Neutrino backgrounds for direct detection of sub-GeV dark matter via electron scattering

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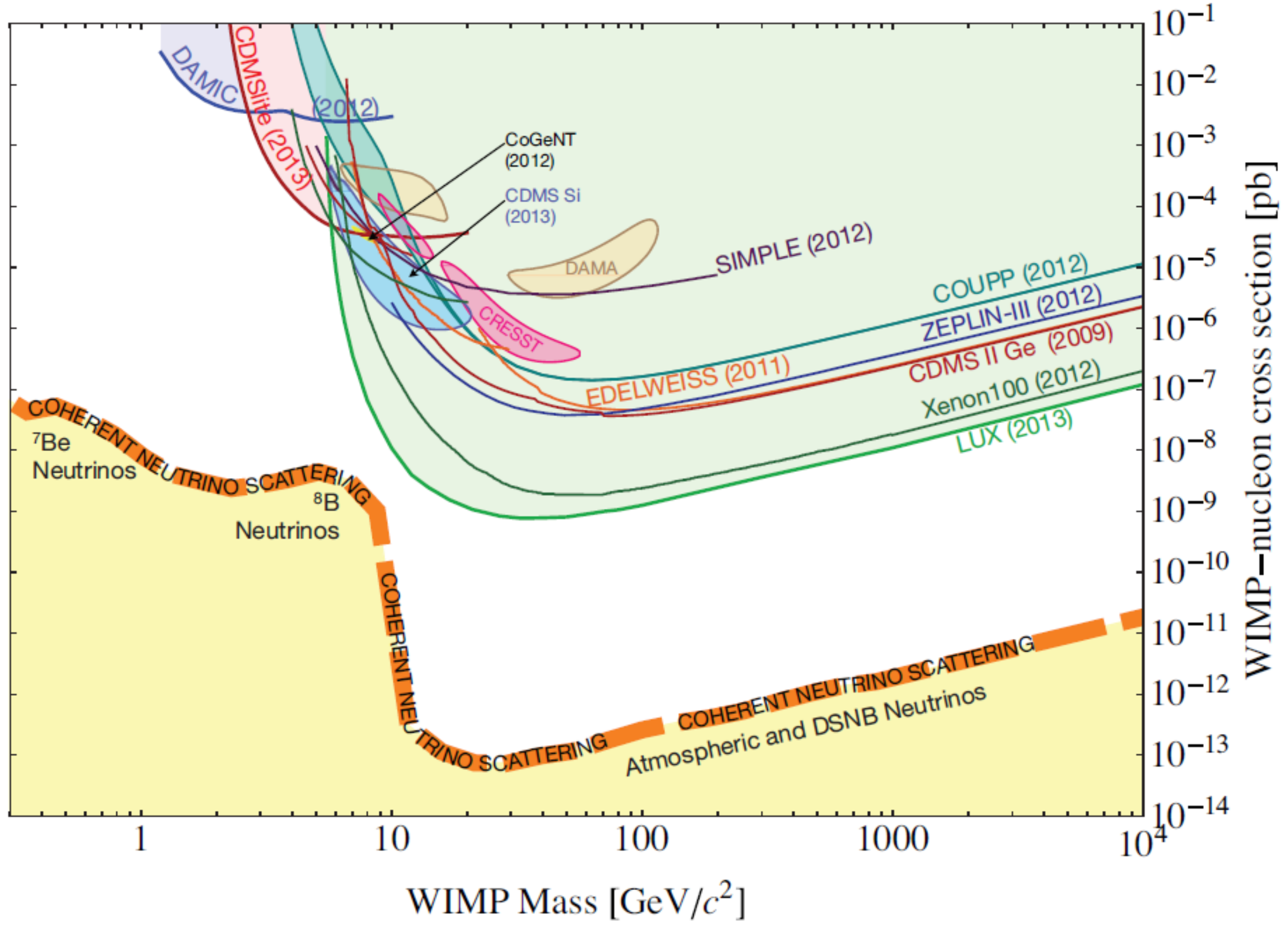
Work in progress with Rouven Essig and Tien-Tien Yu

Introduction

- WIMP phenomenology covers the GeV-TeV scale
- Sub-GeV dark matter ?

