Event rates for WIMP- ^{127}I, ^{75}As scattering

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Introduction

There has been universal agreement among the cosmologists and astronomers that most of the mass of the universe is dark. There are overwhelming evidences to believe that dark matter candidates are mostly nonbaryonic, the baryonic component is roughly 20% [1]. The most promising nonbaryonic cold dark matter candidates are the Weakly Interacting Massive Particles (WIMP) which arise in super symmetric theories of physics beyond the standard model.

^{127}I is among the most popular detector nuclei. There are many experiments which use ^{127}I as detector; see for example [2]. Other important candidate nuclei are ^{73}Ge, ^{75}As, ^{133}Cs and ^{133}Xe. In recent years, the deformed shell model (DSM), based on Hartree-Fock (HF) deformed intrinsic states with angular momentum projection and band mixing, has been established to be a good model to describe the properties of nuclei in the mass range A=60-90 [3]. Recently we have studied the event rates for WIMP with ^{73}Ge as the detector within the DSM model [4] with considerable success. Following this, we have initiated a programe with T. Kosmas and D.K. Papoulias to study many different aspects of dark matter detection using the above candidate nuclei; initial results on neutrino-floor for some of the nuclei are presented in [5]. Thus, DSM is extended to A=$60-135$. In the present paper we will discuss the results for detection rates of the dark matter with ^{127}I and ^{75}As as the detectors.

Formulation

Direct detection of WIMP is most interesting since its flux on earth coming from the galactic halo is expected to be quite large, of the order 10^5 per cm^2 per second. The relevant theory of WIMP-nucleus scattering has been discussed in our earlier publication [4]. For completeness we give here a few important steps. The differential event rate per unit detector mass for a WIMP with mass m_χ can be written as [1]

$$dR = N_t \, \phi \, \frac{d\sigma}{d \mid q \mid^2} f \, d^3 v \, d \mid q \mid^2 \qquad (1)$$

In the above equation, ϕ is the dark matter flux which is equal to $\rho_0 v / m_\chi$; ρ_0 being the local WIMP density. N_t stands for the number of target nuclei per unit mass which is equal to $1/(Am_p)$, A being the mass number of the nucleus in the detector and m_p is the proton mass. f is the WIMP velocity distribution which is assumed to be Maxwell-Boltzmann type. q represents the momentum transfer to the nuclear target. Introducing the dimensionless variable $u = q^2 b^2 / 2$ with b as the oscillator length parameter, the WIMP-nucleus differential cross section in the laboratory frame is given by [4]

$$\frac{d\sigma(u,v)}{du} = \frac{1}{2} \sigma_0 \left(\frac{1}{m_p b} \right)^2 \frac{c^2}{v^2} \frac{d\sigma_A(u)}{du} \; ; \quad (2)$$

with

$$\begin{aligned} \frac{d\sigma_A(u)}{du} = & \left[f_A^0\right]^2 F_{00}(u) + 2 f_A^0 f_A^1 F_{01}(u) + \\ & \left[f_A^1\right]^2 F_{11}(u) + A^2 \times \\ & \left(f_S^0 - f_S^1 \, \tfrac{A-2Z}{A}\right)^2 \mid F(u) \mid^2 . \end{aligned} \qquad (3)$$

In Eq. (3), the first three terms correspond to spin contribution coming mainly from the axial current and the fourth term stands for the coherent part coming mainly from the scalar interaction. Here, f_A^0 and f_A^1 represent

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isoscalar and isovector parts of the axial vector current and similarly f_S^0 and f_S^1 represent isoscalar and isovector parts of the scalar current. The definition of the spin structure functions $F_{\rho\rho'}(u)$ with ρ, $\rho' = 0{,}1$ are given in ref [4]. The event rate is obtained by integrating Eq. (1) with respect to u, velocity v and angle θ, see ref [4] for details. The details of DSM model have been described in many of our earlier publications, see for example [3, 4].

Results

We have used for ^{127}I an effective interaction recently developed by Coraggio et al [6] employing a model space consisting of the orbitals $0g_{7/2}$, $1d_{5/2}$, $1d_{3/2}$, $2s_{1/2}$ and $0h_{11/2}$ with the closed core ^{100}Sn. By particle hole excitations over the lowest configuration, we generate a total of 6 HF configurations. We then perform angular momentum projection and band mixing and obtain the nuclear wave functions which are used for calculating different properties of this nucleus. In this nucleus, four low lying positive parity collective hands have been identified experimentally. They are reasonably well described within the DSM model. DSM correctly reproduces the ground state $5/2^+$ level. The experimentalists have suggested that the low lying positive parity bands should be associated with the proton $d_{5/2}$ and $g_{7/2}$ configurations. We also predict similar structure for these bands Since the spin contributions play an important role in the calculation of event rates, the calculation of magnetic moment is then carried out. DSM provides a reasonable description of the observed magnetic moments. All these are repeated for ^{75}As, with similar success, using a modified Kuo interaction [3].

The event detection rates for different values of m_χ have been calculated using the nucleonic current parameters $f_A^0 = 3.55e-2$, $f_A^1 = 5.31e-2$, $f_S^0 = 8.02e-4$ and $f_S^1 = -0.15 \times f_S^0$. The results are shown in Fig. 1 for detector threshold energy $Q_{th} = 0$, 10 keV. For Q_{th}=0 keV, the highest event rate occurs for ^{127}I at the dark matter mass ~ 35 GeV. For ^{75}As, the corresponding peak occurs at $m_\chi = 40$ GeV. The event rate decreases at higher detector threshold energy but the peak shifts to the higher values of m_χ. The thickness of the curve gives the annual modulation. Due to lack of space, results for elastic and inelastic spin structure functions, nuclear structure coefficients, neutrino-floor etc. for the WIMP-^{127}I, ^{75}As scattering are not presented here and so also are the results for ^{133}Cs and ^{133}Xe. These will be discussed in the talk.

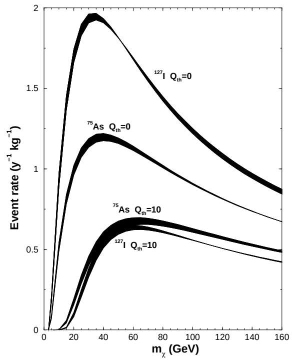

FIG. 1: The event rate in units of $yr^{-1}kg^{-1}$ as a function of dark matter mass for ^{127}I and ^{75}As at detector threshold $Q_{th} = 0, 10\ keV$. The thickness of the curve represents the annual modulation.

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