Cosmic Ray-Boosted Dark Matter at IceCube

Christopher Cappiello

Based on arXiv:2405.00086 (**CC**, Qinrui Liu, Gopolang Mohlabeng, Aaron Vincent)

TeVPA 2024, August 27, 2024

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See talk on Wednesday

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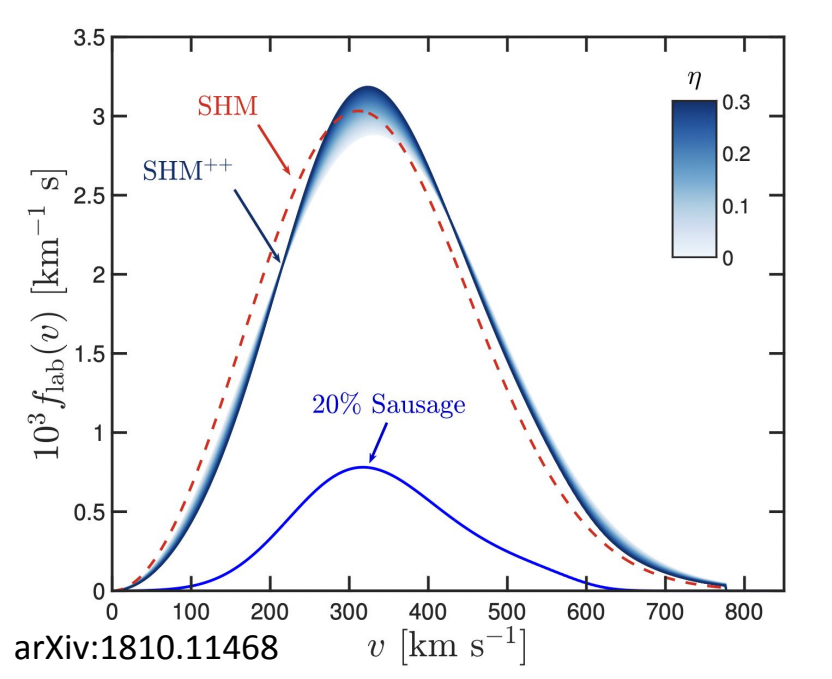
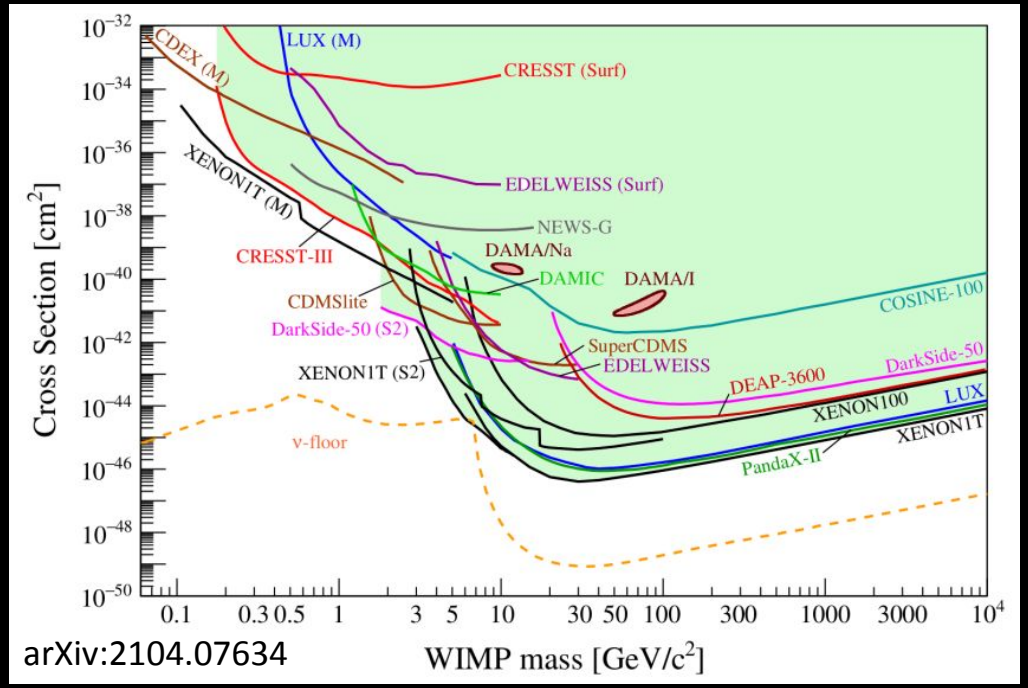
TeVPA 2024, August 27, 2024

What is Dark Matter's Velocity?

