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Synthesis of highly charged nuclear fragments in a Penning-Malmberg trap using antiprotons

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The Antimatter Experiment: Gravity, Interferometry, Spectroscopy (AEgIS) at CERN's Antimatter Decelerator (AD) is used for the production and study of antimatter bound systems, such as antihydrogen for the gravitational influence on a horizontal beam of cold antihydrogen atoms [1]. AEGIS has achieved remarkable performance in trapping antiprotons and successfully demonstrated the pulsed production of Rydberg excited antihydrogen [2,3]. The production process of antihydrogen is achieved through a charge-exchange reaction using laser-excited Rydberg positronium interacting with cold antiprotons stored within a Penning-Malmberg trap.

This technique is currently being adapted for the controlled formation of antiprotonic atoms containing medium-heavy nuclei [4]. So far, antiprotonic atoms were formed in beam-on-target experiments, primarily focusing on light systems such as antiprotonic helium [5,6]. Using the charge-exchange procedure developed for antihydrogen production, antiprotonic atoms can be selectively formed in highly excited Rydberg states inside a trapping environment, enabling precision laser spectroscopy of these systems. The relaxation of the bound antiproton leads to Auger electron and x-ray photon emission, eventually forming a fully or nearly stripped nucleus with the bound antiproton. The subsequent annihilation on the nucleus will result in the formation of highly charged nuclear fragments with a loss of one of more nucleons, these fragments can be captured within a nested trap when the recoil energy is sufficiently low. The rapid capture of the highly charged nuclear fragments opens the avenues for new applications and nuclear structure studies of the synthesized fragments [7].

Recent, experiments at AEgIS have successfully demonstrated the trapping of highly charged ions resulting from antiprotons annihilating with residual nitrogen gas in the cryogenic trap. These highly charged ions were further manipulated and could be identified using time-of-flight spectroscopy. This new advancement open up new possibilities for experiments probing the annihilation mechanisms, allowing further nuclear structure studies of the resulting fragments directly within the trap.

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