Contribution ID: **21**

Type: **not specified**

Muonic Helium Hyperfine Structure Measurements at J-PARC MUSE

Tuesday 27 August 2024 12:00 (30 minutes)

Muonic helium is a hydrogen-like atom composed of a helium atom with one of its two electrons replaced by a negative muon. Its ground-state hyperfine structure (HFS), which results from the interaction of the negative muon magnetic moment and the remaining electron, is very similar to muonium HFS but inverted. Precise measurements of the muonium ground-state HFS interval using a microwave magnetic resonance technique are now in progress at J-PARC by the MuSEUM collaboration [1]. The same method can be used to precisely determine the muonic helium HFS and the negative muon magnetic moment and mass. The world's most intense pulsed negative muon beam at J-PARC Muon Science Facility (MUSE) allows improving previous measurements and testing further CPT invariance by comparing the magnetic moments and masses of positive and negative muons (second-generation leptons). Moreover, a more precise determination of the muonic helium atom HFS will be beneficial to test and improve the theory of the three-body atomic system.

Already, new precise measurements of the muonic helium HFS were performed at zero magnetic field using the high-intensity pulsed negative muon beam at MUSE D-line. Our new result is more precise than both previous measurements at weak and high fields [2,3] done 40 years ago and the first one performed with CH4 admixture (previously Xe) as an electron donor to form neutral muonic helium atoms [4].

High-field measurements are now in preparation at MUSE H-line, using ten times more muon beam intensity than at the D-line, and with decay electrons being more focused on the detector due to the high magnetic field, we aim at improving the accuracy of previous measurements nearly hundred times for muonic helium HFS.

Furthermore, a new experimental approach to recover the negative muon polarization lost during the muon cascade process in helium is being investigated by repolarizing muonic helium atoms using a spin-exchange optical pumping (SEOP) technique [5], which would drastically improve the measurement accuracy, and where a direct improvement by a factor of ten may be realized. The first laser repolarization experiments were recently performed.

An overview of the different features of these new muonic helium atom HFS measurements and the latest results will be presented.

References:

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