The Phonon Background from Gamma Rays in Sub-GeV Dark Matter Detectors

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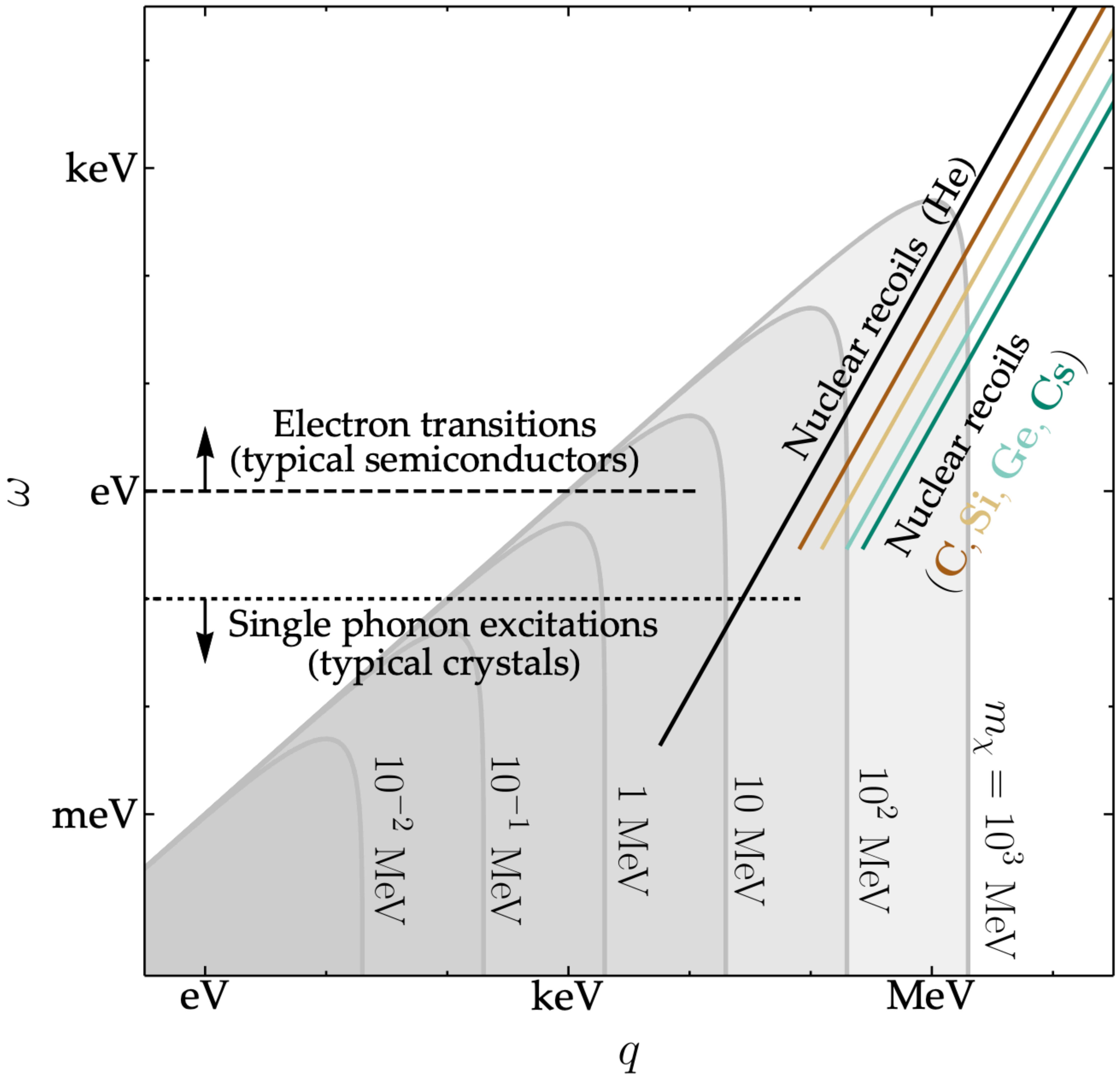
Phenomenology 2022 Symposium

Based on arXiv:2112.09702 with K. Berghaus, R. Essig, Y. Hochberg, and Y. Shoji

Direct Detection of Sub-GeV DM



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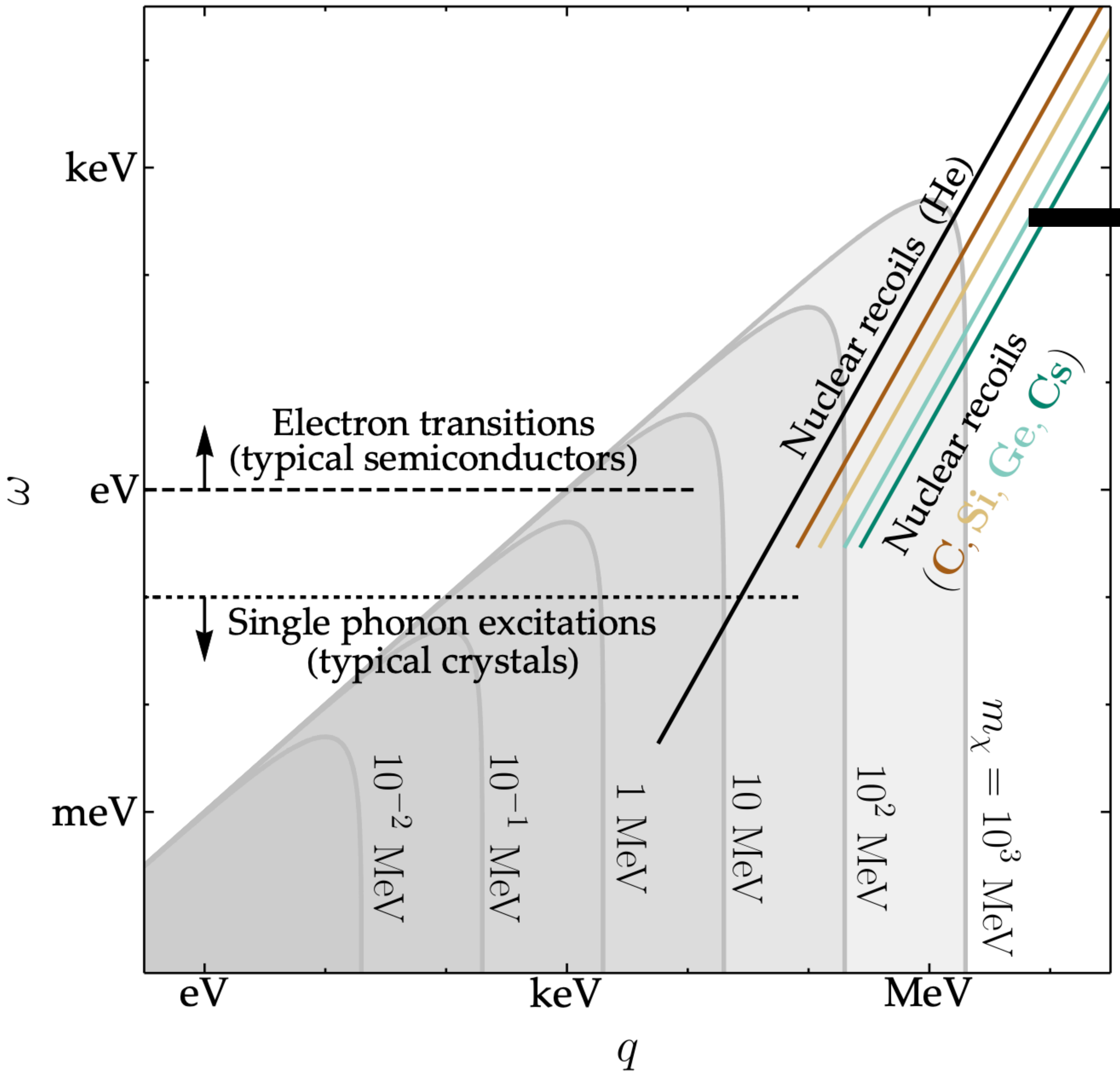