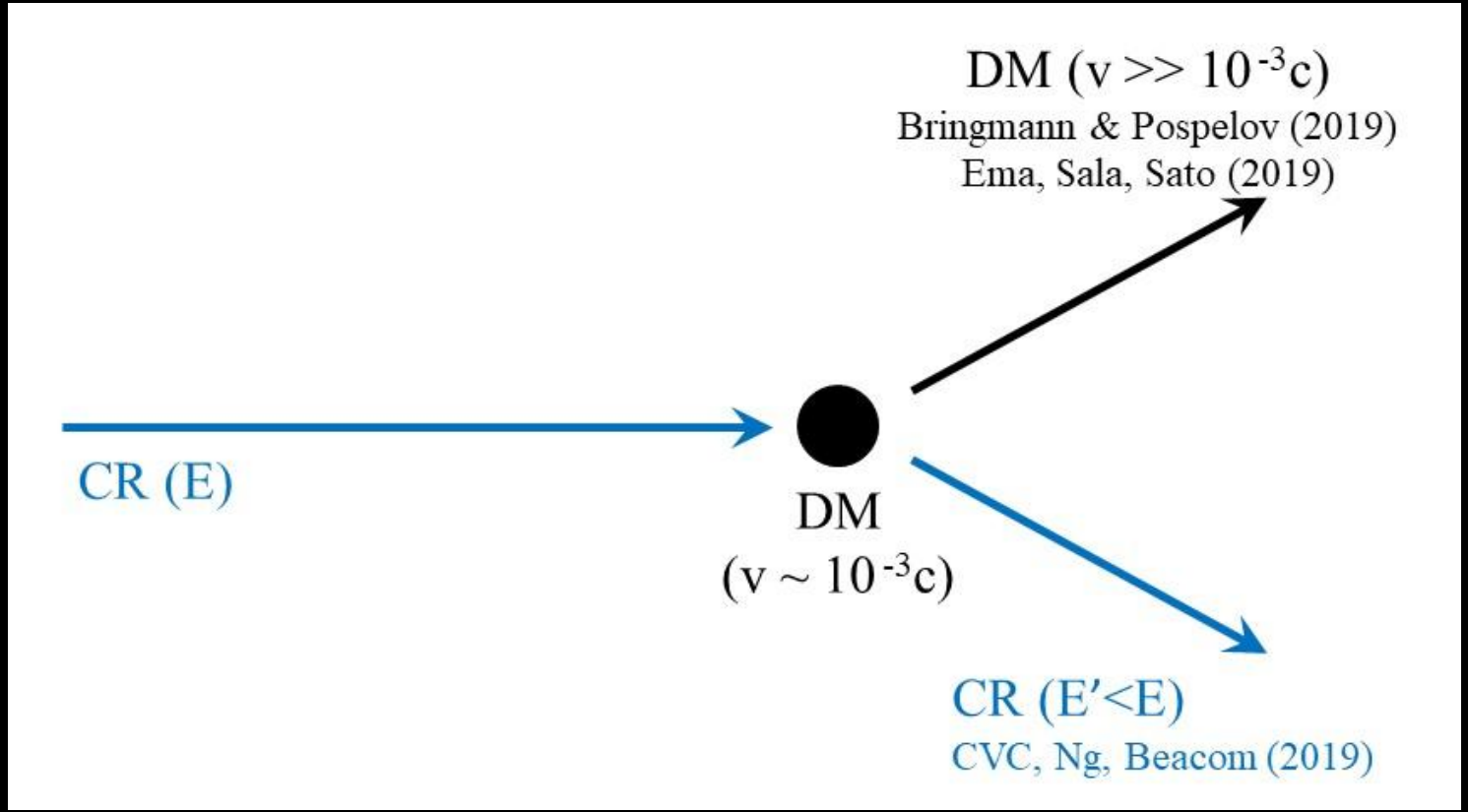


arXiv:1810.11468

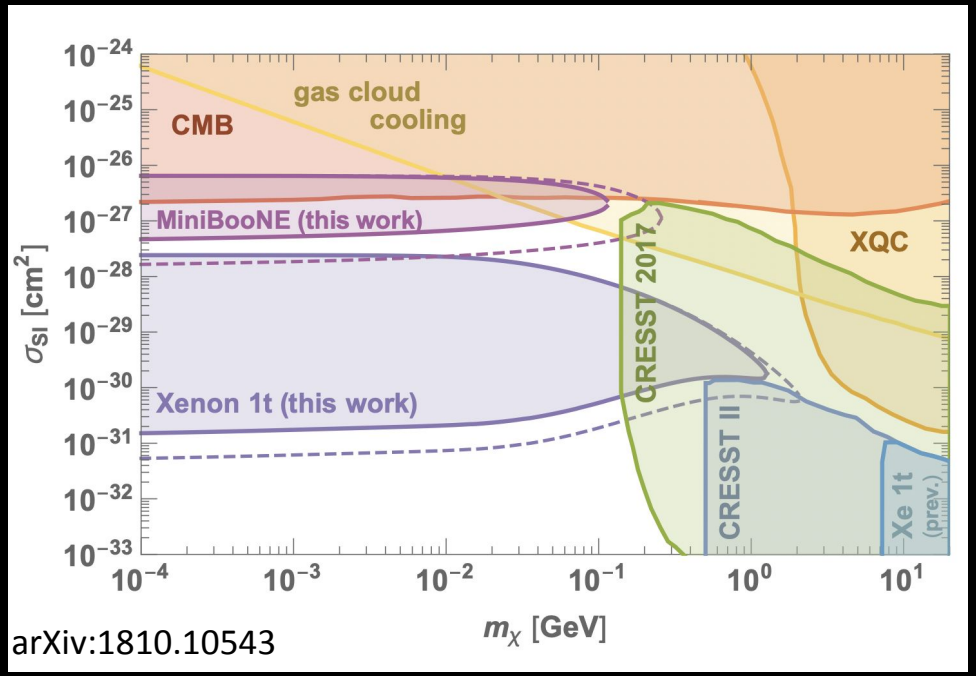


arXiv:2104.07634

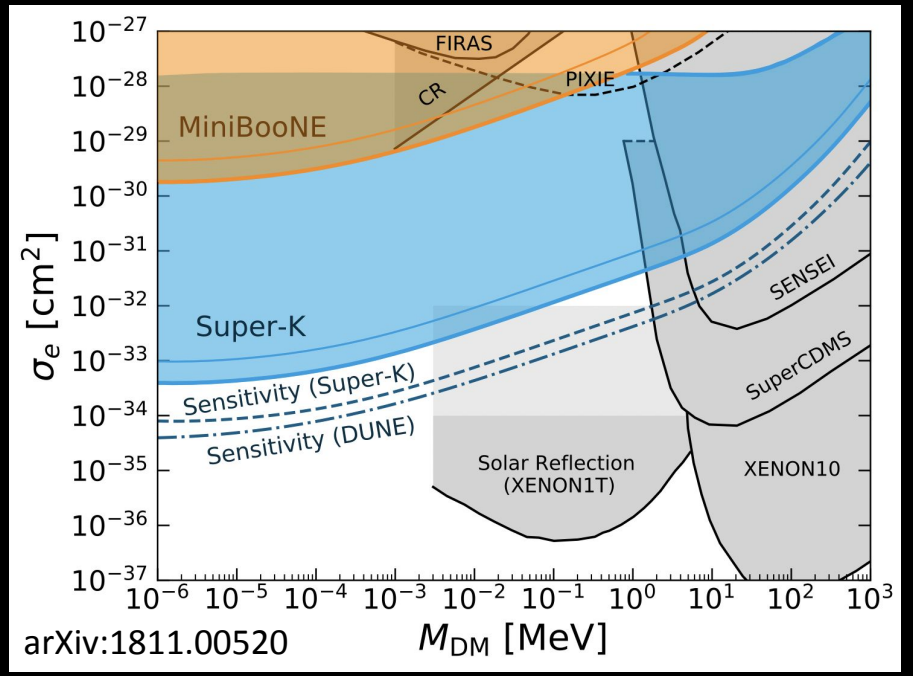
Cosmic Ray Upscattered Dark Matter



Cosmic Ray Upscattered Dark Matter

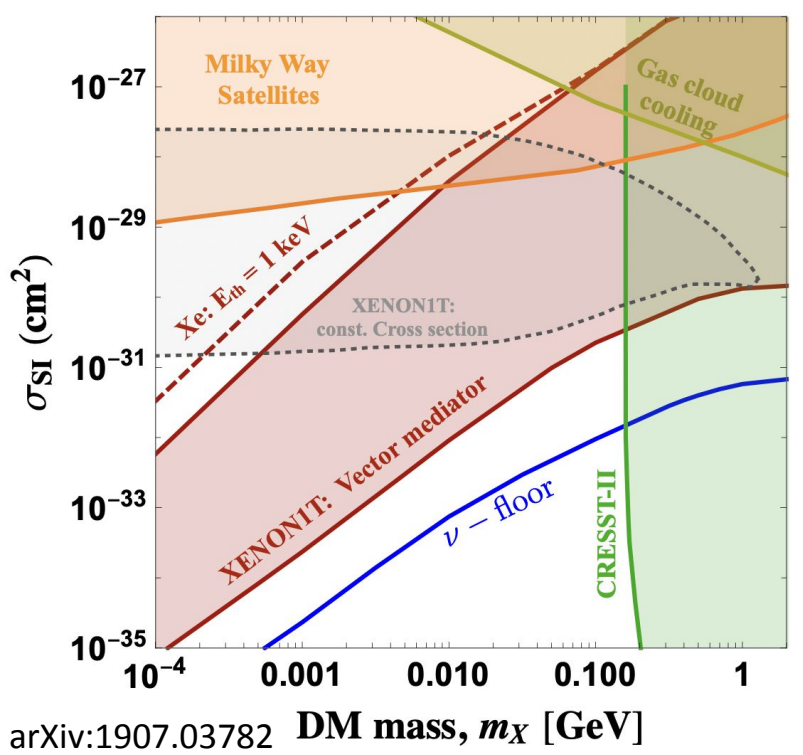


arXiv:1810.10543

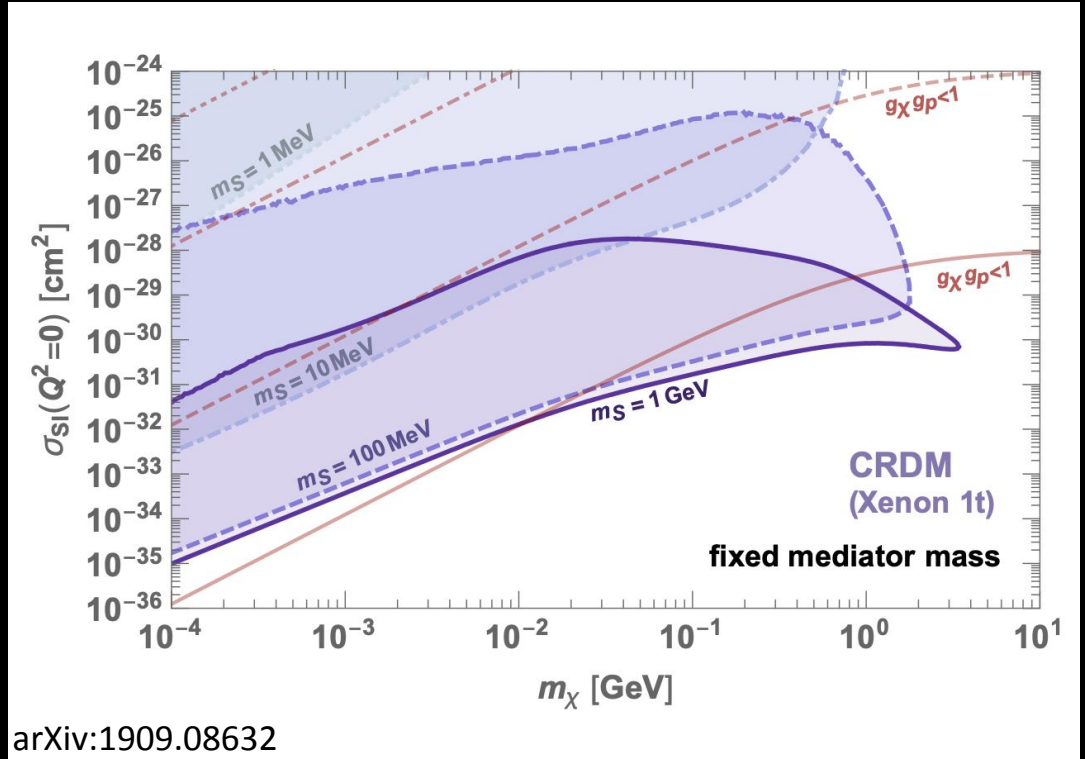


arXiv:1811.00520

Simplified Models For Cosmic Ray DM

