中國科學院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

Review of solar neutrino in 2028

Xue-Feng DING

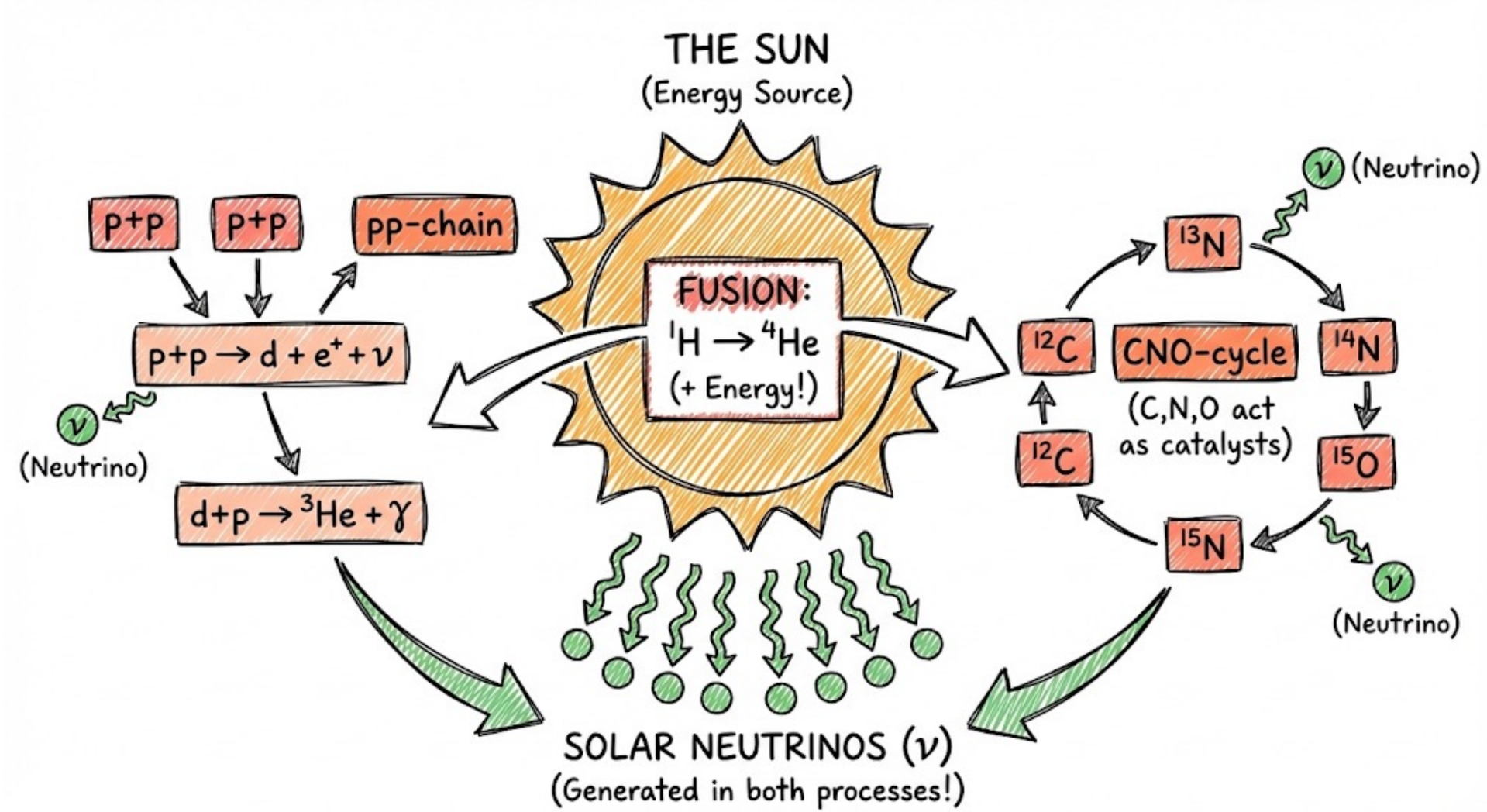
IHEP, CAS

2026 January 28th

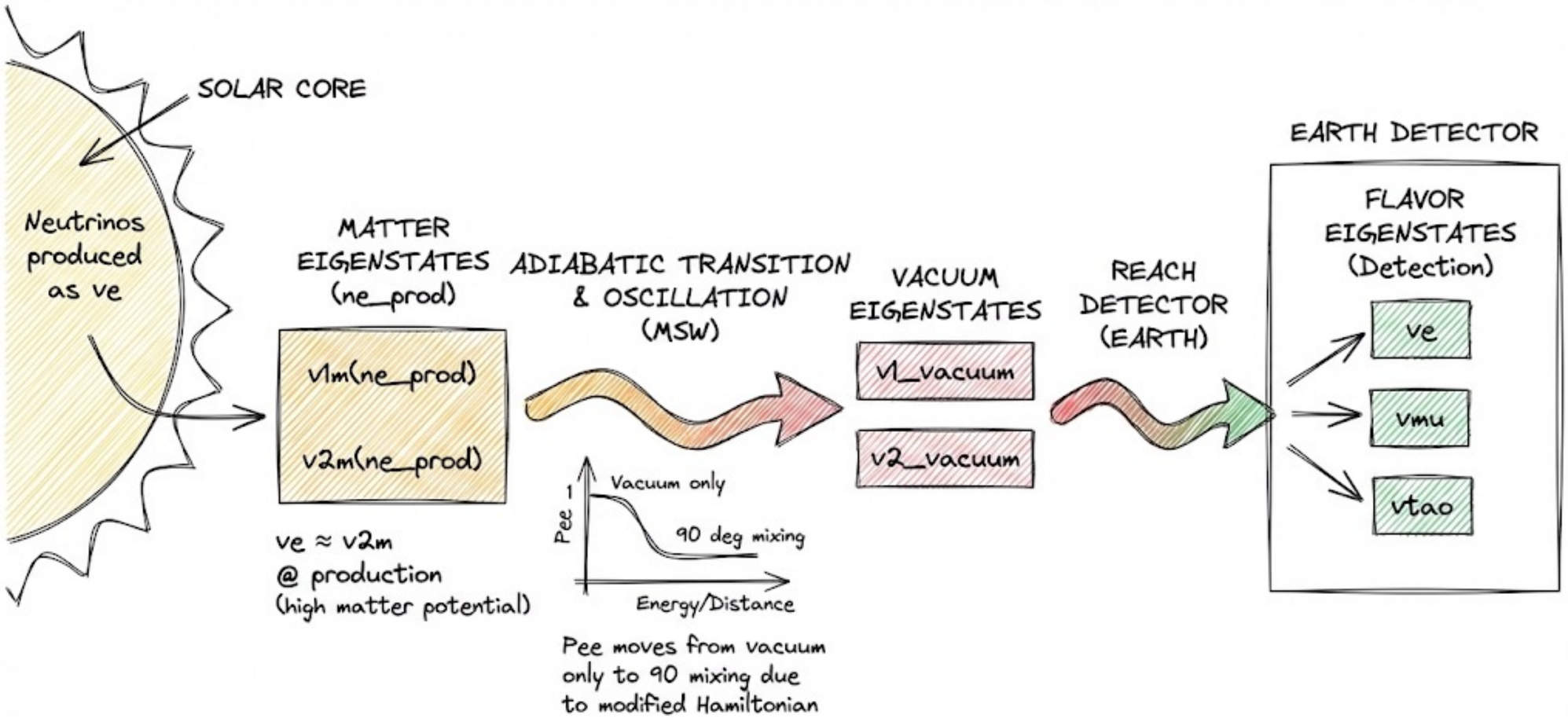
Outline

- Introduction
- Standard solar model
- Neutrino oscillation
- Conclusions

Energy production in the SUN



Adiabatic transition: no oscillation

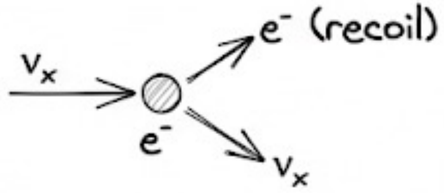


Matter potential modifies Hamiltonian and thus v1m and v2m.

Detection of solar neutrino

Solar Neutrino Detection (ν_e, ν_μ, ν_τ)

1. ES (Elastic Scattering)



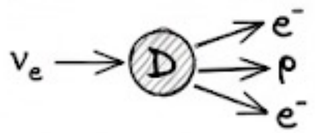
$\nu_x + e^- \rightarrow \nu_x + e^-$ (recoil)

Larger cross section with ν_e.
Need Spectrum Fitting
(e^- recoil spectrum).

2. CC (Charged Current)

ONLY interacts with ν_e!

(a) $\nu_e + D \rightarrow e^- + p + p + e$



(b) $\nu_e + N(A,Z) \rightarrow e^- + N'(A,Z+1)$

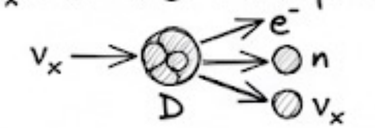
e.g.,
$\nu_e + {}^{13}C \rightarrow e^- + {}^{13}N \rightarrow {}^{13}C + e^+ + \nu_e$
(delayed coincidence)

Human detects CHARGED particles!
Neutrinos interact via W (CC) or Z (NC) bosons.

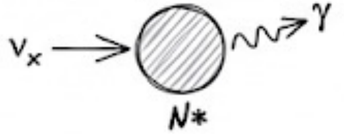
3. NC (Neutral Current)

Interacts with ALL flavors (ν_x), SAME cross section!

