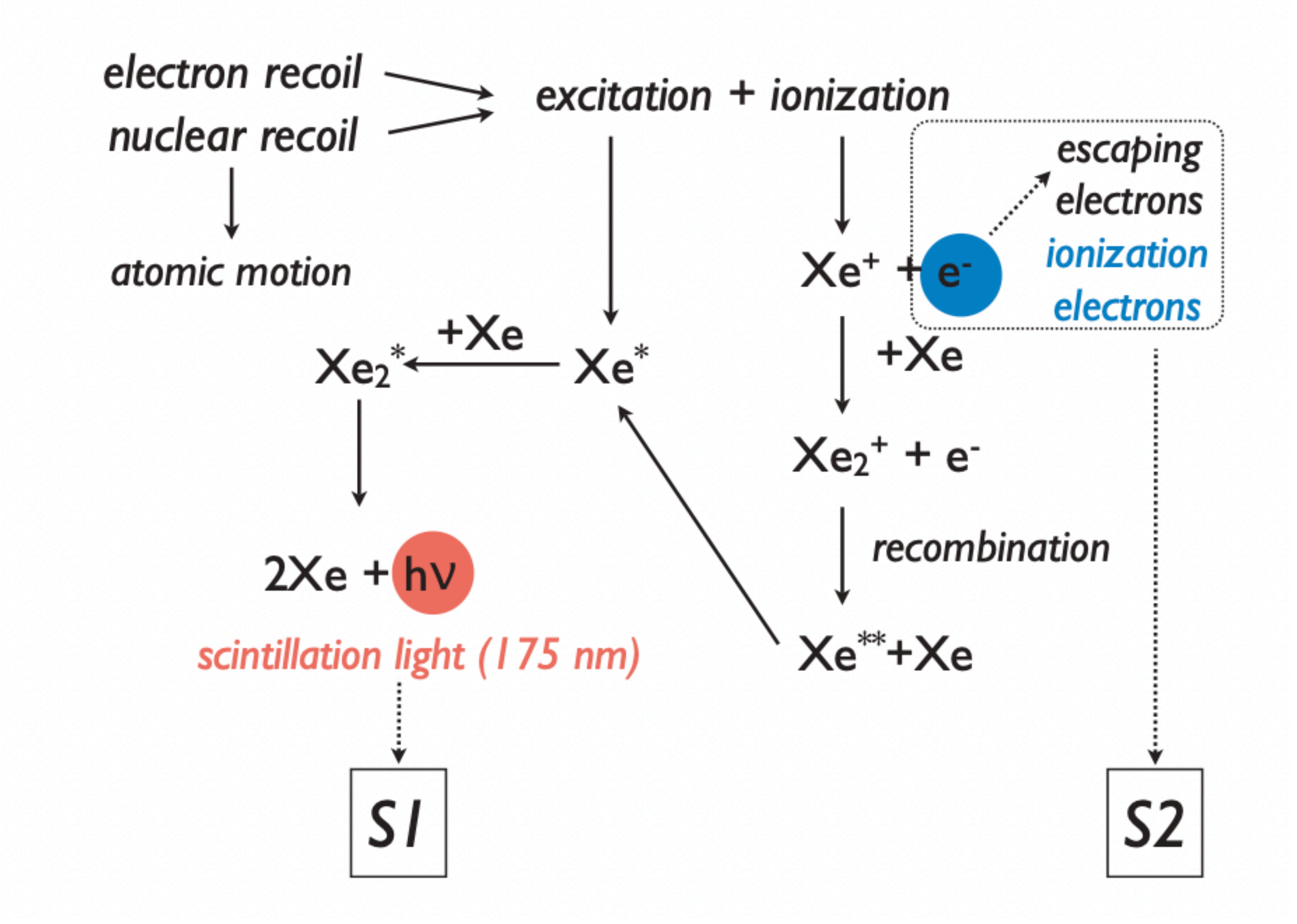


Image credit: 2110.02359, 1903.03026, 0909.1063

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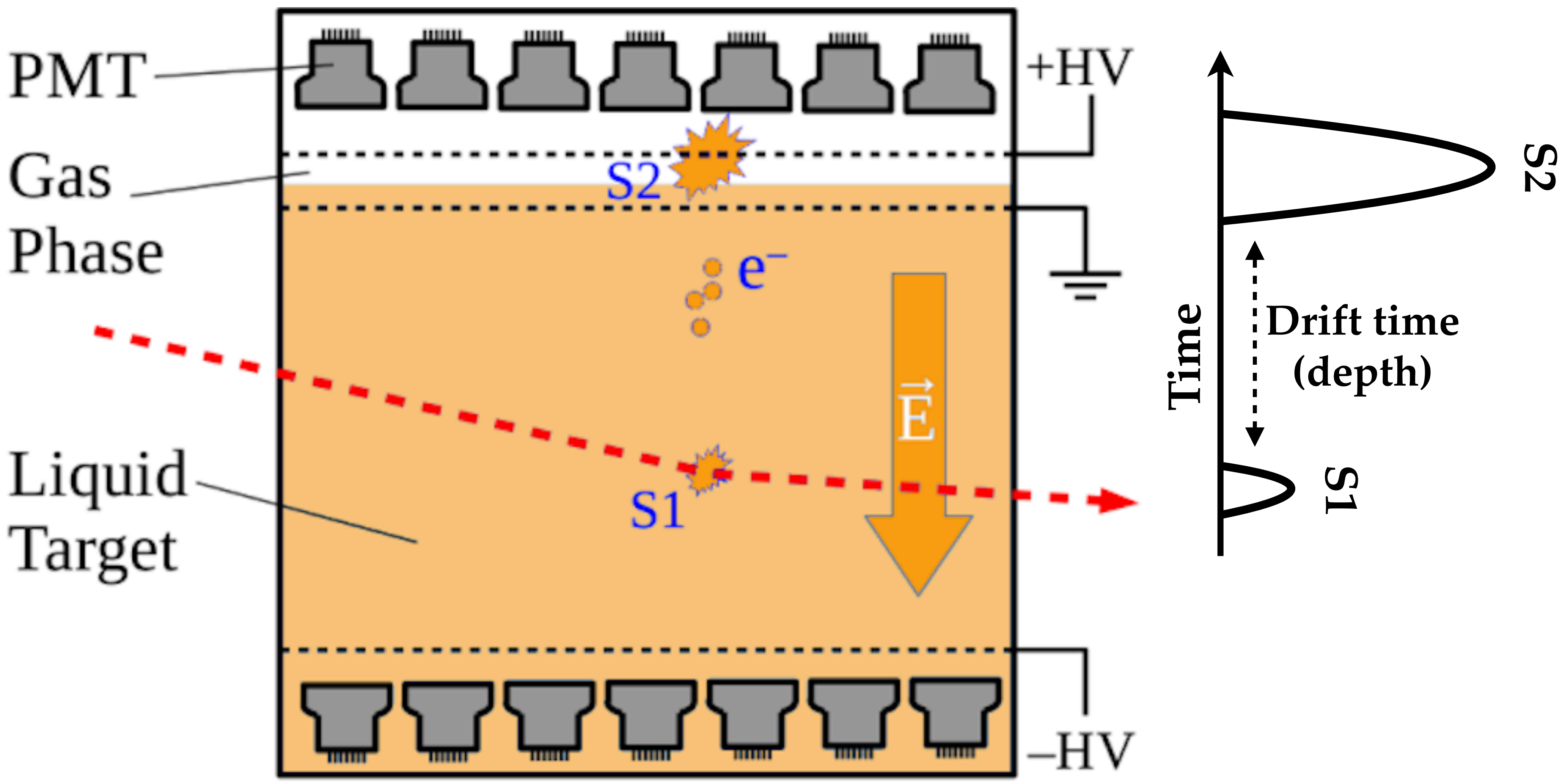
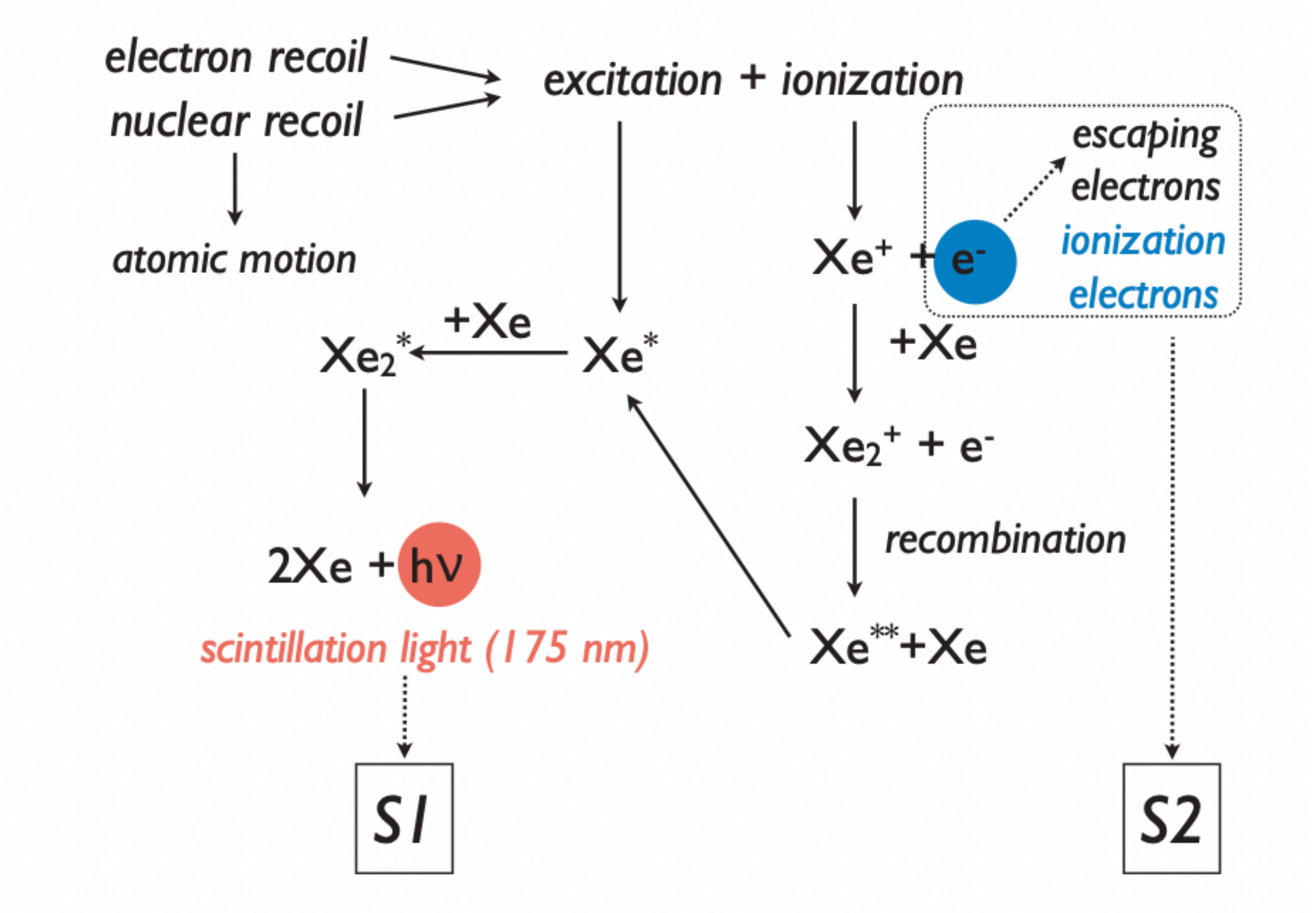
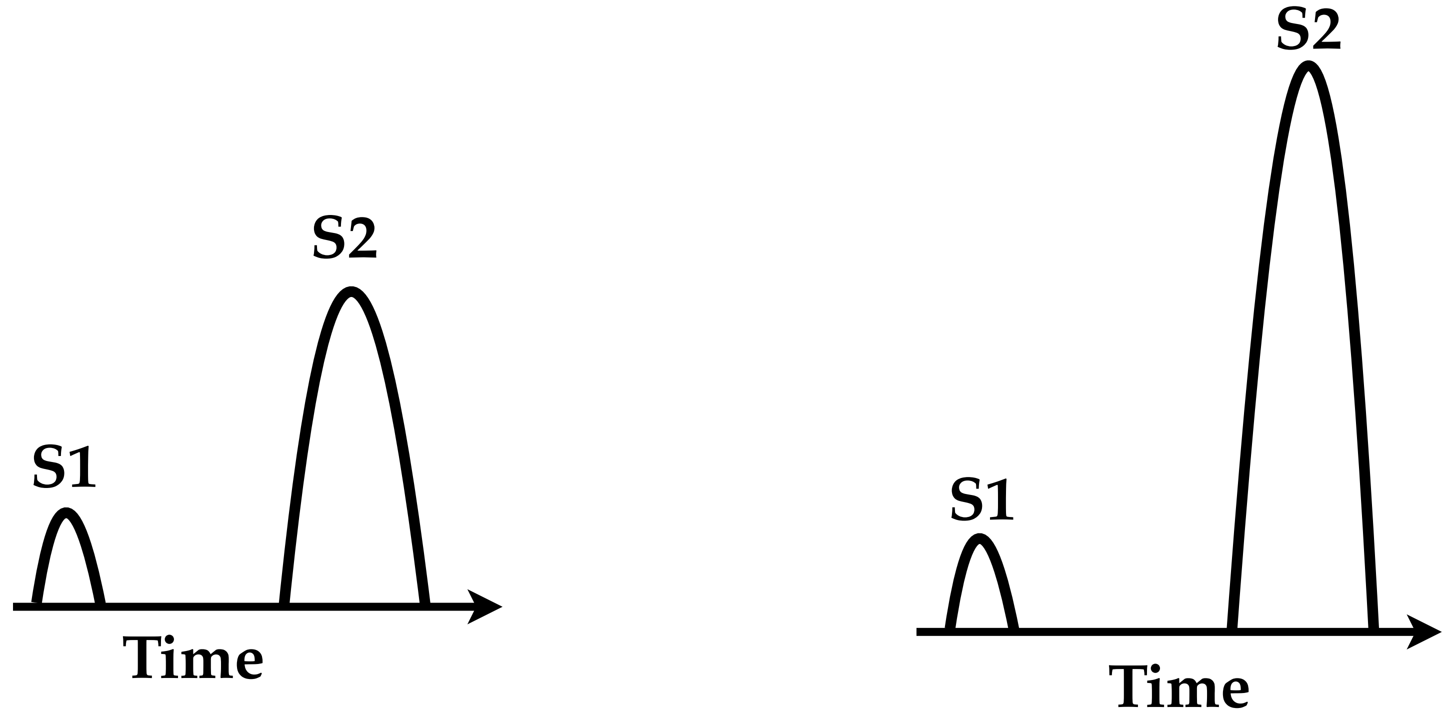




S1-S2 analysis

Nuclear recoil

Electron recoil



S2/S1 << S2/S1

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

$E_{\mathrm{recoil}} \gtrsim 1\,\mathrm{keV}$

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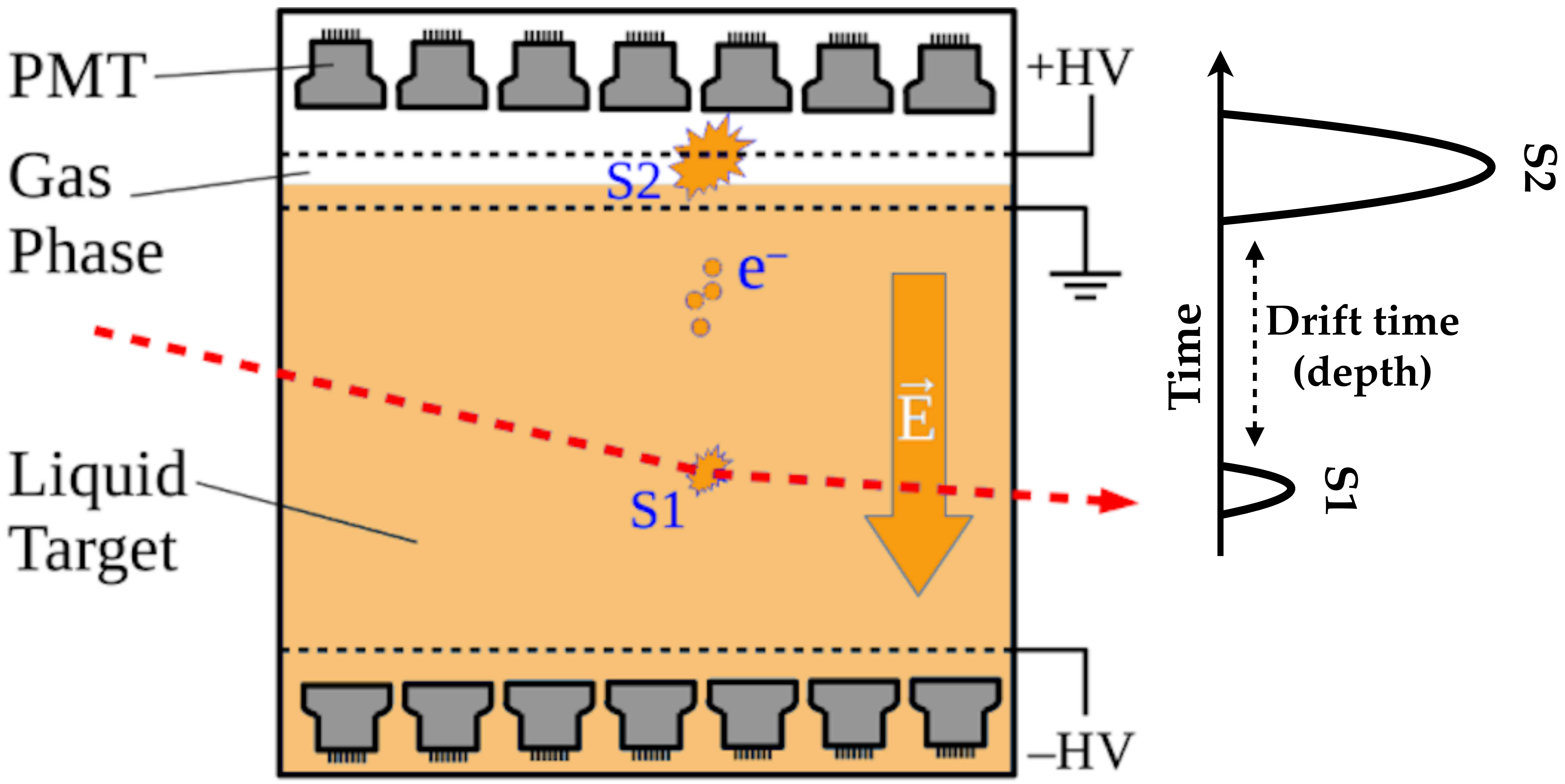
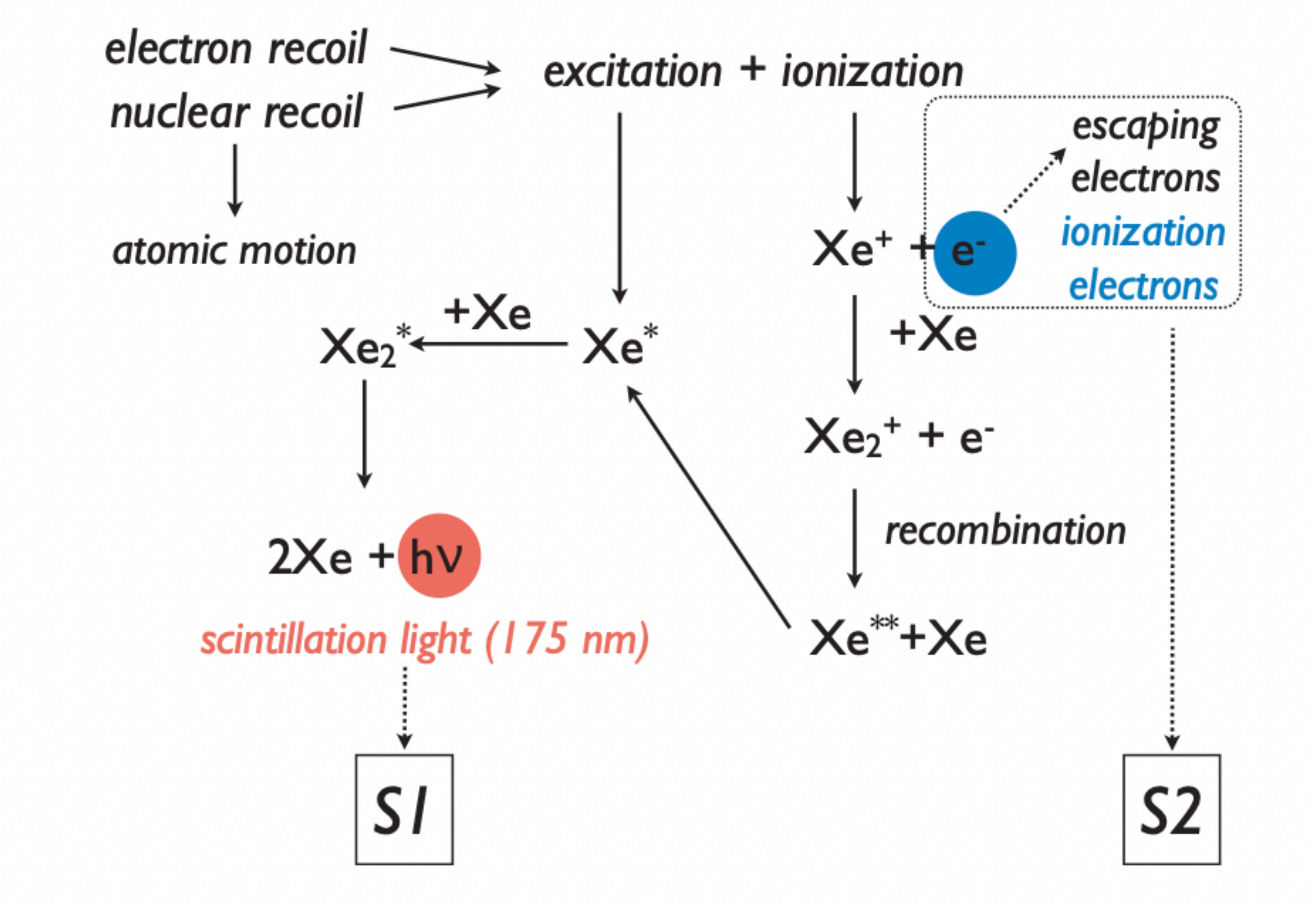
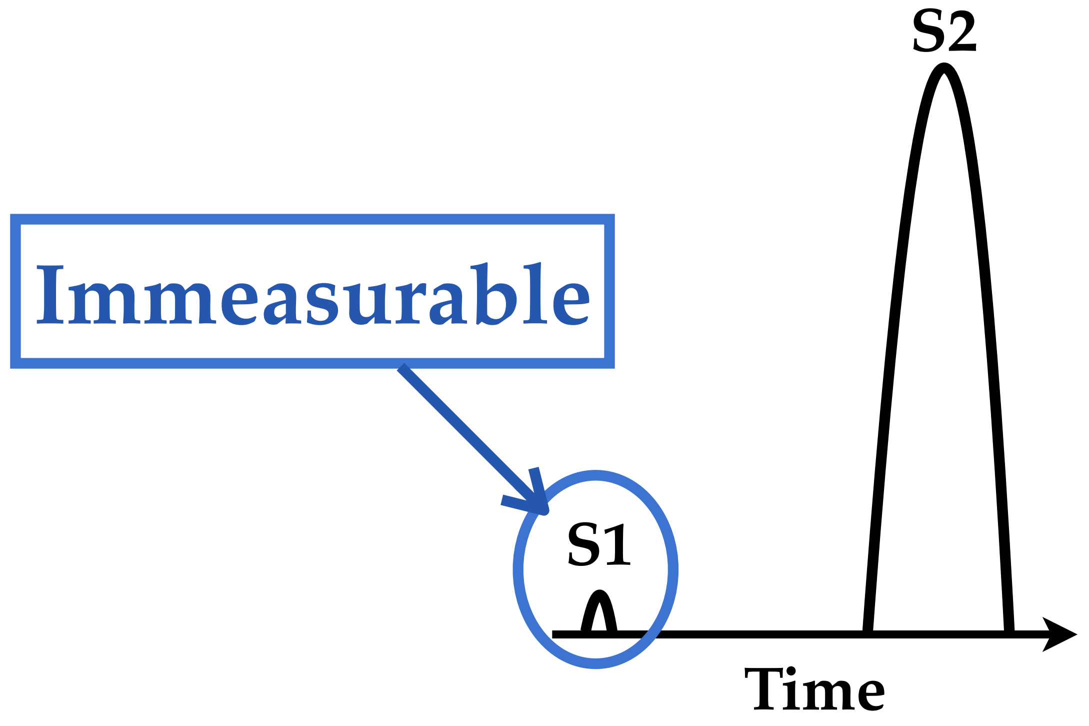




