Contribution ID: **23** Type: **not specified**

Nuclear structure studies using cold antiprotons at AEGIS

Tuesday, July 23, 2024 11:20 AM (20 minutes)

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 trapping antiprotons for the pulsed creation antimatter bound systems such as antihydrogen for studying the gravitational influence on antimatter [2, 3]. Currently, this technique is being developed for the controlled synthesis of antiprotonic atoms inside the Penning-Malmberg trap, where an antiproton—nearly 2000 times heavier than an electron—replaces the orbiting electron in a conventional atom [4, 5]. The deexcitation of the deeply bound antiproton captured in a selected Rydberg state results in the emission of Auger electrons and X-rays. The X-ray emission from the cascade carries vital information for understanding the strong interaction influence on the deeply bound antiproton orbits and may, in some cases, result in direct resonance effects with the nucleus [7, 8]. These resonance phenomena can provide insight into the nuclear density distribution as well as the spin of short-lived nuclear states, accessible for exploration with gamma spectroscopy. As the bound antiproton approaches the nucleus's surface, it will rapidly annihilate, resulting in the formation of highly charged radioactive nuclear recoil fragments [9]. These highly charged fragments can be trapped and further cooled within a nested trap, opening new avenues for precision studies of nuclear structure and fundamental interactions [10]. The AEGIS collaboration have recently demonstrated the trapping of highly charged ions (HCIs) resulting from antiprotons annihilation. Techniques were developed for manipulating the formed HCIs and identifying the fragments using time-of-flight spectroscopy. The ongoing installation of a negative ion source at AEGIS will enable the first co-trapping of negative ions with antiprotons. These developments facilitate the controlled, laser-triggered formation of antiprotonic atoms and the synthesis of cold radioactive highly charged ions (HCIs) within the trap, paving the way for these novel experimental studies.

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Session Classification: Instrumentation and Techniques