Indirect Searches for Dark Matter Signatures at INO

Deepak Tiwari, Anushree Ghosh and Sandhya Choubey
India Based Neutrino Observatory,Harish Chandra Research Institute

Abstract

Weakly Interactive Massive Particles (WIMPs) are among the most favored dark matter candidates. Their capture and subsequent annihilation at the center of Sun/ Earth may give rise to neutrinos, through various annihilation channels.The detection of such neutrinos at INO, which will house a 50-kt Iron Calorimeter (ICAL) can provide insight into the nature of light dark matter.

Introduction

- As the solar system moves through the halo, the WIMPs gets scattered on the particles in the Sun/Earth and lose energy. If their final velocities are lesser than escape velocity at the Sun/Earth, then they get gravitationally trapped by the gravitational potential of the Sun/ Earth and sink to their respective cores.
- The WIMP getting annihilated in the Sun/ Earth will do so into standard model particle that would give neutrinos of different energies.
- The detection of those neutrinos,in principle, can provide information about the nature of Dark matter viz. its mass and cross section.

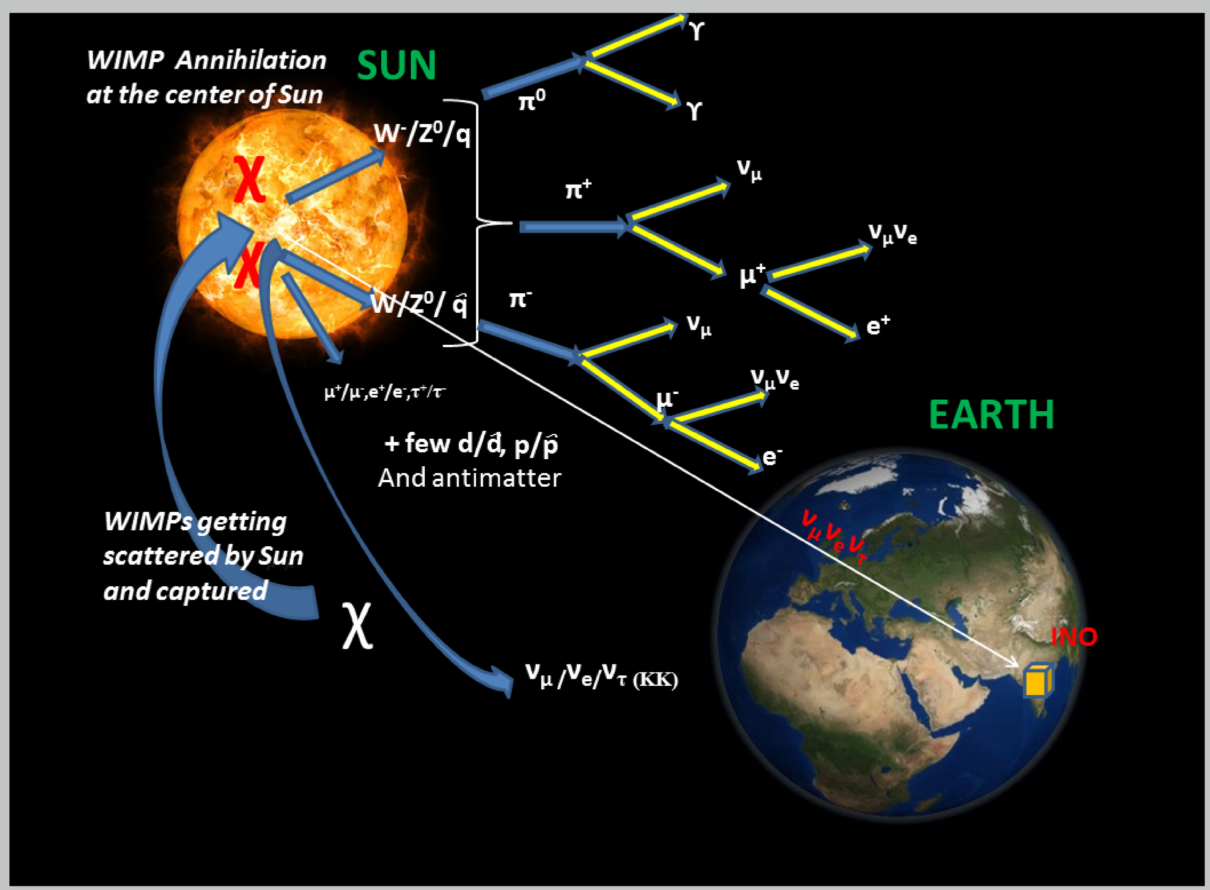

Figure 1: WIMP annihilations in the Sun.

The ICAL@INO Detector

- INO is a proposed underground research facility at Bodi Hills, Tamil Nadu, India.
- ICAL is an upcoming detector at INO, primarily proposed to study atmospehric neutrinos and will comprise 150 layers of glass RPCs and 50-kt magnetised Iron mass.

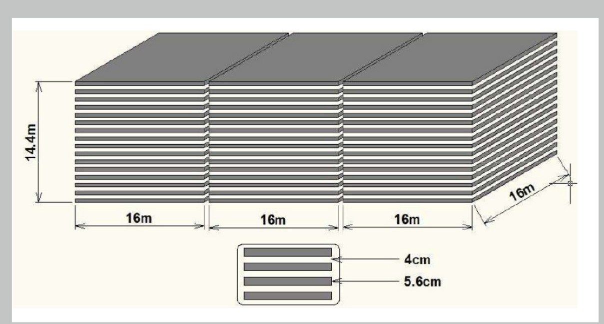

Figure 2: ICAL at INO

Simulation Methods

Start
→ Annihilations in Sun with **WimpAnn/WIMPSIM**