S2 only analysis



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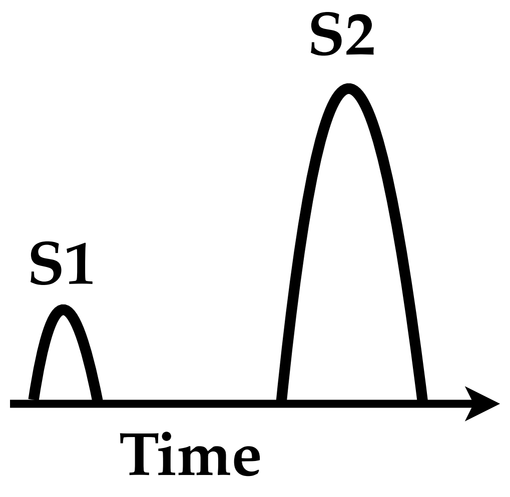

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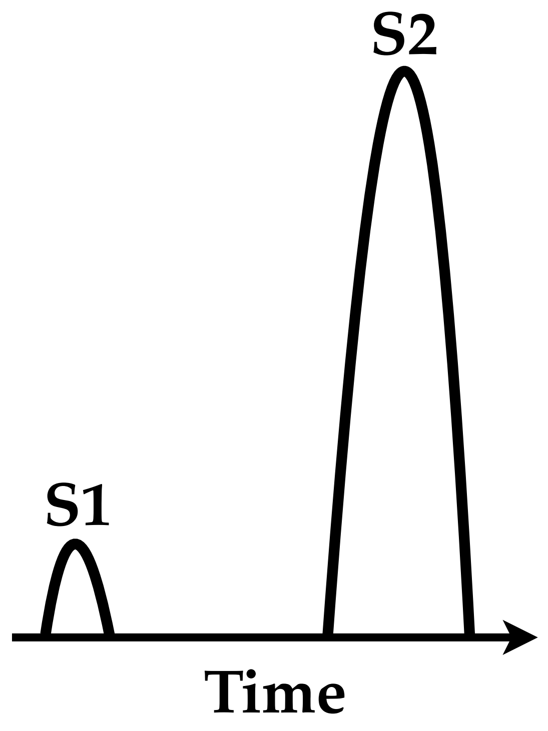

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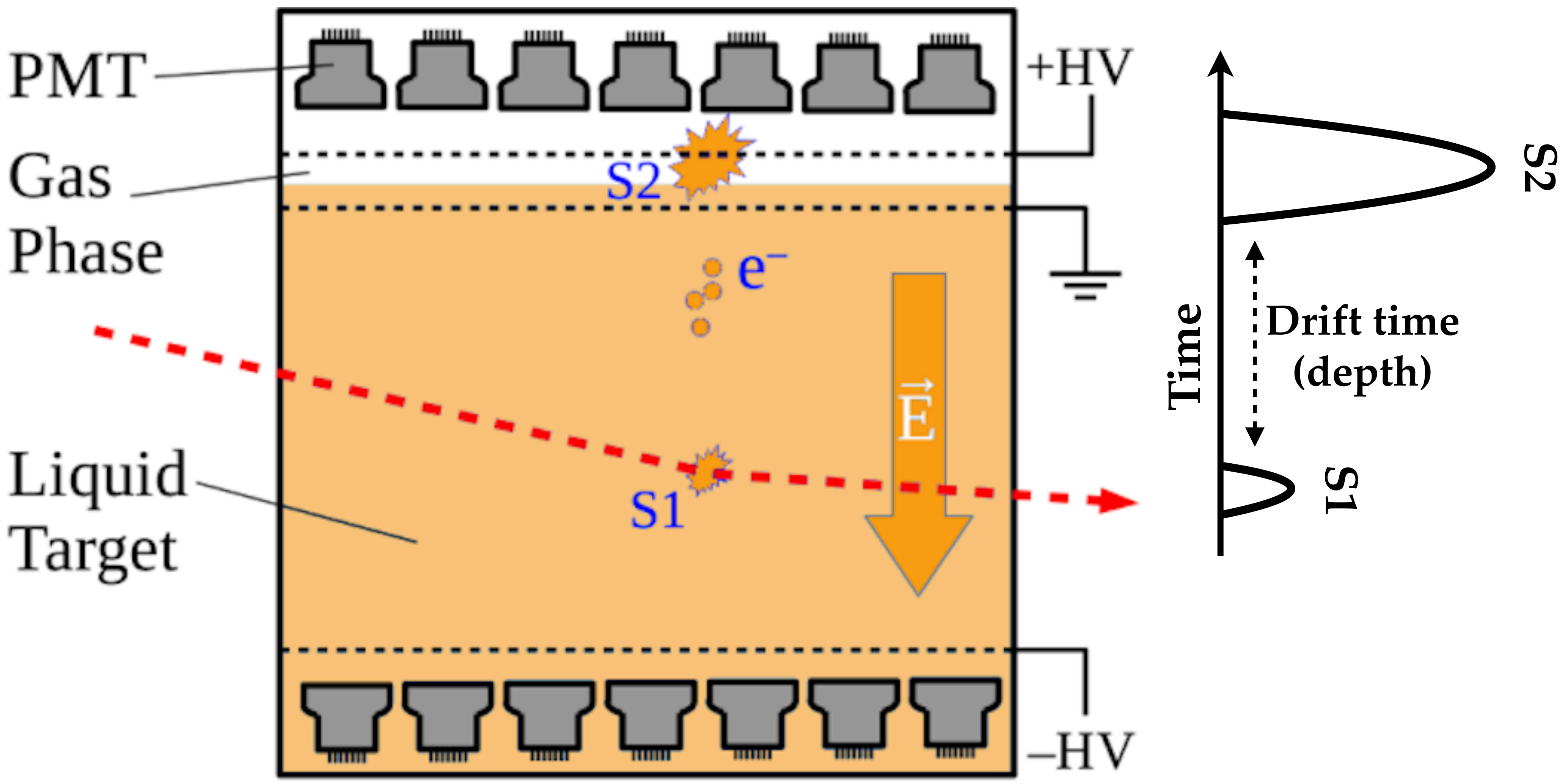

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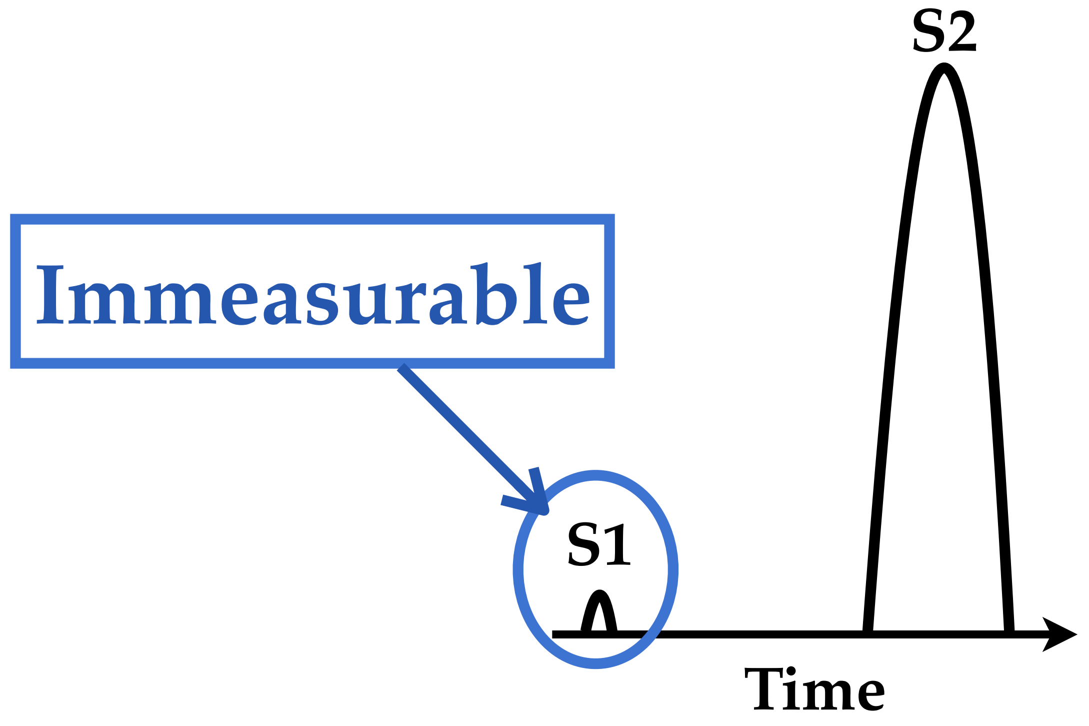

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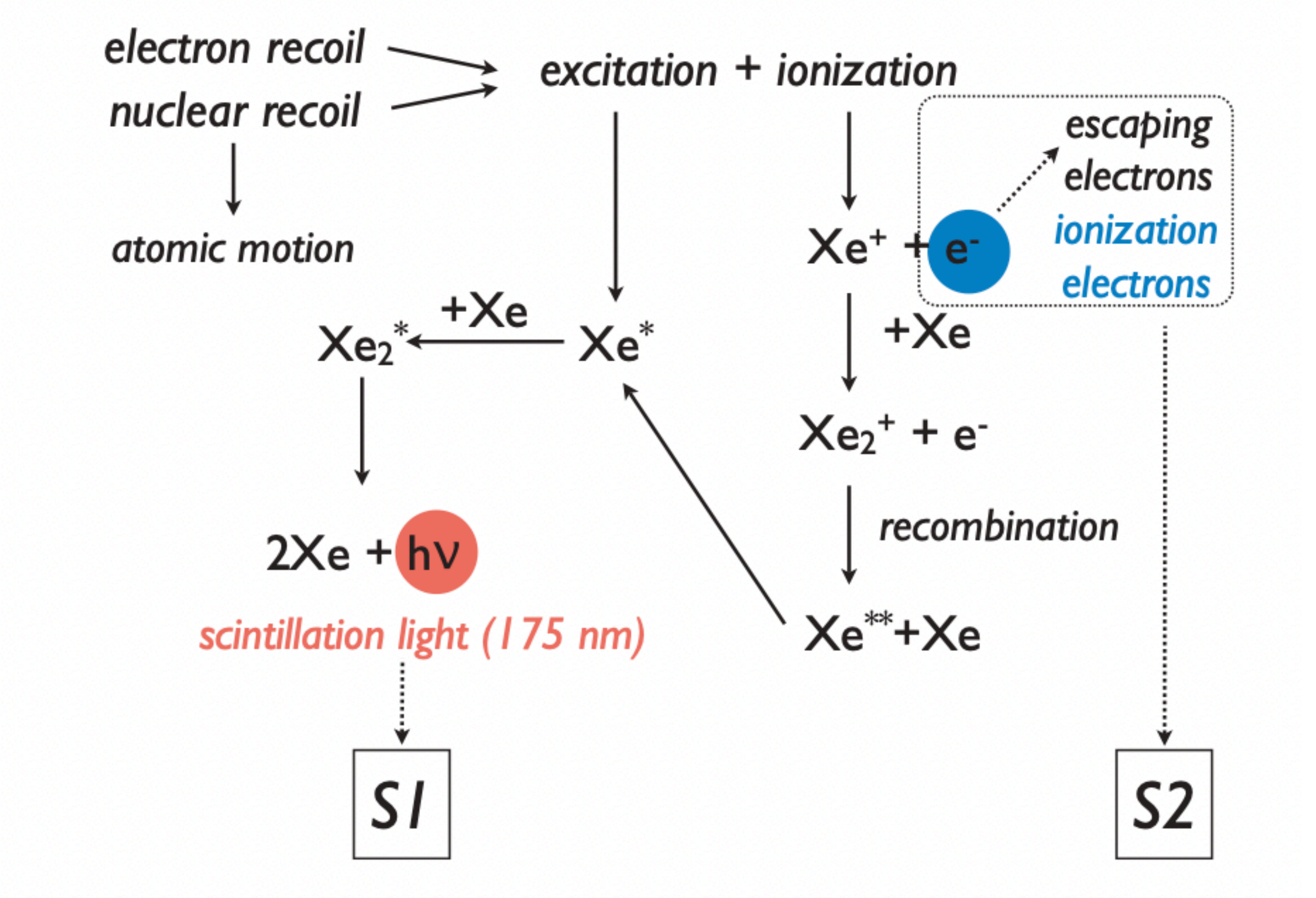

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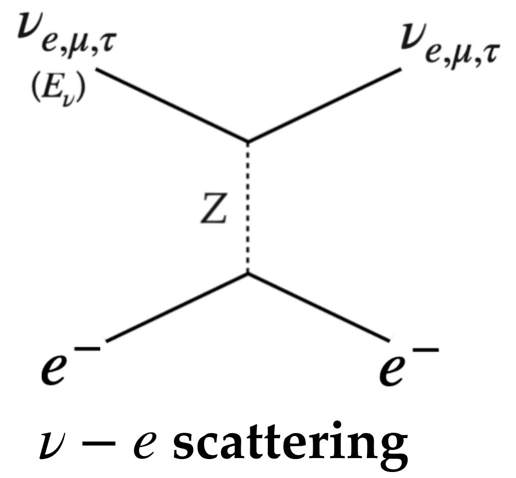

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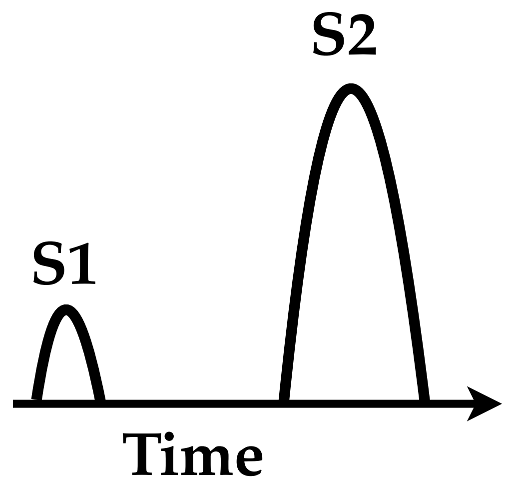

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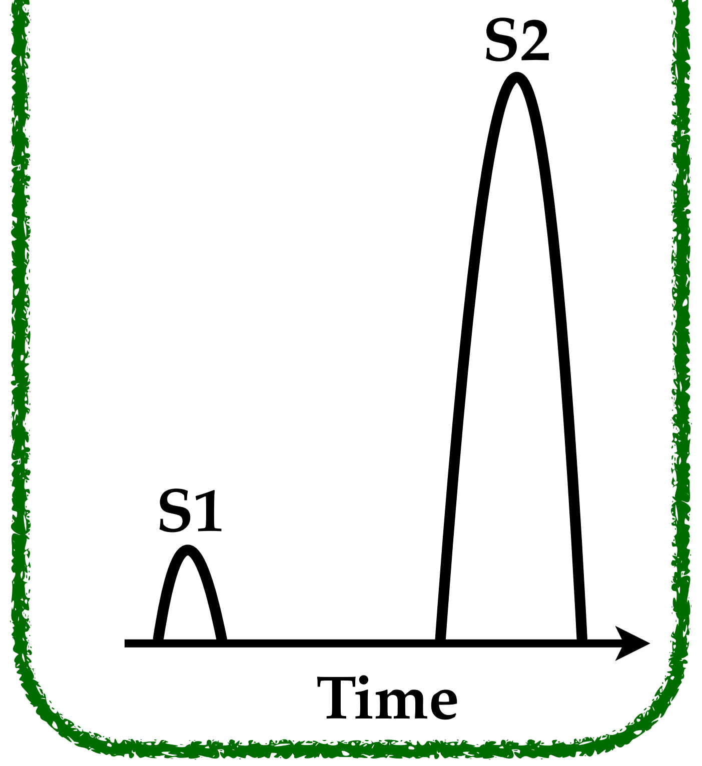

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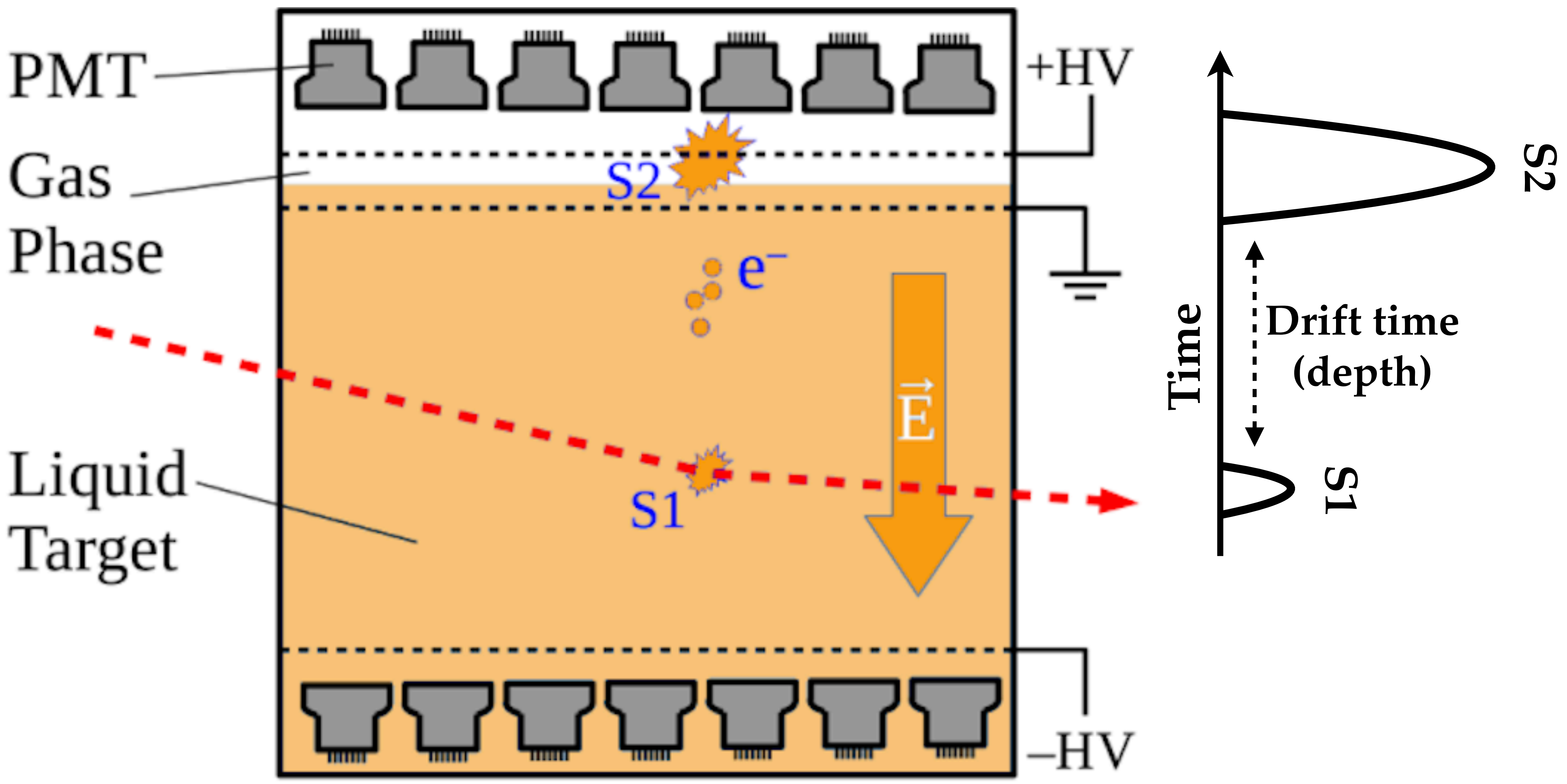

