Evaluation by Simulation of the Search Experiment for Neutrinoless Double Beta Decay Using Nuclear Emulsion Plates and Development of Thick Nuclear Emulsion Plates

M.Takano[1], A.Minamino[1], T.Fukuda[2], T.Matsuo[2], S.Nagahara[2],
T.Kawahara[2], L.Suzui[2], S.Takeshita[2], T.Nishikiori[2] and S.Shimizu[2]
[1]Yokohama National University,
[2]Nagoya University
takano-marin-ky@ynu.jp

Introduction

To understand why neutrinos have extremely small masses and why the present universe is dominated by matter, it is extremely important in particle physics to verify whether neutrinos are Majorana particles. The only realistic way to demonstrate that neutrinos are Majorana particles is the direct observation of neutrinoless double beta decay (0νββ).

Experimental Procedures

To observe 0νββ, it is necessary to measure the kinetic energies of the two emitted β rays. We are planning a search experiment using nuclear emulsion plates, in which the tracks of the two β rays emitted from double beta decay nuclei are recorded and their kinetic energies are reconstructed from the track lengths (Fig. 1). Nuclear emulsion plates are a type of photographic film capable of recording charged particle tracks with submicron spatial resolution. The high spatial resolution allows us to verify whether the two β rays are emitted from a single decay vertex, which provides the advantage of reducing backgrounds other than the ordinary double beta decay (2νββ) to an extremely low level. In addition, while the emulsion layers of conventional nuclear emulsion plates have a thickness of approximately 70–350 μm, in this study we aim to produce plates with a thickness of over 1 mm to fully contain the tracks of the emitted electrons within the emulsion.

Results and Discussion

From Geant4 simulations, in which β rays were injected into nuclear emulsion plates, we confirmed that by reconstructing the lengths of the two emitted β tracks and the delta rays generated along the tracks, and selecting events with a total energy above 2.74 MeV, the signal of 0νββ decay can be detected with an efficiency of 84.6% (Fig. 2). At present, we are also performing simulations including selenium sheets embedded in the emulsion plates, aiming to establish a method to infer the tracks inside the selenium sheets that cannot be recorded. Progress on this study will also be reported.

In addition, toward the development of thick nuclear emulsion plates, we evaluated the drying characteristics of gelatin, the main component of the emulsion. Results from a small-scale dryer showed that drying requires approximately 15 hours for a 0.3 mm-thick layer, 46 hours for a 0.6 mm-thick layer, and 90 hours for a 1 mm-thick layer .Due to the long drying times, we plan to improve the drying process by using a more powerful dryer.

Looking ahead, we will estimate the effects of backgrounds and energy loss within the plates on the reconstruction through simulations. Furthermore, by irradiating the prototype thick emulsion plates with internal conversion electrons and reconstructing the resulting tracks, we aim to verify the performance of the reconstruction method.

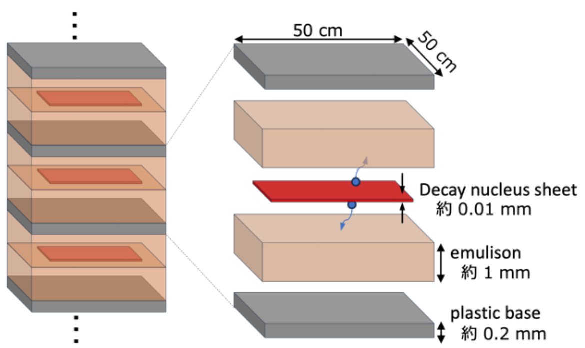

Fig. 1. Structure of the detector

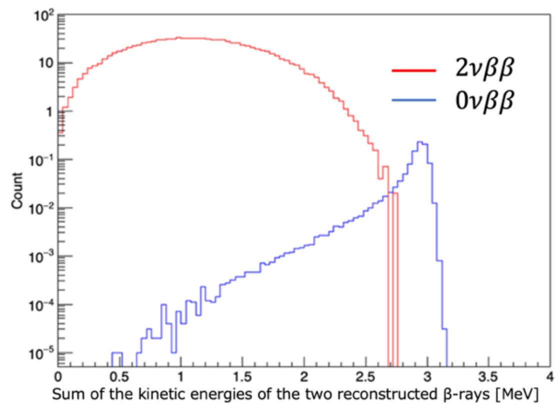

Fig. 2. Sum of the kinetic energies of the two β rays reconstructed from the simulated tracks