Beams production optimisation on ECR4/4M ion sources at GANIL cyclotrons facility

M. Dubois, L. Gouleuf, B. Jacquot, F. Lemagnen, V. Métayer, B. Osmond, A. Ribet
GANIL - Boulevard Henri Becquerel - 14076 Caen Cedex 5

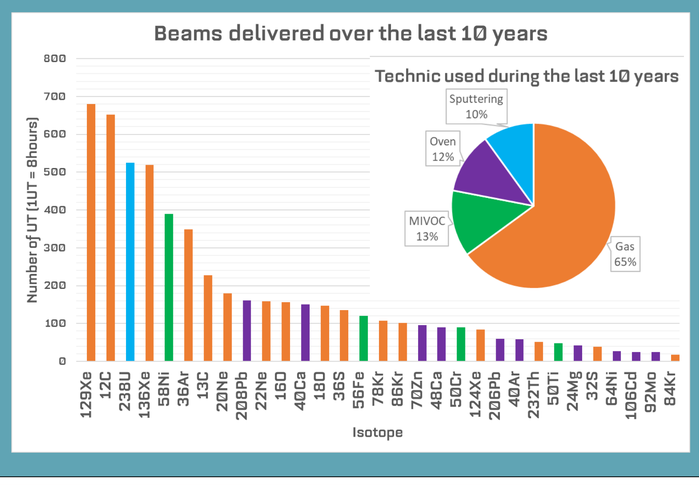
Abstract

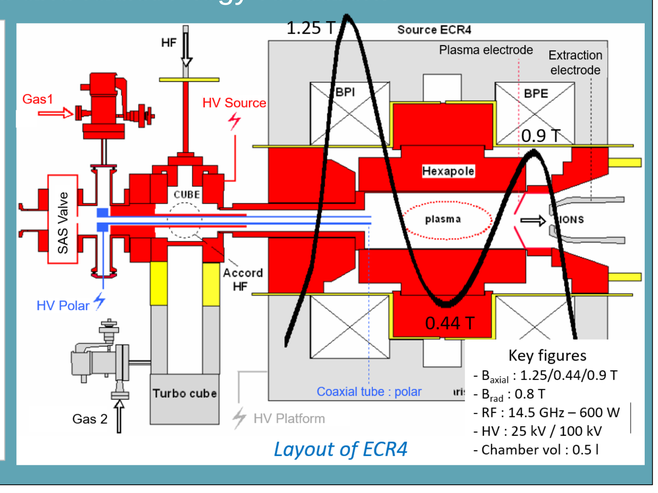
The GANIL (Grand Accélérateur National d'Ions Lourds) in Caen has been producing and accelerating stable and radioactive ion beams for nuclear physics, atomic physics, radiobiology and materials irradiation since 1982.

Following a period of commissioning of the LINAC accelerator, during which cyclotron beam time was reduced, the next objective is to increase beam usage time on both facilities in order to meet the demands of physicists. This is accompanied by a major renovation program aimed at increasing the availability of cyclotron accelerators. With this in mind, several studies have been conducted over the past two years on the ECR4/4M ion sources feeding the cyclotrons in order to identify possible improvements (stability, intensity), but also with the aim of reducing the need for ion source experts, who will have to operate up to four ECR ion sources in parallel. In 2025, the first optimisations were implemented online and the initial results will be presented.

Stable Beams at GANIL – Cyclotron facility

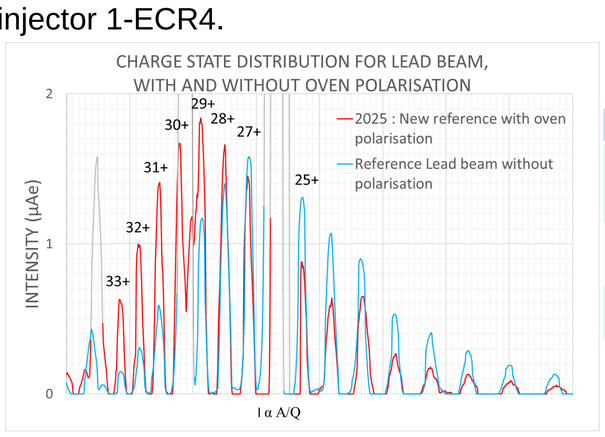
The ECR4/ECR4M are second-generation ECR ion sources. They produce around 5,000 hours of beams each year for the cyclotron machine. Many isotopes (up to 50), ranging from carbon to uranium, can be delivered to the physics community using various techniques (gas, MIVOC, sputtering and an oven). Over the last 10 years, ^{129}Xe and ^{12}C have been in high demand for industrial applications and radiobiology research.





