

## Call for LoI's with new beams at SPIRAL 1

In the beginning of this year, a comprehensive investigation for upgrading the SPIRAL 1 facility was realized by a newly formed committee - GANISOL - in order to provide a wider variety of radioactive ion beams to the GANIL user community. From this investigation it resulted that a number of different new elements may become accessible at SPIRAL 1 within a reasonable time range (2-3 years).

For guiding the R&D work of GANISOL, the GANIL direction launches a call for letters of intent for experiments using new radioactive ion beams within the list shown below.

### List of new possible post-accelerated beams from an upgraded SPIRAL facility

- **Alkali elements** Li – Na – K – Rb + rare earth Sr
- **Metallic elements** including rare earth Mg, Al, Ca, Sc, Cr, Mn, Co, Ni, Cu Zn, Ga, Ge, As, Se
- **Non-metals and Halogens** C, P, S, Cl, Br

### Isotopes

The most standard reaction mechanism for producing radioactive isotopes at SPIRAL is projectile fragmentation on a graphite target. The isotopes of interest produced in such reaction should therefore respect these simple rules:

- N and Z not higher than those of the available GANIL primary beams [1]
- For various technical reasons, the mass of the radioactive nuclei produced in the SPIRAL cave should be  $\leq 90$ .

### Yield estimate for the isotopes of a given element

GANISOL members can be contacted for providing first order estimates for the new isotopes (see contact persons below). Alternatively, you can obtain a first estimate of the in-target yields with the LISE program, assuming a maximum power of 1.5 kW on the graphite SPIRAL target, or the maximum intensity for the primary beam you consider [1]. The final expected yields have to take into account the target ion source, multi-ionization and post-acceleration efficiencies. Typical overall efficiencies that can be expected for half-lives longer than 1s for alkalis and significantly longer for metallic ions are given in Table 1. Yield estimates are given in the appendix for a few representative examples.

Elements	Typical efficiency range (T1/2,A,Z)
Alkali elements and a few rare earth Li – Na – K – Rb + rare earth Sr	$10^{-4} - 10^{-3}$
Metallic ions Mg, Al, Ca, Sc, Cr, Mn, Co, Ni, Cu Zn, Ga, Ge, As, Se	$10^{-5} - 10^{-3}$
Non metals and Halogens C, P, S, Cl, Br	$10^{-6} - 10^{-4}$

**Table 1: List of elements for the new beams and associated expected efficiencies, from the target to the detector setup**

### **Minimum / maximum energies**

The CIME working diagram [3] defines the minimum and maximum energies that can be reached according to the possible charge states of the produced and charge bred isotope. For alkali ions the final charge state distribution will be very similar to the one given in [3] for the closest noble gas. At a later stage, better performances are expected from a charge breeding system that should produce A/q ratios between 4 and 7 on the whole chart of nuclides [4].

### **Contacts**

Please contact GANISOL for further information.

The GANISOL contact persons for the preparation of these LoIs are:

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[1] <http://pro.ganil-spiral2.eu/users-guide/accelerators/available-stable-ion-beams-at-ganil/view>

[2] <http://groups.nsl.mscl.msu.edu/lise/lise.html>

[3] <http://pro.ganil-spiral2.eu/users-guide/accelerators/spiral-beams>

[4] [Nucl. Instrum. Methods Phys. Res., B 266 , 19-20 \(2008\) 4429-4433.](#)

## Appendix: Example of yield estimates

Isotope of interest:  $^{68}\text{Cu}$

We consider the fragmentation of  $^{70}\text{Zn}$ .

- From [1] we see that it is available with the following characteristics: 62.5MeV/A, 4E11 pps. It corresponds to a rather low power of 280 W which matches the limit of 1.5kW (maximum that can be hold by the graphite target).
- LISE [2] provides the fragmentation cross section from the last version of epax: 25.1mb
  - Set-up the right projectile, target (12C), and fragment, and then go to cross section in the “option” tab.
- It also gives the range: 330mg/cm<sup>2</sup>
  - In “Calculations” → “Physical calculator”, set-up the projectile and finally the target within “Range and Energy Loss to”.
- The in-target yield is therefore:  $I(\text{pps}) \cdot \sigma(\text{cm}^2) \cdot dx(\text{g/cm}^2) \cdot N_A(\text{mol}^{-1}) / A(\text{g/mol}) = 4\text{E}11 \cdot 25.1\text{E}-27 \cdot 0.330 \cdot 6.02\text{E}23 / 12 \sim 1.7\text{E}8/\text{s}$
- Cu being a metal, the efficiency is comprised between 10E-5 and 10E-3. That gives 1.7E3 to 1.7E5pps after CIME.
- The max energy depends on the A/q that can be reached. From [4] one expects an A/q of about 5. With such charge state, the CIME working diagram [3] shows that the maximum energy that can be reached is about 10 MeV.

Table 2 shows the result of this calculation for other examples. For  $^{68}\text{Cu}$ , the total intensity is expected to be shared between several isomeric states. Note the intensity limitation on the primary beam for  $^{75}\text{Br}$ : it should never exceed 1.5kW. The maximum energy for post-accelerated  $^{68}\text{Cu}$ ,  $^{70}\text{Se}$  beams is expected to be around 10 MeV/A, and around 12-14 MeV/A for the lighter isotopes. As a warning, this table does not show the possible contaminants for each beam of interest. The potential beam contamination will depend a lot on the target ion source and other techniques that will be used (molecular sidebands, transfer tube material etc.). For any more information, please contact GANISOL.

Fragment	Group	Projectil e	E (MeV/A)	pps	P (W)	$\sigma_{\text{epa}}$ (mb)	dx (mg/cm <sup>2</sup> )	Higher Intensitie s (pps)	Lower Intensitie s (pps)
68Cu	Metals	70Zn	62.5	4E11	2.8E+02	25.1	330	1.66E+05	1.66E+03
70Se	"	78Kr	70.4	1.3E12	1.15E+03	1.72	323	3.62E+04	3.62E+02
22Mg	"	24Mg	95	4.1E12	1.50E+03	1.95	1330	1.49E+05	1.49E+03
47K	Alkalis	48Ca	60.3	1.5E12	7.0E+02	16.1	446	1.95E+05	1.95E+04
34Cl	Halogens	36Ar	95	2.7E12	1.50E+03	39.1	899	4.76E+05	4.76E+03

**Table 2: Estimated intensities for different arbitrary isotopes.**