Searches for Dark Matter annihilation with ICAL

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Abstract

We study prospects of detecting muon events due to neutrinos produced from WIMP (weakly interacting massive particles) annihilation in the center of the sun, the earth and the galaxy at the upcoming 50kt magnetised iron calorimeter (ICAL) detector, to be housed at India-based Neutrino Observatory (INO). The atmospheric neutrinos pose a major background to the indirect searches and can be reduced by an effective background suppression scheme. In our study, we consider WIMP mass (m_χ) upto 100 GeV, several WIMP annihilation channels assuming 100% branching ratio each, and 50kt $\times$ 10 years of ICAL running. We perform a binned χ^2 analysis and present 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 galatic center(GC), the expected exclusion in the $\langle\sigma v\rangle - m_\chi$ are presented.

Introduction

- The milky way galaxy is expected to be inlaid in a WIMP halo with a varying density profile, peaking at its centre.

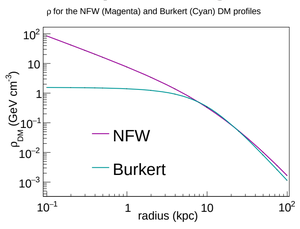

Fig. 1: DM density ρ_{DM} as a function of radial distance r from GC.

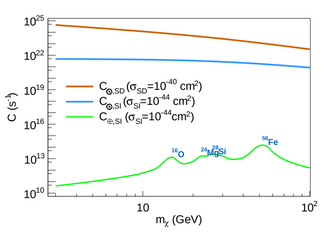

Fig. 2: WIMP capture in the sun ($C_\odot$) and the earth ($C_\oplus$) as a function of m_χ.

- WIMP capture in celestial bodies like the sun, earth, etc. 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.
- Such neutrinos can leave detectable signal at ICAL through charge current interactions.

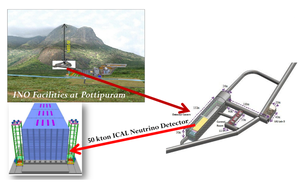

Fig. 3: ICAL@INO

Signal search cones

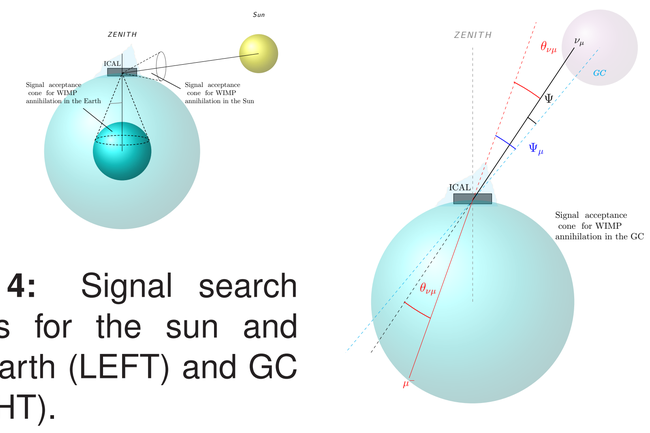

Fig. 4: Signal search cones for the sun and the earth (LEFT) and GC (RIGHT).

Neutrinos from WIMP annihilation

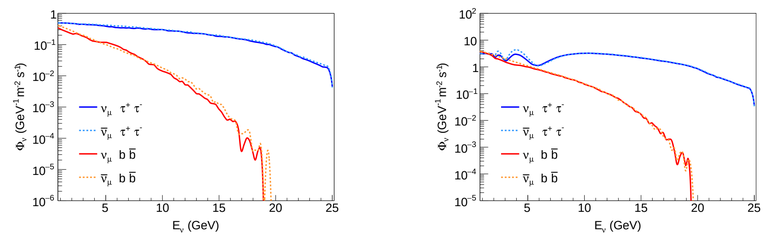

Fig. 5: ν fluxes (Φ_ν) due to annihilation of a 25 GeV WIMP in the sun for $\sigma_{SD} = 10^{-39} cm^2$ (LEFT) and the earth $\sigma_{SI} = 10^{-38} cm^2$, $\langle\sigma v\rangle = 3 \times 10^{-26} cm^3 s^{-1}$ (RIGHT) with 100% Branching Ratio (BR) considered for each channel, calculated using WIMPSIM.

