博士論文

First Search for Majorana Neutrinos in the Inverted Mass Hierarchy Region with KamLAND-Zen

KamLAND-Zen による初めての
逆質量階層構造でのマヨラナニュートリノの探索

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Abstract

The Majorana nature of neutrinos can be a clue to the extremely light neutrino mass and the matter dominant universe. The search for neutrinoless double-beta decay ($0\nu\beta\beta$) is the only realistic way to prove the Majorana nature of neutrinos for now.

In this dissertation, the result of the $0\nu\beta\beta$ search with the KamLAND-Zen experiment is reported. In KamLAND-Zen, ^{136}Xe is used as the double-beta decay nuclei. Enriched xenon is loaded into the liquid scintillator (XeLS) and the XeLS is hold in the nylon made balloon placed at the center of the KamLAND detector. The first observation phase with about 400 kg enriched xenon (KamLAND-Zen 400) started in 2011 and had continued until 2015. In 2019, the new observation phase, KamLAND-Zen 800 started with 745 kg enriched xenon and a cleaner balloon. Due to the cleaner environment, the background contribution from xenon spallation products has become dominant. In this work, the veto method of xenon spallation products is developed and the production rate of this background is investigated. Considering the onsite work related to the detector, the new background estimation method in which the time dependent in the detector is taken in account is also introduced. In the analysis with the data of 523.4 days KamLAND-Zen 800 measurement, significant excess is not found. The 90% C.L limit on the half-life of the $0\nu\beta\beta$ is $T^{0\nu}_{1/2} > 1.98 \times 10^{26}$ year. This limit become more strict by combining the KamLAND-Zen 400 result considering the correlation between the $0\nu\beta\beta$ and the xenon spallation backgrounds. The result is $T^{0\nu}_{1/2} > 2.29 \times 10^{26}$ year. The corresponding limit on the effective Majorana mass is $\langle m_{\beta\beta} \rangle < 36 - 156$ meV. This is the most strict limit in the world. The measurement of the production rate of xenon spallation background is also implemented.