→ *ν Fluxes at 1AU*
→ Event generation with **WimpEvent/WIMPSIM**
→ *ν Fluxes at detector*
→ Flux Normalisation with Annihilation Rate **C++/ROOT code**
→ *Normalised fluxes*
→ Event generation with **NUANCE**
→ *μ events at ICAL*
→ Reconstruction with **ROOT/Geant4 framework**
→ *μ events at Detector*
→ stop

- WIMP annihilations for $\mathbf{m_\chi = 25}$GeV, $\mathbf{2.5 \times 10^6}$ events.
- Oscillation parameters: $\mathbf{2.5 \times 10^6}$,$\theta_{12} = \mathbf{34°}$,$\theta_{13} = \mathbf{9.2°}$,$\theta_{23} = \mathbf{45°}$,$\delta = \mathbf{0}$,$\Delta^2_{21} = \mathbf{7.5 \times 10^{-5}}\mathrm{eV}^2$ and $\Delta^2_{31} = \mathbf{2.4 \times 10^{-3}}\mathrm{eV}^2$
- Flux normalisation: $\frac{dN_\nu}{dtd\Omega dE_\nu} = \frac{\Gamma_{ann}}{4\pi R^2}\sum \mathbf{BR}_i \frac{dN_i}{dE_\nu}$ with ρ_{local} (0.3 Gev/$\mathbf{cm^{-}3}$), $\bar{\mathbf{v}}_{local}$ (270 kms^{-1}),σ =1fb.
- For NUANCE,1000 years of exposure, scaled down to 10 years.
- Values used: 50kt Iron mass,80% detector efficiency, 12 % Energy Resolution, 1% Angular resolution and 99.15% cid efficiency.

Atmospheric Background

- The atmospheric neutrinos are in GeV range and will pose background to the signal neutrinos.
- The signal neutrinos are in the direction of Sun whereas the atmospheric neutrinos come from all directions and its dependence and nature is comparitively well studied.
- By placing an angular cone in the direction of Sun and accepting only those events due to atmospheric neutrinos that fall within that cone, we can significantly reduce the atmospheric background.
- For present work a constant angular cut of **10°** has been applied for all energy bins.

