Title: Solar Neutrinos: from background to signal

Speakers: Tien-Tien Yu

Series: Particle Physics

Date: March 08, 2022 - 1:00 PM

URL: https://pirsa.org/22030020

Abstract: Solar neutrinos are an inevitable background to any dark matter direct detection experiment as they closely mimic the signature of dark matter. In this talk, I will discuss the effects of solar neutrinos on the reach of dark matter-electron scattering experiments, with a focus on semiconductor and xenon-based detectors. In addition, I will present the prospects of measuring and understanding the various solar neutrino components using the same detectors, as well as the effects of non-standard neutrino interactions, thus turning solar neutrinos from a background to an interesting signal in their own right.

Solar Neutrinos: from background to signal

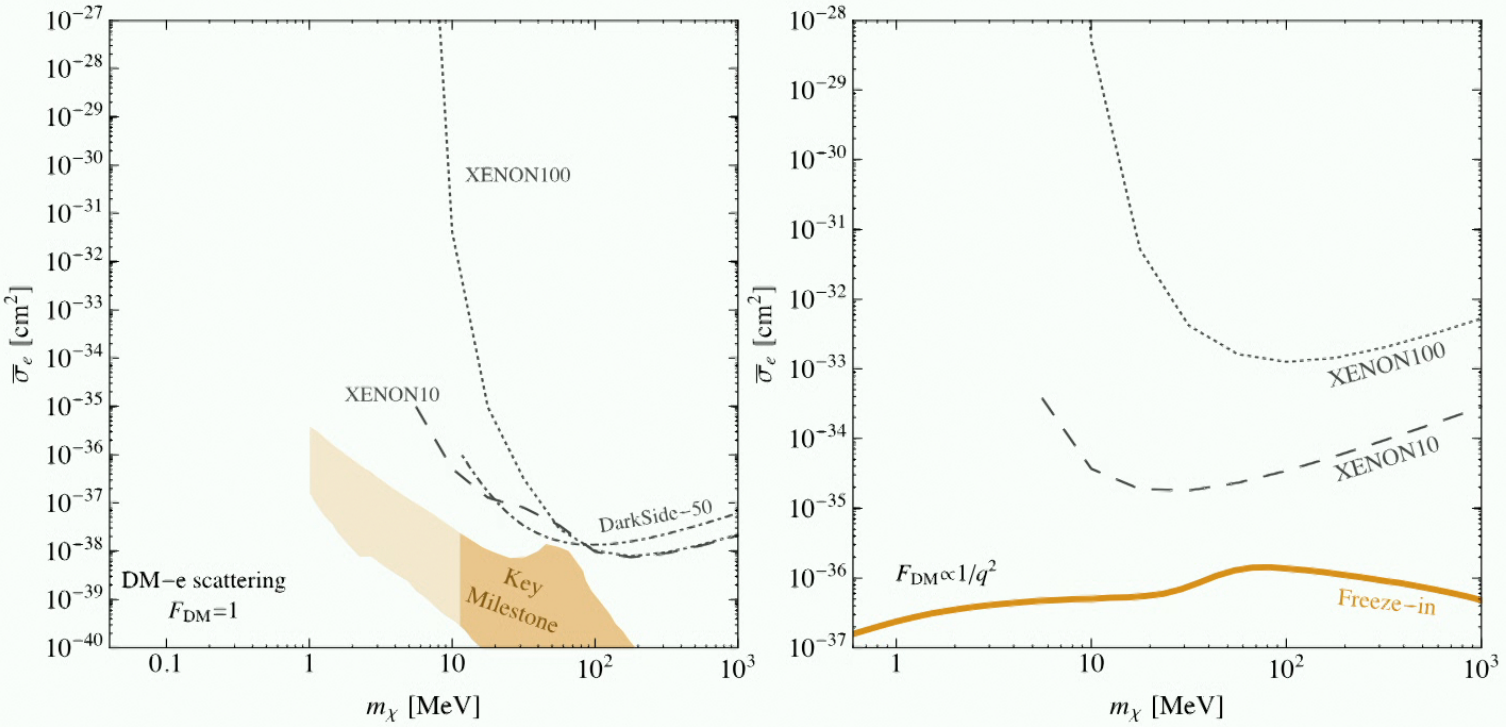
Tien-Tien Yu
(University of Oregon)

based on R. Essig, M. Sholapurkar, **TTY** *Phys.Rev.D* 97 (2018) 9, 095029 [arXiv: 1801.10159]
and
T. Schwemberger, **TTY** [arXiv:2202.01254]

Perimeter Institute — Particle Physics Seminar

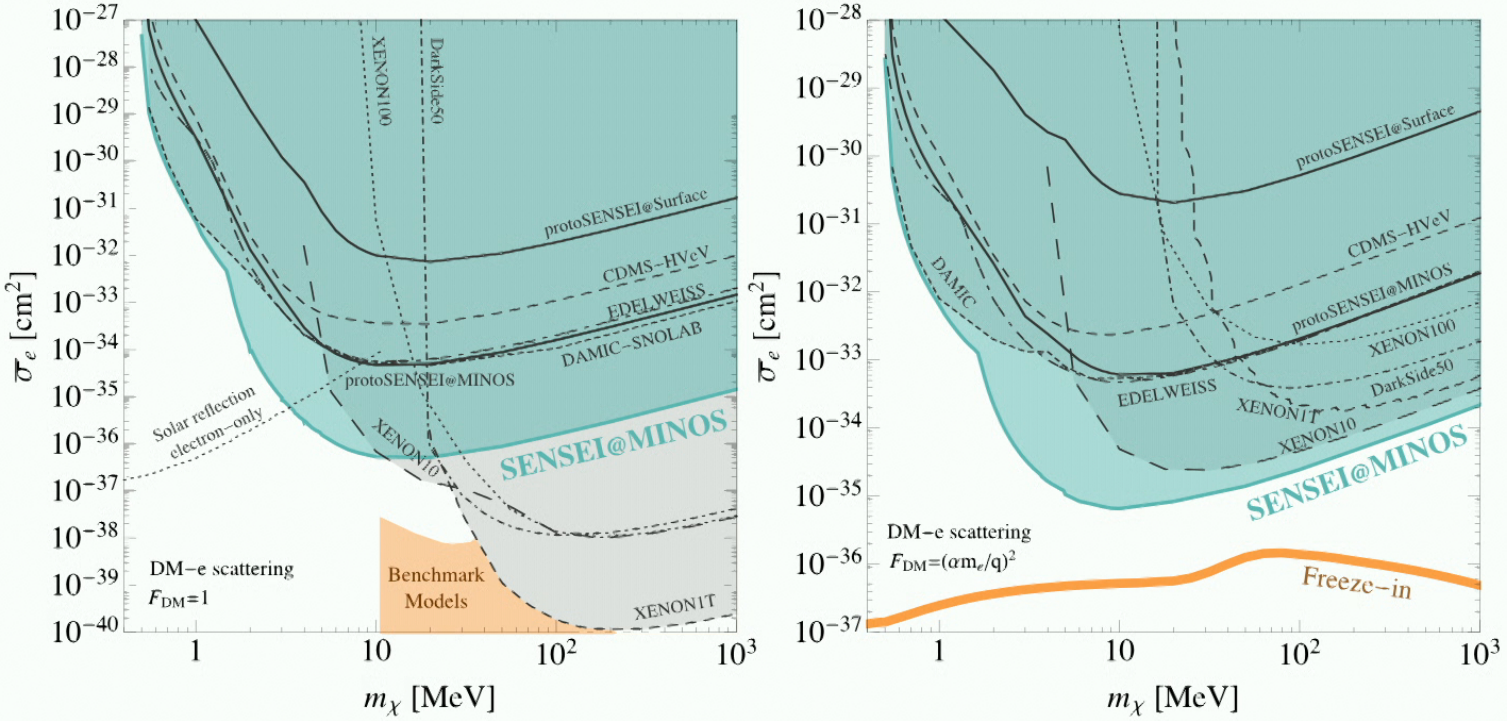
March 8, 2022

DM-e limits in 2018



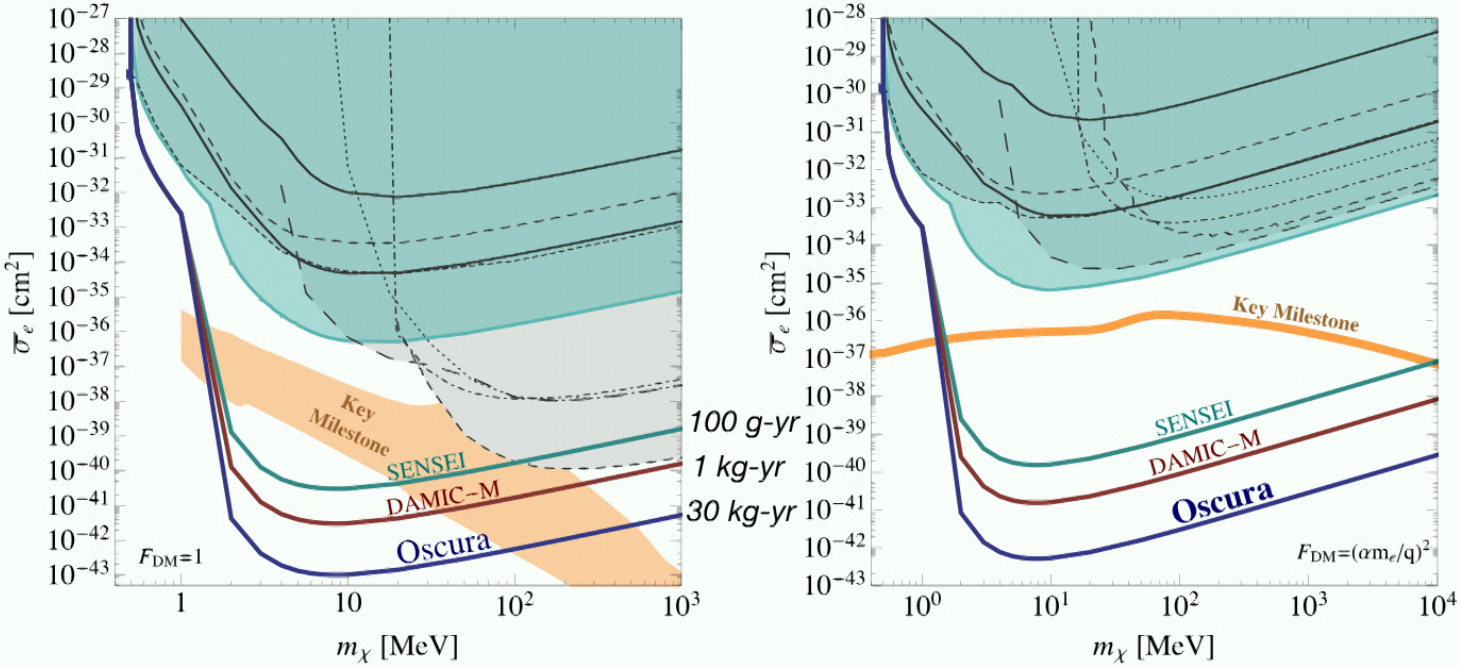
Essig, Volansky, **TTY** *Phys.Rev.D* 96 (2017) 4, 043017 [1703.00910]
DarkSide Collaboration *Phys.Rev.Lett.* 121 (2018) 11, 111303 [1802.06998]

DM-e limits in 2021



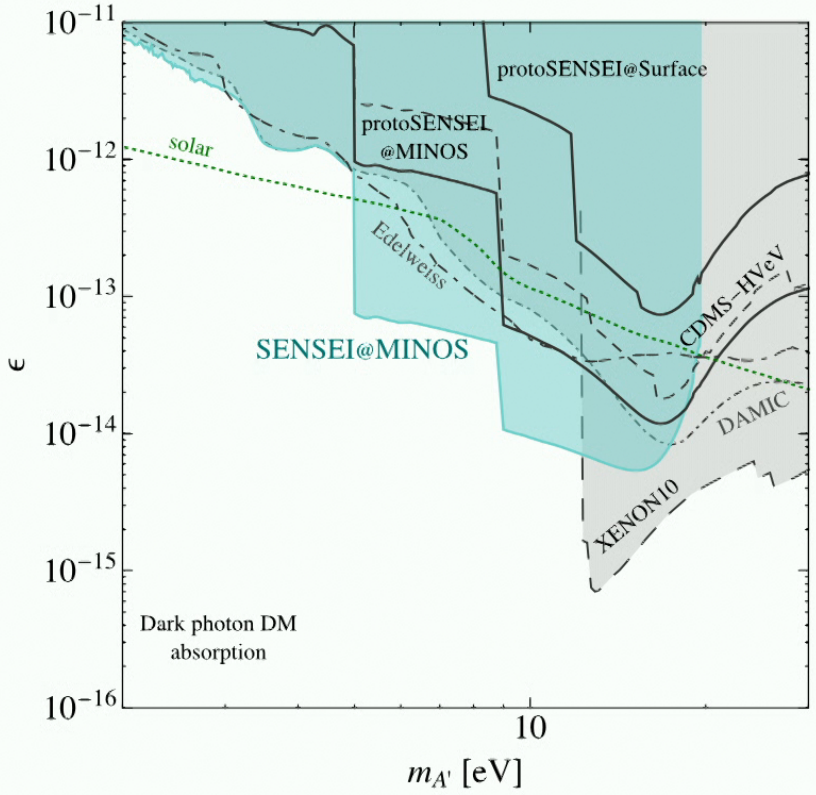
SENSEI collaboration, *Phys.Rev.Lett.* 125 (2020) 17, 171802 [arXiv:2004.11378] - *Editors' Suggestion*

