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The ALPHATRAP g-factor experiment

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The ALPHATRAP experiment [1] at the Max-Planck-Institut für Kernphysik is a cryogenic Penning-trap setup to perform high-precision g-factor measurements on highly charged ions (HCI) up to hydrogenlike $^{208}\mathrm{Pb}^{81+}$, to test bound-state quantum electrodynamics (BS-QED) [2]. In the vicinity of the nucleus, the electrons bound in HCI experience the strongest electric and magnetic fields that can be found in a stable system in the laboratory, which allows for tests of BS-QED under extreme conditions. Furthermore also fundamental constants such as the electron atomic mass [3] or eventually the fine structure constant α can be determined from such systems.

For the measurement of the bound electrons g-factor a cryogenic double Penning-trap setup is used which enables sub-parts-per-billion precision. It has the capability to capture and store HCI that are produced externally in designated ion sources and injected via a room-temperature beamline. Among the ion sources is the Heidelberg electron beam ion trap (HD-EBIT) which is designed to produce even the heaviest HCI or a laser ablation source for the production of singly-charged Be^{+} ions for an envisaged use in sympathetic laser cooling scheme for HCI. The trapped ion's eigenfrequencies can be determined with ultra-high precision in a highly homogeneous magnetic field of the compensated and orthogonal 7-electrode precision trap that allows mitigating inharmonic higher order electric field components. The spin-related magnetic substate of the electron can be detected non-destructively in the analysis trap by making use of the continuous Stern-Gerlach effect which enables spectroscopy of the Larmor precession frequency.

We will present the status of the ALPHATRAP experiment as well as report on recent results on the first measurement of the ground state magnetic moment (g-factor) in a single boronlike $^{40}\mathrm{Ar}^{13+}$ with precision of a few parts per billion [4] and laser spectroscopy of an electric-dipole-forbidden fine structure transition ($2^2P_{1/2}$—$2P_{3/2}$) in $^{40}\mathrm{Ar}^{13+}$, using a novel method which does not rely on any fluorescence signal and that opens up the possibility for further high-precision BS-QED tests.

[1] S. Sturm, et al., The European Physical Journal Special Topics 227.13, 1425-1491 (2019)
[2] S. Sturm, et al., Phys. Rev. Lett. 107.2, 023002 (2011)
[3] S. Sturm, et al., Nature 506.7489, 467 (2014)
[4] Arapoglou et al., accepted for publication in Phys. Rev. Lett.

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