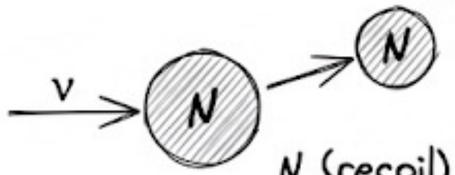
(a) $\nu_x + D \rightarrow e^- + n + p + \nu_x$



(b) $\nu_x + N \rightarrow \nu_x + N^* \rightarrow N + \gamma$

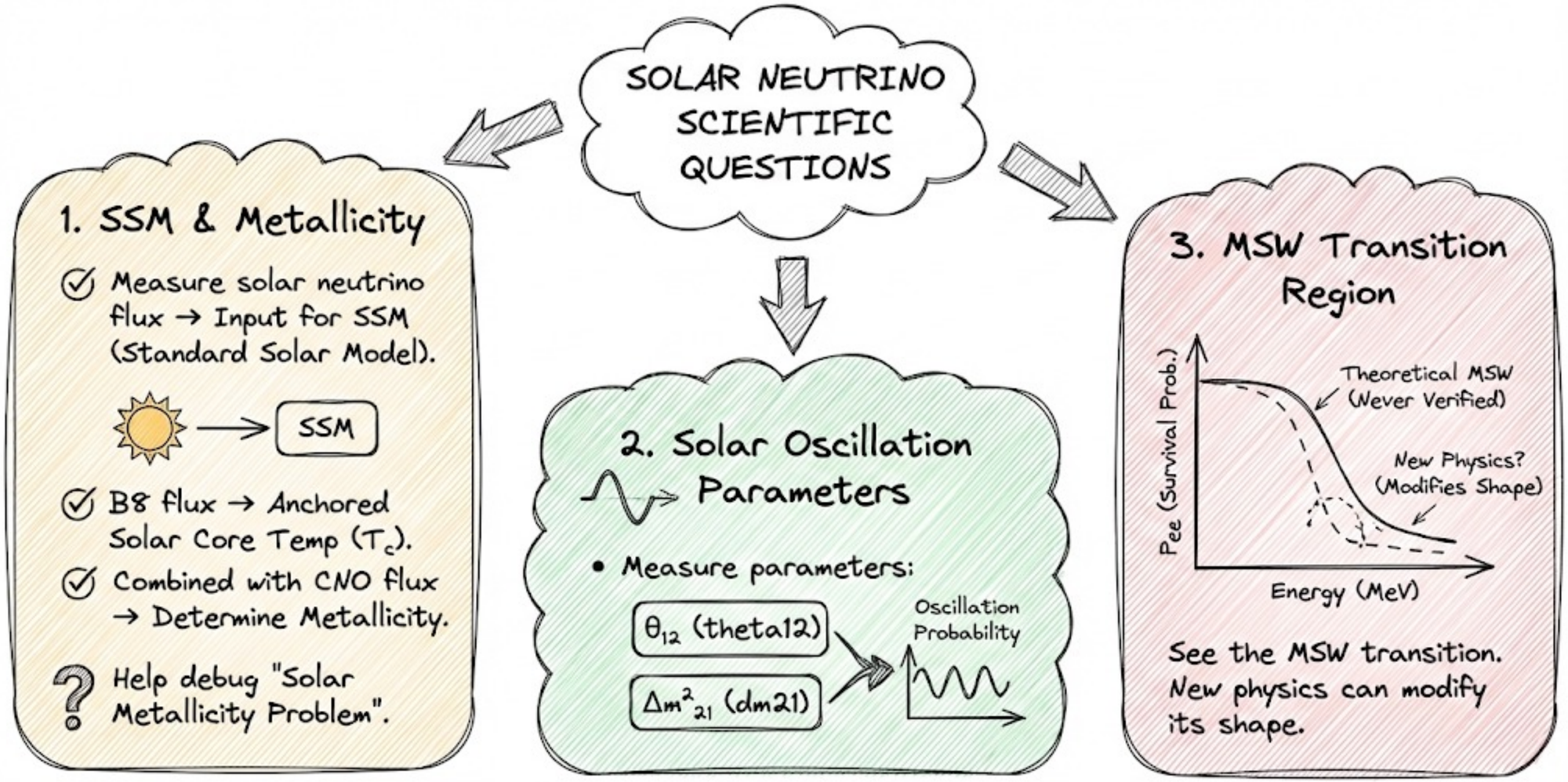


4. CEvNS (Coherent Elastic ν-Nucleus Scattering)

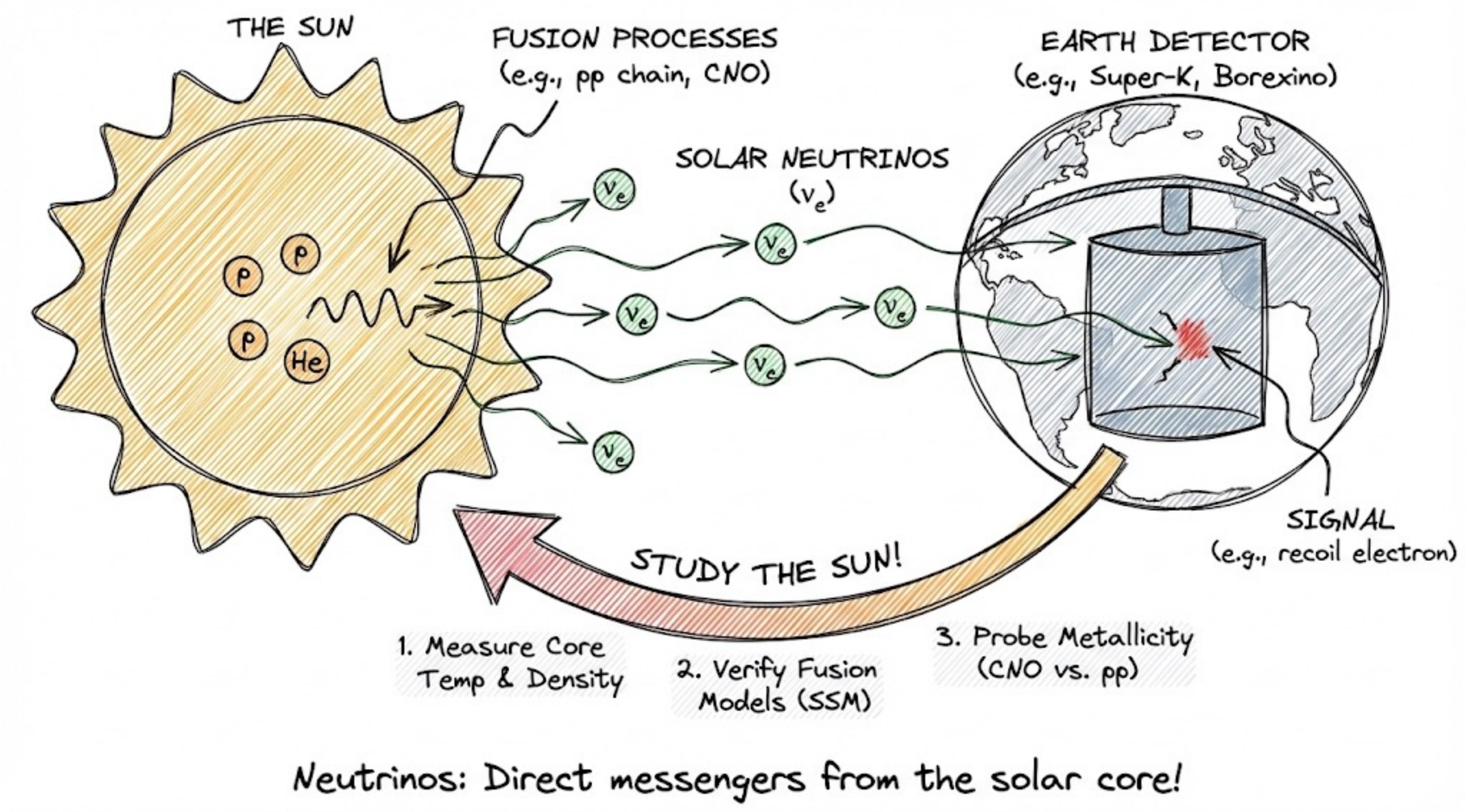


DM Neutrino Floor (e.g., XENONnT).
Coherent scattering off entire nucleus.

