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

Science and Engineering (Mathematical and Physical Sciences)

Title of Project: Search for new physics in rare kaon decays

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Research Area：Particle physics (experiment)
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【Purpose and Background of the Research】

After the Big Bang, the same numbers of particles and anti-particles were created, but after the Universe has cooled down, anti-particles are extremely rare. This means that there was a CP-violating process that changed the balance between the particles and anti-particles. The standard model for particle physics cannot explain such CP-violation that created the matter-dominant universe.

The purpose of this research is to search for new physics beyond the standard model that breaks the CP symmetry.

We will use the $K_L \rightarrow \pi^0 \nu \bar{\nu}$ decay as a probe to search for CP-violating new physics. First, this decay violates the CP symmetry. Second, the branching ratio predicted by the standard model is small (3×10^{-11}), and its theoretical uncertainty is also small (2%), making the decay mode sensitive to new physics effects. If the branching ratio is different from the standard model prediction, it signifies the existence of new physics.

【Research Methods】

We will use the J-PARC high intensity proton accelerators to produce kaons, and look for the decay with the KOTO detector shown in Fig. 1. The two photons from the π^0 decay are observed with the CsI calorimeter placed downstream. To ensure that there are no other observable particles besides the two photons, the decay region is surrounded by detectors such as NCC, FB, MB, and CV.

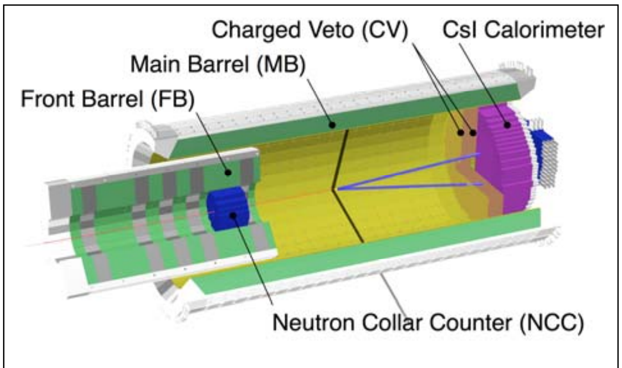

Fig. 1 KOTO detector

In 2013, we collected the first data for 4 days and achieved a sensitivity equivalent to the past best experiment. In 2015 we collected 20 times more data. We will increase our sensitivity by increasing the proton beam intensity, and by applying the following upgrades.

To suppress a new background caused by neutrons hitting the calorimeter directly, we will install 4000 new photo-sensors in front of the calorimeter. The timing difference between the sensor and existing PMTs on the back measures the interaction depth of the incident particles to distinguish between photons and neutrons.

To collect data at high beam power, we will upgrade our data acquisition system. It utilizes new ATCA technology to build events and apply online cuts by counting the number of particles hitting the calorimeter.

【Expected Research Achievements and Scientific Significance】

If the branching ratio is larger than 1×10^{-10}, we can claim the existence of new physics with the 3σ significance. Combined with the results from CERN NA62 experiment that measures branching ratio of the $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ decay, and KEK Belle II experiment, we can constrain models and parameters for the new physics. Even if we do not observe the decay, we can still constrain some new physics models.

【Publications Relevant to the Project】

- T. Masuda *et al.*, “Long-lived neutral-kaon flux measurement for the KOTO experiment”, PTEP 2016, 013C03-1~23 (2016).
- T. Yamanaka, “The J-PARC KOTO Experiment”, PTEP 2012, 02B006-1~7 (2012).

【Term of Project】FY2016-2020

【Budget Allocation】133,800 Thousand Yen

【Homepage Address and Other Contact Information】http://koto.kek.jp