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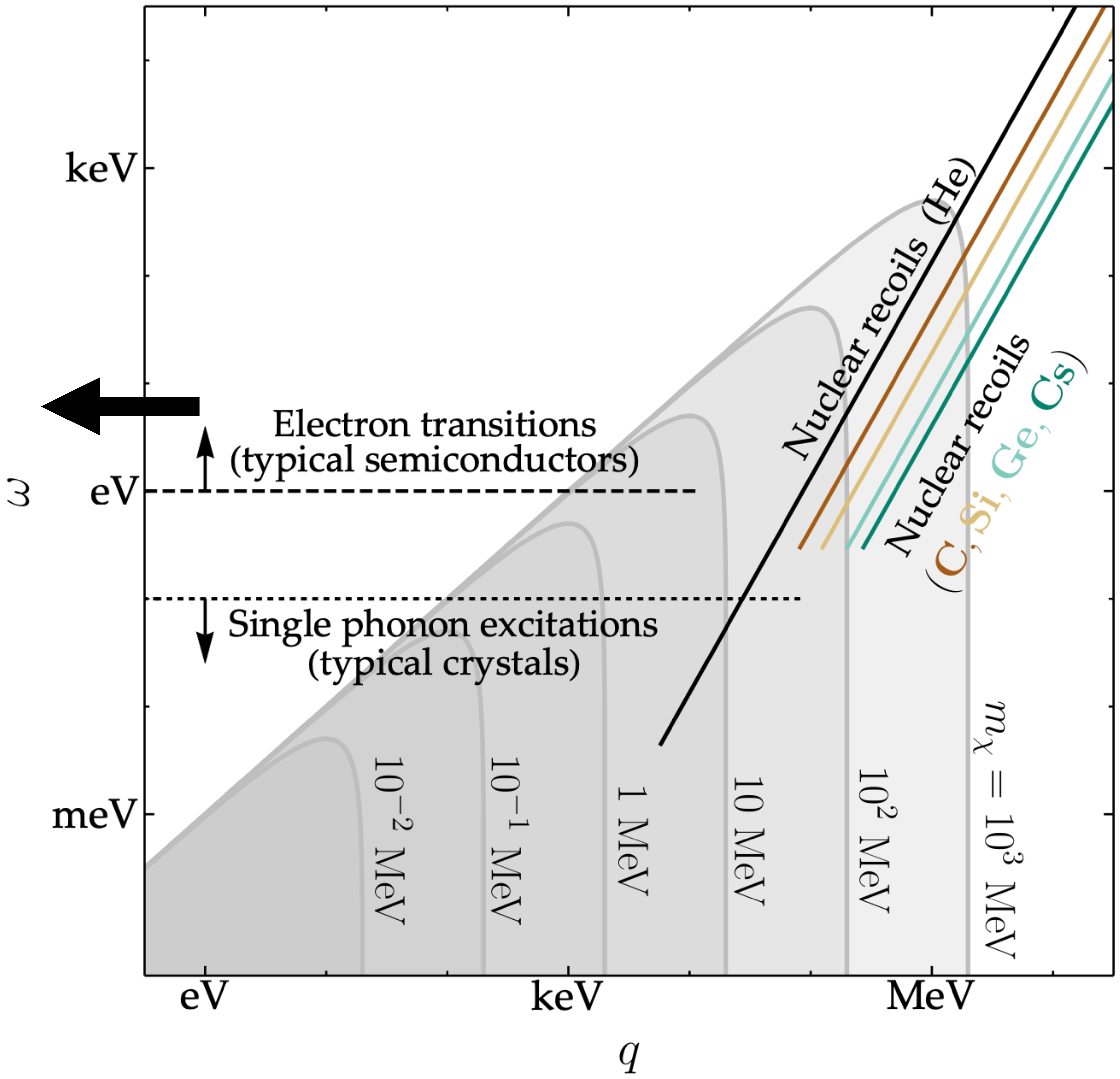
Looking for elastic nuclear recoils :

- Great for GeV-TeV DM (e.g. WIMPS)
- Inefficient energy transfer for DM below ~ GeV
- Prescription fails in the presence of collective excitations

Direct Detection of Sub-GeV DM

Looking for electronic recoils:

- Great for MeV-GeV DM in usual crystals
- Typical bandgap (eV) too high for sub-MeV DM



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Direct Detection of Sub-GeV DM