Looking forward



Projections for future Si Skipper-CCD experiments

Dark Photon DM



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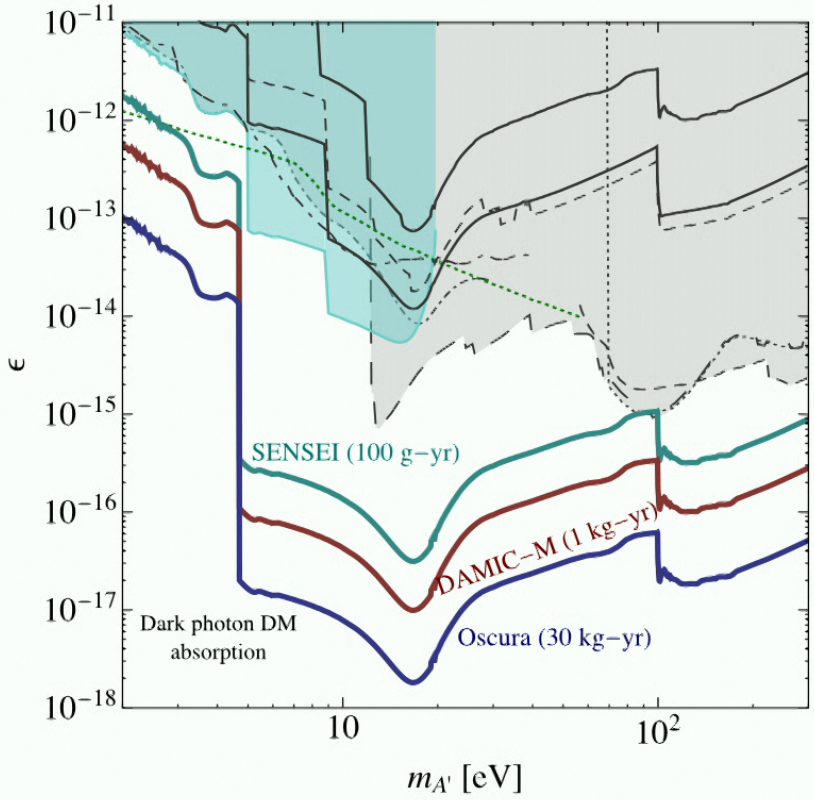
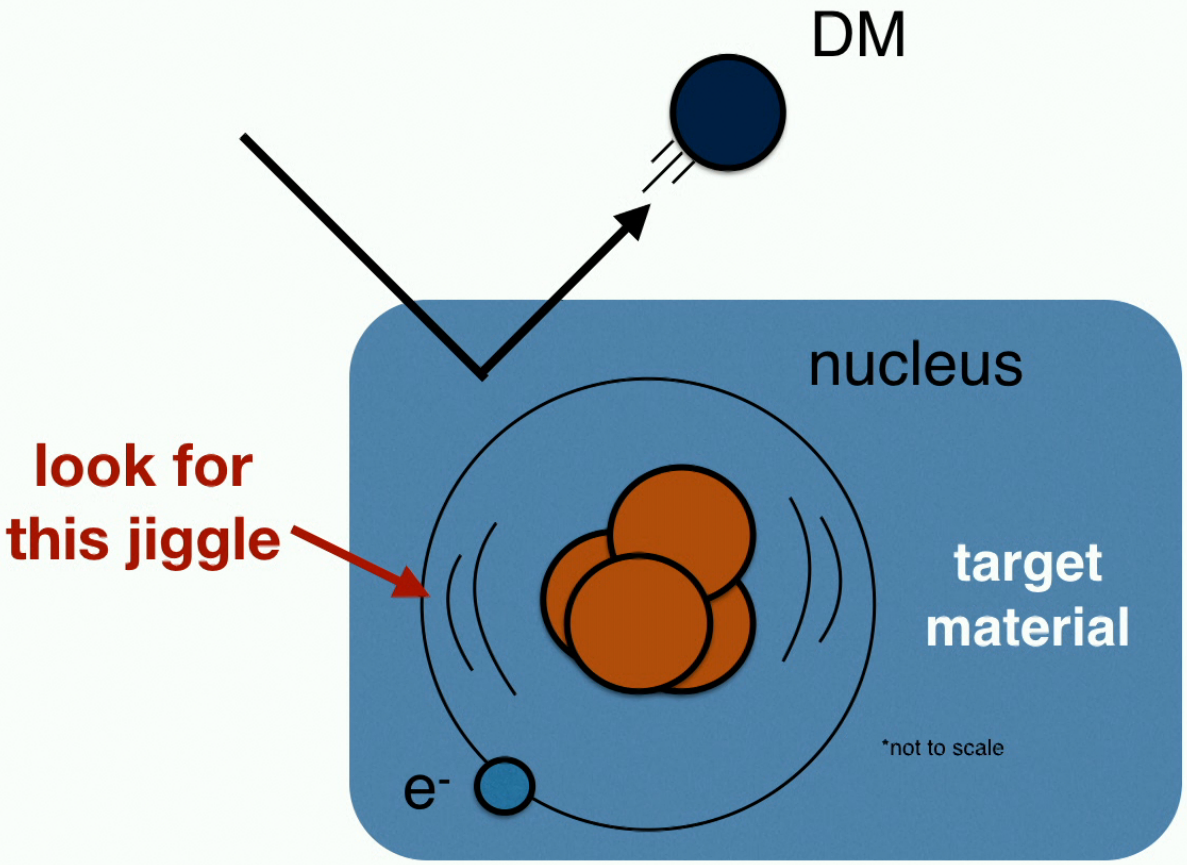


DM Direct Detection



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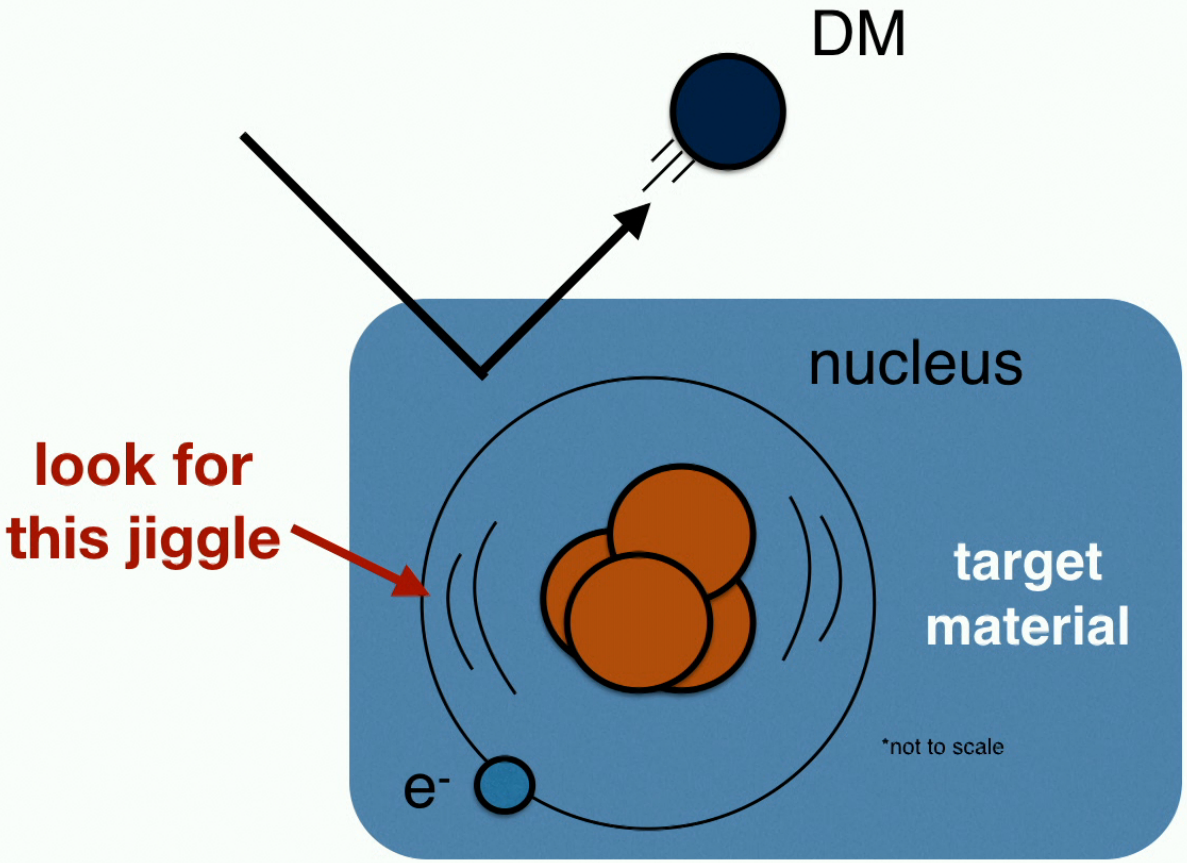
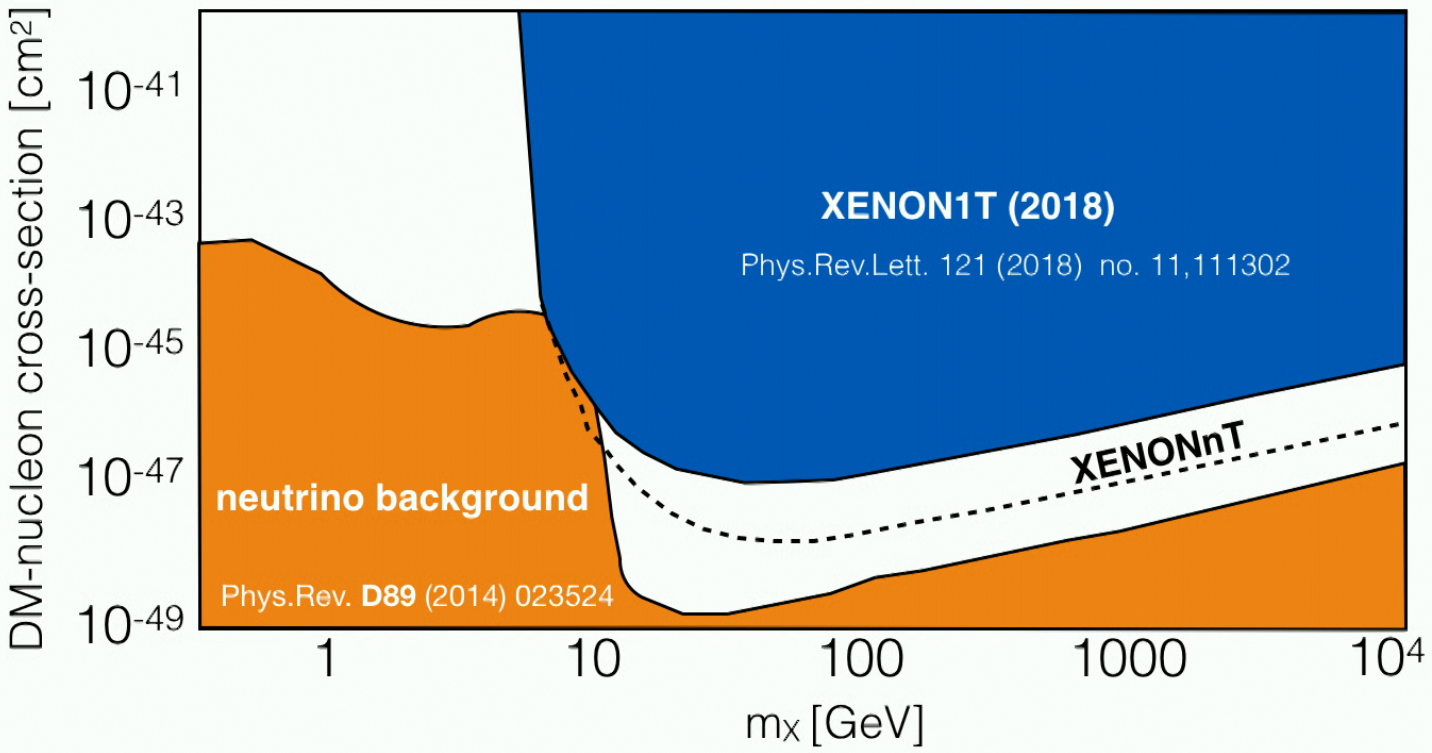


direct detection



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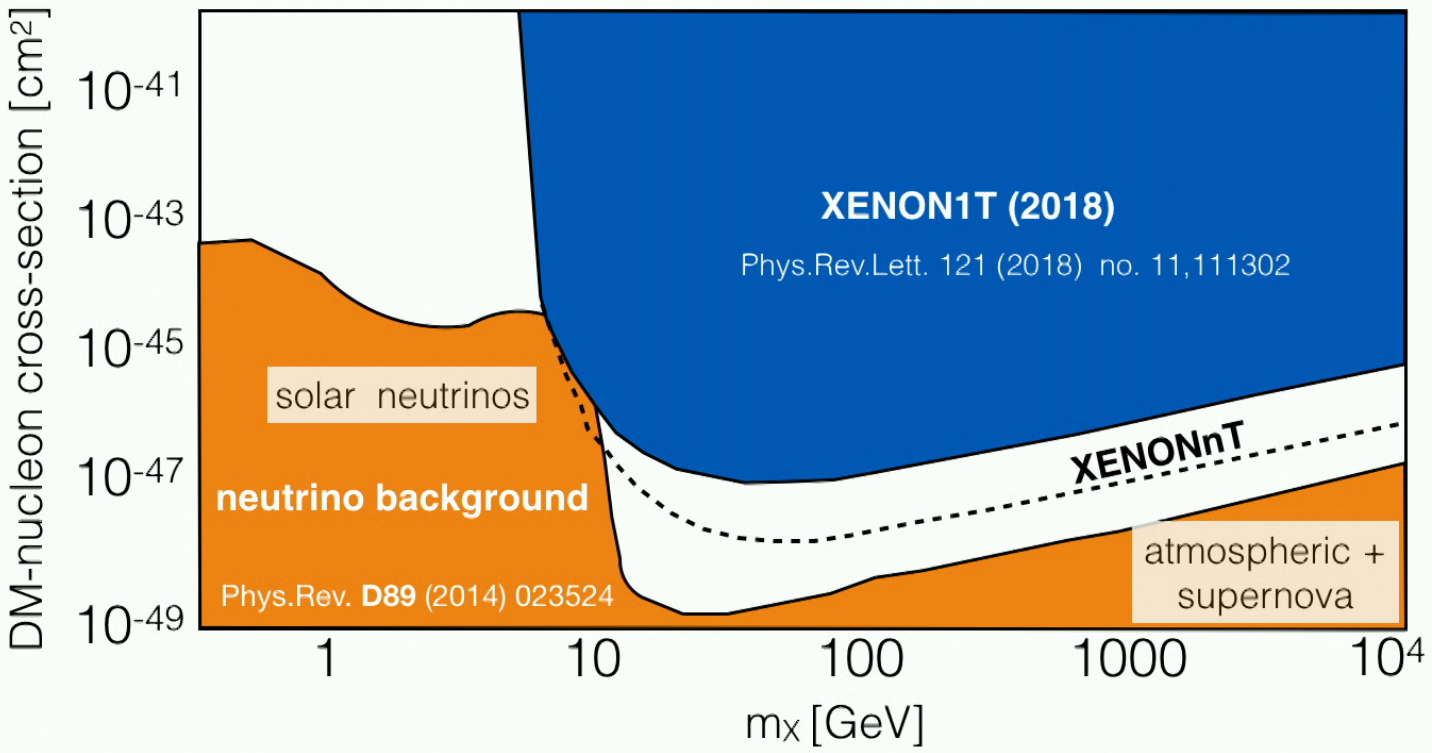
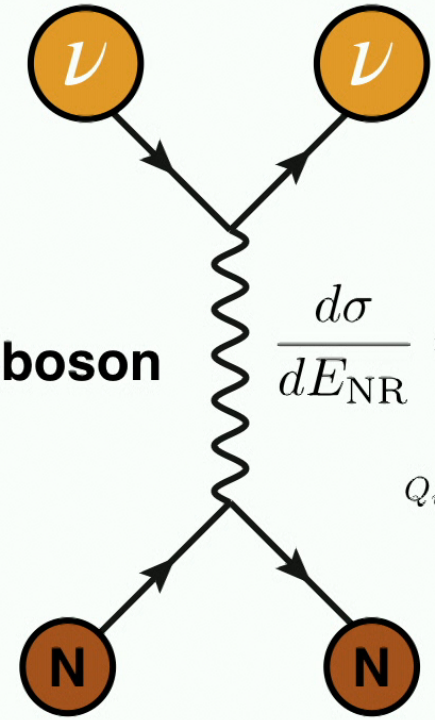


