Antiprotonic helium and CPT invariance

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Recent progress is reviewed in the laser spectroscopy of antiprotonic helium atoms ($\overline{\mathrm{p}}\mathrm{He}^+ \equiv \mathrm{e}^- - \overline{\mathrm{p}} - \mathrm{He}^{++}$) performed at CERN's Antiproton Decelerator facility (AD) by the ASACUSA Collaboration [1, 2]. Laser transitions were induced between Rydberg states (n, ℓ) and $(n \pm 1, \ell - 1)$ of $\overline{\mathrm{p}}\mathrm{He}^+$ ($n \sim 40$ and $\ell \lesssim n - 1$ being the principal and orbital angular momentum quantum numbers of the antiproton orbit).

Comparison of experimental (ν_{exp}) and theoretical [3] (ν_{th}) frequencies for seven transitions in $\overline{\mathrm{p}}^4\mathrm{He}^+$ and five in $\overline{\mathrm{p}}^3\mathrm{He}^+$ yielded an antiproton-to-electron mass ratio of $m_{\bar{\mathrm{p}}}/m_e = 1836.152674(5)$. This agrees with the known proton-to-electron mass ratio at the level of $\sim 2 \times 10^{-9}$. The experiment also set a limit on any *CPT*-violating difference between the antiproton and proton charges and masses, $(Q_{\mathrm{p}} - |Q_{\bar{\mathrm{p}}}|)/Q_{\mathrm{p}} \sim (m_{\mathrm{p}} - m_{\bar{\mathrm{p}}})/m_{\mathrm{p}} < 2 \times 10^{-9}$ to a 90% confidence level (Fig. 1). If on the other hand we assume the validity of *CPT* invariance, the $m_{\bar{\mathrm{p}}}/m_e$ result can be taken to be equal to m_{p}/m_e. This can be used as an input to future adjustments of fundamental constants.

Further improvements in the experimental precision would be possible if the thermal Doppler broadening could be reduced. With a near-resonant two-photon excitation method, currently being developed, it appears possible to determine the antiproton-to-electron mass ratio with a precision comparable to that of the proton-to-electron mass ratio ($\sim 0.5 \times 10^{-9}$).

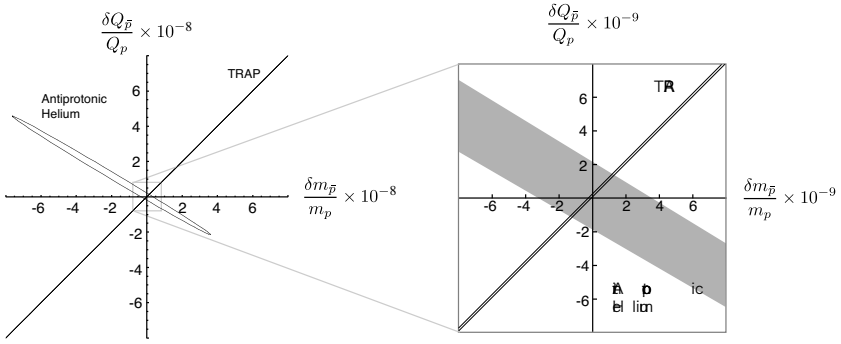

Figure 1: Limits on the difference of mass and charge between proton and antiproton. The charge/mass (Q/M) ratio was measured by the TRAP group [4] whereas $M \cdot Q^2$ by ASACUSA [5]. With the improvement of the experimental technique the allowed region was step-by-step reduced: the present limit is 2 ppb (2×10^{-9}).

References

[1] Home page of the ASACUSA (*Atomic Spectroscopy And Collisions Using Slow Antiprotons*) Collaboration: http://asacusa.web.cern.ch/ASACUSA/

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