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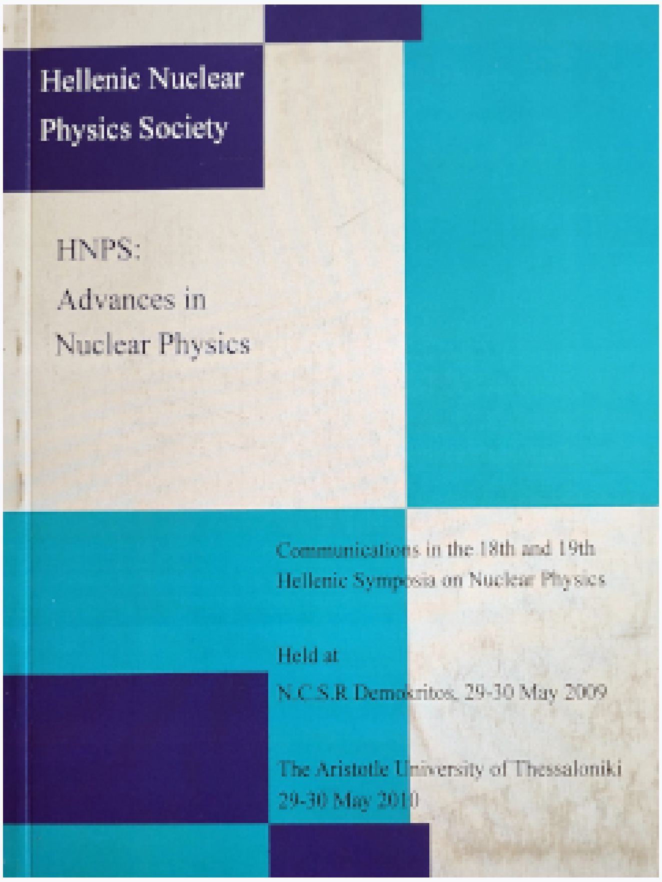

8B and hep solar neutrino detection by terrestrial experiments

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Abstract

Solar neutrino spectra of ^8B and hep neutrinos produced by pp-chain reactions are analysed for various nuclear detectors in current terrestrial experiments. The well known folding method is applied by employing appropriately simulated solar neutrino distributions and using recently calculated total cross section of neutrino-nucleus processes. We focus on the nuclear target of current experiments like MOON and ICARUS as well to other promising nuclear isotopes.

1 Introduction

The main goal of recent experimental and theoretical investigations on phenomena involving neutrinos is to shed light on the open problems to which neutrinos are absolutely crucial. The astrophysical neutrinos play fundamental role in various astrophysical phenomena, therefore, terrestrial experiments detecting astrophysical neutrinos are highly valuable sources of astrophysical information [1].

In the low neutrino-energy region ($E_\nu < 20$ MeV) the solar neutrinos and the lower energy part of the supernova neutrinos are of fundamental interest. The observation of these neutrinos is often based on their interaction with complex nuclei. The study of the corresponding neutrino-nuclear cross section relies on.

In the present work we focus on phenomena related to the standard neutrino-nucleus interaction processes i.e. the neutral- and charged-current reactions of the astrophysical neutrinos with the nuclear detector. In the first case the coherent channel dominates while in the second several channels leading to specific final number excitations are well pronounced. We currently devote a special e ort on calculating convoluted total cross sections for the coherent channels, using the neutrino-energy distributions of the ^8B and hep solar neutrino sources.

2 Formalism of neutrino-nucleus elastic scattering

In neutral-current neutrino-nucleus processes, considered in the present work, intermediate energy solar neutrinos are elastically scattered o a nucleus (A,Z) via the exchange of neutral Z_0 bosons. This process can be represented by the reaction

$$\nu + (A, Z) \rightarrow \nu' + (A, Z)^* \tag{1}$$

where A, Z the mass and atomic number of the nuclear target.

At low energies, relevant for solar neutrinos, the nuclear detector can be treated as a point scatterer mostly remaining in its ground state (coherent process). In such cases nucleons respond coherently and the expression for the di erential cross section, in a good approximation, reduces to

$$\frac{d\sigma}{d(cos\Phi)} = G^2 \frac{sin^2\theta_w}{2\pi} A^2 E_\nu^2 (1 + cos\Phi) \tag{2}$$

where Φ is the scattering angle, θ_w the Weinberg angle and E_ν the incoming neutrino energy [2].

Integrating over all directions, the total cross section for even-even target nuclei ($J = 0$) having proton number Z equal to the neutron number N (N=Z), is approximately proportional to N^2. i.e.

$$\sigma \approx 4 \times 10^{-43} N^2 E_\nu^2 cm^2 MeV^{-2} \tag{3}$$

The coherence factor A^2 in Eq. (2), or equivalently the factor N^2 in Eq. (3), describes one of the main advantages of using the elastic scattering channel for studying the neutrino-nucleus inetraction. For practical cases, the cross section corresponding the neutrino absorption can be a factor of $10^3 - 10^4$ larger than that of the neutrino-electron scattering process.

