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Francis M. Pipkin Award Talk: Proton structure from laser spectroscopy of muonic hydrogen

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Muonic hydrogen (μp) is the bound state of a proton and a negative muon. The large muon mass results in a small Bohr radius of the muonic hydrogen atom which in turn causes a dramatically increased sensitivity of the energy levels in μp to the finite size of the proton's charge and magnetisation distributions. The discovery of long-lived μp atoms in the metastable 2S state [1] enabled us to perform a measurement of the 2S-2P energy splitting (Lamb shift) in muonic hydrogen for the first time [2]. The proton radius we obtained is ten times more accurate, but 7σ away from the current PDG value. This so-called "proton radius puzzle" has caused considerable activity, but no clear solution has been found yet [3]. A second measurement in μp [4] confirms the proton radius obtained in [1], and a combination of both measurements reveals the 2S hyperfine splitting of the μp atom which is sensitive to the magnetic properties of the proton [4].

[1] R. Pohl *et al.*, Phys. Rev. Lett. **97**, 193402 (2006).
[2] R. Pohl *et al.* (CREMA coll.), Nature **466**, 213 (2010).
[3] R. Pohl, R. Gilman, G.A. Miller, K. Pachucki, arXiv 1301.0905.
[4] A. Antognini *et al.* (CREMA coll.), Science (2013), DOI:10.1126/science.1230016

[1]CREMA Collaboration (Charge Radius Experiment with Muonic Atoms)