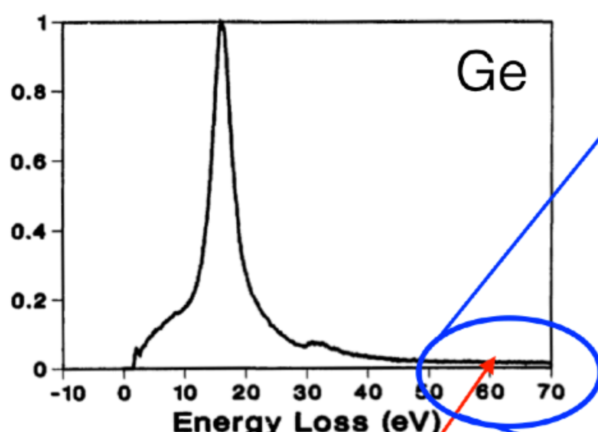
Exotic low-yield nuclear recoil?

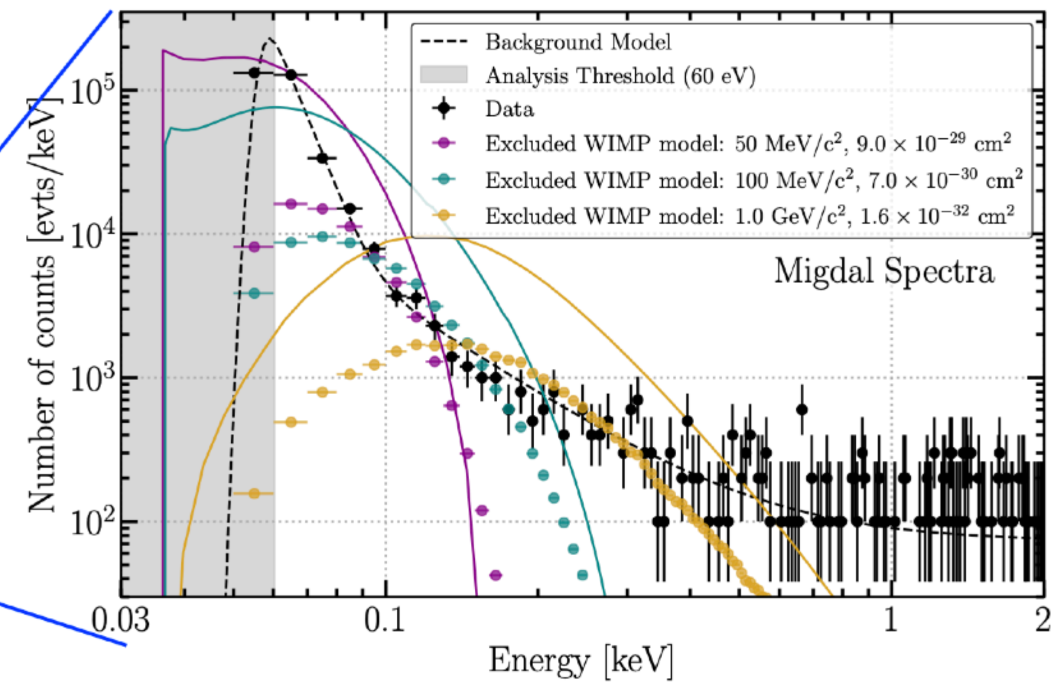
Yoni Kahn
University of Illinois at Urbana-Champaign
EXCESS Workshop, 2/16/21

2 years ago…

A plasmon might look like this…



note the huge tail
on a **linear** scale!



EDELWEISS surface (2019)
Germanium detector

[Aspen, 2/19/20, shortly before the end of the world…]

2 years ago…

Something is making a plasmon at the same rate everywhere in semiconductor detectors

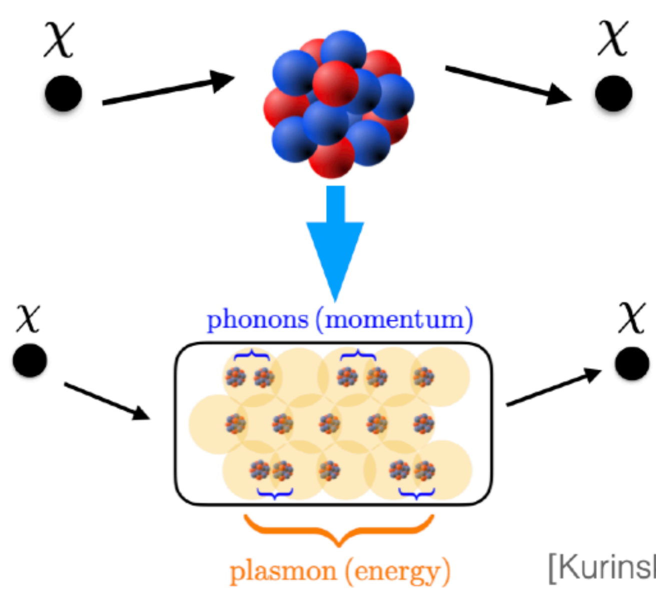
Can it be dark matter?

