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New target ion source systems at GANIL/SPIRAL1: Prospective

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A B S T R A C T

SPIRAL1 facility is currently under transformation (Dubois) [1] in order to extend the range of radioactive ion beam offered to users. It will be able to host a larger variety of target ion source systems by the end of 2016, needed to fulfil the production requirements related to the chemical variety of the isotopes demanded by the physicists. The extent of the transformation is limited by the frame of the safety regulation and by the existing facility. Several combinations of mono-charged or multi-charged ECR, FEBIAD and surface ionization sources with new target materials are becoming possible. Some of these combinations are already under test. A comparison between expected SPIRAL1 performances and results obtained in other facilities is presented with the aim of leading our next developments.

1. SPIRAL1 Upgrade

Since its start in 2001, the SPIRAL1 facility delivers ions only from ionization of gaseous elements. Its upgrade [1] aims to extend the range of available radioactive ion beams [2] to metallic elements by using other ion sources and other target materials (from C to Nb). The final ion mass range will extend from He to Xe. Corresponding post-accelerated energies will range from ~25 A. MeV to ~7 A. MeV. A safety report has been analyzed and approved by the safety authority. The possibilities offered are promising and strengthen the GANIL motivation to develop further the SPIRAL1 facility.

The ions will be directly used as low-charge ions by the LIRAT [3] (Ligne d'Ions Radioactifs A Très basse énergie) or by the DESIR facilities. After being multi-ionized they will alternatively be post-accelerated at energies beyond MeVs, by a cyclotron which also insures a 10^{-4} mass separation.

Up to now, multi-ionization has been performed by using a multi-charged ion ECRIS installed in the production cave. Owing to the hostile environment, the technological constraints limit its performances, in terms of chemical species and of reachable charge state.

To improve the charge state and the variety of accelerated elements, a PHOENIX type ECRIS used as charge breeder [4,5] will be installed on the 1+ (or low charge state, see Fig. 1) beam line, between the cave containing the target ion source system (TISS) and the post-accelerator CIME.

The cave has been transformed in 2012 and 2013 and successfully commissioned in July 2013. It can now host different TISS.

2. Production schemes

Four ionization schemes can be considered to optimize the production:

- The current 0 to N+ atom-to-ion transformation directly performed in the production cave and mainly dedicated to gaseous ionization. The performances of such a method are limited by the existing technologies which are not radiation hard (magnet damage under neutron irradiation for instance) and by the operation cost of such a production system.
- The 0 to 1+ transformation, performed in the cave with singly charged ion sources with technologies that allow for radiation-hard solutions. According to the chemical element, simple ECR, FEBIAD [6] and Surface [7] ion sources can be chosen and are already available. (Remark: The use of a LASER Ion Source (IS) has also been studied but its implementation is too constraining regarding the existing infra-structure). The beam can be used in the existing LIRAT and in the forthcoming DESIR [8] instrumental facilities.
- The two steps 0/1+/N+ charge breeding, using a singly-charged ion TISS installed in the cave and a multi-charged PHOENIX ECRIS placed out of the cave, downstream from a mass separator. This solution will be mainly dedicated for multi-ionization of condensable elements.

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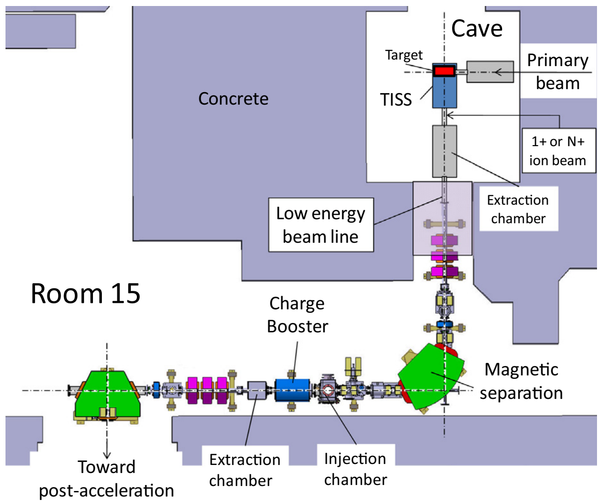

Fig. 1. Schematic of the SPIRAL1 upgrade.

- The 0/1+/N+ conversion directly performed in the cave. As demonstrated earlier [9], this method can lead to interesting performances for short lived isotopes of alkalis and will have to be considered as an alternative solution to the two steps 0/1+/N+ technique.

In addition to new ionization schemes, the authorization to use different combinations of primary beam/target material has been obtained. Up to now, the high energy beams delivered by GANIL could be sent on the graphite target with a maximum intensity of 2.10^{13} pps or a maximum power of 6 kW. In fact, the primary beam intensities of heavy ions were often limited by the performances of the cyclotrons and by the ability of the materials to sustain the power deposited on a short stopping range. Now, it is possible to send a primary beam of ^{12}C 95 A. MeV for target materials going from graphite to Nb, and beyond Nb mass for non-stopping targets if allowed after risk analysis. The ion production possibilities are thus strongly extended.

