DARK MATTER DECAY TO NEUTRINOS

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Dark matter (DM) particles are predicted to decay into Standard Model particles which would produce signals of neutrinos, gamma-rays, and other secondary particles. Neutrinos provide an avenue to probe astrophysical sources of DM particles. We review the decay of dark matter into neutrinos over a range of dark matter masses from MeV/c² to ZeV/c². We examine the expected contributions to the neutrino flux at current and upcoming neutrino and gamma-ray experiments, such as Hyper-Kamiokande, DUNE, CTA, TAMBO, and IceCube Gen-2. We consider galactic and extragalactic signals of decay processes into neutrino pairs, yielding constraints on the dark matter decay lifetime that ranges from $\tau \sim 1.2\times10^{21}$ s at 10 MeV/c² to 1.5×10^{29} s at 1 PeV/c².

NEUTRINO AND GAMMA-RAY EXPERIMENTS

Borexino: Liquid scintillator (MeV). Solar neutrinos. Active mass: 278 tons.

KamLAND: Liquid scintillator (MeV). Extraterrestrial neutrino fluxes. Active mass: 1 kiloton.

DUNE: Liquid Argon TPC (GeV). Atmospheric neutrino fluxes. Active mass: 17 kilotons.

Antares: Sea Water Cherenkov. (GeV-TeV). Atmospheric neutrinos.

SuperKamiokande (SK): Water Cherenkov. (GeV-TeV). Atmospheric neutrinos. Active mass: 22.5 kilotons.

IceCube: Ice-Cherenkov detector. (TeV-PeV). Astrophysical neutrino flux. Active mass: 1 gigaton.

P-ONE: Water Cherenkov (PeV). Extraterrestrial neutrino fluxes.

TAMBO: Water Cherenkov. (PeV). Astrophysical Tau neutrinos.

Auger: Water Cherenkov. Ultra-High-Energy Cosmic Rays (EeV).

GRAND: Radio Array. (EeV) Tau Neutrinos.

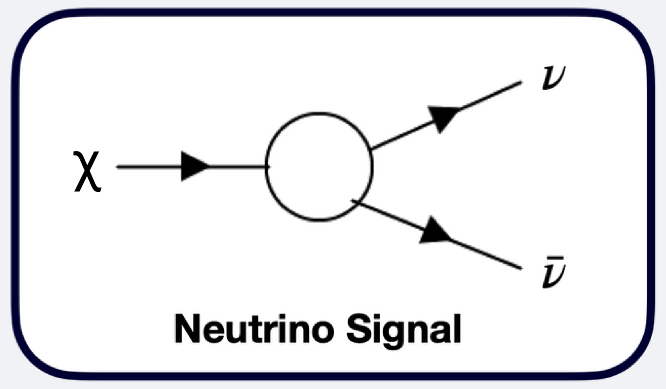
LHAASO: Hybrid Air Shower. Gamma Rays. (GeV - PeV)

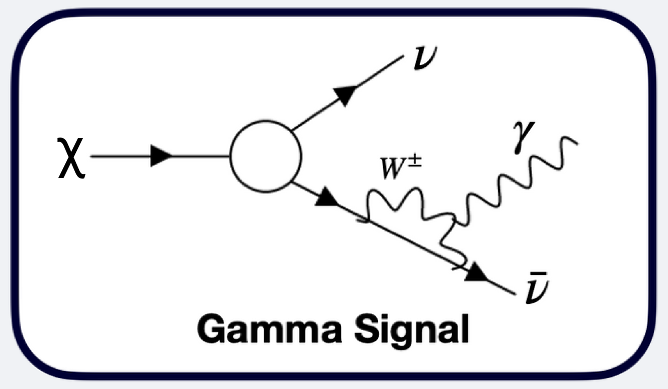
HAWC: Water Cherenkov. Gamma Rays and Cosmic Rays. (GeV - TeV)

CTA: Air Cherenkov. High Energy Gamma Rays. (TeV).

INTRODUCTION

- DM particles decay into Standard Model (SM) particles would produce signals of neutrinos, gamma-rays, and other secondary particles.
- Neutrinos are one of the least constrained channels for Dark Matter searches. We expect a correlated signal above the electroweak scale that will strengthen constraints or evidence of Dark Matter.
- We define two types of signals for DM decay to neutrinos: a prompt neutrino signal and neutrinos with a gamma emission from electroweak processes.





