【Grant-in-Aid for Scientific Research (S)】

Search for Majorana neutrino mass with the world's best sensitivity

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Purpose and Background of the Research

●Outline of the Research

In the early universe, matter and anti-matter, produced equally in high-temperature density, are assumed to annihilate one another. However, the current universe is dominated by only matter. The “mystery of matter-dominated universe” is one of the big problems in particle physics and cosmology, and a neutral elementary particle called neutrino is expected to be a key to the solution. More than 80 years ago, the physicist Ettore Majorana hypothesized that the neutral particle could be its own antiparticle, however, there has been no experimental evidence so far. Recent neutrino measurement results revealed that neutrinos have a tiny mass, and proving Majorana neutrino could be of decisive importance to explain these tiny masses. The practical way to probe the Majorana nature of neutrinos is the search for neutrinoless double-beta decay. Therefore, emphasis is on progress in the double-beta decay research, and future large-scale experiments world-wide are planned. The KamLAND-Zen experiment performs a high sensitivity search for Majorana neutrino mass by using 745 kg enriched xenon loaded into the liquid scintillator (Figure 1).

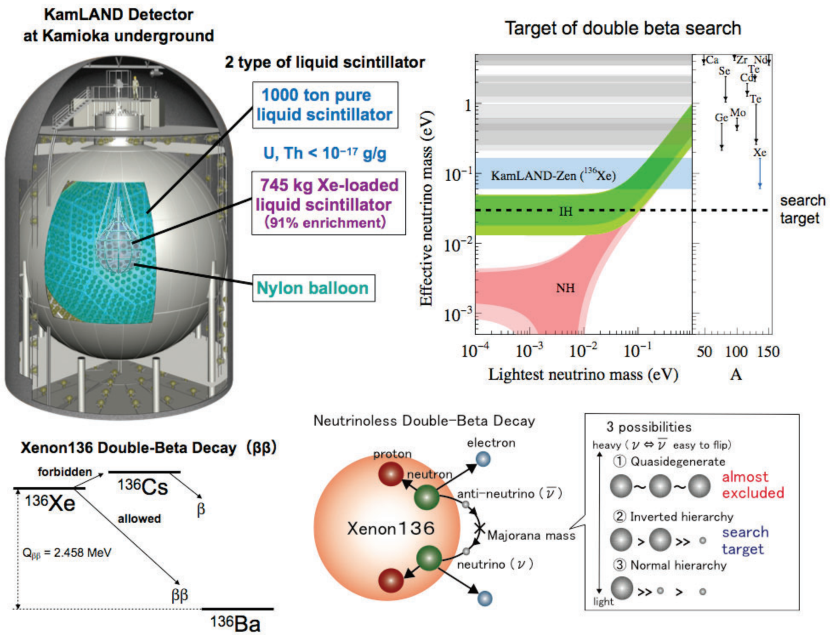

Figure 1. Search for Majorana neutrino mass

●KamLAND-Zen

KamLAND had realized the low-background neutrino experiment by using 1,000 ton liquid scintillator, so the existing detector was suitable also for the neutrinoless double-beta decay search by adding the isotopes of xenon-136. In the first search in 2011 (KamLAND-Zen 400), we were suffered from backgrounds arising from contamination of radioactive impurities during the nylon-balloon construction, however, we have succeeded in their reduction by the xenon and liquid scintillator purification. In 2019, we have started an improved experiment (KamLAND-Zen 800) by increasing the amount of xenon-136 using a cleaner nylon balloon (Figure 2).

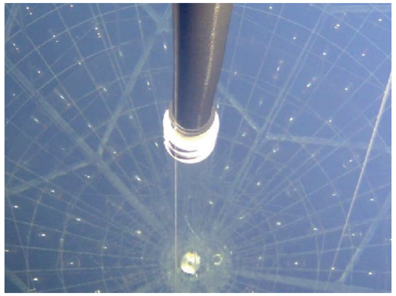

Figure 2. KamLAND-Zen inside view

Expected Research Achievements

KamLAND-Zen has realized the low-background environment, however, the sensitivity of the neutrinoless double-beta decay search is limited by the backgrounds from cosmic-ray muon-induced long-lived spallation products (Figure 3: left) and two-neutrino double-beta decays. The detailed simulation based on nuclear reaction models (Figure 3: right) indicates that all long-lived products decay with gamma-ray emissions, and the number of produced neutrons is larger relative to short-lived products. Therefore, we can reduce the long-lived backgrounds by improved particle-identification with scintillation imaging, and efficient neutron tagging after muon events. In this research, we aim to achieve an effective mass sensitivity of 30 meV to test the inverted mass hierarchy more stringently. In the future, if we realize a detector upgrade plan incorporating new liquid scintillator, light-collecting mirror, and high efficiency light sensor, aiming at light yield increase to reduce the two-neutrino decay backgrounds, a full survey of the inverted hierarchy region with a sensitivity of 20 meV can be achieved. If a positive signal is found, the Majorana nature of neutrinos can be proved, resulting in a big impact on particle physics and cosmology.

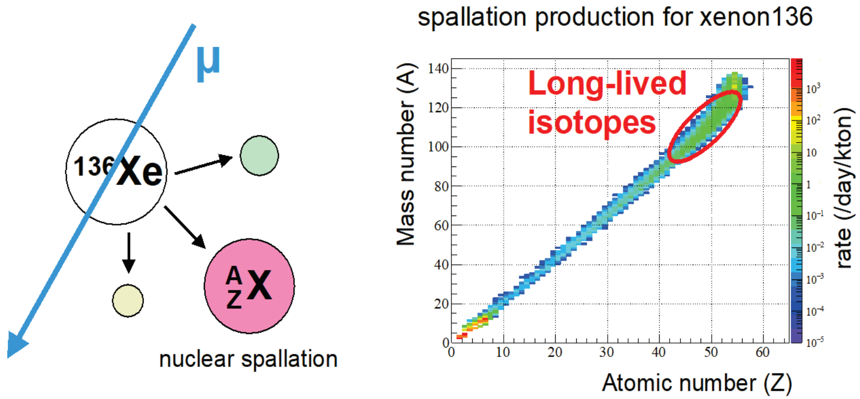

Figure 3. Spallation production for xenon136

Homepage Address, etc.	https://www.awa.tohoku.ac.jp/kamland/