THE NEUTRINO FOG FOR DARK MATTER-ELECTRON SCATTERING EXPERIMENTS

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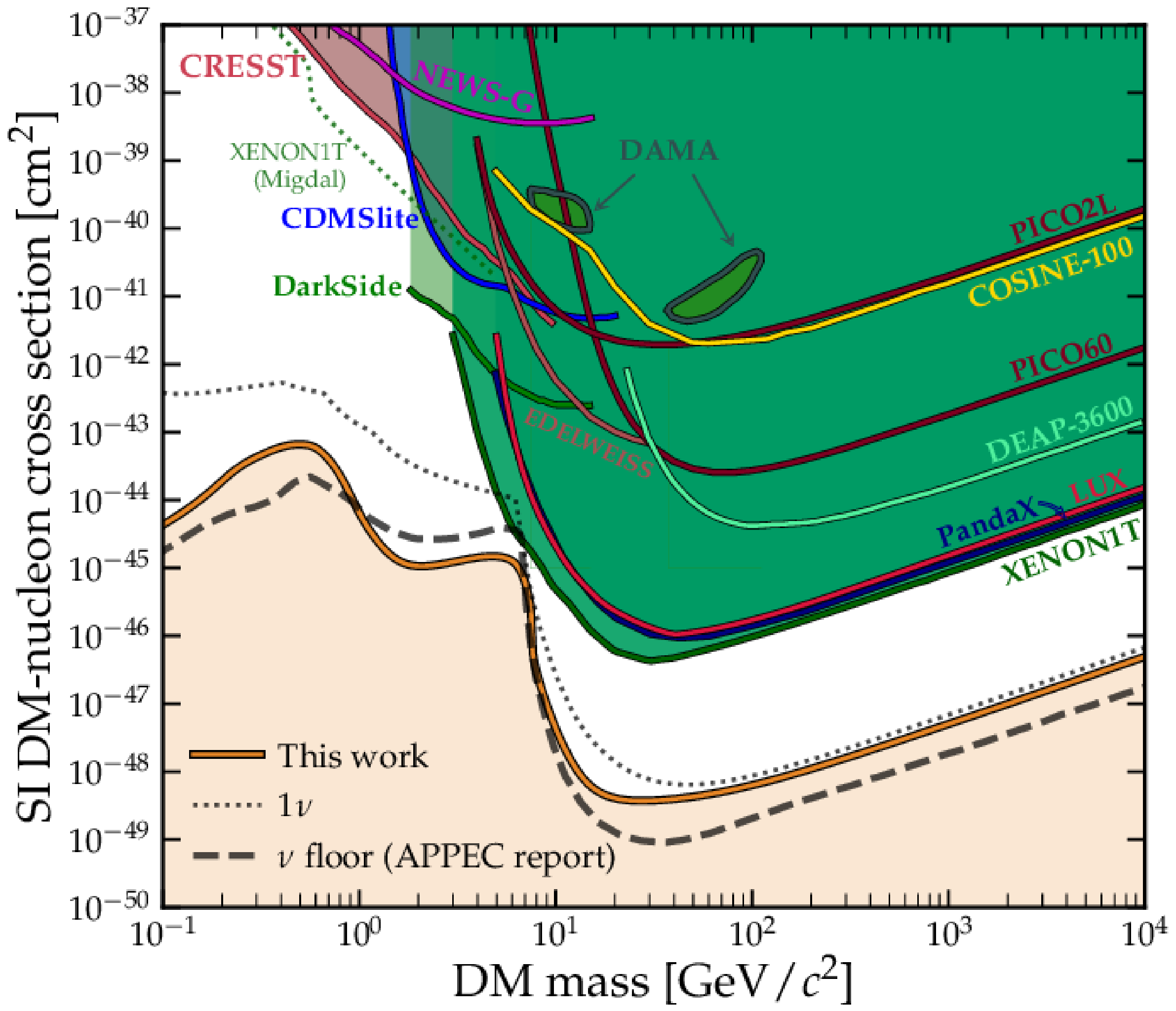
Supervisor: Dr Ciaran O'Hare

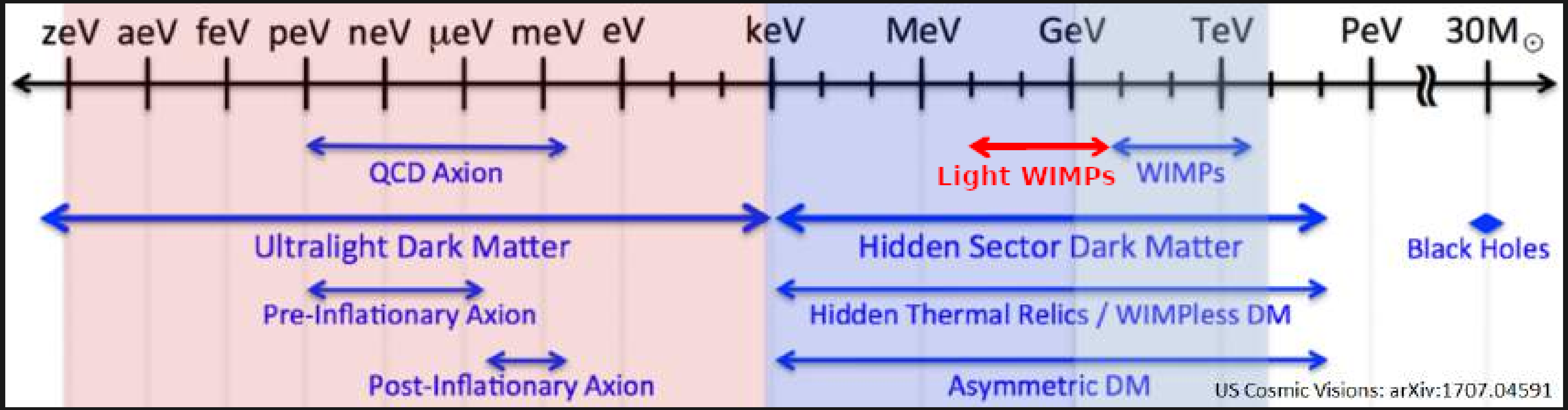
WHAT'S THE DEAL WITH QUEENSLAND?

THE PROBLEM WITH DIRECT DETECTION



- Future experiments will face an irreducible neutrino background
- Cannot be overcome with improved shielding, purification or design
- The current generation of detectors are expected to detect neutrino nuclear recoils within a few years

