Indirect detection of dark matter at INO

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Abstract

Neutrino fluxes arising from WIMP (weakly interacting massive particle) annihilation in the center of the sun($\odot$), earth($\oplus$) and galaxy can leave detectable signatures at the proposed 50-kt Iron Calorimeter (ICAL) detector at the upcoming India-Based Neutrino Observatory (INO). Although the atmospheric neutrinos will pose a serious background to such signal neutrinos, exploiting the excellent angular resolution of the ICAL detector we can suppress it considerably. For WIMP masses (m_χ) upto 100 GeV, with several WIMP annihilation channels assuming 100% branching ratio each, and 500 kt-years of ICAL running, we present the expected exclusion regions in the $\sigma_{SD} - m_\chi$ and $\sigma_{SI} - m_\chi$ for the searches in the sun, where σ_{SD} and σ_{SI} are the WIMP-nucleon spin-dependent (SD) and spin-independent (SI) scattering cross-section, respectively. For annihilation in the earth the expected exclusion regions in $\sigma_{SI} - m_\chi$ and $\sigma_{SI} - \langle\sigma v\rangle$ (for a fixed m_χ) are presented, where $\langle\sigma v\rangle$ is velocity-averaged self-annihilation cross-section. For the searches in the galactic center(GC), the expected exclusion in the $\langle\sigma v\rangle - m_\chi$ are presented.

Introduction

- The milky way is expected to be inlaid in a WIMP halo with a varying density profile, peaking at the galactic centre(GC).

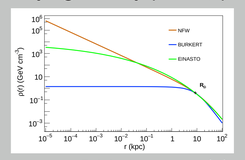


Figure 1: DM density $\rho(r)$ as a function of radial distance r from GC.

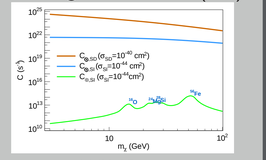


Figure 2: WIMP capture in the sun ($C_\odot$) and the earth ($C_\oplus$) as a function of m_χ.

- WIMP capture in celestial bodies like the sun and earth increases its concentration at their cores.
- At the core of these celestial bodies and other centres of high WIMP concentration such as GC, WIMP could undergo annihilation whose final products include neutrino-antineutrino pairs.
- The interaction of neutrinos $\nu_\mu/\bar{\nu}_\mu$ with iron layers will produce μ^-/μ^- at ICAL through charge current interactions.

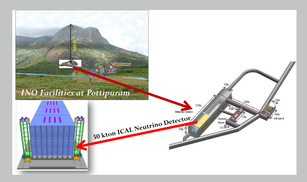
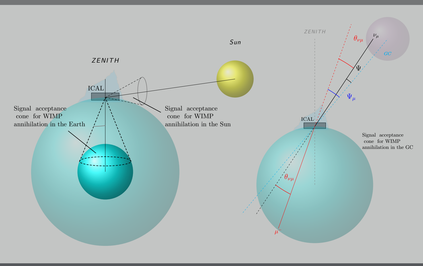


Figure 3: ICAL@INO

Signal search cones



Neurtino fluxes due to WIMP annihilation

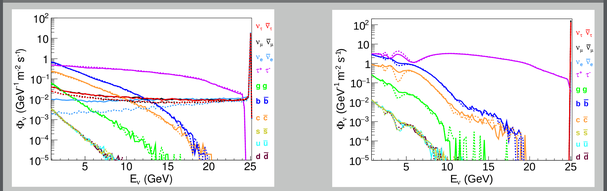


Figure 4: ν_μ (solid) and $\bar{\nu}_\mu$(dotted) fluxes(Φ_ν) as a function of neutrino energy E_ν due to annihilation of a 25 GeV WIMP in the sun for $\sigma_{SD} = 10^{-39}\mathrm{cm}^2$ (LEFT) and the earth $\sigma_{SI} = 10^{-38}\mathrm{cm}^2$, $\langle\sigma v\rangle = 3 \times 10^{-26}\mathrm{cm}^3\mathrm{s}^{-1}$ (RIGHT) with 100% Branching Ratio (BR) considered for each channel, calculated using WIMPSIM.