Scientific question of solar ν

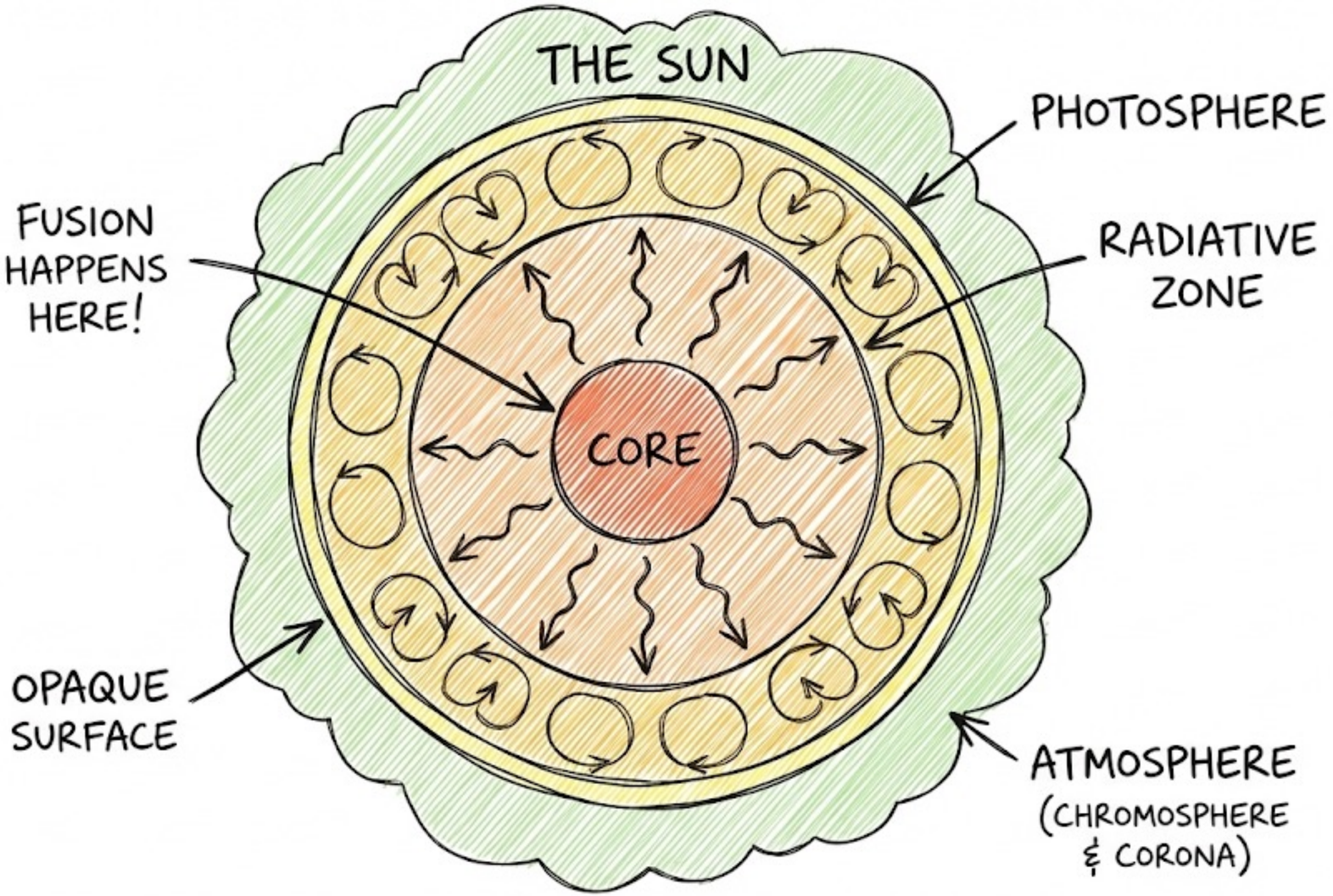


Part 1: study the Sun



Neutrinos: Direct messengers from the solar core!

The Sun


THE SUN
PHOTOSPHERE
FUSION HAPPENS HERE!
RADIATIVE ZONE
CORE
OPAQUE SURFACE
ATMOSPHERE (CHROMOSPHERE & CORONA)

Standard Solar Model

SSM INPUTS & PHYSICS

4 FUNDAMENTAL ASSUMPTIONS & EQUATIONS

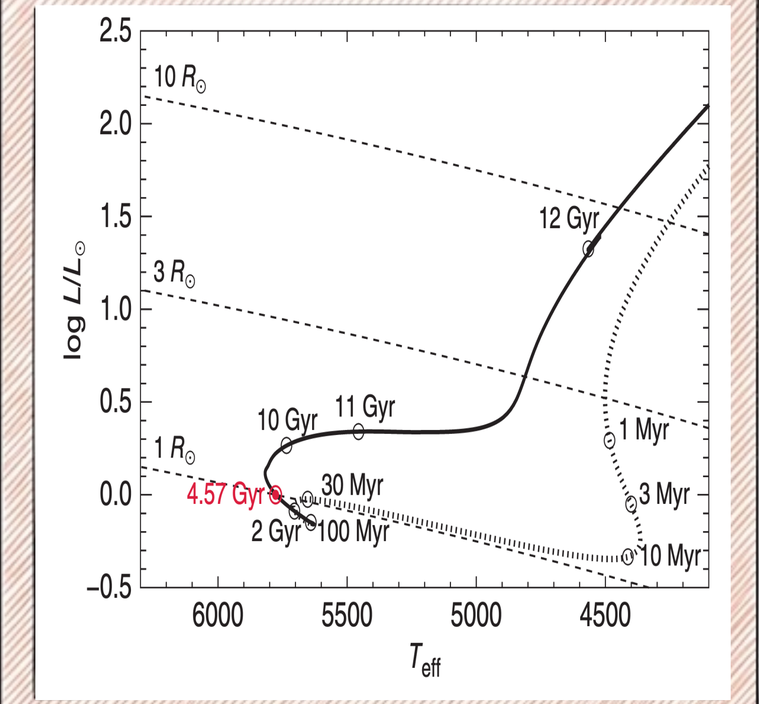
- Hydrostatic Equilibrium
- Energy Transport
- Energy Generation
- Mass Conservation

BOUNDARY CONDITIONS & NUCLEAR PHYSICS

- Radius, Luminosity (Present Sun)
- Photospheric Composition
- Cross-sections, Opacities