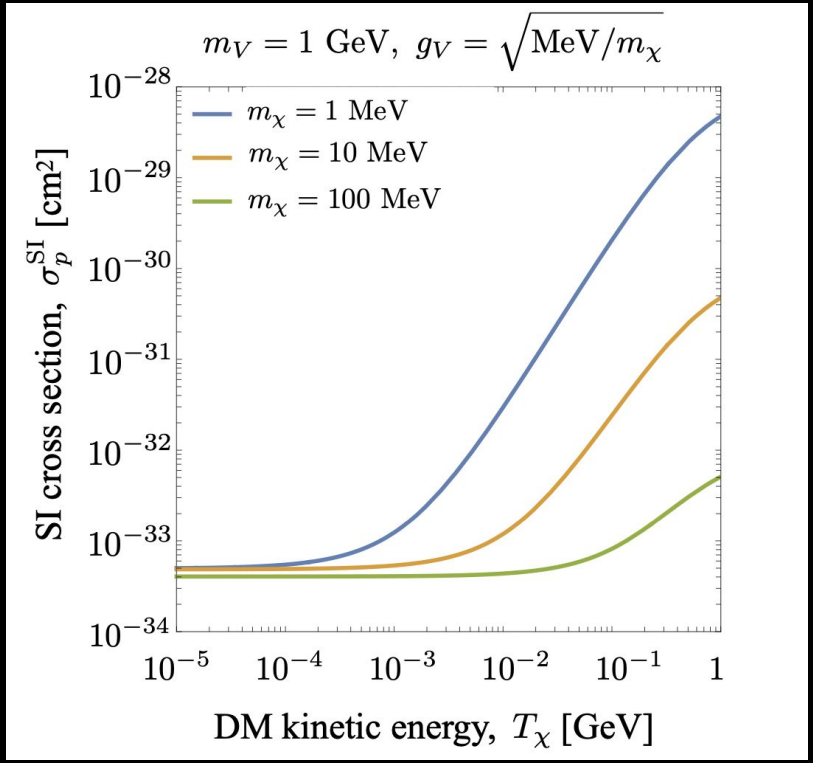


arXiv:1907.03782



arXiv:1909.08632

Simplified Models: Energy Scaling



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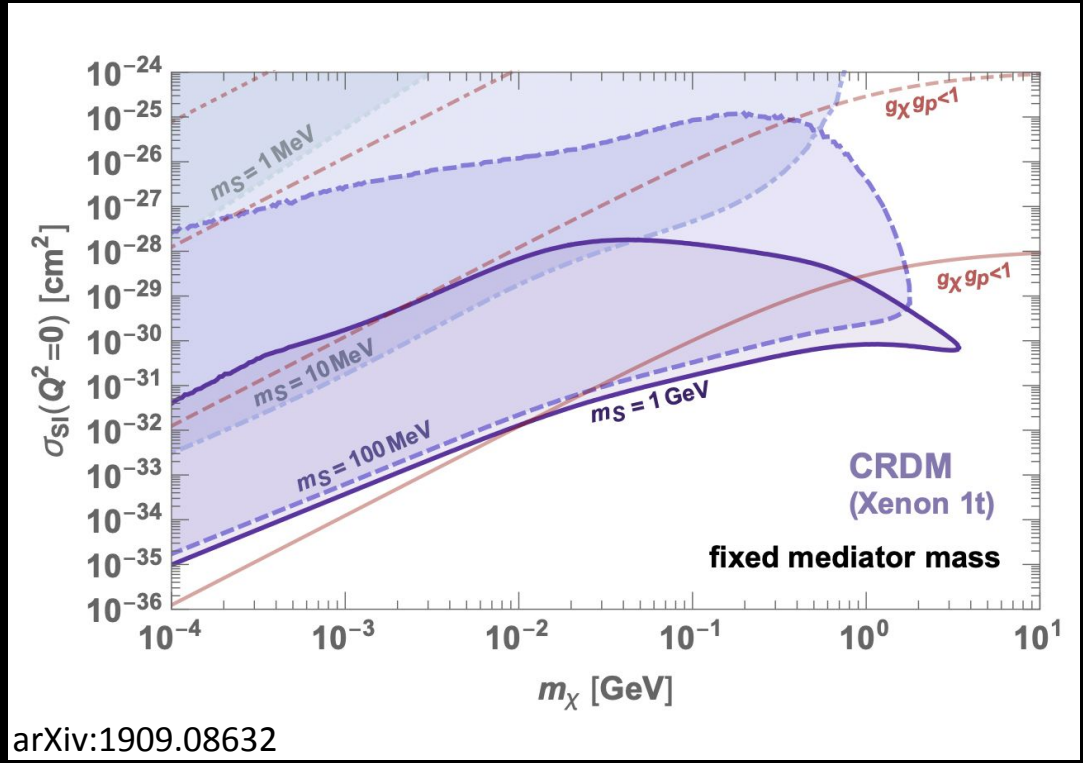

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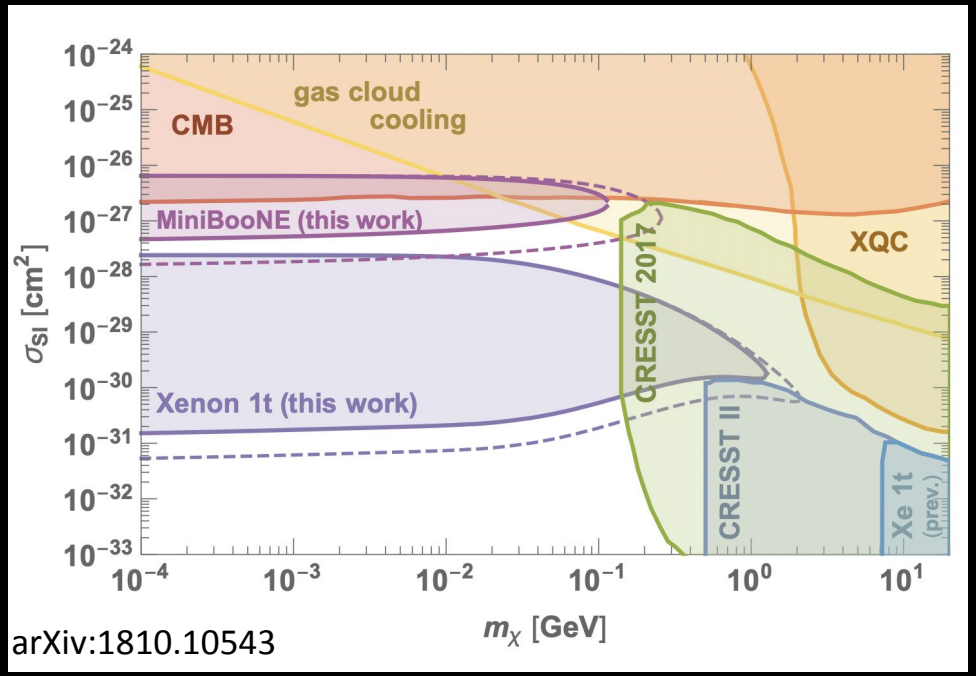

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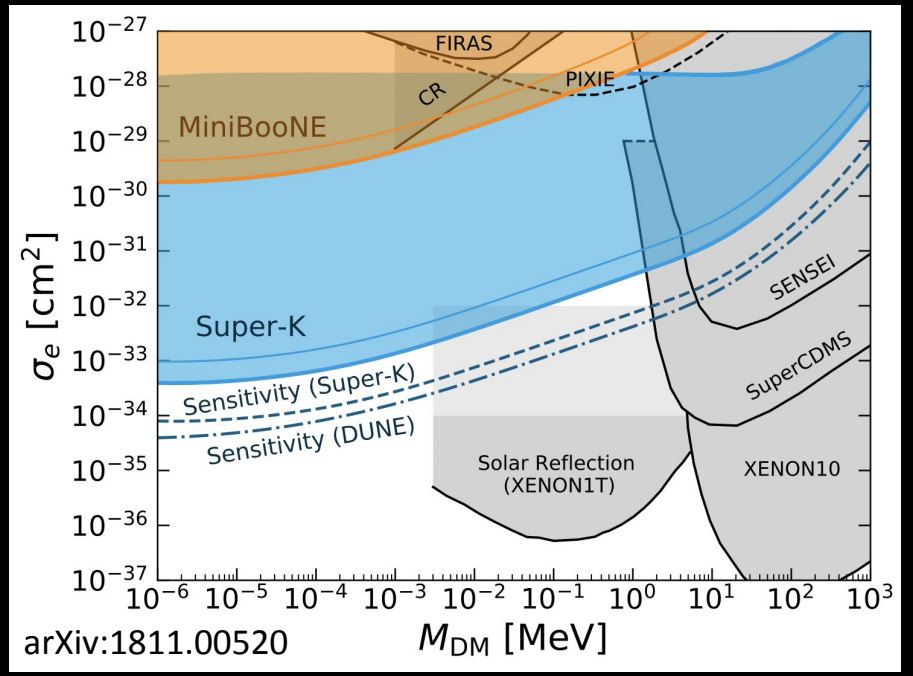