To excite plasmon, need small $\mathbf{q}$ for fixed ω $\implies v \gtrsim 10^{-2}$

Faster than escape velocity! Either need fast DM, or indirect excitation

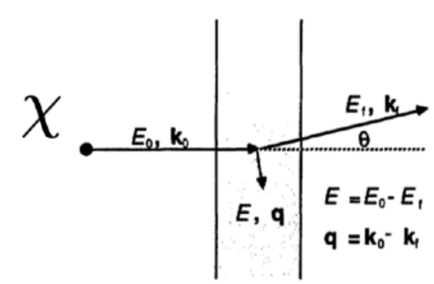
Two scenarios consistent with data so far:

Indirect plasmon excitation



Fast and millicharged

DM is like an electron,
with a long-range force.
Identical dynamics to EELS:
not a 2-body scattering process!



[Kurinsky, Baxter, **YK**, Krnjaic, 2002.06937]

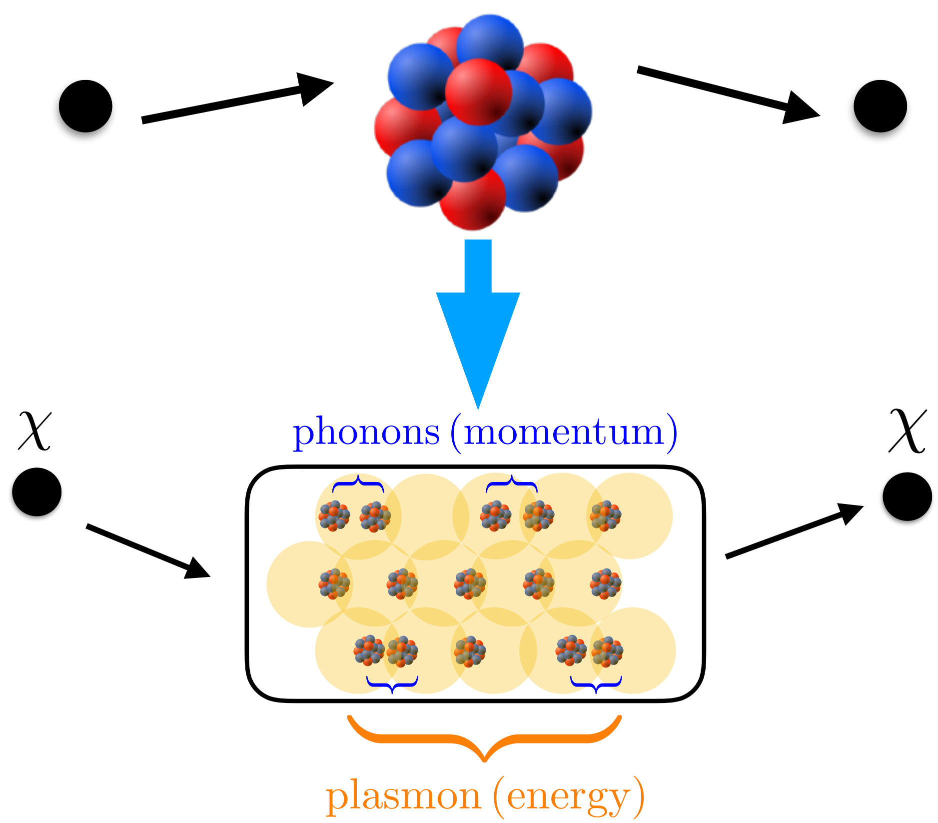
[Aspen, 2/19/20, shortly before the end of the world…]