CEvNS

coherent neutrino-nucleus scattering



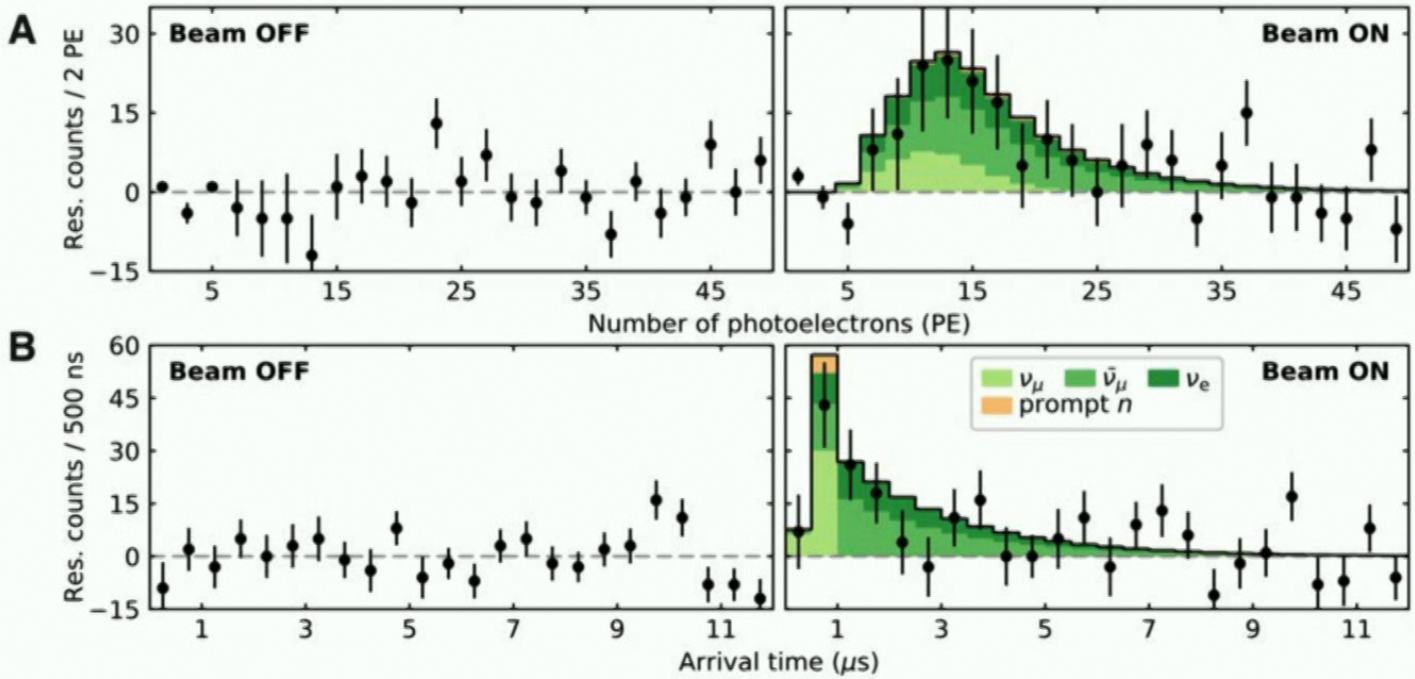
Z-boson

$$\frac{d\sigma}{dE_{\rm NR}} = \frac{G_F^2}{4\pi} Q_w^2 m_N \left(1 - \frac{m_N E_{\rm NR}}{2E_\nu^2}\right) F^2(E_{\rm NR})$$

$Q_w = N - Z(1 - 4\sin^2\theta_w)$

$F(E_{\rm NR}) \simeq 1$

coherent neutrino-nucleus scattering



COHERENT collaboration: Science **357** (2017) 1123-1126, [arXiv:1708.01294]

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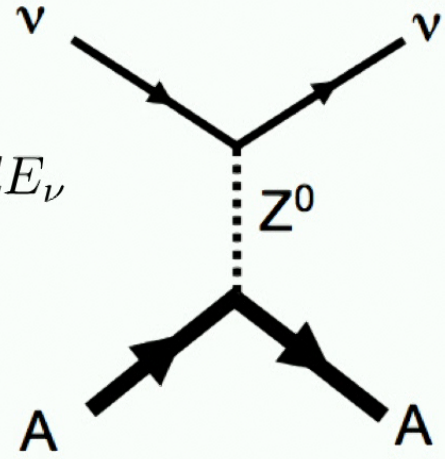
$$\frac{dR}{dE_{\rm NR}} = N_T M T \int_{E_\nu^{\rm min}} \frac{d\sigma}{dE_{\rm NR}} \frac{dN_\nu}{dE_\nu} dE_\nu$$

$E_\nu^{\rm min} = \sqrt{\frac{m_N E_{\rm NR}}{2}}$



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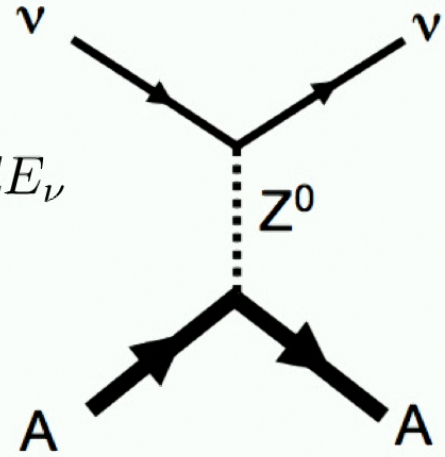
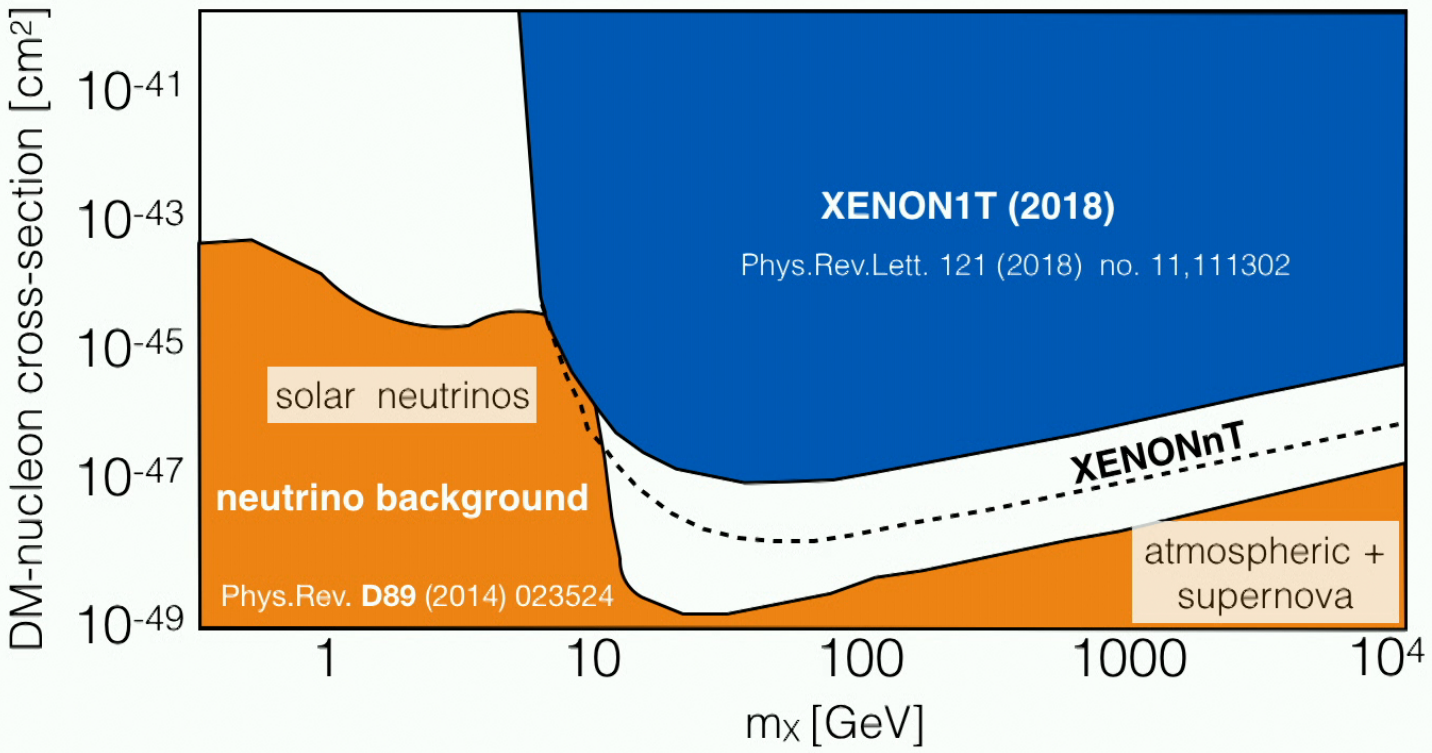
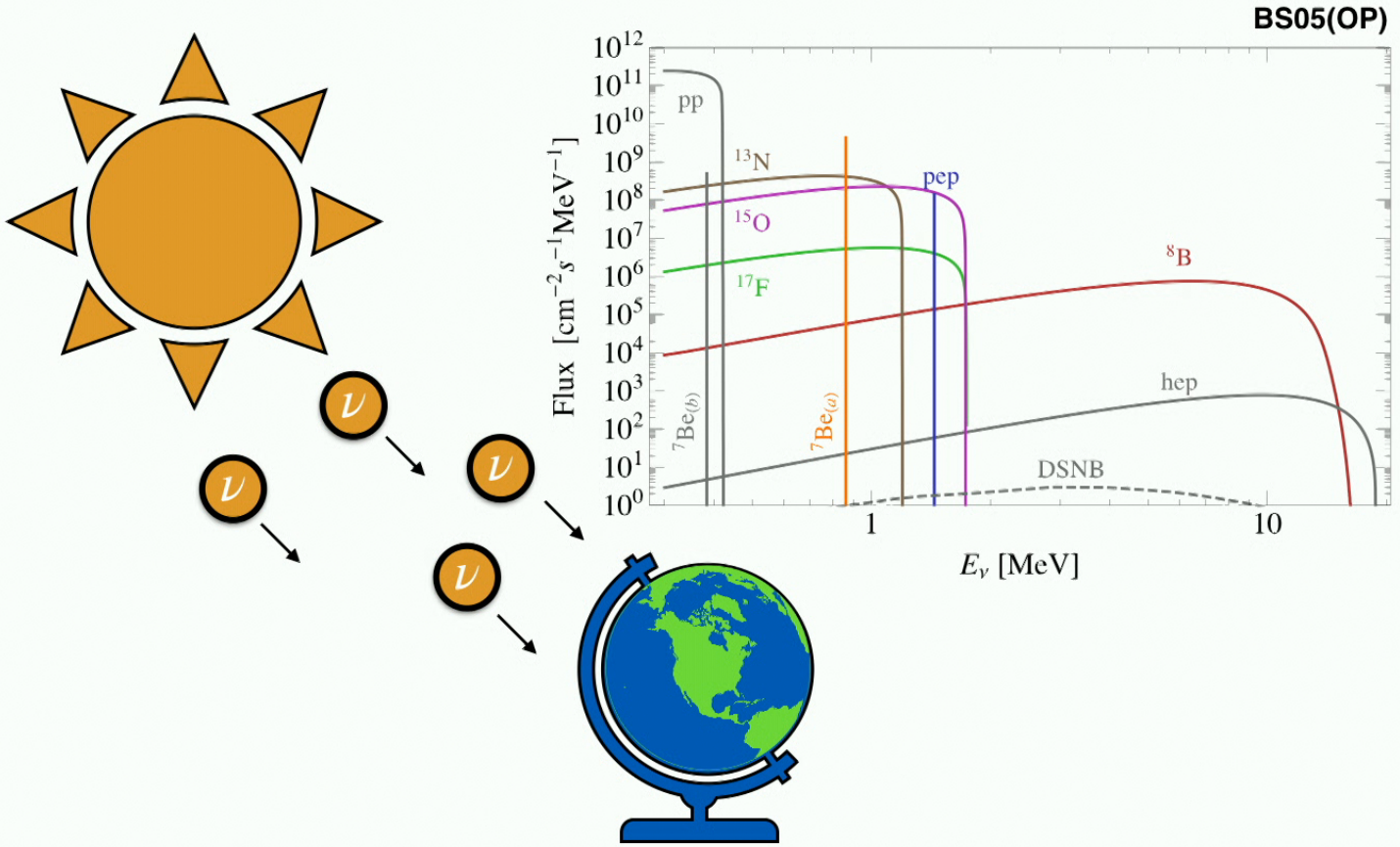