- **Proposed idea: Look for phonon excitations**

*arXiv:1712.06598 Knapen, Lin, Pyle, Zurek

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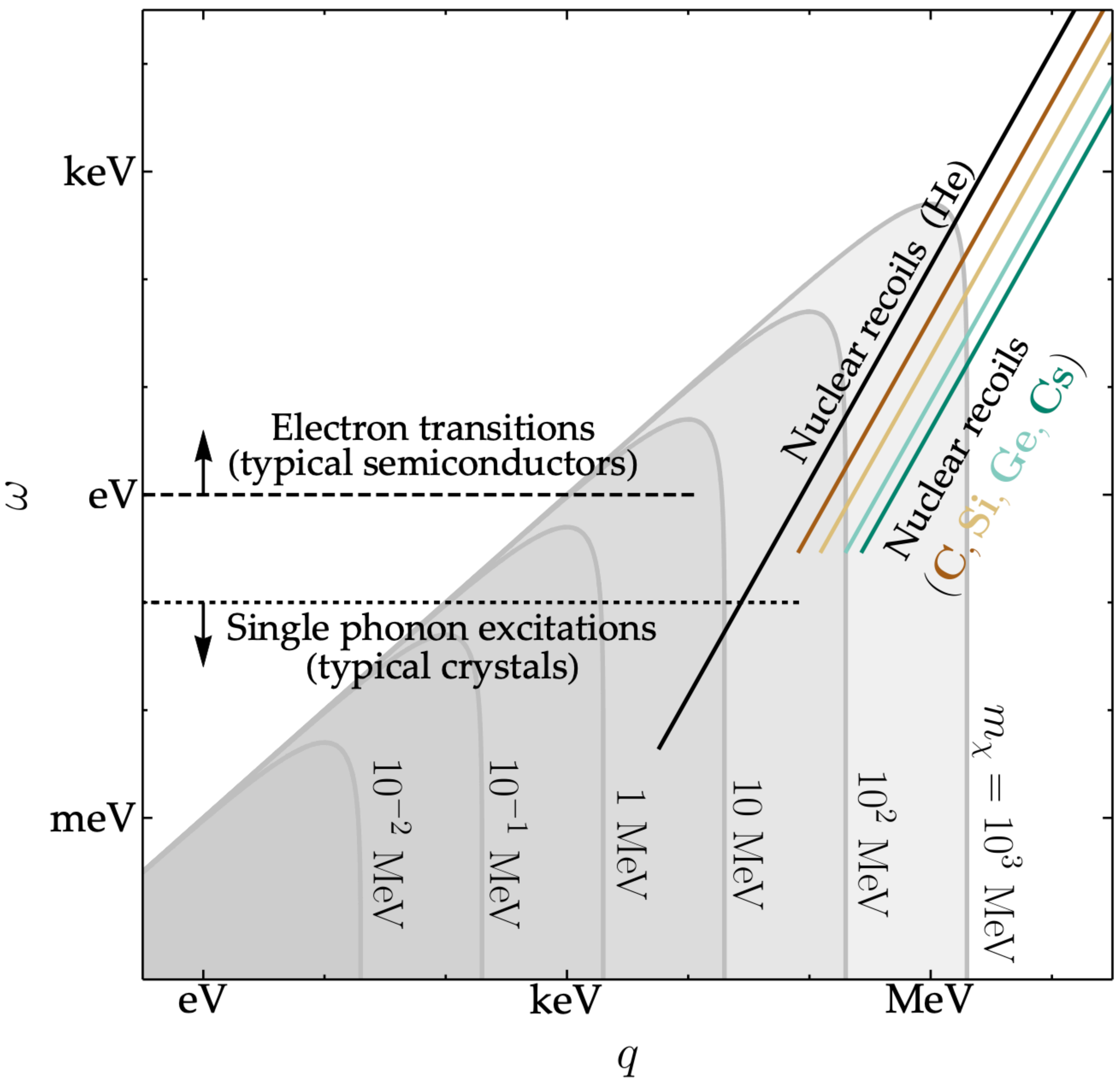

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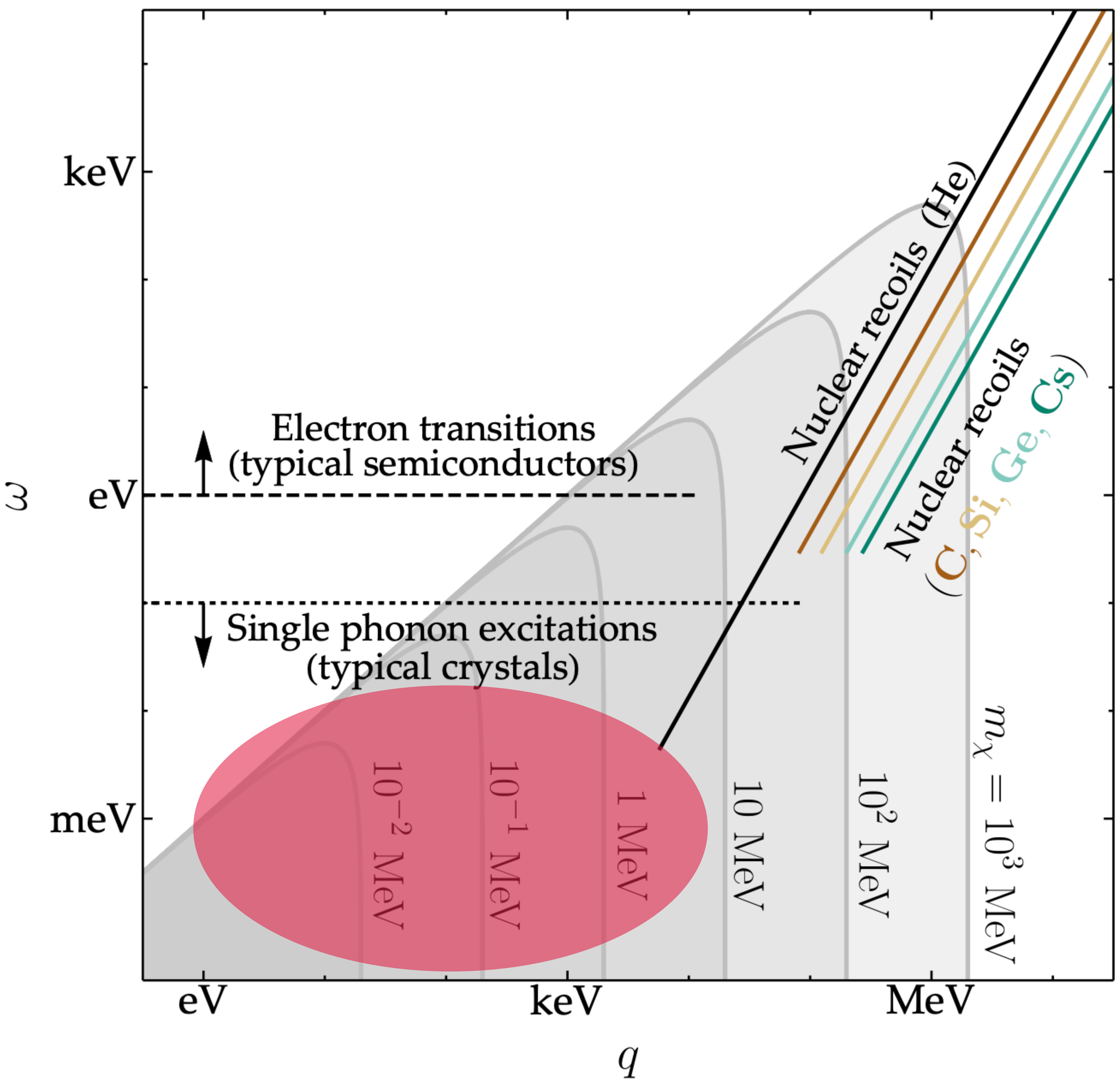
- Allows to probe the kinematic region of sub-MeV DM



