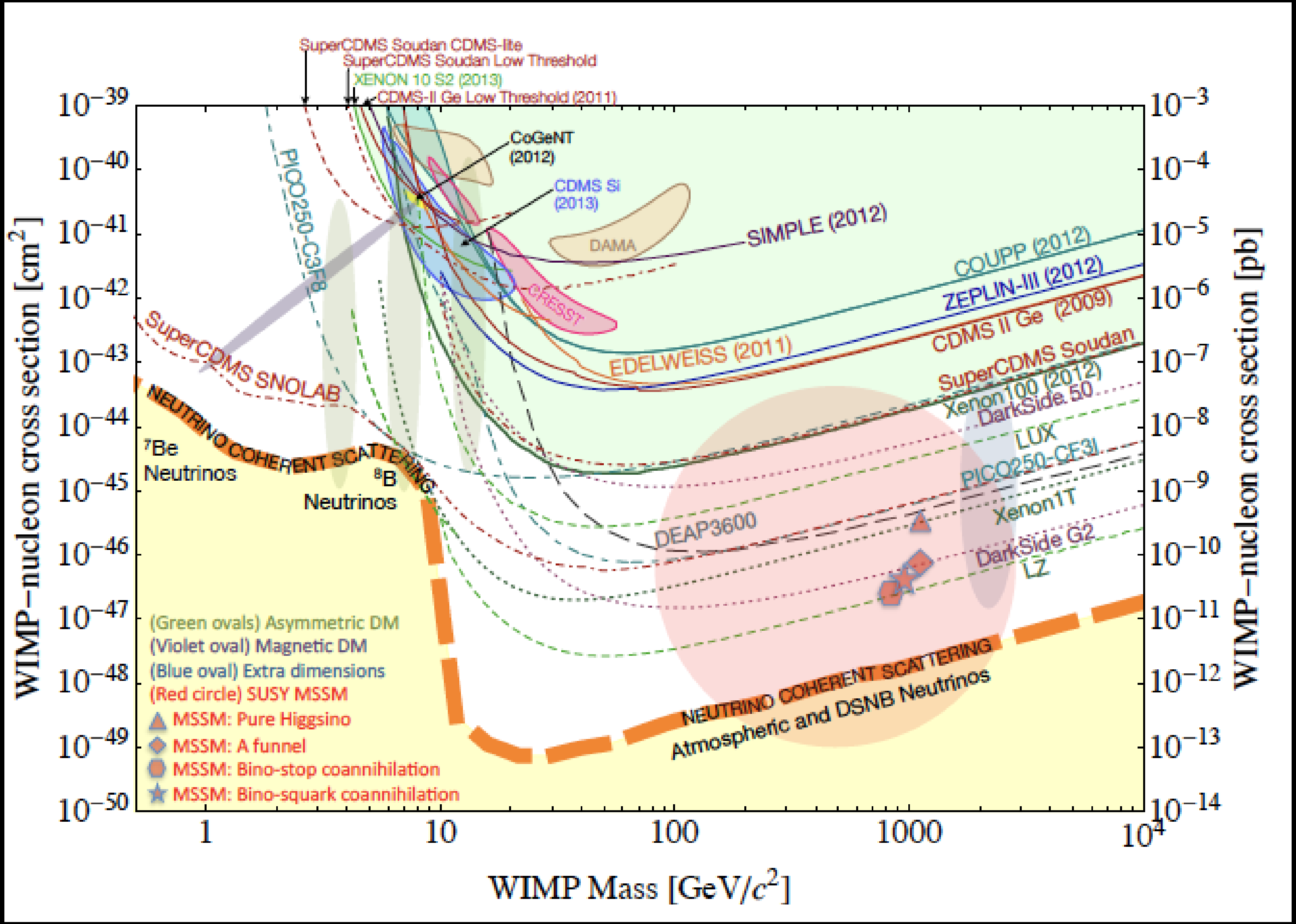
Strong New Limits on Light Dark Matter from Neutrino Experiments