Can be detected via electron scattering



* Billard, Figueroa-Feliciano and Strigari

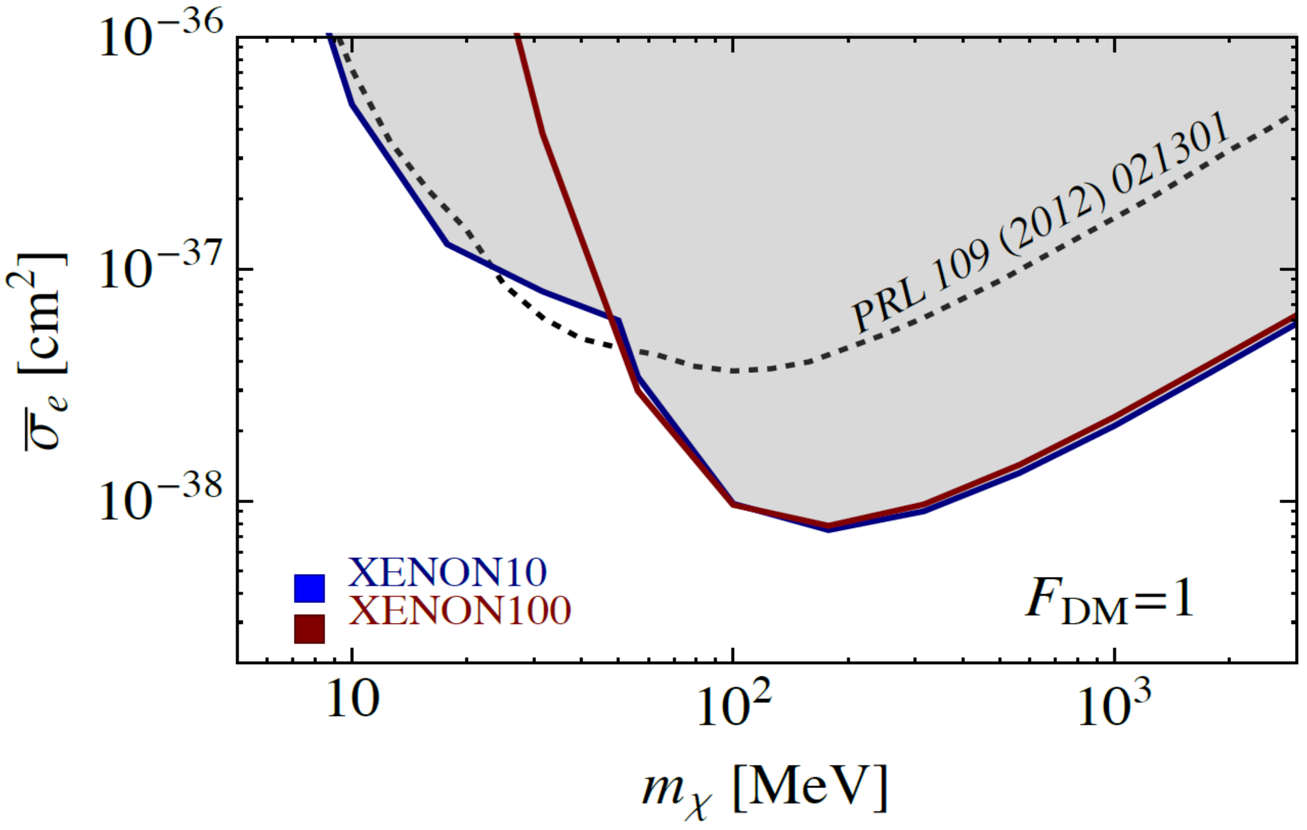
Direct detection of sub-GeV dark matter

- Electrons ionized by DM-electron scattering
- Some of the ways of detecting :

