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Final Results on the Rare Decay $K_L \rightarrow \pi^0 \nu\bar{\nu}$ from the KEK-E391a Experiment

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The neutral-kaon decay $K_L \rightarrow \pi^0 \nu\bar{\nu}$ is a direct CP-violating process caused by a flavor-changing neutral current, and the branching ratio is predicted to be $(2.49 \pm 0.39) \times 10^{-11}$ in the Standard Model. The rare decay is one of the processes expected to have a significant impact on new physics searches. The E391a experiment at the KEK 12-GeV proton synchrotron was the first dedicated search for the $K_L \rightarrow \pi^0 \nu\bar{\nu}$ decay. The final results are reported in this contribution. Combining the data sets in February-April 2005 (Run-2) and October-December 2005 (Run-3), the single event sensitivity was 1.1×10^{-8} and no events were observed in the signal region. The upper limit on the branching ratio was set to be 2.6×10^{-8} at the 90% confidence level. The E391a experiment as a whole has improved the limit from the past experiment (FNAL-KTeV) by a factor of 20.

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1. Introduction

The neutral-kaon decay $K_L \rightarrow \pi^0 \nu\bar{\nu}$ is a direct CP-violating process and the branching ratio of the decay is predicted to be $(2.49 \pm 0.39) \times 10^{-11}$ in the Standard Model. The decay amplitude is proportional to a CKM parameter, $Im(V_{td}) \propto \eta$, corresponding to the CP-violation amplitude in the Standard Model. Since the branching ratio can be calculated with exceptionally small theoretical uncertainties, experimental measurement of the decay precisely determines the CP-violation amplitude. Also, the decay is one of the most sensitive processes to new physics beyond the Standard model [1]. However, the experiment is very challenging because of poor kinematical signatures of single π^0 in the three-body decay against huge amount of background events from other kaon decays, or π^0 and η production by neutron interactions.

2. KEK-E391a experiment

The KEK-E391a experiment, which was carried out at the KEK 12-GeV proton synchrotron in 2004 and 2005, is the first experiment dedicated to the $K_L \rightarrow \pi^0 \nu\bar{\nu}$ decay in order to establish the experimental method. A "π^0+nothing" event with higher transverse momentum of the π^0 is the signature of the decay, where "nothing" means no other visible particle except for the π^0. Thus, decay volume was covered by highly hermetic photon-veto counters and charged-particle veto counters with high detection efficiency. The $\pi^0 \rightarrow \gamma\gamma$ signals were measured by Cesium-Iodide calorimeters at an endcap part. The detail of the detectors and the experimental method are described in Ref [2].

3. Results

The number of K_L was obtained from the $K_L \rightarrow \pi^0\pi^0$ decay to be 8.70×10^9 for the combined sample of Run-2 and Run-3, which gave the single event sensitivity as 1.11×10^{-9}. There were three main sources of backgrounds such as the π^0 produced in the 2nd collar counter (CC02) and in the charged-veto counter (CV) and the η produced in the CV by neutron interactions. We estimated the background levels to be 0.66 (CC02-π^0), less than 0.36 (CV-π^0) and 0.19 (CV-η), respectively. After finalizing all of the selection criteria, the candidate events inside the signal box were examined. No events were observed in the signal region, as shown in Fig. 1. Based on Poisson statistics, the upper limit for the branching ration of the $K_L \rightarrow \pi^0 \nu\bar{\nu}$ was set to 2.6×10^{-8} at the 90% confidence level [2]. The E391a experiment as a whole has improved the limit from the past experiment (FNAL-KTeV) by a factor of 20.

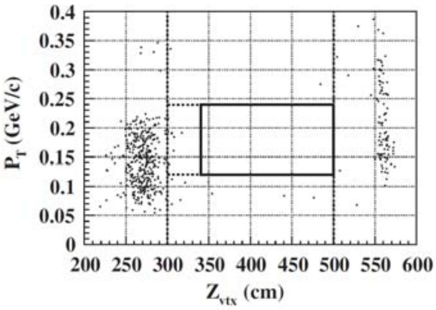

Fig.1 Scatter plot of reconstructed decay vertex and transverse momentum. The box indicates signal region of the $K_L \rightarrow \pi^0 \nu\nu$ decay.

References

[1] http://www.lnf.infn.it/wg/vus/content/Krare.html

[2] J. K. Ahn et al, Phys. Rev. D81, 072004 (2010) , and references therein.