Chris Cappiello

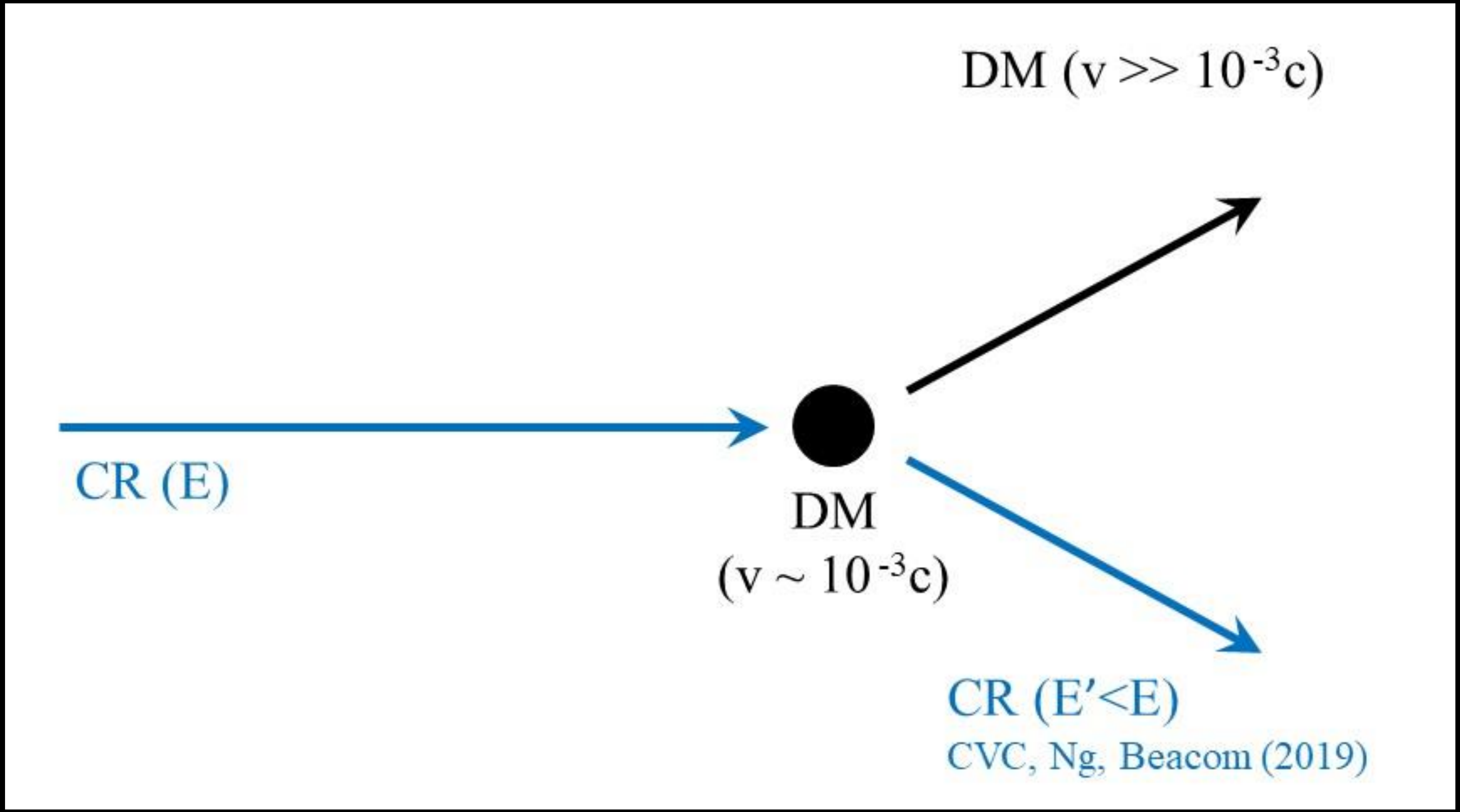
With John Beacom

Traditional Direct Detection Limits



ArXiv:1310.8327

Cosmic Ray Probes of Light Dark Matter



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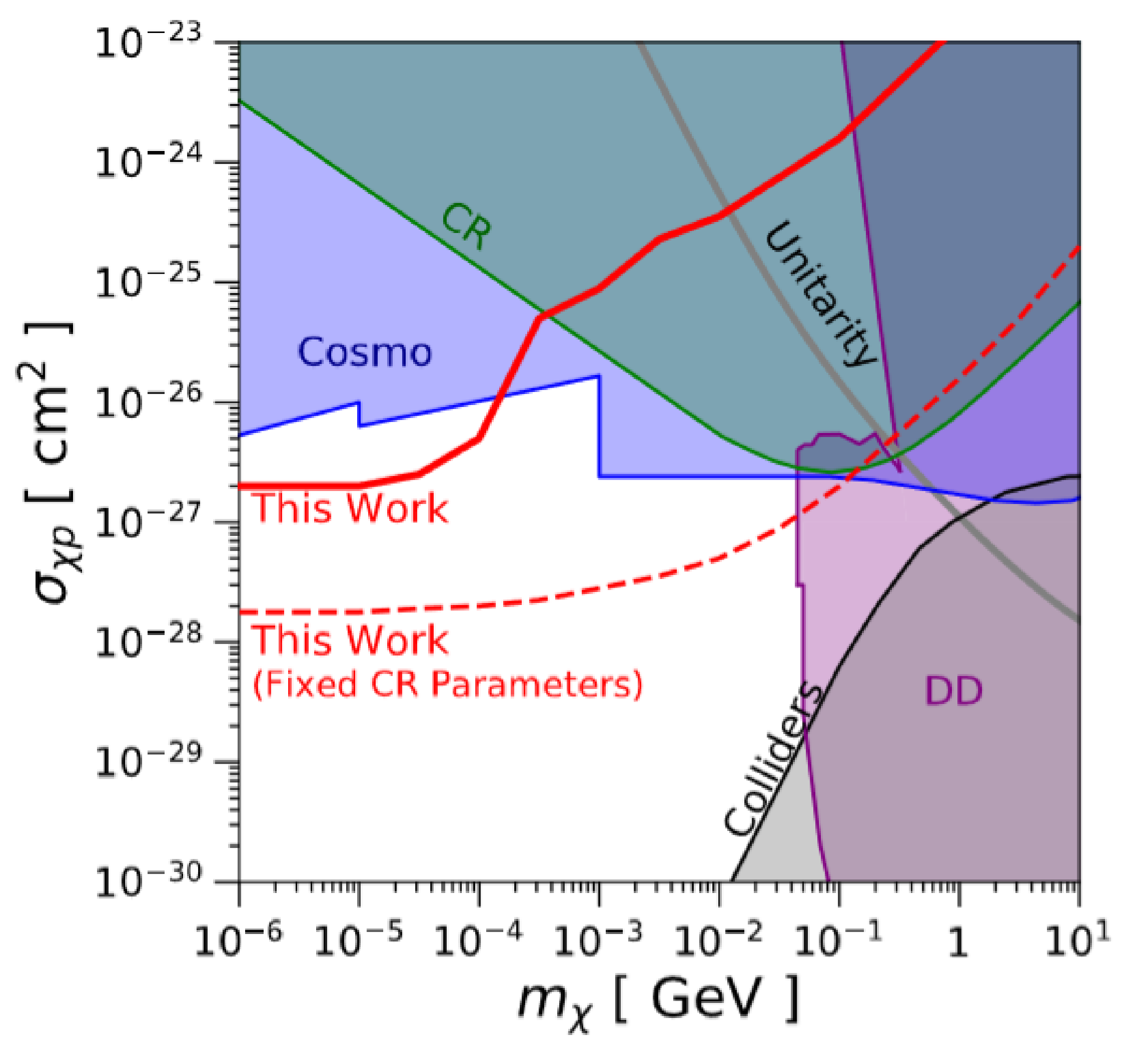
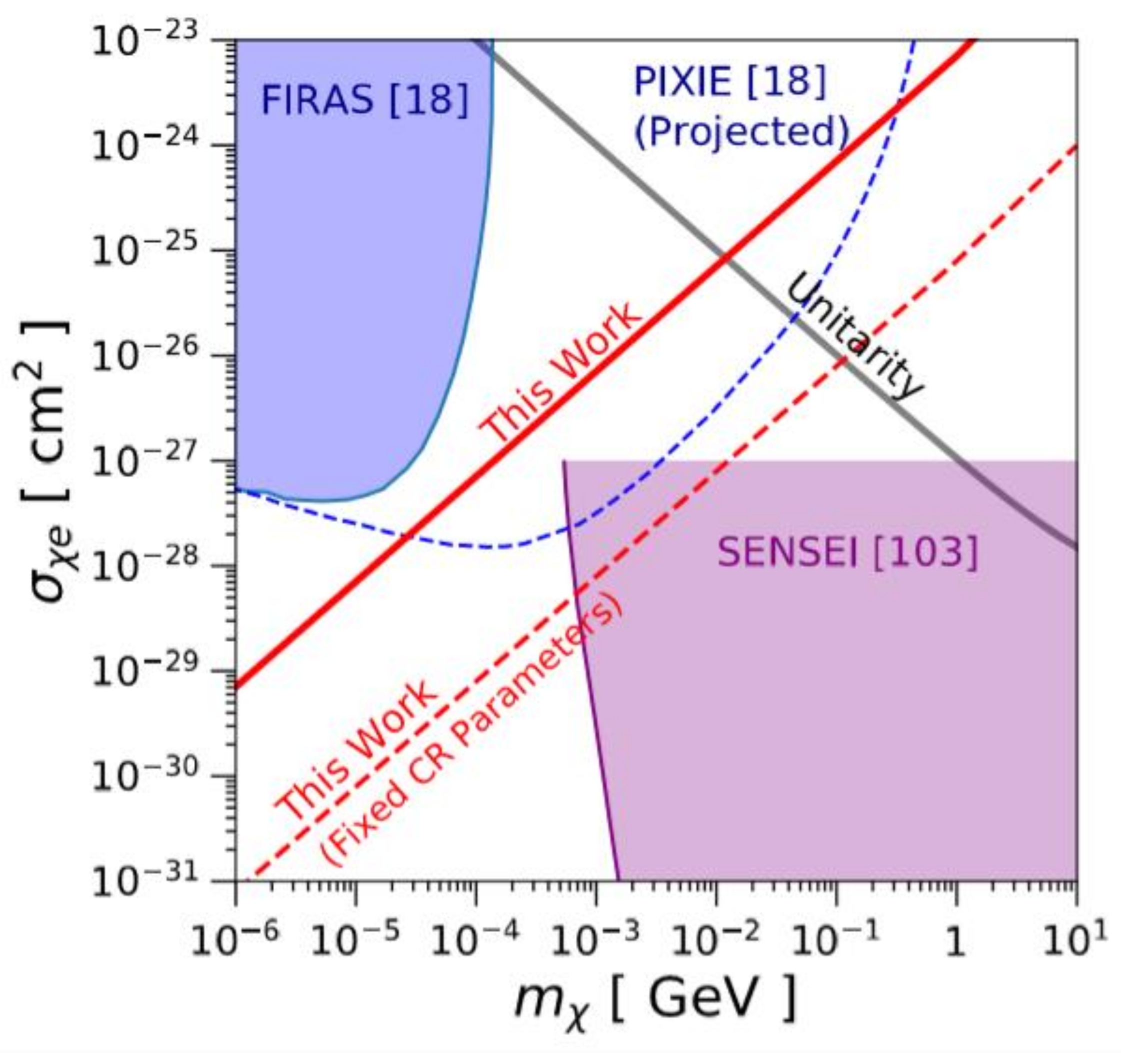
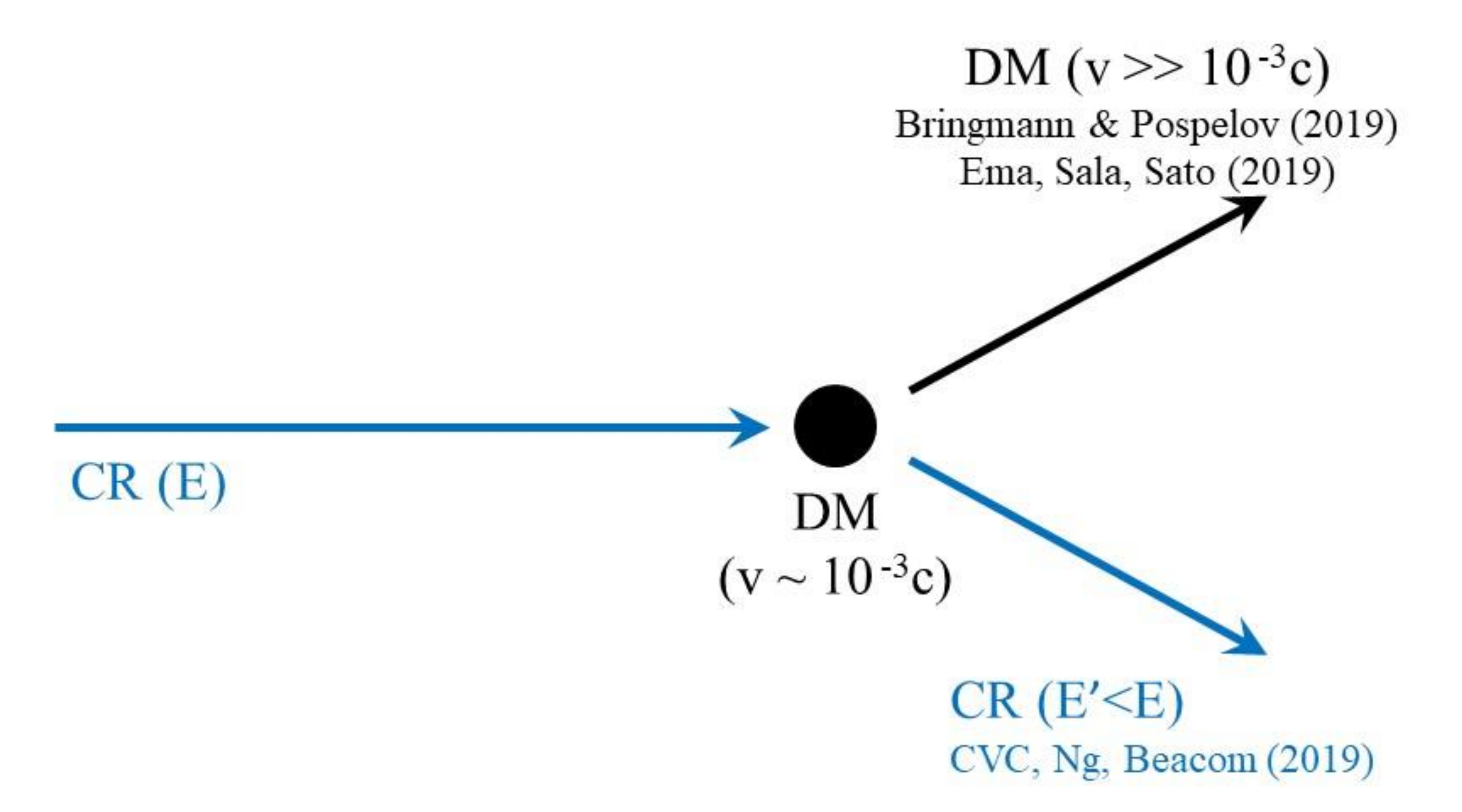




