Nuclear Structure properties significant to neutrinoless double beta decay of ^{124}Sn

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Introduction

The decay rate of neutrinoless double beta process is expected to give the first direct measure of the neutrino mass, if the corresponding nuclear matrix element can be reliably calculated [1]. A major complication in extracting the neutrino mass from the half-life of this decay is the uncertainty in the nuclear matrix element. There are certain experimental observable that may be placed to constrain the calculations of the matrix element [2]. One of the main ingredients in calculating the nuclear matrix element is the wave functions of the initial and final states, which are usually calculated based on different nuclear models [1, 2]. Single-nucleon transfer reactions can be used to probe the occupancy and vacancy of valence orbitals which can help to characterize the ground-state wave functions. The precise measurement of both neutron addition and removal cross-sections can be used to determine the occupation of valence orbits relevant to $0\nu2\beta$-decay, following the Macfarlane and French sum rules [3]. The method consists of requiring a normalization such that for a given orbit characterized by total angular momentum j, the sum of the measured occupancy and vacancy on the same target add up to the degeneracy of the orbit 2j+1. It has been shown that such measurements allowed for a detailed description of the energy and vacancy of the valence orbitals of ^{76}Ge and ^{76}Se, where ^{76}Ge is a candidate for $0\nu2\beta$-decay. The results indicated that the Fermi surface is much more diffuse than in theoretical calculations [4]. Similar measurements have been recently performed on ^{130}Te and ^{130}Xe [5]. Both ^{76}Ge and ^{130}Te are subject of research for $0\nu2\beta$-decay programs known as GERDA, Majorana (for ^{76}Ge) and CUORE (for ^{130}Te).

The present work is aimed to study neutron pickup and stripping transfer cross-sections on one of the $0\nu2\beta$-decay candidate ^{124}Sn and its daughter ^{124}Te. This nucleus is the focus of neutrino-less double beta decay study, at the upcoming underground India based Neutrino Observatory (INO). This information will be useful for constraining calculations of the nuclear matrix element for the $0\nu2\beta$-decay of ^{124}Sn.

Experimental Details

Measurements of transfer cross-sections for reactions (d,p) (p,d) (^{4}He, ^{3}He) (^{3}He, ^{4}He) on enriched ^{124}Sn and ^{124}Te were performed at Split Pole facility at IPN Orsay, France. Thickness of both the targets was around 200μg/cm^2 that were deposited on 20μg/cm^2 CVD Carbon backing. The beam energies were chosen to be a few MeV above the Coulomb barrier where angular distributions

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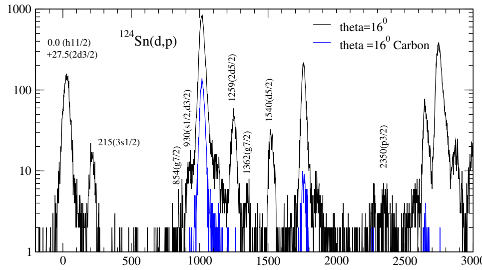

FIG. 1: Excitation energy spectrum for ^{124}Sn(d,p) reaction at 16°. The states corresponding to ℓ = 0,2,4 and 5 of ^{125}Sn are labeled. The background arising from ^{12}C is also marked

are distinctly forward peaked. The (d,p) reactions were carried out at 15 MeV. For (p,d) reaction the proton energy was selected to be 22 MeV, to ensure that the outgoing deuterons were approximately of the same energy as the incident energy of deuterons in the (d,p) reaction. This allows for a similar optical-model parameterization to be used in the DWBA for both the channels, thus minimizing systematic uncertainty. With the same consideration the beam energies for the (^{4}He, ^{3}He) and (^{3}He, ^{4}He) reactions were selected to be 40 MeV and 30 MeV respectively. For the (^{4}He, ^{3}He) and (^{3}He, ^{4}He) reactions, the focus was on the ℓ = 5 and ℓ = 4. The spectrometer was kept at angles 7° and 16° for (d,p) reaction, 7° and 13° for (p,d) and (^{4}He, ^{3}He) reactions, and 7° and 20° for (^{3}He, ^{4}He) reaction. In order to get absolute cross-section estimation of the product of target thickness and spectrometer solid angle is require. This was obtained by measuring elastic scattering in the Coulomb regime for each target using beam of 20-MeV alpha particles.

Analysis and Summary

Sn nuclei with proton closed shell Z=50 and Te nuclei with only two protons beyond the closed shell Z = 50 span the wide neutron number region N = 50-82. The relevant active orbitals are 0g7/2, 1d, 2s1/2, and the unique parity 0h11/2. These states can be populated through ℓ = 4, 2, 0, and 5 transfer, respectively. The states populated via (d,p) reaction for ^{124}Sn target are shown in Fig. 1. The angular distributions of the states for neutron stripping reaction on ^{124}Sn target are plotted in Fig. 2 along with the calculated values, obtained using the code FRESCO [6] (run in DWBA mode). Calculations have been scaled to extract the spectroscopic factor. Standard parameters were used for the bound states and for optical model potential [7, 8]. The spectroscopic factor and occupancies of orbitals populated in (d,p) and (p,d) reactions on ^{124}Sn and ^{124}Te will be presented.

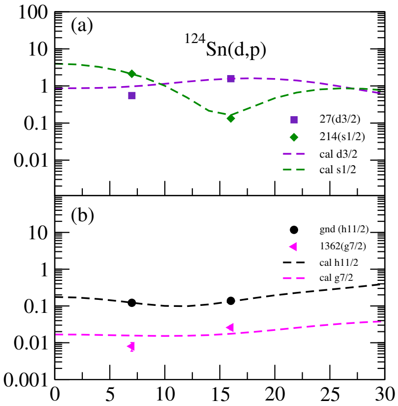

FIG. 2: transfer cross-section for ^{124}Sn(d,p) (a) ℓ = 0 and 2 states (b) ℓ= 4 and 5 states. The DWBA calculations scaled with the spectroscopic factor are shown as dashed lines

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