Chapter 1

Introduction

For many years, the Standard Modle (SM) of particle physics has been the most successful theory of elementary particle physics and tested precisely. The discovery of Higgs Boson has further validated it.

However, in the neutrino sector, many repeated experimental observations of neutrino oscillations, where neutrinos change from one flavour to another, indicate that the SM can not tell the full story. The flavour mixing and the associated non-zero mass is not unambiguously incorporated in the SM, thus leading to physics beyond the SM. The neutrino oscillation experiments cannot answer all the questions about the properties of neutrinos, such as the absolute mass and ~~and~~ origin of the neutrino mass.

Neutrinos can be either Dirac or Majorana fermions due to neutrinos carrying no electric charge. If neutrinos are Dirac particles, their anti-particles would be distinctive; however, if neutrinos are Majorana particles, they would be the anti-particles of themselves. The neutrinoless double beta decay($0\nu\beta\beta$) is the only practical way of studying the neutrinos' Dirac or Majorana nature. In this hypothesised process, two double beta decay happens simtonioulsly, emitting two electrons without accompanying neutrinos; thus, it is forbidden in the SM due to lepton number violation. The observation of the process can confirm neutrinos are Majorana particles, and its decay rate can be used to extract the absolute mass(model dependent) of neutrino.

The SuperNEMO experiment is an ultra-low-background tracker-calorimeter experiment designed to search for ($0\nu\beta\beta$) decay of various isotopes with a capability to reach half-life sensitivity of 10^{26} years corresponding to an effective Majorana neutrino mass of $\langle m_{\beta\beta} \rangle < 50$ -100 meV.

This design allows one to measure the energy of the particles with the calorimeter, as well as to reconstruct the trajectory of the charged particles with the tracker. This unique technique provides a powerful background rejection through the 3D topology of each event. In addition, it can shed light on the mechanism behind the lepton number violation in $0\nu\beta\beta$ due to its unique ability to provide information on the individual electron's energy spectra and their angular distribution. The first module, SuperNEMO Demonstrator, contains 7kg of source isotope ^{82}Se. Other isotopes, such as ^{100}Mo, are also considered for the future. Importantly, because the source and the detector are separated this technology allows many different isotopes to be investigated.

The background is one of the main concerns for a rare events search experiment, such as searching for the $0\nu\beta\beta$ decay. Radon as a radioactive gas from the Uranium (U) and Thorium (Th) decay series, can enter the detector by diffusion, emanation, and contamination, and thus provide a significant background to searching for the $0\nu\beta\beta$ decay as their progenies ^{214}Bi and ^{208}Tl undergoes β decay with high Q_β value which is is sufficiently large to mimic a $0\nu\beta\beta$ decay.

All detector components and construction materials are screened and selected using techniques such as radon emanation measurement, HPGe gamma ray spectroscopy, and mass spectrometry. This screening can not only help to monitor the radiopurity of the materials but also offer a better understanding of the background contribution from different parts of the detector. The measured activities can be fed into the simulations to estimate the number of expected background events during the measurement.

All rare-event searching experiments, including double beta decay and direct dark matter searching experiments require such techniques. The SuperNEMO experiment is aiming to achieve a zero background regime in the region of interest, which requires the radon level inside the detector need to be less than 150mBq/m^3. To address these challenges a dedicated radon detector and a radon concentration line (RnCL) have been developed and deployed for radiopurity assays at UCL.

The demonstrator sensitivity to its radon background in the tracker has beed studied. Analysis tools have been developed to allow the identification of event topologies. Specific topologies and variables are chosen to optimise the measurement of the main background. These variables are used to fit background contributions in a large number of pseudo-experiments in order to estimate the statistical and systematic uncertainties of different exposure times.

1.0.1 Author's contribution

Radon detector:

- Measurements of detector efficiency and background
- Commissioning of an upgraded Rn detector
- Reducing detector background by a factor of 3 with a dedicated system of nitrogen purging
- Updating and maintaining the data acquisition system

Radon concentration line (RnCL):

- Measured the trapping and transfer efficiency of the system
- Designed a new RnCL to measure radon emanation under cryogenics temperature

Radon emanation chambers:

- Assembly, test and commissioning of the second radon emanation chamber
- Measurements of the intrinsic background of the second radon emanation chamber
- Cross-calibration with other institutions using Viton rings

Radon measurements:

- The third quarter-sections of the SuperNEMO tracker
- SuperNEMO gas mixing and delivery system
- Radon emanation measurements of components and materials for the SuperNEMO and LZ experiments

Radon background Monte Carlo studies with the SuperNEMO Demonstrator detector:

- Tracker radon background sensitivity estimation via $1e1\alpha$ topology
- Optimisation of analysis cuts

Presentation of the collaboration's work at Neutrino2018 (poster), IOP2018 (talk), NuPhys2016 (poster).

Bibliography