EVOLUTIONARY CALCULATION

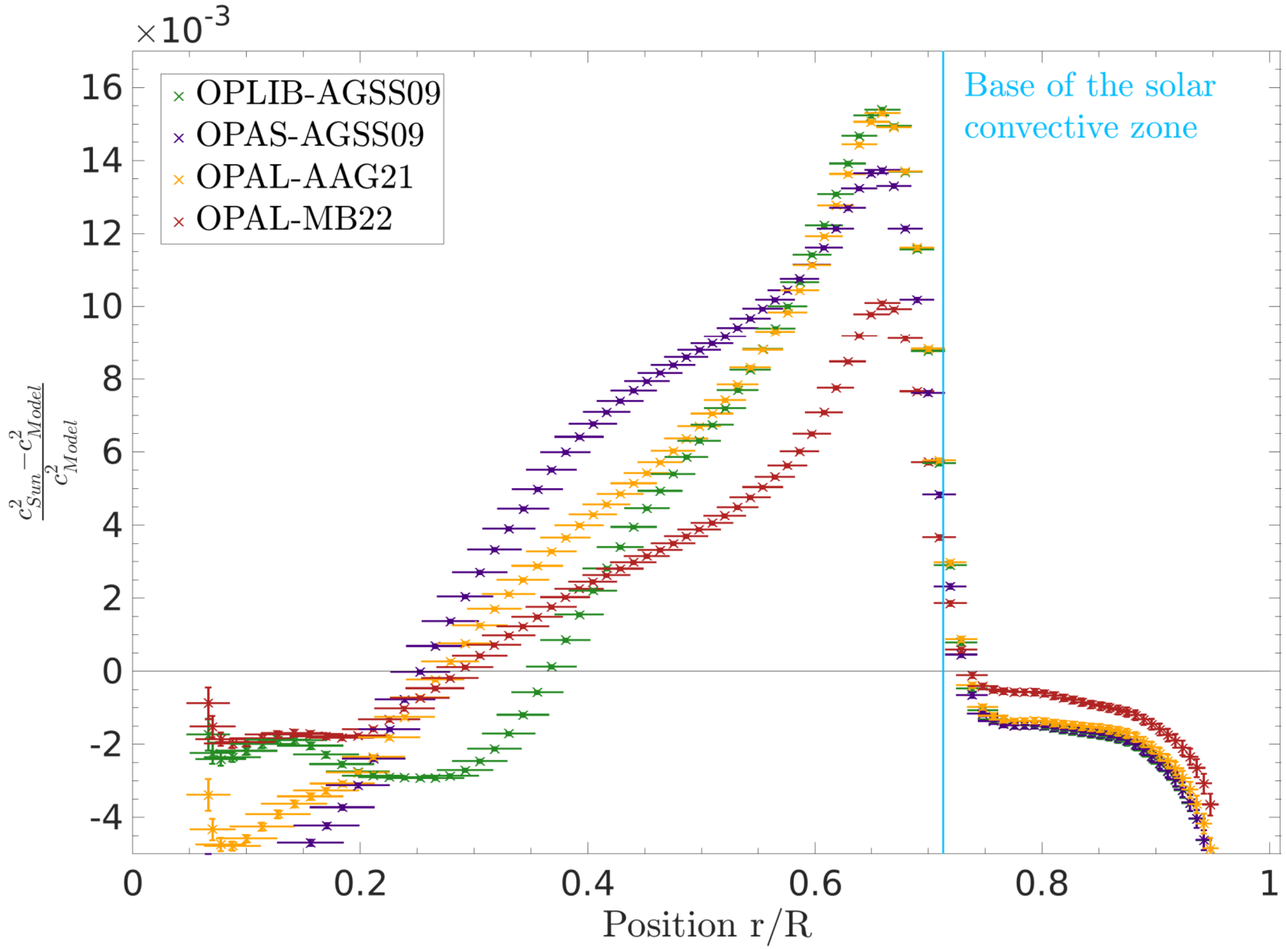
SSM OUTPUTS & EVOLUTION TRACK



Output: Solar Structure & Evolution Path over Time

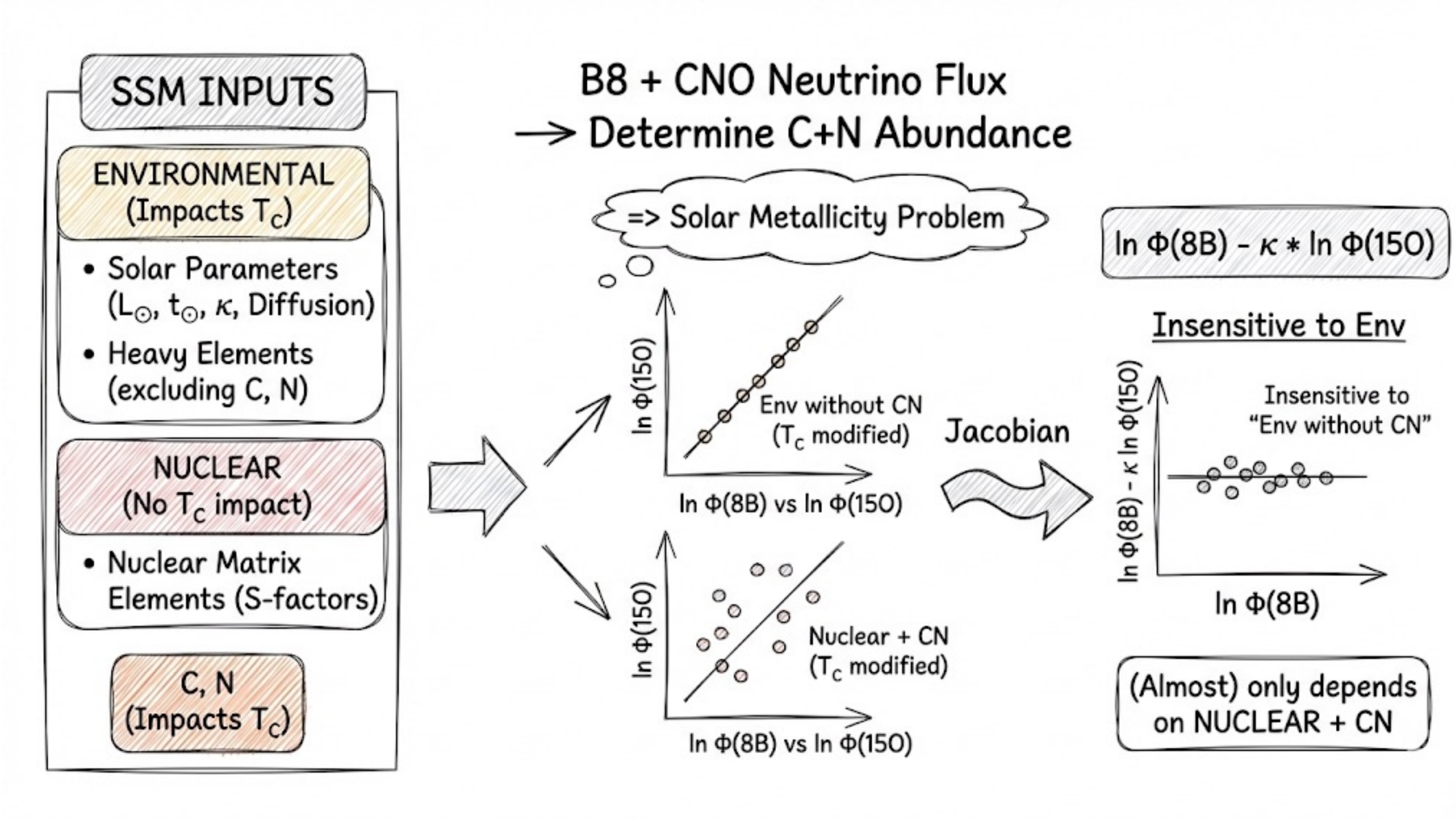
Oberauer, Lothar, Aldo Ianni, and Aldo Serenelli. *Solar Neutrino Physics*. Wiley, 2020. https://doi.org/10.1002/9783527412723.

Solar metallicity problem

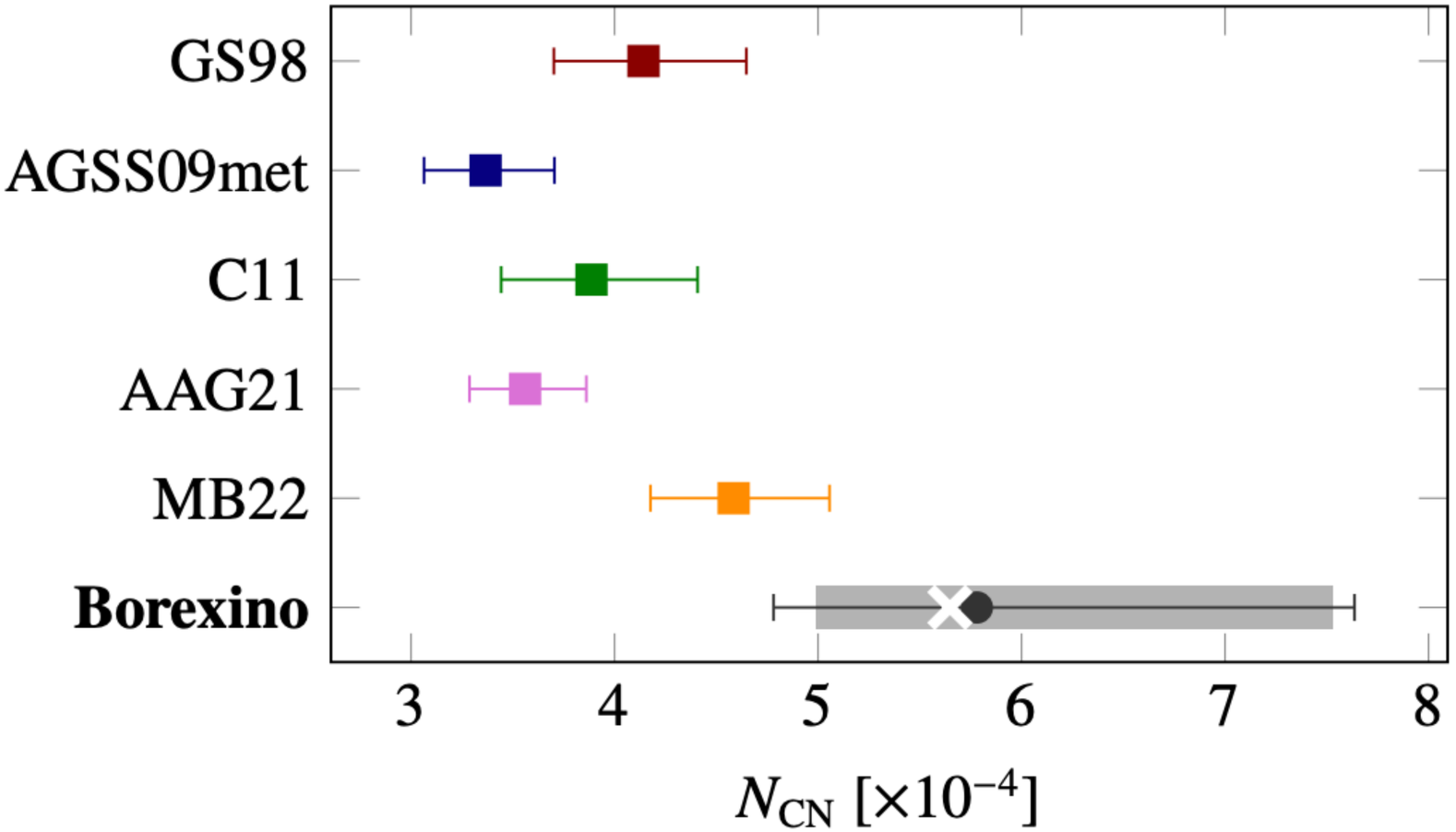


Buldgen, Gael, Gloria Canocchi, Arthur Le Saux, et al. “The Future of Solar Modelling: Requirements for a New Generation of Solar Models.” arXiv:2506.14514. Preprint, arXiv, June 17, 2025. https://doi.org/10.48550/arXiv.2506.14514.