2 years ago…

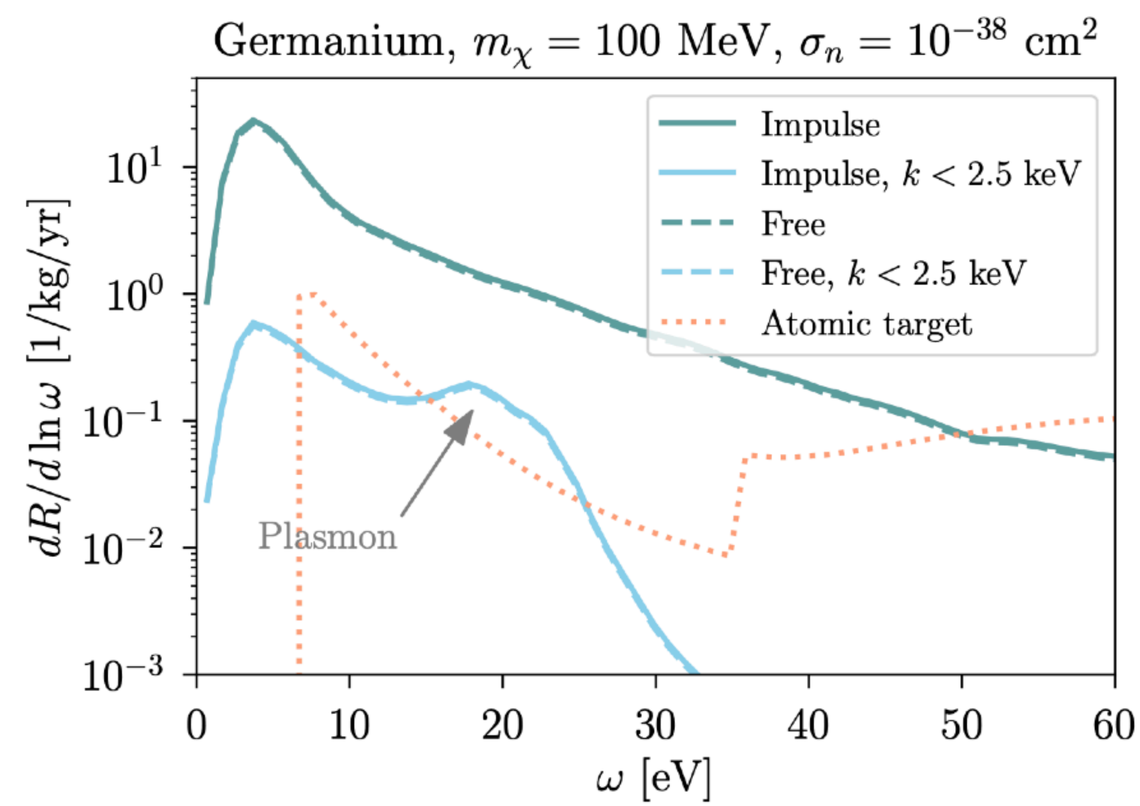
- **There are lots of low-energy excesses** ✓
- **The semiconductor rates are similar everywhere, regardless of overburden, exposure, or detector** (✓)
- Semiconductor events are a mix of heat and charge which does not match traditional ER or NR yields (✓)
- Every semiconductor event is a plasmon excitation ✗
- Dark matter is exciting a plasmon in semiconductors and possibly a combination of electron recoil and Migdal ionization (at lower rates) in noble liquids ✗
- We've been seeing dark matter for the past 10 years? ✗

[Aspen, 2/19/20, shortly before the end of the world…]

Probably not plasmons



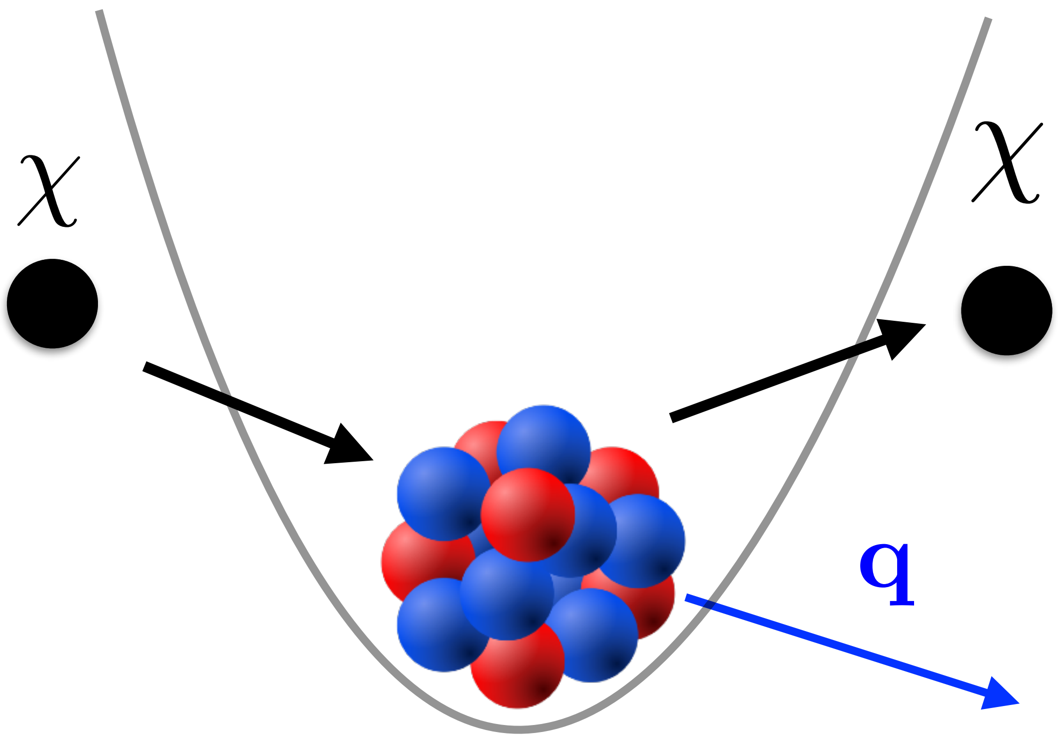
[Kurinsky, Baxter, Kahn, Krnjaic, PRD 2020]



