Synthesis of antihydrogen with adiabatically transported cold antiprotons

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Synopsis A double cusp trap for atomic beam spectroscopy of the hyperfine splitting of antihydrogen has been developed. Synthesis of antihydrogen atoms was studied by directly injecting antiproton beams with a narrow energy width into a positron plasma in the double cusp trap. Within 0.7 s, about 60% of all antihydrogen events were localized which is expected to contribute to a better signal-to-noise ratio in our planned antihydrogen spectroscopy experiments.

The ASACUSA collaboration has been developing a Rabi-like method for atomic beam spectroscopy of hyperfine splitting of antihydrogen ($\bar{\mathrm{H}}$) atoms to test CPT symmetry[1]. A cusp like magnetic field configuration produced by an anti-Helmholtz coil has been utilized to provide spin-polarized $\bar{\mathrm{H}}$ beams[2, 3]. Production and detection of an $\bar{\mathrm{H}}$ beam were successfully demonstrated[4].

A double cusp trap which consists of two sets of anti-Helmholtz coils and a stack of multiple ring electrode has been developed to increase the intensity and the spin-polarization of $\bar{\mathrm{H}}$ beams. For an efficient $\bar{\mathrm{H}}$ production, we have also developed an adiabatic transport of antiprotons ($\bar{p}$s)[5].

Antihydrogen atoms were synthesized by directly injecting a $\bar{p}$ beam into a positron plasma stored in the double cusp trap, which was monitored by using a field-ionization well (FIW). Antihydrogen atoms in high Rydberg states were field ionized and their $\bar{p}$s were accumulated in the FIW. The $\bar{p}$s were released from time to time and detected by surrounding scintillators. Figure 1 shows the time evolution of the rate of field ionized $\bar{p}$s which was measured for non-adiabatic and adiabatic transportation of $\bar{p}$ beams, respectively. In the non-adiabatic case, only 35% of events were counted within the first 0.7 s and the second peak could be recognized around 5 s. Although the time profile in the adiabatic case, that is, a sharp peak at the beginning followed by long and continuous $\bar{\mathrm{H}}$ production, was similar, the second peak disappeared, which implies a less heating of positron plasma. About 60% of antihydrogen events were temporally localized within the first 0.7 s. The high initial production rate of $\bar{\mathrm{H}}$ improves the signal-to-noise ratio of a detector at the end of our spectrometer line.

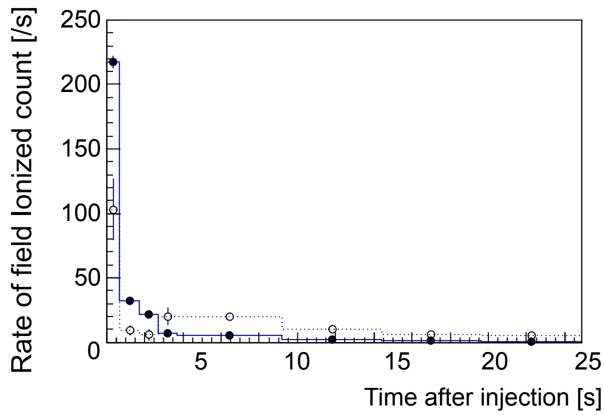

Figure 1. The rate of antihydrogen atoms which field-ionized during the time interval shown by the width of the histogram for adiabatic(solid circle) and a non-adiabatic (open circle) transportation.

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