ArXiv:1810.07705

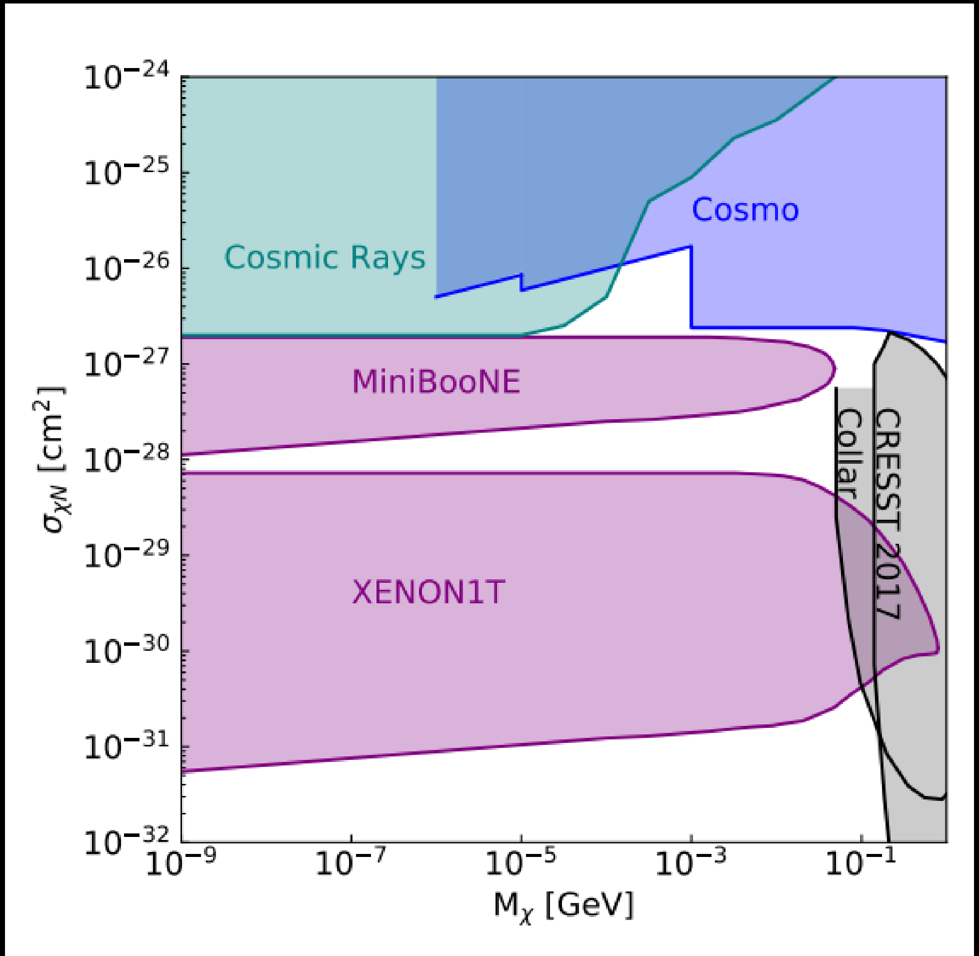
Cosmic Ray Probes of Light Dark Matter



CR-DM Constraints on Scattering with Nuclei

Previous Results (Bringmann & Pospelov)

- Assumed energy-independent cross section
- Recast XENON1T limits, but overburden leads to ceiling
- Search for proton recoils in MiniBooNE to probe higher cross section



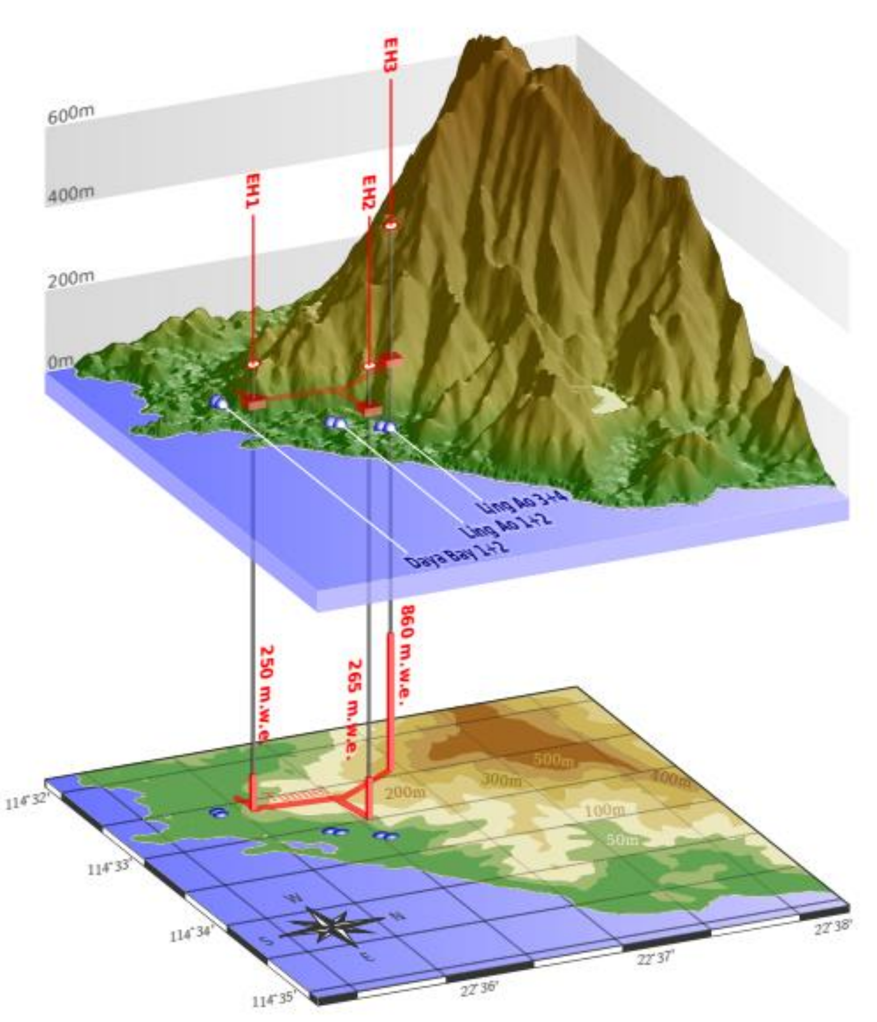
Adapted from ArXiv:1810.10543

Daya Bay

Antineutrino detectors distributed between three experimental halls with different overburdens

