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Muonic Helium HFS Measurements at J-PARC

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Microwave spectroscopy of the ground-state hyperfine structure (HFS) of muonic helium atoms is underway at J-PARC Muon Experimental Facility (MUSE) to determine the magnetic moment and mass of the negative muon with high precision. 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, resulting from the interaction of the magnetic moments of the negative muon and the remaining electron, is very similar to muonium HFS but inverted. Already, new precise measurements of the muonic helium HFS at zero magnetic field were performed 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 done 40 years ago, and the first realized with CH4 admixture to form neutral muonic helium atoms efficiently. 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 a hundred times for muonic helium HFS. To improve further the measurement precision, a new hybrid-SEOP technique to repolarize muonic helium atoms by spin-exchange optical pumping (SEOP) has been developed and successfully demonstrated. This could significantly enhance accuracy, where a direct improvement by a factor of ten may be realized. In the future, we aim to implement this technique in spectroscopic measurements to verify the CPT invariance by comparing the masses of positive and negative muons, and to compare the measured values of the hyperfine structure with precise calculations of the quantum three-body system to verify quantum electrodynamics. An overview of the different features of these new muonic helium atom HFS measurements and the latest results will be presented.

Primary author: STRASSER, Patrick (KEK-IMSS)

Co-author: MUSEUM COLLABORATION

Presenter: STRASSER, Patrick (KEK-IMSS)

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