# Neutron transfer reactions to constrain matrix element for neutrinoless double beta decay of $^{124}$Sn

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## Introduction

Neutrinoless double beta decay (NDBD) is expected to give the first direct measure of the effective neutrino mass.The uncertainty in the latter will be dominated by that in the relevant nuclear matrix element (NME) [1]. Of the various observables that could be used to constrain the NME, the occupancy and vacancy of ground state wavefunctions of the parent and daughter nuclei involved in NDBD, are important ingredients [1, 2]. Single-nucleon transfer reaction cross-sections can be used for this purpose, making use of 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. Such measurements allowed for a 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 neutrinoless 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 $^{124}$Te and $^{124}$Sn were performed at Split Pole facility at IPN Orsay, France. Thickness of both the targets was around 200$\mu$g/cm$^2$ that were deposited on 20$\mu$g/cm$^2$ CVD Carbon backing. The beam energies were chosen to be a few MeV above the Coulomb barrier where angular distributions 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

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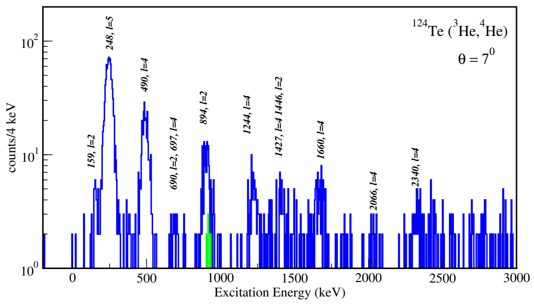


FIG. 1: Excitation energy spectrum for $^{124}$Te($^3$He, $^4$He) reaction at 7°. The states corresponding to $\ell$ = 2,4 and 5 of $^{123}$Te are labeled. The background arising from $^{12}$C is also marked

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 $\ell$ = 5 and $\ell$ = 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 $\ell$ = 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). Standard parameters were used for the bound states and for optical model potential [7]. The occupancies of the valence orbitals deduced from (d,p), (p,d), ($^4$He, $^3$He) and ($^3$He, $^4$He) reactions on $^{124}$Sn, $^{124}$Te targets, have been compared with shell model predictions [8]. The results reveal that the change in neutron vacancy between $^{124}$Sn and $^{124}$Te occurs mainly in $h_{11/2}$ orbital.

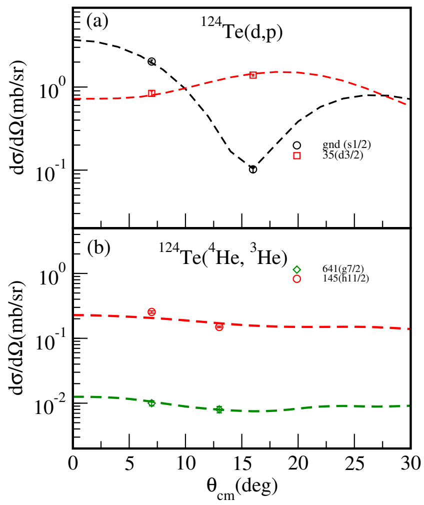


FIG. 2: Transfer cross-section for (a) $\ell$ = 0, 2 states of $^{125}$Te from (d,p) and (b) $\ell$= 4, 5 states of $^{125}$Te from ($^4$He,$^3$He) reactions. The DWBA calculations scaled with the spectroscopic factor are shown as dashed lines

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