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

Brookhaven Forum 2017

Mukul Sholapurkar

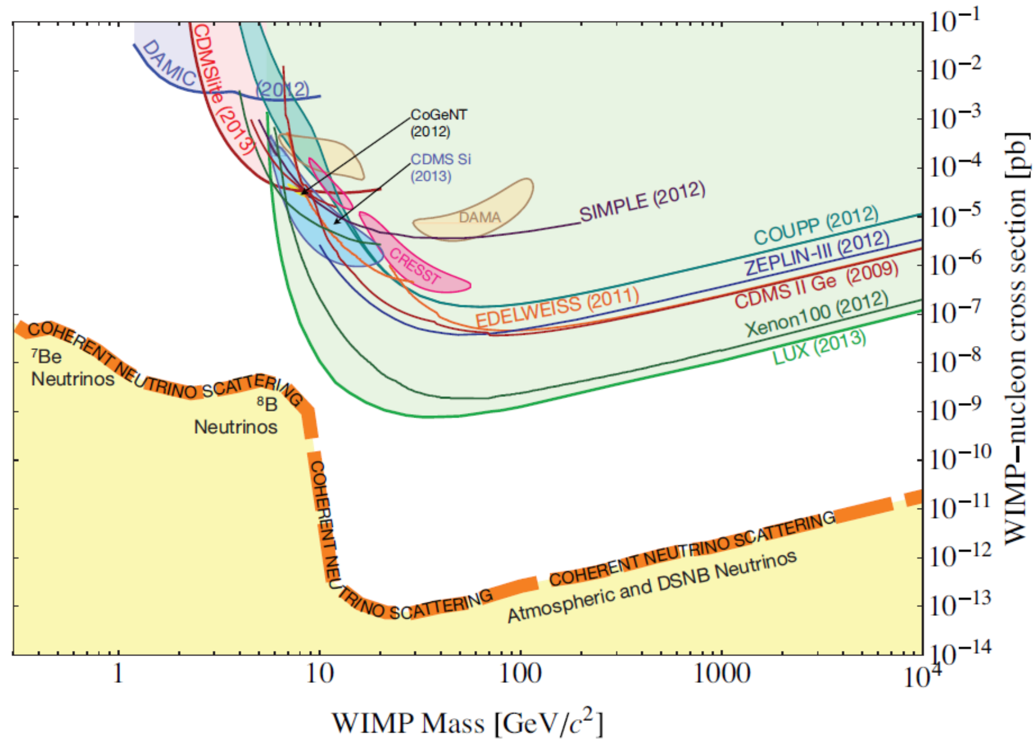
C.N. Yang Institute of Theoretical Physics, Stony Brook

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 ionization



* Billard, Figueroa-Feliciano and Strigari

Direct detection of sub-GeV dark matter

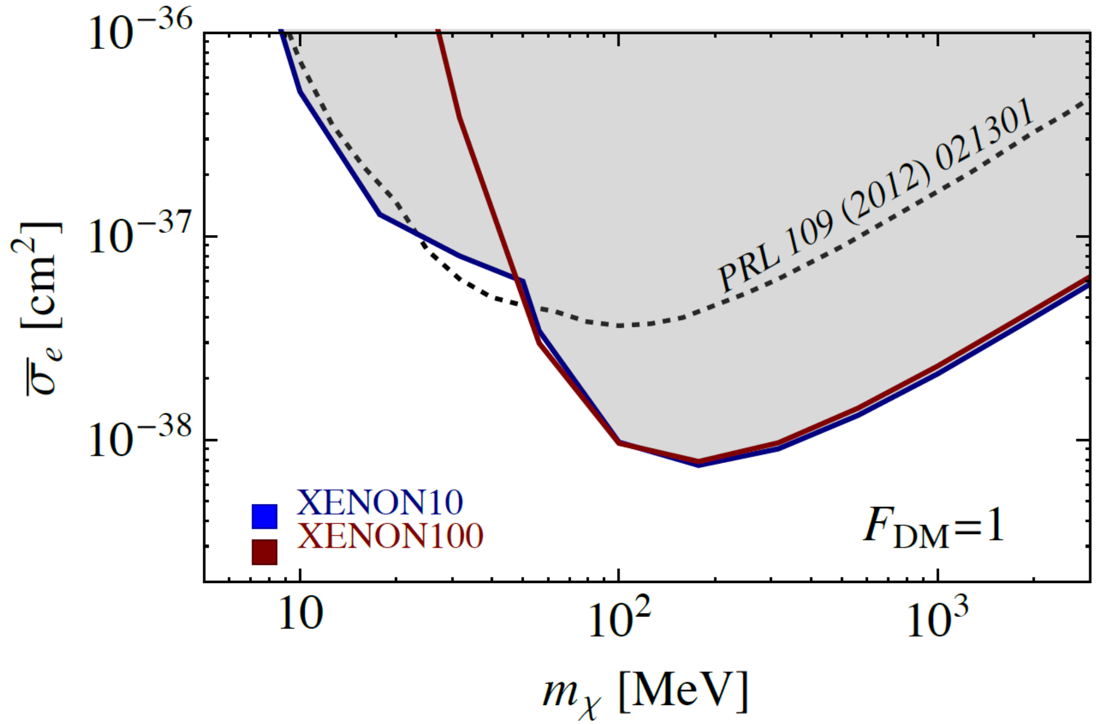
- Electrons ionized by DM-electron scattering or DM absorption