ANALYSIS

The astrophysical differential neutrino flux of Dark Matter decay from the Galactic Center is given by:

$$\frac{d\Phi}{dE} = \frac{1}{4\pi}\frac{dN}{dE}\frac{D(\Omega,x)}{m_\chi \tau_\chi} \qquad D = \int d\Omega \int_{l.o.s.} \rho_\chi(\Omega,x)\, dx$$

where m_χ is the Dark Matter mass, τ is the Dark Matter lifetime, dN/dE is either the neutrino or gamma production spectrum for DM decay to neutrinos.

The D-factor is the integral over the sky solid angle and along the line-of-sight of the dark matter density (NFW profile).

An extragalactic contribution to the neutrino flux is computed, which depends on the dark matter density and takes into account how gamma-rays get attenuated as they traverse the Universe.

RESULTS

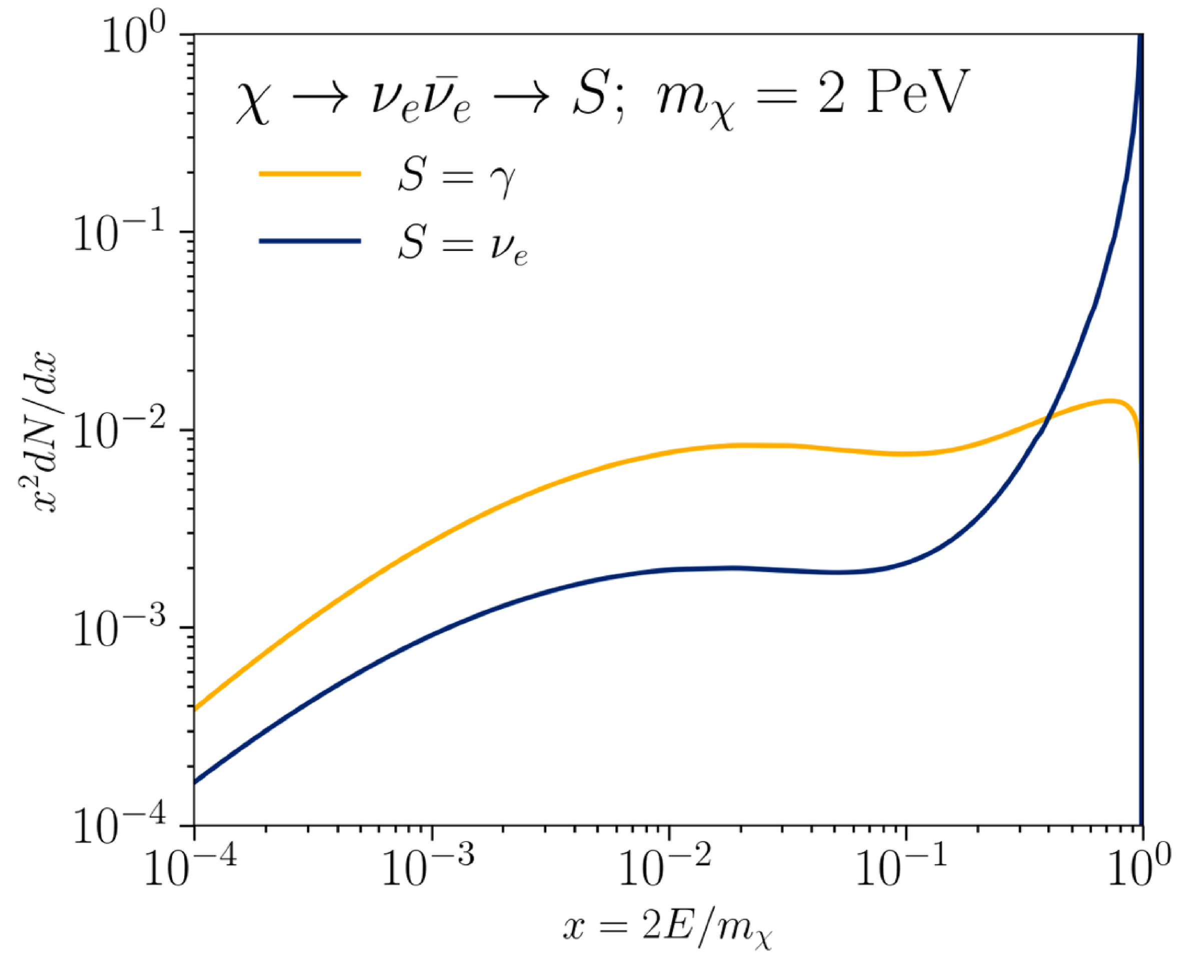


Figure 1: The prompt electron neutrino and photon spectrum resulting from the decay of a 2 PeV DM particle to $\nu_e\bar{\nu}_e$.

