A New Experiment for the Measurement of the *g*-Factors of $^3He^+$ and $^3He^{2+}$

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Recent dramatic advances in quantum-jump spectroscopy of single isolated nucleons in a Penning trap led to most precise measurements of the nuclear magnetic moments of the proton [1, 2] and its antimatter counterpart [3]. Based upon these successes a new experiment dedicated to the measurements of the electronic and nuclear magnetic moments of of $^3He^+$ and $^3He^{2+}$ is being set up at the Max-Planck-Institute für Kernphysik in Heidelberg (Germany). The project aims at the first direct measurement of the nuclear magnetic moment of $^3He^{2+}$ with a relative precision of 10^{-9} or better and an improvement of the ground-state hyperfine splitting in $^3He^+$ by a factor of 10 or better [4]. This will allow the establishment of hyper-polarized ^3He as an independent and accurate magnetometer, which up to now lacks a direct high-precision measurement of the nuclear magnetic moment. Furthermore a measurement of the ground-state hyperfine splitting in $^3He^+$ at a level of 10 ppt precision will complement the determination of nuclear structure effects in ^3He as persued in more sensitive but less precise experiments on muonic systems.

To date direct high-precision measurements of nuclear magnetic moments of single ions in a Penning trap have been demonstrated only for the proton and the antiproton. The employed methods rely on the detection of single spin flips whose detection fidelity is however limited by the radial mode energies of the single trapped particle. If applied to the magnetic moment of the three-times-heavier ^3He, the methods would hinge upon an insufficient detection fidelity. Thus, to meet the challenge of the high-fidelity spin-flip detection in this heavier system, the experiment aims to decrease the mode energy by more than two orders of magnitude compared to classical resistive cooling approaches. This will be achieved by applying sympathetic laser cooling, by coupling the single trapped ^3He ion to a reservoir of laser-cooled beryllium ions at their Doppler temperature. The scheme, which relies on a set of techniques proposed by Heinzen and Wineland [5], is based on the sympathetic coupling of the trapped ^3He ion to a cloud of $^9Be^+$ ions laser-cooled down to the Doppler limit. From this quasi-deterministic cooling scheme a considerable reduction in experimental cycle times and a high-fidelity spin state detection are expected.

In the contribution developments towards sympathetic laser cooling, including the demonstration of laser cooling of a cloud of $^9Be^+$ ions in a highly-advance five-Penning trap system, and the prospects towards the planned ^3He measurements will be presented.

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[4] A. H. Schuessler *et al.*, Phys. Rev. **187**, 5 (1969).
[5] D. J. Heinzen and D. J. Wineland, Phys. Rev. A **42**, 2977 (1990).