High precision spectroscopy of the highly excited states in muonic hydrogen

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The recently realized low energy μ^- beam facility (R–98–03, Muonic Hydrogen Collaboration, http://muhy.web.psi.ch/) opens the way to the practical realization of an idea first presented at the 13^{th} Atomic Physics Conference (Poster Session, Munich, 1993). The goal is to achieve a high precision determination of the μ^- mass via two–photon spectroscopy of highly excited levels in muonic hydrogen.

It happens that the energy difference between the n–levels 18 and 16 is nearly equal to the energy difference between the n–levels 21 and 18. The nearly resonant two–photon transition provides a high excitation efficiency from the initially populated n=16 level to the much less populated n=21 level allowing the transition to be detected as a change in cascade time. A standard *continuous wave* laser at the red 600 nm wavelength in a resonant cavity is sufficient to induce the transition between selected j–levels. A very low density hydrogen target at low magnetic field is used and muon stopping into it is obtained by extraction and phase space rotation of the existing timed few keV μ^- beam into a 100 eV beam. The achievable precision on the muonic Rydberg constant is 3×10^{-10} .

The resulting precise muon mass, can be used, assuming the validity of the CPT–theorem, to achieve, in conjunction with a remeasurement at PSI of the hyperfine structure interval in muonium at the 3×10^{-10} level, a factor of 20 increase in precision in this relevant test of QED in bound systems. Alternatively, as a high precision determination of the μ^+ mass becomes feasible, a test of CPT invariance in the lepton sector to a precision of 3×10^{-10} is made possible.