Precise laser spectroscopy of the antiprotonic helium atom and CPT test on antiproton mass and charge

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The antiprotonic helium atom ($\bar{p}\mathrm{He}^+$) is a three-body system consisting of an antiproton, an electron, and a helium nucleus. Some states (quantum numbers; n, $l \sim 38$) of this exotic atom are known to live anomalously long (lifetime $\sim 3\ \mu$s) for a system including an antiproton. Since its discovery at KEK in 1991, the nature of the atom has been studied well, and precise measurements of the enegy levels have been carried out by using a laser spectroscopic method.

Since 2000, we have done precise (sub-ppm) laser spectroscopy on many transitions of the atom at CERN AD (Antiproton Decelerator). We can do a CPT test on proton-antiproton mass and charge differences by comparing the experiment with theories, as the theories use the known proton mass value for the antiproton mass. In 2000, we obtained a limit on the mass and charge differences (CPT limit; defined as $(m_{\bar{p}} - m_p)/m_p$) of 60 ppb[1]. This value is likely to be improved further by the results in 2001, measured at low densities ($\rho \sim 10^{17}$ cm^{-3}) by using decelerated (5.3 MeV to less than 100 keV) antiproton beam.

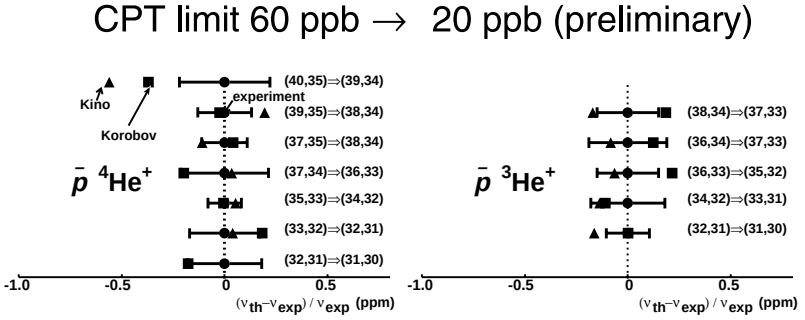

Figure 1: Precise comparison of the transition frequencies of $\bar{p}\mathrm{He}^+$ between the experiment and theories. The circles with error bars on the central lines are experimental values, and two theoretical calculations by Korobov[2] and Kino[3] are also shown.

References

[1] M. Hori *et al.*, Phys. Rev. Lett. **87** (2001) 093401.
[2] V. I. Korobov, Phys. Rev. A **54** (1996) R1749 and private communication (2001).
[3] Y. Kino, private communication (2001).