DARK MATTER - NEUTRINO SCATTERING AT THE GALACTIC CENTER

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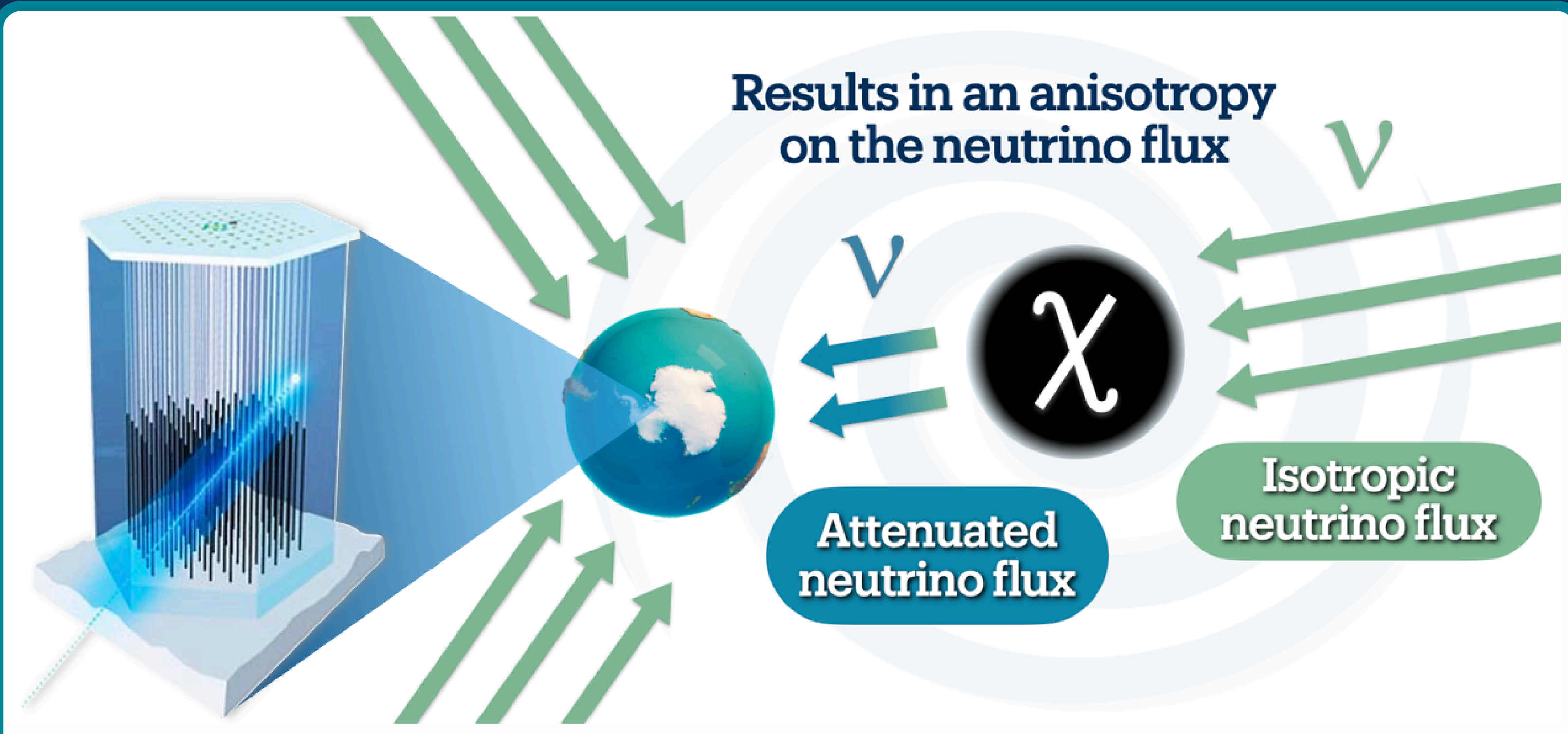
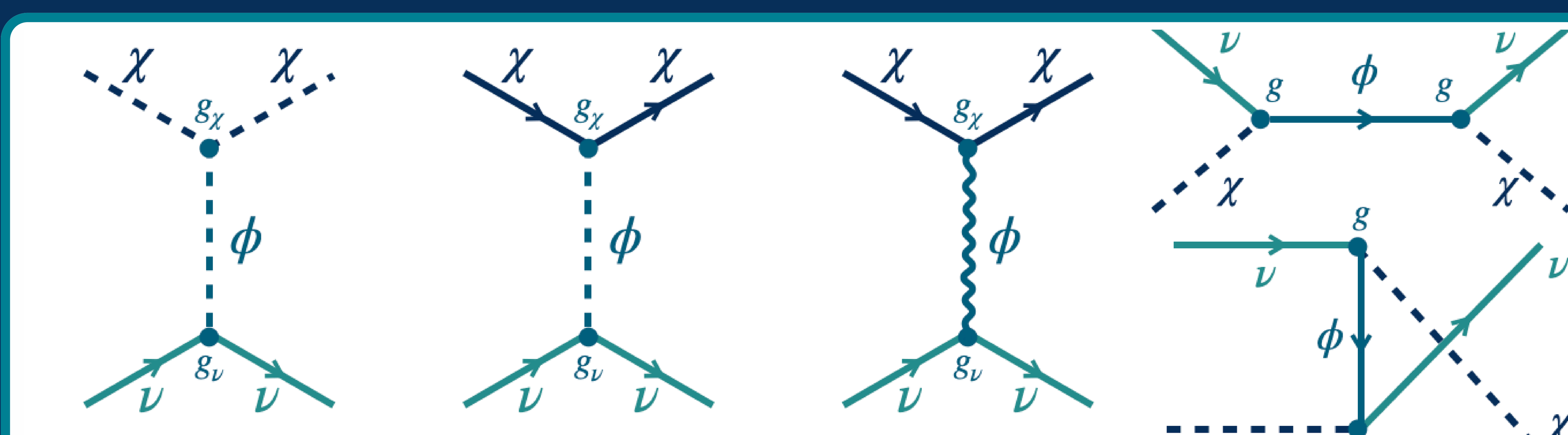
Abstract. Evidence for the existence of dark matter strongly motivates the efforts to study its unknown properties. Additionally, the origin of high-energy astrophysical neutrinos detected by IceCube remains uncertain. Scotogenic models, in which neutrino mass generation occurs through interactions with the dark sector, are some of the leading theories that explain these two mysteries simultaneously. If dark matter and neutrinos couple to each other, we can search for a non-zero elastic scattering cross section. The interaction between an isotropic extragalactic neutrino flux and dark matter would be concentrated in the Galactic Center, where the dark matter column density is largest. The flux of high-energy neutrinos would be attenuated by this scattering, and the resulting signal, with correlated energy and arrival direction, can be observed in IceCube. Using the ten years of IceCube data, we perform an binned likelihood analysis, searching for several potential DM-neutrino interaction scenarios.



