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A novel platform for antiprotonic atom research using Paul and Penning-Malmberg traps

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AEgIS experiment at CERN utilizes a charge-exchange reaction with Rydberg positronium for the formation of a pulsed antihydrogen (Hbar) beam for a gravity measurement in the absence of external fields [1]. Hbar formation with all its intermittent steps is achieved in cryogenic, Ultra High Vacuum conditions, inside of a Penning-Malmberg trap system.

The controlled environment of the AEgIS Penning-Malmberg trap can be used for synthesis of other exotic systems, as well as direct and precise observations of matter-antimatter interactions. In particular, formation of Rydberg antiprotonic atoms inside the traps has been proposed in recent years [2]. In fact, the same charge exchange reaction used by AEgIS for Hbar can be used for substituting an electron with an antiproton on a Rydberg orbit of a heavy ion. The antiproton would then cascade down while the atom undergoes a series of radiative and non radiative transitions to be inevitably destroyed when it reaches the atomic nucleus [3]. Controlled creation of such an antiproton-bound atom in cryogenic trap conditions would would allow recording of the full spectrum of the antiprotonic transitions, measurements of antiproton annihilations on the nucleus and production of nuclear fragments. Eventually, the technique can pave way to novel isotope formation, selective proton/neutron removal, controlled reconstitution of the electron orbitals of depleted nuclei, novel material synthesis by combining nuclear fragments with (partially) reconstituted electron orbitals - e.g. femtotechnology.

As mentioned, the trapping charge exchange reactions of antimatter have to be conducted in the cryogenic UHV conditions of the Penning-Malmbeg trap. Recently, trapping and manipulation of ions has been tested within the AEgIS apparatus with encouraging results. However, most measurements on (Highly Charged) Ions are done in Paul traps, in warm vacuum setting that allow access of extended experimental infrastructure. We have undertaken to build a Paul trap-based ion source, as well as ion beam delivery line in order to provide the AEgIS experiment with controlled pulses of (negative or positive) ions that can be co-trapped with antiprotons (and electrons) for antimatter-matter precision experiments. On the other hand, we are preparing the extraction region of the AEgIS apparatus to host an array of traps, laser and detector systems for collection and manipulation of the highly charged products of the reactions performed in the controlled cryogenic environment. The design of the extraction line is modular, flexible, allowing for constant additions and modifications, transforming the AEgIS experiment into a platform for new particle, nuclear and material physics.

References

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