1- Oven polarization on $^{206}Pb^{31+}$

After technical adaptation on High Voltage (HV) cabinet, the oven polarization was used for $^{206}Pb^{31+}$ production in march 2025 on injector 1-ECR4.



	2025	2007
Average Intensity (µAe) Pb^{31+}	1.1	0.6
Transport up to FC	45 %	28 %
Consumption (µg/h)	27	65

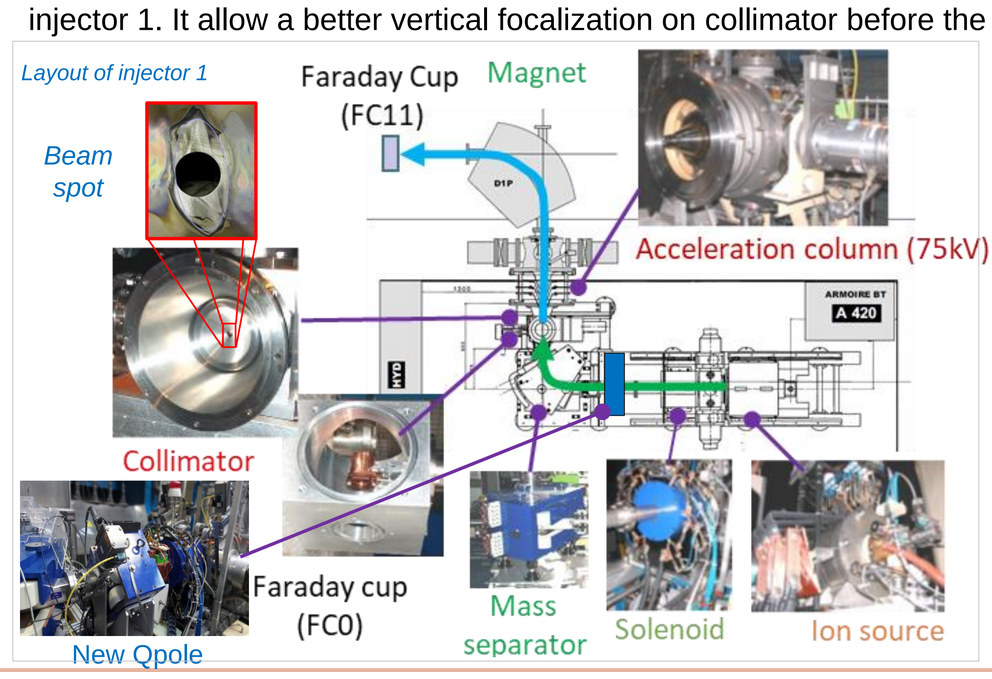
Production parameters comparison

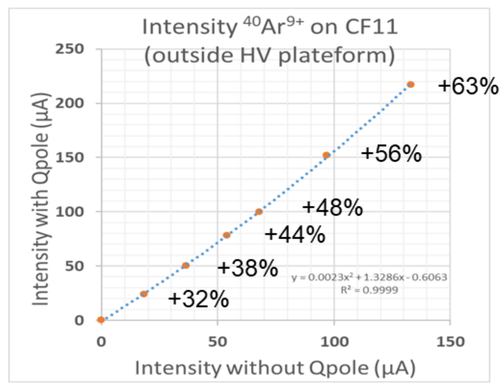
- ❑ Charge state distribution moved to higher charge state
- ❑ Beam transport improve up to the Faraday Cup (FC)
- ❑ Lower consumption

After 20 days of production, measurements confirmed that oven polarization increases the global efficiency of the injector.

