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Laser spectroscopy of metastable pionic helium atoms at Paul Scherrer Institute

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Metastable pionic helium is a three-body exotic atom composed of a helium nucleus, electron, and negatively-charged pion occupying a highly-excited state with a principal and orbital angular momentum quantum numbers of n≈l-1≈17 [1-4]. The atom has a τ=7 ns lifetime. We used the 590 MeV ring cyclotron facility of PSI to synthesize π4He+ and irradiate the atoms with 800 ps-long resonant laser pulses of frequency ν=183760 GHz that induced a pionic transition (n,l)=(17,16)⟶(17,15) [1,2]. This laser transition triggered an electromagnetic cascade that resulted in the pion being absorbed into the helium nucleus [1-3]. The nucleus immediately underwent fission and the neutron, proton, and deuteron fragments were detected by an array of 140 plastic scintillation counters surrounding the target. This constitutes the first laser excitation and spectroscopy of an atom containing a meson.
By further improving the precision of the transition frequencies and comparing them with the results of three-body QED calculations [2,4], the pion mass may be determined to a high precision, as has been done for the case of metastable antiprotonic helium [5,6].

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Collaboration

ASACUSA and PiHe

Primary authors: DAX, Andreas (PSI); SÓTÉR, Anna (ETH Zurich); BARNA, Dániel (Wigner Research Centre); AGHAI-KHOZANI, Hossein (Max Planck Institue of Quantum Optics); HORI, Masaki (Imperial College London and Johannes Gutenberg University Mainz and Max Planck Institute of Quantum Optics)

Presenter: HORI, Masaki (Imperial College London and Johannes Gutenberg University Mainz and Max Planck Institute of Quantum Optics)

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