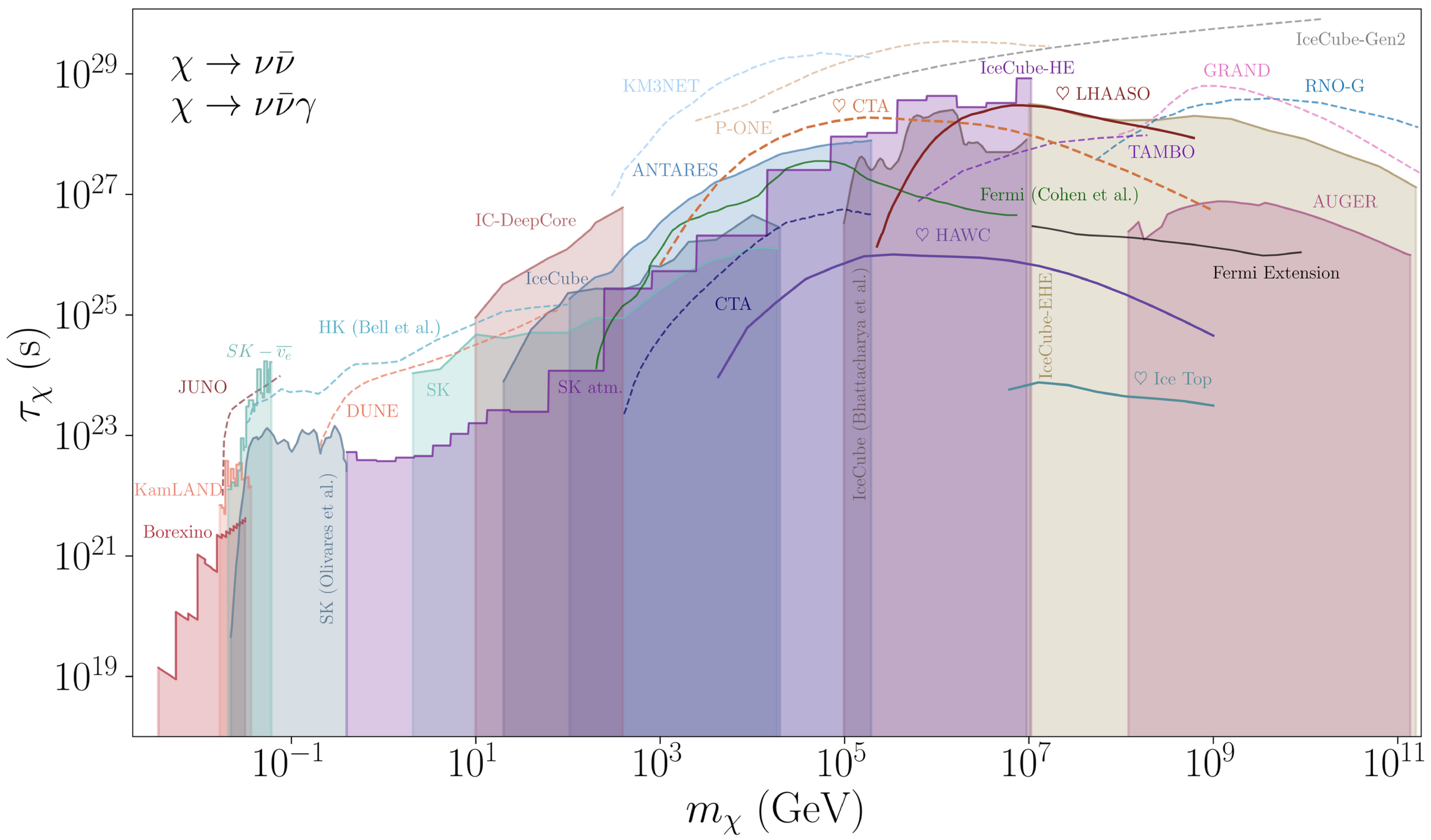


Figure 2: This plot shows the constraints (solid) and projected sensitivities (dashed) of the analysis calculated for the neutrino signals. The sensitivities have been calculated at 90% C.L. without systematic uncertainties.

CONCLUSION AND OUTLOOKS

We can measure both neutrinos and gamma-rays as final products of Dark Matter decay to neutrinos which results in a correlated signature between the neutrino and gamma signal.

Thanks to major experimental advances in neutrino and gamma-ray detection we show the decay lifetime constraints in a wide DM mass range (MeV - ZeV).