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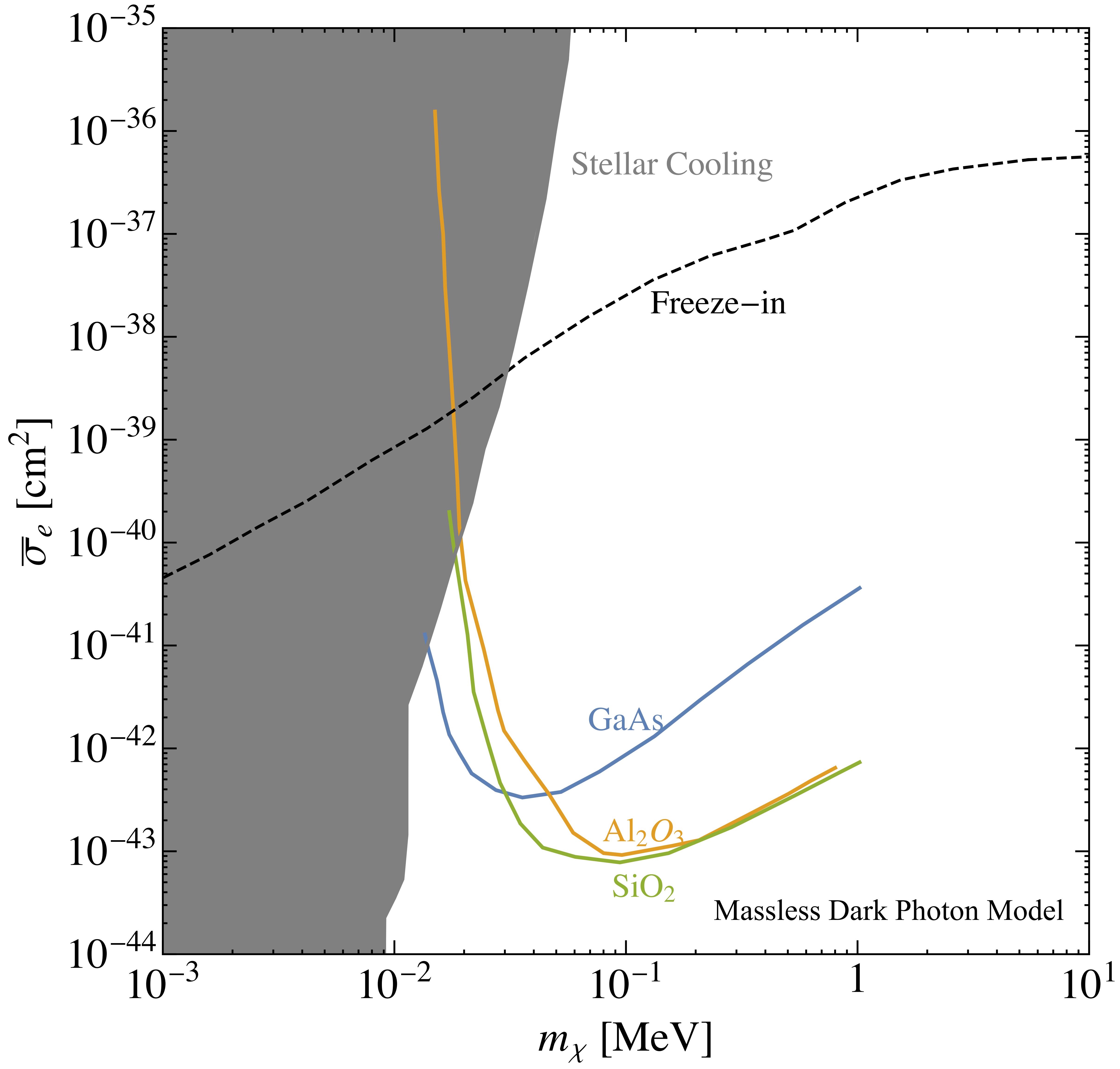
Direct Detection of Sub-MeV DM

- Opens up a possibility of probing well-motivated targets in the sub-MeV parameter space