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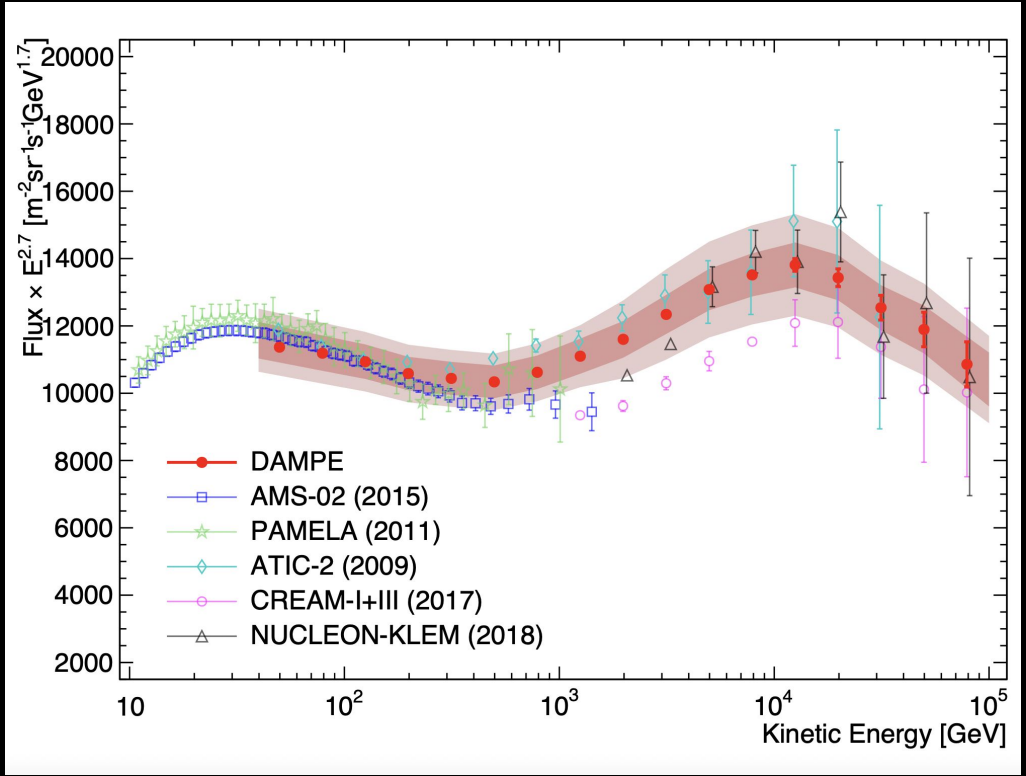
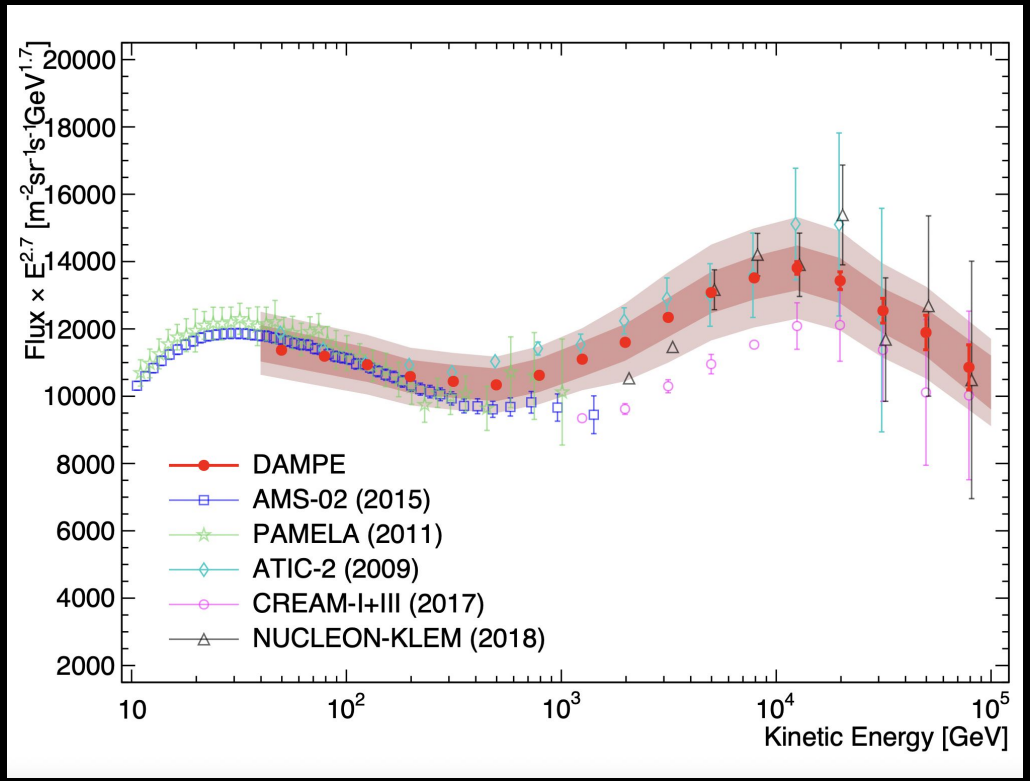
Simplified Models: Energy Scaling

