PROCEEDINGS OF SCIENCE

Status and prospects of the KOTO experiment

PoS(CD15)068

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J-PARC KOTO is a dedicated experiment to search for the rare $K_L \to \pi^0 \nu \bar{\nu}$ decay, which is a sensitive probe for direct CP violation in the quark sector. The decay of $K_L \to \pi^0 \nu \bar{\nu}$ is a Flavor Changing Neutral Current process that is induced through electroweak loop diagrams. The branching ratio for $K_L \to \pi^0 \nu \bar{\nu}$ is predicted to be $(2.8 \pm 0.4) \times 10^{-11}$ in the Standard Model, and the theoretical uncertainty is estimated to be only a few percent. The KOTO experiment takes the same design concepts as the former KEK-E391a experiment, but with a new beam line and new detector components. The current best world limit on the BR($K_L \to \pi^0 \nu \bar{\nu}$) is placed at 2.6×10^{-8} [1] by the E391a experiment. The J-PARC KOTO experiment is aiming to improve the sensitivity by a factor of thousand to reach the predicted branching ratio of $(2.43 \pm 0.39) \times 10^{-11}$.

*The 8th International Workshop on Chiral Dynamics, CD2015 ****
29 June 2015 - 03 July 2015
Pisa,Italy

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[*] Speaker.

1. Beam line

The 30-GeV proton-beam is extracted from the J-PARC main ring and is used to product the kaon particles by hitting a common T1 target. The neutral kaon beam is extracted at the angle of 16 degree with respect to the primary proton beam line, as shown in Fig. 1. A sweeping magnet and two sets of collimation systems are arranged along the kaon beam line to clear charged particles and to suppress the neutrons in the outer edge of the beam. The KOTO detector seats at 100 m downstream from the target. Further descriptions of the KOTO beam line are given in [2].

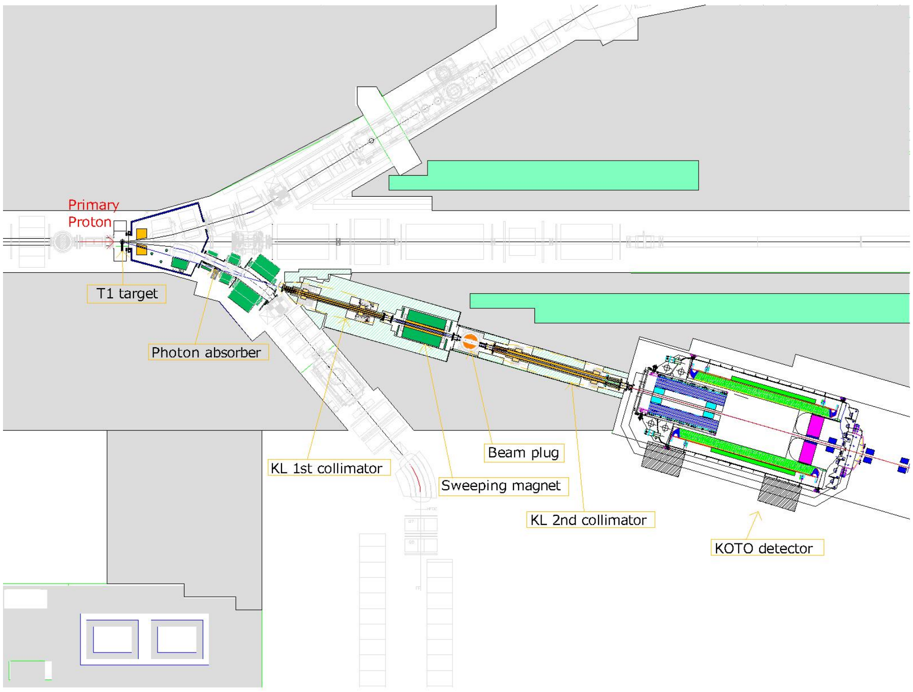

Figure 1: Layout of the KL beamline.

2. Signal Detection

The $K_L \to \pi^0 \nu \bar{\nu}$ event is identified by the two decayed photons from the pion. The photons are measured by the CsI calorimeter, which consists of nearly 3000 KTeV CsI crystals arranged in a disk shape. The smaller crystals in the center square region have the size of $(2.5 \times 2.5 \times 50)$ cm^3 and the larger crystals in the outer part are $(5 \times 5 \times 50)$ cm^3. These two types of the CsI crystals have both smaller cross-section and longer length compared to the CsI crystal $(7 \times 7 \times 30)$ cm^3 used in the past E391a experiment. The new CsI calorimeter will improve the measurement of both impact point and energy for photons. In order to suppress the background events such as $K_L \to \pi^0 \nu \bar{\nu}$ with two decayed photons not hitting the CsI calorimeter, we designed a hermetic detector to cover the entire kaon decay volume, as shown in Fig. 2.