[Knapen, Kozaczuk, Lin, PRL 2021]

Plasmon is just a very subdominant piece of the Migdal effect: spectrum has the wrong shape! (More on this in Yutaro's talk)

Probably not NR below displacement energy



$$\phi_0(\mathbf{p}) = (\pi m_N \omega_0)^{-1/4} e^{-\mathbf{p}^2/{q_0}^2}$$

$$q_0 = \sqrt{2 m_N \omega_0}$$

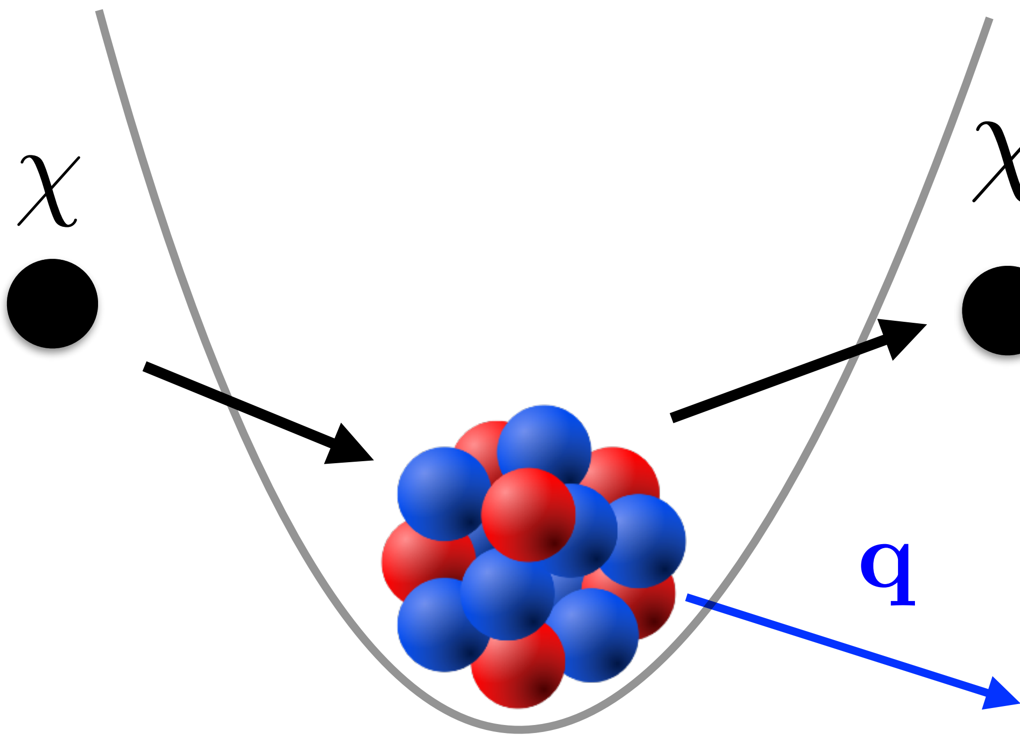
(56 keV for Si)

$$V(r) \approx \frac{1}{2} m_N \omega_0^2 r^2,$$

optical phonon energy ~ 60 meV

[Kahn, Krnjaic, Mandava, PRL 2021]