2- Beam transport on Injector 1

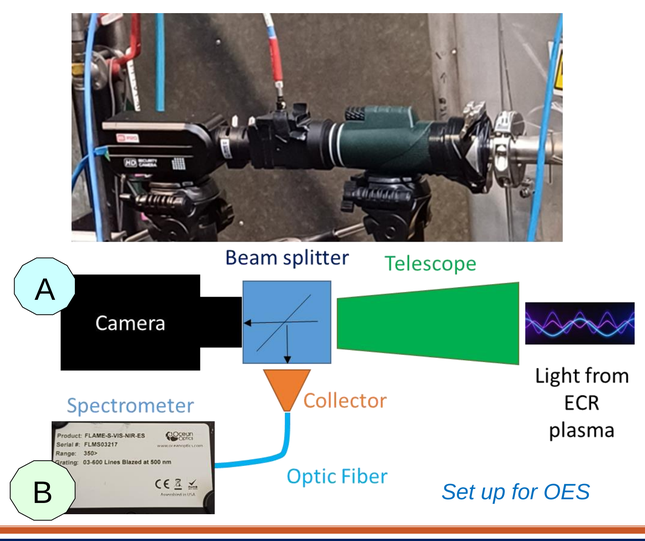
To better compensate for the space charge and improve transport in the accelerator tube at the output of the HV platform, a new Quadrupole has been installed at the end of 2024 on the ion source extraction line on injector 1. It allow a better vertical focalization on collimator before the acceleration column.

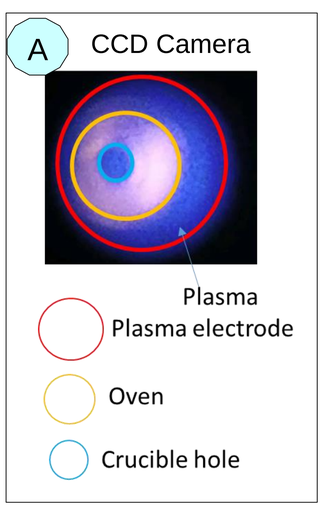


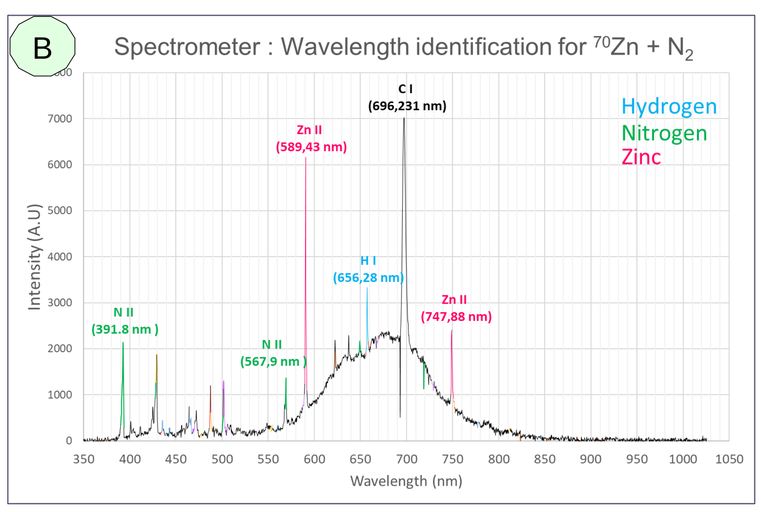


- ❑ 2024: Simulation, Installation and Tests with Ar beam
- ❑ 2025: gain >30% measured for all beams (^{206}Pb, ^{36}Ar, ^{70}Zn, ^{12}C and ^{20}Ne).

3- Optical Emission Spectroscopy (OES)







The OES has been installed on the first magnet of injector 1-ECR4, which is positioned in line with the ion source.

This technique involves analysing the light emitted by the plasma of the ECR source through the plasma electrode within the visible spectrum.

- ❑ Non intrusive technique
- ❑ New information (metal, outgasing, etc.)
- ❑ Observation of instabilities (camera)

In 2025, it was used with gas and metal beams to evaluate operational capabilities.

4- Optimised beam experience

All improvements (1/2/3) as well as a thermal control of gas valve have been used for this experiments.