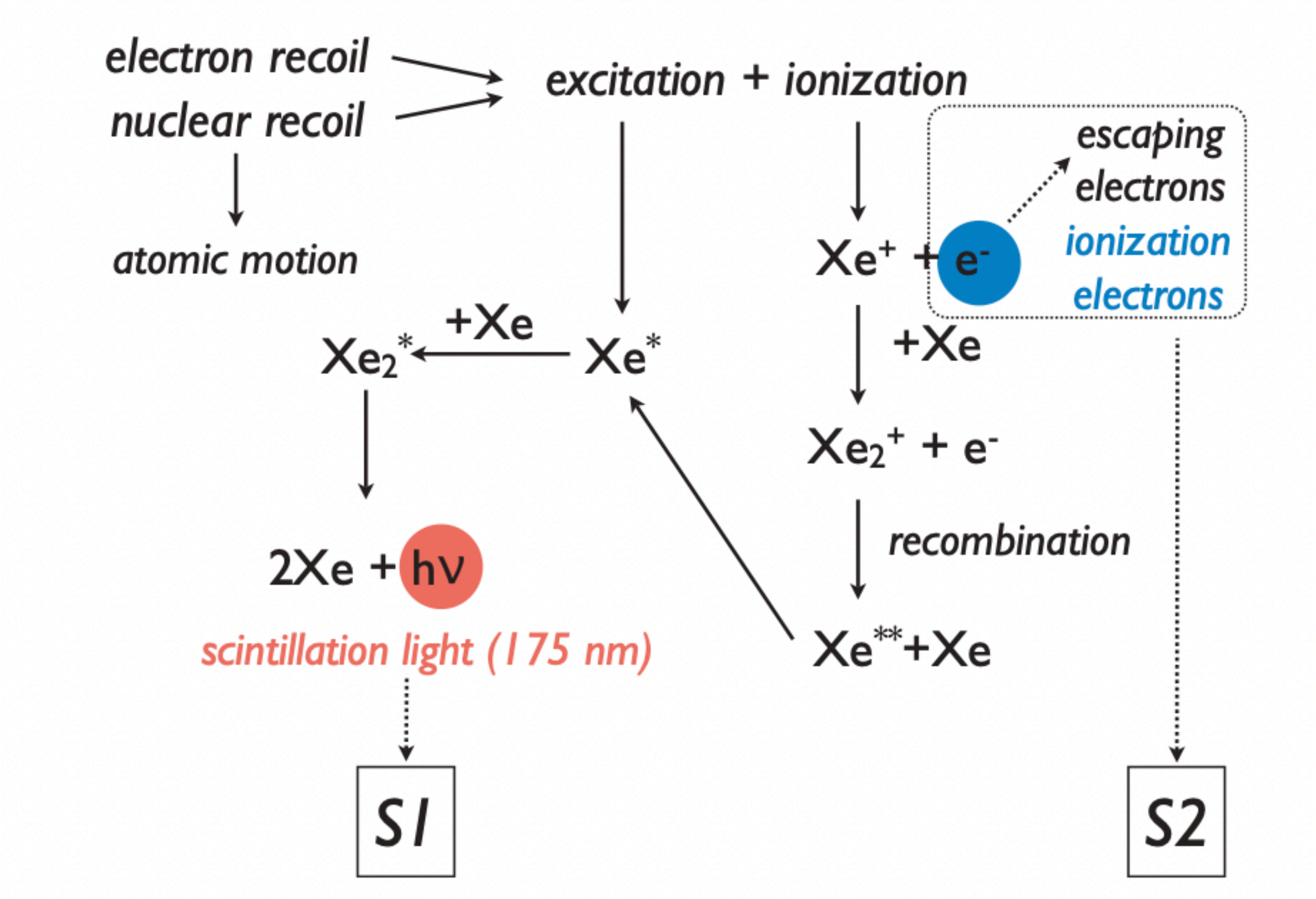

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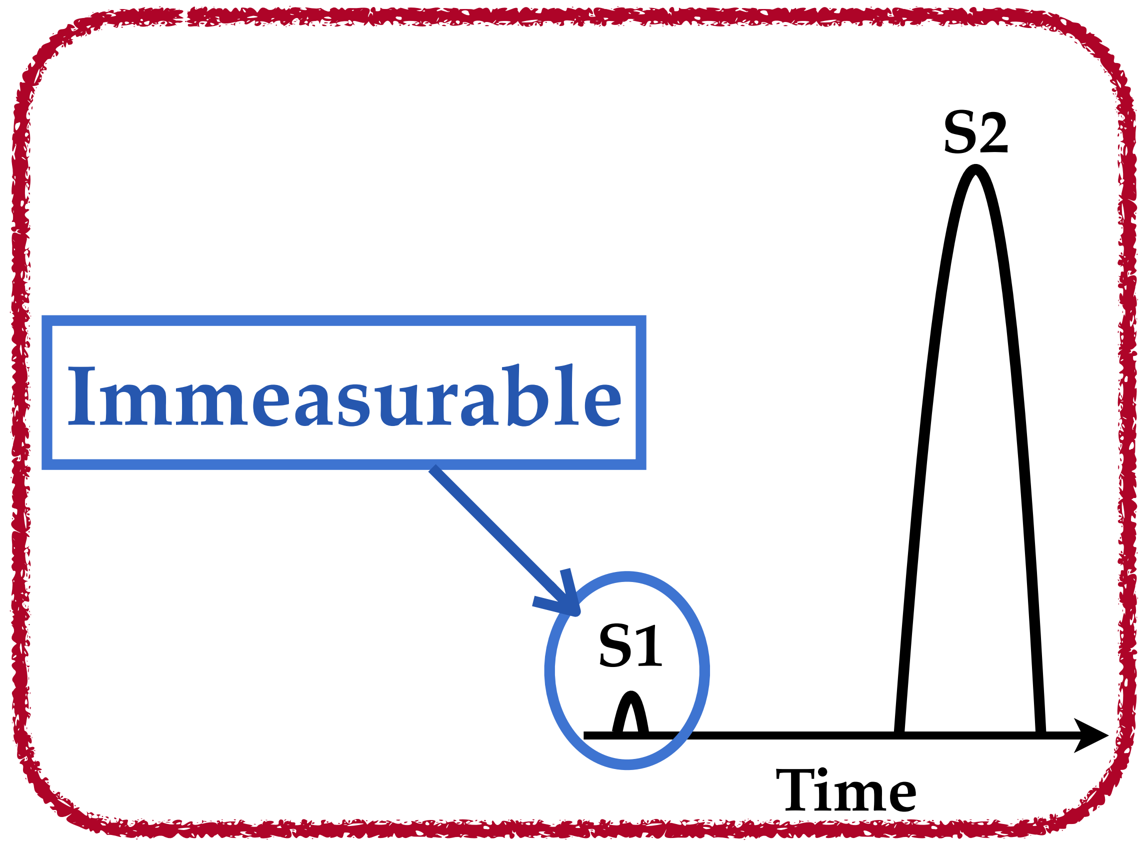

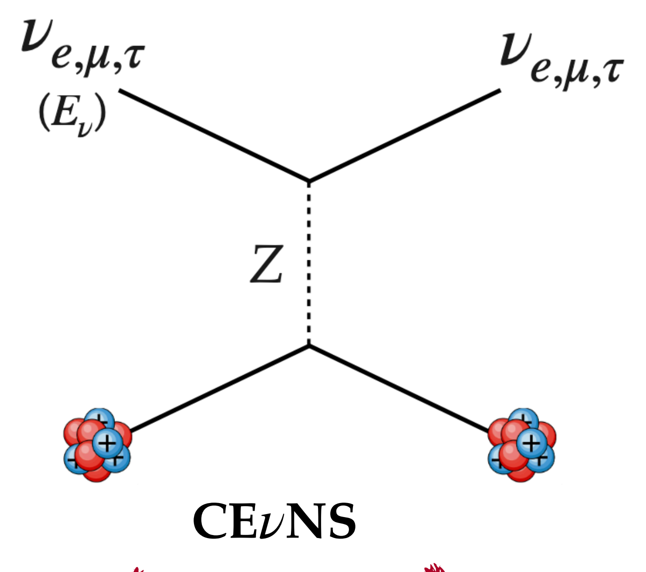

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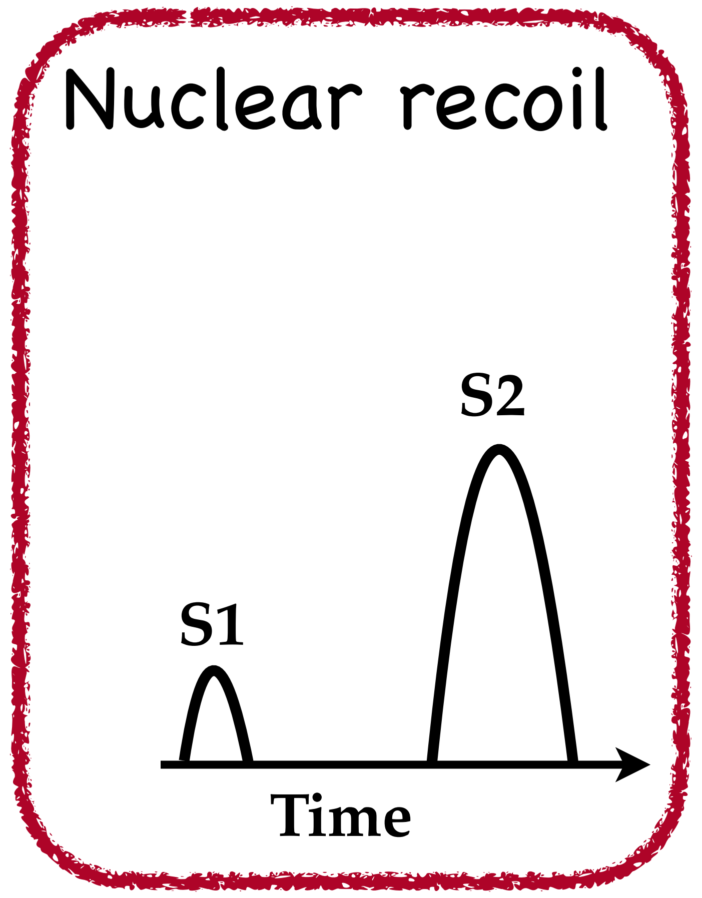

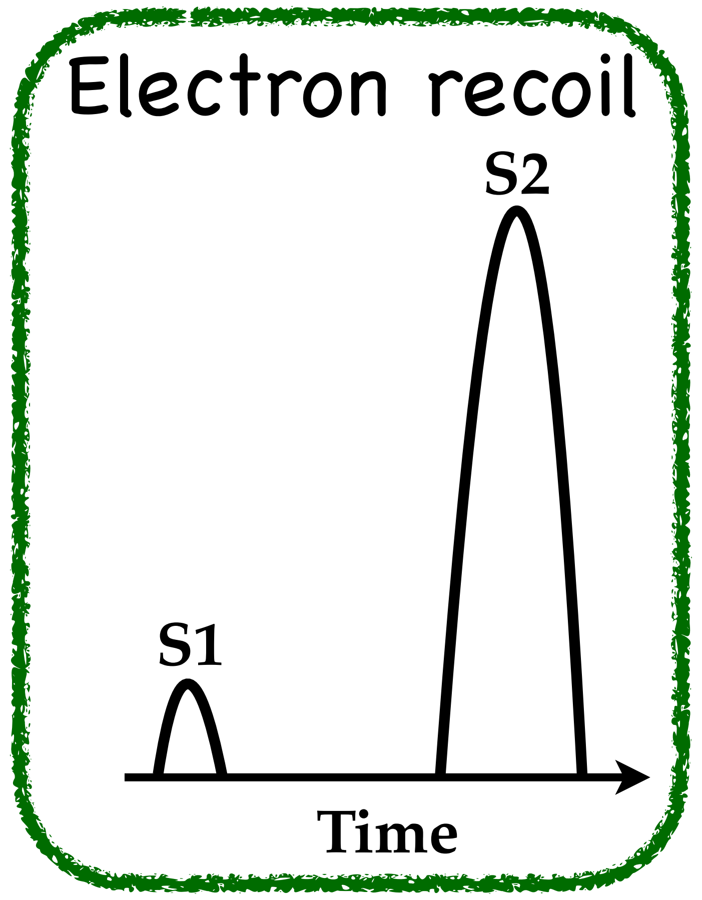

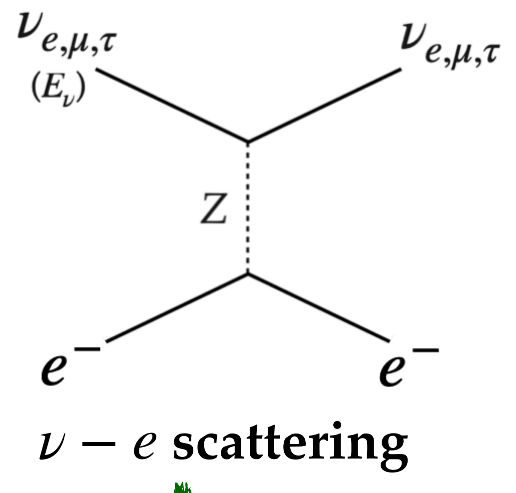

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Neutrino events at DD? nuclear recoil

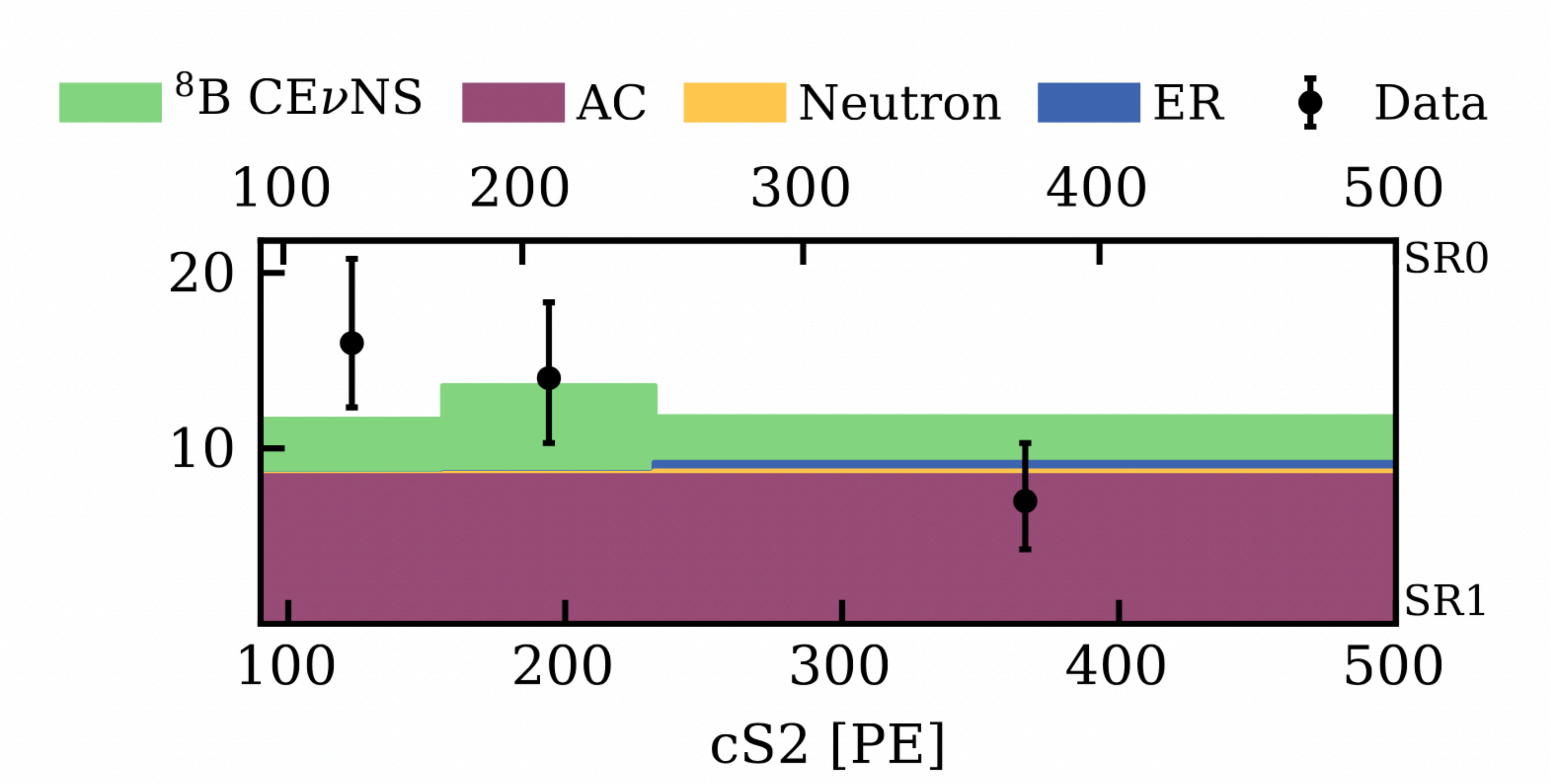
XENONnT


arXiv > nucl-ex > arXiv:2408.02877

Nuclear Experiment

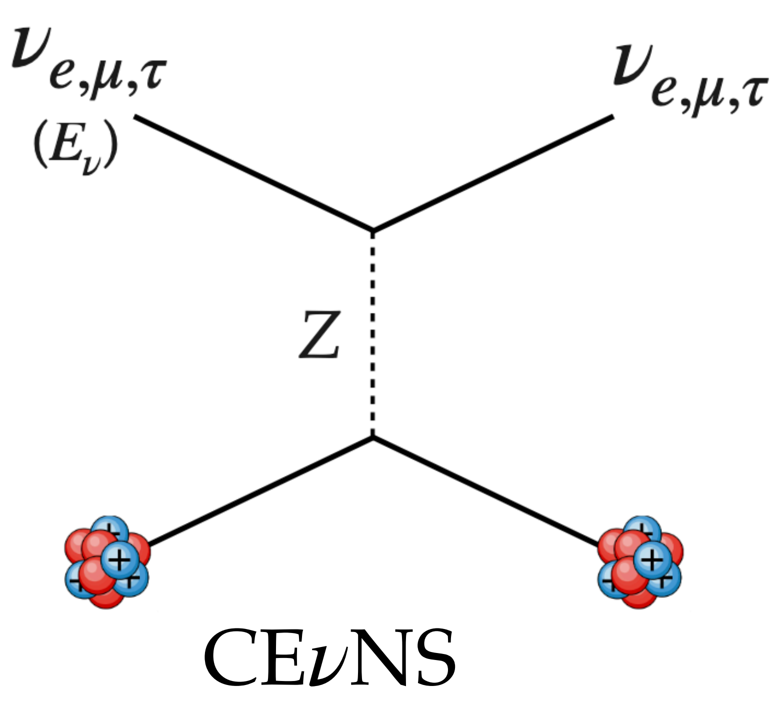
[Submitted on 6 Aug 2024]

First Measurement of Solar ^{8}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 σ



