Measurement of the proton Zemach radius from the hyperfine splitting in muonic hydrogen atom

S. Kanda[a], S. Aikawa[b], K. Ishida[a], M. Iwasaki[a], Y. Ma[a], Y. Matsuda[c], K. Midorikawa[d], Y. Oishi[e], S. Okada[a], N. Saito[d], M. Sato[e], A. Takamine[a], K. S. Tanaka[f], H. Ueno[a], S. Wada[d], and M. Yumoto[d]

[a] *RIKEN Nishina Center for Accelerator-Based Science, RIKEN, Wako, Saitama 351-0198, Japan*
[b] *Department of Physics, Tokyo Institute of Technology, Meguro, Tokyo 152-8551, Japan*
[c] *Graduate School of Arts and Sciences, The University of Tokyo, Meguro, Tokyo 153-8902, Japan*
[d] *RIKEN Center for Advanced Photonics, RIKEN, Wako, Saitama 351-0198, Japan*
[e] *High Energy Accelerator Research Organization (KEK), Tsukuba, Ibaraki 305-0801, Japan*
[f] *Cyclotron and Radioisotope Center, Tohoku University, Sendai, Miyagi, 980-8578, Japan*

The proton is a fundamental constituent of the matter. However, it has a complicated internal structure which is difficult to be fully understood. The internal structure of the proton is described by the electronic and magnetic form factors. The charge radius of the proton is defined by these form factors and has been determined experimentally. In recent years, a significant discrepancy between independent measurements of the proton charge radius was reported [1, 2]. This conflict is known as "proton radius puzzle". Even though various interpretations have been proposed, no definitive solution to the problem has been found yet. In order to shed some light on the puzzle, we proposed a new experiment to determine the proton Zemach radius which is defined as a convolution of the charge distribution with the magnetic moment distribution. The proton Zemach radius can be derived from the hyperfine splitting (HFS) in the muonic hydrogen atom. Figure 1 illustrates the experimental schematic. We aim to perform a laser spectroscopy of the muonic hydrogen HFS with the relative uncertainty of 1 ppm and obtain the proton Zemach radius with 1% precision.

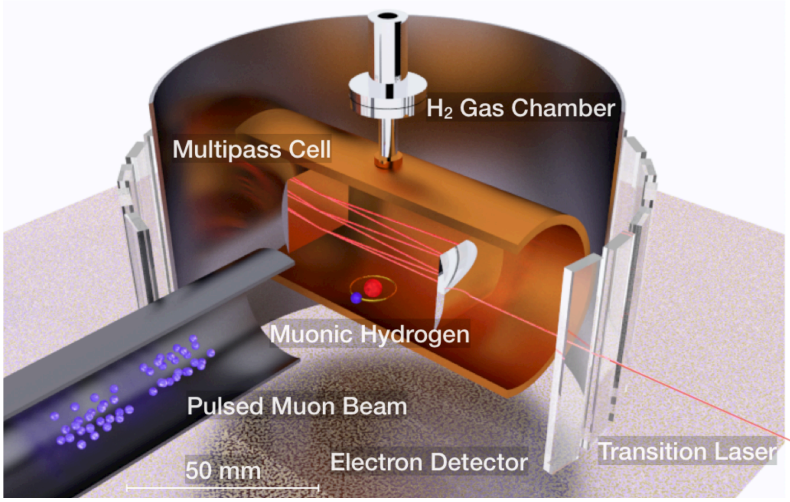

Figure 1: Experimental schematic. Pulsed negative muon beam irradiates the H_2 gas target. Muon is captured by the Coulomb field of the proton and forms a muonic hydrogen atom. The hyperfine transition between the spin singlet state and the triplet states is induced by a mid-infrared laser light. Electrons from muonic hydrogen decay are detected by the electron counter placed around the gas chamber.

[1] A. Antognini *et al.*, Science 339, 417 (2013).
[2] P. J. Mohr, D. B. Newell, and B. N. Taylor, Rev. Mod. Phys. 88, 035009 (2016).