➢ **Semiconductor targets(Ge, Si)**

➢ **Xenon targets**

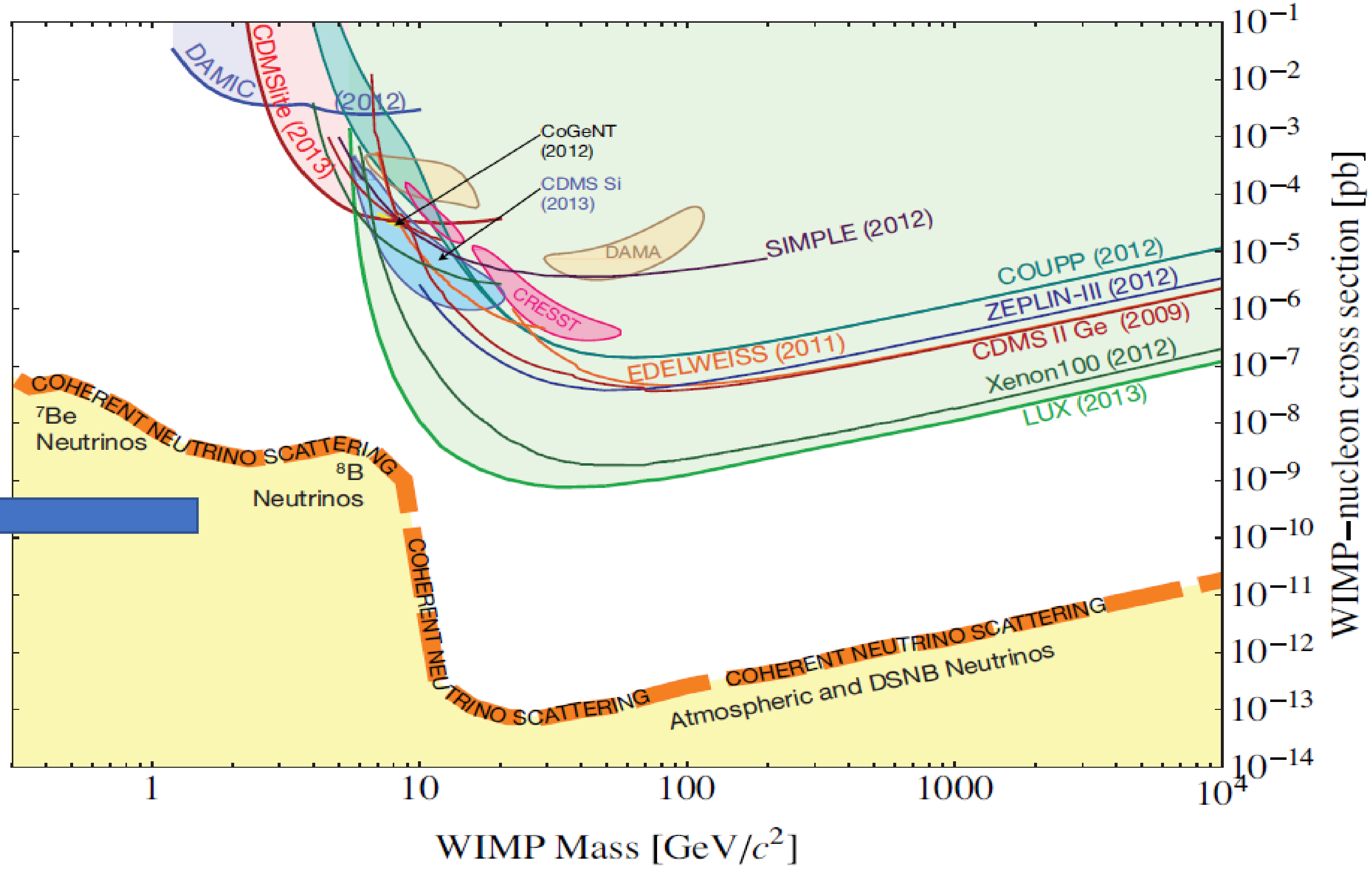
➢ **Scintillators(GaAs, NaI)**



*Essig, Volansky, and T.-T. Yu

WIMP constraints

Neutrino floor

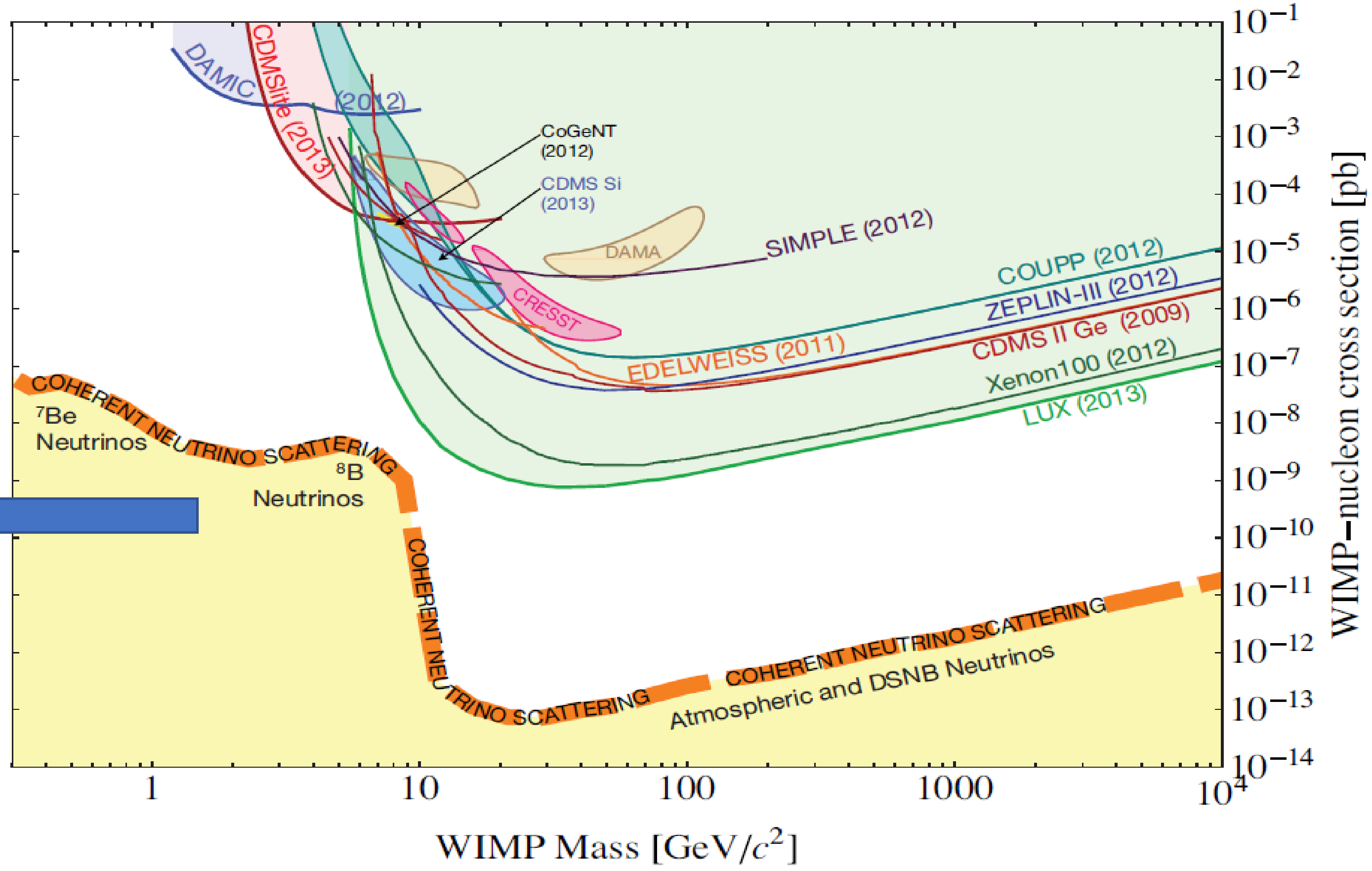


* Billard, Figueroa-Feliciano and Strigari

WIMP constraints

Neutrino floor

Will neutrino background affect LDM-electron scattering ?



* Billard, Figueroa-Feliciano and Strigari

Background for sub-GeV DM-electron scattering ?