Probably not NR below displacement energy



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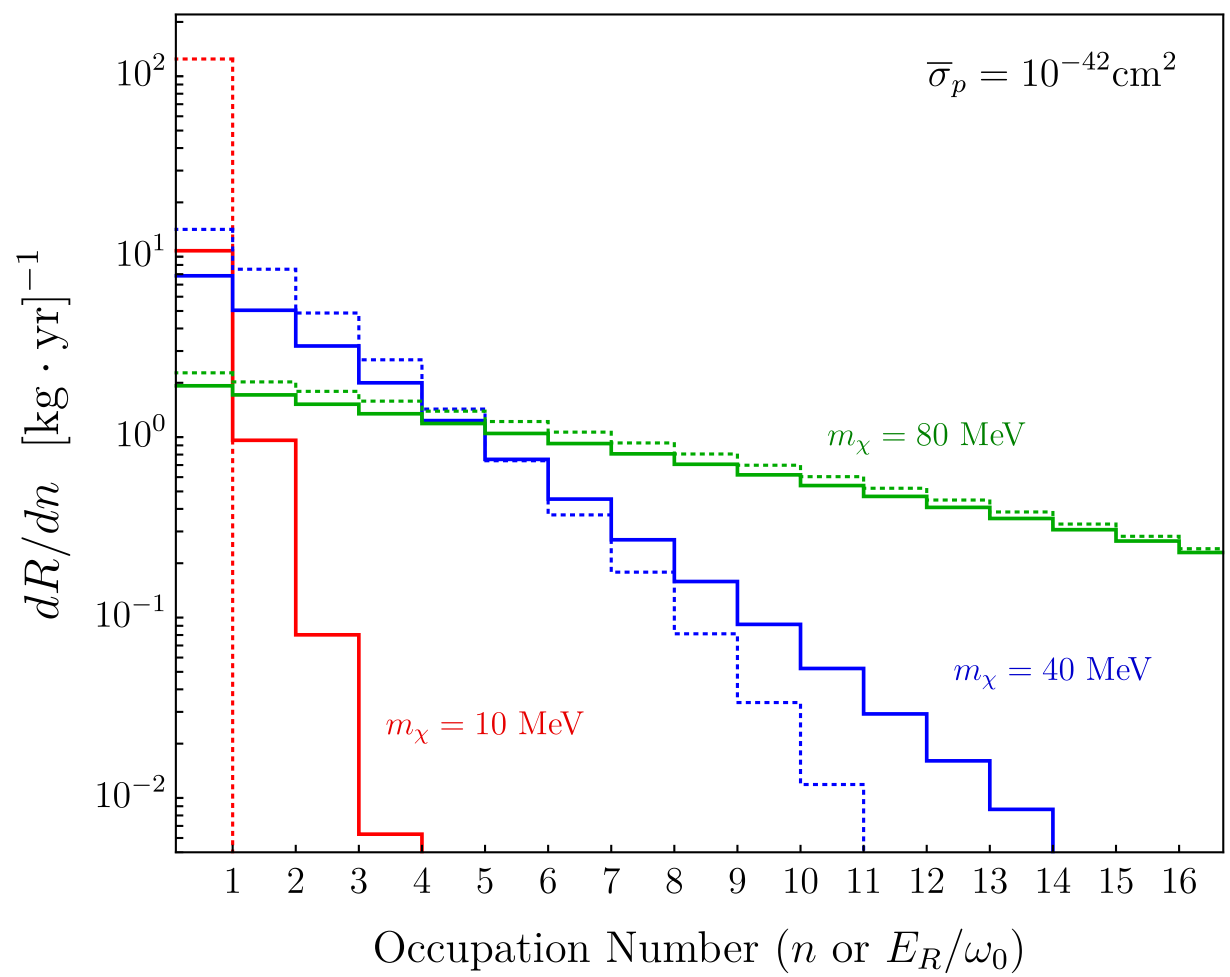
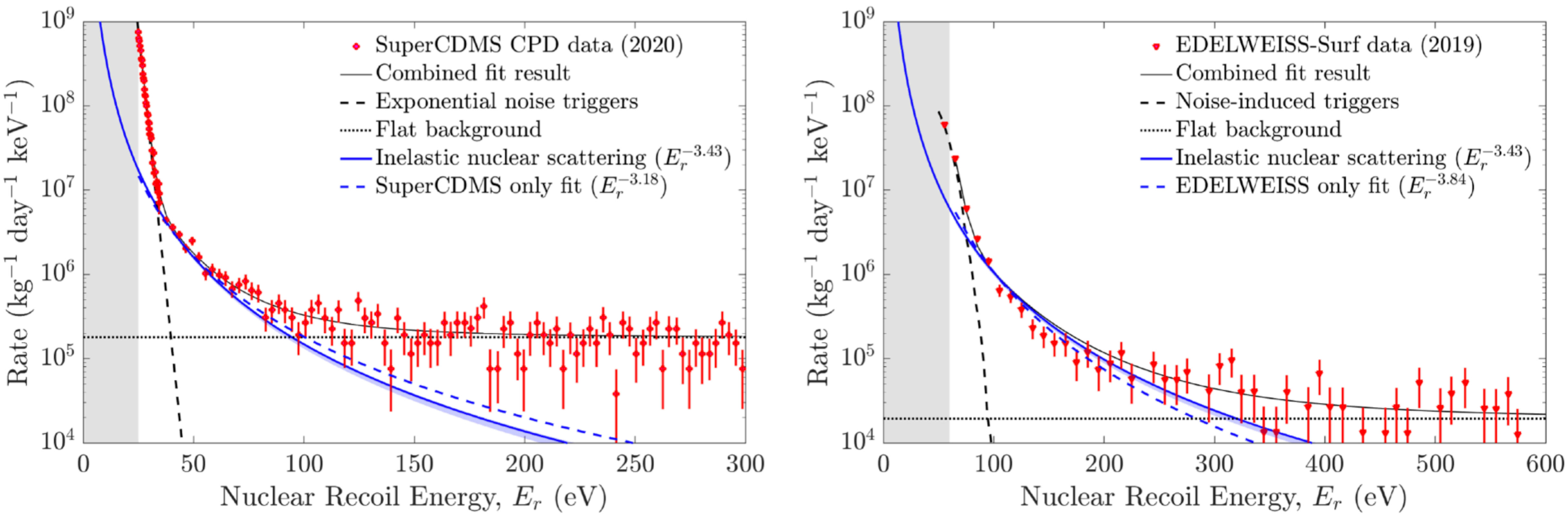