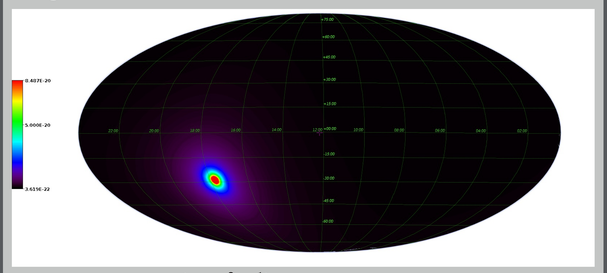


Figure 5: ν fluxes ($\mathrm{cm}^{-2}\mathrm{s}^{-1}$) for 50 GeV WIMP annihilating in GC through $\tau^+\tau^-$ channel for a NFW profile, $\langle\sigma v\rangle = 3 \times 10^{-26}\mathrm{cm}^3\mathrm{s}^{-1}$, calculated using PPPC4DMID.

Atmospheric ν Background

- The signal search cones have to be optimized for maximum sensitivity.
- **The atmospheric neutrinos in the signal search cone represents an irreducible background.**

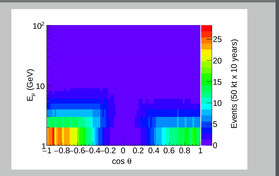


Figure 6: Reconstructed background events with Honda fluxes for Theni site. $\cos\theta = 1$ is upgoing.

Results [500 kt-year ICAL exposure]

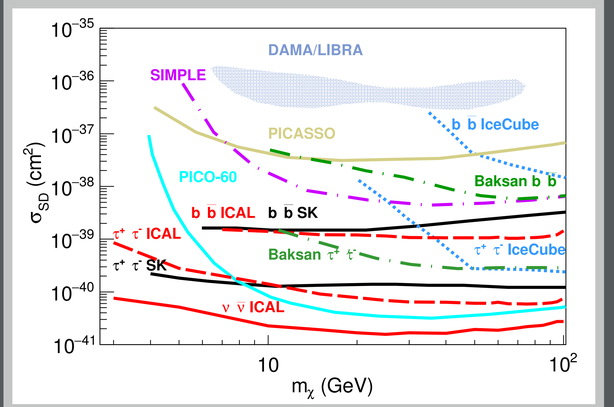


Figure 7: The expected 90 % C.L. sensitivity limits on σ_{SD} from WIMP annihilation in the sun.

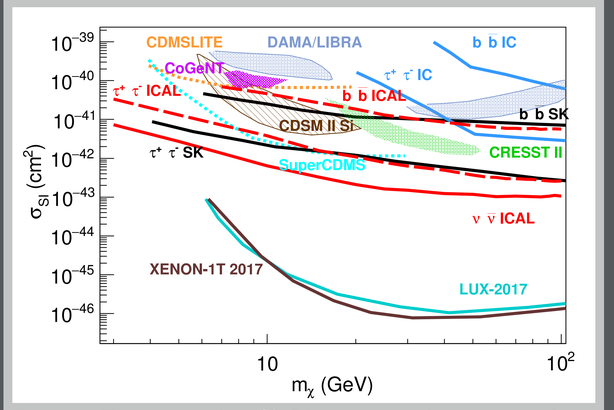


Figure 8: The expected 90 % C.L. sensitivity limits on σ_{SI} from WIMP annihilation in the sun.

