Fundamental Constants and Tests of QED Theory via the Bound Electron g-factor

Matthew Bohman[1, †], **Fabian Heiße**[1], **Charlotte König**[1], **Jialin Liu**[1], **Jonathan Morgner**[1], **José Ramon Crespo López-Urrutia**[1], **Sven Sturm**[1], **and Klaus Blaum**[1]

[1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany
†corresponding author's email: matthew.bohman@mpi-hd.mpg.de

The g-factor of an electron, bound to a bare nucleus or few-electron atomic system, can be calculated to high precision in the framework of quantum electrodynamics (QED) - providing a highly stringent test of the Standard Model of particle physics when it is measured to similarly high precision. The cryogenic precision Penning-trap platform is very well-suited to study such system as it provides not only long-term recombination-free storage of these these systems, a crucial requirement for highly charged ions, but provides non-destructive spin-state determination and high resolution motional frequency determination via the continuous Stern-Gerlach effect [1] and image current detection technique, respectively. At the ALPHATRAP experiment, located at the Max-Planck-Institut für Kernphysik (MPIK) in Heidelberg, Germany, we have used exactly this platform to measure the bound electron g-factor along the periodic table, with experimental precision better than 1×10^{-10} for both hydrogen-like neon ($Z = 10$) [2] and hydrogen-like tin ($Z = 50$) [3] and we are currently building a next-generation ion source that will allow us to produce and trap few-electron highly charged ions up to hydrogen-like lead ($Z = 98$) or uranium ($Z = 82$) that have binding energies in excess of 100 keV. These high-Z systems allow us to measure higher order QED effects that would be unresolved in lighter systems and let us test the limits of high-precision QED calculations. At low Z however, the g-factor of the bound electron can be calculated to the ppt level [4] and below which allows us to use exactly the same experimental procedure to extract related fundamental constants such as the mass of the electron. Using an upgraded experimental apparatus and hydrogen-like $^{12}C^{5+}$ we have recently embarked on a campaign to significantly improve the determination of the electron mass which will directly improve tests of QED in molecular hydrogen ions [5] and can contribute to the determination of the fine structure constant in atom interferometry experiments [6, 7]. I will present the details of this campaign and describe our measurement technique and experimental apparatus, along with an overview of our ongoing efforts to push toward the high-field regime with high-Z HCIs.

References

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