# Improvements to Tifr Low background Experimental Setup (TiLES)

G. Gupta[1], N. Dokania[1], H. Krishnamoorthy[2,3], A. Garai[2,3], C. Ghosh[1], M.S. Pose[1], V. Nanal[1],* and R.G. Pillay[1]
[1] *DNAP, Tata Institute of Fundamental Research, Mumbai,*
[2] *INO, Tata Institute of Fundamental Research, Mumbai, and*
[3] *Homi Bhabha National Institute, Anushaktinagar, Mumbai*

## Introduction

Low background levels are essential to enhance the sensitivity of rare decays studies. Natural radioactivity from the decay chains of $^{235}$U, $^{238}$U and $^{232}$Th series, radioactive primordial nuclei $^{40}$K, cosmic muons and neutrons are the common sources of background. At the sea level, the background is mostly dominated by cosmic-ray muons and their secondary products such as neutrons, gammas and cosmogenic isotopes [1]. In addition, the Radon produced in the U, Th decay chains is gaseous and can be trapped in the volume around the detector. The $^{222}$Rn ($T_{1/2}$ = 3.8 d) and $^{220}$Rn ($T_{1/2}$ = 54.5 s) are produced in the decay chain of $^{238}$U and $^{232}$Th, respectively. The $^{222}$Rn contributes more to the background as it has a longer $T_{1/2}$ compared to $^{220}$Rn. A dedicated low background experimental setup, TiLES is developed at TIFR, for background studies related to neutrinoless double beta decay in $^{124}$Sn [2]. Recently, the setup has been upgraded with the inclusion of $N_2$ flushing and improved cosmic veto systems. This paper describes improvements to the TiLES, which have resulted in reduction in the background level by $\sim$ 39% in the energy range 40-2700 keV.

## Experimental Details

The TiLES consists of a low background, high efficiency HPGe detector (70% relative efficiency) [2]. The detector is shielded with 5 cm low activity OFHC Cu, 10 cm low activity Pb ($^{210}$Pb $<$ 0.3 Bq/kg) and an active cosmic muon veto system using three plastic scintillators (P1, P2, P3). The sensitivity obtained in the setup was $\sim$ 2 mBq/g for $^{40}$K [3]. In order to improve the sensitivity further, the setup is upgraded by adding one more plastic scintillator (P4) and the Radon exclusion box surrounding the HPGe detector and the Pb+Cu shield.

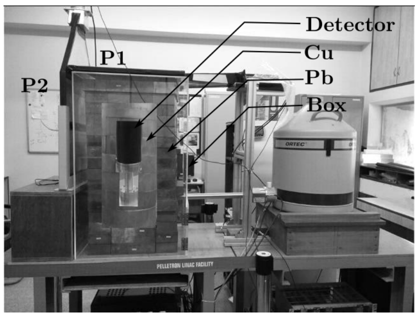


FIG. 1: A schematic picture of TiLES with Cu+Pb shielding arrangement (without P3)

The Radon exclusion box is made of Perspex ($\sim$ 9 mm thick) and the box volume is continuously purged with boil-off $N_2$ at an over-pressure of $\sim$ 8 - 10 mbar to reduce the $^{222}$Rn contamination. The plastic scintillators (50 cm $\times$ 50 cm $\times$ 1 cm each) are arranged outside the Radon exclusion box in a geometry to obtain the best possible muon coverage (see Fig. 1). Data is acquired using a commercial CAEN N6724 digitizer (14-bit, 100 MS/s). The HPGe detector signal is directly given to the digitizer. The plastic scintillator signal (PMT anode output) has fast rise time and is not directly compatible with the digitizer. To overcome this and to combine the multi-

*Electronic address: vnanal@gmail.com

ple veto detector signals (upto 4 channels), a customized unit comprising fast amplifier and a summing stage has been developed. Anti-coincidence between the HPGe detector and the plastic scintillators is perfomed using a C++ based algorithm within the timing window of $\pm 2.5$ $\mu$s. The LAMPS [4] software and ROOT framework is used for the data analysis.