Displacement energy in Si is ~30 eV; below this spectrum is just the usual exponential spectrum of elastic NR, with a longer tail

[Kahn, Krnjaic, Mandava, PRL 2021]

That said, we were right about the power law!



	$C\kappa^2_{\mathrm{Si}}$ [(kg day)$^{-1}$keV$^{\alpha-1}$]	$C\kappa^2_{\mathrm{Ge}}$ [(kg day)$^{-1}$keV$^{\alpha-1}$]	α	$\kappa^2_{\mathrm{Ge}}/\kappa^2_{\mathrm{Si}}$	$\chi^2/d.o.f.$	p-value
Combined fit (Fig. 1)	$10.8^{+5.6}_{-2.6} \times 10^{11}$	$7.9^{+5.0}_{-2.3} \times 10^{12}$	$3.43^{+0.11}_{-0.06}$	$7.2^{+0.7}_{-0.6}$	227.2/174	0.004
SuperCDMS CPD [7] only	$4.1 \pm 1.5 \times 10^{11}$	n/a	$3.18^{+0.10}_{-0.09}$	n/a	121.5/121	0.471
EDELWEISS-Surf [8] only	n/a	$51.4^{+44.2}_{-25.9} \times 10^{12}$	$3.84^{+0.13}_{-0.15}$	n/a	101.3/52	5×10^{-5}

about as perfect a fit as you'll ever find in the real world…

[Abbamonte, Baxter, Kahn, Krnjaic, Kurinsky, Mandava, Wagner, arXiv:2202.03436]