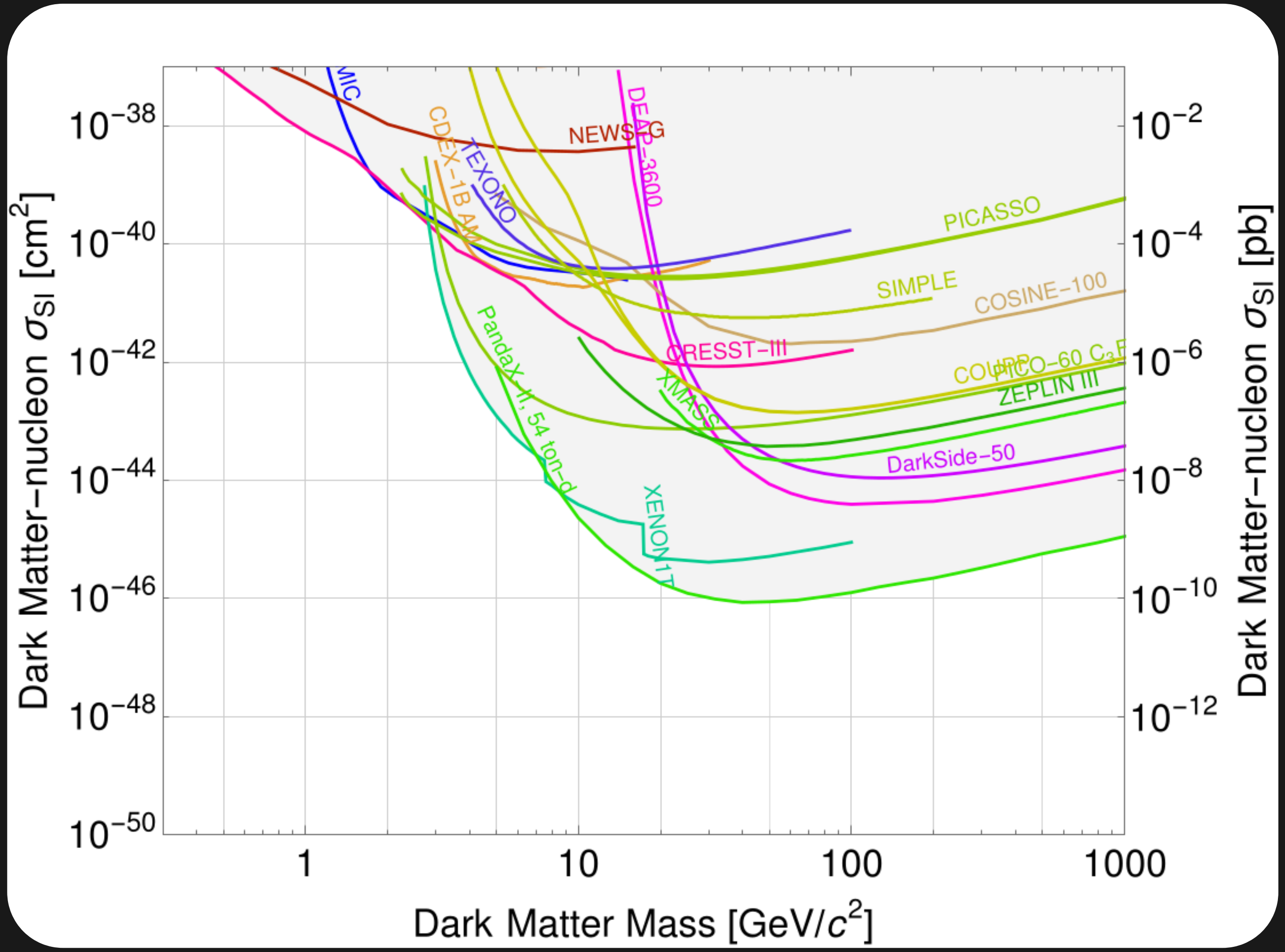
LOW-MASS WIMPS

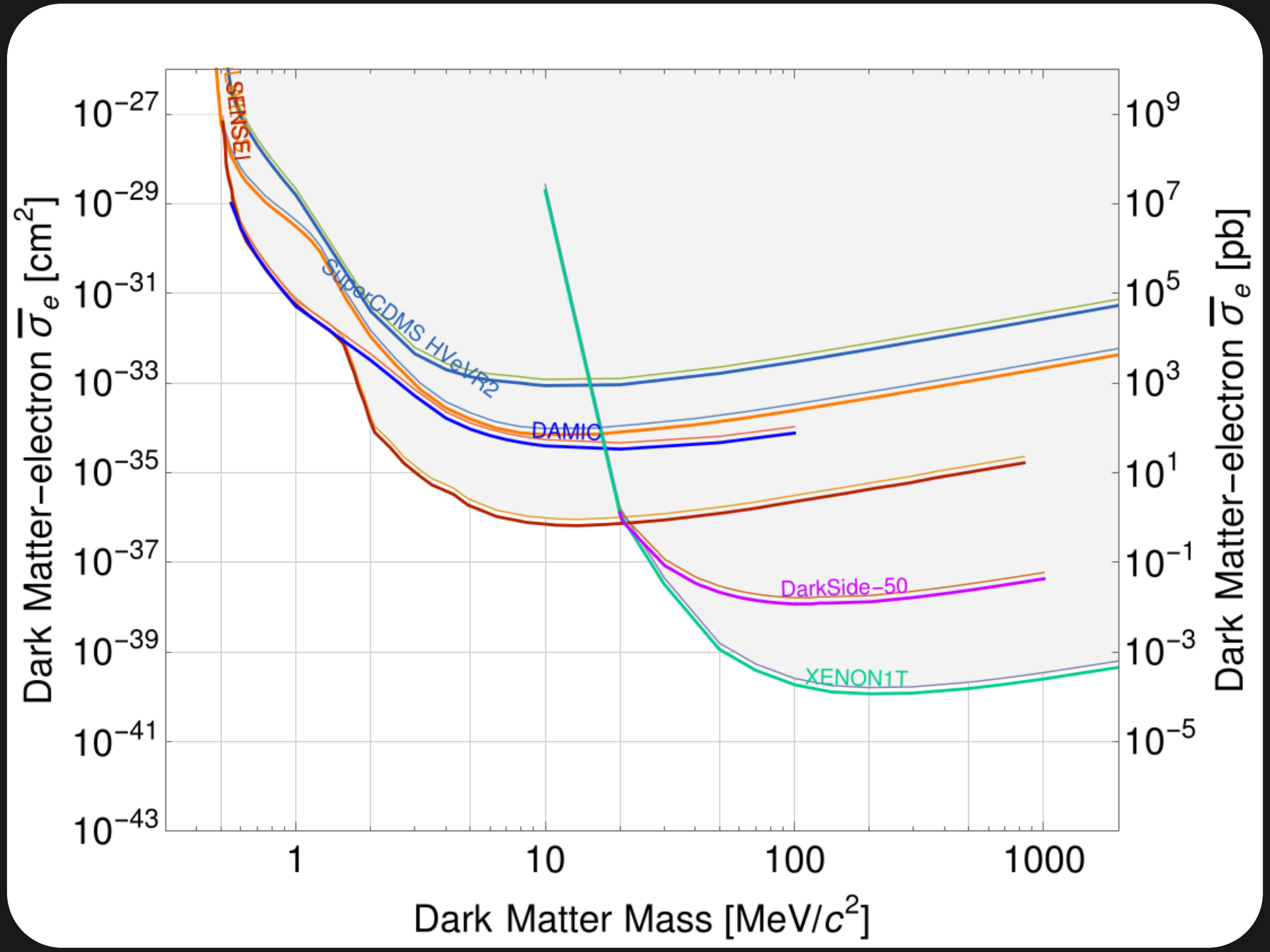


Lee-Weinberg bound $m_\chi \gtrsim 2$ GeV for OK thermal relic density.

- Sub-GeV WIMP models exist, i.e. scalar DM, non-thermal DM etc.
- Recent improvements in technology have begun to make this mass range detectable for the first time.

ELECTRON RECOIL SIGNALS





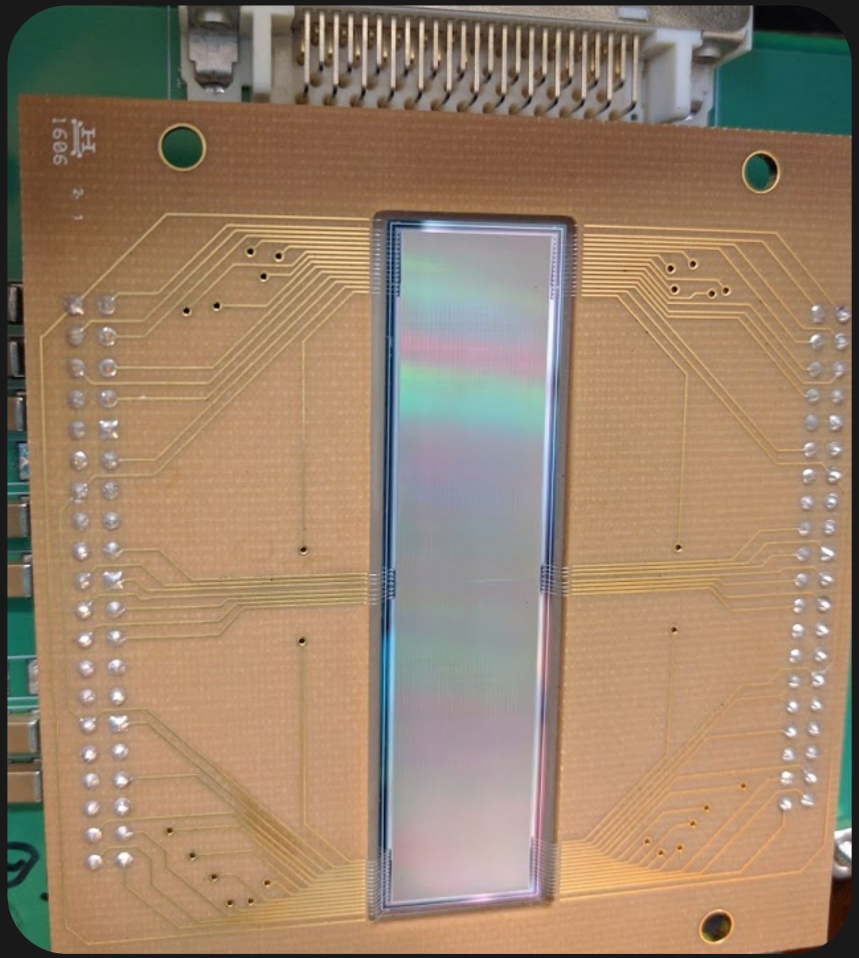
DM $\leftrightarrow$ Nucleus

- $m_\chi \gtrsim 1$ GeV
- Main focus of most current detectors
- Limits down to $\sigma \sim 10^{-46}$

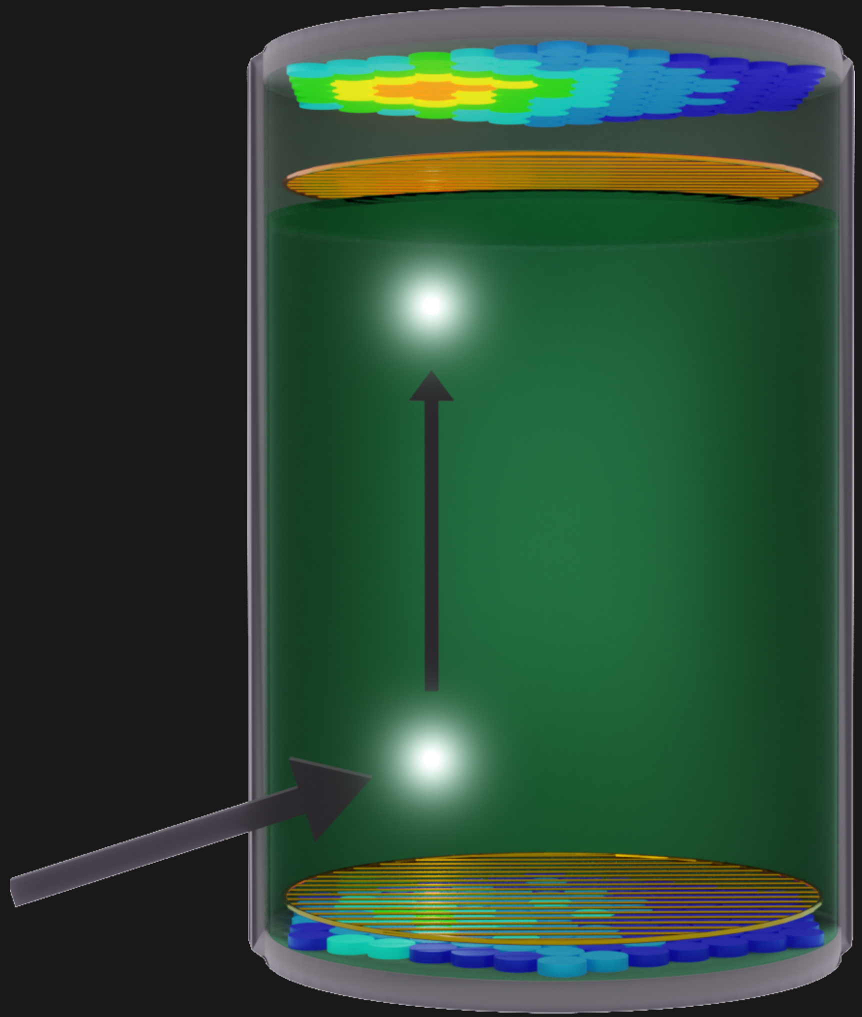
DM $\leftrightarrow$ Electrons

- $m_\chi \lesssim 1$ GeV
- Few experiments capable of measuring
- Limits are much weaker