The **signal** for this analysis is an **attenuation** from **dark matter-neutrino interactions**.

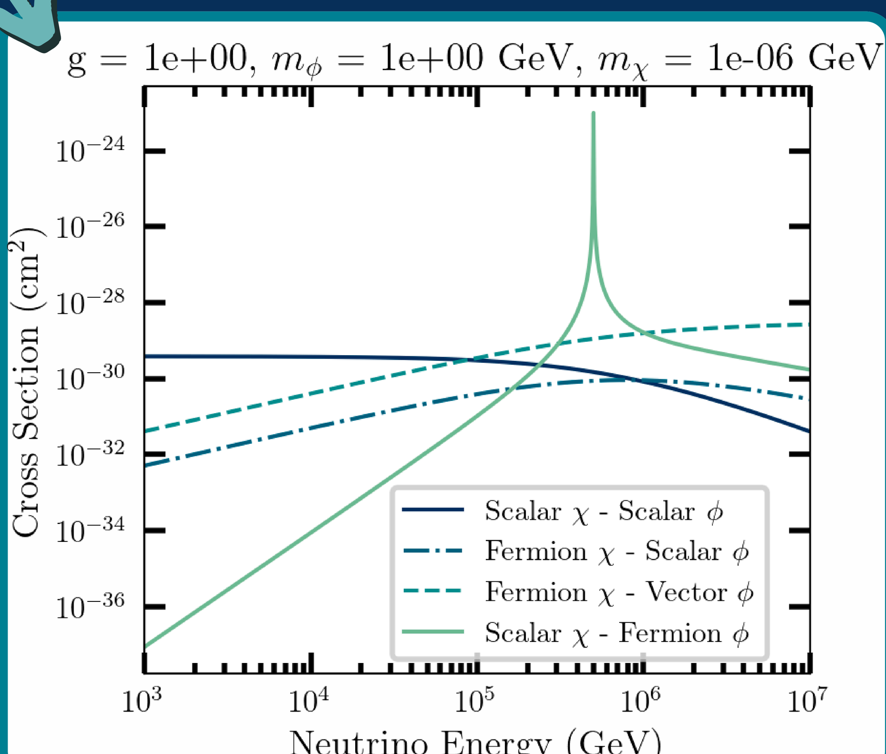
DM - ν Interaction Models

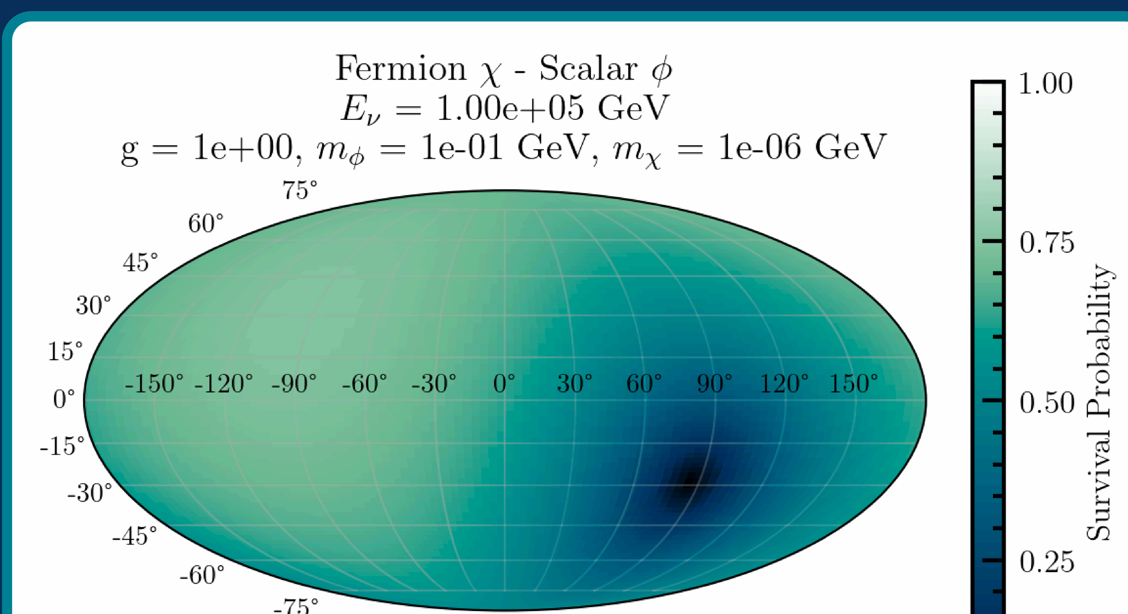


Scalar DM, Scalar Mediator	Fermion DM, Scalar Mediator	Fermion DM, Vector Mediator	Scalar DM, Fermion Mediator
Low E_ν: $\sigma \to$ const; High E_ν: $\sigma \propto E_\nu^{-2}$	Low E_ν: $\sigma \propto E_\nu^{2}$; High E_ν: $\sigma \propto E_\nu^{-1}$	Low E_ν: $\sigma \propto E_\nu^{2}$; High E_ν: $\sigma \to$ const	Low E_ν: $\sigma \propto E_\nu^{2}$; High E_ν: $\sigma \propto E_\nu^{-1}$

Survival Probability

For each interaction model and set of DM parameters, we compute a **ratio** of the **attenuated astrophysical high-energy neutrino flux** with respect to an initial single power law flux.

