Development of an instrument for measuring muon mobility in the gas

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The mobility of charged particles in the gas is directly related to the momentum transfer cross section in collisions between charged particles and gas molecules, which is determined by the interaction potential between the particles. Therefore, mobility measurements also provide detailed information on the wide range of inter-particle potentials across the weak attraction part acting at a distance and the strong repulsion part acting at a short distance.

We are developing a drift tube for measuring muon mobility in order to generate benchmark data for potential energy surfaces and momentum transfer cross sections of muon-attached molecules, and to elucidate quantum mechanical muon transport phenomena in light element gases. Positive muons (~ several MeV) produced by the muon beamline at the J-PARC MLF are decelerated to about 10-100 keV through an aluminum plate about several hundred microns thick. The decelerated muons are injected into the drift tube and repeatedly collide with buffer gas (He ~ 100 kPa), flying about 10 cm before being thermalized. A uniform electric field (~100 V/cm) applied inside the drift tube causes the thermalized muon to move toward the back of the tube with a certain mobility. The drift positive muons decay to positrons with an average energy of 35 MeV in a lifetime of 2.2 μs. The decaying positrons penetrate a 1 mm square polystyrene scintillation fiber, which is placed in a double layer outside the drift tube. The emission from the fiber is observed by a pixel-type avalanche photodiode (MPPC), and is then detected by KALLIOPE (KEK Advanced Linear and Logic board Integrated Optical detector for Positron and Electron). The positron flight direction can be determined by doubling the fiber, and a projection map of the decay position onto the central axis of the drift tube can be obtained. Since the muon velocity distribution in the drift tube can be approximated as a normal distribution, the decay position can be analyzed from the on-axis projection. By expressing the decay position as a function of time, the muon velocity in the drift tube is obtained and the mobility is derived. An experiment to evaluate the muon stop position in gas was performed at the muon S-line of the J-PARC MLF using the above apparatus. Figure 1 shows the drift tube and scintillation fiber trajectory detector connected to the beamline.

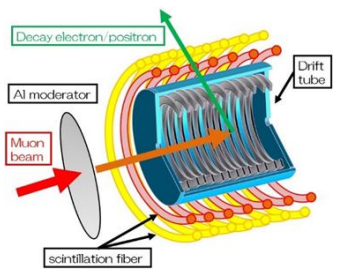

Fig. 1 Drift tube with scintillation fiber.