Solar neutrino as a probe

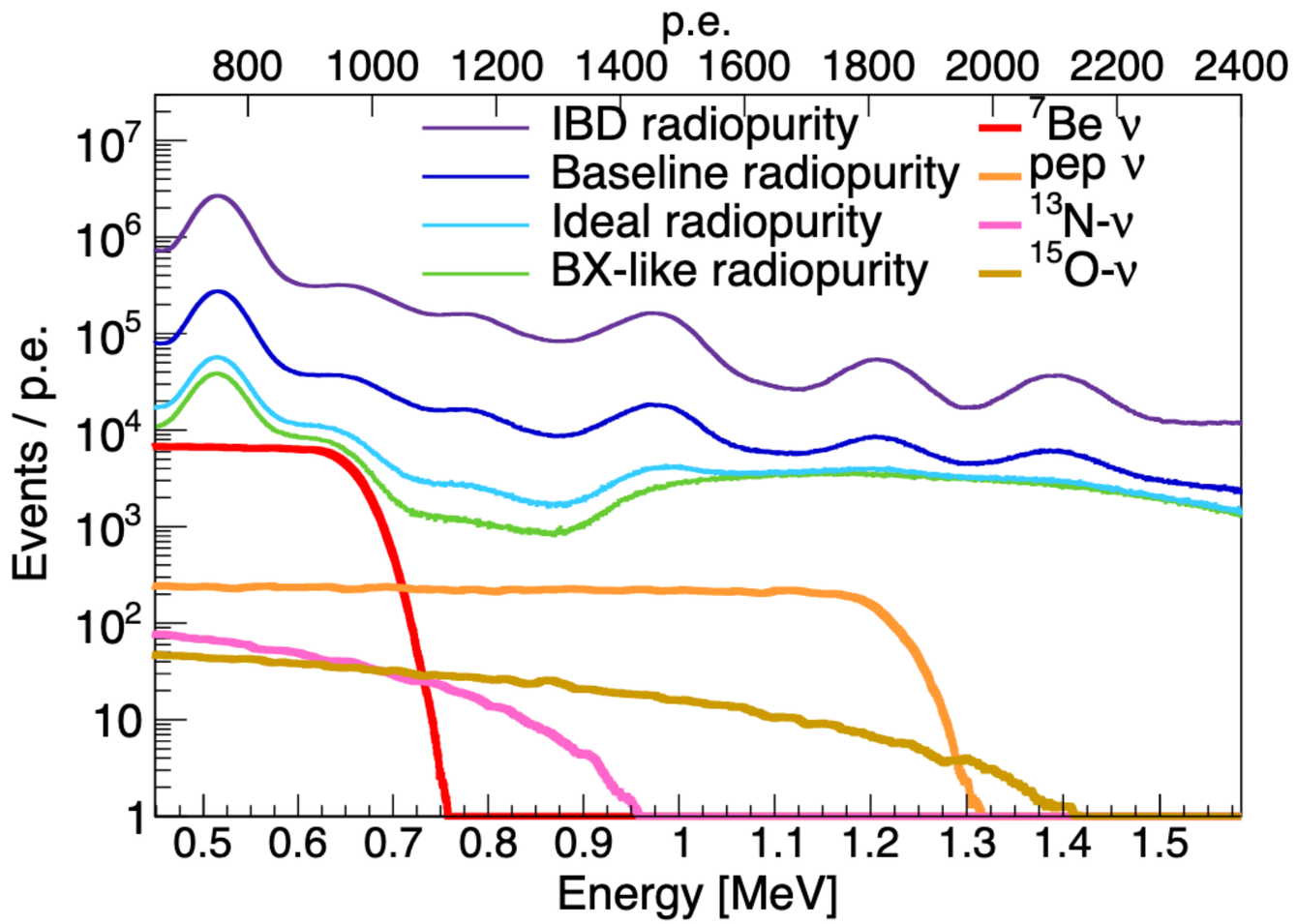


Measured CN abun. by Borexino

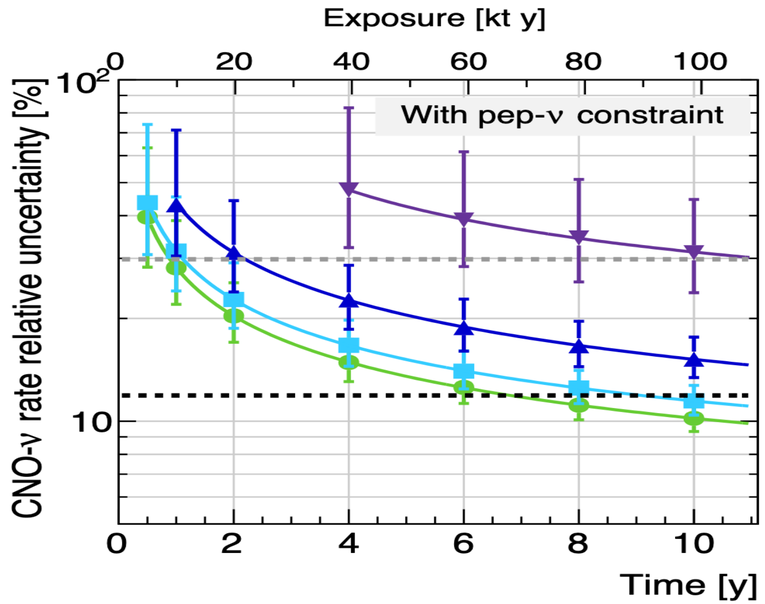


Appel, S., Z. Bagdasarian, D. Basilico, et al. “Improved Measurement of Solar Neutrinos from the Carbon-Nitrogen-Oxygen Cycle by Borexino and Its Implications for the Standard Solar Model.” *Physical Review Letters* 129, no. 25 (2022): 252701. https://doi.org/10.1103/PhysRevLett.129.252701.