In principle, coherent scattering could be used to detect all of the solar neutrino sources in terrestrial experiments. In practice, the ^8B and hep neutrinos (intermediate energy solar neutrinos) which may have energies up to $15 - 18$ MeV, may be easier to detect since both the coherent scattering cross section

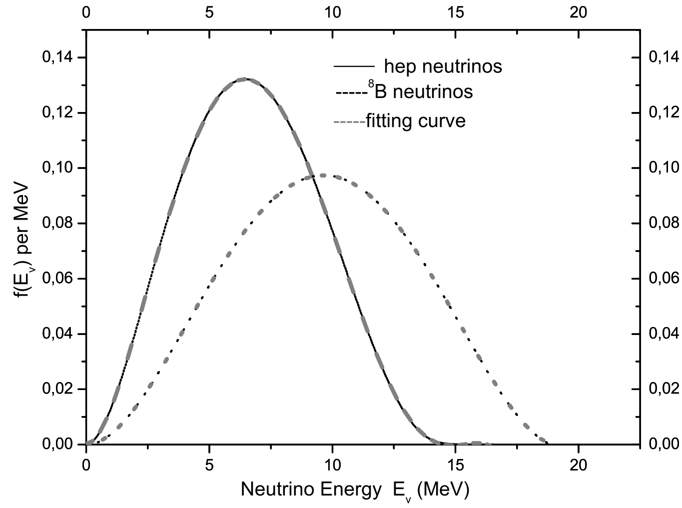

Fig. 1. The solar neutrino energy spectrum for ^8B and hep pp-chain channels.

and the magnitude of the nuclear recoil are proportional to the square of the neutrino energy [3]. While the nuclear models which estimate cross-sections (total or di erential) are not very precise in low energies,$^8B$and hep neutrino energy spectra extends up to 18.8 MeV,which covers the giant resonance region.

In this work we focus on the study of the response of concrete nuclei in the ^8B and hep neutrino energy spectrum. We have chosen a set of four nuclei which are very important from an experiment point of view in ongoing neutrino-detection experiments. Our main goal is to calculate the folded (convoluted) total cross sections of the neutrino spectra of these sources for various reaction channels.

For a specific nuclear detector, the flux averaged cross-section,$\langle\sigma(E_\nu)\rangle$, is expressed as

$$\langle\sigma(E_\nu)\rangle = \int\limits_{E_{thres}}^{\infty} \sigma(E_\nu)f(E_\nu)dE_\nu \tag{4}$$

where E_{thres} is the energy threshold of the neutrino detector.

3 Results and discussion

The energy distributions, $f(E_\nu)$, of ^8B and hep neutrinos predicted by the standard solar model are approximately described by the corresponding curves

Table 1
The coe cients α_κ, of Eq. (6) for the solar neutrino channels ^{8}B- and hep-neutrinos.

Coe cients	^{8}B Neutrinos	hep Neutrinos
α_0	-1.33$\times10^{-4}$	0.00001
α_1	0.0016	-0.00002
α_2	0.01447	0.0042
α_3	-0.0028	-0.00044
α_4	1.78065$\times10^{-4}$	0.00001
α_5	-8.85303$\times10^{-7}$	-2.6641
α_6	-6.11802$\times10^{-7}$	
α_7	4.34285$\times10^{-8}$	
α_8	-1.02536$\times10^{-9}$	

of Fig. 1. These distributions are normalized to unity as

$$\int f(E_\nu)dE_\nu = 1 \tag{5}$$

The analytical polynomial expressions of the form

$$f(E_\nu) = \sum_{\kappa=0}^{8} \alpha_\kappa \, E_\nu^\kappa \,, \tag{6}$$

which fit the above energy distributions shown also in this figure have been estimated by appropriate program. The coe cients α_κ, for each neutrino channel, are listed in Table 1.

Current proposed and ongoing solar neutrino experiments like BOREXINO and SNO+, expect to observe low-rate solar neutrinos as pep and CNO neutrinos significant to study solar physics. Neutrinos will help in understanding the metallicity in the solar core that appears to contrast with recent interpretations of solar surface chemical abundances.

Furthermore, other type of experiments (cryogenic, etc.) are designed with the aim to study coherent neutral-current scattering of neutrinos on nuclei. Such experiments may provide a potential to detect low-energy neutrinos with an excellent energy resolution. Neutrino-induced recoil events may constitute a background to direct dark matter searches [8].

Currently we perform calculations for folded total cross sections of neutrino-nucleus reactions for other interesting neutrino-detection nuclear isotopes such as ^{28}Si and ^{32}S. Such estimations of total cross sections in neutrino-nucleus reactions is of great importance in neutrino detection of existing neutrino detectors and promising nuclear isotopes proposed to be used in future neutrino detection experiments.

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