Shallowest detectors at depth of 250 mwe

Shallower than XENON1T, lower background than MiniBooNE

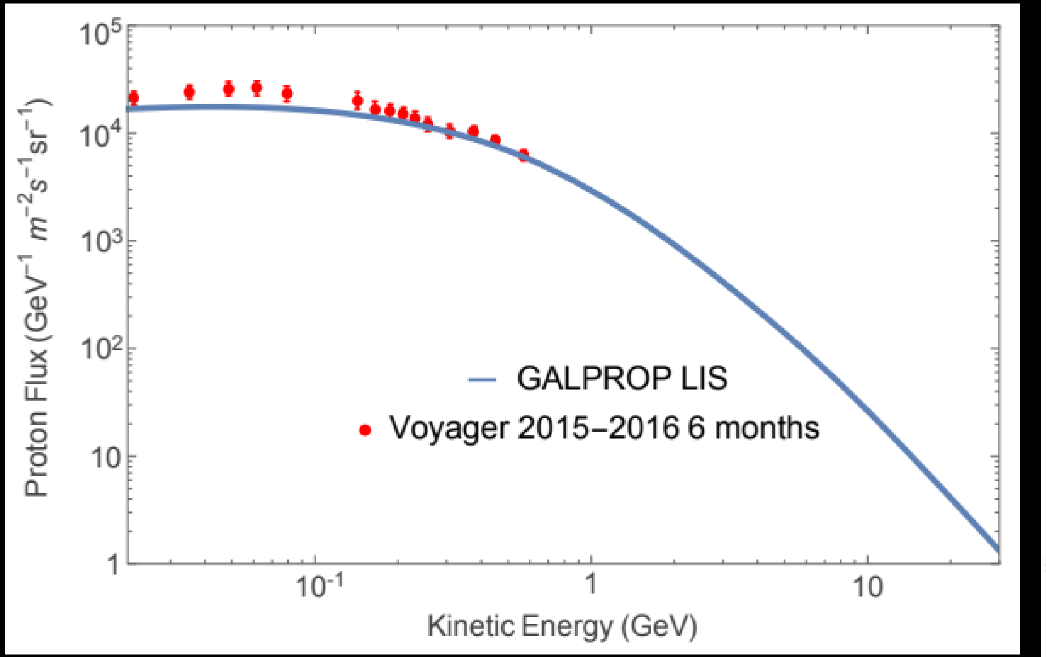


ArXiv:1708.01265

From Cosmic Rays to Dark Matter Detection

From Cosmic Rays to Dark Matter Spectrum

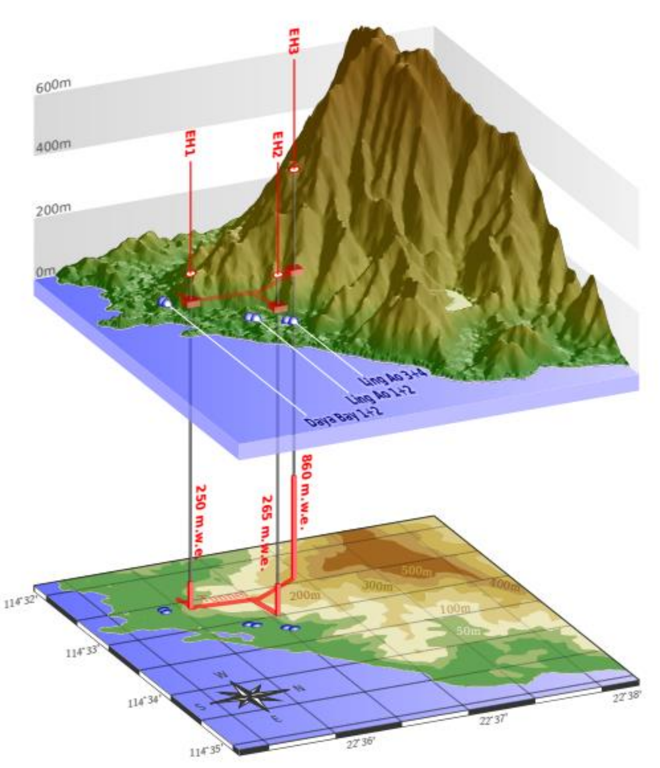
- NFW DM profile
- CR halo: h = 1 kpc, R = 10 kpc



ArXiv:1704.06337

Dark Matter Propagation Through Overburden

- Straight-line trajectory
- Continuous energy loss

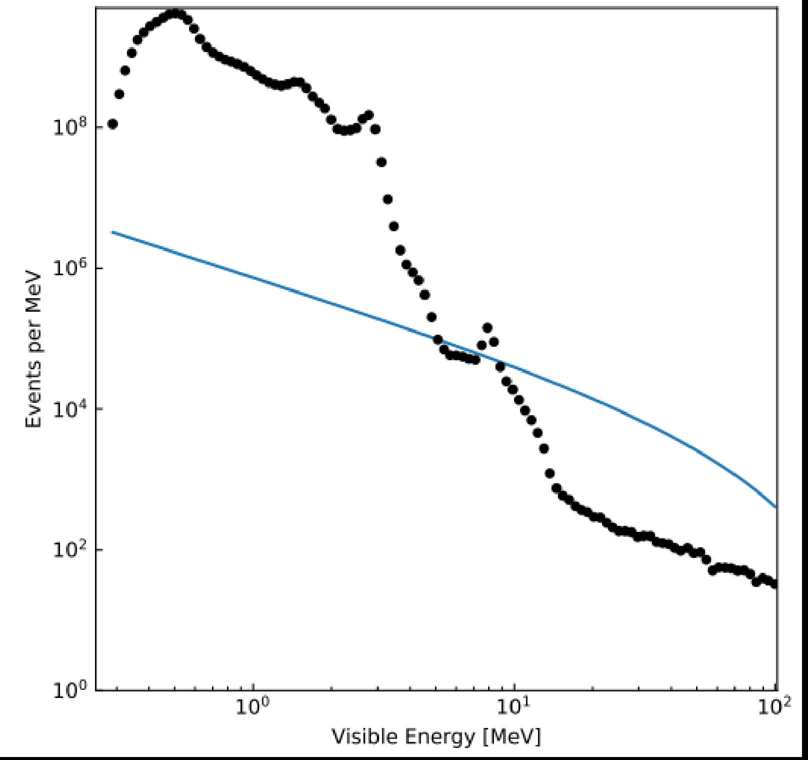


ArXiv:1708.01265

Compute Recoil Distribution

- Compare DM event rate to total measured rate

$\sigma = 10^{-28}$ cm^2, M_{DM} = 1 MeV



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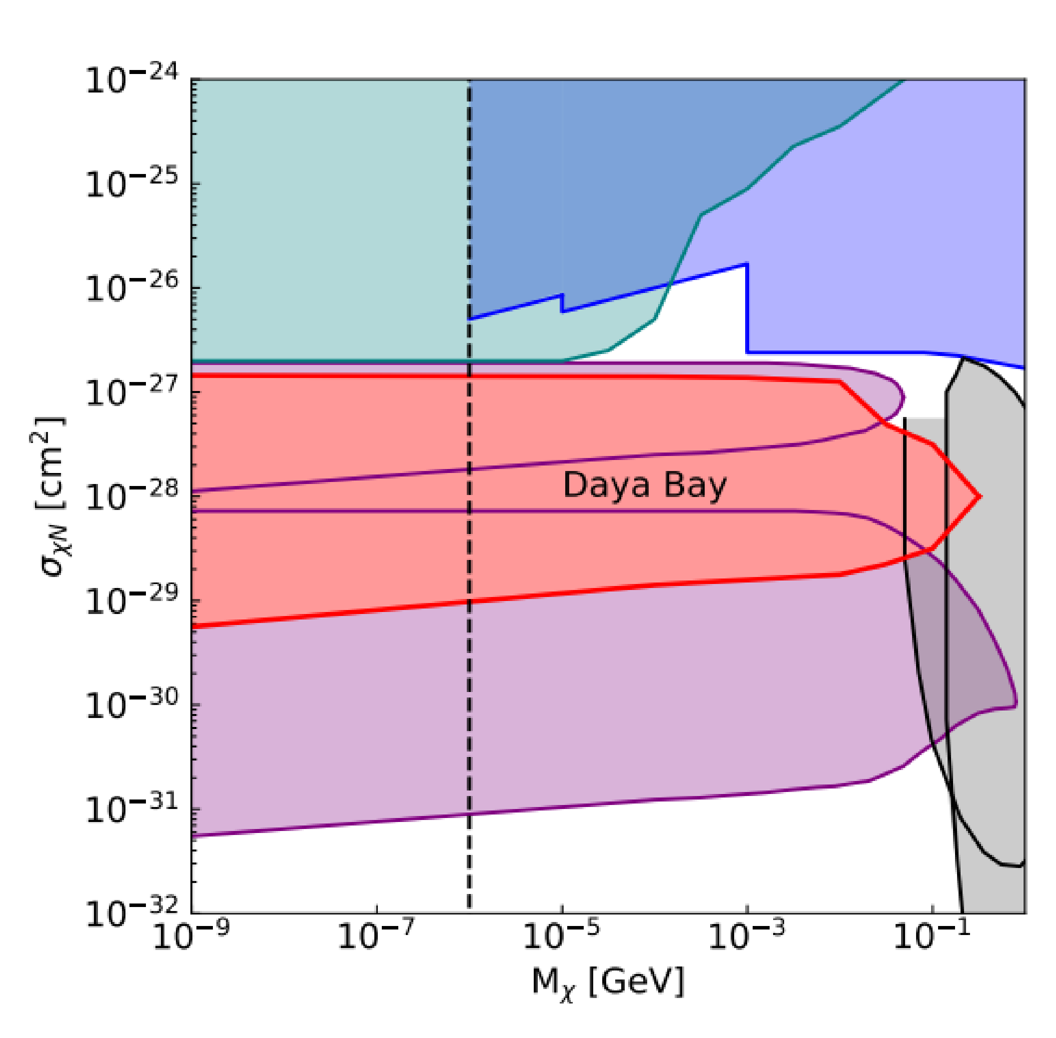


