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JOHANNES GUTENBERG UNIVERSITÄT MAINZ

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

Dec. 1, 2022 at 2 p.m.
IPH Lorentzraum 05-127

Dr. Masaki Hori
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Laser spectroscopy of anti-protonic and mesonic helium atoms

A Metastable antiprotonic helium is a Rydberg exotic atom composed of a helium nucleus, electron, and an antiproton. It is among the hadron-anti-hadron bound systems with the longest known lifetimes. Intense beams of laser light can be used to excite atomic transitions involving the anti-proton orbital. By utilizing sub-Doppler two-photon laser spectroscopy or buffer gas cooling, its atomic transition frequencies were measured to ppb-scale precision. Comparisons with the results of QED calculations allowed the antiproton-to-electron mass ratio to be determined as 1836.1526734(15). The results were used to set upper limits on fifth forces between antiprotons and nucleons at atomic length scales, and on forces that may arise between an electron and antiproton mediated by hypothetical bosons by Mainz theoretical groups. Efforts are currently underway to improve the experimental precision using CERN's ELENA facility.

We also observed narrow spectral lines of these atoms formed in super fluid helium with asurprisingly high spectral resolution of 2 parts per million. This revealed the hyperfinestructure arising from the spin-spin interaction between the antiproton and electron,despite the fact that the atom was surrounded by a dense matrix of normal atoms. Thisphenomenon may imply future possibilities in condensed matter or astrophysical fields.

Metastable pionic helium (πHe+) contains a negative pion occupying a state of n≈l-1≈17, and retains a 7 ns average lifetime. We recently used

the 590 MeV ringcyclotron facility of Paul Scherrer Institute near Zurich to synthesize the atoms, and irradiated them with resonant infrared laser pulses. This induced a pionic transition within the atom and triggered an electromagnetic cascade that resulted in the π- being absorbed into the helium nucleus. This constitutes the first laser excitation and spectroscopy of an atom containing a meson. By improving the experimental precision, the pion mass may bedetermined to a high precision as in the antiproton case. We wish to extend these studies to other atoms containing kaons or hyperons that includes the strange quark.

Bio: Masaki Hori obtained his PhD in 2000 at the University of Tokyo in the field ofnuclear physics. After CERN and JSPS fellowships in Geneva involving antiprotonexperiments and building LHC injector parts, he became group leader at the Max Planck Institute of Quantum Optics in 2008. He obtained a Habilitation and became Privatdozent in 2020 at the Ludwig Maximillians University, while working in a commercial company that develops optical frequency combs. He joined the Institute of Physics of Mainz today as a Heisenberg position. He is spokesperson of the laser spectroscopy experiments of exotic helium atoms at CERN and PSI.

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