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

Broad Section B

Title of Project : Search for new physics in particle physics with world-highest sensitivity of neutral kaon experiment

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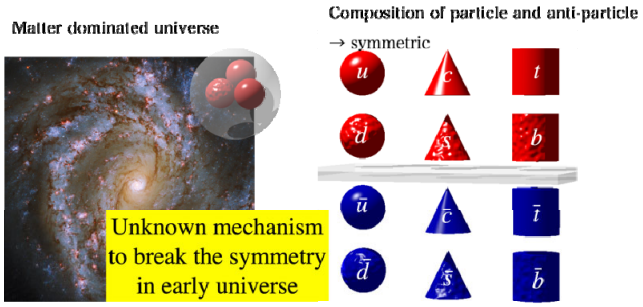
Research Project Number : 21H04995 Researcher Number : 40419445
Term of Project : FY2021-2025 Budget Allocation : 142,700 Thousand Yen
Keyword : Mystery of matter dominated universe, CP violation, Rare neutral kaon decay

【Purpose and Background of the Research】

Composition of particles and anti-particles are symmetric in the particle physics, but however almost no anti-matter is in the universe. Equal numbers of particles and anti-particles are expected in the early hot universe because of the pair-production. Therefore, a new mechanism beyond the standard model of particle physics is necessary to create the matter-dominant universe. For one scenario, unknown physics worked to generate slight asymmetry in the numbers of particles and anti-particles at the early hot universe, both numbers were decreased due to annihilation when the universe cooled down, and finally a tiny number of particles are left in our universe. Such an asymmetry exists also in the standard model of particle physics, but it is too small to generate our matter dominated universe. Therefore, new physics should exist.

A heavy particle may give such an effect. We are searching for it in the higher energy scale beyond the collider energy according to the uncertainty principle in the quantum mechanics. The quantum mechanics allow higher energy scale in a short time, accordingly we are searching for the effect from such a heavy particle with the rare decay, a neutral kaon decaying into a neutral pion and a pair of neutrinos: $K_L \to \pi^0 \nu\nu$.



【Research Methods】

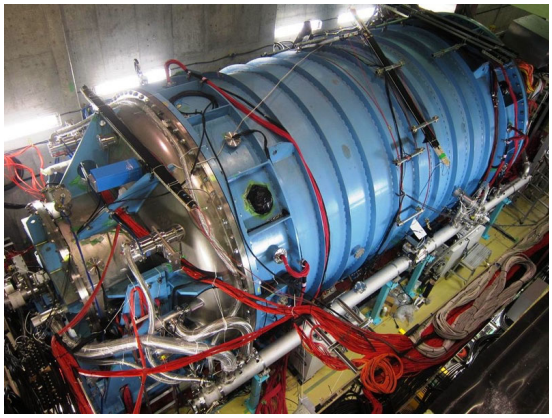
We are conducting the KOTO experiment at J-PARC : a world-highest intensity proton accelerator facility. With huge amount of neutral kaons produced at J-PARC, we are searching for the $K_L \to \pi^0 \nu\nu$, and have achieved world-highest sensitivity. In the analysis of data taken in 2016-2018, we observed 3 candidate events with the expected number of background events of 1.2. New physics effect is possible, although it is within the statistical fluctuation. We will further search for the decay with higher sensitivity by reducing the backgrounds.

Most of the KOTO detectors are within the vacuum tank as shon in the photo. By detecting only two photons from a π^0 , we are searching for the decay.

Charged kaon in the beam is the current main background source. We will develop a 200- μ m thick plastic scintillator sheet to detect charged kaon in the beam. With the improvements of other detectors and upgrading the data acquisition, we will reach the sensitivity 10 times higher than the current one.

【Expected Research Achievements and Scientific Significance】

In the recent theoretical development, a new physics effect is possible even near the current sensitivity. In this



research program, we will conclude the existence of such new physics with the higher sensitivity and with the background reduction. We will develop this world-highest sensitivity experiment, and may find a new physics effect, or constrain new physics models to give a next direction.

【Publications Relevant to the Project】

・ “Study of the $K_L \to \pi^0 \nu\nu$ Decay at the J-PARC KOTO experiment” J. K. Ahn et al Phys.Rev.Lett 126 no.12, 121801 (2021)
・ “Breaking the Grossman-Nir bound in kaon decay” X. G. He, X. D. Ma, J. Tandean and G. Valencia, JHEP 04, 057 (2020)

【Homepage Address and Other Contact Information】

https://koto.kek.jp