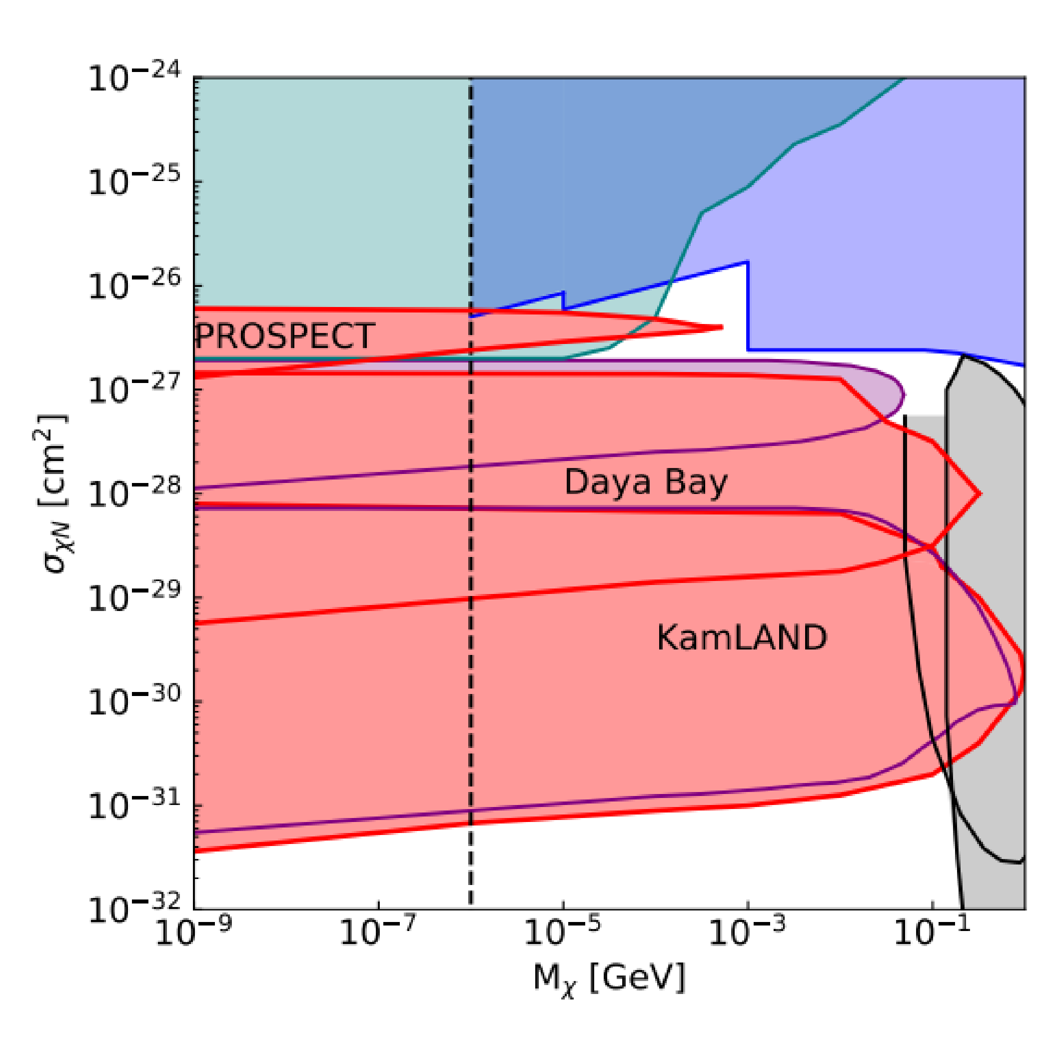
Further Constraints

PROSPECT

- Located at Earth's surface
- Can reach high cross section, but also high background

KamLAND

- 1 km underground, similar to XENON1T
- Low background, but also low ceiling



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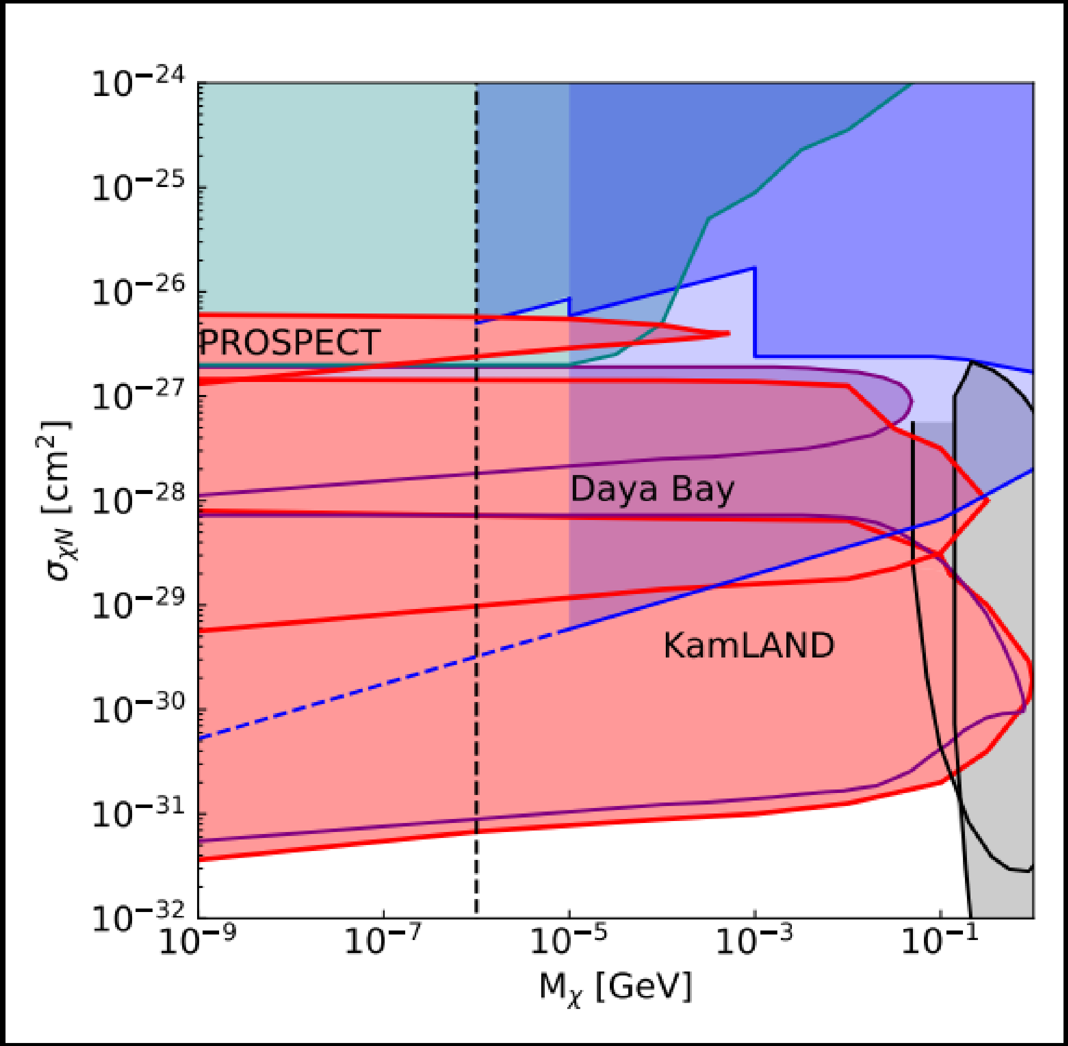
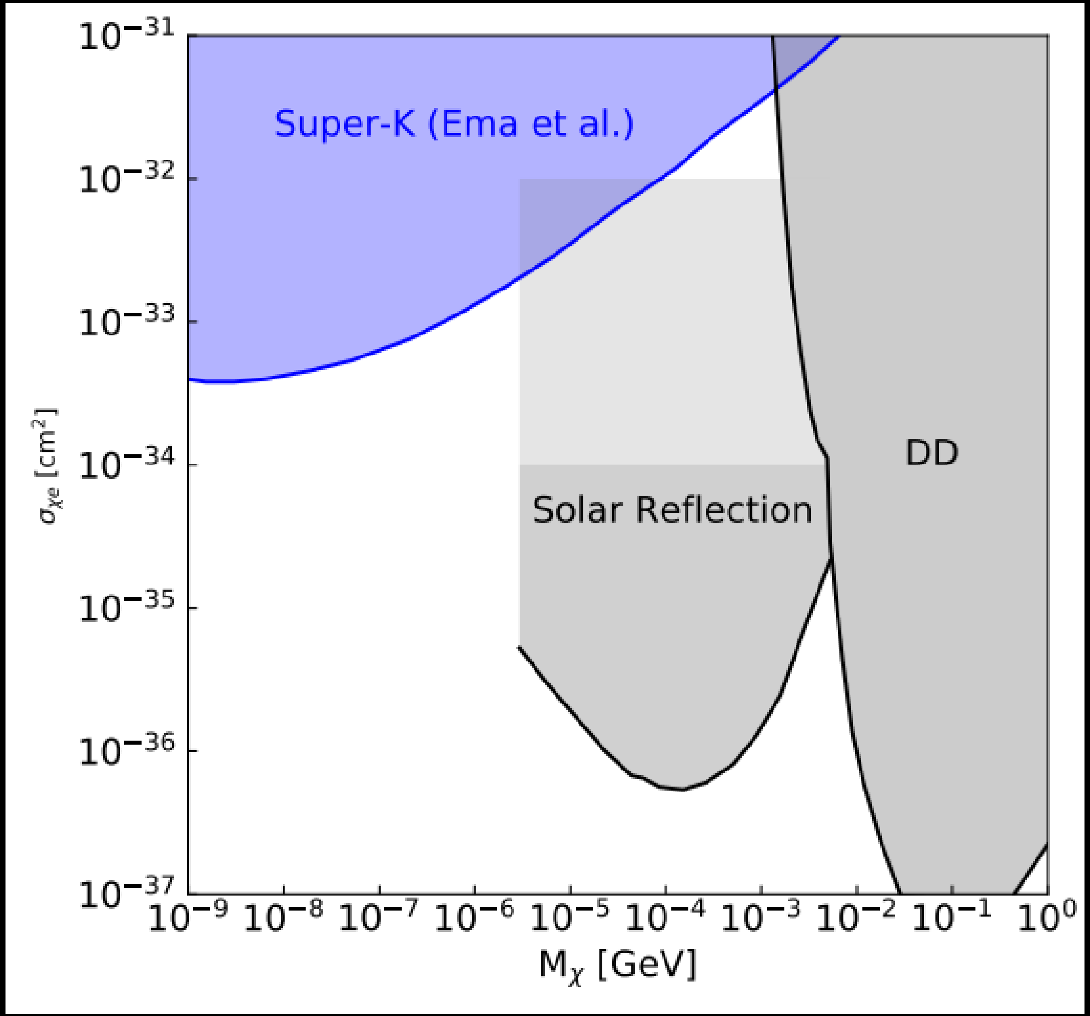