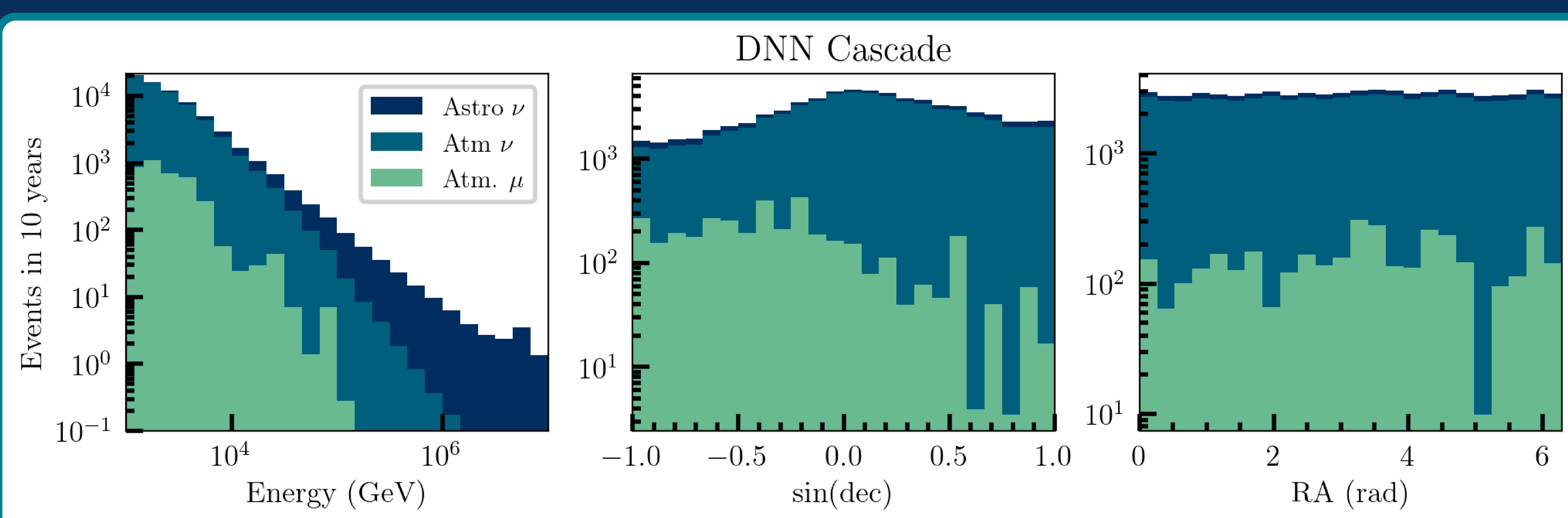




$$\mathscr{P}_{\rm surv} = \frac{\text{Attenuated } \nu \text{ Flux}}{\text{Isotropic Flux}} = \frac{\sum c_i \hat{\phi}_i e^{\lambda_i \tau}}{E^{-\gamma}} \sim \exp\left(\frac{-\sigma\tau}{m_\chi}\right)$$

The **likelihood** of a scattering interaction is proportional to the **column density**; hence, a greater scattering effect should be expected at the **Galactic Center**.

Event Selection



The **event selection** is composed of **cascade-like events** only over **10 years** of data taking of IceCube. The dataset uses a **DNN-based reconstruction**.

Method

We use a **binned Poisson likelihood** and optimize over the model, θ, and nuisance, η, parameters to find the model that best describes the observed data.

$$\mathscr{L} = \sum_i^{\text{bins}} \log \text{Pois}(\vec{x}_i, \mu_i(\vec{\theta}, \vec{\eta}))$$

$$\text{TS} = -2\Delta\text{LLH}$$

$$\vec{x} = \langle E, \delta, \alpha \rangle \quad \vec{\theta} = \langle g, m_\phi, m_\chi \rangle$$

$$\vec{\eta} = \langle n_{\rm astro}, \gamma_{\rm astro} \rangle \quad \vec{\eta}' = \langle n'_{\rm astro} \rangle$$

$$\mu(\vec{\theta}, \vec{\eta}) = \mu^{\text{ex-gc}}_{\text{astro}_\nu}(\vec{\theta}, \vec{\eta}) + \mu^{\text{gc}}_{\text{astro}_\nu}(\vec{\theta}, \vec{\eta}') + \mu^{\text{bkg}}$$

Extragalactic Astrophysical Neutrinos

Follows a power law spectrum

$$\phi(\vec{x}, \vec{\theta}; \vec{\eta}) = n_{\rm astro} E^{-\gamma} \cdot \theta_{att} \propto \sum c_i \hat{\phi}_i e^{\lambda_i \tau}$$