- Some of the ways of detecting :

➢ **Semiconductor targets(Ge, Si)**

➢ **Xenon targets**

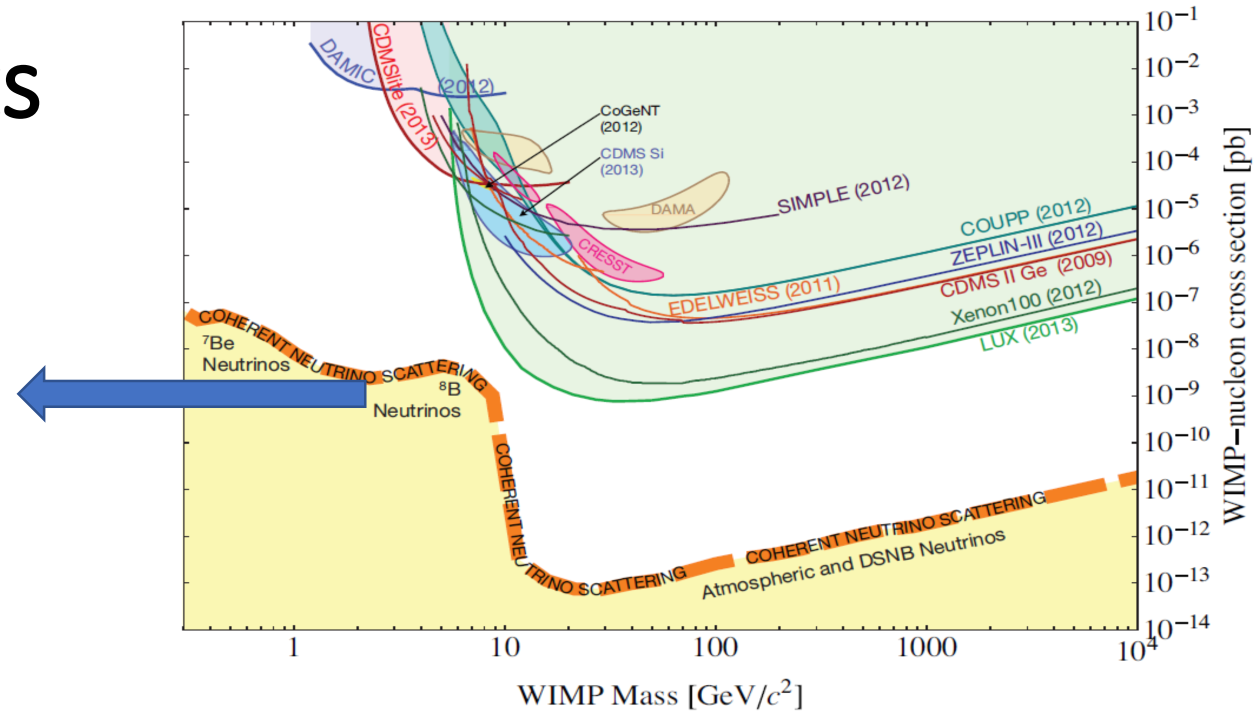
➢ **Scintillators(GaAs, NaI)**



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

WIMP constraints

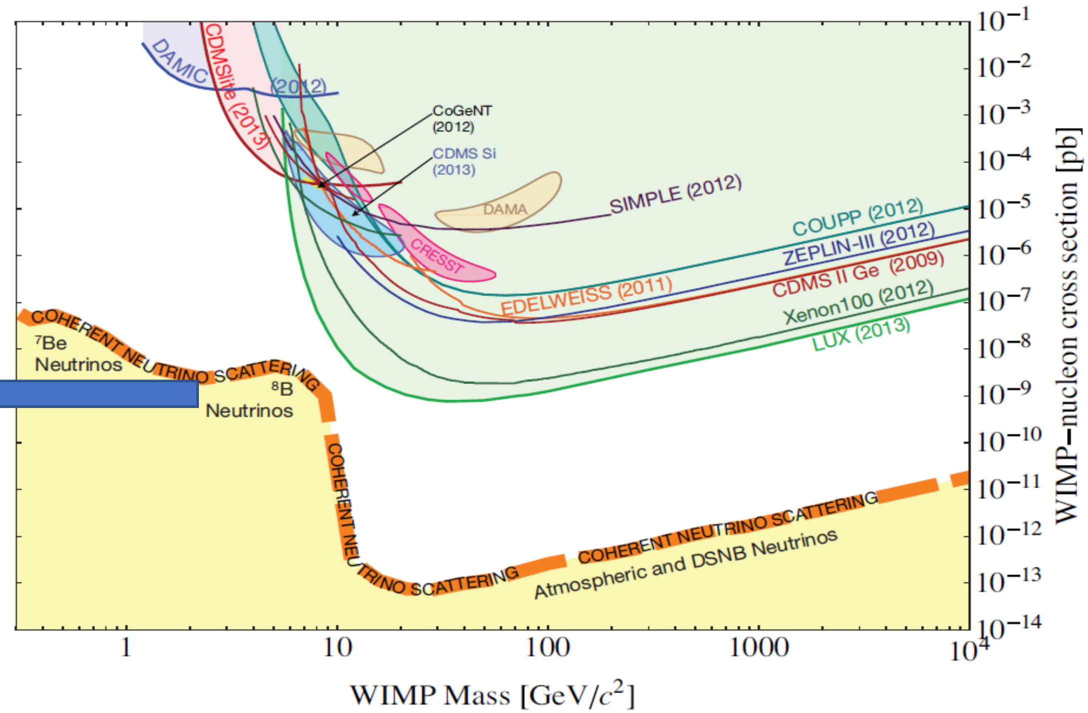
Neutrino floor



* Billard, Figueroa-Feliciano and Strigari

WIMP constraints

Neutrino floor



* Billard, Figueroa-Feliciano and Strigari