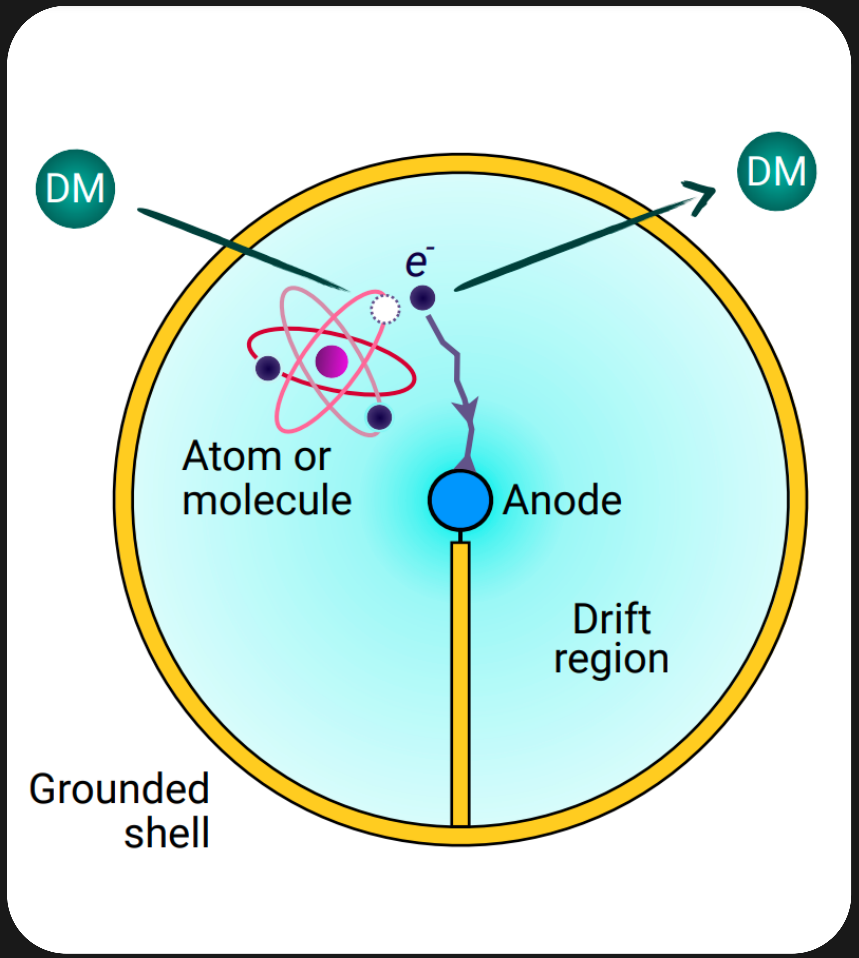
SOLIDS, LIQUIDS AND GASSES



Semiconductor ionisation detectors

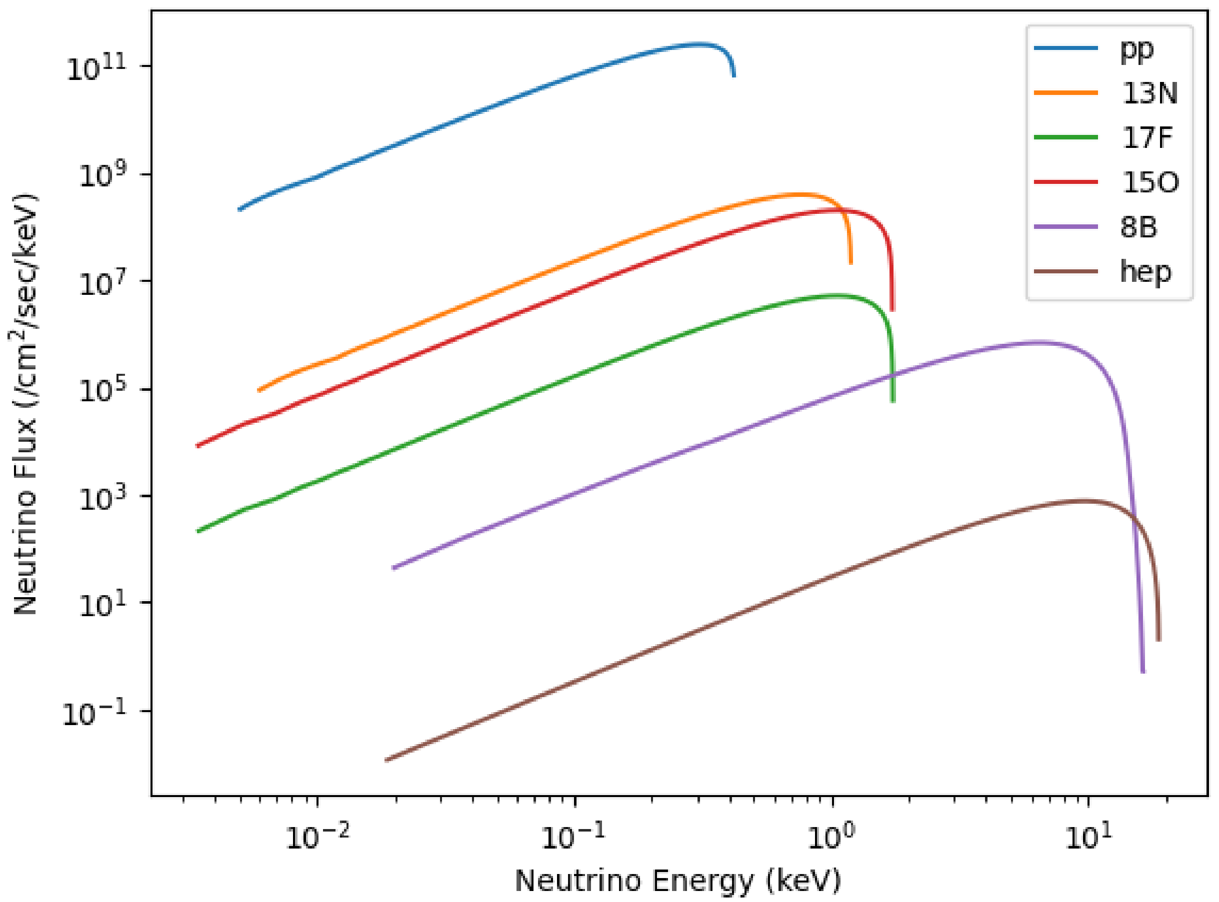


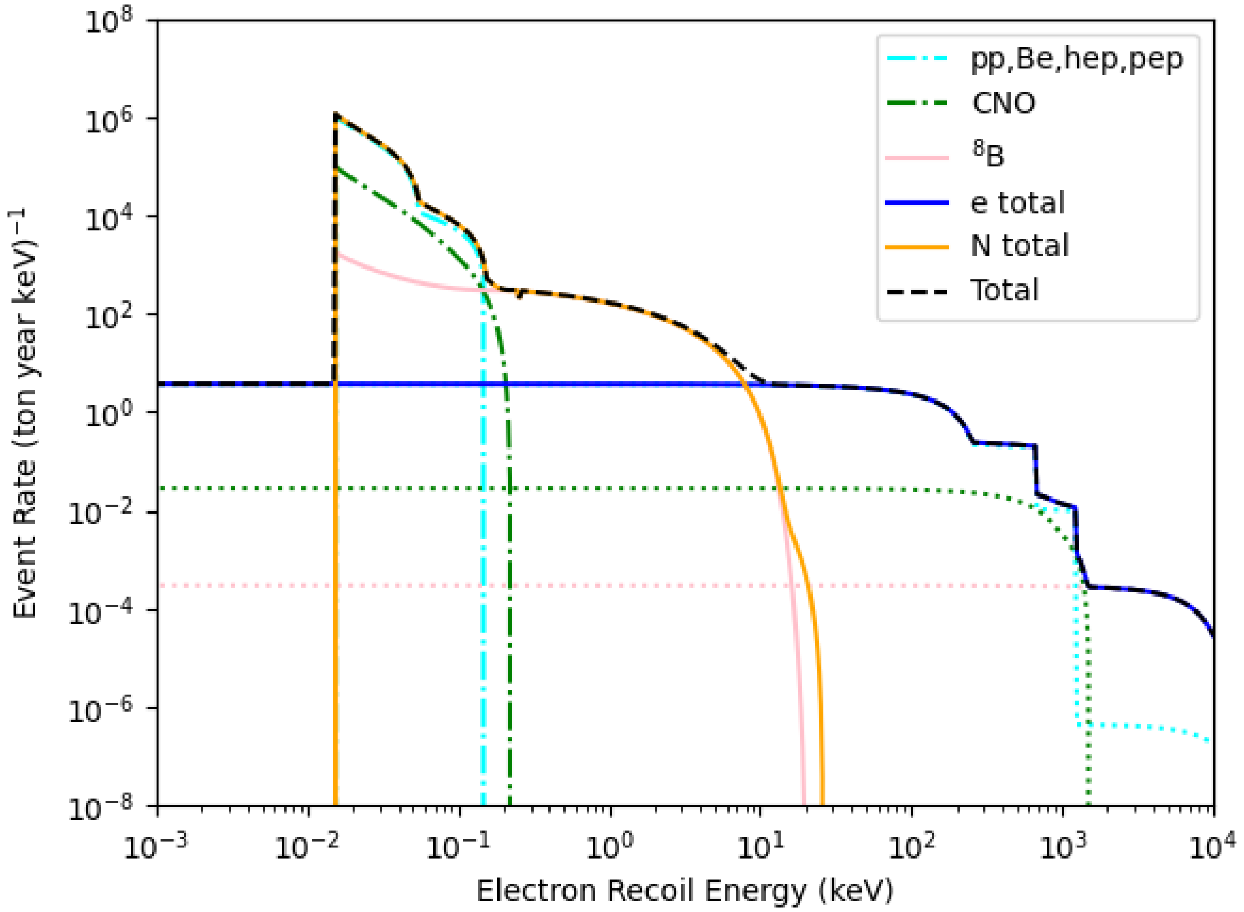
Noble liquid time-projection chambers



Spherical proportion counters

SOLAR NEUTRINOS RATES



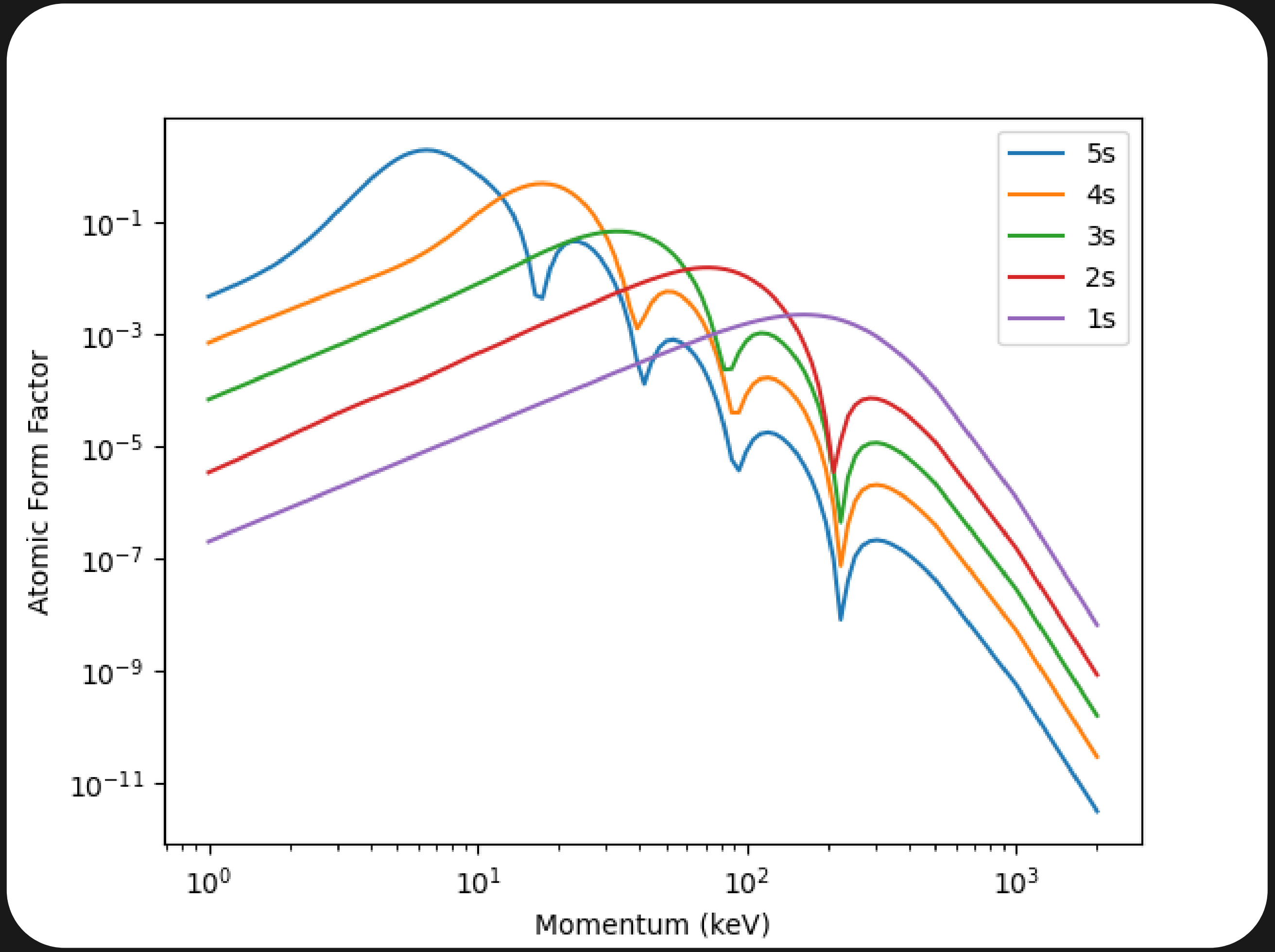


- pp has largest flux, dominates ν-e signal.