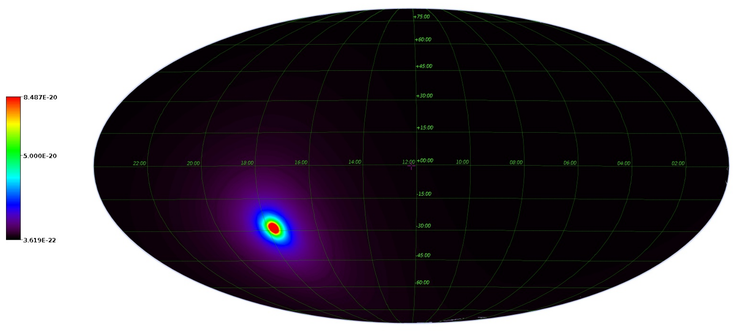

Fig. 6: ν fluxes ($cm^{-2}s^{-1}$) for 50 GeV WIMP annihilating in GC through $\tau^+\tau^-$ channel for a NFW profile, $\langle\sigma v\rangle = 3 \times 10^{-26} cm^3 s^{-1}$, calculated using PPPC4DMID.

Atmospheric ν Background

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

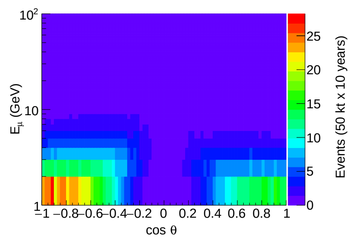

Fig. 7: Reconstructed background events with Honda fluxes for Theni site. $\cos\theta = 1$ is upgoing.

Results

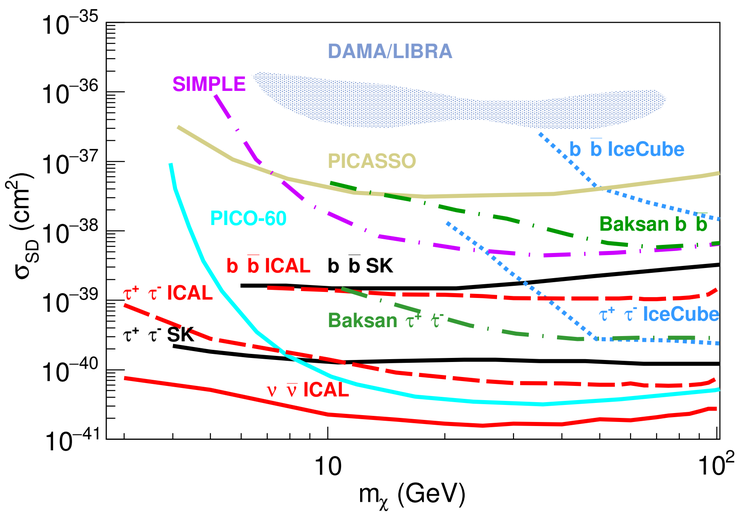

Fig. 8: The expected 90 % C.L. sensitivity limit on σ_{SD} from WIMP annihilation in the sun [500 kt-yrs].

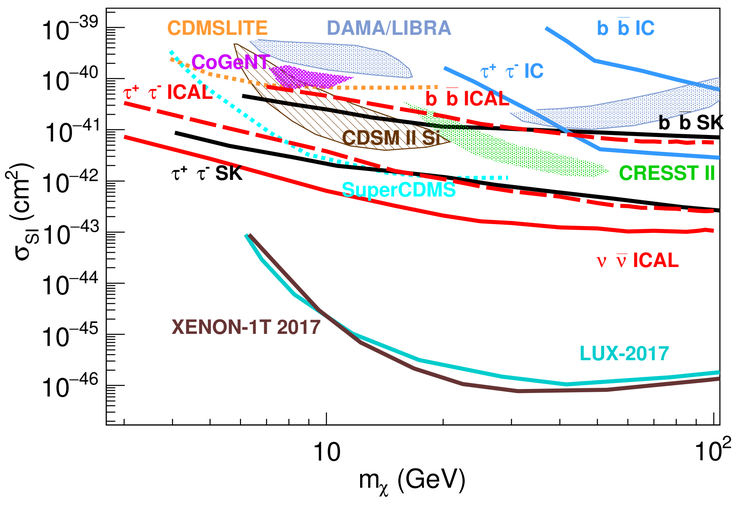

Fig. 9: The expected 90 % C.L. sensitivity limit on σ_{SI} from WIMP annihilation in the sun [500 kt-yrs].

Results contd.

