Master Thesis

Research and Development of Scintillation Balloon for rejecting ^{214}Bi background in KamLAND-Zen

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Abstract

The development of neutrino physics in recent years is remarkable, and neutrino oscillation observations have experimentally proved that the neutrinos have a finite mass. The main themes of physics related to current neutrinos are CP symmetry violation, mass hierarchy, sterile neutrinos, and particle-antiparticle identity (Majorana nature). Searching for neutrinoless double-beta decay ($0\nu\beta\beta$) is the only realistic method for verifying the Majorana nature of neutrinos and has attracted attention all over the world.

In the KamLAND-Zen experiment, the search for $0\nu\beta\beta$ was carried out using ^{136}Xe as a double-beta decay nucleus with 400-kg enriched xenon. It is possible to conduct experiments with the world's highest sensitivity by making use of the extremely low background environment, but further elimination of the background is indispensable for detecting $0\nu\beta\beta$ events. Various backgrounds that overlap $0\nu\beta\beta$ spectrum are discussed, and this study focused on a study on the removal method of ^{214}Bi which is the most dominant in the $0\nu\beta\beta$ region in KamLAND-Zen.

A material of a mini-balloon that xenon loaded liquid-scintillator contains ^{238}U series radioactive impurities. β/γ-ray from ^{214}Bi, the daughter nucleus of ^{238}U series, overlaps with the $0\nu\beta\beta$ signal region and makes to reduce the sensitivity. Generally Bi-Po delayed coincidence method is useful for rejecting such background, but its tagging efficiency is not so high at the near of mini-balloon because almost α-rays from ^{214}Po event are trapped in the mini-balloon matrial nylon due to short mean free path. Here, if the mini-balloon itself can be used as a scintillator to realize light emission for α-rays, it will improve the ^{214}Bi background removal efficiency by delayed coincidence. In this study, we selected and evaluated some films that would be a balloon material with the scintillator property. Along with this, we also developed new liquid scintillator containing wavelength shifter.

As a result, introducing a scintillation balloon made of PolyEthylene-Napthalate and a bis-MSB loaded liquid-scintillator in the KamLAND-Zen, it finds that ^{214}Bi backgrounds will be rejected and the sensitivity will reach the inverted-mass hierarchy region with 1.7-yr exposure time. Furthermore, introducing to next KamLAND-Zen phase with 700-kg enriched xenon, it can reach the inverted-mass hierarchy region with 4-month exposure time and approximately 23-meV of effective mass with 5-yr operation.