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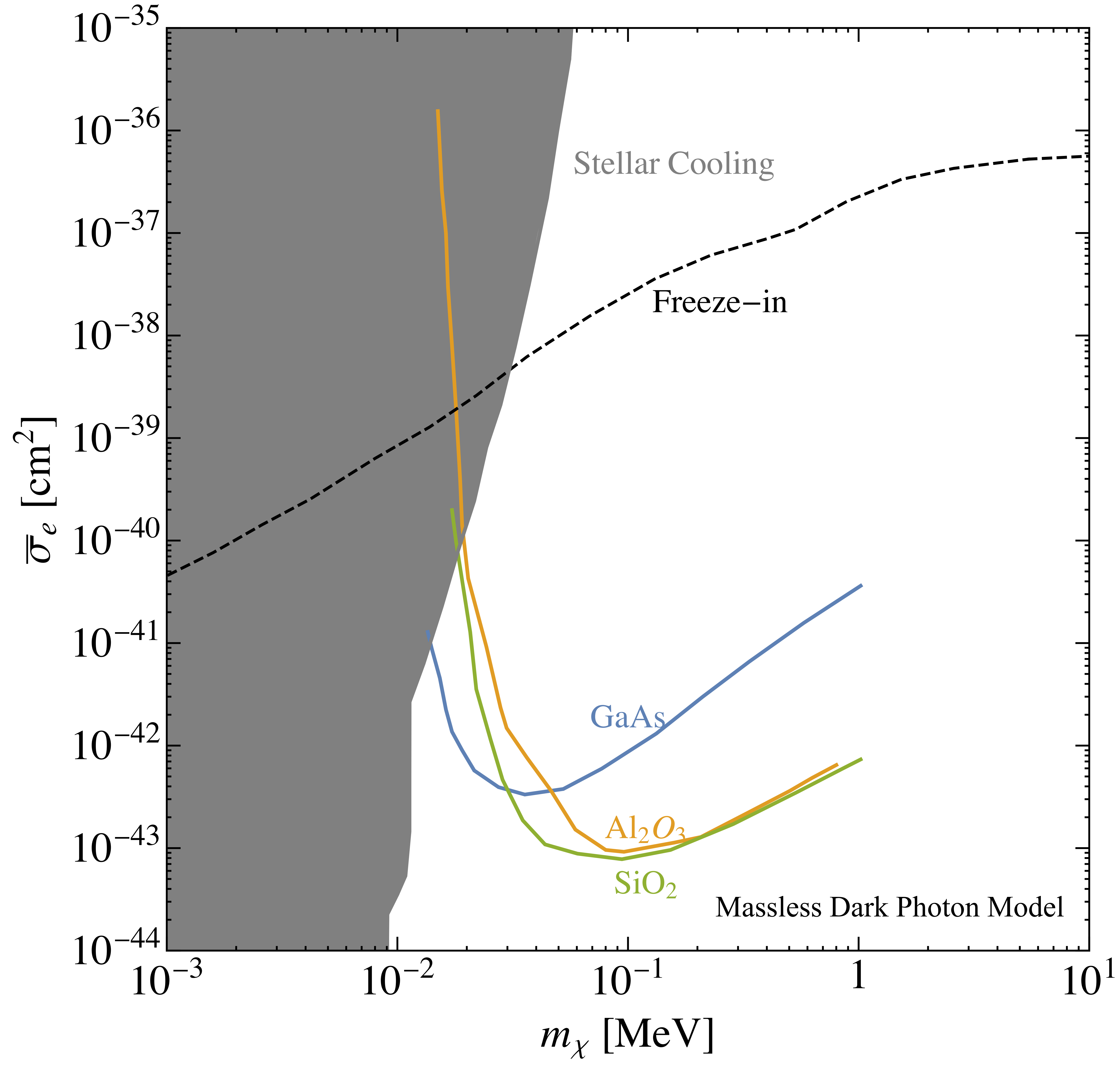
Sensitivity projections assuming background-free kg-year exposure



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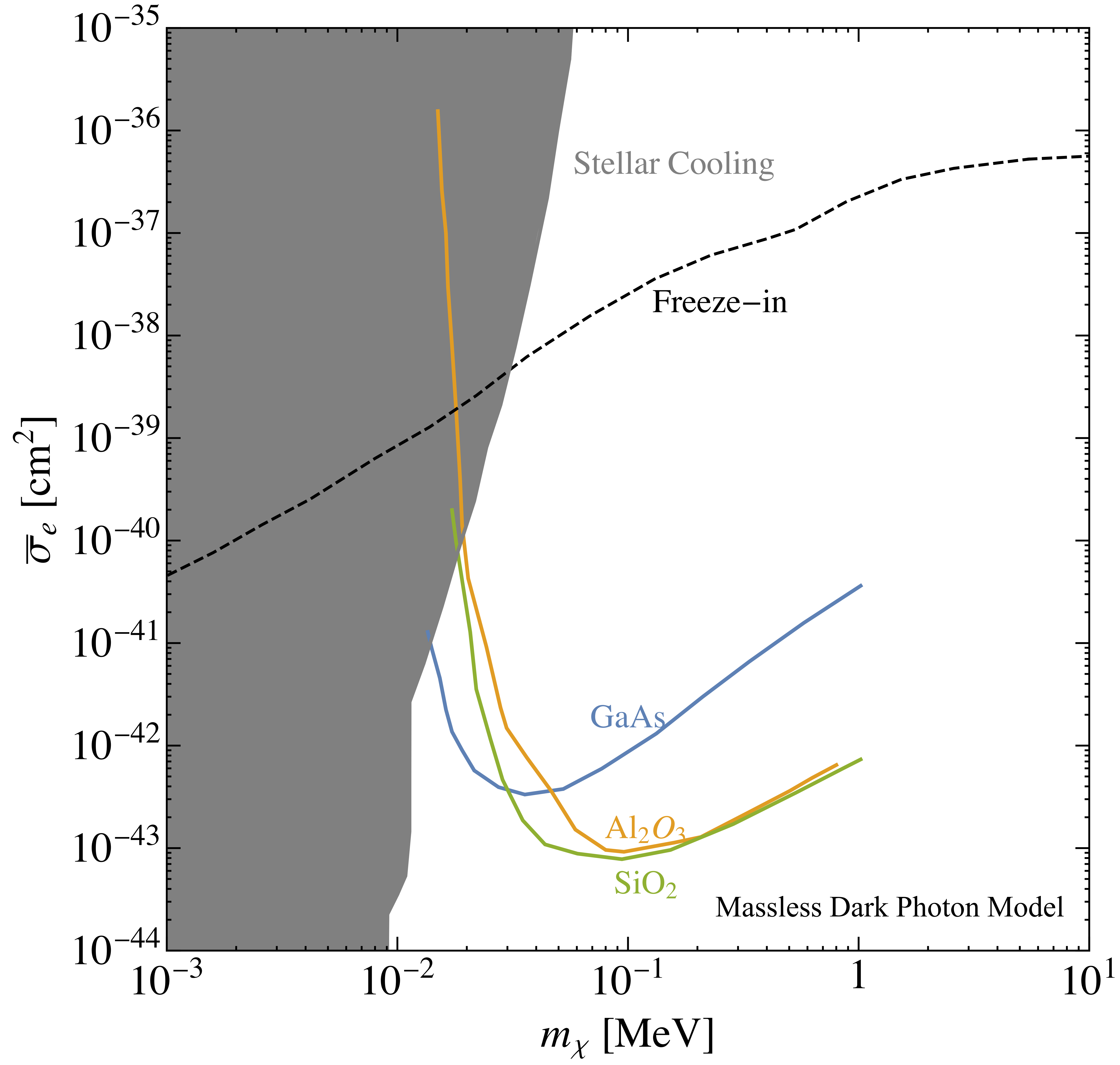