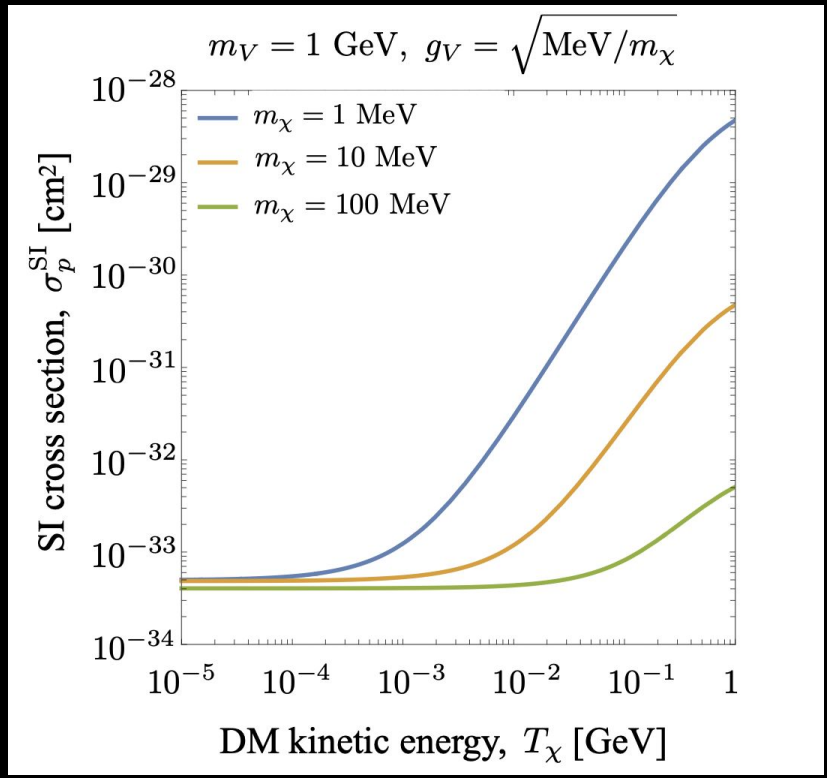


arXiv:1909.12860

Simplified Models: Energy Scaling

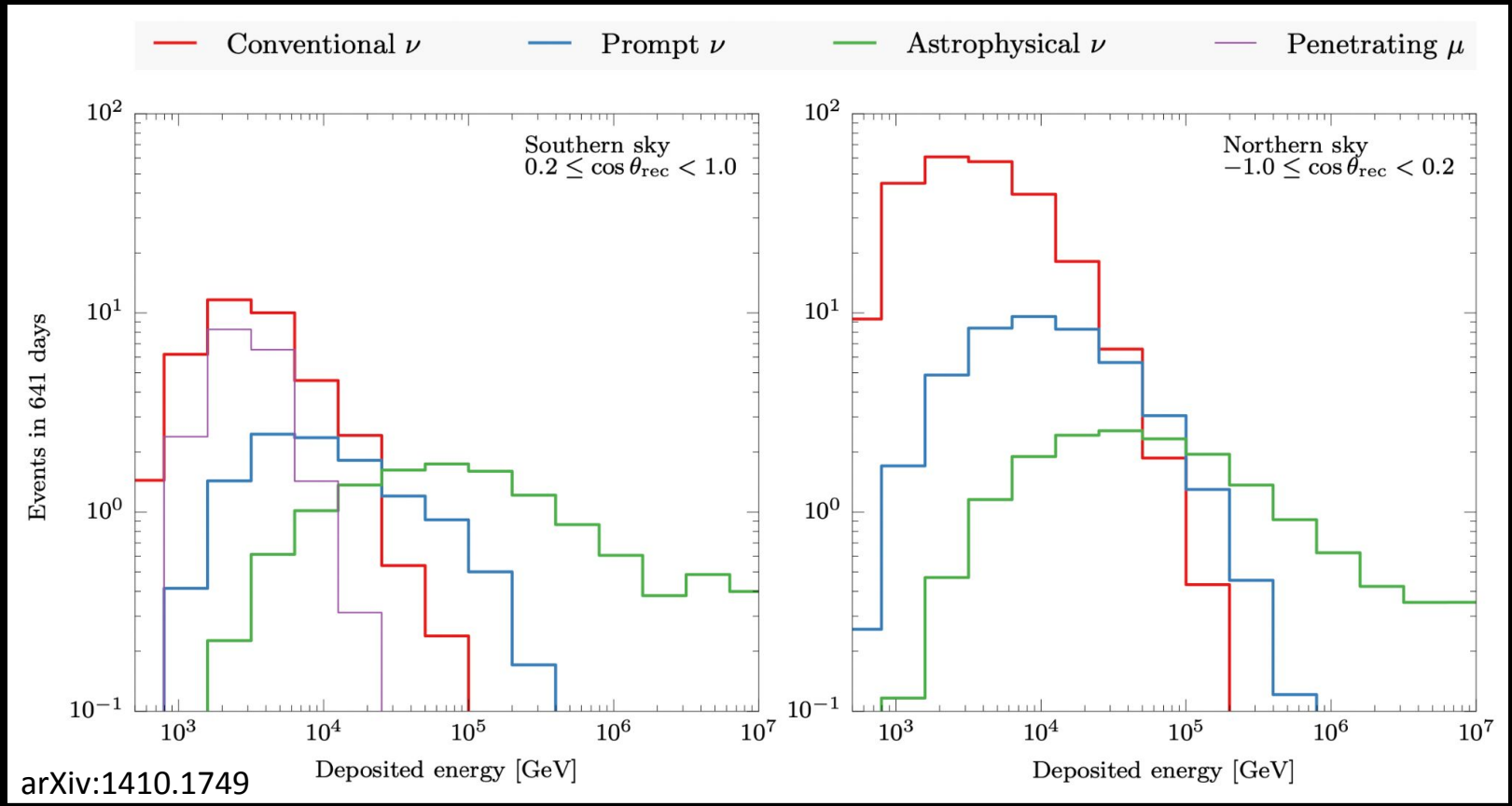


arXiv:1909.12860



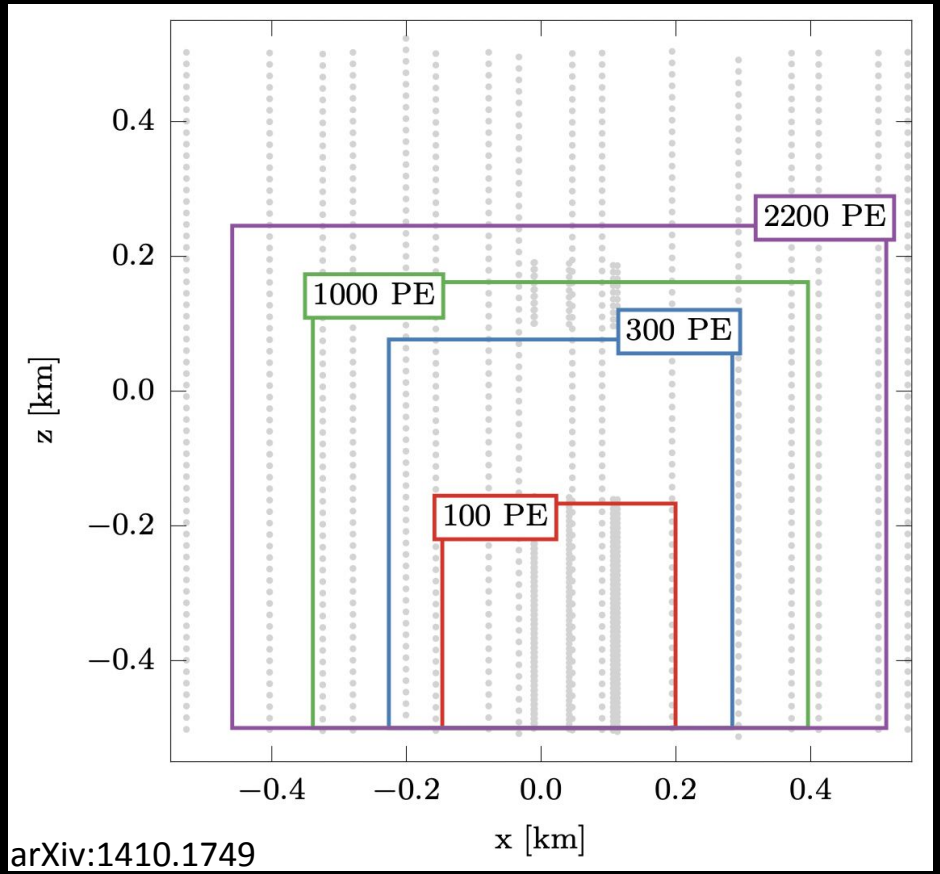
arXiv:1907.03782

TeV-Scale Events at IceCube



arXiv:1410.1749

IceCube Volume



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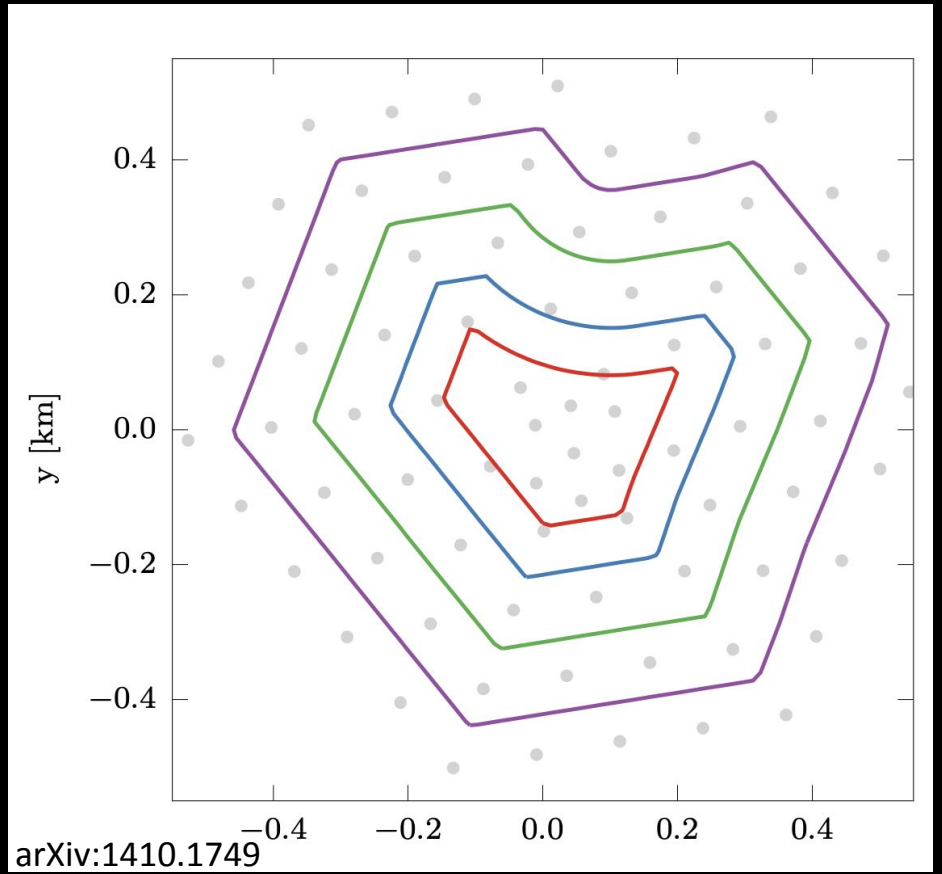