Profile LLH over nuisance parameters

Galactic Astrophysical Neutrinos

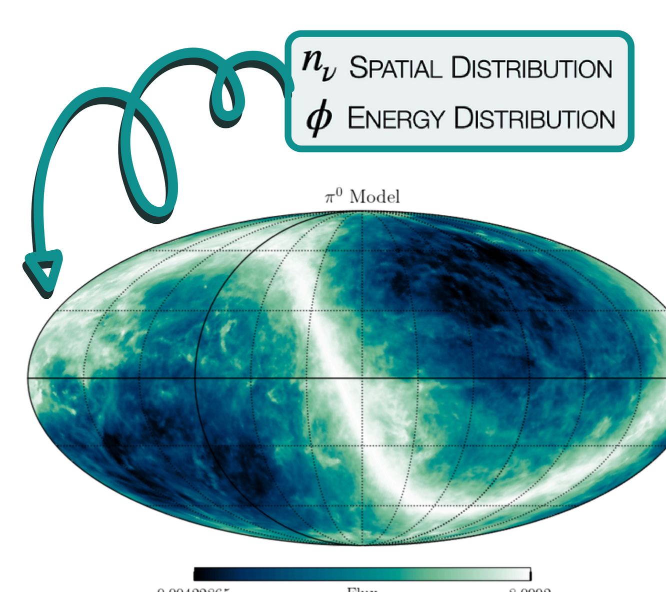
$$\phi(\vec{x}, \theta) = \int_{l.o.s.}^{**} ds\, n_\chi(s)\, \phi(\theta, E, s; \vec{\eta}', \tau(s, \Omega(\vec{x})))$$

From model template of GC ν emission

Profile LLH over nuisance parameters

Data-driven background estimation

n_χ Spatial Distribution
ϕ Energy Distribution



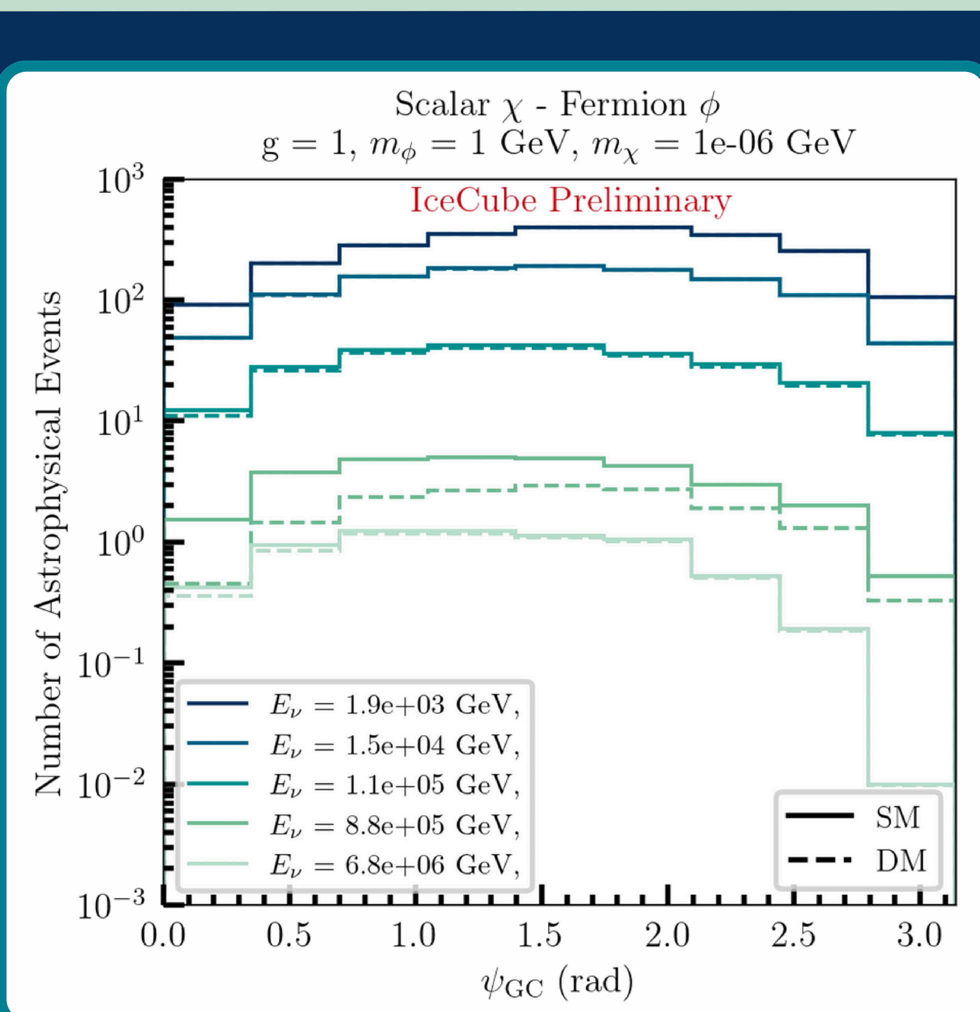
Background: Atmospheric Neutrinos and Muons