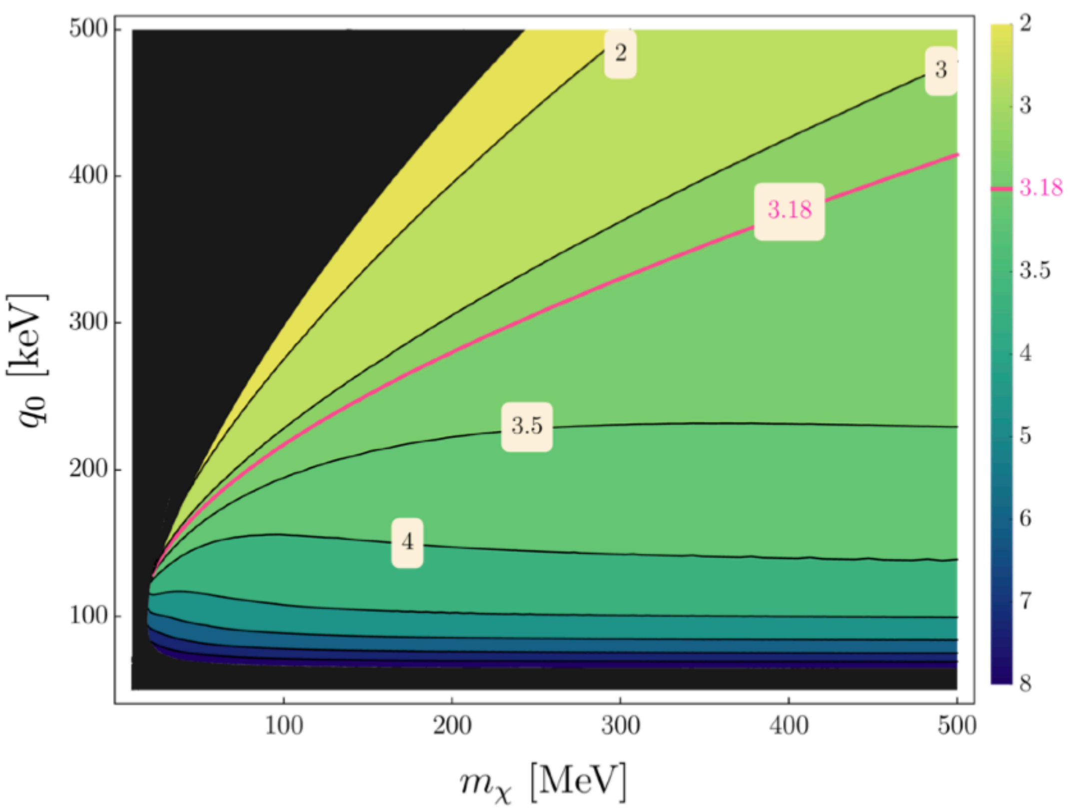
Even so, probably not exotic NR

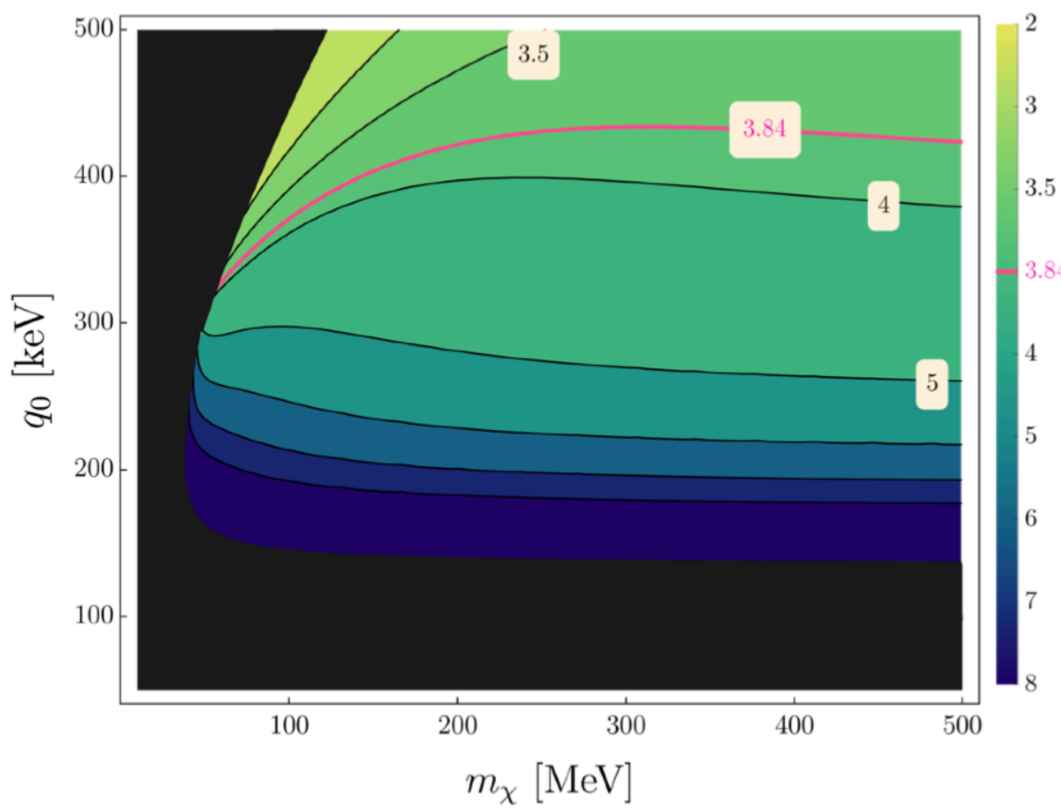
For an isotropic material, but otherwise fully general:

$$\frac{dR}{d\omega} = \frac{\rho_\chi}{m_\chi} \frac{\kappa^2 \bar{\sigma}_n}{2\mu_{\chi n}^2} \frac{1}{2\pi \rho_T} \int dq\, q\, S(q,\omega) \eta\left(v_{\min}\right)$$

$$S(\mathbf{q},\omega) = 2\pi n_0 S(\mathbf{q}) \delta\left(\omega - \frac{q^2}{2 m_N S(\mathbf{q})}\right)$$

$$S(q) = A_q (q/q_0)^n \implies \frac{dR}{d\omega} \propto \omega^{-\frac{2n}{n-2}}$$