- hep and ^8B have highest energy, dominates ν-nucleus signal.

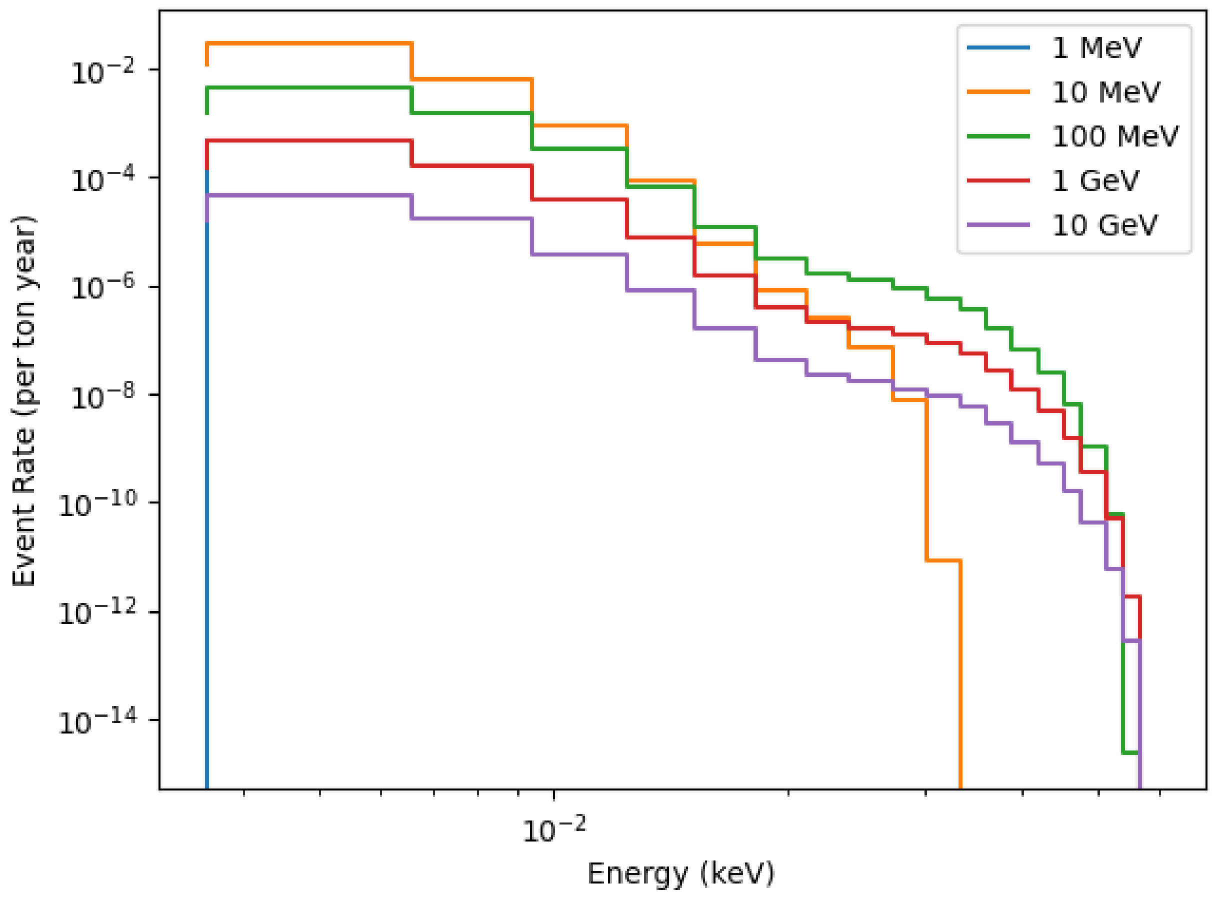
ATOMIC FORM FACTOR

$$K_{njl} = E_H \sum_m \sum_f |\langle f| e^{iq\cdot r} |njlm\rangle|^2 \rho_f(E)$$

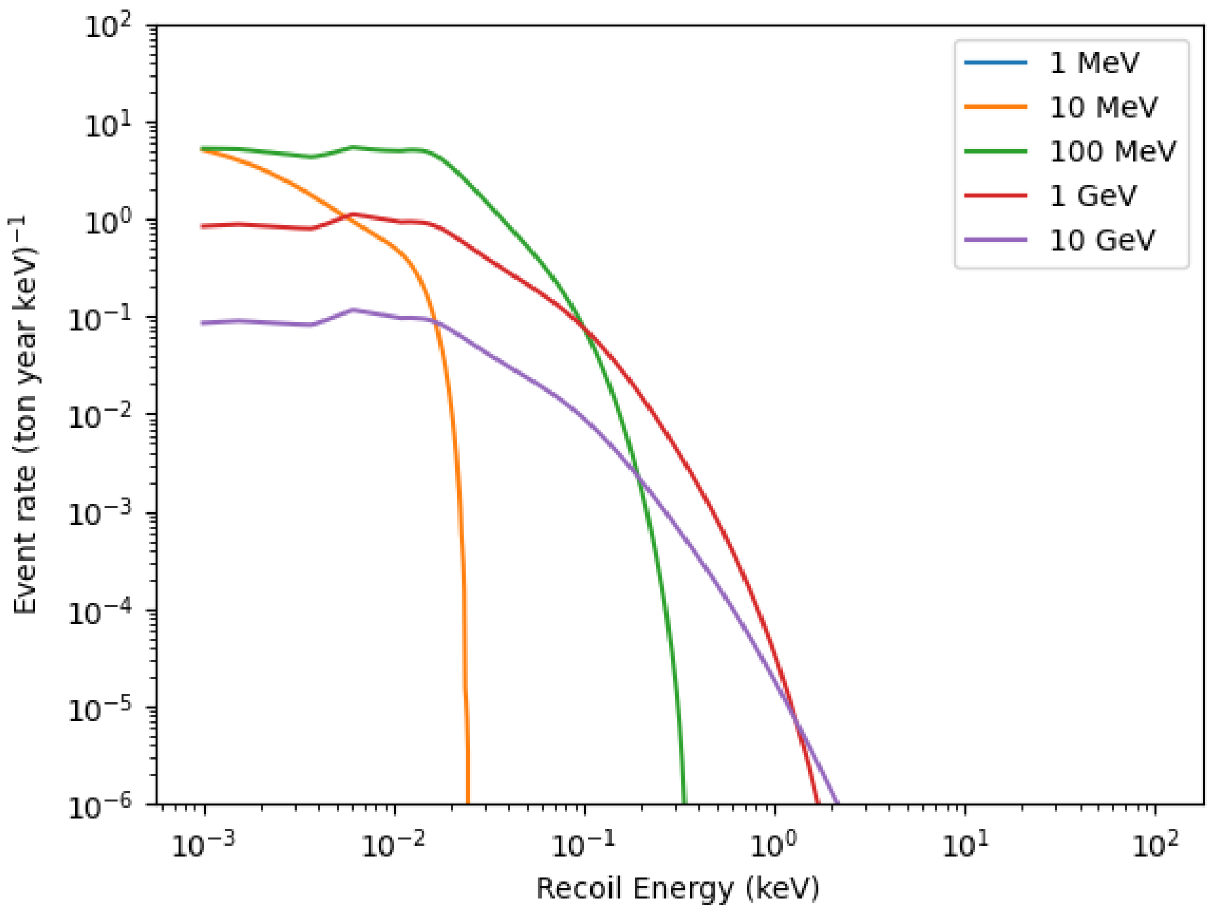
- Electron wavefunctions must be calculated relativistically
- Cannot approximate final state electron as a plane wave
- Requires accurate atomic physics methods



