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Calculations of antihydrogen formation and collisions

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Cold antihydrogen atoms can be used for precision tests of fundamental matter-antimatter symmetries, such as the CPT theorem. Cold antihydrogen was first produced in 2002 by the ATHENA experiment [1] and the ATRAP experiment [2]. In both experiments, as well as the more recent ALPHA experiment, antiatoms are formed by mixing antiprotons and positrons trapped in a nested Penning trap. A lot of theoretical activity has been directed at understanding the basic physics of the formation process, and explanation of experimental observations [3]. In particular, it has been pointed out that because the antiprotons are repeatedly leaving and re-entering the positron plasma, the positron-antiproton system never reaches a steady-state situation [4].

I will give a brief overview of the experiments, and present some results from simulation of antihydrogen formation from antiprotons injected into a positron plasma. Antihydrogen is formed into highly excited Rydberg states. At low temperatures the dominating process is the three-body reaction
p^- + e^+ + e^+ -> (p^- e^+) + e^+.

Formation is however not a one-step process, but in order for the antiatom to gain enough binding energy to survive to the detector a sequence of collisions is needed. Most of the time this leads to re-ionization, but occasionally the antiatoms stabilizes. The dependence of the formation rate on the temperature, density and geometry of the positron plasma will be discussed and compared to experimental results. In order to make trappable antihydrogen the formation process should be optimized to give large binding energies and low kinetic energies of the antiatoms.

I will also present theoretical results for antihydrogen colliding with simple atoms at low temperatures. In particular I will discuss the role of the strong nuclear force in atomantiatom collisions, leading e.g. to annihilation. I will also discuss rearrangement reactions, such as positronium formation.

References

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