Dark Matter & Neutrinos

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Abstract

Dark matter's existence is inferred through its gravitational interaction while its particle nature still remains unknown. Among the various particle candidates proposed, Weakly Interacting Massive Particles (WIMPs) have been widely pursued through direct and indirect detection schemes. Among direct detection experiments, the PICO collaboration uses bubble chambers, located in an underground facility at SNOLAB, filled with superheated C_3F_8 as a detection target. PICO-60, with a threshold of 2.45 keV, set the most stringent direct-detection constraint to date on the WIMP-proton spin-dependent cross section at 3.2×10^{-41}cm^2 for a 25 GeV WIMP [1]. We are actively working towards building the next generation ton-scale chamber PICO-500 which will further explore the WIMP-nucleon parameter space. In that quest, understanding the radiation background at SNOLAB drifts becomes crucial. In particular, the flux of thermal neutrons, fast neutrons, and gamma photons, arising due to radioactivity in the materials surrounding the detector, constitute the principle component of the radiation environment for the underground experiments at SNOLAB. The flux of fast neutrons comprising (α, n) and spontaneous fission constitutes a significant background and the SNO collaboration estimated this flux to be $\sim$ 4000 neutrons m^{-2} day^{-1} $(2\pi\text{sr})^{-1}$, with an unknown spectrum. PICO-2L[2], operating as a very sensitive low background fast neutron detector with shielding removed, measured this fast neutron flux for $\sim$ 20 live-days. We performed a simulation of neutron propagation for PICO-2L to understand the spectral shape of the fast neutron flux, the detector sensitivity and the effect of the drift environment on neutron propagation. For PICO-500, neutrinos from the sun and atmosphere would also be a source of background, and has to be taken into consideration while estimating the detector's WIMP detection sensitivity.

For indirect searches, we search for signatures of WIMP annihilation in the center of the sun($\odot$), earth($\oplus$) and the galaxy which can give rise to neutrino-antineutrino pairs as their final products. We look at the prospects of detecting such neutrinos at the proposed 50-kt Iron Calorimeter (ICAL) detector, at the upcoming India-Based Neutrino Observatory (INO), wherein the interaction of neutrinos ($\nu_\mu/\bar{\nu}_\mu$) with detector iron layers will produce μ^-/μ^+. The atmospheric neutrinos in GeV range will pose a serious background to such signal neutrinos, which fortunately, can be suppressed considerably by exploiting the excellent angular resolution of the ICAL detector. The expected sensitivity limits for 500 kt-years of ICAL exposure are quite competitive to the indirect detection experiments for the WIMP masses (m_χ) < 100 GeV. The expected 90 % C.L. exclusion sensitivity limits for 500 kt-years exposure for $\tau^+\tau^-$ channel (100 % branching ratio) for WIMP-nucleon Spin Dependent (σ_{SD}) and Spin Independent (σ_{SI}) cross-section are found to be [3, 4] $\sigma_{SD,\odot} < 6.87 \times 10^{-41}$ cm^2 and $\sigma_{SI,\odot} < 7.75 \times 10^{-43}$ cm^2 for the WIMP mass (m_χ) = 25 GeV, and $\sigma_{SI,\oplus} = 1.02 \times 10^{-44}$ cm^2 for m_χ =52.14 GeV. For galactic centre searches [5], the expected 90 % C.L. sensitivity limits on velocity averaged annihilation cross-section $\langle\sigma_A v\rangle$ for a 30 GeV WIMP, assuming NFW WIMP profile and 100% branching ratio for each channel are: $\langle\sigma_A v\rangle \leq 1.19 \times 10^{-22}$ cm^{3}s^{-1} for the $\mu^+\mu^-$ channel and $\langle\sigma_A v\rangle \leq 6.35 \times 10^{-23}$cm^{3}s^{-1} for the ν $\bar{\nu}$ channel.

Keywords

Dark Matter, WIMPS, Neutrinos, Muons, bubble chambers, neutrons, PICO, INO

References

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