- Neutrino-electron scattering peaks in a much higher energy range !
- Neutrino-nucleus scattering is in the right energy range.
- Nuclear recoil energy

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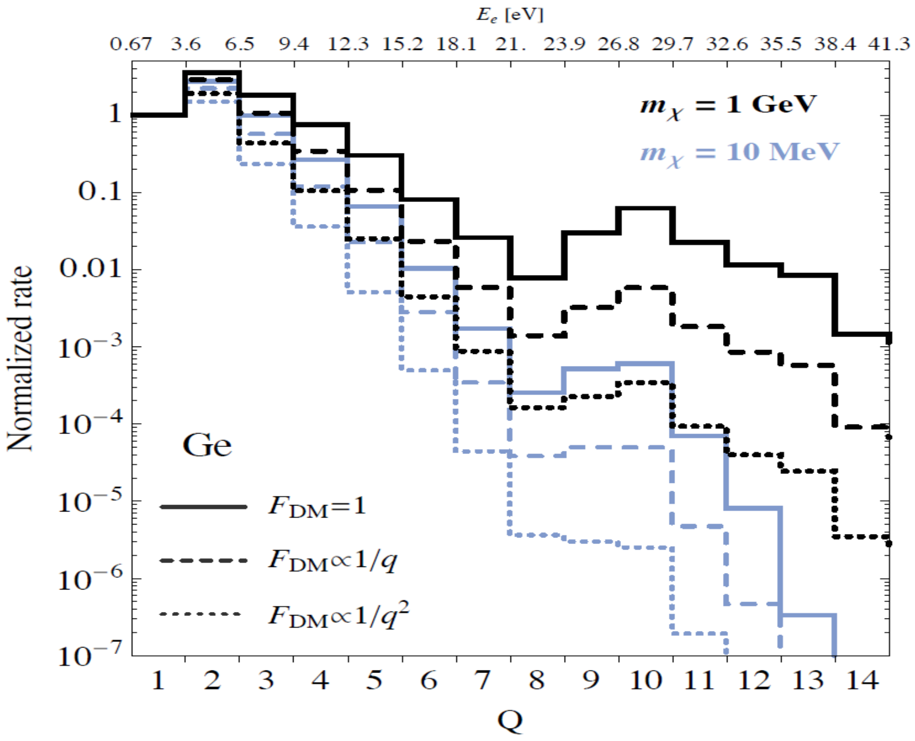
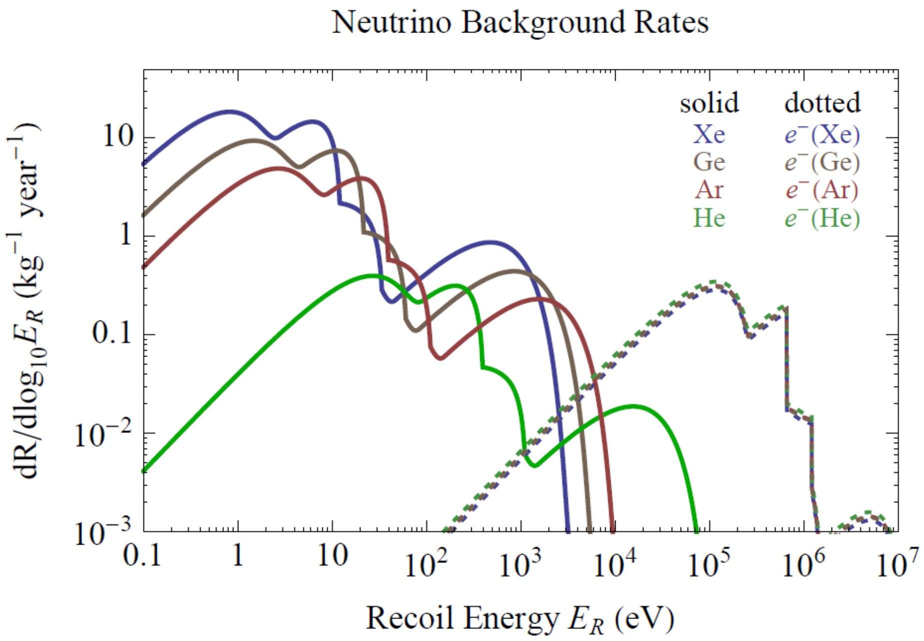
Electron ionization energy ?



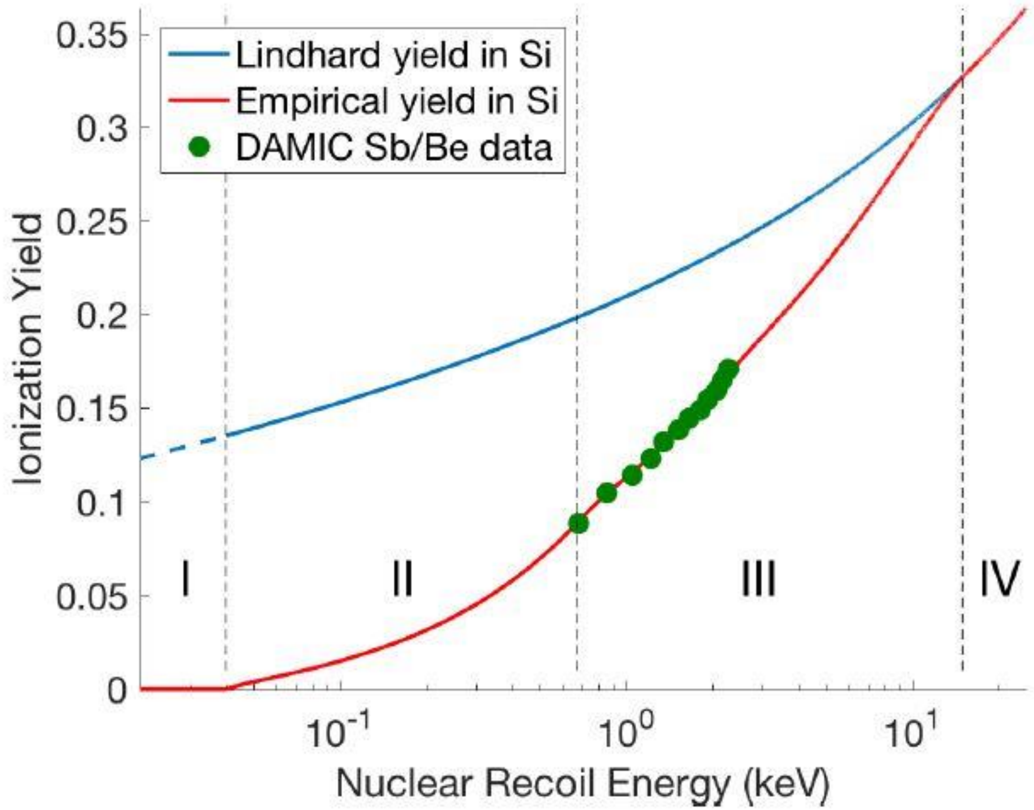
* Essig, Fernandez-Serra, Mardon, Soto, Volansky and T. T. Yu