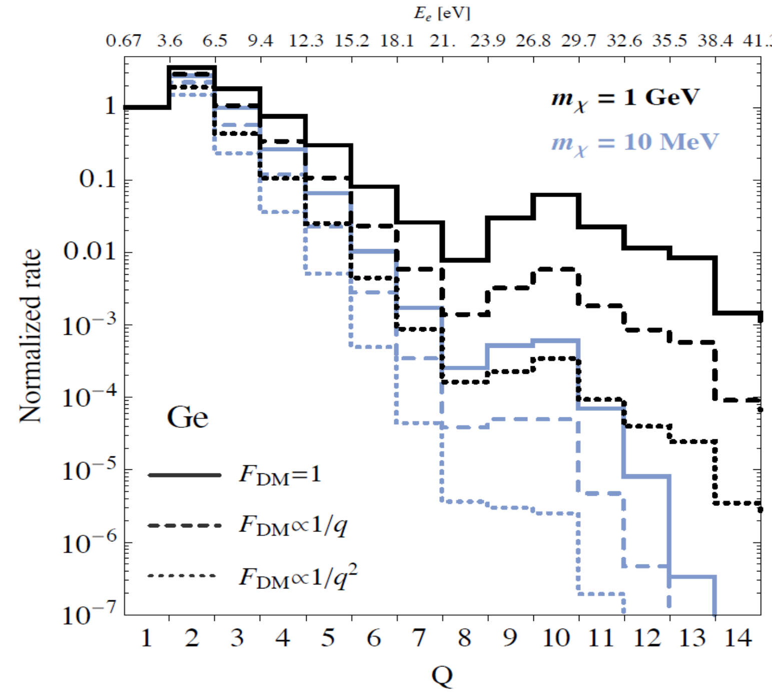
How does neutrino background affect sub-GeV DM induced ionization signals?

Neutrino background for sub-GeV DM-induced ionization

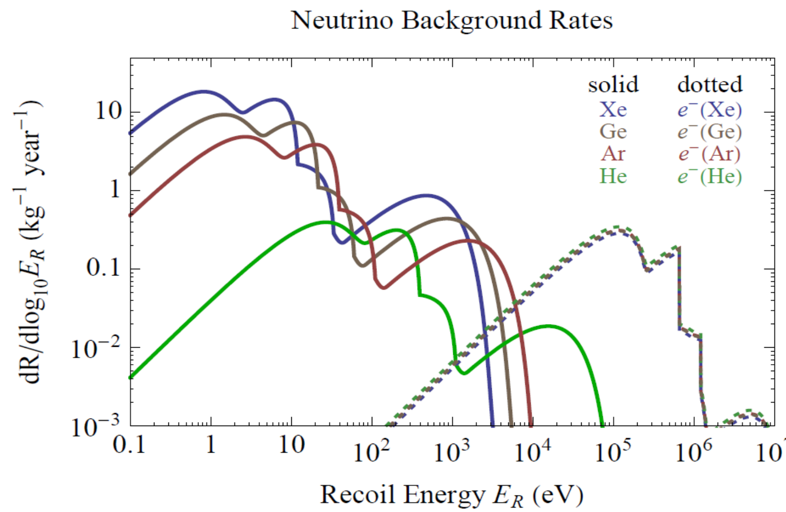
- Neutrino-electron scattering peaks in a much higher energy range !
- Neutrino-nucleus scattering is in the right energy range.
- Nuclear recoil energy

↓

Electron ionization energy ?



