Rare Elements in-Gas Laser Ionization and Spectroscopy at S^3

X. Fléchard* [1], B. Bastin†, P. Creemers‡, R. de Groote‡, P. Delahaye†, R. Ferrer‡, S. Franchoo§, L.P. Gafney‡, L. Ghys‡, W. Gins‡, M. Herbane*, M. Huyse‡, Yu. Kudryavtsev‡, N. Lecesne†, Y. Martinez‡, E. Mogilevskiy‡, J. Piot†, S. Raeder‡, H. Savajols†, S. Sels‡, J.-C. Thomas†, E. Traykov¶, C. Van Beveren‡, P. Van den Bergh‡, P. Van Duppen‡, A. Zadvornaya, on behalf of the S3-LEB collaboration

* Normandie Univ, ENSICAEN, UNICAEN, CNRS/IN2P3, LPC Caen, 14000 Caen, France
†GANIL, CEA/DRF-CNRS/IN2P3, B.P. 55027, 14076 Caen, France
‡KU Leuven, Instituut voor Kern- en Stralingsfysica, B-3001 Leuven, Belgium
§IPNO, Université Paris-Sud 11, CNRS/IN2P3 91406 Orsay, France
¶Université de Strasbourg, IPHC, 67037 Strasbourg, France

Synopsis Resonant laser ionization and spectroscopy are now standard techniques used at radioactive ion beam facilities. They provide pure low energy beams of exotic nuclei and give access to atomic and nuclear ground state properties. We present here the development of REGLIS^3 (Rare Elements in-Gas Laser Ion Source and Spectroscopy at S^3), a new generation device based on the use of a supersonic gas jet. The technique provides both higher spectral resolution and efficiency, as recently demonstrated by our collaboration [1]. Coupled to the future S^3 (Super Separator Spectrometer) of GANIL SPIRAL2, it will offer unique opportunities for atomic and nuclear studies of heavy and super heavy elements.

The heaviest elements can have intriguing atomic and nuclear properties. Valence-electron configurations and ionization potentials are strongly influenced by relativistic effects and, in the nucleus, the competition between short-range nuclear attraction and Coulomb repulsion can lead to unexpected nuclear properties. But experimental data for heavy elements are still rather scarce. For example, lawrencium (Z=103), is the heaviest atom whose ionization potential has been measured. A better understanding of heavy exotic elements requires thus both atomic and nuclear experimental studies.

Resonant laser ionization is a well-established technique to selectively provide radioactive ion beams and measure atomic properties such as ionization potentials, atomic levels, isotope shifts and hyperfine constants. Nuclear spins, charge radii and electromagnetic moments can then also be inferred from these observables. But poor spectral resolution (in the GHz range) and poor efficiency for elements with short half-lives or unfavorable physico-chemical properties limit the practicality of the technique. To overcome these limitations, the heavy-ion beams from S^3 will be stopped and neutralized in a gas-cell filled with flowing argon gas. The atoms of interest are then transported with the buffer gas through a "de Laval nozzle" and exit the cell in a collimated supersonic jet overlapping with the laser beams [2]. The low density and temperature of the jet provide ideal conditions for resonant laser ionization with an improved spectral resolution. Photoions are guided through radio frequency quadrupoles towards a high vacuum section. They can then either be sent to a detection system for counting or be reaccelerated as a pure exotic beam.

The first on-line demonstration of this new technique has been recently performed at the LISOL facility, Louvain La Neuve, Belgium, with $^{212\text{-}215}$Ac isotopes [1]. A strong improvement in spectral resolution was obtained compared to the standard in-gas cell technique (fig. 1). A gain in efficiency and selectivity of about ×20 was also evidenced. These results and the status of the REGLIS^3 setup will be presented at the conference. This work was supported by ANR-13-BS05-013-02

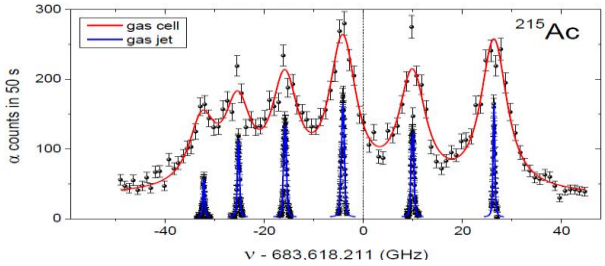

Figure 1. $^2D_{3/2} \rightarrow {}^4P_{5/2}$ transitions of ^{215}Ac measured using the in-gas cell and in-gas jet techniques.

References

[1] R. Ferrer *et al.*, 2017 *Nat. Commun.* **8** 14520 doi: 10.1038/ncomms14520
[2] R. Ferrer *et al.* 2013 *Nucl. Instr. and Meth. B* **317** 570

[1] E-mail: flechard@lpccaen.in2p3.fr