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Studies of highly charged ions formed using antiprotons at AEgIS

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Antimatter Experiment: gravity, Interferometry, Spectroscopy (AEḡIS) achieves pulsed production of antihydrogen using a charge-exchange reaction between antiproton and Rydberg positronium (an electron and a positron in a bound state). The AEḡIS experiment is used to probe antimatter bound systems for measurements of gravitational free fall and precision studies of positronium. More recently a new program has been started which focuses on the controlled formation and studies of antiprotonic atoms - a bound state consisting of antiproton in an orbit around a matter nucleus.

Ongoing developments strive to achieve controlled formation of antiprotonic atoms by co-trapping anions with cold antiprotons. Then one laser would neutralize the ions and subsequently another laser would excite the formed neutral atom to a Rydberg state for a charge-exchange reaction with the antiprotons.

The controlled formation of antiprotonic atoms within the trap allows a detailed spectroscopic study of antiprotonic bound states in a trap.
In the case that an antiprotonic atom is formed, the antiproton would cascade down the electronic energy levels causing emission of Auger electrons and x-rays until the antiproton is close enough to annihilate on the nucleons, resulting in highly charged nuclear fragments. Capturing highly charged positive ions would be of further interest for nuclear structure studies.

A new procedure for proof-of-principle measurement was developed. Low pressure nitrogen gas was introduced into the AEḡIS apparatus. Antiprotons were then trapped inside the apparatus and a nested trap was formed to capture positive ions. Subsequently, the antiprotons were released, and the nested trap was reshaped for time-of-flight (TOF) measurement. Then, the ions in the nested trap were released, and TOF spectra were captured using an MCP. To analyze the TOF spectra, we compared them with simulations. This work has shown that it is possible to trap ions formed by the antiproton interaction with a gas and use the AEḡIS apparatus as a TOF spectrometer capable of giving insights into mass to charge ratios of the ions.

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