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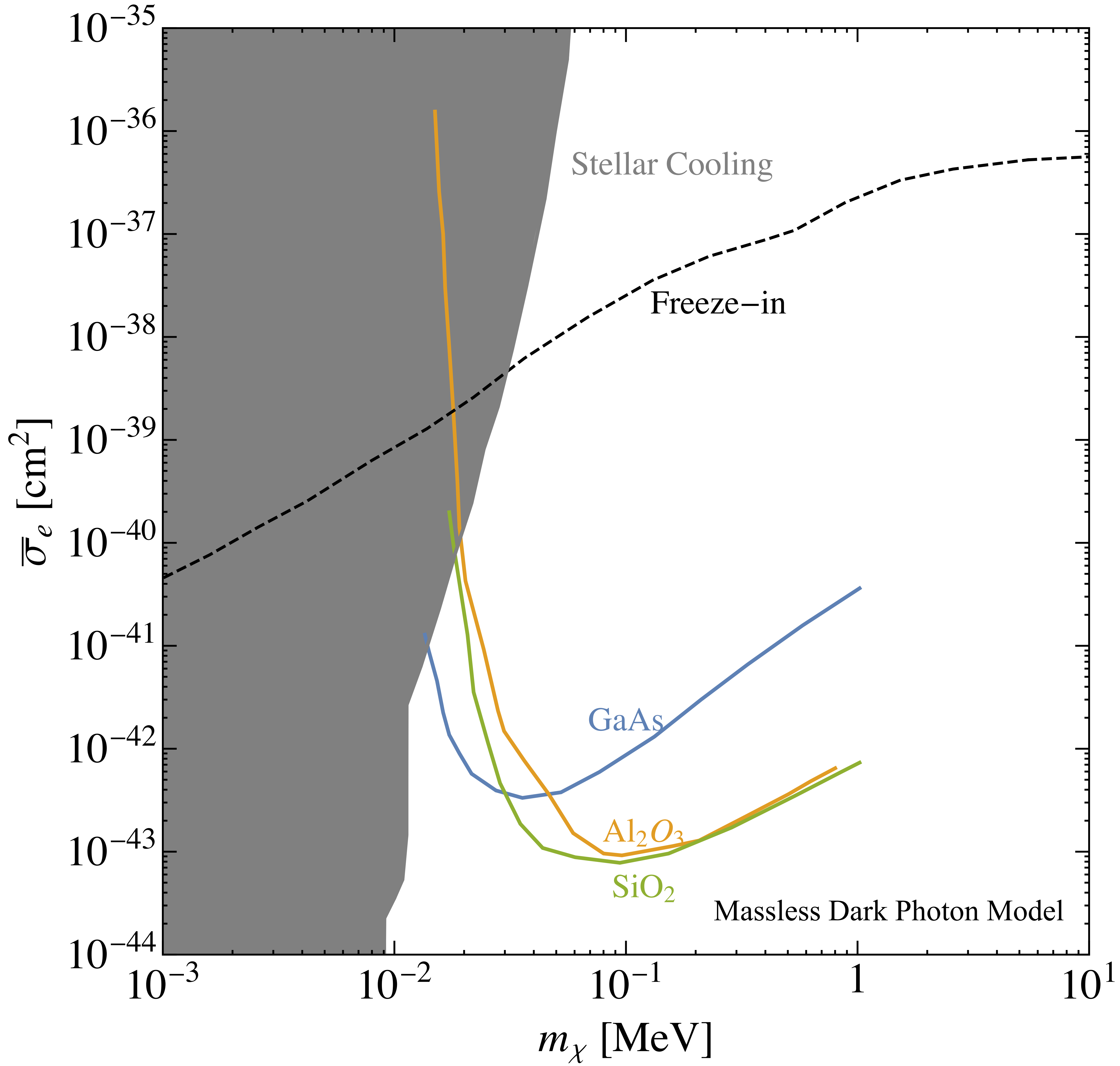
Important to estimate backgrounds in these future detectors



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Photon Background

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- Photon sources:

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  - Radioactivity (environmental and from detector material and shielding)

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Phonons from Coherent Atomic Scattering

$$\frac{d\sigma}{d\Omega d\omega}(q, E_\gamma, \omega) = \frac{d\sigma}{d\Omega}(q, E_\gamma) S(q, \omega)$$

*H. Schober 2014

Coherent Atomic Scattering
Cross Section

Dominated by Thompson Cross section
with individual electrons

$$\frac{d\sigma_T}{d\Omega}(q, \theta) \simeq \frac{\alpha^2}{2m_e^2}\left(1 + \cos^2\theta\right)|g(q)|^2$$

Structure Function

$$S(\vec{q}, \omega) = \sum_f |\langle f|e^{i\vec{q}\cdot\vec{r_N}}|i\rangle|^2 \delta(E_i - E_f - \omega)$$

Can be evaluated in terms of the
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Final Rate: $$\frac{dR}{d\omega}(\omega) = N_T \sum_i \int d\Omega \frac{d\sigma}{d\Omega d\omega}(q, E_{\gamma_i}, \omega) n_{\gamma_i} v$$

