Development of online muon beam profile monitor for the MuSEUM experiment

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Muonium is the bound state of a positive muon and an electron. Because neither muon nor electron has an internal structure, muonium ground state hyperfine splitting (MuHFS) can be the most precise probe for the test of the bound state QED and for the determination of muon mass via the ratio of magnetic moments of a muon and a proton. At J-PARC, we plan to perform a precision measurement of the MuHFS by microwave spectroscopy of muonium. Spectroscopy of the energy states is performed by measurement of positron asymmetry from muonium decays. Our goal is to improve the precision by an order of magnitude compared with that of the most recent experiment. In order to achieve the goal, we utilize J-PARC's highest-intensity pulsed muon beam[2)], highly segmented positron detector with Silicon PhotoMultiplier(SiPM)[3)], and an online/offline muon beam profile monitor.

The online muon beam profile monitor analyses the muon beam from the aspect of beam shape and relative intensity. Requirements for the beam profile monitor are minimum destruction and high reconfigurability of the beam. We utilize thin plastic scintillation fiber and SiPM. Figure 1 shows the conceptual design of the muon beam profile monitor. The detector consists of an one dimensional array of thin plastic scintillation fiber with a 100 μm diameter. The fibers are bound into a bundle and connected to a SiPM. For a front-end electronics, EASIROC front-end chip[4)] was utilized as an ASD (amplifier, shaper, and discriminator). The pulse height is digitized by an external peak holding ADC.

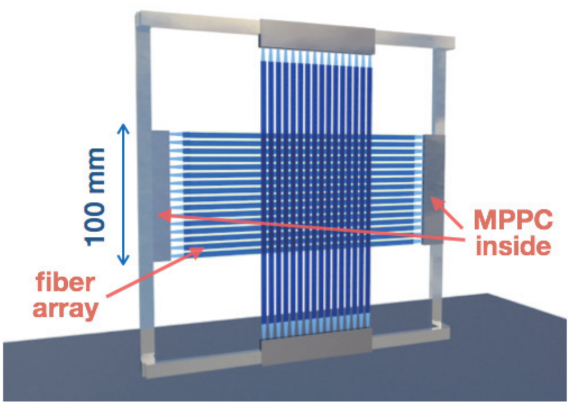

Fig. 1. Conceptual design of the online muon beam profile monitor

Figure 2 shows the developed prototype and its cross-sectional view. The fibers were arrayed on a polyimide film of 25 μm thickness and bonded by epoxy resin. Forty fibers were bound into one band of 4 mm width. Two bands were arrayed with a 2 mm gap. In November 2014, a beam test was performed at J-PARC MLF MUSE D2 beam line. Figure 3 shows the measured photon yield as a function of total muon beam intensity. Saturation in higher intensity region is caused by the limited number of SiPM pixels (in case of this prototype, number of pixels was 667). The beam intensity was controlled by movable slits and measured by an offline beam profile monitor[5)], which consists of a gated image intensifier and a cooled CCD. The movable slits only change beam density and keep beam profile unchanged. Based on the result of the beam test, the design of a full-scale detector is in progress. SiPM with narrower pixel pitch will be used and process of fiber bonding will be optimized for uniform thickness.

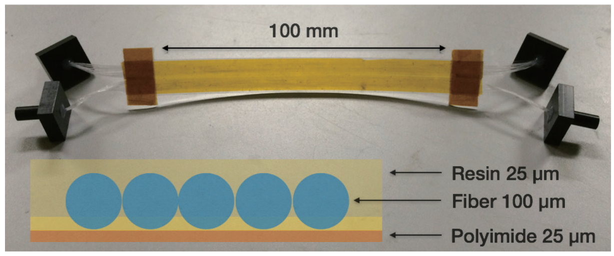

Fig. 2. Developed prototype of the online muon beam profile monitor

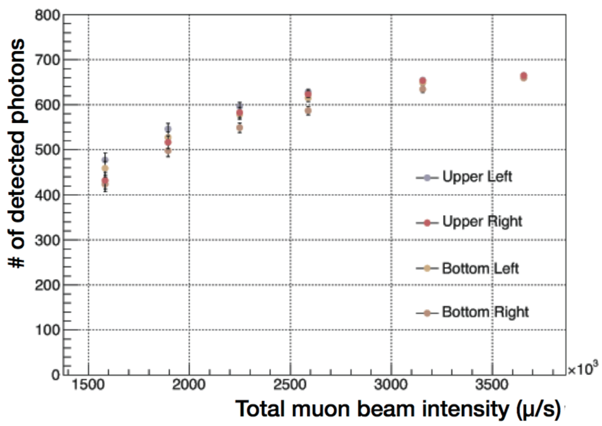

Fig. 3. Measured photon yield

References
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