Present status of spectroscopy of the hyperfine structure and repolarization of muonic helium atoms at J-PARC

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The muonic helium atom $^4\mathrm{He}\mu^-e^-$ is an atom in which one of the two electrons of the ^{4}He atom is replaced by a negative muon. Since the orbital radius of the negative muon is about 400 times smaller than the Bohr radius, we can treat $(^4\mathrm{He}\mu^-)^+$ as a pseudo-nucleus that has a magnetic moment similar to that of a negative muon, and consider a muonic helium atom as a hydrogen-like atom. The ground state hyperfine structure (HFS) of muonic helium atom is caused by the interaction between the magnetic moments of the electron and the negative muon. The HFS of muonic helium atom is similar to muonium, which is a purely leptonic system consisting of positive muon and electron, and it can be measured using the same apparatus and technique as for muonium ground state HFS [1-2].The Experimental setup is shown in Fig. 1.

The measurement of the HFS of muonic helium atom has the potential to improve the precision of the mass of the negative muon by a factor of 50 or more. The mass of the negative muon is very important because it enables us to test the CPT theorem by comparison with positive muon mass. In addition, since muonic helium atom is a three-body system, precise HFS measurements of muonic helium atom will be a powerful probe to test and improve the theory of quantum three-body systems [3].

In previous experiments [4-5], measurement precisions are limited by mainly statistical uncertainty. The reason for the large statistical uncertainty is not only the beam intensity but also the loss of muon spin polarization ($\sim$100% $\rightarrow \sim$ 6%) due to Auger transitions and Stark mixing associated with the formation of muonic helium atom. This depolarization of muons can be recovered by using the Spin Exchange Optical Pumping (SEOP) technique [6]. Our setup of muonic helium repolarization is shown is Fig. 2. We aim to determine the ground state HFS of muonic helium atom with one hundred times higher precision than previous experiments by using the high-intensity negative muon beam of J-PARC and SEOP technique.

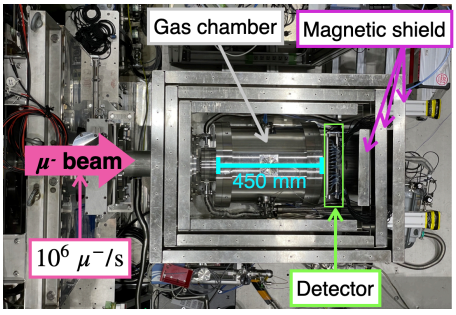

Figure 1: Setup of the HFS measurement.

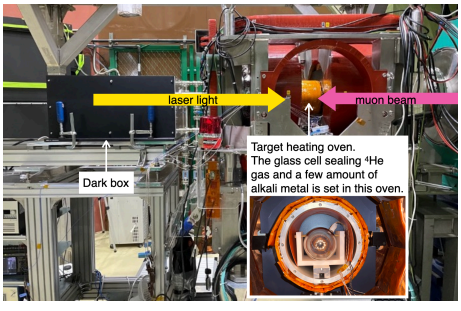

Figure 2: Setup of muonic helium repolarization using SEOP.

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