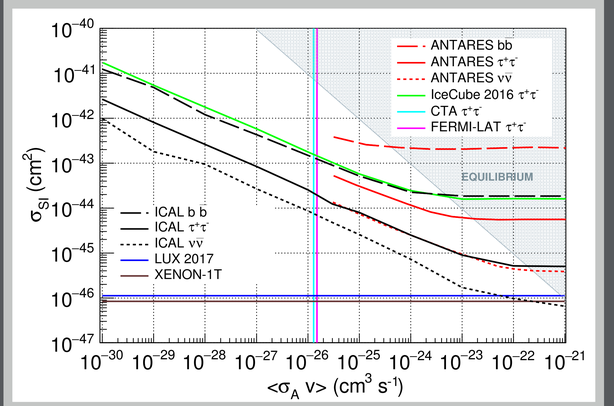


Figure 9: The expected 90% C.L. sensitivity limits on σ_{SI} as a function of $\langle\sigma v\rangle$ for 52.14 GeV WIMP annihilation in the earth.

Results contd. [500 kt-year ICAL exposure]

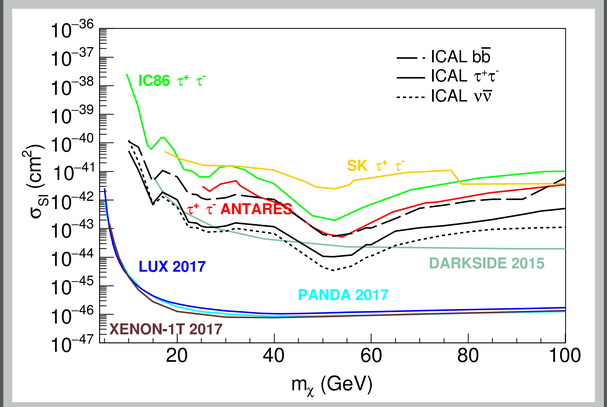


Figure 10: The expected 90 % C.L. sensitivity limits on σ_{SI} from WIMP annihilation in the earth, assuming $\langle\sigma v\rangle = 3 \times 10^{-26}\mathrm{cm}^3\mathrm{s}^{-1}$.

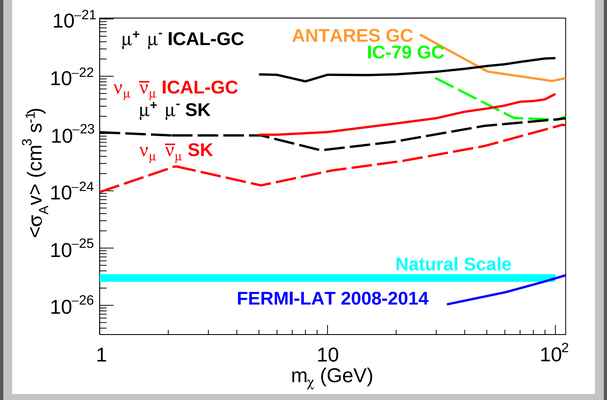


Figure 11: The expected 90 % C.L. sensitivity limits on $\langle\sigma v\rangle$ from WIMP annihilation in the GC assuming NFW profile.

Conclusions

Neutrinos due to WIMP annihilation can leave detectable signatures at ICAL. With an effective atmospheric background suppression, the expected 90 % C.L. sensitivity limits for 500 kt-years of ICAL exposure are competitive to other neutrino experiments for the WIMP masses $m_\chi <$ 100 GeV.

References

[1] S. Choubey, A. Ghosh and D. Tiwari, "Prospects of Indirect Searches for Dark Matter at INO," **JCAP05(2018)006**, [arXiv:1711.02546].

[2] D. Tiwari, A. Ghosh and S. Choubey, "Prospects of indirect searches for dark matter annihilations in the earth with ICAL@INO", **JHEP 05 (2019) 039**, [arXiv:1806.0505].

[3] D. Tiwari, "Indirect Detection of Dark Matter at INO", PhD Thesis, 2018 [http://www.ino.tifr.res.in/ino/theses/2018/Thesis_DeepakTiwari.pdf].