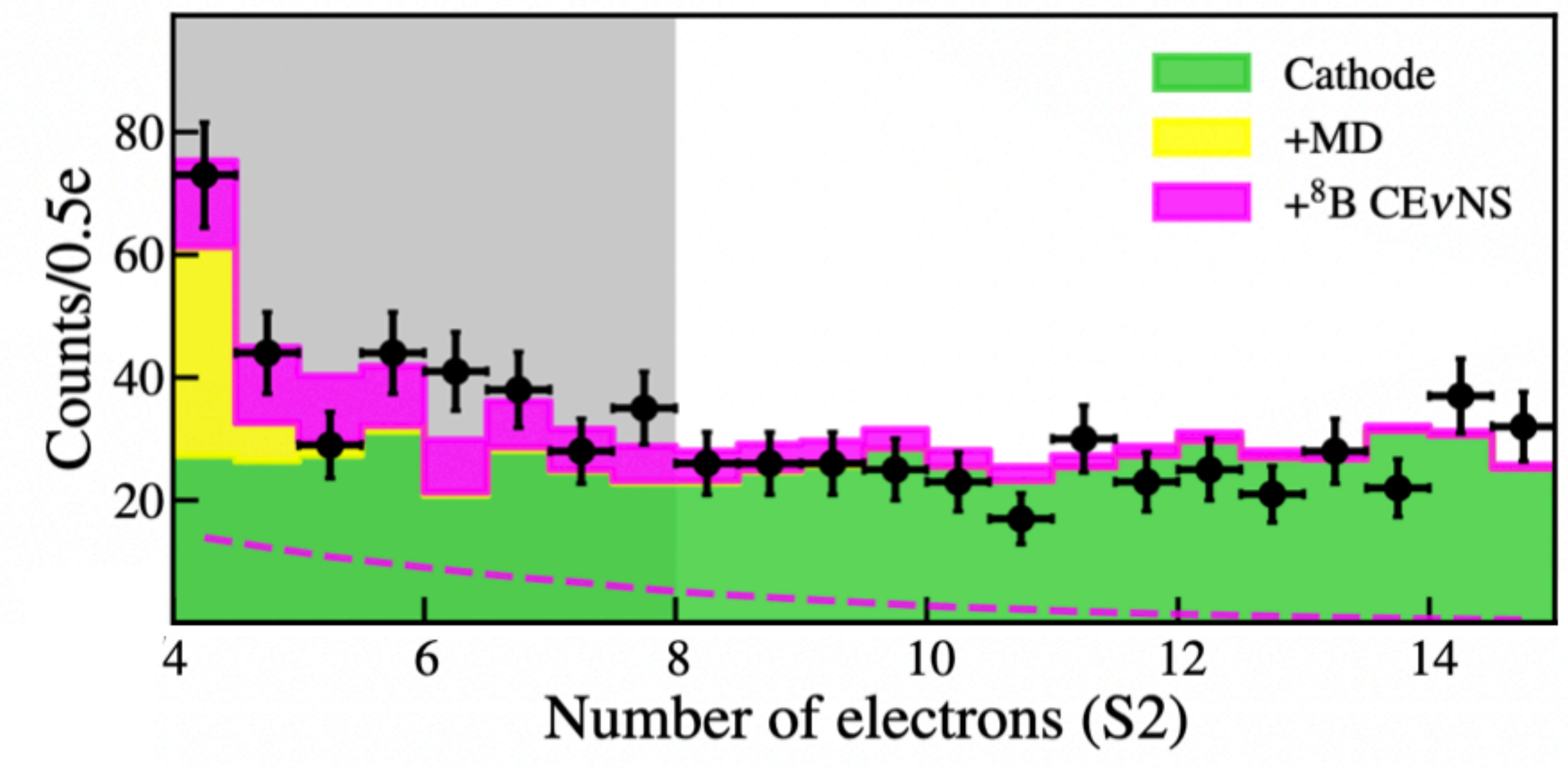
PandaX-4T


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}B Neutrino Flux through Coherent Elastic Neutrino-Nucleus Scattering in PandaX-4T



Observed events: 3.5 ± 1.3 **(S1-S2 analysis)**

Observed events: 78 ± 28 **(S2-only analysis)**

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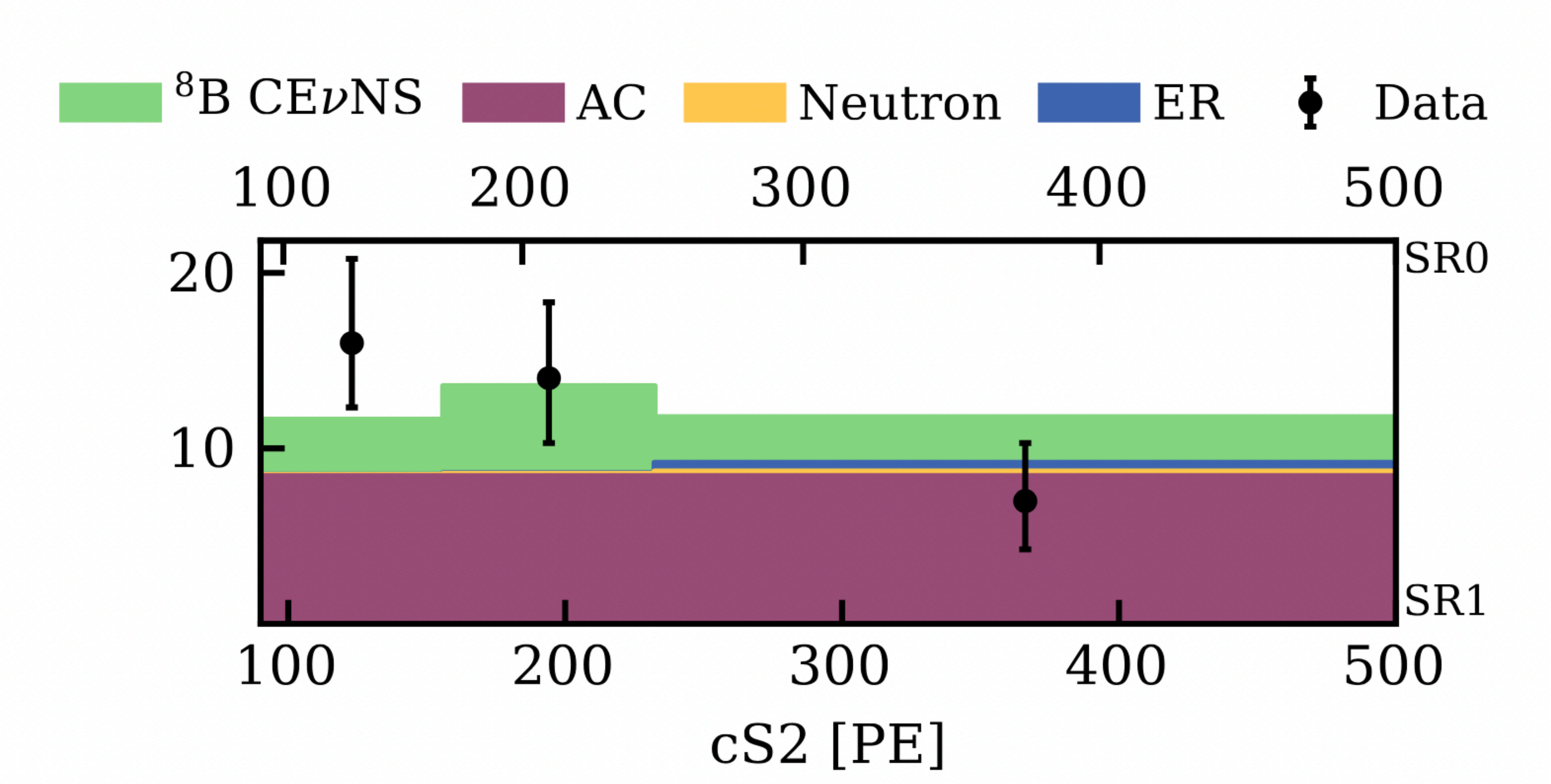

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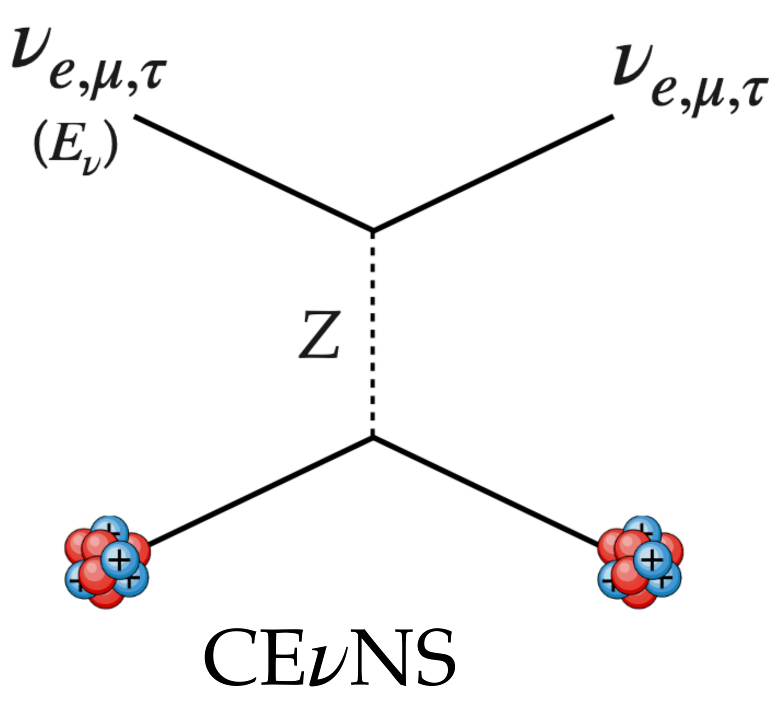

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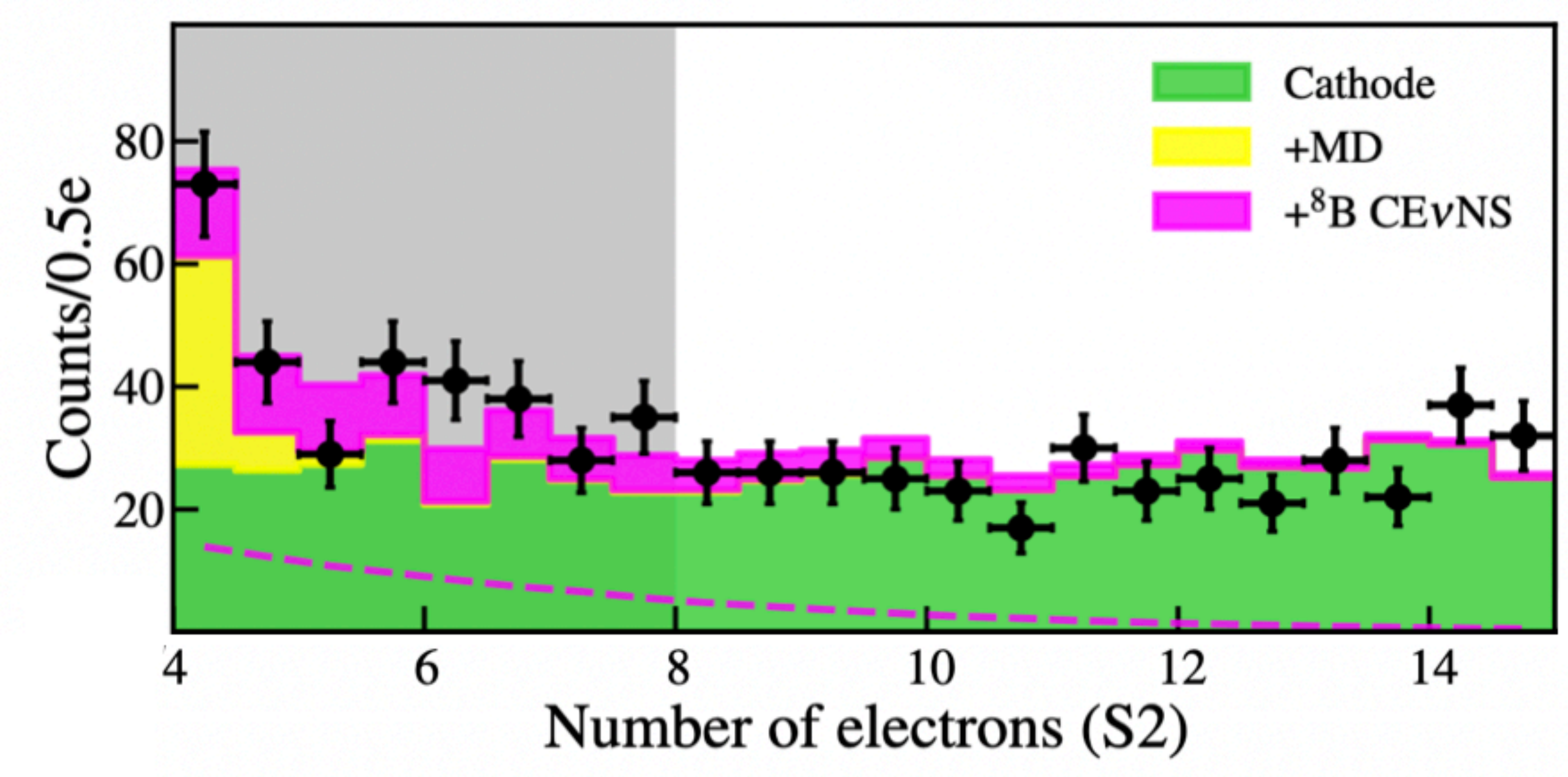

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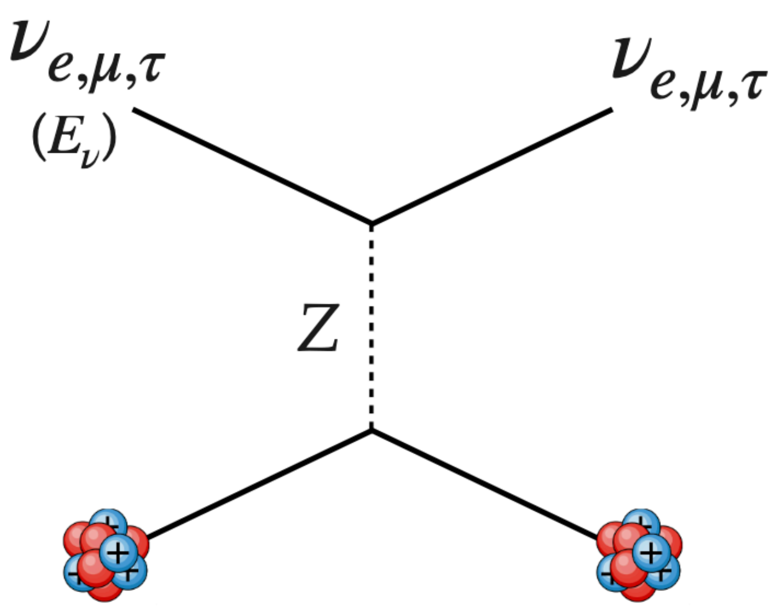
Observing essentially the Standard Model process, can we say something new?

Our results: nuclear recoil



CEνNS

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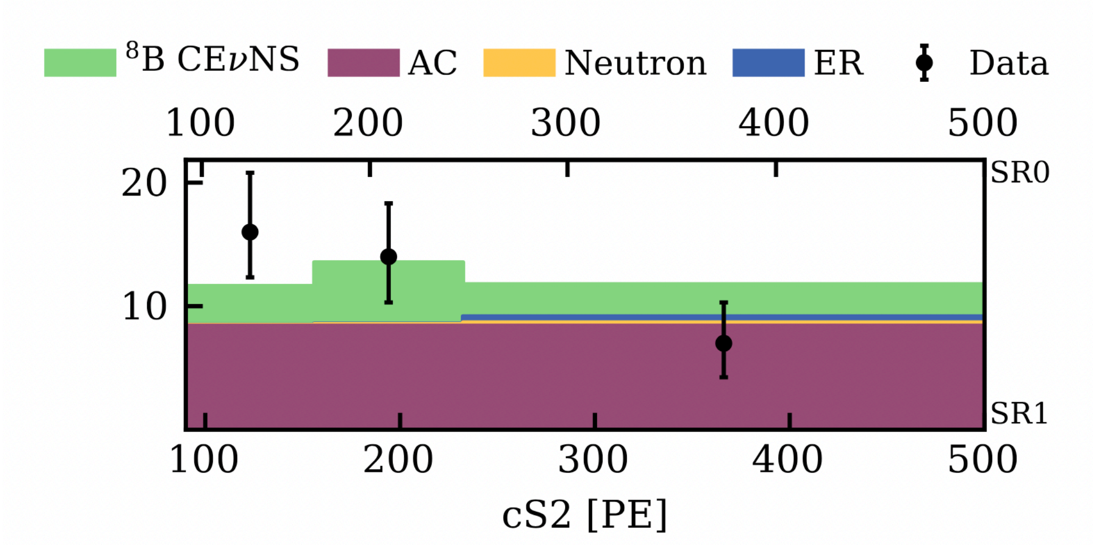

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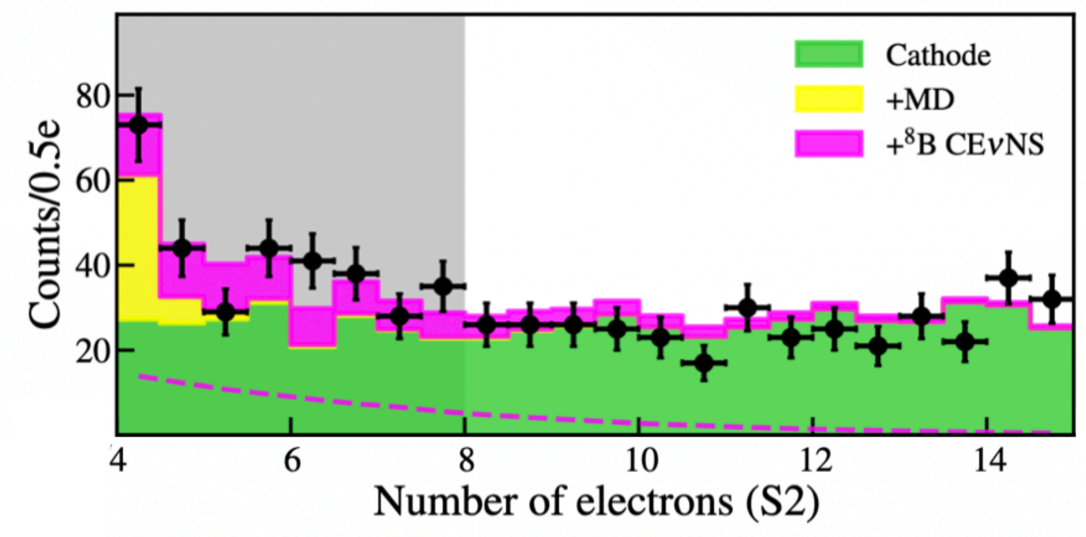

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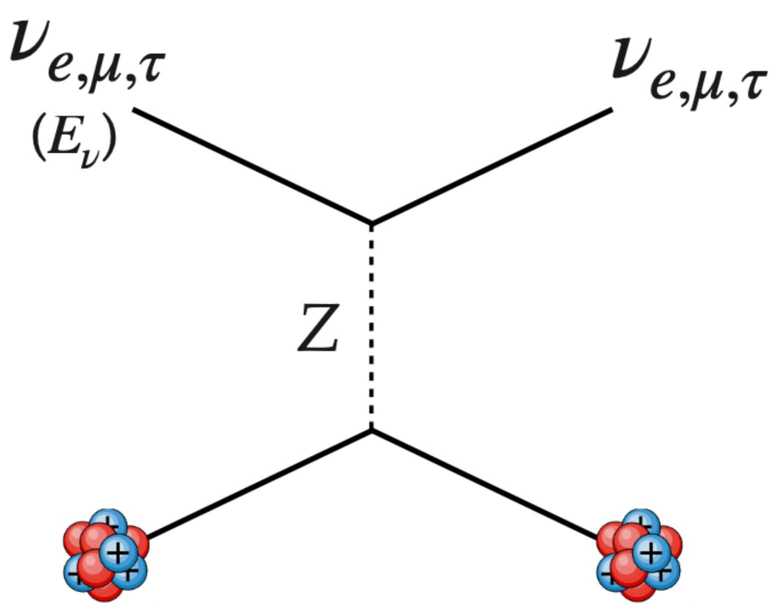

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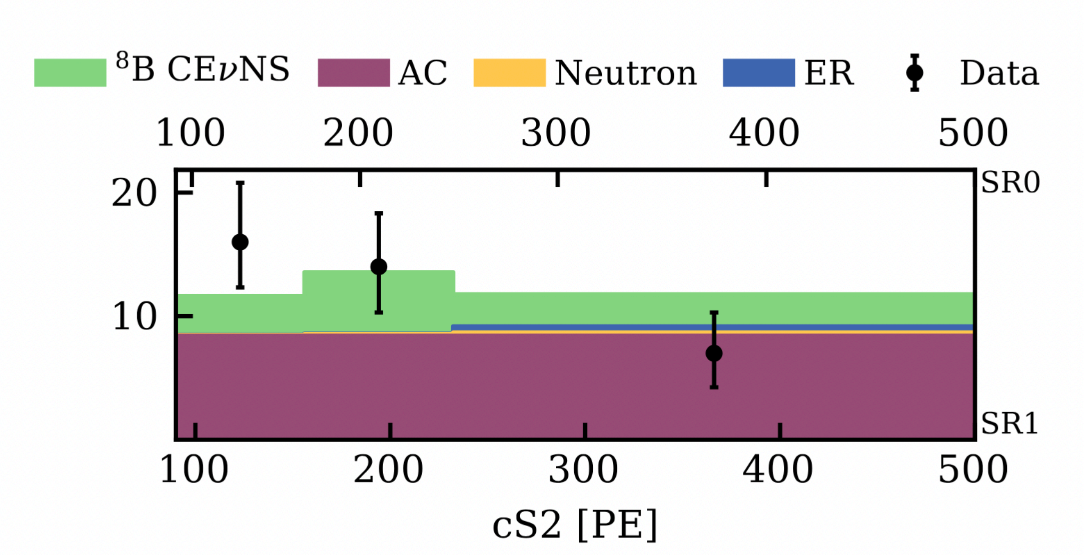

