Energy dependence study of cylindrical drift chamber used for the MTV experiment

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The purpose of the MTV (Mott polarimetry for T-violation) experiment is to find a large time reversal symmetry violation (T-violation) in polarized ^{8}Li β^- decay. T-violation may arise in triple vector correlation (R-correlation) in beta decay. R-correlation causes electron transverse polarization and it can be measured by detecting electron Mott scattering asymmetry. In the MTV experiment, which has been running at TRIUMF-ISAC (Isotope Separator and Accelerator), cylindrical drift chamber (CDC) is used as a tracking detector to measure angles of the electron emission and backward scattering per event.[1)] The physics data were collected in 2017.

In 2018, we studied β^- ray energy dependence of CDC to predict Mott asymmetry measured in our system. The electron emission distribution of β^- decay, ω, is expressed as:[2)]

$$\omega dE_e d\Omega_e \propto 1 + R\vec{\sigma} \cdot \left[\frac{\langle \vec{J} \rangle}{J} \times \frac{\vec{p_e}}{E_e} \right] + \ldots . \quad (1)$$

The definition of R-correlation can be found in this function, where $\vec{J}$ is the spin polarization of the parent nuclei, and $\vec{\sigma}$, $\vec{p_e}$, and E_e are the spin polarization, momentum, and energy of electron, respectively. Coefficient R is predicted from the final state interaction (FSI) between the electron and daughter nucleus. In the standard model, coefficient R of FSI in ^{8}Li β^- decay is predicted as

$$R_{\mathrm{FSI}}(^8\mathrm{Li}) = \frac{\alpha Z m_e}{3 p_e}. \quad (2)$$

Where α is the fine structure constant, Z is the atomic number of daughter nucleus, and m_e is the electron mass. R_{FSI} is a non-zero value but it doesn't violate time reversal symmetry. If a significant difference exists between theoretical R_{FSI} and measured R, it may imply the existence of T-violation. These formulae show that β^- emission distribution depends on β^- ray energy. In our experiment in 2017, we measured β^- emission distribution (Eq. (1)) in its integrated form with E_e. The prediction of expected asymmetry in our detector system requires the determination of the minimum detectable electron energy. In the 2018 experiment, we measured energy spectra detected by CDC using ^{90}Sr radiation source and its energy threshold was deduced.

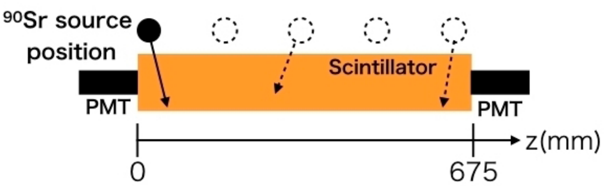

Fig. 1. Setup of the measurement to study the source position dependence.

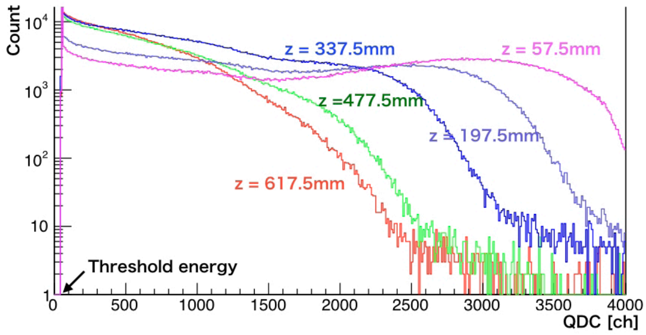

Fig. 2. Energy spectra using ^{90}Sr radiation source at five different positions from the PMT.

The measurement setup consists of stopping scintillation counters (SCs: used as trigger scintillator of CDC) and two PMT attached on both sides of SC. The most significant ambiguity of CDC energy threshold is due to SC whose length is 675 mm. When an electron hits a different point of SC, the amount of photons reaching PMTs also vary. We placed the radiation source on the SC with a collimator at five different positions to measure the ambiguity of energy threshold (Fig. 1). Figure 2 shows the energy spectra using ^{90}Sr radiation source at five different positions from the PMT. The end point energy and threshold are defined by fitting on these data with the intrinsic response function of ^{90}Y β^- ray. The cutoff channels of the spectra correspond to the threshold. From these analyses, we determined the average energy threshold as

$$E_{\mathrm{th}} = (6.5 \pm 2.2) \times 10^{-1}\ \mathrm{MeV}. \quad (3)$$

The energy threshold that was obtained in 2018 is necessary to calculate the asymmetry expected in our detector. In contrast, we need more analyses on the physics data to set final results R. In addition, the development of track detection method by machine learning is in progress to reduce systematic errors.

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