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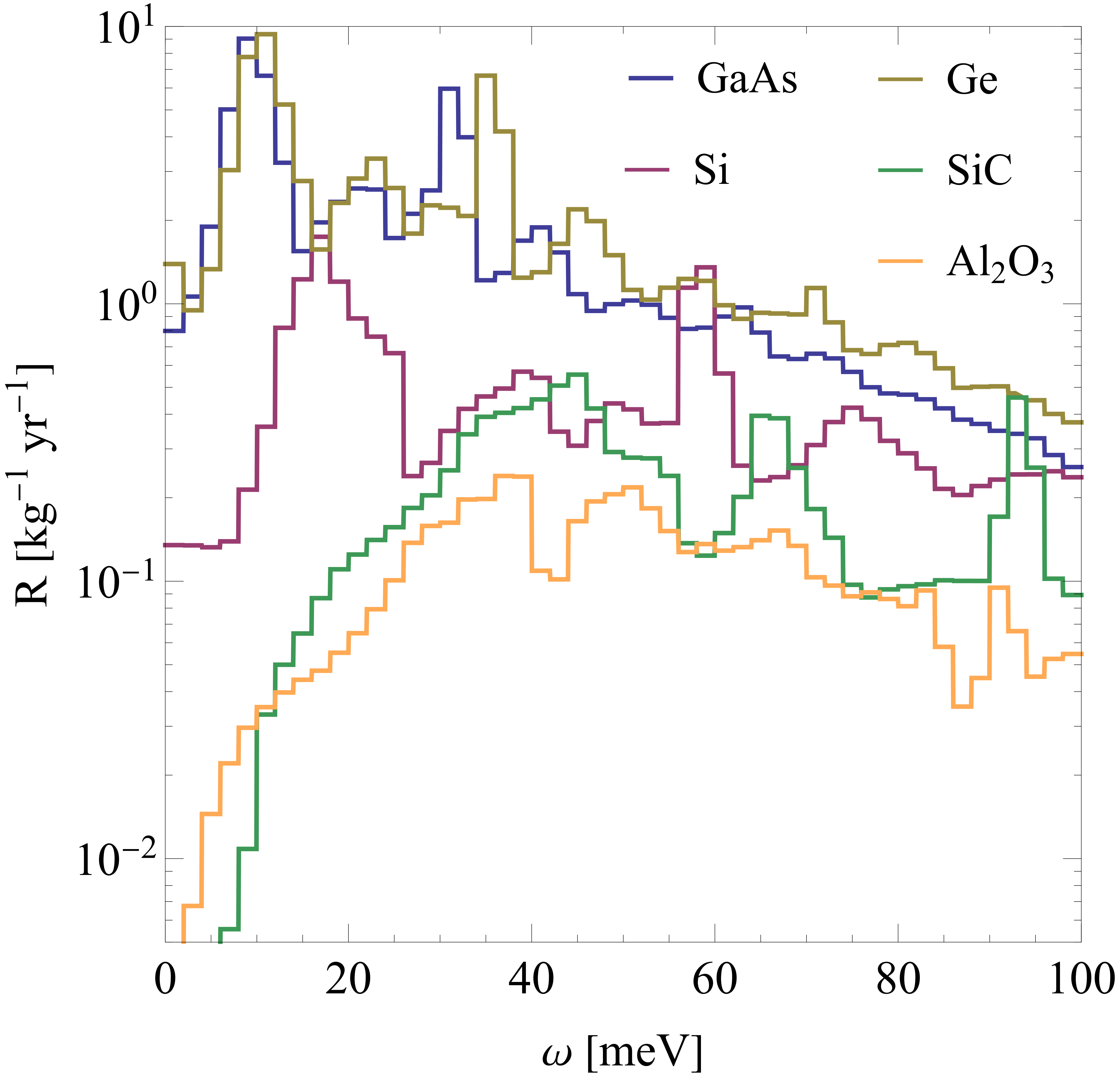


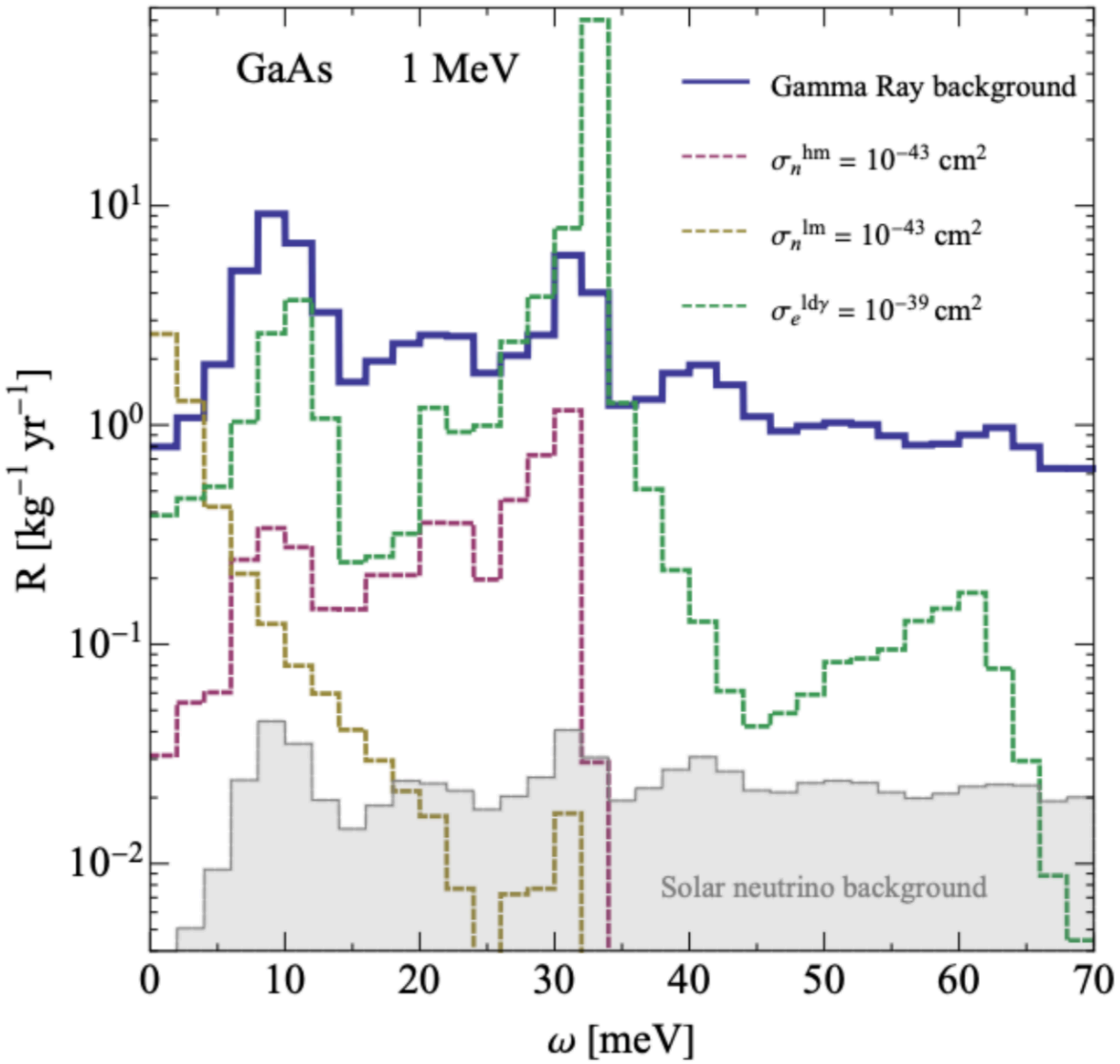
Phonon rates assuming
a typical photon background measured
in a well-shielded
EDELWEISS detector

