論文の内容の要旨

Measurement of muonium hyperfine structure at J-PARC

（J-PARC でのミュオニウム超微細構造測定）

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Introduction Measurement of the ground state hyperfine structure of muonium (muonium HFS) is planned at J-PARC/MLF. The latest result by LAMPF is

$$\Delta HFS_{\mathrm{M}}^{\mathrm{ex}} = 4.463302765(53)\ \mathrm{GHz}\ (12\mathrm{ppb})\ [1]. \tag{1}$$

The latest theoretical calculation is

$$\Delta HFS_{\mathrm{M}}^{\mathrm{th}} = 4.463302891(272)\ \mathrm{GHz}\ (61\mathrm{ppb})\ [2], \tag{2}$$

Muonium is a hydrogen-like bound state of leptons, and its HFS is a good probe for testing QED theory. The muon mass m_μ and magnetic moment μ_μ which are fundamental constants of muon are determined from the muonium HFS experiment at LAMPF. Those constants are also required in the new measurement of anomalous magnetic moment at the J-PARC. Accuracy one digit higher than that of the latest experiment is expected mainly because of high intensity beam line at J-PARC.

Muonium HFS can be determined by both directly measurement in zero field and indirectly measurement of zeeman effect in strong field. This thesis introduces a technical design of the experiment. We aim to start zero field experiment in 2016, high field experiment in 2017.

How to measure Figure 1 shows a process of muonium HFS measurement.

1. Muons polarized to upstream enter the bore of large superconducting solenoid magnet from J-PARC/MLF muon beam line.

2. RF cavity located in a center of the magnet containing pure Kr gas. Muons stop by collisions in the gas and polarized muonium is formed by electron capture process.

3. 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 could be flipped and the angular distribution of high momentum positrons changed from predominantly upstream to downstream with a respect to the beam direction.

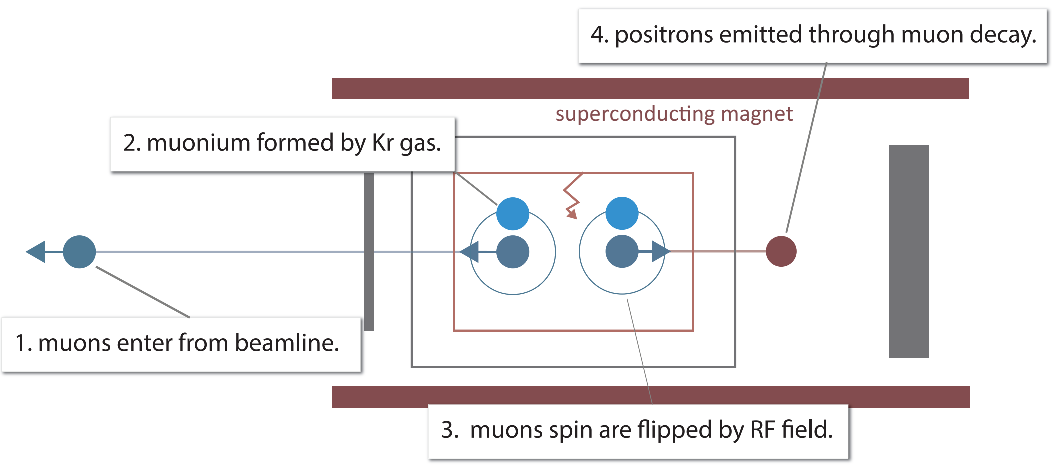

Figure 1: A schematic overview of the experimental setup of the muonium HFS experiment.

Development of apparatus RF system, gas system and the magnetic shield are developed for the experiment. For the precise experiment, RF system should have a stable RF feedback system and a tunability of resonance frequency in the cavity. Gas system has a precise pressure guage and sampling bottles to anlyze the purity in a gas. A magnetic shield is need for zero field experiment to suppress external magnetic field at the level of 100 nT.

