Development of gas system for MuSEUM experiment

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We are planning to measure the energy of ground state hyperfine structure (HFS) of muonium at J-PARC/MLF. Muonium is a hydrogen-like bound state that consists only leptons, and its HFS is a good probe for testing the QED theory. The latest experiment at LAMPF obtained the following value:[1)]

$$\Delta HFS_{\rm M}^{\rm ex} = 4.463302765(53)\ \text{GHz}\ (12\ \text{ppb})\ . \qquad (1)$$

The total uncertainties were determined using the statistical uncertainties. We will achieve an accuracy more than 10 times greater than that of the latest experiment by using the H-line at J-PARC.

Muons polarized in the revese direction of momentum enter the bore of a large superconducting solenoid magnet from the J-PARC/MLF muon beamline. A RF cavity is located at the center of the magnet containing pure Kr gas. Muons stop by collisions in the gas, and polarized muoniums are formed by the electron capture process.

In a magnetic field the ground state splits into four substates. ν_{12} and ν_{34} are obtained by the microwave magnetic resonance technique. High-momentum decay positrons are emitted preferentially in the direction of the muon spin. By driving the transitions with an applied microwave magnetic field perpendicular to the static magnetic field, the muon spin can be reversed and the angular distribution of high-momentum positrons changes from predominantly upstream to downstream with respect to the beam direction. The cavity was designed to be resonant simultaneously in the TM110 mode at the ν_{12} transition frequency and in the TM210 mode at the ν_{34} frequency[2)]. The muonium HFS ($\Delta\nu$) is obtained by summing ν_{12} and ν_{34}.

A Gas chamber surrounds the RF cavity to seal in the Kr gas. The chamber consists of only aluminum and its upstream foil is thin enough (100 μm) for muons to pass through. We performed gas introduction tests in the chamber. The gas pressure is monitored at the 0.02 % level by a silicon pressure transducer. The gas in this system is sampled regularly by small cylinders. Since spin-exchange collisions occur between muonium and paramagnetic contaminant particular oxygen, we intend to determine the purity of a gas at the parts per million level using Q-mass. We studied the performance of the gas panel without gas sampling and precise gas pressure monitoring on November 2014 (Fig. 1). In this test, we measured muonium distributions under several gas pressures (Fig. 2). The gas pressure in the chamber maintain a steady at sub Torr level during this measurement.

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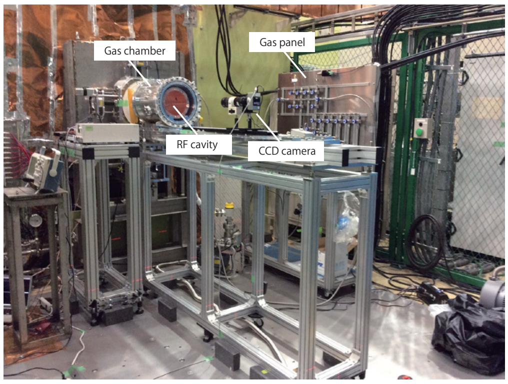

Fig. 1. Experimental setup at 2014A beamtest. The gas chamber is mounted on the support rail. The gas panel is behind the gas chamber.

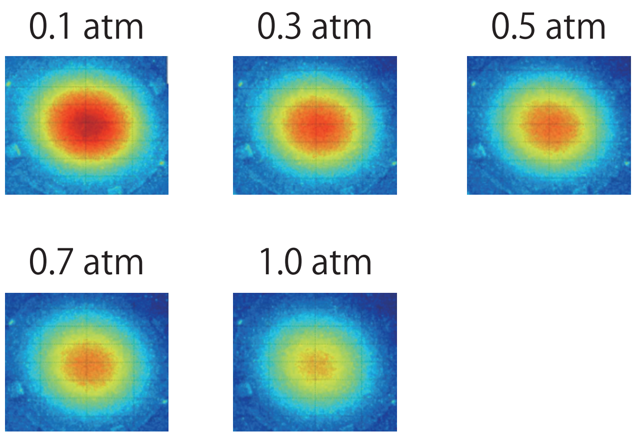

Fig. 2. Muonium distributions at the center of the chamber for different gas pressures.

References
1) W. Liu *et al.*: Phys. Rev. Lett. 82, 711 (1999)
2) K. S. Tanaka on behalf of MuSEUM Collaboration K. S. Tanaka et al.:, JPS Conf. Proc. 2, 010405 (2014)