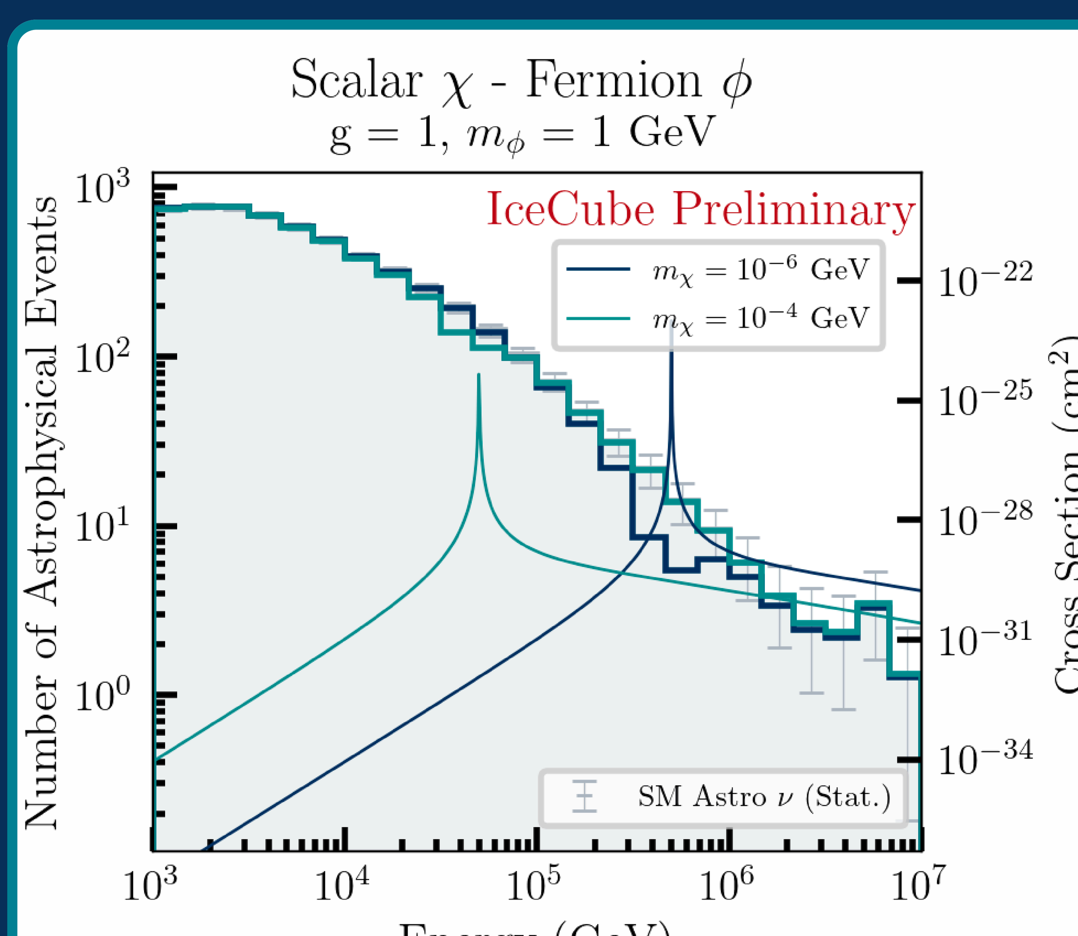
$$\mu^{\rm bkg} = \mu_{\text{atm}_\nu} + \mu_{\text{muon}}$$