JUNO's prospects to CNO

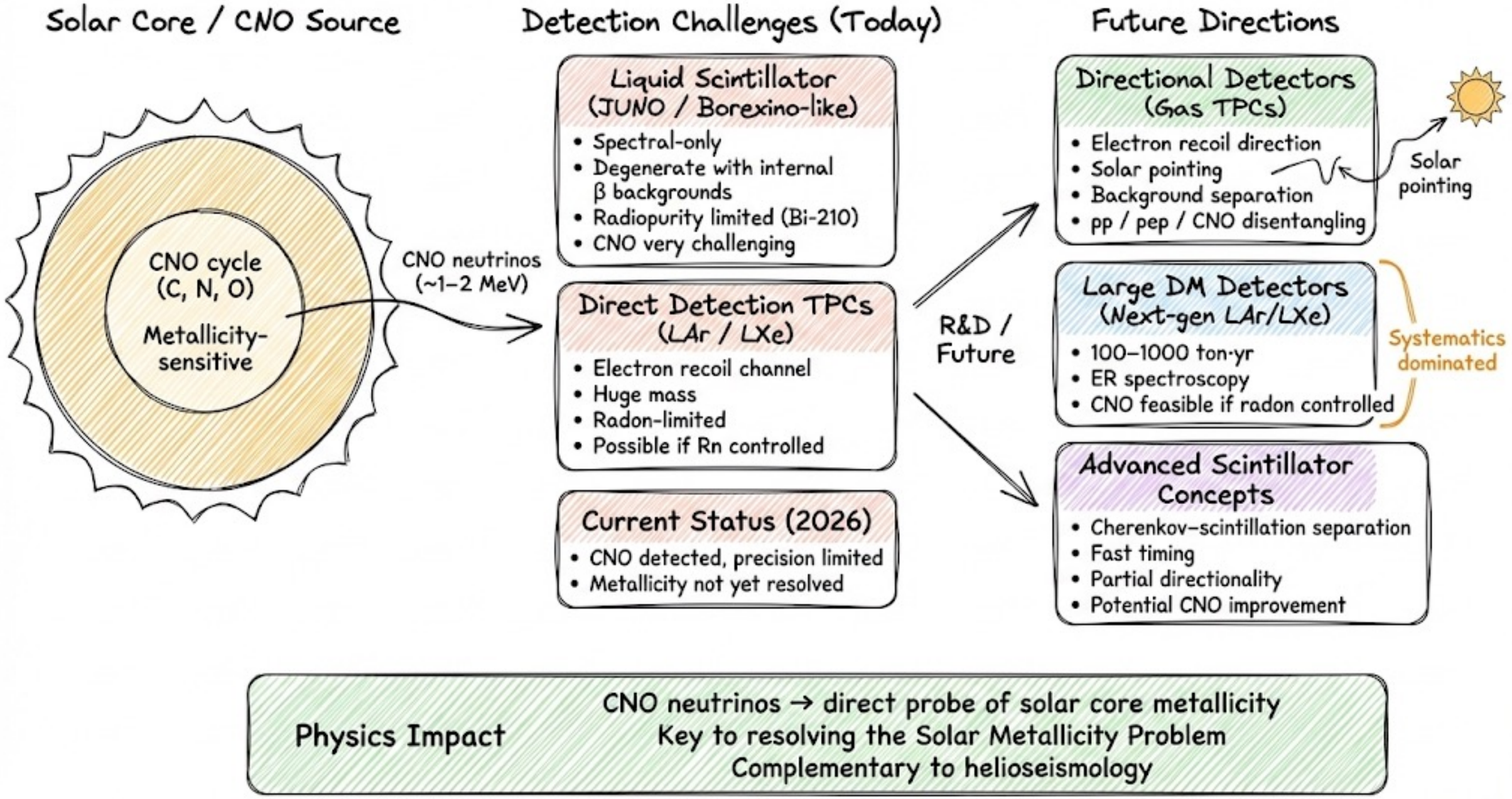


- Limited by internal bkg.
- Direction may help
- Challenging

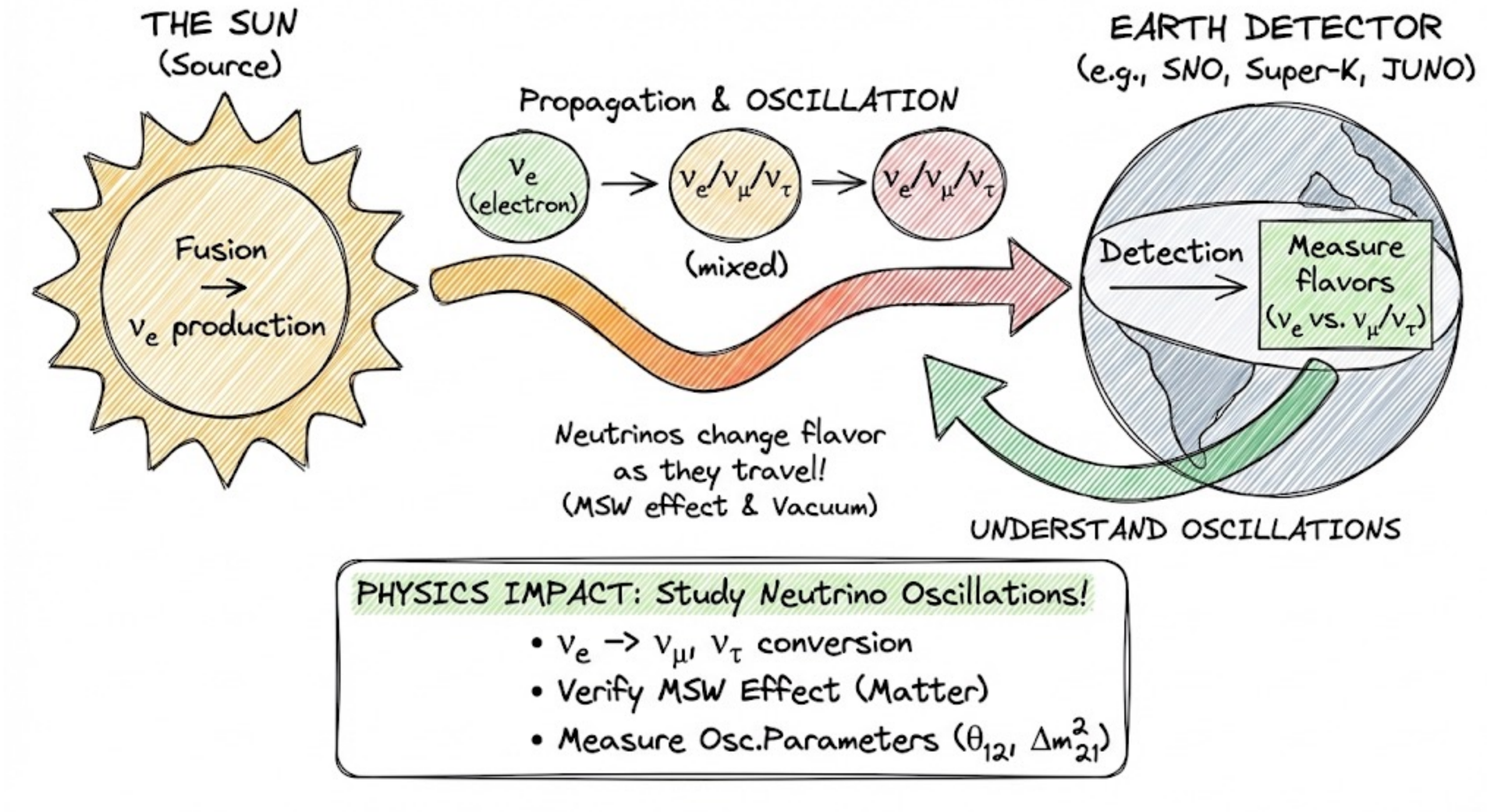


Abusleme, Angel and others. *JUNO Sensitivity to ^{7}Be, Pep, and CNO Solar Neutrinos*. March 2023. 2639017. INSPIRE. https://arxiv.org/abs/2303.03910.

CNO in next years

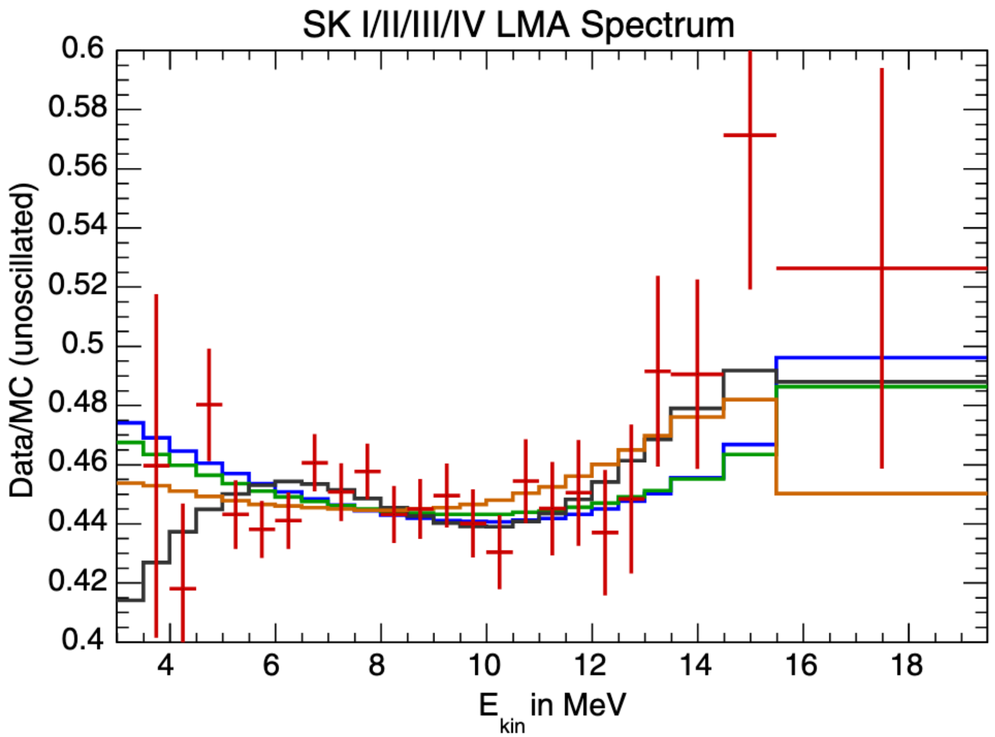


Part 2: study the oscillation



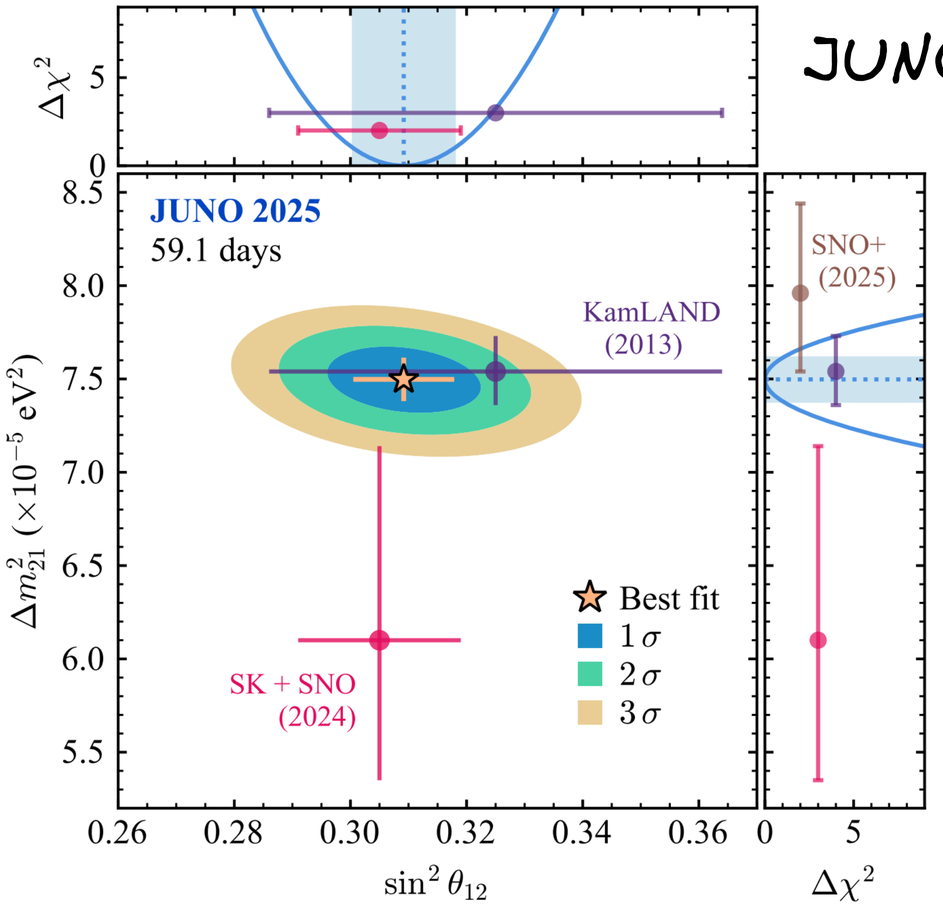
Δm^2_{21} "tension"