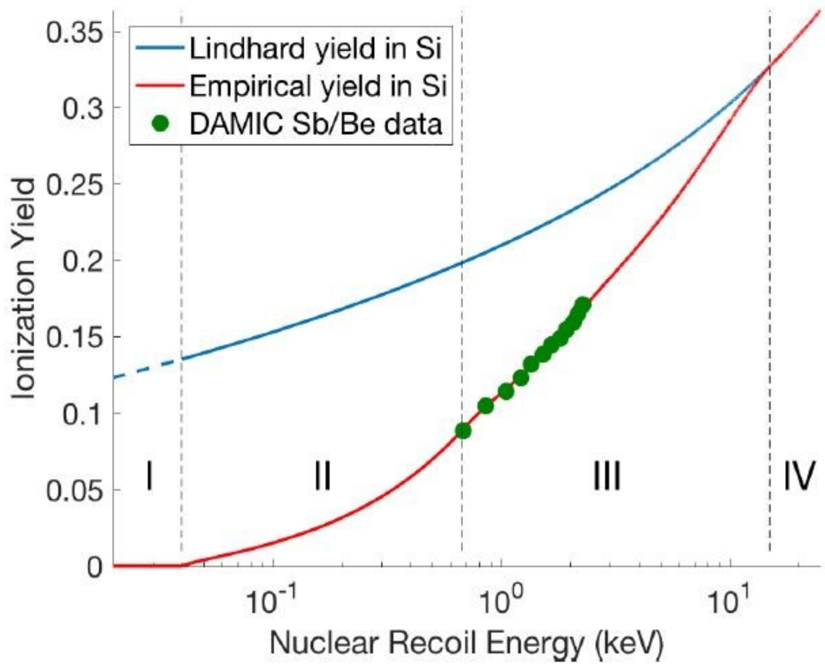
* Essig, Fernandez-Serra, Mardon, Soto, Volansky and T. T. Yu



*Essig, Mardon and Volansky

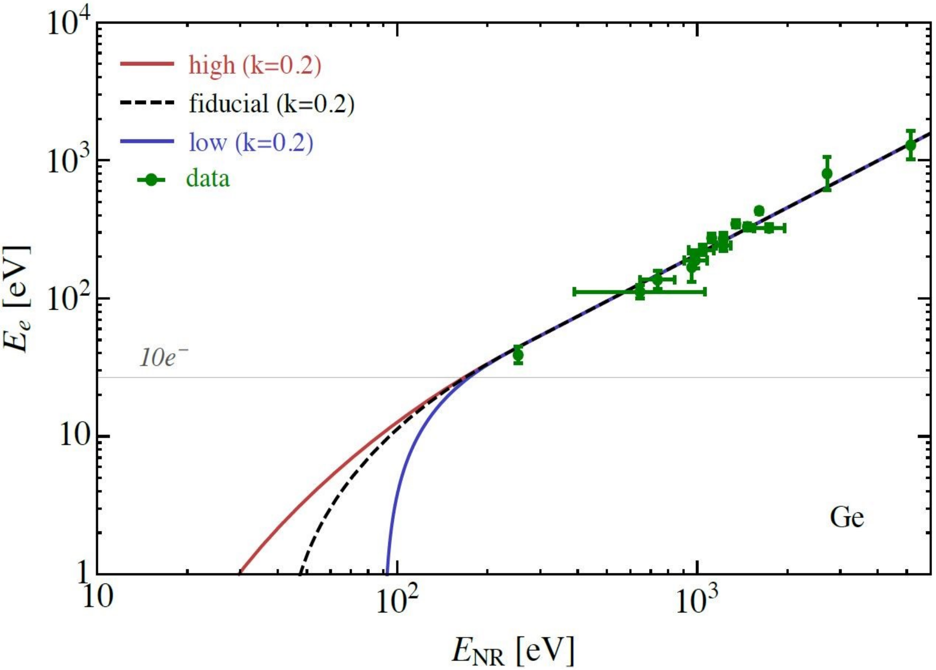
Energy conversion models

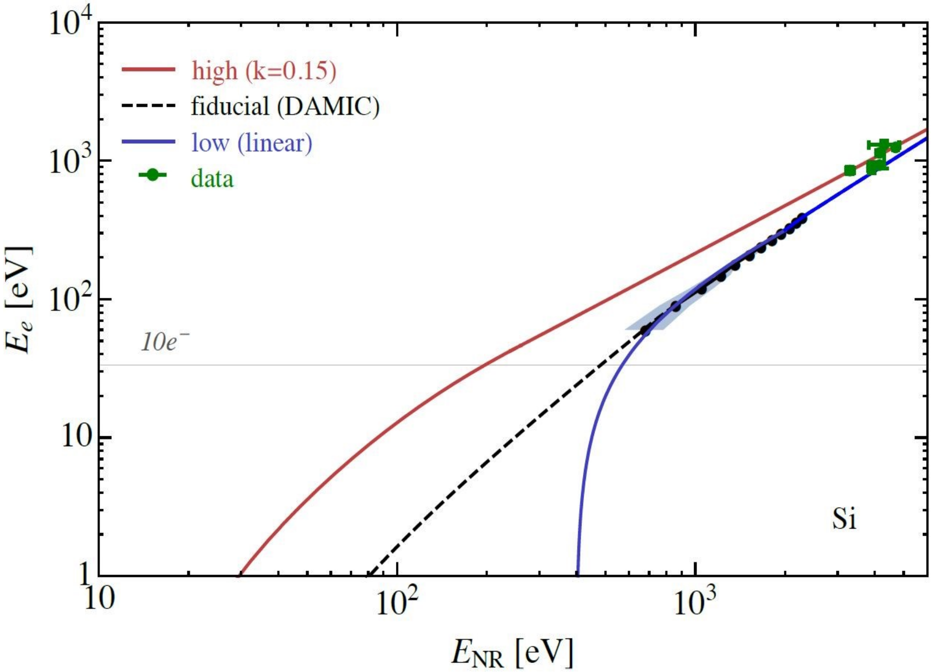
- The most accepted model was developed by Lindhardt in 1963.
- Lindhardt model is not consistent with low energy(~ 1 KeV nuclear recoil energy) data in Si
- Extrapolate to low energies !



