【Grant-in-Aid for Specially Promoted Research】
Science and Engineering (Mathematics/Physics)

Title of Project : Study on neutrino-less double beta decay using the neutrino detector, KamLAND

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Research Area : Physics, Particle/ Nuclear/ Cosmic ray/ Astrophysics

Keyword : Particle physics (experiment)

【Purpose and Background of the Research】

Measurements of squared-mass difference of neutrinos with neutrino oscillations have provided a concrete target of absolute neutrino mass measurement. The most sensitive method of absolute neutrino mass, search for neutrino-less double beta decay, also verifies Majorana-nature of neutrinos (if neutrinos and anti-neutrinos are identical). Double beta-decay takes place when single beta-decay is forbidden but two synchronous decays are allowed at specific energy levels of the nuclei. If neutrinos are Majorana, an anti-neutrino emitted from one beta-decay can be absorbed by another beta-decay as a neutrino, resulting neutrino-less double beta-decay. In this case, neutrinos don't take out energy and the signal becomes a characteristic high-energy event. This event rate is proportional to the square of neutrino mass thus absolute neutrino mass can be measured. In order to verify the facing target, degenerated mass structure (all three neutrinos have similar and rather heavy masses), more than 100kg of double beta-decay nuclei have to be used. There are on-going big projects in the world planned to start in 2011 to 2013, and competitive projects in Japan have been awaited. Key points of the project are large amount of double beta-decay nuclei and very low background environment.

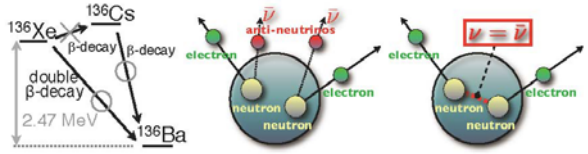

Fig.1 Example of double beta-decay nucleus (left), normal double beta-decay (center), and neutrino-less double beta-decay (right)

【Research Methods】

Among huge neutrino detectors, KamLAND has specially established an ultra-low radioactivity environment with 12 orders of magnitudes lower radio-impurities than ordinary materials. One of the double beta-decay nuclei, Xenon-136, is rare gas. Thus it can be purified easily and can be dissolved in the liquid scintillator up to 3 weight %. It also has a merit that normal double beta-decay is slow. This project suspends a 1.35m-radius balloon at the center of KamLAND. The balloon is filled with the liquid scintilltor containing 200 kg of Xenon-136. This project is very quick and low cost, because the existing apparatus can be fully used. It occupies only 1% of the sensitive volume, allowing parallel observation of neutrinos and having expandability to 1000 kg scale relevant for the next target called as inverted mass hierarchy.

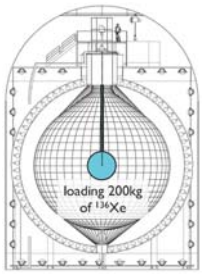

Fig.2 KamLAND detector

【Expected Research Achievements and Scientific Significance】

Successful observation of neutrino-less double beta-decay determines the mass structure of neutrinos and establishes Majorana-nature of neutrinos. This becomes a basis of the seesaw mechanism and the Leptogenesis theory, and explains the fundamental questions known as "beyond the standard model"; how neutrinos get light masses and how matter dominated in the universe. It will make great progresses in the particle and astronomical physics aiming at understanding origin of mater and laws those govern the universe.

【Publications Relevant to the Project】

- "Precision Measurement of Neutrino Oscillation Parameters with KamLAND", The KamLAND Collaboration (S. Abe et al.). Phys.Rev.Lett.100:221803, 2008.
- "Experimental Investigation of Geologically Produced Antineutrinos with KamLAND", The KamLAND Collaboration (T. Araki et al.), Nature 436:499-503, 2005.
- "Measurement of Neutrino Oscillation with KamLAND: Evidence of Spectral Distortion", The KamLAND Collaboration (T.Araki et al.), Phys.Rev.Lett.94:081801, 2005.
- "First Results from KamLAND: Evidence for Reactor Anti-neutrino Disappearance", The KamLAND Collaboration (K. Eguchi et al.), Phys.Rev.Lett.90:021802, 2003.

【Term of Project】 FY2009-2013

【Budget Allocation】 605, 900 Thousand Yen

【 Homepage Address and Other Contact Information】

http://www.awa.tohoku.ac.jp