

Seminar über Quanten-, Atom- und Neutronenphysik (QUANTUM)

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Lorentz-Raum (05-127), Staudingerweg 7

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Spectroscopy of trapped antihydrogen atoms

Precision studies of antihydrogen might shed light on one of the most tantalizing mysteries in today's Physics: the asymmetry of matter-antimatter abundance in the Universe. In this presentation, we review the developments in the experiments ATHENA and ALPHA, housed at CERN's Antiproton Decelerator, leading to the first production of low-energy anti-atoms[1] and later the first trapping of antihydrogen atoms[2]. These exotic atoms can be held for over 15 minutes in the trap[3], thus allowing for a new era of high precision measurements of antimatter. Among the initial measurements, we have put new limits on a possible electrical charge of the anti-atom[4] that, together with independent measurements, put new limits on a possible charge anomaly of the positron. Microwaves can induce spin-flipping transitions[5] and allow for the measurement of the hyperfine constant. The main goal of a high precision two-photon laser spectroscopy on the $1s$ - $2s$ transition has just been started with the observation of the laser excitation[6], and it should evolve into 2017 with a first spectrum leading to comparisons of parts in 10^{11} between these transitions in antihydrogen and its charge conjugate atom. There are prospects for reaching parts in 10^{15} and beyond[7], and those will require further cooling of the anti-atoms[8] and the possibility to trap hydrogen in the same trapping environment as the antihydrogen[9]. Whether the CPT (charge-parity-time) symmetry will hold true at these levels of precision or whether gravity acts the same way – probed firstly by “red shifts” on the transition frequencies – on antimatter atoms, only nature has that answer. As experimenters with this exotic species at hand it is our duty to properly inquire nature's responses on all these issues.

- [1] M. Amoretti et al. (ATHENA Coll.), "Production and detection of cold antihydrogen atoms", Nature 419, 456 (2002)
- [2] G. B. Andresen et al. (ALPHA Collaboration), "Trapped Antihydrogen", Nature 468, 673 (2010)
- [3] G. B. Andresen et al. (ALPHA Collaboration), "Confinement of Antihydrogen for 1,000 Seconds", Nature Physics 7, 558 (2011)
- [4] M. Ahmadi, et al. (ALPHA Coll.) "An improved limit on the charge of antihydrogen from stochastic acceleration", Nature 529, 373 (2016)
- [5] C. Amole, et al. (ALPHA Coll.), "Resonant quantum transitions in trapped antihydrogen atoms", Nature 483, 439(2012)
- [6] M. Ahmadi et al. [ALPHA Coll.], Observation of the 1S-2S transition in trapped antihydrogen, Nature 541, 506 (2017)
- [7] Ch. G. Parthey et al., "Improved Measurement of the Hydrogen 1S-2S Transition Frequency", Phys. Rev. Lett. 107, 203001 (2011); C. L. Cesar, "Zeeman effect on the 1S-2S transition in trapped hydrogen and antihydrogen", Phys. Rev. A 64, 023418 (2001); C. L. Cesar et al., "Two-Photon Spectroscopy of Trapped Atomic Hydrogen", Phys. Rev. Lett. 77, 255 (1996)
- [8] see for example: C. L. Cesar, F. Robicheaux and N. Zagury, "Possible mechanism for enhancing the trapping and cooling of antihydrogen", Phys. Rev. A 80, 041404(R) (2009), and P H Donnan, M C Fujiwara and F Robicheaux, "A proposal for laser cooling antihydrogen atoms", J. Phys. B 46, 025302 (2013)
- [9] C. L. Cesar, "A sensitive detection method for high resolution spectroscopy of trapped antihydrogen, hydrogen and other trapped species", J. Phys. B 49, 074001 (2016)