direct detection



Solar Neutrinos



R. Essig, M.Sholapurkar, **TTY** *Phys.Rev.D* 97 (2018) 9, 095029 [arXiv:1801.10159]

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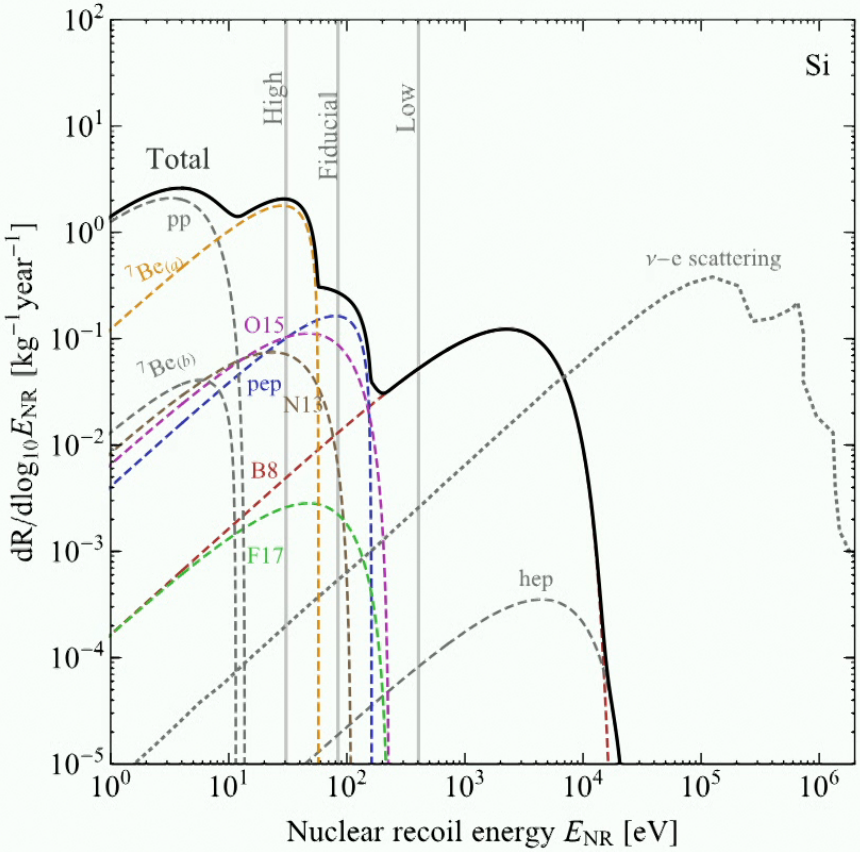
solar neutrino rates



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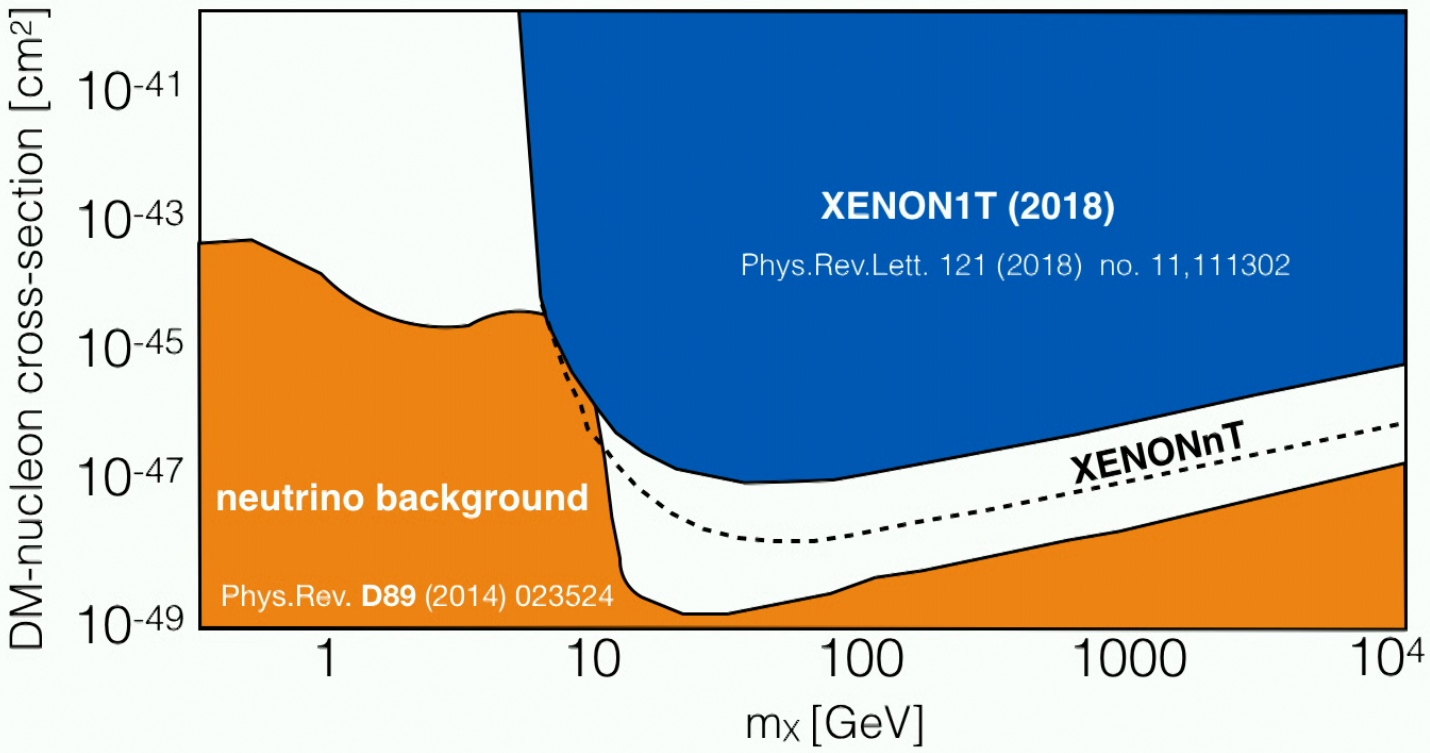
direct detection



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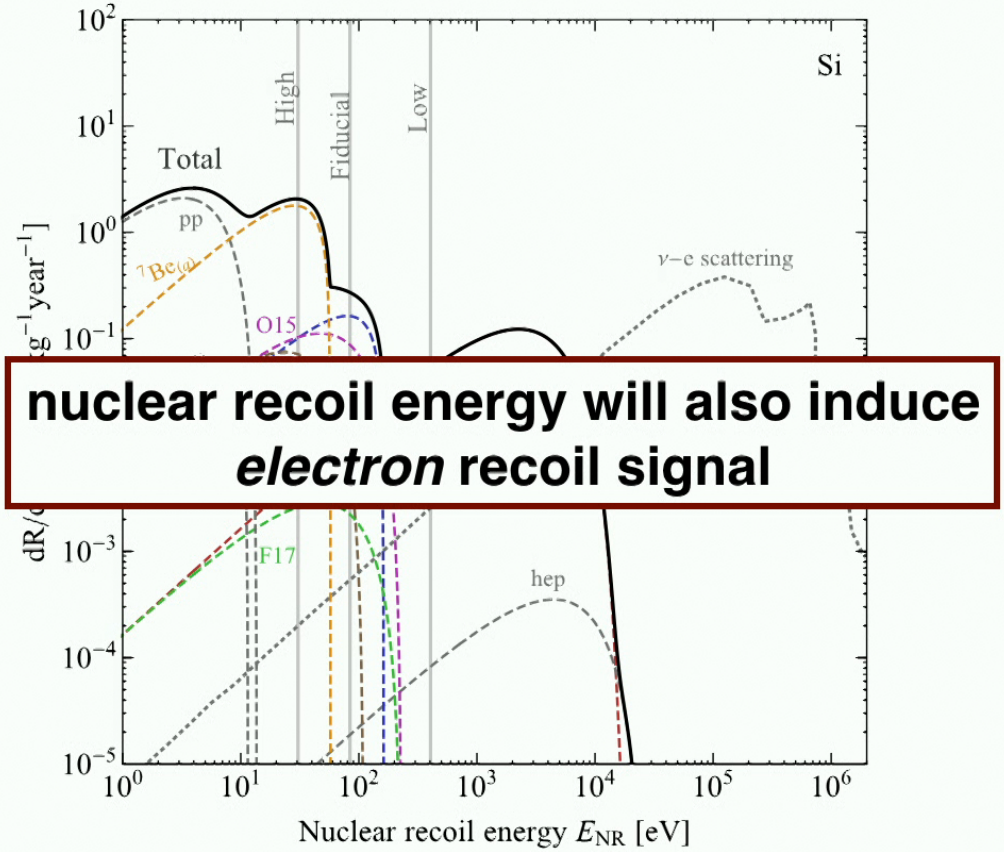


nuclear recoil energy will also induce *electron* recoil signal

R. Essig, M.Sholapurkar, **TTY** *Phys.Rev.D* 97 (2018) 9, 095029 [arXiv:1801.10159]

Lindhard model

$$E_e = Y E_{\mathrm{NR}}$$

ionization efficiency

treat as free parameter

$$Y_{\mathrm{Lindhard}}(E_{\mathrm{NR}}) = \frac{kg(\epsilon)}{1 + kg(\epsilon)},$$

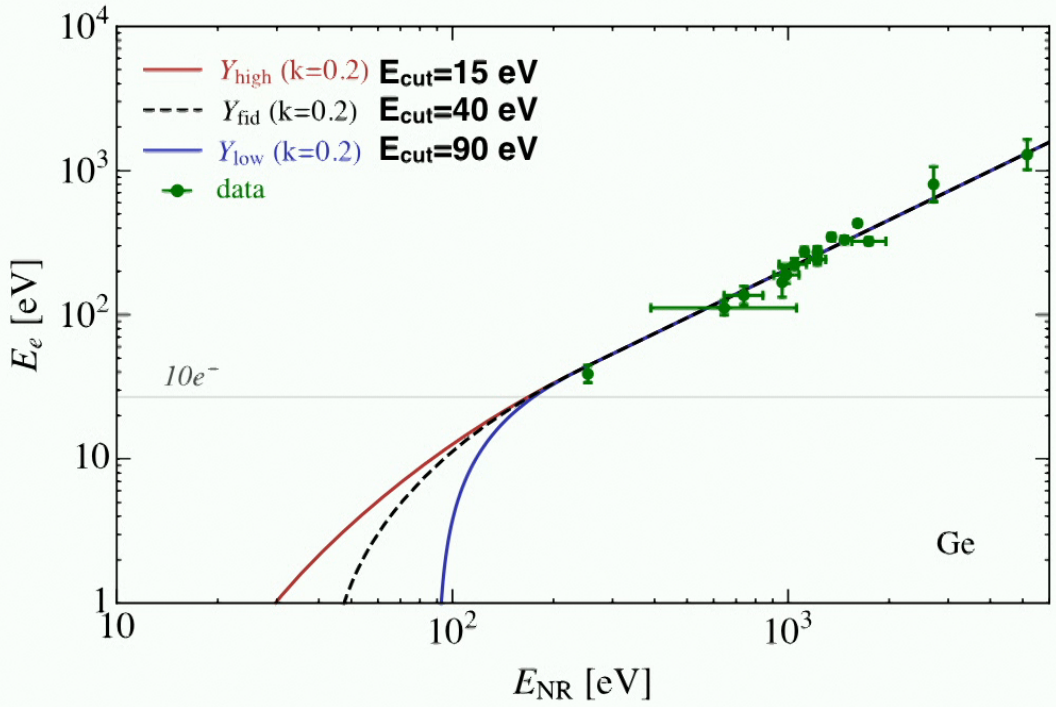
$$g(\epsilon) = 3\epsilon^{0.15} + 0.7\epsilon^{0.6} + \epsilon,$$

$$\epsilon = 11.5 Z^{-7/3} E_{\mathrm{NR}}$$

*recent improvements fold-in atomic binding energy into modeling

ionization efficiency

Lindhard works well for germanium



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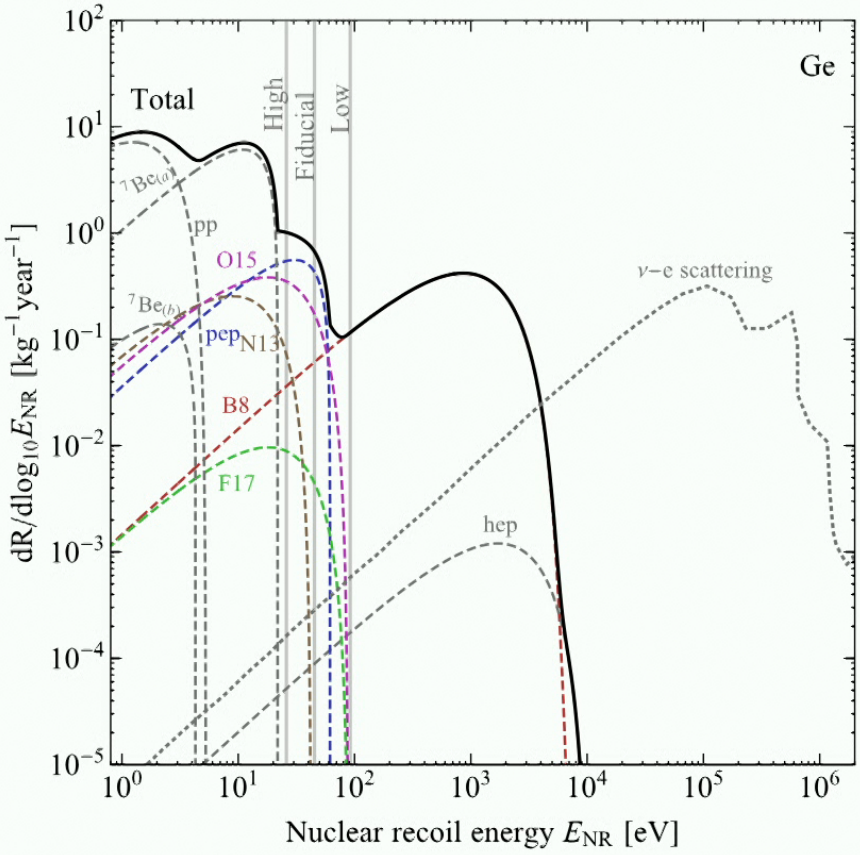