DARK MATTER EVENT RATES



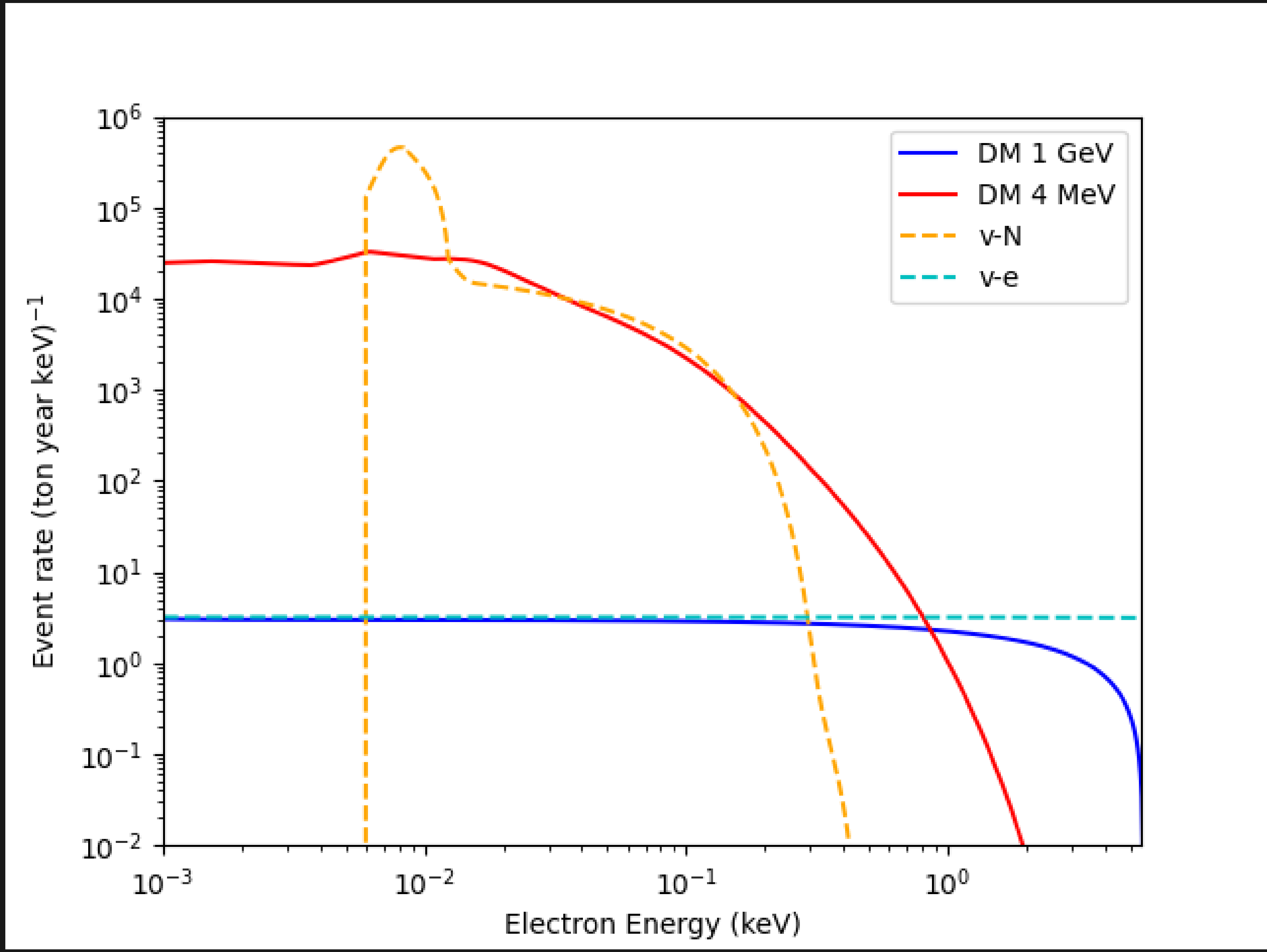
Germanium



Xenon

$$\frac{\mathrm{d}R_\chi}{\mathrm{d}E} = \frac{n_T \rho_{DM}}{m_\chi c^2} \frac{\overline{\sigma}_e}{2 m_e c} \int \mathrm{d}v \frac{f(v)}{v/c} \int_{q_-}^{q_+} a_0^2 q \mathrm{d}q \left| F_\chi^\mu(q) \right|^2 K(E, q)$$

EVENT RATE COMPARISON



QUANTIFYING THE FOG

$$\sigma \propto N^{-1/n}$$

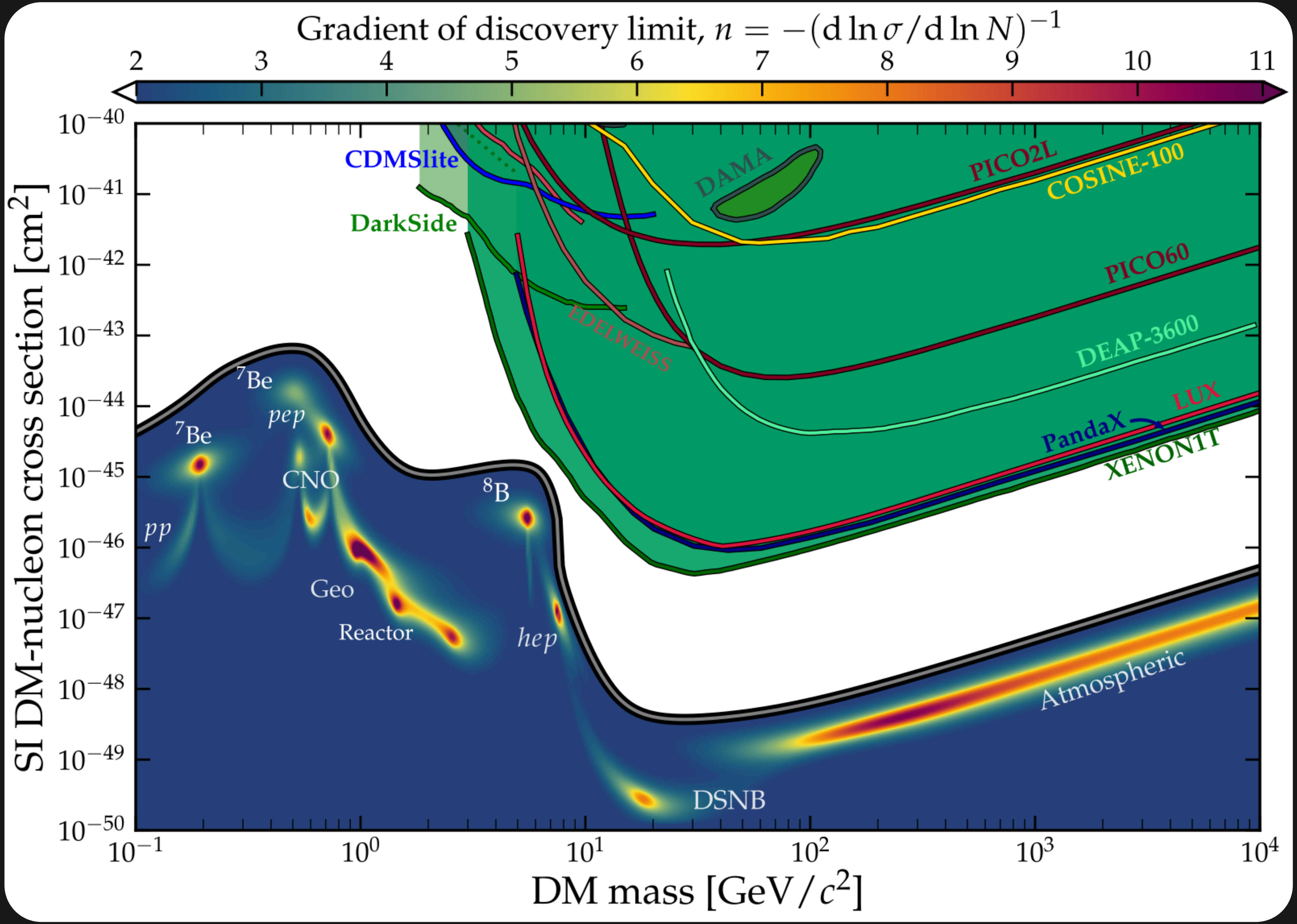
i.e. How does the discovery limit decrease with the exposure?

