International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Determination of the antiproton-to-electron mass ratio by two-photon laser spectroscopy of antiprotonic helium atoms

A. Sótér[1] , M. Hori[1,2], D. Barna[2], A. Dax[2], R. S. Hayano[2], S. Friedreich[3], B. Juhász[3], E. Widmann[3], D. Horváth[4], Luca Venturelli[5], Nicola Zurlo[5]

[1] *Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, D85748 Garching, Germany*
[2] *Department of Physics, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan*
[3] *Stefan Meyer Institut für Subatomare Physik, Boltzmanngasse 3, Vienna 1090, Austria*
[4] *Wigner RCP, Institute for Particle and Nuclear Physics, 1121 Budapest, XII. Konkoly T. M. út 29-33*
[5] *Dipartimento di Ingegneria dell'Informazione, Università di Brescia and Istituto Nazionale di Fisica Nucleare, Gruppo Collegato di Brescia, I-25133 Brescia, Italy*

Contact email: *anna.soter@cern.ch*

The ASACUSA experiment at CERN recently measured the atomic transition frequencies of antiprotonic helium ($\bar{p}$He) to a fractional precision of 2.3-5 parts in 10^9 by non-linear two-photon laser spectroscopy [1]. Antiprotonic helium is a metastable three-body atom [2] consisting of a normal helium nucleus, a ground-state electron, and an antiproton occupying a Rydberg state with high principal and angular quantum numbers n and l, so that $n \sim l + 1$. We irradiated the isotopes $\bar{p}^3$He and $\bar{p}^4$He with two laser beams, which excited nonlinear two-photon transitions of the antiproton of the type $(n, l) \rightarrow (n - 2, l - 2)$. By allowing the atom to simultaneously absorb a photon from each of the two counter-propagating laser beams of similar wavelength, the broadening of the resonance lines caused by the Doppler effect was partially canceled. This resulted in the observation of sharp spectral lines, from which the transition frequencies could be precisely obtained. By comparing these experimental frequencies with the results of three-body QED calculations [3], we derived an antiproton-to-electron mass ratio of 1836.1526736(23), which agrees with the proton-to-electron value known to a similar precision [4].

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