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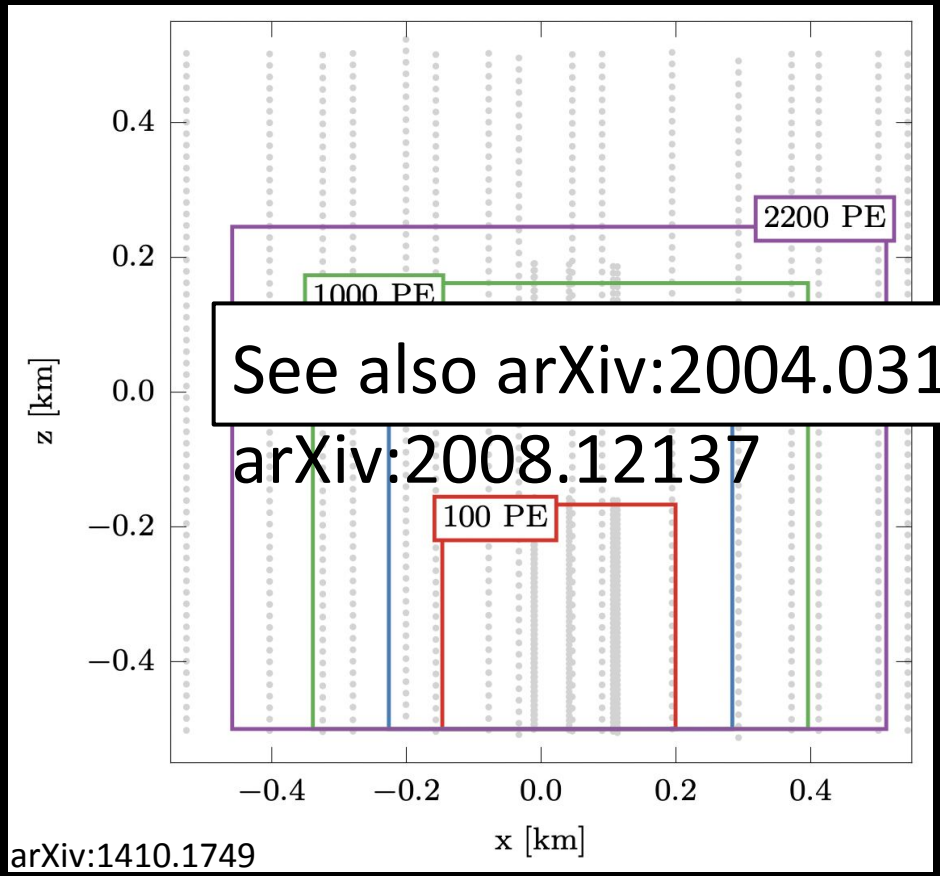
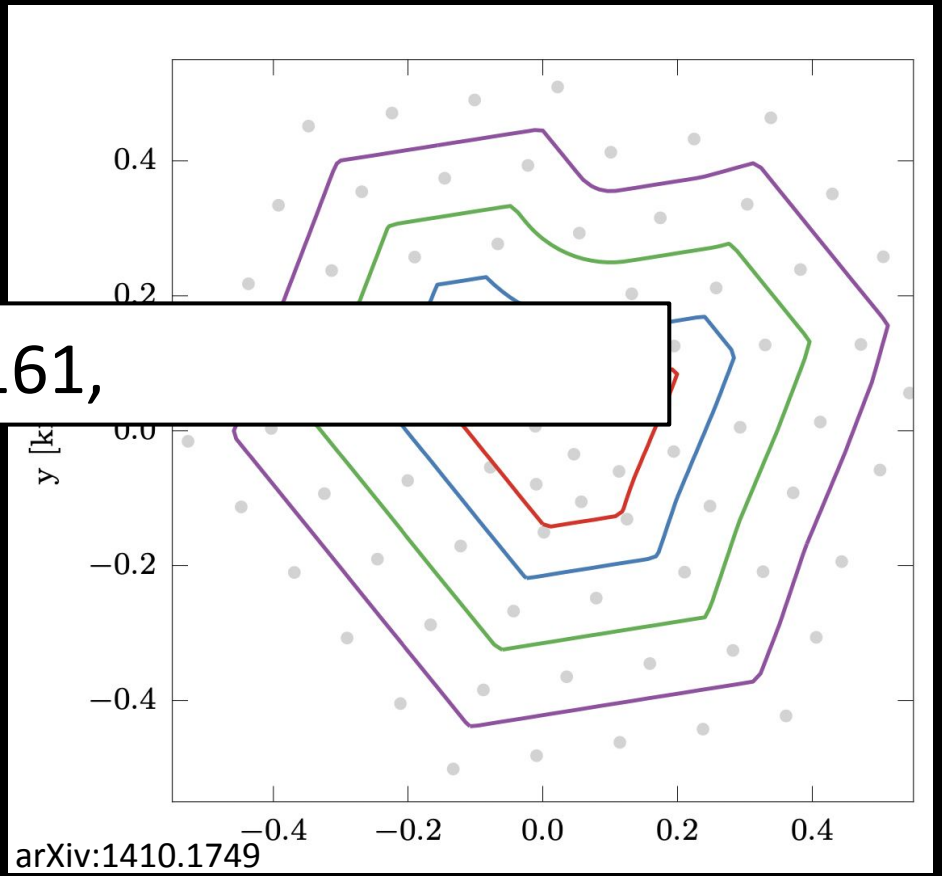
IceCube Volume



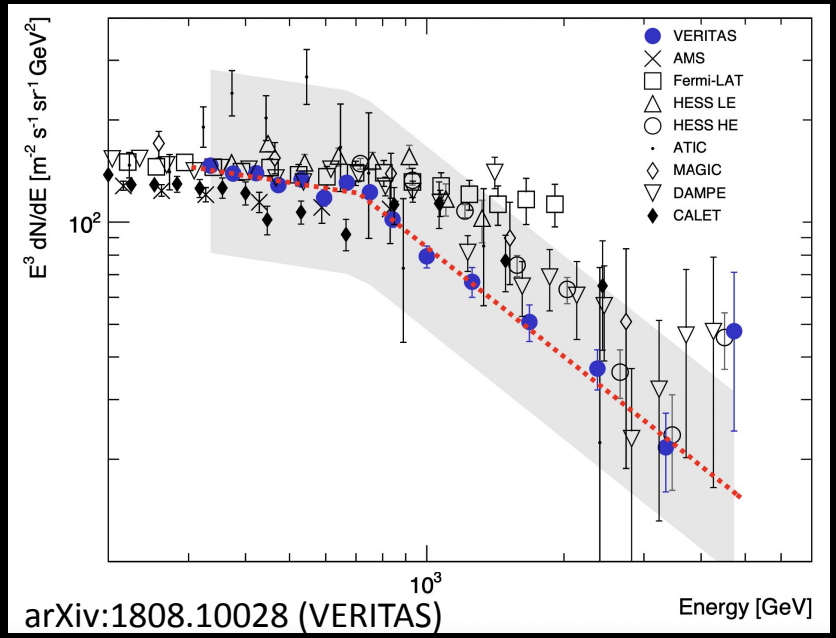
arXiv:1410.1749



arXiv:1410.1749

See also arXiv:2004.03161, arXiv:2008.12137

DM Upscattering by Cosmic Ray Electrons

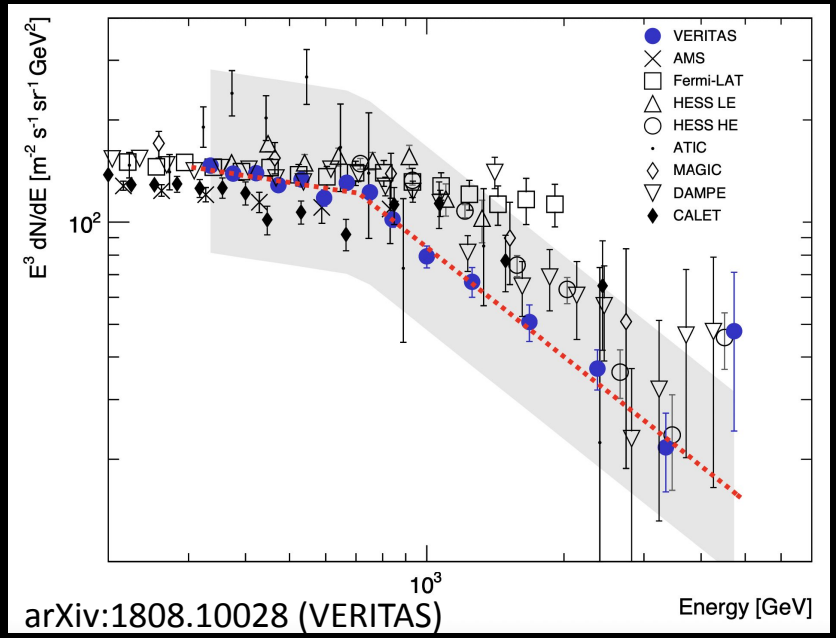


arXiv:1808.10028 (VERITAS)

