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Precise spectroscopy of muonium hyperfine structure at J-PARC

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Muonium is the bound state of a positive muon and an electron. Muonium Spectroscopy Experiment Using Microwave (MuSEUM) collaboration has been performing precise spectroscopy of the ground state muonium hyperfine structure (MuHFS) with high-intensity pulsed muon beam at Japan Proton Accelerator Research Complex (J-PARC). Our goal is a ten-fold improvement in precision of MuHFS compared to the previous experiment at Los Alamos Meson Physics Facility (LAMPF) [1]. In the previous experiments, the dominant uncertainty came from the limited number of muonium used for spectroscopy. We address this issue with the pulsed muon beam with the world's highest intensity available at J-PARC.

One of major motivations for this new measurement is the test of the bound-state QED. Muonium is a purely leptonic system and so is free from the finite size effect of nuclei unlike ordinary atoms. That enables theorists to calculate its energy levels very precisely. In addition, muonium has an additional advantage over other leptonic hydrogen-like exotic atoms such as positronium because of its relatively long lifetime. Hence, muonium is one of the best probes to test the bound-state QED. Although QED is often quoted as the most accurate physics theory, and lightly so as demonstrated in the comparison of the experimental value and theoretical calculation of electron anomalous magnetic moment, the application of QED to a bound state introduces its own difficulties, and its validity needs to be tested.

The other is to contribute towards the measurement of the muon anomalous magnetic moment a_μ. There is a discrepancy of more than 3σ between the theoretical and experimental values of a_μ[2], and it has been suggested that this discrepancy is due to an additional contribution by BSM physics, such as supersymmetric particle loops. In order to address this problem, two groups at J-PARC and Fermilab have been planning to measure a_μ with 4 times higher precision than the previous experiment. In order to determine a_μ in these experiments, they need an additional value of a physical quantity, which is the muon-to-proton magnetic moment ratio μ_μ/μ_p and can be precisely determined from the MuHFS spectroscopy. MuSEUM collaboration aims to achieve the 20 ppb precision of μ_μ/μ_p without comparison of theoretical and experimental MuHFS value.

There have been two types of MuHFS measurement: one is at zero magnetic field and the other is in a high magnetic field (1.7 T). MuSEUM group has been planning to perform both of them because they have different types of systematic uncertainties and so are complementary. In MuSEUM experiment, the zero field measurement is in progress and the high field one is in preparation due to construction of beamline at J-PARC.

In this presentation, we will report the recent results of the measurement at zero magnetic field and R&D for the high magnetic field measurement.

[1] W. Liu, et al., Phys. Rev. Lett. 82, 711 (1999).
[2] A. Keshavarzi, et al., Phys. Rev. D97 114025 (2018).

Secondary track (number)

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