$\sigma =$ the discovery limit

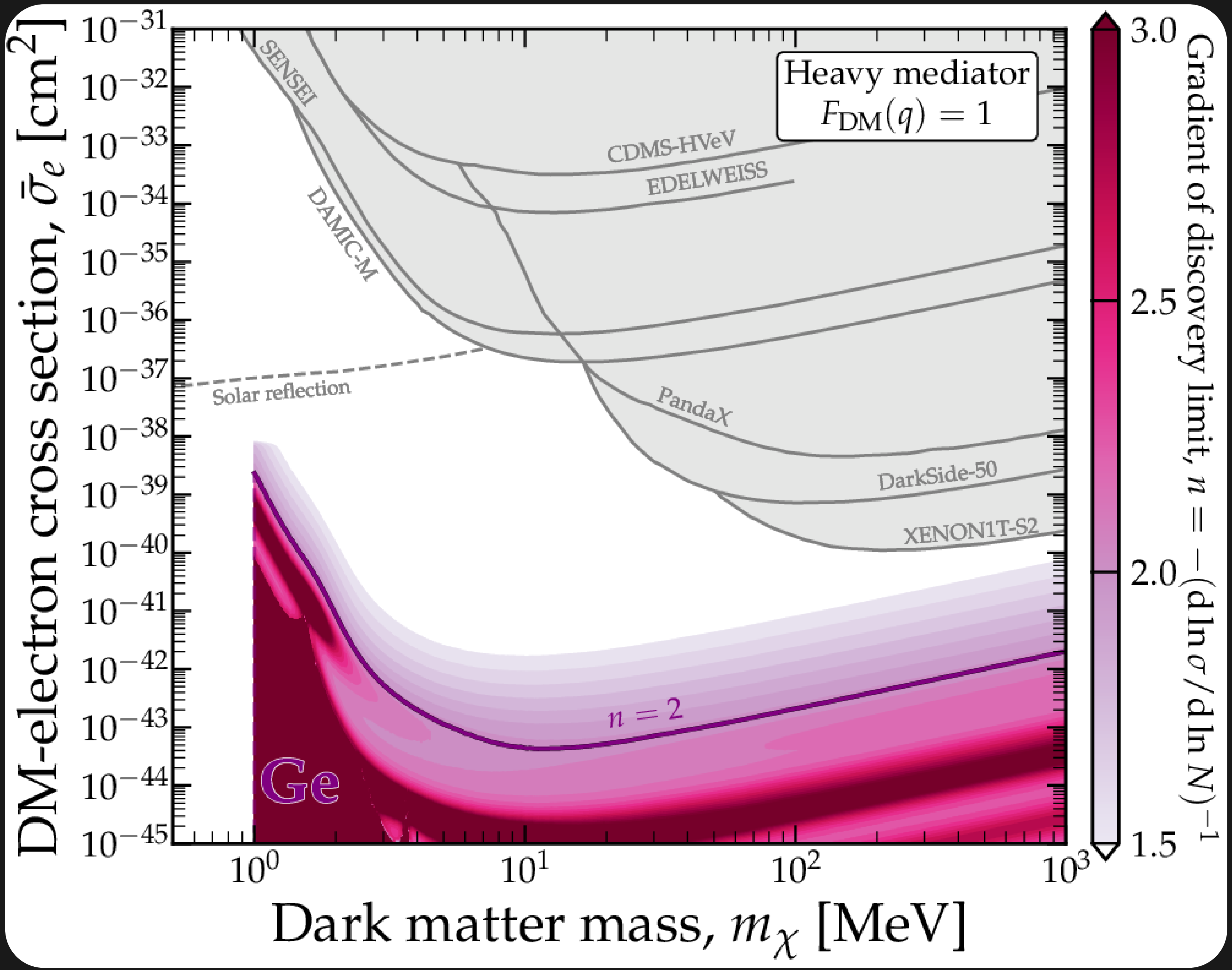
$N =$ the number of background events

$\boxed{n = 2 \Rightarrow \text{Poissonian background subtraction}}$

NEUTRINO FOG FOR NUCLEAR RECOILS

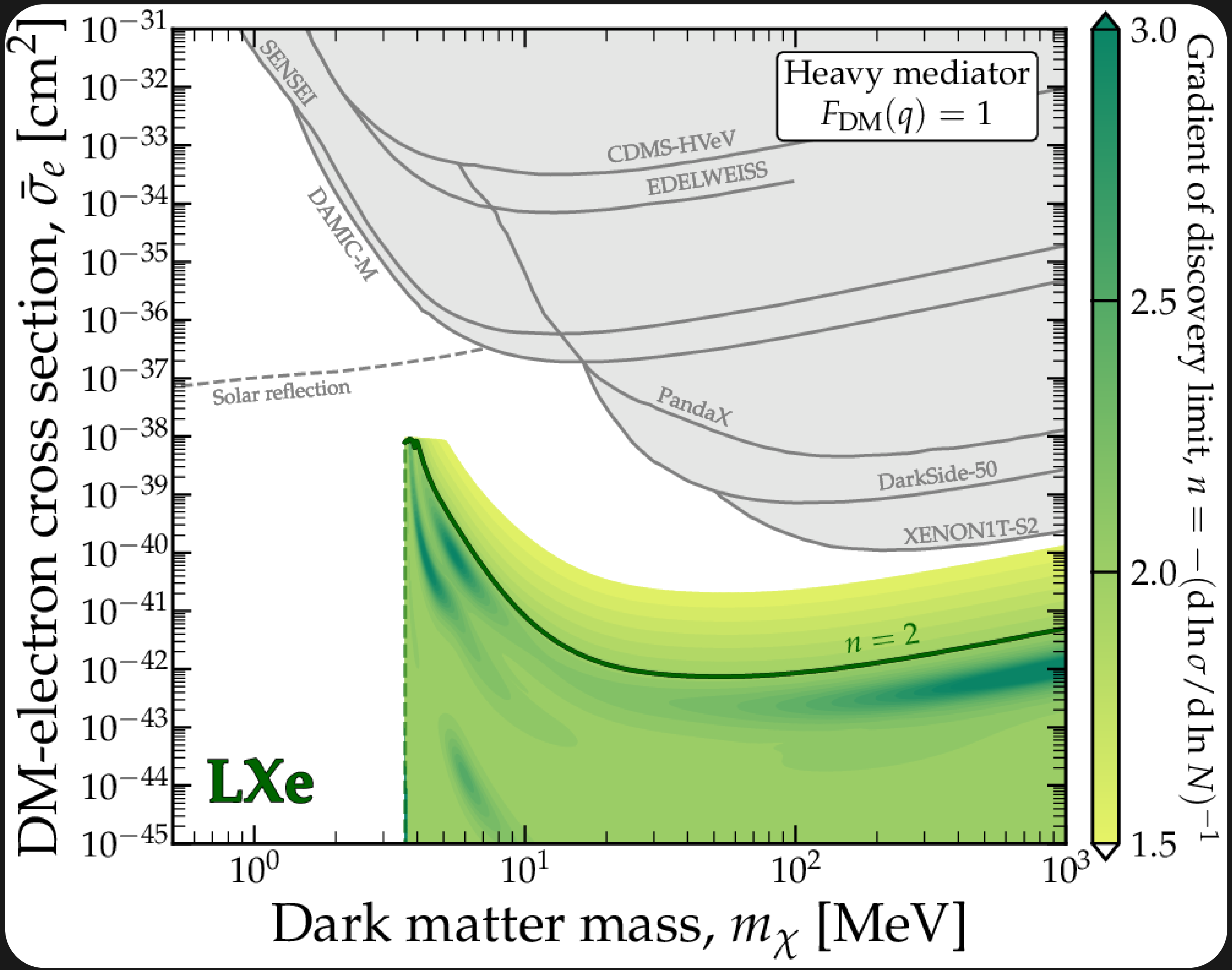


GERMANIUM

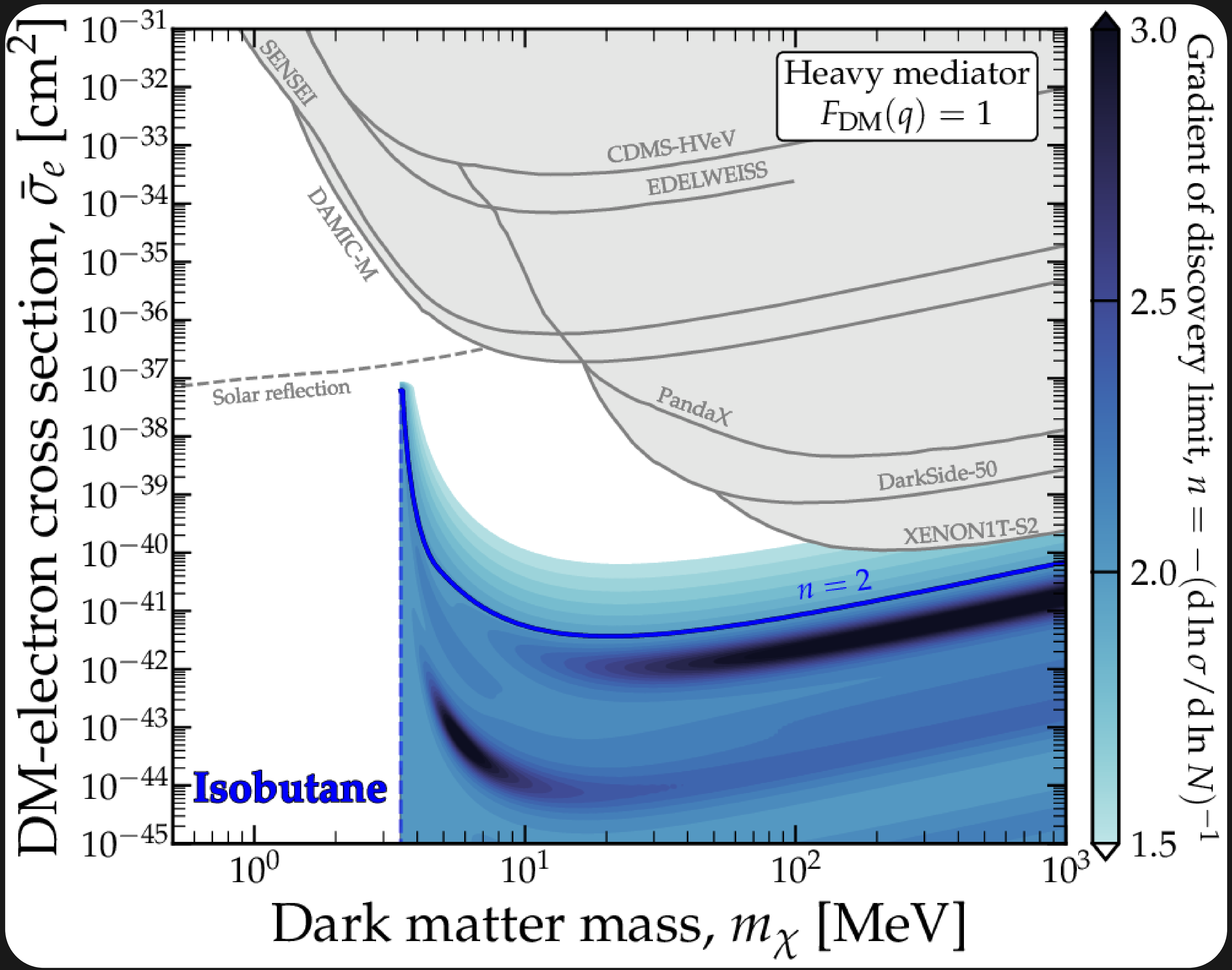


Heavy mediator
$F_{\mathrm{DM}}(q) = 1$
SENSEI
CDMS-HVeV
EDELWEISS
DAMIC-M
Solar reflection
PandaX
DarkSide-50
XENON1T-S2
$n = 2$
Ge
DM-electron cross section, $\bar{\sigma}_e$ [cm^2]
Dark matter mass, m_χ [MeV]
