Light antiprotonic atoms

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The measurement of the characteristic X-radiation emitted from antiprotonic atoms constitutes an antinucleon-nucleus scattering experiment at relative energy zero. The strong interaction manifests in an energy shift and broadening of the low-lying atomic states. Shift and broadening are directly related to the complex antiproton-nucleus scattering length and are sensitive to the medium- and long range part of the antinucleon-nucleus interaction. The hydrogen isotopes allow access to the elementary systems antiproton-proton and -neutron. Light nuclei serve as a testing ground to build up a consistent picture of the antinucleon-nucleus interaction. Furthermore, the study of the atomic cascade and its pressure dependence sheds light on the processes governing the de-excitation of the antiprotonic atoms.

In antiprotonic hydrogen the resolution of hyperfine states, which is equivalent to a double polarisation experiment at threshold, became already possible during the LEAR era. The low precision, however, hinders a sensitive test of the various theoretical approaches. The experimental information on the antiproton-deuteron s-wave interaction urgently needs confirmation from a new measurement and the accuracy of the measurements of the helium isotopes is modest.

For precision studies of the strong-interaction effects high statistics is essential. In order to achieve sufficiently high X-ray yields antiprotonic hydrogen and helium must be formed in dilute gases to reduce the influence of non-radiative de-excitation processes owing to collisions. Therefore, gas targets in the mbar range having both thin entrance and exit windows must be used. Antiproton beams of 100-300 keV are well suited as planned for the low-energy antiproton facility FLAIR at GSI. The possibility to combine an antiproton plasma inside a trap with a gas jet might be considered in context with the improving performance of such devices (e. g., ASACUSA experiment at AD, CERN).

Energies of the low-lying X-ray transitions in hydrogen and helium isotopes are in the range 2-15 keV. For hydrogen, the hadronic effects are of the order of 1 keV and 10-500 meV for the s-wave and p-wave interaction, respectively. Consequently, the measurement requires two different approaches: a direct measurement with semiconductor detectors, e. g., fast CCDs and ultimate resolution by using a Bragg crystal spectrometer. Whereas CCDs allow an efficient reduction of the annihilation induced background by the analysis of the hit pattern, a Bragg spectrometer is self collimating due to the small angular acceptance. Even fast CCDs, processing about 500 frames per second, are limited to a continuous beam of about 10^5 antiprotons per second to avoid over illumination, whereas the crystal spectrometer is not yet rate limited at the design parameters of FLAIR.