3. Current and expected yields

The current GANIL radioactive ion beam intensities and the expected ones are compared to the intensities produced at TRIUMF and ISOLDE (Refs. [10,11]). The goal is to determine which TISSs have to be developed at GANIL and to prioritize these efforts.

Ions from gas: During more than ten years, radioactive ions have been produced at GANIL from noble or molecular gas. The efficiency of the TISS has been progressively improved (shape of the chamber and of the target, conductance of the transfer region, injection of the RF, tightness of the target chamber, magnetic confinement of the ECRIS), leading to higher intensities. They are compared to TRIUMF and ISOLDE ones on Fig. 2. In the case of GANIL, except for $^{6,8}He$ ions which are singly-charged, the intensities correspond to readily multi-charged ions, in contrast with TRIUMF and ISOLDE ones which correspond to 1+ ions. This difference is due to the fact that on SPIRAL1, the atom of gas are directly multi-charged in the TISS, using a multi-charge ECRIS. The GANIL intensities thus only correspond to a fraction of the ions contained in the total ion charge state distribution. This fraction is larger for light elements, owing to the reduced number of charge states.

For short lived isotopes, the advantage of the GANIL TISS is reduced owing to its relatively large volume, which increases the losses during the diffusion and effusion process. To increase the yields, different improvements have been started: increasing the primary beam power sustainable by the target and increasing the efficiency of the ion source. A factor of 4 has been obtained on the production of $^{18}Ne^{5+}$. The effect should be more important

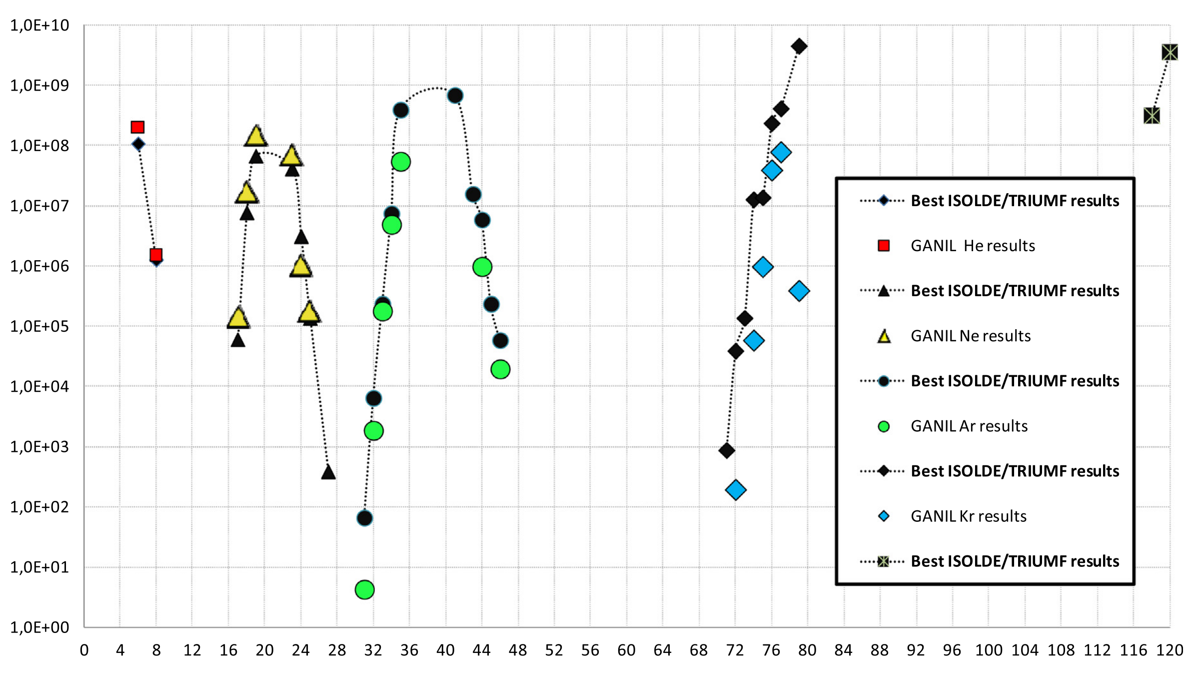

Fig. 2. Singly charged ion yields produced for He, Ne, Ar, Kr and Xe at TRIUMF and ISOLDE (black dots) and multi-charged ion yields produced at GANIL (respectively red, yellow, green, and blue dots) versus mass of isotopes. $^{118,120}Xe$ have not been produced at SPIRAL1 yet. As generally produced for post-acceleration, the GANIL ions are directly multi-charged, except for $^{6,8}He$ which are singly-charged. All the intensities are given for beams before post-acceleration. (For interpretation of the references to colour in this figure caption, the reader is referred to the web version of this article.)