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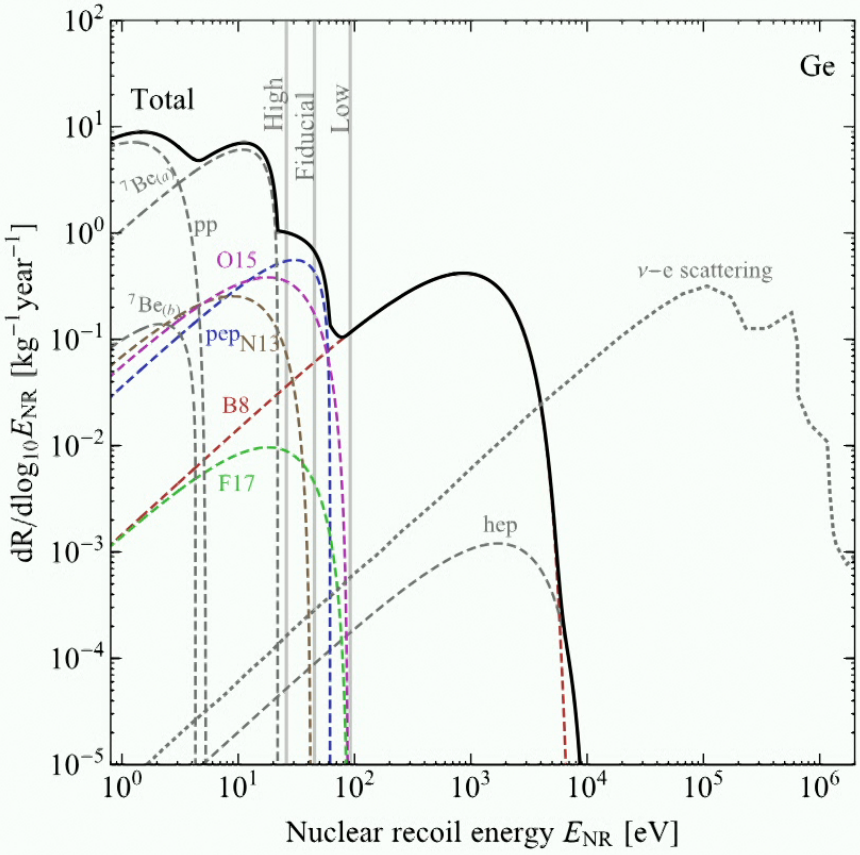

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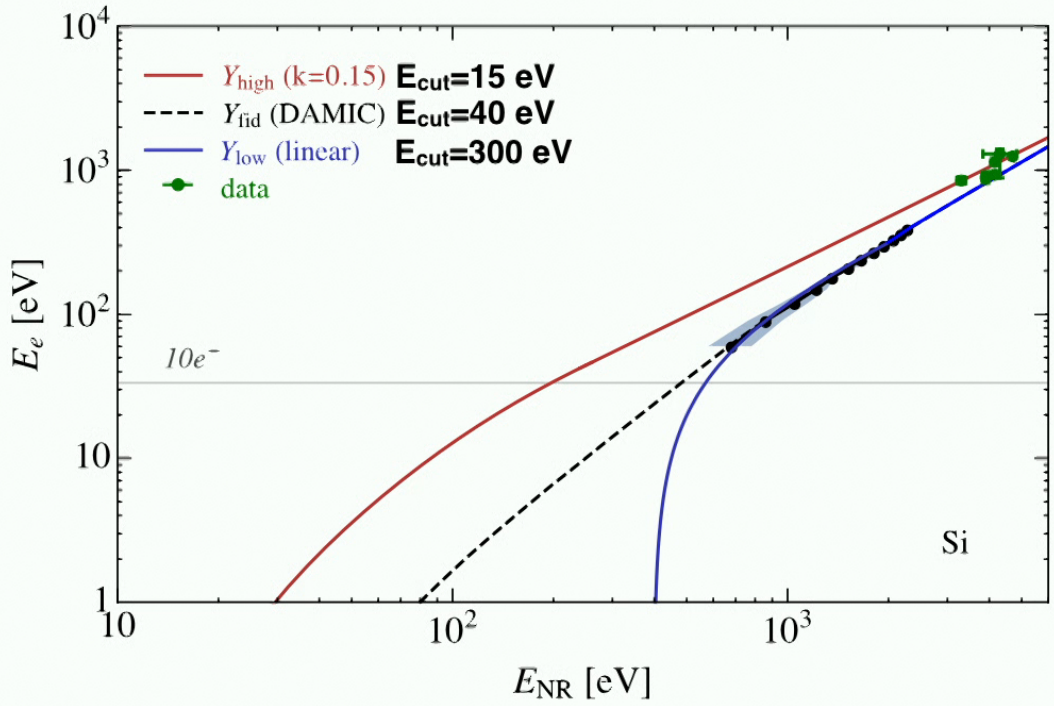
ionization efficiency

but not at low energies for silicon



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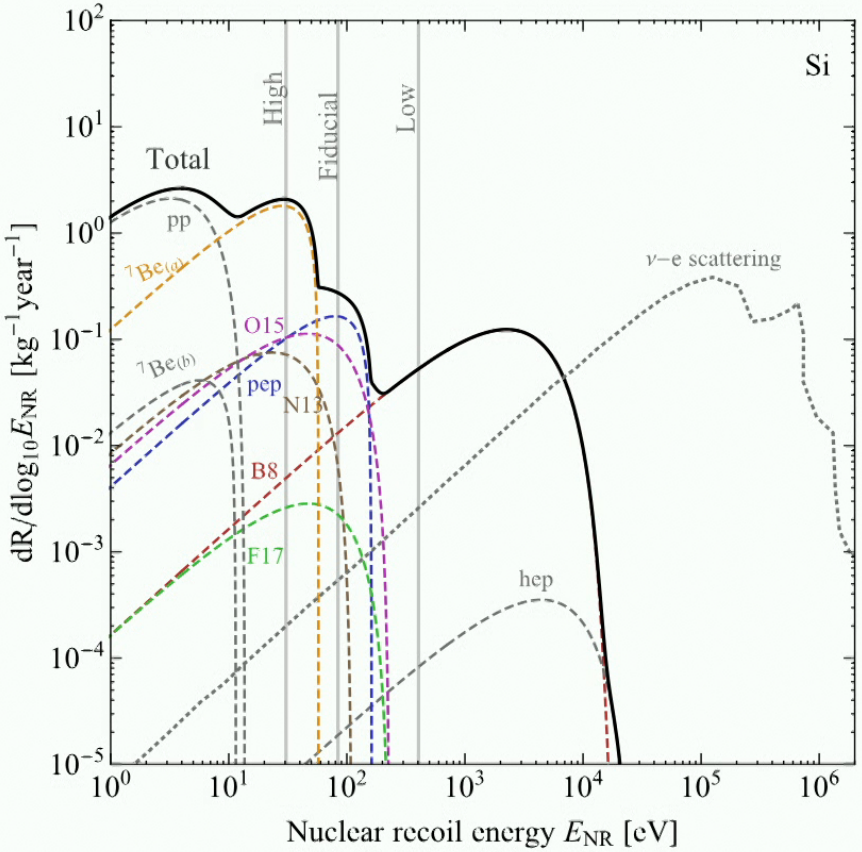

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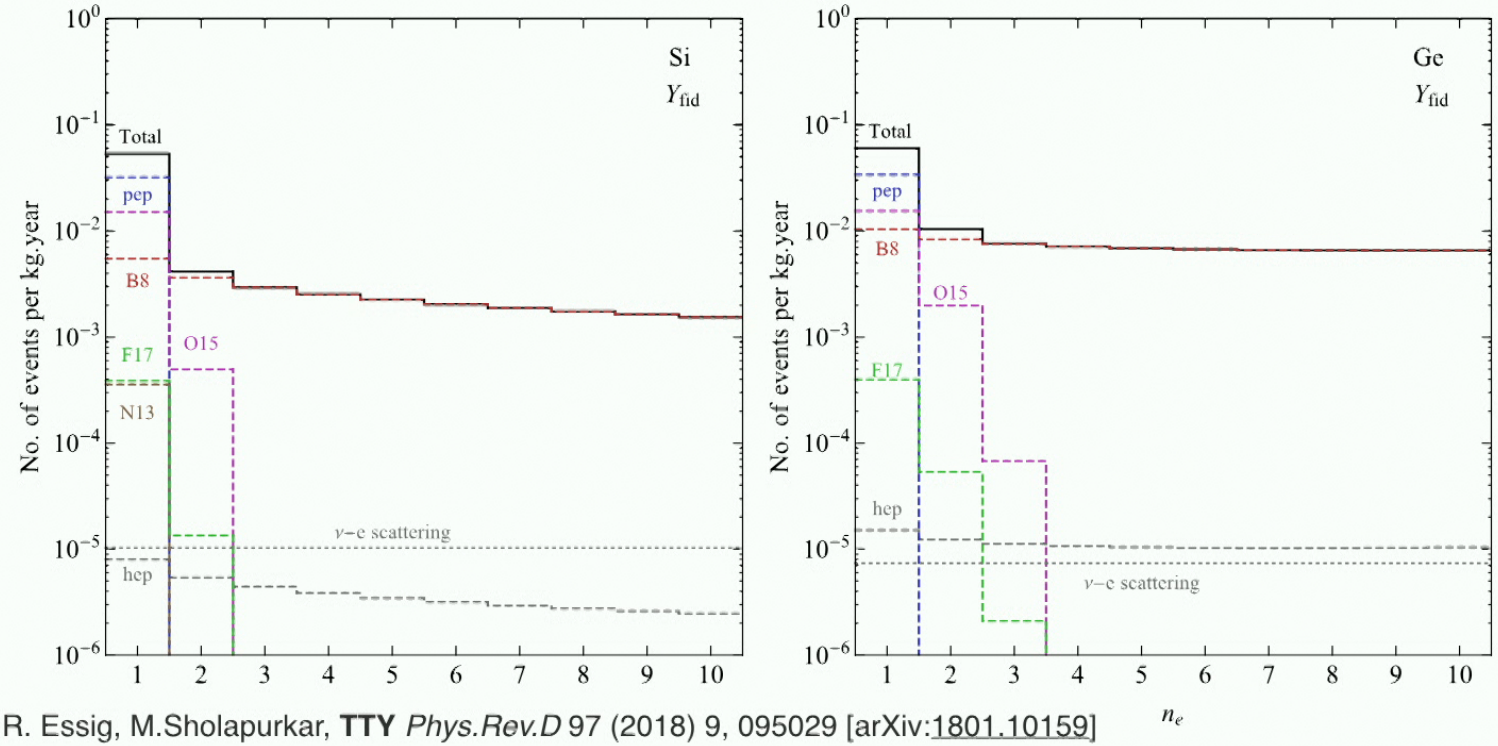
electron recoil energy

$$\frac{dR_e}{dE_e} = \frac{dR_N}{dE_{\rm NR}} \times \frac{1}{(Y(E_{\rm NR}) + E_{\rm NR}\frac{dY(E_{\rm NR})}{dE_{\rm NR}})}$$



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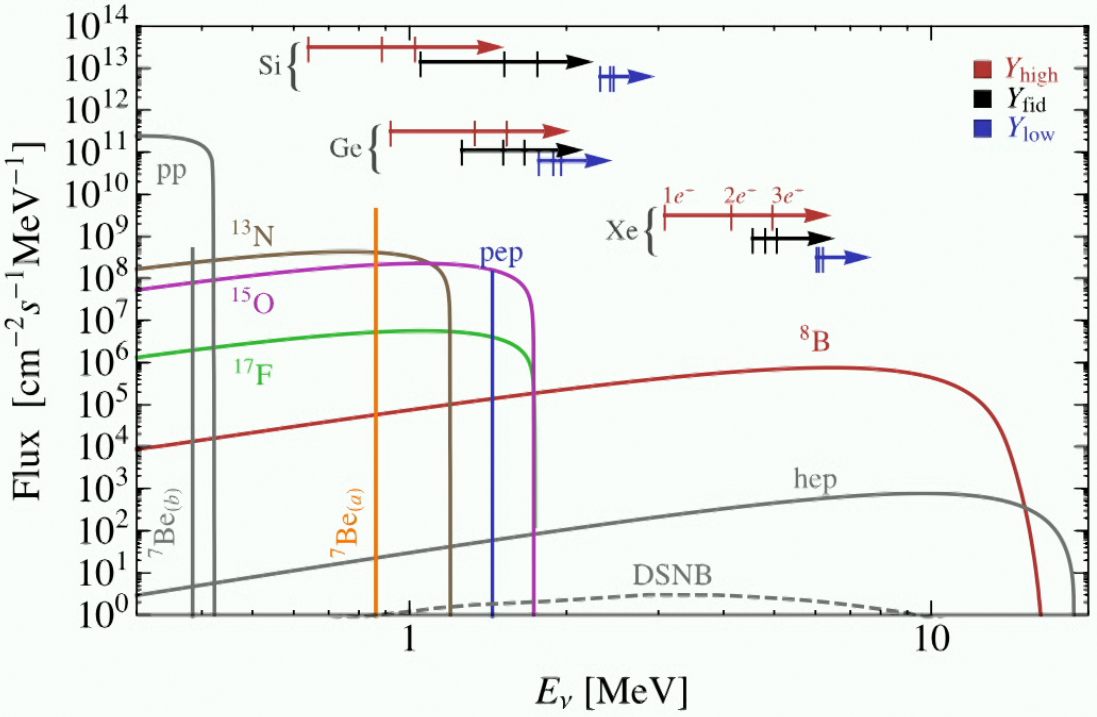