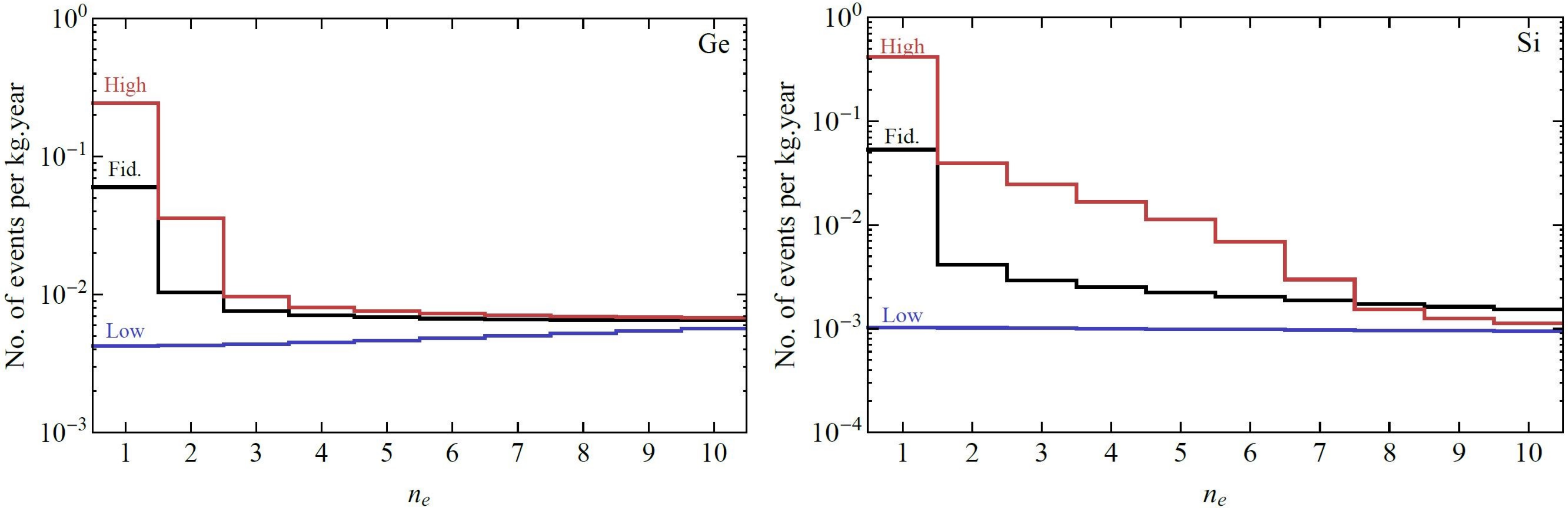
*Agnese et al. (SuperCDMS)

Conversion schemes





Neutrino rates for different conversion schemes



Likelihood analysis for DM-electron scattering

- 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,

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

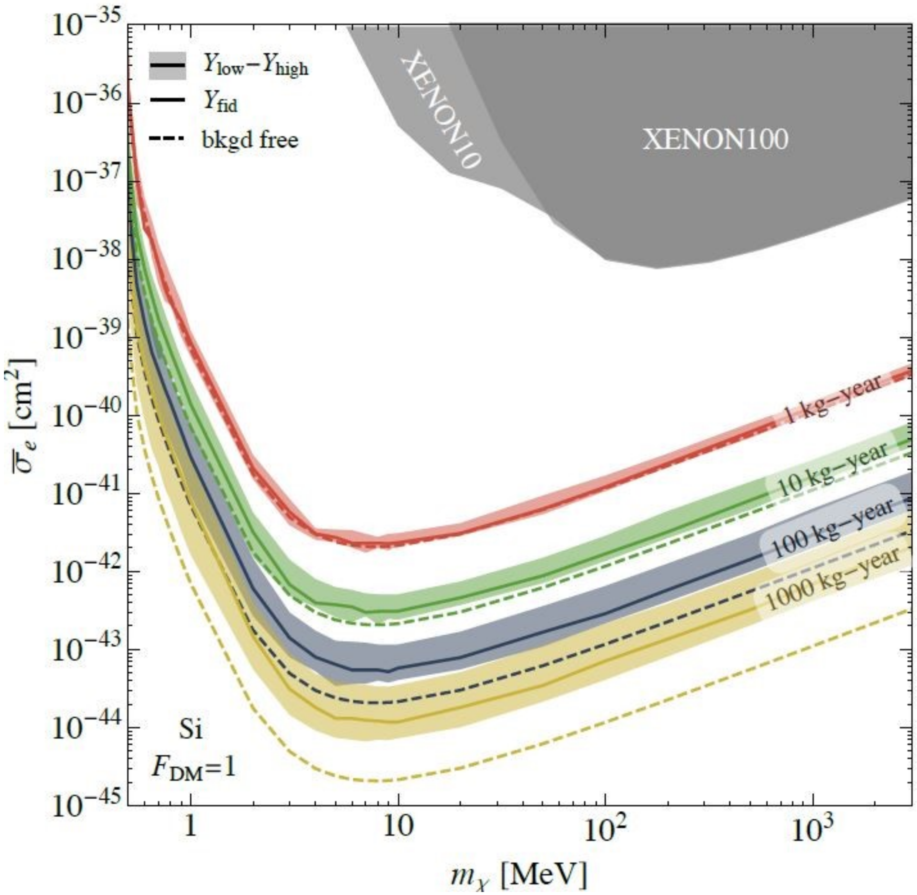
Discovery limits for DM-electron scattering

