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Towards nuclear structure studies using trapped antiprotons at AEgIS

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On behalf of the AEgIS collaboration

At CERN's antimatter factory, antiprotons are routinely produced and cooled in bunches utilizing the ELENA/AD decelerators. The low energy antiprotons are distributed to a wide range of trapping experiments primarily aiming at precision tests of fundamental symmetries and interactions [1]. The Antimatter Experiment: Gravity, Interferometry, Spectroscopy (AEgIS) at the antimatter factory has achieved remarkable performance in using trapped antiprotons for the pulsed creation of antihydrogen for studying the gravitational influence on antimatter and in laser cooling of positronium [2, 3, 4]. Currently, the involved techniques are being extended to the controlled synthesis of antiprotonic atoms inside the Penning-Malmberg trap, where an antiproton—nearly 2000 times heavier than an electron—replaces an orbiting electron in a conventional atom [5, 6].

The transitions between the deeply bound states of an antiprotonic atom are influenced by the strong interaction and can in some cases induce direct nuclear resonance effects, offering insight into the nuclear density and spin of short-lived states via X-ray spectroscopy [7]. As the bound antiproton deexcites after being captured in a Rydberg state, it ejects atomic electrons via the Auger processes before annihilating at the nucleus's surface, resulting in the formation of highly charged nuclear annihilation fragments. These highly charged ions (HCIs) can be trapped and further cooled for experimental studies [8, 9]. Measurements of the yields of the captured nuclear fragments give valuable insight into the annihilation mechanism, opening avenues for precision studies of nuclear structure, such as the neutron-skin [10, 11].

As an initial step towards this goal, the AEgIS collaboration has demonstrated the trapping and TOF spectroscopy of HCIs, produced by antiproton annihilations on Argon and Helium atoms inside the Penning-Malmberg trap. Meanwhile, the ongoing installation of a negative ion source will enable co-trapping of negative ions with antiprotons for the laser-triggered formation of antiprotonic atoms. These developments lay the groundwork for controlled synthesis and spectroscopy of cold radioactive HCIs, advancing studies of fundamental interactions and nuclear structure.

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