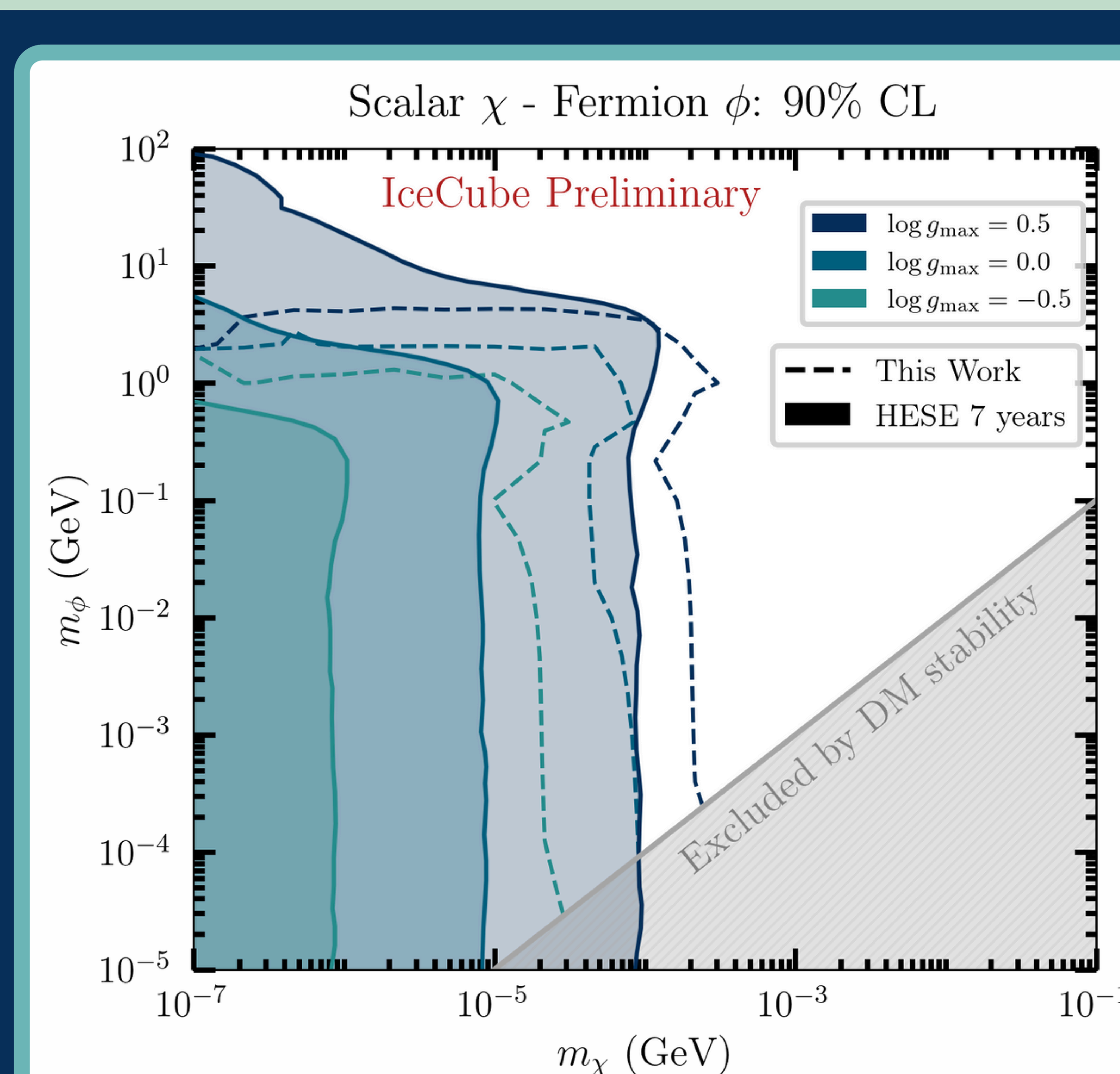
Scrambling MC over right ascension, α

$$\mu^{\rm bkg} = \tilde{\mu}_{\rm data} - \tilde{\mu}^{\rm signal}_{\text{astro}_\nu}(\vec{\theta}, \vec{\eta})$$

Results







Up to **5x improvement** in sensitivities from the previous analysis. New models favoring a broader energy range. Datasets with more statistics and improved reconstruction.

Argüelles, C., Kheirandish, A., Vincent, A. **Phys.Rev.Lett. 119 (2017) 20, 201801**. Olivares-Del Campo, A., et.al. **Phys.Rev.D 97 (2018) 7, 075039**. IceCube Collaboration. **JCAP 10 (2023) 003.**