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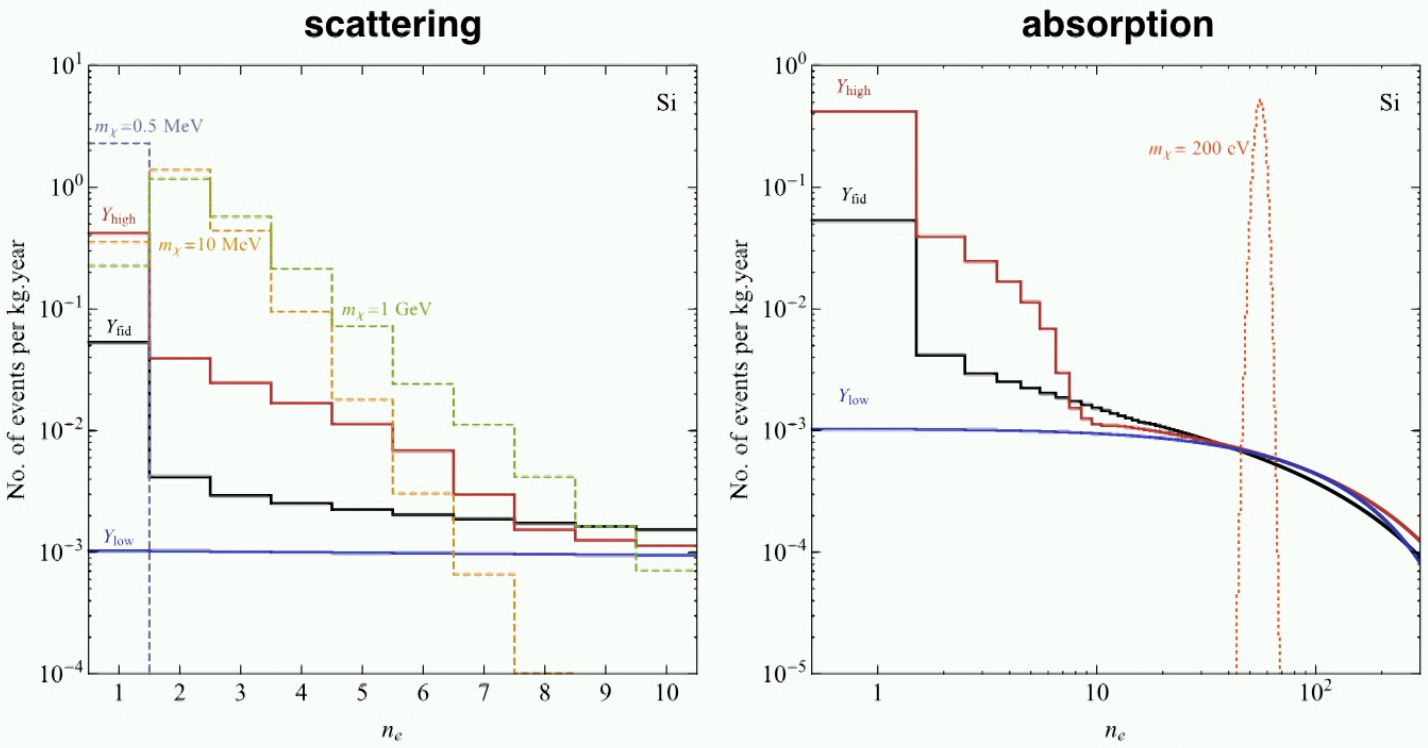
Act I: neutrinos as background

DM vs. neutrino spectra



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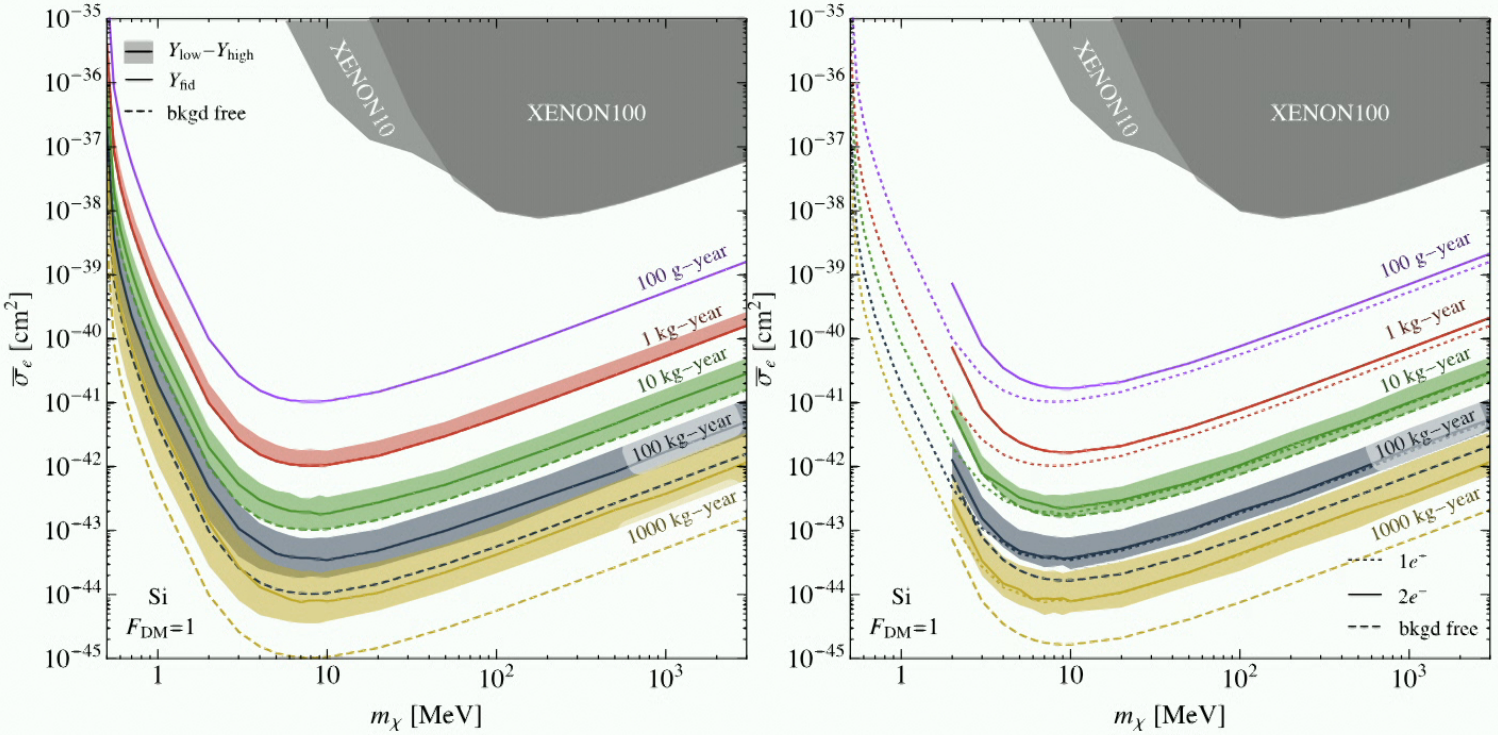
DM-e^- scattering



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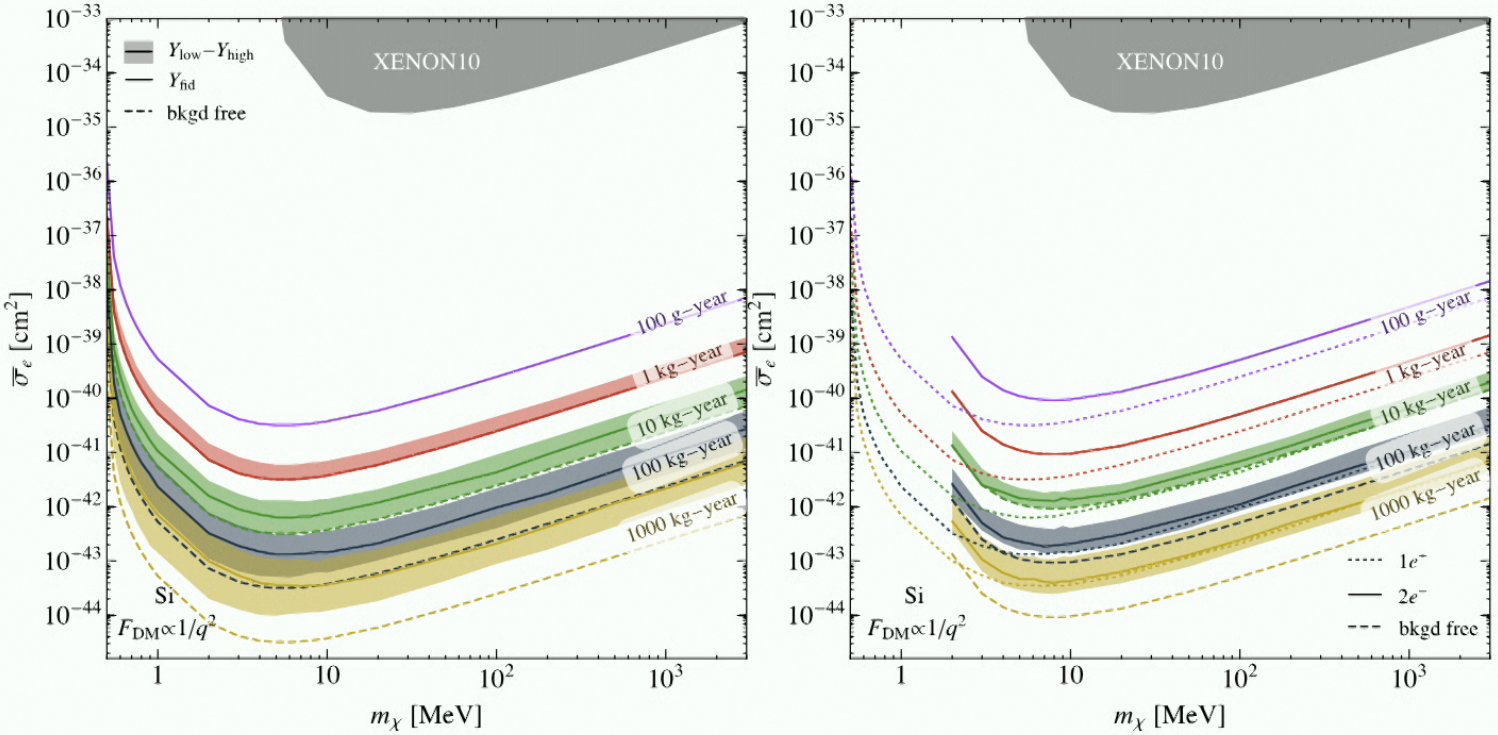

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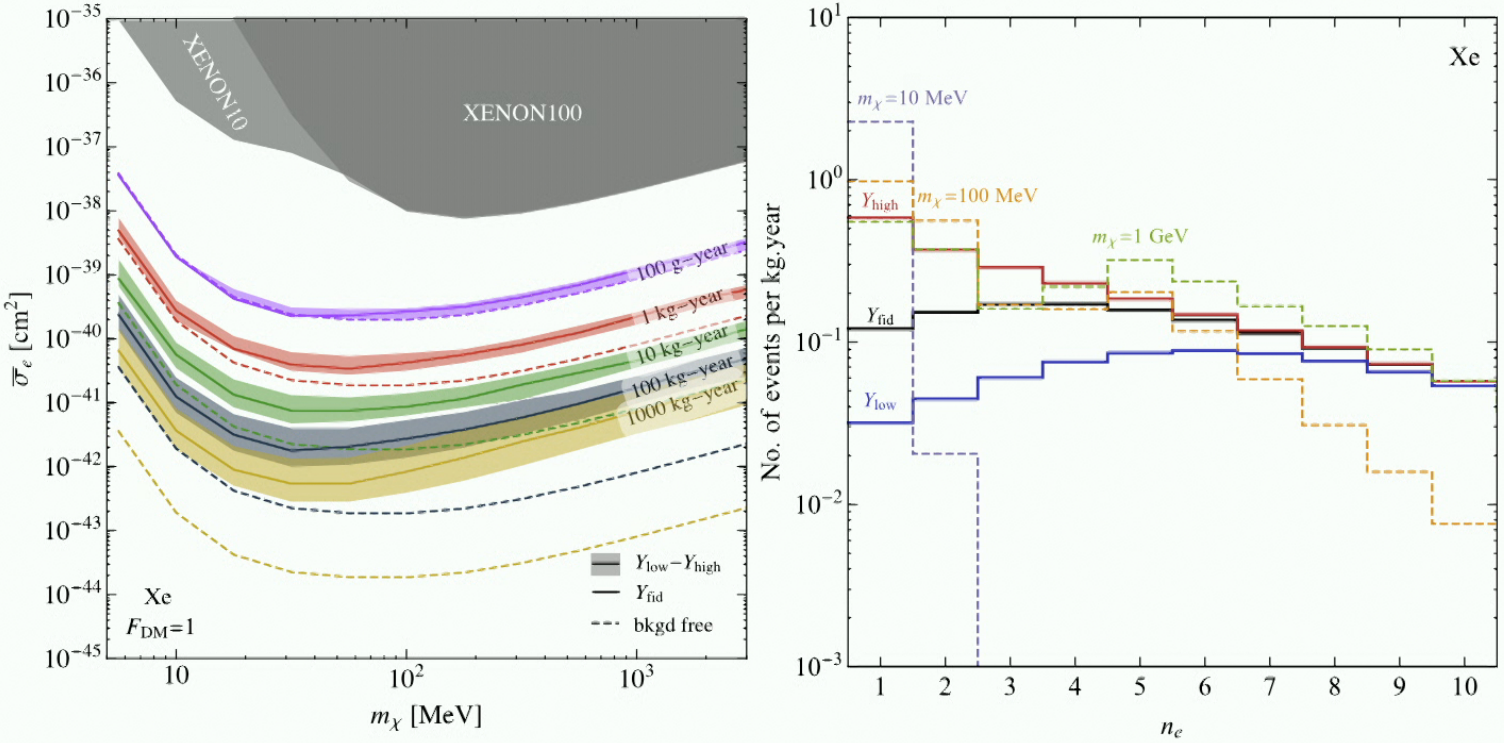
xenon