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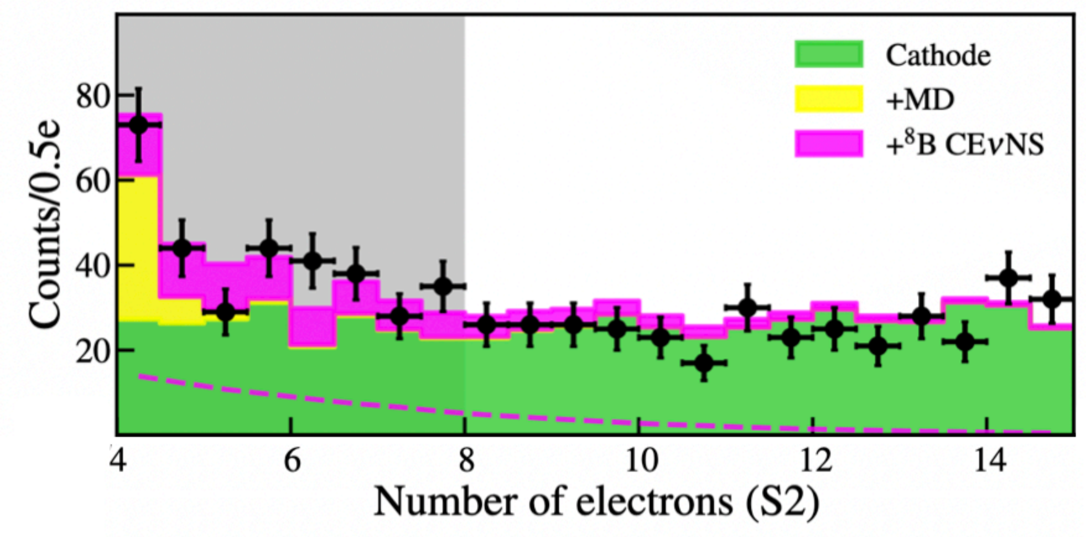

Observed solar ^{8}B events depends on $\sin^2\theta_W$ → One can measure $\sin^2\theta_W$ using these data

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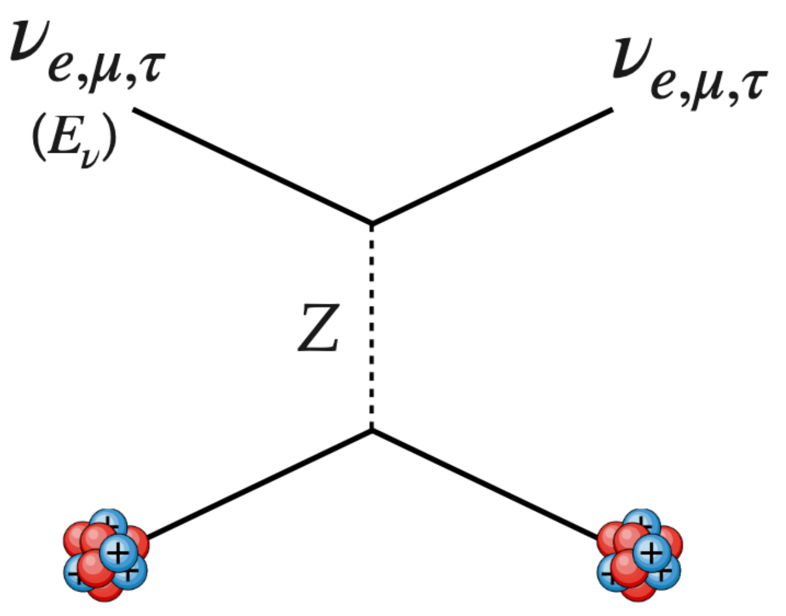

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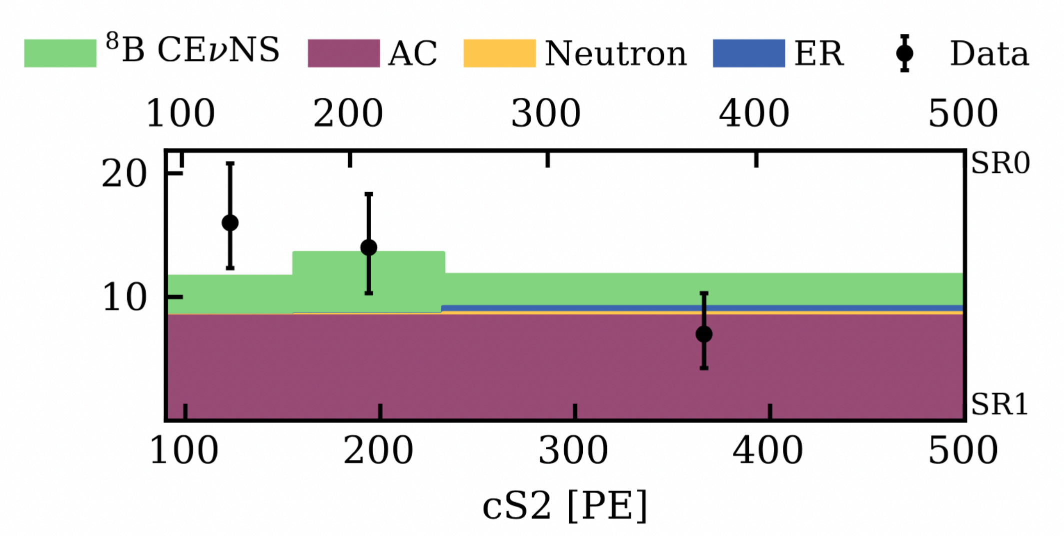

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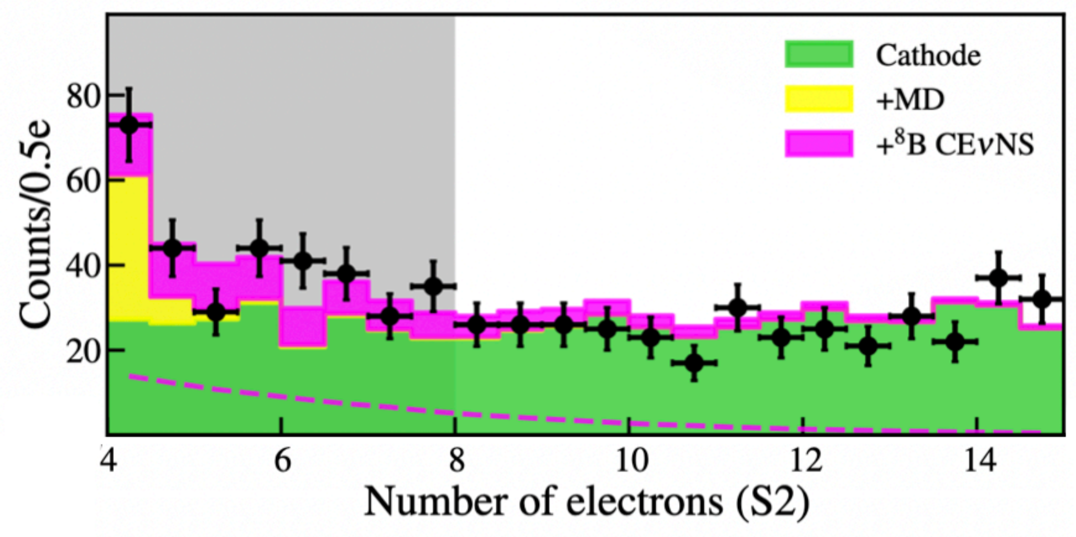

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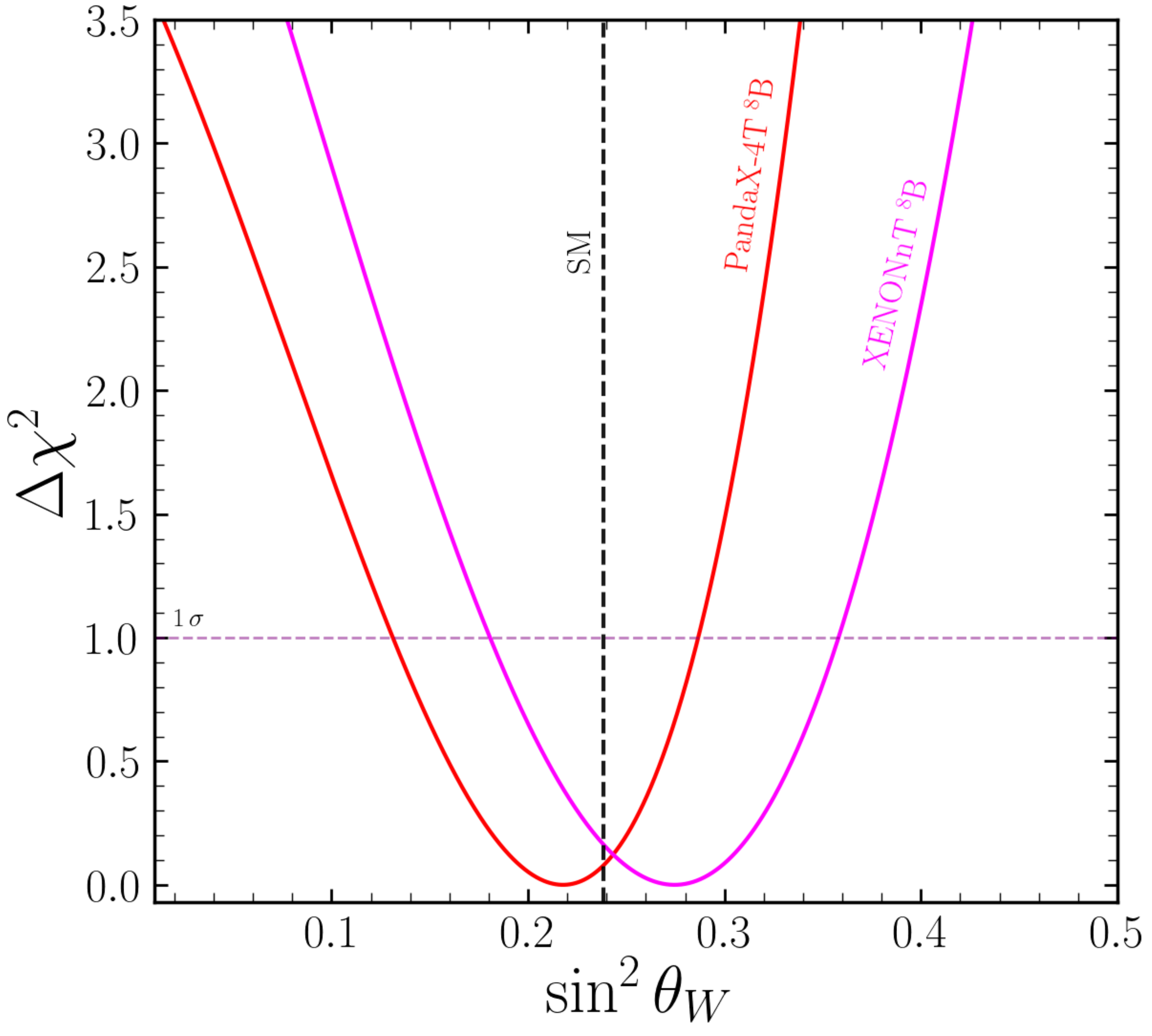

TNM, Boehm; 2409.04385

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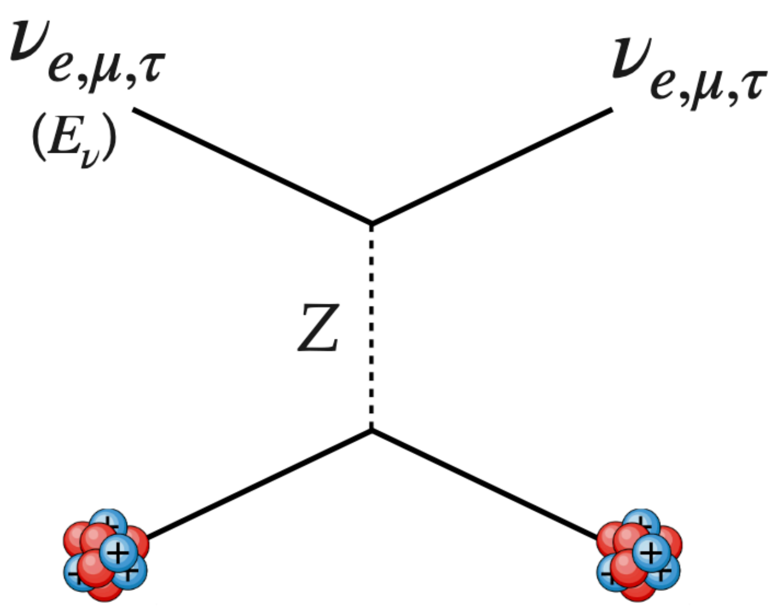

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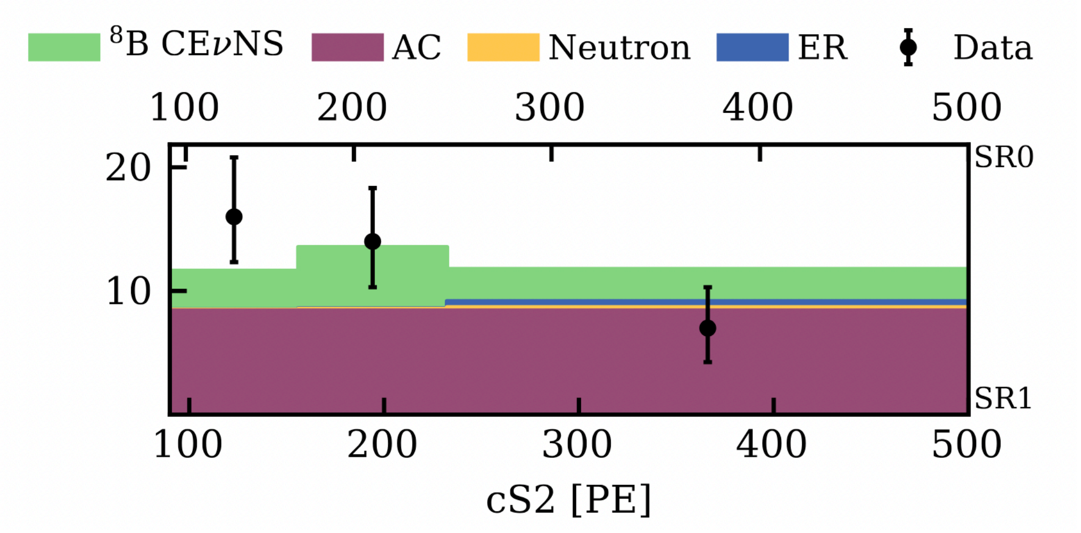

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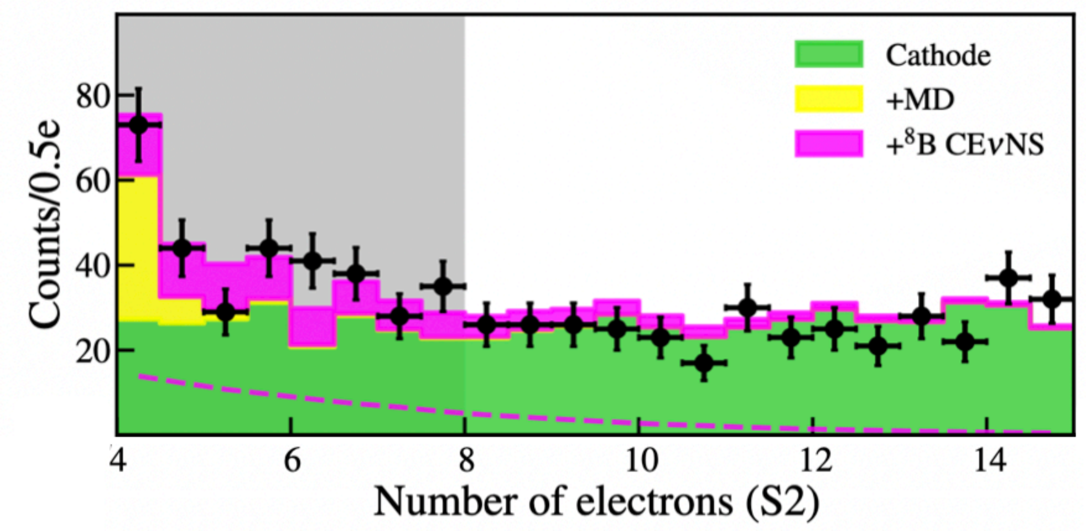

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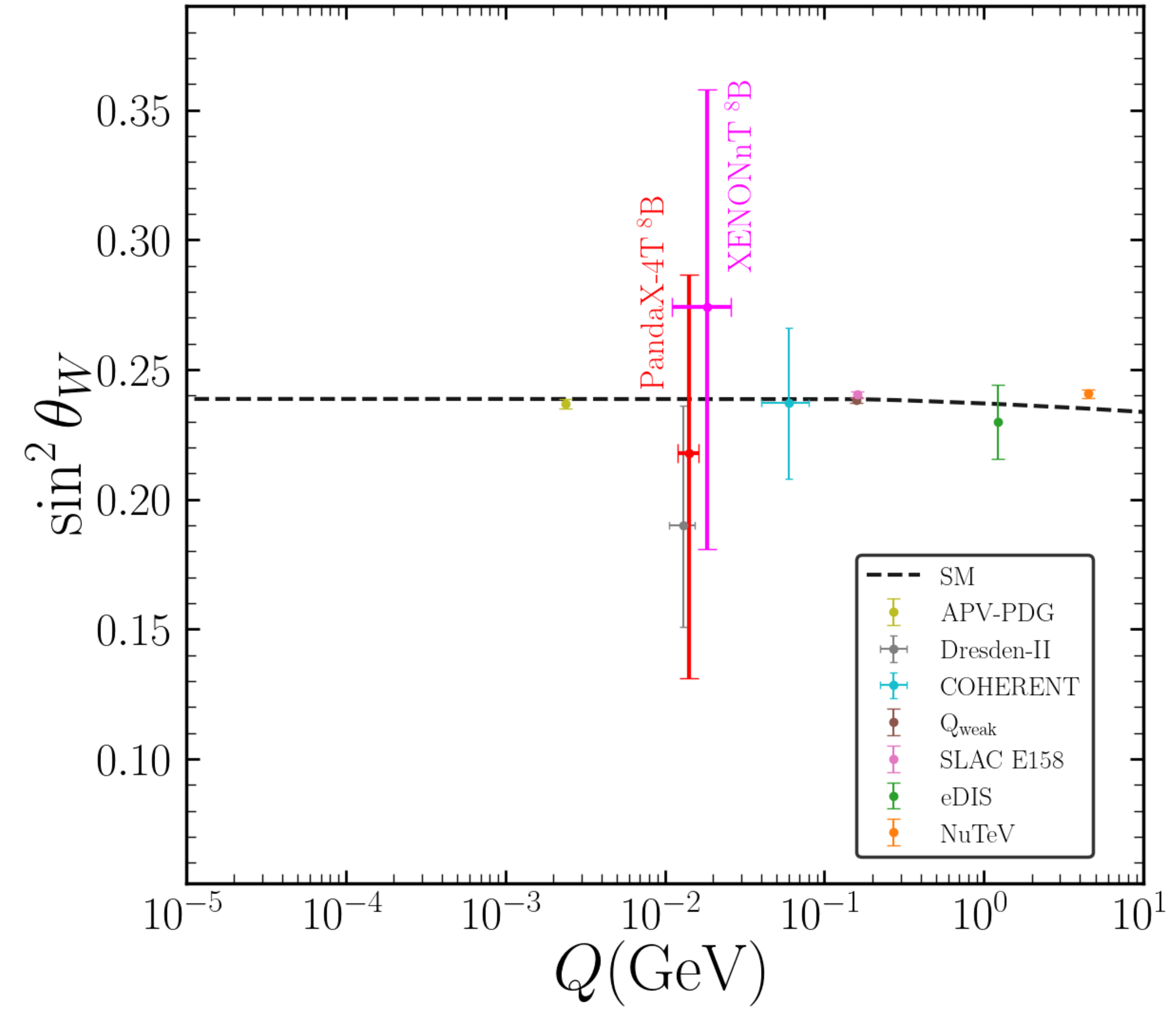
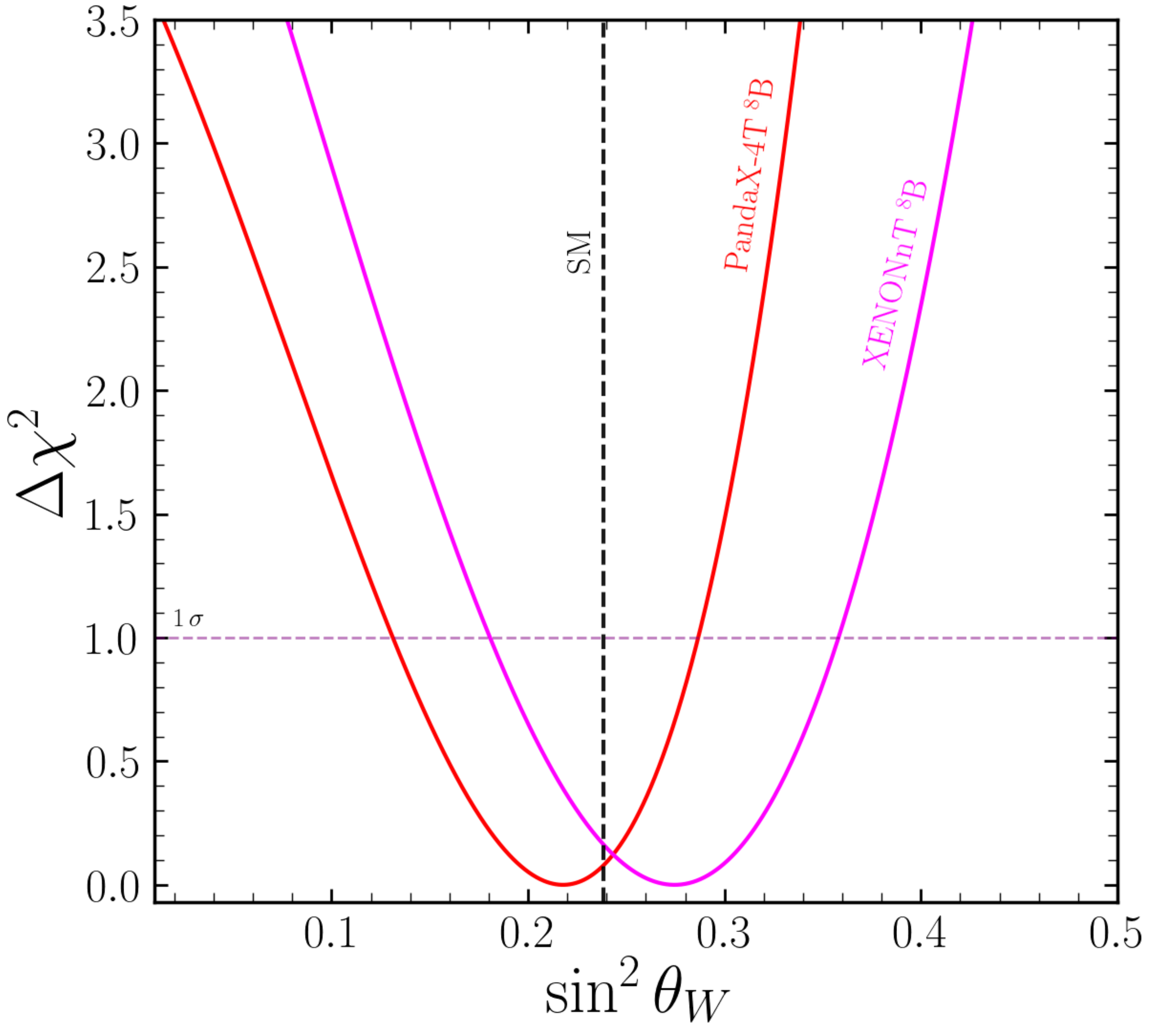


