Experiments using extremely long ion storage times in a cryogenic linear trap

M. Lange* [1], K. Blaum*, M. Froese*, M. Grieser*, O. Heber, S. Menk*, R. Repnow*, Y. Toker‡, R. von Hahn*, A. Wolf*

* Stored and Trapped Ions Division, Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany
†Physics Services, Weizmann Institute of Science, Rehovot 76100, Israel
‡Department of Physics and Astronomy, University of Aarhus, DK-8000 Aarhus C

The cryogenic trap for fast ion beams (CTF) at the Max-Planck-Institut für Kernphysik in Heidelberg has achieved residual gas densities around 2000 cm^{-3}, obtained by cryo-pumping of hydrogen at temperatures of 1.8 K [1]. We present two experiments illustrating the advantages of the resulting low collision rates with stored ions and the resulting storage lifetimes of several minutes.

We have used the CTF to investigate the so-called self-synchronizing mode of operation [2], which can be realized by very shallow mirror potentials leading to a negative frequency dispersion with respect to ion energy. Under these conditions a stored ion bunch stays coherent over an extended period of time. It is believed [2] that the negative dispersion combined with the electrostatic repulsion between the stored ions acts to stabilize a stored bunch. Although previous measurements have shown the existence of this mode of operation, storage times in other ion traps were too short to observe the actual process of decoherence of the ion bunch. We have therefore investigated trapped bunches of N_2^+ and Ar^+ over extended times, using a pick-up electrode. In these measurements we have observed an initially very slow decay of the bunch injected into the trap, which speeds up progressively after 8…12 s and leads to a sudden decay of the bunch after a further few seconds. Revival of the signal after RF-bunching and the nearly constant rate of neutral particles emerging from the trap over the course of the experiment unambiguously prove that the bunch was not lost from the trap but had decayed into a coasting beam.

Secondly, the extremely high vacuum environment of the CTF has also proven highly beneficial for the investigation of thermionic electron emission from molecular and cluster anions: By monitoring the production rate of neutral particles with a micro-channel plate mounted inside the cryogenic environment, the decay of highly excited negative ions coming from a cesium sputter ion source is investigated as a function of storage time [3]. We have also applied this technique to the decay of SF_6^- anions, where a previous investigation [4] found a power-law dependence on time with an exponent of approximately -1.5. Because of the strong suppression of the background of neutral particles originating from residual gas collisions in our trap, we have been able to extend the range over which the thermionic emission rate has been measured from three to six orders of magnitude. Over most of this range our measurement confirms the power law decay, albeit with a slightly different exponent than in [4]. Moreover, we have found that at times longer than 15 ms, becoming accessible because of the much reduced background reaction rate, SF_6^- exhibits a strong deviation from the power law decay, with neutral production rates declining steeply with time. The fact that much of these details would have been obstructed at higher pressures highlights the advantages of cryogenic ion trapping.

References

[1] M. Lange, *et al*., Rev. Sci. Instrum. **81**, 055105 (2010).
[2] H. B. Pedersen, *et al*., Phys. Rev. Lett. **87**, 055001 (2001), Phys. Rev. A. **65**, 042703 (2002).
[3] M. Froese *et al.*, Phys. Rev. A 83, 023202 (2011).
[4] Y. Rajput, *et al*., Phys. Rev. Lett. **100**, 153001 (2008).

* [1] E-mail: Michael.Lange@mpi-hd.mpg.de