What About Electrons?

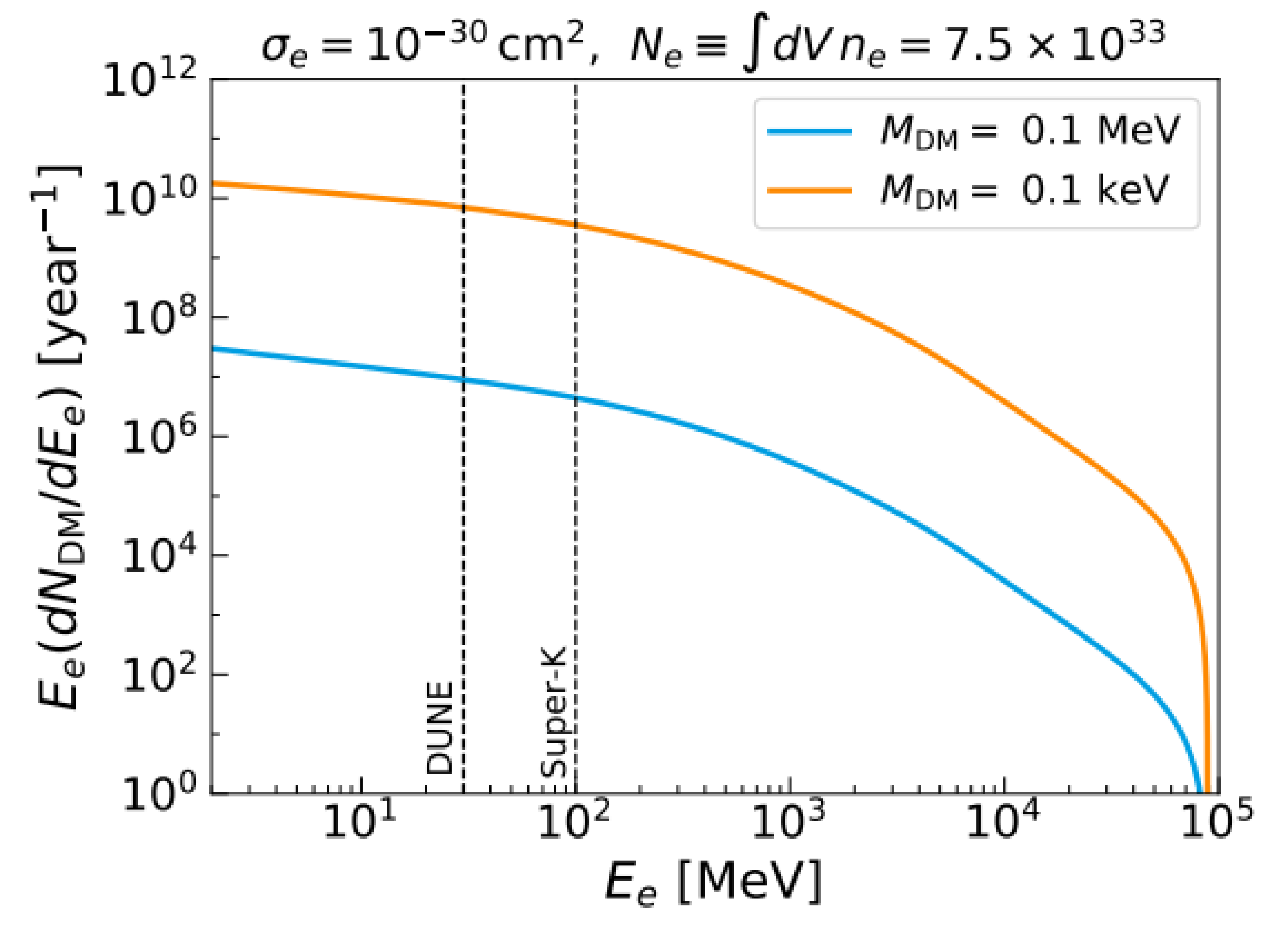
Previous Results (Ema et al.)