*Essig, Mardon and Volansky

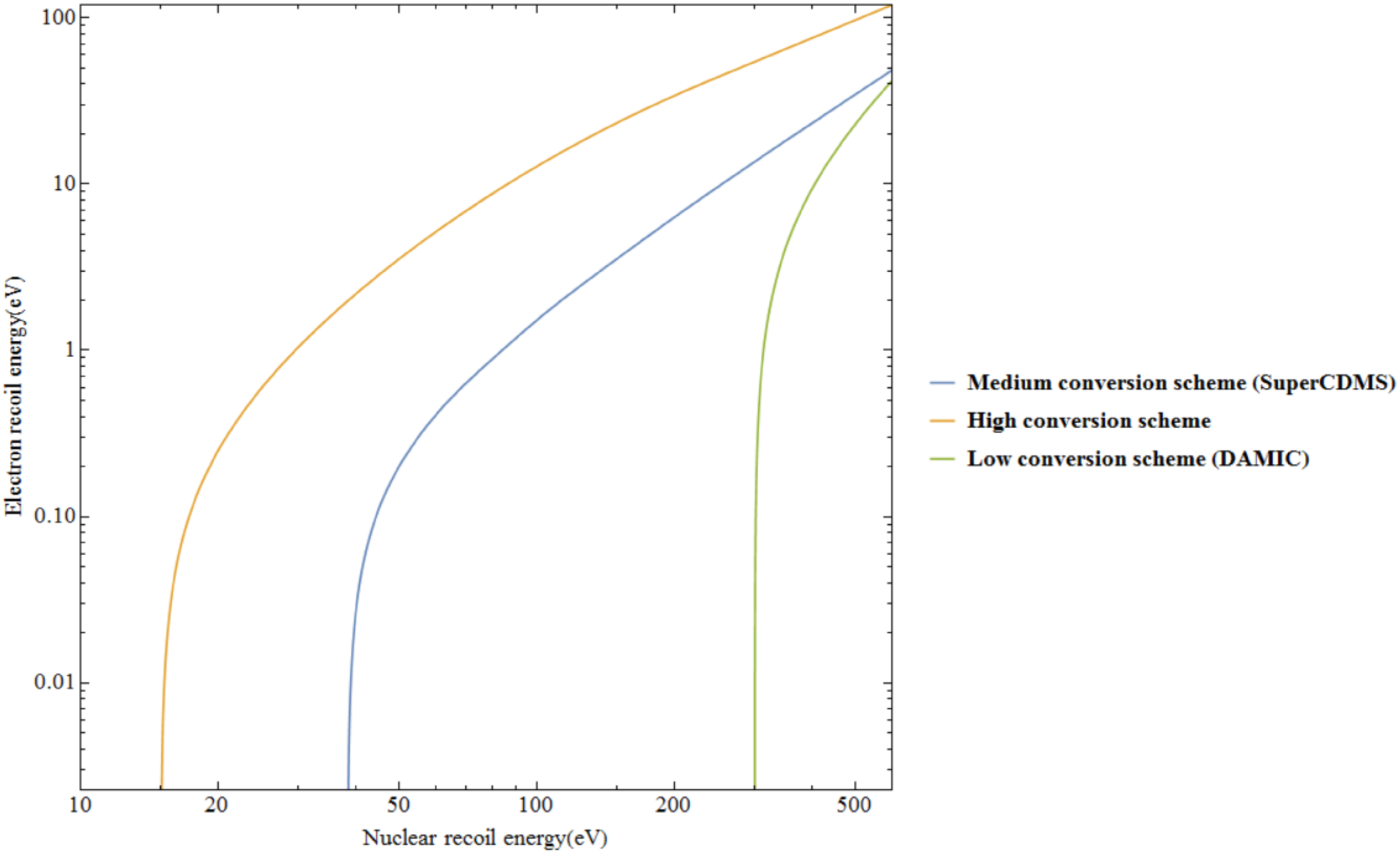
Energy conversion models

- The most accepted model was developed by Lindhardt in 1963.
- Lindhardt model is not consistent with low energy(~ 1 KeV nuclear recoil energy) data in Si
- Extrapolate to low energies !