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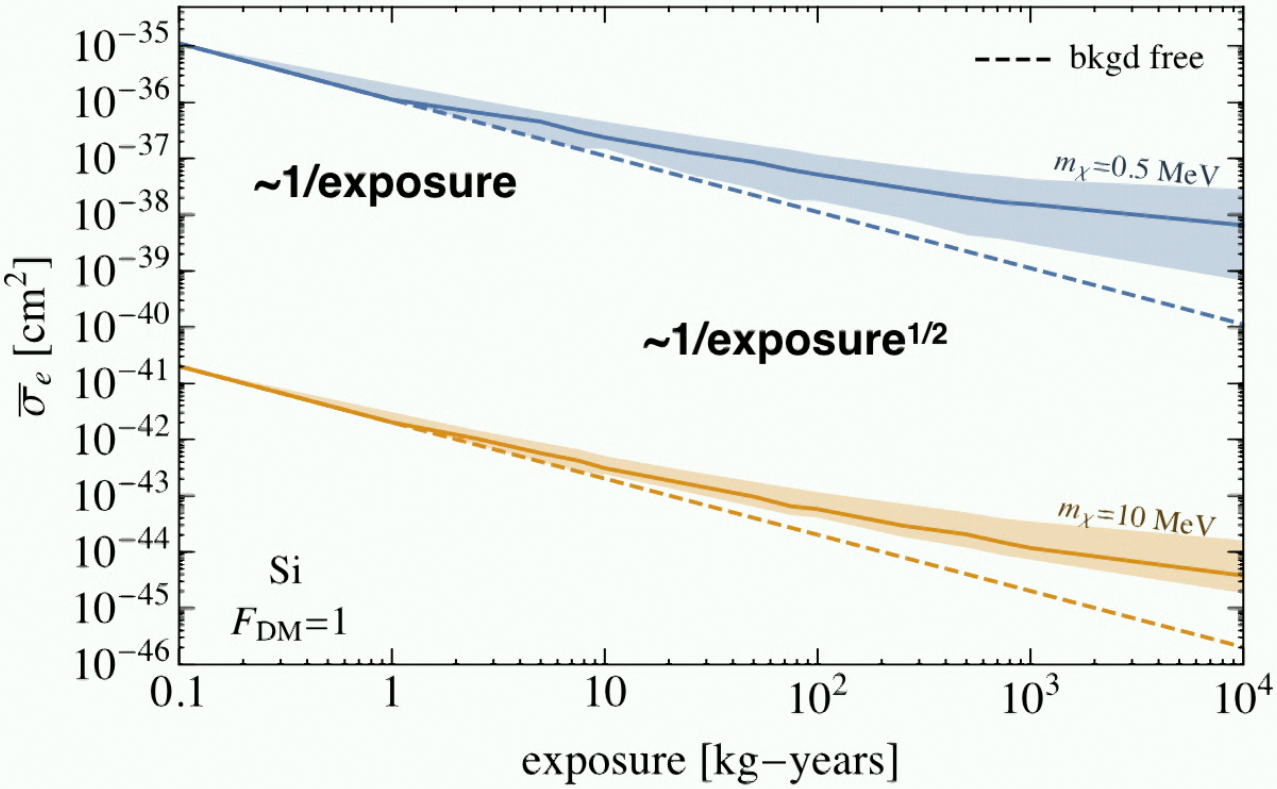

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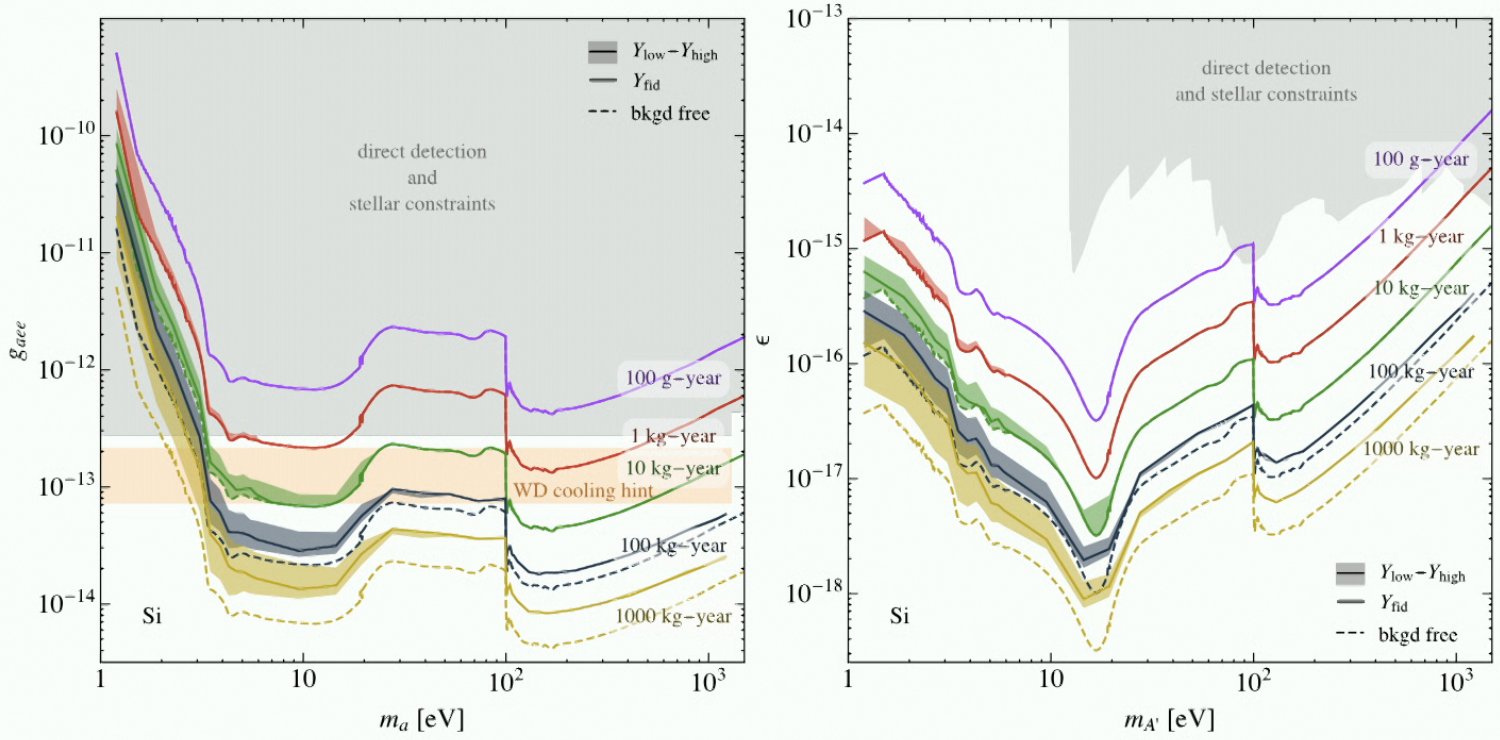
DM absorption



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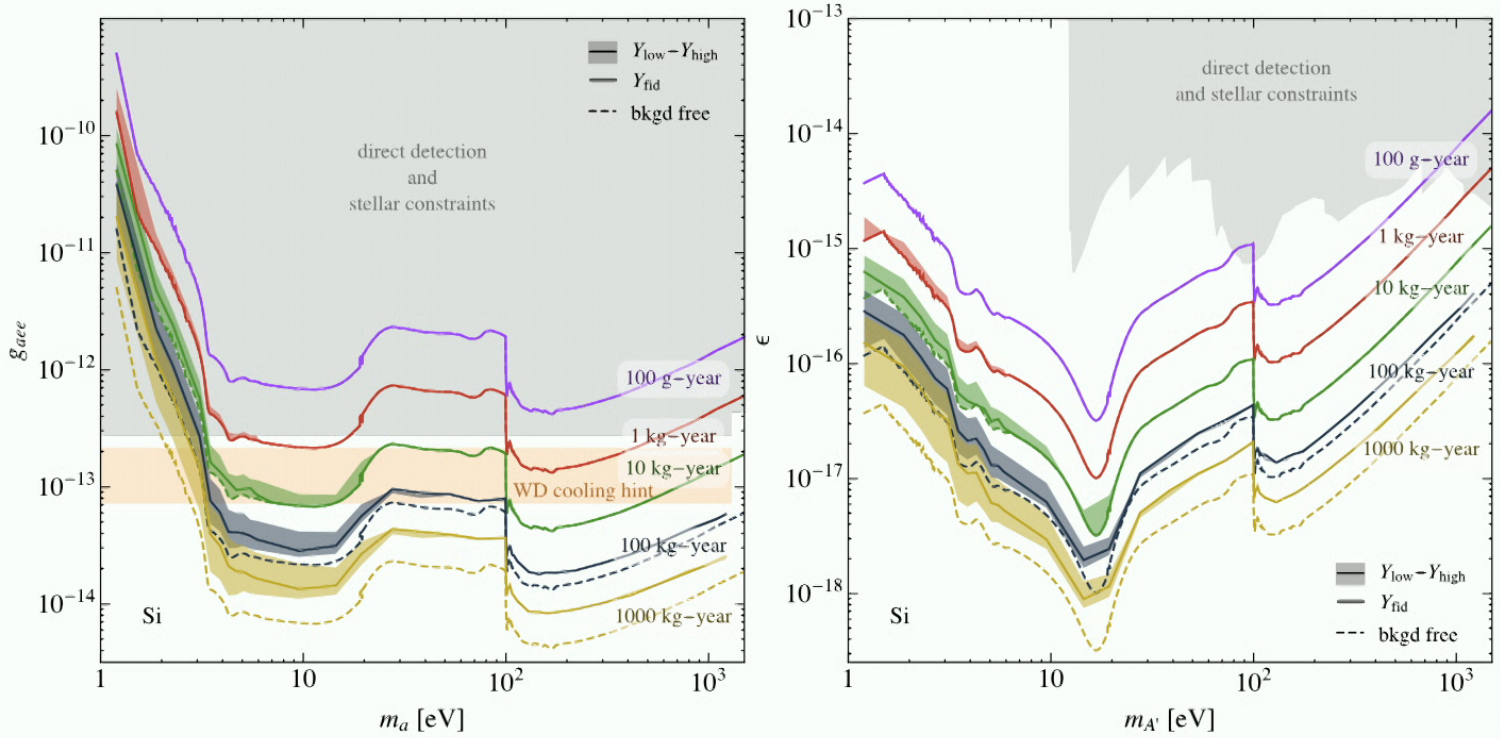

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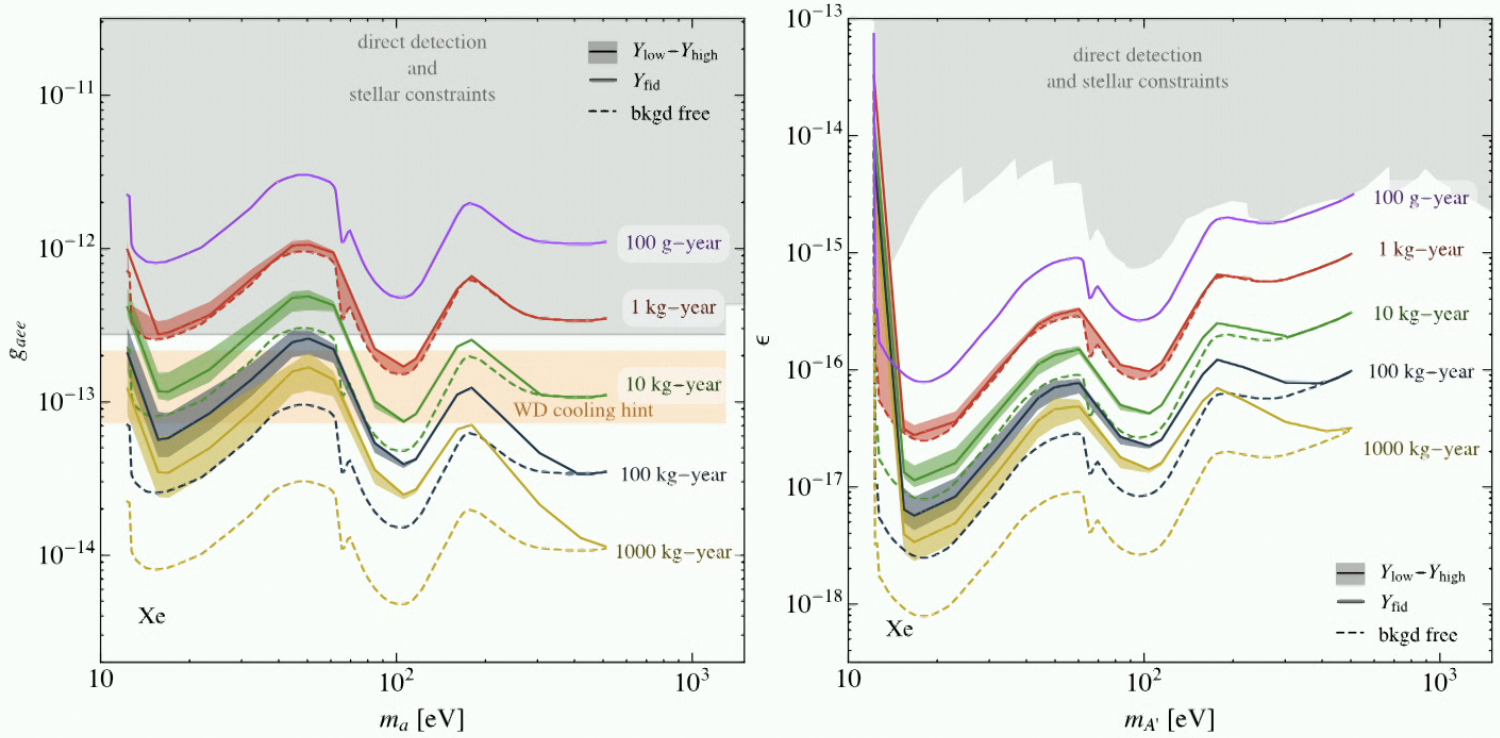

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take-away

- solar neutrinos are only an important background for DM-e scattering in semiconductors for exposures above 1 kg-year
- they are already important for xenon at 100 g-years
- they are important for absorption at ~1 kg-year in both semiconductors and xenon

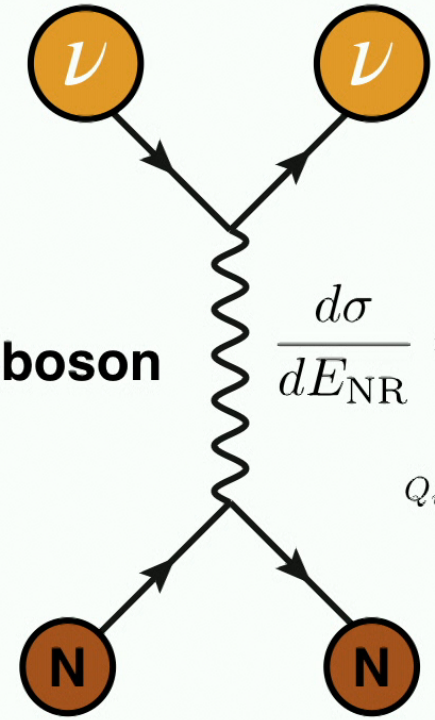
Act II: neutrinos as signal

why is direct detection (potentially) interesting?