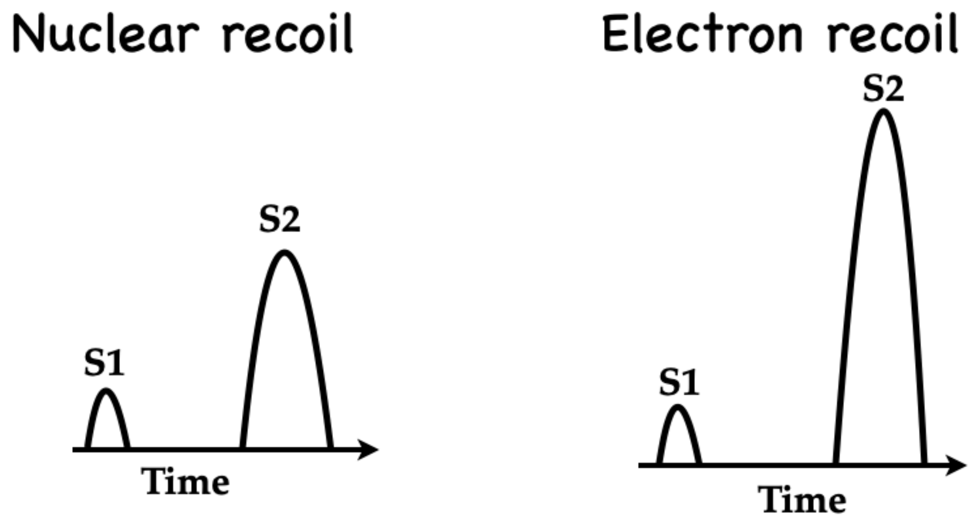
Energy scale determined from recoil energy regime



TNM, Boehm; 2409.04385

Our results: electron recoil

S1-S2 only analysis



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

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

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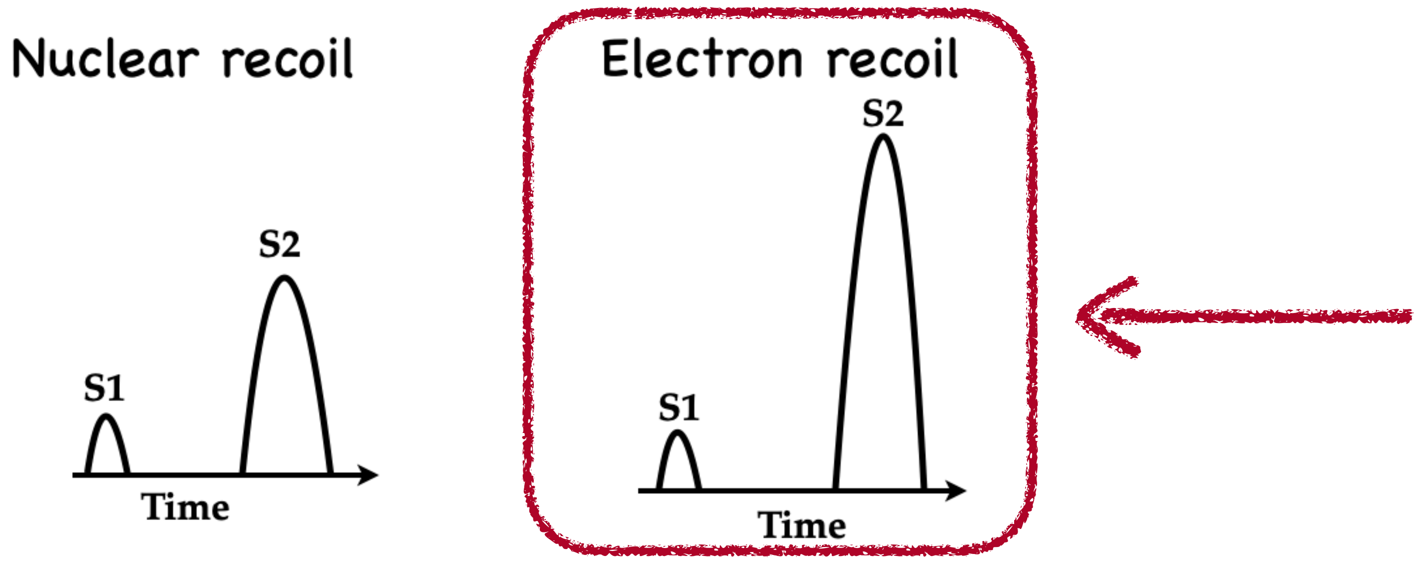

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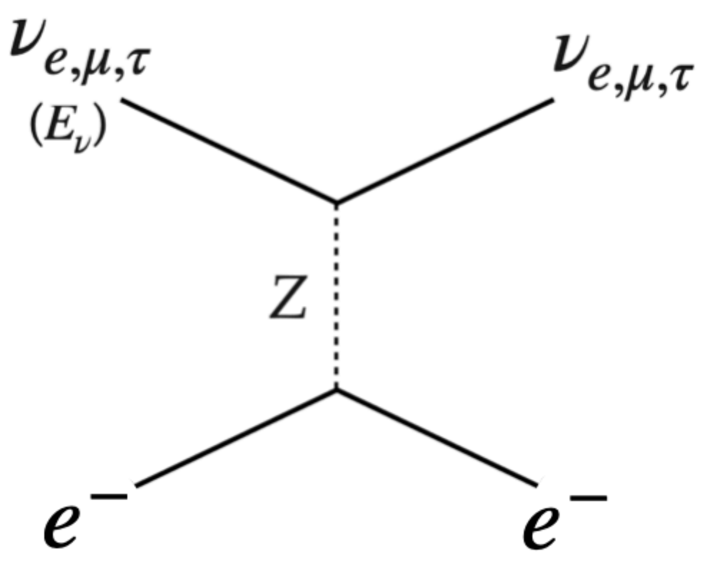

Neutrino-electron scattering

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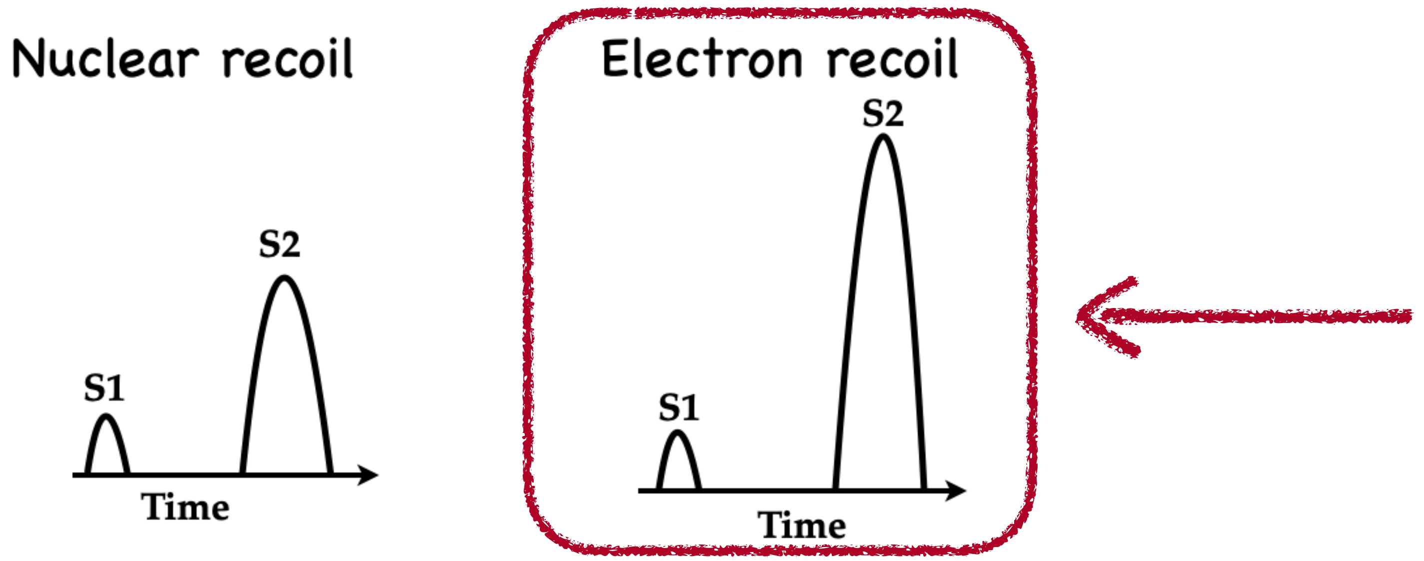

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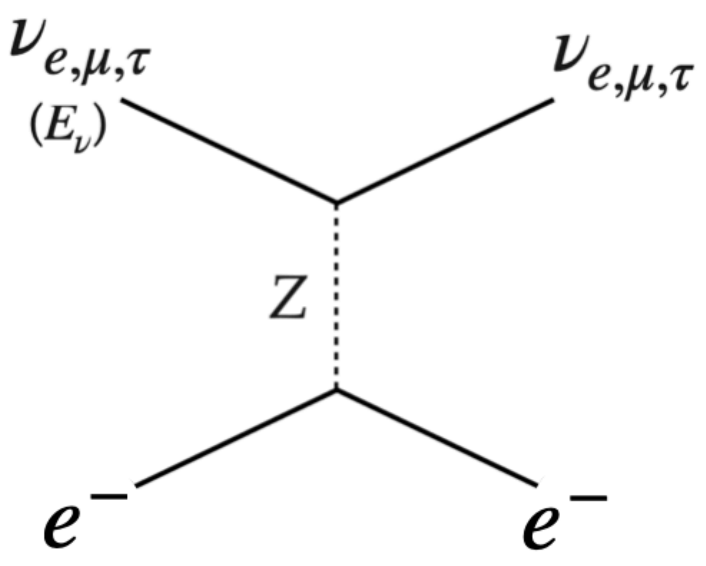

Neutrino-electron scattering

Observed $\nu - e$ events: ~ 60

But statistically not significant due to huge background

XENONnT 2207.11330
LZ 2307.15753
PandaX-4T 2408.07641

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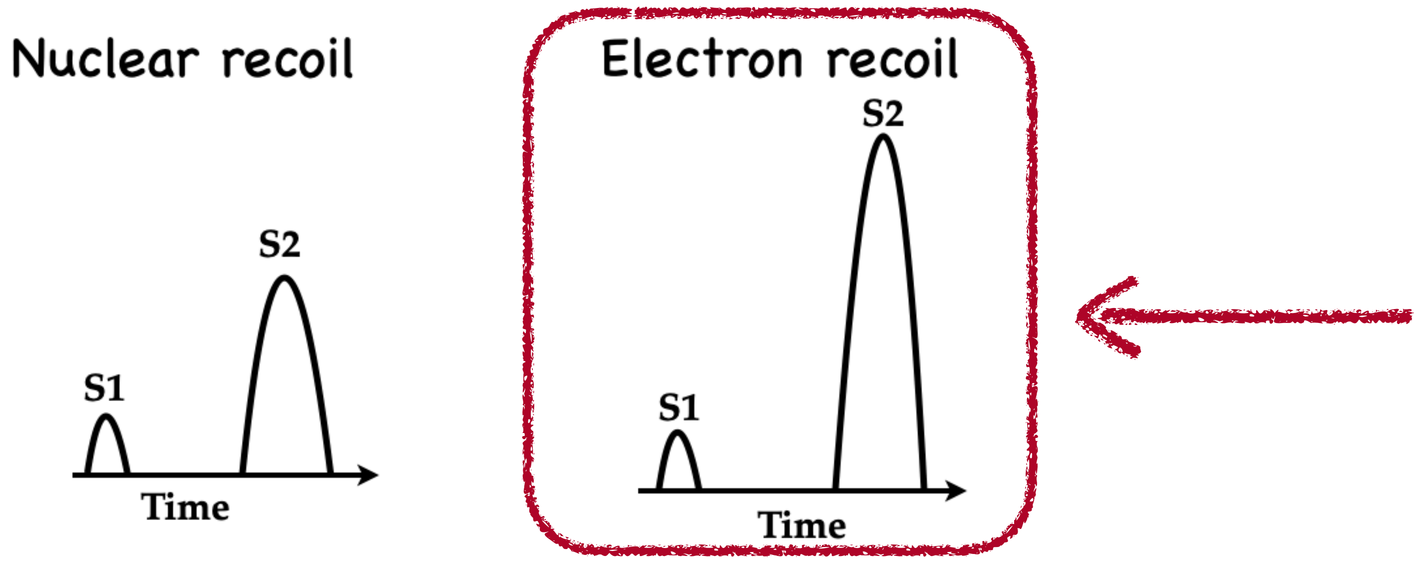

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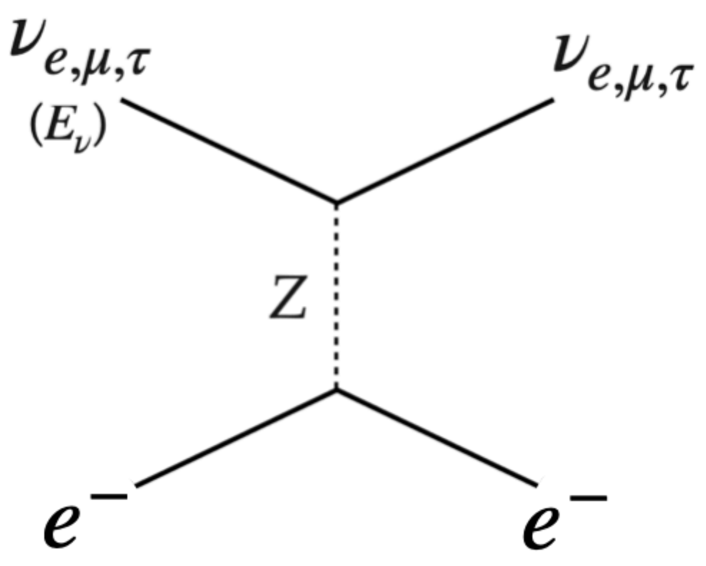

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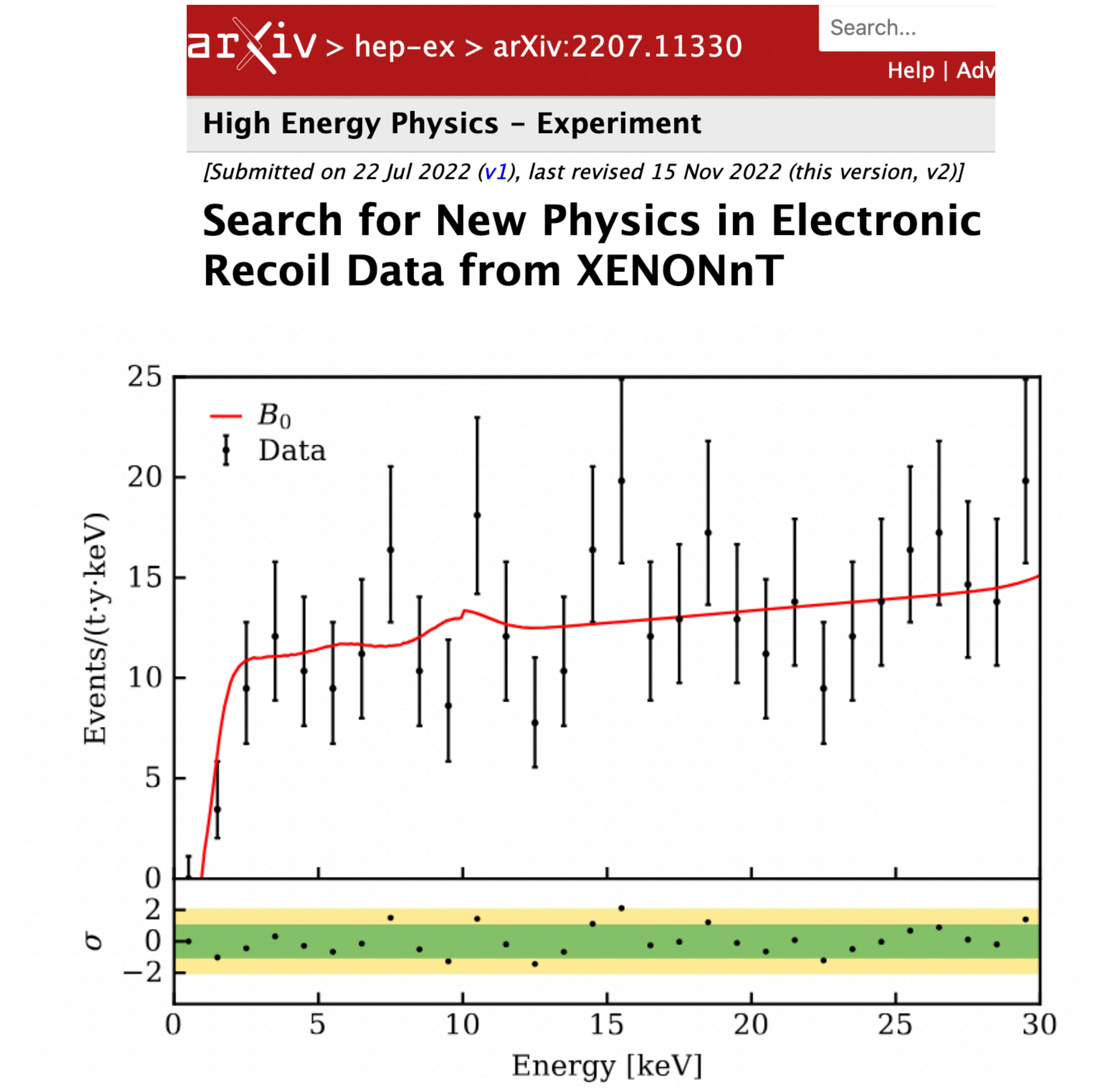
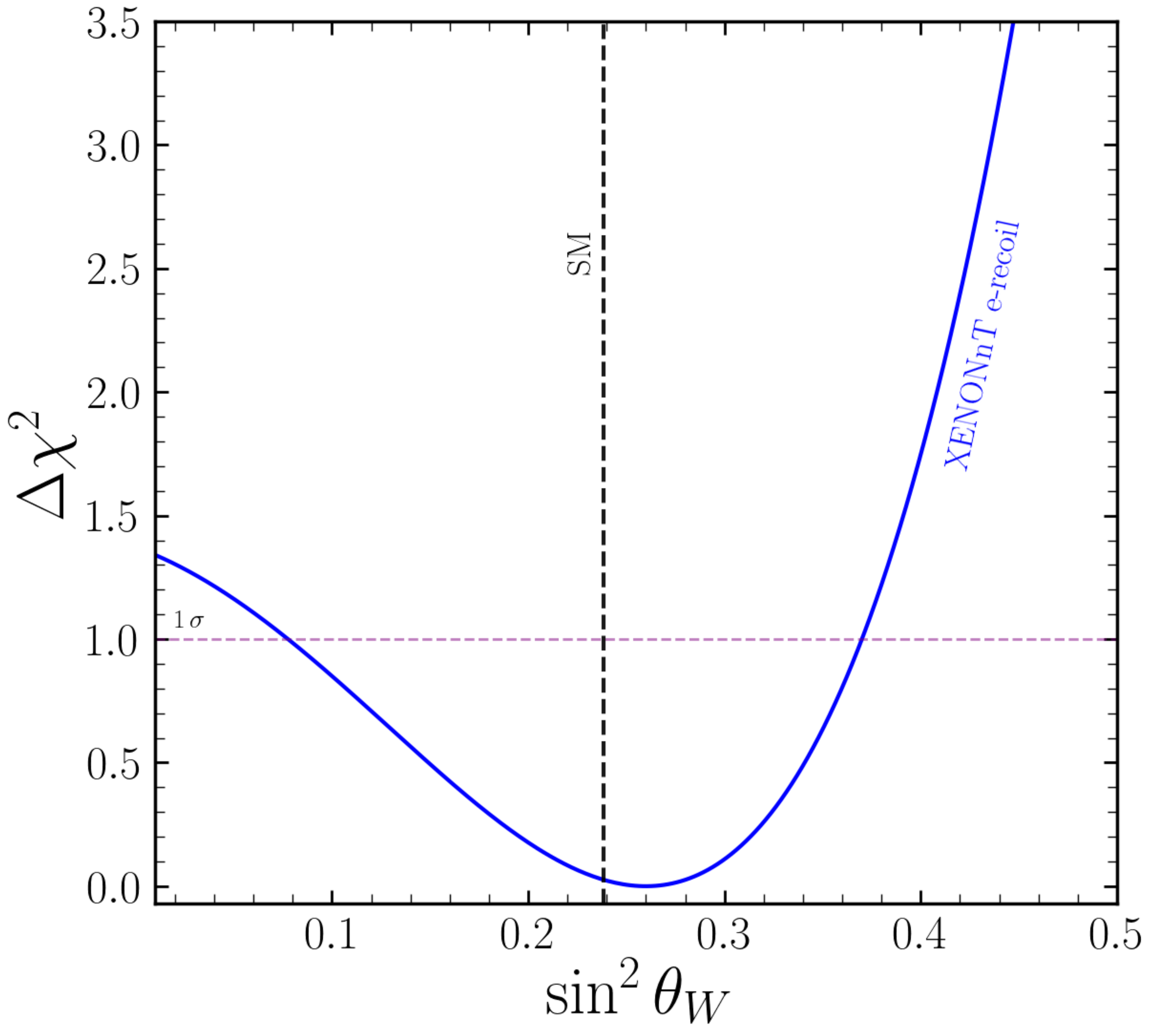