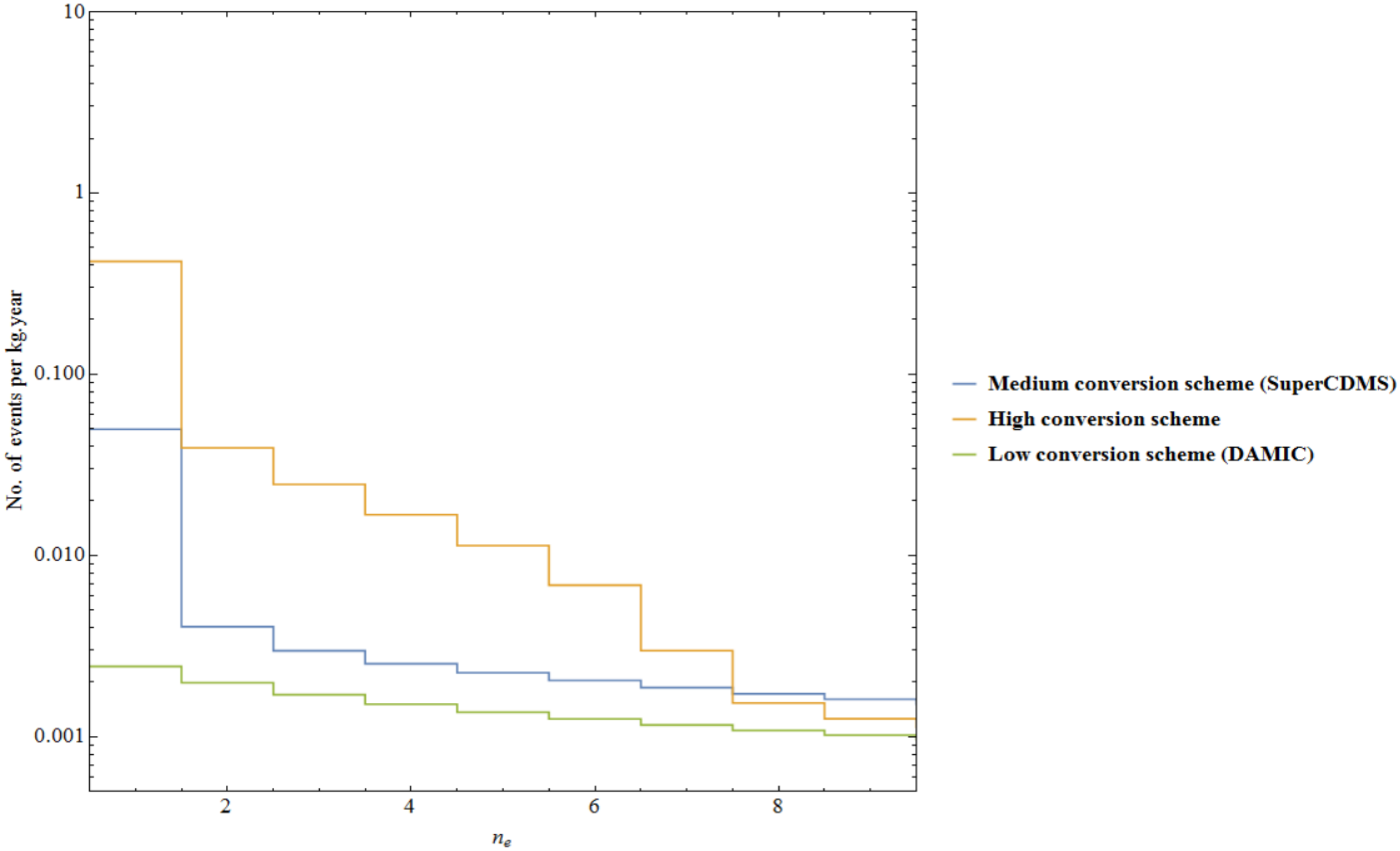


*Agnese et al. (SuperCDMS)

Conversion schemes for Si



Neutrino rates in Si for various conversion schemes



Likelihood analysis

- Hypothesis testing to reject the background hypothesis

The likelihood function is given by,

$$\mathcal{L}(\sigma_{\chi e}, \vec{\phi}) = \frac{e^{-(\mu_\chi + \sum_{j=1}^{n_\nu} \mu_\nu^j)}}{N!} \times \prod_{i=1}^{N} [\mu_\chi f_\chi(n_i) + \sum_{j=1}^{n_\nu} \mu_\nu^j f_\nu^j(n_i)] \times \prod_{i=1}^{n_\nu} \mathcal{L}(\phi_i).$$

The test statistic t is given by,

$$t = -2ln(\lambda),$$

where,

$$\lambda = \frac{\mathcal{L}(\sigma_{\chi e} = 0, \hat{\hat{\vec{\phi}}})}{\mathcal{L}(\hat{\sigma_{\chi e}}, \hat{\vec{\phi}})}.$$

Finding neutrino floor

For a particular dark matter mass, exposure and threshold, we perform the likelihood analysis and use the Wilk's theorem to get the lowest cross-section which gives a 2σ significance.

