A preliminary investigation for a muonium to anti-muonium conversion experiment [S03-10]

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The study on lepton flavor violating (LFV) phenomena is one of the important issues in the modern particle physics in the aim of exploring the physics beyond the Standard Model. The conversion of a muonium atom (μ^+e^-, Mu) to an anti-muonium (μ^-e^+, $\overline{\mathrm{Mu}}$) belongs to such interesting processes and has been studied in many precise experiments. The current experimental bound obtained by Willmann et al. [1] is $G_{\mathrm{Mu}\overline{\mathrm{Mu}}} \leq 3.0 \times 10^{-3} G_F$. The sensitivity of this experiment was limited by backgrounds mainly due to the existence of huge amount of μ^+ decays around the detection environment. There was another experiment performed at TRIUMF in 1990 [2] which chose totally different method. The idea in this experiment is to prove resultant $\overline{\mathrm{Mu}}$ by the existence of tantalum which is produced by μ^- absorption into tungsten nucleus, $\mu^-\mathrm{W} \to \nu_\mu^{184}\mathrm{Ta}$. The merit of this method is that one can search a sign of $\overline{\mathrm{Mu}}$ far from the intense beam environment and can escape from accidentals. Tantalum is identified by the triple coincidence of β decay (τ = 8.7 hours) and successive prompt photon (414 keV) and delayed γ cascade decays (τ = 8.3 μsec, dominantly 921 keV). One of the key points in this method is to understand the fractional probability of ^{184}Ta formation after μ^- capture since it directly reflects to the sensitivity. The main purpose of our experiment is to establish a ^{184}Ta tagging system and evaluate the fraction using the μ^- beam.

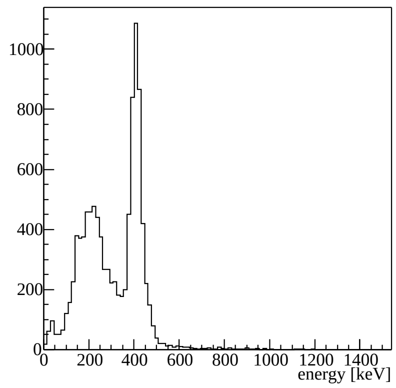

Fig. 1: The energy spectrum of prompt photons.

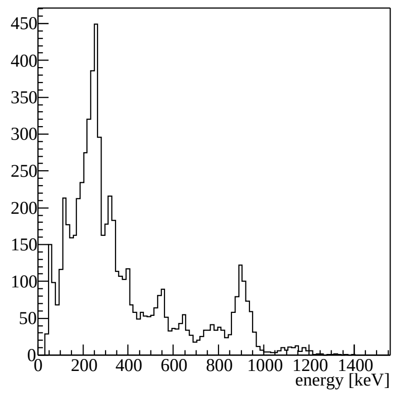

Fig. 2: The energy spectrum of delayed photons.

We prepared 20 tungsten foils which were 100 μm thick and exposed it to 60 MeV/c μ^- beam at the KEK-MSL μ port. The number of μ^- stops in the foils were 4.2×10^6 in total. The ^{184}Ta detector consisted of 6 layers of 2mm-thick, 17cm-square plastic scintillators and 6 NaI(Tl) crystals. Three crystals were located in each side of the scintillator stack, having the cross section of 16.5cm by 17cm in total and the depth of 5.5cm. The tungsten foils were inserted into the gaps between scintillators. The scintillators tagged a β ray from ^{184}Ta decay in coincidence with prompt and delayed photons. Fig. 1 shows the energy spectrum of prompt photons caught by a NaI(Tl) crystal. There is a clear peak at the energy of 414 keV and we required the prompt photon to have a energy consistent with the photoelectric signal in this peak region. The delayed photons are emitted in various sequence of the decay cascade. As can be seen in Fig. 2, there are multi photoelectric peaks which correspond to 537, 921, 1174 keV and their successive cascades. We confirmed that the background contamination was enough small in the triple coincidence data by the measurement without foils. In addition, we checked the time spectrum of delayed photons with various energy selections as well as without any cut, and found the resultant decay times were consistent in all cases to be 8.3 μs. Thus we decided not to imply any cut on energies of delayed photons. After the calibration of the detector efficiency and the calculation of the acceptance, we obtained the fractional probability of ^{184}Ta formation to be 0.03, in contrast with the value 0.107 in [2]. Further studies are necessary to understand this discrepancy especially in β detection efficiency in our detector.

[1] L. Willmann *et al.*, Phys. Rev. Lett. **82**(1999)49.
[2] T. M. Huber *et al.*, Phys. Rev. D**41**(1990)2709.