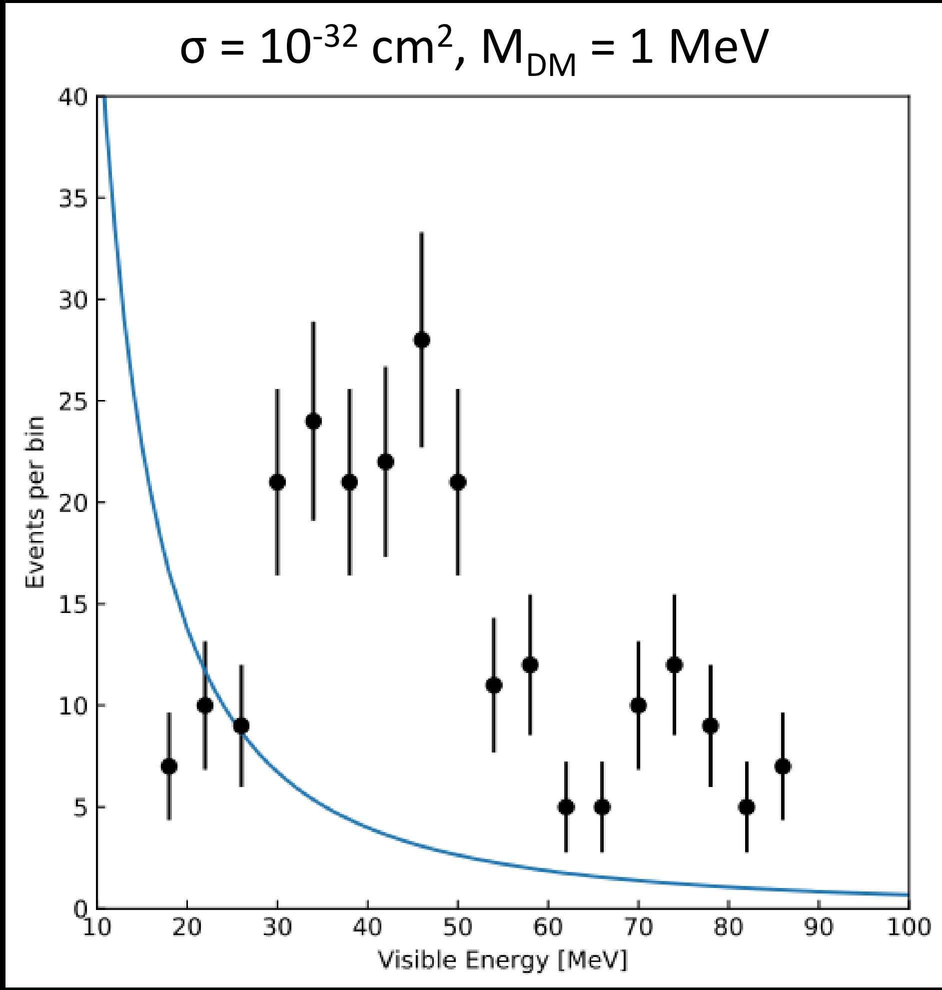
- Upscattered dark matter causes electron recoils in Super-Kamiokande
- Set constraints for mass down to 1 eV



Adapted from ArXiv:1811.00520

What About Electrons?





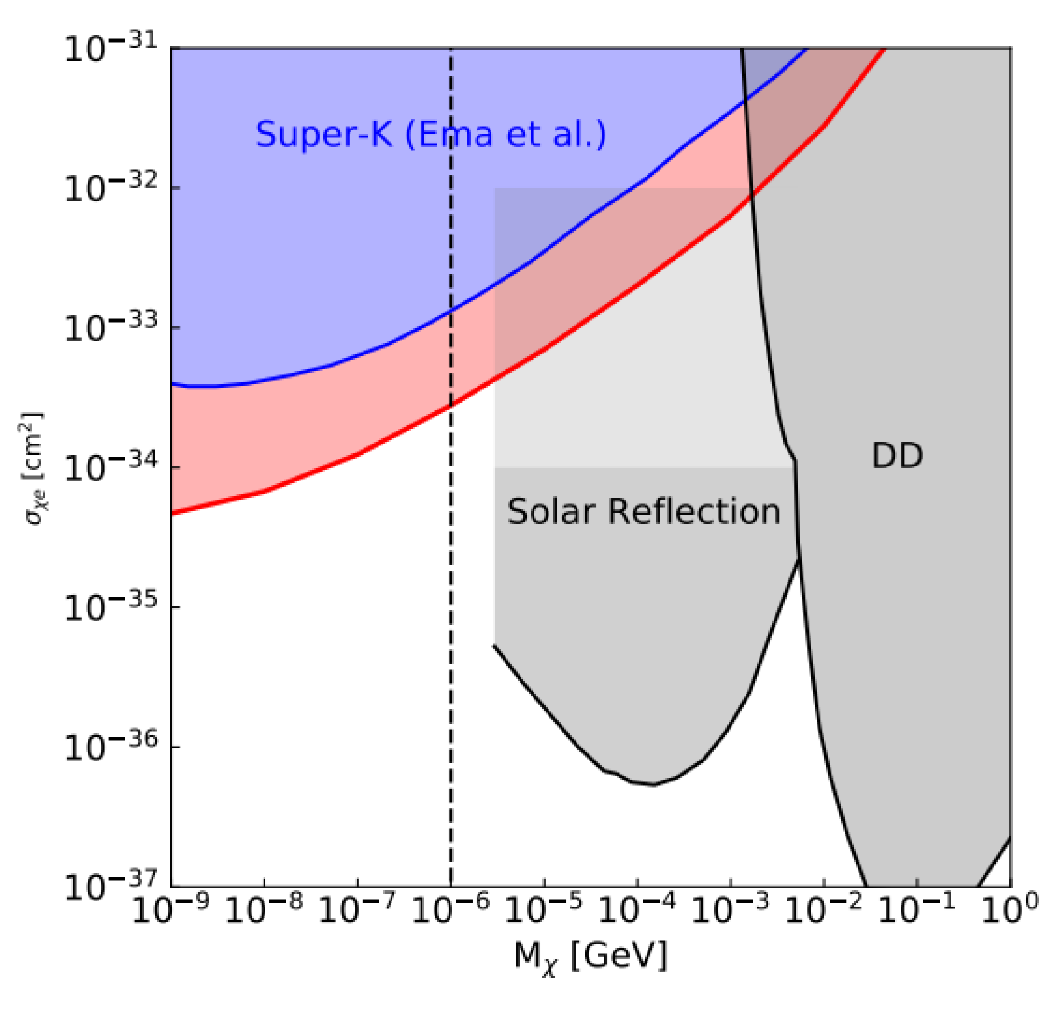
ArXiv:1811.00520

New Constraints from Super-Kamiokande

Recoil spectrum increases rapidly at lower energy

Lower energy gives higher signal/background

Improve sensitivity by close to an order of magnitude



Summary

Cosmic ray-dark matter scattering can be a powerful probe of dark matter, and only gets more powerful as more data is considered

Considering different detector depths allows us to probe different cross sections

Considering different energy range can improve signal/background

From Cosmic Rays to Dark Matter Spectrum

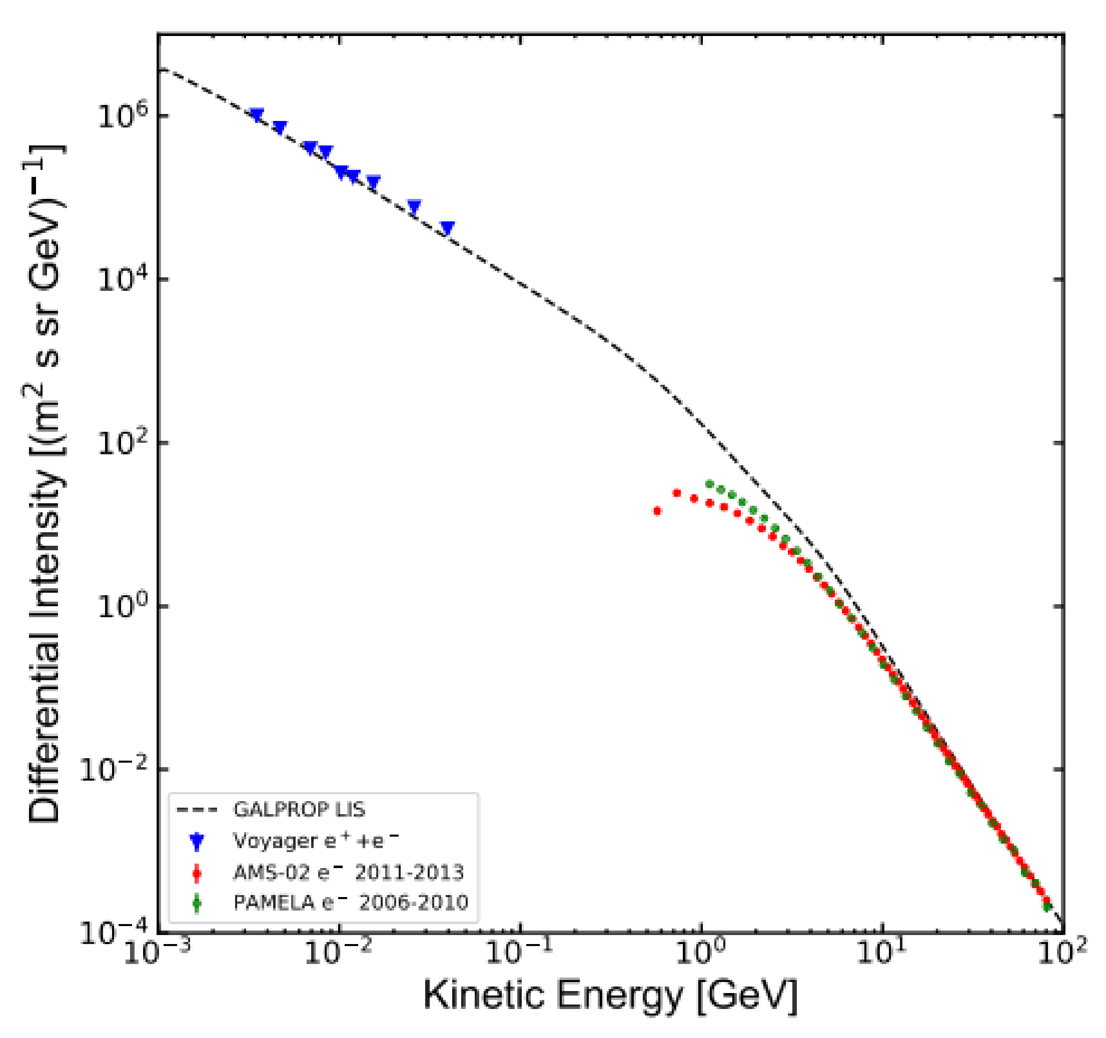
$$\frac{d\Phi_\chi}{dT_i} = \int \frac{d\Omega}{4\pi} \int_{l.o.s.} dl\, \sigma_{\chi i} \frac{\rho_\chi}{m_\chi} \frac{d\Phi_i}{dT_i}$$

$$\frac{d\Phi_\chi}{dT_\chi} = \int_0^\infty dT_i \frac{d\Phi_\chi}{dT_i} \frac{1}{T_\chi^{\max}(T_i)} \Theta[T_\chi^{\max}(T_i) - T_\chi]$$