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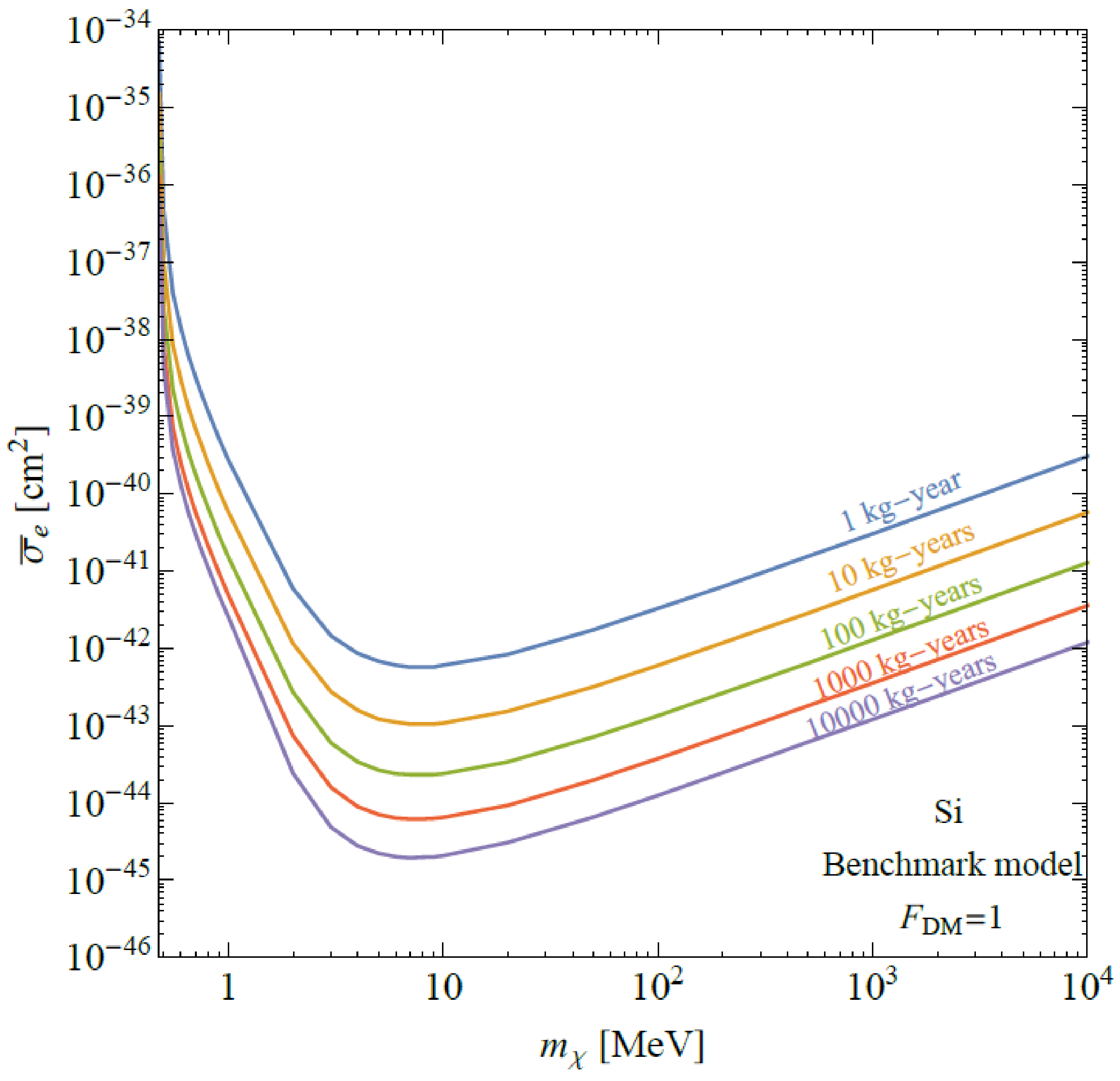
Minimize with respect to thresholds and exposures to get to the floor !