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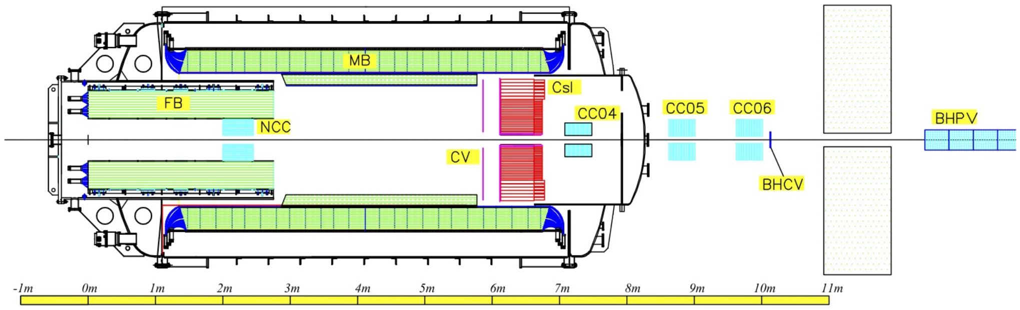


Figure 2: Schematic cross-sectional view of the KOTO detector.

The $K_L \to \pi^0 \nu \bar{\nu}$ signal is then enhanced by requiring no signal in any veto detectors. The decay vertex of $K_L \to \pi^0 \nu \bar{\nu}$ event is then reconstructed by assuming the pion mass, and the signal window is defined in the plane of pion vertex and momentum, as shown in Fig. 3.

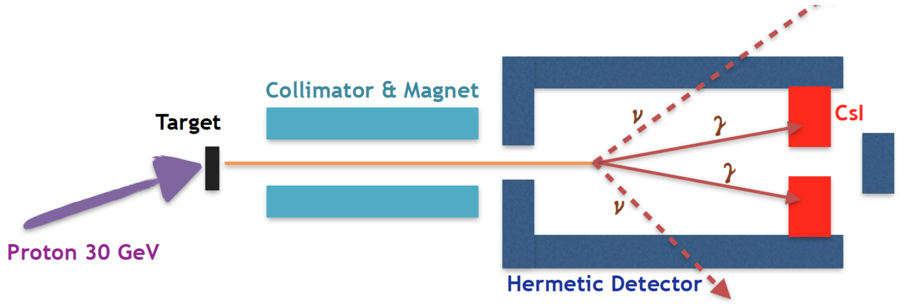


Figure 3: Detection method.

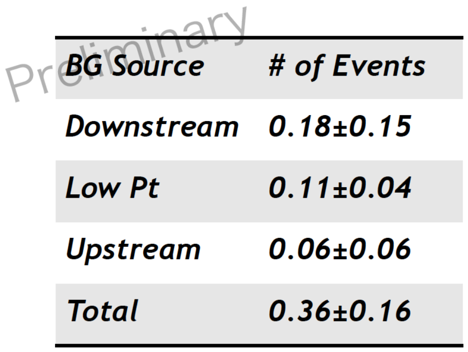
3. Data Analysis

The first physics run was in May of 2013 and was interrupted by a radiation accident in J-PARC Hadron hall. In that period, only 100 hours of physics data was taken, and with these data, the single event sensitivity of $K_L \to \pi^0 \nu \bar{\nu}$ reached 1.29×10^{-8}, which was comparable to the sensitivity of the former E391a experiment. The results of data analysis showed one event remained in the signal region with 0.36 ± 0.16 predicted background events as shown in Fig. 4, which is dominated by the neutron events. Further descriptions are given in [3].

Several changes have been made for future runs to reduce the neutron background events. We replaced the upstream beam window with thinner material to reduce the neutron interaction. A beam profile monitor is installed downstream for fine adjustment of beam direction. We are also studying the CsI shower shape to improve identification of photons and neutrons.

4. Summary and Prospects

KOTO had begun the data taking in May of 2013. With 100 hours of data taking time, we



BG Source	# of Events
Downstream	0.18±0.15
Low Pt	0.11±0.04
Upstream	0.06±0.06
Total	0.36±0.16

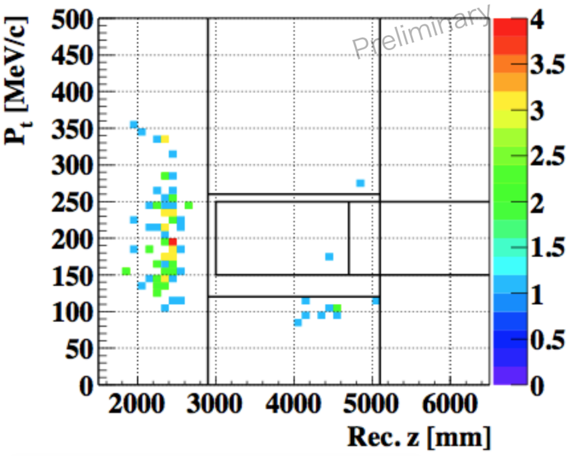


Figure 4: Results of data taken in May of 2013.

reach the same sensitivity of the current best limit. The data taking has resumed in April of 2015, our plan is to reach the Grossman-Nir sensitivity in 2016 and SM sensitivity by 2018.

References

[1] J. K. Ahn *et al.*, Phys. Rev. D. 81, 072004 (2010).

[2] T. Shimogawa *et al.*, Nucl. Instum. Methods A, 623, 585-587 (2010).

[3] K. Shiomi, arXiv:1411.4250 (2014).