SK-I-IV-2016



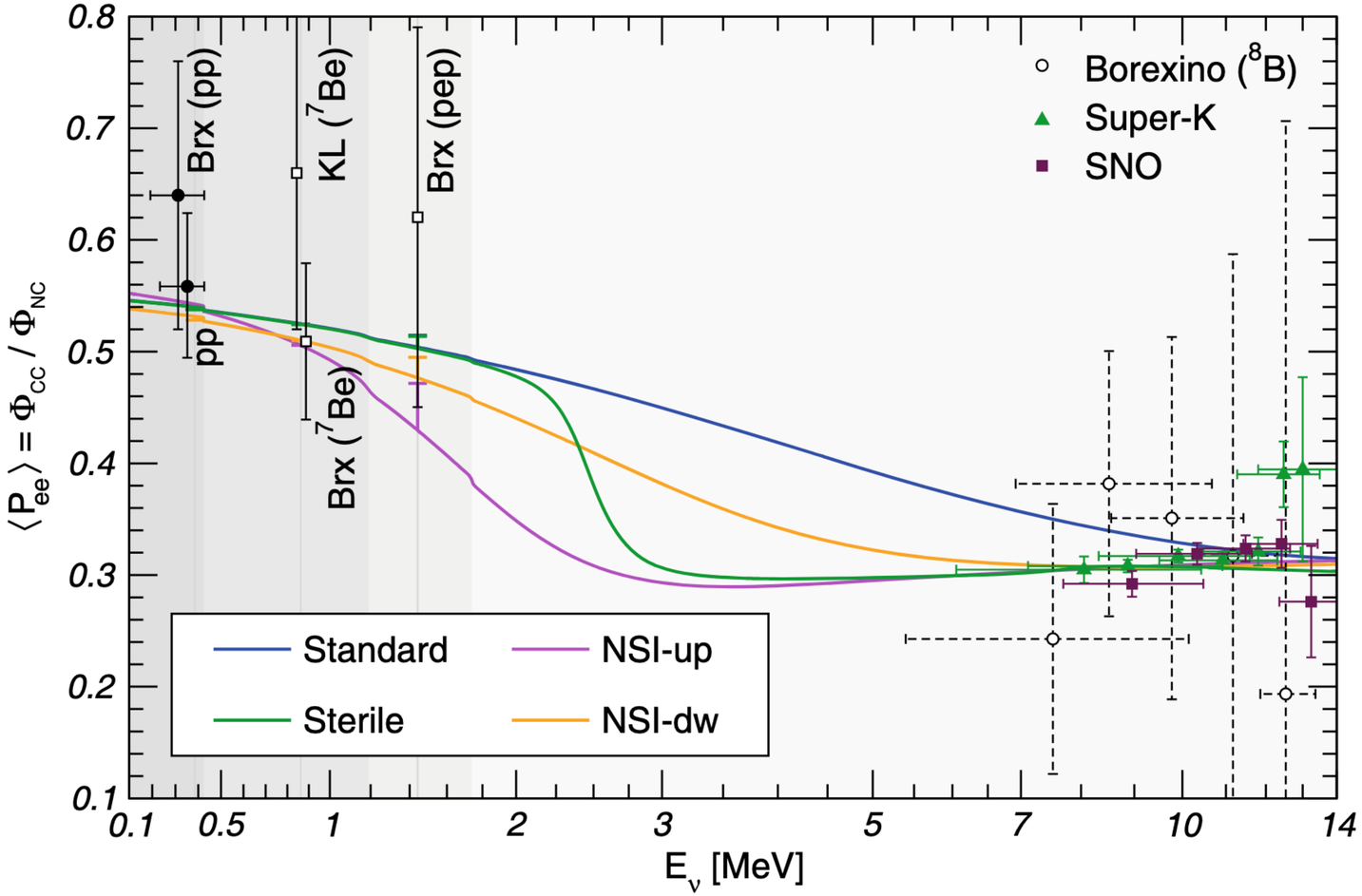
Abe, K., Y. Haga, Y. Hayato, et al. "Solar Neutrino Measurements in Super-Kamiokande-IV." *Physical Review D* 94, no. 5 (2016): 052010. 1472086, p. 052010. INSPIRE. https://doi.org/10.1103/PhysRevD.94.052010.

JUNO-2025



Abusleme, Angel, Thomas Adam, Kai Adamowicz, et al. "First Measurement of Reactor Neutrino Oscillations at JUNO." arXiv:2511.14593. Preprint, arXiv, November 18, 2025. https://doi.org/10.48550/arXiv.2511.14593.

MSW transition region

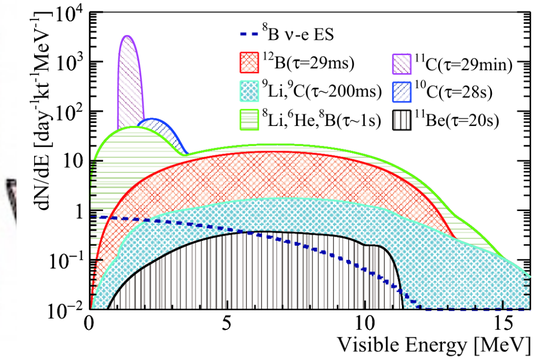


Maltoni, Michele, and Alexei Yu. Smirnov. “Solar Neutrinos and Neutrino Physics.” *The European Physical Journal A* 52, no. 4 (2016): 87. 1383834, p. 87. INSPIRE. https://doi.org/10.1140/epja/i2016-16087-0.

JUNO: 5 MeV ^{8}B ES

SUPER SHORT LIVED (~29ms)

B12: 29.1 ms | 1552 cpd/20kt
(65x signal)



LONG LIVED (>1s)

Li8: 1.21 s | 433 cpd/20kt
(20x signal)

B8: 1.11 s | 363 cpd/20kt
(15x signal)

8B Solar ν ES
Channel Bkg
(5 MeV Analysis)
- Cosmogenic

SHORT LIVED (<1s)

Li9: 257.2 ms | 79 cpd/20kt
(3x signal)

C9: 182.5 ms | 143 cpd/20kt
(6x signal)

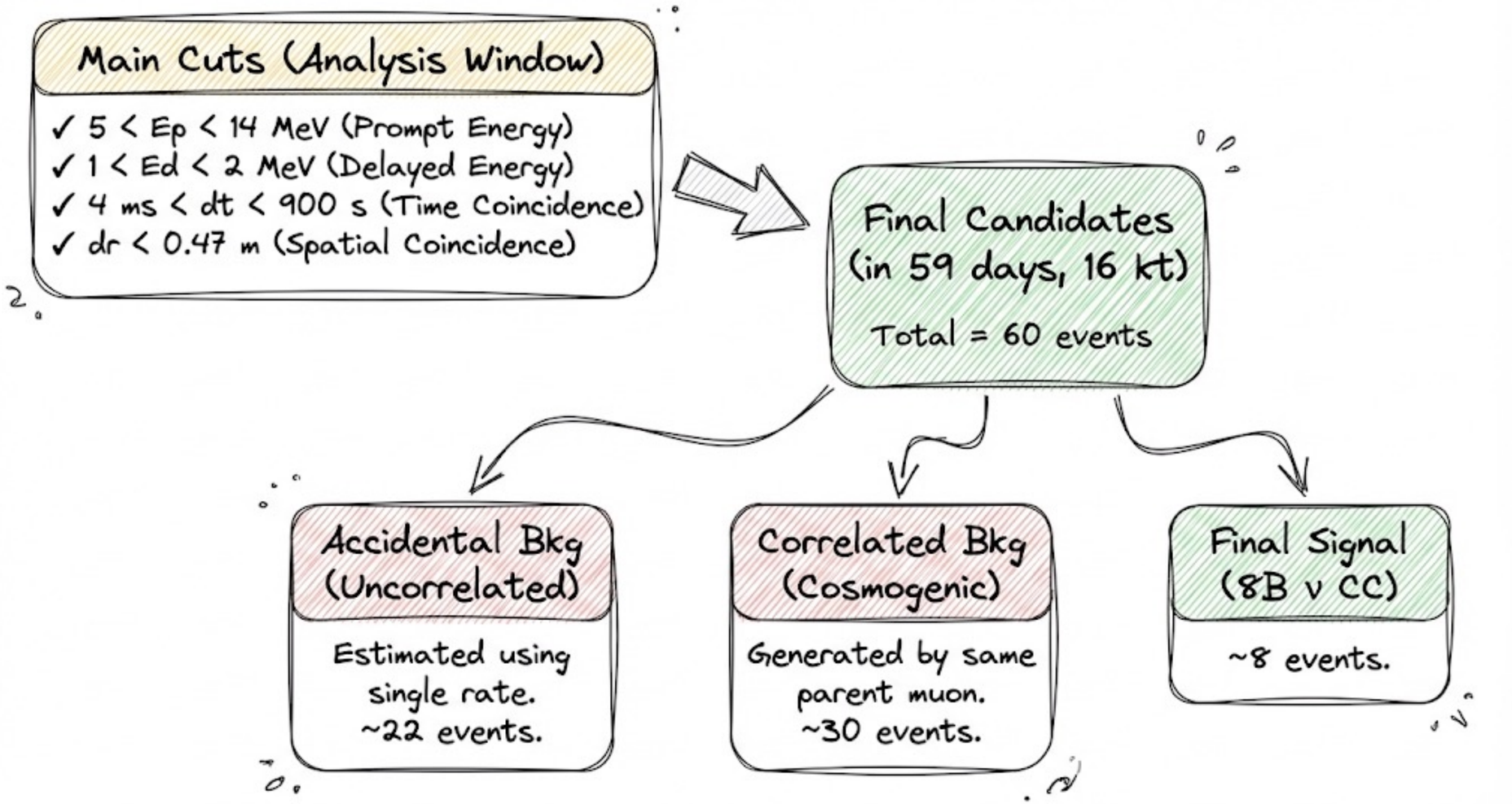
SUPER LONG LIVED (~20s)

Be11: 19.9 s | 40 cpd/20kt
(2x signal)