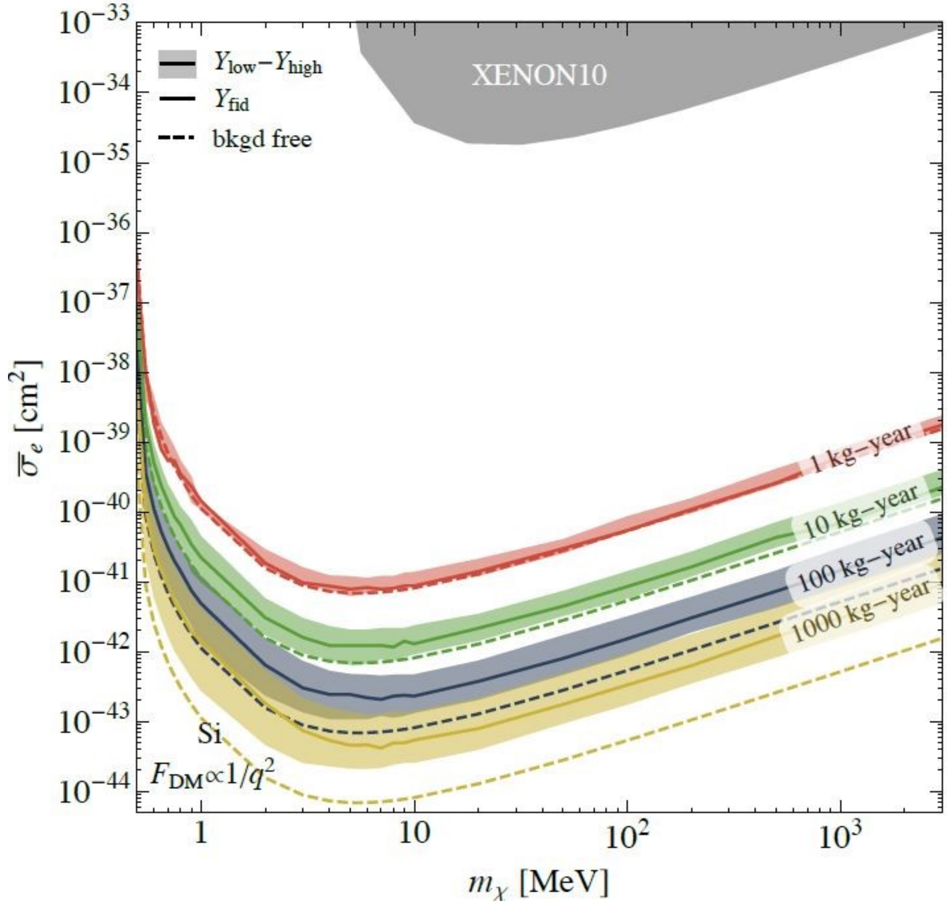
For a particular dark matter mass, exposure and threshold, we perform the likelihood analysis to get the lowest cross-section which gives a 2σ significance in 90% of experiments.