- measure pure neutral current ^{8}B spectrum for the first time
- allows for first direct measurement of neutrino survival probability in “transition region”
- could probe lower energies than existing SNO measurements
- measure survival probability in “vacuum” region
- help understanding of “solar abundance problem”
- non-standard interactions

CEvNS

coherent neutrino-nucleus scattering



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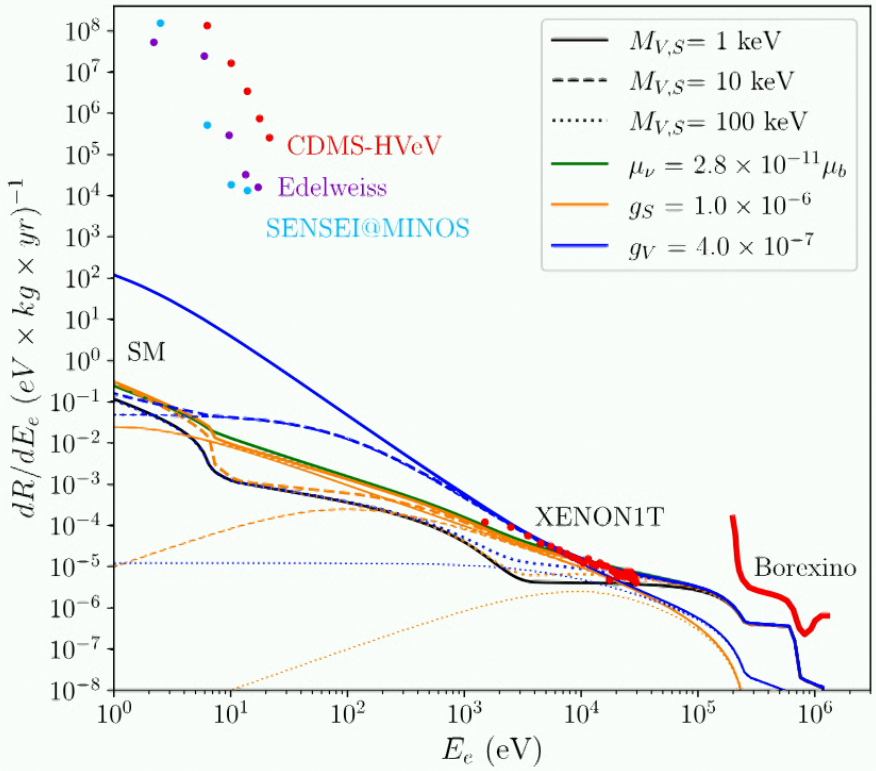
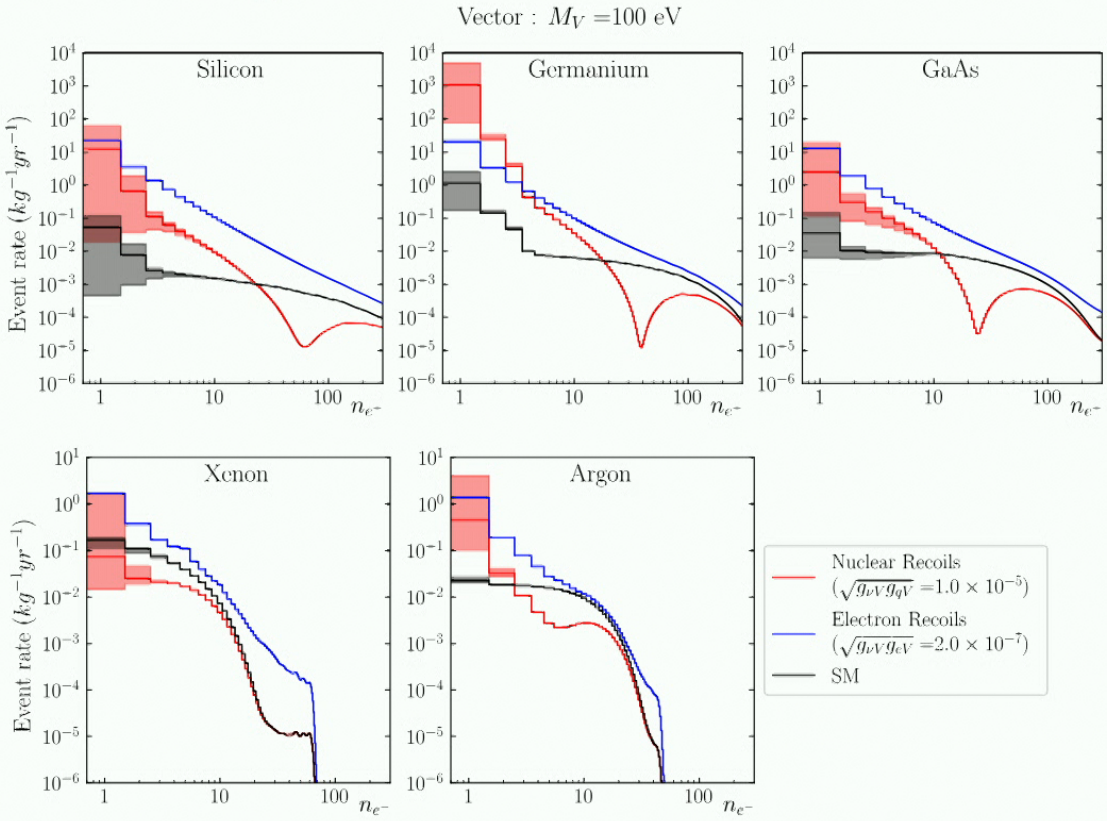
(Si) Recoil Spectra



T. Schwemberger, **TTY** [arXiv:2202.01254]

Simplified Models



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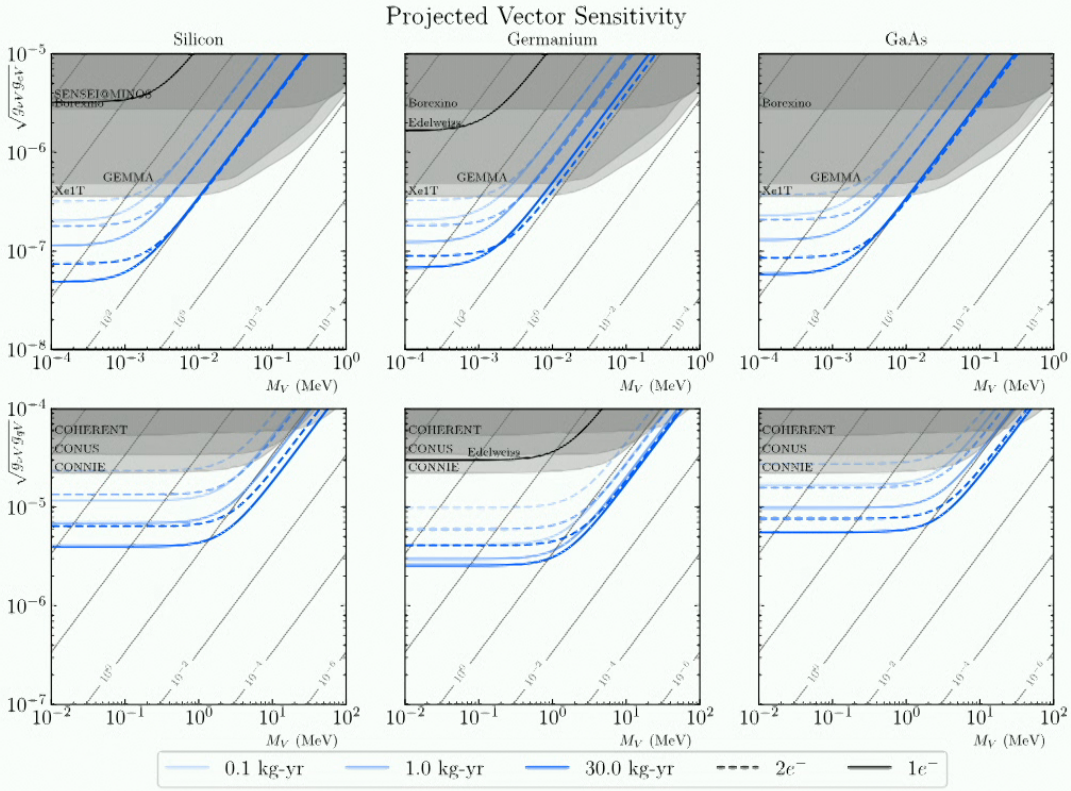

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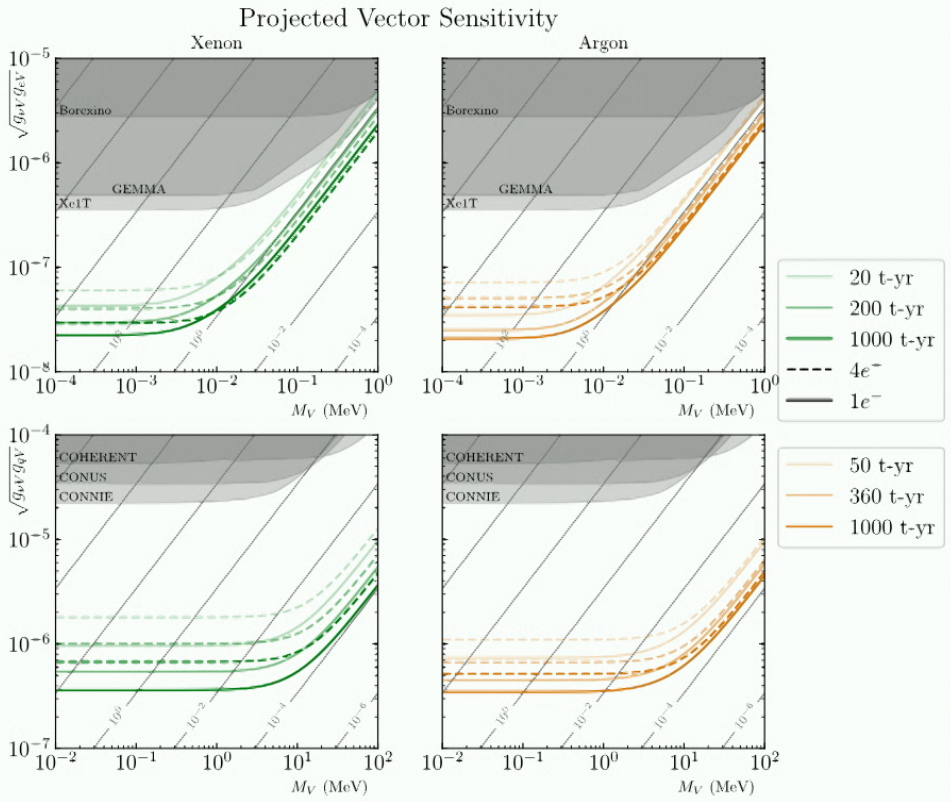
Simplified Models



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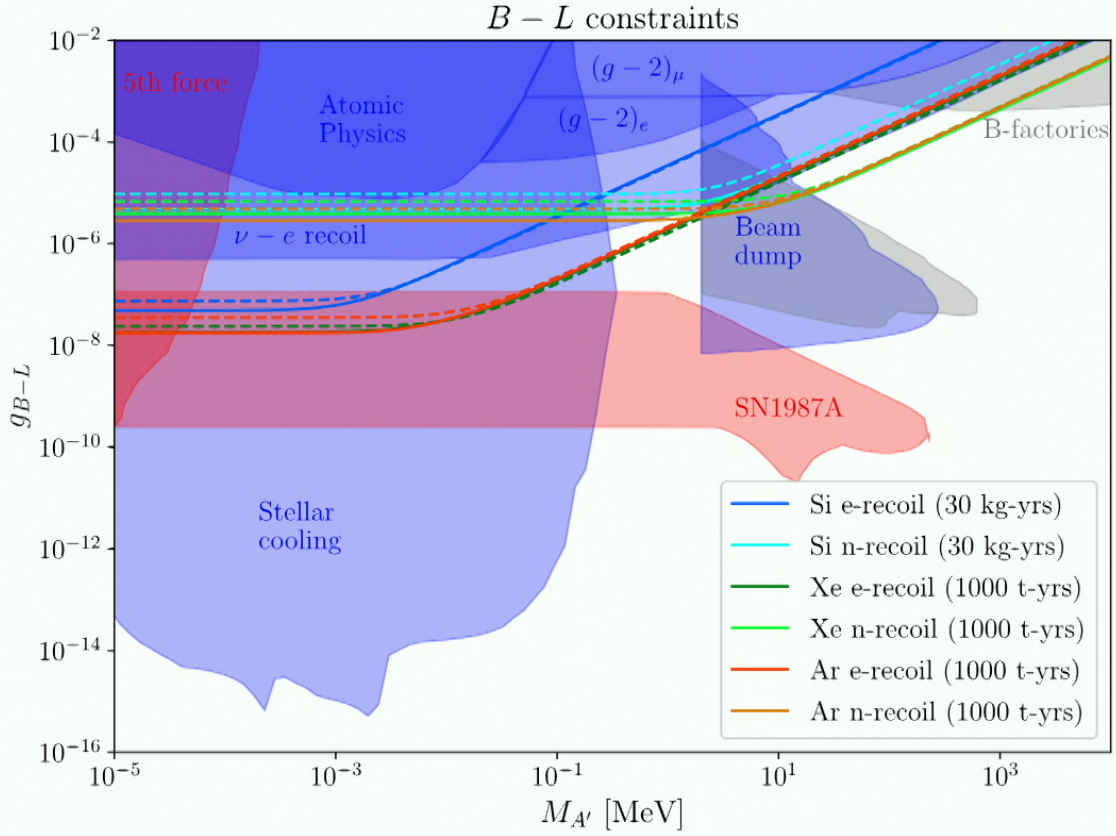
B-L model



T. Schwemberger, **TTY** [arXiv:2202.01254]