

This thesis investigates the potential of the SuperNEMO experiment to probe double beta decay processes and search for physics beyond the Standard Model. After reviewing neutrino properties and the theoretical framework of DBD and various exotic decay modes, the work focuses on the detector response and its impact on measurable observables.

A detailed study of angular correlations demonstrates that detector geometry and reconstruction effects significantly distort the relation between true and measured decay angles, emphasizing the need for accurate detector modeling in physics analyses.

A comprehensive background model is constructed, and sensitivity studies are performed within both Bayesian and frequentist approaches. A multidimensional optimization of the region of interest is shown to improve sensitivity by 10–20%. For an exposure of 17.5 kg, SuperNEMO is projected to achieve competitive limits on $0\nu\beta\beta$ decay of ^{82}Se and world-leading constraints on Majoron-emitting modes, or decays involving right-handed currents.

Finally, a preliminary analysis of the first 2.86 kg of data demonstrates good agreement between simulation and experiment, with extracted background activities and the $2\nu\beta\beta$ half-life consistent with independent measurements.

Overall, this work establishes a unified framework linking detector effects, statistical methods, and physics interpretation, demonstrating that SuperNEMO has strong potential to probe subtle spectral features and contribute to the understanding of neutrino properties and physics beyond the Standard Model.

Keywords: double beta decay, SuperNEMO, neutrino, ^{82}Se , Monte Carlo simulations, Geant4