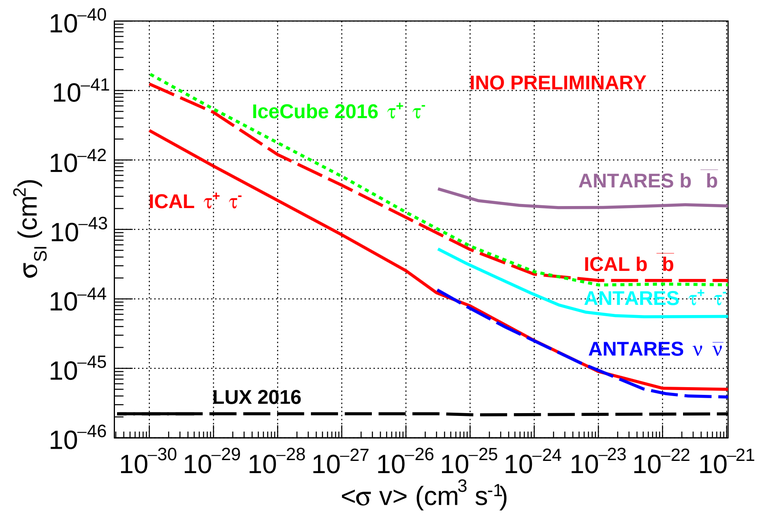

Fig. 10: The expected 90 % C.L. sensitivity limit on $\langle\sigma v\rangle$ as a function of σ_{SI} from WIMP annihilation in the earth for m_χ = 50 GeV [500 kt-yrs].

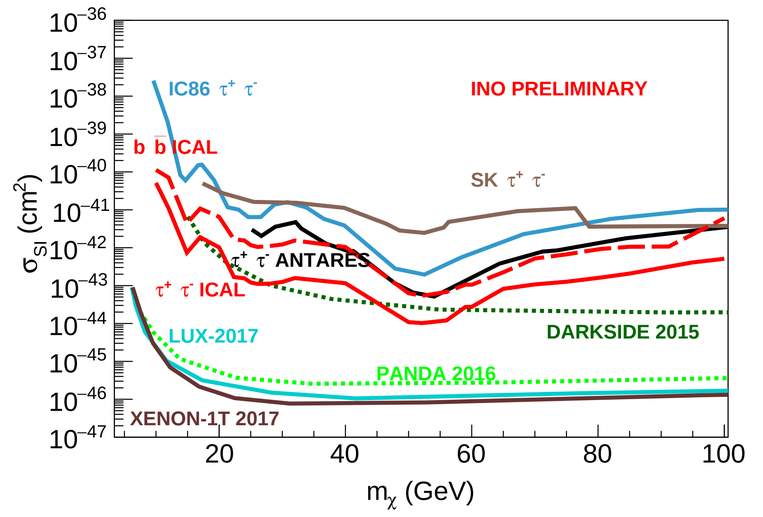

Fig. 11: The expected 90 % C.L. sensitivity limit on σ_{SI} from WIMP annihilation in the earth [500 kt-yrs].

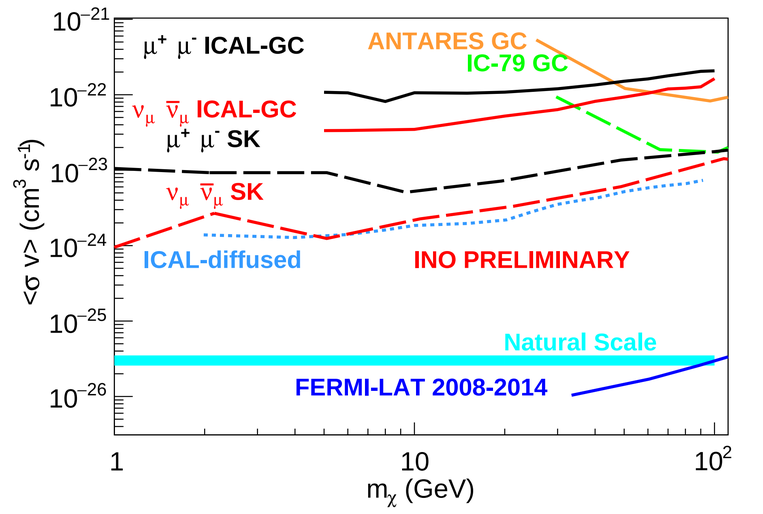

Fig. 12: The expected 90 % C.L. sensitivity limit on $\langle\sigma v\rangle$ from WIMP annihilation in the GC assuming NFW profile [500 kt-yrs].

Conclusions

Neutrinos arising out of WIMP annihilation in the sun, the earth and GC could be used to probe dark matter signatures. With an effective atmospheric background suppression scheme, the expected 90 % C.L. sensitivity limit on σ_{SD} and σ_{SI} for the case of WIMP annihilation in the sun are competitive to the most stringent bounds till date. The SI limits estimated for the earth are better than any other indirect detection experiment. ICAL annihilation searches in the galactic center(GC) are also interesting.

References

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

[2] D. Tiwari, A. Ghosh and S. Choubey, "Prospects of indirect searches for dark matter annihilation in the earth with ICAL@INO," [In preparation]

[3] D. Tiwari and S. Choubey, "Hunting for dark matter in the galactic center with INO," [In preparation]

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