Standard Model test below 1ppt with the 2S-6P transition frequency measurement in atomic hydrogen

Vitaly Wirthl[1, †], Lothar Maisenbacher[1,4], Alexey Grinin[1,5], Arthur Matveev[1], Randolf Pohl[2], Theodor W. Hänsch[1,3], Thomas Udem[1,3]

[1]Max-Planck-Institut für Quantenoptik, Garching, Germany
[2]Johannes Gutenberg-Universität Mainz, Mainz, Germany
[3]Ludwig-Maximilians-Universität München, München, Germany
[4]Present address: University of California, Berkeley, Berkeley, CA, USA
[5]Present address: Northwestern University, Evanston, IL, USA
†corresponding author's email: vitaly.wirthl@mpq.mpg.de

Quantum electrodynamics (QED) forms the basis for all other quantum field theories, upon which the Standard Model of particle physics is constructed. Due to the simplicity of the hydrogen atom, its energy levels can be precisely calculated from bound-state QED and confronted with the experiment. Such a comparison between theory and experiment is linked to the determination of fundamental constants, which enter the theory as parameters. Only if more indepedendent measurements are available than there are parameters, the theory can be tested. For hydrogen, the theory test mainly concerns the Rydberg constant and the proton radius. This requires at least two different transition frequency measurements to determine those, and more measurements to test the theory. Here we report on our 2S-6P transition frequency measurement with a relative uncertainty of 0.7 parts per trillion (ppt), a six-fold improvement over our previous measurement of the 2S-4P transition [1]. This result can be combined with the existing 1S-2S measurement [3] and the 2S-2P muonic hydrogen measurement [4]. We thereby determine the proton radius 2.5 times more accurate than the previous most accurate electronic hydrogen measurement [2] and provide a theory test with an accuracy below 1 ppt, making it one of the most precise tests of the Standard Model.

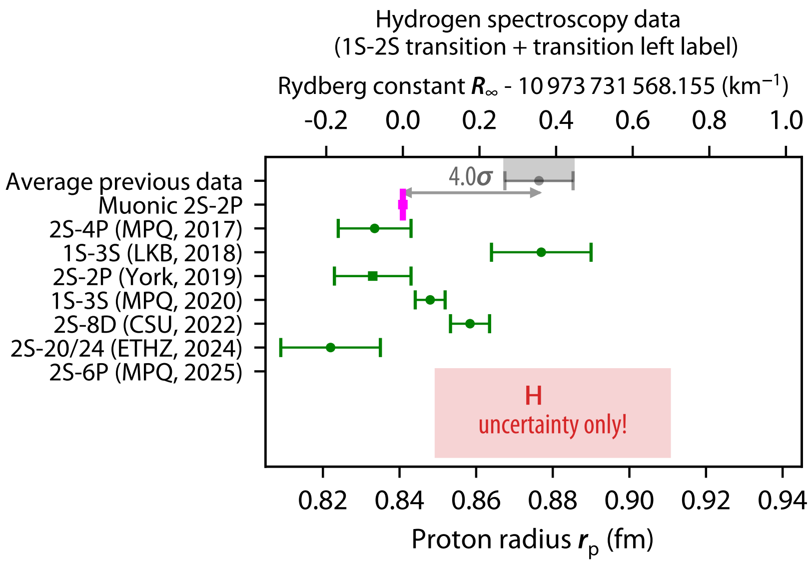

Figure 1: By combining the 1S-2S transition frequency measurement [3] with another transition measurement (left label), the proton radius and the Rydberg constant are determined. The theory test can then be pictured as a redundant determination of these constants. The muonic hydrogen measurement (magenta) [4] is discrepant with the average of all previous data before 2010 (grey). This discrepancy has been called the "proton radius puzzle". Since then more measurements have been done (green, e.g. [5]), where some inconsistencies remain. Our preliminary 2S-6P result in hydrogen with uncertainty shown in red (value will be presented in the talk) is six-fold more accurate that our previous 2S-4P measurement [1], 2.5 times more accurate than our 1S-3S measurement [2], and allows the most accurate theory test in hydrogen to date.

References

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