Fluxes at INO

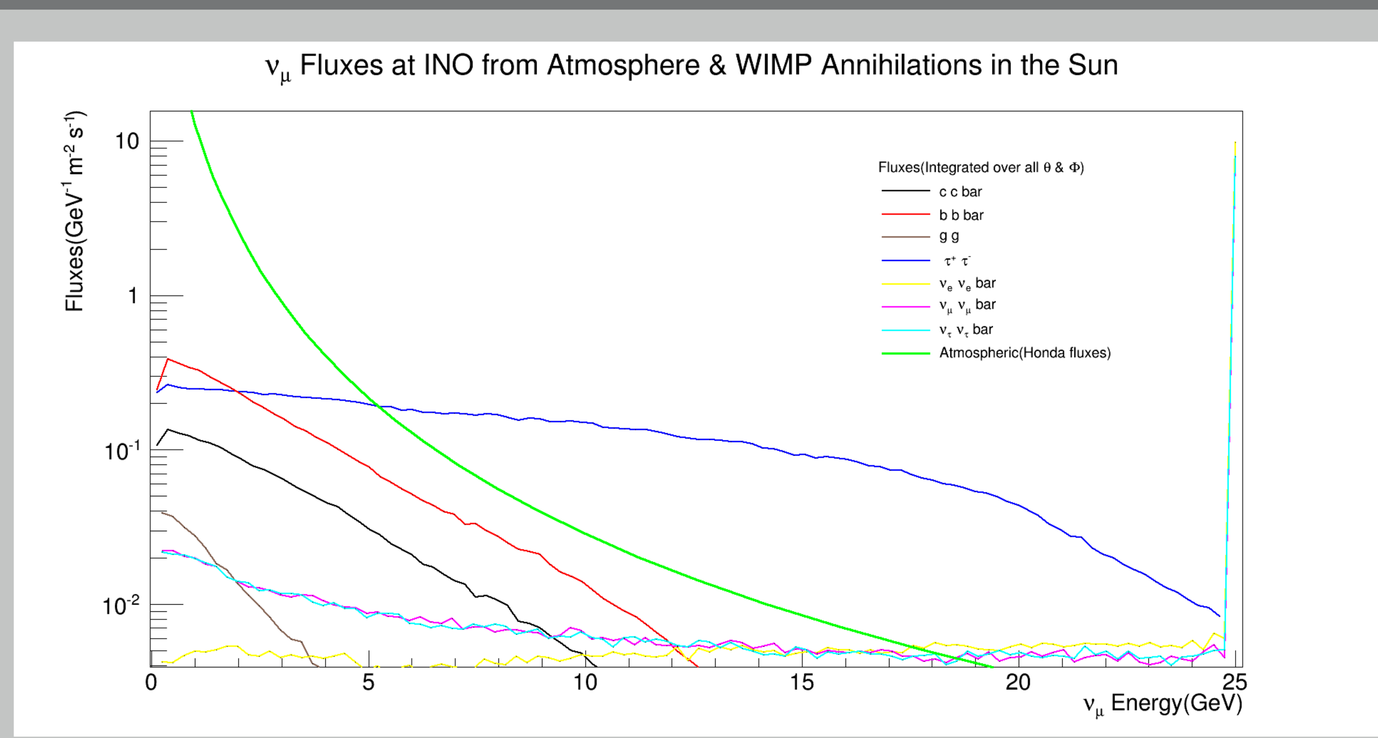

Figure 3: Expected DM Flues at INO due to 25GeV WIMP annihilation in the Sun through various channels.$\chi\chi \to \nu\nu$ constitutes Kaluza-Klien channels.