## Data Analysis and Results

Figure 2 shows the background spectra with and without nitrogen flushing. The effect of $N_2$ flushing is evident from the reduction in the photopeak counts of 351.9 keV ($^{214}$Pb) and 609.3 keV ($^{214}$Bi).

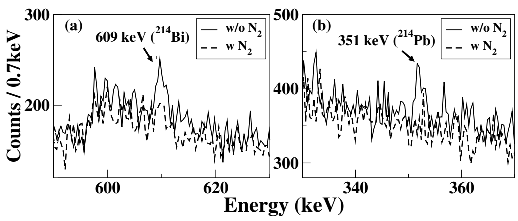


FIG. 2: Gamma ray spectra showing the reduction in photopeak counts of (a) 609.3 keV and (b) 351.9 keV ($T_{counting}$ = 10 d) with $N_2$ flushing.

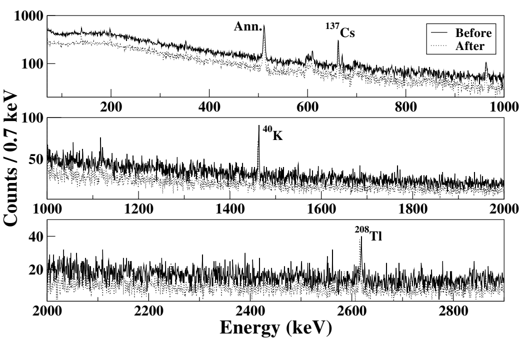


FIG. 3: Ambient backround spectra before and after the shield upgrade ($T_{counting}$ = 7 d).

The addition of the P4 scintillator resulted in further reduction of the background level in the energy range 40-2700 keV by $\sim$ 20%. Figure 3 shows the gamma ray spectra before (i.e. with Cu+Pb, P1-P2-P3) and after the shield upgrade (i.e. with Cu+Pb, P1-P2-P3-P4, $N_2$ flushing). The background level in the energy range 40-2700 keV is signficantly reduced by $\sim$ 39%. Table I lists the observed counts of dominant gamma rays in the ambient background. It can be seen that the photopeaks of 351.9 keV, 511 keV and 609.3 keV are reduced by about a factor of 2, while 1460.8 keV as well as 2614.4 keV are not affected. It should be mentioned that the integral background rate $1.7\times10^4$ /day/kg, is one of the best levels achieved for HPGe setups at sea level [5]. Feasibility of further improvements with neutron shield can be explored.

TABLE I: Comparison of background level before and after the shield upgrade.

| Energy (keV) | Source | Counts[a] (/7 d) | Counts[b] (/7 d) |
|---|---|---|---|
| 139.4 | $^{74}$Ge(n,$\gamma^m$)$^{75}$Ge | 307(62) | 271(66) |
| 197.9 | $^{70}$Ge(n,$\gamma^m$)$^{71}$Ge | 259(87) | 238(50) |
| 351.9 | $^{214}$Pb | 223(62) | - |
| 511 | Ann. | 2523(101) | 1589(84) |
| 609.3 | $^{214}$Bi | 211(51) | 115(39) |
| 661.6 | $^{137}$Cs | 709(54) | 596(54) |
| 669.6 | $^{63}$Cu(n,n$'\gamma^m$)$^{63}$Cu | 171(40) | 56(41) |
| 964.7 | $^{228}$Ac | 266(48) | 187(26) |
| 1115.5 | $^{65}$Zn | 55(22) | 75(33) |
| 1460.8 | $^{40}$K | 227(34) | 215(32) |
| 2614.4 | $^{208}$Tl | 95(24) | 126(28) |
| 40-2700 | | 321791(567) | 195490(442) |

[a]Cu+Pb, P1-P2-P3.
[b]Cu+Pb, P1-P2-P3-P4, $N_2$ flushing.

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## References

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