arXiv > hep-ex > arXiv:2207.11330

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 σ

TNM, Boehm; 2409.04385

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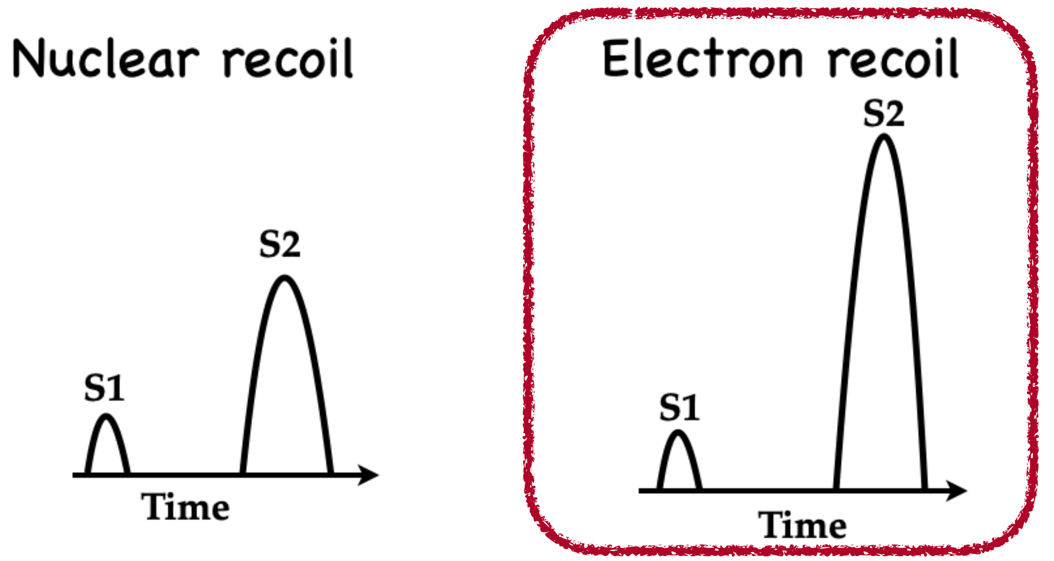

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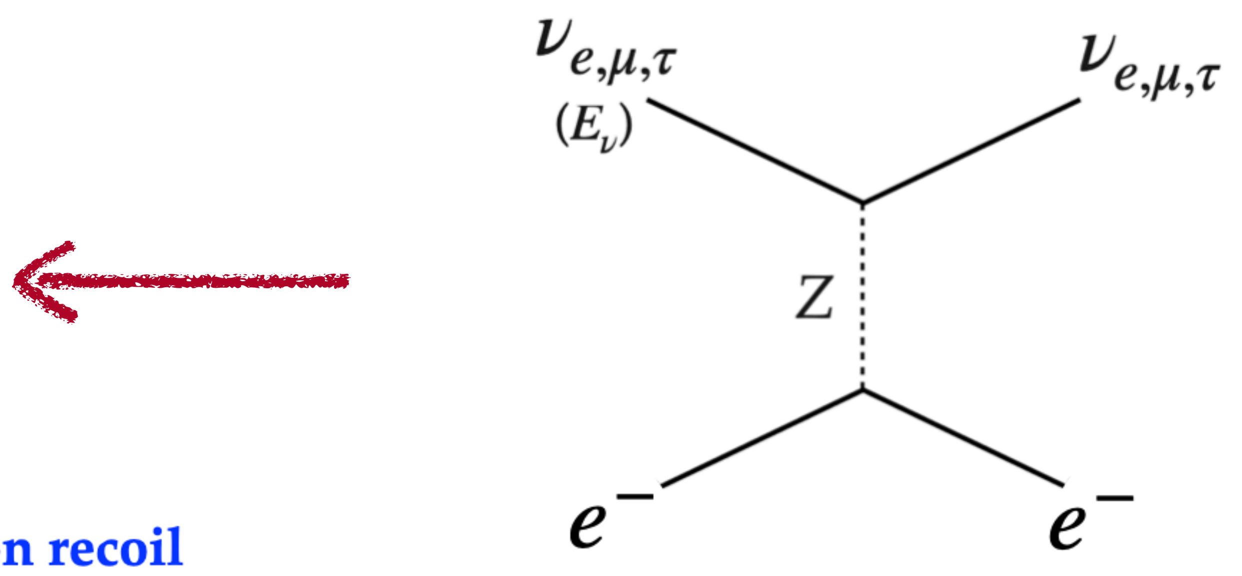

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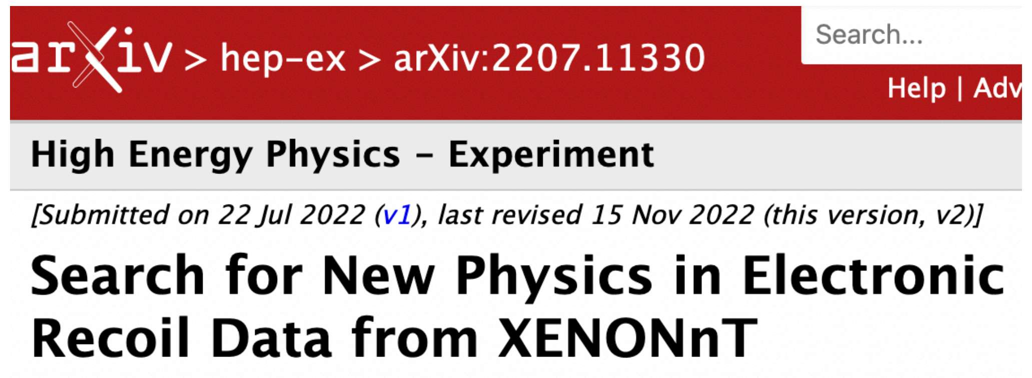
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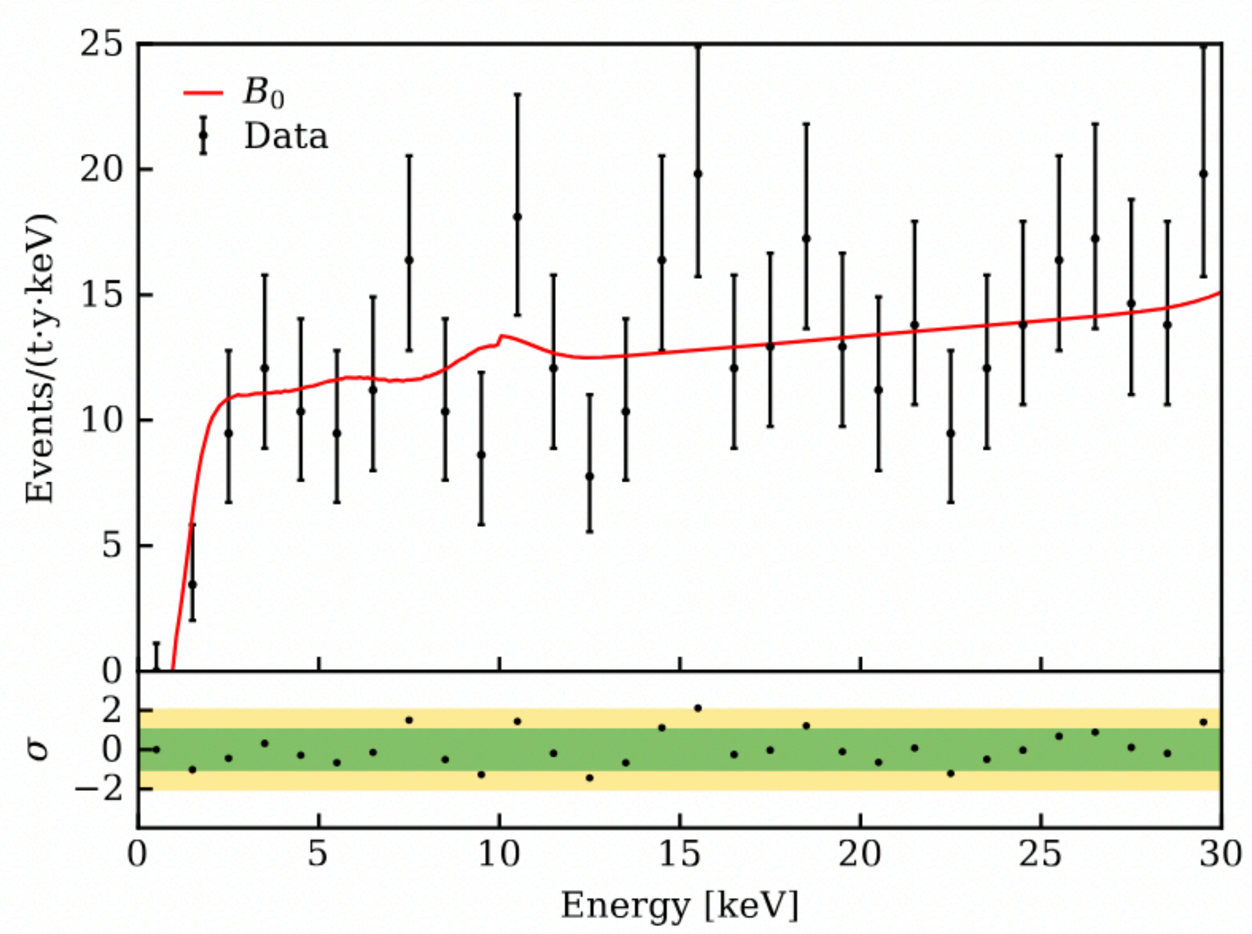

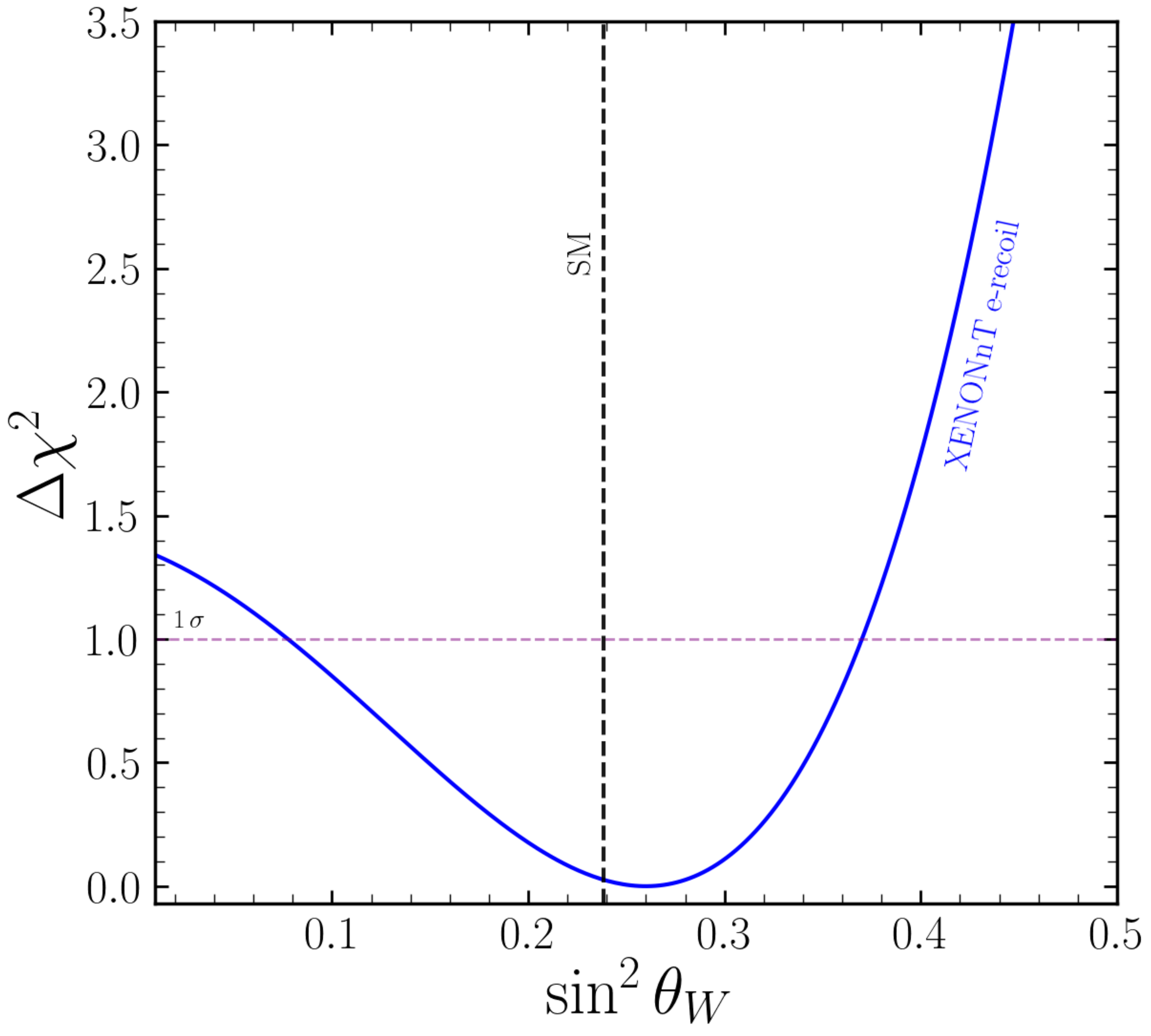

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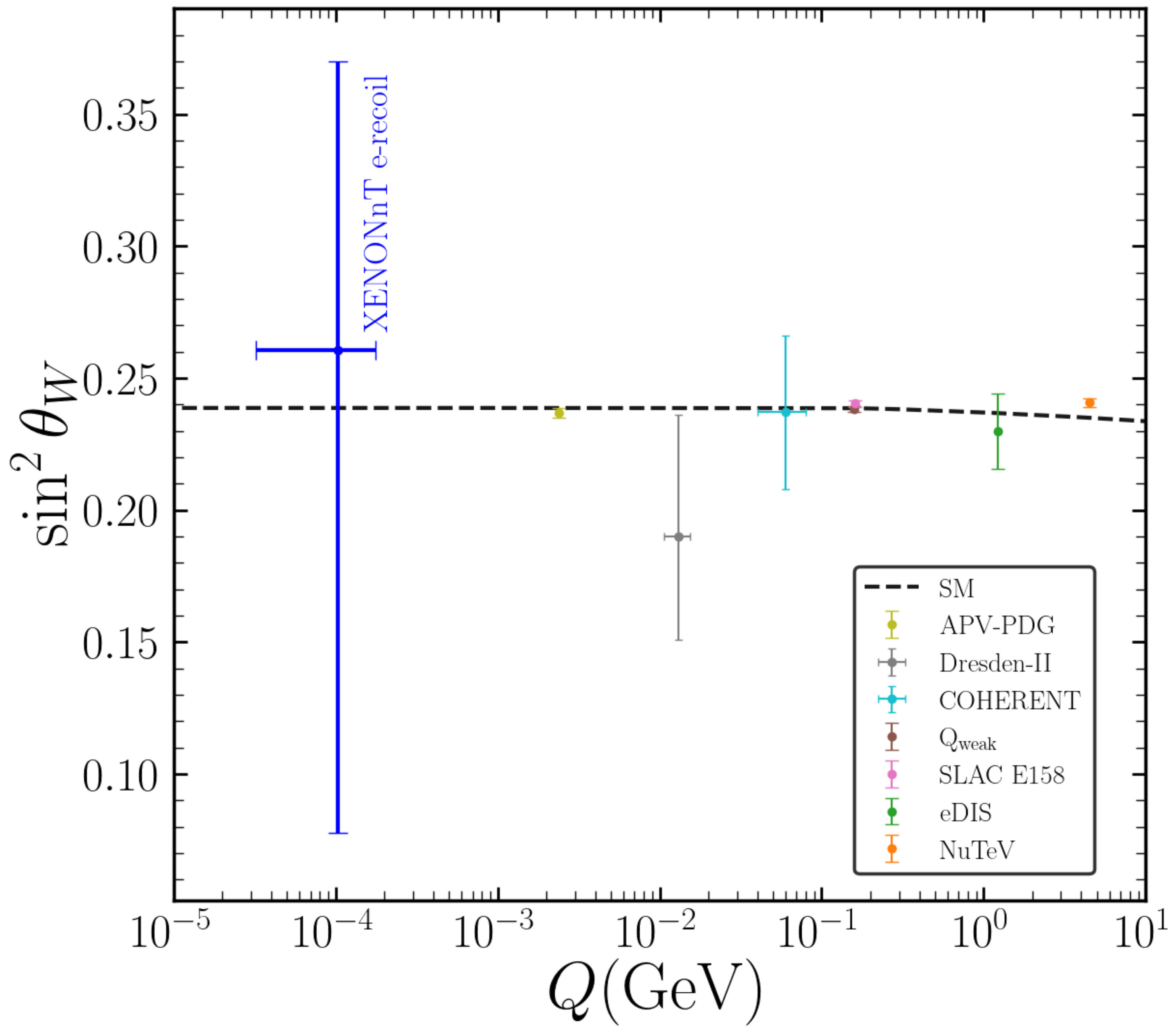
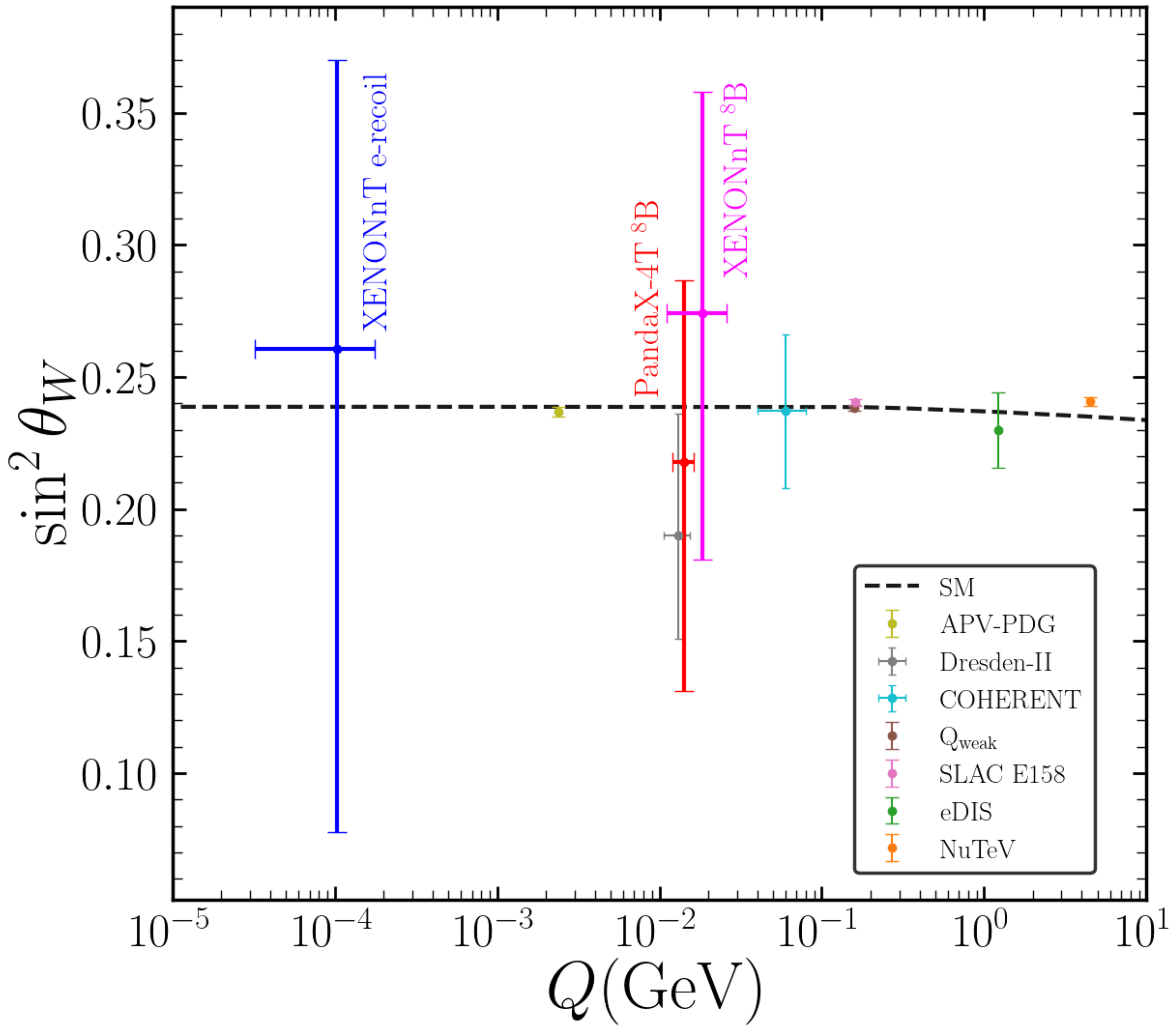