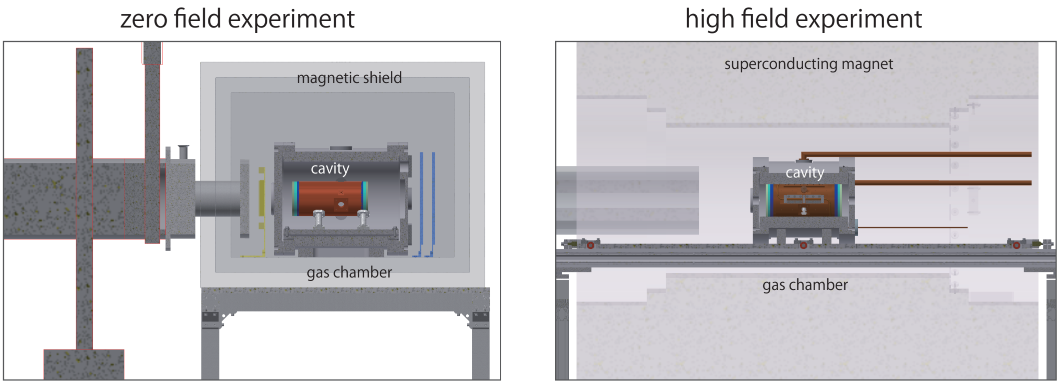

Figure 2: A schematic view of setups for zero field experiment and high field experiment.

Discussion Apparatus for both experiment in zero field and high field are already ready (Figure 2). The systematic uncertainties are already estimated and it is clear that the precision of Mu HFS can be improved by measurement for a day at zero field experiment and for a week at high field experiment (Figure 3).

Conclusion The apparatuses for experiments both in zero field and in high field have been constructed fully. We are confident that all systematic uncertainties are well under control, and one day of beam time at J-PARC MUSE will supersede the precision of latest measurement of muonium HFS in a zero magnetic field. One week of beam time will supersede the precision in a high magnetic field. We had a plan to carry out the zero field experiment at MUSE D Line in last November, but the beam time was aborted because of a trouble in J-PARC accelerator complex. We envisage the resumption of the experiment in early 2016 after restoration of the delivery of muon beams. The first beam at H Line is expected in late fiscal year 2016. The preparation of the high field experiment is under way so that we can start the experiment right after the completion of the beam line.

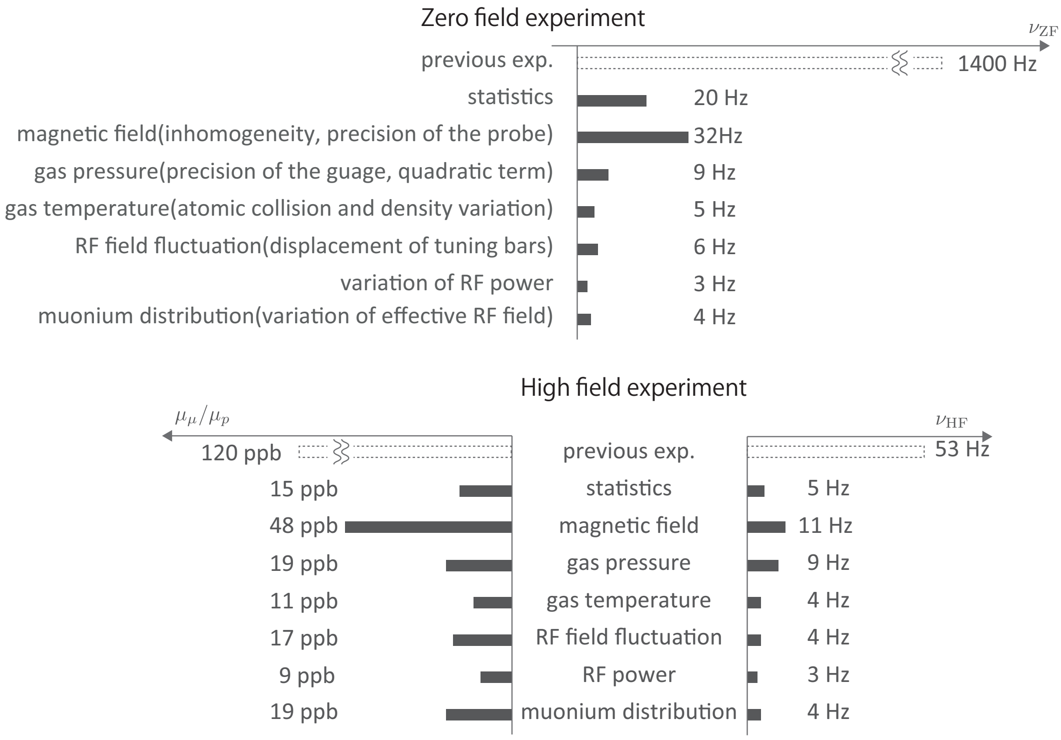

Figure 3: Sources of uncertainty for zero field experiment and high field experiment are listed.

References

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