Could be as high as
~ 100 events per kg.year

Further Considerations

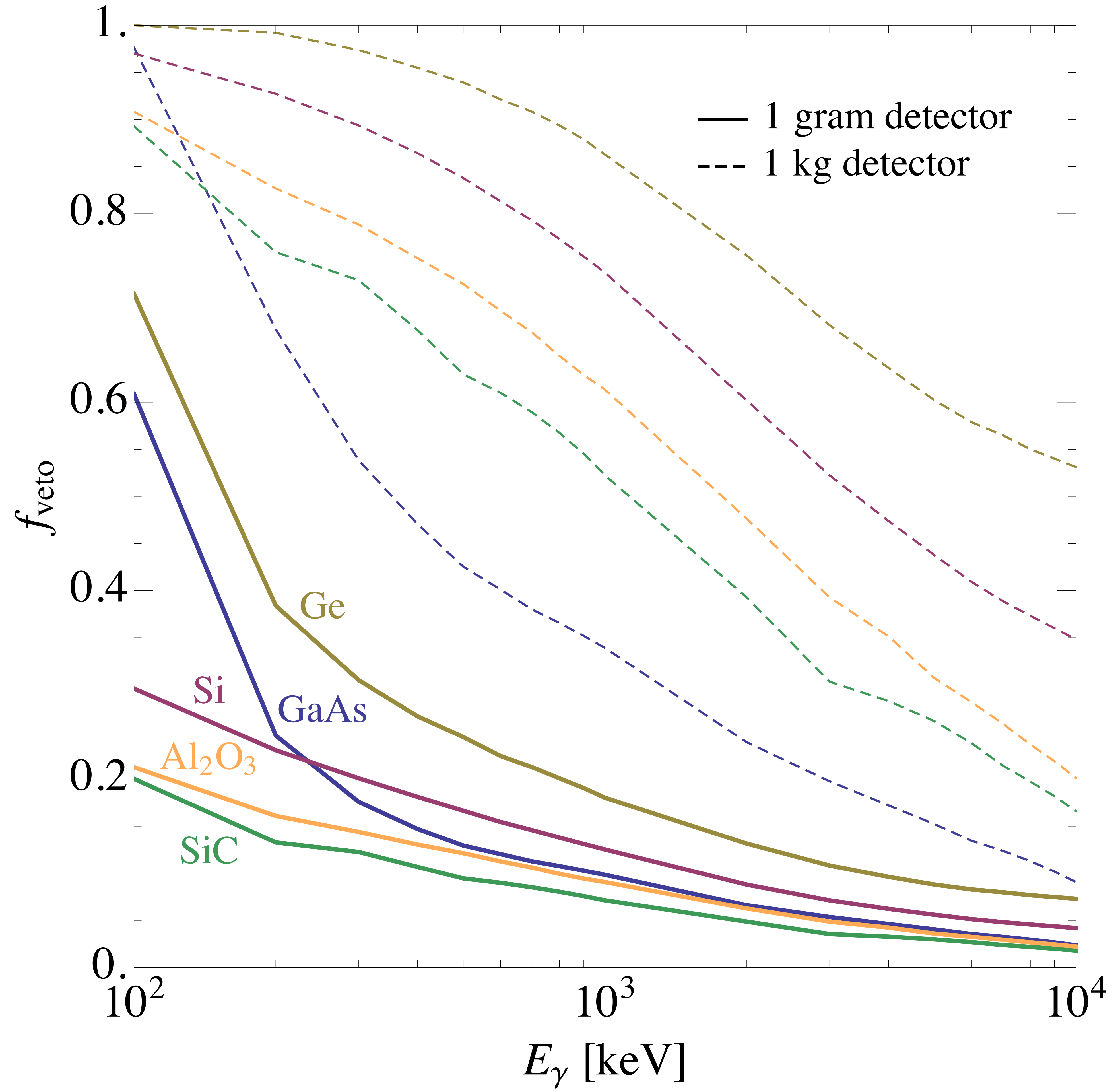
- **Comparisons with DM signal shape and possibility of discrimination:**

  Scalar mediators vs dark photon



Further Considerations

- **Possibility of veto:** Photons creating a phonon background may also create a high energy deposition through Compton scattering or Photoabsorption



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Conclusions

- Phonon excitations by DM offer a possibility of probing sub-MeV DM
- Impurities in detector can emit gamma rays that can excite phonons that could mimic a potential DM signal
- We estimate that this background could be as high as ~ 100 events per kg.year
- Could be mitigated by further improving passive shielding or using an additional active veto