Results

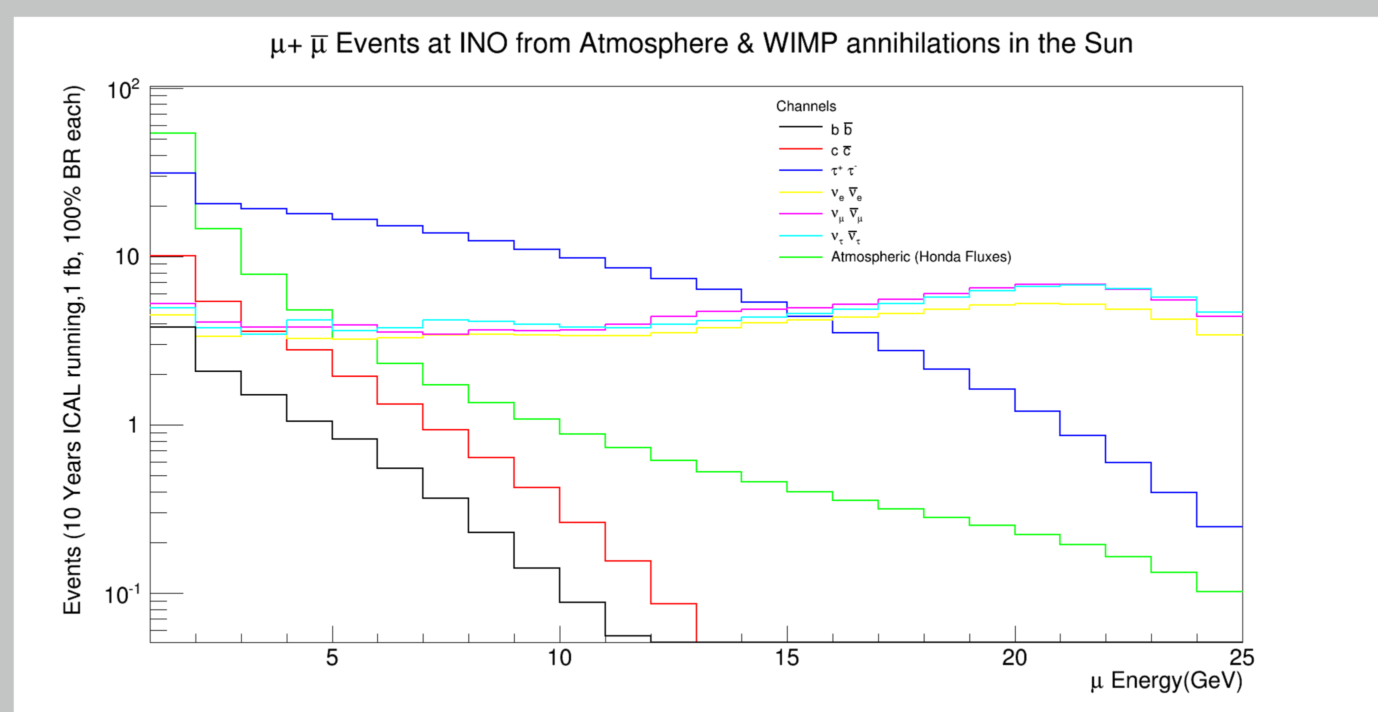

Figure 4: Expected $\mu + \bar{\mu}$ events for 25 GeV WIMP mass,10 years of ICAL running and 1 fb SD DM-nucleon cross section assumed.Constant resolution and efficiencies have been assumed for all energy bins with 1 GeV bin width.

Conclusion

- Neutrinos arising out of WIMP annihilations in the Sun can be used to probe dark matter signatures.
- Among the annihilation channels , KK and $\tau^+\tau^-$ are the most prominent ones, followed by $\mathbf{b\bar{b}, c\bar{c}}$ channels.
- With the present angular cuts on the atmospheric background ,the possibility of detection of WIMPs at ICAL seems feasible.

References

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Acknowledgments

- ITN Invisibles, Members of The INO Collaboration

 deepaktiwari@hri.res.in