Probing a SM parameter in an entirely new regime

TNM, Boehm; 2409.04385

Summary

DD already probing SM in an uncharted territory



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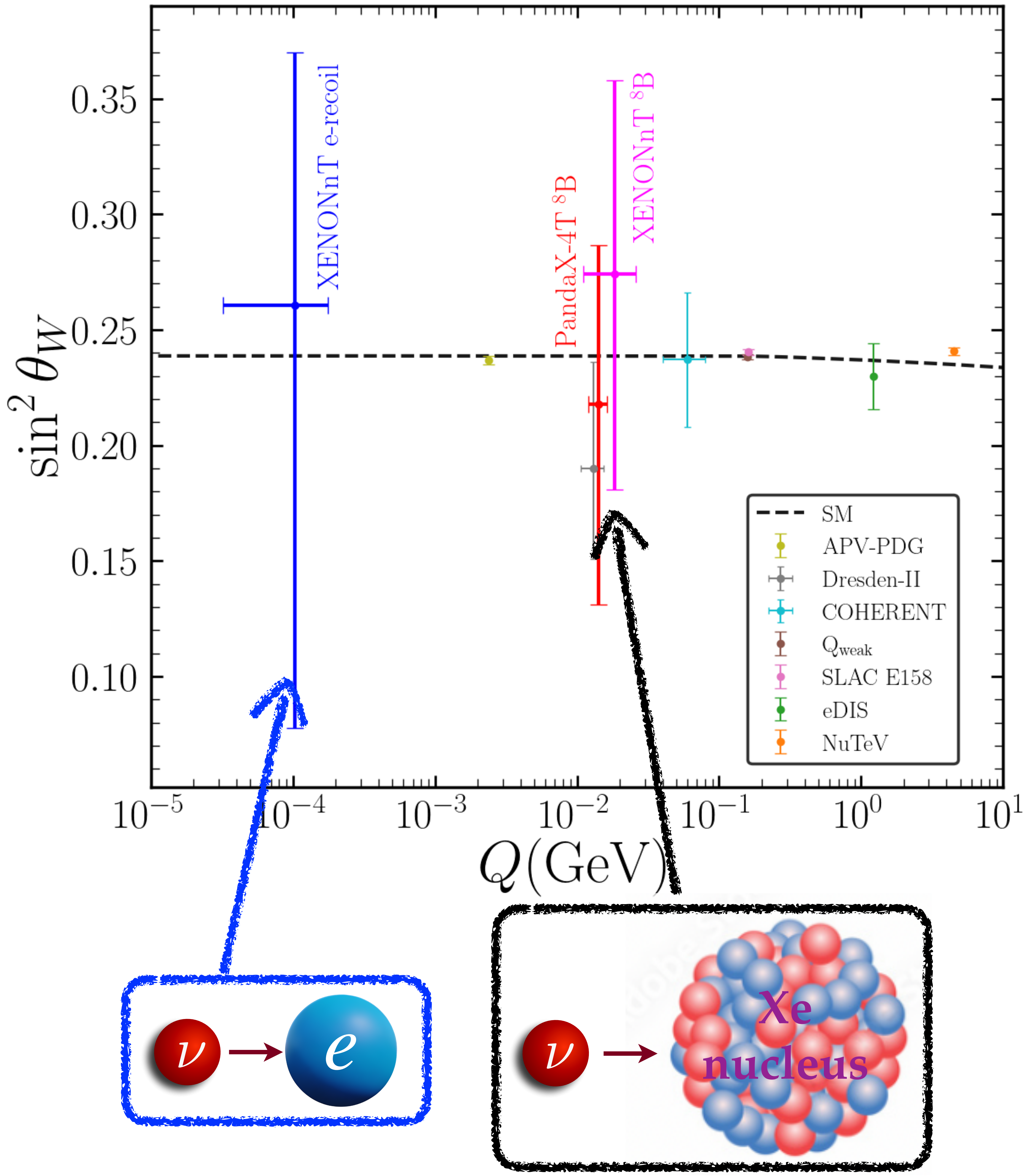

While recoil energy of our analysis similar but heavy Xe nucleus shifts CEνNS in ~10 MeV scale

TNM, Boehm; 2409.04385

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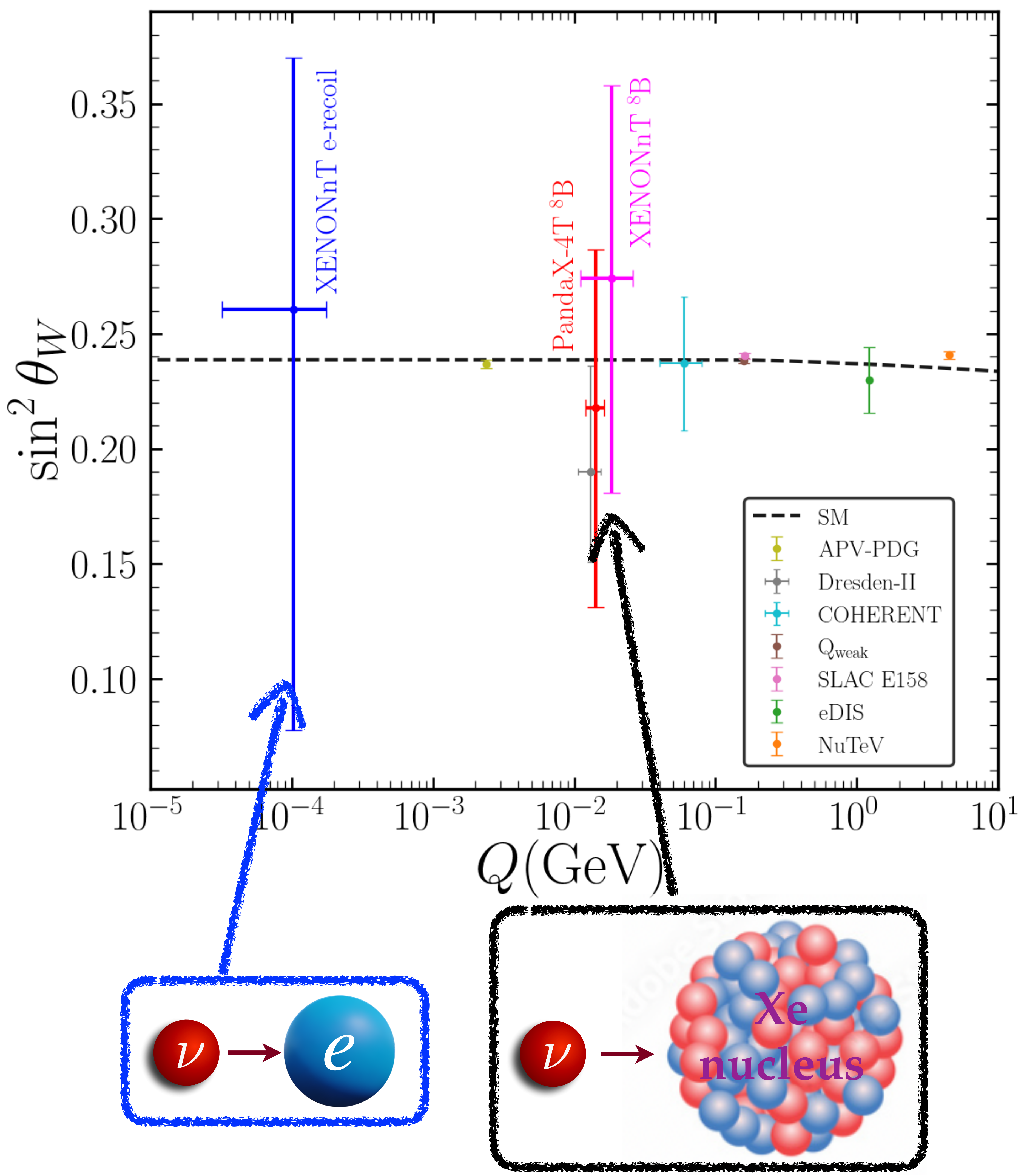

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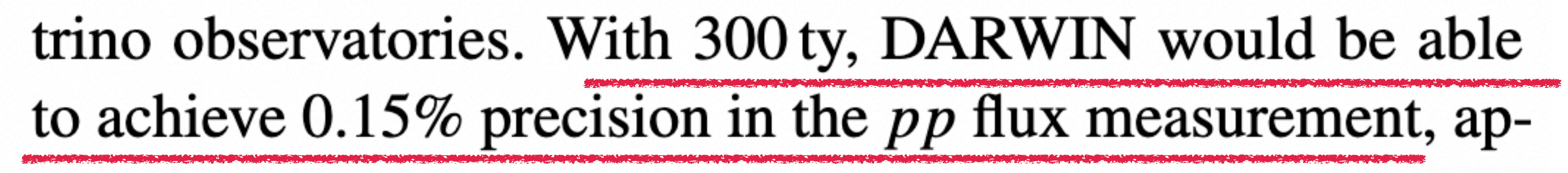
Future Xe based: DARWIN/XLZ, PandaX-xT



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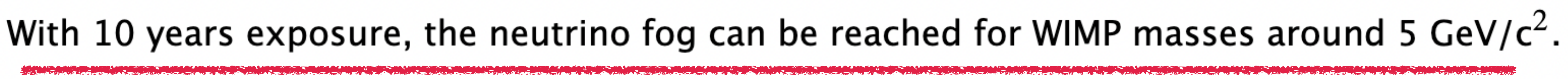
DARWIN, 2006.03114

Future Ar based: DarkSide-20k



With 10 years exposure, the neutrino fog can be reached for WIMP masses around 5 GeV/c^2.

DarkSide-20k, 2407.05813

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Expected to se some CEνNS events - no detailed analysis yet

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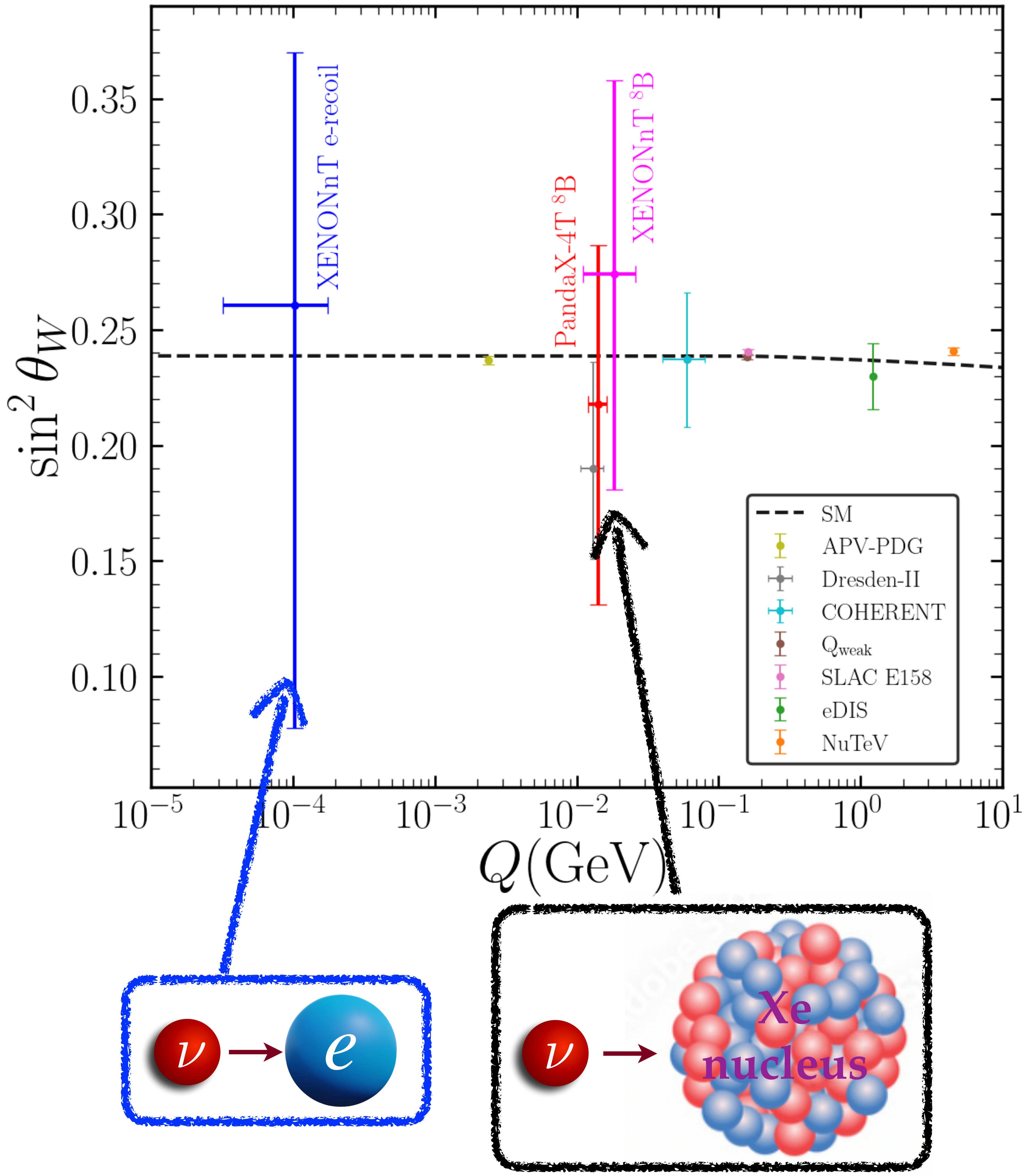

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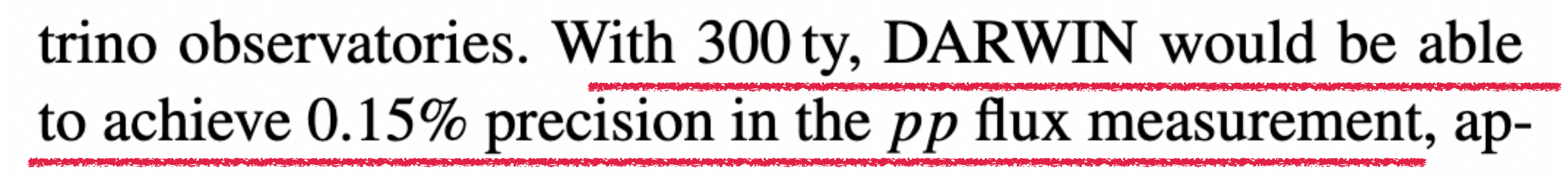
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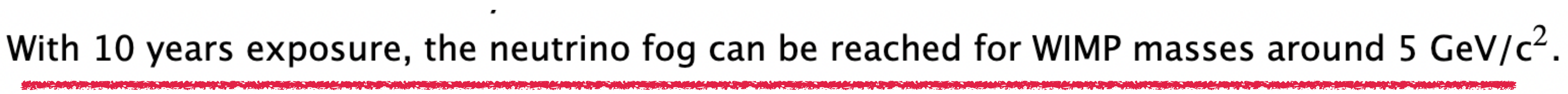
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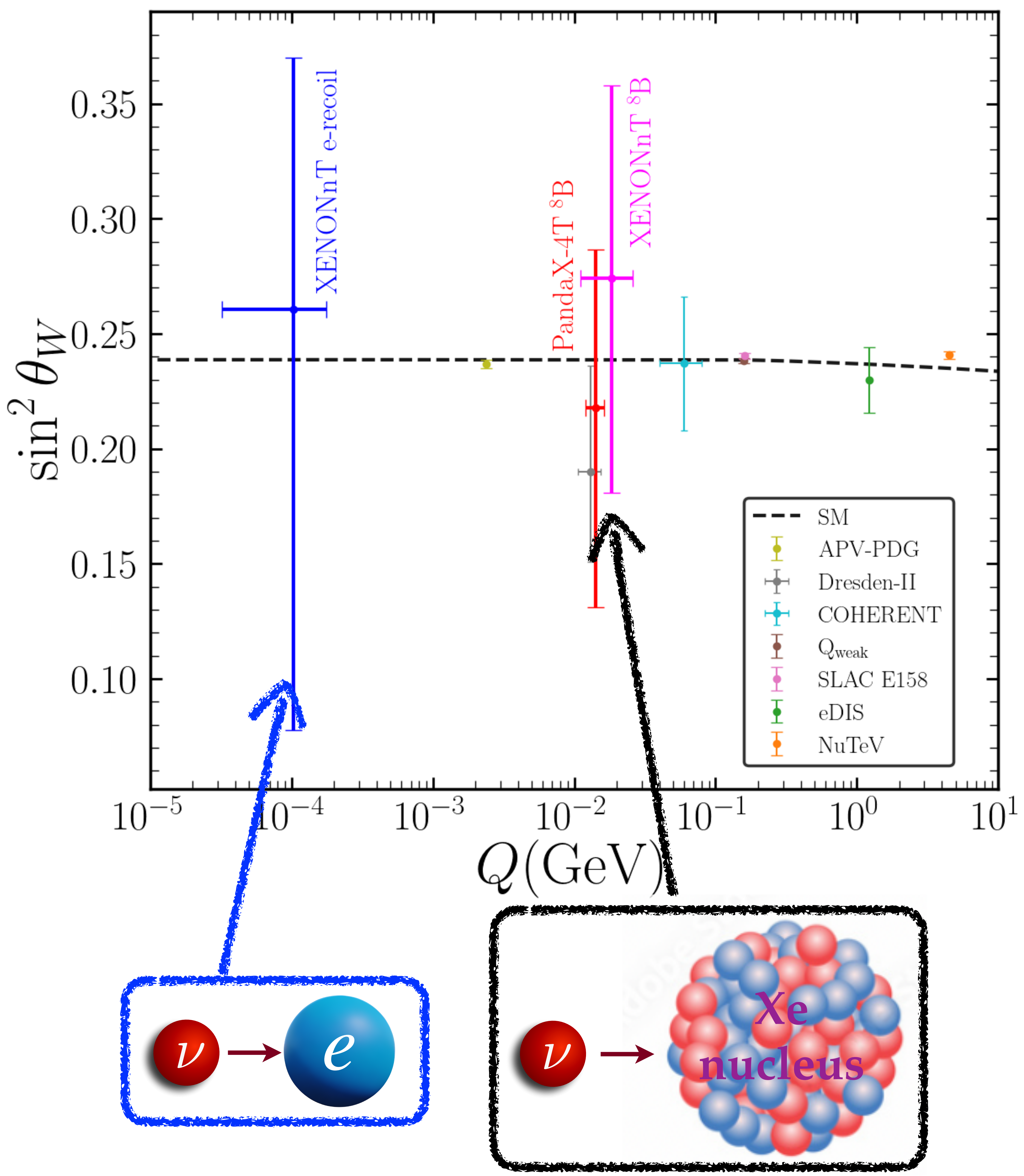

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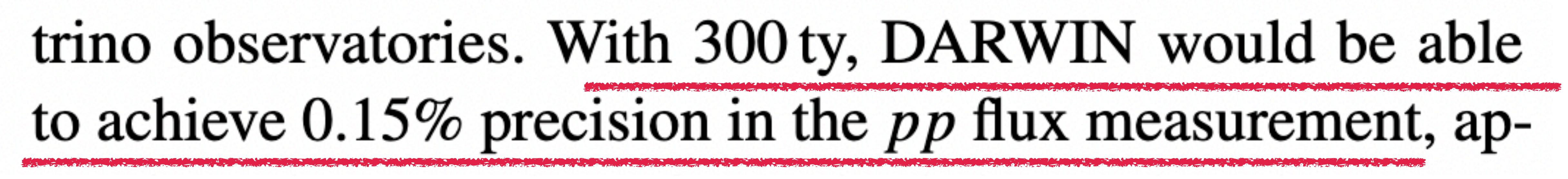
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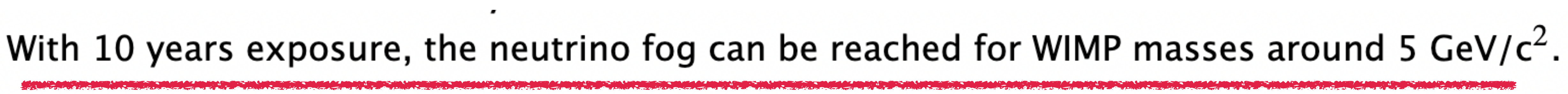
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email: tarak.maity.physics@gmail.com

Thank you