↓

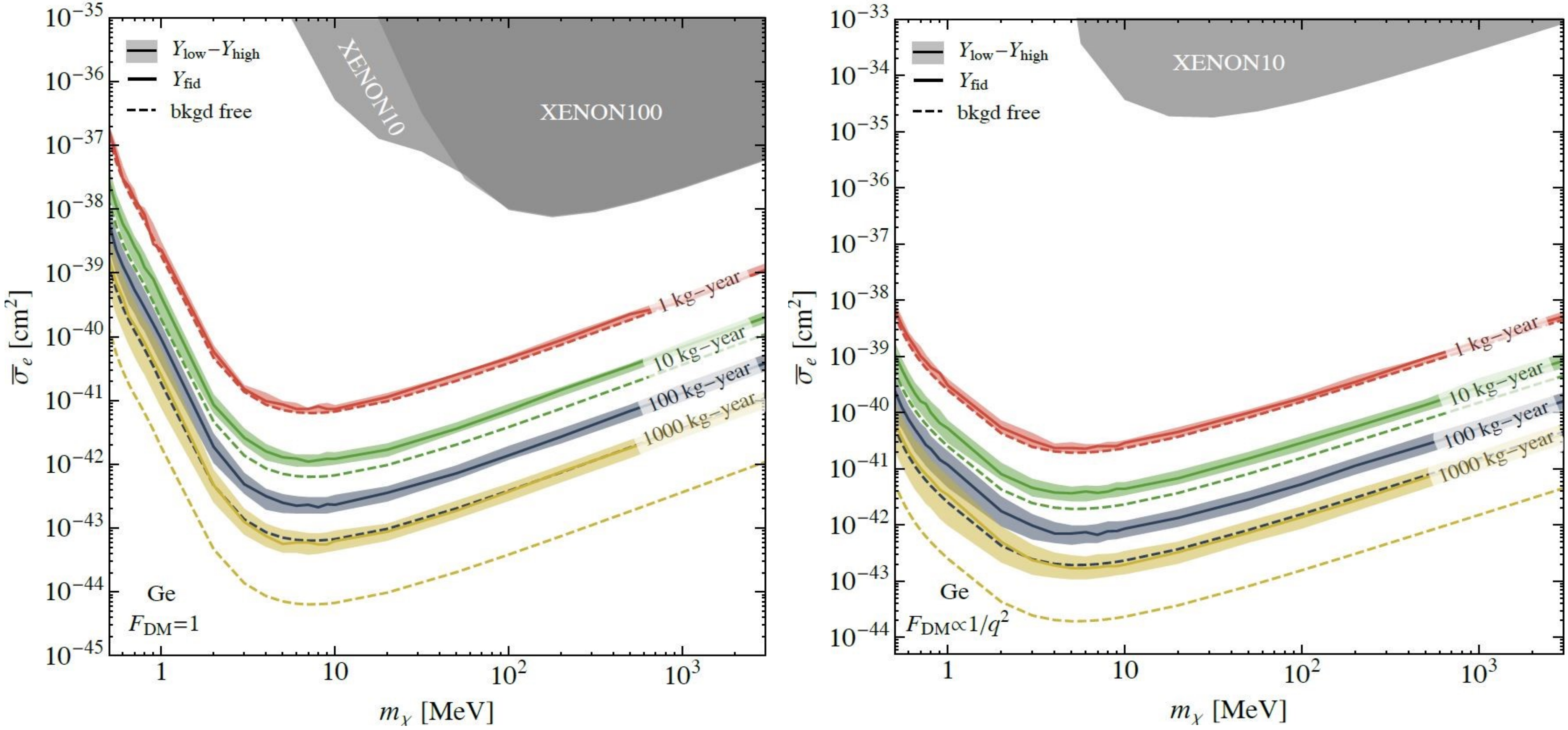
Minimize with respect to thresholds to get the threshold-independent discovery limit.

