

The neutron induced γ -ray background in ^{124}Sn

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Introduction

Neutrinoless double beta decay ($0\nu\beta\beta$ or NDBD) is a second order weak process and an only probe to test Majorana or Dirac nature of neutrino. Further it can probe properties of neutrino such as mass scale and mass hierarchy. The INdia-based TIN Detector (TIN.TIN [1]), a Sn cryogenic superconducting bolometer for the study of $0\nu\beta\beta$ in ^{124}Sn is in R&D stage at TIFR. The $0\nu\beta\beta$ is rare decay process and hence it is essential to understand the background due to surrounding as well as detector material itself. The Neutron induced background is a major concern. To explore the understanding of neutron induced γ -background in ^{124}Sn , it is irradiated at Dhruva reactor for 1 min. The gamma ray spectra just after irradiation and over a prolonged period of ~ 1 -30 days of cool down have been studied to investigate short lived activities.

Experimental Details and data analysis

The 99.26% enriched ^{124}Sn (4 mm \times 4 mm) was procured from ISOTOPE JSC, Russia and irradiated at Dhruva reactor with the thermal neutron flux of 5×10^{13} n/cm²sec for the 1 min. The ^{124}Sn captures slow neutron and it populates ^{125}Sn ($\frac{3}{2}+$, $T_{1/2} = 9.5$ min) and ^{125}Sn ($\frac{11}{2}-$, $T_{1/2} = 9.6$ d) states [4]. The ^{125}Sn beta decays to ^{125}Sb having Q value 2.23

MeV, which will be a background concern for NDBD of ^{124}Sn ($\sim Q_{0\nu\beta\beta} = 2.29$ MeV). Also, the long lived ^{125}Sb decays to ^{125}Te with half life ~ 2.75 years.

For the spectroscopy of ^{125}Sn , the TiLES [2, 3] set-up has been used. Prior to irradiation, radionuclide purity of ^{124}Sn sample was studied in the TiLES for ~ 14 days and no gamma rays were observed above the background, within the measurement sensitivity of TiLES.

The irradiated sample was counted immediately after irradiation and after a 1 day cool down period, aiming to understand short lived neutron induced impurities. Just after irradiation, gamma ray spectrum was acquired using HPGe detector by Radiochemistry Division at BARC. where the highly intense peak of 331.9 keV was observed which was originating from the decay of ^{125}Sn ($T_{1/2} = 10.01 \pm 0.08$ min). The half life of 331.9 keV was tracked and found to be very close to literature value. No additional short lived impurities were observed in the spectrum.

After the cool down of ~ 1 day, sample was brought to TIFR with radiation safety and measured at TIFR using TiLES. The gamma ray spectra shown in Fig. 1. The spectrum shows most of gamma rays decaying from ^{125}Sn and ^{125}Sb with the half life of ~ 10 days and ^{125}Sb to ^{125}Te with half life 2.7 y. Even very weak transitions like 1982 keV with I_γ as small as 0.0032% in ^{125}Sb decay scheme was observed. An identification of various gamma rays were confirmed with , the relative intensity and half life tracking. The half life tracking. Fig. 2 shows half life plots for most intense gamma (1067 keV) and 1889 keV, which

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showed discrepancy in intensity compared to reported value.

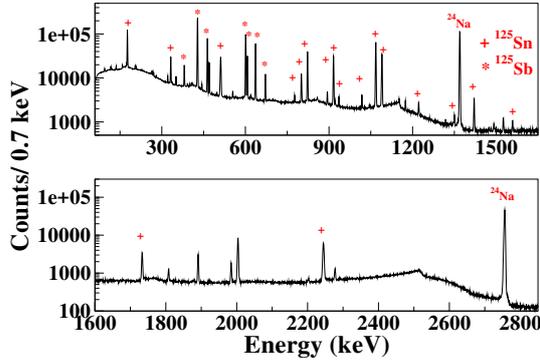


FIG. 1: The γ -ray spectrum of irradiated ^{125}Sn after $T_{\text{cool}} = 1$ d

TABLE I: The Relative Intensity (R.I.) with respect to 1067 keV of selected γ -rays in the decay scheme.

Energy (keV)	Source	Measured R.I.	NNDC R.I. [4]
1186.2	^{125}Sn	0.0027 ± 0.0006	0.0009
1558.1	^{125}Sn	0.0056 ± 0.0008	0.0004
1889.7	^{125}Sn	0.0283 ± 0.0015	0.0074
1982.7	^{125}Sn	0.0124 ± 0.0015	0.0003

The measured half life of all the observed gamma rays due to ^{125}Sn decay is found to be consistent with reference value [4] within measurement error. However, the measured relative intensity of few high energy γ -rays such as 1186 keV, 1557 keV 1889 keV and 1982 keV higher than the literature value in ref. [5]. The higher intensity of γ -rays can be a matter of concern.

Also, ^{24}Na was observed, which can arise due to $^{27}\text{Al}(n,\alpha)^{24}\text{Na}$ reaction channel.

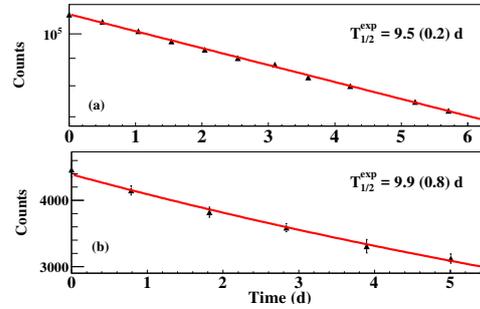


FIG. 2: The Decay of (a) 1067 keV and (b) 1889 keV of ^{125}Sn to excited state of ^{125}Sn .

Summary

The neutron induced gamma ray background in ^{124}Sn is studied using high flux thermal neutron irradiation from Dhruva reactor. Several high energy gamma rays in the range 1-2 MeV are found to have significantly higher intensities, which will have impact on background for *TIN.TIN* experiment

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