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

$$\frac{\mathrm{d}R}{\mathrm{d}E_{dep}} = \left(\frac{5}{9}\right) N_A T_{exp} \int_{T_{\chi,min}}^{\infty} M_{eff}(E_{dep}) \frac{\mathrm{d}\sigma_{\chi e}}{\mathrm{d}E_{dep}} \frac{\mathrm{d}\Phi_\chi}{\mathrm{d}T_\chi}$$

DM Upscattering by Cosmic Ray Electrons



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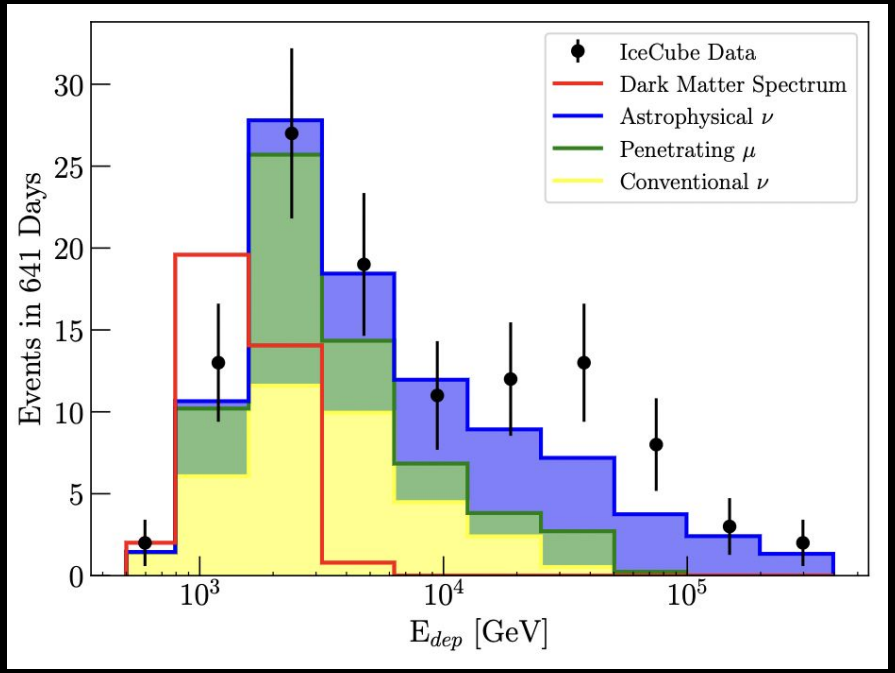
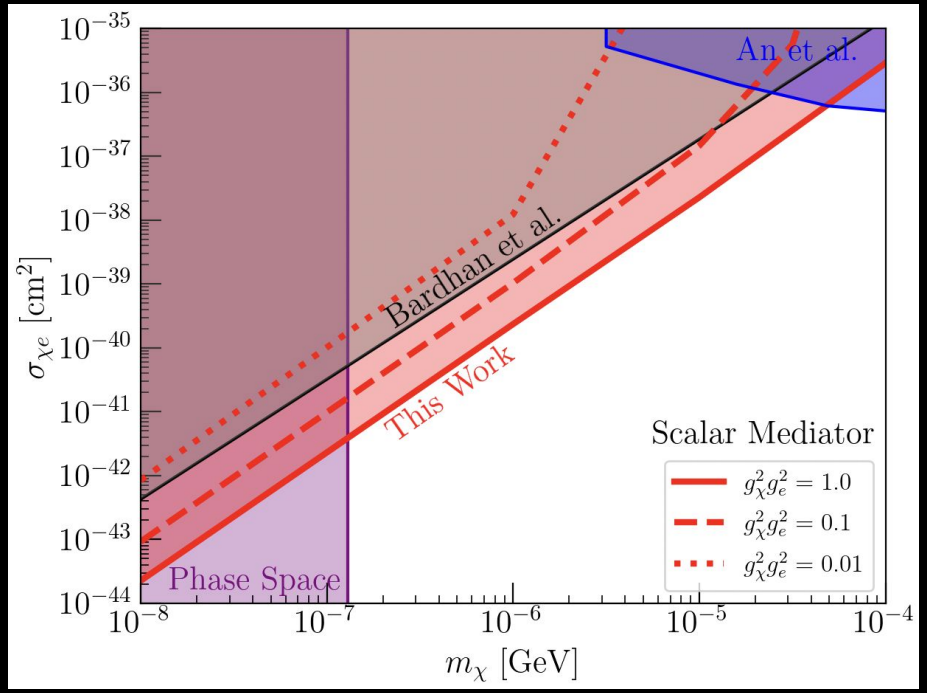
$$\frac{d\Phi_\chi}{dT_\chi} = \int \frac{d\Omega}{4\pi} \int_{l.o.s.} dl \, \frac{\rho_\chi(r)}{m_\chi} \int dT_i \, \frac{d\sigma_{\chi i}}{dT_\chi} \frac{d\Phi_i}{dT_i}$$

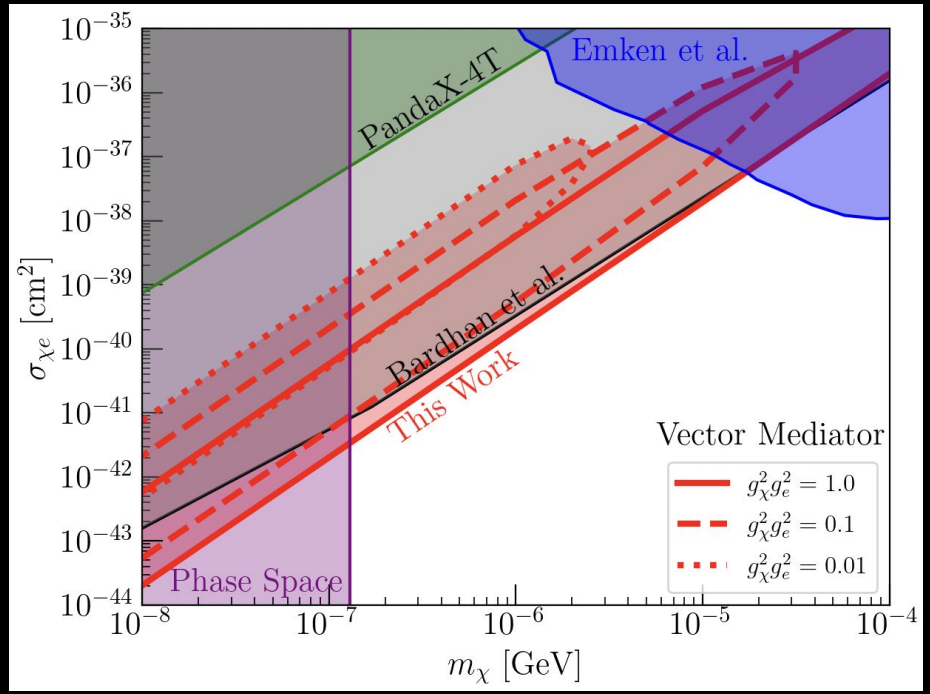
$$\frac{dR}{dE_{dep}} = \left(\frac{5}{9}\right) N_A T_{exp} \int_{T_{\chi,min}}^{\infty} M_{eff}(E_{dep}) \frac{d\sigma_{\chi e}}{dE_{dep}} \frac{d\Phi_\chi}{dT_\chi}$$



- Data from arXiv:1410.1749 (IceCube)
- Perform binned likelihood analysis including neutrino/muon backgrounds modeled by IceCube

DM Upscattering by Cosmic Ray Electrons





Dark Matter Attenuation

High-energy neutrino attenuation in the Earth and its associated uncertainties

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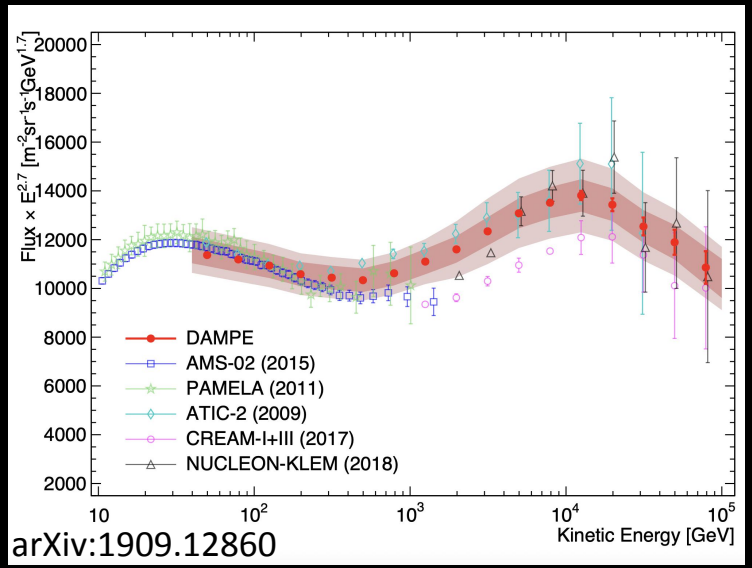
[2] *Department of Physics, Engineering Physics and Astronomy, Queen's University, Kingston ON K7L 3N6, Canada*
[3] *Department of Physics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA*
[4] *Department of Physics and Wisconsin IceCube Particle Astrophysics Center, University of Wisconsin, Madison, WI 53706, USA*