Discovery limits for silicon in the case of DM-electron scattering

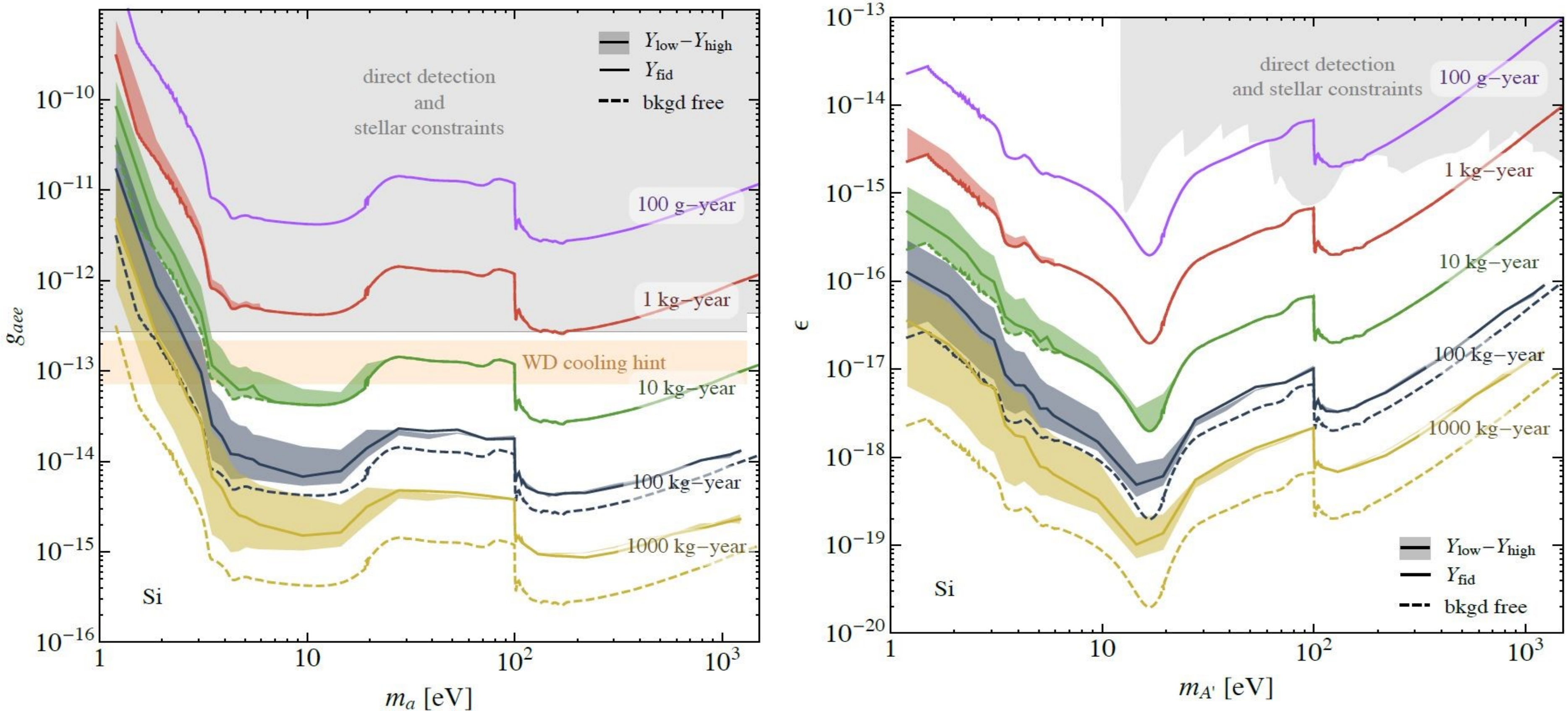




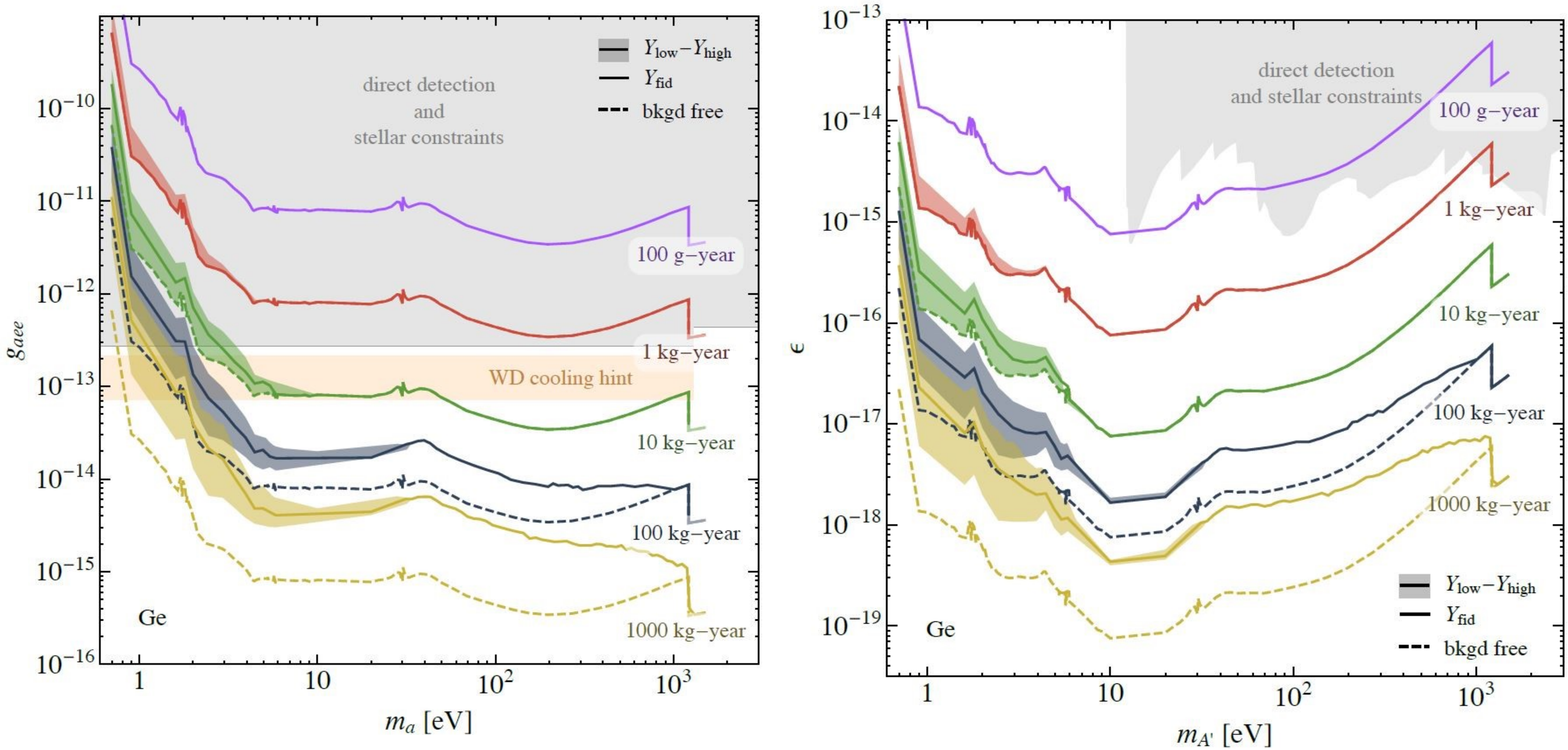
Discovery limits for germanium in the case of DM-electron scattering



Discovery limits for silicon in the case of DM-absorption signal



Discovery limits for germanium in the case of DM-absorption signal



Summary

- In the fiducial estimate, neutrinos will not be a background for sub-GeV DM-electron scattering signal in Si for exposures < 1.4 kg-years and in Ge for exposures < 0.8 kg-year
- Strong DM mass dependence in the saturation of the discovery limits in the case of DM-absorption
- No hard neutrino floor at least till 1000 kg-year exposures even with current neutrino flux uncertainties