$^{70}Zn^{14+}$	Average intensity	Stability 24H	Transport evaluation	Isotope Consumption	Total efficiency	Tuning source
2023 – 12 days	9 µAe	+/-33 %	27 %	183 mg	1.9 %	24 (*)
2025 – 12 days	7 µAe	**+/-12 %**	**58 %**	**67.4 mg**	**4.4 %**	**5**

(*) : Estimates from the partial data show : two tunings per day for four days.

Comparison between 2023-2025

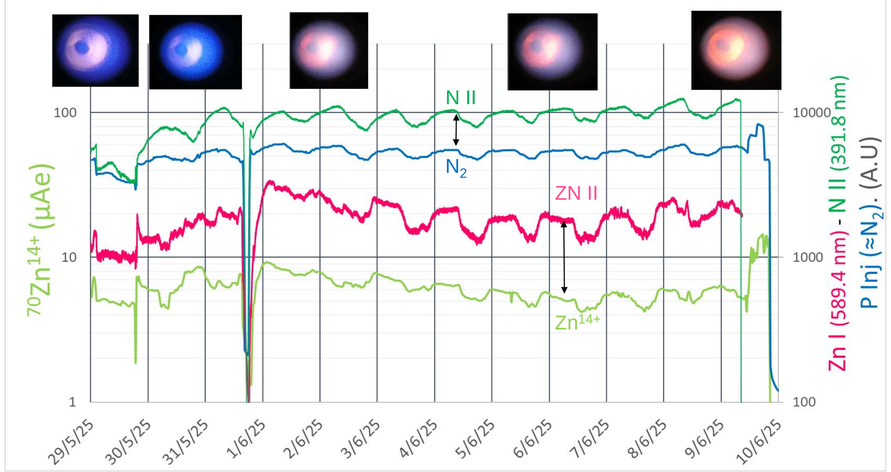
Injector (source+HV platform) performances:

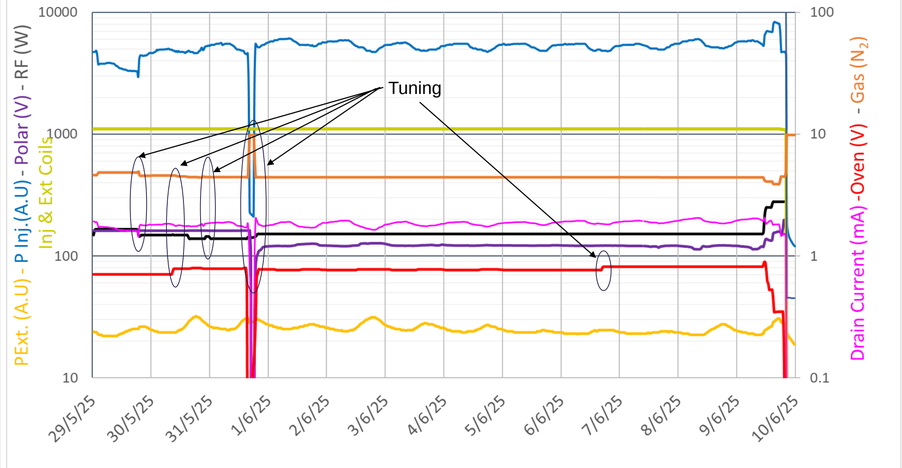
- ❑ Total efficiency of injector: x 2.3
- ❑ Reduction of Isotope consumption (>2)
- ❑ Better stability
- ❑ Ion source tuning reduce by a factor 5

Spectrometer & camera diagnostic:

- ❑ Good correlation between data from spectrometer and ion source parameters
- ❑ Access to Zn flux online
- ❑ Camera give information on stability

⇒ This will be developed into an tool for operators





Conclusions

Over the past two years, numerous optimisations have been carried out to improve the reliability and stability of the cyclotron injector sources, as well as to optimise the beams. Results from 2025 demonstrate the improvements in beam quality and performance control that have been achieved. These improvements will benefit physic experiments and the SPIRAL1 ISOL facility, enabling 1.5kW for a large number of primary beams. Additionally, fewer full-time equivalents will be required for standard ion source operation. This will allow ion source experts to dedicate more time to R&D and new projects while facilitating the parallel operation of several ECR ion sources.

Other optimisations are underway: O_2 cleaning processes and new oven (high and low temperature)…