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Muonic atoms and proton size

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Muonic hydrogen atoms have for a long time been recognized as the ideal tool to study nuclear properties such as charge radii, (magnetic) Zemach radii, or nuclear polarizabilities. Our laser spectroscopy measurements of the Lamb shift in light muonic atoms (H, D, He-3 and He-4) have yielded charge radii with tenfold improved precision. Intriguingly, the proton and deuteron charge radii display large discrepancies to the
previous world average from laser spectroscopy of regular H and D atoms, and from elastic electron scattering. This "proton radius puzzle"has sparked a series of new measurements in regular atoms, such as the 2S-4P transition of atomic hydrogen we have measured in Garching. More
measurements are underway.

On the muonic side, a measurement of the hyperfine splitting of the 1S ground state in muonic hydrogen (which is pursued by 3 collaborations world wide) will yield an order of magnitude improved value for the Zemach radius of the proton that encodes its magnetic properties.

In the future, laser spectroscopy of trapped atomic tritium could improve the triton charge radius by a factor of 300, providing the "missing link"between our precise measurements of H and D on the one hand, and He on the other. Laser spectroscopy oftrapped atomic tritium could improve the triton charge radius by a factor of 300, providing the "missing link"between our precise measurements of H and D on the one hand, and He on the other. Laser spectroscopy of muonic Li and Be ions could improve the corresponding charge radii by a factor of 10. These results would provide highly accurate charge radii required for QED tests in simple atoms, ions, and molecules, and enable new high-precision benchmarks for ab initio nuclear structure calculations.

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