Precision Measurements with Simple Molecular Hydrogen Ions at ALPHATRAP

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Molecular hydrogen ions offer a unique opportunity for testing fundamental physics at high precision. As simple three-body systems, the energy levels and properties of H_2^+, and its isotopologue HD^+, are exactly calculable and precision spectroscopy enables measurement of fundamental constants such as the proton-to-electron mass ratio [1], including possible temporal or spatial variation [2]. In contrast to atomic hydrogen, molecular hydrogen ions have many narrow, laser-accessible transitions and can be trapped and cooled ion traps. This offers not only exciting prospects for metrology[3], but presents a viable method for creating and performing precision measurements on the antimatter counterpart $\bar{H}_2^-$ [4]. We have recently demonstrated long-term trapping and quantum control a single HD^+ molecule in the rovibrational ground state at the ALPHATRAP Penning-trap apparatus [5] culminating in a measurement of the ground state hyperfine structure. This measurement allows us to extract the shielded g-factors of the proton, deuteron, and electron along with the E_4 and E_5 coefficients of the hyperfine Hamiltonian and demonstrates molecular state detection via the continuous Stern-Gerlach effect which we will use in upcoming measurements of rovibrational transitions in HD^+ and H_2^+.

[1] I. V. Kortunov, *et al.*, Nature Physics vol **17**, 569-573 (2021)
[2] M. S. Safronova, *et al.*, Rev. Mod. Phys. **90**, 025008 (2018)
[3] S. Schiller, D. Bakalov, Appl. Phys. B **114**, 213-230 (2014)
[4] E. Myers, Phys. Rev. A **98**, 010101(R) (2018)
[5] S. Sturm *et al.*, Eur. Phys. J. Spec. Top. **227**, 1425-1491 (2019)