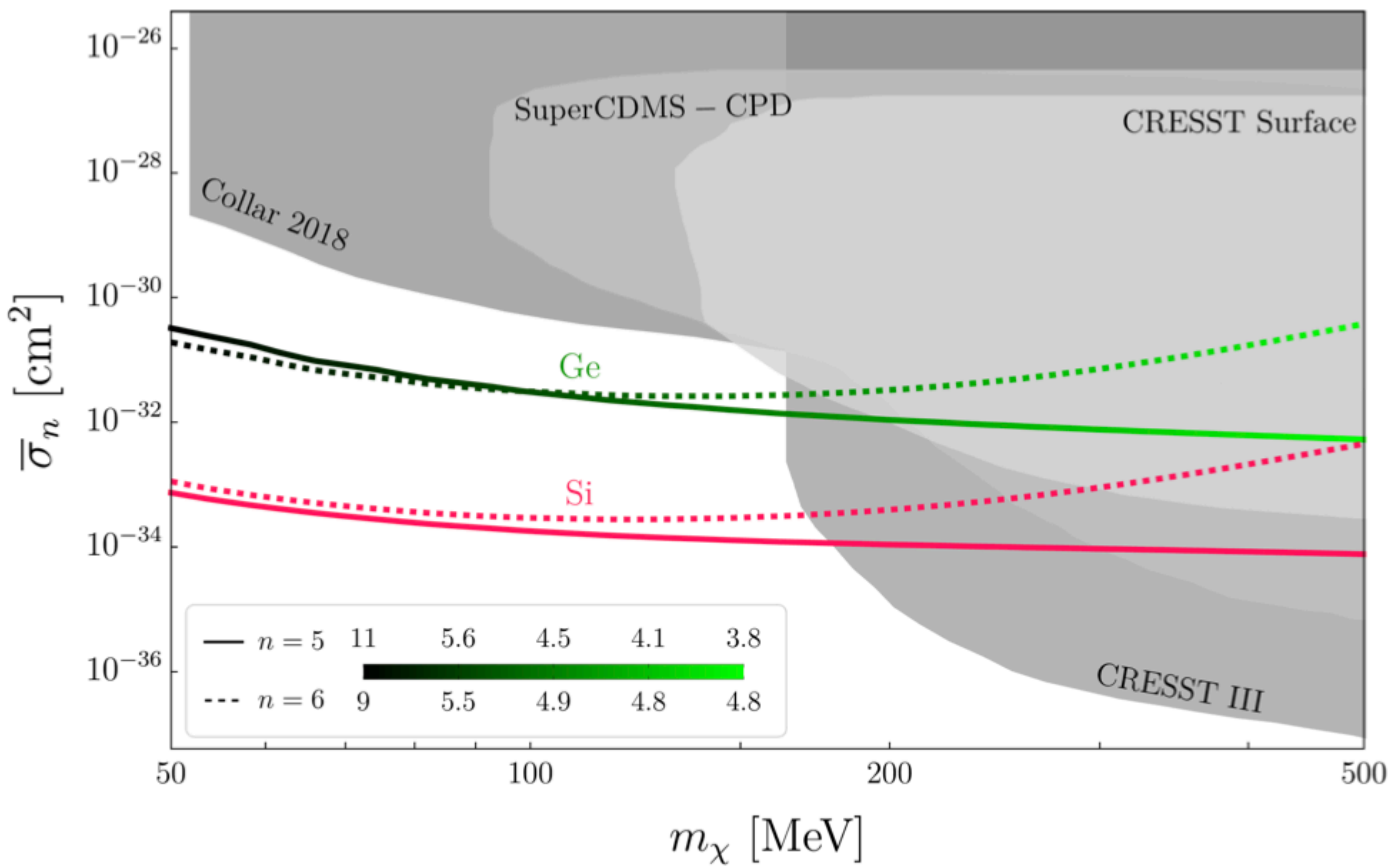




[Abbamonte, Baxter, Kahn, Krnjaic, Kurinsky, Mandava, Wagner, arXiv:2202.03436]

Even so, probably not exotic NR

Works fine for Si, but no way to make this consistent with Ge.



Same kinds of arguments rule out CR neutrons, solar neutrinos, photons, even with exotic structure factors

[Abbamonte, Baxter, Kahn, Krnjaic, Kurinsky, Mandava, Wagner, arXiv:2202.03436]