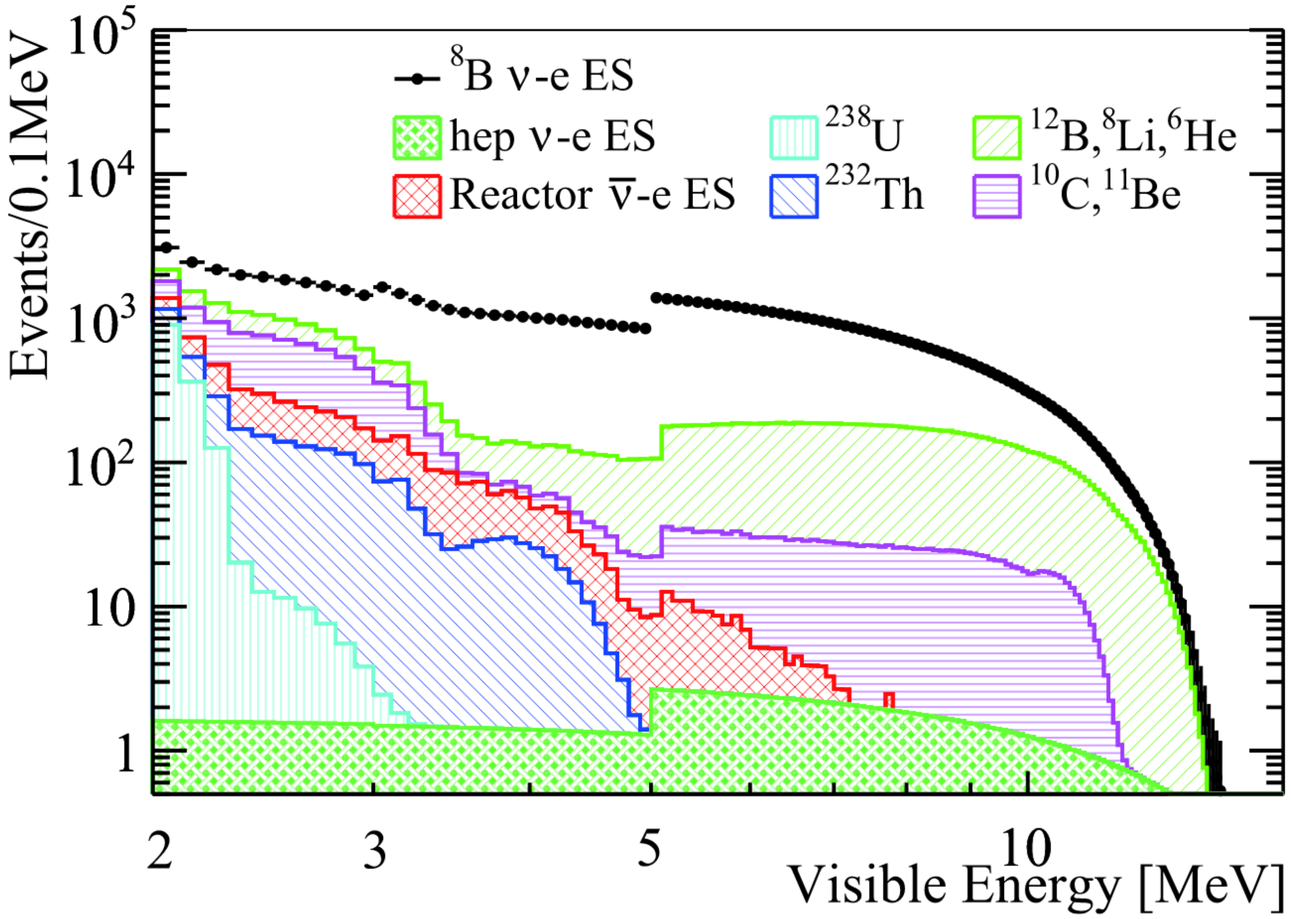
Overall Bkg Rate:
~2610 cpd/20kt, 100x signal

Context: Analysis cut at 5 MeV to suppress these

JUNO: 5 MeV ^{8}B CC

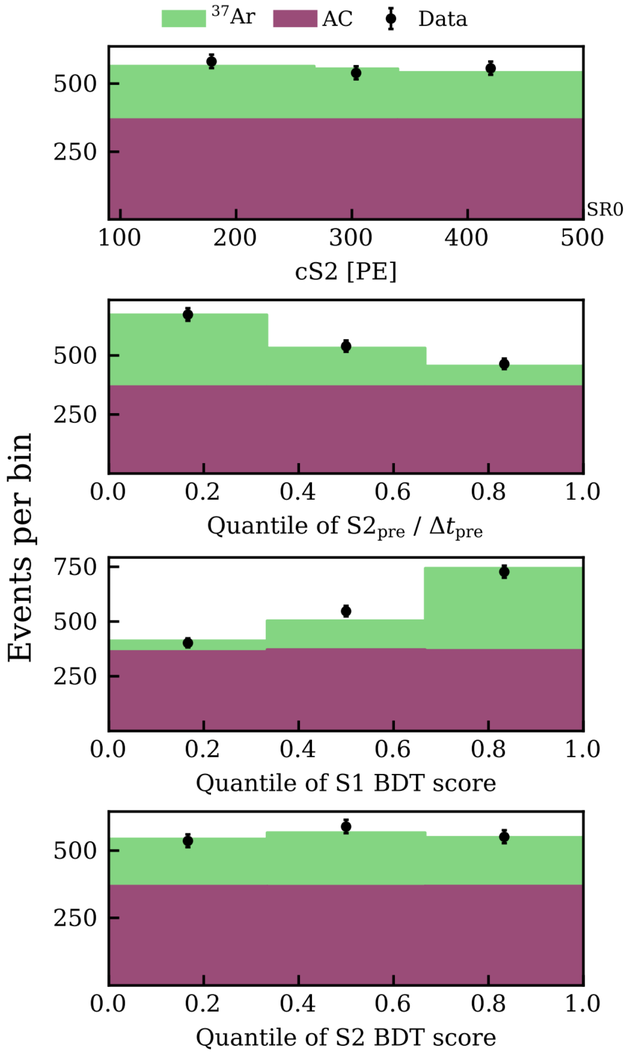


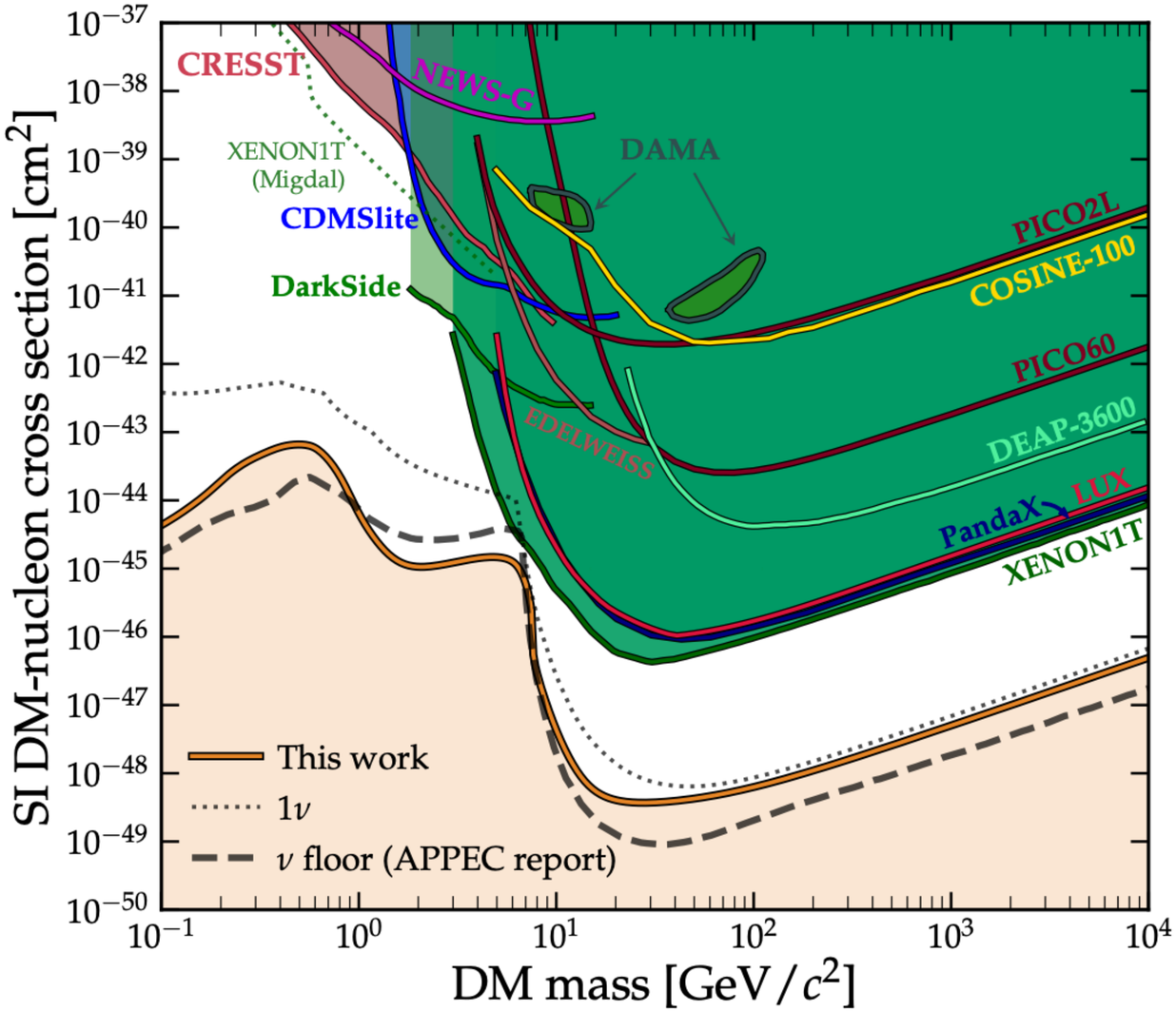
Next: 2 MeV JUNO



Abusleme, Angel, Thomas Adam, Shakeel Ahmad, et al. "Feasibility and Physics Potential of Detecting 8B Solar Neutrinos at JUNO *." *Chinese Physics C* 45, no. 2 (2021): 023004. https://doi.org/10.1088/1674-1137/abd92a.

Dark matter: ER and NR





Conclusions

- Solar neutrinos can study both the Sun and oscillations
- For solar metallicity problem, precise CNO flux is essential
- For solar oscillations, JUNO may push to 2 MeV
- Dark matter is also evolving fast, yet not world leading.