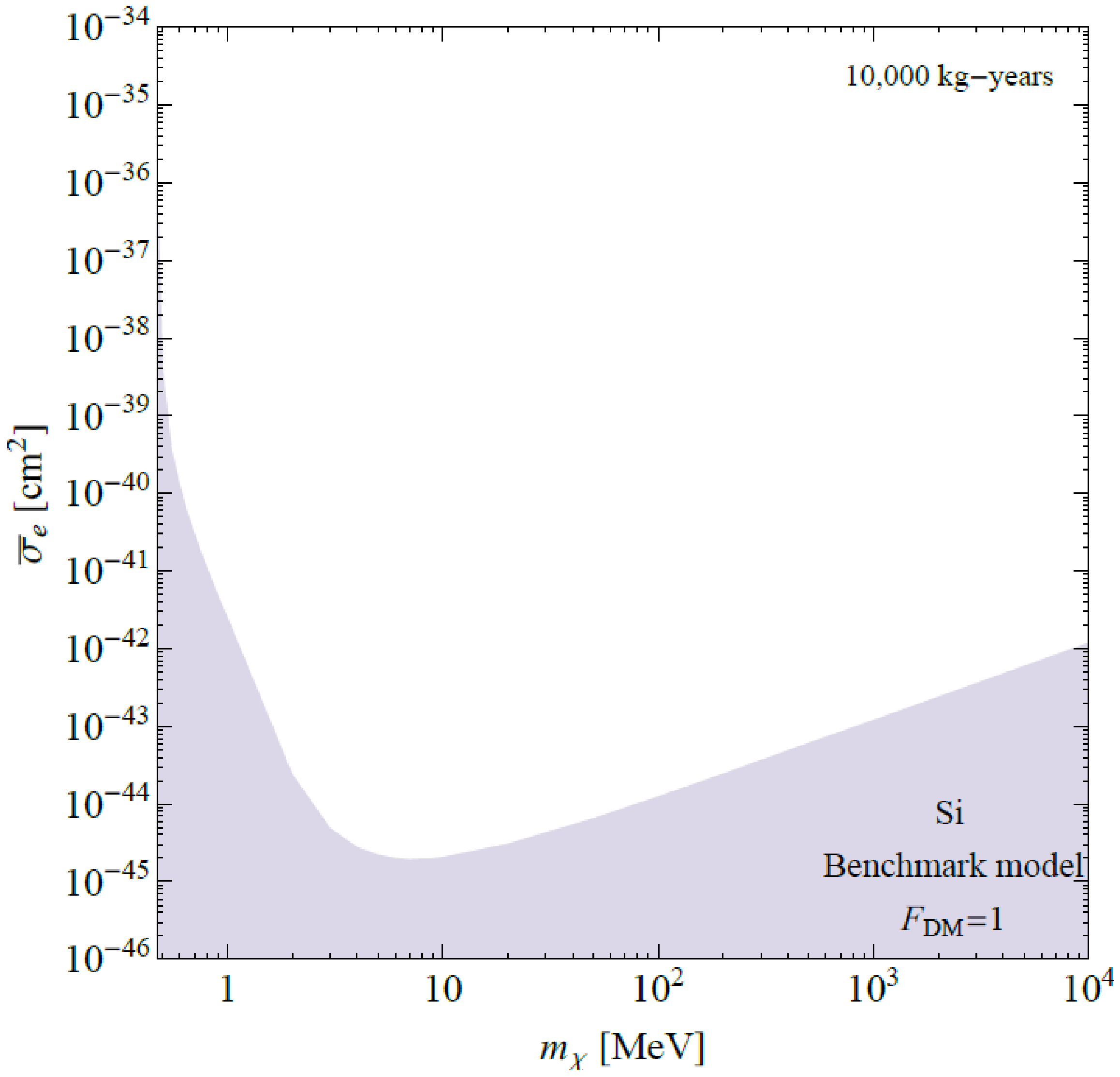
Results

- 2σ significance discovery limits for medium conversion scheme.

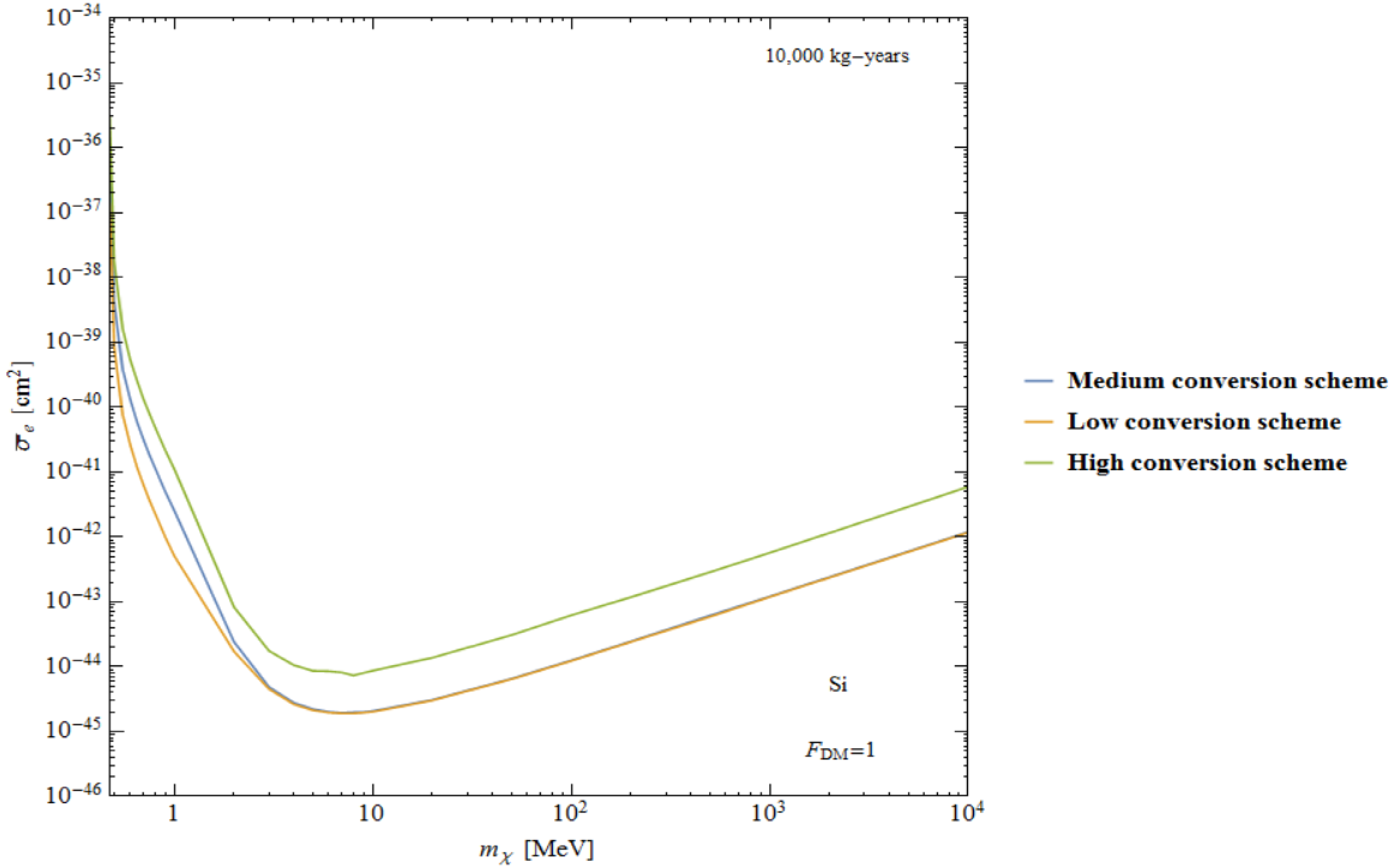


Results

- 2σ significance discovery limit for 10000 kg-year exposure and medium conversion scheme.



Comparison for various conversion schemes



Summary

- Even under conservative assumptions, neutrinos will not be a background for electron recoil searches in Si for exposures < 2 kg-years
- No hard neutrino floor for DM masses more than 1 MeV at least till 10,000 kg-year exposures even with current neutrino flux uncertainties
- Also obtained similar results for Ge which place slightly tighter limits
- Neutrino backgrounds for scintillators like GaAs, NaI, CsI are under study