Gradient of discovery limit, $n = -(\mathrm{d}\ln\sigma/\mathrm{d}\ln N)^{-1}$

LIQUID XENON



ISOBUTANE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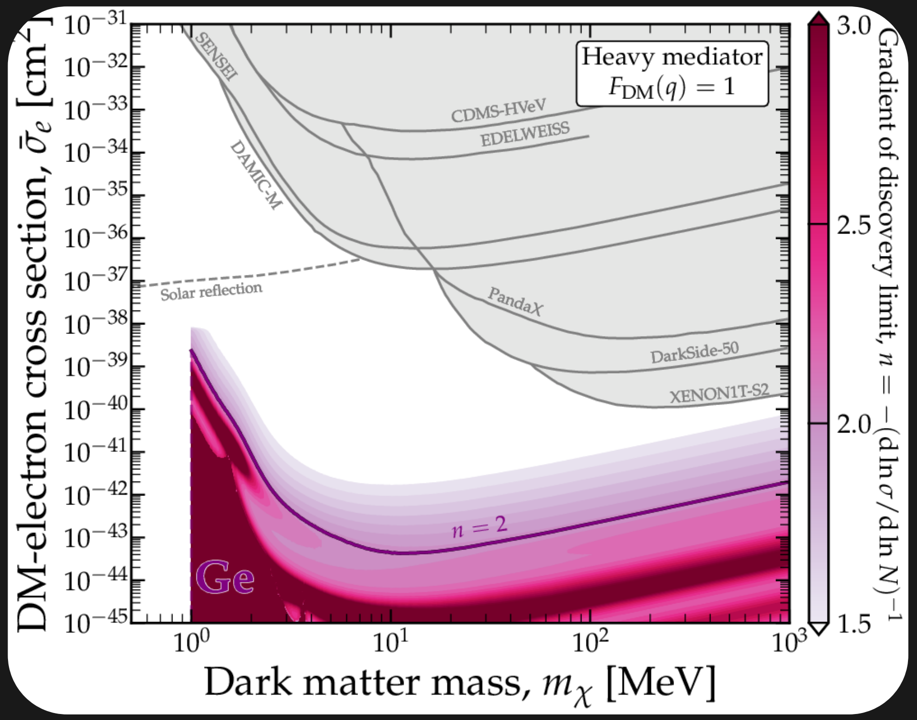
10^{-33}
10^{-34}
10^{-35}
10^{-36}
10^{-37}
10^{-38}
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^0
10^1
10^2
10^3
3.0
2.5
2.0
1.5

ELECTRON RECOIL NEUTRINO FOGS



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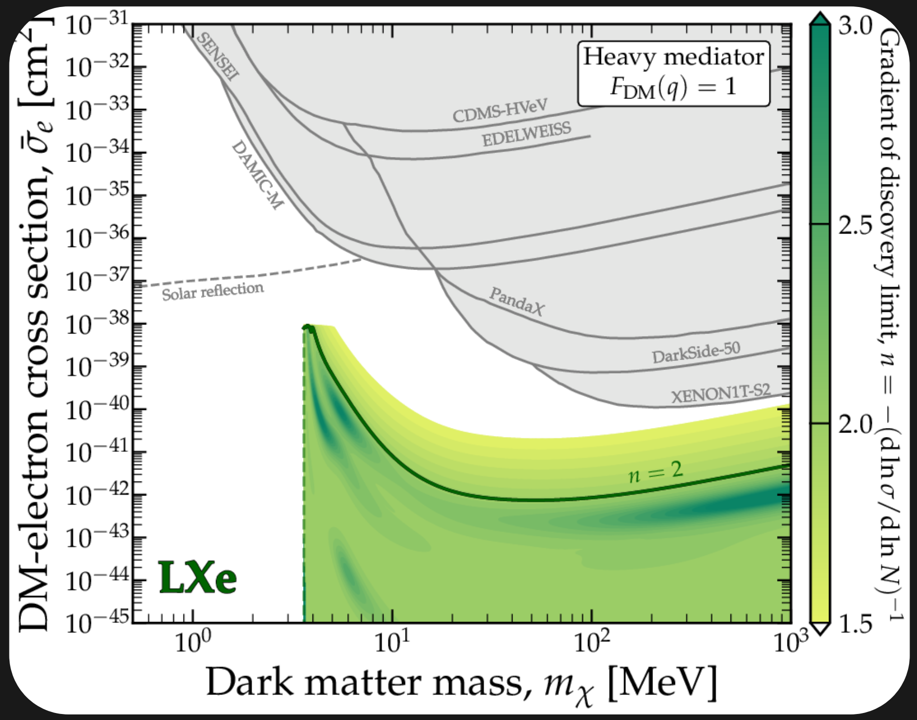
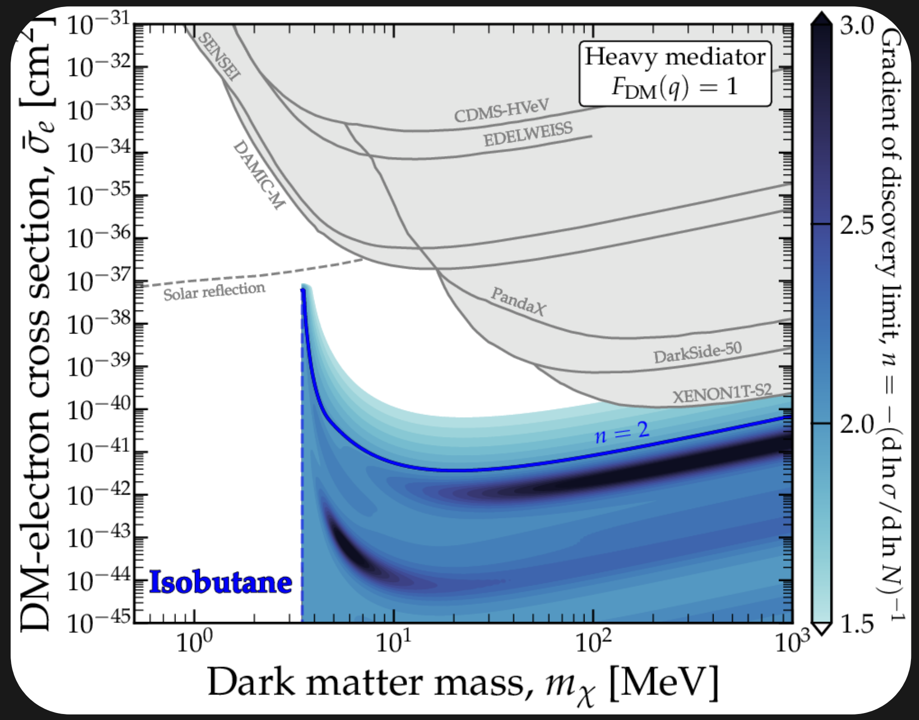
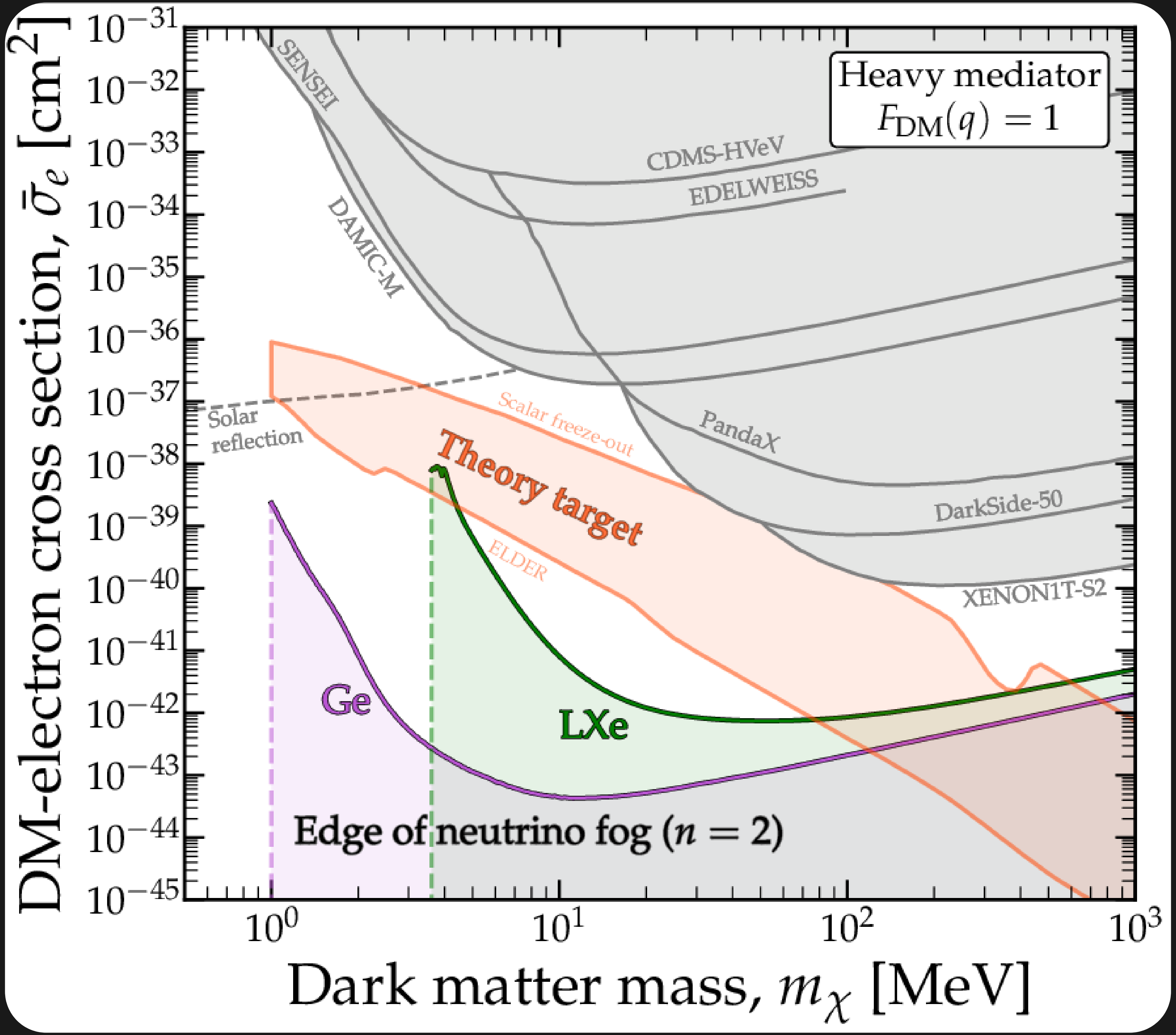


