Development of a slow muon detection system for a muon acceleration

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The measured value of the muon anomalous magnetic moment (g-2) differs from the theoretical value by about three standard deviations[1]. Given that muon anomalous magnetic moment may provide important evidence for the physics beyond the Standard Model, more precise measurements are awaited. A new experiment for the precise measurement of the g-2 and the search for the muon EDM using novel techniques has been planned at J-PARC. One of the most important techniques is the world's first muon RF acceleration to 212 MeV.

For efficient beam capture in the RF accelerator, the input muon beam should have low emittance and low energy (5.6 keV in our case). The conventional surface muon beam typically has 4 MeV energy and large emittance; therefore we plan to develop the low-emittance input beam by using the following method. The muon beam is irradiated onto a thin metal foil. Some of the muons are decelerated to the sub-keV[2] band after passing the foil. Subsequent acceleration to 5.6 keV by an electro-static "SOA lens" will give us a low-emittance beam.

An experiment to establish the muon deceleration and electro-static acceleration was planned in Feb. 2016. Figure 1 shows the experimental setup. After deceleration and acceleration, the muons are transported to the detection system by a series of electro-static quadrupoles and an electro-static bending. The detection system consists of a microchannel plate (MCP) surrounded by scintillation counters with MPPCs. In this paper, we report on the development of the slow muon detection system.

The MCP counts the number of muons with energy in the order of a few keV. The gains of MCP for several kinds of particles including low-energy electrons were measured in order to confirm the muon detection capability[3]. The measured gain for the electron with 500 eV was 2.1×10^7 and is sufficiently large for the detection. The gain depends on the number of secondary electrons generated by the bombardment of the incident particle on the surface of the MCP. The estimated number of secondary electrons for the low-energy muon is expected to be more than that for the electron based on our measurements and the calculation of the energy deposit. We conclude that the expected gain for the muon is sufficiently high to count the low-energy muons.

The scintillation counters are utilized for muon identification by detecting the decay positron from the muon stopped in the MCP. A large acceptance and a large light yield are required to detect as many decay positrons as possible with high efficiencies. The positron counters consist of plastic scintillators, wavelength shifting fibers, and MPPCs to satisfy those requirements. In the cosmic-ray test, we observed the mean light yields of more than 120 photo emissions and obtained counting efficiencies of more than 99.8 % with 90 % confidence level[4].

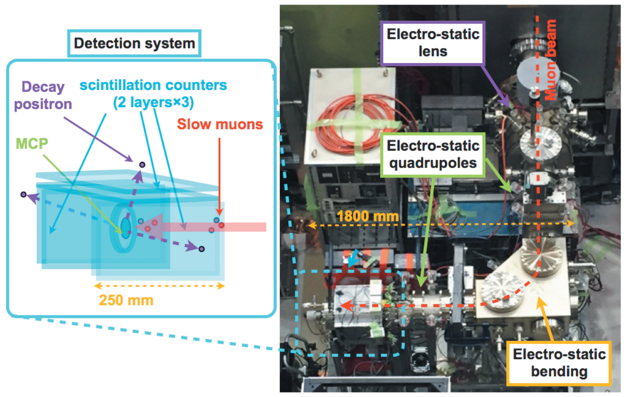

Fig. 1. Detection system for the slow muons comprising detectors (MCP and decay positron counters), the electro-static lens, and the electro-static bending.

Finally, the expected signal and background rates were evaluated using the GEANT4 simulation. The simulation showed that the dominant backgrounds at the MCP were decay positrons from incident beam muons; many muons were stopped at the thin metal foil used for the deceleration or the electro-static bending, and subsequently the decay positrons directly impacted the MCP. A lead shield configuration was optimized with the simulation in order to reject these positron backgrounds. The noise to signal ratio after the optimization was evaluated to be 4.9×10^{-3}. We concluded that it is sufficiently low for the experiment.

In summary, we developed two kinds of detectors, MCP and positron counters, to measure the intensity of the slow muons. We confirmed their good performances and we are ready for demonstration with the muon beam.

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References
1) G.W.Bennett *et al.*, Phys. Rev. D **73**, 072003 (2006).
2) Y. Kuang *et al.*, Phys. Rev. A **35**, 3172 (1987).
3) R. Kitamura *et al.*: The JPS 2015 Annual Meeting, 2015, 21aDF8 (2015)
4) R. Kitamura *et al.*: The JPS 2015 Autumn Meeting, 2015, 25aSG7 (2015)