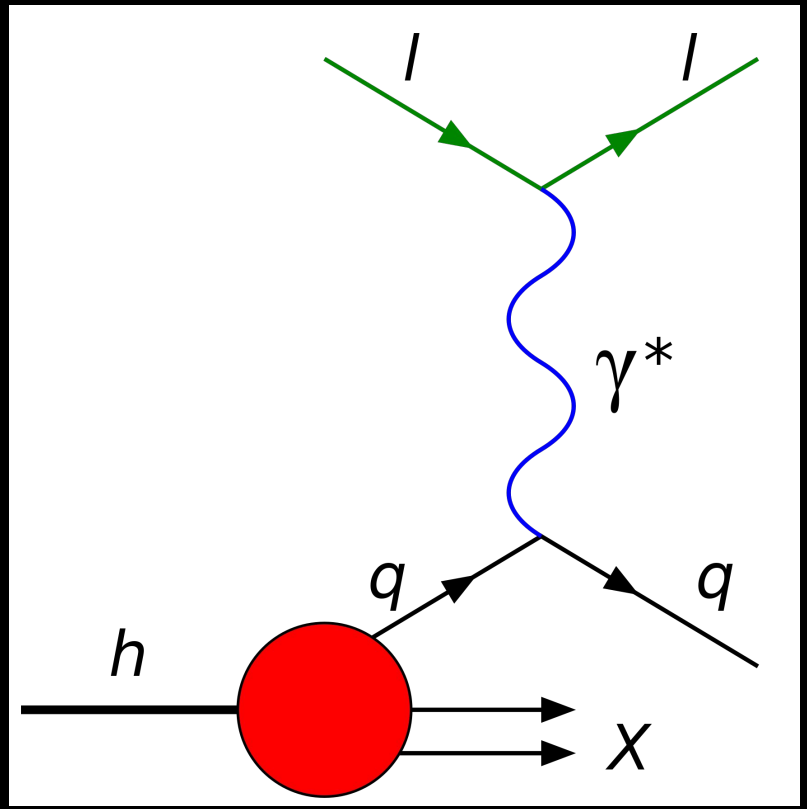
We describe νFATE: Neutrino Fast Attenuation Through Earth, a very rapid method of accurately computing the attenuation of high-energy neutrinos during their passage through Earth to detectors such as IceCube, ANTARES or KM3Net, including production of secondary neutrinos from $\tau^{\pm}$ lepton decay. We then use this method to quantify the error on attenuation due to uncertainties in the isotropic neutrino spectrum, the composition of the Earth, and the parton distribution functions. We show that these can be as large as 20%, which can significantly impact reconstructed astrophysical neutrino parameters, as well as searches for new physics. An implementation of this algorithm is provided as a public code.[1]

$$\frac{\partial}{\partial x}\left(\frac{d\phi_{\nu_\ell}(E_\nu,x)}{dE_\nu}\right) = -\left(\sigma^{\rm NC}_{\nu_\ell}(E_\nu)+\sigma^{\rm CC}_{\nu_\ell}(E_\nu)\right)\frac{d\phi_{\nu_\ell}(E_\nu,x)}{dE_\nu} + \int_E^\infty d\tilde{E}\,\frac{d\sigma^{\rm NC}_{\nu_\ell}(E_\nu,\tilde{E}_\nu)}{dE_\nu}\,\frac{d\phi_{\nu_\ell}(\tilde{E}_\nu,x)}{d\tilde{E}_\nu}$$

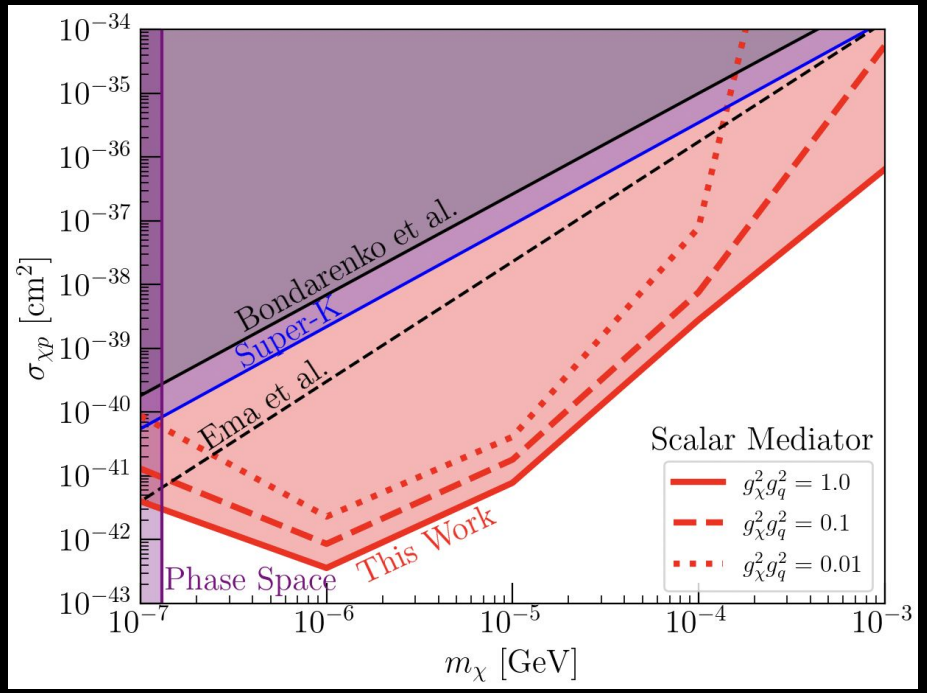
DM Upscattering by Cosmic Ray Protons

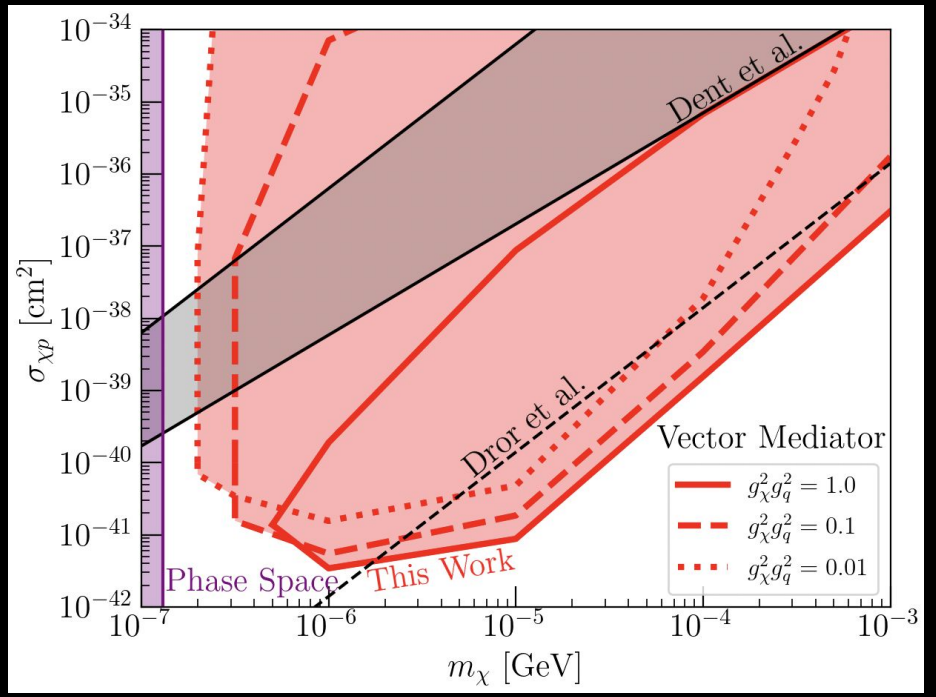


$$\frac{\mathrm{d}\sigma}{\mathrm{d}\nu \mathrm{d}Q^2} = \frac{1}{2\nu} \frac{g_q^2 g_\chi^2}{4\pi (Q^2 + m_Z^2)^2} \times \left(1 - \frac{\nu}{E_\chi} + \frac{\nu^2}{2E_\chi^2} - \frac{Q^2}{4E_\chi^2}\right) F_2(x, Q^2)$$



DM Upscattering by Cosmic Ray Protons





Thank you!