Xenon



Isobutane

SUMMARY



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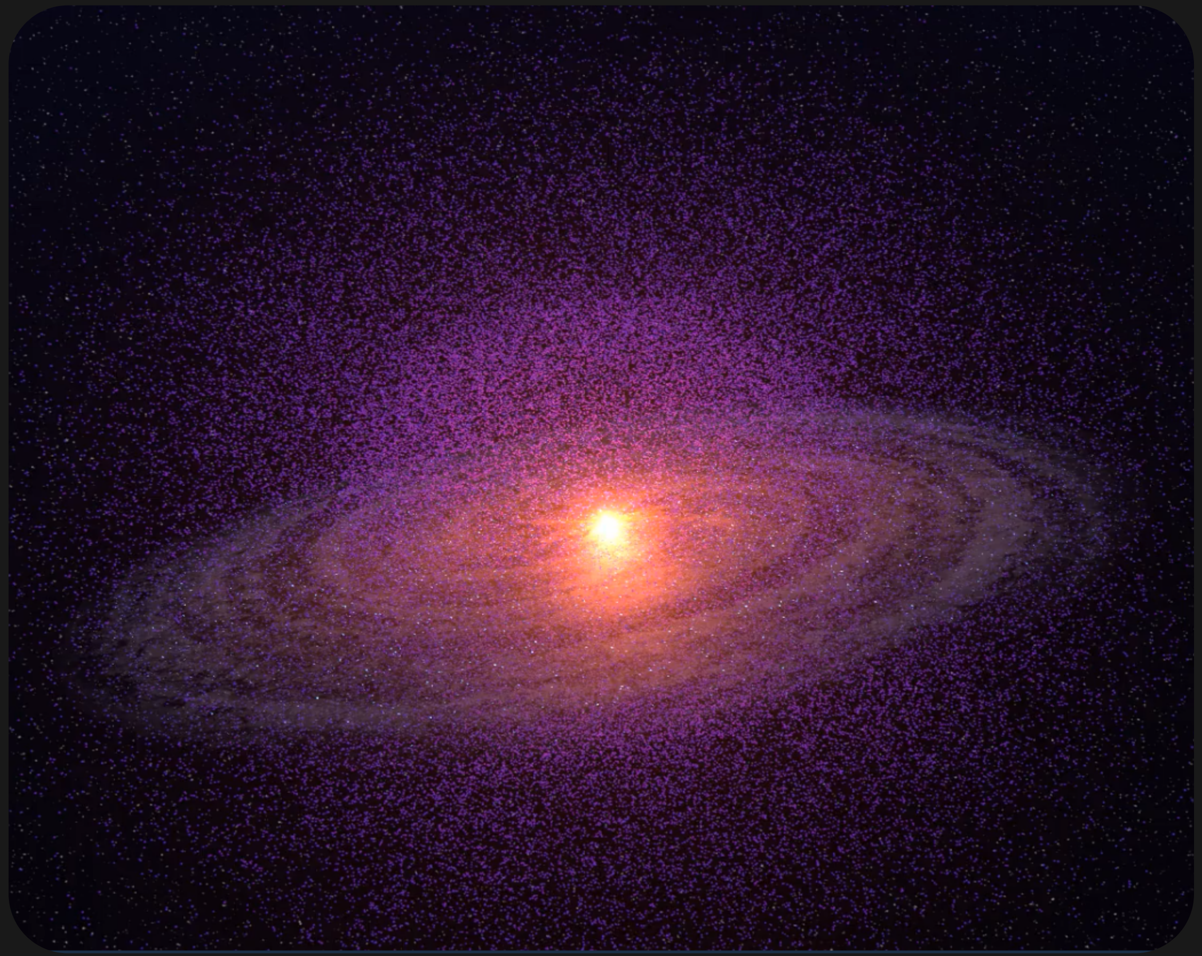
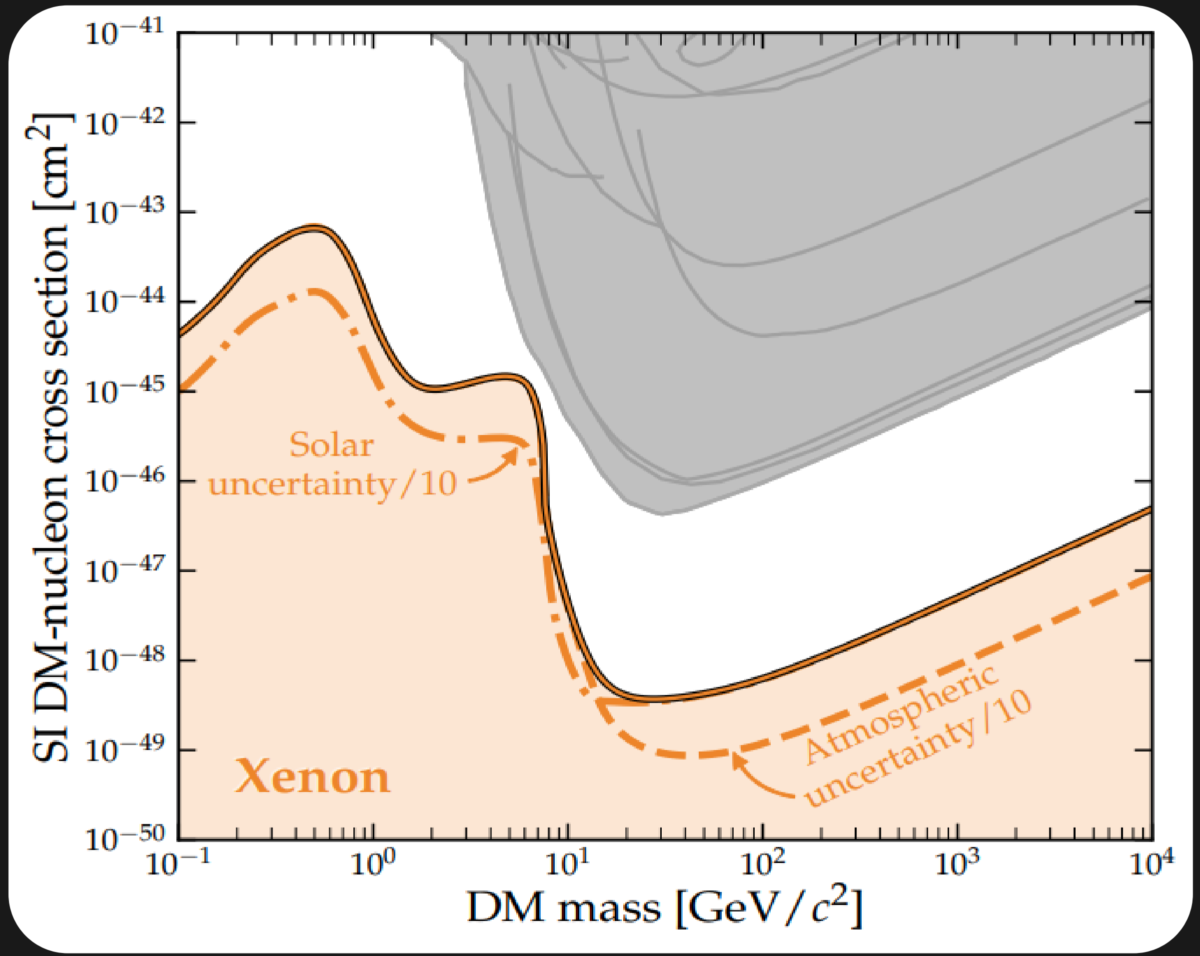
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^0
10^1
10^2
10^3

SOLUTIONS



Directional detection



Reduce neutrino flux uncertainties

THANKS FOR LISTENING!

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