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Precise spectroscopy of muonium hyperfine structure using Kr-He mixture gas

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MuSEUM (Muonium Spectroscopy Experiment Using Microwave) collaboration aims to perform a precise spectroscopy of the ground state muonium hyperfine structure (MuHFS) with high-intensity pulsed muon beam at J-PARC. Our goal is a ten-fold of improvement in a precision of MuHFS compared to the preceding experiment at LAMPF [1]. Muonium is the bound state of a positive muon and an electron. Its hyperfine structure is precisely calculable because muonium is free from the finite size effect of nuclei unlike hydrogen. Therefore, a precision spectroscopy of MuHFS provides the most rigorous test of bound-state QED theory. The muonium hyperfine spectroscopy also gives the muon-to-proton magnetic moment ratio. It is one of two parameters to determine the muon anomalous magnetic moment, which has taken reseachers attention since there is more than 3σ discrepancy between theoretical and experimental values of it [2].

In 2019, we used Kr-He mixture gas instead of Kr gas as a target of muon beam to suppress the systematic uncertainty related to the gas pressure. The transition frequency of muonium measured in a gas varies with its pressure due to the collision between a gas atom and a muonium one, thus we have to extrapolate MuHFS in a vacuum using data at various pressures and this causes the systematic uncertainty. The collision in Kr gas decreases MuHFS, whereas that in He gas was expected to increase it because it shows such a behavior in the measurement of hydrogen HFS [3]. Therefore, we expected reduction of the collisional shift of MuHFS in the Kr-He mixture gas by cancelling out the effects. In the last beamtime in 2019, we successfully observed MuHFS resonance in Kr-He mixture gas, which was the first ovservation of MuHFS using a mixture gas, although the analysis in detail is ongoing. In this presentation, we will report the preliminary result of the measurement.
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