Muonic Anti-Hydrogen; Production and Test of CPT Theorem

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Including antiproton $\bar{p}$, there are four types of hydrogen atoms allowing species involving μ^+ and μ^-: these are the conventional H atom (e^-p), the corresponding anti-atom $e^+\bar{p}$ ($\bar{H}$), and the two muonic counterparts, μ^-p and $\mu^+\bar{p}$. If a method of generating antihydrogen $\bar{H}$ ($e^+\bar{p}$) is established, it is widely discussed that a high-precision spectroscopic measurement on $\bar{H}$, in comparison with the corresponding results for H, may contribute to the verification or falsification of the CPT conservation law. The advantage of the use of the μ^-p, $\mu^+\bar{p}$ pair is obvious. If the CPT-violating interaction is short-range (with an extremely massive exchange boson), such an effect can be seen more easily in the (μ^-p, $\mu^+\bar{p}$) case in comparison with that in the (e^-p, $e^+\bar{p}$) case since the atomic size becomes smaller by 1/207.

Since intense slow μ^+ and Mu beams will soon become available, it will be possible to produce $\mu^+\bar{p}$ through, e.g., the following reaction: Mu + $\bar{p}$ $\rightarrow \mu^+\bar{p}$ + e^-, i.e. thermal Mu and $\bar{p}$ reaction with the energy of $\bar{p}$ optimized for the binding energy of the final state $\mu^+\bar{p}$ ($E_{q.s.}(\mu^-\bar{p}) \sim 2.8$ keV). A crossed-beam experiment with a few keV 10^{10}/s $\bar{p}$ beam onto 10^{10} thermal Mu will produce a few $\mu^+\bar{p}$ atom/s. As for the detection of a formation of the $\mu^+\bar{p}$ atom, 1.9 keV 2p-1s transition photon will be an easiest way.

Precise CPT test will be considered to perform comparative measurements of the following energy intervals with the aid of high precision Resonant Laser Spectroscopy; e.g. ΔE (n = 1, hfs) = 0.183 eV or $\Delta E\ (2^2p_{1/2} - 2^2s_{1/2}) = 0.20$ eV.