$d\phi_i/dT_i$ is local interstellar CR spectrum (LIS)

Integrate over dark matter density distribution times CR spectrum

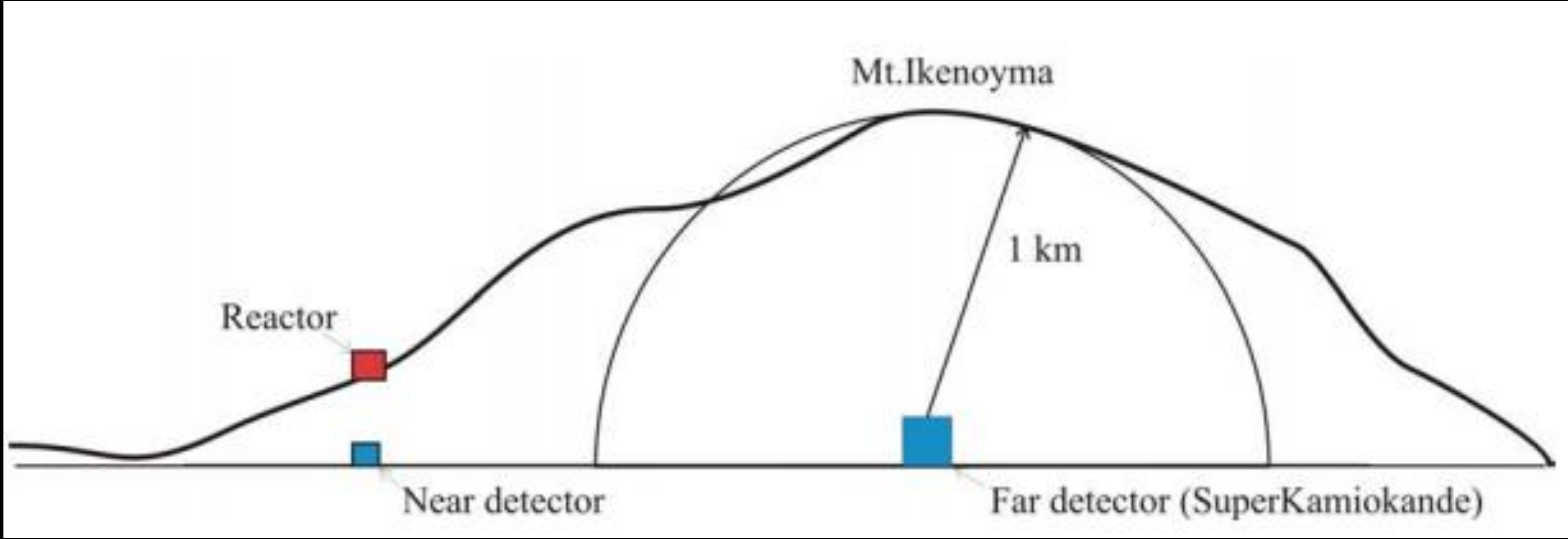
Integrate over all directions to get incoming dark matter flux



ArXiv:1801.04059

Propagation Through Overburden

$$\frac{dT_\chi}{dx} = -\frac{1}{2}\sum_i n_i \sigma_{\chi i} T_r^{\max}$$



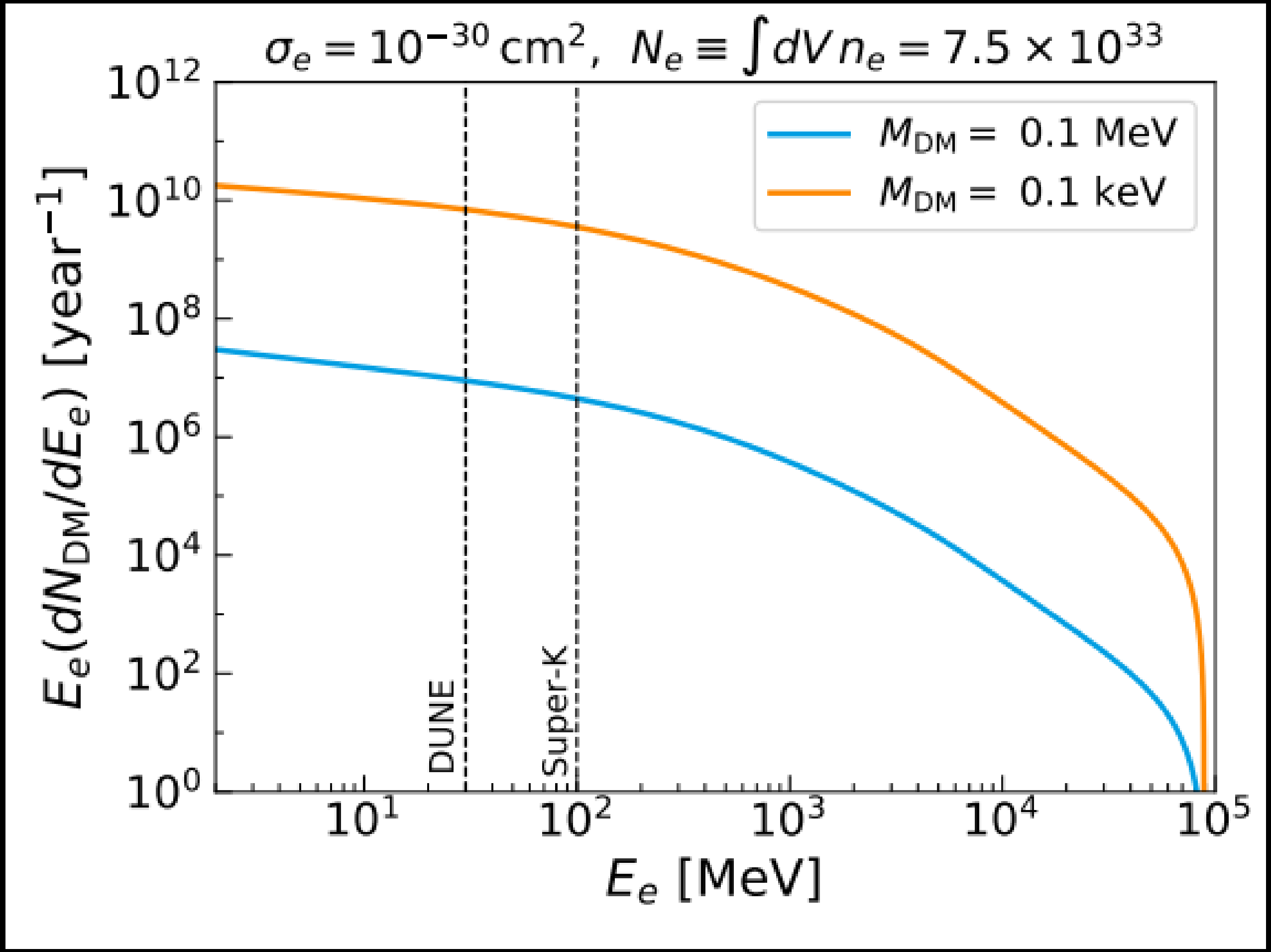
ArXiv:hep-ph/0311181

Detected Recoil Distribution

$$\frac{d\Gamma}{dT_i} = \sigma \int_{T_\chi^{\min}}^{\infty} dT_\chi \, \frac{1}{T_i^{\max}} \frac{d\Phi_\chi^z}{dT_\chi}$$

$d\phi_x^z/dT_x$ is dark matter spectrum at depth z

Integrate over energy to get differential recoil rate



ArXiv:1811.00520