Highly-sensitive negative ion spectroscopy in an electrostatic ion beam trap

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The electron affinity (EA) of a chemical element is defined as the energy released as an electron is attached to a neutral atom. The binding of such an "extra" electron does not arise from the net charge of the atomic system but is a result of complex electron-electron correlations. Hence, precise measurements of EAs are powerful benchmarks of atomic theories reliant on many-body quantum methods, which are typically applied to several atomic spectroscopy studies aiming at answering quantum chemistry, nuclear structure, and fundamental symmetries questions. The EA is also an important parameter for understanding the chemical behavior of an element since it is strongly related to how much such an element is prone to form chemical bonds by sharing electrons.[1] However, the EAs of several rare and radioactive elements are still unknown and detailed information, such as isotope shifts and hyperfine splittings of EAs, is available for only a handful of stable cases.

A standard technique for the precision determination of EAs is the laser photodetachment threshold (LPT) method, in which a photon with sufficient energy is used to detach an electron from a negative ion. This technique has been restricted to mostly stable, abundant species given the low photodetachment probabilities. At CERN-ISOLDE, we have explored the use of the Multi Ion Reflection Apparatus for Collinear Laser Spectroscopy (MIRACLS) technique[2] to enhance the sensitivity of LPT to study the EA landscape among rare and radioactive species. The novel method is based on a Multiple-Reflection Time-of-Flight (MR-ToF) device to trap ions between two electrostatic ion mirrors. This allows us to greatly extend the ions' exposure time to lasers, significantly increasing the sensitivity by orders of magnitude while keeping the high resolution of a collinear geometry.

The technique has been developed offline and employed in the determination of the EA of ^{35}Cl, which is in perfect agreement with the literature value.[3] The achieved precision is competitive to that obtained in previous experiments,[3] yet employing a five orders of magnitude smaller ion sample and using high-resolution continuous wave lasers with much reduced laser power, highlighting the gains in sensitivity of this method. This talk will introduce the novel technique and present its first results as well as its potential for rare isotope sciences.

[1]D. Leimbach *et al*., "The electron affinity of astatine", Nat. Commun. (11) 3824 (2020).
[2]S. Sels *et al*., "First steps in the development of the Multi Ion Reflection Apparatus for Collinear Laser Spectroscopy", Nucl. Instr. Meth. Phys. Res. B (463) 310 (2020).
[3]U. Berzinsh *et al*., "Isotope Shift in the Electron Affinity of Chlorine", Phys. Rev. A (51) 231 (1995).