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Laser spectroscopy of antiprotonic and pionic helium atoms at CERN and PSI

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The ASACUSA collaboration at CERN's Antiproton Decelerator, and the PiHe collaboration at PSI's 590 MeV ring cyclotron facility have carried out laser spectroscopy of metastable antiprotonic and pionic helium atoms. The latter is a three-body exotic atom composed of a helium nucleus, electron, and negative pion occupying a highly-excited state with principal and orbital angular momentum quantum numbers of n≈l-1≈17, which retains a τ=7 ns average lifetime. The atoms were synthesized by using the πE5 beamline of PSI which provides the world's highest-intensity continuous pion beam. The atoms were irradiated with 800 picosecond-long infrared laser pulses that induced a pionic transition (n,l)=(17,16)⟶(17,15) [1-4]. This triggered an electromagnetic cascade that resulted in the π- being absorbed into the helium nucleus. The nucleus 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 experimental precision of the π4He+ transition frequencies and comparing them with the results of three-body QED calculations, the pion mass may be determined to a high precision. Similar measurements have been carried out for metastable antiprotonic helium [5-6] which will be pursued at the new ELENA facility. Limits may also be established on exotic forces that arise between pions or antiprotons and helium nuclei [7].

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