Beamline tune for muonium emission from silica aerogel towards ultra-slow muon project at RIKEN-RAL

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A sharp low-energy muon beam may be realized by accelerating several-eV positive muons, so-called ultra-slow muons, generated by the laser ionization of thermal muonium atoms in vacuum.[1,2] This technology is the focus of attention in material science using μSR techniques and particle physics, e.g., measurement of the muon anomalous magnetic moment, g-2, and electric dipole moment at J-PARC.[3]

Continued research on muonium emission into vacuum from several stopping materials revealed that silica aerogel with a laser-ablated surface is a good candidate.[4] To demonstrate the actual ultra-slow muon production with silica aerogel, a new experimental setup has been prepared at RIKEN-RAL, as previously reported.[5] Here, we report the results of a commissioning run conducted in September 2016.

Positive muons stopping in the surface region of the aerogel target contribute to muonium emission into vacuum. To maximize this for the beam at RIKEN-RAL,[6] we adjusted the thickness of a degrader so that the number of muons stopping in the aerogel is approximately half of the full stop, while the remainder passed through mostly to regions beyond those of interest for muonium decay in vacuum. Since aerogel is the only material capable of muonium production installed in the setup, we can assess the amount of muonium produced by measuring asymmetry amplitudes at time zero of the muonium precession signal with a frequency of 13.9 GHz/T, well separated from the frequency of muons, 136 MHz/T.

Figure 1(a) shows our experimental setup. A three-axis Helmholtz coil system is used for the cancellation of stray magnetic fields, and for applying a transverse field of 0.18 mT to rotate the spin of muonium. Figure 1(b) shows a typical muonium spin rotation asymmetry distribution measured by a set of μSR counters. The fit result shows a rotation cycle of 400 ns being consistent with our expectation for muonium with 0.18 mT. Figure 1(c) shows the measured range curve as a function of the total thickness of aluminum-foil degraders, where degrader thicknesses for "full-stop" and "half-stop" conditions are indicated. The aerogel target has a density of 28 mg/cm^3 and thickness of 7.8 mm which corresponds approximately to the full stop range. The obtained curve was consistent with a momentum bite of 2% assuming a Gaussian distribution at RIKEN-RAL.[6] The absolute values of muonium asymmetry amplitudes are also comparable with what we assessed with a Monte Carlo simulation.

Now we have established the method of degrader tuning and are ready for a laser ionization study.

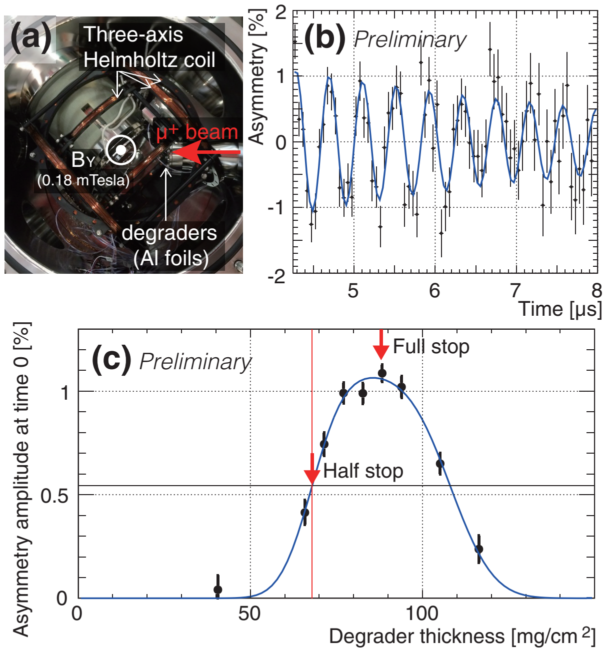

Fig. 1. (a) Photograph of the experimental setup at the Port 3 beamline of the RIKEN-RAL muon facility. (b) A typical muonium spin rotation asymmetry distribution, where the muon exponential decay time dependence has been removed. (c) Range curve obtained by measuring the asymmetry of muonium produced at a silica aerogel target as a function of degrader thickness.

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