Development of Positron Detector for Pulsed μSR Based on Multi-Pixel Photon Counter

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In the pulsed muon facility at J-PARC (MUSE, "Muon Science Establishment"), it is expected that three orders of magnitude more intense muon beam than that of KEK-MSL will be delivered at its full operation, where $10^4 \sim 10^5$ positron events must be recorded at every muon pulse within the time range of mean lifetime for μ^+ (10^{-5} s). Any existing μSR spectrometer for pulsed muon beam would not be able to handle such a high positron event rate, because of the limited segmentation numbers for the positron detectors that would lead to pile-up of events and associated distortion of spectrum. In order to eliminate this pile-up effect, it is necessary to reduce the size of segmented scintillators while increasing their number to keep a sufficient total solid angle. To this end, small and economical positron detectors are necessary. In addition, tolerance to high magnetic field is strongly desired, because μSR measurements are routinely performed under a magnetic field. As an alternative to photomultiplier tubes, we focused on Multi-Pixel Photon Counter (MPPC) which would satisfy the above mentioned requirements, and developed a telescope counter based on MPPC for high energy positron detection.

The detector was tested under exposure to μ^+-e^+ decay positrons under zero field (ZF), and a high magnetic field (HF) at Port-1 of the RIKEN-RAL Muon facility. In ZF, virtually undistorted μ^+-e^+ decay time spectra were observed. The muon life time deduced by a fit using exponential decay was in excellent agreement with the established value. The detection efficiency was estimated to be 57 %, where the reduction might be attributed to enhanced crosstalk and secondary pulse rate due to a relatively high bias voltage. While the normal operation of the detector under a HF of 3.6 T was also confirmed by the observed μ^+-e^+ decay spectra, they showed a distortion probably due to high event rate and/or direct muon hit. The present result would be useful for further optimization of MPPC-based positron detectors.